ASTRONOMY 2021 AUSTRALIA



Includes Nov / Dec 2020 monthly sections

Ken Wallace
Glenn Dawes
Peter Northfield

YOUR GUIDE TO THE NIGHT SKY

CALENDAR 2021

JANUARY

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ASTRONOMY 2021
AUSTRALIA



Glenn Dawes Peter Northfield Ken Wallace

Quasar Publishing 2020

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Illustrations

Front cover is a Hubble image portraying the giant red nebula (NGC 2014) and its smaller blue neighbour (NGC 2020), part of a vast star-forming region in the Large Magellanic Cloud. The image is nicknamed the 'Cosmic Reef' (NASA, ESA and STScI).

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p. 10	MRO HiRISE image of dunes (NASA/JPL-Caltech/University of Arizona)
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Inside front and back covers: Hubble Ultra Deep Field in Fornax. Credit: NASA, ESA, S. Beckwith (STScI) and the HUDF Team.

Rear cover: Meteor 20 Jan 2018 12:38 am Canon 5D Mark IV with Sigma 14 mm f/1.8 DG HSM lens 20 seconds at ISO 3200 (Greg Priestly).

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INTRODUCTION TO THE 2021 EDITION

Welcome to Astronomy 2021, thirty one years in the making—time flies!

This year we are pleased to highlight the work of the renowned Australian astrophotographer, Martin Pugh. Martin's spectacular deep sky images have many times graced the well known NASA APOD site (Astronomy Picture of the Day) and he has won many local and international awards and competitions.

This yearbook contains its regular information, including our monthly features covering the usual diverse range of interests, which include:

- Observing meteors.
- Milky Way supernovae—a very small catalogue!
- Our cover story, an image celebrating the Hubble Telescope's thirtieth anniversary.
- An easy binocular variable star for beginners.
- Ancient legends, common to many constellations

As introduced last year, we have included monthly information for November and December of the previous year.

Part I of Astronomy 2021 is intended as a general quick reference to observing the Solar System. This section is ideal for those just starting to navigate the heavens. The All Sky Maps cover the entire Southern Hemisphere sky in nine easy to use charts.

Part II leans more heavily towards the needs of the seasoned amateur. Included this year are Jupiter moon's mutual events.

Part III, the appendices, include sections on the constellations, bright stars, places of interest, amateur societies and a glossary to explain some of the unavoidable jargon. You can also visit our website where you will find links to all of the sites listed in Part III of this book and other supplementary information.

www.quasarastronomy.com.au

Note: The various organisations listed in Part III may be affected by pandemic restrictions. See their websites or contact them for details.

You may find some data from Part II, previously published in the yearbook, now missing. This was a step taken in 2020 to remove information that today is either well catered for in modern day apps and planetarium programs or made redundant given the technology in today's telescopes. One feature that has returned by popular demand are the lunar occultation pages. If you can't find a feature it is likely now available to download from our website.

Stop and Smell the Roses

In recent times we have learned how the Martians felt in War of the Worlds when brought to their knees by the bacteria of Earth. Unfortunately our education isn't based on fiction. Instead, it was a viral nemesis that introduced a five letter word to the vocabulary of every person on Earth—COVID! At the time of writing, Australia seemed to have escaped much of the horrendous death toll seen overseas, but a second, more deadly outbreak in Victoria as well as 'spot fires' elsewhere, leaves an ongoing uneasy feeling. Given all this, you may be surprised to learn telescope sales are booming! Although it is true many people have returned to hobbies, which can be explained by suddenly having more time on their hands, purchasing a decent telescope however, is a significant investment. Despite living in the most uncertain time since World War II and not knowing whether we'll have a job tomorrow, has it taken a pandemic for people to realise there is more to life than just making enough money to survive? Metaphorically speaking, has the ape man who, more than ever, should be huddled around his fire at night jumping at every rustle in the bushes, dared to lift his eyes and gaze at the stars?

As long as NASA, other space agencies and research institutions are still pushing forward their exploration of the Universe, humans are not always rushing back to the fire and there is hope for the future.

To all our readers, stay well and keep stargazing!

Glenn Dawes Peter Northfield Ken Wallace

NOTE. As we stated above, some lesser used data, published in previous years can be downloaded from our website. Search 'Quasar Publishing' or go to. www.quasarastronomy.com.au

NAKED-EYE STARGAZING

A Fun Pastime for Beginners

Do you find the night sky fascinating? However, when looking up at the stars do they also seem incomprehensible; far removed from the real world that you know? Despite this do you still feel drawn to it, as people have been for thousands of years? Like the ancients, you are using the only equipment they had, the naked eye. In the whole of human history it has only been in the last 400 years that we've had anything better. Unlike those early people, in addition to optical aids, you have available a wealth of knowledge. For example, we don't need to rely on the appearance of certain stars to know when to plant crops any more. We no longer fear the appearance of eclipses or comets. Some ancient astrologers were expected to predict such bad omens under the threat of death! Much of our early interest in the heavens was certainly driven by superstition. Look at how many constellation names are based on Greek and Roman mythology. We do have a little fun in this book occasionally injecting these stories. Things are so much easier now, the ultimate ego driven mindset that the Earth was the centre of the Universe has long died (hang on, doesn't everything revolve around us?)

Putting all this aside, if you are a beginner and approach stargazing as a chance for a little fun and are willing to learn, but not in a hurry to buy a telescope or even binoculars, you have the right attitude. Many people even struggle to understand the difference between the Sun, stars, planets or even galaxies. As long as your sense of wonder remains, the knowledge will come when there is a need to know. We hope this book will help satiate some of this hunger as it arises.

As a general guide to using this book, when we refer to observing in a particular time of the year, e.g., summer, we are talking about the appearance of the evening sky during that season, the most convenient time to look. In reality most of the night sky is available any night (especially in winter), provided you are willing to stay up until dawn. Playing with a planisphere illustrates this quite well. An example is shown on page 9.

A FEW TIPS FOR BEGINNERS

Red light torch. The easiest way to make a red light source (to preserve your night vision) is to cover the front of a torch with several layers of red cellophane, held in place with a rubber band. If you wish to free up your hands, the same can be done with a headlamp. However, they can become annoying when trying to look through an eyepiece.

Compass Bearings. One way to learn the night sky is to start with the more obvious constellations. These stand out well on planispheres, having the main compass bearings marked around the horizon, but how do you relate this to your actual horizon? There are free compass apps available, so just point your phone. Also, taking note of where the Sun sets to get a rough direction for west might help. Remember, shadows point south at midday. Other useful resources are maps or street directories, which are conveniently drawn with north towards the top of the page.

Astronomical Apps. Planetarium Apps have become popular with smart phones and tablets—brilliant! Some are even interactive, identifying the stars, planets and constellations as you move the device around the sky. All this is offered using red light to supposedly preserve your dark adaption. This sounds good but they can't avoid being backlit, which under these low light levels are blinding. We suggest using these devices to help plan your night, then, under the stars use this book, maps or planisphere with a red light torch.

Location. Take a little time to plan where you will observe. There is much to consider. Possibly the most important is security, do you feel safe there? Being in mobile phone range is a nice bonus. Ensure there are no obvious sources of nearby lighting (e.g., roads, security lights). Having a low horizon is good but does it leave you exposed to strong wind, such as on hilltops? If you are low or near water, is fog a concern?

The Attraction of Dark Skies

Observing with the naked eye from the Southern Hemisphere offers much more than northern astronomers had before the invention of the telescope. This is especially the case if you head into the country to escape the bright urban skies on a moonless night. The ancients were very much stuck in mid-latitude Northern Hemisphere locations, with all of the earliest recorded observations coming from Europe, England, the Middle East or Asia. These locations see the bright centre of the Milky Way low in the south in summer, whereas from Australia it passes directly overhead in our autumn and winter evening skies, also a time of the year when the long nights give us *down under* more time to spend soaking up this panorama. The structure of the Milky Way is more appreciated by the wide-angle views available to the unaided eye. With us immersed in the flattened, circular disc of our galaxy we see it edge-on, hence the *river* that flows across the sky. The Sun is around halfway out from the galactic centre, which lies roughly in the direction of the spout star of Sagittarius' Teapot (see All Sky Map No. 6 or 8). Looking with just the eyes two things become apparent. First, how wide this central *milky* area (called the hub) appears with our galaxy tapering and fading out as you follow it towards the opposite end of the sky, around Orion (which is setting early in autumn evenings). Second, the numerous dark lanes that crisscross the Milky Way in this hub. Both aspects are ideal for naked-eye observers. There are other impressive regions in our galaxy quite attractive to the unaided eye such as the number of bright star clouds and clusters also around the centre. Another is the brilliant section from the Southern Cross around to the star-rich Carina nebulae region, which contrasts well with the adjacent dark Coalsack Nebula (All Sky Map No. 1).

Leaving winter and our galaxy, the Southern Hemisphere summer evenings offer the unique Magellanic Clouds. These are smaller galaxies passing nearby, which appear like detached portions of the Milky Way. They are easy to spot under dark skies, as normal clouds look black whereas the Large and Small Magellanic Clouds (LMC and SMC) appear white from the accumulated effect of countless stars (like the *milkiness* of our galaxy). Even the unaided eye can see the prominent bar in the LMC.

Low in the spring northern evening sky lies another member of our local group of galaxies, the Andromeda Galaxy (M31). It has the distinction of being the most distant object easily visible to the unaided eye. Knowing M31 has a similar

structure to the Milky Way and that it appears as a squashed oval, shows we are seeing it nearly edge-on. This year's constellation section in Part I concentrates on bright objects that make up the southern Milky Way.

Dark skies also offer the opportunity to try and see the planet Uranus with the unaided eye. The All Sky Map No. 3 (p. 87) and finder chart (p. 132) will help find this elusive distant member of the Solar System. Also, occasionally the minor planet Vesta can brighten sufficiently to be visible with the naked eye, as it did in 2018.

You can always go on a voyage of discovery. There is a good chance any fuzzy object (unless it is a comet) will be marked on the All Sky Maps (see pp. 84–93).

With any of the naked-eye challenges mentioned in this section, binoculars are very handy and open up a whole new perspective on the night sky (see next page).

DISTANCES ARE TRULY ASTRONOMICAL!

Sometimes the word astronomical is used to describe something that is excessive or exorbitant and that sums up pretty well the scale of the Universe. As someone once said, space is well named because there is a lot of it! We have found that this is one aspect of astronomy that can turn people off—they simply can't relate to its size.

The light-year is defined as the distance light travels in a year. To convert this to a more human scale it is approximately 9,500,000,000,000 kilometres. It's not just your calculator that goes into overflow but your mind as well! Even the eight minutes needed for light to come to Earth from the Sun feels strange when compared to flicking a switch at home and seeing the room instantly illuminated.

The light-year to an astronomer is just a convenient tool. The same can be said for the main source of our astronomical knowledge, light. Is its wavelength any more understandable? The blue part of the visible spectrum is around 450 nanometres or 0.000000450 metres! The best advice is to accept both extremes and move on.

Returning to the speed of light, let's use it to get an idea of the scale of the Universe, well … our small end.

The distance to:

- The Moon, a little over 1 light second.
- The Sun a little over 8 light minutes.
- The average distance to Neptune from the Sun, about 4 light hours (remember this encloses all the currently accepted planets).
- The nearest star, the Alpha Centauri system, just over 4 light-years (ly).
- The brightest star, Sirius 8.6 ly
- Two nearby open star clusters, the Hyades (the face of Taurus the Bull) about 150 ly and the Pleiades is 430 ly.
- Two of the closest globular clusters, M4 in Scorpius is 6,800 ly and NGC 6397 in Pavo is 7,500 ly
- The centre of the Milky Way around 25,000 ly (our galaxy's main disc is around 120,000 ly across)
- The Magellanic Clouds, Large (LMC) is 165,000 ly and Small (SMC) is 200,000 ly.
- The most distant object visible to the naked eye, the Andromeda Galaxy 2,500,000 ly!

Suburban Skies offer much as well!

If you find it hard to escape the city lights there is still a lot to enjoy. Seeing only a few hundred of the brightest stars can make it easier to learn the major constellations. The many stars visible from the country, certainly more than those shown on the All Sky Maps, can swamp distinctive star patterns making them more difficult to find.

Whether your skies are dark or flooded by light pollution, it is still important to try and maintain dark adaption for your eyes. This makes reading star charts and making notes under red light important (see sidebar, A Few Tips for Beginners, p. 5). As part of this, avoid any direct lighting, even if it means sacrificing some horizon by hiding behind your home or fence. If you have the annoying neighbour with a constant backyard light on, invite them over to view the sky. Trying to see past their floodlight might give them the message.

Light polluted skies don't prevent you from easily following the five naked-eye planets, Mercury, Venus, Mars, Jupiter and Saturn. The retrograde loops of the outer planets can be fascinating to follow over a number of months. It makes you appreciate why they were called *aster planetes* (from the Greek meaning wandering star) as they continued to disturb the otherwise reliable fixed heavenly pattern.

Venus is so bright it can be seen in daylight! You need to know precisely where it is and this is where binoculars will help to find it. It's critical to have your eyes focused correctly, which can be difficult in a featureless blue sky. Having the Moon nearby helps address both issues. For your comfort and safety, if observing in daylight we always recommend that you hide the Sun behind a tree or building.

When two celestial bodies are close together it's called a conjunction. They can be quite attractive, especially those involving the brightest planets. Conjunctions between the thin crescent Moon and Venus or Jupiter are spectacular. An example this year is the meeting between all three in the dawn sky on February 11 (see Sky View, p. 34).

Although not covered in the book, it's also fun looking for Earth orbiting satellites. Remember these don't generate any light themselves, they need to reflect sunlight to be visible. Look for low Earth orbiting satellites up to three hours after sunset or before sunrise where they can still *see* the Sun. Look out for those that slowly appear or disappear for no obvious reason, they have likely moved out of, or into, the Earth's shadow. For evening events the shadow rises slowly from the eastern horizon and for mornings drops slowly in the west. The most famous current examples are the International Space Station (ISS) and the Hubble Space Telescope (HST). The Heavens Above website (www.heavens-above.com) will allow you to generate predictions for visibility of these and other satellites for your location. There are also Apps for tablets and smart phones that do the same.

Meteors or shooting stars. These streaks or fireballs occur when particles burn up in the Earth's atmosphere. Most range from about the size of a grain of sand up to a few millimetres (pea size) and are called meteoroids when in space. Those that survive to hit the ground are called meteorites. Around a half dozen meteors per hour can be seen under dark skies, with a tendency for more after midnight. These are the sporadics. Meteors also occur in annual *showers*. This happens when

a sudden increase in number are seen around the same time each year as the Earth passes through or near ancient debris trails left by passing comets. Part I discusses the favourable ones visible this year; also see the introduction on page 9 and page 140 for a list of showers.

A WORD ABOUT BINOCULARS

Probably the most cost-effective accessory for the beginner are binoculars. A reasonable quality pair can be purchased for the same price as a cheap, sub-standard telescope. Binoculars can also be useful for mum and dad, especially if their budding junior astronomer loses interest. They can at least be used for more terrestrial pursuits. Such an investment can be a relatively low cost way of gauging your child's level of interest. We suggest that they should be purchased from a reputable optics or telescope dealer. These people understand the quality required for stargazing. To observe detail on the Moon or to look for Jupiter's moons, avoid just holding them in your hands. Try bracing yourself on something like the arms of a chair, a fence or the roof of a car. Telescope dealers can also assist with mounts to hold the binoculars steady. There are also brackets designed to attach binoculars to a camera tripod. This is probably the cheapest option, especially if you already have a tripod. Keeping the binoculars steady is important if the power of the binoculars is more than 10×. A power of 7× is a reasonable compromise. It can give a good field of view with adequate magnification to glimpse some of the moons of Jupiter. The size of the aperture normally comes down to what is comfortable for a person to hold in the hand and the budget; 7 × 50 binoculars (7 times magnification, 50 mm diameter objective lens) are fairly popular with amateurs.

For the novice, finding your way around the sky is far easier with binoculars than with a telescope. Using a telescope is a bit like looking at the sky through a straw and the view is usually upside down and sometimes mirror-imaged! Even when using low power in a typical amateur telescope, the field of view is only about one degree (maximum). A pair of 7 × 50 binoculars can give a field about seven degrees in diameter (roughly the size of the Southern Cross), or if you like, 40 to 50 times the area visible through a small telescope. It is not unusual for the general public to ask when looking through a telescope, "where in the sky is that?" Looking at the star field doesn't make the location obvious. Having a larger field will help with knowing where you are looking. The field size in degrees is normally marked on the binoculars. To get a feel for how that translates to the sky, look at the Sky View diagrams. Each has a 10° scale marked on it.

Even with binoculars you still need to practice pointing the instrument. There is a tendency to look too low, so if you don't see what you are after, the first thing to try is to tilt the binoculars up. One method that may help is to find an obvious nearby bright star, or better still, a bright star pattern (called an asterism) and star hop across. If your object isn't too high in the sky you can try finding something on the horizon directly under it, like a distinctive tree outline, and move the binoculars up. Another method, that might take a little getting used to, is to stare intently at the area of the sky with your unaided eyes and then move the binoculars into place without moving your eyes. Practice on bright stars first until you are comfortable. Talking of comfort, plan your observing, as it can be very difficult to look directly overhead, especially if the

USES FOR BINOCULARS

There are a multitude of uses for binoculars in amateur astronomy. These include:

- Helping to find stars and planets in a bright twilight sky.
- Looking at the maria (seas), larger craters and rays on the Moon.
- Looking for fainter stars marked in star atlases or on the Sky Views, All Sky Maps and finder charts in this publication
- Binoculars can help in bright, light polluted skies.
- Looking for stars dimmed by the nearby Moon.
- The colours of the stars and planets are more obvious through binoculars. Check out the red colour of Mars, Aldebaran, Betelgeuse and Antares. Contrast the yellow of Alpha (α) Centauri with the blue of Beta (β) Centauri.
- Stars and planets close to the horizon.
- Looking for artificial satellites in the early evening sky. You might find them with the naked eye, but binoculars will help; sometimes they vary in brightness as they tumble. You can follow them further into the Earth's shadow before disappearing.
- Searching out Uranus and Neptune, using the finder charts, see page 132 and All Sky Maps 3 and 8.
- Observing bright comets.
- Looking at bright, wide double stars.
- Observing the moons of Jupiter as they oscillate across and behind the planet from night to night, see the diagrams on pages 121 to 127. The magnification of the binoculars will dictate how close to Jupiter you can see these satellites.
- Some of the bright deep sky objects such as star clusters, Milky Way regions, and the Magellanic Clouds. The galaxies M33 in Triangulum and NGC 253 in Sculptor are worth going after as well. Most Messier objects, marked as 'M__' on the All Sky Maps, are visible in binoculars. The galaxies may need a small telescope.
- Looking for some of the brighter minor planets near opposition. A good exercise is to sketch the field a couple of times a few days apart to see which *star* has moved. Taking the coordinates of a minor planet from Part II, and plotting that position on the All Sky Maps, will help you find the correct area.
- Monitoring the change in magnitude of some of the brighter variable stars (see page 26). There are also a number of organisations that can help with finder charts and predictions. Start with your local astronomical society (p. 150) or organisations such as Variable Stars South www.variablestarssouth.org or AAVSO www.aavso.org.

A lot of the above can be done from a typical suburban backyard. It is not always necessary to drive for hours to reach dark skies.

binoculars are mounted on a tripod. This is where sitting back in a reclining chair and hand-holding the binoculars makes it easier. If your seat doesn't recline, try leaning the tripod on two legs or use a monopod.

Also, it is worth remembering that binoculars are prone to dewing just like a telescope. A couple of cardboard tubes on the front, sticking out about 7 cm, can help prevent moisture forming on the front lens and also minimise stray light. If you do strike dew, place the binoculars in a warm environment for a short time until they clear.

Taking your binoculars out under dark country skies at some stage is a must. It has been said that one of the joys of the Milky Way's companion galaxies, the Magellanic Clouds, is that they show as much detail through a moderate size amateur telescope as that seen by large professional telescopes looking at distant galaxies outside our Local Group. This argument can be extended to our own Milky Way, but in this case the humble binoculars are sufficient. The wide field of binoculars is ideal to show detail in the complex dark lanes and star clouds running through our galaxy, especially around the central galactic hub region in Sagittarius. Some of these dark rifts and star cluster regions are sometimes barely visible to the unaided eye but quite obvious through binoculars. Their wide fields can also show some larger open star clusters such as the Beehive (M44) and the Pleiades (M45) better than they look through the narrow field of view of a telescope.

USING THIS BOOK

One purpose of this book is to help you plan your nights under the stars. Think of it as offering a number of pieces of a picture, the nature of which will vary greatly depending on whether you are using binoculars, a telescope or just your eyes. Such an exercise can be fun, so let's go! Each section of the book has its own introductory pages; following are examples of how to tie them together.

The Moon. The phase of the Moon is a good place to start, the inside front cover will help. Unless you wish to view our natural satellite, or just the planets, New Moon is favoured by most observers, preferring long nights with their skies as dark as possible. Up to First Quarter the morning sky is Moon free as are evenings after Last Quarter. The Rise–Set chart on the first page of each monthly section, helps further define the 'Moon observing' and 'dark' windows. More specific times, on a day-by-day basis for each of the Australian capitals, are presented in Part II (starting page 104).

Observing the Moon (pp. 108–111). Viewing the terminator, the sunrise/sunset line on the Moon, makes our satellite come alive as the crater walls and mountains cast shadows across the surface. Lunar observers love the daily change with something different offered every night. This section helps identify the features on the terminator as the Moon waxes and wanes. Possibly the most unpopular time is Full Moon which presents an overly bright, flat picture which lights up the sky drowning out any nebulous objects, including the most attractive galaxy of all, the Milky Way!

Optimum times for **librations** are presented in the monthly sections, allowing the observer to glimpse features, normally out of sight, that temporarily appear on the limb as our satellite, from our perspective, wobbles in its orbit.

The Planets. Mercury, Venus, Mars, Jupiter and Saturn are naked-eye objects with Uranus and Neptune requiring at least binoculars. To get a quick overview of what is on offer tonight start with the **Visibility of the Planets** (p. 17). As an example we'll use mid-July. Jupiter, Saturn, Neptune, Uranus and Mercury are visible in the morning sky with Mars and Venus in the evening. You will notice that Saturn is approaching the midnight line (with Jupiter not far behind) and likely to be close to opposition and up the whole night, as shown in the July monthly Rise–Set chart. The next month (August section) confirms Saturn and Jupiter are at opposition on the 2nd and 20th respectively.

The **Appearance of the Planets** diagram (first page on each monthly section) gives the relative size and phase (where relevant) for the planets.

It is fascinating to watch **Mercury** in particular as it quickly zips around the Sun. At superior conjunction, behind the Sun and out of sight (e.g. August 1) this inner world is small with a full phase. It then enters the evening sky growing in size with its phase waning as it approaches inferior conjunction (between us and the Sun) on October 10. Mercury then enters the morning sky and the process reverses until superior conjunction is reached again (November 29). It is best to observe this innermost world around times of maximum elongation (conjunctions are too close to the solar glare). This is the time of greatest angular distance from the Sun and greatest height in the sky, for example Mercury in the evening sky on September 14 (eastern elongation). See its high altitude while in conjunction with the Moon on September 9 as it approaches this maximum elongation (Sky View page 69).

Its fellow inner world **Venus** goes through the same process as Mercury but much slower, being further from the Sun. In 2021 a superior conjunction occurs on Mar 26. It slowly rises in the western evening sky reaching a greatest elongation east on October 30, when it then commences to drop back towards Sol to an inferior conjunction early in 2022. All this time it grows in size with its phase waning. This can be followed in the monthly appearance diagrams.

Mars only achieves a reasonable size when near opposition, a time when features such as a polar ice cap and various surface marking are easier to see. Unfortunately this year is not favourable having just come off an opposition in October 2020. The year opens with its disc around 10 arcseconds in diameter which then shrinks steadily. Besides the polar caps possibly visible, its surface will likely remain featureless.

Jupiter, like any of the outer planets, is best observed when the planet transits the meridian (is due north). The ideal time is near opposition when the widest observing window is available with the planet transiting around midnight. The Rise–Set chart (page 60) confirms that this happens for Jupiter in August in 2021 (or from the Visibility of the Planets, page 17). Besides observing its atmospheric belts, the **Great Red Spot (GRS)** is worth looking for; see the table and explanation on pages 118 to 119. An example is the evening of August 15 around 10 pm (EST), a transit that is visible from anywhere in Australia.

Pages 117 and 120–127 cover the **Jovian Satellite Phenomena** as the four major moons shuttle back and forth, crossing in front of and passing behind the planet. They can

look quite attractive when all four are gathered on the same side. Looking on the evening of August 28, the diagram on page 125 shows this well. In this case there is also a drawing on page 64. The *wiggly* diagrams also indicate events are occurring when a moon's line crosses Jupiter. For example on August 15 the evening sees a transit of Callisto start. The next morning (16th, EST) sees a transit of Ganymede commence followed by a transit of Europa (see pages 124 and 125)—overall a busy night!

Saturn, with its impressive ring system (still reasonably open this year) is spectacular in any telescope. It has six moons that are considered observable in amateur equipment; however, they are much fainter than the Jovian satellites. Even *bright* Titan is a lot dimmer. Pages 128 to 129 show a worked example of how to identify their configuration for your date and time. There are also Sky Views in August and September giving illustrations of some actual configurations.

Uranus and **Neptune** can be challenging but are still considered visible in binoculars provided you know where to look. That is why the separate finder charts (p. 132) are needed for these distant planets. To identify four of Uranus' moons and Neptune's Triton, a similar calculation to Saturn is used, see page 131.

Minor Bodies of the Solar System

The monthly sections give dates for opposition of the brighter **minor and dwarf planets**. Observing notes are also presented for prominent **comets**. Positions in the sky of the brightest minor planets and comets are presented on pages 139 and 136–138 respectively. These can be plotted on the All Sky Maps. As an example we'll look at 15 Eunomia on its opposition date. The January monthly text (p. 28) has the minor planet reaching opposition on the 21st at magnitude 8.4 in Cancer. Page 141 tells you Cancer is on All Sky Maps No 4 and 5. The ephemerides (page 139) when plotted on Map 8 gives the location on this date about 2° south-west of star Tegmine (Zeta (ζ) Cancri), moving towards Canis Minor.

Let's assume it's the evening of October 12 and you wish to find Comet 4P/Faye. Part I text (page 72) says the comet "… *is visible in October's morning skies, rising in the late evening. Shining at 10th magnitude, the comet begins the month in Orion, moving into Gemini mid-month*". The Rise–Set chart and Moon section for October, shows the Moon is at First Quarter and setting around midnight, so the morning is great for dark sky observing. The table on page 135 shows Faye to be a month past perihelion (which was September 9) and the ephemerides (page 137) confirms it is close to maximum brightness, rising around 11:30 pm. Carrying out the same exercise, with its position (RA and Dec), like the minor planet (above) Map No 5 is needed. Interpolating between October 9 and 16 the comet looks to be around halfway between Xi (ξ) Orionis and Alhena (Gamma (γ) Geminorum).

Meteors (Shooting Stars). The Part I text gives the best meteor showers for the year suited for Australian latitudes highlighting those that at the time of expected peak activity have dark skies (Moon free). Watching for meteors can be fun at any time. So, when taking a coffee break, sit back and relax. Who knows when an impressive fireball might light up the sky? If you don't go to sleep, you may be the only person to see it. Awesome!

Also available via Quasar

AUSTRALIAN SKY & TELESCOPE

Australian Sky & Telescope is a world-class magazine about the science and hobby of astronomy. Combining the formidable worldwide resources of its venerable parent magazine with the talents of the best science writers and photographers in Australia, the magazine is produced specifically for Southern Hemisphere astronomers. Cost (August 2020) is $59 for one year (6 issues), $110 for two years (12 issues).

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PLANISPHERE

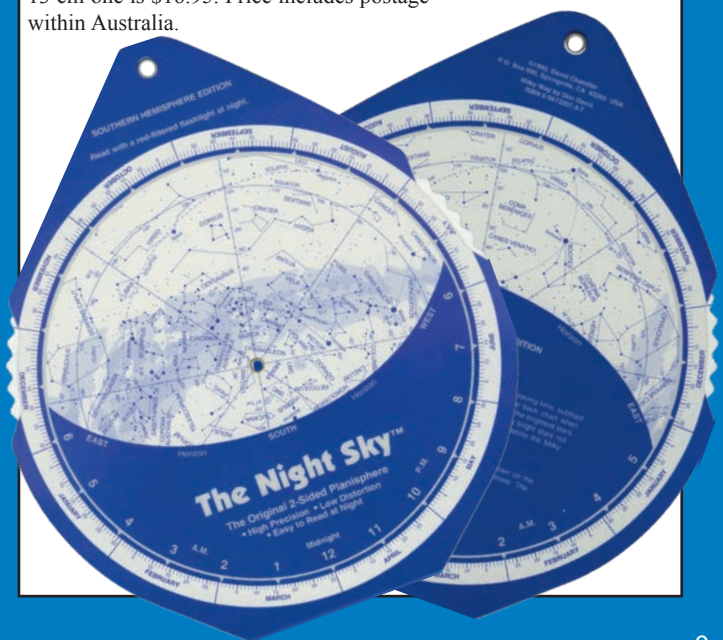
A planisphere makes a great companion to our book. It is a hand-held aid used to identify which stars and constellations are visible on any particular date and time.

Designed for the Southern Hemisphere, the Night Sky planisphere is printed with dark stars on a light background for easy night time readability. The constellations are drawn simply, emphasising the brighter stars. A selection of deep sky objects for binocular viewing is included.

The map scale is larger than on similar sized planispheres because the whole sky does not have to be shown on a single map. The Night Sky's design corrects for distortion of the constellations around the horizon, inherent on single sided planispheres. Its plastic construction makes it durable and moisture resistant.

Using this planisphere is easy. Just turn the disc so the date lines up with the time and it will show you what the sky looks like then. It's that simple!

They come in two sizes: the large 22 cm version is $29.95, the small 13 cm one is $16.95. Price includes postage within Australia.



Probing the Solar System

SUN

In September 2020, the **Parker Solar Probe,** orbiting the Sun, survived its sixth perihelion passage, now down to 13.4 million km (Mkm). During 2021 it will have two flybys of Venus and four close approaches to the Sun, one at 13.4 Mkm, two at 10.4 Mkm and one in November down to 8 Mkm.
www.nasa.gov/content/goddard/parker-solar-probe

ESA Solar Orbiter was launched in February 2020 on a mission dedicated to solar and heliospheric physics and will orbit the Sun between 42 and 150 Mkm. In addition, over the next seven years it will use Venus gravity assists to increase the inclination of the orbit up to 28° allowing observations of the polar area of the Sun. sci.esa.int/web/solar-orbiter

MOON

Lunar Reconnaissance Orbiter has been observing the Moon from its polar orbit since 2009. The data is adding to highly accurate 3D maps, long term study of radiation and examining the mineralogy of the lunar surface.
www.nasa.gov/mission_pages/LRO/main/index.html

MERCURY

BepiColombo, a joint Europe-Japan mission launched in 2018, is still on track for arrival at Mercury in December 2025 for a one year plus mission orbiting the inner planet.
www.stp.isas.jaxa.jp/mercury/p_bepi.html

VENUS

Akatsuki, also known as the Venus Climate Orbiter (VCO), is a Japanese space probe studying the atmosphere of Venus.
global.jaxa.jp/projects/sas/planet_c/

MARS

InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) has been on Mars since November 2018 to study its deep interior. The heat sensing spike, designed to dig down as much as five metres, stopped at about 40 cm. JPL is working on plans to help.
insight.jpl.nasa.gov/home.cfm

Mars Express continues to observe as it has been doing for over 16 years. www.esa.int/esaMI/Mars_Express/

The **Mars Atmosphere and Volatile EvolutioN** (MAVEN) orbiter has collected data during the last two years that allows the creation of a map of wind circulation in the upper atmosphere of Mars. This helps us better understand the workings of the Martian climate.
www.nasa.gov/mission_pages/maven/

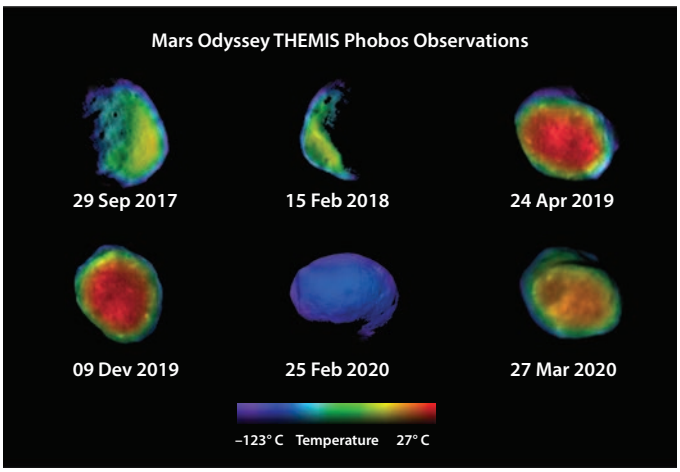
Mars 2020 launched 30 July 2020 and will be landing in Jezaro Crater on Mars 18 February 2021. Based on Curiosity's configuration, it is about 3 m long, 2.7 m wide and 2.2 m tall.
mars.nasa.gov/mars2020/

ExoMars 2022 is a mission to deliver a European rover and a Russian surface platform to Mars. Originally scheduled for July/August 2020, it will now wait until late 2022 for launch.
exploration.esa.int/mars/48088-mission-overview/

On 23 July 2020, the Chinese launched a mission called **Tianwen-1** to Mars. Consisting of an orbiter, lander and rover, it is planned to arrive at Mars in February 2021. It will orbit for a couple of months before attempting the landing at Utopia Planitia, where Viking 2 landed over 40 years ago.

ExoMars Trace Gas Orbiter (TGO) achieved its final 400 km circular orbit in April 2018. After a full Martian year, TGO has now spotted never-before-seen signatures of ozone and carbon dioxide. While both are known (most of Mars's atmosphere is CO_2) what is unusual is where on the electromagnetic spectrum they were found, over the exact wavelength range where they expected to see the strongest signs of methane.
exploration.esa.int/mars/46475-trace-gas-orbiter/

Mars Odyssey, now in its 20th year of operation, continues to be the longest serving of the Martian missions. Three infrared images (19 December, 20 February and 20 March) show the temperature variation of Phobos as it moves in and out of Mars' shadow. mars.jpl.nasa.gov/odyssey/



Mars Reconnaissance Orbiter, now operating for nearly 15 years, continues to compile the most global coverage ever accomplished by a camera at the Red Planet. Data from MRO (as well as Mars Odyssey) has been used to compile a map of likely ice deposits close to the surface which will help determine landing points for future missions.
mars.jpl.nasa.gov/mro/



MRO HiRISE camera captured these sand ripples and the large dune (at centre) on 9 Feb 2009 in Proctor Crater (47.8° S, 30.7° E). Colour has been added to make textures easier to see. Credit NASA/JPL-Caltech/ University of Arizona



Curiosity rover captured its highest-resolution panorama yet of the Martian surface between 24 November and 3 December 2019. Credit NASA/JPL-Caltech/MSSS

Curiosity has now been exploring Mars for over eight years. After more than a year in a clay bearing area, it is making a 1.6 km journey around some deep sand so that it can explore higher up Mount Sharp. mars.jpl.nasa.gov/msl/

The United Arab Emirates (UAE) launched a Mars mission called **Al Amal** (Hope) on 20 July 2020 from Japan. The probe is designed to orbit Mars and study the dynamics in the Martian atmosphere on a global scale, on both diurnal and seasonal time scales. It will arrive at Mars in February 2021. www.emiratesmarsmission.ae

JUPITER

The **Juno** mission continues to orbit Jupiter with close flybuys every 53 days. Recent results from Juno suggest Jupiter is home to what's called 'shallow lightning'. An unexpected form of electrical discharge, this originates from clouds containing an ammonia-water solution, whereas lightning on Earth originates from water clouds. Other new findings suggest the violent thunderstorms for which the gas giant is known may form slushy ammonia-rich hailstones, that Juno's science team calls 'mushballs'; they theorise that mushballs essentially kidnap ammonia and water in the upper atmosphere and carry them into the depths of Jupiter's atmosphere. www.nasa.gov/juno/

MINOR PLANETS

The **OSIRIS-REx** (Origins Spectral Interpretation Resource Identification Security-Regolith Explorer) spacecraft is currently orbiting near-Earth asteroid Bennu. The sample collection attempt is scheduled for 20 October 2020. It will briefly touch Bennu to collect a small sample to return to Earth for study. Planned arrival on Earth with the sample is September 2023. www.nasa.gov/osiris-rex

Hayabusa 2 is on its way back to Earth with samples from asteroid Ryugu. Arrival is scheduled for 6 December 2020 with the sample return capsule parachuting down to Woomera SA. global.jaxa.jp/projects/sat/hayabusa2

ASTRO GALLERY — Martin Pugh

Martin's interest in astronomy coincided with the overwhelming appearance of Comet Hale Bopp in 1997. However, he did not purchase his first telescope and specialist camera until 1999. Inspired by the handful of amateur astrophotographers around at the time, learning and practicing this art form continued over the next few years until the next major equipment upgrade occurred in 2004; just prior to emigrating to Australia.

Then, under dark skies and with his own roll-off roof observatory at his rural property in Yass, astrophotography began in earnest. Martin was able to put all of the theory into practice and secured his first NASA Astronomy Picture of the Day (APOD) on 1 Jun 2006. Since then, Martin has secured 55 APODs (3 collaboratively and 4 using Hubble Legacy Archive data). In addition, he has been placed in the following competitions:

- 2008: South Pacific Star Party – Winner
- 2008: The David Malin Awards – Deep Sky and overall competition winner.
- 2009: Astronomy Photographer of Year (Royal Observatory Greenwich) – Deep Sky and overall competition winner.
- 2010: Astronomy Photographer of Year (Royal Observatory Greenwich) – Runner-up, Deep Sky.
- 2011: The David Malin Awards – Deep Sky winner.
- 2012: Astronomy Photographer of the Year (Royal Observatory Greenwich) – Deep Sky and overall competition winner.
- 2013: The David Malin Awards – Deep Sky and overall competition winner.

Furthermore, his images have appeared in many science publications, magazines, and videos all over the world and more recently one of his images was also used to create the special effects in the blockbuster movie 'Interstellar'.

There are also a few 'crowning moments' of note, particularly:

- The release of a 3-stamp collectors set by Australia Post, to mark the 2009 International Year of Astronomy, which featured Martin's image of M78.
- Recognition and placement in the SBIG Hall of Fame.
- Placement of two images (M27 and IC434) in 'Starstruck' The Art of Astrophotography exhibition (Bates College Museum of Art).

After 39 years of Naval Service, Martin has now retired and established his own remote imaging, data subscription and telescope hosting business from his home in rural Australia.

On the following pages we have some samples of his work. Taken on a Planewave 17" CDK with an SBIG STXL 11002 with AOX (except M13 with an Apogee U16M) and Astrodon filters. Exposures:

M13 9 hours (RGB 3:3:3)
M83 26 hours (HaLRGB 4:7:5:5:5)
IC 2220 40.7 hours (HaLRGB 21:5.7:5:5:4)
NGC 2736 14 hours (Ha OIII 7:7)
NGC 1097 34.5 hours (HaLRGB 5.5:14:5:5:5)
NGC 3532 6 hours (HaRGB 1.5:1.5:1.5:1.5)
NGC 253 25 hours (HaLRGB 3:7:5:5:5)
ETA Carinae 12 hours (Ha SII OIII), no RGB.

You can see more work on his website at:
www.martinpughastrophotography.space



M13 in Hercules



M83 in Hydra



IC 2220
(Toby Jug Nebula) in
Carina

NGC 2736 (Pencil Nebula)
in Vela



ASTRO GALLERY

—

Martin Pugh



NGC 1097
in Fornax



NGC 3532 in Carina
(top right)





NGC 253 (Silver Dollar Galaxy)
in Sculptor



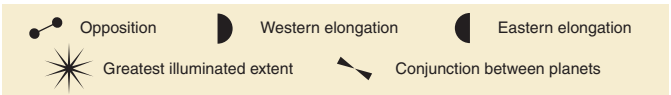
NGC 3372 (Eta
Carinae Nebula)

THE MONTHLY SECTIONS

Each monthly chapter in Part I contains the following:

Rise–Set Chart

This enables you to quickly determine when (or if) a planet or the Moon is visible in the night sky for any day in that month. Each chart has the midnight line centred, with the evening sky below this line and the following morning sky above. The ideal time to observe an outer planet is at the time of transit (represented by dashed lines), which is when it is due north and has reached its maximum altitude. A number of events during the year have been shown with symbols.



These charts give approximate local standard time not taking into account daylight saving (if in force, add one hour).

Highlights

This lists a few interesting events during the month.

Constellations

This is a general discussion on the constellations and stars visible during the month, concentrating on the evenings when most people are out gazing at the night sky. This year we look closely at what makes the south celestial sphere so attractive. Each month a constellation or area of the sky is presented, discussing the brightest deep sky objects. Emphasis is given to the southern Milky Way stretching from Ophiuchus around to Canis Major. In November and December we move away from the plane of our galaxy, concentrating on the unique Clouds of Magellan and some other extragalactic treats.

Appearance of the Planets

This diagram provides the reader with a telescopic view of each planet at the same scale. To make them more attractive we use photographic-like images but you may be surprised how much detail can be viewed directly through a small telescope given good seeing—for example, the Great Red Spot (when visible) and cloud belts on Jupiter. Phases are also shown for Mercury, Venus and Mars and the approximate appearance of Saturn's rings. Each image is shown north up with a date, the planet's angular diameter and magnitude.

The Moon

This provides information on major events relating to the Moon. Included are the Moon's phase, apogee, perigee, libration, occultation of planets, minor planets or bright stars and lunar and solar eclipses.

Lunar Libration

Because of synchronised rotation, the Moon always keeps the same face pointed towards the Earth and we should only see 50% of its surface. In reality, 59% of the surface can be viewed by an effect called libration. The diagrams show the wobble or nod of the Moon during the course of each month.

Lunar Libration is a complicated mix of three different effects, with two being prominent. Firstly, the Moon suffers from a longitudinal wobble; as the Moon approaches perigee its motion through space speeds up, faster than its rotation, and so it does not turn quickly enough to maintain the same face to us, giving us a view around its eastern limb. Then as the Moon moves slower, approaching apogee, it turns a little too much to keep facing us, giving a view beyond the western limb. The second type of libration is a latitudinal nod and is caused by the slight tilt of the Moon's axis. We can see a little over the south pole during one half of each revolution with the north pole hidden; during the other half of its orbit we see over the northern limb while the south pole is hidden from view.

The Planets

Presented are general notes on each planet, including location in the sky and the best time to observe. Emphasis is placed on their suitability for observation and any interesting conjunctions and patterns between the Moon, other Solar System objects, stars and deep sky objects.

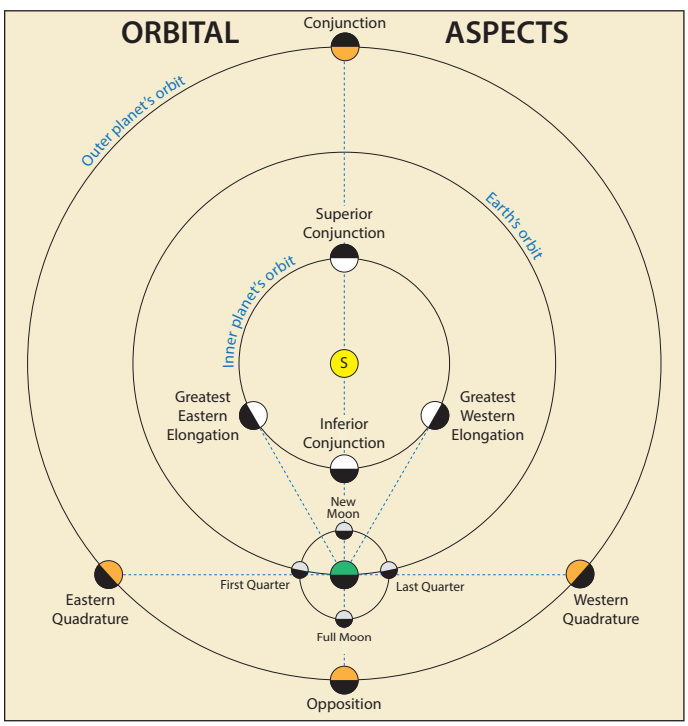
Dwarf Planets and Small Solar System Bodies

Dwarf Planets. This mainly deals with Pluto, but also includes Ceres, Eris and other dwarfs when at opposition.

Minor Planets (or Asteroids) This covers the brightest asteroids that reach opposition each month (12.6 magnitude or brighter). An entry includes the date of opposition (when at or near its brightest), its magnitude and the constellation the asteroid is in at this time. The 15 brightest dwarf and minor planets have ephemerides included in Part II (p. 139). A number also have selected conjunctions included in the diary in Part I. The period considered for the conjunctions in the diary was three months either side of opposition (if it's brighter than 11.0 magnitude throughout) and Ceres, Pallas, Juno and Vesta for the whole year except when near solar conjunction (within 18° of the Sun).

Comets

This section deals with the brightest comets expected to be visible during the year. Although most of the known comets returning this year are quite faint you never know what will be discovered tomorrow. It was only last year (2020) that Comet Neowise (C/2020 F3) came out of nowhere putting on such a spectacular display. Unfortunately, it reserved its best views for the Northern Hemisphere. For further information including ephemerides see pages 134 to 138 in Part II.



Meteor Showers

On any clear night we may see up to five shooting stars per hour. These are known as random or sporadic meteors. There are also annual showers, which return at the same time each year. Each shower seems to radiate from a point in the sky and is named after the constellation or a bright star that the radiant lies near. For example, the radiant for the Leonids lies within the constellation of Leo. The monthly section lists the major showers that are suitable for observation in the Southern Hemisphere this year. A comment is made when the Moon could potentially interfere during their peak period. Information for other known showers is given in Part II (p. 140). It is best to do your searching on moonless nights, away from light polluted cities. In general, more meteors are seen after midnight.

Double Stars

Each month an impressive double star is presented that is ideal to see through small telescopes. They are also marked on the All Sky Maps.

Feature Article

This section concentrates on some topics in popular astronomy. It can include observing, events, history, astronomical equipment and techniques as well as profiles of astronomy enthusiasts.

Diary

This is a list of general phenomena associated with the planets, Moon, minor planets and comets. Included are:

- Phase of the Moon.
- Key events in a planet's orbit.
- Selected conjunctions between the Sun, Moon, planets, comets, minor planets (asteroids), brighter stars and deep sky objects.

Conjunctions. Minor differences can sometimes be found between the separations and times quoted and those found elsewhere in Part I. Some entries are geocentric (the theoretical view from the centre of the Earth), others may have times and separations given in the text or Sky Views as seen from Australia. For conjunctions involving the Moon, the distances given are measured from the centre of the Moon (which has a radius of about one quarter of a degree).

Abbreviations. These include:

G	galaxy (or sometimes SG for spiral, IG irregular, EG elliptical and LG lenticular)		
N	nebula (PN planetary, BN bright and DN dark nebula)		
OC	open cluster	GC	globular cluster
m.p.	minor planet	d.p.	dwarf planet
DS	double star		

There are also some astronomical catalogues including NGC (New General Catalogue), IC (Index Catalogue) and M (Messier Catalogue).

Time. When times are given, both EST and WST are presented. Times are rounded to the nearest hour. We don't include a separate entry for CST as there is only a 30 minute difference from EST. The remaining entries are less time sensitive and either have no time (that is the closest day) or a pm or am designation for an evening or morning event respectively. For timed events that occur in the very early hours (before 2 am) for EST, the WST conversion (subtracting two hours) takes them into the previous day and are shown as 'prev day'.

SOME ASTRONOMICAL TERMS TO GET YOU STARTED

There are several astronomical terms which you'll come across in this book, many of which are defined in the glossary at the end. Here are a few of the more common ones, just to get you started.

Planet. Just like the Earth! A planet is a spheroid of rock or gas that orbits the Sun or another star. The Moon and planets we see in the sky do not glow in their own right. They are only visible due to reflected sunlight.

Dwarf Planet. This is a recently created class of objects, with only five designated so far. This book concentrates on the brightest two, Pluto and Ceres. Incidentally both bodies are ex-planets, but you need to go back to the 19th century for Ceres's demotion to a minor planet.

Minor Planet. These are minor rocky bodies in the Solar System that vary from a few metres to hundreds of kilometres in diameter. There are hundreds of thousands of known minor planets, mostly in the main belt between the orbits of Mars and Jupiter.

Star. Just like the Sun. Stars are enormous spheres of glowing gas that give off tremendous amounts of light and heat. They shine by their own light caused by nuclear reactions going on deep inside them.

Magnitude. The brightness of an object in the sky is known as its magnitude (sometimes abbreviated to 'mag.'). The numbers work backwards. The faintest stars you're likely to see with the naked eye are about 6.0 magnitude (under country skies), while the brightest stars are around zero magnitude, with the most brilliant, Sirius, at –1.4 magnitude. Planets can be much brighter. Venus, for example, can be as bright as –4.5 magnitude, the Full Moon, –12 magnitude.

Waxing, waning, gibbous and crescent. The Moon is considered waxing between New and Full, after this time it is said to be waning. The Moon is gibbous when more than half is illuminated i.e., from after First Quarter to just before Last Quarter. On either side of New Moon, when less than half is lit, it is a crescent. Gibbous and crescent are also sometimes used to describe the appearance of Mercury or Venus. Mars can also be gibbous.

Angles in the sky are measured in degrees. You'll see that the Sky Views have a line showing what an angle of 10° looks like on the scale of these drawings. On the back cover is a scale that can help you measure angles.

Twilight does not fully end until the Sun is 18° below the horizon, when *astronomical* twilight ends. This happens about 90 minutes after sunset (or before sunrise) but it does vary with latitude. Only now is the sky considered truly dark (assuming the Moon is not up). See also civil and nautical twilight in the glossary.

Culmination When an object culminates it has reached its highest point in the sky, this is generally considered to be the best time to observe it. This is sometimes referred to as transiting or crossing the meridian. The meridian is an imaginary line, which starts at due north on the horizon and runs up to overhead (the zenith) and down to due south.

Sky Views

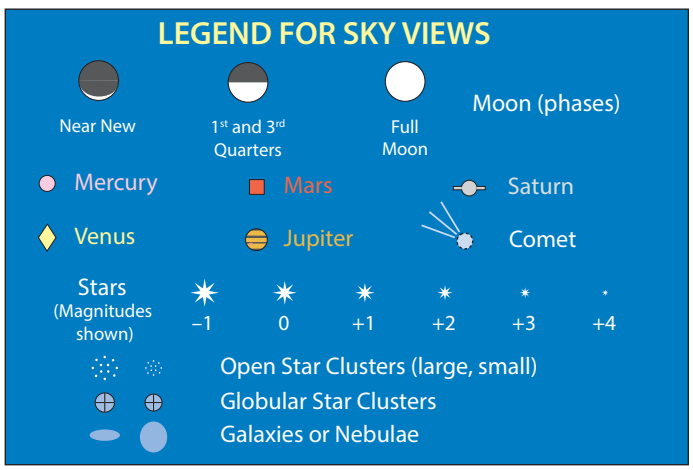
These diagrams are designed to help you find the naked-eye planets. The date and time chosen give the most interesting patterns of the planets and Moon. Sometimes the times correspond to about one hour (or even down to 30 minutes) before sunrise or after sunset. Although this is twilight, it is sometimes necessary to catch a glimpse of the planets when close to the Sun. This is especially needed for Mercury as it never wanders more than 28° from our star. Sky Views which show a twilight view after sunset are called Evening Twilight and morning twilights are Dawn Sky. Those before midnight are Evening Sky and after midnight, Morning Sky.

The Sky Views (see also the legend below) include:

- The Moon (approximate phase) and planets visible to the naked eye.
- All stars down to 4.5 magnitude.
- Names of the brightest stars.
- Bright star clusters, nebulae and galaxies. A prefix of N means the object is in the New General Catalogue (NGC), an I is the Index Catalogue (IC) and M is an entry in the Messier Catalogue.
- Constellations are labelled (capital letters) and have black lines joining key stars to show the constellation's recognisable star pattern.

Saturn and Jupiter Satellites. Both planets have a diagram for months close to their opposition (both August and September in 2021). Only the brightest moons are included. There are key differences between these planets worth keeping in mind.

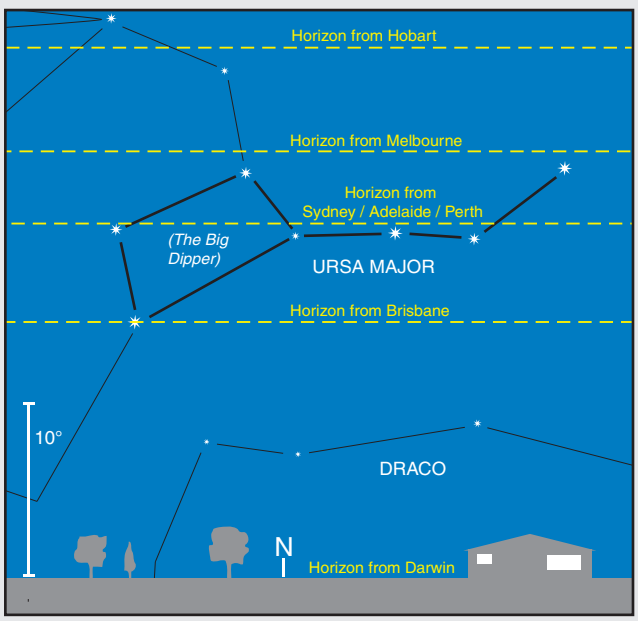
The plane of the orbits of Jupiter's moons is close to the Earth's orbital plane, so we see them shuttle back and forth in straight lines, passing in front of and behind the planet and even in and out of its shadow. Of the bright four Galilean moons, the most distant satellite, Callisto is the exception which spends many years passing over or under Jupiter's disc. However, in 2021 (and 2020) the Earth lies close enough to the plane for Callisto to go through the normal events as mentioned above (see also bottom of p. 120). Saturn's moons orbit in the plane of the rings. As the rings spend most of the time inclined to our line of sight (hence our brilliant view), so the orbits of the satellites are ellipses appearing to pass below, then half an orbit later above the rings. The further out the satellite is, the larger the ellipse. Saturn's moons are considerably fainter than Jupiter's Galilean satellites with Titan the only standout. The inner ones are swamped by the glow of the nearby rings, making them hard to see.



WHAT TIME IS IT? Unless a time zone or a location is specifically mentioned, times given in the Monthly Section will be approximate local standard time. No adjustments are made for Daylight Saving anywhere in this book. When it is in force you will need to add one hour to times given here. e.g., any rise or set time from the charts will need to have one hour added to get daylight saving time.

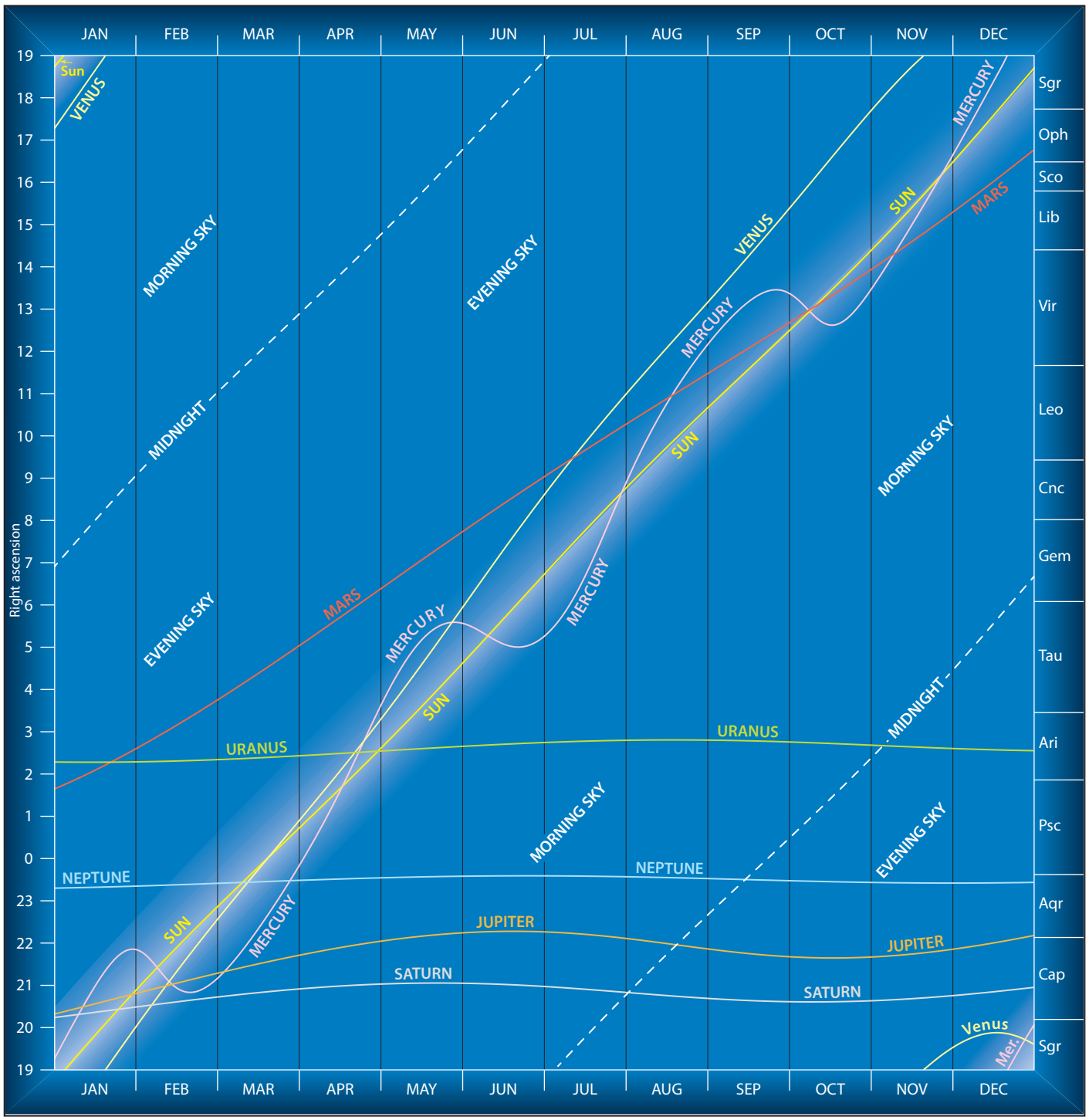
When specific times are referred to in Part I they can be Eastern Standard Time (EST) or Western Standard Time (WST); the mean solar time on the meridians of longitude 150° E and 120° E respectively. For Central Standard Time (CST) subtract 30 minutes from EST times given. Any specific times given for Darwin or Adelaide are CST. Queensland, NSW, ACT, Victoria and Tasmania use EST. SA and NT use CST and WA uses WST.

Uranus, Neptune and Pluto have been excluded from the Sky Views, as they are not generally visible to the naked eye. To see Uranus you would certainly need dark sky conditions. Neptune will need binoculars, while Pluto will need at least a 20 cm telescope to glimpse this faint dwarf planet. In any case, because of the many faint stars of similar brightness close by, separate finder charts (see Part II) are needed for these outer worlds. Their approximate positions are marked on the All Sky Maps to point you to the right area and then go to the finders.



EFFECT OF LATITUDE The Sky Views have been drawn for a latitude of about 33° south of the equator. This is reasonably central for the population distribution of Australia. However, we live in a large continent, which covers a wide range of latitudes. The further you go north the more stars you see that are familiar to our Northern Hemisphere friends. As an example, let's take the Big Dipper. This group of stars is part of the constellation Ursa Major, the Great Bear. From Darwin the group is clearly visible above the horizon. However, from the southern states not all of it is visible. The Big Dipper is best placed in the northern sky in mid-May around 9 pm (mid-June, 7 pm). Also from the south we see very little of the constellation Draco. The diagram is the same scale as a Sky View.

VISIBILITY OF THE PLANETS

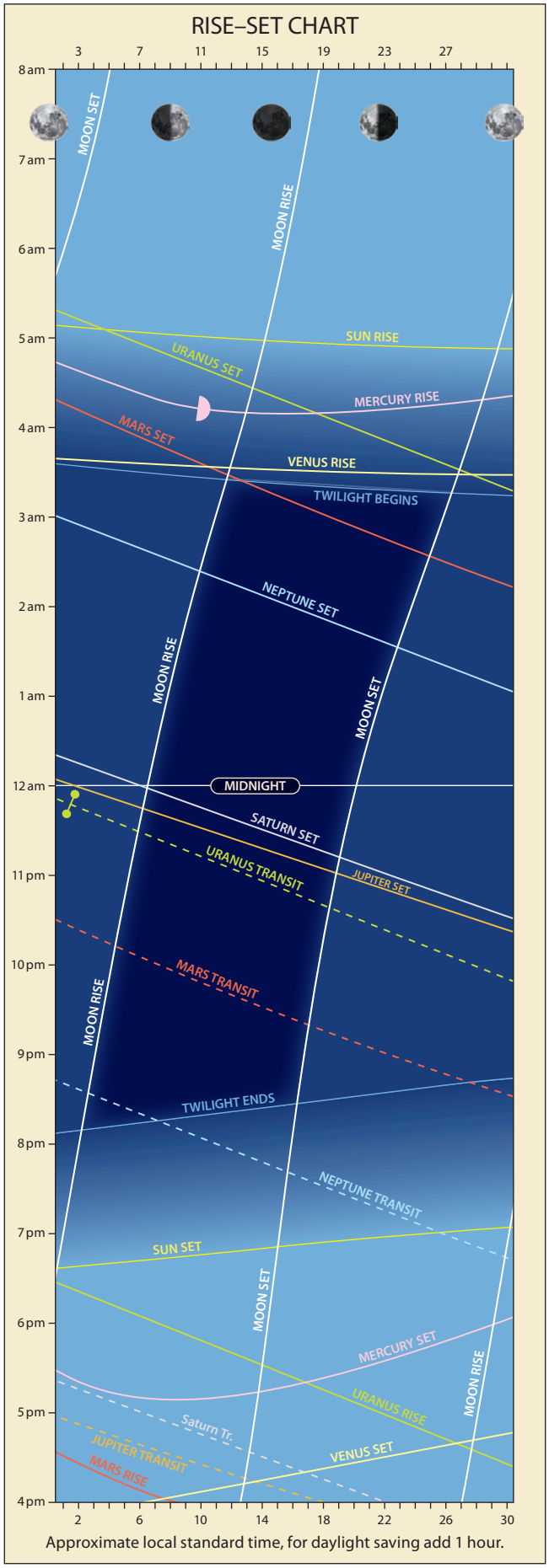


This diagram plots the right ascension of the Sun and planets throughout the year. The light area on either side of the Sun line is that part of the night sky affected by twilight. From this relatively simple diagram a wealth of information can be determined. For example, find your date of observation along the bottom and look up the page until it intersects a planet line. This will show if it is best to view the planet in the morning or evening sky. From the intersection point, a horizontal line to the right vertical axis will show which constellation the planet is in. Mars for example will be in Taurus (Tau) in the March evening sky (also see All Sky Map No. 3)

Mercury and Venus are in either inferior or superior conjunction when they cross the Sun line and at their greatest elongation when furthest from it. The best time to observe these inner planets is when their paths extend beyond twilight. For Mercury, the optimum period in the evening sky is during September and in the mornings late February and March. Early in the year Venus is close to the Sun. It gradually reappears in the evening sky from May, remaining there for the rest of the year.

When an outer planet crosses a midnight line, it is at opposition and visible the entire night, and when crossing the Sun line it is in conjunction. The diagram also shows conjunctions between the planets. When two planet lines cross or are close, they will be near each other in the sky. A fine example this year is when Venus is in conjunction with Mars in July (see Sky View p. 59).

NOVEMBER 2020



Approximate local standard time, for daylight saving add 1 hour.

HIGHLIGHTS

- Venus near the Moon.
- Jupiter, Saturn and Moon form a neat conjunction.
- Uranus at opposition.

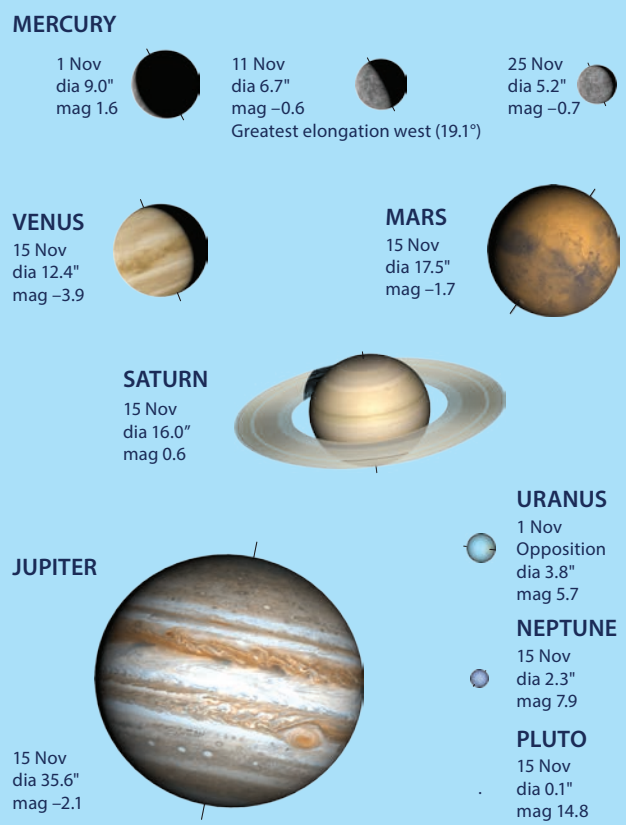
CONSTELLATIONS

In the March 2021 feature, Legacy of the Gods, we briefly mention that a number of the traditional (ancient) constellation stories may have originated from the island of Crete around 2000 BCE. Over the ensuing 4,000 years, precession has caused some of these star patterns to be no longer visible from Mediterranean latitudes.

For a bit of fun, let's turn this discussion on its head. What additional constellations were visible from Australia around the year 2000 BCE that are no longer visible from *down under* today? Maybe there are legends in the Aboriginal Dreamtime of stars no longer visible from Australia? At this time the South Celestial Pole (SCP) was located around one degree from the 4.7 magnitude star Eta^2 Hydri (only slightly brighter than our current pole star, Sigma Octantis at magnitude 5.4).

So how do we translate this to how the sky appeared 4,000 years ago? Firstly the elevation of the SCP would still be close to today, therefore the point in the sky where the stars appear to rotate around from Sydney (latitude 34° S) would still be about 34° above the southern horizon. One way to visualise this is to determine a time/date where Eta^2 Hydri is at a maximum altitude. If you are using a planetarium programme around 10 pm on November 15 would do. In 2020, from Sydney, Eta's elevation is about 56° or approximately 22° above the current position of the SCP. So you need to rotate the entire celestial

APPEARANCE of the PLANETS



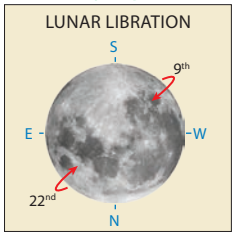
sphere towards the south by 22°, i.e., dropping Eta[2] straight down to an altitude of 34°. The Southern Cross and Pointers, which today are scraping the horizon, are now well below (yes, they were not circumpolar 4,000 years ago).

Looking due north, the stars have gained 22° in altitude so Andromeda, which was sitting on the horizon, is not only well up, you can see all of Perseus as well as Cassiopeia's distinctive W asterism. Camelopardalis and Cepheus are now also making significant appearances.

So, what do we lose? The maximum loss is on the opposite side of the celestial sphere where the Keystone asterism of Hercules now only just clears the horizon and some of Boötes' Kite has disappeared.

It's noteworthy that Polaris was visible from northern Australia. Unfortunately for the Northern Hemisphere it would be quite a while before this star earned its name, for in 2000 BCE the North Celestial Pole was in an isolated barren region of Draco.

THE MOON



1st 1 am (11 pm previous day WST) Full Moon.

8th Midnight (10 pm) Last Quarter.

9th 7 pm (5 pm WST) Maximum Libration (9.4°), bright SW limb. Although not in the zone of librations, the vast 303 km walled plain Bailly is well situated at this time.

14th 10 pm (8 pm WST) Moon at perigee (closest to Earth at 357,837 km).

15th 3 pm (1 pm WST) New Moon.

22nd 3 pm (1 pm WST) First Quarter.

22nd 7 am (5 am WST) Maximum Libration (9.4°), bright NE limb.

27th 10 am (8 am WST) Moon at apogee (furthest from Earth at 405,894 km).

30th 8 pm (6 pm WST) Full Moon (Blue Moon for the eastern and central states). Penumbral eclipse visible from Australia.

THE PLANETS

Mercury reaches its greatest elongation 19° west of the Sun on the 11th. Since the angle of the ecliptic (the plane of the planetary orbits) to the horizon is so shallow at this elongation the planet is barely more than a few degrees above the eastern dawn horizon and effectively unobservable.

Since its greatest elongation last August, **Venus** has been gradually losing altitude as it moves back toward the Sun in the eastern morning sky. From now until mid-February 2021 the planet will still be visible in the brightening dawn twilight before succumbing to the solar glare. On the 13th, the 27-day old waning crescent Moon appears near the planet (see Sky View).

Now past opposition, **Mars,** in Pisces, is unmistakable in the mid-evening northern sky as a bright golden orange *star* shining at –1.7 magnitude mid-month. Although diminishing in size from 20 arcseconds at the beginning of the month to 15 at the end, it is still worth telescope time on those nights of steady seeing when you can crank up the magnification. The Red Planet ends two months of retrograde motion on the 16th and resumes its regular west to east motion across the sky. On the 25th, the 10-day old waxing gibbous Moon appears in the planet's neighbourhood and a little closer on the following evening (see Sky View).

Telescope observations of **Jupiter** should be made early in the evening this month whilst still at a reasonable altitude above the western horizon. The distance between the Solar System's two largest planets decreases during November from

DIARY			
Sun	1st	1 am	(11 pm WST, prev day) Full Moon (406,167 km, furthest for 2020)
Sun	1st	2 am	(Midnight WST, prev day) Uranus at opposition
Mon	2nd		Venus 0.6° E of star Eta Virginis
Mon	2nd		Comet 88P/Howell 0.5° S of star Sigma Sagittarii
Mon	2nd		Mercury at perihelion
Tue	3rd	6 pm	(4 pm WST) star Aldebaran 5° S of Moon
Tue	3rd	6 pm	(4 pm WST) Mercury stationary
Wed	4th	11 pm	(9 pm WST) m.p. 11 Parthenope 0.05° NW of star Xi Piscium
Thu	5th		Comet 88P/Howell 1.1° N of star Tau Sagittarii
Thu	5th		Comet 88P/Howell 0.7° N of Comet 2P/Encke
Sat	7th	6 am	(4 am WST) star Pollux 4° N of Moon
Sun	8th		Venus 0.3° SE of NGC 4691 (G) in Virgo
Sun	8th	7 pm	(5 pm WST) m.p. 3 Juno in conjunction with Sun
Sun	8th	Midn.	(10 pm WST) Last Quarter Moon
Mon	9th	9 pm	(7 pm WST) star Regulus 5° S of Moon
Tue	10th	10 am	(8 am WST) m.p. 4 Vesta 2° S of Moon
Wed	11th	3 am	(1 am WST) Mercury at greatest elongation West (19.1°)
Thu	12th		Venus 0.8° E of NGC 4941 (G) in Virgo
Thu	12th		Mercury at greatest latitude north
Fri	13th	7 am	(5 am WST) Venus 3° S of Moon
Fri	13th	1 pm	(11 am WST) star Spica 7° S of Moon
Sat	14th	3 am	(1 am WST) d.p. Pluto 0.5° S of Jupiter
Sat	14th	7 am	(5 am WST) Mercury 1.5° S of Moon
Sat	14th	10 pm	(8 pm WST) Moon at perigee, 357,837 km
Sun	15th		Mercury 0.8° SW of star Kappa Virginis
Sun	15th		m.p. 4 Vesta 0.2° NE of M95 (SG) in Leo
Sun	15th	3 pm	(1 pm WST) New Moon
Mon	16th		m.p. 4 Vesta 0.2° W of M96 (SG) in Leo
Mon	16th		m.p. 4 Vesta 0.9° SW of M105 (EG) in Leo
Mon	16th	5 am	(3 am WST) Mars stationary
Mon	16th	4 pm	(2 pm WST) star Antares 6° S of Moon
Tue	17th	5 am	(3 am WST) star Spica 4° S of Venus
Thu	19th	5 pm	(3 pm WST) d.p. Pluto 1.5° N of Moon
Thu	19th	9 pm	(7 pm WST) Jupiter 2° N of Moon
Fri	20th	1 am	(11 pm WST, prev day) Saturn 3° N of Moon
Sat	21st		Venus at greatest latitude north
Sat	21st	pm	d.p. Ceres 0.8° SE of Helix Nebula (NGC 7293) in Aquarius
Sun	22nd	3 pm	(1 pm WST) First Quarter Moon
Mon	23rd	10 pm	(8 pm WST) Neptune 5° N of Moon
Wed	25th		Neptune 0.7° E of star Phi Aquarii
Thu	26th	6 am	(4 am WST) Mars 5° N of Moon
Fri	27th	10 am	(8 am WST) Moon at apogee, 405,894 km
Sat	28th	am	m.p. 13 Egeria 1.0° NE of NGC 2192 (OC) in Auriga
Sat	28th	2 am	(Midnight WST, prev day) Uranus 3° N of Moon
Sun	29th	7 pm	(5 pm WST) Neptune stationary
Mon	30th	8 pm	(6 pm WST) Full Moon (401,726 km)
Mon	30th	Midn.	(10 pm WST) star Aldebaran 5° S of Moon

5° to around 2° as Jupiter and Saturn gear-up for a really close rendezvous next month. On the 19th, the 5-day old waxing crescent Moon appears close to the planet (see Sky View).

Saturn follows Jupiter down toward the western evening horizon this month. On the 19th, the 5-day old waxing crescent Moon appears close to Saturn and even closer to Jupiter—a neat view in the late spring sky (see Sky View). By month's end Saturn and Jupiter will be 2° apart and even closer next month.

Uranus is at opposition on the 1st, rising in the early evening eastern sky in Aries and is visible the entire night. With an apparent diameter a little less than four arcseconds you will need a telescope and high magnification to resolve the planet into a disc. Through the telescope, at 5.7 magnitude, Uranus shows no distinguishable atmospheric features, but observers will immediately note its blue/green colour.

Neptune comes to the end of five months in retrograde motion on the 29th and appears high in the early north-western evening sky at the end of astronomical dusk

SMALL SOLAR SYSTEM BODIES

Mid-month minor planet **Vesta** at 8th magnitude passes between the two bright galaxies M95 and M96 in Leo.

Brightest **minor planets** at opposition this month include:

Date	Minor Planet	Constellation	Mag.
1 Nov	8 Flora	Cetus	8.0
26 Nov	51 Nemausa	Taurus	10.6

COMETS

Comet C/2019 N1 (ATLAS) is around 11th magnitude, spending the month in Virgo. It becomes visible in the eastern dawn sky around mid-November and on the 17th the comet is level in the sky with Venus, 6° to the right of this brilliant beacon. At the end of the month, ATLAS has now cleared the dawn sky, at an altitude of 8° at the end of twilight. At this time it has a similar height to Spica and roughly 12° to the right of the star.

DOUBLE STARS

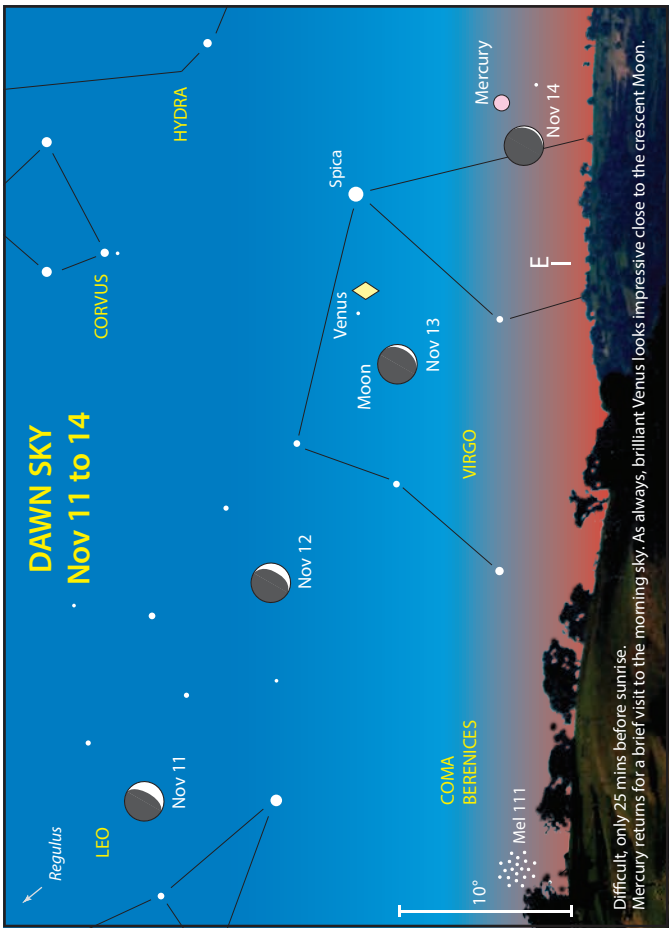
Alpha (α) Fornacis is a binary star in the constellation of Fornax, the Furnace (see All Sky Map No. 2). It is the brightest star in the constellation and is located 46 light-years from the Sun. The star has a high proper motion and about 350,000 years ago it had a close encounter with Nu Horologii (0.265 light-years apart) and both appear to have discs of debris. The pair was discovered by John Herschel in 1835. The A component is a white subgiant star (spectral class F8IV), magnitude 4.0, with a luminosity four times that of the Sun. The B component, magnitude 7.2, appears to be a blue straggler (G7), which has either merged with a third star or accreted material from it in the past. The orbital period is about 269 years and they were closest in 1947 and will be at maximum separation in 2082. The stars are currently separated by 5.4 arcseconds with a position angle of 301° and well resolved in small telescopes.

METEOR SHOWERS

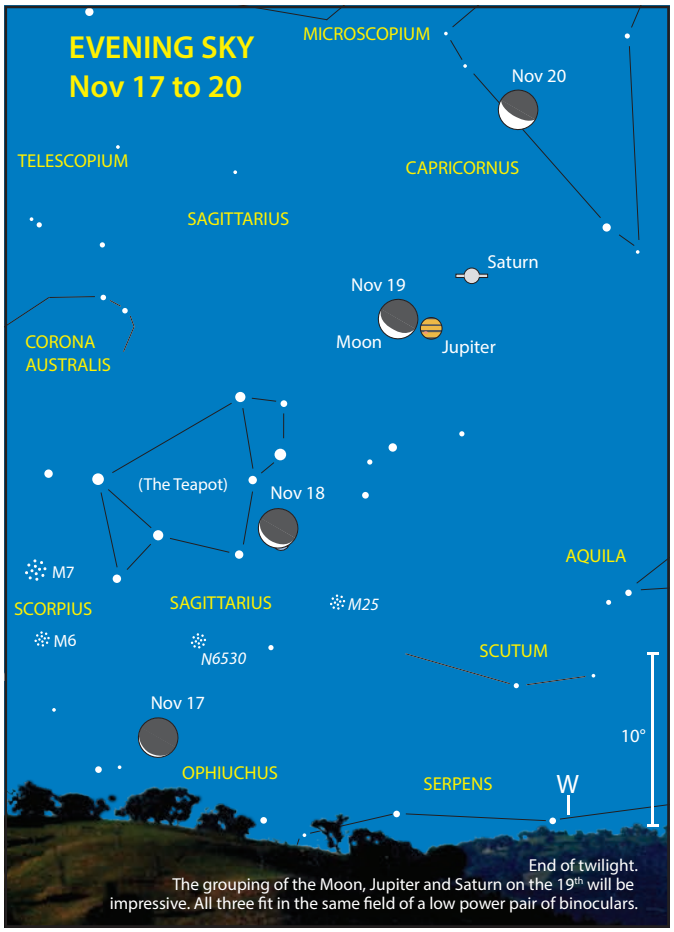
The **Northern Taurids** are active from October 20 to December 10. The shower is composed of two radiants of nearly equal activity ten degrees apart. The Northern Taurids peak around November 12 and the Southern Taurids in October. The Taurids are frequently bright, slow moving, and noted for producing colourful fireballs (although not in every year). Their relative slowness and brightness make them an ideal target for astrophotography. They are associated with Comet 2P/Encke and can be seen from late evening to early morning. There will be no lunar interference this year with New Moon occurring on the 15th.

The **Leonids** are one of the better-known showers. They are associated with the periodic comet 55P/Tempel-Tuttle and are best about every 33 years when the comet returns to perihelion (last in 2001). The Leonids are active from 6th to 30th, with maximum on the morning of the 18th. Current predictions for 2020 indicate a possible zenith hourly rate of 10–20 meteors. We would encourage observers to be on the lookout for updates nearer the time of the shower as this is not one to be missed if active. New Moon on the 15th will leave the morning skies free of interference.

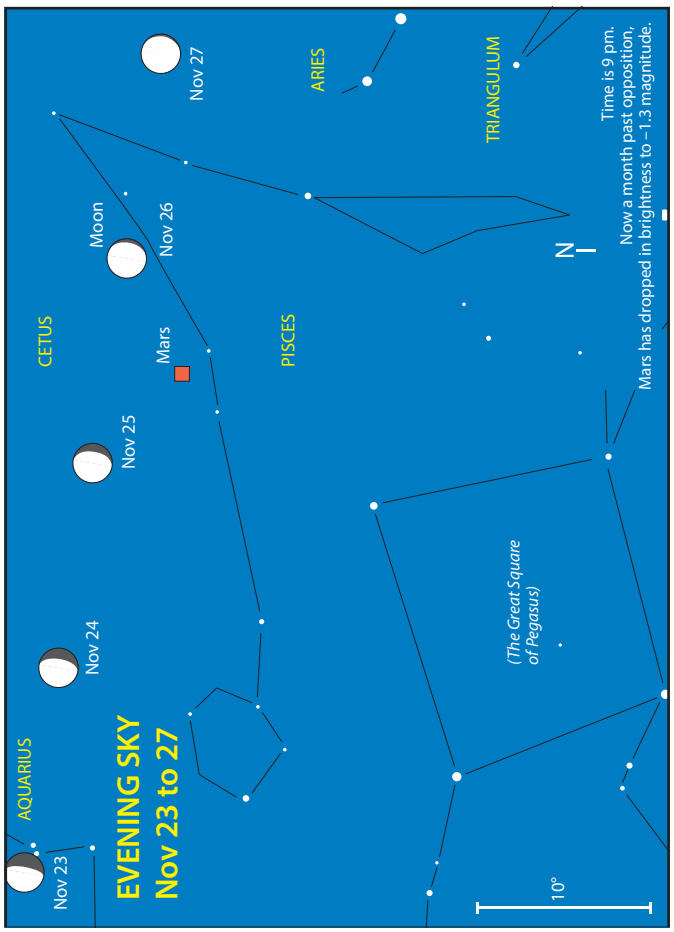


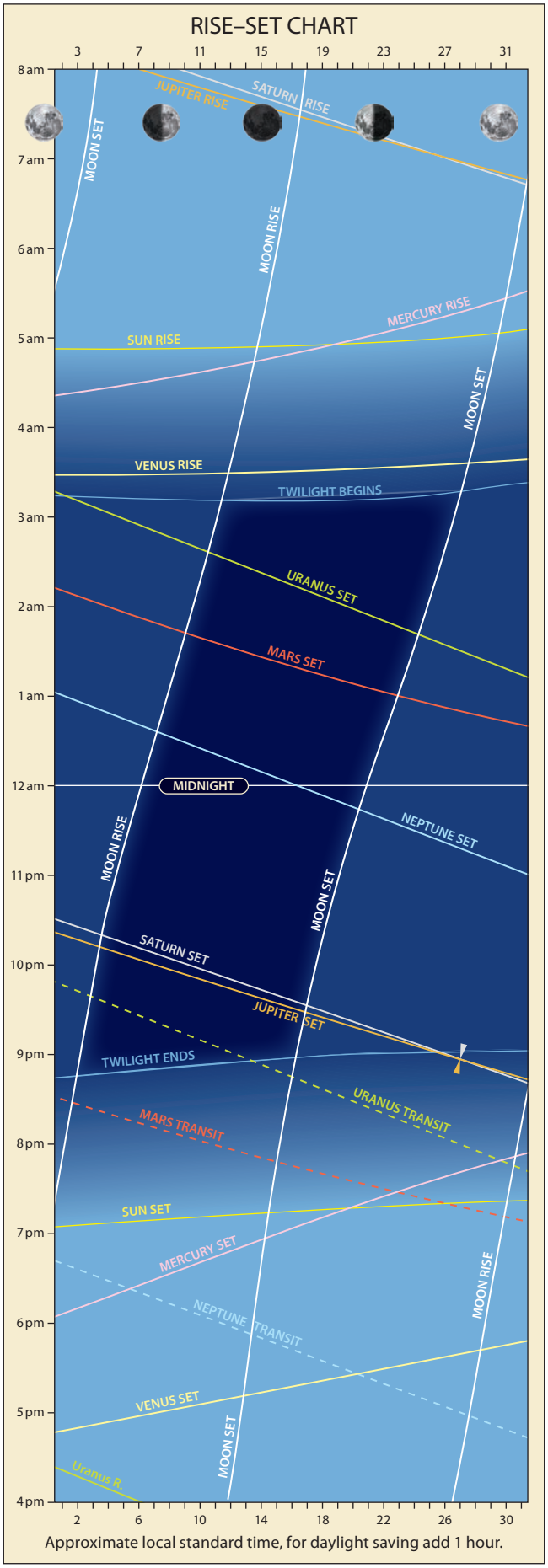


DECEMBER 2020



Approximate local standard time, for daylight saving add one hour.





Approximate local standard time, for daylight saving add 1 hour.

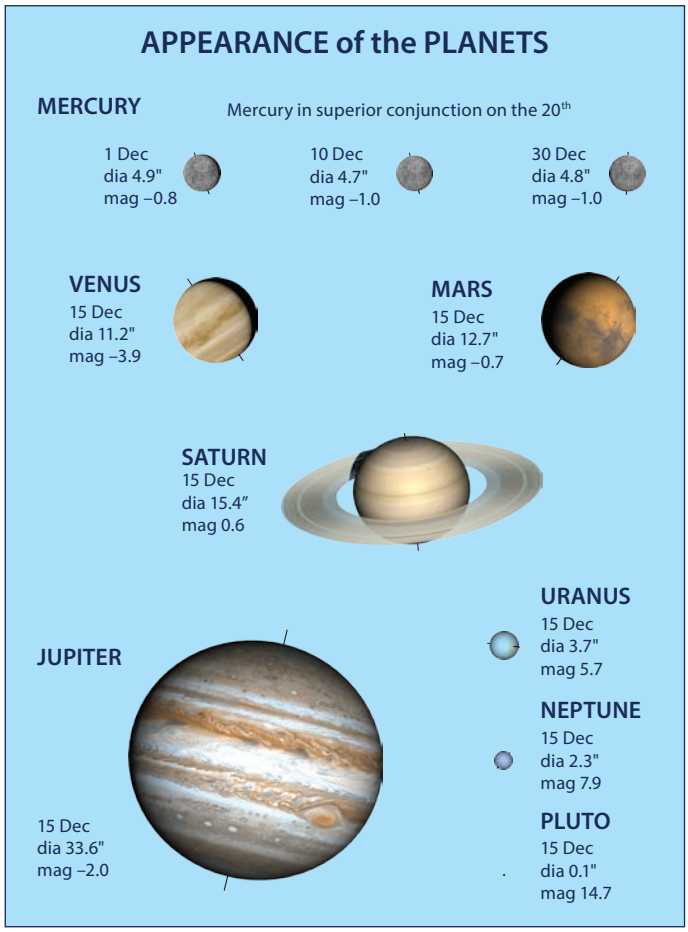
HIGHLIGHTS

- Venus and Moon close.
- Moon, Jupiter and Saturn together.
- Jupiter and Saturn extremely close, rare meeting.

CONSTELLATIONS

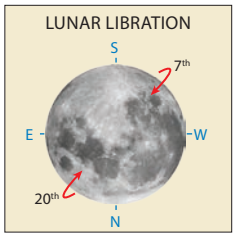
In the March 2021 feature, *Legacy of the Gods*, we mention the legend of Jason and the Argonauts and their quest to steal the golden fleece. The source of the fleece resides in the heavens in the constellation of Aries the Ram. Aries is Latin for ram. Located 24° due west (left) of the Pleiades star cluster it doesn't have much of an asterism to boast about, showing mostly two stars. This region of the sky is so barren that these 2.0 and 2.6 magnitude stars, separated by only 4°, stand out well. The brighter star is Hamal (Alpha (α) Arietis) which is Arabic for lamb. It is a K2 spectral class star (a *cool* 4,200 K) so is yellowy-orange in colour. The other is Sheratan (Beta (β) Arietis), a name whose origin remains a mystery. It is a hotter (8,300 K) A5 class, white star. The sight of both in the same binocular field really shows the colour contrast.

Directly beneath Aries is the constellation of Triangulum, the Triangle. Although its three main stars (around 3rd to 4th magnitude) are arranged in a distinctive narrow isosceles triangle, the name lacks imagination. Especially when one considers it came from the same ancients that brought us a flying horse (Pegasus), magic flying rams (Aries), gods (many) and a sea monster (Cetus)—to name a few! Its slightly more interesting original name was Deltotron, after the depiction of the Greek letter delta (capitalised).



Metallah (Alpha Trianguli) at magnitude 3.4 is the second brightest star in Triangulum. In Arabic it means 'triangle', but its Latin name Caput Trianguli is more appropriately 'head of the triangle', being at the pointy end. Metallah is also a good guide star to the large, face-on spiral galaxy M33, which is a binocular field (4°) west of the star. M33 is a member of the local group of galaxies and well worth looking for with binoculars under dark skies.

THE MOON



7th 3 pm (1 pm WST) Maximum Libration (8.9°), bright SW limb. Hausen Crater (167 km) is well visible and is a distinctive libration zone feature.

8th 11 am (9 am WST) Last Quarter.

13th 7 am (5 am WST) Moon at perigee (closest to Earth at 361,773 km).

15th 2 am (midnight previous day WST) New Moon. Total eclipse of the Sun, not visible from Australia.

20th 5 am (3 am WST) Maximum Libration (9.1°), bright NE limb. Mare Humboldtianum, a 161 km *sea*, which is in the libration zone and is well placed to observe.

22nd 10 am (8 am WST) First Quarter.

25th 3 am (1 am WST) Moon at apogee (furthest from Earth at 405,012 km).

30th 1 pm (11 am WST) Full Moon.

THE PLANETS

Like last month, **Mercury** tends to hug the horizon during December, remaining invisible to observers. The planet is a morning object until superior conjunction (Mercury and Earth on opposite sides of the Sun) on the 20th, when it moves into the western evening twilight.

Venus is visible in the brightening dawn eastern sky. A neat, close conjunction between the 27-day old waning crescent Moon and Venus occurs on the 13th with the pair less than 2° apart (see Sky View). The planet moves slowly towards Antares, being closest on the 24th when they are 5.5° apart.

The **Earth** is at Solstice on the 21st when the days are longest. On this day, the Sun is at its most southerly position with a declination of –23.5°.

In the northern sky as evening twilight ends, **Mars,** in Pisces, is obvious as an orange beacon in a region devoid of bright stars to the upper right of the Great Square of Pegasus. Its post opposition size shrinks from around 15 arcseconds at the beginning of December to 10 arcseconds at year's end. From the 9th to the 15th the Red Planet will be within 1° of Zeta (ζ) Piscium, a splendid double for small telescopes. There is some dispute on the colours of this pair (magnitudes 5.2 and 6.3, separation 23 arcseconds) with the primary described as pale yellow or white and its companion yellow or reddish. On the 23rd and 24th, the waxing gibbous Moon appears in the vicinity of the Red Planet.

Jupiter is visible as it sinks toward the early western evening horizon, spending half the month in Sagittarius before moving into Capricornus. A very neat conjunction occurs on the 17th with the slender crescent of the 3-day old waxing crescent Moon appearing directly above Jupiter and Saturn (see Sky View). It would be best to observe the trio soon after the end

of civil twilight whilst still a reasonable altitude above the horizon. The distance from Jupiter to the northern lunar cusp at this time is 3° (a little further from WA) and the separation between planets is just 0.5° (one Moon diameter).

After this lunar conjunction on the 17th, Jupiter and Saturn remain less than 0.5° apart for the next 7 days and are closest on the 21st at 0.1° apart—a spectacular conjunction (see Sky View). It is rare to see both gas giants in the same field of view of a telescope, so don't miss this one as these big guys only get together every 18–20 years for a rendezvous.

As **Saturn**, together with Jupiter, settles into the western evening twilight the pair provides some great naked-eye and binocular observing this month. Starting at the beginning of December at 2° apart, the gap between the pair narrows culminating in a spectacular and rare conjunction, just 0.1° apart on the 21st (see Sky View). A few days earlier on the 17th, the 3-day old earthshine enhanced crescent Moon appears around 3° above the pair for an impressive triple conjunction (see Sky View).

Uranus, now past opposition, is in the northern evening sky at the end of astronomical twilight in Aries.

Neptune remains within 1° of the 4th magnitude star Phi (φ) Aquarii this month. The planet can only be seen in the western evening sky as it heads toward conjunction in March 2021.

SMALL SOLAR SYSTEM BODIES

Brightest **minor planets** at opposition this month include:

Date	Minor Planet	Constellation	Mag.
7 Dec	16 Psyche	Taurus	9.4
11 Dec	702 Alauda	Auriga	12.0
11 Dec	423 Diotima	Taurus	11.6
11 Dec	79 Eurynome	Taurus/Orion border	9.9
20 Dec	13 Egeria	Auriga	10.0
21 Dec	39 Laetitia	Orion	9.8
29 Dec	52 Europa	Orion/Gemini border	10.0

COMETS

Comet C/2019 N1 (ATLAS) opens December low in the late eastern morning sky in Virgo. It then moves quickly through Hydra and finishes 2020 in Centaurus. Reaching perihelion on the 1st, the comet is around 10th magnitude and slowly brightens during the month. From the 7th to 12th ATLAS is within 2° of the 3rd magnitude star, Pi (π) Hydrae, with closest approach of only 0.2° on the morning of the 10th. By the end of December ATLAS is rising before midnight and on the morning of the 31st is located only 1.5° from the bright star (2nd magnitude) Eta (η) Centauri.

DOUBLE STARS

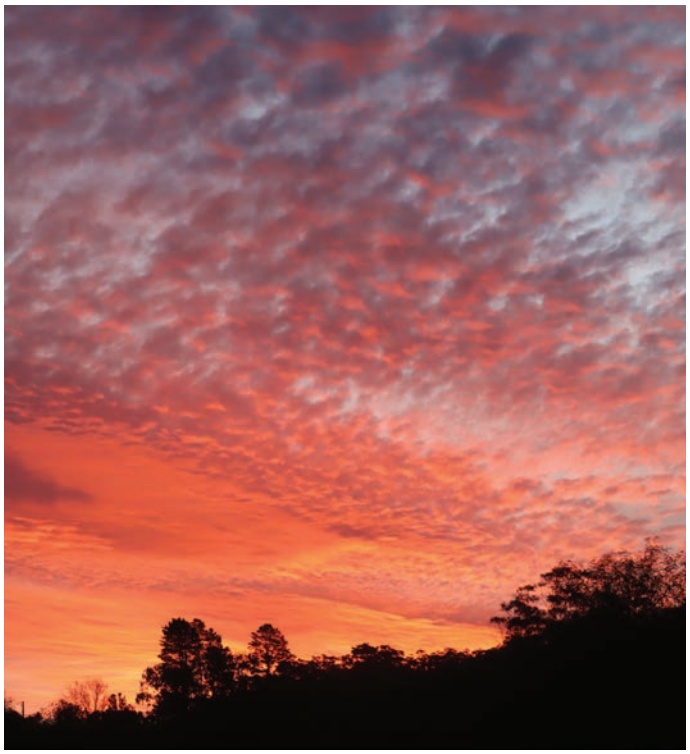
Located near the Orion Nebula (Messier 42), 8 arcminutes south-west from the superb double star Iota (ι) Orionis, is this month's double star **STF 747AB** (All Sky Map No. 2). The bright stars magnitudes 4.7 and 5.5 are separated by 40 arcseconds with a position angle of 228°. Both stars are brilliant white (spectral classes B0.5V and BIV) and are members of the Orion OB1 association. There have been small changes in position angle and separation since the measures taken in 1825. Hipparchus/Tycho data shows different distances to the stars and the pair may represent an optical (line of sight) double. Whilst in the area, look for a fainter, slightly closer pair (STF 745) located 3 arcminutes west. The stars magnitudes 8.3 and 9.4 are separated by 28 arcseconds with a position angle of 347°. This whole area includes the 14 × 14 arcminute open cluster NGC 1980 (Collinder 72, The Lost Jewel of Orion) centred on Iota (ι) Orionis and is a delightful region to explore.

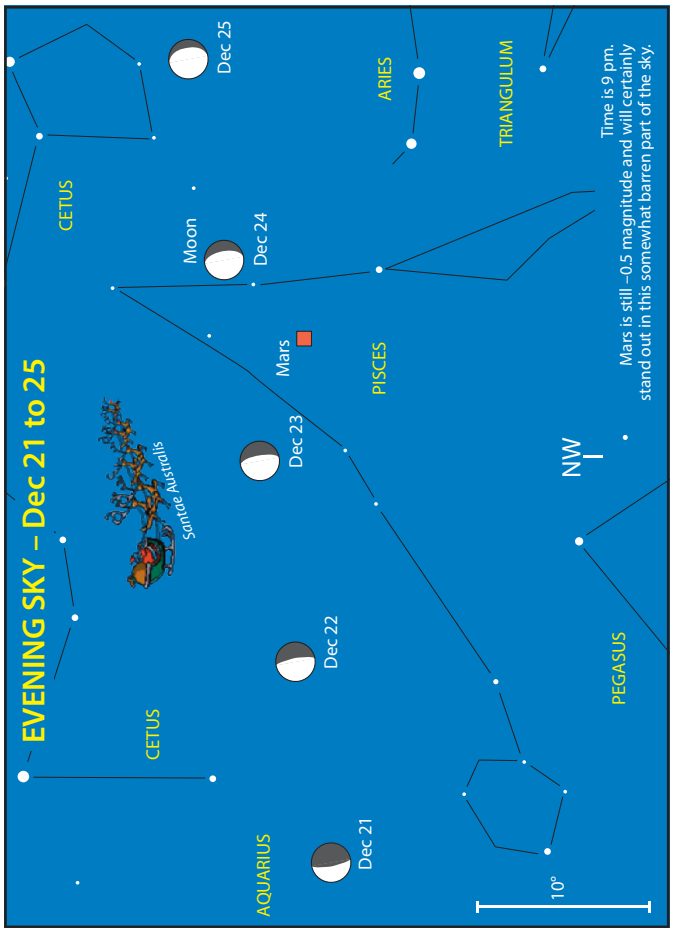
METEOR SHOWERS

The **Geminids** are one of the finest and most reliable of the major annual showers. Visible from the 4th to the 17th, with maximum predicted on the 14th, the Geminids often produce bright, medium-speed meteors. The zenith hourly rate is variable but around 150 is possible. Even though our northern

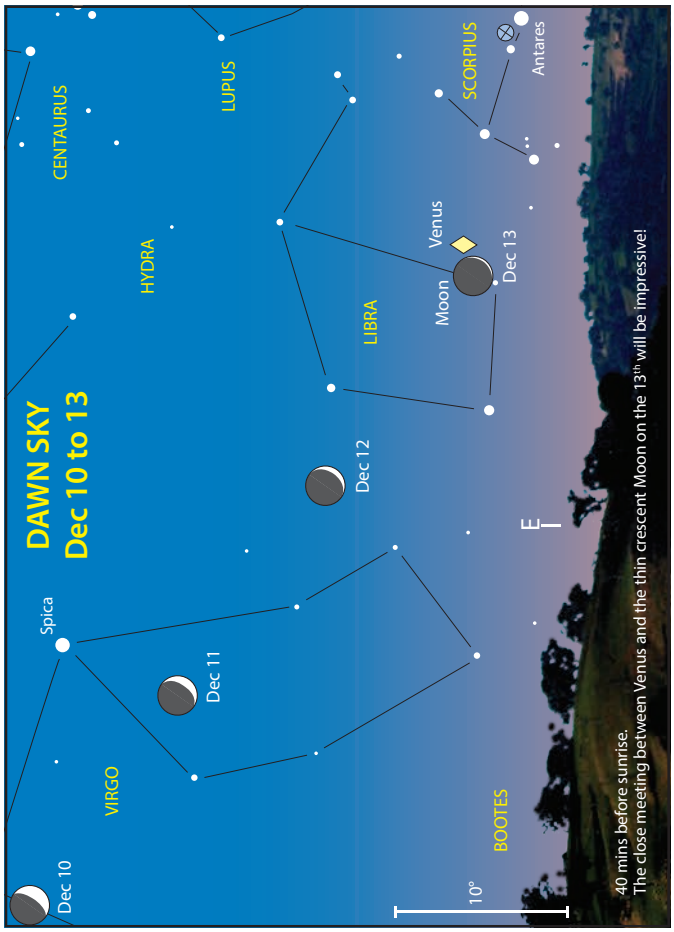
DIARY			
Wed	2nd		Mars at ascending node
Fri	4th	Noon	(10 am WST) star Pollux 4° N of Moon
Fri	4th	pm	m.p. 79 Eurynome 0.4° S of Collinder 65 (OC) in Taurus
Sat	5th		Venus 1.5° NE of star Alpha Librae
Sat	5th		Mercury at descending node
Mon	7th	3 am	(1 am WST) star Regulus 5° S of Moon
Tue	8th	8 am	(6 am WST) m.p. 4 Vesta 0.5° S of Moon
Tue	8th	11 am	(9 am WST) Last Quarter Moon
Thu	10th	10 pm	(8 pm WST) star Spica 7° S of Moon
Sun	13th	7 am	(5 am WST) Moon at perigee, 361,773 km
Sun	13th	7 am	(5 am WST) Venus 1° S of Moon
Tue	15th	2 am	(midn. prev day am WST) New Moon
Wed	16th		Mercury at aphelion
Thu	17th	5 am	(3 am WST) d.p. Pluto 2° N of Moon
Thu	17th	2 pm	(Noon WST) Jupiter 3° N of Moon
Thu	17th	3 pm	(1 pm WST) Saturn 3° N of Moon
Thu	17th	pm	m.p. 79 Eurynome 1.0° S of NGC 1817 (OC) in Taurus
Sat	19th		Venus 0.3° NE of star Beta Scorpii
Sat	19th	pm	m.p. 8 Flora 0.7° NE of NGC 864 (G) in Cetus
Sat	19th	pm	m.p. 79 Eurynome 0.9° S of NGC 1807 (OC) in Taurus
Sun	20th		m.p. 4 Vesta 0.7° S of star Iota Leonis
Sun	20th		Comet 88P/Howell 0.7° SE of star Gamma Capricorni
Sun	20th	1 pm	(11 am WST) Mercury in superior conjunction
Sun	20th	7 pm	(5 pm WST) d.p. Ceres 5° S of Moon
Sun	20th	pm	m.p. 471 Papagena 1.0° SE of star Alpha Piscium
Mon	21st	6 am	(4 am WST) Neptune 5° N of Moon
Mon	21st	8 pm	(6 pm WST) Solstice
Mon	21st	Midn.	(10 pm WST) Saturn 0.1° N of Jupiter
Mon	21st	pm	m.p. 52 Europa 0.5° N of star Gamma Geminorum
Tue	22nd		Comet 88P/Howell 0.6° S of star Delta Capricorni
Tue	22nd	10 am	(8 am WST) First Quarter Moon
Tue	22nd	11 pm	(9 pm WST) Mars 0.1° N of NGC 524 (G) in Pisces
Tue	22nd	pm	P/2009 Q4 (Boattini) 0.6° SE of NGC 1600 (G) in Eridanus
Wed	23rd	11 am	(9 am WST) star Antares 6° S of Venus
Thu	24th	5 am	(3 am WST) Mars 6° N of Moon
Thu	24th	pm	m.p. 16 Psyche 1.2° S of NGC 1647 (OC) in Taurus
Fri	25th	3 am	(1 am WST) Moon at apogee, 405,012 km
Fri	25th	9 am	(7 am WST) Uranus 3° N of Moon
Fri	25th	pm	m.p. 39 Laetitia 1.2° N of star Betelgeuse
Sat	26th	9 pm	(7 pm WST) P/2009 Q4 (Boattini) 0.2° E of star Nu Eridani
Mon	28th		Venus 0.5° N of NGC 6235 (GC) in Ophiuchus
Mon	28th	am	m.p. 4 Vesta 0.5° N of NGC 3705 (G) in Leo
Mon	28th	7 am	(5 am WST) star Aldebaran 5° S of Moon
Wed	30th		Venus 0.6° N of NGC 6287 (GC) in Ophiuchus
Wed	30th	1 pm	(11 am WST) Full Moon (392,772 km)
Thu	31st		d.p. Ceres 0.5° SW of NGC 7492 (GC) in Aquarius
Thu	31st	6 pm	(4 pm WST) star Pollux 4° N of Moon

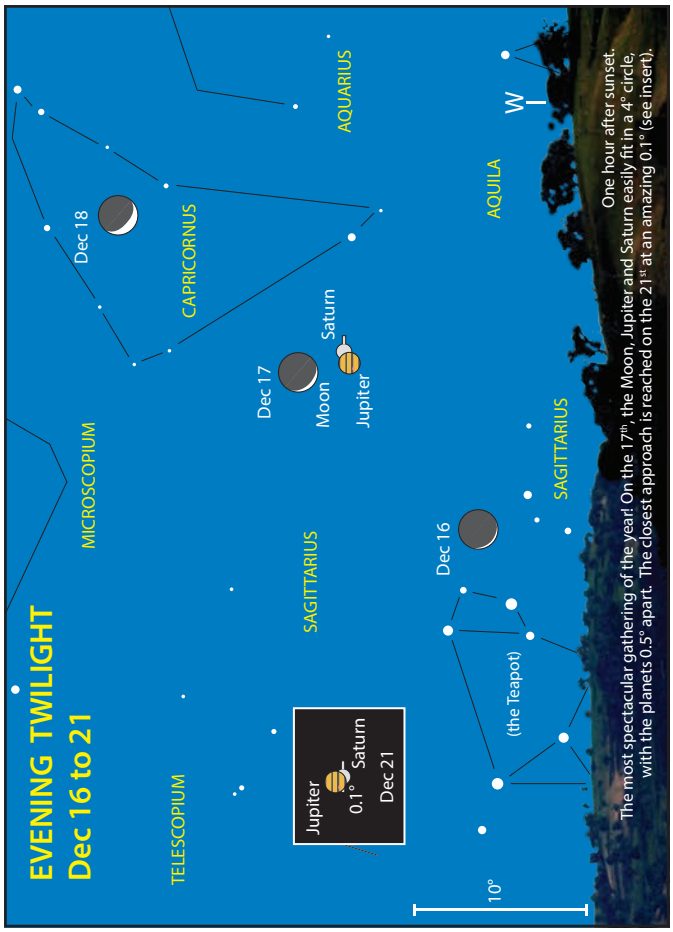
counterparts will see the best of the Geminids, they can still provide a spectacular display for us *down under*, particularly after midnight when the radiant appears above the northern horizon. New Moon on the 15th will leave the mornings skies free of interference.





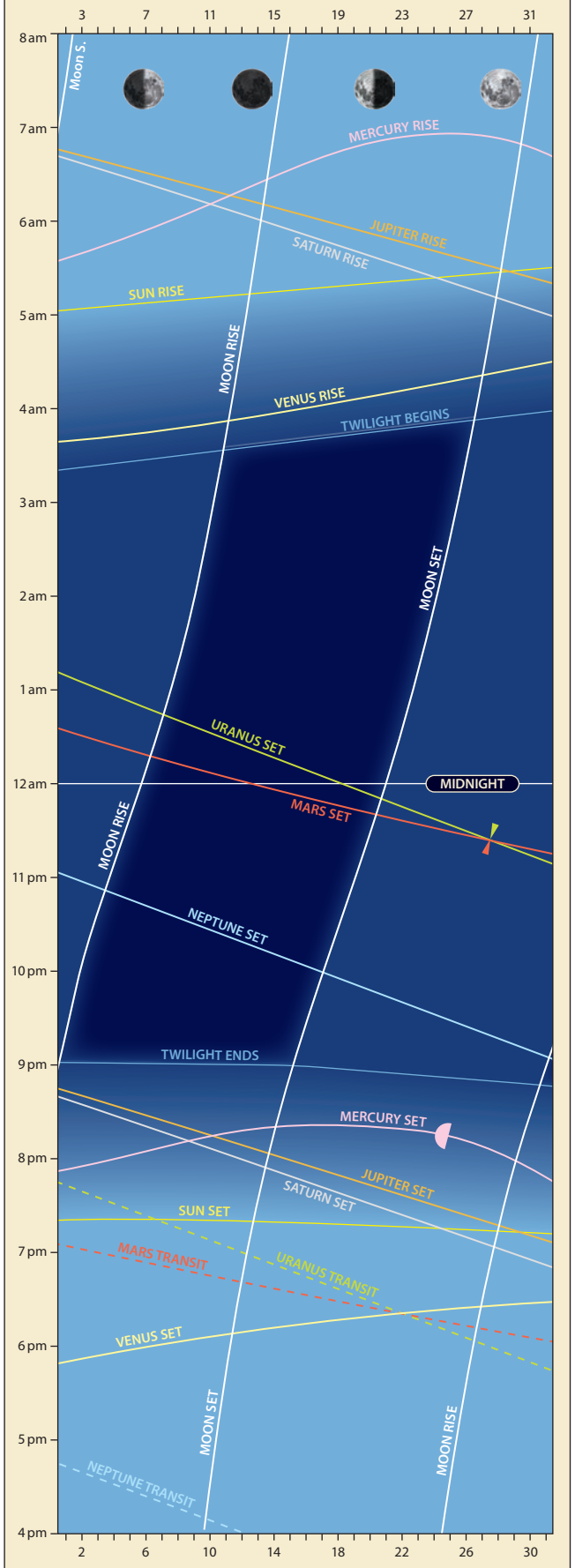
Approximate local standard time, for daylight saving add one hour.





JANUARY 2021

RISE–SET CHART



Approximate local standard time, for daylight saving add 1 hour.

HIGHLIGHTS

- Mercury and Moon close.
- Venus and slender crescent Moon close.
- Mars near the Moon and Uranus.

CONSTELLATIONS

This year 'Constellations' will concentrate on the beauty of the southern celestial hemisphere that we are privileged to live under. With the exception of November and December, each month will highlight an easily recognisable constellation or region in the evening sky, contributing a significant piece to the unique vista of the southern Milky Way. Emphasis has been placed on brighter objects that are ideal targets for binocular observers.

Face north and locate Orion the Hunter, a constellation familiar to both hemispheres. His belt forms the base of the saucepan (All Sky Map No. 2). Following him loyally across the sky are his two dogs, Canis Minor (the lesser dog) and above, Canis Major (the greater dog). The three constellations are joined by their three alpha stars forming a near exact equilateral triangle, the Winter Triangle (yes, named from the Northern Hemisphere). They are Betelgeuse (Orion), Procyon (Canis Minor) and Sirius (Canis Major)—see All Sky Map 4.

Canis Major is easily recognizable, not just because of brilliant Sirius (near the dog's head) but also the four bright stars making up its hind quarters. These are Omicron^2 (o), Epsilon (ε) and Eta (η) in a triangle with Delta (δ) Canis Majoris inside the triangle. From the Northern Hemisphere, where the legends originated, the dog appears to be standing upright on the southern horizon on its back legs.

APPEARANCE of the PLANETS

MERCURY



5 Jan
dia 5.0"
mag –0.9



15 Jan
dia 5.7"
mag –0.9



24 Jan
dia 6.9"
mag –0.7
Greatest elongation East (18.6°)

VENUS



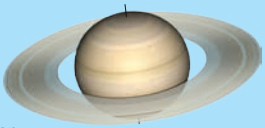
15 Jan
dia 10.4"
mag –3.9

MARS



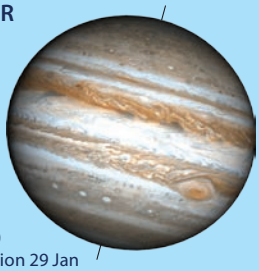
15 Jan
dia 9.1"
mag 0.1

SATURN



1 Jan
dia 15.3″
mag 0.6
conjunction 24 Jan

JUPITER



1 Jan
dia 32.9"
mag –2.0
conjunction 29 Jan

URANUS



15 Jan
dia 3.6"
mag 5.8

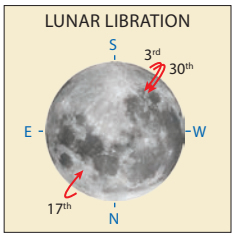
NEPTUNE

15 Jan
dia 2.2"
mag 7.9

Except for the Sun, Sirius is the brightest star in the heavens. While it is true it's intrinsically brighter than the Sun, the star's dominance is mostly because it's close by. At a distance of about eight light-years, it's around double the distance to the nearest star system to Earth, Alpha Centauri. Although Sirius comes from the Greek for 'searing' or 'scorching', it is often called the 'dog star'. Being first seen each year from the Northern Hemisphere in late summer mornings just before sunrise, it often heralds another hot day. Hence the origin of the term 'dog days'. This is also called the star's helical rising. Although it sounds technical, it's just the first time a star becomes visible before sunrise after being in conjunction with the Sun.

A beginner object of note in Canis Major is the bright open star cluster M41. Being clearly visible in binoculars and only 4° from Sirius they both fit in the same field of view. With over 100 stars, ranging in magnitude from 7th down to around 12th, it's a challenge to see how many individual ones are visible in your view.

THE MOON



Our regular readers may note that in this section we normally list occultations of first magnitude stars by the Moon. However, since the occultation of Aldebaran on 3 September 2018 there are no further occurrences with the brightest stars until 25 August 2023 when a new series with Antares begins. The next sequence involving Aldebaran begins on 18 August 2033.

- 3rd Midnight (10 pm WST) Maximum Libration (8.1°), bright SW limb.
- 6th 8 pm (6 pm WST) Last Quarter.
- 10th 2 am (midnight previous day WST) Moon at perigee (closest to Earth at 367,387 km).
- 13th 3 pm (1 pm WST) New Moon.

A Binocular Variable Star – S Carinae

To those just starting their discovery of the Universe, it may come as a surprise that there are stars which vary in brightness. Currently over 150,000 are confirmed and many more suspected. The overall majority of these are either too faint or change so little, the eye would have difficulty noticing any difference. However, there are some that alter so dramatically that, if the Sun was an example, it would dim to be little brighter than the Full Moon! Many have been known to flare up only once, such as many (but not all) novae, or the most extreme example—supernovae, where the entire star is permanently destroyed or transformed. This article will concentrate on the periodic variables suitable for visual observers.

Periodic variable stars fall into two broad camps.

The first are the **intrinsic** type with most of the variability caused by the star swelling and contracting, all due to internal processes.

The others are **extrinsic** where light from the star is physically blocked. The most common example are eclipsing binaries where a fainter star in orbit passes between the star and us. It's worth remembering that the majority of stars are now considered to be binaries. The Earth only needs to be in the same plane as their orbits for us to see an eclipse. Where these stars are close enough for one to cannibalise its companion, this leads to many fascinating variations which are beyond this brief discussion.

The monitoring of the brightness of variable stars contributes greatly to astronomy. For example, Cepheids (an intrinsic type) have been an important stepping stone in our understanding of the scale of the Universe. Studying supernova light curves have led to possibly the greatest discovery of our lifetime—the Universe expansion is accelerating. Mira variables contribute to our knowledge of the evolution of stars. Such work needs studies over many decades across thousands of stars. Professional astronomers have neither the time nor telescope resources to cope. That's where amateur astronomers come in.

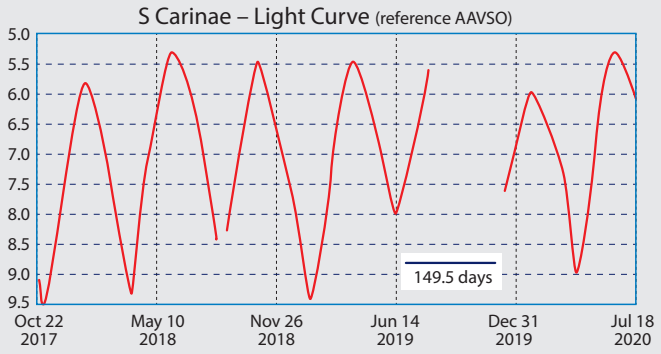
Mira Variables.

The most well-known swelling/contracting type are the Mira or long period variables. They are an ideal place for amateurs to commence observations, as in many cases their brightness varies across a large range and over reliable periods (typically around 100 to 500 days). Of the thousands of Miras known, there are many that, when brightest, would be visible through binoculars. There are only a few dozen with a large brightness range, which allow an observer to follow it through the entire cycle with such instruments. 'S Car' is one of them.

Why Choose S Carinae?

Let's back up, you might ask why chose a binocular variable at all, 'My telescope can see much fainter'? If you are experienced go for it, although binoculars allow a much wider field which makes it not only easier to find the star (not in a narrow field that is inverted or perhaps mirror imaged as well), but can allow a wider choice of standard stars to make comparisons with. The variable star needs to be in the same field of view.

Based upon recent cycles of S Car (see graph), the next two maxima are expected around mid-November 2020 and mid-April 2021. So, looking at early 2021, it will rise from



The graph covers the previous seven cycles going back to late 2017. Gaps are periods where the AAVSO had no data available. The line '149.5 days' represents the historical average period for S Car.

17th 1 am (11 pm previous day WST) Maximum Libration (8.5°), bright NE limb.

21st 7 am (5 am WST) First Quarter.

21st 11 pm (9 am WST) Moon at apogee (furthest from Earth at 404,360 km).

29th 5 am (3 am WST) Full Moon.

30th 7 pm (5 pm WST) Maximum Libration (7.7°), bright SW limb.

THE PLANETS

Late last month **Mercury** slipped into the western evening twilight. By mid-January, the planet appears above Jupiter and Saturn as they head toward their conjunctions with the Sun. On the 14th, the slender crescent of the 1-day old Moon will be just 1.6° from Mercury at the end of civil twilight. This will be a difficult observation with both bodies around 5° from the horizon and binoculars are recommended (see Sky View). The speedy little planet reaches its greatest elongation of 19° east of the Sun on the 24th and thereafter begins its journey toward inferior conjunction (between the Earth and the Sun).

Venus is a brilliant object in the eastern dawn sky from the beginning of the year until mid-February when it becomes too close to the Sun for observation. A most impressive conjunction occurs on the 12th with Venus less than 1° from the limb of the slender crescent 28-day old Moon (see Sky View).

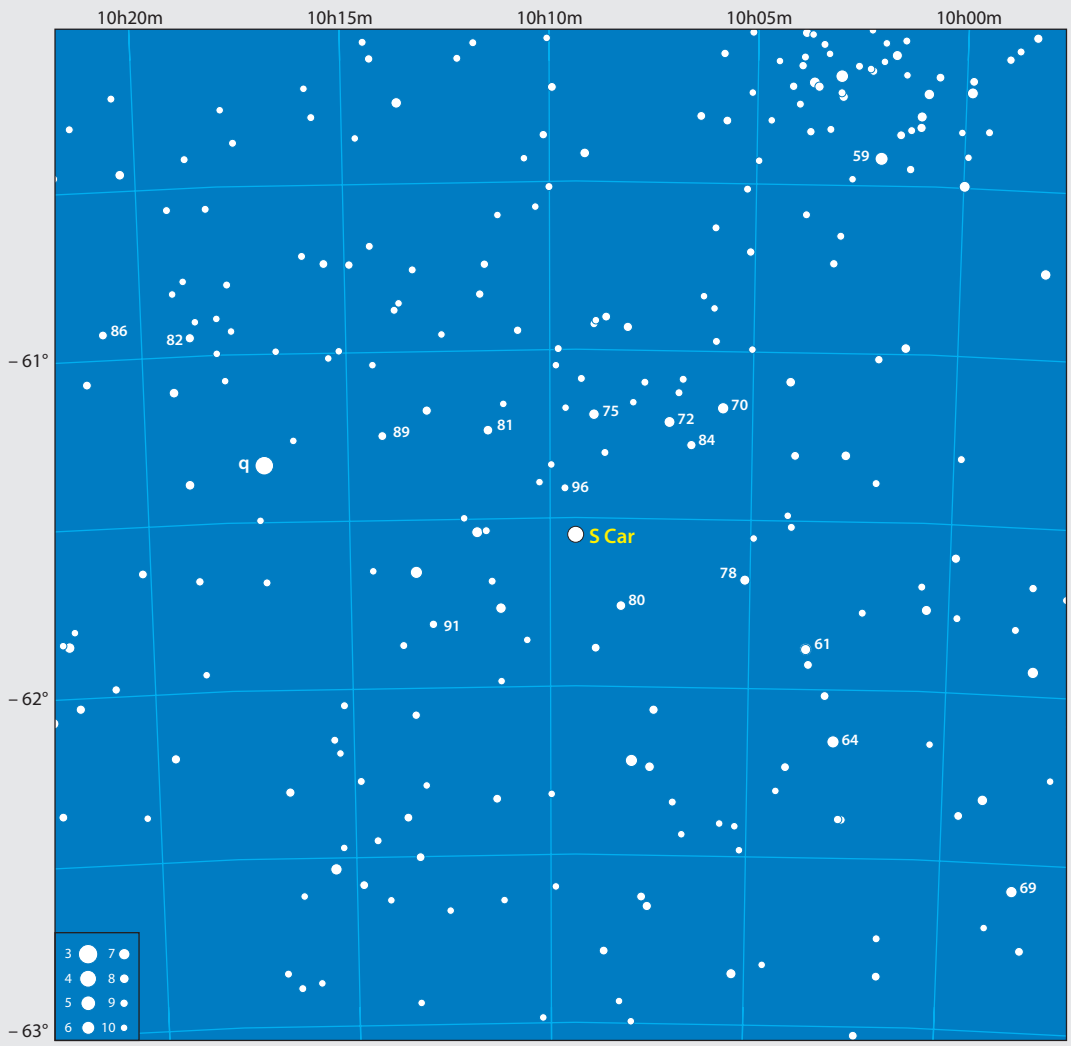
The **Earth** is at perihelion on the 2nd, the closest point in its orbit to the Sun (147,093,154 km or 0.983257 au distant).

a minimum around January/February to maximum in April, just in the sweet spot for observing Carinae high in the early evening sky.

Finding the Star. S Car is in a rich Milky Way region near the Eta Carinae Nebula. Binoculars should have little problem showing the nebula, p and q Carinae (two 3rd magnitude stars in the south-west quadrant) in the same field. 'S' is only 1° west of 'q'. Note the size of the field covered by this map. At 3° it will fill a substantial amount of your binocular field of view. See All Sky Map No. 1 where its location is drawn.

Estimating its Brightness. Become familiar with the star pattern, concentrating on the location of 'S' and the surrounding stars marked with magnitudes (e.g., 72 means 7.2 magnitude). These numbers are how bright they appear visually. Ideally find two of these standard stars where one is brighter than 'S' and the other fainter. As an example, let's say you notice it's brighter than an '81' but fainter than '75' star. You might then compare 'S' to the '78' one, OK, brighter than this one as well? So, you have now placed it between 7.5 and 7.8. Is it closer to one of them? Yes, so, let's call it magnitude 7.6. If it is brightening, a few days later you might see it's now brighter than the 75 but fainter than 72 and so on. It takes practice but visually reliable 0.1 magnitude accuracy can be achieved.

In closing, there are a number of organisations in the world that can not only offer advice but where you can lodge your observations. The American Association of Variable Star Observers (AAVSO) is an invaluable resource where charts similar to our S Car can be downloaded for numerous variables as well as historical light curves. Our curve for S Car is based on the data available from the AAVSO, numbers that were submitted by about 20 observers from all over the world. In terms of Southern Hemisphere resources, Variable Stars South (VSS) is a good contact.



S Car binocular chart (3° square), including reference stars for magnitude estimates.

DIARY			
Fri	1st	am	Comet C/2019 N1 (ATLAS) 1.0° W of star Eta Centauri
Fri	1st	1 am	(11 pm WST, prev day) star Pollux 4° N of Moon
Sun	3rd		Earth at perihelion, 0.983257060 au
Sun	3rd	am	Quadrantids meteor shower, 28 Dec–12 Jan, Moon affected.
Sun	3rd	3 am	(1 am WST) star Regulus 7° SE of Moon
Sun	3rd	Midn.	(10 pm WST) Maximum Libration (8.1°), bright SW limb
Mon	4th	3 am	(1 am WST) Comet C/2019 N1 (ATLAS) 0.2° SE of NGC 5643 (G) in Lupus
Mon	4th	Midn.	(10 pm WST) m.p. 4 Vesta 1.5° N of Moon
Tue	5th		Mercury at greatest latitude south
Tue	5th		Venus 1.0° N of NGC 6401 (GC) in Ophiuchus
Wed	6th	8 pm	(6 pm WST) Last Quarter Moon
Thu	7th	3 am	(1 am WST) star Spica 8° S of Moon
Fri	8th	am	Comet C/2019 N1 (ATLAS) 0.6° W of star Alpha Lupi
Sat	9th	pm	m.p. 10 Hygiea 0.2° S of star Omicron[1] Cancri
Sun	10th	am	Comet C/2019 N1 (ATLAS) 0.6° NE of star Rho Lupi
Sun	10th	2 am	(Midn. WST, prev day) Moon at perigee (367,387 km)
Sun	10th	3 am	(1 am WST) star Antares 9° SE of Moon
Tue	12th	5 am	(3 am WST) Venus 1° N of Moon
Wed	13th	3 pm	(1 pm WST) New Moon
Thu	14th	8 pm	(6 pm WST) Mercury 1.5° N of Moon
Thu	14th	Midn.	(10 pm WST) Uranus stationary
Fri	15th		d.p. Pluto in conjunction with Sun
Sat	16th		Venus at descending node
Sat	16th	9 pm	(7 pm WST) Comet C/2019 N1 (ATLAS) 0.05° S of NGC 5749 (OC) in Lupus
Sun	17th	1 am	(11 pm WST, prev day) Maximum Libration (8.5°), bright NE limb
Sun	17th	8 pm	(6 pm WST) d.p. 1 Ceres 4° S of Moon
Sun	17th	9 pm	(7 pm WST) Neptune 3° N of Moon
Wed	20th	pm	m.p. 14 Irene 1.0° SW of star Iota Cancri
Thu	21st	7 am	(5 am WST) First Quarter Moon
Thu	21st	9 pm	(7 pm WST) Mars 4° NW of Moon
Thu	21st	9 pm	(7 pm WST) Uranus 2° NW of Moon
Thu	21st	11 pm	(9 pm WST) Moon at apogee (404,360 km)
Thu	21st	pm	Uranus 1.5° S of Mars
Sat	23rd		m.p. 4 Vesta stationary
Sat	23rd	pm	m.p. 18 Melpomene 0.2° SW of star Kappa Cancri
Sun	24th		Mercury at ascending node
Sun	24th	am	Comet C/2019 N1 (ATLAS) 2.4° E of star Alpha Centauri
Sun	24th		Mercury at greatest elongation East (18.6°)
Sun	24th		Saturn in conjunction with Sun
Sun	24th	9 pm	(7 pm WST) star Aldebaran 7° SW of Moon
Sun	24th	pm	m.p. 60 Echo 0.8° SW of m.p. 18 Melpomene
Tue	26th		d.p. 1 Ceres 0.8° NW of NGC 7727 (G) in Aquarius
Tue	26th	pm	m.p. 4 Vesta 0.4° SW of NGC 3810 (G) in Leo
Thu	28th	2 am	(Midn. WST, prev day) star Pollux 3° N of Moon
Fri	29th		Mercury at perihelion
Fri	29th	5 am	(3 am WST) Full Moon (381,521 km)
Fri	29th		Jupiter in conjunction with Sun
Sat	30th	3 am	(1 am WST) m.p. 29 Amphitrite 0.05° SE of M105 (EG) in Leo
Sat	30th	3 am	(1 am WST) m.p. 29 Amphitrite 0.1° SW of NGC 3384 (G) in Leo
Sat	30th	Noon	(10 am WST) Mercury stationary
Sat	30th	7 pm	(5 pm WST) Maximum Libration (7.7°), bright SW limb
Sat	30th	10 pm	(8 pm WST) star Regulus 6° SW of Moon

Mars, in the northern sky at the end of evening twilight, is obvious in a region devoid of bright stars. Beginning the month in Pisces, it soon moves into Aries for the remainder of January. Since opposition last October the planet has shed several magnitudes and its disc diameter is now down to 10 arcseconds. Being a non-opposition year, the Red Planet offers little for the visual telescope user as its disc continues to shrink to around 4 arcseconds at year end. Mars will be 4° from the 8-day old waxing gibbous Moon on the 21st (see Sky View). The really neat thing about this conjunction is that if you look at the pair in binoculars you will find 6th magnitude Uranus between them.

Both **Jupiter** and **Saturn** become lost in the western evening twilight as they head toward their solar conjunctions in late January. Last month's amazing conjunction saw the two giants just 0.1° apart, they are now separating and will not rendezvous again until 2040 (at 1.2° apart). Both planets reappear in the dawn sky in mid-February.

Uranus, in Aries, is visible in the early western evening sky. The planet comes to the end of four months of retrograde motion on the 14th and resumes drifting eastward against the stellar background. On the 21st you can easily locate this faint planet (even from suburban skies) with binoculars when it appears between Mars and the crescent Moon. In fact, you can use Mars as a signpost to locate Uranus from the 18th to the 23rd when they are separated by 2° or less.

Neptune begins the month 1° from the 4th magnitude star Phi (φ) Aquarii. Located low in the early western evening sky, the separation between the planet and star increases to 2° by month's end.

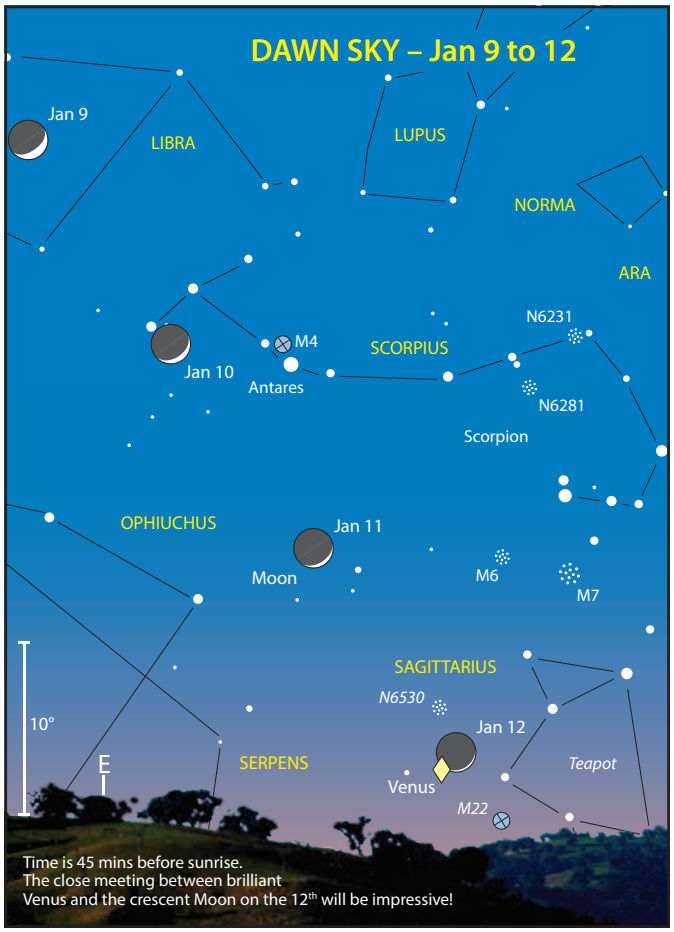
DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

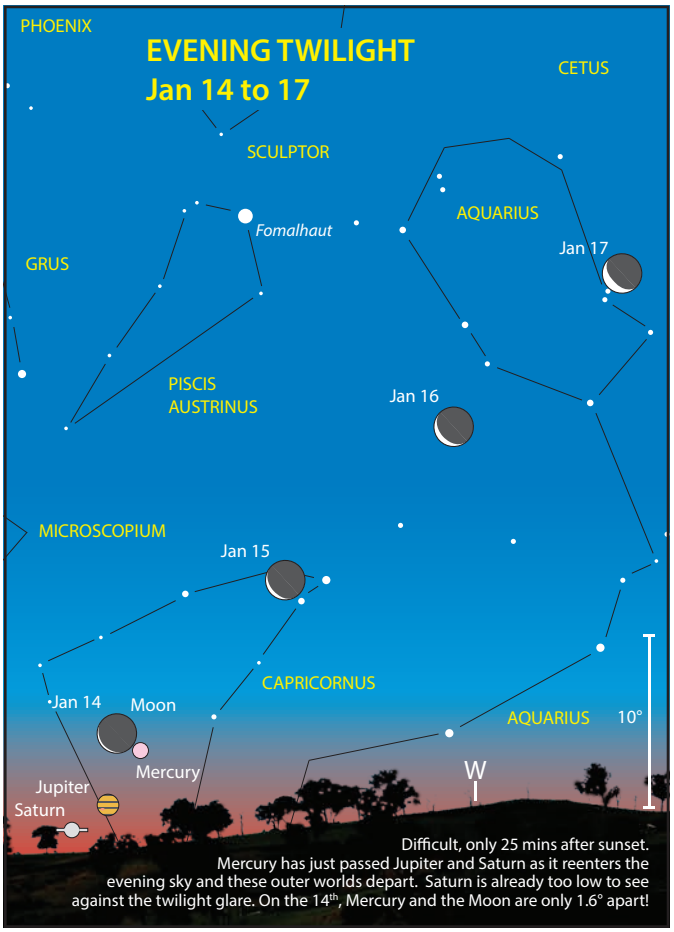
Dwarf planet **Pluto** is in conjunction with the Sun on the 15th and returns to the morning skies in February. As January closes and February opens, m.p. 29 Amphitrite (approaching opposition at 9th magnitude) pays a visit to the famous bright galaxy M105 in Leo (see diary). Brightest minor planets at opposition this month include:

Date	Minor Planet	Constellation	Mag.
1 Jan	54 Alexandra	Gemini	12.4
2 Jan	41 Daphne	Monoceros	11.9
3 Jan	103 Hera	Gemini	11.4
12 Jan	287 Nephthys	Gemini	11.2
16 Jan	196 Philomela	Gemini	11.0
18 Jan	135 Hertha	Cancer	12.0
20 Jan	26 Proserpina	Cancer	11.2
21 Jan	15 Eunomia	Cancer	8.4
24 Jan	14 Irene	Cancer	9.3
28 Jan	10 Hygiea	Cancer	9.9
29 Jan	21 Lutetia	Cancer	11.2

COMETS

Comet C/2019 N1 (ATLAS) opens the year at 10th magnitude in Centaurus, quickly moving into Lupus. On the morning of the 1st, the comet is only 1° west of the bright star Eta (η) Centauri. It is rising late in the evening as the month begins, though it rapidly becomes visible throughout the night as it moves south. Mid-month sees ATLAS move into Circinus,





Approximate local standard time, for daylight saving add one hour.

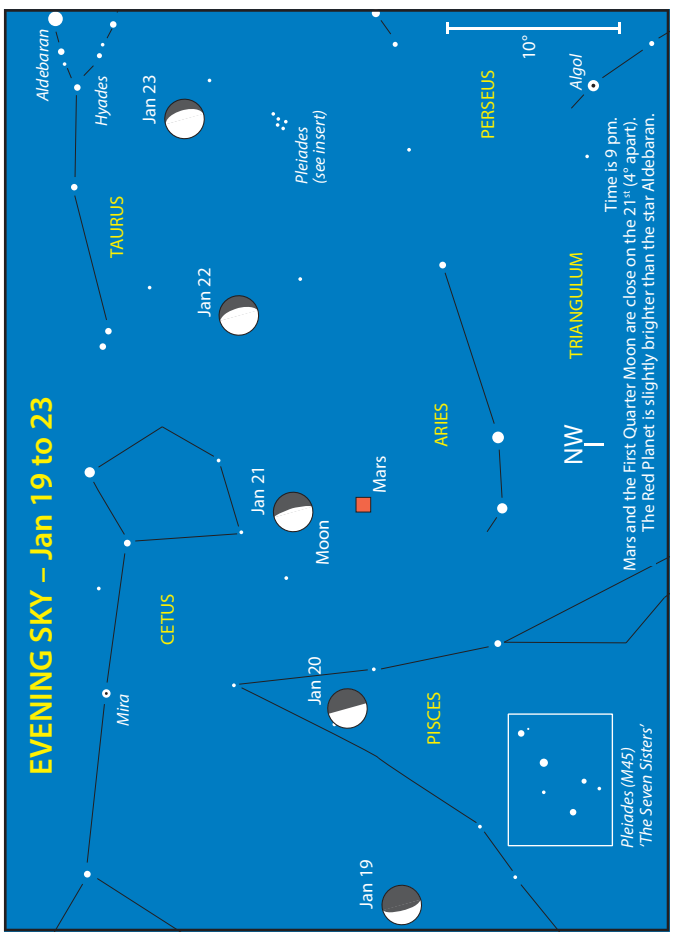
and then Triangulum Australe by month's end, by which time it may have faded to 11th magnitude. Late January will see the comet near Alpha Centauri (see diary).

DOUBLE STARS

Delta (δ) Orionis (Mintaka, 34 Orionis, STFA 14), All Sky Map No. 2, is easily found as the westernmost star in the belt of Orion. Through binoculars or a small telescope the A component, magnitude 2.4 spectral type O9.5II, appears white and the C component, magnitude 6.8, bluish (STFA 14AC). They are currently separated by 56 arcseconds with position angle of 4°. The system comprising Delta Orionis is a group of massive, hot, luminous, rapidly rotating O and B stars. S.W. Burnham in 1892 noted a faint B component magnitude 14.2, located 38 arcseconds from the primary (BU 558AB). In 1978, the A component was found to have a very close visual companion (HEI 42) magnitude 3.8, by Wulff Heintz using a 24-inch refractor, with a separation at that time of 0.15 arcseconds and which has now widened to 0.3 arcseconds. The orbital period has been calculated to be 326 years.

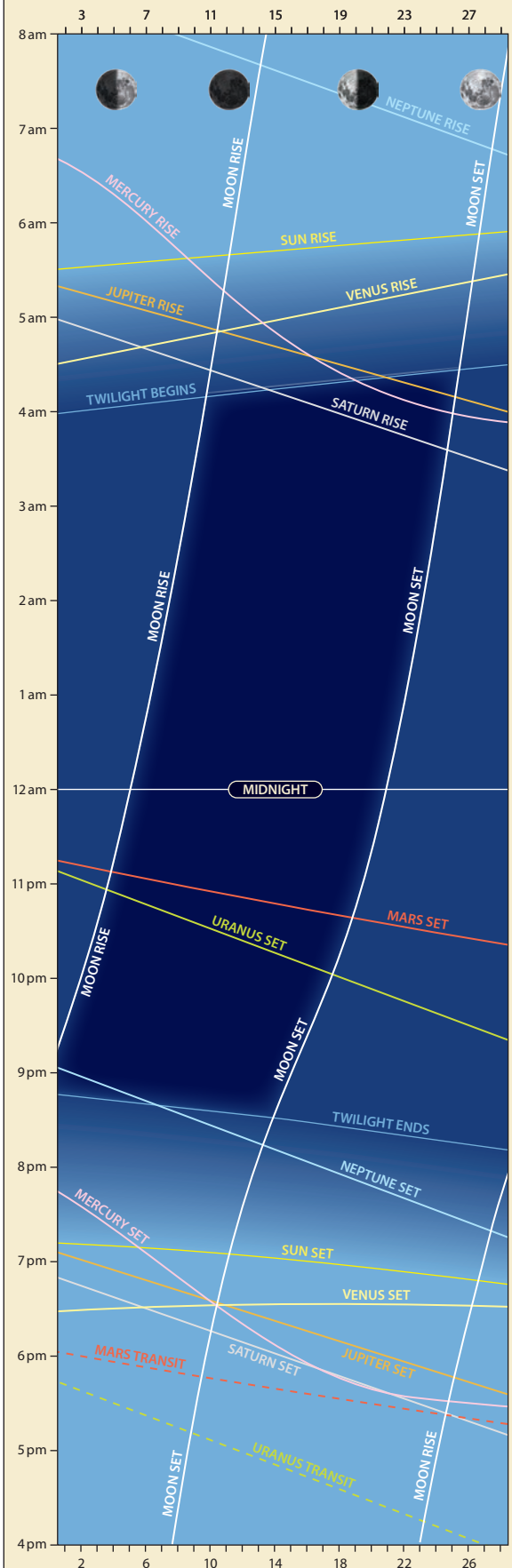
METEOR SHOWER

The **Quadrantids** are a strong and consistent northern shower. They are difficult for southern observers, with the radiant below the early morning north-eastern horizon. Although, if observing before dawn, the occasional long-pathed member may be glimpsed on the morning of the 3rd. The Quadrantids are active from 28 December to 12 January, with up to 40 meteors per hour at their peak. There will be interference from the waning gibbous Moon this year.



FEBRUARY 2021

RISE–SET CHART



Approximate local standard time, for daylight saving add 1 hour.

HIGHLIGHTS

- Mercury between Jupiter and Saturn.
- Venus and Saturn close.
- Venus and Jupiter close.
- Four planets in Capricornus in the morning sky.

CONSTELLATIONS

This month we commence a three-month voyage on the Argo Navis (see also monthly feature page 36). This was one of the original 48 constellations and is named in honour of the mythical ship of Jason and the Argonauts fame. It was subsequently divided into three constellations—Puppis, Vela and Carina.

Of these, Puppis. the ship's stern (or poop deck), takes up more of the sky than either of the others. Although it contains reasonably bright stars, it is the faintest of the three, sometimes appearing from suburbia as a blank section of sky between Vela and Canis Major. It has no obvious asterisms, but the authors have always found the two joined triangles, made up of mostly 3rd magnitude stars, at the southern end of Puppis (starting near Canopus) to be quite distinctive (see All Sky Map No. 4).

The northern half of Puppis intrudes considerably into the Milky Way. This particular region of our galaxy lacks a lot of the nebulae seen elsewhere, the same type of gas and dust clouds responsible for the numerous dark lanes seen in Scorpius, Sagittarius and Ophiuchus (to name a few

APPEARANCE of the PLANETS

MERCURY — Mercury in inferior conjunction on the 8th

1 Feb
dia 8.9"
mag 1.1

20 Feb
dia 9.3"
mag 0.9

28 Feb
dia 8.0"
mag 0.2

VENUS
15 Feb
dia 9.9"
mag –3.9

MARS
15 Feb
dia 7.1"
mag 0.7

SATURN
15 Feb
dia 15.2″
mag 0.7

JUPITER
15 Feb
dia 32.7"
mag –2.0

URANUS
15 Feb
dia 3.5"
mag 5.8

NEPTUNE
15 Feb
dia 2.2"
mag 8.0

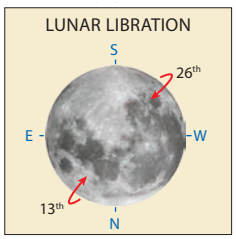
constellations). This transparency makes Puppis a rich hunting ground for star clusters with over a dozen visible in binoculars, although under such low power most appear as fuzzy blobs. With the constellation and its star clusters extending as far north as Sirius, it is no surprise that some were visible from Paris from where Charles Messier compiled his famous list of bright deep sky objects in the late 18th century.

M47 is very large, bright and with a scattering of stars of 6th magnitude, binoculars have no problem resolving individual stars. Only 1° away lies M46—the two making a wonderful binocular double cluster. It's bright, but different from M47, being made up of multitudes of fainter stars, looking more nebulous than its companion through binoculars. M46 also has the telescopic bonus of a planetary nebula, NGC 2438. This small, fuzzy ring is a foreground object (lying in front of the open cluster). Located 9° south of M46 is the third Messier object, M93. Returning to binoculars, this open cluster is as bright as M46, but smaller, with fewer stars, having an overall triangular shape.

We would like to conclude with two special stars in Puppis. Zeta (ζ) Puppis, also known as Naos (Greek for ship), is the brightest star in the constellation. Its modest magnitude of 2.3 certainly understates a truly remarkable star. It is a blue supergiant of spectral class O, making it one of the hottest stars known (40,000K), certainly one of the hottest naked-eye stars.

The other star is L2 Puppis. It is one of the brightest Mira type variable stars known, oscillating between about 6th to 9th magnitude over a period of 141 days. There are only a few variables in the sky with this amplitude whose entire cycle can be viewed easily with binoculars. See page 26 for another bright variable.

THE MOON



4th 5 am (3 am WST) Moon at perigee (closest to Earth at 370,116 km).

5th 4 am (2 am WST) Last Quarter.

12th 5 am (3 am WST) New Moon.

13th 11 am (9 am WST) Maximum Libration (7.9°), bright NE limb, close to New Moon.

18th 8 pm (6 pm WST) Moon at apogee (furthest from Earth at 404,467 km).

20th 5 am (3 am WST) First Quarter.

26th Noon (10 am WST) Maximum Libration (8.3°), near Full Moon.

27th 6 pm (4 pm WST) Full Moon.

THE PLANETS

After inferior conjunction on the 8th, **Mercury** returns to the morning sky. On the 14th the planet appears just 4° to the north of Jupiter—a difficult observation close to the horizon just 25 minutes before sunrise. From the 20th to the end of February, an easier planetary meeting occurs when Mercury appears between the gas giants, Jupiter and Saturn. At this time their higher altitude makes the three planets easier targets in the twilight (see Sky View).

Venus, in the eastern morning dawn sky, has encounters with two of the Solar System's giant planets this month (see Sky View). First, on the 6th and 7th the planet passes within 1° of Saturn. Second, on the 11th it will be less than 1° from Jupiter with the slender crescent of the 29-day old Moon close by. On the following morning the separation between the planets decreases to 0.5°. A low horizon is required, especially for the Jupiter encounter and binoculars will always assist in finding planets in the twilight. From mid-month Venus will be lost in the Sun's glare until its return to the evening sky in May.

Mars is visible in the early north-western evening sky in Aries for most of February. It then moves into Taurus, ending up a few degrees away from the Pleiades (M45) star cluster. On the 19th the First Quarter Moon will be 5° from the planet (see Sky View).

After solar conjunction in January, **Jupiter** returns to the dawn sky this month. A bit of a challenge in a bright sky and at a low altitude, but on the 11th Jupiter will be less than 1° from Venus with the *fingernail* crescent Moon nearby (see Sky View). On the next morning the two bright planets will be just 0.5° apart (see Sky View and Venus section). It is interesting to note that Jupiter, in Capricornus, shares the constellation with Mercury, Venus and Saturn from the 18th to 23rd.

Saturn returns to the morning dawn after solar conjunction last month. A difficult observation on the 6th and 7th as Venus passes within 1° of the Ringed Planet. Binoculars will help with the brightening sky, but you will still need a good low eastern horizon (see Sky View).

DIARY			
Mon	1st	11 pm	(9 pm WST) m.p. 18 Melpomene 0.1° W of star Alpha Cancri
Mon	1st	pm	m.p. 29 Amphitrite 0.8° N of M96 (SG) in Leo
Wed	3rd	am	Comet C/2019 N1 (ATLAS) 0.6° SW of star Gamma Trianguli Australis
Wed	3rd	3 am	(1 am WST) star Spica 10° S of Moon
Thu	4th	5 am	(3 am WST) Moon at perigee (370,116 km)
Thu	4th	pm	m.p. 29 Amphitrite 1.0° N of M95 (SG) in Leo
Fri	5th	4 am	(2 am WST) Last Quarter Moon
Fri	5th	pm	m.p. 18 Melpomene 0.9° NE of M67 (OC) in Cancer
Sat	6th		Saturn 0.7° NE of Venus
Sun	7th	3 am	(1 am WST) star Antares 7° SW of Moon
Sun	7th	pm	m.p. 60 Echo 0.3° SW of M67 (OC) in Cancer
Mon	8th		Mercury at greatest latitude north
Mon	8th		alpha-Centaurids meteor shower, Jan 31 to Feb 20.
Tue	9th		Mercury in inferior conjunction
Wed	10th	3 am	(1 am WST) d.p. Pluto 2° N of Moon
Wed	10th		m.p. 2 Pallas in conjunction with Sun
Thu	11th		Comet 7P/Pons-Winnecke 0.7° S of star Delta Serpentis
Fri	12th	5 am	(3 am WST) New Moon
Sat	13th	11 am	(9 am WST) Maximum Libration (7.9°), bright NE limb
Wed	17th	8 pm	(6 pm WST) Uranus 5° NE of Moon
Thu	18th	5 am	(3 am WST) Jupiter 0.1° W of star Theta Capricorni
Thu	18th	8 pm	(6 pm WST) Mars 8° NE of Moon
Thu	18th	8 pm	(6 pm WST) Moon at apogee (404,467 km)
Sat	20th		Venus at aphelion
Sat	20th	5 am	(3 am WST) First Quarter Moon
Sat	20th	9 pm	(7 pm WST) star Aldebaran 6° S of Moon
Sat	20th	11 pm	(9 pm WST) Mercury stationary
Wed	24th	9 pm	(7 pm WST) star Pollux 6° NW of Moon
Fri	26th	Noon	(10 am WST) Maximum Libration (8.3°), near Full Moon
Sat	27th	1 am	(11 pm WST, prev day) star Regulus 5° S of Moon
Sat	27th	6 pm	(4 pm WST) Full Moon (370,595 km)
Sun	28th		Comet C/2019 N1 (ATLAS) 0.5° N of star Sigma Octantis

Milky Way Supernovae Part 1

In this two-part article we discuss one of the most dramatic events in the Universe, the explosion of a star into a supernova (SN). This month we give an overview of how and when supernovae occur, and the second instalment in April describes the handful of such events witnessed in history within the Milky Way.

To understand how a star can so dramatically self-destruct we need to review how a star works. They live in a continual balance between the energy caused by nuclear fusion pushing out, from in and around the core, and the enormous gravitational pressure from the surrounding gas (plasma) trying to collapse it. When this stable state gets disturbed it can oscillate (expand/contract) creating a variable star, nova or, in the extreme case, a supernova. The Sun has done a pretty good job maintaining its equilibrium for the last five or so billion years, but even good old Sol does have some minor regular oscillations.

At its maximum, a supernova can shine as brightly as several hundred million Suns, perhaps outshining the total brightness of an entire galaxy. Hence, even without optical aid, such a spectacular explosion may be obvious out to tens of thousands of light-years. This would still rival Venus if it was 30,000 light-years away. After the initial detonation, the decline in brightness is very gradual, over a period of several years.

How Often do they Happen?

Despite their spectacular nature, why are there only five unambiguous cases recorded in history. Are Milky Way supernovae that rare? If we look over the last two thousand years there have been many sightings of potential *guest stars,* mostly reported from Asian, European and Arabic countries. There is little doubt they are a mixture of variable stars, novae and supernovae and even comets. So, determining if they are indeed fixed stars visible for at least six months would be a good start. Even knowing what part of the sky they are in at times doesn't help much. There are numerous supernovae remnants (SNR) scattered across the sky so marrying an ancient sighting to a particular SNR can be challenging. Besides the five confirmed SNs, there have been five other reasonable candidates in the common era but they either lacked reliable (or any) records or may have been too heavily obscured by galactic dust to be visible. The only other likely candidate was the guest star observed in 185 CE near the border of Centaurus and Circinus (near Alpha Centauri). This was observed by Chinese astronomers and reported as visible for eight months, possibly reaching negative magnitudes.

We are fortunate that surveys of thousands of galaxies over many years, producing hundreds of supernovae, has greatly helped in determining their frequency.

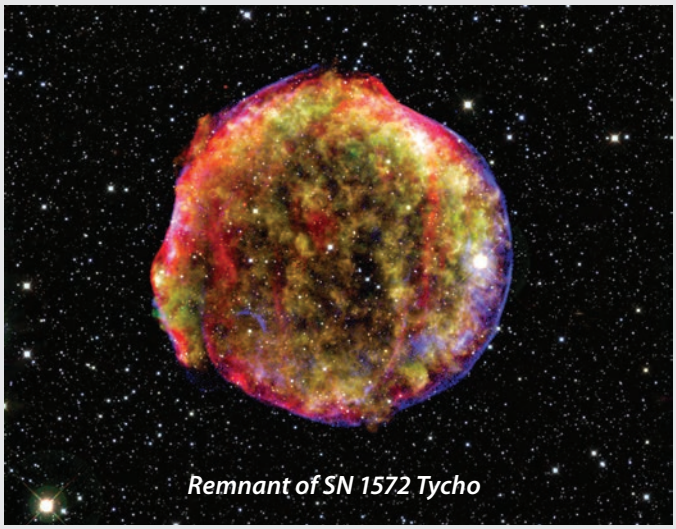
The best estimate for a Milky Way type galaxy, is around one or two per century. Considering modern technology monitors the heavens across the spectrum, including gamma rays and even neutrinos, it is considered unlikely such a dramatic event could occur today anywhere in the Milky Way without being detected.

What Triggers a Supernova?

The most common types of supernovae are called type I and II (spoken as one or two). Type I have a version called Ia. These form in binary star systems and start with one component being a carbon-oxygen rich white dwarf with a mass generally below 1.4 solar masses. The star over many millions of years accretes or draws matter off its companion leading to an increase in mass, hence increasing the inward pressure. This pressure cooker effect leads to a runway nuclear explosion. Because all type Ia SNs ignite under comparable conditions and temperatures this leads to them having the same absolute brightness (–19 magnitude) with similar shaped light curves. They also have a unique identifying feature in their spectrum, a specific silicon line when at peak intensity. This is why they are used as *standard candles* for determining distances to galaxies. Once a SN is determined to be type Ia, the drop in brightness from magnitude –19 gives the distance. If you do the mathematics on SN 1006, assuming an absolute magnitude of –19 at around 7,000 light-years away the result is –7.3 magnitude, agreeing closely with the ancient observations (see Part 2 in April).

Type II SNs are the James Dean stars in the Universe. They live hard and die young. They are a violent explosion of a single massive star, which needs to be at least eight times that of the Sun. There is an upper limit of around 40 solar masses, where super massive stars above this will likely explode then implode directly into black holes.

Lower mass stars, less than 8 solar masses, do not have sufficient pressure to go beyond forming the lightest elements in the periodic table. However, the relentlessly higher mass of our *James Dean* stars continue fusing and creating elements of greater mass right up to iron. Because the pressure diminishes as you get further from the core this results in an onion effect with shells of elements forming, for example by the time the core is now considered iron rich, it is surrounded by a silicon layer which is surrounded by an oxygen shell then out to neon then carbon, helium and hydrogen out to the surface (photosphere). Here is the key point, as the mass of the elements increase, the net energy generated in their fusion decreases, so by the time the core reaches a nickel/iron state the energy production ceases with little outward pressure to support the star. When the core reaches 1.4 solar masses, it dramatically implodes with its inward velocity reaching up to 20% the speed of light! Once its innermost temperature reaches 100 billion degrees kelvin, it violently rebounds



Remnant of SN 1572 Tycho

with enough force to blow apart the remainder of the star. This shock wave and extremely high temperatures exist long enough to create the remaining natural elements of the periodic table.

Stars like these have a life measured in millions not billions of years so are key engines in driving star forming regions in the galaxy, seeding the galactic environment with elements that lead to formation of solar systems, rocky planets and eventually us.

Why are they Visible for so Long?

You may ask why do supernovae continue to glow for so long once they explode? Why don't they act like a firecracker once the initial enormous pressure is relieved? The events release large quantities of radioactive elements which decay, emitting copious energy in the gamma and x-ray part of the spectrum. This radiation causes the rapidly expanding gaseous shell to fluoresce. The resulting SNR continues to be a powerful source of X-rays and radio waves for several thousand years.

Are they a Threat to Life on Earth?

This radiation raises another aspect. Are supernovae just pretty displays or can they potentially put life on Earth at risk? It all comes down to their distance. Gamma rays can deplete the ozone layer leading to global warming. Around twenty SN explosions have occurred in the last 11 million years within 1000 light-years of Earth. In each case warming the Earth by around 4°C.

Based upon studies of the radiation output from SN 1987A, in the Large Magellanic Cloud (a type II), if such an event happened within around 20 light-years of the Earth, it would destroy half of the ozone layer. A SN is considered to happen within 30 light-years, maybe every 200 million years. If the radius is pushed out to 100 light-years the frequency increases to one in 10 million years, 200 light-years to about a million years and out to 1,000 light-years maybe one each 10,000 years. With this knowledge it is interesting to consider how distant our five Milky Way SNs were; they ranged from 6,500 to 14,000 light-years.

The statistics get a little more uncertain if we look at them by type. Type IIs happen more in star forming regions, so it's logical to expect that we would be more likely to have close encounters with such events as the Sun passes through the plane of the Milky Way (closer to the HII regions in the spiral arms) during its 230 million year orbit (the galactic year).

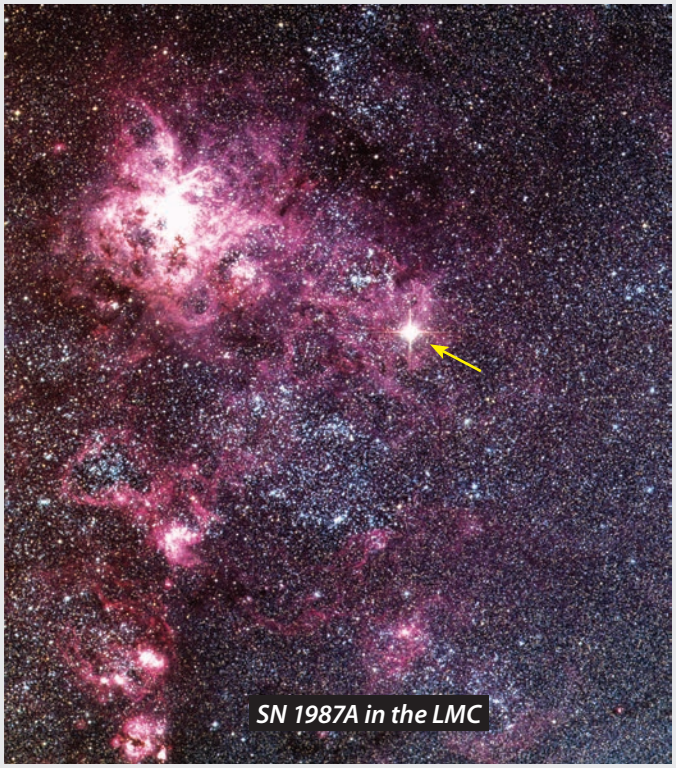
Gamma ray bursts from a 'way too close' supernovae are expected at a rate of one or two every billion years and it has been considered a possible cause for the Ordovician Extinction (450 million years ago) that wiped out 80% of the oceanic life on Earth.

What will be the Next Milky Way Supernova?

There are quite a few stars that are likely candidates but considering there is nearly no knowledge of the expected behaviour of stars just before exploding, predicting the timing for any specific star is like winning the lottery! Examples of bright giant stars that make the list are Antares, Betelgeuse, Spica, Rigel and Deneb, all are possible type IIs. Betelguese's sudden drop by a full magnitude and recovery in late 2019 also raised a few eyebrows.

We'd like to make a special mention of Eta Carinae. Today it is believed to be two massive binary stars (so a type I SN is likely). In the mid 19th century it flared up becoming briefly the second brightest star in the sky (around –1 magnitude). Eta then dropped to 7th magnitude and in the mid 20th century began to brighten reaching its current status of just under 4th magnitude— who knows what it will do!

None of the known possible supernova progenitors are closer than around 150 light-years. Of those mentioned above, Antares is the closest at 550 light-years, so there is little danger here. As for the ones we don't know, well…


SN 1987A in the LMC

Uranus, in Aries, appears low in the early western evening sky after the end of astronomical twilight. The planet remains in the constellation of the Ram until moving into Taurus in 2024.

Neptune becomes lost in the evening twilight as it nears conjunction with the Sun early next month.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Brightest minor planets at opposition this month include:

Date	Minor Planet	Constellation	Mag.
2 Feb	18 Melpomene	Cancer	9.5
2 Feb	60 Echo	Cancer	10.3
5 Feb	94 Aurora	Leo	11.9
7 Feb	88 Thisbe	Cancer	11.7
17 Feb	387 Aquitania	Leo	12.0
22 Feb	29 Amphitrite	Leo	9.1

COMETS

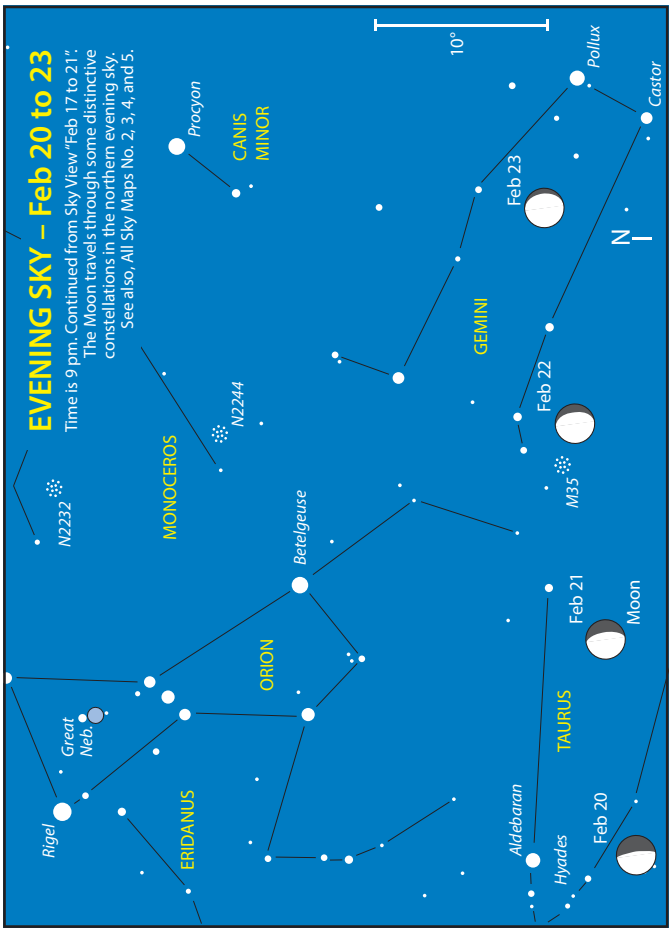
Comet C/2019 N1 (ATLAS) continues its southward trek, passing from Triangulum Australe into Apus and finally Octans, closing out February approximately 2° from the South Celestial Pole. It is around 11th magnitude and will continue to fade slowly. During the month, the comet remains circumpolar, transiting around sunrise.

DOUBLE STARS

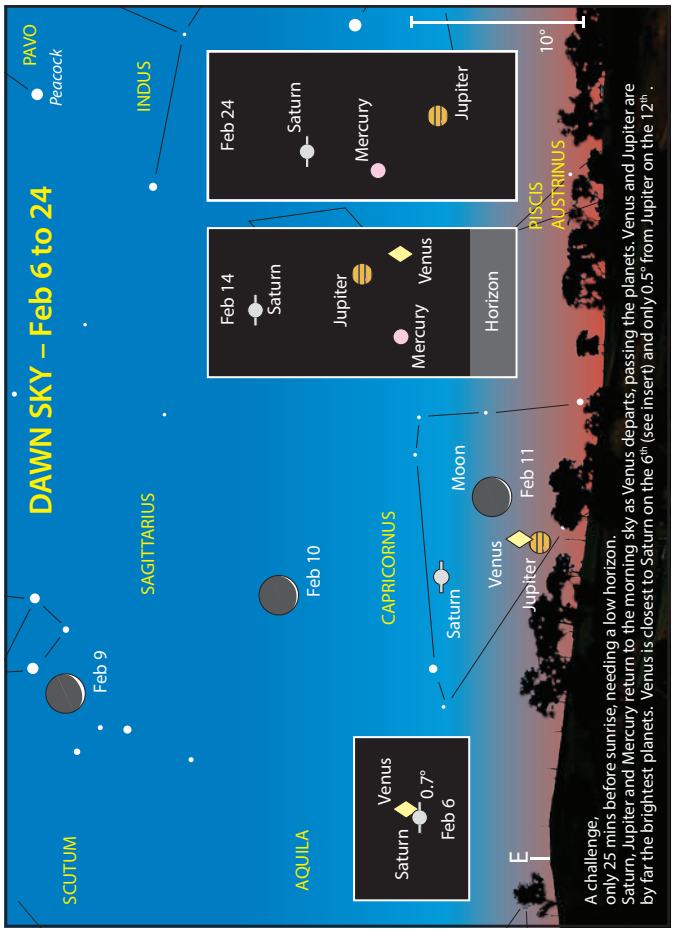
Eta (η) Orionis (DA 5AB), All Sky Map No. 2, is located about 4° from Messier 42 and 3° from the westernmost star in Orion's belt and forms the lip of the Saucepan asterism. In 1848 W.R. Dawes observed this star and discovered it was a close double. William Herschel had previously observed it in 1781 and saw only the distant faint 11th magnitude companion (H 6 67AC, now located 114 arcseconds away at PA 51°). The brilliant white stars are magnitudes 3.6 and 4.9 (spectral types B1V and B2e) and are separated by 1.8 arcseconds with a PA of 77°. It is a challenging tight pair, but can be split with a 150 mm telescope under high magnification. Although originally thought by Dawes to be a true binary, the pair may not actually be connected. Time and more observations are needed. What is known is that the bright A component is a massive multiple star. The Aa and Ab components orbit each other every 7.99 days. The Aa-Ab pair orbits the Ac component with a period of 9.4 years. In addition, the Ac component shows radial velocity variations which could be due to either the presence of a companion star or to β Cepheid-like pulsations on a time scale of 0.864 days.

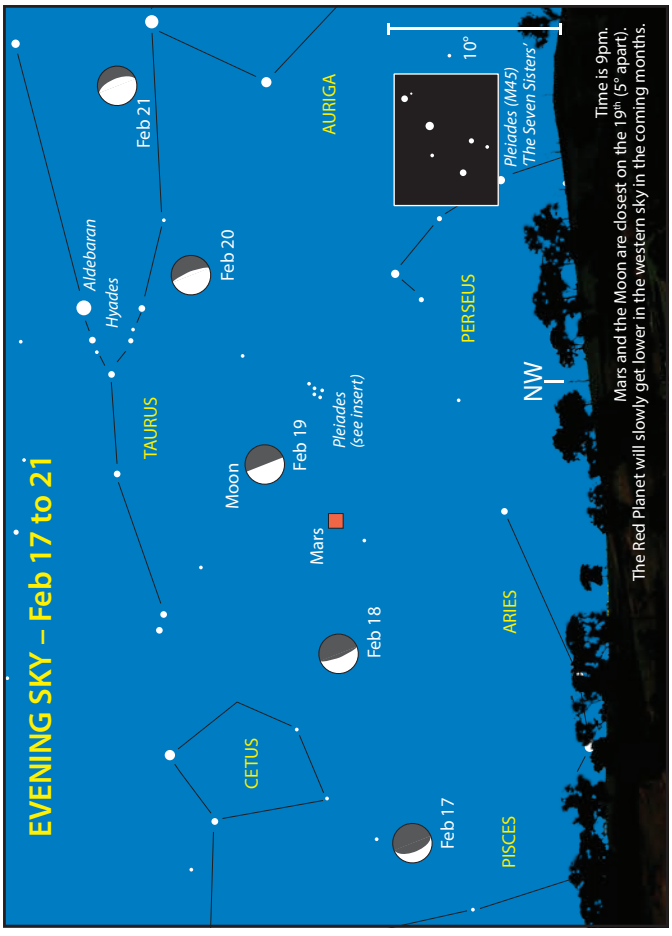
METEOR SHOWER

The **alpha-Centaurids**, one of the main southern summer showers, are active from 31 January to 20 February, with a maximum zenith hourly rate of six around the 8th. The shower is noted for its bright yellow or blue coloured fireballs that frequently reach negative magnitudes. They are also well known for their long-lasting trains that vary from a few seconds to several minutes. Since the radiant is above the horizon all night from most southern locations and their activity is spread over such a wide period, observers are sure to catch the odd meteor at any time.

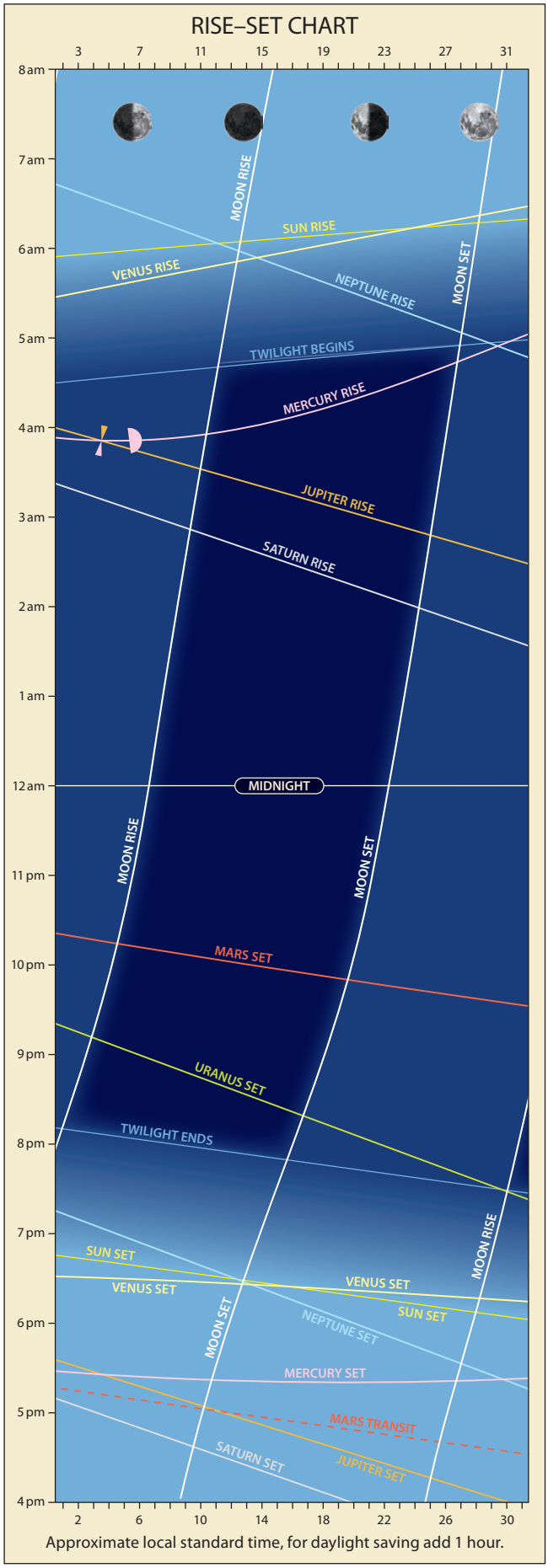


Approximate local standard time, for daylight saving add one hour.





MARCH 2021



Approximate local standard time, for daylight saving add 1 hour.

HIGHLIGHTS

- Mercury at best in morning sky.
- Mercury and Jupiter very close.
- Mercury, Jupiter and Moon form a neat triangle.
- Supermoon.

CONSTELLATIONS

High in the southern evening sky lies a group of 2nd to 4th magnitude stars, arranged in a large oval shape, almost twice the size of Orion. These are the sails of Jason's ship, the Argo Navis, now known as the constellation of Vela (see All Sky Maps No 1 and 4). Being part of the ship, Vela lays on the eastern side of Puppis. Located in the plane of the Milky Way, It is certainly endowed with many deep sky objects.

At the western end of the sails lies Vela's brightest star, Gamma (γ) Velorum. This is a multiple star and binoculars show two white stars of magnitude 1.8 and 4.2, separated by 41 arcseconds. A small telescope clearly shows two additional, slightly yellow companions, one of magnitude 7.4, forming a nice isosceles triangle with its brighter brothers. The other star is magnitude 9.2 and further apart making this multiple appear 'Y' shaped.

Only 2° south we find the brilliant open star cluster NGC 2547. Binoculars show a loose scattering (around 0.5° wide) of about ten 8th magnitude stars. It includes a distinctive curve of stars, running north-south, centred on a 6.4 magnitude white star. A small telescope reveals around 30 fainter members about 10th to 11th magnitude peppering the field. Gamma and the cluster easily fit in the same binocular field, making an attractive view.

APPEARANCE of the PLANETS

MERCURY



6 Mar
dia 7.2"
mag 0.1



15 Mar
dia 6.3"
mag 0.0



25 Mar
dia 5.7"
mag –0.2

Greatest elongation West (27.3°)

VENUS



1 Mar
dia 9.8"
mag –3.9

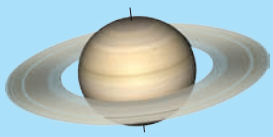
MARS



15 Mar
dia 5.9"
mag 1.1

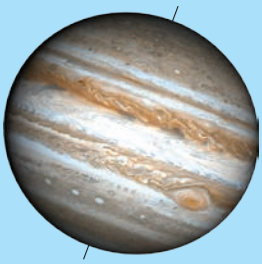
Venus in superior conjunction on the 26th

SATURN



15 Mar
dia 15.6″
mag 0.7

JUPITER



15 Mar
dia 33.7"
mag –2.0

URANUS



15 Mar
dia 3.4"
mag 5.8

NEPTUNE

30 Mar
dia 2.2"
mag 8.0
conjunction 11 Mar

Move clockwise around the sail to the two 2nd magnitude stars, Delta (δ) and Kappa (κ) Velorum. These borrow two other 2nd magnitude stars from neighbouring Carina (Epsilon and Iota Carinae) to form the obvious False Cross asterism (All Sky Map 1).

Within the sails, towards the eastern end, is the globular star cluster, NGC 3201. Being quite bright (7th magnitude) binoculars show an obvious fuzzy ball. A small telescope shows that the globular is quite diffuse with a wide bright centre showing little condensation. A 150–200 mm instrument is needed to occasionally glimpse its brighter (13th mag) stars.

Near Vela's border with Antlia lies the 9th magnitude planetary nebula NGC 3132, better known as the Eight Burst Nebula. Telescopically it shows a prominent 2-arcminute, slightly elliptical ring with a 10th magnitude central star. The interior appears mottled.

The Legacy of the Gods

Did our readers think they were going to escape this year without being enlightened by some legends related to the constellations? Sorry, no. In this article we will concentrate on the interrelationships or stories that link many of these random patterns in the sky. It will allow you to dazzle people at gatherings under the stars with such totally useless knowledge—what a bonus.

Although there have been some minor changes, the 48 traditional constellations as described by Ptolemy in his Almagest (2nd century CE) still exist (see page 141 for a list of all 88 constellations recognised today). By described, we mean he helped define the appearance of the figures, as passed down by the ancient Greeks. He explained their shapes and placement by his descriptive naming convention for many of the stars, for example, today the brightest star in Orion the Hunter is called Rigel, in Arabic meaning foot. Ptolemy called it "the bright star in the left foot".

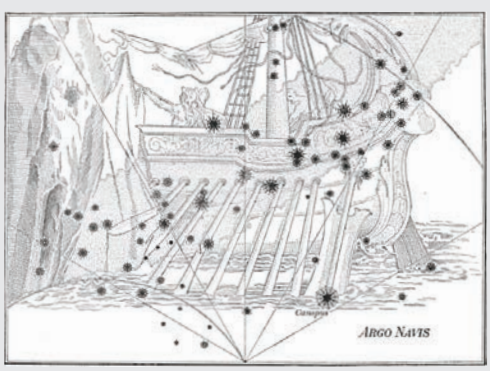
These stories relate to the stars visible at the time from Mediterranean latitudes. However, due to precession over the last 4,000 years, some of the constellations mentioned are no longer visible from Crete, where many of these legends were played out (so possibly created). For example, Ara is now gone with half of Centaurus missing (including both Pointers and all of the Southern Cross).

The ancient Greeks believed the star patterns represented a strange assortment of human-like figures, creatures and miscellaneous objects. The gods had placed these beings in the heavens, often as rewards to recognise great feats or events. As well as being immortals, the Greeks depicted the gods as mostly human in form, interacting openly with mortals and succumbing to the same faults and temptations. A central theme running through many of the stories revolves around Zeus (the king of the gods, known as Jupiter to the Romans) who married his sister, Hera. His infidelity was legendary and the illegitimate children he fathered continually fuelled his wife's hatred, with Hera constantly plotting revenge on these women and children. Not much of a foundation for a religion. In particular, Zeus seemed to have a liking for human ladies and even the great hero and god, Hercules, was his son from a mortal mother.

Because Hercules was immortal, Hera couldn't kill him, so she set out to make his life as miserable as possible. She cast a spell on him and forced Hercules to kill his children. In penance, for an act he had no control over, he undertook the famous 12 labours. An example of Hera's pettiness was during Hercules fight with the multiheaded snake Hydra (the second of his 12 labours, and another constellation), a crab came and nipped him on the foot. In pain, Hercules apparently turned around and squashed it with his foot. In recognition of the crab's effort, Hera placed it in the heavens—the constellation of Cancer. Hercules' tasks included killing a number of other creatures which became constellations, such as: Leo the lion, Taurus the bull and Draco the dragon. Eventually, Zeus placed Hercules amongst the stars.

In February 'Constellations' we mentioned a special constellation of Ptolemy's, the only one to be carved up, Argo Navis (the ship, Argo). In more modern times it was considered too big and now exists as three constellations, Carina the Keel, Vela the Sails and Puppis the Poop Deck.

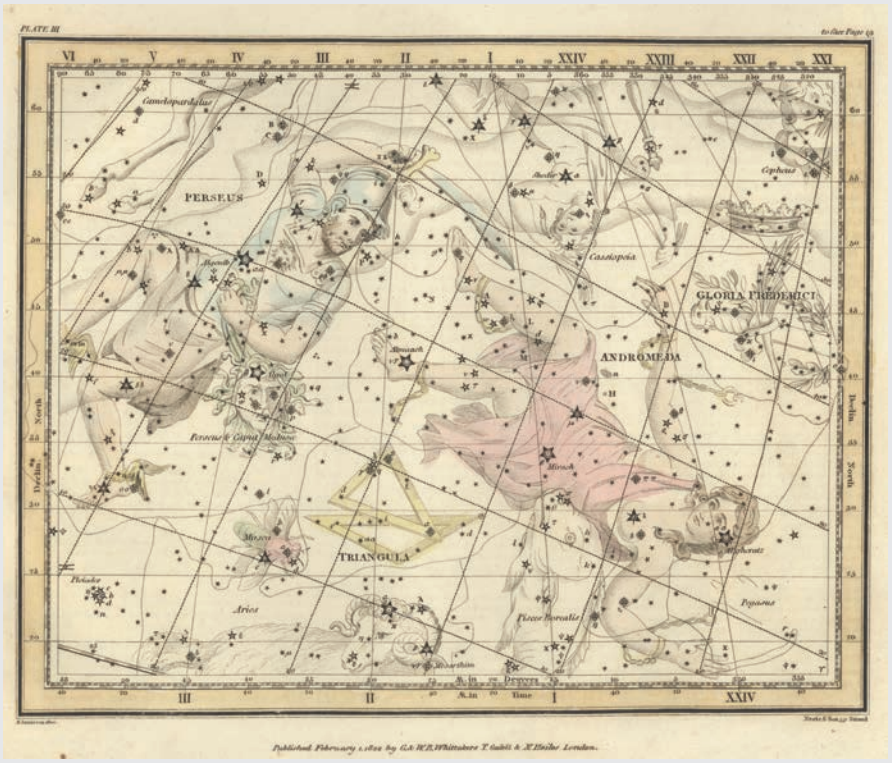
The famous voyage of Jason and his Argonauts has touched on a number of constellation myths. The story began with Jason's father who was the king of Iolcus in Greece, which made Jason his rightful successor. When Jason was a child his ruthless uncle, Pelias seized power. Fearing for his life, his family had Jason smuggled away to be raised by Chiron (see below). On returning to Iolcus as a man, Jason was dishonestly offered the throne by Pelias if he could bring him the golden fleece from Colchis. Pelia knew this would be a long and difficult voyage, hoping Jason would perish in the attempt. Hence the voyage of the Argo. This 50-oared galley was crewed by many Greek heroes, including constellation legends like Hercules (who was taking a break from his labours) and the Gemini twins Castor and Pollux (sometimes called Polydeuces). After many adventures Jason finally returned with the golden fleece, leaving the Argo permanently beached at Corinth. As an ironic twist to this story, when he was an old man Jason returned to the Argo and when he sat down to rest, the rotting timbers in the bow gave way, killing him! The ram, that was the source of the fleece, was immortalised as the constellation of Aries.



Chiron was a centaur (half-man half-horse) and considered to be very wise, knowledgeable and a skilled teacher. He was well respected by the gods and is depicted in the heavens as Centaurus, beside two other related constellations. He is carrying a spear with the impaled wolf, Lupus to be sacrificed on Ara the Altar (or maybe just a barbecue).

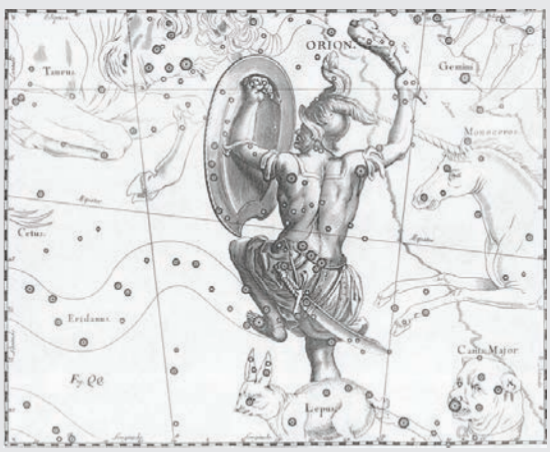
Here's something for people who enjoyed the movie *Clash of the*

Titans. Zeus managed to impregnate the lady Danae by causing a shower of golden rain to fall in her lap (there was no end to Zeus' lust to procreate). This resulted in a son called Perseus, another famous Greek hero and constellation. He was responsible for the slaying of Medusa, one of the Gorgons consisting of three hideously ugly sisters who, when gazed upon, would turn their hapless victims to stone. Perseus is presented in the sky holding the Medusa's head by the hair. It is interesting to note the position of one of Medusa's eyes is the location of the star Beta Persei, also known as Algol, derived from an Arabic phrase meaning 'head of the ghoul'. The star has a long history of being associated with evil, sometimes called the *Demon Star*, not because of the mythology but because the ancients couldn't explain its periodic changing in brightness and colour. Today we know it as the most famous example of an eclipsing binary star (see also page 26).



Perseus is often referred to as the *Rescuer of Andromeda*. He is indeed placed in the heavens next to this maiden's constellation where she is depicted as chained to rocks, awaiting her sacrifice to the sea monster, Cetus (another nearby constellation). In the sky, Andromeda is linked to the constellation of Pegasus by the bright star Alpheratz, part of the great square of Pegasus. Perseus flew in and killed Cetus just as it was starting to attack Andromeda, by turning it to stone with the head of the Medusa. Some variations have Perseus riding Pegasus, but having wings on his sandals he didn't need any help flying. However, this story's connection to Pegasus is much more bizarre. When Perseus decapitated the Medusa, Pegasus (fully grown) sprang out of her body and flew away. In fact, Pegasus comes from a Greek word meaning 'springs'.

Another significant contribution to the mythology of the heavens is Orion the Hunter. The Saucepan asterism along with the bright stars of Rigel and Betelgeuse make this constellation one of the most recognisable in summer evening skies. We have already mentioned his two loyal hunting dogs following him across the sky in January constellations, Canis Minor and Canis Major. Perhaps the least known Orion connection is Lepus the Hare. Lying just below Orion's feet (above for us), this constellation represents the hunter's favourite prey and is seen being chased by his two dogs. Perhaps it was thought a mere rabbit to be a little beneath the stature of such a mighty hunter, for Orion is shown as fighting Taurus. However, there is no mention of a bull in the Orion folklore. Indeed, this bovine was slaughtered by Hercules in one of his labours.

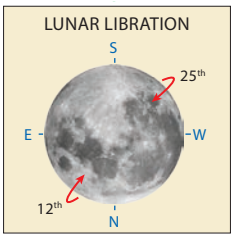


However, Orion does have a connection to the constellation of the bull through the Pleiades, a wonderful, compact, naked-eye star cluster in Taurus. Orion was believed to have a crush on these seven sisters and continually pursued them, as he still chases them across the sky. The Pleaides were named after their mother, Pleione and according to one of the mythologists, it was really Pleione that Orion had his amorous eyes locked on. It doesn't really make much difference, because the nine brightest stars are named after the seven sisters and their parents, Pleione and the father Atlas which make an impressive binocular (if not naked-eye) double star (see insert on All Sky Map No. 3).

Orion's influence also extends across to the opposite side of the sky. Rising in the east in autumn evening skies is the central region of the Milky Way along with Scorpius—heralding the coming winter. At the same time, the western sky sees Orion tilted on his side preparing to set. These bodies share a common legend and being on opposite sides of the celestial sphere is important to this fable. In Greek mythology, Orion was stung to death by the scorpion. So, this heavenly hunter is destined to flee from his deadly enemy for eternity!

In closing, a major difference between this religion and those of the modern monotheistic beliefs is the Greeks never created a cannon (central work) to refer to like the Bible or Quran. Instead these stories have been passed down through tradition or various works such as Homer's Iliad and Odyssey and records from mythologists such as Eratosthenes and Hyginus. So, you may hear some variations on these stories—anyway, enjoy whichever version of these tales you like.

THE MOON



2nd 3 pm (1 pm WST) Moon at perigee (closest to Earth at 365,423 km).

6th Noon (10 am WST) Last Quarter.

12th 10 am (8 am WST) Maximum Libration (8.0°), too close to New Moon.

13th 8 pm (6 pm WST) New Moon.

18th 3 pm (1 pm WST) Moon at apogee (furthest from Earth at 405,253 km).

22nd 1 am (11 pm previous day WST) First Quarter.

25th 9 pm (7 pm WST) Maximum Libration (8.3°), dark SW limb.

29th 5 am (3 am WST) Full Moon, supermoon (see p. 95).

30th 4 pm (2 pm WST) Moon at perigee (closest to Earth at 360,309 km).

DIARY			
Tue	2nd	3 pm	(1 pm WST) Moon at perigee (365,423 km)
Tue	2nd	Midn.	(10 pm WST) star Spica 7° SW of Moon
Wed	3rd		Mars 2.7° S of M45 the Pleiades (OC) in Taurus
Wed	3rd		Mercury at descending node
Fri	5th		m.p. 4 Vesta at opposition
Fri	5th	Midn.	(10 pm WST) star Antares 6° SE of Moon
Sat	6th	5 am	(3 am WST) Jupiter 0.5° SW of Mercury
Sat	6th	Noon	(10 am WST) Last Quarter Moon
Sat	6th		Mercury at greatest elongation West (27.3°)
Tue	9th	pm	m.p. 4 Vesta 1.2° N of star Theta Leonis
Wed	10th	4 am	(2 am WST) Saturn 4° NE of Moon
Wed	10th		Neptune in conjunction with Sun
Thu	11th	am	m.p. 63 Ausonia 0.3° S of star Tau Scorpii
Thu	11th	5 am	(3 am WST) Jupiter 4° NW of Moon
Thu	11th	5 am	(3 am WST) Mercury 5° NE of Moon
Fri	12th	10 am	(8 am WST) Maximum Libration (8.0°), too close to New Moon
Sat	13th	8 pm	(6 pm WST) New Moon
Sun	14th		Comet 7P/Pons-Winnecke 0.3° NW of star Kappa Ophiuchi
Sun	14th		Mercury at aphelion
Sun	14th		Venus at greatest latitude south
Mon	15th	am	gamma Normids meteor shower, Feb 25 to Mar 28.
Wed	17th	7 pm	(5 pm WST) Uranus 3° W of Moon
Thu	18th	3 pm	(1 pm WST) Moon at apogee (405,253 km)
Fri	19th		Mars 0.4° N of star Upsilon Tauri
Fri	19th	8 pm	(6 pm WST) Mars 5° NE of Moon
Fri	19th	8 pm	(6 pm WST) star Aldebaran 8° SE of Moon
Sat	20th		Equinox
Sun	21st	pm	m.p. 230 Athamantis 1.0° N of star Sigma Scorpii
Mon	22nd	1 am	(11 pm WST, prev day) First Quarter Moon
Tue	23rd		Comet C/2019 N1 (ATLAS) 1.3° W of star Gamma Hydri
Tue	23rd	9 pm	(7 pm WST) star Pollux 3° N of Moon
Tue	23rd	pm	star Aldebaran 7° S of Mars
Thu	25th	9 pm	(7 pm WST) Maximum Libration (9.3°), dark SW limb
Fri	26th		Venus in superior conjunction
Fri	26th	8 pm	(6 pm WST) star Regulus 7° SW of Moon
Sat	27th		d.p. 136472 Makemake at opposition
Mon	29th	5 am	(3 am WST) Full Moon (362,174 km)
Tue	30th	2 am	(Midn. WST, prev day) star Spica 7° S of Moon
Tue	30th	5 am	(3 am WST) Neptune 1.5° N of Mercury
Tue	30th	4 pm	(2 pm WST) Moon at perigee (360,309 km)
Tue	30th	11 pm	(9 pm WST) m.p. 18 Melpomene 0.1° SE of star Theta Cancri

THE PLANETS

Mercury opens the month 3° above Jupiter in the morning dawn sky with Saturn higher above the pair. On the 5th and 6th the innermost planet will be just 0.5° from Jupiter, a splendid sight for early morning risers (see Sky View insert). Another neat conjunction occurs on the 11th when the 27-day old slender waning crescent Moon forms a triangle with Mercury and Jupiter (see Sky View). Mercury reaches its greatest elongation of 27° west of the Sun on the 6th. With the ecliptic near vertical, early March is the most favourable time to view the planet in the morning sky this year.

Venus remains too close to the Sun for viewing this month and will be in superior conjunction on the 26th (Earth and Venus on opposite sides of the Sun). The planet will return to grace the evening sky in May where it stays until the end of the year.

The **Earth** is at its autumnal equinox on the 20th. From any place on Earth the Sun rises due east and sets due west, day and night are nearly equal.

In the early western evening twilight, **Mars** begins the month near the Pleiades star cluster (M45) in Taurus. As it moves through the constellation it will be interesting to compare it with the 1st magnitude star Aldebaran (Alpha (α) Tauri), the red eye of the Bull. Both will be of similar magnitude and display a reddish/orange tint. On the 19th, the 5-day old waxing crescent Moon will be less than 5° from the planet (see Sky View).

Jupiter, in Capricornus, is visible in the eastern morning sky before dawn. Mercury appears just 0.5° from Jupiter on the 5th and 6th with Saturn above the pair. At this time Jupiter is by far the brighter of the pair by two full magnitudes (see Sky View insert). The morning of the 11th brings another pleasant morning view with the 27-day old waning crescent Moon near Jupiter with Mercury below (see Sky View).

Saturn is visible in the morning sky above both Mercury and Jupiter. The planet moved into Capricornus in December last year and will remain in the constellation of the *sea goat* until early 2023 when it crosses into Aquarius. On the 10th, the 26-day old waning crescent Moon appears around 4° from the planet.

Uranus, in Aries, is visible low in the western evening sky. By the end of the month the planet will be lost in the evening twilight it moves toward conjunction in early May.

Neptune is in conjunction with the Sun on the 11th and will be lost from view until its reappearance in the morning sky in April.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

On the 27th, dwarf planet 136472 Makemake is at opposition at 17.2 magnitude in Coma Berenices. Brightest minor planets at opposition this month include:

Date	Minor Planet	Constellation	Mag.
4 Mar	4 Vesta	Leo	5.8
11 Mar	409 Aspasia	Crater	10.9
11 Mar	87 Sylvia	Leo	12.3

COMETS

Comet C/2019 N1 (ATLAS) continues its trek in the deep south, opening the month close to the South Celestial Pole. Continuing to fade slowly (possibly around 11.5 magnitude),

the comet goes on to pass between the two Magellanic clouds in the second half of March.

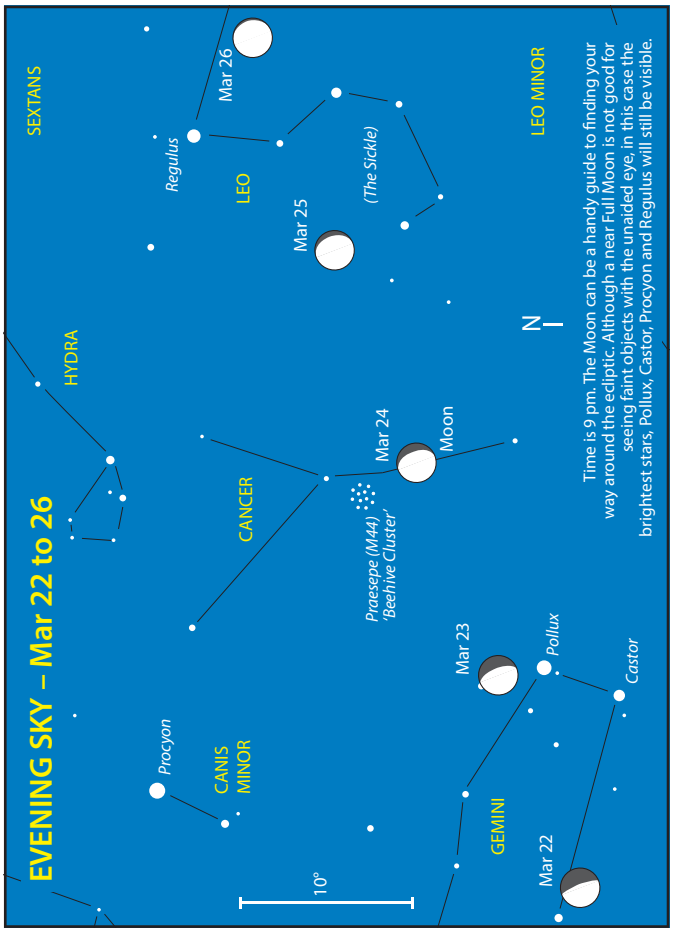
Comet 7P/Pons-Winnecke should brighten from 11th to 10th magnitude this month as it moves eastward through southern Hercules and northern Ophiuchus, rising around midnight and visible until dawn. Mid-month sees the comet close to Kappa (κ) Ophiuchi.

DOUBLE STARS

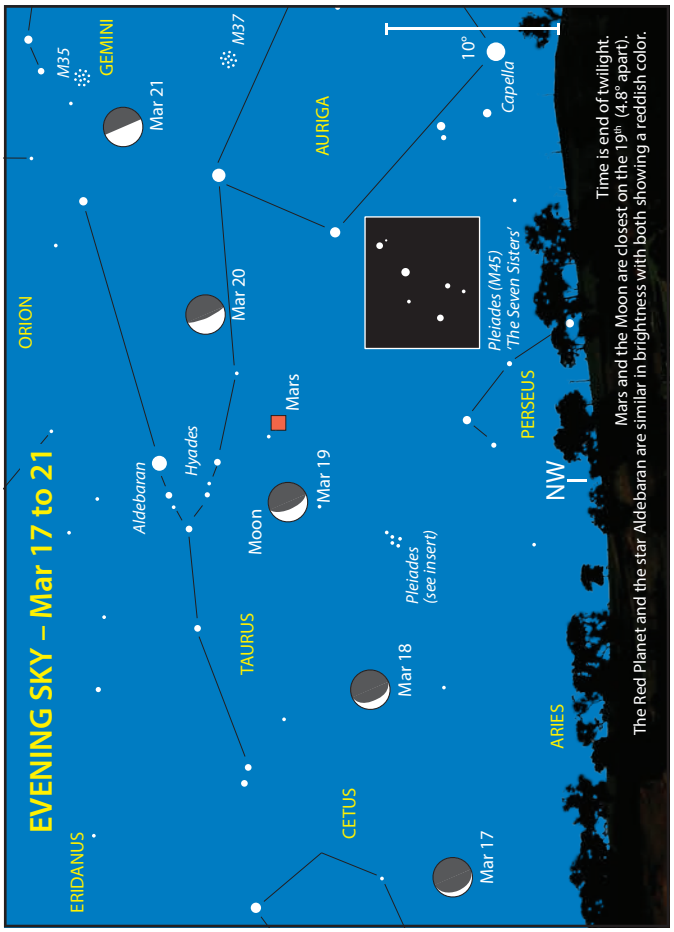
2 Puppis (STF1138), All Sky Map No. 4, is a bright moderately wide pair, located 0.9° east of the lovely open cluster Messier 46. The stars, magnitudes 6.0 and 6.7 (spectral types A2V and A8V) are separated by 17 arcseconds with a position angle of 341°. The stars are cream-white and bluish. There is a faint 10.6 magnitude C component located 100 arcseconds from the primary with a position angle of 229°. Numerous fainter background stars add to the richness of the scene. 2 Puppis is about three times the size of our Sun and is located 254 light-years from the Earth.

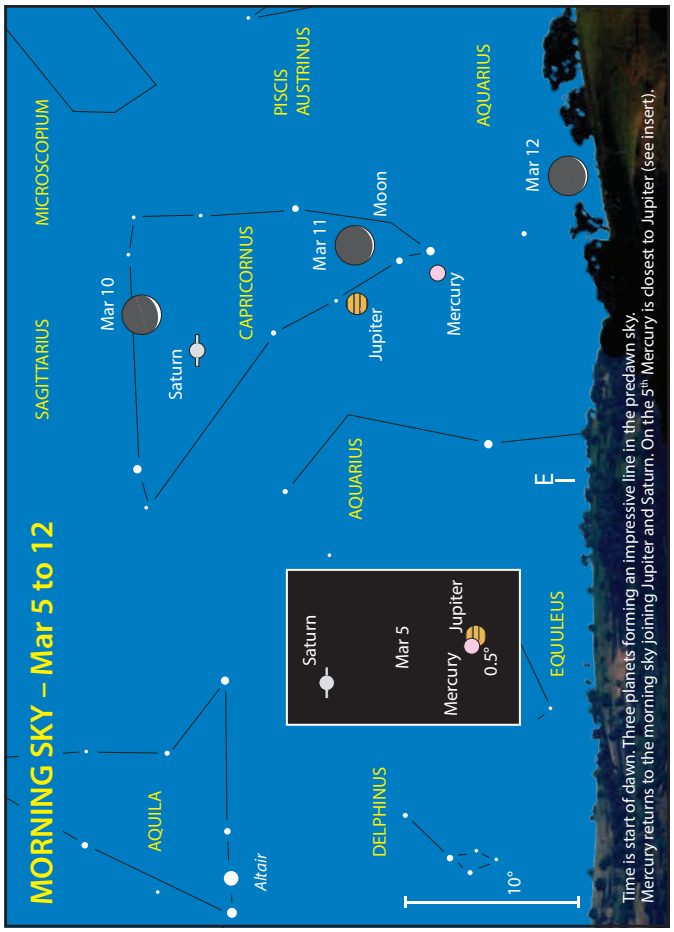
METEOR SHOWER

The **gamma Normids** are active between February 25 and March 28. For most of the period, the rate is low, and members are difficult to sort out from the sporadic background activity. The peak occurs around March 14 when rates can reach six per hour. Generally, the gamma Normids are bright and chiefly yellow, white or orange with about 15% leaving trains. Best viewing is just before dawn on the 15th when the radiant is highest and with no lunar interference.



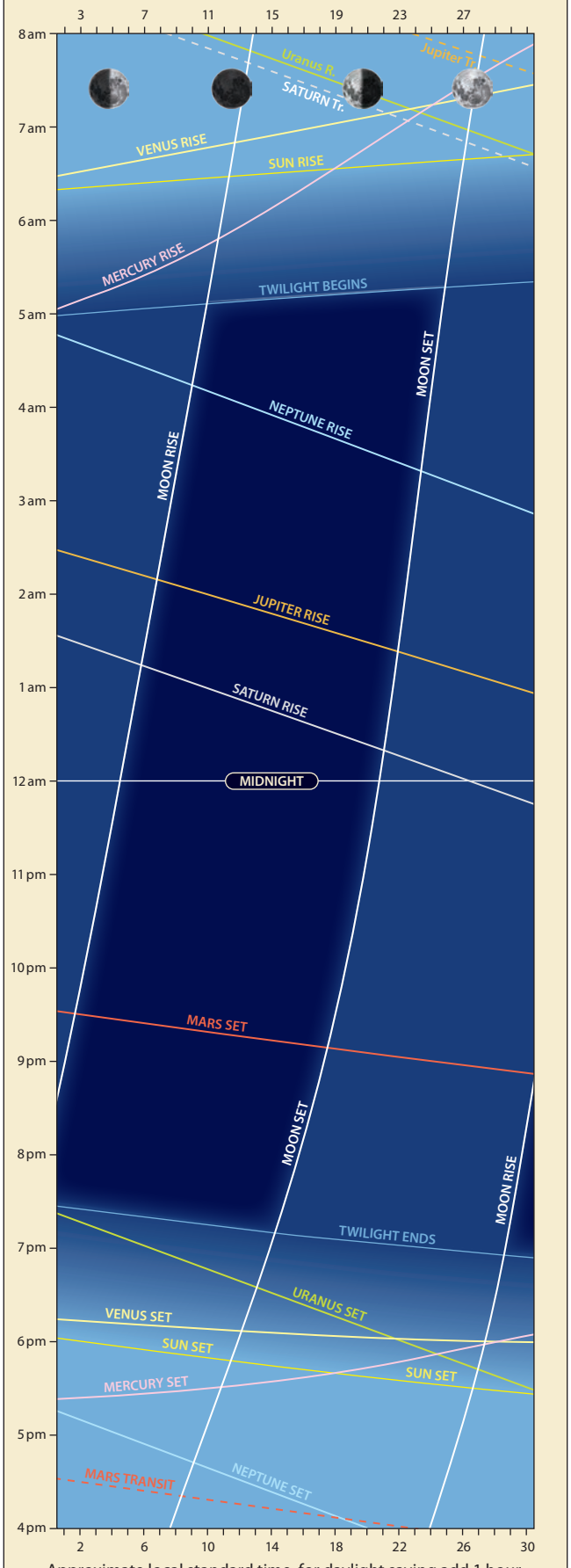
Approximate local standard time, for daylight saving add one hour.





APRIL 2021

RISE–SET CHART



Approximate local standard time, for daylight saving add 1 hour.

HIGHLIGHTS

- Mars and Moon close.
- Mars close to M35.
- Supermoon.

CONSTELLATIONS

This month we complete our beginning observer's guide to the ship Argo, by visiting the final piece of the puzzle, Carina the Keel (All Sky Map No. 1). Find Sirius (Alpha (α) Canis Majoris), Map 4, the brightest star in the night sky and move 36° south to the second brightest star, Canopus (Alpha (α) Carinae). Located at the eastern extreme of the keel, this luminary is not only the brightest star in Carinae, but also in all three Argo Navis constellations. Moving towards the east, the False Cross asterism is the next marker. As mentioned in the March Constellation section, this is made up of four 2nd magnitude stars with two borrowed from Vela and two from Carina.

The highlight of Carina, if not the entire southern Milky Way, is the famous Eta (η) Carinae Nebula (NGC 3372). It is awash with star clusters and nebulae and this brief introduction just scratches the surface. A massive star-forming region, it is located roughly halfway between the Southern Cross and False Cross. Clearly visible to the unaided eye under dark skies as a prominent hazy patch around 3° across, this area has something for everyone no matter what instrument is used. Binoculars show dark lanes dividing the region into three sections. The most prominent of these lanes form a back-to-front capital L shape. For small telescopes, the inside corner contains the reddish coloured star Eta (η) Carinae. This fuzzy

APPEARANCE of the PLANETS

MERCURY Mercury in superior conjunction on the 19th

1 Apr
dia 5.3"
mag –0.5

10 Apr
dia 5.1"
mag –1.1

30 Apr
dia 5.6"
mag –1.2

VENUS
15 Apr
dia 9.7"
mag –3.9

MARS
15 Apr
dia 5.0"
mag 1.4

SATURN
15 Apr
dia 16.3″
mag 0.7

JUPITER
15 Apr
dia 35.9"
mag –2.1

URANUS
15 Apr
dia 3.4"
mag 5.9

NEPTUNE
15 Apr
dia 2.2"
mag 7.9

5th magnitude star, under high magnification and good seeing, reveals the two lobes of gas, that is the Homunculus Nebula. This likely formed in the mid 18th Century when the star went through a nova phase, for a time outshining Canopus (p. 33). Next to Eta is the small dark nebula, known as the Keyhole.

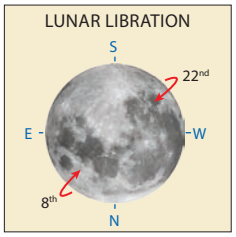
Just outside of the main nebula (2° north-west of Eta) lies a truly breath-taking open star cluster, the Gem Cluster (NGC 3293). Even a small telescope reveals its main 40 blue/white stars (8th to 10th magnitude) arranged in a rough 5-arcminute square shape. The cluster also showcases scattered orange, red and yellow stars—a true pile of assorted gemstones.

Returning to Eta, pan 3° east to another highlight, the Football Cluster (NGC 3532). Its name probably comes from its shape, but its claim to fame, is the cluster's sheer size, covering nearly a full degree of sky and containing around 150 stars evenly distributed. There is a lot to see here. Look for coloured stars and also many arranged in curved lines (see image p. 13).

A 4° jump south from Eta (within the same binocular field) finds the Southern Pleiades, IC 2602. This distinctive open cluster, centred on 3rd magnitude Theta (θ) Carinae, has six 5th magnitude stars within a 1° diameter circle. It is ideal for small binoculars, revealing up to a further 20 fainter stars.

Our last taste of some of the treats Carina has to offer is the globular cluster NGC 2808. Located in the same binocular field as 3rd magnitude, Upsilon (υ) Carinae, it appears as a small 6th magnitude blob 3.5° west of the star. Any small telescope shows it as a round, bright and highly compact object in a brilliant star field. A 150–200 mm instrument is needed to glimpse some individual members of this *stellar city*. In fact, NGC 2808 is considered to be one of the Milky Way's most massive globulars, containing over a million stars!

THE MOON



4th 8 pm (6 pm WST) Last Quarter.

8th 3 am (1 am WST) Maximum Libration (8.8°), dark NE limb.

12th 1 pm (11 am WST) New Moon.

15th 4 am (2 am WST) Moon at apogee (furthest from Earth at 406,119 km).

20th 5 pm (3 pm WST) First Quarter.

22nd 5 pm (3 pm WST) Maximum Libration (10.2°), dark SW limb.

27th 2 pm (Noon WST) Full Moon, supermoon (see table p. 95).

28th 1 am (11 pm previous day WST) Moon at perigee (closest to Earth at 357,378 km).

THE PLANETS

Mercury is only visible during the eastern dawn sky early in the month. The last chance to catch the planet will be on the 11th when the slender crescent of the 28-day old Moon appears 5° above it. The planet itself will be very low 25 minutes before sunrise (see Sky View). Mercury then becomes too close to the Sun for observation as it moves into superior conjunction (Mercury and Earth on opposite sides of the Sun) on the 19th. The smallest of planets next becomes visible when it reappears in the evening dusk in May.

After superior conjunction late last month, **Venus** remains too close to the Sun for observation until May.

In the early north-western evening sky, **Mars** travels through Taurus for most of the month before moving into Gemini. On the 17th, Mars will be just 2° from the 5-day old waxing crescent Moon (see Sky View). The Red Planet passes the outskirts of the open cluster M35 on the 27th. This assembly of 120 magnitude 6–13 stars is visible to the unaided eye under good dark sky conditions, however, the low altitude at this time will require at least binoculars for a good view.

Jupiter is well placed to observe in the morning sky, beginning the month in Capricornus before slipping into Aquarius during the last week. On the morning of 17th, Jupiter

DIARY			
Fri	2nd		Mars 0.5° NW of NGC 1746 (OC) in Taurus
Fri	2nd		Saturn 0.05° W of star 19 Capricorni
Fri	2nd	4 am	(2 am WST) star Antares 6° S of Moon
Sat	3rd		Mercury at greatest latitude south
Sat	3rd	am	m.p. 63 Ausonia 0.7° SW of M62 (GC) in Ophiuchus
Sun	4th	am	m.p. 27 Euterpe 0.5° S of star Omicron Sagittarii
Sun	4th	8 pm	(6 pm WST) Last Quarter Moon
Tue	6th	5 am	(3 am WST) Saturn 9° NE of Moon
Wed	7th	5 am	(3 am WST) Jupiter 8° NW of Moon
Wed	7th		d.p. 1 Ceres in conjunction with Sun
Thu	8th	3 am	(1 am WST) Maximum Libration (8.8°), dark NE limb
Thu	8th	pm	m.p. 12 Victoria 0.6° SE of star Rho[1] Sagittarii
Sat	10th	5 am	(3 am WST) Neptune 5° NW of Moon
Sun	11th		Comet C/2019 N1 (ATLAS) 1.2° E of star Beta Reticuli
Sun	11th	pm	m.p. 230 Athamantis 0.4° SW of star Rho Ophiuchi
Mon	12th	3 am	(1 am WST) m.p. 2 Pallas 0.1° E star 35 Pegasi
Mon	12th	1 pm	(11 am WST) New Moon
Mon	12th	pm	m.p. 9 Metis 0.2° N of NGC 4845 (G) in Virgo
Tue	13th		m.p. 3 Juno stationary
Thu	15th	4 am	(2 am WST) Moon at apogee (406,119 km)
Fri	16th		m.p. 18 Melpomene 1.4° S of M44 Beehive Cluster (OC) in Cancer
Fri	16th	7 pm	(5 pm WST) star Aldebaran 7° S of Moon
Sat	17th	3 am	(1 am WST) Jupiter 0.02° S of star Mu Capricorni
Sat	17th	7 pm	(5 pm WST) Mars 2° E of Moon
Sat	17th	pm	m.p. 9 Metis 0.2° S of NGC 4772 (G) in Virgo
Sun	18th		d.p. 136108 Haumea at opposition
Mon	19th		Comet C/2019 N1 (ATLAS) 1.2° NW of star Alpha Reticuli
Mon	19th		Mercury in superior conjunction
Mon	19th	9 pm	(7 pm WST) star Pollux 5° E of Moon
Tue	20th	5 pm	(3 pm WST) First Quarter Moon
Wed	21st	11 pm	(9 pm WST) m.p. 18 Melpomene 0.15° N of star Delta Cancri
Thu	22nd		m.p. 4 Vesta stationary
Thu	22nd		Mercury at ascending node
Thu	22nd	am	Lyrids meteor shower, Apr 14–30, Moon affected till around 2 am.
Thu	22nd	5 pm	(3 pm WST) Maximum Libration (10.2°), dark SW limb
Thu	22nd	8 pm	(6 pm WST) star Regulus 6° S of Moon
Fri	23rd	pm	pi-Puppids meteor shower, Apr 15–28, Moon will cause interference.
Mon	26th	7 pm	(5 pm WST) star Spica 7° SW of Moon
Mon	26th	pm	m.p. 230 Athamantis 0.3° NE of M80 (GC) in Scorpius
Tue	27th		Mars 0.6° N of M35 (OC) in Gemini
Tue	27th		Mercury at perihelion
Tue	27th	2 pm	(Noon WST) Full Moon (357,616 km)
Tue	27th	pm	m.p. 9 Metis 0.7° S of NGC 4665 (G) in Virgo
Wed	28th		d.p. Pluto stationary
Wed	28th	1 am	(11 pm WST, prev day) Moon at perigee (357,378 km)
Thu	29th	9 pm	(7 pm WST) star Antares 6° SW of Moon

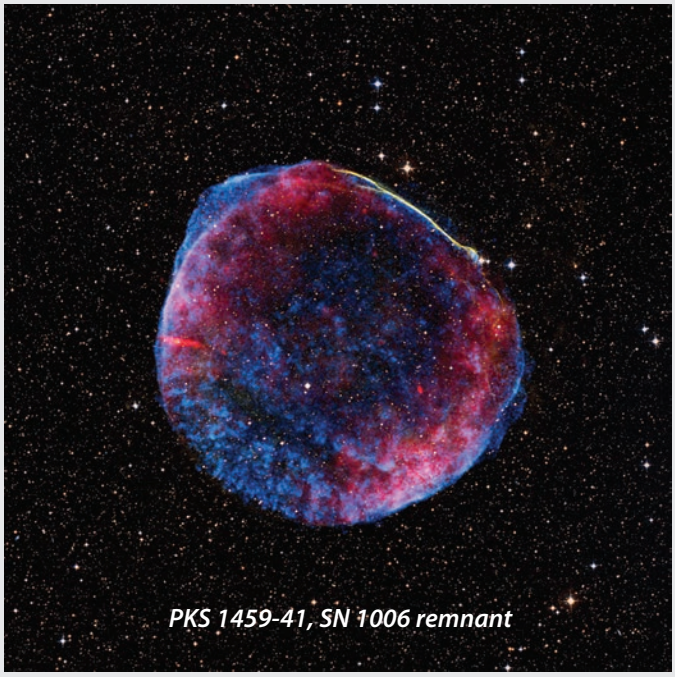
Milky Way Supernovae Part 2 – A Very Short Catalogue

The Guest Star in Di.

"Jingde reign period of Emperor Zhenzong, fifth lunar month, first day (30 May 1006). The Director of the Astronomical Bureau reported that previously, on the second day of the fourth lunar month (1 May 1006), during the initial watch of the night, a large star had been sighted. It was yellow in colour and it appeared to the east of Kulou and to the west of Qiguan. Its brightness had steadily increased. (Its position) was measured as 3 du (deg) in (the lunar lodge) Di. Subsequently the star increased in brightness…"

(Taken from the Chinese manuscript, "Song Huiyao").

The first supernova discovered by humankind deserves a special and expanded treatment for it was also the brightest stellar event ever recorded. Appearing on 30 April 1006 CE, it was discovered from Egypt with Japan and China finding it the following day. Today it is considered to have reached magnitude –7.5 and some sources at the time claimed the star cast shadows at night and was visible during the day! Its location was in the constellation of Lupus and given the time of the year it was well placed in the sky, crossing the meridian about the end of twilight.



PKS 1459-41, SN 1006 remnant

Around 1,000 years ago, China and Egypt would have seen it culminating around 20° to 25° above the southern horizon with Alpha Centauri nearly directly beneath. In fact, thanks to precession, the Pointers and the Southern Cross would have been around 4° higher, instead of just scraping the horizon as seen today (depending on your latitude).

There are good reasons why our quotations here originated from China. At that time oriental astronomers constantly observed the heavens and had the most records. Great astrological significance was assigned to new stars for these events were considered to foretell important events. Although the usual term for a new star-like object was *kexing* (*guest star*) in China, the supernova was consistently described as *Zhoubo*, which signified a bright yellow or golden coloured star. The choice of this colour might have been more politically driven than factual, for such stars were considered to bring peace and prosperity and such news would be well received by the Emperor.

At this time in Asia they divided the night into five equal *geng* (or watches). The initial watch, when the star was first sighted, would begin after dusk. *Kulou* and *Qiguan* were star patterns we now relate to areas of Lupus and Centaurus. *Di*, the third of the lunar lodges called *xiu*, which corresponded to the right ascension region in which SN 1006 lay.

China has records of SN 1006 from as many as nine different sources, including the *Songshi* (History of the Song Dynasty: 960–1279). This document states that the star "*entered the horizon*" during the eighth lunar month, which placed it between 27 August and 24 September. This is consistent with solar conjunction of Lupus. The *Songshi*, also mentioned that "*on the day renyin in the 11th month the Zhoubo star was again seen*". This corresponds to 26 November and it hadn't moved from its position in Di—confirming it was a 'fixed' star.

Despite having reliable records of the discovery, the period the star was visible is uncertain. However, this quote makes it at least three years.

"Dazhong Xiangfu reign period, second year, ninth lunar month, (day) gengwu (9 October 1009). (The Emperor) issued a command that from this day the 'Suburban Sacrifice' should be offered to both the Zhoubo star at Di lunar lodge and Shouxing (Canopus), and that this arrangement should be maintained forever… "

There are a number of supernovae remnants in this area of Lupus and it took until 1965 when Doug Milne and Frank Gardner, using the Parkes Radio Telescope, connected it to the radio source PKS 1459-41. An image is shown (left) and its position, close to the 2nd magnitude star Beta Lupi, has been marked on All Sky Map No. 6.



Crab Nebula (M1)
SN 1054 remnant

makes a close approach to the 5th magnitude star Mu (μ) Capricorni. It makes this gas giant appear to have a fifth moon (for one day anyway) rivalling the brightness of the Galilean satellites.

Saturn is also well placed to observe in the morning sky in Capricornus. On the morning of the 1st and 2nd, it appears to have an extra moon as the 6th magnitude star, 19 Capricorni is located close to this ringed world.

Uranus is lost in the western evening twilight this month as it moves toward its conjunction with the Sun in early May.

Neptune, in Aquarius, returns to the morning eastern dawn sky after its conjunction with the Sun last month.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Over the next three months, m.p. 9 Metis will tour some of the brighter galaxies in the Virgo Cluster (see diary). On the 18th, dwarf planet 136108 Haumea is at opposition at 17.3 magnitude in Boötes. Brightest minor planets at opposition this month include:

Date	Minor Planet	Constellation	Mag.
4 Apr	9 Metis	Virgo	9.5
7 Apr	192 Nausikaa	Corvus	11.4
10 Apr	107 Camilla	Virgo	12.0
14 Apr	97 Klotho	Virgo	12.2
15 Apr	511 Davida	Boötes	11.3
24 Apr	28 Bellona	Virgo	10.9
24 Apr	69 Hesperia	Virgo	11.3
25 Apr	346 Hermentaria	Virgo	11.7

COMETS

Comet 7P/Pons-Winnecke is rising just before midnight and will be visible until dawn and is predicted to brighten from 10th to 9th magnitude. The comet opens April near Alpha (α) Ophiuchi and continues moving eastward through Ophiuchus into Aquila, ending the month near Delta (δ) Aquilae.

And the others…

For the thousands of years humans have been observing the night sky, there have been only four other supernovae recorded in history, despite the brightness they can achieve, even when tens of thousands of light-years away (see also page 32). It is interesting that no Milky Way SNs have been seen since the invention of the telescope.

SN 1054 was in Taurus and was the event that spawned the well-known Crab Nebula (M1). Chinese observers found the star in the eastern morning sky on 4 July 1054. It is thought the supernova reached –6 magnitude and was visible for two years.

SN 1181. The Chinese and Japanese extensively observed this object in Cassiopeia. It was first seen in China on 6 August and remained visible for six months.

SN 1572 (image p. 32), like the SN in 1181, was also in Cassiopeia. It is often referred to as Tycho's Supernova due to Tycho Brahe's extensive observations. The Koreans compared its brilliance to Venus with it reaching –4 magnitude. It was visible for 18 months.

SN 1604 located in Ophiuchus, is the most recent and has been nicknamed Kepler's Supernova. During the year it was visible, Kepler, who is better known for his laws of planetary motion, kept it under close observation. It was about –4th magnitude at its brightest.



Kepler's Supernova, SN 1604 remnant

We would like to close with a special mention of the supernova discovered in 1987. Although it was not in the Milky Way, but instead in a satellite galaxy the Large Magellanic Cloud (LMC), it did reach naked-eye brilliance making it indeed a unique 'guest' star to behold.

SN 1987A (image p. 33) was discovered on the night of February 24, 1987 by Oscar Duhalde, at Las Campanas Observatory (Chile), and independently by New Zealand amateur astronomer, Albert Jones. Located a couple of degrees from the famous Tarantula Nebula, it was found at magnitude 5, after rising some eight magnitudes in the previous 24 hours. The knowledge of this rise was due to photographic records by Sheldon (also at Las Campanas) and McNaught (Siding Springs Observatory, Australia). The supernova peaked at magnitude 2.9 and remained visible in amateur telescopes for over two years.



3C58, SN 1181 remnant

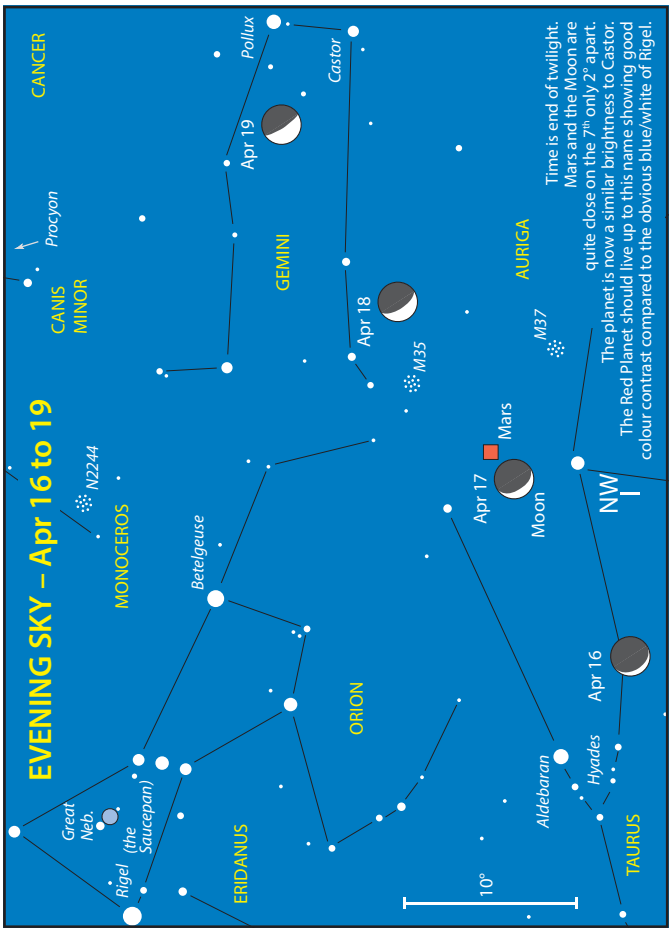
DOUBLE STARS

Dunlop 31 (Y Puppis), All Sky Map No. 4. Located not far from Canopus and 3° north-west of Tau (τ) Puppis in a field of fainter stars is this lovely colourful double star. The magnitude 5.1 primary is yellow (spectral type G8III) and the 7.4 magnitude companion is bluish. The pair is separated by 12.9 arcseconds with a position angle of 321°. Discovered by James Dunlop in 1826, there has been very little change in the measures since. Whether the pair is a true binary or not remains uncertain, however, the spectroscopic parallaxes for both stars give a distance of 160 parsecs, suggesting they are connected.

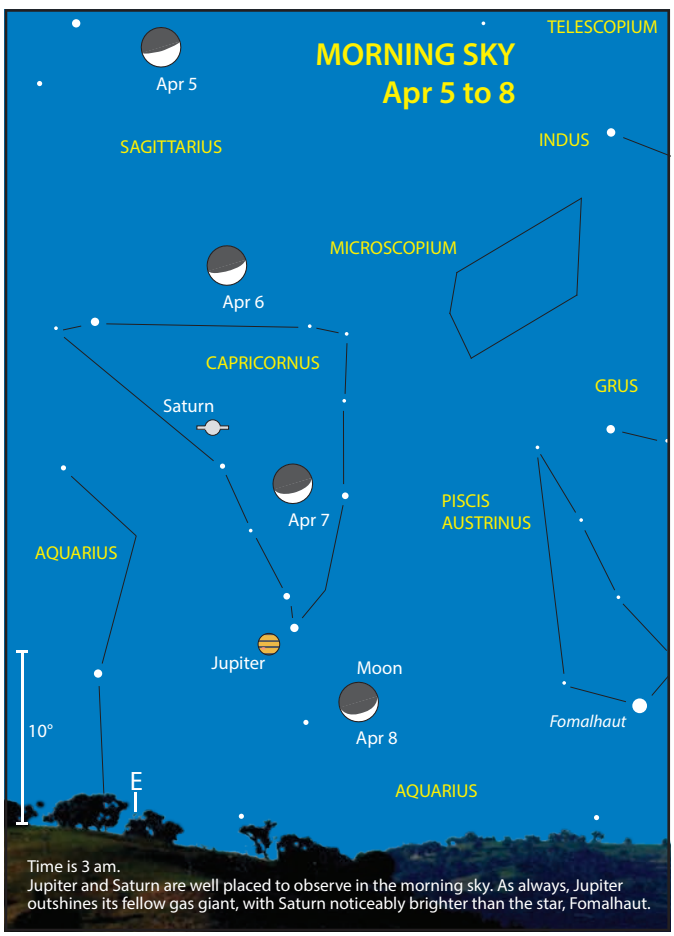
METEOR SHOWERS

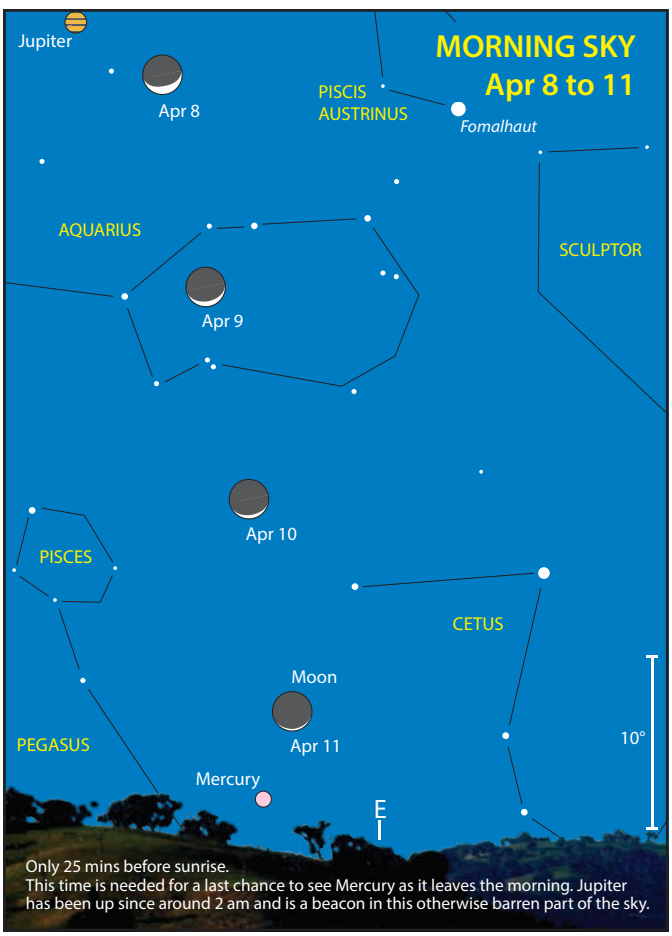
The **Lyrids** are a Northern Hemisphere shower that can be observed south of the equator. They are best seen from April 14–30, with maximum rates during the morning hours of the 22nd and 23rd when their radiant is at its highest. The peak may only last an hour or so, and typically the zenith hourly rate is around 18. The Lyrids have on occasion produced higher rates and because of their erratic nature they are a shower to be watched. At their peak, the Moon will be an issue for an hour or two after midnight.

The **pi-Puppids** are a young southern shower produced by Comet 26P/Grigg-Skjellerup. Best seen from April 15–28, with maximum activity on the 23rd. Leading up to and after maximum the rates are low and difficult to separate from sporadic meteors. The pi-Puppids are noted for their very slow speed, brightness, persistent trains, large proportion of yellow meteors and occasional fireballs. They are best seen from dusk to midnight although this year the gibbous Moon will cause considerable interference.



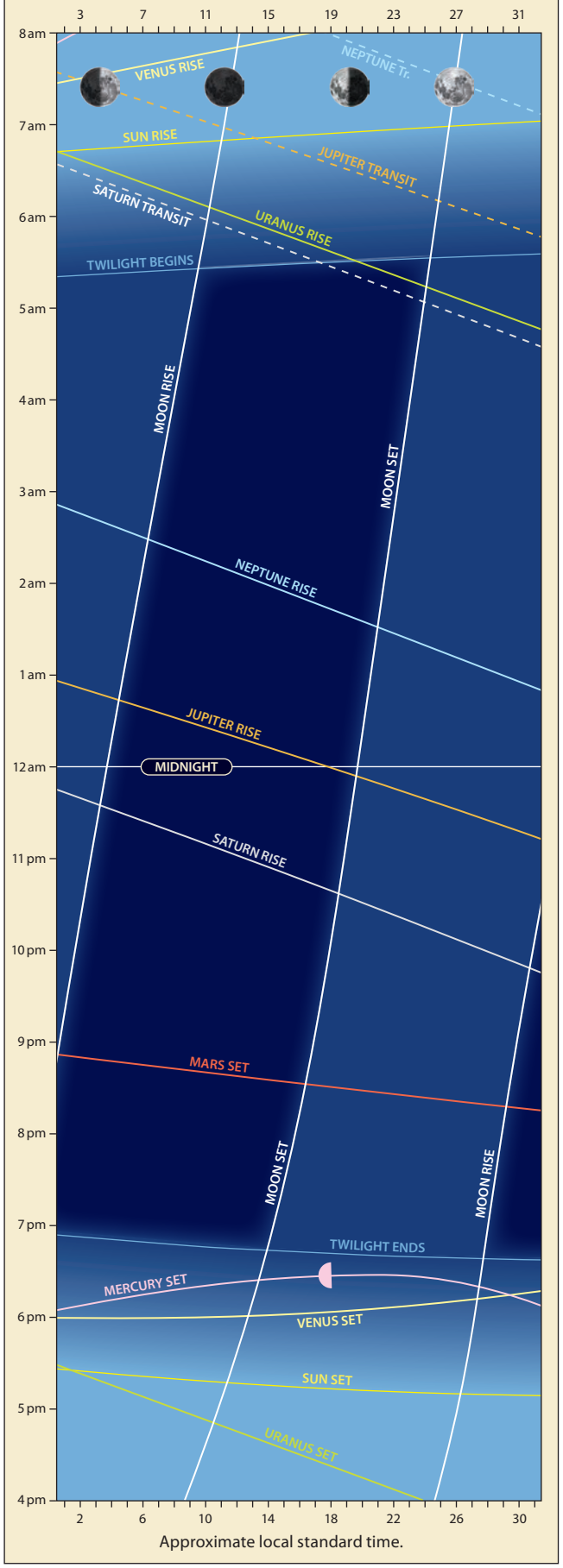
Approximate local standard time.





MAY 2021

RISE–SET CHART



Approximate local standard time.

HIGHLIGHT

- Mercury and Venus very close.
- Mars and Moon close.

CONSTELLATIONS

This month's constellation Crux, better known as the Southern Cross (All Sky Map No. 1), is so iconic to the Southern Hemisphere it features on the flags of five nations: Australia, New Zealand, Papua New Guinea, Samoa and Brazil. It's the smallest constellation with its boundaries lying only a few degrees outside of its four brightest stars. Don't let its stature fool you. Being located in a rich part of the Milky Way, it is well endowed with a number of star clusters. Although there are some visible in binoculars, the field has so many stars it's sometimes difficult to judge where a cluster ends and the surrounding star field begins! A nice example of one within this asterism that does stand out is NGC 4349, lying halfway between Alpha (α) and Epsilon (ε) Crucis.

The bottom and brightest star in the Cross is Alpha Crucis or Acrux. Binoculars show this 0.8 magnitude star to have a 6.0 magnitude companion 1.5 arcminutes away. The smallest telescope reveals the main star as a pair of nearly matched blue/white magnitude 1.4 and 1.9 stars, separated by only five arcseconds.

Returning to the binocular view, there is an obvious colour contrast between blue/white Alpha and the orange coloured top star, Gamma (γ) Crucis. This is also a triple star, an orange primary (mag 1.6) with two white companions, magnitudes 6.4 and 9.2, arranged in a near equilateral triangle shape.

APPEARANCE of the PLANETS

MERCURY

5 May
dia 6.1"
mag –0.8

17 May
dia 8.0"
mag 0.3
Greatest elongation East (22°)

25 May
dia 9.7"
mag 1.4

VENUS

15 May
dia 10.0"
mag –3.9

MARS

15 May
dia 4.4"
mag 1.6

SATURN

15 May
dia 17.1″
mag 0.6

JUPITER

15 May
dia 39.0"
mag –2.3

URANUS

30 May
dia 3.4"
mag 5.9
conjunction 1 May

NEPTUNE

15 May
dia 2.3"
mag 7.9

Pickering's Computers

Edward Charles Pickering (1846 – 1919), an American astronomer and physicist, served as Director of the Harvard College Observatory (HCO) for forty-two years. Under his leadership visual photometric studies were made of 45,000 stars, and the Henry Draper Catalogue was published. An epic work, the catalogue listed positions, magnitudes and spectral types of more than 225,000 stars.



Edward Charles Pickering

In the late 19th century there was not a lot of room for women in astronomy, but in part due to Pickering, a number would make their mark in this male dominated field. The story goes that Pickering was displeased with the slipshod work of his male research staff, and in an outburst informed them "My Scotch maid could do better!" Now the maid was Williamina (Mina) Fleming (1857–1911) and she worked in Pickering's home. From Dundee in Scotland, Mina had moved to the United States with her husband. She took the maid's job to support her young son after her husband abandoned her. Although Mina had no formal higher education, Pickering recognised her talents and in 1881 made her a permanent member of the observatory staff.

Henry Draper (1837 – 1882), a wealthy physician and amateur astronomer, was a pioneer of astrophotography. He had embarked on a photographic survey of the entire sky, with the intention of creating a spectral catalogue. Draper did not finish his project due to his early death at age 45, and his widow made a bequest to the HCO to continue this work.

The funds were a godsend to Pickering, and he began recruiting women to work at the observatory. As the women were paid less than half that of the men, he was now able to double his staff of female human 'computers'. It was tedious work as the women analysed each photographic plate of the night sky, recording the position, brightness and spectral colour of each and every star.



Annie Cannon (seated, foreground centre), Mina Fleming (standing), Antonia Maury (left rear), Henrietta Leavitt (seated far left)

Mina Fleming was put in charge of the group of women that became known as 'Pickering's Harem'. Mina and many of the team would make significant contributions to astronomy, including the Henry Draper Catalogue. Others among the group that would break new ground and cement a place for women in astronomy were: Antonia Maury, Henrietta Leavitt and Annie Cannon.



Williamina (Mina) Fleming

Mina developed a stellar classification system based on the hydrogen content of stars, sorting stars having the most hydrogen (A) followed by the next most (B) etc. She would discover 43 IC (Index Catalogue) objects (mainly planetary nebulae), over 200 variable stars, 10 novae and 94 of the 107 Wolf-Rayet stars known at the time.

Antonia Maury (1866–1952) assisted Pickering in establishing that Zeta (ζ) Ursae Majoris (Mizar) was a spectroscopic binary system, the first to be detected. Antonia was the first to calculate its period and then went on to discover a second such object, the star Beta (β) Aurigue. Aside from specialising in the detection of binary stars, Antonia also developed a stellar classification system; Pickering however ignored this. It would later be taken up by Ejnar Hertzsprung and become the basis of the Hertzsprung-Russell diagram, one of the most useful and powerful tools in astrophysics.

Henrietta Leavitt (1868–1921) discovered more than 2,400 variable stars (mostly in the Magellanic Clouds), more than half of the total known at the time. In 1912 she was the first to discover that a few of the variables showed a distinct pattern, and that the brighter ones seemed to have longer periods. Very soon this class of variable, the Cepheids, would be the yardstick for measuring distances in the Universe by the likes of Hertzsprung and Hubble.

Annie Cannon (1863–1941) developed a third classification system, this time with the stars in order of their spectral class. This system is still in use today. Annie discovered over 300 variables and 5 novae, and her Draper Catalogue Extensions brought the total number of stars in the catalogue to nearly 400,000.

These pioneers were extraordinary women. Employed simply as number–crunchers, they went beyond that role to lay the foundation for many more astronomical discoveries. Yet how often do you hear of these women? When did you last hear of somebody mentioning Henrietta Leavitt for finding the 'standard candle' to galactic distance, or to Annie Cannon for her stellar classification sequence?



Southern Cross region from the Pointers to the Eta Carina complex, including the head of the Emu. Note the colour contrast shown in the brighter stars.

Crux is also well-known for the open star cluster NGC 4755, the Jewel Box. Through binoculars this tight, 10-arcminute, arrowhead shaped group is in the same field as Beta (β) Crucis. A small telescope shows a collection of blue/white stars with a central red star appearing like a ruby in a diamond setting—very attractive. While near Beta Crucis, here's something a little unusual. Only two arcminutes west of Beta is one of the reddest stars known, Ruby (DY Crucis). Being only 9th magnitude it needs a bit of aperture to see the stunning colour (maybe a 100 mm telescope minimum). You'll need to move Beta out of the field to avoid the glare.

Going to a naked-eye view of Crux, it's time to address the elephant in the room, the prominent dark nebulae in the south-east corner. Called the Coal Sack, this 7° irregularly shaped dark gaseous cloud is only visible because it is silhouetted against the glow of our galaxy. It also forms the head of the Aboriginal constellation of the Emu. Can you spot its beak and 5th magnitude eye (star)?

THE MOON

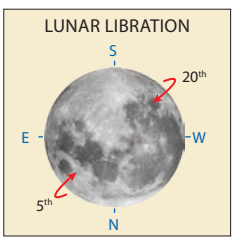
4th 6 am (4 am WST) Last Quarter.

5th 9 am (7 am WST) Maximum Libration (9.7°), dark NE limb.

12th 5 am (3 am WST) New Moon.

12th 8 am (6 am WST) Moon at apogee (furthest from Earth at 406,512 km).

20th 5 am (3 am WST) First Quarter.



20th 1 pm (11 am WST) Maximum Libration (10.3°), dark SW limb.

26th Noon (10 am WST) Moon at perigee (closest to Earth at 357,311 km).

26th 9 pm (7 pm WST) Full Moon, supermoon, the closest Full Moon perigee syzygy of the year (see table p. 95).

THE PLANETS

Mercury moves back into the western evening twilight this month. On the 14th, the 2-day old waxing crescent Moon appears 5° above and north of the planet (see Sky View). An excellent conjunction occurs between Mercury and Venus when they approach within 0.5° on the 29th. If you're looking around 30 minutes after sunset, while you should have no difficulty picking out Venus, binoculars will aid in detecting the fainter Mercury (see Sky View). Mercury reaches its greatest elongation of 22° east of the Sun on the 17th.

Venus climbs away from the Sun and into the western twilight sky to assume its role as the Evening Star this month. As fellow inner planet Mercury heads back down toward the Sun the pair pass each other on the 29th with a separation of just 0.5° (see Sky View).

Mars has been gradually fading since the beginning of the year. However, it is easily distinguished by its distinctive orangish colour in the early north-western evening sky as it travels through Gemini. As a comparison with the nearby stars, Caster and Pollux (Alpha and Beta Geminorum), Mars is very similar in magnitude to Castor but a little fainter than Pollux. On the 16th, the 4-day old waxing crescent Moon will be 2.4° from the planet (see Sky View).

Jupiter, in Aquarius, rises around midnight during the middle of the month. On the 5th, the 23-day old waning crescent Moon appears near the gas giant in the morning sky (see Sky View).

On the morning of the 24th we have six hours of continuous satellite shadows (Io and/or Callisto) on Jupiter (four hours for WA as Jupiter rises during the event). Beginning just after midnight with Io (12.01 am EST), followed at 1:12 am EST when it is joined by Callisto's shadow. The Io shadow departs at 2:19 am EST (12:19 am WST) and finally the Callisto one leaves at 06:03 am EST (04:03 am WST).

Rising in the late evening eastern sky in Capricornus, **Saturn** appears stationary on the 24th. The planet then begins 4.5 months of retrograde motion, travelling from east to west across the sky (see Retrograde Motion p. 94). In the early morning of the 4th, the Last Quarter Moon will be 4° from the Ringed Planet (see Sky View).

Uranus is in conjunction with the Sun on the 1st and reappears in the morning eastern dawn late this month.

Neptune, in Aquarius near the border of Pisces, is only visible in the morning eastern sky, rising around 2 am mid-month.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

On the morning of the 8th, 349 Dembowska (currently at only 11th magnitude) has a close visit to the bright globular cluster M30 in Capricornus. Brightest minor planets at opposition this month include:

Date	Minor Planet	Constellation	Mag.
10 May	389 Industria	Hydra	11.0
11 May	37 Fides	Libra	11.4
18 May	324 Bamberga	Lupus	11.6
22 May	230 Athamantis	Libra	10.2
24 May	704 Interamnia	Lupus	11.4
26 May	128 Nemesis	Scorpius	11.7
29 May	216 Kleopatra	Ophiuchus	12.0

COMETS

Comet 7P/Pons-Winnecke is expected to brighten from 9th to 8th magnitude by the end of May when it reaches perihelion. Beginning the month near Delta (δ) Aquilae, the comet moves south-east through Aquila, passing near Theta (θ) Aquilae mid-month, and then into Aquarius before finishing in Capricornus. Pons-Winnecke is now rising late in the evening and transiting around the start of dawn.

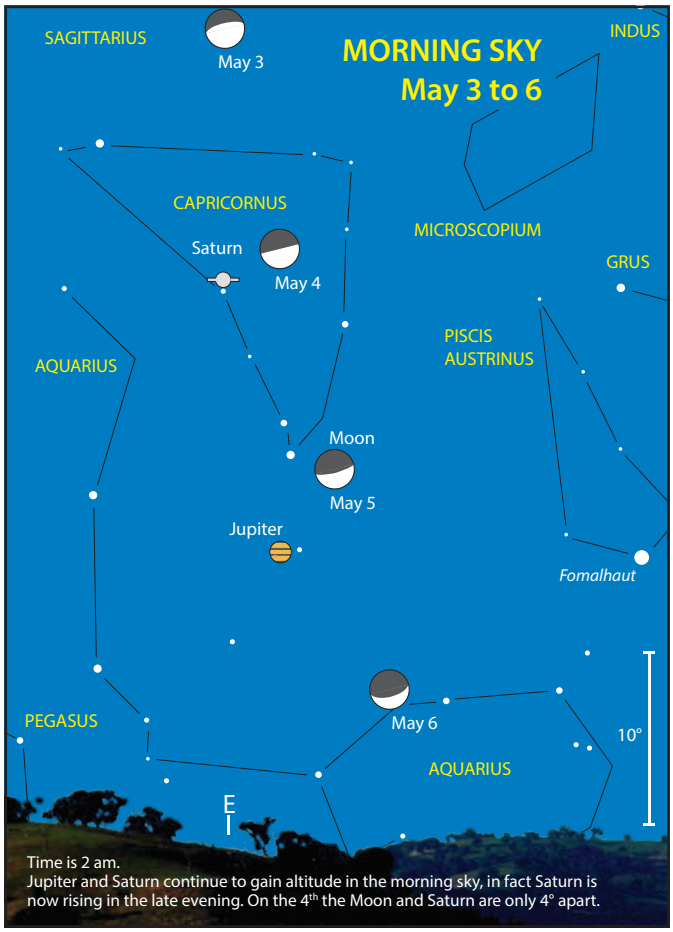
DOUBLE STARS

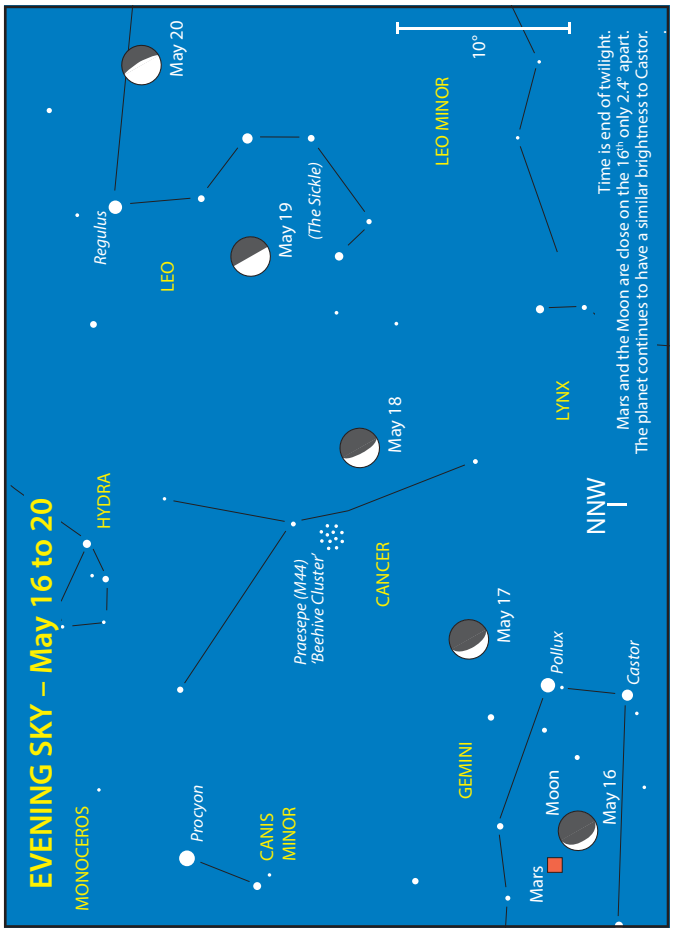
D Centauri (RMK 14), All Sky map No 6, can be found in the middle of Centaurus and forms an almost equilateral triangle with Gamma (γ) Centauri and Delta[1] (δ^1) Centauri. Discovered by Carl Rumker, observing from Parramatta in 1832, this fine colourful pair is best seen in a telescope of 100 mm or more in aperture. The A component is magnitude 5.8, spectral class K3III. The B component is magnitude 7.0. The pair is separated by 2.7 arcseconds with a position angle of 242°. Their colours could be yellow and white, but have been described as orange and white or deep yellow to orange and orangey-red. The separation has slowly been reducing since the measures back in 1837. The A component is a spectroscopic binary and so this is a triple star system.

METEOR SHOWER

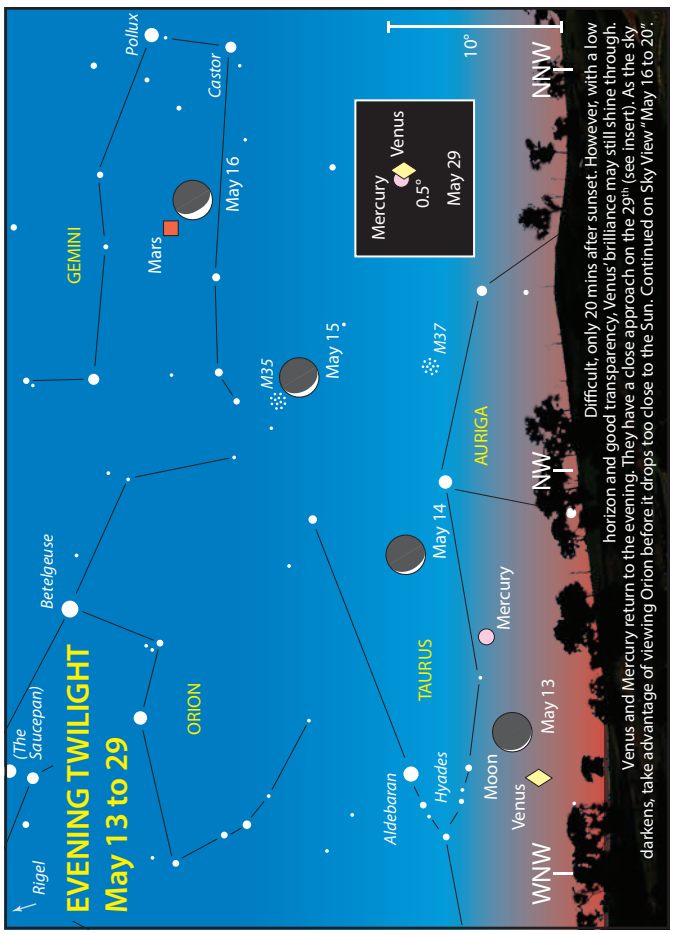
The **eta-Aquarids** are linked with Halley's Comet and rank as one of the most popular of the Southern Hemisphere showers. Visible from April 19 to May 28, they reach their peak on the night of the 6th and the morning of the 7th. The maximum rates will likely be seen just before dawn since the radiant in Aquarius reaches its highest altitude a little after sunrise. The zenith hourly rate will often reach 60 or more meteors per hour. The eta-Aquarids are characterised by their high percentage of persistent trains. They are very swift and are a striking yellow colour. The 25-day old waning crescent Moon should have little effect on pre-dawn observations.

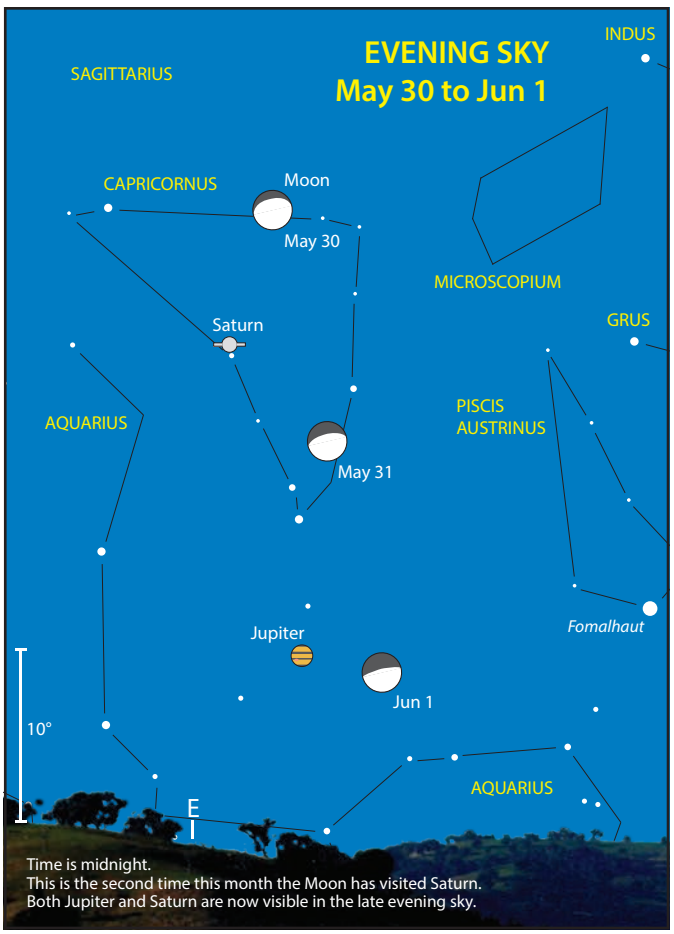
DIARY			
Sat	1st	am	m.p. 80 Sappho 0.8° NW of star Epsilon Aquarii
Sat	1st		Uranus in conjunction with Sun
Sat	1st	pm	m.p. 9 Metis 0.2° S of NGC 4636 (G) in Virgo
Sun	2nd	am	m.p. 89 Julia 0.2° N of star Kappa Capricorni
Sun	2nd	11 pm	(9 pm WST) d.p. Pluto 2° N of Moon
Tue	4th		Mercury 2.2° SE of M44 Beehive Cluster (OC) in Cancer
Tue	4th	3 am	(1 am WST) Saturn 4° N of Moon
Tue	4th	6 am	(4 am WST) Last Quarter Moon
Wed	5th	5 am	(3 am WST) Jupiter 5° N of Moon
Wed	5th	9 am	(7 am WST) Maximum Libration (9.7°), dark NE limb
Fri	7th		Mercury at greatest latitude north
Fri	7th	am	Comet 7P/Pons-Winnecke 1.0° N of star Eta Aquilae
Fri	7th	am	eta-Aquarids meteor shower, Apr 19 to May 28.
Fri	7th	4 am	(2 am WST) Neptune 4° N of Moon
Sat	8th	5 am	(3 am WST) m.p. 349 Dembowska 0.1° N of M30 (GC) in Capricornus
Sun	9th		Venus at ascending node
Mon	10th		Mars 0.7° S of star Epsilon Geminorum
Wed	12th	am	Comet 7P/Pons-Winnecke 0.8° N of star Theta Aquilae
Wed	12th	am	m.p. 12 Victoria 0.5° NW of star Alpha[2] Capricorni
Wed	12th	5 am	(3 am WST) New Moon
Wed	12th	8 am	(6 am WST) Moon at apogee (406,512 km)
Wed	12th	pm	m.p. 230 Athamantis 0.6° SW of star Omega[1] Scorpii
Wed	12th	pm	m.p. 3 Juno 0.5° SW of NGC 6366 (GC) in Ophiuchus
Thu	13th	6 pm	(4 pm WST) star Aldebaran 6° SE of Moon
Fri	14th	9 pm	(7 pm WST) m.p. 29 Amphitrite 0.07° E of star Regulus
Sun	16th	7 pm	(5 pm WST) Mars 3° SW of Moon
Mon	17th		Mercury at greatest elongation East (22.0°)
Mon	17th	7 pm	(5 pm WST) star Pollux 5° NW of Moon
Mon	17th	pm	m.p. 9 Metis 0.6° SE of NGC 4527 (G) in Virgo
Tue	18th		d.p. 1 Ceres 0.6° NW of NGC 864 (G) in Cetus
Wed	19th	8 pm	(6 pm WST) star Regulus 9° SE of Moon
Thu	20th	5 am	(3 am WST) First Quarter Moon
Thu	20th	1 pm	(11 am WST) Maximum Libration (10.3°), dark SW limb
Fri	21st	pm	m.p. 9 Metis 0.2° SE of NGC 4536 (G) in Virgo
Fri	21st	pm	Saturn 0.6° SW of star Theta Capricorni
Sun	23rd	11 pm	(9 pm WST) star Spica 7° S of Moon
Sun	23rd	pm	m.p. 63 Ausonia 0.8° N of star Epsilon Scorpii
Mon	24th	6 am	(4 am WST) Saturn stationary
Wed	26th	Noon	(10 am WST) Moon at perigee (357,311 km)
Wed	26th	9 pm	(7 pm WST) Full Moon (357,461 km, closest for this year)
Thu	27th	3 am	(1 am WST) star Antares 5° S of Moon
Sat	29th	6 pm	(4 pm WST) Venus 0.5° N of Mercury
Sun	30th		Mercury at descending node
Sun	30th	7 am	(5 am WST) d.p. Pluto 2° N of Moon
Sun	30th	Noon	(10 am WST) Mercury stationary
Mon	31st	5 am	(3 am WST) Saturn 6° NE of Moon



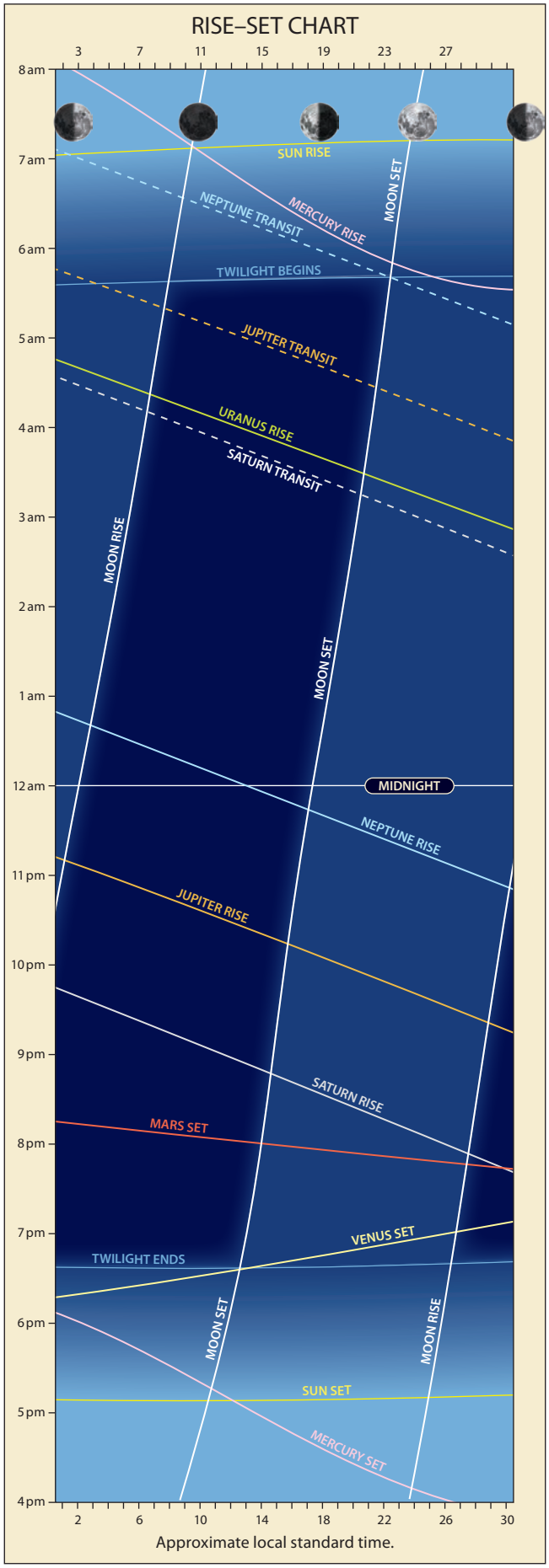


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JUNE 2021



HIGHLIGHTS

- Venus and crescent Moon close.
- Mars crosses the Beehive Cluster.
- Supermoon.

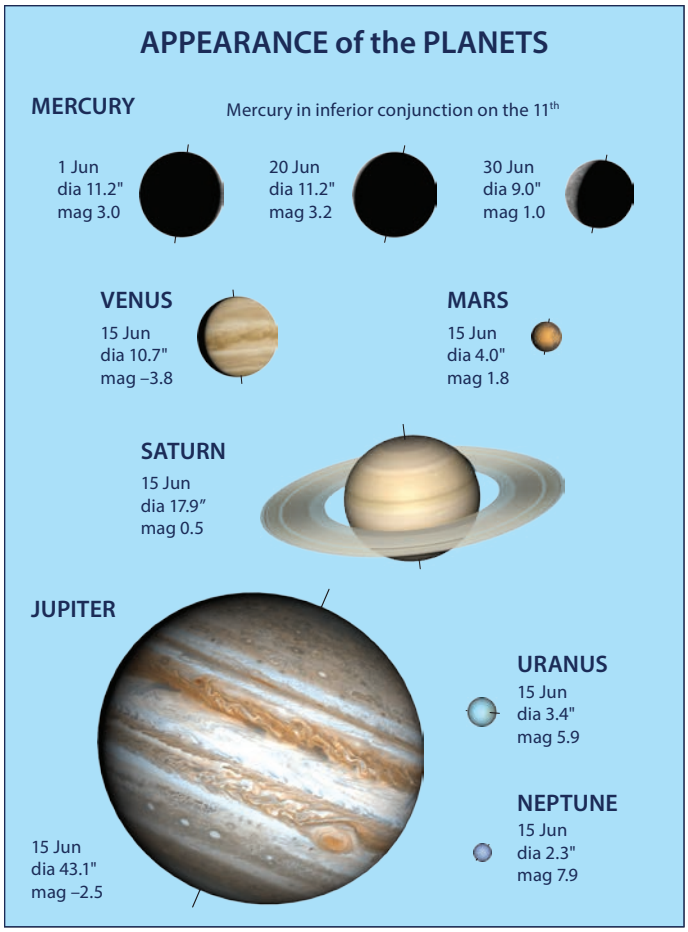
CONSTELLATIONS

This month, features the constellation of Centaurus (All Sky Maps No. 1 and 6). This stands over the Southern Cross, high in the southern evening sky, extending to the zenith. The objects of interest within Centaurus are quite diversified as the constellation extends from the plane of the Milky Way to well outside, into the realm of the galaxies.

Its best-known markers are the Pointers (to Crux) comprised of the two bright stars Alpha (α) and Beta (β) Centauri. Have a look at their distinctive colours, yellow and blue respectively. Alpha, as well as being the closest star to the Solar System and the third brightest in the night sky, is also a brilliant double star. It is more accurate to call it a binary star for the two are in orbit around each other, taking 80 years to complete one circuit. Unfortunately, it will be many years before they separate sufficiently to be seen again as two in typical binoculars. The smallest telescope has no problem splitting them, with its beacons appearing like the lights of a distant approaching car.

There are three outstanding deep sky objects, two easily visible in binoculars. In fact, the globular cluster NGC 5139 is visible to the unaided eye and was at first thought to be a star (well, a fuzzy one) and called Omega Centauri. Containing several million stars, it is the largest and brightest globular cluster known in our galaxy. With Omega being the size of the

APPEARANCE of the PLANETS



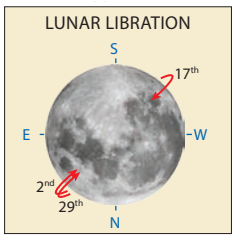
Moon, binoculars give a great view. However, no one forgets their first sight of this star-packed object through a telescope!

The other binocular object is a galaxy, but no ordinary one, the Hamburger Galaxy NGC 5128. It's a lenticular galaxy and can be thought as being somewhere between an elliptical and a spiral. Like any elliptical it certainly resembles an unresolved globular cluster (by unresolved we mean a haze with no individual stars visible). However, its main feature, visible in any telescope, is the pronounced dark band extending around its equator (the meat in the burger). This galaxy is the fifth brightest in the sky (excluding the Milky Way) and the brightest outside our local group. Being close together in the sky (4° apart) a bonus offered by the Hamburger and Omega is that they both fit in the same binocular field!

A telescope is needed for the other highlight, the large edge-on spiral galaxy NGC 4945. Located within a triangle formed by the 5th magnitude stars Xi[1], Xi[2] and f Centauri, this object is easy to find, slashing its way across a corner. This 9th magnitude apparition is 20 arcminutes long and best seen at low power.

There are multiple other worthy objects in Centaurus, many of which are marked on the All Sky Maps. For example, check out the brilliant Blue Planetary Nebula (NGC 3918) and the open star cluster NGC 3766.

THE MOON



2nd 2 am (midnight previous day WST) Maximum Libration (10.1°), dark NE limb.

2nd 5 pm (3 pm WST) Last Quarter.

8th Noon (10 am WST) Moon at apogee (furthest from Earth at 406,228 km).

10th 9 pm (7 pm WST) New Moon.

17th 4 am (2 am WST) Maximum Libration (9.7°), dark SW limb.

18th 2 pm (noon WST) First Quarter.

23rd 8 pm (6 pm WST) Moon at perigee (closest to Earth at 359,956 km).

25th 5 am (3 am WST) Full Moon, supermoon. The last supermoon of the year (see table p. 95).

29th 10 pm (8 pm WST) Maximum Libration (9.8°), dark NE limb.

THE PLANETS

We lose **Mercury** from the evening twilight early in the month as it moves into inferior conjunction (between the Earth and the Sun) on the 11th. This innermost planet then returns to the morning dawn from mid-month onward.

Venus makes an impression on the 12th, appearing like a sparkling diamond just 2° from the 2-day old waxing crescent Moon in the western evening sky (see Sky View). By mid-month, as the planet gains altitude it can be seen after astronomical twilight as it crosses Gemini and into Cancer.

The **Earth** is at Solstice on the 21st when our daylight hours are shortest. On this day, the Sun is at its most northerly position with a declination of +23.5°.

Mars begins the month in the early north-western evening sky in Gemini. It leaves the constellation of the Twins after the first week and moves into Cancer the Crab for the remainder of June. On the 14th, the 4-day old waxing crescent Moon will be 6° from the planet (see Sky View). On the 23rd and 24th

DIARY			
Wed	2nd	2 am	(Midn. WST, prev day) Maximum Libration (10.1°), dark NE limb
Wed	2nd	4 am	(2 am WST) Jupiter 6° NW of Moon
Wed	2nd	5 pm	(3 pm WST) Last Quarter Moon
Wed	2nd	6 pm	(4 pm WST) star Pollux 5° N of Mars
Thu	3rd	5 am	(3 am WST) Neptune 6° NE of Moon
Fri	4th		Mars at greatest latitude north
Mon	7th	6 am	(4 am WST) Uranus 5° NE of Moon
Mon	7th		m.p. 3 Juno at opposition
Tue	8th		m.p. 4 Vesta 0.5° NE of NGC 3593 (G) in Leo
Tue	8th	3 am	(1 am WST) m.p. 2 Pallas 0.1° N of NGC 7619 (G) in Pegasus
Tue	8th	Noon	(10 am WST) Moon at apogee (406,228 km)
Wed	9th	3 am	(1 am WST) m.p. 2 Pallas 0.15° N of NGC 7626 (G) in Pegasus
Thu	10th		m.p. 4 Vesta 0.3° SW of M65 (SG) in Leo
Thu	10th		m.p. 4 Vesta 0.9° SW of NGC 3628 (G) in Leo
Thu	10th		Mercury at aphelion
Thu	10th	9 pm	(7 pm WST) New Moon
Fri	11th		m.p. 4 Vesta 0.4° SW of M66 (SG) in Leo
Fri	11th		Venus 1.0° S of star Epsilon Geminorum
Fri	11th		Mercury in inferior conjunction
Sat	12th		Venus at perihelion
Sat	12th	6 pm	(4 pm WST) Venus 2° S of Moon
Sun	13th		Comet 15P/Finlay 0.5° S of NGC 474 (G) in Pisces
Sun	13th	6 pm	(4 pm WST) star Pollux 3° N of Moon
Sun	13th	pm	m.p. 3 Juno 0.2° NE of star 30 Ophiuchi
Mon	14th		Comet 15P/Finlay 0.5° SE of NGC 520 (G) in Pisces
Mon	14th	6 pm	(4 pm WST) Mars 6° W of Moon
Wed	16th	am	Comet 7P/Pons-Winnecke 0.8° S of Helix Nebula (NGC 7293) in Aquarius
Wed	16th	7 pm	(5 pm WST) star Regulus 6° SW of Moon
Thu	17th		Comet 15P/Finlay 0.6° SW of star Nu Piscium
Thu	17th	am	m.p. 80 Sappho 0.4° NW of M2 (GC) in Aquarius
Thu	17th	4 am	(2 am WST) Maximum Libration (9.7°), dark SW limb
Thu	17th	11 pm	(9 pm WST) m.p. 4 Vesta 2° N of Moon
Fri	18th	2 pm	(Noon WST) First Quarter Moon
Fri	18th	10 pm	(8 pm WST) m.p. 3 Juno 0.1° NE of M10 (GC) in Ophiuchus
Sun	20th	7 pm	(5 pm WST) star Spica 7° SW of Moon
Mon	21st		Solstice
Mon	21st	3 pm	(1 pm WST) Jupiter stationary
Tue	22nd	6 pm	(4 pm WST) star Pollux 5° N of Venus
Wed	23rd	9 am	(7 am WST) Mercury stationary
Wed	23rd	8 pm	(6 pm WST) Moon at perigee (359,956 km)
Wed	23rd	9 pm	(7 pm WST) star Antares 6° SW of Moon
Wed	23rd	pm	m.p. 9 Metis 0.3° SW of NGC 4666 (G) in Virgo
Thu	24th		Comet 15P/Finlay 0.5° NW of star Xi[1] Ceti
Thu	24th		Mars 0.2° E of M44 Beehive Cluster (OC) in Cancer
Thu	24th	pm	m.p. 9 Metis 1.0° NE of star Gamma Virginis
Fri	25th	5 am	(3 am WST) Full Moon (361,561 km)
Sat	26th	am	Comet 7P/Pons-Winnecke 1.6° NE of star Fomalhaut
Sat	26th	8 pm	(6 pm WST) Neptune stationary
Sun	27th		Uranus 0.2° NW of star Omicron Arietas
Sun	27th	9 pm	(7 pm WST) Saturn 4° NW of Moon
Mon	28th	pm	m.p. 27 Euterpe 0.4° S of NGC 6717 (GC) in Sagittarius
Tue	29th	5 am	(3 am WST) Jupiter 4° N of Moon
Tue	29th	10 pm	(8 pm WST) Maximum Libration (9.8°), dark NE limb
Wed	30th		Mercury at greatest latitude south

Mars will cross directly over the Beehive Cluster—also known as Messier 44 or Praesepe. Considered a naked-eye object, the Beehive does need dark skies to be visible. For the best view, a small telescope or binoculars will show the orange/red planet against the background of around eighty 6th magnitude stars.

On the 21st, **Jupiter** appears stationary and thereafter will be in retrograde motion for the next four months, travelling from east to west across the sky (see Retrograde Motion p 94). This reversal of direction also signals that the planet will be in opposition in the not too distant future. Rising in the late eastern evening sky in Aquarius, Jupiter has two encounters with the waning gibbous Moon this month. On the 1st, the 21-day old Moon will be 5° away (see May Sky View) and on the 28th, the 19-day old Moon will be 6° from the planet (see Sky View).

Saturn is now rising in the mid-evening eastern sky in Capricornus. Shining at 0.5 magnitude the planet stands out in this rather inconspicuous constellation containing a few 3rd magnitude stars. On the 27th, the 18-day old waning gibbous Moon will be 4° from Saturn (see Sky View).

Uranus, in Aries, is visible in the pre-dawn eastern sky. During the last week of June, the planet will be just 0.2° from the 5.8 magnitude blue/white star Omicron (o) Arietis—just like a very wide double star. As both planet and star are virtually matched in magnitude, the greenish hue of Uranus will help to identify the planet.

Neptune appears stationary on the 26th and thereafter will be in retrograde motion until December. Mid-month the planet rises a little before midnight and therefore is still basically a morning only object.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

June is a busy month for interesting bright minor planet conjunctions. On the mornings of the 8th and 9th, m.p. 2 Pallas makes a close approach to the galaxy pair NGC 7619 and 7626 in Pegasus (see diary). The night of the 18th sees m.p. 3 Juno sitting close to the northern edge of the globular cluster M10 in Ophiuchus. The evening of the 10th and 11th will see m.p. 4 Vesta (while still around 7th magnitude) have a close flyby of the famous galaxy pair of M65 and M66 in Leo.

Brightest minor planets at opposition this month include:

Date	Minor Planet	Constellation	Mag.
3 Jun	63 Ausonia	Scorpius	9.6
6 Jun	3 Juno	Ophiuchus	10.1
8 Jun	115 Thyra	Scorpius	11.5
14 Jun	30 Urania	Ophiuchus	10.6
18 Jun	433 Eros	Scorpius	11.1
20 Jun	5 Astraea	Sagittarius	10.7

COMETS

Comet 6P/d'Arrest spends June at around 11th magnitude. Transiting in the late evening it is visible most of the night. The comet spends the month slowly moving in Hercules south of (above) Beta Herculis.

Comet 7P/Pons-Winnecke should remain around 8th magnitude this month, rising late in the evening and transiting just before dawn. The comet opens June in Capricornus (passing near Delta (δ) Capricorni in the first week) before returning to Aquarius. It then passes through Piscis Austrinus before concluding the month in Sculptor. On the night of 15th,

Raining Fire In The Sky

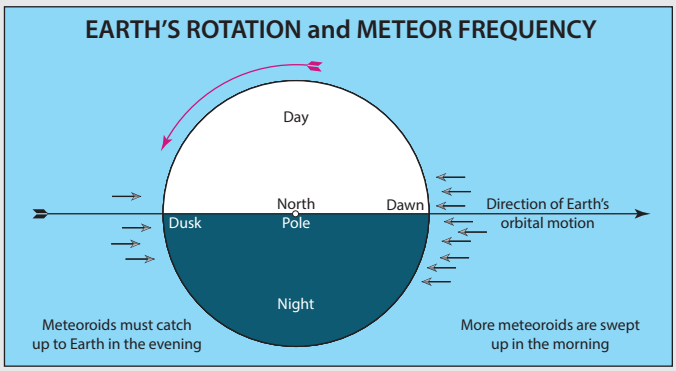
John Denver (1943–1997) wrote one of the most iconic songs of the 1970s after witnessing the Perseid meteor shower. In the song, *Rocky Mountain High*, he describes his experience whilst on a camping trip in Colorado as *"I've seen it rainin' fire in the sky"* an apt and fitting description for one of the Northern Hemisphere's most dependable meteor showers. The next line *"The shadow from the starlight is softer than a lullabye"* is interesting but more on this a little later.

Inspired to see a meteor shower? Like solar eclipse chasing it can be addictive although not necessarily as expensive as having to travel afar. If you intend spending a few hours under the stars watching for meteors, comfort is the key. Although not essential, the purchase of a zero-gravity chair (the modern equivalent of the old Sun loungers) provides a relaxing way to view the sky—just sit back, recline and lock the chair at any position. This style of portable chair is available from camping and hardware stores.

Warm clothing is a major consideration. Hooded down jackets, thermal underwear and more than one layer are all part and parcel of the observer's garb. Spending a few hours outside without moving around will quickly sap your body heat away. For extra protection, during the colder months, a doona or unzipped sleeping bag used as a blanket works well. Take some insect repellent for those mozzies in summer and a thermos of your favourite hot beverage goes well at any time. Don't forget your binoculars. Whilst useless for meteor hunting because of their narrow field, binoculars are great for cruising around the Milky Way.

On any clear night, the number of random or sporadic meteors is somewhat variable. The Moon and light pollution will impact on all but the brightest meteors in their fiery dash across the sky. It is therefore essential to seek out a dark sky location to maximise the number visible. Whilst the sky need not be perfect, the line from Denver's song *"The shadow from the starlight..."* gives one a sense of how dark his location was. Most amateurs are aware that Venus can cast a shadow, but few attempt the very delicate shadow cast by the Milky Way when high in our southern skies.

Generally, under excellent skies around two to four meteors will be visible per hour in the evening with that number doubling by the beginning of astronomical dawn. The rate of sporadic meteors changes because of the Earth's motion:



when evening falls, an observer is looking in the opposite direction from the way that our planet is travelling, and any meteoroids must catch up to us before entering the atmosphere. After midnight the observer's hemisphere faces the direction of travel and this leading side sweeps up all meteoroids in the Earth's path (see diagram).

Meteor showers, unlike the sporadics, occur at predictable times of the year and can provide a spectacular display. However, do not set your expectations overly high as our Northern Hemisphere counterparts are favoured with most of the well-known showers. For example, the Perseids are one of the most dependable of the major annual showers and have been observed for over 2,000 years.

If you live in mid-Australian latitudes (around –35°S), the radiant or the point where the Perseids seem to diverge from the sky will be below the northern horizon. With a zenith hourly rate (ZHR) of around 60 or more at their peak, they reliably provide a rich display in northern latitudes. So, what can we expect south of the equator? This is where the ZHR comes in, the term defines the number of meteors that a single observer would see in one hour if the radiant were at the zenith (the point directly above the observer). It also assumes the limiting magnitude to be +6.5 and the sky cloudless. These optimum conditions are rarely met and with our Perseids example, on average more than half the meteors will be heading in the wrong direction and will not be seen.

Atmospheric extinction will also reduce the brightness and number of meteors—the further you move from the zenith, the thicker the atmosphere. These factors alone will likely lower the ZHR of 60 down to perhaps five or if you are really lucky maybe ten.

So, if you are still keen to brave the morning chill to witness numerous meteors or perhaps a fireball (see images by Greg Priestly on this page and rear cover), maybe the following words from John Denver will give you even greater inspiration. John testified at a USA Senate hearing in 1985 where he (and others) fought a proposal to label music albums with a rating system (similar to movies).

To quote John at the hearing, "My song *Rocky Mountain High* was banned from many radio stations as a drug-related song. This was obviously done by people who had never seen or been to the Rocky Mountains and also had never experienced the elation, celebration of life, or the joy in living that one feels when observing something as wondrous as the Perseids meteor shower on a moonless, cloudless night when there are so many stars that you have a shadow from the starlight, and you are out camping with your friends, your best friends, and introducing them to one of nature's most spectacular light shows for the very first time. Obviously, a clear case of misinterpretation. Mr Chairman, what assurance have I that any national panel to review my music would make any better judgment?"



Image by Greg Priestley, taken at 9 pm from Ilford NSW on 9 October 2015, high in the north-east sky. Canon 5D Mark III, Samyang 14 mm ƒ/2.8 lens, ISO 2500, ISO 2500.

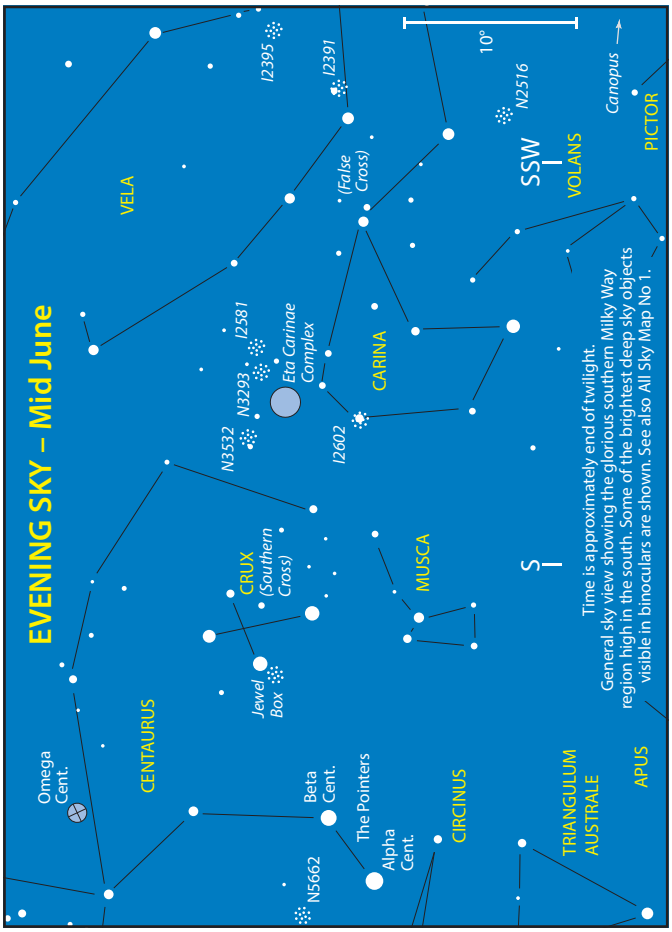
"I had a DSLR shooting a time-lapse pointed in that direction which captured the fireball almost perfectly framed. The photo is a composite of two 30 second exposures, with the gap between the two segments partially real and partially due to the short gap between the two photos. About four minutes after witnessing the fireball, and having all sat down from our excitement, we heard a sonic boom. Based on the propagation speed of sound, this would have placed the explosion at around 80 km distant."

Pons-Winnecke makes a close approach to the Helix Nebula—an imaging and viewing opportunity. The 25th sees it pass near Fomalhaut (see diary).

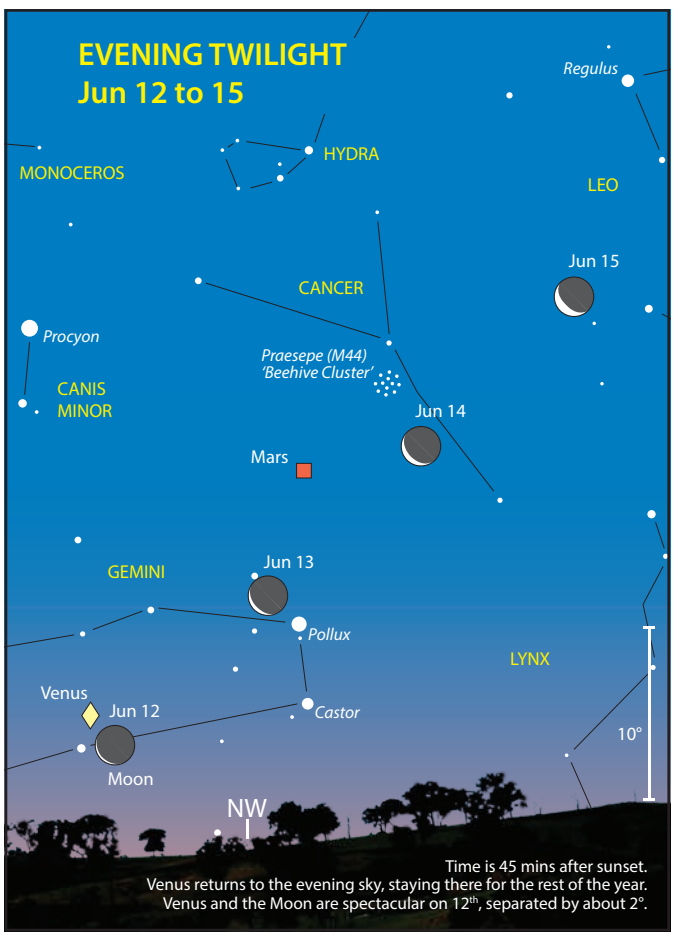
Comet 15P/Finlay is predicted to brighten from 11th to 10th magnitude in June. Rising in the early morning, Finlay begins the month in Cetus. Mid-month sees the comet move into Pisces, then Cetus again, before finishing June in Aries.

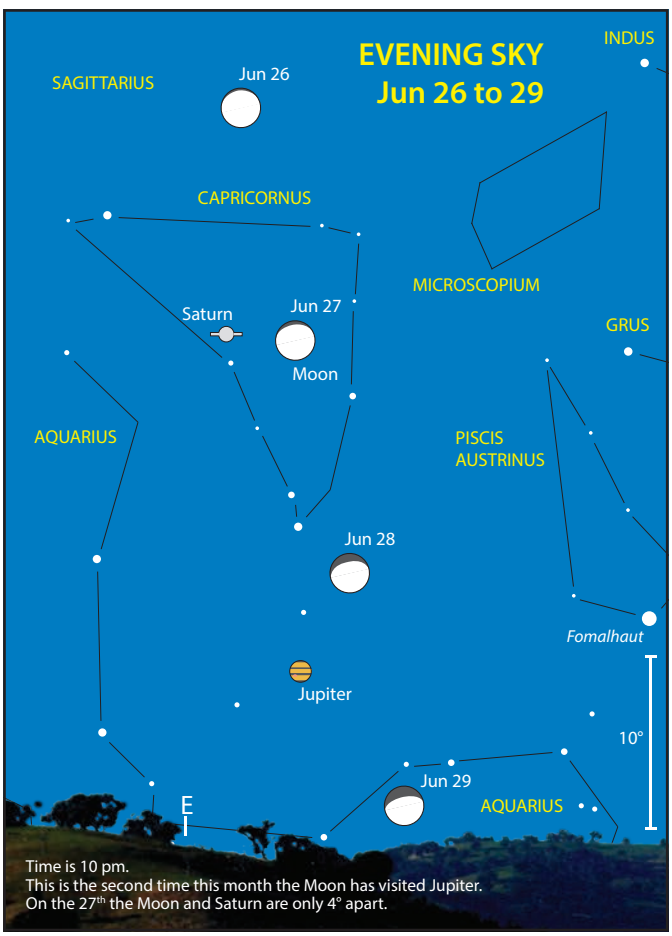
DOUBLE STARS

Epsilon (ε) Boötes (STF 1877AB, 36 Boötes, Izar), All Sky Map No. 7, is located well into the northern sky, north-east of the brilliant star, Arcturus. It is a beautiful pair suitable for telescopes with an aperture of at least 100 mm and high power. The star is located at about the same declination as Pollux. Given its location you will need to wait until it is at maximum altitude as well as steady seeing to split this pair. They were first observed by William Herschel in September 1779. The A component is magnitude 2.6, spectral class K0II-III. The B component is magnitude 4.8, spectral class A2V and is located 185 au from the A component and is also a spectroscopic binary. The AB pair is separated by 2.8 arcseconds with a position angle of 347°. The pair's colours have variously been described as yellow and green, pale orange and sea green as well as orange-yellow and light blue. Hartung, observing from Victoria, described them as deep yellow and white (or bluish by contrast). The pair shares a common proper motion and form a binary with an uncertain orbital period.

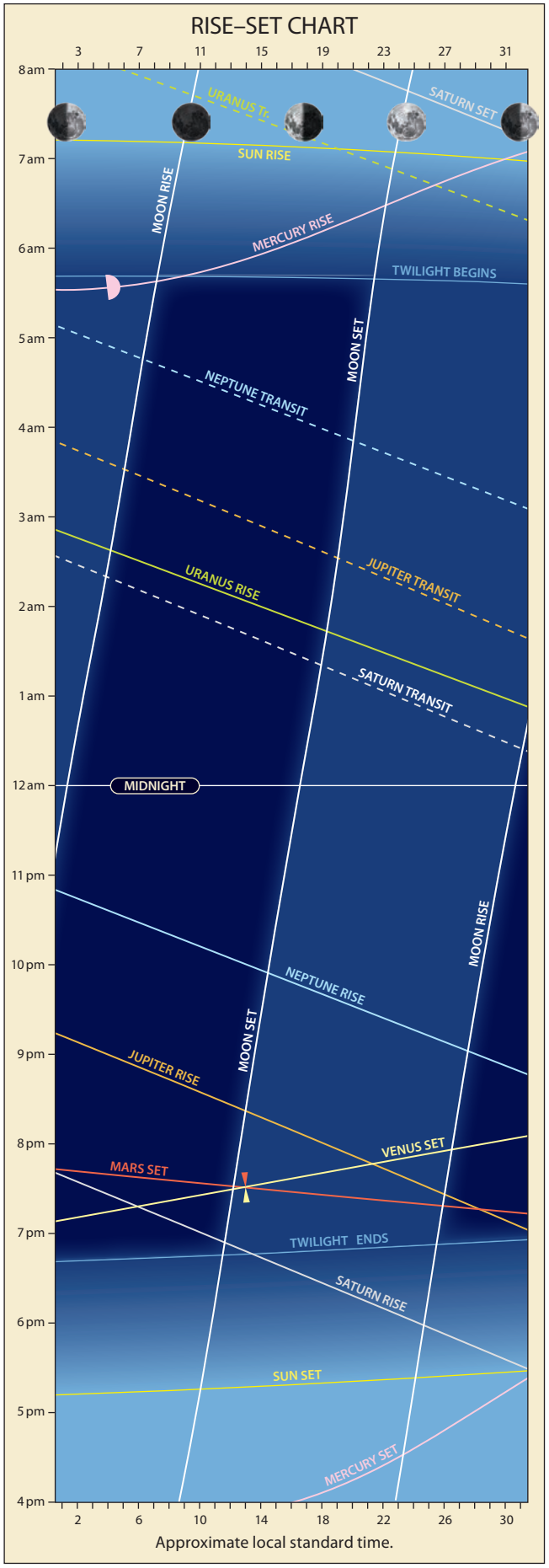


Approximate local standard time.





JULY 2021



HIGHLIGHTS

- Mercury and Moon close.
- Venus, Mars and the Moon together.
- Venus close to Regulus.
- Mars close to Regulus.

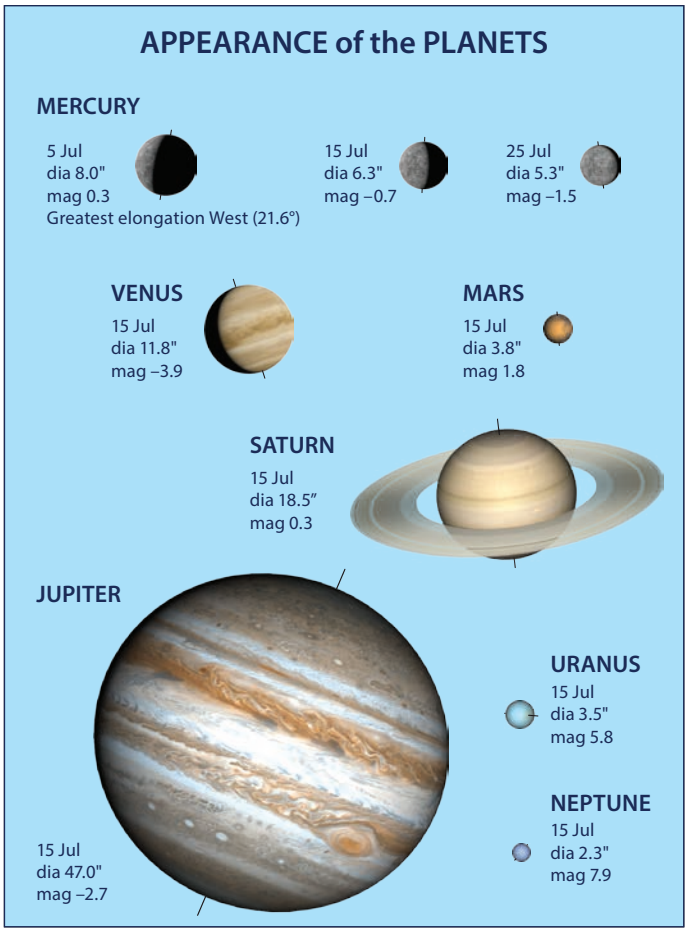
CONSTELLATIONS

This month consists of a brief visit along the Milky Way between the Pointers and Scorpius. It is a region festooned with open star clusters plus dark and bright nebulae. We'll touch on a few of the brighter objects visible in binoculars (see All Sky Maps No 1 and 6).

South-east of Alpha (α) Centauri is the distinctive triangle of 2nd and 3rd magnitude stars appropriately called Triangulum Australe (the Southern Triangle). In the same binocular field north of Beta (β) lies the open cluster NGC 6025. It appears oval in shape and having stars as bright as 8th magnitude, individual members can be glimpsed in binoculars. A small telescope reveals an "S" shaped arrangement of stars.

Only 3° north-east, in the same binocular field is NGC 6087 in the obscure constellation of Norma. Its main two dozen stars (7th to 11th mag) are loosely scattered over 0.2° in a pretty star field. The cluster's 6.5 magnitude brightest member really stands out. A jump northward 4° (keeping 6087 in the binocular field) uncovers Norma's showcase cluster NGC 6067. It's in a brilliant star field being embedded in a bright knot of the Milky Way and only 0.4° north of 5th magnitude Kappa (κ) Normae. This 5th magnitude, irregularly shaped cluster is approximately 0.2° in diameter with dozens of stars visible in telescopes as small as 100 mm. NGC 6067 is awash

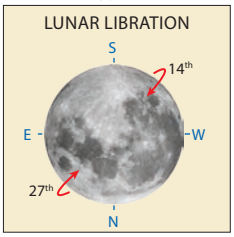
APPEARANCE of the PLANETS



with doubles and curved lines of stars. Near its centre lies its brightest member, an easy double star (nearly matched 9th magnitude components, separated by 9.4 arcseconds). Now, for a voyage of discovery. From NGC 6067 continue in a straight line towards the 90° bend in the tail of Scorpius (a 14° gap or about three binocular fields). Take your time and see how many other clusters are visible.

While in the area, let's look at one of the brightest globular star clusters in the sky. Nestled between Scorpius and Triangulum Australe lies the ancient constellation of Ara. Its pattern is easily recognised with seven 3rd and 4th magnitude stars arranged in an open book shape. Ara's most distinctive feature is the pair of 3rd magnitude stars Beta (β) and Gamma (γ) Arae, 1° apart, forming the southern end of the spine. As an aside, notice the colour contrast between the stars, being distinctively yellow and blue/white respectively. In the same binocular field (just 3° from Beta) is NGC 6397. This relatively loosely packed 6th magnitude globular appears as an obvious fuzzy ball (0.2° in diameter) in binoculars and is spectacular in small telescopes.

THE MOON



2nd 7 am (5 am WST) Last Quarter.

6th 1 am (11 pm previous day WST) Moon at apogee (furthest from Earth at 405,341 km).

10th 11 am (9 am WST) New Moon.

14th 8 am (6 am WST) Maximum Libration (8.7°), dark SW limb.

17th 8 pm (6 pm WST) First Quarter.

21st 8 pm (6 pm WST) Moon at perigee (closest to Earth at 364,520 km).

24th 1 pm (11 am WST) Full Moon.

27th 2 pm (noon WST) Maximum Libration (9.1°), dark NE limb.

31st 11 pm (9 pm WST) Last Quarter.

THE PLANETS

Mercury reaches its greatest elongation of 22° west of the Sun on the 5th and then begins its descent toward Sol and superior conjunction early next month. On the 8th, the 28-day old slender waning crescent Moon (just 4% illuminated by the Sun) appears 5° north of the planet (see Sky View). From then on, Mercury will be increasingly difficult to view as it becomes lost in the solar glare.

Venus, in the early western evening sky, spends the first third of July in Cancer before moving into Leo for the remainder. On the 3rd, Venus passes the outer fringes of Messier 44, the Beehive Cluster or Praesepe. At around 600 light-years away the Beehive is one of the nearest open clusters and is visible to the naked eye under dark skies. Although the inner planet will have quite a glare, this is an ideal event to observe with binoculars.

As the *Evening Star* moves into Leo, it meets up with Mars for an impressive conjunction. On the 12th, Venus will be 1° from the Red Planet with the 2-day old waxing crescent Moon 4° below (see Sky View). The planetary pair then remain within 1° of each other until the 15th and at their closest on the 13th at 0.5°. On the 22nd, Venus will be 1° north of the 1st magnitude star Regulus (Alpha (α) Leonis), the brightest star of the Lion and the 21st brightest star in the night sky (see Sky View).

The **Earth** is at aphelion on the 6th, the furthest point in its orbit from the Sun (152,096,065 km or 1.0166994 au distant).

Mars is beginning to lose altitude in the early north-western evening sky as it moves toward the Sun. Spending the first third of the month in Cancer before wandering into Leo, the planet puts on a final show for us before it succumbs to the brighter twilight sky next month. On the 12th, Mars, Venus and the Moon make an impressive sight (see Sky View) and on the following evening the planetary duo will be a close 0.5° apart. Venus quickly departs the scene and Mars moves on to rendezvous with the 1st magnitude star Regulus (Alpha (α) Leonis) on the 30th when they will be 0.7° apart. Mars, at

"It was that night its turn to be discovered"

For thousands of years people had observed the five known wandering planets. The idea that there may have been more than five never entered their imagination, so it came as a bit of a surprise when another was discovered. The discovery was made by an English amateur astronomer using a homemade telescope.

William Hershel was unsatisfied with the quality of available lenses of the day and began experimenting with reflecting telescopes, the superiority of which generated much interest in English scientific circles. With the poor state of their weather, every clear night was devoted to the study of the skies. Working daily at telescope making and nightly at observing, he rarely stopped for meals, with his sister Caroline feeding him at the telescope. Caroline wrote: "if it had not been for the intervention of a cloudy or moonlight night, I know not when my brother (or I either) should have got any sleep."

It was on the evening of 13 March 1781 as he was observing near the star H Geminorum that he observed what he described as a "curious either nebulous star or perhaps a comet." Comets had been known for a long time and astronomers such as Halley and Newton had calculated their orbits and found them to be shaped like a parabola. However, similar calculations on Herschel's object did not fit—the object was not comet-like.

It was Neville Maskelyne, the Astronomer Royal, who first publicly suggested that the new object might be a planet. After observing the object himself for a few nights, Maskelyne wrote to Dr William Watson, Herschel's friend who had first alerted him to the discovery; "(its motion) convinces me that it is a comet or a new planet but very different from any comet I ever saw." Later he wrote to Herschel "It is likely to be a regular planet moving in an orbit nearly circular around the Sun". Mathematical confirmation of these suspicions come separately from Swedish astronomer Anders Johan Lexell and from the French mathematicians Jean Bochart de Saron and Pierre Laplace in the summer of 1781. Laplace and André Méchain calculated the first elliptical orbit for the planet in 1783. Six months after the discovery, most astronomers acknowledged Hershel's *comet* as a large, new planet. Its calculated orbit placed it

magnitude 1.8 will be slightly fainter than the star at this time although its colour is an obvious indicator.

Jupiter, moving slowly in retrograde in Aquarius, rises in the evening sky (see Sky View). With opposition on 20 August the planet is brilliant at –2.7 magnitude with its disc growing to 47 arcseconds (equatorial diameter) by mid-month. Even the smallest of telescopes will show detail on the planet and the fascinating Galilean satellites as they oscillate back and forth. The constant motion of Io, Europa, Ganymede and Callisto provide a renewed and different view every time they are observed. Since the moons move in a plane that is close to the plane of the Earth's orbit, we can see some interesting events over a period of time. The moons can be occulted by the planet's disc and eclipsed by its shadow, we can see a transit

almost twice as far from the Sun as Saturn and Hershel's observations gave it an estimated diameter of 54,700 km (actual 51,118 km) four and a half times that of Earth. Herschel had doubled the size of the Solar System.

The Royal Society, England's foremost scientific establishment, gave Hershel its Copley Medal in 1781 and honorary membership. Herschel's achievement in discovering the new planet by recognising its disc as being different from the stars stunned the astronomical community. Many would not believe the claims he made about the quality of his telescopes, but when Neville Maskelyne viewed through some of the instruments and declared them to be superior to those of the Royal Observatory, those critics were soon silenced.

In the Summer of 1782, King George III granted Herschel a royal pension of £200 per year to continue his work; in recognition of her contribution, Caroline was given £50 per year, making her the first woman to be a professional astronomer.

By October of 1781, with all the world now acknowledging the planet, the need for a name become urgent. English astronomers, aware of the role the French played in helping verify the planet's orbit were concerned that they would take the honour of naming the object upon themselves. President of the Royal Society, Joseph Banks, wrote to Herschel making just such a point and asking him to name it, but Hershel ignored the request. Indeed, the French were busy inventing names, but quite generously suggested that the planet should be named Herschel.

Another suggestion came from Johann Bode (of Bode's Law) editor of the Berlin Astronomical Yearbook. He suggested Uranus. His reasoning was simple: as Jupiter was the father of Mars, Venus and Mercury, and Saturn was Jupiter's father, and Uranus was Saturn's father, it made sense to keep all the planets part of one family, albeit mythological. These two proposals, along with Neptune, Astraea and others were discussed and debated, yet still Herschel remained silent.

After Hershel's pension came through, with its condition that he live close enough to Windsor Castle that he might show the King and his family the heavens whenever they wished, he wrote to the King suggesting the name Georgium Sidus (George's Star) in his honour. The name was instantly unpopular everywhere except England because of its political flavour, its length and because the object wasn't a star. This left everyone to go their own way: Herschel, then Uranus in France, Uranus in Germany and, for 60 years the Georgian Planet in Britain. It wasn't until 1847 the Nautical Almanac finally used the name Uranus.

Hershel moved to Slough, within sight of Windsor Castle, where he spent the rest of his life, devoting himself full time to astronomy. He was 42 when he found Uranus, but for the next 40 years Herschel led the way in astronomy. He married a widow, Mary Pitt, in 1788 and in 1792 their son, John, was born. From a young age John helped his father and Aunt Caroline in their work. It would be John who would carry on his father's work after William's death.

Herschel died on 25 August 1822, just before his 84th birthday. In his time observing, he had discovered one planet, the 6th and 7th moons of Saturn, two moons of Uranus, the existence of double star systems and the motion of the Sun through space. He had also completed four catalogues of the stars of the heavens. Caroline survived her brother by 26 years, having contributed throughout his observing career, while John would take one of his father's telescopes to the Cape of Good Hope to survey the southern stars, making his own contribution to astronomy.

Hershel did much to dispel the opinion that Uranus was discovered by accident. He was at the time engaged in his second sky survey looking at stars down to magnitude 8, ten times fainter than Uranus. If anyone was to find the planet, this man with his homemade telescope and determination would do it. As Herschel later explained "it was that night its turn to be discovered."



William Hershel 1738–1822

as a moon is silhouetted by Jupiter and observe the shadow of a moon as it is projected onto the cloud tops.

On the morning of the 30th we have a little under five hours of continuous satellite (Callisto and/or Io) shadows on Jupiter

DIARY			
Thu	1st	1 am	(11 pm WST, prev day) Neptune 5° NW of Moon
Thu	1st	pm	Comet 7P/Pons-Winnecke 0.4° NE of star Gamma Sculptoris
Fri	2nd		m.p. 25 Phocaea 0.5° SE of star Zeta Andromedae
Fri	2nd		m.p. 9 Metis 0.7° SW of NGC 4753 (G) in Virgo
Fri	2nd	7 am	(5 am WST) Last Quarter Moon
Sat	3rd		Venus 0.4° N of M44 Beehive Cluster (OC) in Cancer
Sun	4th		Venus at greatest latitude north
Mon	5th	5 am	(3 am WST) Uranus 2° W of Moon
Mon	5th		Mercury at greatest elongation West (21.6°)
Tue	6th	1 am	(11 pm WST, prev day) Moon at apogee (405,341 km)
Tue	6th		Earth at aphelion, 1.016729224 au
Wed	7th	5 am	(3 am WST) star Aldebaran 6° S of Moon
Wed	7th	pm	Comet 7P/Pons-Winnecke 0.3° NE of IC 5332 (G) in Sculptor
Thu	8th		Mercury 0.5° SW of star Zeta Tauri
Thu	8th	6 am	(4 am WST) Mercury 5° SE of Moon
Sat	10th	11 am	(9 am WST) New Moon
Mon	12th		d.p. 1 Ceres 0.5° S of star f Tauri
Mon	12th	6 pm	(4 pm WST) Mars 5° S of Moon
Mon	12th	6 pm	(4 pm WST) Venus 4° S of Moon
Tue	13th		Mars at aphelion
Tue	13th	7 pm	(5 pm WST) star Regulus 5° S of Moon
Tue	13th	pm	Mars 0.5° S of Venus
Wed	14th	8 am	(6 am WST) Maximum Libration (8.7°), dark SW limb
Wed	14th	pm	m.p. 6 Hebe 0.4° NW of NGC 6814 (G) in Aquila
Thu	15th		Mercury 0.5° E of star Eta Geminorum
Fri	16th		Mercury 0.3° E of star Mu Geminorum
Fri	16th	pm	m.p. 27 Euterpe 0.3° N of M22 (GC) in Sagittarius
Sat	17th	7 pm	(5 pm WST) star Spica 6° S of Moon
Sat	17th	8 pm	(6 pm WST) First Quarter Moon
Sun	18th		m.p. 2 Pallas stationary
Sun	18th		d.p. Pluto at opposition
Mon	19th		Mercury at ascending node
Tue	20th	11 pm	(9 pm WST) star Antares 5° S of Moon
Wed	21st	6 pm	(4 pm WST) star Regulus 1.5° S of Venus
Wed	21st	8 pm	(6 pm WST) Moon at perigee (364,520 km)
Wed	21st	pm	m.p. 27 Euterpe 0.2° S of NGC 6642 (GC) in Sagittarius
Sat	24th		Comet 15P/Finlay 0.5° S of star Kappa[1] Tauri
Sat	24th		Mercury at perihelion
Sat	24th	2 am	(Midn. WST, prev day) d.p. Pluto 2° N of Moon
Sat	24th	1 pm	(11 am WST) Full Moon (369,211 km)
Sun	25th	3 am	(1 am WST) Saturn 4° N of Moon
Mon	26th	5 am	(3 am WST) Jupiter 6° NE of Moon
Tue	27th		m.p. 4 Vesta 0.3° SW of M61 (SG) in Virgo
Tue	27th		Venus 1.2° N of star Rho Leonis
Tue	27th	2 pm	(Noon WST) Maximum Libration (9.1°), dark NE limb
Wed	28th		Comet 15P/Finlay 0.2° SE of star Tau Tauri
Wed	28th	4 am	(2 am WST) Neptune 4° N of Moon
Wed	28th	pm	Comet 7P/Pons-Winnecke 0.7° W of star Epsilon Phoenicis
Wed	29th		Southern delta-Aquarids meteor shower, Jul 12 to Aug 23, Full Moon will impair.
Thu	29th	6 pm	(4 pm WST) star Regulus 1° S of Mars
Thu	29th	pm	m.p. 27 Euterpe 1.0° N of M28 (GC) in Sagittarius
Fri	30th		alpha-Capricornids meteor shower, Jul 3 to Aug 15, Last Quarter Moon will interfere.
Sat	31st		m.p. 4 Vesta 0.3° SW of NGC 4457 (G) in Virgo
Sat	31st	11 pm	(9 pm WST) Last Quarter Moon

from the eastern states (the Sun rises about 90 minutes before the end) and 6.5 hours for WA (starting just before midnight on the 29th, see page 124).

With opposition early next month, **Saturn** can be seen rising in the early evening sky in Capricornus. The planet's magnificent rings commenced the year with a tilt of 20° (to Earth) and at opposition they will be slightly narrower at 17°. This is in contrast to their widest angle of 27° (last seen in 2017). The rings will continue to close until the Earth next passes through the ring plane in March 2025 to begin another 15-year cycle. On the 24th, the Full Moon will be seen 5° above the planet (see Sky View).

Uranus, in Aries, is only visible in the morning sky, rising around 2 am mid-month.

Neptune, in Aquarius, rises in the eastern sky around 10 pm mid-month.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

On the 18th, dwarf planet 134340 Pluto at opposition at 14.5 magnitude in Sagittarius. Brightest minor planets at opposition this month include:

Date	Minor Planet	Constellation	Mag.
3 Jul	27 Euterpe	Sagittarius	10.4
8 Jul	48 Doris	Sagittarius	11.8
12 Jul	24 Themis	Sagittarius	12.0
14 Jul	92 Undina	Sagittarius	10.6
14 Jul	65 Cybele	Sagittarius	11.0
17 Jul	6 Hebe	Aquila	8.5
20 Jul	23 Thalia	Sagittarius	11.6
22 Jul	354 Eleonora	Aquila	10.7
23 Jul	372 Palma	Microscopium	12.9
30 Jul	12 Victoria	Aquila	8.8

COMETS

Comet 6P/d'Arrest is predicted to brighten from 11th to 10th magnitude in July. Best viewed in the evening sky (transiting around 9 pm mid-month), the comet is initially located in Hercules and spends the month slowly moving between it and Serpens Cauda.

Comet 7P/Pons-Winnecke moves southward through Sculptor and Phoenix during July. Expected to fade from 8th to 10th magnitude, the comet is rising early in the evening and is visible throughout the night.

Comet 15P/Finlay is likely to peak around 10th magnitude this month, reaching perihelion on the 13th. Rising a few hours before dawn, it begins July in Aries. Moving into Taurus it passes a few degrees south of the Pleiades (M45)—within 6° from the 14th to 19th . In the last week, the comet is within a few degrees north of the Hyades.

DOUBLE STARS

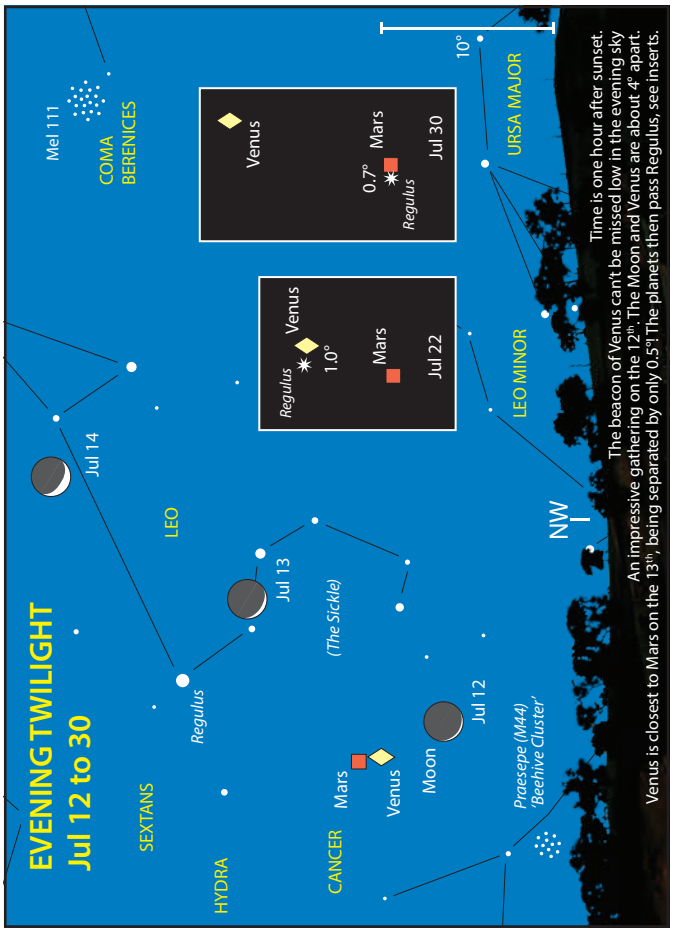
36 Ophiuchi (SHJ 243), All Sky Map No. 6. Is located 10° east of Antares and is an easily split triple star. The A component is magnitude 5.1, spectral class K5Ve and the B component is also magnitude 5.1, spectral class K1V. Because of their inherent faintness, class K dwarf stars are not commonly naked-eye objects. The AB pair is separated by 5 arcseconds with a position angle of 140° and have an orbital period of 471 years. The AB components will be at their

closest in 2148. Visually they both appear yellowish-orange. Located 732 arcseconds at position angle 74° is the magnitude 6.5, spectral class K5V, C component, HD156026. Analysis of data by Luyten in 1941 and data obtained by the Hipparcos satellite, show that the C component is physically related to the AB pair sharing a common proper motion. The system is located 19.4 light-years from the Sun.

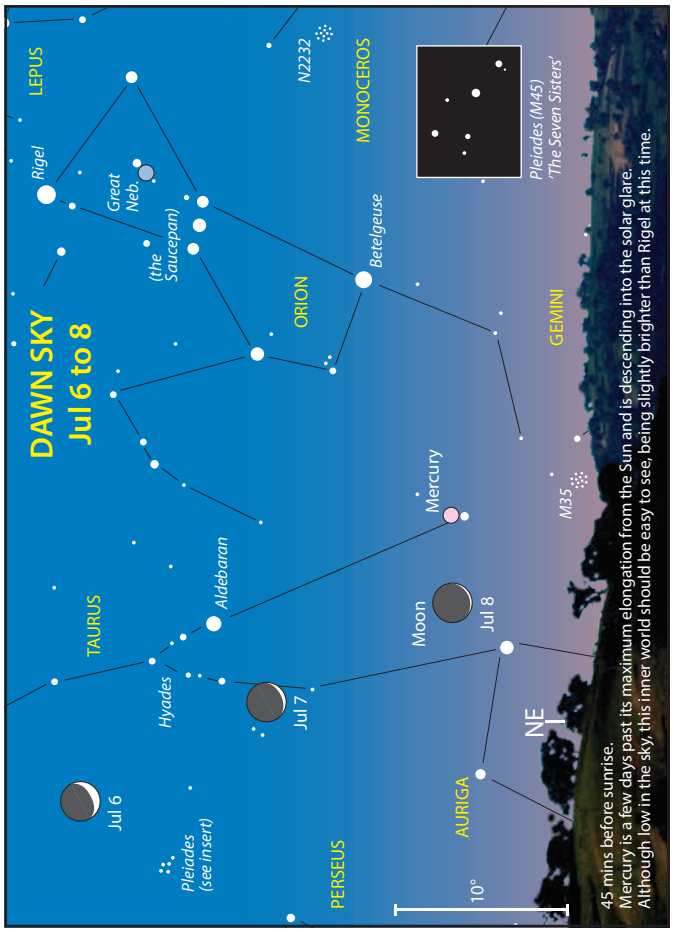
METEOR SHOWERS

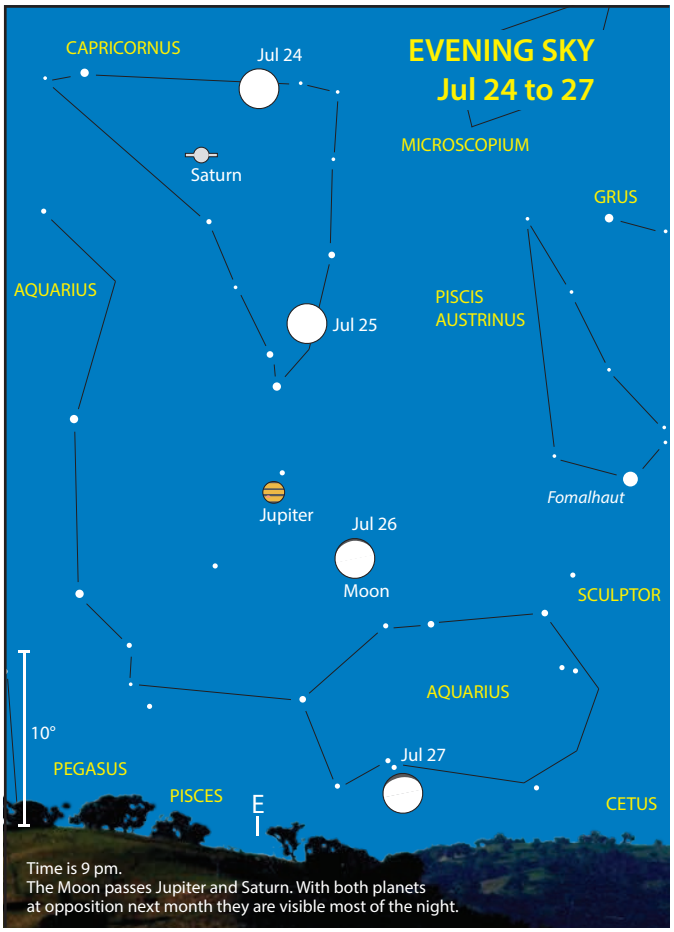
The **Southern delta-Aquarids** are one of the strongest and most consistent of the southern showers. The range of activity of these medium speed meteors extends from 12 July through to 23 August with maximum this month on the night of the 29th and the morning of the 30th. At its peak the delta-Aquarids can produce rates of up to 20 meteors per hour. They are generally faint (bright meteors are the exception), typically white with some blue members and occasionally leaving trains. Unfortunately, the Full Moon on the 24th will impair observation for all but the brightest members.

The **alpha-Capricornids** are noted for their bright, slow meteors with long paths and frequent fireballs. The shower is visible from dusk till dawn, from 3 July through to 15 August. Maximum activity occurs around the 30th, when a zenith hourly rate of five can be expected. Low hourly rates over the period are generally made up by the spectacular nature of this shower. The rising Last Quarter Moon on the 31st will interfere with late evening and morning observations.

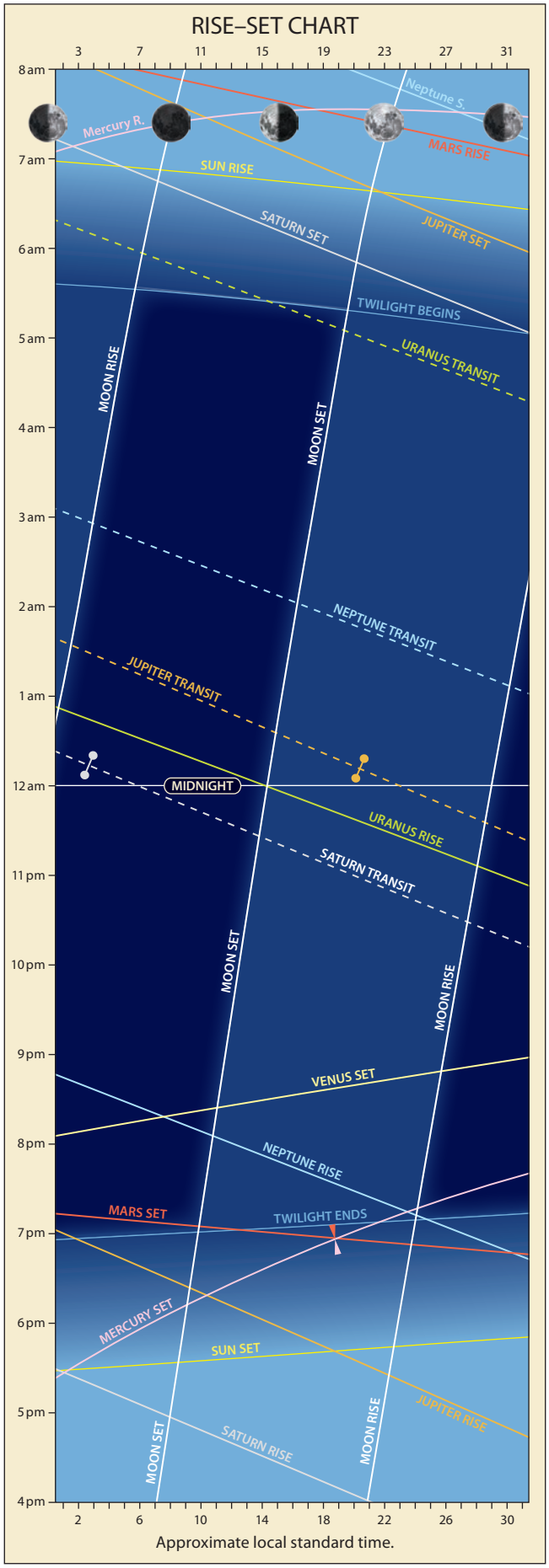


Approximate local standard time.





AUGUST 2021



HIGHLIGHTS

- Mercury and Mars very close.
- Jupiter at opposition.
- Jupiter and Full Moon close.
- Saturn at opposition.

CONSTELLATIONS

For the next three months we will concentrate on the central region (the 'hub') of the Milky Way, covering the constellations of Ophiuchus, Scorpius and Sagittarius (see All Sky Maps No 6 and 8). Being best suited for winter evenings, by September, Sagittarius is getting a bit low in the west so feel free to jump ahead! This area has much to offer the beginner, even to the unaided eye. There are numerous naked-eye bright *star rich* sections, punctuated by many dark lanes and patches of clouds of gas and dust—just look up! Take note of the naked-eye bright knots, for they can be thought of as treasure chests where many of the objects we discuss reside. Also, with most of our galaxy's globular clusters concentrated around the hub, these constellations have more than their fair share. While there are numerous globulars, many are small and can be easily overlooked under the low magnification of binoculars. Of the numerous bright objects within the hub, we can only present here a mere taste of the joys within.

This month's offering is Ophiuchus and can be found by looking due north in the early evening. Below the Scorpion of Scorpius you'll find an asterism of six 2nd and 3rd magnitude stars arranged in a box shape, often referred to as the coffin. It can be a little difficult, needing to have reasonably dark skies to see any stars inside this group with the unaided eye.

APPEARANCE of the PLANETS

MERCURY

Mercury in superior conjunction on the 1st

10 Aug
dia 5.0"
mag –1.1

20 Aug
dia 5.3"
mag –0.4

30 Aug
dia 5.8"
mag –0.1

VENUS

15 Aug
dia 13.6"
mag –4.0

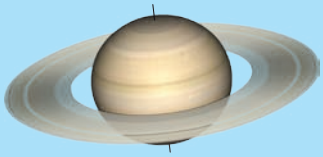


MARS

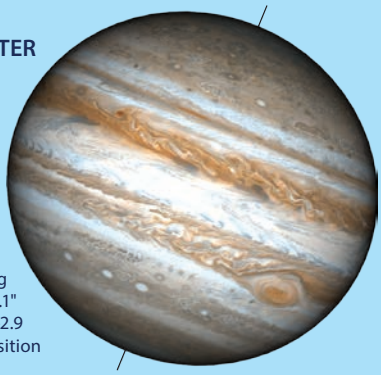
15 Aug
dia 3.6"
mag 1.8

SATURN

2 Aug
dia 18.6″
mag 0.2
Opposition



JUPITER



20 Aug
dia 49.1"
mag –2.9
Opposition

URANUS

15 Aug
dia 3.6"
mag 5.8

NEPTUNE

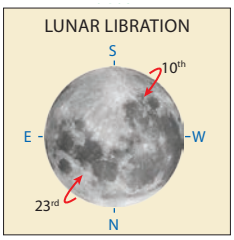
15 Aug
dia 2.4"
mag 7.8

Our journey begins within the coffin. There are two globular clusters visible as fuzzy stars in the same binocular field, M10 and, 3° to its north-west, its slightly fainter companion M12. Telescopes reveal vivid central cores, 2 arcminutes in diameter. M12's halo is much more loosely packed than M10, with stars well resolved, even close to the core.

Move to the naked-eye star Eta (η) Ophiuchi, also called Sabik. Within the same binocular field is the globular star cluster M9. This is a classic example of a bright, but small globular, challenging to binocular users. However, telescopes show an obvious core (2 arcminutes) with a star rich halo extending out to around 5 arcminutes in diameter, dropping off quickly at the edge. West of M9 the star numbers noticeably reduce, leading to an obvious circular, black patch, the dark nebula Barnard 64—both easily fitting in a low power eyepiece field. M9 is the brightest member of a trio of globular clusters, the others are a little over 1° away and best suited for telescopes. To the north-east lies NGC 6356 and south-east is tiny NGC 6342.

Continue moving away from Eta, about halfway to the spout star of the Teapot, we have one of the most distinctive dark nebulae best viewed with the naked eye—the Pipe Nebula. It is complete with a bowl and stem; however, some observers like to include some surrounding dark nebulae to make an elephant. In this case the bowl is its head with the stem the trunk. Enjoy making whatever you like.

THE MOON



- 2nd 6 pm (4 pm WST) Moon at apogee (furthest from Earth at 404,410 km).
- 8th Midnight (10 pm WST) New Moon.
- 10th 5 am (3 am WST) Maximum Libration (8.2°), dark SW limb.
- 16th 1 am (11 pm previous day WST) First Quarter.
- 17th 7 pm (5 pm WST) Moon at perigee (closest to Earth at 369,124 km).
- 22nd 10 pm (8 pm WST) Full Moon.
- 23rd 10 pm (8 pm WST) Maximum Libration (8.5°), near Full Moon
- 30th Noon (10 am WST) Moon at apogee (furthest from Earth at 404,100 km).
- 30th 5 pm (3 pm WST) Last Quarter.

THE PLANETS

On the 1st **Mercury** will be in superior conjunction (Earth and Mercury on opposite sides of the Sun). Thereafter, the planet moves up to meet Mars in the western evening twilight, culminating at a separation of just 0.2° on the 19th. If you have a good western horizon it would be best to wait a little after the end of civil twilight to view under a darker sky (see Sky View).

Shining brightly in the western evening sky, **Venus** leaves Leo and moves into Virgo. On the 11th, the 3-day old waxing crescent Moon will be 4.5° from Venus—not real close but a pleasant sight with earthshine on the portion of the Moon not illuminated by the Sun (see Sky View).

Mars begins the month 1.5° above the 1st magnitude star Regulus in Leo. On the 10th, the planet will be 4.5° from the slender crescent of the waxing Moon in the early western evening twilight (see Sky View). From the 17th to the 21st the innermost planet, Mercury, will be close to the Red Planet and at their closest on the 19th at less than one Moon diameter (see Sky View inserts). At this time Mercury is two magnitudes brighter than Mars. By month's end the planet will be difficult to locate in the twilight as it nears the Sun and its upcoming solar conjunction in early October.

Jupiter, in retrograde, begins the month in Aquarius before its reverse motion takes it back into Capricornus. At close to –3.0 magnitude, Jupiter is very prominent in the early eastern evening sky after sunset. It can only mean one thing when an outer planet rises in the east as the Sun sets in the west—it's opposition time! The equatorial diameter of the gas giant at this opposition is a little over 49 arcseconds. Oppositions repeat after one year and one month (398.9 days) and next year Jupiter reaches its maximum possible diameter of 50 arcseconds (compared to 44 arcseconds at a poor opposition). Regardless of size, any small telescope can show detail of the planet's atmosphere. Look for the polar flattening, changing cloud bands and the massive ancient storm known as the Great Red Spot (GRS). Keep in mind that with a 10-hour rotation period, things move pretty fast on Jupiter, and the GRS is best observed at the time of its meridian passage or at most an hour on either side. Predictions for the Great Red Spot and moon events can be found in Part II. On the 22nd, the Full Moon appears just 4° from the planet (see Sky View).

Early morning on the 16th, for about eight minutes, we have an occurrence of Jupiter with none of the Galilean moons visible outside the disc. At 1:39 am, with Ganymede and Europa already in transit, Io goes into eclipse and eight minutes later Callisto egresses from a transit (see diagram p. 64). The next time we see this is in July 2033.

In addition, this month there are two occurrences of continuous satellite shadows on Jupiter. On the evening of the 1st we have about four hours with Ganymede and/or Europa shadows from eastern states, about 1.5 hours for WA. In both cases, Jupiter rises during the event. Then on the evening of the 15th and morning of the 16th we have just over eight hours with Callisto then Ganymede then Europa shadows from eastern states, about 7.5 hours for WA where we have to wait for sunset.

Saturn comes to opposition on the 2nd, two weeks before Jupiter. Having the two largest planets of the Solar System at their best in the early western evening sky should please all keen planetary observers. There is no denying the absolute beauty of this exquisite world in telescopes of any size. Many amateurs acquired the astronomy bug after seeing Saturn through a telescope for the first time—the view is striking. In general, telescopes in the 50 to 100 mm range will be able to see the rings and the small dark gap known as the Cassini Division. On the planet itself there is a light-coloured band around the equator, and a noticeable darkening and flattening at the poles. Moving to 150 mm and larger should reveal the Encke Gap (a gap in the outermost ring) and the inner translucent Crepe Ring. The near Full Moon appears near the planet on the 20th and 21st (see Sky View).

Toward the end of the month, **Uranus** rises around 11 pm in the eastern evening sky. On the 20th, the planet appears stationary against the background stars and thereafter is in retrograde motion until 2022.

Neptune comes to opposition in mid-September and is now rising around 8 pm mid-month.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Brightest minor planets at opposition this month include:

Date	Minor Planet	Constellation	Mag.
1 Aug	31 Euphrosyne	Indus	12.5
6 Aug	451 Patientia	Microscopium	11.2
12 Aug	349 Dembowska	Piscis Austrinus	9.6
14 Aug	80 Sappho	Equuleus	9.8
19 Aug	43 Ariadne	Aquarius	9.4
21 Aug	71 Niobe	Aquarius	10.8
25 Aug	89 Julia	Aquarius	9.1
28 Aug	654 Zelinda	Pegasus	12.6

COMETS

Comet 4P/Faye opens August around 11th magnitude and slowly brightens. Rising about 1 am, it spends the month in Taurus, being on the edge of the Hyades star cluster for a week starting around the 20th.

Comet 6P/d'Arrest is expected to hover around 10th magnitude this month. Transiting around 7 pm it is best viewed in the evening sky. The comet is in Serpens Cauda initially before moving into Ophiuchus early on where it remains for the remainder of August. Mid-month finds comet d'Arrest near Delta and Epsilon Ophiuchi, closing August near Eta Ophiuchi.

Comet 8P/Tuttle reaches perihelion late in August and is near maximum magnitude (9th). Observations are a challenge, being located low in the dawn sky during the month.

Comet 7P/Pons-Winnecke is predicted to fade from 10th to 11th magnitude this month. Residing in Phoenix, and visible throughout the night it transits in the early morning. It reaches the southernmost point in its apparition at the end of August.

Comet 15P/Finlay fades quickly in August, from 10th to 12th magnitude, rising about an hour before dawn. Beginning the month in Taurus, Finlay moves into Gemini mid-month. On the 2nd, it presents a good display being on the northern edge of the open cluster NGC 1746 in Taurus.

DOUBLE STARS

Eta (η) Lyrae (STF2487), All Sky Maps No. 7 and 9. Located 7° east of the brilliant star Vega (α Lyrae), in the constellation of Lyra, is this month's double. In the field containing this bright pair are three other doubles, all within 7 arcminutes distance. The very unequal A and B stars are magnitudes 4.4 and 8.6 separated by a wide 28 arcseconds with a position angle of 81°. The A component is a blue-white subgiant star, spectral class B2.5IV and is located 1,388 light-years away. It is also a single-lined spectroscopic binary (designated Aa and Ab) with an orbital period of 56.4 days. The name of the Aa component is Aladfar (from the Arabic, 'talons of the eagle'). The bluish B component is spectral class A0 and is only a line of sight component. A very faint magnitude 11.4, C component is located 162 arcseconds away at position angle 151°. However, of more visual appeal is a fine pair of magnitude 8.0 and 8.7 stars (SHJ 289) separated by 39 arcseconds with a position angle of 56°, located 7 arcminutes away to the south-south-west.

METEOR SHOWER

The famous **Perseids** are not easily observable and for many southern observers the radiant will be below the horizon. The Perseids are probably the most dependable of the showers, with records of their activity going back over 2,000 years. Their duration is from 17 July through to 24 August, with maxima predicted for the night of the 12th and the morning of the 13th. In the past this shower has produced some exceptional rates but generally a zenith hourly rate of 60 can be expected. During the peak, the waxing crescent Moon sets early evening leaving the morning hours Moon free.

Shadows and Dust

Stuff to Observe Without a Telescope

There are many different phenomena triggered by the interaction of the light from the Sun or Moon with the Earth's atmosphere or small particles in the Solar System. Well-known solar effects include beautiful sunsets, rainbows and halos. There are also the rarer mock suns. The Moon commonly produces halos and infrequently moonbows. Most people would have seen some of the above, as they are relatively common. Other effects, while common, often go unnoticed or unrecognised for what they are. Under the right conditions, they are visible for anyone to see—a case in point is the Earth's shadow.

We are all familiar with the shadow of the Earth, cast by the Sun, as it passes across the Moon during a total or partial lunar eclipse. However, it is also possible to see the Earth's shadow twice every day, provided you have a clear or reasonably cloudless day. As the Sun sets in the west, turn to the east (reverse for sunrise). You will notice a dark band rising slowly from the eastern horizon and gently tapering to both the north and south. This is the Earth's shadow projected through the atmosphere and into space.

The colour of the shadow is generally a striking dark bluish-purple colour with a pinkish glow above, known as the Belt of Venus. The pink part is caused by light from the Sun being scattered by the Earth's atmosphere. After half to three-quarters of an hour, as day gives way to night, the shadow fades as it merges into the darkening sky. The shadow is most prominent in the east just after sunset, and in the west before sunrise. Where possible, it should be observed from a location with an unobstructed horizon; the effect is quite stunning from a mountain vantage point with a 360° view.

After the Earth's shadow, another easy challenge to observe is the Zodiacal Light (so named because of its relationship with the zodiac). This time face west after the Earth's shadow has gone, allowing time for the sky to darken a little more (reverse for sunrise).

The Zodiacal Light appears as a tenuous conical shaft of light soon after twilight in the western evening sky or before dawn in the eastern morning sky. Being brighter than the Milky Way, it can provide an impressive naked-eye spectacle, measuring up to 20° across at the base on the horizon, gradually tapering as its altitude increases.

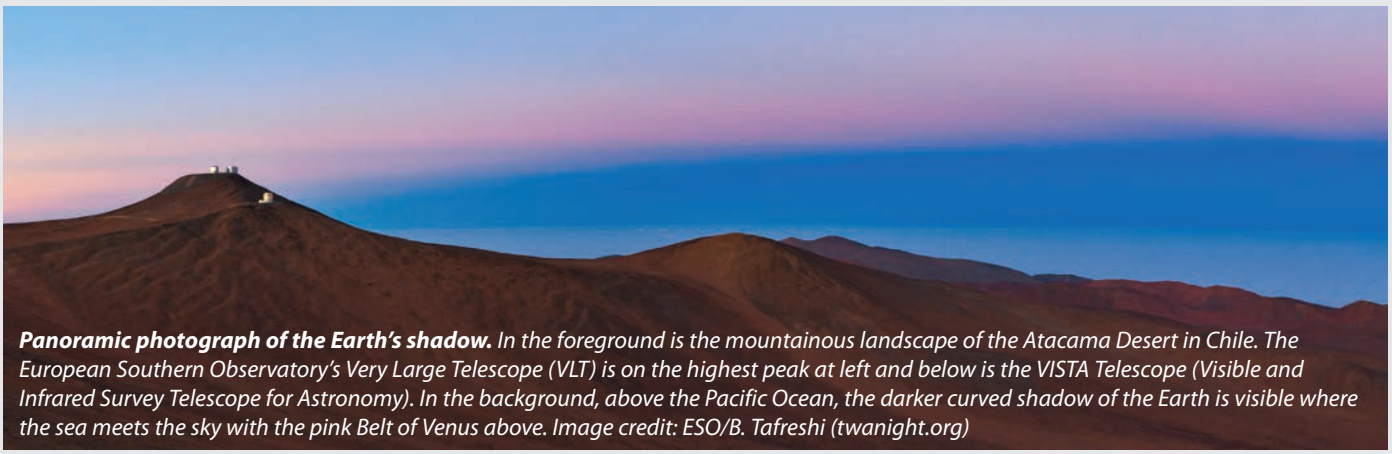
The glow is the result of sunlight reflecting off small particles of dust that lie within the plane of the Solar System. The dust is believed to originate from comet *fall out* and collisions between asteroids, providing a continuous supply of fresh material to the ecliptic. The optimum time to view the Zodiacal Light is when the ecliptic is close to being vertical

DIARY			
Sun	1st	5 am	(3 am WST) Uranus 3° NE of Moon
Mon	2nd		Comet 15P/Finlay 0.2° N of NGC 1746 (OC) in Taurus
Mon	2nd		Mercury in superior conjunction
Mon	2nd		Saturn at opposition
Mon	2nd	6 pm	(4 pm WST) Moon at apogee (404,410 km)
Mon	2nd	pm	Comet 7P/Pons-Winnecke 1.5° W of Comet 19P/Borrelly
Tue	3rd		Mercury at greatest latitude north
Tue	3rd	4 am	(2 am WST) star Aldebaran 7° SE of Moon
Tue	3rd	pm	m.p. 230 Athamantis 0.6° S of star Gamma Librae
Wed	4th	8 pm	(6 pm WST) m.p. 4 Vesta 0.03° S of NGC 4527 (G) in Virgo
Wed	4th	pm	Comet 6P/d'Arrest 0.3° W of star Sigma Serpentis
Thu	5th		m.p. 3 Juno stationary
Thu	5th		m.p. 4 Vesta 0.4° NE of NGC 4536 (G) in Virgo
Sat	7th		Comet 8P/Tuttle 1.0° SW of NGC 2420 (OC) in Gemini
Sat	7th		m.p. 4 Vesta 1.0° SW of NGC 4636 (G) in Virgo
Sat	7th		Venus 0.8° S of star Sigma Leonis
Sun	8th	Midn.	(10 pm WST) New Moon
Sun	8th	pm	m.p. 89 Julia 0.8° SW of star Gamma Aquarii
Mon	9th		m.p. 4 Vesta 0.5° SW of NGC 4643 (G) in Virgo
Mon	9th	pm	m.p. 12 Victoria 1.0° SE of star Theta Aquilae
Mon	9th	pm	m.p. 2 Pallas 0.6° SE of star Theta Piscium
Tue	10th	5 am	(3 am WST) Maximum Libration (8.2°), dark SW limb
Tue	10th	6 pm	(4 pm WST) Mars 5° SW of Moon
Wed	11th	7 pm	(5 pm WST) Venus 5° S of Moon
Fri	13th	am	Perseids meteor shower, Jul 17 to Aug 24.
Fri	13th	8 pm	(6 pm WST) star Spica 7° S of Moon
Sat	14th		Venus 0.4° E of star Beta Virginis
Sat	14th	9 pm	(7 pm WST) m.p. 230 Athamantis 0.1° NE of star Eta Librae
Sun	15th		Mercury 1.2° N of star Rho Leonis
Mon	16th	1 am	(11 pm WST, prev day) First Quarter Moon
Mon	16th	Midn.	(10 pm WST) star Antares 7° SE of Moon
Tue	17th	7 pm	(5 pm WST) Moon at perigee (369,124 km)
Wed	18th	pm	Comet 6P/d'Arrest 1.0° NE of m.p. 3 Juno
Thu	19th		Jupiter at opposition
Thu	19th	6 pm	(4 pm WST) Mars 0.2° NW of Mercury
Thu	19th	pm	m.p. 63 Ausonia 0.4° S of star Tau Scorpii
Fri	20th		Venus 0.9° SW of star Eta Virginis
Fri	20th	3 am	(1 am WST) m.p. 25 Phocaea 0.02° N of IC 1727 (G) in Triangulum
Fri	20th	2 pm	(Noon WST) Uranus stationary
Sat	21st	am	m.p. 25 Phocaea 0.1° S of NGC 672 (G) in Triangulum
Sat	21st	4 am	(2 am WST) Saturn 5° NE of Moon
Sat	21st	pm	m.p. 89 Julia 0.3° S of star Alpha Aquarii
Sun	22nd	7 pm	(5 pm WST) Jupiter 4° NW of Moon
Sun	22nd	10 pm	(8 pm WST) Full Moon (379,232 km)
Mon	23rd		d.p. 1 Ceres 0.7° S of star Gamma Tauri
Mon	23rd	10 pm	(8 pm WST) Maximum Libration (8.5°), near Full Moon
Tue	24th		Comet 4P/Faye 3.5° N of Hyades (OC) in Taurus
Tue	24th	8 pm	(6 pm WST) Neptune 5° NW of Moon
Tue	24th	pm	m.p. 230 Athamantis 0.8° N of star Theta Librae
Wed	25th		Comet 4P/Faye 0.2° S of star Epsilon Tauri
Thu	26th		Mercury at descending node
Thu	26th	3 am	(1 am WST) m.p. 25 Phocaea 0.05° NE of Collinder 21 (OC) in Triangulum
Fri	27th		Comet 4P/Faye 2.4° N of star Aldebaran
Fri	27th		Comet 8P/Tuttle 0.7° NE of star Delta Hydrae
Fri	27th		Venus 0.8° N of NGC 4697 (G) in Virgo
Sat	28th		Mercury 0.9° S of star Beta Virginis
Sat	28th		Venus 0.9° N of NGC 4731 (G) in Virgo
Sat	28th	pm	m.p. 2 Pallas 0.8° SE of star Gamma Piscium
Sun	29th		Venus at descending node
Sun	29th	2 am	(Midn. WST, prev day) Uranus 4° W of Moon
Mon	30th		Comet 15P/Finlay 0.4° E of NGC 2266 (OC) in Gemini
Mon	30th		Mercury 0.7° NW of NGC 4030 (G) in Virgo
Mon	30th	Noon	(10 am WST) Moon at apogee (404,100 km)
Mon	30th	5 pm	(3 pm WST) Last Quarter Moon
Tue	31st		Comet 4P/Faye 0.3° SW of NGC 1647 (OC) in Taurus
Tue	31st		m.p. 44 Nysa 0.7° S of NGC 1647 (OC) in Taurus
Tue	31st	4 am	(2 am WST) star Aldebaran 7° S of Moon

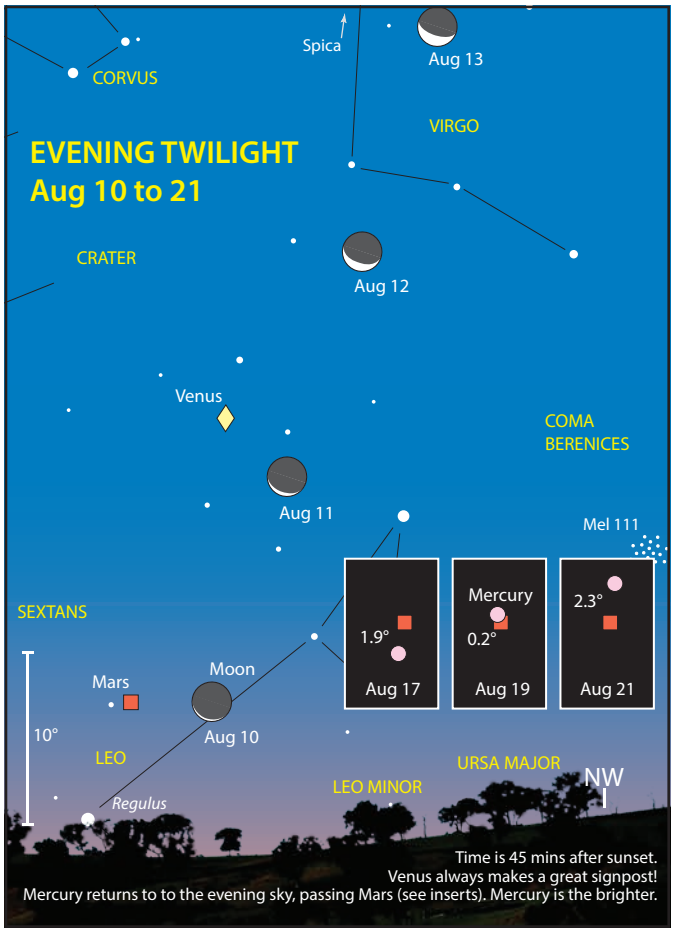
to the horizon. In the Southern Hemisphere, this is August to September in the evening and March to April in the morning. While light pollution does not affect viewing of the Earth's shadow, you will need to be away from the city sky glow to successfully see the Zodiacal Light.

Difficult, but possible to be seen by the experienced observer, are the following two glows that are related to the Zodiacal Light. The Gegenschein or Counterglow moves around the ecliptic 180˚ from the Sun (the anti-solar point); it is an oval glow that measures about 10˚ by 20˚, and being much fainter than the Zodiacal Light, it needs good dark skies. Very difficult to see is the Zodiacal Band, a parallel-sided band that extends from the apex of the Zodiacal Light connecting with the Gegenschein.

The Earth's shadow is colourful and fun to point out to friends whilst explaining some basic Solar System mechanics to them. Pristine dark skies are not required to see the shadow, although places affected by heavy smog may have problems. Except for the Zodiacal Light, the other glow phenomena can be challenging. They require very dark, moonless skies, dark-adapted eyes and the right time of year to successfully see them.



Panoramic photograph of the Earth's shadow. *In the foreground is the mountainous landscape of the Atacama Desert in Chile. The European Southern Observatory's Very Large Telescope (VLT) is on the highest peak at left and below is the VISTA Telescope (Visible and Infrared Survey Telescope for Astronomy). In the background, above the Pacific Ocean, the darker curved shadow of the Earth is visible where the sea meets the sky with the pink Belt of Venus above. Image credit: ESO/B. Tafreshi (twanight.org)*



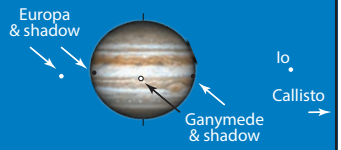
Jupiter's Satellites for August

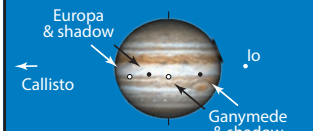
30 arc sec.

Jupiter's Moons can be followed with any small telescope. Here are a few interesting patterns that occur this month. Unless otherwise stated, events are suitable for all of Australia. Specific times of these events can be found in Part II, 'Jupiter Moon Events'. Drawn to normal sky, Jupiter's north pole up, east to the left.

Aug 1, 8:15 pm EST (6:15 pm WST)

Ganymede is currently transiting with its shadow about to egress. Europa's shadow has just ingressed and the satellite and shadow will complete a transit during the evening.



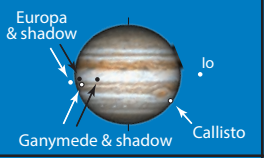


Aug 8, 11:35 pm EST (9:35 pm WST)

A busy night! Europa, Ganymede and their shadows are currently in transit, having all ingressed in the previous 3 hours and will egress in the following hours. Io will disappear into eclipse in the next 10 mins, reappearing from occultation in the morning.

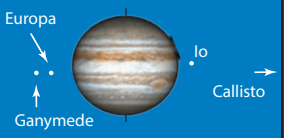
Aug 16, 1:25 am EST (11:25 pm WST 15th)

A busy night! Ganymede and its shadow are transiting, having both ingressed in the previous hour. Europa will soon join its shadow. In 14 mins Io will be eclipsed and Jupiter will be without moons outside the disk until Callisto emerges from its transit at 1:47 EST.



Aug 23, 3:15 am EST (1:15 am WST)

In 10 mins Io will be occulted by Jupiter. In the next 90 mins, Europa, Ganymede and their shadows will commence transiting



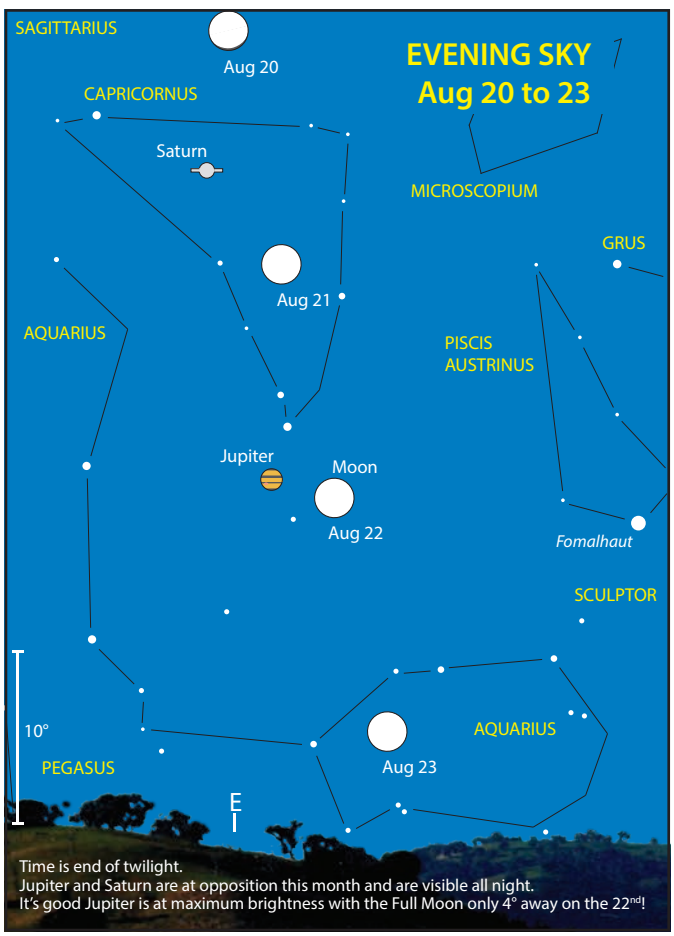
Aug 28, 10:00 pm EST (8:00 pm WST)

1 arc min.



All four moons on one side!
At this time Europa and Io make for a nice 'double', separated by only 4 arcseconds.

Approximate local standard time.



Saturn's Satellites for August

Below are a few interesting patterns of the brightest moons, see also the Introduction to Part I and Satellites of Saturn (Part II) where you can work out the configuration at any time.

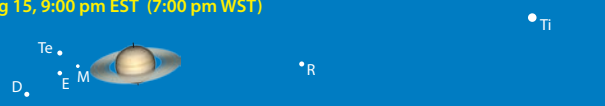
N
E
1 arc min.

Aug 13, midnight EST (10:00 pm WST)



Moons are well scattered with most close to a maximum elongation.
This is certainly a good time to catch the challenging faint inner satellite, Mimas.

Aug 15, 9:00 pm EST (7:00 pm WST)



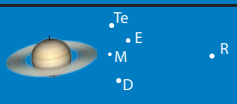
A nice gathering of moons on the eastern side with Rhea and Titan near maximum elongation in the west.

Aug 22, 9:00 pm EST (7:00 pm WST)



Moons are arranged in a nice sweeping line with Titan near maximum elongation in the east.

Aug 24, 8:00 pm EST (6:00 pm WST)

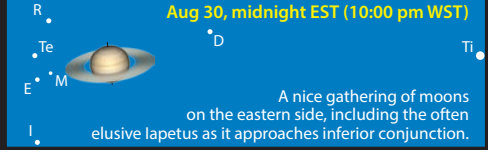




Titan is isolated in the east with the remaining bright moons gathered in the west.

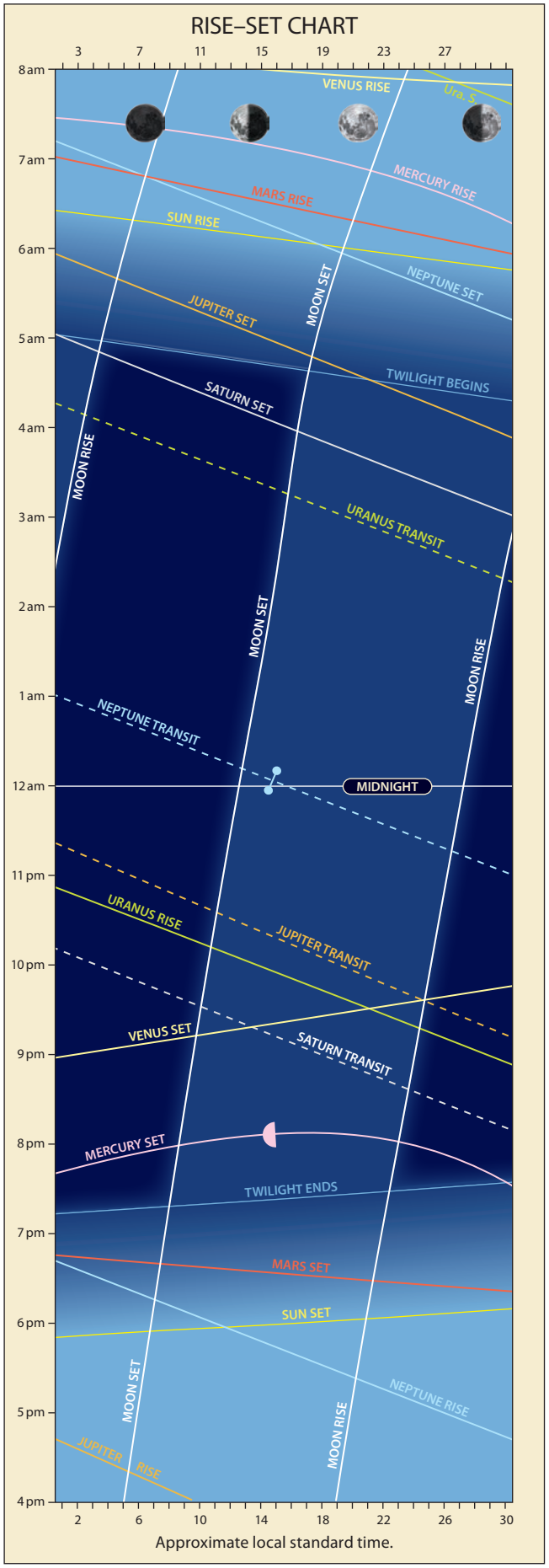
I	Mimas	M
II	Enceladus	E
III	Tethys	Te
IV	Dione	D
V	Rhea	R
VI	Titan	Ti
VII	Iapetus	I

Aug 30, midnight EST (10:00 pm WST)



A nice gathering of moons on the eastern side, including the often elusive Iapetus as it approaches inferior conjunction.

SEPTEMBER 2021



HIGHLIGHTS

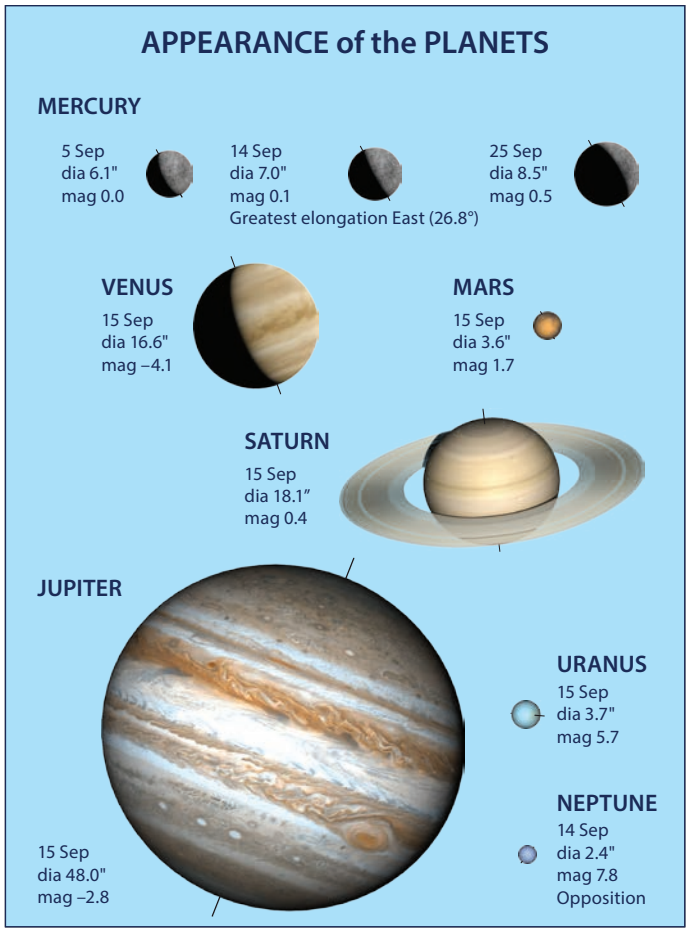
- Mercury and Spica close.
- Venus and Spica close.
- Neptune at opposition.

CONSTELLATIONS

This month we continue our tour of the galaxy's hub, moving into Scorpius. It's one of the few constellations whose asterism actually resembles its creature from mythology, a scorpion (see All Sky Map No. 6).

We'll start with a binocular field, centred on its brightest star Antares (Alpha (α) Scorpii). This luminary is an impressive red colour, living up to its Greek name translating to Rival of Mars. The colour really stands out through binoculars when compared to the obvious blue of its flanking 5th magnitude stars, Sigma (σ) and Tau (τ) Scorpii. These stars are also known as the arteries (Al Niyat); a nod to Antares which was considered by the Arabs as the heart of the scorpion. Only 3° north of Antares is the brilliant binocular triple star, Rho (ρ) Ophiuchi. Three stars (one 5th magnitude and the others 7th) form a tight equilateral triangle (about 3 arcminutes across). Rho appears to be in an empty field but is really embedded in a white fog-like haze, a reflection nebula caused by light from Rho illuminating the surrounding gas clouds. Just west of Antares (1.3° away), lies the brilliant globular star cluster M4. It is large enough to be impressive through binoculars with a telescope showing a bright central core surrounded by an impressive halo, approximately 0.2° across. It shows clumps of stars with numerous doubles and chains in a spectacular Milky Way star field. Returning to Rho, there is another impressive

APPEARANCE of the PLANETS



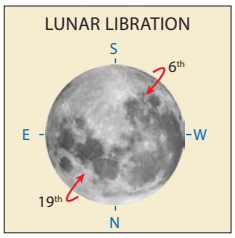
globular, M80, only 2° west, however its small size can be a challenge for binoculars.

As you move down the tail it becomes the realm of the open star clusters. The area around where the tail makes a 90° turn is ideal for binoculars. Zeta (ζ) Scorpii forms a nice triple star shaped like an equilateral triangle with the cluster NGC 6231 next to it. This 3rd magnitude open cluster, comprised of some 40 stars, is dominated by around a dozen 6th to 4th magnitude blue/white stars and has been called the Northern Jewel Box. Only 4° north of Zeta is the bright and wide double star Mu (μ) Scorpii. There are a few other binocular open clusters within about a field size around Zeta, look around.

Continue to the end of the tail, which is comprised of two bright stars close together, Lambda (λ) and Upsilon (υ) Scorpii. Here you may be able to view these stars and two clusters M7 and M6 in the same field (about 6° minimum is needed).

Ptolemy, in the first century CE, created his Almagest, well-known for listing the stars which helped define the positions of the 48 traditional constellations, such as Scorpius. He named Lambda, 'Shaula', Arabic for 'the sting'. Ptolemy also pointed out an object he called "the nebulous star to the rear of the sting". That is why the open star cluster M7 is sometimes called Ptolemy's Cluster, which can be clearly seen as a hazy patch to the naked eye (there were no telescopes in Ptolemy's time). Through binoculars individual stars can be seen out to around 1° in size. M6 is smaller and fainter, mostly due to being more distant than M7 and will appear more like a hazy patch.

THE MOON



6th 5 am (3 am WST) Maximum Libration (8.3°), too close to New Moon.

7th 11 am (9 am WST) New Moon.

11th 8 pm (6 pm WST) Moon at perigee (closest to Earth at 368,461 km).

14th 7 am (5 am WST) First Quarter.

19th 9 pm (7 pm WST) Maximum Libration (8.4°), bright NE limb.

21st 10 am (8 am WST) Full Moon.

27th 8 am (6 am WST) Moon at apogee (furthest from Earth at 404,640 km).

29th Noon (10 am WST) Last Quarter.

The Aristarchus Plateau

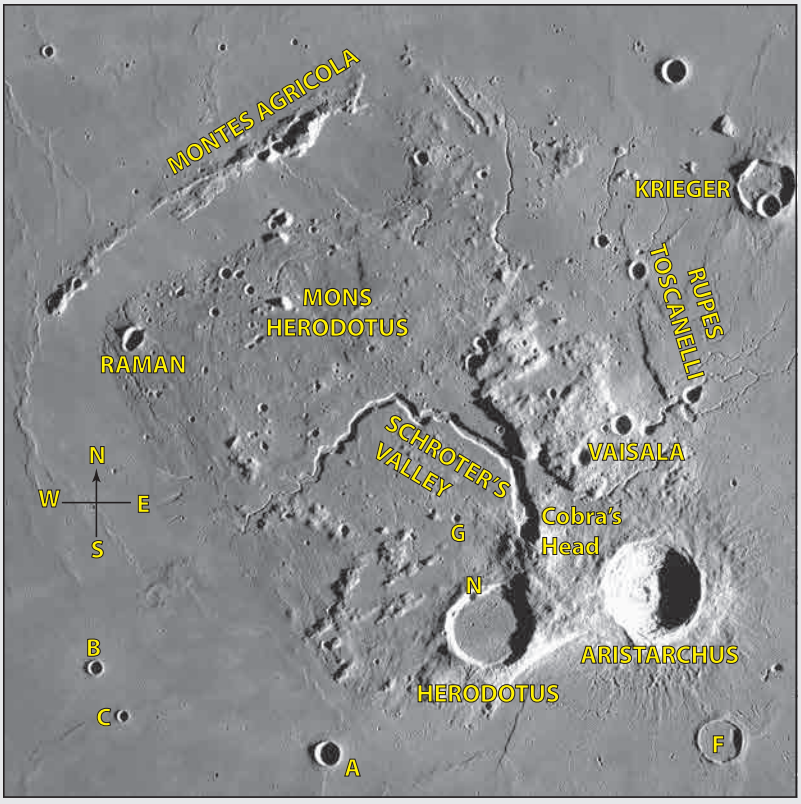
Of all the lunar features, few stand out like the impact crater Aristarchus. It is located near the Moon's north-western limb, on a wide elevated rise, known as the Aristarchus Plateau. Situated on the vast mare, Oceanus Procellarum (Ocean of Storms), the odd-shaped plateau is around 200 km across and stands about 2 km above the mare on the south-eastern side. The region has been a drawcard for lunar observers since the invention of the telescope. It is an area of complex diversity with extremes of high and low reflectance, best observed around four days after First Quarter or three days after Last Quarter Moon (see map, page 111).

At 40 km in diameter and 3 km deep, Aristarchus has terraced walls which are polygonal, and a small central peak rising 300 m above the floor. With an albedo brighter than most lunar features, it can be seen with the naked eye, and remarkably can be identified in the earthshine illuminated portion of a young Moon. With a bright ray system to the south and south-east, it is thought that the impactor came in at a low oblique angle. The brightness of the crater is attributed to its young age of approximately 450 million years, with space weathering not having had sufficient time to darken its ejecta blanket.

The crater was named after Aristarchus of Samos (310–230 BCE), a Greek mathematician and astronomer. He was the first to propose a heliocentric model of the then known Universe with the Earth having a daily axial rotation, and in orbit around the Sun. He also argued that the fixed stars must be very far away since there was no detectable parallax in their apparent position from the moveable Earth.

Adjacent and west of Aristarchus is the slightly smaller crater, Herodotus, at 35 km in diameter. Its floor has been flooded with lava and the crater's rim is uncommonly thin in proportion to its size. A small 4 km crater (N) punches a hole in its northern wall, otherwise, the rim has not suffered a great deal of damage since the crater formed. With its lower albedo, Herodotus is overshadowed by its brilliant neighbour.

Just 25 km north of Herodotus lies the start of Schröter's Valley (Vallis Schröteri), a remarkable sinuous valley. At



THE PLANETS

Mercury enters its best period for evening observation this month when it can be seen in a dark sky free of twilight. Moving through Virgo during the month it has a close encounter with the maiden's brightest star, Spica (Alpha Virginis), on the 21st when the pair are separated by 1.5° (see Sky View). At this time Mercury is about half a magnitude brighter than Spica. Spica is the 16th brightest star in the sky (excluding the Sun) and although it appears as a single star to us, spectroscopic analysis shows a dual pair of suns orbiting around their common centre of gravity in just four days. Mercury reaches its greatest elongation of 26° east of the Sun on the 14th.

Venus, in the western evening sky, spends the first half of September in Virgo before moving into Libra. Whilst in Virgo the planet will be less than 2° from Spica on the 5th and 6th (see Sky View). On the 10th, the 4-day old waxing crescent Moon will be 4° from Venus (see Sky View). Lastly, the 3rd magnitude star Alpha (α) Librae is paid a visit by the *Evening Star* on the 24th. Known also by its Arabic name of Zubenelgenubi, Alpha is an excellent visual binary separated by a wide four arcminutes and easily seen in binoculars as a bright pair of yellow and white suns.

The **Earth** is at its vernal (spring) equinox on the 23rd. From any place on Earth the Sun rises due east and sets due west, day and night are nearly equal.

Mars will be virtually unobservable in the evening sky in September. If you have a good western horizon you may catch it early in the month (see Sky View), but it soon yields to the twilight. The planet will be in conjunction with the Sun on October 8 and will remain hidden in Sol's glare until its reappearance in the eastern dawn sky in late November.

Jupiter is visible together with Saturn in Capricornus high in the north eastern evening sky. Now past opposition, the planet's size and brightness decrease slightly but it is still a pleasure to observe in even the smallest of telescopes. The visible atmosphere of the planet is divided up into dark belts and lighter zones, the most obvious of which are the north and south equatorial belts (NEB and SEB). At first glance an inexperienced observer will see the two belts as straight even bands across the disc, however there is much to be seen as the planet rotates and short-term protuberances, gaps, bright and dark spots are all visible within the bands when the seeing is steady.

Never underestimate the fun of watching the Galilean moons as they shuttle back and forth undergoing satellite transits, shadow transits, occultations and eclipses—just like a miniature Solar System (see Sky View for some interesting moon configurations this month). On the 18th, the 12-day old waxing gibbous Moon will be 4° from Jupiter (see Sky View).

Now past opposition, **Saturn** can be seen high in the eastern evening sky after dusk. This month try looking for the shadow of the planet on the back of the rings (this cannot be seen at opposition as the shadow is directly behind the planet). This shadow, coupled with limb darkening, gives a real 3-D effect in the eyepiece (especially around the end of October/early November).

Although there are six satellites readily visible in most telescopes, some can be tricky to track down. When the rings are edge-on they behave much the same as those of Jupiter, with the rings open they tend to be scattered around the planet and sometimes difficult to separate from background stars. In contrast, at 8th magnitude, Titan, is always conspicuous. On the 17th, the 11-day old waxing gibbous Moon appears near the planet (see Sky View).

Uranus rises in the mid-evening eastern spring sky in Aries. In the early morning hours (around 2 am EST, midnight WST) of the 25th, the planet will be around 0.5° from the limb of the 18-day old waning gibbous Moon.

Neptune is at opposition on the 14th and is visible in the eastern sky after the end of astronomical twilight in Aquarius. Interestingly, it was in this constellation of the *Water Bearer*

160 km in length, it is the largest of its type on the Moon, snaking its way northward before meandering north-west and finally swinging south, and ending at a 1,000 m high cliff on the edge of Oceanus Procellarum. Beginning at a 6 km diameter crater, the valley widens to a 10 km shape that has been nicknamed the *Cobra's Head*, from there, it narrows to around 500 m or less, with a maximum depth of 1,000 m before terminating. Believed to be volcanic in origin, it's not hard to imagine a river of lava flowing down from the heights of the plateau to the plains below.

The whole region is a veritable feast for the observer: craters, domes, rilles, escarpments, mountain ranges, valleys and rays. Most interesting is the fact that the Aristarchus Plateau has been host to more than a third of all reported transient lunar phenomenon (TLP) events. TLPs are short-lived (from a few seconds to several hours) changes in brightness to areas of the Moon ranging from a few to hundreds of kilometres in size. Although there is some scepticism about TLPs due to their mostly anecdotal and singular visual descriptions by amateur and professional astronomers, there does appear to be something behind the numerous reports.

During the Apollo 11 mission in July 1969, Houston requested astronaut Michael Collins (pilot of the Command Module Columbia) to check out a bright glow in the vicinity of Aristarchus after being reported by ground-based astronomers in West Germany. Collins reported back: "Hey, Houston, I'm looking north up toward Aristarchus now, and there's an area that is considerably more illuminated than the surrounding area. It seems to have a slight amount of fluorescence." In NASA's last Apollo mission in 1972, Lunar Module Pilot Harrison Schmitt observed a bright flash near the crater Grimaldi, and his orbiting Command Module Pilot, Ronald Evans noticed a flash near Mare Orientale.

The Aristarchus Plateau was a potential landing site for the cancelled Apollo 18 mission, and sadly we missed that opportunity to explore this fascinating region almost 50 years ago. In April 2020 the private company Intuitive Machines announced that Schröter's Valley would be the target site for its first attempted lunar landing in October 2021. In conjunction with NASA, the lander is tasked with delivering small payloads to the Moon to test its natural resources. A precursor to our return to the Moon and eventual manned missions to Mars.

that in 1846 the German astronomer J.G. Galle discovered the planet—based on mathematical predictions by U. Le Verrier in France. Since discovery, the furthermost planet has only recently completed one orbit of the Sun (in 2011). At 7.8 magnitude and 2.4 arcseconds in diameter the planet requires at least a 100 mm telescope and 200 power to resolve it into a small bluish disc. In late September, Neptune makes a near visit to 6th magnitude star HR 8924 with closest approach on the 23rd.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Brightest minor planets at opposition this month include:

Date	Minor Planet	Constellation	Mag.
11 Sep	2 Pallas	Pisces	8.6
14 Sep	64 Angelina	Pisces	11.8
19 Sep	532 Herculina	Cetus	10.7
27 Sep	121 Hermione	Cetus	11.6

COMETS

Comet 4P/Faye. Reaching perihelion early in September, the comet obtains its maximum magnitude of around 10. Faye is rising about midnight, spending most of the month in Taurus, moving into Orion during the last week.

Comet 6P/d'Arrest, reaching perihelion mid-month, is predicted to remain around 10th magnitude in September. Transiting around sunset, it is well placed to observe in the early evening during September. The comet begins the month in Ophiuchus, near Eta (η) Ophiuchi, moving into Sagittarius mid-month. It conducts a brief tour of some bright deep sky objects (see diary) in the constellation of the archer, including being on the edge of the Trifid Nebula (M20) on the 19th—a show not to miss. Comet d'Arrest ends September amongst the stars of the Teapot asterism.

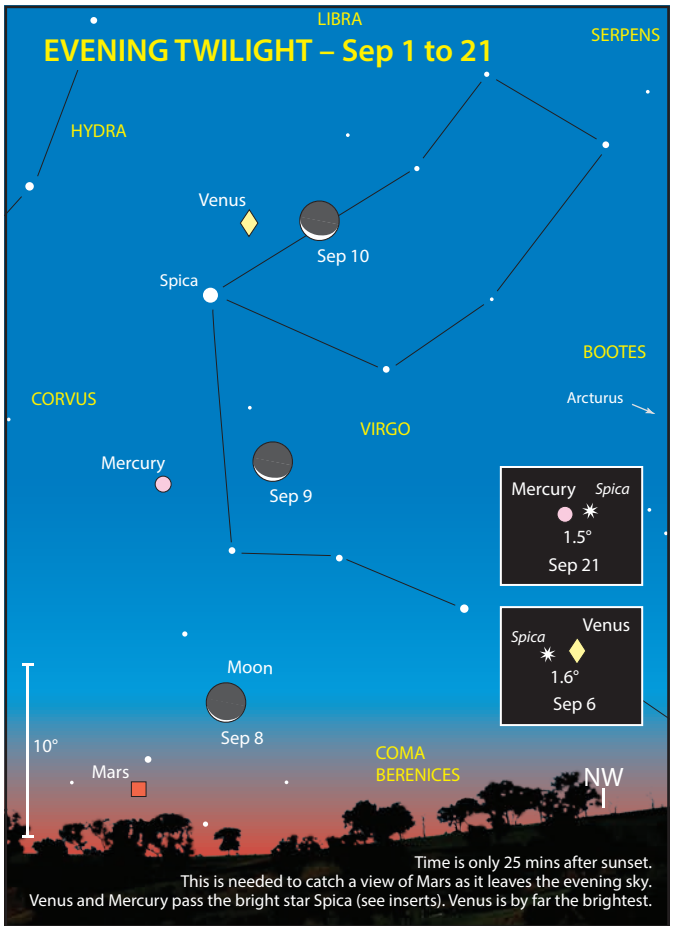
Comet 8P/Tuttle may be glimpsed in September's morning skies just before dawn. Opening the month at 9th magnitude, the comet is in Hydra for all but a few days mid-month (when it travels through Sextans). The second week of September sees the comet near Alpha Hydri.

Comet 67P/Churyumov-Gerasimenko should brighten from 11th to 10th magnitude this month. Rising late in the evening, the comet opens September in Aries, moving into Taurus by the end of the first week. Late September sees the comet in the northern outskirts of the Hyades.

DOUBLE STARS

Rumker 26 (RMK 26), All Sky Map 1. Located in Pavo the Peacock, not far from the trio comprising Rho, Phi^1 and Phi^2 Pavonis, is this attractive close pair. They were found by Christian Carl Ludwig Rumker in 1826 on his return to Sir Thomas Brisbane's private observatory at Parramatta. The A component is magnitude 6.2 (spectral type A2-3IV-V) whilst the B component is magnitude 6.6. The pale yellow pair is currently separated by 2.4 arcseconds with a position angle of 80°. Both position angle and separation are reducing since the measures of John Herschel in 1835. The pair share a similar proper motion and form a long-period binary system.

DIARY			
Wed	1st		Comet 4P/Faye 0.4° N of m.p. 44 Nysa
Wed	1st		Venus 0.4° NW of NGC 4995 (G) in Virgo
Wed	1st		Venus 0.9° NE of NGC 4958 (G) in Virgo
Thu	2nd		d.p. 1 Ceres 0.5° S of star Theta^2 Tauri
Thu	2nd	pm	Comet 6P/d'Arrest 1.0° NE of star Eta Ophiuchi
Fri	3rd		m.p. 22 Kalliope 0.8° SW of m.p. 7 Iris
Fri	3rd		m.p. 7 Iris 0.7° N of M35 (OC) in Gemini
Fri	3rd	6 am	(4 am WST) star Pollux 4° NE of Moon
Sun	5th		m.p. 22 Kalliope 0.2° N of M35 (OC) in Gemini
Sun	5th	pm	star Spica 1.5° S of Venus
Mon	6th		Mercury at aphelion
Mon	6th	5 am	(3 am WST) Max. Libration (8.3°), too close to New Moon
Mon	6th	pm	Comet 6P/d'Arrest 0.8° N of NGC 6356 (GC) in Ophiuchus
Tue	7th	11 am	(9 am WST) New Moon
Thu	9th	7 pm	(5 pm WST) Mercury 7° SW of Moon
Thu	9th	7 pm	(5 pm WST) star Spica 10° SE of Moon
Fri	10th	pm	Venus 4° SW of Moon
Sat	11th		Mercury 1.0° NE of NGC 4699 (G) in Virgo
Sat	11th		m.p. 2 Pallas at opposition
Sat	11th	8 pm	(6 pm WST) Moon at perigee (368,461 km)
Sun	12th		d.p. 1 Ceres 0.9° S of star Aldebaran
Mon	13th	8 pm	(6 pm WST) star Antares 6° SW of Moon
Tue	14th	7 am	(5 am WST) First Quarter Moon
Tue	14th		Mercury at greatest elongation East (26.8°)
Tue	14th		Neptune at opposition
Tue	14th	pm	Comet 6P/d'Arrest 0.7° SW of NGC 6440 (GC) in Sagittarius
Wed	15th		Mercury 0.2° NE of NGC 4939 (G) in Virgo
Thu	16th	3 am	(1 am WST) m.p. 44 Nysa 0.1° SW of star m Tauri
Thu	16th	pm	Comet 6P/d'Arrest 0.4° N of NGC 6469 (OC) in Sagittarius
Thu	16th	pm	m.p. 63 Ausonia 0.3° N of NGC 6316 (GC) in Ophiuchus
Fri	17th	7 pm	(5 pm WST) Saturn 5° NW of Moon
Sat	18th		m.p. 7 Iris 1.0° SW of star Epsilon Geminorum
Sat	18th	3 am	(1 am WST) d.p. 1 Ceres 0.05° S of star Sigma^1 Tauri
Sat	18th	8 pm	(6 pm WST) Jupiter 4° NW of Moon
Sun	19th	8 pm	(6 pm WST) Comet 6P/d'Arrest 0.2° SE of M20 Trifid Nebula (BN) in Sagittarius
Sun	19th	9 pm	(7 pm WST) Maximum Libration (8.4°), bright NE limb
Sun	19th	pm	m.p. 27 Euterpe 0.8° N of M28 (GC) in Sagittarius
Mon	20th	7 pm	(5 pm WST) Neptune 4° NW of Moon
Mon	20th	pm	Comet 6P/d'Arrest 1.0° NE of M8 Lagoon Nebula (BN) in Sagittarius
Tue	21st	10 am	(8 am WST) Full Moon (389,988 km)
Thu	23rd		Neptune 0.02° SE of star HR 8924
Thu	23rd		Venus 0.5° SE of NGC 5728 (G) in Libra
Thu	23rd		Equinox
Thu	23rd	7 pm	(5 pm WST) star Spica 1.5° N of Mercury
Fri	24th		Comet 67P/Churyumov-Gerasimenko 3.7° N of Hyades (OC) in Taurus
Fri	24th	am	Comet 67P/Churyumov-Gerasimenko 0.4° NW of star Epsilon Tauri
Sat	25th	2 am	(Midn. WST, prev day) Uranus 0.5° N of Moon
Sat	25th	pm	Comet 6P/d'Arrest 0.7° S of M28 (GC) in Sagittarius
Sun	26th		Mercury at greatest latitude south
Sun	26th	pm	Comet 6P/d'Arrest 0.5° S of star Lambda Sagittarii
Mon	27th	3 am	(1 am WST) star Aldebaran 7° SE of Moon
Mon	27th	8 am	(6 am WST) Moon at apogee (404,640 km)
Mon	27th	2 pm	(Noon WST) Mercury stationary
Mon	27th	pm	Comet 6P/d'Arrest 0.7° S of NGC 6638 (GC) in Sagittarius
Wed	29th	Noon	(10 am WST) Last Quarter Moon
Wed	29th	pm	m.p. 27 Euterpe 0.5° S of NGC 6642 (GC) in Sagittarius
Thu	30th	7 pm	(5 pm WST) star Spica 2° N of Mercury



Jupiter's Satellites for September

30 arc sec.

Jupiter's Moons can be followed with any small telescope. Here are a few interesting patterns that occur this month. Unless otherwise stated, events are suitable for all of Australia. Specific times of these events can be found in Part II, 'Jupiter Moon Events'. Drawn to normal sky, Jupiter's north pole up, east to the left.

Sep 2, 8:45pm EST (6:45 pm WST)

Io has just reappeared from being eclipsed. Europa and its shadow are currently transiting and will egress later in the evening. Ganymede will soon pass behind Jupiter (be occulted).



1 arc min.

Sep 7, 10:00 pm EST (8:00 pm WST)



Four moons on the same side! In the morning (8th), Io and Europa will be occulted by Jupiter and reappear from eclipse (emerge from Jupiter's shadow).

Sep 10, 12:35 am EST (10:35 pm WST 9th)

Callisto has just reappeared from occultation and in the next 10 mins will go into eclipse, returning later in the morning. Ganymede is about to go into occultation and reappear from eclipse in about 6 hours (best from WA).



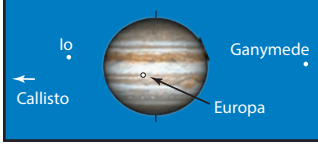
Sep 11, 9:00 pm EST (7:00 pm WST)

1 arc min.



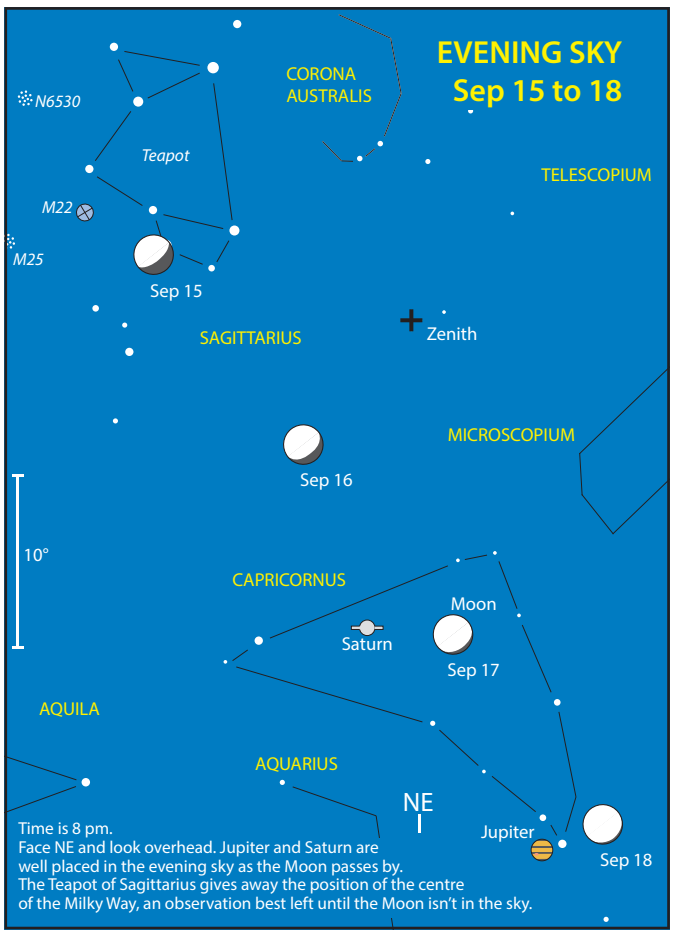
Four moons on the same side! One hour ago Europa reappeared from eclipse (emerged from Jupiter's shadow). This is an eastern states event.

Sep 17, 12:40 am EST (10:40 pm WST 16th)



Io has just reappeared from eclipse. Europa's shadow will commence a transit in 15 mins with both egressing later in the morning.

Approximate local standard time.



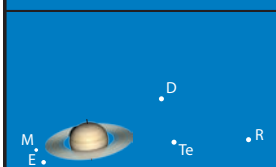
Saturn's Satellites for September

Below are a few interesting patterns of the brightest moons, see also the Introduction to Part I and Satellites of Saturn (Part II) where you can work out the configuration at any time.



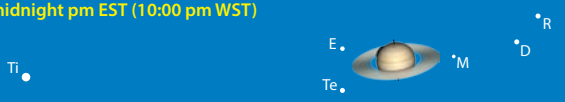
1 arc min.

Sep 2, 9:00 pm EST (7:00 pm WST)



Dione, Tethys and Rhea are near maximum elongations. It shows well how far they range from Saturn's rings at this part of their orbits

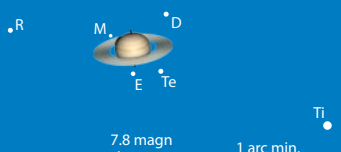
Sep 7, midnight pm EST (10:00 pm WST)



An example of multiple moons close to their maximum elongations. Titan certainly moves a considerable distance from Saturn at this time.

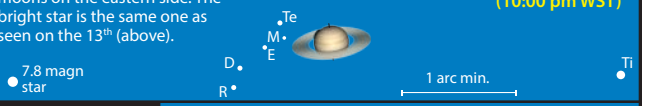
Sep 13, 11:00 pm EST (9:00 pm WST)

The moons are well spread. Saturn is making its closest approach to a bright star. The star should be noticeably brighter than Titan.



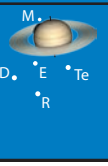
An impressive alignment of moons on the eastern side. The bright star is the same one as seen on the 13th (above).

Sep 14, midnight EST (10:00 pm WST)



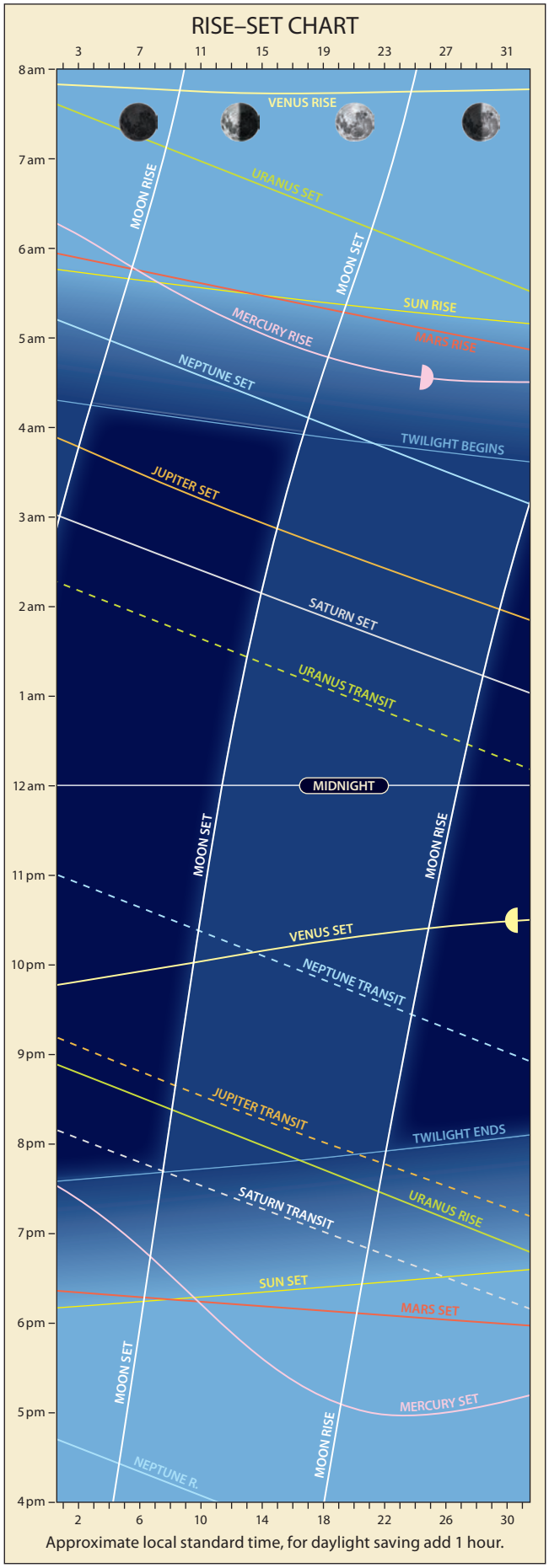
I	Mimas	M
II	Enceladus	E
III	Tethys	Te
IV	Dione	D
V	Rhea	R
VI	Titan	Ti
VII	Iapetus	I

Sep 28, midnight EST (10:00 pm WST)



An interesting gathering of moons to the south of Saturn. Titan is about a day past an inferior conjunction.

OCTOBER 2021



Approximate local standard time, for daylight saving add 1 hour.

HIGHLIGHTS

- Venus near Antares.
- Saturn near the Moon.
- Jupiter close to the Moon.

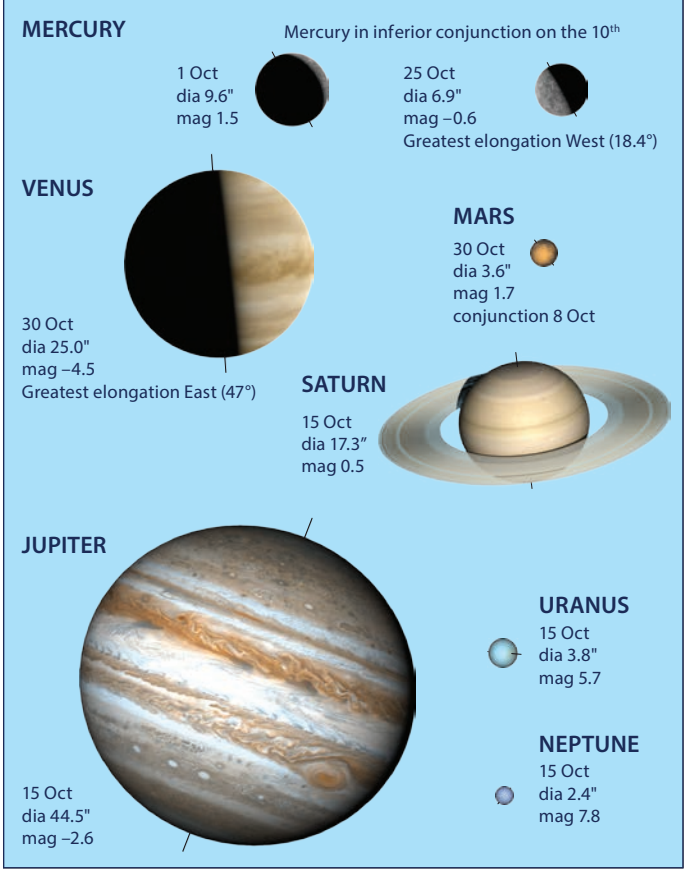
CONSTELLATIONS

Sagittarius is the last of the three 'hub' constellations (see All Sky Map No. 8). It is best known for its characteristic Teapot asterism, made up of nine approximately 3rd magnitude stars. You will need to observe it as early as possible this time of year for as twilight ends, it has already tipped over and is heading for the western horizon. The mixture of bright star regions with obvious dark nebulae, associated with our galaxy, really stands out in Sagittarius. The centre of the Milky Way is located only a few degrees from the 'spout' star, Gamma (γ) Sagittarii, right in the middle of an obvious dark rift, clearly visible to the unaided eye, which runs along the spine of our galaxy. If not for this equatorial band, so common to spiral galaxies, the Milky Way would positively glow in this area. Instead it is highly extinguished, hiding many treasures (in visible light at least), including its central black hole.

Sagittarius contains many globular and open star clusters as well as nebulae. As with Ophiuchus and Scorpius, Sagittarius was far enough north for Messier to catalogue a number of its brighter objects so his 'M' list is a good starting point.

There are eight Messier globular clusters (one of these, M54, is technically the core of a defunct galaxy) which is a similar number to Ophiuchus. Likewise, although bright enough some are difficult to spot with binoculars because they are quite small. For example, there are three within the teapot, M54,

APPEARANCE of the PLANETS

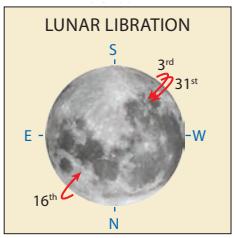


M70 and M69, down near its base formed by a line between Zeta (ζ) and Epsilon (ε) Sagittarii, that look like slightly fuzzy stars. However, M22 which is easily in the same field as the 'lid' star (Lambda), is large and well suited for binoculars. It is also the third brightest globular after Omega Centauri and 47 Tucanae. In the same field with M22 is another binocular globular M28 which is obviously smaller and fainter. Telescopes will see at least two others.

Now into the realm of nebulae and open clusters. From the 'lid' star head roughly in the direction of Antares. Not much more that a binocular field away (about 6°), you come across the dark rift. Some bright knots are clearly seen with the naked eye. One of these is the open star cluster and nebula called the Lagoon Nebula (M8). It is a rare example of a star-forming region visible to the unaided eye. Other famous members of this exclusive club are the Orion Nebula, Eta Carinae region and the Tarantula in the Large Magellanic Cloud. Binoculars even show the dark lane which appears to cut M8 in half. Only 2° north is the more challenging open cluster M21 and the Trifid Nebula (M20), which are brilliant in small telescopes. Continue onto another obvious naked-eye bright knot, M24 or the Sagittarius Star Cloud, which is the best binocular object in the galactic hub. It is an oval about 1.5° long showing a multitude of stars, but it isn't a cluster. It can best be described as a clearing in the dark nebula giving a view some thousands of light-years further and closer to the galactic centre, than its surroundings—very impressive! Just 2° north is the Omega or Swan Nebula (M17). Small telescopes show a bright nebula shaped like a 'tick' mark. Even binoculars reveal an oval shaped fuzzy object.

So ends our brief introduction to the centre of our Milky Way.

THE MOON



3rd 2 pm (noon WST) Maximum Libration (9.0°), bright SW limb. The 167 km crater Hausen brought into view from the libration zone.

6th 9 pm (7 pm WST) New Moon.

9th 3 am (1 am WST) Moon at perigee (closest to Earth at 363,386 km).

13th 1 pm (11 am WST) First Quarter.

16th 5 pm (3 pm WST) Maximum Libration (9.0°), bright NE limb. The 161 km Mare Humboldtianum now visible.

21st 1 am (11 pm previous day WST) Full Moon.

DIARY

Fri	1st		m.p. 22 Kalliope 1.0° NW of star Epsilon Geminorum
Fri	1st		Venus 0.7° NE of NGC 5897 (GC) in Libra
Fri	1st	4 am	(2 am WST) star Pollux 4° NW of Moon
Fri	1st	pm	Comet 6P/d'Arrest 0.6° S of star Phi Sagittarii
Sun	3rd		Venus at aphelion
Sun	3rd	5 am	(3 am WST) star Regulus 9° SE of Moon
Sun	3rd	2 pm	(Noon WST) Maximum Libration (9.0°), bright SW limb
Mon	4th	pm	m.p. 27 Euterpe 0.01° N of M22 (GC) in Sagittarius
Wed	6th		d.p. Pluto stationary
Wed	6th	9 pm	(7 pm WST) New Moon
Wed	6th	pm	Comet 6P/d'Arrest 0.9° NE of star Zeta Sagittarii
Fri	8th		d.p. 1 Ceres stationary
Fri	8th		Mars in conjunction with Sun
Fri	8th	pm	Comet 19P/ Borrelly 0.2° NE of star Gamma Tucanae
Sat	9th		Comet 8P/Tuttle 0.4° NW of star Chi[1] Hydrae
Sat	9th		m.p. 7 Iris 0.5° N of star Delta Geminorum
Sat	9th	3 am	(1 am WST) Moon at perigee (363,386 km)
Sun	10th		Venus 0.8° S of star Delta Scorpii
Sun	10th		Mercury in inferior conjunction
Sun	10th	am	Southern Taurids meteor shower, Sep 10 to Nov 20.
Sun	10th	8 pm	(6 pm WST) star Antares 4° S of Moon
Sun	10th	pm	Venus 7° W of Moon
Mon	11th	Noon	(10 am WST) Saturn stationary
Tue	12th		m.p. 2 Pallas 1.0° NW of star Lambda Aquarii
Wed	13th	1 pm	(11 am WST) First Quarter Moon
Wed	13th	8 pm	(6 pm WST) d.p. Pluto 2° N of Moon
Thu	14th		Uranus 0.2° NW of star Omicron Arietas
Thu	14th	8 pm	(6 pm WST) Saturn 4° NW of Moon
Fri	15th		Mercury at ascending node
Fri	15th	8 pm	(6 pm WST) Jupiter 4° N of Moon
Fri	15th	10 pm	(8 pm WST) Comet 6P/d'Arrest 0.2° NW of M55 (GC) in Sagittarius
Sat	16th		m.p. 3 Juno 0.7° N of star Nu Serpentis
Sat	16th		Venus 1.0° N of NGC 6144 (GC) in Scorpius
Sat	16th	5 pm	(3 pm WST) Maximum Libration (9.0°), bright NE limb
Sat	16th	pm	star Antares 1.5° S of Venus
Sun	17th		Comet 8P/Tuttle 0.3° S of star Xi Hydrae
Sun	17th	am	Comet 67P/Churyumov-Gerasimenko 0.5° NE of M35 (OC) in Gemini
Sun	17th		d.p. 136199 Eris at opposition
Sun	17th	Midn.	(10 pm WST) Neptune 4° N of Moon
Sun	17th	pm	m.p. 25 Phocaea 1.0° NW of star Eta Piscium
Mon	18th	11 am	(9 am WST) Mercury stationary
Mon	18th	9 pm	(7 pm WST) Jupiter stationary
Tue	19th		Mercury at perihelion
Wed	20th		m.p. 7 Iris 0.3° SW of NGC 2420 (OC) in Gemini
Thu	21st		Orionids meteor shower, Oct 2 to Nov 7, Full Moon affected.
Thu	21st	1 am	(11 pm WST, prev day) Full Moon (399,420 km)
Fri	22nd	3 am	(1 am WST) Uranus 3° NE of Moon
Sat	23rd		Venus 0.4° W of M19 (GC) in Ophiuchus
Sun	24th		Comet 67P/Churyumov-Gerasimenko 0.6° NW of star Epsilon Geminorum
Sun	24th	Midn.	(10 pm WST) star Aldebaran 9° SW of Moon
Mon	25th		Venus 0.1° N of NGC 6293 (GC) in Ophiuchus
Mon	25th		Venus at greatest latitude south
Mon	25th	1 am	(11 pm WST, prev day) Moon at apogee (405,615 km)
Mon	25th		Mercury at greatest elongation West (18.4°)
Thu	28th		m.p. 6 Hebe 0.9° S of M75 (GC) in Sagittarius
Thu	28th		Venus 0.4° S of NGC 6355 (GC) in Ophiuchus
Thu	28th	am	Comet 4P/Faye 0.9° SW of star Xi Geminorum
Thu	28th	3 am	(1 am WST) star Pollux 2° NE of Moon
Fri	29th		m.p. 22 Kalliope 0.9° NW of NGC 2331 (OC) in Gemini
Fri	29th	6 am	(4 am WST) Last Quarter Moon
Fri	29th	9 pm	(7 pm WST) Comet 6P/d'Arrest 0.2° N of NGC 6925 (G) in Microscopium
Sat	30th		Mercury at greatest latitude north
Sat	30th		Venus at greatest elongation East (47.0°)
Sat	30th	pm	Comet 19P/ Borrelly 0.5° NE of star Zeta Gruis
Sun	31st		Comet 8P/Tuttle 0.3° N of NGC 4373 (G) in Centaurus
Sun	31st		Comet 8P/Tuttle 0.6° W of IC 3370 (G) in Centaurus
Sun	31st	4 am	(2 am WST) star Regulus 6° S of Moon
Sun	31st	8 am	(6 am WST) Maximum Libration (9.8°), bright SW limb
Sun	31st	9 pm	(7 pm WST) m.p. 80 Sappho 0.1° S of star Beta Aquarii

25th 1 am (11 pm previous day WST) Moon at apogee (furthest from Earth at 405,615 km).

29th 6 am (4 am WST) Last Quarter.

31st 8 am (6 am WST) Maximum Libration (9.8°), bright SW limb. Although just outside the libration zone, the vast 303 km walled plain Bailly is well situated at this time.

THE PLANETS

Mercury begins the month 1.5° south of Spica in the western evening twilight. It then quickly descends toward the Sun and inferior conjunction (between the Earth and the Sun) on the 10th. Returning to the morning dawn, the planet reaches its greatest elongation 18° west of the Sun on the 25th. This is a really poor apparition with Mercury barely a few degrees above the horizon at the end of civil twilight.

Venus, shining brilliantly in the western evening sky, will be in Libra for the first week of October before moving into Scorpius and finally Ophiuchus. On the 9th and 10th, the planet will be 1° from 2nd magnitude Delta (δ) Scorpii, the middle star of the three-star line that makes up the claw region of the Scorpion (see Sky View). A nice colour contrast is seen on the 16th and 17th when Venus appears within 2° of the 1st magnitude star, Antares (Alpha (α) Scorpii). Antares is the brightest star of the constellation and distinctly reddish (see Sky View insert). The planet reaches its greatest elongation of 47° east of the Sun on the 30th. During October, Venus tours some star clusters in Scorpius and Ophiuchus.

Mars is in conjunction with the Sun on the 8th and will not be visible until its reappearance in the morning sky during late November in Libra.

Jupiter is in a perfect position for observing this month, appearing high in the early north-western evening sky. On the 15th, the 10-day old waxing gibbous Moon appears 4° from the planet (see Sky View). Residing in Capricornus since August, the King of Planets appears stationary on the 18th as it comes to the end of four months of retrograde motion. It thereafter resumes its west to east motion across the sky and heads back towards Aquarius.

Like Jupiter, **Saturn** is in an ideal position in the early north-western evening sky for observation. The planet appears stationary on the 11th as it comes to the end of its 4.5-month retrograde loop, it thereafter resumes its west to east motion across the sky. On the 30th the planet is at a point in its orbit known as eastern quadrature, where the Sun-Earth-Saturn angle is 90° (see Orbital Aspects diagram p. 14). At this time as the Sun sets in the west, Saturn will be at its highest altitude in the sky. It is also a favourable time to view the maximum shadow of the planet's globe cast onto the rings, giving Saturn a 3-D appearance. On the 14th, the 9-day old waxing gibbous Moon appears around 4° from the planet (see Sky View).

With opposition early in November, **Uranus** rises in the eastern sky soon after sunset, situated in a barren part of Aries the Ram, near the head region of Cetus the sea monster (or near the tail of Cetus the whale). On the 12th the planet gets within 0.2° of 5.8 magnitude Omicron (o) Arietis.

Now past opposition, **Neptune** transits the meridian (is due north) around 10 pm mid-month in Aquarius.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

On the 17th, dwarf planet 136199 Eris is at opposition at 18.7 magnitude in Cetus. Brightest minor planets at opposition this month include:

Date	Minor Planet	Constellation	Mag.
1 Oct	40 Harmonia	Cetus	9.4
19 Oct	25 Phocaea	Pisces	10.1
21 Oct	129 Antigone	Cetus	11.9

COMETS

Comet 4P/Faye is visible in October's morning skies, rising in the late evening. Shining at 10th magnitude, the comet begins the month in Orion, moving into Gemini mid-month and crossing into Monoceros in the last few days. Late October sees Faye near Gamma (γ) Geminorum.

Comet 6P/d'Arrest is expected to fade from 10th to 11th magnitude by month's end, but still well placed to observe in the early evening. Beginning October in Sagittarius amongst the stars of the Teapot asterism, and visible throughout the evening, the comet remains in Sagittarius for all but the last few days of October, finishing the month in Microscopium. It makes a close visit to the globular cluster M55 on the evening of the 15th.

Comet 8P/Tuttle will likely fade from 10th to 11th magnitude in October. Rising an hour or two before astronomical twilight begins, Tuttle commences the month in Hydra, passing within 0.3° of Xi (ξ) Hydrae (mag 3.5) on the 17th before moving into Centaurus on the 24th.

Comet 67P/Churyumov-Gerasimenko is rising around midnight this month. Predicted to shine around 9th magnitude, the comet begins October in Taurus, moving into Gemini mid-month. On the morning of the 17th it makes a close approach to M35, the bright open cluster in Gemini (see diary). Late October sees the comet near Epsilon (ε) Geminorum.

DOUBLE STARS

107 Aquarii (H 2 24), All Sky Maps No. 2 and 8. Located within the constellation Aquarius, this month's double is a fine pair of pale yellow-white and bluish stars. William Herschel discovered this pair on 23 August 1780. The star is located in a group of fifth and sixth magnitude stars made up of 108, 107, 106, 103 and 104 Aquarii located 14° due west of Deneb Kaitos (β Ceti). The A component is magnitude 5.7 (spectral class A9IV) and the B component (spectral class F2V) is magnitude 6.5. The pair is separated by 7 arcseconds with a position angle of 136°. Since the measures of 1800 the pair has widened and the position angle has decreased. They are easily visible in 150 mm instruments and thought to form a long period binary.

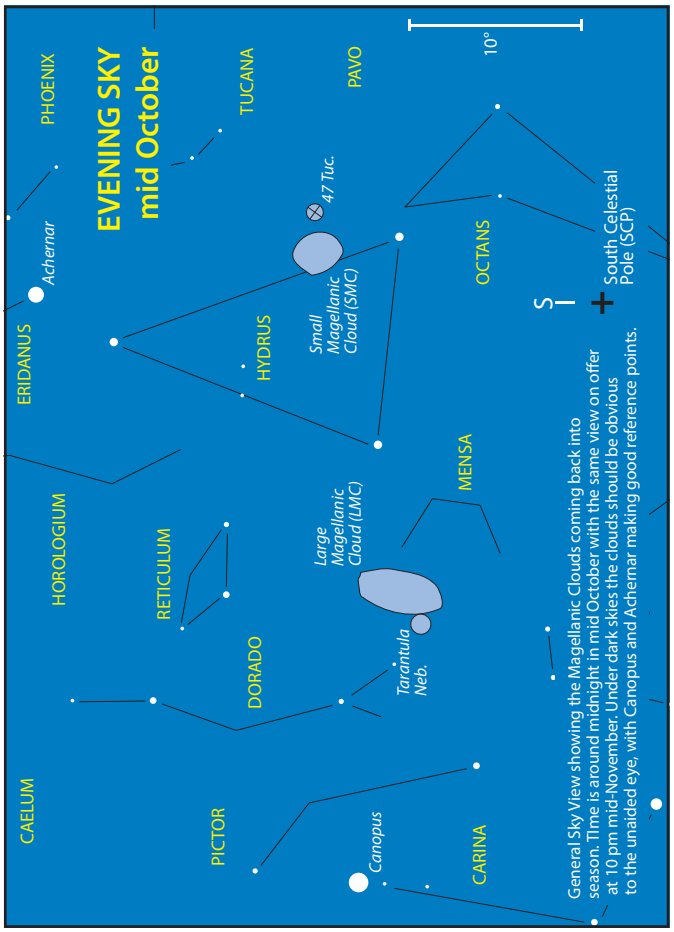
METEOR SHOWERS

The **Southern Taurids** are active from 10 September through to 20 November. The shower is composed of two radiants of nearly equal activity ten degrees apart. The Southern Taurids peak with about 5 meteors per hour around 10 October and the Northern Taurids next month on the 12th. The Taurids are frequently bright, slow moving, and noted for occasionally producing colourful fireballs. They are associated with Comet 2P/Encke and can be seen from late evening to early morning.

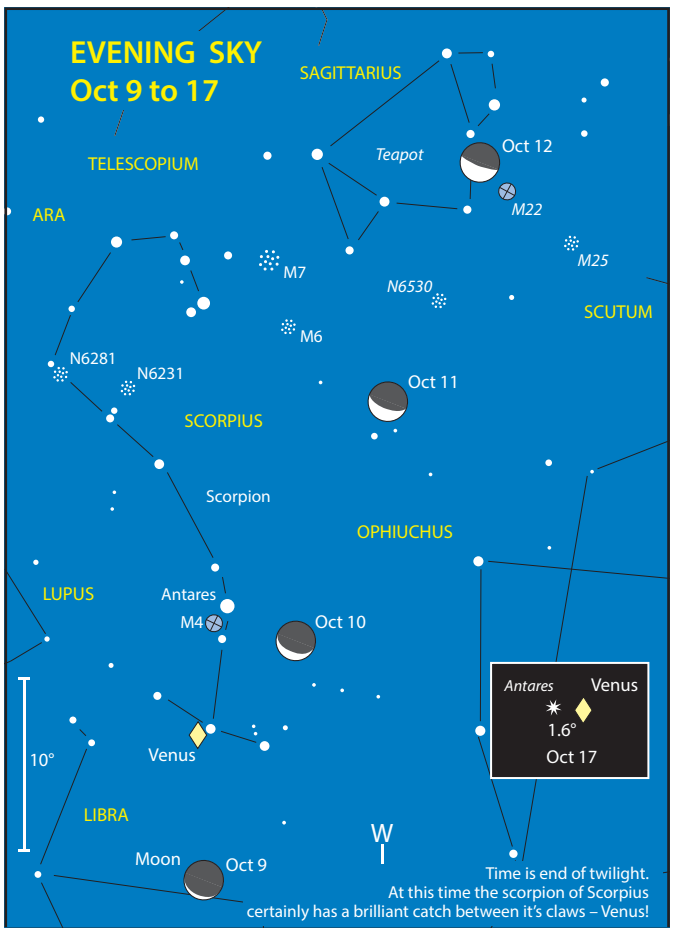
At their peak, the waxing crescent Moon sets late evening leaving the morning sky Moon free.

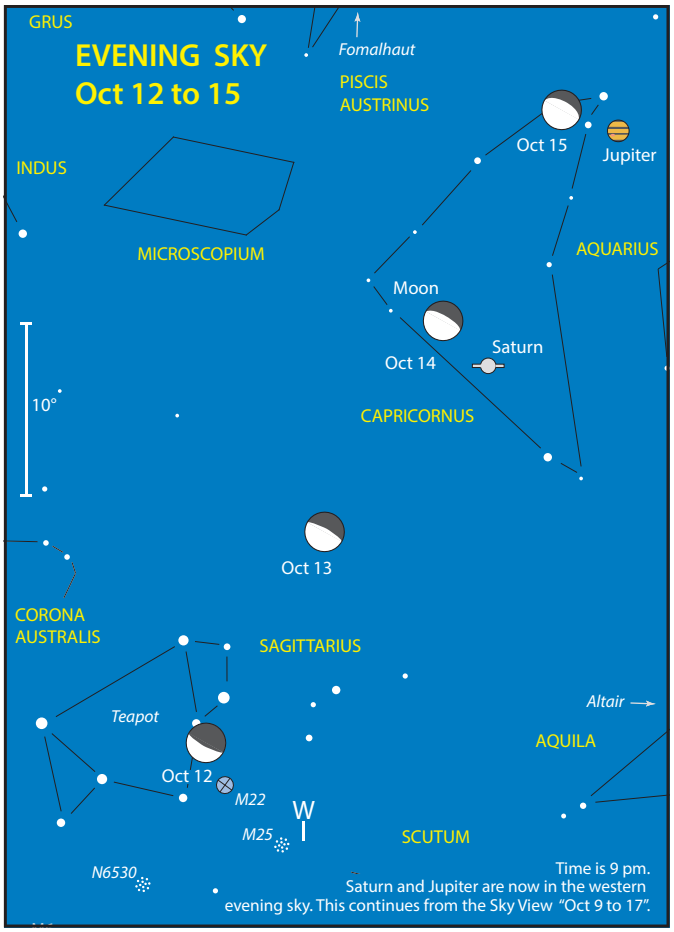
The **Orionids** are best seen from late evening until dawn and are visible from 2 October through to 7 November. Maximum activity is expected around the evening of the 21st through to the morning of the 22nd. Over the past twenty years or so the Orionids have produced rates of around 20 meteors per hour. With many sub-maxima, good rates can be observed on several consecutive nights around this date although the Full Moon on the 21st will hamper observation this year. The Orionids are typically very swift and often bright, with some leaving trains. The shower was first recorded by Chinese observers in 288 CE and is associated with Halley's Comet.



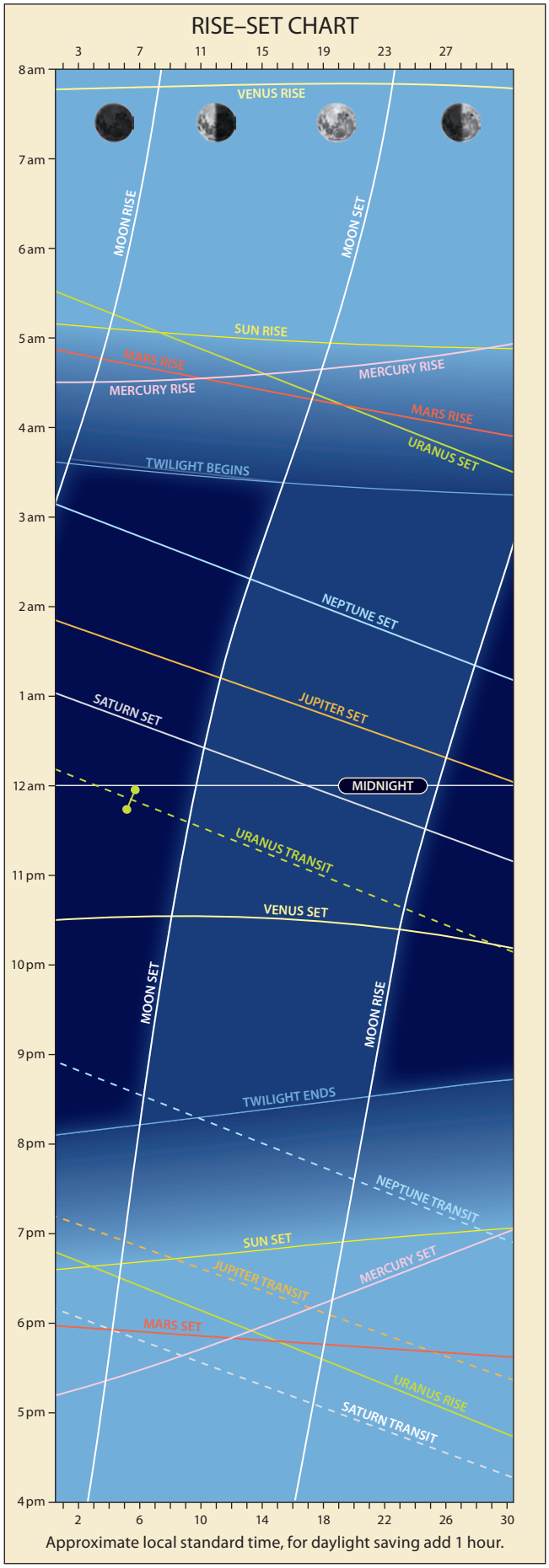


Approximate local standard time, for daylight saving add one hour.





NOVEMBER 2021



HIGHLIGHTS

- Venus and Moon close.
- Venus passes through the Teapot.
- Uranus at opposition.

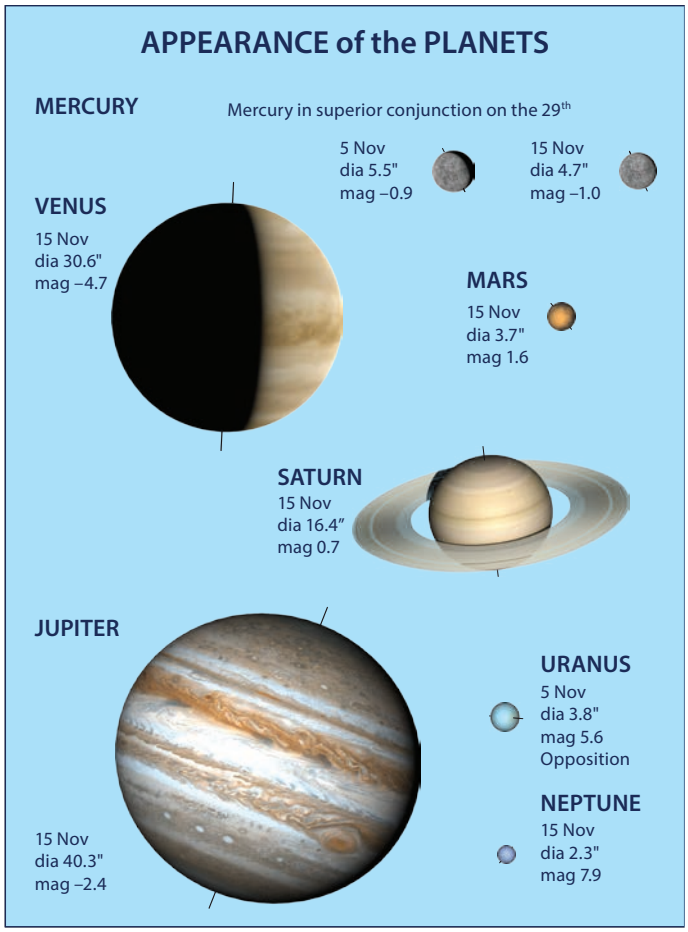
CONSTELLATIONS

At this time of year, early evenings are not suitable for observing the Milky Way, as it's very low in the sky. However, if you can get out into the country, away from hills and city lights, it is fascinating to see an almost uninterrupted ring of our galaxy hugging the horizon as you turn around.

The two Magellanic Clouds (see All Sky Map No. 1) are now conspicuous, appearing to the naked eye as detached sections of the Milky Way in an otherwise barren part of the far southern sky. Here we offer a taste of these magnificent companion galaxies to our own.

The Small Magellanic Cloud (SMC) in Tucana, culminates (is at its highest in the sky) around 9 pm mid-month. Binoculars show this irregularly shaped 4° diameter blob to consist of numerous knots of nebulous-like objects. A medium sized telescope reveals many of these objects are arrangements of small star clusters (mostly around 1 arcminute in diameter each). Their diminutive stature reflects the SMC's remoteness and a high magnification is recommended. To see individual cluster stars, you may need something larger (300 mm plus). One of its finest members is the cluster NGC 371 and its nebula, visible through binoculars as an obvious knot 1° north-east from the centre. A medium size telescope reveals its brightest stars.

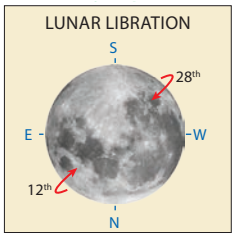
APPEARANCE of the PLANETS



Approximately 1° west of the SMC lies the spectacular globular cluster 47 Tucanae (NGC 104). At 4th magnitude it is certainly a naked-eye object and even binoculars will show you a bright, condensed centre in the same field as the 'cloud'. The view is brilliant in any size telescope but to resolve some stars you may need around a 150 mm instrument. Another impressive globular is NGC 362, near the northern side of the SMC. At 7th magnitude it is easily visible in binoculars but often overlooked for its neighbours the SMC and 47 Tucanae. The cluster is considerably smaller than its big brother, with a dense, but resolvable core in 150–200 mm instruments. Although adjacent to the SMC, 47 Tucanae and NGC 362 are not part of the Cloud but belong to the Milky Way.

The Large Magellanic Cloud (LMC), which straddles the Dorado/Mensa border, is iconic to the southern skies. Although long considered to be a dwarf irregular type (like the SMC) the LMC's most striking feature is a brilliant 4° long bar (common to barred spiral galaxies) easily visible to the naked eye. The smallest binoculars show a large bright knot above the eastern end of the bar—the magnificent Tarantula Nebula. Only a 100–150 mm telescope is needed to reveal this complex of nebulae and star clusters which extends for about 1° in diameter. A magnification of 100× shows detail in the loops radiating from the central body—the legs of the arachnid. A brilliant outlying object is NGC 2032, 1.5° north of the Tarantula. This is an emission nebula with a prominent dark lane easily seen in 150 mm.

A telescopic stroll down the LMC's bar reveals numerous open star clusters, nebulae and globulars, many around 1 arcminute in diameter. An impressive 'bar' object for 150 mm is the star cluster NGC 1910 with the two small clusters NGC 1903 and 1916 only 10 arcminutes away. The LMC extends well above and below the bar. There are dozens more clusters, nebula and background star fields which shape it into a rough 6° diameter circle. Enjoy these splendours of the deep sky.



THE MOON

5th 7 am (5 am WST) New Moon.

6th 8 am (6 am WST) Moon at perigee (closest to Earth at 358,844 km).

11th 11 pm (9 pm WST) First Quarter.

12th 11 pm (9 pm WST) Maximum Libration (10.0°), bright NE limb.

19th 7 pm (5 pm WST) Full Moon.

21st Noon (10 am WST) Moon at apogee (furthest from Earth at 406,279 km).

27th 10 pm (8 pm) Last Quarter.

28th 4 am (2 am WST) Maximum Libration (10.1°), bright SW limb. Libration features on limb washed out due to lunar phase, although many craters near the south pole will be seen to good advantage.

THE PLANETS

Mercury is virtually unobservable this month. At best, the planet is just a few degrees above the eastern dawn horizon in early November (see Sky View), sinking back toward the Sun and superior conjunction (Earth and Mercury on opposite sides of the Sun) on the 29th.

Venus spends the month in Sagittarius, beginning near the galactic centre, then cruising through the region of the Teapot asterism (see Sky View). On the 8th, the planet will be 2° from the 4-day old waxing crescent Moon, an impressive sight in the early western evening sky (see Sky View).

Having been lost in the Sun's glare since conjunction early October, **Mars** finally reappears a few degrees above the horizon at the end of the month, still well in the dawn glare.

DIARY			
Mon	1st		m.p. 2 Pallas stationary
Mon	1st		m.p. 3 Juno 0.2° SW of star Omicron Serpentis
Wed	3rd	pm	d.p. 1 Ceres 0.1° S of star Aldebaran
Thu	4th		Uranus at opposition
Fri	5th	7 am	(5 am WST) New Moon
Fri	5th	pm	m.p. 349 Dembowska 0.4° SE of star Zeta Capricorni
Sat	6th		Comet 67P/Churyumov-Gerasimenko 0.4° S of star Upsilon Geminorum
Sat	6th	8 am	(6 am WST) Moon at perigee (358,844 km)
Sat	6th	8 pm	(6 pm WST) star Antares 7° SE of Moon
Sun	7th		Venus 0.6° N of NGC 6540 (GC) in Sagittarius
Mon	8th	pm	Venus 2° SW of Moon
Tue	9th		Comet 67P/Churyumov-Gerasimenko 1.5° S of star Pollux
Wed	10th	10 pm	(8 pm WST) Saturn 5° NE of Moon
Thu	11th	3 am	(1 am WST) Comet 67P/Churyumov-Gerasimenko 0.1° S of star Phi Geminorum
Thu	11th	10 pm	(8 pm WST) Jupiter 6° NE of Moon
Thu	11th	11 pm	(9 pm WST) First Quarter Moon
Fri	12th		Venus 1.7° S of star Lambda Sagittarii
Fri	12th	11 pm	(9 pm WST) Maximum Libration (10.0°), bright NE limb
Fri	12th	pm	d.p. 1 Ceres 0.5° N of star Theta[1] Tauri
Sat	13th	am	Northern Taurids meteor shower, Oct 20 to Dec 10.
Sun	14th	1 am	(11 pm WST, prev day) Neptune 5° NE of Moon
Wed	17th		Venus 0.3° NE of star Phi Sagittarii
Wed	17th	pm	Comet 19P/ Borrelly 0.3° NE of star Iota Gruis
Wed	17th	pm	d.p. 1 Ceres 0.9° S of star Delta[2] Tauri
Thu	18th		Comet 8P/Tuttle 1.5° NE of Omega Centauri (GC) in Centaurus
Thu	18th	am	Leonids meteor shower, Nov 6–30, near Full Moon affected.
Thu	18th	8 pm	(6 pm WST) Uranus 4° W of Moon
Fri	19th		Venus 0.4° SW of star Sigma Sagittarii
Fri	19th	7 pm	(5 pm WST) Full Moon (405,300 km)
Sat	20th	10 pm	(8 pm WST) star Aldebaran 7° S of Moon
Sun	21st	am	m.p. 22 Kalliope 0.8° W of star Tau Geminorum
Sun	21st	Noon	(10 am WST) Moon at apogee (406,279 km)
Mon	22nd		Mars 0.4° W of star Alpha Librae
Mon	22nd		Mercury at descending node
Mon	22nd	am	alpha-Monocerotids meteor shower, Nov 15–25, Moon affected.
Mon	22nd	9 pm	(7 pm WST) Comet 19P/ Borrelly 0.05° SE of NGC 7552 (G) in Grus
Mon	22nd	pm	d.p. 1 Ceres 1.0° N of star Gamma Tauri
Tue	23rd	9 pm	(7 pm WST) Comet 19P/ Borrelly 0.3° NW of NGC 7582 (G) in Grus
Wed	24th	2 am	(Midn. WST, prev day) star Pollux 6° E of Moon
Sat	27th	3 am	(1 am WST) star Regulus 7° SE of Moon
Sat	27th		d.p. 1 Ceres at opposition
Sat	27th	10 pm	(8 pm WST) Last Quarter Moon
Sun	28th		m.p. 3 Juno 0.2° SW of M16 Eagle Nebula (BN) in Serpens
Sun	28th	4 am	(2 am WST) Maximum Libration (10.1°), bright SW limb
Sun	28th		m.p. 4 Vesta in conjunction with Sun
Mon	29th		Mercury in superior conjunction

Jupiter, in Capricornus, is high in the north-western evening sky at the end of twilight. On the 11th, the First Quarter Moon appears near Jupiter, not the closest of conjunctions but it's always pleasant to see a bright planet near the Moon (see Sky View). Toward the end of the month, Jupiter, Saturn and Venus all appear in a straight line and dominating the early western sky.

Saturn is visible in the early western evening sky in Capricornus. With the planet at quadrature (see Saturn, last month) the maximum extent of the shadow of the planet's globe is cast onto its magnificent rings. When viewing this world, it's interesting to reflect on Galileo's first observations of Saturn when he noted it was flanked by two star-like protrusions. Telescopes have certainly come a long way and changed our view and understanding of the Universe. On the 10th, the 6-day old waxing crescent Moon appears near the planet (see Sky View).

Uranus is at opposition on the 5th, rising in the early evening eastern sky in Aries and visible the entire night. With an apparent diameter a little less than four arcseconds you will need a telescope and high magnification to resolve the planet into a disc. Through the telescope, at 5.6 magnitude Uranus shows no distinguishable atmospheric features, but observers will immediately note its blue/green colour.

Neptune appears high in the early north-western evening sky in Aquarius at the end of astronomical dusk.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet Ceres, near opposition, passes through the Hyades star cluster (the face of the bull of Taurus) this month.

Brightest minor planets at opposition this month include:

Date	Minor Planet	Constellation	Mag.
15 Nov	185 Eunike	Eridanus	11.4
26 Nov	85 Io	Taurus	11.3

Swans in Heaven

Occasionally when attending star parties, away from the glow of city lights, it is not unusual to hear a visitor remark, "I've been watching those clouds for a long time and they don't seem to be moving." Someone may chime in with, "and they're white, where out here clouds are black." There is nothing atmospheric here, they are seeing the Large and Small Magellanic Clouds (LMC and SMC), two satellite galaxies to our Milky Way, located in the constellations of Dorado (the Goldfish) and Tucana (the Toucan) respectfully in the far southern sky. Lying about 20° from the South Celestial Pole (SCP), early navigators valued the clouds for they helped them find the pole. The SMC, LMC and the SCP form a near equilateral triangle (see All Sky Map No. 1). This is a good tip for someone trying to find an approximate position for the SCP when setting up their telescope, if they are fortunate to be away from city lights. This assumes your onboard computer with all the bells and whistles isn't already busy using GPS to locate your position on Earth, setting the clock and prompting for a two-star alignment (but does it also make a good coffee?)

The November *Constellations* gives an overview of some of the objects to view in the clouds and there is a lot to see. The LMC is the largest satellite galaxy to the Milky Way with over 1,000 non-stellar objects recorded, with 200 in the New General Catalogue (NGC) alone!

The *Clouds* are classified as irregular dwarf galaxies, so don't show the obvious 'pin-wheel' appearance of the more classical spirals or even the spherical symmetry of the ellipticals. It is interesting they both show a bar-like structure, with the LMC's clearly visible to the unaided eye.

They are called the Clouds of Magellan because they first entered the literature of astronomy when Pigafello, Magellan's associate and historian, described the clouds during the course of that first round the world trip of 1518–1520. They were called 'Cape Clouds' by the 15th century Portuguese navigators, who saw them in the southern sky as their ships approached the Cape of Good Hope. The captains of these ships reported to Prince Henry of two clouds looking like 'Swans in Heaven'. Man's fascination with the *Clouds* dates back to before recorded history, the indigenous people of Africa and South America knew them. They also starred in the legends of the Australian Aborigines, one version proclaiming them as the souls of two sisters lost in the 'dreaming' when the world was made.

The *Clouds* are not visible from most of the Northern Hemisphere and their uniqueness has certainly contributed to the growth of major observatories in the Southern Hemisphere in recent years. The LMC and SMC are located approximately 165,000 and 200,000 light-years respectively from the Sun. For beings with a life span of less than 100 years it is staggering to think that the light from the supernova, found in the LMC in 1987, had to travel for so long before we could see it. That such a distant object could be clearly visible to the unaided eye just reinforces the incredible brilliance of such a cataclysmic event (see also the supernovae articles in February and April.).

The LMC and SMC are 14,000 and 7,000 light-years in diameter respectively where the Milky Way is around 120,000 light-years. To further put this in perspective, the LMC lies only about six times the distance from us as we lie from the centre of our galaxy. Given the sizes and closeness of the three galaxies it was postulated in the early 20th century that there was likely to be gravitational tidal disruptions between them. This was verified in the 1950s with the first visual evidence of luminous streams emanating from the clouds. Radio astronomy finally confirmed a bridge of hydrogen gas linking the two, discovered by the newly commissioned Parkes Radio Telescope. The early 1970s brought another significant find. Northern Hemisphere astronomers had for a number of years known of a filament of neutral hydrogen gas stretching across 60° of sky. Observations from Parkes extended this to a total of 100° in length linking the Milky Way to the clouds—called the Magellanic Stream. There is still a mystery here, although we have seen many examples of interacting galaxies with their distorted arms consisting of gas and stars, no stars have been found in the main

COMETS

Comet 4P/Faye is in Monoceros, where it remains for the rest of the year. Rising in the mid-evening, the comet is expected to fade from 10th to 11th magnitude by month's end.

Comet 19P/Borrelly is predicted to brighten from 11th to 9th magnitude this month. Residing in Grus, the comet is visible as evening twilight ends until just before dawn. On the evenings of the 22nd and 23rd, Borrelly has a close encounter with the Grus Quartet of Galaxies—great for observers or imagers!

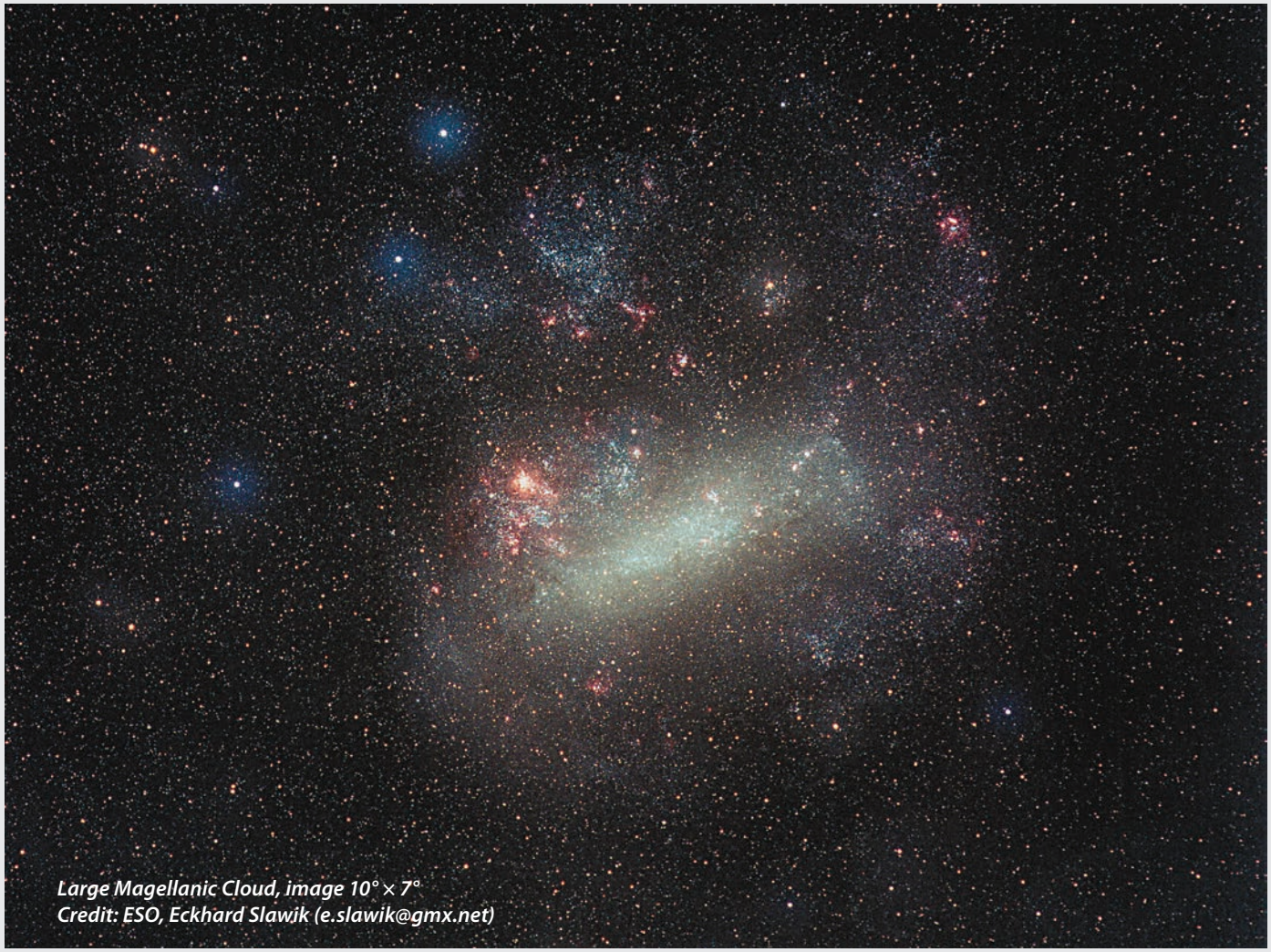
Comet 67P/Churyumov-Gerasimenko, reaching perihelion in early November, is expected to hover around 9th magnitude in the morning skies. Beginning in Gemini, the comet moves into Cancer mid-month where it resides for the remainder of the year. Early November sees the comet near Pollux.

DOUBLE STARS

Beta (β) Tucanae (LCL 119), All Sky Map No. 1. Observing near Cape Town, South Africa, between 1751 and 1752, Nicolas-Louis de Lacaille noted this bright double star. Amazingly, he observed using only a 12.5 mm (0.5 inch) aperture telescope with a magnification of 8× and a field width of almost 3°. Lacaille's observations led to the first systematic southern star catalogue. The field comprises the bright pair β^1 and β^2, and a third bright star β^3, located about 9 arcminutes east south-east. β^1/β^2 and β^3 form a naked-eye pair. The β^1 and β^2 (LCL 119) pair is ideal for a small telescope or a pair of binoculars. The A component is magnitude 4.3 and the B component is magnitude 4.5. The pair is separated by 27 arcseconds with a position angle of 168°. The stars seem to be at the same distance and appear to be part of a number of moving young stars that form the Tucana-Horologium association.

bridge extending from the Milky Way. However, there is no doubt stars exist in the stream between the clouds. Another discovery, likely related to these interactions, is the SMC has been severely disrupted along the axis pointing away from us. So, it could extend back considerably further than the size we see presented in the heavens.

The nearest visual rival, in the extragalactic stakes, to the *Clouds*, is the Andromeda Galaxy which is low in the north during spring and summer Aussie evenings. It is a full-size spiral galaxy, possibly larger than the Milky Way. Andromeda is considerably larger than these dwarf clouds, but much more distant (2.5 million light-years) hence appearing smaller and fainter. As much detail can be seen in the LMC through amateur telescope, as can be viewed in Andromeda through many professional telescopes (not that professionals would be using an eyepiece). It has been stated that if the Clouds of Magellan were visible from the Northern Hemisphere our knowledge of the evolution of stars would have advanced more rapidly during the 20th century.



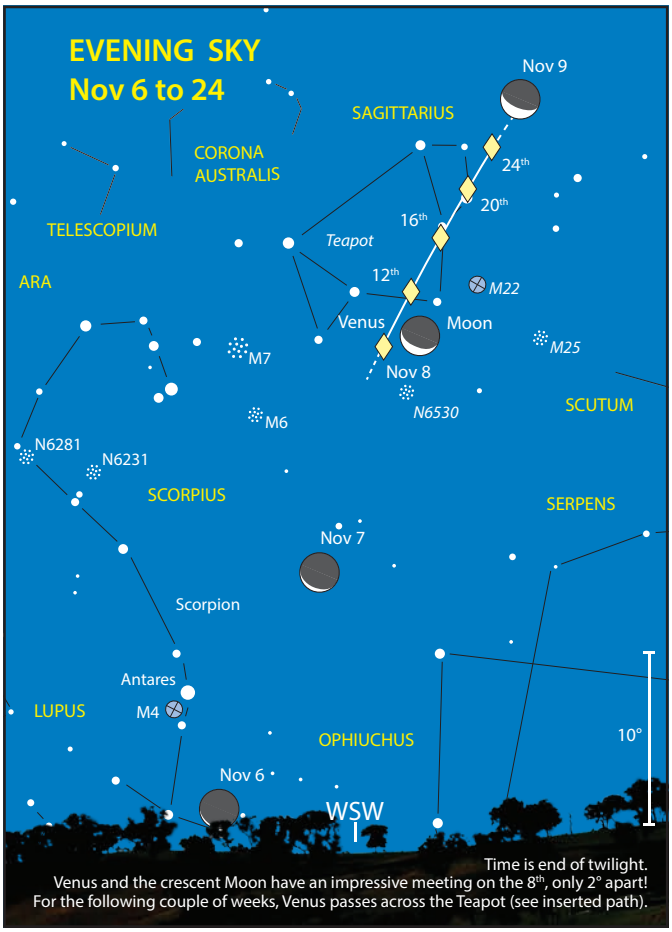
Large Magellanic Cloud, image 10° × 7°
Credit: ESO, Eckhard Slawik (e.slawik@gmx.net)

METEOR SHOWERS

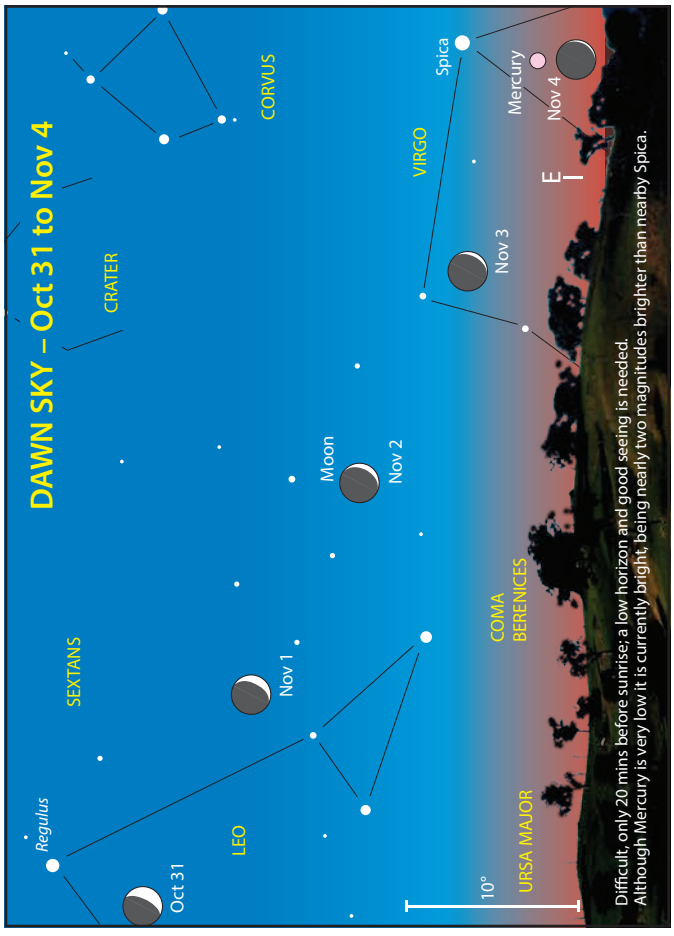
The **Northern Taurids** are active from 20 October to 10 December, with their peak around 12 November. Taurids are frequently bright, slow moving, and noted for producing colourful fireballs (although not in every year). They are associated with Comet 2P/Encke and can be seen from late evening to early morning. The waxing crescent Moon will impair viewing during peak until it sets a little after midnight.

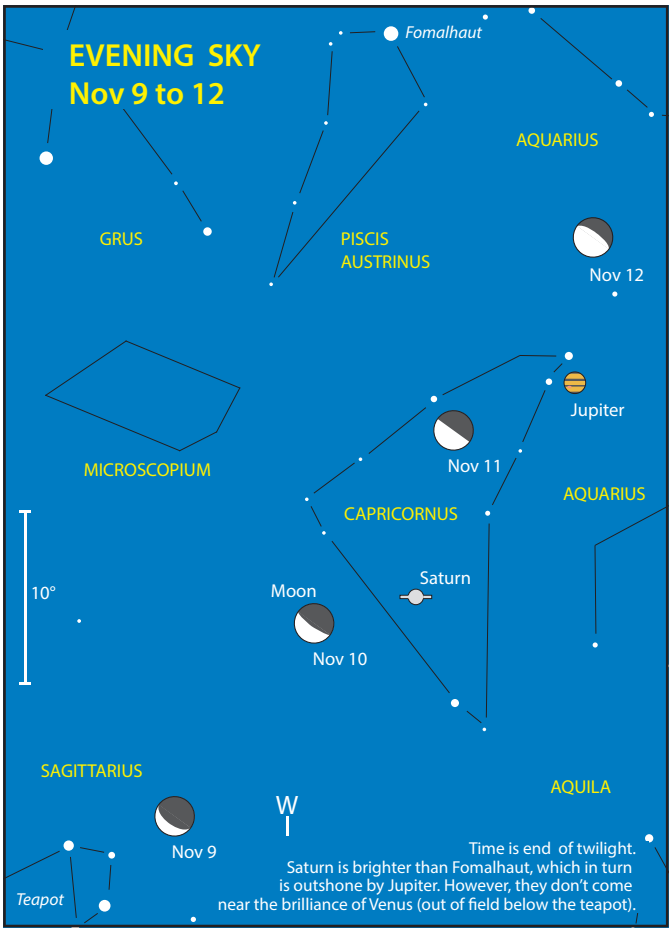
The **Leonids** is one of the better-known showers. It is associated with the periodic comet 55P/Tempel-Tuttle and is best about every 33 years when the comet returns to perihelion (last in 2001). The Leonids are active from the 6th to 30th, with a maximum peak of around 15 meteors per hour predicted for the morning of the 18th. Since Leo rises after midnight there will only be a few hours available before the onset of dawn for observation. During the peak, the near Full Moon will make it difficult for all but the brightest Leonids to be visible.

The **alpha-Monocerotids** are a minor shower, with unusual short-lived outbursts. Active from 15th to 25th, they are expected to peak around the 21st and are best seen after midnight. While the zenith hourly rate is variable, very high rates have been recorded occasionally over the years. Like the Leonids, the Moon will be an issue during the peak this year.

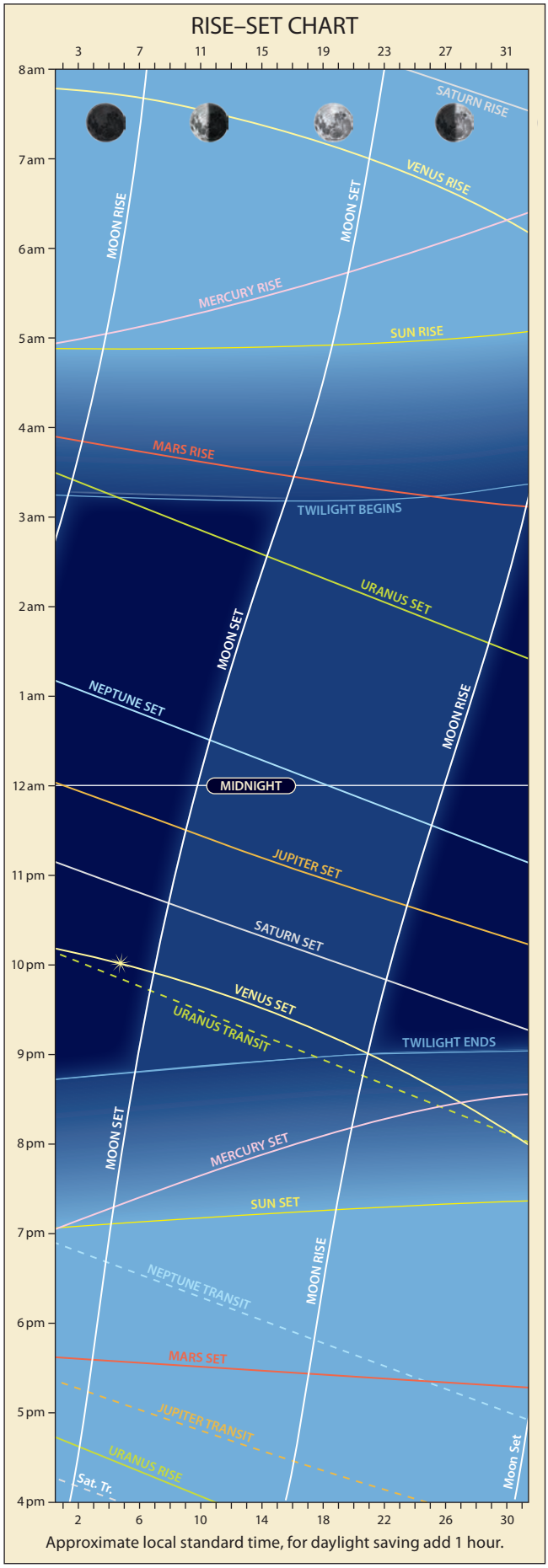


Approximate local standard time, for daylight saving add one hour.





DECEMBER 2021



Approximate local standard time, for daylight saving add 1 hour.

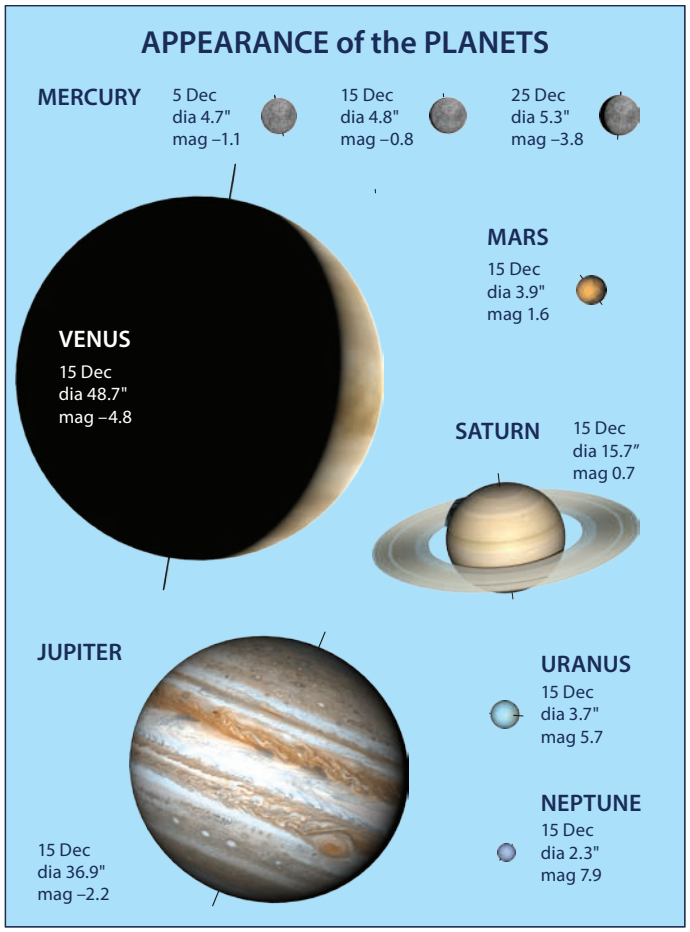
HIGHLIGHTS

- Four bright planets in the western evening sky.
- Venus at greatest brilliancy.
- Mars occulted by the Moon.
- Jupiter near the Moon.
- Crescent Moon visits three planets.
- Mercury near Venus.

CONSTELLATIONS

As discussed in November's constellations, the Milky Way is not easy to observe in the early evening skies at this time of year. Look up to view the southern half of the Universe. What appears to the unaided eye as a featureless sky with a few bright stars is the home of many galaxies and some globular star clusters. Although galaxies exist in all directions it is difficult to see past the bulk of our galaxy as you look close to the plane of the Milky Way. Globular star clusters exist in a more spherical shell around our galaxy, so can pop up anywhere. What is not found in this expanse are open star clusters and nebulae which are mostly in the plane of the Milky Way, as the previous month's 'Constellations' have illustrated well.

Two prominent members of this 'southern' Universe are located in the constellation of Pavo (All Sky Map No. 1). Unfortunately, they are a little out of season by December and are better suited for Winter/Spring months. Low in the south-west is its alpha star, 2nd magnitude Peacock. Approximately 10° to the lower left is the impressive globular cluster NGC 6752. Being around 0.5° in diameter it looks good through binoculars or telescopes. A 150 mm telescope resolves



the brightest stars, which are arranged in various patterns, appearing to overlay the haze of the cluster. It has an obvious bright centre a few arcminutes in diameter. Here's a binocular challenge. Within the same field (4° S of the globular) is the large face-on barred spiral galaxy NGC 6744. Being spread over nearly 0.5° of sky and having a faint surface brightness, it can be tricky to spot. Telescopically, the best views are generally seen using reasonable apertures with wide fields. The elongated core is the most obvious feature.

When looking for bright galaxies, our local group is the place to start. Putting aside the Magellanic Clouds (which were covered last month), our Milky Way's big brother, M31, the Andromeda Galaxy in Andromeda is low in the north and visible to the naked eye (All Sky Map No. 3). Being over 2° in size, it's an ideal binocular object which shows its edge-on nature with a bright central disc fading into the surrounding halo. Small telescopes easily show its two companion galaxies, M32 (0.4° south of the core) and M110 (0.6° north-west).

Another binocular target is local group member, M33, the Pinwheel Galaxy in Triangulum (only 14° to the upper right of M31). It is a bright (6th magnitude), but large, face-on spiral galaxy. Being around 1° in diameter it has a low surface

Cover Image — Cosmic Reef

Our front cover this year is from the Hubble telescope. The image shows how young, energetic, massive stars illuminate and shape their region with strong winds and intense ultraviolet radiation. Here we have the giant red nebula (NGC 2014) and its smaller blue companion (NGC 2020) that are part of a vast star-forming region in the Large Magellanic Cloud. The image is nicknamed the Cosmic Reef, because the nebulae resemble an undersea world.

The centrepiece of NGC 2014 is a grouping of bright, hefty stars, each 10 to 20 times more massive than our Sun. The stars' ultraviolet radiation heats the surrounding dense gas. The massive stars also unleash fierce winds of charged particles that blast away lower-density gas, forming the bubble-like structures seen at the top. The stars' powerful stellar winds are pushing gas and dust to the denser bottom side of the nebula, where it is piling up, creating a series of dark ridges bathed in starlight. The blue areas in NGC 2014 reveal the glow of oxygen, heated to around 11,000° C by the blast of ultraviolet light. The cooler, red gas indicates the presence of hydrogen and nitrogen.

By contrast, the seemingly isolated blue nebula at lower right (NGC 2020) has been created by a solitary mammoth star 200,000 times brighter than our Sun. The blue gas was ejected by the star through a series of eruptive events during which it lost part of its outer envelope of material.

The image, taken by Hubble's Wide Field Camera 3, commemorates the Earth-orbiting observatory's 30 years in space. Image credit NASA, ESA, and STScI



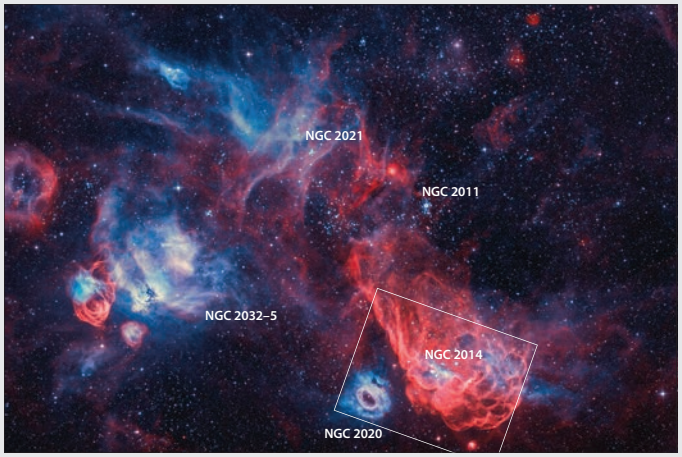


Image above: NGC 2020-2021-2032 (Martin Pugh) with cover rectangle shown.

Lower left, ground-based image of the LMC Credit: Eckhard Slawik (e.slawik@gmx.net). Cover and image above marked.

Image below, cover image.

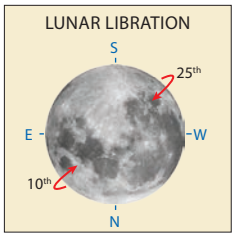


brightness and suits wide field instruments like binoculars. It's easy to locate the area which is only 4° west (right) of 3rd magnitude Alpha Trianguli, Mothallah (also All Sky Map No. 3).

Moving beyond the local group, there is a bright galaxy NGC 253, the Silver Dollar in Sculptor (All Sky Map No. 2). Belonging to the Sculptor Galaxy Group, it is still relatively close at only 10 million light-years. It is an 8th magnitude edge-on spiral and being 0.3° long, a good binocular target. A medium size telescope (150 mm) shows the surface mottled. Only 1.7° south-east of the galaxy, lies a gem of a globular cluster, NGC 288. A 150 mm telescope shows a smattering of 12th magnitude stars across an evenly dispersed, bright, broad nucleus. At 8th magnitude the globular may be visible in the same binocular field as NGC 253.

There are many galaxies and a few globular clusters spread across this region. A lot of the brighter ones are listed in the Deep Sky Objects list (pages 143–5). Many need at least medium size telescopes (200 mm plus) to see reasonably well. The majority showing photographic spiral arms and star cluster regions often require at least 300 mm instruments to glimpse these regions, However, don't underestimate what can be caught in binoculars provided the skies are dark enough—try just looking around!

THE MOON



4th 6 pm (4 pm WST) New Moon.

4th 8 pm (6 pm WST) Moon at perigee (closest to Earth at 356,794 km).

10th 5 pm (3 pm WST) Maximum Libration (10.4°), bright NE limb. At this libration, features in the zone of librations will be washed out along the limb due to the absence of shadow relief. The effects of libration are most readily observed by watching the position of Mare Crisium over the course of a lunar month. This prominent feature will be seen to drift back and forth toward the limb as the Moon nods and wobbles in its orbit. On this day Mare Crisium will be as far from the limb as it can possibly be.

11th Noon (10 am WST) First Quarter.

18th Noon (10 am WST) Moon at apogee (furthest from Earth at 406,320 km).

19th 3 pm (1 pm WST) Full Moon.

25th 8 pm (6 pm WST) Maximum Libration (9.6°), bright SW limb. Libration features on limb washed out due to lunar phase, although many craters near the south pole will be seen to good advantage.

27th Noon (10 am WST) Last Quarter.

THE PLANETS

Mercury returns to the western evening twilight and best seen late in the month sharing the sky with Venus, Saturn and Jupiter. On the 27th the duo of Mercury and Venus will be parallel to the horizon and best viewed about 30 minutes after sunset. They appear at their closest on the 29th at 4.2° apart (see Sky View).

After eight months as the Evening Star, **Venus** rapidly descends back toward the Sun. By month's end it will be lost in the Sun's glare as it nears inferior conjunction early in January. Venus reaches its greatest brilliancy on the 4th at –4.7 magnitude—known as *greatest illuminated extent*. It is defined as when the planet's illuminated portion or day side covers the greatest amount of sky. At this time, we see Venus one-quarter illuminated, just like a 3 or 4-day old Moon. On the 7th the 4-day old waxing crescent Moon appears about 5° above the planet. The Moon then goes on to visit Saturn on the 8th and Jupiter on the 9th (see Sky View).

DIARY			
Wed	1st	3 am	(1 am WST) star Spica 8° S of Moon
Thu	2nd		Mercury at aphelion
Thu	2nd	8 am	(6 am WST) Neptune stationary
Thu	2nd	pm	Phoenicids meteor shower, Nov 28 to Dec 9.
Fri	3rd	4 am	(2 am WST) Mars 4° SE of Moon
Sat	4th		Comet 19P/ Borrelly 0.7° W of IC 5332 (G) in Sculptor
Sat	4th	6 pm	(4 pm WST) New Moon
Sat	4th	8 pm	(6 pm WST) Moon at perigee (356,794 km)
Sat	4th	9 pm	(7 pm WST) Comet 6P/d'Arrest 0.3° N of star Epsilon Piscis Austrini
Tue	7th	pm	Venus 5° W of Moon
Wed	8th	am	Puppid-Velids meteor shower, Dec 1–15
Wed	8th	9 pm	(7 pm WST) Saturn 5° NW of Moon
Thu	9th	9 pm	(7 pm WST) Jupiter 4° NW of Moon
Fri	10th	5 pm	(3 pm WST) Maximum Libration (10.4°), bright NE limb
Fri	10th	10 pm	(8 pm WST) Neptune 10° NE of Moon
Fri	10th	Midn.	(10 pm WST) m.p. 2 Pallas 0.5° S of Moon
Fri	10th	pm	m.p. 44 Nysa 0.7° N of NGC 1817 (OC) in Taurus
Sat	11th		m.p. 80 Sappho 1.0° NE of m.p. 43 Ariadne
Sat	11th	Noon	(10 am WST) First Quarter Moon
Sat	11th	pm	m.p. 44 Nysa 0.9° N of NGC 1807 (OC) in Taurus
Tue	14th	am	Geminids meteor shower, Dec 4–20.
Wed	15th	9 pm	(7 pm WST) Uranus 2° W of Moon
Fri	17th		Comet 104P/Kowal 2 0.8° NW of NGC 7606 (G) in Aquarius
Fri	17th	Midn.	(10 pm WST) star Aldebaran 7° SE of Moon
Sat	18th		Mars 1.0° SW of star Beta Scorpii
Sat	18th	am	m.p. 22 Kalliope 0.5° SW of star Theta Geminorum
Sat	18th	Noon	(10 am WST) Moon at apogee (406,320 km)
Sat	18th	9 pm	(7 pm WST) Venus stationary
Sat	18th	10 pm	(8 pm WST) m.p. 25 Phocaea 0.07° E of star f Piscium
Sun	19th		Mars 0.3° SW of star Omega[1] Scorpii
Sun	19th		Mars at descending node
Sun	19th	3 pm	(1 pm WST) Full Moon (405,935 km, furthest for this year)
Mon	20th		Venus at ascending node
Tue	21st	10 pm	(8 pm WST) m.p. 25 Phocaea 0.1° N of NGC 474 (G) in Pisces
Wed	22nd	1 am	(11 pm WST, prev day) star Pollux 3° NW of Moon
Wed	22nd		Solstice
Thu	23rd		Mercury at greatest latitude south
Sat	25th	3 am	(1 am WST) star Regulus 7° SW of Moon
Sat	25th	8 pm	(6 pm WST) Maximum Libration (9.6°), bright SW limb
Mon	27th	4 am	(2 am WST) star Antares 5° S of Mars
Mon	27th	Noon	(10 am WST) Last Quarter Moon
Mon	27th	pm	Comet 4P/Faye 0.4° S of NGC 2254 (OC) in Monoceros
Mon	27th	pm	m.p. 25 Phocaea 0.4° S of NGC 520 (G) in Pisces
Wed	29th		Comet 6P/d'Arrest 5.3° W of Comet 19P/Borrelly
Wed	29th	2 am	(Midn. WST, prev day) star Spica 7° SW of Moon
Wed	29th	8 pm	(6 pm WST) Venus 4° N of Mercury
Fri	31st		Uranus 0.4° S of star 29 Arietas

The **Earth** is at Solstice on the 22nd when the days are longest. On this day, the Sun is at its most southerly position with a declination of –23.5°.

Mars is visible in the eastern dawn sky in Libra during the first half of the month. It then crosses the claw region of Scorpius and lastly into Ophiuchus. On the 3rd, the planet will be 4° to the south of the slender crescent of the waning 28-day old Moon— binoculars and a good eastern horizon will help you see it in the dawn sky (see Sky View). On 1 January 2022 in the early morning hours, Mars will be occulted by the 27-day old waning crescent Moon (see Sky View). The area of visibility of the occultation will be roughly anywhere south of a line drawn from Canberra to Adelaide, including all of Tasmania (see Lunar Occultations pp. 113–16 for times). From other areas, if the Moon has risen, Mars will appear very close to the northern cusp of the Moon. For example, from Sydney, the planet will be just a few arcminutes from the Moon at 4:36 am. There will be some interference from the brightening dawn sky.

In the western evening sky **Jupiter** stands out at the end of twilight, the only bright star nearby being 1st magnitude Fomalhaut in Piscis Austrinus. If you want to view the planet through a telescope, you should do so early in the month before it loses too much altitude. Jupiter's brightness has decreased a little over half a magnitude since its opposition last August. Its equatorial diameter has also diminished by 32% to 37 arcseconds (49 at opposition). On the 9th, the 6-day old waxing crescent Moon will be 4° from the planet (see Sky View).

Saturn is visible low in the western evening sky, setting around 10 pm mid-month. Although a little too low for meaningful telescopic observations of the planet, the waxing crescent Moon provides a pleasant visual display at the end of twilight. First, on the 7th the Moon will be seen near Venus, then on the following evening near Saturn and finally on the 9th near Jupiter. With each visit the Moon appears within 5° of the planet.

Uranus, now past opposition, is in the northern evening sky at the end of astronomical twilight in Aries, transiting the meridian around 9 pm mid-month.

Neptune comes to the end of five months in retrograde on the 2nd and appears high in the early north-western evening sky at the end of astronomical dusk.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Brightest minor planets at opposition this month include:

Date	Minor Planet	Constellation	Mag.
9 Dec	42 Isis	Taurus	10.7
10 Dec	44 Nysa	Taurus	9.0
17 Dec	270 Anahita	Taurus	11.2
20 Dec	17 Thetis	Orion	11.5
24 Dec	32 Pomona	Orion	11.1
29 Dec	22 Kalliope	Auriga	10.1

COMETS

Comet 19P/Borrelly may brighten from 9th to 8th magnitude by month's end. Beginning December in Sculptor, the comet moves into Cetus late in the month. Visible as evening twilight ends, the comet will be setting around midnight by the end of the year.

Comet 67P/Churyumov-Gerasimenko is rising in the late evening and well placed to observe in December's morning skies. Predicted to fade from 9th to 10th magnitude, the comet moves slowly through Cancer throughout the month.

Comet 104P/Kowal 2 is predicted to brighten from 11th to 10th magnitude this month. Visible in the early evening hours, the comet is in Aquarius for all but the last two days of December, when it then moves into Pisces.

DOUBLE STARS

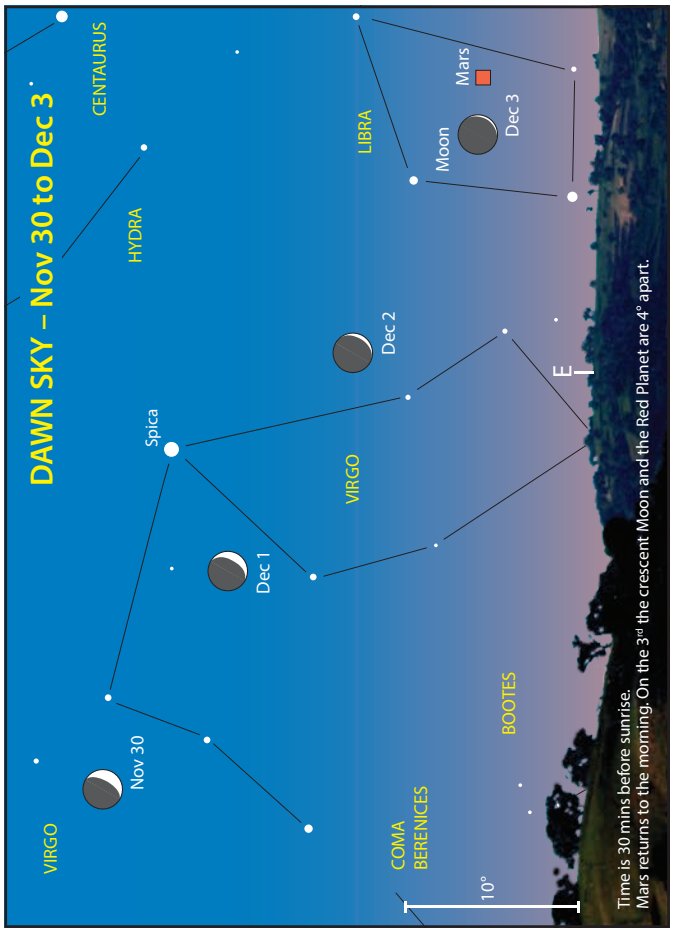
Pi (π) Arietis (STF 311, 42 Ari). All Sky Map No. 3. Located 780 light-years away is this delightful, very unequal triple comprising A, B and C components set within a lovely star field. The yellowish-white A component is magnitude 5.3, the bluish B component is magnitude 8.0 and the faint C component is 10.7. The A and B components are separated by 3.3 arcseconds with a position angle of 118°. The A and C components are separated by 26 arcseconds with a position angle of 113°. There has been little change since the measurements made in 1821. The best views are seen with telescopes with at least 100 mm of aperture using high magnification. The A component has another companion discovered during a lunar occultation. It is also a spectroscopic binary with a period of 3.85 days. Thus there are at least four stars in this system. Only 13 arcminutes west north-west is the lovely red star, T Ari and to the east is a diamond shaped group of four stars. Also nearby is the small open cluster DoDz 1.

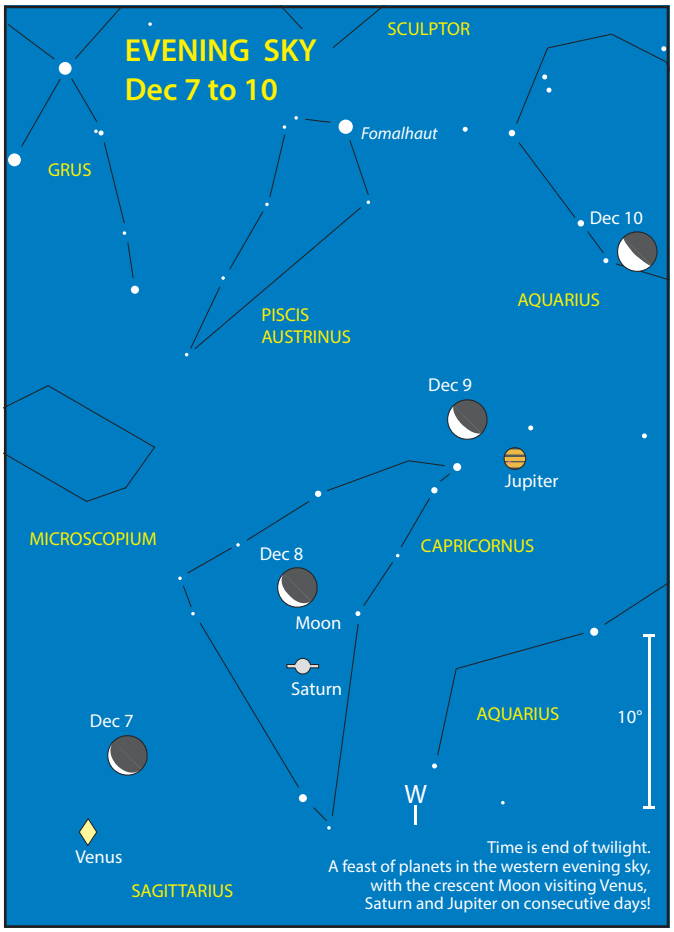
METEOR SHOWERS

The **Phoenicids** are a southern shower discovered in 1956 during its only known major outburst when rates of 100 plus were observed. There have been three minor bursts since then and some significant activity in 2014, they are therefore a shower to keep an eye on, just in case. Their period of activity appears to be 28 November through to 9 December, with maxima around the 2nd. The Phoenicids' radiant culminates at dusk so early evening viewing should provide the best activity. This year offers perfect conditions for this shower with New Moon on the 4th.

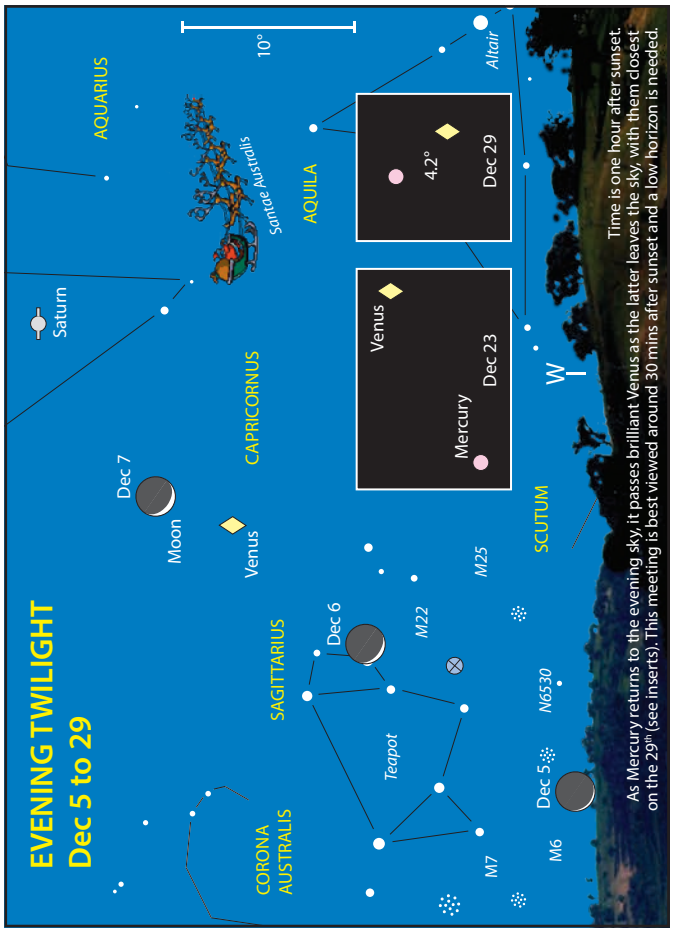
The **Puppid-Velids** are a vast complex system of showers active during November and December. Each radiant is so close that visual observation cannot easily separate them. They are active from 1–15 December and could produce a peak zenith hourly rate of 10 around the evening of the 7th and morning of the 8th. The radiant culminates after midnight and, with First Quarter approaching, the morning skies will be Moon free during the peak this year.

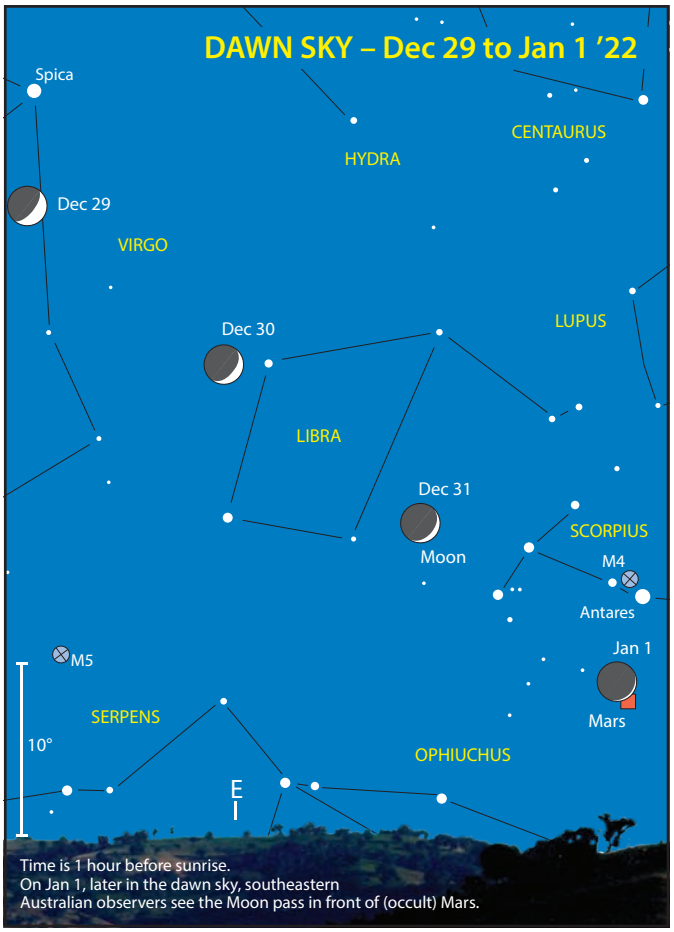
The **Geminids** are one of the finest and reliable of the major annual showers. Visible from the 4th to 20th, with maximum predicted on the evening of the 13th and morning of the 14th. The Geminids often produce bright, medium-speed meteors with zenith hourly rates of up to 150. Even though our northern counterparts will see the best of the Geminids, they can still provide a spectacular display for us *down under*. The waxing gibbous Moon will be a hindrance until after 2 am but from then until dawn the sky will be Moon free.





Approximate local standard time, for daylight saving add one hour.





ALL SKY MAPS 2021

Introduction These maps have been created to show you the entire night sky at any time of the year from anywhere in Australia, New Zealand, South Africa and parts of South America.

Who can use them? Anyone, and you don't need binoculars or a telescope to be at ease finding your way around the sky and recognising all of the constellations.

The limiting magnitude of the stars is 5.5. If you live in a suburban area, you will not see the fainter stars marked on the maps. Some of the obscure constellations may not be visible at all; a pair of binoculars will help. Under dark, country skies, where you can see the Milky Way, you will be able to see all these stars plus numerous fainter ones not included on the maps.

How Do I Use Them? There are nine maps. Map 1 Looking South covers the far southern sky. Then there are four pairs of maps, one pair (a Centre and a North map) for each season.

To use the Looking South map, face south and rotate the chart to get the correct orientation. Use a distinctive star pattern like the Pointers and the Southern Cross (Crux) to help. From mid-Australian latitudes and further south, Crux is circumpolar (never sets).

The rest of the maps are used as follows. Turn to the relevant season and rotate the book onto its side so the right hand North page is on the bottom and look towards the north. The northern sky, directly above the horizon, is represented on the North map and as you progress up the sky towards the overhead point (or zenith) you will cross over onto the Centre map.

The seasonal views are a little arbitrary. As you will see in the Notes section on the maps, an evening view around the relevant time of the year was chosen. However, if you are willing to stay up all night there is only a small part of the entire sky not available to you, especially in winter. Rotating a planisphere illustrates this quite well (p. 9).

What does the fine black grid represent? These are the right ascension (RA) and declination (Dec.) lines. The RA line, which starts on the due north point (N on the North charts) and runs vertically up the page, crossing through the point directly overhead and heading down to the southern horizon, is called the local central meridian. When objects cross this meridian they are said to be culminating and they have reached their highest point in the sky. Looking at the Spring (North) chart, the RA of the central meridian at 11 pm on 20 August is approximately 21 hours. The constellation of Cygnus is transiting the meridian. In a couple of hours (around 1 am) the star Alpha (α) Pegasi (Markab), with an RA close to 23 hours, will culminate.

The declination indicates which areas of the charts will pass directly overhead. This happens when an object has the same declination as your latitude. Let's take an example for Hobart (latitude around 43° S). Looking at the Autumn (Centre) map on 20 March at 9 pm the star Suhail, with a declination close to –43°, will pass overhead.

What do the dashed lines, labelled with city names, on the North maps mean? Australia is a large country and your latitude dictates how far north in the sky you can see. These lines represent the declination furthest north you can see from each of the cities. If a star is very close, but still above your dashed line, it will be visible if only briefly, assuming you have a low flat northern horizon. To see all the sky, as depicted in the North maps, you would need to be at a latitude similar to Darwin.

What are the planet lines? Lines are shown to indicate the approximate path in the sky for Mars, Jupiter, Saturn, Uranus, Neptune and Pluto for the year. With the exception of Mars, once you have found the general area you can go to the relevant finder chart. The path for Mars has the position marked for each month and thus replaces a separate finder chart. The Moon, Mercury and Venus are not shown. The Sky View diagrams (see Part I) show the location and optimum time to observe these objects.

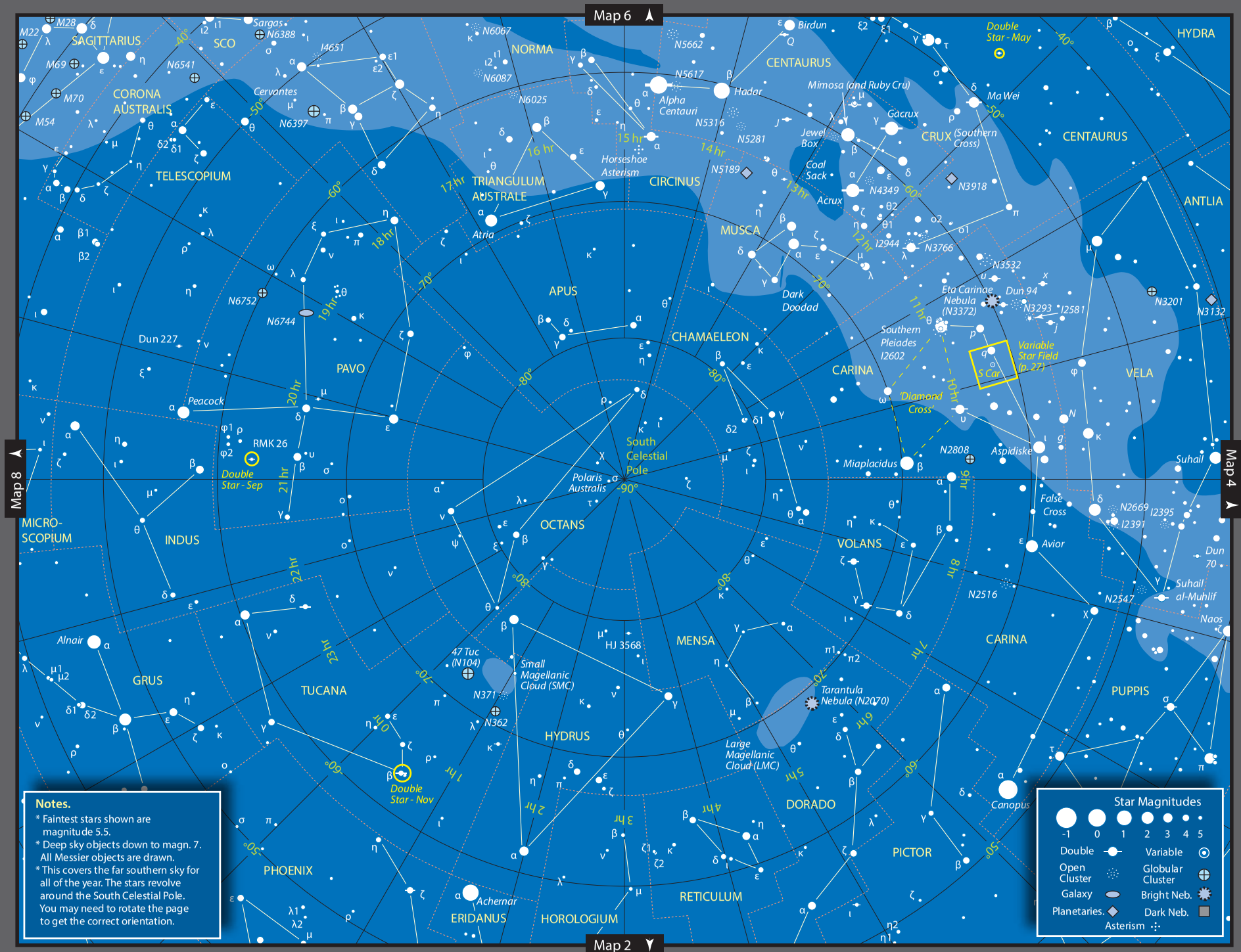
What else is shown on the maps?

- Deep sky objects down to magnitude 7 and all of the Messier objects (see the legend). These objects are identified by their common names (such as asterisms), Messier number (M), NGC (N) or IC (I) catalogue numbers. Most of the star clusters should be visible through a pair of binoculars. The galaxies, planetary and diffuse nebulae may need a small telescope. The objects shown have been updated to include those mentioned in the constellation section this year. Most are suitable for binoculars.
- Constellation lines. The orange dotted lines are the boundaries and the solid lines joining some of the brighter stars help us to recognise the constellation's pattern.
- A light blue shading shows the Milky Way and Magellanic Clouds.

Special objects marked this year include the monthly double stars. Those mentioned in the Part I sections are labelled with the specific month and circled. Also, a few of the brighter carbon stars (circled) – using binoculars, can you see their distinctive red colour? The position of the brilliant supernova that occurred in 1006 CE in Lupus and the field for S Car (p. 27) are also marked.



Star trails, taken by David Marriott at the ASNSW South Pacific Star Party 2014

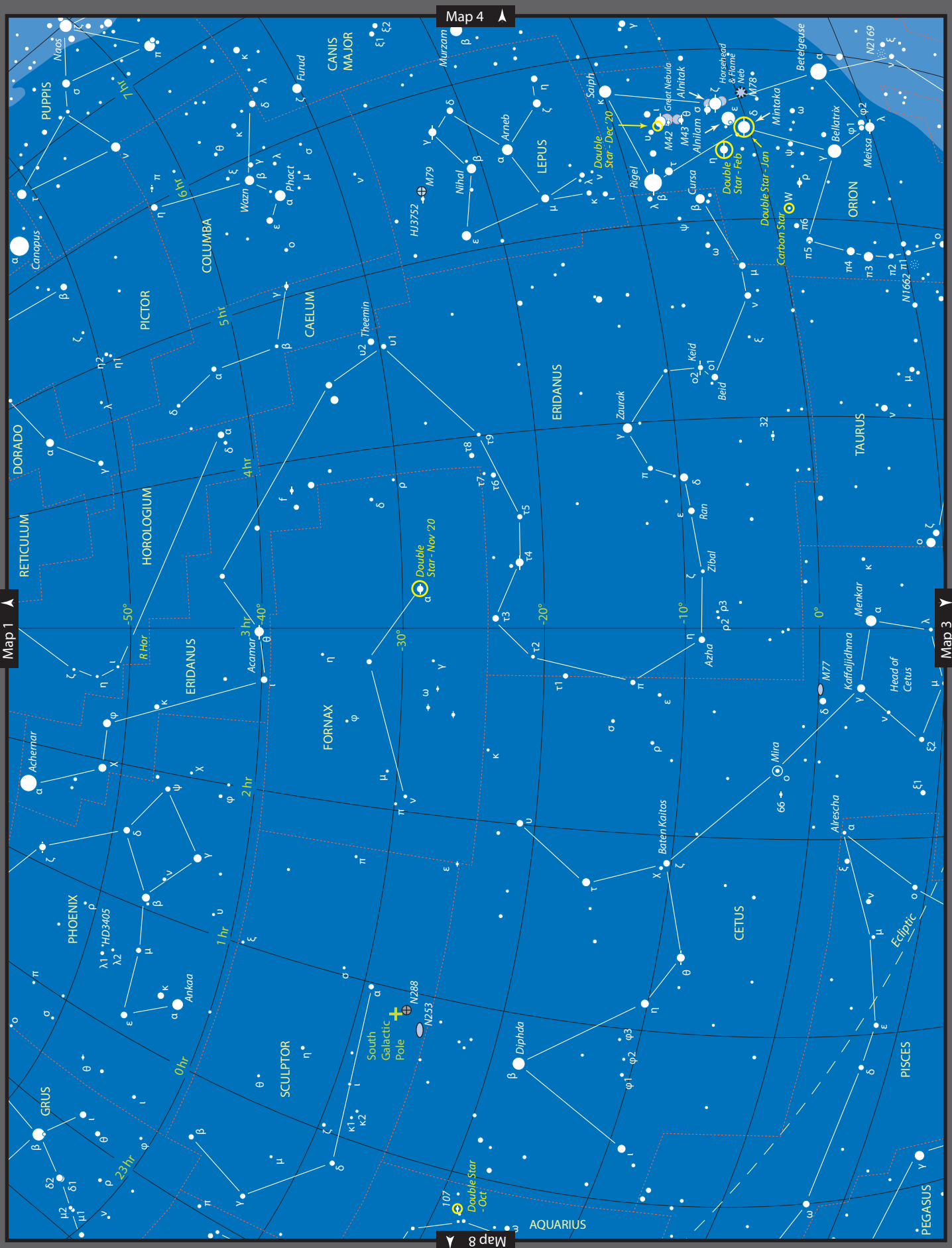


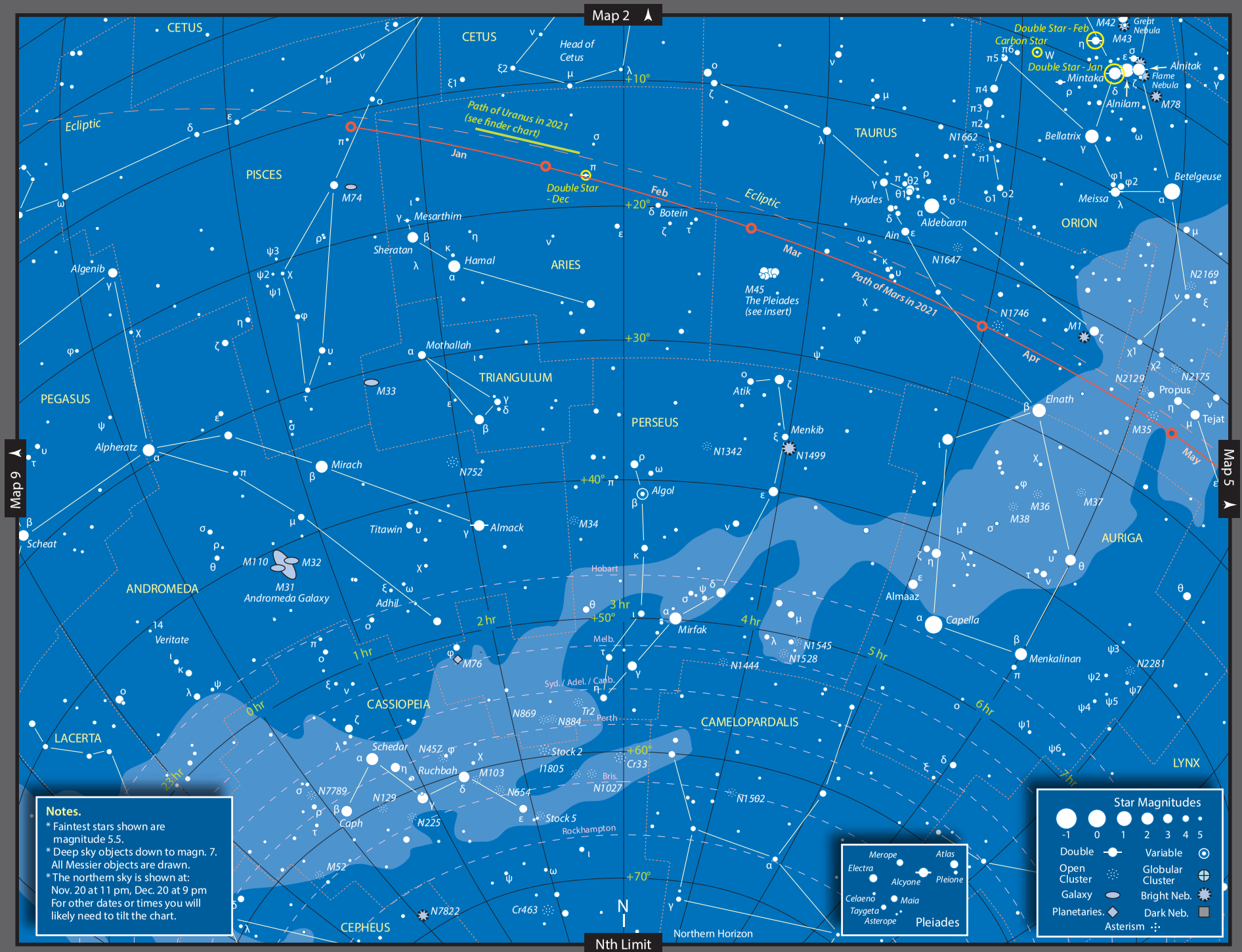
Notes.

* Faintest stars shown are magnitude 5.5.
* Deep sky objects down to magn. 7. All Messier objects are drawn.
* This covers the far southern sky for all of the year. The stars revolve around the South Celestial Pole. You may need to rotate the page to get the correct orientation.

Map 1 - Looking South

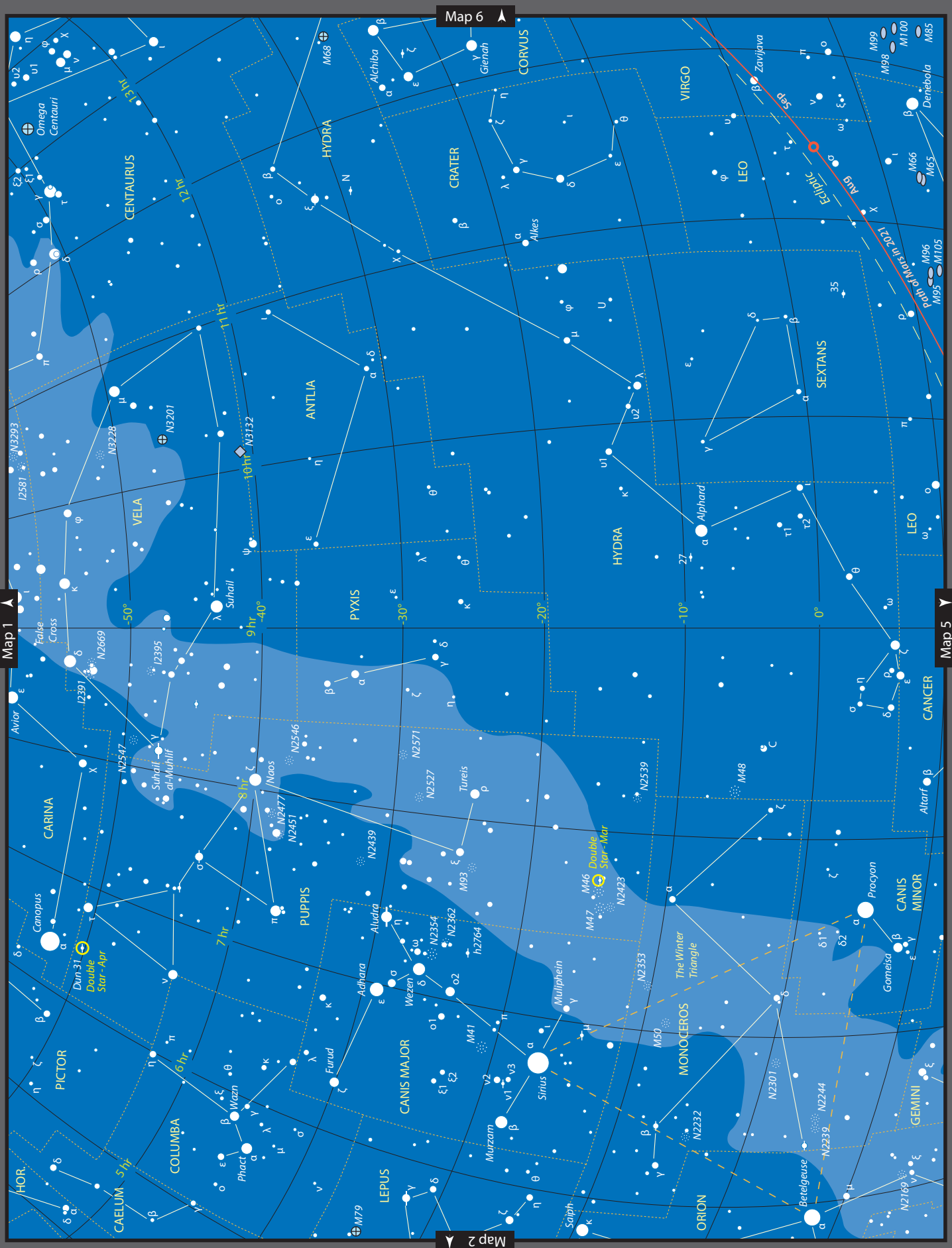
Map 2 - Summer (Centre)

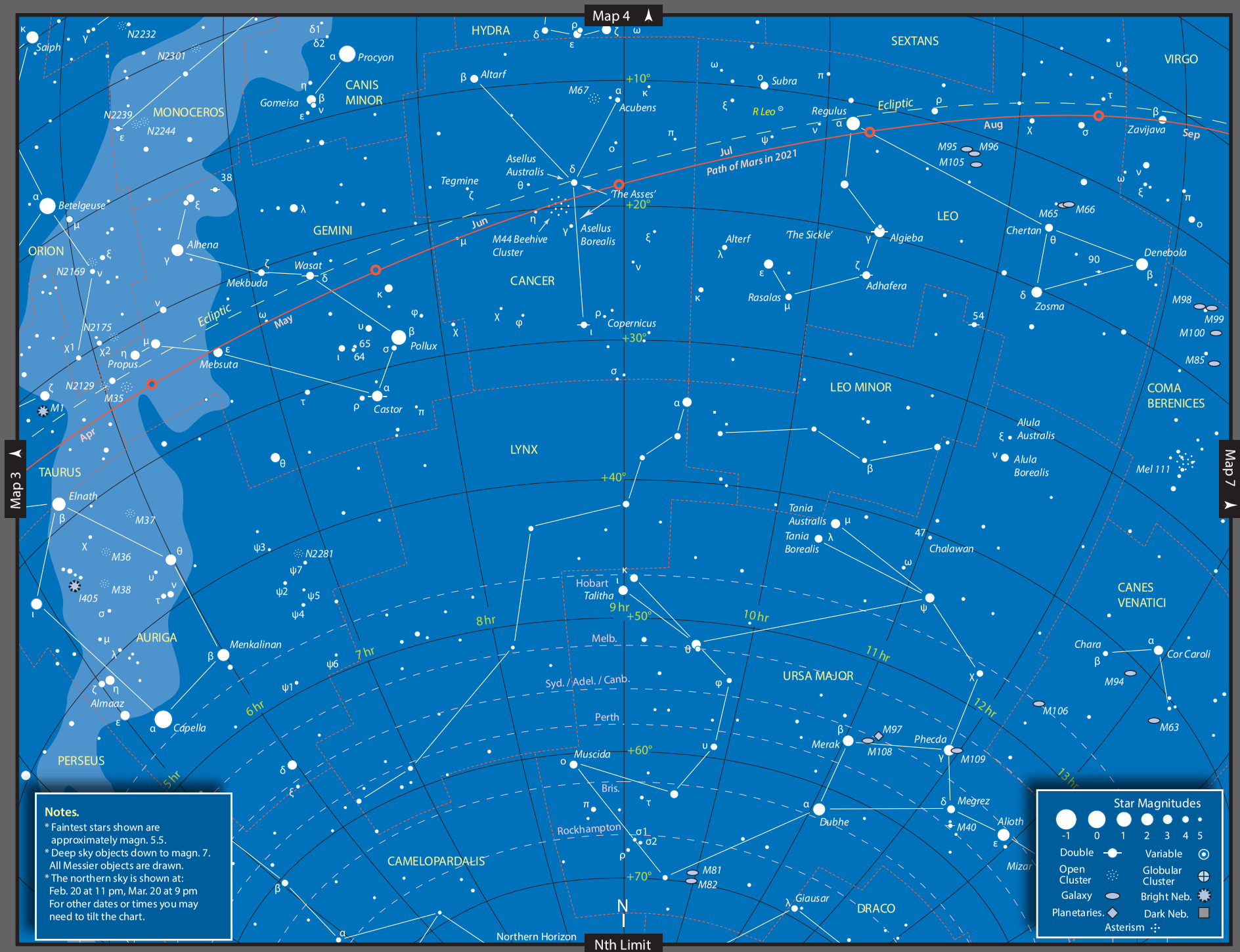




Map 3 - Summer (North)

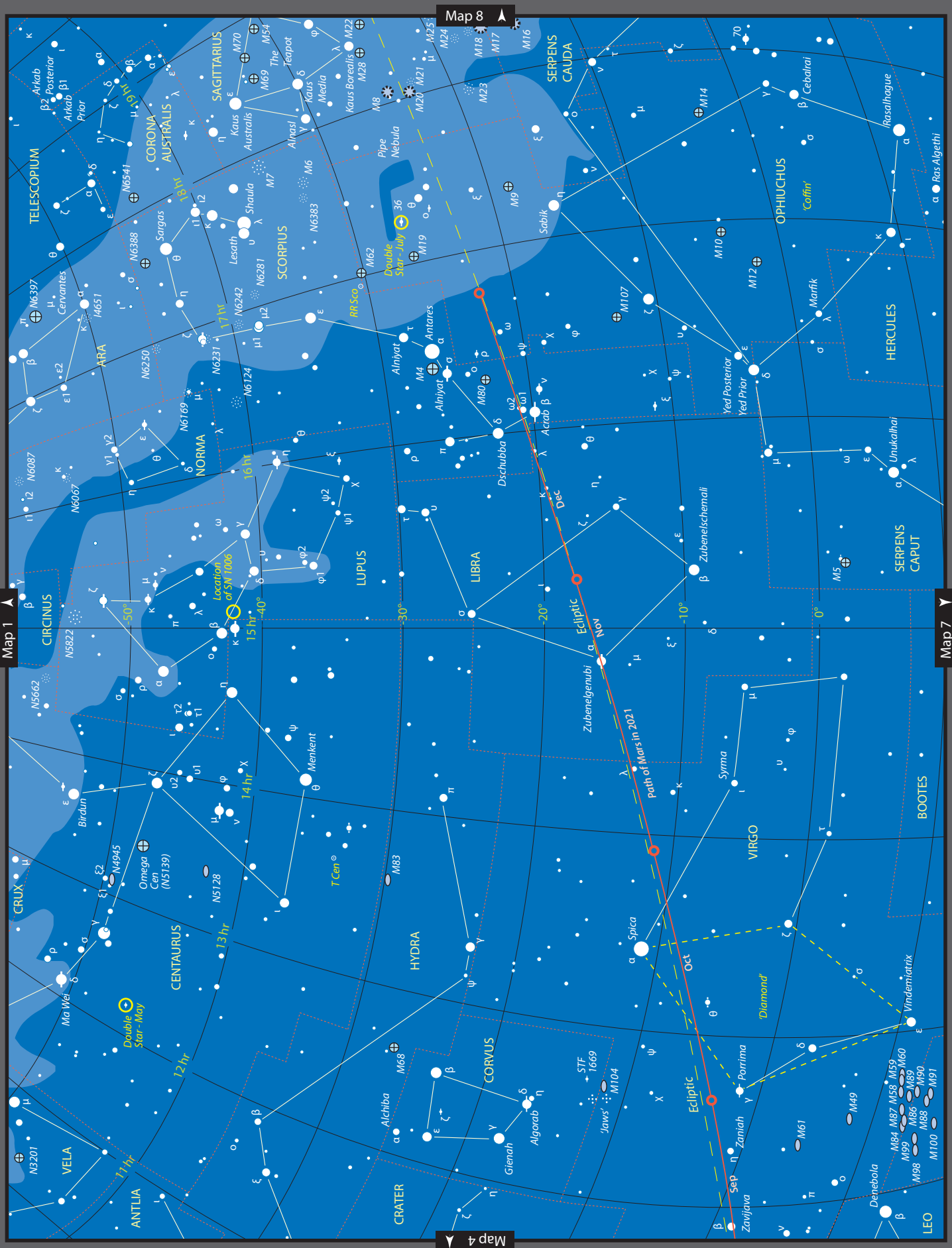
Map 4 - Autumn (Centre)

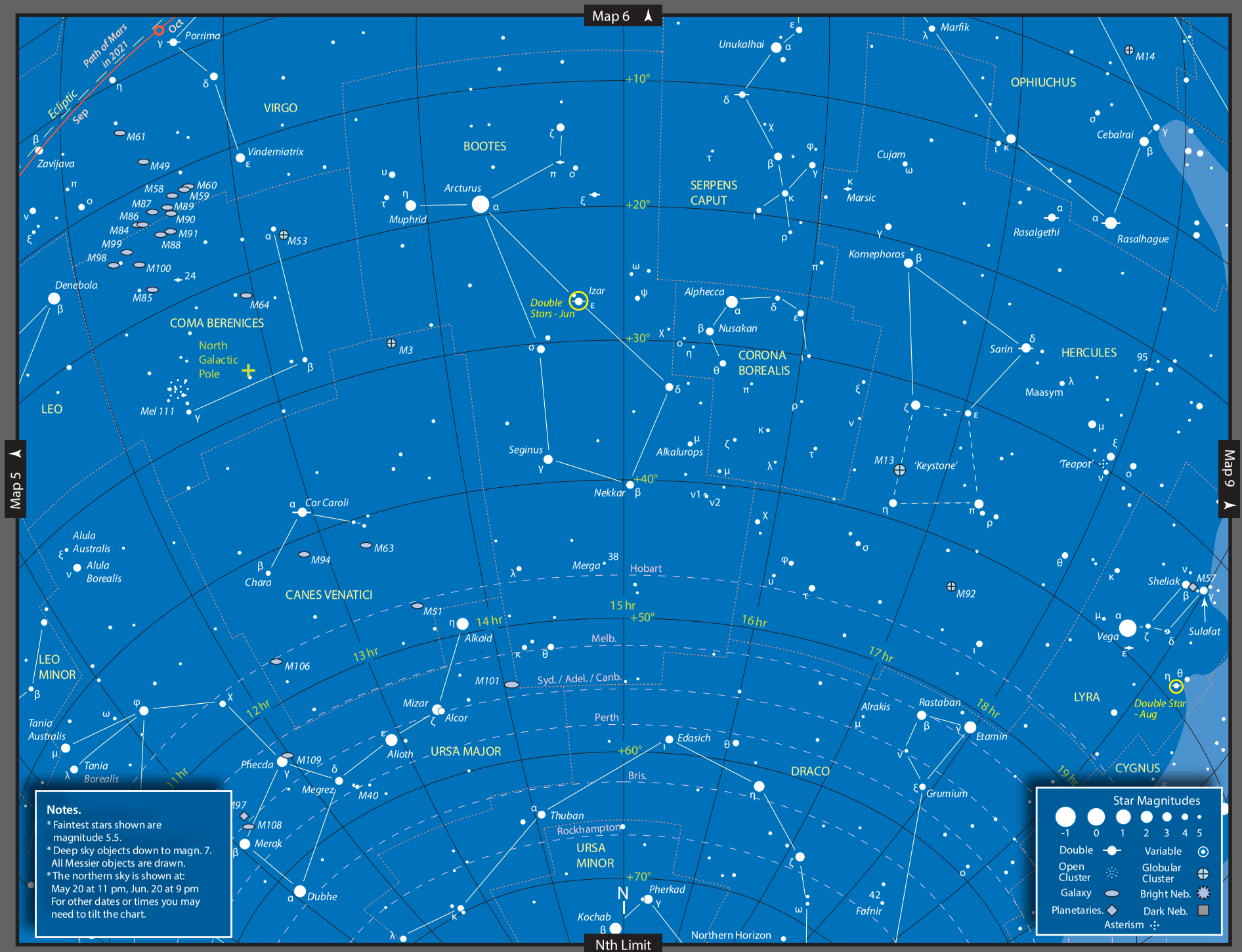




Map 5 - Autumn (North)

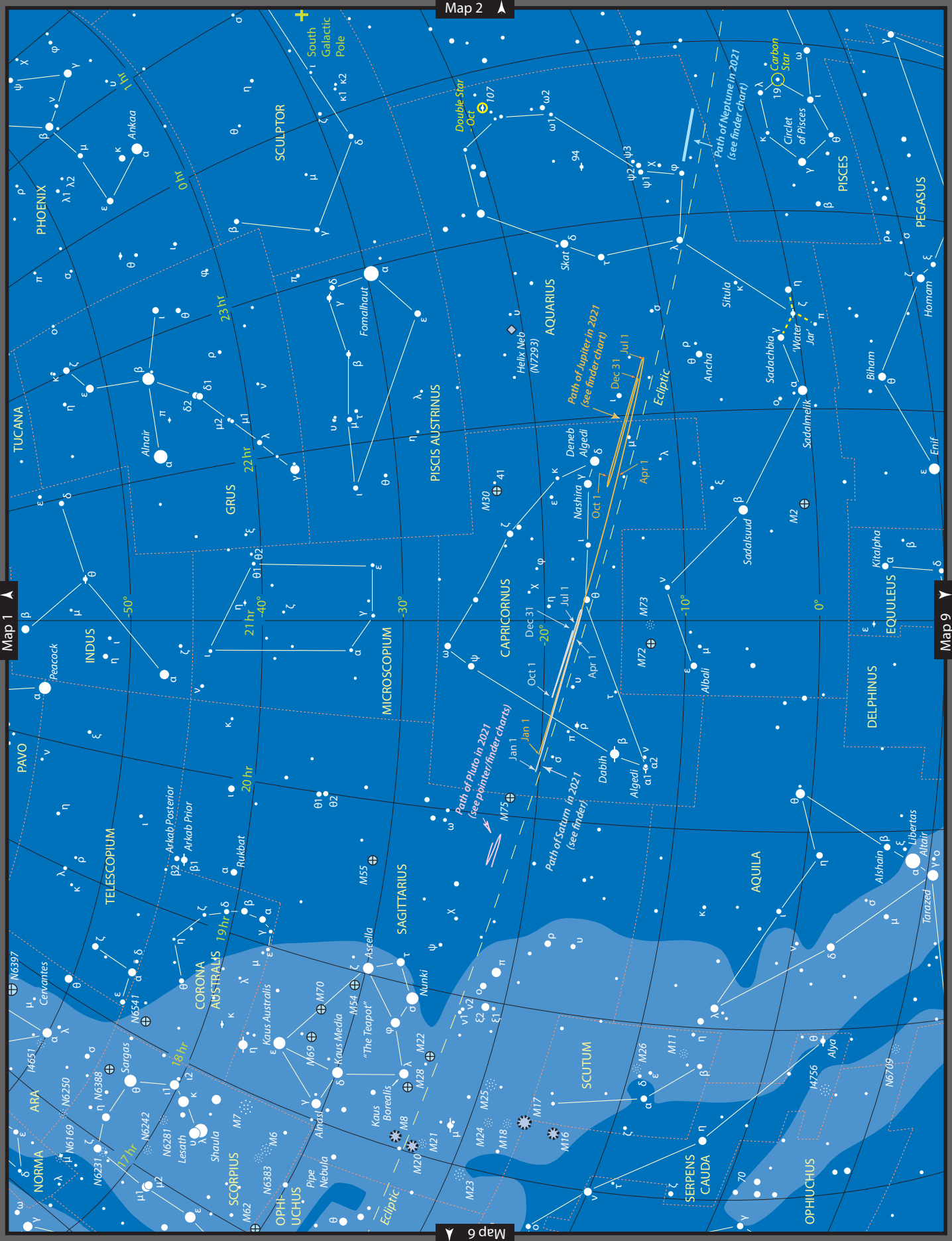
Map 6 - Winter (Centre)

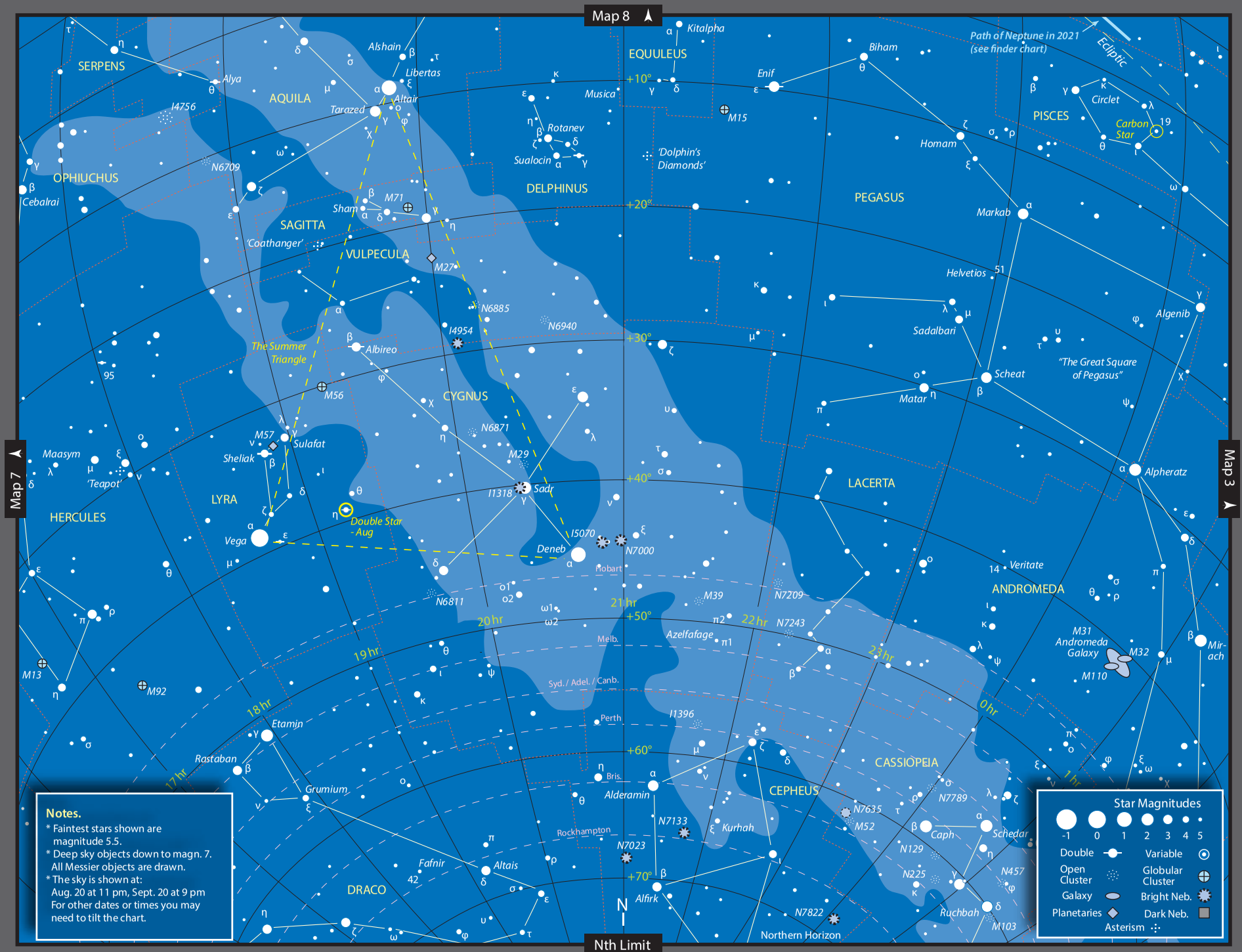




Map 7 - Winter (North)

Map 8 - Spring (Centre)





Map 9 - Spring (North)

This introduction is only brief, as specific explanations are located in the relevant sections.

Time. There are four time zones used in Part II: Eastern Standard Time (EST), Central Standard Time (CST), Western Standard Time (WST) and Universal Time (UT). Local times are used wherever we have location specific data, such as the rise and set times of the Sun and Moon. As in Part I, **no allowance has been made for Daylight Saving Time.** When in force you will need to add one hour to the times given.

Universal Time, or UT, is the mean time for the meridian of Greenwich, England, reckoned from midnight. EST is 10 hours ahead of UT, CST is 9.5 hours ahead and WST is 8 hours ahead. For example, midnight UT, or 0 hr, is equal to 10:00 hr (10:00 am) EST, 9:30 hr (9:30 am) CST and 8:00 hr (8:00 am) WST.

The 24 hour clock is often used in astronomy for example, 16:00 is the same as 4:00 pm. This avoids the need to distinguish between 'am' and 'pm' and is frequently used in Part II of this book, for example for rising and setting times.

The satellite data for Saturn, Uranus and Neptune use decimal days. There are worked examples on these pages to further explain this.

Locations: Rise and set times for the Sun and Moon are given for specific cities. The latitudes and longitudes used are:

Adelaide	34° 54' S	138° 36' E	Brisbane	27° 30' S	153° 01' E
Canberra	35° 15' S	149° 08' E	Darwin	12° 23' S	130° 44' E
Hobart	42° 48' S	147° 13' E	Melbourne	37° 50' S	145° 00' E
Perth	31° 57' S	115° 51' E	Sydney	33° 54' S	151° 15' E

Astronomical Coordinates or Positions. The astronomical positions are given in equatorial coordinates. These are Right Ascension (RA) and Declination (Dec) which are analogous to longitude and latitude on Earth. RA is the longitude component but, unlike its terrestrial counterpart, it is not measured in degrees, but in hours. The 360 degrees, for once around the sky, are divided into 24 one-hour divisions. Each hour is further divided, like a clock, into minutes and seconds. Declination is the counterpart to latitude but does not use north or south. Instead, objects north of the celestial equator have positive (+) declinations; those south have negative (–). The Right Ascension and Declination grid has been marked on the All Sky Maps (see previous pages). The RA has a line for each hour and the Declination has a line every 10°. The finders also have them marked.

The Earth's daily rotation on its polar axis causes the stars to appear to rotate around a point in the sky. From southern latitudes, including Australia, this point is called the South Celestial Pole and is at declination –90° (see All Sky Map 1 in the All Sky Maps). The North Celestial Pole, not visible from the Southern Hemisphere, is at +90°. The celestial equator and poles can be described as projections on the sky of their terrestrial counterparts.

Position Tables. Right Ascension and Declination are calculated for 0 hr UT on the date listed (Epoch 2000.0). All positions are geocentric. There is no allowance for the parallax effect of the observer being on the surface of the Earth. Positions for the dwarf and minor planets and comets are given in weekly intervals and correspond to Saturdays. Positions for the Sun and Moon and planets are not included here, but are on our website. www.quasarastronomy.com.au

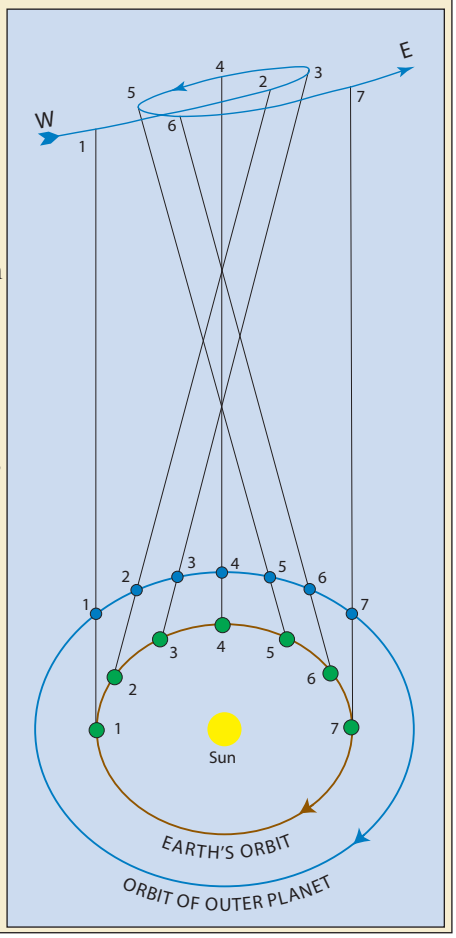
Rise and Set Times. Those given are when the upper limb of the object is coincident with the theoretical horizon. The times are adjusted for atmospheric refraction. The intervals used for Moon rise and set are daily with the Sun weekly and correspond to Saturdays. Also see note on time zones under Time (above). Rise and set times for the planets are on our website. www.quasarastronomy.com.au

Use of Star Atlases. As the Earth orbits the Sun the polar axis, around which the stars rotate (the celestial poles) appears to never change no matter what time of the year you are observing. However, the positions of the poles do slowly move against the star field. This is called precession and is caused by the Earth's axis slowly wobbling, like a spinning top as it slows down, over thousands of years. 'Epoch 2000.0' refers to

RETROGRADE MOTION

The finder charts for the outer planets have one thing in common, an apparent motion with a loop or 'S' shape. This only applies to the period around opposition. See the All Sky Maps or the Finder Charts for examples. The diagram below illustrates the combined effects of the orbital motions of Earth and an outer planet to explain this loop.

In the diagram, the top section represents the path of an outer planet against the celestial sphere with south up. As the Earth moves around the Sun, faster than this outer planet (let's call it Uranus), our home planet overtakes it. The result is a loop in its path against the celestial sphere. This apparent reversal in the planet's movement is known as retrograde motion, and during this time the planet appears to move among the stars from east to west, instead of west to east. At positions 1 and 2, Uranus continues its west to east path and begins to slow to position 3 as the Earth catches up. Between 3 and 5, Uranus is in retrograde motion and it is at opposition (in line with the Earth and the Sun) at 4. At points 3 and 5, the planet is said to be stationary. After 5, as the Earth passes the slower planet, Uranus continues its west to east direction.



Because the orbits of the outer planets are inclined to that of the Earth's, thus having some north/south motion, the path can never be a straight line. It will always be a loop or an S-bend.

an object's position relative to where the celestial poles (+/– 90° in declination) were in the year 2000. The All Sky Maps and finder charts are Epoch 2000.0.

Field of View in a Telescope. All the satellite diagrams and finder charts in this book are drawn to normal sky orientation, that is east to the left, and north to the top (in the sky, east and west are opposite to terrestrial maps). Binoculars (and the eyes) or straight Newtonians show this appearance (the Newtonian image will be upside down). Telescope systems that use an odd number of mirrors will reverse the image. The common use of star diagonals in Schmidt-Cassegrains or traditional refractors causes this reversal.

Finder Charts. No finder charts are presented for Mercury or Venus. Their rapid motion during the year causes them to cover a very large section of the sky, which is difficult to cater for adequately in the space available. Considering how bright these objects are, the Sky View diagrams (see Part I) should be sufficient to act as finders. With regard to Mars, the All Sky Maps give adequate detail to easily find the Red Planet, so no additional finder is needed. There are separate finder charts for Jupiter, Saturn, Uranus, Neptune and Pluto, and the approximate track for each is also shown on the All Sky Maps. This acts as a pointer to help you find the smaller field of the finder charts.

Supermoons! The table below shows the so called supermoons for 2021. They occur when the time of the Moon's perigee (the point in its orbit when closest to the Earth) happens close to the time of Full Moon. This can be observed by comparing the dates (below) to those of perigee and Full Moon for the month of interest (see Moon section in Part 1). As you can see, the Moon is not exactly super large and the effect is possibly enhanced by having the impressive fully lit globe close to the horizon with its surrounding trees and buildings. This is known as the 'Moon Illusion'.

Downloads. On our website we have a separate downloadable PDF for each of the eight locations on the opposite page. Each file includes: daily geocentric positions of the Sun and Moon and weekly positions for the planets. It also has location specific planet rise and set times.
www.quasarastronomy.com.au

FULL MOON at PERIGEE (Supermoon)

Date of FM	Time of FM [1]	Note [7]	Geocentric Distance (km)	Geocentric Diameter (arcminutes)	Relative Distance [2]	Relative Brightness [3]	Date of Perigee [4]	Time of Perigee [1]	Nearest Perigee [5]
Mar 29	04:48		362,170	32.99	0.959	1.252/1.127	Mar 30	16:12	1.475
Apr 27	13:32		357,615	33.41	0.995	1.290/1.155	Apr 28	01:24	0.495
May 26	21:14	t	357,462 [6]	33.43	0.997	1.291/1.156	May 26	11:52	–0.390
Jun 25	04:40		361,558	33.05	0.965	1.257/1.130	Jun 23	19:58	–1.363

1: Time given is EST, subtract 30 minutes for CST and two hours for WST.

2: The relative distance is equal to 1 when the Full Moon occurs at perigee and 0 when FM occurs at apogee. Any FM occuring at a relative distance of 0.9 or greater is by definition a supermoon.

3: The relative brightness is composed of two values that express that of the Full Moon relative to its brightness at the current apogee (left) and at its mean distance (right). A supermoon is typically 1.3 times (or 30%) brighter than a Full Moon at apogee, and 1.15 times (or 15%) brighter than a Full Moon at the Moon's mean distance.

4: The date of the nearest perigee.

5: Nearest perigee gives the time difference (in days) between nearest perigee and Full Moon. Note that the Full Moon occurs within two days of perigee for most supermoons.

6: The closest Full Moon perigee syzygy of the year.

7: Lunar Eclipse (t = total p = partial e = penumbral)

MOON PHASE (UT)

Lunation	New Moon		First Quarter		Full Moon		Last Quarter	
1212							Jan 6	09:37
1213	Jan 13	05:00	Jan 20	21:02	Jan 28	19:16	Feb 4	17:37
1214	Feb 11	19:06	Feb 19	18:47	Feb 27	08:17	Mar 6	01:30
1215	Mar 13	10:21	Mar 21	14:40	Mar 28	18:48	Apr 4	10:02
1216	Apr 12	02:31	Apr 20	06:59	Apr 27	03:32	May 3	19:50
1217	May 11	19:00	May 19	19:13	May 26	11:14	Jun 2	07:24
1218	Jun 10	10:53	Jun 18	03:54	Jun 24	18:40	Jul 1	21:11
1219	Jul 10	01:17	Jul 17	10:11	Jul 24	02:37	Jul 31	13:16
1220	Aug 8	13:50	Aug 15	15:20	Aug 22	12:02	Aug 30	07:13
1221	Sep 7	00:52	Sep 13	20:39	Sep 20	23:55	Sep 29	01:57
1222	Oct 6	11:05	Oct 13	03:25	Oct 20	14:57	Oct 28	20:05
1223	Nov 4	21:15	Nov 11	12:46	Nov 19	08:57	Nov 27	12:28
1224	Dec 4	07:43	Dec 11	01:36	Dec 19	04:35	Dec 27	02:24

PERIGEE AND APOGEE (UT)

Perigee			Apogee		
Date	Time	Distance (km)	Date	Time	Distance (km)
Jan 9	15:37	367,387	Jan 21	13:11	404,360
Feb 3	19:03	370,116	Feb 18	10:22	404,467
Mar 2	05:18	365,423	Mar 18	05:03	405,253
Mar 30	06:16	360,309	Apr 14	17:46	406,119
Apr 27	15:22	357,378	May 11	21:53	406,512
May 26	01:50	357,311	Jun 8	02:27	406,228
Jun 23	09:55	359,956	Jul 5	14:47	405,341
Jul 21	10:24	364,520	Aug 2	07:35	404,410
Aug 17	09:16	369,124	Aug 30	02:22	404,100
Sep 11	10:03	368,461	Sep 26	21:44	404,640
Oct 8	17:28	363,386	Oct 24	15:28	405,615
Nov 5	22:18	358,844	Nov 21	02:13	406,279
Dec 4	10:04	356,794	Dec 18	02:15	406,320

GEOCENTRIC PHENOMENA (UT)

Planet	Greatest Elongation East	Stationary	Inferior Conjunction	Stationary	Greatest Elongation West	Superior Conjunction
Mercury	24 Jan, 2 h (18.6°) 17 May, 6 h (22.0°) 14 Sep, 4 h (26.8°)	30 Jan, 2 h 30 May, 2 h 27 Sep, 4 h	8 Feb, 14 h 11 Jun, 1 h 9 Oct, 16 h	20 Feb, 13 h 22 Jun, 23 h 18 Oct, 1 h	6 Mar, 11 h (27.3°) 4 Jul, 20 h (21.6°) 25 Oct, 5 h (18.4°)	19 Apr, 2 h 1 Aug, 14 h 29 Nov, 5 h
Venus	29 Oct, 21 h (47.0°)	18 Dec, 11 h				26 Mar, 7 h

Planet	Stationary	Conjunction	Stationary	Opposition	Stationary	Earth	
Mars		8 Oct, 4 h				Perihelion	2 Jan, 14 h
Jupiter		29 Jan, 2 h	21 Jun, 5 h	20 Aug, 0 h	18 Oct, 11 h	Equinox	20 Mar, 10 h
Saturn		24 Jan, 3 h	23 May, 20 h	2 Aug, 6 h	11 Oct, 2 h	Solstice	21 Jun, 4 h
Uranus	14 Jan, 14 h	30 Apr, 20 h	20 Aug, 4 h	5 Nov, 0 h		Aphelion	5 Jul, 22 h
Neptune		11 Mar, 0 h	26 Jun, 10 h	14 Sep, 9 h	1 Dec, 22 h	Equinox	22 Sep, 19 h
Pluto		14 Jan	28 Apr	17 Jul, 23 h	6 Oct	Solstice	21 Dec, 16 h

HELIOCENTRIC PHENOMENA (UT)

Planet	Greatest Latitude South	Ascending Node	Perihelion	Greatest Latitude North	Descending Node	Aphelion
Mercury	5 Jan 3 Apr 30 Jun 26 Sep 23 Dec	24 Jan 22 Apr 19 Jul 15 Oct	29 Jan 27 Apr 24 Jul 19 Oct	8 Feb 7 May 3 Aug 30 Oct	3 Mar 30 May 26 Aug 22 Nov	14 Mar 10 Jun 6 Sep 2 Dec
Venus	 14 Mar 25 Oct	 9 May 20 Dec	12 Jun	4 Jul	16 Jan 29 Aug	20 Feb 3 Oct
Mars				4 Jun	19 Dec	13 Jul
Jupiter, Saturn, Uranus, and Neptune have no events in 2021						

SOLAR SYSTEM DATA – SUN, MOON, PLANETS and PLUTO

	Sun	Moon	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Mean Distance from Sun (× 10^3 km)	-	-	57856	108132	149492	227780	777776	1425983	2867760	4492800	5745000
Mean Distance from Sun (Earth = 1)	-	-	0.387	0.723	1.000	1.524	5.203	9.540	19.180	30.700	39.670
Magnitude at Opposition	−26.8	−12.74 [11]	0.16 [12]	−4.07 [12]	−3.5 [13]	−2.01	−2.70	0.67	5.52	7.84	13.7
Equatorial Diameter (km)	1392530	3474.8	4879.4	12103.6	12756.3	6792.4	142984	120536	51118	49528	2370
Flattening [1]	0	0	0	0	0.00335281	0.005886	0.064874	0.097962	0.022927	0.017081	0
No of Moons	-	-	0	0	1	2	79	82	27	14	5
Mass (× 10^{24} kg)	1.9884×10^{30}	0.073458	0.3301	4.8673	5.9721986	0.64169	1898.1	568.31	86.809	102.41	0.013041
Mass (Earth = 1)	332946	0.012300	0.0553	0.8150	1.0000000	0.10745	317.8	95.16	14.536	17.148	0.002184
Volume (Earth = 1)	1300000	0.02	0.06	0.86	1	0.15	1323	752	64	54	0.007
Sidereal Period [2]	-	27.32 d	87.97 d	224.7 d	365.256 d	687 d	11.86 y	29.46 y	84.01 y	164.8 y	249.9 y
Synodic Period (Days) [3]	-	29.4	115.8	583.9	-	779.8	398.8	378.0	369.7	367.5	366.7
Axial Rotation (Days) [4]	25.38 [9]	27.32166	58.6462	−243.0185	0.99726963	1.02595676	0.41354 [14]	0.44401 [14]	−0.71833	0.67125	−6.3872
Albedo [5]	-	0.12	0.106	0.65	0.367	0.150	0.52	0.47	0.51	0.41	0.3
Eccentricity [6]	-	0.0549	0.20562	0.00681	0.01681	0.09333	0.04837	0.05582	0.0471	0.00855	0.2486
Inclination [7]	-	5° 08' 40"	7° 00' 00"	3° 23' 38"	0° 00' 00"	1° 51' 01"	1° 18' 28"	2° 29' 29"	0° 46' 22"	1° 46' 38"	17° 09' 00"
Obliquity [8]	7° 15' [10]	6° 41'	0° 01'	2° 38'	23° 26'	25° 11'	3° 07'	26° 45'	82° 14'	28° 20'	60° 25'

Notes (above and opposite):

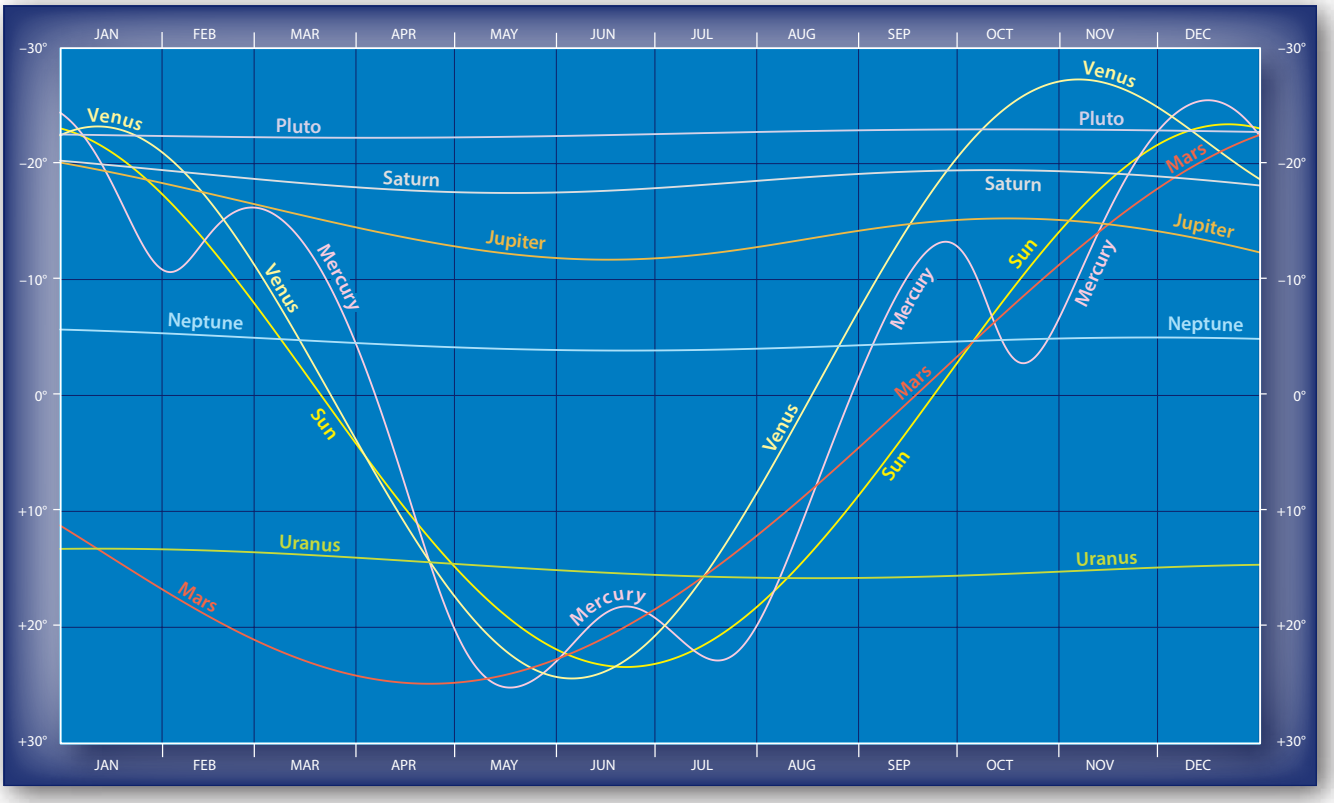
1 The ratio of the difference of equatorial and polar radii to equatorial radius.
2 The planet's year.
3 The period of the planet's orbit with respect to the Earth.
4 The planet's day. A negative sign indicates the rotation is retrograde with respect to the north pole.
5 The ratio of the sunlight reflected to that received.
6 The measure of how long or thin the ellipse of the planet's orbit is.
7 The angle of the planet's orbit from the plane of the ecliptic.
8 The degree of inclination of the planet's equator to its orbit
9 Equatorial region (polar areas of the Sun rotate in 29–30 days).
10 To the ecliptic.
11 From the Earth.
12 At mean greatest elongation.
13 As seen from the Sun.
14 Based on System III rotation. Similar to systems I or II except a radio source within the planet is the reference point.
15 Value is uncertain.
16 Retrograde
17 The 20 new moons of Saturn announced in 2019, making Saturn King.
18 Maximum elongation at mean opposition

The satellite table (right) covers those currently known (as of August 2020). Some are not yet named, instead they have a preliminary designation such as S/2007 S3.

SOLAR SYSTEM DATA — SATELLITES

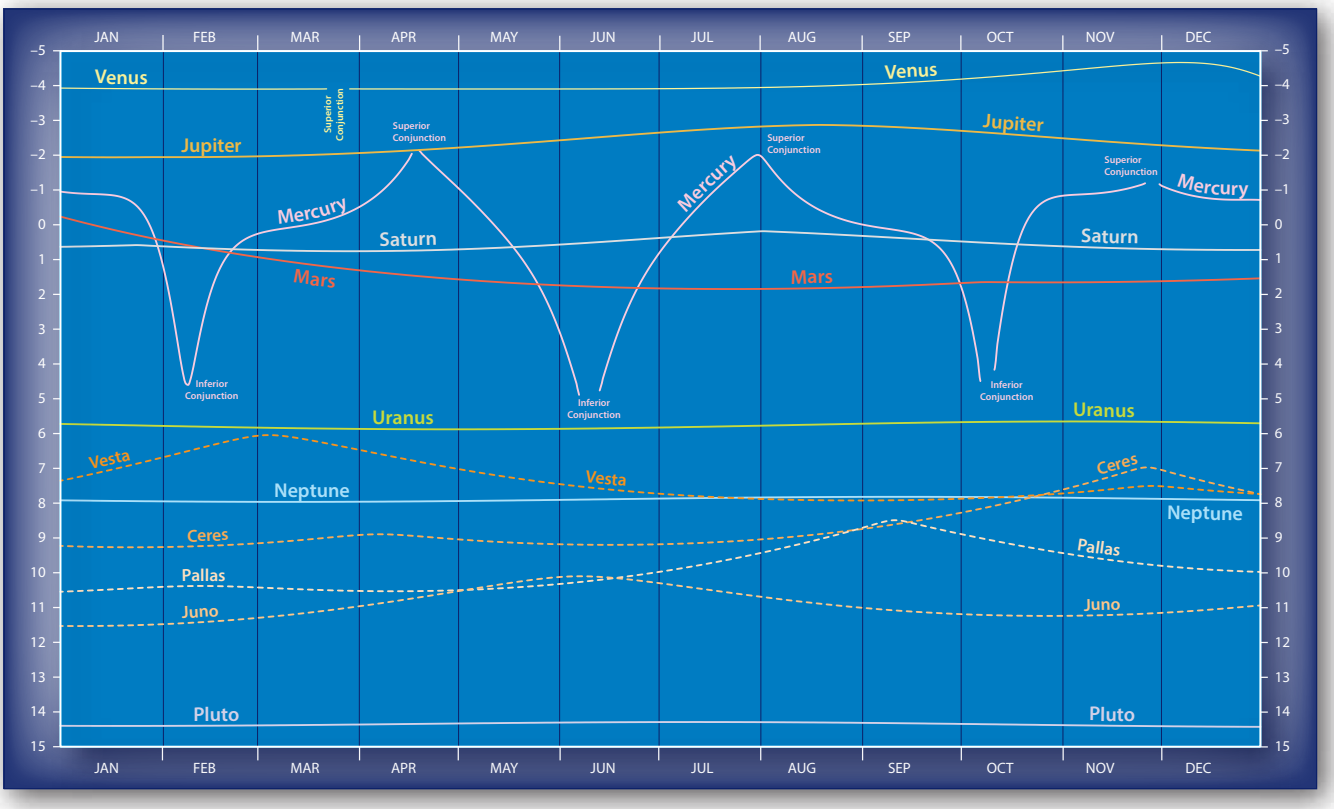
SATELLITE	ORBITAL PERIOD (days)	SEP[18]	SEMI MAJOR AXIS (x 10^3km)	RADIUS (km)	MAG AT OPP
Earth					
Moon	27.321661		384.400	1,737.4	–12.74
Mars					
Phobos	0.31891023	25"	9.380	13.4 × 11.2 × 9.2	11.9
Deimos	1.2624407	1.0'	23.460	7.5×6.1×5.2	13.0
Jupiter					
Metis	0.295	42"	128.00	30×20×17	17.5
Adrastea	0.298	42"	129.00	10×8×7	18.7
Amalthea	0.49817908	59"	181.40	125 × 73 × 64	14.1
Thebe	0.675	1.2'	221.90	58×49×42	16.0
Io	1.769137761	2.3'	421.80	1829 × 1819 × 1816	5.0
Europa	3.551181055	3.7'	671.10	1563 × 1560 × 1560	5.3
Ganymede	7.15455325	5.9'	1,070.40	2631.2	4.6
Callisto	16.689017	10.3'	1,882.70	2410.3	5.7
Themisto	130.02	40.7'	7504	4	21.0[R]
Leda	240.93	1.02°	11,164.00	5[15]	19.0
Himalia	250.56	1.04°	11,460.00	85	14.6
S/2018 J1	252.0		11,483	3[15]	22.9
S/2017 J4	252.1		11,525	3[15]	23.0
Lysithea	259.20	1.07°	11,717.00	12[15]	18.3
Elara	259.64	1.07°	11,740.00	40	16.3
Dia	287.0	1.10°	12,118.00	1.0[15]	22.4
Carpo	455.0[7]	1.55°	17,056.04	1.5[15]	23.0
S/2003 J12	489.67	1.82°	17,830	0.5	23.9[R]
Valetudo	533.3		18,980	1[15]	24.0
Euporie	555.2[16]	1.78°	19,509.12	1.0[15]	23.1
S/2003 J3	583.87	1.74°	20,221	1.0[15]	23.4[R]
Chaldene	591.7[16]	1.85°	20,299.46	1.9[15]	22.5
Mneme	599.65[16]	1.87°	20,500.28	1.0[15]	23.3
S/2003 J18	598.13	2°	20,508	1.0[15]	23.4[R]
Helike	601.40[16]	1.87°	20,540.27	2.0[15]	22.6
S/2017 J7	602.6		20,627	2[15]	23.6
Iocaste	606.3[16]	1.88°	20,642.86	2.6[15]	22.5
S/2016 J1	602.7		20,650.845	0.5	24
S/2017 J3	606.3		20,694	2[15]	23.4
Thyone	610.0[16]	1.89°	20,769.90	2.0[15]	22.3
Orthosie	613.6[16]	1.90°	20,849.89	1.0[15]	23.1
Harpalyke	617.3[16]	1.91°	20,917.72	2.2[15]	22.2
Euanthe	620.9[16]	1.91°	20,983.14	1.5[15]	22.8
S/2010 J2	618.84		21,004	1.0[15]	24.0[R]
Hermippe	624.6[16]	1.92°	21,047.99	2.0[15]	22.1
S/2003 J16	622.8[8]	1.98°	21,097	1.0[15]	23.3[R]
Praxidike	624.6[16]	1.92°	21,098.10	3.4[15]	22.5
Ananke	629.80[16]	1.92°	21,254.00	10[15]	18.8
Thelxinoe	635.82[16]	1.94°	21,316.68	1.0[15]	23.5
S/2017 J9	639.2		21,487	3[15]	22.8
Taygete	650.1[16]	1.97°	21,671.85	2.5[15]	22.9
Erinome	661.1[16]	1.99°	21,867.75	1.6[15]	22.8
Aitne	679.3[16]	2.03°	22,274.41	1.5[15]	22.7
Kale	679.4[16]	2.03°	22,300.64	1.0[15]	23.0
Kallichore	681.94[16]	2.03°	22,335.35	1.0[15]	23.7
S/2017 J6	683.0		22,455	2[15]	23.5
Sponde	690.3[16]	2.05°	22,548.24	1.0[15]	23.0
S/2003 J15	689.7[8]	2.13°	22,627	1.0[15]	23.5[R]
Isonoe	704.9[16]	2.08°	22,804.70	1.9[15]	22.5
Hegemone	715[16]	2.10°	23,006.33	1.5[15]	22.8
S/2003 J10	716.25	2.33°	23,042	1.0[15]	23.6[R]
Herse	715.4[16]	2.10°	23,097.00	1.0[15]	23.4
S/2011 J2	718.37		23,124	1[15]	23.5[R]
S/2017 J5	719.5		23,232	2[15]	23.5
S/2017 J8	719.6		23,233	1[15]	24.0
S/2017 J2	723.1		23,303	2[15]	23.5
S/2003 J9	733.32	2.16°	23,385	0.5[15]	23.7[R]
Carme	734.17[16]	2.12°	23,401.00	15[15]	17.6
Megaclite	734.1[16]	2.14°	23,439.08	2.7[15]	22.1
S/2011 J1	736.35		23,446	1[15]	23.7[R]
S/2010 J1	736.5		23,449	1[15]	23.2[R]
Eukelade	735.27[16]	2.14°	23,485.28	2.0[15]	22.6
S/2003 J5	738.75	2.32°	23,495	2[15]	22.4[R]
S/2003 J19	740.41	2.2°	23,533	1[15]	23.7[R]
Cyllene	737.80[16]	2.14°	23,544.84	1.0[15]	23.2
S/2017 J1	734.2		23,547.105	1[15]	23.8
S/2003 J23	732.46	2.32°	23,567	1[15]	23.6[R]
Pasiphae	743.61[16]	2.16°	23,629.00	18[15]	17.0
Aoede	747[16]	2.16°	23,743.83	2.0[15]	22.5
Arche	748.7[16]	2.16°	23,765.12	1.5[15]	22.8
Pasithee	748.76[16]	2.17°	23,780.14	1.0[15]	23.2
Eurydome	752.4[16]	2.17°	23,830.94	1.5[15]	22.7
S/2003 J4	755.25	2.24°	23,929	1[15]	23.0[R]
Sinope	758.89[16]	2.17°	23,942.00	14[15]	18.1
Kalyke	767[16]	2.20°	24,135.61	2.6[15]	21.8
Autonoe	778.0[16]	2.22°	24,413.09	2.0[15]	22.0
Callirrhoe	736[16]	2.24°	24,596.24	4.3[15]	20.7
Kore	807.20[16]	2.27°	24,974.03	1.0[15]	23.6
S/2003 J2	980.53	2.71°	28,347	1[15]	23.2[R]
Saturn					
S/2009 S1	0.4715	19"	117	0.15	
Pan	0.575	22"	133.58	14.2	19.4
Daphnis	0.594	22"	136.50	3.9	23.4
Atlas	0.602	22"	137.67	20.9 × 18.1 × 8.9	19.0
Prometheus	0.613	22"	139.38	66.3 × 39.5 × 30.7	15.8
Pandora	0.629	23"	141.72	51.6 × 39.8 × 32.0	16.4
Epimetheus	0.694	24"	151.41	58.0 × 58.7 × 53.2	15.6
Janus	0.695	24"	151.46	97.4 × 96.9 × 77.2	14.4
Aegaeon	0.8081	27"[15]	167.5	0.25	27[R]
Mimas	0.942421813	30"	185.54	207 × 197 × 191	12.8
Methone	1.01	31"	194.44	1.6	25.1
Anthe	1.037	32"	197.70	1[15]	26[15]
Pallene	1.14	34"	212.28	2.2	24.5
Enceladus	1.370217855	38"	238.20	257 × 251 × 248	11.8
Calypso	1.888	48"	294.71	15.0×11.5×7	18.7
Telesto	1.888	48"	294.71	15.7 × 11.7 × 10.4	18.5
Tethys	1.887802160	48"	294.99	540 × 531 × 528	10.3
Polydeuces	2.74	1.0'	377.20	1.3	24.8
Helene	2.737	1.0'	377.42	16.5	18.4
Dione	2.736914742	1.0'	377.65	562	10.4
Rhea	4.517500436	1.4'	527.37	764	9.7
Titan	15.94542068	3.3'	1,221.80	2,575	8.4
Hyperion	21.2766088	4.0'	1,481.10	164 × 130 × 107	14.4
Iapetus	79.3301825	9.6'	3,561.85	736	11.0
Kiviuq	449.2	30.5'	11,319.01	8[15]	22.7
Ijiraq	451.4	30.6'	11,359.25	6[15]	22.6
Phoebe	548.2[16]	34.7'	12,893.24	110	16.7
Paaliaq	686.9	40.3'	14,985.05	13[15]	21.0
Skathi	728.2[16]	41.6'	15,471.94	4[15]	23.6
S/2004 S37[17]	752.88		16003.3	2[15]	25.1
Albiorix	783.5	44.4'	16,495.93	16[15]	20.5
S/2007 S2	799.8975	0.78°	16,560	3	24.4
Bebhionn	834.8	45.6'	16,950.00	3[15]	24.1
S/2004 S31[17]	853.80		17402.8	2[15]	24.9
S/2004 S29[17]	858.77		17470.7	2[15]	24.9
Skoll	878.3[16]	47.4'	17,610.00	3[15]	24.5
Erriapus	871.2	47.9'	17,807.71	5[15]	23.9
Tarqeq	887.5	48.2'	17,920.00	3.5[15]	23.9
Tarvos	926.2	48.4'	17,977.24	7[15]	22.3
Greip	921.2[16]	48.7'	18,105.00	3[15]	24.4
Siarnaq	895.6	49.0'	18,201.44	21[15]	20.4
Hyrrokkin	931.8[16]	49.0'	18,217.13	4[15]	23.5
Mundilfari	952.6[16]	49.5'	18,412.67	3[15]	23.8
S/2004 S13	905.82	0.88°	18,450	3	24.5
S/2004 S17	913.125	0.89°	18,600	2	25.2
Bergelmir	1,005.9[16]	50.4'	18,750.00	3[15]	24.2
S/2006 S1	971.565	54'	18,981.135	3	24.6
Narvi	1,003.9[16]	51.5'	19,140.48	2.5[15]	23.8
Suttungr	1,016.7[16]	51.6'	19,185.70	4[15]	23.9
S/2004 S20[17]	990.23		19211	2[15]	25.0
Aegir	1,116.5[16]	52.1'	19,350.00	3[15]	24.4
S/2004 S12	1,048.2675	57'	19,650	2.5	24.8
Bestla	1,083.6[16]	52.9'	19,650.00	3.5[15]	23.8
S/2004 S27[17]	1033.0		19776.7	2[15]	24.5
S/2004 S7	1,103.055	57'	19,800	3	24.5
Farbauti	1,086.1[16]	53.3'	19,800.00	2.5[15]	24.7
Hati	1,038.7[16]	53.7'	19,950.00	3[15]	24.4
Thrymr	1,094.3[16]	53.7'	19,957.54	4[15]	23.9
S/2004 S22[17]	1080.4		20379.9	1.5[15]	25.3
S/2004 S30[17]	1084.1		20424	1.5[15]	25.4
S/2004 S25[17]	1095.0		20544.5	1.5[15]	25.2
S/2007 S3	1,099.4025	58.8'	20,578	2.5	24.9
S/2006 S3	1,143.2325	1°	21,132	3	24.6
S/2004 S23[17]	1164.3		21427	2[15]	24.8
S/2004 S32[17]	1175.3		21564.2	2[15]	25.0
S/2004 S28[17]	1197.2		21791.3	2[15]	24.9
S/2004 S35[17]	1208.1		21953.2	2[15]	24.6
Fenrir	1,260.3[16]	59.7'	22,200.00	2[15]	25.0
Fornjot	1,490.9[16]	59.7'	22,200.00	3[15]	24.6
Surtur	1,297.7[16]	60.0'	22,290.00	3[15]	24.8
Kari	1,233.6[16]	1.00°	22,350.00	3.5[15]	23.9
S/2004 S39[17]	1277.5		22790.4	1[15]	25.5
S/2004 S38[17]	1295.8		23006.2	2[15]	25.1
Jarnsaxa	964.7[16]	1.04°	23,190.00	3[15]	24.7
Loge	1,312.0[16]	1.04°	23,190.00	3[15]	24.6
S/2004 S24[17]	1317.6		23231.3	1.5[15]	25.2
Ymir	1,315.4[16]	1.04°	23,305.87	10[15]	22.4
S/2004 S36[17]	1354.2		23698.7	1.5[15]	25.3
S/2004 S33[17]	1361.5		23764.8	2[15]	25.0
S/2004 S21[17]	1365.1		23810.4	1.5[15]	25.4
S/2004 S34[17]	1412.5		24358.9	1.5[15]	25.3
S/2004 S26[17]	1624.2		26737.8	2[15]	25.0
Uranus					
Cordelia	0.335	4"	49.75	25×18×18	23.1
Ophelia	0.376	4"	53.76	27×19×19	22.8
Bianca	0.435	4"	59.17	27	22.0
Cressida	0.46356960	5"	61.77	41	21.1
Desdemona	0.47364960	5"	62.66	35	21.5
Juliet	0.49306549	5"	64.36	53	20.6
Portia	0.51319592	5"	66.10	70	19.9
Rosalind	0.55845953	5"	69.93	36	21.3
Cupid	0.616	6"	74.80	8.9	25.9
Belinda	0.62352747	6"	75.26	45	21.0
Perdita	0.638	6"	76.42	13.3	24.0
Puck	0.76183287	7"	86.00	81	19.2
Mab	0.923	7"	97.73	12.4	25.4
Miranda	1.41347925	10"	129.87	240 × 234 × 233	15.3
Ariel	2.52037935	14"	190.95	581 × 578 × 578	13.2
Umbriel	4.1441772	20"	266.00	585	14.0
Titania	8.7058717	33"	436.30	789	13.0
Oberon	13.4632389	44"	583.52	761	13.2
Francisco	266.6[16]	5.4'	4,276.00	7[15]	25.0
Caliban	579.6[16]	9.1'	7,170.00	49	22.4
Stephano	675.7[16]	10.3'	7,942.00	10[15]	24.1
Trinculo	759.7[16]	10.8'	8,571.02	7[15]	25.4
Sycorax	1,289.0[16]	15.4'	12,216.00	95	20.8
Margaret	1,694.8	18.1'	14,345.00	7.5[15]	25.2
Prospero	1,948.1[16]	20.3'	16,089.00	15[15]	23.2
Setebos	2,303.1[16]	22.7'	17,988.00	17.5[15]	23.3
Ferdinand	2,823.4[16]	26.4'	20,901.00	8[15]	25.1
Neptune					
Naiad	0.294	2"	48.227	33	23.9
Thalassa	0.311	2"	50.075	41	23.3
Despina	0.334655	2"	52.526	75	22.0
Galatea	0.428745	3"	61.953	88	21.9
Larissa	0.554654	3"	73.548	97	21.5
S/2004 N1	0.950	5"	105.284	9	26.5
Proteus	1.122315	6"	117.647	210	19.8
Triton	5.8768541[16]	17"	354.759	1,353	13.0
Nereid	360.13	4.4'	5,513.4	170	19.7
Halimede	1,881.00	12.4'	15,728.00	25[15]	24.5
Sao	2,914.63	17.7'	22,422.00	13.5[15]	25.4
Laomedeia	3,166.65	18.6'	23,571.00	16.5[15]	25.4
Psamathe	9,116.45	36.9'	46,695.00	18[15]	25.6
Neso	9,737.36	38.3'	48,387.00	21.5[15]	24.6
Pluto					
Charon	6.38723	1"	19.571	604	17.3
Styx	20.16	2"	42.393	10	27.0
Nix	24.8562	2"	48.671	13	23.4
Kerberos	32.17	2"	57.729	14	26.1
Hydra	38.2065	2"	64.698	30.5	22.9

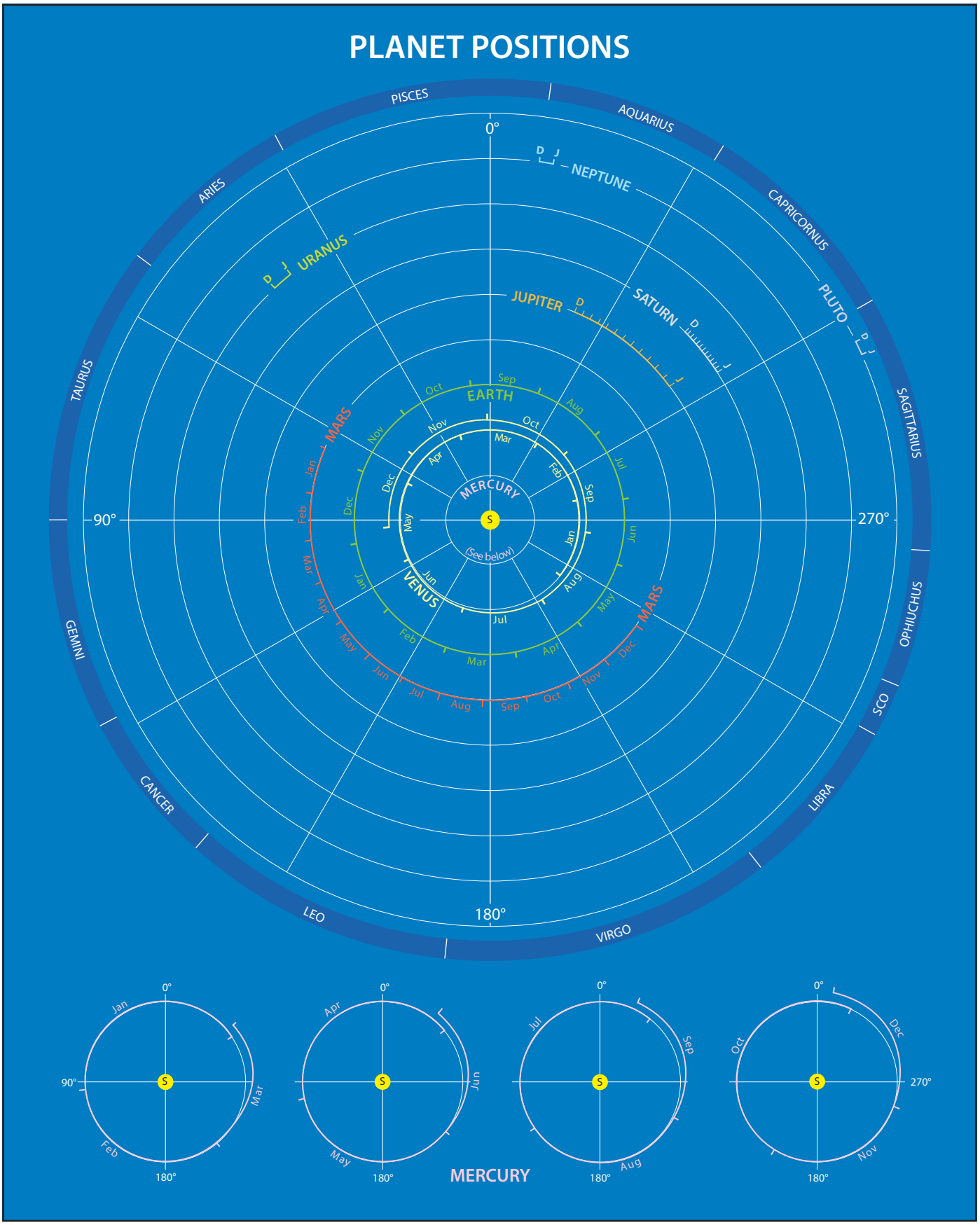
DECLINATIONS of the SUN, PLANETS and PLUTO



In general, the further south a planet is (lower declination), the higher in the northern sky it is, as seen from most of Australia. The higher in the sky, the less atmosphere you have to look through and the more stable the image being less prone to turbulence. This can be particularly relevant when trying to observe a planet under high magnification.

MAGNITUDES of the PLANETS, BRIGHT DWARF and MINOR PLANETS





This diagram illustrates the relative positions of the planets during the course of their orbits in 2021. The relationships between the major Solar System bodies are clearly shown. The diagram is drawn as viewed from above (north of) the Solar System. The drawing has been simplified in that the planetary orbits are not shown as ellipses and the Sun and planet distances are not drawn to scale. The thirteen named constellations are those situated on the ecliptic.

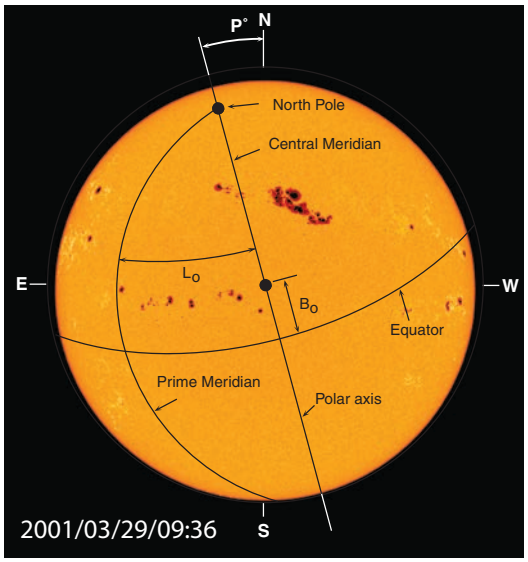
SUN RISE, SUN SET and ASTRONOMICAL TWILIGHT

	ADELAIDE (CST)				BRISBANE (EST)				CANBERRA (EST)				DARWIN (CST)				
	Twilight	Sun		Twilight	Twilight	Sun		Twilight	Twilight	Sun		Twilight	Twilight	Sun		Twilight	
	Begin	Rise	Set	End	Begin	Rise	Set	End	Begin	Rise	Set	End	Begin	Rise	Set	End	
Jan 2	03:20	05:06	19:33	21:18	03:25	04:57	18:47	20:19	03:06	04:53	19:22	21:08	05:07	06:26	19:16	20:35	Jan 2
9	03:28	05:12	19:33	21:17	03:31	05:02	18:48	20:19	03:14	04:59	19:22	21:06	05:12	06:30	19:18	20:36	9
16	03:37	05:19	19:32	21:13	03:38	05:07	18:48	20:17	03:23	05:06	19:20	21:03	05:17	06:34	19:20	20:37	16
23	03:46	05:26	19:29	21:08	03:45	05:13	18:46	20:14	03:33	05:13	19:17	20:57	05:21	06:37	19:20	20:36	23
30	03:56	05:33	19:24	21:01	03:53	05:19	18:43	20:09	03:43	05:20	19:13	20:50	05:25	06:41	19:20	20:35	30
Feb 6	04:06	05:40	19:19	20:53	04:00	05:24	18:39	20:03	03:52	05:27	19:07	20:42	05:29	06:43	19:19	20:33	Feb 6
13	04:15	05:47	19:12	20:43	04:07	05:30	18:34	19:57	04:02	05:35	19:00	20:32	05:33	06:46	19:17	20:30	13
20	04:24	05:54	19:04	20:34	04:13	05:35	18:28	19:50	04:11	05:42	18:52	20:22	05:35	06:48	19:14	20:26	20
27	04:33	06:01	18:55	20:23	04:19	05:39	18:22	19:42	04:20	05:48	18:44	20:12	05:37	06:49	19:10	20:22	27
Mar 6	04:40	06:07	18:46	20:13	04:24	05:44	18:14	19:34	04:27	05:54	18:34	20:01	05:39	06:50	19:07	20:18	Mar 6
13	04:47	06:13	18:37	20:02	04:29	05:48	18:07	19:25	04:35	06:01	18:25	19:50	05:40	06:51	19:02	20:13	13
20	04:54	06:19	18:27	19:52	04:33	05:51	17:59	19:17	04:41	06:06	18:15	19:40	05:41	06:51	18:58	20:08	20
27	05:00	06:24	18:17	19:41	04:37	05:55	17:51	19:09	04:48	06:12	18:05	19:29	05:41	06:51	18:53	20:04	27
Apr 3	05:06	06:30	18:08	19:31	04:41	05:59	17:44	19:01	04:53	06:18	17:55	19:20	05:41	06:52	18:49	19:59	Apr 3
10	05:11	06:35	17:58	19:22	04:44	06:02	17:36	18:54	04:59	06:23	17:46	19:10	05:41	06:52	18:45	19:55	10
17	05:16	06:41	17:49	19:14	04:48	06:06	17:29	18:47	05:04	06:29	17:37	19:02	05:41	06:53	18:41	19:52	17
24	05:21	06:46	17:41	19:06	04:51	06:09	17:22	18:41	05:09	06:35	17:28	18:54	05:42	06:53	18:37	19:49	24
May 1	05:26	06:52	17:33	18:59	04:54	06:13	17:16	18:36	05:14	06:40	17:21	18:47	05:42	06:54	18:34	19:46	May 1
8	05:31	06:57	17:27	18:53	04:57	06:17	17:11	18:31	05:19	06:46	17:14	18:41	05:42	06:55	18:32	19:45	8
15	05:35	07:03	17:21	18:49	05:00	06:21	17:07	18:28	05:23	06:51	17:08	18:36	05:43	06:57	18:30	19:43	15
22	05:39	07:08	17:16	18:45	05:03	06:25	17:04	18:26	05:28	06:56	17:04	18:32	05:44	06:59	18:29	19:43	22
29	05:43	07:13	17:13	18:42	05:06	06:29	17:02	18:24	05:32	07:01	17:00	18:30	05:46	07:01	18:28	19:43	29
Jun 5	05:47	07:17	17:11	18:41	05:09	06:32	17:01	18:23	05:35	07:06	16:58	18:29	05:47	07:03	18:28	19:44	Jun 5
12	05:50	07:20	17:11	18:41	05:12	06:35	17:00	18:24	05:38	07:09	16:58	18:28	05:49	07:05	18:29	19:45	12
19	05:52	07:23	17:11	18:42	05:14	06:37	17:01	18:25	05:40	07:11	16:58	18:29	05:51	07:06	18:30	19:46	19
26	05:53	07:24	17:13	18:44	05:15	06:39	17:03	18:26	05:42	07:13	17:00	18:31	05:52	07:08	18:32	19:48	26
Jul 3	05:54	07:24	17:16	18:46	05:16	06:39	17:05	18:29	05:42	07:13	17:03	18:33	05:53	07:09	18:34	19:49	Jul 3
10	05:53	07:23	17:19	18:49	05:16	06:38	17:08	18:31	05:41	07:11	17:06	18:37	05:54	07:09	18:36	19:51	10
17	05:51	07:20	17:24	18:53	05:15	06:37	17:12	18:34	05:39	07:09	17:11	18:40	05:54	07:09	18:37	19:52	17
24	05:48	07:16	17:28	18:57	05:13	06:34	17:15	18:37	05:36	07:05	17:15	18:44	05:54	07:08	18:39	19:53	24
31	05:44	07:11	17:33	19:01	05:09	06:30	17:19	18:39	05:32	07:00	17:21	18:48	05:53	07:07	18:41	19:54	31
Aug 7	05:38	07:05	17:39	19:05	05:05	06:25	17:23	18:42	05:27	06:53	17:26	18:52	05:51	07:04	18:42	19:54	Aug 7
14	05:32	06:57	17:44	19:09	05:01	06:20	17:26	18:45	05:20	06:46	17:31	18:57	05:49	07:01	18:42	19:55	14
21	05:24	06:49	17:49	19:14	04:55	06:13	17:29	18:48	05:12	06:38	17:36	19:01	05:46	06:58	18:43	19:54	21
28	05:16	06:40	17:54	19:18	04:48	06:06	17:33	18:51	05:04	06:29	17:41	19:06	05:43	06:54	18:43	19:54	28
Sep 4	05:07	06:31	17:59	19:23	04:41	05:59	17:36	18:54	04:55	06:19	17:47	19:11	05:39	06:49	18:43	19:54	Sep 4
11	04:57	06:21	18:04	19:28	04:33	05:51	17:39	18:57	04:45	06:09	17:52	19:16	05:34	06:44	18:43	19:54	11
18	04:47	06:11	18:09	19:33	04:25	05:43	17:42	19:00	04:35	05:59	17:57	19:21	05:29	06:40	18:43	19:53	18
25	04:37	06:01	18:14	19:39	04:17	05:34	17:45	19:03	04:24	05:49	18:02	19:27	05:24	06:35	18:43	19:53	25
Oct 2	04:26	05:51	18:19	19:45	04:08	05:26	17:49	19:07	04:13	05:39	18:07	19:33	05:19	06:30	18:43	19:54	Oct 2
9	04:15	05:42	18:25	19:52	03:59	05:19	17:52	19:12	04:02	05:29	18:13	19:40	05:14	06:26	18:43	19:55	9
16	04:04	05:32	18:31	19:59	03:51	05:11	17:56	19:17	03:51	05:20	18:19	19:48	05:10	06:21	18:44	19:56	16
23	03:54	05:24	18:37	20:07	03:43	05:05	18:00	19:22	03:41	05:11	18:25	19:56	05:05	06:18	18:45	19:58	23
30	03:44	05:16	18:43	20:16	03:35	04:59	18:05	19:28	03:30	05:03	18:32	20:05	05:02	06:15	18:47	20:00	30
Nov 6	03:34	05:09	18:50	20:25	03:29	04:53	18:10	19:35	03:21	04:56	18:38	20:14	04:58	06:13	18:49	20:03	Nov 6
13	03:26	05:03	18:57	20:34	03:23	04:49	18:15	19:42	03:13	04:50	18:45	20:24	04:56	06:11	18:51	20:07	13
20	03:19	04:59	19:04	20:44	03:18	04:47	18:21	19:49	03:06	04:46	18:52	20:33	04:55	06:11	18:54	20:11	20
27	03:14	04:56	19:11	20:53	03:15	04:45	18:26	19:56	03:00	04:43	18:59	20:43	04:54	06:11	18:58	20:15	27
Dec 4	03:11	04:55	19:17	21:01	03:14	04:45	18:32	20:03	02:57	04:42	19:06	20:51	04:55	06:13	19:02	20:20	Dec 4
11	03:09	04:55	19:23	21:09	03:14	04:46	18:37	20:09	02:55	04:42	19:11	20:58	04:57	06:15	19:05	20:24	11
18	03:10	04:57	19:27	21:14	03:15	04:48	18:41	20:13	02:56	04:44	19:16	21:04	04:59	06:18	19:09	20:28	18
25	03:14	05:00	19:31	21:17	03:19	04:51	18:44	20:17	03:00	04:47	19:19	21:07	05:03	06:21	19:13	20:31	25

SUN RISE, SUN SET and ASTRONOMICAL TWILIGHT

	HOBART (EST)				MELBOURNE (EST)				PERTH (WST)				SYDNEY (EST)				
	Twilight	Sun		Twilight	Twilight	Sun		Twilight	Twilight	Sun		Twilight	Twilight	Sun		Twilight	
	Begin	Rise	Set	End	Begin	Rise	Set	End	Begin	Rise	Set	End	Begin	Rise	Set	End	
Jan 2	02:22	04:37	19:53	22:07	03:08	05:02	19:46	21:39	03:35	05:15	19:26	21:05	03:05	04:48	19:10	20:53	Jan 2
9	02:33	04:44	19:52	22:02	03:16	05:08	19:45	21:37	03:42	05:20	19:27	21:04	03:12	04:54	19:10	20:52	9
16	02:46	04:52	19:49	21:55	03:26	05:16	19:43	21:32	03:50	05:27	19:26	21:02	03:20	05:00	19:09	20:48	16
23	03:00	05:01	19:44	21:45	03:37	05:23	19:40	21:25	03:59	05:33	19:23	20:57	03:30	05:07	19:06	20:43	23
30	03:14	05:10	19:38	21:33	03:48	05:31	19:35	21:17	04:08	05:40	19:20	20:51	03:39	05:14	19:02	20:37	30
Feb 6	03:28	05:20	19:30	21:21	03:59	05:39	19:28	21:08	04:16	05:46	19:15	20:44	03:49	05:21	18:56	20:29	Feb 6
13	03:42	05:29	19:20	21:07	04:10	05:47	19:21	20:57	04:25	05:53	19:09	20:36	03:58	05:28	18:50	20:20	13
20	03:55	05:39	19:10	20:54	04:20	05:55	19:12	20:46	04:33	05:59	19:02	20:27	04:06	05:35	18:42	20:10	20
27	04:07	05:48	18:59	20:40	04:30	06:02	19:03	20:34	04:40	06:04	18:54	20:18	04:14	05:41	18:34	20:01	27
Mar 6	04:18	05:57	18:48	20:26	04:39	06:09	18:53	20:23	04:47	06:10	18:46	20:09	04:21	05:47	18:25	19:50	Mar 6
13	04:28	06:05	18:35	20:12	04:47	06:16	18:42	20:11	04:53	06:15	18:37	19:59	04:28	05:53	18:16	19:40	13
20	04:38	06:13	18:23	19:58	04:55	06:23	18:32	20:00	04:58	06:20	18:28	19:49	04:34	05:58	18:07	19:30	20
27	04:47	06:22	18:11	19:45	05:02	06:29	18:21	19:48	05:03	06:25	18:19	19:40	04:40	06:03	17:57	19:20	27
Apr 3	04:56	06:30	17:59	19:33	05:08	06:36	18:11	19:38	05:08	06:29	18:10	19:31	04:46	06:09	17:48	19:10	Apr 3
10	05:03	06:37	17:47	19:21	05:15	06:42	18:00	19:27	05:13	06:34	18:01	19:23	04:51	06:14	17:39	19:01	10
17	05:11	06:45	17:36	19:10	05:21	06:48	17:50	19:18	05:17	06:39	17:53	19:15	04:56	06:19	17:30	18:53	17
24	05:18	06:53	17:25	19:00	05:26	06:55	17:41	19:10	05:21	06:43	17:46	19:08	05:00	06:24	17:22	18:46	24
May 1	05:25	07:01	17:15	18:51	05:32	07:01	17:33	19:02	05:25	06:48	17:39	19:02	05:05	06:30	17:14	18:39	May 1
8	05:32	07:09	17:06	18:43	05:37	07:07	17:25	18:55	05:29	06:53	17:33	18:56	05:09	06:35	17:08	18:33	8
15	05:38	07:16	16:58	18:37	05:42	07:13	17:19	18:50	05:33	06:58	17:28	18:52	05:14	06:40	17:02	18:29	15
22	05:44	07:23	16:52	18:32	05:47	07:19	17:14	18:46	05:37	07:03	17:24	18:49	05:18	06:45	16:58	18:25	22
29	05:49	07:29	16:47	18:28	05:51	07:24	17:10	18:43	05:41	07:07	17:21	18:47	05:21	06:50	16:55	18:23	29
Jun 5	05:53	07:35	16:44	18:26	05:55	07:29	17:08	18:42	05:44	07:11	17:19	18:46	05:25	06:54	16:53	18:22	Jun 5
12	05:57	07:39	16:43	18:25	05:58	07:33	17:07	18:41	05:47	07:14	17:19	18:46	05:28	06:57	16:53	18:22	12
19	05:59	07:42	16:43	18:26	06:01	07:35	17:08	18:42	05:49	07:16	17:20	18:47	05:30	06:59	16:53	18:23	19
26	06:00	07:43	16:45	18:28	06:02	07:36	17:09	18:44	05:50	07:18	17:21	18:49	05:31	07:01	16:55	18:24	26
Jul 3	06:00	07:42	16:48	18:30	06:02	07:36	17:12	18:46	05:51	07:18	17:24	18:51	05:32	07:01	16:58	18:27	Jul 3
10	05:59	07:40	16:53	18:34	06:01	07:35	17:16	18:50	05:50	07:17	17:27	18:54	05:31	07:00	17:01	18:30	10
17	05:56	07:36	16:59	18:39	05:59	07:32	17:21	18:54	05:49	07:14	17:31	18:57	05:29	06:57	17:05	18:33	17
24	05:52	07:31	17:05	18:44	05:56	07:27	17:26	18:58	05:46	07:11	17:36	19:01	05:26	06:53	17:10	18:37	24
31	05:46	07:24	17:12	18:50	05:51	07:21	17:32	19:02	05:42	07:06	17:40	19:04	05:22	06:48	17:15	18:41	31
Aug 7	05:39	07:16	17:19	18:56	05:45	07:14	17:38	19:07	05:37	07:01	17:44	19:08	05:17	06:42	17:20	18:45	Aug 7
14	05:31	07:06	17:26	19:02	05:38	07:06	17:44	19:12	05:31	06:54	17:49	19:12	05:11	06:35	17:25	18:49	14
21	05:21	06:56	17:34	19:08	05:29	06:57	17:49	19:18	05:25	06:47	17:53	19:15	05:04	06:27	17:29	18:53	21
28	05:10	06:45	17:41	19:15	05:20	06:48	17:55	19:23	05:17	06:39	17:58	19:19	04:56	06:19	17:34	18:57	28
Sep 4	04:59	06:33	17:48	19:22	05:10	06:38	18:01	19:28	05:09	06:30	18:02	19:23	04:47	06:10	17:39	19:02	Sep 4
11	04:47	06:20	17:56	19:30	05:00	06:27	18:07	19:34	05:00	06:21	18:06	19:27	04:37	06:00	17:44	19:07	11
18	04:34	06:08	18:03	19:38	04:49	06:16	18:13	19:41	04:51	06:12	18:10	19:32	04:27	05:51	17:48	19:12	18
25	04:20	05:56	18:11	19:47	04:37	06:05	18:19	19:47	04:41	06:02	18:15	19:36	04:17	05:41	17:53	19:17	25
Oct 2	04:06	05:43	18:19	19:56	04:25	05:54	18:25	19:54	04:31	05:53	18:19	19:42	04:07	05:31	17:58	19:23	Oct 2
9	03:52	05:31	18:27	20:06	04:13	05:44	18:31	20:02	04:21	05:44	18:24	19:47	03:56	05:22	18:04	19:29	9
16	03:38	05:19	18:35	20:17	04:01	05:34	18:38	20:11	04:11	05:36	18:29	19:54	03:46	05:13	18:09	19:36	16
23	03:24	05:08	18:44	20:28	03:50	05:24	18:45	20:20	04:02	05:28	18:34	20:01	03:36	05:04	18:15	19:44	23
30	03:10	04:58	18:53	20:41	03:39	05:16	18:52	20:30	03:53	05:21	18:40	20:08	03:26	04:57	18:21	19:52	30
Nov 6	02:57	04:49	19:02	20:54	03:28	05:08	19:00	20:40	03:45	05:15	18:46	20:16	03:17	04:50	18:28	20:01	Nov 6
13	02:44	04:41	19:11	21:08	03:18	05:01	19:08	20:51	03:38	05:10	18:52	20:25	03:09	04:45	18:34	20:10	13
20	02:33	04:34	19:20	21:22	03:10	04:56	19:15	21:02	03:32	05:06	18:58	20:33	03:03	04:41	18:41	20:19	20
27	02:23	04:30	19:28	21:36	03:04	04:53	19:22	21:12	03:28	05:04	19:05	20:41	02:58	04:38	18:48	20:28	27
Dec 4	02:16	04:27	19:36	21:48	02:59	04:51	19:29	21:22	03:25	05:03	19:11	20:49	02:55	04:37	18:54	20:36	Dec 4
11	02:11	04:26	19:43	21:58	02:57	04:51	19:35	21:30	03:24	05:04	19:16	20:55	02:54	04:37	18:59	20:43	11
18	02:11	04:28	19:48	22:05	02:58	04:53	19:40	21:35	03:26	05:06	19:20	21:01	02:55	04:39	19:04	20:48	18
25	02:14	04:31	19:51	22:08	03:01	04:56	19:44	21:39	03:29	05:09	19:24	21:04	02:58	04:43	19:07	20:52	25

ORIENTATION OF THE SUN



Sun image shows active region 9393, hosting a large sunspot group. On 29 March 2001, the sunspot area within the group spanned an area of more than 13 times the entire surface of the Earth! It was the source of numerous flares and coronal mass ejections, including the largest flare recorded (at the time) in 25 years on 2 April 2001. Caused by intense magnetic fields emerging from the interior, a sunspot appears to be dark only when contrasted against the rest of the solar surface, because it is slightly cooler than the unmarked regions. Courtesy of SOHO/[MDI] consortium.

SYNODIC ROTATION NUMBERS (UT)		
Rotation	Month	d.dd
2240	Jan	22.28
2241	Feb	18.62
2242	Mar	17.94
2243	Apr	14.23
2244	May	11.48
2245	Jun	7.69
2246	Jul	4.88
2247	Aug	1.09
2248	Aug	28.33
2249	Sep	24.59
2250	Oct	21.88
2251	Nov	18.18
2252	Dec	15.50

Date (0 h UT)	P°	B_o°	L_o°
Jan 2	+ 1.5	- 3.2	266.9
9	- 1.9	- 3.9	174.8
16	- 5.2	- 4.7	082.6
23	- 8.4	- 5.3	350.4
30	- 11.4	- 5.9	258.2
Feb 6	- 14.2	- 6.4	166.1
13	- 16.8	- 6.7	073.9
20	- 19.1	- 7.0	341.7
27	- 21.0	- 7.2	249.5
Mar 6	- 22.7	- 7.3	157.3
13	- 24.1	- 7.2	065.1
20	- 25.2	- 7.1	332.8
27	- 25.9	- 6.8	240.5
Apr 3	- 26.2	- 6.4	148.2
10	- 26.2	- 6.0	055.8
17	- 25.9	- 5.5	323.4
24	- 25.2	- 4.9	230.9
May 1	- 24.1	- 4.2	138.4
8	- 22.7	- 3.4	045.9
15	- 20.9	- 2.7	313.3
22	- 18.8	- 1.9	220.8
29	- 16.5	- 1.0	128.1
Jun 5	- 13.8	- 0.2	035.5
12	- 11.0	+ 0.7	302.8
19	- 8.0	+ 1.5	210.2
26	- 4.9	+ 2.3	117.5

Date (0 h UT)	P°	B_o°	L_o°
Jul 3	- 1.7	+ 3.1	024.9
10	+ 1.5	+ 3.8	292.2
17	+ 4.6	+ 4.5	199.6
24	+ 7.6	+ 5.2	107.0
31	+ 10.5	+ 5.7	014.4
Aug 7	+ 13.2	+ 6.2	281.8
14	+ 15.7	+ 6.6	189.3
21	+ 18.0	+ 6.9	096.8
28	+ 20.0	+ 7.1	004.3
Sep 4	+ 21.8	+ 7.2	271.8
11	+ 23.3	+ 7.3	179.3
18	+ 24.5	+ 7.2	086.9
25	+ 25.4	+ 7.0	354.5
Oct 2	+ 26.0	+ 6.7	262.2
9	+ 26.3	+ 6.3	169.8
16	+ 26.1	+ 5.8	077.5
23	+ 25.7	+ 5.2	345.1
30	+ 24.8	+ 4.6	252.8
Nov 6	+ 23.5	+ 3.9	160.5
13	+ 21.9	+ 3.1	068.2
20	+ 19.9	+ 2.3	335.9
27	+ 17.5	+ 1.4	243.7
Dec 4	+ 14.9	+ 0.5	151.4
11	+ 11.9	- 0.4	059.2
18	+ 8.8	- 1.3	327.0
25	+ 5.5	- 2.2	234.7

P ° Position angle of Polar Axis. (+ when pole east of north point, – if west)

B_o° Heliocentric Latitude of centre of Sun

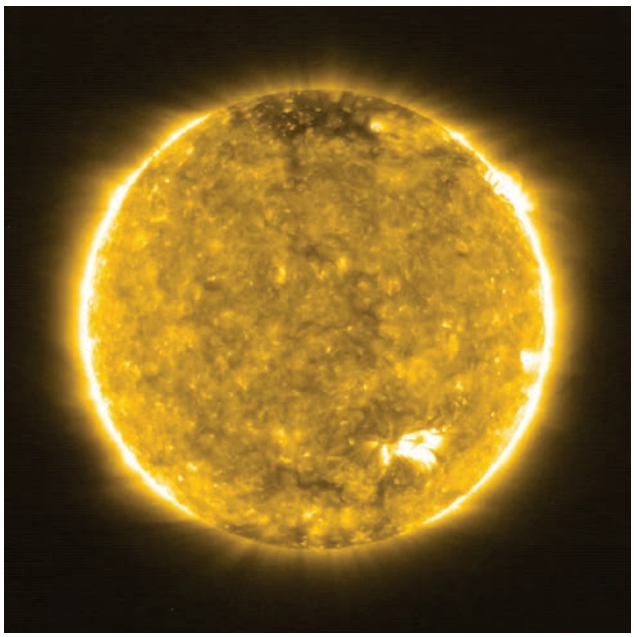
L_o° Heliocentric Longitude of centre of Sun

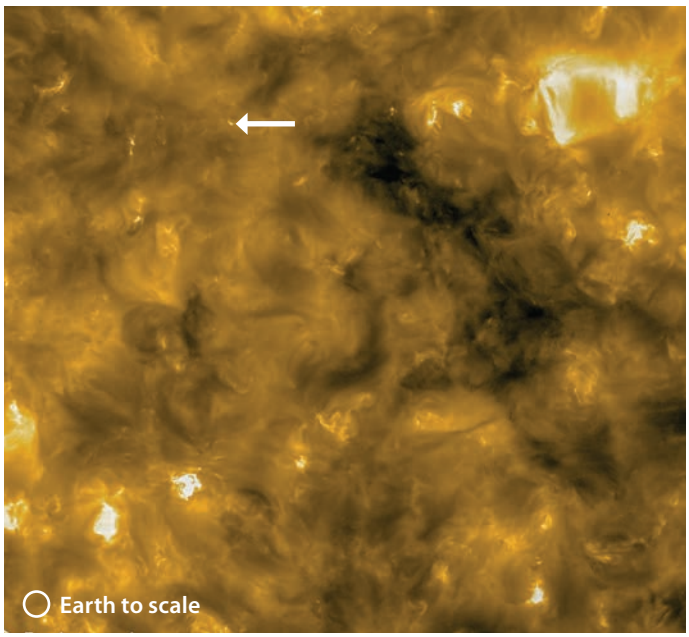
At the date of commencement of each synodic rotation period the value of L_o° is zero; that is, the prime meridian passes through the central point of the disc. The rotation period of the Sun depends on latitude. The sidereal period of rotation at the equator is 25.38 days. The mean synodic period is 27.28 days.

Example: Heliocentric Longitude value for 11 March at 2 pm WST. 2 pm WST is 6 hours UT (0 hr UT is 8 am WST). To get the value for 11 March (0 hr UT) start with the value from the main table for 6 March (157.3°) plus 4 days which from the daily variation table is –52.7°. Then you add the value for 6 hours, which is –3.3°. The calculation becomes:

157.3° + (–52.7°) + (–3.3°) = 101.3° (If negative, add 360°, if > 360°, subtract 360°)

VARIATION OF L_o°					
Daily		Hourly			
1	– 13.2	1	– 0.6	13	– 7.1
2	– 26.4	2	– 1.1	14	– 7.7
3	– 39.6	3	– 1.7	15	– 8.2
4	– 52.7	4	– 2.2	16	– 8.8
5	– 65.9	5	– 2.8	17	– 9.3
6	– 79.1	6	– 3.3	18	– 9.9
		7	– 3.8	19	– 10.4
		8	– 4.4	20	– 11.0
		9	– 4.9	21	– 11.5
		10	– 5.5	22	– 12.1
		11	– 6.0	23	– 12.6
		12	– 6.6	24	– 13.2





Extreme Ultraviolet Imager on ESA's Solar Orbiter spacecraft images, 30 May 2020. On the close-up image to the right, the arrow points to one of the ubiquitous features of the solar surface, called 'campfires'. Credit Solar Orbiter/EUI Team/ESA and NASA; CSL, IAS, MPS, PMOD/WRC, ROB, UCL/MSSL

SOLAR AND LUNAR ECLIPSES

During 2021 there are four eclipses, two of the Sun and two of the Moon. Of the solar eclipses there will an annular and a total. One of the lunar eclipses is total and the other partial.

The magnitudes quoted in this section are not a measure of brightness. For solar eclipses it is the fraction of the Sun's diameter occulted by the Moon. It is strictly a ratio of diameters and should not be confused with eclipse obscuration, which is a measure of the Sun's surface area occulted by the Moon. For lunar eclipses it is the fraction of the Moon's diameter occulted by the Earth's penumbral or umbral shadow. By convention, the magnitude for all eclipses is given at the instant of greatest eclipse.

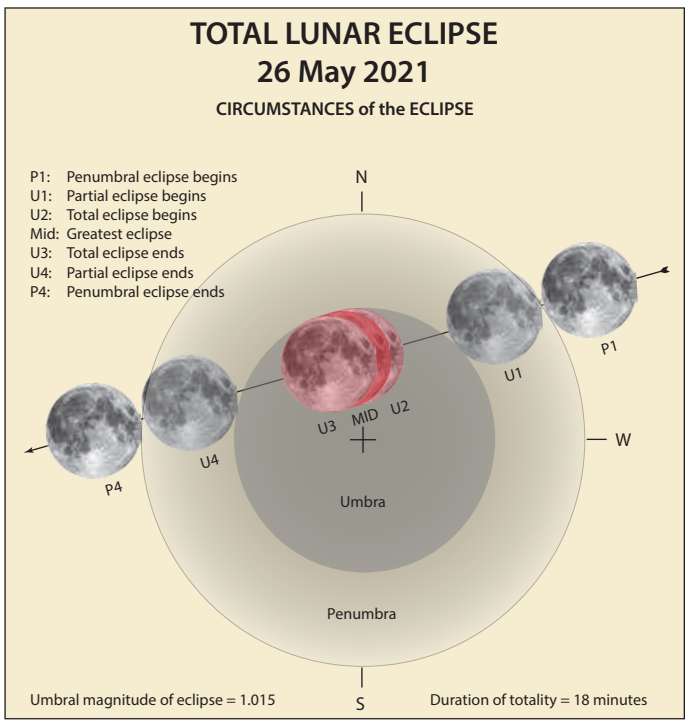
To cater for all observers, we use four time zones in the eclipse section, UT, EST, CST and WST **and no account is made for daylight saving time (add one hour if applicable)**. Carefully check the data you are using when planning your observing.

26 May — Total eclipse of the Moon

This total lunar eclipse is the first visible over Australia since 2018. From the eastern states the eclipse will be visible in its entirety. From central Australia the early penumbra stages begin during evening twilight and from Western Australia the Moon will be partially emersed in the umbral shadow by the end of twilight. The eclipse transpires in the *claw* region of the constellation of Scorpius, a little to the north of its 1st magnitude star Antares.

At this eclipse the Moon will make a very shallow pass through the umbral shadow resulting in just 18 minutes of totality. With the umbral magnitude of the eclipse at just 1.015, the lunar disc will remain relatively bright, especially along its northern limb. It is unlikely that the whole Moon will be awash with the spectacular reddish-brown hue expected when passing close to the centre of the umbra.

26 May		UT	EST	CST	WST
Penumbral eclipse begins	P1	08:46	6:46 pm	6:16 pm	4:46 pm
Partial eclipse begins	U1	09:45	7:45 pm	7:15 pm	5:45 pm
Total eclipse begins	U2	11:10	9:10 pm	8:40 pm	7:10 pm
Greatest eclipse	Mid	11:19	9:19 pm	8:49 pm	7:19 pm
Total eclipse ends	U3	11:28	9:28 pm	8:58 pm	7:28 pm
Partial eclipse ends	U4	12:53	10:53 pm	10:23 pm	8:53 pm
Penumbral eclipse ends	P4	13:51	11:51 pm	11:21 pm	9:51 pm



10 June — Annular eclipse of the Sun

The ring of fire of this annular solar eclipse follows a path across northern Canada, Greenland and north eastern Russia. Outside the area of annularity, a partial eclipse will be visible from much of Asia, Europe and the United States. Greatest eclipse of 3 minutes 51 seconds occurs in the water between Ellesmere Island (Canada) and Greenland. The eclipse magnitude is 0.9435.

19 November — Partial eclipse of the Moon

The last lunar eclipse of the year is almost a total lunar eclipse. With an umbral magnitude of 0.9742 a tiny portion of its southern limb will remain in the penumbra at mid-eclipse, and therefore classified as a partial eclipse. Unfortunately, it's not the best of eclipses for Australian viewers with mid-eclipse occurring before the end of civil twilight, with the Moon very low in altitude or below the horizon.

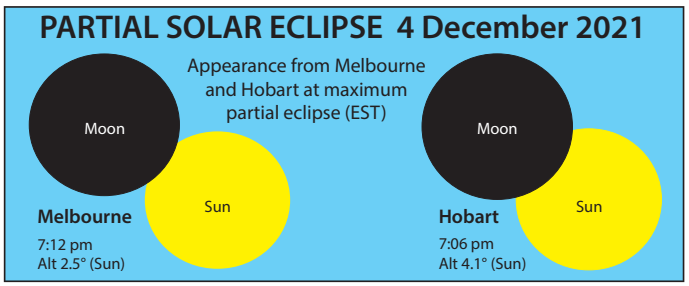
At the end of civil twilight, with the Moon past mid-eclipse, observers from the eastern states will see it mostly or partially immersed in the umbral shadow. From Western Australia the Moon will be half-way out of the penumbra.

4 December — Total eclipse of the Sun

This total eclipse of the Sun begins off the coast of Antarctica in the South Pacific Ocean, it crosses Antarctica before ending in the South Atlantic Ocean. The only way to view the total eclipse would be from one of the many cruise ships currently planned. With a magnitude of 1.0367, the duration of greatest eclipse is 1 minute 54 seconds and occurs over the ocean just off the Ronne Ice Shelf.

From parts of the very south eastern portion of mainland Australia, and all of Tasmania, a partial eclipse will be visible, albeit at a very low altitude. Using safe solar observing techniques, keen photographers with a vantage point over the ocean, could image most of the partial eclipse as the Sun sets.

Circumstances from Melbourne and Hobart (EST)



Location	Ecl. Start	Sun Alt.	Max Ecl.	Sun Alt.	Ecl. End	Sun Alt.
Melbourne	6:53 pm	5.7°	7:12 pm	2.5°	7:30 pm	−0.4°
Hobart	6:34 pm	9.3°	7:06 pm	4.1°	7:37 pm	−0.3°

ADELAIDE (CST) MOON RISE AND SET BRISBANE (EST)

	JANUARY		FEBRUARY		MARCH		APRIL	
	Rise	Set	Rise	Set	Rise	Set	Rise	Set
1	21:27	06:39	21:51	08:50	20:22	07:43	20:43	10:08
2	22:08	07:42	22:22	09:57	20:54	08:52	21:30	11:20
3	22:44	08:48	22:54	11:04	21:28	10:02	22:24	12:29
4	23:17	09:53	23:28	12:12	22:06	11:12	23:23	13:32
5	23:49	10:59	DNR	13:21	22:48	12:22	DNR	14:27
6	DNR	12:05	00:06	14:30	23:35	13:31	00:25	15:13
7	00:20	13:11	00:49	15:38	DNR	14:37	01:29	15:52
8	00:52	14:20	01:39	16:42	00:30	15:36	02:31	16:26
9	01:28	15:30	02:36	17:40	01:29	16:28	03:32	16:55
10	02:08	16:41	03:38	18:31	02:32	17:12	04:31	17:22
11	02:55	17:50	04:43	19:14	03:36	17:50	05:28	17:48
12	03:49	18:54	05:47	19:50	04:38	18:22	06:24	18:14
13	04:49	19:50	06:50	20:22	05:39	18:52	07:21	18:41
14	05:54	20:39	07:51	20:51	06:38	19:19	08:17	19:10
15	07:00	21:19	08:49	21:18	07:35	19:45	09:14	19:42
16	08:04	21:54	09:46	21:44	08:32	20:11	10:11	20:18
17	09:05	22:24	10:42	22:11	09:28	20:39	11:08	21:00
18	10:04	22:51	11:38	22:39	10:25	21:09	12:03	21:47
19	11:01	23:18	12:34	23:10	11:22	21:42	12:55	22:41
20	11:57	23:44	13:32	23:46	12:19	22:21	13:43	23:40
21	12:53	DNS	14:29	DNS	13:16	23:05	14:26	DNS
22	13:49	00:11	15:26	00:27	14:10	23:56	15:05	00:43
23	14:46	00:41	16:21	01:15	15:02	DNS	15:40	01:49
24	15:44	01:14	17:11	02:10	15:49	00:53	16:13	02:56
25	16:42	01:52	17:57	03:11	16:31	01:56	16:45	04:05
26	17:39	02:37	18:38	04:17	17:09	03:02	17:18	05:16
27	18:32	03:28	19:15	05:25	17:44	04:11	17:54	06:29
28	19:21	04:26	19:49	06:34	18:18	05:20	18:34	07:43
29	20:05	05:30			18:51	06:31	19:19	08:59
30	20:44	06:36			19:25	07:42	20:12	10:13
31	21:18	07:43			20:02	08:55		

	MAY		JUNE		JULY		AUGUST	
1	21:11	11:21	23:16	12:29	DNR	12:00	00:45	11:47
2	22:15	12:21	DNR	13:02	00:05	12:26	01:42	12:18
3	23:20	13:12	00:18	13:31	01:02	12:52	02:40	12:52
4	DNR	13:54	01:17	13:57	01:58	13:18	03:37	13:32
5	00:24	14:29	02:13	14:23	02:54	13:47	04:34	14:18
6	01:26	15:00	03:09	14:49	03:51	14:19	05:27	15:11
7	02:25	15:27	04:05	15:16	04:49	14:55	06:17	16:09
8	03:23	15:53	05:02	15:45	05:46	15:37	07:01	17:11
9	04:19	16:18	05:59	16:18	06:42	16:25	07:41	18:15
10	05:15	16:45	06:56	16:57	07:34	17:20	08:16	19:20
11	06:11	17:12	07:53	17:41	08:22	18:19	08:48	20:24
12	07:08	17:43	08:48	18:31	09:04	19:21	09:18	21:30
13	08:05	18:18	09:38	19:26	09:41	20:24	09:48	22:35
14	09:02	18:58	10:24	20:26	10:15	21:28	10:19	23:43
15	09:58	19:43	11:04	21:27	10:46	22:32	10:52	DNS
16	10:51	20:35	11:40	22:31	11:15	23:36	11:30	00:52
17	11:40	21:31	12:12	23:34	11:45	DNS	12:15	02:02
18	12:24	22:32	12:43	DNS	12:17	00:42	13:07	03:12
19	13:03	23:35	13:13	00:39	12:52	01:51	14:06	04:18
20	13:38	DNS	13:44	01:45	13:33	03:02	15:12	05:17
21	14:11	00:40	14:17	02:54	14:21	04:14	16:21	06:07
22	14:42	01:46	14:56	04:06	15:17	05:24	17:29	06:50
23	15:13	02:53	15:41	05:20	16:21	06:30	18:34	07:26
24	15:47	04:03	16:34	06:34	17:30	07:27	19:37	07:57
25	16:24	05:15	17:36	07:45	18:40	08:15	20:37	08:26
26	17:06	06:30	18:43	08:47	19:47	08:55	21:36	08:52
27	17:56	07:46	19:52	09:40	20:51	09:29	22:34	09:19
28	18:53	09:00	21:00	10:24	21:52	09:59	23:31	09:46
29	19:58	10:06	22:05	11:00	22:51	10:26	DNR	10:16
30	21:05	11:03	23:06	11:32	23:48	10:53	00:29	10:49
31	22:12	11:50			DNR	11:19	01:27	11:26

	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
1	02:24	12:10	02:49	12:40	03:13	14:37	02:41	15:37
2	03:18	12:59	03:32	13:42	03:44	15:43	03:13	16:49
3	04:09	13:55	04:10	14:46	04:14	16:52	03:49	18:04
4	04:56	14:56	04:44	15:52	04:45	18:03	04:32	19:20
5	05:37	16:00	05:16	16:59	05:20	19:18	05:23	20:35
6	06:14	17:05	05:47	18:07	06:00	20:34	06:23	21:42
7	06:48	18:11	06:18	19:17	06:46	21:48	07:30	22:39
8	07:19	19:18	06:51	20:28	07:41	22:57	08:41	23:25
9	07:49	20:25	07:27	21:42	08:43	23:57	09:52	DNS
10	08:20	21:34	08:08	22:55	09:50	DNS	10:59	00:04
11	08:53	22:44	08:56	DNS	10:58	00:48	12:02	00:36
12	09:30	23:55	09:52	00:04	12:04	01:29	13:02	01:04
13	10:12	DNS	10:54	01:08	13:08	02:03	14:00	01:31
14	11:02	01:05	12:00	02:02	14:09	02:33	14:58	01:56
15	11:58	02:11	13:07	02:48	15:08	03:00	15:55	02:22
16	13:02	03:12	14:12	03:27	16:06	03:26	16:53	02:50
17	14:08	04:04	15:15	04:00	17:03	03:52	17:51	03:21
18	15:15	04:48	16:15	04:29	18:01	04:18	18:48	03:56
19	16:20	05:25	17:14	04:56	18:59	04:47	19:44	04:36
20	17:24	05:57	18:13	05:22	19:57	05:20	20:36	05:23
21	18:25	06:26	19:11	05:48	20:54	05:56	21:23	06:14
22	19:24	06:53	20:09	06:16	21:49	06:39	22:05	07:11
23	20:22	07:19	21:07	06:46	22:39	07:26	22:41	08:10
24	21:20	07:46	22:05	07:20	23:25	08:19	23:14	09:10
25	22:18	08:15	23:01	07:58	DNR	09:17	23:44	10:11
26	23:16	08:46	23:54	08:42	00:05	10:16	DNR	11:13
27	DNR	09:22	DNR	09:32	00:40	11:18	00:12	12:15
28	00:14	10:03	00:43	10:27	01:12	12:20	00:40	13:19
29	01:09	10:49	01:27	11:26	01:42	13:24	01:09	14:26
30	02:01	11:42	02:06	12:28	02:11	14:29	01:42	15:37
31			02:41	13:32			02:20	16:51

Note: DNR or DNS means Moon does not rise or set on that day. The reason for this lies in the Moon's rapid daily motion from west to east. Consecutive days show the Moon to rise (or set) more than 24 hours later. Hence, if the Moon rises just before midnight on the 1st of the month, it may not rise again until after midnight on the 2nd. Therefore it becomes an event for the 3rd of the month with no event on the 2nd.

	JANUARY		FEBRUARY		MARCH		APRIL	
	Rise	Set	Rise	Set	Rise	Set	Rise	Set
1	20:40	06:28	21:18	08:26	19:52	07:15	20:29	09:24
2	21:24	07:29	21:54	09:28	20:29	08:20	21:19	10:32
3	22:04	08:30	22:31	10:30	21:08	09:25	22:14	11:39
4	22:42	09:32	23:09	11:34	21:49	10:30	23:13	12:41
5	23:17	10:33	23:51	12:38	22:35	11:37	DNR	13:37
6	23:53	11:34	DNR	13:43	23:25	12:42	00:14	14:26
7	DNR	12:36	00:37	14:48	DNR	13:46	01:15	15:09
8	00:30	13:40	01:29	15:52	00:20	14:45	02:14	15:46
9	01:09	14:46	02:26	16:50	01:19	15:39	03:11	16:19
10	01:53	15:53	03:27	17:43	02:20	16:26	04:06	16:51
11	02:43	17:00	04:30	18:29	03:21	17:07	04:59	17:20
12	03:39	18:03	05:31	19:09	04:20	17:44	05:52	17:50
13	04:39	19:01	06:30	19:45	05:17	18:17	06:44	18:20
14	05:42	19:52	07:27	20:18	06:12	18:48	07:37	18:53
15	06:45	20:36	08:21	20:49	07:05	19:18	08:30	19:28
16	07:46	21:15	09:14	21:19	07:58	19:49	09:24	20:07
17	08:44	21:49	10:06	21:49	08:50	20:20	10:19	20:50
18	09:39	22:20	10:59	22:21	09:43	20:53	11:13	21:39
19	10:32	22:50	11:52	22:56	10:37	21:29	12:05	22:32
20	11:24	23:20	12:46	23:34	11:31	22:10	12:54	23:29
21	12:16	23:51	13:41	DNS	12:26	22:56	13:40	DNS
22	13:08	DNS	14:36	00:17	13:20	23:47	14:22	00:29
23	14:02	00:24	15:30	01:06	14:12	DNS	15:01	01:31
24	14:57	01:00	16:22	02:00	15:01	00:43	15:39	02:34
25	15:53	01:41	17:11	03:00	15:46	01:43	16:16	03:38
26	16:49	02:27	17:56	04:02	16:29	02:46	16:53	04:44
27	17:43	03:19	18:37	05:06	17:08	03:50	17:34	05:51
28	18:33	04:16	19:15	06:11	17:46	04:55	18:18	07:01
29	19:20	05:17			18:23	06:01	19:07	08:12
30	20:03	06:20			19:02	07:07	20:02	09:23
31	20:42	07:23			19:44	08:15		

	MAY		JUNE		JULY		AUGUST	
1	21:02	10:30	22:58	11:47	23:36	11:28	00:06	11:29
2	22:05	11:30	23:56	12:24	DNR	11:58	00:59	12:03
3	23:08	12:23	DNR	12:57	00:29	12:27	01:53	12:40
4	DNR	13:09	00:50	13:27	01:21	12:58	02:48	13:22
5	00:08	13:48	01:43	13:56	02:14	13:30	03:43	14:10
6	01:07	14:23	02:35	14:26	03:07	14:05	04:36	15:02
7	02:02	14:54	03:27	14:56	04:02	14:44	05:27	15:58
8	02:55	15:24	04:20	15:29	04:57	15:28	06:14	16:58
9	03:48	15:53	05:14	16:06	05:51	16:17	06:57	17:58
10	04:39	16:23	06:08	16:46	06:44	17:11	07:36	18:59
11	05:32	16:54	07:03	17:32	07:33	18:08	08:12	19:59
12	06:25	17:28	07:57	18:22	08:18	19:07	08:47	21:00
13	07:19	18:06	08:48	19:16	08:59	20:06	09:21	22:01
14	08:14	18:48	09:35	20:14	09:36	21:06	09:56	23:04
15	09:08	19:35	10:18	21:12	10:11	22:05	10:34	DNS
16	10:01	20:26	10:58	22:12	10:45	23:05	11:16	00:08
17	10:50	21:21	11:35	23:11	11:19	DNS	12:03	01:15
18	11:36	22:19	12:09	DNS	11:55	00:07	12:57	02:21
19	12:19	23:19	12:44	00:11	12:34	01:10	13:58	03:26
20	12:58	DNS	13:19	01:13	13:19	02:17	15:02	04:26
21	13:35	00:19	13:57	02:17	14:10	03:25	16:07	05:19
22	14:10	01:21	14:40	03:23	15:08	04:33	17:12	06:06
23	14:46	02:23	15:29	04:33	16:12	05:39	18:13	06:46
24	15:24	03:28	16:24	05:44	17:19	06:38	19:12	07:22
25	16:05	04:35	17:27	06:53	18:25	07:29	20:08	07:54
26	16:52	05:46	18:33	07:57	19:28	08:13	21:02	08:25
27	17:45	06:58	19:39	08:52	20:28	08:51	21:56	08:56
28	18:44	08:09	20:44	09:40	21:25	09:25	22:50	09:27
29	19:48	09:15	21:44	10:20	22:20	09:57	23:44	10:00
30	20:54	10:14	22:42	10:56	23:13	10:27	DNR	10:36
31	21:57	11:04			DNR	10:57	00:39	11:16

	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
1	01:33	12:01	01:59	12:29	02:36	14:13	02:14	15:01
2	02:27	12:51	02:44	13:28	03:11	15:15	02:51	16:08
3	03:19	13:46	03:26	14:29	03:45	16:19	03:32	17:18
4	04:07	14:44	04:05	15:31	04:22	17:25	04:19	18:31
5	04:51	15:45	04:41	16:33	05:01	18:34	05:13	19:43
6	05:32	16:46	05:16	17:36	05:45	19:46	06:14	20:50
7	06:10	17:48	05:52	18:41	06:35	20:57	07:21	21:49
8	06:46	18:50	06:29	19:47	07:32	22:05	08:30	22:39
9	07:20	19:52	07:10	20:56	08:34	23:06	09:36	23:22
10	07:56	20:56	07:55	22:05	09:40	23:59	10:39	23:59
11	08:33	22:01	08:47	23:13	10:45	DNS	11:38	DNS
12	09:14	23:08	09:44	DNS	11:48	00:45	12:34	00:31
13	10:00	DNS	10:45	00:16	12:48	01:23	13:28	01:02
14	10:52	00:15	11:49	01:13	13:44	01:57	14:22	01:31
15	11:50	01:20	12:52	02:02	14:39	02:29	15:15	02:01
16	12:52	02:20	13:54	02:44	15:33	02:59	16:09	02:33
17	13:56	03:15	14:53	03:21	16:26	03:28	17:03	03:07
18	15:00	04:02	15:49	03:54	17:20	03:59	17:58	03:45
19	16:01	04:43	16:44	04:25	18:14	04:31	18:52	04:28
20	17:00	05:20	17:38	04:56	19:09	05:07	19:44	05:15
21	17:57	05:53	18:32	05:26	20:04	05:46	20:33	06:06
22	18:52	06:24	19:26	05:57	20:57	06:30	21:17	07:01
23	19:46	06:55	20:21	06:31	21:48	07:18	21:57	07:57
24	20:40	07:25	21:16	07:08	22:35	08:11	22:33	08:54
25	21:35	07:58	22:10	07:49	23:18	09:06	23:07	09:51
26	22:29	08:32	23:03	08:34	23:57	10:03	23:39	10:48
27	23:24	09:11	23:52	09:24	DNR	11:01	DNR	11:46
28	DNR	09:54	DNR	10:18	00:33	11:59	00:12	12:46
29	00:18	10:41	00:38	11:15	01:07	12:58	00:46	13:48
30	01:10	11:33	01:21	12:13	01:40	13:58	01:23	14:54
31			01:59	13:13			02:05	16:03

CANBERRA (EST) MOON RISE AND SET DARWIN (CST)

	JANUARY		FEBRUARY		MARCH		APRIL	
	Rise	Set	Rise	Set	Rise	Set	Rise	Set
1	21:14	06:24	21:38	08:36	20:09	07:29	20:29	09:55
2	21:55	07:28	22:09	09:43	20:41	08:38	21:15	11:07
3	22:31	08:33	22:41	10:50	21:15	09:48	22:09	12:16
4	23:04	09:39	23:15	11:58	21:52	10:58	23:08	13:19
5	23:36	10:44	23:52	13:07	22:33	12:09	DNR	14:14
6	DNR	11:50	DNR	14:16	23:21	13:18	00:10	15:00
7	00:06	12:57	00:35	15:25	DNR	14:24	01:14	15:40
8	00:39	14:06	01:25	16:29	00:15	15:23	02:17	16:13
9	01:14	15:16	02:21	17:27	01:14	16:15	03:18	16:43
10	01:54	16:27	03:23	18:18	02:17	16:59	04:17	17:10
11	02:40	17:37	04:28	19:01	03:21	17:37	05:14	17:35
12	03:34	18:41	05:32	19:38	04:24	18:10	06:11	18:01
13	04:34	19:38	06:36	20:10	05:25	18:39	07:07	18:27
14	05:39	20:26	07:36	20:38	06:24	19:06	08:04	18:56
15	06:45	21:07	08:35	21:05	07:22	19:32	09:01	19:28
16	07:49	21:41	09:32	21:31	08:18	19:58	09:58	20:04
17	08:51	22:11	10:28	21:57	09:15	20:25	10:55	20:45
18	09:50	22:39	11:24	22:26	10:11	20:55	11:51	21:33
19	10:48	23:05	12:21	22:57	11:09	21:28	12:43	22:26
20	11:43	23:31	13:19	23:32	12:06	22:06	13:31	23:25
21	12:39	23:58	14:16	DNS	13:03	22:51	14:13	DNS
22	13:35	DNS	15:13	00:13	13:58	23:41	14:52	00:28
23	14:33	00:27	16:08	01:00	14:49	DNS	15:27	01:34
24	15:31	01:00	16:59	01:55	15:36	00:38	16:00	02:42
25	16:29	01:38	17:45	02:56	16:19	01:41	16:32	03:51
26	17:26	02:22	18:26	04:02	16:57	02:47	17:05	05:02
27	18:20	03:13	19:03	05:10	17:32	03:56	17:40	06:15
28	19:09	04:11	19:36	06:19	18:05	05:06	18:20	07:30
29	19:52	05:15			18:37	06:16	19:05	08:45
30	20:31	06:21			19:11	07:28	19:57	09:59
31	21:06	07:28			19:48	08:41		
	MAY		JUNE		JULY		AUGUST	
1	20:56	11:08	23:02	12:17	23:51	11:47	00:32	11:33
2	22:00	12:08	DNR	12:50	DNR	12:13	01:29	12:04
3	23:05	12:59	00:04	13:18	00:48	12:38	02:27	12:38
4	DNR	13:41	01:03	13:45	01:44	13:05	03:24	13:18
5	00:10	14:17	02:00	14:10	02:41	13:33	04:21	14:03
6	01:12	14:47	02:56	14:35	03:38	14:05	05:15	14:56
7	02:11	15:14	03:52	15:02	04:36	14:41	06:04	15:54
8	03:09	15:40	04:48	15:31	05:33	15:23	06:49	16:56
9	04:05	16:05	05:46	16:04	06:29	16:11	07:28	18:00
10	05:01	16:31	06:44	16:42	07:22	17:05	08:03	19:05
11	05:58	16:59	07:41	17:26	08:09	18:04	08:35	20:10
12	06:55	17:29	08:35	18:16	08:52	19:06	09:05	21:15
13	07:52	18:04	09:26	19:11	09:29	20:10	09:35	22:22
14	08:50	18:43	10:11	20:11	10:02	21:13	10:05	23:29
15	09:46	19:29	10:51	21:13	10:33	22:18	10:38	DNS
16	10:39	20:20	11:27	22:16	11:02	23:22	11:16	00:38
17	11:28	21:17	12:00	23:20	11:32	DNS	12:00	01:49
18	12:12	22:17	12:30	DNS	12:03	00:29	12:52	02:59
19	12:51	23:20	13:00	00:25	12:38	01:37	13:51	04:05
20	13:26	DNS	13:30	01:31	13:18	02:48	14:57	05:04
21	13:58	00:25	14:04	02:40	14:06	04:00	16:06	05:55
22	14:29	01:31	14:42	03:52	15:02	05:11	17:14	06:37
23	15:00	02:39	15:26	05:06	16:06	06:17	18:20	07:13
24	15:33	03:49	16:19	06:21	17:15	07:14	19:23	07:45
25	16:10	05:01	17:21	07:32	18:25	08:03	20:24	08:13
26	16:52	06:17	18:28	08:35	19:32	08:43	21:22	08:39
27	17:41	07:33	19:37	09:28	20:37	09:16	22:20	09:06
28	18:38	08:47	20:46	10:11	21:38	09:46	23:18	09:33
29	19:42	09:53	21:51	10:48	22:37	10:13	DNR	10:02
30	20:50	10:50	22:52	11:19	23:35	10:39	00:16	10:35
31	21:57	11:38			DNR	11:06	01:14	11:12
	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
1	02:11	11:55	02:36	12:25	03:01	14:22	02:28	15:23
2	03:06	12:45	03:19	13:27	03:31	15:29	02:59	16:35
3	03:57	13:40	03:58	14:31	04:01	16:38	03:35	17:50
4	04:43	14:41	04:32	15:37	04:32	17:50	04:17	19:07
5	05:25	15:45	05:04	16:44	05:06	19:04	05:08	20:22
6	06:02	16:51	05:34	17:53	05:45	20:20	06:08	21:29
7	06:35	17:57	06:05	19:03	06:31	21:35	07:15	22:26
8	07:06	19:04	06:37	20:15	07:26	22:44	08:26	23:13
9	07:36	20:11	07:13	21:28	08:28	23:45	09:37	23:51
10	08:07	21:20	07:54	22:41	09:34	DNS	10:44	DNS
11	08:39	22:30	08:42	23:52	10:43	00:35	11:48	00:23
12	09:16	23:41	09:37	DNS	11:50	01:16	12:48	00:52
13	09:58	DNS	10:39	00:55	12:54	01:51	13:47	01:18
14	10:47	00:52	11:45	01:50	13:55	02:21	14:44	01:43
15	11:43	01:58	12:52	02:36	14:54	02:48	15:42	02:09
16	12:46	02:59	13:57	03:14	15:52	03:13	16:39	02:37
17	13:53	03:51	15:00	03:47	16:50	03:39	17:38	03:07
18	15:00	04:35	16:01	04:16	17:48	04:05	18:35	03:42
19	16:06	05:12	17:01	04:43	18:46	04:34	19:31	04:22
20	17:09	05:44	17:59	05:09	19:44	05:06	20:23	05:08
21	18:11	06:13	18:57	05:35	20:42	05:42	21:11	05:59
22	19:10	06:40	19:56	06:02	21:36	06:24	21:52	06:56
23	20:09	07:06	20:54	06:32	22:27	07:12	22:29	07:55
24	21:07	07:33	21:52	07:05	23:12	08:04	23:01	08:56
25	22:05	08:01	22:49	07:44	23:52	09:02	23:31	09:57
26	23:03	08:32	23:42	08:28	DNR	10:02	23:59	10:58
27	DNR	09:08	DNR	09:17	00:28	11:03	DNR	12:01
28	00:01	09:48	00:31	10:12	01:00	12:06	00:27	13:05
29	00:56	10:34	01:15	11:11	01:29	13:09	00:56	14:12
30	01:49	11:27	01:54	12:13	01:58	14:15	01:28	15:23
31			02:29	13:17			02:06	16:38

Note: DNR or DNS means Moon does not rise or set on that day. The reason for this lies in the Moon's rapid daily motion from west to east. Consecutive days show the Moon to rise (or set) more than 24 hours later. Hence, if the Moon rises just before midnight on the 1st of the month, it may not rise again until after midnight on the 2nd. Therefore it becomes an event for the 3rd of the month with no event on the 2nd.

	JANUARY		FEBRUARY		MARCH		APRIL	
	Rise	Set	Rise	Set	Rise	Set	Rise	Set
1	21:13	08:02	22:14	09:38	20:53	08:23	21:57	10:03
2	22:02	08:58	22:58	10:33	21:38	09:19	22:53	11:06
3	22:48	09:54	23:42	11:27	22:24	10:16	23:51	12:09
4	23:33	10:49	DNR	12:23	23:13	11:15	DNR	13:09
5	DNR	11:43	00:28	13:20	DNR	12:14	00:50	14:06
6	00:16	12:37	01:16	14:19	00:05	13:15	01:49	14:59
7	00:59	13:31	02:08	15:20	01:00	14:15	02:45	15:46
8	01:43	14:28	03:04	16:21	01:57	15:14	03:38	16:29
9	02:30	15:26	04:03	17:20	02:56	16:09	04:29	17:09
10	03:21	16:28	05:03	18:15	03:53	17:00	05:17	17:47
11	04:16	17:30	06:01	19:05	04:49	17:47	06:03	18:23
12	05:15	18:32	06:57	19:51	05:42	18:30	06:49	18:59
13	06:16	19:31	07:50	20:33	06:32	19:09	07:35	19:36
14	07:16	20:26	08:39	21:12	07:20	19:47	08:21	20:14
15	08:14	21:15	09:27	21:50	08:07	20:23	09:09	20:55
16	09:09	21:59	10:13	22:26	08:53	21:00	09:58	21:39
17	10:00	22:39	10:59	23:03	09:39	21:37	10:49	22:26
18	10:49	23:17	11:45	23:41	10:26	22:16	11:41	23:16
19	11:35	23:54	12:32	DNS	11:14	22:58	12:32	DNS
20	12:21	DNS	13:21	00:21	12:04	23:43	13:23	00:08
21	13:06	00:30	14:12	01:04	12:55	DNS	14:13	01:03
22	13:52	01:07	15:05	01:51	13:48	00:32	15:01	01:58
23	14:41	01:45	15:59	02:42	14:40	01:24	15:47	02:54
24	15:31	02:27	16:52	03:37	15:32	02:19	16:32	03:50
25	16:23	03:12	17:45	04:33	16:22	03:15	17:16	04:46
26	17:17	04:02	18:35	05:31	17:11	04:12	18:03	05:43
27	18:12	04:55	19:22	06:29	17:57	05:10	18:51	06:42
28	19:05	05:51	20:08	07:27	18:43	06:07	19:43	07:44
29	19:56	06:49			19:29	07:04	20:39	08:48
30	20:45	07:46			20:16	08:02	21:39	09:54
31	21:30	08:43			21:05	09:02		
	MAY		JUNE		JULY		AUGUST	
1	22:40	10:58	DNR	12:26	DNR	12:24	00:53	12:48
2	23:41	11:59	00:21	13:09	00:40	13:00	01:40	13:28
3	DNR	12:55	01:11	13:48	01:26	13:36	02:29	14:11
4	00:40	13:45	01:59	14:25	02:12	14:13	03:19	14:57
5	01:35	14:29	02:45	15:01	02:58	14:51	04:11	15:47
6	02:26	15:10	03:30	15:37	03:46	15:32	05:04	16:39
7	03:15	15:48	04:16	16:14	04:36	16:16	05:56	17:34
8	04:02	16:24	05:02	16:53	05:27	17:03	06:46	18:29
9	04:47	17:00	05:51	17:35	06:19	17:54	07:33	19:23
10	05:32	17:36	06:41	18:20	07:11	18:47	08:19	20:17
11	06:18	18:14	07:32	19:08	08:02	19:42	09:02	21:10
12	07:06	18:54	08:24	19:59	08:51	20:36	09:44	22:03
13	07:54	19:36	09:16	20:52	09:37	21:29	10:26	22:56
14	08:45	20:22	10:06	21:46	10:21	22:22	11:08	23:51
15	09:36	21:11	10:53	22:40	11:03	23:14	11:54	DNS
16	10:28	22:03	11:38	23:33	11:44	DNS	12:43	00:49
17	11:19	22:56	12:21	DNS	12:26	00:06	13:36	01:49
18	12:08	23:50	13:03	00:25	13:10	01:00	14:34	02:51
19	12:55	DNS	13:45	01:18	13:57	01:56	15:36	03:54
20	13:40	00:44	14:29	02:12	14:48	02:56	16:38	04:55
21	14:24	01:38	15:15	03:08	15:45	03:58	17:39	05:51
22	15:07	02:32	16:05	04:07	16:46	05:03	18:36	06:43
23	15:51	03:27	17:01	05:10	17:50	06:07	19:31	07:29
24	16:37	04:23	18:01	06:15	18:53	07:07	20:22	08:12
25	17:27	05:23	19:05	07:21	19:53	08:03	21:11	08:51
26	18:21	06:26	20:09	08:25	20:50	08:53	21:58	09:29
27	19:20	07:31	21:11	09:24	21:43	09:38	22:45	10:07
28	20:22	08:38	22:09	10:16	22:32	10:18	23:33	10:44
29	21:26	09:43	23:03	11:03	23:20	10:57	DNR	11:23
30	22:28	10:43	23:53	11:45	DNR	11:34	00:21	12:05
31	23:26	11:38			00:06	12:11	01:11	12:50
	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
1	02:02	13:38	02:27	14:05	03:23	15:27	03:21	15:55
2	02:54	14:29	03:16	14:59	04:05	16:21	04:06	16:53
3	03:46	15:22	04:03	15:54	04:48	17:16	04:55	17:56
4	04:37	16:17	04:48	16:48	05:33	18:14	05:49	19:02
5	05:26	17:13	05:32	17:43	06:20	19:16	06:49	20:11
6	06:12	18:07	06:15	18:38	07:12	20:20	07:54	21:17
7	06:57	19:02	06:59	19:34	08:09	21:26	09:00	22:19
8	07:40	19:56	07:44	20:33	09:10	22:32	10:04	23:14
9	08:23	20:50	08:33	21:34	10:13	23:34	11:04	DNS
10	09:06	21:46	09:26	22:37	11:16	DNS	12:00	00:02
11	09:51	22:44	10:22	23:41	12:17	00:31	12:52	00:46
12	10:40	23:44	11:22	DNS	13:13	01:21	13:40	01:25
13	11:32	DNS	12:24	00:43	14:06	02:06	14:27	02:03
14	12:29	00:45	13:24	01:41	14:55	02:47	15:13	02:39
15	13:28	01:48	14:22	02:35	15:43	03:25	16:00	03:16
16	14:29	02:48	15:17	03:22	16:29	04:02	16:48	03:54
17	15:29	03:45	16:08	04:06	17:16	04:38	17:37	04:34
18	16:27	04:37	16:58	04:46	18:03	05:15	18:28	05:17
19	17:22	05:24	17:45	05:24	18:52	05:54	19:19	06:04
20	18:13	06:07	18:32	06:01	19:41	06:36	20:11	06:53
21	19:03	06:47	19:19	06:38	20:33	07:20	21:00	07:44
22	19:51	07:25	20:07	07:16	21:24	08:07	21:48	08:36
23	20:38	08:03	20:56	07:56	22:15	08:57	22:33	09:29
24	21:25	08:40	21:47	08:38	23:03	09:48	23:15	10:20
25	22:14	09:19	22:38	09:24	23:50	10:41	23:55	11:11
26	23:03	10:00	23:29	10:12	DNR	11:33	DNR	12:01
27	23:54	10:43	DNR	11:02	00:34	12:24	00:35	12:51
28	DNR	11:29	00:20	11:55	01:17	13:16	01:15	13:43
29	00:45	12:19	01:08	12:48	01:58	14:07	01:57	14:37
30	01:37	13:11	01:55	13:41	02:39	15:00	02:42	15:35
31			02:40	14:34			03:31	16:38

HOBART (EST) MOON RISE AND SET MELBOURNE (EST)

	JANUARY		FEBRUARY		MARCH		APRIL	
	Rise	Set	Rise	Set	Rise	Set	Rise	Set
1	21:44	06:08	21:50	08:37	20:17	07:33	20:17	10:20
2	22:21	07:15	22:16	09:50	20:44	08:48	21:00	11:38
3	22:52	08:25	22:42	11:03	21:12	10:04	21:50	12:50
4	23:20	09:36	23:10	12:16	21:44	11:20	22:49	13:54
5	23:46	10:47	23:43	13:31	22:20	12:36	23:54	14:47
6	DNR	11:59	DNR	14:45	23:04	13:50	DNR	15:31
7	00:12	13:11	00:21	15:57	23:56	14:58	01:01	16:05
8	00:38	14:26	01:08	17:03	DNR	15:57	02:08	16:34
9	01:08	15:41	02:03	18:01	00:56	16:47	03:14	16:59
10	01:43	16:57	03:06	18:49	02:02	17:28	04:18	17:21
11	02:25	18:10	04:14	19:28	03:10	18:01	05:21	17:42
12	03:16	19:15	05:23	20:00	04:17	18:29	06:22	18:03
13	04:16	20:10	06:31	20:27	05:23	18:54	07:23	18:25
14	05:23	20:55	07:37	20:51	06:27	19:16	08:25	18:49
15	06:33	21:32	08:40	21:13	07:30	19:37	09:27	19:16
16	07:42	22:01	09:42	21:34	08:32	19:59	10:28	19:49
17	08:49	22:27	10:43	21:56	09:33	20:21	11:29	20:27
18	09:53	22:50	11:44	22:20	10:34	20:47	12:26	21:14
19	10:55	23:11	12:45	22:47	11:36	21:16	13:18	22:08
20	11:55	23:32	13:47	23:18	12:37	21:51	14:03	23:09
21	12:56	23:55	14:48	23:56	13:37	22:32	14:43	DNS
22	13:57	DNS	15:47	DNS	14:33	23:22	15:17	00:16
23	14:58	00:20	16:43	00:42	15:23	DNS	15:47	01:27
24	16:01	00:49	17:32	01:37	16:08	00:21	16:14	02:40
25	17:02	01:23	18:14	02:40	16:46	01:26	16:41	03:55
26	18:00	02:05	18:51	03:50	17:19	02:37	17:08	05:12
27	18:54	02:55	19:22	05:03	17:49	03:51	17:37	06:31
28	19:40	03:54	19:51	06:18	18:16	05:07	18:10	07:53
29	20:20	05:00			18:43	06:24	18:51	09:14
30	20:53	06:11			19:11	07:42	19:39	10:33
31	21:23	07:24			19:42	09:01		

	MAY		JUNE		JULY		AUGUST	
1	20:37	11:43	22:55	12:41	23:57	11:58	00:51	11:28
2	21:42	12:43	DNR	13:09	DNR	12:20	01:53	11:54
3	22:51	13:31	00:02	13:33	00:59	12:41	02:55	12:24
4	00:00	14:09	01:06	13:55	02:01	13:02	03:57	13:01
5	DNR	14:39	02:08	14:15	03:02	13:26	04:56	13:44
6	01:07	15:05	03:09	14:36	04:04	13:53	05:50	14:37
7	02:11	15:28	04:10	14:58	05:06	14:26	06:38	15:36
8	03:14	15:49	05:11	15:23	06:07	15:05	07:20	16:42
9	04:15	16:09	06:13	15:52	07:04	15:51	07:55	17:51
10	05:16	16:30	07:15	16:26	07:57	16:46	08:25	19:01
11	06:17	16:53	08:15	17:07	08:42	17:48	08:52	20:12
12	07:19	17:19	09:10	17:56	09:21	18:54	09:16	21:23
13	08:21	17:50	10:00	18:53	09:54	20:02	09:40	22:35
14	09:22	18:26	10:43	19:55	10:22	21:11	10:05	23:48
15	10:20	19:10	11:20	21:02	10:48	22:21	10:33	DNS
16	11:14	20:01	11:51	22:10	11:12	23:31	11:05	01:03
17	12:02	20:59	12:18	23:19	11:36	DNS	11:45	02:19
18	12:43	22:03	12:43	DNS	12:02	00:43	12:33	03:33
19	13:18	23:11	13:08	00:30	12:31	01:58	13:32	04:40
20	13:48	DNS	13:33	01:42	13:06	03:14	14:40	05:38
21	14:15	00:21	14:01	02:57	13:50	04:32	15:52	06:26
22	14:41	01:33	14:33	04:15	14:43	05:46	17:05	07:04
23	15:06	02:46	15:12	05:35	15:48	06:52	18:16	07:34
24	15:33	04:02	16:02	06:54	16:59	07:47	19:25	08:00
25	16:04	05:21	17:01	08:07	18:13	08:32	20:31	08:24
26	16:40	06:43	18:10	09:09	19:26	09:07	21:35	08:45
27	17:25	08:04	19:23	09:59	20:36	09:35	22:38	09:07
28	18:19	09:21	20:36	10:38	21:43	10:00	23:41	09:29
29	19:24	10:29	21:47	11:10	22:47	10:22	DNR	09:54
30	20:34	11:24	22:53	11:36	23:49	10:43	00:43	10:22
31	21:45	12:07			DNR	11:05	01:45	10:56

	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
1	02:45	11:36	03:11	12:07	03:19	14:22	02:32	15:38
2	03:41	12:25	03:50	13:13	03:44	15:35	02:58	16:56
3	04:32	13:22	04:24	14:23	04:08	16:50	03:28	18:17
4	05:16	14:25	04:53	15:34	04:34	18:08	04:04	19:40
5	05:53	15:34	05:19	16:47	05:02	19:29	04:50	20:58
6	06:25	16:45	05:44	18:02	05:35	20:51	05:48	22:05
7	06:53	17:57	06:09	19:18	06:16	22:10	06:56	22:59
8	07:19	19:09	06:36	20:36	07:06	23:21	08:10	23:42
9	07:43	20:23	07:05	21:55	08:07	DNS	09:25	DNS
10	08:08	21:37	07:41	23:14	09:16	00:20	10:38	00:15
11	08:35	22:54	08:24	DNS	10:29	01:06	11:47	00:42
12	09:06	DNS	09:17	00:27	11:41	01:43	12:53	01:05
13	09:43	00:10	10:19	01:31	12:50	02:12	13:57	01:26
14	10:29	01:25	11:28	02:24	13:57	02:37	15:00	01:46
15	11:24	02:34	12:39	03:06	15:01	02:59	16:02	02:07
16	12:28	03:34	13:50	03:39	16:04	03:20	17:05	02:30
17	13:37	04:24	14:58	04:07	17:07	03:40	18:07	02:56
18	14:49	05:03	16:05	04:31	18:10	04:02	19:09	03:27
19	16:00	05:36	17:09	04:53	19:13	04:26	20:07	04:04
20	17:09	06:03	18:13	05:13	20:16	04:53	20:59	04:48
21	18:16	06:26	19:16	05:35	21:16	05:26	21:45	05:40
22	19:21	06:48	20:19	05:57	22:12	06:05	22:24	06:38
23	20:24	07:09	21:23	06:22	23:03	06:51	22:56	07:41
24	21:28	07:31	22:25	06:52	23:46	07:45	23:24	08:46
25	22:31	07:54	23:24	07:26	DNR	08:45	23:48	09:52
26	23:33	08:21	DNR	08:08	00:23	09:49	DNR	10:59
27	DNR	08:52	00:18	08:57	00:54	10:55	00:11	12:07
28	00:34	09:30	01:06	09:53	01:20	12:03	00:34	13:17
29	01:32	10:15	01:47	10:56	01:45	13:12	00:57	14:30
30	02:24	11:07	02:22	12:02	02:08	14:23	01:24	15:47
31			02:53	13:11			01:55	17:07

Note: DNR or DNS means Moon does not rise or set on that day. The reason for this lies in the Moon's rapid daily motion from west to east. Consecutive days show the Moon to rise (or set) more than 24 hours later. Hence, if the Moon rises just before midnight on the 1st of the month, it may not rise again until after midnight on the 2nd. Therefore it becomes an event for the 3rd of the month with no event on the 2nd.

	JANUARY		FEBRUARY		MARCH		APRIL	
	Rise	Set	Rise	Set	Rise	Set	Rise	Set
1	21:38	06:34	21:56	08:51	20:26	07:45	20:40	10:17
2	22:18	07:38	22:26	10:00	20:56	08:56	21:25	11:32
3	22:52	08:45	22:56	11:09	21:28	10:08	22:18	12:42
4	23:24	09:52	23:28	12:19	22:04	11:20	23:17	13:45
5	23:53	11:00	DNR	13:29	22:44	12:32	DNR	14:39
6	DNR	12:08	00:04	14:40	23:30	13:43	00:20	15:24
7	00:22	13:17	00:45	15:50	DNR	14:49	01:25	16:02
8	00:53	14:27	01:34	16:55	00:24	15:49	02:29	16:34
9	01:27	15:39	02:30	17:53	01:23	16:40	03:31	17:02
10	02:05	16:51	03:32	18:42	02:27	17:23	04:32	17:28
11	02:50	18:02	04:38	19:24	03:32	17:59	05:31	17:52
12	03:43	19:06	05:44	19:59	04:37	18:31	06:29	18:16
13	04:43	20:03	06:49	20:30	05:39	18:58	07:27	18:41
14	05:49	20:50	07:51	20:57	06:40	19:24	08:25	19:08
15	06:56	21:29	08:51	21:22	07:39	19:48	09:24	19:39
16	08:02	22:02	09:50	21:46	08:37	20:13	10:23	20:13
17	09:05	22:31	10:48	22:11	09:35	20:39	11:21	20:54
18	10:06	22:56	11:45	22:38	10:33	21:07	12:16	21:41
19	11:04	23:21	12:44	23:08	11:32	21:39	13:08	22:35
20	12:02	23:46	13:42	23:42	12:31	22:16	13:55	23:35
21	12:59	DNS	14:41	DNS	13:28	22:59	14:37	DNS
22	13:57	00:11	15:39	00:22	14:23	23:50	15:14	00:39
23	14:55	00:39	16:34	01:09	15:15	DNS	15:48	01:47
24	15:55	01:11	17:24	02:04	16:01	00:48	16:19	02:56
25	16:54	01:48	18:09	03:06	16:42	01:51	16:49	04:07
26	17:52	02:31	18:48	04:13	17:18	02:59	17:20	05:20
27	18:45	03:22	19:23	05:23	17:52	04:09	17:54	06:35
28	19:33	04:21	19:55	06:34	18:23	05:21	18:31	07:52
29	20:15	05:25			18:54	06:34	19:15	09:09
30	20:53	06:33			19:25	07:47	20:06	10:25
31	21:26	07:42			20:00	09:02		

	MAY		JUNE		JULY		AUGUST	
1	21:05	11:34	23:14	12:39	DNR	12:05	00:53	11:46
2	22:09	12:34	DNR	13:10	00:08	12:29	01:51	12:15
3	23:15	13:24	00:18	13:37	01:06	12:53	02:50	12:48
4	DNR	14:04	01:18	14:02	02:04	13:18	03:49	13:27
5	00:21	14:38	02:17	14:26	03:02	13:45	04:46	14:12
6	01:25	15:07	03:14	14:50	04:01	14:16	05:40	15:04
7	02:26	15:33	04:12	15:15	05:00	14:51	06:30	16:03
8	03:25	15:57	05:10	15:43	05:59	15:32	07:13	17:06
9	04:23	16:21	06:09	16:15	06:55	16:19	07:51	18:12
10	05:21	16:45	07:08	16:52	07:47	17:14	08:25	19:19
11	06:18	17:11	08:06	17:35	08:34	18:14	08:55	20:26
12	07:17	17:40	09:01	18:24	09:15	19:17	09:23	21:33
13	08:16	18:14	09:51	19:20	09:51	20:22	09:51	22:41
14	09:14	18:52	10:36	20:21	10:23	21:28	10:20	23:50
15	10:11	19:37	11:15	21:24	10:52	22:33	10:51	DNS
16	11:05	20:29	11:49	22:29	11:20	23:40	11:27	01:01
17	11:53	21:26	12:20	23:35	11:48	DNS	12:10	02:13
18	12:36	22:28	12:49	DNS	12:17	00:48	13:01	03:24
19	13:14	23:32	13:17	00:41	12:50	01:58	14:00	04:31
20	13:47	DNS	13:46	01:50	13:29	03:11	15:06	05:29
21	14:18	00:39	14:17	03:00	14:15	04:25	16:16	06:19
22	14:47	01:46	14:54	04:14	15:11	05:37	17:26	07:00
23	15:16	02:56	15:37	05:30	16:15	06:43	18:34	07:34
24	15:48	04:08	16:28	06:46	17:25	07:39	19:38	08:04
25	16:22	05:23	17:29	07:57	18:36	08:26	20:41	08:31
26	17:03	06:40	18:37	09:00	19:45	09:05	21:41	08:56
27	17:51	07:58	19:48	09:52	20:51	09:37	22:41	09:20
28	18:47	09:12	20:57	10:34	21:54	10:05	23:40	09:46
29	19:51	10:19	22:04	11:09	22:55	10:31	DNR	10:14
30	21:00	11:15	23:07	11:39	23:54	10:55	00:39	10:45
31	22:08	12:01			DNR	11:20	01:38	11:22

	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
1	02:36	12:04	03:02	12:34	03:21	14:37	02:43	15:43
2	03:31	12:53	03:44	13:37	03:49	15:46	03:13	16:56
3	04:22	13:49	04:20	14:43	04:18	16:57	03:47	18:14
4	05:08	14:51	04:53	15:51	04:47	18:10	04:28	19:32
5	05:48	15:56	05:23	17:00	05:19	19:27	05:17	20:48
6	06:24	17:03	05:52	18:10	05:57	20:45	06:16	21:55
7	06:55	18:12	06:21	19:22	06:41	22:01	07:24	22:51
8	07:24	19:20	06:51	20:36	07:34	23:11	08:36	23:37
9	07:53	20:30	07:25	21:52	08:36	DNS	09:48	DNS
10	08:22	21:40	08:04	23:06	09:44	00:10	10:57	00:13
11	08:53	22:52	08:51	DNS	10:53	00:59	12:02	00:44
12	09:27	DNS	09:46	00:17	12:02	01:39	13:04	01:10
13	10:08	00:05	10:48	01:21	13:07	02:12	14:05	01:35
14	10:56	01:17	11:54	02:15	14:10	02:40	15:04	01:58
15	11:52	02:24	13:02	03:00	15:11	03:06	16:03	02:23
16	12:55	03:25	14:09	03:37	16:11	03:30	17:02	02:49
17	14:03	04:16	15:14	04:08	17:10	03:53	18:02	03:18
18	15:11	04:59	16:17	04:35	18:09	04:18	19:01	03:52
19	16:19	05:34	17:18	05:00	19:09	04:46	19:57	04:31
20	17:24	06:05	18:18	05:25	20:09	05:16	20:49	05:16
21	18:27	06:32	19:18	05:49	21:07	05:51	21:36	06:08
22	19:28	06:57	20:18	06:15	22:02	06:32	22:17	07:05
23	20:28	07:21	21:18	06:43	22:53	07:20	22:52	08:05
24	21:28	07:47	22:17	07:16	23:37	08:13	23:23	09:07
25	22:28	08:13	23:14	07:53	DNR	09:11	23:51	10:10
26	23:28	08:43	DNR	08:36	00:16	10:12	DNR	11:13
27	DNR	09:17	00:08	09:25	00:50	11:15	00:17	12:18
28	00:26	09:57	00:56	10:21	01:21	12:20	00:43	13:24
29	01:22	10:43	01:40	11:21	01:49	13:25	01:11	14:33
30	02:15	11:35	02:17	12:25	02:16	14:32	01:41	15:46
31			02:51	13:30			02:17	17:02

PERTH (WST) MOON RISE AND SET SYDNEY (EST)

	JANUARY		FEBRUARY		MARCH		APRIL	
	Rise	Set	Rise	Set	Rise	Set	Rise	Set
1	21:23	06:52	21:53	08:58	20:25	07:49	20:53	10:08
2	22:05	07:54	22:26	10:03	20:59	08:57	21:42	11:18
3	22:43	08:58	23:00	11:08	21:35	10:04	22:37	12:26
4	23:18	10:02	23:36	12:14	22:15	11:13	23:36	13:28
5	23:51	11:06	DNR	13:21	22:58	12:21	DNR	14:23
6	DNR	12:09	00:16	14:28	23:48	13:29	00:38	15:09
7	00:24	13:14	01:01	15:35	DNR	14:33	01:41	15:49
8	00:58	14:21	01:52	16:38	00:43	15:32	02:42	16:24
9	01:36	15:29	02:49	17:36	01:43	16:24	03:41	16:55
10	02:18	16:39	03:51	18:27	02:45	17:09	04:37	17:24
11	03:07	17:47	04:55	19:11	03:47	17:48	05:33	17:51
12	04:02	18:50	05:58	19:49	04:48	18:22	06:28	18:19
13	05:03	19:47	06:59	20:22	05:47	18:52	07:22	18:47
14	06:07	20:35	07:58	20:52	06:44	19:21	08:17	19:18
15	07:11	21:17	08:54	21:20	07:40	19:49	09:13	19:51
16	08:14	21:53	09:49	21:48	08:35	20:17	10:09	20:29
17	09:14	22:24	10:44	22:17	09:29	20:46	11:05	21:12
18	10:11	22:53	11:38	22:47	10:24	21:17	11:59	22:00
19	11:06	23:21	12:33	23:20	11:20	21:53	12:51	22:54
20	12:00	23:49	13:29	23:57	12:16	22:32	13:39	23:53
21	12:54	DNS	14:26	DNS	13:12	23:18	14:22	DNS
22	13:49	00:18	15:22	00:39	14:06	DNS	15:02	00:55
23	14:44	00:49	16:17	01:28	14:57	00:09	15:39	01:59
24	15:41	01:24	17:07	02:23	15:45	01:06	16:14	03:05
25	16:39	02:03	17:54	03:24	16:28	02:08	16:48	04:12
26	17:35	02:49	18:36	04:28	17:08	03:13	17:23	05:20
27	18:28	03:41	19:15	05:35	17:45	04:20	18:01	06:31
28	19:18	04:39	19:50	06:42	18:20	05:28	18:43	07:44
29	20:02	05:42			18:55	06:36	19:31	08:58
30	20:42	06:47			19:31	07:46	20:25	10:10
31	21:18	07:52			20:10	08:56		

	MAY		JUNE		JULY		AUGUST	
1	21:25	11:17	23:26	12:27	DNR	12:01	00:46	11:54
2	22:29	12:17	DNR	13:01	00:10	12:29	01:41	12:27
3	23:33	13:08	00:26	13:31	01:05	12:56	02:37	13:03
4	DNR	13:51	01:23	14:00	01:59	13:24	03:34	13:44
5	00:35	14:27	02:18	14:27	02:54	13:55	04:29	14:31
6	01:35	14:59	03:12	14:54	03:50	14:28	05:23	15:24
7	02:33	15:28	04:06	15:23	04:46	15:06	06:12	16:22
8	03:28	15:56	05:01	15:54	05:43	15:50	06:58	17:23
9	04:23	16:23	05:57	16:29	06:38	16:39	07:38	18:25
10	05:17	16:50	06:53	17:08	07:30	17:33	08:15	19:29
11	06:11	17:20	07:49	17:53	08:17	18:32	08:48	20:32
12	07:07	17:52	08:43	18:44	09:00	19:32	09:20	21:35
13	08:03	18:28	09:34	19:39	09:39	20:34	09:52	22:39
14	08:59	19:10	10:19	20:38	10:14	21:36	10:24	23:44
15	09:54	19:56	11:01	21:39	10:46	22:38	11:00	DNS
16	10:47	20:48	11:38	22:40	11:18	23:41	11:40	00:52
17	11:36	21:44	12:12	23:42	11:49	DNS	12:26	02:00
18	12:20	22:44	12:44	DNS	12:23	00:45	13:20	03:09
19	13:00	23:46	13:16	00:45	13:00	01:52	14:20	04:14
20	13:37	DNS	13:49	01:49	13:43	03:01	15:26	05:12
21	14:11	00:49	14:25	02:56	14:33	04:11	16:33	06:04
22	14:44	01:53	15:05	04:06	15:31	05:21	17:39	06:47
23	15:17	02:58	15:53	05:19	16:35	06:26	18:43	07:25
24	15:53	04:06	16:48	06:31	17:43	07:23	19:44	07:57
25	16:32	05:17	17:50	07:41	18:51	08:12	20:42	08:27
26	17:17	06:30	18:57	08:43	19:57	08:53	21:39	08:56
27	18:08	07:45	20:05	09:37	20:59	09:29	22:35	09:24
28	19:07	08:57	21:11	10:21	21:58	10:00	23:31	09:53
29	20:12	10:02	22:14	10:59	22:55	10:29	DNR	10:24
30	21:18	10:59	23:13	11:32	23:50	10:57	00:27	10:59
31	22:24	11:47			DNR	11:25	01:24	11:38

	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
1	02:19	12:22	02:44	12:53	03:13	14:45	02:45	15:40
2	03:14	13:13	03:28	13:54	03:45	15:49	03:19	16:50
3	04:05	14:08	04:07	14:57	04:17	16:56	03:58	18:03
4	04:51	15:08	04:43	16:01	04:51	18:06	04:43	19:18
5	05:34	16:11	05:17	17:06	05:28	19:18	05:36	20:31
6	06:12	17:15	05:50	18:12	06:10	20:32	06:37	21:38
7	06:47	18:19	06:22	19:20	06:58	21:45	07:45	22:35
8	07:20	19:24	06:57	20:29	07:54	22:53	08:55	23:22
9	07:52	20:29	07:36	21:41	08:57	23:53	10:03	DNS
10	08:25	21:36	08:19	22:52	10:03	DNS	11:08	00:02
11	09:00	22:44	09:09	DNS	11:10	00:44	12:09	00:35
12	09:39	23:53	10:06	00:01	12:15	01:26	13:08	01:05
13	10:24	DNS	11:08	01:03	13:17	02:02	14:04	01:33
14	11:15	01:02	12:13	01:58	14:16	02:33	14:59	02:01
15	12:12	02:07	13:18	02:45	15:13	03:02	15:55	02:28
16	13:15	03:07	14:22	03:24	16:09	03:29	16:51	02:58
17	14:21	04:00	15:23	03:59	17:05	03:57	17:48	03:31
18	15:26	04:44	16:21	04:29	18:01	04:25	18:44	04:07
19	16:30	05:23	17:19	04:58	18:57	04:56	19:39	04:49
20	17:31	05:57	18:15	05:26	19:54	05:30	20:31	05:36
21	18:30	06:27	19:11	05:54	20:50	06:08	21:18	06:28
22	19:28	06:56	20:08	06:23	21:44	06:51	22:00	07:24
23	20:24	07:24	21:05	06:55	22:34	07:40	22:38	08:22
24	21:21	07:52	22:01	07:30	23:20	08:33	23:12	09:21
25	22:17	08:23	22:57	08:10	DNR	09:29	23:43	10:20
26	23:14	08:56	23:49	08:55	00:01	10:28	DNR	11:20
27	DNR	09:33	DNR	09:45	00:37	11:28	00:13	12:20
28	00:10	10:15	00:38	10:40	01:11	12:29	00:43	13:23
29	01:04	11:02	01:23	11:39	01:42	13:30	01:15	14:28
30	01:56	11:55	02:03	12:39	02:13	14:34	01:49	15:37
31			02:39	13:41			02:30	16:49

Note: DNR or DNS means Moon does not rise or set on that day. The reason for this lies in the Moon's rapid daily motion from west to east. Consecutive days show the Moon to rise (or set) more than 24 hours later. Hence, if the Moon rises just before midnight on the 1st of the month, it may not rise again until after midnight on the 2nd. Therefore it becomes an event for the 3rd of the month with no event on the 2nd.

	JANUARY		FEBRUARY		MARCH		APRIL	
	Rise	Set	Rise	Set	Rise	Set	Rise	Set
1	21:02	06:19	21:29	08:28	20:00	07:20	20:23	09:43
2	21:44	07:22	22:01	09:34	20:33	08:29	21:10	10:55
3	22:21	08:26	22:33	10:41	21:08	09:38	22:04	12:04
4	22:54	09:31	23:08	11:48	21:46	10:47	23:03	13:06
5	23:27	10:36	23:46	12:56	22:28	11:57	DNR	14:01
6	23:58	11:42	DNR	14:04	23:16	13:06	00:05	14:48
7	DNR	12:48	00:30	15:12	DNR	14:11	01:08	15:28
8	00:31	13:55	01:20	16:16	00:10	15:10	02:11	16:02
9	01:07	15:05	02:16	17:15	01:09	16:03	03:11	16:33
10	01:48	16:15	03:18	18:06	02:12	16:47	04:09	17:00
11	02:35	17:24	04:22	18:49	03:15	17:26	05:06	17:27
12	03:29	18:28	05:26	19:27	04:17	17:59	06:01	17:53
13	04:29	19:25	06:29	19:59	05:18	18:29	06:57	18:20
14	05:34	20:14	07:29	20:29	06:16	18:57	07:53	18:50
15	06:39	20:55	08:27	20:56	07:13	19:24	08:49	19:22
16	07:43	21:30	09:23	21:23	08:09	19:51	09:46	19:59
17	08:44	22:01	10:18	21:50	09:04	20:19	10:43	20:40
18	09:42	22:30	11:14	22:19	10:00	20:49	11:38	21:28
19	10:39	22:56	12:10	22:51	10:57	21:23	12:30	22:22
20	11:34	23:23	13:07	23:27	11:54	22:01	13:18	23:20
21	12:29	23:51	14:04	DNS	12:50	22:46	14:01	DNS
22	13:24	DNS	15:01	00:08	13:45	23:37	14:41	00:23
23	14:21	00:21	15:55	00:56	14:37	DNS	15:17	01:28
24	15:19	00:54	16:46	01:50	15:24	00:33	15:50	02:35
25	16:17	01:33	17:33	02:51	16:07	01:36	16:23	03:43
26	17:13	02:17	18:14	03:56	16:46	02:41	16:57	04:53
27	18:07	03:09	18:52	05:03	17:22	03:49	17:33	06:04
28	18:56	04:06	19:27	06:12	17:56	04:58	18:13	07:18
29	19:41	05:09			18:29	06:08	19:00	08:33
30	20:20	06:15			19:04	07:18	19:52	09:47
31	20:55	07:22			19:41	08:30		

	MAY		JUNE		JULY		AUGUST	
1	20:52	10:55	22:55	12:05	23:42	11:38	00:21	11:27
2	21:55	11:55	23:56	12:39	DNR	12:04	01:18	11:58
3	23:00	12:47	DNR	13:09	00:39	12:31	02:15	12:33
4	DNR	13:29	00:54	13:36	01:34	12:58	03:12	13:13
5	00:04	14:06	01:51	14:02	02:30	13:27	04:08	13:59
6	01:05	14:37	02:46	14:28	03:27	13:59	05:02	14:51
7	02:04	15:05	03:41	14:55	04:24	14:36	05:52	15:49
8	03:01	15:31	04:37	15:25	05:21	15:18	06:37	16:50
9	03:56	15:57	05:34	15:59	06:16	16:06	07:17	17:54
10	04:51	16:24	06:31	16:37	07:09	17:00	07:53	18:58
11	05:47	16:52	07:28	17:21	07:57	17:59	08:25	20:02
12	06:43	17:23	08:22	18:11	08:40	19:00	08:56	21:07
13	07:40	17:58	09:13	19:06	09:18	20:03	09:26	22:12
14	08:37	18:38	09:59	20:05	09:52	21:06	09:58	23:18
15	09:33	19:24	10:40	21:07	10:23	22:09	10:32	DNS
16	10:26	20:15	11:16	22:09	10:53	23:13	11:10	00:27
17	11:15	21:12	11:49	23:13	11:24	DNS	11:55	01:37
18	11:59	22:12	12:20	DNS	11:56	00:19	12:47	02:46
19	12:39	23:14	12:51	00:17	12:32	01:26	13:47	03:52
20	13:15	DNS	13:23	01:22	13:13	02:36	14:52	04:51
21	13:48	00:18	13:57	02:30	14:01	03:48	16:00	05:42
22	14:20	01:23	14:36	03:41	14:58	04:58	17:08	06:26
23	14:52	02:30	15:21	04:54	16:02	06:04	18:13	07:02
24	15:26	03:39	16:15	06:08	17:10	07:02	19:15	07:35
25	16:03	04:51	17:16	07:19	18:19	07:50	20:15	08:04
26	16:46	06:05	18:23	08:22	19:26	08:31	21:13	08:31
27	17:36	07:21	19:32	09:15	20:29	09:06	22:10	08:58
28	18:34	08:34	20:39	10:00	21:30	09:37	23:07	09:26
29	19:38	09:40	21:44	10:37	22:28	10:05	DNR	09:56
30	20:45	10:38	22:44	11:09	23:25	10:31	00:04	10:29
31	21:51	11:26			DNR	10:59	01:01	11:07

	SEPTEMBER		OCTOBER		NOVEMBER		DECEMBER	
1	01:58	11:51	02:24	12:20	02:50	14:15	02:19	15:13
2	02:53	12:40	03:07	13:21	03:21	15:21	02:52	16:24
3	03:44	13:36	03:46	14:25	03:52	16:29	03:29	17:38
4	04:31	14:36	04:21	15:30	04:24	17:39	04:12	18:54
5	05:13	15:39	04:54	16:36	05:00	18:53	05:03	20:09
6	05:50	16:44	05:25	17:44	05:40	20:08	06:03	21:16
7	06:25	17:49	05:57	18:53	06:26	21:22	07:11	22:13
8	06:56	18:55	06:30	20:04	07:21	22:31	08:21	23:01
9	07:27	20:02	07:07	21:16	08:23	23:32	09:31	23:40
10	07:59	21:10	07:49	22:29	09:30	DNS	10:37	DNS
11	08:33	22:19	08:37	23:38	10:37	00:23	11:40	00:13
12	09:10	23:29	09:33	DNS	11:44	01:05	12:40	00:42
13	09:53	DNS	10:34	00:42	12:47	01:40	13:37	01:09
14	10:42	00:39	11:40	01:37	13:47	02:11	14:34	01:35
15	11:39	01:45	12:46	02:24	14:46	02:39	15:31	02:02
16	12:42	02:46	13:51	03:03	15:43	03:05	16:28	02:30
17	13:48	03:38	14:53	03:37	16:40	03:31	17:25	03:02
18	14:54	04:23	15:53	04:06	17:37	03:58	18:23	03:37
19	15:59	05:01	16:52	04:34	18:34	04:28	19:18	04:17
20	17:02	05:34	17:49	05:01	19:32	05:00	20:10	05:03
21	18:02	06:04	18:47	05:27	20:29	05:37	20:58	05:55
22	19:01	06:31	19:44	05:56	21:23	06:19	21:40	06:51
23	19:59	06:58	20:42	06:26	22:14	07:07	22:17	07:50
24	20:56	07:26	21:39	07:00	23:00	08:00	22:50	08:50
25	21:54	07:55	22:36	07:39	23:40	08:57	23:21	09:50
26	22:51	08:27	23:29	08:23	DNR	09:56	23:50	10:51
27	23:48	09:03	DNR	09:13	00:16	10:57	DNR	11:52
28	DNR	09:43	00:18	10:07	00:49	11:59	00:18	12:56
29	00:43	10:30	01:02	11:06	01:19	13:01	00:48	14:02
30	01:36	11:22	01:42	12:08	01:49	14:06	01:21	15:12
31			02:18	13:11			02:00	16:25

OBSERVING THE MOON

The Moon has something for everyone, whether you are using binoculars or a telescope. In fact, many features are visible to the naked eye. The so-called *Man in the Moon* is a pattern formed by a number of prominent seas, although south of the equator, more people report seeing a *rabbit*.

The Moon maps are drawn with south to the top giving a correct view as we see it from the Southern Hemisphere. After New Moon the phase grows (or waxes) from a thin phase on the eastern limb (left edge of the left hand map) toward the right. After Full Moon the bright limb starts to wane or shrink away from the eastern limb. Approximately 14 to 15 days after a feature has been on the terminator it is there again but this time illuminated from the opposite direction with shadows going the other way (it is sunrise before Full Moon and sunset after). This is why the table below goes only a few days beyond Full Moon, because the features would be repeated. If you are able to view until well into the morning, beyond Third Quarter, you will be treated to a whole new perspective. For the first 1 to 2 days after being New the Moon is too close to the Sun and the horizon to give good views. It is better to wait until a couple of days beyond Full Moon (e.g. 17 days) to see these features return to the terminator under dark, night skies.

The Table: The lunar features listed are those on the terminator (the day/night line) for the age of the Moon, that is the number of days after New Moon. The presumed position of the terminator is only approximate for this can vary depending on the libration or even the time of day. Objects on the terminator give a true 3D effect with the low Sun angle sometimes resulting in complex, interesting shadows from peaks, crater walls, ridges and mountains. Seeing a *star* suspended in an otherwise dark crater as the sunlight touches the peak of its central mountain is impressive! For each day the features are listed starting in the south (top of the page) and moving north (down) along the terminator. The list covers prominent objects or those that present an observing challenge, such as ridges on the crater floor. The majority are craters unless otherwise named such as Mare for seas (see key list on the maps). The number following a crater's name is its diameter in kilometres. Note, there are numerous features that give great views over a number of lunar days (such as seas), but may not be listed on subsequent days.

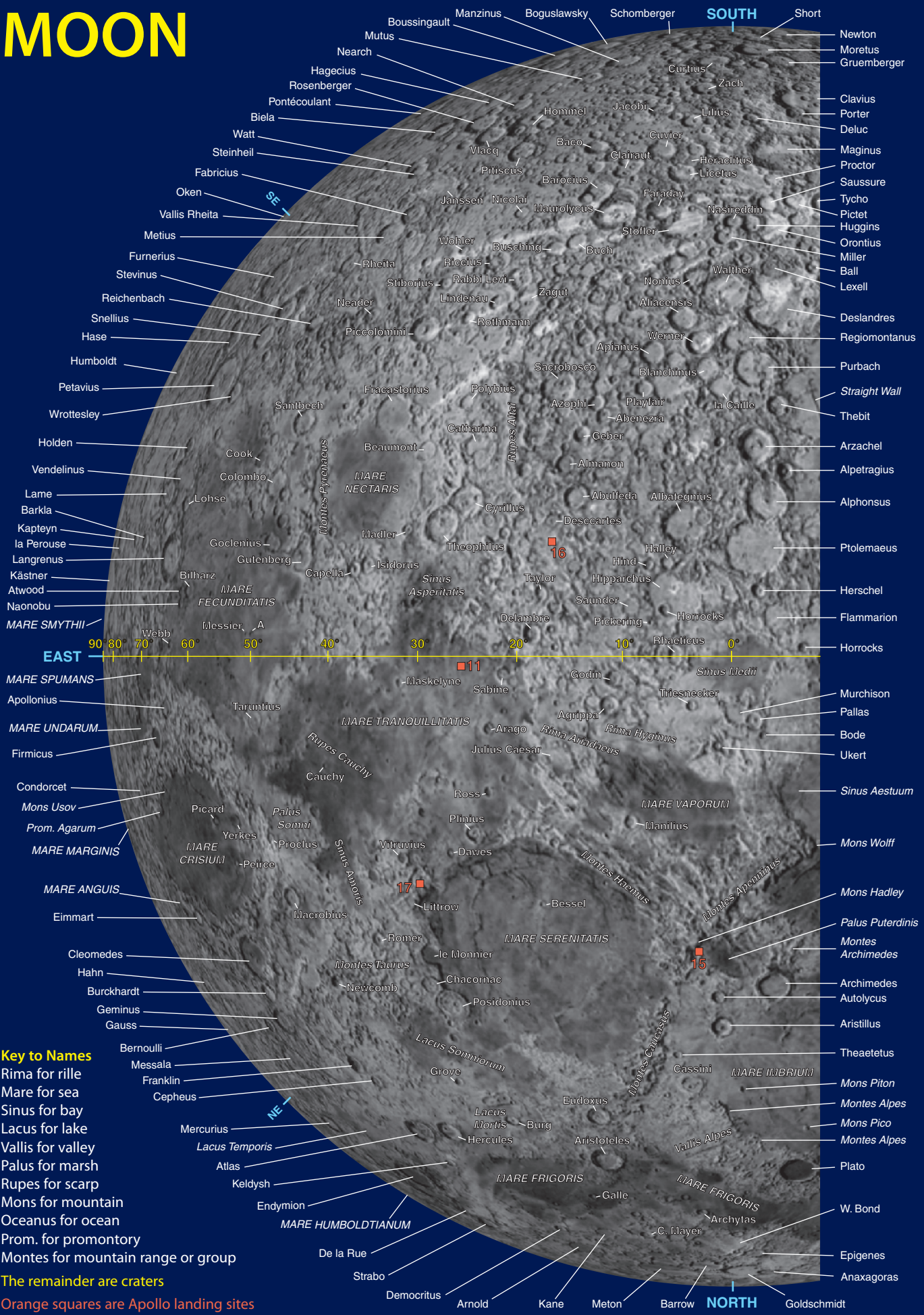
FEATURE	NOTES
Day 3 (48° E)	
Biela (76 km)	three central peaks
Furnerius, Petavius, Vendelinus and Langrenus	easily recognised row of four craters
Furnerius (130 km)	look for small crater on floor
Petavius (177 km)	central mountain and rille
Vendelinus (150 km) and Lame (84 km)	merged craters (Lame was a later impact)
Langrenus (132 km)	terraced walls, double central peak
Mare Fecunditatis	Sea of Fertility, note ridges on floor
Picard (24 km) and Peirce (19 km)	prominent on floor of Mare Crisium
Mare Crisium	one of the most prominent features on the Moon (Sea of Crises)
Cleomedes (132 km)	look for rille on floor
Geminus (87 km)	terraced walls, central peak
Endymion (124 km)	smooth, dark-floored crater
Day 4 (40° E)	
Vlacq (89 km)	has prominent central peak, paired with Rosenberger
Janssen (24 km)	old, northern wall destroyed by heavy cratering
Vallis Rheita	crater chain, next to Rheita
Rheita (70 km)	has nice central peak, forms a line with Metius and Fabricius
Neander (52 km)	contains small central peak and crater
Mare Fecunditatis	Sea of Fertility
Taruntius (57 km)	prominent on Mare Fecunditatis
Messier (13 km)	pair of small craters with two prominent rays running west (on Mare Fecunditatis)
Macrobius (64 km)	a good landmark
Franklin (54 km) and Cepheus (39 km)	pair, Franklin has central peak
Atlas (87 km)	prominent on terminator
Day 5 (28° E)	
Mare Nectaris	Sea of Nectar in full view
Fracastorius (120 km)	on northern edge of Mare Nectaris, has a lava-flooded floor with the northern rim destroyed
Capella (64 km) and Isidorus (41 km)	distinctive pair on northern edge of Mare Nectaris. Capella has a central peak with a valley cutting through the crater
Mare Tranquillitatis	Sea of Tranquility, partly revealed
Maskelyne (24 km)	small prominent crater in southern region of Mare Tranquillitatis
Rupes Cauchy	a scarp casting shadows on Mare Tranquillitatis

FEATURE	NOTES
Posidonius (101 km)	impressive, circular walled plain
Lacus Somniorum	Lake of Dreams
Atlas (87 km) and Hercules (67 km)	prominent pair of craters near Mare Frigoris
Mare Frigoris	Sea of Cold
Day 6 (20° E)	
Manzinus (97 km)	deep crater with small craters on floor
Mutus (76 km)	paired with Manzinus with three small craters nearby
Hommel (120 km)	south of Pitiscus, with two obvious internal craters
Pitiscus (82 km)	prominent crater with central peak
Maurolycus (116km)	old, heavily cratered floor
Catharina (101 km), Cyrillus (93 km) and Theophilus (104 km)	Theophilus and Cyrillus are overlapping craters, these three make a very distinctive group
Delambre (46 km)	near equator
Arago (26 km), Ross (27 km) and Plinius (43 km)	three distinctive, isolated craters on western Mare Tranquillitatis
Bessel (16 km)	small isolated crater on Mare Serenitatis
Mare Serenitatis	Sea of Serenity
Eudoxus (67 km) and Aristoteles (88 km)	an impressive pair of craters near Mare Frigoris
Day 7 (4° E) — First Quarter	
Curtius (95 km)	contains three small mountain peaks
Lilius (62 km)	prominent central peak (casts a long spire shadow at low Sun angles)
Cuvier (78 km), Heraclitus (97 km) and Licetus (76 km)	three craters in an obvious triangle
Stöfler (126 km)	large flat floored crater with smaller crater Faraday crushing its eastern wall
Aliacensis (81 km) and Werner (71 km)	pair of striking craters
Azophi (48 km), Abenezra (42 km) and Gerber (46 km)	obvious group of three craters
Albategnius (134 km)	has a distinctive central mountain with flat plain, the western wall contains Klein
Hipparchus (153 km)	eroded crater
Horrocks (30 km)	sits on northern edge of Hipparchus
Godin (36 km) and Agrippa (46 km)	nice isolated pair, Agrippa has an obvious central peak
Mare Vaporum	Sea of Vapours, has series of ridges and Hyginus Rille
Manilius (39 km)	prominent, isolated crater in eastern Mare Vaporum
Mare Serenitatis	now in full view
Montes Caucasus	eastern edge of Mare Imbrium, casting large shadows

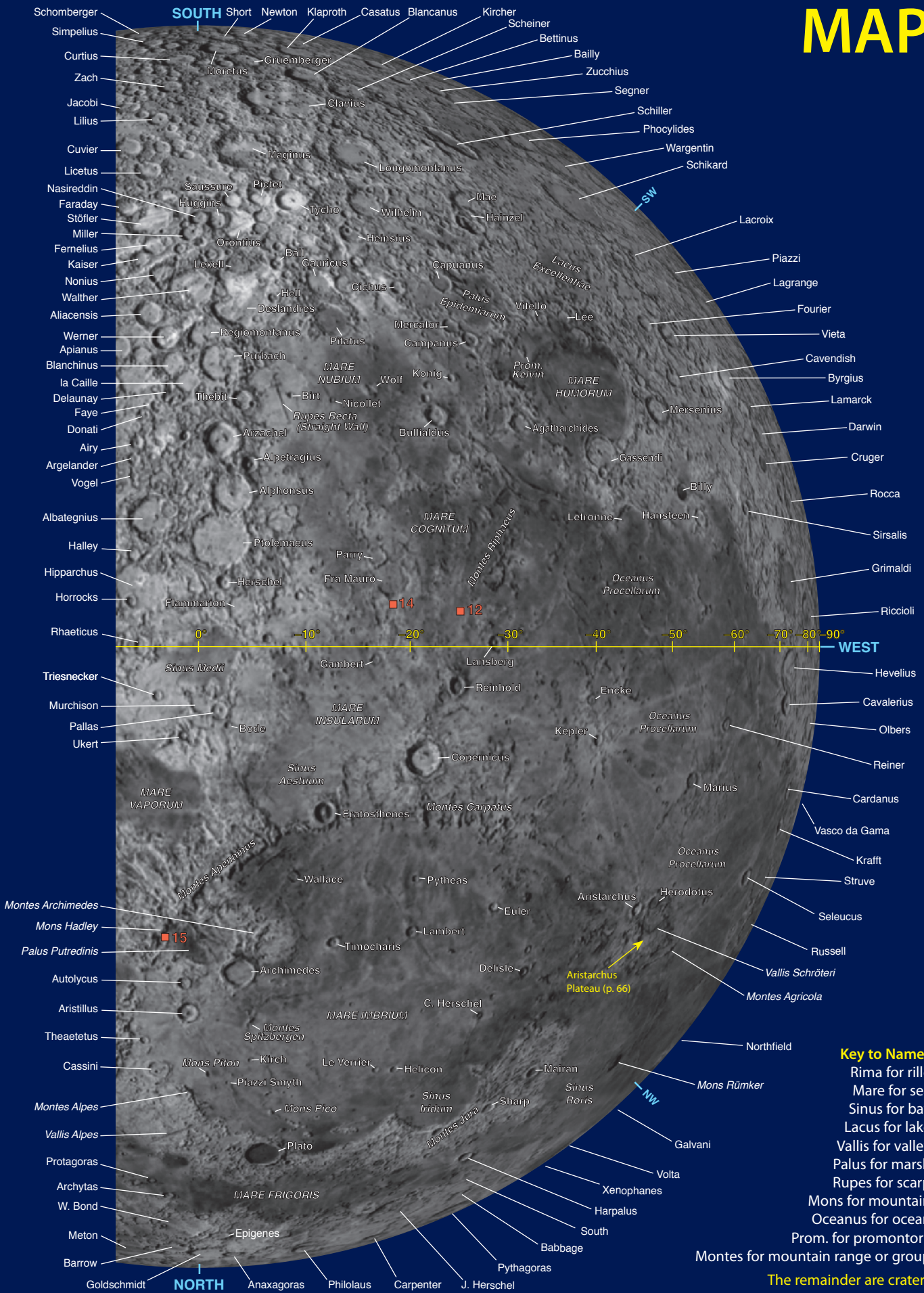
FEATURE	NOTES
Day 8 (4° W)	
Purbach (124 km)	damaged, containing slopes and ridges
Arzachel, Alphonsus and Ptolemaeus	possibly the most recognisable line of three craters on the Moon
Arzachel (97 km)	terraced walls with the floor having a central peak, small craters and a rille
Alphonsus (117 km)	central peak with two rilles running along the floor
Ptolemaeus (160 km)	a vast flat floor with degraded walls, note the small crater Ammonius (north-east of centre)
Herschel (41 km)	obvious crater close to Ptolemaeus (north side)
Ptolemaeus to Walther (132 km)	extending the Ptolemaeus group of three south to Walther, line of six large craters
Sinus Medii	Bay of the Centre (marking the Centre of the Moon)
Triesnecker (28 km)	prominent crater isolated in Sinus Medii
Mones Apennine	eastern end of this mountain range, on south-east edge of Mare Imbrium
Mare Imbrium	Sea of Rains, eastern part in view
Autolycus (39 km)	makes a distinctive pair with Aristillus to the north
Aristillus (56 km)	three central mountain peaks
Cassini (57 km)	crater in northern Mare Imbrium, with two smaller craters on floor
Vallis Alpes (Alpine Valley)	cuts through Montes Alpes
Montes Alpes	northern edge of Mare Imbrium
Day 9 (15° W)	
Moretus (117 km)	not far from the south pole, another distinctive crater with a central mountain that casts eye-catching shadows
Clavius (232 km)	a number of smaller craters are on the floor (location of Clavius Base, from where TMA-1 was discovered—for those Sci-Fi fans)
Rays extending to the east from Tycho	these develop as the Moon gets closer to full
Tycho (87 km)	prominent crater in the southern uplands, at low Sun angles its central peak casts a *witch's hat* shadow (location of TMA-1, see Clavius above)
Hell (35 km)	well defined crater in flat plain of Deslandres
Pitatus (88 km)	on southern edge of Mare Nubium, a flat lava filled crater with central peak
Mare Nubium	Sea of Clouds, eastern portion
Nicollet	small distinctive crater in the middle of Mare Nubium
Rupes Recta (Straight Wall)	running north-south (120 km) on eastern edge of Mare Nubium, small crater Birt is just west
Eratosthenes (58 km)	at the western end of the Apennines, has terraced walls and a central peak
Mones Apennine	the mountain range is now in full sunlight
Archimedes (80 km)	distinctive, flat floored crater in Mare Imbrium
Mons Piton and Mons Pico	two obvious isolated mountains in northern Mare Imbrium, both cast long shadows at low Sun angles
Plato (101 km)	at the northern end of Mare Imbrium, casts interesting shadows from its jagged crater walls and has challenging 1 km diameter craters on its floor
Day 10 (27° W)	
Longomontanus (149 km)	a walled plain with several craters around the edge of the floor plus some peaks
Mare Nubium	now in full sunlight
Bullialdus A, B and Konig (23 km)	a group of three craters, just south of Bullialdus, standing out well against the dark floor of Mare Nubium
Bullialdus (60 km)	prominent crater in Mare Nubium with terraced walls and multiple peaked central mountain
Lansberg (39 km)	isolated crater with central peak in Mare Insularum
Reinhold (45 km)	distinctive crater, near Lansberg in Mare Insularum

FEATURE	NOTES
Copernicus (91 km)	possibly the most recognisable crater on the Moon. It has terraced walls and a prominent central peak with surrounding ejector rays, standing out well against the dark floored mare. Located on the border of Mare Insularum and Mare Imbrium
Crater chain	a challenge, this string of craters (4–7 km) is between Copernicus and Eratosthenes, running roughly towards the south-east
Day 11 (40° W)	
Scheiner (115 km)	west of Clavius, this crater has four small craters on its floor. Makes a good pair with Blancanus.
Schiller (180 km)	this prominent elongated crater has an obvious ridge running along its floor visible at low Sun angles
Hainzel (73 km)	has an odd shape showing signs of multiple impacts in the past
Vitello (42 km)	on southern edge of Mare Humorum is a steep walled crater with central mountain
Gassendi (110 km)	contains a double mountain peak and several rilles and hills on the floor
Kepler (33 km)	in eastern part of Oceanus Procellarum is this well known rayed crater. These rays develop as the Moon gets closer to full.
Sinus Iridum	this obvious bay in north-west Mare Imbrium is probably a lava filled remnant of an old impact
Day 12 (55° W)	
Schickard (216 km)	has a dark floor with white stripe
Aristarchus (39 km)	the brightest feature on the near side of the Moon. This is even visible when lit only by earthshine (near New Moon). It sits on a smooth, dark plateau.
Herodotus (36 km)	next to Aristarchus. The prominent winding valley, Schröter's, extends from Herodotus towards the north.
Day 13 and 14 (about 70°–80° W)	
Bailly (295 km)	a large, foreshortened crater near the south pole limb, presents great views with favourable librations
Wargentin (84 km)	was once a crater but now filled with lava to the brim forming a plateau, that appears to stand above the surface with the right Sun angle
Mersenius (84 km)	west of Mare Humorum, has a lava-flooded floor with small crater pits
Billy (46 km)	prominent crater with a dark floor
Grimaldi (228 km)	large, foreshortened, dark floored crater is an obvious signpost
Hevelius (109 km) and Cavalerius (60 km)	a distinctive pair near western limb. Hevelius is a walled plain with a small central peak and crisscross pattern of rilles
Cardanus (51 km) and Krafft (53 km)	impressive pair near limb against backdrop of dark plain of Oceanus Procellarum
Struve (175 km) and Russell (105 km)	both are extremely foreshortened limb features, appearing to merge
Mons Rumker	a well known lunar dome (mound-like), isolated in Sinus Roris
Pythagoras (129 km)	very close to the northern pole limb, is extremely foreshortened but displays good terraced walls and twin central peaks
Day 15 — Full Moon	
Bright Rays from craters	the most prominent example is Tycho (dominates the southern hemisphere). The rays of Copernicus, Aristarchus and Kepler form a triangle. Also worthwhile looking at are Stevinus, Proclus (fan shaped ejecta) and Anaxagoras
Bright craters	there are a number of these which include Dionysius, Byrgius, and Censorinus
Dark features	all the seas and walled plains of Grimaldi, Endymion and Plato
Day 16 to 17 (about 70°–80° E)	
Furnerius, Petavius, Vendelinus and Langrenus	seen at best (better view than day 3)
Mare Crisium	best phase to see the wrinkled ridges on floor

MOON


SOUTH
NORTH
EAST
WEST
NE
SE
Manzinus
Boguslawsky
Schomberger
Short
Boussingault
Mutus
Nearch
Hagecius
Rosenberger
Pontécoulant
Biela
Watt
Steinheil
Fabricius
Oken
Vallis Rheita
Metius
Furnerius
Stevinus
Reichenbach
Snellius
Hase
Humboldt
Petavius
Wrottesley
Holden
Vendelinus
Lame
Barkla
Kapteyn
la Perouse
Langrenus
Kästner
Atwood
Naonobu
MARE SMYTHII
MARE SPUMANS
Apollonius
MARE UNDARUM
Firmicus
Condorcet
Mons Usov
Prom. Agarum
MARE MARGINIS
MARE ANGUIS
Eimmart
Cleomedes
Hahn
Burckhardt
Geminus
Gauss
Bernoulli
Messala
Franklin
Cepheus
Mercurius
Lacus Temporis
Atlas
Keldysh
Endymion
MARE HUMBOLDTIANUM
De la Rue
Strabo
Democritus
Arnold
Kane
Meton
Barrow
Goldschmidt
Anaxagoras
W. Bond
Archytas
C. Mayer
Epigenes
Plato
MARE FRIGORIS
Galle
Aristoteles
Eudoxus
Lacus Mortis
Burg
Hercules
Lacus Somniorum
Grove
Montes Taurus
Newcomb
Chacornac
Posidonius
Cassini
MARE IMBRIUM
Mons Piton
Montes Alpes
Mons Pico
Montes Alpes
Vallis Alpes
Montes Caucasus
Aristillus
Autolycus
Archimedes
Palus Puterdinis
Montes Archimedes
Mons Hadley
Montes Apenninus
Mons Wolff
Sinus Aestuum
MARE VAPORUM
Manilius
Plinius
Ross
Littrow
Bessel
Romer
le Monnier
MARE SERENITATIS
Macrobius
Sinus Amoris
Montes Haemus
Dawes
Vitruvius
Proclus
Peirce
MARE CRISIUM
Yerkes
Picard
Palus Somni
Cauchy
Rupes Cauchy
Julius Caesar
Rima Ariadaeus
Rima Hyginus
Arago
MARE TRANQUILLITATIS
Agrippa
Taruntius
Maskelyne
Sabine
Godin
Sinus Medii
Triesnecker
Murchison
Pallas
Bode
Ukert
Horrocks
Flammarion
Pickering
Delambre
Saunder
Herschel
Hipparchus
Taylor
Sinus Asperitatis
Bilharz
Capella
Isidorus
Gutenberg
Goclenius
Madler
Theophilus
Cyrillus
Descartes
Abulfeda
Albategnius
Alphonsus
Ptolemaeus
Halley
Hind
Rhaeticus
Webb
Messier
A
MARE FECUNDITATIS
Lohse
Colombo
Cook
Beaumont
Montes Pyrenaeus
MARE NECTARIS
Rupes Altai
Catharina
Almanon
Geber
Arzachel
Alpetragius
Santbech
Fracastorius
Polybius
Azophi
Playfair
Abenezra
la Caille
Thebit
Straight Wall
Purbach
Sacrobosco
Blanchinus
Apianus
Werner
Regiomontanus
Deslandres
Aliacensis
Nonius
Walther
Lexell
Ball
Orontius
Miller
Huggins
Tycho
Pictet
Saussure
Proctor
Maginus
Clavius
Porter
Deluc
Curtius
Zach
Newton
Moretus
Gruemberger
Hommel
Jacobi
Lilius
Baco
Cuvier
Vlacq
Clairaut
Heraclitus
Licetus
Pitiscus
Barocius
Janssen
Nicolai
Mutrolycus
Faraday
Nasireddin
Stoffler
Wohler
Busching
Buch
Riccius
Rheita
Stiborius
Rabbi Levi
Zagut
Lindenau
Neader
Rothmann
Piccolomini
Lambert
Timocharis
Harpalus
Diophantus
Eratosthenes
Copernicus
Reinhold
Aristarchus
Herodotus
Prinz
Schröter's Valley
Cobra Head
Cobra Head
Hansteen
Gruithuisen
Gruithuisen
Mairan
Milichius
Seleucus
Krieger
Marius
Reiner
Encke
Kepler
Hevelius
Letronne
Oceanus Procellarum
Sharp
Helicon
Hercules
Atlas
Lacus Temporis
Mercurius
Montes Riphaeus
Montes Harbinger
Montes Agricola
Montes Recti
Montes Secchi
Montes Rook
Montes Carpatus
Montes Spitzbergen
Montes Cordillera
Montes Altai
Montes Caucasus
Montes Alpes
Montes Apenninus
Montes Archimedes
Montes Haemus
Montes Taurus
Montes Pyrenaeus

MAP



Aristarchus Plateau (p. 66)

Key to Names

Rima for rille
Mare for sea
Sinus for bay
Lacus for lake
Vallis for valley
Palus for marsh
Rupes for scarp
Mons for mountain
Oceanus for ocean
Prom. for promontory
Montes for mountain range or group
The remainder are craters
Orange squares are Apollo landing sites

LUNAR OCCULTATIONS

INTRODUCTION

An occultation happens when a body passes in front of a more distant astronomical object. As viewed from Earth, no Solar System body occults more stars, more often, than our own Moon. The reasons for this are:

1. Its large angular size. Although the Moon is small in comparison to the planets, it appears large (0.5° wide) because of its proximity. The Moon travels along a 0.5° wide path across the sky, as does the Sun.
2. The rapid motion of the Moon across the sky. It completes one orbit about every 28 days.
3. With it moving approximately in the plane of the ecliptic, as do most Solar System bodies, each month the Moon crosses the heavily star populated Milky Way. It also occasionally occults the Sun and the planets. An eclipse of the Sun is indeed the most spectacular lunar occultation!

From month to month the Moon does not occult the same stars. In fact over a number of years it drifts in declination between plus and minus 28°. The brighter stars that the Moon occults are listed in the Zodiacal Catalogue (ZC). There are about 3500 stars in the ZC.

The Moon moves from west to east, so it rises and sets later each day. From just after New Moon to just before Full Moon, stars being occulted disappear behind part of the dark limb and reappear from the bright limb. The limb is another term for the edge of the Moon. After Full Moon a star disappears on the bright limb and reappears on the dark limb. There is no dark limb at Full Moon.

Dark limb events, in particular disappearances, are the easiest to observe. Following a star until it *winks out* is much easier than scanning the lunar limb, waiting for it to suddenly reappear. The brighter the star, the more spectacular the event. The following tables present the easier to observe occultations for 2021 as predicted for **Adelaide**, **Brisbane**, **Canberra**, **Darwin**, **Hobart**, **Melbourne**, **Perth** and **Sydney**. Both events, the disappearance and reappearance, are not necessarily included. An event may not be present because:

1. The Moon is in daylight.
2. The Moon is too close to or below the horizon.
3. For faint stars, events on a bright limb (in particular reappearances) are difficult to observe and have been omitted.

THE TIMING OF OCCULTATIONS.

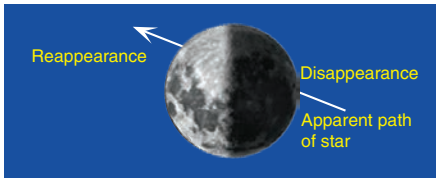
Besides being a spectacular event, the observation of occultations is an area in which the amateur can make a scientific contribution.

TIMING EQUIPMENT. Historically, amateurs timed these events by recording a radio time signal along with their voice calling out the events. There are several more modern techniques in use today. Most observers are now using a combination of video and a GPS signal to record an occultation. See links below for more information.

TELESCOPE REQUIREMENTS. These vary greatly with the brightness of the star being observed, the brightness of the Moon (how close to Full Moon) and whether the event is on a bright or dark limb. Disappearances of first magnitude stars on the dark limb can be observed with the naked eye.

For further information on timing methods for occultations it would be worth contacting your local astronomical society (see Part III) or the International Occultation Timing Association.

www.lunar-occultations.com/iota/iotandx.htm
www.occultations.org.nz



LUNAR OCCULTATION TABLES

The faintest stars, which have occultation predictions on the following pages, are approximately 6.5 magnitude. The criteria for selection are complex involving the Sun and Moon altitude, star magnitude and whether it is a bright or dark limb event.

EXPLANATION

EST the date and time of the occultation, hr and min are in EST except Adelaide and Darwin using CST and Perth using WST.

OBJECT n, nn, nnn, nnnn ZC catalogue number
ggg ccc Greek letter and constellation abbreviation
n ccc Flamsteed number and constellation
name of planet, satellite or deep sky object.

PD event, consisting of two letters.
The first letter is the type of Event: D = Disappearance and R = Reappearance. The second letter represents: D = Dark limb, B = a bright limb event. G indicates a graze at or near the location. M means a miss with a graze nearby.

Mag magnitude of the star.

Elg elongation or separation of the Moon from the Sun as measured in degrees.

Alt altitude of the Moon during the occultation.

PA position angle is the position the event occurs on the limb of the Moon (measured as degrees east of north).

A coefficient of longitude (see below)

B coefficient of latitude (see below)
NB. For some stars (including those close to a graze) A and B would be useless, no values are shown.

CALCULATING EVENT TIME FOR OTHER LOCATIONS

Unless the event is close to a graze (PA is close to 0° or 180°) this method will give a good approximation for any location within about 500 km from the city's table you are working from. The formula is:

The predicted time at your location is given by

$$\text{Predicted Time} = \text{Time from Table} + (A \times n) + (B \times p)$$

where A and B are taken from the tables for your nearest city and n and p are given by

n = your longitude – reference longitude

p = reference latitude – your latitude

you need to preserve the signs of n and p , that is, whether they are positive or negative and it is best to use your closest city.

WORKED EXAMPLE

An observer wishes to calculate a more accurate time for the reappearance of Lam Sgr on May 28 for their location in Albury NSW (146° 55' E, 36° 05' S). Canberra is the closest city, therefore we start with the data from its table.

The change in longitude from Canberra (decimal degrees)
= 146.92° – 149.13° = – 2.21° — 'n' (–)

The change in latitude from Canberra (decimal degrees)
= 35.25° – 36.08° = – 0.83° — 'p' (–)

From the Canberra table, the time of the event is 22:20 EST and the values of A and B are + 1.7 and + 0.5 respectively.

Therefore the equation becomes:

22:20 + (+1.7 × –2.21°) + (+0.5 × –0.83°)
= 22:20 + (–3.8) + (–0.4)
= 22:20 + (–4.2) = 22:16

The event will be visible from Albury approximately four minutes earlier than Canberra, i.e., about 10:16 pm (EST) on May 28.

Lunar occultation predictions calculated using Occult version 4.10.1.0 by D. Herald.

LUNAR OCCULTATION TABLE

ADELAIDE (34° 54' S, 138° 36' E)

CST	Object	PD	Mag	Elg°	Alt°	PA°	A	B
Jan 04 00:37	52 Leo	RD	5.5	125	20	284	1.2	−1.4
Jan 05 03:57	Xi Vir	DB	4.8	111	44	66	3.5	0.7
Jan 31 23:18	Iot Leo	DB	3.9	144	21	74	1.3	−0.7
Feb 01 00:11	Iot Leo	RD	3.9	143	30	340	1.0	−2.6
Feb 20 19:33	665	DD	5.7	97	32	138	3.9	−2.6
Feb 20 20:12	665	RB	5.7	97	30	186	1.5	4.6
Mar 04 23:24	Zet Lib	RD	5.5	109	14	222	1.3	1.2
Mar 08 04:42	2719	DB	5.8	67	47	115	0.9	−1.8
Mar 28 02:57	Ome Vir	DD	5.2	164	26	110	1.0	0.3
Apr 01 22:10	Nu Sco	DB	4.1	127	15	44	1.1	0.8
Apr 01 22:30	Nu Sco	RD	4.1	127	19	1	−1.3	−3.8
Apr 01 22:30	X 22139	RD	5.4	127	19	1	−1.3	−3.8
Apr 03 05:01	44 Oph	DB	4.2	111	79	163	1.3	−5.2
Apr 03 05:42	44 Oph	RD	4.2	111	76	220	2.6	4.5
Apr 04 04:26	Lam Sgr	DB	2.8	98	69	159	0.8	−5.5
Apr 04 05:05	Lam Sgr	RD	2.8	97	76	214	3.0	4.3
Apr 16 18:49	Tau Tau	RB	4.3	46	14	223	1.8	2.6
Apr 29 04:02	47 Lib	RD	6.0	157	56	256	1.8	1.5
Apr 30 02:29	24 Oph	DD	5.6	144	78	188		
Apr 30 02:43	24 Oph	RD	5.6	144	78	207		
May 04 03:46	Chi Cap	DB	5.3	90	50	90	1.6	−1.0
May 04 05:07	Chi Cap	RD	5.3	90	66	239	2.0	0.9
May 08 05:16	49	DB	6.1	43	21	28	0.5	1.3
May 17 18:35	Ome Cnc	RB	5.9	61	24	336	0.5	−1.5
May 20 21:47	52 Leo	DD	5.5	98	29	60	3.3	3.5
May 20 22:18	52 Leo	RB	5.5	98	24	7	−1.1	−3.8
May 21 22:38	Ome Vir	DD	5.2	111	33	170	0.1	−2.2
May 21 23:27	Ome Vir	RB	5.2	112	25	259	1.5	1.8
May 27 04:43	Ome Oph	DB	4.5	176	34	73	0.6	1.7
May 27 05:38	Ome Oph	RD	4.5	176	22	303	0.7	0.1
May 27 23:00	44 Oph	DB	4.2	164	58	140	0.7	−2.5
May 28 00:02	44 Oph	RD	4.2	164	70	254	2.3	0.2
May 28 21:19	Lam Sgr	DD	2.8	151	26	184		
May 28 21:27	Lam Sgr	RD	2.8	151	27	199	5.8	8.7
May 29 22:27	52 Sgr	DB	4.6	136	26	105	0.3	−1.5
May 29 23:09	51 Sgr	RD	5.6	136	35	294	0.5	−1.8
May 29 23:30	52 Sgr	RD	4.6	136	39	260	1.0	−0.7
May 31 23:38	Eps Cap	DB	4.5	110	15	142	−0.7	−4.1
Jun 01 00:05	Eps Cap	RD	4.5	110	21	196	1.3	2.8
Jun 01 02:23	Kap Cap	DB	4.7	109	47	68	1.5	−0.1
Jun 01 03:45	Kap Cap	RD	4.7	108	63	252	2.0	0.2
Jun 23 00:31	47 Lib	DD	6.0	149	55	133	1.6	−1.0
Jun 23 05:04	Bet[1] Sco	DD	2.6	152	2	108	−0.1	0.5
Jun 23 23:49	24 Oph	DD	5.6	163	75	151	1.6	−3.0
Jun 26 02:44	Psi Sgr	DB	4.9	167	69	87	1.9	0.7
Jun 26 03:59	Psi Sgr	RD	4.9	166	54	251	1.2	1.5
Jun 27 21:27	Chi Cap	RD	5.3	142	17	219	0.7	0.6
Jun 28 00:03	Phi Cap	DB	5.2	141	47	64	1.5	0.1
Jun 28 01:20	Phi Cap	RD	5.2	140	62	265	2.0	−0.5
Jul 17 18:37	80 Vir	DD	5.7	89	60	75	3.3	1.2
Jul 17 19:26	80 Vir	RB	5.7	89	56	359	0.2	−3.6
Jul 20 23:59	Ome Oph	DD	4.5	132	48	26	0.5	9.3
Jul 21 00:18	Ome Oph	RB	4.5	132	44	356	2.5	−7.8
Jul 21 18:46	44 Oph	DD	4.2	144	50	140	0.5	−2.5
Jul 21 19:47	44 Oph	RB	4.2	144	62	256	2.1	−0.1
Jul 22 17:38	Lam Sgr	DB	2.8	157	25	177	−2.5	−6.2
Jul 22 17:53	Lam Sgr	RB	2.8	157	28	205	3.1	3.8
Jul 23 18:32	51 Sgr	DD	5.6	171	22	82	0.4	−0.8
Jul 23 18:52	52 Sgr	DD	4.6	171	26	116	0.1	−1.8
Jul 23 19:50	52 Sgr	RB	4.6	171	38	249	1.1	−0.4
Jul 25 21:09	Kap Cap	DB	4.7	160	27	108	0.5	−1.9
Jul 25 22:05	Kap Cap	RD	4.7	160	39	223	1.3	0.9
Aug 04 06:21	103 Tau	DB	5.5	53	23	114	2.7	−2.0
Aug 05 05:44	139 Tau	RD	4.8	43	11	286	1.5	−1.7
Aug 13 20:07	65 Vir	DD	5.9	61	28	198		
Aug 13 20:20	65 Vir	RB	5.9	61	26	220		
Aug 14 19:08	Kap Vir	RB	4.2	73	52	283	1.8	0.3
Aug 16 20:02	Ome[1] Sco	MB	3.9	100	68	200		
Aug 19 03:49	Lam Sgr	DD	2.8	131	4	162	2.2	−4.0
Aug 19 19:39	Psi Sgr	DD	4.9	140	62	61	2.1	0.6
Aug 19 20:51	Psi Sgr	RB	4.9	141	76	298	2.1	−1.8
Aug 21 18:42	Phi Cap	DD	5.2	166	25	93	0.5	−1.2
Aug 21 19:47	Phi Cap	RB	5.2	166	39	245	1.2	−0.1
Aug 24 04:52	Psi[2] Aqr	DB	4.4	164	36	70	1.0	1.6
Aug 24 05:56	Psi[2] Aqr	RD	4.4	163	23	225	0.3	2.0
Aug 26 23:04	Mu Psc	DB	4.8	130	16	27	0.2	1.2
Aug 27 00:05	Mu Psc	RD	4.8	130	27	266	1.4	−1.1
Sep 01 05:11	125 Tau	DB	5.2	73	23	47	1.2	0.4
Sep 13 21:53	24 Oph	DD	5.6	85	35	38	0.0	3.9
Sep 13 22:29	24 Oph	RB	5.6	85	28	331	1.5	−1.7
Sep 27 02:37	Ups Tau	DB	4.3	115	27	78	2.0	−0.4
Sep 27 03:27	72 Tau	DB	5.5	115	31	63	2.0	0.4
Sep 27 04:06	Ups Tau	RD	4.3	115	32	231	2.0	1.0
Sep 27 05:02	72 Tau	RD	5.5	115	31	251	2.4	0.8
Oct 01 05:14	Ome Cnc	RD	5.9	70	21	231	1.5	0.3
Oct 15 20:48	Kap Cap	DD	4.7	119	73	79	2.3	0.7
Oct 15 22:06	Kap Cap	RB	4.7	120	62	220	1.0	2.4
Nov 07 20:32	39 Oph	DD	5.2	35	13	72	−0.2	1.4
Nov 14 01:14	Psi[2] Aqr	DD	4.4	115	15	55	0.1	1.8
Nov 20 21:56	693	RD	6.0	167	18	221	0.6	0.5
Nov 28 02:08	52 Leo	RD	5.5	88	10	253	0.7	−0.8
Dec 08 20:35	Chi Cap	DD	5.3	57	32	101	0.9	0.8
Dec 08 21:23	Chi Cap	RB	5.3	57	22	210	−0.4	2.2
Dec 18 00:50	72 Tau	DD	5.5	163	26	136	2.5	−1.3
Jan 1 '22 03:53	Mars	DB	1.5	28	7	65	0.2	−0.3
Jan 1 '22 04:27	Mars	RD	1.5	27	14	346	−0.8	−2.4

BRISBANE (27° 30' S, 153° 01' E)

EST	Object	PD	Mag	Elg°	Alt°	PA°	A	B
Jan 04 01:17	52 Leo	RD	5.5	125	36	305	1.8	−1.7
Jan 05 01:12	1687	RD	6.2	112	30	295	1.3	−1.6
Jan 10 04:04	Nu Sco	DB	4.1	45	26	170	−0.7	−3.1
Jan 10 04:04	X 22139	DB	5.4	45	26	170	−0.7	−3.1
Jan 26 01:47	132 Tau	DD	5.0	142	7	144	−0.3	−1.2
Feb 01 00:21	Iot Leo	MB	3.9	144	41	31		
Feb 02 04:01	16 Vir	DB	5.0	129	58	182	−0.2	−3.7
Feb 02 04:48	16 Vir	RD	5.0	129	53	255	3.4	1.6
Feb 20 20:35	665	DD	5.7	97	30	121	2.2	−0.6
Mar 04 22:59	34 Lib	RD	5.8	109	14	266	0.3	−0.8
Mar 05 00:03	Zet Lib	RD	5.5	109	27	271	0.7	−1.0
Mar 26 01:17	14[3]5	DD	6.5	137	17	118	0.6	0.0
Mar 27 18:36	Iot Leo	MB	3.9	160	17	24		
Apr 04 02:17	2659	RD	6.2	99	49	326	0.4	−3.2
Apr 04 05:02	Lam Sgr	DB	2.8	98	84	112	2.4	−1.3
Apr 10 05:09	3506	RD	6.1	25	13	307	0.3	−3.9
Apr 16 18:38	Tau Tau	DD	4.3	46	16	92	1.2	0.9
Apr 20 21:07	Lam Cnc	DD	5.9	91	24	140	0.7	−0.9
Apr 21 18:28	79 Cnc	RB	6.0	102	40	315	2.1	−1.7
Apr 29 04:59	47 Lib	RD	6.0	157	39	283	1.2	0.4
Apr 30 02:54	24 Oph	DB	5.6	144	80	126	2.1	−1.5
Apr 30 04:10	24 Oph	RD	5.6	144	63	260	2.0	1.1
Apr 30 04:10	X138346	RD	6.3	144	63	260	2.0	1.1
May 01 00:18	63 Sgr	RD	6.2	131	52	270	1.6	−0.8
May 04 04:44	Chi Cap	DB	5.3	90	69	65	2.3	0.8
May 17 19:10	4 Cnc	DD	6.3	61	22	76	2.1	1.5
May 21 23:09	Ome Vir	DD	5.2	111	26	121	0.8	−0.2
May 27 23:39	44 Oph	DB	4.2	164	73	95	2.2	−0.6
May 28 00:21	2510	RD	6.2	164	82	267	2.5	0.0
May 28 01:01	44 Oph	RD	4.2	164	87	295	2.2	−1.1
May 28 21:22	Lam Sgr	DB	2.8	151	30	118	0.3	−1.6
May 28 22:24	Lam Sgr	RD	2.8	150	44	266	1.3	−0.7
May 29 23:03	52 Sgr	DB	4.6	136	38	63	1.4	0.2
May 30 00:06	52 Sgr	RD	4.6	136	52	301	1.2	−2.2
May 31 23:52	Eps Cap	DB	4.5	110	22	93	0.5	−1.0
Jun 01 00:59	Eps Cap	RD	4.5	110	37	243	1.3	0.2
Jun 01 03:25	Kap Cap	DB	4.7	109	68	46	2.0	1.7
Jun 01 04:52	Kap Cap	RD	4.7	108	81	261	2.7	0.4
Jun 23 01:20	47 Lib	DD	6.0	149	39	107	1.2	0.2
Jun 24 00:36	24 Oph	DD	5.6	163	63	115	2.0	−0.6
Jun 24 00:36	X138346	DD	6.3	163	63	115	2.0	−0.6
Jun 24 20:09	63 Sgr	DD	6.2	176	44	103	1.0	−1.2
Jun 26 03:45	Psi Sgr	DB	4.9	167	51	81	1.4	1.1
Jun 26 04:53	Psi Sgr	RD	4.9	167	36	252	0.6	1.4
Jun 27 22:07	Chi Cap	RD	5.3	142	29	262	0.8	−0.6
Jun 28 01:07	Phi Cap	DB	5.2	141	68	36	2.0	2.3
Jun 28 02:21	Phi Cap	RD	5.2	140	82	281	3.0	−0.8
Jul 21 18:47	2510	DD	6.2	143	56	128	1.1	−2.0
Jul 21 19:21	44 Oph	DD	4.2	144	63	95	1.9	−0.8
Jul 21 20:40	44 Oph	RB	4.2	144	81	300	2.0	−1.6
Jul 22 17:43	Lam Sgr	DD	2.8	157	30	117	0.3	−1.6
Jul 22 18:46	Lam Sgr	RB	2.8	157	43	267	1.3	−0.7
Jul 23 19:20	51 Sgr	DD	5.6	171	36	29	2.4	2.9
Jul 23 19:23	52 Sgr	DD	4.6	171	37	74	1.2	−0.3
Jul 23 20:30	52 Sgr	RB	4.6	171	52	290	1.4	−1.6
Jul 24 04:58	2907	DD	6.2	174	19	32	−0.5	2.3
Jul 25 21:43	Kap Cap	DB	4.7	160	40	73	1.3	−0.2
Jul 25 23:02	Kap Cap	RD	4.7	160	58	251	2.0	0.2
Aug 05 05:20	139 Tau	DB	4.8	43	16	45	0.4	0.6
Aug 13 20:24	65 Vir	DD	5.9	60	20	143	0.5	−1.0
Aug 13 21:15	66 Vir	DD	5.8	61	9	164	0.3	−2.1
Aug 14 18:44	Kap Vir	DD	4.2	73	54	98	2.1	0.4
Aug 14 19:55	Kap Vir	RB	4.2	73	39	321	1.1	−1.3
Aug 16 20:22	Ome[1] Sco	DD	3.9	100	61	135	1.9	−1.5
Aug 16 21:31	Ome[1] Sco	RB	3.9	100	45	256	1.4	1.5
Aug 19 21:09	Psi Sgr	DD	4.9	140	88	8		
Aug 19 21:31	Psi Sgr	RB	4.9	141	85	339		
Aug 21 19:22	Phi Cap	DD	5.2	166	39	57	1.4	0.5
Aug 21 20:35	Phi Cap	RB	5.2	166	55	276	1.9	−1.1
Aug 24 05:44	Psi[2] Aqr	DB	4.4	164	20	73	0.5	1.4
Aug 26 23:51	Mu Psc	DB	4.8	130	33	18	0.4	2.1
Aug 27 00:57	Mu Psc	RD	4.8	130	45	266	2.5	−0.6
Sep 13 22:46	24 Oph	DD	5.6	85	16	20	−1.8	5.9
Sep 13 22:46	X138346	DD	6.3	85	16	20	−1.8	5.9
Sep 18 02:45	27 Cap	DD	6.3	139	15	48	−0.2	1.7
Sep 20 02:13	74 Aqr	DD	5.8	163	39	344	−2.1	5.8
Sep 27 03:43	Ups Tau	DB	4.3	115	40	85	3.0	0.1
Sep 27 04:37	72 Tau	DB	5.5	115	39	67	2.7	1.1
Oct 01 04:57	Ome Cnc	DB	5.9	71	28	128	2.5	−2.1
Oct 15 19:24	Eps Cap	RB	4.5	118	80	248	2.4	0.9
Oct 15 21:57	Kap Cap	DD	4.7	119	61	86	2.2	0.9
Oct 15 23:04	Kap Cap	RB	4.7	120	46	210	0.3	2.6
Oct 16 19:08	56 Aqr	DD	6.4	131	65	354	0.0	6.6
Oct 17 19:19	Psi[3] Aqr	RB	5.0	143	56	274	2.6	−1.0
Oct 25 02:28	740	RD	6.3	135	38	257	2.8	0.4
Nov 06 18:36	Ome[1] Sco	DD	3.9	20	13	26	−1.5	5.7
Nov 06 18:53	Ome[1] Sco	RB	3.9	20	9	351	1.8	−4.3
Nov 19 19:19	14 Tau	DD	6.1	179	12	83	0.8	−0.8
Nov 19 19:43	13 Tau	RD	5.7	179	16	266	1.1	−0.8
Nov 19 20:24	14 Tau	RD	6.1	179	24	215	0.4	1.1
Nov 20 22:45	693	RD	6.0	167	34	213	1.0	1.5
Nov 25 00:39	Psi Cnc	RD	5.7	123	21	309	2.2	−2.3
Nov 28 02:48	52 Leo	RD	5.5	87	26	271	1.6	−1.0
Nov 29 03:35	1687	RD	6.2	75	30	20	−1.2	−8.6
Dec 08 21:20	Chi Cap	DD	5.3	57	15	106	0.4	0.5
Dec 18 01:44	72 Tau	DD	5.5	163	21	110	1.5	0.3

LUNAR OCCULTATION TABLE

CANBERRA (35° 15' S, 149° 08' E)

EST	Object	PD	Mag	Elg°	Alt°	PA°	A	B
Jan 04 01:23	52 Leo	RD	5.5	125	29	287	1.6	−1.4
Jan 05 01:18	1687	RD	6.2	112	24	278	1.2	−1.3
Feb 01 00:06	Iot Leo	DB	3.9	144	31	66	2.1	−0.1
Feb 01 00:51	Iot Leo	RD	3.9	144	37	354	0.6	−3.1
Feb 20 20:39	665	DD	5.7	97	26	154	2.2	−5.7
Mar 04 23:02	34 Lib	RD	5.8	109	13	240	0.5	−0.3
Mar 05 00:05	Zet Lib	RD	5.5	109	25	245	1.0	−0.4
Mar 08 05:25	2719	DB	5.8	67	58	103	1.5	−1.4
Mar 27 18:26	Iot Leo	DD	3.9	160	9	65	0.6	−0.5
Mar 27 19:07	Iot Leo	RB	3.9	160	17	343	0.8	−2.8
Mar 28 03:36	Ome Vir	DD	5.2	164	16	98	0.7	0.9
Apr 04 05:12	Lam Sgr	DB	2.8	98	78	149	1.8	−4.2
Apr 04 06:01	Lam Sgr	RD	2.8	97	80	217	2.3	3.8
Apr 10 05:24	3506	RD	6.1	25	13	268	0.4	−1.2
Apr 16 18:28	Tau Tau	DD	4.3	46	15	114	1.2	0.5
Apr 20 21:20	Lam Cnc	DD	5.9	91	19	180	−1.5	−3.8
Apr 29 04:47	47 Lib	RD	6.0	157	44	255	1.2	1.7
Apr 30 03:07	24 Oph	DB	5.6	144	76	166	1.3	−5.0
Apr 30 03:45	24 Oph	RD	5.6	144	70	222	2.3	4.5
May 04 04:36	Chi Cap	DB	5.3	90	62	92	2.1	−0.8
May 04 05:58	Chi Cap	RD	5.3	90	75	230	1.9	1.7
May 17 18:48	Ome Cnc	DD	5.9	61	21	26		
May 17 18:57	Ome Cnc	RD	5.9	61	19	12		
May 21 23:12	Ome Vir	DD	5.2	111	25	153	0.4	−1.2
May 27 05:17	Ome Oph	DB	4.5	176	24	84	0.4	1.2
May 27 06:13	Ome Oph	RD	4.5	176	13	290	0.2	0.5
May 27 23:42	44 Oph	DB	4.2	164	68	126	1.4	−1.9
May 28 00:56	44 Oph	RD	4.2	164	79	264	2.2	0.2
May 28 19:50	2659	RD	6.2	152	12	282	−0.2	−1.2
May 28 21:39	Lam Sgr	DB	2.8	151	32	150	−0.4	−2.9
May 28 22:20	Lam Sgr	RD	2.8	150	41	232	1.7	0.5
May 29 23:03	52 Sgr	DB	4.6	136	36	94	0.8	−1.2
May 29 23:45	51 Sgr	RD	5.6	136	45	306	0.7	−2.4
May 30 00:12	52 Sgr	RD	4.6	136	50	270	1.4	−1.0
Jun 01 00:05	Eps Cap	DB	4.5	110	23	128	0.0	−3.0
Jun 01 00:48	Eps Cap	RD	4.5	110	32	207	1.3	1.8
Jun 01 03:11	Kap Cap	DB	4.7	109	59	72	1.9	0.1
Jun 01 04:36	Kap Cap	RD	4.7	108	72	241	2.0	1.1
Jun 13 17:39	1169	RB	5.3	32	13	335	−0.1	−1.2
Jun 23 01:17	47 Lib	DD	6.0	149	43	135	1.3	−0.8
Jun 24 00:38	24 Oph	DD	5.6	163	64	148	1.8	−2.5
Jun 26 03:33	Psi Sgr	DB	4.9	167	57	100	1.7	0.5
Jun 26 04:37	Psi Sgr	RD	4.9	167	43	235	0.6	2.0
Jun 27 22:06	Chi Cap	RD	5.3	142	27	230	0.9	0.3
Jun 28 00:50	Phi Cap	DB	5.2	141	59	65	1.8	0.3
Jun 28 02:12	Phi Cap	RD	5.2	140	73	257	2.2	0.3
Jul 01 00:48	3506	RD	6.1	104	22	293	0.9	−2.8
Jul 21 00:32	Ome Oph	DD	4.5	132	38	42	0.4	3.9
Jul 21 01:09	Ome Oph	RB	4.5	132	31	335	1.4	−2.0
Jul 21 19:07	2510	DD	6.2	143	57	164	−0.1	−4.1
Jul 21 19:25	44 Oph	DD	4.2	144	60	124	1.2	−1.9
Jul 21 20:39	44 Oph	RB	4.2	144	74	269	2.1	−0.3
Jul 22 17:59	Lam Sgr	DD	2.8	157	31	148	−0.3	−2.8
Jul 22 18:42	Lam Sgr	RB	2.8	157	40	234	1.6	0.4
Jul 23 19:09	51 Sgr	DD	5.6	170	32	70	0.9	−0.4
Jul 23 19:26	52 Sgr	DD	4.6	171	36	103	0.6	−1.5
Jul 23 20:33	52 Sgr	RB	4.6	171	49	260	1.4	−0.6
Jul 25 21:46	Kap Cap	DB	4.7	160	37	104	1.0	−1.7
Jul 25 22:50	Kap Cap	RD	4.7	160	50	222	1.5	1.2
Aug 11 18:10	Ome Vir	RB	5.2	34	21	334	0.3	−1.2
Aug 13 20:39	65 Vir	DD	5.9	60	19	187	0.2	−5.2
Aug 14 18:40	Kap Vir	DD	4.2	73	54	129	1.5	−0.9
Aug 14 19:54	Kap Vir	RB	4.2	73	41	291	1.3	0.2
Aug 16 20:41	Ome[1] Sco	DD	3.9	100	58	183	1.2	−9.7
Aug 16 20:59	Ome[1] Sco	RB	3.9	100	55	210	1.8	9.8
Aug 19 20:31	Psi Sgr	DD	4.9	140	74	57	2.2	1.3
Aug 19 21:46	Psi Sgr	RB	4.9	141	79	294	2.4	−1.1
Aug 21 19:20	Phi Cap	DD	5.2	166	36	87	0.9	−1.0
Aug 21 20:32	Phi Cap	RB	5.2	166	50	247	1.6	0.0
Aug 24 04:57	Psi[1] Aqr	DB	4.2	164	32	358	−0.5	3.5
Aug 24 05:30	Psi[1] Aqr	RD	4.2	164	26	298	1.5	0.2
Aug 24 05:31	Psi[2] Aqr	DB	4.4	164	26	84	0.8	1.4
Aug 26 23:38	Mu Psc	DB	4.8	130	24	40	0.6	0.7
Aug 27 00:51	Mu Psc	RD	4.8	130	37	248	1.6	−0.1
Sep 13 22:23	24 Oph	DD	5.6	85	26	55	0.1	2.3
Sep 20 01:44	74 Aqr	DD	5.8	163	47	3	−0.3	3.5
Sep 27 03:33	Ups Tau	DB	4.3	115	31	97	2.8	−0.5
Sep 27 04:21	72 Tau	DB	5.5	115	32	77	2.5	0.5
Sep 27 04:57	Ups Tau	RD	4.3	115	31	219	2.0	1.8
Oct 15 19:06	Eps Cap	RB	4.5	118	70	227	1.8	1.6
Oct 15 21:44	Kap Cap	DD	4.7	119	64	101	2.6	0.1
Oct 15 22:41	Kap Cap	RB	4.7	120	53	197	0.1	3.1
Oct 17 19:15	Psi[3] Aqr	RB	5.0	143	48	250	1.7	0.0
Nov 06 19:01	Ome[1] Sco	RB	3.9	20	13	315	0.5	−0.3
Nov 06 19:23	Ome[2] Sco	RB	4.3	20	9	277	0.0	0.8
Nov 14 01:44	Psi[2] Aqr	DD	4.4	115	6	62	−0.1	1.6
Nov 19 19:44	13 Tau	RD	5.7	179	10	247	0.6	−0.4
Nov 19 20:14	14 Tau	RD	6.1	179	14	196	−0.3	1.6
Nov 20 22:31	693	RD	6.0	167	24	198	0.2	1.7
Nov 25 00:47	Psi Cnc	RD	5.7	123	14	293	1.7	−1.7
Nov 28 02:49	52 Leo	RD	5.5	88	19	252	1.3	−0.7
Dec 08 21:15	Chi Cap	DD	5.3	57	21	122	1.0	0.2
Dec 08 21:46	Chi Cap	RB	5.3	57	15	191	−0.9	2.7
Dec 18 01:39	72 Tau	DD	5.5	163	19	135	1.3	−0.7
Jan 1 '22 04:31	Mars	DB	1.5	28	17	44	1.8	1.7
Jan 1 '22 04:47	Mars	RD	1.5	27	20	12	−2.0	−4.7

DARWIN (12° 23' S, 130° 44' E)

CST	Object	PD	Mag	Elg°	Alt°	PA°	A	B
Jan 03 23:40	52 Leo	RD	5.5	125	11	352	1.3	−4.6
Jan 06 04:45	1813	DB	5.7	97	62	78	3.7	0.5
Jan 06 05:37	1813	RD	5.7	97	72	2	−0.1	−4.2
Jan 10 03:51	Nu Sco	RD	4.1	45	6	253	0.3	0.2
Jan 10 03:51	X 22139	RD	5.4	45	6	253	0.3	0.2
Jan 26 00:45	132 Tau	DD	5.0	142	38	123	1.8	−1.2
Jan 26 01:59	132 Tau	RB	5.0	142	25	242	1.9	1.6
Jan 28 02:40	Kap Gem	MD	3.6	166	37	199		
Feb 02 02:37	16 Vir	DD	5.0	129	60	201	−2.7	−8.0
Feb 02 03:01	16 Vir	RD	5.0	129	65	236	7.0	4.5
Feb 09 05:22	2771	DB	5.6	36	16	88	0.4	−0.3
Feb 20 20:47	665	RB	5.7	97	49	256	3.0	1.0
Mar 08 04:21	2719	DB	5.8	67	30	50	2.1	1.6
Mar 08 05:06	2719	RD	5.8	67	40	333	0.0	−3.6
Mar 23 00:18	37 Gem	DD	5.7	100	13	161	−1.1	−3.0
Apr 03 04:05	44 Oph	DB	4.2	111	67	86	2.8	0.0
Apr 03 04:49	2510	RD	6.2	111	75	278	2.8	−0.5
Apr 03 05:30	44 Oph	RD	4.2	110	78	308	2.5	−2.0
Apr 04 01:08	2659	RD	6.2	99	16	342	−1.1	−3.3
Apr 04 03:31	Lam Sgr	DB	2.8	98	47	85	1.9	−0.2
Apr 04 04:52	Lam Sgr	RD	2.8	97	64	299	2.1	−1.7
Apr 16 19:09	Tau Tau	RB	4.3	46	30	278	1.7	0.1
Apr 20 19:44	Lam Cnc	DD	5.9	91	53	137	2.3	−2.1
Apr 20 21:12	Lam Cnc	RB	5.9	92	44	269	2.7	0.4
Apr 29 03:29	47 Lib	RD	6.0	158	71	339	1.7	−3.5
Apr 30 01:17	24 Oph	DB	5.6	144	60	106	2.0	−0.9
Apr 30 02:40	24 Oph	RD	5.6	144	77	300	2.3	−1.5
Apr 30 23:15	63 Sgr	RD	6.2	131	20	277	0.4	−0.6
May 02 06:12	2804	DB	5.8	115	72	151	4.8	−7.1
May 21 21:58	Ome Vir	DD	5.2	111	60	116	2.2	−0.9
May 21 23:15	Ome Vir	RB	5.2	112	44	323	0.9	−1.7
May 27 22:20	44 Oph	DB	4.2	164	38	86	1.4	−0.2
May 27 22:56	2510	RD	6.2	164	47	281	1.5	−0.8
May 27 23:25	44 Oph	RD	4.2	164	53	316	1.0	−2.1
May 28 21:28	Lam Sgr	RD	2.8	150	13	276	0.2	−0.5
May 29 22:52	52 Sgr	RD	4.6	136	18	329	−0.7	−2.9
Jun 01 00:08	Eps Cap	RD	4.5	110	9	278	0.1	−0.7
Jun 03 06:13	3458	DB	6.2	83	71	98	4.0	−0.9
Jun 23 00:35	47 Lib	DD	6.0	149	61	34		
Jun 23 23:09	24 Oph	DD	5.6	163	77	75	3.3	0.8
Jun 26 02:23	2804	RD	5.8	167	74	222	2.3	2.8
Jul 21 19:10	44 Oph	RB	4.2	144	44	313	0.7	−1.9
Jul 25 21:44	Kap Cap	RD	4.7	160	24	308	0.4	−2.5
Jul 27 22:38	3458	RD	6.2	135	12	193	0.7	3.1
Jul 29 04:07	49	DB	6.1	121	76	56	2.4	1.6
Jul 29 05:38	49	RD	6.1	121	73	217	1.7	2.4
Aug 01 02:03	31 Ara	RD	5.6	88	15	173	−1.2	4.8
Aug 03 06:39	51 Tau	DB	5.6	64	48	71	2.4	0.6
Aug 04 06:07	103 Tau	DB	5.5	53	33	31	0.4	2.0
Aug 13 19:18	65 Vir	DD	5.9	60	51	107	2.0	−0.4
Aug 13 20:13	66 Vir	DD	5.8	61	38	113	1.4	−0.6
Aug 13 20:31	65 Vir	RB	5.9	61	33	319	1.0	−1.5
Aug 13 21:22	66 Vir	RB	5.8	61	21	306	0.7	−0.9
Aug 16 18:41	Ome[1] Sco	DD	3.9	100	78	107	2.7	−0.9
Aug 16 19:17	Ome[2] Sco	DD	4.3	100	81	130	2.2	−1.9
Aug 16 20:11	Ome[1] Sco	RB	3.9	100	74	306	2.5	−1.6
Aug 16 20:45	Ome[2] Sco	RB	4.3	101	67	278	2.7	−0.1
Aug 18 00:52	39 Oph	DD	5.2	116	25	88	0.8	0.5
Aug 19 03:49	Lam Sgr	DD	2.8	130	0	68	−0.4	0.9
Aug 24 05:37	Psi[2] Aqr	DB	4.4	163	36	3	−0.4	3.6
Aug 24 06:18	Psi[2] Aqr	RD	4.4	163	26	289	1.5	−0.5
Aug 31 02:16	Tau Tau	RD	4.3	85	13	269	0.8	−0.4
Sep 12 19:57	Lam Lib	DD	5.0	71	50	113	2.0	−0.7
Sep 12 21:13	Lam Lib	RB	5.0	71	32	276	1.2	0.2
Sep 15 18:46	Sig Sgr	RB	2.1	110	67	243	3.1	1.3
Sep 18 01:28	Chi Cap	DD	5.3	138	42	76	1.3	0.9
Sep 18 02:34	Chi Cap	RB	5.3	139	27	227	0.2	1.6
Sep 21 21:08	49	RD	6.1	172	29	253	1.1	0.3
Sep 25 03:52	Sig Ari	DB	5.5	137	62	99	4.4	−0.5
Sep 25 05:05	Sig Ari	RD	5.5	137	53	192	1.3	4.1
Sep 27 01:23	Kap Tau	DB	4.2	116	28	82	1.5	−0.1
Sep 27 01:26	67 Tau	DB	5.3	115	29	107	2.4	−1.5
Sep 27 02:22	67 Tau	RD	5.3	115	40	193	−0.2	3.2
Sep 27 02:39	Kap Tau	RD	4.2	115	43	217	1.0	1.8
Sep 27 03:08	Ups Tau	DD	4.3	115	47	344		
Sep 27 03:31	Ups Tau	RD	4.3	115	50	316	9.5	−8.3
Oct 01 04:47	Ome Cnc	RD	5.9	70	28	299	2.1	−1.7
Oct 29 02:32	Ups[1] Cnc	RD	5.7	91	17	252	0.7	0.2
Nov 14 02:06	Psi[3] Aqr	DD	5.0	115	9	125	0.9	−1.7
Nov 16 21:49	Mu Psc	DD	4.8	149	68	56	2.4	1.5
Nov 16 23:22	Mu Psc	RB	4.8	149	68	215	1.8	2.5
Nov 21 02:52	95 Tau	RD	6.2	166	49	318	4.0	−4.3
Nov 22 05:07	125 Tau	DB	5.2	154	35	122	1.7	−1.1
Nov 26 02:52	Xi Cnc	DB	5.2	110	37	154	2.5	−3.8
Nov 26 03:59	Xi Cnc	RD	5.2	110	48	240	3.5	1.8
Nov 26 04:54	79 Cnc	RD	6.0	110	54	253	4.0	0.9
Nov 29 03:23	Ome Vir	RD	5.2	75	19	230	1.1	2.6
Dec 06 19:05	Sig Sgr	RB	2.1	29	27	264	0.7	0.6
Dec 08 21:03	Chi Cap	DD	5.3	57	28	30	−0.1	2.2
Dec 08 21:53	Chi Cap	RB	5.3	57	17	277	0.6	0.2
Dec 17 03:36	13 Tau	DD	5.7	153	12	116	0.4	−0.6
Dec 17 23:28	Ups Tau	DD	4.3	163	55	87	3.6	0.2
Dec 18 00:26	72 Tau	DD	5.5	163	52	69	3.2	1.2
Dec 18 01:10	Ups Tau	RB	4.3	163	47	230	2.8	2.2
Dec 22 03:14	Ome Cnc	RD	5.9	152	52	256	3.8	0.9
Dec 30 05:36	Mu Lib	DB	5.3	54	40	70	2.4	0.7

LUNAR OCCULTATION TABLE

HOBART (42° 48' S, 147° 13' E)

EST	Object	PD	Mag	Elg°	Alt°	PA°	A	B
Jan 04 01:29	52 Leo	RD	5.5	125	23	275	1.5	−1.2
Feb 01 00:08	Iot Leo	DB	3.9	144	25	83	1.5	−1.0
Feb 01 01:07	Iot Leo	RD	3.9	143	32	335	1.0	−2.0
Mar 27 18:31	Iot Leo	DD	3.9	160	6	80	0.5	−1.2
Mar 27 19:24	Iot Leo	RB	3.9	160	15	328	0.8	−2.1
Mar 28 03:31	Ome Vir	DD	5.2	164	15	126	0.5	0.2
Apr 01 22:48	Nu Sco	DB	4.1	127	25	55	1.0	−0.3
Apr 01 22:48	X [2]2139	DB	5.4	127	25	55	1.0	−0.3
Apr 01 23:18	Nu Sco	RD	4.1	127	30	352	−0.6	−3.1
Apr 01 23:18	X 22139	RD	5.4	127	30	352	−0.6	−3.1
Apr 05 03:01	Chi Sgr	DB	5.0	86	41	34	1.9	1.6
Apr 05 03:39	Chi Sgr	RD	5.0	85	48	330	0.3	−4.4
Apr 10 05:30	3506	RD	6.1	25	12	241	0.3	−0.4
Apr 16 18:24	Tau Tau	DD	4.3	46	11	133	0.9	0.1
May 04 04:45	Chi Cap	DB	5.3	90	59	124	1.9	−3.1
May 04 05:37	Chi Cap	RD	5.3	90	65	201	1.3	3.3
May 08 05:49	49	DB	6.1	43	26	62	0.9	−0.3
May 17 18:18	Ome Cnc	DD	5.9	61	18	65	2.3	1.6
May 20 22:16	52 Leo	DD	5.5	98	18	76	1.6	2.0
May 21 23:29	Ome Vir	DD	5.2	111	19	196	−1.5	−6.0
May 26 04:36	32 Lib	DD	5.6	169	20	49	0.0	3.3
May 27 05:09	Ome Oph	DB	4.5	176	28	106	0.6	0.8
May 27 06:06	Ome Oph	RD	4.5	176	18	269	0.1	1.2
May 28 00:00	44 Oph	DB	4.2	164	66	158	0.7	−3.7
May 28 00:44	44 Oph	RD	4.2	164	70	231	2.4	2.1
May 28 02:23	51 Oph	DB	4.8	163	67	51	1.8	2.7
May 28 03:15	51 Oph	RD	4.8	163	60	324	1.7	−1.9
May 28 22:07	Lam Sgr	MD	2.8	151	37	190		
May 29 06:42	2719	RD	5.8	147	36	314	1.4	−0.4
May 29 23:14	52 Sgr	DB	4.6	136	37	119	0.4	−2.1
May 29 23:58	51 Sgr	RD	5.6	136	45	278	1.0	−1.4
May 30 00:14	52 Sgr	RD	4.6	136	48	243	1.4	−0.1
Jun 01 03:12	Kap Cap	DB	4.7	109	54	99	1.8	−1.4
Jun 01 04:22	Kap Cap	RD	4.7	108	63	217	1.4	1.9
Jun 03 01:45	Psi[3] Aqr	RD	5.0	85	17	301	0.4	−3.4
Jun 13 17:41	1169	RB	5.3	32	9	310	0.6	0.2
Jun 23 01:29	47 Lib	DD	6.0	149	41	176	1.4	−5.1
Jun 26 03:29	Psi Sgr	DB	4.9	167	57	125	1.9	−0.7
Jun 26 04:18	Psi Sgr	RD	4.9	167	48	213	0.3	3.0
Jun 27 21:54	Chi Cap	RD	5.3	142	24	188	1.9	4.4
Jun 28 00:50	Phi Cap	DB	5.2	141	54	92	1.6	−1.0
Jun 28 02:03	Phi Cap	RD	5.2	140	65	232	1.6	1.1
Jul 01 00:59	3506	RD	6.1	104	21	261	0.7	−1.1
Jul 17 19:22	80 Vir	DD	5.7	89	49	87	2.1	0.8
Jul 17 20:22	80 Vir	RB	5.7	90	42	340	0.7	−1.8
Jul 19 00:26	20[8]8	DD	6.2	105	15	93	0.2	1.2
Jul 21 00:11	Ome Oph	DD	4.5	132	43	76	1.0	1.7
Jul 21 01:12	Ome Oph	RB	4.5	132	32	304	0.9	0.2
Jul 21 19:42	44 Oph	DD	4.2	144	59	153	0.5	−3.2
Jul 21 20:32	44 Oph	RB	4.2	144	67	238	2.3	1.1
Jul 21 22:22	51 Oph	DD	4.8	145	70	32	2.3	5.7
Jul 21 22:53	51 Oph	RB	4.8	145	67	346	1.7	−5.6
Jul 22 18:29	Lam Sgr	MB	2.8	157	37	190		
Jul 23 02:26	2719	DD	5.8	160	44	33	0.1	3.2
Jul 23 19:15	51 Sgr	DD	5.6	171	33	94	0.5	−1.3
Jul 23 19:40	52 Sgr	DD	4.6	171	37	131	0.3	−2.6
Jul 23 20:31	52 Sgr	RB	4.6	171	47	231	1.5	0.4
Jul 24 04:29	2907	DD	6.2	174	32	62	0.2	1.8
Jul 25 22:10	Kap Cap	DB	4.7	160	40	149	0.6	−8.9
Jul 25 22:28	Kap Cap	RD	4.7	160	43	177	1.4	7.9
Aug 05 06:35	139 Tau	RD	4.8	43	12	254	1.2	−0.8
Aug 11 18:13	Ome Vir	RB	5.2	34	19	306	0.6	0.1
Aug 14 18:48	Kap Vir	DD	4.2	73	49	158	0.9	−2.0
Aug 14 19:45	Kap Vir	RB	4.2	73	41	260	1.5	1.7
Aug 16 19:22	Bet[1] Sco	MD	2.6	100	65	21		
Aug 19 01:47	2659	DD	6.2	129	27	9	−2.0	6.3
Aug 19 20:25	Psi Sgr	DD	4.9	140	67	86	1.8	−0.3
Aug 19 21:45	Psi Sgr	RB	4.9	141	73	267	1.9	0.2
Aug 21 19:31	Phi Cap	DD	5.2	166	36	116	0.7	−2.4
Aug 21 20:25	Phi Cap	RB	5.2	166	46	217	1.4	1.1
Aug 24 04:35	Psi[1] Aqr	DB	4.2	164	36	13	0.1	2.7
Aug 24 05:19	Psi[2] Aqr	DB	4.4	164	28	95	1.0	1.3
Aug 24 05:22	Psi[1] Aqr	RD	4.2	164	27	283	1.1	1.1
Aug 24 06:10	Psi[2] Aqr	RD	4.4	163	19	204	0.0	2.3
Aug 26 23:36	Mu Psc	DB	4.8	130	19	63	0.7	−0.4
Aug 27 00:48	Mu Psc	RD	4.8	130	30	229	1.0	0.3
Sep 01 05:54	125 Tau	DB	5.2	73	19	73	1.8	−0.3
Sep 12 21:29	47 Lib	DD	6.0	71	26	27	−0.8	7.8
Sep 13 22:08	24 Oph	DD	5.6	85	32	79	0.5	1.6
Sep 13 23:06	24 Oph	RB	5.6	85	21	290	0.4	0.8
Sep 20 01:21	74 Aqr	DD	5.8	163	48	19	0.4	2.7
Sep 27 03:34	Ups Tau	DB	4.3	115	24	110	2.7	−1.0
Sep 27 04:15	72 Tau	DB	5.5	115	24	88	2.2	0.0
Sep 27 04:41	Ups Tau	RD	4.3	115	24	206	1.4	1.6
Oct 15 21:43	Kap Cap	DD	4.7	119	60	129	3.8	−2.4
Oct 15 22:12	Kap Cap	RB	4.7	120	56	173	−1.2	5.3
Oct 17 19:10	Psi[3] Aqr	RB	5.0	143	42	226	1.2	0.6
Oct 24 01:36	39 Tau	RD	5.9	146	25	318	5.1	−3.7
Oct 25 03:20	98 Tau	RD	5.8	135	22	324	3.4	−2.2
Nov 07 20:52	39 Oph	DD	5.2	35	11	103	0.0	0.9
Nov 08 22:38	Lam Sgr	DD	2.8	50	5	46	−0.7	1.7
Nov 14 01:32	Psi[2] Aqr	DD	4.4	115	11	71	0.1	1.6
Nov 25 00:56	Psi Cnc	RD	5.7	123	9	281	1.3	−1.5
Nov 28 02:51	52 Leo	RD	5.5	88	14	235	1.2	−0.4
Jan 1 '22 04:30	Mars	DB	1.5	28	18	71	0.4	−0.8
Jan 1 '22 05:11	Mars	RD	1.5	27	25	338	−0.4	−2.4

MELBOURNE (37° 50' S, 145° 00' E)

EST	Object	PD	Mag	Elg°	Alt°	PA°	A	B
Jan 04 01:20	52 Leo	RD	5.5	125	24	281	1.5	−1.3
Jan 05 01:17	1687	RD	6.2	112	20	271	1.1	−1.3
Feb 01 00:00	Iot Leo	DB	3.9	144	26	76	1.6	−0.8
Feb 01 00:54	Iot Leo	RD	3.9	143	34	342	0.9	−2.4
Mar 04 23:00	34 Lib	RD	5.8	109	10	224	0.8	0.6
Mar 05 00:00	Zet Lib	RD	5.5	109	21	226	1.5	0.7
Mar 08 05:24	2719	DB	5.8	67	54	116	1.2	−1.9
Mar 20 19:06	99 Tau	RB	5.8	76	24	333	2.2	−3.4
Mar 27 19:11	Iot Leo	RB	3.9	160	14	337	0.7	−2.5
Mar 28 03:31	Ome Vir	DD	5.2	164	19	112	0.7	0.4
Apr 01 22:46	Nu Sco	DB	4.1	127	22	40	2.0	1.4
Apr 01 23:02	Nu Sco	RD	4.1	127	25	7	−1.8	−4.7
Apr 01 23:02	X 22139	RD	5.4	127	25	7	−1.8	−4.7
Apr 04 02:32	2659	RD	6.2	99	45	280	1.0	−1.4
Apr 04 05:29	Lam Sgr	GD	2.8	98	76	184		
Apr 16 18:22	Tau Tau	DD	4.3	46	16	123	1.3	0.2
Apr 16 19:22	Tau Tau	RB	4.3	46	8	221	1.5	2.6
Apr 29 04:37	47 Lib	RD	6.0	157	49	243	1.4	2.4
Apr 30 23:59	63 Sgr	RD	6.2	131	41	208	4.1	4.8
May 04 04:31	Chi Cap	DB	5.3	90	57	101	1.8	−1.5
May 04 05:46	Chi Cap	RD	5.3	90	69	224	1.8	1.8
May 08 05:48	49	DB	6.1	43	26	43	0.7	0.5
May 17 18:21	Ome Cnc	DD	5.9	61	23	56	3.0	2.1
May 20 22:25	52 Leo	DD	5.5	98	22	56	2.9	4.2
May 21 23:15	Ome Vir	DD	5.2	111	26	170	0.0	−2.0
May 22 00:00	Ome Vir	RB	5.2	111	18	256	1.2	2.0
May 27 05:12	Ome Oph	DB	4.5	176	29	89	0.5	1.2
May 27 06:10	Ome Oph	RD	4.5	176	18	286	0.3	0.7
May 27 23:43	44 Oph	DB	4.2	164	64	141	1.0	−2.6
May 28 00:46	44 Oph	RD	4.2	164	74	251	2.3	0.6
May 28 21:53	Lam Sgr	DB	2.8	151	32	177	−2.3	−6.6
May 28 22:08	Lam Sgr	RD	2.8	151	35	205	3.4	4.1
May 29 23:04	52 Sgr	DB	4.6	136	33	106	0.5	−1.6
May 29 23:48	51 Sgr	RD	5.6	136	42	292	0.7	−1.8
May 30 00:10	52 Sgr	RD	4.6	136	46	258	1.3	−0.6
Jun 01 00:18	Eps Cap	DB	4.5	110	23	154	−1.1	−7.9
Jun 01 00:34	Eps Cap	RD	4.5	110	26	182	2.1	6.5
Jun 01 03:04	Kap Cap	DB	4.7	109	54	79	1.7	−0.5
Jun 01 04:26	Kap Cap	RD	4.7	108	67	237	1.9	1.0
Jun 13 17:40	1169	RB	5.3	32	14	319	0.5	−0.3
Jun 23 01:14	47 Lib	DD	6.0	149	47	145	1.4	−1.4
Jun 24 00:40	24 Oph	DD	5.6	163	66	165	1.6	−4.7
Jun 26 03:24	Psi Sgr	DB	4.9	167	61	104	1.8	0.2
Jun 26 04:29	Psi Sgr	RD	4.9	167	48	234	0.7	2.1
Jun 27 22:00	Chi Cap	RD	5.3	142	23	215	1.0	0.9
Jun 28 00:43	Phi Cap	DB	5.2	141	53	74	1.6	−0.3
Jun 28 02:03	Phi Cap	RD	5.2	140	67	251	2.0	0.4
Jul 01 00:50	3506	RD	6.1	104	19	282	0.6	−1.9
Jul 17 19:23	80 Vir	DD	5.7	89	54	71	3.1	1.9
Jul 17 20:08	80 Vir	RB	5.7	89	49	359	0.2	−3.6
Jul 21 00:21	Ome Oph	DD	4.5	132	44	53	0.9	3.0
Jul 21 01:07	Ome Oph	RB	4.5	132	35	326	1.3	−1.2
Jul 21 19:27	44 Oph	DD	4.2	144	57	138	0.8	−2.5
Jul 21 20:30	44 Oph	RB	4.2	144	68	255	2.1	0.1
Jul 22 18:12	Lam Sgr	DD	2.8	157	31	172	−1.6	−5.2
Jul 22 18:31	Lam Sgr	RB	2.8	157	35	210	2.7	2.8
Jul 23 19:08	51 Sgr	DD	5.6	171	29	83	0.6	−0.9
Jul 23 19:28	52 Sgr	DD	4.6	171	33	116	0.3	−1.9
Jul 23 20:28	52 Sgr	RB	4.6	171	45	247	1.4	−0.2
Jul 25 21:48	Kap Cap	DB	4.7	160	34	117	0.7	−2.5
Jul 25 22:40	Kap Cap	RD	4.7	160	45	211	1.4	1.7
Aug 05 06:28	139 Tau	RD	4.8	43	14	268	1.4	−1.0
Aug 14 18:37	Kap Vir	DD	4.2	73	55	143	1.3	−1.5
Aug 14 19:47	Kap Vir	RB	4.2	73	44	278	1.5	0.7
Aug 16 20:43	Ome[1] Sco	MB	3.9	100	60	198		
Aug 19 20:20	Psi Sgr	DD	4.9	140	68	68	2.0	0.4
Aug 19 21:39	Psi Sgr	RB	4.9	141	78	285	2.2	−0.8
Aug 21 19:20	Phi Cap	DD	5.2	166	32	99	0.7	−1.5
Aug 21 20:25	Phi Cap	RB	5.2	166	45	237	1.4	0.3
Aug 24 04:50	Psi[1] Aqr	DB	4.2	164	36	356	−0.6	3.6
Aug 24 05:23	Psi[1] Aqr	RD	4.2	164	30	299	1.8	0.2
Aug 24 05:24	Psi[2] Aqr	DB	4.4	164	30	84	0.9	1.4
Aug 24 06:21	Psi[2] Aqr	RD	4.4	163	19	214	0.1	2.2
Aug 26 23:35	Mu Psc	DB	4.8	130	20	44	0.5	0.4
Aug 27 00:46	Mu Psc	RD	4.8	130	32	247	1.3	−0.2
Sep 01 05:49	125 Tau	DB	5.2	73	23	62	1.7	0.0
Sep 13 22:16	24 Oph	DD	5.6	85	31	60	0.3	2.2
Sep 13 23:07	24 Oph	RB	5.6	85	21	308	0.7	0.0
Sep 20 01:36	74 Aqr	DD	5.8	163	50	0	−0.4	3.7
Sep 27 03:24	Ups Tau	DB	4.3	115	28	95	2.6	−0.7
Sep 27 04:10	72 Tau	DB	5.5	115	29	77	2.3	0.2
Sep 27 04:45	Ups Tau	RD	4.3	115	29	218	1.8	1.5
Oct 15 21:33	Kap Cap	DD	4.7	119	66	101	2.6	0.0
Oct 15 22:32	Kap Cap	RB	4.7	120	57	199	0.3	3.1
Nov 06 18:59	Ome[1] Sco	RB	3.9	20	17	310	0.5	−0.1
Nov 07 20:57	39 Oph	DD	5.2	35	10	88	−0.2	1.1
Nov 08 22:50	Lam Sgr	DD	2.8	50	2	28	−1.1	2.3
Nov 14 01:40	Psi[2] Aqr	DD	4.4	115	11	64	0.1	1.7
Nov 20 22:26	693	RD	6.0	167	19	199	0.1	1.4
Nov 25 00:45	Psi Cnc	RD	5.7	123	10	292	1.4	−1.7
Nov 28 02:46	52 Leo	RD	5.5	88	15	246	1.1	−0.7
Dec 08 21:10	Chi Cap	DD	5.3	57	26	121	1.1	0.3
Dec 08 21:43	Chi Cap	RB	5.3	57	20	191	−0.8	2.8
Dec 18 01:36	72 Tau	DD	5.5	163	19	147	1.4	−2.0
Jan 1 '22 04:26	Mars	DB	1.5	28	14	63	0.5	−0.4
Jan 1 '22 05:00	Mars	RD	1.5	27	20	348	−0.7	−2.7

LUNAR OCCULTATION TABLE

PERTH (31° 57' S, 115° 51' E)

WST	Object	PD	Mag	Elg°	Alt°	PA°	A	B
Jan 05 01:36	Xi Vir	DB	4.8	111	26	93	1.3	−1.2
Jan 05 02:43	Xi Vir	RD	4.8	111	38	327	1.2	−2.3
Jan 06 03:16	1813	DB	5.7	97	40	153	0.9	−2.4
Jan 06 04:24	1813	RD	5.7	97	50	278	2.3	−0.9
Jan 31 22:13	Iot Leo	RD	3.9	143	10	338	0.7	−2.7
Feb 08 03:29	4 Sgr	DB	4.7	49	17	53	0.8	0.2
Feb 08 04:05	4 Sgr	RD	4.7	49	24	335	−0.6	−2.9
Feb 08 04:46	2602	DB	5.4	49	33	119	0.3	−1.7
Feb 08 05:16	9 Sgr	DB	5.9	48	39	122	0.5	−1.9
Feb 25 01:11	Lam Cnc	DD	5.9	145	21	52	3.0	3.1
Mar 04 03:41	2110	RD	6.3	119	69	333	1.0	−2.6
Mar 08 02:59	2719	DB	5.8	67	25	140	−0.3	−2.5
Mar 08 03:48	2719	RD	5.8	67	35	240	1.4	0.1
Mar 28 00:59	Ome Vir	DD	5.2	164	45	138	1.2	−1.1
Apr 02 00:20	2343	RD	6.3	125	41	324	0.2	−2.3
Apr 03 05:19	51 Oph	DB	4.8	110	81	56	2.7	2.3
Apr 04 00:07	2659	RD	6.2	99	16	255	0.3	−0.6
Apr 04 02:38	Lam Sgr	MD	2.8	98	46	191		
Apr 05 01:10	Chi Sgr	RD	5.0	85	16	322	−0.6	−2.6
Apr 05 05:46	51 Sgr	DB	5.6	84	72	70	2.3	0.5
Apr 29 01:41	47 Lib	RD	6.0	157	78	243	3.2	1.8
Apr 29 06:14	Bet^{1} Sco	DB	2.6	156	31	68	0.6	1.9
Apr 29 06:14	2303	DB	4.8	156	31	67	0.6	2.0
May 02 05:05	Psi Sgr	DB	4.9	115	83	75	2.3	0.8
May 04 01:49	Chi Cap	DB	5.3	90	25	94	0.5	−1.2
May 04 02:58	Chi Cap	RD	5.3	90	40	248	1.3	−0.2
May 04 06:12	Phi Cap	DB	5.2	89	77	66	2.3	0.9
May 20 19:20	52 Leo	DD	5.5	98	44	107	2.3	−0.5
May 20 20:39	52 Leo	RB	5.5	98	40	324	1.1	−1.2
May 21 19:21	1687	DD	6.2	111	48	76	3.4	0.4
May 26 18:50	2338	DD	6.4	179	17	81	0.3	−0.8
May 26 19:51	2343	DB	6.3	179	29	52	1.7	0.6
May 26 20:18	2343	RB	6.3	178	35	357	−1.0	−3.8
May 27 02:57	Ome Oph	DB	4.5	176	56	44	1.6	4.2
May 27 03:36	Ome Oph	RD	4.5	176	48	340	1.8	−3.3
May 27 21:28	44 Oph	DD	4.2	164	38	192		
May 27 21:35	44 Oph	RD	4.2	164	40	205		
May 29 21:30	51 Sgr	RD	5.6	136	14	273	0.0	−1.0
May 29 21:41	52 Sgr	RD	4.6	136	16	238	0.5	−0.1
Jun 01 00:27	Kap Cap	DB	4.7	109	23	67	0.7	−0.3
Jun 01 01:35	Kap Cap	RD	4.7	108	38	266	1.2	−0.9
Jun 21 02:09	95 Vir	DD	5.5	123	9	123	0.2	0.0
Jun 22 22:19	47 Lib	DD	6.0	149	77	141	1.6	−2.1
Jun 23 03:37	Bet^{1} Sco	DD	2.6	152	19	75	0.1	1.5
Jun 23 03:37	2303	DD	4.8	152	19	74	0.1	1.5
Jun 23 04:28	Bet^{1} Sco	RB	2.6	152	8	304	0.3	0.0
Jun 23 21:45	24 Oph	DD	5.6	163	70	175	−0.3	−5.6
Jun 26 00:28	Psi Sgr	DB	4.9	167	77	66	2.3	0.9
Jun 26 01:48	Psi Sgr	RD	4.9	166	81	285	2.4	−0.5
Jun 27 23:13	Phi Cap	RD	5.2	140	36	272	1.0	−1.1
Jul 25 20:15	Kap Cap	RD	4.7	160	16	217	0.7	0.9
Jul 29 03:00	49	RD	6.1	121	55	197	0.8	2.6
Aug 03 04:46	51 Tau	DB	5.6	64	21	98	1.9	−1.4
Aug 03 05:38	56 Tau	DB	5.3	64	28	89	2.1	−0.8
Aug 03 05:51	51 Tau	RD	5.6	64	30	205	0.6	1.6
Aug 04 05:29	103 Tau	RD	5.5	53	18	251	1.2	−0.4
Aug 14 22:42	2 Lib	DD	6.2	76	12	181	1.0	−4.8
Aug 17 23:08	39 Oph	DD	5.2	116	46	145	2.0	−1.9
Aug 17 23:51	39 Oph	RB	5.2	116	37	220	0.1	3.4
Aug 18 02:07	2510	DD	6.2	117	11	125	0.4	0.0
Aug 18 02:32	44 Oph	DD	4.2	117	6	110	0.0	0.4
Aug 19 02:04	Lam Sgr	DD	2.8	130	24	103	0.5	0.6
Aug 19 02:56	Lam Sgr	RB	2.8	131	13	241	−0.3	1.5
Aug 19 18:39	Psi Sgr	RB	4.9	141	50	292	1.1	−1.7
Aug 20 04:06	51 Sgr	DD	5.6	145	12	107	0.2	0.6
Aug 24 03:04	Psi^{2} Aqr	DB	4.4	163	58	26	0.8	2.6
Aug 24 04:12	Psi^{2} Aqr	RD	4.4	163	45	261	1.6	1.3
Aug 31 02:43	716	RD	6.3	84	13	306	2.6	−3.5
Sep 16 02:16	Psi Sgr	DD	4.9	114	9	98	−0.1	0.7
Sep 17 23:16	Chi Cap	DD	5.3	138	66	104	2.7	−0.1
Sep 18 00:14	Chi Cap	RB	5.3	139	54	201	0.2	3.2
Sep 25 01:50	Sig Ari	DB	5.5	137	41	137		
Sep 25 02:02	Sig Ari	RB	5.5	137	41	150		
Sep 27 00:27	Kap Tau	RD	4.2	115	12	177	−1.7	4.0
Sep 27 00:45	Ups Tau	DB	4.3	115	15	29	0.0	1.1
Sep 27 01:49	Ups Tau	RD	4.3	115	24	276	2.2	−1.2
Sep 27 02:29	72 Tau	RD	5.5	115	29	295	3.4	−2.1
Sep 30 05:07	47 Gem	DB	5.8	81	26	56	1.9	0.4
Oct 01 03:19	Ome Cnc	RD	5.9	70	6	263	0.7	−0.9
Oct 15 19:56	Kap Cap	RB	4.7	120	76	267	2.6	0.0
Oct 24 04:30	621	RD	6.1	145	28	284	2.2	0.4
Nov 07 19:20	39 Oph	DD	5.2	35	26	15	−2.1	7.6
Nov 07 19:34	39 Oph	RB	5.2	36	23	347	3.0	−5.4
Nov 09 22:45	52 Sgr	DD	4.6	65	11	21	−1.0	2.6
Nov 13 23:45	Psi^{2} Aqr	DD	4.4	115	34	25	0.3	2.6
Nov 14 00:41	Psi^{2} Aqr	RB	4.4	116	22	269	0.7	1.2
Nov 16 19:35	Mu Psc	DD	4.8	149	38	80	1.9	−0.5
Nov 16 20:47	Mu Psc	RB	4.8	149	48	201	0.8	2.1
Nov 21 00:50	95 Tau	RD	6.2	165	34	272	2.9	−0.2
Dec 08 19:55	Chi Cap	RB	5.3	57	40	251	0.8	1.5
Dec 08 22:12	Phi Cap	DD	5.2	59	13	107	0.3	0.6
Dec 17 21:22	Ups Tau	DD	4.3	163	31	115	3.5	−2.0
Dec 17 22:04	72 Tau	DD	5.5	163	34	96	2.9	−0.6
Dec 17 22:20	Ups Tau	RB	4.3	163	35	192	0.6	2.7
Dec 21 04:00	47 Gem	RD	5.8	162	21	286	1.6	0.4
Dec 30 04:17	Mu Lib	DB	5.3	54	29	145	0.1	−2.1

SYDNEY (33° 54' S, 151° 15' E)

EST	Object	PD	Mag	Elg°	Alt°	PA°	A	B
Jan 04 01:24	52 Leo	RD	5.5	125	31	291	1.7	−1.4
Jan 05 01:19	1687	RD	6.2	112	27	282	1.3	−1.4
Feb 01 00:11	Iot Leo	DB	3.9	144	34	58	2.7	0.6
Feb 01 00:47	Iot Leo	RD	3.9	144	39	3	0.1	−3.8
Feb 15 19:18	14 Cet	RB	5.9	42	19	235	0.6	2.0
Feb 20 20:39	665	DD	5.7	97	26	145	2.0	−2.6
Mar 04 23:03	34 Lib	RD	5.8	109	14	247	0.5	−0.5
Mar 05 00:06	Zet Lib	RD	5.5	109	27	252	1.0	−0.6
Mar 27 18:26	Iot Leo	DD	3.9	160	12	61	0.7	−0.2
Mar 27 19:05	Iot Leo	RB	3.9	160	19	348	0.8	−3.0
Mar 28 03:39	Ome Vir	DD	5.2	164	15	90	0.7	1.1
Apr 04 02:31	26^{6}9	RD	6.2	99	51	300	1.0	−2.0
Apr 04 05:11	Lam Sgr	DB	2.8	98	80	140	2.0	−3.2
Apr 04 06:10	Lam Sgr	RD	2.8	97	79	225	2.2	3.0
Apr 16 18:31	Tau Tau	DD	4.3	46	14	109	1.1	0.6
Apr 20 21:14	Lam Cnc	DD	5.9	91	19	166	−0.3	−2.0
Apr 21 17:54	Xi Cnc	RB	5.2	102	32	293	2.2	−1.1
Apr 29 04:51	47 Lib	RD	6.0	157	42	260	1.1	1.4
Apr 30 03:05	24 Oph	DB	5.6	144	76	156	1.6	−3.5
Apr 30 03:55	24 Oph	RD	5.6	144	67	231	2.1	3.1
May 01 00:17	63 Sgr	RD	6.2	131	50	246	1.9	0.1
May 04 04:39	Chi Cap	DB	5.3	90	65	87	2.2	−0.5
May 21 23:11	Ome Vir	DD	5.2	111	24	145	0.5	−0.9
May 27 05:20	Ome Oph	DB	4.5	176	22	82	0.3	1.3
May 27 06:14	Ome Oph	RD	4.5	176	11	292	0.2	0.4
May 27 23:43	44 Oph	DB	4.2	164	70	119	1.6	−1.6
May 28 00:12	2510	RD	6.2	164	76	239	2.7	1.5
May 28 01:01	44 Oph	RD	4.2	164	80	271	2.2	−0.1
May 28 19:48	2659	RD	6.2	152	13	288	−0.2	−1.3
May 28 21:35	Lam Sgr	DB	2.8	151	33	141	−0.1	−2.5
May 28 22:24	Lam Sgr	RD	2.8	150	43	242	1.6	0.1
May 29 23:03	52 Sgr	DB	4.6	136	38	87	0.9	−0.9
May 29 23:43	51 Sgr	RD	5.6	136	46	314	0.6	−2.9
May 30 00:14	52 Sgr	RD	4.6	136	52	276	1.4	−1.2
Jun 01 00:02	Eps Cap	DB	4.5	110	24	119	0.2	−2.4
Jun 01 00:53	Eps Cap	RD	4.5	110	35	216	1.3	1.3
Jun 01 03:16	Kap Cap	DB	4.7	109	62	68	2.0	0.3
Jun 01 04:42	Kap Cap	RD	4.7	108	74	243	2.1	1.1
Jun 13 17:37	1169	RB	5.3	31	13	346	−0.6	−2.1
Jun 23 01:19	47 Lib	DD	6.0	149	41	130	1.3	−0.6
Jun 24 00:39	24 Oph	DD	5.6	163	63	142	1.9	−1.9
Jun 26 03:37	Psi Sgr	DB	4.9	167	54	98	1.6	0.5
Jun 26 04:41	Psi Sgr	RD	4.9	167	41	236	0.5	2.0
Jun 27 22:08	Chi Cap	RD	5.3	142	29	238	0.9	0.0
Jun 28 00:55	Phi Cap	DB	5.2	141	62	61	1.9	0.6
Jun 28 02:18	Phi Cap	RD	5.2	140	75	259	2.3	0.3
Jul 01 00:45	3506	RD	6.1	104	23	301	1.0	−3.6
Jul 21 00:38	Ome Oph	DD	4.5	132	35	36	0.1	4.6
Jul 21 01:09	Ome Oph	RB	4.5	132	29	340	1.6	−2.7
Jul 21 19:02	2510	DD	6.2	143	58	153	0.4	−3.3
Jul 21 19:26	44 Oph	DD	4.2	144	62	117	1.4	−1.7
Jul 21 20:43	44 Oph	RB	4.2	144	77	276	2.1	−0.5
Jul 22 17:55	Lam Sgr	DD	2.8	157	32	139	−0.1	−2.4
Jul 22 18:46	Lam Sgr	RB	2.8	157	43	243	1.5	0.0
Jul 23 19:11	51 Sgr	DD	5.6	170	34	62	1.1	−0.1
Jul 23 19:26	52 Sgr	DD	4.6	171	37	96	0.8	−1.2
Jul 23 20:35	52 Sgr	RB	4.6	171	52	266	1.5	−0.8
Jul 25 21:46	Kap Cap	DB	4.7	160	39	98	1.1	−1.4
Jul 25 22:55	Kap Cap	RD	4.7	160	53	227	1.6	1.0
Aug 05 05:18	139 Tau	DB	4.8	43	10	60	0.6	−0.2
Aug 11 18:09	Ome Vir	RB	5.2	34	21	343	0.1	−1.6
Aug 13 20:34	65 Vir	DD	5.9	60	19	175	0.4	−3.0
Aug 14 18:42	Kap Vir	DD	4.2	73	53	122	1.6	−0.6
Aug 14 19:57	Kap Vir	RB	4.2	73	39	297	1.2	0.0
Aug 16 20:35	Ome^{1} Sco	DD	3.9	100	58	168	1.6	−4.6
Aug 16 21:11	Ome^{1} Sco	RB	3.9	100	51	224	1.4	4.7
Aug 19 20:38	Psi Sgr	DD	4.9	140	78	51	2.3	1.9
Aug 19 21:49	Psi Sgr	RB	4.9	141	79	299	2.5	−1.4
Aug 21 19:21	Phi Cap	DD	5.2	166	38	81	1.1	−0.7
Aug 21 20:35	Phi Cap	RB	5.2	166	53	252	1.7	−0.1
Aug 24 05:01	Psi^{1} Aqr	DB	4.2	164	30	358	−0.5	3.5
Aug 24 05:33	Psi^{1} Aqr	RD	4.2	164	24	299	1.3	0.2
Aug 24 05:34	Psi^{2} Aqr	DB	4.4	164	24	84	0.7	1.3
Aug 26 23:41	Mu Psc	DB	4.8	130	27	38	0.7	0.8
Aug 27 00:55	Mu Psc	RD	4.8	130	39	249	1.7	0.0
Sep 13 22:26	24 Oph	DD	5.6	85	24	53	−0.1	2.4
Sep 18 02:34	27 Cap	DD	6.3	139	20	59	0.0	1.6
Sep 20 01:48	74 Aqr	DD	5.8	163	45	4	−0.2	3.4
Sep 27 03:39	Ups Tau	DB	4.3	115	33	97	2.9	−0.4
Sep 27 04:27	72 Tau	DB	5.5	115	33	77	2.6	0.6
Sep 27 05:04	Ups Tau	RD	4.3	115	31	220	2.1	1.9
Oct 15 19:12	Eps Cap	RB	4.5	118	73	229	1.9	1.6
Oct 15 21:49	Kap Cap	DD	4.7	119	62	102	2.6	0.2
Oct 15 22:45	Kap Cap	RB	4.7	120	51	196	0.0	3.2
Oct 17 19:18	Psi^{3} Aqr	RB	5.0	143	51	252	1.9	0.0
Nov 06 19:02	Ome^{1} Sco	RB	3.9	20	11	318	0.5	−0.5
Nov 06 19:24	Ome^{2} Sco	RB	4.3	20	7	278	−0.1	0.7
Nov 19 19:45	13 Tau	RD	5.7	179	12	248	0.7	−0.4
Nov 19 20:16	14 Tau	RD	6.1	179	17	196	−0.2	1.6
Nov 20 22:33	693	RD	6.0	167	26	198	0.2	1.8
Nov 25 00:48	Psi Cnc	RD	5.7	123	17	295	1.8	−1.7
Nov 28 02:51	52 Leo	RD	5.5	88	22	256	1.5	−0.8
Dec 08 21:17	Chi Cap	DD	5.3	57	19	122	0.9	0.1
Dec 08 21:48	Chi Cap	RB	5.3	57	13	192	−0.9	2.7
Dec 18 01:41	72 Tau	DD	5.5	163	18	129	1.3	−0.3
Jan 1 '22 04:36	Mars	MB	1.5	27	20	29		

JUPITER MOON MUTUAL EVENTS

The plane of Jupiter's moons is close to that of the Earth's orbit. About every six years the two planes cross and for a few months we can see the moons eclipse and occult each other. The drop in brightness does not just depend on the relative magnitudes of the satellites. It also varies depending on whether the event is complete e.g., how much of the shadow (eclipse) or the moon (occultation) covers the other moon during an event.

Date	EST		WST		Vis	Event	Mag	d.Mag	Jup Limb	Sat Sep
	Start	End	Start	End						
7 Jan	19:43	20:17	17:43	18:17	E	II Ec I	5.1	0.634	12.71	2.58
18 Jan	19:19	19:33	17:19	17:33	E	II Ec I	5.1	0.875	79.61	4.02
23 Feb	07:54	08:02	05:54	06:02	W	II Ec I	5.1	0.896	76.55	9.32
28 Feb	05:10	05:11	03:10	03:11	E	I Oc II	5.1	0.001	15.49	
1 Mar	04:51	04:53	02:51	02:53	E	IV Oc I	5.2	0.016	45.04	
7 Mar	06:37	06:39	04:37	04:39	W	I Ec II	5.1	0.015	30.56	22.42
7 Mar	07:31	07:34	05:31	05:34	W	I Oc II	5.1	0.186	20.27	
9 Mar	06:18	06:29	04:18	04:29	W	I Ec IV	5.2	0.249	113.42	44.90
11 Mar	06:00	06:05	04:00	04:05	W	III Oc II	4.8	0.262	49.50	
15 Mar	05:15	05:30	03:15	03:30	E	I Oc III	4.7	0.062	0.30	
18 Mar	07:12	07:16	05:12	05:16	W	III Ec II	4.8	0.072	32.31	45.36
20 Mar	04:04	04:10	02:04	02:10	E	II Ec I	5.0	0.626	73.47	22.31
26 Mar	02:39	02:48	00:39	00:48	E	III Ec IV	4.9	0.110	117.59	91.71
27 Mar	06:21	06:27	04:21	04:27	W	II Ec I	5.0	0.509	72.55	26.32
29 Mar	04:58	05:14	02:58	03:14		I Ec III	4.7	0.040	50.19	23.03
1 Apr	02:20	02:24	00:20	00:24	E	I Ec II	5.0	0.423	54.04	34.74
1 Apr	03:48	03:50	01:48	01:50	E	I Oc II	5.0	0.068	38.17	
6 Apr	05:52	06:00	03:52	04:00		II Oc III	4.7	0.283	103.79	
8 Apr	04:32	04:37	02:32	02:37		I Ec II	5.0	0.581	60.69	37.76
9 Apr	02:13	02:18	00:13	00:18	E	III Oc I	4.6	0.365	27.46	
13 Apr	03:30	03:37	01:30	01:37	E	II Ec IV	5.3	0.051	50.45	88.11
13 Apr	04:24	04:29	02:24	02:29		I Oc III	4.6	0.120	52.82	
14 Apr	05:39	06:30	03:39	04:30		III Oc IV	4.8	0.182	234.36	
15 Apr	06:45	06:50	04:45	04:50	W	I Ec II	4.9	0.626	67.28	40.44
16 Apr	02:32	02:37	00:32	00:37	E	III Ec I	4.6	0.160	3.30	61.78
16 Apr	05:10	05:14	03:10	03:14		III Oc I	4.6	0.085	40.98	
20 Apr	03:50	04:38	01:50	02:38		IV Ec I	5.0	0.446	71.55	72.29
20 Apr	04:32	04:46	02:32	02:46		IV Ec III	4.8	1.393	14.90	128.06
20 Apr	04:32	04:39	02:32	02:39		I Ec III	4.6	0.213	13.75	57.73
21 Apr	01:50	02:00	23:50^{p}	00:00	E	IV Ec I	5.0	1.113	71.77	96.73
21 Apr	02:16	02:20	00:16	00:20	E	II Ec I	4.9	0.126	68.76	40.57
21 Apr	04:02	04:41	02:02	02:41		IV Ec II	5.2	0.363	55.83	60.80
23 Apr	05:16	05:22	03:16	03:22		III Ec I	4.5	0.324	15.63	64.83
27 Apr	07:23	07:29	05:23	05:29	W	I Ec III	4.5	0.358	0.10	64.15
28 Apr	04:31	04:34	02:31	02:34		II Ec I	4.9	0.048	67.40	44.50
29 Apr	04:56	05:04	02:56	03:04		I Ec IV	5.0	0.332	48.13	109.89
30 Apr	02:40	02:48	00:40	00:48	E	III Ec II	4.6	0.465	71.06	71.69
30 Apr	06:07	06:56	04:07	04:56		II Oc IV	5.1	0.030	111.52	
30 Apr	08:02	08:09	06:02	06:09	W	III Ec I	4.5	0.501	28.61	66.90
5 May	06:46	06:47	04:46	04:47	W	II Ec I	4.8	0.001	65.90	48.38
7 May	05:57	06:05	03:57	04:05		III Ec II	4.5	0.351	79.16	73.97
10 May	02:33	02:39	00:33	00:39	E	I Ec II	4.8	0.626	89.69	46.58
15 May	07:41	07:49	05:41	05:49	W	III Ec IV	4.6	0.075	175.17	153.62
17 May	04:48	04:53	02:48	02:53		I Ec II	4.7	0.549	95.79	47.18
24 May	07:03	07:09	05:03	05:09	W	I Ec II	4.7	0.416	101.71	47.17
25 May	00:14	00:27	22:14^{p}	22:27^{p}	E	IV Ec III	4.5	0.906	193.66	149.79
26 May	01:36	01:44	23:36^{p}	23:44^{p}	E	II Ec III	4.4	0.867	20.67	87.89
2 Jun	04:50	04:58	02:50	02:58		II Ec III	4.4	0.475	13.41	90.42
4 Jun	23:17	23:33	21:17	21:33	E	III Ec I	4.2	0.567	97.91	56.37
9 Jun	08:04	08:11	06:04	06:11	W	II Ec III	4.3	0.203	6.47	91.75
8 Jun	23:48	23:54	21:48	21:54	E	I Ec III	4.2	0.448	46.74	83.46
11 Jun	00:44	00:49	22:44^{p}	22:49^{p}	E	I Ec II	4.6	0.164	115.24	44.21
12 Jun	03:42	04:22	01:42	02:22		III Ec I	4.2	0.567	101.88	46.45
12 Jun	07:58	08:44	05:58	06:44	W	III Ec I	4.2	0.567	62.63	40.60
13 Jun	00:58	01:10	22:58^{p}	23:10^{p}		III Ec I	4.2	0.559	104.24	62.09
16 Jun	02:31	02:36	00:31	00:36		I Ec III	4.2	0.272	60.21	81.73
18 Jun	03:03	03:07	01:03	01:07		I Ec II	4.5	0.099	119.97	41.77
19 Jun	07:18	07:44	05:18	05:44	W	II Ec IV	4.8	0.361	85.93	92.07
20 Jun	04:10	04:18	02:10	02:18		III Ec I	4.1	0.372	101.21	65.14
23 Jun	05:14	05:19	03:14	03:19		I Ec III	4.1	0.143	73.12	78.19
25 Jun	05:22	05:26	03:22	03:26		I Ec II	4.5	0.052	124.16	38.62
27 Jun	07:11	07:17	05:11	05:17	W	III Ec I	4.1	0.180	94.61	66.01
30 Jun	08:00	08:04	06:00	06:04	W	I Ec III	4.1	0.054	85.40	72.85
2 Jul	07:43	07:46	05:43	05:46	W	I Ec II	4.4	0.019	127.71	34.82
5 Jul	20:54	20:56	18:54	18:56	E	I Ec II	4.4	0.008	129.23	32.69
23 Jul	05:38	06:04	03:38	04:04		III Ec IV	4.2	0.003	235.65	37.58
2 Aug	08:00	10:05	06:00	08:05	W	III Oc II	4.0		149.17	
9 Aug	04:03	04:57	02:03	02:57		III Oc II	4.0	0.465	47.28	
9 Aug	06:13	07:18	04:13	05:18		III Ec II	4.0	0.205	84.22	7.68
16 Aug	20:03	20:35	18:03	18:35		III Ec II	4.0	0.465	198.37	2.00
16 Aug	20:43	20:53	18:43	18:53		III Oc II	4.0	0.015	199.65	
23 Aug	00:33	01:26	22:33^{p}	23:26^{p}		III Oc II	4.0	0.456	38.09	
22 Aug	23:59	01:02^{n}	21:59	23:02		III Ec II	4.0	0.465	44.73	0.41
24 Aug	00:47	01:08	22:47^{p}	23:08^{p}		III Ec II	4.0	0.420	205.28	5.58
31 Aug	05:02	05:15	03:02	03:15		III Ec II	4.0	0.120	205.20	13.26
16 Nov	20:26	20:43	18:26	18:43	E	III Oc I	4.3	0.049	30.45	

The mutual events table above has the following information

Date of the event (month and day).

Start and **end** times of the events (hh:mm) in EST and/or WST. (n is next day, p is previous day)

Vis where E indicates the event is more suitable for eastern states, W is for events more suitable for observation from Western Australia. A blank means the event is suitable for most of Australia.

Event description e.g., II Oc I means satellite II occults (passes in front of) satellite I. Event II Ec I, means satellite I passes into satellite II's shadow. Satellite I is Io, II is Europa, III is Ganymede and IV is Callisto.

Mag combined magnitude of the pair of satellites in the event.

d.Mag expected maximum drop of the combined magnitude.

Jup Limb angular apparent distance of the occulted or eclipsed satellite from the limb of the planet (in arcseconds).

Sat Sep angular apparent distance of the eclipsed satellite from the eclipsing one (in arcseconds).

JUPITER — LONGITUDE OF CENTRAL MERIDIAN

SYSTEM I (° at 0 hr UT)

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Date
1	045.1	252.4	347.6	197.3	251.3	105.4	164.1	022.9	241.9	300.6	153.6	205.5	1
2	202.8	050.0	145.3	355.1	049.1	263.3	322.1	181.0	039.9	098.5	311.4	003.2	2
3	000.4	207.7	303.0	152.8	206.9	061.2	120.1	339.0	197.9	256.4	109.1	160.9	3
4	158.1	005.4	100.7	310.6	004.8	219.2	278.1	137.0	355.9	054.3	266.9	318.6	4
5	315.7	163.0	258.4	108.4	162.6	017.1	076.1	295.1	153.9	212.2	064.7	116.3	5
6	113.3	320.7	056.1	266.2	320.5	175.0	234.2	093.1	311.9	010.1	222.4	273.9	6
7	271.0	118.4	213.8	063.9	118.3	333.0	032.2	251.2	109.9	168.0	020.2	071.6	7
8	068.6	276.1	011.5	221.7	276.2	130.9	190.2	049.2	267.9	325.8	178.0	229.3	8
9	226.3	073.7	169.3	019.5	074.0	288.8	348.2	207.3	065.9	123.7	335.7	027.0	9
10	023.9	231.4	327.0	177.3	231.9	086.8	146.2	005.3	223.9	281.6	133.5	184.6	10
11	181.6	029.1	124.7	335.1	029.7	244.7	304.2	163.3	021.8	079.4	291.2	342.3	11
12	339.2	186.8	282.4	132.8	187.6	042.7	102.2	321.4	179.8	237.3	088.9	140.0	12
13	136.9	344.5	080.1	290.6	345.5	200.6	260.3	119.4	337.8	035.1	246.7	297.6	13
14	294.5	142.1	237.9	088.4	143.3	358.6	058.3	277.5	135.8	193.0	044.4	095.3	14
15	092.2	299.8	035.6	246.2	301.2	156.5	216.3	075.5	293.7	350.8	202.1	253.0	15
16	249.8	097.5	193.3	044.0	099.1	314.5	014.3	233.5	091.7	148.7	359.9	050.6	16
17	047.5	255.2	351.1	201.8	256.9	112.4	172.4	031.6	249.6	306.5	157.6	208.3	17
18	205.1	052.9	148.8	359.6	054.8	270.4	330.4	189.6	047.6	104.3	315.3	006.0	18
19	002.8	210.6	306.5	157.4	212.7	068.4	128.4	347.6	205.5	262.2	113.1	163.6	19
20	160.4	008.3	104.3	315.2	010.6	226.3	286.4	145.7	003.5	060.0	270.8	321.3	20
21	318.1	166.0	262.0	113.0	168.5	024.3	084.5	303.7	161.4	217.8	068.5	118.9	21
22	115.8	323.7	059.8	270.9	326.4	182.3	242.5	101.7	319.4	015.6	226.2	276.6	22
23	273.4	121.3	217.5	068.7	124.3	340.2	040.6	259.8	117.3	173.4	023.9	074.2	23
24	071.1	279.0	015.3	226.5	282.1	138.2	198.6	057.8	275.2	331.3	181.6	231.9	24
25	228.7	076.7	173.0	024.3	080.0	296.2	356.6	215.8	073.2	129.1	339.3	029.5	25
26	026.4	234.4	330.8	182.1	237.9	094.2	154.7	013.8	231.1	286.9	137.0	187.2	26
27	184.0	032.1	128.5	339.9	035.8	252.2	312.7	171.8	029.0	084.7	294.7	344.8	27
28	341.7	189.8	286.3	137.8	193.8	050.2	110.7	329.9	186.9	242.5	092.4	142.5	28
29	139.4		084.0	295.6	351.7	208.2	268.8	127.9	344.8	040.2	250.1	300.1	29
30	297.0		241.8	093.4	149.6	006.1	066.8	285.9	142.7	198.0	047.8	097.8	30
31	094.7		039.5		307.5		224.9	083.9		355.8		255.4	31

SYSTEM II (° at 0 hr UT)

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Date
1	175.7	146.4	027.9	001.1	186.2	163.8	353.6	335.8	318.3	148.1	124.6	307.6	1
2	325.7	296.4	178.0	151.3	336.4	314.0	144.0	126.2	108.7	298.4	274.7	097.7	2
3	115.7	086.5	328.1	301.4	126.6	104.3	294.3	276.6	259.0	088.6	064.8	247.7	3
4	265.7	236.5	118.2	091.5	276.8	254.6	084.7	067.0	049.4	238.9	215.0	037.8	4
5	055.7	026.5	268.2	241.7	067.0	044.9	235.1	217.5	199.8	029.2	005.1	187.8	5
6	205.7	176.6	058.3	031.8	217.2	195.2	025.4	007.9	350.1	179.4	155.3	337.9	6
7	355.8	326.6	208.4	182.0	007.4	345.5	175.8	158.3	140.5	329.7	305.4	127.9	7
8	145.8	116.7	358.5	332.1	157.7	135.8	326.2	308.7	290.8	119.9	095.5	278.0	8
9	295.8	266.7	148.6	122.3	307.9	286.1	116.6	099.1	081.2	270.1	245.6	068.0	9
10	085.8	056.8	298.7	272.4	098.1	076.5	267.0	249.5	231.6	060.4	035.8	218.1	10
11	235.8	206.8	088.8	062.6	248.3	226.8	057.4	039.9	021.9	210.6	185.9	008.1	11
12	025.8	356.9	238.9	212.7	038.6	017.1	207.7	190.3	172.3	000.8	336.0	158.1	12
13	175.9	146.9	029.0	002.9	188.8	167.4	358.1	340.8	322.6	151.1	126.1	308.2	13
14	325.9	297.0	179.1	153.1	339.0	317.7	148.5	131.2	112.9	301.3	276.2	098.2	14
15	115.9	087.0	329.2	303.2	129.3	108.0	298.9	281.6	263.3	091.5	066.3	248.2	15
16	265.9	237.1	119.3	093.4	279.5	258.4	089.3	072.0	053.6	241.7	216.4	038.3	16
17	055.9	027.1	269.4	243.6	069.8	048.7	239.7	222.4	203.9	031.9	006.5	188.3	17
18	206.0	177.2	059.5	033.7	220.0	199.0	030.1	012.8	354.2	182.1	156.6	338.3	18
19	356.0	327.2	209.6	183.9	010.3	349.4	180.5	163.2	144.6	332.3	306.7	128.4	19
20	146.0	117.3	359.7	334.1	160.5	139.7	330.9	313.6	294.9	122.5	096.8	278.4	20
21	296.0	267.4	149.8	124.3	310.8	290.0	121.3	104.0	085.2	272.7	246.9	068.4	21
22	086.1	057.4	299.9	274.4	101.0	080.4	271.7	254.4	235.5	062.9	036.9	218.5	22
23	236.1	207.5	090.0	064.6	251.3	230.7	062.1	044.8	025.8	213.1	187.0	008.5	23
24	026.1	357.6	240.1	214.8	041.6	021.1	212.5	195.2	176.1	003.3	337.1	158.5	24
25	176.2	147.6	030.2	005.0	191.8	171.4	002.9	345.6	326.4	153.4	127.2	308.5	25
26	326.2	297.7	180.4	155.2	342.1	321.8	153.3	136.0	116.7	303.6	277.3	098.5	26
27	116.2	087.8	330.5	305.4	132.4	112.1	303.8	286.4	267.0	093.8	067.3	248.6	27
28	266.2	237.8	120.6	095.6	282.6	262.5	094.2	076.8	057.3	243.9	217.4	038.6	28
29	056.3		270.7	245.8	072.9	052.9	244.6	227.1	207.6	034.1	007.5	188.6	29
30	206.3		060.9	036.0	223.2	203.2	035.0	017.5	357.8	184.3	157.5	338.6	30
31	356.3		211.0		013.5		185.4	167.9		334.4		128.6	31

Jupiter is a gas giant and we can only view the upper atmospheric features. Just a small telescope (even a 60 mm instrument) is required to view the equatorial belts and the Great Red Spot. When the seeing is good, numerous breaks can be glimpsed in the belts, as well as many minor spots.

There is no single rotation period for the features of Jupiter. The speed of any feature on the surface depends on its latitude, hence the multiple rotation systems used. To monitor the movement and development of any feature, amateurs record the time a feature crosses the central meridian of the planet. This central meridian is an imaginary line drawn from the north to south pole of Jupiter which passes through the centre of the disc.

The longitude can be worked out from the tables here. All the times on the main tables are calculated for 0 hr UT of date. You will need to add multiple hours and minutes from the small Increase in Longitude tables below. For example, the longitude of central meridian for Jupiter (System I) for 5 July at 2:20 am EST would be calculated as follows. First subtract 10 hours to convert to UT i.e., 16:20 hrs on 4 July. From the table, the longitude on 4 July is 278.1°. To this add an adjustment for the 16 hours, which is 225.3°, and finally for the 20 minutes add 12.2°. These add up to 515.6°, less 360° giving a final answer of 155.6°.

GREAT RED SPOT TRANSIT TIME

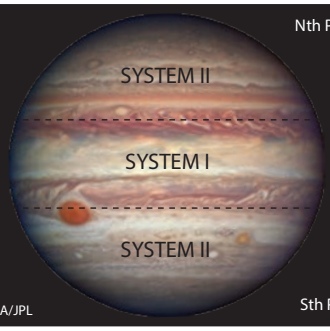
The GRS can best be seen from about one hour before transiting the central meridian to one hour after. During this two-hour period it will move approximately 70% of the width of Jupiter at its latitude. It can be seen a further 30 minutes either side of this period, but it tends to appear foreshortened and merging with the limb. The longitude of the GRS (System II) does drift over the years and inconsistently. For example the following are some actual values for June: 2013 (197°), 2014 (214°), 2015 (228°), 2016 (248°), 2017 (274°), 2018 (290°), 2019 (312°) and 2020 (337°). The table of data for 2021 (opposite) has been based on 359°. For every degree of longitude greater than 359° it will transit 1.6 minutes later than shown (for every degree less than 359°, transit is 1.6 minutes earlier). If the recent trend continues the value could range from about 20 minutes earlier than shown here as the year opens to 20 minutes later by the end of 2021. This is an estimated midpoint of the GRS. The spot is about 15° in diameter, so it takes around 24 minutes to transit. The longitude of the GRS was obtained from the JUPOS website. jupos.privat.t-online.de/

Increase In Longitude
SYSTEM I
Rotation: 9 h 50 m 30.003 s

hr	deg°	hr	deg°	min	deg°
1	036.6	13	115.5	5	03.0
2	073.2	14	152.1	10	06.1
3	109.7	15	188.7	15	09.1
4	146.3	16	225.3	20	12.2
5	182.9	17	261.8	25	15.2
6	219.5	18	298.4	30	18.3
7	256.1	19	335.0	35	21.3
8	292.6	20	011.6	40	24.4
9	329.2	21	048.2	45	27.4
10	005.8	22	084.7	50	30.5
11	042.4	23	121.3	55	33.5
12	079.0	24	157.9	60	36.6

SYSTEM I applies to all features situated on or between the North component of the South Equatorial Belt and the South component of the North Equatorial Belt.

SYSTEM II applies to the remainder of the surface.



Jupiter image credit NASA/JPL

Nth Polar Region
Nth Nth Temperate Belt
Nth Temperate Belt
Nth Equatorial Belt
Nth and Sth components
Equatorial Zone
Sth Equatorial Belt
Sth and Nth components
Sth Temperate Belt
Sth Sth Temperate Belt
Sth Polar Region

Increase In Longitude
SYSTEM II
Rotation: 9 h 55 m 40.062 s

hr	deg°	hr	deg°	min	deg°
1	036.3	13	111.4	5	03.0
2	072.5	14	147.7	10	06.0
3	108.8	15	183.9	15	09.1
4	145.0	16	220.2	20	12.1
5	181.3	17	256.5	25	15.1
6	217.6	18	292.7	30	18.1
7	253.8	19	329.0	35	21.2
8	290.1	20	005.2	40	24.2
9	326.4	21	041.5	45	27.2
10	002.6	22	077.8	50	30.2
11	038.9	23	114.0	55	33.2
12	075.1	24	150.3	60	36.3

JUPITER — GREAT RED SPOT

Date	1st	2nd	3rd
Jan 4			(20:30)
Feb 22	(6:23)		
Feb 23	4:14		
Feb 25	5:54		
Feb 27	(5:33)		
Mar 2	5:03		
Mar 4	(4:42)		
Mar 6	(6:21)		
Mar 7	4:13		
Mar 9	5:52 *		
Mar 11	(5:31)		
Mar 12	3:23		
Mar 14	5:02		
Mar 16	(4:41)		
Mar 18	(6:19)		
Mar 19	4:11		
Mar 21	5:50 *		
Mar 23	(5:29)		
Mar 24	3:20		
Mar 26	4:59		
Mar 28	(4:38)		
Mar 29	2:30		
Mar 30	(6:17)		
Mar 31	4:09		
Apr 2	5:48 *		
Apr 4	(5:26)		
Apr 5	3:18		
Apr 7	4:57 *		
Apr 9	6:35 *		
Apr 10	2:27		
Apr 11	(6:14)		
Apr 12	4:06		
Apr 14	5:45 *		
Apr 15	1:36		
Apr 16	(5:23)		
Apr 17	3:15		
Apr 18	(7:02)		
Apr 19	4:54 *		
Apr 21	6:32 *		
Apr 22	2:24		
Apr 23	(6:11)		
Apr 24	4:02 *		
Apr 26	5:41 *		
Apr 27	1:33		
Apr 28	(5:20)		

Date	1st	2nd	3rd
Apr 29	3:11		
Apr 30	(6:58)		
May 1	4:50 *		
May 3	6:28 *		
May 4	2:20		
May 5	(6:07)		
May 6	3:58 *		
May 8	5:37 *		
May 9	1:28		
May 10	(5:15)		
May 11	3:07 *		
May 12	(6:54)		
May 13	4:45 *		
May 14	0:37		
May 15	6:24 *		
May 16	2:15		
May 17	(6:02)		
May 18	3:54 *		23:45
May 20	5:32 *		
May 21	1:24		
May 22	7:11 *		
May 23	3:02 *		
May 24	(6:49)		
May 25	4:40 *		
May 26	0:32		
May 27	6:19 *		
May 28	2:10 *		
May 29	(5:57)		
May 30	3:48 *		23:40
May 31	(7:36)		
Jun 1	5:27 *		
Jun 2	1:18		
Jun 3	7:05 *		
Jun 4	2:56 *		22:48
Jun 5	(6:43)		
Jun 6	4:35 *		
Jun 7	0:26		
Jun 8	6:13 *		
Jun 9	2:04 *		
Jun 10	(5:51)		
Jun 11	3:43 *		23:34
Jun 12	(7:30)		
Jun 13	5:21 *		(23:12)
Jun 14	1:12		
Jun 15	6:59 *		

Date	1st	2nd	3rd
Jun 16	2:50 *		22:42
Jun 17	(6:37)		
Jun 18	4:28 *		(22:20)
Jun 19	0:20		
Jun 20	6:07 *		(23:58)
Jun 21	1:58		21:49
Jun 22	(5:45)		
Jun 23	3:36 *		23:27
Jun 24	(7:23)		
Jun 25	5:14 *		(23:06)
Jun 26	1:05		
Jun 27	6:52 *		
Jun 28	2:43 *		22:35
Jun 29	(6:30)		
Jun 30	4:22 *		(22:13)
Jul 1	0:13		
Jul 2	6:00 *		(23:51)
Jul 3	1:51		21:42
Jul 4	(5:38)		
Jul 5	3:29 *		23:20 *
Jul 6	(7:16)		
Jul 7	5:07 *		(22:58)
Jul 8	0:58		20:49
Jul 9	6:45 *		
Jul 10	2:36 *		22:28
Jul 11	(6:23)		
Jul 12	4:14 *		(22:06)
Jul 13	0:05		
Jul 14	5:52 *		(23:43)
Jul 15	1:43		21:35
Jul 16	(5:30)		
Jul 17	3:21 *		23:13 *
Jul 18	(7:08)		
Jul 19	4:59 *		(22:51)
Jul 20	0:50		20:42
Jul 21	6:37 *		
Jul 22	2:28 *		22:20 *
Jul 23	(6:15)		
Jul 24	4:06 *		23:58 *
Jul 25		19:49	
Jul 26	5:44 *		(23:36)
Jul 27	1:35		21:27
Jul 28	(5:22)		
Jul 29	3:13 *		23:05 *
Jul 30	(7:00)	18:56	

Date	1st	2nd	3rd
Jul 31	4:51 *		(22:42)
Aug 1	0:42		20:34
Aug 2	6:29 *		
Aug 3	2:20 *		22:12 *
Aug 4	(6:07)		
Aug 5	3:58 *		23:49 *
Aug 6		19:41	
Aug 7	5:36 *		(23:27)
Aug 8	1:27	(19:18)	21:18
Aug 9	(5:14)		
Aug 10	3:05 *		22:56 *
Aug 11	(6:52)	18:47	
Aug 12	4:43 *		(22:34)
Aug 13	0:34	(18:25)	20:25
Aug 14	6:21 *		
Aug 15	2:12 *		22:03 *
Aug 16	(5:59)	17:54	
Aug 17	3:50 *		23:41 *
Aug 18		19:32	
Aug 19	5:28 *		(23:19)
Aug 20	1:19	(19:10)	21:10
Aug 21	(5:06)		
Aug 22	2:57 *		22:48 *
Aug 23	(6:44)	18:39	
Aug 24	4:35 *		(22:26)
Aug 25	0:26	(18:17)	20:17
Aug 26	6:13 *		
Aug 27	2:04 *		21:55 *
Aug 28	(5:51)	17:47	
Aug 29	3:42 *		23:33 *
Aug 30		19:25	
Aug 31	5:20 *		(23:11)
Sep 1	1:11	(19:03)	21:03
Sep 2	(4:58)		
Sep 3	2:49 *		22:41 *
Sep 4		18:32	
Sep 5	4:27 *		(22:19)
Sep 6	0:18	(18:10)	20:10
Sep 7	(4:05)		(23:57)
Sep 8	1:57	(19:48)	21:48
Sep 9		17:39	
Sep 10	3:35 *		23:26 *
Sep 11		19:17	
Sep 12	(3:13)		(23:04)
Sep 13	1:04	(18:55)	20:55

Date	1st	2nd	3rd
Sep 14	(4:51)		
Sep 15	2:42 *		22:34 *
Sep 16		18:25	
Sep 17	4:20 *		(22:12)
Sep 18	0:12	(18:03)	20:03
Sep 19	(3:59)		(23:50)
Sep 20	1:50	(19:41)	21:41
Sep 21		17:33	
Sep 22	3:28 *		23:20 *
Sep 23		19:11	
Sep 24	(3:06)		(22:58)
Sep 25	0:58	(18:49)	20:49
Sep 27	2:36 *		22:27 *
Sep 28		18:19	
Sep 29	(2:14)		(22:06)
Sep 30	0:06	(17:57)	19:57
Oct 1	(3:53)		(23:44)
Oct 2	1:44	(19:36)	21:36
Oct 4	3:22 *		23:14 *
Oct 5		19:05	
Oct 6	(3:01)		(22:52)
Oct 7	0:52	(18:44)	20:44
Oct 9	2:31 *		22:22 *
Oct 10		18:14	
Oct 11	(2:09)		(22:01)
Oct 12	0:01		19:52
Oct 13			(23:39)
Oct 14	1:39	(19:31)	21:31
Oct 16	(1:18)		23:09 *
Oct 17		19:01	
Oct 18			(22:48)
Oct 19	0:48	(18:39)	20:39
Oct 21	(0:27)		22:18 *
Oct 22		18:09	
Oct 23	(2:05)		23:57 *
Oct 24		19:48	
Oct 25			(23:35)
Oct 26	1:35	(19:27)	21:27
Oct 28	(1:14)		23:06 *
Oct 29		18:57	
Oct 30			(22:44)
Oct 31	0:44	(18:36)	20:36
Nov 2	(0:23)		22:15 *
Nov 3		18:06	
Nov 4			23:54 *

Date	1st	2nd	3rd
Nov 5		19:45	
Nov 6			(23:32)
Nov 7		(19:24)	21:24
Nov 9	(1:11)		23:03 *
Nov 10		18:54	
Nov 11			(22:42)
Nov 12	0:42	(18:33)	20:33
Nov 14	(0:21)		22:12 *
Nov 16			23:51 *
Nov 17		19:43	
Nov 18			(23:30)
Nov 19		(19:22)	21:22
Nov 21			23:01 *
Nov 22		18:52	
Nov 23			(22:40)
Nov 24			20:31
Nov 26	(0:19)		22:10 *
Nov 28			23:50 *
Nov 29		19:41	
Nov 30			(23:29)
Dec 1		(19:20)	21:20
Dec 3			22:59 *
Dec 4		18:51	
Dec 5			(22:38)
Dec 6			20:30
Dec 8			22:09 *
Dec 10			(21:48)
Dec 11		19:40	
Dec 13		(19:19)	21:19
Dec 15			(20:58)
Dec 16		18:50	
Dec 17			(22:38)
Dec 18			20:29
Dec 20			22:09 *
Dec 22			(21:48)
Dec 23		19:40	
Dec 25		(19:19)	21:19
Dec 27			(20:58)
Dec 28		18:50	
Dec 30			20:29

1st, 2nd or 3rd GRS

h:mm EST (Eastern only)
h:mm* EST (All States)
(h:mm) WST (WA only)

Predictions are shown for transit times for Sydney and Perth (giving a reasonable indication for eastern and western Australia). Times have been excluded when Jupiter is near conjunction (within 18° of the Sun) or below the horizon. If a transit is predicted when Jupiter is close to the horizon, the GRS may still be seen at least one hour before or after the time (allowing it to have some altitude). Predictions during daylight hours have also been omitted, except for those within 30 minutes after sunrise or before sunset. Even if there is a transit close to sunrise or sunset, the GRS can be seen well into the twilight period.

With a transit occurring every 9 hours 55 min 40 secs, two or three transits will occur every day, but a maximum of two are visible from any location. The three columns represent the 1st, 2nd and 3rd transits for each day. Note if the first transit for the day in EST is before 2 am, the event will be the last transit (3rd) for the previous day in WST (assuming Jupiter is visible). When the same transit is visible across the country, only the EST time is given followed by an asterisk (*). To get the WST time subtract two hours from the EST. For CST subtract 30 minutes from EST. For an event only visible from WA the time is given in brackets (WST). Daylight Saving is not allowed for, you will need to add one hour to the times in the table when in effect.

For example, on 16 October the first transit is only visible from WA at 1:18 am WST. The 3rd transit for the day is visible Australia wide at 23:09 EST or 11:09 pm EST (10:39 pm CST, 9:09 pm WST).

JUPITER'S MOONS

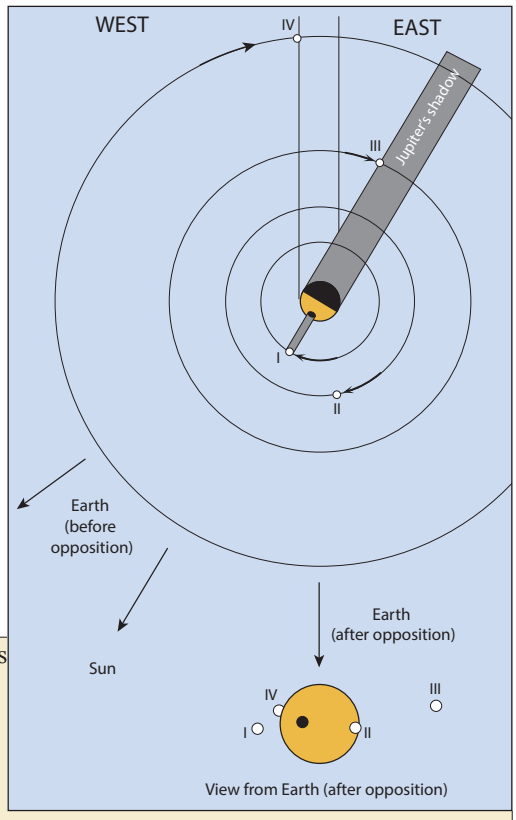
Jupiter, with its many moons, can be likened to a miniature Solar System. Like the planets, these moons all lie in a similar plane. Although there are 79 known Jovian satellites, most of them are too faint for amateur equipment. The four Galilean Satellites, named after their discoverer, Galileo, are bright enough to be visible in small telescopes or moderate-sized binoculars. The dance of these moons, as they pass back and forth across Jupiter, is illustrated in *Jupiter Moon Events* on the following pages. All the moons orbit in roughly the same plane, which is very close to the plane of the Earth's orbit. Hence we see the Jovian system as edge-on. This is the key point to understanding the satellite phenomena. From Earth, we see four types of events. They are:

1. The satellite passes in front of Jupiter. This is called a satellite transit.
2. The shadow of a satellite can move across the *surface* of the planet. This is called a satellite shadow transit. The start of a satellite or shadow transit is called its ingress; the finish, its egress.

   Before opposition, the shadow transit of a satellite will commence before that of the satellite itself. After opposition, the satellite will transit before the shadow. Jupiter's opposition date in 2021 is 20 August.
3. A satellite can go into occultation, that is, pass behind the disc of Jupiter.
4. A satellite can be eclipsed as it passes into Jupiter's shadow. The closer Jupiter is to opposition (or conjunction), the more likely that the eclipse events, or at least one event (disappearance or reappearance) will be hidden by the planet's disc. This is especially relevant for the close-in satellites. Positions for the disappearance (d) and reappearance (r) for each moon, relative to Jupiter, for each month, are presented in the diagram below.

The four moons Io, Europa, Ganymede and Callisto are bright enough to be seen in binoculars (7× or greater is recommended). It may be necessary to mount the binoculars on a tripod to help keep them steady. Initially, try looking for Callisto when it is furthest from Jupiter (maximum elongation). This happens approximately every eight days; an example would be 19 August.

To see the moons with binoculars may take a little practice. The power or magnification of the binoculars will determine how close to Jupiter you can follow a moon. Of course, with a small telescope you would have no problem following the moons and their shadows as they cross the disc of Jupiter. Watching a moon fade and disappear as it moves into Jupiter's shadow (an eclipse) is very impressive.



This diagram illustrates all of the Jupiter satellite events. It is only an example and does not represent any particular date.

Viewed from the Earth (after opposition):

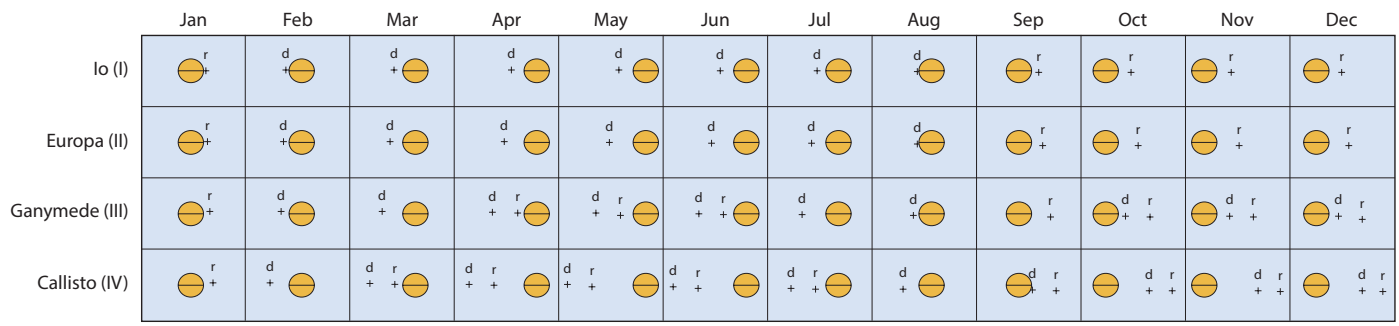
Satellite I	(Io) shadow is currently in transit. The satellite itself would have recently egressed from a transit.
Satellite II	(Europa) has just commenced a satellite transit (ingress).
Satellite III	(Ganymede) is about to be eclipsed (disappear).
Satellite IV	(Callisto) may be about to move out of sight as it is occulted by Jupiter's disc.

JUPITER'S MOON EVENTS Legend (following pages)

Column 1	Date (only appears for the first event each day).
Column 2	Time in EST.
Column 3	Time in WST, a (p) after the time means it is on the previous day.
Column 4	I = Io, II = Europa, III = Ganymede, IV = Callisto
Column 5	Oc = Occultation, Sh = Shadow Transit, Tr = Satellite Transit, Ec = Eclipse
Column 6	I = Ingress, E = Egress, D = Disappearance, R = Reappearance
Column 7	Visibility where E indicates the event is more suitable for the eastern states, W is for events more suitable for observation from Western Australia. A blank here means the event is suitable for most of Australia.

Note: In these tables, some events may happen (as seen from your location) while Jupiter is just below the horizon, or while the Sun is just above the horizon. This allows for the variation in rise and set times for Jupiter and the Sun across Australia. Events near conjunction, with Jupiter closer than 18° to the Sun, have been omitted.

ECLIPSE POSITIONS

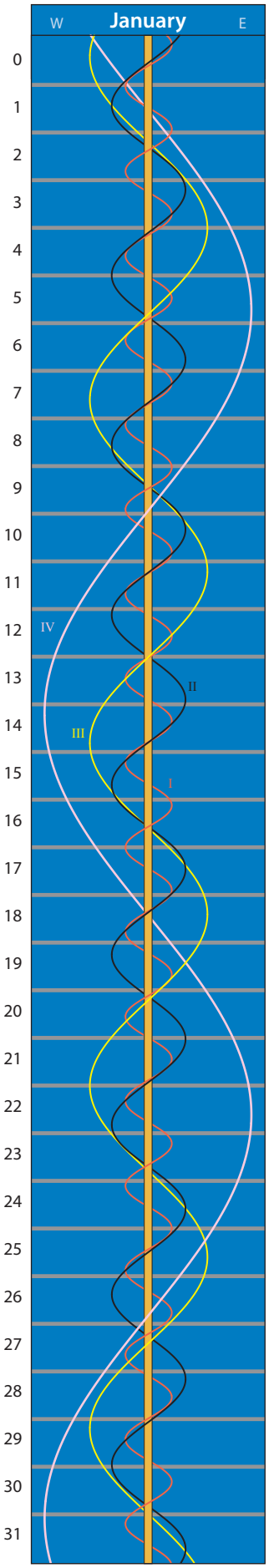


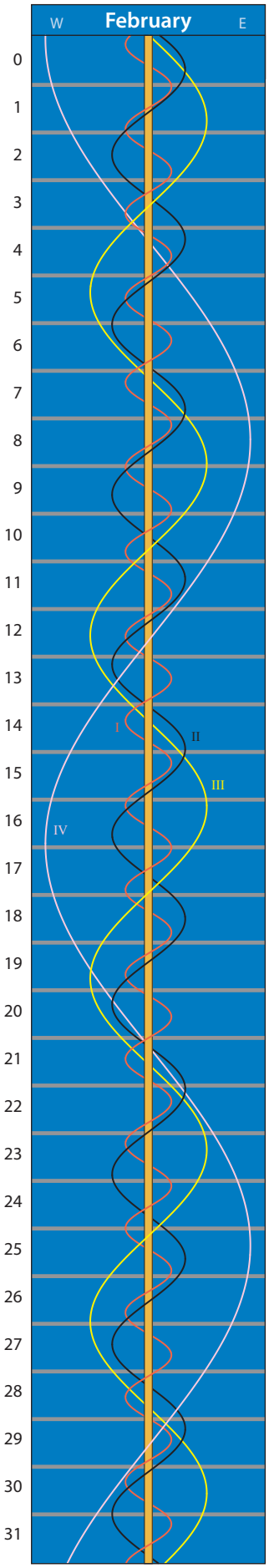
These diagrams show the positions of the eclipse events for each satellite for mid-month, relative to Jupiter. An eclipse happens when the moon passes into (disappearance or d) or out of (reappearance or r) Jupiter's shadow; west to the left, east to the right.

JUPITER MOON EVENTS

The diagrams here show the patterns the four major moons of Jupiter make as they shuttle back and forth. Each complete period represents one orbit of the satellite. Each horizontal grey date line represents midnight; the top edge of the line is midnight EST (14 hr UT), the bottom edge of the line is midnight WST (16 hr UT). The close pair of parallel vertical lines, running down the centre, represents the disc of Jupiter. It is interesting to compare the times when each moon passes over these lines, with the satellite's transit times. The same can be done with the occultation times, that is when the line disappears behind Jupiter.

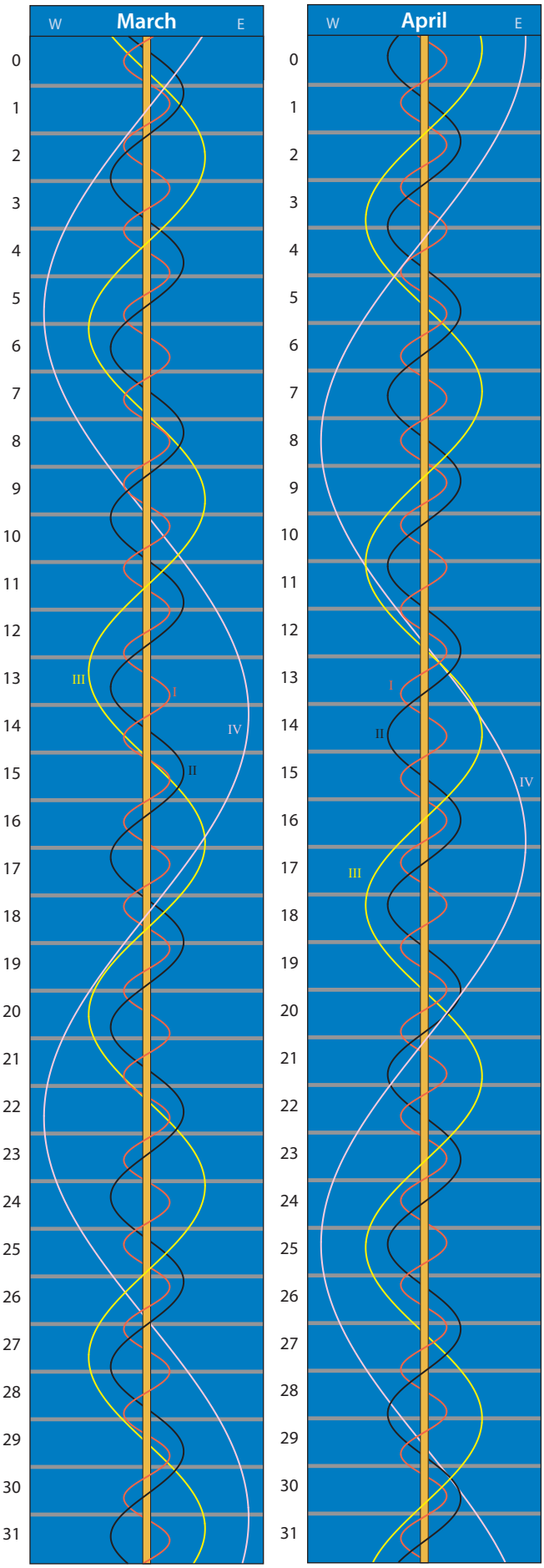
Satellite: **I** is **Io**
II is **Europa**
III is **Ganymede**
IV is **Callisto.**





Day	EST	WST	Sat	Event	Vis
January					
5	22:35	20:35	III	Tr E	W
	22:35	20:35	I	Tr I	W
6	19:49	17:49	I	Oc D	E
	22:31	20:31	I	Ec R	W
February					
21	07:29	05:29	IV	Oc R	W
25	04:19	02:19	III	Sh E	E
26	06:47	04:47	I	Sh I	W
	07:16	05:16	I	Tr I	W
27	04:05	02:05	I	Ec D	E
	06:54	04:54	I	Oc R	W
28	04:04	02:04	I	Tr E	E
	05:32	03:32	II	Ec D	E
March					
1	06:26	04:26	IV	Sh I	W
2	04:31	02:31	II	Tr E	E
4	04:41	02:41	III	Sh I	E
	07:03	05:03	III	Tr I	W
7	03:47	01:47	I	Tr I	E
	05:27	03:27	I	Sh E	E
	06:05	04:05	I	Tr E	W
	08:06	06:06	II	Ec D	W
9	04:27	02:27	II	Tr I	E
	06:01	04:01	II	Sh E	W
	07:22	05:22	II	Tr E	W
10	04:14	02:14	IV	Oc R	E
13	07:54	05:54	I	Ec D	W
14	05:04	03:04	I	Sh I	E
	05:48	03:48	I	Tr I	
	07:21	05:21	I	Sh E	W
	08:06	06:06	I	Tr E	W
15	05:27	03:27	I	Oc R	E
	05:28	03:28	III	Oc R	E
16	05:43	03:43	II	Sh I	
	07:17	05:17	II	Tr I	W
18	04:27	02:27	II	Oc R	E
	05:26	03:26	IV	Sh E	E
	08:15	06:15	IV	Tr I	W
21	06:57	04:57	I	Sh I	W
	07:48	05:48	I	Tr I	W
22	04:17	02:17	I	Ec D	E
	07:27	05:27	I	Oc R	W
23	03:44	01:44	I	Sh E	E
	04:36	02:36	I	Tr E	E
	08:19	06:19	II	Sh I	W
25	07:14	05:14	II	Oc R	W
29	06:11	04:11	I	Ec D	W
	06:46	04:46	III	Ec D	W
30	03:20	01:20	I	Sh I	E
	04:18	02:18	I	Tr I	E
	05:37	03:37	I	Sh E	
	06:35	04:35	I	Tr E	W
31	03:57	01:57	I	Oc R	E
April					
1	05:08	03:08	II	Ec D	
2	04:24	02:24	III	Tr E	E
3	03:08	01:08	II	Sh E	E
	05:11	03:11	II	Tr E	
4	04:37	02:37	IV	Tr I	E
5	08:05	06:05	I	Ec D	W
6	05:13	03:13	I	Sh I	
	06:17	04:17	I	Tr I	W
	07:31	05:31	I	Sh E	W
	08:35	06:35	I	Tr E	W
7	02:34	00:34	I	Ec D	E
	05:56	03:56	I	Oc R	
8	03:04	01:04	I	Tr E	E
	07:43	05:43	II	Ec D	W
9	04:18	02:18	III	Sh E	E
	05:05	03:05	III	Tr I	
10	02:50	00:50	II	Sh I	E
	05:04	03:04	II	Tr I	
	05:44	03:44	II	Sh E	
	07:57	05:57	II	Tr E	W
12	02:08	00:08	II	Oc R	E
	05:16	03:16	IV	Ec D	
13	07:07	05:07	I	Sh I	W
	08:15	06:15	I	Tr I	W
14	04:28	02:28	I	Ec D	
	07:55	05:55	I	Oc R	W

JUPITER MOON EVENTS

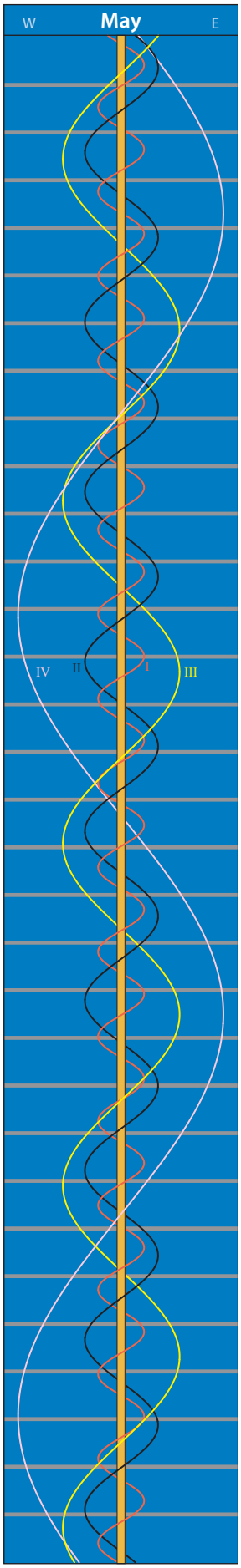


Day	EST	WST	Sat	Event	Vis
15	02:45	00:45	I	Tr I	E
	03:53	01:53	I	Sh E	E
	05:03	03:03	I	Tr E	
16	02:24	00:24	I	Oc R	E
	04:39	02:39	III	Sh I	
	08:18	06:18	III	Sh E	W
17	05:26	03:26	II	Sh I	
	07:48	05:48	II	Tr I	W
	08:20	06:20	II	Sh E	W
19	04:52	02:52	II	Oc R	
20	03:15	01:15	III	Oc R	E
21	05:19	03:19	IV	Tr E	
	06:22	04:22	I	Ec D	
22	03:29	01:29	I	Sh I	E
	04:43	02:43	I	Tr I	
	05:47	03:47	I	Sh E	
	07:01	05:01	I	Tr E	W
23	04:22	02:22	I	Oc R	
	08:39	06:39	III	Sh I	W
24	01:30	23:30 (p)	I	Tr E	E
	08:01	06:01	II	Sh I	W
26	02:10	00:10	II	Ec D	E
	07:35	05:35	II	Oc R	W
27	02:23	00:23	III	Ec R	E
	03:50	01:50	III	Oc D	
	07:29	05:29	III	Oc R	W
28	02:45	00:45	II	Tr E	E
	08:15	06:15	I	Ec D	W
29	04:14	02:14	IV	Ec R	
	05:23	03:23	I	Sh I	
	06:40	04:40	I	Tr I	W
	07:41	05:41	I	Sh E	W
30	02:44	00:44	I	Ec D	E
	06:19	04:19	I	Oc R	

May

Day	EST	WST	Sat	Event	Vis
1	01:09	23:09 (p)	I	Tr I	E
	02:09	00:09	I	Sh E	E
	03:27	01:27	I	Tr E	
3	04:46	02:46	II	Ec D	
4	02:44	00:44	III	Ec D	E
	06:23	04:23	III	Ec R	
	08:01	06:01	III	Oc D	W
5	02:33	00:33	II	Tr I	E
	02:48	00:48	II	Sh E	E
	05:25	03:25	II	Tr E	
6	07:17	05:17	I	Sh I	W
	08:36	06:36	I	Tr I	W
7	04:38	02:38	I	Ec D	
	07:03	05:03	IV	Sh I	W
	08:15	06:15	I	Oc R	W

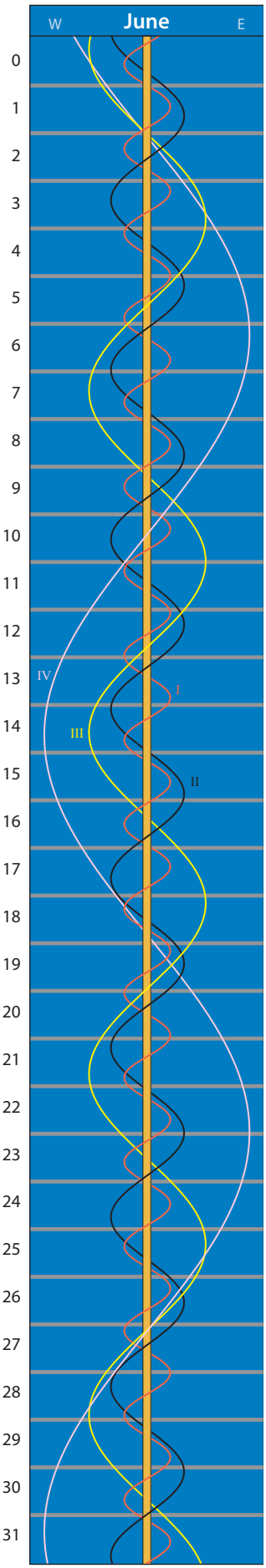
Day	EST	WST	Sat	Event	Vis
8	00:32	22:32 (p)	IV	Tr E	E
	01:41	23:41 (p)	III	Tr E	E
	01:45	23:45 (p)	I	Sh I	E
	03:05	01:05	I	Tr I	
	04:03	02:03	I	Sh E	
	05:23	03:23	I	Tr E	
9	02:44	00:44	I	Oc R	E
10	07:21	05:21	II	Ec D	W
11	06:44	04:44	III	Ec D	W
12	02:30	00:30	II	Sh I	E
	05:12	03:12	II	Tr I	
	05:23	03:23	II	Sh E	
	08:03	06:03	II	Tr E	W
14	02:15	00:15	II	Oc R	E
	06:31	04:31	I	Ec D	
15	00:17	22:17 (p)	III	Sh E	E
	02:08	00:08	III	Tr I	E
	03:39	01:39	I	Sh I	
	05:00	03:00	I	Tr I	
	05:46	03:46	III	Tr E	
	05:57	03:57	I	Sh E	
	07:18	05:18	I	Tr E	W
16	01:00	23:00 (p)	I	Ec D	E
	04:39	02:39	I	Oc R	
	06:19	04:19	IV	Oc D	
17	00:25	22:25 (p)	I	Sh E	E
	01:47	23:47 (p)	I	Tr E	E
19	05:05	03:05	II	Sh I	
	07:49	05:49	II	Tr I	W
	07:58	05:58	II	Sh E	W
21	04:53	02:53	II	Oc R	
	08:25	06:25	I	Ec D	W
22	00:37	22:37 (p)	III	Sh I	E
	04:17	02:17	III	Sh E	
	05:33	03:33	I	Sh I	
	06:11	04:11	III	Tr I	
	06:55	04:55	I	Tr I	W
	07:51	05:51	I	Sh E	W
	23:57	21:57	II	Tr E	E
23	02:53	00:53	I	Ec D	
	06:33	04:33	I	Oc R	
24	00:01	22:01 (p)	I	Sh I	E
	01:12	23:12 (p)	IV	Sh I	E
	01:23	23:23 (p)	I	Tr I	E
	02:19	00:19	I	Sh E	
	03:41	01:41	I	Tr E	
	06:03	04:03	IV	Sh E	
25	01:01	23:01 (p)	I	Oc R	E
	23:51	21:51	III	Oc R	E
26	07:40	05:40	II	Sh I	W
28	01:50	23:50 (p)	II	Ec D	
	07:28	05:28	II	Oc R	W



Day	EST	WST	Sat	Event	Vis
29	04:37	02:37	III	Sh I	
	07:27	05:27	I	Sh I	W
	08:16	06:16	III	Sh E	W
	08:48	06:48	I	Tr I	W
	23:40	21:40	II	Tr I	E
	23:50	21:50	II	Sh E	E
30	02:31	00:31	II	Tr E	
	04:47	02:47	I	Ec D	
	08:26	06:26	I	Oc R	W
31	01:55	23:55 (p)	I	Sh I	
	03:17	01:17	I	Tr I	
	04:13	02:13	I	Sh E	
	05:34	03:34	I	Tr E	
	23:15	21:15	I	Ec D	E

June

Day	EST	WST	Sat	Event	Vis
1	02:54	00:54	I	Oc R	
2	00:03	22:03 (p)	I	Tr E	E
	00:09	22:09 (p)	III	Oc D	E
	00:24	22:24 (p)	IV	Oc D	E
	03:46	01:46	III	Oc R	
	04:57	02:57	IV	Oc R	
4	04:26	02:26	II	Ec D	
5	08:38	06:38	III	Sh I	W
	23:32	21:32	II	Sh I	E
6	02:12	00:12	II	Tr I	
	02:24	00:24	II	Sh E	
	05:02	03:02	II	Tr E	
	06:41	04:41	I	Ec D	
7	03:49	01:49	I	Sh I	
	05:09	03:09	I	Tr I	
	06:07	04:07	I	Sh E	
	07:27	05:27	I	Tr E	W
	23:18	21:18	II	Oc R	E
8	01:09	23:09 (p)	I	Ec D	
	04:45	02:45	I	Oc R	
	22:42	20:42	III	Ec D	E
	23:37	21:37	I	Tr I	E
9	00:36	22:36 (p)	I	Sh E	E
	01:55	23:55 (p)	I	Tr E	
	02:21	00:21	III	Ec R	
	04:00	02:00	III	Oc D	
	07:37	05:37	III	Oc R	W
	23:13	21:13	I	Oc R	E
10	00:11	22:11 (p)	IV	Sh E	E
	08:01	06:01	IV	Tr I	W
11	07:02	05:02	II	Ec D	W
13	02:07	00:07	II	Sh I	
	04:41	02:41	II	Tr I	
	04:59	02:59	II	Sh E	
	07:30	05:30	II	Tr E	W
	08:34	06:34	I	Ec D	W
14	05:43	03:43	I	Sh I	
	07:00	05:00	I	Tr I	
	08:01	06:01	I	Sh E	W
	09:18	07:18	I	Tr E	W



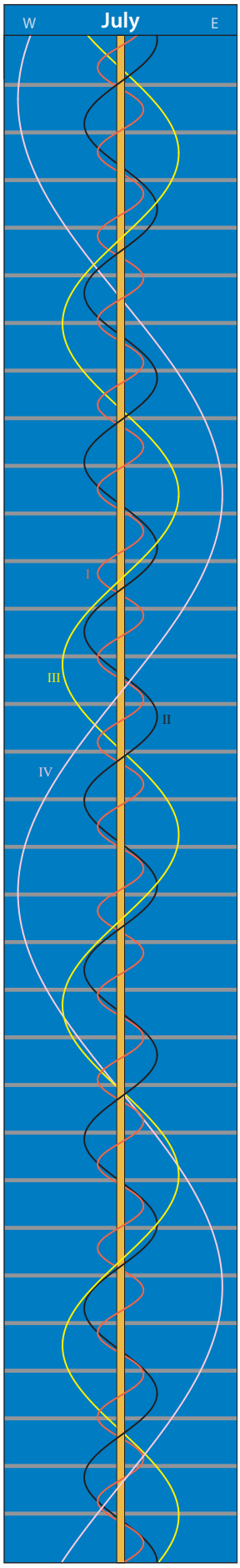
Day	EST	WST	Sat	Event	Vis
15	01:49	23:49 (p)	II	Oc R	
	03:03	01:03	I	Ec D	
	06:36	04:36	I	Oc R	
16	00:11	22:11 (p)	I	Sh I	E
	01:28	23:28 (p)	I	Tr I	
	02:30	00:30	I	Sh E	
	02:41	00:41	III	Ec D	
	03:46	01:46	I	Tr E	
	06:20	04:20	III	Ec R	
	07:48	05:48	III	Oc D	W
17	01:03	23:03 (p)	I	Oc R	
	22:13	20:13	I	Tr E	E
18	05:48	03:48	IV	Ec D	
	22:01	20:01	IV	Oc R	E
20	01:15	23:15 (p)	III	Tr E	
	04:41	02:41	II	Sh I	
	07:08	05:08	II	Tr I	W
	07:33	05:33	II	Sh E	W
21	07:37	05:37	I	Sh I	W
	08:50	06:50	I	Tr I	W
	22:57	20:57	II	Ec D	E
22	04:17	02:17	II	Oc R	
	04:56	02:56	I	Ec D	
	08:25	06:25	I	Oc R	W
23	02:05	00:05	I	Sh I	
	03:18	01:18	I	Tr I	
	04:24	02:24	I	Sh E	
	05:35	03:35	I	Tr E	
	06:41	04:41	III	Ec D	
	23:09	21:09	II	Tr E	E
	23:25	21:25	I	Ec D	E
24	02:52	00:52	I	Oc R	
	21:45	19:45	I	Tr I	E
	22:52	20:52	I	Sh E	E
25	00:03	22:03 (p)	I	Tr E	
27	00:17	22:17 (p)	III	Sh E	
	00:42	22:42 (p)	IV	Tr I	
	01:19	23:19 (p)	III	Tr I	
	04:54	02:54	III	Tr E	
	05:08	03:08	IV	Tr E	
	07:16	05:16	II	Sh I	W
29	01:33	23:33 (p)	II	Ec D	
	06:43	04:43	II	Oc R	
	06:50	04:50	I	Ec D	
30	03:59	01:59	I	Sh I	
	05:06	03:06	I	Tr I	
	06:18	04:18	I	Sh E	
	07:24	05:24	I	Tr E	W
	22:44	20:44	II	Tr I	E
	23:24	21:24	II	Sh E	E

July

Day	EST	WST	Sat	Event	Vis
1	01:18	23:18 (p)	I	Ec D	
	01:33	23:33 (p)	II	Tr E	
	04:41	02:41	I	Oc R	
	22:28	20:28	I	Sh I	E
	23:33	21:33	I	Tr I	

JUPITER MOON EVENTS

Day	EST	WST	Sat	Event	Vis
2	00:46	22:46(p)	I	Sh	E
	01:51	23:51(p)	I	Tr	E
	23:07	21:07	I	Oc R	E
4	00:37	22:37(p)	III	Sh	I
	04:16	02:16	III	Sh	E
	04:54	02:54	III	Tr	I
	08:29	06:29	III	Tr	E W
	23:57	21:57	IV	Ec	D
5	04:42	02:42	IV	Ec	R
6	04:10	02:10	II	Ec	D
	08:44	06:44	I	Ec	D W
	09:07	07:07	II	Oc	R W
7	05:54	03:54	I	Sh	I
	06:54	04:54	I	Tr	I
	08:12	06:12	I	Sh	E W
	09:12	07:12	I	Tr	E W
	22:16	20:16	III	Oc	R E
	23:07	21:07	II	Sh	I
8	01:05	23:05(p)	II	Tr	I
	01:59	23:59(p)	II	Sh	E
	03:12	01:12	I	Ec	D
	03:54	01:54	II	Tr	E
	06:28	04:28	I	Oc	R
9	00:22	22:22(p)	I	Sh	I
	01:21	23:21(p)	I	Tr	I
	02:41	00:41	I	Sh	E
	03:39	01:39	I	Tr	E
	21:40	19:40	I	Ec	D E
	22:18	20:18	II	Oc	R E
10	00:54	22:54(p)	I	Oc	R
	21:09	19:09	I	Sh	E E
	22:05	20:05	I	Tr	E E
11	04:38	02:38	III	Sh	I
	08:17	06:17	III	Sh	E W
	08:26	06:26	III	Tr	I W
13	06:47	04:47	II	Ec	D
	07:45	05:45	IV	Sh	I W
	20:45	18:45	IV	Tr	E E
14	07:48	05:48	I	Sh	I W
	08:41	06:41	I	Tr	I W
15	01:42	23:42(p)	II	Sh	I
	01:45	23:45(p)	III	Oc	R
	03:24	01:24	II	Tr	I
	04:33	02:33	II	Sh	E
	05:06	03:06	I	Ec	D
	06:13	04:13	II	Tr	E
	08:14	06:14	I	Oc R	W
16	02:17	00:17	I	Sh	I
	03:07	01:07	I	Tr	I
	04:35	02:35	I	Sh	E
	05:25	03:25	I	Tr	E
	20:05	18:05	II	Ec D	E
	23:34	21:34	I	Ec	D
17	00:38	22:38(p)	II	Oc	R
	02:40	00:40	I	Oc	R
	20:45	18:45	I	Sh I	E
	21:34	19:34	I	Tr I	E
	23:04	21:04	I	Sh	E
	23:52	21:52	I	Tr	E

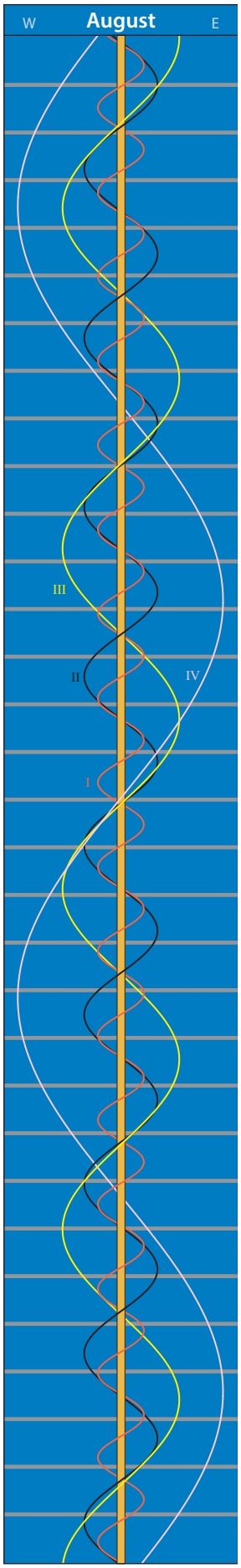


Day	EST	WST	Sat	Event	Vis
18	08:38	06:38	III	Sh I	W
	21:06	19:06	I	Oc R	E
21	22:41	20:41	III	Ec	D
	22:50	20:50	IV	Ec	R
22	01:00	23:00(p)	IV	Oc	D
	04:16	02:16	II	Sh	I
	05:10	03:10	III	Oc	R
	05:20	03:20	IV	Oc	R
	05:41	03:41	II	Tr	I
	07:00	05:00	I	Ec	D
	07:07	05:07	II	Sh E	W
	08:30	06:30	II	Tr E	W
23	04:11	02:11	I	Sh	I
	04:53	02:53	I	Tr	I
	06:29	04:29	I	Sh	E
	07:11	05:11	I	Tr E	W
	22:42	20:42	II	Ec	D
24	01:28	23:28(p)	I	Ec	D
	02:58	00:58	II	Oc	R
	04:25	02:25	I	Oc	R
	22:40	20:40	I	Sh	I
	23:19	21:19	I	Tr	I
25	00:58	22:58(p)	I	Sh	E
	01:37	23:37(p)	I	Tr	E
	19:57	17:57	I	Ec D	E
	20:24	18:24	II	Sh E	E
	21:38	19:38	II	Tr E	E
	22:51	20:51	I	Oc	R
26	19:27	17:27	I	Sh E	E
	20:03	18:03	I	Tr E	E
29	02:41	00:41	III	Ec	D
	06:50	04:50	II	Sh	I
	07:57	05:57	II	Tr I	W
	08:31	06:31	III	Oc R	W
	08:54	06:54	I	Ec D	W
30	01:57	23:57(p)	IV	Sh	I
	06:06	04:06	I	Sh	I
	06:38	04:38	I	Tr	I
	06:40	04:40	IV	Sh	E
	07:12	05:12	IV	Tr I	W
	08:24	06:24	I	Sh E	W
	08:56	06:56	I	Tr E	W
31	01:20	23:20(p)	II	Ec	D
	03:22	01:22	I	Ec	D
	05:15	03:15	II	Oc	R
	06:09	04:09	I	Oc	R

August

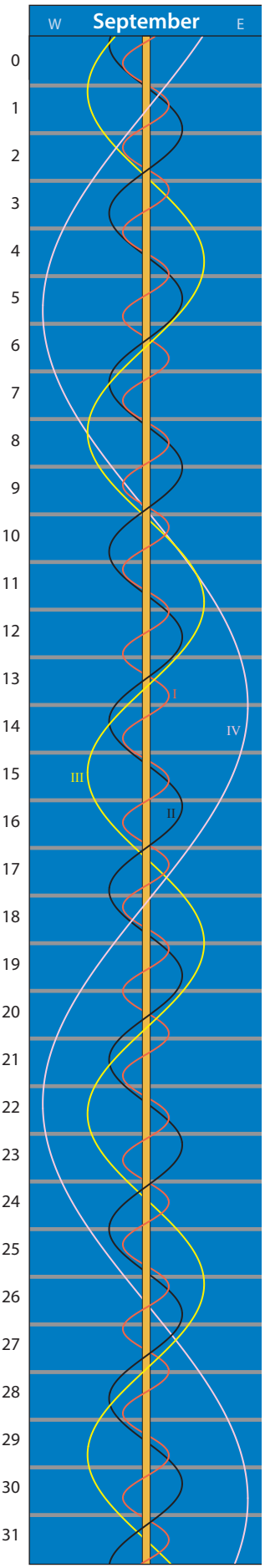
Day	EST	WST	Sat	Event	Vis
1	00:34	22:34(p)	I	Sh	I
	01:04	23:04(p)	I	Tr	I
	02:53	00:53	I	Sh	E
	03:22	01:22	I	Tr	E
	20:08	18:08	II	Sh I	E
	20:19	18:19	III	Sh E	E
	21:04	19:04	II	Tr I	E
	21:51	19:51	I	Ec	D
	22:11	20:11	III	Tr	E
	22:58	20:58	II	Sh	E
	23:52	21:52	II	Tr	E

Day	EST	WST	Sat	Event	Vis
2	00:35	22:35(p)	I	Oc	R
	19:03	17:03	I	Sh I	E
	19:30	17:30	I	Tr I	E
	21:21	19:21	I	Sh	E
	21:48	19:48	I	Tr	E
3	19:01	17:01	I	Oc R	E
5	06:41	04:41	III	Ec	D
6	08:00	06:00	I	Sh I	W
	08:22	06:22	I	Tr I	W
7	03:57	01:57	II	Ec	D
	05:16	03:16	I	Ec	D
	07:31	05:31	II	Oc R	W
	07:53	05:53	I	Oc R	W
	19:51	17:51	IV	Oc R	E
8	02:29	00:29	I	Sh	I
	02:48	00:48	I	Tr	I
	04:47	02:47	I	Sh	E
	05:06	03:06	I	Tr	E
	20:41	18:41	III	Sh	I
	21:55	19:55	III	Tr	I
	22:42	20:42	II	Sh	I
	23:18	21:18	II	Tr	I
	23:45	21:45	I	Ec	D
9	00:20	22:20(p)	III	Sh	E
	01:29	23:29(p)	III	Tr	E
	01:33	23:33(p)	II	Sh	E
	02:06	00:06	II	Tr	E
	02:19	00:19	I	Oc	R
	20:58	18:58	I	Sh	I
	21:14	19:14	I	Tr	I
	23:16	21:16	I	Sh	E
	23:32	21:32	I	Tr	E
10	18:13	16:13	I	Ec D	E
	20:40	18:40	II	Oc	R
	20:45	18:45	I	Oc	R
14	06:35	04:35	II	Ec	D
	07:10	05:10	I	Ec D	W
15	04:24	02:24	I	Sh	I
	04:32	02:32	I	Tr	I
	06:42	04:42	I	Sh E	W
	06:50	04:50	I	Tr E	W
	20:11	18:11	IV	Sh	I
	21:26	19:26	IV	Tr	I
16	00:42	22:42(p)	III	Sh	I
	00:50	22:50(p)	IV	Sh	E
	01:11	23:11(p)	III	Tr	I
	01:17	23:17(p)	II	Sh	I
	01:31	23:31(p)	II	Tr	I
	01:39	23:39(p)	I	Ec	D
	01:47	23:47(p)	IV	Tr	E
	04:03	02:03	I	Oc	R
	04:07	02:07	II	Sh	E
	04:19	02:19	II	Tr	E
	04:20	02:20	III	Sh	E
	04:45	02:45	III	Tr	E
	22:53	20:53	I	Sh	I
	22:58	20:58	I	Tr	I



Day	EST	WST	Sat	Event	Vis
17	01:11	23:11(p)	I	Sh	E
	01:16	23:16(p)	I	Tr	E
	19:54	17:54	II	Ec	D E
	20:08	18:08	I	Ec	D
	22:28	20:28	I	Oc	R
	22:55	20:55	II	Oc	R
18	19:40	17:40	I	Sh	E E
	19:42	17:42	I	Tr	E E
19	18:23	16:23	III	Oc	R E
22	06:16	04:16	I	Tr	I
	06:19	04:19	I	Sh	I
	08:34	06:34	I	Tr	E W
	08:37	06:37	I	Sh	E W
23	03:29	01:29	I	Oc	D
	03:44	01:44	II	Tr	I
	03:52	01:52	II	Sh	I
	04:26	02:26	III	Tr	I
	04:43	02:43	III	Sh	I
	05:51	03:51	I	Ec	R
	06:32	04:32	II	Tr	E W
	06:42	04:42	II	Sh	E W
	08:01	06:01	III	Tr	E W
	08:20	06:20	III	Sh	E W
24	00:42	22:42(p)	I	Tr	I
	00:48	22:48(p)	I	Sh	I
	03:00	01:00	I	Tr	E
	03:06	01:06	I	Sh	E
	05:40	03:40	IV	Oc	D
	21:55	19:55	I	Oc	D
	22:18	20:18	II	Oc	D
25	00:19	22:19(p)	I	Ec	R
	01:26	23:26(p)	II	Ec	R
	19:08	17:08	I	Tr	I E
	19:17	17:17	I	Sh	I E
	21:26	19:26	I	Tr	E
	21:35	19:35	I	Sh	E
26	18:04	16:04	III	Oc	D E
	18:48	16:48	I	Ec	R E
	19:39	17:39	II	Tr	E E
	19:59	17:59	II	Sh	E
	22:21	20:21	III	Ec	R
29	08:00	06:00	I	Tr	I W
	08:14	06:14	I	Sh	I W
30	05:13	03:13	I	Oc	D
	05:57	03:57	II	Tr	I
	06:27	04:27	II	Sh	I W
	07:42	05:42	III	Tr	I W
	07:45	05:45	I	Ec	R W
31	02:26	00:26	I	Tr	I
	02:43	00:43	I	Sh	I
	04:44	02:44	I	Tr	E
	05:01	03:01	I	Sh	E
	23:39	21:39	I	Oc	D

Day	EST	WST	Sat	Event	Vis
September					
1	00:34	22:34(p)	II	Oc	D
	02:14	00:14	I	Ec	R
	04:04	02:04	II	Ec	R
	19:02	17:02	IV	Sh	E E
	20:52	18:52	I	Tr	I
	21:12	19:12	I	Sh	I
	23:10	21:10	I	Tr	E
	23:30	21:30	I	Sh	E
2	18:05	16:05	I	Oc	D E
	19:04	17:04	II	Tr	I E
	19:44	17:44	II	Sh	I E
	20:42	18:42	I	Ec	R
	21:21	19:21	III	Oc	D
	21:53	19:53	II	Tr	E
	22:34	20:34	II	Sh	E
3	02:22	00:22	III	Ec	R
	17:59	15:59	I	Sh	E E
6	06:57	04:57	I	Oc	D W
7	04:11	02:11	I	Tr	I
	04:38	02:38	I	Sh	I
	06:29	04:29	I	Tr	E W
	06:56	04:56	I	Sh	E W
8	01:23	23:23(p)	I	Oc	D
	02:51	00:51	II	Oc	D
	04:08	02:08	I	Ec	R
	06:42	04:42	II	Ec	R W
	22:37	20:37	I	Tr	I
	23:07	21:07	I	Sh	I
9	00:55	22:55(p)	I	Tr	E
	01:25	23:25(p)	I	Sh	E
	19:49	17:49	I	Oc	D E
	19:56	17:56	IV	Oc	D E
	21:18	19:18	II	Tr	I
	22:19	20:19	II	Sh	I
	22:37	20:37	I	Ec	R
10	00:08	22:08(p)	II	Tr	E
	00:22	22:22(p)	IV	Oc	R
	00:40	22:40(p)	III	Oc	D
	00:43	22:43(p)	IV	Ec	D
	01:09	23:09(p)	II	Sh	E
	05:16	03:16	IV	Ec	R
	06:22	04:22	III	Ec	R W
	19:21	17:21	I	Tr	E E
	19:54	17:54	I	Sh	E E
11	20:00	18:00	II	Ec	R E
13	17:57	15:57	III	Tr	E E
	20:25	18:25	III	Sh	E
14	05:56	03:56	I	Tr	I W
	06:34	04:34	I	Sh	I W
15	03:08	01:08	I	Oc	D
	05:08	03:08	II	Oc	D W
	06:03	04:03	I	Ec	R W
16	00:23	22:23(p)	I	Tr	I
	01:03	23:03(p)	I	Sh	I
	02:41	00:41	I	Tr	E
	03:21	01:21	I	Sh	E
	21:34	19:34	I	Oc	D
	23:34	21:34	II	Tr	I

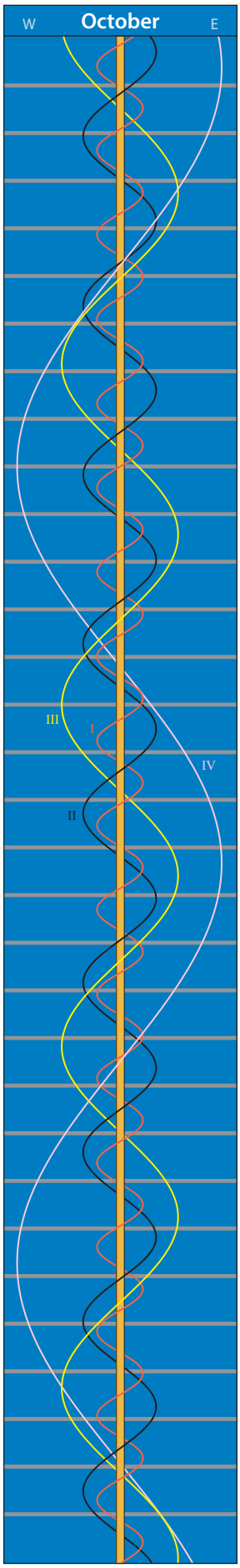


JUPITER MOON EVENTS

Day	EST	WST	Sat	Event	Vis
17	00:32	22:32(p)	I	Ec	R
	00:55	22:55(p)	II	Sh	I
	02:24	00:24	II	Tr	E
	03:44	01:44	II	Sh	E
	04:01	02:01	III	Oc	D
	18:49	16:49	I	Tr	I E
	19:31	17:31	I	Sh	I E
	21:07	19:07	I	Tr	E
	21:49	19:49	I	Sh	E
18	01:58	23:58(p)	IV	Tr	I
	06:27	04:27	IV	Tr	E W
	18:18	16:18	II	Oc	D E
	19:00	17:00	I	Ec	R E
	22:38	20:38	II	Ec	R
20	20:50	18:50	III	Sh	I
	21:21	19:21	III	Tr	E
21	00:26	22:26(p)	III	Sh	E
22	04:54	02:54	I	Oc	D W
23	02:09	00:09	I	Tr	I
	02:58	00:58	I	Sh	I
	04:27	02:27	I	Tr	E W
	05:16	03:16	I	Sh	E W
	23:20	21:20	I	Oc	D
24	01:52	23:52(p)	II	Tr	I
	02:27	00:27	I	Ec	R
	03:30	01:30	II	Sh	I
	04:42	02:42	II	Tr	E W
	06:20	04:20	II	Sh	E W
	20:36	18:36	I	Tr	I
	21:27	19:27	I	Sh	I
	22:54	20:54	I	Tr	E
	23:45	21:45	I	Sh	E
25	20:38	18:38	II	Oc	D
	20:55	18:55	I	Ec	R
26	01:16	23:16(p)	II	Ec	R
	18:14	16:14	I	Sh	E E
	18:57	16:57	IV	Ec	D E
	23:27	21:27	IV	Ec	R
27	19:38	17:38	II	Sh	E E
	21:12	19:12	III	Tr	I
28	00:48	22:48(p)	III	Tr	E
	00:52	22:52(p)	III	Sh	I
	04:28	02:28	III	Sh	E W
30	03:57	01:57	I	Tr	I W
	04:54	02:54	I	Sh	I W
	06:15	04:15	I	Tr	E W

October

Day	EST	WST	Sat	Event	Vis
1	01:08	23:08(p)	I	Oc	D
	04:12	02:12	II	Tr	I W
	04:22	02:22	I	Ec	R W
	06:06	04:06	II	Sh	I W
	18:24	16:24	III	Ec	R E
	22:24	20:24	I	Tr	I
	23:23	21:23	I	Sh	I

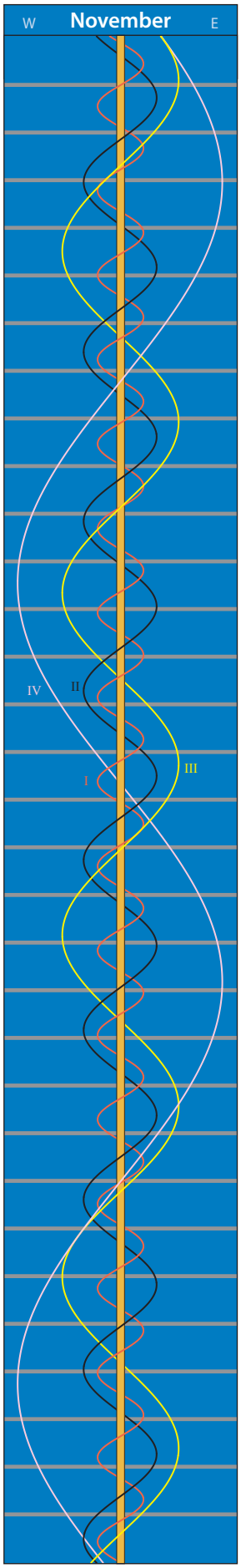


Day	EST	WST	Sat	Event	Vis
2	00:42	22:42(p)	I	Tr	E
	01:41	23:41(p)	I	Sh	E
	19:35	17:35	I	Oc	D E
	22:50	20:50	I	Ec	R
	23:01	21:01	II	Oc	D
3	03:54	01:54	II	Ec	R W
	19:09	17:09	I	Tr	E E
	20:09	18:09	I	Sh	E E
4	19:24	17:24	II	Sh	I E
	20:13	18:13	II	Tr	E E
	21:44	19:44	IV	Tr	E
	22:13	20:13	II	Sh	E
5	00:43	22:43(p)	III	Tr	I
	02:58	00:58	IV	Sh	I
	04:20	02:20	III	Tr	E W
	04:53	02:53	III	Sh	I W
7	05:46	03:46	I	Tr	I W
8	02:56	00:56	I	Oc	D
	18:51	16:51	III	Ec	D E
	22:26	20:26	III	Ec	R
9	00:13	22:13(p)	I	Tr	I
	01:18	23:18(p)	I	Sh	I
	02:31	00:31	I	Tr	E
	03:36	01:36	I	Sh	E W
	21:23	19:23	I	Oc	D
10	00:46	22:46(p)	I	Ec	R
	01:26	23:26(p)	II	Oc	D
	18:40	16:40	I	Tr	I E
	19:47	17:47	I	Sh	I E
	20:58	18:58	I	Tr	E
	22:05	20:05	I	Sh	E
11	19:14	17:14	I	Ec	R E
	19:46	17:46	II	Tr	I E
	22:00	20:00	II	Sh	I
	22:36	20:36	II	Tr	E
12	00:49	22:49(p)	II	Sh	E
	04:19	02:19	III	Tr	I W
13	02:28	00:28	IV	Oc	D
	19:52	17:52	II	Ec	R E
15	04:45	02:45	I	Oc	D W
	21:46	19:46	III	Oc	R
	22:53	20:53	III	Ec	D
16	02:03	00:03	I	Tr	I
	02:28	00:28	III	Ec	R
	03:14	01:14	I	Sh	I W
	04:21	02:21	I	Tr	E W
	23:13	21:13	I	Oc	D
17	02:41	00:41	I	Ec	R
	03:54	01:54	II	Oc	D W
	20:31	18:31	I	Tr	I E
	21:43	19:43	I	Sh	I
	22:49	20:49	I	Tr	E
18	00:01	22:01(p)	I	Sh	E
	21:10	19:10	I	Ec	R
	22:12	20:12	II	Tr	I

Day	EST	WST	Sat	Event	Vis
19	00:36	22:36(p)	II	Sh	I
	01:03	23:03(p)	II	Tr	E
	03:25	01:25	II	Sh	E W
	18:30	16:30	I	Sh	E E
20	22:30	20:30	II	Ec	R
21	21:16	19:16	IV	Sh	I
22	01:39	23:39(p)	IV	Sh	E
	21:52	19:52	III	Oc	D
23	01:30	23:30(p)	III	Oc	R
	02:54	00:54	III	Ec	D W
	03:55	01:55	I	Tr	I W
24	01:04	23:04(p)	I	Oc	D
	04:36	02:36	I	Ec	R W
	22:23	20:23	I	Tr	I
	23:39	21:39	I	Sh	I
25	00:41	22:41(p)	I	Tr	E
	01:57	23:57(p)	I	Sh	E
	19:32	17:32	I	Oc	D E
	23:05	21:05	I	Ec	R
26	00:41	22:41(p)	II	Tr	I
	03:13	01:13	II	Sh	I W
	03:31	01:31	II	Tr	E W
	19:09	17:09	I	Tr	E E
	20:25	18:25	I	Sh	E E
	20:34	18:34	III	Sh	E E
27	19:40	17:40	II	Oc	D E
28	01:08	23:08(p)	II	Ec	R
29	19:12	17:12	IV	Oc	D E
	19:20	17:20	II	Sh	E E
	23:48	21:48	IV	Oc	R
30	01:41	23:41(p)	III	Oc	D
31	02:57	00:57	I	Oc	D W

November

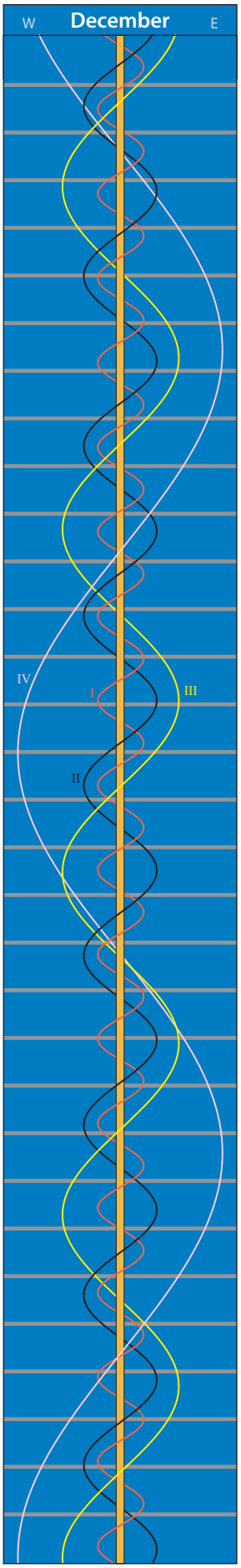
Day	EST	WST	Sat	Event	Vis
1	00:16	22:16(p)	I	Tr	I
	01:35	23:35(p)	I	Sh	I
	02:34	00:34	I	Tr	E W
	03:52	01:52	I	Sh	E W
	21:25	19:25	I	Oc	D
2	01:01	23:01(p)	I	Ec	R
	03:12	01:12	II	Tr	I W
	18:44	16:44	I	Tr	I E
	19:17	17:17	III	Tr	E E
	20:04	18:04	I	Sh	I E
	21:02	19:02	I	Tr	E
	21:02	19:02	III	Sh	I
	22:21	20:21	I	Sh	E
3	00:36	22:36(p)	III	Sh	E
	19:29	17:29	I	Ec	R E
	22:13	20:13	II	Oc	D
4	03:45	01:45	II	Ec	R W
5	19:08	17:08	II	Sh	I E
	19:19	17:19	II	Tr	E E
	21:56	19:56	II	Sh	E
7	02:38	00:38	IV	Tr	I W
	19:52	17:52	IV	Sh	E E



Day	EST	WST	Sat	Event	Vis
8	02:10	00:10	I	Tr I	W
	03:31	01:31	I	Sh I	W
	23:19	21:19	I	Oc D	
9	02:56	00:56	I	Ec R	W
	19:35	17:35	III	Tr I	E
	20:39	18:39	I	Tr I	E
	21:59	19:59	I	Sh I	
	22:56	20:56	I	Tr E	
	23:13	21:13	III	Tr E	
10	00:17	22:17(p)	I	Sh E	
	01:04	23:04(p)	III	Sh I	
	21:25	19:25	I	Ec R	
11	00:49	22:49(p)	II	Oc D	
	18:46	16:46	I	Sh E	E
12	19:02	17:02	II	Tr I	E
	21:44	19:44	II	Sh I	
	21:53	19:53	II	Tr E	
13	00:33	22:33(p)	II	Sh E	
14	19:42	17:42	II	Ec R	E
16	01:14	23:14(p)	I	Oc D	W
	01:44	23:44(p)	IV	Ec D	W
	22:34	20:34	I	Tr I	
	23:36	21:36	III	Tr I	
	23:55	21:55	I	Sh I	
17	00:52	22:52(p)	I	Tr E	W
	02:13	00:13	I	Sh E	W
	19:43	17:43	I	Oc D	E
	23:20	21:20	I	Ec R	
18	19:21	17:21	I	Tr E	E
	20:41	18:41	I	Sh E	E
19	21:39	19:39	II	Tr I	
20	00:21	22:21(p)	II	Sh I	
	00:30	22:30(p)	II	Tr E	
	19:01	17:01	III	Ec D	E
	22:34	20:34	III	Ec R	
21	22:19	20:19	II	Ec R	
23	20:54	18:54	IV	Tr I	E
24	00:31	22:31(p)	I	Tr I	W
	01:32	23:32(p)	IV	Tr E	W
	01:51	23:51(p)	I	Sh I	W
	21:39	19:39	I	Oc D	
25	01:16	23:16(p)	I	Ec R	W
	19:00	17:00	I	Tr I	E
	20:20	18:20	I	Sh I	E
	21:18	19:18	I	Tr E	
	22:37	20:37	I	Sh E	
26	19:45	17:45	I	Ec R	E
27	00:18	22:18(p)	II	Tr I	W
	21:20	19:20	III	Oc R	
	23:04	21:04	III	Ec D	
28	19:27	17:27	II	Oc D	E
29	00:56	22:56(p)	II	Ec R	W
30	19:06	17:06	II	Sh E	E

December

Day	EST	WST	Sat	Event	Vis
1	23:36	21:36	I	Oc D	
2	20:00	18:00	IV	Ec D	E
	20:58	18:58	I	Tr I	E
	22:16	20:16	I	Sh I	
	23:15	21:15	I	Tr E	
3	00:09	22:09(p)	IV	Ec R	W
	00:33	22:33(p)	I	Sh E	W
	21:41	19:41	I	Ec R	
4	19:02	17:02	I	Sh E	E
	21:53	19:53	III	Oc D	
5	01:30	23:30(p)	III	Oc R	W
	22:09	20:09	II	Oc D	
7	19:12	17:12	II	Tr E	E
	21:43	19:43	II	Sh E	
8	20:44	18:44	III	Sh E	E
9	01:35	23:35(p)	I	Oc D	W
	22:56	20:56	I	Tr I	
10	00:11	22:11(p)	I	Sh I	W
	01:14	23:14(p)	I	Tr E	W
	20:04	18:04	I	Oc D	E
	20:38	18:38	IV	Tr E	E
	23:36	21:36	I	Ec R	W
11	19:43	17:43	I	Tr E	E
	20:57	18:57	I	Sh E	E
13	00:53	22:53(p)	II	Oc D	W
14	21:32	19:32	II	Sh I	
	21:56	19:56	II	Tr E	
15	00:20	22:20(p)	II	Sh E	W
	19:56	17:56	III	Tr E	E
	21:15	19:15	III	Sh I	E
16	00:46	22:46(p)	III	Sh E	W
	19:29	17:29	II	Ec R	E
17	00:55	22:55(p)	I	Tr I	W
	22:03	20:03	I	Oc D	
18	19:25	17:25	I	Tr I	E
	20:36	18:36	I	Sh I	E
	21:43	19:43	I	Tr E	
	22:53	20:53	I	Sh E	W
19	20:01	18:01	I	Ec R	E
21	21:50	19:50	II	Tr I	
22	00:10	22:10(p)	II	Sh I	W
	00:42	22:42(p)	II	Tr E	W
	20:38	18:38	III	Tr I	E
23	00:15	22:15(p)	III	Tr E	W
	22:06	20:06	II	Ec R	
25	00:03	22:03(p)	I	Oc D	W
	21:25	19:25	I	Tr I	E
	22:31	20:31	I	Sh I	W
	23:43	21:43	I	Tr E	W
26	00:48	22:48(p)	I	Sh E	W
	21:56	19:56	I	Ec R	
27	19:17	17:17	I	Sh E	E
	22:31	20:31	IV	Sh I	W
29	00:37	22:37(p)	II	Tr I	W
30	19:49	17:49	II	Oc D	E



SATURN'S MOONS

These pages help you find the position of Saturn's major satellites. Note that dates and times here are given in days and fractions of a day in UT. You will need to convert your local time to this format first. Table 3 will help.

The worked examples here are based on a diagram of the satellite's configuration for 30 August midnight EST (see page 64).

Rhea and Dione

Table 1 presents the times of the first greatest elongation to the east for each month. This location is the day 0 point on the Apparent Orbits diagram (below). The procedure is to work out how many orbits have elapsed since the first elongation of the month, then discard the completed number of orbits and convert the remaining fraction back to days so its position can be read directly off the diagram below. You wish to determine the position of **Rhea** for the date above.

1. Convert to UT as a fractional day (table 3) to get 30.583 UT.
2. Subtract the date of the greatest elongation east for Rhea for August, i.e., 30.583 – 4.375 = 26.208
3. Express this as the number of orbits by dividing by the period i.e., 26.208 /4.518 = 5.800
4. Discard any complete orbits (5 in this case) leaving 0.800
5. Multiply by the period, 0.800 × 4.518 = 3.614 days or about 3 days and 15 hours after elongation east.
6. Looking at the orbital path for Rhea (see Apparent Orbits diagram, below), the satellite is north-east of Saturn

Table 1: **Saturn Satellites — Time of Greatest Elongation East** (dd.ddd UT)

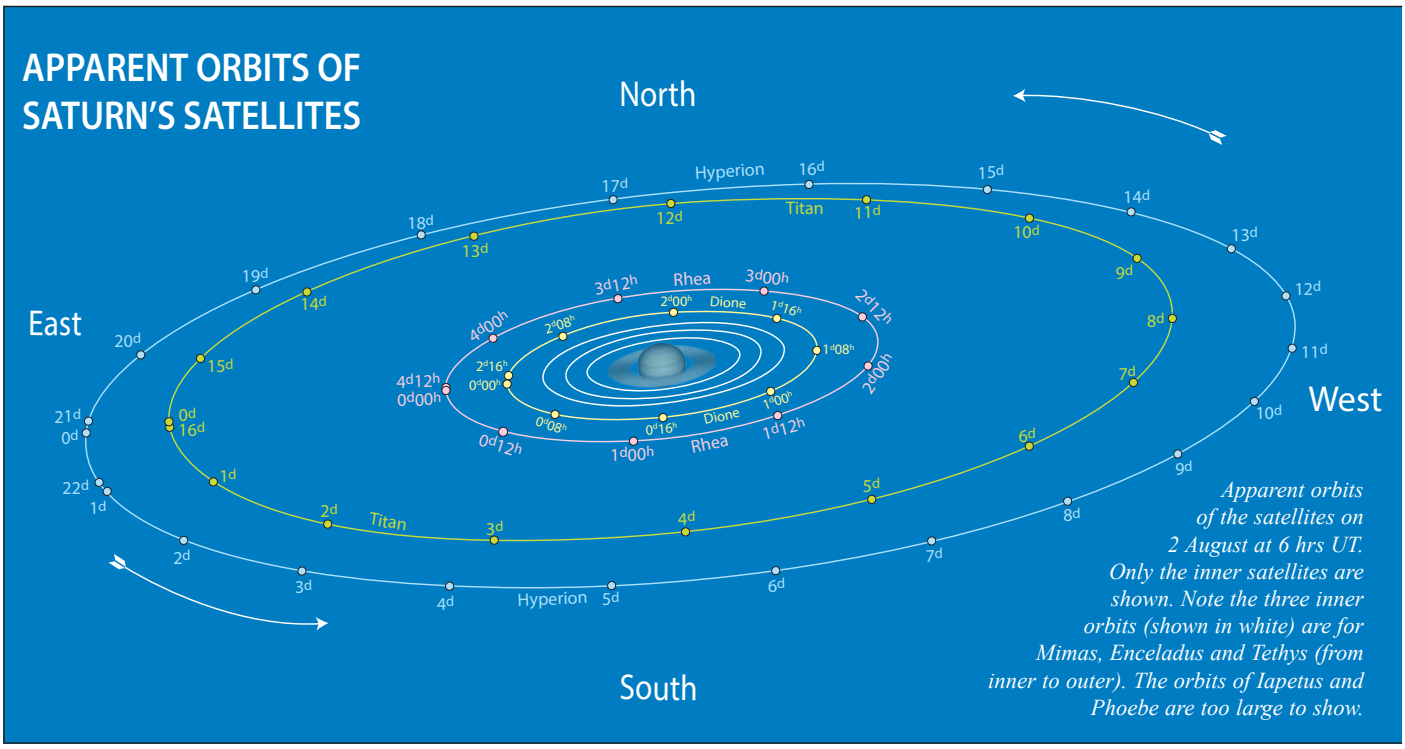
Moon	Mimas	Enceladus	Tethys	Dione	Rhea
Magnitude [1]	12.8	11.8	10.2	10.4	9.6
Max Elong. [1]	0' 30"	0' 38"	0' 48"	1' 01"	1' 25"
Period (days) [2]	0.942	1.370	1.888	2.737	4.518
Month	**Elongation East (d.ddd)**				
January	1.315	1.358	1.096	2.811	3.961
February	1.427	1.888	2.209	1.945	4.631
March	1.708	1.303	2.542	1.337	3.774
April	1.814	1.827	1.759	3.200	4.430
May	1.030	1.976	1.970	3.315	1.551
June	1.127	1.119	1.174	2.421	2.174
July	1.278	1.258	1.371	2.516	3.780
August	1.371	1.765	2.452	1.606	4.375
September	1.465	2.273	1.647	3.433	4.972
October	1.621	1.045	1.848	3.534	2.066
November	1.725	1.564	1.057	2.645	2.696
December	1.891	1.719	1.274	2.768	4.346

Notes 1. When at opposition 2. Mean Synodic Period

Mimas, Enceladus and Tethys

The procedure is similar to Rhea and Dione with the times of the first greatest elongation east for each month also being listed in Table 1. However, these inner moons are so close to Saturn that while the orbits are represented on the diagram, it is difficult to put the day markers on and still have it readable. As above we calculate the fraction of the orbit and then estimate its position. Like the other major moons, these three still orbit in the same direction (anticlockwise), so three quarters of an orbit (0.75) would place it north of Saturn.

Estimate the position for Tethys using the same date, August 30.583 UT; 14.900 orbits have elapsed since the first greatest elongation east for August on 2.452 UT. Discarding the completed orbits leaves 0.900 of an orbit. This is east of Saturn approaching its next elongation east.



Apparent orbits of the satellites on 2 August at 6 hrs UT. Only the inner satellites are shown. Note the three inner orbits (shown in white) are for Mimas, Enceladus and Tethys (from inner to outer). The orbits of Iapetus and Phoebe are too large to show.

Titan and Hyperion

Because of their long orbital periods, compared to the moons shown opposite, it is possible to list all of their greatest eastern elongations for the year (see Table 2). Therefore, all you need to do is work out the number of days that have elapsed since the most recent elongation and read this position directly off the diagram.

Using our previous example 30 August midnight EST (30.583 UT), Titan is about 7.4 days past its most recent greatest elongation east (August 23.228 UT), which puts it west of Saturn. The diagrams opposite and on page 64 show this very well.

Table 3
Converting Time in Australia to Universal Time (UT) *

EST	WST	Fraction of day (UT)
6 pm	4 pm	0.333
7 pm	5 pm	0.375
8 pm	6 pm	0.417
9 pm	7 pm	0.458
10 pm	8 pm	0.500
11 pm	9 pm	0.542
midnight	10 pm	0.583
1 am	11 pm	0.625
2 am	midnight	0.667
3 am	1 am	0.708
4 am	2 am	0.750
5 am	3 am	0.792
6 am	4 am	0.833
7 am	5 am	0.875
8 am	6 am	0.917

*After midnight it is still the previous day in UT, for example 1 am (EST) on the 21st = 20.625 days UT

Table 2
Time of Greatest Elongation East (UT)

Moon	Titan	Hyperion
Magnitude [1]	8.4	14.4
Max. Elong. [1]	3' 17"	3' 59"
Period (days) [2]	15.945	21.277
	Elongation (d.ddd)	
January	11.750	9.210
	27.781	30.630
February	12.810	21.114
	28.834	
March	16.849	14.590
April	1.853	5.032
	17.844	26.484
May	3.818	17.910
	19.775	
June	4.714	8.266
	20.636	29.599
July	6.544	20.922
	22.441	
August	7.334	11.181
	23.228	
September	8.132	1.450
	24.049	22.769
October	9.985	14.050
	25.940	
November	10.913	4.370
	26.903	25.756
December	12.908	17.090
	28.923	

Notes 1. When at opposition
2. Mean Synodic Period

Table 4: **Iapetus**

Magnitude [1] 11.0
Max Elong. [1] 9' 35"
Period (days) [2] 79.331

Elongation East		Inferior Conjunction		Elongation West		Superior Conjunction	
		Jan	4.104	Jan	25.238	Feb	15.110
Mar	6.758	Mar	26.372	Apr	16.566	May	6.742
May	26.103	Jun	14.183	Jul	4.722	Jul	24.570
Aug	12.309	Aug	31.437	Sep	20.600	Oct	11.103
Oct	29.977	Nov	18.771	Dec	9.487	Dec	30.441

Notes 1. When at opposition
2. Mean Synodic Period

Iapetus

This moon's orbit is too large to place on the Apparent Orbits diagram. The shape of its orbit is similar to the others but more inclined and over twice the diameter of Hyperion's. In fact, even when you know its general direction it can sometimes be difficult to distinguish it from stars of similar brightness. Table 4 shows this moon's greatest elongations east, inferior conjunctions (due south of Saturn), greatest elongations west and superior conjunctions (north of Saturn) for the year. Taking the same example date and time as above, 30 August midnight EST (30.583 UT), the most recent event was an eastern elongation on August 12.309 (UT). Iapetus is 18.3 days past this time, nearing an inferior conjunction, so it is to the south of the planet.

SATURN'S RINGS

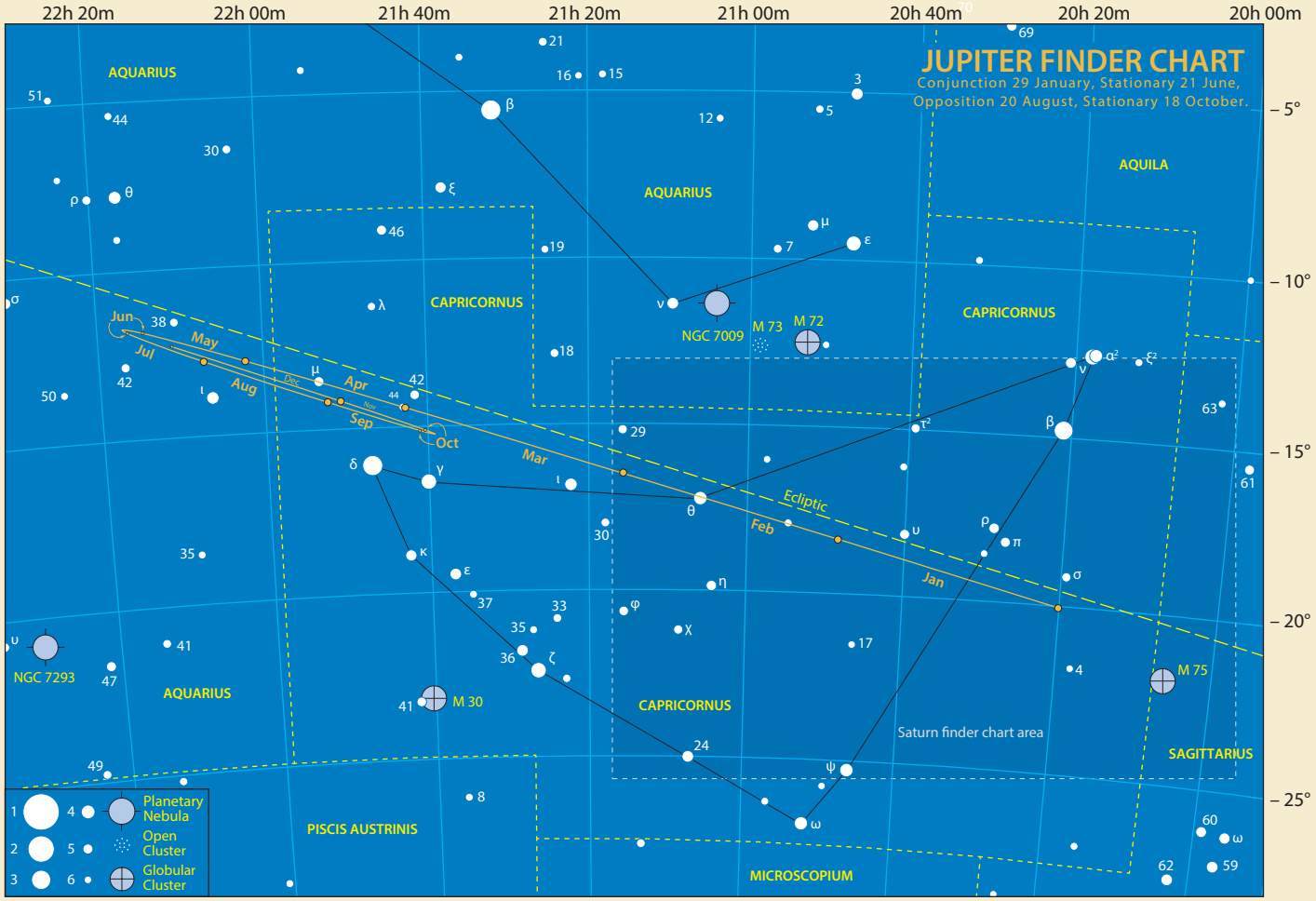
Date	Major "	Minor "	B °
Jan 2	34.6	12.3	20.8
Jan 10	34.5	12.1	20.5
Jan 18	34.4	11.9	20.2
Jan 26	34.4	11.7	19.9
Feb 3	34.4	11.5	19.6
Feb 11	34.5	11.4	19.2
Feb 19	34.7	11.2	18.9
Feb 27	34.9	11.1	18.6
Mar 7	35.1	11.0	18.3
Mar 15	35.4	10.9	18.0
Mar 23	35.7	10.9	17.7
Mar 31	36.1	10.9	17.5
Apr 8	36.5	10.9	17.3
Apr 16	37.0	10.9	17.1
Apr 24	37.5	10.9	17.0
May 2	38.0	11.0	16.8
May 10	38.5	11.1	16.8
May 18	39.0	11.2	16.7
May 26	39.5	11.4	16.8
Jun 3	40.0	11.6	16.8
Jun 11	40.5	11.8	16.9
Jun 19	40.9	12.0	17.0
Jun 27	41.3	12.2	17.2
Jul 5	41.7	12.4	17.4
Jul 13	41.9	12.7	17.6
Jul 21	42.1	12.9	17.8
Jul 29	42.2	13.1	18.1
Aug 6	42.2	13.2	18.3
Aug 14	42.1	13.4	18.5
Aug 22	42.0	13.5	18.7
Aug 30	41.7	13.5	18.9
Sep 7	41.4	13.5	19.1
Sep 15	41.0	13.5	19.2
Sep 23	40.5	13.4	19.3
Oct 1	40.1	13.3	19.4
Oct 9	39.6	13.2	19.4
Oct 17	39.0	13.0	19.4
Oct 25	38.5	12.8	19.4
Nov 2	38.0	12.6	19.3
Nov 10	37.5	12.3	19.2
Nov 18	37.0	12.1	19.0
Nov 26	36.6	11.8	18.8
Dec 4	36.2	11.5	18.6
Dec 12	35.8	11.3	18.3
Dec 20	35.5	11.0	18.0
Dec 28	35.2	10.7	17.7

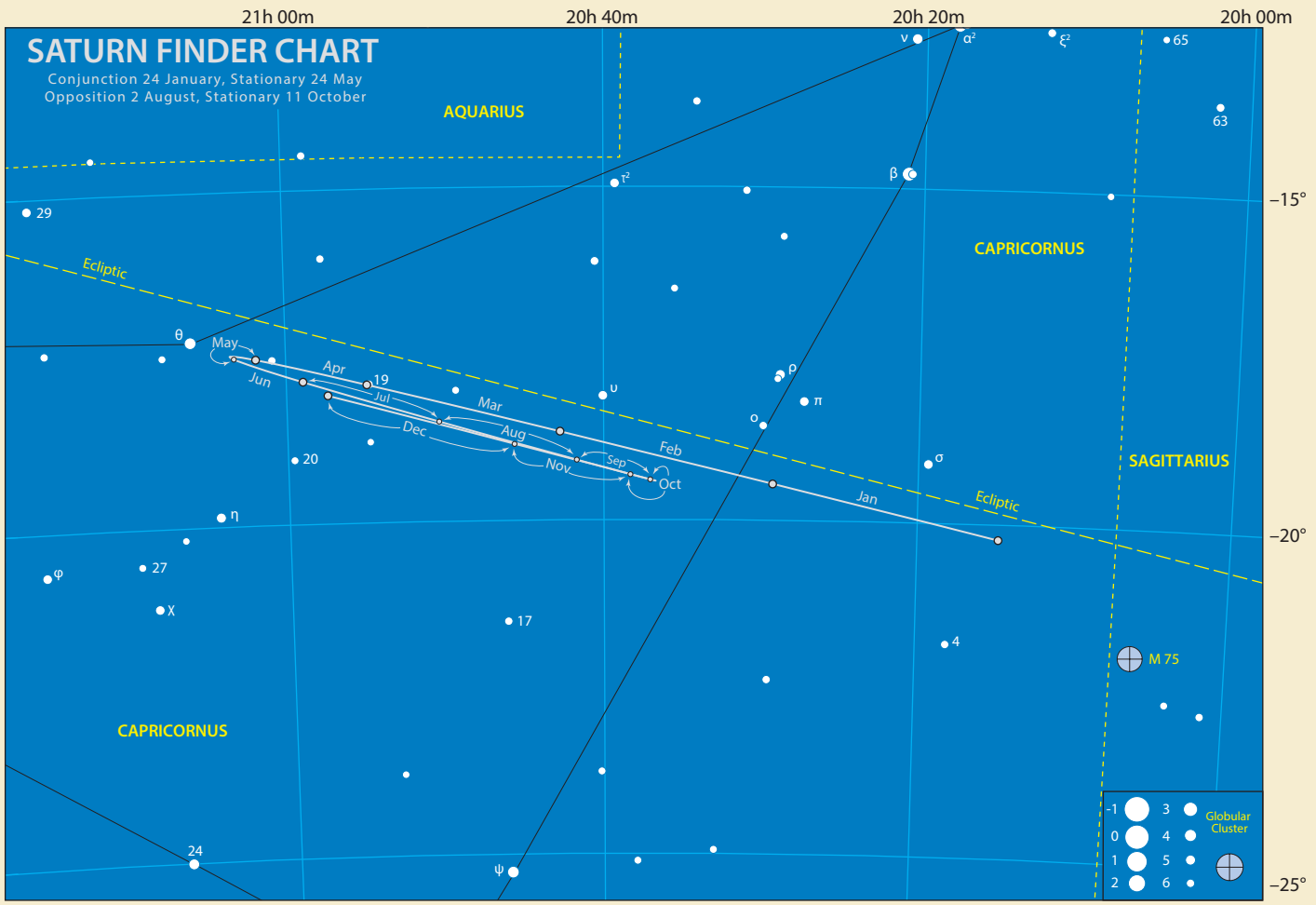
The Appearance of the Planets diagrams in Part I show how open the rings are for 2021. The plane of the rings is tilted, with respect to the plane of the ecliptic, by 28°. Saturn's year is 29.5 Earth years. During this period the Earth can be up to 28° above or below the plane of the rings. Every seven years, after each of these maximum ring openings, the Earth passes through the plane of the rings and they are seen as edge-on. The rings were last edge-on during 2009. During 2021 they are closing up again, the next edge-on is in 2025.

Major and minor axes (in arcseconds) are for the outer edge of the outer ring. To work out the size of the other rings, multiply by the following factors.

Inner edge of outer ring	0.8932
Outer edge of inner ring	0.8596
Inner edge of inner ring	0.6726
Inner edge of dusky ring	0.5477

B is the tilt of the rings.

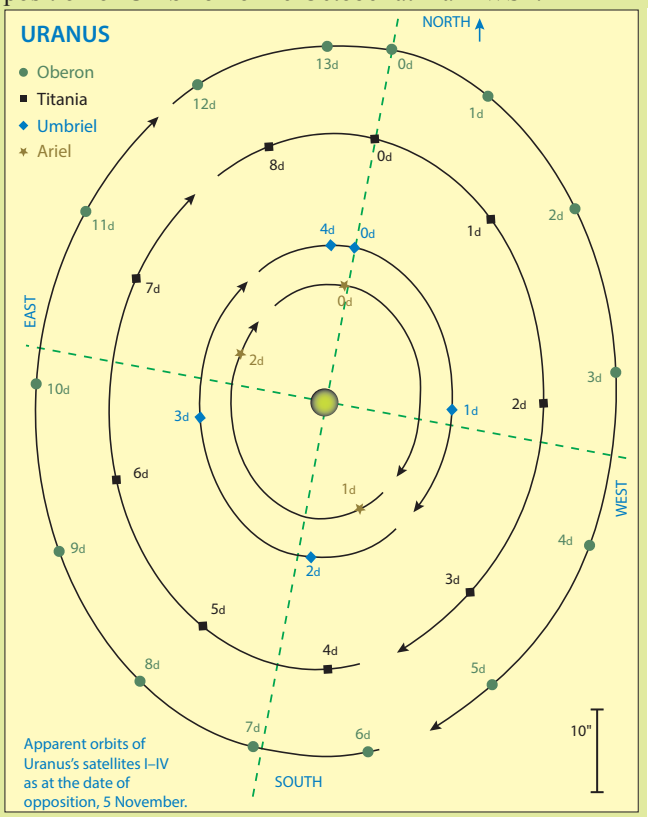

JUPITER FINDER CHART
Conjunction 29 January, Stationary 21 June,
Opposition 20 August, Stationary 18 October.
22h 20m
22h 00m
21h 40m
21h 20m
21h 00m
20h 40m
20h 20m
20h 00m
– 5°
– 10°
– 15°
– 20°
– 25°
AQUARIUS
AQUILA
CAPRICORNUS
PISCIS AUSTRINIS
MICROSCOPIUM
SAGITTARIUS
NGC 7009
M 73
M 72
NGC 7293
M 30
M 75
Saturn finder chart area
Ecliptic
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Planetary Nebula
Open Cluster
Globular Cluster


SATURN FINDER CHART
Conjunction 24 January, Stationary 24 May
Opposition 2 August, Stationary 11 October
21h 00m
20h 40m
20h 20m
20h 00m
–15°
–20°
–25°
AQUARIUS
CAPRICORNUS
SAGITTARIUS
M 75
Ecliptic
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Globular Cluster

SATELLITES OF URANUS AND NEPTUNE

This page helps you find the position of Uranus's major satellites and Neptune's moon Triton. Dates and times are in days and fractions of a day in UT. You need to convert your local time to UT first. Table 1 will help.

URANUS Table 2 presents the times of the first greatest elongation to the *north* for each month for **Ariel**, **Umbriel**, **Titania and Oberon**. This location is the day 0 (zero) point on the Apparent Orbits diagram. As with Saturn's satellites, the procedure is to work out how many orbits have elapsed since the first elongation of the month. Then discard the completed number of orbits and convert the remaining fraction back to days so its position can be read directly off the diagram. This is best illustrated with an example. You wish to determine the position of **Umbriel** for 26 October at 1 am WST.



1. Convert to UT as a fractional day. 26 October at 1 am (WST) = 25.708 UT
2. Subtract the date of the greatest elongation north for October, i.e. 25.708 – 4.223 = 21.485 days
3. Divide by the period to get the number of orbits, i.e. 21.485 / 4.144 = 5.185 orbits.
4. Discarding whole orbits leaves 0.185 (about little under two tenths of an orbit)
5. Multiply by the period, 0.185 × 4.144 = 0.767 days (18.4 hours)
6. Looking at its orbital path (see Apparent Orbits diagram), the satellite is approaching the 1-day mark, towards the north-west.

NEPTUNE The procedure for finding Neptune's major satellite **Triton** is identical to above, except the times of the first greatest elongation *east* for each month is listed in Table 2. The orientation of Triton's orbit places this day 0 (zero) point closer to north-east of Neptune (see diagram).

An example. Estimate the position for Triton for September 15 at 10 pm EST. 1.858 orbits have elapsed since its greatest elongation east on Sep 4.581 UT. Discarding the one orbit leaves 0.858. Multiplying by 5.877 (its period) gives 5.042 days. From the diagram the moon is north of Neptune, just past the 5-day marker.

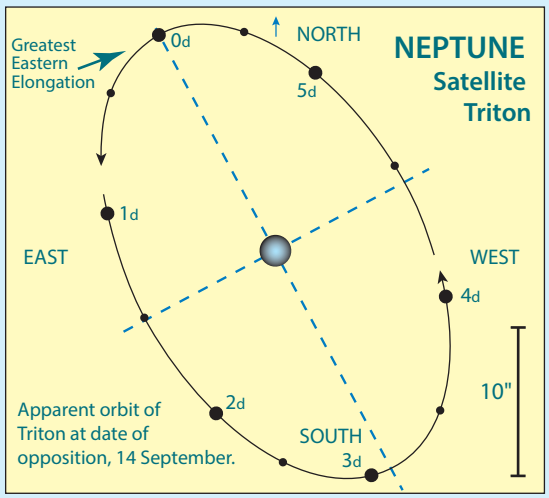


Table 1: **Converting Time in Australia to Universal Time (UT)**

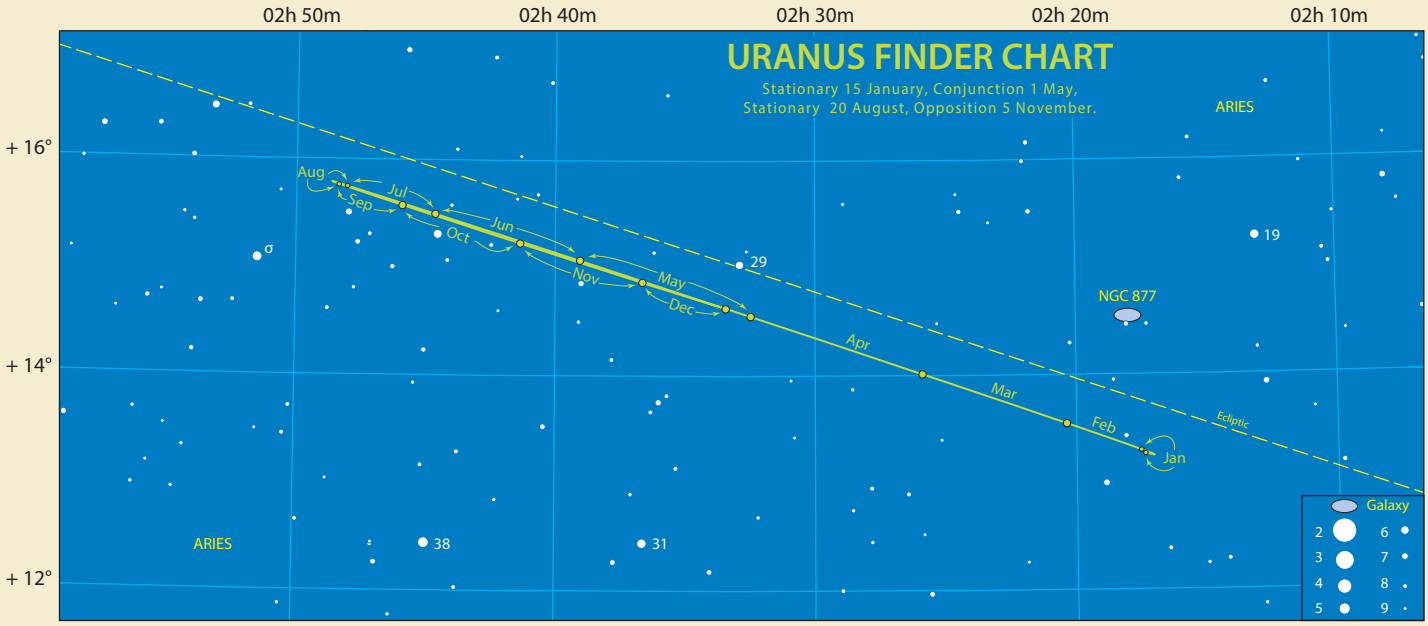
EST	WST	Fraction of day (UT)
6 pm	4 pm	0.333
7 pm	5 pm	0.375
8 pm	6 pm	0.417
9 pm	7 pm	0.458
10 pm	8 pm	0.500
11 pm	9 pm	0.542
midnight	10 pm	0.583
1 am	11 pm	0.625
2 am	midnight	0.667
3 am	1 am	0.708
4 am	2 am	0.750
5 am	3 am	0.792
6 am	4 am	0.833
7 am	5 am	0.875
8 am	6 am	0.917

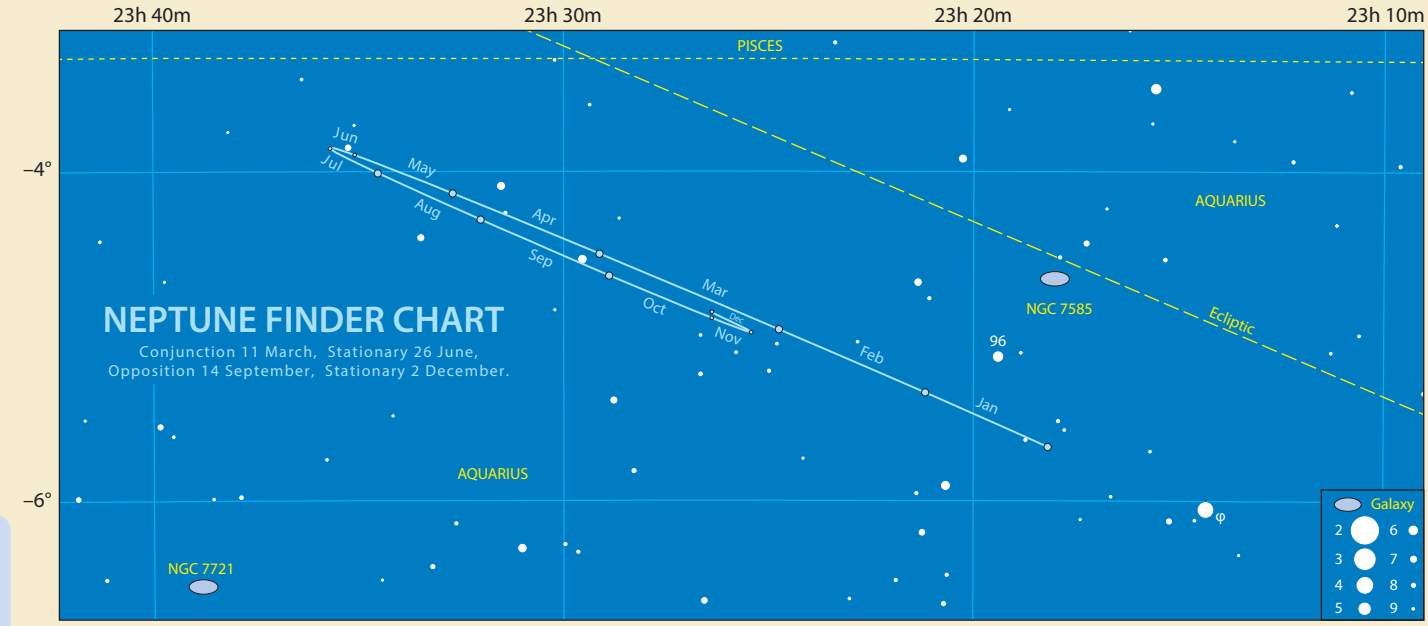
After midnight it is still the previous day in UT, e.g., 1 am (EST) on the 21st = 20.625 days UT

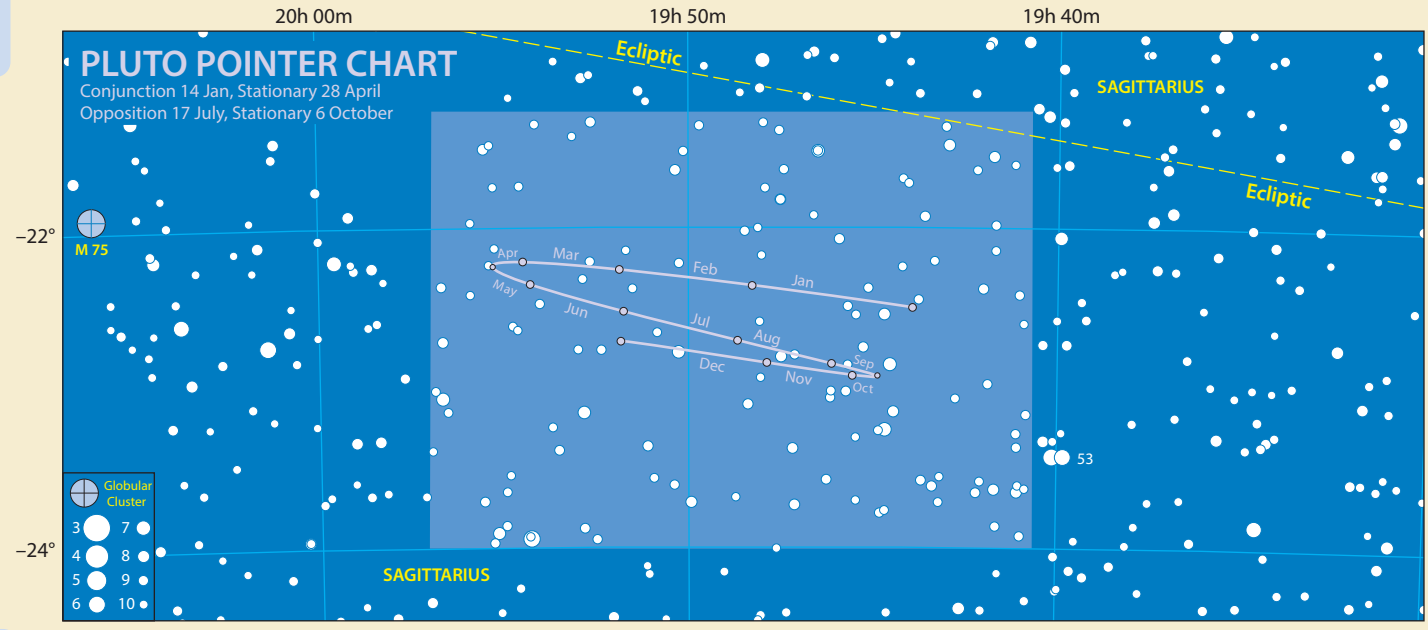
Table 2: **Time of Greatest Elongation North or East** (UT)

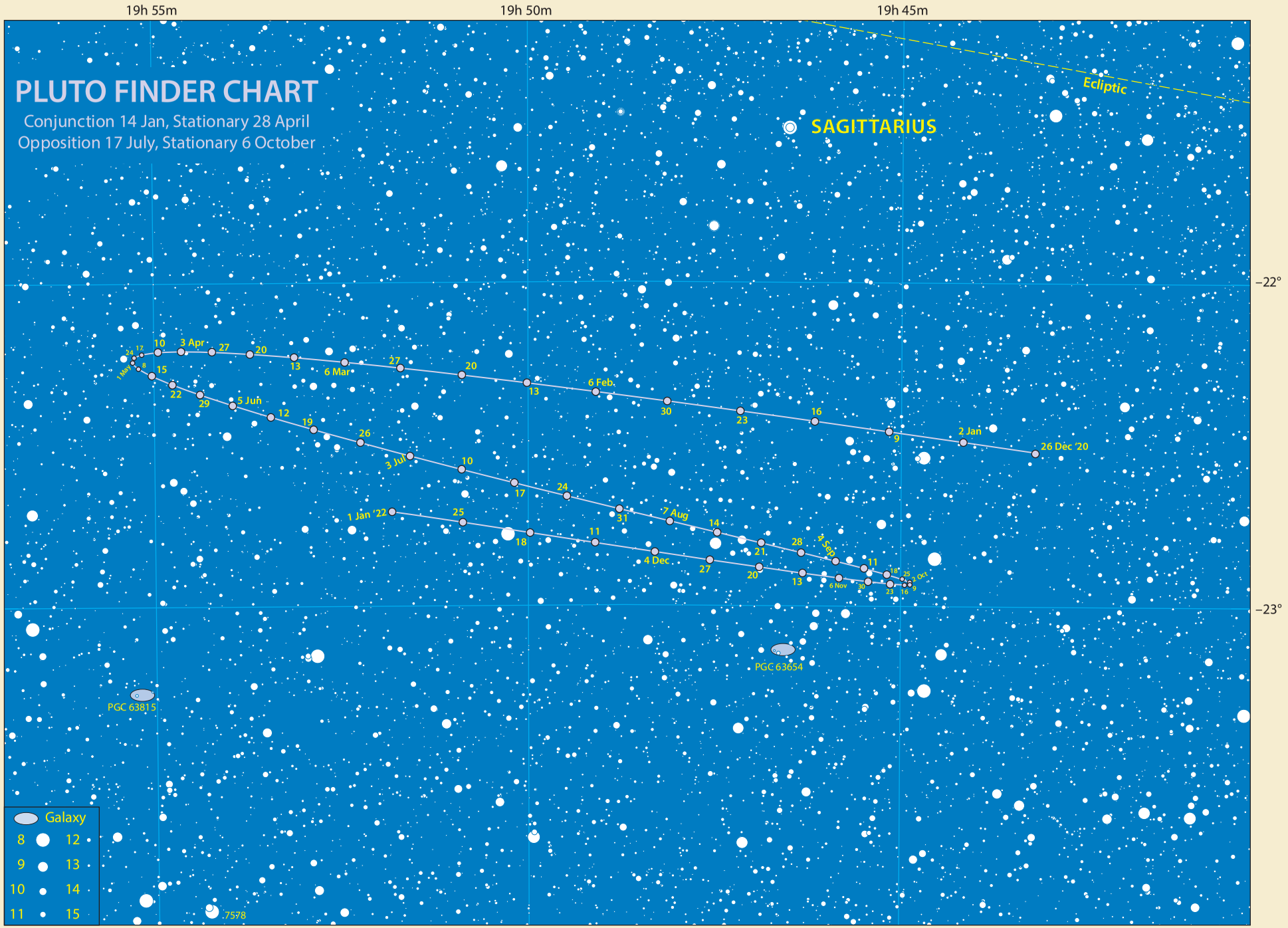
Planet	**Uranus**				**Neptune**
Moon	**Ariel**	**Umbriel**	**Titania**	**Oberon**	**Triton**
Magnitude [1]	13.7	14.5	13.5	13.7	13.5
Max Elong. [1]	0' 14"	0' 20"	0' 33"	0' 44"	0' 17"
Period (days) [2]	2.520	4.144	8.706	13.463	5.877
Month	**Elongation North (d.ddd)**				**East** (d.ddd)
January	1.831	3.736	4.477	8.172	6.692
February	1.078	1.747	8.301	4.097	5.066
March	3.324	2.757	6.416	3.018	6.434
April	2.567	4.907	1.526	12.390	4.801
May	2.808	3.911	6.336	9.302	4.169
June	2.048	1.914	1.442	5.211	2.542
July	2.287	5.059	6.252	2.119	1.922
August	1.527	3.063	1.362	11.492	6.187
September	3.288	1.069	5.181	7.421	4.581
October	1.012	4.223	1.300	4.353	3.978
November	2.779	2.235	5.132	13.755	2.374
December	3.027	1.249	1.258	10.687	1.764

Notes 1. When at opposition 2. Sidereal Period


URANUS FINDER CHART
Stationary 15 January, Conjunction 1 May,
Stationary 20 August, Opposition 5 November.
02h 50m
02h 40m
02h 30m
02h 20m
02h 10m
+ 16°
+ 14°
+ 12°
ARIES
Aug
Sep
Jul
Oct
Jun
Nov
May
Dec
Apr
Mar
Feb
Jan
Ecliptic
29
19
NGC 877
38
31
Galaxy
2 6
3 7
4 8
5 9


NEPTUNE FINDER CHART
Conjunction 11 March, Stationary 26 June,
Opposition 14 September, Stationary 2 December.
23h 40m
23h 30m
23h 20m
23h 10m
PISCES
AQUARIUS
−4°
−6°
Jun
Jul
May
Aug
Apr
Sep
Mar
Oct
Dec
Nov
Feb
Jan
Ecliptic
NGC 7585
96
φ
NGC 7721
Galaxy
2 6
3 7
4 8
5 9


PLUTO POINTER CHART
Conjunction 14 Jan, Stationary 28 April
Opposition 17 July, Stationary 6 October
20h 00m
19h 50m
19h 40m
Ecliptic
SAGITTARIUS
−22°
−24°
M 75
Apr
Mar
Feb
Jan
May
Jun
Jul
Aug
Dec
Nov
Sep
Oct
53
Globular Cluster
3 7
4 8
5 9
6 10


19h 55m
19h 50m
19h 45m
PLUTO FINDER CHART
Conjunction 14 Jan, Stationary 28 April
Opposition 17 July, Stationary 6 October
Ecliptic
SAGITTARIUS
−22°
−23°
1 Jan
17
10
3 Apr
27
20
13
6 Mar
27
20
13
6 Feb.
30
23
16
9
2 Jan
26 Dec '20
8
15
22
29
5 Jun
12
19
26
3 Jul
10
17
24
31
7 Aug
14
21
28
4 Sep
11
18
25
2 Oct
9
16
23
30
6 Nov
13
20
27
4 Dec
11
18
25
1 Jan '22
PGC 63815
PGC 63654
7578
Galaxy
8 12
9 13
10 14
11 15

COMETS FOR 2021

WHAT IS A COMET? It is a member of the Solar System, which is normally in a highly elongated orbit around the Sun. The orbits of periodic, or regularly reappearing comets, are quite eccentric or oval compared to those of the planets. Comets also differ from the planets by being far less massive and containing significant quantities of water (in the form of ice) and rocks/dust. The time a periodic comet takes to orbit the Sun varies greatly from comet to comet. One of the shortest period comets, 2P/Encke, takes just over three years to orbit the Sun. There are also a number of comets that are not expected to return for hundreds of years. Each year sees the discovery of comets that have not been recorded before.

As a comet draws closer to the Sun, the nucleus heats up and the ice sublimates forming a cloud called a coma around the core. The coma can be tens of thousands of kilometres in diameter. The solar wind, on its outward journey from the Sun, sweeps the coma cloud of its lightweight ionised particles forming the ion tail of the comet. This tail always points away from the Sun. The other tail that can form is a dust tail. This is made up of dust grains that trail behind the comet along its path. The lost material from the coma will continue to be replenished from the nucleus as long as the comet stays close to the Sun. Comets do not always have tails. In fact some may only show a coma.

Comets are normally named after their discoverers (up to the first three to report the find). There are also other designations given to comets (you will see examples on the following pages). The prefix 'P/' means the comet is periodic. The number before the 'P' indicates the number of the periodic comet. For example Comet 4P/Faye indicates it was the 4th comet confirmed to be periodic. The prefix is not assigned until the comet is found on a later return. You will also see references to another naming system, best explained with an example. The ATLAS comet, mentioned opposite, is referred to as 'C/2019 N1'. 2019 refers to the year of the discovery, N is the 13th half-month period ('I' is not used) during the year and the 1 shows it was the first discovery in this half month. Therefore C/2019 N1 (ATLAS) was the first comet discovered in the first half of July 2019.

There is no such thing as a typical comet. Like people, they are all slightly different. The orbit, overall brightness, size of the coma and tail can vary dramatically from comet to comet and even from return to return. To watch one brighten, develop a tail and then fade away over a period of a few weeks can be a fascinating experience.

This section is devoted to the brightest comets that are expected to be observable during 2021. The table opposite lists the comets that are expected to brighten to at least 13th magnitude sometime during the year, along with their orbital elements. This is the data required to calculate their locations in the sky. The elements are followed by ephemerides (a list of expected positions in the sky and magnitude estimates for different dates). These positions can be plotted on the All Sky Maps to get an idea of where they are in the sky. The magnitude parameters can often be inaccurate, having been based on their behaviour on previous returns. There are also non-gravitational effects associated with comets, which can render predicted ephemerides inaccurate, especially when extrapolating orbital elements from previous returns.

Often you will read references to a comet's return being favourable (well placed) or unfavourable. There are a few factors that determine this. For example, when the comet is at its expected maximum brightness, its apparent position in the sky could be too close to the Sun or on the opposite side of the Sun from Earth. This would be considered unfavourable.

There are many other comets not listed here expected in 2021, but they are extremely faint and would require large telescopes or long exposure images to detect them, but who knows what could be discovered tonight?

NOTES ON SELECTED COMETS

Greg Bryant

4P/Faye: This comet was discovered by French astronomer Herve Faye at the Royal Observatory, Paris, on 23 November 1834. Observed over a period of five months, during which time it reached naked-eye visibility, it was soon determined to be of short period in nature. The comet was successfully recovered at its next return in 1850, several months before perihelion.

Faye has been sighted at each successive return, except for the poor apparitions of 1903 and 1918. With an orbital period of 7.5 years, its next return after the September 2021 perihelion will be in 2029.

6P/d'Arrest: German astronomer Heinrich d'Arrest first sighted this comet on 28 June 1851 from Leipzig, Germany, and it was followed for over three months. Shortly after its discovery, it was suggested that the comet was the same as one observed in 1678. However, the idea was not revisited until 1990 when orbital calculations proved the linkage.

With an orbital period of around 6.5 years, comet d'Arrest has been seen at most of its returns, and at every return since 1963. Its best apparition was in 1976 when it passed just 0.15 au from Earth and brightened to 5th magnitude. Following its September 2021 perihelion, the comet will next return in 2028.

7P/Pons-Winnecke: The famed French comet hunter Jean Louis Pons discovered this comet from Marseilles, France, on 12 June 1819. The comet was followed for just over a month, and while it appeared to be periodic, predictions for future returns weren't successful. Then, in 1858, Friedrich Winnecke accidentally rediscovered the comet. Since then, Pons-Winnecke has been seen at all but four of its returns.

During its 2021 apparition, Pons-Winnecke will be 0.45 au from Earth on 12 June, a fortnight after perihelion, and its closest approach to Earth since 1945. With a period of around 6 years, Pons-Winnecke will return again in 2027.

8P/Tuttle: This comet is named after American astronomer Horace Tuttle, who sighted the comet on 5 January 1858. Calculations later that month showed the comet was the same as one sighted by Pierre Mechain in 1790, with an orbital period of 13.7 years.

Since 1858, comet Tuttle has been observed at every return with the exception of 1953. At its most recent return in 2008, Tuttle passed within 0.26 au of Earth and was faintly visible to the unaided eye.

After its perihelion passage in August 2021, Tuttle will next return in 2035. Looking farther ahead, comet Tuttle will pass within 0.18 au of Earth around Christmas 2048 and should be naked eye again.

15P/Finlay: South African astronomer William Finlay discovered this comet on 26 September 1886 from the Cape of Good Hope, South Africa. Observations over the next few months determined its periodic nature (6.6 years) and Finlay himself recovered the comet at its next return in 1893.

At its last return in 2014–15, comet Finlay underwent two surges in brightness of several magnitudes around the time of perihelion. Finlay reaches perihelion in July 2021, and then will return in 2028. Later this century, comet Finlay is expected to be visible to the unaided eye in 2034 and 2060 on account of its close passages to Earth.

19P/Borrelly: Discovered by French astronomer Alphonse Borrelly on 28 December 1904, its periodic orbit (7 years) was confirmed over the course of several months and the comet was recovered at its next return in 1911. Since then, the comet has only been missed at the returns of 1939 and 1946. In 2001, the Deep Space 1 spacecraft flew past Borrelly, the first up-close imaging of a comet since Halley in 1986.

Comet Borrelly reaches perihelion in early 2022. At its next return, in 2028, Borrelly will pass within 0.42 au of Earth, its closest approach since its discovery.

67P/Churyumov-Gerasimenko: Here's a classic case of mistaken identity. Soviet astronomers Churyumov and Gerasimenko were conducting a survey of known comets. An image they thought they had taken of comet 32P/Comas Sola on 11 September 1969 turned out to be a new comet. With a period of around 6.5 years, Churyumov-Gerasimenko has been seen at every return since its discovery.

The European spacecraft Rosetta orbited Churyumov-Gerasimenko for two years from 2014–2016, and deployed a lander on the comet's surface.

104P/Kowal 2 was discovered by Charles Kowal at Palomar Observatory in the United States in January 1979. Within several weeks, the comet was determined to be periodic in nature, orbiting the Sun every 6 years, though its returns in 1985 and 2010 were missed. Close approaches to Jupiter have been shifting the comet's orbit closer to the Sun, and will do so again in 2031.

C/2019 N1 (ATLAS): Discovered on images taken with a 0.5 m Schmidt telescope in Hawaii by the Asteroid Terrestrial-impact Last Alert System (ATLAS) team on 5 July 2019, the comet is at perihelion in December 2020. The ATLAS team thus far has 32 comets to its name.

Greg Bryant is Sky & Telescope magazine's Southern Hemisphere contributing editor and can be reached at gchbryant@fastmail.fm. He has been following comets since the mid 1980s and enjoys noting each year's new comet discoveries.

BRIGHT COMETS FOR 2021 — ORBITAL ELEMENTS (Equinox 2000.0)

Comet Name	Perihelion Date yyyy mm dd.dddd	q au	e	Period years	ω °	Ω °	i °	H1	K1
C/2019 N1 (ATLAS)	2020 12 01.7901	1.704535	0.999952		193.4468	13.5728	82.4274	6.5	10.0
7P/Pons-Winnecke	2021 05 27.1116	1.234238	0.638474	6.3	172.5956	93.3754	22.3637	9.0	10.0
15P/Finlay	2021 07 13.5411	0.991991	0.717042	6.5	347.8240	13.7135	6.7975	9.5	25.0
8P/Tuttle	2021 08 27.7447	1.026008	0.820241	13.6	207.4890	270.2039	54.9112	7.0	20.0
4P/Faye	2021 09 09.4273	1.618895	0.576690	7.5	206.9756	192.9605	8.0130	5.5	21.0
6P/d'Arrest	2021 09 17.7679	1.354609	0.612812	6.5	178.1045	138.9356	19.5123	9.0	10.0
67P/Churyumov-Gerasimenko	2021 11 02.0615	1.210620	0.649703	6.4	22.1333	36.3336	3.8715	9.5	14.0
104P/Kowal 2	2022 01 11.1792	1.072804	0.665414	5.9	227.1643	207.3650	5.7249	10.5	20.0
19P/Borrelly	2022 02 01.8283	1.306302	0.637643	6.8	351.9146	74.2475	29.3050	4.5	25.0

COMET ORBITAL ELEMENTS (above)

Perihelion Date The date of closest approach to the Sun.

q The perihelion distance in au (astronomical units).

e The eccentricity of the comet's orbit. Values less than one indicate a known periodic comet with an elliptical orbit. A value equal to or greater than one indicates: an open orbit (a once only visitor to the Solar System), it has a very long period (thousands of years) or it is newly discovered and astronomers have not clearly defined its orbit.

Period The comet's period (time taken for one orbit of the Sun) in years.

ω Argument of Perihelion. The angle from the ascending node to perihelion (measured in the plane of the comet's orbit in the direction of motion of the comet).

Ω Longitude of Ascending Node. The point of intersection between the plane of the comet's orbit and the plane of the Earth's orbit (ecliptic) as the comet moves north.

i Inclination. Angle between the plane of the comet's orbit and the plane of the ecliptic. A value greater than 90° means the comet's orbit direction is retrograde (moves in the opposite direction to the planets).

H1 The absolute total magnitude of the comet, which is the theoretical brightness of the comet if it were 1 au from the Sun and the Earth.

K1 A constant used in calculating the comet's total magnitude (see explanation in Comet Ephemerides next page for further details).

Calculation of ephemerides from these elements is complex (but not difficult with the power of home technology) but beyond the scope of this book.

7P/Pons-Winnecke

Date	RA	Dec	Δ	R	Rise	Transit	Set	Mag	Con
	h m	° '	au	au	hh:mm	hh:mm	hh:mm		
09 Jan	14 19.0	+11 02	1.993	1.894	01:29	07:01	12:32	13.4	Boo
16 Jan	14 34.5	+10 40	1.939	1.780	01:16	06:49	12:21	13.1	Boo
23 Jan	14 50.5	+10 22	1.885	1.668	01:03	06:37	12:11	12.9	Boo
30 Jan	15 06.9	+10 08	1.832	1.560	00:51	06:26	12:00	12.6	Boo
06 Feb	15 23.7	+09 58	1.779	1.457	00:40	06:15	11:50	12.3	Ser
13 Feb	15 41.0	+09 52	1.726	1.357	00:29	06:04	11:40	12.0	Ser
20 Feb	15 58.7	+09 48	1.675	1.262	00:19	05:55	11:30	11.7	Ser
27 Feb	16 17.0	+09 47	1.624	1.172	00:10	05:46	11:21	11.5	Her
06 Mar	16 35.8	+09 45	1.575	1.087	00:01	05:37	11:12	11.2	Her
13 Mar	16 55.2	+09 42	1.527	1.007	23:49	05:29	11:04	10.9	Oph
20 Mar	17 15.2	+09 35	1.482	0.931	23:41	05:21	10:57	10.6	Oph
27 Mar	17 35.8	+09 20	1.439	0.861	23:34	05:14	10:50	10.3	Oph
03 Apr	17 57.2	+08 56	1.399	0.795	23:26	05:08	10:45	10.0	Oph
10 Apr	18 19.4	+08 16	1.362	0.734	23:19	05:03	10:42	9.7	Oph
17 Apr	18 42.5	+07 17	1.328	0.678	23:12	04:58	10:40	9.4	Oph
24 Apr	19 06.5	+05 53	1.300	0.626	23:05	04:55	10:40	9.1	Aql
01 May	19 31.5	+04 00	1.276	0.580	22:57	04:52	10:43	8.9	Aql
08 May	19 57.6	+01 33	1.257	0.540	22:49	04:50	10:48	8.7	Aql
15 May	20 24.6	−01 31	1.243	0.505	22:40	04:50	10:55	8.5	Aql
22 May	20 52.2	−05 12	1.236	0.478	22:30	04:50	11:05	8.3	Aqr
29 May	21 20.2	−09 27	1.235	0.458	22:19	04:50	11:18	8.2	Aqr
05 Jun	21 48.1	−14 08	1.239	0.446	22:06	04:51	11:31	8.2	Cap
12 Jun	22 15.1	−19 02	1.250	0.442	21:51	04:50	11:45	8.2	Aqr
19 Jun	22 40.5	−23 57	1.266	0.446	21:33	04:48	11:59	8.3	Aqr
26 Jun	23 03.6	−28 42	1.288	0.456	21:11	04:44	12:11	8.4	PsA
03 Jul	23 23.9	−33 08	1.315	0.473	20:46	04:37	12:22	8.6	Scl
10 Jul	23 40.6	−37 11	1.346	0.495	20:16	04:26	12:29	8.8	Scl
17 Jul	23 53.4	−40 48	1.381	0.522	19:42	04:11	12:34	9.0	Phe
24 Jul	00 02.1	−43 58	1.420	0.554	19:03	03:52	12:36	9.2	Phe
31 Jul	00 06.7	−46 39	1.462	0.589	18:19	03:29	12:33	9.5	Phe
07 Aug	00 07.2	−48 50	1.506	0.630	17:33	03:02	12:26	9.8	Phe
14 Aug	00 04.1	−50 28	1.553	0.674	16:44	02:31	12:13	10.1	Phe
21 Aug	23 58.3	−51 31	1.601	0.724	15:58	01:59	11:54	10.3	Phe
28 Aug	23 50.6	−51 59	1.651	0.778	15:16	01:24	11:25	10.6	Phe
04 Sep	23 42.2	−51 54	1.702	0.838	14:41	00:48	10:48	10.9	Phe
11 Sep	23 34.1	−51 19	1.755	0.904	14:14	00:12	10:04	11.2	Phe
18 Sep	23 27.0	−50 17	1.807	0.977	13:52	23:33	09:17	11.5	Phe
25 Sep	23 21.5	−48 53	1.861	1.055	13:34	23:00	08:29	11.8	Gru
02 Oct	23 17.8	−47 14	1.914	1.140	13:19	22:29	07:42	12.1	Gru
09 Oct	23 15.9	−45 23	1.968	1.230	13:04	22:00	06:57	12.4	Gru
16 Oct	23 15.6	−43 25	2.022	1.327	12:50	21:32	06:15	12.7	Gru
23 Oct	23 16.8	−41 22	2.077	1.430	12:37	21:05	05:36	12.9	Gru
30 Oct	23 19.3	−39 16	2.130	1.538	12:24	20:40	04:59	13.2	Gru

6P/d'Arrest

Date	RA	Dec	Δ	R	Rise	Transit	Set	Mag	Con
	h m	° '	au	au	hh:mm	hh:mm	hh:mm		
03 Apr	16 43.5	+06 39	2.223	1.546	22:06	03:55	09:39	13.4	Her
10 Apr	16 47.6	+08 03	2.173	1.443	21:47	03:31	09:11	13.2	Her
17 Apr	16 50.5	+09 33	2.123	1.347	21:27	03:06	08:42	12.9	Her
24 Apr	16 52.1	+11 05	2.073	1.258	21:05	02:40	08:12	12.7	Oph
01 May	16 52.4	+12 38	2.024	1.176	20:42	02:13	07:41	12.4	Her
08 May	16 51.2	+14 07	1.974	1.102	20:17	01:45	07:08	12.2	Her
15 May	16 48.5	+15 28	1.925	1.036	19:51	01:14	06:33	11.9	Her
22 May	16 44.5	+16 36	1.877	0.978	19:23	00:43	05:59	11.7	Her
29 May	16 39.4	+17 25	1.829	0.928	18:52	00:10	05:24	11.5	Her
05 Jun	16 33.5	+17 50	1.782	0.885	18:20	23:34	04:49	11.2	Her
12 Jun	16 27.2	+17 47	1.737	0.849	17:47	23:00	04:15	11.0	Her
19 Jun	16 21.2	+17 12	1.692	0.820	17:11	22:26	03:44	10.9	Her
26 Jun	16 16.0	+16 05	1.649	0.797	16:35	21:54	03:14	10.7	Her
03 Jul	16 12.1	+14 25	1.607	0.778	15:59	21:22	02:47	10.5	Her
10 Jul	16 10.0	+12 15	1.568	0.765	15:23	20:52	02:24	10.4	Ser
17 Jul	16 09.9	+09 36	1.531	0.755	14:48	20:25	02:04	10.2	Ser
24 Jul	16 12.2	+06 35	1.497	0.749	14:14	20:00	01:47	10.1	Her
31 Jul	16 16.9	+03 13	1.465	0.746	13:43	19:37	01:33	10.0	Ser
07 Aug	16 24.0	−00 24	1.437	0.747	13:13	19:17	01:23	9.9	Oph
14 Aug	16 33.6	−04 11	1.412	0.751	12:44	18:59	01:15	9.9	Oph
21 Aug	16 45.8	−08 03	1.392	0.758	12:18	18:43	01:10	9.8	Oph
28 Aug	17 00.4	−11 55	1.376	0.770	11:55	18:30	01:08	9.8	Oph
04 Sep	17 17.4	−15 41	1.364	0.786	11:34	18:20	01:08	9.8	Ser
11 Sep	17 36.8	−19 15	1.357	0.806	11:15	18:11	01:11	9.9	Oph
18 Sep	17 58.4	−22 30	1.355	0.831	10:58	18:05	01:16	9.9	Sgr
25 Sep	18 22.1	−25 22	1.357	0.861	10:44	18:01	01:21	10.0	Sgr
02 Oct	18 47.4	−27 44	1.365	0.897	10:34	18:00	01:28	10.1	Sgr
09 Oct	19 14.0	−29 35	1.377	0.938	10:26	17:59	01:34	10.2	Sgr
16 Oct	19 41.5	−30 53	1.393	0.985	10:21	17:59	01:39	10.4	Sgr
23 Oct	20 09.2	−31 36	1.414	1.037	10:18	17:59	01:42	10.6	Sgr
30 Oct	20 36.7	−31 48	1.439	1.094	10:17	17:59	01:42	10.8	Mic
06 Nov	21 03.5	−31 31	1.467	1.157	10:17	17:58	01:40	11.0	Mic
13 Nov	21 29.4	−30 49	1.499	1.225	10:18	17:56	01:36	11.2	PsA
20 Nov	21 54.0	−29 46	1.533	1.298	10:20	17:53	01:28	11.4	PsA
27 Nov	22 17.4	−28 25	1.571	1.376	10:20	17:49	01:19	11.7	PsA
04 Dec	22 39.5	−26 52	1.610	1.458	10:21	17:43	01:08	11.9	PsA
11 Dec	23 00.3	−25 09	1.652	1.545	10:20	17:37	00:55	12.1	PsA
18 Dec	23 20.0	−23 18	1.695	1.635	10:19	17:29	00:40	12.4	Aqr
25 Dec	23 38.7	−21 24	1.740	1.729	10:16	17:20	00:25	12.6	Aqr
01 Jan'22	23 56.5	−19 27	1.786	1.827	10:12	17:10	00:09	12.8	Cet
08 Jan'22	00 13.4	−17 30	1.832	1.927	10:08	16:58	23:49	13.1	Cet
15 Jan'22	00 29.7	−15 33	1.880	2.030	10:02	16:47	23:32	13.3	Cet
22 Jan'22	00 45.3	−13 38	1.929	2.135	09:56	16:35	23:14	13.5	Cet

COMET EPHEMERIDES

Date at 0 hr UT (10 am EST, 9:30 am CST and 8 am WST).

RA, Dec Right Ascension and Declination are for equinox 2000.0

Δ (delta) Geocentric distance (from the Earth) in au.

R Heliocentric distance (from the Sun) in au.

Rise, Transit, Set Times given are for mid-latitude Australia and will vary between locations. Where no rise or set time is given, the comet is circumpolar or below the northern horizon.

Mag This is the expected total magnitude of the comet. The value is only an estimate and for periodic comets it is usually based on the behaviour of its brightness during previous return(s).

Con Constellation abbreviation (see p. 141 for full name).

The estimate of total magnitude is normally calculated using:

$$\text{Mag} = H1 + 5 \log (\Delta) + K1 \log R$$

See the table of elements (previous page) for the values of H1 and K1. For many comets the K1 value is equal to 10. For newly discovered comets the value of K1 is mostly assumed to be equal to 10 until its light curve can be studied in detail. The brightness of a comet is often very uncertain, especially for those newly discovered. In fact, it is now believed that comets making their first visit to the Sun have an average K1 value of approximately 7.5. Comets have also been known to suddenly flare up or fade away and some have even shown a different behaviour in their light curve (changed values for H1 and K1) after perihelion compared to before. There are also constants of H2 and K2 used by astronomers which refer to the absolute magnitude and the K constant for the nucleus of the comet. These are not used in this publication.

15P/Finlay

Date	RA	Dec	Δ	R	Rise	Transit	Set	Mag	Con
	h m	° '	au	au	hh:mm	hh:mm	hh:mm		
08 May	22 45.4	−15 27	1.360	1.308	00:53	07:38	14:22	13.4	Aqr
15 May	23 14.0	−12 28	1.299	1.239	01:03	07:39	14:14	12.8	Aqr
22 May	23 43.7	−09 07	1.241	1.182	01:15	07:42	14:07	12.2	Aqr
29 May	00 14.2	−05 27	1.186	1.138	01:28	07:44	14:00	11.6	Psc
05 Jun	00 45.5	−01 32	1.136	1.108	01:42	07:48	13:53	11.1	Cet
12 Jun	01 17.4	+02 29	1.092	1.091	01:57	07:52	13:47	10.6	Cet
19 Jun	01 49.5	+06 29	1.054	1.088	02:12	07:57	13:40	10.3	Psc
26 Jun	02 21.7	+10 18	1.024	1.097	02:27	08:01	13:35	10.0	Cet
03 Jul	02 53.8	+13 49	1.004	1.116	02:41	08:05	13:29	9.8	Ari
10 Jul	03 25.6	+16 57	0.993	1.144	02:55	08:09	13:24	9.7	Tau
17 Jul	03 56.7	+19 38	0.993	1.178	03:07	08:13	13:20	9.8	Tau
24 Jul	04 27.1	+21 51	1.004	1.216	03:16	08:16	13:16	10.0	Tau
31 Jul	04 56.4	+23 37	1.024	1.257	03:24	08:17	13:12	10.3	Tau
07 Aug	05 24.4	+24 56	1.054	1.297	03:29	08:18	13:08	10.6	Tau
14 Aug	05 51.0	+25 53	1.091	1.337	03:31	08:17	13:03	11.1	Tau
21 Aug	06 16.1	+26 30	1.136	1.374	03:31	08:14	12:59	11.6	Gem
28 Aug	06 39.5	+26 50	1.186	1.407	03:28	08:10	12:53	12.1	Gem
04 Sep	07 01.1	+26 58	1.240	1.436	03:22	08:04	12:47	12.6	Gem
11 Sep	07 21.1	+26 56	1.298	1.460	03:14	07:57	12:39	13.2	Gem

4P/Faye

Date	RA	Dec	Δ	R	Rise	Transit	Set	Mag	Con
	h m	° '	au	au	hh:mm	hh:mm	hh:mm		
22 May	00 19.8	+05 51	1.957	2.371	02:31	08:17	14:02	13.5	Psc
29 May	00 35.9	+07 20	1.920	2.284	02:23	08:05	13:47	13.2	Psc
05 Jun	00 52.5	+08 47	1.885	2.198	02:16	07:55	13:32	13.0	Psc
12 Jun	01 09.4	+10 12	1.852	2.115	02:10	07:44	13:18	12.7	Psc
19 Jun	01 26.8	+11 35	1.820	2.033	02:03	07:34	13:04	12.5	Psc
26 Jun	01 44.6	+12 53	1.790	1.954	01:58	07:24	12:50	12.3	Psc
03 Jul	02 02.8	+14 07	1.761	1.878	01:52	07:15	12:37	12.0	Ari
10 Jul	02 21.5	+15 15	1.735	1.805	01:46	07:06	12:25	11.8	Ari
17 Jul	02 40.5	+16 16	1.711	1.735	01:41	06:57	12:13	11.6	Ari
24 Jul	02 59.9	+17 08	1.690	1.668	01:35	06:49	12:03	11.4	Ari
31 Jul	03 19.5	+17 52	1.671	1.604	01:29	06:41	11:53	11.2	Ari
07 Aug	03 39.2	+18 25	1.655	1.544	01:23	06:33	11:43	11.0	Tau
14 Aug	03 59.0	+18 46	1.641	1.486	01:16	06:25	11:35	10.9	Tau
21 Aug	04 18.5	+18 57	1.631	1.432	01:09	06:17	11:26	10.7	Tau
28 Aug	04 37.8	+18 55	1.624	1.380	01:00	06:09	11:18	10.6	Tau
04 Sep	04 56.5	+18 42	1.620	1.332	00:51	06:01	11:10	10.5	Tau
11 Sep	05 14.6	+18 18	1.619	1.286	00:40	05:51	11:01	10.4	Tau
18 Sep	05 31.7	+17 43	1.621	1.242	00:27	05:41	10:52	10.4	Tau
25 Sep	05 47.7	+16 59	1.627	1.200	00:14	05:29	10:43	10.3	Tau
02 Oct	06 02.5	+16 07	1.635	1.161	23:55	05:16	10:33	10.3	Ori
09 Oct	06 15.8	+15 09	1.647	1.123	23:38	05:02	10:21	10.3	Ori
16 Oct	06 27.4	+14 06	1.662	1.088	23:19	04:46	10:09	10.3	Gem
23 Oct	06 37.2	+13 00	1.679	1.055	22:58	04:28	09:54	10.3	Gem
30 Oct	06 45.1	+11 54	1.699	1.024	22:35	04:08	09:38	10.4	Gem
06 Nov	06 50.9	+10 50	1.722	0.997	22:10	03:47	09:19	10.4	Mon
13 Nov	06 54.6	+09 49	1.747	0.974	21:44	03:23	08:58	10.5	Mon
20 Nov	06 56.1	+08 56	1.774	0.955	21:15	02:57	08:34	10.6	Mon
27 Nov	06 55.5	+08 10	1.803	0.943	20:45	02:28	08:08	10.7	Mon
04 Dec	06 53.0	+07 36	1.834	0.937	20:13	01:59	07:40	10.9	Mon
11 Dec	06 48.9	+07 14	1.867	0.940	19:41	01:27	07:09	11.1	Mon
18 Dec	06 43.8	+07 05	1.901	0.952	19:08	00:54	06:37	11.3	Mon
25 Dec	06 38.1	+07 09	1.936	0.975	18:34	00:21	06:03	11.5	Mon
01 Jan '22	06 32.4	+07 25	1.973	1.009	18:02	23:45	05:30	11.7	Mon
08 Jan'22	06 27.3	+07 51	2.011	1.054	17:31	23:12	04:56	12.0	Mon
15 Jan'22	06 23.1	+08 25	2.050	1.111	17:01	22:40	04:22	12.3	Mon
22 Jan'22	06 20.3	+09 04	2.090	1.178	16:32	22:10	03:51	12.6	Ori
29 Jan'22	06 18.9	+09 47	2.130	1.255	16:05	21:41	03:20	12.9	Ori
05 Feb'22	06 18.9	+10 30	2.171	1.341	15:40	21:14	02:50	13.2	Ori

67P/Churyumov-Gerasimenko

Date	RA	Dec	Δ	R	Rise	Transit	Set	Mag	Con
	h m	° '	au	au	hh:mm	hh:mm	hh:mm		
17 Jul	01 02.8	+01 56	1.761	1.286	23:20	05:20	11:16	13.5	Cet
24 Jul	01 18.2	+03 27	1.708	1.183	23:11	05:08	11:00	13.1	Psc
31 Jul	01 34.4	+05 02	1.655	1.084	23:04	04:56	10:44	12.7	Psc
07 Aug	01 51.5	+06 41	1.603	0.991	22:58	04:46	10:29	12.3	Psc
14 Aug	02 09.7	+08 23	1.552	0.904	22:53	04:36	10:15	12.0	Cet
21 Aug	02 29.2	+10 11	1.503	0.824	22:50	04:28	10:02	11.6	Cet
28 Aug	02 50.2	+12 03	1.457	0.751	22:49	04:22	09:50	11.2	Ari
04 Sep	03 12.9	+13 59	1.413	0.684	22:49	04:17	09:40	10.8	Ari
11 Sep	03 37.6	+15 58	1.372	0.625	22:52	04:14	09:32	10.4	Tau
18 Sep	04 04.2	+17 57	1.334	0.574	22:57	04:13	09:25	10.0	Tau
25 Sep	04 32.9	+19 53	1.301	0.531	23:04	04:14	09:20	9.7	Tau
02 Oct	05 03.4	+21 41	1.272	0.496	23:13	04:17	09:17	9.4	Tau
09 Oct	05 35.1	+23 16	1.248	0.468	23:22	04:21	09:16	9.2	Tau
16 Oct	06 07.3	+24 34	1.230	0.447	23:31	04:26	09:17	9.0	Gem
23 Oct	06 38.9	+25 31	1.217	0.433	23:38	04:30	09:17	8.9	Gem
30 Oct	07 09.1	+26 10	1.211	0.424	23:43	04:32	09:18	8.8	Gem
06 Nov	07 36.6	+26 32	1.212	0.419	23:44	04:32	09:16	8.8	Gem
13 Nov	08 00.9	+26 44	1.218	0.418	23:42	04:29	09:12	8.8	Cnc
20 Nov	08 21.4	+26 50	1.232	0.420	23:35	04:22	09:05	8.9	Cnc
27 Nov	08 37.8	+26 57	1.250	0.424	23:24	04:10	08:53	9.0	Cnc
04 Dec	08 50.0	+27 07	1.275	0.429	23:09	03:56	08:37	9.1	Cnc
11 Dec	08 58.0	+27 22	1.304	0.437	22:50	03:36	08:17	9.3	Cnc
18 Dec	09 01.9	+27 44	1.339	0.447	22:28	03:12	07:52	9.5	Cnc
25 Dec	09 02.1	+28 09	1.377	0.462	22:02	02:45	07:24	9.8	Cnc
01 Jan '22	08 59.1	+28 34	1.418	0.481	21:34	02:14	06:51	10.0	Cnc
08 Jan'22	08 53.7	+28 55	1.463	0.506	21:02	01:42	06:17	10.3	Cnc
15 Jan'22	08 47.0	+29 08	1.509	0.539	20:28	01:07	05:42	10.7	Cnc
22 Jan'22	08 39.9	+29 10	1.558	0.581	19:54	00:32	05:07	11.0	Cnc
29 Jan'22	08 33.3	+29 01	1.609	0.632	19:19	23:56	04:34	11.4	Cnc
05 Feb'22	08 28.1	+28 41	1.661	0.692	18:45	23:23	04:02	11.8	Cnc
12 Feb'22	08 24.5	+28 13	1.714	0.761	18:12	22:51	03:33	12.2	Cnc
19 Feb'22	08 22.8	+27 39	1.768	0.840	17:41	22:22	03:06	12.6	Cnc
26 Feb'22	08 22.8	+27 01	1.823	0.927	17:11	21:55	02:40	13.0	Cnc
05 Mar'22	08 24.6	+26 19	1.878	1.022	16:43	21:29	02:17	13.4	Cnc

104P/Kowal 2

Date	RA	Dec	Δ	R	Rise	Transit	Set	Mag	Con
	h m	° '	au	au	hh:mm	hh:mm	hh:mm		
23 Oct	21 42.7	−08 40	1.489	0.760	13:06	19:32	02:00	13.4	Cap
30 Oct	21 45.6	−09 23	1.432	0.759	12:39	19:07	01:37	13.0	Cap
06 Nov	21 51.3	−09 54	1.377	0.758	12:16	18:45	01:17	12.7	Cap
13 Nov	21 59.6	−10 11	1.325	0.755	11:56	18:26	00:58	12.3	Aqr
20 Nov	22 10.5	−10 13	1.276	0.751	11:39	18:09	00:41	12.0	Aqr
27 Nov	22 23.9	−10 02	1.230	0.744	11:26	17:55	00:27	11.7	Aqr
04 Dec	22 39.6	−09 35	1.188	0.733	11:15	17:43	00:14	11.3	Aqr
11 Dec	22 57.8	−08 53	1.152	0.720	11:08	17:34	00:02	11.0	Aqr
18 Dec	23 18.3	−07 55	1.121	0.705	11:03	17:26	23:49	10.7	Aqr
25 Dec	23 41.1	−06 40	1.098	0.688	11:02	17:22	23:41	10.5	Aqr
01 Jan '22	00 06.3	−05 10	1.082	0.671	11:03	17:19	23:34	10.3	Psc
08 Jan'22	00 33.8	−03 23	1.074	0.655	11:08	17:19	23:29	10.2	Cet
15 Jan'22	01 03.6	−01 21	1.074	0.641	11:16	17:21	23:26	10.2	Cet
22 Jan'22	01 35.7	+00 53	1.083	0.632	11:26	17:26	23:25	10.2	Cet
29 Jan'22	02 09.6	+03 16	1.100	0.630	11:39	17:32	23:25	10.3	Cet
05 Feb'22	02 45.0	+05 41	1.124	0.635	11:53	17:40	23:26	10.5	Cet
12 Feb'22	03 21.3	+08 01	1.155	0.650	12:08	17:49	23:28	10.8	Cet
19 Feb'22	03 57.6	+10 07	1.192	0.676	12:22	17:57	23:31	11.2	Tau
26 Feb'22	04 33.2	+11 55	1.234	0.713	12:35	18:05	23:34	11.6	Tau
05 Mar'22	05 07.4	+13 21	1.280	0.760	12:46	18:11	23:37	12.0	Ori
12 Mar'22	05 39.7	+14 24	1.330	0.819	12:54	18:16	23:39	12.5	Ori
19 Mar'22	06 09.8	+15 05	1.382	0.888	12:58	18:19	23:39	13.1	Ori

19P/Borrelly

Date	RA	Dec	Δ	R	Rise	Transit	Set	Mag	Con
	h m	° '	au	au	hh:mm	hh:mm	hh:mm		
04 Sep	00 07.1	−56 27	2.112	1.330		01:12		13.2	Phe
11 Sep	23 58.9	−57 44	2.060	1.297		00:36		12.9	Phe
18 Sep	23 48.9	−58 34	2.007	1.270		23:55		12.6	Tuc
25 Sep	23 38.0	−58 54	1.955	1.249		23:17		12.3	Tuc
02 Oct	23 27.4	−58 42	1.904	1.233		22:39		11.9	Tuc
09 Oct	23 17.9	−57 57	1.852	1.220		22:01		11.6	Tuc
16 Oct	23 10.6	−56 40	1.802	1.210		21:26		11.3	Tuc
23 Oct	23 06.0	−54 55	1.752	1.202	09:49	20:55	08:03	11.0	Gru
30 Oct	23 04.1	−52 43	1.703	1.195	10:10	20:25	06:42	10.7	Gru
06 Nov	23 05.0	−50 07	1.656	1.190	10:19	19:59	05:41	10.4	Gru
13 Nov	23 08.3	−47 09	1.610	1.185	10:24	19:35	04:47	10.0	Gru
20 Nov	23 13.9	−43 52	1.566	1.181	10:28	19:13	03:59	9.7	Gru
27 Nov	23 21.3	−40 15	1.524	1.178	10:30	18:52	03:17	9.4	Gru
04 Dec	23 30.3	−36 21	1.485	1.176	10:32	18:34	02:37	9.1	Scl
11 Dec	23 40.7	−32 10	1.449	1.175	10:34	18:16	02:01	8.9	Scl
18 Dec	23 52.2	−27 43	1.415	1.176	10:35	18:01	01:28	8.6	Scl
25 Dec	00 04.6	−23 04	1.386	1.179	10:36	17:45	00:56	8.4	Cet
01 Jan '22	00 17.9	−18 12	1.361	1.185	10:38	17:31	00:26	8.2	Cet
08 Jan'22	00 32.0	−13 12	1.340	1.196	10:39	17:17	23:55	8.1	Cet
15 Jan'22	00 46.8	−08 07	1.324	1.210	10:40	17:04	23:28	8.0	Cet
22 Jan'22	01 02.3	−03 00	1.313	1.229	10:42	16:52	23:01	7.9	Cet
29 Jan'22	01 18.6	+02 05	1.307	1.253	10:45	16:41	22:36	7.9	Cet
05 Feb'22	01 35.6	+07 04	1.307	1.283	10:48	16:30	22:12	7.9	Psc
12 Feb'22	01 53.5	+11 54	1.312	1.318	10:51	16:20	21:50	8.0	Ari
19 Feb'22	02 12.3	+16 29	1.323	1.358	10:56	16:12	21:28	8.2	Ari
26 Feb'22	02 32.1	+20 49	1.338	1.403	11:01	16:04	21:07	8.4	Ari
05 Mar'22	02 52.9	+24 50	1.358	1.453	11:08	15:58	20:47	8.6	Ari
12 Mar'22	03 14.8	+28 29	1.383	1.508	11:15	15:52	20:28	8.9	Ari
19 Mar'22	03 37.8	+31 46	1.412	1.567	11:23	15:48	20:11	9.2	Per
26 Mar'22	04 01.9	+34 38	1.445	1.630	11:32	15:44	19:56	9.6	Per
02 Apr'22	04 27.0	+37 05	1.481	1.697	11:41	15:42	19:42	9.9	Per
09 Apr'22	04 53.0	+39 06	1.520	1.767	11:49	15:40	19:31	10.3	Aur
16 Apr'22	05 19.5	+40 41	1.562	1.841	11:56	15:39	19:21	10.7	Aur

8P/Tuttle

Date	RA	Dec	Δ	R	Rise	Transit	Set	Mag	Con
	h m	° '	au	au	hh:mm	hh:mm	hh:mm		
03 Jul	05 32.5	+38 28	1.321	2.204	06:49	10:44	14:38	11.1	Aur
10 Jul	05 58.5	+35 50	1.260	2.147	06:35	10:42	14:49	10.7	Aur
17 Jul	06 23.8	+32 45	1.204	2.092	06:19	10:40	15:00	10.2	Aur
24 Jul	06 48.3	+29 13	1.154	2.039	06:02	10:37	15:11	9.8	Gem
31 Jul	07 12.1	+25 15	1.110	1.989	05:45	10:33	15:22	9.4	Gem
07 Aug	07 35.2	+20 50	1.074	1.941	05:26	10:28	15:32	9.1	Gem
14 Aug	07 58.0	+16 02	1.048	1.899	05:06	10:24	15:41	8.8	Cnc
21 Aug	08 20.4	+10 52	1.031	1.863	04:46	10:18	15:51	8.6	Cnc
28 Aug	08 42.8	+05 26	1.026	1.835	04:25	10:13	16:00	8.5	Hya
04 Sep	09 05.3	−00 13	1.032	1.816	04:05	10:08	16:10	8.6	Hya
11 Sep	09 28.2	−05 56	1.049	1.808	03:45	10:03	16:21	8.7	Hya
18 Sep	09 51.4	−11 38	1.076	1.812	03:25	09:59	16:32	8.9	Hya
25 Sep	10 15.2	−17 09	1.113	1.828	03:05	09:56	16:45	9.2	Hya
02 Oct	10 39.5	−22 24	1.157	1.857	02:45	09:52	16:58	9.6	Hya
09 Oct	11 04.5	−27 17	1.208	1.897	02:25	09:50	17:13	10.0	Hya
16 Oct	11 29.9	−31 42	1.265	1.946	02:06	09:47	17:28	10.5	Hya
23 Oct	11 55.7	−35 40	1.326	2.003	01:47	09:46	17:44	11.0	Hya
30 Oct	12 21.8	−39 07	1.390	2.067	01:28	09:44	18:00	11.4	Cen
06 Nov	12 48.1	−42 06	1.457	2.135	01:09	09:43	18:16	11.9	Cen
13 Nov	13 14.2	−44 38	1.525	2.204	00:50	09:42	18:32	12.4	Cen
20 Nov	13 40.0	−46 45	1.595	2.274	00:32	09:40	18:47	12.8	Cen
27 Nov	14 05.3	−48 30	1.667	2.343	00:13	09:38	19:01	13.3	Cen

C/2019 N1 (ATLAS)

Date	RA	Dec	Δ	R	Rise	Transit	Set	Mag	Con
	h m	° '	au	au	hh:mm	hh:mm	hh:mm		
07 Nov'20	13 33.2	−08 23	1.736	2.632	03:58	10:22	16:47	11.0	Vir
14 Nov'20	13 40.0	−12 04	1.721	2.574	03:27	10:02	16:37	10.9	Vir
21 Nov'20	13 47.0	−15 52	1.710	2.510	02:55	09:42	16:27	10.8	Vir
28 Nov'20	13 54.0	−19 50	1.705	2.442	02:22	09:21	16:19	10.8	Vir
05 Dec'20	14 01.1	−24 00	1.705	2.372	01:49	09:01	16:12	10.7	Hya
12 Dec'20	14 08.4	−28 22	1.710	2.300	01:13	08:40	16:08	10.6	Hya
19 Dec'20	14 15.9	−32 59	1.720	2.229	00:34	08:20	16:06	10.6	Cen
26 Dec'20	14 23.5	−37 51	1.734	2.160	23:47	08:01	16:09	10.6	Cen
02 Jan	14 31.4	−43 00	1.753	2.095	22:58	07:41	16:20	10.5	Lup
09 Jan	14 39.6	−48 25	1.777	2.037	21:55	07:22	16:44	10.5	Lup
16 Jan	14 48.3	−54 04	1.805	1.988	20:13	07:03	17:49	10.6	Lup
23 Jan	14 57.6	−59 56	1.837	1.950		06:45		10.6	Cir
30 Jan	15 08.0	−65 56	1.872	1.925		06:28		10.6	TrA
06 Feb	15 20.5	−71 59	1.911	1.913		06:13		10.7	Aps
13 Feb	15 38.0	−77 57	1.953	1.916		06:03		10.8	Aps
20 Feb	16 13.2	−83 42	1.998	1.934		06:13		10.9	Oct
27 Feb	20 11.9	−88 22	2.045	1.965		09:53		11.1	Oct
06 Mar	02 18.7	−85 00	2.095	2.009		15:15		11.2	Oct
13 Mar	03 02.1	−80 15	2.147	2.063		15:32		11.4	Hyi
20 Mar	03 21.3	−75 50	2.200	2.126		15:24		11.6	Hyi
27 Mar	03 34.6	−71 51	2.255	2.197		15:10		11.7	Hyi
03 Apr	03 45.5	−68 18	2.312	2.272		14:54		11.9	Hyi
10 Apr	03 55.1	−65 10	2.370	2.351		14:36		12.1	Ret
17 Apr	04 04.1	−62 26	2.429	2.431		14:17		12.3	Ret
24 Apr	04 12.6	−60 05	2.489	2.512		13:59		12.5	Ret
01 May	04 20.7	−58 06	2.551	2.592		13:39		12.6	Ret
08 May	04 28.5	−56 27	2.612	2.670		13:19		12.8	Dor
15 May	04 36.1	−55 07	2.675	2.745	01:43	13:00	00:19	13.0	Dor
22 May	04 43.3	−54 04	2.738	2.817	01:56	12:39	23:22	13.1	Dor
29 May	04 50.3	−53 19	2.801	2.885	01:52	12:18	22:45	13.3	Pic
05 Jun	04 56.9	−52 48	2.865	2.949	01:40	11:58	22:14	13.4	Pic

Processed image from the WISPR instrument on NASA's Parker Solar Probe of Comet NEOWISE, as seen on 5 July 2020. The lower, broader tail is the comet's dust tail, while the thinner, upper tail is the comet's ion tail. Credits: NASA/Johns Hopkins APL/Naval Research Lab/Parker Solar Probe/Guillermo Stenborg



BRIGHT DWARF AND MINOR PLANET POSITIONS (0 HR UT, EPOCH 2000.0)

As well as the planets, their moons and the comets, the Solar System contains numerous smaller bodies—dwarf and minor planets (asteroids). There are now hundreds of thousands of such bodies catalogued. Most of these are found in the asteroid belt between the orbits of Mars and Jupiter. The majority of these objects are extremely faint and difficult to observe. Many can be found by imaging the area, at least twice, over several days and detecting them as they move against the distant star field. The same can be achieved by observing the field and making drawings over several days to detect which *star* has moved. Be sure you have the right field of view. Only about sixty of these bodies can be considered bright (by amateur standards) and most of them only around their time of opposition.

Included are ephemerides for 14 bright minor or dwarf planets at opposition in 2021, plus 7 Iris (opposition 13 Jan 2022). These include the most well-known four (Ceres, Pallas, Juno and Vesta) with the rest reaching magnitude 9.5 or brighter. As only 15 bright ones are considered here, 1 Ceres is the only dwarf planet that makes the grade.

1 Ceres

Date	RA hh mm	Dec ° ′	Mag
Jul 10	03 28.7	+12 17	9.2
17	03 37.9	+12 51	9.2
24	03 46.7	+13 22	9.2
31	03 55.3	+13 49	9.1
Aug 7	04 03.4	+14 14	9.1
14	04 11.0	+14 35	9.0
21	04 18.1	+14 54	8.9
28	04 24.6	+15 10	8.9
Sep 4	04 30.4	+15 24	8.8
11	04 35.3	+15 35	8.7
18	04 39.3	+15 45	8.6
25	04 42.3	+15 53	8.5
Oct 2	04 44.1	+16 00	8.3
9	04 44.7	+16 06	8.2
16	04 44.0	+16 11	8.1
23	04 42.0	+16 16	7.9
30	04 38.6	+16 21	7.7
Nov 6	04 34.0	+16 25	7.6
13	04 28.3	+16 31	7.4
20	04 21.9	+16 36	7.2
27	04 14.9	+16 43	7.0
Dec 4	04 07.9	+16 51	7.2
11	04 01.2	+17 00	7.3
18	03 55.2	+17 12	7.5
25	03 50.1	+17 26	7.7

2 Pallas

Date	RA hh mm	Dec ° ′	Mag
Jun 19	23 26.7	+08 39	10.2
26	23 29.8	+08 42	10.1
Jul 3	23 32.2	+08 40	10.0
10	23 33.8	+08 29	9.9
17	23 34.4	+08 11	9.8
24	23 34.2	+07 43	9.7
31	23 33.1	+07 04	9.5
Aug 7	23 31.0	+06 15	9.4
14	23 28.0	+05 16	9.2
21	23 24.1	+04 06	9.1
28	23 19.7	+02 46	8.9
Sep 4	23 14.7	+01 19	8.7
11	23 09.4	−00 14	8.6
18	23 04.2	−01 50	8.7
25	22 59.2	−03 25	8.8
Oct 2	22 54.7	−04 57	9.0
9	22 50.9	−06 23	9.1
16	22 48.0	−07 41	9.2
23	22 46.1	−08 50	9.3
30	22 45.2	−09 49	9.5
Nov 6	22 45.4	−10 38	9.6
13	22 46.7	−11 17	9.7
20	22 49.0	−11 47	9.7
27	22 52.3	−12 07	9.8
Dec 4	22 56.4	−12 20	9.9

3 Juno

Date	RA hh mm	Dec ° ′	Mag
Mar 20	17 29.8	−09 34	11.1
27	17 32.6	−09 05	11.0
Apr 3	17 34.6	−08 33	11.0
10	17 35.5	−08 01	10.9
17	17 35.5	−07 27	10.8
24	17 34.4	−06 53	10.7
May 1	17 32.2	−06 19	10.5
8	17 29.1	−05 48	10.4
15	17 25.0	−05 18	10.3
22	17 20.1	−04 53	10.2
29	17 14.7	−04 31	10.2
Jun 5	17 08.8	−04 16	10.1
12	17 02.8	−04 06	10.1
19	16 56.9	−04 02	10.2
26	16 51.4	−04 06	10.2
Jul 3	16 46.5	−04 15	10.3
10	16 42.3	−04 31	10.4
17	16 39.0	−04 51	10.5
24	16 36.7	−05 17	10.6
31	16 35.4	−05 46	10.7
Aug 7	16 35.2	−06 18	10.8
14	16 35.9	−06 53	10.8
21	16 37.7	−07 29	10.9
28	16 40.4	−08 06	11.0
Sep 4	16 44.0	−08 43	11.0

4 Vesta

Date	RA hh mm	Dec ° ′	Mag
Jan 2	11 33.3	+09 50	7.1
9	11 36.8	+10 02	7.0
16	11 39.0	+10 23	6.8
23	11 39.9	+10 54	6.7
30	11 39.4	+11 35	6.5
Feb 6	11 37.4	+12 24	6.4
13	11 34.0	+13 19	6.2
20	11 29.3	+14 19	6.0
27	11 23.6	+15 20	5.9
Mar 6	11 17.3	+16 18	5.8
13	11 10.7	+17 09	5.9
20	11 04.3	+17 51	6.0
27	10 58.7	+18 22	6.2
Apr 3	10 54.0	+18 39	6.3
10	10 50.6	+18 45	6.4
17	10 48.7	+18 38	6.5
24	10 48.2	+18 20	6.7
May 1	10 49.2	+17 53	6.8
8	10 51.5	+17 17	6.9
15	10 55.1	+16 33	7.0
22	10 59.8	+15 43	7.1
29	11 05.6	+14 47	7.2
Jun 5	11 12.2	+13 45	7.3
12	11 19.6	+12 40	7.4
19	11 27.7	+11 30	7.4

6 Hebe

Date	RA hh mm	Dec ° ′	Mag
May 1	19 51.5	−08 09	10.3
8	19 56.3	−07 46	10.2
15	20 00.2	−07 25	10.0
22	20 02.8	−07 10	9.9
29	20 04.3	−07 01	9.7
Jun 5	20 04.5	−06 59	9.5
12	20 03.3	−07 06	9.4
19	20 00.8	−07 23	9.2
26	19 57.0	−07 51	9.0
Jul 3	19 52.0	−08 31	8.8
10	19 46.1	−09 21	8.6
17	19 39.5	−10 21	8.5
24	19 32.8	−11 29	8.5
31	19 26.4	−12 42	8.6
Aug 7	19 20.7	−13 57	8.7
14	19 16.1	−15 12	8.8
21	19 12.9	−16 25	9.0
28	19 11.3	−17 34	9.1
Sep 4	19 11.4	−18 37	9.2
11	19 13.2	−19 34	9.3
18	19 16.7	−20 24	9.4
25	19 21.7	−21 07	9.5
Oct 2	19 28.2	−21 42	9.6
9	19 36.0	−22 10	9.7
16	19 45.0	−22 30	9.8

7 Iris

Date	RA hh mm	Dec ° ′	Mag
Jul 10	03 54.1	+23 12	9.9
17	04 11.8	+23 53	9.9
24	04 29.4	+24 26	9.9
31	04 47.1	+24 51	9.9
Aug 7	05 04.5	+25 08	9.9
14	05 21.7	+25 18	9.8
21	05 38.7	+25 19	9.8
28	05 55.2	+25 13	9.8
Sep 4	06 11.2	+24 59	9.7
11	06 26.6	+24 39	9.7
18	06 41.4	+24 13	9.6
25	06 55.4	+23 42	9.6
Oct 2	07 08.6	+23 06	9.5
9	07 20.8	+22 27	9.4
16	07 31.9	+21 45	9.4
23	07 41.8	+21 01	9.3
30	07 50.4	+20 17	9.2
Nov 6	07 57.5	+19 33	9.1
13	08 03.1	+18 51	9.0
20	08 06.9	+18 11	8.8
27	08 08.9	+17 34	8.7
Dec 4	08 09.0	+17 03	8.6
11	08 07.0	+16 36	8.4
18	08 03.2	+16 15	8.3
25	07 57.7	+15 59	8.1

9 Metis

Date	RA hh mm	Dec ° ′	Mag
Jan 9	13 13.3	−01 17	11.0
16	13 19.4	−01 41	10.9
23	13 24.6	−01 59	10.8
30	13 28.6	−02 09	10.7
Feb 6	13 31.5	−02 12	10.6
13	13 33.0	−02 07	10.5
20	13 33.1	−01 55	10.3
27	13 31.8	−01 35	10.2
Mar 6	13 29.1	−01 10	10.0
13	13 25.0	−00 39	9.9
20	13 19.8	−00 05	9.7
27	13 13.7	+00 30	9.6
Apr 3	13 07.0	+01 04	9.5
10	13 00.2	+01 35	9.6
17	12 53.7	+01 59	9.7
24	12 47.8	+02 17	9.9
May 1	12 42.8	+02 26	10.1
8	12 39.0	+02 27	10.3
15	12 36.4	+02 19	10.4
22	12 35.0	+02 02	10.6
29	12 34.9	+01 39	10.7
Jun 5	12 36.1	+01 08	10.9
12	12 38.3	+00 32	11.0
19	12 41.5	−00 10	11.1
26	12 45.7	−00 56	11.2

12 Victoria

Date	RA hh mm	Dec ° ′	Mag
May 8	20 11.7	−13 00	10.5
15	20 20.2	−11 39	10.4
22	20 27.5	−10 16	10.2
29	20 33.5	−08 53	10.1
Jun 5	20 38.0	−07 31	9.9
12	20 41.0	−06 12	9.7
19	20 42.3	−04 57	9.6
26	20 42.0	−03 50	9.4
Jul 3	20 40.0	−02 52	9.2
10	20 36.5	−02 06	9.0
17	20 31.8	−01 34	8.9
24	20 26.4	−01 16	8.8
31	20 20.7	−01 14	8.8
Aug 7	20 15.3	−01 25	8.8
14	20 10.7	−01 49	9.0
21	20 07.4	−02 21	9.1
28	20 05.7	−02 59	9.3
Sep 4	20 05.7	−03 39	9.5
11	20 07.5	−04 20	9.7
18	20 11.1	−04 57	9.8
25	20 16.2	−05 29	10.0
Oct 2	20 22.9	−05 56	10.2
9	20 30.8	−06 16	10.3
16	20 39.8	−06 28	10.5
23	20 49.8	−06 33	10.6

14 Irene

Date	RA hh mm	Dec ° ′	Mag
Jan 2	08 57.2	+25 31	9.9
9	08 52.8	+26 30	9.7
16	08 47.1	+27 30	9.5
23	08 40.5	+28 28	9.4
30	08 33.4	+29 21	9.4
Feb 6	08 26.3	+30 05	9.5
13	08 19.9	+30 38	9.7
20	08 14.5	+31 01	9.8
27	08 10.7	+31 13	10.0
Mar 6	08 08.5	+31 16	10.1
13	08 08.1	+31 09	10.2
20	08 09.5	+30 55	10.4
27	08 12.5	+30 34	10.5
Apr 3	08 17.1	+30 07	10.6
10	08 23.1	+29 35	10.7
17	08 30.3	+28 58	10.8
24	08 38.6	+28 16	10.9
May 1	08 47.7	+27 29	11.0
8	08 57.6	+26 37	11.0
15	09 08.2	+25 41	11.1
22	09 19.3	+24 41	11.1
29	09 30.8	+23 36	11.2
Jun 5	09 42.7	+22 28	11.2
12	09 54.8	+21 15	11.3
19	10 07.2	+19 59	11.3

15 Eunomia

Date	RA hh mm	Dec ° ′	Mag
Jan 2	08 33.6	+17 25	8.8
9	08 26.8	+17 13	8.6
16	08 19.3	+17 03	8.5
23	08 11.5	+16 54	8.4
30	08 04.0	+16 46	8.6
Feb 6	07 57.2	+16 37	8.8
13	07 51.5	+16 29	9.0
20	07 46.9	+16 20	9.2
27	07 43.9	+16 10	9.4
Mar 6	07 42.2	+15 60	9.5
13	07 42.0	+15 49	9.7
20	07 43.2	+15 36	9.8
27	07 45.6	+15 22	10.0
Apr 3	07 49.1	+15 06	10.1
10	07 53.6	+14 49	10.2
17	07 59.0	+14 29	10.3
24	08 05.2	+14 07	10.4
May 1	08 12.0	+13 42	10.5
8	08 19.3	+13 14	10.6
15	08 27.2	+12 44	10.7
22	08 35.4	+12 11	10.7
29	08 44.0	+11 35	10.8
Jun 5	08 52.9	+10 56	10.8
12	09 02.0	+10 14	10.9
19	09 11.3	+09 29	10.9

18 Melpomene

Date	RA hh mm	Dec ° ′	Mag
Jan 2	09 24.4	+08 06	10.1
9	09 20.0	+08 44	9.9
16	09 14.4	+09 32	9.8
23	09 07.8	+10 27	9.7
30	09 00.7	+11 28	9.5
Feb 6	08 53.6	+12 31	9.6
13	08 46.8	+13 33	9.8
20	08 40.9	+14 32	10.0
27	08 36.0	+15 26	10.2
Mar 6	08 32.6	+16 13	10.3
13	08 30.6	+16 52	10.5
20	08 30.0	+17 24	10.7
27	08 31.0	+17 48	10.9
Apr 3	08 33.2	+18 05	11.0
10	08 36.6	+18 16	11.2
17	08 41.2	+18 20	11.3
24	08 46.6	+18 18	11.4
May 1	08 52.9	+18 10	11.5
8	08 60.0	+17 57	11.6
15	09 07.6	+17 39	11.7
22	09 15.7	+17 17	11.8
29	09 24.3	+16 50	11.9
Jun 5	09 33.2	+16 20	11.9
12	09 42.5	+15 45	12.0
19	09 52.0	+15 07	12.0

29 Amphitrite

Date	RA hh mm	Dec ° ′	Mag
Jan 2	10 55.9	+11 59	10.2
9	10 56.0	+11 57	10.1
16	10 54.6	+12 03	9.9
23	10 51.9	+12 15	9.8
30	10 47.8	+12 33	9.6
Feb 6	10 42.5	+12 55	9.5
13	10 36.3	+13 19	9.3
20	10 29.5	+13 43	9.1
27	10 22.5	+14 05	9.2
Mar 6	10 15.8	+14 23	9.4
13	10 09.7	+14 36	9.6
20	10 04.6	+14 42	9.7
27	10 00.7	+14 42	9.9
Apr 3	09 58.1	+14 34	10.1
10	09 56.9	+14 21	10.2
17	09 57.0	+14 02	10.4
24	09 58.4	+13 37	10.5
May 1	10 00.9	+13 07	10.6
8	10 04.5	+12 32	10.7
15	10 09.0	+11 53	10.8
22	10 14.4	+11 10	10.9
29	10 20.5	+10 24	11.0
Jun 5	10 27.2	+09 34	11.1
12	10 34.5	+08 41	11.2
19	10 42.2	+07 45	11.2

40 Harmonia

Date	RA hh mm	Dec ° ′	Mag
Jul 10	00 43.0	−00 36	11.2
17	00 49.9	−00 11	11.1
24	00 55.8	+00 06	10.9
31	01 00.7	+00 16	10.8
Aug 7	01 04.3	+00 17	10.7
14	01 06.6	+00 09	10.5
21	01 07.5	−00 07	10.3
28	01 06.9	−00 32	10.2
Sep 4	01 04.7	−01 05	10.0
11	01 01.0	−01 44	9.8
18	00 56.0	−02 27	9.6
25	00 50.1	−03 11	9.5
Oct 2	00 43.6	−03 53	9.4
9	00 36.9	−04 30	9.5
16	00 30.7	−04 59	9.7
23	00 25.2	−05 18	9.9
30	00 20.9	−05 26	10.0
Nov 6	00 18.1	−05 22	10.2
13	00 16.7	−05 07	10.4
20	00 16.8	−04 41	10.6
27	00 18.4	−04 07	10.7
Dec 4	00 21.4	−03 24	10.9
11	00 25.7	−02 34	11.0
18	00 31.0	−01 39	11.1
25	00 37.4	−00 38	11.2

43 Ariadne

Date	RA hh mm	Dec ° ′	Mag
May 29	21 45.3	−11 10	11.3
Jun 5	21 53.3	−10 06	11.2
12	21 60.0	−09 07	11.0
19	22 05.3	−08 13	10.9
26	22 09.0	−07 26	10.7
Jul 3	22 11.2	−06 47	10.6
10	22 11.6	−06 17	10.4
17	22 10.2	−05 57	10.2
24	22 07.1	−05 48	10.1
31	22 02.5	−05 50	9.9
Aug 7	21 56.8	−06 01	9.7
14	21 50.3	−06 21	9.5
21	21 43.6	−06 47	9.5
28	21 37.3	−07 16	9.7
Sep 4	21 32.0	−07 46	9.9
11	21 28.0	−08 13	10.2
18	21 25.5	−08 36	10.4
25	21 24.8	−08 53	10.6
Oct 2	21 25.7	−09 03	10.8
9	21 28.3	−09 07	11.1
16	21 32.3	−09 03	11.2
23	21 37.6	−08 52	11.4
30	21 44.1	−08 35	11.6
Nov 6	21 51.6	−08 10	11.7
13	21 59.9	−07 39	11.9

89 Julia

Date	RA hh mm	Dec ° ′	Mag
Jun 5	22 21.7	−12 24	11.0
12	22 27.0	−11 08	10.8
19	22 31.2	−09 52	10.7
26	22 34.1	−08 38	10.5
Jul 3	22 35.7	−07 25	10.4
10	22 35.8	−06 14	10.2
17	22 34.4	−05 06	10.0
24	22 31.3	−04 03	9.8
31	22 26.7	−03 03	9.6
Aug 7	22 20.7	−02 09	9.4
14	22 13.6	−01 21	9.2
21	22 05.8	−00 41	9.1
28	21 57.8	−00 07	9.1
Sep 4	21 50.2	+00 20	9.2
11	21 43.4	+00 41	9.4
18	21 37.8	+00 58	9.5
25	21 33.9	+01 12	9.7
Oct 2	21 31.7	+01 25	9.9
9	21 31.2	+01 38	10.0
16	21 32.5	+01 53	10.2
23	21 35.4	+02 11	10.3
30	21 39.7	+02 33	10.5
Nov 6	21 45.4	+02 59	10.6
13	21 52.3	+03 29	10.7
20	22 00.2	+04 04	10.8

METEOR SHOWERS

What is a meteor shower?

A meteor shower is no more than the leftover debris from a comet. A comet has been best described as a *dirty snowball*, a conglomerate of ice, gas, dust and larger particles that become meteoroids when freed from the nucleus. When a comet is near perihelion, very fine dust particles are released from the nucleus as it is warmed by the Sun. These particles are then pushed away by solar radiation or solar wind to form the classic dust tail of a comet. Pieces that are too large to be blown away end up strewn along the comet's orbit to become meteoroids.

Ultimately the meteoroids spread out over the comet's orbit, somewhat like an elliptical-shaped donut. The effects of solar radiation and the slight gravity tug from the planets will, over time, break up the stream. If the Earth passes through a meteoroid stream we will experience a meteor shower. A typical visual meteor may be as small as a grain of sand, up to the size of a small pea. Particles in space that strike the Earth's atmosphere will have a minimum speed of 11 km/s (if the body is at rest when swept up by the Earth), and an upper limit of 73 km/s. The Leonid meteors, at 71 km/s, are the fastest of the showers.

Incredible velocities such as these (a bullet from a rifle travels at about one kilometre per second) result in the meteor's kinetic energy being converted to heat when it strikes the atmosphere at an altitude of about 100 km. The surrounding air is heated to incandescence by friction and as a consequence we can observe these tiny bodies as they self-destruct in our atmosphere.

Individual meteors during a shower appear to originate from a common point in the sky, known as the radiant. This focal point is often named after the constellation in which the meteors appear. The particles of meteoroid streams travel though space in parallel paths. The apparent divergence from the radiant is only an illusion, due to the effect of perspective. The way that trees and buildings converge on either side of a long straight road is the same effect that is seen when a meteor shower occurs far above an observer.

The table of Meteor Showers has been compiled from the Meteor Shower Calendar produced by the International Meteor Organization (IMO). It is the most accurate listing for naked-eye meteor observing available today. The table is complete in that both northern and southern showers are listed. Serious meteor observing should be carried out under dark skies, and preferably without the Moon. The best showers for this year, taking into consideration the lunar phase, are summarised in each monthly section.

In addition to the showers catalogued, an average of about 5 to 10 sporadic or random meteors are visible per hour under dark sky conditions. More meteors are seen in the morning sky than in the evening; as the morning sky is facing the Earth's motion in space we tend to *run into* and *sweep up* meteors, whereas evening meteors must have sufficient velocity to catch up to the speeding Earth. Amateurs wishing to follow up an interest in meteors, and even make a contribution to meteor science, should contact the International Meteor Organization. www.imo.net/

SHOWER	MOON PHASE	ACTIVITY DURATION	MAX ACT	RADIANT		VEL km/s	ZHR
				RA	Dec		
Quadrantids (QUA)	NM	Dec 28 – Jan 12	Jan 03	230˚	+49˚	41	110
alpha-Centaurids (ACE)	LQ	Jan 31 – Feb 20	Feb 08	210˚	-59˚	58	6
gamma-Normids (GNO)	NM	Feb 25 – Mar 28	Mar 14	239˚	-50˚	56	6
Lyrids (LYR)	FQ	Apr 14 – Apr 30	Apr 22	271˚	+34˚	49	18
pi-Puppids (PPU)*	FQ	Apr 15 – Apr 28	Apr 23	110˚	-45˚	18	var
eta-Aquarids (ETA)	LQ	Apr 19 – May 28	May 06	338˚	-01˚	66	50
eta-Lyrids (ELY)	NM	May 03 – May 14	May 08	287˚	+44˚	43	3
June Bootids (JBO)*	FM	Jun 22 – Jul 02	Jun 27	224˚	+48˚	18	var
Pisces Austrinids (PAU)	LQ	Jul 15 – Aug 10	Jul 29	341˚	-30˚	35	5
Southern delta-Aquarids (SDA)	LQ	Jul 12 – Aug 23	Jul 30	340˚	-16˚	41	25
alpha-Capricornids (CAP)	LQ	Jul 03 – Aug 15	Jul 30	307˚	-10˚	23	5
Perseids (PER)	FQ	Jul 17 – Aug 24	Aug 12	048˚	+58˚	59	100
kappa-Cygnids (KCG)	FQ	Aug 03 – Aug 25	Aug 17	286˚	+59˚	25	3
Aurigids (AUR)	LQ	Aug 28 – Sep 05	Sep 01	091˚	+39˚	66	6
September Perseids (SPE)	NM	Sep 05 – Sep 21	Sep 09	048˚	+40˚	64	5
Draconids (DRA)*	NM	Oct 06 – Oct 10	Oct 08	262˚	+54˚	20	10
Southern Taurids (STA)	FQ	Sep 10 – Nov 20	Oct 10	032˚	+09˚	27	5
delta-Aurigids (DAU)	FQ	Oct 10 – Oct 18	Oct 11	084˚	+44˚	64	2
epsilon-Geminids (EGE)	FM	Oct 14 – Oct 27	Oct 18	102˚	+27˚	70	3
Orionids (ORI)	FM	Oct 02 – Nov 07	Oct 21	095˚	+16˚	66	20
Leo Minorids (LMI)	FM	Oct 19 – Oct 27	Oct 24	162˚	+37˚	62	2
Northern Taurids (NTA)	FQ	Oct 20 – Dec 10	Nov 12	058˚	+22˚	29	5
Leonids (LEO)	FM	Nov 06 – Nov 30	Nov 18	152˚	+22˚	71	10
alpha-Monocerotids (AMO)	FM	Nov 15 – Nov 25	Nov 21	117˚	+01˚	65	Var
Phoenicids (PHO)	NM	Nov 28 – Dec 09	Dec 02	018˚	-53˚	18	Var
Puppid-Velids (PUP)	NM	Dec 01 – Dec 15	Dec 07	123˚	-45˚	40	10
Monocerotids (MON)	FQ	Dec 05 – Dec 20	Dec 09	100˚	+08˚	42	3
sigma-Hydrids (HYD)	FQ	Dec 03 – Dec 20	Dec 09	127˚	+02˚	58	7
Geminids (GEM)	FQ	Dec 04 – Dec 20	Dec 13	112˚	+33˚	35	150
Coma Berenicids (COM)	FM	Dec 12 – Dec 23	Dec 16	175˚	+18˚	65	3
Dec. Leonis Minorids (DLM)	FM	Dec 05 – Feb 04	Dec 19	161˚	+30˚	64	5
Ursids (URS)	FM	Dec 17 – Dec 26	Dec 22	217˚	+75˚	33	10

Table Notes (above)

Shower Name The shower is named after the constellation (sometimes obsolete) in which the radiant appears, or a bright star near that point. A shower marked with an asterisk (*) is only occasionally active.

Moon Phase The phase of the Moon nearest the date of maximum activity. If a Full Moon occurs near a shower's maximum period, only the very brightest of meteors will be seen.

Activity Duration The approximate dates when the shower is active.

Max Act The date when maximum activity can be expected.

Radiant The position of the shower radiant in right ascension and declination (RA is expressed in degrees). These coordinates refer to the radiant position on the date of maximum activity.

Vel The geocentric velocity through the atmosphere in kilometres per second. The range can be from about 11 km/s (very slow) to 71 km/s (very fast), medium speed is about 40 km/s.

ZHR Zenithal Hourly Rate at peak period. A theoretical rate assuming the radiant to be at the zenith with a sky limiting magnitude of 6.5 (perfect conditions).

CONSTELLATIONS — Abbreviations and Culmination at 9 pm

Name	Genitive	Abr.	Map	Cul.
Andromeda	Andromedae	And	3, 9	Nov 23
Antlia	Antliae	Ant	4, 6	Apr 10
Apus	Apodis	Aps	1	Jul 5
Aquarius	Aquarii	Aqr	8	Oct 9
Aquila	Aquilae	Aql	8, 9	Aug 30
Ara	Arae	Ara	1, 6	Jul 25
Aries	Arietis	Ari	3	Dec 14
Auriga	Aurigae	Aur	3, 5	Feb 4
Boötes	Boötis	Boo	7	Jun 16
Caelum	Caeli	Cae	2, 4	Jan 15
Camelopardalis	Camelopardalis	Cam	3, 5	Feb 6
Cancer	Cancri	Cnc	5, 4	Mar 16
Canes Venatici	Canum Venaticorum	CVn	5, 7	May 22
Canis Major	Canis Majoris	CMa	4, 2	Feb 16
Canis Minor	Canis Minoris	CMi	5, 4	Feb 28
Capricornus	Capricorni	Cap	8	Sep 22
Carina	Carinae	Car	1, 4	Mar 17
Cassiopeia	Cassiopeiae	Cas	3, 9	Nov 23
Centaurus	Centauri	Cen	1, 6	May 14
Cepheus	Cephei	Cep	9, 3	Nov 13
Cetus	Ceti	Cet	2, 3	Nov 29
Chamaeleon	Chamaeleontis	Cha	1	Apr 15
Circinus	Circini	Cir	1, 6	Jun 14
Columba	Columbae	Col	4, 2	Feb 1
Coma Berenices	Comae Berenices	Com	7, 5	May 17
Corona Australis	Coronae Australis	CrA	8, 6	Aug 14
Corona Borealis	Coronae Borealis	CrB	7	Jul 3
Corvus	Corvi	Crv	6, 4	May 12
Crater	Crateris	Crt	4, 6	Apr 26
Crux	Crucis	Cru	1	May 12
Cygnus	Cygni	Cyg	9	Sep 13
Delphinus	Delphini	Del	9, 8	Sep 14
Dorado	Doradus	Dor	2, 1	Jan 31
Draco	Draconis	Dra	7, 9	Jul 8
Equuleus	Equulei	Equ	9, 8	Sep 22
Eridanus	Eridani	Eri	2, 1	Dec 25
Fornax	Fornacis	For	2	Dec 17
Gemini	Geminorum	Gem	5, 4	Feb 19
Grus	Gruis	Gru	8, 1	Oct 12
Hercules	Herculis	Her	7, 9	Jul 28
Horologium	Horologii	Hor	2, 1	Dec 25
Hydra	Hydrae	Hya	4, 6	Apr 29
Hydrus	Hydri	Hyi	1	Dec 10
Indus	Indi	Ind	1, 8	Sep 26
Lacerta	Lacertae	Lac	9	Oct 12
Leo	Leonis	Leo	5, 7	Apr 15
Leo Minor	Leonis Minoris	LMi	5, 7	Apr 9
Lepus	Leporis	Lep	2, 4	Jan 28
Libra	Librae	Lib	6	Jun 23
Lupus	Lupi	Lup	6	Jun 23
Lynx	Lyncis	Lyn	5, 3	Mar 5
Lyra	Lyrae	Lyr	9, 7	Aug 18
Mensa	Mensae	Men	1	Jan 28
Microscopium	Microscopii	Mic	8	Sep 18
Monoceros	Monocerotis	Mon	4, 5	Feb 19
Musca	Muscae	Mus	1	May 14
Norma	Normae	Nor	6, 1	Jul 3
Octans	Octantis	Oct	1	Circum
Ophiuchus	Ophiuchi	Oph	6, 7	Jul 26
Orion	Orionis	Ori	2, 3	Jan 27
Pavo	Pavonis	Pav	1, 8	Aug 29
Pegasus	Pegasi	Peg	9, 3	Oct 16
Perseus	Persei	Per	3	Dec 22
Phoenix	Phoenicis	Phe	2, 8	Nov 18
Pictor	Pictoris	Pic	1, 2	Jan 30
Pisces	Piscium	Psc	3, 9	Nov 11
Piscis Austrinus	Piscis Austrini	PsA	8	Oct 9
Puppis	Puppis	Pup	4, 2	Feb 22
Pyxis	Pyxidis	Pyx	4	Mar 21
Reticulum	Reticuli	Ret	1	Jan 3
Sagitta	Sagittae	Sge	9	Aug 30
Sagittarius	Sagittarii	Sgr	8, 6	Aug 21
Scorpius	Scorpii	Sco	6, 8	Jul 18
Sculptor	Sculptoris	Scl	2, 8	Nov 10
Scutum	Scuti	Sct	8	Aug 15
Serpens	Serpentis	Ser	6, 7	Jul 21
Sextans	Sextantis	Sex	4	Apr 8
Taurus	Tauri	Tau	3, 5	Jan 14
Telescopium	Telescopii	Tel	8, 1	Aug 24
Triangulum	Trianguli	Tri	3	Dec 7
Triangulum Australe	Trianguli Australis	TrA	1	Jul 7
Tucana	Tucanae	Tuc	1	Nov 1
Ursa Major	Ursae Majoris	UMa	5, 7	Apr 25
Ursa Minor	Ursae Minoris	UMi	7	Jun 27
Vela	Velorum	Vel	4, 1	Mar 30
Virgo	Virginis	Vir	6, 7	May 26
Volans	Volantis	Vol	1	Mar 4
Vulpecula	Vulpeculae	Vul	9	Sep 8

BRIGHTEST and NEAREST STARS (next page)

The column descriptions are:

Designation The name of the star in the system created by Bayer, who numbered the stars in the constellations using Greek letters (p. 152). They were usually ordered by their brightness, Alpha being the brightest in most cases.

Name Common name for each star.

Constellation The star's constellation.

RA and Dec. The position of the star, epoch 2000.0.

Magnitude App. The apparent magnitude as seen in the sky.

Magnitude Abs. The absolute magnitude. This is a good indication of how the stars' true luminosities compare. It is the brightness of the star if placed at a distance of 10 parsecs (approximately 32.6 light-years) from Earth.

Spectral Type The spectral classification of the star (see below).

Parallax see glossary.

Proper Motion see glossary.

Distance, ly is light-year and **pc** is parsec, see glossary.

Note (d) is a visual double star.
(sb) is a spectroscopic binary.
(eb) is an eclipsing binary.
(v) indicates the star is variable.

The spectral type of a star gives a broad indication of its temperature and colour. The primary classes are **O**, **B**, **A**, **F**, **G**, **K** and **M**, remembered by the mnemonic **O**h **B**e **A** **F**ine **G**irl(**G**uy) **K**iss **M**e.

There are also the *colder* star classes **L** and **T**. The classes are then broken down into ten subclasses (1 to 10) and also given a luminosity class I, II, III, IV, etc. A discussion of this is beyond this publication.

- The **O** class stars are the hottest blue stars.
- **B** and **A** are white (e.g., Sirius, Rigel).
- **F** and **G** are yellow (e.g., Capella, and the Sun).
- Late **K** (subclass > 5) and **M** stars are the cooler orange and red stars (e.g., Aldebaran, Betelgeuse).

It is an interesting exercise trying to see the colour of stars, but it is worthwhile knowing the limitations of the human eye. The photosensitive part of the eye is the retina. It consists of two types of light receptors, rods and cones. The cones perceive colour and rods see only shades of grey. The cones only work when there is sufficient light. Starlight, to the unaided eye, activates rods and cones to different degrees. Faint stars are only seen as grey (that is no colour).

The colours of stars can be imaged simply. Mount a camera on a tripod and take a time exposure of several minutes. The resulting star trails often show the colours very well. An equatorially tracked time exposure (for example piggy-backed on a telescope) with the camera slightly out of focus results in nicely coloured discs of the brightest stars. If in focus, the colour of the brightest stars can be lost as their images can saturate the detector. All such photography should be conducted in country areas, away from city lights.

THE BRIGHTEST STARS

	Designation	Name	Constellation	RA (2000.0)	Dec (2000.0)	Magnitude App	Magnitude Abs	Spectral Type	Parallax	Distance pc	Distance ly	Note
1	α CMa	Sirius	Canis Major	06 45.1	−16 43	−1.44	1.5	A1 V	0.3800	2.63	8.58	d
2	α Car	Canopus	Carina	06 23.9	−52 42	−0.74	−5.6	F0 Ib	0.0104	96	310	
3	α Cen	Rigil Kent	Centaurus	14 39.6	−60 50	−0.28	4.1	G2V + K0V	0.7472	1.34	4.37	d
4	α Boo	Arcturus	Boötes	14 15.7	+19 11	−0.05	−0.3	K2 III	0.0889	11.3	36.7	
5	α Lyr	Vega	Lyra	18 36.9	+38 47	0.03	0.6	A0 V	0.1289	7.76	25.3	v
6	α Aur	Capella	Auriga	05 16.7	+46 00	0.08	−0.5	G8III + G0III	0.0773	12.9	42.2	sb, v
7	β Ori	Rigel	Orion	05 14.5	−08 12	0.15	−6.8	B8 Ia	0.0042	240	780	d, v
8	α CMi	Procyon	Canis Minor	07 39.3	+05 14	0.38	2.7	F5 IV–V	0.2861	3.50	11.4	d
9	α Eri	Achernar	Eridanus	01 37.7	−57 14	0.45	−2.8	B5 IV	0.0227	44.1	144	v
10	α Ori	Betelgeuse	Orion	05 55.2	+07 24	0.50	−5.2	M2 Iab	0.0076	131	430	v
11	β Cen	Hadar	Centaurus	14 03.8	−60 22	0.61	−5.4	B1 II + B	0.0062	161	525	d, v
12	α Cru	Acrux	Crux	12 26.6	−63 06	0.74	−4.2	B0.5IV + B0.5V	0.0102	98	320	d
13	α Aql	Altair	Aquila	19 50.8	+08 52	0.76	2.2	A7 IV–V	0.1950	5.13	16.7	
14	α Tau	Aldebaran	Taurus	04 35.9	+16 31	0.87	−0.6	K5 III	0.0501	20.0	65	v
15	α Sco	Antares	Scorpius	16 29.4	−26 26	0.96	−5.1	M1.5Iab + B4V	0.0067	150	490	d, v
16	α Vir	Spica	Virgo	13 25.2	−11 10	0.98	−3.5	B1III–IV + B2V	0.0124	80	262	sb, v
17	β Gem	Pollux	Gemini	07 45.3	+28 02	1.15	1.1	K0 III	0.0967	10.3	33.7	
18	α PsA	Fomalhaut	Piscis Austrinus	22 57.7	−29 37	1.16	1.7	A3 V	0.1301	7.69	25.1	
19	α Cyg	Deneb	Cygnus	20 41.4	+45 17	1.25	−7.2	A2 Ia	0.0020	500	1600	v
20	β Cru	Mimosa	Crux	12 47.7	−59 41	1.26	−3.9	B0.5 III	0.0093	108	353	v
21	α Leo	Regulus	Leo	10 08.4	+11 58	1.36	−0.5	B7 V	0.0421	23.8	78	d
22	ε CMa	Adhara	Canis Major	06 58.6	−28 58	1.50	−4.1	B2 II	0.0076	132	430	d
23	α Gem	Castor	Gemini	07 34.6	+31 53	1.58	0.6	A1V + Am	0.0633	15.8	52	d, sb
24	λ Sco	Shaula	Scorpius	17 33.6	−37 06	1.62	−5.0	B1.5 III	0.0046	215	700	sb, v
25	γ Cru	Gacrux	Crux	12 31.2	−57 07	1.63	−0.5	M3 III	0.0371	27.0	88	v
26	γ Ori	Bellatrix	Orion	05 25.1	+06 21	1.64	−2.7	B2 III	0.0134	75	243	
27	β Tau	Elnath	Taurus	05 26.3	+28 36	1.65	−1.4	B7 III	0.0249	40.2	131	
28	β Car	Miaplacidus	Carina	09 13.2	−69 43	1.67	−1.0	A0 III	0.0293	34.1	111	
29	ε Ori	Alnilam	Orion	05 36.2	−01 12	1.69	−6.4	B0 Ia	0.0024	410	1340	
30	γ Vel	Regor	Vela	08 09.5	−47 20	1.70	−5.4	O9Ib + WC8	0.0039	258	840	sb, v

THE NEAREST STARS

Note, this list does not include some recently discovered brown dwarf stars.

No	Star Name		Constellation	RA 2000.0 hh mm.m	Dec ° '	Magnitude Apparent	Magnitude Absolute	Spect Type	Parallax "	Proper Motion "/yr	Distance pc	Distance ly
--	Sun					−26.72	4.85	G2 V				
1	Proxima Centauri		Centaurus	14 29.7	−62 40	11.09	15.53	M5.5 V	0.7720	3.85	1.30	4.23
	Alpha Centauri	A	Centaurus	14 39.6	−60 50	0.01	4.38	G2 V	0.7472	3.71	1.34	4.37
		B				1.34	5.71	K0 V				
2	Barnard's Star		Ophiuchus	17 57.8	+04 41	9.53	13.22	M4.0 V	0.5470	10.36	1.83	5.96
3	Wolf 359		Leo	10 56.5	+07 00	13.44	16.55	M6.0 V	0.4191	4.70	2.39	7.78
4	Lalande 21185		Ursa Major	11 03.3	+35 58	7.47	10.44	M2.0 V	0.3934	4.80	2.54	8.29
5	Sirius	A	Canis Major	06 45.1	−16 43	−1.44	1.46	A1 V	0.3800	1.34	2.63	8.58
		B				8.44	11.34	DA2				
6	L 726-8 (UV Ceti)	A	Cetus	01 39.0	−17 57	12.54	15.40	M5.5 V	0.3737	3.37	2.68	8.73
		B				12.99	15.85	M6.0 V				
7	Ross 154		Sagittarius	18 49.8	−23 50	10.43	13.07	M3.5 V	0.3369	0.67	2.97	9.68
8	Ross 248		Andromeda	23 41.9	+44 10	12.29	14.79	M5.5 V	0.3160	1.62	3.16	10.32
9	Epsilon Eridani		Eridanus	03 32.9	−09 27	3.73	6.19	K2 V	0.3100	0.98	3.23	10.52
10	Lacaille 9352		Piscis Austrinus	23 05.9	−35 51	7.34	9.75	M1.5 V	0.3036	6.90	3.29	10.74
11	Ross 128		Virgo	11 47.7	+00 48	11.13	13.51	M4.0 V	0.2987	1.36	3.35	10.92
12	L 789-6 (EZ Aquarii)	A	Aquarius	22 38.6	−15 18	13.33	15.64	M5.0 V	0.2895	3.25	3.45	11.27
		B				13.27	15.58	M				
		C				14.03	16.34	M				
13	Procyon	A	Canis Minor	07 39.3	+05 14	0.38	2.66	F5 IV–V	0.2861	1.26	3.50	11.40
		B				10.70	12.98	DA				
14	61 Cygni	A	Cygnus	21 06.9	+38 45	5.21	7.49	K5.0 V	0.2860	5.28	3.50	11.40
		B				6.03	8.31	K7.0 V				
15	Σ 2398	A	Draco	18 42.8	+59 38	8.90	11.16	M3.0 V	0.2830	2.24	3.53	11.53
		B				9.69	11.95	M3.5 V				
16	Groombridge 34	A	Andromeda	00 18.4	+44 01	8.08	10.32	M1.5 V	0.2806	2.92	3.56	11.63
		B				11.06	13.30	M3.5 V				
17	Epsilon Indi		Indus	22 03.4	−56 47	4.69	6.89	K5 Ve	0.2758	4.70	3.63	11.83
18	DX Cancri		Cancer	08 29.8	+26 47	14.78	16.98	M6.5 V	0.2758	1.29	3.63	11.83
19	Tau Ceti		Cetus	01 44.1	−15 56	3.49	5.68	G8 Vp	0.2744	1.92	3.64	11.89
20	GJ 1061		Horologium	03 36.0	−44 31	13.03	15.21	M5.5 V	0.2720	0.81	3.68	11.99
21	YZ Ceti		Cetus	01 12.5	−17 00	12.02	14.17	M4.5 V	0.2688	1.37	3.72	12.13
22	Luyten's Star		Canis Minor	07 27.4	+05 14	9.86	11.97	M3.5 V	0.2638	3.74	3.79	12.37

DEEP SKY OBJECTS

Catalogue #	Bennett	Type	Con	Mag	Size	RA	Dec	Mth 10pm	Map	Notes
NGC 55	1	G	Scl	7.9	32'×6'	00 14.9	–39 11	10		A bright galaxy in the Sculptor Group
NGC 104	2	GC	Tuc	4.0	43'	00 24.1	–72 05	10	1	47 Tucanae
NGC 205		G	And	8.1	22'×11'	00 40.4	+41 41	10	3,9	M110
NGC 221		G	And	8.1	9'×7'	00 42.7	+40 52	10	3,9	M32
NGC 224		G	And	3.4	3.2°×1.0°	00 42.7	+41 16	10	3,9	M31, Andromeda Galaxy
NGC 247	3	G	Cet	9.2	21'×7'	00 47.1	–20 46	10		
NGC 253	4	G	Scl	7.2	28'×7'	00 47.6	–25 18	10		Silver Coin galaxy. Large, bright edge-on spiral
SMC		G	Tuc	2.3	6.6°×3.7°	00 52.6	–72 48	10	1	Small Magellanic Cloud
NGC 288	5	GC	Scl	8.1	14'	00 52.8	–26 35	10		Near galaxy NGC 253
NGC 300	6	G	Scl	8.3	22'×16'	00 54.9	–37 41	10		
NGC 346		BN	Tuc	10.3	14'×11'	00 59.1	–72 11	10		Nebula in the SMC
NGC 362	7	GC	Tuc	6.8	13'	01 03.2	–70 51	11	1	
NGC 598		G	Tri	5.7	71'×42'	01 33.9	+30 39	11	3	M33, Triangulum Galaxy
NGC 613	8	G	Scl	10.1	6'×4'	01 34.3	–29 25	11		
NGC 628		G	Psc	9.4	11'×10'	01 36.7	+15 47	11	3	M74
NGC 891		G	And	9.9	14'×3'	02 22.6	+42 21	11		
NGC 1039		OC	Per	5.2	35'	02 42.1	+42 47	11	3	M34
NGC 1068	9	G	Cet	8.9	7'×6'	02 42.7	–00 01	11	2	M77, Cetus A
NGC 1097	10	G	For	9.5	9'×6'	02 46.3	–30 17	11		
NGC 1232	10a	G	Eri	10.1	7'×7'	03 09.8	–20 35	12		
NGC 1261	11	GC	Hor	8.4	7'	03 12.3	–55 13	12		
NGC 1269		G	Eri	8.5	11'×10'	03 17.3	–41 06	12		
NGC 1291	12	G	Eri	8.6	10'×8'	03 17.3	–41 08	12		
NGC 1313	13	G	Ret	8.7	9'×7'	03 18.3	–66 30	12		
NGC 1316	14	G	For	8.5	12'×9'	03 22.7	–37 13	12		
NGC 1350	14a	G	For	10.7	5'×3'	03 31.1	–33 38	12		
NGC 1360	15	PN	For	9.4	11'×8'	03 33.2	–25 52	12		
NGC 1365	16	G	For	9.6	11'×6'	03 33.6	–36 08	12		
NGC 1380	17	G	For	10.2	5'×2'	03 36.5	–34 59	12		
NGC 1387	18	G	For	10.9	3'×3'	03 37.0	–35 31	12		
NGC 1399	19	G	For	9.6	7'×7'	03 38.5	–35 27	12		In Fornax galaxy group
NGC 1398	19a	G	For	9.8	7'×5'	03 38.9	–26 20	12		
NGC 1404	20	G	Eri	10.2	3'×3'	03 38.9	–35 35	12		
NGC 1433	21	G	Hor	10.1	7'×6'	03 42.0	–47 13	12		
Pleiades		OC	Tau	1.2	2°	03 47.0	+24 07	12	3	M45, Contains Merope Nebula
NGC 1512	21a	G	Hor	10.6	9'×6'	04 03.9	–43 21	12		
NGC 1532		G	Eri	9.9	11'×3'	04 12.1	–32 52	12		
NGC 1535	22	PN	Eri	9.4	48"×42"	04 14.3	–12 44	12		
NGC 1549	23	G	Dor	9.7	5'×4'	04 15.7	–55 36	12		
NGC 1553	24	G	Dor	9.4	5'×3'	04 16.2	–55 47	12		Near galaxy NGC 1549
NGC 1566	25	G	Dor	9.7	7'×5'	04 20.0	–54 56	12		
NGC 1617	25a	G	Dor	10.7	4'×2'	04 31.7	–54 36	12		
NGC 1672	26	G	Dor	10.2	7'×6'	04 45.7	–59 15	12		
NGC 1763	27	BN	Dor		25'×20'	04 56.8	–66 24	12		
NGC 1783	28	GC	Dor	10.9	3'	04 58.9	–66 00	12		Part of LMC
NGC 1818	30	OC	Dor	9.7	3'	05 04.2	–66 24	1		
NGC 1792	29	G	Col	10.2	5'×3'	05 05.2	–37 59	1		
NGC 1808	31	G	Col	9.9	7'×4'	05 07.7	–37 31	1		Near galaxy NGC 1792

Catalogue #	Bennett	Type	Con	Mag	Size	RA	Dec	Mth 10pm	Map	Notes
NGC 1866	33	OC	Dor	9.7	5'	05 13.5	–65 28	1		
NGC 1851	32	GC	Col	7.1	11'	05 14.1	–40 03	1		
LMC		G	Dor	0.4	10.8°×9.2°	05 23.6	–69 45	1	1	Large Magellanic Cloud
NGC 1904	34	GC	Lep	7.7	9'	05 24.2	–24 31	1	2	M79, Rich and compressed, well resolved
NGC 1912		OC	Aur	6.4	21'	05 28.7	+35 51	1	3,5	M38, 100 stars, magnitude 9.5 in splendid field
NGC 1952		BN	Tau	8.4	6'×4'	05 34.5	+22 01	1	5,3	M1, Crab Nebula
NGC 1976		BN	Ori	4.0	90'×60'	05 35.3	–05 23	1	2	M42, Orion Nebula
NGC 1982		BN	Ori	7.0	20'×15'	05 35.5	–05 16	1	2	M43, de Mairan's Nebula; part of Orion Nebula
NGC 1960		OC	Aur	6.0	12'	05 36.3	+34 08	1	3,5	M36, 60 stars, magnitude 9 to 14
NGC 2070	35	BN	Dor	8.3	40'×25'	05 38.6	–69 06	1	1	Tarantula Nebula
NGC 2068		BN	Ori	8.0	8'×6'	05 46.8	+00 05	1	2,3	M78, Brightest and largest in group of four nebulae
NGC 2099		OC	Aur	5.6	23'	05 52.3	+32 33	1	3,5	M37, 150 stars, magnitude 9 to 12.5
NGC 2168		OC	Gem	5.1	28'	06 08.9	+24 21	1	3,5	M35, 200 stars, magnitude 9 to 16
NGC 2174		BN	Ori		40'×30'	06 09.4	+20 40	1		Near open cluster M35
NGC 2214	36	OC	Dor	10.9	4'	06 12.8	–68 16	1		Edge of LMC
NGC 2243	36a	OC	CMa	9.4	5'	06 29.8	–31 17	1		
NGC 2237		BN	Mon	5.5	90'×90'	06 30.9	+05 03	1		Rosette Nebula
NGC 2287		OC	CMa	4.5	38'	06 46.0	–20 45	1	4	M41, 80 stars, magnitude 7 and fainter, with magnitude 6.9 red star near centre
NGC 2298	37	GC	Pup	9.3	7'	06 49.0	–36 00	1		
NGC 2323		OC	Mon	5.9	16'	07 02.5	–08 23	2	4	M50, Rich cluster, 80 stars magnitude 8 to 12
NGC 2362		OC	CMa	4.1	8'	07 18.7	–24 57	2	4	Tau Canis Majoris
NGC 2392		PN	Gem	8.6	47"×43"	07 29.2	+20 55	2		Eskimo Nebula
NGC 2422		OC	Pup	4.4	29'	07 36.6	–14 29	2	4	M47, Large coarse cluster with 30 stars
NGC 2438		PN	Pup	11.0	73"×68"	07 41.8	–14 44	2		In M46
NGC 2437		OC	Pup	6.1	27'	07 41.8	–14 49	2	4	M46, Rich open cluster, 100 stars, planetary nebula NGC 2438 in same field
NGC 2440		PN	Pup	9.3	74"×42"	07 41.9	–18 13	2		
NGC 2447		OC	Pup	6.2	22'	07 44.5	–23 51	2	4	M93, 80 stars magnitude 8 to 13
NGC 2477		OC	Pup	5.8	27'	07 52.2	–38 32	2	4	160 stars, magnitude 10 to 12, central concentration
NGC 2467	37a	BN	Pup	7.1	15'	07 52.5	–26 26	2		Near open cluster M93
NGC 2489	38	OC	Pup	7.9	8'	07 56.2	–30 04	2		
NGC 2516		OC	Car	3.8	29'	07 58.1	–60 45	2	1	80 stars 6th mag. and fainter, central concentration
NGC 2547		OC	Vel	4.7	20'	08 10.2	–49 12	2	4	Rich in stars with strong central concentration
NGC 2506	39	OC	Mon	7.6	8'	08 12.0	–10 47	2		Caldwell 54
NGC 2548		OC	Hya	5.8	54'	08 13.7	–05 45	2	4	M48, Large cluster of 80 stars magnitude 8 to 13
NGC 2627	40	OC	Pyx	8.4	11'	08 37.3	–29 57	2		
NGC 2632		OC	Cnc	3.1	95'	08 40.0	+19 40	2	5	M44, Beehive Cluster
NGC 2671	40a	OC	Vel	11.6	4'	08 46.2	–41 53	2		
NGC 2682		OC	Cnc	6.9	29'	08 51.4	+11 49	2	5	M67, 200 stars magnitude 10 to 15, large and rich

See page 145 for legend.

Catalogue #	Bennett	Type	Con	Mag	Size	RA	Dec	Mth 10pm	Map	Notes
NGC 2808	41	GC	Car	6.3	14'	09 12.0	–64 52	3	1	Large and rich, compressed centre, mag. 13 to 15
NGC 2903		G	Leo	9.0	13'×6'	09 32.2	+21 30	3		
NGC 2972	41a	OC	Vel	9.9	4'	09 40.3	–50 20	3		
NGC 2997	41b	G	Ant	9.4	9'×7'	09 45.6	–31 11	3		
NGC 3114		OC	Car	4.2	35'	10 02.5	–60 08	3		Rich cluster, stars magnitude 9 to 14
NGC 3115	42	G	Sex	8.9	7'×3'	10 05.2	–07 43	3		
NGC 3132	43	PN	Vel	8.2	84"×53"	10 07.0	–40 26	3	4	Eight-burst Nebula
NGC 3201	44	GC	Vel	6.8	18'	10 17.6	–46 25	3	4	
NGC 3242	45	PN	Hya	8.6	45"×36"	10 24.8	–18 39	3		Ghost of Jupiter
NGC 3293		OC	Car	4.7	6'	10 35.8	–58 13	3	1	
NGC 3351		G	Leo	9.7	7'×5'	10 44.0	+11 42	3	5	M95
NGC 3372		BN	Car	3.0	120'×120'	10 45.1	–59 52	3	1	Eta Carinae
NGC 3368		G	Leo	9.3	8'×5'	10 46.8	+11 49	3	5	M96
NGC 3379		G	Leo	9.3	5'×5'	10 47.8	+12 35	3	5	M105, in group of three galaxies
NGC 3532		OC	Car	3.0	55'×50'	11 05.2	–58 44	4	1	Rich and large, 150 stars magnitude 7 to 12
NGC 3521		G	Leo	9.0	11'×5'	11 05.8	–00 02	4		
NGC 3621	46	G	Hya	9.2	12'×7'	11 18.3	–32 49	4		
NGC 3623		G	Leo	9.3	10'×3'	11 18.9	+13 05	4	5	M65
	47	OC	Car	8.5	5'	11 19.7	–63 30	4		Melotte 105
NGC 3627		G	Leo	8.9	9'×4'	11 20.2	+13 00	4	5	M66
NGC 3628		G	Leo	9.5	15'×3'	11 20.3	+13 35	4		Near galaxies M65/66
NGC 3766		OC	Cen	5.3	12'	11 36.2	–61 37	4	1	Rich cluster, 100 stars magnitude 7 to 12
IC 2948		BN	Cen	7.0	1.2°×0.8°	11 39.4	–63 28	4		Running Chicken Nebula
NGC 3918		PN	Cen	8.4	13"	11 50.3	–57 11	4		
NGC 3960	48	OC	Cen	8.3	6'	11 50.9	–55 41	4		
NGC 3923	49	G	Hya	10	6'×4'	11 51.0	–28 48	4		
NGC 4192		G	Com	10.1	10'×3'	12 13.8	+14 54	4	7	M98
NGC 4216		G	Vir	10.0	8'×2'	12 15.9	+13 09	4		Edge-on galaxy
NGC 4254		G	Com	9.9	5'×5'	12 18.8	+14 25	4	7	M99
NGC 4258		G	CVn	8.4	19'×7'	12 19.0	+47 18	4	5,7	M106
NGC 4303		G	Vir	9.6	7'×6'	12 21.9	+04 28	4	6,7	M61
NGC 4321		G	Com	9.4	7'×6'	12 22.9	+15 49	4	7	M100
NGC 4361		PN	Crv	10.9	2'×2'	12 24.5	–18 47	4		
NGC 4374		G	Vir	9.1	7'×6'	12 25.1	+12 53	4	7	M84, Bright centre, in same field as M86
NGC 4382		G	Com	9.1	7'×6'	12 25.4	+18 11	4	7	M85
NGC 4372	50	GC	Mus	7.2	19'	12 25.8	–72 40	4		Caldwell 108
NGC 4406		G	Vir	8.9	9'×6'	12 26.2	+12 57	4	7	M86
NGC 4472		G	Vir	8.4	10'×8'	12 29.8	+08 00	4	7	M49
NGC 4486		G	Vir	8.6	8'×7'	12 30.8	+12 23	4	7	M87, Virgo A
NGC 4501		G	Com	9.6	7'×4'	12 32.0	+14 25	4	7	M88
NGC 4548		G	Com	10.1	5'×4'	12 35.4	+14 30	4	7	M91
NGC 4552		G	Vir	9.8	5'×5'	12 35.7	+12 33	4	7	M89
NGC 4565		G	Com	9.6	16'×2'	12 36.3	+25 59	4		
NGC 4569		G	Vir	9.5	10'×4'	12 36.8	+13 10	4	7	M90
NGC 4579		G	Vir	9.7	6'×5'	12 37.7	+11 49	4	7	M58, Bright diffuse nucleus, dark lanes
NGC 4590	51	GC	Hya	7.3	12'	12 39.5	–26 45	4	6	M68, Rich and compressed
NGC 4594	52	G	Vir	8.0	9'×4'	12 40.0	–11 37	4	6	M104, Sombrero Galaxy
NGC 4621		G	Vir	9.6	5'×4'	12 42.0	+11 39	4	7	M59
NGC 4631		G	CVn	9.2	16'×3'	12 42.1	+32 32	4		Whale Galaxy
NGC 4649		G	Vir	8.8	7'×6'	12 43.7	+11 33	4	7	M60

Catalogue #	Bennett	Type	Con	Mag	Size	RA	Dec	Mth 10pm	Map	Notes
NGC 4697	53	G	Vir	9.2	7'×5'	12 48.6	–05 48	4		Caldwell 52
NGC 4699	54	G	Vir	10.2	4'×3'	12 49.0	–08 40	4		
NGC 4736		G	CVn	8.2	11'×9'	12 50.9	+41 07	4	5,7	M94
NGC 4753	55	G	Vir	10.5	6'×3'	12 52.4	–01 12	4		
NGC 4755		OC	Cru	4.2	10'	12 53.6	–60 21	4	1	Jewel Box
NGC 4826		G	Com	8.5	10'×5'	12 56.7	+21 41	4	7	M64, Black Eye Galaxy
NGC 4833	56	GC	Mus	8.4	14'	12 59.6	–70 52	4		Near globular cluster NGC 4372
NGC 4945	57	G	Cen	8.6	20'×4'	13 05.4	–49 28	5	6	Big edge-on spiral, small galaxy in same field
NGC 4976	58	G	Cen	10.2	6'×3'	13 08.6	–49 30	5		
NGC 5024		GC	Com	7.7	13'	13 12.9	+18 10	5	7	M53, Bright centre region, very compressed
NGC 5055		G	CVn	8.6	13'×7'	13 15.8	+42 02	5	5,7	M63, Sunflower Galaxy
NGC 5061	59	G	Hya	10.5	4'×3'	13 18.1	–26 50	5		
NGC 5068	59a	G	Vir	9.8	7'×6'	13 18.9	–21 02	5		
NGC 5128	60	G	Cen	6.8	26'×20'	13 25.5	–43 01	5		Centaurus A (radio source)
NGC 5139	61	GC	Cen	3.9	36'	13 26.8	–47 29	5	6	Omega Centauri
NGC 5194		G	CVn	8.4	11'×8'	13 29.9	+47 12	5	7	M51, Whirlpool Galaxy
NGC 5189	62	PN	Mus	10.3	140"	13 33.5	–65 58	5	1	Dunlop's best planetary nebula
NGC 5236	63	G	Hya	7.5	15'×13'	13 37.0	–29 52	5	6	M83, Southern Pinwheel Galaxy
NGC 5253	63a	G	Cen	10.7	5'×2'	13 39.9	–31 39	5		
NGC 5272		GC	CVn	6.3	18'	13 42.2	+28 23	5	7	M3, Large bright globular, brightens suddenly towards the middle
NGC 5286	64	GC	Cen	7.4	9'	13 46.4	–51 22	5		
IC 4406		PN	Lup	11.0	2'×2'	14 22.4	–44 09	5		Retina Nebula
NGC 5634	66	GC	Vir	9.5	5'	14 29.6	–05 59	5		
NGC 5617	65	OC	Cen	6.3	10'	14 29.8	–60 43	5		
NGC 5824	67	GC	Lup	9.1	6'	15 04.0	–33 04	6		
NGC 5897	68	GC	Lib	8.4	13'	15 17.4	–21 01	6		
NGC 5904		GC	Ser	5.7	23'	15 18.6	+02 05	6	6	M5, Bright, large very compressed in middle, slightly oval in shape
NGC 5927	69	GC	Lup	8	6'	15 28.0	–50 40	6		
NGC 5986	70	GC	Lup	7.6	10'	15 46.1	–37 47	6		
NGC 5999	71	OC	Nor	9	3'	15 52.2	–56 28	6		
NGC 6005	72	OC	Nor	10.7	3'	15 55.8	–57 26	6		
	72a	OC	Nor	11.2	5'	16 01.5	–53 32	6		Tr 23 (Trumpler)
NGC 6067		OC	Nor	5.6	12'	16 13.2	–54 13	6	6	100 stars, large brightness range, central conc.
NGC 6093	73	GC	Sco	7.3	9'	16 17.0	–22 59	6	6	M80, Strong central concentration, bright and large
NGC 6121	75	GC	Sco	5.4	26'	16 23.6	–26 32	6	6	M4, Near Antares
NGC 6124		OC	Sco	5.8	40'	16 25.3	–40 39	6	6	Near planetary nebula NGC 6153
NGC 6101	74	GC	Aps	9.2	11'	16 25.8	–72 12	6		Caldwell 107
NGC 6144	77	GC	Sco	9	9'	16 27.3	–26 02	6		
NGC 6134	76	OC	Nor	7.2	6'	16 27.7	–49 09	6		
NGC 6139	78	GC	Sco	9.1	6'	16 27.7	–38 51	6		
NGC 6171	79	GC	Oph	7.8	10'	16 32.5	–13 03	6	6	M107
NGC 6167	79a	OC	Nor	6.7	7'	16 34.4	–49 36	6		
NGC 6192	79b	OC	Sco	8.5	7'	16 40.3	–43 22	6		
NGC 6193		OC	Ara	5.2	14'	16 41.3	–48 46	6		In nebula NGC 6188
NGC 6205		GC	Her	5.8	17'	16 41.7	+36 28	6	7	M13, Great Hercules Cluster

Catalogue #	Bennett	Type	Con	Mag	Size	RA	Dec	Mth 10 pm	Map	Notes
NGC 6218	80	GC	Oph	6.1	15'	16 47.2	–01 57	6	6	M12
NGC 6216	81	OC	Sco	10.1	4'	16 49.4	–44 44	6		
NGC 6235	82	GC	Oph	8.9	5'	16 53.4	–22 11	6		
NGC 6231		OC	Sco	2.6	14'	16 54.2	–41 49	6	6	A few stars with strong central concentration
IC 4628		BN	Sco		1.5° × 1.5°	16 57.0	–40 27	6		Prawn Nebula
NGC 6254	83	GC	Oph	6.6	15'	16 57.1	–04 06	6	6	M10
NGC 6253	84	OC	Ara	10.2	5'	16 59.1	–52 43	6		
NGC 6266	85	GC	Oph	6.4	14'	17 01.2	–30 07	7	6	M62
NGC 6273	86	GC	Oph	6.8	14'	17 02.6	–26 16	7	6	M19
NGC 6284	87	GC	Oph	8.9	6'	17 04.5	–24 46	7		
NGC 6287	88	GC	Oph	9.3	5'	17 05.2	–22 42	7		
NGC 6293	89	GC	Oph	8.3	8'	17 10.2	–26 35	7		
NGC 6302		PN	Sco	9.7	83" × 24"	17 13.7	–37 06	7		Bug Nebula
NGC 6304	90	GC	Oph	8.3	7'	17 14.5	–29 28	7		
NGC 6316	91	GC	Oph	8.1	5'	17 16.6	–28 08	7		
NGC 6341		GC	Her	6.5	14'	17 17.1	+43 08	7	7,9	M92
NGC 6318	91a	OC	Sco	11.8	5'	17 17.8	–39 27	7		
NGC 6333	92	GC	Oph	7.9	9'	17 19.2	–18 31	7	6	M9
NGC 6356	93	GC	Oph	8.2	7'	17 23.6	–17 49	7		
NGC 6352	94	GC	Ara	7.8	7'	17 25.5	–48 25	7		Caldwell 81
NGC 6362	95	GC	Ara	8.1	11'	17 31.9	–67 03	7		
NGC 6388	96	GC	Sco	6.8	9'	17 36.3	–44 44	7		
NGC 6402	97	GC	Oph	7.6	12'	17 37.6	–03 15	7	6,7	M14
NGC 6405		OC	Sco	4.2	33'	17 40.3	–32 15	7	6,8	M6, Butterfly Cluster
NGC 6397	98	GC	Ara	5.3	26'	17 40.7	–53 40	7	1,6	Loose structure, possibly the nearest globular
NGC 6440	98a	GC	Sgr	9.3	5'	17 48.9	–20 22	7		
NGC 6445	98b	PN	Sgr	11.2	3' × 1'	17 49.2	–20 01	7		Crescent Nebula
NGC 6441	99	GC	Sco	7.4	8'	17 50.2	–37 03	7		
NGC 6475		OC	Sco	3.3	80'	17 53.9	–34 48	7	6,8	M7, Ptolemy's Cluster
NGC 6494		OC	Sgr	5.5	30'	17 57.1	–18 59	7	6,8	M23, 150 stars, moderate brightness range, lies in good star field
NGC 6496	100	GC	CrA	8.6	7'	17 59.0	–44 16	7		
NGC 6514		BN	Sgr	6.3	20' × 20'	18 02.7	–22 58	7	6,8	M20, Trifid Nebula
NGC 6520		OC	Sgr	7.6	6'	18 03.4	–27 53	7		Near Barnard 86
NGC 6522	101	GC	Sgr	9.9	6'	18 03.6	–30 02	7		Near NGC 6528
NGC 6523		BN	Sgr	5.0	45' × 30'	18 03.7	–24 23	7	6,8	M8, Lagoon Nebula
NGC 6531		OC	Sgr	5.9	15'	18 04.2	–22 29	7	6,8	M21
NGC 6528	102	GC	Sgr	9.6	4'	18 04.8	–30 03	7		Near NGC 6522
NGC 6544	103	GC	Sgr	7.5	9'	18 07.3	–25 00	7		
NGC 6541	104	GC	Cra	6.3	13'	18 08.0	–43 42	7	8	
NGC 6553	105	GC	Sgr	8.3	9'	18 09.3	–25 54	7		
NGC 6572		PN	Oph	8.0	16" × 13"	18 12.1	+06 51	7		
NGC 6569	106	GC	Sgr	8.4	6'	18 13.6	–31 50	7		
NGC 6603	107a	OC	Sgr	11.1	5'	18 18.4	–18 25	7		In M24, Sagittarius Star Cloud
NGC 6584	107	GC	Tel	7.9	8'	18 18.6	–52 13	7		
NGC 6611		BN	Ser	6.0	120' × 25'	18 18.8	–13 47	7	8	M16, Eagle Nebula
		OC	Sgr	3.0	95'	18 19.6	–18 10	7	6,8	M24, Small Sagittarius Star Cloud
NGC 6613		OC	Sgr	6.9	9'	18 19.9	–17 08	7	8	M18
NGC 6618	108	BN	Sgr	6.0	20' × 15'	18 20.8	–16 11	7	8	M17, Swan Nebula
NGC 6624	109	GC	Sgr	7.6	9'	18 23.7	–30 22	7		

Catalogue #	Bennett	Type	Con	Mag	Size	RA	Dec	Mth 10 pm	Map	Notes
NGC 6626	110	GC	Sgr	6.9	11'	18 24.5	–24 52	7	6,8	M28, Large, round, increasingly compressed in the middle
NGC 6633		OC	Oph	4.6	20'	18 27.3	+06 31	7		Near open cluster IC 4756
NGC 6638	111	GC	Sgr	9.2	7'	18 30.9	–25 30	7		
NGC 6637	112	GC	Sgr	7.7	7'	18 31.4	–32 21	7	1,6,8	M69
IC 4725		OC	Sgr	4.6	29'	18 31.8	–19 07	7	8	M25, 30 stars loosely scattered
NGC 6642	112a	GC	Sgr	8.9	5'	18 31.9	–23 29	7		
NGC 6652	113	GC	Sgr	8.5	4'	18 35.8	–32 59	7		
NGC 6656	114	GC	Sgr	5.2	24'	18 36.4	–23 54	7	8	M22, Fine globular, only Omega Centauri and 47 Tucanae are brighter
NGC 6681	115	GC	Sgr	7.8	8'	18 43.2	–32 18	7	1,6,8	M70
NGC 6694		OC	Sct	8.0	14'	18 45.2	–09 24	7	8	M26
NGC 6705	116	OC	Sct	5.8	13'	18 51.1	–06 16	7	8	M11, Wild Duck Cluster
NGC 6712	117	GC	Sct	8.1	7'	18 53.1	–08 42	7		
NGC 6720		PN	Lyr	9.4	86" × 62"	18 53.6	+33 02	7	7,9	M57, Ring Nebula
NGC 6715	118	GC	Sgr	7.7	9'	18 55.1	–30 29	7	8	M54
NGC 6723	119	GC	Sgr	6.8	11'	18 59.6	–36 38	7		
NGC 6726		BN	CrA		2' × 2'	19 01.7	–36 53	8		
NGC 6744	120	G	Pav	8.3	20' × 13'	19 09.8	–63 51	8	1	
NGC 6752	121	GC	Pav	5.4	20'	19 10.9	–59 59	8	1	Starfish Cluster
NGC 6779		GC	Lyr	8.3	7'	19 16.6	+30 11	8	9	M56, Irregularly round, compressed in the middle
NGC 6809	122	GC	Sgr	6.3	19'	19 40.0	–30 58	8	8	M55
NGC 6818	123	PN	Sgr	10.0	22" × 15"	19 44.0	–14 09	8		Near galaxy NGC 6822
NGC 6838		GC	Sge	8.3	7'	19 53.8	+18 47	8	9	M71
NGC 6853		PN	Vul	7.3	8' × 6'	19 59.6	+22 43	8	9	M27, Dumbbell Nebula
NGC 6864	124	GC	Sgr	8.6	6'	20 06.1	–21 55	8	8	M75
NGC 6913		OC	Cyg	6.6	10'	20 23.9	+38 32	8	9	M29
NGC 6981	125	GC	Aqr	9.2	6'	20 53.5	–12 32	8	8	M72
NGC 6992		BN	Cyg	7.0	60' × 8'	20 56.4	+31 43	8		Part of Veil Nebula
NGC 7000		BN	Cyg	4.0	100' × 60'	21 01.8	+44 12	9	9	North American Nebula
NGC 7009	126	PN	Aqr	8.3	44" × 23"	21 04.2	–11 22	9		Saturn Nebula
NGC 7078		GC	Peg	6.4	12'	21 30.0	+12 10	9	9	M15, Bright, irregularly round, well resolved into faint stars
NGC 7092		OC	Cyg	4.6	31'	21 32.2	+48 26	9	9	M39, Northern limit
NGC 7089	127	GC	Aqr	6.5	13'	21 33.5	–00 49	9	8	M2
NGC 7099	128	GC	Cap	6.9	11'	21 40.4	–23 11	9	8	M30
NGC 7293	129	PN	Aqr	6.3	15' × 12'	22 29.6	–20 50	9	8	Helix Nebula
NGC 7410	129a	G	Gru	10.6	6' × 2'	22 55.0	–39 40	9		
	129b	G	Gru	9.97	5' × 3'	22 57.0	–36 28	9		IC 1459
NGC 7662		PN	And	8.6	32" × 28"	23 25.9	+42 32	10		Snowball Nebula
NGC 7793	130	G	Scl	9.1	9' × 6'	23 57.8	–32 36	10		

LEGEND

Catalogue Catalogue number (NGC New General Catalogue, IC Index Catalogue)

Bennett Bennett Catalogue number

Type Object type:

- G Galaxy
- GC Globular Cluster
- OC Open Cluster
- BN Bright Nebula
- PN Planetary Nebula

Con Constellation

Mag Magnitude of object

Size In arcminutes (most PN in arcseconds)

RA Right Ascension (hh mm.m, Epoch 2000.0)

Dec Declination (° ', Epoch 2000.0)

Mth 10 pm Month the object is highest at 10 pm.

Map All Sky Map number

Notes Common name and/or description

PLACES OF ASTRONOMICAL INTEREST

Note: The entries listed on these and following pages may be affected by pandemic restrictions. See their websites or contact for details.

NEW SOUTH WALES & ACT

BATHURST OBSERVATORY RESEARCH FACILITY

They operate their 'Open Nights' public observatory tours on a regular basis, catering for school groups and the general public. The facility is also dedicated to meteorite research and the meteorite collection is open by request. Information on tour dates and times can be found on the website. Regular updates are also on their facebook page. Email <info@bathurstobservatory.com.au>. www.bathurstobservatory.com.au www.facebook.com/BathurstObservatory

CANBERRA DEEP SPACE COMMUNICATION COMPLEX

The Complex, located at Tidbinbilla, 35 km south-west of Canberra, is a major link in NASA's Deep Space Network and managed on their behalf by the CSIRO. Tidbinbilla provides two-way radio communications with distant spacecraft exploring our Solar System and beyond. The centrepiece is the 70-metre antenna dish, the largest in Australia. The Visitor Centre incorporates audio/visual presentations, exhibits, models and images from spacecraft and includes a real Moon rock. The new Deep Space Café and gift shop sells meals and souvenirs. Contact Korinne McDonnell (02) 6201 7809, (02) 6201 7838, email <pr@cdscc.nasa.gov>. www.cdscc.nasa.gov/ facebook.com/CanberraDSN

CRAGO OBSERVATORY

This observatory is operated by the Astronomical Society of NSW. It is located on Bowen Mountain near North Richmond (north-west of Sydney). It houses a 40 cm telescope. The observatory enjoys the darkest sky in the Sydney region and is open on Saturday nights nearest to Last Quarter Moon. Visitors most welcome. Status updates for weather will be posted on the Facebook page around 4 pm on observing nights. Call Paul Hatchman 0413 047 782, email <VP_Crago@asnsw.com>. www.asnsw.com/crago/index.html www.facebook.com/CragoObs/

CSIRO PARKES RADIO TELESCOPE

The Parkes Observatory is located 20 km north of Parkes (just off the Newell Highway). This landmark radio telescope is over 50 years old, but still considered one of the best single dish radio telescopes in the world. As well as a great view of the telescope, the visitors centre has displays and a 3D Theatre. There is also the Dish Café and a picnic area with free gas barbecues. Souvenirs and educational material are available. Contact (02) 6861 1777, email <VCStaff-PA@csiro.au>. www.csiro.au/parkes

DUBBO OBSERVATORY

Dubbo's 'Star Attraction' is located next to the Western Plains Zoo. Sky presentations are projected in their theatrette, followed by viewing through their telescopes including a large 17". Bring your SLR camera to take astrophotos through this scope or over the internet with their CCD camera. Contact 0488 425 940. www.tenbyobservatory.com/dubbo_observatory

GREEN POINT OBSERVATORY

The observatory is operated by the Sutherland Astronomical Society (SAS) in Sydney. The building houses 41 cm and 35 cm telescopes. Visitors are welcome any Thursday night, with guest speakers on the 1st Thursday of the month. The society also runs regular open nights for the general public. Contact secretary by email <info@sasi.net.au>. www.sasi.net.au

MACQUARIE UNIVERSITY ASTRONOMICAL OBSERVATORY

Located on the Macquarie University campus at North Ryde, this observatory is open to the public on various nights (unless raining) for several months during the year, see website for dates and status. Astronomy students will guide you with a range of telescopes. goto.mq/observatory

MACQUARIE UNIVERSITY PLANETARIUM

The Digitarium Epsilon planetarium projector system and portable GoDome also run public sessions during some school holidays, see website for details. Bookings are essential. goto.mq/planetarium

MILROY OBSERVATORY

Milroy Observatory at Coonabarabran operates nightly stargazing sessions with Donna the Astronomer on most clear nights. They cater for the general public, groups of amateur astronomers or school groups. Please call to make a booking. Contact 0428 288 244, email <info@milroyobservatory.com.au> or message on Facebook. www.milroyobservatory.com.au www.facebook.com/milroyCoonabarabran

MUDGEE OBSERVATORY

Mudgee Observatory caters for school groups, organised tours and the general public. The observatory is situated 15 mins west of Mudgee. The theatre and flat screen planetarium runs features on the night sky and the Sun. A variety of telescopes and binoculars are available for visitors as well as conducted tours of the night sky. Bookings essential. Ph (02) 6373 3431, 0428 560 039, email <john@mudgeeobservatory.com.au>. www.mudgeeobservatory.com.au

PORT MACQUARIE OBSERVATORY

This observatory is operated by the Port Macquarie Astronomical Association Inc. It is open to the public on Wednesday and Sunday nights for viewing through the telescope (weather permitting) and a presentation. See their website for times and events and follow them on Facebook for current news and updates. Email <pmobs.info@gmail.com>. portastronomy.com.au

SCIENCE SPACE

Operated by the University of Wollongong, this public science centre includes the full dome planetarium, an observatory, exhibits and a gift and resource shop. The planetarium has the latest immersive full-dome technology. The observatory houses a telescope used to observe the Sun and stars. The Science Shop has a range of educational materials and telescopes. Contact (02) 4286 5000 (option 2), Fax (02) 4283 6665, email <science-space@uow.edu.au>. www.sciencespace.com.au

SIDING SPRING OBSERVATORY

Siding Spring Observatory (SSO) is Australia's premier optical astronomy research facility and is home to telescopes from many organisations within Australia and around the world. Siding Spring nestles into the Warrumbungle mountains at the entrance to the Warrumbungle National Park, 30 minutes west of Coonabarabran. The Visitor Centre includes a café serving light meals, souvenir shop and an astronomy exhibit. From the Visitor Centre there is access to the viewing gallery of the 3.9 m AAT and special tours can be organised on request for groups, information can be found on their website. StarFest is a celebration of astronomy at SSO every October long weekend, see website. www.starfest.org.au www.sidingspring.com.au

SYDNEY OBSERVATORY

This historic observatory is situated near The Rocks on Observatory Hill, overlooking Sydney Harbour. It offers a variety of tours and displays. See website for details. Sydney Observatory is part of the Museum of Applied Arts and Sciences. www.maas.museum/Sydney-observatory

THE AUSTRALIA TELESCOPE COMPACT ARRAY – NARRABRI

The Australia Telescope operates in the radio region of the spectrum. It uses high technology to combine the signals from a number of dishes, to obtain the performance of a single theoretical dish a number of kilometres in diameter. The Compact Array is located at CSIRO's Paul Wild Observatory near Narrabri. It consists of six 22 m dishes, five spaced along a 3 km track with a sixth 3 km to the west. From the visitor's centre there are great views of the dishes, displays and video presentations. www.narrabri.atnf.csiro.au

WARRUMBUNGLE OBSERVATORY

The observatory is located at Coonabarabran and is open to the public for night viewing through a number of telescopes. Visitors are encouraged to bring DSLR cameras for astrophotography. The observatory can be hired by amateurs to take advantage of the 51 cm telescope and CCD for imaging and photometry. Piers are available for Meade and Celestron telescopes. The site also hosts remote controlled telescopes for Northern Hemisphere observers and is part of the Sierra Stars Observatory Network. Contact Peter Starr 0488 425 112, email <starr_peter@hotmail.com>. www.tenbyobservatory.com

WESTERN SYDNEY UNIVERSITY PENRITH OBSERVATORY

The Western Sydney University Penrith Observatory runs public astronomy nights, public hands-on workshops, private school and group programs. A visit can include listening to lectures on various aspects of astronomy, a 3D astronomy movie and viewing through a variety of telescopes. www.westernsydney.edu.au/observatory

QUEENSLAND

ALLOWAY OBSERVATORY

The observatory, situated approximately 6 km south of Bundaberg, is operated by the Bundaberg Astronomical Society. The 6 metre dome houses a 480 mm Newtonian telescope and a 12 inch Meade telescope with CCD imaging. The observatory opens to the public on the 1st Friday of the month weather permitting and other nights can also be arranged for large groups. Contact Mark Sugars 0409 697 734, or Mac Jonson on 07 4153 6469 email <macsen2@yahoo.com>. alloway-observatory-bundaberg.webs.com

CHARLEVILLE COSMOS CENTRE AND OBSERVATORY

The Charleville Cosmos Centre is located in the airport precinct off Sturt St (Mitchell Highway). They offer Big Sky night time observatory sessions and more personalised sessions in the new Darth Star Observatory or perhaps you choose to toast marshmallows around a special fire pit listening to stories of astronomy at Universal Dreaming. During the day the centre conducts several activities including viewing the Sun through a very large solar telescope, Astronomy by Day which includes many interactive displays, the brand new Astrodome Planetarium (watch movies on a dome screen) and so much more. Guides are regularly on site to ask questions, phone: (07) 4654 7771. Special programmes can be arranged for groups and schools by contacting (07) 4656 8360 or (07) 4654 2787. <Enquiries@cosmoscentre.com>. www.cosmoscentre.com www.experiencecharleville.com.au

THE SIR THOMAS BRISBANE PLANETARIUM

This world class planetarium is located at the Brisbane Botanic Gardens, Mt Coot-tha, at Toowong in Brisbane. Programs are presented in their Cosmic Skydome. All shows include a current night sky tour recreated in the dome. The Planetarium upgraded its digital projection system in 2019 and can now recreate the observable Universe at 7K resolution with many more astronomical features available. The display areas contain astronomical and space items including a large display of Aboriginal and Torres Strait Islander astronomy. The shop has educational products and souvenirs. Telescope sessions must be pre-booked. School shows are also available during weekdays and are available to the public on a space-available basis. Open Tue—Sun (Monday during Qld school holidays). Ph (07) 3403 2578, email <bop@brisbane.qld.gov.au>. www.brisbane.qld.gov.au/planetarium/ www.facebook.com/BrisbanePlanetarium

SPRINGBROOK MOUNTAIN OBSERVATORY

Springbrook National Park is high in the McPherson Range, and the observatory is located 700 m above sea level away from light pollution, 45 minutes from Surfers Paradise. Holiday accommodation is available on the mountain for up to 10, or a single or couple on site. They are open to the general public, astronomical groups, schools, and researchers by appointment. This facility houses a number of telescopes for night time viewing. See website or contact them on Facebook for details. www.springbrookobservatory.com.au

SOUTH AUSTRALIA

STOCKPORT OBSERVATORY

Owned and operated by the Astronomical Society of South Australia (ASSA), the observatory is located in the small town of Stockport, approximately 80 km north of Adelaide. Public star parties are held in February, May, August and November. See website for details. ASSA Info Line (08) 8261 3354, <observatories@assa.org.au>. www.assa.org.au/facilities/stockport/

THE BACKYARD UNIVERSE

The Backyard Universe does a fun and educational multicultural tour of the night sky with a laser pointer, together with views through our telescopes of many objects in our wonderful southern skies. Scheduled 90 minute public tours operate at venues south of Adelaide, see website for details. Also available for school and private group tours. Bookings are essential. Email <tbu@thebackyarduniverse.com.au>. www.thebackyarduniverse.com.au

THE HEIGHTS OBSERVATORY

The Heights School Observatory is located at the Heights School, Modbury Heights, Adelaide. There are two main telescopes, a 14" and a research quality 12.5" plus two Coronado solar scopes. Private bookings are accepted. Ph (08) 8263 6244. Contact Andrew Cool, email <andrew@cool.id.au> www.theheights.sa.edu.au/observatory.html www.adelaideobservatory.org

TASMANIA

LAUNCESTON PLANETARIUM

The planetarium is at the Queen Victoria Museum's Inveresk site. See their website for details of shows. Contact (03) 6323 3777. www.qvmag.tas.gov.au

VICTORIA

ASTROTOURS SWINBURNE

The Centre for Astrophysics and Supercomputing at Swinburne University of Technology is offering public 3D tours through the Universe in the Virtual Reality theatre during school holidays. AstroTour sessions can also be booked for school groups (Years 3–12) throughout the year. Contact Dr Rebecca Allen, email <astrotour@swin.edu.au>. astronomy.swin.edu.au/astrotour/

BALLARAT MUNICIPAL OBSERVATORY

The observatory has several historic telescopes including the Jelbart (125 mm refractor), the Oddie (220 mm Newtonian), the Baker Great Equatorial Telescope (650 mm Newtonian) and a 300 mm Newtonian. The Adcock-Federation telescope (406 mm) has disabled-access. Observatory open Tuesday to Saturday. Bookings essential. See website for open times and calendar of events Contact open hours (03) 5332 7526 or after hours for bookings 0429 199 312, email <info@ballaratobservatory.org.au>. observatory.ballarat.net

MELBOURNE PLANETARIUM

This is Australia's first digital planetarium and is at Scienceworks in Spotswood, see website for details. museumvictoria.com.au/planetarium/

MOUNT BURNETT OBSERVATORY

New members are most welcome. Individuals and families wanting to look through their telescopes can join in one of their Public Viewing Nights. These run approximately once a month subject to the weather. They are very popular and must be pre-booked. Email or phone for further details. In addition to weekly members nights they have regular Young Observers, Deep Sky, Radio Astronomy and Astrophotography sessions. Also a new AstroArts group. Contact Mount Burnett Observatory hotline 0490 665 004, email <info@mbo.org.au>. www.facebook.com/MtBurnettObservatory mbo.org.au Also on twitter @mbobservatory

WESTERN AUSTRALIA

ASTRO TOURS OF THE KIMBERLEY

Broome's Astronomy Experience is a two hour live performance educational and entertaining experience using big telescopes under dark skies. It operates in Broome from April to October a number of times a week according to the schedule and booking facility found on the website. Bookings essential. Greg Quicke, aka #spacegandalf, is a BBC and ABC TV presenter for Stargazing Live with Professor Brian Cox and other astronomy related programs. Contact Greg Quicke 0417 949 958, email <greg@astrotours.net> . www.astrotours.net

GDC OBSERVATORY

The Gravity Discovery Centre Observatory is part of the Gravity Precinct and shares its bushland with the AIGO research centre and the Zadko Telescope and the USAFA Falcon Telescope Network. The observatory boasts professional staff and five telescopes including the largest for public viewing in WA. Events include their Monster Telescope, Indigenous Astronomy and specialised astronomy sessions. Located under dark skies, it is an hours drive north of Perth. Contact (08) 9575 7577 (Office). www.gravitycentre.com.au/observatory

PERTH OBSERVATORY

Perth Observatory is situated in the stunning Perth Hills, an easy 40 minutes drive (35 km) east of Perth. It is Western Australia's oldest astronomical institution, possessing a long tradition of research and public outreach. Now solely operated by the Perth Observatory Volunteer Group, the Observatory provides a wide range of night and daytime (including school) tours and activities. It also offers a star adoption program and conducts offsite events throughout the state. Visit their website for tour bookings and further information or contact by phone.(08) 9293 8255 or email <info@perthobservatory.com.au>. www.perthobservatory.com.au twitter.com/perthobs www.instagram.com/perthobservatory

EVENTS

AUSTRALIA

NATIONAL SCIENCE WEEK

Held in August each year, it celebrates Australian science and aims to increase public awareness of the role that science, engineering, mathematics, innovation and technology play in our daily lives and to encourage younger people to become involved. Astronomy is a key component, and amateur societies are ideally placed for such outreach. Support is available for event holders. See the website for more information. www.scienceweek.net.au

NEW SOUTH WALES

CWAS ASTROFEST

The CWAS AstroFest is sponsored by the Central West Astronomical Society and held annually in July. The AstroFest incorporates a two day conference and related activities including the David Malin Astrophotography Exhibition

and Competition which is open to all amateur astrophotographers. World-renowned professional and amateur astronomers also share their knowledge and experiences. Contact John Sarkissian (Local Organising Committee), email <astrofest@cwas.org.au>. www.cwas.org.au/astrofest/

MACQUARIE UNIVERSITY ASTRONOMY OPEN NIGHTS

These nights are designed for the general public. Activities include a special guest speaker, commercial stands and telescopes operated by MQ academic/research staff and local amateurs. They are held once a year on a Saturday night around a First Quarter Moon. The venue is Macquarie University in North Ryde, Sydney, commencing around 6:30 pm. See website for dates and details. physics.mq.edu.au/aon

SOUTH PACIFIC STAR PARTY

An annual national gathering of amateurs for observing under country skies. It is held at the Astronomical Society of NSW's property at Ilford, NSW. This major event now attracts over 300 people. Advance registrations required. See the society website for more details. Email <secretary@asnsw.com>. www.asnsw.com/spsp

NACAA

The National Australian Convention of Amateur Astronomers is a regular national forum at which amateur astronomers can exchange experiences, stay abreast of the latest trends, foster co-operative activities between individuals, societies and the professional sphere. They are held over Easter every two years. The next NACAA will be held in Melbourne in 2022, hosted by the Astronomical Society of Victoria. More details on website. www.nacaa.org.au

QUEENSLAND

BAS MOON & PLANET TELESCOPE VIEWING NIGHTS

The Brisbane Astronomical Society (BAS) holds regular free public viewing nights at Mt Coot-tha Lookout in Brisbane and at Maleny Golf Club on the Sunshine Coast. These are usually the first Saturday after the New Moon. Check website for dates and times. Email <info@bas.asn.au>. www.bas.asn.au/index.php/events

QUEENSLAND ASTROFEST (DUCKADANG, QLD)

The Queensland Astrofest is held annually at the Lions Club Camp Duckadang, situated at Linville 160 km north-west of Brisbane. There is bunk house accommodation and room for camping and caravans. Power is also available. Queensland Astrofest boasts a nine day format, and is normally held late August. Each Saturday has vendor sales and talks. Workshops are run covering various topics. The renowned Astro-Feast is held on the last Saturday night. More details are on the website. Registration usually opens April/May, early bookings are recommended. Contact registrar, email <registrar@qldastrofest.org.au>. www.qldastrofest.org.au

URBAN OBSERVERS

The South East Queensland Astronomical Society holds free public viewing nights 'Urban Observers' at the Barrett Street Reserve, Bracken Ridge (entry off Jude St) on the Saturday night around First Quarter Moon of each month (weather permitting). Special events are also organised. All welcome. Contact Julie Straayer 0411 047 439, email <urbanobs@seqas.org>. www.seqas.org

SOUTH AUSTRALIA

VICSOUTH DESERT SPRING STAR PARTY

See entry for VicSouth under Victoria.

VICTORIA

VICSOUTH DESERT SPRING STAR PARTY

Jointly hosted by the Astronomical Society of Victoria and the Astronomical Society of South Australia, the VicSouth Desert Spring Star Party is an annual weekend of astronomy, held at the Little Desert Nature Lodge about 16 km south of Nhill in western Victoria, roughly equidistant between Melbourne and Adelaide. It offers a weekend of social, astronomical and observing activities. See website for more details. www.vicsouth.info

VASTROC (VIC)

Victorian Amateur Astronomical Societies' Conventions (VASTROC) are held every second year (alternating years with NACAA). Activities include speakers, workshops, displays, observing and the convention dinner. More details on the VASTROC website when available. vastroc.net

ORGANISATIONS

AUSTRALIA

THE ASTRONOMICAL SOCIETY OF AUSTRALIA

This is the society of professional astronomers in Australia. It has a society website and a second Australian Astronomy site providing links, both professional and amateur, and including links to educational material. Contact the ASA Secretary (A/Prof. John O'Byrne), email <asa.secretary@sydney.edu.au>. asa.astronomy.org.au ASA site www.astronomy.org.au Australian Astronomy site

VARIABLE STARS SOUTH

VSS is an international association of astronomers, amateur and professional, researching the under-explored realm of southern variable stars. VSS covers most techniques of variable star research: visual observing, imaging with DSLRs and CCD cameras and spectrography. Its research is project-oriented, often involving professional/amateur collaboration. Its 'home' is its website, visit it for further information and contacts. Email <markgblackford@outlook.com>. www.variablestarssouth.org

AUSTRALASIAN DARK SKY ALLIANCE

ADSA is promoting the preservation of the night environment, through education, public, policy and people. Contact Marnie Ogg, Director, email <info@australasiandarkskyalliance.org>. www.australasiandarkskyalliance.org

INTERNATIONAL DARK-SKY ASSOCIATION

IDA's goal is to preserve and protect the night-time environment and our heritage of dark skies through quality outdoor lighting. Contact Dr Kellie Pendoley, VP of the IDA, and Australasian contact., email <kellie.pendoley@penv.com.au>. www.darksky.org

NEW SOUTH WALES

SYDNEY OUTDOOR LIGHTING IMPROVEMENT SOCIETY INC.

Since 1998 SOLIS has been working at protecting the view of the night sky by promoting better outdoor lighting. Contact Mike Chapman, email <mike.chapman@solis.asn.au>. www.solis.asn.au

COURSES

MSATT – ASTRONOMY PROJECTS FOR HIGH SCHOOL STUDENTS

MSATT is an educational facility designed for student-centred research projects in astronomy. The facility consists of two primary instruments (300 mm Schmidt-Cassegrain and 400 mm Newtonian) with auxiliary instruments and cameras for visual work, imaging, spectroscopy, photometry and astrometry. Students operate MSATT, a teaching telescope suite at ANU's historic Mount Stromlo Observatory, to complete extended investigations based on their own observations. In most cases, an astronomer is appointed as the student's mentor for the duration of the project. Students produce a referenced and refereed report which can often contribute to their formal school assessment. No experience with astronomy or telescopes is necessary and any Year 9–12 student from the ACT region is welcome to apply. Students wishing to visit MSATT or take on projects in 2021* should contact Geoff McNamara for a copy of the MSATT Student Guide. There is no cost for any MSATT activities. *The 2021 observing season begins on Monday 26/4/21. Contact Geoff McNamara phone/text 0449 966 200, email <geoffrey.mcnamara@ed.act.edu.au>. msatt.teamapp.com/ www.facebook.com/MSATTAustralia/

PRACTICAL ASTRONOMY (SASPAC)

A practical astronomy course for beginners and interested amateurs. This is an eight week course conducted by Sutherland Astronomical Society Inc (SASI). Each lecture is followed by observations with the society's equipment (weather permitting). Refer to website for course dates. Contact the Education Officer 0408 207 927, email <info@sasi.net.au>. www.sasi.net.au

SYDNEY UNIVERSITY ASTRONOMY COURSES

The University Centre for Continuing Education runs regular astronomy courses on the main Sydney University campus, with occasional bus tours to NSW observatories. See website for more information. cce.sydney.edu.au

Note: The entries listed on these and following pages may be affected by pandemic restrictions. See their websites or contact for details.

TASMANIA

NIGHT SKY EXPLORER COURSE (HOBART)

Beginner astronomy courses are conducted by members of the Astronomical Society of Tasmania, details on their website.
Email Richard <regulus1951@gmail.com>. www.astas.org.au

VICTORIA

ASTRONOMY PUBLIC LECTURES

The Centre for Astrophysics & Supercomputing have free public lectures on astronomy at the Hawthorn campus of Swinburne University of Technology. See website for details. astronomy.swin.edu.au/outreach/?topic=freelectures

MOBILE PLANETARIUMS

NEW SOUTH WALES

MACQUARIE UNIVERSITY MOBILE PLANETARIUM

Their planetarium projector system and portable GoDome is available, by arrangement, for groups of up to 40 people per session. The planetarium simulates the night sky. You can take a tour of the local Solar System, peer into the depths of the galaxy, or watch amazing new planetarium movies. Presentations can be tailored to the interests and age of your groups. See the website for details. goto.mq/planetarium

SKYWORKS PLANETARIUM

Skyworks Planetarium is a multi-award winning travelling educational resource employing the use of a STARLAB Portable Planetarium to visit schools and youth groups. Since starting in 2000, Skyworks has become the most active planetarium in greater Sydney. Programs are curriculum based to suit years K–12. Contact Geoff and Diana Zenner 0419 112 899, <info@skyworks.net.au>. www.skyworks.net.au

QUEENSLAND

STARLAB EDUCATION

Starlab Education provides astronomy and Earth science presentations throughout Queensland. Fully trained presenters visit your school or venue with a 'Cosmodome Science Theatre & Planetarium' or a 'Starlab Planetarium' to provide educational programs tailored to suit your level of interest and understanding. Contact Paul Tickner 0417 394 354, email <info@starlab.net.au>. www.starlab.net.au

NIGHT SKY SECRETS PLANETARIUM

Night Sky Secrets operate a Cosmodome Planetarium in North and Far North Queensland. They conduct both 3D Surround movies and Classic Planetarium presentations in schools, museums and events across Northern Queensland. Contact 1 300 843 759. www.nightskysecrets.com.au/news/events/

RESOURCES

AUSTRALIA

AUSTRALIAN SKY & TELESCOPE MAGAZINE

Australian Sky & Telescope is a world-class magazine about the science and hobby of astronomy. Combining the worldwide resources of its venerable parent magazine with the talents of the best science writers and photographers in Australia, it is produced specifically for the Southern Hemisphere astronomer. Delivering the latest news and developments in astronomy six times a year, Australian Sky & Telescope caters for everyone with an interest in space and astronomy, from the absolute beginner to the seasoned observer. Contact (02) 9439 1955, Fax (02) 9439 1977, email <info@skyandtelescope.com.au>. www.skyandtelescope.com.au

ICEINSPACE

IceInSpace is a community website dedicated to promoting amateur astronomy in the Southern Hemisphere. They aim to help stargazers discover, discuss and enjoy the night sky. IceInSpace is free to join and use, all you need is a valid email address. By registering you will be able to post topics, upload content and images and access other features. IceInSpace is the largest and most active astronomy community in the Southern Hemisphere, with over 13,500 members. Contact Mike Salway, email <mike@iceinspace.com.au>. www.iceinspace.com.au

WESTERN AUSTRALIA

STARGAZERS CLUB WA

Stargazing and astronomy for beginners. Stargazers Club WA runs telescope classes, stargazing nights, astrophotography for beginners and hosts special trips to dark skies in country WA. See their website for costs and details. Contact Carol 0427 554 035, email <begin@stargazersclubwa.com.au>. www.stargazersclubwa.com.au

ASTRONOMY EDUCATION SERVICES

Astronomy Education Services (AES) specialises in school incursions, Scout/youth/special interest groups and visiting rural communities. Activities include day presentations with safe viewing of the Sun and stargazing nights with telescopes. See their website and Facebook page for more details. Contact Richard Tonello 0417 961 357, email <richard@astro-ed-services.com>. www.astro-ed-services.com

SOCIETIES

NEW SOUTH WALES & ACT

The **Astronomical Society of Albury Wodonga** meets regularly on the 1st Wednesday of each month (except January) at La Trobe University, Wodonga at 7 pm. Contact David Thurley (02) 6040 3704 www.facebook.com/AstronomicalSocietyAlburyWodonga

The **Astronomical Society of NSW** holds two meetings per month at Epping, runs two observing sites in NSW and publishes a monthly journal. The society welcomes members from all over Australia, as well as overseas. See their website for further details. Contact <secretary@asnsw.com>. www.asnsw.com

The **Astronomical Society of the Hunter** meets on the 1st Friday each even month at 6:30 PM. Contact Col Maybury 0427 889 653 <colmaybury@bigpond.com>.

The **Astronomical Society of Coonabarabran** meets on the 3rd Wednesday each month at 7:30 pm at Room EG01, Coonabarabran TAFE campus, Robertson Street, Coonabarabran. Contact Donna Burton secretary 0428 288 244 <Donna@born2fly.com.au>.

The **Canberra Astronomical Society** meetings are held on the 3rd Thursday of each month except June and December starting at 8 pm. An Introductory meeting begins one hour before the main meeting. The venue is usually the Duffield Lecture Theatre, Mt. Stromlo Observatory, ACT. Contact Fay Neil (02) 6231 0851 <casadmin@gmail.com>. casastronomy.org.au

The **Central West Astronomical Society Inc (Parkes)** meetings are held on the 1st Friday of the month except January, at the Parkes Observatory Visitors Centre, commencing 7:30 pm, visitors welcome. Contact Secretary <secretary@cwas.org.au>. www.cwas.org.au

The **Clarence Valley Astronomical Society** Contact Steve Fletcher (02) 6643 3288 <arrowdodgerfletch@hotmail.com>.

The **Coffs Harbour Astronomical Society Inc** meets on the 1st Monday of each month (except January) at 7 pm at the Boambee East Community Centre, cnr. Bruce King Drive and Pacific Highway, Boambee East. Contact Win Howard (02) 6653 2742 <winhoward@iprimus.com.au>.

The **Illawarra Astronomical Society** meets at 7:30 pm, every 2nd Tuesday of the month at the Wollongong Science Centre.
Contact <IAS.secretary@outlook.com>. iasenquiry.wixsite.com/website

The **Macarthur Astronomical Society** meet in Campbelltown, NSW, on the 3rd Monday of the month, with guest speakers and workshops. They also schedule three dark-sky observing nights per month.
Contact <contact@macastro.org.au>. www.macastro.org.au

The **Northern Sydney Astronomical Society Inc** meets at St Ignatius College at Lane Cove 3rd Tuesday of every month.
Contact <nsas@nsas.org.au>. www.nsas.org.au

The **Port Macquarie Astronomical Association Inc** holds regular monthly meetings. Check their Website and Facebook page for further information.
Contact <pmobs.info@gmail.com>. portastronomy.com.au

The **Shoalhaven Astronomers** meet at the University Of Wollongong, Shoalhaven Campus, Library and Resources Centre, Seminar Room LG.25 on the 3rd Friday of the month at 7 for 7:30 pm. Contact Mark Town (president) 0474 859 788 <astronomers@shoalhaven.net.au> .www.shoalhavenastronomers.asn.au

The **Sutherland Astronomical Society** meets every Thursday at 7:30 pm at the Green Point Observatory near Sutherland (cnr Green Point and Caravan Head Roads Oyster Bay), with the main meeting and guest speaker on the 1st Thursdays. Contact Maree Emett (Sec) <info@sasi.net.au>. www.sasi.net.au

The **Sydney City Skywatchers** meet at Sydney Observatory on the 1st Monday of the month (except January and December) at 6:30 pm. Contact Secretary, Elizabeth (02) 9398 9705 www.sydneycityskywatchers.org

The **Sydney North-west Astronomy Group (SNAG)** has viewing and imaging only (no meetings) on Friday nights under clear skies at Kenthurst. Contact Ken Petersen 0412 358 194 <ken.petersen6@telstra.com>.

The **Newcastle Astronomical Society** meetings are held on the last Friday each month (except December), at the University of Newcastle, General Purpose building 1, level 1, at 7:30 pm. Contact Alan Meehan 0408 789 908 <info@nas.org.au>. www.nas.org.au

The **University of New England and Northern Tablelands Astronomical Society** meetings are held 1st Tuesday each month at the Kirby Observatory at 7 for 7:30 pm. Contact Anne Parnell (02) 6772 1958 <parnellansw@gmail.com>. www.unentas.org.au

The **Western Sydney Amateur Astronomy Group Inc** meets at 7:30 pm on the 3rd Wednesday of the month at Penrith Observatory, Western Sydney University, Werrington Campus. Hear interesting guest speakers and attend astronomy workshops. Contact <enquiry@wsaag.org>. wsaag.org

The **Tamworth Regional Astronomy Club Inc** holds meetings on the 1st Saturday of every month. The evening commences at 7 pm with an astronomy presentation (approx. 30 minute talk) and then telescopic viewing. The venue is the Astronomy & Science Centre, adjacent to the Botanical Gardens, Piper St, Tamworth. (Public are welcome).
www.tamworthastronomy.com.au

The **Wollongong Amateur Astronomy Club** has monthly meetings on the 1st Thursday of the month, at 7:30 pm, at the Unanderra Community Centre, Princess Highway Unanderra. Visitors are most welcome to attend. Contact Jeff Pountney on 0423 972 181 or Joe Perulero on 0466 146 005.
waacers.createmybb3.com

NORTHERN TERRITORY

The **Gove Amateur Astronomers** meets as advised for viewing nights on a Saturday close to the New Moon at a local dark sky site. Their nights are announced on their Facebook page. www.facebook.com/GoveAstronomers

QUEENSLAND

The **Astronomical Association of Queensland** meetings will be on nominated Saturdays each month from February to December. The normal venue is Lecture Theatre 222, the Parnell Building (School of Maths and Physics), located on the south side of the Great Court, The University of Queensland, St Lucia Campus. Meetings generally commence at 4 pm. Dates of meetings and further details are published on their website. Contact the General Secretary via the 'Contact Us' form on their website. www.aaq.org.au

The **Brisbane Astronomical Society** hold meetings each month except January and December, see their website for meeting night details. Contact Peter Allison 0488 140 755 <President@bas.asn.au> .www.bas.asn.au

The **Bundaberg Astronomical Society** meetings are held at Alloway Observatory on Fridays, see website for more info.
alloway-observatory-bundaberg.webs.com

The **FNQ Astronomers Group** meet periodically in the Cairns region (Far North Qld) in conjunction with astronomical events as advised on the Facebook page. Contact Ian Maclean 0417 601 490
www.facebook.com/FNQAstronomers

The **Astronomy Group of Mount Isa** meets at their dark sky observing site at the Lions Youth Camp on Lake Moondarra (17 km outside of Mount Isa). Meetings are held monthly, usually the Saturday preceding New Moon. Contact Grant Szabadics 0437 748 163 (AH) <gszabadics@bigpond.com>.

The **Redlands Astronomical Society** meets on the 2nd Tuesday of the month at Ormiston College, Ormiston (27 km SE of Brisbane), see website for details. Contact President Rhondda Nickols 0403 185 586 <redlandsastronomicalsociety@gmail.com>. www.ras.org.au

The **Scenic Rim Astronomy Association** meets twice a month on Saturdays near the New Moon at their dark site at Laravale (under one hour south of Brisbane), often having a guest speaker or workshop before twilight ends. Contact Joel Bladen (President) 0431 436 500 <sraasecretary@gmail.com>.
sraa.org.au

The **South East Queensland Astronomical Society** meets 3rd Tuesday of the month at Bracken Ridge Library from January to November. Meetings commence at 7:30 pm. Contact Julie Straayer 0411 047 439 <juliestraayer@hotmail.com>. www.seqas.org

The **Southern Astronomical Society** has monthly meetings at 26–42 Charlies Crossing Road North, Upper Coomera Qld 4209, see website for details. Contact Brendan Junge 0414 750 083 www.sas.org.au

The **Townsville Astronomy Group Inc** holds a monthly public viewing at the Strand in Townsville. In addition there is viewing at a dark site at Oak Valley, usually on two Saturdays around New Moon. Details and updates can be found on their website and in their Facebook group.
www.astronomytsv.org.au

SOUTH AUSTRALIA

The **Astronomical Society of South Australia** meetings are held on the 1st Wednesday each month (except January) at the University of Adelaide, North Terrace Campus. Contact <info@assa.org.au>. www.assa.org.au

TASMANIA

The **Astronomical Society of Tasmania** has regular meetings and observing activities throughout Tasmania. Contact Hobart – Steve Harvey 0444 525 566, Launceston – Geoff Blackman 0438 390 681, Devonport – Peter Sayers (03) 6424 2588 or email <info@astas.org.au>. www.astas.org.au

VICTORIA

The **Astronomical Society of Victoria** has monthly meetings, held at 8 pm on the 2nd Wednesday each month, except January, at the National Herbarium, Birdwood Ave, South Yarra. The ASV has 19 specialist sections that also hold regular meetings. Contact Linda Richmond (Public Relations Officer) (03) 9888 7130 www.asv.org.au

The **Astronomy Benalla** meets on the 3rd Wednesday of each month (unless otherwise specified on website!) at 7:30 pm at Benalla Hockey Club Room, Churchill Park, Waller St Benalla. Contact Jeff Knight (President) 0407 532 674 www.astronomybenalla.org.au

The **Astronomical Society of Geelong** meets every Friday at 7:30 pm at the ASG Club Room, Geelong Showgrounds, Breakwater Road, Geelong.
www.asog.org.au

The **Ballaarat Astronomical Society** holds members meetings, 2nd Friday of the month, beginning in February. Contact 0429 199 312 <bas@ballaratobservatory.org.au>. observatory.ballarat.net

The **Latrobe Valley Astronomical Society** meets on the 2nd Tuesday each month (except Dec and Jan) at the Wirilda Park and Conference Centre, Tyers; call for details. Contact Chris Morley 0417 583 239 <info@LVAstro.org>. www.LVAstro.org

The **Mornington Peninsula Astronomical Society** meetings are held on the 3rd Wednesday of each month (except December) at 8 pm at The Briars Astronomy Centre, The Briars Historic Park, 450 Nepean Highway, Mount Martha. Contact Peter Skilton 0419 253 252 <welcome@mpas.asn.au> . www.mpas.asn.au

The **Mount Burnett Astronomical Society** is open for members every Friday night from 7:30 pm. Contact Mount Burnett Observatory hotline 0490 665 004 <info@mbo.org.au>. mbo.org.au

The **Snake Valley Astronomical Association** meet and observe at the SVAA Clubroom at 825 Linton-Carngham Rd Snake Valley on the closest Friday to the New Moon each month. ballaratman.wixsite.com/svastro

The **Tallangatta & District Astronomy Club Inc** get together once a month at the Tallangatta Showgrounds (10 Coorilla St) and various other locations for night sky observing. Contact Zachary West 0438 863 739 <tallangattaastronomyclub@gmail.com>.mathewshields76.wixsite.com/tadac

WESTERN AUSTRALIA

The **Astronomical Society of the South West** has observing nights at their observatory south of Bunbury on the two Fridays before the New Moon. There is an active junior group which meets twice monthly. Contact Phil Smith (08) 9721 1586 <enquiries@assw.org.au>. www.assw.org.au

The **Astronomical Society of Western Australia** has regular meetings, see website for details. Contact <aswa.info@aswa-inc.org.au>. aswa-inc.org.au

GLOSSARY

Albedo The ratio of the amount of light reflected from a Solar System object to that received by it. A perfectly reflecting body has an albedo of 1.0 or 100%. The average lunar albedo is 0.12 or 12%.

Algol A variable star of a class known as eclipsing variables. Algol's brightness fluctuates every 69 hours as it is eclipsed by its fainter companion.

Almanac A set of tables giving positions of Sun, Moon and planets at various times, plus other astronomical information; an ***Ephemeris***.

Altazimuth coordinates The angular height (***altitude***) of an object above or below the horizon and its angular direction (***azimuth***) from north measured towards the east.

Altitude The angular elevation of an object above or below the horizon.

Angular diameter The apparent diameter of an object measured in degrees.

Angular separation The angular distance between two celestial bodies measured in degrees.

Aphelion The point in an orbit of a body most distant from the Sun. It is the opposite to ***perihelion***.

Apogee The point at which a body in orbit around the Earth reaches its farthest distance from the Earth. It is the opposite to ***perigee.***

Arcminute An angular measure (each degree is divided into 60 arcminutes).

Arcsecond An angular measure. Each degree contains 3600 arcseconds, and each ***arcminute*** contains 60 arcseconds.

Asterism A recognisable grouping of visible stars. The stars may belong to one or more constellations. The grouping will have a name, for example 'The Teapot' in Sagittarius.

Asteroid See ***Minor Planet***.

Astronomical unit The average distance from Earth to the Sun, approximately 149.6 million km, which equals 1 au.

Azimuth Horizontal coordinate of an object's position in the sky. Derived by drawing an imaginary vertical line from the object to the horizon below. The position is then expressed in degrees east from the north point.

Celestial equator A projection of the Earth's equator onto the ***celestial sphere***.

Celestial poles Points on the ***celestial sphere*** directly above the Earth's poles about which all the stars seem to rotate; known as the north and south celestial poles (NCP and SCP).

Celestial sphere Imaginary sphere of infinite size surrounding the Earth to which celestial bodies seem to be attached.

Circumpolar Objects in the sky which never set. To determine which objects are circumpolar from a particular place, subtract the observer's latitude from 90°. This provides the minimum ***declination*** it must have to be considered circumpolar.

Colour index The difference in the magnitudes of an object measured at two different wavelengths. It is a measure of the colour (temperature) of a star.

Coma The head of a ***comet***, usually the brightest part. Also a defect in an optical system.

Comet Small icy body that orbits the Sun and produces a coma and often tails of gas and dust when approaching the Sun.

Conjunction An alignment of two bodies; their least ***angular separation*** as seen from Earth. When an object is said to be in conjunction, it is with the Sun (unless stated otherwise).

Conjunction — Inferior When an ***inferior planet*** (Mercury or Venus) passes between the Sun and the Earth.

Conjunction — Superior When the Earth and an ***inferior planet*** (Mercury or Venus) are situated on opposite sides of the Sun.

Constellation A pattern of stars identified by name, usually of mythological people, animals, or objects.

Cosmology The study of the large-scale structure and evolution of the Universe.

CST Central Standard Time.

Culmination The instant when a celestial body crosses the ***meridian***; an object culminates when it reaches its highest point above the observer's horizon.

Declination (Dec) One part of the equatorial coordinate system used to specify the location of an object in the sky. It is the angular distance of a body north (+) or south (–) of the ***celestial equator*** and is analogous to lines of latitude on the Earth.

Diurnal motion The daily motion of the sky produced by rotation of the Earth, causing the rising and setting of the Sun, Moon, planets and stars.

Eccentricity A measure of how long or thin an ellipse is. The closer the eccentricity is to zero, the more circular the orbit.

Eclipse When one object passes in front of or into the shadow of another.

Eclipse of the Moon When the Moon passes into the shadow of the Earth. It is a total eclipse when the Moon is immersed in the umbral shadow, partial if only partly covered by the ***umbra***, and penumbral if the Moon passes only through the ***penumbra*** of the Earth's shadow.

Eclipse of the Sun When the Moon passes in front of the Sun. It is total when the Moon has a larger ***angular diameter*** than the Sun and completely covers the disc, annular if smaller (leaving a ring of sunlight surrounding the Moon), and partial if only partly covered.

Ecliptic The plane of the Earth's orbit projected onto the ***celestial sphere***. It can also be defined as the Sun's path against the stars.

Ellipse An oval. The shape of the orbit of the planets. The axes of an ellipse are called the minor axis and major axis.

Elongation The ***angular separation*** of two bodies. The greatest elongations of Mercury and Venus occur when the planets are at their largest angular distance from the Sun, as viewed from the Earth.

Emission nebula A cloud of glowing gas excited by ultraviolet radiation from hot stars.

Ephemeris (plural ephemerides) A tabulated list of positions for an object calculated from its orbital elements.

Epoch A date chosen as a reference point for observations. This book uses Epoch 2000.0 for all coordinate data and is compatible with modern star atlases.

Equation of Time The difference between apparent and mean solar time.

Equinox The two times of the year when the Sun crosses the ***celestial equator***; vernal or spring equinox occurs about September 21, and autumnal equinox about March 22.

EST Eastern Standard Time.

Galactic equator The great circle along the line of the Milky Way, marking the central plane of our ***galaxy***.

Galaxy A large disc or ball of billions of stars and ***nebulae***. They are the largest individual structures in the Universe.

Galilean satellites Named after their discoverer, Galileo Galilei. The four brightest satellites of Jupiter: Io, Europa, Ganymede, and Callisto (also known as the Jovian satellites).

Geocentric As viewed or measured from the centre of the Earth.

Gibbous Phase of a planet or the Moon more than fifty percent illuminated. For example, the Moon is gibbous between First and Last Quarter.

Globular Cluster A huge sphere containing thousands of stars. They surround our ***galaxy*** and are seen in other nearby galaxies.

Heliocentric As viewed or measured from the centre of the Sun.

Hour Angle The angular measure of the distance of an object from the local ***meridian***.

Inclination The angle that the plane of the orbit of one astronomical body makes with the plane of the orbit of another. Usually in reference to the ***ecliptic***.

Inferior planet A planet orbiting the Sun inside Earth's orbit. That is, Mercury or Venus.

Julian date The number of days since noon on 1 January 4713 BCE It is useful for astronomical observations as it saves confusion with other calendars. The starting date chosen was arbitrary but far enough back in time for there to be no astronomical records prior to then.

Large Magellanic Cloud (LMC) Satellite ***galaxy*** to our own Milky Way system, appearing to the unaided eye as a large nebulous patch situated in the ***constellation*** of Dorado. From mid southern latitudes the LMC is ***circumpolar***.

Librations The gentle rocking motion of the Moon as it orbits the Earth that allows observation of the side that normally faces away from our planet. In total, through this irregular motion fifty-nine percent of the Moon can be seen.

Light-year The distance that light traverses in a vacuum during one year (approximately 9,460,529,700,000 km).

Lunation The period of time between two consecutive New Moons.

Magnitude Brightness scale of stellar objects. From one magnitude to the next the ratio of brightness is the 5th root of 100, or approximately 2.5. The lower the number the brighter the star. The brightest stars as seen from Earth are magnitude –1 (except for the Sun which is –26.7). The faintest visible to the unaided eye are magnitude 6 (under dark skies).

Magnitude — absolute The magnitude a star would have if it were viewed from a distance of 10 ***parsecs*** (32.6 ***light-years***).

Meridian The local meridian is an imaginary line running directly overhead from north to south. The ***right ascension*** on the meridian equals local ***sidereal*** time.

Meteor (also shooting or falling star***)*** A small particle striking the Earth's atmosphere that is heated to incandescence by friction with air molecules.

Meteor shower A group of ***meteors*** that appear to originate from a small region of the sky (the radiant).

Meteor swarm (or ***stream***) ***Meteoroids*** grouped in a localised region in orbit around the Sun (the source of ***meteor showers***).

Meteorite A ***meteor*** that survives its trip through the atmosphere and reaches the ground.

Meteoroid A small solid particle moving in orbit about the Sun.

Minor planet (***Asteroid***) Small rocky objects which revolve around the Sun. Most lie between the orbits of Mars and Jupiter in the asteroid belt.

Nadir The point on the ***celestial sphere*** directly opposite the ***zenith.***

Nebula A cloud of interstellar gas and dust. See also ***emission, reflection*** and ***planetary nebula.***

Node One of two points at which an orbit passes through a reference plane (usually the ***ecliptic***).

Oblateness The ratio of the difference of equatorial and polar radii to equatorial radius.

Obliquity The degree of inclination (or tilt) of a planet's equator to its orbital plane.

Occultation The disappearance of one celestial body behind another.

Open star cluster A loose grouping of stars numbering from a few dozen to hundreds.

Opposition When a celestial body is opposite the Sun in the sky as viewed from Earth.

Orbit The path followed by one body as it moves around another.

Parallax An apparent shift in the positions of nearby stars (relative to more distant ones) from the changing position of the Earth in its orbit around the Sun. The size of the shift can be used to measure the distances to the nearer stars.

Parsec A unit of distance used by astronomers which is equal to 3.26 ***light-years***. A parsec is defined as the distance to a celestial body whose ***parallax*** is one arcsecond.

Penumbra Area of partial illumination in the shadow of a planet surrounding the ***Umbra***. Also zone of intermediate brightness between a sunspot and the solar photosphere.

Perigee The point at which a body in orbit around the Earth most closely approaches the Earth. It is opposite to ***apogee.***

Perihelion The point in an orbit closest to the Sun, of a comet, planet or minor planet. It is opposite to ***aphelion***.

Perturbation Small changes in the motion of a body caused by the gravitational effects of another body.

Planetary nebula An expanding shell of gas ejected from a star. The outer layers of a red giant during the latter stages of its evolution, the core of which becomes a white dwarf.

Planisphere A handheld aid used to identify which constellations are visible to an observer on any particular date and time.

Polar axis The axis around which a celestial body rotates.

Proper motion The small change in position of nearby stars due to motion across the line of sight (measured in seconds of arc per year).

Quadrature When two celestial bodies have apparent longitudes that differ by 90° as viewed from a third body.

Reflection nebula A gas cloud illuminated by a nearby star.

Retrograde motion 1. An actual motion contrary to the general direction of the bodies in the Solar System. An example of actual retrograde motion is Neptune's satellite Triton.

2. Apparent retrograde motion is the westward motion of a planet with respect to the stars. This occurs near ***opposition*** for the outer planets and near ***inferior conjunction*** for the inner planets.

Right ascension (RA) Part of the equatorial coordinate system used to specify the location of an object in the sky. It is the angular distance of an object from an imaginary line in the sky. It is analogous to lines of longitude on the Earth but is measured in hours (24 hrs = 360°).

Sidereal time A method of keeping time which uses the motion of the stars rather than the Sun. One sidereal day is equal to 23 hrs 56 m 4 s.

Small Magellanic Cloud (SMC) Satellite ***galaxy*** to our own Milky Way, appearing to the unaided eye as a nebulous patch in the constellation of Tucana. From mid southern latitudes the SMC is ***circumpolar***.

Solstice The time when the Sun is farthest from the ***celestial equator***. In the Southern Hemisphere around 21 June marks the shortest day of the year, and around 21 December marks the longest day.

Spectral type A star's spectral classification determined by its ***spectrum***.

Spectrum The light of an object spread out like a rainbow. As well as a continuous spectrum, a star normally shows a distinctive set of dark and bright lines which are characteristic of its composition.

Superior planet A planet orbiting the Sun outside Earth's orbit.

Synodic period The time that it takes for an object to reappear at the same point in the sky, relative to the Sun, as observed from Earth.

Transit The passage of Mercury or Venus in front of the Sun's disc or the passage of a satellite or its shadow across the face of its planet.

Transit the meridian or meridian passage The passage of a heavenly body across the ***meridian***.

Twilight The short period of time before sunrise and after sunset during which there is not complete darkness.

Twilight — astronomical Astronomical twilight ends (in the evening sky) or begins (in the morning sky) when the Sun is 18° below the horizon.

Twilight — civil Civil twilight ends or begins when the Sun is 6° below the horizon.

Twilight — nautical Nautical twilight ends or begins when the Sun is 12° below the horizon.

Umbra Zone of maximum darkness in the shadow of a planet. Also the darkest part of a sunspot.

Universal time (UT) A time system measured from the Meridian of Greenwich in England.

WST Western Standard Time.

Zenith The point directly overhead (90° in altitude).

Zenithal Hourly Rate A general guide to the expected intensity of any given meteor shower. It is a theoretical rate, assuming the radiant is at the ***zenith*** with a sky limiting magnitude of 6.5.

Zodiac The traditional twelve constellations that lie across the ***ecliptic*** (astrologers ignore Ophiuchus, which also lies across the ecliptic).

GREEK ALPHABET

α	Alpha	ε	Epsilon	ι	Iota	ν	Nu	ρ	Rho	φ	Phi
β	Beta	ζ	Zeta	κ	Kappa	ξ	Xi	σ	Sigma	χ	Chi
γ	Gamma	η	Eta	λ	Lambda	ο	Omicron	τ	Tau	ψ	Psi
δ	Delta	θ	Theta	μ	Mu	π	Pi	υ	Upsilon	ω	Omega

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0° 1° 2° 3° 4° 5° 6° 7° 8° 9° 10° 15° 20° 25°

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Astronomer-at-Large

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