DARK SKY PLACES

Discover the UK's best places for observing free from the frustration of light pollution

1 Moore's Reserve, South Downs National Park
Bronze tier International Dark Sky Reserve since 2016
www.southdowns.gov.uk/enjoy/dark-night-skies

2 Isle of Sark
International Dark Sky Community since 2011
www.sark.co.uk

3 Bodmin Moor
Silver tier International Dark Sky Landscape since 2017
www.cornwall-aonb.gov.uk/bodminmoor

4 Exmoor National Park
Silver tier International Dark Sky Reserve since 2011
www.exmoor-nationalpark.gov.uk

5 Brecon Beacons National Park
Silver tier International Dark Sky Reserve since 2013
www.beacons-npa.gov.uk

6 Elan Valley Estate
Silver tier International Dark Sky Park since 2015
www.elanvalley.org.uk

7 Snowdonia National Park
Silver tier International Dark Sky Reserve since 2015
www.snowdonia.gov.wales

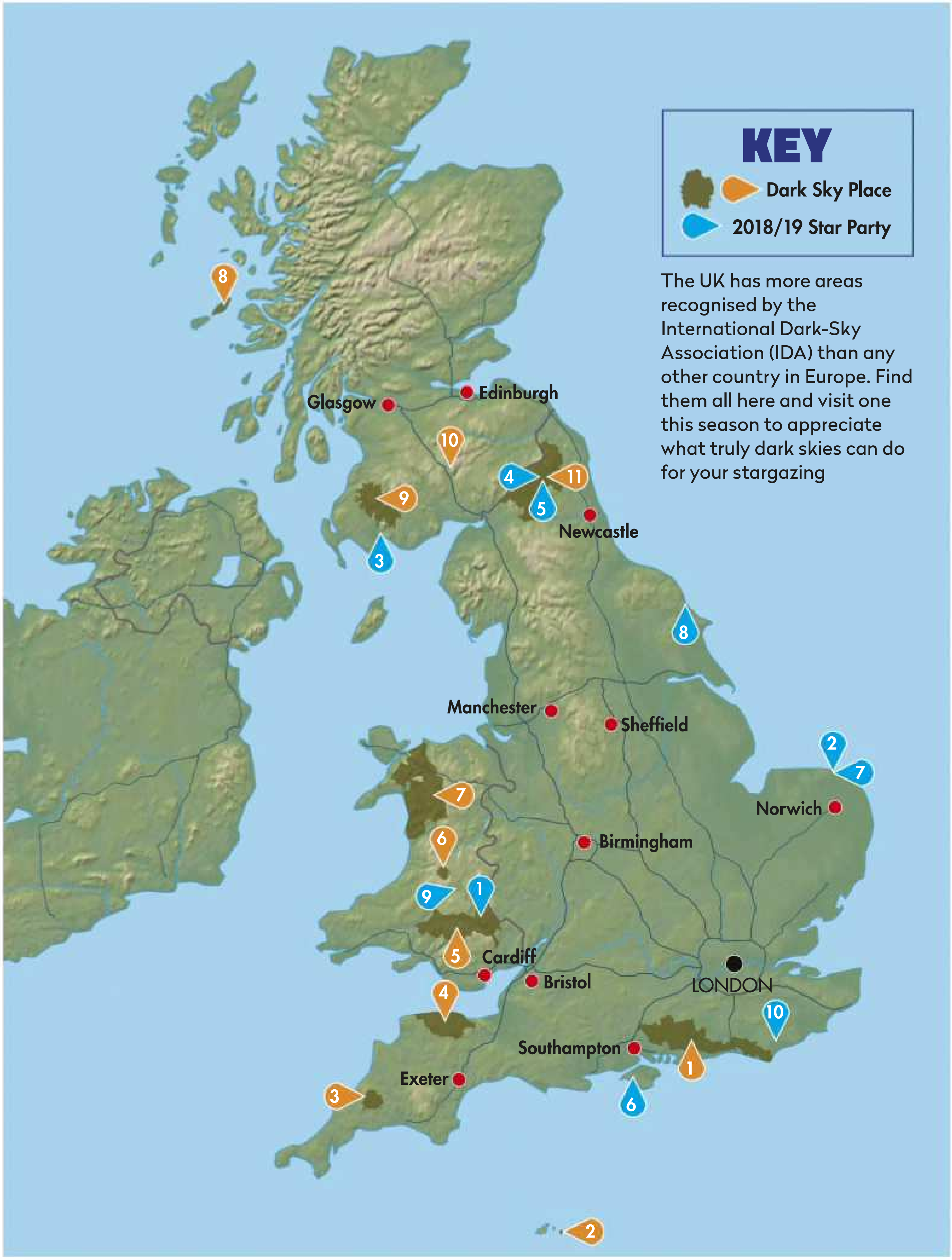
8 Isle of Coll
International Dark Sky Community since 2013
darkskycoll.co.uk

9 Galloway Forest Park
Gold tier International Dark Sky Park since 2009
www.forestry.gov.uk/darkskygalloway

10 Moffat
International Dark Sky Community since 2016
www.visitmoffat.co.uk

11 Northumberland National Park and Kielder Water & Forest Park
Gold tier International Dark Sky Park since 2013
www.northumberlandnationalpark.org.uk

Find out more about the IDA, its dark sky accreditation and dark sky sites around the world at **darksky.org**. To find more dark sky sites locally in the UK visit the Dark Sky Discovery website at **www.darkskydiscovery.org.uk**



The UK has more areas recognised by the International Dark-Sky Association (IDA) than any other country in Europe. Find them all here and visit one this season to appreciate what truly dark skies can do for your stargazing

STAR PARTIES IN 2018-2019

Join a host of fellow astronomers for pitch black nights of observing at a star party

1 AstroCamp
Date: Autumn, 8-11 September 2018. Spring, 27-30 April 2019
Info: **astrocamp.awesomeastronomy.com**

2 Equinox SkyCamp
Date: 6-13 September 2018
Info: **las-skycamp.org**

3 Galloway Gathering
Date: Autumn, 3-8 October 2018. Spring, 27 February-4 March 2019
Info: **www.gallowayastro.com**

4 Kielder Star Camp
Date: Autumn, 10-15 October 2018. Spring, 6-11 March 2019
Info: **sites.google.com/a/richarddarn.com/kielder-forest-star-camp-bookings/what-is-the-star-camp**

5 People's Star Party
Date: 2-3 November 2018
Info: **kieldercampsite.co.uk/events/the-peoples-star-party-stargazing-for-beginners-2**

6 Isle of Wight Star Party
Date: March 2019 (dates TBC)
Info: **www.iowstarparty.org/IOWSP/Location.html**

7 Spring Star Party
Date: 1-8 April 2019
Info: **www.starparty.org**

8 StarFest
Date: August 2019 (dates TBC)
Info: **www.scarborough-ryedale-as.org.uk/saras/starfest/about-starfest**

9 Solarsphere
Date: August 2019 (dates TBC)
Info: **www.solarsphere.events**

10 Herstmonceux Astronomy Festival
Late August 2019 (dates TBC)
Info: **www.the-observatory.org**

BBC

TOP TECHNIQUES FOR IMAGING THE ICE GIANTS

THE UK'S BIGGEST SELLING ASTRONOMY MAGAZINE

Sky at Night

#160 SEPTEMBER 2018

FREE MINI MAG

THE NEW OBSERVING SEASON

Get ready for the return of dark skies

- Autumn-winter 18-19 observing guide
- Quick kit maintenance
- Best new equipment
- Star parties and dark sky places

Colours of the COSMOS

Create your best ever astrophotos with 8 easy ways to capture colour

The Sun sets on DAWN

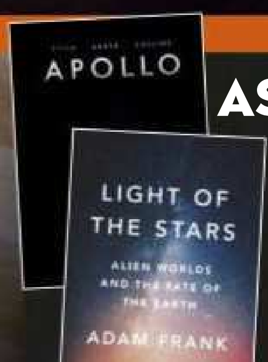
What the first ever mission to the two largest asteroids has revealed

WATCH THE SKY AT NIGHT

Observing the cosmic dawn from the Australian outback

JUPITER'S NEW MOONS

We speak to the planet hunter who discovered a trove of Jovian satellites



ASTRO BOOK PREVIEWS

An Apollo 11 graphic novel and the search for life beyond Earth

FREE EXTRA CONTENT ONLINE

Welcome

We can help you make the most of the returning long nights

Putting together the great, free mini mag that you'll find in this issue got us really excited about the start of the new observing season. With more time to spend under the stars as the nights lengthen, our mini mag looks ahead to the best times to see everything that we love: planets, galaxies, clusters, nebulae, the Moon and much more. You'll also find tips on getting your scope dark-sky ready, and all the star parties and dark sky places in the UK.

With the nights lengthening, it's also a good time for us amateur astronomers to consider an observing getaway. We have an expert view of some of the darkest areas in that favourite destination for a summer holiday, Portugal, written by one of the country's top astrophotographers, Miguel Claro. Turn to page 72 to discover why you shouldn't discount it in winter as well!

On the subject of astrophotography our feature on page 36 looks at a key factor when creating images of any target in the night sky: colour. Often the subject of healthy debate, colour is an important element in the artistry of astrophotography, and writer Will Gater guides you through the practical ways in which you can portray it as accurately as possible.

For suggestions of great targets to image or observe, why not try our weekly eNewsletter? Delivered to your email inbox every seven days it also tells you the Moon phases for the week, moonrise times and more. To subscribe visit **www.skyatnightmagazine.com/iframe/newsletter-signup**.

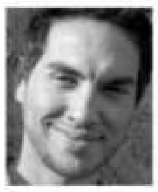
Enjoy the issue!

Chris Bramley Editor

PS Our next issue goes on sale 20 September.

This month's contributors include...

Miguel Claro
Astrophotographer



Let Miguel be your tour guide on a trip around the beautiful dark sky sites of his homeland, Portugal. *Page 72*

Lucie Green
Solar physicist

Lucie is looking forward to the imminent launch of Solar Orbiter, a sun-seeking ship she helped to design. *Page 19*

Chris Lintott
***Sky at Night* presenter**

This month a new way of measuring the mass of distant stars using a technique called microlensing has caught Chris's eye. *Page 13*

Jasmin Fox-Skelly
Science writer

With the NASA Dawn mission about to run out of fuel, Jasmin assesses what it's revealed for us about Vega and Ceres. *Page 31*

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Sky at Night Lots of ways to enjoy the night sky...

TELEVISION
Find out what *The Sky at Night* team will be exploring in this month's episode on page 17

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Visit our website for reviews, competitions, astrophotos, observing guides and our forum

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All the details of our latest issue, plus news from the magazine and updates to our website

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Listen to the *BBC Sky at Night Magazine* team and guests discuss the latest astro news

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Subscribe for the best targets to observe each week, delivered to your inbox: **bit.ly/sky-enews**

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C = on the cover

NEW TO ASTRONOMY?
Get started with The Guide on page 78 and our online glossary at www.skyatnightmagazine.com/dictionary

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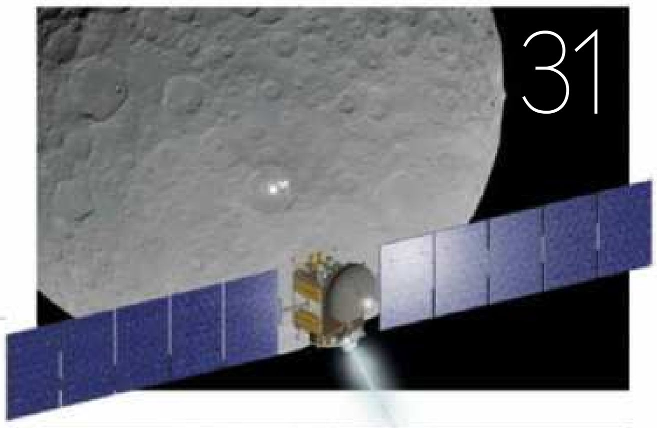


Regulars

SEPTEMBER'S BONUS CONTENT

HOW TO FIND IT

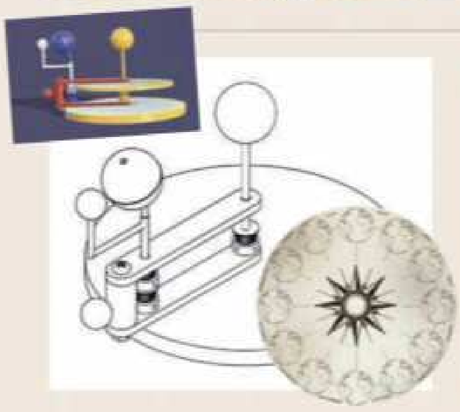
Visit **www.skyatnightmagazine.com/bonuscontent**, select September's bonus content from the list and enter the authorisation code **DQVYG4T** when prompted

THERE'S MORE ONLINE

September highlights

Watch *The Sky at Night*

In a remote part of western Australia lies the Murchison Radio-astronomy Observatory, which earlier this year gave astronomers a glimpse of the cosmic dawn: the moment starlight first flooded the Universe. Chris travels to the Australian outback to visit this remarkable site and find out how radio astronomy is changing the way we view the cosmos.



Build a model of the Sun, Moon and Earth

Download extra images and diagrams to help with this month's *How To...* build a tellurion project on page 81.

Interview: the tale of Jupiter's new moons

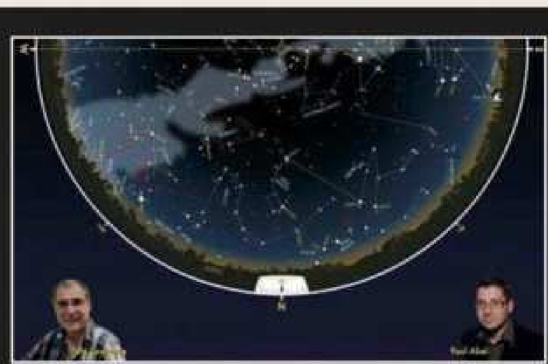
Scott Sheppard reveals how he and his planet-hunting colleagues found a dozen unknown Jovian satellites.

Marking 100 years of Holst's *The Planets*

Download two movements from the celebrated celestial work, then read our feature on page 42 of this issue.

And much more...

- ▷ Hotshots gallery
- ▷ Eye on the sky
- ▷ Extra EQMOD files
- ▷ Binocular tour
- ▷ Equipment review guide
- ▷ Desktop wallpaper
- ▷ Observing forms
- ▷ Deep-sky tour chart



EVERY MONTH

Virtual Planetarium

With Paul Abel and Pete Lawrence

Explore September's night-sky highlights with Paul and Pete

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The circle of star life

Where massive and exploding stars meet cold cosmic gas, stellar newborns are sure to follow

VERY LARGE TELESCOPE, 11 JULY 2018

Newborn stars illuminate surrounding cosmic gas, causing it to glow bright blue in this image taken of star cluster RCW 38. We are able to view incredible celestial scenes such as this because of the infrared capabilities of modern telescopes, which can see through dark dusty clouds and reveal the secrets of the Universe.

Nicely contrasting the blue stellar nursery is a dark, rust-coloured region of cooler clouds, stretching across the middle of the image. The dust and gas may eventually coalesce and collapse under its own gravity to form new stars and perhaps even new planetary systems. This process may also be triggered by the radiation emitted by massive stars or the powerful energy released by exploded stars – called supernovae – as they approach the end of their lives.

ESO/K. MUZIC

▲ Galactic glitter

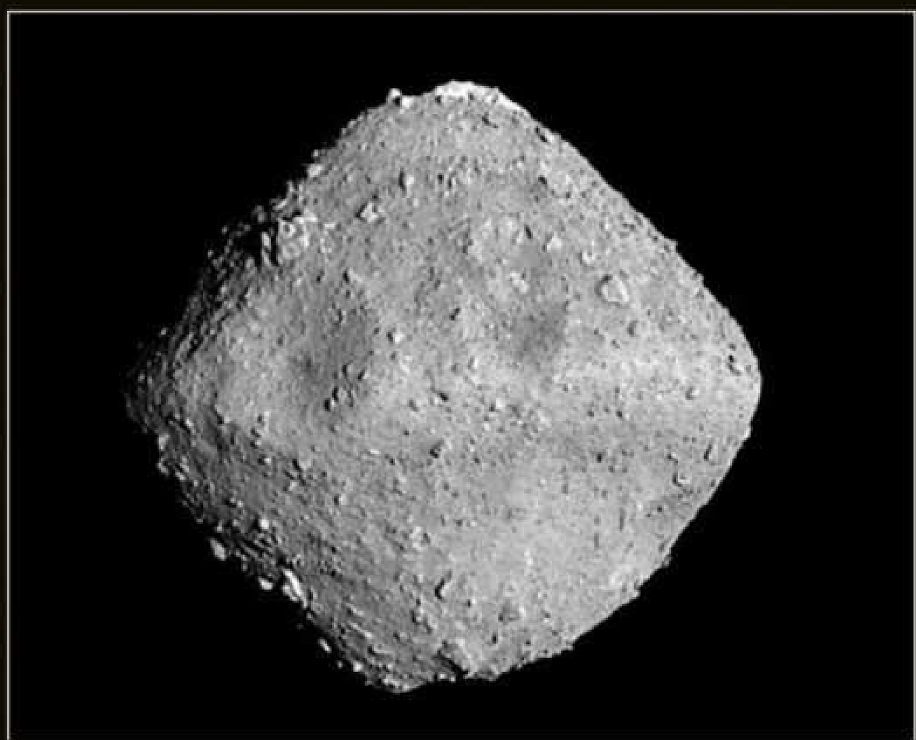
HUBBLE SPACE TELESCOPE, 23 JULY 2018

The multi-coloured specks in images of galaxies reveal a lot about how active the galaxy is. Spiral galaxy NGC 6744 has a core filled with old yellow stars and in the outer arms, blue spots indicate young star clusters, while pink regions point to areas of star formation. NGC 6744 is 200,000 lightyears across: twice the diameter of our own Milky Way.

Ryugu rendezvous ▶

HAYABUSA2 SPACECRAFT, 26 JUNE 2018

The Japan Aerospace Exploration Agency's Hayabusa2 spacecraft took this image of asteroid 162173 Ryugu as it arrived in situ around the object, around 300 million km from Earth. The next stage involves depositing three rovers and a lander on the asteroid. Hayabusa2 is scheduled to return a sample of the ancient space rock to Earth by 2020.



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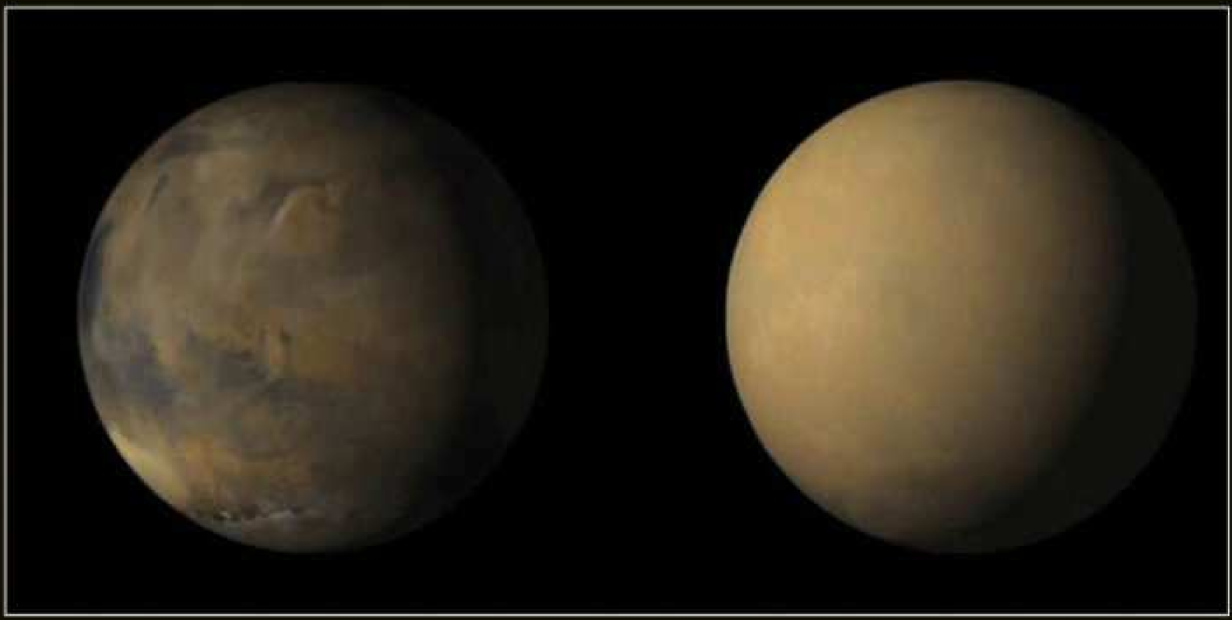


◀ Before and after

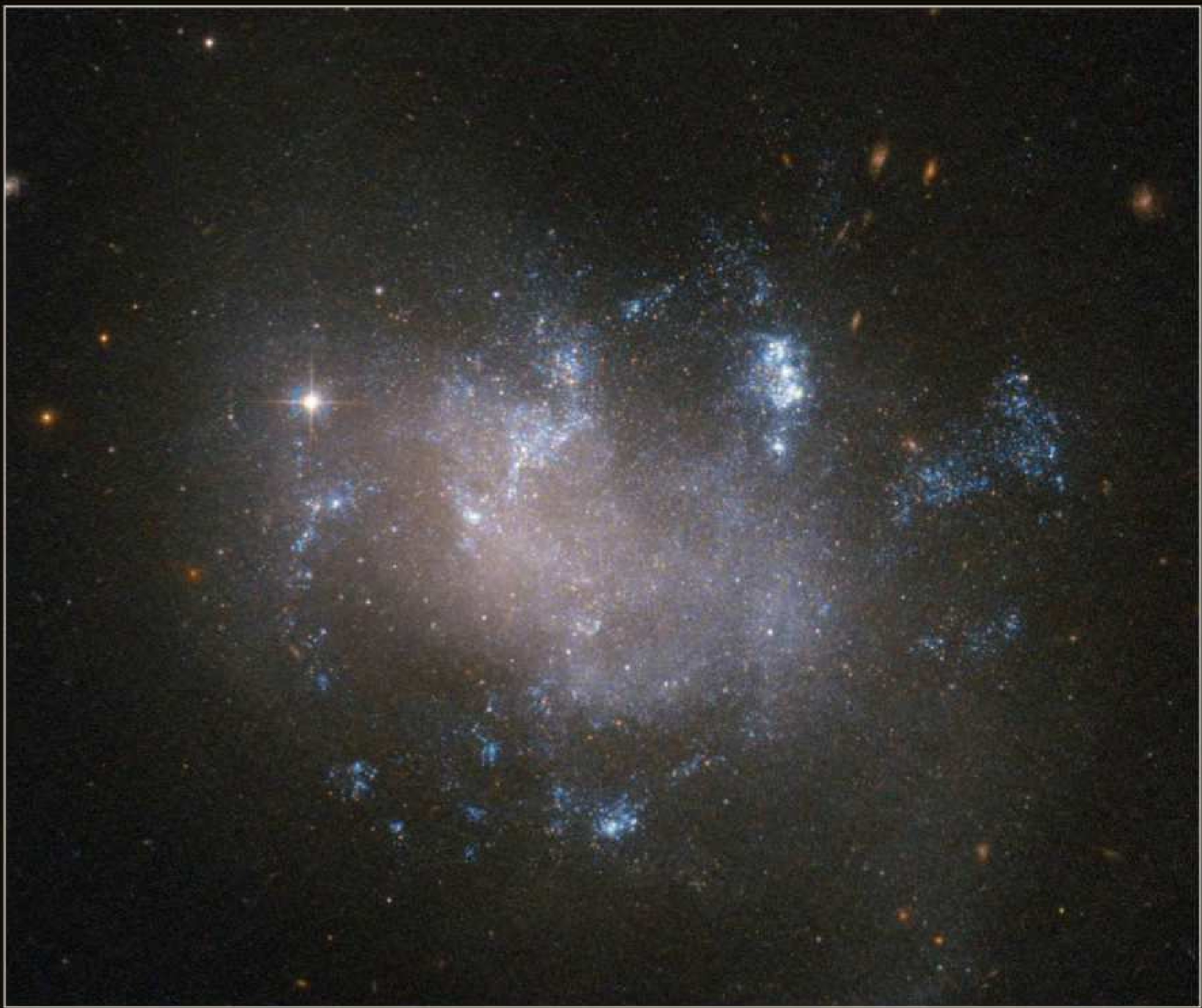
MARS RECONNAISSANCE ORBITER, 19 JULY 2018

Two images reveal the effect of a global dust storm raging across the Red Planet. Left shows Mars on 28 May 2018, and right shows the same view on 1 July. Storms on Mars whipped up the rust-coloured dust and smothered the entire planet, causing problems for the solar-powered Opportunity rover whose solar panels cannot charge its batteries in darkness. These dust storms occur every six to eight years, but scientists still don't understand exactly what causes them (more on page 51).

Cosmic measuring stick ▶

HUBBLE SPACE TELESCOPE, 9 JULY 2018

In 2008 14-year-old Caroline Moore, a young amateur astronomer from New York, discovered a supernova in galaxy UGC 12682, located 70 million lightyears away. Further research revealed it to be a Type Ia supernova, which is a category of exploded white dwarf star. Because these supernovae have consistent luminosity, their apparent intensity when viewed from Earth can be used to measure distances in the cosmos.



◀ Seeing blue

VERY LARGE TELESCOPE, 18 JULY 2018

Neptune glows bright blue in this new image, captured using a telescopic method called laser tomography. This computerised technique helps the VLT compensate for 'seeing', which is the name given to the blurring caused by Earth's atmosphere, thus creating a clear image.

YOUR BONUS CONTENT

A gallery of these and more stunning space images

Bulletin

The latest astronomy and space news written by **Elizabeth Pearson**

PLUS CUTTING EDGE

Our experts examine the hottest new astronomy research papers

COMMENT

by Chris Lintott

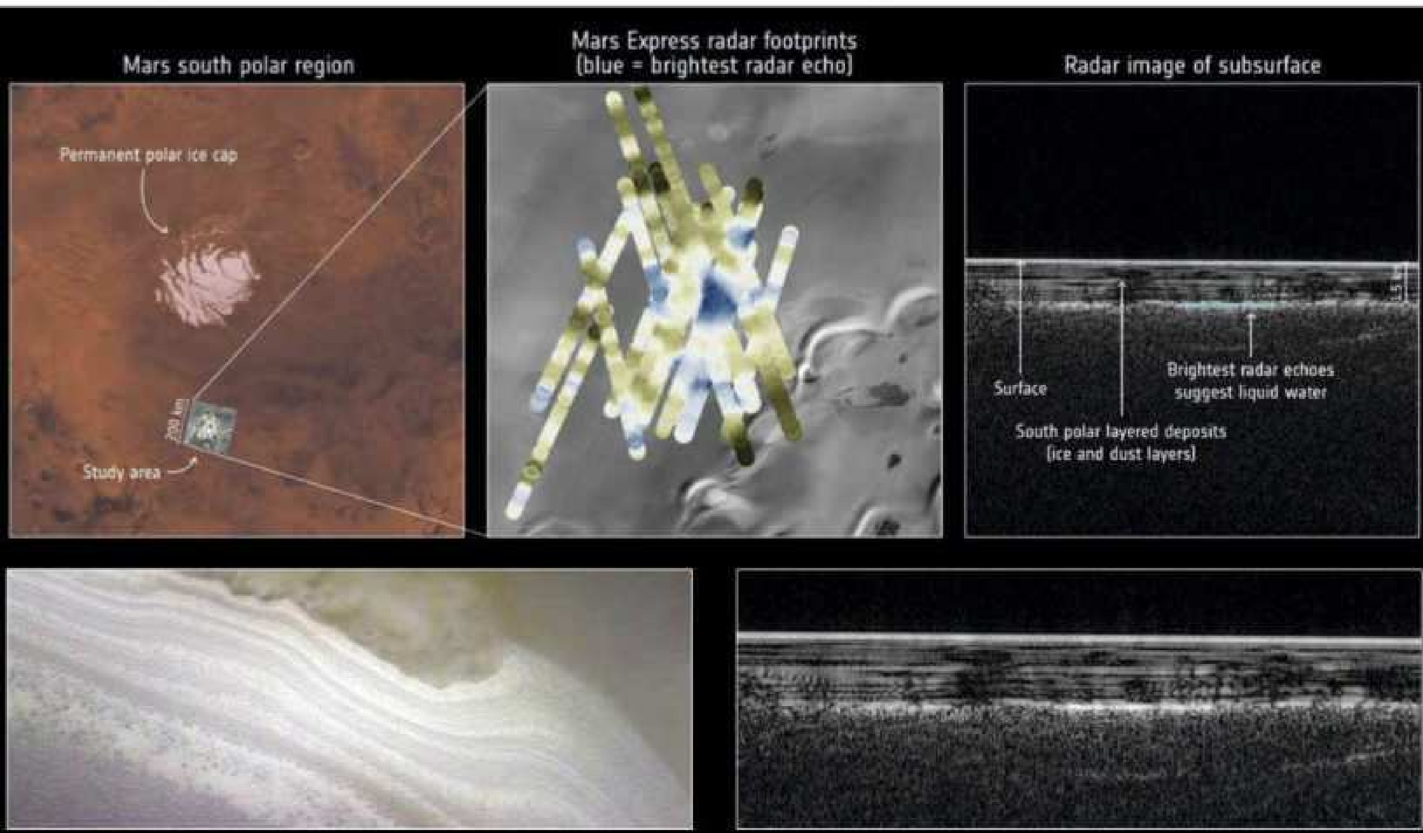
The nearly annual 'discovery' of water on Mars has become something of a joke, as evidence has rolled in that reveals the role that this most precious of substances has played in the Red Planet's history.

This latest discovery, though, is genuinely exciting – liquid water on the planet *now.*

Or at least some briny slush. The temperature in the region is so low that what's been found can't possibly be pure water. Salt lowers the melting point of ice, so in order to be liquid this 'lake' must be salty enough to be uninhabitable by even the most extreme halophilic (salt-loving) bacteria found on Earth.

Does that mean no Martian bacteria exist in this strange lake? I'm not sure. If life was once common there it's possible to imagine evolution inventing ways of coping even with conditions that are this extreme. Maybe one day we'll drill through the Martian ice and take a look.

CHRIS LINTOTT co-presents *The Sky at Night*



▲ (Top row and bottom right) Data from Mars Express's Advanced Radar appears to reveal a subsurface lake on Mars. (Bottom left) An ExoMars image from May 2018 showing layered deposits at the south pole of Mars

Evidence of water FOUND ON MARS

Mars Express detects possible reservoir beneath Martian south pole

After decades of searching, evidence of a reservoir of liquid water has been found beneath the surface of Mars. The discovery was made by ESA's Mars Express spacecraft, using its Mars Advanced Radar for Subsurface and Ionosphere Sounding instrument (MARSIS), the first radar sounder ever to orbit another planet.

MARSIS uses radar signals to probe the upper layers of Mars's south polar region, allowing astronomers to piece together the structure hidden beneath. The top 1.5km appear to be made up of layers of dust and ice, but underneath this is a particularly reflective layer. Repeated measurements revealed that the body of water is at least several tens of centimetres deep and around 20km wide.

"This subsurface anomaly on Mars has radar properties matching water or water-rich sediments," says Roberto Orosei, the principal investigator of the MARSIS experiment, who led the study. "This is just one small study area; it is an exciting prospect to think there could be more of these underground pockets of water elsewhere, yet to be discovered," says Orosei.

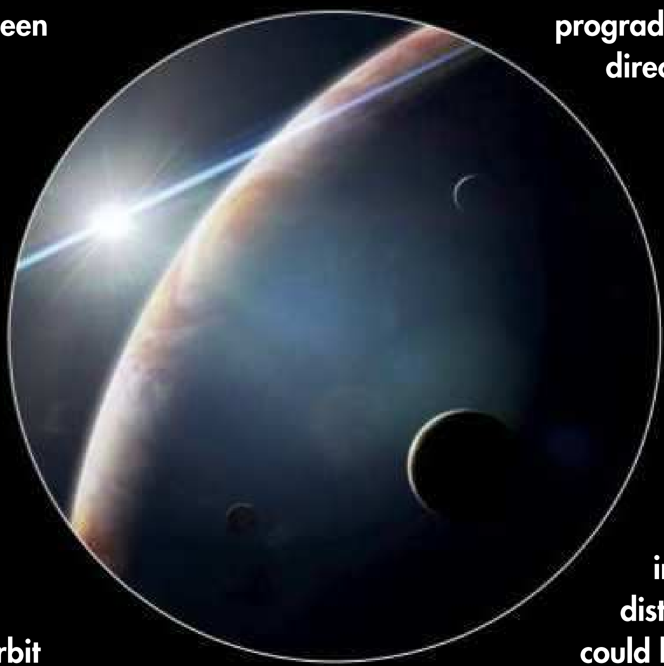
Though we know that Mars used to be wet billions of years ago, this is the first time liquid water has been found on the planet as it is now. It's thought that the water is salty; this, combined with the pressure from the rocks above, would prevent it from either evaporating away or freezing.

"This thrilling discovery is a highlight for planetary science and will contribute to our understanding of the evolution of Mars, the history of water on our neighbour planet and its habitability," says Dmitri Titov, the project scientist for Mars Express.

▸ **See Comment, left**

skyatnightmagazine.com 2018

12 new moons found at Jupiter



▲ Jupiter extends its lead over Saturn as the planet with the most moons

A dozen new moons have been discovered around Jupiter, bringing its total to 79. The moons were discovered by chance in 2017, when a team searching for a ninth planet on the outskirts of our Solar System found some odd objects near the planet. It took astronomers another year to show they were orbiting Jupiter.

Nine are part of a distant swarm of moons moving in retrograde, meaning they orbit in the opposite direction to Jupiter's spin. Two are closer to Jupiter and have a prograde orbit, meaning the same direction as Jupiter's spin.

"Our other discovery is a real oddball with an orbit like no other known Jovian moon," says Scott S Sheppard of the Carnegie Institution for Science. It's also Jupiter's smallest known moon at less than 1km in diameter.

The moon, which the team calls Valetudo, moves in prograde but at the same distance as the retrogrades. It could be the remnant of a large moon that collided with another, creating the retrograde swarms.
carnegiescience.edu

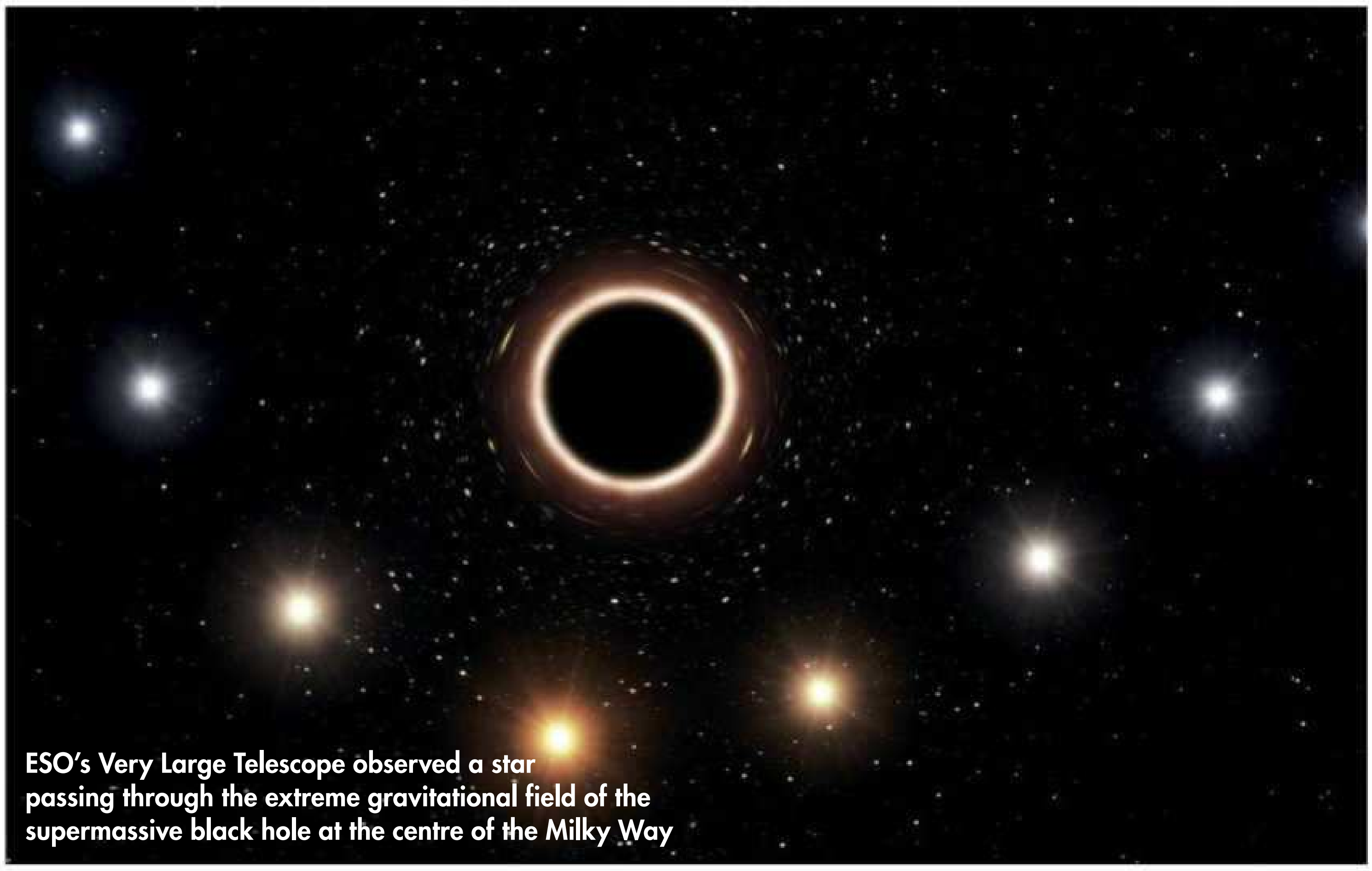
Black hole proves Einstein right

Extreme test around behemoth at Milky Way's centre observed by ESO

The first ever test of Einstein's theory of general relativity under the extreme gravity near a supermassive black hole has been a success.

Astronomers observed S2, a star that orbits around the black hole at the centre of the Milky Way. In May 2018, S2 made its closest approach at a distance of less than 20 billion km (134 times the Earth-Sun distance). This accelerated the star to relativistic speeds. According to Einstein's theory, its path should be subtly deflected from that predicted by Newtonian physics alone, a difference which ESO's Very Large Telescopes was able to see.

"Here in the Solar System we can only test the laws of physics now and under certain circumstances. So it's very important to also check that those laws are still valid where the gravitational fields are very much stronger," says Françoise Delplancke from ESO.
www.eso.org



ESO's Very Large Telescope observed a star passing through the extreme gravitational field of the supermassive black hole at the centre of the Milky Way

NEWS IN BRIEF

LONG LOST LOCAL GALAXY

The Milky Way has a long-lost sibling. Recent simulations show that dwarf galaxy M32 is the core of a galaxy that was once as large as our own but had its outer stars stripped away by Andromeda. "Astronomers have been studying the Local Group – the Milky Way, Andromeda and their companions – for so long. It was shocking to realise that the Milky Way had a large sibling, and we never knew about it," says Eric Bell from the University of Michigan who co-led the study.

MARS ROVER NEEDS A NAME

Tim Peake and ESA have launched a new competition to name the ExoMars rover, which will head to the Red Planet in 2020. Any citizen of an ESA member or associate member state can suggest a name for the rover, which will investigate how Mars has changed over time and how habitable the world was in the past. The competition closes on 10 October and the winner will be chosen by a panel of judges. For more details visit: **exploration.esa.int/mars/**

NEWS IN BRIEF

UK INVESTS IN SPACEPORTS

The UK Space Agency is investing in not one, but five potential spaceports. Funding has been granted to develop a new vertical launch platform in Sutherland, Scotland. Small satellites could begin launching from the site by the early 2020s. Several other sites in the UK, including Cornwall, also received funding to investigate their potential as launch sites for vehicles that take off horizontally like an aeroplane, such as Virgin Galactic's SpaceShipTwo.

EXOPLANET SPEED SEARCH

A novel technique could allow astronomers to find exoplanets with long orbits in a matter of months rather than decades. The new method combines the observations of exoplanet-hunting missions with detailed data about the host star from telescopes such as the Kepler and Gaia space observatories. Currently, exoplanet hunters have to wait for a planet to orbit its star three times to make a detection, meaning it would take 30 years to uncover a planet that takes 10 years to orbit.

ARTIST IMPRESSION COURTESY OF PERFECT CIRCLE PV, HARVARD-SMITHSONIAN/ CENTER FOR ASTROPHYSICS/D. A. AGUILAR, ICECUBE/NSF

The IceCube telescope in Antarctica has found a clue to the origins of cosmic rays

Neutrino burst solves mystery of COSMIC RAY ORIGINS

Ghostly particles offer a key to the origins of high-energy rays

Astronomers are a step closer to solving the century-old conundrum of where cosmic rays come from, having located the source of a burst of neutrinos, the ghostly sub-atomic particles created at the same time as the rays.

The neutrino burst was detected on 22 September 2017 by the IceCube telescope in Antarctica, and astronomers calculated its rough location in the sky. After a year of follow-up observations, they have pinpointed its origin to a blazar – a galaxy with a rapidly spinning black hole that fires out jets of particles. This particular blazar flared up in visible light around the same time the neutrinos were emitted.

This is only the second time that neutrinos have been detected outside the Solar System and the first time they have been traced back to the centre of another galaxy.

"Neutrinos rarely interact with matter," says Paul O'Brien, head of Physics and Astronomy at the University of Leicester and a member of the observing team. "To detect them at all from the cosmos is amazing, but to have a possible source identified is a triumph. This result will allow us to study the most distant, powerful energy sources in the Universe in a completely new way."

Discovered in 1910, cosmic rays are particles with enough energy to travel between galaxies. Unfortunately, discovering what creates such energetic particles has been difficult as the rays' flight is deflected by the magnetic fields they meet along the way. This means the direction in which they arrive at Earth doesn't necessarily point back to where they were created.

But cosmic rays are not born alone: when they are created, neutrinos form alongside them. As neutrinos have no charge, they are unaffected by magnetic fields and so astronomers can follow their path to discover where they came from.

"This event – the first time we've been able to associate light with the source of a high-energy neutrino – occurred less than five weeks after the first joint detection of light and gravitational waves," says Phil Evans, the development scientist for Swift, a telescope that followed up the detection. "We truly are entering the era of multi-messenger astronomy."

icecube.wisc.edu

CUTTING EDGE

Our experts examine the hottest new research

Measuring the mass of Proxima Centauri

Before you can calculate the weight of a planet, you first have to calculate the weight of its star

Thanks to an infintesimally tiny wobble we now know the mass of Proxima Centauri (imaged here by Hubble)

ESA/HUBBLE & NASA

Recently, I've spent a lot of time thinking about how little we really know about the Universe. The broad picture – how galaxies and stars and planets form and evolve – seems clear, but the nitty gritty details are more difficult to pin down. Even when it comes to the objects closest to us, we still know less than we'd like.

Take Proxima Centauri, for example. The nearest star to the Solar System, it's a faint red dwarf and companion to the much brighter twin stars of Alpha Centauri. It's right there – a little over four lightyears away – and yet until recently we didn't have a good idea of how massive it was.

Understanding the star's mass became more than a curiosity when a planet was discovered in orbit around Proxima at a distance that might make it a habitable world. If we know the mass of the planet, we can work out whether it might be rocky. But since the planet has only been detected indirectly by observing the pull of its gravity on the star itself, you can't know the properties of the planet better than the properties of the star.

Luckily, in February 2016 Proxima passed close to a more distant star, allowing an international team to make use of a technique called microlensing. The light from the distant source is bent by the gravity of Proxima, in a way precisely predicted by Einstein's relativity; the effect is a small scale version of what happens in the spectacular gravitational lenses that reveal distant galaxies.

Blind searches for microlensing events – where the instrument monitors the brightness of many tens or even hundreds of thousands of stars hoping to catch the odd microlensing event – have been used before to hunt for dark matter and free-floating planets, but this one was predicted.

That's just as well, because it was the opposite of spectacular. Using the SPHERE instrument on the Very Large Telescope in Chile, the researchers saw the background star shift by not much more than a milliarcsecond, which is about the size of a pound coin in Edinburgh as seen from London. That degree of precision requires careful calibration and processing of data, but the results are worth it.

> "The background shifted by not much more than a milliarcsecond, which is about the size of a pound coin in Edinburgh as seen from London"

The mass of Proxima is, it turns out, 15 per cent that of the Sun (with an error margin of around 40 per cent). This is larger than had been calculated by studying the star alone, and that has consequences for the planet, whose minimum mass is now at least one and a half times that of Earth. This is getting to the point where we should imagine not a large Earth, but a mini-Neptune. There is good news for planet fans, though.

A single transit, possibly the result of a second planet in the system, was spotted in August 2016. But as no second transit has been seen no one can confirm if it was due to a background binary star rather than a planet. However, if there were a background binary in the system it should have revealed itself in the microlensing event. It didn't. Now we know the star's mass, the Proxima system may have more surprises in store.

CHRIS LINTOTT is an astrophysicist and co-presenter of *The Sky at Night* on BBC TV. He is also the director of the Zooniverse project

CHRIS LINTOTT was reading… *The gravitational mass of Proxima Centauri measured with SPHERE from a microlensing event* by A Zurlo, et al.
Read it online at arxiv.org/abs/1807.01318

NEWS IN BRIEF

BLACK HOLE HUNTING

A new study shows that the outskirts of spiral galaxies could be rich hunting grounds for black holes. Astronomers looked for the remnants of supernovae that create black holes, and found that the outer edges of spirals have favourable conditions for them to form. The work may help scientists determine which galaxies they should be looking out for to find electromagnetic signals from massive black holes, such as visible light or gamma ray emissions.

METEORITE IN BOTSWANA

A meteorite first spotted while still in space has been recovered from Botswana's Central Kalahari Game Reserve. A team from the University of Arizona tracked the meteorite when it entered Earth's atmosphere on 2 June 2018. They were then able to calculate the predicted impact site and mount an expedition to find the rock. As astronomers know the rock's orbit they will be able to work out where it originated in the asteroid belt and study the meteorite in context.

Juno finds new volcano on Io

Hundreds more could be lurking on the volcanic world

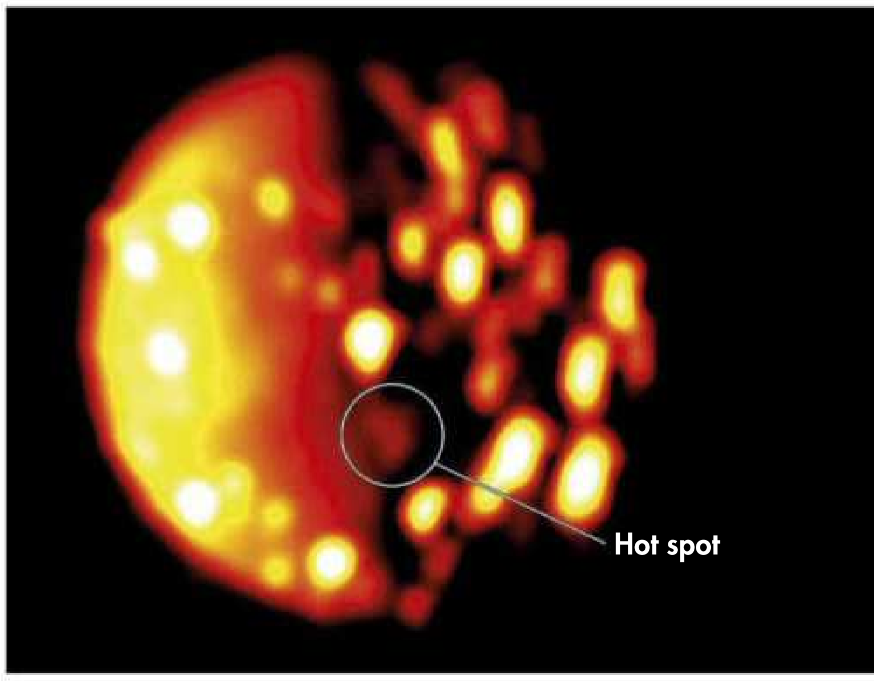
A new volcano may have been discovered on Jupiter's moon Io, the most volcanically active world in the Solar System.

The volcano was revealed by the Juno spacecraft's Jovian InfraRed Auroral Mapper (JIRAM) camera, which found a hot spot close to the moon's south pole, 300km away from the nearest previously mapped warm patch.

"We are not ruling out movement or modification of a previously discovered hot spot, but it is difficult to imagine that one could travel such a distance and still be considered the same feature," says Alessandro Mura, a Juno co-investigator from the National Institute for Astrophysics in Rome.

Over 150 active volcanoes have been found on Io, but scientists estimate that perhaps another 250 could be waiting to be discovered.

www.missionjuno.swri.edu



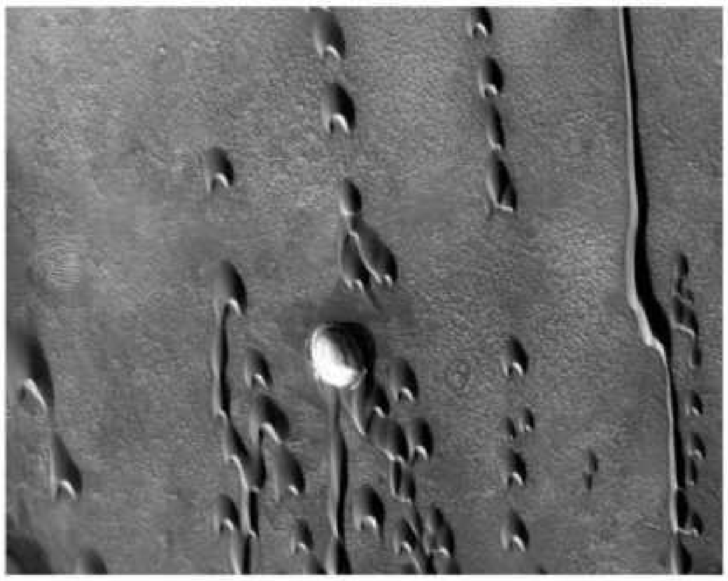
▲ Juno's infrared camera detected an apparently new hot spot on Io during a flypast on 16 December 2017

Spectral dunes hint at Martian past

Ghost dunes – the negative spaces left behind by ancient sand dunes – have been spotted on the Martian surface. The spectral dunes – which appear to have been formed some two billion years ago – are orientated at an angle to the present prevailing winds on Mars, suggesting that air currents used to move in a different direction.

"The fact that the wind was different [when the ghost dunes formed] tells us that the environmental conditions on Mars aren't static over long time scales; they have changed over the past couple of billion years, something we need to know to interpret the geology of Mars," says Mackenzie Day from the University of Washington in Seattle who led the study.

www.washington.edu



▲ Contemporary dunes on Mars (above) are created by wind from the east, unlike the newly found ghost dunes

LOOKING BACK THE SKY AT NIGHT

17 September 1965

On 17 September 1965, Patrick Moore took a look at quasi-stellar objects, or quasars. These strange objects look like stars, but are enormously bright when viewed at radio wavelengths and had been mystifying astronomers ever since they were first detected in the 1950s.

In 1962, astronomers were able to use an occultation of a quasar by the Moon to determine that the quasar was over three billion lightyears away. The results amazed them. If this were true then the quasar would have to be producing more light than even the brightest galaxies in the Universe in a space smaller than our Solar System.

It would take a further decade of study to discover what force of nature could create such an enormous glow – the swirling discs of gas and dust that race around a supermassive black hole. Friction heats the gas to billions of degrees, causing it to glow intensely.

▲ The properties of quasars were astonishing astronomers in the 1960s

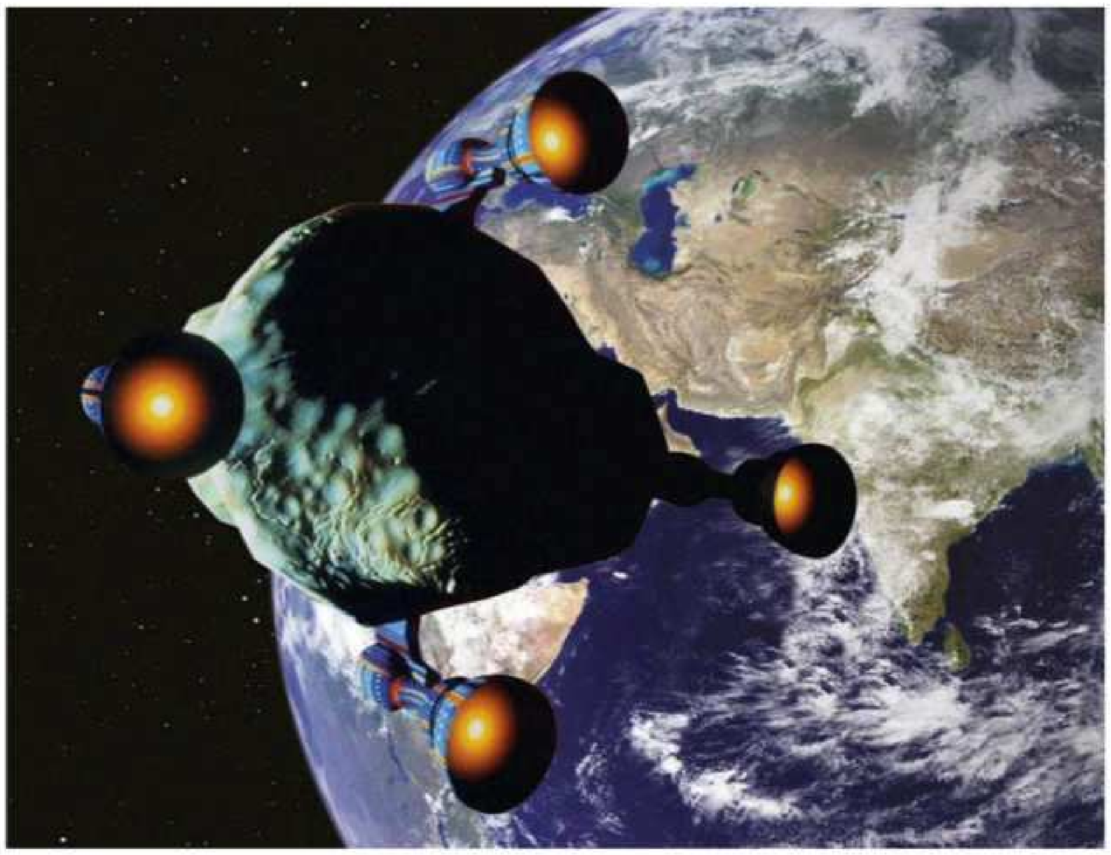
NASA/CXC/SAO, SETI INSTITUTE, NASA/JPL-CALTECH/SWRI/ASI/INAF/JIRAM, NASA/JPL/UNIVERSITY OF ARIZONA, ESO/M. KORNMESSER

CUTTING EDGE

Our experts examine the hottest new research

Stabilising space rocks

Asteroid mining could soon be a reality, but how could we capture one of these lucrative space rocks?



JULIAN BAUM/SCIENCE PHOTO LIBRARY

▲ **Attaching four rockets to an asteroid can stop it spinning but a fifth might be needed to set it on a new course**

Asteroids present something of a double-edged sword for us Earthlings. On the one hand, some could present a grave danger to life on Earth, if they're on a collision course to impact. On the other, many asteroids promise huge riches if we can successfully launch missions to mine them; they can provide a source of precious metals or volatile compounds that could be refined into rocket fuel to drive further space exploration.

In both of these cases, mission controllers would probably need to first stabilise the topsy-turvy spin of the asteroid – to 'detumble' it – before attempting to shift its orbit. If you try to fire a large rocket motor on an asteroid to push it off its collision trajectory with Earth before you've first stopped it tumbling madly then it can be very hard to control effectively.

The best way to attempt to stabilise the tumble of an asteroid would be to land a formation of rocket thrusters onto its surface, and have them fire in a carefully coordinated sequence to slow and eventually stop the spinning in three dimensions. The problem is that smaller asteroids aren't conveniently spherical bodies. They're shaped more like knobbly potatoes, or even worse, like two blobs stuck together. Understanding how to effectively detumble such a complex – and often rapidly rotating – shape is very difficult. Where would be the best place to land the different thrusters onto the surface? What pattern should they fire in to stabilise the asteroid as quickly or fuel-efficiently as possible?

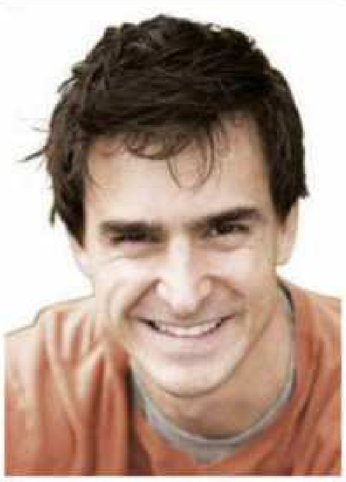
These are exactly the questions that Michael Bazzocchi and M Reza Emami at the Institute for Aerospace Studies, University of Toronto, have been investigating. They've developed a computer model that simulates the action of thrusters landed onto the surface of any given asteroid. Mathematicians have already proved that the minimum number of fixed thrusters needed to provide full attitude control of a tumbling body is four. Bazzocchi and Emami have therefore considered a scenario where a mothership rendezvous with an asteroid, deploys four thrusters to its surface to bring its spin under control, before a fifth, large rocket is landed on the stabilised asteroid to shunt it into a new orbit.

Once it's been fed the data on the asteroid's shape and its specific mode of rotation in three dimensions (perhaps determined by telescope light curves or radar mapping), Bazzocchi and Emami's code first calculates the inertial properties of the oddly shaped body. It then determines the optimum landing placement of the small thrusters for detumbling the asteroid, as well as the best control system for ensuring that the complicated pattern of thruster firing stabilises the spin as quickly as possible.

> "The asteroid's tumble could be stabilised by their optimised thruster configuration in only about 15 hours"

When they demonstrated their code with a test case – a simulated asteroid with a mass of around 250 tonnes and rotation rates similar to small near-Earth asteroids – they found that the asteroid's tumble could be successfully stabilised by their optimised thruster configuration in only about 15 hours. This is substantially less than the year or so currently required to redirect the asteroid onto a new orbit.

With the growing commercial interest in exploiting asteroid resources, this is exactly the sort of mission architecture that might become commonplace for space miners in the near future.



LEWIS DARTNELL is an astrobiology researcher at the University of Westminster and the author of *The Knowledge: How to Rebuild our World from Scratch* (www.the-knowledge.org)

LEWIS DARTNELL was reading… *Formation of multiple landers for asteroid detumbling* by Michael CF Bazzocchi and M Reza Emami. **Read it online at doi.org/10.1016/j.asr.2018.05.011**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Spring/Summer Events 2018
Plan ahead and catch us at the Webb Society in Cambridge on Saturday June 2nd & at the North West Astronomy Festival, Runcorn on Saturday July 7th. We will also return to the Norman Lockyer Observatory for the SW Astrofair on Saturday August 11th.
We have a programme of events over the weeks & months ahead including Solar observation days and open evenings, as well as our courses and private tuition, all here at our own dark sky location near Ely in Cambridgeshire. Contact us by phone or email for an up-to-date listing, or see our website www.widescreen-centre.co.uk
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What's on

Our pick of the best events from around the UK

British Science Festival 2018

Various locations, Hull, 11-14 September

The longest-standing science festival in Europe will be returning to the UK this September. Spread over five days, there are 120 events to attend, from lectures and debates to performances and installations at a number of venues throughout the city.

The schedule includes a range of lectures including 'Poetry and Science: The Space In Between', in which astrophysicist Dame Jocelyn Bell Burnell is joined by poet Lemn Sissay to discuss poetry's effect on science and vice versa. Science author and *Sky at Night* regular Jim Al-Khalili debates 'The AI Revolution: Hopes, Fears and Opportunities'. Then there's 'Distortions in Spacetime', where you can step into a virtual black hole exhibition, and 'Howl at the Moon', a seven metre-wide installation of detailed NASA lunar imagery accompanied by singing from the University of Hull Chapel Choir.

The festival also features Jon Butterworth, a researcher at CERN, on what mysteries remain in our Universe; plus talks on gravitational waves; how the Universe may end; what strange sounds are coming from space; and whether astronomy can save Earth's species. Even Brexit and jet lag for plants take their place in the line-up of events.

The festival is free, however high-demand events are ticketed. Free tickets can be booked on the festival's website.
www.britishsciencefestival.org

BEHIND THE SCENES

THE SKY AT NIGHT IN SEPTEMBER

BBC Four, **9 September,** 10pm (first repeat BBC Four, **13 July,** 7.30pm)*

Scientists are working out how to exploit asteroids but could they also threaten Earth?

EXPEDITION ASTEROID

This month's episode will look at the alarming number of space rocks that are currently orbiting close to Earth, the US and Japanese attempts to return chunks of asteroids to Earth and the UK-wide network of detection cameras that has been set up with the specific aim of catching a falling meteor.

**Check www.bbc.co.uk/skyatnight for subsequent repeat times*

Gravitational waves

Royal College, Strathclyde University, Glasgow, 20 September, 7.30pm

The Astronomical Society of Glasgow (ASG) presents a lecture on gravitational waves following their direct detection in September 2015. 'Listening to Einstein's Universe: The Detection of Gravitational Waves' will be presented by Dr Peter Murray (pictured) of the University of Glasgow. The lecture is preceded by either a social event, the perfect opportunity to meet other avid astronomers, or a presentation on this month's stargazing highlights. All ASG's public lectures are free.
www.theasg.org.uk

Stargazing and astrophotography

Brecon Beacons National Park Visitor Centre, Libanus, 1, 15, 29 September, 9pm

This unique opportunity allows you to tour the night sky in one of the UK's few Dark Sky-certified areas. Learn how to effectively use binoculars, set up a telescope, navigate via star maps and capture some astro images. Equipment is supplied and no prior knowledge is required. Tickets are £55 and advance booking is necessary. You need to check the event is going ahead before travelling. More info is available at the Dark Sky Wales website.
darkskywalestrainingservices.co.uk

Small Space Day

National Space Centre, Exploration Drive, Leicester, 10 September, 10am

Small Space Day is a fun, interactive way for children to learn about the Universe. Activities such as a special planet show, alien art, sensory story time, sing-a-long-a-space and a 'Tinytarium' will keep young minds busy. All-day tickets include a full-dome planetarium show: choose from the 'Astronaut George Show' or 'We Are Stars', narrated by Andy Serkis. Tickets are £14 for adults, £11 for children aged 5-16 and concessions, and free for children under five.
spacecentre.co.uk/event/small-space-day-toddler-takeover

MORE LISTINGS ONLINE

Visit our website at **www.skyatnightmagazine.com/whats-on** for the full list of this month's events from around the country.

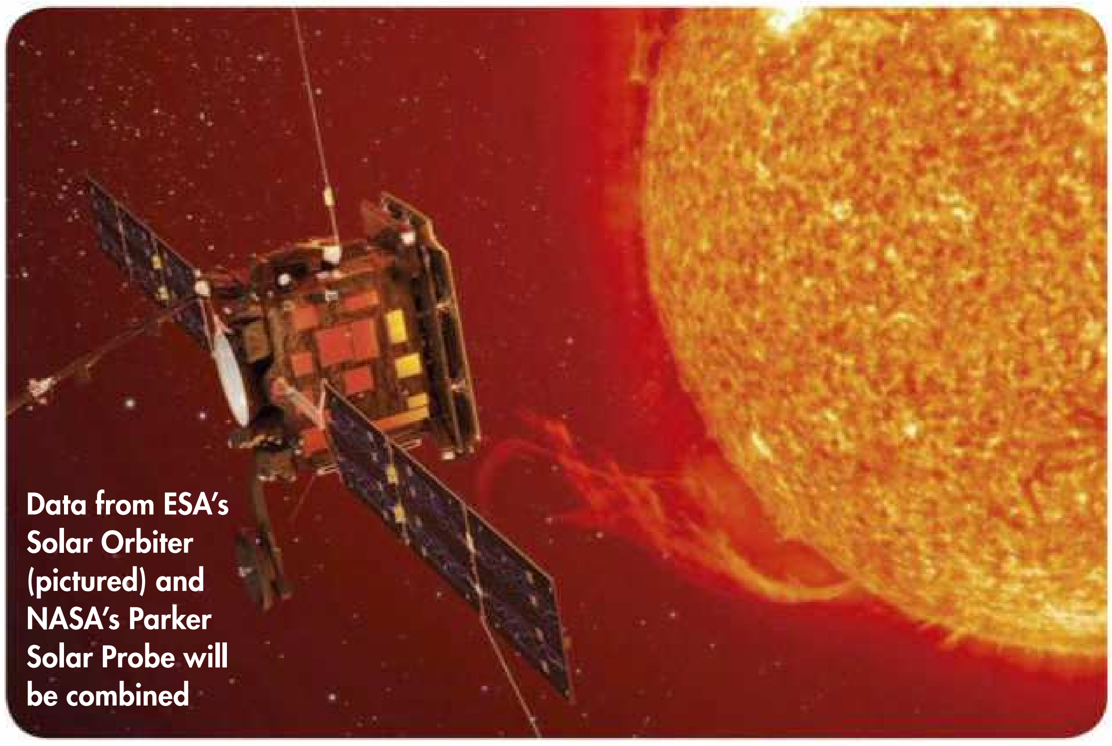
To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the web page.

BRITISH SCIENCE ASSOCIATION, THE ASTRONOMICAL SOCIETY OF GLASGOW, ALLAN RICHARD TROW, ISTOCK

A PASSION FOR SPACE

with **Professor Lucie Green**

The reason why the solar wind moves so incredibly fast may be on the verge of finally being explained



Data from ESA's Solar Orbiter (pictured) and NASA's Parker Solar Probe will be combined

ESA

Two decades ago I first started thinking about what science could be done with a spacecraft orbiting close to the Sun. We only have the chance to study one star with any degree of intimacy, and it's the one at the centre of our very own Solar System.

Of course, I wasn't the first to ponder this. A report written by the Simpson Committee of America's National Academy of Science in 1958, at the very start of the Space Age, recommended "a solar probe to pass inside the orbit of Mercury to study the particles and fields in the vicinity of the Sun". This feat was eventually achieved by the Helios 2 spacecraft in the mid-1970s, and extremely valuable data was collected.

The spacecraft made measurements of the so-called solar wind, which is a gusty stream of particles and magnetic fields generated by the Sun's million-degree atmosphere. An atmosphere this hot has such a high pressure that it cannot be fully restrained by the Sun's gravitational pull and the top layer escapes into space.

What's puzzling, though, is the fact that the solar wind moves at much higher speeds than expected. There must be some physical processes that provide the wind with an additional acceleration. The question is, what are these processes? The Helios 1 and 2 spacecraft helped pose this question, but were not able to answer it. For this, different observations are needed and luckily for scientists like me they are just around the corner.

The hot questions

Solar Orbiter, the mission to provide answers to these long-standing questions, is a European Space Agency spacecraft with strong NASA involvement that's in the final stages of its build at the moment. I was lucky enough to visit the spacecraft at Airbus in Stevenage while the final instruments were being added and the first remote communications tests began. You can see what I got up to in the August episode of *The Sky at Night* (which will still be available on BBC iPlayer for a couple of weeks after this issue goes on sale).

Solar Orbiter has been specifically designed to answer science questions posed by myself and other scientists; questions that can only be answered by getting up close to the Sun and studying it with cameras that both image the surface and atmosphere, and that sense the particles and fields around the spacecraft.

Through the solar wind, solar ejections and high-energy particles, the Sun creates and controls an enormous bubble that is effectively its extended atmosphere – the heliosphere. Living on a planet in this atmosphere, we can see the space weather this creates on Earth. The solar wind also strips the atmosphere from Mars and creates aurora in the skies of planets that have magnetic fields, like Earth, Jupiter and Saturn.

Due for launch in early 2020, Solar Orbiter will allow us to study solar emissions in detail and, crucially, look back to where they originated from for the first time. Combined with data collected by NASA's Parker Solar Probe, my decades-old dream may finally be realised.

PROFESSOR LUCIE GREEN is a solar physicist at UCL's Mullard Space Science Laboratory in Surrey

JON CULSHAW'S

EXOPLANET EXCURSIONS

A colossal blue hypergiant has a seriously damaging effect on Jon's ship

Fuelled by an unusually strong impulse to witness a cosmic display almost beyond imagination, I'm piloting my ship, The Perihelion, to the blue hypergiant HD 37974, an object of staggering incandescence 170,000 lightyears away in the Large Magellanic Cloud.

The view of the Milky Way is utterly jaw-dropping from the outside, here in this satellite galaxy. It's like images of our Galaxy shimmering over the deserts of Earth at night, but much more defined and immensely brighter: the light level of 70 full Moons across an Earth night sky.

Steering the ship closer to star HD 37974 brings into focus a remarkable debris disc of matter that loops so widely around it. The star and debris disc together have the profound and surreal appearance of a massively upscaled version of Saturn. But in place of a gas giant planet, there's a colossal, blue hypergiant star, 70 times the mass of the Sun and 1.4 million times as luminous. And in place of Saturn's ring system, there's a ring of material sufficient in volume to create an entire planetary system – if the conditions of stellar ferocity could ever allow such settlement to occur.

As the Milky Way's shimmering garlands of light accent the background of this 'Saturn Star', I can't help but recall some classic lines from the great Les Dawson: "As I gazed up to observe the majesty of the night sky, a myriad points of light as the stars glistened just like diamonds cast across black velvet. With Jupiter, Mars and Saturn festooned in their orbital majesty, the rising crescent Moon ascended from the horizon like an ambered chariot. As I gazed up to observe this magical sight, I thought to myself, I really must put a roof on this lavatory."

But I mustn't let my mind wander in an environment so potentially dangerous as this is. The Perihelion's heat and radiation shields and gravity regulators are working fine but I must maintain maximum attention and vigilance.

Observing this debris disc brings a rather sad feeling that the violence of the parent star means no formation of any planets and moons could ever take place. The young, formative exoplanet recently discovered around the star PDS 70 by ESA's VLT is a kind of planet formation that could never take place here!

It's time I was off. I attempt to leave but the ship is straining. It can only be that remaining too long so recklessly close to the Saturn Star has caused a destructive systems failure in my ship. While musing over Les Dawson I was oblivious to the cataclysmic damage being absorbed by my brave Perihelion, the situation exacerbated by my previous misadventure in the trinary system in Centaurus.

Without any ability to program a specific departure destination, my priority must be to evacuate from this system immediately, and blindly. The interstellar equivalent of triggering the ejector seat and being jettisoned off to who knows where.

JON CULSHAW is an impressionist, comedian, and guest on *The Sky at Night*

MAIN ILLUSTRATION: MARK GARLICK, SPACECRAFT: PAUL WOOTTON, PHOTO: EMMA SAMMS

Interactive

EMAILS ◢ LETTERS ◢ TWEETS ◢ FACEBOOK

Email us at **inbox@skyatnightmagazine.com**

This month's top prize: four Philip's books

PHILIP'S The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Mark Thompson's *Stargazing with Mark Thompson* and Heather Couper and Nigel Henbest's *2018 Stargazing.*

An ingenious solution

MESSAGE OF THE MONTH

I have a small roll-off roof observatory with a pier at the bottom of my garden, and although I get a good view of the ecliptic and the southern sky from it, my neighbour's trees obscure Polaris. Not being able to align my NEQ6 mount with its polarscope, I planned to use a compass to find true north and a digital spirit level to adjust the altitude. This is where my plan fell apart, as I got different readings depending on where I placed the compass. Although I've been careful not to introduce ferrous materials where possible, a fair number of nails went into the observatory's construction; it's Clyde built, like a battleship, and many of my other DIY jobs!

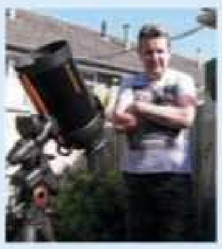
I mentioned my problem to a friend with an interest in meteorology and he mentioned the sundial in his garden. I have often used the Sun's shadow to align a telescope when observing sunspots. But it never crossed my mind to wind the observatory roof back in daylight to create a True North Solar Compass – letting the midday Sun (or 1pm BST) cast a north-south meridian shadow of the pier on the floor.

Archie Howitt, Edinburgh

Ingenious problem solving, Archie: the simple solutions are often the most satisfying. Here's to many evenings of well-aligned observing as the nights lengthen! **– Ed**

Tales from THE EYEPIECE

This month's tale comes from Mark Bowles, Plymouth Astronomical Society



As a young lad I was keen on cricket and, along with a group of friends, thought about joining our local outfit, Selsey Cricket Club, of which Patrick Moore was then a patron. With some trepidation, we plucked up the courage to visit Patrick at his home, the Farthings. I knocked on Patrick's door; none of us thought he would answer, but we were wrong. Before I knew it, we were all sitting around Patrick's dining table chatting with him about cricket.

My attention was drawn elsewhere, however, as I'd spotted Patrick's array of telescopes in the garden. While none of us joined the cricket club, the sight of those telescopes and the possibilities of what I could see with them hit me for six – from that very day I caught the bug, as opposed to being caught in the slips.

Email your own tales to us at TalesfromtheEyepiece@themoon.co.uk

Shoot the Moon

I had my first telescope bought for me by my family last Christmas; it's a Sky-Watcher StarTravel 102 on an EQ3 Pro Go-To mount. I've recently captured two images of the Moon, the first captured in February this year using a Nikon D200 DSLR camera with a Baader Semi-Apo filter fitted to the star diagonal. The second was captured on the 25 June 2018, using the same telescope and a Bresser MikrOkular HD eyepiece camera

Tweets

Thomas Mitchell
@TNM1973 • Jul 21
@skyatnightmag @bluedotfestival
Here's a photo of the Lovell telescope with NLC above from a few weeks ago #bluedotfestival

SOCIETY in focus

Seven Sisters Astronomical Society (SSAS) is a small group of amateur astronomers based in East Sussex. On 22 June 2018 the society attended the National Trust's Sheffield Park and Garden for the Waterlily Festival and an evening of stargazing. Weather conditions were perfect and we managed to set up four telescopes: two Meade 8-inch Go-Tos, a Sky-Watcher 10-inch Dobsonian and a Sky-Watcher 6-inch reflector. As the light faded, SSAS members were busy observing, and visitors of all ages left that evening filled with new knowledge and excitement having seen the Moon, Jupiter and Saturn. At 11pm the event closed to the public, but some SSAS members remained behind and observed until the early hours.

The following morning we were back in the field for solar observing, which went on until 3pm. There was a steady flow of visitors walking through the park, enjoying picnics and observing the Sun between the scattering of clouds! The clouds thickened later in the afternoon, which gave us a few hours rest, before we set up the telescopes again for our evening event, with around 50 members of the public. By then there were breaks in the clouds, and we were able to observe the Moon through the telescopes for over an hour.

We had a wonderful weekend, not only with the weather, but also experiencing the wonderful Waterlily Festival that weekend.
Annabel Simes, Social media coordinator, Seven Sisters Astronomical Society

To find out more about Seven Sisters Astronomical Club visit their website at ssasonline.wordpress.com or follow the club on Facebook

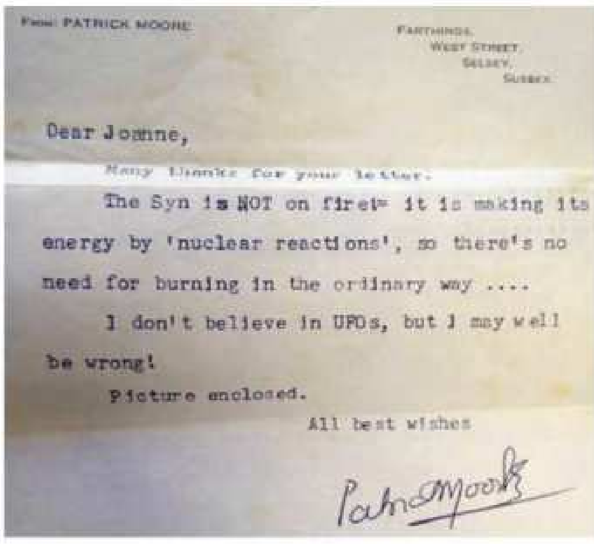
(90 frames stacked in RegiStax 6 from a 20-inch video). I am very new to all of this but would like to receive any helpful feedback. I think the crater on the closer Moon surface shot is Copernicus.
Stuart Lave, via email

Well done with those images, Stuart, they're well focused. There's advice on creating realistic colour in astrophotos in our feature on page 36, which may be useful. **– Ed**

Hot topic

The article on the Parker Solar Probe on page 39 of the July issue mentioned that one of the big mysteries about the Sun is that the temperature of the corona is around 300 times hotter than the solar surface, when ordinarily you'd expect things to get cooler as you move further from them. Perhaps instead of thinking of the Sun like a campfire a better analogy is to think of it like a volcanic eruption, where the highest temperature material from the core bursts through the crust and has to travel a larger distance from the crust in order to cool down.
William Smith, via email

That's a great take on the issue, William. What makes the Sun different from a volcano is that the change in temperature is the other way around: plasma from the Sun gets hotter as it moves further from its surface. I hope missions like Parker and the UK-built Solar Orbiter will shed more light on why this is. **– Ed**



From: PATRICK MOORE
FARTHINGS, WEST STREET, SELSEY, SUSSEX.

Dear Joanne,

Many thanks for your letter.

The Syn is NOT on fire! it is making its energy by 'nuclear reactions', so there's no need for burning in the ordinary way ....

I don't believe in UFOs, but I may well be wrong!

Picture enclosed.

All best wishes

Patrick Moore

Patrick in the attic

I found this letter from Patrick Moore when I was clearing the attic: one of his many replies to my many rambling letters. Growing up we only had two TV channels and *The Sky at Night* was one of the highlights of my week. As an 11-year-old girl from the west of Ireland, the fact that he took the time to reply to my letters made me feel like my opinion was important and encouraged me to keep asking questions. I also loved the fact he misspelt a lot of words – I can't spell either!
Joanne Maher, Dublin

Thanks for sharing the letter, Joanne. I can't help reading it with Patrick's distinctive voice in my head! **– Ed.**

Meanwhile on FACEBOOK...

WE ASKED: Where are your favourite dark-sky places?

Peter Hughes: Beaghmore Stone Circle, County Tyrone, Northern Ireland.

Peter Louer: The Caldera, Teide National Park, Tenerife.

Gillian Rushforth: My paddock!

Siân Monument: Anglesey in North Wales.

Allan Trow: Elan Valley and Broadhaven South Beach, Pembrokeshire.

Mark Edmonds: North Northumberland. Plenty of dark skies up there.

Danny Astro Kenealy: North Wales is pretty much the only place I go now.

Michelle Boots: Siblyback Lake, Bodmin Moor.

Michelle Charlton: Kielder Observatory.

Jim Ban D: Snelling Farm campsite in Dorset near Bovington. Go there every year.

Tony Horton: On Kangaroo Island off the south coast of Australia the LMC and SMC were both easily naked eye objects and the views were stunning.

Benny Coyac: Big Sur, CA.

Tweets

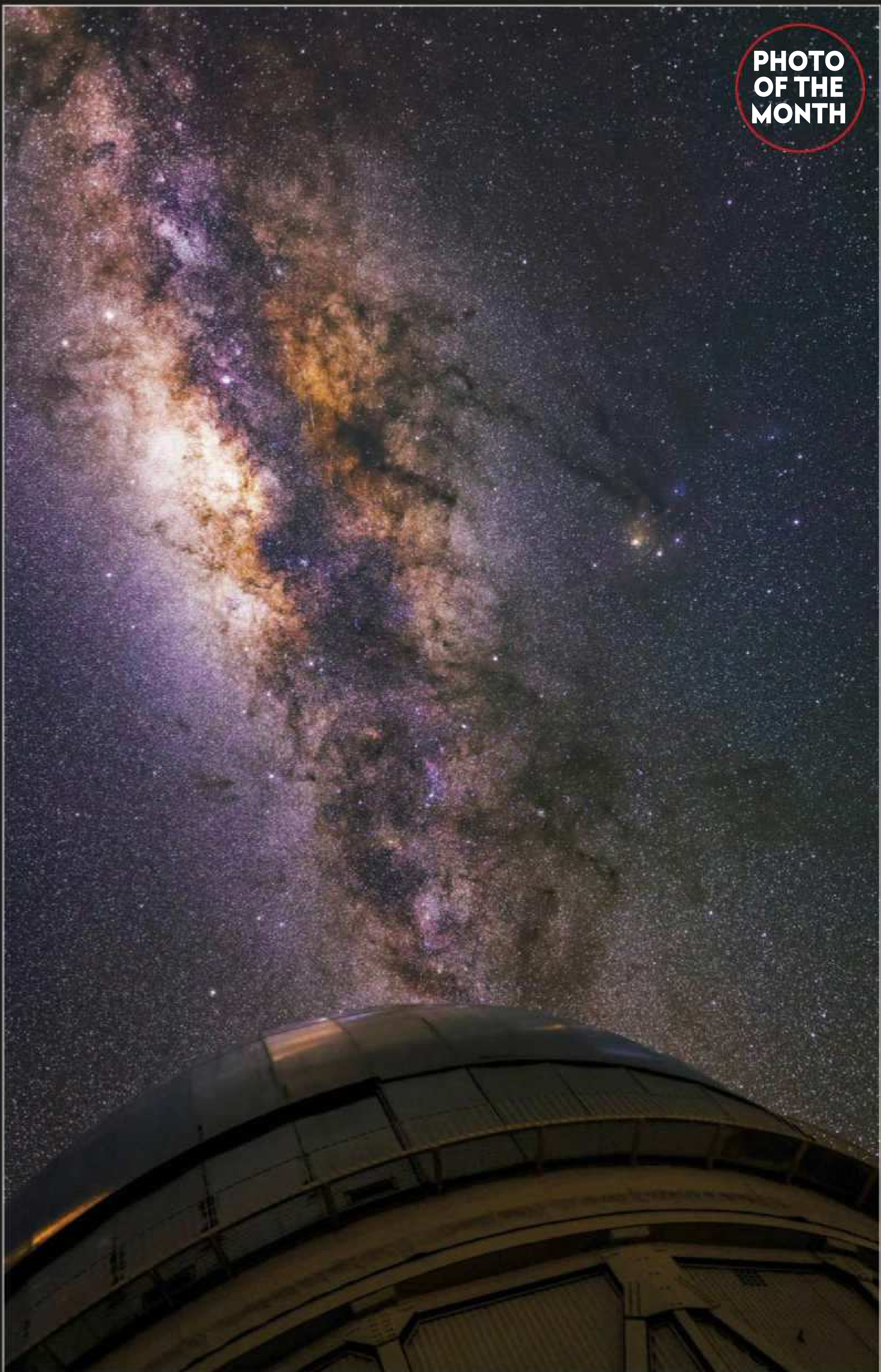
Craig
@craigharvey87 • Jul 16
Mars reflecting in the sea, with a nice display of airglow too. Mars looks spectacular as it rises, then throughout the night, and it'll only get better until it reaches opposition on 27/7. #astronomy #astrophotography @VirtualAstro @skyatnightmag @astro_timpeake @ROGAstronomers

Hotshots

This month's pick of your very best astrophotos

YOUR BONUS CONTENT

A gallery containing these and more of your stunning images



◀ The Milky Way

GUILLAUME DOYEN, CERRO TOLOLO INTER-AMERICAN OBSERVATORY, CHILE, 13 JUNE 2018

Guillaume says: "Visiting Chile had always been an ambition of mine, and this picture is sort of a meeting between amateur and professional astronomy. The shooting star next to the galactic bulge also reminds me that our dreams really can come true."

Equipment: Canon EOS 700D DSLR camera, Sigma Art 18-35mm lens, Sky-Watcher Star Adventurer mini mount
Exposure: ISO 3200, 30"
Software: DxO OpticsPro, Lightroom, Photoshop

***BBC Sky at Night Magazine* says:** "This is one of the crispest and most detailed images of our Galaxy we've ever seen. A highlight is the reflection on the top of the dome, mirroring the link between the cosmos and the technology we have developed to help us understand it."

About Guillaume: "The Universe has fascinated me ever since childhood, and I grew up with the desire to know more about space and dedicate my professional life to astronomy. I fell in love with astrophotography in 2013 and bought my first DSLR for that purpose. I am very excited about astronomical phenomena, and would also like to get involved in collaborative astronomy to support scientists, simply by doing science at home."

▲ Noctilucent clouds

SARAH AND SIMON FISHER, BROMSGROVE, WORCESTERSHIRE, 22 JUNE 2018

Sarah says: "This was our first sighting in two years! Conditions were ideal and we had no breeze so we set up our tripod and enjoyed the show."

Equipment: Canon EOS 600D DSLR camera, 18-55mm lens Exposure: ISO 400, 4"

The Carina Nebula ▶

MARIO RICHTER, NAMIBIA, 12 MAY 2018

Mario says: "During my recent trip to Namibia, I focused on astrophotography. This nebula, the first object we viewed, was the most impressive, as well as the most photogenic."

Equipment: Canon EOS 60D DSLR, Takahashi FSQ-106ED refractor, Losmandy G-11 equatorial mount Exposure: 37x480" Software: Photo Mate R3

◀ The Iris Nebula

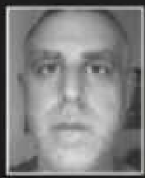
PETE LAWRENCE, LISBURN, COUNTY ANTRIM, APRIL, MAY 2018

Pete says: "I spend time on this nebula towards the end of every season to improve on previous efforts. This year I was trying to capture the iconic dust clouds that surround it, which came out quite well."

Equipment: Atik 428EX mono camera, Sky-Watcher Quattro 200 CF Imaging Newtonian, Sky-Watcher NEQ6 Pro mount Exposure: L 230x3', R 82x2', G 81x2', B 80x2' Software: SGPro, PixInsight, Lightroom

◀ The Sunflower Galaxy

MARK CROWTHER, CHELTENHAM, 19 MAY 2018



Mark says: "I have limited view of the sky from my garden and have to wait until objects cross the meridian and then capture them before they 'set' behind the block of flats next door. I chose the Sunflower Galaxy as it was the most interesting object that evening, which I'd not previously imaged."

Equipment: ZWO ASI 1600MM-C camera, TS-Optics 8-inch f/8 Ritchey Chrétien astrograph, iOptron iEQ45 Pro mount **Exposure:** LRGB 12x300" each **Software:** PixInsight, GIMP

The Cygnus Wall ▶

STEVE AND JANE KOMAREK, NOTTINGHAM, 3 JULY 2018

Steve says: "A lot of hard work has gone into this image and I am really happy with the outcome. Unfortunately I had to be really ruthless with my subs and therefore I had to dump five hours worth."

Equipment: Atik 490EX CCX camera, Sky-Watcher Quattro 200 CF Imaging Newtonian, Sky-Watcher HEQ5 Pro mount **Exposure:** Ha 25x, SII 18x, OIII 17x; each 600" **Software:** Nebulosity, Photoshop

◀ Strawberry Moon

ESTHER HANKO, KATWIJK, PURMEREND, THE NETHERLANDS, 28 JUNE 2018

Esther says: "I was on the beach watching the sunset and waiting for sea sparkle when I suddenly noticed this gorgeous orange moonrise behind me! The cyclists passed through the field of view just as I had configured my camera for the shot."

Equipment: Canon EOS 60D DSLR camera, Samyang 135mm f/2 lens
Exposure: ISO 400, 30"

ENTER TO WIN A PRIZE!

ALTAIR ✶ ASTRO We've teamed up with Altair Astro UK to offer the winner of next month's Hotshots an Altair Astro Premium 1.25-inch CLS-CCD Filter with UV/IR Block & AR Coating, designed to reduce the effects of light pollution and skyglow for DSLR, CCD or CMOS cameras – www.altairastro.com • 01263 731505

Submit your pictures via www.skyatnightmagazine.com/astrophotography/gallery or email hotshots@skyatnightmagazine.com. T&Cs: www.immediate.co.uk/terms-and-conditions

DAWN'S SUNSET

Around 500 million km from Earth, Dawn will finally run out of fuel orbiting Ceres

As NASA's Dawn spacecraft burns up its last fuel reserves, **Jasmin Fox-Skelly** looks back at what this 11-year mission has taught us about our Solar System

NASA/JPL-CALTEC

One of NASA's most audacious space missions is drawing to a close this month. The Dawn spacecraft has spent the last 11 years travelling to and orbiting around not one, but two of the oldest and most massive residents of the asteroid belt between Mars and Jupiter – the asteroid Vesta and the dwarf planet Ceres.

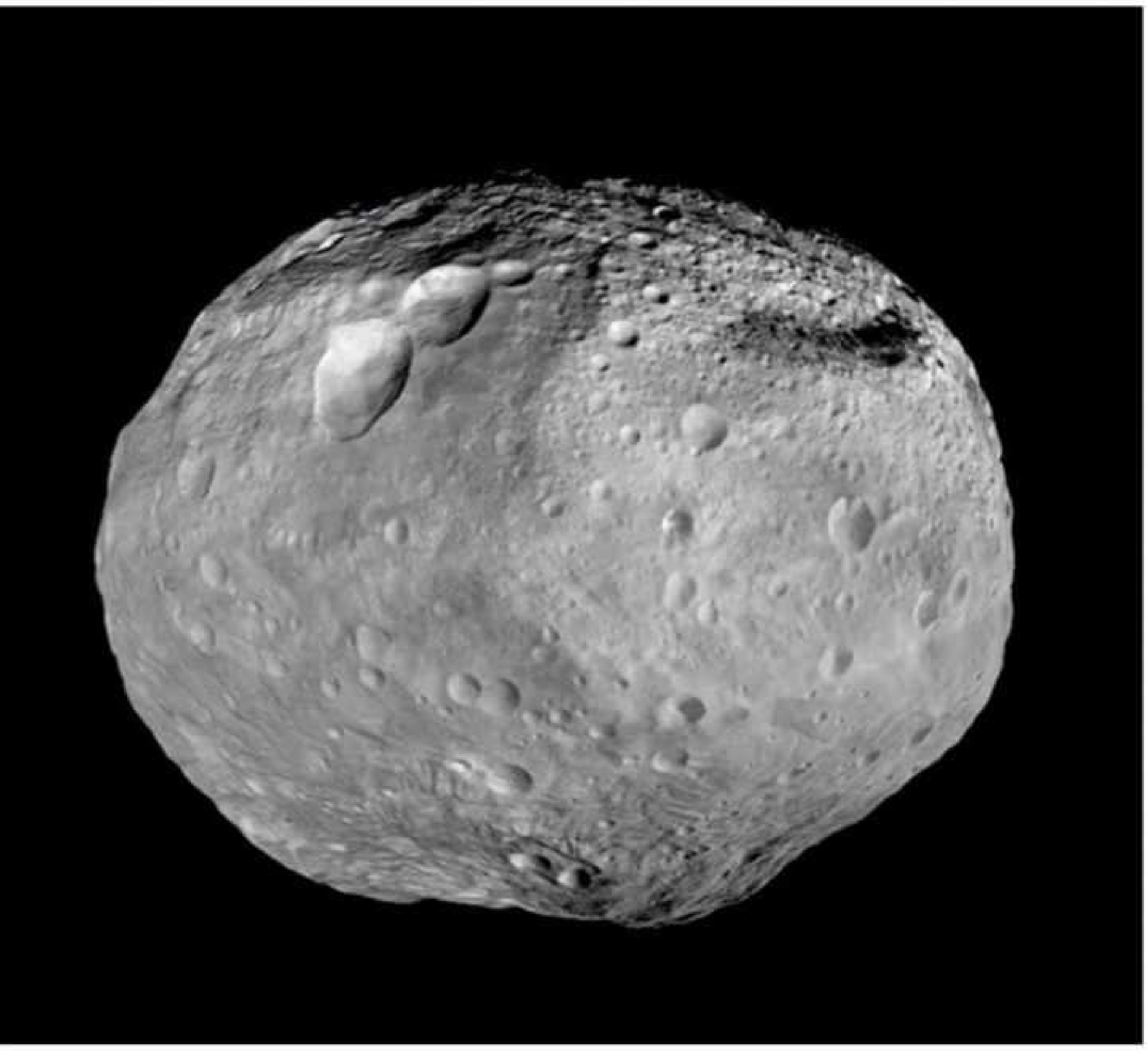
"Dawn is the first mission to orbit a body in the main asteroid belt, the first to visit a dwarf planet and the first to orbit two extraterrestrial bodies in a single mission," says Carol Raymond, principal investigator of the Dawn mission at NASA's Jet Propulsion Laboratory (JPL) in Pasadena, California.

The mission examined these two fossils – formed 4.6 billion years ago at the beginning of the Solar System – to shed light on the processes and environments that created the planetary system we know so well. With Dawn coming to the end of its fuel reserves, and the end of its mission, we look back at what the spacecraft has taught us about the formation of our Solar System.

Dawn launched on 27 September 2007, arriving at its first target, Vesta, on 16 July 2011. Scientists

▲ Above top: A view of Vesta's south pole showing the giant crater, Rheasilvia, which is about 90 per cent the size of Vesta's diameter

Above bottom: One of the meteorites that has reached Earth which is believed to have originated on Vesta



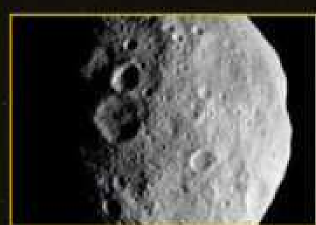
◄ NASA informally christened the three craters at the top left of Vesta the Snowman. The bulge at the bottom is the central peak of the Rheasilvia crater which, at 22km tall, just pips Olympus Mons as the tallest mountain in the Solar System

DAWN MISSION TIMELINE

27 September 2007
NASA's Dawn spacecraft is launched from Cape Canaveral Air Force Station, Florida, on a Delta 7925H rocket and starts its four-year journey to the asteroid belt

February 2009
Dawn uses the power of Mars's gravity to slingshot onwards to Vesta and Ceres

July 2011
Dawn arrives at Vesta and enters orbit around the asteroid



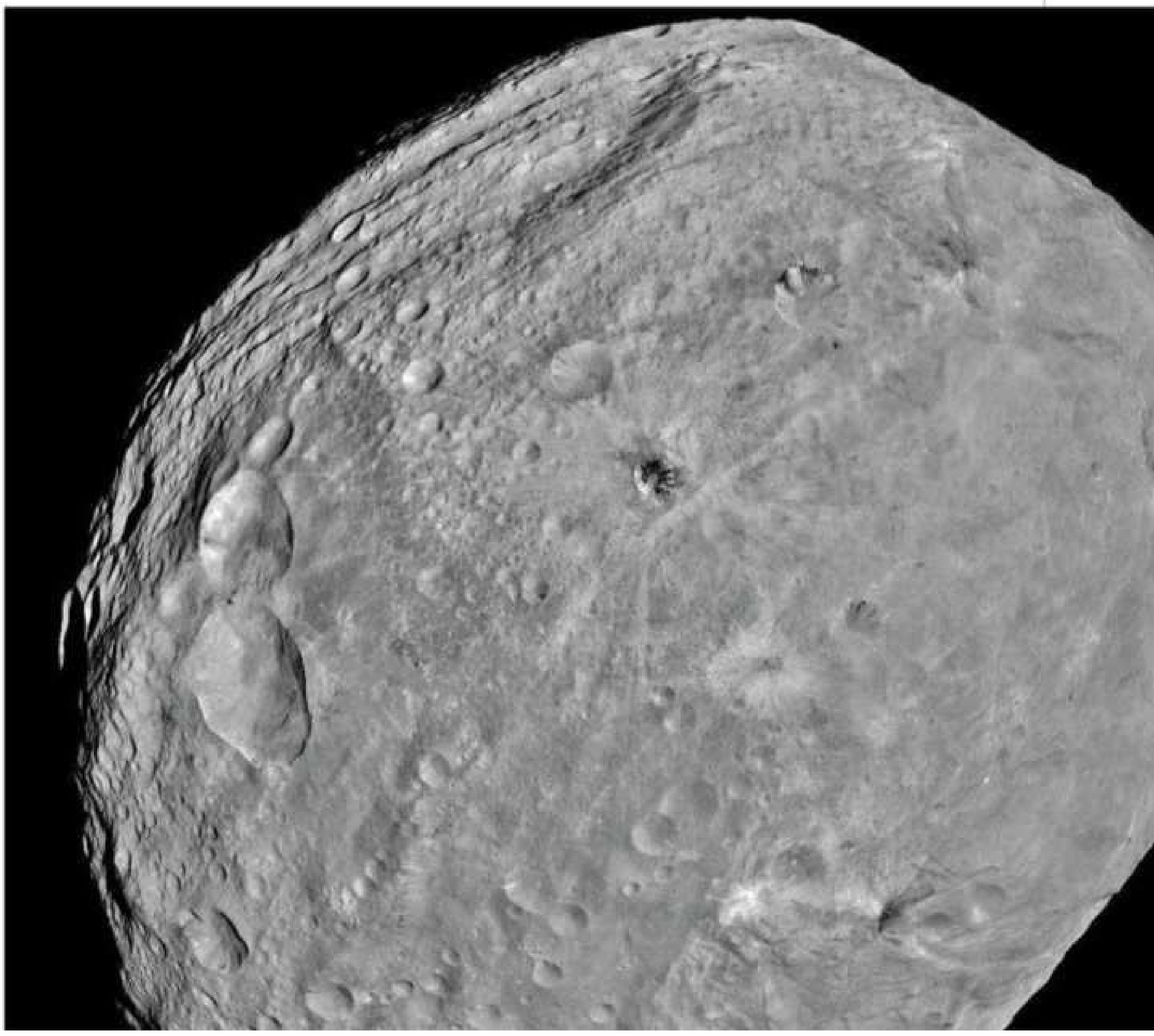
30 August 2012
Dawn leaves Vesta to head to Ceres, and takes a goodbye photograph of Vesta as it leaves

February 2015
Dawn gets closer to Ceres; its cameras pick up mysterious bright spots on the dwarf planet's surface

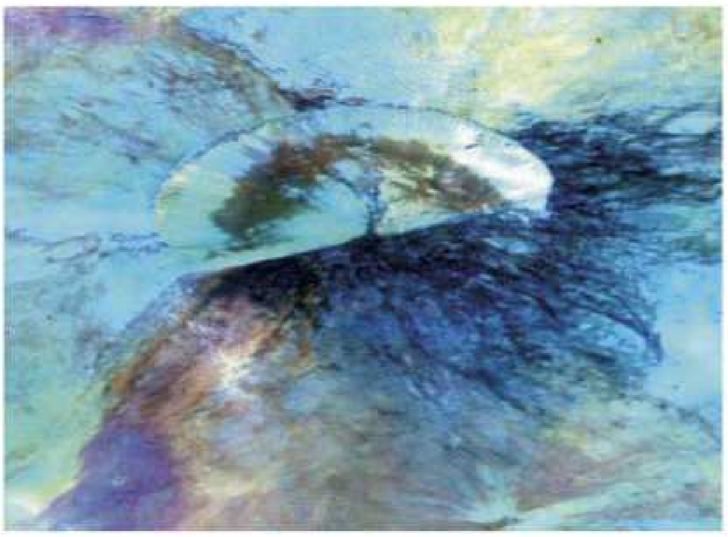
March 2015
Dawn arrives at Ceres initially entering a polar orbit and obtaining its first full topographic map

19 October 2017
NASA announces that the mission will be extended until Dawn's hydrazine fuel runs out

June 2018
Dawn conducts its final orbit of Ceres, flying as close as 35km above its surface and as far away as 4,000 km



► Vesta imaged by Dawn on 24 July 2011 from a distance of 5,200km. The asteroid is the second-largest object in the asteroid belt, beaten only by Ceres



▼ Vesta's 17km crater Antonia, in false colour to maximise subtle differences in the rocks

already knew quite a lot about the giant asteroid before Dawn arrived, having previously recorded Vesta's spectra – the patterns of light given off by an object, which reveal its composition. The results indicated that Vesta was compositionally very similar to hundreds of meteorites found on Earth, suggesting they may have originated on the asteroid. Images from the Hubble Space Telescope showing a gigantic crater at Vesta's southern pole further backed up this idea; a huge impact could have blasted pieces of Vesta all over the Solar System, with some of those pieces ending up on Earth as meteorites.

Dawn allowed astronomers to zoom into the asteroid and observe its features in more detail. Not only did Dawn's instruments confirm that the supposed Vesta meteorites had indeed originated on the asteroid, but analysis of the asteroid's composition showed that it has tectonic features, including a crust and a silicate mantle. Gravity data, which can map the asteroid's internal structure, also indicated that Vesta has a dense and possibly metallic core. This means that Vesta was once volcanically active, making it more like a planet than the inert piece of rock many other asteroids are thought to be.

Water puzzle

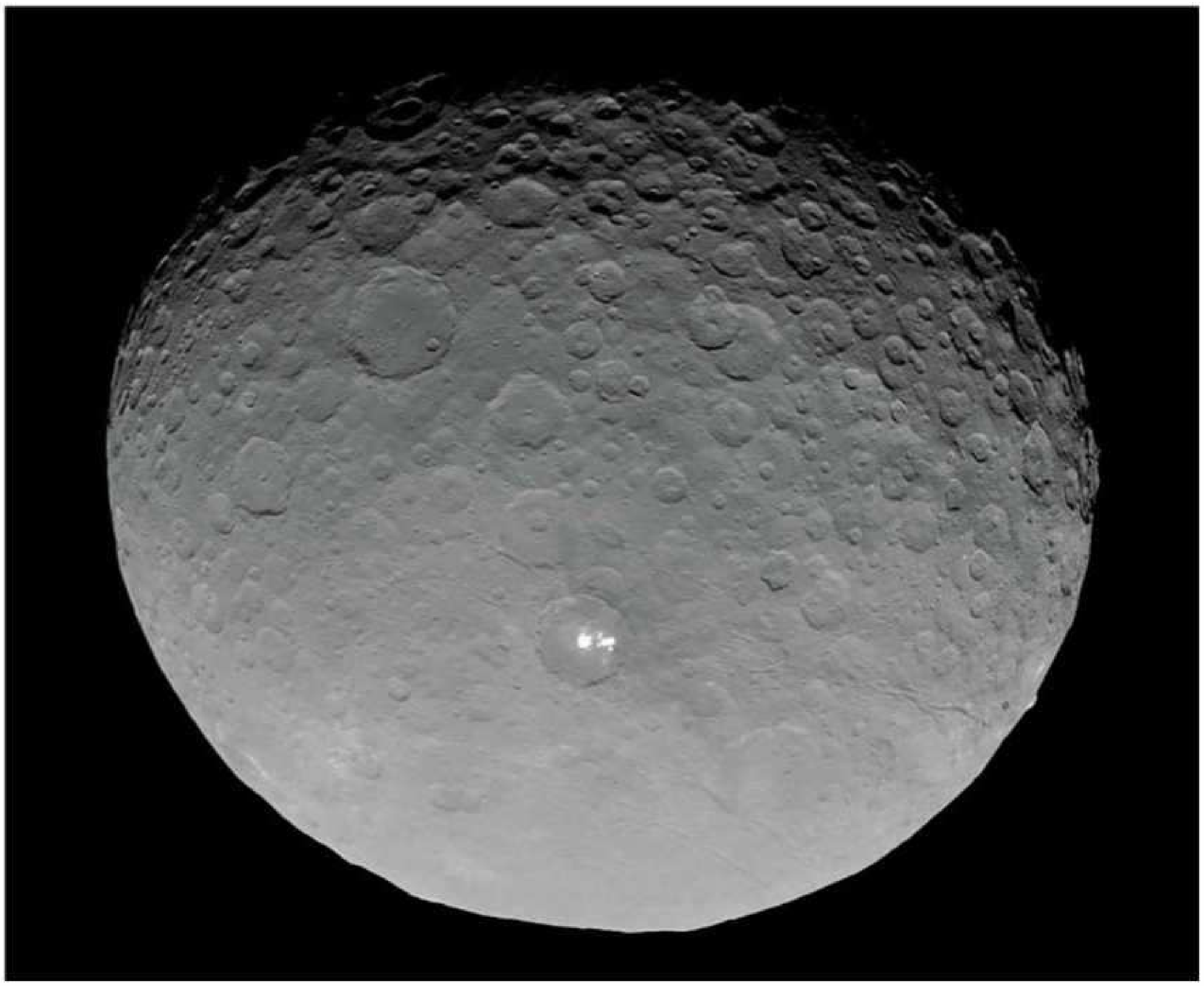
On top of this finding, scientists were surprised to see a lot of water-rich materials on Vesta's surface, particularly in older terrains. That's odd as it was previously thought that without the protection of an atmosphere, Vesta was too warm to hold on to any water. Meteorites from Vesta are known to be richer in carbon than one would expect. One explanation is that the carbon and water-rich material could have come from outside Vesta, possibly when it was struck by two massive chunks of debris from much further out in the Solar System.

With its mission complete, Dawn left Vesta on 4 September 2012 and headed for Ceres. When it approached the dwarf planet in 2015 the spacecraft spotted hundreds of curious bright spots glinting on its surface. The spots were mostly concentrated in and around impact craters, particularly the large Occator crater. Analysis showed that the bright spots are made from sodium carbonate, which astronomers believe is evidence of an ancient ocean beneath the crust in the process of freezing.

"Ceres once hosted a global ocean until it froze," explains Raymond, "leaving carbonates in the shallow subsurface that form bright spots when exposed by impacts. The majority of the bright spots are due to these crustal salts, which have been exposed by landslides and small impacts.

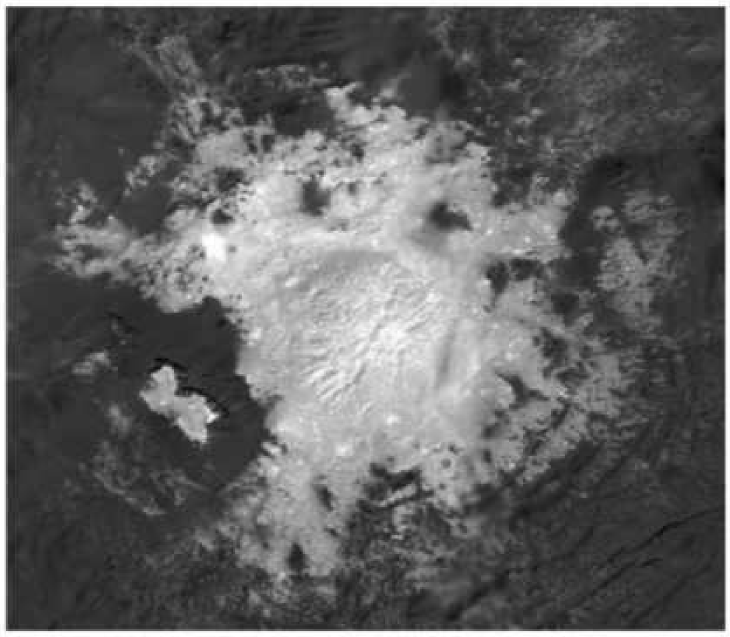
"However, those spots found inside the Occator crater have a different origin. They are produced ►

NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA X 7, NASA/JPL-CALTECH/HAP MCSWEEN (UNIVERSITY OF TENNESSEE) AND ANDREW BECK AND TIM MCCOY (SMITHSONIAN INSTITUTION), NASA, NASA/USGS, NASA/JPL-CALTECH X 2



◄ The brightest spot on Ceres is Cerealia Facula in the centre of Occator crater. Just to the left is a less bright cluster called Vinalia Faculae

ABOUT THE WRITER
Jasmin Fox-Skelly is an astronomy and science writer based in Cardiff. She has a BSc in Neuroscience and an MSc in Science Communication



▲ Above left: A close-up of Cerealia Facula. Ceres's bright spots are created by deposits of sodium carbonate

Above right: Ceres's volcanic mountain Ahuna Mons. On its steepest side, it is about 3km high, with a diameter of about 120km

NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA X 2, NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA/PSI X 2, AKIHIRO IKESHITA, NASA'S GODDARD SPACE FLIGHT CENTER, SOUTHWEST RESEARCH INSTITUTE, SSI/ASU/P. RUBIN/NASA/JPL-CALTECH

► by the extrusion of briny [salty] liquid from Ceres's interior. When the water evaporates it leaves behind a salty deposit."

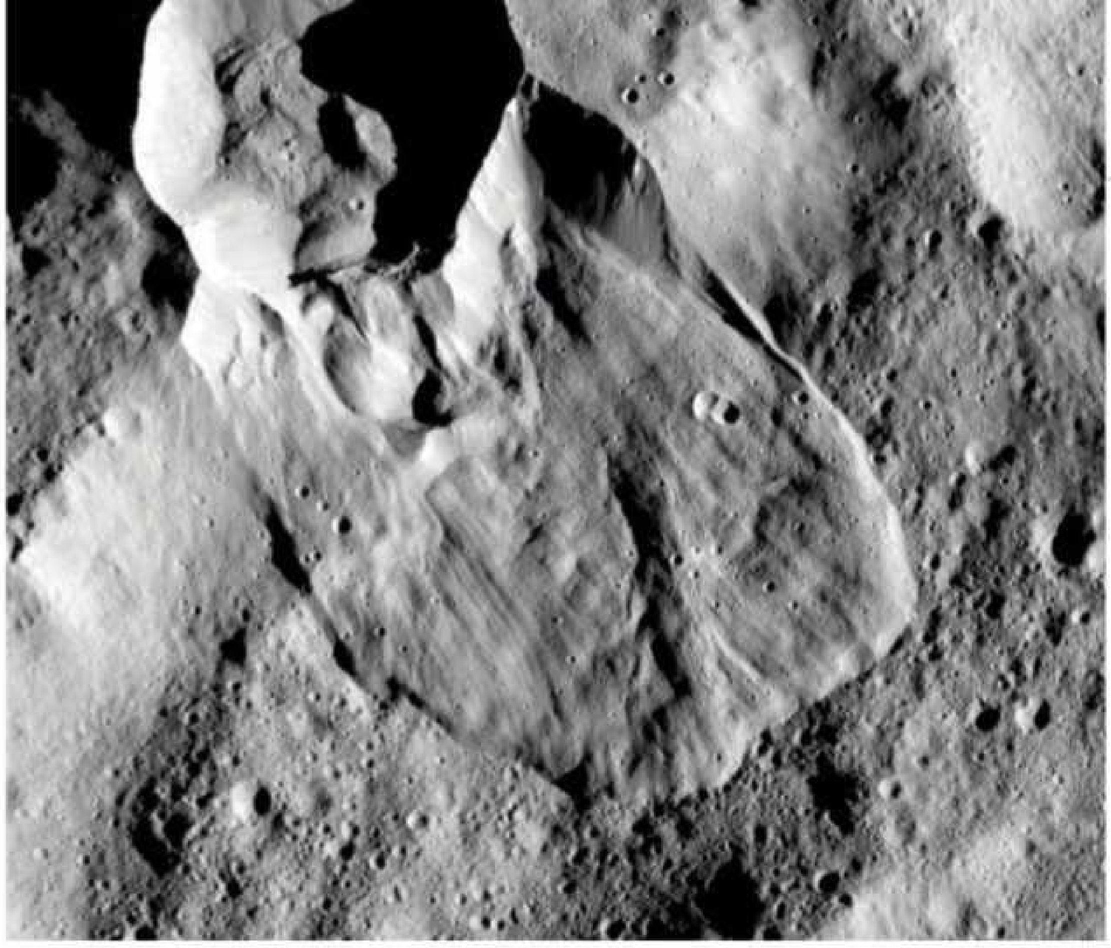
Scientists think this liquid is being forced up from a magma chamber below, making Ceres volcanically active, though not in the classical sense. Instead of rock, these 'cryovolcanos' are made from salt and mud, which erupts as briny water. Only one, Ahuna Mons, is currently active. There could have been several other cryovolcanos in Ceres's past, but geologists are still interpreting the data.

Another remarkable discovery relates to the origin of Ceres. Its chemistry suggests that it didn't form in the asteroid belt, but further out in the Solar System, before migrating inwards.

"Its ammonia-rich clays indicate that the dwarf planet actually formed in a colder environment than where it currently resides," says Raymond. "Ceres is similar in bulk composition to many moons of the giant planets, like Europa and Enceladus. In fact, similar salts have been found on Ceres and in the plumes of Saturn's moon Enceladus. This means it may be related to those icy moons."

What's lurking in the deeps?

So studying Ceres may also help us learn more about these moons, whose structures and internal compositions are hidden by ice. Scientists are particularly interested in learning about the environmental conditions in their deep oceans – and now in Ceres's too – as they contain two of the main ingredients thought necessary for life: water and organic carbon compounds. However, according to Raymond the chance of life forming



▲ **Dawn revealed many landslides on Ceres, which researchers believe have been shaped by a significant amount of water ice. The one above has been designated a 'Type 1' flow feature, which are mostly found at high altitudes**

on Ceres is quite unlikely. "Small dwarf planets like Ceres are not expected to have been warm long enough for complex organic molecules to develop," she says.

But that does not totally discount the possibility of life growing on, or in, the dwarf planet. "The Dawn data suggest Ceres's early ocean was habitable. That is, it could sustain conditions suitable for life if life were introduced in its interior, for example via material ejected from Earth by large impacts."

After a decade of discovery, Dawn is fast approaching the end of its mission. Soon the spacecraft will breathe its last breath and run out of the hydrazine fuel that powers the thrusters. But in June the team still had enough left to alter Dawn's orbit so that it skimmed 34km above the surface of Ceres – 10 times closer than the spacecraft had ever been before. Here the cameras and instruments could send back the most detailed photos of the world yet. This includes recording gamma rays and neutron spectra, which will tell scientists more about the chemical makeup of Ceres's uppermost layer, including how much water it contains.

But now the mission is drawing to a close. Without thrusters to control its movements and orientation, Dawn won't be able to point its scientific instruments at Ceres, or direct its antenna toward Earth to communicate. Scientists don't know exactly when the fuel will run out, but their best guess is August or September. However, the probe will orbit around Ceres for at least 50 years. Perhaps a future mission will return to Ceres and be able to watch Dawn rising up over the horizon.

WHAT COMES NEXT?

The missions in the pipeline to other asteroids, which will build on Dawn's legacy

Hayabusa2

The Hayabusa2 spacecraft was launched in 2014 by the Japan Aerospace Exploration Agency (JAXA) in order to study the asteroid Ryugu. It arrived in late June and will stay for 18 months. During this time its operators will land a small probe and three miniature rovers, while the main spacecraft takes samples to return to Earth. The mission will depart from Ryugu in December 2019, arriving home in 2020.

OSIRIS-REx

NASA's OSIRIS-REx launched on September 8, 2016 from Cape Canaveral Air Force Station, and will travel to near-Earth asteroid Bennu. On 17 August 2018 the spacecraft will be able to take its first photograph of Bennu from a distance of 1.9 million km, before arriving at its destination on 3 December. The craft will then survey the space rock before returning to Earth with its asteroid samples in 2023.

Lucy

NASA's Lucy mission will perform the first close-up investigation of the Trojans, a population of primitive asteroids orbiting close to Jupiter. The Trojans are remnants of the primordial material that formed the outer planets, and they hold vital clues to understanding the history of the Solar System. Lucy will launch in 2021 and fly by six Trojans and one main belt asteroid between 2025 and 2033.

Psyche

NASA's Psyche mission will study a unique target: a 210km-wide metallic asteroid, the only known object of its kind in the Solar System. It's thought to be the exposed core of a planet that was destroyed before it had finished forming thus giving astronomers a window into planetary cores, which are usually hidden from view. Psyche is scheduled to launch in October 2023 and arrive at the asteroid in 2030.

COLOURS OF THE COSMOS

Astrophotographer **Will Gater** explores the use of colour in astro imaging and offers advice on how to strike the right balance when shooting the stars

Astrophotographers face many challenges when capturing views of the night sky, but one element of the craft presents a particular collection of hurdles all its own: colour. Capturing, processing and interpretation of colour in astronomical imagery is arguably the most complex, and sometimes controversial, facet of the subject.

Colour deep-sky imaging using filters requires a skilful blend of art and science to produce spectacular results. But even when taking 'simpler' wide-field and nightscape images, astrophotographers must tackle issues such as light pollution that can dramatically affect what's shown.

Combine all this with the fact that we don't all see colours the same, that we will view images via different mediums and – perhaps most crucially – that everyone has their own opinions on what they like to see, and you can begin to see why colour in astrophotography is often a source of passionate debate. And that's before you even consider that we're talking about pictures your eyes could never see!

In this article we'll look at some of the practical ways you can approach the treatment of colour in your own astrophotography. While there should always be room for artistic licence, our advice is based on the premise that we want to represent celestial phenomena as accurately as possible. The challenge here is to produce not just a captivating image but also one where we've objectively assessed what the scene should actually look like.

Nowadays, with powerful editing software that can drastically manipulate a digital image file, it is in the post-processing of an astrophoto where many colour choices are made. But the moment of capture – particularly in nightscape and star-trail photography – will always be a crucial moment that hugely influences the tone and the interplay of dark and light in a shot.

ABOUT THE WRITER
Will Gater is an astronomy writer and presenter. Follow him on Twitter at @willgater or visit willgater.com

WILL GATER

Contrast versus detail

Imagine you're shooting a twilight nightscape, including a bright planet, using a DSLR. With a short exposure you might capture a darker, higher-contrast scene, with rich twilight colours but little foreground detail; perhaps just black silhouettes. Using a long exposure the same view would look markedly different: the sky would be brighter while the overall contrast would likely be lower, but you could pick up more detail in the shadows. You could even aim to blend two such exposures ▸

Insight Investment Astronomy Photographer of the Year

With colour mastered, why not consider your image for the 2019 Astronomy Photographer of the Year competition? The 2018 winners will be announced in October. Visit: www.rmg.co.uk/astrophoto

A great way to emphasise the different colours of stars is with a star trail image

WILL GATER X 2, KLAUS EDER/CCDGUIDE.COM

▲ The different star colours in Auriga: bright nearly-white Capella (top right), orangey K-type Hassaleh (bottom right) and the blueish B-type Elnath (bottom left)

▸ in post-processing. Whatever the approach, the point is that in the act of selecting the exposure for an image, you're already making an important decision that will affect the colours in the final picture and – even if inadvertently – the feelings it'll convey and how it will direct the viewer's eye. Of course, such aesthetic considerations are only one side of the coin. Since you're aiming for a faithful rendition of the view depicted, you also need to think about the science of what's shown; and it's this that should ultimately provide the guide for the processing and enhancement of colour in any kind of astrophotography, from planetary imaging to long-exposure, deep-sky work.

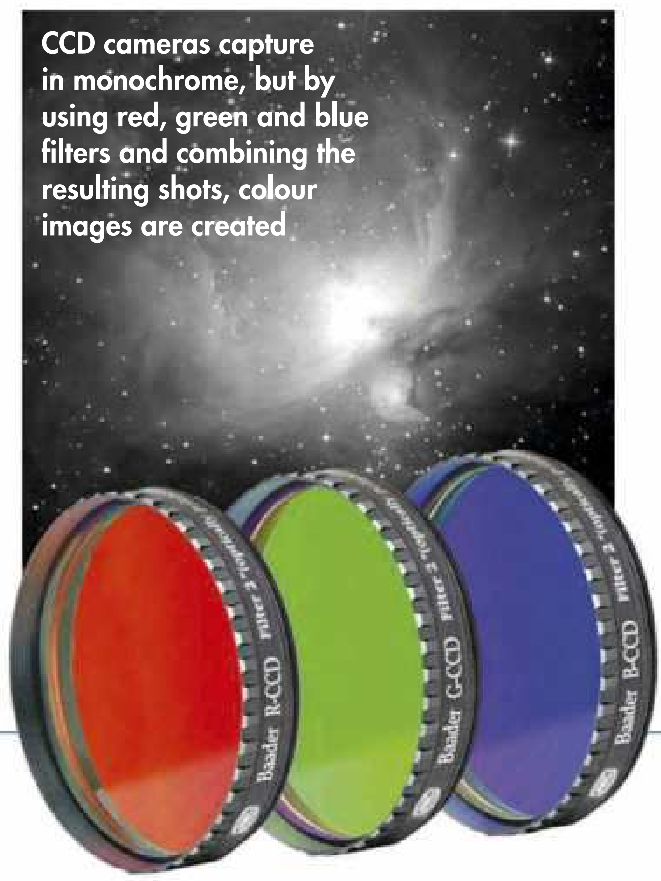
"Use some basic astrophysics to guide how you tweak colours in post processing"

Take, for example, the bright band of the Milky Way, which is a central element in countless astro images. Our Galaxy's core is composed of older, more red and yellow stars, while the spiral arms in its disc are inhabited by hot, young, bright, blue-white stars. So in long-exposure images showing the Milky Way stretching across the sky, we would expect the star fields of the Galaxy's central bulge, in and around the constellations of Sagittarius and Ophiuchus, to have more of a yellowish-white colour to them; while further away from the core – where the disc of the Galaxy traverses Cygnus and Cassiopeia – the Milky Way's star fields should show more blueish-white tones. Often these rich star fields also show a hint of ochre and brown in places;

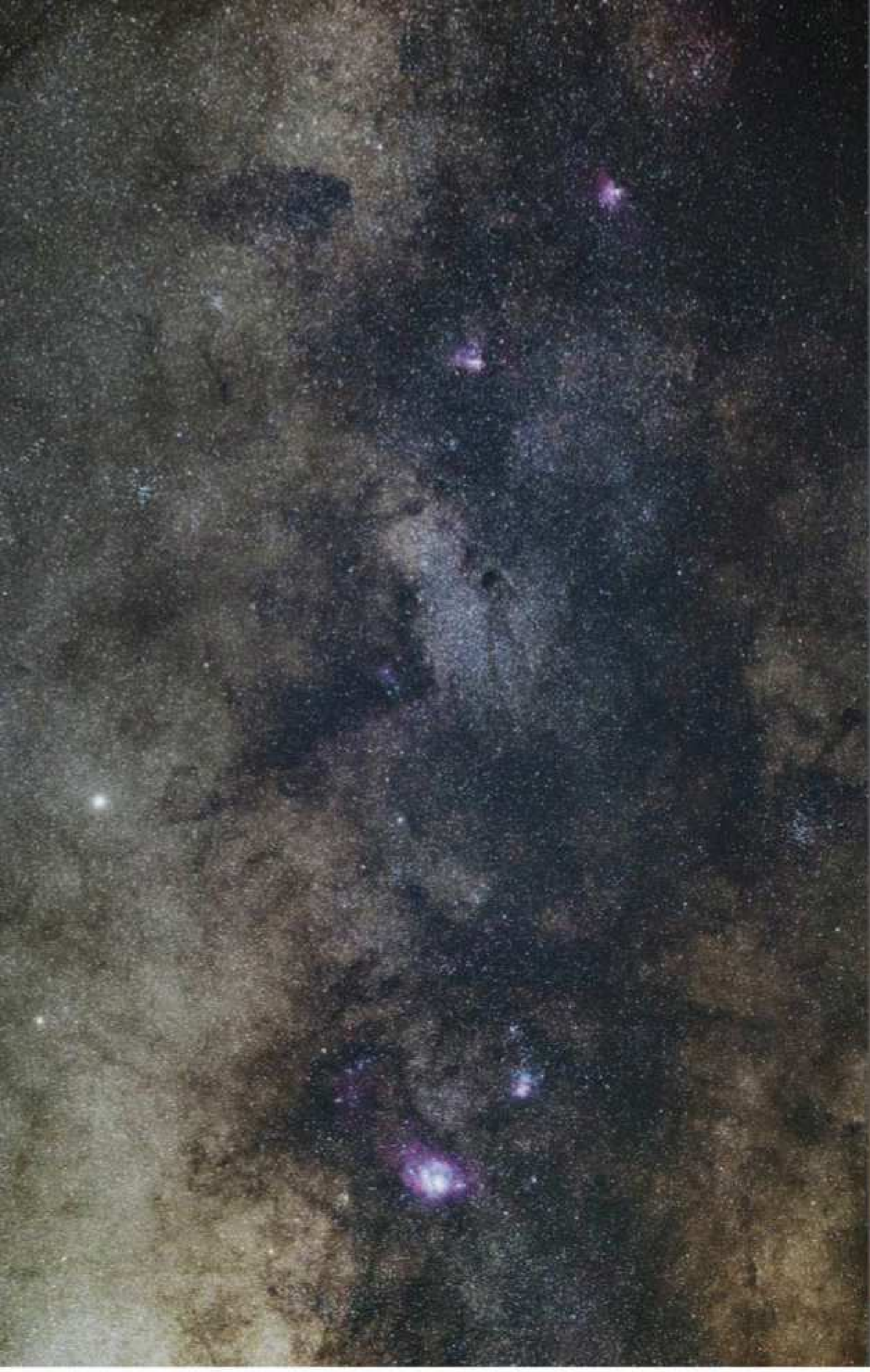
USING CCD CAMERAS

Many of the most spectacular deep-sky images of galaxies, nebulae and star clusters are taken not with one-shot colour cameras such as DSLRs, but with specially cooled astronomical 'CCD' (charged-couple device) cameras with monochrome sensors. These produce greyscale RAW images, and in order to create vibrant full-colour images, astrophotographers need to use a set of filters on their lenses. For example, to capture a scene in the kind of palette most people see in – where trees are green, the sky is blue, strawberries are red – the imager must capture exposures through red, green and blue filters and later combine this data into a full-colour – sometimes called 'true' colour – 'RGB' image in image-editing software. Like all astro images, these pictures still need to be colour balanced carefully as sometimes filters can let in more or less light of certain colours, or the camera sensor itself might be more sensitive to some colours.

Many high-end astronomical image-stacking and processing programs contain automatic colour balancing features or tools to remove or neutralise background colour casts. These are usually excellent, though can sometimes produce an 'off' result, so do take time to look carefully at your final image's colour; make manual adjustments if necessary and use any preview function available to move back and forth between iterations of the image as you tweak the colour.



CCD cameras capture in monochrome, but by using red, green and blue filters and combining the resulting shots, colour images are created



Case study 1: Milky Way star fields

A wide-field image and an extreme close-up reveal two different palettes for our Galaxy

When processing these images the colours of the Milky Way star fields were a prime consideration. In the wide view (right) we've ensured the yellowy-white regions near the Galactic core give way to more blue-white stars in the spiral arms. In the long-exposure image (left) we were careful to preserve the ochres and browns often seen where rich fields of stars intermingle with dark dust and gas

this is where their light is reddened by interstellar dust and gas clouds, so don't be put off if your Milky Way images have some muddy brown colours – they are real!

The challenge of achieving pleasing and accurate star colours crops up wherever there are stars depicted in an image, but it's perhaps most keenly felt in long-exposure, deep-sky work. Here again, though, you can use some basic astrophysics to guide how you tweak colours during post-processing.

The colours of stars

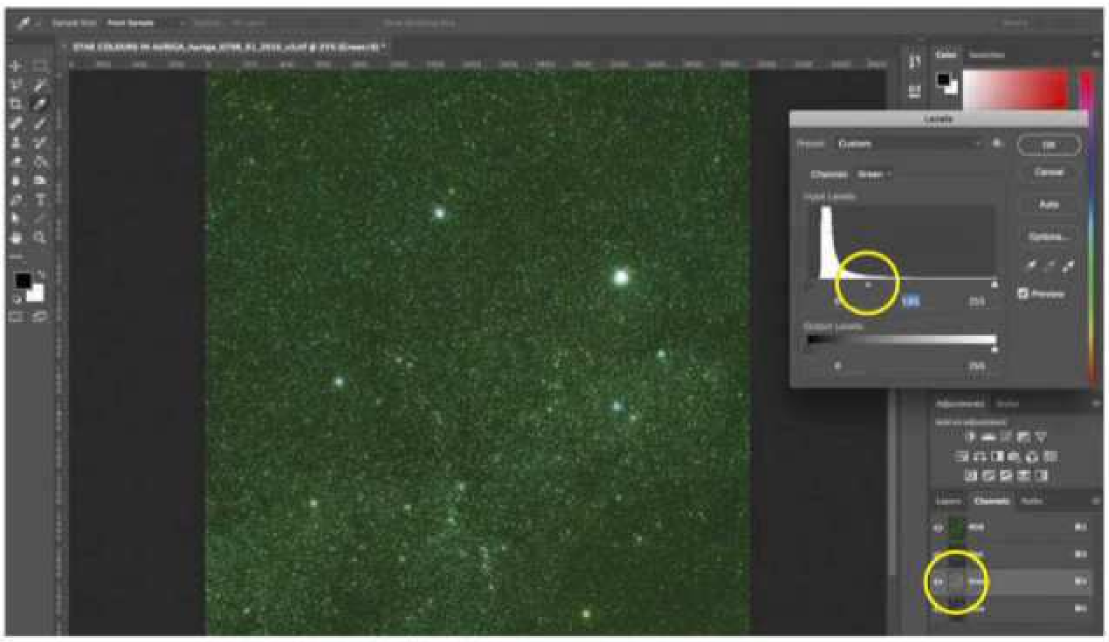
Professional astronomers group stars into 'spectral types', which tell us about the appearance of key chemical 'fingerprints' in their light as well as their temperature. It's the differing temperatures between stars that cause the colour variations we see. For example, a hot 'O-type' star like Mintaka in Orion's Belt appears blueish, while a cooler 'K-type' star, such as Aldebaran, will have an orange tint. Among the other spectral types there are also 'F-type' stars, which tend to appear closer to white. These are of particular use to astrophotographers as you can use a planetarium programme, like Stellarium or Starry Night, to find such a star in your image. Then during editing and processing, check that you have it showing a neutral white-ish colour; this way you can be confident that the overall colour balance of your image is accurate.

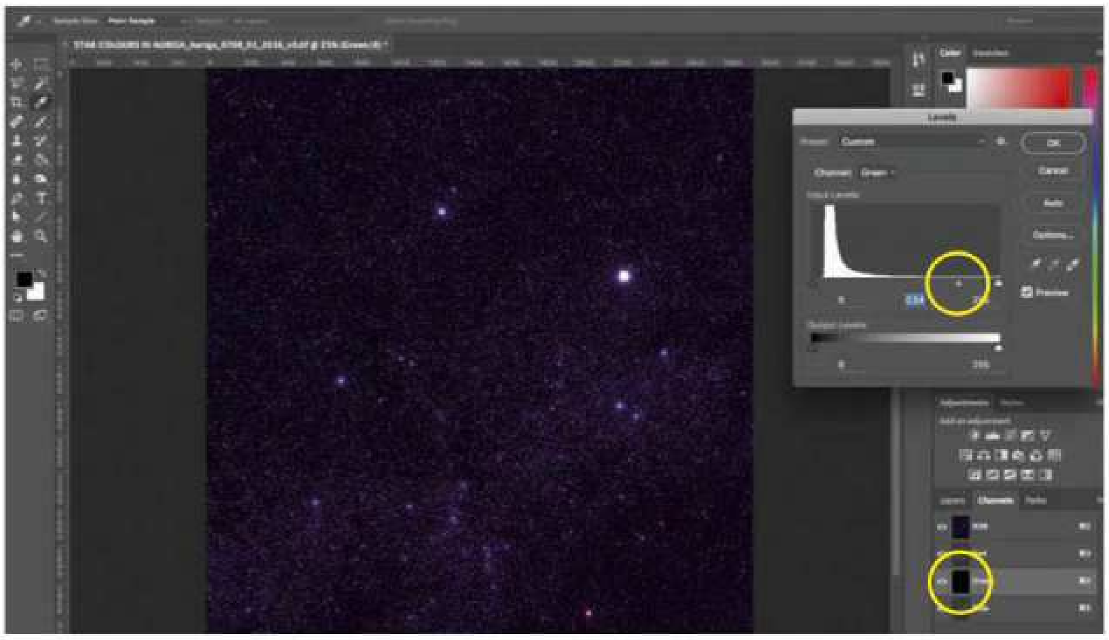
When examining and processing colour in astro images it's often easy to concentrate on the main features, while forgetting about the background; do so at your peril. Backgrounds present their own complications. The night sky is not perfectly black so, in most cases, when tweaking the colour of an image you should aim for a neutral, extremely dark ▸

▸ grey backdrop. However, certain deep-sky images can be the exception, as they often feature regions of colourful nebulosity across the whole frame.

Sometimes, though, there will be strong colour casts or gradients within an image that affect the background. Occasionally these will come from natural sources, so we'd argue for preserving them and making sure they're faithfully portrayed. For example, you'd expect colour images taken in deep twilight, or when a Full Moon is high up, to show a washed-out background with a blue cast – and note that when a full Moon is rising it initially washes the sky out with a yellow-grey light that changes to a whiter, bluer hue as the lunar disc gains altitude.

Similarly, nightscape photographers imaging from dark-sky locations often capture the atmospheric phenomenon known as 'airglow', which can create greeny-blue swathes of colour across an image. Airglow can really throw off the processing of an image if it's not recognised as being present in a shot, as the photographer desperately tries to correct the strong, green background gradients.





▲ **In Photoshop you can adjust the levels for each of the red, green and blue channels individually**

Learn to love levels

However, the most common cause of background gradients or colour casts is usually light pollution. Specialist filters can reduce the effects of this unwanted intrusion to a certain extent, but some – in doing so – impart their own colour cast to a photo, which has to be dealt with in processing later.

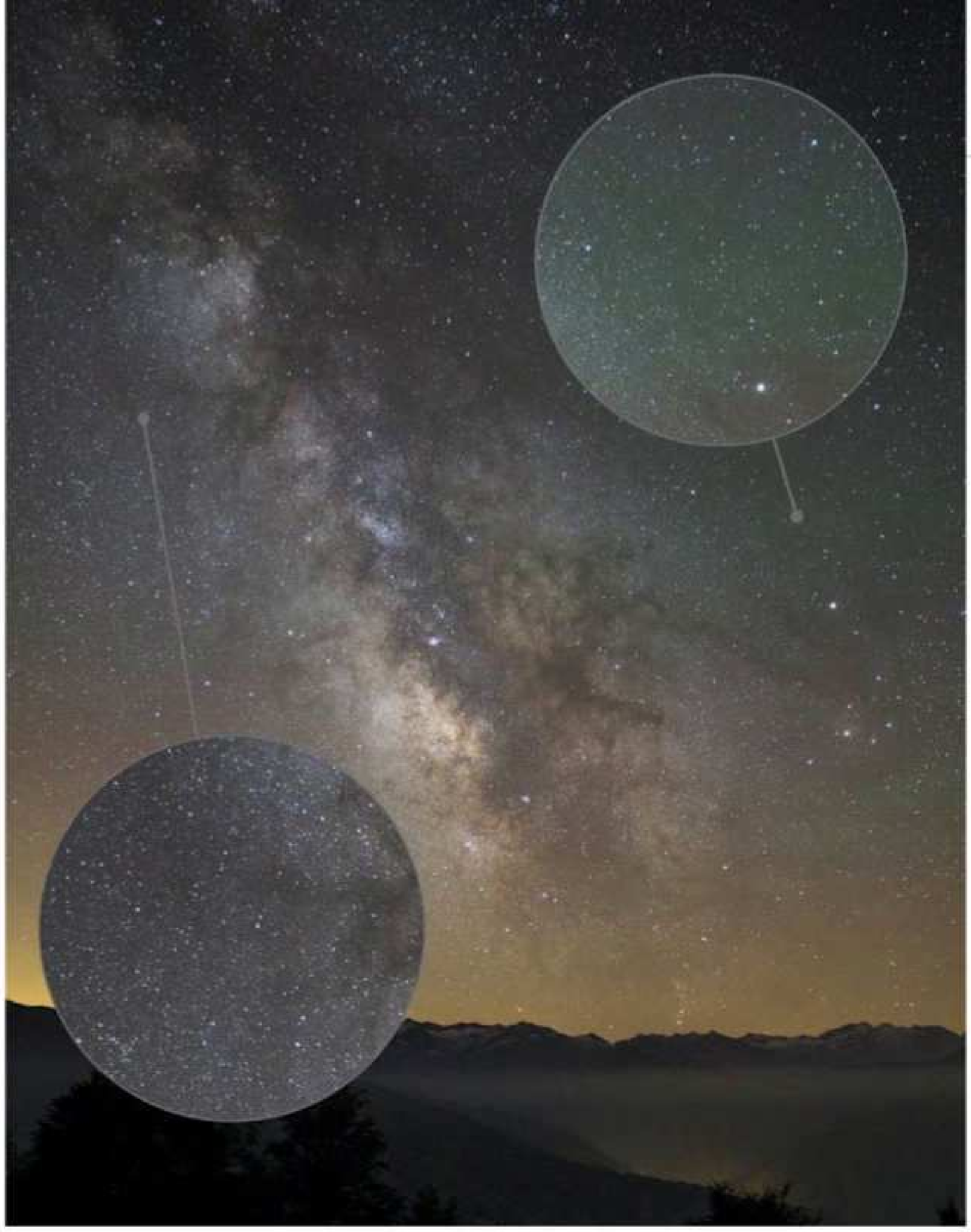
How, then, do you go about correcting and tweaking the colour of an astro image in image-editing software? One of the ways to begin to correct or 'balance' the colour within an astrophoto is to use the 'levels' tool commonly found in software like Photoshop and GIMP. Usually this feature is used to increase the brightness and contrast in an image, to pull out detail. However by choosing to adjust individual colour channels, one at a time, you can also vary the colour balance within a shot. To get a feel for how this alters the colours in an image, first

Case study 2: Nightscape at twilight

Don't make the mistake that your backgrounds have to be an inky black expanse every time

This image of Orion and the bright star Sirius was captured during twilight meaning the background sky in the RAW image had a noticeable blue colour cast; since it was a natural effect, we wanted to preserve it during post-processing rather than try to remove it. Similar blue-white colour casts and gradients can appear in wide-field images taken when the full, or nearly full, Moon is high in the sky.

WILL GATER X 3



Case study 3: A messy wide-field Milky Way

Balancing light pollution and sky glow with your chosen starscape can present some tricky challenges

This image highlights some of the challenges that astrophotographers face when dealing with colour balancing in wide-field images. There are strong orange gradients from light pollution above the horizon line, while in the shadows on the right there are several bands of green airglow. We've attempted to keep the background sky as close to a neutral grey as possible while also preserving the colours of the Milky Way.

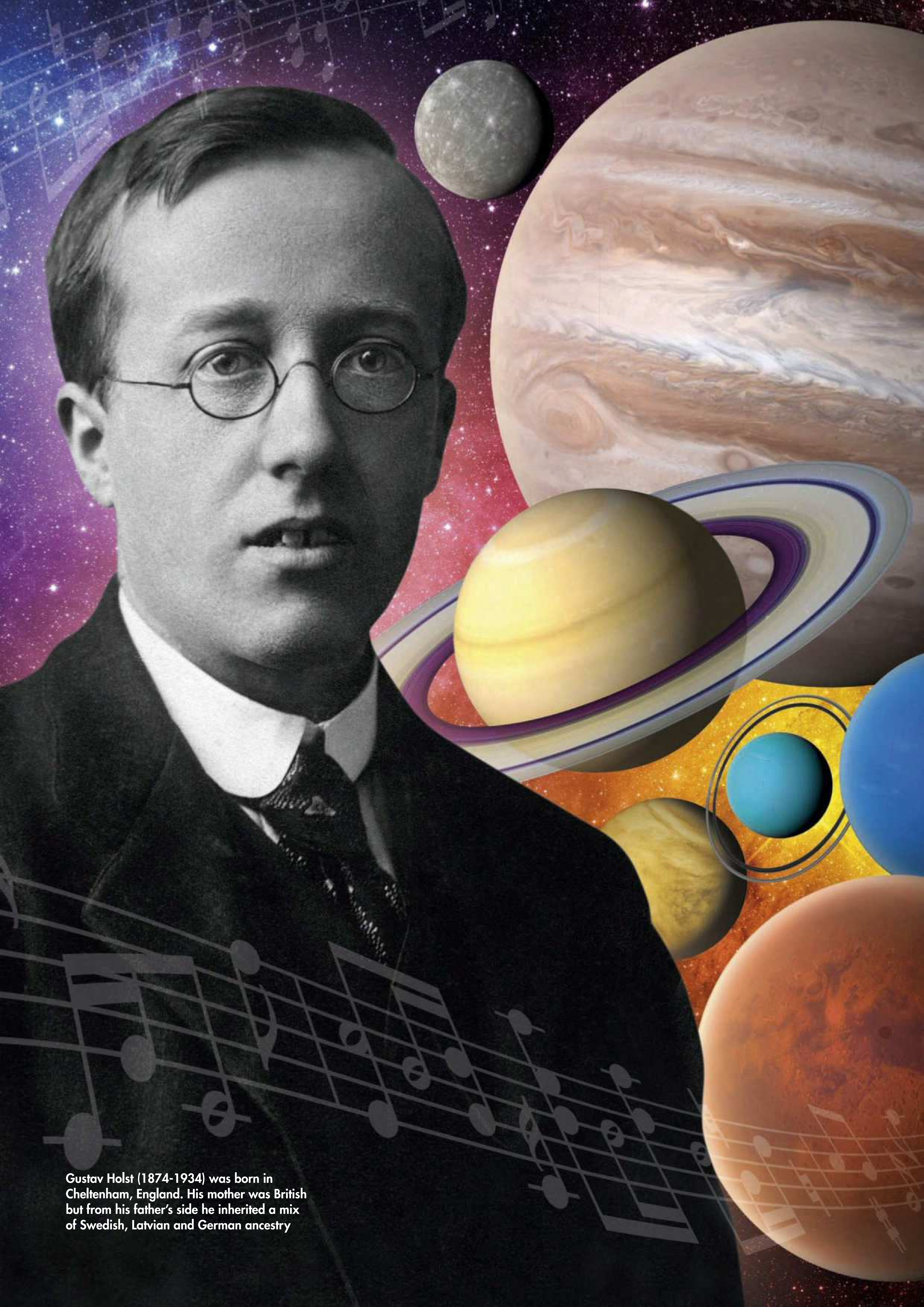
▲ **Astrophotographers tend to 'cool' aurorae shots by adding more cyan to their natural green using the temperature controls**

select a colour channel (either red, green or blue) from the drop down 'channel' menu and then move the middle 'slider' icon in the 'input levels' window; you'll see the colour of your image in the main window change, and by further experimenting with the different channels and other sliders hopefully you'll get close to an image tone you're happy with.

Both Photoshop and GIMP also have an advanced 'Colour balance' tool that enables you to alter the balance of colour in an image between three pairs of colours: cyan and red; magenta and green; and yellow and blue. Adjustments made with this feature can be applied – independently – to the shadows, midtones and highlights of an image, meaning it's incredibly useful for precision colour correction.

Some image-editing programs also have a feature that can be used to adjust a picture's 'temperature'; in other words, how yellow or blue the tones in the final image will be. This tool is frequently used by aurora photographers – for aesthetic reasons – to give an image a 'cooler' feel, with the natural, green colour of the auroral light becoming a more greeny-cyan hue. How far you are willing to push this is a matter of personal taste.

And that is, of course, true of everything we've discussed in this article: how far, and in which chromatic direction, you want to take your colour balancing and correcting is ultimately down to you, and will likely vary from image to image depending on a multitude of factors. But, hopefully, armed with the ideas we've looked at here you'll have some fresh ideas and new perspectives to consider the next time you're shooting and processing a celestial shot of your own.



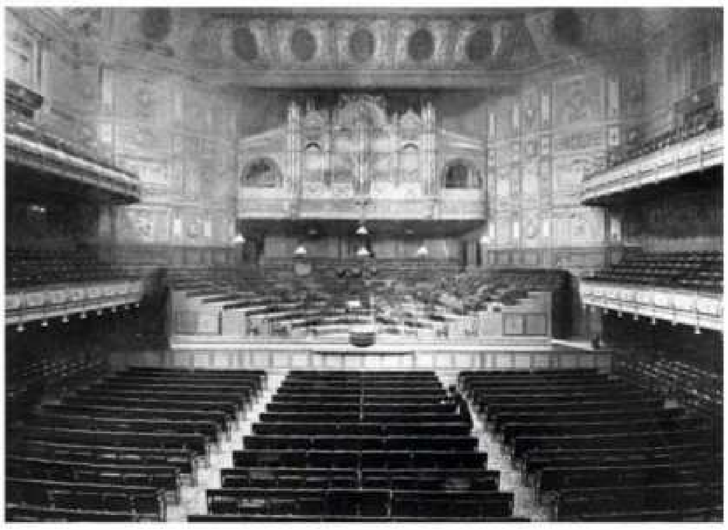
Gustav Holst (1874-1934) was born in Cheltenham, England. His mother was British but from his father's side he inherited a mix of Swedish, Latvian and German ancestry

Music of the SPHERES

Holst's epic orchestral suite *The Planets* was first performed 100 years ago this month. But what, asks **Andrew Green**, inspired this masterpiece?

When it comes to blockbuster musical depictions of outer space, Gustav Holst's *The Planets* is where it all began. The bespectacled, unassuming British composer smashed it: seven planets captivatingly imagined in sound. This undisputed masterpiece was first heard 100 years ago this month, at London's Queen's Hall. It still entrances audiences around the world today: listen to the music while contemplating planetary images in a darkened room and it's impossible not to be moved.

The Planets was largely composed during the Great War, although 'Mars: the Bringer of War' (which Holst wanted to sound 'terrifying') in fact predates the conflict. Holst wasn't medically fit to fight in the war, but in late summer 1918 the YMCA invited him to organise musical activities for troops stationed in Salonica (modern-day Thessaloniki, Greece). The finishing touches to *The Planets* were inscribed at the YMCA's London HQ, while Holst sat waiting for his papers. That first performance was given thanks to financial support from a benefactor – Holst's friend and fellow composer Henry Balfour Gardiner – and rushed through before Holst departed; the orchestra was only able to rehearse for a couple of hours before that historic first performance took place.



▲ **Destroyed during the blitz, London's Queen's Hall hosted the first performance of *The Planets* in 1918**

The Musical Times declared *The Planets* "one of the most ambitious achievements in modern British music," although some critics were nonplussed. Too modern for them. "Noisy and pretentious", said one. Very soon, though, it was recognised for what it is: a musical phenomenon like no other.

Space, the vinyl frontier

As early as 1921 *The Planets* was available in a complete recording, Holst himself conducting the London Symphony Orchestra. This Columbia New Process Records release ('The Only Records Without Scratch!') cost a stiff (but not astronomical) 52s 6d. That's a bit over £2 – more than a hundred quid now.

Debate continues over Holst's motivation for writing the music. Yes, his new-found curiosity for astrology had something to do with it (reflected in the subtitles given to the music for each planet), but Holst detested being asked what the work 'meant'. Besides, any debate is meaningless to the millions of *Planets* admirers who've known instinctively that this stunning music evokes the wonder and mystery of outer space.

To understand the immediate impact of *The Planets* it's surely relevant that it was written during the first great ►

ISTOCK X 8, NASA, CHRONICLE/ALAMY STOCK PHOTO

In 2010, Hans Graf conducts the Houston Symphony Orchestra through a rousing performance of 'Jupiter, The Bringer of Jollity'

▲ A 19th century magic lantern slide showing the motion of Venus and Mercury

▸ era of popular astronomy. Ever more sophisticated photographic wizardry enabled the capture of jaw-dropping images from around the cosmos. These found their way into books, newspapers and journals (such as *The Observatory*, which is still going strong). Magic lantern slides of celestial objects were a staple at public lectures across the country. Speakers could record their discourses on heavenly bodies using the newly invented spectroscope. In the same month *The Planets* made its debut, the Leicester Literary and Philosophical Society was advertising its forthcoming lecture 'Astronomy in Daily Use' by Arthur Hinks, Gresham Professor of Astronomy. Early in 1918, a Miss Iris Yeoman had given a course of lectures on astronomy in Bath, "Specially Suited for Children".

Astronomy for the masses

The steady trickle of books on astronomy in the 19th century had become a flood by the second decade of the 20th. One go-to reference volume in 1918 would have been Sir Frank Dyson's recent *Astronomy: a Handy Manual for Students and Others*. A Scottish newspaper, the *Kirkintilloch Herald*, listed *Practical Astronomy* by H Macpherson FRAS as one of its 'People's Books' in 1918. And if 'practical astronomy' was indeed your goal, then RAE Opticians in Glasgow was ready to mail you a telescope. Prices

THE PLANETS' ASTRONOMICAL ACCOMPANIMENT

V603 Aquila (Nova Aquilae 1918) was sighted in the same year Holst's suite was first performed

When the brightest nova recorded in the era of the telescope appeared in the skies in 1918 it was amateur astronomers who led the observations. Zygmunt Laskowski, a Polish medic and part-time astronomer, perhaps saw Nova Aquilae first. Or was it Félix de Roy, secretary of the Astronomical Society of Antwerp, who happened to be at Thornton Heath in Surrey on 8 June 1918, when he observed the nova? The phenomenon was also sighted that night by UK amateur, Grace Cook. Newspapers reeled off a string of other hobbyists reporting the same observation: including Mr Denning of Bristol, Mr Owen of Abergavenny and FW Longbottom of Chester.

Giving a lecture on Nova Aquilae in 1918, Sir Frank Dyson mentioned a sighting by, "an invalid in London, who was in the habit of watching the stars while lying in bed". Such amateurs might ask, said Sir Frank, "what the professional astronomers were doing?" Quite. The brightness of Nova Aquilae – it peaked at mag. –0.5 and took 12 days to fade three magnitudes – grabbed headlines. And the brewers Davenports CB Ltd didn't miss a trick in running an advert (recreated, right) for its 'New Star' beer.

ISTOCK X 7, NASA X 5

▲ The influence of *The Planets* can be heard in John Williams' lush scores for the *Star Wars* films

ranged from 30/- to 105/- (£1.50 to £5.25 which equates to around £80 to £250 in today's money).

In an age before TV, radio and all things online, people got out more. Remember? And meetings of local astronomical associations were increasingly popular destinations. The umbrella organisation here was the British Astronomical Society, formed in 1890 specifically to support amateur astronomers. Its initial 48-member council included four women, including Elizabeth Brown (head of the BAS's Solar Section) and the legendary Agnes Mary Clerke, author of the best-selling (and still highly readable) *A Popular History of Astronomy in the 19th Century*.

Planetary influence

Amateur astronomers in wartime must have found plenty to distract them up above, then. And there was more. Much more. Remarkably, one of the 20th century's landmark celestial events happened to be observable that very summer *The Planets* premiered. Namely, the brightest nova recorded in the era of the telescope: V603 Aquilae (aka, Nova Aquilae 1918) in the constellation Aquila. This reached a peak magnitude of −0.5. The sighting was big news, even making an impression on the man in the street.

So audiences for the first performances of *The Planets* are very likely to have included those who pondered the marvels of the Universe. By the mid-1920s it had been performed on multiple occasions in the UK and other English-speaking countries, including the US. It also triumphed in cities not renowned (even now) for taking much interest in British music: Vienna, Berlin, Paris, Rome.

The Planets gave Gustav Holst a public profile no other work of his achieved. It was a matter of deep civic pride in his home town of Cheltenham, which in 1927 presented Holst with a celebratory painting by local artist Harold Cox. This featured a Cotswold night sky showing the planets that had been visible when the famous work was first performed.

The Planets' influence on music since? Hard to pin down, but any composer writing 'space music' now must be aware of this intimidating predecessor. Royal Philharmonic Orchestra managing director James Williams suggested on the radio earlier this year that it's difficult to imagine that John Williams's music for *Star Wars* wasn't inspired by Holst to some degree. Strong in the Force, *The Planets* is.

ABOUT THE WRITER
Andrew Green is an oral history research fellow at the University of Hertfordshire, and the proud owner of two telescopes

YOUR BONUS CONTENT
Download and listen to *The Planets*' Mars and Jupiter movements

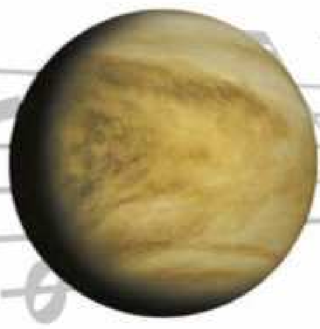
PLAYING THE PLANETS

How well does Holst's *The Planets* represent its original subject matter?

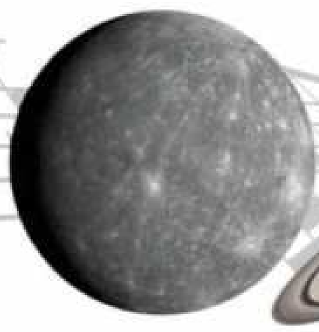
The Planets, in performance order, comprises: Mars, Venus, Mercury, Jupiter, Saturn, Uranus and Neptune. There's no need to argue about Pluto's planetary status; it simply hadn't been sighted by 1918.

Musical considerations meant Holst didn't order his *Planets* according to their distance from the Sun. The music for five of Holst's *Planets* in particular suggest images with which the astronomer can identify.

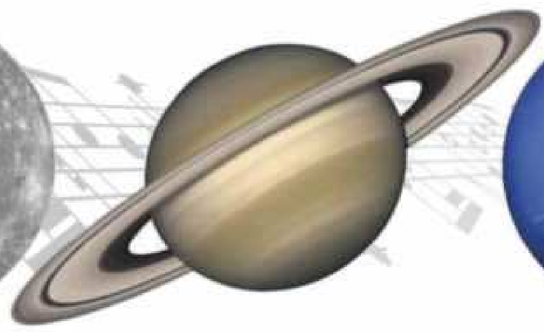
Mars
Mars is frighteningly depicted as 'The Bringer of War', which references the fiery appearance of 'The Red Planet'.



Venus
This movement, subtitled 'The Bringer of Peace', reflects the beacon that is the brightest in appearance of all our Sun's planets.



Mercury
'The Winged Messenger' is a skittish, helter-skelter depiction of a planet that races round the Sun on the most rapid orbit of all – just 88 Earth days.



Saturn
'The Bringer of Old Age' is a wonderful contrast to Mercury, reflecting the ponderously moving planet, with a lethargic orbit of 29 Earth years.

Neptune
'The Mystic' rounds off Holst's masterpiece in ethereal fashion, taking its cue from the far-distant planet's mysterious blue hue.

CAPTURE THE MOON

Meet the camera that thinks it's a telescope – Nikon's new COOLPIX P1000 Megazoom

Imagine a compact camera with a zoom so powerful it can capture craters on the moon. And with such a wide angle, it can even effortlessly shoot dramatic, sweeping earthscapes. That's what you get with Nikon's all-new COOLPIX P1000 – the world's only compact camera to boast a 125x optical zoom.

The COOLPIX P1000 is a complete revelation for sky-watchers. Not only will this 16-megapixel camera shoot remarkably sharp images, even at ultra-high telephoto lengths, it also delivers superb results in low light. Budding movie-makers will be happy too, as this sharp-shooter is equally at home recording super-telephoto 4k/UHD video footage. And, at less than a quarter of the weight of the average D-SLR camera, it's the perfect companion even if you're on the move.

Nikon

Fly me to the moon – and beyond
The 125x optical zoom is the world's biggest, offering a range of 24–3000mm. And the 250x Dynamic Fine Zoom digitally extends the upper limit to an incredible 6000mm.

Jaw-dropping shots
The bright f/2.8 – f/8 NIKKOR lens, 16 MP sensor, and RAW support combine to deliver sharp results even when shooting at ultra-high-telephoto focal lengths.

Super-telephoto 4K (UHD) movies
Easily record 4K/UHD 30p footage, or full HD (1080p) video at frame rates of up to 60p – get up close to the rocket launch or film stunning images of the sky at night.

Always find your target
A large grip and well-positioned controls make it easy to adjust the zoom quickly and smoothly. No matter what the sky reveals, you'll be ready.

Be ready: a universe of accessories
Give yourself more scope by mounting Nikon Speedlights and microphones on the camera's hot shoe.

Share the wonder: stay connected via SnapBridge
Keep your camera connected to your smart device to sync incredible photos as you shoot, then share them instantly. Or use your smart device to shoot remotely.

Find out more about Nikon's superb line up of cameras and lenses at nikon.co.uk

The Sky Guide September

The UK's view of the summer Milky Way is challenged by short nights around the solstice. But September offers an excellent opportunity to witness our Galaxy's true splendour

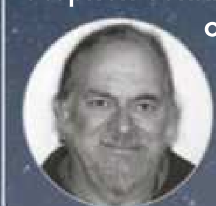
PETE LAWRENCE

GET THE SKY GUIDE WEEKLY

For weekly updates on what's best to observe, sign up to our email newsletter: **www.skyatnightmagazine.com/iframe/newsletter-signup**

ABOUT THE WRITERS

Pete Lawrence is an astronomer and astro imager who presents *The Sky at Night* monthly on BBC Four



Stephen Tonkin is a binocular observer. Find his tour of the best sights for both eyes on page 58

RED LIGHT FRIENDLY

To preserve your night vision, this Sky Guide can be read using a red light under dark skies

DON'T MISS...

- ✦ Neptune reaches opposition
- ✦ Getting ready for comet 46P/Wirtanen's autumn voyage
- ✦ Saturn's impressive deep-sky backdrop of the Trifid and Lagoon nebulae plus M21

SEPTEMBER **HIGHLIGHTS**

Your guide to the night sky this month

SATURDAY ▶

1 At mag. –4.3, Venus can be seen in daylight. due south at 16:00 BST (15:00 UT). It currently lies 1.2° south and slightly west of the bright star Spica (Alpha (α) Virginis) in Virgo. Both may be visible through a telescope in daylight. Venus has an altitude of approximately 25° at this time.

SUNDAY

2 Comet 21P/ Giacobini-Zinner is predicted to be at mag. +7.1 this evening and is conveniently positioned, passing a degree to the southwest of the bright star Capella (Alpha (α) Aurigae) at 01:00 BST (00:00 UT) on 3 September.

MONDAY

3 If you can find Jupiter during the day, there's a double shadow transit (Io and Europa) happening between 18:25 BST (17:25 UT) and 19:05 BST (18:05 UT). Jupiter's altitude is 19° at the start of the event and 17° at the end, moving from just west of south to south-southwest.

FRIDAY

7 Neptune is at opposition embedded within the constellation of Aquarius, the Water Bearer.

SUNDAY

9 The low-rate Piscid meteor shower peaks today, coinciding with the new Moon. This has a zenithal hourly rate (ZHR) of 10 meteors per hour. In addition, another low-rate shower, the Epsilon Perseids, also reaches its peak today with a ZHR of five meteors per hour.

MONDAY

10 Comet 21P/ Giacobini-Zinner reaches perihelion, the point in its orbit when it's closest to the Sun – see page 53 for further details.

WEDNESDAY

12 Mag. +7.0 comet 21P/ Giacobini-Zinner will scrape the southwest extremities of the mag. +5.6 open cluster M37 in Auriga this evening.

THURSDAY ▶

13 Just after sunset, look towards the southwest where you should be able to spot the 20%-lit waxing crescent Moon. Mag. –1.7 Jupiter is located 6° below and left of the Moon as seen from the UK. If you have a flat horizon, look for bright Venus too.

MONDAY

17 Following sunset, look for mag. +0.9 Saturn 1.7° below and right of the 58%-lit waxing gibbous Moon.

FAMILY STARGAZING – ALL MONTH

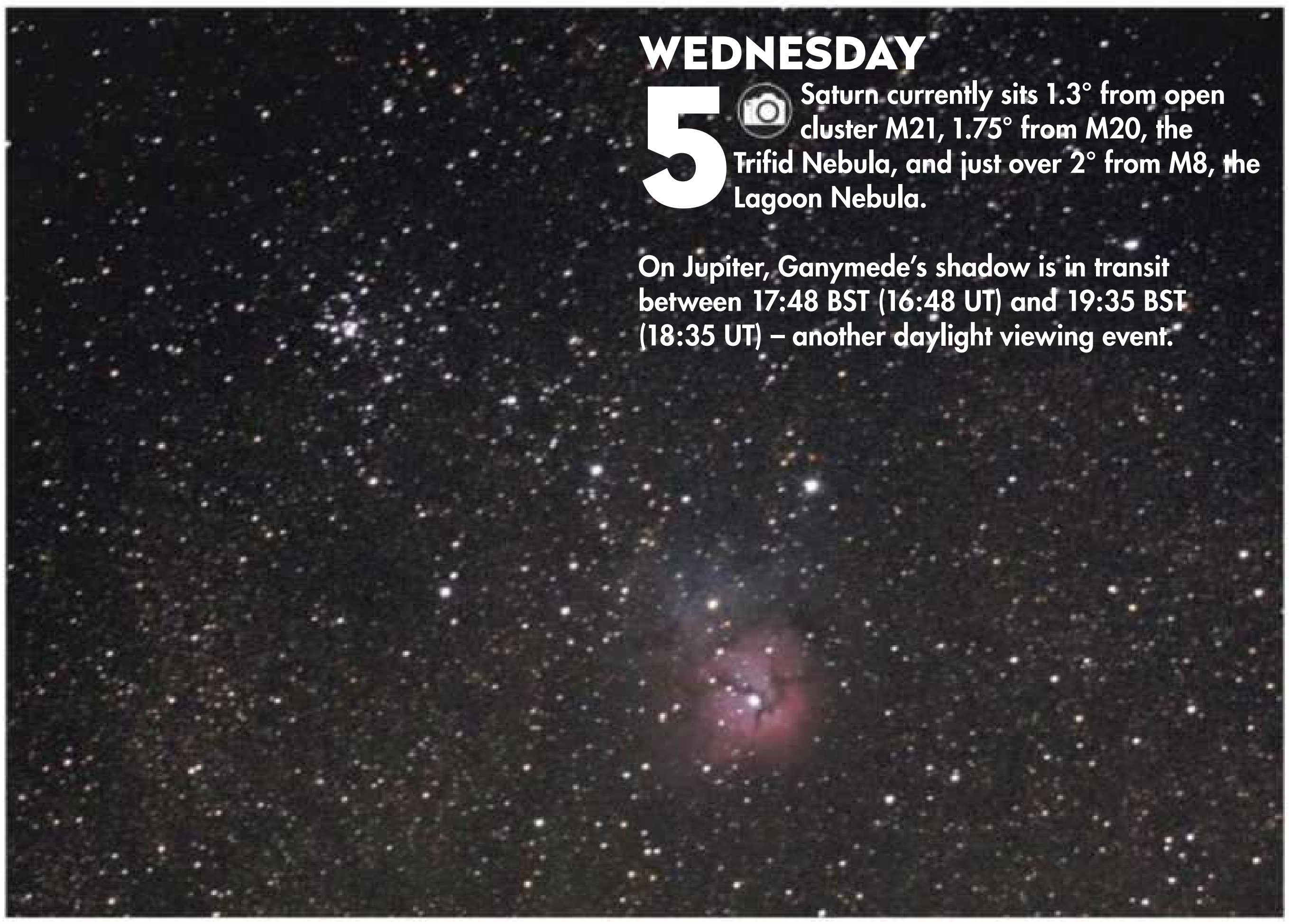
Saturn is the next brightest object to the right of Mars in the early evening sky. It's very low at present but if you have a telescope, it's worth a look. Use a low magnification to start only increasing it if the conditions will allow it. For a youngster, looking at Saturn for the first time can be really impressive It should be possible to see the two main rings (A and B) and, under steady conditions, even the gap known as the Cassini division that separates them. Explain that the A-ring has a diameter of 274,000km but is only about 10-30m thick.

www.bbc.co.uk/cbeebies/shows/stargazing

PETE LAWRENCE X 6

◀ TUESDAY

25 Full Moon occurs this morning at 03:54 BST (02:54 UT). Being the closest full Moon to the northern hemisphere's autumn equinox makes this the Harvest Moon for 2018.



WEDNESDAY 5

Saturn currently sits 1.3° from open cluster M21, 1.75° from M20, the Trifid Nebula, and just over 2° from M8, the Lagoon Nebula.

On Jupiter, Ganymede's shadow is in transit between 17:48 BST (16:48 UT) and 19:35 BST (18:35 UT) – another daylight viewing event.

SATURDAY ▶ 15

Mag. +7.1 comet 21P/ Giacobini-Zinner will be north of mag. +5.1 M35 in Gemini this morning and south of the cluster this evening.

SUNDAY 16

Mars is now at perihelion, a time when its southern hemisphere is receiving its maximum dose of solar radiation. This situation may lead to the creation of extensive dust storms. Turn to page 53 for further information.

WEDNESDAY 19

Tonight it's the turn of mag. –1.6 Mars to get a visit from the Moon. Both objects appear separated by 5.5° around 23:30 BST (22:30 UT) when they will be above the south-southwest horizon. The Moon will be at the 75%-lit gibbous phase.

SUNDAY 23

The northern hemisphere's autumn equinox occurs at 02:55 BST (01:55 UT) when the centre of the Sun's disc crosses the celestial equator moving north to south.

Look for Crater Eddington, this month's Moonwatch target (page 58), near the morning terminator.

MONDAY 24

Today, mag. +7.3 comet 21P/ Giacobini-Zinner will be crossing NGC 2264, the Cone Nebula complex.

SUNDAY ▶ 30

The 74%-lit waning gibbous Moon this morning will be located within the 'V' of the Hyades open cluster in Taurus. The Moon's disc is more or less centrally positioned within the cluster just before dawn.

NEED TO KNOW

The terms and symbols used in *The Sky Guide*

UNIVERSAL TIME (UT) AND BRITISH SUMMER TIME (BST)

Universal Time (UT) is the standard time used by astronomers around the world. British Summer Time (BST) is one hour ahead of UT.

RA (RIGHT ASCENSION) AND DEC. (DECLINATION)

These coordinates are the night sky's equivalent of longitude and latitude, describing where an object is on the celestial 'globe'.

FAMILY FRIENDLY Objects marked with this icon are perfect for showing to children

NAKED EYE Allow 20 minutes for your eyes to become dark-adapted

PHOTO OPP Use a CCD, planetary camera or standard DSLR

BINOCULARS 10x50 recommended

SMALL/ MEDIUM SCOPE Reflector/SCT under 6 inches, refractor under 4 inches

LARGE SCOPE Reflector/SCT over 6 inches, refractor over 4 inches

GETTING STARTED IN ASTRONOMY

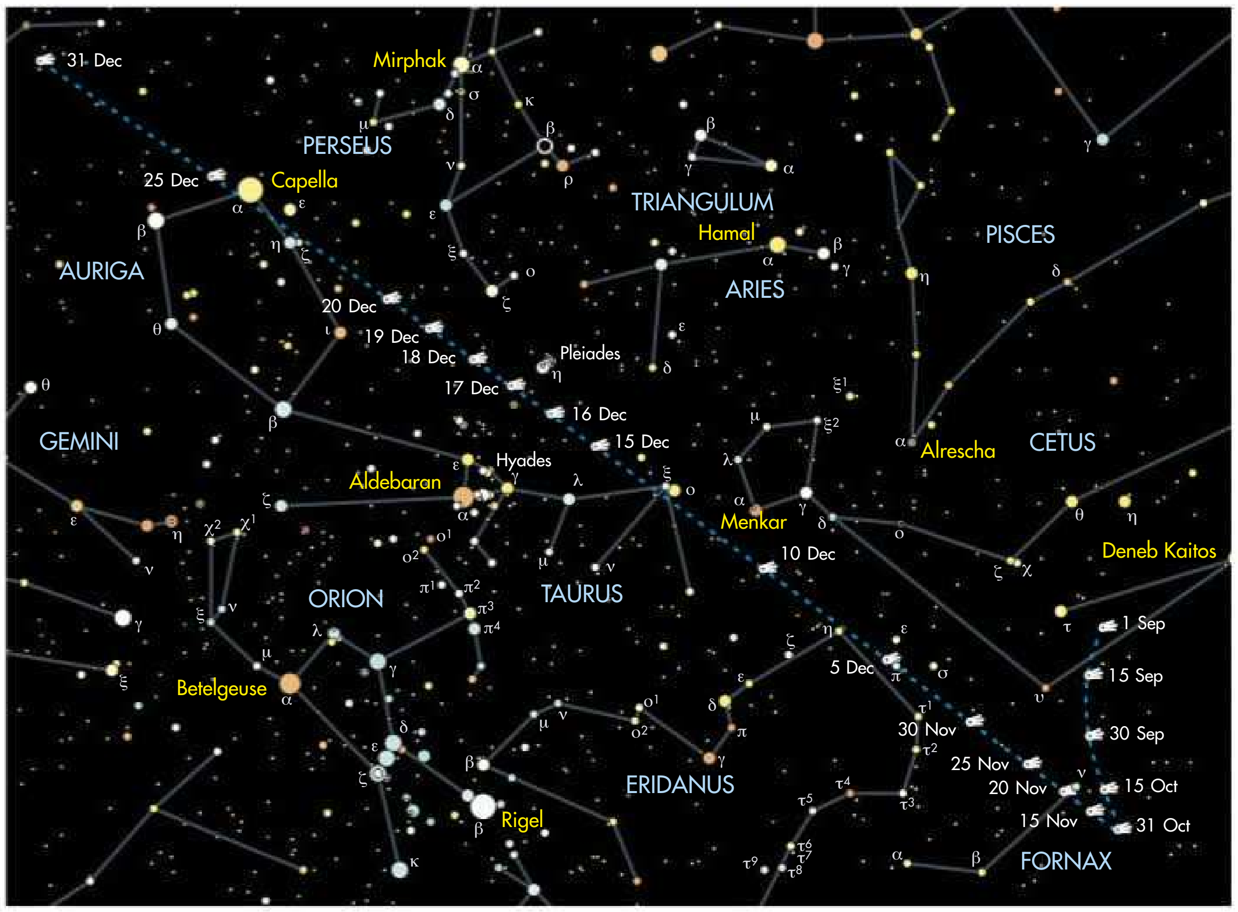
If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing a scope.

THE BIG **THREE**

The three top sights to observe or image this month

DON'T **MISS**

Comet 46P/Wirtanen



▲ The path of 46P/Wirtanen for the rest of the year. This month it travels through Cetus, the Whale

WHEN: All month; brightening towards the end of September

Comet 46P/Wirtanen is set to put on a show for the northern hemisphere over the next few months. A short-period comet orbiting the Sun every 5.4 years, Wirtanen is notorious because it was the original target for ESA's Rosetta mission. A missed launch window re-directed Rosetta to 67P/Churyumov-Gerasimenko and the rest, as they say, is history.

Discovered on 17 January 1948 by American astronomer Carl A Wirtanen, 46P belongs to the Jupiter family of comets. These have aphelia – greatest distance from the Sun – between 5 and 6 AU and are influenced by Jupiter's gravity.

Wirtanen's next perihelion – closest approach to the Sun – occurs on 12 December 2018, coinciding with a particularly favourable 11.7 million km approach to Earth on 16 December. Consequently, 46P/Wirtanen could get as bright as third magnitude; an easy naked-eye object. A world-wide observing campaign has been organised to capitalise on this favourable appearance, Wirtanen retaining target potential for future explorative space missions.

At present Wirtanen is low in Cetus, tracking below mag. +3.5 Tau (τ) Ceti. It is currently around mag. +11.8. During September its position worsens, reaching a point 4° west of mag. +4.0 Upsilon (υ) Ceti on the night of 13/14 September when it should be a magnitude brighter than it was at the start of the month. From here it dives rapidly southward, all the while getting brighter. It's most southerly position occurs at the start of November when, at mag. +7.0, it'll be in Fornax at declination –33°.

For the rest of November it accelerates north, officially leaving Fornax on 28 November and passing back into Cetus. At this time it should be naked-eye visible, around mag. +5.1. Predicted to be mag. +4.5 on 5 December, it passes close to mag. +4.2 Pi (π) Ceti as it moves into Eridanus. On 7 December, rapidly moving north, the mag. +4.3 comet appears close to mag. +3.9 Eta (η) Eridani.

The fourth magnitude comet then passes west of mag. +2.5 Menkar (Alpha (α) Ceti) on the morning of 11 December and slips into Taurus on the morning of 12 December. It tracks between the Pleiades and Hyades open clusters on the morning and evening of 16 December when it's also closest to Earth. It's predicted to be an easy naked-eye mag. +3.8 object at this time.

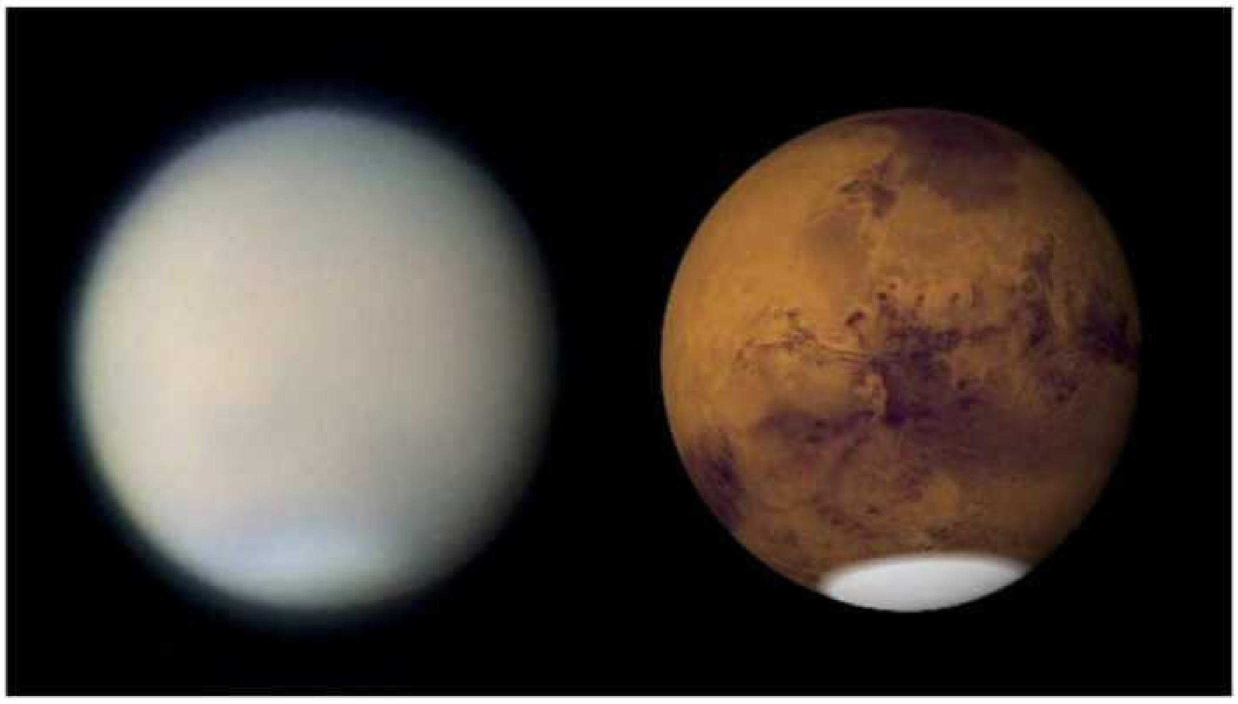
Fading to mag. +4.2, Wirtanen passes close to bright Capella (Alpha (α) Aurigae) on the night of 23 December. It'll probably remain naked eye until the first week of January 2019 when, at around sixth magnitude, it moves into Ursa Major.

Closest to Earth in mid-December, naked-eye comet Wirtanen will pass between the Pleiades (pictured) and Hyades open clusters

PETE LAWRENCE X 4

Mars at perihelion

WHEN: 6 September



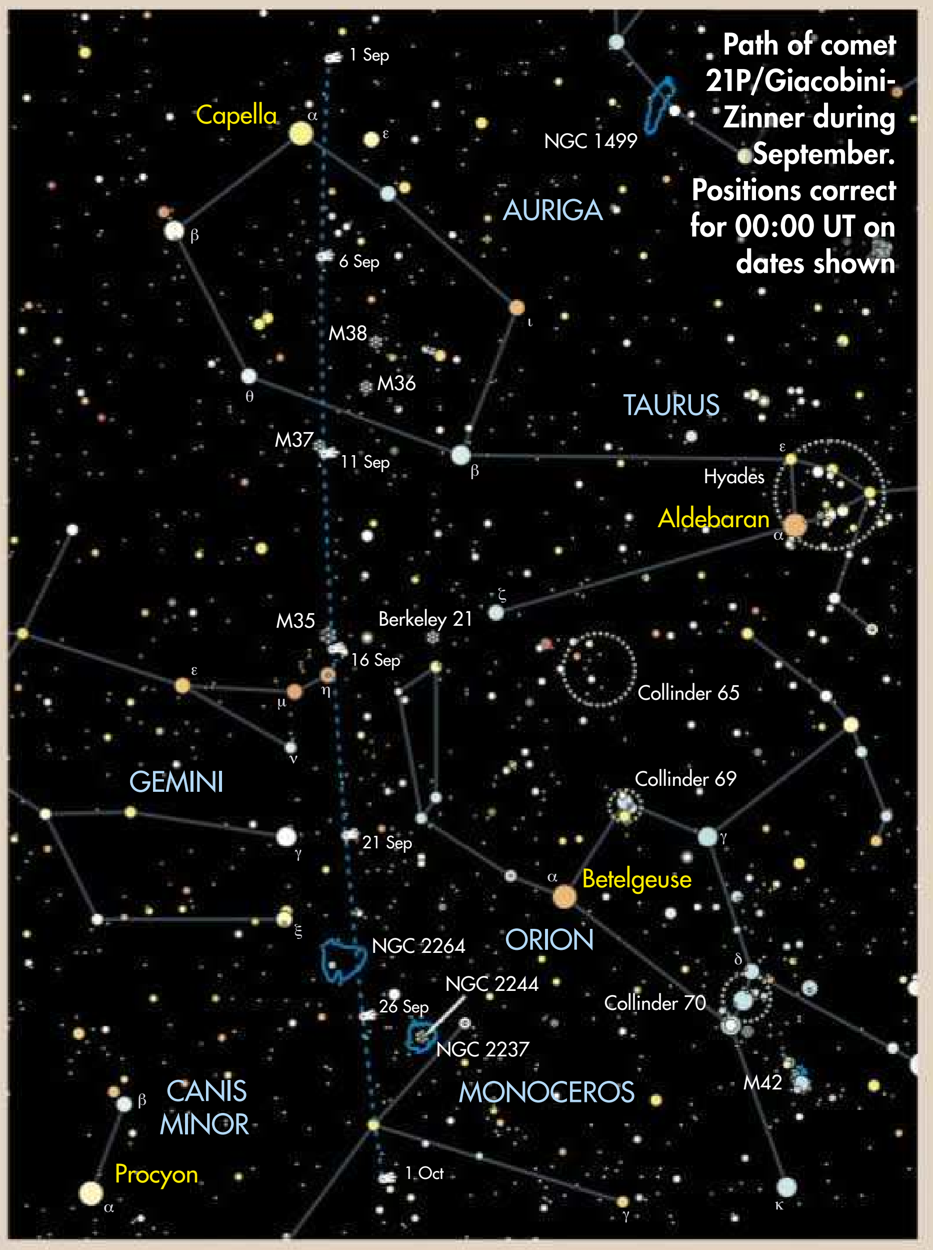
▲ A dusty Mars imaged on 23 June, 2018 (left) and a simulated view of how it should've looked

Following its opposition on 27 July 2018, the planet Mars is set to reach perihelion on 6 September, the point in its orbit when it will be closest to the Sun. In this position the solar radiation landing on the planet's surface may be strong enough to kick off dust storms. Some of these may be small, lasting for a short period of time, while some can be long lived and spread to cover much of the planet's globe. Despite now being past opposition, Mars still presents a decent apparent diameter and so you should enthusiastically grasp this opportunity to monitor such activity.

It's the planet's southern hemisphere that is tilted towards the Sun at perihelion, so major dust storms tend to originate in this location. Having said that, a large and persistent storm which unusually originated in the northern hemisphere has already been spotted. This particular storm diminished the appearance of many of the planet's features including its distinctive polar caps. Consequently, observing the planet was that bit more difficult just before and after opposition.

The largest Martian dust storm ever recorded was in 1971 and coincided with the arrival of the Mariner 9 spacecraft. The mission had to be put on pause for a few weeks to allow the storm to subside so that the largely blank planet beneath could reveal surface features once again.

As Mars is now receding from us its apparent size is reducing. However, its maximum UK altitude is slowly improving, meaning that now is a good time to see whether you can spot and record any dust storms. They typically start in depressed areas such as the Hellas Basin or the giant Vallis Marineris and start off looking like bright patches filling the contours of those features, after which they'll either become more extensive or simply fade from view.



Comet 21P/Giacobini-Zinner

WHEN: All month; perihelion on 10 September

With the excitement surrounding the close approach and perihelion passage of 46P/Wirtanen, we shouldn't forget another favourably placed and relatively bright comet currently visible. 21P/Giacobini-Zinner is predicted to be around mag. +7.2 at the start of September, brightening as it reaches perihelion on 10 September.

21P is particularly well positioned for the UK on the night of 2/3 September as it passes very close to the bright star Capella (Alpha (α) Aurigae). It then passes from the northeast to the east of the mag. +4.2 open cluster Collinder 62 on the morning and evening of 5 September, before clipping the western edge of mag. +5.6 M37 on the evening of 10 September. At this time the comet will be at its brightest, around mag. +7.0.

The comet jumps from the north to the south of the spectacular mag. +5.1 open cluster M35 in Gemini on the nights of 14/15 and 15/16 September. It then tracks parallel with the 'base' of Gemini before passing through the Cone Nebula complex in Monoceros, the Unicorn, on the nights of 23/24 and 24/25 September.

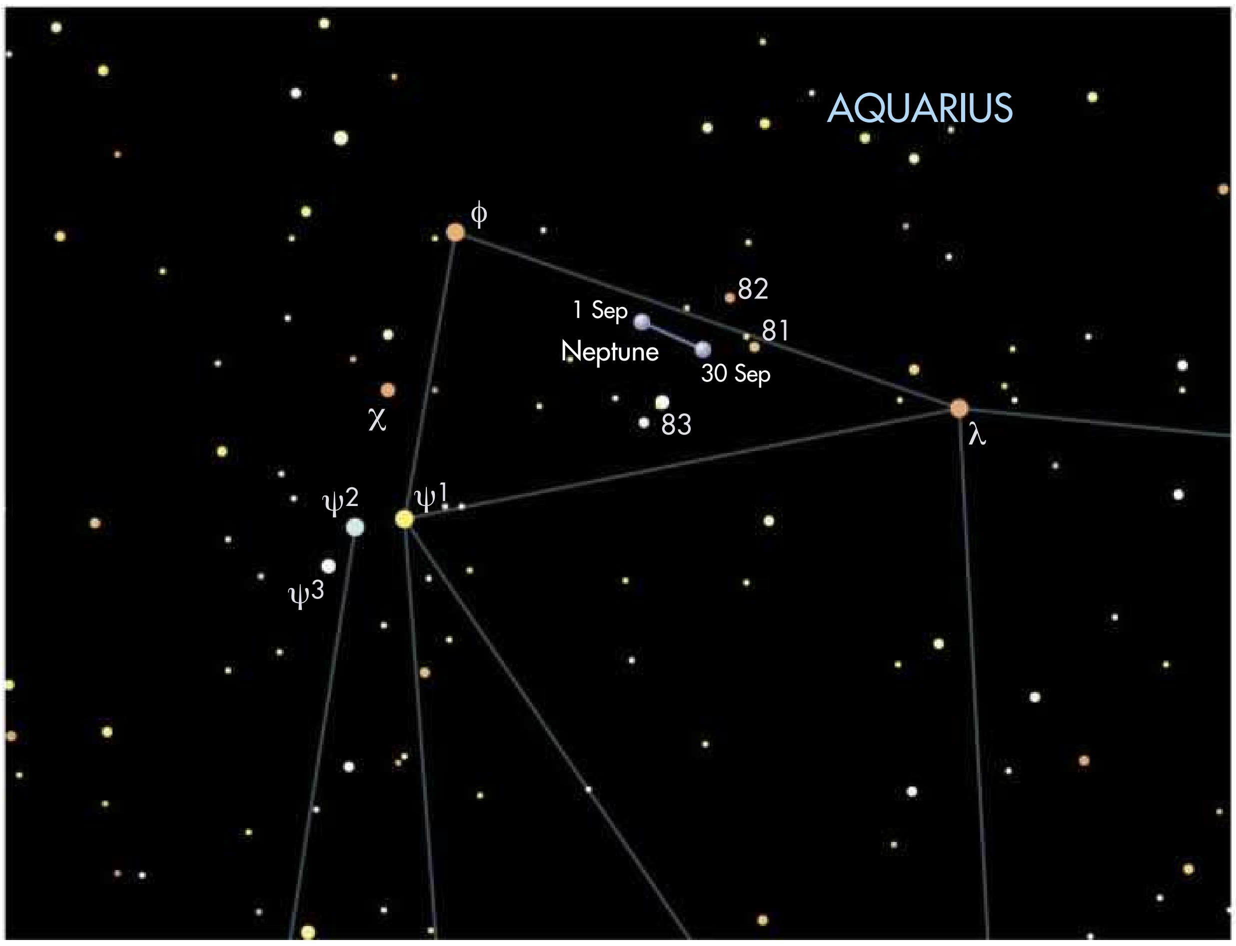
Although the comet is expected to have faded to mag. +7.6 by the end of the month, this still means it's in the 'bright' comet category and should certainly be a fairly easy binocular object.

THE **PLANETS**

PICK OF THE MONTH

Neptune

Best time to see: 7 September, (01:10 BST) 00:10 UT
Altitude: 30°
Location: Aquarius
Direction: South
Features: Colour, banding (camera required), brightest moon – Triton
Equipment: 200mm or larger

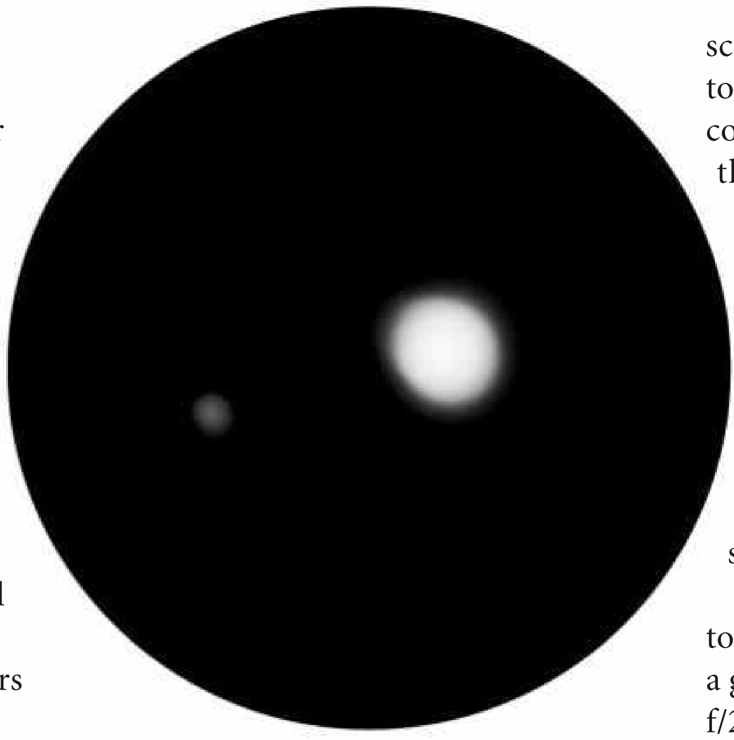


▲ Although at opposition, Neptune is still so faint you need to know exactly where to look for it

Neptune reaches opposition on 7 September. This is a position in the sky when the planet's ecliptic longitude is exactly 180° around the sky from the Sun. In other words, from an Earth-based observer's point of view, an object at opposition will appear in the opposite direction in the sky relative to the Sun.

Geometrically this positions Earth closer to Neptune, making the planet appear bigger and brighter than at other times. In theory at least! The problem with Neptune is that with an average distance from the Sun of 4.5 billion km, the opposition advantage is pretty small and the planet's appearance at opposition is much the same as it is away from opposition.

Consequently, during September the planet's magnitude remains at +7.8 and its apparent diameter stays at a rather small 2.3 arcseconds. At this level of brightness Neptune can only be seen with the assistance of a pair of binoculars when it will appear like a faint star positioned between mag. +4.2 Phi (ϕ) and mag. +3.7 Lambda (λ) Aquarii. A 4-inch scope or larger is the recommended to bring out the planet's beautiful blue colour, while for a convincing view of the disc, you'll need a magnification of 200x or higher.



▲ A deliberately over-exposed image of Neptune reveals the presence of Triton nearby

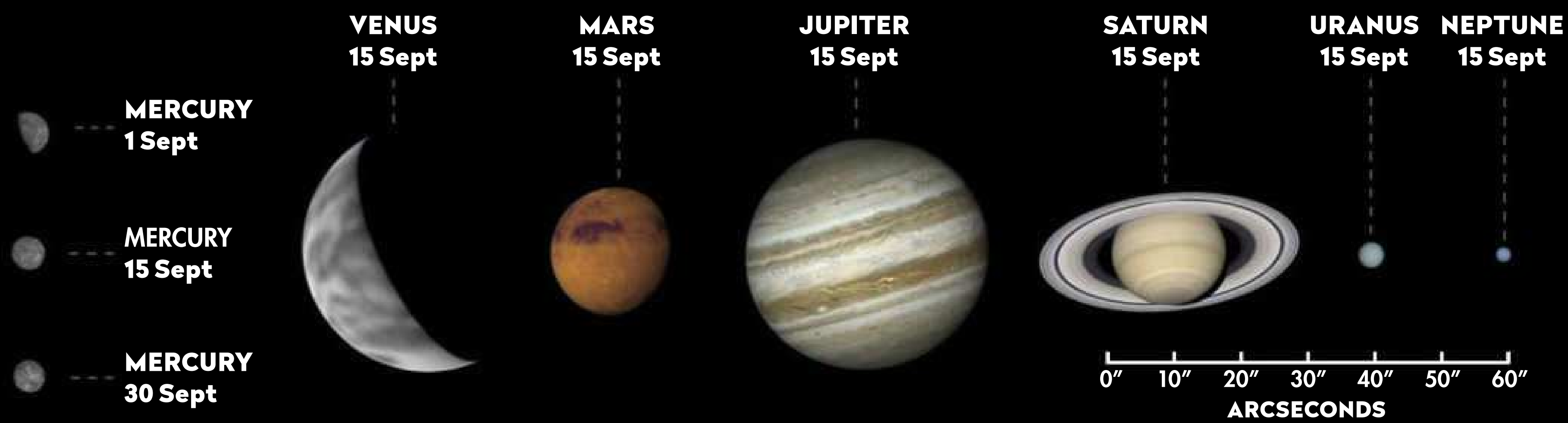
Despite its great distance from Earth, Neptune's largest moon, Triton, also provides a great observing challenge for amateur telescopes. It shines at mag. +13.5 which makes it a viable target for a 3-inch or larger scope. A magnification of at least 250x should show it close to its parent planet.

Planetary imaging setups can be used to reveal detail on Neptune's globe. As a general guideline, aim to work in the f/25-f/30 range. Extended capture times are fine for Neptune; video sequences as long as 10-15 minutes are quite normal.

PETE LAWRENCE X 3

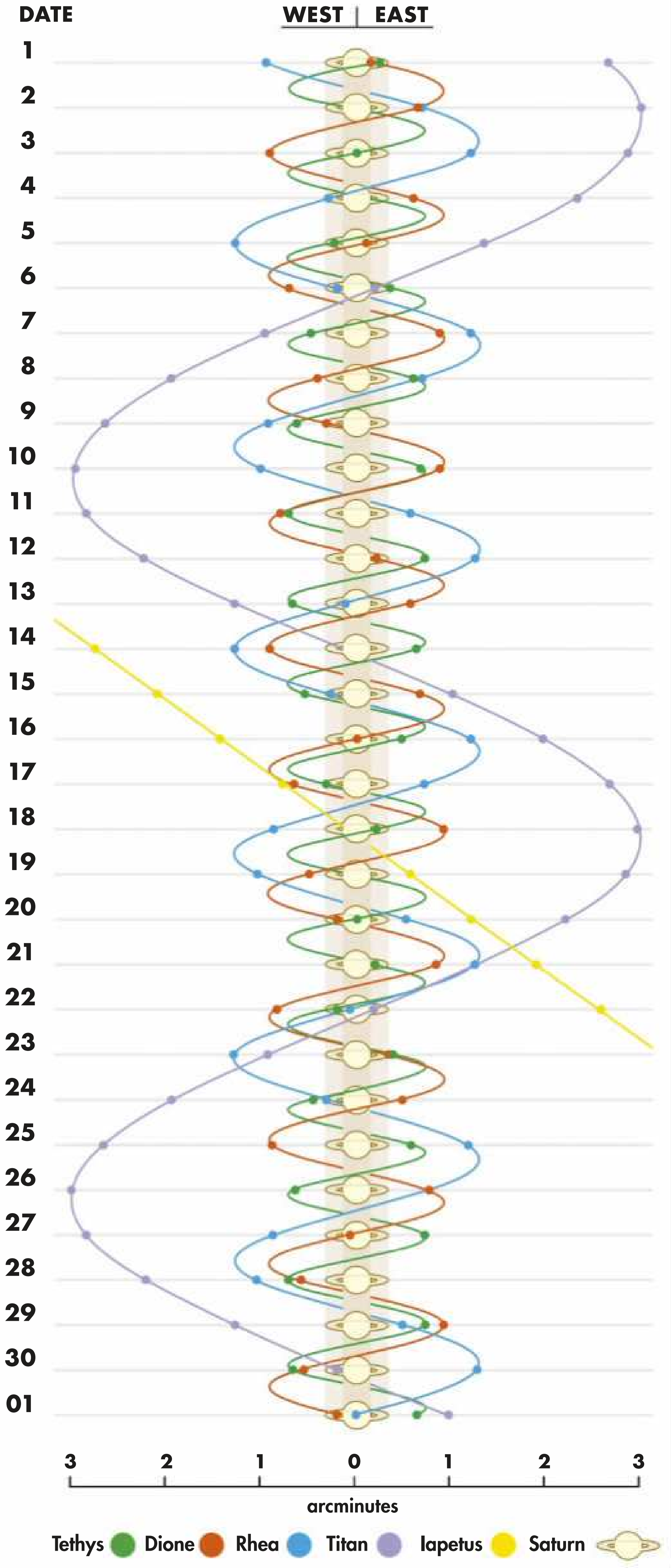
THE PLANETS IN SEPTEMBER

The phase and relative sizes of the planets this month. Each planet is shown with south at the top, to show its orientation through a telescope



SATURN'S MOONS SEPTEMBER

Using a small scope you'll be able to spot Saturn's biggest moons. Their positions change dramatically during the month, as shown on the diagram. The line by each date represents 01:00 BST (00:00 UT).



Mercury

Best time to see: 1 Sept, 05:30 BST (04:30 UT)
Altitude: 6° (low)
Location: Leo
Direction: East-northeast

Mercury is a morning object, very well positioned at the start of the month. On 1 September, mag. –0.7 Mercury rises in the east-northeast 100 minutes before sunrise, appearing as a 6 arcsecond, 65%-lit, gibbous disc through a telescope.

The phase continues to increase over subsequent mornings as Mercury passes along the far side of its orbit relative to Earth. On 8 September, mag. –1.2 Mercury is preceded by a lovely 3% waning crescent Moon, 9° to the west, which rises one hour before the planet above the east-northeast horizon.

Things become trickier mid-month when Mercury closes in on the Sun. On 15 September, at mag. –1.5, Mercury rises 40 minutes before sunrise. Superior conjunction occurs on 21 September. Mercury's re-emergence into the evening sky at the end of September is poor, the planet having limited altitude following sunset.

Venus

Best time to see: 1 Sept, 20:20 BST (19:20 UT)
Altitude: 2.5° (Very low)
Location: Virgo
Direction: West-southwest

Venus is currently poorly positioned after sunset. At the start of September, the mag. –4.3 planet sets 50 minutes after the Sun. By the end of the month this figure has dropped to just five minutes!

Consequently, the best way to see Venus is during the day. If you do this (remembering to take great caution when the Sun is above the horizon) then it's possible to watch Venus change from a 39%-lit crescent, 29 arcseconds across on 1 September, to a 17%-lit crescent, 46 arcseconds across by the end of the month.

Mars

Best time to see: 1 Sept, 22:30 BST (21:30 UT)
Altitude: 11°
Location: Capricornus
Direction: South

Although not high in UK skies, Mars shines away at mag. –2.1 in the evenings at the start of September, with a decent apparent size of 20 arcseconds. As the Earth-Mars distance increases, the Red Planet's appearance changes rapidly. By mid-month it's significantly dimmer at mag. –1.7, with an 18 arcsecond disc. By 30 September, Mars is at mag. –1.3 with a 15 arcsecond diameter.

Jupiter

Best time to see: 13 Sept, 20:00 BST (19:00 UT)
Altitude: 9° (low)
Location: Libra
Direction: Southwest

Jupiter is just about hanging on as an evening object but is very low as darkness falls at the start of September. By month end, mag. –1.7 Jupiter will have drifted slightly east to lie in the centre of Libra.

Saturn

Best time to see: 1 Sept, 20:50 BST (19:50 UT)
Altitude: 14°
Location: Sagittarius
Direction: South

At the start of the month, Saturn appears west of south as darkness falls. A 58%-lit waxing gibbous Moon lies less than 2° from the mag. +0.9 planet on 17 September.

Uranus

Best time to see: 30 Sept, 02:45 BST (01:45 UT)
Altitude: 48°
Location: Aries
Direction: South

Uranus is in Aries moving slowly west towards Pisces. It's well positioned, reaching its highest point in the sky under dark conditions. It shines at mag. +5.7 and presents a beautiful green colour through a telescope.

YOUR BONUS CONTENT Planetary observing forms

THE NORTHERN HEMISPHERE IN SEPTEMBER

KEY TO STAR CHARTS

- Arcturus — STAR NAME
- PERSEUS — CONSTELLATION NAME
- GALAXY
- OPEN CLUSTER
- GLOBULAR CLUSTER
- PLANETARY NEBULA
- DIFFUSE NEBULOSITY
- DOUBLE STAR
- VARIABLE STAR
- THE MOON, SHOWING PHASE
- COMET TRACK
- ASTEROID TRACK
- STAR-HOPPING PATH
- METEOR RADIANT
- Circlet — ASTERISM
- PLANET
- QUASAR

STAR BRIGHTNESS:

- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER

- N E S W — COMPASS AND FIELD OF VIEW
- MILKY WAY

CHART: PETE LAWRENCE

WHEN TO USE THIS CHART

1 SEPTEMBER AT 01:00 BST
15 SEPTEMBER AT 00:00 BST
30 SEPTEMBER AT 23:00 BST

On other dates, stars will be in slightly different positions because of Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

HOW TO USE THIS CHART

1. **HOLD THE CHART** so the direction you're facing is at the bottom.
2. **THE LOWER HALF** of the chart shows the sky ahead of you.
3. **THE CENTRE OF THE CHART** is the point directly over your head.

SUNRISE/SUNSET IN SEPTEMBER*

DATE	SUNRISE	SUNSET
1 Sep 2018	06:19 BST	20:00 BST
11 Sep 2018	06:36 BST	19:36 BST
21 Sep 2018	06:53 BST	19:11 BST
1 Oct 2018	07:11 BST	18:47 BST

MOONRISE IN SEPTEMBER*

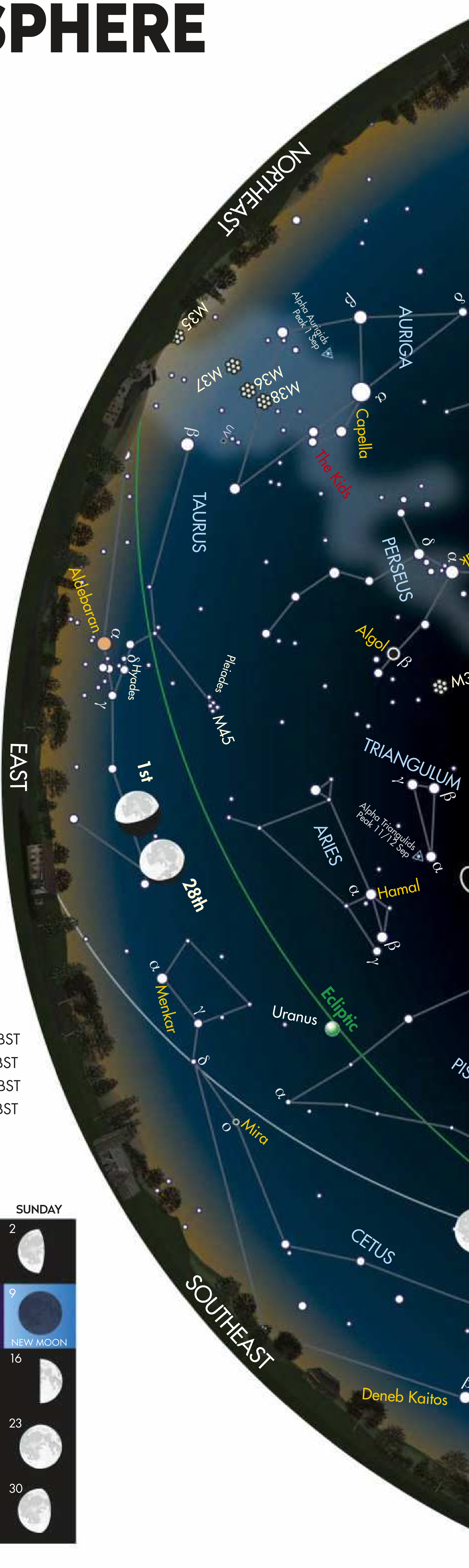
MOONRISE TIMES

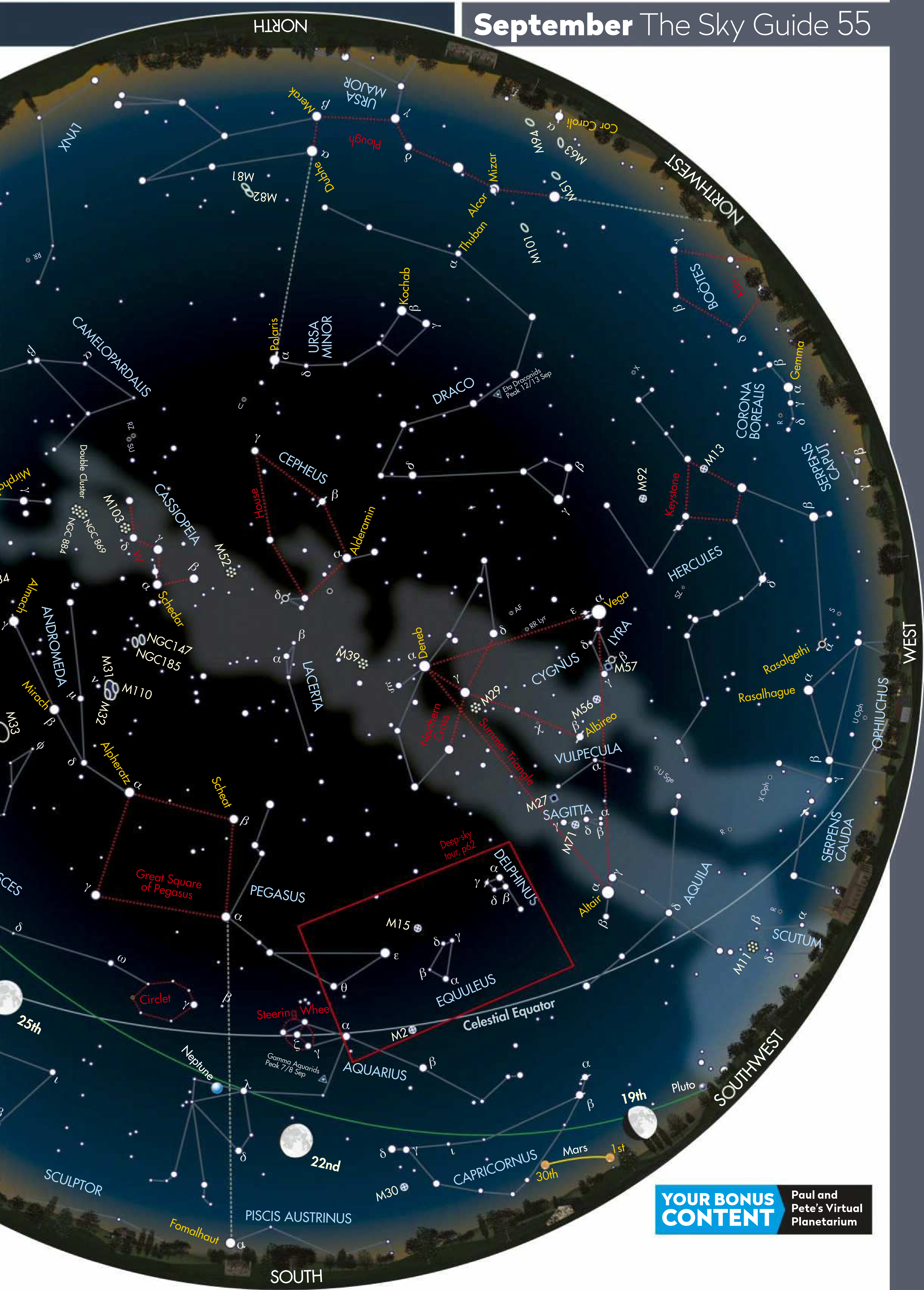
01 Sep 2018, 22:41 BST	17 Sep 2018, 15:34 BST
05 Sep 2018, 00:42 BST	21 Sep 2018, 18:13 BST
09 Sep 2018, 05:44 BST	25 Sep 2018, 19:39 BST
13 Sep 2018, 11:07 BST	29 Sep 2018, 21:13 BST

*Times correct for the centre of the UK

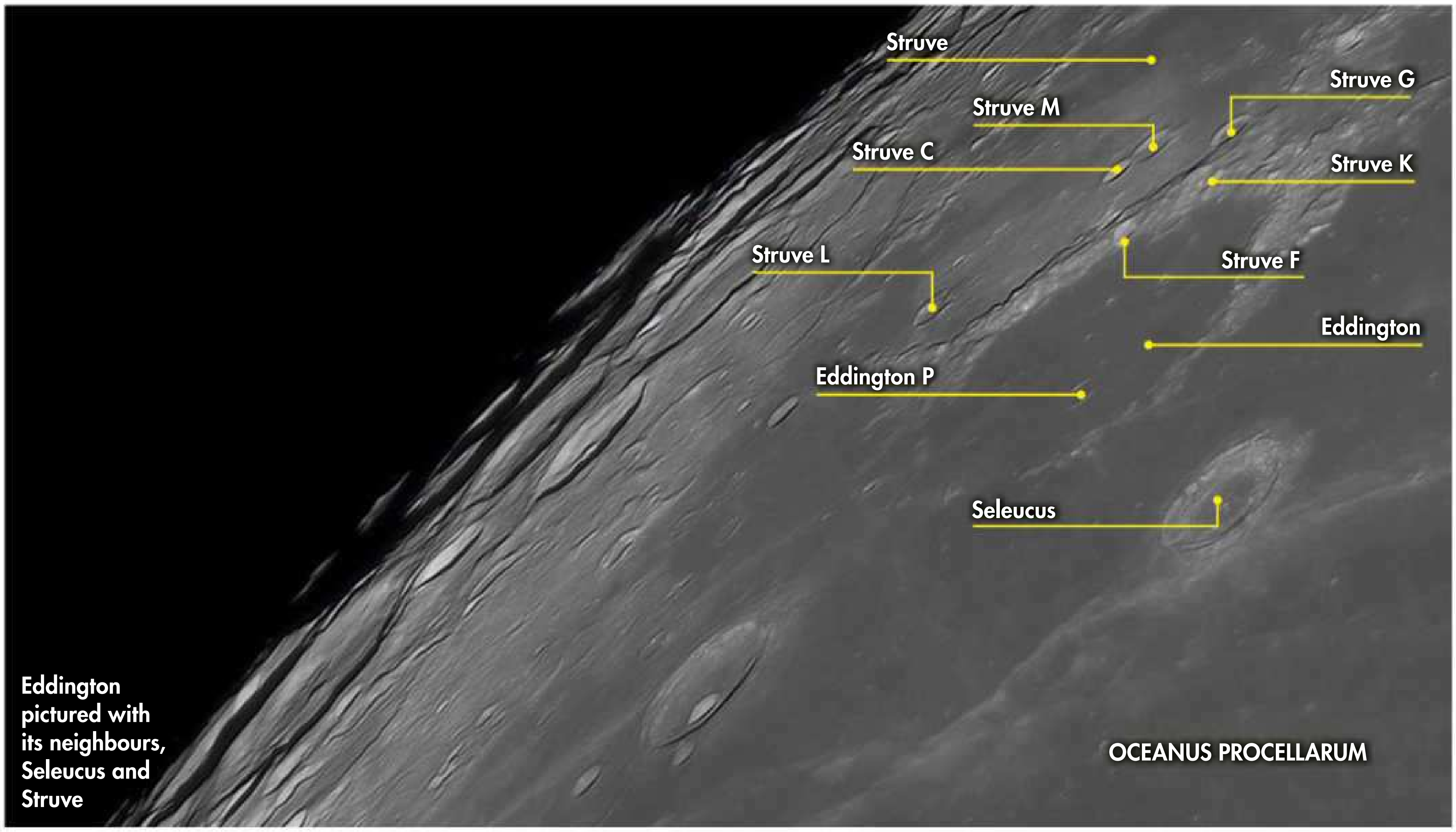
LUNAR PHASES IN SEPTEMBER

MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
					1	2
3	4	5	6	7	8	9 NEW MOON
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25 FULL MOON	26	27	28	29	30





YOUR BONUS CONTENT Paul and Pete's Virtual Planetarium

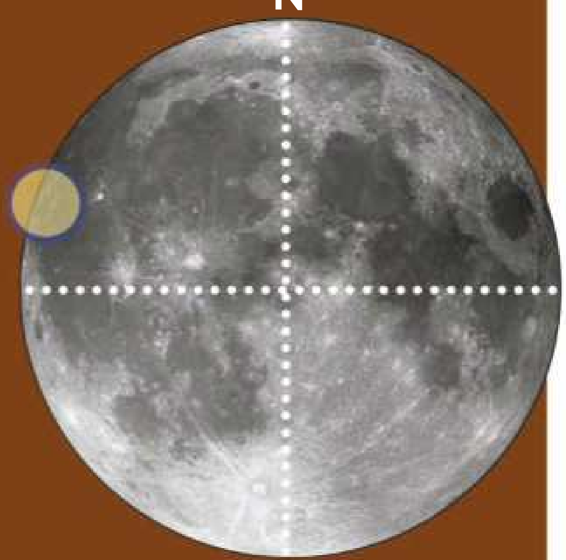


Eddington pictured with its neighbours, Seleucus and Struve

MOON**WATCH**

Eddington

Type: Walled plain
Diameter: 134km
Longitude/latitude: 72° west, 21.5° north
Age: Older than 3.92 billion years
Best time to see: Five days after last quarter (7-8 Sept) or six days after first quarter (22-24 Sept)
Minimum equipment: 10x binoculars



"A crater with a diameter the distance of Cardiff to Birmingham"

Eddington is a large feature which appears very close to the Moon's western limb as seen from Earth. This means it's affected by the Moon's libration state, the apparent rock-and-roll motion which allows us to actually see 59% of the Moon's surface over time.

It's a crater that has been flooded by lava, resulting in a lunar feature known as a walled plain. Its vast 134km diameter is ringed by highland material, most obvious to the north and west. The eastern rim becomes quite thin, making it tricky to see visually. Towards the southeast, the rim all but disappears into the lava of the Oceanus Procellarum.

As you view Eddington, marvel at the fact that it has a diameter equal to the distance from Birmingham to Cardiff. Under the correct lighting conditions, when you move your gaze closer to the limb it becomes evident that although large, Eddington is dwarfed by the less distinct form of 171km **Struve** to its immediate west. Struve is so massive that the former designation of Eddington was Struve A.

Unlike Eddington's dark and fairly distinctive floor, Struve is harder to discern because it's covered in lighter material disguising its appearance. There are several small but distinctive craters within Struve that stand out. These include **Struve C** (11km), **Struve G** (14km), **Struve L** (15km) and **Struve M** (15km).

Struve F (9km) and **Struve K** (6km) sit on the rim wall which divides Struve from Eddington. Thereafter, passing into the area bounded by Eddington's rim, there's a distinct lack of features. A number of really small craterlets pockmark Eddington's floor but these are difficult to see with smaller instruments. The largest and most identifiable crater within Eddington's rim is 12km **Eddington P** but it is dark, like its primary, and easily overlooked. All that remains of Eddington P are two sections of rim, one to the east and one to the west. If we could view the crater from above, it would appear like a pair of brackets.

Immediately to the east of Eddington lies the distinctive 43km **Seleucus**. This is a lovely circular crater with a wide, terraced rim, a flat floor and a central mountain complex. A narrow outline of ejecta frames the crater, which suggests that Seleucus existed before its surroundings were flooded with lava. The Soviet craft Luna 13 touched down on the Moon on Christmas Eve 1966 and its landing site is located approximately 50km to the southeast of Seleucus.

The best view of Eddington occurs – as is the case with many lunar features – when the Sun is low in its sky. This is typically when the phase is approaching full Moon or new Moon. At this time of year, early risers are rewarded with a decent view of the waning crescent, which results in a lovely pre-new Moon view. This coincides with the northern hemisphere's autumn placing the early morning, waning crescent Moon higher in the sky than at any other time of the year.

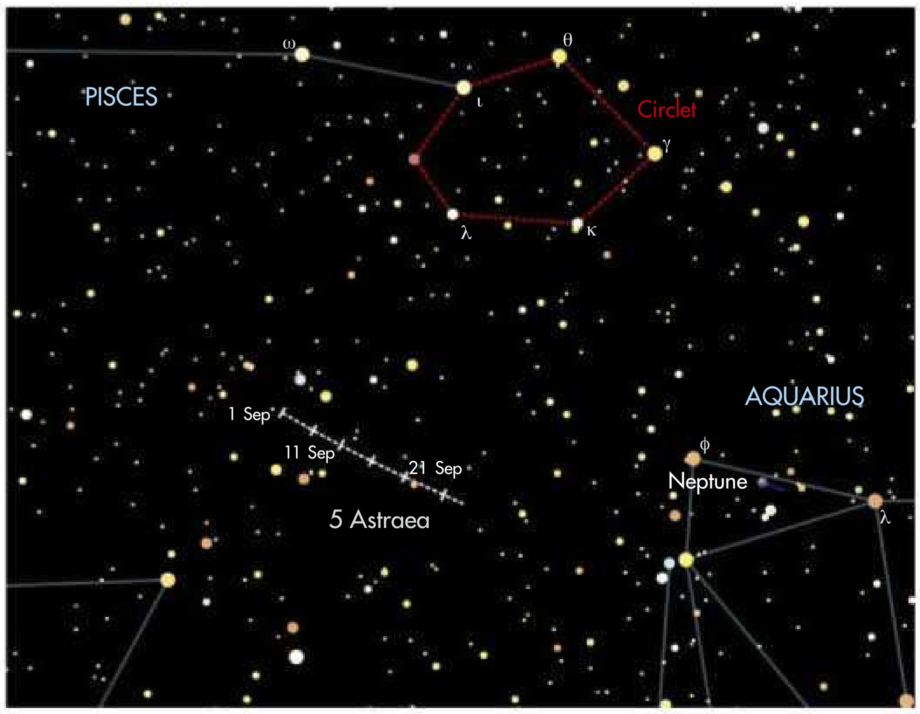
PETE LAWRENCE X 3

COMETS AND **ASTEROIDS**

Follow the September journey of the game-changing 'fifth' asteroid, Astraea

The first four asteroids ever discovered are sometimes referred to as the 'big four', despite 1 Ceres having been promoted to the new class of dwarf planet 12 years ago. 1 Ceres, 2 Pallas, 3 Juno and 4 Vesta tend to be visualised as a group and their individual names are fairly well known. This is in part because of their narrow discovery window. After Ceres was first identified in 1801, the other three were all discovered by 1807.

It's fair to say that the next asteroid to be identified is less well known. 5 Astraea was discovered by Karl Ludwig Hencke on 8 December 1845 and part of the reason for its relative obscurity is the 38 years and eight months gap between Vesta being found and its discovery. Although physically unremarkable,



▲ **Astraea will travel from Pisces into Aquarius during September**

Astraea's discovery broke the belief that the big four were unique and opened the flood gates for the multitude of asteroids discovered since.

It's an S-type or silicaceous (stony) asteroid and is quite reflective with an albedo of 22.7%. A body's albedo is a measure of how much incoming light it reflects. The brightest asteroid, Vesta, has an albedo of 42.3% which is notably higher than the modern average value of 30% attributed to the Earth.

Astraea's size is 167x123x82km which gives a mean diameter of 119km, very close to a value of 115km +/- 6km derived from occultation observations on 6 June 2008. It has an orbit which takes it out as far as 3.1 AU from the Sun and in as close as 2.1 AU. The orbital period is 1,508 days (4.13 years). During favourable oppositions Astraea can reach mag. +8.7 and at its dimmest, shines at mag. +12.9.

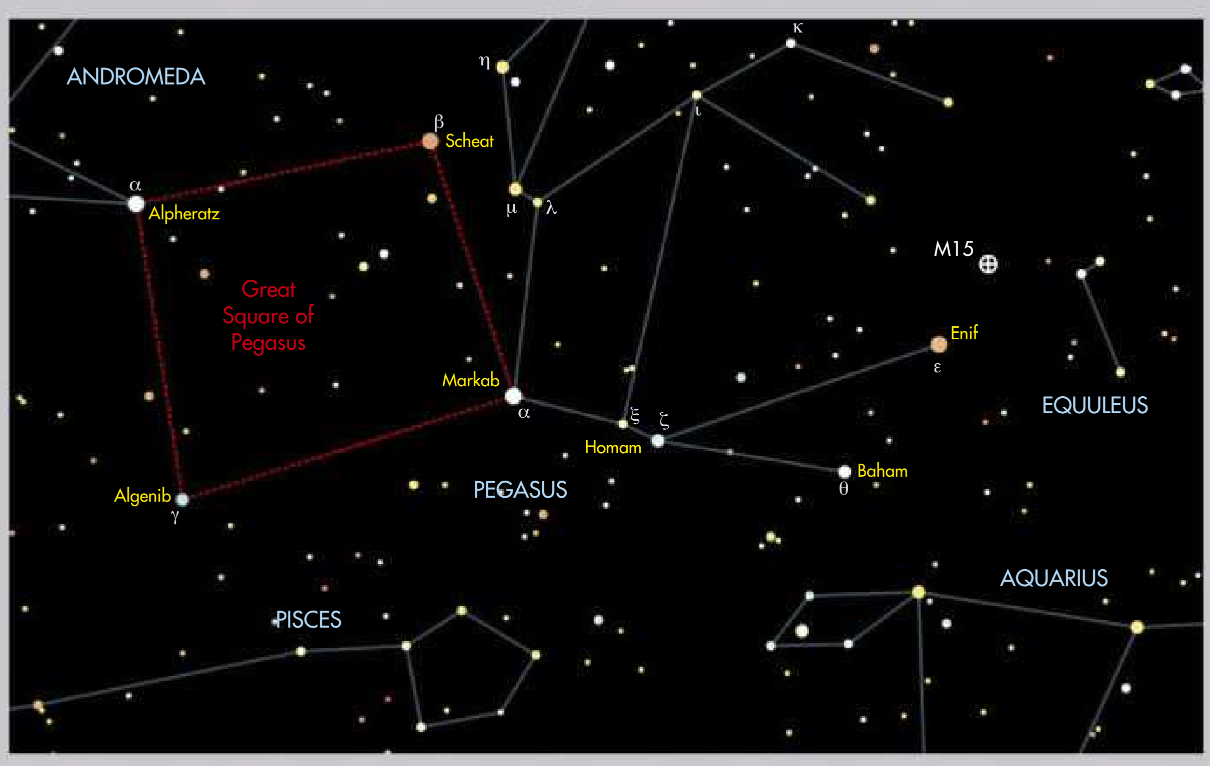
5 Astraea comes into opposition on 18 September when it'll have a telescope-friendly magnitude of +10.8. Throughout September it passes from Pisces into Aquarius, travelling on a path that takes it approximately 10° south of the centre of the Circlet asterism in Pisces.

STAR OF **THE MONTH**

Epsilon (ε) Pegasi is full of intriguing surprises

The Great Square of Pegasus is one of the iconic asterisms of autumn, forming a large, and – to be honest – rather blank pattern which is supposed to depict the torso of an upside-down flying horse. Markab (Alpha (α) Pegasi) marks the southwest corner of the square but is not the brightest star in Pegasus. That honour goes to mag. +2.4 Enif (Epsilon (ε) Pegasi) which forms the horse's nose. In truth the star Sirrah (Delta (δ) Pegasi) should be brightest but, marking the northeast corner of the Great Square, this star was re-assigned to become Alpheratz (Alpha (α) Andromedae) back in 1928 and so is not technically in Pegasus.

Enif itself is a cool orange supergiant of spectral class K2. Its distance as measured by the Hipparcos satellite is 690 lightyears and it has a diameter 185 times larger than our Sun's. Through the eyepiece it is an optical double with a mag. +8.7 line-of-sight companion, 144 arcseconds away at position angle 318°. Position angle is the angle of the



▲ **Enif, the nose of Pegasus, and its companion star create a pendulum-like optical illusion**

companion as measured eastward from north. The view is worthy of note because it creates an unusual effect.

Centre the pair in the eyepiece using a magnification around 60-100x. While looking at the pair, tap the side of the eyepiece to make the view wobble at right angles to the imaginary line connecting both stars. When you do this, Enif appears to move normally back and forth while the dimmer companion appears to swing like the pendulum of a clock but out of sync. This optical illusion is believed to be due to the longer time it takes the light from the dimmer star to register on your retina, and is the reason why Enif and its companion are collectively known as the 'Pendulum Star'.

Enif has other surprises too. In 1972 it became as bright as Altair (Alpha (α) Aquilae), a five-fold increase in brightness. This was very short lived, lasting for around 10 minutes and is believed to have been caused by a rare superflare eruption on the star.

STEPHEN TONKIN'S
BINOCULAR **TOUR**

A pretend comet, a giant star, a celestial picture puzzle and more sights to see around Hercules

☑ Tick the box when you've seen each one

1 M13
10x50 About a third of the way down the western side of Hercules's Keystone asterism, you'll find a distinct 'fuzzy blob', which you might even be able to see with your naked eye in very transparent skies. In binoculars, the Great Globular Cluster in Hercules looks like a comet, brightening towards the core. This is why Charles Messier included it in his famous list of objects that comet hunters should not be fooled by. Even in urban skies, M13 should be detectable in 10x50 binoculars. This ball of about 300,000 stars is 22,200 lightyears away and has a diameter of 145 lightyears. ☐ **SEEN IT**

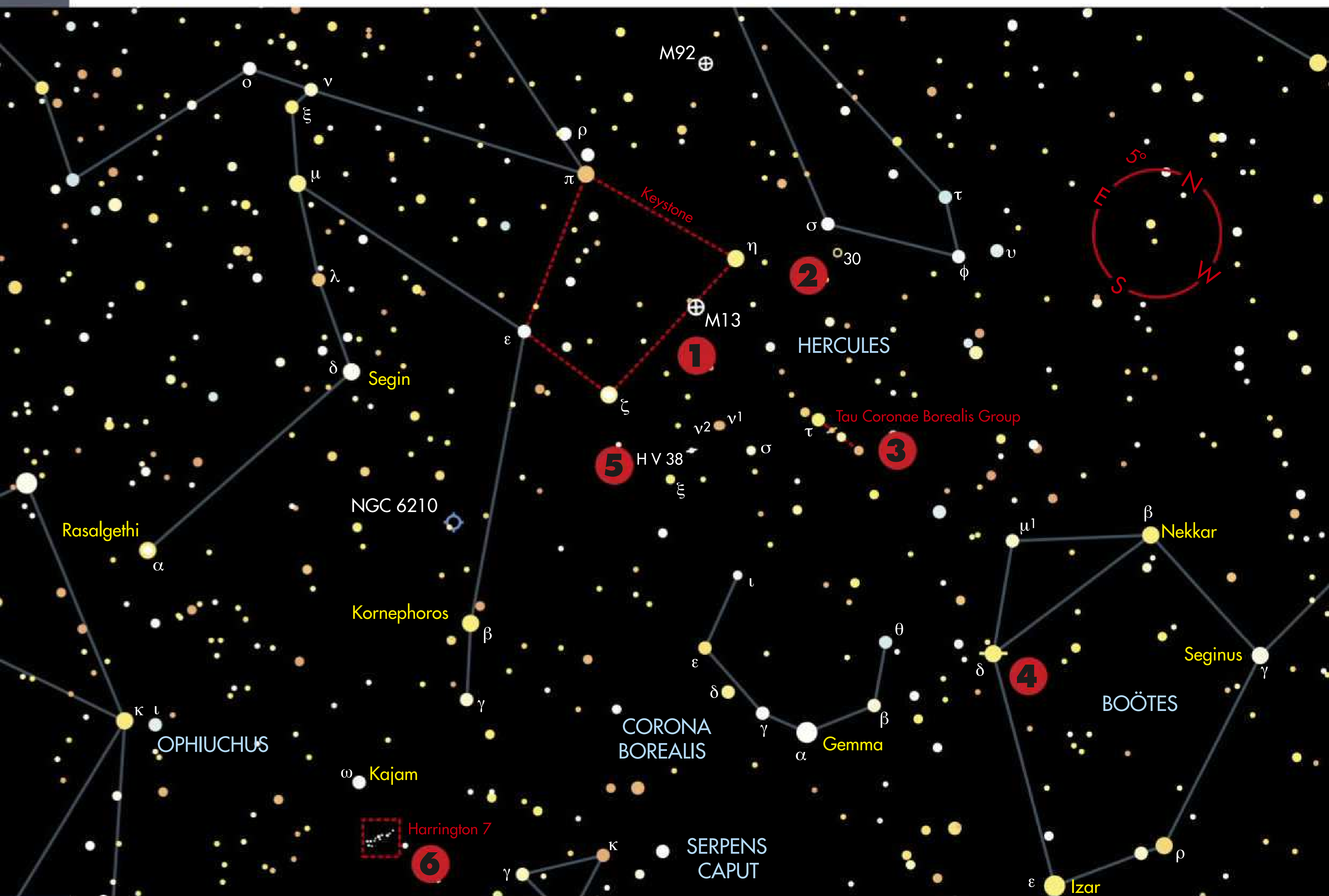
2 30 HERCULIS
10x50 The distinctly orange 30 Herculis (also known as g Her), lies 1° west-southwest of Sigma (σ) Herculis. This semi-regular variable star swings between about mag. +4.4 and mag. +5.5 with a period of 73 to 93 days between maxima. It has a radius of 230 Suns, larger than Earth's orbit. Despite its size, its mass is similar to the Sun's, and so it shows us how our star will evolve. It is preparing to lose its outer shell as a planetary nebula and leave its core to decay as a white dwarf. ☐ **SEEN IT**

3 TAU (τ) CORONAE BOREALIS GROUP
10x50 From 30 Her, head 6.5° southwest to find mag. +4.7 Tau (τ) Coronae Borealis, the brightest in a straight line of five stars running east-west for 2.6°. All but the central one shine brighter than mag. +6, and binoculars reveal their colours. Notice that the mag. +5.6 stars at each end of the chain are a deeper yellow than the others, while the star at the eastern end is almost white. Under dark skies you should find that the fainter central star easily resolves into a widely separated triple star. ☐ **SEEN IT**

4 DELTA (δ) BOÖTIS
10x50 Our next stop is another multiple star, the mag. +3.5 Delta (δ) Boötis. The primary in this pair is a giant star that shines a deep yellow and is nearly 60 times more luminous than the Sun. Its paler mag. +7.8 companion appears to be 105 arcseconds away. Like 30 Her, it is another Sun-like star, but this one is earlier in its evolutionary development. This binary pair is 117 lightyears away; they have a separation of at least 0.6 lightyears and an orbital period of at least 120,000 years. ☐ **SEEN IT**

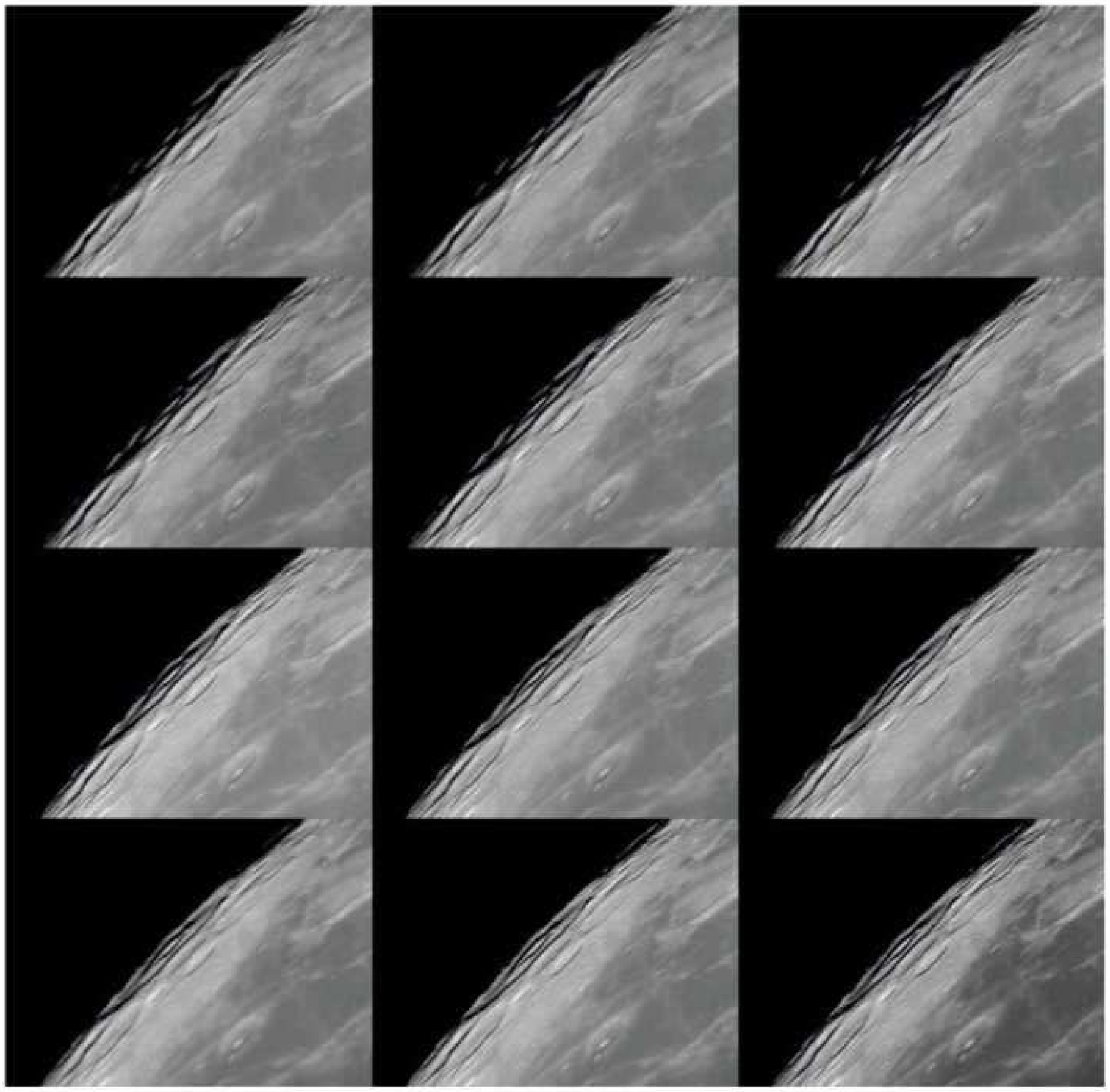
5 H V 38
15x70 We'll switch up to larger binoculars for our final two objects. Midway between Xi (ξ) and Nu (ν) Coronae Borealis, is an unremarkable mag. +6.4 white star, H V 38. The 'H' refers to Herschel's double star catalogue; the 'V' tells us that the separation is between 30 and 60 arcseconds. The companion, which lies in the direction of Nu, is at the lower end of this range (32 arcseconds), and it is a mere mag. +9.7, which, unless you have good skies, could be near the limit of your binoculars. ☐ **SEEN IT**

6 HARRINGTON 7
15x70 Identify Kajam (Omega (ω) Herculis) and pan 2° west to a golden 8th magnitude star. This is part of a 1.3°-long chain of fainter stars that runs roughly north-south. Currently best seen in the early evening, it's an interesting test of pareidolia – our inclination to find pictures in abstract images. It's been variously described as a zigzag, a dragon, a tadpole and a flower. What do you see? ☐ **SEEN IT**



THE SKY GUIDE **CHALLENGE**

Making the most of the ever-changing shadow effects near the Moon's terminator



▲ **Crater Einstein emerges from the shadows in this sequence of stills taken 20 minutes apart**

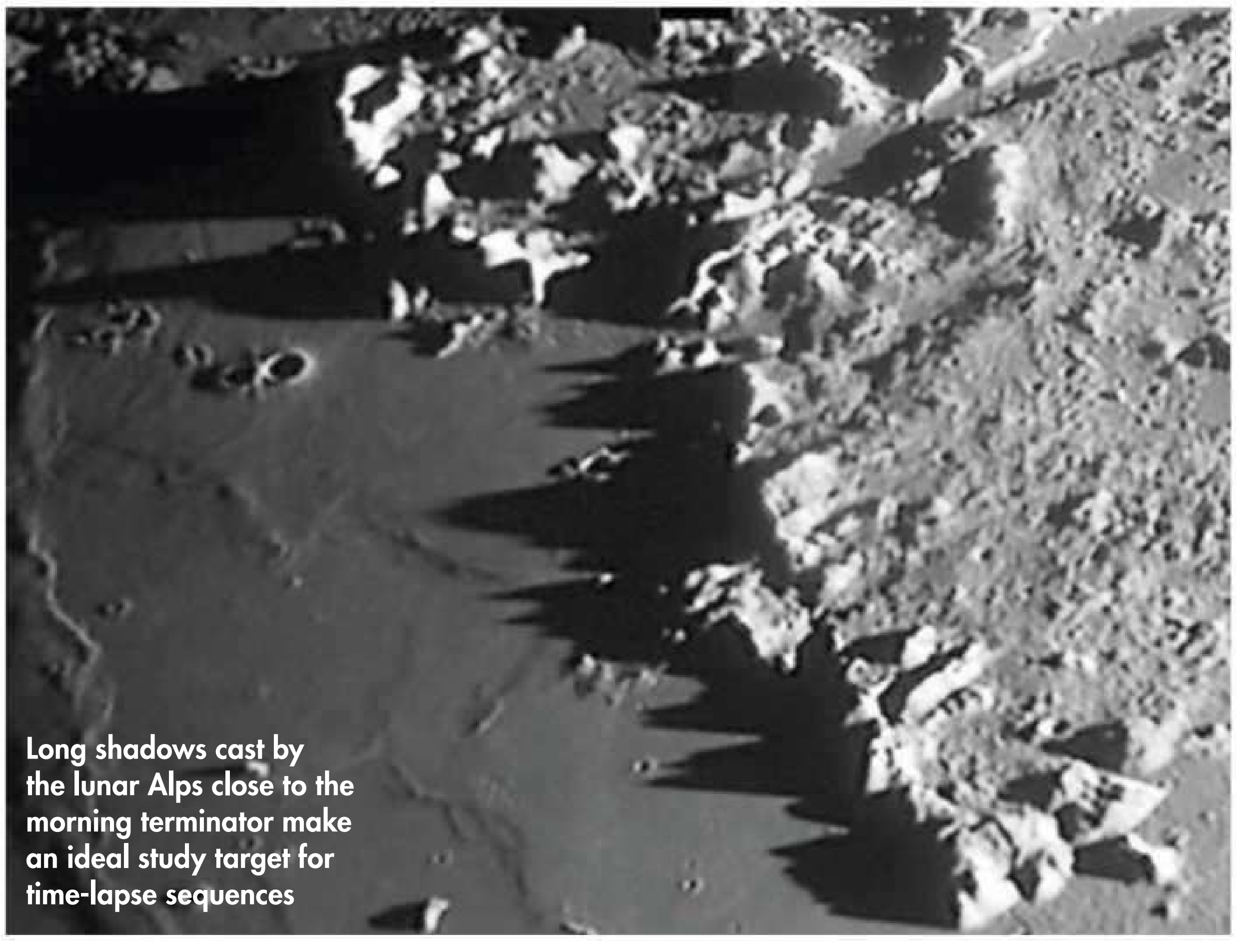
At an average 384,400km away, the Moon is close enough for us to see a variety of geological features on its surface. These are made more dramatic by the way sunlight interacts with them and an interesting challenge is to devise a way to illustrate how these shadowy effects appears to change over time.

The phases of the Moon repeat after one synodic month, or approximately 29.5 days. Over the course of one Earth day the Sun appears to move 360/29.5=12.2° across the Moon's sky. With patience over an extended observing session it's possible to see subtle changes in the way the shadows are being cast, especially close to the terminator, the constantly progressing longitudinal division between lunar night and lunar day. Here sunlight shines obliquely across the lunar surface while the slow yet unrelenting movement of the Sun creates the most extreme changes in the length of the shadows. Watching the top of a high mountain or elevated crater rim shining against dark, shadowed surroundings is similarly mesmerising.

Revealing this motion with a camera requires you to take still images over a period of time. Arranging the results in a grid or – better still – animating them in sequence, reveals the motion in the lunar shadows. The results vary depending on the image-scale (magnification) and techniques used. A high frame-rate camera can be used to capture short movie sequences, which can then be registered and stacked into detailed high-resolution images that you can turn into an animated time-lapse sequence. The extra detail such images produce will reveal even more intricate and intriguing changes in the shadows. The larger the image scale, the less time you need between stills to show motion.

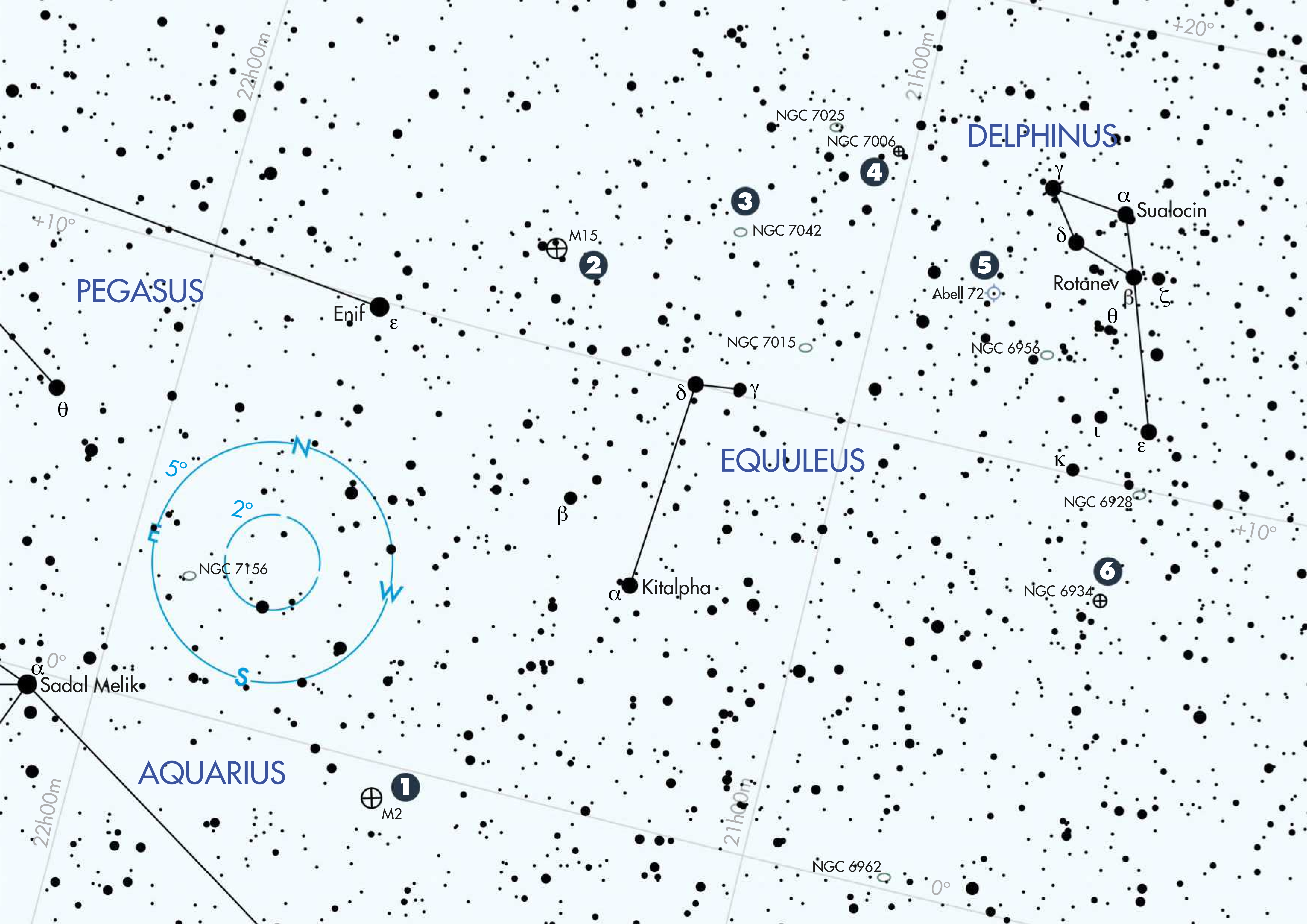
An effective technique is to centre on a recognisable feature that's close to the terminator. We would recommend a telescope focal length of over 2m. Aim to capture an image every five minutes. If using a high frame rate camera, restrict captures to less than 60s repeated every five minutes. If you have one, a red or infrared pass filter used in conjunction with a mono high frame-rate camera will help reduce some effects of seeing.

Continue your capture run for at least an hour. Load each result in time order into a separate layer using a layer-based editor. Load the earliest result at the bottom. Make all but the bottom two images invisible and align the upper image with the base image. Repeat, working your way up the layer stack carefully aligning each image with the base layer. Once done, crop to remove any edge gaps revealed during alignment. Arrange in a grid or, if your software provides animation facilities, animate the sequence to show the shadows creeping across the lunar surface.



Long shadows cast by the lunar Alps close to the morning terminator make an ideal study target for time-lapse sequences

PETE LAWRENCE X 3


DELPHINUS
EQUULEUS
PEGASUS
AQUARIUS
Sualocin
Rotanev
Enif
Kitalpha
Sadal Melik
M15
M2
NGC 7025
NGC 7006
NGC 7042
NGC 7015
NGC 6956
NGC 6928
NGC 6934
NGC 6962
NGC 7156
Abell 72
22h00m
21h00m
+20°
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DEEP-SKY TOUR

Globulars galore on a clusterbusting voyage around Delphinus

☑ Tick the box when you've seen each one

1 M2

M2 is a bright, large globular cluster in Aquarius located approximately two-thirds of the way along a line joining Epsilon (ε) Pegasi to Beta (β) Aquarii (not shown on the chart). With a listed magnitude of +6.4 and a decent visual diameter, it's an easy target for smaller instruments. A 6-inch scope shows it as a glowing haze with an almost stellar core. Upping the aperture to 10-inch increases light grasp and resolution, allowing most of the member stars to be resolved. Here the brightest part of the cluster appears elongated into an 8x6 arcminute oval. The general haze around its bright centre can be traced further than this using magnifications around 200x. ☐ **SEEN IT**

2 M15

M15 is even easier to find than M2. This globular cluster (which, like M2 was discovered by French astronomer Jean-Dominique Maraldi in 1746) is best located by extending a line from Theta (τ) Pegasi to Epsilon (ε) Pegasi and extending that line for half the distance again. This is a lovely object which is interesting to compare and contrast with M2. M15 is far more compact, appearing approximately 5 arcminutes across through a 6-inch scope. Increased magnification hints at a mottled texture across the entire cluster. A 10-inch scope at high power reveals a small but definitely non-stellar core surrounded by a mass of resolved stars. Through a 12-inch instrument M15 is a delight, offering a one arcminute core surrounded by a bright five arcminute inner region, which itself is surrounded by a 12 arcminute outer halo. ☐ **SEEN IT**

3 NGC 7042

Our next target is significantly trickier to track down than the previous two. NGC 7042 is an Sb-type spiral galaxy in Pegasus, located 3° 52 arcminutes west and 1° 40 arcminutes north of M15. It has a listed magnitude of +12.8, making it best suited to larger apertures. Discovered by William Herschel in 1784, it forms one of a pair of galaxies, the other being the barred spiral NGC 7043. Of the two, NGC 7042 appears larger and brighter, with NGC 7034 being around mag. +14.6. These are distant objects estimated to be around 200 million lightyears away. NGC 7042's apparent diameter is around 2 arcminutes. ☐ **SEEN IT**

4 NGC 7006

We hop next door into Delphinus, the Dolphin, for our next target, the mag. +10.5 globular cluster, NGC 7006. This can be found 3° and 34 arcminutes to the east of the double star marking the dolphin's nose, Gamma (γ) Delphini. Compared to M2 and M15, this is a tricky globular. Through a 6-inch scope it appears rather small at just one arcminute across. NGC 7006 is around four times further away than M15 with a distance estimated at 160,000 lightyears. Smaller instruments tend to show it looking like a fuzzy star but larger apertures will begin to reveal its true globular nature and start to resolve its component stars. ☐ **SEEN IT**

◂ **M15 is a compact globular cluster with a mottled texture that looks especially good viewed through a 12-inch telescope**

THIS DEEP-SKY TOUR HAS BEEN AUTOMATED

ASCOM-enabled Go-To mounts can now take you to this month's targets at the touch of a button, with our Deep-Sky Tour file for the EQTOUR app. Find it online.

5 ABELL 72

The Abell catalogue contains some very faint planetary nebulae, but fortunately Abell 72 is one of the brighter ones. Even so, it still requires a larger aperture to see well. Abell 72 is located 3° and 13 arcminutes east, and 40 arcminutes south, of Gamma (γ) Delphini. It has a listed magnitude of +12.7 but this is spread across a relatively large disc approximately 2 arcminutes in diameter. Consequently the surface brightness of Abell 72 is relatively low. A 12-inch scope reveals a degree of irregularity at magnifications around 100x. The use of an OIII filter is highly recommended here as this helps add some contrast to the object. ☐ **SEEN IT**

6 NGC 6934

Our final target is another globular cluster located to the south of the main pattern of Delphinus, 3° and 55 arcminutes south of mag. +4.0 Epsilon (ε) Delphini. Another one of William Herschel's discoveries (this one made in September 1785), NGC 6934 is about 50,000 lightyears from Earth and the cluster stars within it are estimated to be about 10 billion years old. A 6-inch instrument will show the mag. +8.7 cluster as a north-south elongated haze, 1.5 arcminutes across at its longest dimension. A 10-inch scope unsurprisingly gives a better view, as it partially resolves its globular nature at higher powers. A 9th magnitude star appears two arcminutes west of the cluster's core. NGC 6934 remains unresolved through a 12-inch scope even at high magnifications. Through such an aperture, the apparent size of the globular is a fraction under two arcminutes across. ☐ **SEEN IT**

YOUR BONUS CONTENT

Print out this chart and take an automated Go-To tour

CHART: PETE LAWRENCE, PHOTO: GÜNTER KERSCHHUBER/CCDGUIDE.COM

ASTRO**PHOTOGRAPHY**

From the UK, the Milky Way looks at its most majestic where it crosses with the constellation of Cygnus

Photographing the Milky Way in Cygnus

RECOMMENDED EQUIPMENT

DSLR camera, fast medium-wide lens, remote shutter release.

THE BIG PICTURE

THE MILKY WAY MAY BE HUGE BUT CAPTURING IT REQUIRES SUBTLETY

The band of the Milky Way is made up of the myriad stars in our galaxy. Visually, these stars are so distant that they blend into a misty path that appears to snake across the sky. The brightest part of the Milky Way as seen from the UK runs through Cygnus but getting a good view of this is a matter of timing. Although the Milky Way is best placed in July, it is still well positioned and in darker skies throughout September. Pulling its subtle features out in a photograph takes a gentle touch: overdo it and the Milky Way will look false; underdo it and the subtle nature of its appearance will be lost.

The beautiful summer Milky Way is a delight to behold. The brightest part should be the core, which lies in the direction of Sagittarius. However, from the UK this region lies very close to the southern horizon and the effect of its brilliance is somewhat lost. Higher up, the section that passes through Cygnus is bright and better placed. Seen against dark skies, this part is quite magnificent.

The Cygnus Milky Way is a fairly easy target for a DSLR with an average-sized lens. A lens with a focal length of 30mm fitted to a non-full-frame (eg, APS-C) DSLR covers an area of 40x28°, so any lens with a focal length under 30mm will be perfect for the shot we're trying for. As the Milky Way is linear, orientate the lens so the long frame axis runs along the plane of the Milky Way. Centre the view on Sadr (Gamma (γ) Cygni) with the vertical of the Northern Cross asterism aligned with the long centre line of the image frame and you're good to go.

A mid-ISO value (in the middle of your camera's full range) will probably work best, but feel free to experiment. Be aware that too much ISO will introduce noise that may be hard to see as it'll take on the appearance of extra stars. After taking an image, repeat using the same exposure and settings but put the lens cap on. This will reveal how much unwanted noise your camera is actually generating. Such shots, known as dark frames, are useful to keep. Take a number of them, which can then be averaged together to form a master dark. This can then be subtracted from the main 'light' frames to remove this noise.

The length of shot you can get away with depends on how your camera is mounted and how bright your sky is. If you're using a fixed tripod you'll be limited by sky rotation. Here, use the 500 rule: divide 500 by the focal length of your lens to get the longest exposure in seconds that will not produce noticeable star trailing. If your sky is bright then an extended exposure at a high ISO may result in an over-exposed image. This means you need to reduce either the sensitivity, the exposure time or both.

Taking multiple exposures of the same area and stacking them will help improve the quality of the signal – the stars – and reduce random, thermal noise. You can stack the frames with programs like the freeware DeepSkyStacker or the commercial PixInsight. It can also be done manually but is laborious in contrast to the automatic routines built into this type of software.

Manually, the process requires you to calibrate each image before loading it as a separate layer in a master graphic. After creating your master dark frame, it should be loaded as an upper layer above the image to be calibrated. Setting its blend mode to difference will then remove the noise. Save the calibrated image with a prefix, eg, "DFC_" to indicate it's been dark frame calibrated.

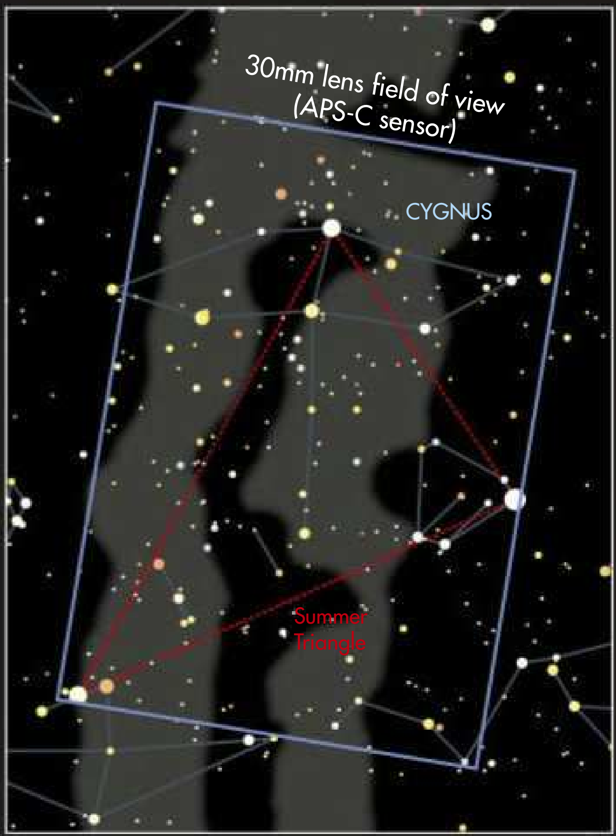
Once done, carefully align each calibrated image with the bottom image. Then set the transparency of all layers, except the bottom one, to (100/n)%, where n is the total number of layers. This manual process also works for producing your master dark frame, although no base alignment is required for the component dark frames.

✉ **Send your images to: hotshots@skyatnightmagazine.com**

STEP BY STEP

STEP 1

A fast lens with a focal length shorter than 30mm is ideal for this shot. By fast we mean one with a low minimum f/number. Anything below f/4 will be fine; anything lower than f/2.8 will be very well-suited to the job. The 30mm figure quoted here is for non-full-frame DSLRs. If you're using a full-frame model the figure is 20mm or shorter.



STEP 2

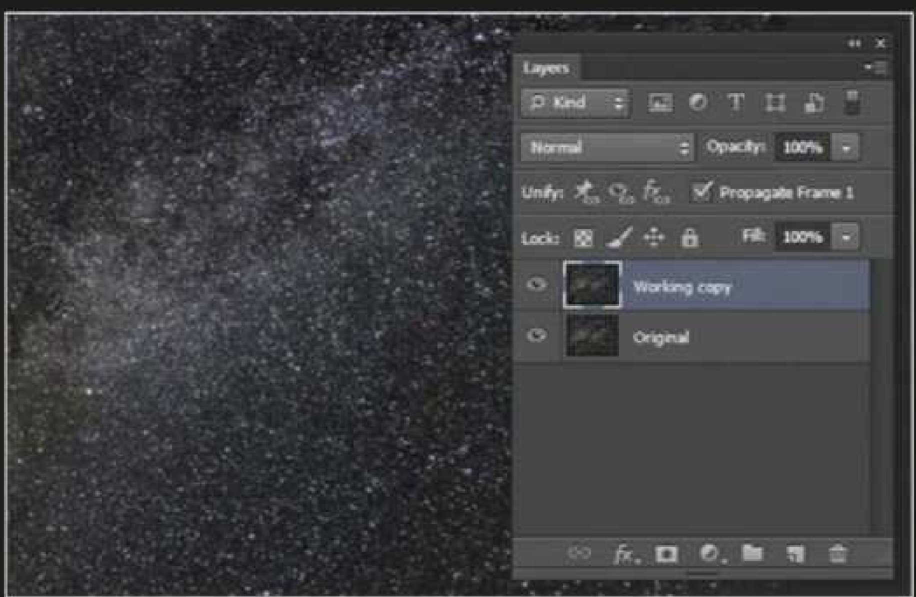
Choose a medium ISO. Set the lens to manual focus and focus at infinity. Set the lens aperture to its lowest f/stop and check whether this introduces distorted stars at the edge of the frame. If it does, close the aperture by a stop or two. As ever, your camera's RAW format (use RAW + large JPG for convenience) will give the best results.

STEP 3

The exposure you use will be determined by your mount type and sky brightness. For fixed mounts, a maximum exposure in seconds of 500 divided by your lens focal length in mm will avoid trails. For a 30mm lens, this equates to 17s. Review your results. If too dark, lengthen the exposure or up the ISO. If too bright reduce exposure or lower ISO.

STEP 4

Noise in images can be further reduced by taking multiple dark frames and averaging them together. To take a dark frame simply cap the lens and take another shot using exactly the same exposure you used for the Milky Way shot – the 'light' frame. Apply the master dark to each light frame as described in the main text.



STEP 5

Take at least nine light frames. Register and stack them as described in the main text. Save the averaged master light frame as a flattened image. Load into your photo editor and duplicate the layer. The base layer should be left untouched with adjustments applied only to the upper layer. This allows you to compare your adjustments to the original.

STEP 6

Increase the brightness slightly, followed by an increase in contrast. Do not overdo this and make the view look unnatural. To reduce orange light pollution, open Levels and select the red channel. Reduce red until image shows a green hue. Repeat with the green channel until image looks slightly blue. Repeat with the blue channel until image looks balanced.

Glamping with the stars

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Thanks to new technology, detailed images of Neptune and Uranus are within the grasp of even amateur astronomers

Imaging the ICE GIANTS

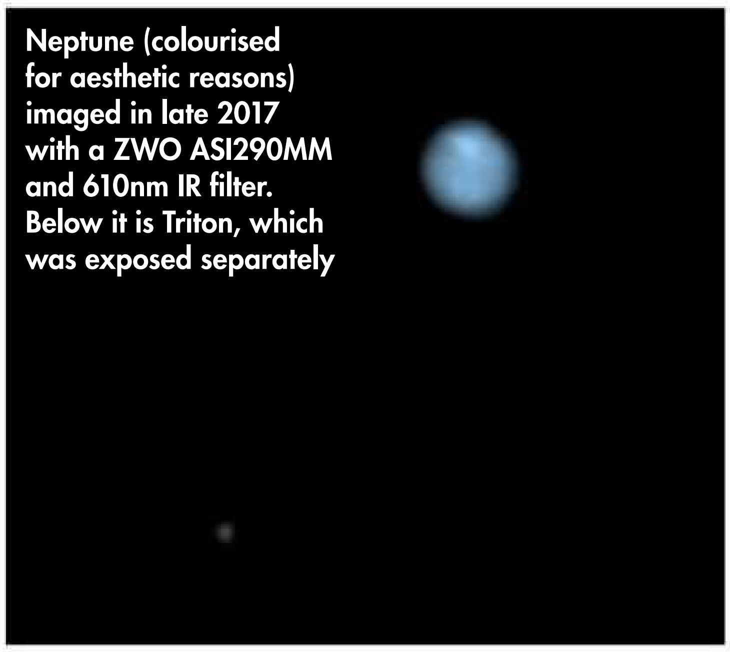
Using the latest imaging techniques, **Martin Lewis** reveals how you too can capture surface details on the most distant planets in the Solar System, Uranus and Neptune

Uranus on 18 December 2017, showing surface details in infrared. The lighter polar region is tipped to the right. The moons were exposed separately from the planet and in visible light, not IR

Planetary imagers in the UK face tough times over the next few years as Saturn, Jupiter and Mars, all reach opposition well south of the celestial equator. Their apparitions will be short and, as they'll be relatively low in the sky, the blurring effects of our atmosphere will make much more of an impact. In these lean times distant Uranus and Neptune will remain higher in the sky and an increasing number of imagers will be turning their attention to the different challenges they present.

Although both planets are physically very large, their remoteness means they are angularly very small. Uranus is a diminutive 3.7 arcseconds across – just over twice the diameter of Jupiter's moon Ganymede – while Neptune is just 2.4 arcseconds in diameter. What's more, in the outer reaches of the Solar System there's very little sunlight and so they shine dimly with very low surface brightnesses, compounding the problems of small size.

Despite these difficulties, in recent years amateurs have been able to detect details on these remote worlds using the latest cameras and imaging techniques and by capturing in infrared (IR) light. Although relatively bland in visible wavelengths, when imaged in IR Uranus shows belts, polar features and occasional spots. Neptune is plainer in IR but as its northern hemisphere has moved into summer in recent years large, lighter spots have been tracked by amateurs using larger telescopes. Here we'll look at how you too can reveal these elusive details in your images of the ice giants. ▸



Neptune (colourised for aesthetic reasons) imaged in late 2017 with a ZWO ASI290MM and 610nm IR filter. Below it is Triton, which was exposed separately

ISTOCK X 2, MARTIN LEWIS X 2

New cameras to the rescue

▲ Top: The Altair GP-CAM 290M mono camera (reviewed in our March 2018 issue) features a state-of-the-art Sony Exmor IMX290 sensor

Above: Even if your camera has an IR-sensitive sensor you will still benefit from using IR filters as well

To record planetary images, astronomers usually place high-speed digital video cameras at the focal point of their telescopes. With an intervening Barlow lens to enlarge the image, they record thousands of video frames directly onto a computer. The best of these are later processed with special software to filter out and average the blurring effects of our atmosphere. The software outputs a very low-noise master image that can be sharpened to show significantly more surface detail than any other current imaging method.

Uranus and Neptune are small and dim in visible light, and unfortunately even dimmer in the IR wavelengths needed to capture surface details. To image them successfully, though, you need to use an IR sensitive camera in combination with dedicated IR filters. Fortunately, in recent years CMOS chip manufacturers, in particular Sony, have made great advances in the IR sensitivity of their camera sensors. Sony's chips, such as the monochrome IMX290 and even the colour IMX224, are great performers in the IR band and are incorporated into cameras made by manufacturers such as ZWO (see page 98), QHY and Altair Astro.

One benefit of imaging the ice giants in IR is that the seeing is invariably better in IR than in visible light because the longer wavelengths are less prone to the blurring effects of our atmosphere. The steadier view in the IR goes some small way to explaining why people are now having fewer problems imaging these tough targets.

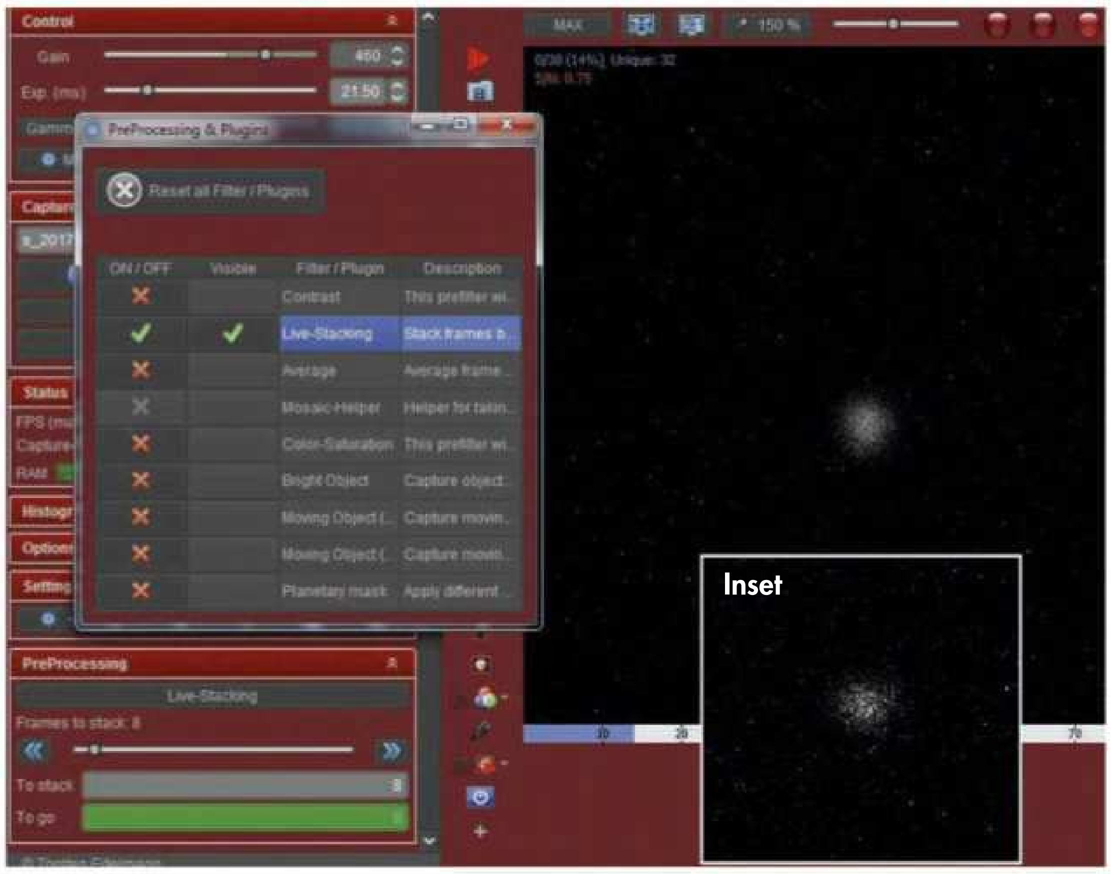
Until the arrival of these new IR sensitive cameras, frame exposure times for Uranus and Neptune were 100 milliseconds (msec) or more. This made imaging very difficult because unless the seeing was rock steady these relatively long exposures would lead to movement that smeared the image. One of the key features of most of these new highly IR-sensitive CMOS cameras, however, is their very low read noise, which allows the cameras to be used at high gain. This amplification of the image makes possible much shorter exposures while maintaining image brightness, without the image degenerating into a mess of noisy columns or rows.

"One benefit of imaging ice giants in infrared is that the seeing is invariably better"

WWW.SECRETSTUDIO.NET, MARTIN LEWIS X 2, PETE LAWRENCE

Techniques for imaging the ICE GIANTS

▲ **Neptune: a single IR frame of 17msec and gain 1000x with an ASI290MM camera and 610nm filter, showing severe shot noise (left); a stack of 3,000 frames with much lower noise (middle); a stacked image processed in RegiStax (right)**



▼ **The live stacking feature in FireCapture helps reduce noise levels and aids focussing. The last eight frames are being aligned and stacked here. Inset is the image of Neptune before live stacking, for comparison**

The 'high gain, short exposure' developments described opposite open the door to a method of planetary imaging that maintains image brightness and reduces atmospheric smearing through much-reduced exposure times. Instead of exposures of 100-200msec you can now have suitable image brightness with much more reasonable exposures of 10-20msec. With short exposures, however, comes another challenge. The low surface brightness of Uranus and Neptune means that the number of photons landing on each pixel of the camera sensor becomes painfully small, giving rise to high levels of 'shot noise'.

Shot noise is the main source of noise in planetary imaging and stems from the particle nature of light. Photons from an object arrive at random intervals, so the number captured by a pixel over the length of a frame also fluctuates randomly. Since each image pixel varies in this way, the planet ends up looking noisy. The fewer photons, the worse the shot noise relative to the signal. In fact, there's a square root relationship between the two. So, for example, a frame exposure that is 9x shorter, the frame's shot noise (relative to the image) will be 3x worse.

But don't be too concerned about noise in individual frames: what matters is the noise in the final stack. Remember, with shorter exposure times you can capture more frames in a given period, and with a 9x shorter exposure you should have 9x as many frames to stack. Because a square root relationship exists between the number of frames in the stack and the noise, the 9x increase in the number of frames reduces the noise in the stack by 3x – exactly compensating for the 3x worse noise in each individual frame.

This balancing act between exposure time and stack size, which fixes the overall level of shot noise, gives us a key principle of modern planetary imaging. From the perspective of noise in the stacked image, it's not the gain and exposure used for each individual frame that matters, but the total accumulated exposure time of the whole stack.

Keeping focused

The shorter exposures will allow you to gather more frames in your recording to make up for the high frame noise, as long as you maintain the same overall video duration. With Uranus and Neptune being so dim, however, don't expect to get nice smooth images showing details with a one-minute video – you will need to stack a total of at least 5 to 10 minutes' worth of data for the signal to start to dominate over the shot noise.

As mentioned earlier, the high shot noise in individual frames can lead to focusing problems. One technique to help here is to carefully swap your IR filter for a luminance filter of the same glass thickness. Once you've dropped the gain, the increase in brightness will mean a much better signal-to-noise ratio, allowing you to focus more accurately. Don't forget to switch things back after focusing and before hitting the record button.

A second focusing solution uses the live stacking preview feature of FireCapture, a camera control program. In this, the last eight or so frames are continuously aligned and stacked. This significantly reduces shot noise but overexposes the preview image, so drop the gain before attempting to focus. ▸

Scopes, filters and magnification

Given the faintness and small size of these targets, imaging details in IR only really becomes a realistic proposition with 8-inch scopes and above. Even then it is important that you choose a night of good seeing, collimate accurately, allow the scope to properly cool prior to imaging and choose your telescope magnification appropriately.

Too high a magnification and the planet becomes overly faint with no benefit in resolution; too low and although the planet's brightness might be improved, you lose resolution because there aren't enough pixels to render all the detail the scope can provide. There's a rule of thumb in planetary imaging that will help you optimise magnification: pick a power which gives an effective focal ratio of 3x to 5x the pixel size in microns. For instance, with an IMX290 chip that has 2.9µm pixels, pick a magnification that gives you f/9 to f/14.5, while for the IMX224 chip and its 3.5µm pixels, you want a focal ratio of f/10.5 to f/17.5. Selecting your Barlow lens's power to stay within these bands gives you the best chance of imaging success.

When imaging the ice giants you need to choose a filter that lets IR light through but blocks visible wavelengths, which would otherwise decrease the contrast of subtle surface features. Look for IR filters with a wide acceptance band to maintain image brightness, such as the Baader red 610nm longpass filter, the Baader IR pass 685nm filter and the Astronomik Planet Pro 642 filter.

"Too high a magnification and the planet becomes faint with no benefit in resolution; too low and you lose resolution"

▸ You'll need an 8-inch (200mm) scope at the very least. A compact Schmidt-Cassegrain will do nicely

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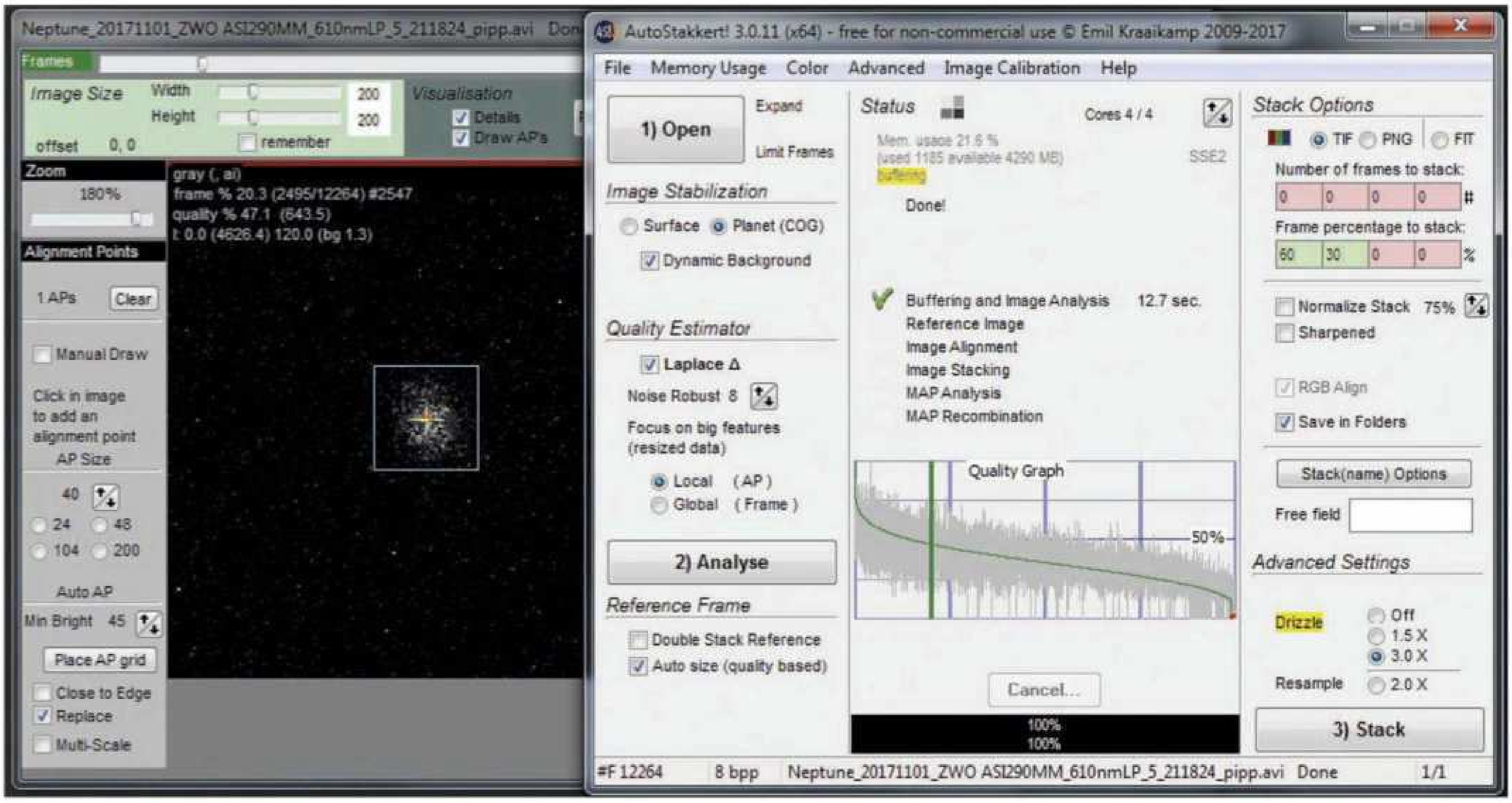
Processing your videos



▲ **AutoStakkert! is processing the video to reduce it to a single stacked and aligned master frame. Here, Planet mode with noise robust set at eight gives a positionally stable image**

With your data captured, next you need to process it to draw out subtle surface details. First, use the freeware program AutoStakkert! to convert your video to a stacked image. With the frames being so noisy you will need to experiment with Planet mode and Surface mode, and use high NR (noise robust) values from six to eight. Play with these settings and hit the Analyse button to see which setting gives the most stable planet position and the best transition from good quality to bad when you move the frame slider left to right on the analysed video.

Once happy with the settings, select your stack size to values in the range of 60 to 30 per cent of frames and then place a single alignment box comfortably around the planet. Set drizzle to 3x enlarge (which gives a bigger planet for RegiStax wavelets to work on later) and hit the Stack button. When it finishes, open the output in RegiStax and go to the wavelets stage. Adjust the sliders in the same way as you would for the brighter planets to bring out any subtle details on the surface.

You can then do further processing in Photoshop to reduce noise or bring out detail – maybe even create a composite, adding in moons taken during separate exposure runs in visible light with longer exposures. To improve the look of an image one common thing is to change the colour balance, adding false colour to give the planets the bluish or bluish-green colour they have to the eye in visible light (see the feature on page 36).

So if you have a medium or large scope and want new planetary imaging challenges this autumn and winter, have a go at capturing surface details on Uranus and Neptune. With an IR sensitive digital video camera and the latest imaging techniques, you too could be part of the new movement in astro imaging that is capturing surface details on these remote giant worlds.

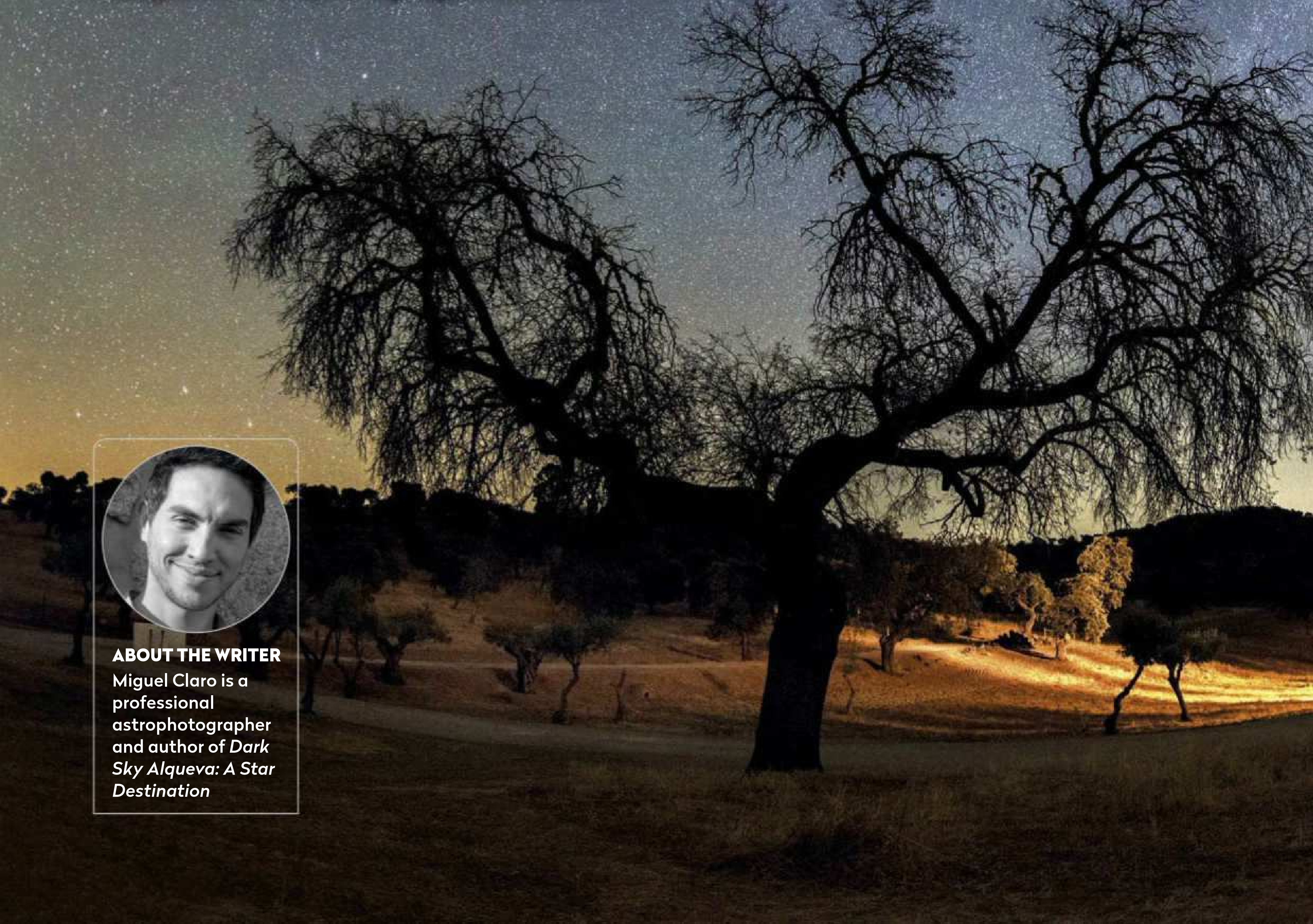
ABOUT THE WRITER

Martin Lewis is a keen astronomer with an in-depth knowledge of how to best image the trickiest of targets. Visit www.skyinspector.co.uk

Dark sky PORTUGAL

Lisbon-based astrophotographer **Miguel Claro** reveals the top stargazing sites his Iberian homeland has to offer

Located on the edge of Europe, Portugal boasts some spectacular dark-sky sites to share with all of its visitors. In the eastern part of the southern Alentejo province is Dark Sky Alqueva, the first 'Starlight Tourism Destination' in the world. This certified reserve is 7,000km^2 in area and sits next to Lake Alqueva, the largest artificial lake in Western Europe. Portugal is well-suited to astrophotographers and amateur astronomers with beautiful landscapes, castles, vineyards, islands, rivers and megalithic monuments that can often be seen under a shining Milky Way. Over the next few pages, we reveal the best regions of the country for stargazing tourists to savour.



ABOUT THE WRITER
Miguel Claro is a professional astrophotographer and author of *Dark Sky Alqueva: A Star Destination*

The Milky Way over Parque de Natureza de Noudar in Barrancos

◄ The headquarters of Dark Sky Alqueva in Cumeada, where all the street lamps are adjustable LEDs

▼ A glorious image of the Rosette Nebula, taken from Cumeada

Cumeada

This small village is home to the official observatory of Dark Sky Alqueva, equipped with cutting-edge telescopes for solar and deep-sky observations. The building – a renovated former primary school – also contains a permanent astrophotography exhibition and a small museum. Whenever the observatory is operating, the light flux from the entire village is reduced to just 10 per cent, allowing amazing views of the Milky Way. 5km away is Campinho, home of the annual Dark Sky Party, which welcomes 1,600 people over two nights.
More info: darkskyalqueva.com/en/dark-sky-observatory

The landscape around the former mine of Mina de São Domingas has a red, Martian-like feel

Mértola

Located in the south of Portugal, Mértola is the most recent addition to the expanded territory of Dark Sky Alqueva. This village is located on a hilltop where a beautiful medieval castle provides lovely views of the Guadiana River. It is also one of the few places on the Iberian peninsula where the Iberian lynx has been reintroduced, saving it from the verge of extinction. Mértola includes Mina de São Domingos, an old mine in a really dark region where the reddish hue of the landscape is reminiscent of the surface of Mars.
More info: visitmertola.pt/en ►

MIGUEL CLARO X 5

PORTUGAL'S BEST STARGAZING SITES

Plan your stargazing trip to Portugal and pay a visit to some of the country's dark-sky hotspots

1 Cumeada
2 Mértola
3 Pulo do Lobo
4 Parque de Natureza de Noudar
5 Reguengos De Monsaraz
6 Pampilhosa da Serra
7 Mourão
8 Portel
9 Serra do Alvão

Pulo do Lobo

The most dramatic stretch of the Guadiana River, this area near Mértola is a favourite of the dark-sky regions in the south of Portugal. It is a perfect place to see a winter Milky Way and capture the faint light of the gegenschein. At this point the river bed is reduced to a narrow strait a few metres wide in a gorge that plunges 35m at its deepest, and Pulo do Lobo is actually the name of the waterfall on this section. The name 'Pulo do Lobo' means 'Wolf's Leap', as, according to legend, only a brave animal would attempt to leap over this narrow gorge.

More info: www.roteirodoalqueva.com/natureza/pulo-do-lobo
Also: www.terraspulodolobo.com

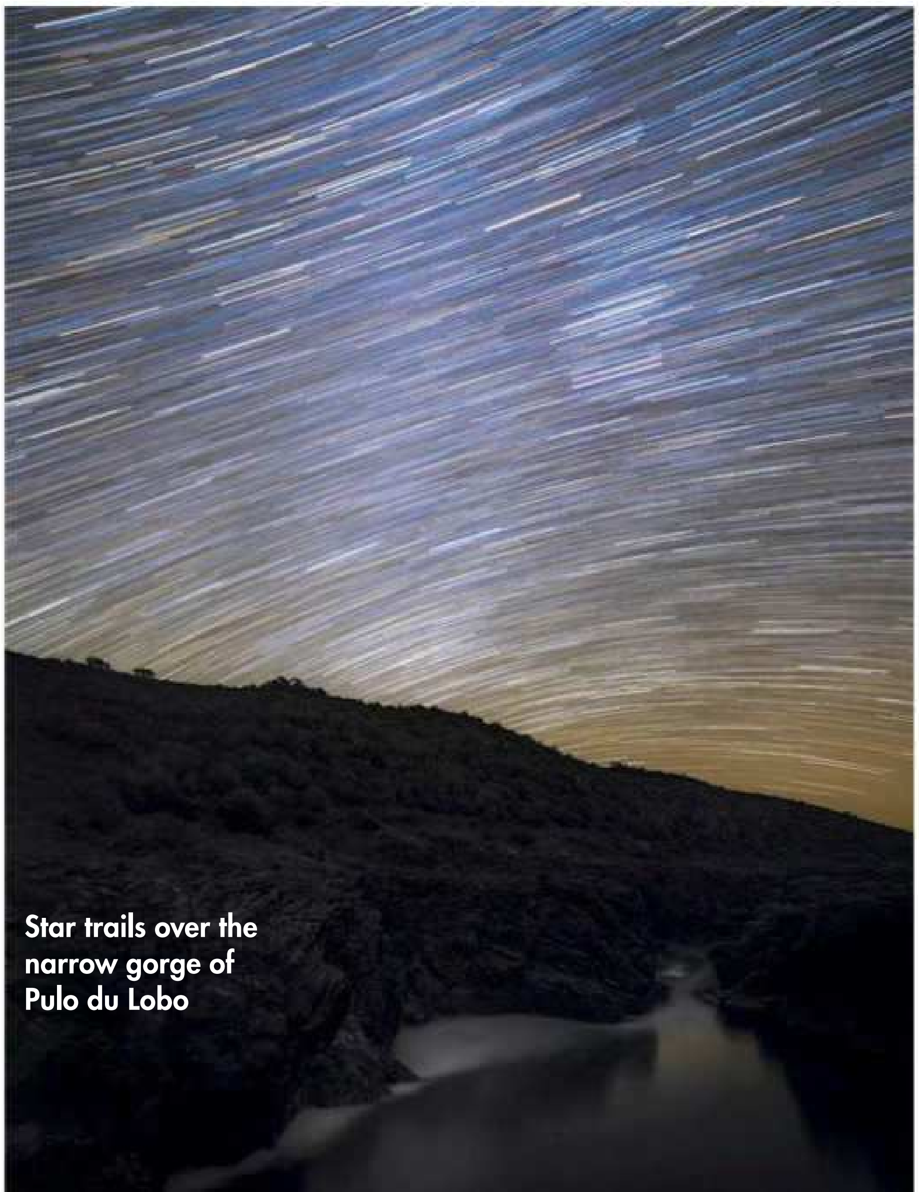
MIGUEL CLARO X 5, MAP: ISTOCK

▼ The Sun – displaying some sunspots – rises over the castle of Noudar

Parque de Natureza de Noudar

Noudar is a Nature Park located in Barrancos near the Spanish border and boasts some of the darkest skies in the Dark Sky Alqueva region. A place where life exists in a state of pure wilderness, the area includes an old castle, which provides a perfect setting to watch the sunset as you begin your astrophotography session. The area is so quiet and safe that it is safe to set up a telescope and leave the camera shooting all night long, while relaxing in a swimming pool under a starry sky.

More info: www.parquenoudar.com/en/estate/presentation



Star trails over the narrow gorge of Pulo du Lobo


The megalithic monuments of Cromeleque do Xerez in Monsaraz


The full Moon over Castle Monsaraz

Reguengos De Monsaraz

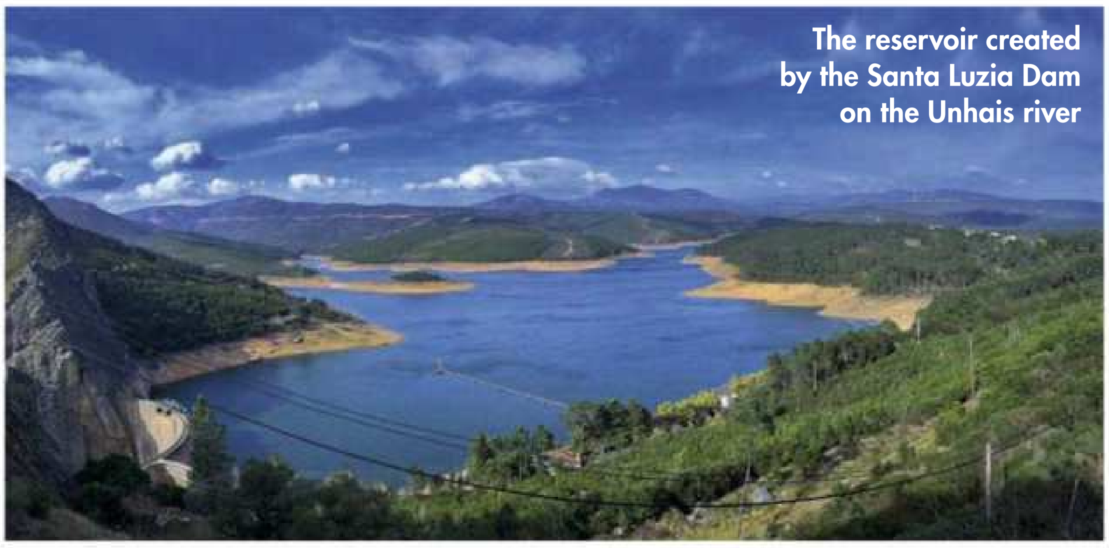
Being the European City of Wine 2015, Reguengos is an important producer of the drink and a great place for night-time activities, like blind wine-tasting under the stars, or horse riding in the moonlight. Not far from the main city of Reguengos is Cumeada Observatory, and 20km away is Monsaraz, a hilltop medieval village inside a castle in a region full of megalithic monuments and ancient olive trees. From there, visitors can enjoy the sight of dozens of small islands within Lake Alqueva.

More info: www.cm-reguengos-monsaraz.pt/en

Pampilhosa da Serra

Located in the centre of Portugal, there is an area surrounding the region of Pampilhosa da Serra that has been targeted as a future designated stargazing site by the same team that develops the Dark Sky brand, following the success of Alqueva. The project, named Dark Sky Aldeias de Xisto, covers the Rede das Aldeias de Xisto, a network of 27 historic villages that stretches between Castelo Branco and Coimbra. Researchers are now mapping the quality of the sky to establish those villages with the necessary dark-sky conditions, meaning this may soon be another protected Dark Sky area.

More info: aldeiasdoxisto.pt ▸


The reservoir created by the Santa Luzia Dam on the Unhais river

Mourão

Separated from Monsaraz by the 250km^2 Lake Alqueva – Europe's largest man-made lake, which contains 200 small islands – Mourão is a perfect place to consider the connection between the night sky and the landscape. The area also includes a beautiful castle that has hosted the Starlight Party Alqueva on two occasions, as well as a river beach and the nearby museum of Aldeia da Luz.

More info: www.cm-mourao.pt/pt/Paginas/home.aspx

Airglow on the horizon, shot from Mourão

Portel

Portel is also home to a medieval castle, although this one has sadly fallen to ruin over the years. However, it provides a beautiful setting for those who love shooting astrophotography amongst interesting landscapes. Nearby is the small village of Vera Cruz, with historical connections to the Knights Templar. The Portel region is surrounded by water, making it very good for aquatic activities, and nearby is Moura, a place where you can canoe under the stars, ending the night with a picnic of regional food and wine.

More info: www.cm-portel.pt/en

The ruins of the medieval Castle of Portel

MIGUEL CLARO X 3, ISTOCK X 3

◄ **A serene mountain lake in Serra do Alvão**

Serra do Alvão

Vila Real is a city in the northern part of Portugal. Despite not being designated as a Dark Sky area, the area is home to a majestic mountain range called Serra do Alvão situated at a height of about 1,060m above sea level. Visitors should seek out the small lagoon at Cimeira dam, which is a beautiful setting for astrophotography or observing. Also situated in Alvão is the beautiful Agarez waterfall, 8m high.

More info: dourovalley.eu/en

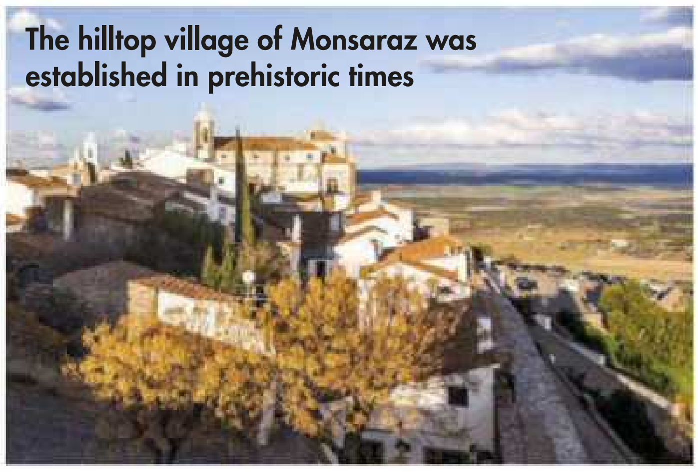
ALQUEVA BY DAY

It's the jewel in the crown of Portuguese dark skies, but this beautiful region has much more to offer visitors

If you feel inspired to visit Alqueva, rest assured there are plenty of fun and interesting things for the whole family (even non-astronomers) to do during the day. In Alentejo, the Sun rises early, bringing with it the opportunity to try a beautiful balloon ride over large fields of vineyards, olive and cork trees. After landing, you can fill up on a typical regional breakfast served in one of the many rural hotels in the area. Alqueva includes nine different counties with a variety of castles to appreciate, and my advice is to take in the sights from the medieval village of Monsaraz, which offers a stunning hilltop view. Not far away, visit the Sem-Fim restaurant for lunch in an old olive factory, followed by a boat trip that will lead you to one of the isolated islands in the great lake. Monsaraz and Mourão also have a river beach where you can catch some Sun, relax and swim. Before twilight, be sure to view a beautiful sunset over a stone circle or another of the incredible megalithic monuments that can be found from Évora up to Monsaraz, like Almendres or Xarez. We believe that these stones may have been the first observatories used by our ancestors to mark important events like the solstice, equinox or some star alignments, and may also have operated as astronomical calendars.

Moonlit nights are perfect for horse riding or canoeing in Moura, while bird watching, hiking and wildlife observing can all be done in Mértola. And don't forget to visit the colourful acid Mars-like landscape of the old mine of São Domingos. Ⓢ

▲ **A balloon trip will give you a breathtaking view of the Alentejo region**



The hilltop village of Monsaraz was established in prehistoric times

The area around the old São Domingos mine looks almost Martian

SKILLS

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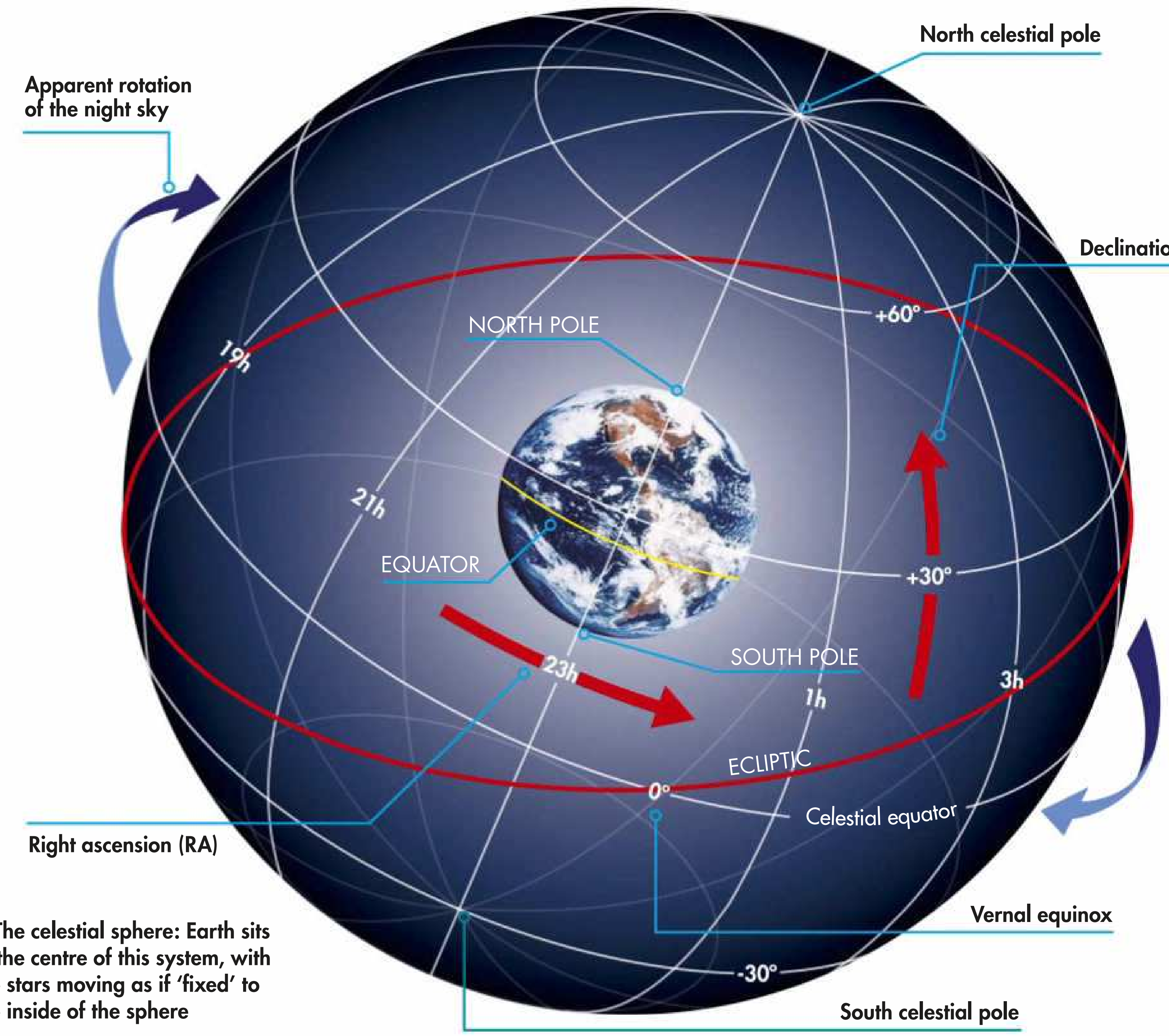
The Guide

With
Paul Money

A beginner's guide to celestial coordinates

There's more than one way to locate a star, but you only really need to know two



▲ The celestial sphere: Earth sits at the centre of this system, with the stars moving as if 'fixed' to the inside of the sphere

So, what coordinates would you like to use to locate your star? Altaz? RA and Dec.? Ecliptic? Galactic? Is the Universe trying to confuse us? Why are there so many?

The coordinates we use to locate places on Earth – longitude and latitude – seem simple enough. You can pinpoint anywhere by knowing how many degrees, minutes and seconds somewhere is north or south of the equator, and east or west of the Prime Meridian. Why not adapt this system for the sky and leave it at that?

Put simply, it's because the sky appears to be constantly on the move as the Earth both spins and orbits around the Sun. And unlike Earth's surface, the sky has many possible frames of reference to use depending on what you want to achieve or, indeed, where you might be viewing from.

Assuming you're viewing from Earth – as most of us will be (for now) – there are two main systems astronomers use which differ quite significantly, but which both have their particular practical uses.

Altaz – which is short for altitude and azimuth – is, like longitude and latitude, measured in degrees, minutes and seconds. It describes an object's place in the sky at any given moment in relation to the horizon: degrees along it (azimuth) and degrees up from it (altitude).

Degrees of difference

This system is specific to your location on Earth. So, for example, if someone in Edinburgh sees a star at 46° high in the southern sky, someone in London will see that same star at 51° instead. This is because London is just over 5° further south than Edinburgh on Earth's surface.

Also, because Earth is rotating this means the altaz coordinates are constantly changing as the stars move across the sky. This is why planetarium software shows the altaz coordinates changing in real time when you click on any target in the sky.

This is a problem addressed by the **Equatorial** system, a way of pinpointing a star that is standardised wherever on Earth you happen to be. Put simply, it takes the imaginary grid of latitude and longitude lines from Earth's surface and projects them onto the sky, to create what is known as the celestial sphere. It ignores the fact that stars are different distances from us and thinks of them all as if they were painted on the inner surface of a vast, hollow globe with a tiny Earth at its centre.

So Earth's equator is extended outwards to become the celestial equator, while Earth's poles become celestial north (roughly Polaris, the Pole Star) and celestial south. Lines of latitude become lines of declination (Dec., measured in degrees, arcminutes and arcseconds), which indicate how far north (a positive value from 0° to 90°) or south (a negative value from 0° to -90°) of the celestial equator the object lies. Lines of longitude become right ascension (RA), measured in hours, minutes and seconds east from where the celestial equator intersects the ecliptic (or the plane of Earth's orbit) for the vernal equinox. Why the sudden change to hours? It's a logical extension of timing the passage of objects as Earth rotates, with the sky literally divided into 24 hours. So in one hour of time a star will move (roughly) across 15° of sky (360° ÷ 24 hours).

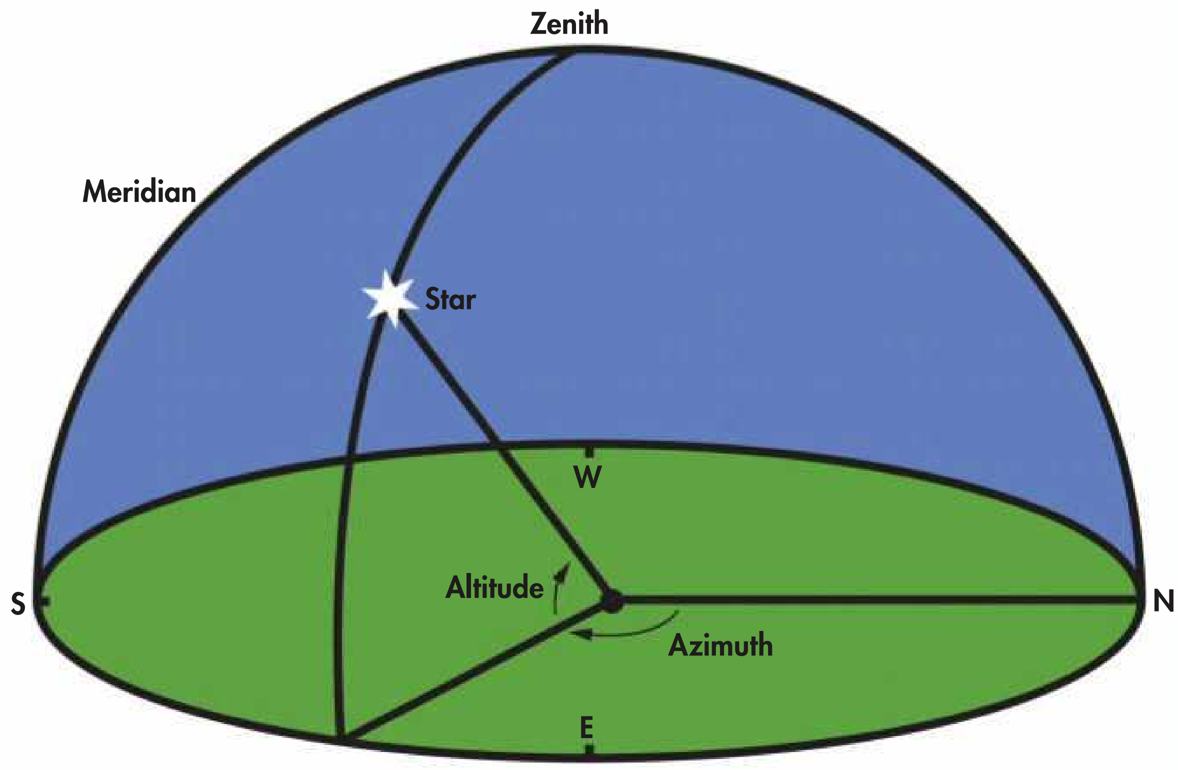
So what you end up with is equatorial coodinates that looks something like this one for the star Alnitak in Orion's belt: 05h 40m 45.52666s, –01° 56' 34.2649".

There is a little glitch in the system, owing to the fact that a wobble in the Earth's axis means that equatorial coordinates drift through 360° over a period of 25,772 years. So, for example, the north celestial pole today lies near Polaris but 5,000 years ago it lay close to Thuban in Draco. This gradual change means that equatorial star maps need to be reset periodically: mid-last century they were set to use the stars' positions as seen from Earth in 1950 as the reference point, whereas current charts use 2000.

So, if the equatorial system works so well, why do we still need altaz? That's down to telescope mounts. Altaz mounts are generally cheaper and quicker to set up, but equatorial mounts are a must-have for astrophotography, which relies on tracking objects. Neither is 'better' than the other. It's horses for courses. And they're both a little more accurate than, "Second star to the right, and straight on till morning."

Astronomy writer and broadcaster PAUL MONEY is reviews editor for BBC Sky at Night Magazine

Altaz coordinates



▷ **Altitude** is the angular distance of an object above the local horizon. It ranges from 0° at the horizon to 90° at the zenith, the spot directly overhead.

▷ **Azimuth** is the angular distance of an object from local north, measured along the horizon. An object due North has an azimuth of 0°; due east is 90°; due south is 180°; due west is 270°.

Even more coordinates

Along with the standard two coordinate systems there are several others that you may come across that are not usually useful for amateur astronomy

▷ **Ecliptic longitude/latitude** – There are two variations, geocentric and heliocentric. Geocentric uses Earth's orbital plane as a reference and was used in ancient times to work out the positions of the planets in the sky. Heliocentric uses the Sun at its centre and is used for accurately working out the positions of the planets and their orbital elements.

▷ **Galactic longitude/latitude** – Beyond our Solar System the normal coordinate system breaks down completely so the plane of our Galaxy is used for the reference plane instead but with the Solar System still at the centre and the Galactic centre used as a fixed point of reference.

▷ **The Supergalactic system** – This system uses the distribution of several of the largest galactic supercluster groups as its plane of reference.

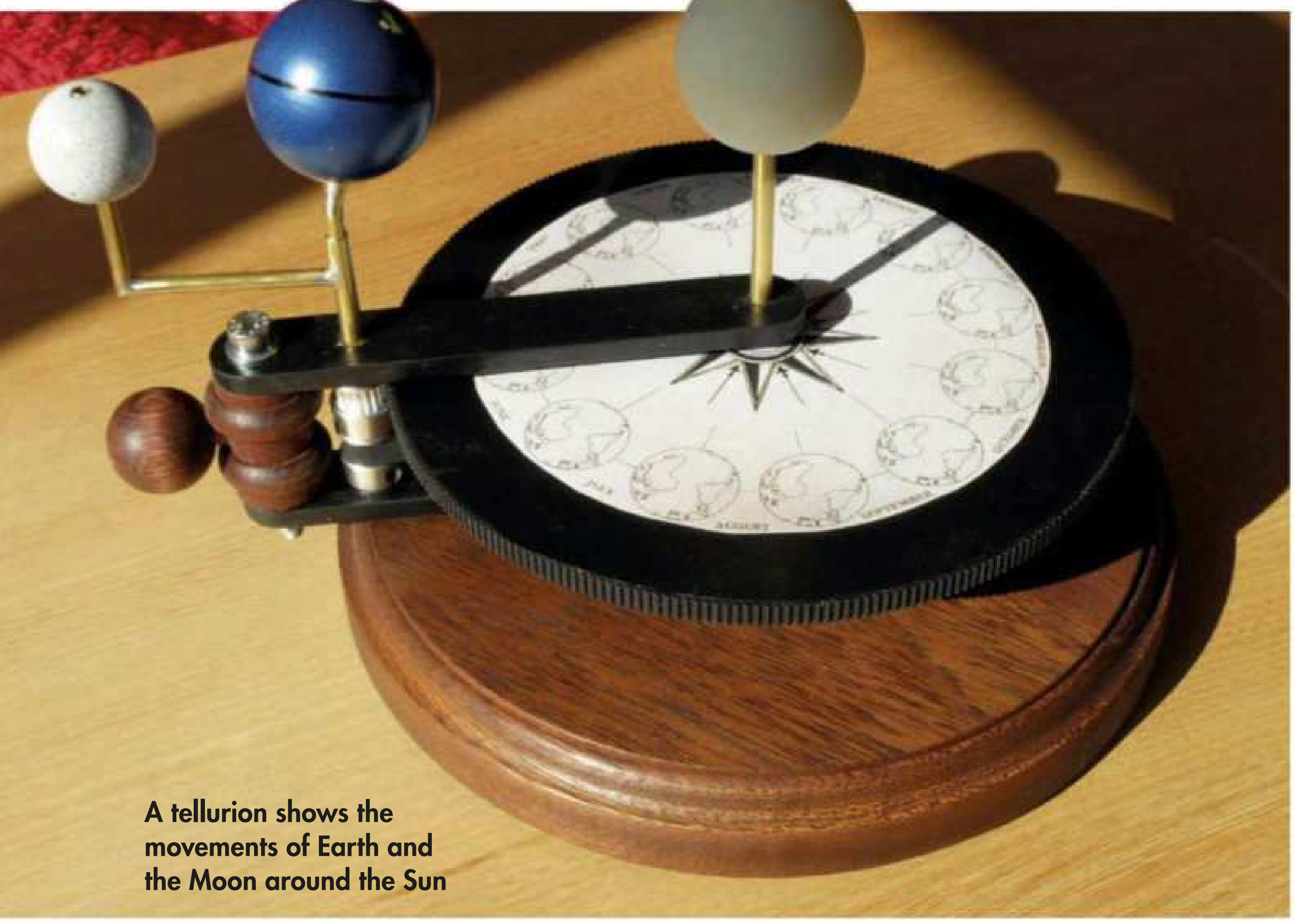
▷ **International Celestial Reference System (ICRS)** – This is almost the same as the equatorial system but uses the centre of our Solar System instead of Earth for reference.

How to...

With
Mark Parrish

Make a tellurion

Construct a home-built working model of the Sun, the Moon and Earth



A tellurion shows the movements of Earth and the Moon around the Sun

This month's project is a tellurion – a working model of Earth, the Moon and the Sun. As well as being educational, this model looks great when displayed in your living room or study. We designed our tellurion so that it's simple to build, utilising parts that are readily purchased online. By making some careful calculations we were able to choose gear ratios to produce accurate movements of the Moon and Earth as the main arm is rotated by hand around the Sun.

The design is built around a central 'year disc'. This has a section of GT2 belt glued around its circumference, forming a gear with 267 teeth. The model Moon is rotated by a 20-tooth pulley meshing with this gear, which gives a ratio of 20/267 (1/13.35). This means it will complete 13.35 orbits of the Earth per year or one orbit every 27.34 days – very close to the real Moon's sidereal month of 27.32 days. Like the real thing, model Earth's axis is inclined on its mounting by 23.4° from vertical and a pair of 20-tooth pulleys and a toothed belt make sure it maintains this inclination as the system orbits the Sun.

Seasons

One full orbit around the Sun represents a calendar year. By adding a printed disc (free to turn so it can be synchronised with the positions on a known date) you can indicate the current month. During the northern hemisphere's winter, Earth's south pole is tilted in the general direction of the Sun, which appears low in the sky for us in the UK. In the northern hemisphere's summer, the north pole is tilted in the Sun's direction with a correspondingly high Sun for us. This demonstrates our seasons very nicely.

The tropics are observed as the most northerly and southerly points where the Sun is directly overhead.

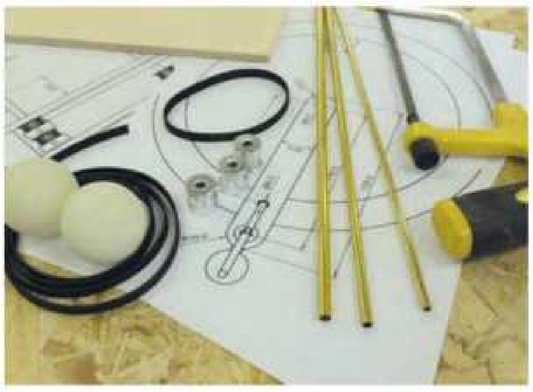
It is possible to turn the Earth sphere by hand to demonstrate the passage of days and how the Sun appears to rise and set. By imagining the 'fixed' star field on the walls of your room and varying the position of Earth around the Sun it is possible to explain how the stars appear to move across the sky during the night, and why much of the night sky is only visible for part of the year.

Phases of the Moon

Because the Moon is fixed on its axis arm the same face always looks towards Earth (as it does in reality). We incorporated a small bulb in our model so the Sun can be illuminated, but a torch can also be used ▸

ALL PICTURES: MARK PARRISH

TOOLS AND MATERIALS



Tools
A junior hacksaw; coping saw; drill and bits for tube (4mm, 5mm, 6mm); small pliers; soldering kit; small files.

Materials
A small sheet of good quality plywood or MDF (6mm thickness, about A3 size); a set of 300mm-long brass tubes (4mm, 5mm, 6mm).

Sundries
Two table tennis balls, 20mm diameter; wooden ball; three 20-tooth GT2 pulleys (5mm bore); approximately 550mm of GT2 belt; one 112-tooth GT2 closed belt; four M5 washers; one 50mm M6 screw/washer/nut; a bulb, battery and wires if you want to illuminate the Sun.

Finish
Some paints for celestial bodies; paint or wood varnish to provide a nice finish for the base; felt pads for bearings and feet.

▲ An illuminated Sun means the tellurion can demonstrate Moon phases

▸ to simulate the Sun's rays striking Earth and the Moon. It should therefore be possible to demonstrate how the phases of the Moon are formed during a month. Note that in the model there is a solar and a lunar eclipse every month instead of the usual New Moon and Full Moon. The reason we get far fewer eclipses than this in reality is because the real Moon's orbit of Earth is inclined to Earth's orbit of the Sun by 1.54°, which means that most of the time the Moon is slightly above or below the plane of Earth's orbit as it passes behind us or in front of the Sun – hence no eclipses. It is beyond the scope of our model to recreate this, but nevertheless it is easy to imagine the New and Full Moon.

The crucial elements of the model are the supporting arms. We found that model shops sell packs of 4mm, 5mm and 6mm brass tube that fit inside each other – perfect for the job. Earth and the Sun are table tennis balls; the Moon is a wooden ball from a craft shop. To build the rest of our model we used 6mm plywood, which is flat and quite easy to cut. We were going to stick a few layers together for the base but sourced a nice offcut of hardwood instead. It got us thinking that there are many ways to customise the tellurion. Whether you keep yours simple or get fancy, we are sure that you will have a lot of fun building and demonstrating it. Ⓢ

MARK PARRISH is a bespoke designer. See more of his work at buttondesignco.uk

YOUR BONUS CONTENT

Download plans, diagrams and extra photos to help you build your tellurion

ALL PICTURES: MARK PARRISH

STEP 1

Print out the downloadable drawings and templates and use them to carefully mark out the plywood sections before cutting out the shapes. It is a good idea to use a sharp point to mark through the centre of each hole to aid accurate drilling.

STEP 2

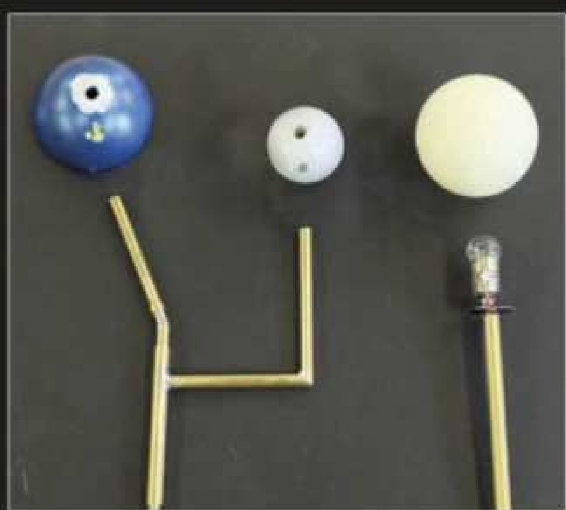
After cutting out, tape the plywood arms together. Use a 6mm drill to drill through both at once – this ensures the holes will line up later on. Mount the year disc on a piece of scrap and rotate it against a sander to get a perfect circle.

STEP 3

Drill holes in some scrap wood to support the tubes as you saw them to length. File the ends flat while held in the block. Cut mitres almost all the way through to help form the bends. Make sure there are no burrs so the tubes pass smoothly through each other.

STEP 4

After checking against the plans, carefully solder the parts of the Earth and Moon arms together. Make sure joints are freshly sanded and use a solder with a flux core to ensure a good joint. A normal electrical iron should suffice. File off any surplus.



STEP 5

Drill holes in the Earth and Moon balls. Glue a 5mm tube through Earth's axis and solder a small shoulder on the arm so it rotates without dropping down. If you are using a bulb, make sure the Sun has a larger hole and supporting 'cup' on its tube.

STEP 6

Carefully paint all the parts. Cut a section of belt and glue it round the circumference of the year disc. Build the Sun arm first then fit the Earth and Moon arms. Make sure you have fitted the Sun electrics if required then complete with the year disc and base.

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- Guided tour of Mateus Palace and gardens
- Enjoy dinner at a typical Portuguese quinta
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Image PROCESSING

With
Scott Tully

INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR
Advice from a 2017 shortlisted Our Sun entrant

IAPY masterclass: Mercury's Silhouette Against Our Star

How to capture both detail and impressive solar glow in one shot using two exposures


The final image of Mercury's transit of the Sun on 9 May 2016

Mercury's Silhouette Against Our Star was created using two different photos of the Sun, captured during the Mercury transit on 9 May 2016. The equipment used was a Hutech-modified Canon 6D and a Vixen ED103S refractor with a Baader solar filter, all of which was mounted on a Losmandy GM8 tracking mount.

Here we explain the technique used for blending the two different exposures in Photoshop to create an image that shows a greater range of details.

First, capture the Sun's glow with an overexposed image. Then take another image that is properly exposed to capture the details. Shoot in RAW format and, after downloading the images, open them in the Photoshop plug-in Adobe Camera Raw Process the overexposed photo with a warm tone to make it look more natural than the cool tone of the solar filter; do this by raising the temperature, then lowering the tint slightly. Bring out the highlights from the glow surrounding the Sun by raising the highlights, clarity and vibrance.

Create a warm tone for the detailed image as well, making similar adjustments to the ones made to the first image. To accentuate details, lower the exposure, highlights and blacks while raising the shadows, whites, clarity and vibrance. To add sharpening and noise reduction click on the detail settings and raise the sharpening amount along with the masking and luminance (when you're adjusting the masking you can hold the option/alt key to view progress).

Two become one

Next, from Camera Raw open both images in Photoshop. Zoom in when working on finer details (click **view** > **zoom in**); sometimes the closer the better. To save your progress at any point use the Photoshop format to save files with layers: click **file** > **save as** > **Photoshop** > **save**. Use the overexposed Sun as a background and place the detailed image over it. To do this select the move tool and click the tab

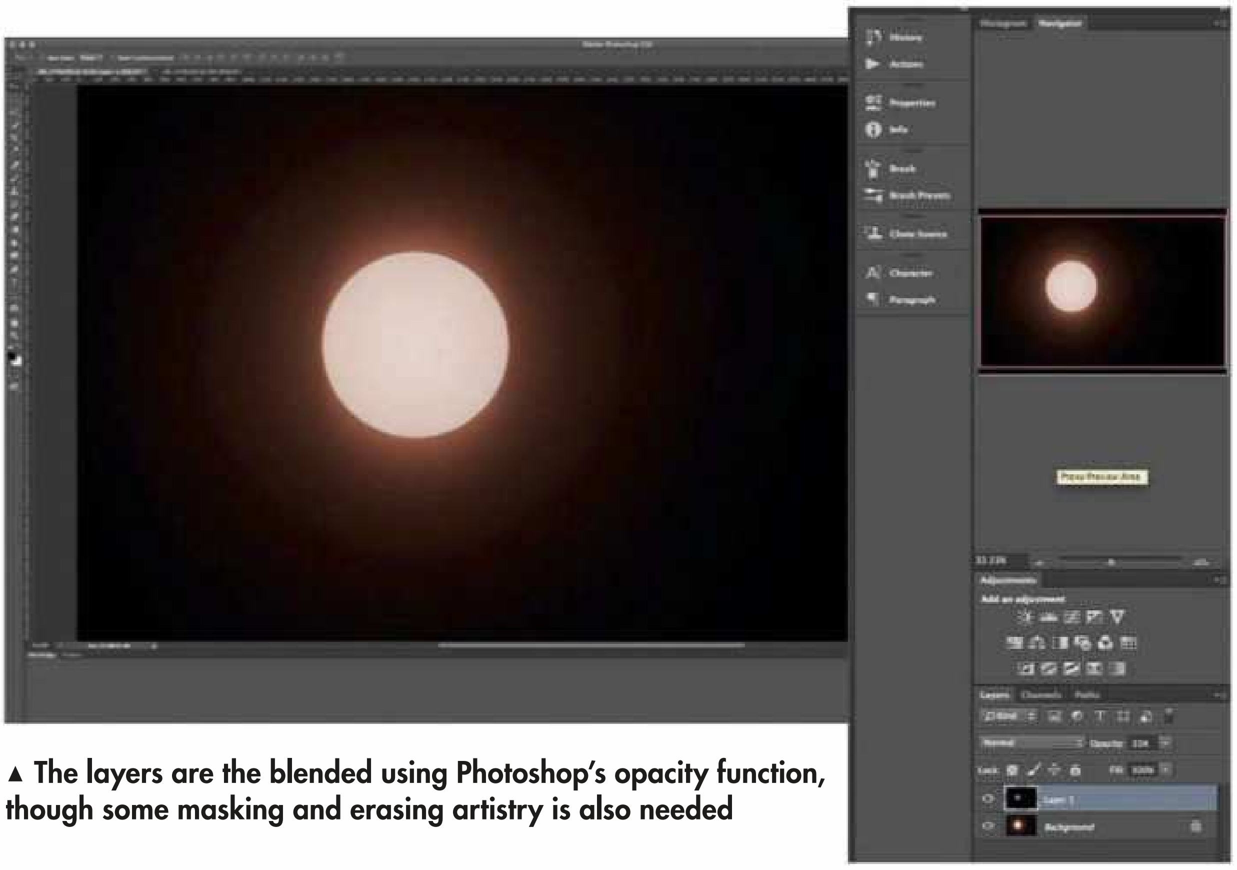

RAW image from camera settings: 1/2000 sec at ISO 800

RAW image with adjustments

▲ An overexposed image is used to capture to Sun's glow. The cool 'tone' needs warming up

ALL PICTURES: SCOTT TULLY

▲ **Another properly exposed image is used to capture the detail – including Mercury**



▲ **The layers are the blended using Photoshop's opacity function, though some masking and erasing artistry is also needed**

at the top for the detailed image then move it to the left of the screen. This separates the image from the main Photoshop page so you can work with both. Click on the detailed image again then drag and drop it onto the background image. Lower the opacity under the tab for layer adjustments so you can see through the layer then zoom in and align the two Suns. Now with the detailed image (layer one) selected, adjust the layer opacity to blend the images so the details remain but the background is prominent. Go by eye for this stage and use what looks best.

Now select the eraser tool, click the size adjustment at the top and select the soft round pressure opacity brush from the menu. Set the brush size around 500 pixels and the eraser's opacity and flow settings at 100 per cent then select the airbrush icon. Erase the outer edge of the Sun and the surrounding black by keeping most of the eraser on the black with very little on the Sun's edge. This reveals the brighter glow from the background layer with a soft fade effect. Get close enough so only a small amount on the Sun's edge shows through from the brighter layer. Be patient with this step; it will take several tries to get it just right. Now erase the rest of the black background on layer one.

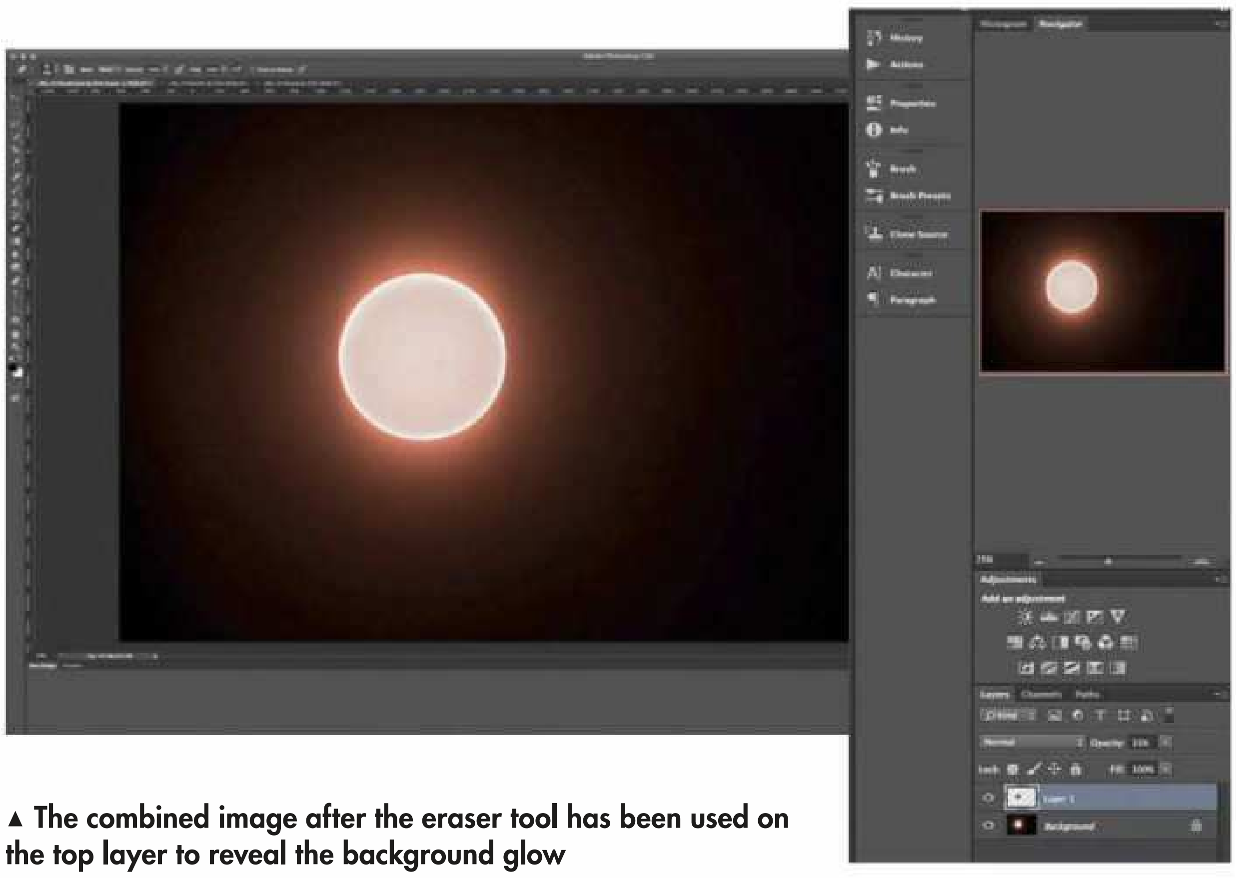
Change the opacity and flow to around 30 per cent and erase the inside edge of the Sun. Place the centre of the eraser on the Sun's rim, then move slowly and evenly around the edge. When you have it where you like it, hold down shift and click on the background layer to select and highlight both layers. At the top click **layer** > **merge layers**.

The last paste

With the image opacity lightened on layer one, Mercury and the sunspots become lighter. To fix this, select the original detailed image and, holding shift, use the lasso tool to circle the planet and sunspots then click **edit** > **copy**. Select the file you were working on click **edit** > **paste**. Now lower the opacity to see through the pasted layer. Select the move tool and align them onto the area where they belong. Switch the eraser to 100 per cent and erase what you don't want, then blend it with the opacity layer adjustment. The same copy-and-paste technique is used with the glow around the sides of the Sun where it's faded, although depending on your type of scope and filter you may not have a fade in the surrounding glow. Merge the layers then crop the image. Click **file** > **save as** > **Tiff** > **save**.

Do final adjustments for colour and highlights in Lightroom using your judgement for what looks best.

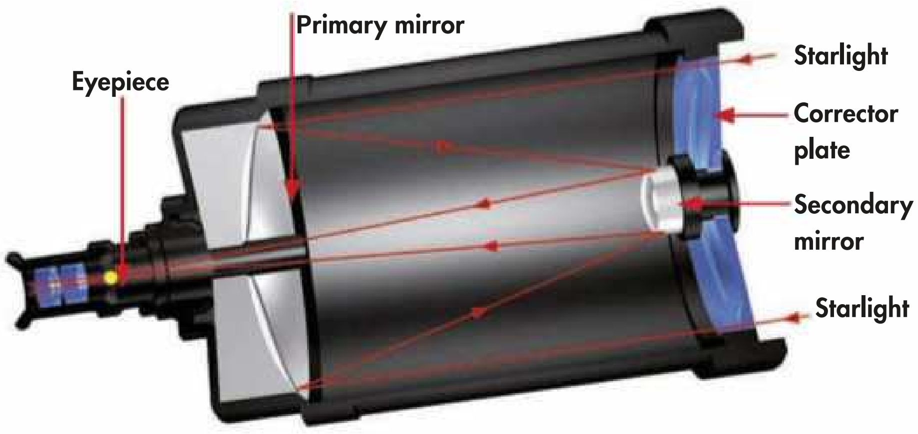
See more of SCOTT TULLY's photography at www.flickr.com/photos/stully



▲ **The combined image after the eraser tool has been used on the top layer to reveal the background glow**

Scope DOCTOR

With **Steve Richards**



▲ A photon needs a GPS to navigate through an SCT

Our equipment specialist cures your optical ailments and technical maladies

◄ The Zenithstar 61 is ideal for wide-field observing and you can make its view even wider

I have a William Optics Zenithstar 61 teleacope. I'm using it with a 0.6x flattener-reducer. What is this doing, and what magnification would I get with a 25mm eyepiece?

PHIL CREMMEN

The William Optics Zenithstar 61 is a portable, well-made refractor with a short focal length of 360mm making it ideal for wide-field observations. The multi-coated, doublet optics use low-dispersion FPL-53 glass so the scope is also suitable for imaging deep-sky objects. As with all refractors, a field flattener or field flattener-focal reducer is recommended for imaging purposes but it is unusual to use such an adaptor for observational use. There's no reason why you shouldn't use one for this purpose as it will allow you to observe even larger swathes of the night sky than the instrument already displays.

The magnification of a telescope-eyepiece setup is calculated by dividing the focal length of the telescope by the focal length of the eyepiece, which in the case of your Zenithstar gives 360÷25 = 14.4x magnification. This type of magnification is in the binocular realm and will deliver great views of large asterisms, constellations and many deep-sky objects, but planets and the Moon will be very small indeed. The field of view will be 4.7° across, or roughly the equivalent of nine Moon widths.

Inserting a 0.6x focal reducer produces an effective focal length of 360x0.6, which equals 216mm, yielding a magnification of 8.64x, which equates to a field of view of approximately 15 Moon widths.

FIRST LIGHT OPTICS, PAUL WOOTTON

When I look at Jupiter with my Celestron CPC I see a huge black spot in the centre. What could be causing this?

SUSY EDYVEAN

The Celestron CPC range of telescopes are of the Schmidt-Cassegrain design, with a large concave primary mirror at the base, a corrector plate at the front and a convex secondary mirror attached to the corrector plate on the inside of the tube.

The light they collect follows a complex path: it travels through the corrector plate to the primary mirror; back up the telescope's tube in a converging beam to the secondary mirror; back down the tube again and through a hole in the middle of the primary mirror; and finally through the focuser and star diagonal to reach the eyepiece. All in the name of an effectively long focal length.

Tha black spot you are seeing is the shadow of the secondary mirror, indicating that you have not achieved correct focus.

STEVE'S TOP TIP

How do I reduce light pollution?

Light pollution is a major modern-day issue for astronomers, robbing observers and astrophotographers alike of clear views of the fainter celestial objects.

The most effective way of dealing with light pollution is to travel to a dark-sky site, usually out in the countryside away from street lighting, but this isn't always possible, of course.

Astrophotographers can make use of special light pollution suppression filters to remove some pollution effects during post-processing. Observers don't have it so easy but a good ultra-high contrast (UHC) filter can help here. However, no filter will brighten a celestial object; all the filters can do is help to remove the unwanted light.

STEVE RICHARDS is a keen astro imager and an astronomy equipment expert

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BBC Sky at Night MAGAZINE

Reviews

Bringing you the best in equipment and accessories each month, as reviewed by our team of astro experts

HOW WE RATE

Each category is given a mark out of five stars according to how well it performs. The ratings are:

★★★★★ Outstanding
★★★★★ Very good
★★★★★ Good
★★★★★ Average
★★★★★ Poor/Avoid

This month's reviews

FIRST LIGHT

BOOKS

GEAR

Find out more about how we review equipment at **www.skyatnightmagazine.com/scoring-categories**

SEE INTERACTIVE 360° MODELS OF ALL OUR FIRST LIGHT REVIEWS AT WWW.SKYATNIGHTMAGAZINE.COM

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90
A sleek Dobsonian that's admirably easy to set up and get using

FIRST **LIGHT**

See an interactive 360° model of this scope at **www.skyatnightmagazine.com/omprodob**

Omegon ProDob N 203/1200 telescope

WORDS: MARTIN LEWIS

A low-cost, no-fuss Newtonian with some very smooth moves

VITAL STATS

- **Price** £530
- **Optics** 8-inch (203mm), f/6 primary mirror
- **Focal length** 1,200mm
- **Mount** Dobsonian
- **Extras** 32mm SWAN wide-field 2-inch eyepiece; fan and 8xAA battery box (batteries not included); red dot finder; eyepiece tray
- **Weight** base 12.3kg, tube 11.3kg
- **Supplier** Omegon
- **Tel** +49 8191 940490
- **www.**omegon.eu

A Newtonian reflector on a Dobsonian mount is often regarded as an ideal starter telescope. Easy and quick to set up, with no complicated electronics or mount alignment, it has a big enough aperture to see significant detail on planets, the Moon and deep-sky objects, but is small enough to be easily transportable. Such scopes can be great value for money if they're well designed, well built and boast good optics. We tested an 8-inch (203mm) Dobsonian scope from Omegon that ticked all these boxes. The scope is a member of its ProDob range which also includes versions with 10-inch (254mm) and 12-inch (304mm) diameter mirrors (£670 and £850 respectively).

The instrument came well packed in two cardboard containers. One long box contained the preassembled optical tube, while another squat, package held the parts to build the rocker box mount. Assembly mainly consisted of putting the particle board rocker box together which was intuitive and straightforward. Clear instructions are provided but they are limited to the assembly; there's little information on using the scope and none on collimation, a vital part of setting up a Newtonian reflector. But we did manage to collimate the scope and once done, it held alignment quite well. A 32mm Super Wide Angle eyepiece, mirror-cooling fan, battery box and a red dot finder complete the system.

SKY SAYS... Great optics and smooth-running bearings make this a great entry-level observing scope

Setting up the scope to observe at night was so easy that we got the scope out several times just for a quick 10-minute observing session. The rocker box is reasonably light and has a handle to help lug it to an observing spot. You can carry the scope by the two altitude bearings, which then drop into the U-shaped cut-outs in the rocker box. Remove the tube's front cover, switch on the finder, drop in an eyepiece and you're ready to observe – all in about two minutes from start to finish!

Fine-detail focussing

Our first session with the scope was on a steady night a few weeks before solstice, a period when it never gets really dark. The scope had been stored ▸

Smooth altitude and azimuth bearings

The design of the altitude and azimuth bearings plays a big part in the ease of use of a Dobsonian. The friction of the bearings needs to be just right; they also eed to have a smooth feel with minimal 'stiction', otherwise it would make it hard to follow objects as drifting slowly across the night sky by making small incremental nudges. This is all quite difficult to achieve in a big scope and even harder in a small, lightweight scope where there is little downwards force. For azimuth movement the scope uses a large 'lazy Susan'-type bearing. Normally such bearings are too light but Omegon corrects this with a friction control knob at the centre which allows you to add compression to the bearing and increase the friction. The altitude bearings are similarly adjustable and are wonderful and attractive pieces of engineering. As well as being able to adjust the friction you can move them up or down the tube to improve the scope balance; a great feature. Omegon has done a great job with the bearings on this scope.

ALL PICTURES: WWW.THESECRETSTUDIO.NET

Finder

The scope comes with a red (or green – you have the option to swap) dot finder. The dot has adjustable brightness, although at night we always used it on the lowest red dot setting. The direction is adjustable, but we found the spring pressure poor over half its range, which made lining it up with the main scope a little difficult.

Primary mirror cell

The primary mirror is supported on three pads in a well-designed black aluminium mirror cell. There is a low-vibration fan blowing on the rear of the mirror. The fan is powered by eight AA batteries and it dramatically reduces mirror cool-down times. For collimation the cell is adjustable using a simple push-pull design with six plastic thumb knobs.

FIRST **LIGHT**

SKY SAYS...
Now add these:

1. Omegon 2-inch eyepiece and filter set

2. Omegon Pro 2-inch UHC filter

3. Omegon smartphone holder for finder shoes

▸ in an outside garage, so it needed very little cooling before use. The first object we targeted was Jupiter at 20° altitude using our own 7mm Nagler eyepiece. Wow! The planet snapped into focus and showed lots of belt and spot features with deep contrast, an indication of fine optics. Next, with the same eyepiece, M13, the Great Globular Cluster in Hercules, looked glorious with loads of stars, while the famous double binary Epsilon (ε) Lyrae was perfectly defined, the four components cleanly split and the stars' airy discs clean and round. With the supplied 32mm eyepiece giving a wider field of view we swept up to M57, the Ring Nebula, which again was captivating – nicely defined and sitting among a lovely sea of faint summer stars.

On other nights we achieved similar results, with the scope's high-contrast optics producing great views of deep-sky objects and making the Moon in particular quite mesmerising. We even had hints of the Veil Nebula on solstice night with an OIII filter screwed into our 16mm Nagler eyepiece.

On opposition night, at only 10° altitude, Saturn was a glorious sight in surprisingly steady skies, showing a dusky, darker equatorial belt and a clear Cassini division in the rings. Star testing later showed a very similar defocussed star image either side of focus indicating a smooth and nearly perfect parabolic shape to the primary.

Apart from the great optics we were impressed with the friction control on the altitude and azimuth axes which really helped make the scope easy to use. It's nice to find that a fairly simple and straightforward piece of equipment has been so well designed and solidly built. We would have no hesitation in recommending the Omegon ProDob N 203/1200 for beginners as well as those more experienced astronomers who want a good simple scope to reconnect with the skies. Ⓢ

Verdict

Assembly	★★★★★
Build and design	★★★★☆
Ease of use	★★★★☆
Features	★★★★☆
Optics	★★★★★
OVERALL	★★★★☆

Secondary mirror and holder

The secondary mirror is glued to a black aluminium holder, which is held by the spider's central boss and a single screw. Three cross-head push screws allow adjustment of the mirror orientation during collimation. The whole assembly is a well-made version of a traditional and well-proven design, although a no-tool version would have been a welcome improvement.

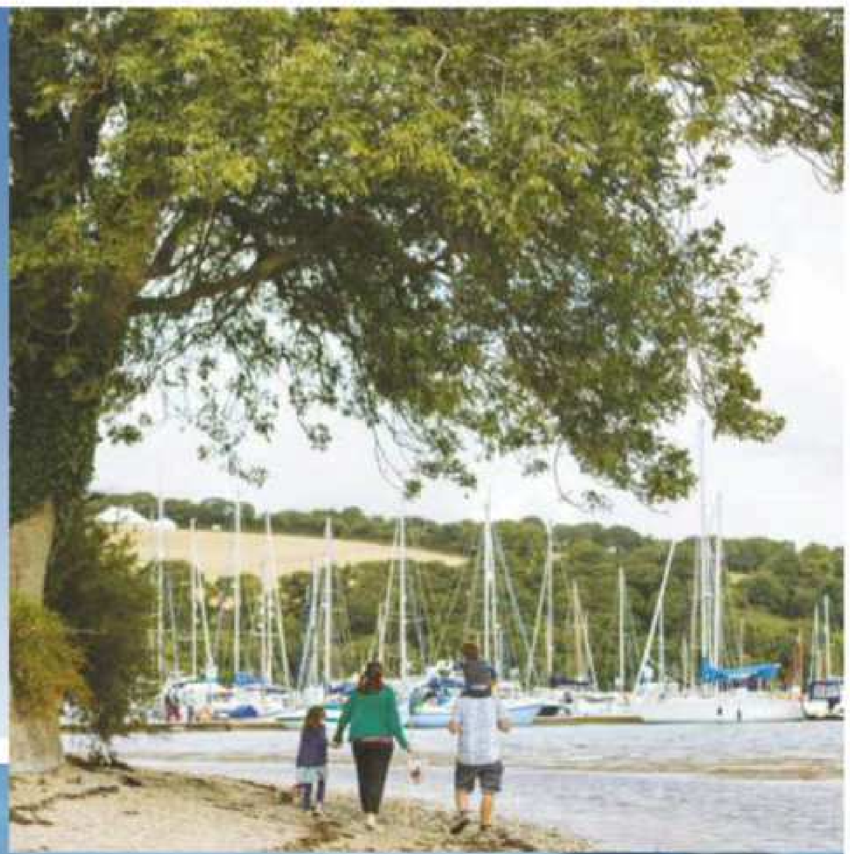
Focuser

The focuser is a handsome dual-speed Crayford design with a smooth action and a positive feel with no slip or play in it. The focuser has a lock on the barrel and will take 2-inch eyepieces, as well as 1.25-inch ones with the supplied adaptor, which is also T-threaded.

Primary mirror

Sitting in its cell at the bottom of the black steel optical tube is the 8-inch (203mm), f/6, parabolic primary mirror. This has enhanced reflectivity front coatings and a fine-ground rear face. Placed at the exact centre of the front face is a black marker ring for much easier collimation when you use the right tools (not included).


Explore, enjoy, escape




DRAKE

FIRST **LIGHT**

See an interactive 360° model of this mount at www.skyatnightmagazine.com/skyeqm35

Sky-Watcher EQM-35 Pro Go-To mount

WORDS: TIM JARDINE

A trustworthy tracker with a handy transforming trick up its sleeve

VITAL STATS

- **Price** £629
- **Load capacity** 10kg in EQ mode, 6.5kg in lightweight mode
- **Hand controller** SynScan flash upgradeable
- **Database** 42,900 objects with complete Messier, NGC and IC catalogues
- **Autoguider port** ST-4 with 0.25, 0.5, 0.75 & 1x guide rate
- **Periodic error correction** Yes
- **PC compatible** Yes
- **Tripod weight** 5.7kg
- **Mount head weight** 4.38kg (3.28kg with dec. axis removed)
- **Counterweights** 2x3.4kg
- **Total weight** 16.88kg
- **Supplier** Optical Vision Ltd
- **Tel** 01359 244200
- **www**.opticalvision.co.uk

SKY SAYS...
Two mounts in one, and both of them are incredibly reliable

With the addition of the EQM-35 Pro to its comprehensive range of mounts, Sky-Watcher is filling the niche between lightweight travelling mounts, and the more sturdy and accurate mounts suitable for astrophotography. At first glance you'd be forgiven for mistaking this new mount for the ever popular EQ3 version, but the similarity is only surface deep, as the EQM-35 Pro boasts significant upgrades over its little sibling and can be niftily transformed into a lighter weight photo mount (see the 'Lighten up' boxout).

When the mount was delivered in a single box containing the mount head, the tripod and two counterweights, we were slightly taken aback by its weight, expecting something a little lighter. In fact, the tripod in the box is made of steel, rather than aluminium, and is similar to ones used for larger capacity mounts. There are also two counterweights at 3.4kg each. It took us around 30 minutes to set the mount up the first time, but only a few minutes on subsequent occasions. Right from the outset, we were encouraged by the solid, stable platform provided by this sturdy little mount.

The sound of science

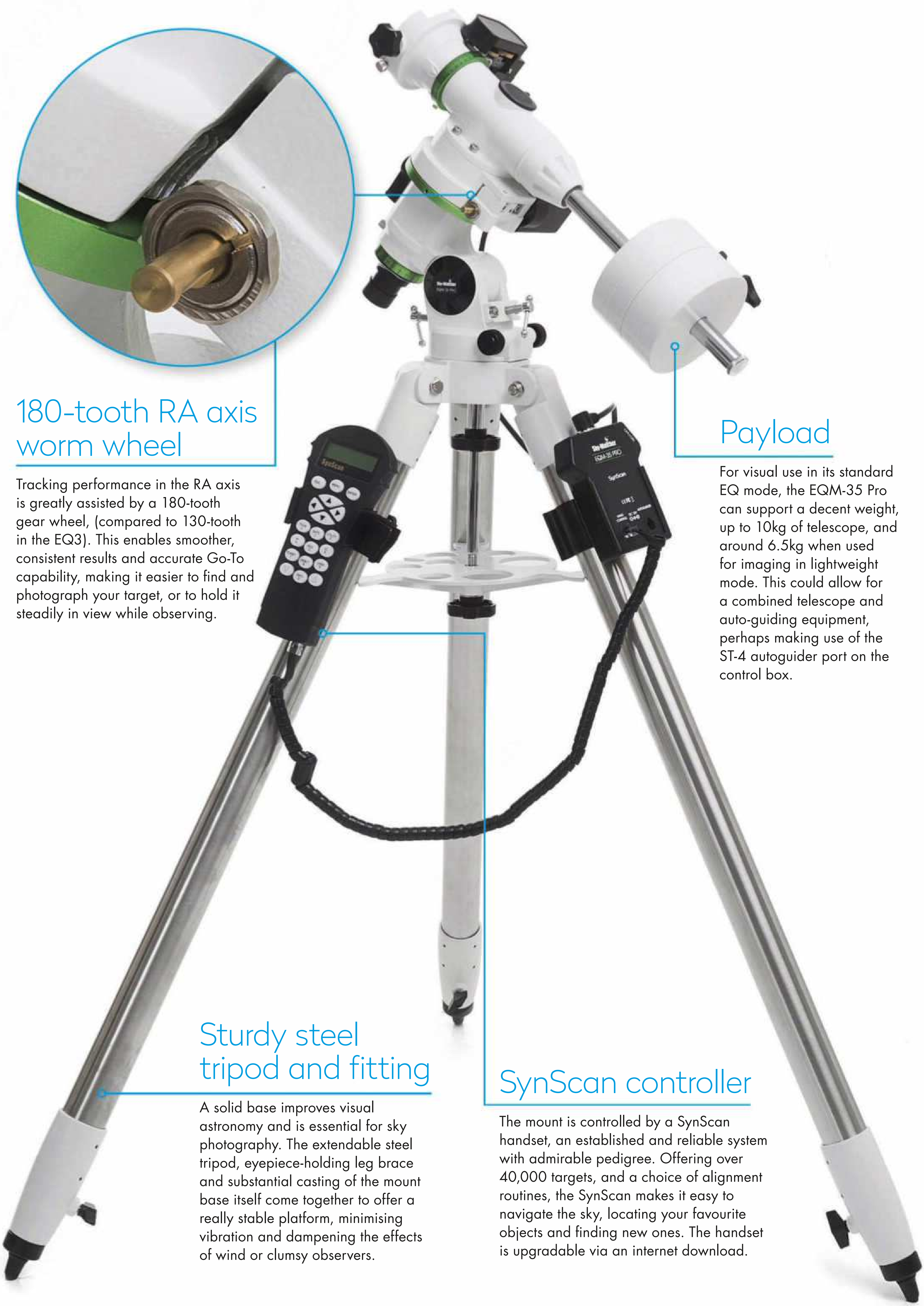
A cigar socket power lead is provided, requiring a 3A, 12V DC supply. This connects to a control box, which clips onto one of the tripod legs. The SynScan controller has a holder held in place by a Velcro strap, although we did find this a little awkward to use in the dark. In standard configuration, the mount makes a sound not unlike a dentist's drill, but it isn't loud enough to get your neighbours complaining.

After very quickly polar aligning the mount and fitting our 3-inch refractor to it, we did a two-star alignment using Dubhe and Arcturus, then selected a nicely positioned star with plenty of movement across the sky, Vega, to test for tracking accuracy. We used a 10mm Plössl crosshair eyepiece for this, giving a magnification of 50x. The mount dropped onto Vega nicely, and after a couple of nudges to centralise ▸

Lighten up

The 'M' in the mount's name stands for 'modular', because the EQM-35 Pro offers users the option to strip it down into a lighter weight version, similar to Sky-Watcher's Star Adventurer mount but with higher capacity and a sturdier platform. The transition to lightweight photographic mode is made by removing the dec. axis completely from the mount. This is quickly achieved by removing four bolts from the dec. head, which comes off with the counterweight bar, allowing a supplied Vixen dovetail puck to be fitted. This reduces the weight by over 1kg. At this stage it's possible to fit extra accessories, available separately. To fit our DSLR with a heavy 200mm lens attached, we were loaned the Sky-Watcher L-shaped bracket and counterweight. This configuration allows you to slew to your desired target using the RA axis of the mount, and then manually adjust the camera to centre the object. We used the Moon, and the mount tracked it steadily once again, hardly deviating position after 30 minutes. Alternatively, a simple ball head fitting can hold a camera too, with no counterweight necessary.

▲ Stripped-down versions of the mount, one with an L-bracket (left), the other with a ball head (right)



180-tooth RA axis worm wheel

Tracking performance in the RA axis is greatly assisted by a 180-tooth gear wheel, (compared to 130-tooth in the EQ3). This enables smoother, consistent results and accurate Go-To capability, making it easier to find and photograph your target, or to hold it steadily in view while observing.

Payload

For visual use in its standard EQ mode, the EQM-35 Pro can support a decent weight, up to 10kg of telescope, and around 6.5kg when used for imaging in lightweight mode. This could allow for a combined telescope and auto-guiding equipment, perhaps making use of the ST-4 autoguider port on the control box.

Sturdy steel tripod and fitting

A solid base improves visual astronomy and is essential for sky photography. The extendable steel tripod, eyepiece-holding leg brace and substantial casting of the mount base itself come together to offer a really stable platform, minimising vibration and dampening the effects of wind or clumsy observers.

SynScan controller

The mount is controlled by a SynScan handset, an established and reliable system with admirable pedigree. Offering over 40,000 targets, and a choice of alignment routines, the SynScan makes it easy to navigate the sky, locating your favourite objects and finding new ones. The handset is upgradable via an internet download.

FIRST LIGHT

SKY SAYS…
Now add these:

1. Counterweight (1kg) and shaft for Star Adventurer

2. Dovetail L-bracket for Star Adventurer

3. Fotomate H-28QR heavy-duty tripod ball head

▸ it, we sat back to watch the star drifting out of the crosshair. Our notes from the session read: "Two minutes – zero drift. Five minutes – zero drift. 10 minutes – zero drift. WOW!" Only after 25 minutes did Vega just start to move away from the crosshair. Impressive, especially given the minimal time spent setting up and aligning the mount.

Having established the mount's smooth, accurate tracking ability, we set about testing some more realistic scenarios. Swapping to our 4.5mm, 72° eyepiece gave us a useful 110x magnification, and we enjoyed slewing around the sky to such targets as the Ring Nebula, the Great Globular Cluster in Hercules, Albireo (Beta (b) Cygni) in Cygnus and many others, all of which were efficiently located. The mount was equally capable of finding and tracking planetary targets, and we enjoyed views of Jupiter and the Moon. The EQM-35 Pro steadfastly refused to yield to nudges and bumps, and Jupiter was still central in the view even after we invited some hamfisted, inexperienced passers-by to take a look.

We also tested the mount using our Pentax 75 SDHF refractor with an Atik 11000 full-frame CCD to take an image of the North America Nebula. Using bi-colour narrowband images we combined 12x5-minute unguided exposures in H-alpha, and 7x5-minute unguided in OIII, giving a total exposure time of 95 minutes taken with the EQM-35 in standard EQ mount mode. We also used the mount in its stripped-down mode with our Canon 6D, ISO 200, f/2.8, 70-200mm zoom lens set at 70mm. We captured a wider field view from Cygnus to Lyra using 15x5-minute unguided exposures with satisfying results indeed.

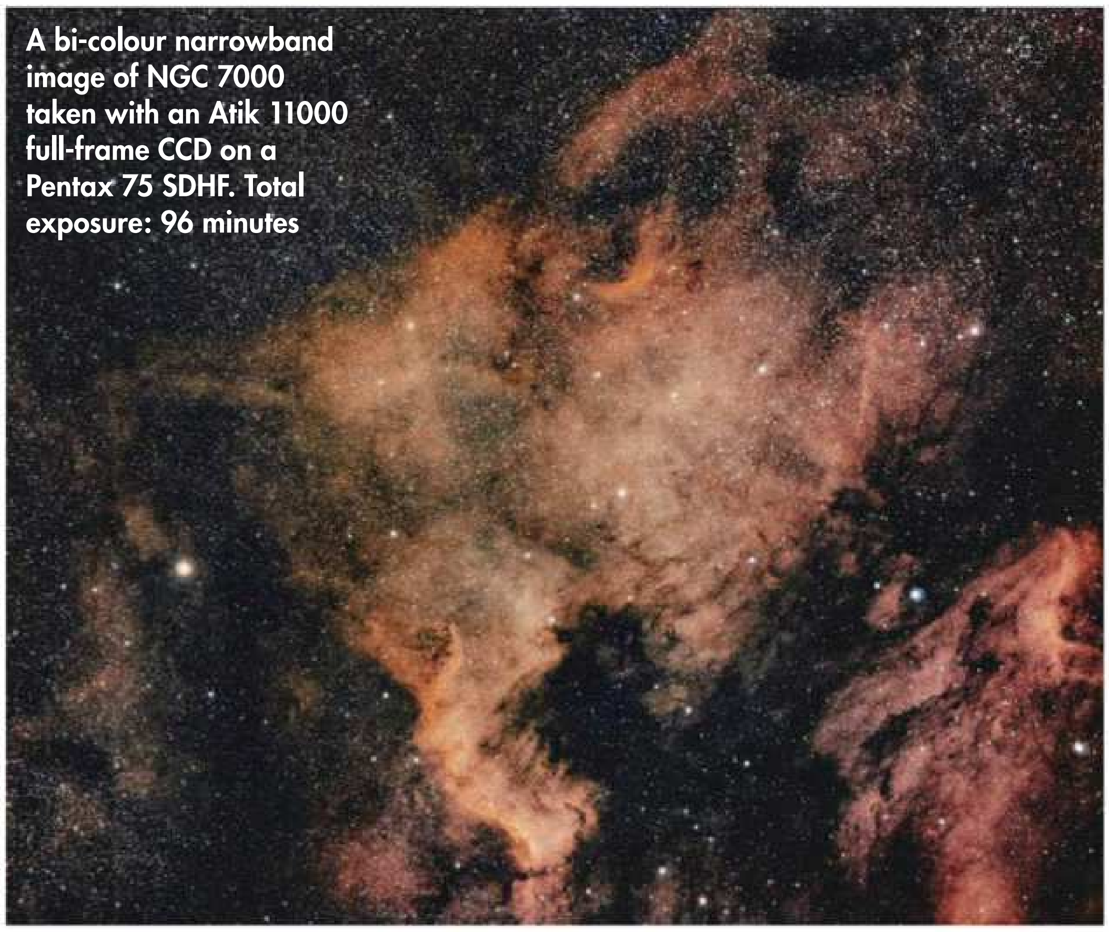
Overall the EQM-35 Pro offers beginners and old hands a stable, accurate mount that can be handily converted with ease into a more portable version. S

Verdict

Assembly	★★★★☆
Build and design	★★★★☆
Ease of use	★★★★☆
Go-To accuracy	★★★★☆
Stability	★★★★☆
OVERALL	★★★★☆

Polarscope

A key factor for EQ mount accuracy is polar alignment. Using the built-in polarscope, along with the altitude and azimuth bolts, we were able to quickly identify Polaris, adjust the mount until it rotated around the inscribed circle in the scope, and then enjoy views that stayed centred for long periods.



A bi-colour narrowband image of NGC 7000 taken with an Atik 11000 full-frame CCD on a Pentax 75 SDHF. Total exposure: 96 minutes

Cygnus to Lyra taken with a Canon 6D at ISO 200, f/2.8 70-200mm zoom lens set at 70mm; using 15x5-minute unguided exposures

WWW.THESECRETSTUDIO.NET, TIM JARDINE X 2

See an interactive 360° model of this camera at **www.skyatnightmagazine.com/zwoasipro**

ZWO ASI094MC Pro cooled full-frame camera

WORDS: GARY PALMER

ZWO has pushed Sony's in-vogue IMX094 sensor a little further... at a cost

VITAL STATS

- **Price** £3,680
- **Sensor** Sony IMX094 full-frame sensor (36x24mm)
- **Resolution** 36MP (7,376x4,928)
- **Pixel size** 4.88μm
- **Max FPS at full resolution** 5FPS
- **Exposure range** 32μs-2000s
- **Size** 86mm diameter
- **Weight** 640g
- **Supplier** 365 Astronomy
- **Tel** 0203 384 5187
- **www.**365astronomy.com

ZWO has been around for quite a long time now and has been pushing the boundaries of CMOS camera capabilities with every new model. On paper, its latest camera looks to push those boundaries to a whole new level. The ZWO ASI094MC Pro cooled full-frame camera has some impressive specifications and hefty rice tag to match.

This is the first full-frame camera for ZWO so we were eager to get imaging with it. Inside the box, the camera arrives in its own padded carry bag and comes with quite a few accessories. It shares the same cylindrical shape as other cooled cameras in the ZWO range. Taking the cap off the camera reveals a formidable-sized sensor measuring 36x24mm, giving a diagonal measurement of 43mm. On the back of the camera there's a dual USB3 and USB2 port along with two USB2 ports that act as a hub for accessories such as motor focusers and filter wheels. There's also a 12V socket for the cooler, though there's no power supply included with the camera. It would have been nice to see one in the box considering the price ZWO is charging.

> ***SKY SAYS...***
> For a CMOS it has impressive colours as well as fine detail, but it doesn't come cheap

After downloading the driver package the camera was ready to go. On the first clear night the Moon was quite bright, so we gave the camera a run in video mode. Setting the camera up on a 5-inch refractor with an 800mm extension tube it was easy to resolve a good image of the Moon on screen. The maximum speed of the camera in full- frame is 5FPS and, setting a capture of 200 frames, it didn't take too long for the SER video file to download. You can can increase the speed of the camera considerably by changing the region of interest (ROI) settings.

Sensor sensibility

One of the big differences with this camera is that it uses a Sony imaging sensor and not one originally made for high-speed barcode reading. This gives very good colours in capture and live displays on a screen, without the green cast seen with a lot of one-shot colour cameras on the market.

With a change of telescope on another night we pointed the camera at Mars, setting it to 95FPS ▸

Tuning up Sony's IMX094 Exmor sensor

Sony's IMX094 Exmor sensor is already very good and ZWO has tuned it to get the best performance. In full frame mode the resolution is 36MP (7,376x4,928) with a pixel size of 4.88μm. A read noise of 2.1e @24db gain makes the camera very sensitive, so that fine detail resolves well in images of targets like M51, the Whirlpool Galaxy; being able to capture the rear dust lanes in short exposures was a real treat. The rich and vibrant colours captured in the images make it a joy to use. The front glass is IR coated and seems to have an antistatic treatment as it stayed clean all through testing. The Bayer matrix is set at RGGB, though some capture software can flip this reading, so it may have to be set to BGRG in processing to attain the correct colours. In ROI mode for deep-sky imaging it's one of the first CMOS sensors to show no banding in the background of the images. This, along with its ability to switch to planetary imaging, makes this camera a really good tool for any astro imager.

ALL PICTURES: WWW.THESECRETSTUDIO.NET

Tilt adaptor

On the front casing is a built-in tilt adaptor for aligning the sensor to the optical train. A set of push and pull screws makes adjustments easy. The tilt adaptor can be used to counter any sag in a focuser that may cause distortion in the image.

Heated front glass

Behind the protective glass of the sensor is a built-in heater. Because of the size of the glass, the heater is needed to stop dew forming on the glass inside or out when the TEC cooler is running. It can be adjusted in the capture software.

Cooling

A two-stage thermoelectric cooler is built in to the camera, allowing the temperature to be regulated to between –30° and –35° below ambient using the capture software. In the body of the camera is a built-in heat sink and on the rear is a MagLev fan.

USB sockets

A range of USB sockets on the back of the camera allow connection to a multitude of equipment. The combined USB2 and USB3 socket can be connected to an external hub to allow for use of longer cables than the one supplied. Having a dual USB2 hub also cuts down on the amount of cables running to and from the camera.

FIRST **LIGHT**

▲ A dusty Mars; 300 frames from 3,000

▲ M51 with an f/2.2 RASA; 100x30" shots

▲ M13 (left) and M27, both captured with an f/2.2 RASA; 50x30" exposures

▲ The North America Nebula taken through a 70mm quad refractor; a single 10-minute image

▲ The Moon imaged using the ZWO ASI094MC Pro and a 125 EDF refractor; 20 frames stacked from 20 captured

SKY SAYS…
Now add these:
1. ZWO 12V 5A AC-to-DC adaptor
2. ZWO 86mm holder ring/ bracket for ZWO ASI Pro cameras
3. ZWO miniscope 30mm f/4 mini guidescope

▸ and a 640x480 ROI. With Mars being low and in the midst of its dust storm it was hard to resolve detail, but the results did show that the camera can be a bit of an all-rounder at imaging.

A few nights later we switched over to an f/2.2 Rowe-Ackermann Schmidt Astrograph (RASA) telescope. In full frame mode the camera will run outside the imaging circle on this type of setup and create vignetting, so it gave us a good chance to try the ROI modes. The first target was the Whirlpool Galaxy, M51, running 30-second exposures with the cooling set to –30° below ambient temperature. The camera performed very well, not dropping any frames when capturing in high bit mode. We moved through a few targets including M13, the Great Globular Cluster in Hercules, and M27, the Dumbbell Nebula.

In full-frame mode the camera is best suited to an aperture of around 70-100mm, so we set the camera up on a 70mm quad refractor for the next outing, going for wide-field targets like the North America Nebula. Setting longer exposure times of 180 seconds worked very well. There was no amp glow in the images in USB2 mode, even when connected via 10m USB2 extension leads, and this made processing with calibration frames very easy. Setting up with a 152mm triplet we took a chance on M31, the Andromeda Galaxy, which was rising in the north against a bit of a light blue summer night sky. Running in full-frame at 60 second exposures for 50 minutes resolved lots of nice detail in the dust lanes and the core. When we processed the images, it was nice to see some rich colours from a CMOS camera.

The ZWO may have an expensive price tag, but it really is a great performer. **S**

Verdict

Build and design	★★★★★
Connectivity	★★★★★
Ease of use	★★★★★
Features	★★★★½
Imaging quality	★★★★★
OVERALL	★★★★★

Spacers

M48 adaptors are included with the camera in two sizes. The 21mm and 16.5mm adaptors, combined with the back focus of the sensor round up to 55mm. This is suitable for imaging systems like the RASA and imaging setups using reducers. It makes it really easy to use with no guessing.

WWW.THESECRETSTUDIO.NET, GARY PALMER X 6

Books

New astronomy and space titles reviewed

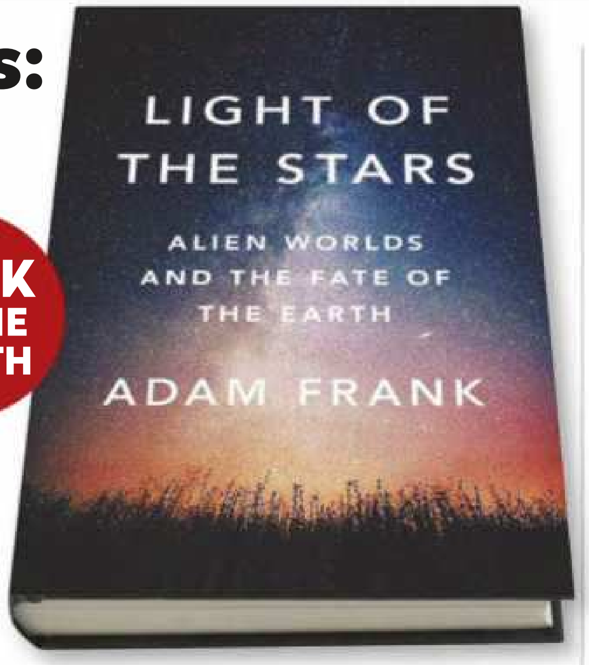
RATINGS

★★★★★ Outstanding
★★★★☆ Good
★★★☆☆ Average
★★☆☆☆ Poor
★☆☆☆☆ Avoid

Light of the Stars:
Alien Worlds and the Fate of the Earth

Adam Frank
WW Norton
£20 ● HB

BOOK OF THE MONTH

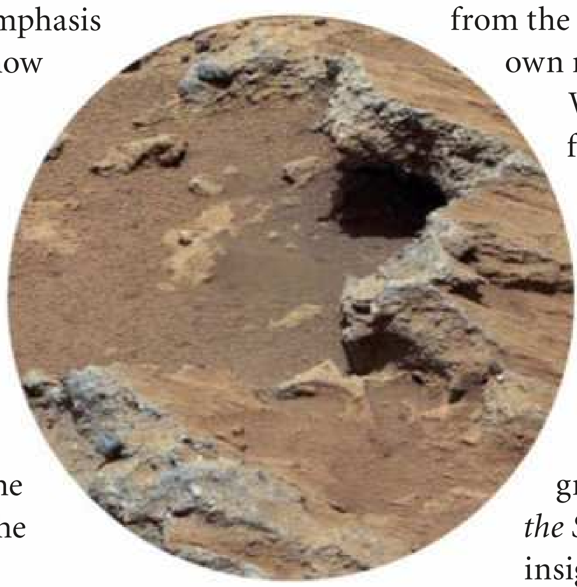


On 1 November 1961, at the Green Bank conference flanked by the great Enrico Fermi and Carl Sagan, Frank Drake presented an equation that would shape an entire field. With seven variables including the fraction of planets on which life actually appears, Drake's equation broke down the age-old question, "Are we alone in the Universe?" into smaller, researchable pieces. *Light of the Stars*, however, is so much more than a discussion of one equation.

Adam Frank approaches the topic of exo-civilisations from a very different point of view, with an emphasis on climate change and how we are creating a lasting impact on the planet we call home, author Say farewell to the idea of aliens with oversized heads and hello to Darwinian evolution and astrobiology.

The book relives the crucial moments from the last century that paved the way for astrobiology becoming more science than fiction. This includes the Byurakan meeting of Soviet and US scientists which, during the Cold War, transcended international politics as the two sides united over a discussion of our place in the Universe. It is here we meet the Kardashev scale for measuring the progress of a civilisation based on the energy it has at its disposal.

From observations of the greenhouse effect on Venus to the dry riverbeds on Mars, we can apply insights gained from our own Solar System to make predictions about the likelihood of life elsewhere. Understandably, probabilities and estimates are not enough for everyone, but Frank takes the time to carefully dissect the pessimistic opinions of prominent researchers from the past in light of his own research.



A dry Martian riverbed discovered by the Curiosity rover

NASA/JPL-CALTECH/MSSS

With an easy-to-follow writing style, Frank has thoughtfully tackled the concept of life beyond Earth, without resorting to fantasies of 'little green men'. *Light of the Stars* is a concise and insightful read, which, aside from being very difficult to put down, will leave you wanting to learn more about the potential for life amongst the stars. So sit down and get comfortable, as you may be glued to this book for some time.

★★★★★

AMBER HORNSBY is a postgraduate researcher at Cardiff University and a writer for @astrobites

TWO MINUTES WITH
Adam Frank

For how long have humans pondered the existence of life beyond Earth?
For thousands of years. The ancient Greeks were arguing about it. In the medieval period the Church made it heresy to discuss 'other worlds'. After Newton, people became pretty optimistic that the heavens were full of life. By the beginning of the 20th century, however, scientists had reason to think that planets were rare and therefore life was too. Now we know almost every star in the sky has planets.

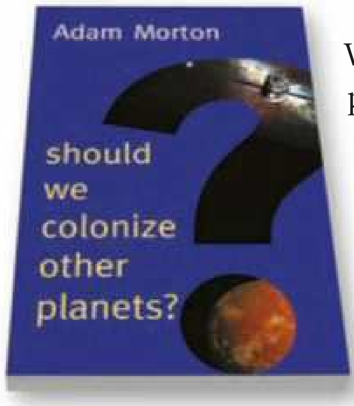
It seems we are only just starting to take the idea of alien life seriously.
Recently discovering there are 10 billion trillion planets in the right place for life to form pushed us to take alien life seriously. Exploring our own Solar System for 50 years has also given us profound insights into the possibilities for life. We've just become a spacefaring race *and* we've triggered climate change. This makes us see ourselves as a true planetary species. That makes us ask, "Have there been others?" with a new urgency.

What might the prospect of life on other worlds tell us about our own planet?
As I've shown in my research and in the book, any technological civilisation that emerges on any planet will likely trigger some form of climate change. We're like cosmic teenagers and not the first to go through this. The question is, then, are we smart enough to be counted among the cosmic civilisations that make the right choices and see it through?

ADAM FRANK *is a professor of astrophysics at the University of Rochester, New York*

Should We Colonize Other Planets?

Adam Morton
Polity
£9.99 ● PB



What exactly is the point of human space exploration? This timely and well-written polemic examines the arguments for and against human colonisation of other planets, in particular Mars, in the light of various ambitions to establish future colonies there.

Scientifically, it's going to be a challenge. Adam Morton reminds us just how difficult it will be to protect humans against all the hazards of a months-long journey, and also of the huge quantity of resources required to support any successful colony. The surface and atmosphere of Mars will also have to be terraformed to support humans and Morton estimates that this will cost trillions of dollars, arguing that this money might be better spent on reversing existing environmental damage to Earth.

SpaceX and Mars One are promoting their Mars-bound missions as a way of ensuring the future of the human race. Morton takes issue with this line of thinking, arguing that perhaps we're too wedded to the concept of humans as a biological species and that we might do better to consider the idea of colonisation via robots uploaded with our memories. As well as offering some practical advantages, he points out that humans are continuing to evolve and perhaps robots with human thought processes are simply a future stage in our evolution.

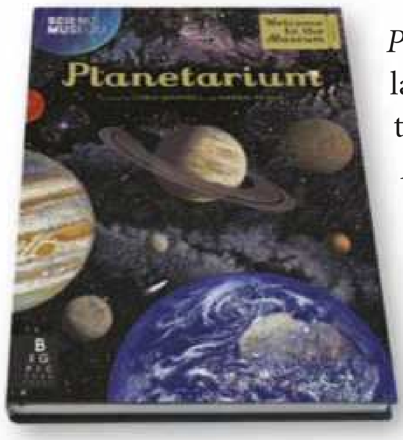
This book's brevity makes it a surprisingly easy read, but some readers may prefer more detailed arguments. What's not in doubt is that it's essential we discuss these important and difficult questions before we go any further down the road to Mars.

★★★★☆

PIPPA GOLDSCHMIDT *is an astronomy and science writer*

Planetarium

Raman Prinja, Chris Wormell
Templar Publishing
£20 ● HB



Planetarium is the latest instalment in the *Welcome to the Museum* series of books produced by London's Science Museum. Previous volumes included such titles as *Botanicum*, *Animalium* and *Dinosaurium* (you can probably guess their respective subject matters), and this astronomy-themed tome is an excellent addition to the collection.

The first thing that catches your eye are the beautiful illustrations. They are quite simply stunning and will instantly entice readers of any age into the book. It's rather like being drawn into a magical world with colour, mystery and excitement.

The reader's taken on a whistle stop tour of the Universe and provided with concise descriptions of the planets within the Solar System, as well as comets and meteors, from the Big Bang right through to the fate of our Universe. There are also sections on exoplanets and black holes, while Professor Raman Prinja briefly discusses the constellations visible from both hemispheres, which would each be worthy of separate books. Each subject is split into a gallery, like a museum for the mind's eye, and every illustration is given its own accompanying text, which allows the reader to gain a sense of the scale of the topic being described and provides an excellent reference point.

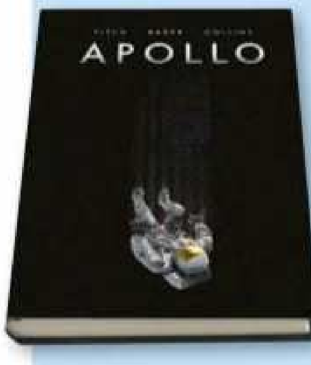
Such a broad spectrum of topics is covered that the book cannot delve into detailed science, but there are plenty of snappy and interesting facts on each page that all readers will be able to enjoy and learn from, no matter their level of understanding of the subject. This book is a worthwhile addition to any astronomer's library, ideal for leafing through on a cloudy evening to let the mind wander into the mysteries of our Universe.

★★★★☆

KATRIN RAYNOR EVANS is an amateur astronomer, a Fellow of the Royal Astronomical Society and the librarian for Cardiff Astronomical Society

Apollo

Matt Fitch, Chris Baker, Mike Collins
SelfMadeHero
£15.99 ● HB



It is rare to be swept away on a flying carpet of excitement, but that is exactly the breathless, non-stop pace created in this graphic novel. Impeccably accurate dialogue and exquisite imagery crafted by comic strip artist Mike Collins combine to regale us with the story of Apollo 11, the first piloted landing on the Moon in July 1969. Against a backdrop of political jealousy and racial and military tensions, the authors weave an account that is thought-provoking and unashamedly patriotic.

Its beautifully drawn portraiture is so true to life that for diehard Apollo fans even lesser-known characters scarcely require identification. Neil Armstrong imagines his long-dead daughter in his mind's eye on the Sea of Tranquility, while the dissatisfaction of Buzz Aldrin's overbearing father betrays his thinly-veiled disgust at his son being second on the Moon.

A thread of tragedy weaves through the story. Its imagery darkens with the Apollo 1 fire, which snatched three astronauts' lives, and a scratchy rendition of their grieving comrades reveals their angst at a race to the Moon that was being run too fast. Tormented president Richard Nixon is haunted by the memory of JFK and beset by America's war-dead in Vietnam. If Apollo 11 succeeds, he knows history will laud JFK. But if it fails, history will curse Nixon.

Apollo 11 seized and held the world's stage and even today its magnetic pull on the human spirit remains undiminished. This wonderful graphic novel is a testament to the mission's enduring legacy.

★★★★☆

BEN EVANS *is an astronomy writer and author of several books on human spaceflight*

Gear

Elizabeth Pearson rounds up the latest astronomical accessories

1 ZWO atmospheric dispersion corrector

Price £107 • **Supplier** 365 Astronomy 020 3384 5187 • www.365astronomy.com

Eliminate the effects of atmospheric dispersion with ZWO's corrector. It comes with a bubble level to help you get the best views possible.

2 Shuttle 3D puzzle

Price £12.99 • **Supplier** The Gift Experience 01691 624170 • www.thegiftexperience.co.uk

Build your own space shuttle. The pieces of this 3D puzzle slot together without glue, so that you can either keep the finished model or dismantle it to build all over again.

3 Baader ClickLock clamp

Price From £55 • **Supplier** Harrison Telescopes www.harrisontelescopes.co.uk

This connector locks eyepieces and accessories securely in place with a simple twist, doing away with fiddly thumb screws and bulky holders. Models are scope specific.

4 TeleVue 3-6mm Nagler Zoom 1.25-inch eyepiece

Price £389 • **Supplier** Telescope House 01342 837098 • www.telescopehouse.com

This zoom lens allows you to adapt to differing atmospheric conditions to ensure crisp views while observing the planets. Its 10mm eye-relief gives a comfortable viewing experience.

5 Star Walk 2

Price In-app purchases • **Supplier** Vito Technology • www.vitotechnology.com

This beautiful app lets you explore the night sky on your phone. Click on stars and deep-sky objects to learn more about them. Available on iTunes and Android.

6 Glow-in-the-dark astronomy hoodie

Price $45 • **Supplier** Cognitive Surplus cognitive-surplus.com

Keep warm and stylish as the days turn colder with the help of this hoodie adorned with vintage astronomy images. When night falls, the images glow in the dark.

WHAT I REALLY WANT TO KNOW IS...

Why is the Sun's corona so hot?

Professor Gregory Fleishman is trying to find out why temperatures are sent soaring in the solar atmosphere

INTERVIEWED BY PAUL SUTHERLAND

The Sun is the one star astronomers can study close up. Features such as sunspots and prominences are obvious. But one characteristic has remained a mystery since it was discovered by X-ray satellites in the 1970s: that the Sun's outer atmosphere, or corona, is more than a hundred times hotter than the visible surface, or photosphere. That's counter-intuitive, surely?

The photosphere reaches temperatures of around 5,000°C, but this soars to a million degrees or more in the corona. The mystery is one of the greatest challenges for solar modelling, and I have been leading a team trying to understand the physical mechanisms behind it.

From Earth, we can only see the delicate glow of the Sun's corona during a total solar eclipse because it is so faint. So solar astronomers turn to dedicated Sun-watching satellites in space, which are able to observe the Sun in a range of wavelengths. Our own work has largely used NASA's Solar Dynamics Observatory (SDO) which has been investigating activity on the Sun since 2010.

In particular, we need to view the Sun in extreme ultraviolet (EUV) light to see how the temperature is distributed within the corona. In addition, we have to make measurements of the photosphere's magnetic field to compute electric currents.

Invisible forces

The corona is not only hot, it also looks structured when observed in EUV. On any high-resolution photo of the corona you will see a lot of loops and bright, arc-like structures. Such loops trace the magnetic field structure in the Sun. What is puzzling is that next to a bright loop you can find similar magnetic field lines that are less visible because they are not filled with glowing plasma.

With the aid computer modelling and our SDO observations, we created a 3D replica of an active region on the Sun. This revealed regions in the corona known as magnetic flux tubes – concentrations of magnetic fields – which carry an electrical current. We were surprised to find that the flux tubes carrying the strongest electrical currents were bright in our model but very faint or invisible in actual observations of the Sun.

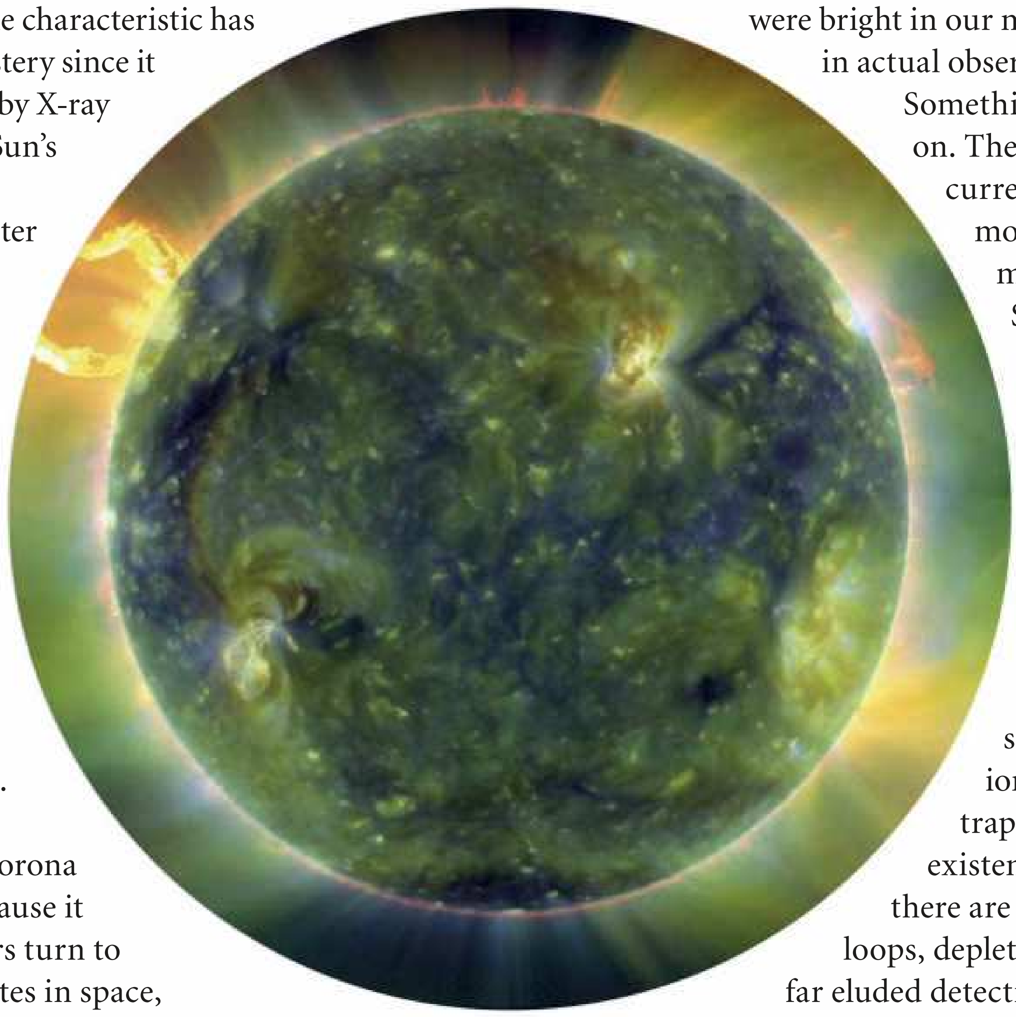
Something unexpected was going on. The presence of strong electric currents tells us that there is more energy, and presumably more heat, in those flux tubes. So it was puzzling that the emissions were not brighter.

We already knew that flux tubes contain elevated levels of heavy metal ions in considerably greater proportions than found in the photosphere. What we discovered was that in the loops carrying a reasonably strong electric current, the iron ions reside in what we call 'ion traps' at the base of the loops. The existence of these traps implies that there are other highly energetic coronal loops, depleted of iron ions, which have so far eluded detection in the EUV range. Only metal ions, with their fluctuating electrons, produce emissions which make them visible, which could be why the loops were dimmer than expected.

Though there are various theories, no one can yet fully explain how energy is carried along magnetic field lines into the corona to produce such incredible levels of heat. One thing that's clear is that before we can find out more about how this energy is generated, we must do more to map and quantify the corona's thermal structure.

Our observations suggest that the corona may contain even more thermal energy than is directly observed in the EUV range. However, this energy *is* visible in other wavelengths. We plan to do more to investigate with the aid of instruments aboard two other solar observatories, Japan's Hinode satellite and NASA's Interface Region Imaging Spectrograph (IRIS), as well as millimeter and sub-millimeter data from the ALMA telescope in Chile.

These will provide us with a more detailed picture of what is going on in the Sun's corona, and help give us a greater physical understanding of the processes involved.



▲ **An EUV (extreme ultraviolet) image of the Sun captured using the Atmospheric Imaging Assembly (AIA) on NASA's Solar Dynamics Observatory (SDO)**

SOLAR DYNAMICS OBSERVATORY/NASA

ABOUT PROFESSOR GREGORY FLEISHMAN

Gregory Fleishman is Distinguished Research Professor at the Center for Solar-Terrestrial Research, part of the physics department at the New Jersey Institute of Technology

THE SOUTHERN HEMISPHERE IN SEPTEMBER

With Glenn Dawes

WHEN TO USE THIS CHART

1 SEP AT 00:00 UT
15 SEP AT 23:00 UT
30 SEP AT 22:00 UT

The chart accurately matches the sky on the dates and times shown. The sky is different at other times as the stars crossing it set four minutes earlier each night. We've drawn the chart for latitude –35° south.

SEPTEMBER HIGHLIGHTS

Venus and Jupiter are prominent in the early western evening sky. Venus is considerably brighter and located below the gas giant, which is a similar brightness to Mars, in the north. Venus, opening the month only 1° from Spica, rises and slowly approaches Jupiter. The nearby crescent moon is most attractive from the 12th-14th. By month's end the planets reach their closest separation – around 14° – and travel together until Venus drops towards the Sun and into conjunction in late October.

STARS AND CONSTELLATIONS

September boasts many constellations with water connections: Capricornus (the Sea Goat), Aquarius (the Water Bearer) and Delphinus (the Dolphin). However, the view from the south also has a strong avian theme, something Northern Hemisphere observers may not appreciate. They might share Aquila (the Eagle) and Cygnus (the Swan) with us but the far south adds four more exclusive birds: Grus (the Crane), Phoenix (the mythical bird), Tucana (the Tucana) and Pavo (the Peacock).

THE PLANETS

Venus in Virgo and Jupiter in Libra are obvious in the west shortly after sunset (see above), setting at 21:30 and 22:30 respectively (mid month). Prior to Venus departing there are three other planets available. Saturn, in Sagittarius, is transiting (due north) during twilight, with Mars in Capricornus two hours later. Neptune, in Aquarius, follows around midnight. Uranus in Aries shouldn't be forgotten either – it rises around 21:00 (mid month). Planet spotters will be busy.

DEEP-SKY OBJECTS

In the far southern constellation of Indus, start at mag. +4.4 star Delta (δ) Indi, then move 3° southwest to find a brilliant binocular triple star, JC 25 (RA 21h 44.0m, Dec -57° 20'), arranged in a dog-leg shape. Starting from its central mag +6.5 star, one mag. +6.9 companion is located 2.5 arcminutes north, with the other mag. +7.3 star 3.1 arcminutes southwest. All three are distinctly yellow.

Returning to Delta Indi, move 3.8° north to uncover the mag. +9.9 irregular galaxy, IC 5152 (pictured – RA 22h 02.7m, Dec -51° 18'). Its claim to fame is being a member of the local group of galaxies. Visually this oval-shaped (1.5 arcminutes x 3.0 arcminutes) haze appears evenly lit but observing it is a bit of a challenge, as the galaxy has to compete with the glow of a bright (mag. +7.8) star on its northwestern edge.

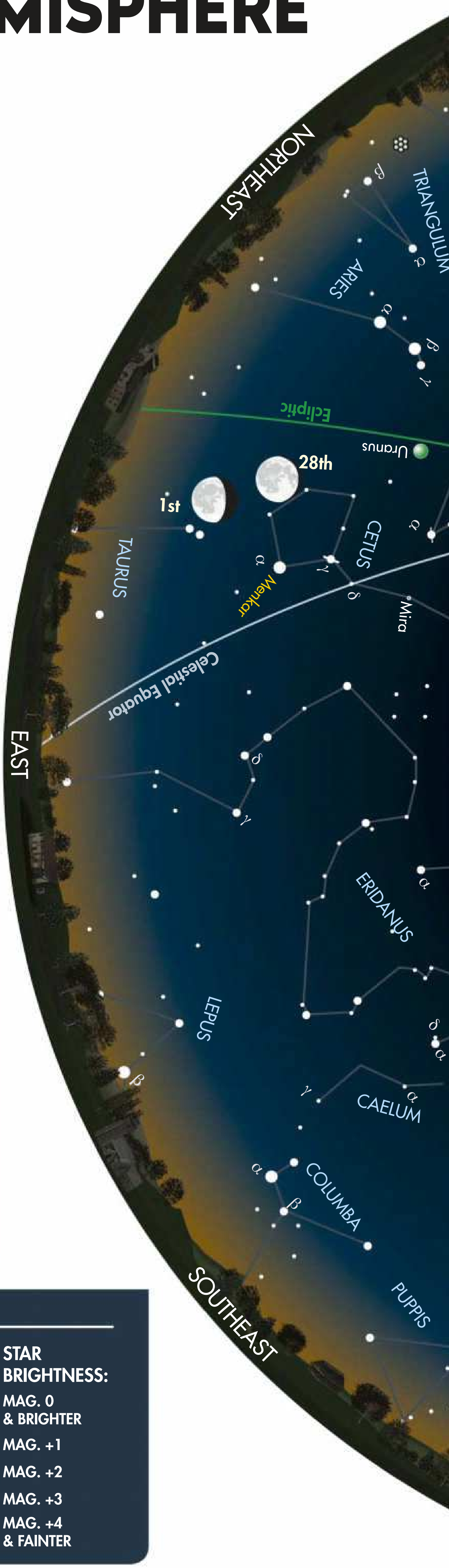
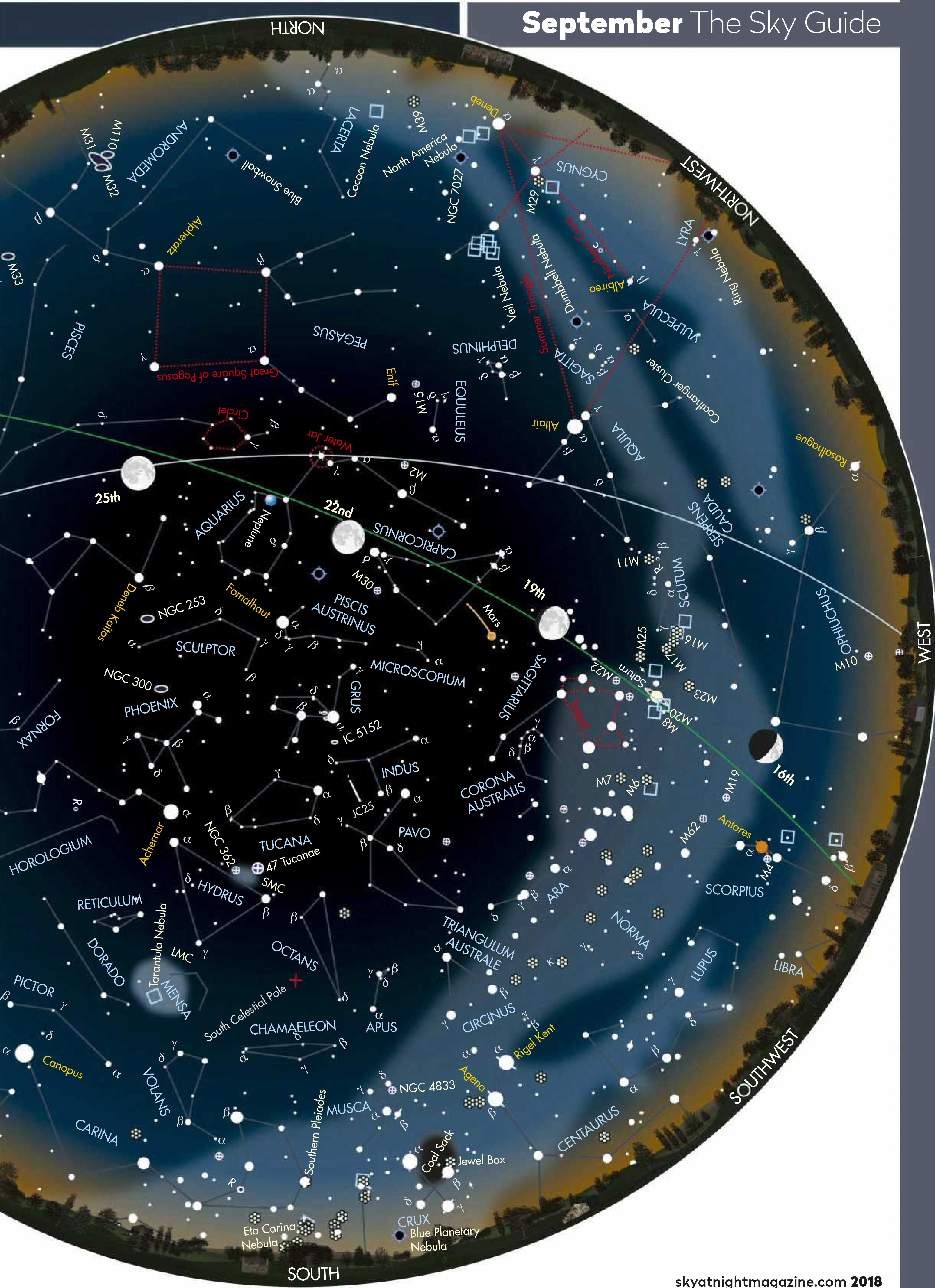


CHART KEY

GALAXY
OPEN CLUSTER
GLOBULAR CLUSTER
PLANETARY NEBULA
DIFFUSE NEBULOSITY
DOUBLE STAR
VARIABLE STAR
COMET TRACK
ASTEROID TRACK
METEOR RADIANT
QUASAR
PLANET

STAR BRIGHTNESS:
MAG. 0 & BRIGHTER
MAG. +1
MAG. +2
MAG. +3
MAG. +4 & FAINTER

CHART: PETE LAWRENCE, IMAGE: STSCI


NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
ANDROMEDA
LACERTA
CYGNUS
Deneb
Cocoon Nebula
North America Nebula
Blue Snowball
M39
M31
M110
M32
M33
NGC 7027
M29
Alpheratz
Northern Cross
Albireo
LYRA
Ring Nebula
Veil Nebula
Summer Triangle
Dumbbell Nebula
VULPECULA
PISCES
PEGASUS
DELPHINUS
SAGITTA
Great Square of Pegasus
Enif
M15
EQUULEUS
Coathanger Cluster
Circlet
Water Jar
Altair
AQUILA
Rasalhague
M2
25th
22nd
19th
16th
AQUARIUS
Neptune
CAPRICORNUS
SERPENS CAUDA
M11
SCUTUM
OPHIUCHUS
Deneb Kaitos
NGC 253
Fomalhaut
M30
PISCIS AUSTRINUS
Mars
M25
M16
M17
M10
SCULPTOR
MICROSCOPIUM
Saturn
M22
M23
M20
M8
NGC 300
PHOENIX
GRUS
IC 5152
SAGITTARIUS
Teapot
FORNAX
INDUS
CORONA AUSTRALIS
M7
M6
M19
HOROLOGIUM
Achernar
NGC 362
TUCANA
47 Tucanae
JC25
PAVO
M62
Antares
M4
SMC
HYDRUS
RETICULUM
ARA
SCORPIUS
NORMA
DORADO
Tarantula Nebula
LMC
OCTANS
TRIANGULUM AUSTRALE
LUPUS
LIBRA
PICTOR
MENSA
South Celestial Pole
CHAMAELEON
APUS
CIRCINUS
Rigel Kent
Canopus
VOLANS
MUSCA
NGC 4833
Agena
CENTAURUS
CARINA
Southern Pleiades
Coal Sack
Jewel Box
CRUX
Eta Carina Nebula
Blue Planetary Nebula

BBC Sky at Night MAGAZINE

FREE MINI MAG

Your guide to the new OBSERVING SEASON

Get ready for the return of dark skies with this look ahead to the best sights from autumn 2018 to spring 2019, and more

ISTOCK

INSIDE

OBSERVING GUIDE

September to March

As the nights get longer, we reveal what to see this autumn and winter

With darker nights ahead and the winter constellations emerging into the pre-dawn skies, astronomers across the country are stirring from their summer hibernation. We're entering that wonderful time of year when surveying the skies can resume in earnest.

This guide to the night skies over the next few months will fully prepare you for what's in store. So dust off your dew shields, bag some binoculars and collimate your telescopes... the new season of stargazing is upon us!

Constellations

▲ **Orion, with its belt and sword, is one of the most instantly recognisable constellations in the winter sky**

September's night sky is still dominated by the summer constellations, which make their way westwards as the month goes on. To get your bearings, look for the huge asterism known as the Summer Triangle. It's made up of the stars Vega (in the constellation Lyra), Deneb (in Cygnus) and Altair (in Aquila). September is also the time to get a last glimpse of the Milky Way region around Scutum before it starts to disappear into the sunset.

As we move into the first half of October, the constellation of Pegasus is sitting high in the south at around 11pm. Use the asterism of the Great Square of Pegasus to jump to surrounding constellations including Andromeda, Triangulum and the fainter Pisces and Equuleus.

"The constellations put on a magnificent show in December and you won't fail to find something to marvel at on a clear night"

By the time November comes around, there are several interesting constellations high overhead that are rich in celestial sights (read more about those in 'Galaxies', 'Double stars and clusters' and 'Nebulae'). Cassiopeia and Perseus are prime examples, as is Auriga, with its telltale bright star Capella. Meanwhile, in the east, the winter constellations are starting to appear over the horizon.

The constellations put on a magnificent show in December and you won't fail to find something to marvel at on a clear night. Towards the south, for example, you'll find the unmistakable shape of Orion accompanied by the constellations Taurus and Gemini. As December gives way to January, the constellation of Canis Major follows Orion into the west and we're left with the less grand, but still object-rich, constellations of Cancer and Leo. These are high in the south at around 2am in the middle of the month.

Towards the middle of February, the constellations of Coma Berenices, Canes Venatici and Virgo join Leo in the south and southeast, providing an absolute feast of galaxies if you want to hunt down these so-called 'faint fuzzies'. If you're staying up really late you'll even see the Summer Triangle popping back into view in the east at about four in the morning.

In March, look out for the constellations of Boötes, Corona Borealis and Hercules in the east. The last is home to several interesting deep-sky targets. By around midnight, Orion has nearly set in the west, while in the northeast, the bright star Deneb shows that Cygnus is coming back into view.

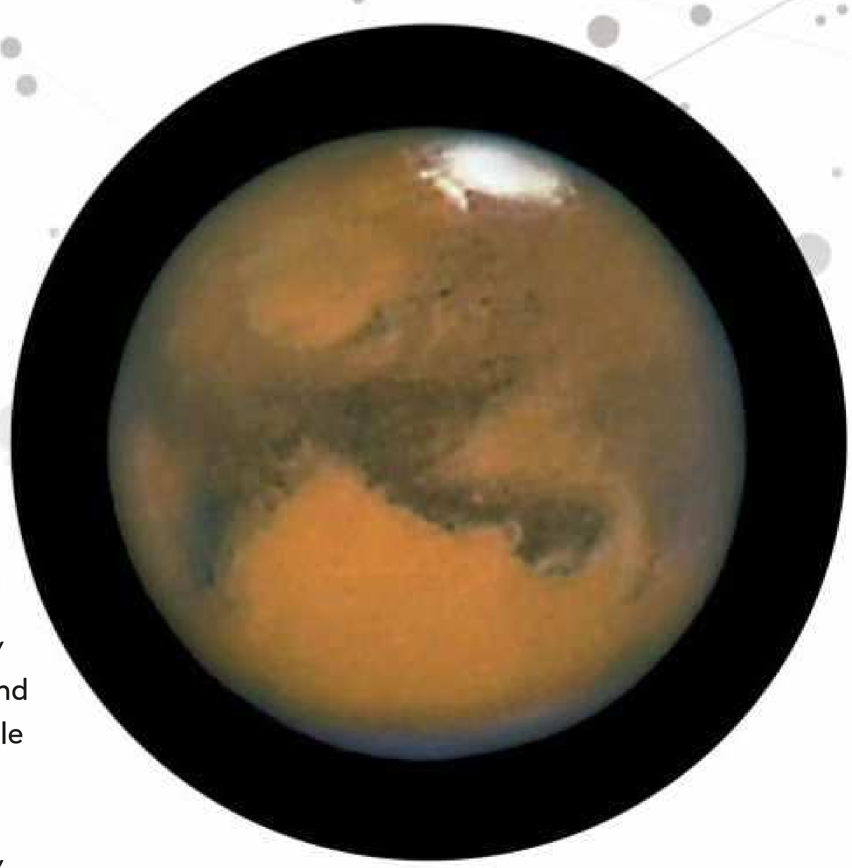
The planets

In September, most of the bright planets lie low to the horizon. Jupiter, Saturn and Mars spend the month scraping along barely rising above 16° in altitude. They are, however, dazzling enough to shine through the evening twilight. Venus is best seen during the day, its luminosity a saving grace. Uranus and Neptune fare better, the latter reaching opposition on 7 September. Mercury also puts in a creditable effort, starting September bright and well positioned, rising more than an hour before sunrise, but moves closer to the Sun as the month goes on.

Through October, November and eventually December the bright planets continue to confound. Jupiter moves closer to the Sun, until by the end of November it is in conjunction, remaining out of visibility until mid-January. Venus is lost to the Sun as October progresses and re-emerges as a morning object by mid-November, remaining that way into early spring. Saturn is lost behind the Sun by mid-November also, while the best time to see Mercury is mid-December.

For planetary observers it's really Mars, Uranus and Neptune that are the saving graces of the winter. Despite progressively dimming and reducing in size these three planets at least remain at a high altitude; they're best seen after sunset in the southwest before midnight.

With the turn of the New Year, Jupiter rallies a little to make a return as a morning object, closely accompanied by Venus. The largest planet in the Solar System is best seen in early January, but even then doesn't attain much height before sunrise. By mid-February, Saturn has reappeared as a morning object too, and both gas giants rise before Venus throughout March. The spring evenings continue to host Mars, Uranus and Neptune, with the Red Planet becoming progressively smaller and dimmer, but gaining altitude from January to March. Mercury meanwhile, is best seen at the end of February, shortly after sunset, low to the western horizon.



▲ Mars will be one of the best planets to observe this season, a highlight in an otherwise rather fallow period for planets

Galaxies

If you're new to astronomy, or perhaps haven't done much deep-sky observing before, the new season offers several bright and easy-to-find galaxies for you to get to grips with.

What better way to start off the season than with the glorious bright galaxies on show in September's night sky? Pride of place in the constellation of Andromeda is M31, the fabulous Andromeda Galaxy. Through a 6-inch scope it'll appear as a large ellipse with a bright centre and perhaps a hint of the dust lanes that sweep across it. From a dark sky site, you can spot M31 with the naked eye. By mid-October it's high in the south after midnight. Nearby, in the constellation of Triangulum, is the galaxy M33, which is another good target for a 4- to 6-inch scope.

As the season moves on, look out for the galaxies M81 in Ursa Major as well as M51 in the constellation of Canes Venatici. The rough location of M81, Bode's Galaxy, can be found by extending an imaginary line from the star Phi (φ) Ursa Majoris to Upsilon (υ) Ursa Majoris by twice the distance between the two. M51, the Whirlpool Galaxy, can be found very close to the bright star Alkaid (Eta (η) Ursae Majoris), which marks the end of the handle of the Plough asterism.

By midnight in mid-February, the constellation of Leo is relatively high in the south, giving you the opportunity to track down several interesting galaxies contained within its borders. These include M65 and M66 (both discovered by Charles Messier in 1780), which can be found below the bright star Chertan (Theta (θ) Leonis).

Of course, there's one galaxy on show during the winter months that you'll need no equipment to see, just your eyes and some clear dark skies. That's the bright band of our very own Milky Way. It is a magnificent sight as it stretches across the inky sky, putting on a particularly good show between the months of September and December.

▼ The Whirlpool Galaxy is a winter sky treat

Double stars and clusters

► The M35 cluster consists of several hundred stars, 120 of which are brighter than mag. +13

There's going to be a bewildering array of double stars and star clusters to see over the coming months. At about 10pm in September you'll find the globular cluster M13 sitting in Hercules in the west. Locate it by scanning the northwest corner of the famous 'Keystone' asterism. A small telescope of around six inches will resolve many of the cluster's stars.

In October, the constellation Lyra will be high in the south right after sunset. In Lyra you'll find the multiple star system Epsilon (ε) Lyrae, which is also known as the 'Double Double'. A small telescope reveals that each of this intriguing pair is also made up of two stars. Also use a small telescope to look for the wonderful Double Cluster (composed of the open clusters NGC 869 and NGC 884) between Perseus and iopeia.

In November, the constellation of Taurus sits high in the south by 11pm. Here you'll find two of the finest open clusters in the northern hemisphere: the Hyades and Pleiades. Both are very clear to the naked eye, even from fairly light-polluted sites. The Hyades is an unmistakable 'V' shape with the bright star Aldebaran at its eastern tip. The Pleiades is a little further away and is a magnificent sight in binoculars or a 2.5-inch refractor.

December and January boast two lovely open clusters. Through a small 4-inch scope, M35 sits quite close to the star Propus (Eta (η) Geminorum) in the constellation of Gemini. Through a pair of binoculars you should also look out for M44, the Beehive Cluster, at the centre of the constellation of Cancer.

In late February find the sparkling open clusters M36, M37 and M38 in the constellation of Auriga, high in the south around 7pm. In mid-March, the constellation of Coma Berenices will be high in the south. To the naked eye the cluster Melotte 111, near the star Gamma (γ) Comae Berenices, appears as a fuzzy patch. A pair of binoculars will reveal a glittering collection of around 40 stars.

▲ M42, the Orion Nebula, will be in its optimum position for viewing from the UK in January

FRANZ KLAUSER/CCDGUIDE.COM, ROBERT SCHULZ/CCDGUIDE.COM, ISTOCK, STEVE MARSH

Nebulae

There's a handful of nebulae to look out for over the next few months. If you're up for a challenge you could try searching for the North America Nebula (NGC 7000) in the southwest during the middle of October. It's located very close to the brightest star in Cygnus, Deneb (Alpha (α) Cygni), and can be spotted with binoculars. You'll need clear, dark skies to see it. Some observers also report that a specialist nebula filter held over an eye helps them spot it. You'll have until early January to look for it before it sinks into the twilight.

As Cygnus disappears in the west, the constellation of Orion rises in the east. By January, Orion is in the south by 9.15pm, making it ideally placed for observation. From dark skies you should be able to spot M42, the Orion Nebula, with the naked eye. Binoculars will show it as a fuzzy star at the heart of Orion's Sword. Turning even a modest 4- to 6-inch telescope on the nebula will show its swirling clouds of gas with stars nestled in and around it. If you have access to a large telescope – perhaps at a local society – make sure you train it on M42; it's a breathtaking sight, with great tendrils of sweeping gas enveloping the nebula's heart of stars. Also look for the Running Man Nebula (NGC 1977) just to the north.

Meteor showers

▲ You could see up to 50 meteors an hour at the height of the Geminids on 13/14 December

When Earth passes through the trail of dust and debris usually left by a comet, a meteor shower occurs. It's a great opportunity to grab some friends for a meteor-spotting session, as the more eyes you employ the better chance you'll have of success.

Although meteor showers do appear from specific directions, you can simply lie back and look up to observe them. To give yourself the best chance of seeing a shower, head away from light-polluted sites and towards a place where you can see as much of the sky as possible. You won't need any equipment to see them, but it's a good idea to record the path, characteristics and estimated brightness of any shooting stars you do see.

Of all the meteor showers due over the course of the new season there are a few that stand out as the ones it's worth trying to see if the weather is good. Around 17 November, the Leonid meteor shower reaches its peak. You can expect to see up to 10 meteors an hour if you're lucky, though light from the waxing gibbous Moon will wash some out. The Geminid meteor shower in December is generally quite impressive. You can expect to see 50 or so meteors an hour on the night of the peak on 13/14 December. The best time to look will be from half-past midnight until dawn. In January, look out for the Quadrantid meteor shower, which peaks on 3/4 January. With dark skies and the Moon out of the way, you could see up to 100 meteors an hour.

Comets

Predicting the appearance of a bright comet can be tricky, but some reports suggest that Comet 21P/Giacobini-Zinner may stay be visible to the naked eye through September. Other comets worth keeping an eye on this season are 38P/Stephan-Oterma from November and 46P/Wirtanen throughout December.

The Moon

The Moon's changing phase means there's always something to explore. With a good pair of binoculars you can spot many of the Moon's larger craters, the darker and smoother 'seas' and the most prominent mountain ranges. A small telescope will show all these in more detail, and reveal smaller features such as rilles, ridges and detail inside the larger craters. In fact, there are countless lunar features you can see if your skies are clear. However, here are a few that we reckon you should observe this season, along with the best times to look out for them.

▲ There are always a host rilles, ridges and craters to marvel at on the Moon

The crater Copernicus will be a stunning sight on 20 October, 17 November, 17 December, 17 January, 14 February and 16 March. A 4-inch telescope will show its magnificent walls, bright ejecta blanket and central peak well. Also worth a look on these nights is the region around the Sinus Iridum, the 'Bay of Rainbows'. There will be several other fascinating lunar features on show in the area on the nights of 18 and 19 October; 17 and 18 November; 16 and 17 December; 15 and 16 January; 13 and 14 February and 15 and 16 March. A small telescope of between four and six inches will show them all well.

Start by looking for crater Plato and the Valles Alpes near the terminator in the Moon's northern hemisphere. Moving south along the terminator you'll see the craters Archimedes, Aristillus, Eratosthenes and the magnificent Montes Apenninus. As you cross the Moon's equator you'll see the craters Ptolemaeus, Alphonsus, Arzachel and the huge lunar fault Rupes Recta or 'the Straight Wall'. To the south beyond them, you'll find the heavily cratered south polar region. Also look out for the lunar mountains Mons Piton, Mons Pico and the mountain range Montes Teneriffe on these dates. They'll be easy to spot with a 4- to 6-inch telescope.

On the nights of 13 October, 12 November, 10 December, 9 January, 8 February and 10 March, the craters Petavius and Langrenus along with the Mare Crisium will be on show just after sunset.

Finally on 15 October, 14 November, 14 December, 12 January, 10 February and 12 March, the impressive craters Theophilus, Cyrillus and Catharina are beautifully lit on or near the terminator. A 4-inch scope will show them well, near the Mare Nectaris.

► **So, armed with this article and our extensive observing guide, you'll be well on your way to enjoying what should be a packed few months.**

THE NEW-SEASON SCOPE SERVICE

Make sure that your telescope and mount are in optimum condition for dark skies by carrying out the following simple but effective checks and adjustments

Check the calibration of your polarscope

It is easy to knock your polarscope out of alignment while you're carrying your mount around; many people never bother to calibrate it properly in the first place. Now is the time to complete this important task.

Clean your eyepieces

Eyelash grease accumulates on your eyepiece lenses. Use a blast of air to remove dust, then clean the surface with lens-cleaning fluid and a microfibre cloth.

Revitalise your counterbalance weights

Counterbalance weights seem to get a bit of a bashing if photographs of second-hand mounts are anything to go by. Keep them looking smart and rust-free with a paint touch-up brush.

Clean the mounting hardware and the outside of the tube

Dust and grit can find their way between your tube rings and the telescope tube itself. Clean the linings of the tube rings to avoid scratches when you rotate or adjust the position of the tube.

Mark out your mount's home position

Many popular Go-To mounts have a 'Home' or 'Park' position from which you start each alignment session. Placing markers on your mount's axes will help you set up speedily and accurately.

Check your tripod legs

We tend to take tripods for granted, but frequently opening and closing their legs can lead to loose bolts. Have a quick check over each bolt to avoid expensive accidents.

WWW.SECRETSTUDIO.NET, PAUL WHITFIELD X 2, ISTOCK

Equipment upgrade

If you're considering some new kit for the new season, then look no further: here are some of the best pieces *BBC Sky at Night Magazine* has reviewed recently

Opticron Oregon Observation 20x80 binoculars
£149 › Opticron › www.opticron.co.uk › 01582 726522
Double stars, planets and the Moon snap to a sharp focus with these budget-priced big binos, which present galaxies and nebulae beautifully thanks to their large objective lenses and multicoated optics. For extra stability, fix them to a tripod with the mounting bar.
Reviewed in the April 2018 issue

Sky-Watcher SkyMax-127 with AZ-GTi Wi-Fi mount
£529 › Optical Vision › www.opticalvision.co.uk › 01359 244200
This setup's 5-inch aperture optics work well for lunar, planetary and deep-sky observing, while its Wi-Fi-enabled mount can be controlled with a wired hand controller, laptop or smartphone app. A great option for those just beginning to explore the night.
Reviewed in the January 2018 issue

Explore Scientific ED102 FCD-100 refractor
£1,267 › Telescope House › www.telescopehouse.com › 01342 837098
A 4-inch triplet lens design and multilayer coatings deliver zero colour fringing practically to the edge of this short tube's field of view. Great for visual observation, its short focal length makes it ideal for astrophotographers looking to capture faint, deep-sky objects out in the field.
Reviewed in the November 2017 issue

iOptron CEM25P portable equatorial mount
£799 › Altair Astro › www.altairastro.com › 01263 731505
Thanks to its Z-shaped design, this 4.7kg equatorial mount can carry a 12kg load capacity. Its accurate tracking makes it a good foundation for astrophotography, and its precise slewing means it'll place targets right in the eyepiece once selected from the 59,000 objects in the controller's database.
Reviewed in the November 2017 issue

Altair Astro GPCAM2 290C colour camera
£219.99 › Altair Astro › www.altairastro.com › 01263 731505
A real all-rounder, the sensitive colour CMOS chip in this eyepiece-sized camera is capable of capturing great colour shots of faint nebulae and galaxies as well as brighter targets like the Moon and the planets. If you're after a first dedicated astro camera, this is one to consider.
Reviewed in the October 2017 issue

Celestron X-CEL LX 3x Barlow lens
£102 › David Hinds › www.dhinds.co.uk › 01525 852696
With internal micro-baffling and three-element multicoated optics, this ocular accessory provides a clear and crisp boost in magnification for all your eyepieces. A brass compression ring to keep eyepieces firmly in place and reassuringly solid construction enhance its lightweight and compact design.
Reviewed in the May 2017 issue