ASTRONOMY

2020 AUSTRALIA

Includes Nov / Dec 2019 monthly sections

YOUR GUIDE TO THE NIGHT SKY

Ken Wallace
Glenn Dawes
Peter Northfield

CALENDAR 2020

JANUARY

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DECEMBER

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ASTRONOMY 2020

AUSTRALIA

Glenn Dawes   Peter Northfield   Ken Wallace

Quasar Publishing 2019

Acknowledgements

Some of the information for this yearbook was adapted from the following sources:

- Astronomical Almanac for the Year 2020 (US Naval Observatory and UK Hydrographic Office)
- Astronomical Tables of the Sun, Moon and Planets (Meeus)
- Atlas of the Moon (Rükl)
- Cambridge Guide to the Constellations (Bakich)
- Comet orbital elements (International Astronomical Union)
- Exploring the Moon (Massey)
- International Astronomical Union
- International Meteor Organisation Calendar
- Mathematical Astronomy Morsels series, volumes 1 to 5 (Meeus)
- NASA/JPL websites
- Stars (Jim Kaler)
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- Multiyear Interactive Computer Almanac 1800–2050 version 2.22 (MICA) (US Naval Observatory)
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We (the authors) are responsible for any remaining errors. We have learned after doing this for 30 years is, no matter how thorough and excruciatingly detailed the checking is, some things are bound to slip through (followed by a heartfelt, mind-numbing sigh)—Quasar Publishing axiom.

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Illustrations

Front cover image is Earthrise over Compton crater (LRO NASA/GSFC/Arizona State University).

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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: A wide-field image shows the Milky Way stretching across the southern sky. Credit ESO and A. Fujii

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Astronomy 2020
Contents

INTRODUCTION TO THE 2020 EDITION

Welcome to Astronomy 2020, our thirtieth edition.

We are pleased to reintroduce a general astronomy lead article, which this year has been generously supplied by Associate Professor Michael Brown (many thanks). Professor Brown points out how an observer, using just a typical amateur sized telescope, with relatively low cost modern imaging systems, can contribute significantly to science. Another new inclusion for 2020 is monthly information for November and December of the previous year (2019), more on that below.

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

- The history behind the creation of the constellations.
- Is the globular cluster Omega Centauri a remnant of a past satellite galaxy to our Milky Way.
- Observing the Coma/Virgo Supercluster of Galaxies.
- Astronomy of the Incas.
- The closest star Proxima Centauri and its planet.
- LRO gives amazing close up views of the Moon.

Part I of Astronomy 2020 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. 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

For the Times they are a-Changin' …

This year we have made some format changes. We now include the November and December monthly sections from the previous year so our customers can immediately use this edition without having to refer to two books.

We have also removed some data. To decide what could be taken out we reviewed how the people, who value our book, participate in the hobby and how has this evolved over the years. For the true beginners with little more than a sense of wonder and a thirst to know, we believe they are well catered for in Astronomy 2020. Telescope users have become polarised into two camps. There are those we call the pure observers who, with some knowledge, spend their money on the optics, taking a more low cost approach to their mounts. Then there are the people who ride the back of the technology revolution turning to computer controlled scopes, now much more affordable instruments, that can automatically slew to an object selected from its database.

Keeping this in mind, we had a hard look at the sea of numbers in Part II. Printed rise and set times for all the planets are not used by the beginner or pure observer and not needed by the techies. Besides, no one observes the planets (or anything) close to the horizon unless they have to. For this reason we believe the approximate times given in the Rise–Set charts in Part I should suffice. Often the transit times for the outer planets are more valuable, when the planet is high in the northern sky with minimal atmospheric turbulence. Using the same reasoning, the position tables of the Sun, Moon and planets are either not used or not necessary.

When we started these books in 1990 there was no internet (believe it or not!), so some of the information we supplied wasn't easily obtainable elsewhere. Today a lot is available either online, from computer programmes or through cheap (or free) astronomy/planetarium apps on mobile devices. The lunar occultation tables are no longer included as the Occult software (written by Australian David Herald) is readily available for download and it can tailor event times for your location. Also, Julian Date and Sidereal time are better catered for by apps or are made redundant by telescope computer systems. We hope our loyal customers understand these decisions.

As we stated above, some relatively little used information has been removed from this year's book. The data will instead be available on our website. This includes position of the Sun, Moon and planets, as well as the rise and set times for the planets and lunar occultation predictions for the capital cities.
www.quasarastronomy.com.au/downloads.html

Whether you are interested in capturing photons by your eye, hunched over an eyepiece, or electronically for that stunning image, we hope you remember to occasionally sit back and soak in the Universe.

Wishing you clear skies and see you next year.

Glenn Dawes Peter Northfield Ken Wallace

The largest visible-light telescopes available to professional astronomers have primary mirrors metres wide, and in the near future visible-light telescopes will have apertures tens of metres wide. This is a very different league from the 10 to 30 centimetre apertures of most amateur astronomers.

However, many of the key discoveries in astrophysics were made with telescopes only 10 to 30 centimetres in size. Furthermore, with near ubiquity of digital imaging—including digital SLRs, webcams and even mobile phone cameras—amateur astronomers now have access to more powerful equipment than professional astronomers did a century ago.

It is thus possible for you to retrace the history of astrophysics using your own telescope. While a large telescope, dark sky site and digital camera certainly help, there's a lot to see with your own eyes and a small telescope, even from suburban sites.

THE EARTH AND SOLAR SYSTEM

Galileo's telescopic observations of the planets changed our view of the Solar System. While the four Galilean Moons of Jupiter and Saturn's rings get the attention, the phases of Venus are perhaps a more powerful tool for understanding how our Solar System works.

In the Ptolemaic view of the Solar System, with the planets and Sun travelling around the Earth, Venus is never further than the Sun. As a consequence, in the Ptolemaic model we should mostly see the night side of Venus, with only a sunlit crescent of Venus being visible.

However, follow the phases of Venus throughout the year with your telescope and you can see an almost full Venus. This demonstrates that you are seeing Venus when it's further from us than the Sun, as you can see most of the daytime side of the planet. The angular size of Venus also changes dramatically as its phase changes, as you'd expect if the distance to Venus from Earth were changing dramatically.

Celestron 14" Edge with SBIG CCD camera

Today's amateur telescopes, with improved mounts and cameras, are more powerful instruments than large professional telescopes from a century ago. Amateur astronomers can thus retrace the development of astrophysics, and even observe recently discovered exoplanets.

Does your telescope have an equatorial mount? If so, then when you align your telescope's mount with the celestial pole, you are basically creating a mechanical model of the rotating Earth. Perhaps keep this in mind if a Flat Earther ever gate crashes your local star party.

Almost anyone can take an image of the stars appearing to move around a celestial pole. But did you know you can measure the changing positions of the celestial poles?

Many amateur astronomers are aware that the position of the celestial poles shifts from year to year, because the Earth's axis slowly shifts. This is because the Earth isn't a perfect sphere and spins like a spinning top, so its axis precesses. This means astronomical coordinates are tied to particular dates (epochs), reflecting when the Earth's axis was pointed in a particular direction.

But did you know you can use the position of the celestial poles to measure the Earth's motion through space? As the Earth moves at 30 kilometres each second, and light moves at 300,000 kilometres each second, the position of the celestial poles appears to oscillate with an amplitude of 1 in 10,000. This corresponds to plus or minus 20 arcseconds, which is well within reach of amateur equipment.

To measure the changing position of the celestial poles, all that is required are images of the celestial pole with your telescope's tracking off. The circular star trails will identify the current location of the pole. Even observations three months apart will show a shift greater than 10 arcseconds. Jason Wright's (open access) article in Research Notes of the American Astronomical Society[1] provides more details on how you can carry out this intriguing experiment. You can, with your own telescope, measure the Earth flying through space.

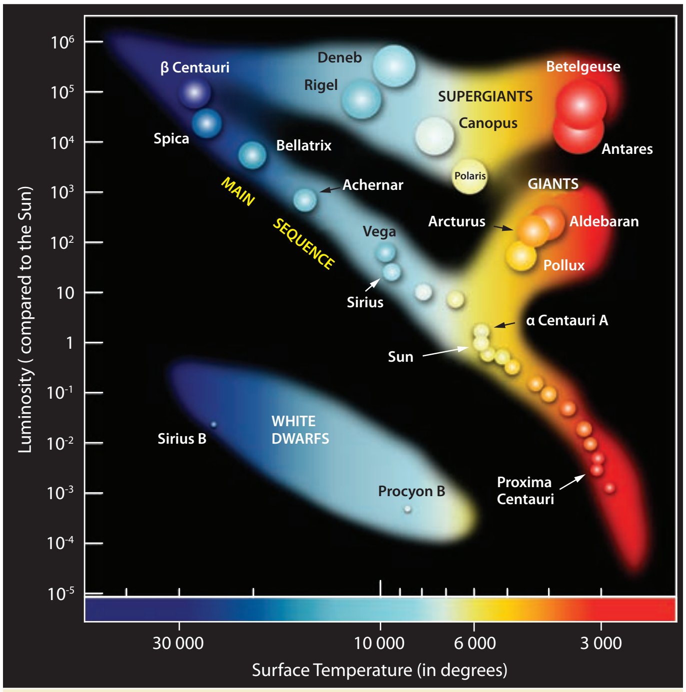
COLOURS

Even with the unaided eye you can see the colours of stars. Red Betelgeuse and blue Rigel in Orion are classic examples of this. These colours reflect the surface temperatures of the stars, with hotter stars having bluer colours. Betelgeuse has a surface temperature just over 3000 degrees Celsius while Rigel's surface roasts at 11,000 degrees Celsius.

Unsurprisingly, given two stars of the same size, the hotter star will be brighter than the cooler star. It is thus informative that Betelgeuse and Rigel, both of which are in the ballpark of 750 light-years from Earth, are comparably bright in the night sky. How is this possible? Well, Betelgeuse is much larger than Rigel. Rigel isn't exactly small, having a diameter 80 times that of the Sun, but Betelgeuse is far larger, with a diameter 900 times that of the Sun.

While Betelgeuse and Rigel are giants, more typical main-sequence stars also show a range of colours and thus temperatures. Vega and Sirius are blue, the Sun and Alpha Centauri A are yellow-white while dim Proxima Centauri is red.

The sequence of colour, from blue to red, reflects a sequence of luminosity and mass, from high to low. Ejnar Hertzsprung and Henry Norris Russell were the first astronomers to fully appreciate this sequence of colour, luminosity and mass during the early 20th century and Hertzsprung-Russell diagrams are central to our understanding of stars.



The Hertzsprung-Russell diagram illustrating the luminosities of stars as a function of their temperature and colours (credit ESO)

Although blue stars are typically more massive than red stars, they consume hydrogen in their cores so rapidly that they have relatively short lifetimes, measured in millions rather than billions of years. You can thus age date celestial objects by the presence or absence of bright blue stars.

The Pleiades cluster, visible to the unaided eye and spectacular with the wide-field telescope, is dominated by bright blue stars and is roughly 100 million years old. The Jewel Box cluster, a popular target for southern amateur astronomers, is also dominated by bright blue stars, although it also contains a bloated red giant star that is approaching the end of its life.

In contrast, the globular cluster Omega Centauri lacks short-lived blue main-sequence stars. Instead, the brightest stars in this 12 billion year old star cluster are red giants, and this can be clearly seen in amateur images taken of Omega Centauri.

Using amateur telescopes equipped with digital cameras, it is possible to create a Hertzsprung-Russell diagram using images of star clusters taken with blue and green (or green and red) filters. While accurate photometric calibration of amateur astronomers' images has historically been challenging, such calibrations are becoming easier with the availability of all-sky photometry of bright stars. For example, the Hipparcos catalogue photometry available via the Aladin database (aladin.u-strasbg.fr) and the AAVSO Photometry All-Sky Survey (APASS; www.aavso.org/apass).

If you know the magnitudes of bright stars in your images, then you can use Pogson's formula to convert digital counts into astronomical magnitudes, so the bright star magnitudes can anchor the magnitudes of faint stars. Measuring stars with a range of magnitudes and colours in a star cluster and using a spreadsheet program you can create your own Hertzsprung-Russell diagram. You can see the blue main sequence stars in the Jewel Box or the red giants in Omega Centauri for yourself.

A SPECTRUM OF LIGHT AND THE EXPANDING UNIVERSE

Spectroscopy, where light is split into a rainbow of colour, has traditionally been the domain of professional astronomers. Often the exposure times were long, and careful guiding was required to keep faint objects on a spectrograph slit. But digital imaging has made spectroscopy far more accessible that it once was.

For about $250, it is possible to buy a diffraction grating that can convert your digital imager into a *slitless* spectrograph. While noisier and less precise than a slit spectrograph, it makes spectroscopy relatively easy and opens up new ways of seeing the Universe.

Each image taken with a slitless spectrograph contains a white light image and an offset spectrum of every celestial object in the field-of-view. An easy spectroscopic target for southern observers is Eta Carinae and the Homunculus Nebula. The nebula features prominent lines of distinct colour associated with hydrogen gas. In particular, the red hydrogen alpha and blue hydrogen beta lines leap out at the observer. These bright hydrogen lines, which have well-measured laboratory colours (wavelengths), also provide simple means of calibrating the relationship between pixel coordinates and wavelength (colour), which comes in handy when looking at more challenging celestial objects.

The spectrum of Betelgeuse has hydrogen lines but unlike Eta Carinae and the Homunculus Nebula these lines are seen in absorption (rather than emission) against a continuous spectrum of light. Planetary nebulae and novae can also be rewarding targets for amateur spectroscopy.

Omega Centauri, credit Joe Cauchi

Amateur astronomers' images of open and globular clusters can reveal the colours of stars. In young open clusters one can find bright blue stars that fall on the *main sequence*, whereas in older globular clusters the brightest stars are bloated red giants.

Lets now go further afield. The Universe is expanding, with distant galaxies and quasars rushing away from us, and this expansion can be measured using the red shift of hydrogen lines. Since the slitless spectra are a bit rough, we want something to be *really* moving away from us and we want it to be bright too. Quasars fit the bill.

Quasar 3C 273 is an incredibly luminous object, powered by the in-fall of matter towards a black hole. Its spectrum also includes the distinctive hydrogen lines. With a 20-cm telescope, diffraction grating and digital camera, it should be possible to measure the spectrum of 3C 273 within an hour (even at a suburban site). Incredibly, the hydrogen lines of 3C 273 have been shifted redward by 16%, implying that 3C 273 is moving at almost 16% of the speed of light. That's 45,000 kilometres every second.

The vast speed of 3C 273 also reflects its vast distance. It is almost two billion light-years from Earth—in other words, you are seeing light that's taken two billion years to reach us and you are looking two billion years into the past. The view from your backyard may be a little more expansive than you originally thought.

NEW PLANETS

While you can retrace the past four centuries of astrophysics with your telescope, you can also connect with more recent developments in astrophysics.

Since the 1990s, thousands of planets have been discovered beyond our own Solar System, and dozens of them can be (indirectly) detected with small telescopes.

Many of the recently discovered exoplanets (planets beyond our own Solar System) were found using the transit technique. Some planets orbiting other stars pass directly between their stars and us, blocking a tiny part of the star's light. For a Jupiter-sized planet orbiting a Sun-sized star, the star dims by just 1%. Amateur astronomers are now regularly detecting these planet transits.

The bright quasar 3C 273 is over 2 billion light-years away but is accessible to amateur astronomers. With a visual magnitude of 13 it can be seen with small optical telescopes at dark sites, although it isn't that much to look at. With a diffraction grating and digital detector amateur astronomers can measure the red shift of the quasar. Credit wikimedia commons

Anthony Wesley

The method of detecting them is relatively simple, but practice definitely makes perfect. If you can measure the brightness of a star with a transiting planet and a neighbouring star, you can detect the 1% dimming caused by the transit of the planet. By comparing to a neighbouring star, you can remove complicating factors such as changes in the scattering and absorption of light by the Earth's atmosphere. Monash University undergraduate students, using 11 inch and 14 inch telescopes in suburban Melbourne, have detected several planet transits. To be fair, these were on nights better than the average for Melbourne.

The Transiting Exoplanet Survey Satellite, TESS, will discover thousands of new exoplanets. While many of the planets TESS discovers will be too small for amateurs to observe using transits, it will detect larger gas giant planets too and these will often be orbiting stars brighter than magnitude 12. Thus newly discovered worlds are within reach of backyard telescopes.

LUCK

If you've used a telescope, you are probably aware of seeing, the blurring of celestial objects caused by turbulence in the Earth's atmosphere. It is also responsible for the twinkling of stars, which is particularly bad when the weather is unsettled.

Professional astronomers, using large telescopes, now use adaptive optics to correct for the turbulence caused by our atmosphere. This includes deformable mirrors and (in some instances) artificial sodium laser guide stars. Apart from some tip-tilt systems using natural guide stars, adaptive optics is beyond the reach of the amateur astronomer community. However, there's another option increasingly used by amateurs to beat seeing. It involves pure luck.

Typically a star viewed through a telescope will be broken up into multiple images, which will rapidly move around as the turbulence in our atmosphere moves and fluctuates. But occasionally, for a fraction of a second, the turbulence lines up in a way to produce diffraction-limited images. This is lucky imaging, and amateur astronomers using telescopes and cameras taking very short exposures (e.g., video frame rates) have been using it to obtain spectacular images.

Australian amateur astronomer Anthony Wesley has established himself as an international leader (perhaps the leader) in observing Jupiter. In 2009 he detected a dark smudge on Jupiter, the result of a comet or asteroid impact, which was subsequently studied in detail with the Hubble Space Telescope. The amateur's discovery has led to new research and insights by professional astronomers. Wesley also took video footage of the flash of an impact on Jupiter in 2010.

More recently, Wesley has been using lucky imaging to monitor changes in the Great Red Spot. The detail in his images surpasses what was possible with ground-based telescopes during the 20th century. In mid-2019 Wesley and other amateur astronomers saw *flakes* peeling off the great Great Red Spot. This, combined with changes in the colour of the spot over recent years, has made some astronomers speculate that the Great Red Spot's demise is imminent. Regardless of what happens, the lucky images of amateur astronomers will improve our understanding of Jupiter, a planet first observed by Galileo with a telescope over four centuries ago.

Anthony Wesley's images of Jupiter provide an excellent illustration of what is possible using amateur telescopes and very short exposures. By selecting the tiny fraction of images where the impact of seeing is minimised, one can achieve very high angular resolution images.

Associate Professor Michael Brown is an astronomer at Monash University specialising in galaxy evolution, active galactic nuclei and wide-field astronomical surveys. He is best known for measuring the slow growth of very massive galaxies and the multi-wavelength spectra of galaxies. He is the coordinator of Monash University's observational astronomy units, where students analyse data taken with large telescopes and observe with 20 to 35 cm aperture telescopes. He began astronomical observing as a child with his grandfather's 50 mm refractor, and for visual observing he now uses an old orange-tube Celestron C8.

FURTHER READING

AAVSO CCD Photometry Guide
www.aavso.org/ccd-photometry-gude

[1] *Proving Heliocentrism and Measuring the Astronomical Unit in a Laboratory Astronomy Class Via the Aberration of Starlight* by Jason Wright, Research Notes of the AAS, iopscience.iop.org/article/10.3847/2515-5172/aad0f5

The Revival of Amateur Spectroscopy by Maurice Gavin, Sky & Telescope
www.skyandtelescope.com/get-involved/pro-am-collaboration/the-revival-of-amateur-spectroscopy/

Exoplanet observing for amateurs by Bruce Gary, brucegary.net/book_EOA/EOA.pdf

An Introduction to Lucky Imaging for Astrophotography by Richard S. Wright Jr, Sky & Telescope, www.skyandtelescope.com/astronomy-blogs/imaging-foundations-richard-wright/lucky-imaging/

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 13.

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 China. 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 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 Carina star-rich 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

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? If you don't have a compass, taking note of where the Sun sets to get a rough direction for west might help. Also, 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 (tilt and pan) the device around the sky. All this is offered using red light to supposedly preserve your dark adaption. This sounds good, however 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 nice but does it leave you exposed to strong wind, such as on hilltops? If you are low or near water is fog a concern?

structure to the Milky Way and that it appears as a squashed oval, shows we are seeing it nearly edge-on. Occasionally these and other naked-eye deep sky objects will be mentioned in Constellations in the monthly sections.

Dark skies also offer the opportunity to try and see the planet Uranus with the unaided eye. The All Sky Map No 3 (p. 89) 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 self-discovery. There is a good chance any fuzzy object (unless it is a comet) will be marked on the All Sky Maps (see pp. 87–95).

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 approximately 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 100,000 ly across)
- The Magellanic Clouds, Large (LMC) is 160,000 ly and Small (SMC) is 190,000 ly.
- The most distant object visible to the naked-eye, the Andromeda Galaxy 2,300,000 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. 9). 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 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 the Moon and Venus on the evening of January 28 (see Sky View, p. 31).

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 16 and page 139 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 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. There are also a number of organisations that can help with finder charts and predictions. Start with your local astronomical society (p. 149) 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

The 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; below gives 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 106).

Observing the Moon (pp. 110–113). 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. 19). As an example we'll use mid-October. Jupiter, Saturn and Mercury are visible in the evening sky with Uranus and Venus in the morning. You will notice that Mars is near the midnight line and likely to be close to opposition and up the whole night, which is correct as shown in the October monthly Rise–Set chart. In fact, Uranus is approaching the midnight line, crossing it at the end of the month. The November section confirms Uranus is at opposition on the 1st and up the whole night.

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 18) this inner world is small with a full phase. It then enters the evening sky growing in size but its phase waning as it approaches inferior conjunction (between us and the Sun) on October 26. Mercury then enters the morning sky and the process reverses until superior conjunction is reached again (December 20). 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 highest in the sky, for example Mercury in the evening sky on October 2. See also its altitude while in conjunction with the Moon on September 19 (Sky View page 71).

Its fellow inner world **Venus** goes through the same process as Mercury but much slower, being further from the Sun. In 2020 a greatest elongation east (evening sky) occurs early on March 25 and it then spends the following three months increasing in size as its phase shrinks towards inferior conjunction on June 4.

Mars only achieves a reasonable size when near opposition. At other times, its reddish disc remains small and possibly featureless. Fortunately 2020 sees an opposition, a time when features such as a polar ice cap and various surface marking are easier to see. This assumes the planet doesn't have another globe encircling dust storm which spoiled what should have been an excellent opposition in 2018. The appearance diagrams in the monthly section show well its size increasing as it heads towards opposition in October. There is also a more detailed guide in Part II on observing the planet and its two elusive satellites.

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 57) confirms that this happens for Jupiter in mid-July. Besides observing its atmospheric belts, the **Great Red Spot (GRS)** is worthwhile looking for; see the table and explanation on pages 118 to 119. An example is the evening of May 28 around 11:53 pm (EST), a transit that is visible from anywhere in Australia.

Pages 120 to 127 cover the **Jovian Satellite Phenomena** as the four major moons shuffle 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 21, the diagram on page 125 shows this well. In this case there is also a drawing (see Sky View page 65). The *wiggly* diagrams also indicate events are occurring when a moon's line crosses Jupiter. For example on July 6 the evening sees an occultation of Io followed by a transit of Europa (and shadow). The next morning sees Ganymede eclipsed and then occulted (see page 124)—overall a busy night!

Saturn, with its impressive ring system (still well 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 shows a worked example of how to identify their configuration for your date and time. There are also Sky Views in July and August 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 predicted 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 138 and 136–137 respectively. These can be plotted on the All Sky Maps to get an approximate position. As an example we'll look at 532 Herculina on its opposition date. The July monthly text (p. 59) has the minor planet reaching opposition on the 2nd at magnitude 9.3 in Sagittarius. Page 140 tells you Sagittarius is on All Sky Maps No 8 and 6. The ephemerides (page 138) when plotted on Map 8 gives the location on this date about 3° east of M25, moving roughly in the direction of the Teapot's lid star Lambda Sagittarii.

Let's assume it's the evening of August 2 and you wish to find Comet 2P/Encke before it fades too much. Part I text (page 63) says the comet "… *opens August in the constellation of Corvus, at a predicted 8th magnitude, setting around 10 pm*". Carrying out the same exercise with its position (p. 137) it is best to use Map No 6. Interpolating between August 1 and 8, the comet is not far from one of the trapezium stars, Gamma Corvi (perhaps 2°). The ephemerides (page 137) also confirms it's setting later and hence gaining altitude in the evening sky.

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!

Probing the Solar System

SUN

As of September 2019, the **Parker Solar Probe,** orbiting the Sun, has just finished the third of three 24 million-km perihelions and having transmitted over 22 GB of data back after the second, is waiting until it gets a little further from the Sun before sending the next lot. Later in 2019 it will get another Venus gravity assist to lower the perihelion distance to 18.7 million km for the following two approaches. Eventually it will end up with a close approach of about 6 million km by 2025. www.nasa.gov/content/goddard/parker-solar-probe

MOON

Lunar Reconnaissance Orbiter has been observing the Moon since September 2009, over ten years now. It has provided the largest volume of data ever collected by a planetary science mission. The image below shows the geologically complex region west of Plato crater, width is 57 kilometres. Credit NASA/GSFC/Arizona State University.
www.nasa.gov/mission_pages/LRO/main/index.html

Chandrayaan-2, India's second lunar mission was launched 22 July 2019 and arrived as planned including the separation of the lander, Vikram. Unfortunately, contact with Vikram was lost as it approached the lunar surface. The orbiter has found it and communication attempts are continuing. The Chandrayaan-2 orbiter will continue its mission for at least one year and as many as seven. It is equipped with eight different science instruments to study the moon from above. These include: a high resolution camera (0.3 m, the highest of any lunar mission), a lunar terrain mapping camera, a solar X-ray monitor, an imaging infrared spectrometer, a dual frequency synthetic aperture radar for studying moon water ice and lunar mapping, a sensor to study the moon's thin exosphere and a dual frequency radio science experiment to study the moon's ionosphere. www.isro.gov.in/chandrayaan2-home-0

MERCURY

BepiColombo is the first large-scale joint Europe-Japan mission. Launched 19 October 2018, this mission consists of two orbiters and will conduct comprehensive studies of Mercury, including the magnetic field, the magnetosphere, the interior and the surface. Its planned arrival at Mercury is December 2025 for a one year plus mission.
www.stp.isas.jaxa.jp/mercury/p_bepi.html

VENUS

Akatsuki, also known as the Venus Climate Orbiter (VCO), is a Japanese (JAXA) space probe to study the atmosphere of Venus. It is in a 10-day equatorial orbit of the planet (compared to the polar orbit of previous probes, Venus Express and Pioneer Venus Orbiter) allowing different coverage.
global.jaxa.jp/projects/sas/planet_c/

MARS

Opportunity landed on Mars in January 2004, in Perseverance Valley on the west rim of Endeavour Crater. Contact with the rover was lost in May 2018, after a large dust storm likely obscured its solar arrays. The rover is now considered to be lost. www.nasa.gov/mission_pages/mer/

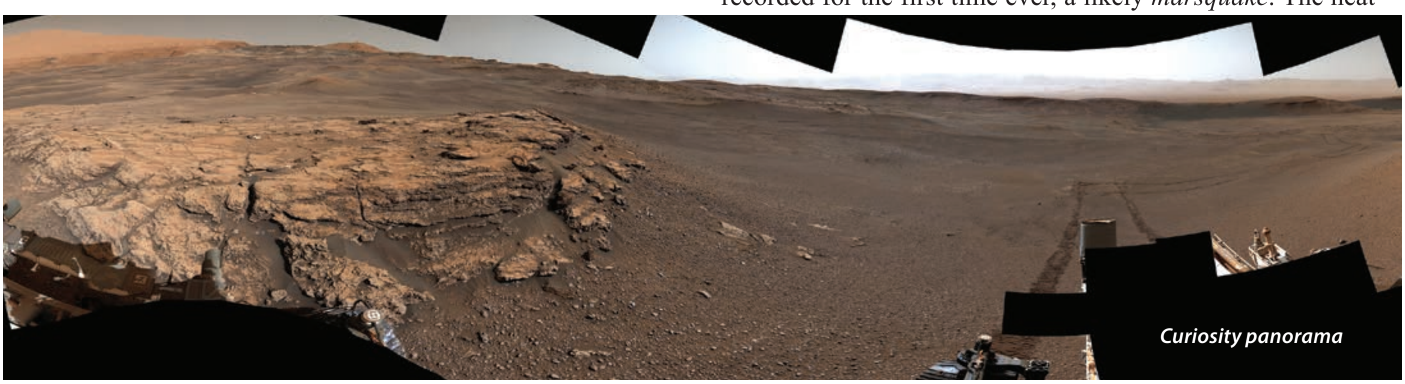
Curiosity has now been exploring Mars for over seven years and is still in the Vera Rubin Ridge area. Having worked around their drill problem, the probe has now dug 22 full-depth holes. mars.jpl.nasa.gov/msl/

ExoMars Trace Gas Orbiter (TGO) arrived at Mars in October 2016 and achieved its 400 km circular orbit in April 2018. New evidence of the impact of the recent planet-encompassing dust storm on water in the atmosphere, and a surprising lack of methane, are among the scientific highlights of TGO's first year in orbit. exploration.esa.int/mars/46475-trace-gas-orbiter/

Mars Odyssey, now in its 19th year of operation, continues to be the longest serving of the Martian missions. In May 2019 the probe imaged Phobos in full phase for the first time using its thermal camera. mars.jpl.nasa.gov/odyssey/

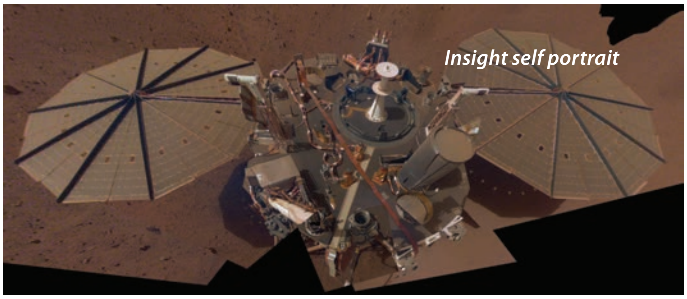
Mars Reconnaissance Orbiter, now operating for over 13 years, continues to compile the most global coverage ever accomplished by a camera at the Red Planet. HiRISE has imaged CO_2 ice sublimating, migrating sand dunes and meteorite strikes reshaping the landscape. MRO is the primary relay for Curiosity. mars.jpl.nasa.gov/mro/

InSight (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) landed on Mars 26 November 2018 to study its deep interior. In April 2019 it measured and recorded for the first time ever, a likely *marsquake*. The heat



Curiosity panorama

sensing spike, designed to dig down as much as five metres, stopped at about 30 cm. While it may have encountered a rock, JPL is working on plans to help. insight.jpl.nasa.gov/home.cfm


Insight self portrait

Mars Express continues to observe as it has been doing for over 14 years. It revealed the first geological evidence of a system of ancient interconnected lakes that once lay deep beneath the Red Planet's surface, five of which may contain minerals crucial to life. www.esa.int/esaMI/Mars_Express/

The **Mars Atmosphere and Volatile EvolutioN** (MAVEN) orbiter recently started changing its orbit in preparation to cover the Mars 2020 rover's entry when it arrives in February 2021. When not conducting relay communications, MAVEN continues to study the structure and composition of the upper atmosphere of Mars. It has enough fuel to operate until at least 2030. www.nasa.gov/mission_pages/maven/

Mars 2020 is planned for launch in July/August 2020 and landing 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 2020 is a mission to deliver a European rover and a Russian surface platform to Mars. The rover has completed its construction activities in the UK and has now heading to France for testing under the conditions of the Red Planet's environment. It is scheduled for launch July/August 2020 with arrival at Mars in March 2021, although they have to resolve a problem with its parachutes first. exploration.esa.int/mars/48088-mission-overview/

JUPITER

The **Juno** mission continues to orbit Jupiter with close flybuys every 53 days. Recent results show the first definitive detection beyond our world of an internal magnetic field that changes over time, a phenomenon called secular variation. Juno determined this is most likely driven by the planet's deep atmospheric winds. www.nasa.gov/juno/

Jupiter's turbulent Southern Hemisphere from Juno 21 Dec 2018. This captures the Great Red Spot, as well as a massive storm called Oval BA. Credit: NASA/JPL-Caltech/SwRI/MSSS, enhanced by Gerald Eichstädt and Sean Doran (CC BY-NC-SA).

DWARF PLANETS

The **Dawn** spacecraft mission ended 31 October 2018 when its fuel ran out. Among its accomplishments, Dawn showed how important location was to the way objects in the early Solar System formed and evolved. Dawn also reinforced the idea that dwarf planets could have hosted oceans over a significant part of their history—and potentially still do. dawn.jpl.nasa.gov

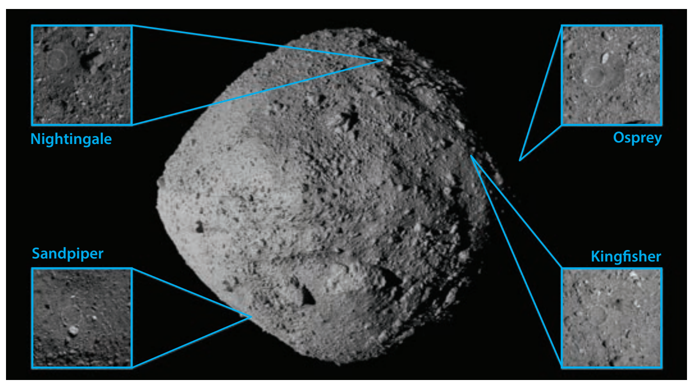
MINOR PLANETS

The **New Horizons** probe flew by Kuiper Belt Object 2014 MU69 (nicknamed Ultima Thule) on 1 January 2019. It will take until around August 2020 to transmit all the observation data. While doing that, the spacecraft will observe more


KBO MU69 (Ultima Thule)

KBOs with its onboard LOng Range Reconnaissance Imager (LORRI). These images will be used to study the rotation rates and surface properties of these KBOs, and to search for satellite systems around them. pluto.jhuapl.edu

The **OSIRIS-REx** (Origins Spectral Interpretation Resource Identification Security-Regolith Explorer) spacecraft is currently orbiting near-Earth asteroid Bennu. At the end of the orbiting phase, the probe will briefly touch Bennu to collect a



Potential Bennu landing sites

small sample to return to Earth for study. Planned departure is around March 2021 with arrival back here in 2023. www.nasa.gov/osiris-rex

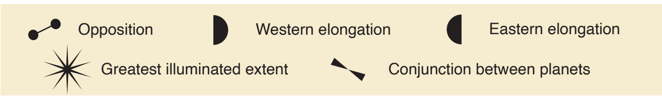
Hayabusa 2 arrived at Ryugu 27 June 2018. In July 2019 the probe performed its second touch manoeuvre. The release of the small rover is being planned. global.jaxa.jp/projects/sat/hayabusa2/

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, with an emphasis on the evenings when most people are out gazing at the night sky. This is ideal for those armed with nothing more than their eyes and their curiosity. A diverse range of subjects is covered including times to observe, what to look for in the Milky Way and some of the legends and mythology surrounding the heavens.

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 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 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.

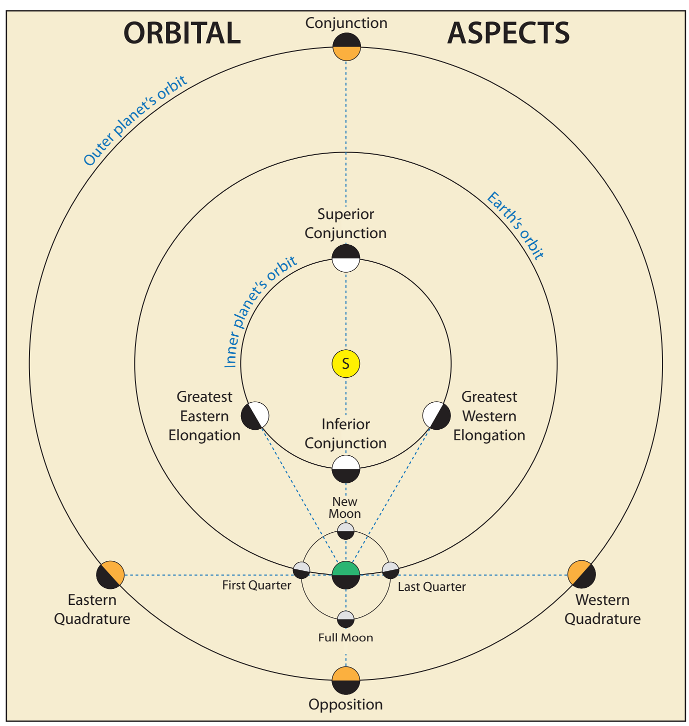
Dwarf Planets and Small Solar System Bodies

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

Minor Planets (or Asteroids) This section covers the brightest asteroids that reach opposition each month (12.6 magnitude or brighter). An entry includes the date of opposition (when it is 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. 138). 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 as usual are quite faint the early evening sky has some treats in store this year. For example, catch comet 2P/Encke in July and August around 8th magnitude and 88P/Howell well placed from August to October at approximately 9th magnitude. Also, try for C/2017T2 PANSTARRS as it rises out of the north and fades from 6th to 8th magnitude during June to August. For further information including ephemerides see pages 134 to 137 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—those largely unaffected by moonlight in the mornings during their peak period. Information for other known showers is given in Part II (p. 139). 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. With the exception of lunar phases (which are given to the nearest minute) 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 (see article on page 60).

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 formally end until the Sun is 18° below the horizon; this is called astronomical twilight. This happens about 90 minutes after sunset (or before sunrise) but it does vary with latitude. Only when astronomical twilight has ended is the sky considered truly dark (assuming the Moon is not up). There is also civil and nautical twilight, see the glossary.

Culmination When an object culminates it has reached its highest point in the sky and 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 the south.

Sky Views

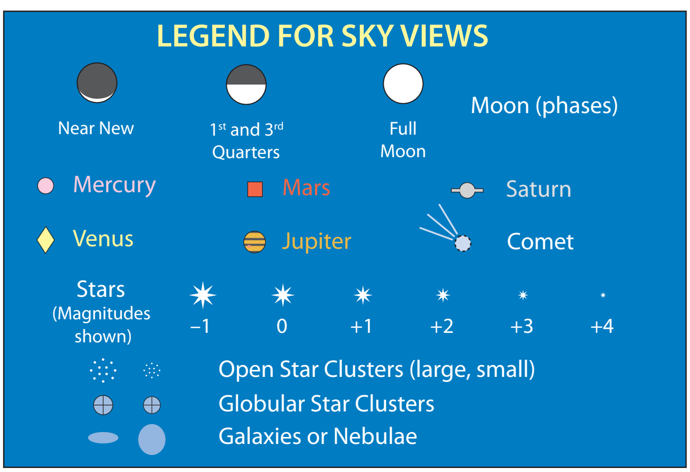
These diagrams are designed to help you find the naked-eye planets. The date and time chosen give the most interesting patterns of the planets and Moon. Sometimes the times correspond to about one hour (or even down to 30 minutes) before sunrise or after sunset. Although this is twilight, it is sometimes 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 or on 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. Each planet has a diagram for months close to their opposition (both July and August in 2020). Only the brightest moons are included. There are key differences worth keeping in mind between these planets.

The plane of the orbits of Jupiter's moons is close to the Earth's orbital plane, so we see them shuffle 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 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.

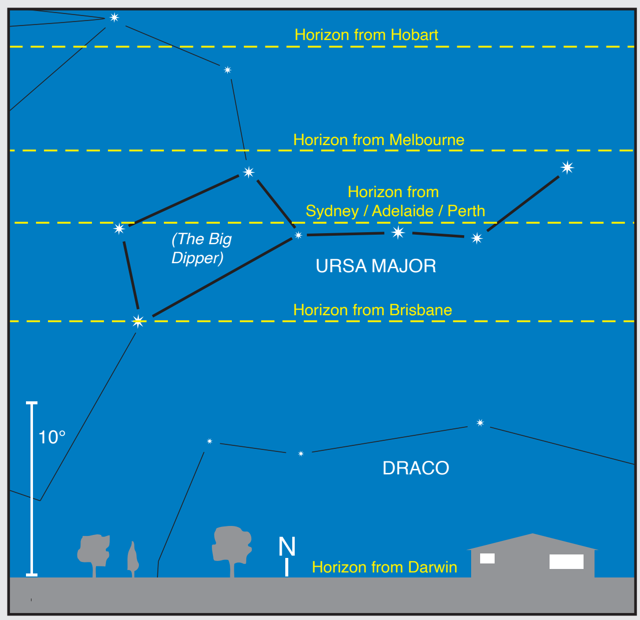


WHAT TIME IS IT? Unless a time zone or a location is specifically mentioned, times given in the Monthly Section will be approximate local standard time. No adjustments are made for Daylight Saving anywhere in this book. When it is in force you will need to add one hour to times given here. e.g., any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

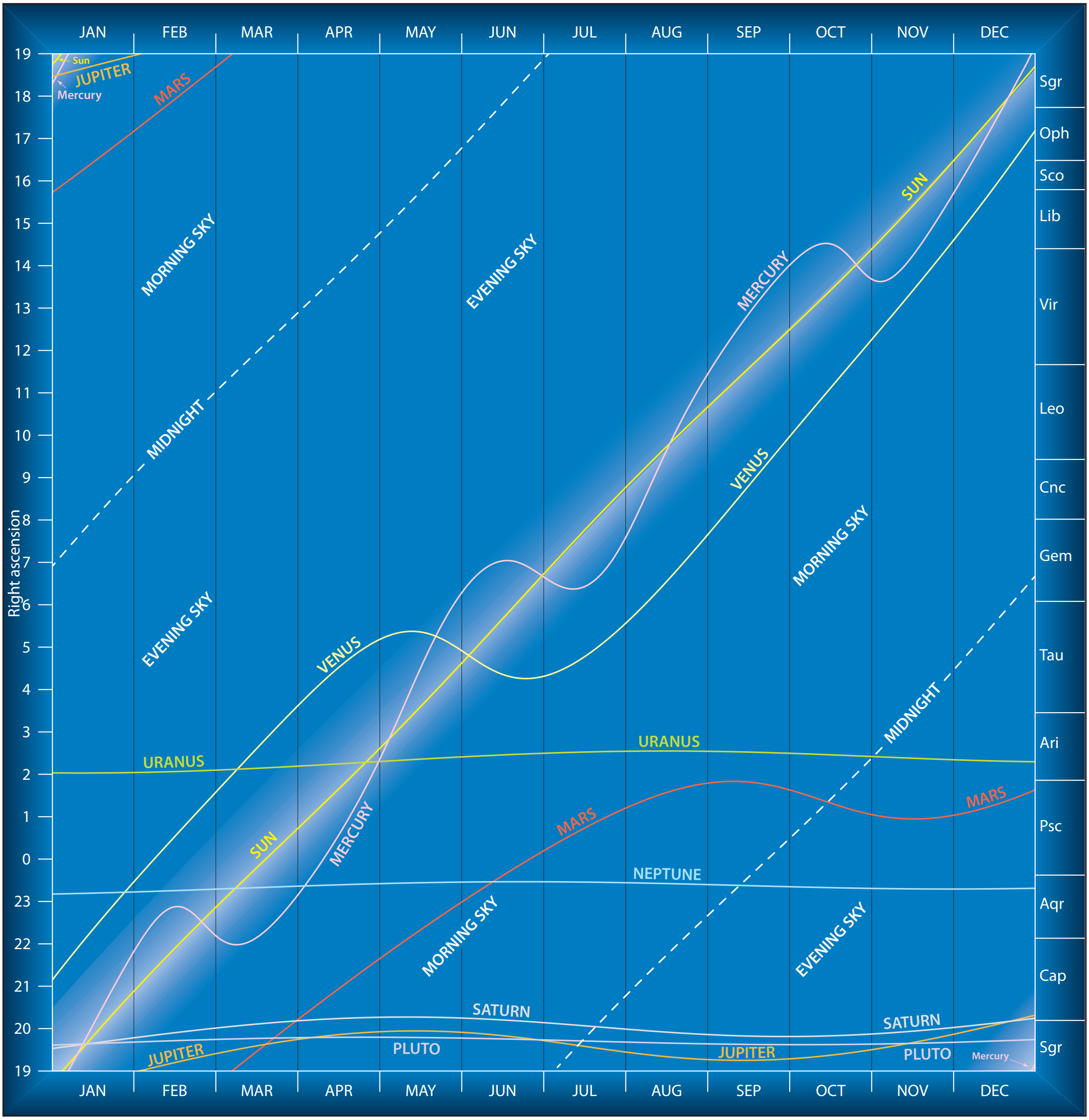
The inner ones are swamped by the glow of the nearby rings, making them hard to see.

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 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 Pisces (Psc) in the November evening sky (also see All Sky Map No. 3)

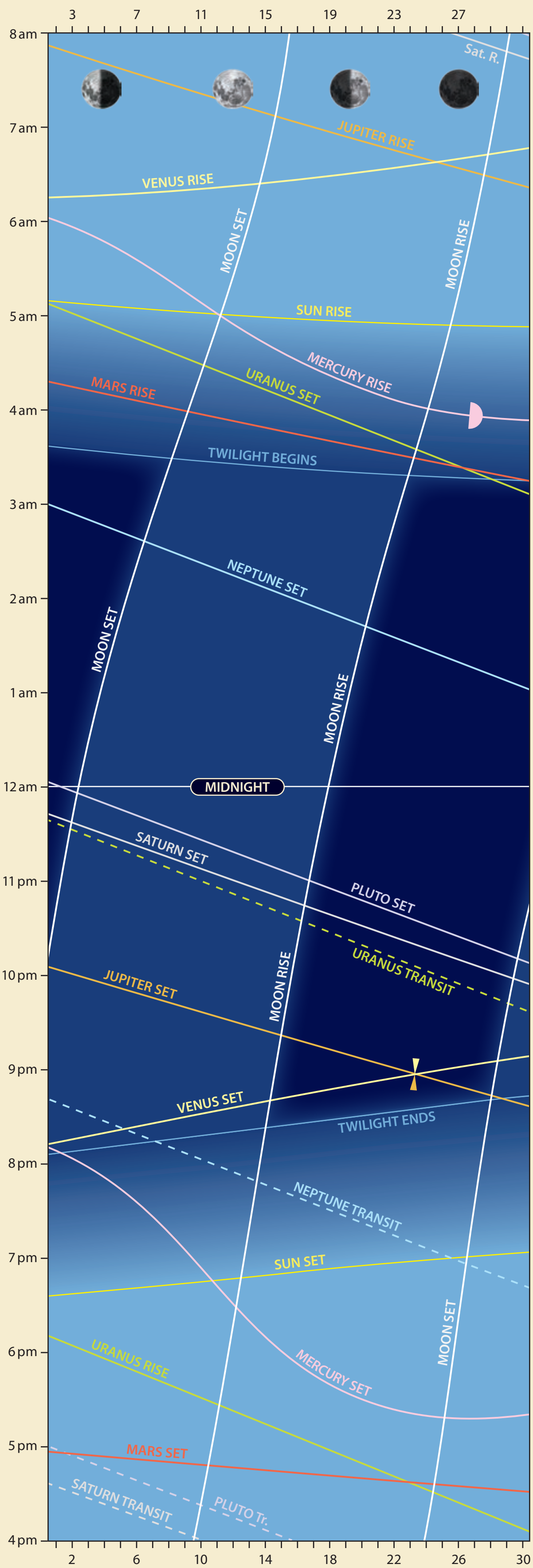
Mercury and Venus are in either inferior or superior conjunction when they cross the Sun line and at their greatest elongation when furthest from it. The best time to observe these inner planets is when their paths extend beyond the twilight. For Mercury, the optimum period in the evening sky is mid-September to mid-October and in the mornings mid-March to early April. Venus is visible until mid-May in the evening sky, returning to the morning in June.

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 Jupiter is in conjunction with Saturn in December (see Sky View p. 85).

NOVEMBER 2019

RISE–SET CHART



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

HIGHLIGHTS

- Venus and Jupiter close.
- Venus, Jupiter and the Moon—an awesome view!
- Moon and Jupiter close.
- Mars, Mercury and the Moon together.
- Saturn has two meetings with the Moon.

CONSTELLATIONS

Look south in the evening to the three prominent stars, Canopus, Achernar and Fomalhaut. They lie in a straight line, equidistantly placed, spanning 80° of sky. They are great starting points when trying to explore the somewhat challenging, faint far southern sky. These luminaries also mark three distinct regions.

With Canopus now rising in the south-east it heralds the return of the splendid southern Milky Way. The false cross will soon follow to the south with Sirius and Orion appearing further around to the east.

Achernar being high means it's a great time to attack the diverse star clusters and nebulae of the two Magellanic Clouds. Seeing the LMC and SMC clearly is a good indication of how dark your location is. Another test is if you can easily follow the numerous fourth magnitude stars that make up the river Eridanus all the way from Achernar back to its headwaters near Rigel in Orion (see All Sky Map No 2). It's worthwhile remembering that an equilateral triangle using the centre of the LMC and SMC as two corners, the third corner drawn below the clouds is a rough estimate for south and the South Celestial Pole.

APPEARANCE of the PLANETS

MERCURY Mercury in inferior conjunction on the 12th

1 Nov
dia 8.6"
mag 0.5

28 Nov
dia 6.8"
mag –0.6
Greatest elongation west (20.1°)

VENUS

15 Nov
dia 11.1"
mag –3.8

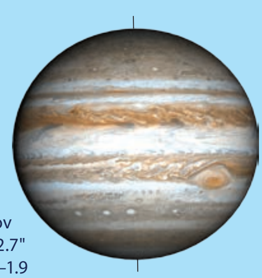
MARS

15 Nov
dia 3.8"
mag 1.8

SATURN

15 Nov
dia 15.7"
mag 0.6

JUPITER



15 Nov
dia 32.7"
mag –1.9

URANUS

15 Nov
dia 3.7"
mag 5.7

NEPTUNE

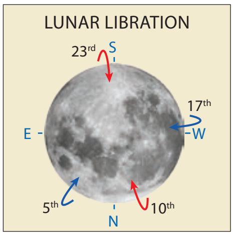
15 Nov
dia 2.3"
mag 7.9

PLUTO

15 Nov
dia 0.1"
mag 14.8

Although Fomalhaut is isolated, knowing its proximity to the curved neck of Grus makes its identification easy. Being well out of the galactic plane makes the star a good signpost for seeking distant galaxies, especially within Sculptor and Grus.

THE MOON



- 4th 8 pm (6 pm WST) First Quarter.
- 5th 8 pm (6 pm WST) Minimum Libration (5.9°), bright NE limb.
- 7th 7 pm (5 pm WST) Moon at apogee (furthest from Earth at 405,058 km).
- 10th 10 pm (8 pm WST) Maximum Libration (6.9°), dark NW limb.
- 12th Midnight (10 pm WST) Full Moon.
- 17th 4 am (2 am WST) Minimum Libration (4.8°), bright SW limb.
- 20th 7 am (5 am) Last Quarter.
- 23rd 1 pm (11 am WST) Maximum Libration (6.7°), dark SE limb.
- 23rd 6 pm (4 pm WST) Moon at perigee (closest to Earth at 366,716 km).
- 27th 1 am (11 pm previous day WST) New Moon.

THE PLANETS

Mercury opens the month in the western evening twilight although it is soon lost as it heads toward the Sun and inferior conjunction (between the Earth and the Sun) on the 12th. During this conjunction there will be a transit of Mercury over the Sun's disc. This will be the 4th of 14 transits of Mercury to occur this century but unfortunately it will not be visible from Australia. The next two transits of Mercury occur in 2032 and 2039 and will be visible from down under. Returning to the morning sky after transit (see Sky View), Mercury reaches its greatest eastern elongation 20° from the Sun on the 28th, albeit not a favourable one. Mercury and Mars have a conjunction with a very thin crescent (27-day old) Moon on the 25th (see Sky View). This will be challenging, being deep in the morning dawn sky, needing a very low eastern horizon.

Venus, in the western evening twilight, spends the first week of November in Scorpius, then moves across Ophiuchus, and finally into Sagittarius for the last week of the month. During its travels the planet passes near two of Messier's globular clusters, M80 on the 7th at 1° and M28 on the 30th at 0.4°. A nice pairing between the two brightest planets occurs on the 23rd and 24th when Venus and Jupiter appear less than 2° from each other, not an overly close conjunction but attractive nonetheless (see Sky View).

Mars, in Virgo, is only visible in the morning eastern dawn sky. Its proximity to the horizon renders it difficult to see as the sky brightens (see Sky View). The Red Planet has a meeting with the Moon and Mercury on the 25th (see Mercury).

As **Jupiter** nears its conjunction with the Sun next month it becomes too low in the western evening sky for useful telescopic observation. Visually however, there are two neat conjunctions worthy of note. Firstly, Venus rises up beneath the King of Planets for a meeting on the 23rd and 24th, the pair just 2° apart (see Sky View). Secondly, on the 28th, the slender fingernail crescent of the 2-day old Moon appears around 2° from the planet before setting and even closer from WA at 1° (see Sky View). Jupiter moves into Sagittarius midmonth (joining Saturn) after spending 12 months in Ophiuchus, the constellation of The Archer then becomes the planet's home until mid-December 2020.

Saturn is visible low in the western evening sky, setting around 11 pm midmonth. With solar conjunction occurring in mid-January this is the last month for any meaningful telescopic observations, early November is best before too much altitude is lost. On the 2nd, the bright limb of the 6-day old waxing crescent Moon appears very close to the planet at the end of astronomical twilight (see Sky View). From the eastern states Saturn will be less than 1° from the limb and for the central and western parts of Australia the distance will be less than 2°. On the 30th, the 4-day old waxing crescent Moon appears above the planet (see Sky View).

Uranus, just past opposition, transits the meridian (is due north) around 11 pm midmonth in Aries.

Neptune comes to the end of five months in retrograde on the 28th and appears high in the north-western evening sky at the end of astronomical dusk.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto**, in Sagittarius, sets around 11 pm in the western evening sky.

Brightest **Minor Planets** at opposition this month include:

Date	Minor Planet	Constellation	Mag.
2 Nov	196 Philomela	Cetus	10.9
3 Nov	41 Daphne	Cetus	12.3
4 Nov	94 Aurora	Aries	11.5
12 Nov	4 Vesta	Cetus	6.5
26 Nov	10 Hygiea	Taurus	10.3
27 Nov	409 Aspasia	Taurus	11.1
28 Nov	88 Thisbe	Taurus	10.9

COMETS

Comet C/2017 T2 (PANSTARRS) resides in Auriga throughout November, rising in the mid-evening and visible throughout the night. If observing in the late morning, try the first and last weeks of the month to avoid moonlight. While expected to brighten to 9th magnitude, its northern motion means it is appearing lower in the sky each night. The end of November will see it near zero-magnitude Capella.

Comet 260P/McNaught is likely to fade from 12th to 13th magnitude this month. Slowly moving through Andromeda, the comet transits in the late evening, low in the northern sky and is best seen from northern Australia.

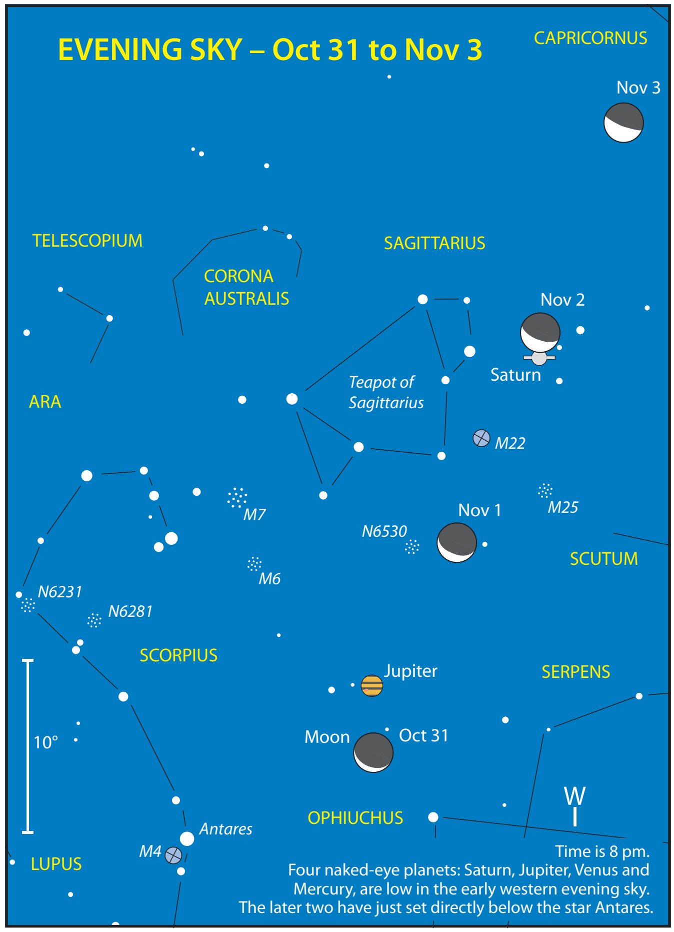
DOUBLE STARS

Lambda Arietis (All Sky Map 3). Just two degrees west of Alpha Arietis (Hamal), Lambda Arietis is a fine pair consisting of a magnitude 4.8 A component and a magnitude 6.7 B companion. The stars are separated by 37 arcseconds with a position angle of 48 degrees. The colours are yellowish-white and blue. Located 129 light-years away, there has been no change in position angle and only minor change in separation since the measures of Herschel in 1777. This is consistent with a binary system with an orbital period estimated to be on the order of 33,000 years.

DIARY

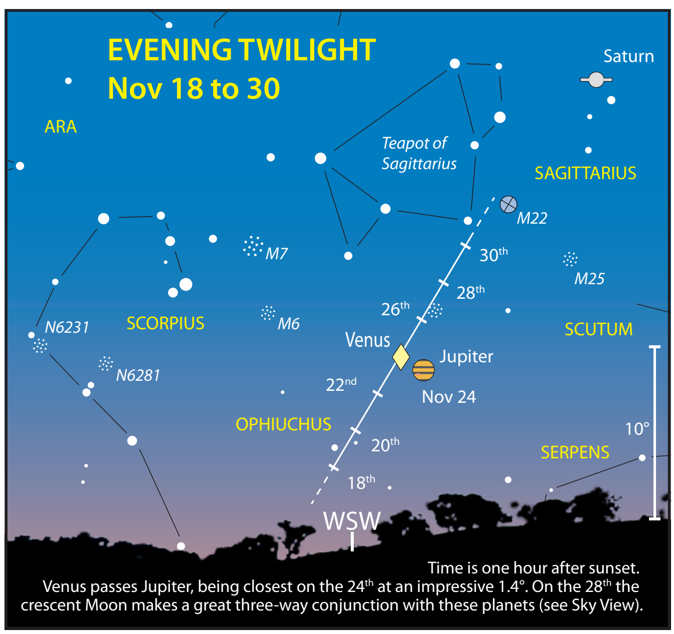
Fri	1st	6 am	(4 am WST) Mercury stationary
Sat	2nd	8 pm	(6 pm WST) Saturn 1° W of Moon
Sat	2nd	10 pm	(8 pm WST) d.p. Pluto 4° E of Moon
Sun	3rd	am	Comet C/2017 T2 (PANSTARRS) 1.3° E of M38 (OC) in Auriga
Mon	4th		Venus 1.6° N of star Delta Scorpii
Mon	4th	8:23 pm	(6:23 pm WST) First Quarter Moon
Tue	5th		Venus 0.8° S of star Omega^1 Scorpii
Tue	5th		m.p. 4 Vesta 0.3° S of star Omicron Tauri
Wed	6th		m.p. 3 Juno 0.3° N of NGC 4030 (G) in Virgo
Wed	6th	am	m.p. 97 Klotho 0.4° SE of star Pi^6 Orionis
Wed	6th	pm	m.p. 9 Metis 0.3° NW of NGC 741 (G) in Pisces
Thu	7th	7 pm	(5 pm WST) Moon at apogee: 405,058 km
Fri	8th		Venus 1.0° N of M80 (GC) in Scorpius
Fri	8th	1 am	(11 pm WST, prev day) Neptune 4° W of Moon
Fri	8th	pm	m.p. 16 Psyche 0.2° NW of star Theta Capricorni
Sat	9th		Venus 1.2° NE of star Rho Ophiuchi
Sat	9th	1 am	(11 pm WST, prev day) star Spica 3° S of Mars
Sat	9th	9 pm	(7 pm WST) star Antares 4° S of Venus
Sat	9th	pm	m.p. 39 Laetitia 0.8° N of star Gamma Capricorni
Sun	10th	am	m.p. 28 Bellona 0.5° SE of star Lambda Orionis
Sun	10th	am	m.p. 28 Bellona 0.3° NW of star Phi^2 Orionis
Mon	11th		Jupiter 0.7° N of NGC 6401 (GC) in Ophiuchus
Mon	11th		Mercury at ascending node
Mon	11th	8 pm	(6 pm WST) Uranus 4° W of Moon
Tue	12th	1 am	(11 pm WST, prev day) Mercury in inferior conjunction
Tue	12th	7 pm	(5 pm WST) m.p. 4 Vesta at opposition
Tue	12th	11:34 pm	(9:34 pm WST) Full Moon (393,972 km)
Thu	14th	10 pm	(8 pm WST) star Aldebaran 7° S of Moon
Thu	14th	10 pm	(8 pm WST) m.p. 9 Metis 0.1° N of NGC 676 (G) in Pisces
Fri	15th	am	Comet C/2017 T2 (PANSTARRS) 1.0° NE of NGC 1857 (OC) in Auriga
Sat	16th		Venus 1.0° N of NGC 6284 (GC) in Ophiuchus
Sat	16th		Mercury at perihelion
Sat	16th	pm	m.p. 39 Laetitia 0.6° N of star Delta Capricorni
Mon	18th		Venus 0.4° S of NGC 6325 (GC) in Ophiuchus
Mon	18th	2 am	(Midnight WST, prev day) star Pollux 6° N of Moon
Tue	19th		Venus 0.7° N of star Theta Ophiuchi
Wed	20th	3 am	(1 am WST) star Regulus 7° S of Moon
Wed	20th	7:11 am	(5:11 am WST) Last Quarter Moon
Thu	21st	1 am	(11 pm WST, prev day) Mercury stationary
Fri	22nd		Venus 0.6° S of NGC 6401 (GC) in Ophiuchus
Fri	22nd		d.p. 1 Ceres 0.7° S of NGC 6553 (GC) in Sagittarius
Sat	23rd	6 pm	(4 pm WST) Moon at perigee: 366,716 km
Sun	24th	2 am	(Midnight WST, prev day) star Spica 8° S of Moon
Sun	24th	7 pm	(5 pm WST) Mars 4° S of Moon
Sun	24th	Midnight	(10 pm WST) Jupiter 1.5° N of Venus
Mon	25th	1 pm	(11 am WST) Mercury 2° S of Moon
Tue	26th		Mercury at greatest latitude north
Tue	26th	am	Comet C/2017 T2 (PANSTARRS) 1.0° NE of star Epsilon Aurigae
Wed	27th		Venus 0.7° SE of M8 Lagoon Nebula (BN) in Sagittarius
Wed	27th	am	Comet C/2017 T2 (PANSTARRS) 2.4° SW of star Capella
Wed	27th	1:06 am	(11:06 pm WST, prev day) New Moon
Thu	28th		Venus at aphelion
Thu	28th	6 am	(4 am WST) Neptune stationary
Thu	28th	7 pm	(5 pm WST) Jupiter 2° S of Moon
Thu	28th	7 pm	(5 pm WST) Venus 6° E of Moon
Thu	28th	8 pm	(6 pm WST) Mercury at greatest elongation West (20.1°)
Fri	29th	8 am	(6 am WST) d.p. 1 Ceres 4° S of Moon
Sat	30th		Venus 0.4° W of M28 (GC) in Sagittarius
Sat	30th	8 pm	(6 pm WST) d.p. Pluto 3° W of Moon
Sat	30th	8 pm	(6 pm WST) Saturn 6° W of Moon
Sat	30th	10 pm	(8 pm WST) d.p. 1 Ceres 2° S of Venus

EVENING SKY – Oct 31 to Nov 3



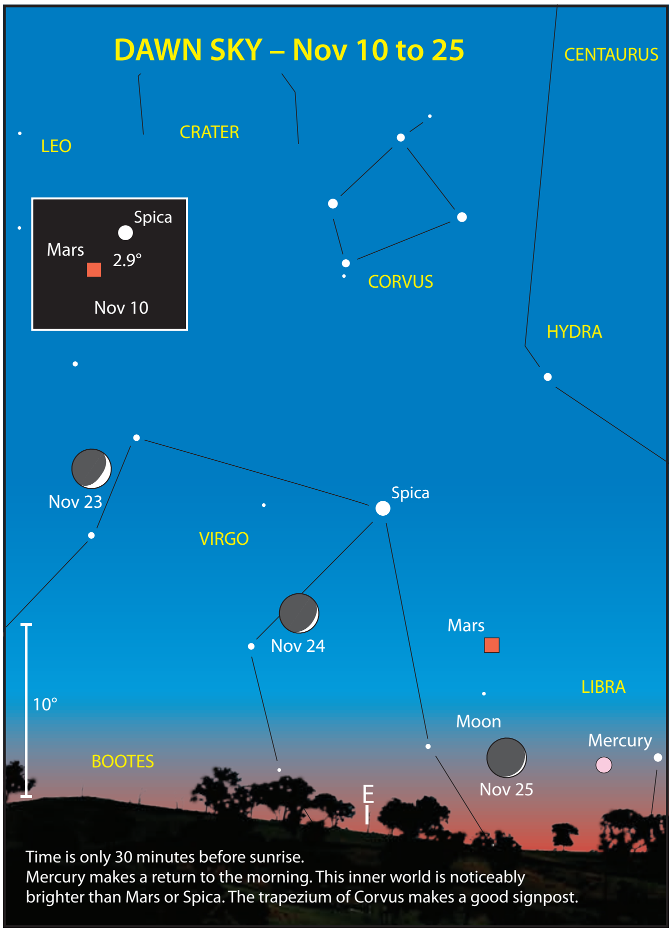
Time is 8 pm.
Four naked-eye planets: Saturn, Jupiter, Venus and Mercury, are low in the early western evening sky.
The later two have just set directly below the star Antares.

EVENING TWILIGHT Nov 18 to 30

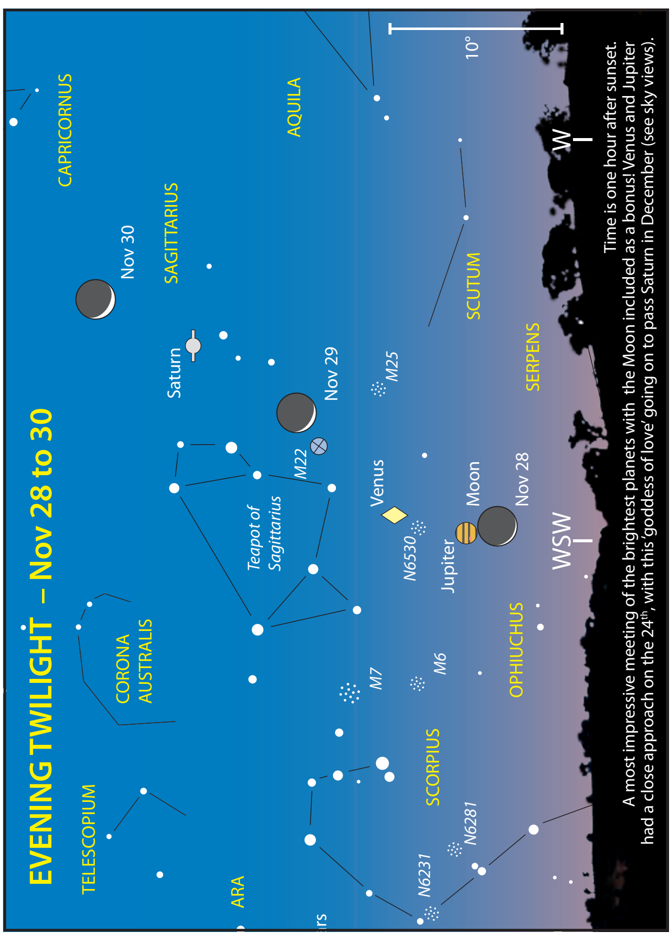


Time is one hour after sunset.
Venus passes Jupiter, being closest on the 24th at an impressive 1.4°. On the 28th the crescent Moon makes a great three-way conjunction with these planets (see Sky View).

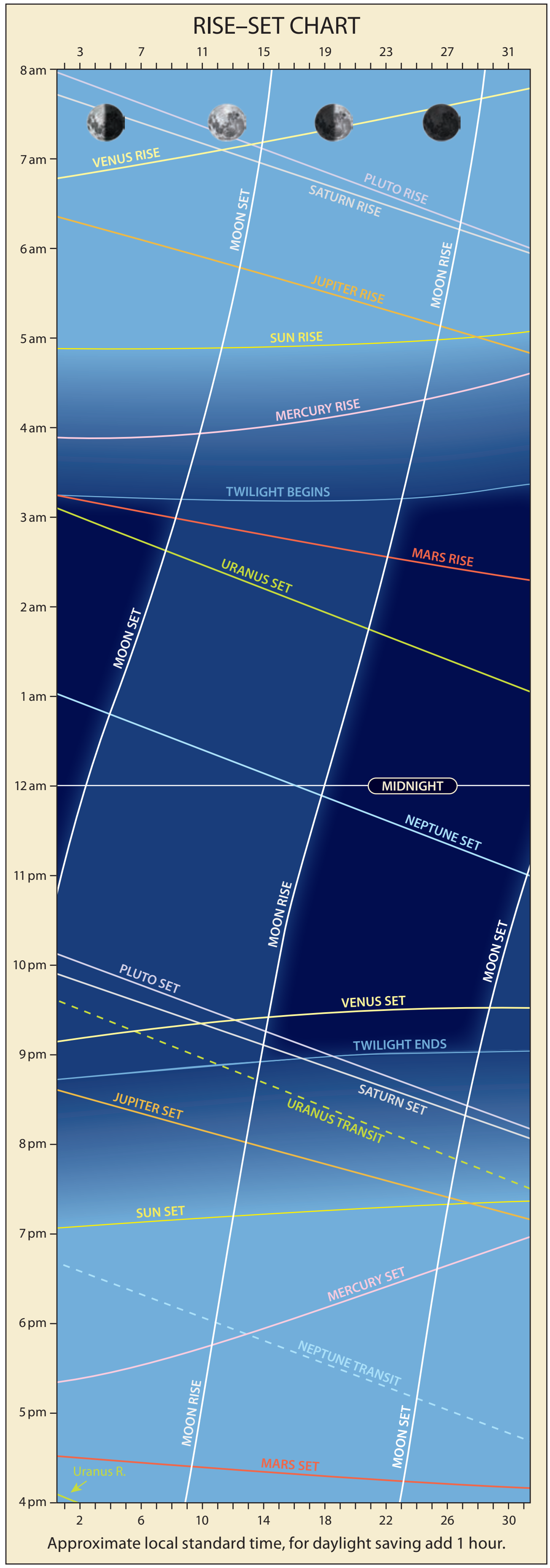
NOVEMBER 2019



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



DECEMBER 2019



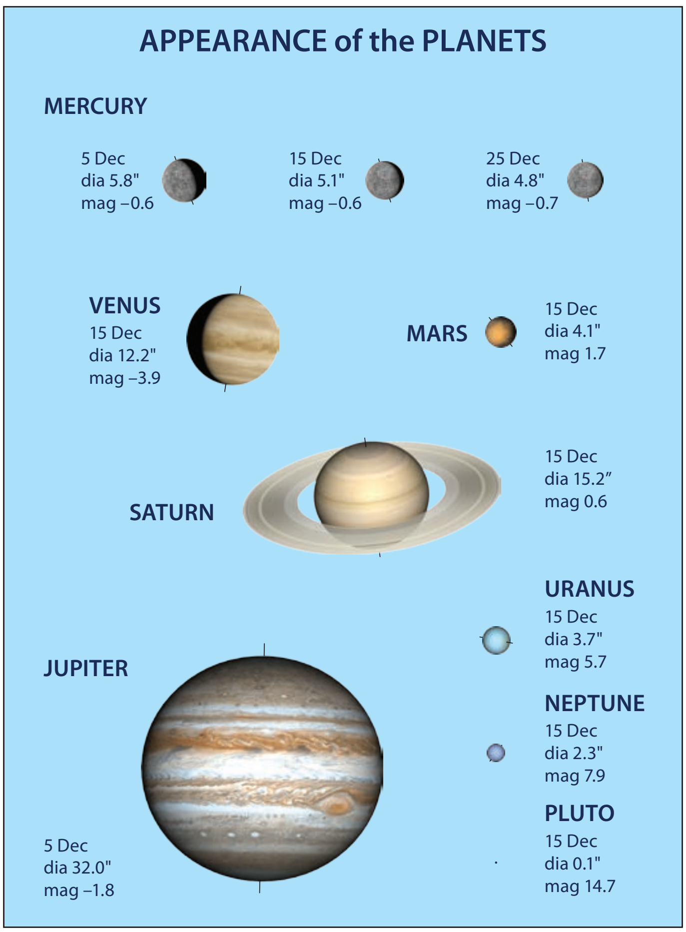
HIGHLIGHTS

- Venus passes close to M22.
- Venus and Saturn nearby.
- Venus and crescent Moon together.
- The Phoenicids meteor shower.

CONSTELLATIONS

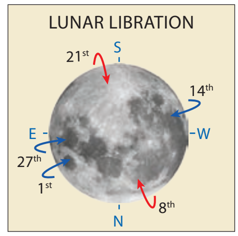
The constellation of Orion is in the north-east evening sky. Its two brightest stars are Rigel (Beta Orionis), south of (above) the belt stars, and Betelgeuse (Alpha), below. They are similar in brightness and both extremely luminous supergiants. However their difference in colour, visible to the naked-eye, hints at being very dissimilar stars.

Rigel has a hot surface temperature of 11,000K (spectral class B8), about double that of the Sun, which explains its blue/white colour. The star began its life only about eight million years ago at a mass 24 times the Sun. It has evolved quickly, already losing three solar masses through its solar wind. Having exhausted the hydrogen in its core the star has swollen to one hundred times the Sun's diameter. Rigel's luminosity is 200 thousand times Sol and lights up the surrounding dust clouds including the Witch Head Nebula (IC 2118). A testament to its brightness is being approximately 1,000 light-years distant and still achieving the rank of the seventh brightest star in the heavens (magnitude 0.1). It will likely end its days as a type II supernova and is one of the closet known potential supernova progenitors.



On the other hand Betelgeuse is a relatively cool star and at only 3,000K (class M1) surface temperature, explains its red colour. Like many stars in the Orion association it is only a few million years old, and like Rigel, due to its large mass (17× Sun) it has evolved rapidly using up the hydrogen in its core and expanding to one of the largest stars known. It is so big, if it was placed where the Sun is, its photosphere would extend more than halfway to Jupiter—swallowing up Mercury, Venus, Earth and Mars! Betelgeuse's diameter is approximately 0.05 arcseconds and has been imaged directly by the Hubble Telescope. The star's luminosity is about 100 thousand times the Sun's (mostly in the infrared) and is around 500 light-years away.

THE MOON



1st 10 am (8 am WST) Minimum Libration (5.8°), bright NE limb. In general the effects of libration are most readily observed with the unaided eye or binoculars by watching the position of Mare Crisium over the course of the first half of a lunar month (a few days after New Moon to Full Moon). This prominent feature will be seen to drift back and forth toward the limb as the Moon nods and wobbles in its orbit.

4th 5 pm (3 pm WST) First Quarter.

5th 2 pm (noon WST) Moon at apogee (furthest from Earth at 404,446 km).

8th 6 am (4 am WST) Maximum Libration (7.1°), dark NW limb.

12th 3 pm (1 pm WST) Full Moon.

14th 9 pm (7 pm WST) Minimum Libration (4.2°), bright SW limb.

19th 6 am (4 am WST) Moon at perigee (closest to Earth at 370,265 km).

19th 3 pm (1 pm WST) Last Quarter.

21st 1 am (11 pm previous day WST) Maximum Libration (6.9°), dark SE limb.

26th 3 pm (1 pm WST) New Moon. Annular eclipse of the Sun, partial phases visible from northern parts of Australia.

27th 9 am (7 am WST) Minimum Libration (5.0°), too close to New Moon.

THE PLANETS

Mercury, in the morning eastern sky, tends to hug the horizon this month. Even seasoned observers will have trouble locating the planet in the twilight (see Sky View). Mercury will be in superior conjunction (Mercury and Earth on opposite sides of the Sun) on 10 January 2020.

Venus, blazing gloriously in the early western evening sky, spends two thirds of the month in Sagittarius before moving into Capricornus. It opens the month very close to the *lid* star of the Teapot and then spends the next two weeks visiting some bright stars and globular clusters in Sagittarius, including a pass within 1° of the remarkable globular cluster M22 on the 2nd and 3rd. Venus is also within 2° of Saturn on the 10th and 11th (see Sky View). To round the year off, a picturesque sight occurs when the 3-day old waxing crescent Moon appears 4°

above (a little further from WA) the Evening Star on the 29th (see Sky View).

The **Earth** is at Solstice on the 22nd when the days in the Southern Hemisphere are longest. On this day, the Sun is at its most southerly position with a declination of –23.4°.

Mars, moving through Libra in the early morning eastern sky, is visible in a truly dark sky for the first time since conjunction (see Sky View). In October 2020, the Red Planet will be at opposition again, providing us with a close view of this intriguing world.

Jupiter can only be seen at the beginning of the month low in the western dusk sky in Sagittarius (see Sky View). The planet will be in conjunction on the 28th and too close to the Sun for observation until its reappearance in the morning sky late next month.

We lose **Saturn** this month as it moves closer to the Sun and its conjunction in mid-January. Interestingly, although obviously not observable, is the fact that the planet will be occulted by the Sun at this conjunction. This last occurred in 1991, with the next in 2034.

Venus pays the Ringed Planet a visit on the 10th and 11th at a distance of around 2°. This is best observed in the twilight when you can see Venus, then a pair of binoculars can assist with locating Saturn if necessary (see Sky View).

Uranus in Aries, its home constellation until 2024 when it will move into Taurus, transits the meridian (is due north) around 8:30 pm midmonth.

Neptune, in Aquarius is setting around midnight midmonth and is best seen in the western evening sky this month.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto** sets around 9 pm midmonth. This distant world will be in conjunction with the Sun in January and will return to the morning skies in February.

Brightest **Minor Planets** at opposition this month include:

Date	Minor Planet	Constellation	Mag.
2 Dec	97 Klotho	Eridanus	9.9
10 Dec	28 Bellona	Orion	10.4
22 Dec	387 Aquitania	Orion	12.3
30 Dec	69 Hesperia	Monoceros	10.4

COMETS

Comet **C/2017 T2 (PANSTARRS)** will be lost from view for southern Australian observers as December progresses. Beginning the month in Auriga, the 8th magnitude comet quickly moves into Perseus, where it remains for the rest of December, except for a one week sojourn into Camelopardalis around Christmas. By the end of the year, it will be transiting in the late evening. Moonlight interferes in the first half of December. PANSTARRS reaches perihelion in May 2020, when it may reach 6th magnitude. It will be observable again in the Southern Hemisphere shortly after perihelion.

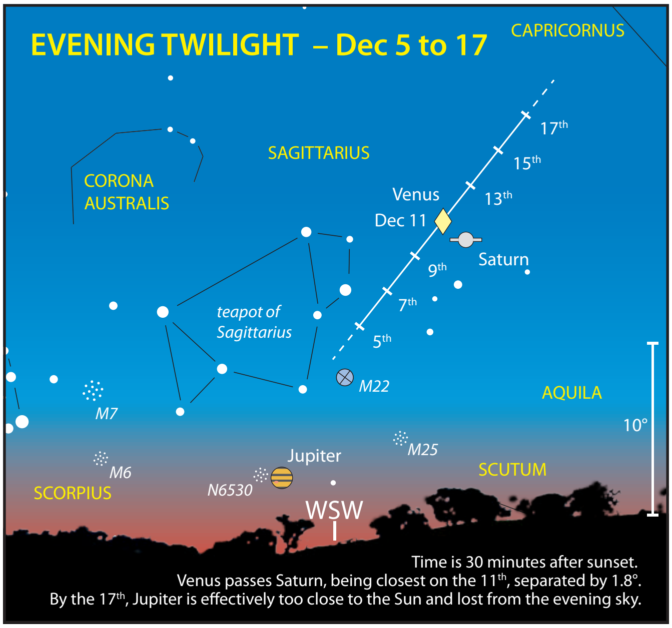
DOUBLE STARS

Chi Tauri (All Sky Map 3). Situated not far from the Pleiades, this lovely pair of unequal white and yellowish stars is easily seen in small telescopes. The stars, magnitudes 5.4 and 8.5, are separated by 19 arcseconds with a position angle of 25 degrees. The primary has a mass 2.6 times that of the Sun and may also be a binary. The secondary is a double-lined spectroscopic binary comprising F type and G type stars. Slow drift in the radial velocity of the secondary (Chi Tauri B) indicates the presence of another component (Bc), currently thought to be a pair of K type stars. The system is located approximately 291 light-years from Earth.

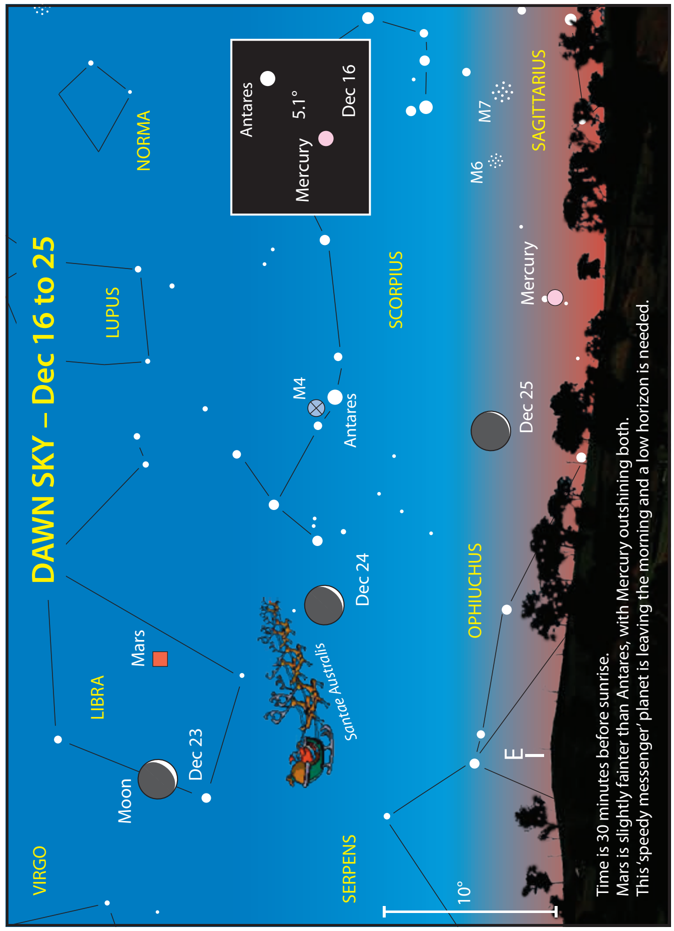
DIARY			
Sun	1st		Venus 0.7° N of star Lambda Sagittarii
Sun	1st	am	m.p. 7 Iris 0.8° N of star Lambda Ceti
Tue	3rd		Venus 1.0° SE of M22 (GC) in Sagittarius
Tue	3rd		m.p. 3 Juno 0.3° N of NGC 4546 (G) in Virgo
Tue	3rd	Noon	(10 am WST) m.p. 2 Pallas in conjunction with Sun
Wed	4th	4:58 pm	(2:58 pm WST) First Quarter Moon
Wed	4th	10 pm	(8 pm WST) Neptune 4° N of Moon
Thu	5th	2 pm	(Noon WST) Moon at apogee: 404,446 km
Fri	6th		Venus 1.8° N of star Sigma Sagittarii
Sun	8th	9 pm	(7 pm WST) Uranus 5° N of Moon
Mon	9th	10 pm	(8 pm WST) m.p. 4 Vesta 4° S of Moon
Wed	11th	3 pm	(1 pm WST) Saturn 2° N of Venus
Wed	11th	10 pm	(8 pm WST) star Aldebaran 3° S of Moon
Thu	12th	3:12 pm	(1:12 pm WST) Full Moon (382,864 km)
Fri	13th		Mars 0.2° NE of star alpha^1 Librae
Fri	13th		d.p. 1 Ceres 0.3° N of star Phi Sagittarii
Fri	13th	10 pm	(8 pm WST) d.p. Pluto 1° N of Venus
Fri	13th	pm	Comet C/2017 T2 (PANSTARRS) 0.7° NE of NGC 1545 (OC) in Perseus
Sun	15th	4 am	(2 am WST) star Pollux 5° N of Moon
Sun	15th	pm	Comet C/2017 T2 (PANSTARRS) 0.4° NE of NGC 1528 (OC) in Perseus
Mon	16th	2 am	(Midnight WST, prev day) star Antares 5° S of Mercury
Tue	17th	3 pm	(1 pm WST) star Regulus 4° S of Moon
Tue	17th	pm	m.p. 69 Hesperia 0.7° S of NGC 2264 (OC) in Monoceros
Thu	19th		Venus 0.4° SW of M75 (GC) in Sagittarius
Thu	19th		m.p. 15 Eunomia 0.8° SE of star Alpha Aquarii
Thu	19th		Mercury at descending node
Thu	19th	6 am	(4 am WST) Moon at perigee: 370,265 km
Thu	19th	2:57 pm	(12:57 pm WST) Last Quarter Moon
Thu	19th	10 pm	(8 pm WST) Comet C/2017 T2 (PANSTARRS) 0.15° SE of NGC 1496 (OC) in Perseus
Fri	20th		Venus at greatest latitude south
Sat	21st	3 am	(1 am WST) star Spica 10° S of Moon
Sun	22nd	2 pm	(Noon WST) Solstice
Mon	23rd	Noon	(10 am WST) Mars 4° S of Moon
Tue	24th	6 pm	(4 pm WST) star Antares 7° S of Moon
Wed	25th	pm	m.p. 69 Hesperia 0.7° N of NGC 2251 (OC) in Monoceros
Thu	26th	3:13 pm	(1:13 pm WST) New Moon
Fri	27th	10 pm	(8 pm WST) Saturn 1° N of Moon
Sat	28th	1 am	(11 pm WST, prev day) d.p. Pluto 0.5° N of Moon
Sat	28th	4 am	(2 am WST) Jupiter in conjunction with Sun
Sun	29th	8 pm	(6 pm WST) Venus 3° W of Moon
Mon	30th		m.p. 15 Eunomia 0.9° NW of star Zeta^1 Aquarii
Mon	30th		Mercury at aphelion
Tue	31st		m.p. 3 Juno 0.4° N of NGC 4941 (G) in Virgo
Tue	31st	9 pm	(7 pm WST) Neptune 7° N of Moon
Tue	31st	pm	m.p. 9 Metis 0.3° S of star Omicron Piscium

METEOR SHOWERS

The **Phoenicids** are a southern shower discovered in 1956, during its only known major outburst when hourly rates of around 100 plus were observed. There have been three minor bursts since then and some significant activity in 2014. The IMO have predicted another surge in 2019. The period of activity appears to be 28 November through 9 December, with maxima around the 2nd. The radiant culminates at dusk and sets in the early morning hours. Their very low velocity will help in identification from the sporadics. This year the morning hours will be Moon-free.

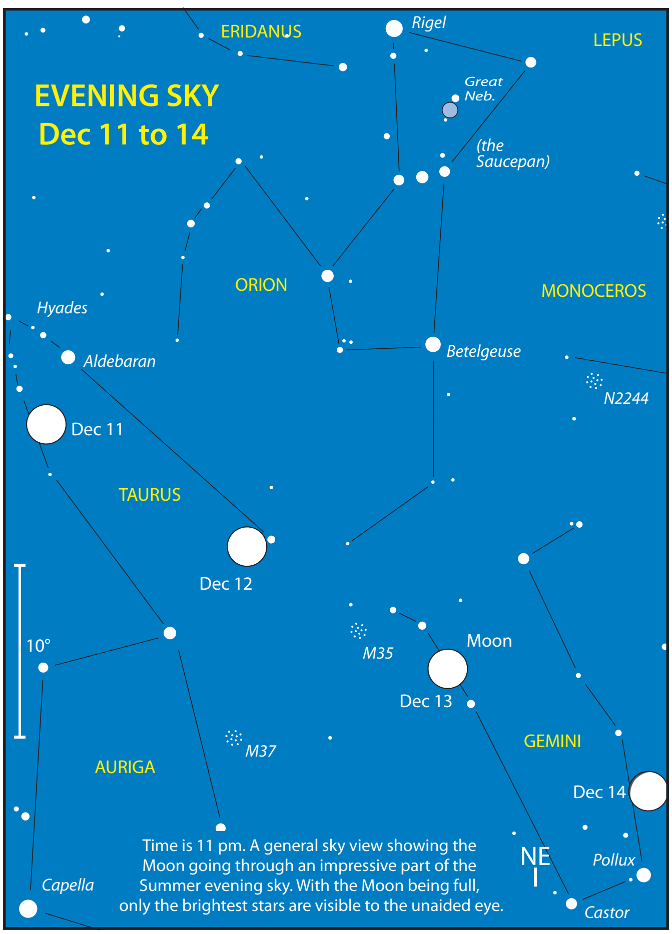


Time is 30 minutes after sunset.
Venus passes Saturn, being closest on the 11th, separated by 1.8°.
By the 17th, Jupiter is effectively too close to the Sun and lost from the evening sky.

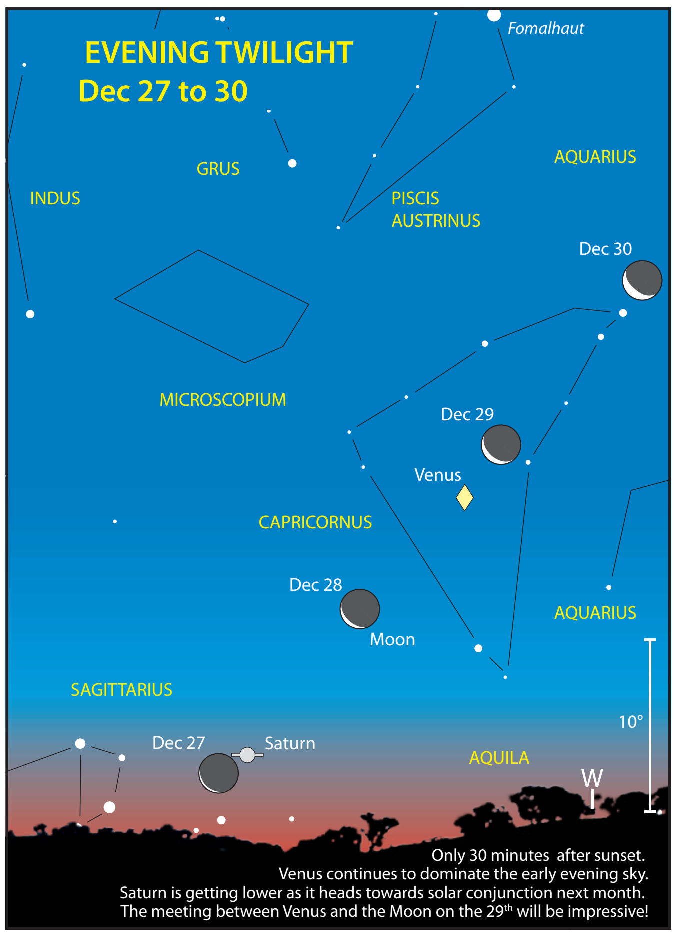


Time is 30 minutes before sunrise.
Mars is slightly fainter than Antares, with Mercury outshining both.
This 'speedy messenger' planet is leaving the morning and a low horizon is needed.

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

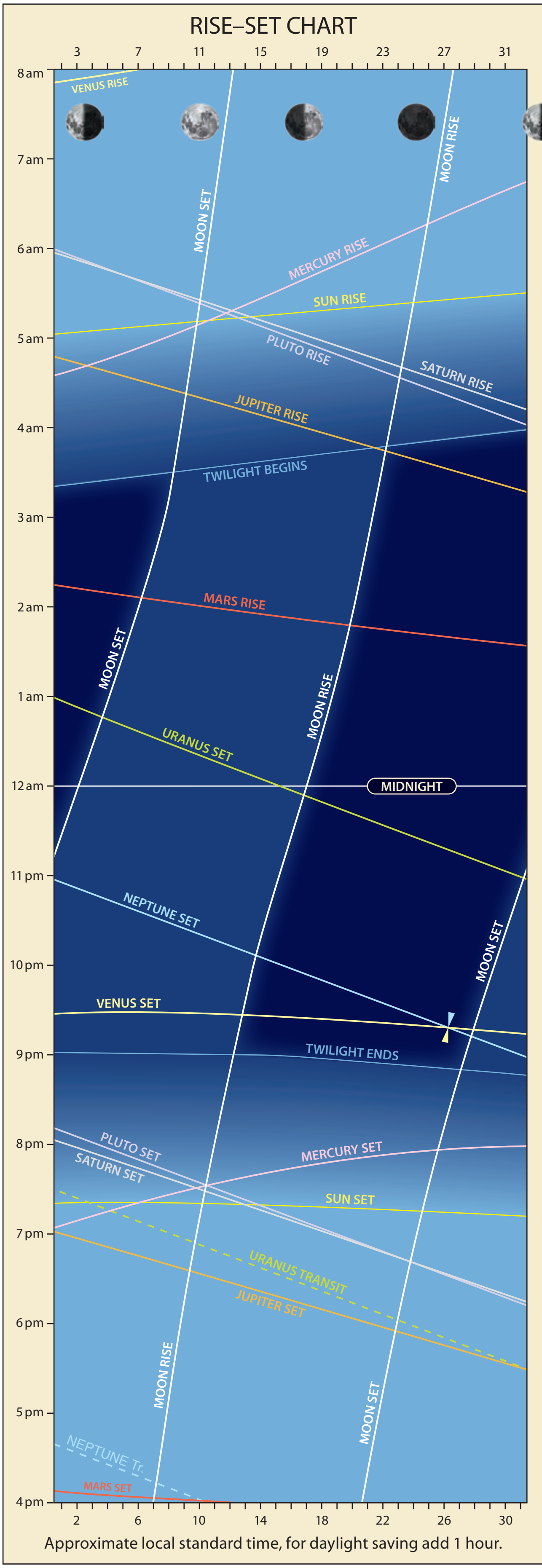


Time is 11 pm. A general sky view showing the Moon going through an impressive part of the Summer evening sky. With the Moon being full, only the brightest stars are visible to the unaided eye.



Only 30 minutes after sunset.
Venus continues to dominate the early evening sky.
Saturn is getting lower as it heads towards solar conjunction next month.
The meeting between Venus and the Moon on the 29th will be impressive!

JANUARY 2020



HIGHLIGHTS

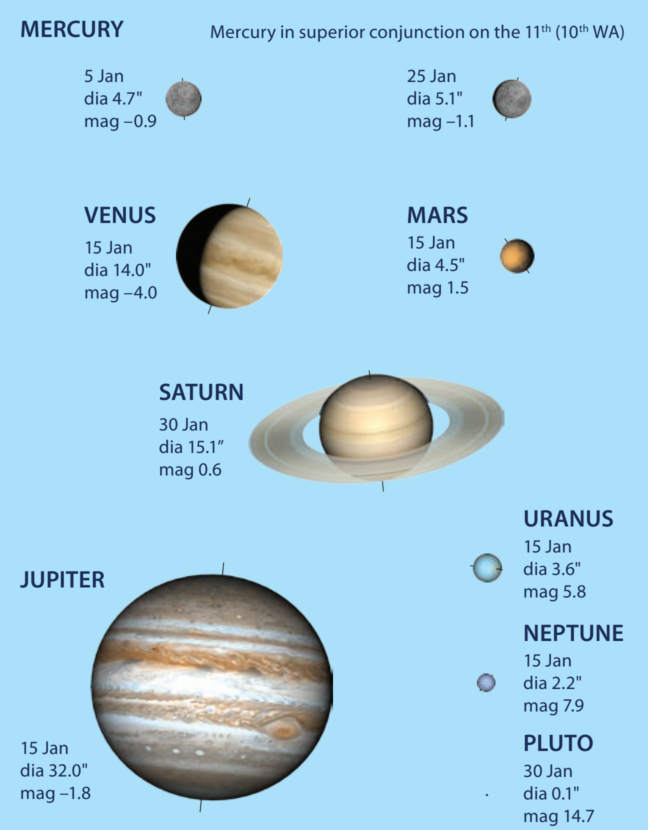
- Venus and Neptune close.
- Venus and Moon close.
- Mars and Moon close.
- Jupiter and Moon close.

CONSTELLATIONS

This month we concentrate on the wonders of the northern evening sky, all available to anyone who wishes to just look up. Orion dominates the view. Although this hunter is upside down from the Southern Hemisphere, the Saucepan asterism is oriented correctly. Its base is the hunter's three belt stars with the handle being the sword hanging (up) from his belt. Above the belt you'll find the bright blue star, Rigel (Beta Orionis), which forms part of the biggest and brightest asterism in the sky, the Winter Hexagon (the name betraying its Northern Hemisphere origin).

To trace out this pattern proceed anticlockwise, dropping to Aldebaran, the brightest and alpha star in Taurus the Bull. Continue down to Capella, the brightest star in Auriga. This is the lowest member of the hexagon, being perched only around 5° to 10° above the northern horizon from Australia. Head eastward to the Gemini Twins, Castor and Pollux and then up to Procyon, the only obvious marker for Canis Minor. Finish this circuit by heading up to the highest member and brightest star in the sky, Sirius (Alpha Canis Majoris).

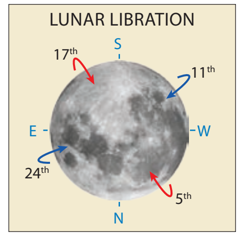
APPEARANCE of the PLANETS



The Milky Way is more in the easterly half of the sky with our galaxy passing through the Winter Hexagon. It's interesting that the milky haze is nowhere near as prominent here as compared to the hub (more for winter evenings). This is because we are looking opposite the busy centre, if you like we have turned our back on the CBD and are peering out at the suburbs.

The constellations which make up the summer members of the zodiac are a mixed bag in terms of their visibility. Going from west to east, Aries has really only a couple of not so bright stars making its presence known (see also December 2020 constellations). Then Taurus is a big improvement showing the face of the bull (the Hyades Cluster) complete with the *eye* star, Aldebaran. Next up is Gemini, with the twins' heads signposted by the stars Castor and Pollux. It's then onto Cancer the Crab which is nearly invisible and best known for the Beehive star cluster (M44), which appears as a small cloud to the unaided eye. These are the most northerly zodiacal constellations so they remain close to the northern horizon from Australian mid-latitudes.

THE MOON



Our regular readers may note that in this section we normally list occultations of the Moon and first magnitude stars. However, since the occultation of Aldebaran on 3 September 2018 there will be none with brightest stars until 25 August 2023 when a new series

Learning Astronomy Under the Stars

People learn by doing. This is so obvious to anyone who's attempted to develop skills in anything from computer programming to bush walking. When it comes to science education, it's relatively easy to teach in traditional laboratories using small-scale equipment. But when it comes to astronomy, it's a little trickier; telescopes—good ones—are expensive and, for most teachers, somewhat mysterious. Consequently, astronomy education is often limited to one-off field nights at a local observatory, or with a dusty school telescope that sits idle for most of the year.

This is such a great pity since astronomy, it can be argued, is the ultimate science; by definition, all other branches of science are carried out on this one, small planet. What if we could introduce students to the cosmos using large, sophisticated instruments, working on projects that last not just a single night, but months?

One solution to this problem is MSATT*, the McNamara-Saunders Astronomical Teaching Telescopes, an astronomical teaching observatory at Mount Stromlo Observatory in the ACT. MSATT consists of two domes housing 300 mm and 400 mm telescopes, co-mounted with auxiliary telescopes and instruments. Students from Years 9 to 12 apply for projects across a wide range of astronomical phenomena.

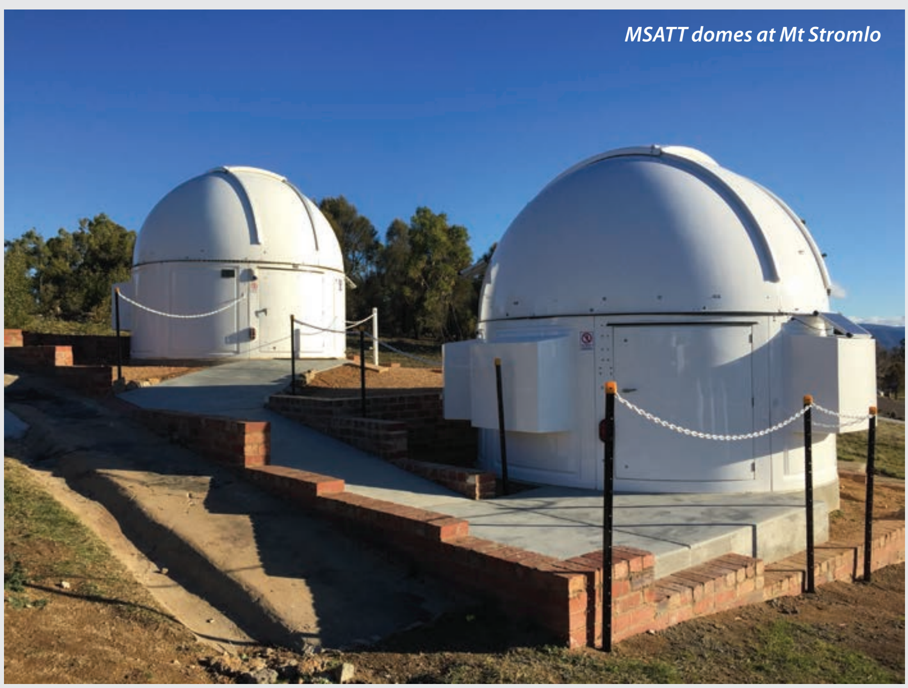
The facility is designed for use by students; during regular weekly sessions of up to two hours over the course of six months, students use the facility to make their own observations. They learn to operate the facility independently, attaching and calibrating instruments, driving the telescopes, and obtaining their own images or data. Students then learn how to analyse the data and prepare formal, fully referenced and refereed reports. They do this with the assistance of a mentor—often an astronomy doctoral student or post-doc from ANU's Research School of Astronomy and Astrophysics—who is assigned to work with them for the duration of their project.

Projects completed so far include measuring the mass of Jupiter and the speed of light, investigating fundamental properties of variable stars such as size and distance, or learning techniques such as photometry and spectroscopy for galactic and extragalactic studies. Each project is tailored to the needs and abilities of the individual student. Importantly, MSATT has been designed so that no experience with astronomy or telescopes is necessary, and any student from the ACT region is welcome to apply for a project at MSATT.

There is no cost involved in any MSATT activities.

Students interested in undertaking a project at MSATT should contact:

Geoff McNamara AM
Manager, MSATT
Mount Stromlo Observatory, ACT
geoffrey.mcnamara@ed.act.edu.au Ph: 0449 966 200
More information at: msatt.teamapp.com
*Pronounced "em-sat":



MSATT domes at Mt Stromlo

with Antares begins. The next sequence of occultations of Aldebaran begins on 18 August 2033.

- 2nd Noon (10 am WST) Moon at apogee (furthest from Earth at 404,580 km).
- 3rd 3 pm (1 pm WST) First Quarter.
- 5th 8 am (6 am WST) Maximum Libration (7.4°), dark NW limb.
- 11th 5 am (3 am WST) Full Moon. Penumbral eclipse visible from most of Australia (see Part II for details).
- 11th Midnight (10 pm WST) Minimum Libration (4.6°), bright SW limb.
- 14th 6 am (4 am WST) Moon at perigee (closest to Earth at 365,958 km).
- 17th 9 pm (7 pm WST) Maximum Libration (7.4°), dark SE limb.
- 17th 11 pm (9 pm WST) Last Quarter.
- 23rd 1 pm (11 am WST) Daylight occultation of Jupiter by the Moon, visible from parts of Australia, New Zealand and Madagascar. Caution, close to the Sun.
- 24th 8 am (6 am WST) Minimum Libration (4.9°), Too close to New Moon.
- 25th 8 am (6 am WST) New Moon.
- 30th 7 am (5 am WST) Moon at apogee (furthest from Earth at 405,393 km).

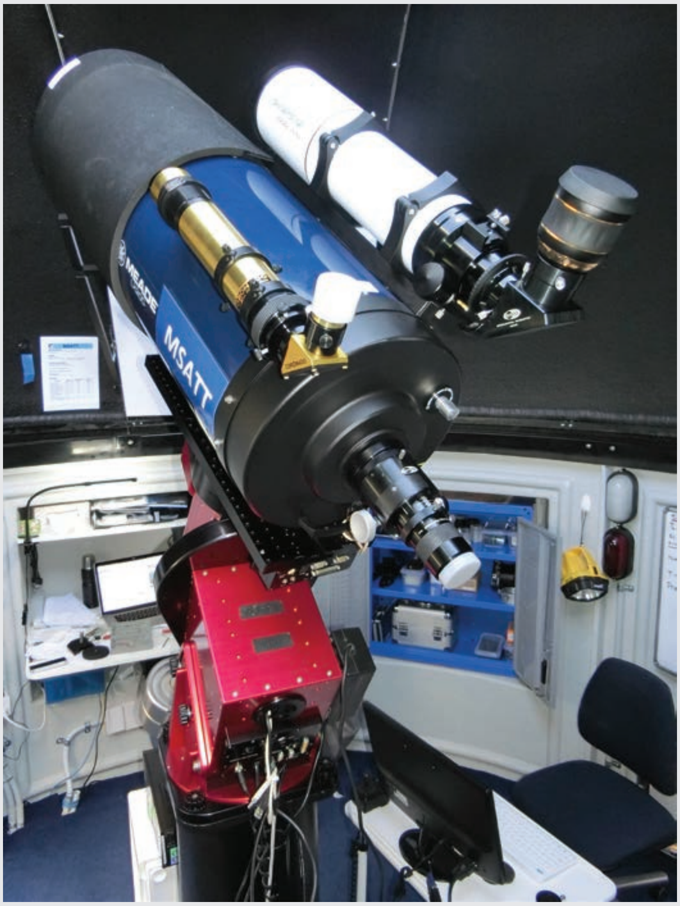
THE PLANETS

Mercury presents a difficult target this month, never straying far from the glare of the Sun. After superior conjunction (Mercury and Earth on opposite sides of the Sun) on the 11th, the planet moves east of the Sun and into the evening sky (see Sky View).

Venus is a brilliant object in the western evening sky from the beginning of the year until late May when it becomes too close to the Sun for observation. In the second week of June it reappears in the eastern morning sky where it stays until the end of the year. On the 27th, Venus and the outermost planet Neptune will be within 0.5° of each other. A telescope or binoculars plus a good western horizon will be required—try looking about an hour after sunset. On the 28th, the 3-day old waxing crescent Moon appears nearby the planets (see Sky View). On this evening, the separation between Venus and Neptune has increased to 0.7° with the 4th magnitude star Phi Aquarii lying between the duo (see Sky View).

The **Earth** is at perihelion on the 5th, the closest point in its orbit to the Sun (147,091,209 km or 0.983244 au distant).

Beginning the year in the eastern morning sky, **Mars** spends the first week in Libra then crosses the claw region of Scorpius before settling in Ophiuchus for the second half of the month. On the 17th Mars and Antares are in conjunction, being 5° apart (see Sky Views). Whilst in Ophiuchus, the constellation



MSATT-1, Meade LX200 ACF, 300 mm ƒ10

MSATT-2, Orion Optics 400 mm ƒ4 Newtonian of the Serpent Holder, the planet has a close encounter with the 25-day old waning crescent Moon on the 21st (see Sky View). During January and February the Red Planet passes in front of the galactic hub, having a number of conjunctions with bright deep sky objects in Ophiuchus and Sagittarius.

Mars observers can look forward to a reasonably favourable opposition in October this year. Let's hope there isn't a repeat of the planet encircling dust storm that obscured surface features during the 2018 apparition (and effectively put an end to NASA's storm-struck Opportunity rover).

Jupiter, in Sagittarius, is visible low in the eastern dawn sky towards the end of January. The planet will be interesting to observe over the coming years with speculation on the longevity of the Great Red Spot (GRS). In 2017 high-resolution images taken by the Gemini North Telescope on Mauna Kea in Hawaii revealed some fascinating events in Jupiter's atmosphere. These included cloud-like features or streamers peeling off the GRS, leading astronomers to wonder if the GRS could be unravelling and breaking up or disappearing in the not too distant future (see images page 8). The GRS has been shrinking since its discovery hundreds of years ago when it was big enough to swallow three Earths with room to spare, now only one could fit inside the vortex. In the dawn sky on the 23rd, the 27-day old waning crescent Moon will be near the planet (see Sky View).

Saturn is in conjunction with the Sun on the 14th effectively ruling out observation of the planet until its reappearance in the morning skies in February.

From mid-January until May, **Uranus** can only be seen in the western evening sky in Aries. The planet will remain within the constellation of the Ram until 2024 when it moves into Taurus. Uranus comes to the end of four months in retrograde on the 11th and resumes drifting eastward against the stellar background.

Neptune, in Aquarius, is located low in the evening western sky. If searching for the planet with binoculars this month, try finding the 4th magnitude star Phi Aquarii first. Neptune begins January within 1° of Phi and ends 0.5° away at month's end. Neptune and Venus have a close encounter on the 27th and 28th, see Venus for details.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto** is in conjunction with the Sun on the 13th and returns to the morning skies in February.

Brightest **Minor Planets** at opposition this month include:

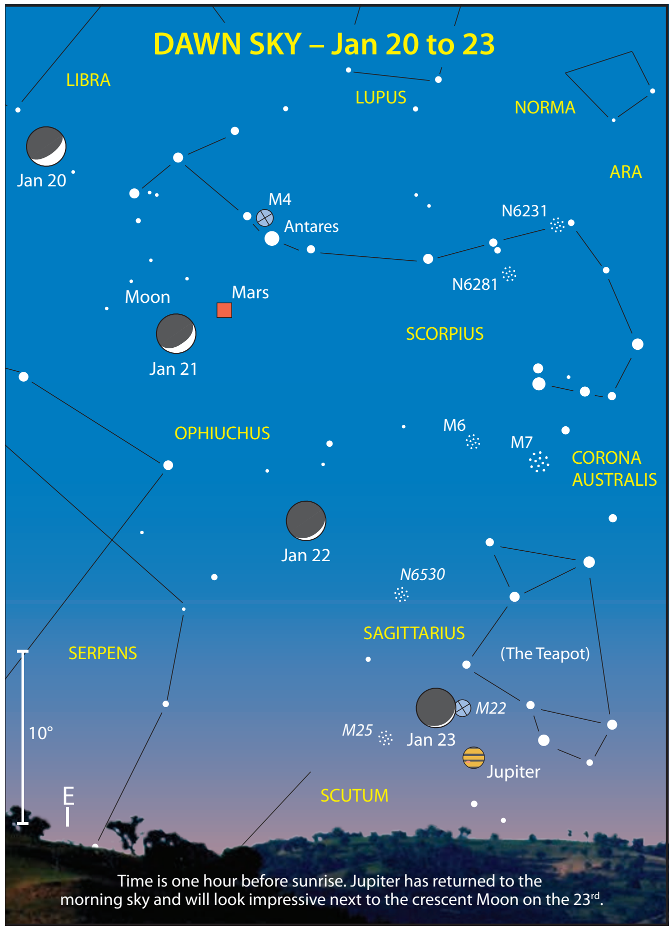
Date	Minor Planet	Constellation	Mag.
2 Jan	389 Industria	Gemini	11.0
9 Jan	192 Nausikaa	Gemini	10.0
15 Jan	511 Davida	Gemini	9.6
17 Jan	87 Sylvia	Gemini	12.3
18 Jan	63 Ausonia	Gemini	11.0
21 Jan	5 Astraea	Cancer	8.9
23 Jan	230 Athamantis	Canis Minoris	10.4
30 Jan	107 Camilla	Cancer	11.8

DIARY

Wed	1st		m.p. 4 Vesta stationary
Thu	2nd	Noon	(10 am WST) Moon at apogee, 404,580 km
Fri	3rd	am	m.p. 192 Nausikaa 0.3°S of star Castor
Fri	3rd	2:45 pm	(12:45 pm WST) First Quarter Moon
Sun	5th	4 am	(2 am WST) Uranus 5° N of Moon
Sun	5th	6 pm	(4 pm WST) Earth at perihelion, 0.983243564 au
Mon	6th	3 am	(1 am WST) m.p. 4 Vesta 2° S of Moon
Tue	7th		Venus 0.9°N of star Gamma Capricorni
Tue	7th		m.p. 3 Juno 0.3°N of star Theta Virginis
Tue	7th	3 am	(1 am WST) m.p. 192 Nausikaa 0.1°SE of star Rho Geminorum
Wed	8th		Venus 0.9°NW of star Delta Capricorni
Wed	8th	8 am	(6 am WST) star Aldebaran 3° S of Moon
Thu	9th		Mars 0.7°S of star Beta Scorpii
Thu	9th	pm	m.p. 4 Vesta 0.5°SE of star Mu Ceti
Fri	10th		Mars 0.3°E of star Omega^{1} Scorpii
Sat	11th	1 am	(11 pm WST, prev day) Mercury in superior conjunction
Sat	11th	5:21 am	(3:21 am WST) Full Moon (371,543 km)
Sat	11th	1 pm	(11 am WST) star Pollux 5° N of Moon
Sat	11th	5 pm	(3 pm WST) Uranus stationary
Sun	12th	am	m.p. 27 Euterpe 0.3°S of NGC 4073 (G) in Virgo
Mon	13th	10 pm	(8 pm WST) star Regulus 4° S of Moon
Mon	13th	11 pm	(9 pm WST) d.p. Pluto in conjunction with Sun
Tue	14th	1 am	(11 pm WST, prev day) Saturn in conjunction with Sun
Tue	14th	4 am	(2 am WST) d.p. Ceres in conjunction with Sun
Tue	14th	6 am	(4 am WST) Moon at perigee, 365,958 km
Fri	17th	10 am	(8 am WST) m.p. 3 Juno 3° S of Moon
Fri	17th	1 pm	(11 am WST) star Spica 8° S of Moon
Fri	17th	2 pm	(Noon WST) star Antares 5° S of Mars
Fri	17th	10:58 pm	(8:58 pm WST) Last Quarter Moon
Fri	17th	pm	m.p. 511 Davida 0.2°NE of star Kappa Geminorum
Sun	19th		Mercury at greatest latitude south
Tue	21st	1 am	(11 pm WST, prev day) star Antares 7° S of Moon
Tue	21st	4 am	(2 am WST) Mars 3° S of Moon
Thu	23rd		Venus 0.9°S of star Lambda Aquarii
Thu	23rd	1 pm	(11 am WST) Jupiter 0.5° N of Moon
Sat	25th	7:42 am	(5:42 am WST) New Moon
Sun	26th		Mars 0.4°SE of NGC 6235 (GC) in Ophiuchus
Tue	28th		Venus 0.4°NE of star Phi Aquarii
Tue	28th	4 pm	(2 pm WST) Neptune 4° N of Moon
Tue	28th	8 pm	(6 pm WST) Neptune 0.5° W of Venus
Tue	28th	8 pm	(6 pm WST) Venus 3° N of Moon
Wed	29th		Jupiter 0.1°S of NGC 6717 (GC) in Sagittarius
Thu	30th		Mars 0.2°SE of NGC 6287 (GC) in Ophiuchus
Thu	30th	7 am	(5 am WST) Moon at apogee, 405,393 km
Fri	31st	am	m.p. 27 Euterpe 0.6°W of NGC 4179 (G) in Virgo
Fri	31st	pm	m.p. 511 Davida 0.7°SW of star Upsilon Geminorum

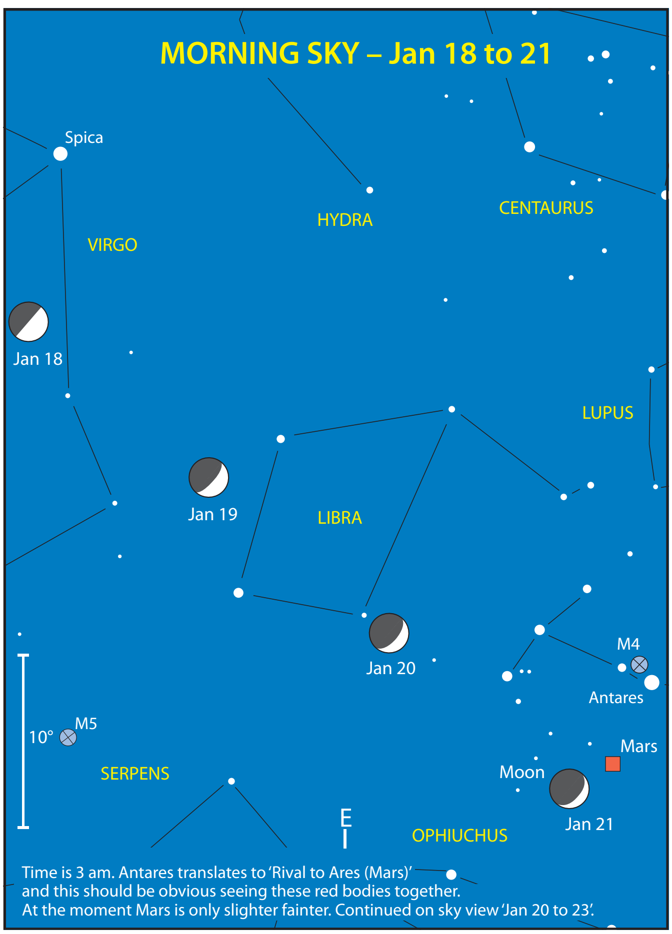
DOUBLE STARS

This month's double star is located in the famous star cluster the Pleiades (Messier 45). **Alcyone (Eta Tauri)** is the brightest star in this conspicuous open cluster (All Sky Map 3 insert). The Pleiades are about 100 million years old and located 444 light-years from Earth. Alcyone is a white magnitude 2.8 star (spectral type B5IIIe) and is a multiple star system. It has a low-mass companion that orbits the primary star every four days and a more massive companion (about half as massive as the primary) orbiting at about the same distance that separates Jupiter and the Sun. Through a small telescope Alcyone has B, C and D companion stars. The B component, magnitude 6.3 is a white A-type star separated from Alcyone A by 117 arcseconds at position angle 290°. The C component is a Delta-Scuti-type variable located 181 arcseconds from Alcyone A with a position angle of 313 degrees. Its magnitude varies from 8.25 to 8.30 over a period of 73 minutes. The D component is a yellow-white F-type star, magnitude 8.7 situated 191 arcseconds from the primary with a position angle of 296 degrees.

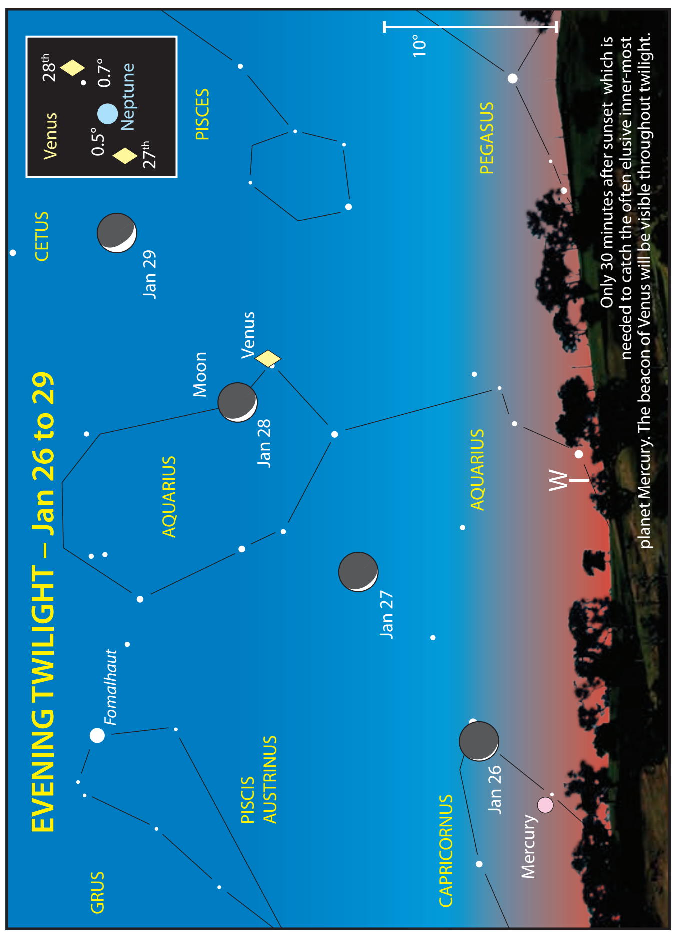


Time is one hour before sunrise. Jupiter has returned to the morning sky and will look impressive next to the crescent Moon on the 23rd.

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

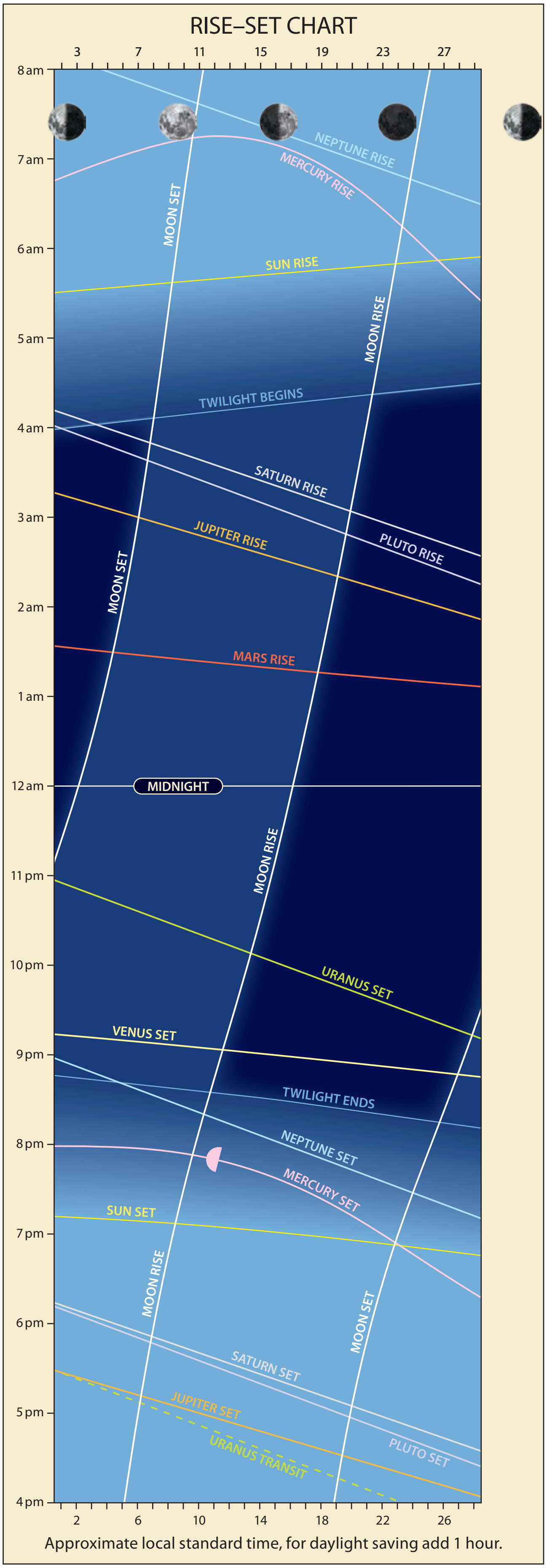


Time is 3 am. Antares translates to 'Rival to Ares (Mars)' and this should be obvious seeing these red bodies together. At the moment Mars is only slighter fainter. Continued on sky view 'Jan 20 to 23'.



Only 30 minutes after sunset which is needed to catch the often elusive inner-most planet Mercury. The beacon of Venus will be visible throughout twilight.

FEBRUARY 2020



FEBRUARY

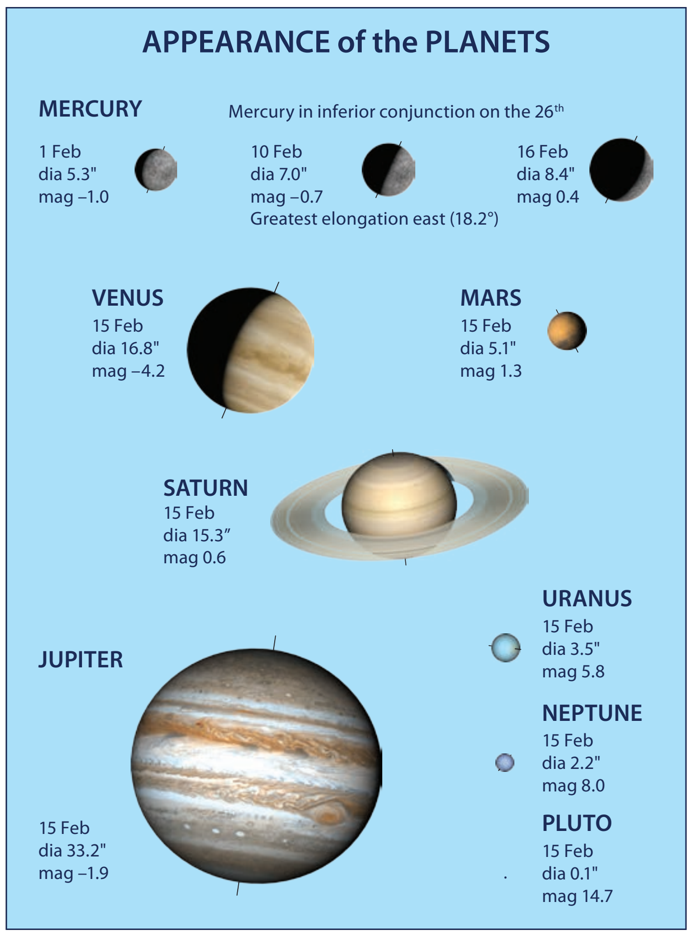
HIGHLIGHTS

- Venus with Moon nearby.
- Mars between the Lagoon and Trifid Nebulae.
- Mars and Moon close.
- Mars passes by the globular M22.
- Mars, Jupiter and Saturn in Sagittarius.
- Jupiter and Moon very close.
- Saturn and Moon close.

CONSTELLATIONS

As stated in January's constellations, the Winter Hexagon in the northern evening sky is spectacular. Within this grouping of stars lies a further asterism, three bright stars forming the Winter Triangle. The group's name betrays its Northern Hemisphere origins (like the Hexagon). Forming an almost exact equilateral triangle they show quite a memorable contrast in colour, reflecting their difference in temperature. The top and hottest member is blue/white Sirius or Alpha Canis Majoris. It has a surface temperature of 9,940 K. Going clockwise you'll come to yellow coloured Procyon (Alpha Canis Minoris) a somewhat *cooler* 6,530 K. Finally, there is Betelgeuse (Alpha Orionis) the coldest star of the group. At 3,500 K it's a red giant appearing distinctly orange to the naked-eye. For comparison, the Sun at 5,800 K comes in slightly colder than Procyon.

Not far from Procyon begins the longest and largest (by area) constellation in the sky, Hydra the Water Snake. It tends to go unnoticed because it is made up of mainly 4th magnitude stars and needs dark skies to observe with unaided eyes. The head

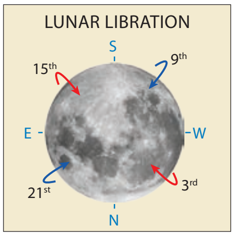


is a tight squashed semicircle of five stars (5° across), roughly halfway between the bright stars Regulus and Procyon. Hydra's alpha star, Alphard, lies 17° south-east of the head and at 2.0 magnitude is memorable for being so isolated. In fact, its Arabic translation is 'the solitary one'. Hydra's body then slithers its way east passing other lesser-known constellations such as Sextans (the Sextant), Antlia (the Air Pump) and Crater (the Cup). It then dives past Corvus (the Crow) to finish between Virgo and Centaurus, near 1st magnitude Spica.

As usual with myths there have been more than one associated with this serpent, but one that ties together some of these constellations comes from the Greeks. The god Apollo had a trusted sacred crow. One day the bird tried to trick Apollo, instead of bringing him water in a cup it contained a snake. Apollo saw through this treachery and banished the cup, snake and crow into the heavens.

You can also glimpse its southern counterpart, Hydrus the Lesser Water Snake. It consists of a triangle of 3rd magnitude stars, between the two Magellanic Clouds, near the bright star Achernar, low in the south-west.

THE MOON



- 2nd Noon (10 am WST) First Quarter.
- 3rd 5 am (3 am WST) Maximum Libration (7.6°), dark NW limb.
- 9th 4 pm (2 pm WST). Minimum Libration (5.6°), Full Moon.
- 9th 6 pm (4 pm WST) Full Moon, supermoon (see table p. 97).
- 11th 6 am (4 am WST) Moon at perigee (closest to Earth at 360,461 km).
- 15th 5 am (3 am WST) Maximum Libration (7.7°), dark SE limb.
- 16th 8 am (6 am WST) Last Quarter.
- 21st 3 pm (1 pm WST). Minimum Libration (5.6°), Too close to New Moon.
- 24th 2 am (midnight previous day WST) New Moon.
- 26th 10 pm (8 pm WST) Moon at apogee (furthest from Earth at 406,278 km).

THE PLANETS

For the second month this year **Mercury** remains in the solar glare. Reaching its greatest elongation 18° east of the Sun on the 10th does not improve things as the planet will only be a few degrees above the horizon at the end of civil twilight. Its evening apparition ends on the 26th as it moves into inferior conjunction (between the Earth and the Sun).

Unmistakable in the early western evening sky, **Venus** spends the month moving across Pisces. The constellation of the Fishes is made up mainly of faint stars (none brighter than 4th magnitude), its most distinguishing feature being the Circlet, an asterism of six stars forming a circle. Although not really close, the 3-day old waxing crescent Moon and the bright planet make an attractive sight on the 27th (see Sky View).

Rising around 1 am, **Mars** traverses the centre of our Milky Way galaxy as it moves from Ophiuchus into Sagittarius. While visiting the constellation of the Archer, the Red Planet joins the next two planets out from the Sun, Jupiter and Saturn. The passage of Mars between the Lagoon and Trifid nebulae on the 18th provides a great wide-field imaging opportunity. On the 19th, the 25-day old waxing crescent Moon appears close to Mars (see Sky View). On the 29th the planet passes by the outliers of the grand globular cluster M22, one of the finest in the sky.

Jupiter, in Sagittarius, is visible in the eastern morning sky before dawn. On the 20th, a spectacular conjunction for early risers occurs when Jupiter appears just 0.3° from the slender crescent of the 26-day old waning Moon (see Sky View).

DIARY

Sat	1st		Mars at descending node
Sat	1st	1 pm	(11 am WST) Uranus 5° N of Moon
Sun	2nd	11:42 am	(9:42 am WST) First Quarter Moon
Sun	2nd	9 pm	(7 pm WST) m.p. 4 Vesta 2° S of Moon
Mon	3rd		Mars 0.7°N of NGC 6325 (GC) in Ophiuchus
Tue	4th	5 pm	(3 pm WST) star Aldebaran 3° S of Moon
Fri	7th		Mars 0.4°N of NGC 6369 (PN) in Ophiuchus
Fri	7th		Mercury at ascending node
Fri	7th	11 pm	(9 pm WST) star Pollux 5° N of Moon
Sun	9th		Jupiter 0.8°S of star Omicron Sagittarii
Sun	9th	5:33 pm	(3:33 pm WST) Full Moon (362,477 km)
Mon	10th		Mars 0.5°N of NGC 6401 (GC) in Ophiuchus
Mon	10th	8 am	(6 am WST) star Regulus 4° S of Moon
Mon	10th	Midnight	(10 pm WST) Mercury at greatest elongation East (18.2°)
Tue	11th	6 am	(4 am WST) Moon at perigee, 360,461 km
Wed	12th		Mercury at perihelion
Thu	13th		m.p. 3 Juno stationary
Thu	13th		Saturn at descending node
Thu	13th	8 pm	(6 pm WST) m.p. 3 Juno 0.5° S of Moon
Thu	13th	8 pm	(6 pm WST) star Spica 8° S of Moon
Thu	13th	9 pm	(7 pm WST) m.p. 511 Davida 0.05°W of star Iota Geminorum
Sat	15th		m.p. 532 Herculina 0.9°S of m.p. 129 Antigone
Sat	15th		Venus at ascending node
Sun	16th	am	m.p. 23 Thalia 0.5°N of star Mu Virginis
Sun	16th	8:17 am	(6:17 am WST) Last Quarter Moon
Sun	16th	8 pm	(6 pm WST) Mercury stationary
Mon	17th	4 am	(2 am WST) star Antares 8° S of Moon
Tue	18th		Mars 0.7°S of M20 Trifid Nebula (BN) in Sagittarius
Tue	18th		m.p. 2 Pallas 1.0°N of IC 4756 (OC) in Serpens
Tue	18th	11 pm	(9 pm WST) Mars 1° S of Moon
Wed	19th		Mars 0.7°N of M8 Lagoon Nebula (BN) in Sagittarius
Thu	20th	4 am	(2 am WST) Jupiter 0.5° N of Moon
Thu	20th	6 pm	(4 pm WST) d.p. Pluto 1° N of Moon
Thu	20th	Midnight	(10 pm WST) Saturn 2° N of Moon
Fri	21st	11 pm	(9 pm WST) d.p. Ceres 3° S of Moon
Sat	22nd		Mercury at greatest latitude north
Mon	24th	1:32 am	(11:32 pm WST, prev day) New Moon
Wed	26th		Jupiter at descending node
Wed	26th	Noon	(10 am WST) Mercury in inferior conjunction
Wed	26th	10 pm	(8 pm WST) Moon at apogee, 406,278 km
Thu	27th	10 pm	(8 pm WST) Venus 6° N of Moon
Fri	28th		Venus 0.6°N of NGC 524 (G) in Pisces
Fri	28th		Mars 0.2°SE of NGC 6642 (GC) in Sagittarius
Fri	28th	10 pm	(8 pm WST) Uranus 4° N of Moon
Sat	29th		Mars 0.3°NW of M22 (GC) in Sagittarius

Saturn appears low in the eastern pre-dawn sky after its conjunction with the Sun last month. In Sagittarius, the planet moves into Capricornus during the second half of March. It returns to the constellation of the Archer in early July only to move back into Capricornus in mid-December. On the 21st, the 27-day old slender crescent of the waning Moon and Saturn appear close (see Sky View).

Uranus, in Aries, appears low in the early western evening sky after the end of astronomical twilight.

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

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto**, in Sagittarius, returns to the pre-dawn eastern sky after its conjunction with the Sun last month. Pluto shares the constellation of the Archer with Mars, Jupiter and Saturn this month.

All to do About Nothing!

The American sitcom Seinfeld recently celebrated its 30th anniversary. It referred to itself as a show about nothing! Well that sums up the constellations as well. What better description can there be of a random pattern of unrelated stars being used to immortalise historical, mostly mythical figures or quite ordinary inanimate objects? However, in a way their creation makes sense. At the time there was little understanding of what the stars were, let alone the enormous distances from us and each other. To the ancients, the stars in a group were likely related and making these symbolic assignments helped to create some order around an otherwise random, incomprehensible collection of lights. Astrology is just an extension of this very human trait. Also, in those days people were much more tuned to the stars for practical purposes such as heralding the oncoming seasons and telling when to sow crops.

The History

Much of the history of the modern constellations we now follow is lost in time. Around 700 BCE, Homer and Hesoid mentioned in their writings, Orion and the Great Bear. At this time the Babylonians, in the country now known as Iraq, had already created a set of zodiacal constellations (those that the Sun makes its annual pilgrimage through). Many of these are thought to have originated with their predecessors, the Sumerians, as far back as 2000 BCE.

The next major contribution came from the astronomer Eudoxus (390–340 BCE) who apparently learned of these constellations from priests in Egypt and introduced them to the Greeks. These were published in works called Enoptron and Pheanomena, which have been lost. Interestingly, the complete knowledge of the ancient Greek constellations was preserved in a poem, also called Pheanomena, by Aratus (310–240 BCE), so he played a significant role in the history of the constellations. Aratus had 48 constellations but not exactly the same as Ptolemy's (see below). For example, there was a constellation called Water (now part of Aquarius) and the Pleiades was considered a separate constellation. Also, Equuleus and Corona Australis didn't exist yet.

The astronomer Ptolemy in the second century CE, based in Alexandria Egypt, pulled together a summary of Greek astronomy. This included a catalogue of 1,000 stars arranged into 48 constellations. The brightness and positions of the stars were taken from the work of the Greek astronomer Hipparchus (190–120 BCE). When it came to naming the stars the mythical constellation figures became important. The practice of assigning Greek letters to the brightest stars wouldn't happen until the early 17th century by Bayer. So, Ptolemy's entries were instead quite descriptive based on their constellation's persona, for example Aldebaran in Taurus was called "the reddish one on the southern eye" (of the bull).

After Ptolemy's time Greek astronomy went into decline. By the 8th century the interest in astronomy was now concentrated in Baghdad. Ptolemy's work was subsequently translated to Arabic and called Almagest (the greatest), as we know it today. A great Arabic astronomer, Azophi (903–986) produced his own version of the catalogue called the Book of Fixed Stars where lots of the Arabic star names we know today were included. The history of many were already so old their meanings were lost while others were just the translation of Ptolemy's description, for example Fomalhaut is an extract from the Arabic translation for Mouth of the Southern Fish.

Ptolemy's constellations are essentially what we use today (but extended). In fact, celestial cartographers followed it for some 1,500 years. Of the original 48 only one no longer exists with the large constellation of Argo Navis being broken up into Carina, Vela and Puppis by Lacaille. On our constellation summary (page 140) we have marked the remaining 47 Ptolemaic contributions.

The Origin of the Ancient Constellations

So far, we've covered how the constellations were passed down through the ages, but who first assigned each of the star patterns to specific legends? A clue comes from that part of the sky that was left blank, the area permanently out of sight below the southern horizon for these Northern Hemisphere dwellers. For one thing the centre of the 'nothing' area does not correspond to where the South Celestial Pole is today, and its size gives an indication of the latitude of the creators (the more north the less that is seen in the south). So, taking into account precession (the shifting of the poles as the Earth slowly wobbles) they most likely originated in the second millennium BCE around latitude 36° north. So, this data fits well with the Sumerians living in Mesopotamia being the originators of a lot more than just the zodiacal constellations.

There is evidence that their interpretations of the sky were modified by another civilisation. The Minoan empire was expanding on the island of Crete around 3000 to 2000 BCE and had plenty of contact with the Babylonians. Crete was definitely in the sweet spot for the required latitude as well. Also, it's interesting that many of the legends depicted are set in Crete. The Minoans were destroyed by a massive volcanic eruption around 1700 BCE. This was one of the greatest natural disasters in history and possibly the source of the legend of Atlantis. It has been proposed that people fleeing this catastrophe made their way to Egypt with their constellations that then waited there for Eudoxus.

The Southern Sky Extensions

By the 17th century the European age of exploration was in full swing. Petrus Plancius, a Dutch cartographer, requested Pieter Keyser, a Dutch navigator, to extend the star charts to the South Celestial Pole. Keyser was a pilot on the first Dutch expedition fleet to the East Indies. The ships spent many months in Madagascar where Keyser made his observations. His stars first appeared in a map by Plancius in 1598, where 12 new constellations were identified: Apus, Chamaeleon, Dorado, Grus, Hydrus, Indus, Musca, Pavo, Phoenix, Triangulum Australe, Tucana and Volans. It is possible the inventor of these constellations was Frederick de Houtman, who was also a member of this expedition and made his own star observations. However, it is thought by some Plancius may have invented them. There seems to be no doubt that he was responsible for Columba, Monoceros, Crux and Camelopardalis.

As the accuracy of astronomical observations improved, Hevelius (1611–1687) introduced ten new constellations, seven of which are still recognised: Canes Venatici, Lacerta, Leo Minor, Lynx, Scutum, Sextans and Vulpecula. This completed the northern celestial sphere. The remaining southern gaps were finally filled by the French astronomer, Nicolas Louis de Lacaille (1713–1762). He set up a small observatory at the Cape of Good Hope. He returned to France in 1754 and presented a map to the French Royal Academy of Sciences, the highlight being 14 new constellations. They were: Antlia, Caelum, Circinus, Fornax, Horologium, Mensa, Microscopium, Norma, Octans, Pictor, Pyxis, Reticulum, Sculptor and Telescopium. Unlike previous creators of constellations, Lacaille preferred to create his mostly around scientific instruments. It was obvious these contributions were modern as microscopes and telescopes didn't exist until the 17th century. Lacaille was also responsible for breaking up the original Argo Navis.

In summary, if you take all the constellations mentioned in this article, plus Coma Berenices (see May 'Constellations') and Ptolemy's 47, the total is 88.

And the winner is …!

It was generally accepted that many of the older constellations that had been made obsolete (prior to Lacaille) would remain dead, but the debate over the constellations continued. For example, Johann Elert Bode (1747–1836) produced an extensive atlas Uranographia in 1801 which had 100 constellations! It was time to put this matter to bed. The astronomy world set up the International Astronomical Union to govern many issues such as naming celestial objects, so this was high on their list of priorities. At its first general assembly in 1922, the IAU officially adopted the 88 constellations to cover the full sky. Despite needing to fine tune the positions of some borders, this finally set in stone our structuring of the heavens.

So that's it. Is this all a lot to do about nothing? We'll leave you to decide.

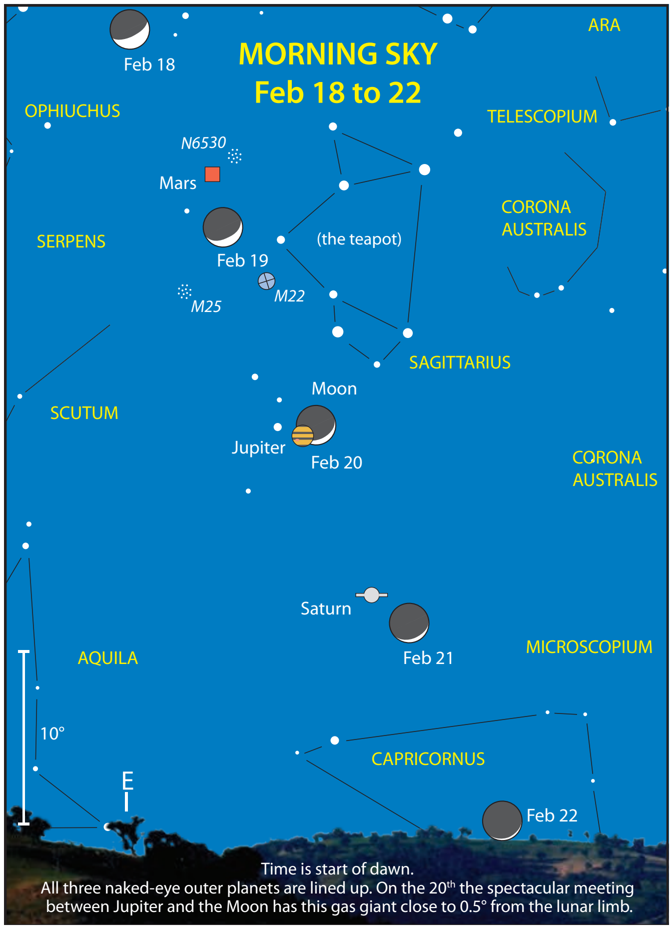
Reproduction of a Dürer wood cutting depicting the southern sky in Ptolemy's time, showing the south celestial gap.

Brightest **Minor Planets** at opposition this month include:

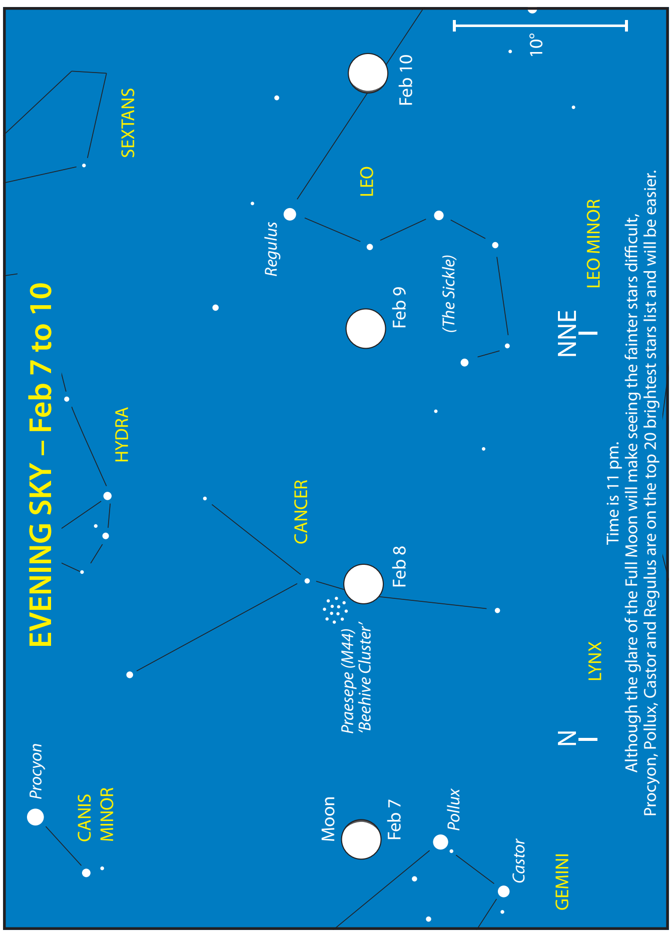
Date	Minor Planet	Constellation	Mag.
2 Feb	43 Ariadne	Cancer	11.0
2 Feb	37 Fides	Cancer	10.1
3 Feb	346 Hermentaria	Cancer	11.1
18 Feb	12 Victoria	Sextans	11.1
29 Feb	30 Urania	Sextans/Leo border	10.6

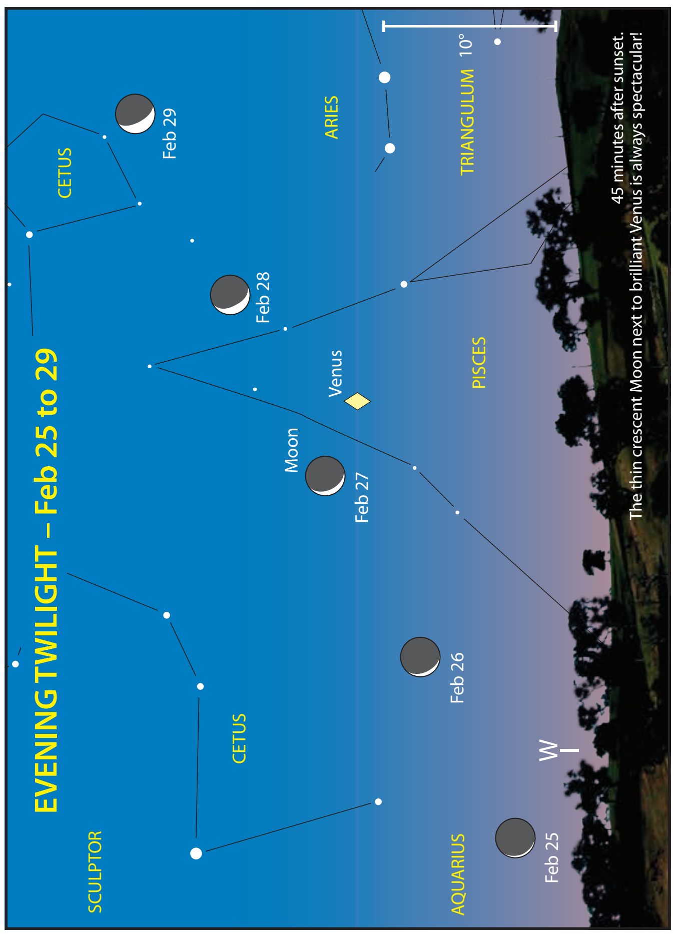
DOUBLE STARS

Zeta (ζ) Orionis (Alnitak) is one of the bright belt stars of the constellation Orion (All Sky Map No 2). This is a stunning pair of unequal white stars that needs good seeing and is challenging because of the closeness of the pair and glare of the primary. At low power there is an easy fainter (magnitude 9.5) C component with a separation of 58 arcseconds and position angle of 10° (which may not be part of the system). However, the real prize is the very close companion nestled next to the bright primary. The primary star (Aa) is a magnitude 1.9 hot blue supergiant (spectral class O9.2Ib). The B component magnitude 3.7 is located just 2.4 arcseconds away at position angle 166°. All three stars (A, B and C) are visible through small telescopes with high magnification. The AB pair has an orbital period of 1,500 years. The primary star also has a very close companion (Ab) detected interferometrically and spectroscopically. The stars are members of the Orion OB1 and Collinder 70 association.



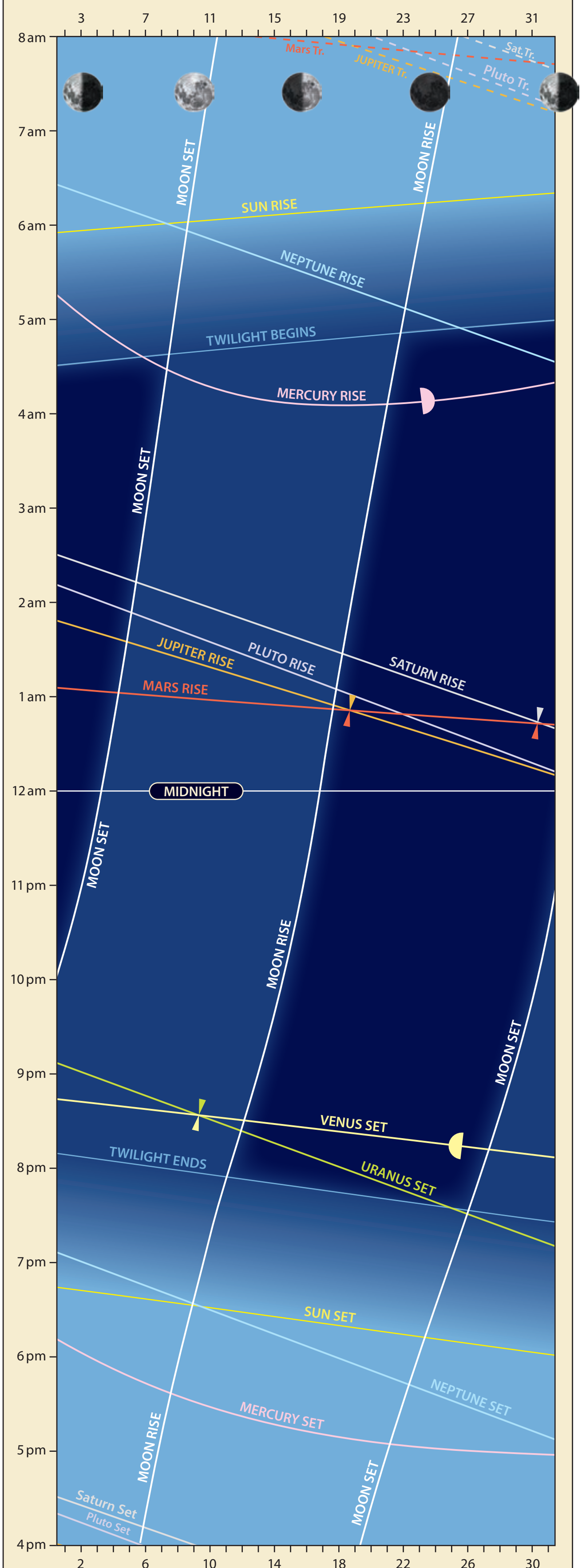
Approximate local standard time, for daylight saving add one hour.





MARCH 2020

RISE–SET CHART



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

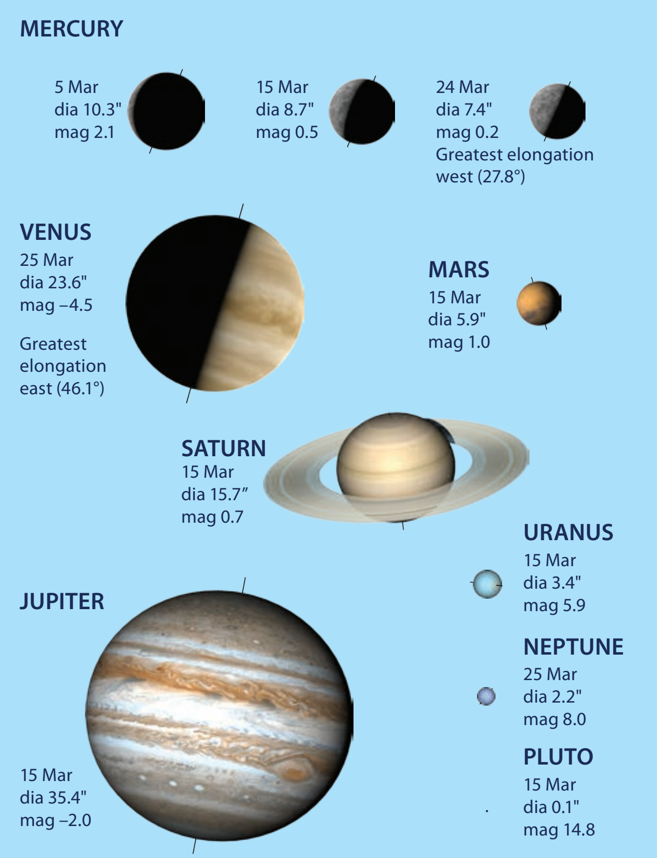
HIGHLIGHTS

- Mercury and Moon close.
- Venus and Uranus close.
- Venus with Moon nearby.
- Moon near Mars, Jupiter and Saturn and all in Sagittarius.
- Mars close to Jupiter.
- Mars close to Saturn.

CONSTELLATIONS

The late evening sees two distinctive constellations near the horizon. Rising in the east, along with the central region of the Milky Way, is Scorpius the Scorpion—heralding the coming winter. At the same time, the western sky sees the summer icon, 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. There are a number of variations in Greek mythology on how Orion died. One version had Orion and the goddess Artemis as lovers. She was not only the goddess of the hunt and the Moon, but also chastity. Her twin brother, Apollo, wished to protect Artemis from losing her innocence. So, loathed by this relationship he sent a giant scorpion which killed Orion. Artemis in her grief appealed to Zeus to immortalise Orion by placing him amongst the stars. Zeus consented and also decided to add the scorpion as a memorial to this hero's death. So, as Scorpius rises, this mighty heavenly hunter is destined to flee from his deadly enemy for eternity!

APPEARANCE of the PLANETS



A Beautiful Globe of Stars

"All the good stuff is in the Southern Hemisphere"
Bart Bok (1906–1983)

There is no doubt that Omega Centauri (below) is the king of the globular clusters and one of the showpieces of the southern skies. It is the brightest and largest of this class of object and easily visible to the unaided eye under dark skies. Binoculars reveal a hazy ball somewhat like a tailless comet. A description that fits well as many mistook Omega for Halley's Comet when it passed near the cluster in 1986. The true splendour of this majestic Moon sized object is revealed when a telescope is trained upon it. In the words of Sir John Herschel, *"Truly astonishing … the richest and largest object of its kind in the heavens, whose stars are literally innumerable."*

Omega's recorded history goes back as far as Ptolemy who catalogued it in his 2nd century Almagest. It was given its current designation by Johann Bayer in his 1603 Uranometria, believing it to be a star, he marked it accordingly with a Greek letter. Despite its stellar prefix, Edmond Halley listed it as one of six *"luminous spots or patches"* that he observed in 1677. It would be our own James Dunlop that recognised its true nature when he observed it from Parramatta Observatory in 1826. Dunlop listed Omega as object number 440 in his catalogue of southern nebulae and clusters and described it as *"… a beautiful globe of stars very gradually and moderately compressed to the centre; the stars are rather scattered preceding and following, and the greatest condensation is rather north of the centre, the stars are of slightly mixed magnitudes, of a white colour."*

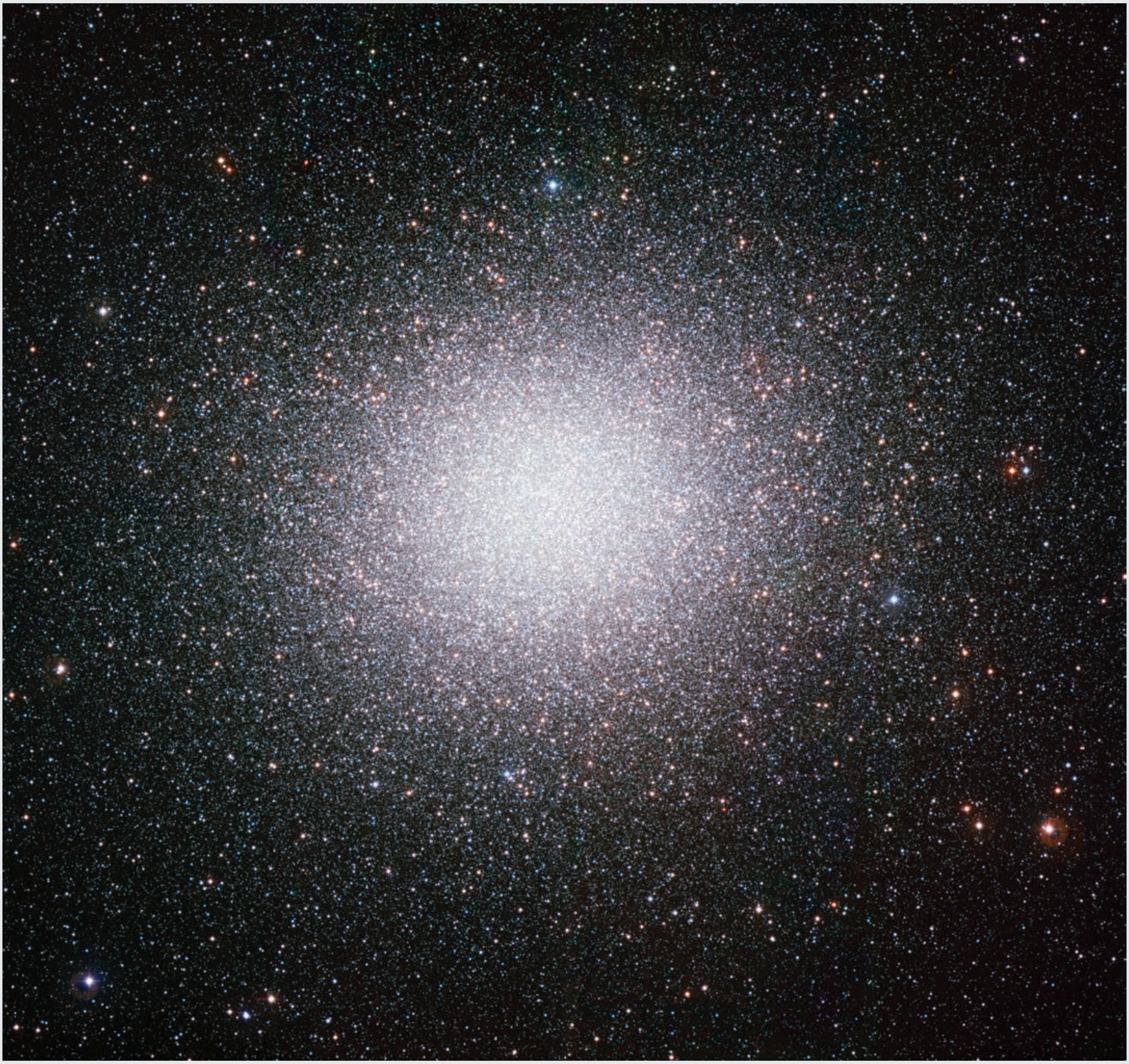


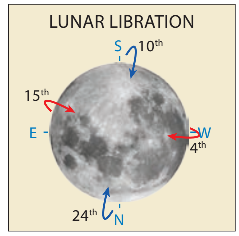
Image 1. The globular cluster Omega Centauri seen in all its splendour in this image captured with the WFI camera from ESO's La Silla Observatory. Credit: ESO

MARCH

There are many other mythical connections in the constellations related to Orion, possibly the most well-known being his two hunting dogs, the constellations of Canis Major and Canis Minor. One of them was called Procyon which is the name of the star, Alpha Canis Minoris. Orion and his dogs spent time chasing a hare, the constellation of Lepus. Hyginus, realising this foe was a little beneath a hunter of Orion's stature, instead had him pursue the bull (Taurus).

Another myth was Orion fell in love with Pleione. She wasn't interested in Orion and Pleione and her daughters spent seven years running from Orion. Eventually Zeus took pity on them and hid them in the heavens as stars. The daughters were also known as the Pleiades (Seven Sisters), which is now the common name for the prominent (naked-eye) star cluster M45 in Taurus. One of its stars is called, Pleione. So, Orion continues to chase her, this time across the sky!

THE MOON



- 3rd 6 am (4 am WST) First Quarter.
- 4th 4 pm (2 pm WST) Maximum Libration (7.9°), dark NW limb.
- 10th 4 am (2 am WST) Full Moon, Supermoon (see table p. 97).
- 10th 7 am (5 am WST) Minimum Libration (6.4°), Full Moon.
- 10th 4 pm (2 pm WST) Moon at perigee (closest to Earth at 357,122 km).
- 15th 8 am (6 am WST) Maximum Libration (7.7°), dark SE limb.
- 16th 8 pm (6 pm WST) Last Quarter.
- 24th 5 am (3 am WST) Minimum Libration (6.6°), too close to New Moon.

Image 2. NASA's Hubble Space Telescope took this panoramic view of a colourful assortment of 100,000 stars residing in the crowded core of Omega in July 2009. Credit: NASA, ESA, and the Hubble SM4 ERO Team

Globular clusters are densely packed conglomerations of very ancient stars, estimated to be between 10 and 12 billion years old. Containing hundreds of thousands to millions of members, they are generally made up of low-metal stars like the Population II stars of our own galaxy. Globulars are so tightly packed that the average density is about 0.4 stars per cubic parsec, increasing toward the centre (Image 2) from 100 to 1000 per cubic parsec. Globulars are not uncommon in the Universe and the Hubble Space Telescope (HST) has uncovered more than 22,400 just in the core of the Coma cluster of galaxies.

Although similar in appearance to the other 150 or so globulars that form a halo around the core of our galaxy, Omega may not be what it seems. Containing about 10 million suns within its 270 light-year diameter sphere, it lies at a distance of 16,000 light-years from us. Most globulars are populated with stars of similar age and chemical composition. Omega, however, has at least two generations of stars, including low-metal Population II and higher metallicity (those with elements heavier than hydrogen or helium) Population I stars.

In 2008 a study was made of the motion of stars at the cluster's core from observations made at the Gemini Observatory in Chile and the HST. The researchers concluded that an intermediate mass black hole roughly 40,000 times that of the Sun resides in Omega's centre. More recent work has cast doubt on some of the first group's findings but they have not ruled out a black hole. They did however downsize it to no more than 12,000 solar masses.

The presence of a black hole plus a stellar makeup uncharacteristic of typical globulars has led astronomers to theorise that Omega may be the remnant of a dwarf satellite galaxy of the Milky Way. Further supporting this theory is its unique retrograde orbit that is almost coplanar with the Milky Way disc. Long ago, this once larger galaxy was greatly depleted of stars and gas through tidal stripping by the mother galaxy.

At four million solar masses, Omega is the most massive globular belonging to our galaxy. However, if we extend our search to include the local group of galaxies, we will find a similar globular with at least twice Omega's mass. Called Mayall II (Image 3), it orbits the Andromeda Galaxy and is the most luminous globular in the local group. Mayall II has millions of stars, a suspected intermediate mass black hole and unusual metallicity in its stars. Like Omega, Mayall II is considered to be the remnant nucleus of a dwarf galaxy.

Next time you observe Omega through a telescope, imagine what it would be like living on a planet near the centre of that *star city*. You would be dazzled by a sky absolutely saturated with brilliant stars. On second thoughts, the night sky would be ruined, and our view of the Universe would be limited to just a few light-years!

Image 3. An interesting globular cluster due to its unusual metallicity and possible home to an intermediate mass black hole, Mayall II or G1 is part of the Andromeda galaxy. Credit HST and Judy Schmidt.

24th 7 pm (5 pm WST) New Moon.

25th 1 am (11 pm previous day WST) Moon at apogee (furthest from Earth at 406,692 km).

THE PLANETS

Mercury returns to the eastern morning sky for a favourable apparition this month. In fact, with its greatest elongation of 28° west of the Sun on the 24th, the period from mid-March to early April is ideal for morning observation. On the 22nd, the slender crescent of the 27-day old Moon, just 6% illuminated by the Sun, appears close to Mercury (see Sky View).

Venus reaches its greatest elongation 46°east of the Sun on the 25th and thereafter begins its sunward journey toward inferior conjunction in early June. While not really close, the 4-day old waxing crescent Moon and the bright planet make an attractive sight in the early western sky on the 28th (see Sky View). On the 8th and 9th, Venus passes within 2° of the outer planet Uranus. A good western horizon and binoculars will aid in finding this bluish/green world.

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 equal.

Mars, rising around 1 am in Sagittarius, begins the month less than 1° from the bright globular cluster M22. With the forthcoming opposition in October the Martian disc has steadily increased in size since the beginning of the year. At 6 arcseconds in diameter this month, telescopes in the 10–20 cm range (or larger) will provide some surface detail and a glimpse of the south polar cap as it emerges from the darkness of winter. On the 18th and 19th the waning crescent Moon will appear near Mars, Jupiter and Saturn, all in Sagittarius. On the 20th and 21st the Red Planet will be less than 1° from Jupiter and on the 31st just 1° from Saturn (see Sky View).

At midmonth, **Jupiter** rising around 1 am in Sagittarius, makes an impressive scene together with Mars and Saturn in the morning sky. On the 19th, the 24-day old waning crescent Moon appears between Jupiter and Saturn (see Sky View). To round the month off, the Giant Planet and Mars meet up for a close rendezvous on the 20th and 21st when they are less than 1° apart (see Sky View).

Saturn remains a morning object in March, rising in the east in Sagittarius before crossing over into Capricornus late in the month. On the 19th, the 24-day old waning crescent Moon will be near the planet (see Sky View). From 31 March to 2 April, Saturn and Mars will be just 1° apart—a nice colour contrast between the dusky/white and yellow/orange orbs (see Sky View).

Uranus, in Aries, is low in the western evening sky this month. By late March the planet sets at the end of astronomical twilight as it moves toward conjunction in April. On the 8th and 9th, Uranus will be within 2° of the brighter inner planet Venus (see Venus and Sky View).

Neptune, now moving toward solar conjunction on the 8th, will be lost from view until its reappearance in the morning sky in early April.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto**, in Sagittarius, rises around 1 am midmonth. On the 23rd and 24th Mars will be 0.3° from Pluto.

Early in March, minor planet **Herculina** passes between the Eagle Nebula (M 16) and the open star cluster NGC 6605 in Serpens.

DIARY

Sun 1st	4 pm	(2 pm WST) m.p. 4 Vesta 0.1° N of Moon
Mon 2nd		m.p. 532 Herculina 0.3°N of NGC 6605 in Serpens
Mon 2nd		m.p. 532 Herculina 0.9°S of M16 Eagle Nebula (BN) in Serpens
Tue 3rd	2 am	(Midnight WST, prev day) star Aldebaran 3° S of Moon
Tue 3rd	5:57 am	(3:57 am WST) First Quarter Moon
Fri 6th		Mars 0.7°S of NGC 6717 (GC) in Sagittarius
Fri 6th	10 am	(8 am WST) star Pollux 5° N of Moon
Sun 8th	8 pm	(6 pm WST) star Regulus 5° S of Moon
Sun 8th	10 pm	(8 pm WST) Neptune in conjunction with Sun
Mon 9th	6 pm	(4 pm WST) Mercury stationary
Mon 9th	7 pm	(5 pm WST) Uranus 2° S of Venus
Tue 10th		m.p. 532 Herculina 0.1°S of star Gamma Scuti
Tue 10th	3:48 am	(1:48 am WST) Full Moon (357,400 km)
Tue 10th	4 pm	(2 pm WST) Moon at perigee, 357,122 km
Thu 12th	2 am	(Midnight WST, prev day) m.p. 3 Juno 1.5° N of Moon
Thu 12th	4 am	(2 am WST) star Spica 8° S of Moon
Sun 15th	1 pm	(11 am WST) star Antares 7° S of Moon
Mon 16th		Mercury at descending node
Mon 16th	7:34 pm	(5:34 pm WST) Last Quarter Moon
Mon 16th	9 pm	(7 pm WST) m.p. 511 Davida 0.05°S of NGC 2371 (PN) in Gemini
Tue 17th		d.p. Ceres 1.0°N of star Zeta Capricorni
Tue 17th	pm	m.p. 6 Hebe 0.3°SW of NGC 5248 (G) in Boötes
Wed 18th	6 pm	(4 pm WST) Mars 0.5° N of Moon
Wed 18th	8 pm	(6 pm WST) Jupiter 1.5° N of Moon
Thu 19th	1 am	(11 pm WST, prev day) d.p. Pluto 1° N of Moon
Thu 19th	10 am	(8 am WST) Saturn 2° N of Moon
Fri 20th		Venus at perihelion
Fri 20th	2 pm	(Noon WST) Equinox
Fri 20th	4 pm	(2 pm WST) Jupiter 0.5° N of Mars
Sat 21st	2 am	(Midnight WST, prev day) d.p. Ceres 3° S of Moon
Sun 22nd	4 am	(2 am WST) Mercury 4° N of Moon
Mon 23rd		d.p. Pluto 0.3°E of Mars
Mon 23rd	3 pm	(1 pm WST) d.p. Pluto 0.01° N of Mars
Tue 24th	Noon	(10 am WST) Mercury at greatest elongation West (27.8°)
Tue 24th	7:28 pm	(5:28 pm WST) New Moon
Wed 25th	1 am	(11 pm WST, prev day) Moon at apogee, 406,692 km
Wed 25th	8 am	(6 am WST) Venus at greatest elongation East (46.1°)
Thu 26th		m.p. 192 Nausikaa 0.1°S of NGC 2331 (OC) in Gemini
Thu 26th	am	m.p. 23 Thalia 0.9°NE of star Mu Virginis
Fri 27th		Mercury at aphelion
Fri 27th	7 am	(5 am WST) Uranus 4° N of Moon
Sat 28th	9 pm	(7 pm WST) Venus 7° N of Moon
Sun 29th	5 pm	(3 pm WST) m.p. 4 Vesta 0.2° N of Moon
Mon 30th		Mars 0.7°N of M75 (GC) in Sagittarius
Mon 30th	8 am	(6 am WST) star Aldebaran 4° S of Moon
Tue 31st	9 pm	(7 pm WST) Saturn 1° N of Mars

Brightest **Minor Planets** at opposition this month include:

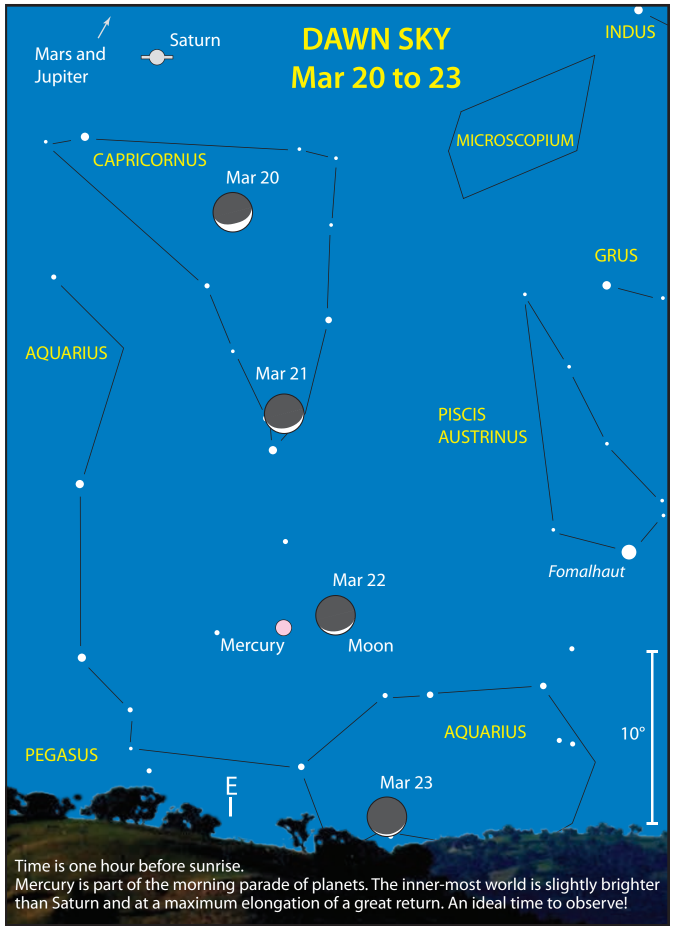
Date	Minor Planet	Constellation	Mag.
7 Mar	115 Thyra	Sextans/Leo border	10.9
9 Mar	128 Nemesis	Leo	11.8
14 Mar	27 Euterpe	Leo/Virgo border	9.4
20 Mar	25 Phocaea	Crater	11.6
21 Mar	704 Interamnia	Crater	11.3
23 Mar	324 Bamberga	Crater/Virgo border	11.9
27 Mar	71 Niobe	Hydra	10.4
27 Mar	80 Sappho	Virgo	11.7

COMETS

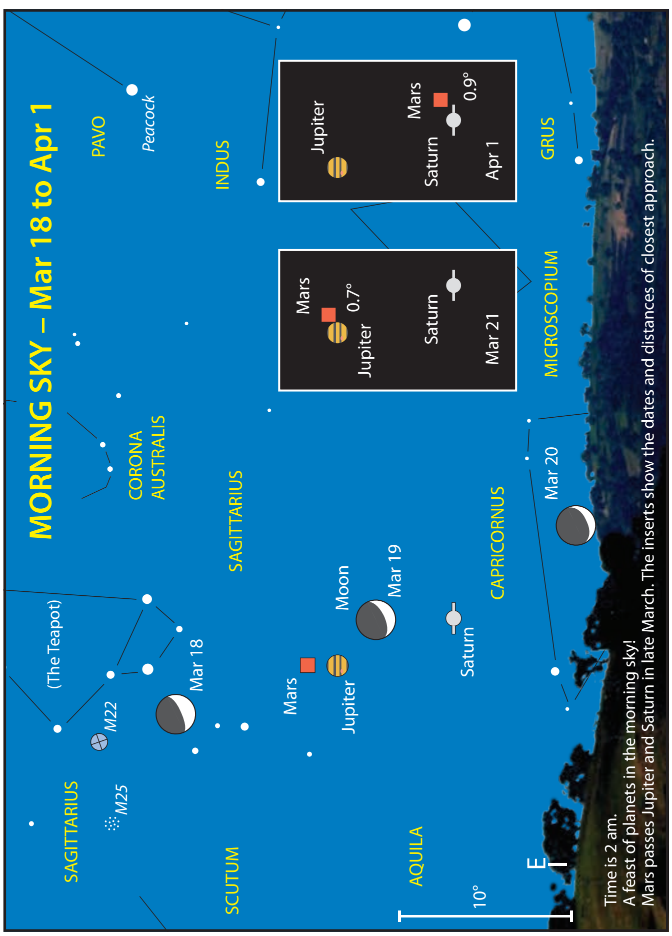
Comet 88P/Howell will brighten to 12th magnitude by mid-March, becoming visually observable for the first time since its last perihelion passage in 2015. Located in the constellation of Virgo throughout the month, and indeed for several months to come, comet Howell rises during evening twilight and is visible the rest of the night, transiting in the early morning.

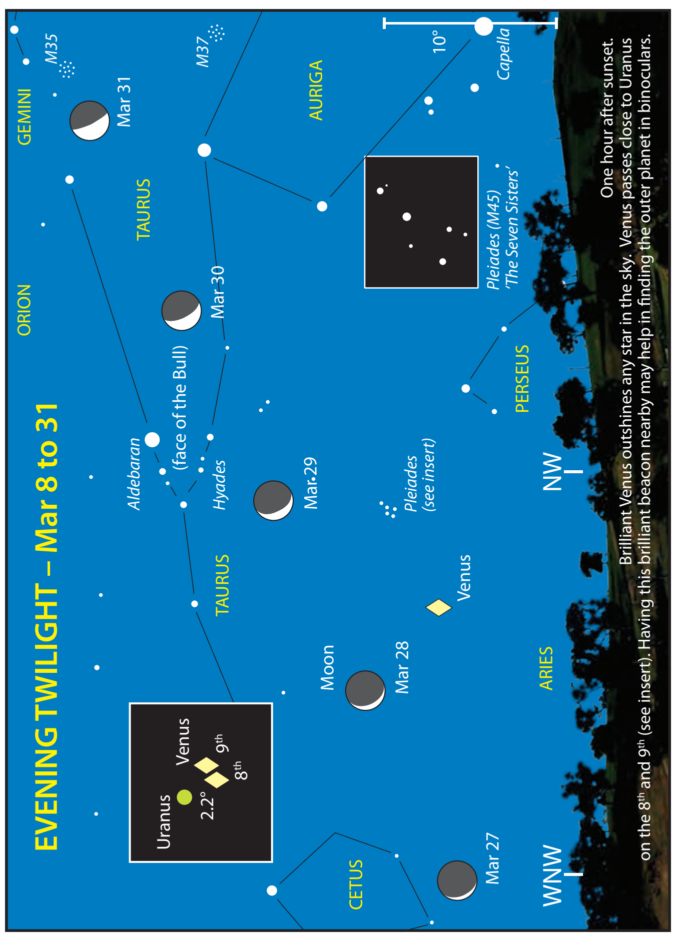
DOUBLE STARS

Nu^1 (ν^1) Canis Majoris is a fine pair, well suited for a small telescope (All Sky Map No 4). It forms a flattened isosceles triangle with Sirius and Beta Canis Majoris (Murzam). To also help you find it, look for the star in between Nu^2 (ν^2) and Nu^3 (ν^3). The yellow primary, magnitude 5.8, is a G5III-type star with a mass 1.41 times that of the Sun. The magnitude 7.4 bluish-white companion is an F-type main sequence star separated from the primary by 17 arcseconds with a position angle 264°. The system is located 350 light-years from the Sun.

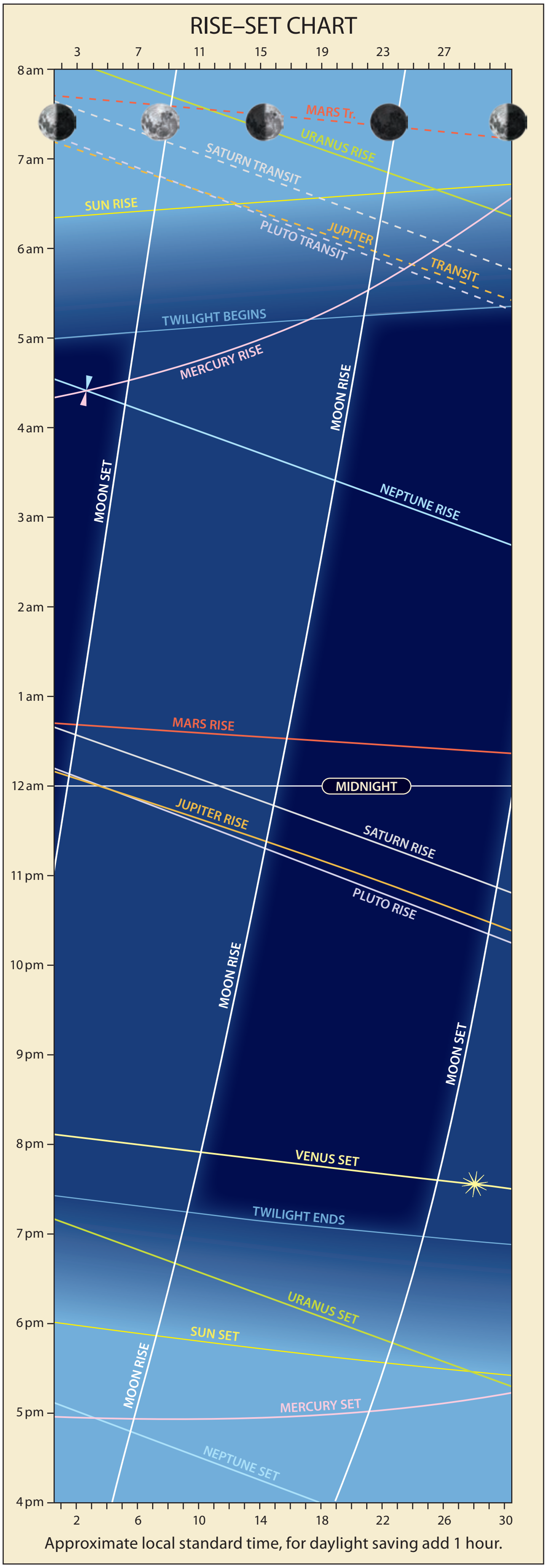


Approximate local standard time, for daylight saving add one hour.





APRIL 2020



HIGHLIGHTS

- ❍ Mercury and Moon close.
- ❍ Mercury and Neptune close.
- ❍ Venus at greatest brilliancy.
- ❍ Mars and Saturn close.
- ❍ Mars and Moon close.
- ❍ Jupiter with Moon nearby.
- ❍ Saturn with Moon nearby.

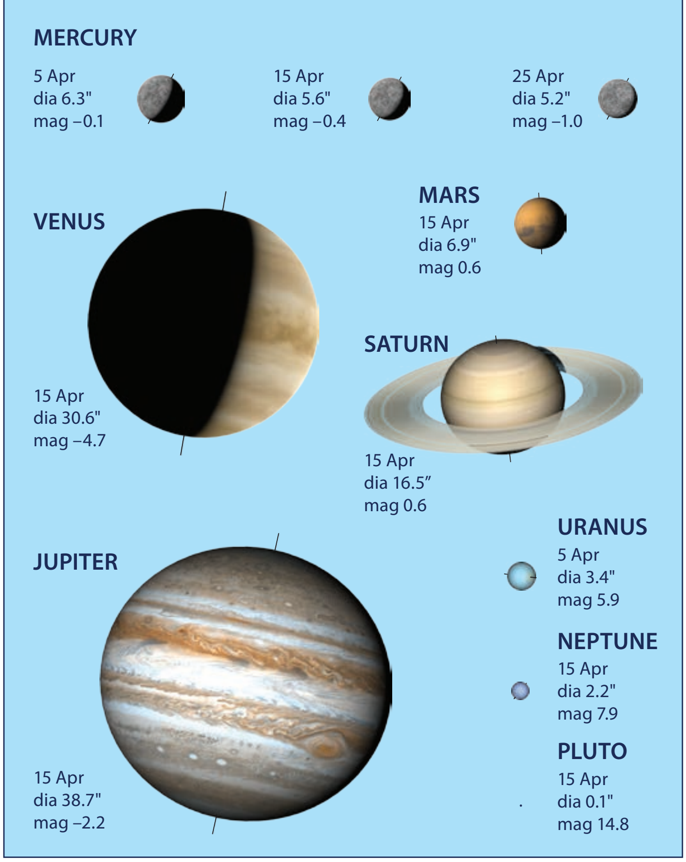
CONSTELLATIONS

Autumn evenings have an extra 60–90 minutes of dark sky over the summer months and the lack of winter cold is a bonus!

Some claim this is the best season to observe from the Southern Hemisphere. It certainly offers skies of contrast. Looking north you are seeing well out of the plane of our rich galaxy—note the fewer stars visible. As usual the ecliptic is present and with it an assortment of constellations of the zodiac, such as Cancer, Leo, Virgo and, rising in the east, Scorpius (see below). Leo is certainly recognisable, once you accept the upside-down view of the crouching lion we see from down under. His head and chest appear as the Sickle asterism.

High in the south are the impressive and most southerly regions of the Milky Way. The majority of the Northern Hemisphere doesn't get to see this rich area. The markers here are the bright stars of the Southern Cross (Crux) with its two pointer stars (Alpha and Beta Centauri), then westward to the False Cross and the star Canopus (Alpha Carinae). Various nebulae and star clusters reside here, all impressive

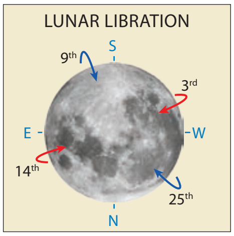
APPEARANCE of the PLANETS



and tantalising even through the wide field of binoculars. The False Cross around to Canopus is the area of the obsolete constellation of Argo Navis, the ship from Jason and the Argonauts. It's now broken up. South of the cross is Carina the Keel. The cross links Carina to its sail Vela, which is visible by a roughly oval shaped asterism of faint stars. Between Vela and Canis Major is Puppis the Poop Deck, the stern of the Argo.

Heading to the east, the Aboriginal constellation of the Emu isn't made of stars at all, but dark nebulae (gas/dust) seen silhouetted against the glow of our galaxy. Its head, called the Coal Sack, can't be missed, tucked into the south-east corner of the Southern Cross (Crux). If you look closely there is even a beak and a faint star for an eye! The Emu's somewhat disjointed narrow neck runs down between the Pointers, through Lupus, widening out into a broad body, comprised of a complex of dark lanes in Scorpius. In the early evening it appears to be sitting on the south-east horizon this time of year.

THE MOON



- 1st 8 pm (6 pm WST) First Quarter.
- 3rd 11 am (9 am WST) Maximum Libration (8.3°), dark SW limb.
- 8th 4 am (2 am WST) Moon at perigee (closest to Earth at 356,907 km).
- 8th 1 pm (11 am WST) Full Moon, Supermoon, the closest Full Moon perigee syzygy of the year (see table p. 97).
- 9th 4 am (2 am WST) Minimum Libration (6.2°), Full Moon.
- 14th Midnight (10 pm WST) Maximum Libration (7.6°), dark NE limb.
- 15th 9 am (7 am WST) Last Quarter.
- 21st 5 am (3 am WST) Moon at apogee (furthest from Earth at 406,462 km).
- 23rd Noon (10 am WST) New Moon.
- 25th 10 am (8 am WST) Minimum Libration (5.7°), dark NW limb.

THE PLANETS

Early April sees **Mercury** at its best in the eastern morning sky and as a bonus an encounter with the Solar System's outermost planet, Neptune, is thrown in. Although not as close, nor as aesthetically pleasing as the Mercury/Neptune conjunction in April last year, it still provides a satisfying view in binoculars or a low power telescope field. The planetary pair are at their closest on the 4th at 1.4° apart and a little further at 1.6° on the following morning. From midmonth onwards Mercury again becomes difficult to spot in the dawn sky as it moves toward superior conjunction early next month. On the 22nd the planet will be close to the slender crescent of the waning Moon (see Sky View). With the Moon around 24 hours from new, it could be a challenge low in the dawn sky, binoculars and a good horizon are needed.

Venus traverses the constellation of Taurus in the early evening western sky this month, crossing over the Pleiades star cluster on the 3rd and 4th (see Sky View). Although its main member stars are quite bright (3rd to 4th magnitude) the brilliance of this inner planet may overpower what is normally one of the brightest open clusters.

Interestingly, Galileo observed the Pleiades in 1610. Instead of the six or seven stars visible to the unaided eye, Galileo counted over 40 and recorded the positions of 36 of these in a sketch. His observations of the Pleiades, Orion, the Beehive cluster and the Milky Way brought him to the conclusion that the Universe contained an unfathomable number of stars.

Venus reaches its greatest brilliancy on the 28th at –4.7 magnitude—also known as greatest illuminated extent. It is defined as when the planet's illuminated portion or dayside covers the greatest amount of sky. At this time, we see Venus one-quarter illuminated, just like a 3 or 4-day old Moon.

In the early morning eastern sky **Mars** begins the month just 1° from Saturn in Capricornus. Both planets are virtually the same magnitude at this time (about 0.7), but the yellow/

DIARY			
Wed	1st	8:21 pm	(6:21 pm WST) First Quarter Moon
Thu	2nd	8 pm	(6 pm WST) star Pollux 4° N of Moon
Fri	3rd		Venus 0.5°S of M45 the Pleiades (OC) in Taurus
Fri	3rd	6 am	(4 am WST) m.p. 3 Juno at opposition
Sat	4th		Venus 0.8°E of M45 the Pleiades (OC) in Taurus
Sat	4th	1 am	(11 pm WST, prev day) Neptune 1.5° N of Mercury
Sat	4th	pm	m.p. 3 Juno 0.7°NE of NGC 4845 (G) in Virgo
Sun	5th	5 am	(3 am WST) star Regulus 4° S of Moon
Mon	6th		d.p. Pluto 0.7°S of Jupiter
Mon	6th	8 pm	(6 pm WST) d.p. Pluto 1° S of Jupiter
Tue	7th	pm	m.p. 27 Euterpe 1.0°NE of star Sigma Leonis
Wed	8th	4 am	(2 am WST) Moon at perigee, 356,907 km
Wed	8th	5 am	(3 am WST) m.p. 3 Juno 3° N of Moon
Wed	8th	12:35 pm	(10:35 am WST) Full Moon (357,030 km, closest for this year)
Wed	8th	5 pm	(3 pm WST) star Spica 7° S of Moon
Thu	9th		m.p. 511 Davida 0.6°N of star Sigma Geminorum
Fri	10th		Venus at greatest latitude north
Sat	11th	10 pm	(8 pm WST) star Antares 7° S of Moon
Sat	11th	pm	m.p. 3 Juno 0.5°SW of star Delta Virginis
Wed	15th	8 am	(6 am WST) d.p. Pluto 1° N of Moon
Wed	15th	8:56 am	(6:56 am WST) Last Quarter Moon
Wed	15th	9 am	(7 am WST) Jupiter 2° N of Moon
Wed	15th	7 pm	(5 pm WST) Saturn 2° N of Moon
Thu	16th		Mercury at greatest latitude south
Thu	16th	3 pm	(1 pm WST) Mars 2° N of Moon
Sat	18th	3 am	(1 am WST) d.p. Ceres 3° S of Moon
Sat	18th	6 am	(4 am WST) star Aldebaran 10° S of Venus
Sun	19th	5 pm	(3 pm WST) Neptune 4° N of Moon
Mon	20th	pm	m.p. 40 Harmonia 0.8°S of star Iota Virginis
Tue	21st	5 am	(3 am WST) Moon at apogee, 406,462 km
Thu	23rd	12:26 pm	(10:26 am WST) New Moon
Sun	26th		d.p. Pluto stationary
Sun	26th	3 am	(1 am WST) Mars 0.1°S of star Iota Capricorni
Sun	26th	2 pm	(Noon WST) star Aldebaran 4° S of Moon
Sun	26th	7 pm	(5 pm WST) Uranus in conjunction with Sun
Sun	26th	9 pm	(7 pm WST) m.p. 4 Vesta 0.1° S of Moon
Mon	27th	1 am	(11 pm WST, prev day) Venus 6° N of Moon
Tue	28th	11 am	(9 am WST) Venus greatest illuminated extent
Tue	28th	3 am	(1 am WST) m.p. 129 Antigone 0.05°N of NGC 6814 (G) in Aquila
Thu	30th		m.p. 5 Astraea 0.2°N of M44 Beehive Cluster (OC) in Cancer
Thu	30th	1 am	(11 pm WST, prev day) star Pollux 5° N of Moon

Cover Story—Lunar Reconnaissance Orbiter

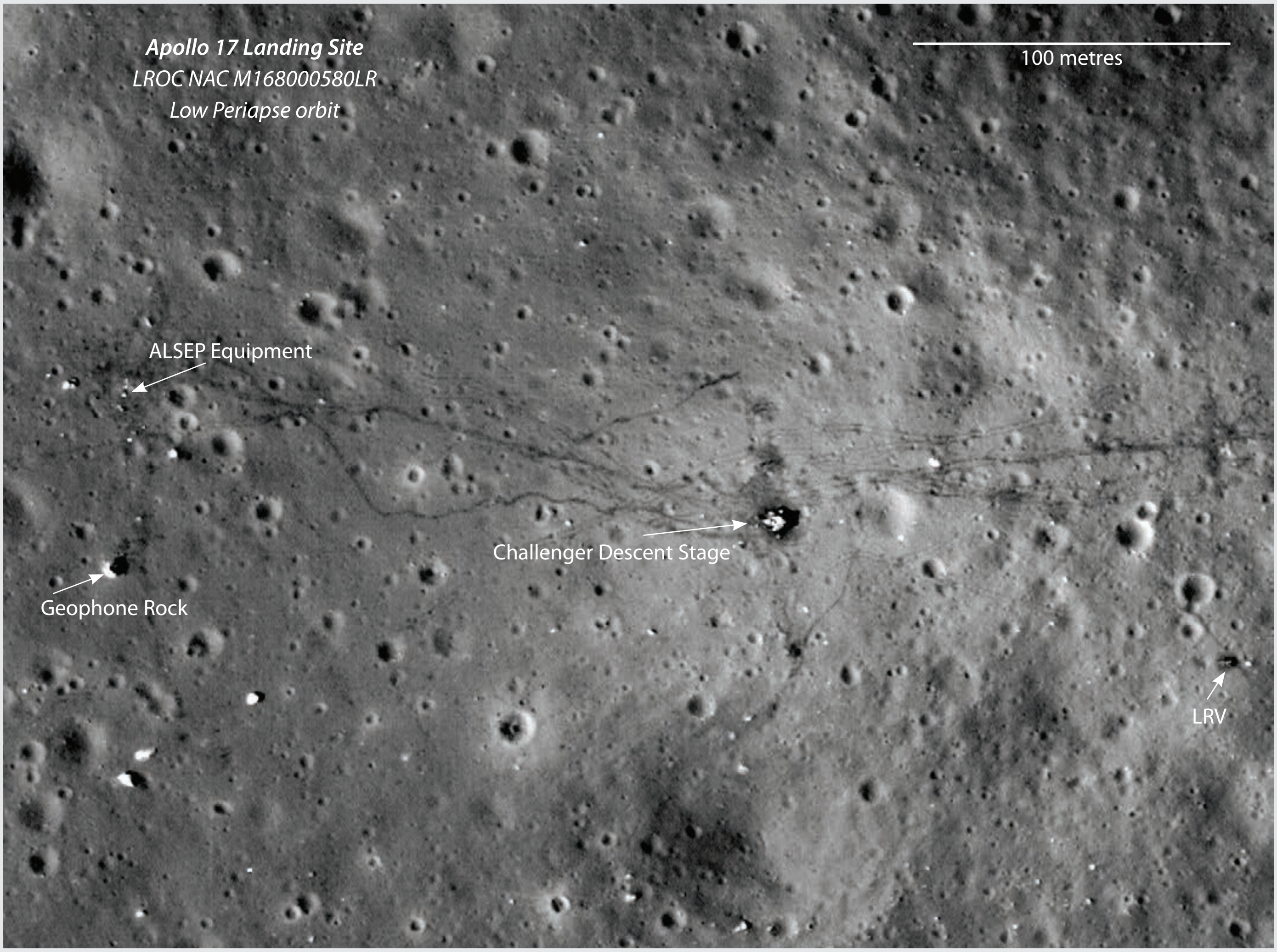
We have been exploring the Moon with robotic probes for close to 60 years. The earliest examples, undertaken by NASA and the Soviet Union, were at best very low-resolution images snapped as they flew by our satellite or more promising, sharper, tantalising close views just before the helpless machine crashed into the lunar surface. Technology has moved on with a plethora of increasingly sophisticated probes having visited over the decades. The Moon has continued to have its mysteries with many considering it the proving ground to test technology designed to go beyond. Today Japan, China and India have had orbiters. China was the first to place a lander on the far side of the Moon. Even Israel, a country not immediately thought of when talking about space travel, had a failed landing attempt.

At the time of writing, NASA's Lunar Reconnaissance Orbiter (LRO) had just had its 10th anniversary, being launched on June 18, 2009. It was the first mission to the Moon by the USA since Lunar Prospector in 1998. Its high resolution mapping of the Moon's surface, both near and far sides, has been unprecedented. Before LRO, we had more detailed maps of Mars than we did of our only natural satellite. Spending most of its time in a 50 km high polar orbit, LRO has generated a 3D map of 98% of the Moon down to 100-metre resolution. The remaining 2% is mostly polar areas that are in constant darkness. LRO's high volume of data has been assisted by the Moon being close, having a dedicated tracking station, and therefore not relying on sharing NASA's Deep Space network. Some 3D images can be viewed online, all you need is a pair of standard red-green stereo glasses. In 2010 an LRO generated topographic map was released to the public.

In March 2013 a lunar impact flash was seen from Earth. LRO has since identified the crater that formed using 'temporal pairing', comparing more recent images to those initially taken. Any changes since 2010 have been called 'splotches' and believed to be related to lunar impacts. These are not just craters but also any changes to the surface or damage/fragments, related to a debris field. In March 2016 the imaging team had reported over 47,000 new splotches on the Moon!

A highlight was to locate and image, to a resolution of 0.5 to 2 metres/pixel, old Russian and NASA landers, including the Apollo sites. With Apollo not only were the descent stages, rovers and scientific instruments clearly visible but also their shadows. Even walking trails and the tracks left by the wheels of the rovers can be seen! So, a message for the Moon hoaxers, ether accept this or argue they are faked as well! This might also be hard for the flat-earthers to justify.

It is believed there are vast reserves of frozen water locked up in the permanently shadowed southern polar region, a valuable



orange of Mars will be very distinctive from the dusky white of Saturn. The Red Planet separates from Saturn and continues its journey across this constellation of the Sea Goat meeting up with the 24-day old waning crescent Moon for a conjunction on the 17th (see Sky View).

Jupiter rises before midnight in the eastern evening sky, although the best naked-eye views will be later in the morning with Mars and Saturn below this bright planet and the galactic centre high above the trio. On the 15th, the Last Quarter Moon and Jupiter will be close (see Sky View).

Rising around 1 am in Capricornus at the beginning of the month **Saturn** appears just 1° from Mars, before the faster moving Red Planet moves away. On the 16th, the 23-day old waning crescent Moon appears close to the Ringed Planet (see Sky View). On the 21st the planet is at a point in its orbit known as western quadrature, where the Sun-Earth-Saturn angle is 90° (see Orbital Aspects diagram p. 16). This means that as the Sun sets in the west, Saturn will be at its highest altitude in the sky.

Uranus is in conjunction with the Sun on the 26th and will not be observable until its reappearance in the morning eastern sky in late May.

Neptune appears in the morning eastern dawn sky after its conjunction with the Sun last month. This outermost planet and Mercury meet up on the 4th and 5th when they are less than 2° apart (see Mercury).

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto** rises in the late evening eastern sky in Sagittarius. It appears stationary on the 26th before beginning five months of retrograde motion. From the beginning of April to the 12th, Jupiter will be around 1° from this distant world.

At the end of April, **Astraea**, having now faded to 11th magnitude, passes across M44 the Beehive cluster, perhaps an imaging opportunity.

Brightest **Minor Planets** at opposition this month include:

Date	Minor Planet	Constellation	Mag.
2 Apr	216 Kleopatra	Virgo/Corvus border	12.1
2 Apr	3 Juno	Virgo	9.5
4 Apr	6 Hebe	Virgo	9.9
13 Apr	354 Eleonora	Boötes	10.1
13 Apr	65 Cybele	Virgo	11.0
17 Apr	89 Julia	Centaurus	11.0
23 Apr	40 Harmonia	Virgo	9.8
23 Apr	92 Undina	Virgo	11.5
24 Apr	23 Thalia	Virgo	10.0
26 Apr	24 Themis	Virgo	10.9
27 Apr	48 Doris	Virgo/Libra border	11.5

COMETS

Comet 88P/Howell continues its slow trek through the constellation of Virgo this month. Expected to brighten from 12th to 11th magnitude, the comet is visible throughout the night until just before dawn. It is now transiting (due north) in the late evening.

DOUBLE STARS

Gamma (γ) Volantis is located in the southern constellation of the Flying Fish (Volans), about 9° to the east of the Large Magellanic Cloud (All Sky Map 1). The star is a lovely bright wide binary. The brighter component (γ^2) magnitude 3.9 is a

resource for future human occupancy. Also launched with LRO was the Lunar Crater Observation and Sensing Satellite (LCROSS). This created two lunar impacts in the southern polar region crater Cabeus. Its mission was successful with the detection of water as it was thrown into space.

LRO is monitoring the radiation environment of the Moon which is vital for future human stays. The Cosmic Ray Telescope for the Effects of Radiation (CRaTER) experiment measures how the radiation interacts with a Tissue-Equivalent Plastic (TEP). CRaTER even detected cosmic rays daily with enough energy to go through the sides of the telescope. This was at an unanticipated level and will need to be taken into account when designing future lunar accommodation.

LRO has also contributed greatly to our geological knowledge of the Moon. More than 3,000 lobate scarps have been found. The distribution and orientation of these faults are believed to reflect the Moon's stretching/shrinking pattern created by gravitational tides between the Moon and the Earth.

Different minerals absorb and release energy with unique signatures. The Diviner Lunar Radiometer Experiment has produced high-resolution infrared maps revealing widespread lunar soils richer in sodium than those expected purely from the anorthosite crust. This may reveal variations in the chemistry and cooling rates of the magma oceans that created the early crust.

Although, LRO's initial mission was for only a year, this has been extended a number of times and the space probe is expected to remain active well into the 2020s, returning useful data on lunar resources and potential future landing sites.

The Cover Image—Earthrise over Compton Crater

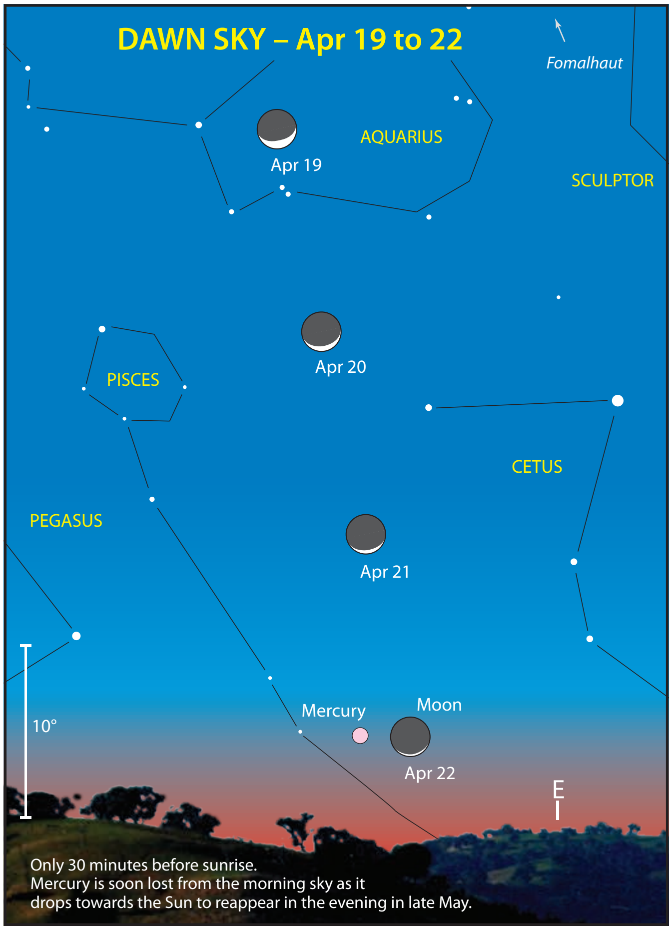
Taking an image of the Earth in the same frame as the Moon was not an easy task for LRO. It had to slew to its side as the probe shot over the surface at nearly two kilometres per second! At the time LRO was flying over the far side crater Compton at an altitude of 134 km. The Earth was near local noon centred over the Atlantic Ocean off the west coast of Africa. The parts of the Moon shown were close to the terminator, hence the long shadows visible, including those cast by the crater's central peak in the foreground. The dark band cutting off the bottom of the Earth is from the part of the Moon still in night. To get the high resolution (detail) in the image the Narrow Angle Camera (NAC) was used but this is black and white only. For the colour in the Earth the Wide-Angle Camera (WAC) was needed. However, the WAC resolution is 75 times lower than the NAC. So, while the lunar image needed only one NAC scan, something like 20 to 50 images were taken of the Earth through the WAC to improve the resolution and colour. The colour is only approximate having to combined images taken through narrow band filters. Another aspect of the heavy image processing needed was to balance the Earth's intense *beacon* compared to the still faintly illuminated, morning lunar surface.

pale-yellow star (spectral type KOIII) whilst the companion (γ^1), magnitude 5.4, is a bluish star (spectral type F2V). The stars are separated by 14 arcseconds with a position angle of 296°. The pair is a splendid sight in small telescopes. The orbital period is at least 7,500 years and the system is located approximately 142 light-years from Earth.

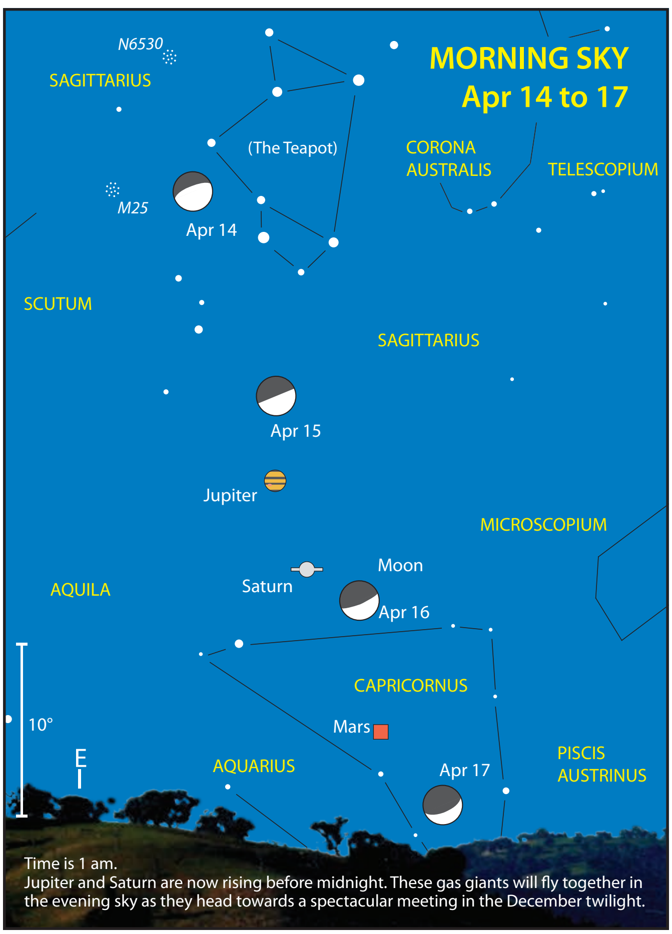
METEOR SHOWERS

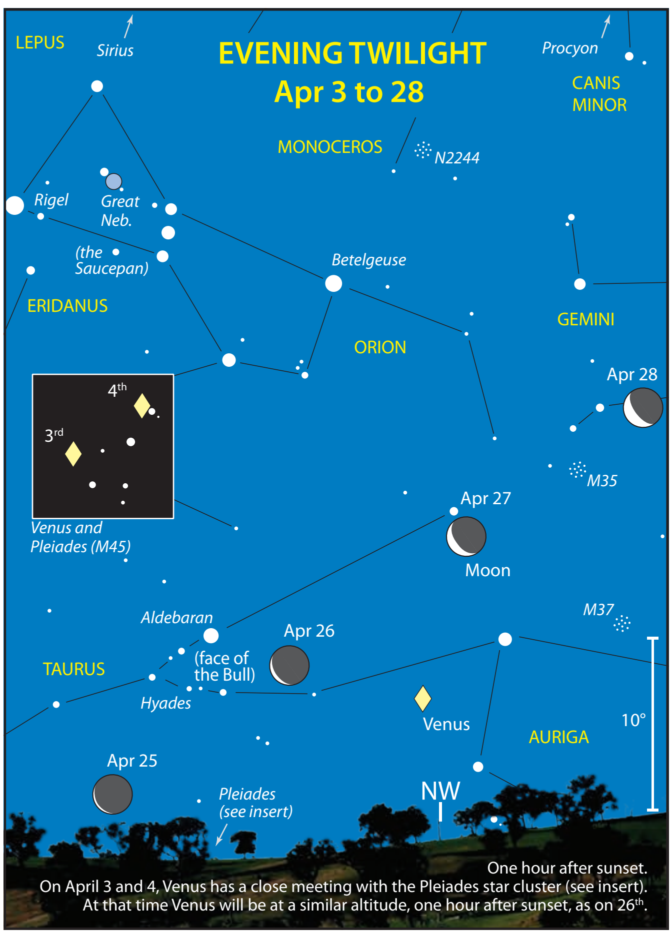
The **Lyrids** are best viewed from the Northern Hemisphere, but they are visible south of the equator. They are best seen well past midnight in the Southern Hemisphere from the 14th to the 30th, with maximum predicted on the 22nd. Maximum rates may only last an hour or so, and typically, the zenith 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. In 1982, American observers noticed a short peak of 90 per hour. Conditions are perfect this year with New Moon on the 23rd.

The **pi-Puppids** are a young southern shower first observed in 1972 and produced by Comet 26P/Grigg-Skjellerup. Best seen from the 15th to the 28th, with maximum activity on the 23rd. Leading up to and after maximum the rates are low and difficult to separate from sporadic meteors. The peak can vary greatly in intensity, sometimes nil, occasionally three to four per hour or more (40 in 1977 and 1982, 13 in 1983). The pi-Puppids are noted for their very slow speed, brightness, persistent trains, large proportion of yellow meteors and occasional fireballs. Conditions are excellent this year with New Moon on the 23rd. They are best seen prior to local midnight, before the radiant becomes too low.



Approximate local standard time.





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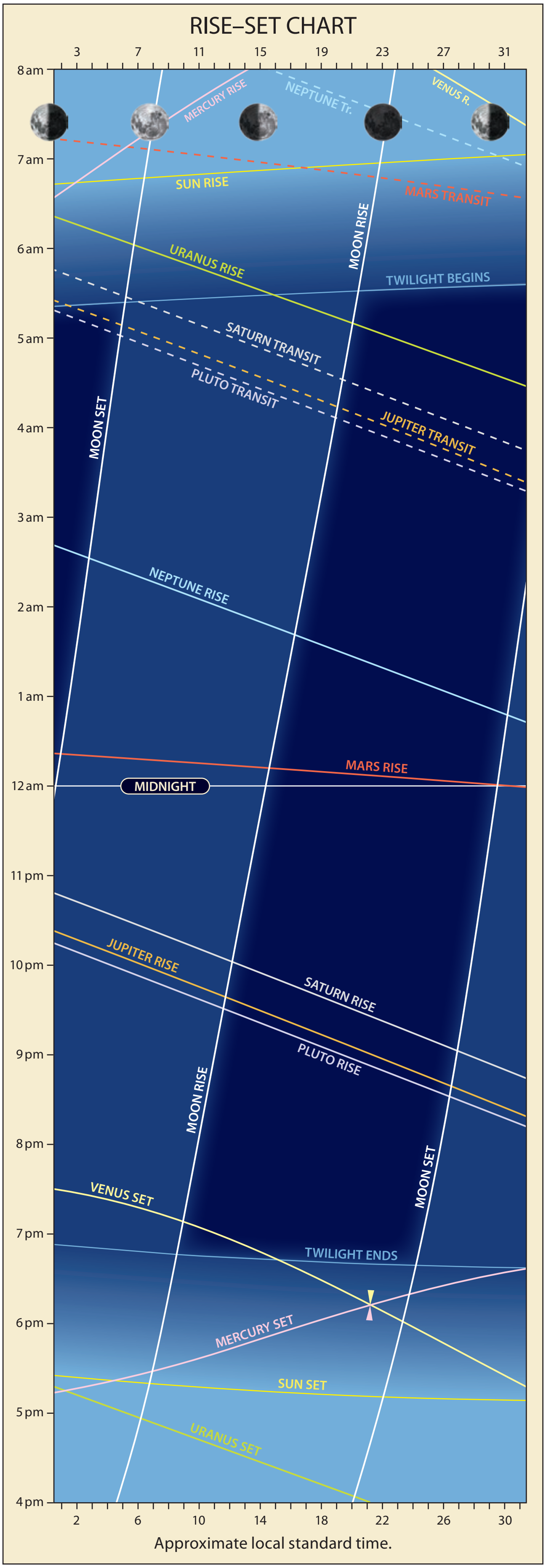


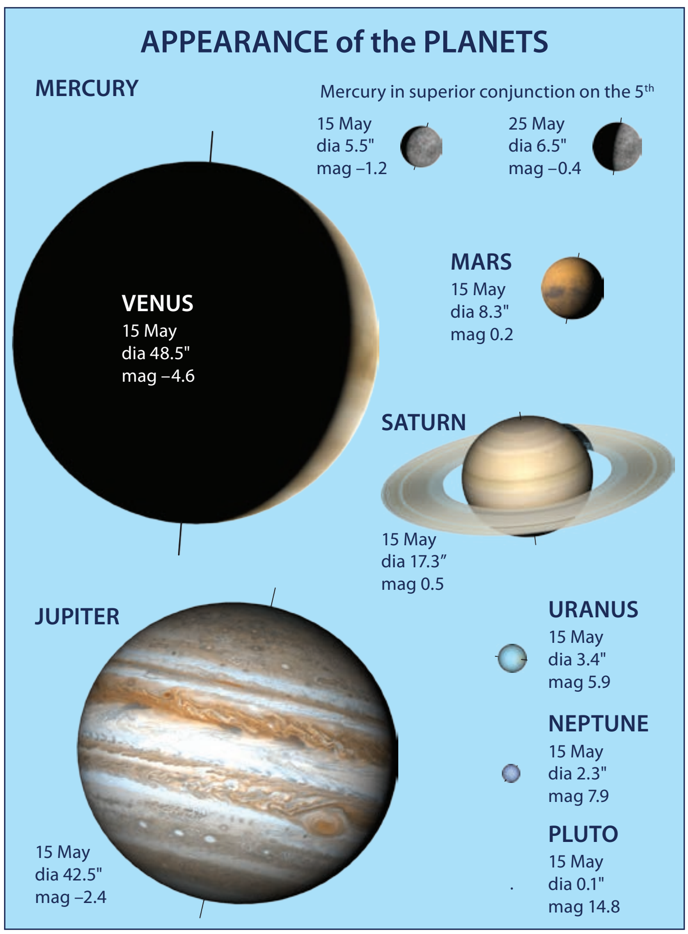
HIGHLIGHT

- Mercury and Venus close.
- Mercury, Venus and Moon close.
- Mars and Moon together.
- Jupiter, Saturn and Moon, an impressive meeting!

CONSTELLATIONS

Between Leo and Boötes lies the almost indistinguishable constellation of Coma Berenices. The history of its mythology is centred on the constellation's most prominent deep sky object, the bright open star cluster, Melotte 111. It's something Coma Berenices has in common with Cancer the Crab, the most distinguishing feature being an open star cluster. In the case of Cancer it is the Beehive Cluster (M44).

Returning to Mel 111, being visible to the unaided eye this hazy patch was referred to by Ptolemy as a lock of hair but was not included as a constellation in his original 48 in the Almagest. At the time this fuzzy area was considered part of Leo the Lion. Over the centuries there were various owners of this celestial hairpiece. Caspar Vopel in 1536 created a celestial globe where this area had grown into a separate constellation. Today, Coma Berenices (Latin for Berenice's Hair) is a nod to Queen Berenice II of Egypt (3rd century BCE) who *gave* her hair to the goddess Aphrodite by placing it in her temple, hoping to secure her husband King Ptolemy III's safe return from battle. The hair apparently disappeared, with the court astronomer claiming to have found it in the heavens, the star cluster with the somewhat less romantic name of Mel 111.



The Coma/Virgo Supercluster of Galaxies Part 1

In the autumn evening sky, low in the north, lies the Coma/Virgo Supercluster of Galaxies, the largest gathering of galaxies easily accessible to amateurs. It is estimated to have around two thousand members. Even our local galaxy group, which includes the Milky Way, is a member (on its fringe). It is a sobering thought that superclusters, best described as gatherings of smaller clusters, on the grandest scale of the Universe are considered normal. We are fortunate that the core of the closest example is well displayed, lying outside the plane of the Milky Way and hence away from 'local' obscuring dust and gas.

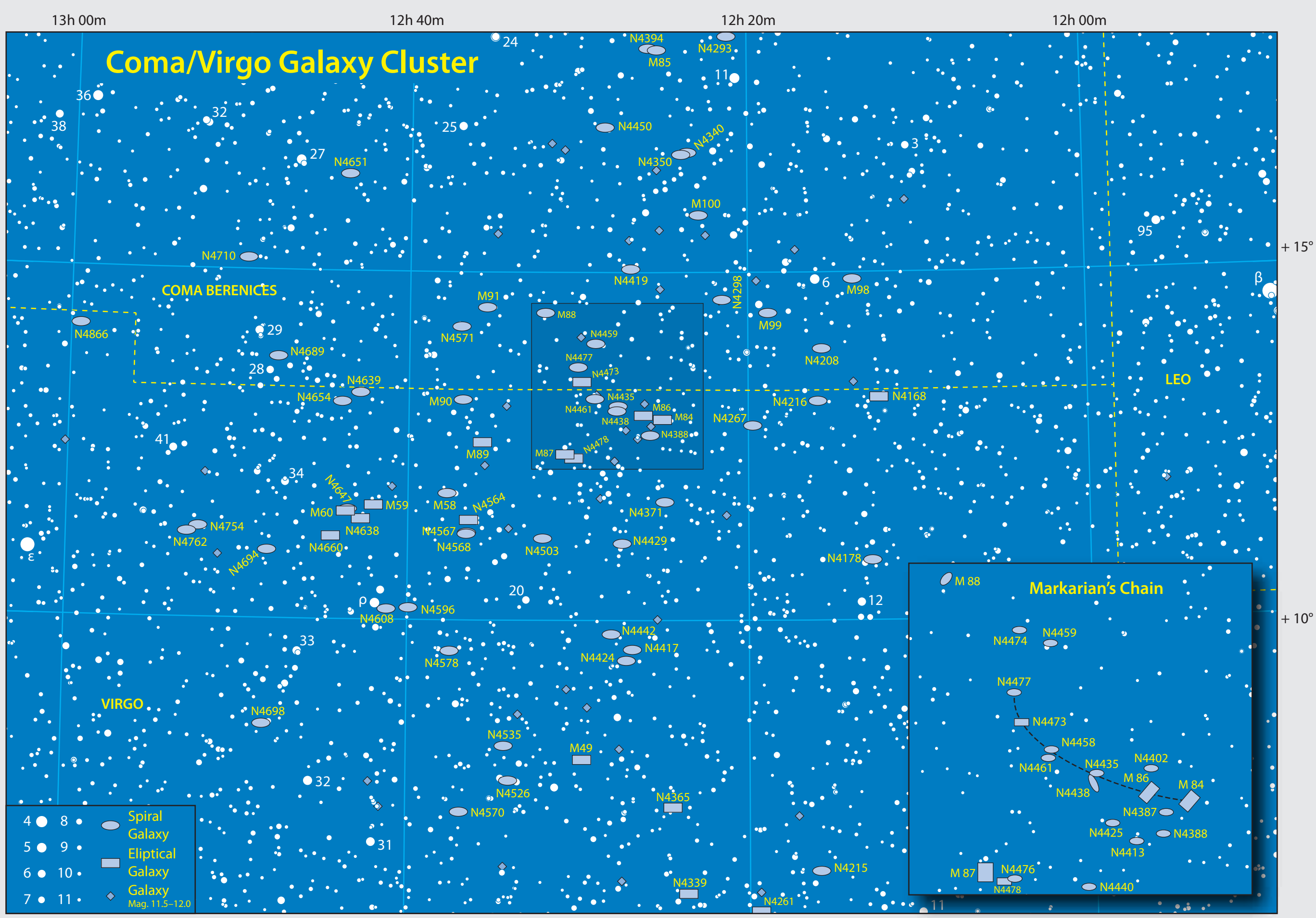
The bulk of this supercluster lies in the direction of the constellations of Virgo and Coma Berenices. It has a central oval-shaped concentration, which straddles these two, measuring approximately 15 degrees (running north-south) by 10 degrees wide, located between the stars of Denebola (Beta Leonis) and Vindemiatrix (Epsilon Virginis). However, being so relatively close, the Coma/Virgo cluster has galaxies as far away as Centaurus, Canes Venatici and Ursa Major. The compact centre is certainly a hidden treasure, as the naked-eye sees only a blank sky with a scattering of faint stars.

Charles Messier's Contribution

Charles Messier was a French comet hunter of the 18th century. Although he found 13 comets, he is best remembered for the list of deep sky objects that he and his associate Pierre Mechain compiled. Today, 110 Messiers are recognised. The original purpose of the catalogue was to identify fixed deep sky objects that might be mistaken for comets. However, with the quality of today's optics even the smallest telescope easily reveals the true nature of most of the Messier open and globular star clusters. It's the hazy galaxies that remain as potential false comets. Anyone looking for comets in Virgo had better be patient to wait and see if it moves, for identifying a new faint fuzzy amongst all the other fixed fuzzies is challenging!

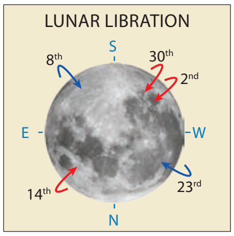
Binocular Observations shouldn't be Dismissed!

Messier used only a 100 mm (4 inch) refractor and despite this lack of aperture, sixteen of this supercluster's brightest members still made the cut. He did amateur observers a great favour by short-listing the best. The majority of Messier galaxies in this group are even visible through binoculars under dark, moonless skies (they are marked on All Sky Maps 6 and 7). To be realistic, binoculars only ever show members of this group as very small, featureless fuzzies. Using the word 'fuzzies' seems so demeaning considering the billions of stars that make up these deep space juggernauts. Being so diminutive in binoculars they can be easily missed or mistaken for faint stars, however, the low magnification results in an apparent higher surface brightness making them easier to see. Also, having a few visible in the same wide field of binoculars helps in identifying the galaxies. While still talking binocular targets, the northern and southern limits of the main group are approximately marked by M85 and M61 (not shown on chart below) respectively. However, there are



Here's a tale of two crowns. The semicircle of faint stars between Boötes and Hercules is called Corona Borealis for Northern Crown. Traditional depictions show a typical royal jewel-encrusted crown supposedly made of gold worn by Princess Ariadne, daughter of King Minos of Crete, when she married the god Dionysus. In the south lies its counterpart, Corona Australis or Southern Crown. It is a similar semicircle of faint stars below the Teapot of Sagittarius. This crown's traditional visualisation is very different from its northern cousin, being more a wreath of intertwined branches, reminiscent of ancient Roman head wear. It most likely relates to the Sagittarius myth, with a wreath having fallen off his head and now lying at the feet of this centaur.

THE MOON



1st 7 am (5 am WST) First Quarter.

2nd 4 am (2 am WST) Maximum Libration (8.3°), dark SW limb.

6th 1 pm (11 am WST) Moon at perigee (closest to Earth at 359,654 km).

7th 9 pm (7 pm WST) Full Moon, Supermoon (see table p. 97).

8th 3 am (1 am WST) Minimum Libration (5.3°), Full Moon.

significant outlying members, such as the famous Sombrero Galaxy M104 which lies on the northern border of Virgo with Corvus (11° west from the star Spica). As an aside, the Sombrero is a true amateur telescopic gem which should not be missed. With its prominent dark equatorial band it looks similar to its photographic images.

Although scattered members continue low into the north, from Australia they can become a challenge. The large open star cluster Mel 111 lives up to its expectation as ideal for binoculars. However, trying to observe the Needle Galaxy (NGC 4565), another supposed binocular target (only 3° east of Mel 111) is difficult. Although poor seeing isn't necessarily a problem for observing extended objects (like galaxies), the closer to the horizon the more extinction is caused by the thickening atmosphere and sky glow becomes a problem.

A Telescopic Feast!

A moderately sized telescope reveals hundreds of galaxies. These brighter members are mostly spiral or elliptical type galaxies, with the majority of the cluster consisting of faint dwarf and irregular types. There is insufficient space to delve into descriptions of individual galaxies, but here are the features worth looking for when observing. Broadly speaking there are three main regions; the outermost zone or halo, a nebulous brighter central area called the core, and the innermost nucleus. Not all may be present, for example the ellipticals resemble unresolved globular star clusters, including being mostly spherical—appearing round. Like globulars these galaxies can have a faint outer halo region which gradually brightens as you get closer to the centre, so where a halo starts and a core begins is sometimes difficult to determine. Also, like globulars, they can have distinctive cores, some brighter or broader than others. The spirals are more likely to differentiate these regions. They may or may not have a distinctive nucleus and when present they can be so compact to be described as stellar or star-like. The core is generally the most obvious feature, being composed of the hub or even bars, as with barred spirals. Finally, there is the generally faintest component, the outer halo, the ghostly image of the arms. Being flattened discs, a spiral's appearance is greatly affected by how much they are tilted from our perspective. The more tilt the more oval. The gems are the rarer totally edge-on examples where sometimes, equatorial dark bands can be seen bisecting the long axis. This is often a feature amongst spirals—look at how our edge-on view of the Milky Way is disrupted by its complex of dark dust and gas lanes. The Needle Galaxy (earlier) is another famous example.

The remainder of this article will concentrate on the centre of the cluster. Located approximately 10° east of Denebola, this is a truly extraordinary collection of closely packed, bright galaxies within only a few degrees of sky (see chart opposite). A good starting point is the remarkable collection Markarian's Chain—eight galaxies arranged in an arc just 1.5° long. The western end is comprised of the impressive, bright pair of elliptical galaxies M84 and M86. Returning to the discussion above about the features of different types, compare these ellipticals with the nearby edge-on spiral galaxy, NGC 4388. These three form the corners of an equilateral triangle, and being separated by only 17 arcminutes, fit in the same telescopic field of view—magic! Heading eastward, next up is the distinctive close pair of galaxies called the 'eyes'. This is followed by another duo NGC 4461 and 4458. Moving north-east you'll cross the border into Coma Berenices to NGC 4473 and onto the final link in the chain NGC 4477. These objects are so close together it is a pleasure to *galaxy hop* between them and then onto the surrounding fuzzies.

Continued in Part 2, page 55.

Western end of Markarian's chain. Note, the three galaxies in a triangle on the right, M86, M84 and NGC 4388. Credit Joe Cauchi

14th 4 pm (2 pm WST) Maximum Libration (7.8°), dark NE limb.

14th Midnight (10 pm WST) Last Quarter.

18th 6 pm (4 pm WST) Moon at apogee (furthest from Earth at 405,583 km).

23rd 4 am (2 am WST) New Moon.

23rd 3 pm (1 pm WST) Minimum Libration (5.0°), too close to New Moon.

30th 8 am (6 am WST) Maximum Libration (7.8°), dark SW limb.

30th 2 pm (noon WST) First Quarter.

THE PLANETS

Mercury will be in superior conjunction (Mercury and Earth on opposite sides of the Sun) on the 5th and thereafter returns to the western evening twilight. Although unobservable, it is interesting to note that at this conjunction Mercury is occulted by the Sun's disc. Typically, the ratio of occultations of Mercury by the Sun verses transits of the planet across the face of the Sun is around 2:1.

On the 22nd, Mercury will be just 1° south of Venus. At the end of civil twilight, the altitude of the duo will be around 5° so a low horizon is needed, and binoculars will greatly assist in locating these inner planets. On the 24th, another binocular challenge, this time with Mercury, Venus and the Moon. The three bodies form a triangle fitting into a 4° circle, again you will need a reasonable horizon and begin sweeping at the end of civil twilight. The Moon will be a slender crescent just 1.5 days old (see Sky View).

We lose **Venus** from the evening sky toward the end of this month as it approaches inferior conjunction (between the Earth and Sun) in early June. On the 22nd, Venus and Mercury will be within 1° of each other and on the 24th the young waning crescent Moon joins the pair (see Sky View). Binoculars will assist in the twilight sky.

Rising just after midnight **Mars** spends the first third of May in Capricornus before moving into Aquarius. On the 15th and 16th, the planet will be close to the waning crescent Moon (see Sky View). Although just eight arcseconds in diameter this month, observers of the Red Planet may notice that the south polar cap has begun to shrink.

Jupiter reaches an apparent stationary point in its orbit on the 15th, marking the beginning of four months in retrograde motion, when the planet moves from east to west across the sky (see Retrograde Motion p. 96). Rising in the late eastern evening sky in Sagittarius, the King of Planets remains within 5° of Saturn throughout the month. On the 12th, the 20-day old waning gibbous Moon appears close to the planet and forms a neat triangle with Saturn as they rise (see Sky View).

Rising in the mid-evening eastern sky in Capricornus, **Saturn** begins 4.5 months of retrograde motion on the 11th. On the 12th, the 20-day old waning gibbous Moon forms a triangle with Saturn and Jupiter (see Sky View).

Uranus returns to the eastern dawn sky this month after its conjunction with the Sun in April.

Neptune, in Aquarius, is only visible in the morning eastern sky, rising around 1:30 am midmonth.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto**, in Sagittarius, rises around 9 pm midmonth in the eastern evening sky.

Brightest **Minor Planets** at opposition this month include:

Date	Minor Planet	Constellation	Mag.
12 May	349 Dembowska	Libra	10.2
16 May	270 Anahita	Libra	11.0
23 May	42 Isis	Libra/Scorpius border	10.0
24 May	451 Patientia	Scorpius	11.3
28 May	654 Zelinda	Scorpius/Lupus border	11.7

DIARY

Fri	1st	6:38 am	(4:38 am WST) First Quarter Moon
Sat	2nd	1 pm	(11 am WST) star Regulus 4° S of Moon
Sun	3rd	11 pm	(9 pm WST) m.p. 40 Harmonia 0.15°N of NGC 5427 (G) in Virgo
Mon	4th		Mars 1.0°NW of star Delta Capricorni
Mon	4th	pm	m.p. 6 Hebe 0.4°S of NGC 4866 (G) in Virgo
Tue	5th		Mercury at ascending node
Tue	5th	7 am	(5 am WST) m.p. 3 Juno 4° N of Moon
Tue	5th	8 am	(6 am WST) Mercury in superior conjunction
Tue	5th	pm	Comet 88P/Howell 0.2°S of NGC 4753 (G) in Virgo
Wed	6th	3 am	(1 am WST) star Spica 7° S of Moon
Wed	6th	1 pm	(11 am WST) Moon at perigee, 359,654 km
Thu	7th	8:45 pm	(6:45 pm WST) Full Moon (361,183 km)
Sat	9th		m.p. 2 Pallas 0.5°W of star Alpha Sagittae
Sat	9th	8 am	(6 am WST) star Antares 6° S of Moon
Sun	10th		Mercury at perihelion
Mon	11th		Venus 1.4°SW of star Beta Tauri
Mon	11th		m.p. 2 Pallas stationary
Mon	11th	7 pm	(5 pm WST) Saturn stationary
Tue	12th		Mars 0.2°N of star Iota Aquarii
Tue	12th	4 pm	(2 pm WST) d.p. Pluto 1.5° N of Moon
Tue	12th	8 pm	(6 pm WST) Jupiter 2° N of Moon
Wed	13th	4 am	(2 am WST) Saturn 3° N of Moon
Wed	13th	8 pm	(6 pm WST) Venus stationary
Thu	14th	pm	Comet 88P/Howell 0.7°S of NGC 4666 (G) in Virgo
Fri	15th	12:03 am	(10:03 pm WST, prev day) Last Quarter Moon
Fri	15th	3 am	(1 am WST) m.p. 4 Vesta 5° S of Venus
Fri	15th	4 am	(2 am WST) Jupiter stationary
Fri	15th	Noon	(10 am WST) Mars 3° N of Moon
Sat	16th	2 am	(Midnight WST, prev day) d.p. Ceres 4° S of Moon
Sat	16th	pm	m.p. 27 Euterpe 0.4°NE of star Sigma Leonis
Sun	17th	1 am	(11 pm WST, prev day) Neptune 4° N of Moon
Sun	17th	7 pm	(5 pm WST) star Aldebaran 7° S of Mercury
Mon	18th	6 pm	(4 pm WST) Moon at apogee, 405,583 km
Wed	20th		Mercury at greatest latitude north
Wed	20th	pm	Comet 88P/Howell 0.2°N of star Gamma Virginis
Thu	21st	2 am	(Midnight WST, prev day) Uranus 4° N of Moon
Fri	22nd	6 pm	(4 pm WST) Venus 1° N of Mercury
Sat	23rd	3:39 am	(1:39 am WST) New Moon
Sun	24th	1 pm	(11 am WST) Venus 4° N of Moon
Sun	24th	9 pm	(7 pm WST) Mercury 3° N of Moon
Mon	25th	1 am	(11 pm WST, prev day) m.p. 4 Vesta 0.5° S of Moon
Tue	26th	4 pm	(2 pm WST) m.p. 4 Vesta 3° S of Mercury
Wed	27th		m.p. 3 Juno stationary
Wed	27th	6 am	(4 am WST) star Pollux 5° N of Moon
Thu	28th	pm	m.p. 6 Hebe 0.8°SE of NGC 4689 (G) in Coma Berenices
Fri	29th	7 pm	(5 pm WST) star Regulus 4° S of Moon
Sat	30th		Mercury 1.2°N of M35 (OC) in Gemini
Sat	30th	1:30 pm	(11:30 am WST) First Quarter Moon

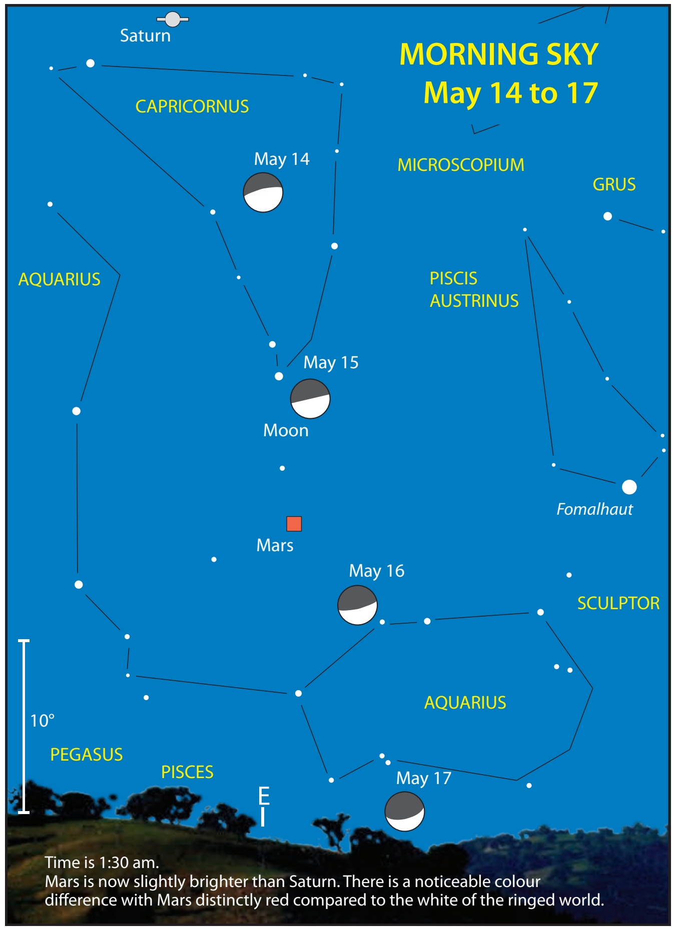
COMETS

Comet 88P/Howell makes its closest approach to Earth during this year's apparition, at a distant 1.08 au. Opening the month at 11th magnitude, the comet is in the constellation of Virgo throughout all of May, visible during the night until just after midnight. By month's end, it could be 10th magnitude. Howell is having a busy return with May and June seeing a tour of a number of galaxies in Virgo. From 13 May to 8 June the comet is within 1° of the 3rd magnitude star, Gamma (γ) Virginis.

Comet 249P/LINEAR is predicted to brighten to 12th magnitude during May. At month's end the comet is in the north-west evening sky at the end of twilight on the border of Cancer and Gemini.

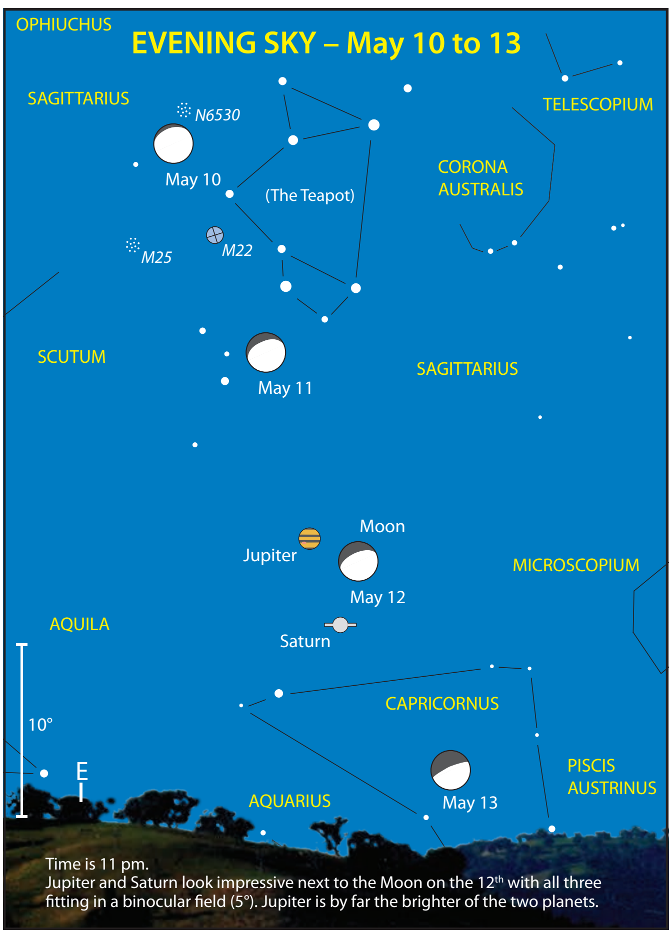
DOUBLE STARS

N Hydrae is an impressive double (All Sky Map 4), situated between Corvus and Antlia, just north of magnitude 3.5 Xi Hydrae, itself a wide unequal double, magnitudes 3.5 and 10.7, separation 68 arcseconds. N Hydrae's nearly matched stars, magnitudes 5.7 and 5.6 (both spectral class F8V) are separated by 9.7 arcseconds with a position angle of 211°. Any small telescope will show the components.

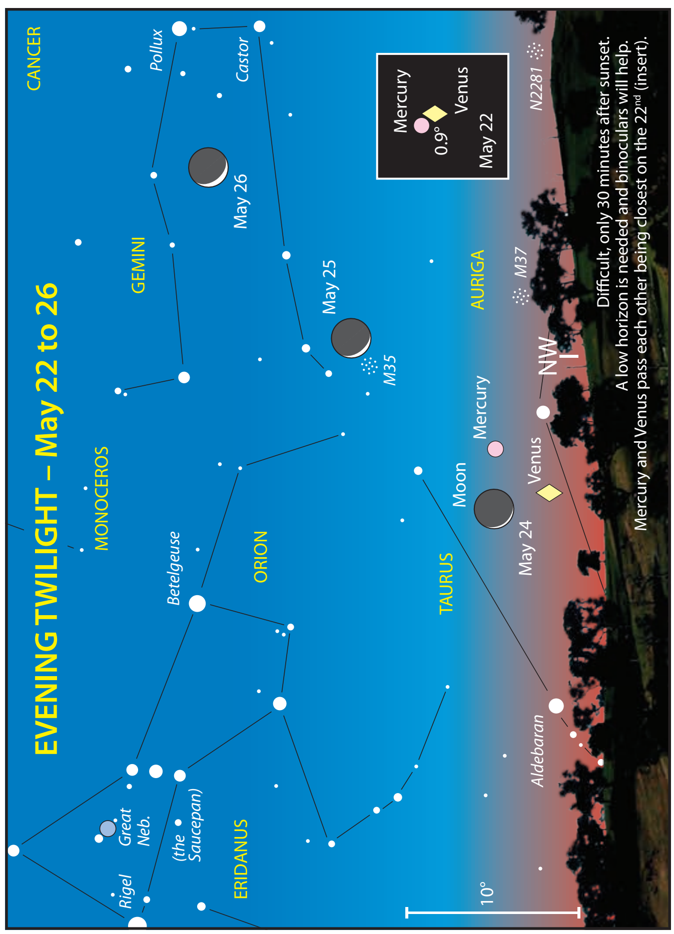


Time is 1:30 am.
Mars is now slightly brighter than Saturn. There is a noticeable colour difference with Mars distinctly red compared to the white of the ringed world.

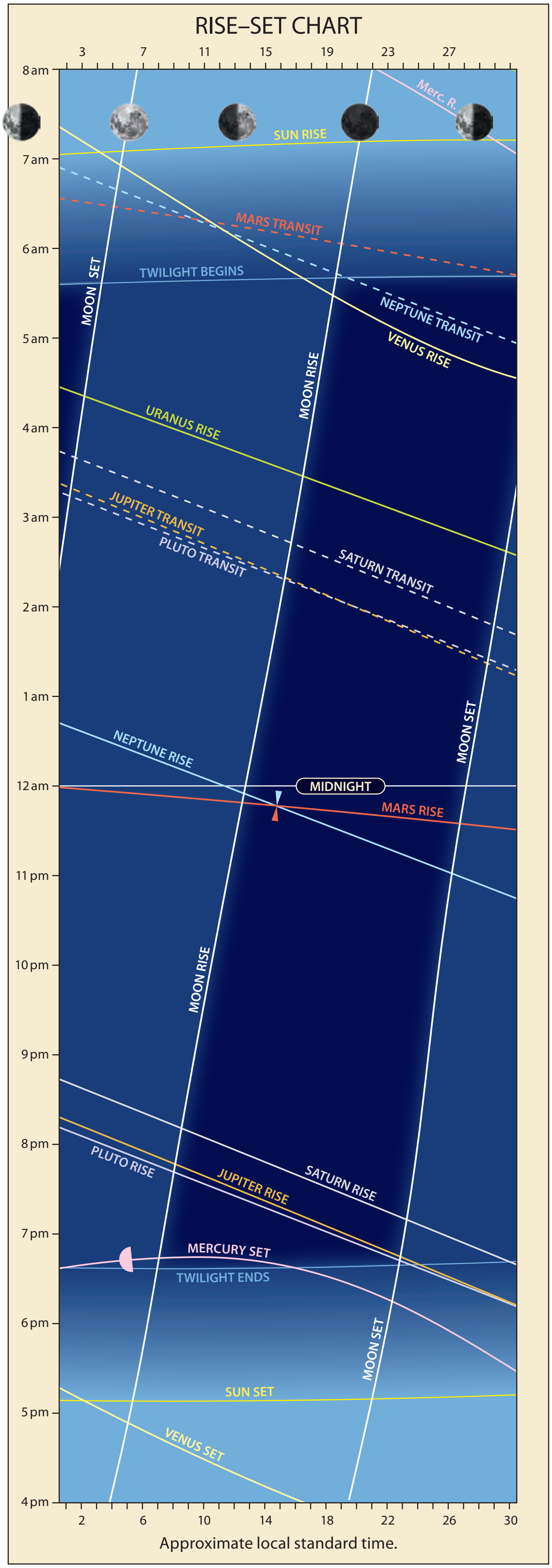
Approximate local standard time.



Time is 11 pm.
Jupiter and Saturn look impressive next to the Moon on the 12th with all three fitting in a binocular field (5°). Jupiter is by far the brighter of the two planets.



JUNE 2020



HIGHLIGHTS

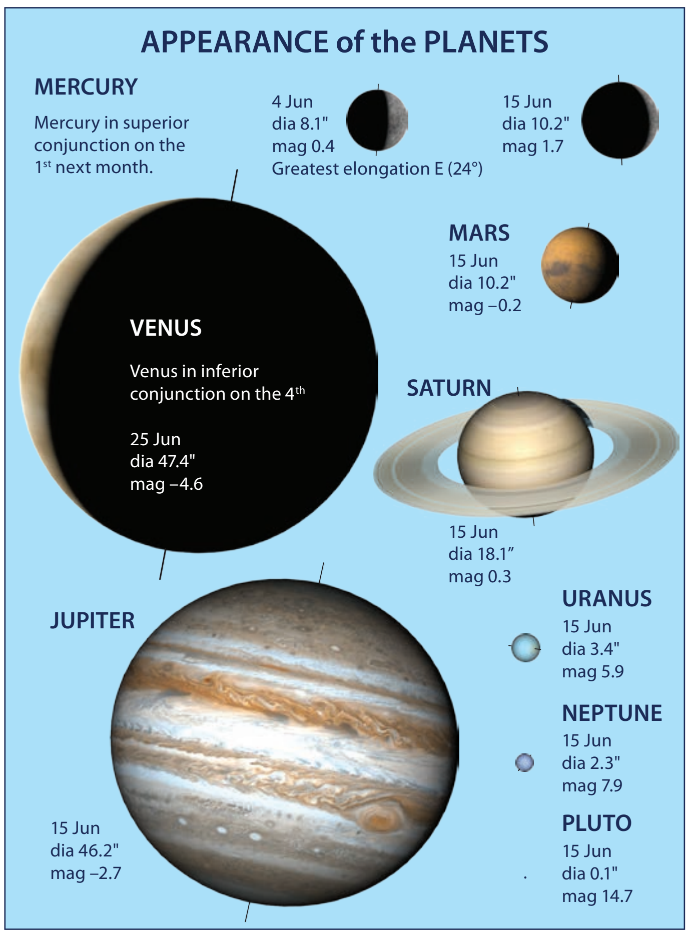
- Venus and Moon close.
- Mars and Moon close.
- Mars and Neptune close.
- Jupiter, Saturn and Moon together.

CONSTELLATIONS

This month, a rest from mythology to contrast two very different stars, both bright and isolated in the northern evening sky this time of year. High in the north-west is the only bright member of the constellation of Virgo, the 15th brightest star in the night sky, Spica (Alpha Virginis). The other is closer to the horizon and the 4th brightest, the alpha star to Boötes, Arcturus. Even the unaided eye can detect a difference, Spica is quite blue, where Arcturus is orange-yellow—but this is just the tip of the iceberg!

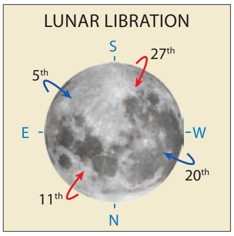
Spica has an apparent magnitude of 1.0 and is located 260 light-years distant. It is a binary star consisting of two very hot components with spectral classes of B1 III and B2 V, with temperatures of 22,400 K and 18,500 K respectively. Now it gets interesting. The stars orbit each other in only four days and are separated by 0.12 au. Their closeness causes gravitational distortions with each pulling the other out of shape (from the normal expected sphere). Spica is slightly variable, with a range of only 0.92 to 1.04 magnitudes. This is thought to be due to the pair periodically presenting different diameters as they orbit. Spica is considered the brightest rotating ellipsoidal variable in the sky.

Arcturus has an apparent magnitude of 0.15 and is located only 36 light-years away. Its closeness is the only reason it outshines Spica, for Arcturus has an absolute magnitude of



only –0.1 compared to Spica's –3.5. Arcturus is considerably cooler (4,300 K, a spectral class K1.5 III) and although only 1.5 times the mass of the Sun, its diameter is 26× larger! This is accurately known because its size coupled with its closeness makes it possible to directly measure it, 0.021 arcseconds. The star is the closest giant star to the Sun.

THE MOON



- 3rd 2 pm (noon WST) Moon at perigee (closest to Earth at 364,366 km).
- 5th 12 pm (10 am WST) Minimum Libration (4.3°), bright SE limb.
- 6th 5 am (3 am WST) Full Moon. Penumbral eclipse visible from Australia (see Part II for details).
- 11th Midnight (10 pm WST) Maximum Libration (7.7°), dark NE limb.
- 13th 4 pm (2 pm WST) Last Quarter.
- 15th 11 am (9 am WST) Moon at apogee (furthest from Earth at 404,595 km).
- 20th 9 am (7 am WST) Minimum Libration (4.8°), too close to New Moon.
- 21st 5 pm (3 pm WST) New Moon. Annular eclipse of the Sun, not visible from Australia (see Part II for details).
- 27th 3 am (1 am WST) Maximum Libration (7.2°), dark SW limb.
- 28th 6 pm (4 pm WST) First Quarter.
- 30th Noon (10 am WST) Moon at perigee (closest to Earth at 368,958 km).

THE PLANETS

Mercury, in the western evening twilight, spends the month wandering through the constellation of the Twins, Castor and Pollux. Interestingly, Gemini (Latin for twins) is one of the few constellations that actually looks like its namesake, although the pair of stick-like figures are lost in the twilight at this time. Mercury reaches its greatest elongation 24° east of the Sun on the 4th and then begins its descent back toward the Sun and inferior conjunction on 1 July. As Mercury prepares to leave the evening sky, it has a visitor, the thin crescent (1-day old) Moon. Both are deep in the twilight glare so a low horizon is needed and binoculars will help.

Venus reappears in the midmonth morning sky after undergoing inferior conjunction (between the Earth and Sun) on the 4th and remains close to the rising Hyades star cluster in Taurus until mid-July. On the 15th, Venus comes close to Taurus temporarily giving the Bull a second eye to complement Aldebaran. Venus can be seen with the 27-day old waning crescent Moon nearby on the 19th (see Sky View).

The **Earth** is at Solstice on the 21st when our daylight hours in the Southern Hemisphere are shortest. On this day, the Sun is at its most northerly position with a declination of +23.4°.

On the 7th **Mars** will be at its western quadrature, where the Sun-Earth-Mars angle is 90° (see Orbital Aspects diagram p. 16). At this time, Mars displays its minimum phase with 84% of the planet's surface illuminated by the Sun when viewed from Earth. Even a small telescope will show the disc to be distinctly gibbous in shape—just like the Moon three or four days before or after Full Moon. In the 17th century, Galileo was first to note the odd shape of the planet in those early pioneering days of the telescope. Rising around midnight, the Martian disc reaches 11 arcseconds in diameter this month and observers who began observations earlier in the year will note the south polar cap is shrinking. From the 12th to 16th Mars and Neptune will be 2° or less apart (closest at 1.6° on the 14th). Binoculars will be required to spot Neptune near Mars, although a telescope will be necessary to show colour in the contrasty pair of red and blue planets well. On the 13th, the Last Quarter (22-day old) Moon appears near Mars (see Sky View).

Jupiter will be at opposition next month and appears brilliant at –2.7 magnitude as it rises in the early evening sky in Sagittarius. On the 8th, the 18-day old waning gibbous Moon appears near the planet (see Sky View). Even the smallest of telescopes will show detail on the planet and the fascinating Galilean satellites as they shuttle 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 as a moon is silhouetted by Jupiter and observe the shadow of a moon as it is projected onto the cloud tops (for the next two months, July and August, we present some special Sky View diagrams showing interesting moon configurations during the month. Also see Part II for moon events).

Rising around 8 pm midmonth, **Saturn** spends all of June in Capricornus before crossing into Sagittarius early in July. The planet's rings are a major point of interest for most observers and since they were at their widest in 2017 with a tilt of 27° (to Earth) they have been gradually closing. This year begins with a ring tilt angle of 24°, it then narrows to 20° mid-year and reopens to 21° in December. The Earth next passes through the ring plane in March 2025 to begin another 15-year cycle. The late evening views of Saturn and Jupiter in the eastern sky are pleasing with the pair just 6° apart. On the 8th and 9th, the waning gibbous Moon adds to the scene (see Sky View).

Uranus, in Aries, is only visible in the eastern morning sky, rising around 3:30 am midmonth.

Neptune appears stationary on the 24th, and then begins to move in retrograde until late November. Rising a little before midnight, the planet has an encounter with Mars between the 12th and the 16th (see Mars).

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto**, in Sagittarius, rises around 7 pm midmonth in the eastern evening sky. From the 20th to month's end, Jupiter, in retrograde, will be within 1° of Pluto. Starting the end of June, minor planet **Herculina** takes a slow tour of Sagittarius for the next five months, visiting a number of deep sky objects and bright stars.

Brightest **Minor Planets** at opposition this month include:

Date	Minor Planet	Constellation	Mag.
4 Jun	372 Palma	Norma	13.4
5 Jun	31 Euphrosyne	Norma/Ara border	12.4
12 Jun	85 Io	Ophiuchus	10.7
22 Jun	64 Angelina	Sagittarius	11.5
28 Jun	7 Iris	Sagittarius	8.8

COMETS

Comet 2P/Encke reaches perihelion this month on the 26th at a distance of 0.34 au from the Sun. Its approach to the Sun has not been favourable for observing, but careful observers may catch the comet at 8th magnitude in evening twilight skies in the last week of June (if you can see Pollux, look to its left to upper left approximately 8° to 10° away) as it straddles the border of the constellations of Gemini and Cancer.

Comet 88P/Howell is slowly moving westward through the constellation of Virgo. Predicted to be around 10th magnitude in brightness, the comet is an evening target, transiting around the end of twilight and setting shortly after midnight. For the first week of June Howell is within 1° of Gamma Virginis.

June opens with **Comet 249P/LINEAR** at 12th magnitude in the constellation of Gemini, low in the evening sky. It is lost from view early in the month as the comet sinks into the solar glare. LINEAR reaches perihelion on the 29th.

Comet C/2017 T2 (PANSTARRS) will become visible for most observers in Australia in the last two weeks of June as it moves south following its perihelion passage in May. Perhaps shining at 7th magnitude, PANSTARRS is low in the northern evening sky, in the constellation of Canes Venatici, setting mid-evening. It is best to observe as soon as possible after twilight. In the latter half of the month, the comet has some nice conjunctions with galaxies in Ursa Major and Canes Venatici. This is best seen from northern Australia.

DOUBLE STARS

Eta (η) Lupi or RMK 21 is located in the southern constellation of Lupus the Wolf (All Sky Map No 6), 441 light-years from the Sun. The star is an unequal multiple star system and is part of the Upper Centaurus-Lupus grouping of stars born at roughly the same time. The white A component (magnitude 3.4) is a class B2.5IV young dwarf with a luminosity 4,570 times that of the Sun. The B component

DIARY			
Mon	1st	1 pm	(11 am WST) m.p. 3 Juno 4° N of Moon
Tue	2nd	Noon	(10 am WST) star Spica 7° S of Moon
Wed	3rd	2 pm	(Noon WST) Moon at perigee, 364,366 km
Thu	4th	4 am	(2 am WST) Venus in inferior conjunction
Thu	4th	11 pm	(9 pm WST) Mercury at greatest elongation East (23.6°)
Fri	5th		Comet C/2017 T2 (PANSTARRS) 1.2°E of star Alpha Ursae Majoris
Fri	5th		Comet 249P/LINEAR 0.3°S of NGC 2392 (PN) in Gemini
Fri	5th		Venus at descending node
Fri	5th	8 pm	(6 pm WST) star Antares 7° S of Moon
Sat	6th		Mercury 1.0°SW of star Epsilon Geminorum
Sat	6th	5:12 am	(3:12 am WST) Full Moon (369,005 km)
Sun	7th		Comet 249P/LINEAR 0.7°W of star Delta Geminorum
Mon	8th		Comet C/2017 T2 (PANSTARRS) 0.6°NE of NGC 3542 (G) in Ursa Major
Tue	9th	1 am	(11 pm WST, prev day) d.p. Pluto 1.5° N of Moon
Tue	9th	3 am	(1 am WST) Jupiter 2° N of Moon
Tue	9th	Noon	(10 am WST) Saturn 3° N of Moon
Wed	10th		Mercury 1.0°SW of Comet 249P/LINEAR
Fri	12th		Comet 249P/LINEAR 0.1°SW of star Epsilon Geminorum
Fri	12th		Mercury at descending node
Fri	12th	10 pm	(8 pm WST) Neptune 1.5° N of Mars
Sat	13th	9 am	(7 am WST) Neptune 5° N of Moon
Sat	13th	10 am	(8 am WST) Mars 3° N of Moon
Sat	13th	4:24 pm	(2:24 pm WST) Last Quarter Moon
Sun	14th		Venus 1.1°NW of star Epsilon Tauri
Mon	15th	11 am	(9 am WST) Moon at apogee, 404,595 km
Tue	16th		Comet C/2017 T2 (PANSTARRS) 0.4°S of star Gamma Ursa Majoris
Tue	16th		Comet C/2017 T2 (PANSTARRS) 0.6°W of M109 (SG) in Ursa Major
Wed	17th	Noon	(10 am WST) Uranus 4° N of Moon
Thu	18th	6 am	(4 am WST) Mercury stationary
Fri	19th		m.p. 6 Hebe 0.2°NE of NGC 4754 (G) in Virgo
Fri	19th		Comet C/2017 T2 (PANSTARRS) 0.4°E of NGC 4026 (G) in Ursa Major
Fri	19th	7 pm	(5 pm WST) Venus 0.5° S of Moon
Sat	20th		m.p. 471 Papagena 1.4°N of star Theta Ceti
Sat	20th		Comet C/2017 T2 (PANSTARRS) 0.4°SW of NGC 4088 (G) in Ursa Major
Sat	20th	3 am	(1 am WST) star Aldebaran 4° S of Moon
Sat	20th	9 pm	(7 pm WST) m.p. 6 Hebe 0.1°NE of NGC 4762 (G) in Virgo
Sat	20th	pm	Comet 88P/Howell 0.7°SW of NGC 4691 (G) in Virgo
Sun	21st		Comet C/2017 T2 (PANSTARRS) 0.3°SE of NGC 4100 (G) in Ursa Major
Sun	21st	8 am	(6 am WST) Solstice
Sun	21st	4:41 pm	(2:41 pm WST) New Moon
Mon	22nd	6 pm	(4 pm WST) Mercury 4° S of Moon
Tue	23rd		Mercury at aphelion
Tue	23rd	Noon	(10 am WST) star Pollux 5° N of Moon
Wed	24th		m.p. 27 Euterpe 1.0°NE of star Beta Virginis
Wed	24th		m.p. 471 Papagena 0.6°NW of NGC 584 (G) in Cetus
Wed	24th		Comet C/2017 T2 (PANSTARRS) 0.2°SW of NGC 4217 (G) in Canes Venatici
Wed	24th		Comet C/2017 T2 (PANSTARRS) 0.7°SW of M109 (SG) in Ursa Major
Wed	24th	4 am	(2 am WST) Neptune stationary
Thu	25th	4 am	(2 am WST) Venus stationary
Fri	26th		m.p. 471 Papagena 0.8°N of NGC 596 (G) in Cetus
Fri	26th		Comet C/2017 T2 (PANSTARRS) 0.5°SE of NGC 4242 (G) in Canes Venatici
Fri	26th	1 am	(11 pm WST, prev day) star Regulus 4° S of Moon
Fri	26th	pm	m.p. 532 Herculina 0.9°NW of NGC 6716 (OC) in Sagittarius
Sat	27th	pm	Comet 88P/Howell 1.2°NE of NGC 4697 (G) in Virgo
Sun	28th	6:16 pm	(4:16 pm WST) First Quarter Moon
Sun	28th	11 pm	(9 pm WST) m.p. 3 Juno 3° N of Moon
Sun	28th	pm	m.p. 532 Herculina 0.9°NW of Collinder 394 (OC) in Sagittarius
Mon	29th	9 am	(7 am WST) d.p. Pluto 0.5° S of Jupiter
Mon	29th	7 pm	(5 pm WST) star Spica 8° S of Moon
Tue	30th		m.p. 6 Hebe 1.3°SW of star Epsilon Virginis
Tue	30th	Noon	(10 am WST) Moon at perigee, 368,958 km
Tue	30th	pm	d.p. Pluto 0.7°S of Jupiter

(magnitude 7.5) is located 15 arcseconds from A at position angle 19°. 'B' appears to be a two solar mass, class A4 dwarf, with a luminosity 15 times that of the Sun. The orbital period is estimated to be at least 26,000 years. There is a 10th magnitude C component which is only a line of sight optical companion. However, also part of the system is the D component (10th magnitude) located 135 arcseconds away at position angle 293°.

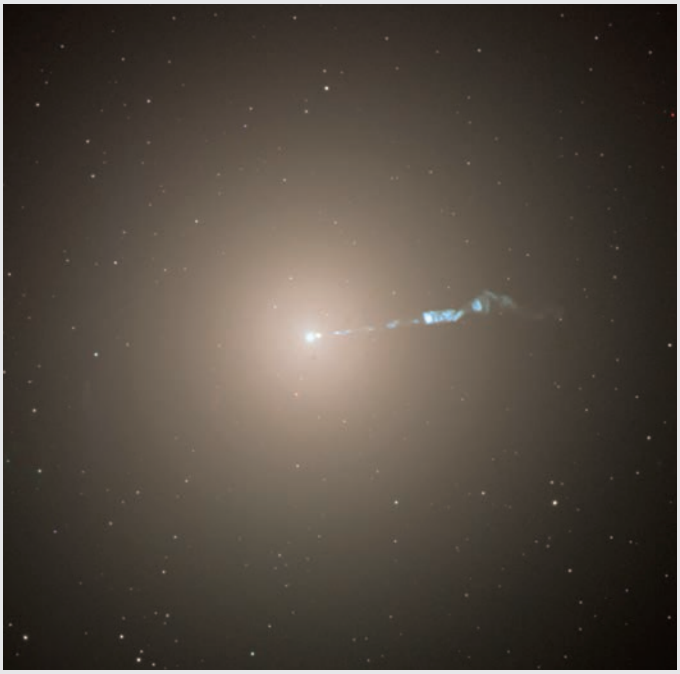
The Coma/Virgo Supercluster of Galaxies Part 2

M87—A Giant amongst Giants!

Any article on this galactic supercluster must include the remarkable giant elliptical galaxy M87 (NGC 4486), just a short jump (1.2° east-south-east) from the M86/M84 pair (see chart p. 48). It is considered close to the gravitational centre of the entire supercluster, at a distance of 55 to 60 million light-years. So, all the member galaxies, including the local group (of which we belong) are in orbit around this region.

Although it is not unusual to have prominent ellipticals taking centre stage in galaxy clusters, compared to the size of all other members of the Coma/Virgo supercluster, M87 is truly a monster and considered one of the most massive galaxies known.

Visually the galaxy is round with a diameter of approximately seven arcminutes and a bright condensed core—features easily seen in the smallest of telescopes. This yields a diameter of around 140,000 light-years, larger than the Milky Way's estimated 100,000. However, being spherical (an E0 in Hubble's classification) its volume far exceeds the mostly flattened (spiral) structure of our galaxy. But this only addresses the obvious visual component. Long exposure images by David Malin (AAO) has shown a significant elongated (oval) extension, comparable to the angular size of the Moon! M87's mass is considered to be around 2,000 to 3,000 million solar masses, much greater than our galaxy. It also has an extraordinary globular cluster count of around 12,000, which totally swamps the Milky Way's meagre 150 to 200.



The elliptical galaxy M87. The jet is a black-hole-powered stream of material that is being ejected from M87's core. Credit: NASA, ESA and the Hubble Heritage Team (STScI/AURA)

The galaxy's core is extremely turbulent and 'bright' across much of the electromagnetic spectrum and called an 'active galactic nucleus'. M87 is also referred to as Virgo A for its strong radio source and the core is considered the origin of the X-ray object called Virgo X-1.

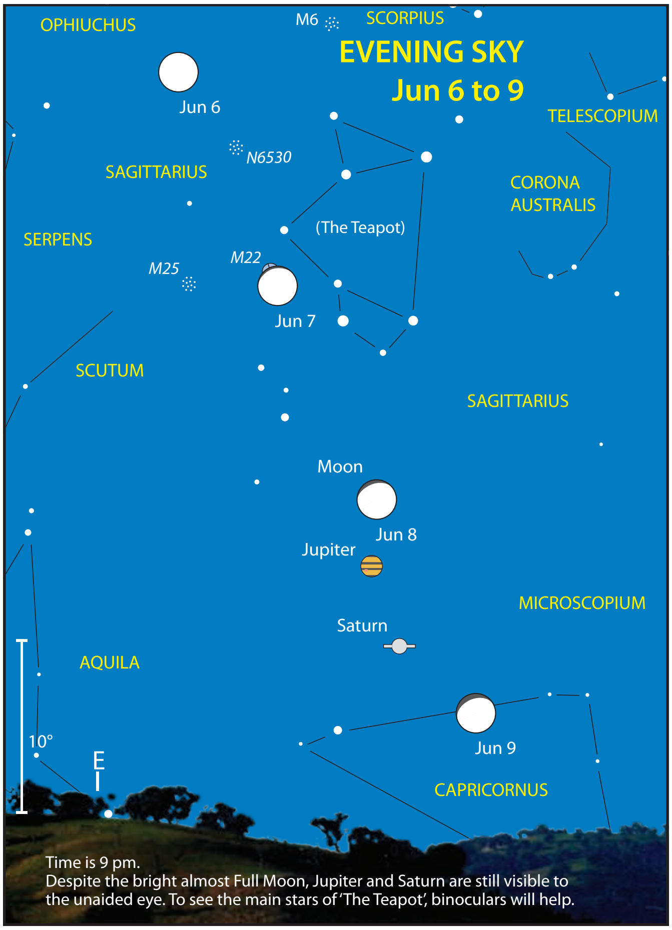
Another aspect of this central turmoil was the discovery by Heber Curtis, of the Lick Observatory in 1918, of a jet extending from the core towards the north-east. Halton Arp in 1966 discovered a less obvious jet going in the opposite direction. These jets are made up of knots of material escaping the core at a significant fraction of the speed of light! Studies of the stellar dynamics in the core of M87 concluded its activity and origin of the jets was a supermassive black hole. Initial estimates pegged its size from around 2 to 5 billion solar masses.

Event Horizon Telescope (EHT)

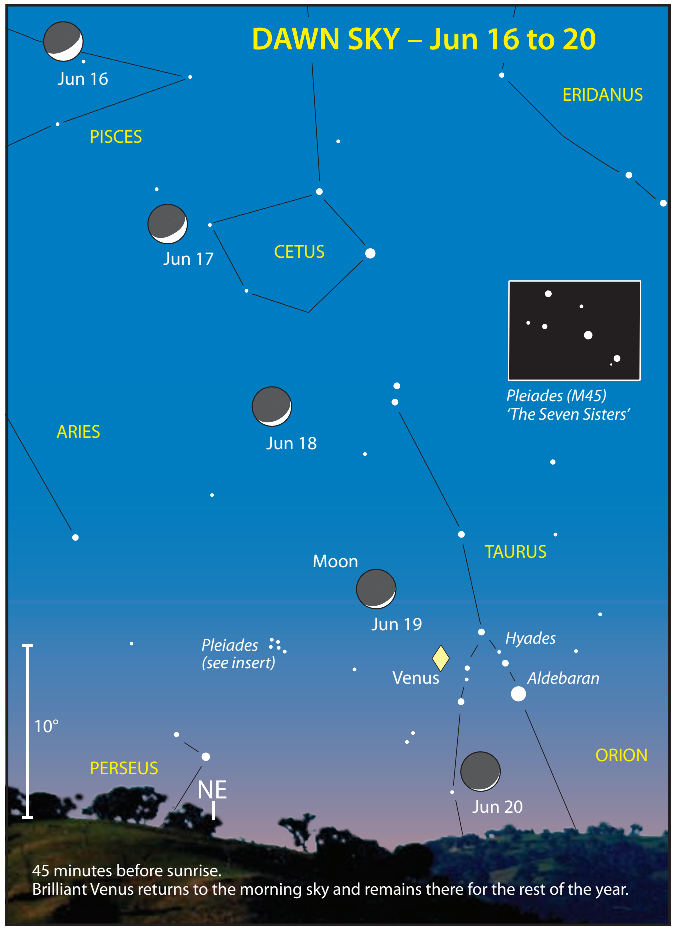
EHT is an array of radio telescopes across the world, to date involving 20 countries. The combination of observations by very long baseline interferometry (VLBI) can yield a resolution to that approaching a single radio telescope the size of the Earth. The aim was to observe objects down to the size of supermassive black hole's event horizons (hence the name). Its main targets were the two black holes suspected to be the largest visible from Earth, the one in the centre of the Milky Way called 'Sgr A*' and the other in M87 known as 'M87*'. The M87* results (see image) were exactly as predicted by Einstein's theory of general relativity. It shows a dark region caused by bending of light consistent with an underlying event horizon 40,000 million kilometres across, as expected from a 6,500 million solar mass black hole.

First image of a black hole, using Event Horizon Telescope observations of the centre of the galaxy M87. The image shows a bright ring formed as light bends in the intense gravity around a black hole. Credit: Event Horizon Telescope Collaboration

JUNE

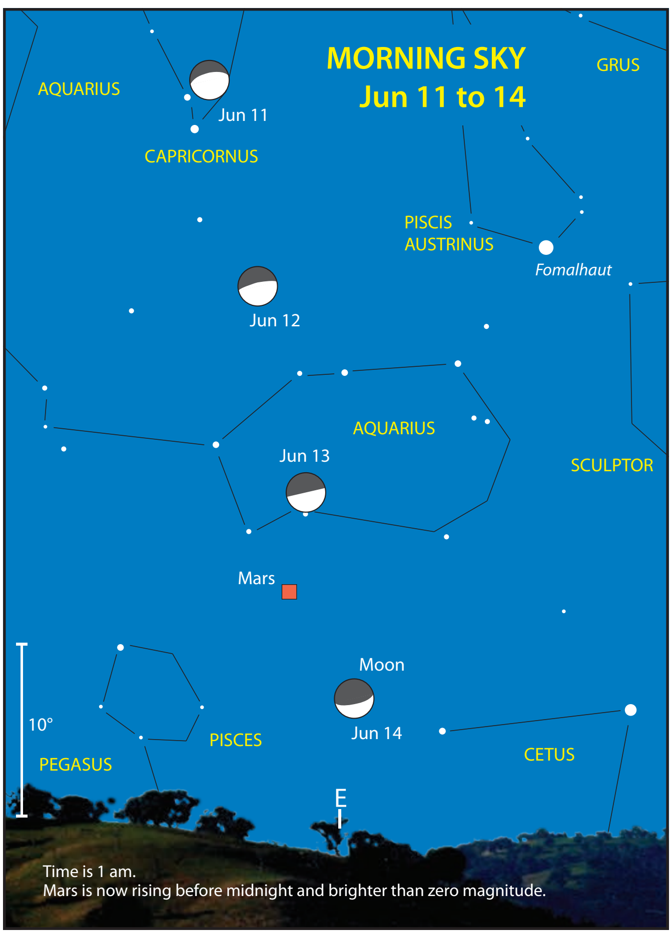


Time is 9 pm.
Despite the bright almost Full Moon, Jupiter and Saturn are still visible to the unaided eye. To see the main stars of 'The Teapot', binoculars will help.

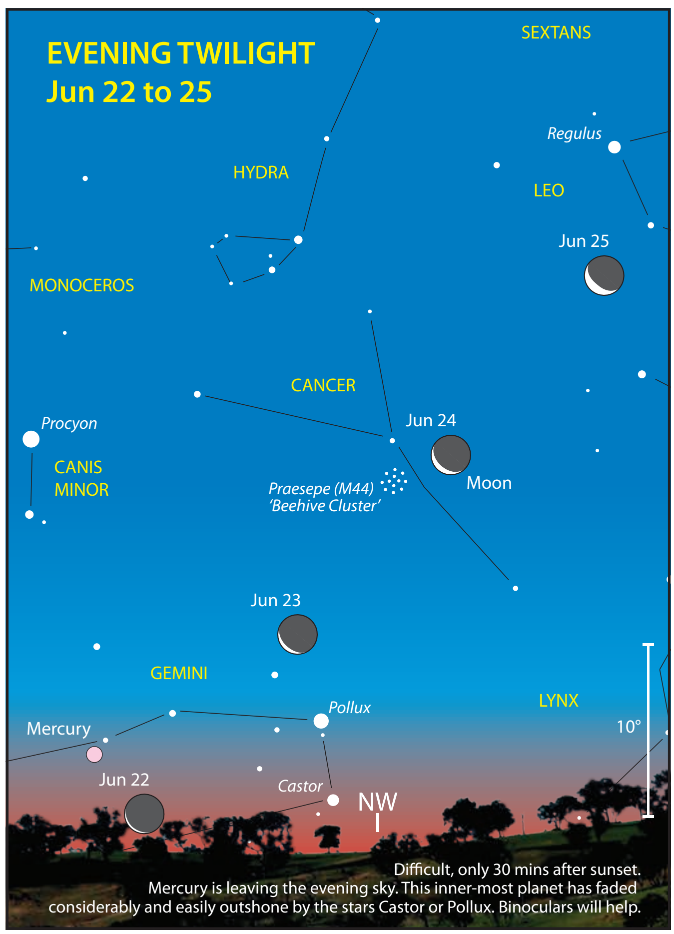


45 minutes before sunrise.
Brilliant Venus returns to the morning sky and remains there for the rest of the year.

Approximate local standard time.

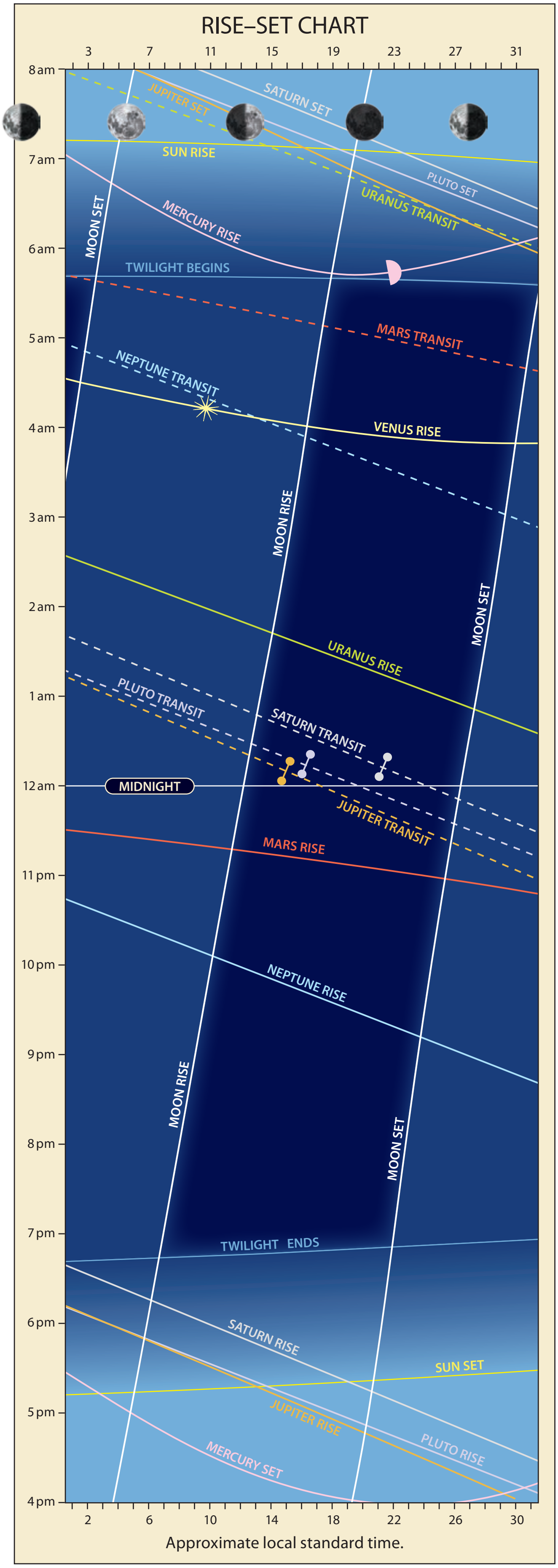


Time is 1 am.
Mars is now rising before midnight and brighter than zero magnitude.



Difficult, only 30 mins after sunset.
Mercury is leaving the evening sky. This inner-most planet has faded considerably and easily outshone by the stars Castor or Pollux. Binoculars will help.

JULY 2020



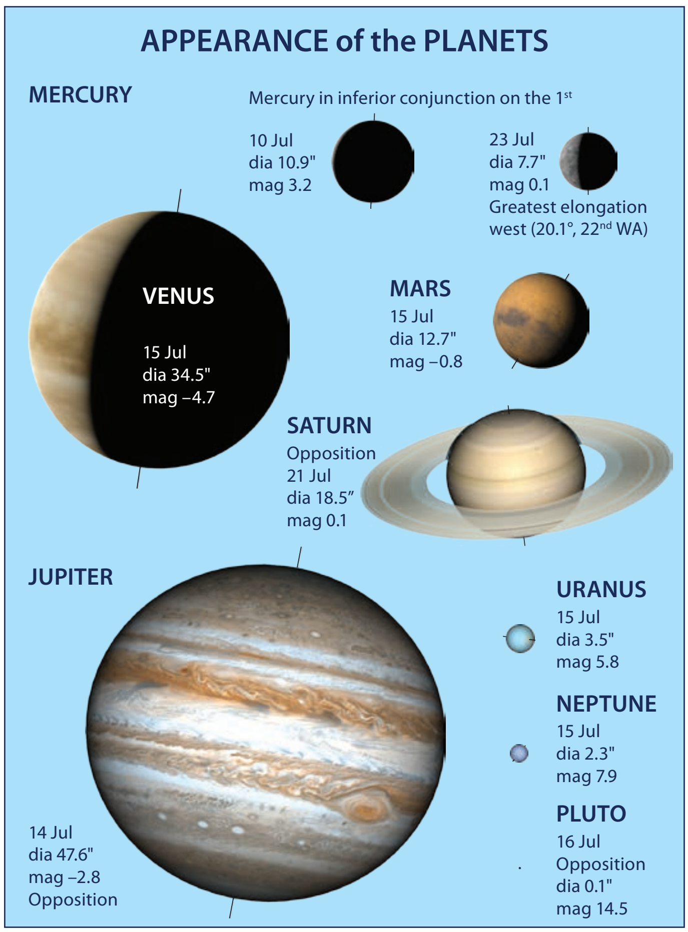
HIGHLIGHTS

- Mercury with Moon nearby.
- Venus at greatest brilliancy.
- Mars and Moon close.
- Jupiter at opposition.
- Saturn at opposition.
- Venus and Aldebaran very close.
- Saturn's meeting with the Moon.

CONSTELLATIONS

In winter the southern half of the evening sky offers a richness of star patterns unequalled elsewhere. Having the central hub of the Milky Way passing overhead is astounding with unmistakable markers such as Scorpius and its sweeping tail ending near the Teapot of Sagittarius, being hard to miss even from the suburbs. These two constellations are also the most southerly members of the zodiac. The next member to the west is Libra the Scales showing as four faint stars in a diamond shape and then Virgo the Virgin, without any noticeable patterns. However, Virgo has an isolated bright alpha star, Spica (see also June constellations) which can be identified by looking for the nearby easily identified four stars (arranged in a trapezium) of Corvus the Crow.

The most southerly region of our galaxy is still visible running off to the south-west, the Southern Cross and Pointers are the clearest signposts. South of Centauri's pointer stars lies three fainter stars in a distinctive triangle named Triangulum Australe, you guessed it, the Southern Triangle (its northern counterpart is discussed in December 2020 Constellations).



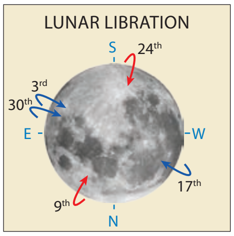
JULY

Between this constellation and the end of Scorpius' tail lies the butterfly shaped constellation called Ara the Altar. The constellation is not as obvious as some, comprised of six mostly 2nd and 3rd magnitude stars.

Talking of butterflies, look low in the north and find a similar shaped asterism but lopsided and on its side, the constellation of Hercules. This is one of the most ancient constellations. This figure's original identity was lost, but still considered a person (god?) with his arms upraised and one knee bent and a foot on the head of Draco the Dragon (a constellation a bit far north for mid-latitude Aussies). The Greeks only knew him as the 'kneeling one'. Eratosthenes finally identified him as Hercules, the son of Zeus. He is shown as exhausted and wounded from defeating the dragon that guarded the apples of Hesperides. This was number 11 of the 12 labours Hercules needed to gain immortality.

Like Ara, this constellation is made up of mostly fainter stars, and is flanked by two bright ones. To the right is Vega (Alpha Lyrae) and to the left is Arcturus. This is the alpha star to Boötes the Bear Watcher, whose mostly faint stars are shaped like a traditional kite but upside down from Australia.

THE MOON



- 3rd — 9 am (7 am WST). Minimum Libration (4.0°), bright SE limb.
- 5th — 3 pm (1 pm WST) Full Moon. Penumbral eclipse not visible from Australia (see Part II for details).
- 9th — 10 pm (8 pm WST) Maximum Libration (7.5°), dark NE limb.
- 13th — 5 am (3 am WST) Moon at apogee (furthest from Earth at 404,199 km).
- 13th — 10 am (8 am WST) Last Quarter.
- 17th — 6 am (4 am WST) Minimum Libration (5.1°), bright NW limb.
- 21st — 4 am (2 am WST) New Moon.
- 24th — 11 am (9 am WST) Maximum Libration (6.8°), dark SW limb.
- 25th — 3 pm (1 pm WST) Moon at perigee (closest to Earth at 368,361 km).
- 27th — 11 pm (9 pm WST) First Quarter.
- 30th — 10 pm (8 pm WST). Minimum Libration (4.5°), bright SE limb.

THE PLANETS

Mercury begins the month in inferior conjunction (between the Earth and the Sun) before moving into the eastern morning twilight. After reaching its greatest elongation 20° west of the Sun on the 23rd, the innermost planet begins its sunward journey. On the 19th, the 28-day old waning crescent Moon appears around 5° to the north of the planet (see Sky View).

The view along the pre-dawn eastern horizon with **Venus**, Taurus, Orion and Canis Major is stunning under country winter skies. Venus passes through the Hyades star cluster early in July, On the 12th and 13th the brilliant planet will be 1° from the 1st magnitude star Aldebaran (Alpha Tauri). This brightest star of Taurus, the 14th brightest in the night sky, marks the red eye of the Bull. On the 17th, the 26-day old waning crescent Moon makes an attractive sight together with Venus and Aldebaran (see Sky View). Venus reaches its greatest illuminated extent (see April Venus section for definition) on the 10th at –4.7 magnitude.

The **Earth** is at aphelion on the 4th, the furthest point in its orbit from the Sun (152,095,317 km or 1.016694 au distant).

Mars, rising around 11 pm, spends the early part of July in Pisces before moving into Cetus and then back into Pisces at month's end. The south polar cap is now in rapid retreat, and it is possible for dust storms to occur during this time. On the 11th, the 21-day old waning gibbous Moon appears close to the Red Planet (see Sky View).

Blazing splendidly at –2.8 magnitude, **Jupiter** comes to opposition on the 14th. As the planet orbits the Sun once every 11.9 years, oppositions occur every 399 days or about every 13 months. Visible above the eastern horizon at astronomical dusk the planetary giant's equatorial diameter reaches 47.6 arcseconds, making it a fitting target for small telescopes. It is interesting that out of the two major gas giants in our Solar System, most amateurs tend to vote Saturn as their favourite. As pretty as Saturn is, it is Jupiter that excels with its dynamic atmospheric action and the varying dance of the four Galilean moons. On its oblate disc the small telescope user will see two main cloud belts known as the north and south equatorial belts (NEB and SEB). Within the SEB lies the Great Red Spot (GRS), the largest known cyclone in the Solar System. Besides shrinking over the years, the GRS in recent times appears to be unravelling as streamers have been observed peeling off the maelstrom (see p. 8). Predictions for the Great Red Spot and moon events (see also Sky View for some interesting moon configurations this month) can be found in Part II. On the 5th, at astronomical dusk, the Full Moon appears above Jupiter and Saturn in Sagittarius (see Sky View).

Saturn comes to opposition on the 21st, just one week after Jupiter. A good time to view both planets at their best as they rise in the eastern sky in Sagittarius after astronomical dusk. Even seasoned amateurs never tire of the beauty of this Ringed Planet. Jupiter's turbulent atmosphere may show more action but the captivating view in small instruments is exquisite. The rings of the planet can be seen even in the smallest telescope. Galileo saw the rings in 1610 but was unable to identify what they were because of the limitations of his lenses. He claimed the planet had 'ears'. The larger the telescope the more detail visible in the ring structure under steady skies. The Encke Gap in the outermost ring and the inner translucent Crepe Ring are a good test of instrument and seeing. It is also interesting to note the flattening at the poles and the light-coloured band around the equator of the globe.

On the 6th, the 16-day old waning gibbous Moon appears 2° (3° from WA) from the rising planet (see Sky View). On the 20th, any Saturnians looking sunward (if sitting on the northern face of the rings) will see the Earth undergoing a rare 12-hour transit of the Sun. See also the Sky View for some interesting Saturnian moon configurations this month.

Uranus, in Aries, is only visible in the morning sky, rising around 1:30 am midmonth.

Neptune, in Aquarius, rises in the evening eastern sky.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto** is at opposition on the 16th at magnitude 14.5 in Sagittarius and above the horizon the entire night. It is presently 4,946 million km (33.0629 au) from Earth, with its light taking four hours and thirty-five minutes to reach us.

Brightest **Minor Planets** at opposition this month include:

Date	Minor Planet	Constellation	Mag.
2 Jul	532 Herculina	Sagittarius	9.3
3 Jul	121 Hermione	Sagittarius	12.0
7 Jul	185 Eunike	Serpens	11.7
13 Jul	2 Pallas	Vulpecula/Sagitta border	9.6
15 Jul	129 Antigone	Sagittarius	9.9

COMETS

Comet 2P/Encke is in the evening sky this month, moving away from the Sun with each passing day. The comet opens July low in the north-east sky, setting around the end of twilight. Its altitude then steadily climbs as it slowly fades. Encke moves through several constellations during the month, starting in Cancer and ending near the four bright stars of Corvus.

Comet 88P/Howell is high in the evening sky as twilight ends during July and sets around midnight. Located in the constellation Virgo throughout the month, the comet is expected to brighten from 10th to 9th magnitude. From the 21st to 25th, Howell will be within 2° of the bright star, Spica (Alpha Virginis).

Comet C/2017 T2 (PANSTARRS) is in Canes Venatici as July opens, low in the northern evening sky at the end of twilight and predicted to be shining at 7th magnitude. Moving into Coma Berenices midmonth, PANSTARRS will gradually climb in altitude throughout July as it moves south. By the end of the month, the comet is likely to have faded to 8th magnitude.

DOUBLE STARS

Xi (ξ) Scorpii is located in a peninsula of sky now allocated to Scorpius (All Sky Map No 6). It is a fine multiple star system with the AB pair comprising of magnitude 5.2 and 4.9 ("B" being the brighter) white stars currently separated by only 1.1 arcseconds with a position angle of 10°. A large scope with very steady seeing is needed to resolve this pair. 'AB' are probably F4 and F5 hydrogen-fusing dwarfs both with masses of 1.5 times that of the Sun. The orbital period is 45.9 years and were last closest in 1997. In contrast, there is an easy C component, a G class yellowish star of magnitude 7.3, located 7.6 arcseconds away at position angle 42°. In the same area (nearly 5 arcminutes south-east of Xi) look for a nearby triple (STF 1999) comprising 7.5 and 8.1 magnitude stars (spectral class G8 and K3) separated by 12 arcseconds with a faint 11.4 magnitude C component (probably a line of sight star) 83 arcseconds away. The A and B companions are located about 7,400 astronomical units from Xi with an orbital period of 250 million years. So, if we exclude the C component of STF 1999, we may have a quintuple star system. To add to the complexity, for some reason Xi Scorpii is listed as the D companion to the fainter triple. All the above stars fit neatly into the same telescopic field.

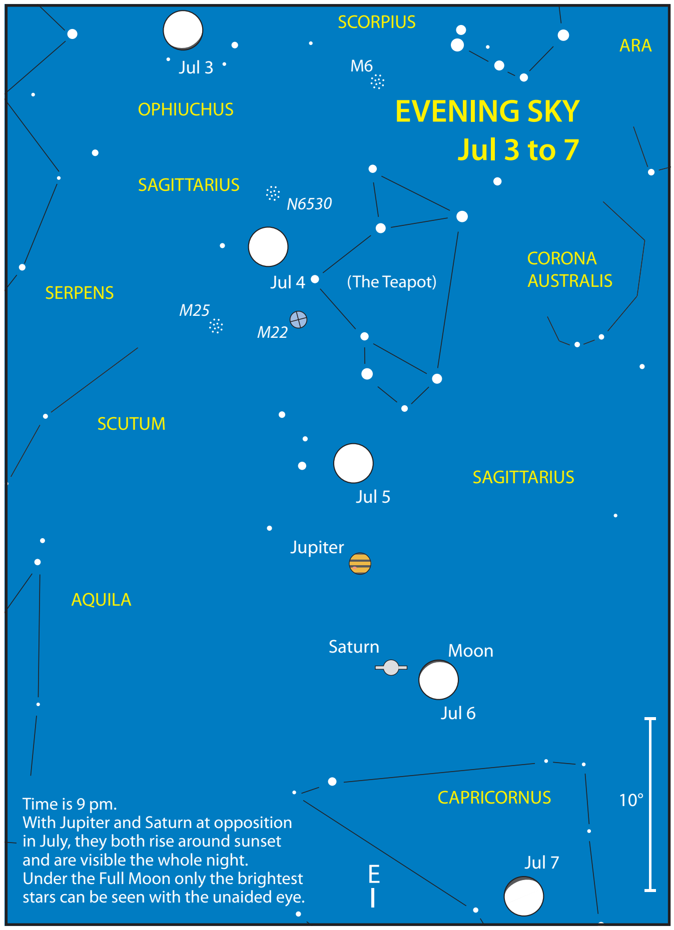
DIARY			
Wed	1st		Comet C/2017 T2 (PANSTARRS) 0.3°S of NGC 4490 (G) in Canes Venatici
Wed	1st	1 pm	(11 am WST) Mercury in inferior conjunction
Fri	3rd		m.p. 8 Flora 0.7°S of NGC 520 (G) in Pisces
Fri	3rd	3 am	(1 am WST) star Antares 6° S of Moon
Sat	4th	10 pm	(8 pm WST) Earth at aphelion, 1.016694252 au
Sun	5th		Venus 0.4°S of star Delta^1 Tauri
Sun	5th		m.p. 3 Juno 1.0°NE of NGC 4665 (G) in Virgo
Sun	5th	2:44 pm	(12:44 pm WST) Full Moon (379,150 km)
Sun	5th	4 pm	(2 pm WST) m.p. 4 Vesta in conjunction with Sun
Mon	6th		Venus 0.3°S of star Delta^2 Tauri
Mon	6th	8 am	(6 am WST) Jupiter 2° N of Moon
Mon	6th	9 am	(7 am WST) d.p. Pluto 1° N of Moon
Mon	6th	7 pm	(5 pm WST) Saturn 2° N of Moon
Mon	6th	pm	m.p. 532 Herculina 0.6°SE of Palomar 8 (GC) in Sagittarius
Tue	7th		Comet 2P/Encke 0.7°NW of M67 (OC) in Cancer
Tue	7th	pm	m.p. 7 Iris 0.5°S of NGC 6595 (BN) in Sagittarius
Wed	8th		Comet 2P/Encke 1.0°SW of star Alpha Cancri
Wed	8th		Mars at greatest latitude south
Fri	10th		Venus at aphelion
Fri	10th	5 pm	(3 pm WST) Neptune 4° N of Moon
Fri	10th	6 pm	(4 pm WST) Venus greatest illuminated extent
Sat	11th	pm	m.p. 7 Iris 0.7°N of star Mu Sagittarii
Sun	12th		Comet 88P/Howell 0.2°E of NGC 4995 (G) in Virgo
Sun	12th	6 am	(4 am WST) Mars 2° N of Moon
Sun	12th	5 pm	(3 pm WST) star Aldebaran 1° S of Venus
Sun	12th	5 pm	(3 pm WST) Mercury stationary
Mon	13th		d.p. Ceres stationary
Mon	13th		Mercury at greatest latitude south
Mon	13th	5 am	(3 am WST) Moon at apogee, 404,199 km
Mon	13th	9:29 am	(7:29 am WST) Last Quarter Moon
Mon	13th	Noon	(10 am WST) m.p. 2 Pallas at opposition
Tue	14th		m.p. 471 Papagena 1.0°N of NGC 779 (G) in Cetus
Tue	14th	6 pm	(4 pm WST) Jupiter at opposition
Tue	14th	10 pm	(8 pm WST) Uranus 4° N of Moon
Thu	16th		m.p. 3 Juno 0.4°SW of star Delta Virginis
Thu	16th	5 am	(3 am WST) d.p. Pluto at opposition
Fri	17th	Noon	(10 am WST) star Aldebaran 4° S of Moon
Fri	17th	5 pm	(3 pm WST) Venus 3° S of Moon
Sat	18th		Comet 2P/Encke 0.3°N of star Alpha Sextantis
Sun	19th	2 pm	(Noon WST) Mercury 4° S of Moon
Tue	21st	3:33 am	(1:33 am WST) New Moon
Tue	21st	8 am	(6 am WST) Saturn at opposition
Wed	22nd		m.p. 8 Flora 0.5°S of NGC 741 (G) in Pisces
Thu	23rd		Comet 88P/Howell 1.3°NE of star Spica
Thu	23rd	1 am	(11 pm WST, prev day) Mercury at greatest elongation West (20.1°)
Thu	23rd	7 am	(5 am WST) star Regulus 4° S of Moon
Sat	25th	3 pm	(1 pm WST) Moon at perigee, 368,361 km
Sun	26th		Mercury 1.0°NW of star Zeta Geminorum
Sun	26th	1 pm	(11 am WST) m.p. 3 Juno 3° N of Moon
Sun	26th	Midnight	(10 pm WST) star Spica 7° S of Moon
Mon	27th	10:33 pm	(8:33 pm WST) First Quarter Moon
Wed	29th		Mercury 0.5°S of star Delta Geminorum
Wed	29th	pm	m.p. 532 Herculina 0.6°NW of NGC 6629 (PN) in Sagittarius
Thu	30th	9 am	(7 am WST) star Antares 6° S of Moon
Fri	31st	pm	m.p. 7 Iris 1.0°S of M23 (OC) in Sagittarius

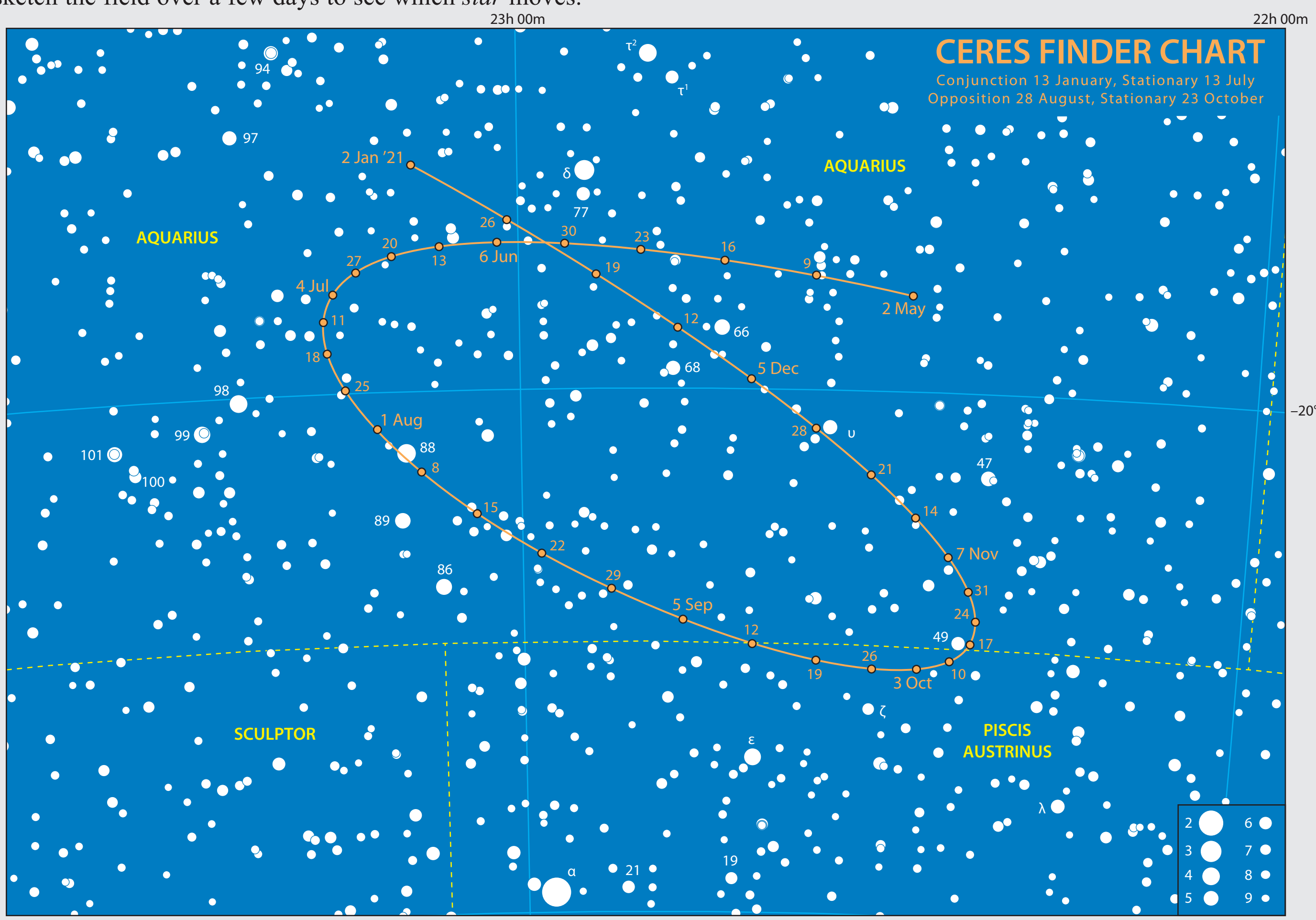
Ceres—the Forgotten Planet!

In 2006 Pluto was demoted from a planet to a dwarf planet by the International Astronomical Union. Did you know this wasn't the first planetary sacking? Ceres was discovered on January 1, 1801. It was the first body to be found between the orbits of Mars and Jupiter and earned the rank of planet. Soon numerous other bodies were found with similar orbits, establishing the main belt of asteroids (minor planets), so Ceres, in the 1850s, found itself demoted to an asteroid. With the revised definition of a planet in 2006, neither Pluto nor Ceres had cleared their orbits but certainly both were massive enough to be round, which placed them in the newly created dwarf planet category. Ceres is the only known round asteroid in the main belt or for that matter inside the orbit of Neptune.

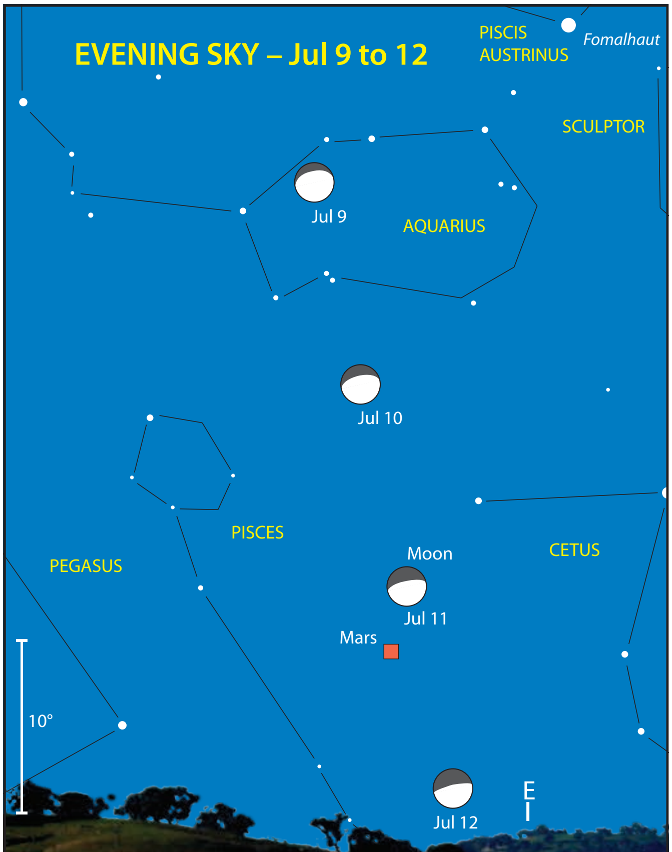
To this day Ceres is still believed to be the largest asteroid with a diameter close to 1,000 km, accounting for around 30% of the total mass of the hundreds of thousands of known main belt asteroids. It's not the brightest, with Vesta taking this honour. However, Ceres stands out as easily the second brightest, spending most of its time around 9th magnitude, reaching into the sevens at opposition. Only a few dozen asteroids get close to 9th magnitude and then only at their oppositions. The table on page 138 illustrates this well.

Ceres remains within reach of small binoculars year round, in particular when at opposition. The finder chart below shows this period for 2020 and includes stars down to 9th magnitude, so should be adequate to find the dwarf planet. See also All Sky Map 8. When there are a lot of stars, you might need to sketch the field over a few days to see which *star* moves.

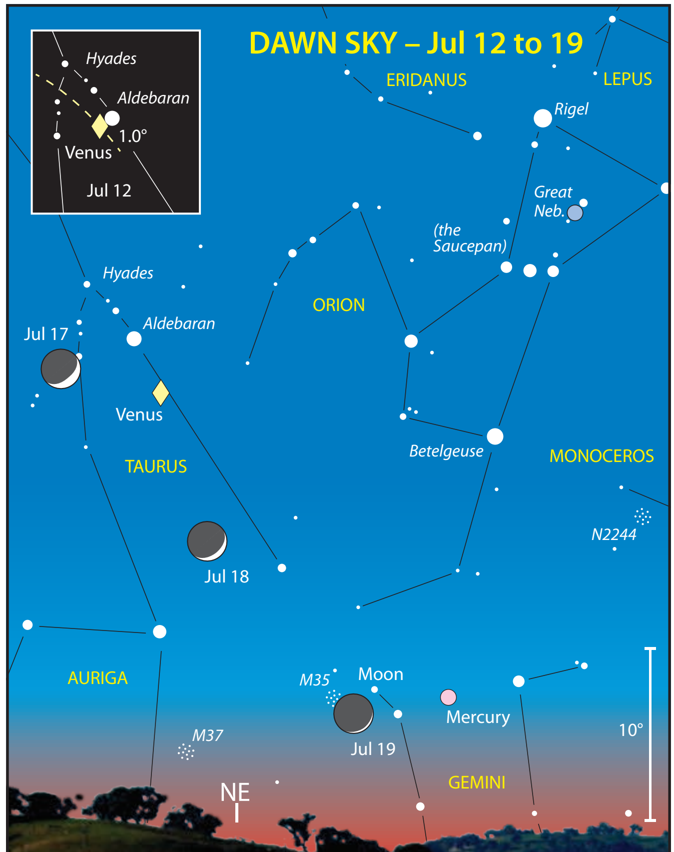




JULY



Time is midnight.
Mars continues to brighten as it heads towards its opposition in October.



Only 30 mins before sunrise. This time is needed to catch Mercury, for Venus has been up for over two hours. In the first half of July, Venus passes through the Hyades. The insert gives the date that Venus and Aldebaran are closest.

Approximate local standard time.

Jupiter's Satellites for July

1 arc min.

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.

Jul 4, 11:00 pm EST (9:00 pm WST)

In the next hour Io will be eclipsed and the morning of 5th will see it reappear from occultation as well as Europa eclipsed.

Jul 6, 10:00 pm EST (8:00 pm WST)

Europa and its shadow are currently transiting and will egress later in the night.
The early morning hours will see Ganymede pass into Jupiter's shadow (eclipsed).

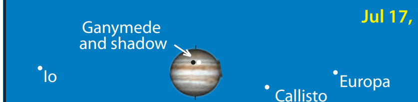
Jul 8, 10:00 pm EST (8:00 pm WST)

Four moons on one side.
The three closest to Jupiter will gradually draw together as the night progresses.

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

Approximately 30 minutes earlier Io emerged from behind Jupiter and in the next 30 minutes Europa and its shadow will commence transiting.

Jul 17, 10:00 pm EST (8:00 pm WST)



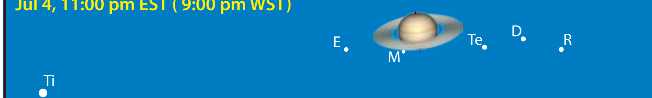
Ganymede and its shadow are currently in transit having moved in front of Jupiter (ingressed) earlier in the evening. They will egress over the next couple of hours.

Saturn's Satellites for July

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.

Jul 4, 11:00 pm EST (9:00 pm WST)

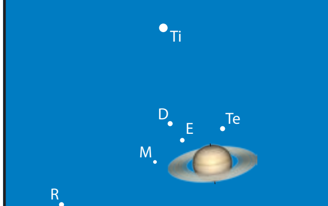


Titan is just past a maximum eastern elongation with Tethys, Dione and Rhea close to their maximum western elongations.

Jul 11, 11:00 pm EST (9:00 pm WST)

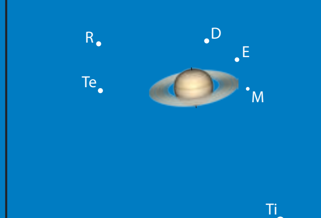
Titan is close to a maximum western elongation with Rhea and Dione near their eastern maximum elongations.

Jul 16, 11:00 pm EST (9:00 pm WST)



An arrangement of moons on the north side with Titan just past superior conjunction.

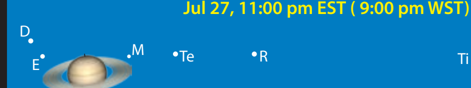
Jul 24, 11:00 pm EST (9:00 pm WST)



The moons are well spread around Saturn with Titan just past inferior conjunction.

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

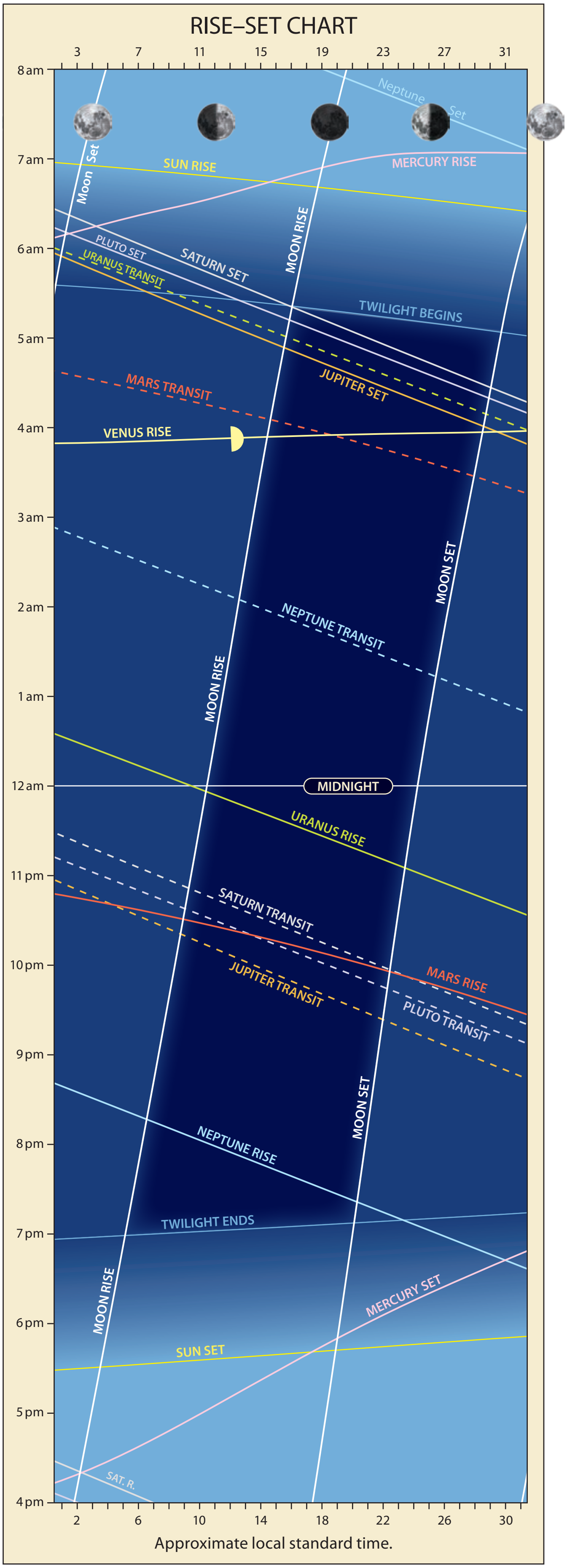
Jul 27, 11:00 pm EST (9:00 pm WST)



A nice alignment of moons with Tethys, Rhea and Titan near maximum western elongations.

JULY

AUGUST 2020



HIGHLIGHTS

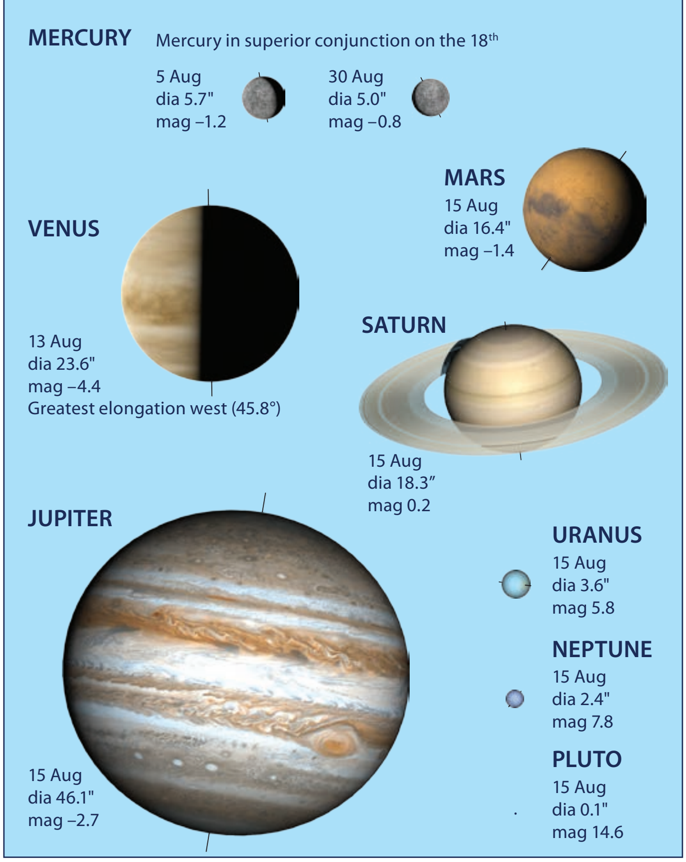
- Venus and Moon close.
- Mars and Moon close.
- Moon near Jupiter and Saturn, twice!

CONSTELLATIONS

As you saw in July Constellations we are pleased to endorse the beauty of the Milky Way, waiting for anyone to seek out dark skies and just look up—the ultimate wide-angle view! We also promoted the central hub which is easily identified by the prominent asterisms of the Scorpion and the Teapot which pass overhead in August early evenings. However, don't overlook the impressive views on offer for a pair of binoculars. Their wide angle can give breathtaking views of the intricacies of the intertwining dark and bright nebula, not apparent through the much narrower fields of telescopes. Many of the open clusters are large enough to give the best views this way, for example M7 near Scorpius' stinger. The bright star cloud M24 being two degrees across is ideal. Most of the deep sky objects marked in this region on the All Sky Maps (see Maps 6 and 8) are bright enough for binoculars, however you need to remember the trade-off here. The low power needed for the wide views make compact objects appear small and easy to miss. Obvious examples of bright but tiny objects are the Messier globular star clusters in Sagittarius. They will appear as small blobs, a similar situation to that found with binocular views of galaxies in the Coma/Virgo supercluster, although the galaxies are noticeably fainter—see page 48.

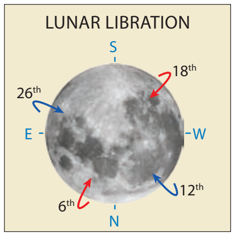
From the hub of our galaxy continue scrolling with your binoculars westward along its 'milky' path. If you have a wide

APPEARANCE of the PLANETS



enough field of view to fit in the Southern Cross, you will be amazed at how rich this area is in faint stars. However, if you want busy, check out the Vela star clusters and nebulae region, located roughly halfway between the Southern Cross and False Cross.

THE MOON



- 4th 2 am (midnight previous day WST) Full Moon.
- 6th 8 am (6 am WST) Maximum Libration (7.3°), dark NE limb.
- 9th Midnight (10 pm WST) Moon at apogee (furthest from Earth at 404,659 km).
- 12th 3 am (1 am WST) Last Quarter.
- 12th 11 am (9 am WST) Minimum Libration (5.3°), bright NW limb.
- 18th 8 pm (6 pm WST) Maximum Libration (6.9°), too close to New Moon.
- 19th 1 pm (11 am WST) New Moon.
- 21st 9 pm (7 pm WST) Moon at perigee (closest to Earth at 363,513 km).
- 26th 4 am (2 am WST) First Quarter.
- 26th 1 pm (11 am WST) Minimum Libration (5.7°), bright SE limb.

THE PLANETS

With superior conjunction (**Mercury** and Earth on opposite sides of the Sun) on the 18th, Mercury moves from the dawn into the evening dusk. However, the planet tends to stay close to the horizon making observation difficult. The best time to glimpse this elusive world in the evening sky will be from mid-September to mid-October when visible after the end of astronomical twilight.

Finally leaving Taurus early this month, **Venus** makes its way across the club section of Orion before ending up in Gemini for the second half of August. In the north-eastern morning sky, Venus can be seen near the 4th magnitude star Nu Geminorum (a nice double star) on the 16th with the 26-day old waning crescent Moon directly below (see Sky View). The planet reaches its greatest elongation 46° west of the Sun on the 13th. Despite being surrounded by many stellar luminaries, found in our The Brightest Stars list (p. 141), Venus as usual continues to outshine them all.

On the 3rd, **Mars** will be at perihelion. It is this point in its 687-day orbit when it is closest to the Sun (1.38138 au). If the Sun, Earth and Mars were all to line up at this time we would have a particularly good view of the Red Planet (e.g., in 2003 and to a slightly lesser degree in 2018). This year, by the time the Earth catches up to Mars for opposition in October the perihelion sweet spot has passed. Nonetheless, it will still be a reasonable opposition with the planet reaching 22.56 arcseconds in diameter (compared to 25.11 arcseconds in 2003 and 24.31 in 2018). Visual observers will note the rapidly diminishing south polar cap and the possible formation of dust storms. In Pisces near the border of Cetus, Mars rises around 10 pm midmonth. On the 9th, the 20-day old waning gibbous Moon appears close to the Red Planet (see Sky View).

Having just passed opposition (mid-July), **Jupiter** is still brilliant at –2.7 magnitude, well up in the eastern sky at the end of twilight. Twice this month the waxing gibbous Moon appears between Jupiter and Saturn in Sagittarius, on the 2nd at 13 days old and on the 29th at 11 days old (see Sky Views). Besides the shuffling dance of the four Galilean moons (see Sky View for some interesting moon configurations this month), there are changes in the planet's atmosphere that are worth looking for. The most obvious and easiest to identify features on the planet are the dark north (NEB) and south equatorial (SEB) belts. 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 can be visible within the bands. With Jupiter's fast 10-hour rotation period, things move pretty quickly, and a feature noted in a belt will move perceptibly in less than a half an hour. In view of recent changes in the Great Red Spot, it too warrants scrutiny although with the planet's rapid spin there is only a narrow window in which to observe it. Predictions for when the Great Red Spot is visible are in Part II. It takes a little patience and practice to tease out the detail when observing planetary detail but when the air is steady it is surprising what can be seen.

Just past opposition, **Saturn** is found in the eastern evening sky in Sagittarius. As August progresses, telescope users will begin to see the shadow of its globe cast on the back of the rings. This shadow cannot be seen close to opposition as it is projected directly behind the planet from our point of view. This effect coupled with limb darkening provides a real 3D effect, especially when the planet is at quadrature (see diagram on p. 16) when the shadow is at its maximum (April and October). Twice this month the waxing gibbous Moon appears close to the planet and Jupiter (above). See also the Sky View for some interesting Saturnian moon configurations this month.

Uranus, in Aries, rises in the late eastern evening sky around 11:30 pm midmonth. On the 16th the planet appears stationary against the background stars and thereafter is in retrograde motion until early 2021.

Coming to opposition early next month **Neptune**, in Aquarius, rises as astronomical twilight ends.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto**, now past opposition transits the meridian (is due north) around 10 pm midmonth.

Dwarf planet **Ceres** is at opposition on the 28th in Aquarius at 7.7 magnitude. On the night of the 3rd, minor planet **Antigone** (10th magnitude) makes a very close approach to the star Upsilon Sagittarii.

Brightest **Minor Planets** at opposition this month include:

Date	Minor Planet	Constellation	Mag.
5 Aug	44 Nysa	Capricornus	10.5
28 Aug	20 Massalia	Aquarius	9.6

COMETS

Comet 2P/Encke opens August in the constellation of Corvus, at a predicted 8th magnitude, setting around 10 pm. It passes across Corvus' trapezium on the 2nd and 3rd. As the month progresses, Encke will move further south as it climbs higher in the sky and will be setting later in the evening. At month's end, the comet is likely to be around 11th magnitude, in Lupus and setting around 1 am.

Comet 88P/Howell is in the constellation Virgo for the first half of August and then crosses into neighbouring Libra. Predicted to be around 9th magnitude in brightness, Howell is setting late in the evening.

Comet C/2017 T2 (PANSTARRS) is in Coma Berenices for the first week of August, shining at 8th magnitude before moving into Boötes and then finishing the month in Virgo. In the north-western evening sky, the comet will begin to slowly sink back towards the Sun and spends the month setting around 9 pm. By the end of August, it may have faded to 9th magnitude.

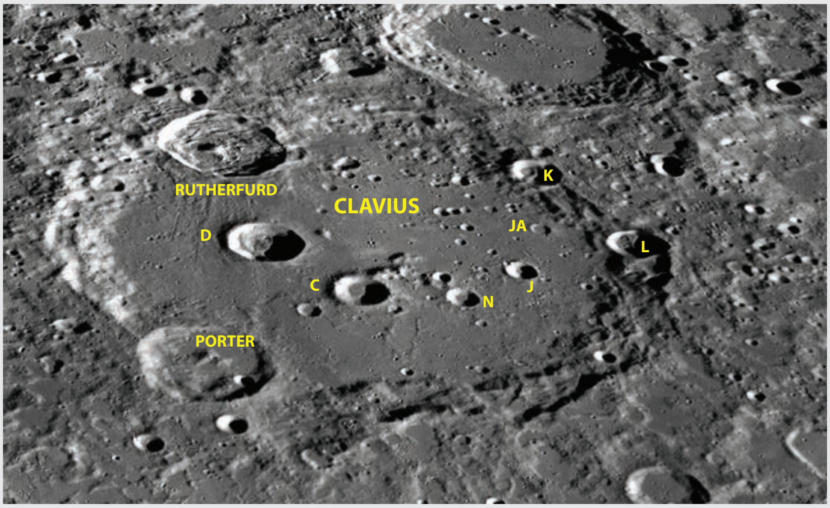
DOUBLE STARS

Delta[1] (δ[1]) and **Delta[2] (δ[2]) Chamaeleontis** (All Sky Map No. 1). Here's a brief visit to the South Celestial Pole region to a delightful wide pair ideal for binoculars. From Australia the constellation Chamaeleon is circumpolar. The brighter component is yellow Delta[2] at magnitude 4.5, whilst 6 arcminutes away Delta[1] at magnitude 5.5 is distinctly bluish-white. Delta[1] is located around 350 light-years from the Sun and is actually a very close double star. The pair is designated

Clavius

The time around First Quarter (FQ) is always a favourite with lunar observers as impressive landscapes come into view. In the period immediately after FQ, as the terminator begins to sweep across Mares Imbrium, Insularum and Nubium some well known features are revealed, including Plato and the rayed crater and Copernicus. In the chaotic southern highlands Tycho and Clavius emerge from the dark.

Clavius crater, one of the largest on the near side at 225 km was formed by an asteroid collision some four billion years ago. It is well preserved and distinct despite being bombarded by smaller impactors after its formation. The imposing structure was named after Christopher Clavius (1538–1612), a German astronomer and mathematician. Clavius was noted for his calendar reform which is still in use today as the Gregorian calendar.



Clavius crater, credit LRO

The naming convention of lunar craters after prominent astronomers and scientists was established by Giovanni Riccioli (1598–1671). Riccioli opposed the heliocentric system and he assigned the largest craters for those that supported his views, including his predecessor Clavius. It is interesting that he then named one of the Moon's most prominent craters after Nicolaus Copernicus whose model of the Universe placed the Sun at the centre rather than the Earth. Riccioli did say however, that he "… flung Copernicus into the Ocean of Storms (Oceanus Procellarum)". Perhaps Riccioli was a closet heliocentrist and as a Jesuit he could not openly support Copernican theory.

With good eyesight Clavius can be seen without optical aid as a conspicuous notch in the terminator of an 8 to 9-day old Moon (a day or so after FQ). When viewed through a telescope at this time with a low sunrise angle, you can see a band of shadow on the floor at the base of both the east and west walls, demonstrating the floor of this giant crater follows the curvature of the Moon. Interestingly, if you stood in the centre of this 3.5 km deep depression you would only see a flat plain in all directions, the walls lost beyond the curve.

Aside from its immense size the most remarkable feature of Clavius is the curving chain of craters of decreasing size that are within its interior. Staring with the 48 km diameter Rutherfurd on the south wall with its offset central peak, then there is the 28 km crater D, 21 km C, 13 km N, 12 km J and finally a tiny craterlet JA against the west wall. Atop the crater walls is the 53 km diameter Porter with a double central peak on the north side, and the smaller 24 km L and 20 km K on the opposite wall.

The whole area makes fascinating viewing particularly when the terminator progresses across Clavius. Over the course of several hours, complex changes in light and shadow will reveal many surprises across the floor including dozens of craterlets and the remains of a central massif (against the rim of crater C).

For the sci-fi buffs, Clavius is the location for the Clavius Base from Arthur C. Clarke's 2001: A Space Odyssey (both book and film versions).

I 294 and consists of a magnitude 6.2 primary (spectral class K0III) and a magnitude 6.5 secondary separated by only 0.8 arcseconds with a position angle of 85°. Very good seeing and at least a 20 cm telescope are needed to resolve this challenging pair.

DIARY		
Sat	1st	Mercury at ascending node
Sat	1st	Venus at greatest latitude south
Sun	2nd	Comet 2P/Encke 1.5°SE of star Gamma Corvi
Sun	2nd	10 am (8 am WST) Jupiter 1.5° N of Moon
Sun	2nd	4 pm (2 pm WST) d.p. Pluto 1° N of Moon
Sun	2nd	4 pm (2 pm WST) star Pollux 7° N of Mercury
Sun	2nd	11 pm (9 pm WST) Saturn 2° N of Moon
Mon	3rd	Mars at perihelion
Mon	3rd	3 am (1 am WST) m.p. 8 Flora 0.1°NW of NGC 864 (G) in Cetus
Mon	3rd	3 pm (1 pm WST) m.p. 4 Vesta 0.2° S of Mercury
Mon	3rd	11 pm (9 pm WST) m.p. 129 Antigone 0.03°W of star Upsilon Sagittarii
Tue	4th	1:59 am (11:59 pm WST, prev day) Full Moon (389,877 km)
Tue	4th	pm m.p. 20 Massalia 1.4°NW of star Lambda Aquarii
Wed	5th	d.p. Ceres 0.1°SE of star c^2 Aquarii
Thu	6th	Mercury at perihelion
Fri	7th	1 am (11 pm WST, prev day) Neptune 4° N of Moon
Sat	8th	am Mars 0.7°NW of NGC 520 (G) in Pisces
Sat	8th	am Mars 0.7°S of NGC 488 (G) in Pisces
Sun	9th	6 pm (4 pm WST) Mars 1° N of Moon
Sun	9th	Midnight (10 pm WST) Moon at apogee, 404,659 km
Tue	11th	7 am (5 am WST) Uranus 4° N of Moon
Wed	12th	2:45 am (12:45 am WST) Last Quarter Moon
Thu	13th	10 am (8 am WST) Venus at greatest elongation West (45.8°)
Thu	13th	9 pm (7 pm WST) star Aldebaran 4° S of Moon
Fri	14th	7 pm (5 pm WST) Comet 2P/Encke 1.4°S of star Phi Hydrae
Sat	15th	Venus 0.3°SW of star Nu Geminorum
Sat	15th	11 pm (9 pm WST) Venus 4° S of Moon
Sun	16th	Mercury at greatest latitude north
Sun	16th	3 am (1 am WST) Uranus stationary
Mon	17th	6 am (4 am WST) star Pollux 4° N of Moon
Mon	17th	7 pm (5 pm WST) m.p. 4 Vesta 2° S of Moon
Mon	17th	pm m.p. 129 Antigone 1.4°W of star Rho^1 Sagittarii
Tue	18th	1 am (11 pm WST, prev day) Mercury in superior conjunction
Wed	19th	12:42 pm (10:42 am WST) New Moon
Wed	19th	pm m.p. 7 Iris 1.0°SE of NGC 6440 (GC) in Sagittarius
Fri	21st	9 pm (7 pm WST) Moon at perigee, 363,513 km
Sat	22nd	pm m.p. 42 Isis 0.5°N of star Delta Scorpii
Sun	23rd	6 am (4 am WST) star Spica 7° S of Moon
Sun	23rd	8 am (6 am WST) m.p. 3 Juno 4° N of Moon
Mon	24th	Venus 0.6°S of star Zeta Geminorum
Tue	25th	m.p. 3 Juno 0.8°SW of star Zeta Virginis
Wed	26th	3:58 am (1:58 am WST) First Quarter Moon
Wed	26th	3 pm (1 pm WST) star Antares 6° S of Moon
Thu	27th	7 pm (5 pm WST) Comet 2P/Encke 1.8°S of star Tau Librae
Fri	28th	10 pm (8 pm WST) d.p. Ceres at opposition
Sat	29th	m.p. 4 Vesta 0.2°SW of M44 Beehive Cluster (OC) in Cancer
Sat	29th	Noon (10 am WST) Jupiter 1.5° N of Moon
Sat	29th	9 pm (7 pm WST) d.p. Pluto 1° N of Moon
Sun	30th	3 am (1 am WST) Saturn 2° N of Moon
Mon	31st	am m.p. 11 Parthenope 0.3°S of star Xi^2 Ceti

Jupiter's Satellites for August

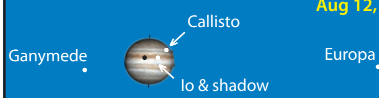
1 arc min.

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 3, 9:15 pm EST (7:15 pm WST)

Satellite events involving Callisto are a little rare. This outermost Galilean moon has just reappeared from occultation and is about to be eclipsed by Jupiter's shadow.

Aug 12, 2:00 am EST (midnight 11th WST)



Io and shadow plus Callisto are in transit with Ganymede coming out of eclipse. For the last 90 minutes (i.e. from Io starting to transit), only one moon (Europe) has been visible away from Jupiter's disc.

Aug 18, 11:00 pm EST (9:00 pm WST)

Ganymede will shortly be occulted (pass behind) Jupiter. Io and its shadow will transit across Jupiter during the morning of the 19th.

Aug 21, 9:00 pm EST (7:00 pm WST)

Io is currently coming out of eclipse which will result in all four moons on one side.

Aug 28, 11:00 pm EST (9:00 pm WST)

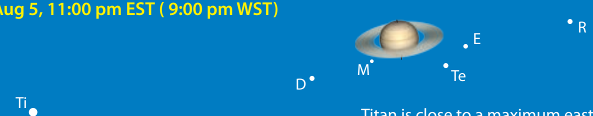
Io has just reappeared from eclipse and Callisto's shadow has commenced a transit.

Saturn's Satellites for August

N
E
1 arc min.

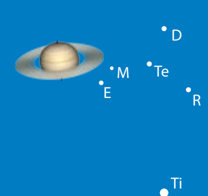
Below are a few interesting patterns of the brightest moons, see also the Introduction to Part I and Satellites of Saturn (Part II) where you can work out the configuration at any time.

Aug 5, 11:00 pm EST (9:00 pm WST)



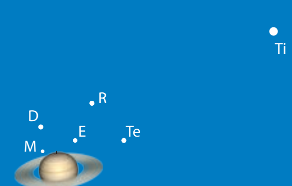
Titan is close to a maximum eastern elongation with the moons strung out in a near straight line.

Aug 9, 11:00 pm EST (9:00 pm WST)



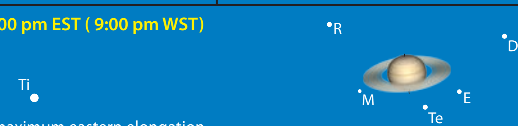
An interesting gathering of the moons on the west side of Saturn.

Aug 15, 11:00 pm EST (9:00 pm WST)



Another grouping of moons, this time on the north side of Saturn.

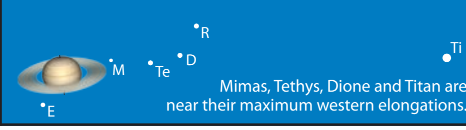
Aug 20, 11:00 pm EST (9:00 pm WST)



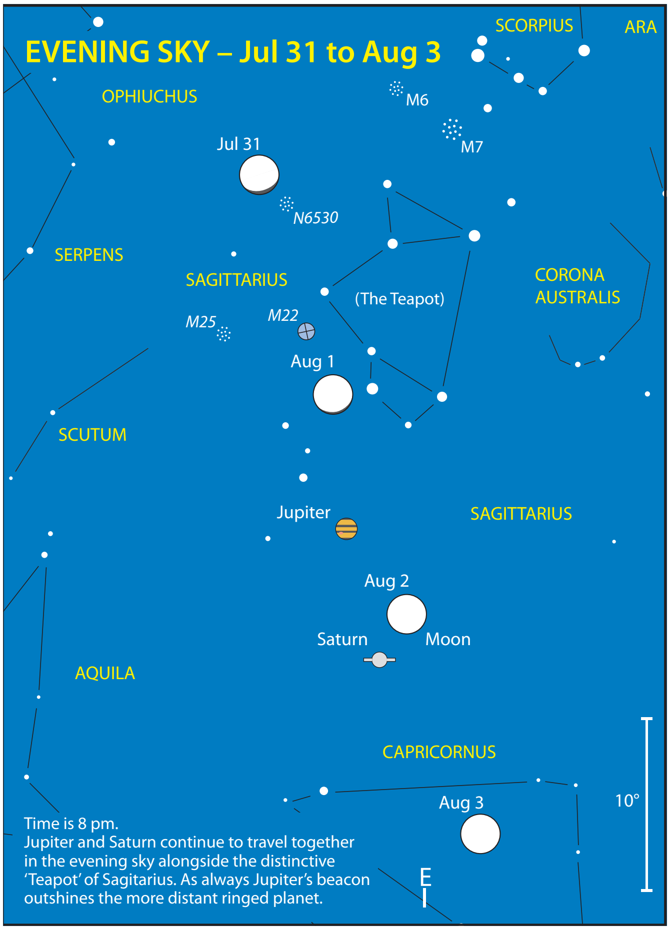
Titan is at a maximum eastern elongation with the remaining moons well scattered around Saturn.

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

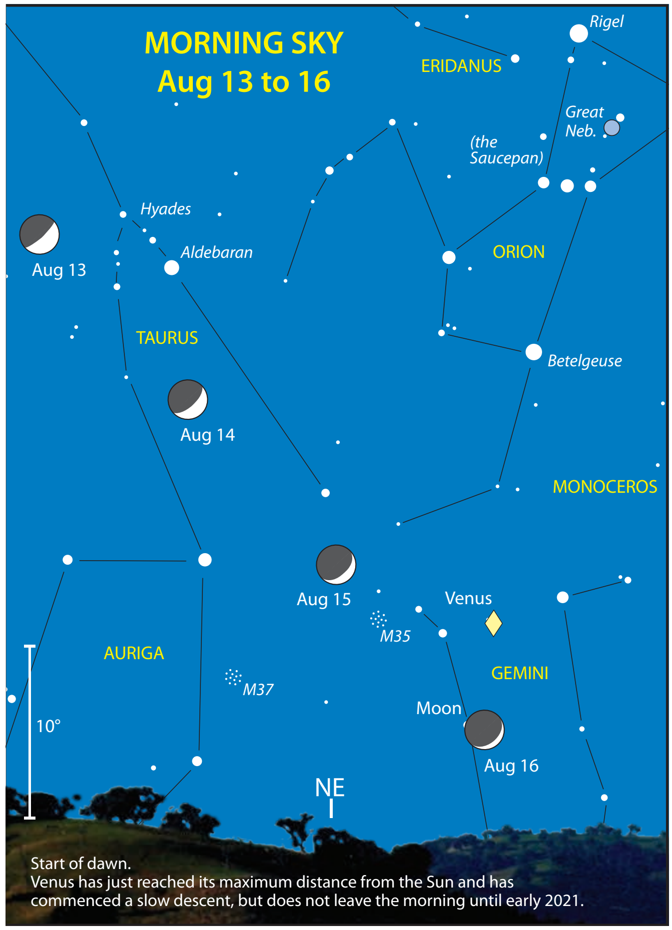
Aug 28, 11:00 pm EST (9:00 pm WST)



Mimas, Tethys, Dione and Titan are near their maximum western elongations.

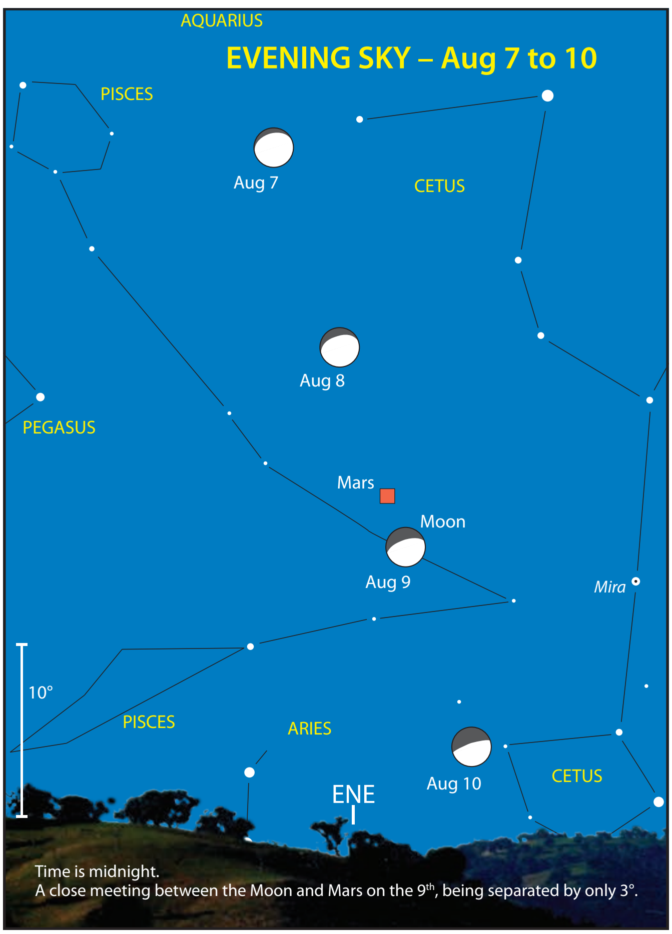


Time is 8 pm.
Jupiter and Saturn continue to travel together in the evening sky alongside the distinctive 'Teapot' of Sagitarius. As always Jupiter's beacon outshines the more distant ringed planet.

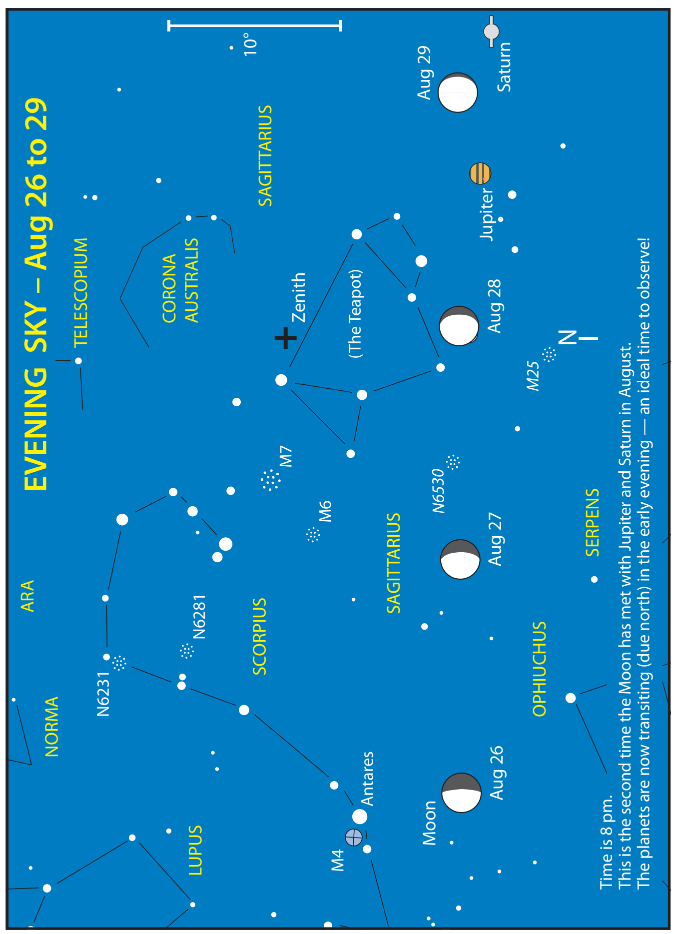


Start of dawn.
Venus has just reached its maximum distance from the Sun and has commenced a slow descent, but does not leave the morning until early 2021.

Approximate local standard time.

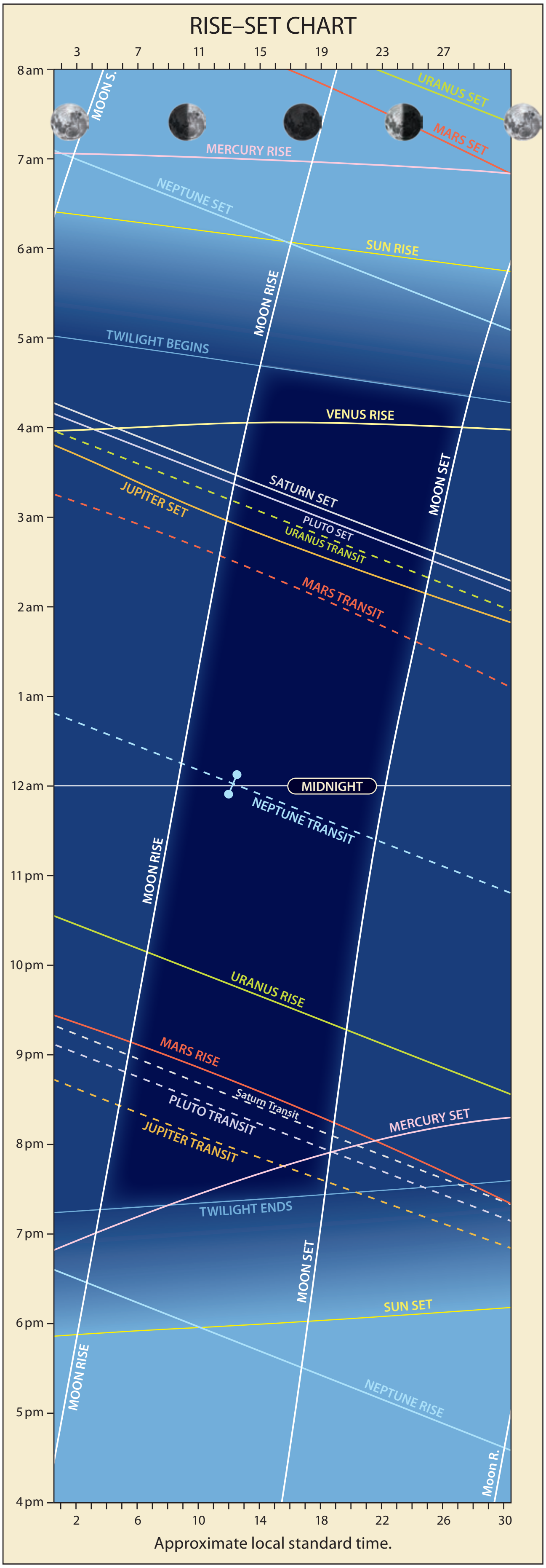


Time is midnight.
A close meeting between the Moon and Mars on the 9th, being separated by only 3°.



Time is 8 pm.
This is the second time the Moon has met with Jupiter and Saturn in August.
The planets are now transiting (due north) in the early evening — an ideal time to observe!

SEPTEMBER 2020



HIGHLIGHTS

- ❍ Mercury, Spica and Moon form a neat triangle.
- ❍ Mercury and Spica close.
- ❍ Moon near Mars.
- ❍ Moon and Jupiter very close and an opportunity to see the planet in daylight.
- ❍ Neptune at opposition.

CONSTELLATIONS

With the Milky Way now getting lower in the west, the sky becomes less cluttered with multitudes of stars and bright deep sky objects. What has rotated into view are a number of fainter constellations, which to the suburban observer are becoming even more obscure as the night sky grows brighter from light pollution. When these patterns were assigned their myths, they were quite obvious to the ancients—all done with their unaided eyes! Now, thanks to the brightening sky many of us have to travel further and further afield to get the same experience.

In August Constellations we used the humble pair of binoculars to explore the wonders of the Milky Way, such as bright and dark nebulae, from the country. Now, we'll turn these aids on fainter star asterisms from the city. Most of the following are made up of stars of around 4th magnitude and may be easier to recognise from suburbia without the multitude of other, slighter fainter stars visible under dark skies. Also, it is a good idea to take note of how many degrees you can see at once (normally marked on the binoculars) compared to the size of the asterism, that is, will it fit into one field? If you get lost the All Sky Maps can help.

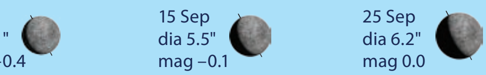
APPEARANCE of the PLANETS

MERCURY

5 Sep
dia 5.1"
mag –0.4

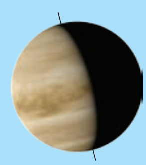
15 Sep
dia 5.5"
mag –0.1

25 Sep
dia 6.2"
mag 0.0



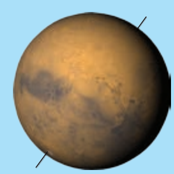
VENUS

15 Sep
dia 17.4"
mag –4.2



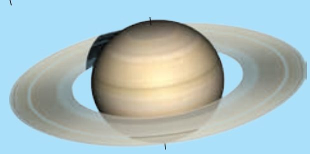
MARS

15 Sep
dia 20.9"
mag –2.1

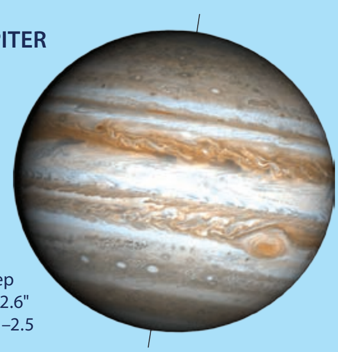


SATURN

15 Sep
dia 17.6"
mag 0.4



JUPITER



15 Sep
dia 42.6"
mag –2.5

URANUS

15 Sep
dia 3.7"
mag 5.7

NEPTUNE

Opposition
12 Sep
dia 2.4"
mag 7.8

PLUTO

15 Sep
dia 0.1"
mag 14.7

Working away from the Milky Way, first up is Delphinus, located 10° east of the bright star, Altair. Its most distinctive feature is four stars in a tight diamond shape (3°) with one above, totalling 6° in length. Next up is Corona Australis (under the base of Sagittarius' Teapot) where you can follow its semicircle of stars as it curves around for approximately 8°. Just above the Great Square of Pegasus is the Circlet of Pisces. Its six stars are arranged in a hexagon about 6° across. Jump 12° westward to Aquarius' Water jar, a distinctive group of four stars with three in a triangle (4° wide) and one in the middle.

Here's an easy one to finish with. The bright star Vega can't be missed low in the north-west (warning: it does set early). This is the alpha star of Lyra. The remainder of this small constellation can be summed up by four stars arranged in a narrow rectangle (the long side measuring 5°), starting only 2° above Vega. Happy hunting!

DIARY			
Wed	2nd		m.p. 2 Pallas stationary
Wed	2nd	3 am	(1 am WST) star Pollux 8° N of Venus
Wed	2nd	3:22 pm	(1:22 pm WST) Full Moon (399,203 km)
Wed	2nd	pm	m.p. 42 Isis 0.4°S of M80 (GC) in Scorpius
Thu	3rd		Comet 88P/Howell 0.9°S of star Iota[1] Librae
Thu	3rd	7 am	(5 am WST) Neptune 4° N of Moon
Sat	5th	8 pm	(6 pm WST) Comet 88P/Howell 0.1°S of NGC 5897 (GC) in Libra
Sun	6th	3 pm	(1 pm WST) Mars 0.03° S of Moon
Sun	6th	4 pm	(2 pm WST) Moon at apogee, 405,607 km
Sun	6th	pm	m.p. 7 Iris 0.7°S of M23 (OC) in Sagittarius
Mon	7th	2 pm	(Noon WST) Uranus 3° N of Moon
Tue	8th		Mercury at descending node
Tue	8th	pm	m.p. 532 Herculina 1.1°SW of M28 (GC) in Sagittarius
Thu	10th	4 am	(2 am WST) Mars stationary
Thu	10th	5 am	(3 am WST) star Aldebaran 4° S of Moon
Thu	10th	7:26 pm	(5:26 pm WST) Last Quarter Moon
Sat	12th		Comet 2P/Encke 2.6°N of star Epsilon Scorpii
Sat	12th	6 am	(4 am WST) Neptune at opposition
Sun	13th	10 am	(8 am WST) Jupiter stationary
Sun	13th	3 pm	(1 pm WST) star Pollux 4° N of Moon
Mon	14th		Mercury 0.5°W of NGC 4697 (G) in Virgo
Mon	14th	3 pm	(1 pm WST) Venus 4° S of Moon
Tue	15th		Venus 1.0°S of star Delta Cancri
Tue	15th	2 am	(Midnight WST, prev day) m.p. 4 Vesta 2° S of Moon
Tue	15th	pm	m.p. 532 Herculina 0.9°SW of star Lambda Sagittarii
Wed	16th	2 am	(Midnight WST, prev day) star Regulus 4° S of Moon
Thu	17th	9:00 pm	(7:00 pm WST) New Moon
Fri	18th		Mercury 0.5°S of NGC 4958 (G) in Virgo
Fri	18th		Comet 88P/Howell 1.3°S of star Delta Scorpii
Fri	18th	Midnight	(10 pm WST) Moon at perigee, 359,082 km
Fri	18th	pm	d.p. Ceres 0.8°N of NGC 7314 (G) in Piscis Austrinus
Sat	19th		Mercury at aphelion
Sat	19th	8 am	(6 am WST) Mercury 6° S of Moon
Sat	19th	3 pm	(1 pm WST) star Spica 7° S of Moon
Sun	20th	7 am	(5 am WST) m.p. 3 Juno 4° N of Moon
Tue	22nd	7 pm	(5 pm WST) star Spica 0.5° S of Mercury
Tue	22nd	9 pm	(7 pm WST) star Antares 6° S of Moon
Tue	22nd	Midnight	(10 pm WST) Equinox
Wed	23rd	7 pm	(5 pm WST) m.p. 4 Vesta 2° N of Venus
Wed	23rd	pm	m.p. 532 Herculina 0.8°S of NGC 6638 (GC) in Sagittarius
Thu	24th		Comet C/2017 T2 (PANSTARRS) 0.6°NE of star Mu Virginis
Thu	24th		Comet 88P/Howell 0.6°N of star Sigma Scorpii
Thu	24th	11:55 am	(9:55 am WST) First Quarter Moon
Fri	25th	5 pm	(3 pm WST) Jupiter 1.5° N of Moon
Sat	26th		Comet 88P/Howell 0.9°NE of NGC 6144 (GC) in Scorpius
Sat	26th		Comet 88P/Howell 1.0°N of star Antares
Sat	26th		Venus at ascending node
Sat	26th	2 am	(Midnight WST, prev day) d.p. Pluto 1.5° N of Moon
Sat	26th	7 am	(5 am WST) Saturn 2° N of Moon
Tue	29th	1 pm	(11 am WST) Saturn stationary
Wed	30th	Noon	(10 am WST) Neptune 4° N of Moon

Proxima

In 1915, an astronomer named Richard Thorburn Ayton Innes (1861–1933) was blinking plates taken at the Union Observatory in Johannesburg using the 10-inch Franklin-Adams Telescope. The first plate taken in April 1910 of the region around the double star Alpha Centauri was blinked against one taken in July 1915. After spending about 40 hours (over a period of a fortnight) studying the plates he discovered a faint star about 2° from Alpha Centauri that had moved, and this star had a similar proper motion to Alpha.

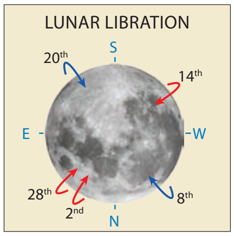
Innes believed the star to be closer than Alpha Centauri, but parallax measures would be the only way to prove this. He was beaten to the punch by a Dutch astronomer named Joan Voûte who published his results first. Soon after Innes came up with his own value for the parallax, partly based on Voûte's results. Innes announced in 1917 (without sufficient evidence) that the star must be the nearest star to our Solar System and suggested the name Proxima Centaurus "nearest (star) of Centaurus". It would be another decade or so before a precise value of Proxima's parallax was determined and Innes' guess proved correct.

Long suspected as being a third component of the Alpha Centauri AB system, it wasn't until 2017 that it was established the three bodies were gravitationally bound. The difficulty in making this observation lay in Proxima's faintness, making it hard to reliably estimate its radial velocity. Measures made with the HARPS instrument on the 3.6-metre telescope at the ESO's La Silla Observatory in Chile provided the necessary accuracy for each star in the system, showing that they are indeed a triplet.

At 4.23 light-years distant, Proxima (also known as Alpha Centauri C) has an apparent visual magnitude of 11 and requires at least a 100 mm aperture telescope to view it. It currently orbits the AB pair at a distance of around 13,000 au with a period of 550,000 years. Compared with our Sun its angular diameter is just $^1/_7$th, mass around $^1/_8$th and an average density of about 33 times. If viewed from the AB pair the dwarf would appear as a faint 5th magnitude star.

Proxima is one of billions of red dwarf stars littered throughout our galaxy. All of which are too dim to be seen with the unaided eye. Their small masses (a few tenths that of the Sun) make them much cooler and fainter than our Sun and undetectable beyond about 1,000 light-years. Many of these stars belong to a remarkable type of variable star known as flare stars, of which UV Ceti is the class prototype.

THE MOON



2nd 4 am (2 am WST) Maximum Libration (7.4°), bright NE limb. The 160 km dark floored Mare Humboldtianum seen to best advantage during this libration.

2nd 3 pm (1 pm WST) Full Moon.

6th 4 pm (2 pm WST) Moon at apogee (furthest from Earth at 405,607 km).

8th 11 am (9 am WST) Minimum Libration (5.0°), bright NW limb.

10th 7 pm (5 pm WST) Last Quarter.

14th 8 pm (6 pm WST) Maximum Libration (8.1°), bright SW limb. The 300 km Mare Orientale brought into view. One of the youngest of the lunar basins, it is only visible during favourable librations such as this one.

17th 9 pm (7 pm WST) New Moon.

18th Midnight (10 pm WST) Moon at perigee (closest to Earth at 359,082 km).

20th 3 pm (1 pm WST) Minimum Libration (5.7°), bright SE limb. The 141 km flooded walled plain Lyot brought into view.

24th Noon (10 am WST) First Quarter.

28th 7 am (5 am WST) Maximum Libration (8.1°), bright NE limb.

THE PLANETS

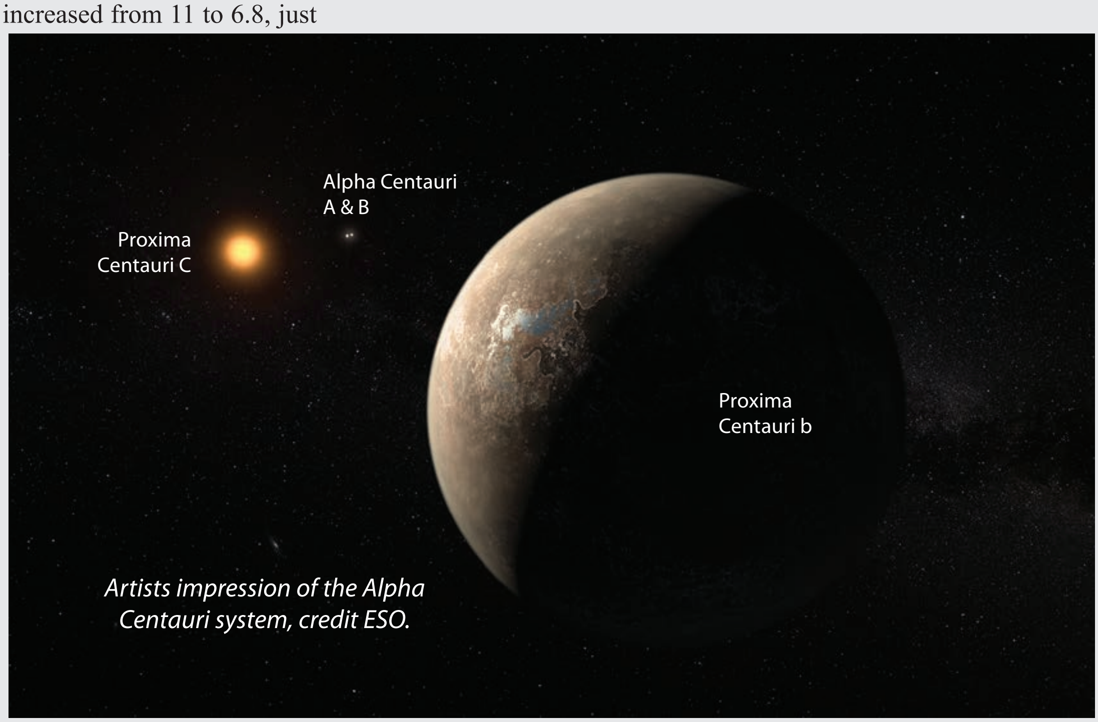
Mercury begins its best period for evening observation this month. Meandering through Virgo, the smallest of planets will be visible from midmonth in a dark sky at the end of astronomical twilight. A very pleasant sight awaits naked-eye observers on the 19th when the 2-day old waxing crescent Moon, the 1st magnitude star Spica and Mercury form a neat triangle in the western sky (see Sky View). A few days later on the 22nd Mercury and Spica appear just 0.3° apart, the

Flare stars can dramatically surge in brightness over a wide wavelength range from X-rays to radio waves. Occurring at irregular and unpredictable intervals, a flare can last from a few minutes to several hours.

Proxima had been a suspect flare star back in the 1950s and has been monitored since then. In the 1960s there was an amateur/professional collaboration involving the CSIRO Radiophysics Division and the Astronomical Society of NSW. This joint effort combined both optical and radio observing, to find if there was any correlation between visual flares and radio outbursts. The programme lasted ten years with UV Ceti and Proxima being two of the targets.

In March 2016, the Evryscope (an array of small telescopes continuously monitoring the sky) detected a massive flare from Proxima. In the previous two years the Evryscope recorded 23 other large flares, but this was 10 times the size of any of those. Proxima's brightness increased by 1,000 times over 10 seconds, this was followed by a smaller flare, with the whole event lasting less than two minutes. Proxima's apparent visual magnitude increased from 11 to 6.8, just below the naked-eye threshold.

There was much excitement when astronomers announced the presence of an exoplanet (Proxima b) in orbit around Proxima in 2016. The planet, about 1.3 times the mass of the Earth, orbits just 7.5 million km (0.05 au) from Proxima, completing one lap every 11.2 Earth days. Because Proxima is small and faint, its habitable or goldilocks zone is much closer in than say a star like our Sun. It is in this region where Proxima b orbits.



Artists impression of the Alpha Centauri system, credit ESO.

Although there was initially some hope that Proxima b was an Earth-type life bearing planet, it is now considered unlikely. There are several factors that affect its candidature as a nearby abode of life as we know it. It is very likely to be tidally locked to its parent star, one side very hot, the other extremely cold and dark. The constant bombardment of powerful flares, not to mention the occasional super-flare, would eventually strip any existing atmosphere away. It is also estimated that the UV light produced by the recent super-flare reached Proxima b with 100 times the intensity required to kill even UV-hardy micro-organisms.

These findings have serious implications in the hunt for Earth-like exoplanets. Red dwarf stars account for roughly 75% of the Galaxy's stellar population, and two-thirds of these are active flare stars. Although greatly reducing the number of stars that may harbour life supporting planets, we are still left with billions of candidates.

"The Universe is a pretty big place. If it's just us, seems like an awful waste of space." – Carl Sagan.

planet is north (right) of Spica and at zero magnitude is a full magnitude brighter than the star.

Venus, in the morning eastern dawn sky, travels from Gemini, across Cancer and into Leo this month. On the 30th, the planet will be situated within a few degrees of the 1st magnitude star Regulus (Alpha Leonis) the brightest of Leo's stars and the 21st brightest star in the night sky. On the 14th, the 25-day old waning crescent Moon will be north of Venus. While not really close the pair will look stunning in the morning sky (see Sky View).

The **Earth** is at its vernal (spring) equinox on the 22nd. From any place on Earth the Sun rises due east and sets due west, day and night are equal.

Rising around 8:30 pm midmonth, **Mars** begins retrograde motion against the background stars on the 10th. This reversal continues until 16th November with the planet appearing to move backwards (toward the west) in Pisces. With opposition approaching in mid-October, Mars increases in angular diameter during the month from 19 to a little over 22 arcseconds and brightens from –1.8 to –2.5 magnitude. The beginning of September through to the end of October is the optimum period for visual observers. On the 5th the 18-day old waning gibbous Moon appears near the planet and a little closer on the following evening (see Sky View).

Jupiter is visible high in the northern sky as it transits the meridian around astronomical dusk. On the 13th, the planet appears stationary as it comes to the end of four months of retrograde motion. After a comparatively close association between the Solar System's two largest planets during the year, this reversal in Jupiter's apparent motion will culminate in a very intimate conjunction in December.

On the 25th, the 9-day old Moon appears less than 2° (3° from WA) from the planet in the early evening sky (see Sky View). Jupiter (and Venus) are bright enough to be seen with the naked-eye and binoculars in the daytime if you know where to look. This conjunction between the Moon and Jupiter provides the perfect opportunity for this challenge. During mid-afternoon the Moon's northern limb will be just two Moon diameters from Jupiter, an ideal marker to find the planet. Use binoculars first on the Moon and once you spot the planet and note its position lower the binoculars and try to see the planet's bright pinprick of light without optical aid.

In Sagittarius, **Saturn** transits the meridian (is due north and at its highest altitude) around 8 pm midmonth. The planet appears stationary on the 29th as it comes to the end of its 4.5-month retrograde loop, it thereafter resumes its west to east motion across the sky. Saturn has at least 62 satellites, the brightest at 8.4 magnitude is Titan. It can be easily seen in a small telescope or good binoculars. Another six moons become available to instruments in the 200 to 250 mm range (Mimas, Enceladus, Tethys, Dione, Rhea and Iapetus) although identification can be difficult. When the planet's rings are open these fainter moons can be harder to separate from background stars as they tend to be scattered all around the planet, unlike the neat orderly shuffling of Jupiter's Galilean moons. See page 128 for details on where the Saturnian satellites are located during the year.

Uranus rises in the mid-evening eastern spring sky in Aries, just a few degrees from the tail region of Cetus the Whale.

Neptune is at opposition on the 12th and is visible in the eastern sky after the end of astronomical twilight in Aquarius. With an opposition diameter of 2.4 arcseconds it is close to the limit that an amateur telescope under good seeing can resolve into a perceptible disc. The planet's largest moon, Triton at 2,706 km in diameter, is the seventh largest moon in the Solar System. It is the only large moon with a retrograde orbit and after our own Moon is the largest in relation to its primary. At 13th magnitude, a moderately large telescope (250–300 mm) is required to see this moon, thought to be a captured dwarf planet from the Kuiper Belt (to calculate its position relative to Neptune see page 131).

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto**, in Sagittarius, crosses the meridian (is due north) around 8 pm midmonth.

Brightest **Minor Planets** at opposition this month include:

Date	Minor Planet	Constellation	Mag.
9 Sep	17 Thetis	Aquarius	10.7
10 Sep	22 Kalliope	Aquarius	10.5
11 Sep	19 Fortuna	Pisces	9.2
19 Sep	32 Pomona	Pisces	11.3
30 Sep	68 Leto	Cetus	9.5

COMETS

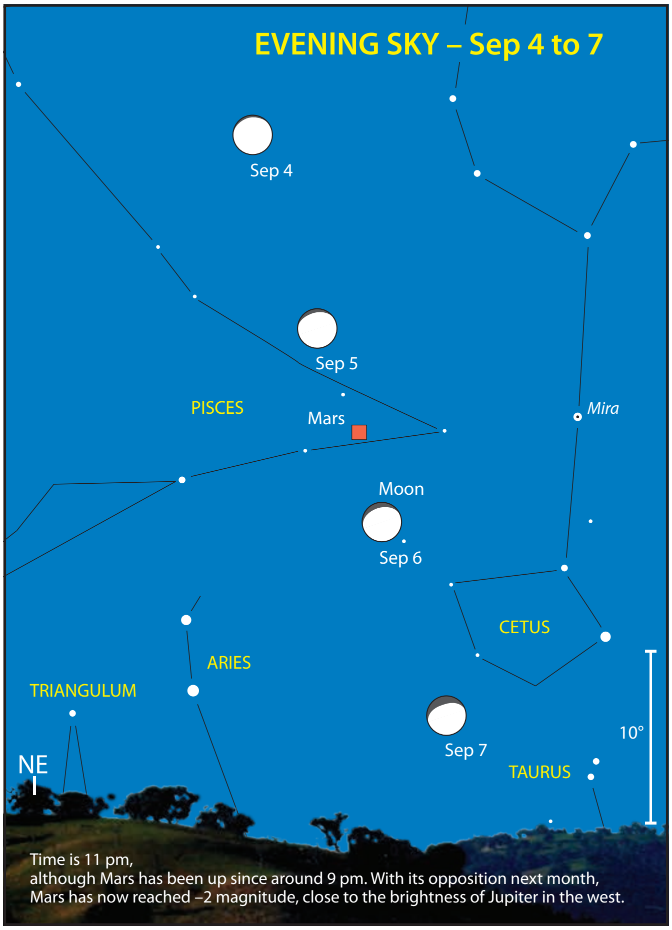
Comet 2P/Encke, setting around 1 am, is likely to fade from 11th to 13th magnitude this month as it moves from the constellation of Lupus into Scorpius (and the Milky Way environs) in the evening sky.

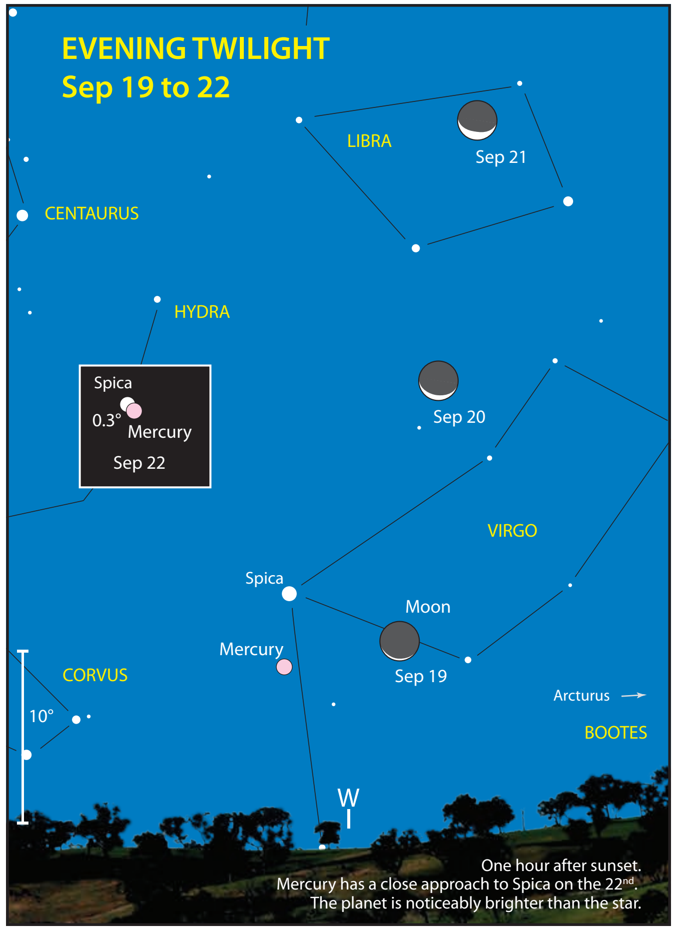
Comet 88P/Howell reaches perihelion this month on the 27th at a distance of 1.35 au from the Sun. Shining at 9th magnitude, the comet opens September in the constellation Libra, moving into Scorpius midmonth, and is setting late in the evening. From mid-September to early November, Howell has an impressive tour of the galactic hub, including quite a few bright stars and deep sky objects—imaging opportunities! See diary entries.

Comet C/2017 T2 (PANSTARRS) is in the constellation Virgo for all but the last few days of September, when it moves into Libra. Setting around 9 pm, PANSTARRS is predicted to fade from 9th to 10th magnitude by month's end.

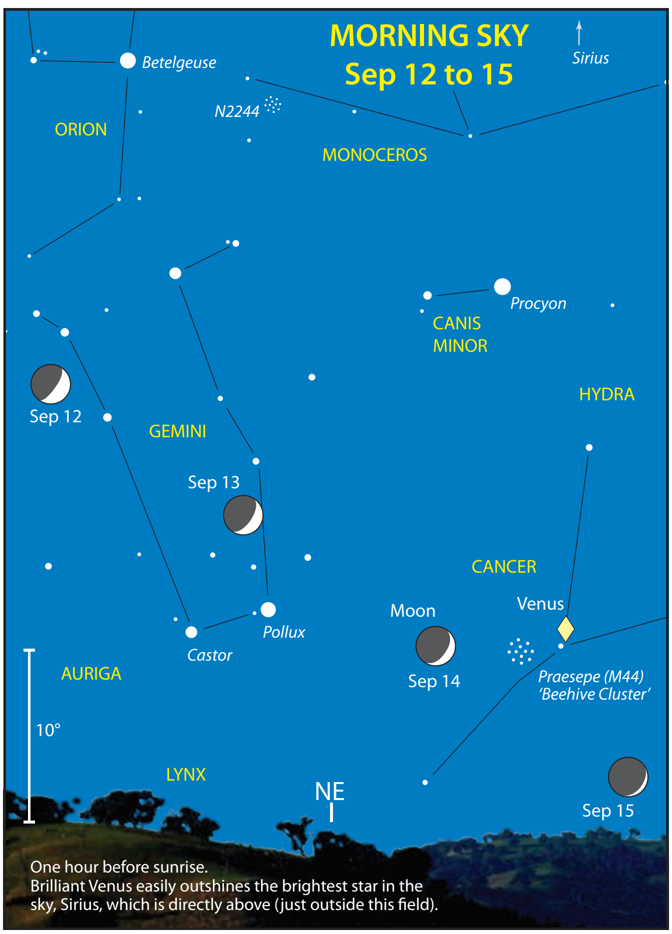
DOUBLE STARS

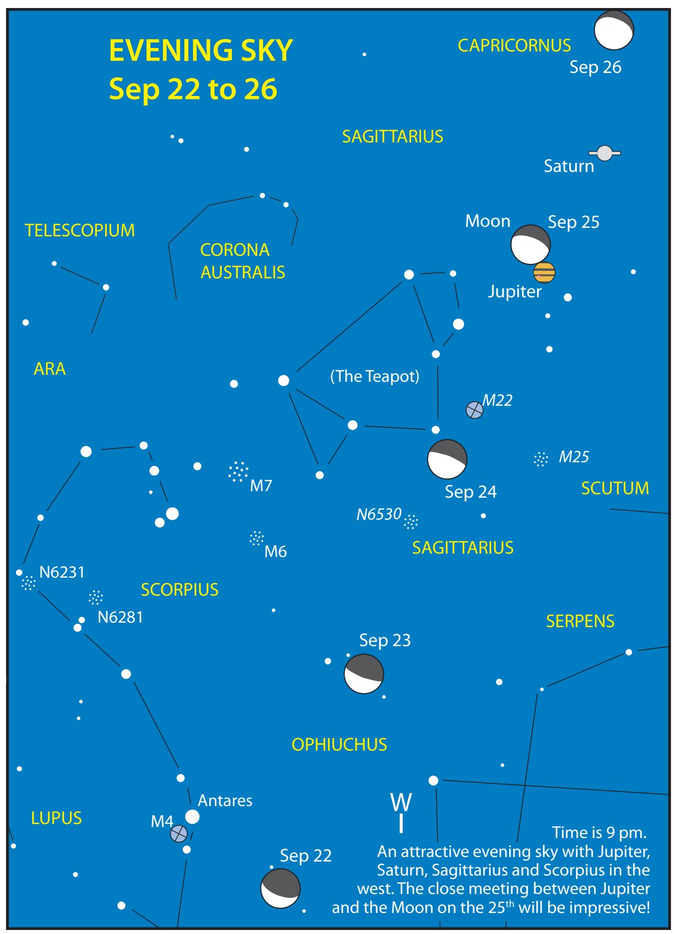
Gamma (γ) Piscis Austrini is a double star in the constellation of the Southern Fish, not far from the bright star Fomalhaut. The stars are an unequal pair with magnitudes 4.5 (A) and 8.2 (B) separated by 4.0 arcseconds with a position angle of 255°. The white A component is a chemically interesting star with an atmosphere rich in heavy elements, spectral class A0VpSrCrEu and is estimated to be about 214 million years old with a mass 2.9 times that of the Sun. The B component is a F5V main sequence star. The pair show common proper motion and probably represent a binary system. The orbital period is uncertain and is estimated to be about 3,000 years. The system is currently located about 216 light-years from the Sun. However, about 1.8 million years ago it came closest to the Sun at a distance of 157 light-years.





Approximate local standard time.





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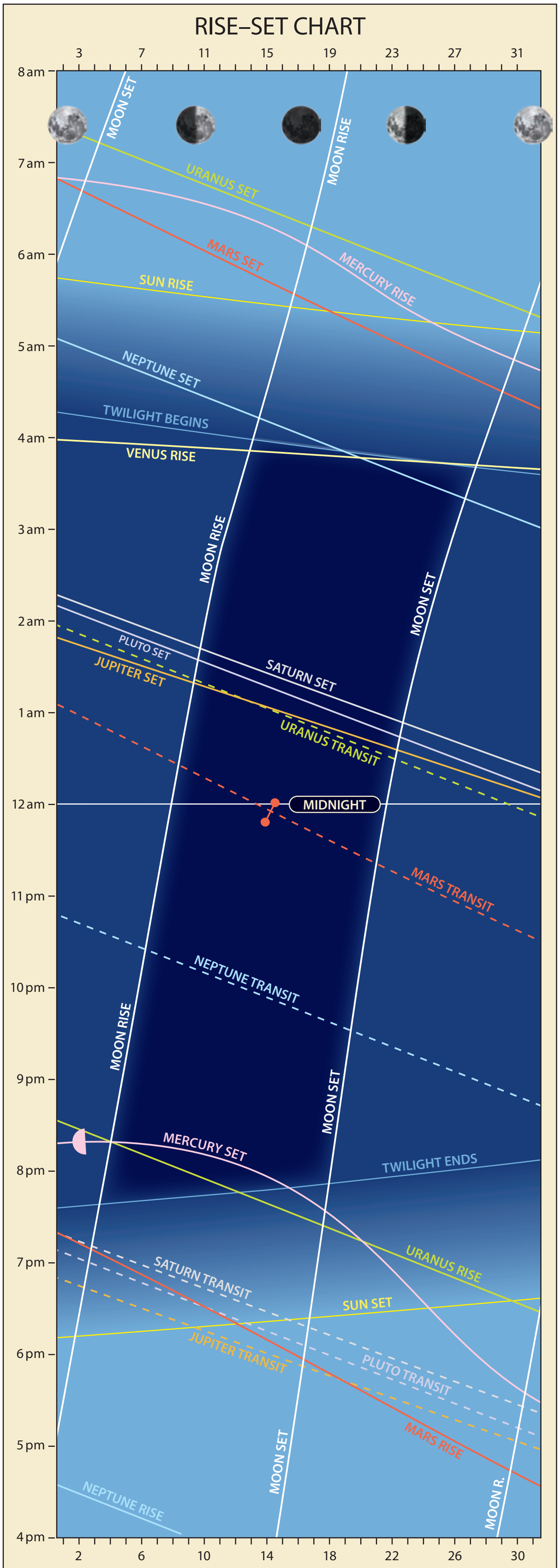


Approximate local standard time, for daylight saving add 1 hour.

HIGHLIGHTS

- Mars at opposition.
- Mars and Moon close twice this month.
- Venus and Regulus very close.
- Jupiter, Saturn and Moon together.

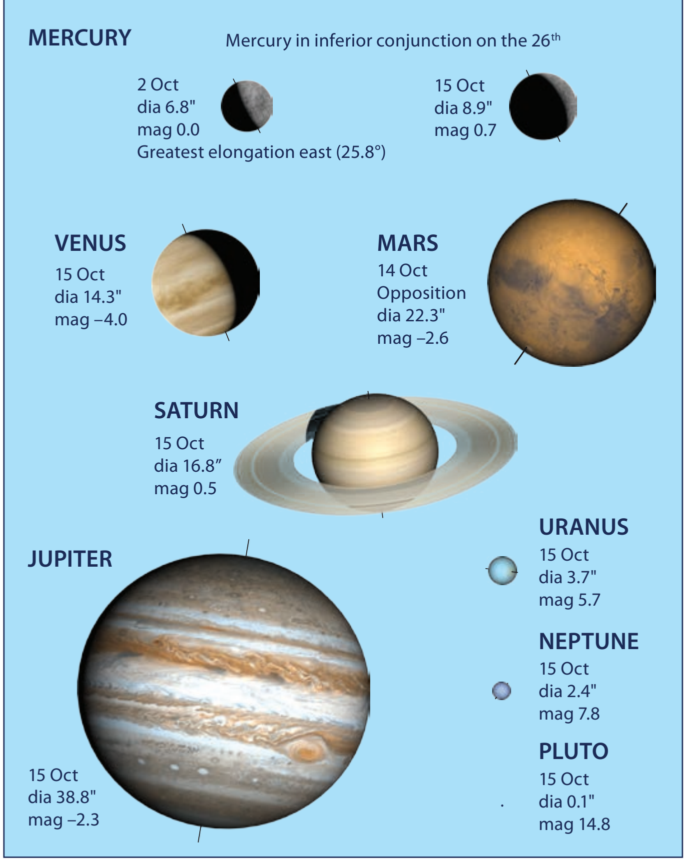
CONSTELLATIONS

Spring is very much a transition phase, between the famous Milky Way constellations (its hub and southern regions) of winter departing and the arrival of Summer's galactic treats. Besides the nights getting shorter and warmer, another example of winter's demise is seeing Sagittarius' Teapot tilting over (perhaps spilling its stellar tea) as it sets in the west. Sighting summer's constellation of Orion rising really highlights the naming of the Saucepan asterism. From our southern latitudes its base, the three belt stars, are sitting nearly flat on the eastern horizon.

Continuing our naked-eye review of the constellations making up the signs of the zodiac, from Sagittarius heading eastward there are: Capricornus, Aquarius, Pisces and Aries. It is just as well these constellations have the distinction of the Sun passing through them, for visually, they are a poor show! One notable feature is the Smile asterism (or roof, depending on which way you look) made up by the main, but faint (mostly 4th magnitude) stars of Capricornus.

Starting from Capricornus, let's move south and away from the ecliptic. Next up is Piscis Austrinus, the Southern Fish. At first the only obvious feature is the 1st magnitude *mouth* star, Fomalhaut. From here, fainter stars taper off to the west showing the body (minus tail fins). Next southward is possibly the most distinctive and isolated asterism of the deep

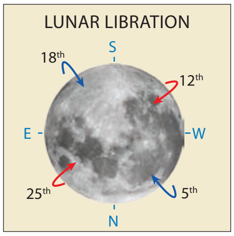
APPEARANCE of the PLANETS



OCTOBER

south, Grus the Crane. Its curved long neck looks like a bow (as in a bow and arrow). Next up, is an isolated bright (0.5 magnitude) star, Achernar. This is the alpha star to one of the longer constellations, Eridanus the River. Try tracing the approximately 40 stars (around 4th magnitude) all the way back to its *headwaters* near Orion.

THE MOON



2nd 7 am (5 am WST) Full Moon.

4th 3 am (1 am WST) Moon at apogee (furthest from Earth at 406,321 km).

5th Midnight (10 pm WST) Minimum Libration (4.4°), bright NW limb.

10th 11 am (9 am WST) Last Quarter.

12th 6 pm (4 pm WST) Maximum Libration (9.1°), bright SW limb. Although not in the zone of librations, the vast 303 km walled plain Bailly is well situated at this time.

17th 6 am (4 am WST) New Moon.

17th 10 am (8 am WST) Moon at perigee (closest to Earth at 356,912 km).

18th 1 pm (11 am WST) Minimum Libration (4.9°), bright SE limb.

23rd 11 pm (9 pm WST) First Quarter.

25th 9 am (7 am WST) Maximum Libration (9.1°), 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 the first half of a lunar month (a few days after New Moon to Full Moon). This prominent feature will be seen to drift back and forth toward the limb as the Moon nods and wobbles in its orbit. Around this date Mare Crisium will be as far from the limb as it can be.

31st 5 am (3 am WST) Moon at apogee (furthest from Earth at 406,394 km).

31st 11 pm (WA only) Full Moon (Blue Moon)

THE PLANETS

Mercury, in the western evening sky, is visible for the first half of October in a dark sky at the end of astronomical twilight. With the planet reaching its greatest elongation east (26°) of the Sun on the 2nd it begins to move back toward Sol and will be in inferior conjunction (between the Earth and the Sun) on the 26th. Next month sees the planet gracing the dawn skies.

Venus opens the month in the eastern dawn sky near the 1st magnitude star Regulus (Alpha Leonis), the brightest of Leo's stars. On the 3rd the pair will be separated by just 0.3°. Of the 100 brightest stars in the sky, Regulus is closest to the ecliptic. Because of its position it is regularly occulted by the Moon and sometimes by Mercury and Venus. The next

DIARY			
Fri	2nd	2 am	(Midnight WST, prev day) Mercury at greatest elongation East (25.8°)
Fri	2nd	7:05 am	(5:05 am WST) Full Moon (405,149 km)
Fri	2nd	pm	m.p. 7 Iris 1.4°S of M24 Sagittarius Star Cloud (OC) in Sagittarius
Sat	3rd		m.p. 52 Europa 0.5°N of star Gamma Geminorum
Sat	3rd		Comet C/2017 T2 (PANSTARRS) 1.0°SW of NGC 5812 (G) in Libra
Sat	3rd	10 am	(8 am WST) star Regulus 0.1° S of Venus
Sat	3rd	1 pm	(11 am WST) Mars 0.5° N of Moon
Sun	4th		d.p. Pluto stationary
Sun	4th	3 am	(1 am WST) Moon at apogee, 406,321 km
Sun	4th	7 pm	(5 pm WST) Uranus 3° N of Moon
Mon	5th		Comet C/2017 T2 (PANSTARRS) 0.3°SW of star Delta Librae
Mon	5th		Comet 88P/Howell 0.4°SE of M19 (GC) in Ophiuchus
Wed	7th		Comet 88P/Howell 0.3°E of NGC 6293 (GC) in Ophiuchus
Wed	7th	Noon	(10 am WST) star Aldebaran 5° S of Moon
Thu	8th	pm	m.p. 11 Parthenope 0.7°SE of NGC 864 (G) in Cetus
Thu	8th	pm	m.p. 471 Papagena 0.7°N of NGC 1084 (G) in Eridanus
Fri	9th		Venus 0.6°NE of star Rho Leonis
Fri	9th		Mercury at greatest latitude south
Fri	9th	pm	m.p. 8 Flora 0.9°NW of star Alpha Ceti
Sat	10th		Comet 88P/Howell 0.6°S of NGC 6355 (GC) in Ophiuchus
Sat	10th	10:40 am	(8:40 am WST) Last Quarter Moon
Sat	10th	Midnight	(10 pm WST) star Pollux 4° N of Moon
Sat	10th	pm	m.p. 532 Herculina 0.3°NE of star Phi Sagittarii
Mon	12th		m.p. 3 Juno 0.3°S of NGC 5634 (GC) in Virgo
Tue	13th		m.p. 7 Iris 0.4°S of M25 (OC) in Sagittarius
Tue	13th	7 am	(5 am WST) m.p. 4 Vesta 2° S of Moon
Tue	13th	Noon	(10 am WST) star Regulus 4° S of Moon
Tue	13th	11 pm	(9 pm WST) Mars 0.1°N of NGC 488 (G) in Pisces
Wed	14th	9 am	(7 am WST) Mars at opposition
Wed	14th	10 am	(8 am WST) Venus 4° S of Moon
Wed	14th	2 pm	(Noon WST) Mercury stationary
Sat	17th		Comet C/2017 T2 (PANSTARRS) 2.4°S of star Beta Librae
Sat	17th	5:31 am	(3:31 am WST) New Moon
Sat	17th	10 am	(8 am WST) Moon at perigee, 356,912 km
Sun	18th		m.p. 2 Pallas 0.7°NE of star Theta Serpentis
Sun	18th	5 am	(3 am WST) Mercury 7° S of Moon
Sun	18th	8 am	(6 am WST) m.p. 3 Juno 5° N of Moon
Sun	18th	pm	m.p. 129 Antigone 0.25°S of Saturn
Sun	18th	pm	m.p. 471 Papagena 0.5°S of NGC 1022 (G) in Cetus
Sun	18th	pm	m.p. 532 Herculina 0.6°S of star Sigma Sagittarii
Tue	20th	6 am	(4 am WST) star Antares 6° S of Moon
Tue	20th	9 pm	(7 pm WST) star Regulus 2° S of m.p. 4 Vesta
Fri	23rd		d.p. Ceres stationary
Fri	23rd	3 am	(1 am WST) Jupiter 2° N of Moon
Fri	23rd	8 am	(6 am WST) d.p. Pluto 1.5° N of Moon
Fri	23rd	2 pm	(Noon WST) Saturn 3° N of Moon
Fri	23rd	11:23 pm	(9:23 pm WST) First Quarter Moon
Mon	26th		Venus 0.8°N of star Beta Virginis
Mon	26th		m.p. 2 Pallas 0.7°SW of NGC 6755 (OC) in Aquila
Mon	26th	4 am	(2 am WST) Mercury in inferior conjunction
Tue	27th	4 pm	(2 pm WST) Neptune 4° N of Moon
Wed	28th		m.p. 532 Herculina 0.8°N of star Tau Sagittarii
Wed	28th		Mercury at ascending node
Thu	29th		m.p. 7 Iris 0.7°N of NGC 6716 (OC) in Sagittarius
Fri	30th		Venus at perihelion
Fri	30th	2 am	(Midnight WST, prev day) Mars 3° N of Moon
Fri	30th	pm	m.p. 11 Parthenope 1.3°NW of star Alpha Piscium
Sat	31st		Comet 88P/Howell 0.2°E of star Phi Sagittarii
Sat	31st	1 am	(11 pm WST, prev day) m.p. 8 Flora 0.008°N of star Gamma Ceti
Sat	31st	5 am	(3 am WST) Moon at apogee, 406,394 km
Sat	31st	11 pm	(9 pm WST) Uranus 3° N of Moon
Sat	31st	pm	m.p. 129 Antigone 0.3°N of M75 (GC) in Sagittarius

lunar occultation is in 2025, the next planetary occultation of Regulus is by Venus in 2044.

Reaching –2.6 magnitude this month, **Mars** appears as a vivid golden orange *star* as it rises in the early evening sky in Pisces. The planet is at opposition on the 14th and attains a diameter of 22.45 arcminutes at closest approach on the 7th. Note that the time of closest approach is not necessarily coincident with the time of opposition and can vary by as much as two weeks. This apparition will be the last favourable one (with a disc diameter above 20 arcseconds) until the July 2033 and September 2035 oppositions.

The last favourable opposition in 2018 was tainted by a planet encircling dust storm that hid surface features (and effectively killed off NASA's storm-struck Opportunity rover). These dust storms tend to be more frequent during the Southern Hemisphere spring and summer when the planet is closest to the Sun. Although obscuring the landscape, the storms are one of the most spectacular Solar System events to watch as they develop. Localised storms will alter the familiar appearance of surface features and planet engulfing storms will hide all but the highest peaks of the huge mountain ranges and volcanoes. Observers will note that by now the south polar cap has shrunk and is just visible as a little white spot. See also Part II where the Martian oppositions are covered in more detail.

On the 2nd, the Full Moon appears above Mars as it rises in the east and on the following evening a little closer and below the planet (see Sky View). Another visitation occurs on the 29th, with the 13-day old waxing gibbous Moon near Mars.

Jupiter is visible in the western evening sky in Sagittarius. Since the planet's July opposition, observers will note a decrease in image size, down from around 48 to 39 arcseconds. Less noticeable but still significant is the brightness decrease from –2.8 to –2.3 magnitude. On the 22nd, the 6-day old waxing crescent Moon appears near the planet (see Sky View).

In Sagittarius, **Saturn** is visible in the western evening sky. On the 18th 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. 16). At this time as the Sun sets, 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 truly 3D appearance. On the 23rd, the First Quarter Moon appears close to the planet (see Sky View).

With opposition at the beginning of November, **Uranus** rises in the east soon after sunset. The planet's magnitude at opposition is 5.7 and those with keen eyesight should have no difficulty seeing this outer world from a dark sky location. If your skies are not perfect, try locating the two 4th magnitude stars in the tail of Cetus (Mu Ceti and Xi^2 Ceti). Then, using binoculars sweep about 6° north of the stars and you will find Uranus forming the apex of an isosceles triangle.

Now past opposition, **Neptune** transits the meridian (is due north) around 9:30 pm midmonth in Aquarius. For those trying to find the outer planet, it remains close to the 4th magnitude star Phi Aquarii, this month approximately 1° east-north-east of the star.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto** appears stationary on the 4th ending five months of retrograde motion. It transits the meridian (is due north) around 6 pm midmonth in Sagittarius. On the night of the 30th, minor planet **Flora** (magnitude 8.0) has a very close encounter with the star Gamma Ceti (see diary).

Brightest **Minor Planets** at opposition this month include:

Date	Minor Planet	Constellation	Mag.
17 Oct	194 Prokne	Cetus	10.6
23 Oct	11 Parthenope	Cetus/Pisces border	9.4
24 Oct	67 Asia	Pisces/Aries border	10.7
26 Oct	471 Papagena	Cetus	9.5
31 Oct	45 Eugenia	Cetus	11.6

COMETS

Comet 88P/Howell is in the constellation Scorpius for the first two days of October, and then spends the rest of the month in Ophiuchus and Sagittarius. On the 16th, Howell passes only 2° north of the galactic centre. From the 26th to November 4 the comet makes a crossing of the Teapot of Sagittarius. Setting late in the evening, it's around 9th magnitude though it will be starting to fade.

Comet C/2017 T2 (PANSTARRS) is low in the early western evening sky and by the end of October deep in the twilight glow. Located in the constellation Libra throughout the month, PANSTARRS should be around 10th magnitude.

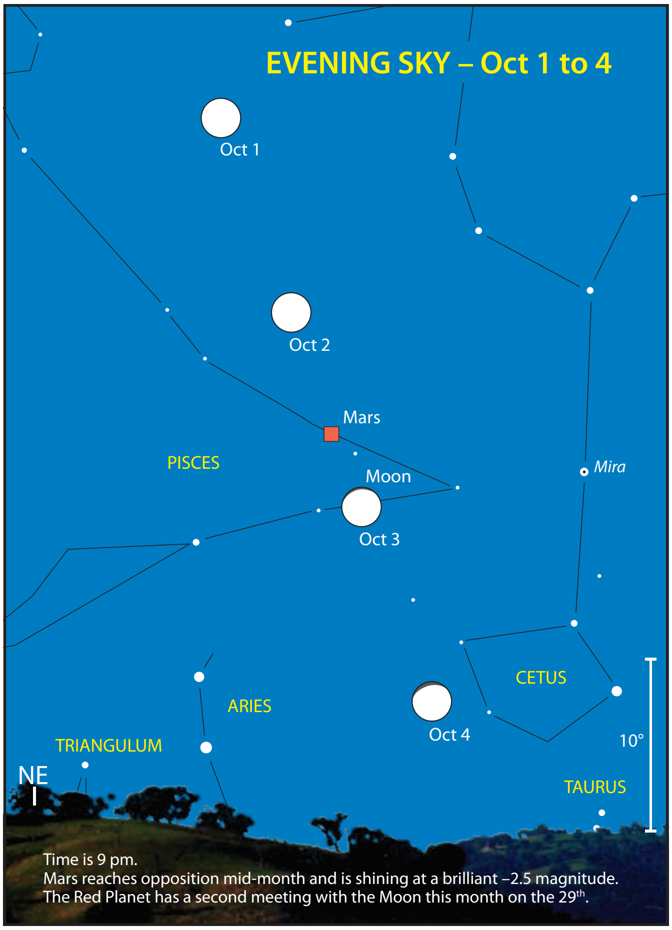
DOUBLE STARS

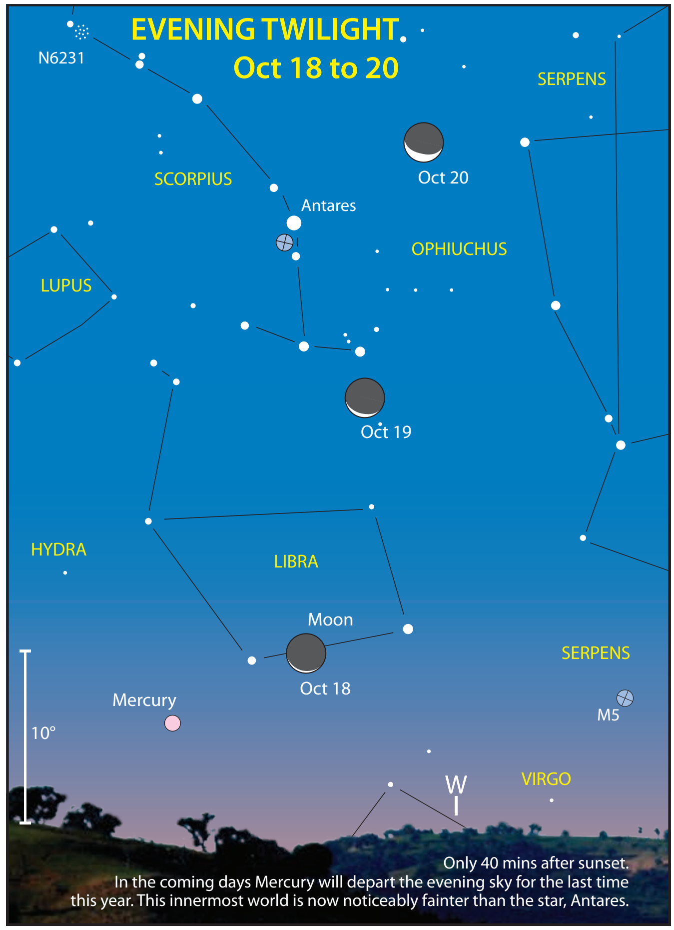
Epsilon (ε) Sculptoris (All Sky Map No 2) is located in a constellation famous for its lovely galaxies, Sculptor. It's a faint southern constellation introduced by Nicolas Louis de Lacaille in the 18th century who originally named it Apparatus Sculptoris (the Sculptor's studio) but the name was later shortened to Sculptor. The stars are magnitudes 5.4 and 8.5 separated by 5.1 arcseconds with a position angle of 20°. The primary is a F2V subgiant with a mass 1.37 times that of the Sun and the secondary is a G9V main sequence dwarf. They appear yellowish-white and yellow respectively. For completeness, there are also two faint optical components C (magnitude 15) and D (magnitude 11.74).

METEOR SHOWERS

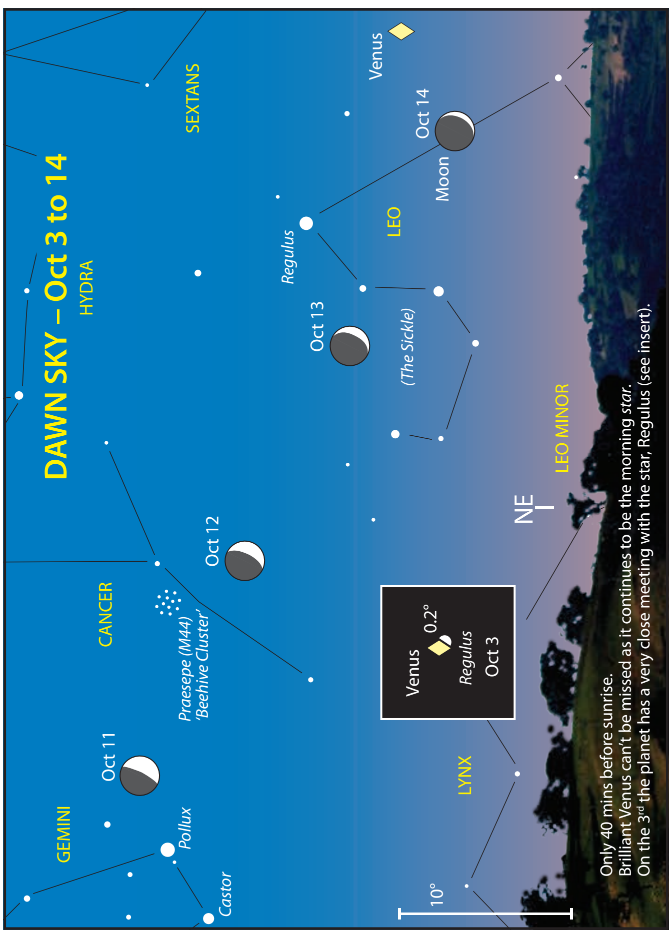
The **Southern Taurids** are bright slow meteors active from September 19 through to November 20. The shower is composed of two radiants of nearly equal activity ten degrees apart. The Southern Taurids peak around October 10 (Last Quarter Moon) and the Northern Taurids next month on the 12th. The Taurids are frequently bright, slow moving, and noted for producing colourful fireballs (although not every year).

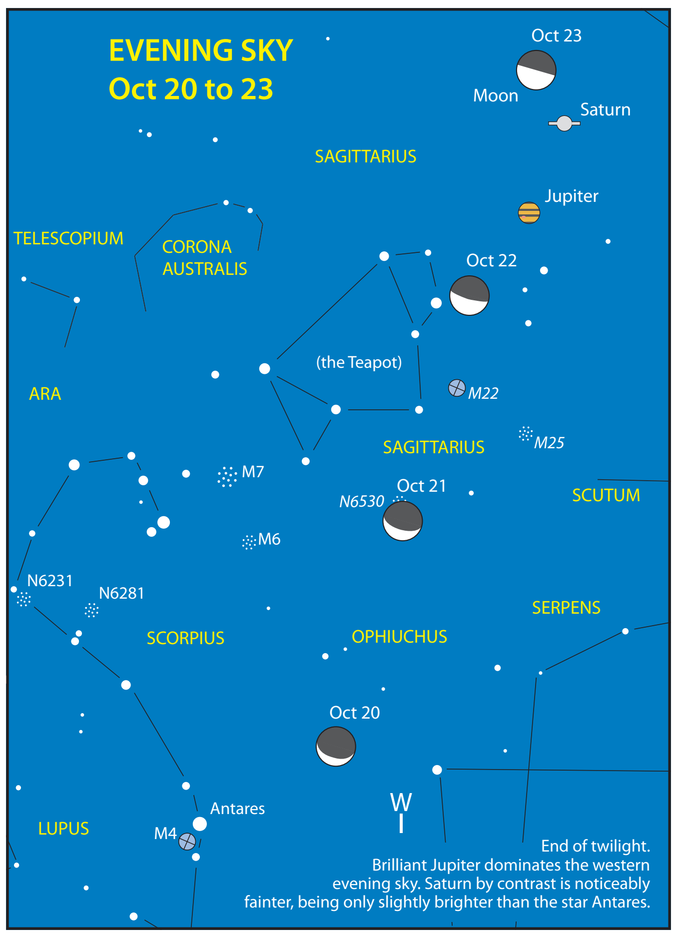
The **Orionids** are best seen from late evening until dawn and are visible from October 2 through to November 7. Maximum activity is expected around the 21st (Moon will be 5 days old and setting around 10 pm) but with many sub-maxima, good rates can be observed on several consecutive nights around this date. The Orionids provide a prominent display that has, over the past twenty years, produced rates of 14 to 31 meteors per hour. Both 2006 and 2007 produced very strong zenith hourly rates, better than the normal peak seen on two or three consecutive nights, at best up to 50–70. The Orionids are typically very swift and often bright, with some leaving trains.





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





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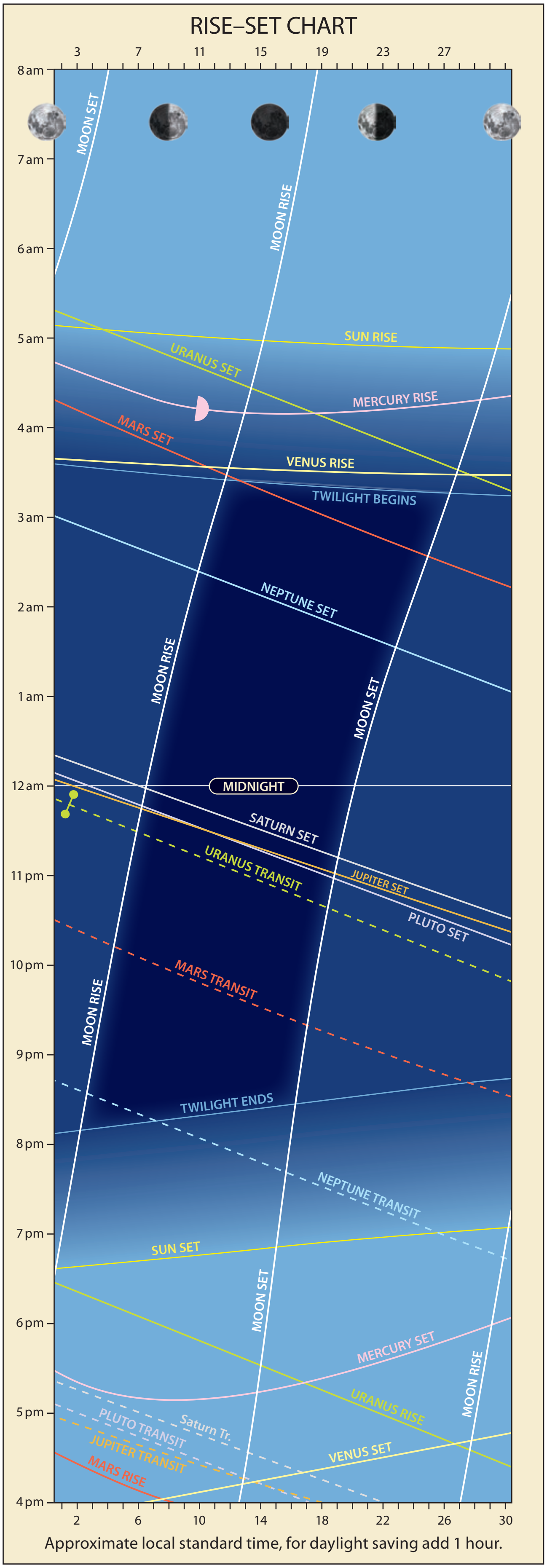


HIGHLIGHTS

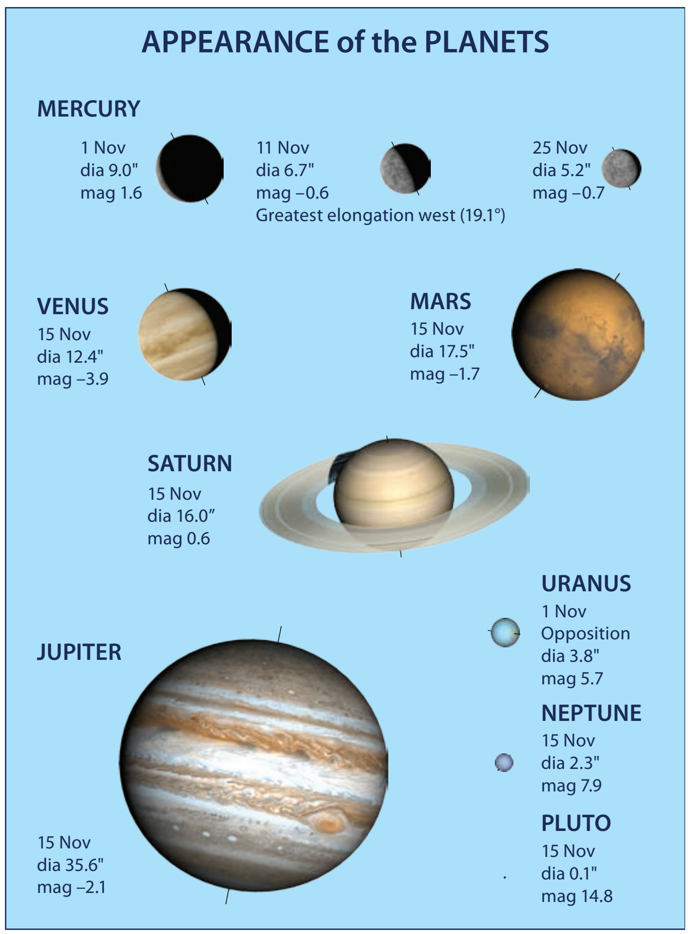
- Venus near the Moon.
- Jupiter, Saturn and Moon form a neat conjunction.
- Uranus at opposition.

CONSTELLATIONS

In the February monthly feature we discussed the origins of the constellations. We mentioned the influence that precession had on the star pattens that were visible at the time to the Northern Hemisphere people who assigned the myths.

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? Maybe there are legends in the Aboriginal Dreamtime of stars no longer visible from Australia (assume, mid-latitude)? At this time the South Celestial Pole (SCP) was located around one degree from the 4.7 magnitude star Eta^2 Hydri (only a slight improvement over 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^2's elevation is about 56° or approximately 22° above the current position of the SCP. So you need to rotate the entire celestial sphere towards the south by 22°, i.e., dropping Eta^2 straight



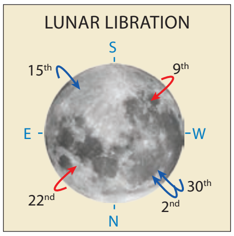
down to an altitude of 34°. The Southern Cross and Pointers, which today are scraping the horizon, are now well below (yes, they were not circumpolar 4,000 years ago).

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.
- 2nd 4 pm (2 pm WST) Minimum Libration (3.6°), bright NW limb.
- 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.
- 15th 7 pm (5 pm WST) Minimum Libration (3.6°), too close to 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 9 am (7 am WST) Minimum Libration (3.0°), Full Moon.
- 30th 8 pm (6 pm WST) Full Moon (Blue Moon for the eastern and central states). Penumbral eclipse visible from Australia (see Part II for details).

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 midmonth. 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).

DIARY

Sun	1st	12:49 am	(10:49 pm WST, prev day) Full Moon (406,167 km, furthest for this year)
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	11:46 pm	(9:46 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	3:07 pm	(1:07 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	2:45 pm	(12:45 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	7:30 pm	(5:30 pm WST) Full Moon (401,726 km)
Mon	30th	Midnight	(10 pm WST) star Aldebaran 5° S of Moon

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 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.

Astronomy of the Inca Part 1

[2] Machu Picchu by Ken Wallace

At its height, in the 15th and 16th centuries, the Incan empire had spread from its base in ancient Peru and encompassed lands from modern day Ecuador, Chile, Bolivia, Argentina and Colombia. The Spanish introduced Smallpox when they landed in what is today Mexico, the disease contributing to the defeat of a weakened Aztec army. By the time Francisco Pizarro and the conquistadors established the first Spanish settlement in Peru (May 1532) the disease had spread south and wiped out a staggering 65–90% of the Inca people. The great Inca nation now debilitated by European diseases and civil war fell to Pizarro's small army.

The extensive Incan road system, stretching an incredible 40,000 km across their empire, more than likely aided in the rapid spread of the introduced diseases. Sadly, the conquistadors made a point of looting and eradicating most traces of Incan culture. Without a written language, our understanding of the Inca has come mainly from reports by Spanish missionaries after the conquest (they did record information with knotted string known as quipu. These were used for inventory management, tax, labour and census counts. Some researchers believe the quipu may also be more than a numeric system and a possible form of writing). The present-day native peoples of the Andes are also an invaluable source of the myths and legends that have been passed down through the generations.

Without modern tools or the wheel, the Inca people were certainly skilled stonemasons. The Fortress of Sacsayhuamán[1] overlooking the city of Cusco, used blocks weighing 90 to 200 tonnes. Another example is the City of Machu Picchu[2] (the Lost City of the Incas) which is considered the greatest example of Incan engineering. Their exquisite architecture features stones so precisely fitted and jointed without mortar, that they have survived over five centuries in the earthquake prone zone of the Andes.

As polytheists, the Inca had many gods. Viracocha was the supreme god, the creator of the Universe and all living things.

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

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto**, in Sagittarius, sets around 11 pm in the western evening sky. From the 7th to 18th Jupiter will be within 1° of Pluto. Midmonth 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 88P/Howell is in the constellation Sagittarius moving into neighbouring Capricornus on the 22nd. As it continues to move away from both Earth and the Sun, the comet is expected to fade from 9th to 10th magnitude and will be setting late in the evening. On the 5th, Howell will be 1.1° north of the Teapot star Tau Sagittarii. Here's a challenge. Between them (0.4° north of the star) will be an extremely faint Comet Encke (14th magnitude)—good luck!

DOUBLE STARS

Alpha (α) Fornacis is a binary star in the constellation of Fornax, the Furnace. 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

Inti was the god of the Sun and there was a temple devoted to him in each city. Mama Quilla the goddess of the Moon was also seen as the goddess of marriage. There were many other gods responsible for certain aspects of life such as the weather etc.

It would appear the Inca had a very detailed knowledge of the movements of the Sun, Moon and stars. Many of their buildings and structures have been found to have definite astronomical orientations and uses. Observations at these *observatories* were used to determine times for religious celebrations, when the seasons changed and the best time for sowing and harvesting crops. It was noted by the Spanish chronicler Pedro de Gamboa as early as 1572 that the Inca constructed columns of stone on the mountains and hills overlooking Cusco. These served as an annual timepiece to determine the solstices and the seasons.

Continued in part 2, page 82.

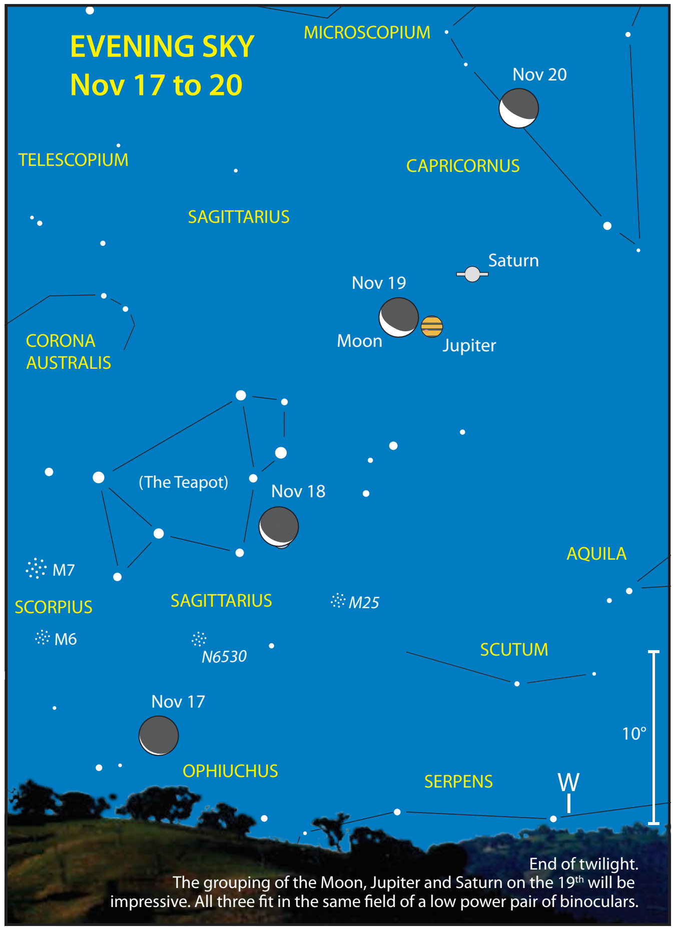
[1] *Sacsayhuamán by Ken Wallace*

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.

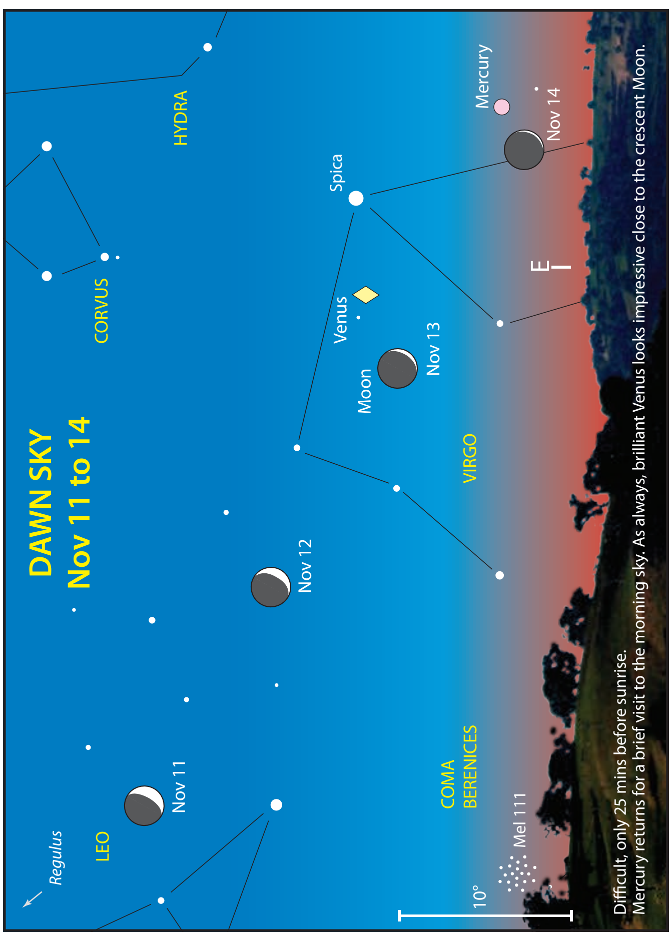
METEOR SHOWERS

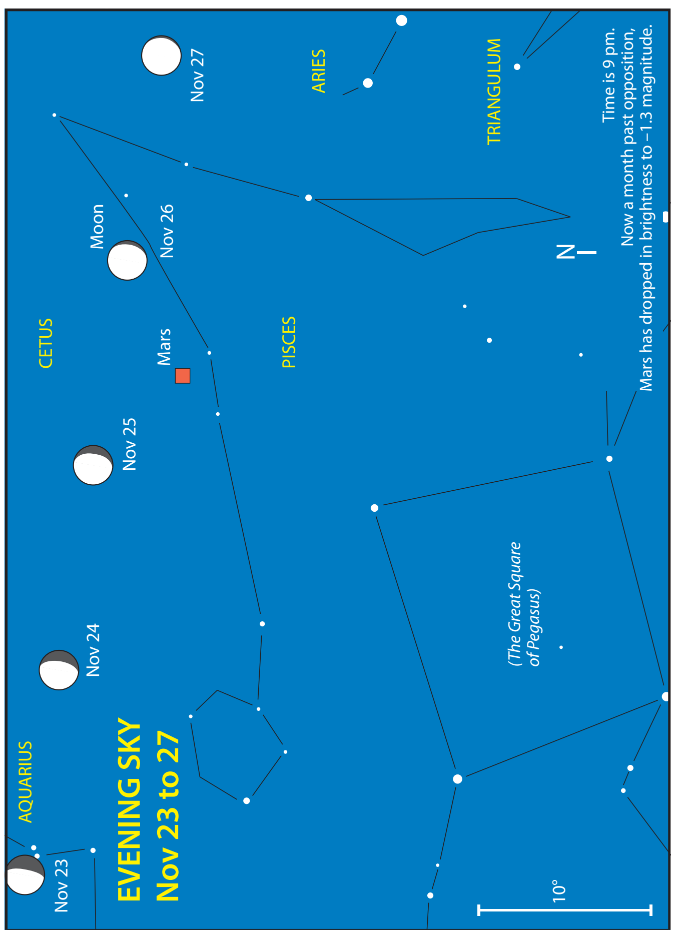
The **Northern Taurids** are active from October 20 to December 10. The shower is composed of two radiants of nearly equal activity ten degrees apart. The Northern Taurids peak around November 12 and the Southern Taurids in October. The Taurids are frequently bright, slow moving, and noted for producing 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** 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 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.



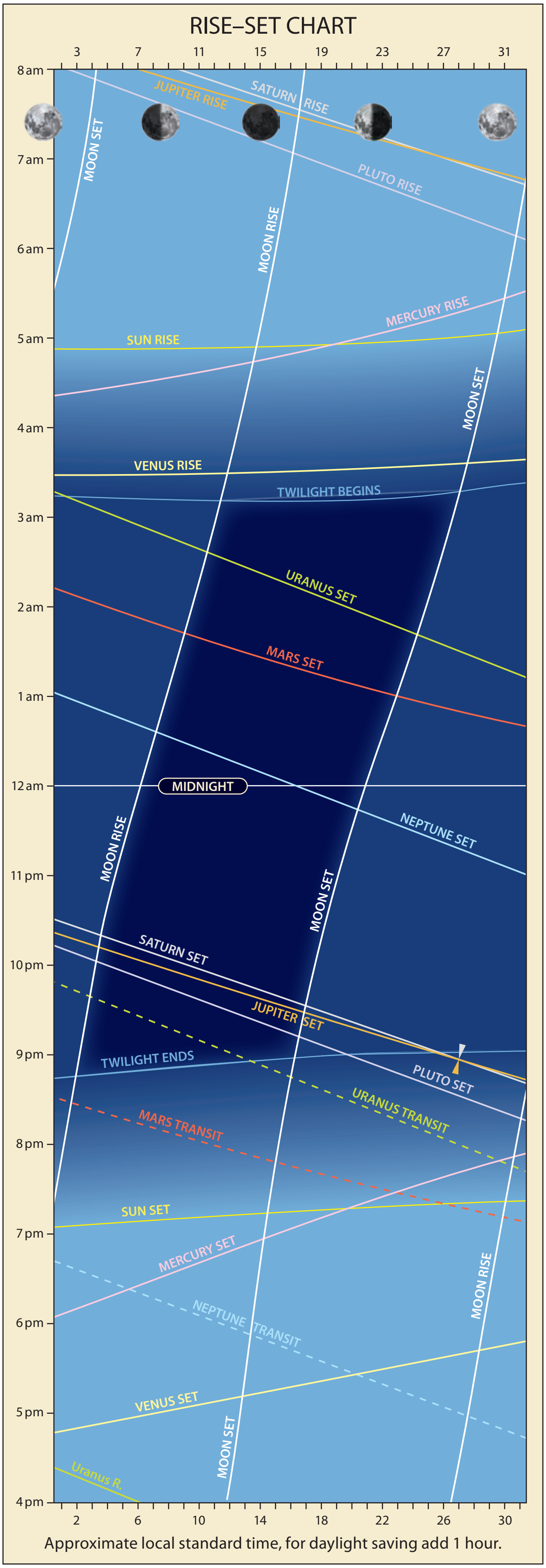
Approximate local standard time, for daylight saving add one hour.





NOVEMBER

DECEMBER 2020



HIGHLIGHTS

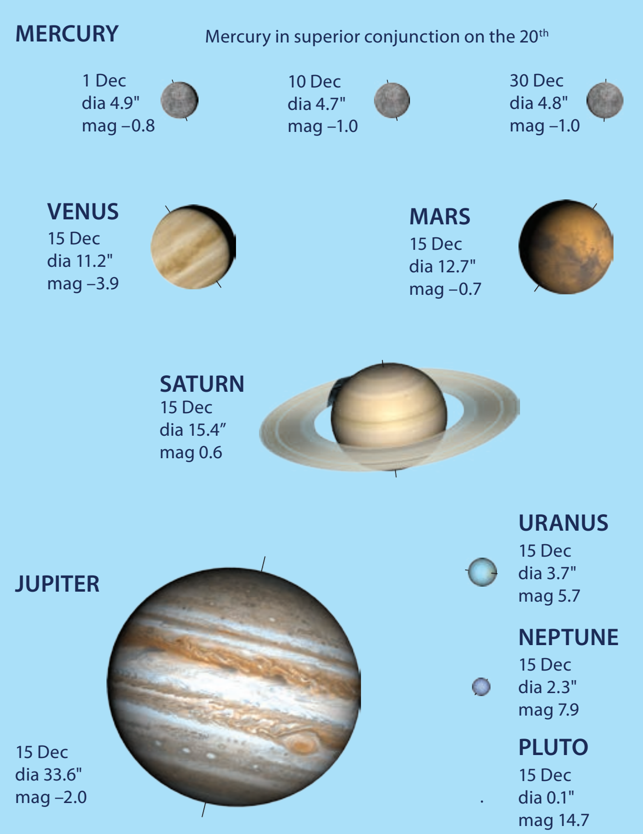
- Venus and Moon close.
- Moon, Jupiter and Saturn together.
- Jupiter and Saturn extremely close, rare meeting.

CONSTELLATIONS

Part of the legend of Jason and the Argonauts had this hero steal the golden fleece by slaying a dragon that never slept. Well, we know that their famous ship is immortalised in our southern winter skies, but the source of the fleece also resides in the heavens, as 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 these 2.0 and 2.6 magnitude stars, separated by only 4°, stand out well. The brighter star is Hamal (Alpha 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 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.

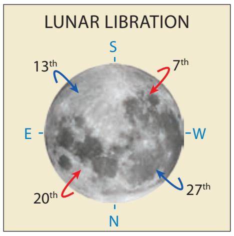
Directly beneath Aries is the constellation of Triangulum, the Triangle. Although its three main stars (around 3rd to 4th magnitude) are arranged in a distinctive narrow isosceles triangle, the name lacks imagination. Especially when one considers it came from the same ancients that brought us a flying 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).

APPEARANCE of the PLANETS



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 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).
- 13th 9 pm (7 pm WST) Minimum Libration (2.4°), too close to New Moon.
- 15th 2 am (midnight previous day WST) New Moon. Total eclipse of the Sun, not visible from Australia (see Part II for details).
- 20th 5 am (3 am WST) Maximum Libration (9.1°), bright NE limb. Mare Humboldtianum, 161 km sea, which is in the libration zone 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).
- 27th 7 pm (5 pm WST) Minimum Libration (2.8°), dark NW limb.
- 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 Piscium, a splendid double for small telescopes. There is some

Astronomy of the Inca Part 2

Although many structures had long been suspected to be of astronomical significance, it has only been in recent years that serious studies have been carried out. In 2012 a joint team of Polish and Peruvian researchers, using 3D laser-scanning techniques at Machu Picchu, were able to confirm many of the astronomical connections of this 15th century citadel.

The June solstice could be determined with great accuracy when a shaft of light, shining through a window in the Sun Temple[3], or Torreon, fell upon a slab of granite. The same north-eastern facing window could also be used to define each individual day from May through August and to sight the first heliacal rising of the Pleiades. The Pleiades played a major role in Incan life and their emergence in the dawn sky marked the time of crop harvest and the beginning of the year. The Pleiades were known as *Qullqa* which means storehouse and to this day an annual festival associated with the harvest and New Year is held by the local indigenous peoples near Cusco, Peru.


[3] The Sun Temple, Machu Picchu by Ken Wallace

Intimachay, or *cave of the Sun*, is a small cavern with east and north facing windows. Sunlight entering through these apertures at various times of the year would indicate summer and winter solstices and the autumn and spring equinoxes. For example, sunlight entering the eastern window during the vernal (spring) equinox is visible through the northern window against a scale on the wall.

On the dizzying heights of Huayna Picchu mountain overlooking the citadel below lies a building that appears to have a definite astronomical purpose. Inkaraqay, or El Mirador (*vantage point*), has a niche on the back of a wall that has two observation openings 5 cm in diameter around 1.6 m above the floor. Through the northern of these precisely made and oriented holes, sunrise can be observed directly above the distant summit of Yanantin Mountain (a sacred Andean peak) during the June solstice. The southern hole shows the helical rising of the Pleiades as it appears to be climbing the southern slope of the same mountain.

A kite shaped stone orientated to the cardinal compass points is also thought to represent the Southern Cross. It is located in a courtyard near the Temple of the Three Windows, its one metre major axis runs directly north/south. The exact use of the stone is not known although Crux was of great significance in Incan mysticism. Known as Chakana, meaning *chair*, it represents the three tiers of the world: the heavens, the world of the living and the underworld.

The Intihuatana[4] is a stone resembling a sundial and that may have been one of its uses. Set atop a terraced pyramid at Machu Picchu, the one metre high by two metre diameter instrument is beautifully carved from a single piece of granite. It has many faces, planes and levels but the exact purpose of these complex angles is unknown. It is one of the few remaining examples of this type of instrument that was placed in the centre of most Incan cities. The Spaniards in their quest to eradicate the Incan religion destroyed all they could find. Fortunately the conquistadors did not discover Manchu Picchu. As a testament to the amazing astronomical knowledge of the Inca the *gnomon* has an inclination of 13° matching the latitude of the site. At of this angle, during the March and September equinoxes, the gnomon does not cast a shadow.

Astronomical observatories such as those at Machu Picchu can be found throughout the Incan empire. With the task of feeding their population, the observations of the Sun, Moon and stars provided them with a clock and calendar to plan their agricultural and spiritual activities.

Like most cultures the Inca created constellations in the night sky and in common with the Australian Aboriginal they visualised constellations both stellar and dark. The first were made up using stars in typical connect-the-dots fashion that we are familiar with. These would form inanimate shapes of gods and heroes etc. The second type they visualised existed in the Great Rift, the dark clouds that lie between us and the Sagittarius-Carina arm of our galaxy. Within these dust lanes they imagined the outlines of animals they were familiar with. These creatures came to drink from the celestial river that hid the heavenly glow of the Milky Way and included the following;

1. A serpent, a sinuous dark region between Epsilon Canis Majoris and Crux.
2. A toad, the area between Theta Carinae and Lambda Centauri.
3. The tinamou (a partridge like bird) represented as the Coal Sack (in Crux).
4. A llama, between Crux and epsilon Scorpii. The dark constellation of the Llama is the same as that identified by the indigenous peoples of Australia as the *Emu in the Sky*. The difference is that the Emu's head is the Coal Sack, whereas the Llama's head begins around The Pointers and incorporates Alpha and Beta Centauri as its eyes.
5. A baby llama below the mother llama.
6. A fox, between the tail of Scorpius and Sagittarius.
7. A second tinamou in Scutum.

The Milky Way, known as Mayu, was a fundamental object of Incan cosmology and was the celestial counterpart (or reflection) of the Vilcanota River that flows through the Sacred Valley of the Inca. So strong was this belief that they thought that water flowing in the heavenly river came back to Earth in the rainy season.

Sadly, much was lost due to the Spanish conquest of the Americas. Archaeoastronomy, once considered as part pseudo-science, is now becoming a mainstream discipline and a fundamental tool in helping to understand how ancient cultures lived and connected with the world around them.

[4] The Intihuatana, Machu Picchu. Note the angled gnomon. By Ken Wallace

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 Aquarii this month. The planet can only be seen in the western evening sky as it heads toward conjunction in March 2021.

DWARF PLANETS and SMALL SOLAR SYSTEM BODIES

Dwarf planet **Pluto** sets around 9 pm midmonth. This distant world will be in conjunction with the Sun on 14 January and will return to the morning skies in February.

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 88P/Howell is in the constellation of Capricornus for all but the last few days of December, when it will then be found in the adjoining constellation of Aquarius. Setting late in the evening, Howell is expected to fade from 10th to 11th magnitude by month's end.

Comet P/2009 Q4 (Boattini) is predicted to brighten to 12th magnitude this month. Reaching perihelion on the 27th, at a distance of 1.3 au from the Sun, it's a favourable apparition as the comet will be less than 0.4 au from Earth at the time. Visible throughout the night, though best seen when the comet is at its highest late in the evening, Boattini resides in the constellation of Eridanus throughout December.

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

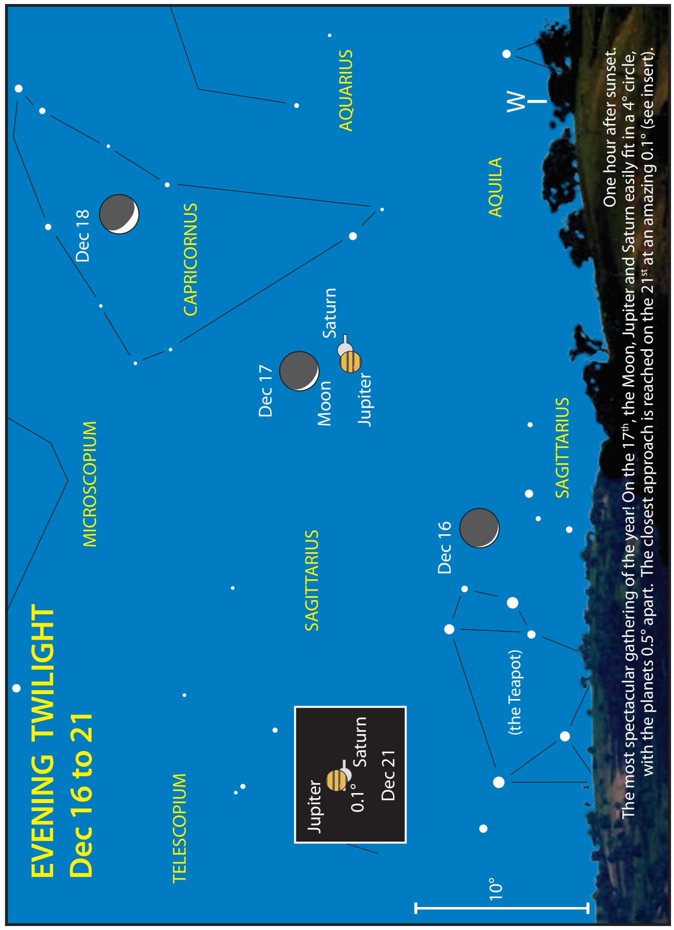
DIARY

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	10:37 am	(8:37 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	2:17 am	(12:17 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	Midnight	(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	9:41 am	(7:41 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	1:28 pm	(11:28 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

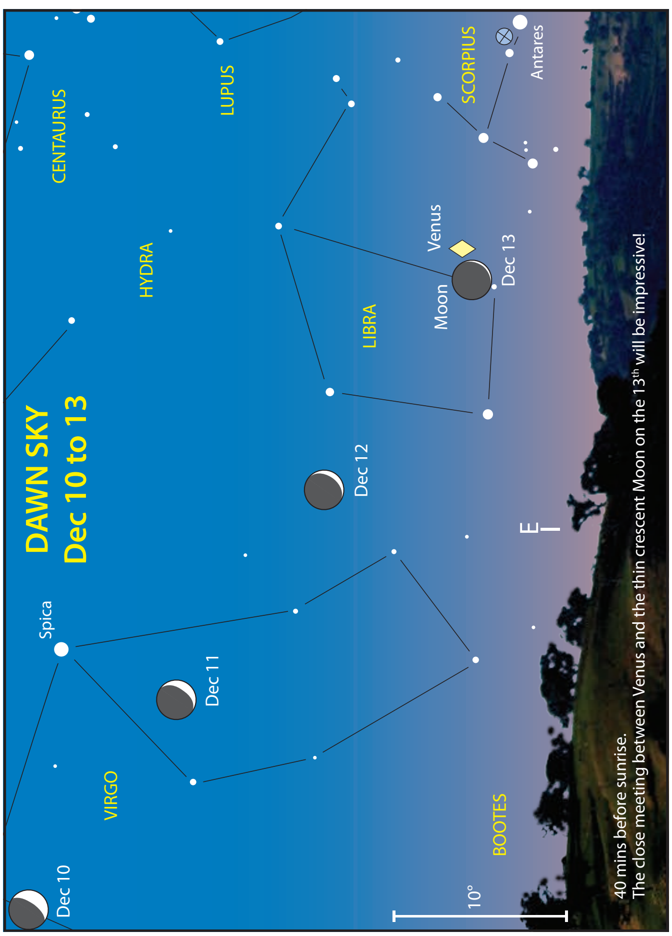
brilliant white (spectral classes B0.5V and BIV) and are members of the Orion OB1 association. There have been small changes in position angle and separation since the measures taken in 1825. Hipparchus/Tycho data shows different distances to the stars and the pair may represent an optical (line of sight) 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.

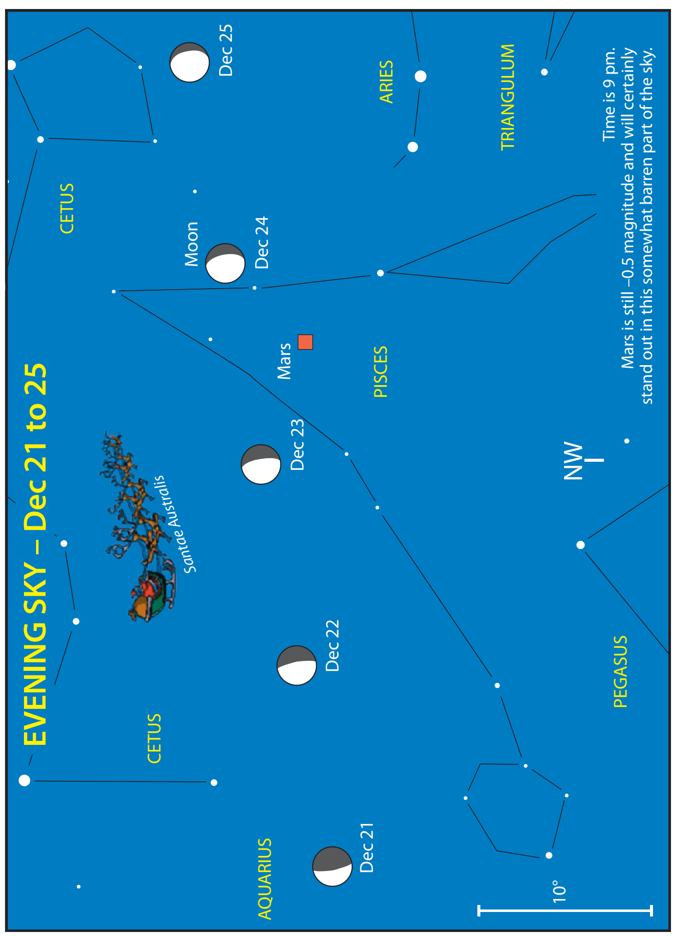
METEOR SHOWERS

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 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.





ALL SKY MAPS

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 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. 13).

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?

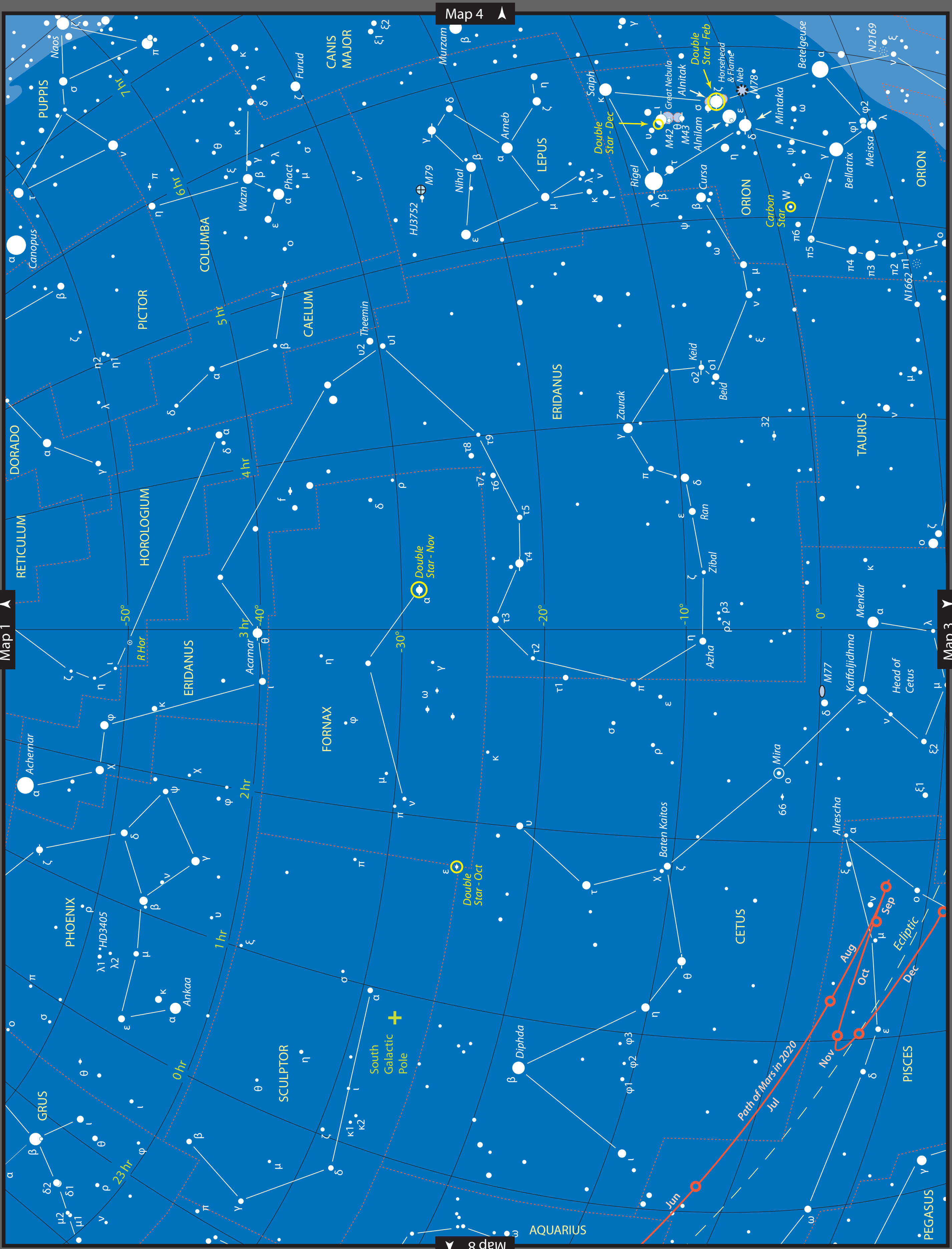
- Deep sky objects down to magnitude 7 and all of the Messier objects (see the legend). These objects are identified by their common names (such as asterisms), Messier number (M), NGC (N) or IC (I) catalogue numbers. Most of the star clusters should be visible through a pair of binoculars. The galaxies, planetary and diffuse nebulae may need a small telescope.
- 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? Additionally, the approximate position of the Coma/Virgo Supercluster of Galaxies map (see p. 48) and the location of the dwarf planet Ceres near opposition (see finder chart on p. 60) are shown.

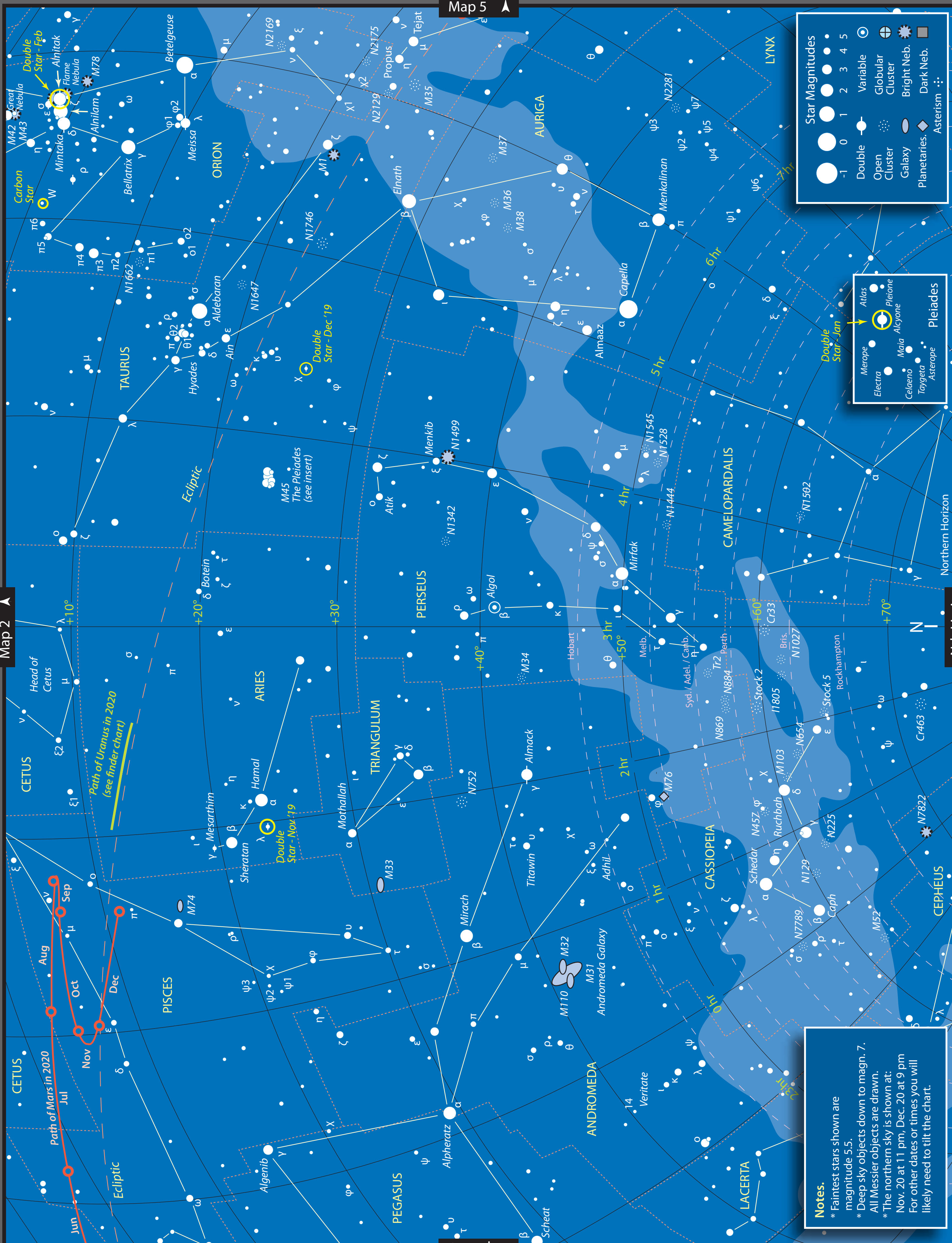
Greg Priestley image of South Celestial Pole region with ex-Fleurs Radio Telescope dish in foreground.

Map 1 - Looking South

Map 2 - Summer (Centre)



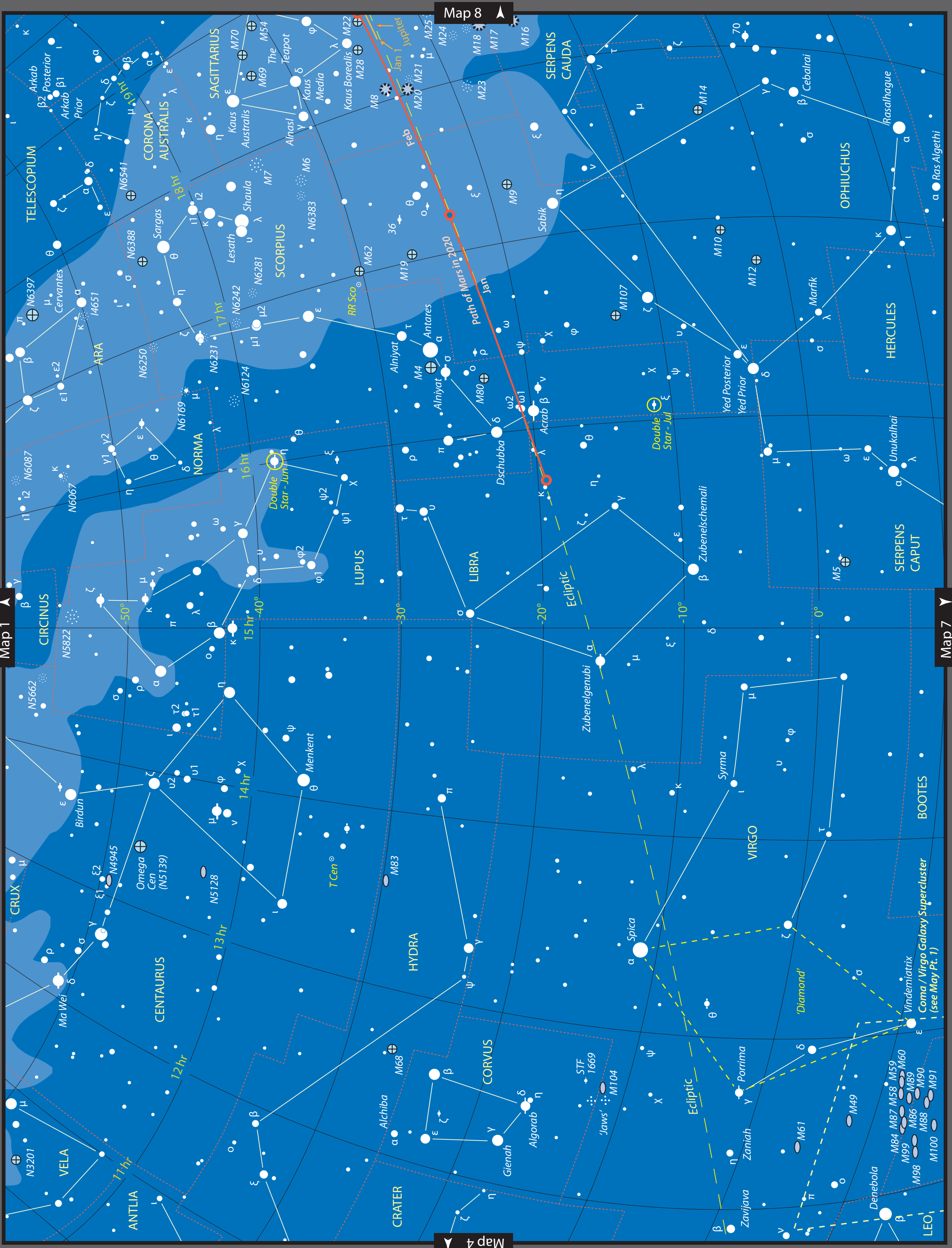
Map 3 - Summer (North)



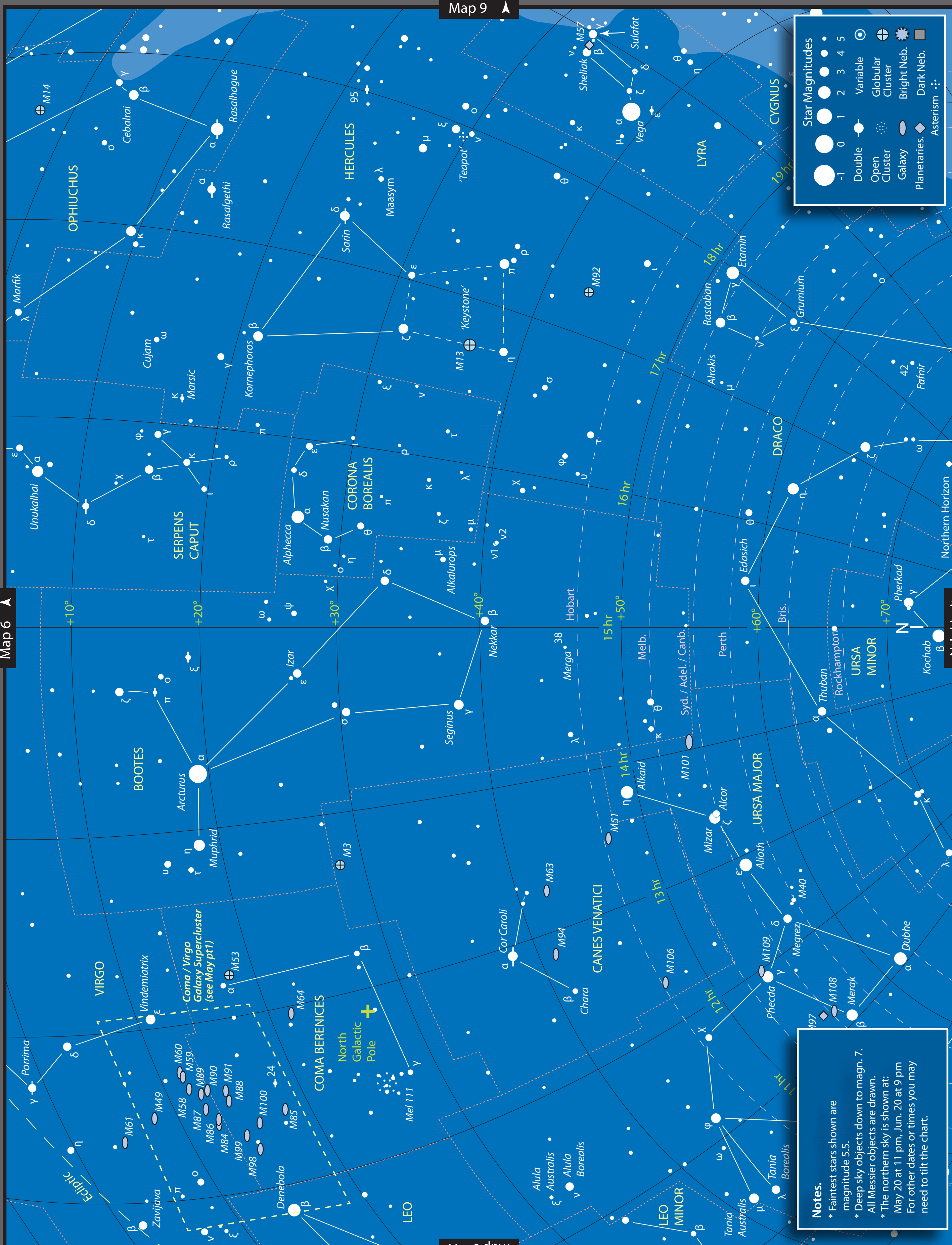
Map 4 - Autumn (Centre)

Map 5 - Autumn (North)

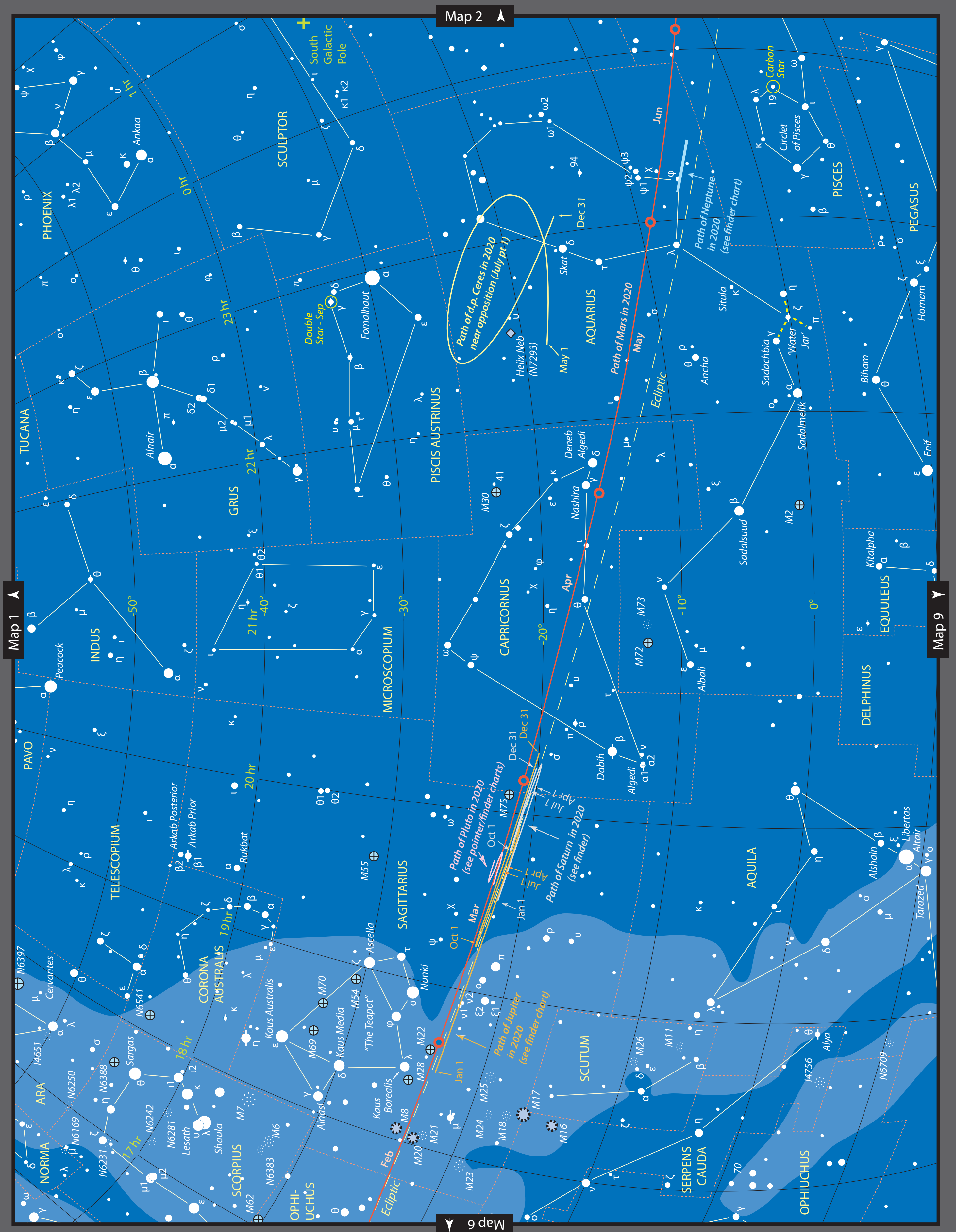
Map 6 - Winter (Centre)

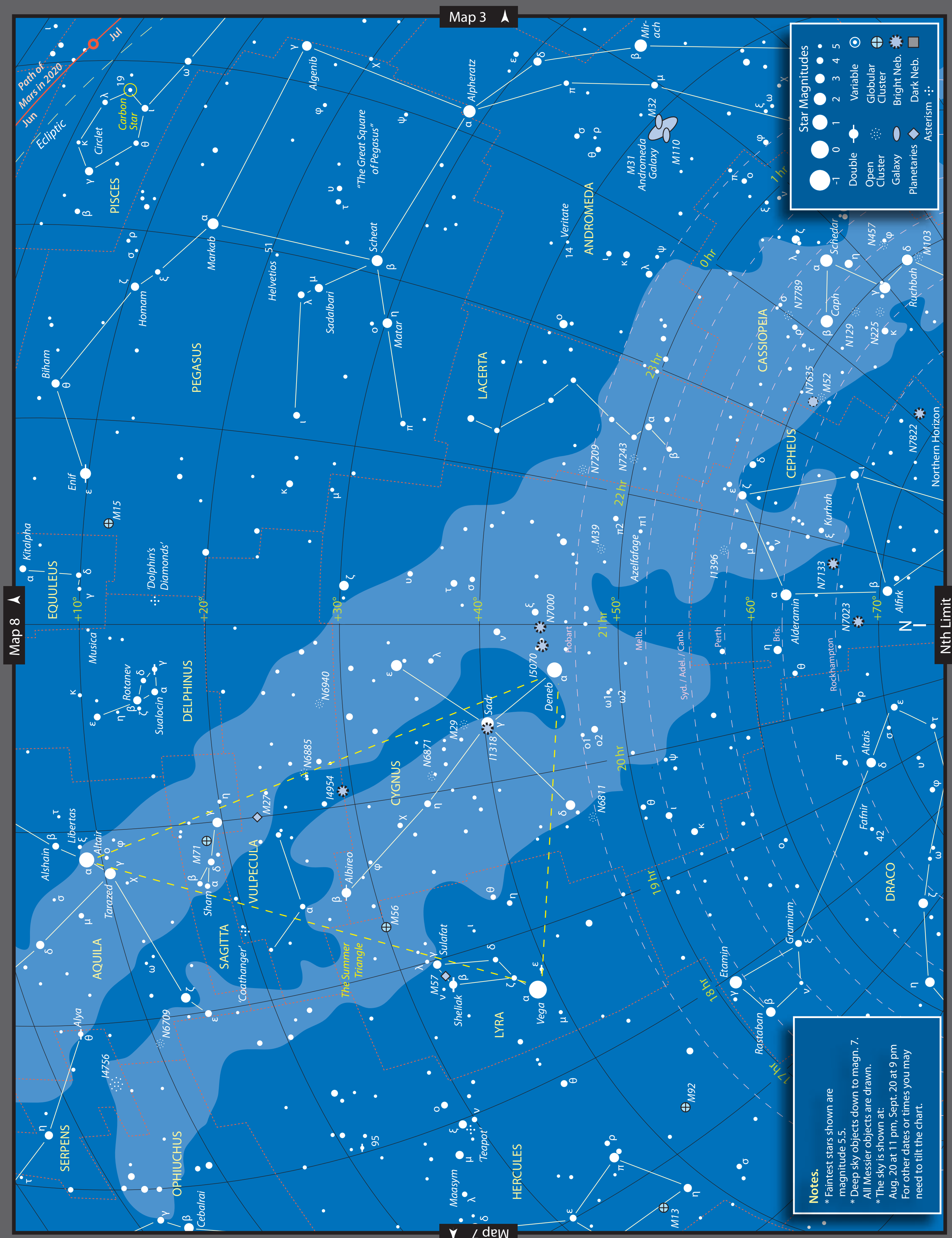


Map 7 - Winter (North)



Map 8 - Spring (Centre)





Map 3
Map 7
Map 8
Nth Limit
Star Magnitudes
-1 0 1 2 3 4 5
Double
Variable
Open Cluster
Globular Cluster
Galaxy
Bright Neb.
Planetaries
Dark Neb.
Asterism
Notes.
* Faintest stars shown are magnitude 5.5.
* Deep sky objects down to magn. 7. All Messier objects are drawn.
* The sky is shown at: Aug. 20 at 11 pm, Sept. 20 at 9 pm For other dates or times you may need to tilt the chart.
Path of Mars in 2020
Jun
Jul
Ecliptic
Circlet
Carbon Star
PISCES
PEGASUS
"The Great Square of Pegasus"
Algenib
Alpheratz
Markab
Scheat
Homam
Biham
Enif
Matar
Sadalbari
Helvetios
ANDROMEDA
M31 Andromeda Galaxy
M32
M110
Mir-ach
Veritate
LACERTA
CASSIOPEIA
Schedar
Caph
Ruchbah
N457
M103
N7789
N129
N225
N7635
M52
CEPHEUS
N7822
Northern Horizon
Kurhah
Alderamin
Alfirk
N7133
N7023
Rockhampton
Bris.
Perth
Syd. / Adel. / Canb.
Melb.
Hobart
N7209
N7243
M39
Azelfafage
I1396
N7000
I5070
Deneb
Sadr
I1318
M29
N6871
N6940
N6885
I4954
CYGNUS
M27
VULPECULA
Albireo
M56
M71
Sham
SAGITTA
'Coathanger'
The Summer Triangle
Sulafat
M57
Sheliak
LYRA
Vega
N6811
DELPHINUS
'Dolphin's Diamonds'
Rotanev
Sualocin
Musica
EQUULEUS
Kitalpha
M15
AQUILA
Altair
Alshain
Tarazed
Libertas
Alya
N6709
I4756
SERPENS
OPHIUCHUS
Cebalrai
HERCULES
Maasym
'Teapot'
M92
M13
Rastaban
Etamin
Grumium
DRACO
Fafnir
Altais
0 hr
1 hr
23 hr
22 hr
21 hr
20 hr
19 hr
18 hr
17 hr
+10°
+20°
+30°
+40°
+50°
+60°
+70°

PART II — THE SOLAR SYSTEM

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.*

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.*

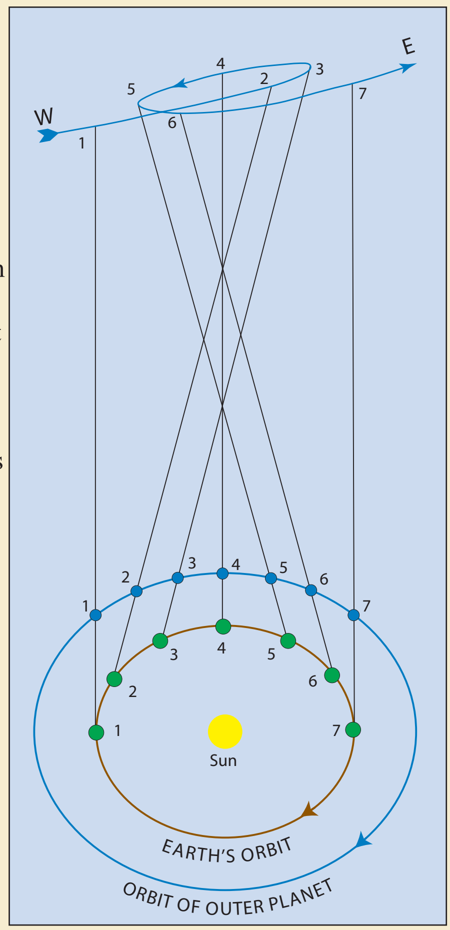
Use of Star Atlases. As the Earth orbits the Sun the polar axis, around which the stars rotate (the celestial poles) appears to never change no matter what time of the year you are observing. However, the positions of the poles do slowly move against the star field. This is called precession and is caused 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 its traditional finder has been included on these maps. 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 2020. They occur when 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 below dates 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 previous 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 and a table with lunar occultation predictions.

www.quasarastronomy.com.au/downloads.html

FULL MOON at PERIGEE (Supermoon)

Date of FM	Time of FM[1]	Geocentric Distance (km)	Geocentric Diameter (arcminutes)	Relative Distance[2]	Relative Brightness[3]	Date of Perigee[4]	Time of Perigee[1]	Nearest Perigee[5]
Feb 09	17:33	362,479	32.97	0.955	1.251 / 1.125	Feb 11	06:31	1.540
Mar 10	03:48	357,404	33.43	0.994	1.292 / 1.157	Mar 10	16:33	0.532
Apr 08[6]	12:35	357,035	33.47	0.997	1.296 / 1.159	Apr 08	04:08	–0.352
May 07	20:45	361,184	33.08	0.967	1.261 / 1.133	May 06	13:03	–1.321

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.

MOON PHASE (UT)

Lunation	New Moon		First Quarter		Full Moon		Last Quarter	
1200			Jan 3	04:45	Jan 10	19:21	Jan 17	12:58
1201	Jan 24	21:42	Feb 2	01:42	Feb 9	07:33	Feb 15	22:17
1202	Feb 23	15:32	Mar 2	19:57	Mar 9	17:48	Mar 16	09:34
1203	Mar 24	09:28	Apr 1	10:21	Apr 8	02:35	Apr 14	22:56
1204	Apr 23	02:26	Apr 30	20:38	May 7	10:45	May 14	14:03
1205	May 22	17:39	May 30	03:30	Jun 5	19:12	Jun 13	06:24
1206	Jun 21	06:41	Jun 28	08:16	Jul 5	04:44	Jul 12	23:29
1207	Jul 20	17:33	Jul 27	12:33	Aug 3	15:59	Aug 11	16:45
1208	Aug 19	02:42	Aug 25	17:58	Sep 2	05:22	Sep 10	09:26
1209	Sep 17	11:00	Sep 24	01:55	Oct 1	21:05	Oct 10	00:40
1210	Oct 16	19:31	Oct 23	13:23	Oct 31	14:49	Nov 8	13:46
1211	Nov 15	05:07	Nov 22	04:45	Nov 30	09:30	Dec 8	00:37
1212	Dec 14	16:17	Dec 21	23:41	Dec 30	03:28		

PERIGEE AND APOGEE (UT)

Apogee			Perigee		
Date	Time	Distance (km)	Date	Time	Distance (km)
Jan 2	01:30	404,580	Jan 13	20:21	365,958
Jan 29	21:27	405,393	Feb 10	20:28	360,461
Feb 26	11:34	406,278	Mar 10	06:30	357,122
Mar 24	15:23	406,692	Apr 7	18:09	356,907
Apr 20	19:00	406,462	May 6	03:03	359,654
May 18	07:45	405,583	Jun 3	03:38	364,366
Jun 15	00:57	404,595	Jun 30	02:13	368,958
Jul 12	19:27	404,199	Jul 25	05:02	368,361
Aug 9	13:50	404,659	Aug 21	10:57	363,513
Sep 6	06:29	405,607	Sep 18	13:48	359,082
Oct 3	17:22	406,321	Oct 16	23:46	356,912
Oct 30	18:45	406,394	Nov 14	11:43	357,837
Nov 27	00:29	405,894	Dec 12	20:42	361,773
Dec 24	16:31	405,012			

GEOCENTRIC PHENOMENA (UT)

Planet	Superior Conjunction	Greatest Elongation East	Stationary	Inferior Conjunction	Stationary	Greatest Elongation West
Mercury	10 Jan, 15 h	10 Feb, 14 h (18.2°)	16 Feb, 10 h	26 Feb, 2 h	9 Mar, 8 h	24 Mar, 2 h (27.8°)
	4 May, 22 h	4 Jun, 13 h (23.6°)	17 Jun, 20 h	1 Jul, 3 h	12 Jul, 7 h	22 Jul, 15 h (20.1°)
	17 Aug, 15 h	1 Oct, 16 h (25.8°)	14 Oct, 4 h	25 Oct, 18 h	3 Nov, 8 h	10 Nov, 17 h (19.1°)
	20 Dec, 3 h					
Venus		24 Mar, 22 h (46.1°)	13 May, 10 h	3 Jun, 18 h	24 Jun, 18 h	13 Aug, 0 h (45.8°)

Planet	Conjunction	Stationary	Opposition	Stationary	Conjunction	Stationary	Opposition	EARTH	
Mars		9 Sep, 18 h	13 Oct, 23 h	15 Nov, 19 h				Perihelion	5 Jan, 8 h
Jupiter		14 May, 18 h	14 Jul, 8 h	13 Sep, 0 h				Equinox	20 Mar, 4 h
Saturn	13 Jan, 15 h	11 May, 9 h	20 Jul, 22 h	29 Sep, 3 h				Solstice	20 Jun, 22 h
Uranus				11 Jan, 7 h	26 Apr, 9 h	15 Aug, 17 h	31 Oct, 16 h	Aphelion	4 Jul, 12 h
Neptune	8 Mar, 12 h	23 Jun, 18 h	11 Sep, 20 h	29 Nov, 9 h				Equinox	22 Sep, 14 h
Pluto	13 Jan, 13 h	26 Apr, 13 h	15 Jul, 19 h	4 Oct, 6 h				Solstice	21 Dec, 10 h

HELIOCENTRIC PHENOMENA (UT)

Planet	Perihelion	Aphelion	Ascending Node	Greatest Latitude North	Descending Node	Greatest Latitude South
Mercury	Feb 12	Mar 27	Feb 7	Feb 22	Mar 16	Jan 19
	May 10	Jun 23	May 5	May 20	Jun 12	Apr 16
	Aug 6	Sep 19	Aug 1	Aug 16	Sep 8	Jul 13
	Nov 2	Dec 16	Oct 28	Nov 12	Dec 5	Oct 9
Venus	Mar 20	Jul 10	Feb 15	Apr 10	Jun 5	Aug 1
	Oct 30		Sep 26	Nov 21		
Mars	Aug 3		Dec 2		Feb 1	Jul 8
Jupiter					Feb 26	
Saturn					Feb 13	
Uranus, and Neptune have no events in 2020						

SOLAR SYSTEM DATA – SUN, MOON, PLANETS and PLUTO

	Sun	Moon	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Mean Distance from Sun ($\times 10^3$ 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	62	27	14	5
Mass ($\times 10^{24}$ 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:

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

The satellite table (right) covers those currently known (as of August 2019). Some are not yet named, instead they have a preliminary designation such as S/2007 S3.

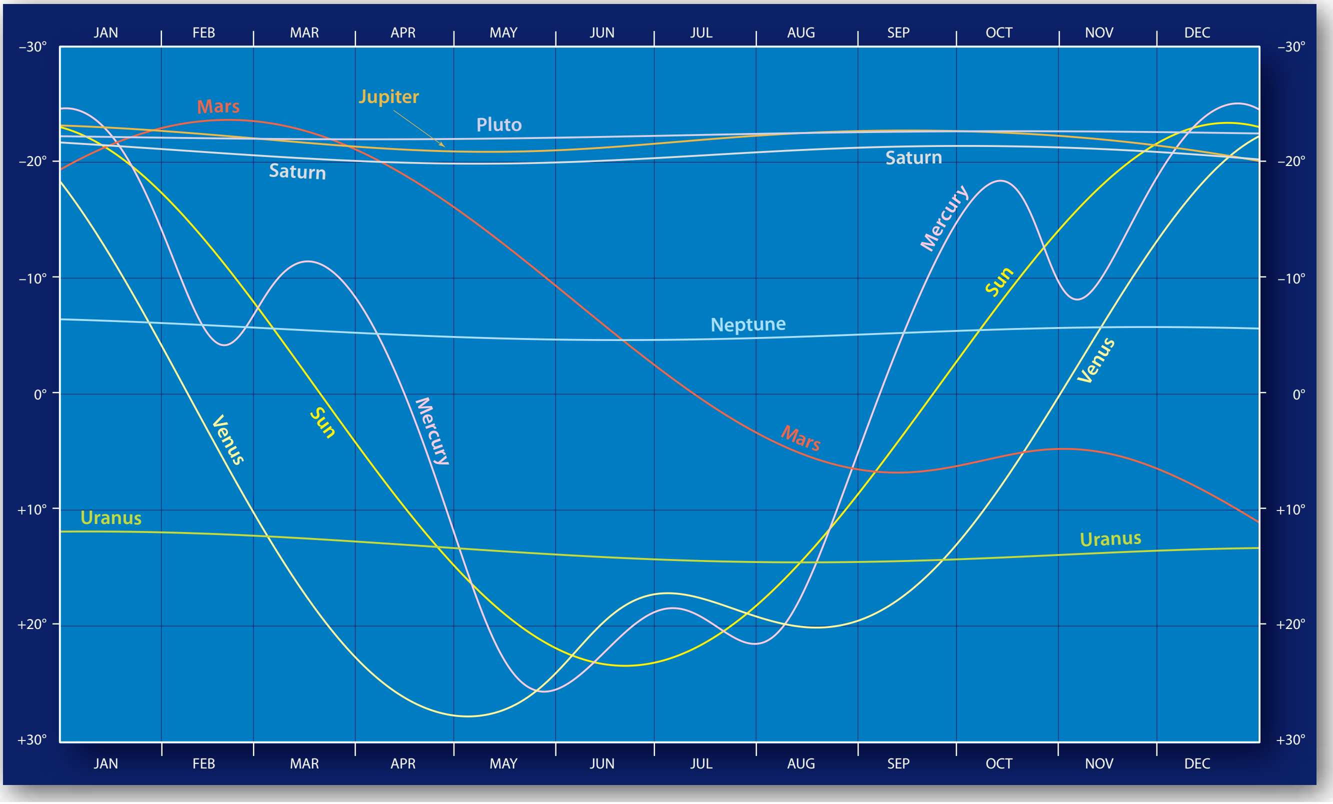
SOLAR SYSTEM DATA — SATELLITES

PLANET	SATELLITE	ORBITAL PERIOD (days)	MAX. ELONG AT MEAN OPPOSITION	SEMIMAJOR AXIS (× 10³ km)	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' 02"	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	01' 13"	221.90	58 × 49 × 42	16.0
	Io	1.769137761	02' 18"	421.80	1829 × 1819 × 1816	5.0
	Europa	3.551181055	03' 40"	671.10	1563 × 1560 × 1560	5.3
	Ganymede	7.15455325	05' 51"	1,070.40	2631.2	4.6
	Callisto	16.689017	10' 18"	1,882.70	2410.3	5.7
	Themisto	130.02	40' 44"	7504	4	21.0R
	Leda	240.93	1° 00' 58"	11,164.00	5 [15]	19.0
	Himalia	250.56	1° 02' 34"	11,460.00	85	14.6
	S/2018 J1	252.0		11483	3 [15]	22.9
	S/2017 J4	252.1		11525	3 [15]	23.0
	Lysithea	259.20	1° 03' 58"	11,717.00	12 [15]	18.3
	Elara	259.64	1° 04' 03"	11,740.00	40	16.3
	Dia	287.0	1° 06' 15"	12,118.00	1.0 [15]	22.4
	Carpo	455.0[7]	1° 33' 14"	17,056.04	1.5 [15]	23.0
	S/2003 J12	489.67	1° 49' 12"	17830	0.5	23.9R
	Valetudo	533.3		18980	1 [15]	24.0
	Euporie	555.2 [16]	1° 46' 38"	19,509.12	1.0 [15]	23.1
	S/2003 J3	583.87	1° 44' 24"	20221	1.0 [15]	23.4R
	Chaldene	591.7 [16]	1° 50' 57"	20,299.46	1.9 [15]	22.5
	Mneme	599.65 [16]	1° 52' 03"	20,500.28	1.0 [15]	23.3
	S/2003 J18	598.13	2°	20508	1.0 [15]	23.4R
	Helike	601.40 [16]	1° 52' 16"	20,540.27	2.0 [15]	22.6
	S/2017 J7	602.6		20627	2 [15]	23.6
	Iocaste	606.3 [16]	1° 52' 50"	20,642.86	2.6 [15]	22.5
	S/2016 J1	602.7		20650.845	0.5	24
	S/2017 J3	606.3		20694	2 [15]	23.4
	Thyone	610.0 [16]	1° 53' 31"	20,769.90	2.0 [15]	22.3
	Orthosie	613.6 [16]	1° 53' 58"	20,849.89	1.0 [15]	23.1
	Harpalyke	617.3 [16]	1° 54' 20"	20,917.72	2.2 [15]	22.2
	Euanthe	620.9 [16]	1° 54' 41"	20,983.14	1.5 [15]	22.8
	S/2010 J2	618.84		21004	1.0 [15]	24.0R
	Hermippe	624.6 [16]	1° 55' 03"	21,047.99	2.0 [15]	22.1
	S/2003 J16	622.8[8]	1° 58' 48"	21097	1.0 [15]	23.3R
	Praxidike	624.6 [16]	1° 55' 19"	21,098.10	3.4 [15]	22.5
	Ananke	629.8[0] [16]	1° 55' 03"	21,254.00	10 [15]	18.8
	Thelxinoe	635.82 [16]	1° 56' 31"	21,316.68	1.0 [15]	23.5
	S/2017 J9	639.2		21487	3 [15]	22.8
	Taygete	650.1 [16]	1° 58' 27"	21,671.85	2.5 [15]	22.9
	Erinome	661.1 [16]	1° 59' 31"	21,867.75	1.6 [15]	22.8
	Aitne	679.3 [16]	2° 01' 44"	22,274.41	1.5 [15]	22.7
	Kale	679.4 [16]	2° 01' 53"	22,300.64	1.0 [15]	23.0
	Kallichore	681.9[4] [16]	2° 02' 04"	22,335.35	1.0 [15]	23.7
	S/2017 J6	683.0		22455	2 [15]	23.5
	Sponde	690.3 [16]	2° 03' 14"	22,548.24	1.0 [15]	23.0
	S/2003 J15	689.7[8]	2° 7' 48"	22627	1.0 [15]	23.5R
	Isonoe	704.9 [16]	2° 04' 38"	22,804.70	1.9 [15]	22.5
	Hegemone	715 [16]	2° 05' 44"	23,006.33	1.5 [15]	22.8
	S/2003 J10	716.25	2° 19' 48"	23042	1.0 [15]	23.6R
	Herse	715.4 [16]	2° 06' 14"	23,097.00	1.0 [15]	23.4
	S/2011 J2	718 [37]		23124	1 [15]	23.5R
	S/2017 J5	719.5		23232	2 [15]	23.5
	S/2017 J8	719.6		23233	1 [15]	24.0
	S/2017 J2	723.1		23303	2 [15]	23.5
	S/2003 J9	733.32	2° 9' 36"	23385	0.5 [15]	23.7R
	Carme	734.17 [16]	2° 07' 14"	23,401.00	15 [15]	17.6
	Megaclite	734.1 [16]	2° 08' 06"	23,439.08	2.7 [15]	22.1
	S/2011 J1	736.35		23446	1 [15]	23.7R
	S/2010 J1	736.5		23449	1 [15]	23.2R

PLANET	SATELLITE	ORBITAL PERIOD (days)	MAX. ELONG AT MEAN OPPOSITION	SEMIMAJOR AXIS (× 10³ km)	RADIUS (km)	MAG AT OPP
Jupiter	Eukelade	735.27 [16]	2° 08' 21"	23,485.28	2.0 [15]	22.6
	S/2003 J5	738.75	2° 19' 12"	23495	2!15	22.4R
	S/2003 J19	740.41	2° 12' 0"	23533	1 [15]	23.7R
	Cyllene	737.80 [16]	2° 08' 41"	23,544.84	1.0 [15]	23.2
	S/2017 J1	734.2		23547.105	1 [15]	23.8
	S/2003 J23	732.46	2° 19' 12"	23567	1 [15]	23.6R
	Pasiphae	743.61 [16]	2° 09' 18"	23,629.00	18 [15]	17.0
	Aoede	747 [16]	2° 09' 46"	23,743.83	2.0 [15]	22.5
	Arche	748.7 [16]	2° 09' 53"	23,765.12	1.5 [15]	22.8
	Pasithee	748.76 [16]	2° 09' 58"	23,780.14	1.0 [15]	23.2
	Eurydome	752.4 [16]	2° 10' 14"	23,830.94	1.5 [15]	22.7
	S/2003 J4	755.25	2° 14' 24"	23929	1 [15]	23.0R
	Sinope	758.89 [16]	2° 10' 20"	23,942.00	14 [15]	18.1
	Kalyke	767 [16]	2° 11' 54"	24,135.61	2.6 [15]	21.8
	Autonoe	778.0 [16]	2° 13' 25"	24,413.09	2.0 [15]	22.0
	Callirrhoe	736 [16]	2° 14' 25"	24,596.24	4.3 [15]	20.7
	Kore	807.20 [16]	2° 16' 29"	24,974.03	1.0 [15]	23.6
	S/2003 J2	980.53	2° 42' 36"	28347	1 [15]	23.2R
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	27R
	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' 01"	377.20	1.3	24.8
	Helene	2.737	1' 01"	377.42	16.5	18.4
	Dione	2.736914742	1' 01"	377.65	562	10.4
	Rhea	4.517500436	1' 25"	527.37	764	9.7
	Titan	15.94542068	3' 17"	1,221.80	2,575	8.4
	Hyperion	21.2766088	3' 59"	1,481.10	164 × 130 × 107	14.4
	Iapetus	79.3301825	9' 35"	3,561.85	736	11.0
	Kiviuq	449.2	30' 27"	11,319.01	8 [15]	22.7
	Ijiraq	451.4	30' 33"	11,359.25	6 [15]	22.6
	Phoebe	548.2 16	34' 41"	12,893.24	110	16.7
	Paaliaq	686.9	40' 18"	14,985.05	13 [15]	21.0
	Skathi	728.2 16	41' 37"	15,471.94	4 [15]	23.6
	Albiorix	783.5	44' 22"	16,495.93	16 [15]	20.5
	S/2007 S2	799.8975	0° 46' 48"	16,560	3	24.4
	Bebhionn	834.8	45' 36"	16,950.00	3 [15]	24.1
	Skoll	878.3 16	47' 22"	17,610.00	3 [15]	24.5
	Erriapus	871.2	47' 54"	17,807.71	5 [15]	23.9
	Tarqeq	887.5	48' 12"	17,920.00	3.5 [15]	23.9
	Tarvos	926.2	48' 21"	17,977.24	7 [15]	22.3
	Greip	921.2 16	48' 42"	18,105.00	3 [15]	24.4
	Siarnaq	895.6	48' 57"	18,201.44	21 [15]	20.4
	Hyrrokkin	931.8 16	49' 00"	18,217.13	4 [15]	23.5
	Mundilfari	952.6 16	49' 32"	18,412.67	3 [15]	23.8
	S/2004 S13	905.82	0° 52' 48"	18,450	3	24.5
	S/2004 S17	913.125	0° 53' 24"	18,600	2	25.2
	Bergelmir	1,005.9 16	50' 26"	18,750.00	3 [15]	24.2
	S/2006 S1	971.565	0° 54' 0"	18,981.135	3	24.6
	Narvi	1,003.9 16	51' 29"	19,140.48	2.5 [15]	23.8
	Suttungr	1,016.7 16	51' 36"	19,185.70	4 [15]	23.9

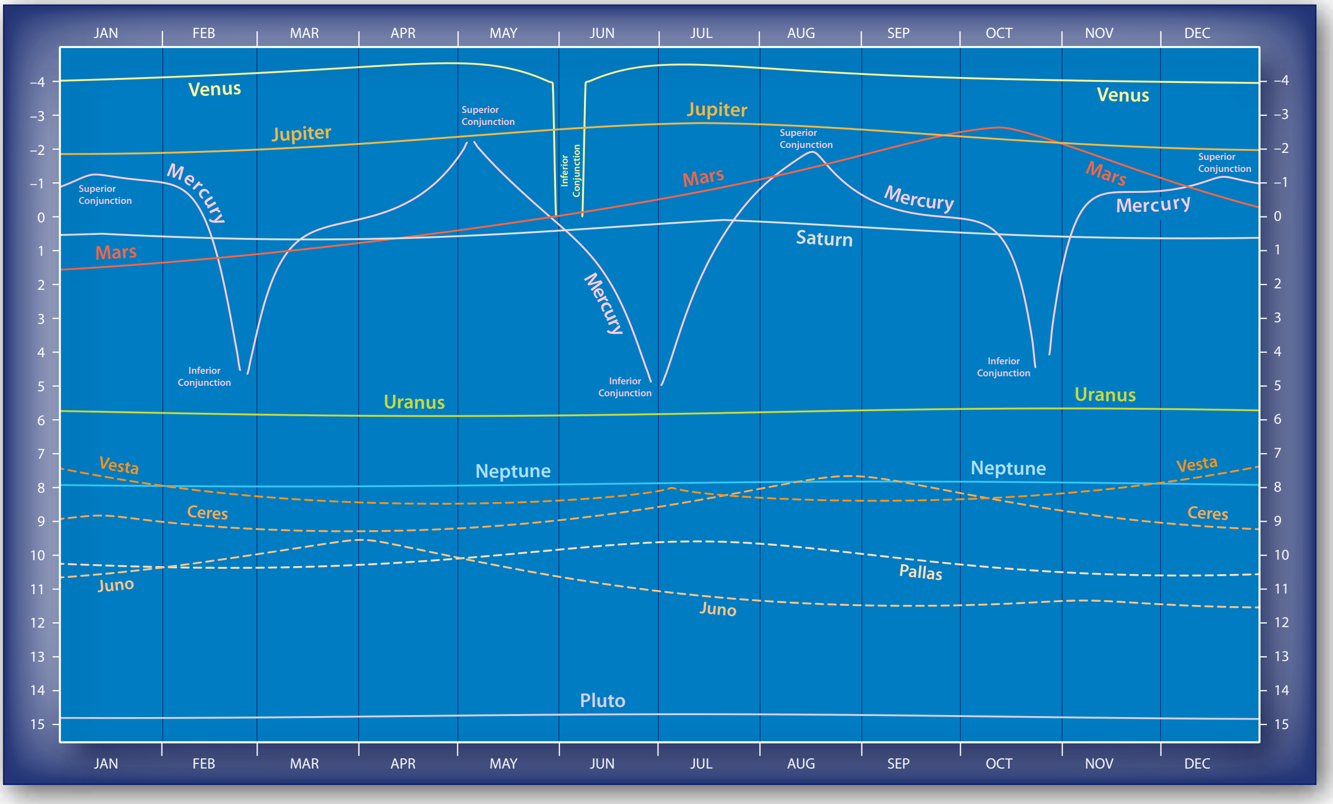
PLANET	SATELLITE	ORBITAL PERIOD (days)	MAX. ELONG AT MEAN OPPOSITION	SEMIMAJOR AXIS (× 10³ km)	RADIUS (km)	MAG AT OPP
Saturn	Aegir	1,116.5 16	52' 03"	19,350.00	3 [15]	24.4
	S/2004 S12	1,048.2675	0° 57' 0"	19,650	2.5	24.8
	Bestla	1,083.6 16	52' 51"	19,650.00	3.5 [15]	23.8
	S/2004 S7	1,103.055	0° 57' 0"	19,800	3	24.5
	Farbauti	1,086.1 16	53' 15"	19,800.00	2.5 [15]	24.7
	Hati	1,038.7 16	53' 40"	19,950.00	3 [15]	24.4
	Thrymr	1,094.3 16	53' 41"	19,957.54	4 [15]	23.9
	S/2007 S3	1,099.4025	0° 58' 48"	20,578	2.5	24.9
	S/2006 S3	1,143.2325	1° 0' 0"	21,132	3	24.6
	Fenrir	1,260.3 16	59' 43"	22,200.00	2 [15]	25.0
	Fornjot	1,490.9 16	59' 43"	22,200.00	3 [15]	24.6
	Surtur	1,297.7 16	59' 57"	22,290.00	3 [15]	24.8
	Kari	1,233.6 16	1° 00' 07"	22,350.00	3.5 [15]	23.9
	Jarnsaxa	964.7 16	1° 02' 22"	23,190.00	3 [15]	24.7
	Loge	1,312.0 16	1° 02' 22"	23,190.00	3 [15]	24.6
	Ymir	1,315.4 16	1° 02' 41"	23,305.87	10 [15]	22.4
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' 24"	4,276.00	7 [15]	25.0
	Caliban	579.6 16	9' 03"	7,170.00	49	22.4
	Stephano	675.7 16	10' 19"	7,942.00	10 [15]	24.1
	Trinculo	759.7 16	10' 50"	8,571.02	7 [15]	25.4
	Sycorax	1,289.0 16	15' 24"	12,216.00	95	20.8
	Margaret	1,694.8	18' 07"	14,345.00	7.5 [15]	25.2
	Prospero	1,948.1 16	20' 19"	16,089.00	15 [15]	23.2
	Setebos	2,303.1 16	22' 43"	17,988.00	17.5 [15]	23.3
	Ferdinand	2,823.4 16	26' 24"	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' 22"	5,513.4	170	19.7
	Halimede	1,881.00	12' 26"	15,728.00	25 [15]	24.5
	Sao	2,914.63	17' 44"	22,422.00	13.5 [15]	25.4
	Laomedeia	3,166.65	18' 38"	23,571.00	16.5 [15]	25.4
	Psamathe	9,116.45	36' 55"	46,695.00	18 [15]	25.6
	Neso	9,737.36	38' 15"	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

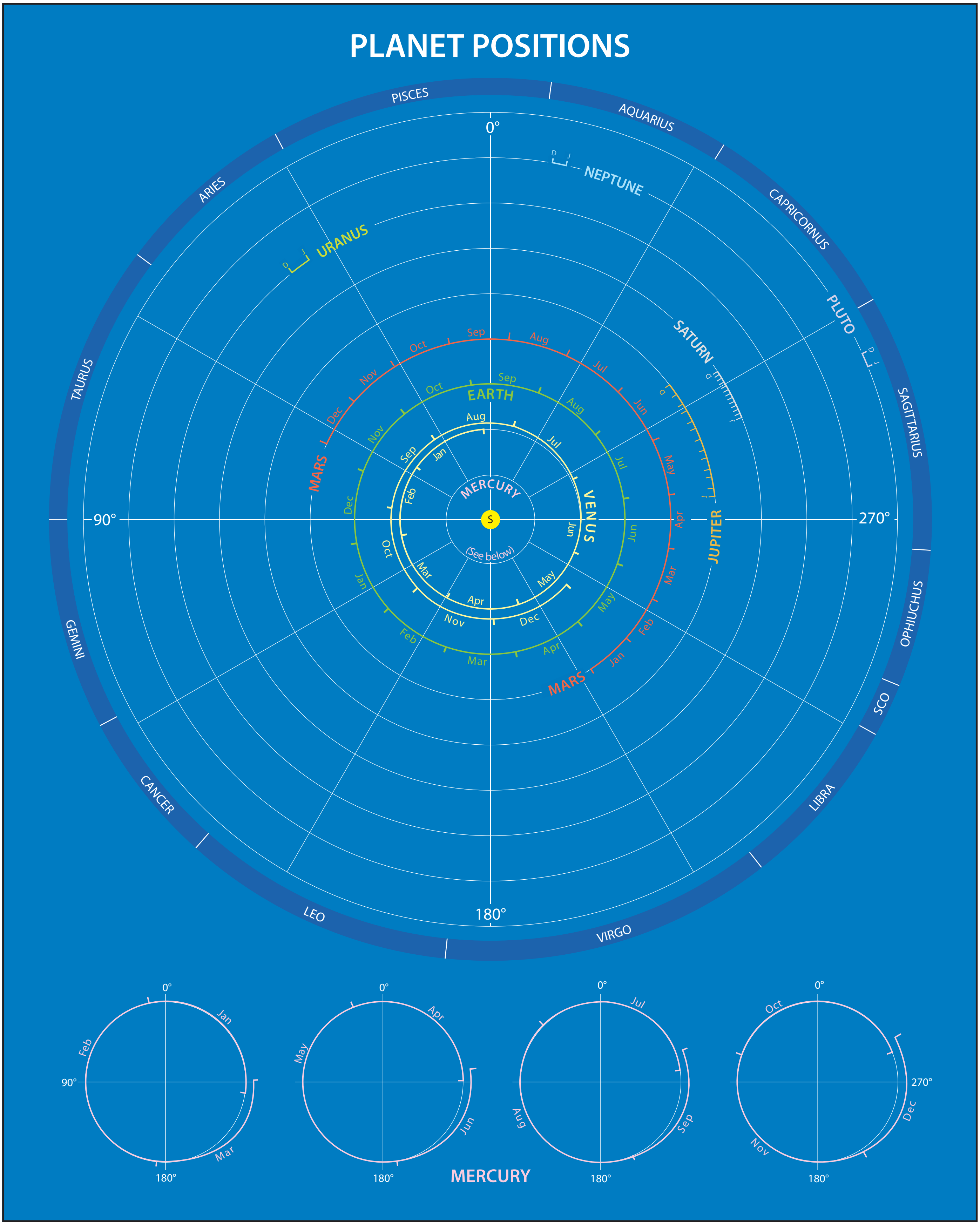
DECLINATIONS of the SUN, PLANETS and PLUTO



In general, the further south a planet is (negative 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 2020. 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

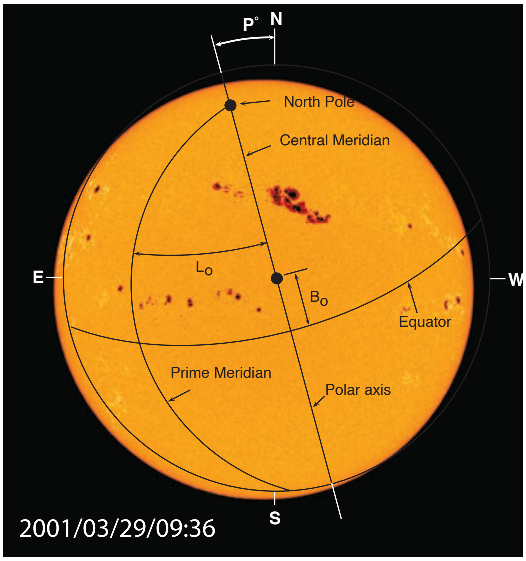
SUN RISE, SUN SET and ASTRONOMICAL TWILIGHT

	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 4	03:22	05:07	19:33	21:18	03:26	04:58	18:47	20:19	03:08	04:54	19:22	21:08	05:08	06:27	19:17	20:35	Jan 4
11	03:29	05:13	19:33	21:16	03:32	05:03	18:48	20:19	03:15	05:00	19:22	21:06	05:13	06:31	19:19	20:36	11
18	03:38	05:20	19:31	21:12	03:39	05:08	18:47	20:17	03:24	05:07	19:20	21:02	05:17	06:34	19:20	20:37	18
25	03:48	05:27	19:28	21:07	03:46	05:14	18:46	20:13	03:34	05:14	19:17	20:56	05:22	06:38	19:20	20:36	25
Feb 1	03:58	05:34	19:23	20:59	03:54	05:20	18:43	20:08	03:44	05:21	19:12	20:49	05:26	06:41	19:20	20:35	Feb 1
8	04:08	05:41	19:17	20:51	04:01	05:25	18:38	20:02	03:54	05:29	19:06	20:40	05:30	06:44	19:18	20:32	8
15	04:17	05:49	19:10	20:42	04:08	05:31	18:33	19:56	04:04	05:36	18:59	20:31	05:33	06:46	19:16	20:29	15
22	04:26	05:55	19:03	20:32	04:14	05:36	18:27	19:48	04:13	05:43	18:51	20:21	05:36	06:48	19:13	20:25	22
29	04:34	06:02	18:54	20:21	04:20	05:40	18:20	19:40	04:21	05:49	18:42	20:10	05:38	06:49	19:10	20:21	29
Mar 7	04:42	06:08	18:45	20:11	04:25	05:44	18:13	19:32	04:29	05:56	18:33	19:59	05:39	06:50	19:06	20:17	Mar 7
14	04:49	06:14	18:35	20:00	04:30	05:48	18:06	19:24	04:36	06:02	18:23	19:49	05:40	06:51	19:02	20:12	14
21	04:55	06:20	18:25	19:50	04:34	05:52	17:58	19:15	04:43	06:07	18:13	19:38	05:41	06:51	18:57	20:07	21
28	05:01	06:25	18:16	19:40	04:38	05:56	17:50	19:07	04:49	06:13	18:03	19:28	05:41	06:51	18:53	20:03	28
Apr 4	05:07	06:31	18:06	19:30	04:42	05:59	17:42	19:00	04:54	06:19	17:54	19:18	05:41	06:52	18:48	19:59	Apr 4
11	05:12	06:36	17:57	19:21	04:45	06:03	17:35	18:53	05:00	06:24	17:44	19:09	05:41	06:52	18:44	19:55	11
18	05:17	06:42	17:48	19:12	04:48	06:06	17:28	18:46	05:05	06:30	17:35	19:00	05:41	06:53	18:40	19:51	18
25	05:22	06:47	17:40	19:05	04:51	06:10	17:21	18:40	05:10	06:36	17:27	18:52	05:42	06:53	18:37	19:48	25
May 2	05:27	06:53	17:32	18:58	04:55	06:14	17:16	18:35	05:15	06:41	17:19	18:46	05:42	06:54	18:34	19:46	May 2
9	05:31	06:58	17:26	18:52	04:58	06:18	17:11	18:31	05:20	06:47	17:13	18:40	05:43	06:56	18:31	19:44	9
16	05:36	07:04	17:20	18:48	05:01	06:22	17:06	18:28	05:24	06:52	17:07	18:35	05:43	06:57	18:29	19:43	16
23	05:40	07:09	17:16	18:44	05:04	06:26	17:03	18:25	05:28	06:57	17:03	18:32	05:45	06:59	18:28	19:43	23
30	05:44	07:13	17:13	18:42	05:07	06:29	17:01	18:24	05:32	07:02	17:00	18:30	05:46	07:01	18:28	19:43	30
Jun 6	05:47	07:17	17:11	18:41	05:10	06:33	17:00	18:23	05:36	07:06	16:58	18:28	05:48	07:03	18:28	19:44	Jun 6
13	05:50	07:21	17:11	18:41	05:12	06:35	17:01	18:24	05:39	07:09	16:58	18:28	05:49	07:05	18:29	19:45	13
20	05:52	07:23	17:11	18:42	05:14	06:37	17:02	18:25	05:41	07:12	16:58	18:29	05:51	07:07	18:31	19:47	20
27	05:54	07:24	17:13	18:44	05:15	06:39	17:03	18:27	05:42	07:13	17:00	18:31	05:52	07:08	18:32	19:48	27
Jul 4	05:54	07:24	17:16	18:47	05:16	06:39	17:06	18:29	05:42	07:13	17:03	18:34	05:53	07:09	18:34	19:50	Jul 4
11	05:53	07:22	17:20	18:50	05:16	06:38	17:09	18:32	05:41	07:11	17:07	18:37	05:54	07:09	18:36	19:51	11
18	05:51	07:19	17:24	18:53	05:14	06:36	17:12	18:34	05:39	07:08	17:12	18:41	05:54	07:09	18:38	19:52	18
25	05:47	07:15	17:29	18:57	05:12	06:33	17:16	18:37	05:36	07:04	17:16	18:45	05:54	07:08	18:39	19:53	25
Aug 1	05:43	07:10	17:34	19:01	05:09	06:29	17:20	18:40	05:31	06:59	17:21	18:49	05:53	07:06	18:41	19:54	Aug 1
8	05:37	07:03	17:39	19:06	05:05	06:24	17:23	18:43	05:25	06:52	17:27	18:53	05:51	07:04	18:42	19:54	8
15	05:31	06:56	17:45	19:10	05:00	06:18	17:27	18:46	05:19	06:44	17:32	18:58	05:49	07:01	18:43	19:55	15
22	05:23	06:48	17:50	19:14	04:54	06:12	17:30	18:48	05:11	06:36	17:37	19:02	05:46	06:57	18:43	19:54	22
29	05:15	06:39	17:55	19:19	04:47	06:05	17:33	18:51	05:02	06:27	17:42	19:07	05:42	06:53	18:43	19:54	29
Sep 5	05:05	06:29	18:00	19:24	04:40	05:57	17:36	18:54	04:53	06:17	17:47	19:12	05:38	06:48	18:43	19:54	Sep 5
12	04:56	06:19	18:05	19:29	04:32	05:49	17:40	18:57	04:43	06:07	17:53	19:17	05:33	06:44	18:43	19:54	12
19	04:45	06:09	18:10	19:34	04:24	05:41	17:43	19:00	04:33	05:57	17:58	19:22	05:28	06:39	18:43	19:53	19
26	04:35	05:59	18:15	19:40	04:15	05:33	17:46	19:04	04:22	05:47	18:03	19:28	05:23	06:34	18:43	19:53	26
Oct 3	04:24	05:49	18:20	19:46	04:06	05:25	17:49	19:08	04:11	05:37	18:08	19:35	05:18	06:29	18:43	19:54	Oct 3
10	04:13	05:40	18:26	19:53	03:58	05:17	17:53	19:13	04:00	05:27	18:14	19:42	05:14	06:25	18:43	19:55	10
17	04:02	05:31	18:32	20:01	03:50	05:10	17:57	19:18	03:49	05:18	18:20	19:49	05:09	06:21	18:44	19:56	17
24	03:52	05:22	18:38	20:09	03:42	05:03	18:01	19:23	03:39	05:10	18:26	19:57	05:05	06:17	18:45	19:58	24
31	03:42	05:15	18:44	20:17	03:34	04:58	18:06	19:29	03:29	05:02	18:33	20:06	05:01	06:14	18:47	20:01	31
Nov 7	03:33	05:08	18:51	20:27	03:28	04:53	18:11	19:36	03:20	04:55	18:40	20:16	04:58	06:12	18:49	20:04	Nov 7
14	03:25	05:02	18:58	20:36	03:22	04:49	18:16	19:43	03:11	04:50	18:47	20:25	04:56	06:11	18:52	20:07	14
21	03:18	04:58	19:05	20:46	03:18	04:46	18:22	19:50	03:05	04:45	18:54	20:35	04:55	06:11	18:55	20:12	21
28	03:13	04:56	19:12	20:55	03:15	04:45	18:27	19:57	02:59	04:43	19:00	20:44	04:54	06:12	18:59	20:16	28
Dec 5	03:10	04:55	19:18	21:03	03:14	04:45	18:32	20:04	02:56	04:42	19:07	20:52	04:55	06:13	19:02	20:20	Dec 5
12	03:09	04:55	19:23	21:10	03:14	04:46	18:37	20:10	02:55	04:42	19:12	20:59	04:57	06:15	19:06	20:25	12
19	03:11	04:58	19:28	21:15	03:16	04:49	18:42	20:14	02:57	04:44	19:17	21:04	05:00	06:19	19:10	20:29	19
26	03:14	05:01	19:31	21:18	03:20	04:52	18:45	20:17	03:00	04:48	19:20	21:07	05:03	06:22	19:13	20:32	26

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 4	02:24	04:38	19:53	22:06	03:10	05:03	19:46	21:39	03:37	05:16	19:26	21:05	03:06	04:49	19:10	20:53	Jan 4
11	02:35	04:46	19:51	22:01	03:18	05:10	19:45	21:36	03:44	05:21	19:27	21:04	03:13	04:55	19:10	20:51	11
18	02:48	04:54	19:48	21:53	03:28	05:17	19:43	21:31	03:52	05:28	19:25	21:01	03:22	05:02	19:08	20:48	18
25	03:02	05:03	19:43	21:43	03:39	05:25	19:39	21:24	04:00	05:34	19:23	20:56	03:31	05:09	19:05	20:42	25
Feb 1	03:17	05:12	19:36	21:31	03:50	05:33	19:34	21:16	04:09	05:41	19:19	20:50	03:41	05:16	19:01	20:35	Feb 1
8	03:31	05:22	19:28	21:18	04:01	05:41	19:27	21:06	04:18	05:47	19:14	20:43	03:50	05:23	18:55	20:27	8
15	03:44	05:31	19:19	21:05	04:12	05:48	19:19	20:55	04:26	05:54	19:07	20:35	03:59	05:29	18:48	20:18	15
22	03:57	05:40	19:08	20:51	04:22	05:56	19:10	20:44	04:34	06:00	19:00	20:26	04:08	05:36	18:41	20:09	22
29	04:09	05:49	18:57	20:37	04:32	06:03	19:01	20:32	04:41	06:05	18:52	20:16	04:15	05:42	18:32	19:59	29
Mar 7	04:20	05:58	18:45	20:23	04:40	06:10	18:51	20:21	04:48	06:11	18:44	20:07	04:23	05:48	18:24	19:49	Mar 7
14	04:30	06:07	18:33	20:09	04:48	06:17	18:40	20:09	04:54	06:16	18:35	19:57	04:29	05:54	18:14	19:38	14
21	04:40	06:15	18:21	19:56	04:56	06:24	18:30	19:58	04:59	06:21	18:26	19:48	04:36	05:59	18:05	19:28	21
28	04:49	06:23	18:09	19:43	05:03	06:30	18:19	19:46	05:04	06:25	18:17	19:38	04:41	06:04	17:55	19:18	28
Apr 4	04:57	06:31	17:57	19:30	05:10	06:37	18:09	19:36	05:09	06:30	18:09	19:30	04:47	06:09	17:46	19:09	Apr 4
11	05:05	06:39	17:45	19:19	05:16	06:43	17:59	19:26	05:14	06:35	18:00	19:21	04:52	06:15	17:37	19:00	11
18	05:12	06:47	17:34	19:08	05:22	06:49	17:49	19:16	05:18	06:40	17:52	19:14	04:56	06:20	17:28	18:52	18
25	05:19	06:55	17:23	18:58	05:27	06:56	17:40	19:08	05:22	06:44	17:44	19:07	05:01	06:25	17:20	18:44	25
May 2	05:26	07:02	17:13	18:49	05:33	07:02	17:32	19:01	05:26	06:49	17:38	19:01	05:06	06:31	17:13	18:38	May 2
9	05:33	07:10	17:05	18:42	05:38	07:08	17:24	18:54	05:30	06:54	17:32	18:56	05:10	06:36	17:07	18:33	9
16	05:39	07:17	16:57	18:36	05:43	07:14	17:18	18:49	05:34	06:59	17:27	18:52	05:14	06:41	17:02	18:28	16
23	05:44	07:24	16:51	18:31	05:48	07:20	17:13	18:45	05:38	07:03	17:23	18:49	05:18	06:46	16:57	18:25	23
30	05:50	07:30	16:47	18:28	05:52	07:25	17:10	18:43	05:41	07:08	17:21	18:47	05:22	06:50	16:55	18:23	30
Jun 6	05:54	07:36	16:44	18:26	05:56	07:30	17:08	18:42	05:44	07:11	17:19	18:46	05:25	06:54	16:53	18:22	Jun 6
13	05:57	07:39	16:43	18:25	05:59	07:33	17:07	18:41	05:47	07:14	17:19	18:46	05:28	06:58	16:53	18:22	13
20	05:59	07:42	16:43	18:26	06:01	07:35	17:08	18:42	05:49	07:17	17:20	18:47	05:30	07:00	16:53	18:23	20
27	06:01	07:43	16:46	18:28	06:02	07:36	17:10	18:44	05:50	07:18	17:22	18:49	05:31	07:01	16:55	18:25	27
Jul 4	06:00	07:42	16:49	18:31	06:02	07:36	17:13	18:47	05:51	07:18	17:25	18:52	05:32	07:01	16:58	18:27	Jul 4
11	05:59	07:40	16:54	18:35	06:01	07:34	17:17	18:50	05:50	07:16	17:28	18:55	05:31	06:59	17:02	18:30	11
18	05:55	07:36	17:00	18:40	05:58	07:31	17:22	18:54	05:48	07:14	17:32	18:58	05:29	06:57	17:06	18:34	18
25	05:51	07:30	17:06	18:45	05:55	07:26	17:27	18:59	05:45	07:10	17:36	19:01	05:26	06:53	17:11	18:38	25
Aug 1	05:45	07:22	17:13	18:51	05:50	07:20	17:33	19:03	05:41	07:05	17:41	19:05	05:21	06:47	17:16	18:42	Aug 1
8	05:37	07:14	17:20	18:57	05:44	07:13	17:39	19:08	05:36	07:00	17:45	19:08	05:16	06:41	17:20	18:46	8
15	05:29	07:04	17:27	19:03	05:36	07:05	17:45	19:13	05:30	06:53	17:50	19:12	05:10	06:34	17:25	18:50	15
22	05:19	06:54	17:35	19:10	05:28	06:56	17:51	19:18	05:23	06:45	17:54	19:16	05:02	06:26	17:30	18:54	22
29	05:08	06:42	17:42	19:16	05:19	06:46	17:56	19:24	05:16	06:37	17:58	19:20	04:54	06:17	17:35	18:58	29
Sep 5	04:57	06:31	17:50	19:24	05:09	06:36	18:02	19:29	05:07	06:28	18:03	19:24	04:45	06:08	17:40	19:03	Sep 5
12	04:44	06:18	17:57	19:31	04:58	06:25	18:08	19:35	04:58	06:19	18:07	19:28	04:36	05:59	17:45	19:07	12
19	04:31	06:06	18:05	19:39	04:47	06:14	18:14	19:42	04:49	06:10	18:11	19:32	04:26	05:49	17:49	19:13	19
26	04:18	05:53	18:12	19:48	04:35	06:03	18:20	19:48	04:39	06:01	18:15	19:37	04:15	05:39	17:54	19:18	26
Oct 3	04:04	05:41	18:20	19:58	04:23	05:52	18:26	19:56	04:29	05:52	18:20	19:43	04:05	05:29	17:59	19:24	Oct 3
10	03:50	05:29	18:28	20:08	04:11	05:42	18:33	20:04	04:19	05:43	18:25	19:49	03:54	05:20	18:04	19:30	10
17	03:36	05:17	18:37	20:19	03:59	05:32	18:39	20:12	04:10	05:35	18:30	19:55	03:44	05:11	18:10	19:38	17
24	03:21	05:06	18:45	20:31	03:48	05:23	18:46	20:22	04:00	05:27	18:35	20:02	03:34	05:03	18:16	19:45	24
31	03:08	04:56	18:54	20:43	03:37	05:14	18:54	20:32	03:52	05:20	18:41	20:10	03:24	04:56	18:22	19:54	31
Nov 7	02:54	04:47	19:03	20:57	03:26	05:07	19:01	20:42	03:44	05:14	18:47	20:18	03:16	04:49	18:29	20:02	Nov 7
14	02:42	04:39	19:12	21:11	03:17	05:00	19:09	20:53	03:37	05:09	18:53	20:26	03:08	04:44	18:35	20:11	14
21	02:31	04:33	19:21	21:25	03:09	04:56	19:16	21:04	03:31	05:06	19:00	20:35	03:02	04:40	18:42	20:21	21
28	02:21	04:29	19:30	21:38	03:03	04:53	19:24	21:14	03:27	05:04	19:06	20:43	02:57	04:38	18:49	20:29	28
Dec 5	02:15	04:27	19:37	21:50	02:59	04:51	19:30	21:23	03:25	05:03	19:12	20:50	02:54	04:37	18:55	20:37	Dec 5
12	02:11	04:26	19:44	21:59	02:57	04:51	19:36	21:31	03:25	05:04	19:17	20:56	02:54	04:37	19:00	20:44	12
19	02:11	04:28	19:48	22:06	02:58	04:53	19:41	21:36	03:26	05:06	19:21	21:01	02:55	04:40	19:05	20:49	19
26	02:15	04:32	19:52	22:08	03:02	04:57	19:44	21:39	03:30	05:10	19:24	21:04	02:59	04:43	19:08	20:52	26

ORIENTATION OF THE SUN



SYNODIC ROTATION NUMBERS (UT)		
Rotation	Month	d.dd
2226	Jan	6.38
2227	Feb	2.72
2228	Mar	1.06
2229	Mar	28.37
2230	Apr	24.64
2231	May	21.87
2232	Jun	18.07
2233	Jul	15.27
2234	Aug	11.49
2235	Sep	7.74
2236	Oct	5.01
2237	Nov	1.30
2238	Nov	28.61
2239	Dec	25.93

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.

Date	P°	B_o°	L_o°	Date	P°	B_o°	L_o°
Jan 4	+ 0.9	- 3.3	031.3	Jul 4	- 1.1	+ 3.2	149.2
11	- 2.5	- 4.1	299.2	11	+ 2.0	+ 4.0	056.5
18	- 5.8	- 4.8	207.0	18	+ 5.1	+ 4.6	323.9
25	- 9.0	- 5.4	114.8	25	+ 8.1	+ 5.3	231.3
Feb 1	- 11.9	- 6.0	022.6	Aug 1	+ 11.0	+ 5.8	138.7
8	- 14.7	- 6.4	290.5	8	+ 13.6	+ 6.3	046.1
15	- 17.2	- 6.8	198.3	15	+ 16.1	+ 6.7	313.6
22	- 19.4	- 7.1	106.1	22	+ 18.4	+ 7.0	221.1
29	- 21.4	- 7.2	013.9	29	+ 20.4	+ 7.1	128.6
Mar 7	- 23.0	- 7.3	281.7	Sep 5	+ 22.1	+ 7.2	036.1
14	- 24.3	- 7.2	189.5	12	+ 23.6	+ 7.2	303.7
21	- 25.3	- 7.0	097.2	19	+ 24.7	+ 7.1	211.3
28	- 25.9	- 6.7	004.9	26	+ 25.6	+ 6.9	118.9
Apr 4	- 26.2	- 6.4	272.6	Oct 3	+ 26.1	+ 6.6	026.5
11	- 26.2	- 5.9	180.2	10	+ 26.3	+ 6.2	294.2
18	- 25.8	- 5.4	087.7	17	+ 26.1	+ 5.7	201.8
25	- 25.0	- 4.7	355.3	24	+ 25.5	+ 5.1	109.5
May 2	- 23.9	- 4.0	262.8	31	+ 24.6	+ 4.5	017.2
9	- 22.4	- 3.3	170.2	Nov 7	+ 23.3	+ 3.7	284.9
16	- 20.6	- 2.5	077.7	14	+ 21.6	+ 2.9	192.6
23	- 18.4	- 1.7	345.1	21	+ 19.5	+ 2.1	100.3
30	- 16.0	- 0.9	252.5	28	+ 17.1	+ 1.2	008.1
Jun 6	- 13.3	- 0.0	159.8	Dec 5	+ 14.3	+ 0.3	275.8
13	- 10.5	+ 0.8	067.2	12	+ 11.4	- 0.6	183.6
20	- 7.4	+ 1.6	334.5	19	+ 8.2	- 1.4	091.3
27	- 4.3	+ 2.5	241.9	26	+ 4.9	- 2.3	359.1

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 7 March (281.7°) 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:

281.7° + (–52.7°) + (–3.3°) = 225.7° (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

SOLAR AND LUNAR ECLIPSES

During 2020 there are six eclipses, two of the Sun and four of the Moon. Of the solar eclipses there will an annular and a total. All of the lunar eclipses are penumbral. All in all, a rather poor year for eclipses over Australia.

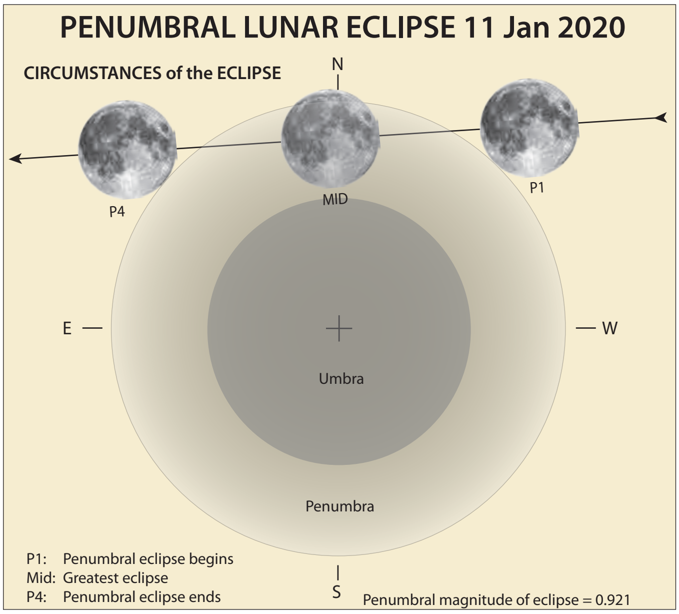
The magnitudes quoted in this section are not a measure of brightness. For solar eclipses it is the fraction of the Sun's diameter occulted by the Moon. It is strictly a ratio of diameters and should not be confused with eclipse obscuration, which is a measure of the Sun's surface area occulted by the 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.

11 January **Penumbral eclipse of the Moon**

The first eclipse of the year is a penumbral lunar eclipse, visible from Asia, Australia, Europe and Africa. The brightening dawn sky will interfere with the view from the eastern and central regions of the continent. Western Australia will get the best view and with a magnitude of 0.921 the Moon will be deeply immersed in the penumbral shadow. Penumbral eclipses are rather subtle affairs with the Moon going through the diffuse outer shadow of the Earth. A casual observer would probably not notice any change in the Moon's appearance. However, due to its depth, keen observers in WA should see a definite darkening on the Moon's southern highlands at mid-eclipse.

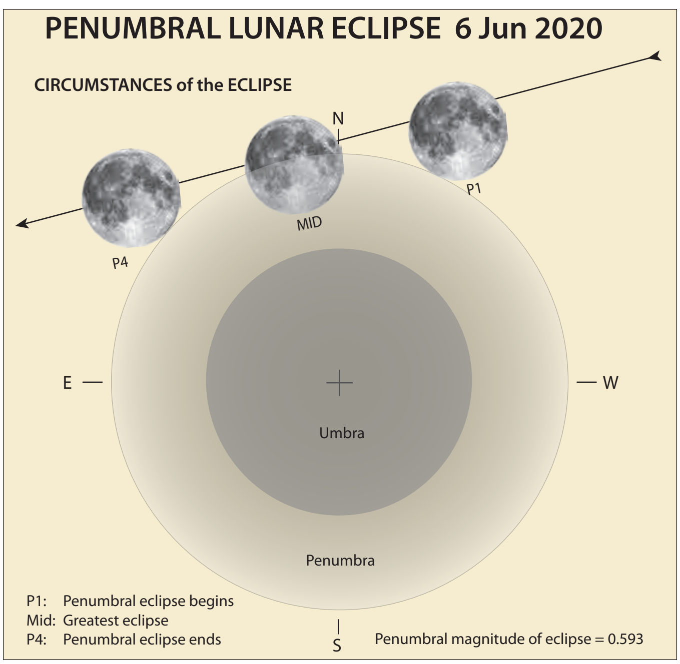
		UT(10th)	EST(11th)	CST(11th)	WST(11th)
Penumbral eclipse begins	P1	17:05.7	3:06 am	2:36 am	1:06 am
Mid-eclipse	Mid	19:10.0	Dawn	Dawn	3:10 am
Penumbral eclipse ends	P4	21:14.4	Below horizon	Below horizon	Dawn



6 June — Penumbral eclipse of the Moon

The second penumbral lunar eclipse is visible from Asia, Australia, Africa and parts of Europe and South America. At magnitude 0.593 the Moon will be a little more than half immersed as it slides through the penumbra at mid-eclipse. Experienced observers may detect a very slight degree of shading on the lunar southern highlands. From Australia, WA is favoured, although it's probably not worth getting up early for.

		UT (5th)	EST (6th)	CST (6th)	WST (6th)
Penumbral eclipse begins	P1	17:43.3	3:43 am	3:13 am	1:43 am
Mid-eclipse	Mid	19:25.1	5:25 am	4:55 am	3:25 am
Penumbral eclipse ends	P4	21:06.6	Below horizon	Dawn	5:07 am



21 June — Annular eclipse of the Sun

The ring of fire of this annular eclipse follows a path across central Africa, southern Asia and China. Whilst a partial eclipse will be visible from the top end of Australia, it occurs at low altitude and close to sunset. From Darwin mid-eclipse happens at 6:05 pm CST with the Sun just 5° above the horizon. The eclipse ends as the Sun sets. The magnitude from Darwin is 0.11 with just 4.3% of the Sun covered.

About the only other reasonably accessible place (although remote) in Australia would be the tip of the Cape York Peninsula. where mid-eclipse occurs as the Sun sets at 6:14 pm EST. The magnitude from Cape York is 0.22 with 11.6% of the Sun covered.

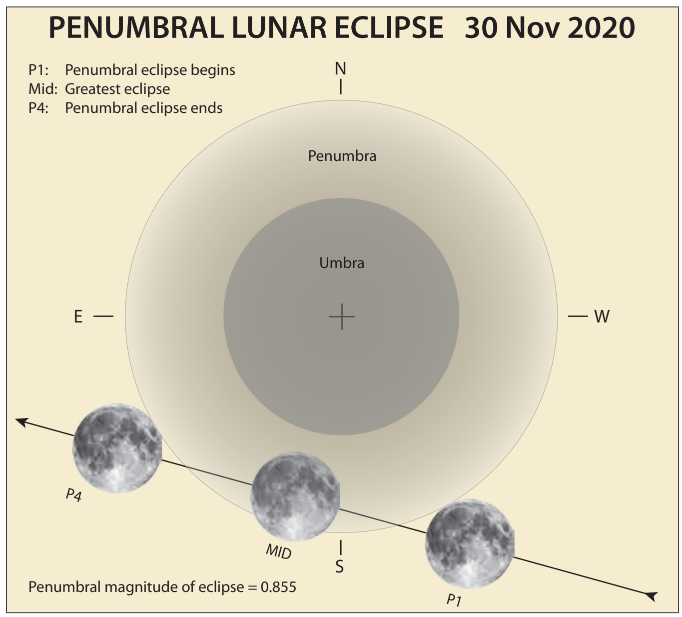
5 July (UT) — Penumbral eclipse of the Moon

The third penumbral eclipse of the Moon is not visible from Australia. South America and most of Africa and North America will witness a barely perceptible eclipse with a penumbral magnitude of 0.38.

30 November — Penumbral eclipse of the Moon

The fourth and final penumbral lunar eclipse of the year is visible from Australia, North and South America and parts of Asia. It will only be observers in the eastern states that see anything of this eclipse. With a reasonably deep penumbral magnitude of 0.855, the northern limb of the Moon will appear a shade or two darker than a normal full Moon at mid-eclipse, at least to an observant person.

		UT	EST	CST	WST
Penumbral eclipse begins	P1	07:30.0	Below horizon	Below horizon	Below horizon
Mid-eclipse	Mid	09:42.9	7:43 pm	Below horizon	Below horizon
Penumbral eclipse ends	P4	11:55.8	9:56 pm	9:26 pm	7:56 pm



14 December (UT) — Total eclipse of the Sun

The eclipse path begins over the Pacific Ocean and makes first contact with land near Puerto Saavedra in Chile where the locals can enjoy around two minutes of totality. Continuing across South America the path exits the continent near Balneario El Cóndor in Argentina where totality lasts for about 1 minute 50 seconds. The path then makes a watery track across the south Atlantic Ocean with the eclipse ending at sunset off the coast of Namibia, Africa. Outside of the totality zone a partial eclipse will be seen from the bottom tip of South America to as far north as the southern parts of Bolivia, Paraguay and Brazil. Maximum duration of totality is 2 minutes 10 seconds over Argentina, with a path width of 90 km.

ADELAIDE (CST) MOON RISE AND SET BRISBANE (EST)

ADELAIDE (CST)

	JANUARY Rise	JANUARY Set	FEBRUARY Rise	FEBRUARY Set	MARCH Rise	MARCH Set	APRIL Rise	APRIL Set
1	10:26	23:36	11:56	23:27	11:40	22:30	13:26	23:24
2	11:21	DNS	12:52	23:58	12:38	23:07	14:20	DNS
3	12:16	00:04	13:50	DNS	13:37	23:49	15:10	00:24
4	13:11	00:31	14:50	00:33	14:37	DNS	15:56	01:29
5	14:07	00:59	15:52	01:13	15:35	00:39	16:37	02:39
6	15:05	01:28	16:53	02:00	16:30	01:37	17:15	03:50
7	16:06	02:01	17:51	02:55	17:20	02:42	17:51	05:02
8	17:08	02:39	18:45	03:58	18:05	03:52	18:27	06:15
9	18:11	03:24	19:33	05:07	18:45	05:04	19:04	07:28
10	19:11	04:16	20:15	06:19	19:23	06:17	19:43	08:40
11	20:07	05:15	20:54	07:31	19:59	07:30	20:27	09:52
12	20:57	06:21	21:29	08:43	20:35	08:42	21:14	11:00
13	21:42	07:30	22:04	09:53	21:12	09:53	22:07	12:04
14	22:21	08:40	22:39	11:01	21:52	11:03	23:03	13:01
15	22:57	09:50	23:16	12:09	22:35	12:10	DNR	13:51
16	23:30	10:58	23:55	13:15	23:23	13:14	00:00	14:34
17	DNR	12:05	DNR	14:19	DNR	14:13	00:58	15:12
18	00:04	13:11	00:39	15:20	00:15	15:06	01:56	15:44
19	00:38	14:16	01:27	16:17	01:11	15:53	02:52	16:14
20	01:15	15:22	02:20	17:08	02:08	16:34	03:48	16:41
21	01:56	16:25	03:16	17:53	03:05	17:09	04:43	17:08
22	02:41	17:25	04:13	18:32	04:02	17:41	05:37	17:34
23	03:31	18:21	05:11	19:07	04:58	18:10	06:33	18:02
24	04:26	19:11	06:08	19:38	05:53	18:37	07:29	18:32
25	05:23	19:55	07:04	20:06	06:48	19:04	08:26	19:06
26	06:21	20:33	07:59	20:34	07:43	19:31	09:25	19:44
27	07:19	21:06	08:53	21:01	08:38	19:59	10:24	20:27
28	08:16	21:37	09:48	21:28	09:34	20:30	11:21	21:18
29	09:11	22:05	10:43	21:57	10:31	21:05	12:16	22:14
30	10:06	22:32			11:30	21:45	13:06	23:17
31	11:01	22:59			12:28	22:31		

	MAY Rise	MAY Set	JUNE Rise	JUNE Set	JULY Rise	JULY Set	AUGUST Rise	AUGUST Set
1	13:52	DNS	14:19	01:35	14:03	02:50	15:06	05:06
2	14:33	00:23	14:53	02:44	14:43	03:59	16:04	06:03
3	15:11	01:31	15:28	03:53	15:28	05:07	17:05	06:53
4	15:46	02:40	16:06	05:04	16:19	06:14	18:06	07:36
5	16:21	03:51	16:49	06:15	17:16	07:16	19:07	08:14
6	16:56	05:02	17:38	07:25	18:17	08:12	20:05	08:46
7	17:34	06:14	18:33	08:31	19:18	09:00	21:02	09:15
8	18:15	07:27	19:32	09:31	20:19	09:41	21:57	09:43
9	19:01	08:38	20:33	10:23	21:19	10:16	22:52	10:09
10	19:53	09:47	21:34	11:07	22:16	10:47	23:47	10:36
11	20:49	10:49	22:33	11:45	23:12	11:15	DNR	11:04
12	21:48	11:44	23:31	12:17	DNR	11:42	00:43	11:35
13	22:48	12:31	DNR	12:47	00:07	12:08	01:41	12:10
14	23:47	13:11	00:27	13:14	01:02	12:35	02:40	12:50
15	DNR	13:46	01:22	13:40	01:58	13:05	03:39	13:38
16	00:45	14:17	02:17	14:07	02:55	13:38	04:37	14:33
17	01:41	14:45	03:12	14:35	03:54	14:15	05:32	15:35
18	02:36	15:11	04:09	15:06	04:54	14:59	06:22	16:42
19	03:31	15:38	05:07	15:41	05:54	15:51	07:06	17:52
20	04:26	16:05	06:07	16:21	06:51	16:49	07:46	19:03
21	05:22	16:34	07:07	17:08	07:43	17:53	08:22	20:13
22	06:19	17:06	08:06	18:02	08:30	19:01	08:56	21:23
23	07:18	17:43	09:01	19:02	09:12	20:10	09:30	22:33
24	08:17	18:25	09:50	20:06	09:49	21:19	10:05	23:42
25	09:16	19:14	10:34	21:13	10:24	22:27	10:42	DNS
26	10:13	20:09	11:13	22:20	10:57	23:34	11:23	00:50
27	11:05	21:10	11:48	23:27	11:29	DNS	12:09	01:57
28	11:52	22:14	12:21	DNS	12:04	00:42	13:00	03:00
29	12:33	23:20	12:54	00:34	12:42	01:50	13:57	03:58
30	13:11	DNS	13:27	01:42	13:24	02:57	14:56	04:50
31	13:46	00:28			14:12	04:03	15:57	05:35

	SEPTEMBER Rise	SEPTEMBER Set	OCTOBER Rise	OCTOBER Set	NOVEMBER Rise	NOVEMBER Set	DECEMBER Rise	DECEMBER Set
1	16:57	06:13	17:42	05:48	19:19	05:38	20:05	05:20
2	17:56	06:47	18:37	06:14	20:16	06:08	21:02	06:02
3	18:53	07:17	19:32	06:40	21:14	06:42	21:55	06:51
4	19:49	07:44	20:28	07:07	22:11	07:20	22:44	07:47
5	20:44	08:11	21:24	07:35	23:06	08:05	23:28	08:47
6	21:39	08:37	22:21	08:06	23:58	08:55	DNR	09:50
7	22:35	09:04	23:19	08:42	DNR	09:52	00:07	10:54
8	23:31	09:34	DNR	09:22	00:45	10:53	00:42	12:00
9	DNR	10:07	00:16	10:09	01:28	11:58	01:14	13:07
10	00:29	10:44	01:11	11:02	02:06	13:05	01:46	14:14
11	01:27	11:27	02:02	12:02	02:41	14:13	02:19	15:24
12	02:24	12:18	02:49	13:07	03:15	15:23	02:53	16:35
13	03:19	13:16	03:31	14:15	03:48	16:34	03:32	17:49
14	04:10	14:20	04:10	15:25	04:23	17:47	04:16	19:01
15	04:57	15:28	04:45	16:36	05:01	19:02	05:08	20:10
16	05:38	16:39	05:20	17:49	05:43	20:16	06:06	21:12
17	06:16	17:51	05:55	19:02	06:32	21:27	07:10	22:04
18	06:52	19:03	06:31	20:16	07:26	22:31	08:15	22:48
19	07:27	20:15	07:11	21:30	08:27	23:27	09:19	23:25
20	08:02	21:27	07:56	22:41	09:30	DNS	10:21	23:56
21	08:39	22:38	08:46	23:46	10:33	00:14	11:20	DNS
22	09:20	23:48	09:42	DNS	11:34	00:53	12:17	00:25
23	10:05	DNS	10:42	00:44	12:33	01:26	13:12	00:51
24	10:56	00:54	11:43	01:34	13:30	01:56	14:07	01:17
25	11:51	01:55	12:44	02:16	14:26	02:23	15:03	01:43
26	12:50	02:49	13:43	02:52	15:21	02:48	16:00	02:11
27	13:50	03:35	14:41	03:24	16:16	03:14	16:57	02:42
28	14:50	04:15	15:37	03:52	17:12	03:41	17:56	03:17
29	15:49	04:49	16:32	04:18	18:09	04:10	18:54	03:58
30	16:46	05:20	17:27	04:44	19:07	04:42	19:50	04:46
31			18:22	05:10			20:41	05:40

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.

BRISBANE (EST)

	JANUARY Rise	JANUARY Set	FEBRUARY Rise	FEBRUARY Set	MARCH Rise	MARCH Set	APRIL Rise	APRIL Set
1	10:04	23:02	11:20	23:05	10:59	22:13	12:36	23:13
2	10:55	23:33	12:13	23:39	11:54	22:53	13:31	DNS
3	11:46	DNS	13:08	DNS	12:51	23:37	14:23	00:12
4	12:38	00:03	14:05	00:17	13:48	DNS	15:12	01:15
5	13:30	00:35	15:04	01:00	14:46	00:28	15:57	02:21
6	14:25	01:08	16:04	01:48	15:42	01:26	16:40	03:28
7	15:22	01:44	17:02	02:44	16:34	02:29	17:20	04:36
8	16:21	02:25	17:58	03:46	17:23	03:35	18:01	05:44
9	17:22	03:11	18:49	04:52	18:08	04:44	18:42	06:52
10	18:22	04:04	19:36	06:01	18:50	05:53	19:26	08:00
11	19:19	05:04	20:19	07:09	19:31	07:01	20:12	09:07
12	20:12	06:07	20:59	08:16	20:11	08:08	21:03	10:13
13	21:00	07:14	21:38	09:21	20:52	09:15	21:56	11:15
14	21:43	08:20	22:17	10:26	21:36	10:20	22:52	12:12
15	22:23	09:26	22:57	11:29	22:22	11:25	23:48	13:04
16	23:01	10:29	23:40	12:32	23:12	12:27	DNR	13:49
17	23:39	11:32	DNR	13:33	DNR	13:25	00:44	14:29
18	DNR	12:34	00:26	14:32	00:04	14:18	01:38	15:05
19	00:17	13:36	01:16	15:28	00:59	15:06	02:31	15:38
20	00:58	14:37	02:09	16:20	01:54	15:49	03:23	16:09
21	01:41	15:38	03:04	17:07	02:49	16:28	04:14	16:39
22	02:29	16:37	03:59	17:49	03:43	17:03	05:06	17:09
23	03:20	17:33	04:54	18:27	04:36	17:35	05:57	17:40
24	04:14	18:24	05:48	19:01	05:28	18:06	06:50	18:14
25	05:10	19:09	06:40	19:33	06:19	18:36	07:44	18:50
26	06:06	19:50	07:32	20:04	07:10	19:07	08:39	19:31
27	07:01	20:27	08:23	20:34	08:01	19:39	09:36	20:16
28	07:55	21:01	09:14	21:05	08:54	20:13	10:32	21:07
29	08:47	21:32	10:06	21:38	09:48	20:50	11:27	22:03
30	09:38	22:03			10:44	21:32	12:18	23:04
31	10:29	22:33			11:40	22:20		

	MAY Rise	MAY Set	JUNE Rise	JUNE Set	JULY Rise	JULY Set	AUGUST Rise	AUGUST Set
1	13:07	DNS	13:49	01:09	13:44	02:11	14:55	04:17
2	13:52	00:07	14:27	02:12	14:28	03:16	15:53	05:14
3	14:33	01:11	15:06	03:17	15:16	04:21	16:52	06:06
4	15:13	02:16	15:49	04:23	16:09	05:25	17:51	06:52
5	15:52	03:22	16:35	05:30	17:06	06:27	18:48	07:32
6	16:32	04:28	17:27	06:37	18:05	07:23	19:42	08:08
7	17:14	05:36	18:22	07:42	19:04	08:13	20:35	08:41
8	17:59	06:44	19:21	08:42	20:03	08:57	21:27	09:12
9	18:49	07:52	20:20	09:35	20:58	09:36	22:18	09:42
10	19:42	08:58	21:19	10:22	21:52	10:10	23:10	10:12
11	20:38	10:00	22:15	11:03	22:44	10:42	DNR	10:44
12	21:36	10:55	23:09	11:39	23:36	11:12	00:03	11:18
13	22:34	11:45	DNR	12:12	DNR	11:42	00:57	11:56
14	23:31	12:28	00:02	12:43	00:27	12:13	01:53	12:39
15	DNR	13:06	00:53	13:12	01:19	12:46	02:50	13:27
16	00:25	13:40	01:44	13:43	02:13	13:22	03:47	14:22
17	01:18	14:11	02:36	14:14	03:09	14:02	04:43	15:23
18	02:09	14:41	03:29	14:48	04:06	14:48	05:35	16:28
19	03:00	15:11	04:24	15:26	05:04	15:40	06:23	17:34
20	03:51	15:42	05:21	16:09	06:01	16:38	07:07	18:40
21	04:44	16:14	06:19	16:57	06:55	17:40	07:48	19:46
22	05:38	16:50	07:16	17:51	07:45	18:45	08:26	20:51
23	06:33	17:29	08:12	18:50	08:31	19:50	09:04	21:56
24	07:30	18:14	09:03	19:52	09:12	20:55	09:43	23:01
25	08:27	19:03	09:50	20:56	09:51	21:58	10:24	DNS
26	09:23	19:58	10:33	21:59	10:28	23:01	11:09	00:06
27	10:16	20:58	11:12	23:02	11:05	DNS	11:57	01:09
28	11:06	21:59	11:50	DNS	11:44	00:04	12:50	02:11
29	11:51	23:02	12:27	00:04	12:25	01:08	13:46	03:09
30	12:32	DNS	13:04	01:07	13:11	02:12	14:44	04:02
31	13:11	00:05			14:01	03:15	15:42	04:49

	SEPTEMBER Rise	SEPTEMBER Set	OCTOBER Rise	OCTOBER Set	NOVEMBER Rise	NOVEMBER Set	DECEMBER Rise	DECEMBER Set
1	16:39	05:30	17:15	05:14	18:38	05:18	19:17	05:08
2	17:34	06:07	18:06	05:45	19:32	05:51	20:12	05:52
3	18:28	06:41	18:58	06:14	20:26	06:28	21:05	06:42
4	19:20	07:12	19:50	06:44	21:22	07:09	21:56	07:37
5	20:12	07:43	20:42	07:16	22:16	07:55	22:42	08:35
6	21:03	08:12	21:36	07:51	23:08	08:46	23:24	09:35
7	21:55	08:43	22:31	08:29	23:57	09:42	DNR	10:36
8	22:48	09:16	23:26	09:11	DNR	10:41	00:03	11:37
9	23:43	09:52	DNR	09:59	00:43	11:42	00:40	12:39
10	DNR	10:32	00:21	10:52	01:25	12:45	01:17	13:42
11	00:39	11:17	01:13	11:51	02:04	13:49	01:53	14:47
12	01:35	12:08	02:02	12:53	02:43	14:54	02:32	15:54
13	02:30	13:05	02:48	13:57	03:20	16:00	03:15	17:03
14	03:22	14:07	03:30	15:03	04:00	17:08	04:03	18:12
15	04:12	15:12	04:11	16:09	04:42	18:18	04:57	19:20
16	04:57	16:19	04:50	17:17	05:28	19:29	05:57	20:21
17	05:40	17:26	05:29	18:25	06:20	20:37	06:59	21:16
18	06:20	18:33	06:11	19:34	07:16	21:41	08:02	22:03
19	06:59	19:40	06:55	20:44	08:17	22:38	09:03	22:43
20	07:39	20:48	07:43	21:52	09:18	23:27	10:01	23:19
21	08:20	21:55	08:36	22:56	10:18	DNS	10:57	23:51
22	09:05	23:01	09:32	23:55	11:17	00:10	11:50	DNS
23	09:53	DNS	10:31	DNS	12:12	00:47	12:42	00:21
24	10:45	00:05	11:30	00:46	13:05	01:20	13:33	00:51
25	11:41	01:05	12:28	01:31	13:57	01:51	14:25	01:21
26	12:39	02:00	13:24	02:11	14:48	02:20	15:18	01:52
27	13:37	02:48	14:18	02:46	15:40	02:49	16:12	02:26
28	14:34	03:31	15:11	03:18	16:32	03:20	17:08	03:04
29	15:29	04:09	16:02	03:48	17:26	03:52	18:04	03:48
30	16:23	04:43	16:53	04:17	18:21	04:28	18:59	04:36
31			17:45	04:47			19:52	05:30

CANBERRA (EST) MOON RISE AND SET DARWIN (CST)

CANBERRA (EST)

Day	JANUARY Rise	JANUARY Set	FEBRUARY Rise	FEBRUARY Set	MARCH Rise	MARCH Set	APRIL Rise	APRIL Set
1	10:12	23:23	11:42	23:14	11:27	22:16	13:13	23:09
2	11:07	23:51	12:39	23:44	12:25	22:52	14:07	DNS
3	12:02	DNS	13:37	DNS	13:24	23:35	14:57	00:09
4	12:57	00:18	14:37	00:19	14:24	DNS	15:43	01:14
5	13:54	00:45	15:39	00:59	15:22	00:25	16:24	02:24
6	14:52	01:15	16:40	01:45	16:17	01:22	17:02	03:35
7	15:53	01:48	17:38	02:40	17:07	02:27	17:38	04:48
8	16:55	02:25	18:32	03:43	17:52	03:37	18:14	06:01
9	17:58	03:09	19:20	04:52	18:32	04:49	18:50	07:14
10	18:58	04:01	20:02	06:04	19:10	06:03	19:29	08:27
11	19:54	05:00	20:41	07:17	19:46	07:16	20:12	09:38
12	20:45	06:06	21:16	08:28	20:21	08:28	21:00	10:47
13	21:29	07:15	21:51	09:39	20:58	09:39	21:52	11:51
14	22:08	08:25	22:25	10:47	21:38	10:49	22:48	12:49
15	22:44	09:35	23:02	11:55	22:21	11:57	23:46	13:39
16	23:17	10:44	23:41	13:02	23:09	13:01	DNR	14:22
17	23:50	11:51	DNR	14:06	DNR	14:01	00:44	14:59
18	DNR	12:57	00:25	15:08	00:01	14:54	01:42	15:32
19	00:25	14:03	01:13	16:04	00:56	15:41	02:38	16:01
20	01:01	15:08	02:05	16:55	01:53	16:21	03:34	16:28
21	01:42	16:12	03:01	17:40	02:50	16:57	04:29	16:55
22	02:27	17:13	03:58	18:20	03:48	17:28	05:24	17:21
23	03:17	18:08	04:56	18:54	04:44	17:57	06:19	17:49
24	04:11	18:58	05:54	19:25	05:39	18:24	07:15	18:19
25	05:08	19:42	06:50	19:54	06:34	18:51	08:13	18:52
26	06:07	20:20	07:45	20:21	07:29	19:18	09:12	19:29
27	07:05	20:54	08:40	20:47	08:24	19:46	10:11	20:13
28	08:02	21:24	09:35	21:15	09:21	20:16	11:08	21:03
29	08:57	21:52	10:30	21:44	10:18	20:51	12:03	22:00
30	09:52	22:19			11:17	21:30	12:54	23:02
31	10:47	22:46			12:15	22:16		

Day	MAY Rise	MAY Set	JUNE Rise	JUNE Set	JULY Rise	JULY Set	AUGUST Rise	AUGUST Set
1	13:39	DNS	14:06	01:21	13:50	02:36	14:51	04:53
2	14:20	00:08	14:39	02:30	14:29	03:45	15:49	05:50
3	14:58	01:16	15:14	03:39	15:14	04:54	16:50	06:41
4	15:33	02:26	15:52	04:50	16:05	06:01	17:52	07:24
5	16:07	03:36	16:35	06:01	17:01	07:04	18:52	08:01
6	16:43	04:48	17:24	07:12	18:02	07:59	19:51	08:34
7	17:20	06:00	18:18	08:18	19:04	08:47	20:48	09:03
8	18:01	07:13	19:17	09:18	20:05	09:28	21:43	09:30
9	18:47	08:25	20:18	10:10	21:04	10:03	22:38	09:56
10	19:38	09:33	21:19	10:55	22:02	10:34	23:34	10:23
11	20:34	10:36	22:19	11:32	22:58	11:02	DNR	10:50
12	21:33	11:31	23:17	12:05	23:53	11:29	00:30	11:21
13	22:33	12:19	DNR	12:34	DNR	11:55	01:28	11:56
14	23:32	12:59	00:13	13:01	00:48	12:22	02:27	12:36
15	DNR	13:34	01:08	13:27	01:44	12:51	03:26	13:23
16	00:30	14:04	02:03	13:54	02:42	13:24	04:24	14:18
17	01:27	14:32	02:59	14:22	03:41	14:01	05:19	15:20
18	02:22	14:59	03:56	14:52	04:41	14:45	06:09	16:27
19	03:17	15:25	04:54	15:27	05:41	15:36	06:53	17:37
20	04:12	15:52	05:54	16:07	06:38	16:34	07:33	18:48
21	05:08	16:21	06:55	16:53	07:31	17:38	08:09	19:59
22	06:06	16:53	07:53	17:47	08:18	18:46	08:43	21:09
23	07:05	17:29	08:48	18:47	08:59	19:55	09:17	22:19
24	08:04	18:11	09:37	19:51	09:37	21:04	09:51	23:28
25	09:04	18:59	10:21	20:58	10:11	22:12	10:28	DNS
26	10:00	19:54	11:00	22:06	10:43	23:20	11:09	00:37
27	10:52	20:55	11:36	23:13	11:16	DNS	11:54	01:44
28	11:39	21:59	12:09	DNS	11:50	00:28	12:46	02:47
29	12:21	23:06	12:41	00:20	12:28	01:36	13:42	03:46
30	12:58	DNS	13:14	01:28	13:10	02:44	14:41	04:37
31	13:33	00:13			13:58	03:50	15:42	05:22

Day	SEPTEMBER Rise	SEPTEMBER Set	OCTOBER Rise	OCTOBER Set	NOVEMBER Rise	NOVEMBER Set	DECEMBER Rise	DECEMBER Set
1	16:42	06:01	17:28	05:35	19:05	05:24	19:52	05:05
2	17:41	06:34	18:24	06:01	20:03	05:54	20:49	05:48
3	18:39	07:04	19:19	06:27	21:01	06:28	21:43	06:37
4	19:35	07:32	20:15	06:53	21:58	07:06	22:32	07:32
5	20:30	07:58	21:11	07:22	22:54	07:50	23:15	08:32
6	21:25	08:24	22:08	07:53	23:45	08:41	23:54	09:35
7	22:21	08:51	23:06	08:27	DNR	09:37	DNR	10:40
8	23:18	09:20	DNR	09:08	00:33	10:39	00:29	11:46
9	DNR	09:53	00:03	09:54	01:15	11:43	01:02	12:52
10	00:16	10:30	00:58	10:47	01:53	12:50	01:33	14:00
11	01:14	11:13	01:49	11:47	02:29	13:59	02:05	15:10
12	02:12	12:03	02:36	12:52	03:02	15:09	02:40	16:22
13	03:07	13:01	03:18	14:00	03:35	16:20	03:18	17:35
14	03:58	14:05	03:57	15:10	04:09	17:34	04:02	18:48
15	04:44	15:13	04:33	16:22	04:47	18:48	04:53	19:57
16	05:26	16:24	05:07	17:35	05:29	20:03	05:51	20:59
17	06:04	17:37	05:41	18:48	06:17	21:14	06:54	21:51
18	06:39	18:49	06:18	20:02	07:12	22:19	08:00	22:35
19	07:13	20:01	06:57	21:16	08:12	23:14	09:04	23:12
20	07:48	21:13	07:42	22:27	09:15	DNS	10:06	23:44
21	08:25	22:25	08:32	23:33	10:18	00:01	11:06	DNS
22	09:05	23:35	09:27	DNS	11:19	00:40	12:03	00:12
23	09:51	DNS	10:27	00:32	12:19	01:14	12:59	00:38
24	10:41	00:41	11:28	01:22	13:16	01:43	13:54	01:04
25	11:36	01:42	12:29	02:04	14:12	02:10	14:50	01:30
26	12:35	02:36	13:28	02:40	15:07	02:35	15:46	01:58
27	13:35	03:22	14:26	03:11	16:02	03:01	16:44	02:28
28	14:35	04:02	15:23	03:39	16:58	03:28	17:43	03:03
29	15:34	04:37	16:18	04:06	17:56	03:56	18:41	03:44
30	16:32	05:07	17:13	04:31	18:54	04:29	19:37	04:31
31			18:09	04:57			20:28	05:25

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.

DARWIN (CST)

Day	JANUARY Rise	JANUARY Set	FEBRUARY Rise	FEBRUARY Set	MARCH Rise	MARCH Set	APRIL Rise	APRIL Set
1	11:18	23:54	12:13	DNS	11:43	23:36	13:07	DNS
2	12:04	DNS	13:01	00:18	12:33	DNS	14:02	00:48
3	12:49	00:31	13:50	00:58	13:25	00:20	14:57	01:45
4	13:34	01:07	14:42	01:41	14:20	01:09	15:50	02:45
5	14:21	01:44	15:37	02:29	15:17	02:02	16:42	03:45
6	15:10	02:23	16:35	03:21	16:14	03:00	17:31	04:45
7	16:02	03:05	17:34	04:18	17:11	04:00	18:20	05:45
8	16:57	03:52	18:32	05:19	18:05	05:03	19:08	06:45
9	17:55	04:42	19:28	06:22	18:57	06:05	19:57	07:45
10	18:54	05:38	20:21	07:24	19:46	07:06	20:48	08:46
11	19:52	06:37	21:11	08:26	20:34	08:06	21:41	09:47
12	20:49	07:39	21:58	09:25	21:22	09:06	22:35	10:48
13	21:42	08:41	22:45	10:23	22:11	10:04	23:30	11:47
14	22:32	09:41	23:31	11:20	23:00	11:03	DNR	12:43
15	23:18	10:39	DNR	12:16	23:52	12:02	00:26	13:36
16	DNR	11:36	00:18	13:13	DNR	13:00	01:20	14:24
17	00:04	12:31	01:06	14:09	00:45	13:56	02:11	15:08
18	00:48	13:26	01:57	15:05	01:38	14:49	03:01	15:49
19	01:33	14:21	02:49	16:00	02:32	15:39	03:48	16:28
20	02:20	15:17	03:42	16:52	03:24	16:26	04:34	17:04
21	03:09	16:13	04:36	17:41	04:15	17:09	05:19	17:40
22	04:00	17:09	05:28	18:27	05:04	17:49	06:04	18:17
23	04:53	18:04	06:18	19:09	05:51	18:27	06:50	18:54
24	05:47	18:56	07:07	19:49	06:36	19:03	07:37	19:33
25	06:41	19:45	07:53	20:27	07:21	19:40	08:25	20:15
26	07:33	20:30	08:39	21:03	08:06	20:16	09:16	21:00
27	08:23	21:12	09:24	21:39	08:52	20:54	10:08	21:50
28	09:11	21:51	10:09	22:16	09:39	21:34	11:02	22:42
29	09:58	22:28	10:55	22:55	10:28	22:16	11:57	23:38
30	10:43	23:04			11:19	23:03	12:51	DNS
31	11:28	23:41			12:12	23:53		

Day	MAY Rise	MAY Set	JUNE Rise	JUNE Set	JULY Rise	JULY Set	AUGUST Rise	AUGUST Set
1	13:43	00:35	14:49	02:17	15:04	02:59	16:30	04:47
2	14:33	01:33	15:34	03:13	15:54	03:57	17:27	05:44
3	15:22	02:31	16:21	04:10	16:47	04:57	18:23	06:38
4	16:09	03:29	17:11	05:09	17:43	05:58	19:17	07:27
5	16:55	04:27	18:04	06:10	18:41	06:57	20:08	08:13
6	17:43	05:26	19:00	07:12	19:38	07:54	20:57	08:54
7	18:33	06:26	19:57	08:13	20:34	08:47	21:44	09:33
8	19:25	07:27	20:55	09:12	21:27	09:35	22:29	10:10
9	20:19	08:29	21:52	10:07	22:17	10:19	23:14	10:46
10	21:16	09:30	22:46	10:57	23:04	10:59	00:00	11:23
11	22:13	10:30	23:37	11:43	23:50	11:37	DNR	12:00
12	23:10	11:26	DNR	12:24	DNR	12:13	00:47	12:40
13	DNR	12:18	00:25	13:03	00:35	12:49	01:36	13:23
14	00:04	13:05	01:11	13:39	01:20	13:26	02:28	14:10
15	00:55	13:48	01:56	14:15	02:07	14:04	03:22	15:02
16	01:44	14:27	02:41	14:52	02:55	14:46	04:17	15:58
17	02:31	15:04	03:27	15:29	03:46	15:31	05:14	16:57
18	03:16	15:41	04:14	16:09	04:39	16:21	06:09	17:57
19	04:01	16:17	05:04	16:53	05:35	17:15	07:02	18:57
20	04:46	16:53	05:56	17:40	06:32	18:13	07:52	19:57
21	05:33	17:32	06:51	18:31	07:28	19:12	08:40	20:55
22	06:21	18:13	07:46	19:27	08:21	20:12	09:27	21:52
23	07:11	18:58	08:42	20:24	09:12	21:11	10:12	22:49
24	08:04	19:46	09:36	21:23	10:00	22:08	10:59	23:47
25	08:58	20:38	10:28	22:20	10:46	23:04	11:47	DNS
26	09:53	21:33	11:17	23:17	11:31	23:59	12:37	00:45
27	10:48	22:30	12:03	DNS	12:15	DNS	13:30	01:44
28	11:40	23:28	12:47	00:13	13:01	00:55	14:25	02:42
29	12:30	DNS	13:32	01:08	13:49	01:52	15:21	03:39
30	13:18	00:25	14:17	02:03	14:40	02:50	16:17	04:33
31	14:04	01:21			15:34	03:49	17:11	05:23

Day	SEPTEMBER Rise	SEPTEMBER Set	OCTOBER Rise	OCTOBER Set	NOVEMBER Rise	NOVEMBER Set	DECEMBER Rise	DECEMBER Set
1	18:02	06:09	18:21	06:08	19:21	06:35	19:48	06:38
2	18:51	06:51	19:06	06:45	20:10	07:14	20:41	07:27
3	19:39	07:31	19:52	07:20	21:00	07:56	21:34	08:18
4	20:24	08:08	20:37	07:57	21:52	08:41	22:26	09:12
5	21:10	08:45	21:24	08:35	22:45	09:30	23:16	10:08
6	21:55	09:21	22:13	09:15	23:38	10:22	DNR	11:03
7	22:41	09:58	23:04	09:58	DNR	11:16	00:04	11:58
8	23:29	10:36	23:56	10:44	00:29	12:12	00:49	12:53
9	DNR	11:17	DNR	11:34	01:19	13:09	01:33	13:47
10	00:19	12:02	00:50	12:28	02:07	14:05	02:17	14:42
11	01:11	12:51	01:43	13:24	02:53	15:01	03:02	15:39
12	02:05	13:43	02:36	14:22	03:39	15:58	03:49	16:39
13	03:00	14:40	03:26	15:21	04:25	16:56	04:39	17:41
14	03:54	15:39	04:16	16:19	05:12	17:57	05:34	18:45
15	04:48	16:39	05:03	17:18	06:02	18:59	06:32	19:49
16	05:39	17:39	05:50	18:17	06:56	20:03	07:33	20:51
17	06:29	18:38	06:38	19:17	07:53	21:08	08:35	21:48
18	07:17	19:37	07:27	20:19	08:53	22:10	09:34	22:39
19	08:04	20:36	08:19	21:21	09:53	23:08	10:30	23:25
20	08:51	21:36	09:13	22:24	10:52	DNS	11:22	DNS
21	09:40	22:36	10:10	23:26	11:48	00:01	12:10	00:06
22	10:31	23:36	11:08	DNS	12:40	00:48	12:57	00:44
23	11:25	DNS	12:06	00:24	13:30	01:30	13:42	01:21
24	12:20	00:37	13:02	01:18	14:16	02:09	14:27	01:57
25	13:17	01:35	13:55	02:06	15:02	02:46	15:13	02:33
26	14:12	02:30	14:45	02:51	15:47	03:22	16:00	03:10
27	15:07	03:21	15:33	03:31	16:32	03:58	16:49	03:50
28	15:59	04:08	16:19	04:09	17:18	04:34	17:41	04:34
29	16:48	04:51	17:04	04:46	18:06	05:13	18:34	05:21
30	17:35	05:31	17:49	05:21	18:56	05:54	19:28	06:12
31			18:35	05:57			20:22	07:06

HOBART (EST) MOON RISE AND SET MELBOURNE (EST)

HOBART (EST)

	JANUARY Rise	JANUARY Set	FEBRUARY Rise	FEBRUARY Set	MARCH Rise	MARCH Set	APRIL Rise	APRIL Set
1	10:11	23:38	11:57	23:13	11:49	22:08	13:45	22:52
2	11:10	DNS	12:58	23:39	12:51	22:41	14:39	23:53
3	12:10	00:01	14:00	DNS	13:54	23:21	15:27	DNS
4	13:09	00:24	15:04	00:10	14:56	DNS	16:08	01:02
5	14:10	00:47	16:09	00:46	15:55	00:08	16:45	02:16
6	15:13	01:12	17:12	01:30	16:48	01:06	17:17	03:33
7	16:18	01:41	18:10	02:24	17:35	02:12	17:48	04:51
8	17:24	02:15	19:01	03:28	18:15	03:26	18:18	06:10
9	18:29	02:55	19:45	04:40	18:50	04:44	18:49	07:29
10	19:30	03:45	20:23	05:56	19:22	06:03	19:23	08:48
11	20:25	04:44	20:56	07:14	19:52	07:22	20:01	10:04
12	21:12	05:52	21:26	08:32	20:22	08:40	20:45	11:17
13	21:52	07:05	21:55	09:48	20:54	09:57	21:36	12:23
14	22:26	08:20	22:24	11:02	21:29	11:12	22:31	13:21
15	22:56	09:35	22:56	12:15	22:08	12:24	23:31	14:10
16	23:25	10:49	23:31	13:26	22:53	13:32	DNR	14:50
17	23:53	12:02	DNR	14:35	23:44	14:33	00:33	15:24
18	DNR	13:13	00:11	15:39	DNR	15:26	01:34	15:52
19	00:22	14:24	00:57	16:36	00:40	16:10	02:35	16:17
20	00:54	15:34	01:49	17:26	01:40	16:48	03:35	16:40
21	01:31	16:41	02:46	18:09	02:41	17:20	04:35	17:02
22	02:13	17:44	03:46	18:45	03:42	17:47	05:34	17:25
23	03:01	18:40	04:48	19:16	04:42	18:12	06:34	17:48
24	03:55	19:29	05:49	19:43	05:42	18:35	07:35	18:13
25	04:54	20:10	06:50	20:07	06:42	18:57	08:37	18:42
26	05:56	20:44	07:49	20:30	07:41	19:19	09:40	19:17
27	06:58	21:14	08:49	20:52	08:41	19:43	10:42	19:57
28	07:59	21:40	09:48	21:15	09:42	20:10	11:41	20:46
29	08:59	22:04	10:48	21:40	10:43	20:41	12:36	21:43
30	09:58	22:26			11:45	21:17	13:24	22:48
31	10:57	22:49			12:47	22:00		

	MAY Rise	MAY Set	JUNE Rise	JUNE Set	JULY Rise	JULY Set	AUGUST Rise	AUGUST Set
1	14:07	23:58	14:15	01:25	13:45	02:55	14:34	05:26
2	14:43	DNS	14:43	02:39	14:19	04:09	15:33	06:23
3	15:16	01:11	15:13	03:54	15:00	05:23	16:36	07:11
4	15:46	02:26	15:46	05:11	15:48	06:33	17:41	07:51
5	16:14	03:42	16:24	06:27	16:44	07:37	18:46	08:24
6	16:44	05:00	17:09	07:42	17:46	08:31	19:49	08:53
7	17:16	06:18	18:01	08:51	18:51	09:17	20:51	09:17
8	17:52	07:36	19:00	09:51	19:56	09:54	21:51	09:40
9	18:34	08:53	20:04	10:41	21:00	10:25	22:51	10:02
10	19:22	10:05	21:08	11:23	22:02	10:51	23:51	10:24
11	20:17	11:09	22:12	11:56	23:03	11:15	DNR	10:47
12	21:18	12:04	23:14	12:25	DNR	11:37	00:52	11:14
13	22:20	12:48	DNR	12:49	00:03	11:59	01:54	11:45
14	23:23	13:25	00:15	13:12	01:02	12:22	02:57	12:21
15	DNR	13:56	01:15	13:34	02:03	12:47	03:59	13:06
16	00:26	14:22	02:15	13:56	03:05	13:15	04:58	14:01
17	01:26	14:46	03:15	14:20	04:08	13:48	05:51	15:04
18	02:26	15:08	04:16	14:46	05:12	14:29	06:38	16:15
19	03:26	15:30	05:19	15:16	06:14	15:19	07:19	17:30
20	04:25	15:52	06:23	15:53	07:11	16:17	07:53	18:46
21	05:26	16:17	07:26	16:37	08:02	17:24	08:24	20:03
22	06:28	16:44	08:26	17:30	08:45	18:36	08:52	21:19
23	07:31	17:17	09:20	18:31	09:22	19:50	09:20	22:34
24	08:35	17:56	10:07	19:38	09:54	21:04	09:49	23:49
25	09:36	18:42	10:47	20:50	10:23	22:18	10:21	DNS
26	10:33	19:37	11:22	22:02	10:51	23:32	10:57	01:03
27	11:24	20:40	11:52	23:15	11:18	DNS	11:39	02:14
28	12:08	21:48	12:20	DNS	11:47	00:45	12:29	03:20
29	12:45	22:59	12:47	00:28	12:20	01:58	13:25	04:19
30	13:18	DNS	13:14	01:41	12:57	03:11	14:26	05:09
31	13:48	00:11			13:42	04:21	15:30	05:51

	SEPTEMBER Rise	SEPTEMBER Set	OCTOBER Rise	OCTOBER Set	NOVEMBER Rise	NOVEMBER Set	DECEMBER Rise	DECEMBER Set
1	16:35	06:25	17:33	05:48	19:27	05:21	20:25	04:51
2	17:38	06:55	18:33	06:10	20:29	05:47	21:23	05:31
3	18:40	07:20	19:33	06:31	21:31	06:16	22:17	06:18
4	19:41	07:43	20:33	06:53	22:31	06:51	23:04	07:14
5	20:41	08:05	21:34	07:17	23:28	07:33	23:44	08:16
6	21:41	08:27	22:36	07:44	DNR	08:22	DNR	09:23
7	22:41	08:50	23:37	08:15	00:19	09:20	00:18	10:33
8	23:42	09:14	DNR	08:52	01:04	10:24	00:49	11:44
9	DNR	09:43	00:36	09:37	01:43	11:33	01:16	12:57
10	00:44	10:16	01:32	10:30	02:16	12:46	01:42	14:10
11	01:46	10:57	02:22	11:31	02:46	14:00	02:09	15:26
12	02:45	11:46	03:06	12:39	03:14	15:15	02:37	16:44
13	03:40	12:44	03:44	13:52	03:41	16:33	03:10	18:03
14	04:29	13:50	04:17	15:08	04:10	17:52	03:49	19:20
15	05:12	15:03	04:47	16:26	04:42	19:13	04:37	20:31
16	05:48	16:20	05:16	17:45	05:18	20:33	05:33	21:32
17	06:21	17:38	05:45	19:04	06:02	21:47	06:37	22:23
18	06:51	18:56	06:15	20:25	06:54	22:53	07:46	23:03
19	07:19	20:14	06:49	21:44	07:54	23:47	08:54	23:35
20	07:48	21:32	07:29	22:59	08:59	DNS	10:01	DNS
21	08:20	22:49	08:15	DNS	10:05	00:31	11:05	00:02
22	08:55	DNS	09:09	00:07	11:11	01:06	12:07	00:26
23	09:36	00:04	10:10	01:05	12:15	01:35	13:08	00:47
24	10:24	01:14	11:13	01:53	13:17	01:59	14:08	01:08
25	11:19	02:16	12:18	02:32	14:18	02:22	15:08	01:30
26	12:19	03:09	13:22	03:03	15:18	02:43	16:09	01:53
27	13:22	03:52	14:25	03:30	16:18	03:04	17:12	02:20
28	14:26	04:29	15:26	03:54	17:19	03:26	18:14	02:51
29	15:30	04:59	16:26	04:16	18:21	03:50	19:15	03:28
30	16:32	05:25	17:26	04:37	19:23	04:18	20:11	04:13
31			18:26	04:58			21:01	05:07

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.

MELBOURNE (EST)

	JANUARY Rise	JANUARY Set	FEBRUARY Rise	FEBRUARY Set	MARCH Rise	MARCH Set	APRIL Rise	APRIL Set
1	10:26	23:42	12:01	23:28	11:48	22:28	13:38	23:18
2	11:23	DNS	12:59	23:57	12:48	23:03	14:32	DNS
3	12:19	00:08	13:59	DNS	13:48	23:45	15:21	00:19
4	13:16	00:34	15:00	00:30	14:49	DNS	16:05	01:25
5	14:14	01:00	16:03	01:09	15:47	00:34	16:45	02:36
6	15:13	01:28	17:04	01:55	16:41	01:32	17:21	03:49
7	16:15	02:00	18:03	02:50	17:30	02:37	17:55	05:04
8	17:19	02:36	18:56	03:53	18:14	03:48	18:29	06:19
9	18:22	03:19	19:42	05:03	18:53	05:02	19:04	07:34
10	19:23	04:10	20:23	06:16	19:28	06:18	19:42	08:48
11	20:19	05:10	21:00	07:31	20:02	07:33	20:23	10:01
12	21:08	06:16	21:34	08:44	20:36	08:47	21:10	11:11
13	21:51	07:27	22:06	09:56	21:11	10:00	22:01	12:16
14	22:28	08:39	22:39	11:07	21:49	11:11	22:57	13:14
15	23:02	09:50	23:14	12:16	22:32	12:20	23:56	14:03
16	23:34	11:00	23:53	13:24	23:19	13:26	DNR	14:45
17	DNR	12:09	DNR	14:30	DNR	14:25	00:55	15:21
18	00:06	13:17	00:35	15:32	00:10	15:18	01:54	15:53
19	00:38	14:24	01:23	16:29	01:06	16:04	02:52	16:21
20	01:14	15:31	02:15	17:20	02:03	16:44	03:49	16:47
21	01:53	16:36	03:11	18:04	03:02	17:18	04:45	17:12
22	02:37	17:37	04:09	18:42	04:00	17:49	05:42	17:37
23	03:26	18:33	05:08	19:16	04:58	18:16	06:38	18:03
24	04:21	19:23	06:07	19:45	05:55	18:42	07:36	18:31
25	05:18	20:05	07:04	20:12	06:51	19:07	08:35	19:03
26	06:18	20:42	08:01	20:38	07:47	19:33	09:35	19:40
27	07:17	21:15	08:57	21:03	08:44	19:59	10:35	20:23
28	08:15	21:43	09:53	21:29	09:42	20:29	11:33	21:12
29	09:13	22:10	10:50	21:57	10:41	21:02	12:28	22:09
30	10:09	22:36			11:41	21:41	13:18	23:12
31	11:05	23:01			12:40	22:26		

	MAY Rise	MAY Set	JUNE Rise	JUNE Set	JULY Rise	JULY Set	AUGUST Rise	AUGUST Set
1	14:02	DNS	14:24	01:37	14:02	02:57	15:00	05:18
2	14:42	00:19	14:55	02:48	14:40	04:07	15:59	06:15
3	15:18	01:29	15:28	03:59	15:24	05:18	17:00	07:05
4	15:51	02:41	16:05	05:11	16:14	06:26	18:03	07:47
5	16:24	03:53	16:46	06:24	17:11	07:29	19:05	08:23
6	16:57	05:06	17:34	07:36	18:11	08:24	20:05	08:54
7	17:33	06:21	18:27	08:43	19:14	09:11	21:03	09:22
8	18:13	07:35	19:26	09:43	20:17	09:51	22:00	09:47
9	18:57	08:49	20:28	10:35	21:18	10:25	22:57	10:12
10	19:48	09:58	21:30	11:18	22:17	10:54	23:54	10:37
11	20:44	11:01	22:31	11:54	23:14	11:21	DNR	11:04
12	21:43	11:56	23:31	12:26	DNR	11:46	00:52	11:33
13	22:44	12:43	DNR	12:53	00:11	12:11	01:51	12:07
14	23:44	13:22	00:28	13:19	01:07	12:36	02:51	12:46
15	DNR	13:55	01:25	13:44	02:05	13:04	03:51	13:32
16	00:44	14:24	02:21	14:09	03:04	13:35	04:50	14:27
17	01:41	14:51	03:18	14:35	04:04	14:12	05:44	15:30
18	02:38	15:16	04:17	15:05	05:06	14:54	06:33	16:38
19	03:34	15:41	05:17	15:38	06:06	15:45	07:16	17:50
20	04:31	16:06	06:18	16:17	07:03	16:44	07:54	19:02
21	05:29	16:34	07:19	17:03	07:55	17:49	08:28	20:15
22	06:28	17:04	08:18	17:56	08:41	18:58	09:01	21:27
23	07:28	17:40	09:13	18:57	09:21	20:08	09:32	22:38
24	08:29	18:21	10:01	20:02	09:57	21:19	10:05	23:49
25	09:28	19:08	10:44	21:10	10:29	22:29	10:40	DNS
26	10:25	20:03	11:22	22:19	11:00	23:39	11:20	01:00
27	11:17	21:05	11:55	23:28	11:31	DNS	12:04	02:08
28	12:03	22:10	12:26	DNS	12:04	00:48	12:55	03:12
29	12:43	23:18	12:57	00:37	12:40	01:58	13:51	04:11
30	13:19	DNS	13:29	01:47	13:20	03:07	14:51	05:02
31	13:52	00:27			14:07	04:15	15:53	05:46

	SEPTEMBER Rise	SEPTEMBER Set	OCTOBER Rise	OCTOBER Set	NOVEMBER Rise	NOVEMBER Set	DECEMBER Rise	DECEMBER Set
1	16:55	06:23	17:44	05:53	19:27	05:38	20:17	05:15
2	17:55	06:55	18:41	06:18	20:26	06:06	21:15	05:57
3	18:54	07:24	19:38	06:43	21:25	06:39	22:08	06:46
4	19:51	07:50	20:35	07:08	22:23	07:16	22:56	07:41
5	20:48	08:14	21:33	07:35	23:19	07:59	23:39	08:42
6	21:45	08:39	22:32	08:04	DNR	08:50	DNR	09:46
7	22:42	09:05	23:31	08:38	00:10	09:47	00:16	10:52
8	23:40	09:33	DNR	09:17	00:57	10:49	00:50	12:00
9	DNR	10:04	00:28	10:03	01:38	11:55	01:21	13:08
10	00:39	10:40	01:23	10:57	02:15	13:04	01:50	14:18
11	01:39	11:22	02:14	11:57	02:49	14:14	02:21	15:30
12	02:37	12:12	03:00	13:03	03:20	15:26	02:53	16:44
13	03:32	13:10	03:41	14:12	03:51	16:39	03:30	17:59
14	04:22	14:15	04:18	15:25	04:24	17:54	04:13	19:13
15	05:07	15:25	04:52	16:38	05:00	19:11	05:03	20:23
16	05:47	16:38	05:24	17:53	05:40	20:27	06:00	21:24
17	06:24	17:52	05:57	19:08	06:27	21:39	07:04	22:16
18	06:57	19:06	06:31	20:24	07:21	22:44	08:10	22:58
19	07:30	20:20	07:09	21:40	08:21	23:39	09:16	23:34
20	08:03	21:34	07:52	22:52	09:24	DNS	10:19	DNS
21	08:38	22:47	08:41	23:59	10:29	00:25	11:20	00:04
22	09:17	23:59	09:36	DNS	11:32	01:03	12:19	00:31
23	10:01	DNS	10:36	00:57	12:32	01:35	13:16	00:55
24	10:50	01:06	11:38	01:46	13:31	02:03	14:13	01:19
25	11:45	02:07	12:40	02:27	14:28	02:28	15:10	01:44
26	12:45	03:01	13:41	03:02	15:25	02:52	16:08	02:11
27	13:46	03:46	14:40	03:32	16:22	03:16	17:08	02:40
28	14:47	04:25	15:38	03:58	17:20	03:41	18:08	03:14
29	15:48	04:58	16:35	04:23	18:18	04:09	19:06	03:53
30	16:47	05:27	17:32	04:47	19:18	04:40	20:02	04:40
31			18:29	05:12			20:53	05:34

PERTH (WST) MOON RISE AND SET SYDNEY (EST)

PERTH (WST)

	JANUARY Rise	JANUARY Set	FEBRUARY Rise	FEBRUARY Set	MARCH Rise	MARCH Set	APRIL Rise	APRIL Set
1	10:34	23:37	11:58	23:33	11:40	22:38	13:22	23:36
2	11:27	DNS	12:53	DNS	12:37	23:17	14:16	DNS
3	12:20	00:06	13:50	00:05	13:35	DNS	15:07	00:36
4	13:14	00:34	14:49	00:42	14:34	00:01	15:53	01:41
5	14:09	01:04	15:49	01:23	15:32	00:52	16:36	02:49
6	15:06	01:35	16:49	02:12	16:26	01:50	17:16	03:59
7	16:05	02:10	17:48	03:08	17:17	02:54	17:54	05:09
8	17:06	02:49	18:42	04:11	18:03	04:03	18:32	06:20
9	18:08	03:35	19:31	05:19	18:46	05:14	19:11	07:31
10	19:08	04:28	20:15	06:29	19:25	06:25	19:52	08:42
11	20:04	05:28	20:55	07:40	20:03	07:36	20:37	09:51
12	20:55	06:33	21:32	08:50	20:40	08:46	21:26	10:58
13	21:40	07:41	22:08	09:58	21:19	09:55	22:19	12:01
14	22:21	08:50	22:45	11:04	22:01	11:03	23:15	12:58
15	22:58	09:58	23:24	12:10	22:46	12:09	DNR	13:48
16	23:34	11:04	DNR	13:15	23:35	13:12	00:12	14:31
17	DNR	12:09	00:05	14:17	DNR	14:10	01:09	15:09
18	00:09	13:13	00:50	15:18	00:28	15:03	02:06	15:43
19	00:45	14:17	01:39	16:14	01:23	15:50	03:01	16:14
20	01:24	15:21	02:32	17:04	02:19	16:31	03:54	16:43
21	02:06	16:23	03:28	17:50	03:15	17:07	04:48	17:10
22	02:53	17:22	04:24	18:30	04:11	17:40	05:41	17:39
23	03:43	18:18	05:21	19:05	05:06	18:10	06:35	18:08
24	04:38	19:07	06:16	19:38	05:59	18:39	07:29	18:40
25	05:35	19:52	07:11	20:07	06:52	19:07	08:26	19:15
26	06:32	20:31	08:04	20:36	07:46	19:36	09:23	19:54
27	07:29	21:05	08:57	21:04	08:39	20:06	10:21	20:39
28	08:24	21:37	09:51	21:33	09:34	20:38	11:17	21:30
29	09:18	22:06	10:45	22:04	10:30	21:14	12:12	22:27
30	10:11	22:35			11:28	21:56	13:03	23:29
31	11:04	23:03			12:25	22:43		

	MAY Rise	MAY Set	JUNE Rise	JUNE Set	JULY Rise	JULY Set	AUGUST Rise	AUGUST Set
1	13:49	DNS	14:22	01:42	14:11	02:51	15:19	05:03
2	14:32	00:34	14:57	02:49	14:53	03:59	16:17	05:59
3	15:11	01:40	15:35	03:56	15:40	05:06	17:17	06:50
4	15:48	02:48	16:15	05:05	16:32	06:11	18:17	07:34
5	16:24	03:57	17:00	06:14	17:29	07:13	19:16	08:12
6	17:02	05:06	17:50	07:23	18:29	08:08	20:13	08:45
7	17:41	06:16	18:46	08:28	19:30	08:57	21:08	09:16
8	18:25	07:27	19:45	09:27	20:30	09:38	22:01	09:45
9	19:13	08:37	20:45	10:19	21:27	10:14	22:55	10:13
10	20:05	09:44	21:45	11:04	22:23	10:47	23:49	10:41
11	21:02	10:46	22:43	11:43	23:17	11:16	DNR	11:11
12	22:01	11:40	23:39	12:17	DNR	11:44	00:43	11:43
13	22:59	12:28	DNR	12:47	00:10	12:12	01:40	12:20
14	23:57	13:09	00:33	13:16	01:04	12:41	02:38	13:02
15	DNR	13:44	01:27	13:43	01:58	13:12	03:36	13:50
16	00:53	14:16	02:20	14:12	02:55	13:46	04:33	14:46
17	01:48	14:46	03:14	14:41	03:52	14:26	05:28	15:48
18	02:41	15:14	04:09	15:14	04:51	15:11	06:18	16:54
19	03:35	15:42	05:06	15:50	05:50	16:03	07:04	18:03
20	04:28	16:10	06:05	16:32	06:47	17:02	07:45	19:12
21	05:23	16:41	07:04	17:20	07:40	18:06	08:23	20:20
22	06:19	17:15	08:02	18:15	08:28	19:12	08:59	21:28
23	07:16	17:53	08:57	19:15	09:11	20:20	09:35	22:35
24	08:15	18:37	09:47	20:18	09:49	21:26	10:11	23:43
25	09:13	19:26	10:32	21:24	10:25	22:32	10:50	DNS
26	10:09	20:22	11:12	22:29	11:00	23:38	11:33	00:49
27	11:01	21:22	11:49	23:34	11:35	DNS	12:21	01:55
28	11:49	22:26	12:24	DNS	12:11	00:44	13:13	02:57
29	12:31	23:31	12:58	00:40	12:51	01:50	14:09	03:55
30	13:10	DNS	13:33	01:45	13:35	02:56	15:08	04:46
31	13:47	00:36			14:24	04:01	16:08	05:31

	SEPTEMBER Rise	SEPTEMBER Set	OCTOBER Rise	OCTOBER Set	NOVEMBER Rise	NOVEMBER Set	DECEMBER Rise	DECEMBER Set
1	17:07	06:11	17:48	05:49	19:18	05:45	20:02	05:30
2	18:04	06:45	18:41	06:16	20:14	06:16	20:58	06:14
3	18:59	07:17	19:35	06:44	21:11	06:52	21:51	07:04
4	19:54	07:46	20:29	07:12	22:07	07:32	22:40	08:00
5	20:47	08:14	21:24	07:42	23:02	08:17	23:25	08:59
6	21:41	08:42	22:20	08:15	23:54	09:08	DNR	10:01
7	22:35	09:11	23:16	08:52	DNR	10:05	00:05	11:04
8	23:30	09:42	DNR	09:34	00:41	11:06	00:41	12:08
9	DNR	10:16	00:12	10:21	01:25	12:09	01:16	13:13
10	00:27	10:55	01:07	11:15	02:05	13:14	01:49	14:19
11	01:24	11:39	01:58	12:15	02:41	14:21	02:24	15:26
12	02:21	12:31	02:45	13:19	03:17	15:29	03:00	16:36
13	03:15	13:29	03:29	14:25	03:52	16:38	03:41	17:48
14	04:07	14:32	04:09	15:34	04:29	17:49	04:28	18:59
15	04:54	15:40	04:46	16:43	05:09	19:02	05:21	20:07
16	05:37	16:49	05:23	17:54	05:53	20:15	06:20	21:08
17	06:17	17:59	06:00	19:05	06:44	21:24	07:23	22:00
18	06:54	19:09	06:38	20:17	07:40	22:28	08:27	22:45
19	07:31	20:19	07:21	21:29	08:40	23:23	09:30	23:23
20	08:08	21:29	08:07	22:38	09:42	DNS	10:30	23:56
21	08:47	22:38	08:59	23:43	10:44	00:10	11:27	DNS
22	09:29	23:46	09:55	DNS	11:44	00:50	12:22	00:26
23	10:16	DNS	10:55	00:40	12:41	01:25	13:16	00:53
24	11:08	00:51	11:55	01:30	13:37	01:56	14:10	01:21
25	12:04	01:51	12:54	02:13	14:31	02:24	15:04	01:49
26	13:03	02:45	13:52	02:50	15:24	02:51	15:59	02:18
27	14:02	03:31	14:48	03:23	16:18	03:19	16:56	02:51
28	15:00	04:12	15:43	03:52	17:12	03:47	17:53	03:28
29	15:58	04:47	16:36	04:20	18:08	04:18	18:50	04:10
30	16:53	05:19	17:30	04:48	19:05	04:52	19:45	04:58
31			18:24	05:15			20:37	05:53

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.

SYDNEY (EST)

	JANUARY Rise	JANUARY Set	FEBRUARY Rise	FEBRUARY Set	MARCH Rise	MARCH Set	APRIL Rise	APRIL Set
1	10:05	23:14	11:32	23:07	11:16	22:10	13:00	23:04
2	10:59	23:42	12:28	23:38	12:13	22:47	13:55	DNS
3	11:53	DNS	13:26	DNS	13:12	23:30	14:45	00:04
4	12:48	00:09	14:25	00:13	14:12	DNS	15:31	01:09
5	13:44	00:38	15:26	00:53	15:10	00:19	16:13	02:17
6	14:41	01:08	16:27	01:40	16:05	01:17	16:52	03:28
7	15:41	01:41	17:26	02:35	16:55	02:21	17:29	04:40
8	16:43	02:19	18:20	03:38	17:41	03:30	18:05	05:52
9	17:45	03:04	19:08	04:46	18:22	04:42	18:43	07:04
10	18:46	03:56	19:52	05:57	19:00	05:55	19:23	08:16
11	19:42	04:55	20:31	07:09	19:37	07:07	20:07	09:27
12	20:33	06:00	21:07	08:20	20:14	08:19	20:55	10:35
13	21:18	07:09	21:43	09:30	20:51	09:29	21:47	11:39
14	21:58	08:19	22:18	10:38	21:32	10:38	22:43	12:36
15	22:34	09:28	22:55	11:45	22:16	11:45	23:40	13:27
16	23:09	10:35	23:35	12:50	23:04	12:49	DNR	14:10
17	23:43	11:41	DNR	13:54	23:56	13:48	00:38	14:48
18	DNR	12:47	00:19	14:55	DNR	14:41	01:35	15:21
19	00:18	13:52	01:08	15:52	00:51	15:28	02:31	15:51
20	00:55	14:57	02:00	16:43	01:47	16:09	03:26	16:19
21	01:36	16:00	02:56	17:28	02:44	16:46	04:20	16:46
22	02:21	17:00	03:53	18:08	03:41	17:18	05:14	17:13
23	03:12	17:56	04:50	18:43	04:37	17:47	06:09	17:42
24	04:06	18:46	05:47	19:15	05:31	18:15	07:05	18:12
25	05:03	19:30	06:42	19:44	06:25	18:42	08:02	18:46
26	06:01	20:09	07:37	20:12	07:20	19:10	09:00	19:24
27	06:58	20:43	08:31	20:39	08:14	19:39	09:58	20:08
28	07:55	21:14	09:25	21:07	09:10	20:10	10:56	20:58
29	08:50	21:43	10:20	21:37	10:07	20:45	11:50	21:55
30	09:44	22:10			11:05	21:25	12:41	22:56
31	10:38	22:38			12:03	22:11		

	MAY Rise	MAY Set	JUNE Rise	JUNE Set	JULY Rise	JULY Set	AUGUST Rise	AUGUST Set
1	13:27	DNS	13:57	01:13	13:43	02:25	14:46	04:41
2	14:09	00:02	14:31	02:21	14:23	03:34	15:44	05:38
3	14:48	01:09	15:07	03:29	15:08	04:42	16:45	06:28
4	15:24	02:18	15:46	04:39	16:00	05:49	17:46	07:12
5	15:59	03:28	16:29	05:50	16:56	06:51	18:45	07:50
6	16:35	04:38	17:18	06:59	17:57	07:47	19:43	08:23
7	17:13	05:50	18:13	08:06	18:58	08:35	20:40	08:53
8	17:55	07:02	19:12	09:06	19:59	09:17	21:34	09:21
9	18:41	08:13	20:13	09:58	20:58	09:52	22:29	09:48
10	19:33	09:21	21:13	10:43	21:54	10:24	23:24	10:15
11	20:29	10:24	22:12	11:21	22:50	10:53	DNR	10:44
12	21:28	11:19	23:10	11:54	23:44	11:20	00:19	11:15
13	22:28	12:07	DNR	12:24	DNR	11:47	01:16	11:50
14	23:26	12:47	00:05	12:52	00:38	12:15	02:15	12:31
15	DNR	13:23	00:59	13:19	01:34	12:45	03:14	13:18
16	00:24	13:54	01:54	13:46	02:31	13:18	04:12	14:13
17	01:19	14:23	02:49	14:15	03:29	13:56	05:06	15:15
18	02:14	14:50	03:45	14:46	04:29	14:40	05:57	16:21
19	03:08	15:17	04:43	15:21	05:28	15:31	06:42	17:31
20	04:02	15:44	05:42	16:01	06:25	16:29	07:23	18:41
21	04:58	16:14	06:42	16:48	07:18	17:33	08:00	19:51
22	05:55	16:46	07:40	17:42	08:06	18:40	08:34	21:00
23	06:53	17:23	08:35	18:42	08:48	19:49	09:09	22:09
24	07:52	18:06	09:25	19:46	09:26	20:57	09:44	23:17
25	08:51	18:54	10:10	20:52	10:01	22:04	10:22	DNS
26	09:47	19:49	10:49	21:59	10:35	23:11	11:03	00:25
27	10:40	20:49	11:26	23:05	11:08	DNS	11:49	01:32
28	11:27	21:53	11:59	DNS	11:44	00:18	12:41	02:35
29	12:09	22:59	12:33	00:11	12:22	01:25	13:37	03:33
30	12:48	DNS	13:06	01:18	13:04	02:32	14:36	04:25
31	13:23	00:06			13:52	03:38	15:36	05:10

	SEPTEMBER Rise	SEPTEMBER Set	OCTOBER Rise	OCTOBER Set	NOVEMBER Rise	NOVEMBER Set	DECEMBER Rise	DECEMBER Set
1	16:36	05:49	17:20	05:25	18:54	05:18	19:40	05:00
2	17:34	06:23	18:15	05:52	19:51	05:48	20:36	05:43
3	18:31	06:54	19:09	06:19	20:48	06:22	21:30	06:32
4	19:26	07:22	20:04	06:46	21:45	07:01	22:19	07:27
5	20:21	07:49	21:00	07:15	22:41	07:45	23:03	08:26
6	21:15	08:16	21:57	07:47	23:33	08:36	23:43	09:29
7	22:11	08:44	22:54	08:22	DNR	09:32	DNR	10:33
8	23:07	09:14	23:50	09:03	00:20	10:33	00:19	11:38
9	DNR	09:47	DNR	09:49	01:03	11:37	00:52	12:44
10	00:04	10:24	00:45	10:43	01:42	12:44	01:24	13:51
11	01:02	11:08	01:37	11:42	02:18	13:51	01:57	15:00
12	01:59	11:58	02:24	12:46	02:53	15:00	02:33	16:11
13	02:54	12:56	03:07	13:54	03:27	16:11	03:12	17:23
14	03:45	13:59	03:46	15:03	04:02	17:23	03:57	18:36
15	04:32	15:07	04:23	16:14	04:40	18:37	04:48	19:44
16	05:15	16:18	04:58	17:25	05:23	19:51	05:46	20:46
17	05:53	17:29	05:33	18:38	06:12	21:01	06:50	21:39
18	06:30	18:40	06:11	19:51	07:07	22:06	07:54	22:24
19	07:05	19:51	06:51	21:04	08:07	23:02	08:58	23:01
20	07:41	21:02	07:36	22:15	09:09	23:49	10:00	23:33
21	08:18	22:13	08:27	23:21	10:12	DNS	10:58	DNS
22	09:00	23:23	09:22	DNS	11:13	00:29	11:55	00:02
23	09:45	DNS	10:22	00:19	12:12	01:03	12:50	00:29
24	10:36	00:29	11:23	01:09	13:08	01:33	13:44	00:56
25	11:31	01:29	12:23	01:52	14:03	02:01	14:39	01:22
26	12:30	02:23	13:22	02:29	14:58	02:27	15:35	01:51
27	13:30	03:10	14:19	03:01	15:52	02:53	16:33	02:22
28	14:29	03:51	15:15	03:30	16:48	03:20	17:31	02:58
29	15:28	04:26	16:09	03:57	17:44	03:50	18:29	03:39
30	16:24	04:57	17:04	04:23	18:42	04:23	19:24	04:26
31			17:59	04:50			20:16	05:20

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, for the features would be repeated. If you are able to view 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

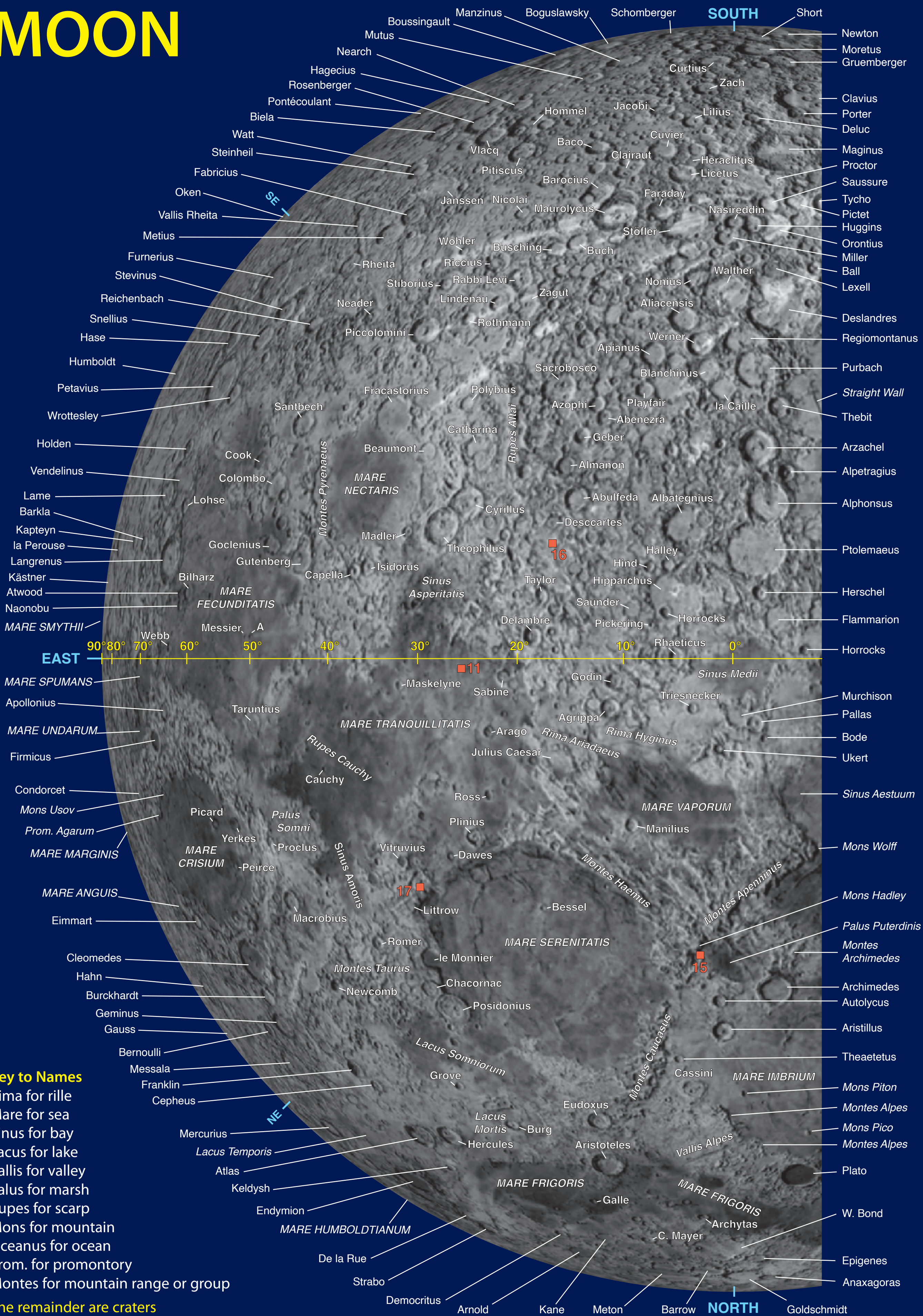
The lunar features listed are those on the terminator (the day/night line) for the age of the Moon, that is the number of days after New Moon. The presumed position of the terminator is only approximate for this can vary depending on the libration or even the time of day. Objects on the terminator give 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
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

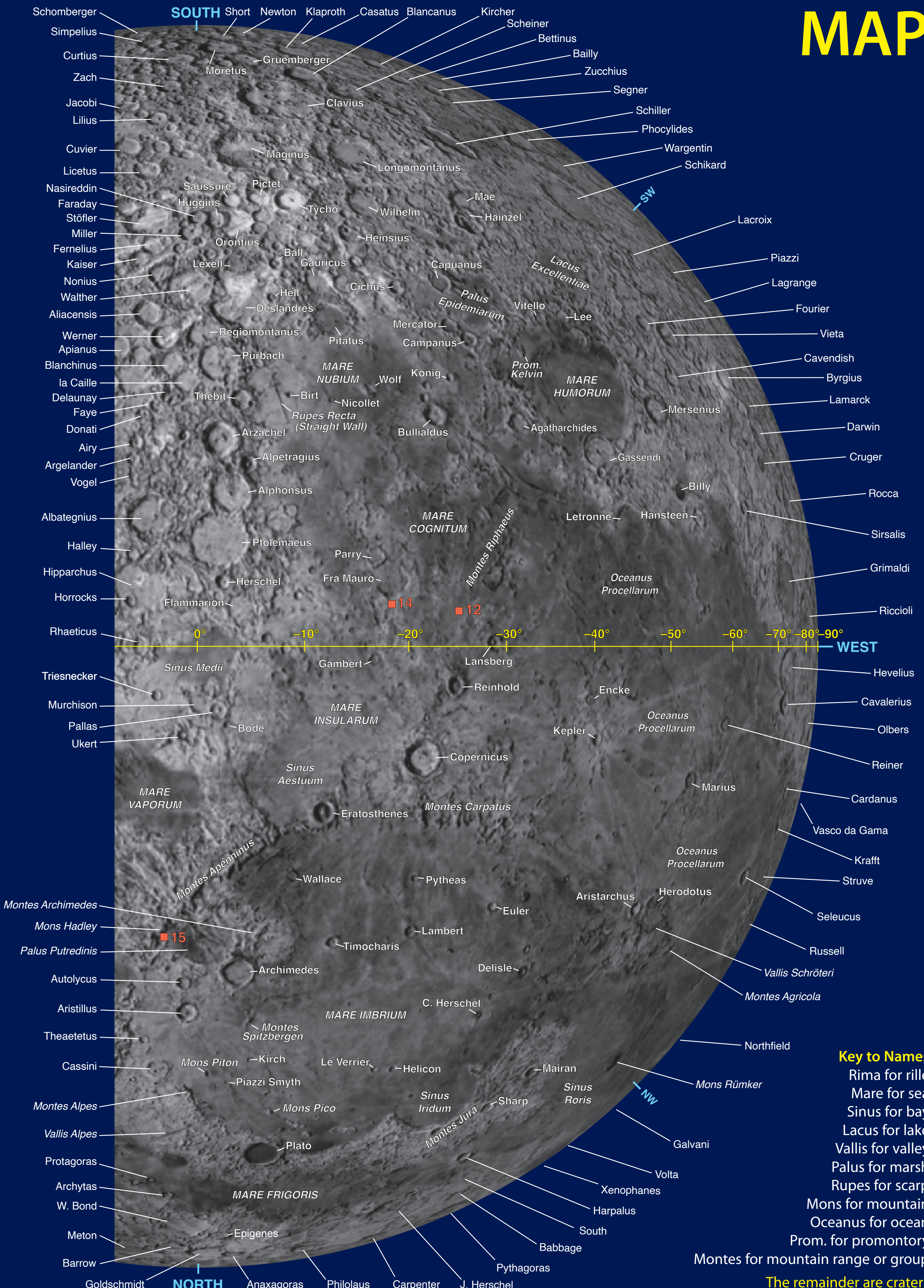


Key to Names
Rima for rille
Mare for sea
Sinus for bay
Lacus for lake
Vallis for valley
Palus for marsh
Rupes for scarp
Mons for mountain
Oceanus for ocean
Prom. for promontory
Montes for mountain range or group

The remainder are craters

Orange squares are Apollo landing sites

MAP



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OPPOSITION OF MARS 2020

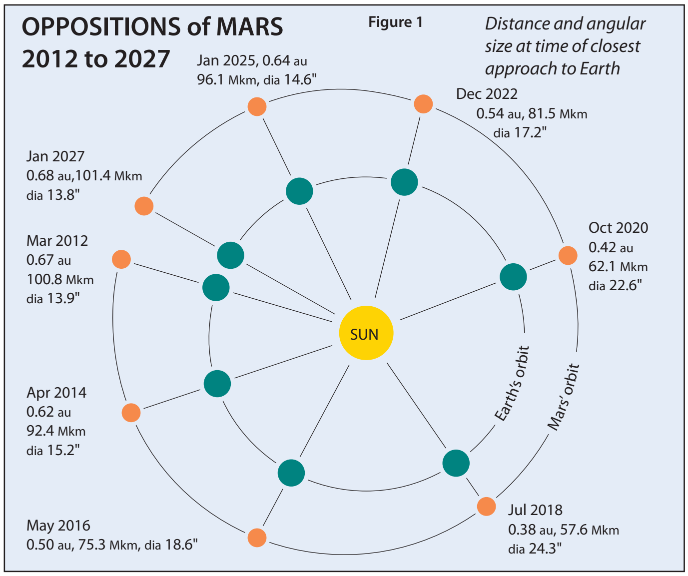
Of all the planets in the Solar System, Mars has long been the most fascinating. Others are bigger, prettier, closer and brighter, but Mars holds a place in people's imaginations. Only on Mars will you see thawing and growing polar caps, great planet-wide dust storms, cloud forming downwind from the largest volcanoes in the Solar System, and ever-changing surface features.

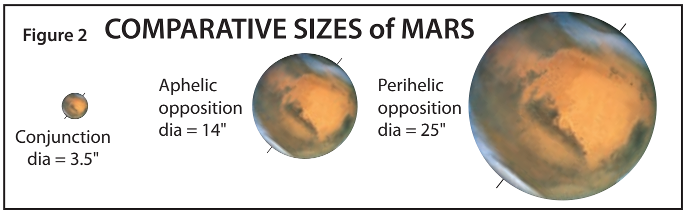
This year, Mars comes to opposition on October 14, seven days after its closest approach to Earth at 62.07 million km (Mkm) (0.415 au). The timing of opposition and closest approach can vary by up to two weeks since the orbits of Mars and Earth are eccentric and inclined to each other. If they were circular and coplanar (in the same geometric plane) these events would occur at the same instant.

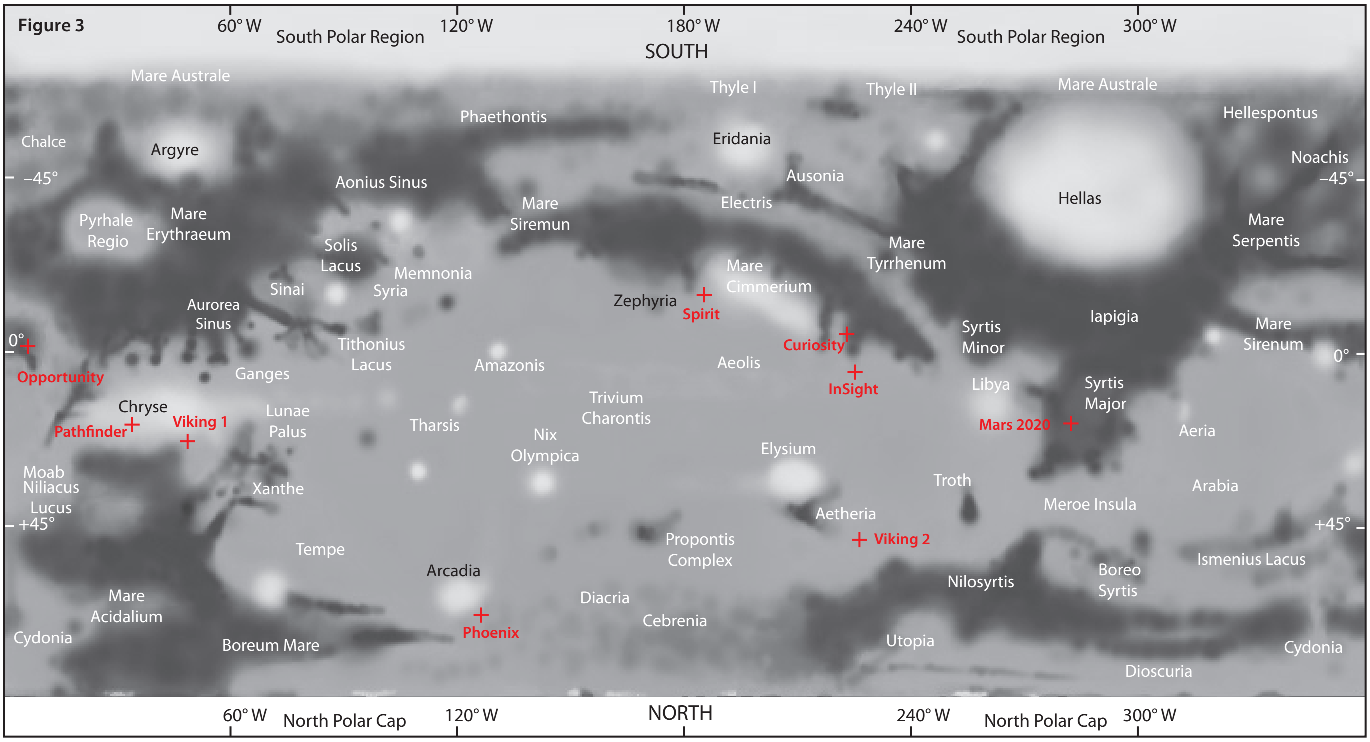
Not all oppositions of Mars are favourable; some give a better perspective than others. When the Earth passes Mars in its orbit every 26 months, we get a close view of the planet (Figure 1). When Mars is at or near perihelion at the same time, we get a particularly good view, for example the 2003 opposition. The reason for this is the elliptical orbit of Mars. On average, the planet is 228 Mkm from the Sun, but this distance varies by a considerable 42 Mkm. At an aphelic opposition (Mars furthest from the Sun) the planet averages 99 Mkm from Earth, and when at a perihelic opposition (Mars closest to the Sun), it will average around 57 Mkm from us.

Much was made of the fact that Mars came nearer to Earth in 2003 than at any time in close to 60,000 years. Whilst true, the difference between Mars' diameter during favourable perihelic oppositions (as this years is) varies only by a few arcseconds at most. For example, in 2003 the planet's maximum diameter was 25.11 arcseconds compared with this year's 22.6, that's 2.5 arcseconds or 90% the size of the best ever opposition. Mars' disc remains above 20 arcseconds in diameter during most of September and all of October, providing visual observers with a reasonable sized target.

Oppositions in the early months of the year are always unfavourable as Mars is near aphelion. Perihelic oppositions occur late in the year, and fortunately for Southern Hemisphere observers, Mars is at its greatest southerly declination at that time (that is, high in our sky). The favourable perihelic oppositions occur every 15 to 17 years and it will not be until 2035 that we will again see the planet at its largest angular size. When Mars is in conjunction its disc is only 3.5 arcseconds (") in diameter, smaller than distant Uranus. At a poor opposition, the diameter is 14", increasing to 25" at a perihelic opposition see (Figure 2).







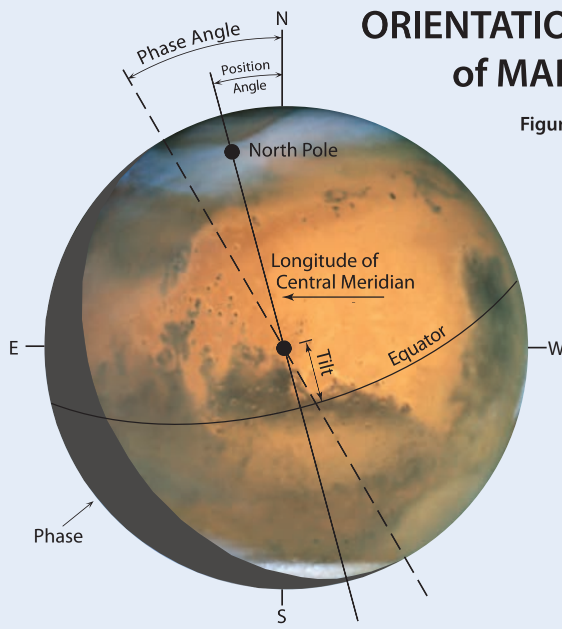
This will be the last perihelic opposition until the next series of three in 2033, 35 and 37. This year, September and October will be the prime time to train those telescopes, large and small, on the Red Planet. The detail you observe at opposition will depend on telescope size and those moments when the seeing magically settles down for a few seconds. With good optics and steady skies try pushing the telescope to its maximum usable magnification—considered to be twice the aperture in millimetres (for an 80 mm telescope this will be 160×). With the arrival of modern-day imaging technology, the study of Martian surface features is no longer solely restricted to the favourable oppositions; many amateurs are doing superb work in this field.

Since the Martian day is about 40 minutes longer than Earth's day, surface features cross the central meridian 40 minutes later each night. As this delay is about 9° of longitude per day, observations made at the same time each night will see all surface features cross the central meridian in under six weeks. The Martian dust storms, which can be global and last for months, may well obscure some surface features or even create a total block-out; but the study of these storms is still important to our understanding of the workings of the planet's atmosphere.

The iron-rich soils of Mars, which give the Red Planet its colour, were shown by the Viking Landers to be much lighter in colour than the rocks underneath. Depending on the season, high velocity winds can lift the soil and transport it around the planet. Sometimes the rocky surface is uncovered, showing a darker area; and at other times, dark areas can be covered by lighter dust as storms deposit millions of tonnes of material over the landscape. Even with the constant movement of dust around the planet, several easily recognisable regions can be seen and identified from opposition to opposition. The most prominent of the dark areas is Syrtis Major, a wedge-shaped region just north of the equator. Directly below Syrtis Major in the south is a light contrasting area known as Hellas, a depression that when covered in light dust is very conspicuous. The mysterious Eye of Mars or Solis Lacus (Lake of the Sun) is also located in the Southern Hemisphere, a small dark region ringed by

ORIENTATION of MARS

Figure 4



NOTES on the Physical Ephemeris Table (next page).

Cent Mer: Longitude of Central Meridian, is the longitude that is centred on the disc.

Tilt: is the degrees that Mars' north pole is tilted towards (+) or away (–) as seen from Earth. It is also the latitude of the centre of the disc.

Phase: Is the fraction of the disc illuminated by the Sun. At opposition the phase is at maximum.

Phase Angle: The number of degrees (east of north) the phase is rotated.

P.A.: (Position Angle) is the degrees east that Mars' north pole is rotated from north.

Diagram does not represent any particular date.

ASPECTS of MARS – OPPOSITION 2020

Figure 5

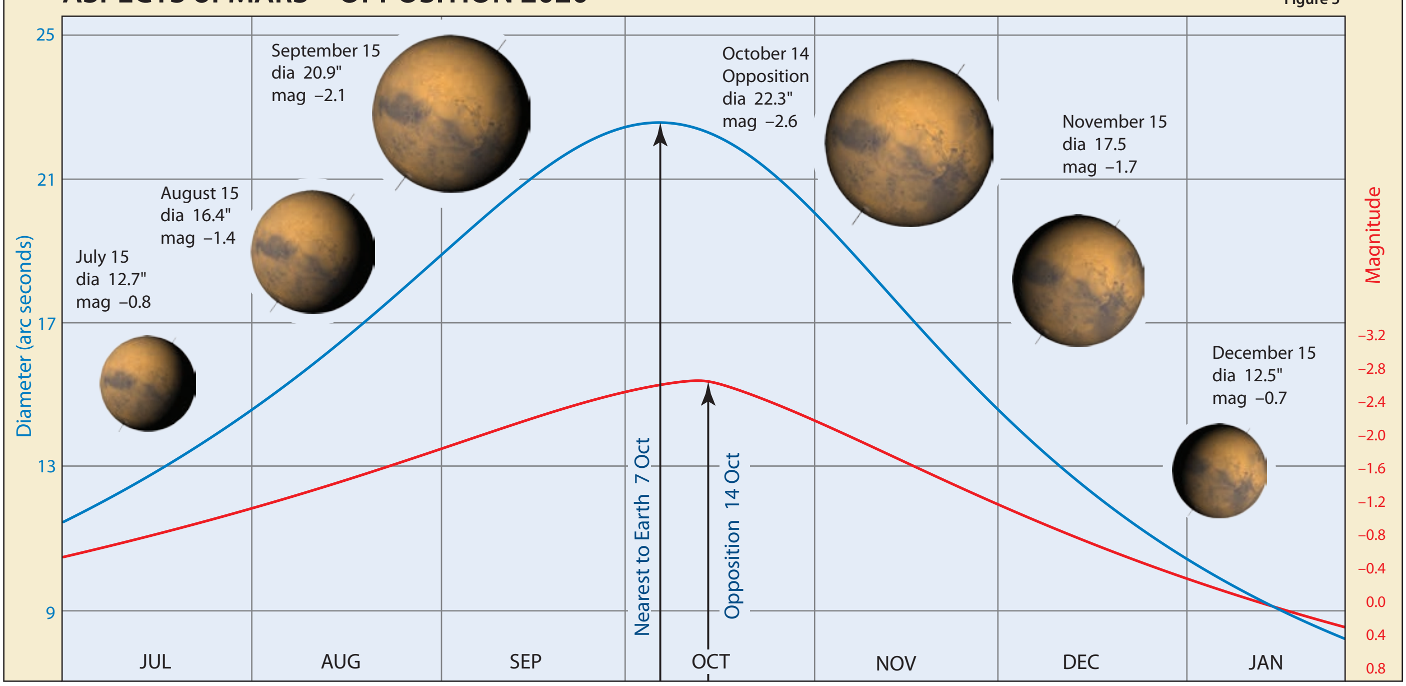


Table 1 Physical Ephemeris (0 hr UT).
See Figure 4 for description.

lighter material. At some oppositions the Eye is outstanding, and at others it is difficult because of the shifting sands of Mars (see map, Figure 3)

Mars can certainly be enjoyed at any opposition through a telescope; however, the view can be enhanced dramatically by the use of filters. The improvement in contrast by using various coloured filters brings hard to detect areas into prominence. A red or orange filter will highlight dark features; green or red filters are best for detecting the projections and boundaries of the polar caps. Yellow and green filters can distinguish surface frost and fog from lower level cloud, and blue or violet filters will show the higher-level clouds. Dust storms are best seen through yellow, orange and red filters.

There are many unsolved mysteries of the Red Planet and in a scientific light the amateur can still contribute. Monitoring the Martian atmosphere and surface features will assist in our understanding of the geological and atmospheric mechanics of this strange planet. Even with centuries of Earth based telescope scrutiny, and years of surveillance by orbiting spacecraft and rovers, Mars still has many secrets. Only by the dedication and enthusiasm of astronomers (mostly amateurs) will some of the mysteries be solved.

Calculating longitude of central meridian for a particular date and time.

First convert your local time to UT correcting the date if needed. Next, from Table 1, select the central meridian figure for the date. Now take the hour and minute values from the Increase in Longitude (Table 2). Add these three numbers. If the result is greater than 360° subtract 360° from it.

For example an observation at 1:20 am EST on October 9, converts to 15:20 UT on October 8. From the tables above our calculation is 224.3° + 219.3° + 4.9° = 448.5° Subtracting 360° to get a result less than 360° gives us a longitude of central meridian of 88.5°. The longitudes are shown on the map (Fig. 3). Around this time Solis Lacus will be crossing the central meridian.

Table 2: Central Meridian – Increase in Longitude

min	deg°	min	deg°
10	2.4	40	9.7
20	4.9	50	12.2
30	7.3	60	14.6

hr	deg°	hr	deg°
1	014.6	13	190.1
2	029.2	14	204.7
3	043.9	15	219.3
4	058.5	16	233.9
5	073.1	17	248.6
6	087.7	18	263.2
7	102.3	19	277.8
8	117.0	20	292.4
9	131.6	21	307.0
10	146.2	22	321.7
11	160.8	23	336.3
12	175.5	24	350.9

Date	Cent Mer°	Tilt°	Phase	Phase Angle	P.A.°
Aug 15	355.3	–19.0	0.884	39.9	324.6
Aug 16	345.8	–18.9	0.885	39.6	324.5
Aug 17	336.4	–18.9	0.887	39.3	324.4
Aug 18	327.0	–18.8	0.889	38.9	324.4
Aug 19	317.6	–18.7	0.891	38.6	324.3
Aug 20	308.3	–18.6	0.893	38.2	324.2
Aug 21	298.9	–18.5	0.895	37.9	324.2
Aug 22	289.5	–18.4	0.897	37.5	324.1
Aug 23	280.2	–18.4	0.899	37.1	324.1
Aug 24	270.9	–18.3	0.901	36.7	324.0
Aug 25	261.5	–18.2	0.903	36.3	324.0
Aug 26	252.2	–18.2	0.905	35.9	323.9
Aug 27	242.9	–18.1	0.907	35.5	323.9
Aug 28	233.7	–18.1	0.909	35.0	323.9
Aug 29	224.4	–18.0	0.912	34.6	323.8
Aug 30	215.1	–18.0	0.914	34.1	323.8
Aug 31	205.9	–17.9	0.916	33.6	323.8
Sep 1	196.7	–17.9	0.919	33.1	323.7
Sep 2	187.4	–17.8	0.921	32.6	323.7
Sep 3	178.2	–17.8	0.924	32.1	323.7
Sep 4	169.0	–17.8	0.926	31.6	323.7
Sep 5	159.9	–17.8	0.928	31.0	323.7
Sep 6	150.7	–17.7	0.931	30.5	323.7
Sep 7	141.5	–17.7	0.933	29.9	323.6
Sep 8	132.4	–17.7	0.936	29.3	323.6
Sep 9	123.3	–17.7	0.939	28.7	323.6
Sep 10	114.2	–17.7	0.941	28.1	323.6
Sep 11	105.1	–17.7	0.944	27.5	323.6
Sep 12	096.0	–17.8	0.946	26.8	323.6
Sep 13	086.9	–17.8	0.949	26.2	323.6
Sep 14	077.9	–17.8	0.951	25.5	323.6
Sep 15	068.8	–17.8	0.954	24.8	323.7
Sep 16	059.8	–17.9	0.956	24.1	323.7
Sep 17	050.8	–17.9	0.959	23.4	323.7
Sep 18	041.8	–18.0	0.961	22.7	323.7
Sep 19	032.8	–18.0	0.964	21.9	323.7
Sep 20	023.8	–18.1	0.966	21.2	323.8
Sep 21	014.9	–18.2	0.969	20.4	323.8
Sep 22	006.0	–18.2	0.971	19.6	323.8
Sep 23	357.0	–18.3	0.973	18.8	323.8
Sep 24	348.1	–18.4	0.975	18.0	323.9
Sep 25	339.2	–18.5	0.978	17.2	323.9
Sep 26	330.3	–18.6	0.980	16.4	324.0
Sep 27	321.4	–18.6	0.982	15.6	324.0
Sep 28	312.5	–18.7	0.984	14.7	324.1
Sep 29	303.7	–18.8	0.985	13.9	324.1
Sep 30	294.8	–19.0	0.987	13.0	324.2
Oct 1	286.0	–19.1	0.989	12.1	324.2
Oct 2	277.1	–19.2	0.990	11.3	324.3
Oct 3	268.3	–19.3	0.992	10.4	324.3
Oct 4	259.5	–19.4	0.993	9.5	324.4
Oct 5	250.7	–19.5	0.994	8.6	324.5
Oct 6	241.9	–19.7	0.995	7.8	324.5
Oct 7	233.1	–19.8	0.996	6.9	324.6
Oct 8	224.3	–19.9	0.997	6.0	324.7
Oct 9	215.5	–20.0	0.998	5.2	324.7
Oct 10	206.7	–20.2	0.999	4.3	324.8
Oct 11	197.9	–20.3	0.999	3.6	324.9
Oct 12	189.1	–20.4	0.999	2.9	325.0
Oct 13	180.3	–20.6	1.000	2.3	325.0
Oct 14	171.5	–20.7	1.000	2.1	325.1

Date	Cent Mer°	Tilt°	Phase	Phase Angle	P.A.°
Oct 15	162.7	–20.9	1.000	2.3	325.2
Oct 16	153.9	–21.0	0.999	2.7	325.3
Oct 17	145.1	–21.1	0.999	3.4	325.4
Oct 18	136.3	–21.3	0.999	4.1	325.4
Oct 19	127.5	–21.4	0.998	4.9	325.5
Oct 20	118.7	–21.5	0.997	5.8	325.6
Oct 21	109.8	–21.7	0.997	6.6	325.7
Oct 22	101.0	–21.8	0.996	7.4	325.8
Oct 23	092.2	–21.9	0.995	8.3	325.8
Oct 24	083.3	–22.0	0.994	9.1	325.9
Oct 25	074.4	–22.2	0.992	9.9	326.0
Oct 26	065.6	–22.3	0.991	10.8	326.1
Oct 27	056.7	–22.4	0.990	11.6	326.1
Oct 28	047.8	–22.5	0.988	12.4	326.2
Oct 29	038.9	–22.6	0.987	13.2	326.2
Oct 30	030.0	–22.7	0.985	14.0	326.3
Oct 31	021.1	–22.8	0.984	14.7	326.4
Nov 1	012.1	–22.9	0.982	15.5	326.4
Nov 2	003.2	–23.0	0.980	16.2	326.5
Nov 3	354.2	–23.1	0.978	17.0	326.5
Nov 4	345.2	–23.2	0.976	17.7	326.5
Nov 5	336.2	–23.3	0.974	18.4	326.6
Nov 6	327.2	–23.4	0.972	19.1	326.6
Nov 7	318.2	–23.5	0.970	19.8	326.6
Nov 8	309.1	–23.6	0.968	20.5	326.7
Nov 9	300.1	–23.7	0.966	21.1	326.7
Nov 10	291.0	–23.7	0.964	21.8	326.7
Nov 11	281.9	–23.8	0.962	22.4	326.7
Nov 12	272.8	–23.9	0.960	23.0	326.7
Nov 13	263.7	–23.9	0.958	23.6	326.7
Nov 14	254.6	–24.0	0.956	24.2	326.7
Nov 15	245.5	–24.0	0.954	24.7	326.7
Nov 16	236.3	–24.1	0.952	25.3	326.7
Nov 17	227.2	–24.1	0.950	25.8	326.7
Nov 18	218.0	–24.2	0.948	26.4	326.6
Nov 19	208.8	–24.2	0.946	26.9	326.6
Nov 20	199.6	–24.3	0.944	27.4	326.6
Nov 21	190.3	–24.3	0.942	27.9	326.5
Nov 22	181.1	–24.3	0.940	28.3	326.5
Nov 23	171.9	–24.4	0.938	28.8	326.5
Nov 24	162.6	–24.4	0.936	29.2	326.4
Nov 25	153.3	–24.4	0.934	29.7	326.4
Nov 26	144.0	–24.4	0.933	30.1	326.3
Nov 27	134.7	–24.5	0.931	30.5	326.2
Nov 28	125.4	–24.5	0.929	30.9	326.2
Nov 29	116.1	–24.5	0.927	31.3	326.1
Nov 30	106.8	–24.5	0.926	31.6	326.0
Dec 1	097.4	–24.5	0.924	32.0	326.0
Dec 2	088.1	–24.5	0.922	32.4	325.9
Dec 3	078.7	–24.5	0.921	32.7	325.8
Dec 4	069.3	–24.5	0.919	33.0	325.7
Dec 5	059.9	–24.5	0.918	33.3	325.7
Dec 6	050.5	–24.4	0.916	33.7	325.6
Dec 7	041.1	–24.4	0.915	34.0	325.5
Dec 8	031.7	–24.4	0.913	34.2	325.4
Dec 9	022.3	–24.4	0.912	34.5	325.3
Dec 10	012.8	–24.4	0.911	34.8	325.2
Dec 11	003.4	–24.3	0.909	35.0	325.1
Dec 12	353.9	–24.3	0.908	35.3	325.0
Dec 13	344.5	–24.2	0.907	35.5	324.9
Dec 14	335.0	–24.2	0.906	35.8	324.8

FINDING MARS' MOONS

We rarely hear of people trying to observe Phobos or Deimos because the assumption is often made that it is too hard. If it wasn't for the brilliant beacon of the Red Planet all you would need is a 20 cm telescope to see them! In reality it is difficult, but not impossible, although your technique and timing is critical. The aim is to separate the planet and satellite as much as possible (and a night with good seeing is needed). In practice a time around a Martian opposition is needed and even then the moon should be near a maximum elongation, as graphically illustrated on the diagram. These are the '0 hr' positions (east of the planet) or on the western side around 15 hr for Deimos and 4 hr for Phobos. This page can be used to work out where the moons are in their orbits at any time from the beginning of August to the end of November 2020.

It might be worthwhile experimenting with an occulting bar to block the glare of Mars. This can be a thin strip of aluminium foil or a wire placed in the focal plane of a high power eyepiece. This focal point can sometimes be indicated by a field stop in the form of an annular disc at the telescope end of the eyepiece. Position it; perhaps using tape, across the eyepiece ensuring it crosses the centre. A narrow strip of a dark (or dense) filter can sometimes be used to dramatically reduce the Martian glare but still see the disc. This way it is easier to judge the position of where the satellite should be using the location and size of Mars as a reference. An inexpensive plastic filter is preferred, being easier to cut and place across the field stop. When using the 'bar' orientate it to run north to south and know which side to look for the moon(s). If you are using a telescope without any tracking, such as a Dobsonian, remember objects on the western side are the first to leave the field. This is a good way to get your bearings. Also, don't fight with the scope to keep Mars just where you want it, especially under high power. It is best to leave your telescope in one position and let the Earth's rotation bring Mars and its satellites in and out of occultation; that way vibration is minimised.

The advantage to observing close to opposition is well illustrated in the diagram. Look at the dramatic increase in the angular size of the maximum elongations from Aug 15 to Oct 14. Deimos has moved from 45" to 62" (arcseconds) from the limb of Mars, Phobos from 13" to 18". Over the same period the brightness of the moons increases significantly as well, Deimos from 12.5 to 11.8 magnitude and Phobos from 11.4 to 10.7. Even though Phobos is the brighter of the pair, it is quite close to Mars and hence more challenging.

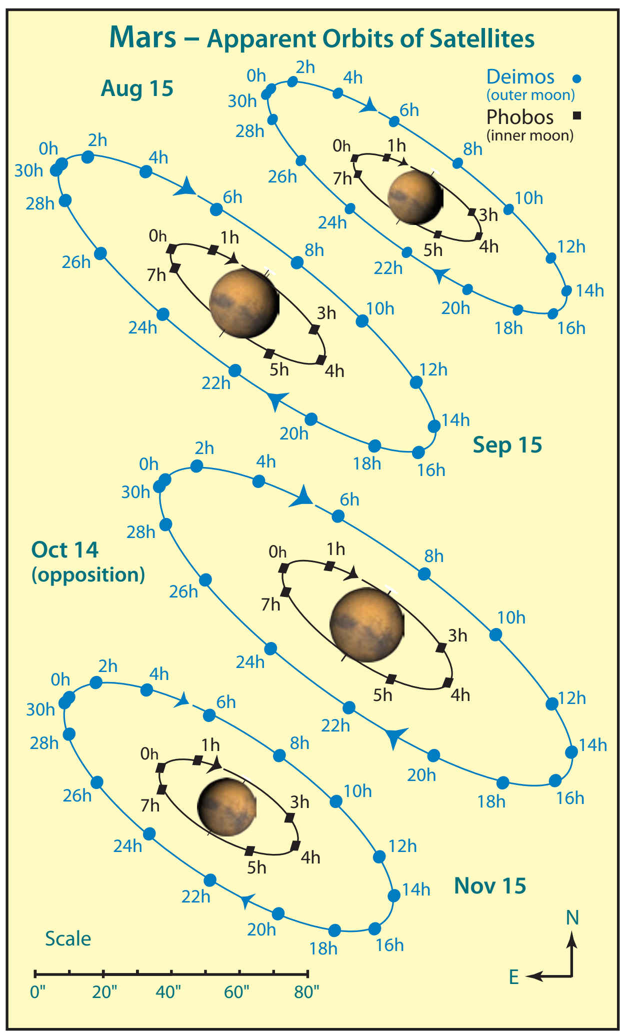
Time of Greatest Elongation East (UT)		
Moon	**Phobos**	**Deimos**
Magnitude [1]	10.5	11.7
Max. Elong. [1]	0' 31"	1' 18"
Period (days) [2]	0.3189	1.2624
	Elongation (d.ddd)	
August	1.038	1.933
	10.289	10.783
	20.179	20.892
September	1.302	1.263
	10.229	10.100
	20.116	20.196
October	1.275	1.550
	10.204	10.379
	20.085	20.467
November	1.204	2.083
	10.131	10.917
	20.017	21.017

Notes 1. Closest to Earth (Oct 6)
2. Mean Synodic Period

How to find Phobos and Deimos

The table presents the times of the first greatest elongation to the east after 0 hr UT on the 1st, 10th and 20th of each month. These are times when the moon should be at the '0 hr' (zero hour) location on the Apparent Orbits diagram. Like the satellites of Saturn, Uranus and Neptune, the procedure is to work out how many orbits have elapsed since the most recent eastern elongation listed on the table. Then discard the completed number of orbits and convert the remaining fraction of days back to hours so its position can be read directly off the diagram. This is best illustrated with an example. You wish to determine the position of **Deimos** for Oct 8 at 11 pm EST.

1. Convert to UT as a fractional day. Oct 8 at 11 pm (EST) = 8.542 UT (use table 3, page 129).
2. Subtract the date of the most recent greatest elongation east for Oct, i.e. 8.542 – 1.550 = 6.992
3. Express this as the number of orbits by dividing by the period 6.992 / 1.2624 = 5.538
4. Discarding the five completed orbits leaves 0.538
5. Multiply by the period, 0.538 × 1.2624 = 0.680 days.
6. Multiply 0.680 days × 24 = 16.3 hours.
7. Looking at the orbital path for Deimos for Oct 14 (see Apparent Orbits diagram), the satellite is just past the 16 hour mark and within the last hour passed through a western maximum elongation and this would be a good time to try and observe it.



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	238.7	087.3	342.1	194.4	251.3	108.5	169.5	028.2	244.3	298.9	148.3	198.2	1
2	036.4	245.1	139.9	352.2	049.2	266.5	327.6	186.2	042.2	096.7	306.0	355.8	2
3	194.1	042.8	297.6	150.1	207.1	064.6	125.6	344.2	200.0	254.4	103.7	153.5	3
4	351.7	200.5	095.4	308.0	005.1	222.6	283.6	142.2	357.9	052.2	261.3	311.1	4
5	149.4	358.2	253.2	105.8	163.0	020.6	081.7	300.2	155.8	209.9	059.0	108.8	5
6	307.1	156.0	051.0	263.7	321.0	178.6	239.7	098.2	313.6	007.7	216.7	266.4	6
7	104.8	313.7	208.8	061.6	118.9	336.6	037.8	256.1	111.5	165.4	014.4	064.1	7
8	262.5	111.4	006.6	219.4	276.9	134.7	195.8	054.1	269.3	323.2	172.0	221.7	8
9	060.2	269.2	164.4	017.3	074.8	292.7	353.8	212.1	067.2	120.9	329.7	019.4	9
10	217.8	066.9	322.2	175.2	232.8	090.7	151.9	010.0	225.0	278.7	127.4	177.0	10
11	015.5	224.6	120.0	333.1	030.8	248.7	309.9	168.0	022.9	076.4	285.1	334.6	11
12	173.2	022.4	277.8	131.0	188.7	046.8	107.9	326.0	180.7	234.1	082.7	132.3	12
13	330.9	180.1	075.6	288.8	346.7	204.8	266.0	123.9	338.5	031.9	240.4	289.9	13
14	128.6	337.9	233.4	086.7	144.7	002.8	064.0	281.9	136.4	189.6	038.1	087.6	14
15	286.3	135.6	031.2	244.6	302.6	160.9	222.0	079.8	294.2	347.3	195.7	245.2	15
16	084.0	293.4	189.0	042.5	100.6	318.9	020.1	237.7	092.0	145.0	353.4	042.9	16
17	241.7	091.1	346.8	200.4	258.6	116.9	178.1	035.7	249.8	302.8	151.0	200.5	17
18	039.4	248.9	144.7	358.3	056.6	275.0	336.1	193.6	047.6	100.5	308.7	358.1	18
19	197.1	046.6	302.5	156.2	214.5	073.0	134.1	351.5	205.5	258.2	106.4	155.8	19
20	354.8	204.4	100.3	314.1	012.5	231.1	292.2	149.5	003.3	055.9	264.0	313.4	20
21	152.5	002.1	258.1	112.0	170.5	029.1	090.2	307.4	161.1	213.6	061.7	111.1	21
22	310.2	159.9	056.0	269.9	328.5	187.1	248.2	105.3	318.9	011.3	219.3	268.7	22
23	107.9	317.7	213.8	067.9	126.5	345.2	046.2	263.2	116.7	169.0	017.0	066.3	23
24	265.6	115.4	011.6	225.8	284.5	143.2	204.2	061.1	274.5	326.7	174.6	224.0	24
25	063.3	273.2	169.5	023.7	082.5	301.3	002.2	219.1	072.2	124.4	332.3	021.6	25
26	221.0	071.0	327.3	181.6	240.5	099.3	160.3	017.0	230.0	282.1	129.9	179.3	26
27	018.7	228.7	125.1	339.5	038.5	257.3	318.3	174.9	027.8	079.8	287.6	336.9	27
28	176.5	026.5	283.0	137.5	196.5	055.4	116.3	332.7	185.6	237.5	085.2	134.5	28
29	334.2	184.3	080.8	295.4	354.5	213.4	274.3	130.6	343.4	035.2	242.9	292.2	29
30	131.9		238.7	093.3	152.5	011.5	072.3	288.5	141.1	192.9	040.5	089.8	30
31	289.6		036.5		310.5		230.3	086.4		350.6		247.5	31

SYSTEM II (° at 0 hr UT)

Date	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Date
1	281.8	253.9	287.4	263.2	091.1	071.8	263.9	246.1	225.6	051.4	024.2	205.3	1
2	071.9	044.0	077.5	053.4	241.4	222.2	054.3	036.5	015.9	201.5	174.3	355.3	2
3	221.9	194.1	227.7	203.6	031.7	012.6	204.7	186.8	166.1	351.6	324.3	145.3	3
4	012.0	344.2	017.8	353.8	182.0	163.0	355.1	337.2	316.4	141.7	114.4	295.3	4
5	162.0	134.3	168.0	144.1	332.3	313.4	145.5	127.5	106.6	291.9	264.4	085.3	5
6	312.1	284.4	318.2	294.3	122.7	103.8	296.0	277.9	256.8	082.0	054.5	235.3	6
7	102.1	074.5	108.3	084.5	273.0	254.1	086.4	068.2	047.0	232.1	204.5	025.4	7
8	252.2	224.6	258.5	234.8	063.3	044.5	236.8	218.6	197.3	022.2	354.6	175.4	8
9	042.2	014.7	048.7	025.0	213.6	194.9	027.2	008.9	347.5	172.3	144.6	325.4	9
10	192.3	164.8	198.8	175.3	004.0	345.3	177.6	159.2	137.7	322.5	294.7	115.4	10
11	342.4	314.9	349.0	325.5	154.3	135.7	328.0	309.6	287.9	112.6	084.7	265.4	11
12	132.4	105.0	139.2	115.8	304.6	286.1	118.4	099.9	078.1	262.7	234.7	055.4	12
13	282.5	255.2	289.3	266.0	095.0	076.5	268.8	250.2	228.3	052.8	024.8	205.4	13
14	072.5	045.3	079.5	056.3	245.3	226.9	059.2	040.5	018.5	202.9	174.8	355.4	14
15	222.6	195.4	229.7	206.6	035.6	017.3	209.6	190.8	168.7	353.0	324.9	145.5	15
16	012.7	345.5	019.9	356.8	186.0	167.7	360.0	341.2	318.9	143.1	114.9	295.5	16
17	162.7	135.6	170.1	147.1	336.3	318.2	150.4	131.5	109.1	293.2	264.9	085.5	17
18	312.8	285.8	320.3	297.4	126.7	108.6	300.8	281.8	259.3	083.2	055.0	235.5	18
19	102.9	075.9	110.4	087.6	277.0	259.0	091.2	072.1	049.5	233.3	205.0	025.5	19
20	253.0	226.0	260.6	237.9	067.4	049.4	241.6	222.4	199.6	023.4	355.0	175.5	20
21	043.0	016.1	050.8	028.2	217.7	199.8	032.0	012.7	349.8	173.5	145.0	325.5	21
22	193.1	166.3	201.0	178.5	008.1	350.2	182.4	162.9	140.0	323.6	295.1	115.5	22
23	343.2	316.4	351.2	328.7	158.5	140.6	332.7	313.2	290.1	113.6	085.1	265.6	23
24	133.3	106.5	141.4	119.0	308.8	291.0	123.1	103.5	080.3	263.7	235.1	055.6	24
25	283.3	256.7	291.6	269.3	099.2	081.4	273.5	253.8	230.5	053.8	025.1	205.6	25
26	073.4	046.8	081.9	059.6	249.6	231.8	063.9	044.1	020.6	203.9	175.2	355.6	26
27	223.5	197.0	232.1	209.9	039.9	022.2	214.3	194.3	170.8	353.9	325.2	145.6	27
28	013.6	347.1	022.3	000.2	190.3	172.7	004.6	344.6	320.9	144.0	115.2	295.6	28
29	163.7	137.2	172.5	150.5	340.7	323.1	155.0	134.9	111.1	294.1	265.2	085.6	29
30	313.7		322.7	300.8	131.1	113.5	305.4	285.1	261.2	084.1	055.2	235.6	30
31	103.8		112.9		281.4		095.7	075.4		234.2		025.6	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.

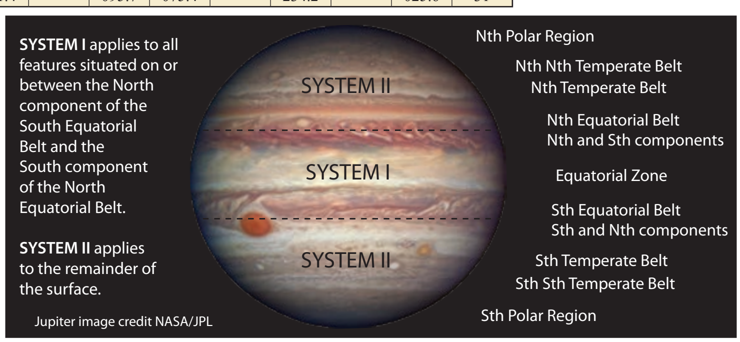
The longitude can be worked out from the tables here. All the times on the main tables are calculated for 0 hr UT of date. You will need to add multiple hours and minutes from the small Increase in Longitude tables below. For example, the longitude of central meridian for Jupiter (System I) for 5 July 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 283.6°. 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 521.1°, less 360° giving a final answer of 161.1°.

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: 2012 (180°), 2013 (197°), 2014 (214°), 2015 (228°), 2016 (248°), 2017 (274°), 2018 (290°) and 2019 (312°). The table of data for 2020 (opposite) has been based on 334°. For every degree of longitude greater than 334° it will transit 1.6 minutes later than shown (for every degree less than 334°, 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 2020. 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



Jupiter image credit NASA/JPL

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 22	3:57		
Jan 24	5:36		
Jan 26	(5:15)		
Jan 29	4:46		
Jan 31	(4:25)		
Feb 2	(6:04)		
Feb 3	3:55		
Feb 5	5:34 *		
Feb 7	(5:13)		
Feb 8	3:05		
Feb 10	4:44		
Feb 12	(4:23)		
Feb 14	(6:02)		
Feb 15	3:53		
Feb 17	5:32 *		
Feb 19	(5:11)		
Feb 20	3:02		
Feb 22	4:41 *		
Feb 24	(4:20)		
Feb 25	2:12		
Feb 26	(5:59)		
Feb 27	3:51		
Feb 29	5:29 *		
Mar 2	(5:08)		
Mar 3	3:00		
Mar 5	4:38 *		
Mar 7	6:17 *		
Mar 8	2:09		
Mar 9	(5:56)		
Mar 10	3:47 *		
Mar 12	5:26 *		
Mar 13	1:18		
Mar 14	(5:05)		
Mar 15	2:56		
Mar 16	(6:44)		
Mar 17	4:35 *		
Mar 19	6:14 *		
Mar 20	2:05		
Mar 21	(5:52)		
Mar 22	3:44 *		
Mar 24	5:22 *		
Mar 25	1:14		
Mar 26	(5:01)		
Mar 27	2:52 *		
Mar 28	(6:40)		
Mar 29	4:31 *		
Mar 30	0:22		
Mar 31	6:10 *		

Date	1st	2nd	3rd
Apr 1	2:01		
Apr 2	(5:48)		
Apr 3	3:40 *		
Apr 5	5:18 *		
Apr 6	1:09		
Apr 7	(4:57)		
Apr 8	2:48 *		
Apr 9	(6:35)		
Apr 10	4:26 *		
Apr 11	0:18		
Apr 12	6:05 *		(23:56)
Apr 13	1:56		
Apr 14	(5:43)		
Apr 15	3:35 *		23:26
Apr 17	5:13 *		
Apr 18	1:04		
Apr 19	(4:51)		
Apr 20	2:43 *		
Apr 21	(6:30)		
Apr 22	4:21 *		
Apr 23	0:12		
Apr 24	6:00 *		(23:51)
Apr 25	1:51		
Apr 26	(5:38)		
Apr 27	3:29 *		23:21
Apr 29	5:07 *		(22:59)
Apr 30	0:59		
May 1	6:46 *		
May 2	2:37 *		22:28
May 3	(6:24)		
May 4	4:15 *		
May 5	0:07		
May 6	5:53 *		(23:45)
May 7	1:45		
May 8	(5:32)		
May 9	3:23 *		23:14
May 10	(7:10)		
May 11	5:01 *		(22:53)
May 12	0:52		
May 13	6:39 *		
May 14	2:31 *		22:22
May 15	(6:17)		
May 16	4:09 *		(22:00)
May 17	0:00		
May 18	5:47 *		(23:38)
May 19	1:38		21:29
May 20	(5:25)		
May 21	3:16 *		23:08

Date	1st	2nd	3rd
May 22	(7:03)		
May 23	4:54 *		(22:46)
May 24	0:45		
May 25	6:32 *		
May 26	2:23 *		22:15
May 27	(6:10)		
May 28	4:02 *		23:53 *
May 30	5:40 *		(23:31)
May 31	1:31		21:22
Jun 1	7:18 *		
Jun 2	3:09 *		23:00 *
Jun 3	(6:56)		
Jun 4	4:47 *		(22:38)
Jun 5	0:38		20:29
Jun 6	6:25 *		
Jun 7	2:16 *		22:07 *
Jun 8	(6:03)		
Jun 9	3:54 *		23:45 *
Jun 10	(7:41)	19:36	
Jun 11	5:32 *		(23:23)
Jun 12	1:23		21:14
Jun 13	7:10 *		
Jun 14	3:01 *		22:52 *
Jun 15	(6:48)		
Jun 16	4:39 *		(22:30)
Jun 17	0:30		20:21
Jun 18	6:17 *		
Jun 19	2:08 *		21:59 *
Jun 20	(5:55)		
Jun 21	3:46 *		23:37 *
Jun 22	(7:33)	19:28	
Jun 23	5:24 *		(23:15)
Jun 24	1:15	(19:06)	21:06
Jun 25	7:02 *		
Jun 26	2:53 *		22:44 *
Jun 27	(6:40)	18:35	
Jun 28	4:31 *		(22:22)
Jun 29	0:22		20:13
Jun 30	6:09 *		
Jul 1	2:00 *		21:51 *
Jul 2	(5:47)		
Jul 3	3:38 *		23:29 *
Jul 4	(7:25)	19:20	
Jul 5	5:16 *		(23:07)
Jul 6	1:07	(18:58)	20:58
Jul 7	6:54 *		
Jul 8	2:45 *		22:36 *
Jul 9	(6:31)	18:27	

Date	1st	2nd	3rd
Jul 10	4:23 *		(22:14)
Jul 11	0:14	(18:05)	20:05
Jul 12	6:01 *		(23:52)
Jul 13	1:52	(19:43)	21:43
Jul 14	(5:38)	17:34	
Jul 15	3:30 *		23:21 *
Jul 16	(7:16)	19:12 *	
Jul 17	5:08 *		(22:59)
Jul 18	0:59	(18:50)	20:50
Jul 19	6:46 *	16:41	
Jul 20	2:37 *		22:28 *
Jul 21	(6:24)	18:19	
Jul 22	4:15 *		(22:06)
Jul 23	0:06	(17:57)	19:57
Jul 24	5:53 *		(23:44)
Jul 25	1:44	(19:35)	21:35
Jul 26	(5:31)	17:26	
Jul 27	3:22 *		23:13 *
Jul 28		19:05	
Jul 29	5:00 *		(22:51)
Jul 30	0:51	(18:43)	20:43
Jul 31	(4:38)		
Aug 1	2:29 *		22:21 *
Aug 2		18:12	
Aug 3	4:07 *		23:59 *
Aug 4		19:50 *	
Aug 5	(3:45)		(23:37)
Aug 6	1:37	(19:28)	21:28
Aug 7	(5:24)	17:19	
Aug 8	3:15 *		23:06 *
Aug 9		18:57	
Aug 10	4:53 *		(22:44)
Aug 11	0:44	(18:36)	20:36
Aug 12	(4:31)		
Aug 13	2:22 *		22:14 *
Aug 14		18:05	
Aug 15	4:01 *		23:52 *
Aug 16		19:43 *	
Aug 17	(3:39)		(23:30)
Aug 18	1:30	(19:22)	21:22
Aug 19		17:13	
Aug 20	3:08 *		23:00 *
Aug 21		18:51	
Aug 22	(2:47)		(22:38)
Aug 23	0:38	(18:30)	20:30
Aug 24	(4:25)		
Aug 25	2:16 *		22:08 *
Aug 26		17:59	

Date	1st	2nd	3rd
Aug 27	3:55 *		23:46 *
Aug 28		19:38 *	
Aug 29	(3:33)		(23:25)
Aug 30	1:25	(19:16)	21:16
Aug 31		17:07	
Sep 1	3:03 *		22:55 *
Sep 2		18:46	
Sep 3	(2:42)		(22:33)
Sep 4	0:33	(18:24)	20:24
Sep 6	2:11 *		22:03 *
Sep 7		17:54	
Sep 8	(1:50)		23:41 *
Sep 9		19:33	
Sep 10			(23:20)
Sep 11	1:20	(19:11)	21:11
Sep 13	(0:59)		22:50 *
Sep 14		18:42	
Sep 15	(2:37)		(22:29)
Sep 16	0:29	(18:20)	20:20
Sep 18	2:07 *		21:59 *
Sep 19		17:50	
Sep 20	(1:46)		23:38 *
Sep 21		19:29	
Sep 22			(23:16)
Sep 23	1:16	(19:08)	21:08
Sep 25	(0:55)		22:47 *
Sep 26		18:38	
Sep 27			(22:25)
Sep 28	0:25	(18:17)	20:17
Sep 30	(0:04)		21:56 *
Oct 1		17:47	
Oct 2	(1:43)		23:35 *
Oct 3		19:26	
Oct 4			(23:13)
Oct 5	1:13	(19:05)	21:05
Oct 7	(0:52)		22:44 *
Oct 8		18:35	
Oct 9			(22:23)
Oct 10	0:23	(18:14)	20:14
Oct 12	(0:02)		21:53 *
Oct 13		17:45	
Oct 14			23:32 *
Oct 15		19:24	
Oct 16			(23:11)
Oct 17		(19:03)	21:03
Oct 19	(0:50)		22:42 *
Oct 20		18:33	
Oct 21			(22:21)

Date	1st	2nd	3rd
Oct 22	0:21	(18:12)	20:12
Oct 24	(0:00)		21:52 *
Oct 26			23:31 *
Oct 27		19:22	
Oct 28			(23:10)
Oct 29		(19:01)	21:01
Oct 31			22:40 *
Nov 1		18:32	
Nov 2			(22:19)
Nov 3			20:11
Nov 5		(19:50)	21:50
Nov 7			(21:29)
Nov 8		19:21	
Nov 9			(23:09)
Nov 10		(19:00)	21:00
Nov 12			22:39 *
Nov 13		18:31	
Nov 14			(22:19)
Nov 15			20:10
Nov 17		(19:50)	21:50
Nov 19			(21:29)
Nov 20		19:20	
Nov 22		(19:00)	21:00
Nov 24			(20:39)
Nov 25		18:31	
Nov 26			(22:18)
Nov 27			20:10
Nov 29		(19:49)	21:49
Dec 1			(21:28)
Dec 2		19:20	
Dec 4		(18:59)	20:59
Dec 6			(20:38)
Dec 7		18:30	
Dec 9			20:09
Dec 11		(19:49)	
Dec 13			(21:28)
Dec 14		19:20	
Dec 16		(18:59)	20:59
Dec 18			(20:38)
Dec 21			20:09
Dec 23		(19:48)	
Dec 26		19:20	
Dec 28		(18:59)	
Dec 30			(20:38)

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 19 October the first transit is only visible from WA at 12:50 am WST. The 3rd transit for the day is visible Australia wide at 22:42 EST or 10:42 pm EST (10:12 pm CST, 8:42 pm WST).

JUPITER'S MOONS

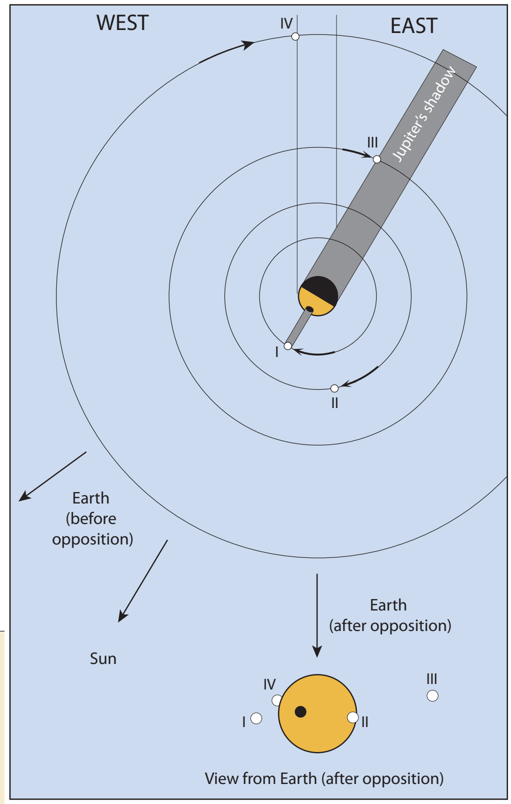
Jupiter, with its many moons, can be likened to a miniature Solar System. Like the planets, these moons all lie in a similar plane. Although there are 79 known Jovian satellites, most of them are too faint for amateur equipment. The four Galilean Satellites, named after their discoverer, Galileo, are 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 2020 is 14 July.
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 January 3.

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):

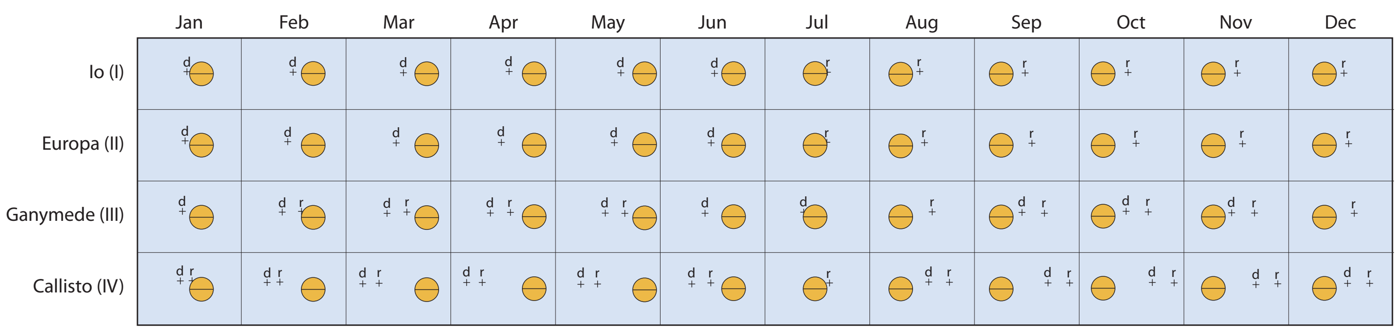
Satellite I	(Io) shadow is currently in transit. The satellite itself would have recently egressed from a transit.
Satellite II	(Europa) has just commenced a satellite transit (ingress).
Satellite III	(Ganymede) is about to be eclipsed (disappear).
Satellite IV	(Callisto) may be about to move out of 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



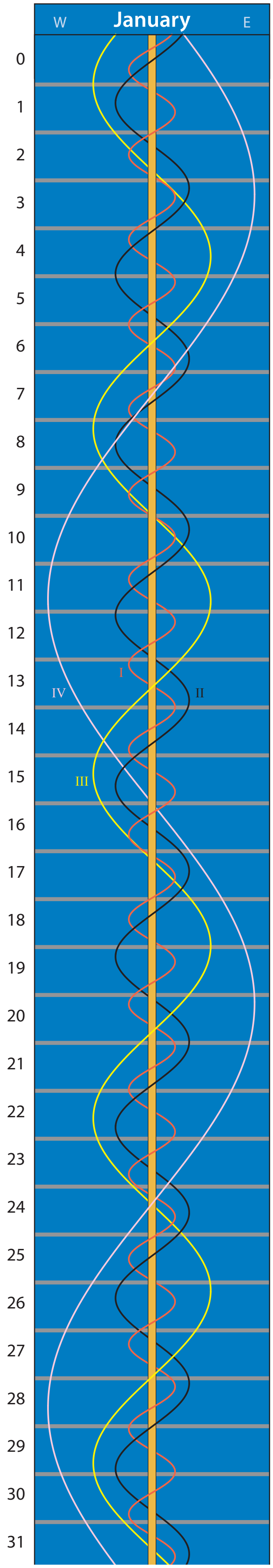
These diagrams show the positions of the eclipse events for each satellite for midmonth, relative to Jupiter. An eclipse happens when the moon passes into (disappearance or d) or out of (reappearance or r) Jupiter's shadow; west to the left, east to the right.

JUPITER MOON EVENTS

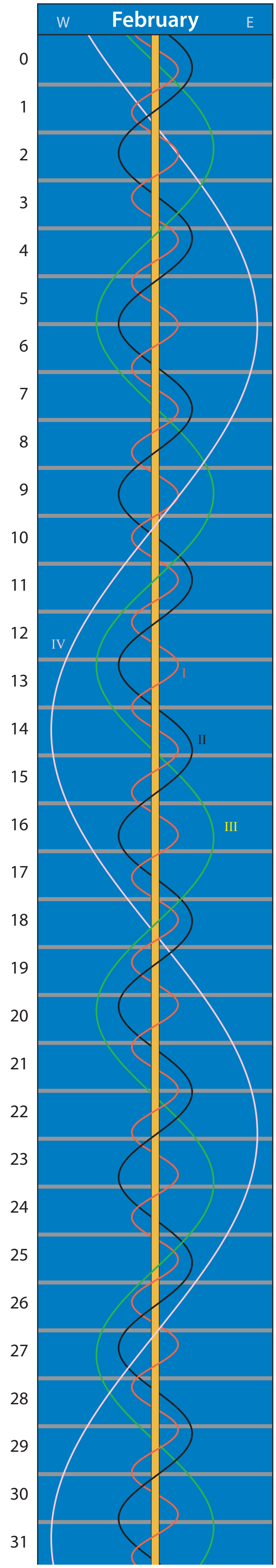
The diagrams here show the patterns the four major moons of Jupiter make as they shuttle back and forth. Each complete period represents one orbit of the satellite. Each horizontal grey date line represents midnight; the top edge of the line is midnight EST (14 hr UT), the bottom edge of the line is 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			
20	04:54	02:54	II	Oc R	E
23	07:01	05:01	I	Sh I	W
	07:28	05:28	I	Tr I	W
24	04:21	02:21	I	Ec D	E
	04:42	02:42	IV	Sh I	E
	07:04	05:04	I	Oc R	W
	07:07	05:07	IV	Sh E	W
	07:15	05:15	III	Ec D	W
25	03:44	01:44	I	Sh E	E
	04:13	02:13	I	Tr E	E
27	04:01	02:01	II	Ec D	E
31	06:15	04:15	I	Ec D	W
		February			
1	03:23	01:23	I	Sh I	E
	03:59	01:59	I	Tr I	E
	05:38	03:38	I	Sh E	W
	06:14	04:14	I	Tr E	W
2	03:36	01:36	I	Oc R	E
3	06:36	04:36	II	Ec D	W
4	03:35	01:35	III	Tr I	E
	03:59	01:59	III	Sh E	E
	06:38	04:38	III	Tr E	W
5	03:02	01:02	II	Tr I	E
	04:24	02:24	II	Sh E	E
	05:45	03:45	II	Tr E	W
8	05:17	03:17	I	Sh I	
	05:59	03:59	I	Tr I	W
	07:32	05:32	I	Sh E	W
9	05:36	03:36	I	Oc R	W
10	05:24	03:24	IV	Tr I	
11	04:59	02:59	III	Sh I	E



Day	EST	WST	Sat	Event	Vis
12	04:18	02:18	II	Sh I	E
	05:49	03:49	II	Tr I	W
	07:00	05:00	II	Sh E	W
14	02:46	00:46	II	Oc R	E
15	07:11	05:11	I	Sh I	W
16	04:32	02:32	I	Ec D	E
	07:36	05:36	I	Oc R	W
17	02:29	00:29	I	Tr I	E
	03:54	01:54	I	Sh E	E
	04:44	02:44	I	Tr E	E
19	06:53	04:53	II	Sh I	W
21	05:33	03:33	II	Oc R	
22	02:10	00:10	III	Ec R	E
	02:44	00:44	III	Oc D	E
	05:53	03:53	III	Oc R	W
23	06:25	04:25	I	Ec D	W
24	03:33	01:33	I	Sh I	E
	04:28	02:28	I	Tr I	
	05:48	03:48	I	Sh E	W
	06:44	04:44	I	Tr E	W
25	04:05	02:05	I	Oc R	E
27	04:53	02:53	IV	Tr E	
28	03:37	01:37	II	Ec D	E
29	03:08	01:08	III	Ec D	E
	06:10	04:10	III	Ec R	W
	07:05	05:05	III	Oc D	W
		March			
1	03:29	01:29	II	Tr E	E
2	05:26	03:26	I	Sh I	
	06:27	04:27	I	Tr I	W
	07:41	05:41	I	Sh E	W
3	02:47	00:47	I	Ec D	E
	06:04	04:04	I	Oc R	W
4	02:10	00:10	I	Sh E	E
	03:13	01:13	I	Tr E	E
6	03:24	01:24	IV	Ec D	E
	06:12	04:12	II	Ec D	W
	06:22	04:22	IV	Ec R	W
7	07:06	05:06	III	Ec D	W
8	03:28	01:28	II	Tr I	E
	04:02	02:02	II	Sh E	
	06:14	04:14	II	Tr E	W
9	07:20	05:20	I	Sh I	W
10	04:41	02:41	I	Ec D	
	08:02	06:02	I	Oc R	W
11	01:20	23:20(p)	III	Tr I	E
	01:48	23:48(p)	I	Sh I	E
	02:55	00:55	I	Tr I	E
	04:04	02:04	I	Sh E	
	04:32	02:32	III	Tr E	
	05:11	03:11	I	Tr E	
12	02:32	00:32	I	Oc R	E
15	03:54	01:54	II	Sh I	
	06:11	04:11	II	Tr I	W
	06:37	04:37	II	Sh E	W
17	03:12	01:12	II	Oc R	E
	06:34	04:34	I	Ec D	W



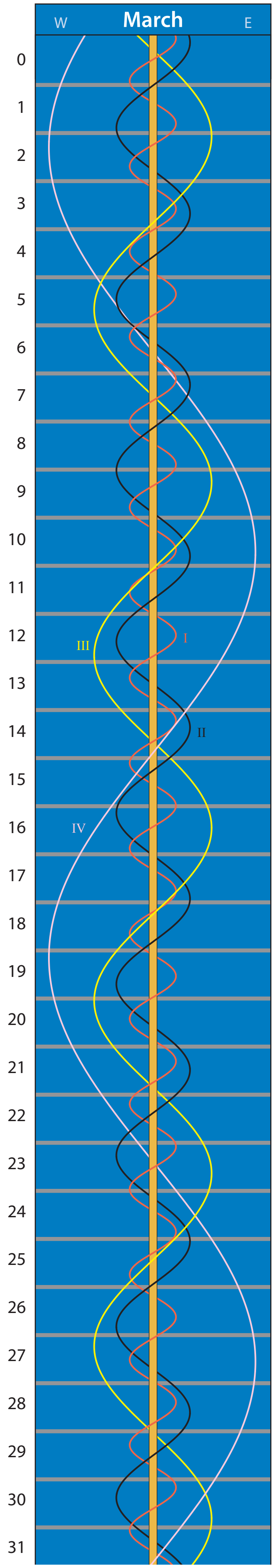
JUPITER

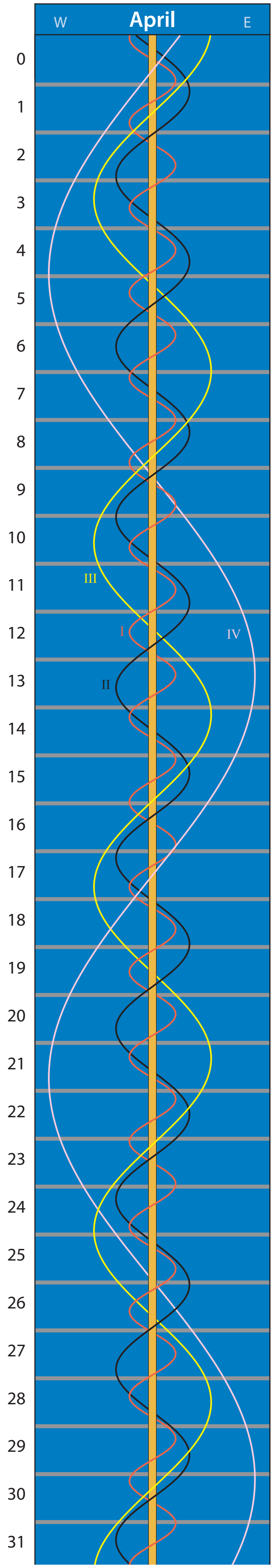
JUPITER MOON EVENTS

Day	EST	WST	Sat	Event	Vis
18	03:42	01:42	I	Sh I	
	03:55	01:55	III	Sh E	
	04:53	02:53	I	Tr I	
	05:35	03:35	III	Tr I	
	05:57	03:57	I	Sh E	
	07:09	05:09	I	Tr E	W
19	01:03	23:03(p)	I	Ec D	E
	04:29	02:29	I	Oc R	
20	01:38	23:38(p)	I	Tr E	E
22	06:28	04:28	II	Sh I	W
24	00:40	22:40(p)	II	Ec D	E
	05:55	03:55	II	Oc R	
25	04:50	02:50	III	Sh I	
	05:36	03:36	I	Sh I	
	06:50	04:50	I	Tr I	W
	07:51	05:51	I	Sh E	W
	07:55	05:55	III	Sh E	W
26	00:57	22:57(p)	II	Tr E	E
	02:56	00:56	I	Ec D	
	06:26	04:26	I	Oc R	W
27	01:19	23:19(p)	I	Tr I	E
	02:20	00:20	I	Sh E	E
	03:35	01:35	I	Tr E	
28	00:54	22:54(p)	I	Oc R	E
29	03:15	01:15	III	Oc R	
31	03:15	01:15	II	Ec D	
	04:32	02:32	IV	Sh I	
	07:43	05:43	IV	Sh E	W

April

Day	EST	WST	Sat	Event	Vis
1	07:29	05:29	I	Sh I	W
2	00:50	22:50(p)	II	Tr I	E
	01:02	23:02(p)	II	Sh E	E
	03:36	01:36	II	Tr E	
	04:49	02:49	I	Ec D	
	08:21	06:21	I	Oc R	W
3	01:58	23:58(p)	I	Sh I	E
	03:15	01:15	I	Tr I	
	04:13	02:13	I	Sh E	
	05:31	03:31	I	Tr E	
4	02:50	00:50	I	Oc R	
5	00:00	22:00(p)	I	Tr E	E
	02:05	00:05	III	Ec R	E
	04:06	02:06	III	Oc D	
	07:23	05:23	III	Oc R	W
7	05:51	03:51	II	Ec D	
9	00:53	22:53(p)	II	Sh I	E
	03:22	01:22	IV	Oc D	
	03:26	01:26	II	Tr I	
	03:36	01:36	II	Sh E	
	06:13	04:13	II	Tr E	
	06:43	04:43	I	Ec D	W
	07:14	05:14	IV	Oc R	W
10	03:51	01:51	I	Sh I	
	05:10	03:10	I	Tr I	
	06:07	04:07	I	Sh E	
	07:26	05:26	I	Tr E	W
11	00:36	22:36(p)	II	Oc R	E
	01:11	23:11(p)	I	Ec D	E
	04:44	02:44	I	Oc R	
	23:38	21:38	I	Tr I	E





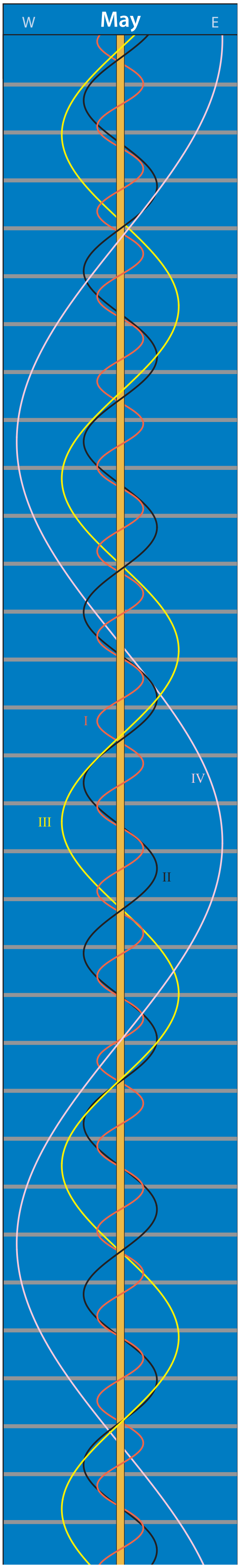
Day	EST	WST	Sat	Event	Vis
12	00:35	22:35(p)	I	Sh E	E
	01:55	23:55(p)	I	Tr E	
	02:56	00:56	III	Ec D	
	06:04	04:04	III	Ec R	
	08:09	06:09	III	Oc D	W
14	08:26	06:26	II	Ec D	W
16	01:18	23:18(p)	III	Tr E	E
	03:26	01:26	II	Sh I	
	06:01	04:01	II	Tr I	
	06:10	04:10	II	Sh E	
	08:36	06:36	I	Ec D	W
17	01:52	23:52(p)	IV	Sh E	
	05:45	03:45	I	Sh I	
	07:04	05:04	I	Tr I	W
	08:01	06:01	I	Sh E	W
18	03:04	01:04	I	Ec D	
	03:13	01:13	II	Oc R	
	06:38	04:38	I	Oc R	W
19	00:13	22:13(p)	I	Sh I	E
	01:32	23:32(p)	I	Tr I	
	02:29	00:29	I	Sh E	
	03:49	01:49	I	Tr E	
	06:55	04:55	III	Ec D	W
20	01:06	23:06(p)	I	Oc R	E
22	23:52	21:52	III	Sh E	E
23	01:57	23:57(p)	III	Tr I	
	05:16	03:16	III	Tr E	
	06:00	04:00	II	Sh I	
	08:34	06:34	II	Tr I	W
	08:44	06:44	II	Sh E	W
24	07:39	05:39	I	Sh I	W
25	00:20	22:20(p)	II	Ec D	E
	04:57	02:57	I	Ec D	
	05:48	03:48	II	Oc R	
	08:31	06:31	I	Oc R	W
26	01:19	23:19(p)	IV	Oc R	
	02:07	00:07	I	Sh I	
	03:25	01:25	I	Tr I	
	04:23	02:23	I	Sh E	
	05:42	03:42	I	Tr E	
	23:26	21:26	I	Ec D	E
27	00:36	22:36(p)	II	Tr E	E
	02:59	00:59	I	Oc R	
	22:52	20:52	I	Sh E	E
28	00:10	22:10(p)	I	Tr E	E
30	00:41	22:41(p)	III	Sh I	E
	03:52	01:52	III	Sh E	
	05:51	03:51	III	Tr I	
	08:33	06:33	II	Sh I	W

May

Day	EST	WST	Sat	Event	Vis
2	02:56	00:56	II	Ec D	
	06:50	04:50	I	Ec D	W
	08:21	06:21	II	Oc R	W
3	04:01	02:01	I	Sh I	
	05:17	03:17	I	Tr I	
	06:17	04:17	I	Sh E	
	07:34	05:34	I	Tr E	W
	23:12	21:12	III	Oc R	E

I is Io, II is Europa, III is Ganymede, IV is Callisto

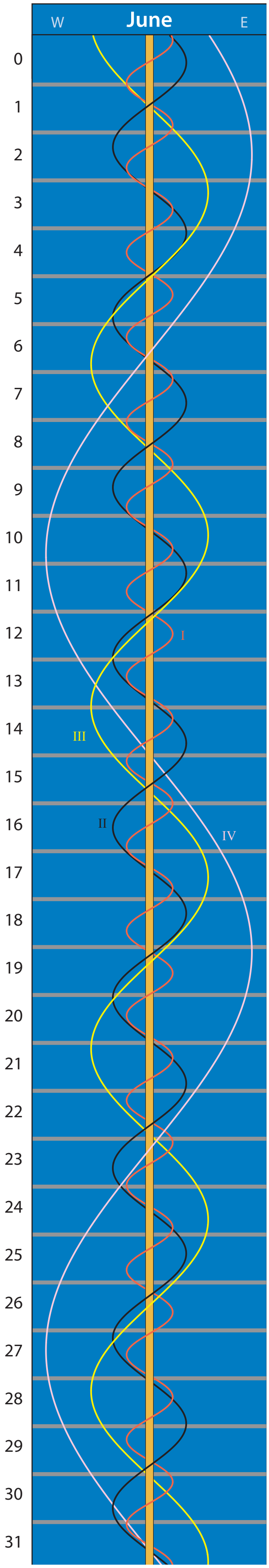
Day	EST	WST	Sat	Event	Vis
4	00:19	22:19(p)	II	Tr I	E
	00:34	22:34(p)	II	Sh E	
	01:19	23:19(p)	I	Ec D	
	03:06	01:06	II	Tr E	
	04:16	02:16	IV	Tr I	
	04:50	02:50	I	Oc R	
	08:17	06:17	IV	Tr E	W
	22:29	20:29	I	Sh I	E
	23:45	21:45	I	Tr I	E
5	00:45	22:45(p)	I	Sh E	
	02:02	00:02	I	Tr E	
	23:17	21:17	I	Oc R	E
7	04:40	02:40	III	Sh I	
	07:51	05:51	III	Sh E	W
9	05:32	03:32	II	Ec D	
	08:44	06:44	I	Ec D	W
10	05:55	03:55	I	Sh I	
	07:08	05:08	I	Tr I	W
	08:11	06:11	I	Sh E	W
	22:00	20:00	III	Ec R	E
	23:38	21:38	III	Oc D	E
11	00:23	22:23(p)	II	Sh I	
	02:46	00:46	II	Tr I	
	02:59	00:59	III	Oc R	
	03:08	01:08	II	Sh E	
	03:12	01:12	I	Ec D	
	05:33	03:33	II	Tr E	
	06:40	04:40	I	Oc R	
12	00:23	22:23(p)	I	Sh I	
	01:36	23:36(p)	I	Tr I	
	02:39	00:39	I	Sh E	
	03:18	01:18	IV	Ec D	
	03:53	01:53	I	Tr E	
	06:54	04:54	IV	Ec R	W
	21:40	19:40	I	Ec D	E
13	00:06	22:06(p)	II	Oc R	
	01:07	23:07(p)	I	Oc R	
	22:20	20:20	I	Tr E	E
14	08:39	06:39	III	Sh I	W
16	08:08	06:08	II	Ec D	W
17	07:48	05:48	I	Sh I	W
	08:58	06:58	I	Tr I	W
	22:46	20:46	III	Ec D	E
18	01:59	23:59(p)	III	Ec R	
	02:57	00:57	II	Sh I	
	03:20	01:20	III	Oc D	
	05:05	03:05	I	Ec D	
	05:11	03:11	II	Tr I	
	05:41	03:41	II	Sh E	
	06:41	04:41	III	Oc R	
	07:58	05:58	II	Tr E	W
	08:29	06:29	I	Oc R	W
19	02:17	00:17	I	Sh I	
	03:25	01:25	I	Tr I	
	04:33	02:33	I	Sh E	
	05:42	03:42	I	Tr E	
	21:26	19:26	II	Ec D	E
	23:33	21:33	I	Ec D	
20	02:33	00:33	II	Oc R	
	02:56	00:56	I	Oc R	
	21:53	19:53	I	Tr I	E
	23:02	21:02	I	Sh E	E



Day	EST	WST	Sat	Event	Vis
21	00:10	22:10(p)	I	Tr E	
	00:57	22:57(p)	IV	Tr E	
	21:10	19:10	II	Tr E	E
	21:23	19:23	I	Oc R	E
25	02:45	00:45	III	Ec D	
	05:30	03:30	II	Sh I	
	05:59	03:59	III	Ec R	
	06:57	04:57	III	Oc D	W
	06:58	04:58	I	Ec D	W
	07:34	05:34	II	Tr I	W
	08:15	06:15	II	Sh E	W
26	04:11	02:11	I	Sh I	
	05:14	03:14	I	Tr I	
	06:27	04:27	I	Sh E	
	07:31	05:31	I	Tr E	W
27	00:02	22:02(p)	II	Ec D	
	01:27	23:27(p)	I	Ec D	
	04:44	02:44	I	Oc R	
	04:59	02:59	II	Oc R	
	22:39	20:39	I	Sh I	E
	23:41	21:41	I	Tr I	
28	00:56	22:56(p)	I	Sh E	
	01:58	23:58(p)	I	Tr E	
	20:38	18:38	III	Tr I	E
	20:45	18:45	II	Tr I	E
	21:17	19:17	IV	Ec D	E
	21:32	19:32	II	Sh E	E
	23:11	21:11	I	Oc R	
	23:32	21:32	II	Tr E	
	23:59	21:59	III	Tr E	
29	01:01	23:01(p)	IV	Ec R	
	06:32	04:32	IV	Oc D	
	20:25	18:25	I	Tr E	E
June					
1	06:43	04:43	III	Ec D	
	08:04	06:04	II	Sh I	W
	08:52	06:52	I	Ec D	W
2	06:05	04:05	I	Sh I	
	07:01	05:01	I	Tr I	W
	08:21	06:21	I	Sh E	W
3	02:39	00:39	II	Ec D	
	03:20	01:20	I	Ec D	
	06:31	04:31	I	Oc R	
	07:21	05:21	II	Oc R	W
4	00:33	22:33(p)	I	Sh I	
	01:28	23:28(p)	I	Tr I	
	02:50	00:50	I	Sh E	
	03:45	01:45	I	Tr E	
	20:34	18:34	III	Sh I	E
	21:20	19:20	II	Sh I	E
	21:49	19:49	I	Ec D	E
	23:05	21:05	II	Tr I	
	23:50	21:50	III	Sh E	
5	00:06	22:06(p)	II	Sh E	
	00:09	22:09(p)	III	Tr I	
	00:57	22:57(p)	I	Oc R	
	01:52	23:52(p)	II	Tr E	
	03:30	01:30	III	Tr E	
	19:55	17:55	I	Tr I	E
	21:18	19:18	I	Sh E	E
	22:12	20:12	I	Tr E	E

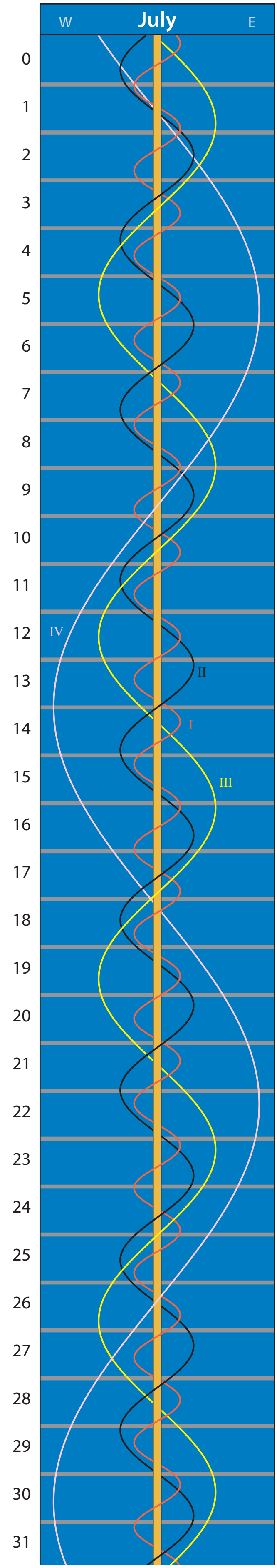
Day	EST	WST	Sat	Event	Vis
6	04:30	02:30	IV	Sh I	
	08:16	06:16	IV	Sh E	W
	20:33	18:33	II	Oc R	E
9	07:59	05:59	I	Sh I	W
	08:48	06:48	I	Tr I	W
10	05:14	03:14	I	Ec D	
	05:15	03:15	II	Ec D	
	08:17	06:17	I	Oc R	W
11	02:28	00:28	I	Sh I	
	03:15	01:15	I	Tr I	
	04:44	02:44	I	Sh E	
	05:32	03:32	I	Tr E	
	23:42	21:42	I	Ec D	
	23:54	21:54	II	Sh I	
12	00:33	22:33(p)	III	Sh I	
	01:23	23:23(p)	II	Tr I	
	02:39	00:39	II	Sh E	
	02:43	00:43	I	Oc R	
	03:35	01:35	III	Tr I	
	03:49	01:49	III	Sh E	
	04:10	02:10	II	Tr E	
	06:57	04:57	III	Tr E	
	20:56	18:56	I	Sh I	E
	21:41	19:41	I	Tr I	E
	23:13	21:13	I	Sh E	
	23:58	21:58	I	Tr E	
13	21:09	19:09	I	Oc R	E
	22:53	20:53	II	Oc R	
14	21:46	19:46	IV	Oc D	
15	01:54	23:54(p)	IV	Oc R	
	20:45	18:45	III	Oc R	E
17	07:07	05:07	I	Ec D	W
	07:52	05:52	II	Ec D	W
18	04:22	02:22	I	Sh I	
	05:00	03:00	I	Tr I	
	06:39	04:39	I	Sh E	
	07:17	05:17	I	Tr E	W
19	01:36	23:36(p)	I	Ec D	
	02:27	00:27	II	Sh I	
	03:39	01:39	II	Tr I	
	04:28	02:28	I	Oc R	
	04:33	02:33	III	Sh I	
	05:13	03:13	II	Sh E	
	06:26	04:26	II	Tr E	
	07:00	05:00	III	Tr I	
	07:50	05:50	III	Sh E	W
	22:50	20:50	I	Sh I	
	23:26	21:26	I	Tr I	
20	01:07	23:07(p)	I	Sh E	
	01:43	23:43(p)	I	Tr E	
	20:04	18:04	I	Ec D	E
	21:11	19:11	II	Ec D	
	22:54	20:54	I	Oc R	
21	01:11	23:11(p)	II	Oc R	
	19:36	17:36	I	Sh E	E
	20:09	18:09	I	Tr E	E
22	19:34	17:34	II	Tr E	E
	22:32	20:32	IV	Sh I	
23	00:06	22:06(p)	III	Oc R	
	02:25	00:25	IV	Sh E	
	03:23	01:23	IV	Tr I	
	07:30	05:30	IV	Tr E	W
24	09:01	07:01	I	Ec D	W

JUPITER MOON EVENTS



Day	EST	WST	Sat	Event	Vis
25	06:16	04:16	I	Sh I	
	06:45	04:45	I	Tr I	
	08:33	06:33	I	Sh E	W
	09:02	07:02	I	Tr E	W
26	03:29	01:29	I	Ec D	
	05:01	03:01	II	Sh I	
	05:54	03:54	II	Tr I	
	06:12	04:12	I	Oc R	
	07:47	05:47	II	Sh E	W
	08:32	06:32	III	Sh I	W
	08:41	06:41	II	Tr E	W
27	00:45	22:45(p)	I	Sh I	
	01:11	23:11(p)	I	Tr I	
	03:02	01:02	I	Sh E	
	03:28	01:28	I	Tr E	
	21:58	19:58	I	Ec D	
	23:48	21:48	II	Ec D	
28	00:38	22:38(p)	I	Oc R	
	03:28	01:28	II	Oc R	
	19:13	17:13	I	Sh I	E
	19:37	17:37	I	Tr I	E
	21:30	19:30	I	Sh E	
	21:54	19:54	I	Tr E	
29	18:18	16:18	II	Sh I	E
	19:01	17:01	II	Tr I	E
	19:04	17:04	I	Oc R	E
	21:05	19:05	II	Sh E	
	21:49	19:49	II	Tr E	
	22:37	20:37	III	Ec D	
30	03:25	01:25	III	Oc R	
July					
1	09:20	07:20	IV	Ec D	W
2	08:11	06:11	I	Sh I	W
	08:29	06:29	I	Tr I	W
3	05:23	03:23	I	Ec D	
	07:35	05:35	II	Sh I	W
	07:56	05:56	I	Oc R	W
	08:08	06:08	II	Tr I	W
4	02:39	00:39	I	Sh I	
	02:55	00:55	I	Tr I	
	04:56	02:56	I	Sh E	
	05:12	03:12	I	Tr E	
	23:52	21:52	I	Ec D	
5	02:22	00:22	I	Oc R	
	02:25	00:25	II	Ec D	
	05:44	03:44	II	Oc R	
	21:08	19:08	I	Sh I	
	21:21	19:21	I	Tr I	
	23:25	21:25	I	Sh E	
	23:38	21:38	I	Tr E	
6	18:20	16:20	I	Ec D	E
	20:48	18:48	I	Oc R	
	20:52	18:52	II	Sh I	
	21:15	19:15	II	Tr I	
	23:39	21:39	II	Sh E	
7	00:02	22:02(p)	II	Tr E	
	02:36	00:36	III	Ec D	
	06:42	04:42	III	Oc R	
	17:53	15:53	I	Sh E	E
	18:04	16:04	I	Tr E	E
8	18:51	16:51	II	Oc R	E

Day	EST	WST	Sat	Event	Vis
9	17:42	15:42	IV	Tr I	E
	20:34	18:34	IV	Sh E	
	21:48	19:48	IV	Tr E	
10	07:17	05:17	I	Ec D	W
	19:51	17:51	III	Sh E	
	20:16	18:16	III	Tr E	
11	04:34	02:34	I	Sh I	
	04:39	02:39	I	Tr I	
	06:51	04:51	I	Sh E	
	06:56	04:56	I	Tr E	
12	01:46	23:46(p)	I	Ec D	
	04:06	02:06	I	Oc R	
	05:02	03:02	II	Ec D	
	07:59	05:59	II	Oc R	W
	23:03	21:03	I	Sh I	
	23:05	21:05	I	Tr I	
13	01:19	23:19(p)	I	Sh E	
	01:22	23:22(p)	I	Tr E	
	20:14	18:14	I	Ec D	
	22:31	20:31	I	Oc R	
	23:26	21:26	II	Sh I	
	23:28	21:28	II	Tr I	
14	02:13	00:13	II	Sh E	
	02:16	00:16	II	Tr E	
	06:36	04:36	III	Ec D	
	17:31	15:31	I	Tr I	E
	17:31	15:31	I	Sh I	E
	19:48	17:48	I	Tr E	
	19:48	17:48	I	Sh E	
15	18:17	16:17	II	Oc D	E
	21:10	19:10	II	Ec R	
17	09:07	07:07	I	Oc D	W
	20:11	18:11	III	Tr I	
	20:31	18:31	III	Sh I	
	23:32	21:32	III	Tr E	
	23:51	21:51	III	Sh E	
18	02:32	00:32	IV	Oc D	
	06:23	04:23	I	Tr I	
	06:29	04:29	I	Sh I	
	07:27	05:27	IV	Ec R	W
	08:40	06:40	I	Tr E	W
	08:46	06:46	I	Sh E	W
19	03:33	01:33	I	Oc D	
	05:56	03:56	I	Ec R	
	07:25	05:25	II	Oc D	W
20	00:49	22:49(p)	I	Tr I	
	00:57	22:57(p)	I	Sh I	
	03:06	01:06	I	Tr E	
	03:14	01:14	I	Sh E	
	21:59	19:59	I	Oc D	
21	00:24	22:24(p)	I	Ec R	
	01:42	23:42(p)	II	Tr I	
	02:01	00:01	II	Sh I	
	04:29	02:29	II	Tr E	
	04:48	02:48	II	Sh E	
	19:15	17:15	I	Tr I	E
	19:26	17:26	I	Sh I	E
	21:32	19:32	I	Tr E	
	21:43	19:43	I	Sh E	
22	18:53	16:53	I	Ec R	E
	20:32	18:32	II	Oc D	
	23:47	21:47	II	Ec R	

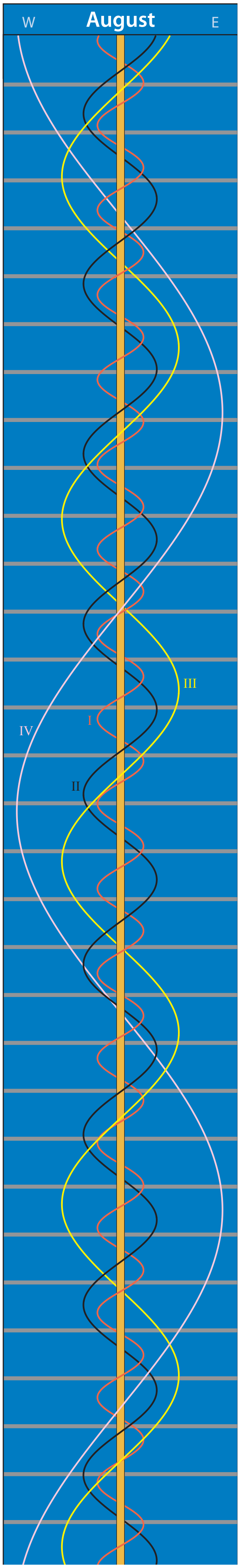


I is Io, II is Europa, III is Ganymede, IV is Callisto

Day	EST	WST	Sat	Event	Vis
24	17:36	15:36	II	Tr E	E
	18:06	16:06	II	Sh E	E
	23:28	21:28	III	Tr I	
25	00:30	22:30(p)	III	Sh I	
	02:48	00:48	III	Tr E	
	03:52	01:52	III	Sh E	
	08:07	06:07	I	Tr I	W
	08:23	06:23	I	Sh I	W
26	05:17	03:17	I	Oc D	
	07:50	05:50	I	Ec R	W
	07:54	05:54	IV	Tr I	W
27	02:34	00:34	I	Tr I	
	02:52	00:52	I	Sh I	
	04:50	02:50	I	Tr E	
	05:09	03:09	I	Sh E	
	23:43	21:43	I	Oc D	
28	02:19	00:19	I	Ec R	
	03:56	01:56	II	Tr I	
	04:36	02:36	II	Sh I	
	06:43	04:43	II	Tr E	W
	07:23	05:23	II	Sh E	W
	17:57	15:57	III	Ec R	E
	21:00	19:00	I	Tr I	
	21:21	19:21	I	Sh I	
	23:16	21:16	I	Tr E	
	23:38	21:38	I	Sh E	
29	18:09	16:09	I	Oc D	E
	20:47	18:47	I	Ec R	
	22:48	20:48	II	Oc D	
30	02:25	00:25	II	Ec R	
	17:43	15:43	I	Tr E	E
	18:07	16:07	I	Sh E	E
31	17:53	15:53	II	Sh I	E
	19:51	17:51	II	Tr E	
	20:41	18:41	II	Sh E	

August

Day	EST	WST	Sat	Event	Vis
1	02:46	00:46	III	Tr I	
	04:30	02:30	III	Sh I	
	06:06	04:06	III	Tr E	W
	07:52	05:52	III	Sh E	W
2	07:01	05:01	I	Oc D	W
3	04:18	02:18	I	Tr I	
	04:47	02:47	I	Sh I	
	06:35	04:35	I	Tr E	W
	07:04	05:04	I	Sh E	W
	20:56	18:56	IV	Oc R	
	21:26	19:26	IV	Ec D	
4	01:27	23:27(p)	I	Oc D	
	01:37	23:37(p)	IV	Ec R	
	04:13	02:13	I	Ec R	
	06:11	04:11	II	Tr I	W
	07:11	05:11	II	Sh I	W
	21:57	19:57	III	Ec R	
	22:45	20:45	I	Tr I	
	23:16	21:16	I	Sh I	
5	01:01	23:01(p)	I	Tr E	
	01:33	23:33(p)	I	Sh E	
	19:54	17:54	I	Oc D	
	22:42	20:42	I	Ec R	

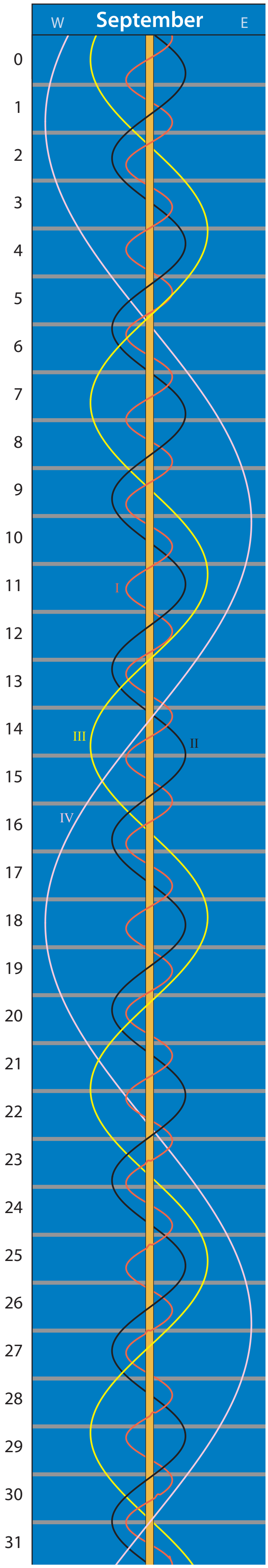


Day	EST	WST	Sat	Event	Vis
6	01:06	23:06(p)	II	Oc D	
	05:02	03:02	II	Ec R	
	17:45	15:45	I	Sh I	E
	19:28	17:28	I	Tr E	E
	20:02	18:02	I	Sh E	
7	19:19	17:19	II	Tr I	E
	20:28	18:28	II	Sh I	
	22:06	20:06	II	Tr E	
	23:16	21:16	II	Sh E	
8	06:07	04:07	III	Tr I	W
9	18:21	16:21	II	Ec R	E
10	06:04	04:04	I	Tr I	W
	06:42	04:42	I	Sh I	W
11	03:13	01:13	I	Oc D	
	06:08	04:08	I	Ec R	W
	19:53	17:53	III	Oc D	
	22:24	20:24	IV	Tr I	
12	00:30	22:30(p)	I	Tr I	
	01:11	23:11(p)	I	Sh I	
	01:57	23:57(p)	III	Ec R	
	02:27	00:27	IV	Tr E	
	02:47	00:47	I	Tr E	
	03:28	01:28	I	Sh E	
	04:44	02:44	IV	Sh I	
	21:39	19:39	I	Oc D	
13	00:37	22:37(p)	I	Ec R	
	03:24	01:24	II	Oc D	
	18:57	16:57	I	Tr I	E
	19:40	17:40	I	Sh I	E
	21:14	19:14	I	Tr E	
	21:57	19:57	I	Sh E	
14	19:05	17:05	I	Ec R	E
	21:36	19:36	II	Tr I	
	23:03	21:03	II	Sh I	
15	00:24	22:24(p)	II	Tr E	
	01:52	23:52(p)	II	Sh E	
16	20:58	18:58	II	Ec R	
18	04:59	02:59	I	Oc D	W
	23:18	21:18	III	Oc D	
19	02:17	00:17	I	Tr I	
	03:06	01:06	I	Sh I	
	04:34	02:34	I	Tr E	
	05:23	03:23	I	Sh E	W
	05:57	03:57	III	Ec R	W
	23:25	21:25	I	Oc D	
20	02:32	00:32	I	Ec R	
	05:45	03:45	II	Oc D	W
	19:47	17:47	IV	Ec R	E
	20:44	18:44	I	Tr I	
	21:35	19:35	I	Sh I	
	23:01	21:01	I	Tr E	
	23:52	21:52	I	Sh E	
21	17:52	15:52	I	Oc D	E
	21:00	19:00	I	Ec R	
	23:56	21:56	II	Tr I	
22	01:39	23:39(p)	II	Sh I	
	02:43	00:43	II	Tr E	
	04:28	02:28	II	Sh E	
	18:21	16:21	I	Sh E	E
	19:56	17:56	III	Sh E	
23	18:56	16:56	II	Oc D	E
	23:36	21:36	II	Ec R	

Day	EST	WST	Sat	Event	Vis
25	17:46	15:46	II	Sh E	E
26	02:47	00:47	III	Oc D	
	04:05	02:05	I	Tr I	
	05:01	03:01	I	Sh I	W
	06:07	04:07	III	Oc R	W
	06:21	04:21	I	Tr E	W
27	01:13	23:13(p)	I	Oc D	
	04:27	02:27	I	Ec R	W
	22:32	20:32	I	Tr I	
	23:30	21:30	I	Sh I	
28	00:48	22:48(p)	I	Tr E	
	01:47	23:47(p)	I	Sh E	
	19:40	17:40	I	Oc D	E
	22:50	20:50	IV	Sh I	
	22:55	20:55	I	Ec R	
29	02:17	00:17	II	Tr I	
	03:07	01:07	IV	Sh E	
	04:15	02:15	II	Sh I	W
	05:04	03:04	II	Tr E	W
	17:59	15:59	I	Sh I	E
	19:16	17:16	I	Tr E	E
	19:50	17:50	III	Tr E	E
	20:16	18:16	I	Sh E	
	20:32	18:32	III	Sh I	
	23:57	21:57	III	Sh E	
30	21:19	19:19	II	Oc D	
31	02:13	00:13	II	Ec R	

September

Day	EST	WST	Sat	Event	Vis
1	18:16	16:16	II	Tr E	E
	20:22	18:22	II	Sh E	
2	05:53	03:53	I	Tr I	W
3	03:01	01:01	I	Oc D	
4	00:21	22:21(p)	I	Tr I	
	01:26	23:26(p)	I	Sh I	
	02:37	00:37	I	Tr E	
	03:43	01:43	I	Sh E	W
	21:29	19:29	I	Oc D	
5	00:51	22:51(p)	I	Ec R	
	04:41	02:41	II	Tr I	W
	18:48	16:48	I	Tr I	E
	19:54	17:54	I	Sh I	E
	20:06	18:06	III	Tr I	
	21:05	19:05	I	Tr E	
	22:11	20:11	I	Sh E	
	23:20	21:20	IV	Oc D	
	23:26	21:26	III	Tr E	
6	00:32	22:32(p)	III	Sh I	
	03:25	01:25	IV	Oc R	
	03:58	01:58	III	Sh E	W
	19:19	17:19	I	Ec R	E
	23:45	21:45	II	Oc D	
7	04:50	02:50	II	Ec R	W
8	17:53	15:53	II	Tr I	E
	20:09	18:09	II	Sh I	
	20:41	18:41	II	Tr E	
	22:59	20:59	II	Sh E	
9	18:01	16:01	III	Ec R	E
10	04:51	02:51	I	Oc D	W
	18:08	16:08	II	Ec R	E

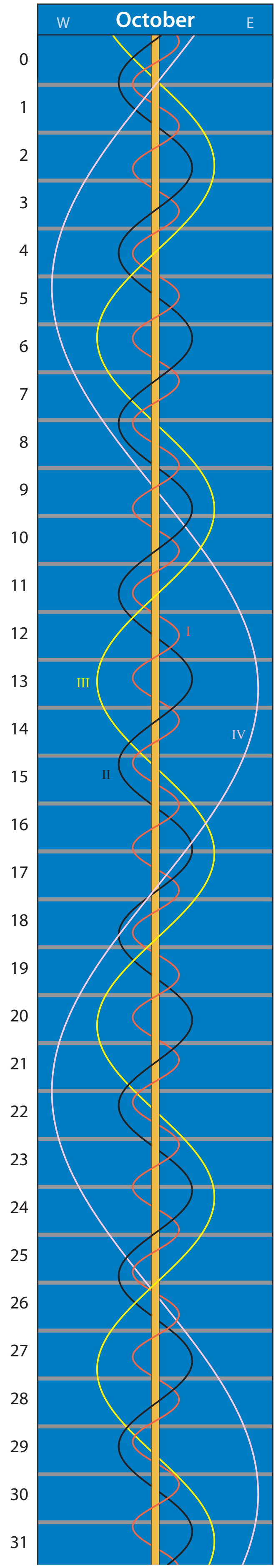


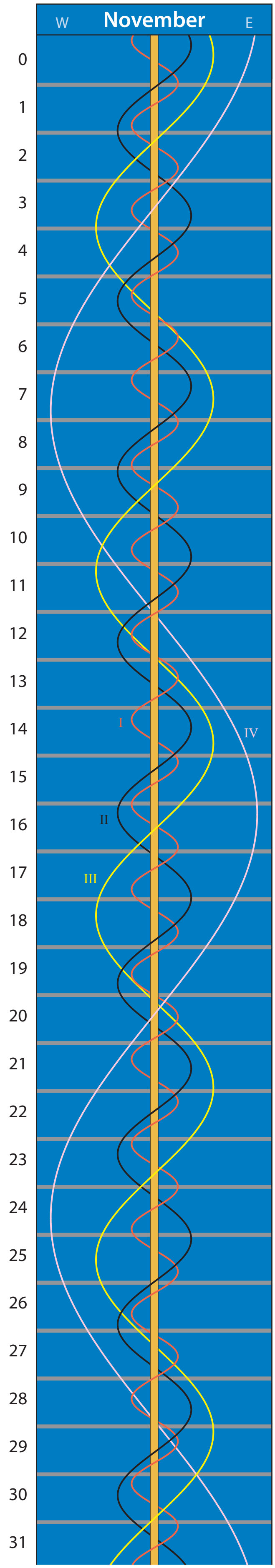
Day	EST	WST	Sat	Event	Vis
11	02:11	00:11	I	Tr I	
	03:21	01:21	I	Sh I	W
	04:28	02:28	I	Tr E	W
	23:19	21:19	I	Oc D	
12	02:46	00:46	I	Ec R	
	20:39	18:39	I	Tr I	
	21:50	19:50	I	Sh I	
	22:55	20:55	I	Tr E	
	23:46	21:46	III	Tr I	
13	00:07	22:07(p)	I	Sh E	
	03:06	01:06	III	Tr E	W
	04:32	02:32	III	Sh I	W
	21:15	19:15	I	Ec R	
14	02:13	00:13	II	Oc D	
	18:36	16:36	I	Sh E	E
	21:20	19:20	IV	Sh E	
15	20:21	18:21	II	Tr I	
	22:45	20:45	II	Sh I	
	23:09	21:09	II	Tr E	
16	01:35	23:35(p)	II	Sh E	
	18:35	16:35	III	Ec D	E
	22:02	20:02	III	Ec R	
17	20:46	18:46	II	Ec R	
18	04:02	02:02	I	Tr I	W
19	01:10	23:10(p)	I	Oc D	
	04:41	02:41	I	Ec R	W
	22:30	20:30	I	Tr I	
	23:45	21:45	I	Sh I	
20	00:47	22:47(p)	I	Tr E	
	02:02	00:02	I	Sh E	
	03:31	01:31	III	Tr I	W
	19:38	17:38	I	Oc D	E
	23:10	21:10	I	Ec R	
21	04:43	02:43	II	Oc D	W
	18:14	16:14	I	Sh I	E
	19:15	17:15	I	Tr E	E
	20:31	18:31	I	Sh E	
22	20:03	18:03	IV	Oc R	E
	22:50	20:50	II	Tr I	
23	01:22	23:22(p)	II	Sh I	
	01:39	23:39(p)	II	Tr E	
	03:44	01:44	IV	Ec D	W
	04:12	02:12	II	Sh E	W
	20:52	18:52	III	Oc R	
	22:36	20:36	III	Ec D	
24	02:03	00:03	III	Ec R	
	17:58	15:58	II	Oc D	E
	23:22	21:22	II	Ec R	
26	03:02	01:02	I	Oc D	W
27	00:23	22:23(p)	I	Tr I	
	01:40	23:40(p)	I	Sh I	
	02:40	00:40	I	Tr E	W
	03:57	01:57	I	Sh E	W
	21:31	19:31	I	Oc D	
28	01:05	23:05(p)	I	Ec R	
	18:51	16:51	I	Tr I	E
	20:09	18:09	I	Sh I	E
	21:08	19:08	I	Tr E	
	22:26	20:26	I	Sh E	
29	19:34	17:34	I	Ec R	E

Day	EST	WST	Sat	Event	Vis
30	01:23	23:23(p)	II	Tr I	
	03:58	01:58	II	Sh I	W
	04:11	02:11	II	Tr E	W
	21:22	19:22	III	Oc D	
	22:49	20:49	IV	Tr I	

October

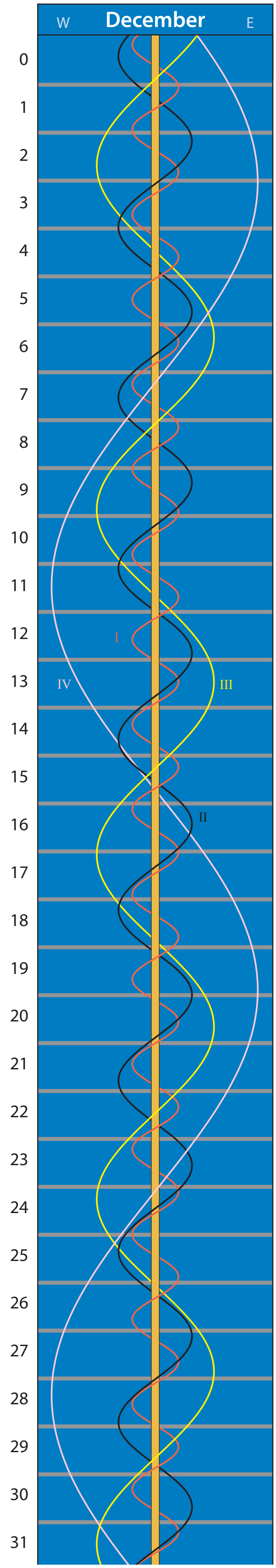
Day	EST	WST	Sat	Event	Vis
1	00:44	22:44(p)	III	Oc R	
	02:36	00:36	III	Ec D	W
	02:56	00:56	IV	Tr E	W
	20:32	18:32	II	Oc D	
2	01:59	23:59(p)	II	Ec R	W
3	20:08	18:08	II	Sh E	E
4	02:17	00:17	I	Tr I	W
	03:36	01:36	I	Sh I	W
	20:03	18:03	III	Sh E	E
	23:25	21:25	I	Oc D	
5	03:01	01:01	I	Ec R	W
	20:46	18:46	I	Tr I	
	22:05	20:05	I	Sh I	
	23:02	21:02	I	Tr E	
6	00:22	22:22(p)	I	Sh E	
	21:30	19:30	I	Ec R	
7	18:50	16:50	I	Sh E	E
8	01:19	23:19(p)	III	Oc D	
	23:07	21:07	II	Oc D	
9	21:51	19:51	IV	Ec D	
10	02:21	00:21	IV	Ec R	W
	19:54	17:54	II	Sh I	E
	20:04	18:04	II	Tr E	E
	22:46	20:46	II	Sh E	
11	18:38	16:38	III	Tr E	E
	20:36	18:36	III	Sh I	
12	00:05	22:05(p)	III	Sh E	
	01:20	23:20(p)	I	Oc D	W
	22:41	20:41	I	Tr I	
	23:59	21:59	I	Sh I	
13	00:57	22:57(p)	I	Tr E	
	02:17	00:17	I	Sh E	W
	19:49	17:49	I	Oc D	E
	23:25	21:25	I	Ec R	
14	18:29	16:29	I	Sh I	E
	19:26	17:26	I	Tr E	E
	20:46	18:46	I	Sh E	
16	01:44	23:44(p)	II	Oc D	W
17	19:53	17:53	II	Tr I	E
	21:03	19:03	IV	Tr E	
	22:31	20:31	II	Sh I	
	22:43	20:43	II	Tr E	
18	01:23	23:23(p)	II	Sh E	W
	19:19	17:19	III	Tr I	E
	22:42	20:42	III	Tr E	
19	00:36	22:36(p)	III	Sh I	
	20:31	18:31	II	Ec R	E
20	00:37	22:37(p)	I	Tr I	
	01:55	23:55(p)	I	Sh I	W
	02:54	00:54	I	Tr E	W
	21:45	19:45	I	Oc D	





Day	EST	WST	Sat	Event	Vis
21	01:21	23:21(p)	I	Ec R	W
	19:06	17:06	I	Tr I	E
	20:24	18:24	I	Sh I	E
	21:23	19:23	I	Tr E	
	22:41	20:41	I	Sh E	
22	19:50	17:50	I	Ec R	E
24	22:33	20:33	II	Tr I	
25	01:09	23:09(p)	II	Sh I	W
	01:23	23:23(p)	II	Tr E	W
	23:26	21:26	III	Tr I	
26	20:32	18:32	IV	Ec R	E
	23:07	21:07	II	Ec R	
27	02:34	00:34	I	Tr I	W
	23:42	21:42	I	Oc D	
28	21:03	19:03	I	Tr I	
	22:19	20:19	I	Sh I	
	23:20	21:20	I	Tr E	
29	00:36	22:36(p)	I	Sh E	W
	18:39	16:39	III	Ec D	E
	21:45	19:45	I	Ec R	
	22:09	20:09	III	Ec R	
30	19:05	17:05	I	Sh E	E
November					
1	01:15	23:15(p)	II	Tr I	W
2	20:25	18:25	II	Oc D	E
3	01:44	23:44(p)	II	Ec R	W
	23:22	21:22	IV	Sh I	
4	01:40	23:40(p)	I	Oc D	W
	19:58	17:58	II	Sh E	E
	23:01	21:01	I	Tr I	
5	00:15	22:15(p)	I	Sh I	W
	01:18	23:18(p)	I	Tr E	W
	20:10	18:10	I	Oc D	E
	21:11	19:11	III	Oc R	
	22:40	20:40	III	Ec D	
	23:41	21:41	I	Ec R	W
6	18:43	16:43	I	Sh I	E
	19:48	17:48	I	Tr E	E
	21:00	19:00	I	Sh E	
9	23:08	21:08	II	Oc D	
11	19:43	17:43	II	Sh I	E
	20:12	18:12	II	Tr E	E
	22:36	20:36	II	Sh E	
	23:13	21:13	IV	Oc D	
12	01:00	23:00(p)	I	Tr I	W
	22:02	20:02	III	Oc D	
	22:09	20:09	I	Oc D	
13	01:27	23:27(p)	III	Oc R	W
	01:37	23:37(p)	I	Ec R	W
	19:30	17:30	I	Tr I	E
	20:38	18:38	I	Sh I	E
	21:46	19:46	I	Tr E	
	22:56	20:56	I	Sh E	
14	20:05	18:05	I	Ec R	E
16	20:11	18:11	III	Sh E	E
18	20:07	18:07	II	Tr I	E
	22:21	20:21	II	Sh I	
	22:58	20:58	II	Tr E	W
19	01:14	23:14(p)	II	Sh E	W

Day	EST	WST	Sat	Event	Vis
20	00:09	22:09(p)	I	Oc D	W
	20:14	18:14	II	Ec R	E
	21:29	19:29	I	Tr I	
	22:10	20:10	IV	Sh E	
	22:34	20:34	I	Sh I	
	23:46	21:46	I	Tr E	W
21	00:51	22:51(p)	I	Sh E	W
	22:01	20:01	I	Ec R	
22	19:19	17:19	I	Sh E	E
23	19:53	17:53	III	Tr E	E
	20:39	18:39	III	Sh I	E
24	00:12	22:12(p)	III	Sh E	W
25	22:54	20:54	II	Tr I	W
27	22:49	20:49	II	Ec R	W
	23:29	21:29	I	Tr I	W
28	00:29	22:29(p)	I	Sh I	W
	19:03	17:03	IV	Oc D	E
	20:39	18:39	I	Oc D	E
	23:30	21:30	IV	Oc R	W
	23:57	21:57	I	Ec R	W
29	18:57	16:57	I	Sh I	E
	20:16	18:16	I	Tr E	E
	21:14	19:14	I	Sh E	E
30	20:48	18:48	III	Tr I	E
December					
1	00:16	22:16(p)	III	Tr E	W
4	20:46	18:46	II	Oc D	E
5	22:40	20:40	I	Oc D	W
6	19:50	17:50	II	Sh E	E
	20:00	18:00	I	Tr I	E
	20:52	18:52	I	Sh I	E
	22:16	20:16	I	Tr E	W
	23:09	21:09	I	Sh E	W
7	20:21	18:21	I	Ec R	E
11	22:17	20:17	III	Ec R	W
	23:34	21:34	II	Oc D	W
13	19:34	17:34	II	Sh I	E
	20:52	18:52	II	Tr E	E
	22:01	20:01	I	Tr I	W
	22:28	20:28	II	Sh E	W
	22:47	20:47	I	Sh I	W
14	19:12	17:12	I	Oc D	E
	22:16	20:16	I	Ec R	W
15	19:33	17:33	I	Sh E	E
	19:54	17:54	IV	Oc R	E
	22:23	20:23	IV	Ec D	W
18	19:54	17:54	III	Oc D	E
20	20:50	18:50	II	Tr I	E
	22:12	20:12	II	Sh I	W
22	19:53	17:53	II	Ec R	E
	20:49	18:49	I	Tr E	E
29	20:15	18:15	III	Sh E	E
	20:33	18:33	I	Tr I	E
	22:28	20:28	II	Ec R	W
	22:50	20:50	I	Tr E	W
30	20:36	18:36	I	Ec R	E



SATELLITES OF SATURN

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 11 July 11 pm EST (see page 61).

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 **Dione** for the date above.

1. Convert to UT as a fractional day (table 3) to get 11.542 UT.
2. Subtract the date of the greatest elongation east for Dione for July, i.e., 11.542 – 3.413 = 8.129
3. Express this as the number of orbits by dividing by the period i.e., 8.129 / 2.737 = 2.970
4. Discard any complete orbits (2 in this case) leaving 0.970
5. Multiply by the period, 0.970 × 2.737 = 2.655 days or about 2 days and 16 hours after elongation east.
6. Looking at the orbital path for Dione (see Apparent Orbits diagram, below), the satellite is almost at its greatest elongation east.

Table 1: **Saturn Satellites — Time of Greatest Elongation East** (dd.ddd UT)

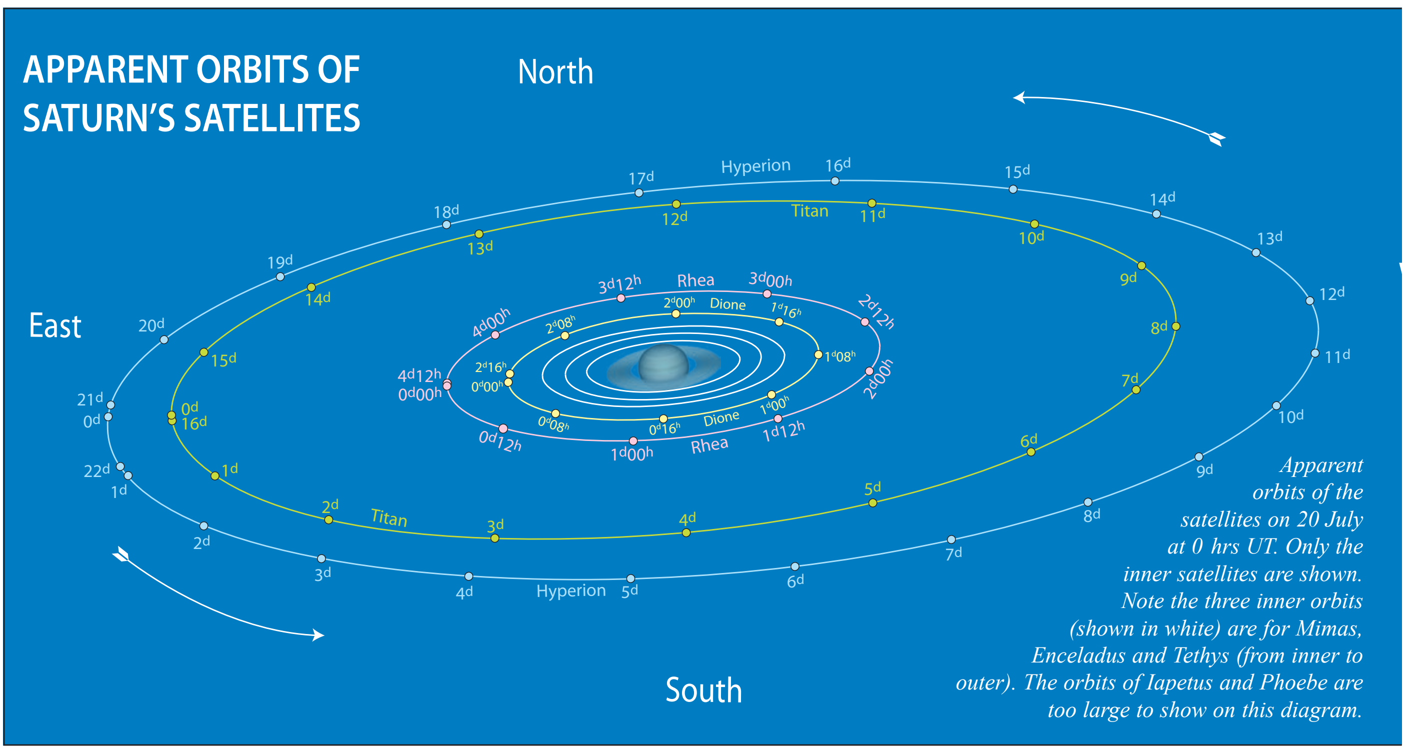
Moon	Mimas	Enceladus	Tethys	Dione	Rhea
Magnitude [1]	12.8	11.8	10.2	10.4	9.6
Max Elong. [1]	0' 30"	0' 38"	0' 48"	1' 01"	1' 25"
Period (days) [2]	0.942	1.370	1.888	2.737	4.518
Month	Elongation East (d.ddd)				
January	1.625	1.471	2.700	1.983	3.908
February	1.738	2.000	1.921	1.117	4.583
March	1.017	1.788	1.254	2.246	2.721
April	1.121	2.308	2.358	1.371	3.375
May	1.279	1.083	2.567	1.483	5.008
June	1.375	1.596	1.767	3.321	1.108
July	1.525	1.733	1.963	3.413	2.708
August	1.617	2.238	1.154	2.500	3.300
September	1.713	1.375	2.238	1.596	3.900
October	1.871	1.521	2.442	1.696	1.000
November	1.033	2.042	1.654	3.550	1.638
December	1.200	2.200	1.871	3.679	3.292

Notes 1. When at opposition 2. Mean Synodic Period

Mimas, Enceladus and Tethys

The procedure is similar to Rhea and Dione above 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, 11 July 11.542 UT; 5.074 orbits have elapsed since the first greatest elongation east for July on 1.963 UT. Discarding the completed orbits leaves 0.074 of an orbit. This is due east of Saturn just after max elongation.



Apparent orbits of the satellites on 20 July at 0 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 on this diagram.

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 11 July 11 pm EST (11.542 UT), Titan is about 7.3 days past its most recent greatest elongation east (July 4.263 UT), which puts it almost due west of Saturn. The diagrams opposite and on page 61 show this very well.

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	10.542	14.075
	26.575	
February	11.604	4.504
	27.625	25.938
March	14.638	18.258
	30.633	
April	15.617	8.550
		29.825
May	1.579	20.988
	17.525	
June	2.454	11.113
	18.367	
July	4.263	2.229
	20.154	23.279
August	5.046	13.363
	20.942	
September	5.854	3.479
	21.779	24.600
October	7.729	15.825
	23.696	
November	8.679	6.092
	24.683	27.392
December	10.696	18.788
	26.721	

Notes 1. When at opposition
2. Mean Synodic Period

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 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	12.475
Feb	1.092	Feb	20.704	Mar	12.958	Apr	2.475
Apr	21.975	May	11.050	May	31.817	Jun	20.783
Jul	9.654	Jul	28.542	Aug	17.692	Sep	7.092
Sep	25.846	Oct	15.346	Nov	4.842	Nov	25.908
Dec	15.208						

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 11 July 11 pm EST (11.542 UT), the most recent event was an eastern elongation on July 9.654 UT. Iapetus is 1.9 days past this time, heading towards an inferior conjunction, so it's in the south east quadrant.

SATURN'S RINGS

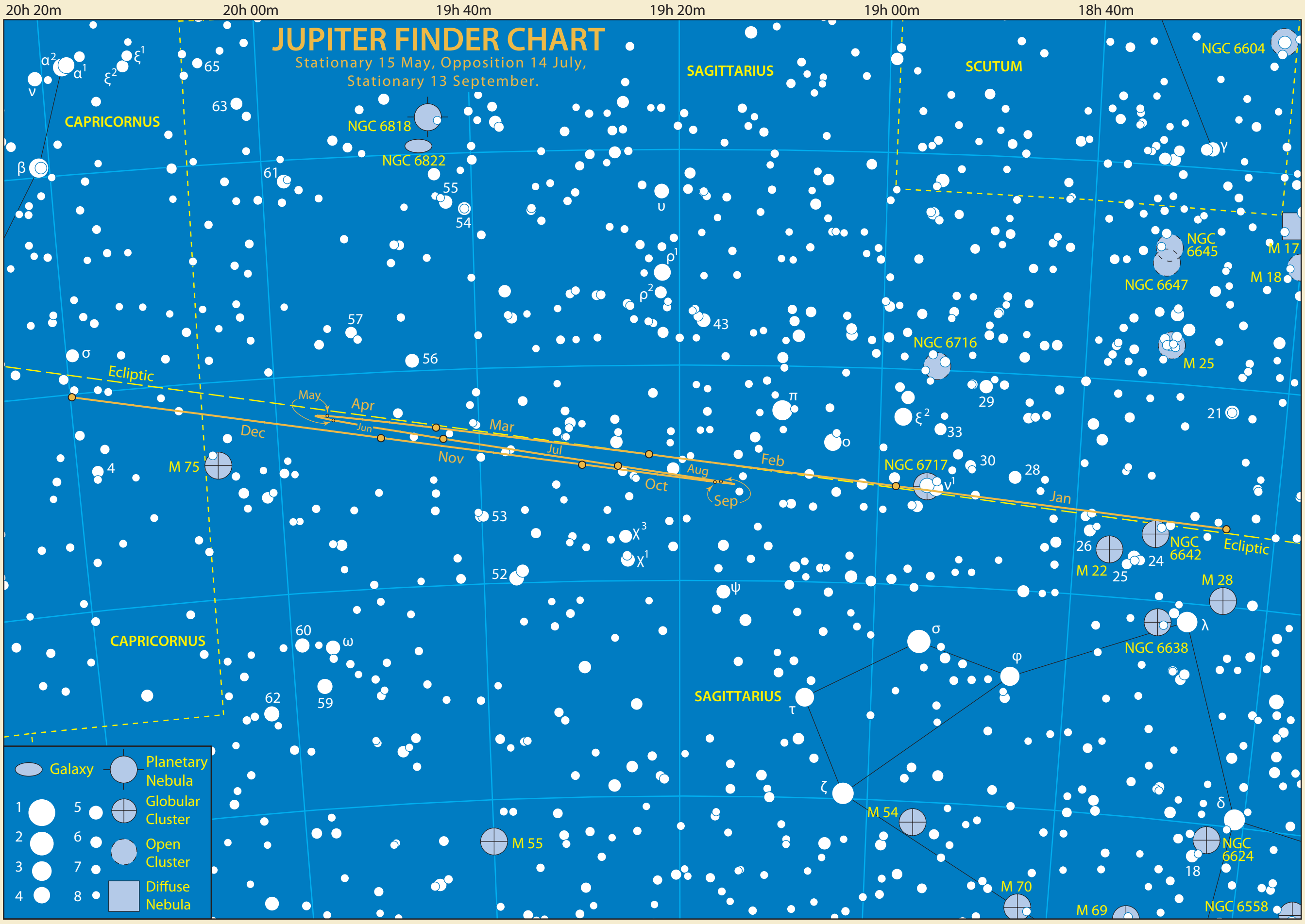
Date	Major "	Minor "	U °	B °
Jan 4	34.28	13.66	164.48	23.48
Jan 12	34.24	13.51	165.47	23.23
Jan 20	34.26	13.37	166.46	22.98
Jan 28	34.33	13.26	167.44	22.71
Feb 5	34.45	13.16	168.39	22.45
Feb 13	34.62	13.08	169.32	22.19
Feb 21	34.84	13.02	170.20	21.94
Feb 29	35.11	12.98	171.04	21.70
Mar 8	35.42	12.96	171.81	21.47
Mar 16	35.78	12.97	172.52	21.26
Mar 24	36.18	13.00	173.15	21.06
Apr 1	36.61	13.06	173.70	20.90
Apr 9	37.07	13.14	174.16	20.76
Apr 17	37.56	13.25	174.52	20.65
Apr 25	38.07	13.38	174.79	20.57
May 3	38.58	13.53	174.95	20.53
May 11	39.10	13.71	175.00	20.53
May 19	39.60	13.90	174.96	20.55
May 27	40.09	14.12	174.81	20.62
Jun 4	40.54	14.34	174.56	20.71
Jun 12	40.94	14.57	174.22	20.84
Jun 20	41.29	14.79	173.08	20.99
Jun 28	41.58	15.01	173.32	21.16
Jul 6	41.78	15.21	172.77	21.35
Jul 14	41.90	15.39	172.19	21.55
Jul 22	41.94	15.54	171.60	21.75
Jul 30	41.88	15.65	171.00	21.94
Aug 7	41.74	15.72	170.42	22.13
Aug 15	41.52	15.75	169.88	22.30
Aug 23	41.22	15.74	169.40	22.45
Aug 31	40.86	15.69	168.99	22.58
Sep 8	40.44	15.60	168.67	22.68
Sep 16	39.98	15.47	168.44	22.76
Sep 24	39.49	15.30	168.32	22.80
Oct 2	38.98	15.11	168.30	22.81
Oct 10	38.47	14.90	168.40	22.79
Oct 18	37.95	14.67	168.60	22.74
Oct 26	37.46	14.43	168.91	22.66
Nov 3	36.98	14.17	169.32	22.54
Nov 11	36.53	13.92	169.83	22.40
Nov 19	36.11	13.66	170.42	22.23
Nov 27	35.73	13.40	171.10	22.03
Dec 5	35.40	13.15	171.84	21.80
Dec 13	35.11	12.90	172.64	21.56
Dec 21	34.86	12.66	173.50	21.29
Dec 29	34.67	12.43	174.39	21.00

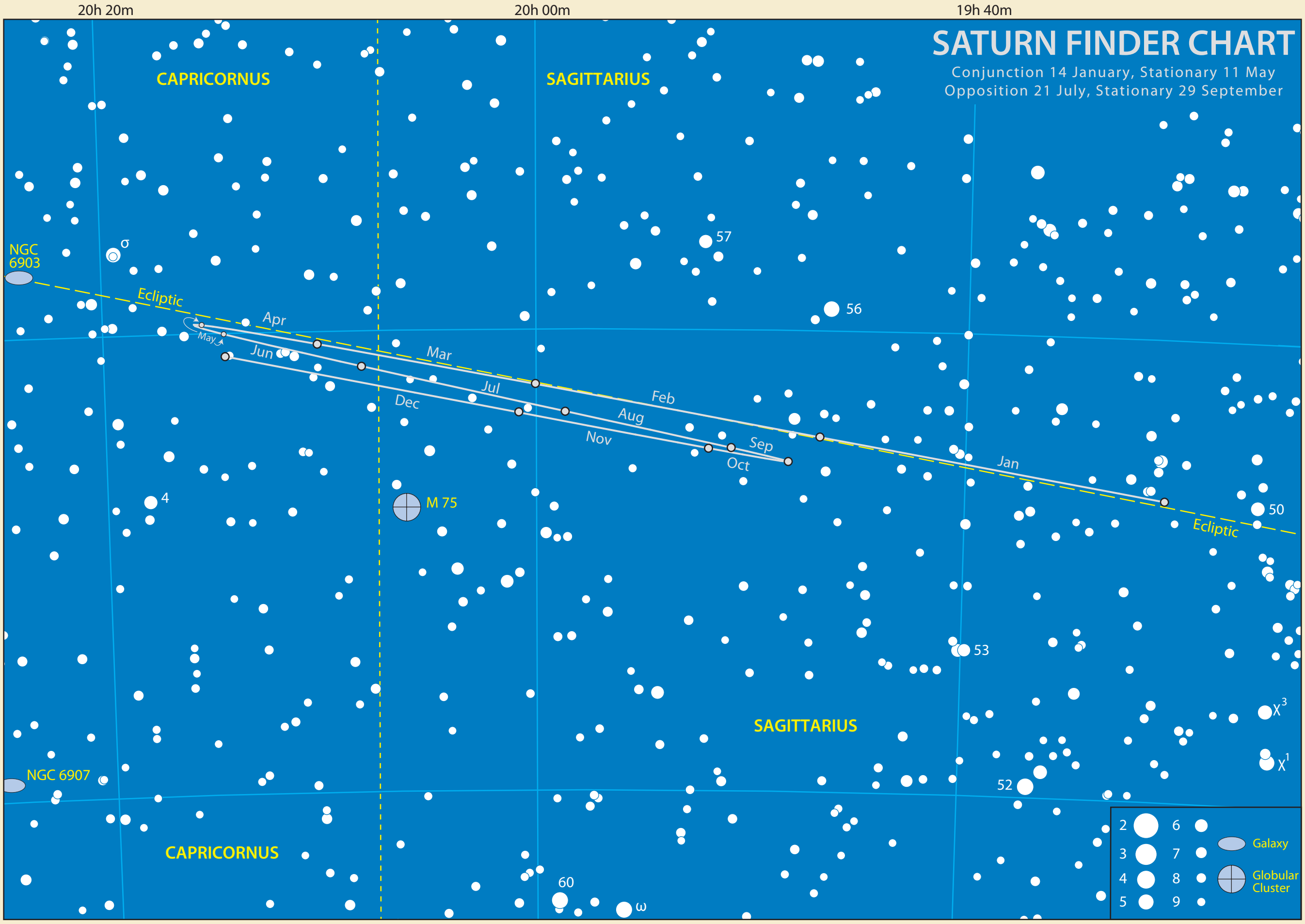
The Appearance of the Planets diagrams in Part I show how open the rings are for 2020. The plane of the rings is tilted, with respect to the plane of the ecliptic, by 28°. Saturn's year is 29.5 Earth years. During this period the Earth can be up to 28° above or below the plane of the rings. Every seven 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 2020 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

U and B are the geocentric longitude and the tilt of the rings respectively.


JUPITER FINDER CHART
Stationary 15 May, Opposition 14 July, Stationary 13 September.
20h 20m
20h 00m
19h 40m
19h 20m
19h 00m
18h 40m
–15°
–20°
–25°
–30°
CAPRICORNUS
SAGITTARIUS
SCUTUM
Ecliptic
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
NGC 6818
NGC 6822
NGC 6604
NGC 6645
NGC 6647
NGC 6716
NGC 6717
NGC 6642
NGC 6638
NGC 6624
NGC 6558
M 17
M 18
M 25
M 22
M 28
M 75
M 55
M 54
M 70
M 69
Galaxy
Planetary Nebula
Globular Cluster
Open Cluster
Diffuse Nebula


SATURN FINDER CHART
Conjunction 14 January, Stationary 11 May
Opposition 21 July, Stationary 29 September
20h 20m
20h 00m
19h 40m
–20°
–25°
CAPRICORNUS
SAGITTARIUS
Ecliptic
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
NGC 6903
NGC 6907
M 75
Galaxy
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

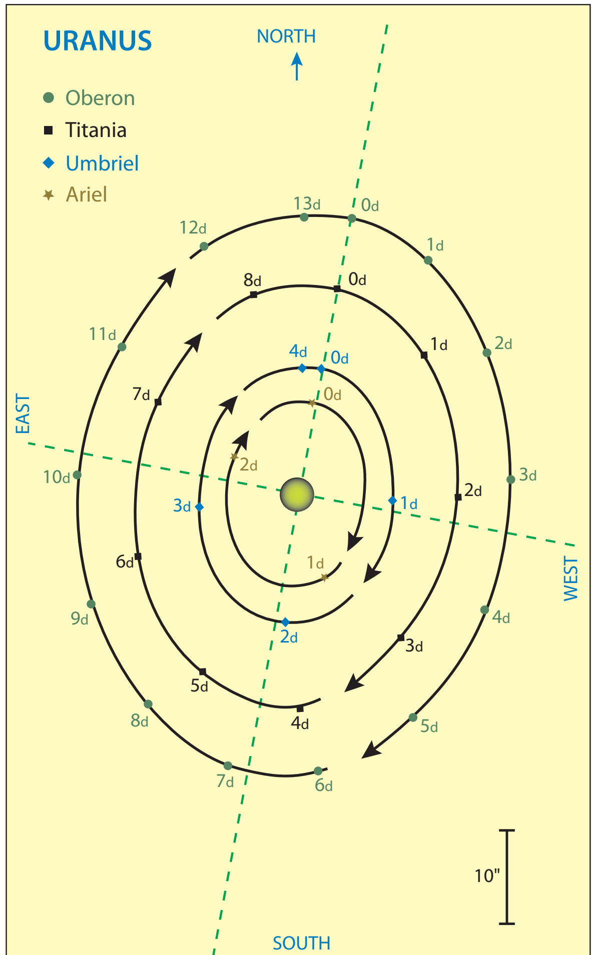
Table 2 presents the times of the first greatest elongation to the *north* for each month for **Ariel**, **Umbriel**, **Titania and Oberon**. This location is the day 0 (zero) point on the Apparent Orbits diagram. As with Saturn's satellites, the procedure is to work out how many orbits have elapsed 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.

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

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 – 4.550 = 21.158 days
3. Divide by the period to get the number of orbits, i.e. 21.158 / 4.144 = 5.106 orbits.
4. Discarding whole orbits leaves 0.106 (about one tenth of an orbit)
5. Multiply by the period, 0.106 × 4.144 = 0.438 days (10.5 hours)
6. Looking at its orbital path (see Apparent Orbits diagram), the satellite is just under half way to the 1-day mark, towards the north-west.

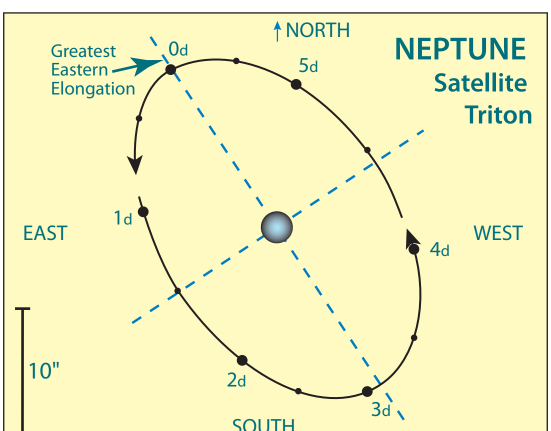


Apparent orbits of Uranus's satellites I–IV as at the date of opposition, 1 November.

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. 1.743 orbits have elapsed since its greatest elongation east on Sep 15.500 UT. Discarding the one orbit leaves 0.743. Multiplying by 5.877 (its period) gives 4.369 days. From the diagram the moon is west of Neptune nearly half way between the 4 and 5 day markers.

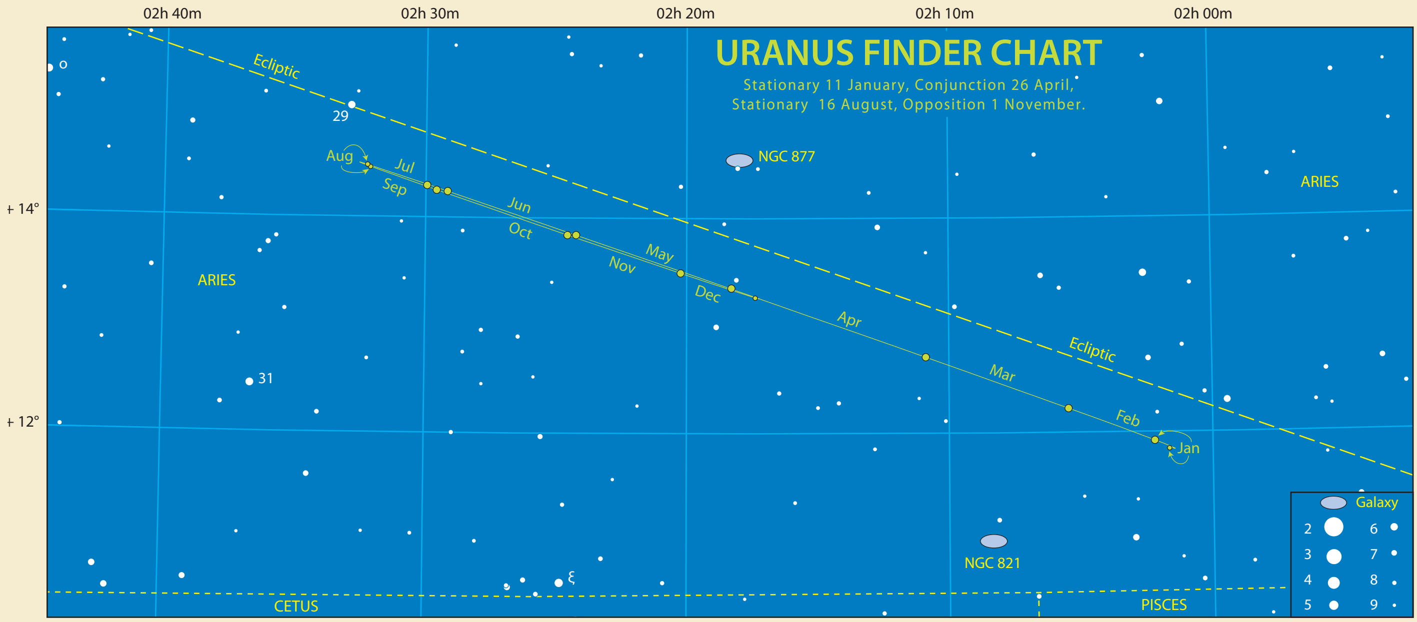


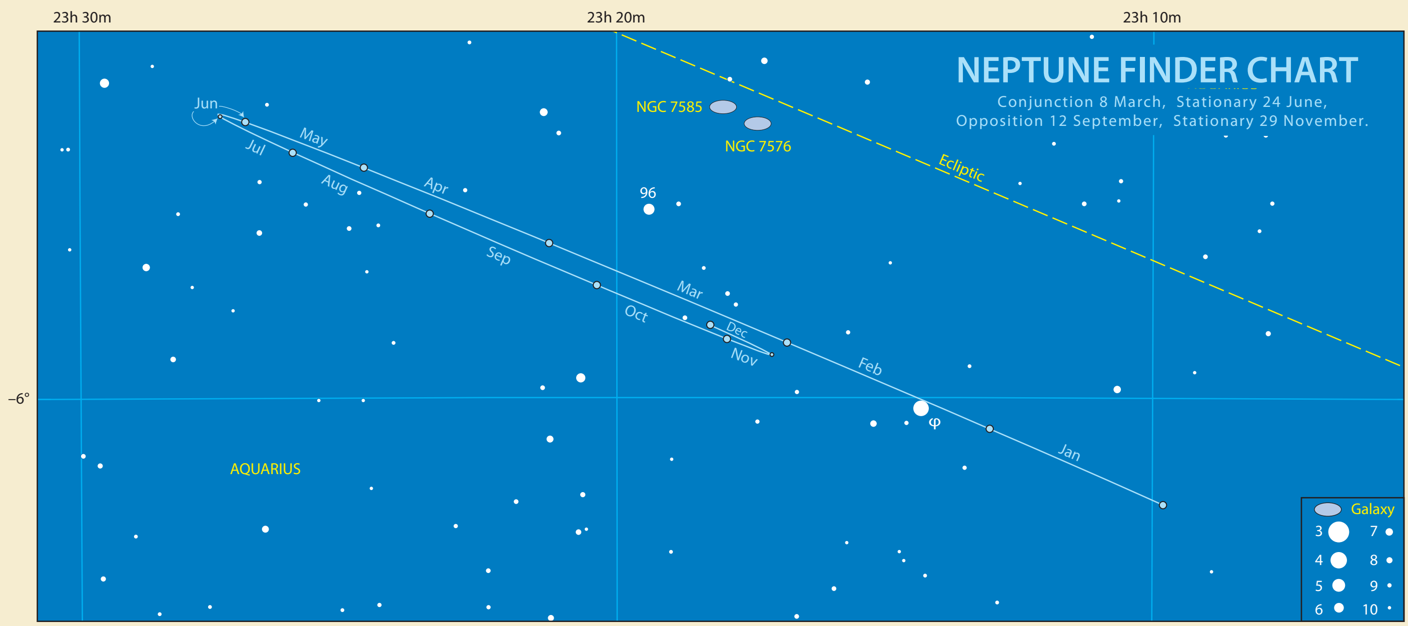
Apparent orbit of Triton at date of opposition, 12 September.

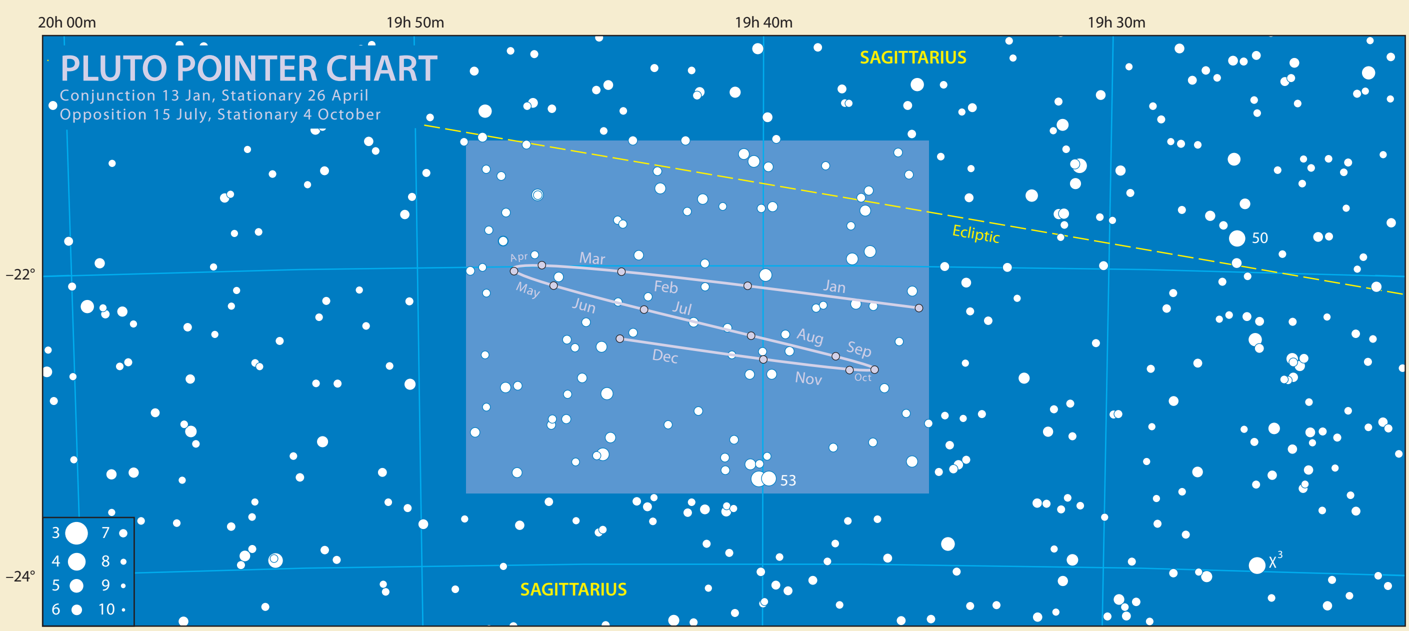
Table 2: **Time of Greatest Elongation North or East** (UT)

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	2.383	5.058	4.858	10.708	2.488
February	1.633	3.071	8.679	6.633	6.733
March	2.879	3.079	5.796	4.554	1.229
April	2.121	1.088	9.613	13.929	5.467
May	2.363	4.233	5.721	10.838	4.838
June	1.604	2.238	9.529	6.750	3.208
July	1.842	1.242	5.638	3.667	2.592
August	1.083	3.392	9.454	13.046	6.858
September	2.846	1.396	4.571	8.971	5.254
October	3.088	4.550	9.396	5.900	4.650
November	2.333	2.563	4.521	1.833	3.046
December	2.583	1.575	9.350	12.238	2.433

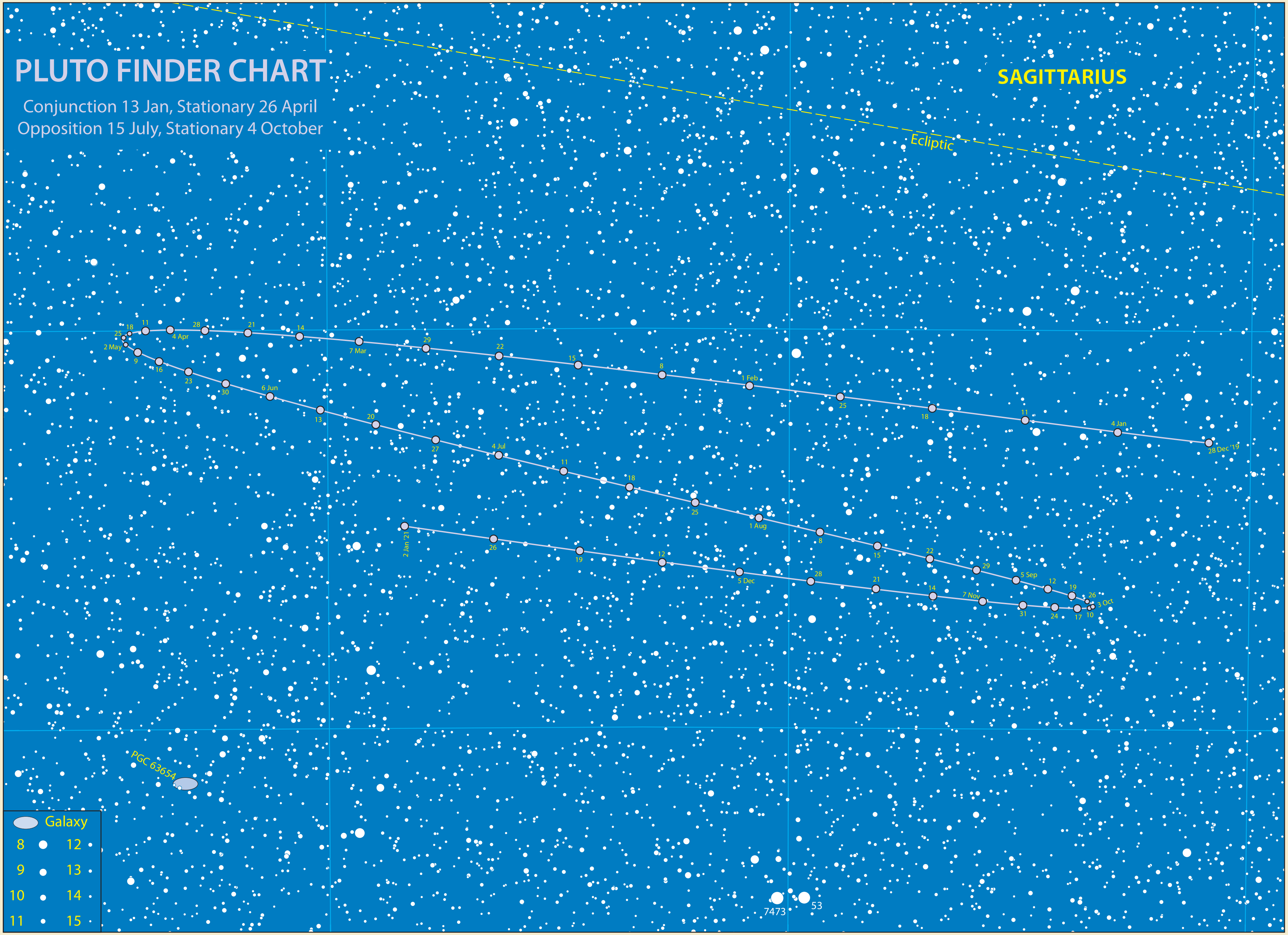
Notes 1. When at opposition 2. Sidereal Period


02h 40m
02h 30m
02h 20m
02h 10m
02h 00m
URANUS FINDER CHART
Stationary 11 January, Conjunction 26 April,
Stationary 16 August, Opposition 1 November.
Ecliptic
29
Aug
Jul
Sep
Jun
Oct
May
Nov
Dec
Apr
Mar
Feb
Jan
NGC 877
NGC 821
ARIES
ARIES
31
+ 14°
+ 12°
CETUS
PISCES
Galaxy
2 6
3 7
4 8
5 9


23h 30m
23h 20m
23h 10m
NEPTUNE FINDER CHART
Conjunction 8 March, Stationary 24 June,
Opposition 12 September, Stationary 29 November.
NGC 7585
NGC 7576
Ecliptic
Jun
May
Jul
Aug
Apr
Sep
Mar
Oct
Dec
Nov
Feb
Jan
96
φ
–6°
AQUARIUS
Galaxy
3 7
4 8
5 9
6 10


20h 00m
19h 50m
19h 40m
19h 30m
PLUTO POINTER CHART
Conjunction 13 Jan, Stationary 26 April
Opposition 15 July, Stationary 4 October
SAGITTARIUS
Ecliptic
Apr
Mar
May
Feb
Jan
Jun
Jul
Aug
Sep
Dec
Oct
Nov
50
53
–22°
–24°
SAGITTARIUS
3 7
4 8
5 9
6 10

NEPTUNE


PLUTO FINDER CHART
Conjunction 13 Jan, Stationary 26 April
Opposition 15 July, Stationary 4 October
SAGITTARIUS
Ecliptic
19h 45m
19h 40m
19h 35m
−22°
−23°
28 Dec '19
4 Jan
1 Feb
7 Mar
4 Apr
2 May
6 Jun
4 Jul
1 Aug
5 Sep
3 Oct
7 Nov
5 Dec
2 Jan '21
PGC 63654
7473
53
Galaxy
8
9
10
11
12
13
14
15

COMETS FOR 2020

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, which returns this year, 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 88P/Howell indicates it was the 88th 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 Pan-STARRS comet, mentioned below, is referred to as 'C/2017 T2'. 2017 refers to the year of the discovery, T is the 19th half-month period ('I' is not used) during the year and the 2 shows it was the second discovery in this half month. Therefore C/2017 T2 (PANSTARRS) was the second comet discovered in the first half of October 2017.

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 2020. 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 2020, 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

2P/Encke One of the best known comets is Encke. This visitor enters our neighbourhood every 3.3 years, and for more than two centuries it was the shortest-period comet known, until the discovery of the asteroid/comet 311P/PANSTARRS (3.2-year period) a few years ago. 2020 sees Encke reach perihelion on 26 June.

In January 1786, the comet was first sighted by the famous French comet hunter Pierre Mechain. He notified fellow comet hunter Charles Messier of its discovery and both astronomers observed the comet two nights later. However, the comet was not sighted again during that apparition.

Nearly ten years were to pass before the comet was seen again. English astronomer Caroline Herschel came across it in November 1795. Her brother, William Herschel, noted that it was visible to the naked-eye.

Yet another ten years were to pass before the comet was *discovered* again. This time, the comet was seen in October 1805 by European astronomers Jeans Pons, Johann Huth, and Alexis Bouvard. Huth estimated it to be 5th magnitude with a tail three degrees in length.

At this time German astronomer Johann Encke entered the picture. Encke studied the positions that had been reported, and suggested (incorrectly) that they fitted an elliptical orbit with a period of 12.1 years.

It wasn't until 1818 that the comet was sighted again. Pons found the comet and it brightened to display a similar appearance to its 1786 apparition. The comet remained observable for nearly seven weeks, enabling a good set of positions to be determined. Olbers was the first to suggest that this comet was the same as those observed in 1786, 1795, and 1805. However, it was Encke who proved mathematically that it was the same comet returning, with a period of 3.3 years.

Encke then proceeded to predict the next return of the comet, with a perihelion date of 24 May, 1822. On 2 June, 1822, Carl Rumker recovered the comet whilst observing at the observatory of Sir Thomas Brisbane in Parramatta, New South Wales. This was only the second comet whose return had been successfully predicted, the first being Halley.

88P/Howell Ellen Howell discovered this comet on photographic plates taken in August 1981 with the 0.46-metre

Schmidt telescope at Palomar. Within a fortnight, the periodic nature of the comet was confirmed. Three close approaches to Jupiter during the 20th century have progressively brought the comet closer to the Sun, from a minimum distance of 2 au to the current 1.4 au. Jupiter will play a role again later this century, pushing the comet out again. This is the eighth observed apparition of comet Howell and this year it is expected to reach 9th magnitude in spring. Perihelion is on 27 September.

249P/LINEAR The most successful ground-based comet discovery program, LINEAR (Lincoln Near-Earth Asteroid Research) has some 223 comets bearing its name, all discovered over a period from 1998 to 2012. This comet was found on 19 October 2006. With a period of just under five years, this will be the fourth observed apparition of the comet.

P/2009 Q4 (Boattini) This comet was discovered by Andrea Boattini on 26 August 2009 during the course of the Catalina Sky Survey near Tucson, Arizona. The survey, running since 1998, uses two telescopes in the region, a 1.5-metre *f*/2 telescope and a 0.68-m Schmidt telescope. This comet was found on images taken with the latter. Not recovered at its last return in 2015, it will be interesting to see the brightness that Boattini attains when it reaches perihelion again on 27 December 2020.

C/2017 T2 (PANSTARRS) Discovered on images taken on 2 October 2017, when its brightness was only 20th magnitude, the comet may reach 7th magnitude around the time of perihelion in May 2020. Unfortunately for us, this apparition favours observers in the Northern Hemisphere.

The Pan-STARRS (Panoramic Survey Telescope and Rapid Response System) survey's initial telescope saw first light in 2010, with its first comet found later that year. Although the program is called Pan-STARRS, comets are named PANSTARRS. Pan-STARRS surveys the whole sky north of declination –47°, searching for moving objects, such as near-Earth asteroids, or objects that vary in brightness. The initial plan was for there to be four 1.8-metre telescopes for the survey, but funding shortages has limited the development to only two instruments.

As at the time of writing, 196 comets have been discovered during the course of the Pan-STARRS survey, ranking it second on the all-time list for ground based surveys, behind LINEAR. The most successful comet discovery program is the space based SOHO satellite. In 2017, the interstellar asteroid Oumuamua was discovered with one of the Pan-STARRS telescopes.

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 2020 — ORBITAL ELEMENTS (Equinox 2000.0)

Comet Name	Perihelion Date yyyy mm dd.dddd	q au	e	Period years	ω °	Ω °	i °	H1	K1
C/2017 T2 (PANSTARRS)	2020 05 04.9617	1.615148	0.999630		92.9940	64.3776	57.2312	3.0	10.0
2P/Encke	2020 06 25.8454	0.336720	0.847998	3.3	186.5623	334.5519	11.7647	10.0	7.0
249P/LINEAR	2020 06 29.4984	0.496754	0.820154	4.6	65.6056	239.1765	8.3968	15.5	16.0
88P/Howell	2020 09 26.6173	1.353087	0.564357	5.5	235.9118	56.6843	4.3837	6.0	15.0
P/2009 Q4 (Boattini)	2020 12 26.9785	1.305674	0.582610	5.5	320.2361	127.4636	11.0155	10.5	33.0

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.

C/2017 T2 (PANSTARRS)

Date	RA h m	Dec ° '	Δ au	R au	Rise hh:mm	Transit hh:mm	Set hh:mm	Elg °	Mag
02 Nov '19	05 35.4	+35 41	2.078	2.848	22:37	02:49	06:57	132.8	9.1
09 Nov '19	05 30.2	+38 02	1.951	2.781	22:16	02:16	06:13	139.7	8.9
16 Nov '19	05 22.6	+40 35	1.838	2.716	21:54	01:42	05:25	146.1	8.7
23 Nov '19	05 12.1	+43 15	1.740	2.650	21:32	01:03	04:30	151.5	8.4
30 Nov '19	04 58.5	+45 56	1.660	2.585	21:10	00:22	03:31	154.4	8.2
07 Dec '19	04 41.8	+48 32	1.598	2.520	20:47	23:35	02:25	153.9	8.0
14 Dec '19	04 22.2	+50 54	1.555	2.456	20:23	22:48	01:15	149.9	7.9
21 Dec '19	04 00.6	+52 55	1.529	2.393	20:01	21:58	23:56	143.6	7.7
28 Dec '19	03 38.1	+54 30	1.520	2.331	19:38	21:08	22:38	136.1	7.6
04 Jan	03 16.3	+55 39	1.525	2.270	19:18	20:19	21:20	128.3	7.5
11 Jan	02 56.4	+56 28	1.541	2.210	19:10	19:32	19:53	120.5	7.4
too far north									
30 May	10 43.3	+66 13	1.660	1.650				71.7	6.3
06 Jun	11 16.6	+61 18	1.667	1.672				72.5	6.3
13 Jun	11 42.6	+55 58	1.687	1.699	17:14	18:10	19:07	73.2	6.4
20 Jun	12 03.7	+50 25	1.718	1.730	15:34	18:04	20:34	73.5	6.6
27 Jun	12 21.5	+44 49	1.763	1.765	14:36	17:54	21:12	73.3	6.7
04 Jul	12 37.1	+39 17	1.822	1.804	13:51	17:42	21:33	72.8	6.9
11 Jul	12 51.0	+33 57	1.893	1.847	13:13	17:29	21:44	71.7	7.1
18 Jul	13 03.7	+28 51	1.977	1.893	12:37	17:14	21:50	70.3	7.3
25 Jul	13 15.6	+24 03	2.071	1.942	12:05	16:58	21:51	68.4	7.5
01 Aug	13 26.9	+19 34	2.175	1.993	11:35	16:42	21:49	66.1	7.7
08 Aug	13 37.7	+15 25	2.287	2.047	11:05	16:25	21:45	63.5	7.9
15 Aug	13 48.1	+11 35	2.405	2.103	10:37	16:08	21:38	60.6	8.1
22 Aug	13 58.4	+08 03	2.527	2.160	10:10	15:51	21:31	57.5	8.4
29 Aug	14 08.4	+04 48	2.653	2.219	09:44	15:33	21:22	54.2	8.6
05 Sep	14 18.2	+01 49	2.781	2.279	09:18	15:15	21:12	50.7	8.8
12 Sep	14 28.0	−00 57	2.909	2.341	08:53	14:58	21:02	47.0	9.0
19 Sep	14 37.6	−03 29	3.036	2.403	08:28	14:40	20:51	43.1	9.2
26 Sep	14 47.2	−05 51	3.161	2.466	08:04	14:22	20:39	39.2	9.4
03 Oct	14 56.8	−08 01	3.283	2.530	07:40	14:03	20:27	35.1	9.6
10 Oct	15 06.3	−10 03	3.401	2.595	07:16	13:46	20:15	30.9	9.8
17 Oct	15 15.7	−11 56	3.514	2.660	06:53	13:28	20:02	26.6	10.0
24 Oct	15 25.1	−13 41	3.621	2.726	06:29	13:10	19:49	22.2	10.1
31 Oct	15 34.5	−15 19	3.721	2.792	06:07	12:51	19:36	17.7	10.3
07 Nov	15 43.7	−16 51	3.814	2.858	05:44	12:33	19:22	13.1	10.5
14 Nov	15 52.9	−18 18	3.900	2.925	05:21	12:14	19:08	8.4	10.6
solar conjunction									
12 Dec	16 28.3	−23 17	4.152	3.192	03:51	11:00	18:09	11.2	11.1
19 Dec	16 36.7	−24 22	4.191	3.259	03:28	10:41	17:54	16.3	11.2
26 Dec	16 44.9	−25 25	4.221	3.326	03:05	10:21	17:38	21.5	11.3

P/2009 Q4 (Boattini)

Date	RA h m	Dec ° '	Δ au	R au	Rise hh:mm	Transit hh:mm	Set hh:mm	Elg °	Mag
14 Nov	04 15.9	−13 02	0.461	1.394	17:58	00:39	07:17	145.6	13.6
21 Nov	04 18.6	−13 21	0.434	1.369	17:32	00:14	06:53	145.8	13.2
28 Nov	04 21.0	−12 59	0.412	1.347	17:08	23:46	06:26	145.7	12.8
05 Dec	04 23.5	−11 51	0.395	1.330	16:46	23:21	05:58	145.3	12.6
12 Dec	04 26.7	−09 54	0.384	1.317	16:27	22:57	05:29	144.8	12.4
19 Dec	04 31.0	−07 08	0.378	1.309	16:12	22:33	04:57	144.1	12.2
26 Dec	04 36.9	−03 39	0.378	1.306	16:00	22:12	04:26	143.2	12.2
02 Jan '21	04 44.7	+00 21	0.384	1.308	15:51	21:53	03:56	142.1	12.3

Hale-Bopp on 8 April 1997 from the VLA, New Mexico. Six minutes on Kodak Royal 1000, 135 mm ƒ/2.8 lens. Glenn Dawes

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.

Elg Elongation; angular distance of the comet from the Sun.

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).

The estimate of total magnitude is normally calculated using:

$$\text{Mag} = \text{H1} + 5\log(\Delta) + \text{K1}\log \text{R}$$

See the table of elements opposite 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.

88P/Howell

Date	RA	Dec	Δ	R	Rise	Transit	Set	Elg	Mag
	h m	° '	au	au	hh:mm	hh:mm	hh:mm	°	
15 Feb	13 40.7	−05 33	1.894	2.536	21:39	04:00	10:17	120.0	13.4
22 Feb	13 42.6	−05 36	1.772	2.491	21:13	03:35	09:51	126.6	13.2
29 Feb	13 43.3	−05 33	1.657	2.446	20:46	03:08	09:25	133.4	12.9
07 Mar	13 42.6	−05 23	1.549	2.400	20:18	02:39	08:56	140.6	12.7
14 Mar	13 40.5	−05 06	1.451	2.355	19:50	02:09	08:25	148.1	12.4
21 Mar	13 37.0	−04 42	1.363	2.308	19:20	01:39	07:53	155.9	12.1
28 Mar	13 32.0	−04 13	1.286	2.262	18:49	01:06	07:20	163.9	11.9
04 Apr	13 25.8	−03 40	1.221	2.216	18:16	00:32	06:44	171.6	11.6
11 Apr	13 18.6	−03 04	1.169	2.169	17:44	23:55	06:08	174.8	11.4
18 Apr	13 10.8	−02 29	1.130	2.122	17:10	23:19	05:31	168.2	11.2
25 Apr	13 03.0	−01 58	1.102	2.076	16:36	22:44	04:54	159.8	11.0
02 May	12 55.6	−01 33	1.086	2.029	16:02	22:09	04:18	151.3	10.8
09 May	12 49.1	−01 17	1.080	1.983	15:29	21:35	03:44	143.1	10.6
16 May	12 44.0	−01 12	1.083	1.936	14:56	21:02	03:11	135.2	10.5
23 May	12 40.6	−01 18	1.093	1.890	14:25	20:31	02:40	127.7	10.3
30 May	12 39.0	−01 38	1.108	1.845	13:55	20:02	02:12	120.8	10.2
06 Jun	12 39.4	−02 09	1.126	1.800	13:27	19:35	01:46	114.4	10.1
13 Jun	12 41.6	−02 52	1.146	1.756	12:59	19:10	01:23	108.5	10.0
20 Jun	12 45.8	−03 46	1.168	1.713	12:33	18:46	01:02	103.1	9.8
27 Jun	12 51.6	−04 51	1.189	1.672	12:09	18:25	00:43	98.2	9.7
04 Jul	12 59.2	−06 05	1.210	1.631	11:46	18:05	00:26	93.8	9.6
11 Jul	13 08.5	−07 27	1.230	1.592	11:24	17:47	00:12	89.7	9.5
18 Jul	13 19.2	−08 56	1.249	1.555	11:03	17:29	23:55	86.1	9.4
25 Jul	13 31.5	−10 33	1.266	1.521	10:43	17:14	23:45	82.8	9.2
01 Aug	13 45.3	−12 14	1.281	1.488	10:24	17:00	23:36	79.9	9.1
08 Aug	14 00.5	−13 59	1.295	1.459	10:07	16:48	23:28	77.3	9.0
15 Aug	14 17.2	−15 47	1.309	1.432	09:51	16:37	23:23	75.0	8.9
22 Aug	14 35.4	−17 35	1.322	1.409	09:36	16:27	23:19	72.9	8.8
29 Aug	14 55.1	−19 21	1.335	1.390	09:23	16:19	23:16	71.2	8.8
05 Sep	15 16.2	−21 03	1.348	1.374	09:11	16:13	23:15	69.6	8.7
12 Sep	15 38.8	−22 38	1.363	1.363	09:01	16:08	23:15	68.3	8.7
19 Sep	16 02.7	−24 04	1.380	1.356	08:52	16:04	23:17	67.2	8.7
26 Sep	16 27.9	−25 17	1.399	1.353	08:46	16:02	23:19	66.2	8.7
03 Oct	16 54.2	−26 15	1.422	1.355	08:41	16:01	23:21	65.3	8.7
10 Oct	17 21.3	−26 55	1.448	1.361	08:38	16:00	23:23	64.6	8.8
17 Oct	17 49.0	−27 16	1.480	1.372	08:37	16:00	23:24	63.8	8.9
24 Oct	18 17.0	−27 17	1.516	1.387	08:37	16:01	23:24	63.1	9.0
31 Oct	18 44.8	−26 58	1.558	1.405	08:39	16:01	23:23	62.3	9.2
07 Nov	19 12.2	−26 20	1.605	1.428	08:41	16:01	23:21	61.5	9.3
14 Nov	19 38.9	−25 23	1.658	1.454	08:44	16:00	23:16	60.5	9.5
21 Nov	20 04.7	−24 12	1.716	1.483	08:46	15:59	23:10	59.5	9.7
28 Nov	20 29.5	−22 47	1.780	1.515	08:48	15:56	23:03	58.3	10.0
05 Dec	20 53.3	−21 11	1.849	1.549	08:49	15:52	22:53	56.9	10.2
12 Dec	21 15.9	−19 27	1.922	1.586	08:50	15:47	22:43	55.4	10.4
19 Dec	21 37.4	−17 38	2.000	1.624	08:49	15:41	22:31	53.7	10.7
26 Dec	21 57.9	−15 44	2.082	1.664	08:48	15:34	22:18	51.8	10.9
02 Jan '21	22 17.5	−13 48	2.166	1.706	08:46	15:26	22:05	49.8	11.2

249P/LINEAR

Date	RA	Dec	Δ	R	Rise	Transit	Set	Elg	Mag
	h m	° '	au	au	hh:mm	hh:mm	hh:mm	°	
23 May	08 24.3	+12 20	0.467	0.907	10:47	16:15	21:44	63.5	13.2
30 May	07 59.6	+16 27	0.445	0.803	10:06	15:23	20:39	50.0	12.2
06 Jun	07 25.3	+21 02	0.430	0.703	09:19	14:21	19:24	34.4	11.2
13 Jun	06 38.8	+25 27	0.436	0.611	08:19	13:08	17:55	16.7	10.3
20 Jun	05 47.3	+28 18	0.481	0.539	07:11	11:49	16:26	5.2	9.6
27 Jun	05 08.8	+28 58	0.577	0.500	06:07	10:43	15:18	17.8	9.5
04 Jul	04 53.7	+28 32	0.709	0.507	05:24	10:01	14:37	27.4	10.0
11 Jul	04 57.0	+27 57	0.851	0.557	04:57	09:36	14:15	33.2	11.1
18 Jul	05 09.4	+27 24	0.984	0.636	04:40	09:21	14:02	37.0	12.3
25 Jul	05 25.1	+26 52	1.100	0.731	04:26	09:09	13:52	40.2	13.5

2P/Encke

Date	RA	Dec	Δ	R	Rise	Transit	Set	Elg	Mag
	h m	° '	au	au	hh:mm	hh:mm	hh:mm	°	
13 Jun	05 40.1	+26 41	1.481	0.476	07:26	12:09	16:52	4.7	8.6
15 Jun	05 55.3	+26 22	1.442	0.442	07:32	12:16	17:01	5.7	8.3
17 Jun	06 11.1	+25 54	1.401	0.411	07:38	12:24	17:10	6.9	8.0
19 Jun	06 27.3	+25 15	1.358	0.384	07:44	12:32	17:21	8.5	7.8
21 Jun	06 43.9	+24 25	1.313	0.361	07:50	12:41	17:33	10.2	7.5
23 Jun	07 00.6	+23 25	1.265	0.346	07:55	12:50	17:45	12.2	7.3
25 Jun	07 17.1	+22 13	1.214	0.338	08:00	12:59	17:57	14.2	7.1
27 Jun	07 33.3	+20 51	1.160	0.338	08:04	13:07	18:09	16.2	7.0
29 Jun	07 48.9	+19 21	1.106	0.348	08:07	13:15	18:22	18.2	7.0
01 Jul	08 03.9	+17 44	1.052	0.365	08:09	13:22	18:34	20.2	7.0
03 Jul	08 18.4	+16 01	0.999	0.388	08:10	13:28	18:46	22.1	7.1
05 Jul	08 32.5	+14 13	0.949	0.416	08:11	13:35	18:57	24.1	7.2
07 Jul	08 46.3	+12 21	0.901	0.447	08:12	13:40	19:09	26.1	7.3
09 Jul	09 00.1	+10 23	0.857	0.481	08:12	13:46	19:20	28.1	7.4
11 Jul	09 14.0	+08 19	0.816	0.517	08:12	13:52	19:32	30.3	7.5
13 Jul	09 28.2	+06 10	0.779	0.553	08:13	13:59	19:44	32.6	7.7
15 Jul	09 42.7	+03 55	0.745	0.590	08:13	14:05	19:56	35.0	7.8
17 Jul	09 57.7	+01 34	0.715	0.627	08:14	14:12	20:10	37.6	7.9
19 Jul	10 13.2	−00 53	0.690	0.664	08:15	14:19	20:24	40.3	7.9
21 Jul	10 29.3	−03 24	0.668	0.700	08:16	14:28	20:39	43.3	8.0
23 Jul	10 46.1	−05 58	0.650	0.737	08:18	14:37	20:55	46.3	8.1
25 Jul	11 03.4	−08 33	0.637	0.773	08:20	14:46	21:11	49.5	8.2
27 Jul	11 21.2	−11 08	0.628	0.809	08:23	14:56	21:29	52.8	8.3
29 Jul	11 39.4	−13 39	0.623	0.844	08:26	15:06	21:46	56.0	8.5
31 Jul	11 58.0	−16 04	0.623	0.879	08:30	15:17	22:04	59.3	8.6
02 Aug	12 16.8	−18 21	0.626	0.914	08:34	15:28	22:21	62.5	8.7
04 Aug	12 35.6	−20 27	0.633	0.948	08:38	15:39	22:39	65.5	8.8
06 Aug	12 54.2	−22 22	0.645	0.981	08:43	15:50	22:56	68.4	9.0
08 Aug	13 12.5	−24 04	0.659	1.014	08:47	16:00	23:12	71.1	9.1
10 Aug	13 30.4	−25 33	0.677	1.047	08:52	16:10	23:27	73.5	9.3
12 Aug	13 47.8	−26 50	0.698	1.079	08:57	16:19	23:41	75.7	9.5
14 Aug	14 04.4	−27 56	0.721	1.111	09:02	16:28	23:54	77.7	9.6
16 Aug	14 20.4	−28 50	0.747	1.143	09:07	16:37	00:09	79.4	9.8
18 Aug	14 35.6	−29 35	0.775	1.174	09:11	16:44	00:19	80.9	9.9
20 Aug	14 50.0	−30 11	0.805	1.204	09:15	16:51	00:28	82.1	10.1
22 Aug	15 03.6	−30 40	0.837	1.234	09:19	16:56	00:36	83.2	10.3
24 Aug	15 16.5	−31 03	0.870	1.264	09:23	17:02	00:42	84.1	10.4
26 Aug	15 28.7	−31 20	0.905	1.294	09:26	17:06	00:48	84.8	10.6
28 Aug	15 40.2	−31 32	0.940	1.323	09:29	17:09	00:52	85.3	10.7
30 Aug	15 51.0	−31 41	0.977	1.351	09:31	17:12	00:56	85.7	10.9
01 Sep	16 01.2	−31 47	1.015	1.380	09:33	17:15	00:59	85.9	11.0
03 Sep	16 10.9	−31 49	1.054	1.408	09:35	17:17	01:01	86.1	11.2
05 Sep	16 20.1	−31 50	1.093	1.435	09:36	17:18	01:02	86.1	11.3
07 Sep	16 28.8	−31 48	1.133	1.463	09:37	17:19	01:03	86.0	11.4
09 Sep	16 37.1	−31 45	1.174	1.490	09:38	17:19	01:03	85.8	11.6
11 Sep	16 45.0	−31 41	1.216	1.517	09:38	17:19	01:03	85.5	11.7
13 Sep	16 52.5	−31 36	1.257	1.543	09:38	17:19	01:02	85.2	11.8
15 Sep	16 59.7	−31 30	1.300	1.569	09:38	17:18	01:01	84.7	11.9
17 Sep	17 06.6	−31 23	1.343	1.595	09:37	17:17	00:59	84.3	12.1
19 Sep	17 13.2	−31 15	1.386	1.621	09:36	17:16	00:57	83.7	12.2
21 Sep	17 19.5	−31 07	1.429	1.646	09:36	17:14	00:55	83.1	12.3
23 Sep	17 25.7	−30 58	1.473	1.671	09:34	17:12	00:53	82.5	12.4
25 Sep	17 31.6	−30 50	1.517	1.696	09:33	17:10	00:50	81.8	12.5
27 Sep	17 37.3	−30 40	1.562	1.720	09:31	17:08	00:47	81.1	12.6
29 Sep	17 42.8	−30 31	1.606	1.744	09:30	17:06	00:44	80.3	12.7

Note, due to the relatively rapid movement of 2P/Encke (above) the data has been presented at two day intervals. The other comets have a seven day interval.

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 known as minor planets or 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 the 14 brightest minor or dwarf planets reaching opposition in 2020, plus 4 Vesta (opposition is 5 Mar 2021). Ceres reaches magnitude 7.7, the rest a maximum of 9.6 or brighter. As only the 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
Jun 6	23 01.7	-17 10	8.9
13	23 06.4	-17 14	8.8
20	23 10.2	-17 24	8.7
27	23 13.1	-17 42	8.6
Jul 4	23 15.0	-18 06	8.5
11	23 15.9	-18 37	8.4
18	23 15.7	-19 14	8.3
25	23 14.3	-19 56	8.2
Aug 1	23 11.8	-20 43	8.0
8	23 08.3	-21 32	7.9
15	23 03.8	-22 21	7.8
22	22 58.5	-23 08	7.7
29	22 52.7	-23 51	7.7
Sep 5	22 46.8	-24 26	7.7
12	22 40.9	-24 54	7.8
19	22 35.5	-25 12	7.9
26	22 30.8	-25 20	8.1
Oct 3	22 26.9	-25 18	8.2
10	22 24.2	-25 07	8.3
17	22 22.6	-24 47	8.4
24	22 22.1	-24 20	8.6
31	22 22.8	-23 47	8.7
Nov 7	22 24.6	-23 08	8.8
14	22 27.5	-22 24	8.8
21	22 31.2	-21 35	8.9

2 Pallas

Date	RA hh mm	Dec ° '	Mag
Apr 18	19 32.6	+14 53	10.2
25	19 35.3	+15 58	10.1
May 2	19 37.1	+17 02	10.1
9	19 38.0	+18 04	10.0
16	19 37.8	+19 01	10.0
23	19 36.6	+19 54	9.9
30	19 34.5	+20 40	9.8
Jun 6	19 31.4	+21 17	9.8
13	19 27.4	+21 45	9.7
20	19 22.7	+22 01	9.7
27	19 17.4	+22 04	9.6
Jul 4	19 11.8	+21 54	9.6
11	19 06.0	+21 30	9.6
18	19 00.3	+20 53	9.6
25	18 55.0	+20 04	9.6
Aug 1	18 50.3	+19 03	9.6
8	18 46.3	+17 54	9.7
15	18 43.2	+16 37	9.8
22	18 41.0	+15 16	9.8
29	18 39.8	+13 52	9.9
Sep 5	18 39.7	+12 27	10.0
12	18 40.5	+11 03	10.1
19	18 42.3	+09 41	10.1
26	18 45.0	+08 22	10.2
Oct 3	18 48.5	+07 07	10.3

3 Juno

Date	RA hh mm	Dec ° '	Mag
Jan 4	13 08.1	-05 14	10.6
11	13 13.3	-05 21	10.6
18	13 17.7	-05 21	10.5
25	13 21.2	-05 14	10.4
Feb 1	13 23.7	-04 59	10.4
8	13 25.1	-04 37	10.3
15	13 25.3	-04 06	10.2
22	13 24.5	-03 28	10.1
29	13 22.5	-02 42	10.0
Mar 7	13 19.5	-01 50	9.9
14	13 15.5	-00 53	9.8
21	13 10.7	+00 06	9.7
28	13 05.5	+01 07	9.6
Apr 4	12 59.9	+02 05	9.6
11	12 54.4	+03 00	9.7
18	12 49.2	+03 49	9.8
25	12 44.6	+04 30	9.9
May 2	12 40.6	+05 02	10.1
9	12 37.6	+05 26	10.2
16	12 35.4	+05 41	10.3
23	12 34.3	+05 47	10.5
30	12 34.2	+05 46	10.6
Jun 6	12 34.9	+05 37	10.7
13	12 36.6	+05 22	10.8
20	12 39.1	+05 01	10.9

4 Vesta

Date	RA hh mm	Dec ° '	Mag
Jul 11	07 09.2	+22 34	8.1
18	07 22.4	+22 19	8.2
25	07 35.6	+22 00	8.2
Aug 1	07 48.8	+21 37	8.3
8	08 01.8	+21 11	8.3
15	08 14.8	+20 42	8.3
22	08 27.6	+20 09	8.4
29	08 40.2	+19 33	8.4
Sep 5	08 52.7	+18 56	8.4
12	09 05.0	+18 16	8.4
19	09 17.1	+17 34	8.4
26	09 28.9	+16 51	8.3
Oct 3	09 40.6	+16 08	8.3
10	09 51.9	+15 23	8.3
17	10 03.0	+14 39	8.3
24	10 13.8	+13 56	8.2
31	10 24.2	+13 14	8.2
Nov 7	10 34.2	+12 34	8.1
14	10 43.8	+11 56	8.0
21	10 52.9	+11 22	8.0
28	11 01.5	+10 52	7.9
Dec 5	11 09.4	+10 26	7.8
12	11 16.7	+10 06	7.7
19	11 23.2	+09 53	7.6
26	11 28.8	+09 48	7.5

5 Astraea

Date	RA hh mm	Dec ° '	Mag
Jan 4	08 21.6	+14 54	9.5
11	08 16.3	+15 29	9.2
18	08 10.2	+16 09	9.0
25	08 03.8	+16 53	9.0
Feb 1	07 57.6	+17 38	9.2
8	07 52.2	+18 22	9.4
15	07 47.9	+19 02	9.6
22	07 45.3	+19 37	9.8
29	07 44.3	+20 06	9.9
Mar 7	07 45.1	+20 30	10.1
14	07 47.7	+20 47	10.3
21	07 51.9	+20 57	10.4
28	07 57.6	+21 01	10.6
Apr 4	08 04.6	+20 59	10.7
11	08 12.7	+20 50	10.8
18	08 21.8	+20 35	10.9
25	08 31.8	+20 14	11.0
May 2	08 42.5	+19 47	11.1
9	08 53.7	+19 14	11.2
16	09 05.5	+18 36	11.3
23	09 17.5	+17 52	11.4
30	09 29.9	+17 02	11.4
Jun 6	09 42.5	+16 08	11.5
13	09 55.3	+15 10	11.5
20	10 08.2	+14 07	11.6

7 Iris

Date	RA hh mm	Dec ° '	Mag
Apr 11	18 50.8	-22 47	10.7
18	18 55.0	-22 32	10.6
25	18 58.1	-22 17	10.4
May 2	18 59.9	-22 03	10.3
9	19 00.6	-21 50	10.2
16	18 59.8	-21 37	10.0
23	18 57.7	-21 26	9.8
30	18 54.2	-21 16	9.7
Jun 6	18 49.4	-21 06	9.5
13	18 43.5	-20 58	9.3
20	18 36.6	-20 49	9.1
27	18 29.2	-20 40	8.8
Jul 4	18 21.6	-20 31	8.9
11	18 14.2	-20 22	9.1
18	18 07.5	-20 14	9.3
25	18 01.7	-20 06	9.4
Aug 1	17 57.2	-19 59	9.5
8	17 54.1	-19 53	9.6
15	17 52.4	-19 49	9.8
22	17 52.3	-19 47	9.9
29	17 53.6	-19 45	10.0
Sep 5	17 56.4	-19 44	10.1
12	18 00.4	-19 44	10.2
19	18 05.7	-19 43	10.2
26	18 12.1	-19 42	10.3

8 Flora

Date	RA hh mm	Dec ° '	Mag
Jul 11	01 38.6	+04 04	10.3
18	01 50.4	+04 48	10.2
25	02 01.8	+05 25	10.1
Aug 1	02 12.7	+05 56	9.9
8	02 22.9	+06 21	9.8
15	02 32.3	+06 38	9.7
22	02 40.7	+06 48	9.6
29	02 48.1	+06 50	9.4
Sep 5	02 54.1	+06 45	9.2
12	02 58.7	+06 33	9.1
19	03 01.7	+06 13	8.9
26	03 02.8	+05 47	8.7
Oct 3	03 02.1	+05 16	8.6
10	02 59.5	+04 43	8.4
17	02 55.2	+04 09	8.2
24	02 49.5	+03 38	8.0
31	02 42.9	+03 13	8.0
Nov 7	02 36.1	+02 58	8.0
14	02 29.6	+02 53	8.2
21	02 24.0	+03 01	8.3
28	02 19.8	+03 21	8.5
Dec 5	02 17.2	+03 54	8.7
12	02 16.4	+04 37	8.9
19	02 17.4	+05 29	9.1
26	02 20.1	+06 28	9.3

11 Parthenope

Date	RA hh mm	Dec ° '	Mag
Jul 11	01 43.9	+06 31	11.2
18	01 52.7	+07 05	11.1
25	02 00.9	+07 32	11.0
Aug 1	02 08.2	+07 53	10.9
8	02 14.7	+08 08	10.8
15	02 20.2	+08 16	10.7
22	02 24.5	+08 17	10.6
29	02 27.6	+08 11	10.5
Sep 5	02 29.3	+07 58	10.4
12	02 29.6	+07 37	10.2
19	02 28.3	+07 10	10.1
26	02 25.6	+06 37	9.9
Oct 3	02 21.6	+06 00	9.8
10	02 16.4	+05 21	9.6
17	02 10.3	+04 41	9.5
24	02 03.8	+04 04	9.4
31	01 57.4	+03 32	9.5
Nov 7	01 51.4	+03 06	9.7
14	01 46.2	+02 49	9.9
21	01 42.1	+02 42	10.1
28	01 39.3	+02 44	10.3
Dec 5	01 37.9	+02 56	10.5
12	01 37.8	+03 16	10.6
19	01 39.1	+03 45	10.8
26	01 41.7	+04 19	10.9

16 Psyche

Date	RA hh mm	Dec ° '	Mag
Jul 11	03 41.9	+17 11	11.2
18	03 53.2	+17 41	11.2
25	04 04.2	+18 08	11.2
Aug 1	04 14.9	+18 31	11.2
8	04 25.2	+18 50	11.1
15	04 35.0	+19 05	11.1
22	04 44.3	+19 16	11.0
29	04 53.0	+19 24	11.0
Sep 5	05 01.0	+19 28	10.9
12	05 08.2	+19 30	10.9
19	05 14.4	+19 29	10.8
26	05 19.7	+19 26	10.7
Oct 3	05 23.9	+19 21	10.6
10	05 26.8	+19 14	10.5
17	05 28.4	+19 06	10.4
24	05 28.5	+18 57	10.2
31	05 27.3	+18 48	10.1
Nov 7	05 24.7	+18 39	10.0
14	05 20.8	+18 29	9.8
21	05 15.7	+18 20	9.7
28	05 09.8	+18 11	9.6
Dec 5	05 03.4	+18 03	9.4
12	04 56.9	+17 57	9.5
19	04 50.7	+17 52	9.6
26	04 45.1	+17 50	9.8

19 Fortuna

Date	RA hh mm	Dec ° '	Mag
Jun 20	23 15.9	-02 48	11.5
27	23 22.1	-02 05	11.4
Jul 4	23 27.3	-01 28	11.2
11	23 31.6	-00 57	11.1
18	23 34.7	-00 33	10.9
25	23 36.7	-00 18	10.8
Aug 1	23 37.2	-00 11	10.6
8	23 36.5	-00 14	10.4
15	23 34.3	-00 27	10.2
22	23 30.8	-00 50	9.9
29	23 26.2	-01 21	9.7
Sep 5	23 20.7	-01 59	9.5
12	23 14.8	-02 42	9.2
19	23 08.9	-03 25	9.5
26	23 03.5	-04 07	9.7
Oct 3	22 59.0	-04 44	9.9
10	22 55.7	-05 14	10.1
17	22 53.8	-05 36	10.2
24	22 53.5	-05 47	10.4
31	22 54.7	-05 49	10.6
Nov 7	22 57.5	-05 41	10.7
14	23 01.7	-05 23	10.8
21	23 07.2	-04 57	11.0
28	23 13.8	-04 23	11.1
Dec 5	23 21.4	-03 41	11.2

20 Massalia

Date	RA hh mm	Dec ° '	Mag
Jun 6	22 43.3	-07 18	11.5
13	22 47.9	-06 49	11.4
20	22 51.5	-06 25	11.2
27	22 54.2	-06 08	11.1
Jul 4	22 55.8	-05 56	11.0
11	22 56.3	-05 52	10.8
18	22 55.6	-05 55	10.7
25	22 53.6	-06 06	10.5
Aug 1	22 50.5	-06 24	10.4
8	22 46.2	-06 49	10.2
15	22 41.0	-07 21	10.0
22	22 35.0	-07 57	9.9
29	22 28.6	-08 36	9.6
Sep 5	22 22.1	-09 15	9.8
12	22 16.0	-09 52	10.0
19	22 10.5	-10 25	10.1
26	22 06.0	-10 53	10.3
Oct 3	22 02.6	-11 14	10.4
10	22 00.6	-11 28	10.5
17	22 00.0	-11 35	10.7
24	22 00.7	-11 34	10.8
31	22 02.7	-11 26	10.9
Nov 7	22 05.9	-11 11	11.0
14	22 10.3	-10 49	11.1
21	22 15.7	-10 21	11.2

27 Euterpe

Date	RA hh mm	Dec ° '	Mag
Jan 4	11 58.7	+02 00	10.9
11	12 03.7	+01 36	10.8
18	12 07.4	+01 21	10.7
25	12 09.6	+01 16	10.5
Feb 1	12 10.2	+01 21	10.4
8	12 09.2	+01 36	10.2
15	12 06.7	+02 01	10.1
22	12 02.6	+02 35	9.9
29	11 57.3	+03 15	9.8
Mar 7	11 51.1	+04 00	9.6
14	11 44.5	+04 45	9.4
21	11 37.8	+05 28	9.6
28	11 31.6	+06 05	9.8
Apr 4	11 26.3	+06 35	10.1
11	11 22.2	+06 56	10.3
18	11 19.4	+07 07	10.5
25	11 18.0	+07 09	10.7
May 2	11 18.0	+07 02	10.9
9	11 19.4	+06 46	11.0
16	11 22.0	+06 23	11.2
23	11 25.7	+05 53	11.3
30	11 30.3	+05 16	11.5
Jun 6	11 35.9	+04 35	11.6
13	11 42.1	+03 48	11.7
20	11 49.1	+02 58	11.8

68 Leto

Date	RA hh mm	Dec ° '	Mag
Jul 11	00 43.1	-04 48	11.2
18	00 49.3	-04 21	11.1
25	00 54.5	-04 00	11.0
Aug 1	00 58.6	-03 45	10.9
8	01 01.4	-03 37	10.7
15	01 02.9	-03 35	10.6
22	01 03.0	-03 39	10.4
29	01 01.6	-03 49	10.3
Sep 5	00 58.7	-04 03	10.1
12	00 54.6	-04 20	9.9
19	00 49.4	-04 37	9.7
26	00 43.4	-04 53	9.6
Oct 3	00 37.1	-05 05	9.5
10	00 30.9	-05 11	9.7
17	00 25.2	-05 09	9.9
24	00 20.4	-05 00	10.1
31	00 16.7	-04 42	10.3
Nov 7	00 14.4	-04 15	10.5
14	00 13.4	-03 41	10.7
21	00 13.9	-02 59	10.9
28	00 15.7	-02 12	11.0
Dec 5	00 18.7	-01 18	11.2
12	00 22.9	-00 21	11.3
19	00 28.1	+00 41	11.4
26	00 34.2	+01 47	11.5

471 Papagena

Date	RA hh mm	Dec ° '	Mag
Jul 11	01 55.4	-05 08	11.2
18	02 04.9	-04 47	11.1
25	02 13.9	-04 32	11.0
Aug 1	02 22.2	-04 22	10.9
8	02 29.8	-04 19	10.8
15	02 36.5	-04 21	10.7
22	02 42.2	-04 30	10.5
29	02 46.8	-04 43	10.4
Sep 5	02 50.1	-05 02	10.3
12	02 52.0	-05 24	10.1
19	02 52.5	-05 49	10.0
26	02 51.4	-06 14	9.9
Oct 3	02 48.8	-06 38	9.7
10	02 44.8	-06 57	9.6
17	02 39.5	-07 09	9.5
24	02 33.4	-07 11	9.5
31	02 26.9	-07 01	9.5
Nov 7	02 20.3	-06 38	9.5
14	02 14.2	-06 02	9.6
21	02 09.0	-05 12	9.7
28	02 04.9	-04 12	9.9
Dec 5	02 02.3	-03 02	10.0
12	02 01.1	-01 45	10.1
19	02 01.4	-00 21	10.3
26	02 03.1	+01 06	10.4

532 Herculina

Date	RA hh mm	Dec ° '	Mag
Apr 11	19 03.5	-14 40	10.6
18	19 08.5	-14 43	10.5
25	19 12.3	-14 49	10.5
May 2	19 14.9	-14 58	10.4
9	19 16.3	-15 13	10.3
16	19 16.3	-15 32	10.2
23	19 15.1	-15 57	10.0
30	19 12.5	-16 28	9.9
Jun 6	19 08.6	-17 04	9.8
13	19 03.7	-17 45	9.7
20	18 57.9	-18 29	9.6
27	18 51.4	-19 16	9.4
Jul 4	18 44.7	-20 05	9.3
11	18 38.2	-20 52	9.5
18	18 32.1	-21 38	9.7
25	18 26.7	-22 21	9.9
Aug 1	18 22.4	-23 02	10.0
8	18 19.3	-23 38	10.2
15	18 17.5	-24 12	10.4
22	18 17.0	-24 42	10.5
29	18 17.8	-25 09	10.6
Sep 5	18 19.8	-25 32	10.8
12	18 23.0	-25 53	10.9
19	18 27.3	-26 11	11.0
26	18 32.6	-26 25	11.1

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)	FQ	Dec 28 – Jan 12	Jan 04	230°	+49°	41	110
alpha-Centaurids (ACE)	FM	Jan 31 – Feb 20	Feb 08	210°	–59°	56	6
gamma-Normids (GNO)	LQ	Feb 25 – Mar 28	Mar 14	239°	–50°	56	6
Lyrids (LYR)	NM	Apr 14 – Apr 30	Apr 22	271°	+34°	49	18
pi-Puppids (PPU)*	NM	Apr 15 – Apr 28	Apr 23	110°	–45°	18	var
eta-Aquarids (ETA)	FM	Apr 19 – May 28	May 05	338°	–01°	66	50
eta-Lyrids (ELY)	FM	May 03 – May 14	May 08	287°	+44°	43	3
June Bootids (JBO)*	FQ	Jun 22 – Jul 02	Jun 27	224°	+48°	18	var
Pisces Austrinids (PAU)	FQ	Jul 15 – Aug 10	Jul 27	341°	–30°	35	5
Southern delta-Aquarids (SDA)	FQ	Jul 12 – Aug 23	Jul 29	340°	–16°	41	25
alpha-Capricornids (CAP)	FQ	Jul 03 – Aug 15	Jul 29	307°	–10°	23	5
Perseids (PER)	LQ	Jul 17 – Aug 24	Aug 12	048°	+58°	59	100
kappa-Cygnids (KCG)	NM	Aug 03 – Aug 25	Aug 17	286°	+59°	25	3
Aurigids (AUR)	FM	Aug 28 – Sep 05	Aug 31	091°	+39°	66	6
September Perseids (SPE)	LQ	Sep 05 – Sep 21	Sep 09	048°	+40°	64	5
Draconids (DRA)*	LQ	Oct 06 – Oct 10	Oct 08	262°	+54°	20	10
Southern Taurids (STA)	LQ	Sep 10 – Nov 20	Oct 10	032°	+09°	27	5
delta-Aurigids (DAU)	LQ	Oct 10 – Oct 18	Oct 11	084°	+44°	64	2
epsilon-Geminids (EGE)	NM	Oct 14 – Oct 27	Oct 18	102°	+27°	70	3
Orionids (ORI)	FQ	Oct 02 – Nov 07	Oct 21	095°	+16°	66	20
Leo Minorids (LMI)	FQ	Oct 19 – Oct 27	Oct 24	162°	+37°	62	2
Northern Taurids (NTA)	NM	Oct 20 – Dec 10	Nov 12	058°	+22°	29	5
Leonids (LEO)	NM	Nov 06 – Nov 30	Nov 18	152°	+22°	71	15
alpha-Monocerotids (AMO)	FQ	Nov 15 – Nov 25	Nov 21	117°	+01°	65	Var
Phoenicids (PHO)	FM	Nov 28 – Dec 09	Dec 02	018°	–53°	18	Var
Puppid-Velids (PUP)	LQ	Dec 01 – Dec 15	Dec 07	123°	–45°	40	10
Monocerotids (MON)	LQ	Dec 05 – Dec 20	Dec 09	100°	+08°	42	3
sigma-Hydrids (HYD)	NM	Dec 03 – Dec 15	Dec 09	127°	+02°	58	7
Geminids (GEM)	NM	Dec 04 – Dec 17	Dec 14	112°	+33°	35	150
Coma Berenicids (COM)	NM	Dec 12 – Dec 23	Dec 16	175°	+18°	65	3
Dec. Leonis Minorids (DLM)	FQ	Dec 05 – Feb 04	Dec 19	161°	+30°	64	5
Ursids (URS)	FQ	Dec 17 – Dec 26	Dec 22	217°	+75°	33	10

Table Notes (above)

Shower Name The shower is named after the constellation 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

Ptolemy's Constellations above are in blue (see p. 34)

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(Guy) **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

See page 144 for legend.

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

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 10pm	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		
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

Catalog 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 (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

Following is a list of places of astronomical interest. These facilities cater to the public with tours and/or displays. Information is subject to change. Links are also on our site: www.quasarastronomy.com.au

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. They also have a Facebook page. Email <info@bathurstobservatory.com.au>.

www.bathurstobservatory.com.au

CANBERRA DEEP SPACE COMMUNICATION COMPLEX (TIDBINBILLA)

The complex is located 35 km south-west of Canberra and is a major link in NASA's Deep Space Network. Tidbinbilla sends and receives radio signals from distant spacecraft in our Solar System. The centrepiece is the 70-metre antenna, the largest in Australia. The Visitor Centre incorporates audio/visual presentations, exhibits, models and images from the spacecraft including an actual Moon rock. The 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/ twitter.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. Contact Paul Hatchman 0413 047 782, email <VP_Crago@asnsw.com>.

www.asnsw.com/crago/index.html or 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

DARBY FALLS OBSERVATORY

The observatory is located on Observatory Road (off the road to Mt. McDonald) Darby Falls, Cowra, Bookings are essential. Contact Mark Monk (02) 6345 1900, email <darbysob@gmail.com>.

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 (see also entry under Mobile Planetariums, page 148) also run public sessions during some school holidays, see website for details. Bookings are essential. goto.mq/planetarium

MILROY OBSERVATORY

Milroy Observatory at Coonabarabran has the largest publicly available telescope as well as a number of others for their evening stargazing sessions. They cater for the public, amateurs and professionals. 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 are essential. Contact (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 opening hours and events and follow them on Facebook for current news and updates. Email <pmobs.info@gmail.com>.

www.pmobs.org.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. These include Australia's two largest optical telescopes, the Australian National University's 3.9 metre Anglo Australian Telescope and the 2.3 metre Advanced Technology Telescope. Examples of international organisations include: the Las Cumbres Observatory Global Telescope Network, iTelescope.Net (the public global online network), the robotic telescopes of HAT-South, Project Solaris (searching for exoplanets), PROMPT (SKYNET) looking for Gamma Ray Bursts and the Korean Microlensing Telescope.

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, more information on the web. Contact Amanda Wherrett (Public enquiries and tour information, Outreach Officer) (02) 6842 6363, email <amanda.wherrett@anu.edu.au>.

www.sidingspring.com.au or www.starfest.org.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

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

SYDNEY OBSERVATORY

Part of the Museum of Applied Arts and Sciences, 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.

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

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, about 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, email Mac Jonson on <macsen2@yahoo.com> or ph (07) 4153 6469.

alloway-observatory-bundaberg.webs.com

CHARLEVILLE COSMOS CENTRE AND OBSERVATORY

The Charleville Cosmos Centre and public observatory is located on the airport precinct off the Cunnamulla Rd. They offer general night-time observing sessions and longer personalised observing sessions. During the day the centre is open and conducts several activities including Sun Viewing through a solar telescope, and Astronomy by Day which includes interactive displays and presentations in the Outback Stargazing Theatre. Guides also give presentations on meteorites from their Cosmos Centre collection several times per day. The planetarium is a new product on offer and available for sessions throughout the day and also offers a night sky option on a cloudy night. Special programmes can be arranged for groups and schools, call(07) 4654 2787 otherwise contact (07) 4654 7771, email <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 concerning 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 Tuesday to Sunday (open on Monday during Qld school holidays). Contact (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. The drive from Surfers Paradise is only 45 minutes. 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 at Stockport in February, May, August and November. See website for details. Contact ASSA Info Line (08) 8261 3354, email <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

UNIVERSITY OF SOUTH AUSTRALIA, ADELAIDE PLANETARIUM

The Adelaide Planetarium is open seven days a week by appointment for group and private bookings. Adult education courses are held throughout the year along with school holiday programs. See website for session times and other information. Bookings essential. Contact (08) 8302 3138, email <adelaide.planetarium@unisa.edu.au>. www.unisa.edu.au/planetarium/

TASMANIA

LAUNCESTON PLANETARIUM

The Launceston 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 D r 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 <bas@cbl.com.au>. observatory.ballarat.net

BENDIGO PLANETARIUM @ DISCOVERY

Part of the Discovery Science and Technology Centre, see website for details. Contact (03) 5444 4400, email <planetarium@discovery.asn.au>.

www.discovery.asn.au

MELBOURNE PLANETARIUM

This is Australia's first digital planetarium and is at Scienceworks in Spotswood. The theatre seats 150 and produces shows for all ages. The planetarium is open seven days a week from 10 am, 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 or email. Contact (08) 9293 8255, email <info@perthobservatory.com.au>. www.perthobservatory.com.au

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 (PARKES)

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 29th NACAA will be held at Parkes NSW in 2020, hosted by the Central West Astronomical Society. 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 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. VicSouth 2019 is scheduled for 25–28 October. In 2020 it is planned for 16–19 October. 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

www.mpas.asn.au/vastroc.html

WESTERN AUSTRALIA

ASTROFEST WA

WA's biggest astronomy festival is held in Perth annually. 2019 was the 10th anniversary. It's free and great family fun with 50+ telescopes to look through, special guest presenters, hands on activities for kids, astrophotography exhibition, space shows, space domes and information stalls. Discover more about astronomy and stargazing in WA and how you can get involved, start studying or begin a career. The next is on Saturday 29 February 2020 from 5:30 pm to 9:30 pm at Curtin Stadium, Curtin University, next to Edinburgh Oval, Bentley. Hosted by Astronomy WA.

www.astronomywa.net.au

ORGANISATIONS

AUSTRALIA

THE ASTRONOMICAL SOCIETY OF AUSTRALIA

The Astronomical Society of Australia 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 through 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

NEW SOUTH WALES & ACT

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 to 12 student from the ACT region is welcome to apply. Students wishing to visit MSATT or take on projects in 2020* should contact Geoff McNamara for a copy of the MSATT Student Guide. There is no cost for any MSATT activities.
*The 2020 observing season begins with the end of daylight saving time on 5/4/20. Contact Geoff McNamara phone/text 0449 966 200,
email <geoffrey.mcnamara@ed.act.edu.au>. msatt.teamapp.com/

PRACTICAL ASTRONOMY (SASPAC)

A practical astronomy course for beginners and interested amateurs. This is a nine 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 of Sydney 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

SOUTH AUSTRALIA

ASTRONOMY COURSES AT ADELAIDE PLANETARIUM

A variety of astronomy themed courses are conducted at the Adelaide Planetarium during the year. See their website (search courses) for details.

www.unisa.edu.au

TASMANIA

NIGHT SKY EXPLORER COURSE (HOBART)

Beginner astronomy courses are conducted by members of the Astronomical Society of Tasmania, details on their website.
Email <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 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 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 & Diana Zenner 0419 112 899,
Fax (02) 9753 1898, email <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 Ian Maclean 0417 601 490.

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 eight 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 <info@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

ASTRONOMICAL SOCIETIES

NEW SOUTH WALES & ACT

ASTRONOMICAL SOCIETY OF ALBURY WODONGA meets regularly on the first Wednesday of each month (except January) at La Trobe University, Wodonga at 7 pm.
Contact David Thurley (02) 6040 3704 <enquiries@asaw.org.au>.

PO Box 1500, Lavington NSW 2641 www.asaw.org.au

ASTRONOMICAL SOCIETY OF NSW meets once per lunar month where professional and amateur astronomers are invited to talk. See their website for details. Contact <secretary@asnsw.com>.

PO Box 870, Epping NSW 1710 www.asnsw.com

ASTRONOMICAL SOCIETY OF THE HUNTER meets at the Billabong Restaurant, East Maitland Bowling Club on the 1st Friday each even month at 6:30 PM. Contact Col Maybury (02) 4937 4664 or 0427 889 653 <cma45714@bigpond.net.au>.

21 Brooks St, Kurri Kurri NSW 2327

ASTRONOMICAL SOCIETY OF COONABARABRAN meets on the third 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>.

PO Box 611, Coonabarabran NSW 2357

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, Weston, ACT. Contact Fay Neil (02) 6231 0851 <casadmin@gmail.com>.

PO Box 1338, Woden ACT 2606 casastronomy.org.au

CENTRAL WEST ASTRONOMICAL SOCIETY INC (PARKES) meetings are held on the first Friday of the month except January, at the Parkes Observatory Visitors Centre, commencing 7:30 pm, visitors welcome. Contact Secretary <secretary@cwas.org.au>.

PO Box 819, Parkes NSW 2870 www.cwas.org.au

CLARENCE VALLEY ASTRONOMICAL SOCIETY Contact Steve Fletcher (02) 6643 3288 <arrowdodgerfletch@hotmail.com>.

97 Skinner St, South Grafton NSW 2460 Find them on Facebook

COFFS HARBOUR ASTRONOMICAL SOCIETY INC meets on the first 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>.

ILLAWARRA ASTRONOMICAL SOCIETY meets at 7:30 pm, every second Tuesday of the month at the Wollongong Science Centre. Contact <IAS.secretary@outlook.com>.

PO Box 3092, Balgownie NSW 2519

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>.

PO Box 17, Minto NSW 2566 www.macastro.org.au

NORTHERN SYDNEY ASTRONOMICAL SOCIETY INC meets at St Ignatius College at Lane Cove third Tuesday of every month. Contact <nsas@nsas.org.au>.

PO Box 56, Lane Cove NSW 1595 www.nsas.org.au

PORT MACQUARIE ASTRONOMICAL ASSOCIATION INC holds regular monthly meetings. Check their Website and Facebook page for further information or contact them at <pmobs.info@gmail.com>.

1A Stewart Street, Port Macquarie NSW 2444 www.pmobs.org.au

SHOALHAVEN ASTRONOMERS meet at the University Of Wollongong, Shoalhaven Campus, Library and Resources Centre, Seminar Room LG.25 on the third Friday of the month at 7 for 7:30 pm.
Contact Mark Town (president) 0434 861 122 <marktown@shoal.net.au>.

PO Box 1053, Nowra NSW 2541 www.shoalhavenastronomers.asn.au

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>.

PO Box 31, Sutherland NSW 1499 www.sasi.net.au

SYDNEY CITY SKYWATCHERS meet at Sydney Observatory on the first Monday of the month (except January and December) at 6:30 pm. Contact Secretary, Elizabeth (02) 9398 9705

Sydney Observatory, 1003 Upper Fort St, Millers Point NSW 2000
www.sydneycityskywatchers.org

SYDNEY NORTHWEST 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>.

25 Tinobah Place, Maryland 2287 www.nas.org.au

UNIVERSITY OF NEW ENGLAND AND NORTHERN TABLELANDS ASTRONOMICAL SOCIETY meetings are held third Tuesday each month at the Kirby Observatory at 7 for 7:30 pm.
Contact Anne Parnell (02) 6772 1958 <parnellansw@gmail.com>.

Ms Anne Parnell, 81 Perrott St Armidale NSW 2350 www.unentas.org.au

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>.

PO Box 400, Kingswood NSW 2747 wsaag.org

TAMWORTH REGIONAL ASTRONOMY CLUB INC holds meetings on the 1st Saturday of every month. The evening will commence at 7 pm with an astronomy presentation (approximately 30 minute talk) and then telescope viewing. The venue is the Conference Room at the Botanic Gardens, Tamworth. (Public are welcome)

A Club BBQ and Technical/Dark-sky night is held two Saturdays after the meeting at the club's Dark Sky Site. Contact phone 0458 772 747 for confirmation and details.

PO Box 1023, Tamworth NSW 2340 www.tamworthastronomy.com.au

WOLLONGONG AMATEUR ASTRONOMY CLUB has monthly meetings on the first 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

GOVE AMATEUR ASTRONOMERS

www.facebook.com/GoveAstronomers

QUEENSLAND

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 'email us' link on the contact page of their website.

PO Box 6101, St Lucia Qld 4067 www.aaq.org.au

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>.

PO Box 15892, City East Qld 4002 www.bas.asn.au

BUNDABERG ASTRONOMICAL SOCIETY meetings are held at Alloway Observatory on Fridays, see website for more info.

alloway-observatory-bundaberg.webs.com

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 601490

www.facebook.com/FNQAstronomers

ASTRONOMY 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>.

PO Box 197, Mount Isa Qld 4825

REDLANDS ASTRONOMICAL SOCIETY meets on the second 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>.

PO Box 2048, Wellington Point Qld 4160 www.ras.org.au

SOUTH EAST QUEENSLAND ASTRONOMICAL SOCIETY meets third 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>.

PO Box 60, Everton Park Qld 4053 www.seqas.org

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

PO Box 867, Beenleigh Qld 4207 www.sas.org.au

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.
Contact David Reitsma 0419 644 313 www.astronomytsv.org.au

SOUTH AUSTRALIA

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>.

GPO Box 199, Adelaide SA 5001 www.assa.org.au

TASMANIA

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>.

GPO Box 1654, Hobart Tas 7001 www.astas.org.au

VICTORIA

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

GPO Box 1059, Melbourne Vic 3001 www.asv.org.au

ASTRONOMY BENALLA meets on the third 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

128 Cowan St, Benalla Vic 3672 www.astronomybenalla.org.au

ASTRONOMICAL SOCIETY OF GEELONG meets every Friday at 7:30 pm at the ASG Club Room, Geelong Showgrounds, Breakwater Road, Geelong.

PO Box 1799, Geelong Vic 3220 www.asog.org.au

BALLAARAT ASTRONOMICAL SOCIETY holds members meetings, 2nd Friday of the month, beginning in February. Contact 0429 199 312 <bas@cbl.com.au>.

PO Box 284, Ballarat Vic 3353 observatory.ballarat.net

LATROBE VALLEY ASTRONOMICAL SOCIETY meets on the second 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>.

PO Box 459, Moe Vic 3825 www.LVAstro.org

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>.

PO Box 596, Frankston Vic 3199 www.mpas.asn.au

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>.

420 Paternoster Road, Mt Burnett, VIC 3781 mbo.org.au

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.

c/o Snake Valley Post Office, Snake Valley Vic 3351

ballaratman.wixsite.com/svastro

WEST AUSTRALIA

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>.

PO Box 1100, Bunbury WA 6231 www.assw.org.au

ASTRONOMICAL SOCIETY OF WESTERN AUSTRALIA meets at 8 pm on the second Monday of every month (except January) at the South Perth Bridge Club, cnr Brittain Street and Barker Avenue, Como. Visitors most welcome. Contact <aswa.info@aswa-inc.org.au>.

PO Box 421, Subiaco WA 6904 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 B.C. 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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Step outside and look up at the night sky. We are fortunate to live in Australia, where the stars of the Southern Hemisphere are spectacular. Does it leave you with a sense of wonder, wanting to know more about the heavens above? Then this book is for you.

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- When will the Moon rise or set?
- Which constellation is that?
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ESTIMATING ANGLES IN THE SKY When 0.5 metres from the eye, each division on this scale corresponds to 1° of arc.

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