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Sky at Night

THE UK'S BIGGEST SELLING ASTRONOMY MAGAZINE

142 MARCH 2017

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REVEALED: What lies behind the glowing green veils of the Northern Lights

Formed from FIRE

Uncover the tumultuous beginnings of our Solar System

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The simple technique that can turn your starscapes into world-class images

THE SKY GUIDE

17 PAGES OF STARGAZING

Observing the Moon: good librations

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VIDEO INTERVIEWS

Discover the NASA missions investigating the birth of the Solar System

THE SKY AT NIGHT

The TV show looks at the latest missions to explore the Galaxy

INTERACTIVE PLANETARIUM

Welcome

Get to grips with the science of Earth's most famous light show

The aurora is a spellbinding sight, and the story of how scientists are discovering more about the processes that create it is equally as fascinating. Their findings illuminate a chain of events that stretch from the Arctic and Antarctic Circles to interplanetary space, and serve as a reminder of the ferocious power streaming from our Sun. Discover more on page 38.

On page 32 we revisit an era when the Solar System was an altogether more dangerous place. Elizabeth Pearson talks to the astronomers modelling our planetary system 3.9 billion years ago and recounts how planets migrated – and possibly ejected altogether – and asteroids were thrown into tumult in dramatic events of which the late heavy bombardment is the most well-known.

Elsewhere this issue we present a comprehensive guide to remote telescopes, the services that allow you to go online and book observing or imaging time with instruments located in areas of pristine dark skies. Which of them is right for parents looking to inspire an interested son or daughter and which for serious imagers? Find out on page 72.

And we have more astrophotography on page 67, where Will Gater is your guide to injecting composition into your images of the night sky. He finds that whether you're taking a nightscape, imaging the Moon or creating or a long-exposure stack of the deep sky, there's plenty that can be transferred from the framing techniques of painting and photography.

Enjoy the issue!

Chris Bramley Editor

PS Next issue goes on sale 23 March

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This month's contributors include...

Maggie Aderin-Pocock
Sky at Night presenter

Maggie recounts her experience controlling one of the world's great observatories when *The Sky at Night* visited La Palma. *Page 21*

Will Gater
Astronomy writer

Will explains how getting to grips with the art of image composition can work wonders in your astrophotos. *Page 67*

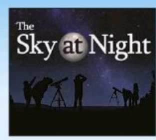
Thierry Legault
Astro imager

Renowned imager Thierry reveals how you can photograph the structure of the ISS as it flies overhead. *Page 82*

Melanie Windridge
Plasma scientist

Melanie explains how Earth and Sun interact with one another to create alluring auroral displays. *Page 81*

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



TELEVISION
The Sky at Night takes a break this month as *Stargazing Live* returns to our screens. See page 19

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C = on the cover

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Get started with The Guide on page 80 and our online glossary at www.skyatnightmagazine.com/dictionary

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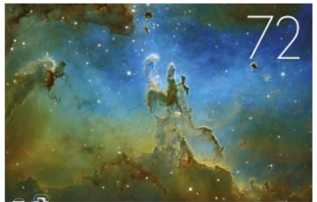

Regulars

MARCH'S BONUS CONTENT

ACCESS THE CONTENT ONLINE AT
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ACCESS CODE: S3NY937

Highlights

Guide to the Galaxy

January's *Sky at Night* is all about our home Galaxy. Maggie and Chris reveal the most detailed 3D map of the Milky Way ever made, and find out how scientists are searching to find its 'missing' matter. US astrophysicist Neil deGrasse Tyson selects his top five most exotic stars in the Galaxy, while Pete Lawrence explains how you can find them in the night sky.

Video interview: the Psyche mission
Lindy Elkins-Tanton talks about her mission to study a metal asteroid and find out more about how planets are born.

Video interview: the Lucy mission
Hal Levison is heading a project that will visit Jupiter's Trojan asteroids to learn the secrets of the Solar System.

Sneak preview: *The Glass Universe*
Read a chapter from Dava Sobel's new book about a pioneering group of 19th-century female astronomers.

and much more...

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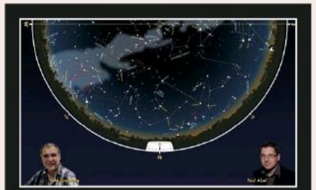

EVERY MONTH
Virtual Planetarium
With Paul Abel and Pete Lawrence
Explore March's night-sky highlights with Paul and Pete.

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A new vista of Orion

VISTA's infrared eye peers past the dust of the Orion A molecular cloud to give us this fresh glimpse of the closest star factory to planet Earth

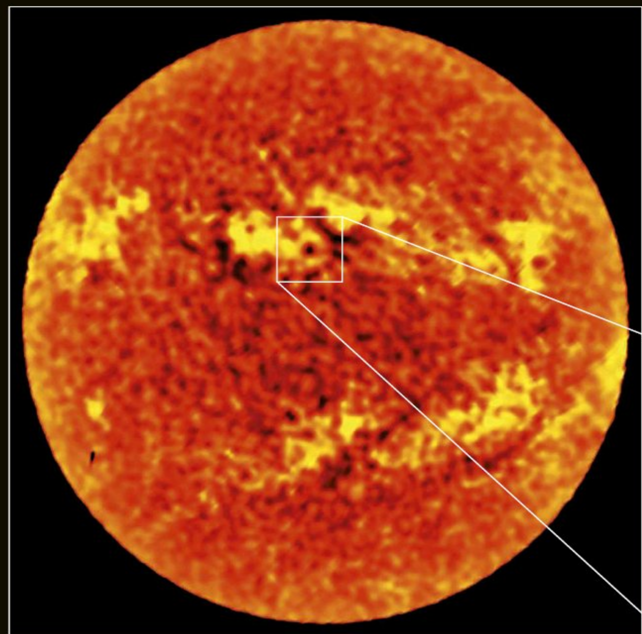
VISTA TELESCOPE, 4 JANUARY 2017

This montage of the Orion A molecular cloud is our most detailed near-infrared image of the region to date. Captured using data from the VISTA infrared survey telescope at ESO's Paranal Observatory in Chile, it shows the entirety of Orion A, which stretches for about 8° south of the Hunter's sword.

This is one of the most studied parts of the Milky Way, and for good reason. It is not only relatively close to Earth, but also an incredibly active region with ongoing star formation being triggered by the death of previous generations of stars. This happens when older stars end their lives in an explosion, causing nearby molecular clouds to collapse and bringing about the formation of new stars to replace them.

VISTA's infrared capabilities mean it can see beyond the dust that would otherwise obscure optical observations, revealing young, hidden stars to astronomers on Earth. In fact, the VISION survey (Vienna Survey in Orion, for which this image was taken), has already catalogued almost 800,000 stars, young stellar objects and distant galaxies in the region. There are plenty of specimens waiting to be studied in our quest to reveal the secrets of stellar birth and death.

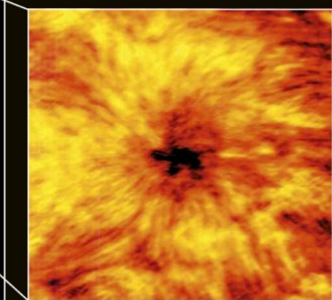
YOUR BONUS CONTENT A gallery of these and more stunning space images



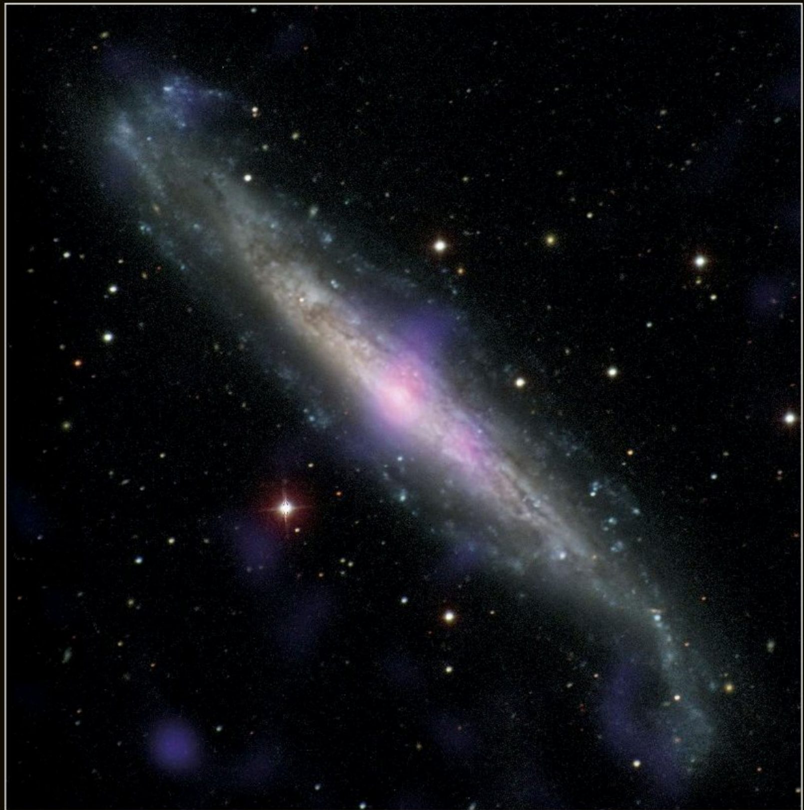
◀ ALMA's solar debut

ALMA, 17 JANUARY 2017

ALMA has begun imaging the Sun for the first time, observing our star's chromosphere in millimetre-wavelength light to produce these amazing images, the highlight being a giant, dark sunspot (shown inset) that is almost twice the diameter of Earth. Sunspots are temporary features on the solar surface, occurring where the magnetic field is particularly concentrated – this causes a drop in temperature that makes the area appear darker.



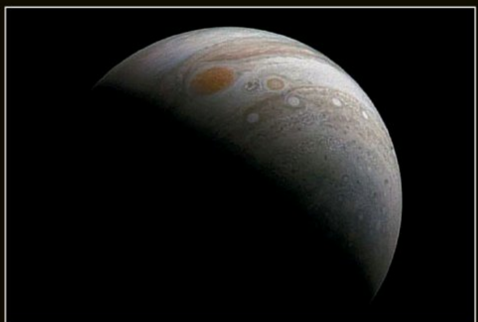
ESO/VISION SURVEY, ALMA (ESO/NAOJ/NRAO)



◀ Bright galactic core

NUSTAR/ CARNEGIE-IRVINE GALAXY SURVEY, 7 JANUARY 2017

Galaxy NGC 1448 contains an active galactic nucleus (AGN), a compact, central region noted for its extreme brightness. AGNs typically outshine all of the stars present in their galaxies and are luminous at all wavelengths. Most are thought to be powered by central supermassive black holes, which accrete matter and convert it to bright light that makes the core shine. This image was captured using the space-based Nuclear Spectroscopic Telescope Array, whose X-ray vision is able to reveal the activity indicative of a central black hole.



▲ Citizen planetary science

JUNO SPACECRAFT, 13 JANUARY 2017

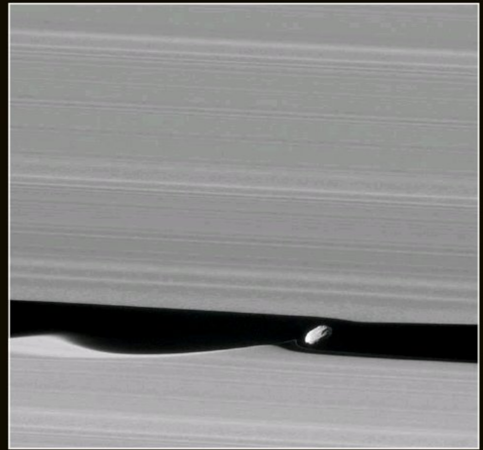
As the Juno spacecraft continues to capture amazing images of Jupiter with its JunoCam instrument, members of the public are being invited to view and process the raw data. This image was created by citizen scientist Roman Tkachenko and clearly shows the Great Red Spot, along with small white blobs just below known as the 'string of pearls'. All of these features are ongoing storms.

▼ Black hole mystery

HUBBLE SPACE TELESCOPE, 9 JANUARY 2017

Like most known spiral galaxies, there is a supermassive black hole at the centre of RX J1140.1+0307. However, this particular specimen has one of the lowest black hole masses of any with a luminous galactic core. The brightness of the galactic centre is greater than can be explained by the mass of the black hole alone, leading astronomers to conclude there must be other, unknown forces at work.

NASA/JPL-CALTECH/CARNEGIE-IRVINE GALAXY SURVEY, NASA/JPL-CALTECH/SWRI/MSSS/ROMAN TKACHENKO, ESA/HUBBLE & NASA, NASA/JPL-CALTECH/SPACE SCIENCE INSTITUTE, ESA/HUBBLE & NASA



◀ Mind the gap

CASSINI SPACECRAFT, 16 JANUARY 2017

The tiny body seen here forging a path through Saturn's A ring is the small moon Daphnis. The channel it moves through, the 42km-wide Keeler Gap, is created by the moon itself. A series of tiny wave-like features can be seen forming in the bottom edge of the gap, the result of the moon's gravitational pull. This incredible view was captured by Cassini from just 28,000km, as it made one of its so-called 'ring grazing' flybys around the planet.

▼ A galactic tail

HUBBLE SPACE TELESCOPE, 23 JANUARY 2017

At a glance NGC 4861 resembles a comet, complete with bright head and wispy tail. It is in fact a galaxy. The stream of stars that appears to follow in its wake is probably the result of interactions with another galaxy, whose gravitational pull could have stretched NGC 4861 as it passed by.

Bulletin

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

PLUS CUTTING EDGE

Our experts examine the hottest new astronomy research papers

BLACK HOLE BEASTS found nearby

The giants had been hiding behind a veil of dust

▲ The active galactic nuclei reside in spiral galaxies NGC 1448 (left) and IC 3639 (right)

NASA/JPL-CALTECH/CARNEGIE-IRVINE GALAXY SURVEY, NASA/JPL-CALTECH/ESO/STSCI

Two superheated black holes have been found hiding behind a veil of dust close to the Milky Way, giving researchers a fantastic view of these cosmic powerhouses.

The black holes reside in the centre of two spiral galaxies, IC 3639 and NGC 1448, 170 and 38 million lightyears away respectively. Images taken with NASA's NuSTAR X-ray observatory revealed that the pair probably house active galactic nuclei – luminous cores created when the material around a central supermassive black hole superheats due to friction. The resulting glow makes active galactic nuclei some of the brightest known objects in the Universe, emitting radiation across most wavelengths, including highly energetic X-rays.

However, they can appear very different depending on how they are orientated. These active galactic nuclei are edge-on to the Milky Way, which is why they have remained hidden for so long despite being relatively nearby.

"Just as we can't see the Sun on a cloudy day, we can't directly see how bright these active galactic nuclei really are because of all the gas and dust surrounding the central engine," says Peter Boorman of the University of Southampton, who led the study of IC 3639.

Even though researchers do not have a clear view of the central region, it is possible to detect X-rays that have been reflected through the dust. NuSTAR is the first X-ray telescope sensitive enough to pick up these reflections.

"It is exciting to use the power of NuSTAR to get important, unique information on these beasts, even in our cosmic backyard where they can be studied in detail," says Daniel Stern, NuSTAR's project scientist.

▶ See Comment, right

COMMENT

by Chris Lintott

Having a supermassive black hole at their centre seems to be something that all but the smallest, puniest galaxies do. It may even be the case that the black holes form first, way back when the Universe was just a few hundred million years old, leaving the rest of a galaxy to coalesce around these seeds.

What is surprising is how active these hidden black holes are. Despite their fearsome reputation, most black holes sit quietly in the centre of their host systems. There was a lot of excitement a few years ago when it seemed like the Milky Way's black hole would consume a cloud of gas which had the same mass of Jupiter – barely a snack on a cosmic scale.

The black holes in these galaxies have begun a much larger meal, and now we know what they're up to they will be objects of great interest.

CHRIS LINTOTT co-presents *The Sky at Night*

NEWS IN BRIEF

PLUTO'S MOON GUARDS ITS AIR

Pluto's atmosphere is protected from the violent stripping force of the solar wind by its moon Charon, according to the latest findings using New Horizons' data.

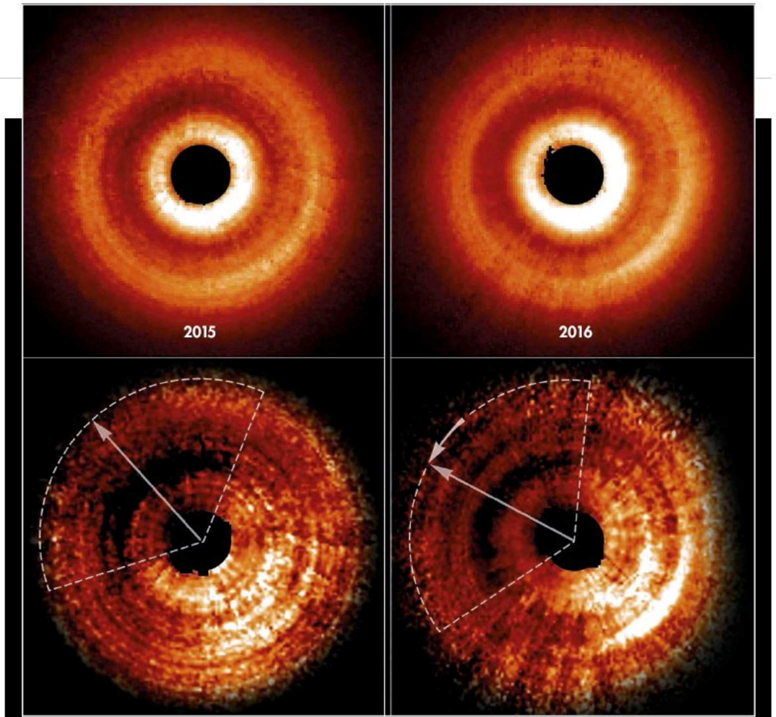
"Charon doesn't always have its own atmosphere, but when it does it creates a shield for Pluto and redirects much of the solar wind around and away," says Carol Paty from Georgia Institute of Technology. This could explain why New Horizons found that the atmospheric loss on the dwarf planet is 100 times less than expected.

MILKY WAY IS A COSMIC THIEF

New simulations show the Milky Way may have stolen its most distant stars from the Sagittarius dwarf galaxy. Simulations indicate that the dwarf could have lost a third of its stars to ours. Over time this may have created three streams of stars, radiating as far as a million lightyears from the galactic centre.

"The star streams that have been mapped so far are like creeks compared to the giant river of stars we predict will be observed eventually," says Marion Dierickx from the Harvard Smithsonian Center for Astrophysics.

NASA/JHUAPL/SWRI, NASA/ESA AND THE HUBBLE HERITAGE TEAM (STSCI/AURA), NASA/ESA AND J. DEBES (STSCI), ESO/Y. BELETSKY, HAGAI PERETS, SSL/ASU/P. RUBIN/NASA/JPL CALTECH, ©SWINBURNE ASTRONOMY PRODUCTIONS



▲ These images reveal how much the shadow has moved around TW Hydrae's disc over the course of a year. The top two panels show that there is uneven brightness; in the enhanced panels below, the shadow is apparent

Alien world's shadow SEEN BY HUBBLE

The planet is too close to its star to be detected directly

A shadow has been spotted moving across the gas and dust disc of a young star in a new study of archived Hubble Space Telescope data, hinting at the presence of an inner planet. The discovery could be the start of a new way to observe young planets orbiting close to their stars.

The star in question, TW Hydrae, is only eight million years old and is still surrounded by a protoplanetary disc, a dense region of gas and dust. Researchers analysed 18 years' worth of Hubble images and found a dark patch moving clockwise around the disc, 16 billion km from the star – this is equivalent to three times the distance between Pluto and the Sun.

What surprised the researchers was that the patch completed an orbit in just 16 years. At that distance it should take centuries to complete one rotation, indicating that the blotch was not physically part of the disc. It might, they say, be a shadow, cast on the outer disc by an inner section that migrated out of the main plane.

"The most plausible scenario is the gravitational influence of an unseen planet, which is pulling material out of the plane of the disc and twisting the inner disc," says John Debes from the Space Telescope Science Institute in Baltimore. "The misaligned disc is inside the planet's orbit."

The planet is estimated to be Jupiter-mass and around 160 million km from the star, a similar orbital distance to that of Earth. Currently Hubble can only directly image planets that are more than 1.5 billion km from their stars, around the same distance as Saturn's orbit. However, if such twisted discs are common in the Galaxy, then it could allow the telescope to examine regions much closer in to stars.

"What is surprising is that we can learn something about an unseen part of the disc by studying the disc's outer region and by measuring the motion, location and behaviour of a shadow," says Debes. "This study shows us that even these large discs, whose inner regions are unobservable, are still dynamic or changing in detectable ways we didn't imagine."

http://hubblesite.org/

VLT to search Alpha Centauri

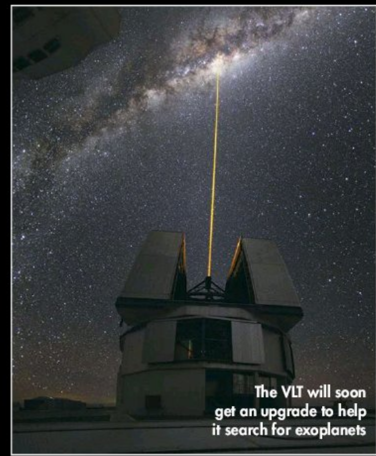
The ESO telescope will be used to scan for exoplanets

The Very Large Telescope (VLT) is to search for exoplanets around nearby star Alpha Centauri, in a recently announced partnership with the Breakthrough Starshot initiative.

Breakthrough Starshot, an endeavour backed by Stephen Hawking, is investigating the feasibility of sending a fleet of nanospacecraft to the star. Now it has enlisted the help of the VLT to search the Alpha Centauri system for potential targets of interest. The VLT can observe in the infrared, a wavelength at which exoplanets glow brightly making it easy to find them. However, the light of the star is still a million times brighter, blinding instruments to potential planets.

By modifying the VLT's VISIR spectrometer, the telescope will be able to perform coronography, where the bright light of the star is blocked out. This will allow VISIR to pick up the infrared glow of orbiting worlds.

http://breakthroughinitiatives.org



The VLT will soon get an upgrade to help it search for exoplanets

Earth may have had other moons

Our Moon may not be the only companion the Earth has ever had, but the last in a chain of smaller satellites, according to a new study.

Currently the leading lunar origin theory is that the Moon formed from the debris left over when a single Mars sized object struck the Earth, but this new study brings that into question.

"Our model suggests that the ancient Earth once hosted a series of moons, each one formed from a different collision with the proto-Earth," says Hagai Perets from the Technion-Israel Institute of Technology.

It's thought the early Earth was bombarded by many impactors, each of which would have left a field of debris around the planet from which a satellite could form. The tidal forces of the Earth would then cause the moons to slowly migrate, potentially causing their orbits to cross.

"It's likely such moonlets were later ejected, or collided with the Earth or with each other to form bigger moons," says Perets.

http://www.technion.ac.il/en

▸ More about the Solar System's past: page 32

The Moon we are so familiar with may not have been the only companion after a collision involving the proto-Earth

NEWS IN BRIEF

NASA'S NEW ASTEROID MISSIONS

Two new Solar System missions have been selected for development by NASA, both of which will investigate questions surrounding the origin of the planets. The Psyche mission will fly to a metallic asteroid of the same name which is believed to be the remnant of a destroyed planet's iron core. The mission aims to launch in 2023, reaching 16 Psyche in 2030. Another mission, Lucy, will undertake a 12-year tour of six of the Trojan asteroids that share Jupiter's orbit and is slated for launch in 2021.

FAST RADIO BURST PINPOINTED

The home of a fast radio burst (FRB) has been located for the first time – in a dwarf galaxy three billion lightyears away. FRBs are highly energetic but short-lived radio pulses, though what causes them remains a mystery. This burst, FRB 121102, is unique in that it was the only known FRB to repeatedly erupt. This allowed scientists to pinpoint its location. It seems the burst came from outside our Galaxy, rather than within.

CUTTING EDGE

Our experts examine the hottest new research

The mystery of the exozodiacal light

Dust choking far flung stars may be behind their unusual brightness – but where does it come from?

▲ Vega in Lyra is thought to be surrounded by an asteroid belt-like band of dusty debris

NASA/JPL-CALTECH

Something odd and mysterious is happening around many of our nearest stars. Surveys of otherwise normal main sequence stars have shown that at least 10 per cent and maybe as many as a third of them are glowing more brightly in the infrared than they should be. The likely culprit is dust close to the star, which can absorb its light and re-emit it in the infrared, but the source of large amounts of hot dust is a mystery.

Such an infrared excess was first detected around Vega, providing a nice in-joke in the 1997 film *Contact* when, having received what appears to be a signal from the star, a control-room astronomer points out that any alien civilisation there would have trouble with the debris around the star. Instead of worrying about hazards to alien shipping, a new paper by a team led by Florian Kirchschlager from Kiel University in Germany stacks the evidence to find out what might be going on.

In our Solar System, dust left behind by short-period comets is sometimes revealed by reflected sunlight, causing a faint glow known as zodiacal light. Observations of these other stars points to exozodiacal light that is typically three times brighter than our own.

While we could always imagine stars other than the Sun to be more pestered by comets, there are two problems. One is that such a large amount of dust would be quickly dispersed by the stellar wind, amongst other processes, and the other is that these effects are greatest closest to the star, just where we need the dust to be for it to be hot enough to generate a nice bright infrared excess.

The Kiel team decide that the solution is to pack the necessary dust into a narrow ring around the star, an arrangement that might be more stable than an even distribution. At least for those stars with the brightest infrared excess, these rings must be spectacular: in order to explain what we see their radius can't be any farther out than Earth is, and in at least one case it must skirt just a few million kilometres above the surface of the star.

But this closeness creates a problem. In the Solar System, dust grains are often like sand grains, made of silicates and incapable of resisting the temperatures they'd encounter in such orbits. Graphite would work – it can survive temperatures up to several thousand degrees, as would other carbonaceous dust – but this makes the problem of the dust's origins worse. You'd need a very special set of comets to deliver just the right kind of dust, for starters. There's an old joke that astronomers turn to blaming magnetic fields for any unexplained phenomenon when they become desperate, and this problem is no different. If the particles are small, they can be charged by the interstellar wind, and once that happens the star's magnetic field might be able to trap them in a ring.

> *"There's an old joke that astronomers turn to blaming magnetic fields when desperate, and this problem is no different"*

It's a model that might just work, but really we need more observations. Only a few dozen of the nearest stars have yet been surveyed, and only when we have more data will we be sure of what's going on - and what the implications for any alien around Vega will be.

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… *Constrains on the structure of hot exozodiacal dust belts* by Florian Kirchschlager et al.
Read it online at https://arxiv.org/abs/1701.07271

A black hole bounty

The deepest X-ray image includes light from 12.5 billion lightyears away

▲ The centre of this image holds the highest concentration of supermassive black holes ever recorded

The deepest ever X-ray image has been taken with NASA's Chandra X-ray observatory. It is believed to show thousands of supermassive black holes.

The image required 11 and a half weeks of Chandra observing time to create, and captures the intense X-rays which are emitted by superheated dust falling into a black hole. It is thought that 70 per cent of the objects seen in the image could be black holes with masses ranging from 100,000 to 10 billion times the mass of the Sun.

"By staring long enough with Chandra, we can find and study large numbers of growing black holes, some of which appear not long after the Big Bang," says team member Bin Luo of Nanjing University in China.
http://chandra.si.edu

Last moonwalker Gene Cernan dies

Gene Cernan, the most recent person to have walked on the lunar surface, passed away on 16 January 2017. Cernan was the commander of Apollo 17, the last crewed mission to the Moon. He spent three days on the lunar surface with fellow astronaut Harrison Schmitt, longer than any other Apollo mission.

After retiring from NASA, Cernan continued to voice his desire for mankind to once again return to our nearest neighbour.

"Yes, I am the last man to have walked on the Moon, and that's a very dubious and disappointing honour. It's been far too long," said Cernan in his memoir.
www.nasa.gov

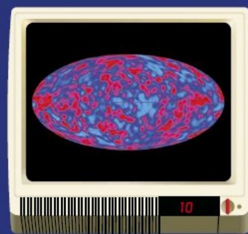
▲ While others looked to Mars, Cernan always advocated a manned return to the Moon

LOOKING BACK THE SKY AT NIGHT
March 1993

On 7 March 1993, the team on *The Sky at Night* looked at the recent results of the Cosmic Background Explorer (COBE).

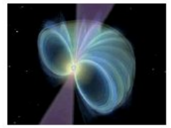
Launched in 1989, COBE spent four years scanning the sky at microwave and infrared wavelengths. It was able to create the most precise map, up to that point, of the cosmic microwave background radiation (CMB). This is the first light of the Universe from when it started to glow 400,000 years after the Big Bang. Over time the once visible light has been stretched out, or redshifted, so that now it has a longer microwave wavelength.

As the structure of the Universe at the time the background was created is imprinted on the CMB, by studying it researchers can see what the Universe was like at these early times. The findings made using COBE's data provided the most compelling proof yet that the Big Bang theory was correct.



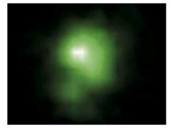
▲ COBE data of the CMB stregthened support for Big Bang theory

NEWS IN BRIEF



COSMIC CLOCKS MISS A TICK

Two newly discovered pulsars appear to be active for short periods of time, challenging the view that these objects are the constant clocks of the Universe. Pulsars are rapidly spinning neutron stars that usually appear to emit radio waves to a steady, constant beat. It's unknown how these pulsars turn their emissions on and off. "These disappearing pulsars may far outnumber normal pulsars. In fact they may redefine what we think of as normal," says Victoria Kaspi of McGill University in Canada.



GALAXIES USED TO GLOW GREEN

Newly formed galaxies may have once glowed green. A study of a deep-field image taken by the Subaru telescope has shown that many of the thousands of galaxies it has observed are enriched with doubly ionised oxygen. This emits a distinctive green glow, more commonly associated with planetary nebulae or compact 'green pea' galaxies. The discovery will help researchers identify and study galaxies during their crucial formation stages 500 million years after the Big Bang.

NASA/CXC/PENN STATE/B.LUO ET AL, NASA X 3, RUSSELL KIGHTLY MEDIA

CUTTING EDGE

Our experts examine the hottest new research

Homing in on Planet Nine

We're taking the first steps in narrowing down where the hypothetical planet may be hiding away

The as-yet-undetected planet is imagined to be similar to Neptune

MARK GARLICK/SCIENCE PHOTO LIBRARY

The argument that there may be an undiscovered planet lurking far in the outer Solar System has been gathering momentum of late. This mysterious world has been dubbed Planet Nine, and several different studies have recently rallied statistical evidence that indicates its existence. Most notably, Konstantin Batygin and Michael Brown claimed last year that clustering of the most distant Kuiper Belt objects (KBOs) is caused by the gravitational nudging of an unseen but massive outer planet. Batygin and Brown estimated that this potential super-Earth world would follow a highly eccentric orbit with a semi-major axis of around 700 AU; around 20 times farther from the Sun than Neptune.

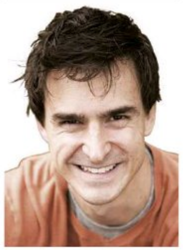
Other astronomers have since argued that this potential planet might explain the 6° tilt of the Sun relative to the ecliptic, or the population of trans-Neptunian objects with highly inclined orbits. The major concern now is to try to actually observe this remote planet. The question is, where in the sky should we target our telescope searches?

Sarah Millholland and Gregory Laughlin, both at the astronomy department of Yale University, have tried to further constrain the range of orbits that this Planet Nine would need to have in order to perturb distant KBOs in the pattern we see. They worked from the assumption that Planet Nine interacts with some of the KBOs in a mean motion resonance – where a celestial body experiences a regular gravitational tug because its orbit is in an exact ratio with another. This can occur with multiple bodies at the same time: the orbits of the Jovian moons Ganymede, Europa and Io, for example, are locked in a 1:2:4 mean motion resonance. If Planet Nine does indeed share an orbital resonance with some of the KBOs, it would really help constrain not only its orbital path, but where exactly along that ellipse it currently is – crucial for pinning down where in the night sky it can be observed.

Using the orbits of 11 KBOs, Millholland and Laughlin ran a series of orbital simulations over the past billion years of Solar System history to determine the orbital parameters of an object that could be gravitationally perturbing these KBOs. They calculate that Planet Nine, if it does exist, is most probably in an orbit with a semi-major axis of 654 AU, and is six to 12 times more massive than the Earth. They were also able to estimate the parameters of the elliptical orbit and the planet's current position. Millholland and Laughlin predict that Planet Nine should be found in the region of the night sky with a right ascension of between 30° and 50°, and a declination of between –20° and 20° – an area roughly centred on the constellation of Cetus, the Whale.

This helps narrow down the search area for our planet-hunting telescopes to hopefully discover Planet Nine. If it is found to exist, a further question is how such a large planet came to form so far from the Sun. One intriguing possibility is that it may have been captured from another star in the sun's birth cluster – Planet Nine could well be an interstellar migrant!

> **"An orbital resonance would really help constrain not only its orbital path, but where exactly along that ellipse it currently is"**



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... *Constraints on Planet Nine's orbit and sky position within a framework of mean motion resonances* by Sarah Millholland and Gregory Laughlin
Read it online at https://arxiv.org/abs/1612.07774

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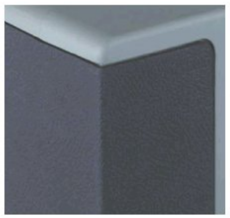

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What's on

Our pick of the best events from around the UK

BRITISH SCIENCE WEEK 2017

PICK OF THE MONTH

▲ There will be events across Britain, including talks, demonstrations and stage shows

British Science Week

Various locations across the UK, 10-19 March

British Science Week is a 10-day, UK-wide festival with a range of events occurring up and down the country. Museums, observatories, science centres, societies, communities and individuals can take part and organise events, with support available from the British Science Association. This year's events so far include pop-up planetariums, sidewalk stargazing, astronomy festivals, demonstrations, workshops and talks.

Learn about the lives of William and Caroline Herschel via Bath-based dance company Forged Line, 'journey into space' with the British Science Association Glasgow, try a spot of lunar observing in Dumfries and Galloway, or take part in a virtual race amongst our neighbouring planets with the new Run the Solar System app, available to download for free during this year's Science Week. The app features a full 10K run through a scaled-down, virtual Solar System, narrated by presenter Dallas Campbell. If you live in London, you can take part in the British Science Association's live 10K race event at Queen Elizabeth Park on Saturday 11 March, complete with a space-themed race village for families and supporters of participants.

For more information on the events happening near you, or to start planning your own, visit the British Science Week website.
www.britishscienceweek.org
www.runthesolarsystem.com

BEHIND THE SCENES

THE SKY AT NIGHT RETURNS IN APRIL

In this year's series returns in late March; check its website for transmission dates

Stargazing Live returns to our TV screens for three nights at the end of March. *The Sky at Night* will take a break this month and return in April for a 60th anniversary special. Access programme news, past episodes, video clips and practical guides from the show's archive at **www.bbc.co.uk/skyatnight**. For up to date info about *Stargazing Live 2017*, visit **www.bbc.co.uk/programmes/b019h4g8**

BRITISH SCIENCE ASSOCIATION X 4, BBC,

Back to Basics

Swinton Masonic Hall, Swinton, Mexborough, 11 March, 10am to 5.30pm

Organised by the British Astronomical Association, this day-long introductory workshop includes talks and practical sessions covering equipment, star charts, lunar and planetary observing, radio astronomy and astro imaging. Places on the workshop are £8 for BAA members and children under 16, and £10 for non-members. A full list of BAA events is available on their website.
www.britastro.org/meetings

The Stardust Programme

Royal College Building, University of Strathclyde, Glasgow, 16 March, 7.30pm.

'Stardust' is an initiative dedicated to exploring how we can monitor and deflect asteroids and remove space debris in order to protect life on planet Earth. In this talk for the Astronomical Society of Glasgow the head of Stardust, Prof Massimiliano Vasile, discusses the programme and how it could keep dangerous debris at bay. Admission is free.
www.theasg.org.uk

Exotic Worlds

Bell Lecture Theatre, Queen's University Belfast, County Antrim, 1 March, 7.30pm

Could a moon around a giant planet be habitable? What would happen if an Earth-like planet were a tiny bit closer to its sun than we are to ours? In this talk for the Irish Astronomical Association, astronomy lecturer Dr Katja Poppenhaeger (pictured) gives a glimpse into the science behind these questions, and shows which stars have potentially habitable worlds around them. Admission is free.
www.irishastro.org.uk

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.

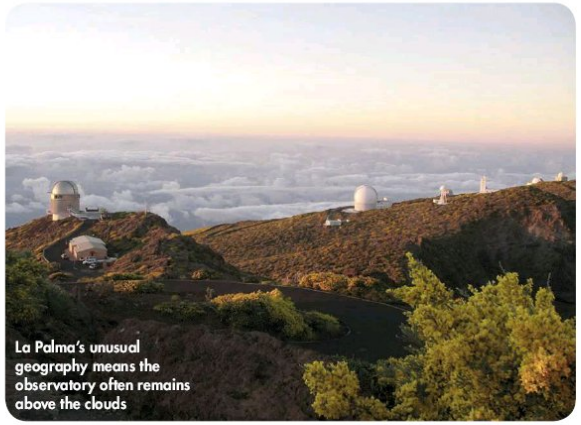
To ensure that your talks, observing evenings and star parties are included, please submit your event by filling in the submission form at the bottom of the page.

A PASSION FOR SPACE

with **Maggie Aderin-Pocock**

The *Sky at Night* presenter goes behind the scenes at La Palma's mountaintop observatory

When people think of the Canary Islands the usual image is Sun, sea and sand, but on the island of La Palma, things are quite different. At the Observatorio del Roque de los Muchachos, 2,400m above sea level, a collection of some of the largest telescopes in Europe keeps a vigil on the skies.



La Palma's unusual geography means the observatory often remains above the clouds

ESO/R. HOOK

It is the ideal location: a dormant volcano, very little light pollution and some of the clearest skies in the world – up to 300 clear nights a year. Due to these great conditions, 14 astronomical facilities are located here, with many different types of telescopes, and for one night only we were given the run of the place on behalf of the *Sky at Night* audience.

Armed with a list of requests from *Sky at Night* viewers, we were able to use its telescopes to gather data. Chris Lintott used the Liverpool Telescope, owned and operated by Liverpool John Moores University. It is a 2m optical telescope that's fully automated, allowing it to be used by professional astronomers across the world, as well as schools in the UK and Ireland. Its automated nature makes it very good at responding to transitory events such as supernovae and gamma-ray bursts; it has a reputation for being first on the scene for many of these events. We programmed it to capture an image of the Waterfall Nebula.

Galaxy hunting

We also received many requests to take an image of a galaxy, and to get this I had the honour of using the largest single aperture telescope in the world, the Gran Telescopio Canarias. This is an impressive beast with a primary mirror 10.4m in diameter, made up of 36 hexagonal segments. The segments are supported and held in place by a 40 tonne armature. All this weight glides smoothly into position on the required point in the sky thanks to the scope's oil-pumped hydraulics.

With its huge mirror, the Gran Telescopio Canarias is designed to look at some of the faintest objects in the night sky. It is sensitive enough to be able to pick up just a few tens of photons per hour and, due to the high efficiency of the optics and detectors, it can look back in time to objects billions of lightyears away. Observations like that take weeks though, and with our time limited to just one night we chose a request to image a nearby galaxy some 30 million lightyears away.

At the CCD readout we were amazed at the details that could be seen: bright stars of our Galaxy in the foreground, the galaxy NCG 891 and then a collection of distant galaxies scattered in the background. The raw data looked fantastic, but then more time was spent processing the image and adding further data captured with a range of wavelength filters to finally produce a beautiful colour image. Our time at the telescopes was short, but we were able to leave with a wealth of data and images that reflect a voyage of discovery charted by the viewers. Thank you for your requests!

Maggie Aderin-Pocock is a space scientist and co-presenter of *The Sky at Night*

JON CULSHAW'S

EXOPLANET EXCURSIONS

Jon remains in the Kepler 16 system to catch a total eclipse in daylight

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

Having decided to remain a little longer in Kepler 16b's home system we are set to witness a quite incredible phenomena. As the light of the two parent stars begins to create a daytime glow of rose and gold blends, there appears a growing 'bite' at the four o'clock position on the fiery edge of Kepler 16A. I'm hoping with all the anticipation I can muster that this is going to progress into a total stellar eclipse!

After 37 minutes it appears to be going that way. At first the bite from the side of the star is similar to the Apple logo. Now, as more of Kepler 16A is obscured, the image is resembling the sickle of the old Soviet flag.

Kepler 16A is a K class star whose light has a subtly different shade to what we're familiar with from the Sun: it shines with a sense of sodium street lighting, giving an intriguing contrast to the partial phases of eclipses we're used to on Earth. Another fascinating difference with this Keplerian eclipse is how Kepler 16B, the other star in the system, is still shining like normal. As Kepler 16A becomes increasingly obscured, there is a far smaller temperature drop and dimming of the daylight.

In the utility store of my ship, the Perihelion, for some reason I can't quite recall, there is a colander. As I hold it up between the two stars, the pinhole effect of the colander's holes shows numerous crescents from the partially eclipsed Kepler 16A and full discs from Kepler 16B. It's very pleasing to build up my collection of observations of differences between this alien eclipse and those we know from Sun and Moon alignments.

Eclipses are always very tense affairs. Factors entirely beyond our control such as cruelly uncooperative weather have the potential to scupper the experience. Here though, on the surface of our Mars-sized moon around gas giant Kepler 16b, the view is pristinely clear. An alien totality is mere moments away. Quickly I glance round to this moon's opposite horizon and, with the eclipse behind me, the vision of gas giant Kepler 16b hangs in the alien sky as if observing the spectacle for itself.

As the final slithers of light become blocked, there are no effects similar to Bailey's Beads or a diamond ring. Perhaps the object causing the eclipse is smooth and uncratered or has a very dense atmosphere. The eventual totality is staggering to behold and creates a scene unlike anything we could witness on Earth. The younger star's outer corona shimmers at greater speed than that of our Sun and has a more fulsome 'golden hour' glow. And for a total eclipse to be happening in the light of day, as Kepler 16B shines on, is rather bizarre: an eclipse scene with an eerie beauty all of its own.

Jon Culshaw is a comedian, impressionist and guest on *The Sky at Night*

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

The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philips: Robin Scagell's *Complete Guide to Stargazing*, Sir Patrick Moore's *The Night Sky*, Robin Scagell and David Frydman's *Stargazing with Binoculars* and Heather Couper and Nigel Henbest's *Stargazing 2017*.

PHILIP'S

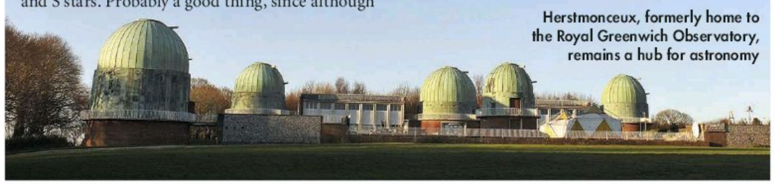
MESSAGE OF THE MONTH

Mnemonic memories

Stephen Tonkin's article on stellar classification and the Hertzsprung-Russell diagram (issue 140) reminded me of the thrill when I first learned these facts. At the time I was an undergraduate studying physics at Birmingham University and, considering the possibility of taking up a career in astronomy, I had taken a vacation course at the Royal Greenwich Observatory, then at Herstmonceux, where I arrived in my minivan (this was 1963). Here we were taught an unforgettable mnemonic for the spectral sequence: 'Oh Be A Fine Girl, Kiss Me Right Now – Slap!' My notes indicate that we were not told much about R, N, and S stars. Probably a good thing, since although you mention the rare S stars, it appears they do not belong to the main sequence, and classes R and N seem to have been replaced by L, T, and Y. This clearly requires a modified mnemonic; the best I have come up with is: "Oh Be A Fine Girl, Kiss Me Long – Truly Yours", but it clearly isn't up to the original. Maybe one of your readers can come up with something better?

Geoffrey Grayer, Newbury

Wonderful memories, Geoffrey! I fear my effort isn't much of an improvement: "Oh Be A Fine Girl, Kiss My Lips – They're Yours!" **– Ed**



Herstmonceux, formerly home to the Royal Greenwich Observatory, remains a hub for astronomy

SOCIAL MEDIA

What you've been saying on Twitter and Facebook

Have your say at **twitter.com/skyatnightmag** and **facebook.com/skyatnightmagazine**

@skyatnightmag asked: Where's your favourite place to observe from? Garden, dark sky site, star party?

@gbc123 The Scottish Dark Sky Observatory is terrific as is the dark sky in Glencoe and Kintyre.

Tony J Eardley Star party, dark skies along with different scopes and like minded people.

Vince Ralph Equipment out in the garden with 5m long leads going inside the house to the PC.

@coedybrenin Elan Valley, Mid Wales – stunning views of night sky, reflected in the still waters of the resevoirs.

@kim_ralls The field next door; unless the farmer's got his sheep in there...

Old sodium streetlights are currently being replaced across Gloucestershire

LEDs are coming

Whilst reading the January edition (issue 140) of your excellent magazine, I noticed an letter from Barry Linton regarding the replacement of the old sodium lighting to the new LED street lighting. Gloucestershire County Council has, for the past 18 months, also been embarking on a replacement programme, and thankfully the work has now arrived in my local area of Stonehouse. I am at present in contact with the council to request shielding on a couple of the street lights, so from my shed I may be able also to see the Milky Way. The light pollution at present from street lighting and neighbouring security lighting (which is on all night and sometimes all day!) really does limit the views when using my Sky-Watcher 127. Keep up the good work.

Matt Ross, Stonehouse, Gloucestershire

Glad to hear your old streetlights are being replaced, Matt. I hope you work something out with the neighbouring security lights. **– Ed**

The heart of the art

I'm a recent subscriber to the magazine and I enjoy the artists impressions and other artwork in the magazine, especially those used in Jon Culshaw's Exoplanet Excursions. I'd like to know how they're created: are they hand drawn or digital?

Nigel Bell, via email

The imagery in Jon Culshaw's Exoplanet Excursions (like the image above) is created digitally by space artist Mark Garlick. Space artists whose work is primarily by hand include David A Hardy and Chelsey Bonestell. **– Ed**

ISTOCK, MARK GARLICK

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Hotshots

YOUR BONUS CONTENT

A gallery containing these and more of your stunning images

This month's pick of your very best astrophotos

▲ NGC 2264 and NGC 2259

CHRIS HEAPY, MACCLESFIELD, 29 DECEMBER 2016

Chris says: "I had imaged this area back in 2014 using a smaller camera, but using the same 5-inch refractor with my new G4-16000 enabled me to capture the surrounding structures at similar resolution, revealing NGC 2259 in the bottom-left corner. Ultraviolet radiation from the central star cluster is ionising oxygen in the area surrounding, resulting in a beautiful ethereal blue glow. During post-processing I was careful to avoid oversaturating the colours as I feel the more subdued palette suits this subject well."

Equipment: Moravian G4-16000 CCD camera, TeleVue NP127is apo refractor, 10 Micron GM 2000 HPS II mount.

***BBC Sky at Night Magazine* says:** "This is one of the most crisp, clear and detailed images of the region we've ever seen. The detail around the Cone Nebula (near the centre) is incredible; so too are the wisps of nebulosity, the dark patches of dust and the countless stars stretching out into the cosmos."

About Chris: "I have been interested in astronomy since the age of 10, inspired by Patrick Moore. Over the past few years I have concentrated on imaging all sorts of objects, from wide-field vistas of galactic nebulae to small galaxies and planetary nebulae."

▲ The Soul Nebula

PAUL FEARN, NORWICH, 28 DECEMBER 201

Paul says: "This is a two-pane mosaic across the centre of the nebula, as it is too big for my field of view. The main battle was with the weather: two nights at –3.5°C, and another hoping to pierce the low lying fog."

Equipment: Atik 314L+ CCD camera, Sky-Watcher Equinox 80 ED apo refractor, Sky-Watcher HEQ5 Pro SynScan mount.

▲ The Orion Nebula

GÁBOR SZENDRŐI, KENDIG, HUNGARY, 23 DECEMBER 2016

Gábor says: "Hungary was covered in a thick blanket of fog with only the highest summits sticking out. My father and I hiked up Kendig, a 726m peak in the Kőszeg Mountains, and found that the fog in the valley had diminished the effect of light pollution, transforming the mountain top into an exceptionally dark observing site."

Equipment: Modified Canon EOS 700D DSLR camera, GPU 100/635 apochromatic refractor, Sky-Watcher AZ-EQ6 GT mount.

◀ Jupiter

PAUL WILLIAMSON, ABU DHABI, UAE, 7 JANUARY 2017

Paul says: "Another 3am start on the final day of my Christmas leave was greeted by wall to wall cloud. At 4am I decided a quick snooze was in order and reset the alarm for 5am. On arrival outside again I was treated to a clear sky and some good seeing conditions. I spent the next 90 minutes shooting only Jupiter, switching between my mono and colour cameras."

Equipment: ZWO ASI224MC CMOS camera, Celestron EdgeHD 14 Schmidt-Cassegrain, Celestron CGEM DX mount.

▲ Star trails and solar panels

MARK PELLEYMOUNTER, CHAPEL LANE SOLAR FARM, DORSET, 2 JANUARY 2017

Mark says: "During winter months when the Milky Way is not at its most spectacular, I like to create star trails to show Earth's rotation, but these kind of images need a strong foreground interest. The hardest part was balancing the light pollution from a nearby town with the sky."

Equipment: Canon EOS 7D DSLR camera, Sigma 10-20mm lens.

◀ The Tarantula Nebula

RAFAEL COMPASSI, BRAZIL, 22 DECEMBER 2016

Rafael says: "This is not an easy target because of the light pollution on the southern horizon from Porto Alegre and the surrounding cities. Even in southern Brazil, the Tarantula Nebula never rises above 50°."

Equipment: Modified Canon EOS Rebel T1i 15.1 DSLR camera, Sky-Watcher Explorer 200P Newtonian reflector, Astronomik CLS CCD clip filter.

▼ Mars, Venus and crescent Moon

BRENDAN ALEXANDER, MAGHERY, COUNTY DONEGAL, IRELAND, 1 JANUARY 2017

Brendan says: "The beach at Maghery on the western coast of Donegal has a Napoleonic-era tower overlooking it. I tried a few exposures with my telephoto lens but it just wasn't doing the scene justice. The clouds were moving in so I decided to try a wide-angle shot with a longer exposure to capture all surroundings and this image was the result."

Equipment: Canon EOS 6D DSLR camera, Sigma 20mm lens.

▲ Trio of craters

SZABOLCS NAGY, WIMBLEDON, LONDON, 4 JANUARY 2016

Szabolcs says: "I have trees all around my balcony, so my session was cut short as the Moon began to play hide and seek. Luckily, some finer details still came through."

Equipment: ZWO ASI120MC CMOS camera, Sky-Watcher 12/1500 Maksutov-Cassegrain, Sky-Watcher Allview mount.

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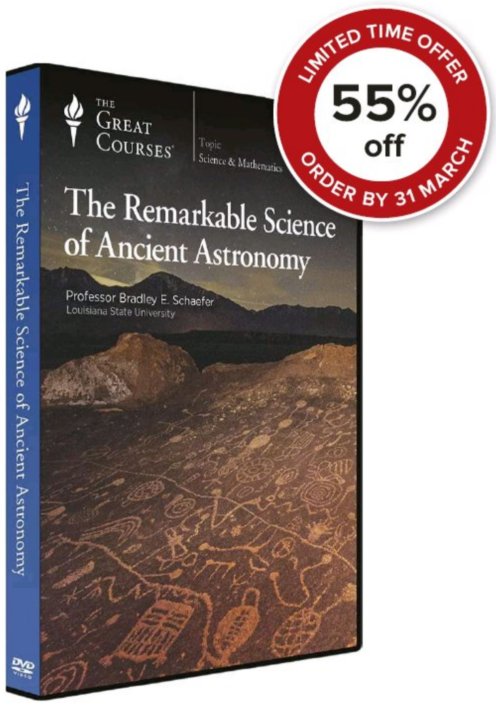

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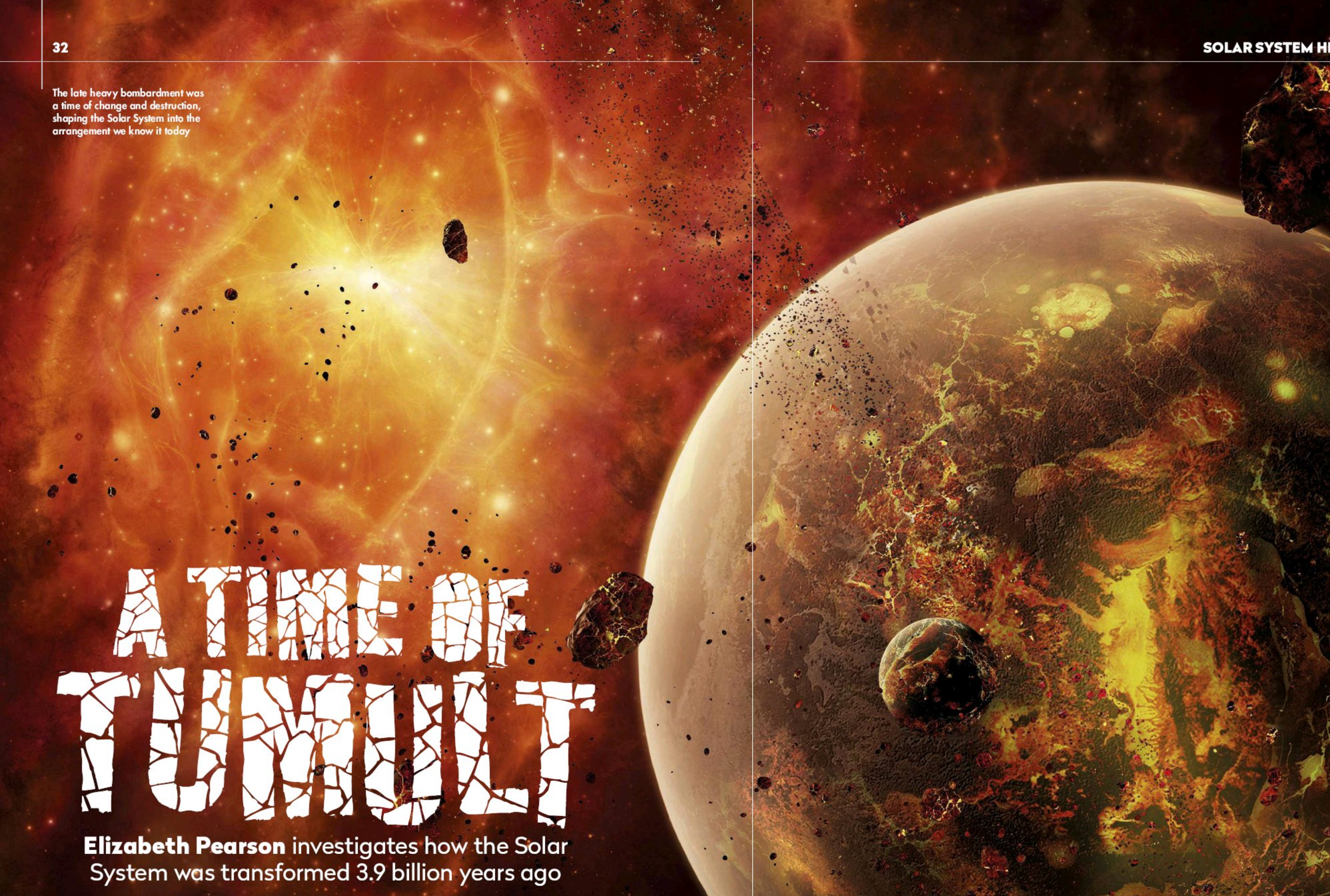


The late heavy bombardment was a time of change and destruction, shaping the Solar System into the arrangement we know it today

A TIME OF TUMULT

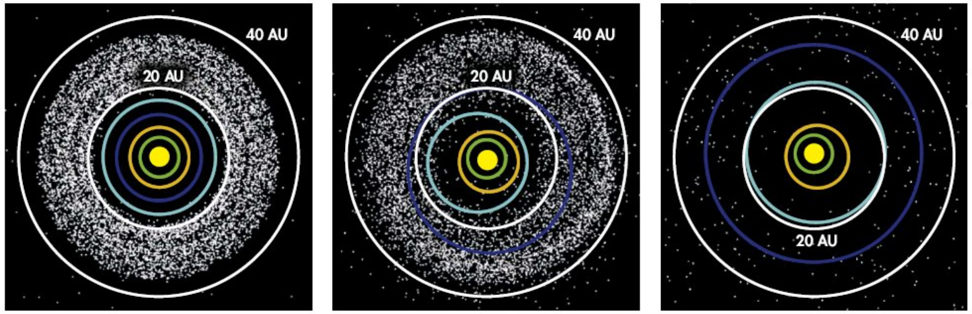
Elizabeth Pearson investigates how the Solar System was transformed 3.9 billion years ago

When the Solar System first formed 4.5 billion years ago it was a violent place. But quickly, by 4.4 billion years or so ago, the planets had calmed into a familiar configuration – several rocky inner worlds surrounded by gas giants ringed by icy objects. Then, four billion years ago, something catastrophic happened. The planets were thrown once more into chaos, and the face of the Solar System changed forever. This period of upheaval reveals startling truths about the evolution of our home planetary system, and perhaps the origins of life itself.

In the Solar System's first hundred million years or so, the beginnings of planets clumped together from the dust of a boiling protoplanetary disc around our young star. Frequently the young planets would collide and grow larger, ►

ISTOCK

ABOUT THE WRITER
Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s news editor. She gained her PhD in extragalactic astronomy at Cardiff University.



▲ The Nice model shows how the icy bodies of the Kuiper Belt could have scattered inwards, upsetting the gravitational balance of the gas giants in the early Solar System. In this example, the turmoil resulted in Neptune and Uranus swapping places in the planetary line-up

▸ though sometimes they would be destroyed entirely. To start, this early Solar System was much like it is today, but there were several key differences.

"Today, we have giant planets from Jupiter at about 5 AU from the Sun to Neptune at about 30 AU," says William Bottke from the Southwest Research Institute in Boulder, Colorado; 1 AU is the distance between the Earth and the Sun. "Modelling work shows the ice giants Neptune and Uranus would never have reached their current sizes if they had to form in the current configuration of the planets. Studies suggested instead that all these bodies formed between about 5 and 20 AU. Beyond that lies the Kuiper Belt. What's interesting about the Kuiper Belt now is that a lot of objects have very special orbits, called resonances. It's very hard to get them into these resonances."

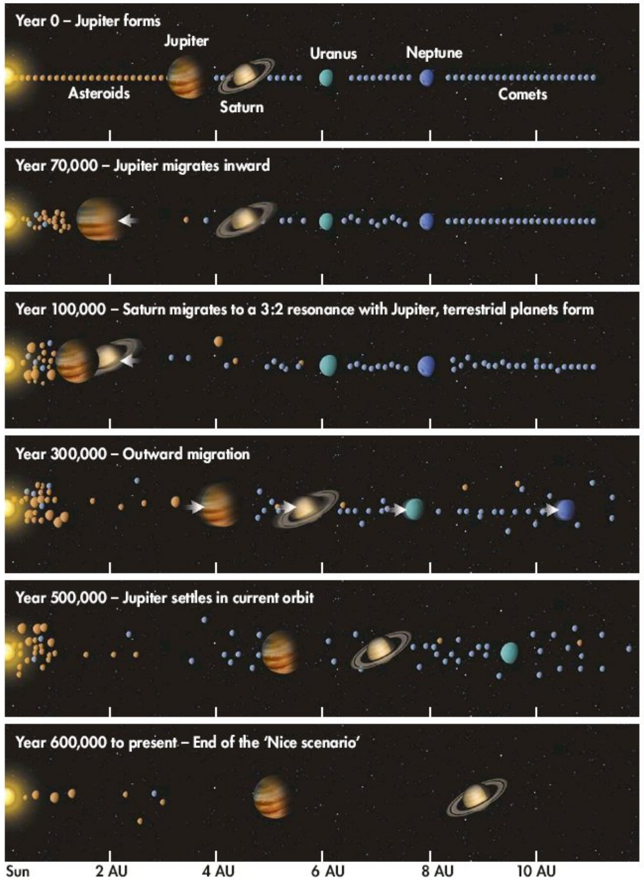
Synced surprise

A resonant orbit occurs when the ratio between the orbits of two bodies is two whole numbers. Pluto and Neptune share a resonance: for every two orbits Pluto makes, Neptune completes three. To explain what might have caused these resonances, as well as the change in the ice giants' positions, a group of researchers in Nice, France, came up with what is now known as the Nice model in 2005.

"They suggested that you had a gigantic Kuiper Belt with maybe 10 Earth masses in it," says Bottke. "This lets you form Neptune and Uranus on reasonable timescales and you can make lots of Pluto-like objects in the primordial disc."

Using this setup, the team created a computer model of the early Solar System. It's thought that a few hundred years after the formation of Jupiter, leftover gas dragged on the planet and caused it to drift deeper

ILLUSTRATIONS BY PAUL WOOTTON, ISTOCK, NASA/JPL/SPACE SCIENCE INSTITUTE, NASA/JPL, NASA/JOHNS HOPKINS UNIVERSITY APPLIED PHYSICS LABORATORY/CARNEGIE INSTITUTION OF WASHINGTON, NASA/USGS



▲ It is thought that Jupiter was the main catalyst behind the planetary migration of the Solar System. Even after the giant planets formed, there was still a lot of gas and dust left behind that decayed Jupiter's orbit, causing it to migrate into the inner Solar System before swinging back out. By the end of its journey the rest of the Solar System was completely reordered

THE LASTING EFFECT

The effects of the bombardment can be seen in more than just the craters left behind

Titan

Saturn's largest moon, Titan, is now covered in a thick nitrogen atmosphere but it's unclear when this was created – during the moon's formation or at a later date. If it formed with the moon, then it must have been much thicker as the bombardment would have blasted much of the gas away. Alternately, it could be that the bombardment provided the energy needed to liberate the gas from ammonia ice on the moon's surface.

Ganymede

Despite being similar in size and composition, Jovian moon Ganymede is very different from its sister, Callisto. While the former has a tectonically evolved surface and a differentiated core, the latter does not. One explanation is that a giant impact struck Ganymede, but not Callisto. The energy from this collision enhanced geologic processes, causing a fully separated iron core and subsurface ocean to form.

Mercury

The Caloris Basin, the largest impact basin on Mercury, was formed during the late heavy bombardment. The collision that created the 1,550km-wide site is thought to have been strong enough that it sent shockwaves through the entire planet, creating an undulating terrain on Mercury's other side. It's also been supposed that the impact could have kickstarted volcanic activity on the planet, which created its smooth plains.

Mars

Bombardment would have melted Mars's subsurface ice and produced enough heat to create a temporary climate that might have had the right conditions for life to start. Unfortunately, such conditions would have only lasted a few million years, before the constant shelling began to erode away more atmosphere than it created. By the end of the era, Mars was the cold and dry planet that we recognise today.

into the Solar System. In time this caused the giant planets to fall into a resonance and their combined gravity acted on the surrounding Kuiper Belt objects, pulling them inwards. In turn, these bodies pulled on the orbits of the gas giants. Though only a small effect compared to that of the planets, little by little the icy rocks began to upset the precarious gravitational balance.

"They found that when the system becomes unstable, Uranus and Neptune move into the primordial disc and actually migrate across it. The giant planets end up with almost identical orbits to what we see today," says Bottke.

This would have thrown the Solar System into disarray. According to the model, Jupiter moved inward while the other gas giants moved out. In turn, the inner planets were jostled and shuffled, pulling some of them into highly eccentric orbits which might have flung some of our siblings out into the Galaxy.

"There's pretty compelling evidence that we didn't start with four giant planets, but five. We had an extra Neptune and then lost it in this process. Jupiter is so massive that anything that encounters it has a good chance of being thrown out of the Solar System," says Bottke.

The addition of a fifth planet to the Nice model also helps to explain observations of the small bodies around Jupiter, as well as certain aspects of the asteroid belt. Could it be that our long-lost sibling is currently floating between the distant stars?

Mass migration

But planets are not the only things that the Nice model predicts being relocated during this time. The Kuiper Belt currently contains around the same mass as Mars, meaning that during this planetary reshuffle, 99 per cent of its mass would have been redistributed. Many Kuiper Belt bodies have been sent hurtling towards the inner Solar System. And it's the scars left behind by these impacts that could help explain a lunar mystery that has been around since the first moonrock samples were brought back by the Apollo missions.

"Many of the Apollo samples, more than you would expect, had been melted in impacts that took place around 3.9 billion years ago," says Barbara Cohen, a planetary scientist at NASA's Marshall Space Flight Center. "You would think that there would be a lot of impact craters from when the Moon formed 4.5 billion years ago, which would fall off as the impactors got used up, but we didn't see any. Instead we saw a lot at 3.9 billion years ago, which was a strange and unusual result."

Apollo scientists hypothesised that 3.9 billion years ago the inner Solar System was pelted with comet-like objects at an impact rate 100 times larger than what's seen today – an era now known as the late heavy bombardment (LHB).

However, all the Apollo samples came from a limited area of the Moon, close to the large Imbrium Basin. This 1,150km-wide crater is the result of a huge impact 3.85-3.9 billion years ago, which then flooded with lava. While this is one of the largest examples of the effect the LHB had on the lunar landscape, there is also the ▸

THE BOMBARDMENT OF EARTH

Despite the exteme conditions of the bombardment, could life have survived the LHB?

On Earth the end of the late heavy bombardment (LHB) coincides with another important epoch for our planet – the emergence of life.

When the LHB was first postulated it was thought that comet-like impactors may have brought the ingredients necessary for life, most notably water. However, findings from missions such as Rosetta show that it's unlikely comets brought any appreciable about of water to the Earth, though they may have brought other prebiotic compounds such as hydrocarbons.

Another theory is that life emerged long before the bombardment, but that all evidence was eradicated by the barrage. If this was so, then only the hardiest of life would have survived. An impact large enough to affect the global environment would have struck every century or so. And around every 10 million years there would have been an impact large enough to melt up to 10 per cent of the surface.

But even such colossal collisions would not have destroyed all havens for life across the planet. While the top few kilometres of ocean might boil away, there could still be enough water left behind for life to survive.

"It's quite possible that life started before, and found ways to protect itself," says Herbert Frey of NASA's Goddard Space Flight Center. "I think life is pretty hardy once it gets started, and it may have found a way to survive through that."

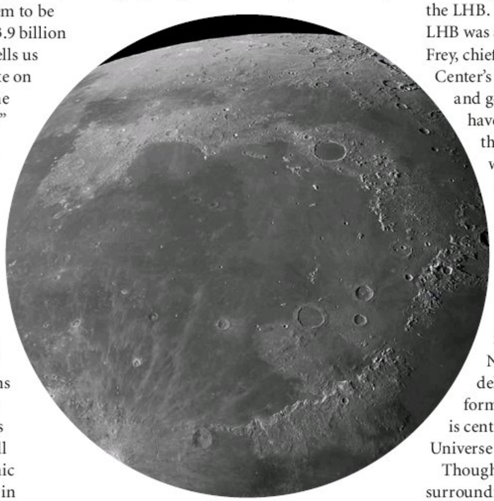
▸ chance that all the Apollo samples were simply the ejecta of this one event. To create a bigger picture Cohen had to look towards our only other samples from the Moon – lunar meteorites.

"The meteorites I've been looking at are from places that the astronauts didn't go, they have different geochemical signatures so we think they are from faraway places," she says. "I didn't find any of them to be very old. We see a big pile up at 3.9 billion years, with a long tail off. This tells us there was a prolonged impact rate on the Moon, and then over time the impacts got smaller and smaller."

The same old story

Other meteorites from the asteroid Vesta tell much the same story, indicating a lack of impacts between four and 4.5 billion years ago. But relying on meteorites means that researchers investigating the bombardment history of the Solar System are constrained, as they can only study what happens to arrive on Earth. It's currently impossible to identify meteorites from Mercury and Venus, and all known Martian rocks are volcanic in origin. This leaves large holes in the impact timeline, ones that are unlikely to be filled until we can test the craters directly. Luckily that day could come relatively soon.

"I'm developing an instrument that we could take to Mars to find impact craters and get geochronology on them," says Cohen. "It would have a precision of around 100 million years, a few per cent the age of the crater. That's good enough to distinguish major geologic events in the planet's history."



▲ All Apollo samples come from the region of the Imbrium Basin – they may all be its ejecta

MARK GARLICK/SCIENCE PHOTO LIBRARY, STEVE MARSH

The recent renaissance in lunar missions means we could soon understand the Moon's history a little better. China's Chang'e programme aims to return the first sample from the Moon in over 40 years in late 2017, and then to land the first ever probe on the far side of the Moon in 2019.

A full impact history will prove useful in solving one of the main debates around the LHB. "The question is whether the LHB was a unique event," says Herbert Frey, chief of NASA Goddard Space Flight Center's planetary geology, geophysics and geochemistry lab. "Astronomers have always been keen to know if this is an impact rate spike or whether it is the tail end of a bombardment that had been going on for a long time and we're just seeing the ones that managed to survive because they came in last."

Understanding the precise timing of the bombardment is key to those considering the Nice model. The length of the delay between the Solar System's formation and the bombardment is central to working out what our Universe looked like before the migration.

Though there are still many mysteries surrounding this era this one is certain – our Solar System became a very different place four billion years ago. ⓢ

Secrets of the AURORA REVEALED

The emerald aurora, seen over Yellowknife in Canada here, is the result of complex interactions between Earth's magnetic field and the solar wind

ISTOCK X 2

Physicist **Melanie Windridge** goes on a mission to the Canadian Arctic to discover why the sky glows green

Stargazers know of the complexity of the heavens, and of the way that observing something can give us insight into the physical processes that shaped it. This is the case, too, with the aurora, despite its diaphanous, capricious nature. Aurorae occur at the footprints of magnetic field lines, so by studying patterns in the aurora we can learn about processes happening out in space.

Canada has a particularly wide view of the auroral canvas and this has shaped the way auroral research is done there. Back in August 2014, I visited just a couple of these observatories – the Athabasca University Geophysical Observatory in Athabasca, and the AuroraMAX observatory in Yellowknife. I was researching for a book about the northern lights – a natural step for a plasma physicist with a fascination with mountains and snow. It was a journey that took me to various Arctic locations learning about the culture, folklore, landscapes and science of the aurora. The science itself is fascinating and varied, combining astronomy, geology, magnetism, atomic physics and more.

Broad benefits

The breadth of Canada's auroral zone means scientists can cover a range of spatial scales in their research: what this means is that they can look in detail at a small area or more broadly at a wide area. Researchers in Scandinavia, with their narrow slice of the auroral oval, use high-tech instruments to make detailed measurements on the smaller scale. Satellites can look at the large, global scale. However, those in Canada can look at the mid-scales with fairly cheap instruments spread over a large region. Funding has been ▸

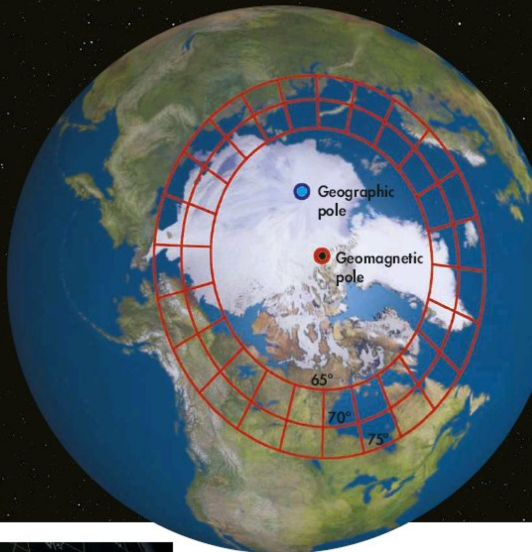
ABOUT THE WRITER
Melanie Windridge is a plasma physicist, speaker and writer with a taste for adventure. Her recent book *Aurora: In Search of the Northern Lights* is out now in paperback.

THE AURORAL ZONE

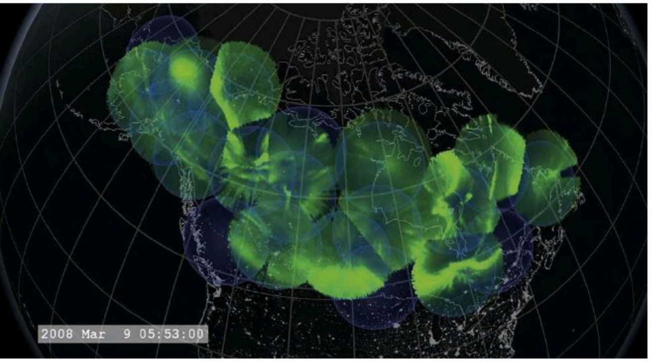
There's a region on Earth where the skies play regular host to the Northern Lights

Earth has a magnetic field rather like a bar magnet in space. The geomagnetic field is fundamental to the creation of the aurora, where charged particles are accelerated down magnetic field lines into Earth's atmosphere, so auroral activity occurs in a ring centred on the magnetic poles.

The auroral zone is the land above which we generally see the aurora, by definition at midnight. It is a band demarcated by magnetic latitude, stretching approximately 1,300km between around 61°N and 73°N magnetic, based on probability. Magnetic latitude differs from geographic latitude because Earth's magnetic axis is not orientated precisely north-south; it is tilted towards Canada in the northern hemisphere, so the auroral oval reaches to lower latitudes in North America than on the other side of the planet. The vast majority of land situated in the auroral zone belongs to Canada.



► Map of the Arctic showing the auroral zone. The ovals are lines of latitude. Canada has the bulk of the land in the auroral zone.



▲ All-sky camera images can be combined to make an aurora map that covers all of Canada

► put into setting up the wide infrastructure, stretching from the east coast at Goose Bay to Inuvik in the far northwest, and managing the large amounts of data that are generated. The approaches are different yet complementary, but they are shaped by the landscape and geographical advantage.

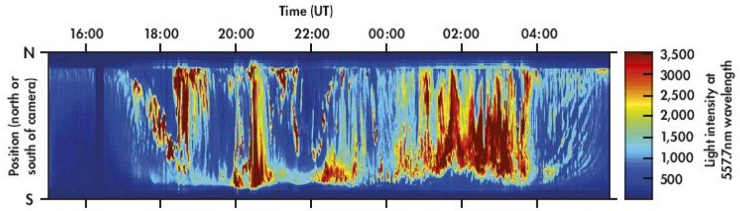
There are tens of these observing stations with similar cameras dotted around the large country. In Athabasca it was a six-domed facility housing other instruments; in Yellowknife, a wooden garden shed with a dome cut into the peaked roof. This and electricity are all you need for automated auroral imaging.

The observing stations are fitted with commercial CCD-based digital cameras that have been modified with state-of-the-art lenses by a team at the University of Calgary, and topped by a fisheye lens to give a wide, circular field of view. Pointing directly upwards, the cameras look out in a cone from horizon to horizon, so they're called all-sky imagers. Up at the altitude of the aurora (around 100km), the field of view is about 1,000km across, so when the images of several cameras are merged together they form a mosaic of aurorae across the entire continent. The cameras turn on at nautical twilight, collect images every six seconds and transmit data via satellite in real time.

Data from these cameras' all-sky images is often analysed by turning it into a keogram, which broadly shows how the aurora varies over a night, both over time and over the ground. These go back to the time when we couldn't make moving videos of the aurora so easily, though they still have scientific value now for quick reference and easy publication.

Modified CCDs with fisheye lenses sit within these domes in Athabasca; inset, the author inside one of them

ILLUSTRATIONS BY PAUL WOOTTON, NASA GODDARD SPACE FLIGHT CENTER SCIENTIFIC VISUALIZATION STUDIO, MELANIE WINDRIDGE X 2, © LANCASTER UNIVERSITY



▲ A keogram made from Digital All-Sky Imager (DASI2) data in the familiar green wavelength (557.7nm). The plots show the auroral activity over an entire night so provide a good, at-a-glance overview. The camera is located near Tromsø, northern Norway

Tracking the lights

Keograms are made by taking a single north-south slice from the centre of every all sky image taken throughout a night. These are then lined up sequentially from left to right. This creates a kind of graph where the X-axis is time and the Y-axis is sky position relative to the camera; the bright parts show the position of the auroral arc. Keograms therefore show the north-south movement of the aurora over time, which in turn provides information about the changes occurring in the Earth's magnetic field.

This information is important to auroral physicists because although the cyclical process that causes the aurora – known as the Dungey Cycle – is now an established concept, there are still elements of the process that scientists don't understand. The magnetic reconnection that causes the aurora is triggered by instabilities that scientists are still trying to fathom.

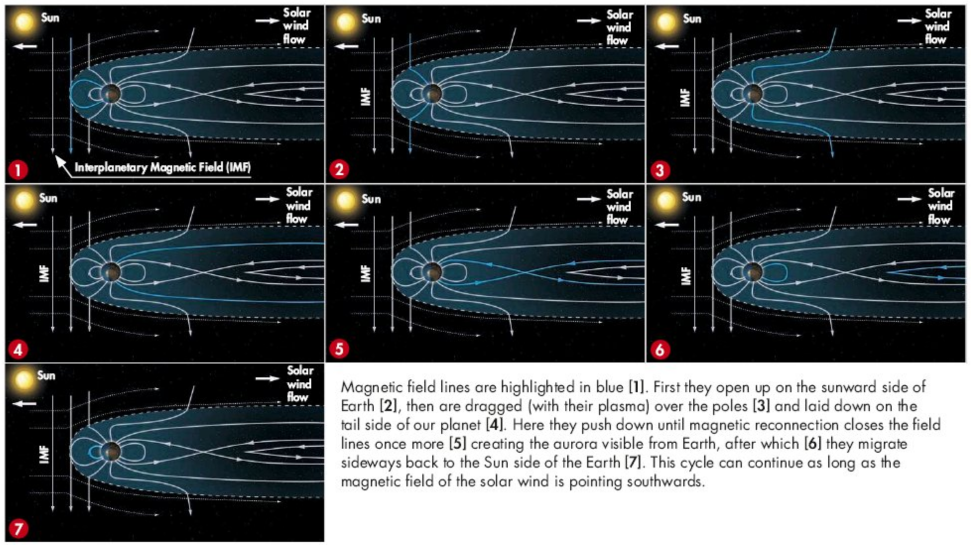
"What causes that instability to start the reconnection process and start closing off the magnetic field on the night side is not well understood," says Jim Wild, professor of space physics at Lancaster University. "Quite what the mechanism is – and where that starts – is one of the big questions."

Even now we have space-based measurements, images from the ground are still valuable. It's the combination of technologies that provides the greatest insight. The advantage of imaging from the ground is better resolution; a downside is clouds blocking the aurora from view.

Specialist all-sky imaging enables scientists to locate particular features of the aurora. "You can work out the position of the feature from some ►

THE DUNGEY CYCLE

The dancing lights are generated by invisible magnetic field lines that dance themselves



Magnetic field lines are highlighted in blue [1]. First they open up on the sunward side of Earth [2], then are dragged (with their plasma) over the poles [3] and laid down on the tail side of our planet [4]. Here they push down until magnetic reconnection closes the field lines once more [5] creating the aurora visible from Earth, after which [6] they migrate sideways back to the Sun side of the Earth [7]. This cycle can continue as long as the magnetic field of the solar wind is pointing southwards.

AURORAL ORIGINS

How solar particles interact with our planet's magnetic field to create a dazzling light show

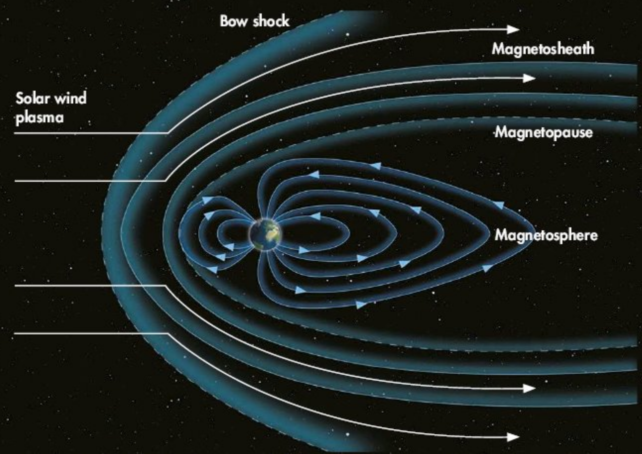
The origins of the aurora rest with our star. The Sun is always throwing out charged particles – mostly electrons and protons – in a moving plasma that we call the solar wind. On top of this, sometimes it releases more matter into the Solar System when the twisted magnetic field lines of the Sun break in a solar eruption or even a giant coronal mass ejection.

A coronal mass ejection is enormous! The Sun throws billions of tonnes of matter out into the Solar System, travelling at millions of kilometres an hour. We and all the other planets in the Solar System sit in this turbulent sea of plasma. This solar wind is constantly buffeting the Earth, sometimes weakly, sometimes strongly.

All these fast charged particles would be dangerous to life, but Earth has a magnetic field, that forms a protective shield called the magnetosphere. The solar wind interacts with Earth's magnetic field, and if the magnetic field in the solar wind points southwards, the interaction is particularly strong; it sets up a cycle of changes in Earth's magnetic field pattern.

This is called the Dungey Cycle and involves magnetic field lines being opened on the sunward side of the planet and closed again behind in a process called magnetic reconnection, where magnetic field lines snap and rejoin in a different configuration. This explosive process accelerates electrons into the Earth's atmosphere on the night side of the planet, causing the aurora.

The aurora is the way our planet protects itself from the battering of the solar wind, absorbing the energy in its magnetic field and dissipating it in a beautiful light show.



▲ As the solar wind hits Earth's magnetic field it is deflected around the outside, flowing in a layer called the magnetosheath. The cavity of the Earth in the solar wind is called the magnetosphere and its boundary is the magnetopause

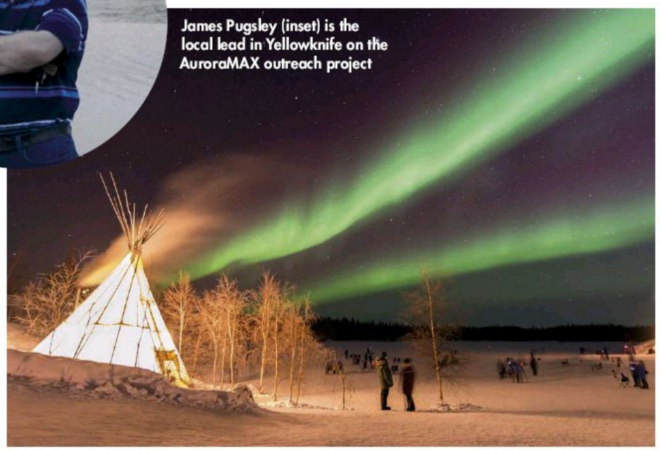
▸ relatively straightforward geometry," says Wild. "There's lots you can do with this quite simple technology."

Studying the auroral features gives insight into the mechanisms out in the magnetosphere – instabilities, wave activity, motions of plasma and boundaries. The aurora we see is like the image projected onto a screen created by a disturbance further out.

The outreach impact

Back in Yellowknife, I met with James Pugsley, president of the Astronomy North Society, who is responsible for local support of the observatory. He's also the voluntary local lead on the AuroraMAX outreach project. He sees it as a huge opportunity to be able to support and promote the science.

"If observation is the key to making discoveries then I will do it! I will go out and watch the aurora for the greater good," he joked. But it is fascinating how through this outreach, the Northern Lights are able to stir something deep inside us – an awed, spiritual response – even though their origins are no longer a mystery. Of course, there is still more to know and one thing is certain; people will be watching and studying the aurora for a long time to come. S



James Pugsley (inset) is the local lead in Yellowknife on the AuroraMAX outreach project

ILLUSTRATION BY PAUL WOOTTON, MELANIE WINDRIDGE, ISTOCK

Grand Canyon National Park is a place of raw beauty – and hopefully by 2019, even darker skies

GRAND DESIGNS

Grand Canyon National Park is set to get a whole lot darker as it embraces its International Dark Sky status, writes Jamie Carter

For anyone after an uplifting experience from nature, the Grand Canyon almost has it all. By day you can stand anywhere along its South Rim and peer down nearly 2,000m into its layer-cake bands of red rock, taking you back two billion years into Earth's deepest history. When the Sun goes down, the combination of a high elevation and dry desert air means clear, cloudless night skies are common. So why doesn't the Grand Canyon National Park have a particularly high reputation among amateur astronomers and astrophotographers?

Five million visitors per year, that's why. Most of them visit Grand Canyon Village on the South Rim, which is easily accessible from Flagstaff in Arizona and only a few hours from Las Vegas in neighbouring Nevada. Over the years the undeniably picturesque properties on the South Rim added lighting. And then more lighting. Even the pathways along the rim were floodlit.

This wilderness gateway is now a major light polluter, but that's all set to change in the wake of the June 2016 announcement that the reserve has been provisionally designated as an International Dark Sky Park. This certification is awarded by the International Dark-Sky Association (IDA), a US-based organisation that encourages others to maintain the darkness of the night sky for future generations.

ABOUT THE WRITER
Eclipse-chaser and dark skies expert Jamie Carter is the author of *A Stargazing Program for Beginners: A Pocket Field Guide*

The 'provisional' status reflects the complex job ahead. There are thousands of light fixtures on both rims and within the canyon itself, and the National Park Service has set a deadline of June 2019 – the park's centenary year – to retrofit two-thirds of them to comply with the IDA's lighting guidelines.

Harking back to darker times

"Technology is coming along nicely, with excellent night sky and eye-friendly choices now on the market, with prices that are becoming competitive with more common fixtures and bulbs," says Jane Rodgers, deputy chief science and resource management at Grand Canyon National Park, who applied for the Dark Sky Park status. "Backpackers and campers within the canyon will look up at the South Rim and see fewer, more subdued lights, most of which are illuminated only for a few hours after sunset and an hour or so before sunrise. The general aesthetics will hark back to the time when the village was first developed, where the natural world dominated and visitors experienced the feel of an amazing night sky."

The Milky Way imaged from Grand Canyon National Park

Not that the national park doesn't already promote itself as a dark-sky destination. Its rangers are well informed about the night sky, and a star party has been held here each June for over a quarter of a century. The next one, 17-24 June 2017, will include talks ▸

iSTOCK, © NPS & GRAND CANYON NATIONAL PARK

DARK PARKS

These 10 US National Parks – most but not all official Dark Sky Parks – are free from urban light pollution, offering some of the darkest and clearest night skies in the world

Natural Bridges National Monument, Utah
The first Dark Sky Park is a favourite of astrophotographers who like to image the Milky Way streaming through the famous Owachomo Bridge.

Grand Canyon-Parashant National Monument, Arizona

Not to be confused with Grand Canyon National Park, this Dark Sky Park is one of the most remote in the US. It spans 1.05 million acres, in the region north of the Colorado River.

Chaco Culture National Historical Park, New Mexico

This Dark Sky Park offers evening night-sky programmes that include constellations of the native Chacoan people, as well as telescope viewing at Chaco Observatory and two annual star parties. Drive three hours south and you can tour the Very Large Array facility.

◀ Arches National Park, Utah

Arches is another iconic location for astrophotographers – not to mention a designated Dark Sky Park where 'night-sky rangers' give regular talks and lead stargazing sessions. Head to the Delicate Arch viewpoint for a great panoramic.

Dead Horse Point State Park, Utah

An hour from Arches, Dead Horse Point offers fantastic views from above a gooseneck in the Colorado River. The campgrounds are excellent, and night-sky rangers also run a programme of stargazing talks and events.

▲ Canyonlands National Park, Utah

Designated in 2015, this Dark Sky Park in southeast Utah now has almost 100 per cent night sky-friendly lighting. Island in the Sky is a great vantage point where a regular night-sky rangers programme in summer is followed by stargazing and telescope viewing.

Bryce Canyon National Park, Utah

Though not an IDA-certified park, Bryce has a long tradition of night-sky education, with 100 astronomy lectures per year held at the visitor centre, followed by guided telescope observing in the car park. A star party is held each June.

The Headlands, Michigan

This Dark Sky Park, an area of undeveloped land along Lake Michigan, is best visited in conjunction with nearby, car-less Mackinac Island. There's no camping here, but there is a dedicated dark sky viewing area on the shoreline.

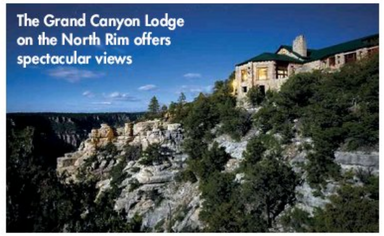
Cedar Breaks National Monument, Utah ▶

Another destination not officially recognised, this stunning geologic amphitheatre hosts an award-winning summer star party at Point Supreme each Saturday night between Memorial Day and Labor Day (the last Monday in May and the first Monday in September). The 3,000m altitude really helps clarity. Stay in Brian Head or nearby Cedar City.

Cherry Springs State Park, Pennsylvania

One of the few Dark Sky Parks in the eastern US, Cherry Springs has its own night-sky viewing area located north of Route 44. Stargazing benches are provided, as well as a summer sky map backlit in red light. Two major star parties are hosted each year.

▲ Mather Point is perhaps the best stargazing spot on the South Rim, and it's only 10 minutes from the visitor centre



The Grand Canyon Lodge on the North Rim offers spectacular views

▸ in the visitor centre, constellation tours and free telescope viewing outside the building and at nearby Mather Point, a 10-minute walk away on the rim.

The north-south divide

At other times of year (May to September pretty much guarantees a dry climate and crystal clear night skies), there are night-time walks and talks by rangers, who often set up a telescope for public use. Amateurs and professional astronomers from nearby Lowell Observatory in Flagstaff (where Clyde Tombaugh discovered Pluto) make visits, while on the darker North Rim, the Saguaro Astronomy Club of Phoenix set up telescopes on the porch of the Grand Canyon Lodge.

Mather Point is the best place for stargazing on the South Rim, though Rodgers is looking into establishing a designated night-sky viewing area. Nearby Hermit's Rest and the many pullouts on the flat Rim Trail are perfect, as are the remoter Desert View and Lipan Point on the South Rim, about 30km drive from Grand Canyon Village.

Alternatively, pitch a tent in one of the reserve's campgrounds. Here you may well find a ranger who can point out the local Navajo tribe's giant constellations: the First Revolving Male, First Revolving Female and the Central Fire. You'll recognise them; they're based on the Plough, Cassiopeia and Polaris, respectively. The constantly turning circumpolar stars represent the Navajo ideal home of a husband, a wife and an abode. By protecting natural darkness as well as the natural landscapes, Grand Canyon is itself committing to a beautiful billion-year marriage all of its own. Ⓢ

The night sky from Chaco Culture National Historical Park on the Colorado Plateau

KEEPING THE COLORADO PLATEAU DARK

Tour the national parks of the southwestern US and you'll mostly remain on the Colorado Plateau, a vast area of high desert, red rock and forests covering 330,000km², and home of the darkest skies in the contiguous 48 states. Covering Arizona, Utah, Colorado and New Mexico, it's here that you'll find eight of the 11 US National Parks that have been certified as Dark Sky Parks – from Canyonlands, Arches and Capitol Reef to Natural Bridges, Grand Canyon-Parashant and Chaco Culture.

"I can't emphasise enough the increasing rarity of places like the Plateau," says John Barentine, programme manager at the International Dark-Sky Association in Phoenix, Arizona. "We saw this recently with the release of the new *World Atlas of Artificial Sky Brightness*, which showed that about 70 per cent of the land area of the US is in a state of perpetual twilight at night, never reaching natural levels of darkness."

Of the 30 per cent that's left, there is nowhere other than on the Colorado Plateau where so much land is readily accessible to the public as national parks. "That's the argument for creating even more Dark Sky Parks there," says Barentine. "With each new park we designate, we add to the total land area on the plateau that's under protection, making it highly likely that the average tourist in the region will hear the dark skies message at least once during their travels."

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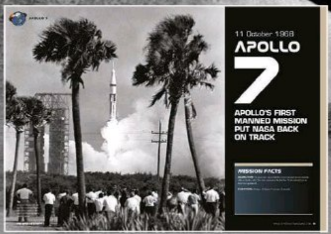

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PETE LAWRENCE

WRITTEN BY **PETE LAWRENCE**

Pete Lawrence is an expert astronomer and astrophotographer with a particular interest in digital imaging. As well as writing *The Sky Guide*, he appears on *The Sky at Night* each month on BBC Four.

THE SKY GUIDE MARCH

PLUS

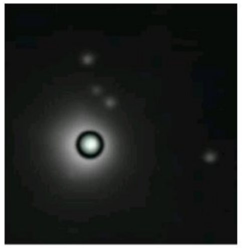
Stephen Tonkin's BINOCULAR TOUR

Turn to page 60 for six of this month's best binocular sights

During the spring months the waxing crescent Moon is particularly well placed in the early evening sky. In March, there are some favourable librations to look out for too, giving us the opportunity to see a little farther around the lunar limb than usual.

MARCH **HIGHLIGHTS**

Your guide to the night sky this month



WEDNESDAY 1 ▶

The waxing crescent Moon (12% lit) is 4° south-southeast of mag. +5.9 Uranus and 4.9° south of mag. +1.3 Mars this evening. The planets are separated by 2°, Uranus lying to the southwest of Mars.

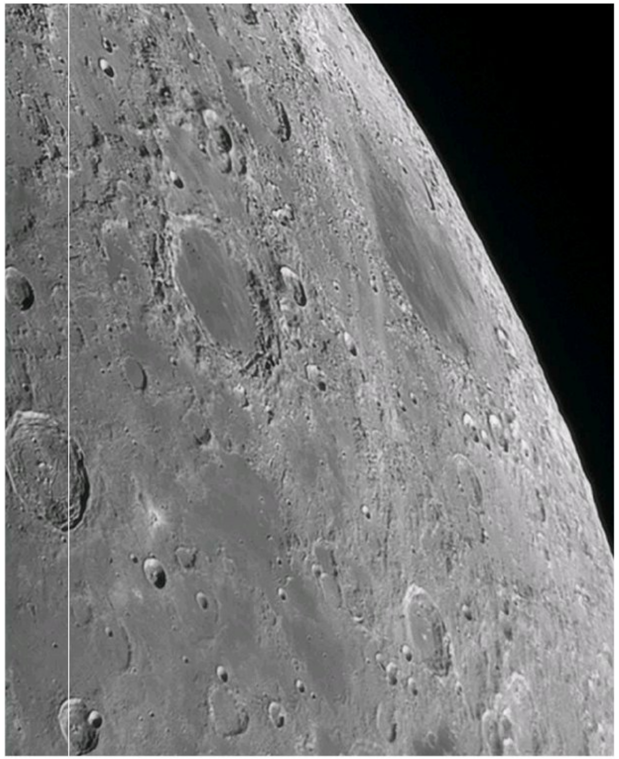
THURSDAY 2

Jupiter is well-positioned for a moon and shadow transit of Ganymede this evening. The shadow transit starts at 22:39 UT on 2 March, ending at 01:10 UT on 3 March. Ganymede transits between 02:06 UT and 04:02 UT on the 3rd.

SATURDAY 4

A lunar occultation of the Hyades cluster in Taurus begins at 20:00 UT. The Moon sets before the occultation ends.

Outer Galilean moon Callisto is just off Jupiter's northern limb at 22:00 UT. Io can also be seen off Jupiter's western limb at this time.



◀ THURSDAY 9

Tonight's waxing gibbous Moon (92% lit) shows a favourable libration for the eastern limb, bringing features such as the Mare Marginis and the Mare Humboldtianum into view.

FRIDAY 10

There's another chance to catch Ganymede and its shadow transiting Jupiter this morning. The shadow transit occurs between 02:37 UT and 05:06 UT, the moon transit between 05:30 UT and 07:26 UT.

SATURDAY 11

This evening Uranus sits just 11 arcseconds from the mag. +8.3 star HIP 6513 in Pisces. Look from 20:00 UT, when the star will lie just 3 arcseconds from Oberon, the outermost of Uranus's bright moons.

TUESDAY 14

The Moon appears close to mag. +2.7 Porrima (Gamma (γ) Virginis) at 00:13 UT, with a true occultation visible from Cornwall and southwest Ireland. It sets after dawn; when it rises again at around 21:00 UT, it'll be just 1.8° from mag. –2.2 Jupiter.

WEDNESDAY 15

Jupiter appears to have an extra moon this evening. This is because it is passing close to the mag. +10.8 star TYC 4964-1346-1. The planet rises around 20:30 UT.

SUNDAY 19

It's inner Galilean moon Io's turn to transit Jupiter. Watch from 23:30 UT. The moon's shadow begins its passage at 23:44 UT, with Io following suit at 00:11 UT on the 20th. The shadow transit ends at 01:55 UT, while the moon leaves the disc at 02:21 UT.

MONDAY 20 ▶

Saturn and the waning gibbous Moon (54% lit) appear 4° apart at 04:00 UT.

The northern hemisphere's spring equinox occurs at 10:29 UT.

WEDNESDAY 22

Ninth-magnitude comet C/2015 V2 Johnson is approximately 3° from mag. +9.4 globular cluster NGC 6229 in Hercules from now until the end of the month.

FRIDAY 24

Jupiter is close to mag. +11.8 star GSC 4964-597. As darkness falls, star and planet are 5 arcminutes apart. By dawn twilight on the 25th, the gap will be 2.5 arcminutes. At 03:29 UT on the 25th – the star will be 8 arcseconds from Ganymede.

PETE LAWRENCE X 5

◀ SATURDAY 25

The Moon visible in the morning sky shows a favourable libration for the western limb.

Venus reaches inferior conjunction, after which it will be a morning planet. See this month's Sky Guide Challenge.

SUNDAY 26

The clocks go forward at 01:00 UT, marking the start of British Summer Time (BST). BST is one hour ahead of UT.

TUESDAY 28 ▶

Seventh-magnitude comet 41P/Tuttle-Giacobini-Kresak is located to the north of the Plough's pan.

WEDNESDAY 29

Mag. –0.3 Mercury is 8° north of a thin waxing crescent Moon (3% lit) at 20:30 BST (19:30 UT) in twilight. They form a celestial triangle with Mars. Look for all three low in the west.

THURSDAY 30

Mag. +1.5 Mars is 6° north of tonight's waxing crescent Moon (9% lit). See them together with mag. –0.2 Mercury low in the west from 20:30 BST (19:30 UT).

FRIDAY 31

This evening the waxing crescent Moon (18% lit) is close to the Hyades and Pleiades open clusters in Taurus.

FAMILY STARGAZING – 9 MAR

The Moon will be visible from just before 15:00 UT today. If the sky is clear, see if you can find the Moon during the day. If not, wait for darkness to fall. Point out that the Moon's face is not uniform but contains bright and dark patches. The dark patches are known as 'seas' but contain no water. They are full of lava which has cooled and solidified. The brighter regions are called the lunar highlands and are higher than the seas. After looking at the Moon for a while, present a piece of paper and pencil, inviting your young observers to draw the Moon's disc.

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 lies 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 OPPORTUNITY
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**

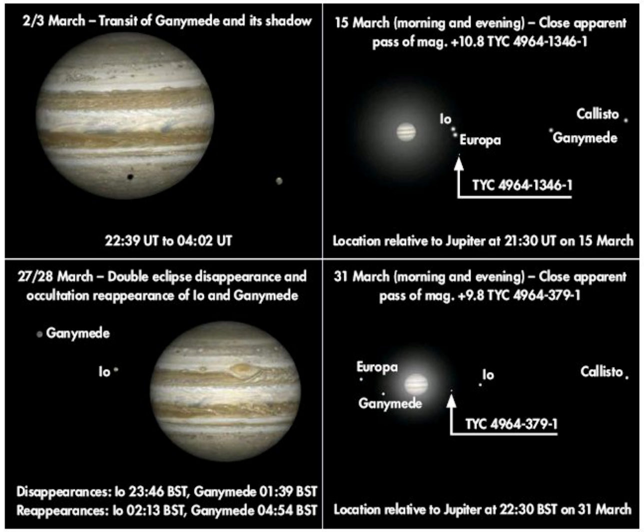
Jovian moon events

WHEN: Throughout March as specified

Jupiter is well positioned for viewing this month, providing some interesting and unusual opportunities close to and around the planet's disc. On 1 March it appears close to two 11th-magnitude stars, mag. +11.7 TYC 4965-932-1 and mag. +11.1 TYC 4965-61-1. On the 2nd you can witness a transit of Ganymede and its shadow, beginning at 22:39 UT and concluding at 01:10 UT on 3 March; Ganymede itself transits between 02:06 UT and 04:02 UT. On 4 March, the outer Galilean moon Callisto appears close to Jupiter's northern limb at 22:00 UT.

A less favourable Ganymede plus shadow transit occurs on the morning of 10 March. The shadow transits between 02:37 UT and 05:06 UT, but the dawn twilight is well underway as Ganymede begins its crossing at 05:30 UT, moving off disc after sunrise at 07:26 UT, as Jupiter is setting.

The waning gibbous Moon (94% lit) rises in close proximity to Jupiter at around 20:30 UT on 14 March. They



▲ Some of the many Jupiter transits, occultations and close passes taking place this month; in these illustrations south is up, as you'd expect to see when viewing Jupiter through a telescope

remain close into the early hours of 15 March, enhanced by the presence of mag. +1.0 Spica (Alpha (α) Virginis) 5° to the south. Viewing Jupiter through a scope at this time should reveal mag. +10.8 star TYC 4964-1346-1 to the west of the planet, though it may look like an additional faint moon. The star is 2 arcminutes east of Jupiter (and close to Europa and Io) at 21:30 UT.

Dark Callisto close to Jupiter's north limb; you can expect a similar sight on 4 March

PETE LAWRENCE X 4

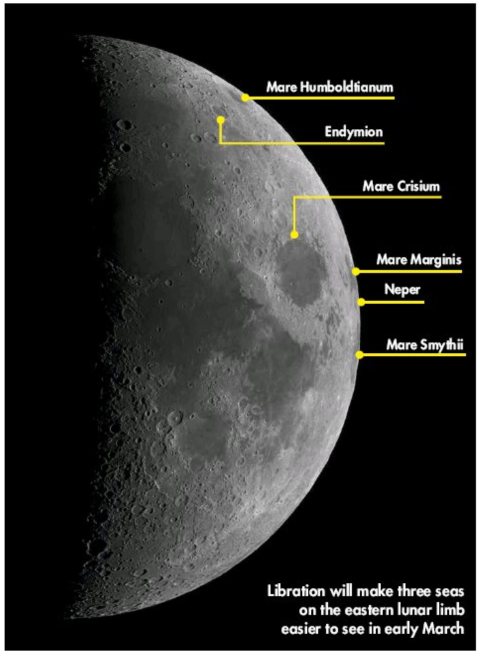
Another stellar encounter occurs on the morning and evening of 25 March when mag. +11.8 GSC 4964-597 appears close to the planet. See if you can spot the faint star 8 arcseconds north of Ganymede at 03:30 UT on 25 March.

There's a good Io plus shadow transit on the morning of 27 March. Io's shadow transit begins at 02:38 BST (01:38 UT), the moon's transit at 02:55 BST (01:55 UT). The shadow passes off disc at 04:49 BST (03:49 UT) with Io following at 05:05 BST (04:05 UT). Later that evening, Io and Ganymede experience a double eclipse-occultation event. At 23:46 BST (22:46 UT), Io is eclipsed by Jupiter's shadow. Ganymede follows suit at 01:39 BST (00:39 UT) on the 28th. Both moons then reappear from occultation behind Jupiter's east limb; Io at 02:13 BST (01:13 UT), Ganymede at 04:54 BST (03:54 UT) during twilight.

As darkness falls on 29 March, two mag. +9.8 stars (TYC 4964-178-1 and TYC 4964-299-1) appear close to Jupiter's disc, above and below the orbital plane of the four Galilean moons. On the morning and evening of 31 March, Jupiter encounters mag. +9.8, TYC 4964-379-1 in line with the moons. All four moons are brighter than mag. +6.0; the star will be identifiable because it'll appear much dimmer.

Good librations

WHEN: 5-12 March and 23-24 March



The Moon rotates once on its axis in the same time it takes it to complete an orbit of Earth. The net result of this is that we always get to see the same face of the Moon – well, almost always. Variations in the Moon's orbital speed caused by its elliptical orbit combine with variations from a 5° orbital tilt, to give us an extra peek around the edge on occasion.

This cumulative effect is called lunar libration. Catching sight of lunar features in what are known as the libration zones – the regions of the Moon right on the limb that move in and out of visibility for earthbound observers – can be tricky. The complication arises because a favourable libration must coincide with a favourable lunar phase when the Moon is in a good position in order to be useful. There's no benefit in a feature being libration favoured if the phase places it in the dark of a lunar night.

On the evening of 9 March, libration favours the Moon's eastern edge. The Moon's 92% phase at this time means this region will be brightly lit and devoid of relief shadows. This works out well for viewing for nearby seas, which include the Mare Humboldtianum, close to 125km-wide crater Endymion. Another libration sea is the Mare Marginis, (close to the limb by the Mare Crisium) and the Mare Smythii (south of the Mare Marginis). Also look out for dark-floored, 138km-wide crater Neper, which sits between these two seas. Libration is favourable for these features from 5-12 March.

A similar good libration for the western limb occurs from 23-27 March but this time the circumstances aren't so great. The Moon will be a waning crescent and very low just before sunrise on these dates. If you can get a look, part of the tantalising Mare Orientale will be on view.

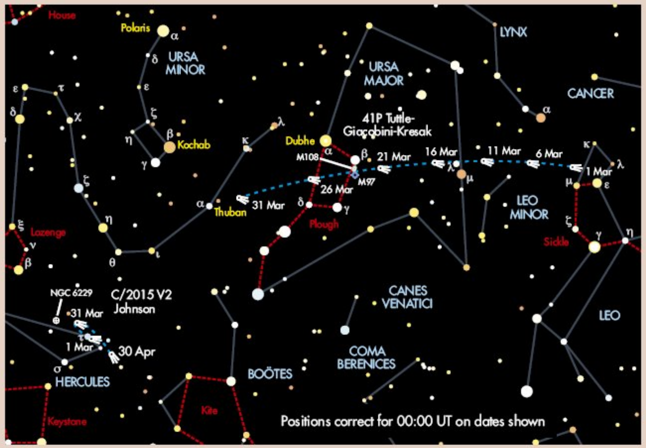
March comets

WHEN: All month; Moon interferes between the 8th and 16th

It's said that comets are like cats: they are unpredictable and will do as they please. Perhaps a better description is that they are like buses. You wait ages for a relatively bright one to come along and then there are several at once.

There are a couple of binocular comets visible this month. In Hercules, passing very close to mag. +3.9 Tau (τ) Herculis on the night of 3/4 March, is C/2015 V2 Johnson. This icy visitor heads a short distance towards globular cluster NGC 6229 throughout March, ending up a little over 2° to the west of the cluster by the end of the month. The comet brightens throughout March from +9.1 to +8.1.

Then there is comet 41P/Tuttle-Giacobini-Kresak, which brightens from mag. +10.0 at to a respectable +6.9 during the month. Unlike C/2015 V2 Johnson, 41P travels a fair distance, starting off to



▲ C/2015 V2 Johnson makes little progress, but 41P/Tuttle-Giacobini-Kresak is a fast mover

the north of the Sickle in Leo and ending up just north of the Plough's pan's pan. It is close to mag. +3.5 Lambda (λ) Ursae Majoris on the nights of 12/13 and 13/14 March, and M108 and M97 in Ursa Major on 21/22 and 22/23 March. It'll be mag. +7.0 at this time and close enough to mag. +2.3 Merak Beta (β) Ursae Majoris that centring the star in a binocular field will easily include the comet in the view.

THE NORTHERN HEMISPHERE IN MARCH

KEY TO STAR CHARTS

CHART: PETE LAWRENCE

WHEN TO USE THIS CHART

1 MARCH AT 00:00 UT
15 MARCH AT 23:00 UT
31 MARCH AT 23:00 BST

On other dates, stars will be in slightly different places due to 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 MARCH*

DATE	SUNRISE	SUNSET
1 Mar 2017	06:57 UT	17:48 UT
11 Mar 2017	06:34 UT	18:07 UT
21 Mar 2017	06:09 UT	18:25 UT
31 Mar 2017	06:45 BST	19:43 BST

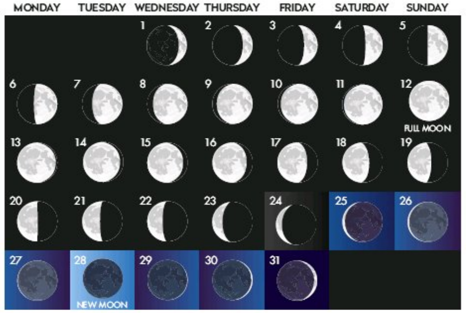
MOONRISE IN MARCH*

MOONRISE TIMES

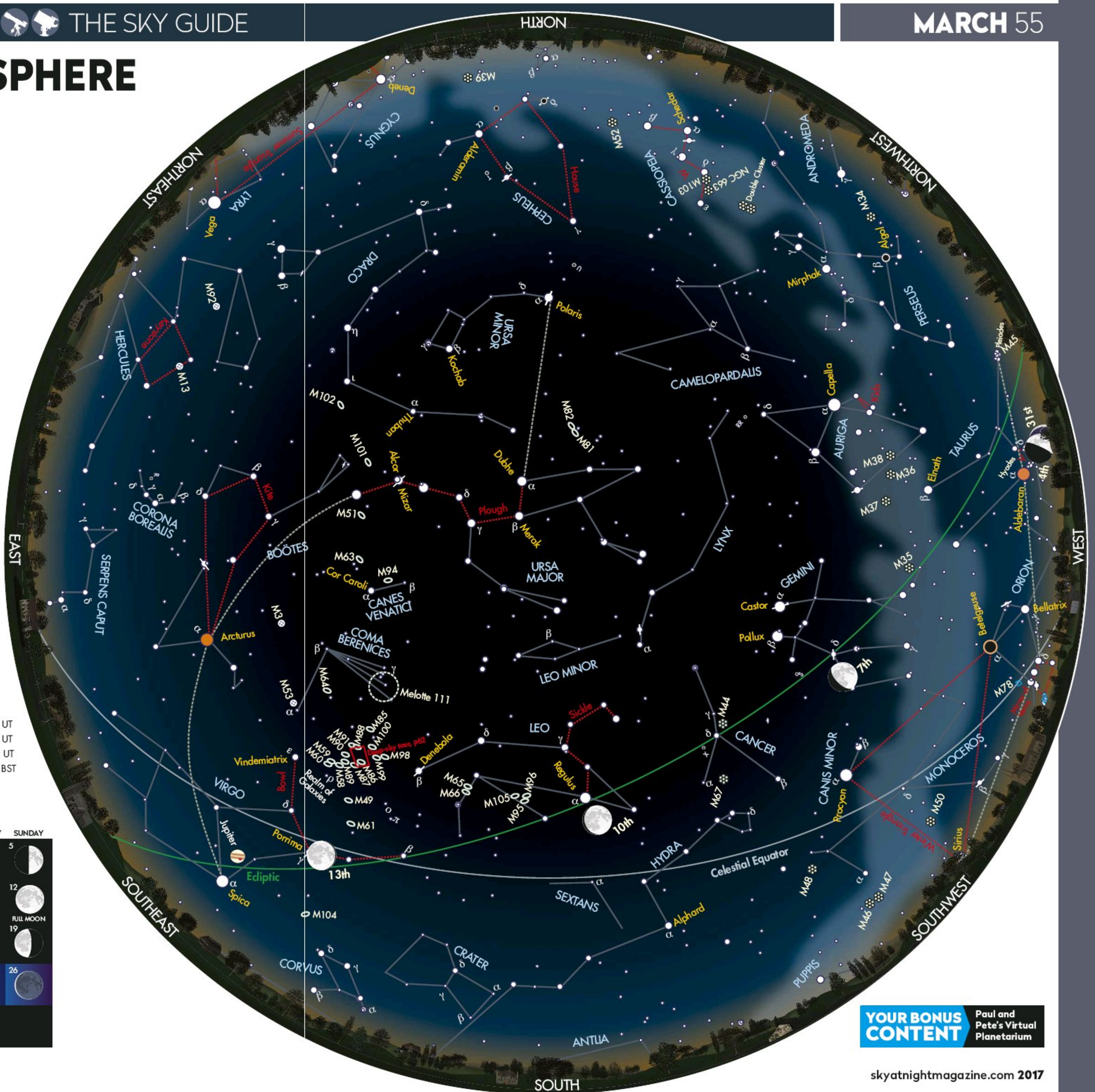
1 Mar 2017, 08:22 UT	17 Mar 2017, 23:39 UT
5 Mar 2017, 10:33 UT	21 Mar 2017, 02:28 UT
9 Mar 2017, 14:31 UT	25 Mar 2017, 05:02 UT
13 Mar 2017, 19:16 UT	29 Mar 2017, 07:49 BST

*Times correct for the centre of the UK

LUNAR PHASES IN MARCH



MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY	SUNDAY
		1	2	3	4	5
6	7	8	9	10	11	12 FULL MOON
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28 NEW MOON	29	30	31		



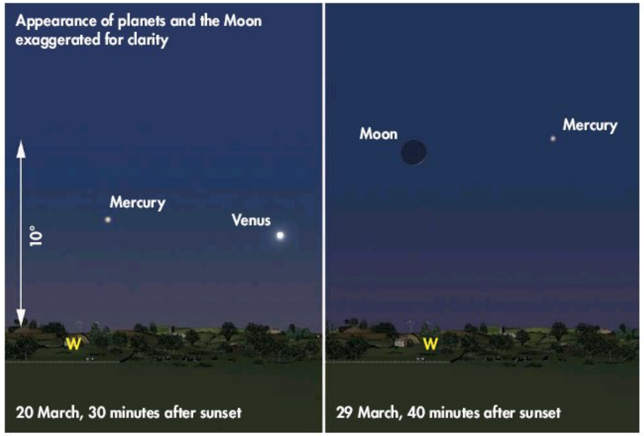
YOUR BONUS CONTENT Paul and Pete's Virtual Planetarium

THE PLANETS

PICK OF THE MONTH

MERCURY

BEST TIME TO SEE: 19 March, 18:50 UT
ALTITUDE: 6° (low)
LOCATION: Pisces
DIRECTION: West
FEATURES: Phase, surface shading occasionally visible through larger scopes
EQUIPMENT: 3-inches or larger



▲ Mercury never strays far from the ecliptic, but is up longer after sunset as it nears elongation

Mercury reaches superior conjunction on 6 March, so it can't be seen at the start of the month. However, the planet makes a rapid and impressive recovery mid month, due mainly to the steep angle the ecliptic makes with the western horizon at sunset at this time of year. Mercury never veers that far from the ecliptic and so its position in the sky is at its best in the spring evening skies.

On 14 March it sets 40 minutes after the Sun, so look for it around 20 minutes after sunset. It will be shining at mag. –1.4. Mag. –4.2 Venus sits 13° above Mercury on this date. If you can manage to get a telescopic view of Mercury after the Sun has set, you'll see it has a tiny, 5-arcsecond disc that is almost a full circle. Mercury's phase on 14 March is 94% lit.

Over the following days Mercury will be travelling along a distant part of its orbit to Earth, but gradually getting closer to us. The situation continues to improve for the rest of the month, making this an excellent opportunity to spot this elusive planet. Although it can be tricky to identify Mercury in an evening twilight sky at first, once you've managed it for the first time, it becomes very much easier on subsequent evenings.

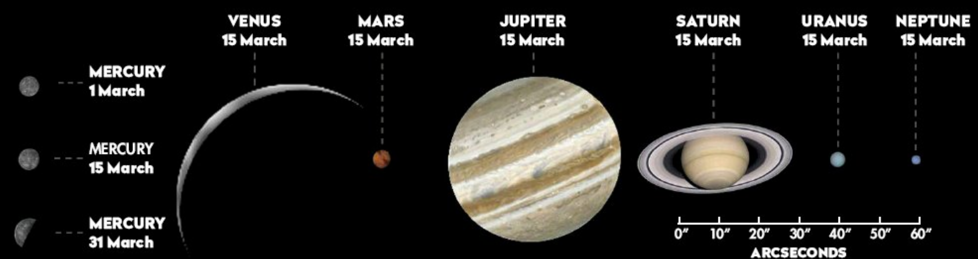
By 31 March, a telescope will show that its disc now appears 7 arcseconds across and just 43% lit. The planet remains bright, being mag. –0.1, and it sets two hours after the Sun. Greatest eastern elongation occurs on 1 April, when the innermost planet will appear to be separated from the Sun by 19°.

Mercury photographed with a smartphone camera in April 2016

PETE LAWRENCE X 3

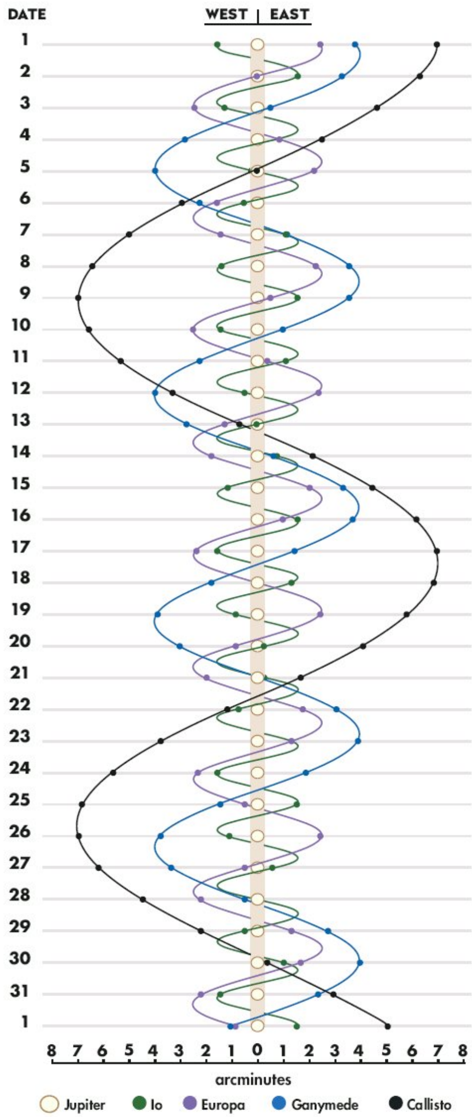
THE PLANETS IN MARCH

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



JUPITER'S MOONS MARCH

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



VENUS

BEST TIME TO SEE: 1 March, from 18:30 UT
ALTITUDE: 24°
LOCATION: Pisces
DIRECTION: West

Venus is a splendid sight at the start of March. Although it's heading back towards the Sun it remains well positioned until mid month, a result of the steep path of evening ecliptic coupled with the planet being north of this plane. Venus is currently on the part of its orbit closest to Earth. Consequently on 1 March it looks large through a scope, with an apparent diameter of 47 arcseconds. It's bright too, shining away at mag. –4.5. The planet remains nicely visible until mid March, after which it's almost as if someone has taken the brakes off. On 16 March, it sets 100 minutes after the Sun and appears almost 1 arcminute across with a phase of just 3% through the eyepiece. By 20 March it sets 70 minutes after the Sun and five days later it reaches inferior conjunction. Amazingly, its position north of the ecliptic brings it back into view in the morning sky quite rapidly. By 31 March it rises an hour before sunrise and shows a 58-arcsecond crescent at just 2% illumination through a scope.

JUPITER

BEST TIME TO SEE: 31 March, 01:50 BST (00:50 UT)
ALTITUDE: 30°
LOCATION: Virgo
DIRECTION: South

Jupiter reaches opposition early next month, making March an ideal time to start observing it. At the start of March Jupiter rises around 21:30 UT, reaching its highest point in the sky (culmination), due south at 03:00 UT. By the end of March its rise time is 20:30 BST (19:30 UT) in twilight. On the 31st, it culminates at 01:50 BST (00:50 UT). Through a scope its disc appears 44 arcseconds across on the 31st, and it shines at mag. –2.4. On the evening of the 14th, it rises above the east-southeast horizon with the Moon, at around 21:00 UT.

SATURN

BEST TIME TO SEE: 31 March, from 05:00 BST (04:00 UT)
ALTITUDE: 12.5°
LOCATION: Sagittarius
DIRECTION: South-southeast

Saturn is a mag. +0.5 morning object for most of the month. It is located in Sagittarius and has a low UK altitude. The rings are well presented, the planet's north pole being tilted towards Earth by 26.5°.

MARS

BEST TIME TO SEE: 1 March, from 19:20 UT
ALTITUDE: 23°
LOCATION: Pisces
DIRECTION: West-southwest

The waxing crescent Moon (12% lit) is 5° below and left of mag. +1.3 Mars on 1 March. Look with a pair of binoculars: the 6th-magnitude dot 2° below and slightly right of Mars is Uranus. Mars moves east against the stars for the remainder of the month, helping the planet maintain position against the horizon at the same time of evening. On the 30th the Moon rejoins the planet, its 9%-lit waxing crescent 6° to the east. Telescopically Mars appears a rather disappointing 4.3 arcseconds across, not much bigger than Uranus.

URANUS

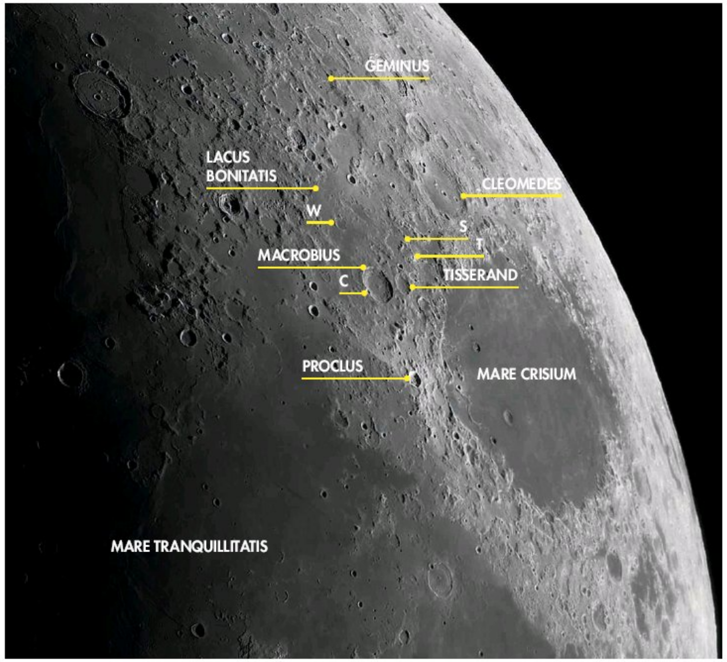
BEST TIME TO SEE: 1 March, 19:45 UT
ALTITUDE: 17°
LOCATION: Pisces
DIRECTION: West

We are now losing Uranus to the rapid growth of the evening twilight. At the start of March the planet is just 17° up as seen from the centre of the UK. When darkness falls at the end of the month, it will no longer be visible.

NEPTUNE

Not visible this month, being at solar conjunction on 2 March.

YOUR BONUS CONTENT Planetary observing forms



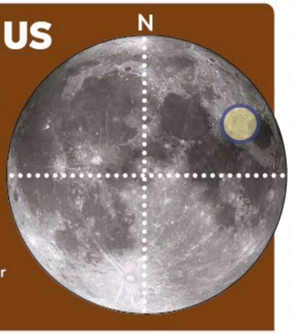
◂ Macrobius has a ridge thrown up from the Crisium basin running through it – though you'll be hard pressed to make it out

"When the Sun is low the terraced walls of the crater really come alive, showing intricate shadow detail"

MOON**WATCH**

MACROBIUS

TYPE: Crater
SIZE: 65km diameter
LOCATION: 46.0°E, 21.3°N
AGE: 3.80-3.85 billion years
BEST TIME TO SEE: Four days after new Moon or three days after full Moon (1-2 March, 15-16 March and 31 March)
EQUIPMENT: 2-inch refractor



Macrobius is a 65km-wide crater situated northwest of the distinctive dark oval of the Mare Crisium. It lies in the complex region of bright highland features interspersed by dark lava 'lakes' that sits between Crisium and the eastern region of the Mare Tranquillitatis. It's a distinctive feature with sharply defined walls. These terrace down to the floor, some 4km below. There appears to have been a significant slippage of material from the walls in towards the centre of the crater as the relatively flat inner floor has half the outer diameter of the crater's rim.

A small complex of peaks can be seen in the centre of Macrobius, which rise to fairly unimpressive heights of around 800m. As with all lunar features with physical height, the presence of a low Sun causes the central complex to have more prominence. At such times the terraced walls of the crater really come alive, showing intricate shadow detail that is fascinating to try and decode with higher magnifications. The rim is interrupted to the west by 10km Macrobius C, a feature that should be visible using a 4-inch or larger scope.

Crater Tisserand (36km) lies just to the east of Macrobius and is of similar age. Both are quite elderly compared to dramatic crater Proclus (28km), some 160km south of Macrobius and close to the western edge of the Mare Crisium. Proclus is a bright ray crater, estimated to have formed sometime over the past 1.1 billion years. Its rays spread across the dark lava floor of the Mare Crisium to the east, as well as covering some of the highland terrain to its northwest and north up towards Macrobius.

The flat dark feature to the northwest of Macrobius is the Lacus Bonitatis, the Lake of Goodness, and immediately to its north is Macrobius W (26km). There's not much of this crater left to see, its insides having been flooded with lava. All that remains is a rather irregular outline, best defined to the north and west. A similar fate appears to have befallen Macrobius S (26km) and T (29km) both east of the main crater and north of Tisserand.

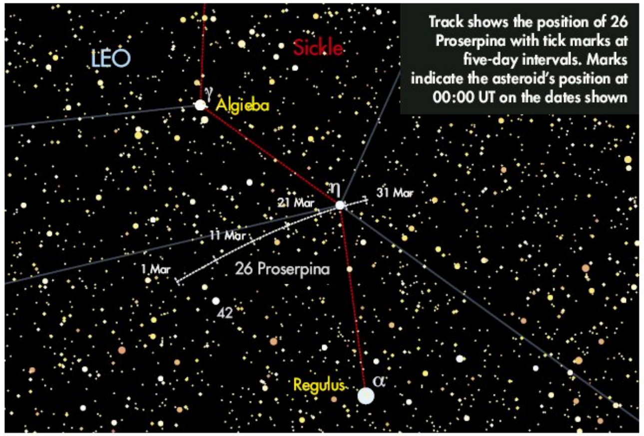
The impact basin of the Mare Crisium is more complex than it looks, with four concentric rings associated with the impact. The inner ring can be seen when the illumination is low over the mare surface. At such times it's possible to see wrinkle ridges defining this 375km-diameter feature. The next one, the 500km-diameter Crisium Ring, is defined by the visible edge of the mare itself. Outside of this are two additional rings, but these are very ill-defined and tricky to see.

The outermost is the 1,075km Geminus Ring, which passes through 86km-wide crater Geminus. In between is the vague form of the Cleomedes Ring, which passes through 126km-wide crater Cleomedes. The Cleomedes Ring arcs around the Mare Crisium, passing through Macrobius – though we have to emphasise that the outer rings are extremely difficult to make out.

PETE LAWRENCE X 3

COMETS AND **ASTEROIDS**

26 Proserpina, the asteroid named after the daughter of Ceres and Jupiter



▲ The rather large asteroid 26 Proserpina scythes through the Lion, passing closest to Eta Leonis

Asteroid 26 Proserpina is one of the 1.1-1.9 million bodies within the asteroid belt larger than 1km across – and with a diameter of 94x90km, it's at the upper end of the asteroid size spectrum. It was discovered in May 1853 by the German astronomer Robert Luther, his second asteroid discovery. It orbits the Sun at an average distance of 397.4 million km, taking 1,581.2 days to complete each trip. After a number of discrepancies in the reported rotation period, it's now known that 26 Proserpina spins once every 13.11 hours. This is a typical S-type asteroid, a name given to silicaceous asteroids that have a stony composition.

During March, 26 Proserpina is an 11th-magnitude object in Leo and requires a telescope to see. It dims from mag. +11.0 on 1 March to +11.6 by the end of the month, but ironically should be easier to spot when it is dimmer thanks to its proximity to mag. +3.5, Eta (η) Leonis. On 1 March, Proserpina is 1.2° to the northeast of mag. +6.2, 42 Leonis. The asteroid then tracks in a gentle west-northwest curve towards Eta Leonis, passing 30 arcseconds south of the star (as seen from the centre of the UK) at 21:00 UT on 24 March. As ever, the best way to identify whether you've actually seen 26 Proserpina is to photograph or sketch the stars in the suspected field of view. Compare similar results from subsequent nights and the asteroid should make itself known because of its movement.

The asteroid is named after the ancient goddess Proserpina, the daughter of Ceres and Jupiter in Roman mythology. Her Greek counterpart is the goddess Persephone, who also has an asteroid named after her, 49km 399 Persephone.

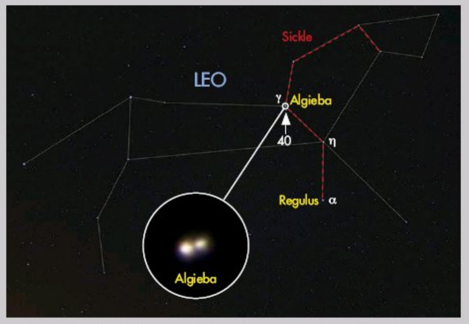
STAR OF **THE MONTH**

Algieba – the tight double whose name means 'forehead' but is part of the Lion's neck

The Sickle asterism, representing the neck and head of the Lion of Leo, is one of the most prominent patterns of the spring sky. It looks like a backward question mark, with the bright mag. +1.4 star Regulus (Alpha (α) Leonis) providing the punctuation dot. Located 4.8° north of Regulus is mag. +3.5 Eta (η) Leonis. Our target star is the next one along the Sickle, Algieba (Gamma (γ) Leonis). Shining at mag. +2.0, it is the most prominent member of the asterism after Regulus.

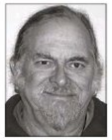
Algieba is a lovely double star formed from an orange-red primary and yellow secondary. A common trap for the unwitting observer is the mag. +4.8 star 40 Leonis, which is 22.5 arcminutes to the south of Algieba, an easy naked eye star. This is sometimes misidentified as the companion. The actual binary system is much tighter, separated by just 4 arcseconds. We'd recommend a 3-inch or larger scope at a magnification of 120x or more to split Algieba. Both stars are giants, taking 510 years to complete one orbit. The brighter star is 180 times as luminous as the Sun, the companion 50 times more luminous.

The distance to the system is estimated to be 126 lightyears, which means that the 4 arcsecond separation equates to a physical separation of around 170 AU – in other words, approximately four times the distance between Pluto and the Sun. The duo's position in the Sickle is odd considering Algieba's Arabic meaning of 'forehead'. If anything it appears located within the Lion's neck.



▲ Don't mistake 40 Leonis as being the companion – it's a decoy

In 2009 it was announced that a planetary system had been discovered around the primary star. To date, it's believed that there are two planets in orbit, one 8.8 times the mass of Jupiter at a distance of 1.2 AU with a period of 429 days. The presence of the other planet remains uncertain but, if it is there, it is estimated to be 2.1x the mass of Jupiter, orbiting 2.6 AU from the star, and taking 3.7 years to complete one orbit.



STEPHEN TONKIN'S BINOCULAR TOUR

A wild variable, a spectral oddity and a deceiving line of sight pair lurk in the region of Canes Venatici

☑ Tick the box when you've seen each one

1 M3

10x50 M3 is one of the best globular clusters in the northern sky. It's found at the midpoint of a line from mag. +3.0 Seginus (Gamma (γ) Boötis) and mag. +4.3 Diadem (Alpha (α) Comae Berenices), appearing as a severely defocused star. If you use averted vision by shifting your gaze to the bright star 0.5° to the southwest, you should notice that the defocused 'star' appears to brighten and grow. This is the glow of the globular's half a million stars. ☐ SEEN IT

2 17 CANUM VENATICORUM

10x50 Find mag. +2.9 Cor Caroli (Alpha (α) Canum Venaticorum) and navigate just over 2.5° in the direction of Seginus. You'll see a widely separated (4.6 arcminutes) pair of stars: mag. +5.9 17 Canum Venaticorum and mag. +6.3 15 Canum Venaticorum. This line-of-sight pairing illustrates how distance affects magnitude: although they appear to be of similar brightness, 15 Canum Venaticorum is six times farther away than 17 Canum Venaticorum, but 25 times as bright. ☐ SEEN IT

3 V CANUM VENATICORUM

15x70 Halfway between Cor Caroli and mag. +1.9 Alkaid (Eta (η) Ursae Majoris) there is a pair of 6th-magnitude stars separated by about 0.25°. Locate them, then pan 1.5° in the direction of 21 Canum Venaticorum where you should find, shining somewhere between mag. +8.5 and +6.5, V Canum Venaticorum. We are vague about the expected magnitude because, although it is often described as a variable with a period of 191.5 days and a range of +7.7 to +6.6, both its range and period have fluctuated wildly in recent years. ☐ SEEN IT

4 LA SUPERBA

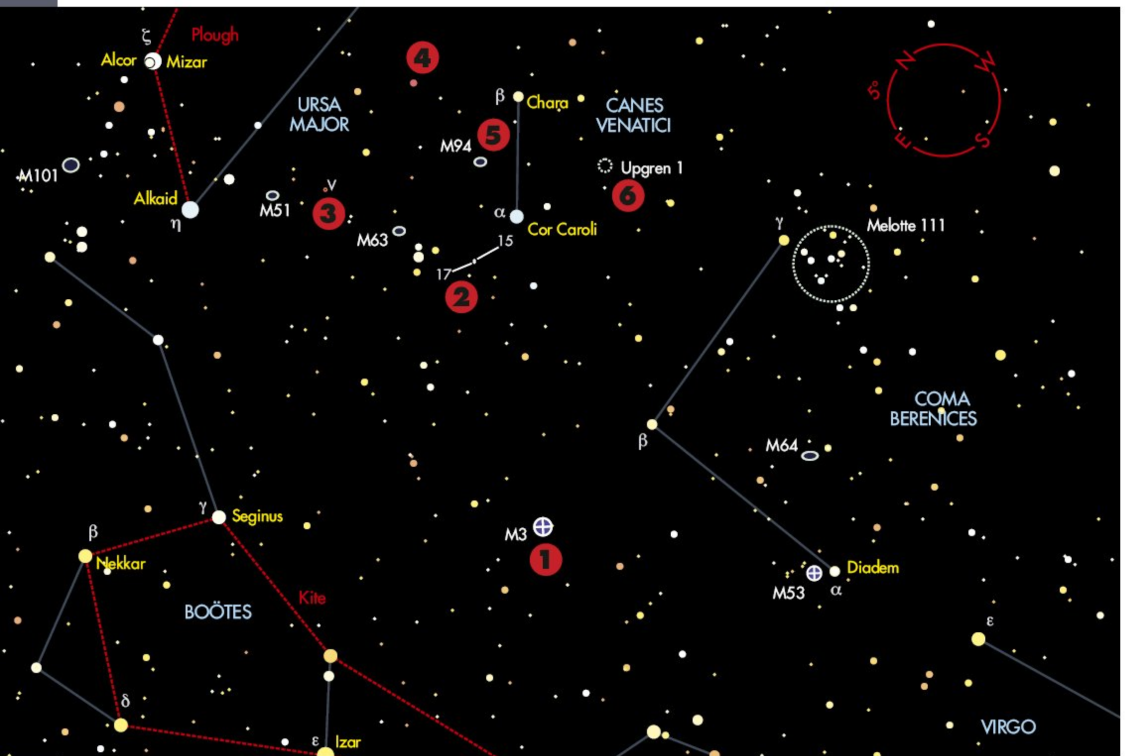
10x50 Locate mag. +4.2 Chara (Beta (β) Canum Venaticorum) and pan 4.5° towards mag. +2.2 Mizar (Zeta (ζ) Ursae Majoris). You'll find a pale orange star (it looks a deeper orange in larger apertures). This is Y Canum Venaticorum, a cool carbon star with a magnitude that varies from +6.3 to +4.7 in a period of about 160 days. Its common name, La Superba, may have led you to expect a more impressive sight, but it was not given because of its colour, but on account of its unusual spectrum, in which absorption lines from carbon compounds weaken much of the light from blue-violet end. ☐ SEEN IT

5 M94

10x50 Our next target is a galaxy. Return to Cor Caroli and imagine a line between it and Chara. At the halfway point, shift your gaze at a right angle for slightly more than 1.5°, towards Alkaid. Here you should find the faint glow of light that is mag. +8.9 spiral galaxy M94, though you may need to use averted vision. Viewing it is easier under dark, transparent skies, so if you are unable to see it in 10x50s either wait for better conditions or try larger binoculars. ☐ SEEN IT

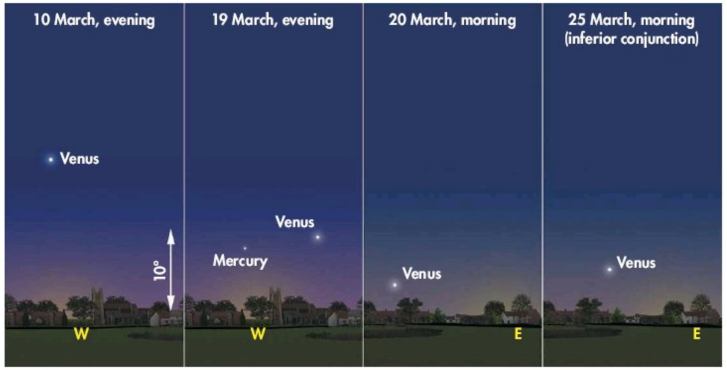
6 UPGREN 1

15x70 We finish with the enigmatic Upgren 1: is it a very old open cluster, two open clusters in the same line of sight, or merely an asterism? Return to the line between Cor Caroli and Chara, and imagine it as being one side of an equilateral triangle with the third apex to the southwest. Just inside this third apex, slightly closer to Cor Caroli, you should see a group of six 8th- and 9th-magnitude stars spanning about 14 arcminutes. Whatever its nature, this sole member of the Upgren Catalogue is a very pretty binocular object. ☐ SEEN IT



THE SKY GUIDE CHALLENGE

Follow Venus through solar conjunction as it moves from the evening sky to the morning



▲ Flat eastern and western horizons are needed to keep sight of Venus through inferior conjunction

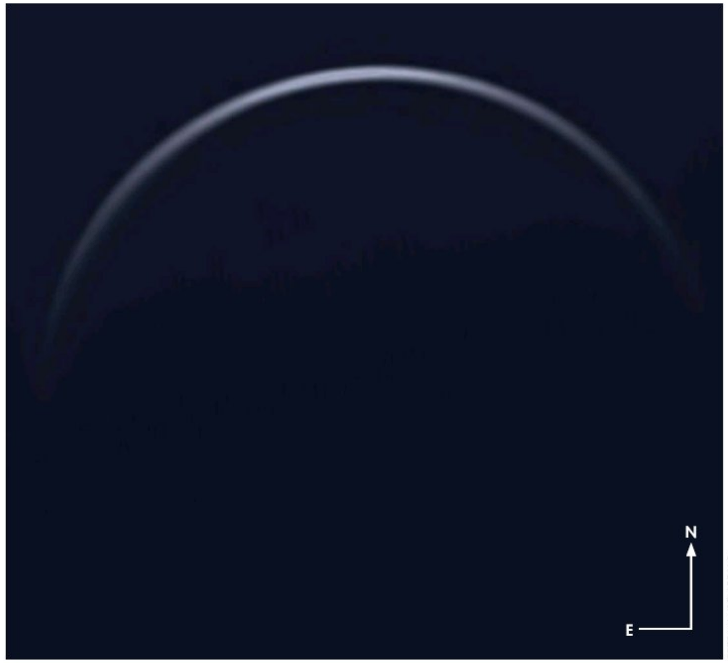
Hopefully, by the time you're reading this you will have been enjoying the spectacle of Venus, blazing away in the western part of the sky after sunset. Sadly this is all set to change as Venus approaches a position known as inferior conjunction, which occurs on 25 March. On this date the planet lines up with the Sun and should be lost from view. However, if the weather is favourable and you have flat western and eastern horizons, it should be possible to keep track of the planet throughout this period with the Sun safely below the horizon.

Of course any activity that requires you to work close to the Sun carries a risk. If any part of the Sun is up, it poses a real threat to your equipment and more importantly your eyes. Care and common sense must prevail at all times.

It should be possible to follow the planet in the evening sky with a telescope quite easily up until 20 March. The eyepiece view will be amazing, Venus showing a slender 16%-lit crescent on 1 March, slimming to just 2% lit on the 20th. It's also huge, measuring nearly an arcminute across, the largest apparent diameter of any planet seen from Earth.

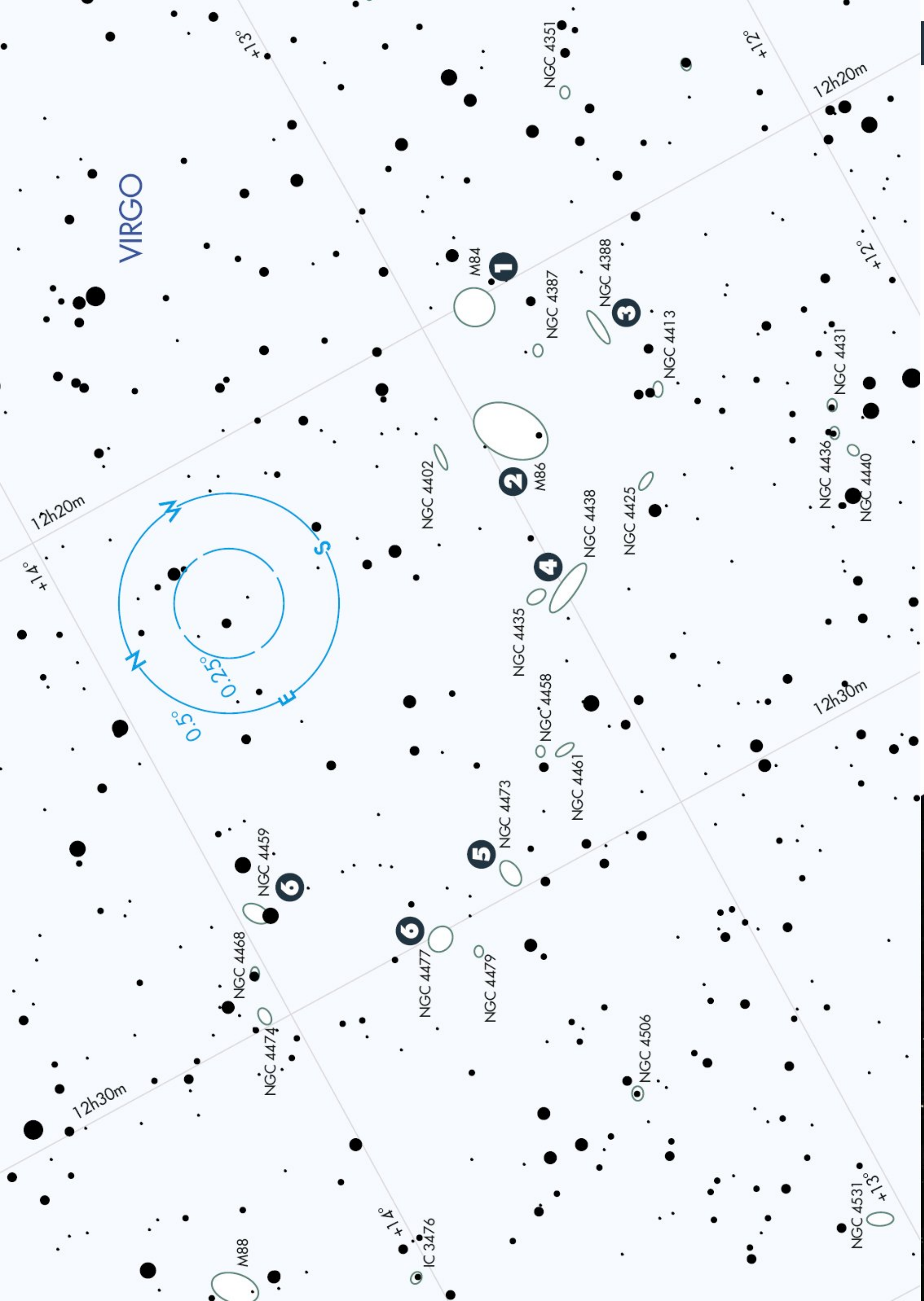
After the 20th the planet gets harder to spot in the west after sunset. It is possible, with luck, to keep track of it right up to inferior conjunction on the 25th and possibly into the next evening as well. However, this is where we can take advantage of Venus's current, very favourable position. At inferior conjunction Venus will pass 8.3° north of the Sun and this allows it to also be visible in the morning sky before sunrise. What's more, its pre-sunrise position after 20 March actually improves with each passing day, right through inferior conjunction giving you a chance to see its amazingly thin, 1%-lit crescent.

If you want to keep a record of its passage through inferior conjunction, then a planetary camera is required. Using such a setup will allow you, with care, to extend the viewing period into the daylight hours. It's not advisable to view Venus visually when it's so close to the Sun in the daytime sky, but a monochrome camera fitted with a red or infrared filter will give a fine view of that amazing crescent. For convenience, we've included a PDF of last month's Astrophotography spread in this month's Bonus Content. This will give you all the information you require to locate and image Venus safely during daylight hours.



PETE LAWRENCE X 3

▲ Venus will be a razor-thin crescent with a massive, almost 1-arcminute diameter disc just before conjunction



DEEP-SKY TOUR

Dig deep into Virgo for this gamut of galaxies, all within Markarian's Chain

☑ Tick the box when you've seen each one

1 M84

This month's targets all belong to Markarian's Chain, a 1.3° curving line of galaxies in the Bowl of Virgo. Locate it midway between mag. +2.1 Denebola (Beta (β) Leonis) and mag. +2.8 Vindemiatrix (Epsilon (ε) Virginis) both of which are shown on our All-Sky Chart. The chain starts with mag. +10.1 M84, a face-on lenticular galaxy 60 million lightyears away. A 6-inch scope shows it as a hazy, 2.5x2-arcminute patch that brightens towards a star-like point at its core. Larger instruments show the core as extended rather than stellar, but reveal little else. For a long time M84 was incorrectly classified as an 'E1' type elliptical, because being face on it is hard to distinguish from that class of galaxy. ☐ SEEN IT

2 M86

Due to the relatively small size of Markarian's Chain, locating other members is easy. Our next stop, M86, sits 17 arcminutes east of M84. Here the elliptical/lenticular confusion continues: M86 is listed variously as an E3 elliptical or an S0 lenticular, though modern classifications favour the latter. It's fractionally brighter than M84 at mag. +9.9, and appears larger and more elongated. That said its overall guise isn't dissimilar to M84, with a 6-inch scope revealing little more than a hazy halo brightening to a star-like point. Through a small scope M86 appears to be 2x1.5 arcminutes in size, but this increases with aperture. A 12-inch scope reveals it as a 3x5-arcminute haze. ☐ SEEN IT

3 NGC 4388

Many of the members of the Virgo Galaxy Cluster are ellipticals, but NGC 4388 is a notable exception. It forms an approximate equilateral triangle with M84 and M86, NGC 4388 marking the triangle's southern point. At mag. +11.0, it's dimmer and harder to see than the two previous galaxies, but really stands out because of its lovely shape. It is an edge-on spiral galaxy with a bright active nucleus. Through a 6-inch scope the galaxy looks like a needle of light, 3x0.5 arcminutes in size, the core region causing a slight bulge. The arms present a mottled appearance through an 8-inch or larger scope, which will also show the core offset to the west of centre. ☐ SEEN IT

4 NGC 4438 & 4435

Up next is a galaxy pair, NGC 4438 and 4435, which can be found 22 arcminutes east of M86. Together these are known as 'Markarian's Eyes' or simply 'The Eyes'. NGC 4438 is the brighter of the two at mag. +11.0, NGC 4435 being +11.7. There is uncertainty as to what is precisely happening between the two galaxies (and possibly M86), but it appears that NGC 4438 is a spiral galaxy gravitationally affected by an interaction with NGC 4435. The pair is separated by 4.3 arcminutes. A 6-inch scope shows NGC 4435 as a small, 1-arcminute haze and NGC 4438 as a larger 3x1 arcminutes. Averted vision really helps with the latter, as NGC 4438's larger size lowers its surface brightness. ☐ SEEN IT

◀ NGC 4438 (bottom) and NGC 4435; it's thought that these galaxies are interacting with one another

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 NGC 4473

We pass mag. +13.0 NGC 4458 and mag. +12.1 NGC 4461 to reach target five, NGC 4473; it is 40 arcminutes northeast of NGC 4438. Here, we've just slipped over the border from Virgo into Coma Berenices. An 8-inch scope shows an elongated haze measuring 1.5x1 arcminutes, with a bright core that appears to have been stretched east-west for a distance of 3-4 arcseconds. This is an elliptical galaxy, which unusually appears to have been flattened into a more disc-like structure. This suggests that it may have been the result of a merger between several galactic nuclei. Don't be afraid to pile the magnification on here to reveal the elongated core. ☐ SEEN IT

6 NGC 4477 & 4459

The penultimate marker of the chain is NGC 4477, a mag. +11.4 barred-lenticular galaxy that lies 12 arcminutes to the north and slightly west of NGC 4473. NGC 4477 is similar to but appears more obvious than 4473. It's reasonably bright and appears larger than 4473. Its core is bright with a mottled surrounding halo when seen with larger instruments. The chain ends with the mag. +11.3 lenticular galaxy, NGC 4459 lying 25 arcminutes north-northeast of NGC 4477. This galaxy is relatively small and concentrated, appearing 1.1 arcminutes across through an 8-inch scope. A mag. +8.7 star, HIP 60918, appears to touch the edge of the galaxy and acts as a useful marker to show you are looking at the right object. ☐ SEEN IT

YOUR BONUS CONTENT

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

CHART: PETE LAWRENCE, PHOTO: JOHANNES CHEDLER/CCDGUIDE.COM

ASTROPHOTOGRAPHY

Lunar close-ups and mosaics

RECOMMENDED EQUIPMENT
8-inch or larger telescope, infrared filter, high frame rate camera, Barlow lens

▲ Close lunar portraits can suffer from poor seeing, which is why stacking is so important

The Moon presents a bright and easily accessible target for astrophotography. Indeed, there are numerous ways to image it, ranging from wide-field scenes captured using a smartphone to impressive close-ups taken with a planetary imaging setup.

Close-up images require long focal lengths and thus ideally a high frame rate camera. The reason for this is that using a long focal length creates a highly magnified image in which you are likely to see the blur caused by atmospheric seeing. A high frame rate camera takes lots of images in rapid succession, which can then be analysed and processed by a freeware registration-stacking program such as AutoStakkert! or RegiStax. These programs are capable of determining the highest quality frames and then averaging them together to produce an image with a higher signal-to-noise ratio. The net result is a cleaner image suitable for further manipulation such as sharpening.

High frame rate results can be emulated to a degree with a stills cameras such as a DSLR by taking a number of images one after the other and running them through a similar registration-stacking process. However, the best method is to use a high frame rate planetary camera, designed to take hundreds or even thousands of shots in a single, short imaging session.

Both colour and mono cameras are suitable, although if the Moon is low you may find that atmospheric dispersion reduces quality. This effect, which gets worse with lowering altitude, spreads the light of an object into a rainbow, resulting in colour fringing. In this instance it's worth obtaining an atmospheric dispersion corrector; an accessory designed to specifically reduce this effect. For lunar mosaics, opt for a mono high frame rate camera fitted with a red or infrared pass filter. The reason for this is that the longer wavelengths at the red end of the spectrum are more resilient to the effects of atmospheric seeing.

Once you've chosen your camera you'll need to decide on your focal length. This can be calculated by the simple formula fl=3.6xDxP, where D is your scope's aperture in millimetres and P is the size of your camera sensor's pixels in microns. An optical amplifier such as a Powermate or Barlow lens will help you achieve the right ball-park value; don't worry about matching the calculated value precisely.

Aim to capture around 800-1,600 frames; the higher the imaging scale, the more frames you'll need. Monitor exposure and ensure that you don't over-saturate to white. Aiming for a value of 70-80 per cent saturation is a good strategy.

Moving methodically across the Moon can be challenging if you're not familiar with its features. Using an equatorially driven mount, the best technique is to orientate the camera so the Moon moves parallel to the bottom of the image frame when you slew in RA. Once achieved, you can work across the area required in strips, overlapping by 15-20 per cent at the edges as you go. Once a strip has been completed, slew in declination to the next strip, ensuring a 15-20 per cent vertical overlap. Work your way along the next strip, and repeat until the entire area has been recorded.

Before you can piece together a lunar mosaic – the subject of this month's Step by Step – you need to process each capture file into a single still image. Programs such as AutoStakkert! can do this automatically, achieved by simply dragging all of the capture files onto the main program window. You'll have to monitor the processing of the first capture and suggest settings where required but after that the other captures will be processed without further ado.

KEY TECHNIQUE

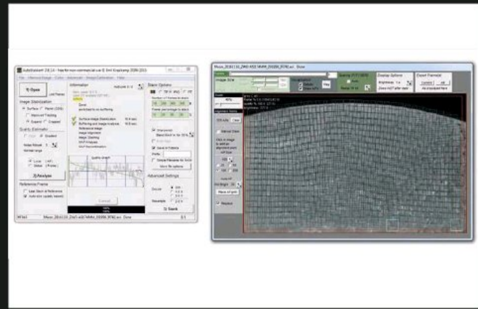
FINDING THE RIGHT MOMENT

The Moon is a beautiful object to photograph. Its dark shadows provide crisp, sharp relief which can really help deliver a dramatic image. While a wide field shot is great at showing a full lunar disc, you'll need to increase image scale to show off those amazing relief shadows. The problem here is that large image scales typically only allow you to record part of the Moon. One way around this is to create a mosaic, where smaller sections are joined together to cover larger areas. There are a number of skills required to create a convincing mosaic that doesn't show the joins.

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

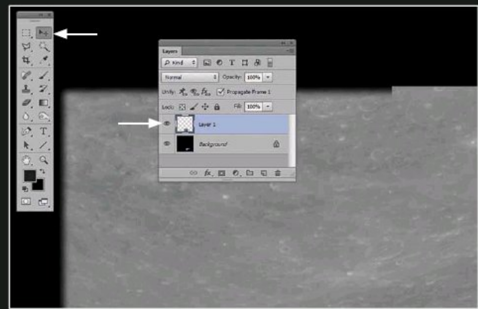
ALL PICTURES: PETE LAWRENCE

STEP BY STEP

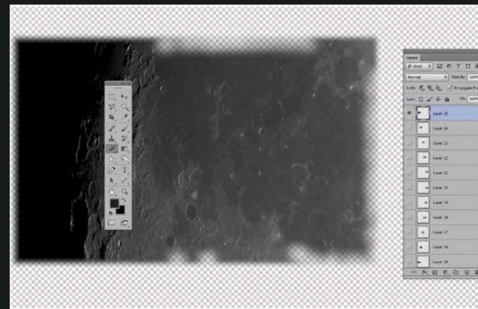


STEP 1
Set your registration-stacking software to save the results as unsharpened and in a lossless format such as FITS, TIFF or PNG; the latter two make subsequent assembly easier. Check to make sure all are artefact free and don't show unwanted blurring, which can happen when batch processing. If any fall short, re-process, marking align features manually.

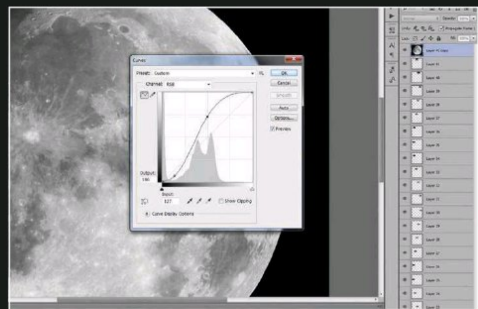
STEP 2
Open a 'corner' image in a layer-based editing program and crop off any bad edges. Make an estimate for how much larger the full mosaic size will be compared to this first piece. Adjust the canvas size in your image editor to accommodate this estimate; don't worry, it can be adjusted later. This will be the master image.



STEP 3
Open the next adjoining image. Crop off any bad edges then create a rectangular selection roughly inset from the frame edge by 50-60 pixels. Feather the edge by 10 pixels. Cut and paste into the master image as a new layer. Move to more-or-less align. Toggle visibility off and on while using the keyboard arrows to bring the new layer into precise alignment.

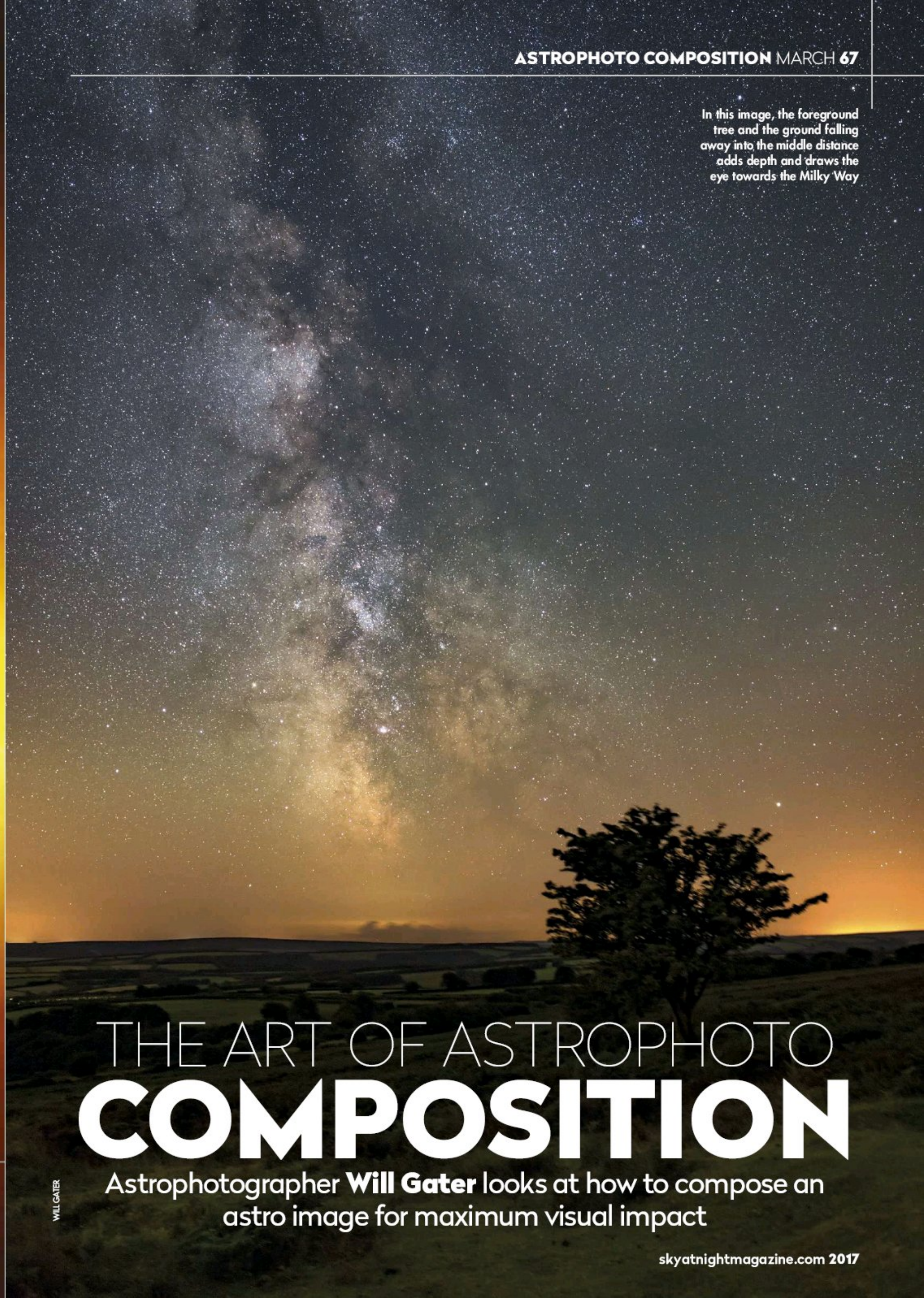


STEP 4
If tonal variations exist, use a Curves adjustment to gradually adjust the new layer to match the base. Check edges for visibility; hiding the base image can help. If edges can still be seen, use the eraser tool (set to 10 per cent) to gently remove them. Dabbing the eraser rather than rubbing across the image tends to work best.



STEP 5
Repeat Steps 3 and 4 until the mosaic is done. Select all layers and duplicate, then flatten the duplicates. Sharpen and use Curves to produce an extreme and unnaturally contrasted version. Examine at actual size, looking for visible joins. If you find any, address it in the layers. Delete the extreme contrast version once done. Once satisfied, save the layers.

STEP 6
Flatten and save the layers as a separate file, then sharpen the result – be careful not to overdo it. Unsharp masking appears more severe in areas of high contrast, so keep a close eye on shadowed regions close to the terminator. Gentle boosts to contrast, brightness and using Curves can elevate the final image, but avoid creating areas of pure white.



In this image, the foreground tree and the ground falling away into the middle distance adds depth and draws the eye towards the Milky Way

WILL GATER

THE ART OF ASTROPHOTO COMPOSITION

Astrophotographer **Will Gater** looks at how to compose an astro image for maximum visual impact

▲ By including several offset objects in deep-sky images you can often create a more dynamic picture

With clear nights at a premium and frequent technical challenges to overcome during image capturing and processing, it's often easy to overlook, or merely forget about, one of the most important elements of the art of astrophotography: image composition. Look at the most celebrated astro images from the best photographers around the world and most, if not all, will be composed in a way that catches and directs the eye, sometimes subtly and other times in a way that stops you in your tracks.

Sure, as imagers, we can all admire and appreciate astounding feats of technical astrophotography – ones that capture features never caught before or that go deeper and wider than others have – but if you want your pictures to grab people, to have an impact and pull viewers in to engage with your work, it is almost always the composition that will do that; if you can combine the two skills then you'll have a world-class image on your hands.

Of course astro image composition also includes additional complications that don't arise in other types of photography. For example, at night it's not always easy to see from a live preview screen or viewfinder on a DSLR how the final processed image will turn out; and with deep-sky CCD imaging we often deal with faint targets whose complete form only really becomes properly visible towards the end of a long processing routine, by which time the framing and arrangement of the shot is a distant memory. With planning, though, we can get around many of these issues.

While some great astro images are the result of serendipitous compositions chosen at the time of capture, often the world's best photographers – particularly of nightscapes – spend a great deal of time thinking in advance about what, when and where they want to shoot as well as exactly how they'll frame their pictures.

If you're shooting nightscapes, for example, it's worth visiting your location in daylight beforehand if you can. This way you can find interesting skylines, angles and foreground objects for your night-time shots while also confirming you know precisely where your celestial subjects – such as the band of the Milky Way, a bright constellation or the Moon – will be in the sky at a certain time; smartphone apps such as The Photographers Ephemeris (http://photoephemeris.com) and PhotoPills (www.photopills.com) are invaluable for this sort of planning. A lot of preparation, whether it's for nightscape photography, wide-field imaging or using a camera attached to a scope, can be done at home on a computer too.

BERNHARD HUBL/CCDGUIDE.COM, MICHAEL KARRER/CCDGUIDE.COM, JAMEN PERCY/ ALAMY STOCK PHOTO, NATIONAL MARITIME MUSEUM/ LONDON, STEVE BROWN

The power of planetaria

The free planetarium program Stellarium (www.stellarium.org) has a plug-in that can overlay the field of view of a given camera/telescope combination onto the night sky. You simply input the specifications of your system and the program will then produce an outline of the frame. The beauty of this is that you can drag this frame across the window, and play around with the composition and framing of your shot before you even step outside. If you have a range of lenses or telescope focal lengths available you can create entries for all of them and then flick between the different fields of view they produce to see which creates the best composition. This is particularly handy when planning images of transient planetary groupings or conjunctions, where you may not intuitively know whether the fields of view you have at your disposal will contain the grouping and frame it well.

▼ The framing of this image forces the eye to travel across the picture and enhances the sense of the lunar surface curving away from us

Being able to simulate a field of view beforehand also gives you a sense of how much 'free space' you have left around your subject in the frame to play with. Using this space effectively is vital for creating engaging astro images, of all types, that feature multiple subjects, foreground features or horizons – all of which are used to balance an image as well as draw the eye in. Let's say, for example, you want to image the Milky Way over a horizon with a tree in the foreground; in Stellarium you can find which of your lenses gives you a field of view big enough to fit a decent swathe of the Galaxy in, say, two thirds of the frame while at the same time giving you enough room to include the ground and your tree in the bottom third. With a planetarium program, like Stellarium, you can add a temporal element to your composition planning – you may find that you can get a better image framing, position or orientation of your subject if you wait an hour, a day, a week and so on.

For deep-sky imaging the field of view calculator on our website (www.skyatnightmagazine.com/field-view-calculator) is particularly useful for showing how much of your frame a Messier object will fill. NASA's 'Dial-A-Moon' webpage, available at https://svs.gsfc.nasa.gov/4537, produces accurate simulations of the Moon's illumination which are helpful for planning high-resolution imaging around the lunar terminator.

With all these tools to hand, then, how does one actually create a captivating composition? If you're after initial inspiration, try thinking about a feeling that you'd like the final image to evoke, or the essence of the view in front of you that you'd like to capture and communicate. For example, you may want to convey a sense of great height in a nightscape; in which case you could make the horizon take up just a small part of the frame. In a similar vein, wide-angle lenses are fantastic at capturing huge areas of sky, but without a well-placed foreground in shot, the true scale and impact of that expanse is often lost.

Foreground objects, trees, buildings and skylines of all sorts can be used to frame celestial subjects ▸

▲ The foreground rocks and mountainous skyline direct the eye towards the central focus, the bright aurora close to the horizon, while the sweeping upper curtains add height and scale to the image

AN EYE FOR COMPOSITION

We speak to Melanie Vandenbrouck, a curator of art at Royal Museums Greenwich and judge for the Insight Astronomy Photographer of the Year competition, about the art of composing an image

What elements make a good photo composition?

MV: I think there are three things perhaps to think about in the first instance. The first is how you are going to arrange the visual elements into a picture. More often than not try to avoid symmetry unless there is a reason for that symmetry.

The second thing is about focus and the way that you want the eye to be led into the image. Having several points of focus means your eye can be led into the image, and it's not a kind of static experience, but it's moving from one point to another. That being said I would avoid having too many because then it becomes quite messy and instead of your eye moving around the image you end up having your eye darting around.

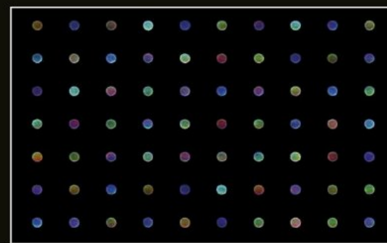
I think that's where the framing comes into play. Sometimes the framing will help you have a very clear sense of focus. Not just about what are the main points of the picture but how your eye is led to read that focus and that movement.

How can imagers improve their compositions?

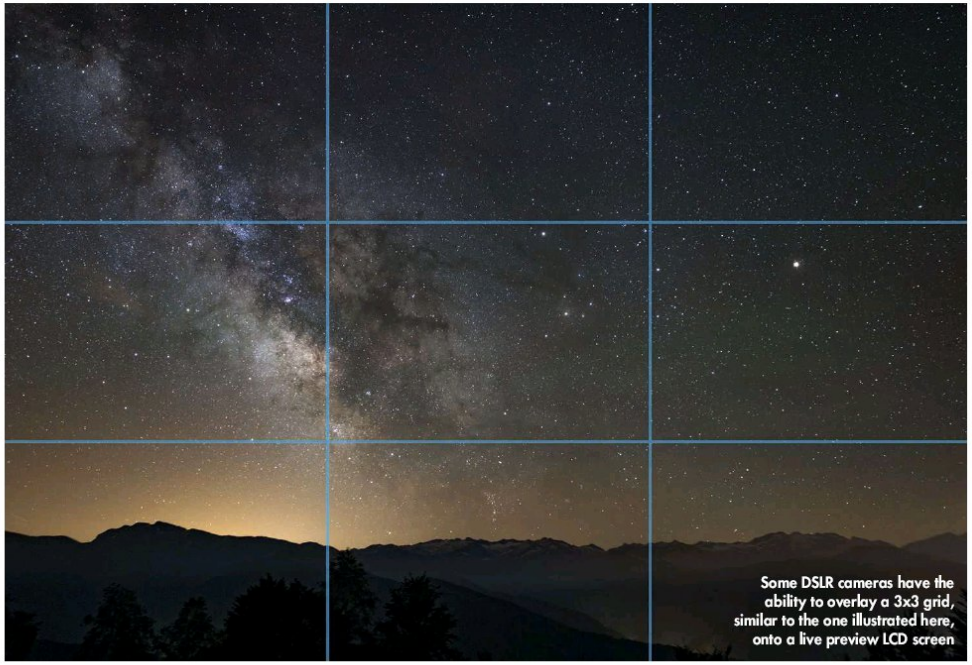
MV: I think the first way would be originality. I will be immediately drawn to something that looks different. It's about finding that way that different elements naturally balance each other or align with each other. And I guess this is something that you only develop through constantly looking at what other people have done and why it's interesting.

Do you have any tips on how to inspire that innovation?

MV: We had a great picture [in the Insight Astronomy Photographer of the Year competition] last year that felt so textured and abstract, it looked like a painting, it looked like a Turner. When I see something like this, or like last year's Sirius picture [shown above right, which won the 2016 Stars and Nebulae category], it seems obvious to me that those photographers were looking at other fields. They're not just thinking about astronomical imagery, they're not just thinking about capturing the object – they are subconsciously or consciously thinking about other art forms. So perhaps I'd invite astrophotographers to go to art galleries and look at how painters compose a landscape; look at, I don't know, Mark Rothko and his abstract pictures all about gradations of tones; perhaps look at textiles or sculpture. Try to get a different sense of how the Universe can be pictured, and enjoyed.



▲ Every dot in this shot is Sirius – the colours are caused by turbluence in Earth's atmosphere



Some DSLR cameras have the ability to overlay a 3x3 grid, similar to the one illustrated here, onto a live preview LCD screen

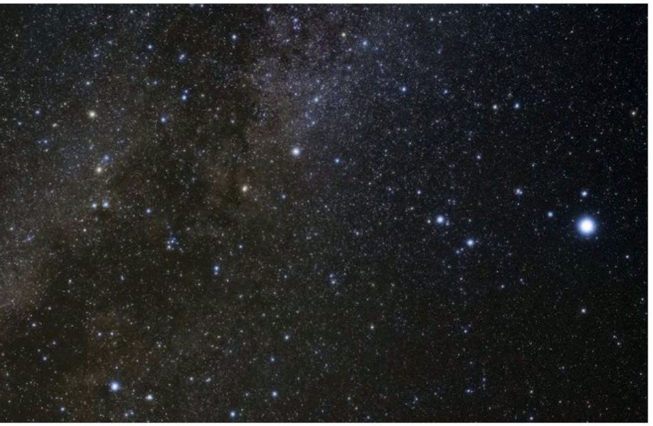
▸ and are at their most effective in an image when used to give depth and direct the eye into the main focus of the picture.

Pulling the viewer in

With long focal length deep-sky or lunar imaging there's less flexibility for these sort of creative choices. However, well-executed mosaics can show surface features or isolated galaxies and nebulae within their wider surroundings, or with other nearby objects; the ensemble can then be framed, or cropped in processing, so as to pull the viewer in and create a scene with real visual impact. Careful positioning and framing of contrasting light and dark areas can be used in any kind of astrophotography to draw attention to specific image elements too.

The placement of foreground features, horizons and celestial subjects in an image, naturally, has a powerful effect on its composition. If you have trouble arranging a shot, try the oft-mentioned 'rule of thirds' by visualising a 3x3 grid overlaid on your image. The important features should be centred along these lines. With a nightscape, for example, if you keep your foreground and skyline within the bottom row and any prominent features – like the Milky Way, large trees or foreground objects – offset near the vertical lines you should find that it creates a well-balanced composition.

You'll find you quickly gain an intuitive sense of what works and what doesn't. But no matter how experienced you become, taking the time to consider composition before your camera starts catching photons will, still, invariably be the difference between capturing a good image and a great one.



▾ Here Lyra and its bright star Vega have been offset with the diagonal band of the Milky Way to create a more visually balanced image than if the constellation had been centred

WILL GATER X 8

ABOUT THE WRITER
Will Gater is an astronomy journalist and presenter. Follow him on Twitter at @willgater.

COMPOSITION CASE STUDIES

Will explores the compositional choices he made while shooting six of his astro images

▲ A bright Perseid meteor
With meteor photography you never know where, or even if, one will appear in frame. I deliberately included a swathe of horizon at the bottom of the shot, knowing that any Perseids would cross the frame roughly diagonally.

The Milky Way ▶
Shooting with a wide-angle lens can sometimes cause issues with composition as there's so much in view and there's not always a clear focal point. Here, however, I liked how the tree's outline mirrors the dust lanes within the Galaxy, as if it were a transition between Earth and the sky. I also kept the ground dark during post-processing to draw the eye upward.

▲ Clouds passing over the full Moon
If I'd used a short (much less than a second) exposure, the clouds racing across the sky here may have looked messy and only slightly blurred, distracting the eye from the Moon. I opted for a longer exposure – waiting for the right cloud density so the Moon would be clear but not overexposed.

▲ Moonlit star trails
By positioning my tripod so the north celestial pole sat offset in the little indent in the treeline on the right, I was able to use the natural, meandering shapes of the branches to draw the eye into the contrasting, circular trails close to Polaris.

Winter constellations ▶
In composing this shot I had two things I needed to address. The first was that I wanted to concentrate on just Taurus, Auriga and Orion – hence the positioning of the tree. Second, there was an encroaching light-pollution dome along the horizon, so I got right up close to the hedgerow so that the twigs would create a visually interesting silhouette while hiding the glow a little.

▲ The Northern Lights over Somerset
I wanted to give a sense of this display's extent, which was impressive even from Somerset. I used a foreground tree to give the picture depth as well as frame the auroral rays at the left; being in silhouette, the tree also helps highlight the purple glow across the top of the entire image. Ⓢ

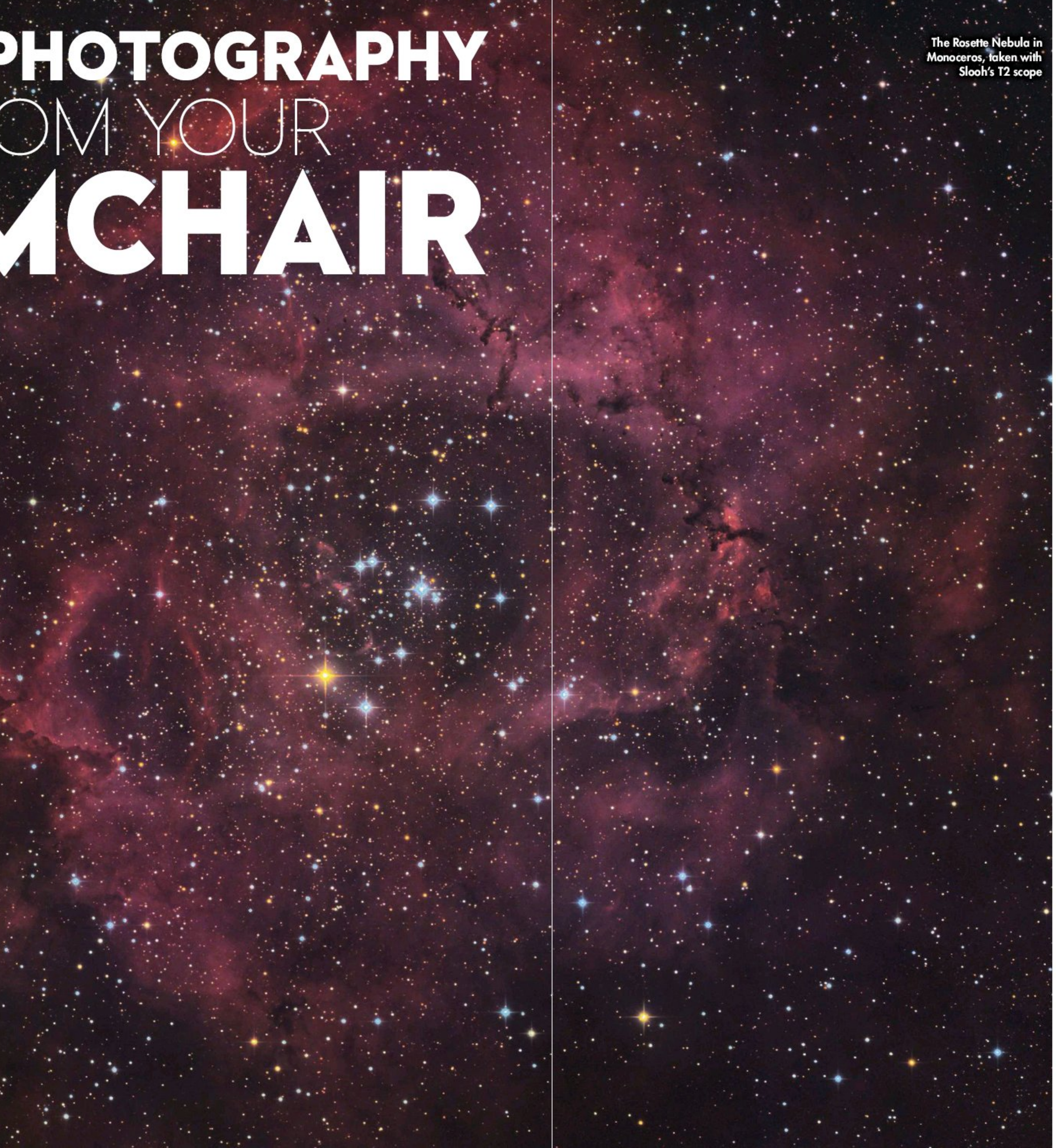
ASTROPHOTOGRAPHY FROM YOUR ARMCHAIR

Michael Moltenbrey explains how you can image the skies on the other side of the world without ever leaving the comfort of your home

Astrophotographers often dream of taking that impossible image, the one that is too faint for the light-polluted sky they live under or beyond the capability of the telescope they can afford. Many astronomers in the northern hemisphere dream of capturing the majesty of the Magellanic Clouds and other southern sky stalwarts, yet are unable to make the arduous and expensive trip to somewhere that they might be able to image them.

There is a solution to these woes, and that's remote astronomy. There are several observatories around the world that let you control their scopes from the comfort of your own computer at home for a reasonable fee, and sometimes even for free. Here we look at five such telescopes to see what each has to offer.

ABOUT THE WRITER
Michael Moltenbrey is a computer scientist. He has been enthused about astronomy since his childhood.



The Rosette Nebula in Monoceros, taken with Slooh's T2 scope

One of the simple 6-inch reflectors in the network

MicroObservatory

The MicroObservatory Robotic Telescope Network, operated by the Harvard Smithsonian Center for Astrophysics with support from NASA, is the most simplistic service here. It relies on a network of automatic 6-inch reflectors along the east and west coasts of the US, each equipped with a CCD camera. As it's aimed at beginners and students, it is free to use.

The service does have limitations. You do not have real-time access to the telescopes, but instead schedule 'jobs' that are automatically distributed to the telescopes depending on capacity. You can only select from a limited list of objects, comprising planets, the Moon (if visible) and a handful of deep-sky objects. There is a limited choice of four different exposure times and whether you would like to use a filter or not. The images are available as GIFs or in their raw FITS format via a common directory on the project's website.

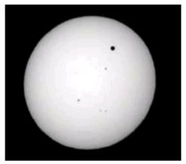
There is still an older ongoing project that allows you to set some more detailed parameters, but for this you have to register and propose a research project. The proposals are reviewed three times per year.

PROS: Good starting point; free and easy access
CONS: Limited flexibility; images are often poor quality

KEY INFO

http://mo-www.cfa.harvard.edu/MicroObservatory
LOCATIONS: Various in the US
EQUIPMENT: Five 6-inch reflectors
PRICE: Free






▲ Clockwise from top left: the Orion Nebula, The Moon, a transit of Venus and the Whirlpool Galaxy

SLOOH.COM, MICROOBSERVATORY X 5


iTelescope's Siding Spring location is home to a slew of telescopes

iTelescope

Currently used by more than 10,000 astronomers, iTelescope is probably the most developed service on the list. Signing up gets you access to a number of different reflectors and refractors, ranging from 3.5 inches to 27.5 inches in aperture and with varying focal lengths. Its sites are in the US, Spain and Australia, allowing you to enjoy the wonders of both northern and southern skies. All are situated in areas with little light pollution and good seeing conditions, and 70 per cent of nights are clear.

Though iTelescope is described as being ready for beginners and offers many tutorials, a basic knowledge of telescopes and astrophotography is helpful since the system allows you to alter almost all imaginable parameters yourself.

The costs for the service are reasonable as you are only charged for the time you actually take photos, and discounts of up to 50 per cent are offered when the Moon is bright. Various membership plans are available, starting from $19.95 per month. This gives you 20 'points' to buy time on telescopes, with additional points available at a dollar each. Each telescope type will cost a certain amount of points – for example the T3, a Takahashi TOA-150, will cost 100 points per hour of imaging time.

Once the images are taken they are available in TIFF and FITs formats on iTelescope's ftp server, or can be uploaded directly to your own cloud drive.

PROS: Many different telescopes and locations; full control and flexibility
CONS: Interface requires practice; prior astrophotography experience recommended

KEY INFO

www.itelescope.net
LOCATIONS: US (California & New Mexico), Spain, Australia (Siding Spring)
EQUIPMENT: 18 telescopes; refractors and reflectors ranging from 3.5 to 27.5 inches
PRICE: From $19.95; additional points cost $1/point


▲ The Carina Nebula, NGC 3372


▲ The majestic comet Lovejoy

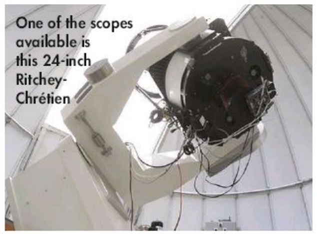
Lightbuckets

Lightbuckets provides a similar service to iTelescope, but is limited to one location in the French Alps. Luckily, this region has low light pollution and good seeing conditions.

Its available telescopes range from a 4.3-inch apochromatic refractor to a 32.3-inch Schmidt-Cassegrain. You can choose between two operating modes, full control and easy imaging. The first allows you to adjust all necessary parameters yourself, while the latter is geared towards beginners: users select the object they want to photograph using the built-in SkyView planetarium software and determine the level of detail desired. The system then automatically chooses parameters and takes the photo, though you do have a choice between colour or monochrome. In both cases, the results taken can be downloaded from the Lightbuckets' servers in the RAW format.

Lightbuckets is not recommended for planetary, lunar or solar photography. The CCD cameras mounted on its telescopes have been particularly chosen for faint deep-sky objects, and Solar System bodies will be too bright.

At the time we used this service, its website made frequent references to a now defunct site in New Mexico and did not list some information – such as the rates – until after we had registered. However, customer service is available seven days a week via email or Skype. Prices for using the telescopes start from $1 per point, with individual telescopes costing between 30 and 120 points per hour.


One of the scopes available is this 24-inch Ritchey-Chrétien


▲ The Cigar Galaxy in Ursa Major


▲ The Pillars of Creation in the Eagle Nebula

PROS: Easy imaging mode is a good starting point for getting into remote astronomy
CONS: Website not up to date; lack of information until after registering

KEY INFO

www.lightbuckets.com
LOCATION: France
EQUIPMENT: Five telescopes; refractors and reflectors ranging from 4.3 to 32.3 inches
PRICE: $1/point; telescopes available from 30 points/hour

ITELESCOPE.NET, JOHN EBERSOLE, ROLANDO LIGUSTRI, LIGHTBUCKETS, LIGHTBUCKETS/JASE JENNINGS X 2, SLOOH X 3, SLOOH/PETER ILAS, SLOOH/DAVID MIHALIC

Slooh

Slooh's domes on Mount Teide in Tenerife; inset: Slooh's T1 half-metre telescope

Slooh is based on a different concept yet again. It regularly livestreams key astronomical events being observed by its telescopes, such as meteor showers and eclipses. When you control your own scope, the feed is also relayed on the website in real-time and full colour to everyone in the community.

Slooh's main observatory is located on Mount Teide in Tenerife, its scopes ranging from a 3.3-inch refractor to a 20-inch reflector, as well as meteor cams and a dedicated solar scope. Another observatory in Chile, this one with a 14-inch reflector and a 3.5-inch refractor, provide access to the southern sky. The CCD cameras mounted on the telescopes provide high resolutions of up to 4,096x4,096 pixels. Both sites are known for their excellent weather conditions and seeing.

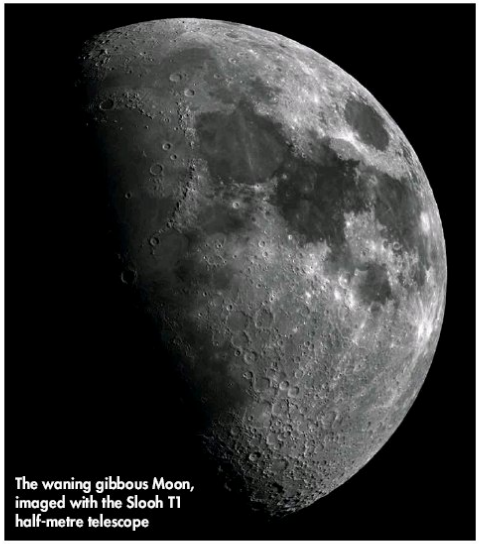
As of this February, you will be able to choose from three membership options: Slooh Crew (free), Apprentice ($4.95/month) and Astronomer ($24.95/month). You do not have to pay per use, but you may be restricted in the number of images you can take depending on the type of membership you opt for. It is also possible to schedule objects for times when you would be otherwise unavailable.

The finished images are stored in your personal storage area on the website. They can be downloaded in FITs format if you subscribe for the Astronomer membership, but Apprentice and Slooh Crew members are limited to PNGs.

PROS: Reasonable prices; free membership options
CONS: Limited flexibility; interface easy to use but limited configuration options

KEY INFO

http://live.slooh.com
LOCATIONS: Tenerife, Chile
EQUIPMENT: 10 telescopes; a range of reflectors, refractors, and a solar scope, plus all-sky cams
PRICE: Slooh Crew (free), Apprentice ($4.95/month), Astronomer ($24.95/month)


The waning gibbous Moon, imaged with the Slooh T1 half-metre telescope


The Triangulum Galaxy


The Western Veil Nebula

Schulman Telescope

▲ This observatory only has one scope, but it is a monster 31.5-inch with a 6m focal length

The Schulman Telescope is hosted by the University of Arizona in the US and is located on nearby Mount Lemmon at an elevation of 2,800m. The location provides you with a dark sky, good seeing and good weather. Between September and June, 70 per cent of the nights should be clear, something you can check via its website.

The telescope has an aperture of 31.5m and a remarkable focal length of almost 6m. As with iTelescope and Lightbuckets you are given full control over each telescope, allowing you to adjust all of the parameters yourself.

Although the interface for controlling the telescope is quite detailed, booking observing time is cumbersome, as no web portal exists for this purpose. Booking enquires have to be made via email or telephone and there is no calendar to show the free slots available. This makes booking via email in particular quite laborious, in spite of the responsive customer service.

There are two operating modes, real-time or scheduled observation. The former allows you to quickly influence your observation by adjusting parameters on the fly, whereas the latter is quite convenient if you have less time. Simply schedule your observation plan and it will be queued and executed automatically as soon as possible. There's no need for you to be in front of your computer.

PROS: Good location; full control of parameters; professional observatory
CONS: Making a reservation is cumbersome

KEY INFO

http://skycenter.arizona.edu/programs/remote_observing/real_time
LOCATION: Mount Lemmon, Arizona
EQUIPMENT: One telescope; 31.5-inch reflector with 5,695mm focal length
PRICE: $200/hour

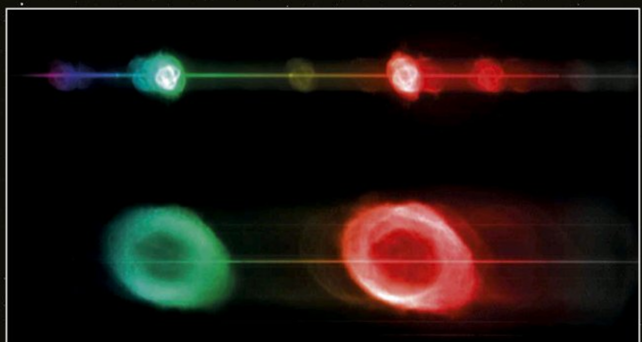
▲ The Whirlpool Galaxy in Canes Venatici

▲ The Horsehead Nebula in Orion

SCHULMAN TELESCOPE X 3, ROBERT SMITH

INSIGHT ASTRONOMY PHOTOGRAPHER OF THE YEAR

AUTOMATED ARTISTRY



The world's premier astrophotography competition, Insight Astronomy Photographer of the Year, has an award dedicated to images captured remotely. The Robotic Scope special prize is open to all astrophotos taken with a telescope that is operated over the internet. Over the years the category has seen some of the most incredible deep-sky images of the competition, views that would be beyond the capability of most amateur telescopes, but that's not the only approach you can take.

Last year's winner, Robert Smith, opted to make use of an instrument little-used by amateurs, the slitless spectrograph on the Liverpool Telescope at the Roque de los Muchachos Observatory in La Palma. This device splits incoming light into its composite colours to show the different wavelengths being emitted by each. His resulting image (pictured left) of the Cat's Eye Nebula in Monoceros and the Ring Nebula in Lyra is not only artful, but scientifically intriguing.

This year's competition opens for entries on 27 February. For more details, visit www.rmg.co.uk/astrophoto

ADVERTISEMENT FEATURE

THE NORTHERN LIGHTS

With holiday companies releasing details of their latest aurora tours, now's the time to start thinking about booking your trip to see the Northern Lights. Remember one thing... never take your eyes off the skies, you never know when that spectacular display might appear.

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Land of the Northern Lights

Magellan departs Tilbury: Tues 10th & Mon 30th October 2017, 14 nights

London Tilbury - Amsterdam (Netherlands) - Olden (Norway) - Kristiansund - Alta - Honningsvåg for North Cape - Tromsø - Trondheim - Åndalsnes - Bergen - London Tilbury.

	Full Fare	Saver Fare
Twin Inner from	£1919	£1149
Twin Ocean View from	£2739	£1679

Land of the Northern Lights to Norway

Magellan departs Tilbury: Sunday 18th February 2018, 14 nights

London Tilbury - Amsterdam (Netherlands) - Ålesund (Norway) - Tromsø - Alta (overnight) - Honningsvåg for North Cape - Trondheim - Åndalsnes - Bergen - London Tilbury.

	Full Fare	Saver Fare
Twin Inner from	£2029	£1019
Twin Ocean View from	£2799	£1399

Land of the Northern Lights to Iceland

Magellan departs Tilbury: Sunday 4th March 2018, 12 nights

London Tilbury - Amsterdam (Netherlands) - Tórshavn (Faroe Islands) - Reykjavik (overnight, Iceland) - Lerwick (Shetland Islands) - Kirkwall (Orkney Islands) - London Tilbury.

	Full Fare	Saver Fare
Twin Inner from	£1679	£809
Twin Ocean View from	£2329	£1129

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SKILLS

Brush up on your astronomy prowess with our team of experts

The Guide

With **Iain Todd**

Demystifying dark sky designations

How the world's darkest sites are classified, and what it means for observers

Even in rural areas light pollution from nearby cities can cause huge problems for astronomers

Night-time light pollution affects nearly 80 per cent of the world. That was the headline finding from a study published in mid 2016 by the Light Pollution Science and Technology Institute in Italy. The study also announced that a third of people on Earth can no longer see the glimmering band of the Milky Way. Clearly, amateur astronomers have a lot to compete with in order to get a decent view of the night sky.

Much work is already being done by concerned bodies to preserve darkness or else achieve it where light pollution looms, resulting in an explosion of sites with 'certified' skies – places where you can be sure of a certain level of darkness or sky quality. You may have come across the terms for some of them, such as 'Milky Way class' sites and 'Dark Sky Reserves', within this very magazine.

Many of these designations come from the International Dark Sky Association (IDA; www.darksky.org), founded in 1988 to support and reward those seeking to improve the quality of the night skies above their homes, towns, cities and even national parks. It works with councils, communities and legislators globally to reduce the glare of artificial lighting, and much of its work involves the introduction of lighting that is more sympathetic to maintaining natural darkness.

ISTOCK X 2

Defining darkness

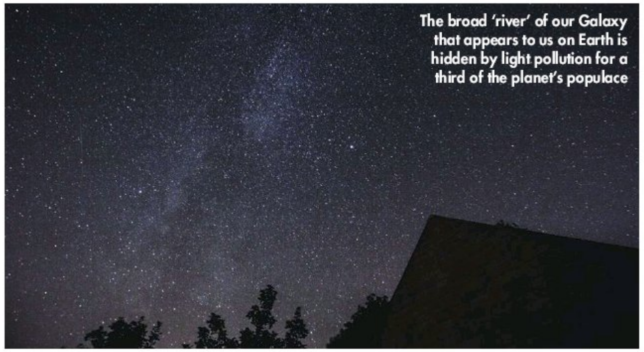
The IDA's Dark Sky Places programme designates the darkest regions around the world in five categories: International Dark Sky Communities, Parks, Reserves, Sanctuaries and Dark Sky Developments of Distinction. These are terms you may have come across, but may still be unsure exactly what they mean.

Towns, cities, municipalities and other populated areas may apply to be recognised as an *International Dark Sky Community*, provided there exists evidence of "exceptional dedication" to the dark-sky cause. Typically, such communities are legally incorporated entities, meaning they are free to enforce their own outdoor lighting policy. This includes islands like Coll in Scotland and Sark in the Channel Islands.

THE BEST OF BRITISH

How dark skies are classified domestically

There are nine IDA-designated Dark Sky Places in the UK, spread across England, Scotland and Wales, plus two more in the Republic of Ireland. There's also a separate scheme run by the home-grown Dark Sky Discovery partnership (DSD; www.darkskydiscovery.org.uk). Led by organisations such as the Royal Observatory Edinburgh, the Royal Astronomical Society and the British Astronomical Association, the DSD partnership recognises over 150 areas as Dark Sky Discovery Sites, where quality views of the night sky persist. These are divided into two categories: Milky Way class and Orion class sites. Milky Way class means the Galaxy must be visible to the naked eye, while Orion class requires that all seven stars in the Orion constellation can be seen unaided.



The broad 'river' of our Galaxy that appears to us on Earth is hidden by light pollution for a third of the planet's populace

The status of *International Dark Sky Park* is awarded to areas where the night-sky brightness is regularly equal to or darker than 20 magnitudes per square arcsecond. The land may be public or private, but there must be public access to the relevant areas. There is, however, no required minimum land area.

An *International Dark Sky Reserve* must experience brightness of no more than 20 magnitudes per square arcsecond and must be public or private land of at least 700km². It must contain a "core area" that meets the minimum criteria, as well as a "peripheral area" that supports the preservation of the core's darkness.

Parks and Reserves are further divided into gold, silver and bronze tiers. Gold means a visual limiting magnitude – in other words, the faintest stars you can see – equal to or greater than +6.8 under clear skies, silver means +6.0 to +6.7 and bronze means +5.0 to +5.9.

Gold calls for a complete lack of lighting on towers or buildings within the area boundary. An array of phenomena should be visible like aurora, airglow, the Milky Way, zodiacal light and faint meteors. Silver means the Milky Way must be visible in summer and winter, while "minor to moderate" illumination from artificial skyglow is allowed. Bronze is awarded to areas that don't meet the silver standard, but which still maintain visible natural sky.

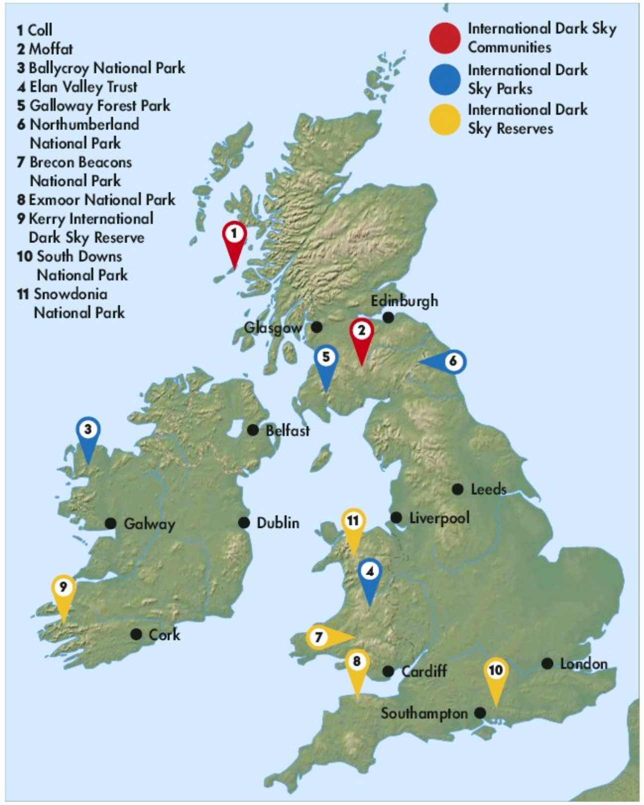
Filling the void

A *Dark Sky Sanctuary* is typically an isolated location with few or no threats to the quality of darkness. The designation was introduced in 2015 to bridge the gap between the Park and Reserve definitions. Such areas are sometimes inaccessible to the general public due to the fragility of their natural darkness and so cannot be considered a Park, but also lack the core/peripheral areas of Reserves. The Sanctuary designation is intended to ensure that there is awareness of their delicate nature, but also that the potential damage caused to the area through public awareness is minimised.

To achieve any of these four designations, a site must apply to the IDA, which gives advice on any changes needed and then provides support to make them happen. There's also a separate *Dark Sky Friendly Development of Distinction* award, which recognises small communities and developments that promote sensitive outdoor lighting. Areas must be nominated by an IDA member and receive support from a community leader and residents.

IDA guidelines say that designations "almost always begin with a small group of individuals who organise to seek formal protection of their nightscape". So if you and your fellow amateur astronomers want to protect darkness in your local area, visit the IDA website to find out more.

Iain Todd is *BBC Sky at Night Magazine's* editorial assistant



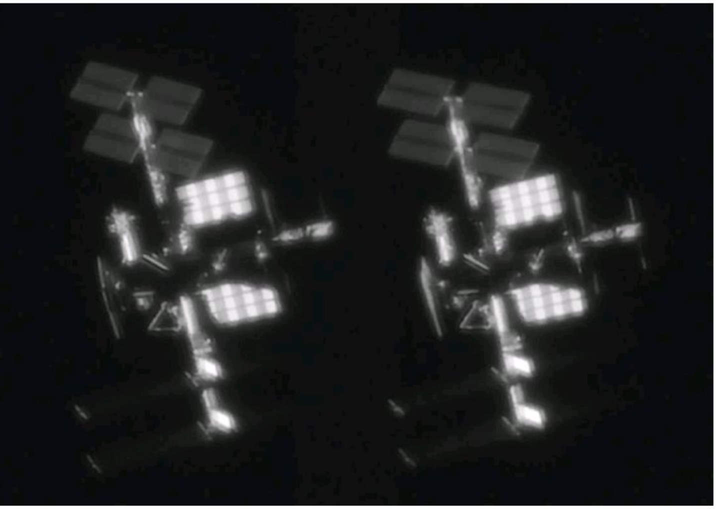
▲ There are nine IDA Dark Sky Places in the UK and two in the Republic of Ireland, any of which will give you an experience of the night sky that's better than from an urban environment

With Thierry Legault

How to...

Image structural detail on the ISS

The tricks you need to reveal the ISS as much more than a flare



▲ Space Shuttle Discovery can be seen docked to the ISS (on the left) in this stereo image from 2011

TOOLS AND MATERIALS

HARDWARE
Telescope and mount, planetary camera or DSLR, laptop.

SOFTWARE
Programs to extract your video frames as stills and edit them afterwards.

If you own a telescope and a camera, you may have already taken detailed pictures of the Moon and the planets. But have you ever imagined chasing the International Space Station and taking pictures of it that reveal its shape and its main structures?

There is a kind of magic to the silent and majestic movement of this huge structure as you watch it sail across the sky. At the incredible speed of almost 8km/s, the ISS accomplishes one orbit around Earth in only 90 minutes. It is often visible over the UK at dawn or dusk.

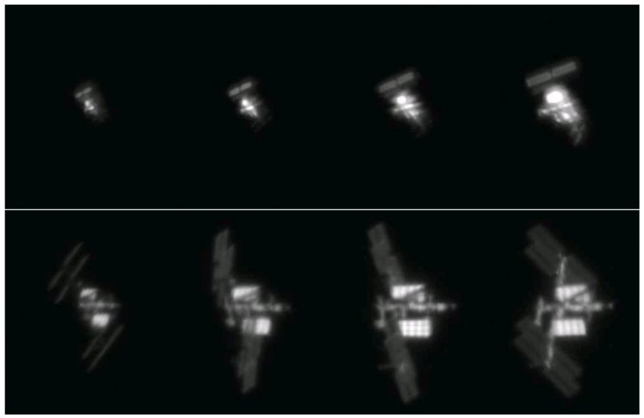
Fortunately, you don't need to calculate the favourable passages by yourself: a variety of applications and websites can do it for you – try Heavens Above (www.heavens-above.com) or CalSky (www.calsky.com). Ideally you are looking for a passage with a culmination of 30° above the horizon as the ISS will appear larger and will be less disturbed by atmospheric turbulence.

Given its brightness and its apparent size – the latter is comparable to Jupiter – the ISS would be an easy target for a planetary imager if it remained still in sky. The downside of its low altitude (400km) – the very reason it is so bright – is that it has an apparent speed of more than 1° per second when overhead.

Even equipped with motors and computerised Go-To systems, most commercial mounts do not possess the timing precision, reactivity or fine range of speeds needed to follow the ISS by programmed tracking: you'll have to do it visually through your finderscope. You can use any kind of mount – Dobsonian, altazimuth or equatorial – so long as it offers smooth and well-balanced manual movements.

One trick that can be employed is to deliberately not polar align an equatorial mount as usual. Instead, align it with the trajectory of the ISS during its targeted passage. To do this, aim the polar axis of the mount opposite the direction the ISS culminates in: for example, if the ISS culminates in the south-southwest, align the polar axis north-northeast. Adjust the latitude of the mount to 90° minus the culmination altitude of the ISS: for example, if the ISS culminates at 60°, set the latitude to 30°. This will make tracking much easier. The movement in declination will be (almost) nothing, and the tracking in right ascension will be the slowest possible.

Any type of telescope can be used. As in planetary imaging, long focal lengths may lead to more detailed pictures – or to more visible tracking difficulties and errors. Use a reliable and stable crosshair finderscope with precise alignment screws. A right-angled erecting model may be more convenient, especially if the ISS passes close to the zenith.



ALL PICTURES: THIERRY LEGAULT

▲ The level of detail you can expect to see with 4-inch (top) and 10-inch (bottom) telescopes

Choose wisely

The most capable cameras for ISS imaging are the ones used in planetary, lunar and solar imaging. A large sensor may help to keep the ISS within its field of view. You can also try a DSLR in video mode, although the ISS will look smaller and will therefore need a longer focal length. Another option, with a DSLR, is the continuous shooting mode (RAW or JPEG).

There is no need to wait for the next passage of the ISS to test and improve your tracking ability: practise on aeroplanes, day or night. At high altitude, their apparent speed is similar to the space station's. If you can, image the ISS with a friend: one of you can track it, the other can check the position of the ISS on the camera or computer screen and adjust the shooting parameters.

Begin with your shortest possible focal length; the exposure time will be shorter and keeping the ISS within the sensor will be easier. Increase your focal length with a Barlow lens only once you have refined your tracking skills. As in planetary imaging, the best results will be obtained in favourable seeing conditions: perseverance an important part of successful ISS imaging. ⓢ

Thierry Legault is a world-renowned astrophotographer whose pictures have been published and broadcast all over the world.

STEP BY STEP

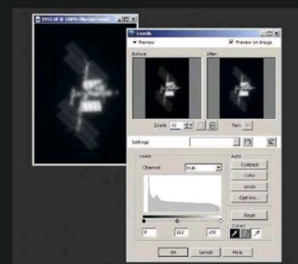
STEP 1
Once your telescope is set up and aligned, aim it at a celestial target: a bright star, a planet or the Moon. Centre it precisely in the field of the camera and then carefully align your finderscope with the optical axis so the views coincide accurately.

STEP 2
Focus the camera on the same target. Fortunately all celestial objects, including the ISS and other satellites, are so far away that all can be considered to be at infinity and need the same focus position. If your focuser features a locking system, use it.

STEP 3
You'll need to adjust the camera parameters by trial and error. For your first attempt, set the exposure to 1/1,000s in 'daylight' colour balance mode; with a DSLR set the ISO to 400-1600, with an astronomical video camera set the gain to a medium value.

STEP 4
Once you're ready to shoot, check that the mount is able to follow the whole trajectory of the ISS in the sky. A few instants before the predicted time, aim the telescope in the direction it will appear above the western horizon. Start recording video.

STEP 5
Spot the ISS with your eyes first, then loosen the mount axis brakes as much as necessary, centre the ISS in the finderscope and track it as smoothly as possible, holding the optical tube, the mount or the counterweight bar. At the end of tracking, stop recording.



STEP 6
If you succeeded in keeping the ISS within the field for a few seconds or more, use an application such as VirtualDub (http://virtualdub.org) to extract all video frames in JPEG, TIFF or BMP format. Tweak the sharpest ones in editing software.

Image PROCESSING

With Steve Richards

Become a master of bi-colour imaging

How to cut your imaging time by a third and mimic the Hubble Space Telescope

Our final image of the Pelican Nebula's sweeping gas clouds and star-forming regions

ALL PICTURES: STEVE RICHARDS

Colour images of deep-sky objects fall into two categories, broadband and narrowband. Broadband images can be captured in a number of ways: either all of the colour data can be recorded simultaneously, as an RGB image using a DSLR or colour CCD camera, or it can be assembled from R, G, B and luminance (L) captures made with a monochrome CCD and external filters. Regardless of the capture method, broadband images deliver an approximation of the colours you would see if your eyes were sensitive enough.

Narrowband images are quite different. They are created using a monochrome CCD camera fitted with a narrowband filter that passes a slim portion of the visible light spectrum – popular filters include hydrogen-alpha (Ha), doubly ionised oxygen (OIII), singly ionised sulphur (SII) and hydrogen-beta (Hb).

By allocating narrowband data to the red, green and blue channels of an image, a process known as 'mapping', you can produce different colour combinations. One of the most popular is known as the 'Hubble Palette', where SII is mapped to red, Ha to green and OIII to blue. The striking false-colour images that result are suitable for scientific examination, although amateur astronomers tend to manipulate their images for a more pleasing colour balance.

Three's a crowd

Bi-colour imaging is another method of producing a false-colour narrowband vista, using just two filters instead of the traditional three. This reduces the amount of data that needs to be captured by a third – ideal for fickle British skies! From our diagram of the visible light spectrum (right), you can see that OIII emissions are on the cusp of green and blue light, something imagers can make use of by mapping Ha to the red channel and OIII to both the green and blue channels.

Although this mapping also produces a false colour image, the appearance is not far removed from a broadband image, but it will have crisper detail as the data has been collected from specific emission regions. Most astrophotographers adjust the colour hues to increase the contrast in certain regions of the image and, as the colours are already false, anything goes.

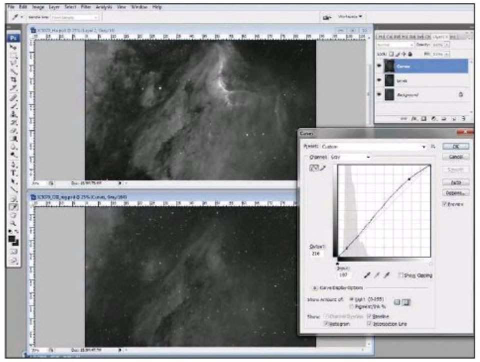
The process starts with stacking your Ha and OIII data into two master files using your normal stacking software. Align the OIII image with the Ha image using your software of choice, then save the aligned OIII image. Open the Ha and aligned OIII files in Photoshop or an equivalent graphics editor and then apply adjustments using Levels and Curves to produce two acceptable mono images. Don't be surprised to discover that the OIII data is generally weaker than the Ha data. Save these files in PSD format with suitable filenames. Flatten both images using **Layer** > **Flatten Image** then select the OIII image and duplicate it using **Image** > **Duplicate**.

The next task is to composite the two images to produce an RGB colour image by mapping Ha, OIII and the OIII Copy to the R, G and B channels respectively. Click on **Window** > **Channels**, then click on the 'menu' button at the top right corner and choose **Merge Channels**. Select **RGB** from the drop-down menu, pick the correct image for each channel and click on OK.

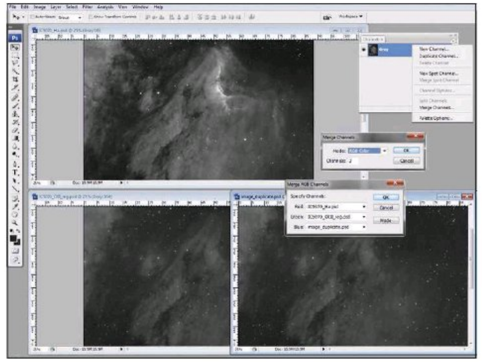
You now have the start point for your colour image. From here, you can decide the colour hue that you want represented in your image. You could choose a good representation of the colours that you'd expect to see if this were a standard RGB colour image, which is the palette produced initially by merging the channels; alternatively, you can also choose a colour palette that increases the contrast between the various regions despite moving away from more natural colours. This is the route we have taken with our image of the Pelican Nebula. Select **Image** > **Adjustments** > **Hue/Saturation** and adjust the hue slider to achieve the colour tones that appeal to you.

Once you have settled on your colour choice, you can continue to process your image conventionally. Careful use of the Selective Colour dialogue box (**Image** > **Adjustments** > **Selective Colour**) lets you tweak individual colour hues minutely, something that allowed us to really enhance the dusty areas. Using the Ha data as a false luminance channel also worked wonders in terms of overall detail.

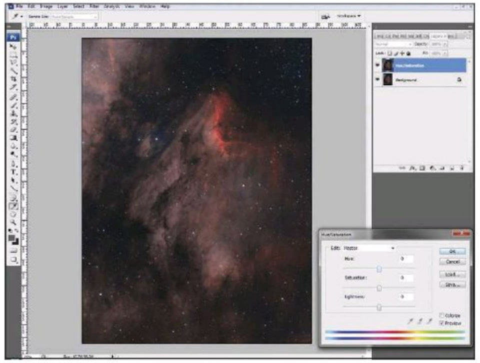
Steve Richards is an expert imager and our Scope Doctor



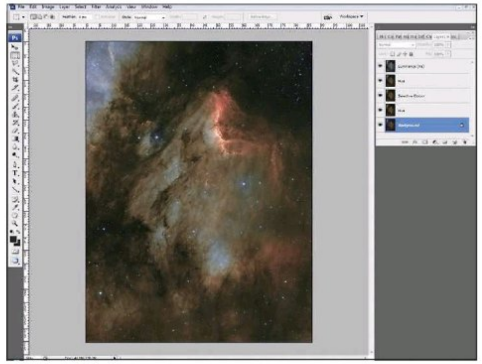
▲ Make preliminary adjustments to your master Ha and OIII files using the Levels or Curves – the OIII data is likely to be weaker than the Ha



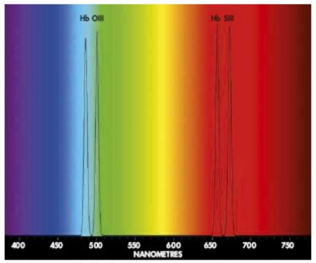
▲ Use the Channels tab's drop-down menu to merge your Ha, OIII and OIII Copy data into the R, G and B channels of a single image



▲ The merged data ready for colour manipulation using the Hue/Saturation tool – this can help you to increase contrast between regions



▲ Once you have merged and chosen your hue/saturation, you can process your image in a graphics editor as you would any other



▲ The visible light spectrum, and where four of the most popular narrowbands sit on it

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Scope DOCTOR

With Steve Richards

Our equipment specialist cures your optical ailments and technical maladies

Capturing a deep-sky image like this is down to a multitude of factors – light pollution is only one

BERNHARD HUBL/CCDGUIDE.COM, PAUL WHITFIELD

I live in a moderately light-polluted area. How do I work out the best exposure time when I'm using stacking to create a deep-sky image?

FRANK STONE

Correct exposure time is dependent on many factors, including the chosen object, telescope aperture, telescope focal length, mount tracking ability, camera type and light pollution. As you would expect, brighter objects require shorter exposures and dimmer objects require longer exposures to capture detail, but also consider your camera's sensitivity. DSLRs and one-shot-colour cameras are less sensitive than monochrome CCD cameras.

Most deep-sky images are produced from multiple images that have been stacked to produce a single image, as this is a great way of increasing the signal-to-noise ratio in your images. Lots of shorter images stacked together go some way towards matching a single exposure of the same total time, but the single exposure will be deeper and contain more detail. However, the stack of shorter exposures will be less noisy so the aim is to take the longest exposures you can and stack as many as possible to get the best of both worlds.

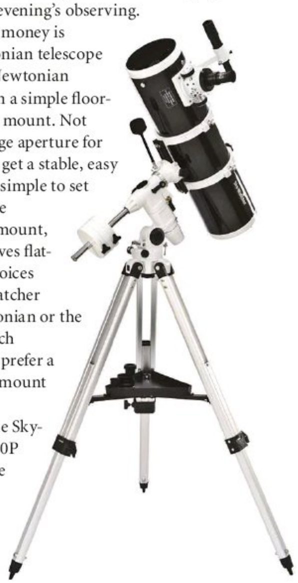
Light pollution places a ceiling on exposure length as this can produce 'fogging', where its orange glow overwhelms the image. It is important to keep exposures below this threshold, which requires some trial and error. For star clusters and globular clusters, 120-180 seconds is a good start. For galaxies and nebulae, 300-600 seconds is a good base if your tracking will allow it. Do remember that these are only rough guides.

I'm a first-time stargazer. What telescopes would you recommend?

HELEN ADAMS

For observing the night sky, the principle is that the larger the telescope's aperture the better, as the more light you can collect the more objects you will be able to see. But – and this is a big but – this must be tempered with considering the ease of setting up the telescope for an evening's observing.

The best value for money is provided by a Dobsonian telescope which comprises a Newtonian reflector mounted on a simple floor-standing altazimuth mount. Not only do you get a large aperture for your money but you get a stable, easy to use mount that is simple to set up after the one-time construction of the mount, which normally arrives flat-packed. Excellent choices would be the Sky-Watcher Skyliner 200P Dobsonian or the Bresser Messier 8-inch Dobsonian. If you'd prefer a more classic type of mount and are prepared to sacrifice aperture, the Sky-Watcher Explorer 150P EQ3-2 should also be on your shortlist.



▸ The Explorer 150P is a good 'classic' scope for beginners

STEVE'S TOP TIP

What's the difference between fast and slow scopes?

The terms 'fast' and 'slow' in this context mainly apply to astrophotography, but have their origins in terrestrial photography where a faster lens allows shorter (faster) exposure lengths to be used.

For a given aperture, a shorter focal length makes a telescope fast and a longer focal length makes a telescope slow and this is quantified by the telescope's focal ratio. The focal ratio of a telescope can be found by dividing its focal length by its aperture. Ratios of 7.0 or below are considered to be fast and those higher than 7.0 are considered to be slow.

Steve Richards is a keen astro imager and an astronomy equipment expert

Email your queries to scopedoctor@skyatnightmagazine.com

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

90 Does this 4-inch apo refractor's lenses effectively counter colour fringing?

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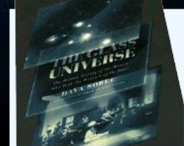
This month's reviews




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

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FIRST LIGHT

See an interactive 360° model of this scope at www.skyatnightmagazine.com/omegon104

Omegon AP 104/650 ED apo refractor

A well-built 4-inch scope that delivers good contrast

WORDS: TIM JARDINE

VITAL STATS

- **Price** £2,300
- **Optics** FPL-53 & FPL-51 apochromatic triplet
- **Aperture** 104mm (4 inches)
- **Focal Length** 650mm (f/6.25)
- **Focuser** 2.9-inch dual-speed hybrid Crayford with 1:10 reduction
- **Extras** 2-inch field flattener, tube clamps, transport case
- **Weight** 6.5kg
- **Supplier** Omegon
- **www.omegon.eu**
- **Tel** +49 (0) 8191 940490

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There is no doubt that the Omegon AP 104/650 ED apochromatic refractor stands out from the crowd. The glossy black tube is stylishly complemented by the red metallic fittings, and the solid build inspires confidence in the quality of the telescope. The fit and feel is certainly that of a professional instrument.

The Omegon AP 104/650 is packaged with a separate 2-inch field flattener, an accessory that prevents the effects of coma at the edges of photographs. The spacing between a flattener and a camera depends on the focal ratio of the telescope. The Omegon 140/650 ED is f/6.25, so we set our full frame DSLR camera to the specified 113mm spacing using our own adaptors.

Our first optical test was to check focus and colour correction across the imaging circle. We found that with the flattener in place the telescope provided sharp round stars to the majority of the field. At the very edges of the full frame picture a little distortion was visible. Cameras with smaller sensors (like CCDs) should be unaffected and produce pictures of crisp stars with tight colour correction.

SKY SAYS... With the flattener in place the telescope provided sharp round stars to the majority of the field

With limited clear skies we used a more sensitive colour CCD camera with a smaller sensor to acquire the night-sky images you see over the page. The scope's multicoated optics, internal baffling and extending dew shield all assisted in creating good contrast in our images and views, and despite the skies being decidedly murky during our photography sessions we were still able to use the scope to produce some reasonable photos in a short time.

The working focal length of 650mm is useful for a wide range of deep-sky objects – powerful enough for larger galaxies and wide enough for extended nebulae. We were pleased to see that even small, faint objects and stars were well resolved, such as the little cluster NGC 206 in the outer arms of the Andromeda Galaxy.

The proof is in the fitting

Astrophotography with the Omegon is straightforward. The geared, 2.9-inch Crayford focuser allows you to attach a camera via a standard 2-inch nosepiece. Removing the end of the focuser reveals an M74 thread, which offers a more solid fitting for larger cameras. ▸

FRINGE-FIGHTING OPTICS

To enjoy views or photographs of the night sky in natural colour is a real pleasure. However, achieving those images requires an apochromatic telescope with special lenses designed to remove chromatic aberration. The Omegon 104/650 ED uses a triplet lens system with air-spaced elements constructed from FPL-53 and FPL-51 glass to bring the major colour wavelengths of light to a matching focus point.

At the eyepiece the effectiveness of the triplet lens was easy to see. We observed bright targets including the Moon, Jupiter, Venus and Mars, carefully checking for any tell-tale blue haloes or green and purple fringing. At the centre of the view we found the colour correction of this lens to be excellent, allowing observation of smaller details in Jupiter's bands and even on Mars, which was not best placed for observing.

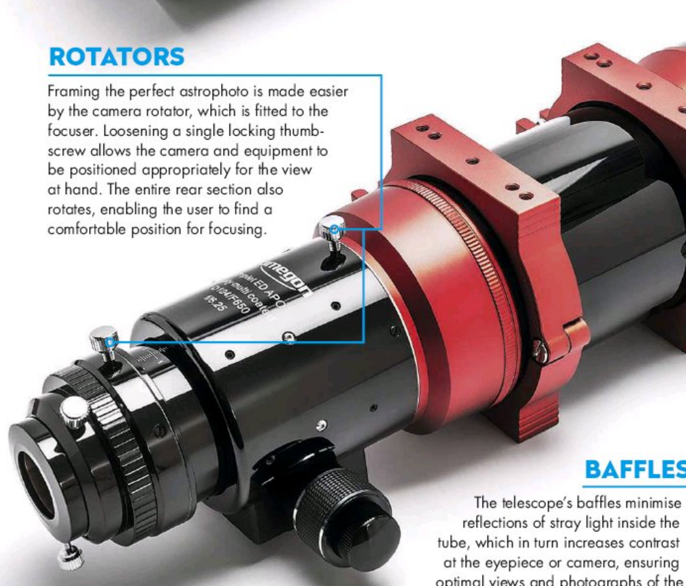
Our cameras confirmed the findings from the eyepiece, a full frame DSLR and colour CCD camera producing images of stars without bloated blue haloes, ably demonstrating that the Omegon 104/650 ED deserves its 'apochromatic' badge.

FIELD FLATTENER

Correcting distortions, or coma, at the edge of the field of view is taken care of by the included field flattener. Camera chip spacing behind the flattener is a generous 113mm (±4mm), allowing for the use of accessories such as filter wheels or off-axis guiders. The rear male thread is M48.

TUBE CLAMPS

The CNC-machined tube clamps provide a solid base for attaching the dovetail of your choice. The clamps are threaded for metric bolts on both sides, with multiple fixing points.



ROTATORS

Framing the perfect astrophoto is made easier by the camera rotator, which is fitted to the focuser. Loosening a single locking thumbscrew allows the camera and equipment to be positioned appropriately for the view at hand. The entire rear section also rotates, enabling the user to find a comfortable position for focusing.

BAFFLES

The telescope's baffles minimise reflections of stray light inside the tube, which in turn increases contrast at the eyepiece or camera, ensuring optimal views and photographs of the fainter objects in the night sky.

FIRST **LIGHT**

TRANSPORT CASE

Protecting your investment is made easier with the custom transport case supplied with the telescope. Constructed from aluminium and reinforced at the corners, the case enhances portability and makes safe storage easier. There is space within the foam cut-out for the tube rings and coma corrector.

SKY SAYS...
Now add these:

1. Omegon 2-inch star diagonal (99 per cent reflection)
2. Omegon Vixen-style finder shoe
3. Omegon prism rail

▸ We were a little hesitant to entrust our cameras to the single thumbscrew lock when using them with a nosepiece. With the temperature dropping through our imaging session we checked focus every few exposures, and had to slightly adjust it each time. Movement using the right-hand coarse focus knob was stiff and jerky, whilst the left-hand knob was loose and completely ineffective. Thankfully the fine-tuning control was working properly. With so much attention given to the rest of the telescope, it seemed slightly odd to have had issues with the focuser; it did not appear to have been correctly set up.

With pictures in the bag we replaced the camera with our eyepieces and enjoyed a few hours of observing. Our target list included planets and faint galaxies, the high contrast of the optics making it possible to pick out some detail in the Whirlpool Galaxy (M51) and good resolution in globular clusters M13 and M3.

At times during the observing session we noticed a little flaring in the stars. Checking back on the photos we had taken revealed that on some of them there was the same issue. We also noticed that within the tube there is a bright brass component of the focuser that has not been blackened, which could cause unwanted reflections.

Aside from those niggles, the Omegon AP 104/650 ED offers impressive views and pictures in a well-made and well-presented package.

VERDICT

BUILD & DESIGN	★★★★☆
EASE OF USE	★★★★☆
FEATURES	★★★½☆
IMAGING QUALITY	★★★★☆
OPTICS	★★★★½
OVERALL	★★★★☆

WWW.THESECRETSTUDIO.NET, TIM JARDINE X 3

The Orion Nebula, stacked from 150 30-second frames that were captured using an Atik 460EX colour CCD

▲ The Monkey Head Nebula, stacked from 30 10-minute exposures (left), and the Pleiades, stacked from 24 10-minute captures (right), both taken with an Atik 460EX colour CCD

See an interactive 360° model of this mount at www.skyatnightmagazine.com/losg11g

Losmandy G11-G equatorial mount

A technical mount, but one that really delivers once you get used to it

WORDS: PETE LAWRENCE

VITAL STATS

- **Price** £3,433
- **Load capacity** 27kg
- **Hand controller** Gemini-2 Mini
- **Database** 40,000 objects
- **Flash upgradeable** Yes
- **Autoguiding** Onboard TTL port, via USB mount control or ethernet connection.
- **Weight** Mount head 13.6kg, tripod 15.9kg
- **Supplier** Ian King Imaging
- **www.iankingimaging.com**
- **Tel** 01580 212356

WWW.THESECRETSTUDIO.NET X 4

The Losmandy G11 is an intermediate-level equatorial mount. It's been around for many years, yet despite many tweaks and refinements since its first incarnation its core design retains the same characteristics that have earned it a loyal following. The version we're reviewing here is the G11-G, fitted with Losmandy's Gemini-2 Mini control system.

The mount is a package of three parts: a tripod, a mount head and the Gemini-2 Mini controller. The tripod is a solid affair constructed from sturdy, black-anodised aluminium tubing. The legs connect to a central column by a pivot and can be folded for transport. In contrast to earlier versions of the G11, this folding leg arrangement makes the mount relatively painless to move around.

The mount head locks into the central column via three hex bolts and when tightened the structure is as solid as a rock. The Gemini-2 Mini bolts to the column in a way that allows it to be tilted to a convenient angle for you. Two 94cm cables connect it to the RA and dec. servo drives. A separate handset and an external 12-18V power supply complete the basic setup.

SKY SAYS... The G11-G is a solid performer suited for remote access thanks to its excellent ethernet connectivity

The Gemini-2 Mini's handset is a curious affair because it's double sided. On one you have a recessed colour touchscreen, through which most operations take place. On the reverse are four directional buttons, used for RA and dec. movement, which duplicate the slewing functions offered via the touchscreen. It took a while for us to get used to this design. The fact there is no hanging loop or securing cradle for the handset appears to be an oversight.

Interface quirks

The touchscreen interface is comprehensive, but can be confusing. The control system is functionally rich, but the interface could be polished more. For example, the electronic display helps you to achieve balance on the RA and dec. axes by reporting how the servos are working. All the technical information you need is there, but the initial reason isn't always obvious.

The Gemini-2 system provides a polar alignment routine to get you within 1° of the pole. Once this has been completed, you can create a 'model' to refine the mount's pointing accuracy. Separate models are constructed for the east and west ▸

GEMINI-2 MINI

The Gemini-2 Mini control system elevates the functionality of the Losmandy G11 mount, providing a 40,000-object Go-To database, non-volatile memory and a real-time clock. All control functions are accessed either via the supplied handset or a web interface operated through an existing network via an ethernet connection. The Mini is a refined version of the previous Gemini controller, with a tidier layout to complement its smaller design. Periodic error correction (PEC) is supported, allowing you to teach the computer about inherent errors in the mount's RA drive. The PEC data can be held permanently. The internal storage also holds sky models that are used to provide greater pointing accuracy to within half an arcminute of the target's position.

Slewing speeds are named Slew, Move, Centre and Guide, representing incrementally slower speeds. The speed is selected by simply pressing a 'button' on the touchscreen display. There's an option to alter the mount specifications should you need to. This could be used for example, if you decided to upgrade to a heavy-duty Losmandy Titan 50; the Gemini-2 Mini can be easily ported across to your new mount.

CONNECTION PORTS

The Gemini-2 Mini provides two USB ports and an ethernet 10/100 port. Additionally there is a port for the dual-sided hand controller, one for an optional serial/GPS unit, an autoguider connection, an external trigger port (labelled E) and a multi-function serial port (F).

HAND CONTROLLER

The Gemini-2 Mini's handset has a dual personality. Most controls are performed via a recessed, full-colour touchscreen interface on one side of the handset. Four direction arrow buttons are presented on the reverse side for convenient slewing. The touchscreen offers auto-colour adjustment using a red light to help preserve night vision.

HD FOLDING TRIPOD

The supporting tripod is well engineered, constructed from machined aluminium and finished with a black anodised coating. The legs themselves are pivoted from a central column and this makes the tripod easy to collapse for transport. The legs are extendable, providing an overall height adjustment of 84-122cm.

FIRST LIGHT

SKY SAYS...
Now add these:
1. **Losmandy 14-inch universal dovetail plate**
2. **Rapid 4A/13.8V mains to regulated power supply**
3. **HiTecAstro mount hub pro**

▸ hemispheres, and these can be stored for later sessions if required. On start-up you can elect to ignore the model via a cold start, or reuse it. If the scope was moved (for example, parked) between sessions, a warm start can work with the previous model after you re-sync the mount with an alignment star. If it has not been moved at all, a warm restart allows you to carry on from where you left off without re-syncing.

When creating our models, we found the accuracy of the system improved noticeably after each suggested hemisphere target had been centred. We also found the Go-To capability to be excellent, the mount placing our chosen targets close to the centre of our field of view each time.

Web ready

The Gemini-2 Mini can be linked to a computer network via an ethernet cable. Accessing the unit's IP address via a standard browser brings up a web interface. This provides a lot of functionality, including cleaner access to the Go-To catalogues and a set of tutorial videos regarding the mount's operation. We found the web interface easy to set up and use. The Gemini-2 Mini integrates well with the ASCOM platform, allowing the mount to be controlled from many ASCOM-compliant planetarium programs. In particular, after installing an ASCOM Gemini.net driver, we had no problem autoguiding the mount via the ethernet connection using the popular PHD Guiding software.

The G11-G is a solid, technical performer ideally suited for remote access thanks to its excellent ethernet connectivity. Beginners may struggle with some of its more technical aspects but under the bonnet, it really does deliver. Its accuracy appears to be extremely good and the G11-G is certainly a suitable candidate for long-exposure precision imaging. Ⓢ

WWW.THESECRETSTUDIO.NET, PETE LAWRENCE

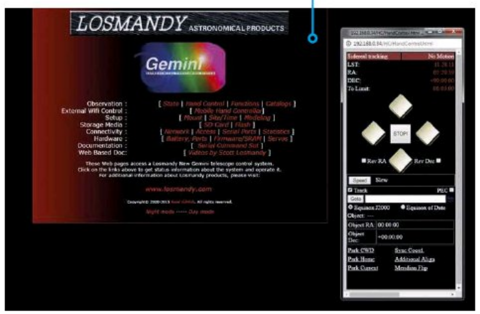
VERDICT	
ASSEMBLY	★★★★½
BUILD & DESIGN	★★★★★
EASE OF USE	★★★★★
GO-TO ACCURACY	★★★★½
STABILITY	★★★★★
OVERALL	★★★★½

RA & DEC. SERVOS

DC servo motors are used for improved accuracy and higher torque. We found these to be quite noisy, emitting a high-pitched whine when fast slewing. The RA worm gear has a diameter of 142.9mm and contains 360 teeth. It's driven by a dual-supported, high-precision brass worm offering a pointing accuracy of 30 arcseconds or better.

ETHERNET CONTROL

Connecting the Gemini-2 Mini to your computer network gives access to its web interface, making remote access very simple. A smartphone or tablet connected to the same network could also access this page. The Gemini-2 Mini and its ethernet link are also compatible with the ASCOM platform. Installing ASCOM's Gemini.net driver, for example, will allow you to autoguide via the high-speed ethernet link.



FIRST **LIGHT**

See an interactive 360° model of this filter at **www.skyatnightmagazine.com/sodiumquark**

Daystar Sodium D-Line Quark eyepiece filter

This little-used wavelength is a welcome addition for solar astronomers

WORDS: GARY PALMER

VITAL STATS

- **Price** £1,099
- **Barrel size** 1.25 inch and 2 inch
- **Tuning range** 589 nm
- **Power** 1.5A/5V USB
- **Extras** Power supply, protective case
- **Weight** 400g
- **Supplier** Altair Astro
- www.altairastro.com

SKY SAYS…
It was easy to pick out the smallest of sunspots, which would be hidden to a hydrogen-alpha setup

Using the sodium wavelength of light for solar astronomy is not a new concept, but one traditionally considered as being quite exotic by amateur astronomers. Perhaps it will become a bit more accessible now that Daystar has added a sodium D-line eyepiece filter to its Quark range.

This eyepiece filter has a bright gold housing at the top to distinguish it from the other Quark variants, but its shape is the same as the original hydrogen-alpha model on account of the 4.3x telecentric Barlow lens housed within. On top of the unit is a 1.25-inch eyepiece holder, on the bottom 1.25-inch and 2-inch mountings for a telescope. As with all of the other Quarks, it has a wing shift control knob and a power supply is included.

The eyepiece filter is designed for air-spaced refractors that have focal ratios of f/4-f/9, and can be used in conjunction with an ultraviolet/infrared-blocking filter. If you need to use an energy rejection filter (ERF), make sure it is a yellow one – a red ERF won't allow the sodium D-line through.

This is quite an exciting product for solar astronomers in the UK as it has a 589nm bandpass, a good area of the spectrum with respect to poor weather conditions or a low winter Sun. Here we are looking at the Sun's photosphere, and in some ways the view through the D-Line can look similar to that given by a white light filter. The changeable UK weather conditions can cause all sorts of issues with solar astronomy – calcium, hydrogen-alpha and white light can produce quite poor results in mid-winter. By narrowing the wavelength, the unwanted parts of the light spectrum are removed and this then gives us a cleaner view of our star.

Setup is easy: all you need to do is attach the ultraviolet/infrared-blocking filter to the front of a star diagonal and then insert the eyepiece filter itself.

Quiet success

The Sun has started to enter a quiet period but we were fortunate to witness a reasonably sized sunspot for our first test, using the Quark in conjunction with a 25mm eyepiece and a 6-inch, f/6 Altair Starwave refractor. The Sun appeared a nice yellow colour, the detail in and around the sunspot sharp and crisp. However, the view was quite bright and this did lead to ▸

A WINNER IN WINTER

The Sodium D-Line Quark is a really good piece of kit for any solar astronomer. The ability to image straight through poor seeing with a low Sun in winter is quite an achievement, as all too often it's not worth setting up your equipment. Having a clear 20mm aperture filter allows the use of the latest large sensor cameras with no distortion to the image.

The filter allows for high-speed imaging due to its brightness compared to the calcium and hydrogen-alpha Quarks, which is useful for making the most of gaps in the cloud to grab images quickly.

On a large aperture telescope with good seeing in the summer it should be possible to make some nice time lapse videos of sunspots and granulation movement. The eyepiece holder can be removed and replaced with an interference eliminator for higher quality images.

This sunspot was imaged using the Sodium Quark – it's a stack of the 250 best frames from a capture run of 1,000

WWW.THESECRETSTUDIO.NET X 4, GARY PALMER

TELECENTRIC BARLOW LENS

Designed for use on f/4 to f/9 refractors, with the built-in 4.3x telecentric Barlow this eyepiece filter delivers a final image of f/17 to f/38. This internal system makes it four times more powerful than a standard solar scope.

POWER PORT

Plug in the power supply and wait for the temperature indicator light to go green; in winter, we did find that this could take up to 15 minutes. The filter can also run on a 1.5A/5V battery pack.

TUNING KNOB

The tuning knob adjusts the centre wavelength by 0.1A with each click, adding or subtracting contrast in the view. This can also be used to compensate for droop on the focuser.

BARREL

This filter has been designed to fit on most refractor-based telescopes and comes with 2-inch and 1.25-inch barrels. The 2-inch barrel has a cut-out to allow for a more precise 1.25-inch mounting.

FIRST LIGHT

SKY SAYS...
Now add these:
1. Altair Hypercam IMX174 camera
2. Altair 2-inch positive lock diagonal
3. Altair interference eliminator

▸ a lack of any granulation detail. In subsequent views with different equipment this remained the case.

For imaging, we attached the eyepiece filter to a 5-inch Astro-Tech TMB-130 refractor and later on a 3-inch Altair Starwave 80ED refractor, using a few different cameras. We were impressed with the detail in the images considering the weather conditions at the time. Attaching a camera is easy – just remove the eyepiece from the Quark and replace it.

Newton's nuisance

This Quark can be used with both monochrome and colour cameras, with mono devices giving the sharpest detail. The fact that views through the sodium D-line are quite bright helps to keep imaging times down, but can produce a phenomenon known as Newton's Rings – a series of visible concentric circles. Optional tilt adaptors are available to compensate for this.

On the screen there was a lot more of the granulation detail that was missing when simply looking through the eyepiece, and when roving over the surface of the Sun it was very easy to pick out the smallest of sunspots, which would be hidden to a hydrogen-alpha setup. Daystar says the sodium D-line Quark can pick up flare footprints, but with the lack of solar activity we didn't see any. The detail around the larger sunspots, however, was very good, and on the videos recorded remained very stable.

It did take a little playing around to get the most from the videos – in the end we found that recording 1,000 frames for each and stacking the 100 top frames gave us the best results – but when we did the D-line Quark gave us more detailed images of sunspots then the calcium and hydrogen-alpha variants. It is a pleasing addition to the Quark family. Ⓢ

VERDICT	
BUILD & DESIGN	★★★★★
EASE OF USE	★★★★☆
FEATURES	★★★★☆
IMAGING QUALITY	★★★★★
VISUAL QUALITY	★★★½☆
OVERALL	★★★★½

WWW.THESECRETSTUDIO.NET

LED
A coloured LED shows progress of the Quark heating up to the correct temperature. At first it is yellow, and remains so for 5-10 minutes, turning green when the filter has settled to its required temperature and is 'on band' for viewing. Red indicates that not enough voltage is reaching the unit or that there is an electrical fault.

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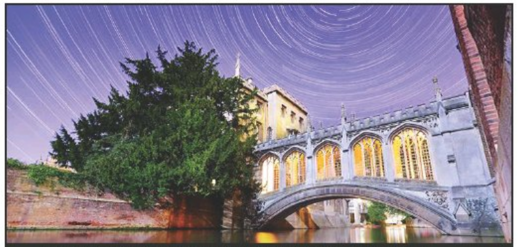

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Books

New astronomy and space titles reviewed

RATINGS

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

The Glass Universe

Dava Sobel
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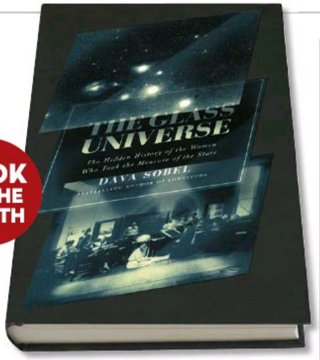
£16.99 ● HB

BOOK OF THE MONTH



Glass plate negatives of the sky systematically taken over 75 years do not sound like the makings of a gripping read. Yet they form the grounding for a web of stories that take us into observatory life at the turn of the 20th century, stories that show us – with the lightest of touches – the obstacles and opportunities that the period offered to women hoping for a career in science. At the same time, they introduce the new ideas that were then emerging about variable stars, galaxies, the composition of stars and their evolution.

This is a book about women in astronomy with few comparisons. It tells the story not of a single pioneer, but of an observatory and the group of women who worked there. In doing so, it bypasses the need to identify heroic acts to justify their fame. Instead, we see the day-to-day experiences of people that today we honour as pioneers – Annie Jump Cannon, Cecilia Helena Payne-Gaposchkin and Henrietta Swan Leavitt – as the observatory supported them in their careers.

The story begins in 1882, when rich heiress Anna Draper met with Harvard College Observatory director Edward Pickering. Draper's husband had spent his life photographing the spectra of stars; she hoped that work could continue, and was prepared to pay for it. Chapter by chapter we are then introduced to the women who helped fund, carry out and shape that project.

There are some wonderful observations in the book, as the women experience certain injustices. As Ms Payne put it, she had originally pictured herself "a rebel against the feminine role," before recognising that her real rebellion "was against being thought, and treated, as inferior." Observatory directors Pickering and then Harlow Shapley tried not to treat women as inferiors, and in that environment the women thrived.

Annie Jump Cannon at her desk at Harvard College Observatory

SMITHSONIAN INSTITUTION ARCHIVES

There are a few loose ends. Hertzsprung appears, joined a few pages later by Russell, yet no diagram follows. The year 1930 comes and goes with no mention of Pluto. These, however, are minor quibbles and very much an aside from the main story, which is told beautifully.

★★★★★

DR EMILY WINTERBURN *is the author of* The Stargazer's Guide: How to Read our Night Sky

TWO MINUTES WITH Dava Sobel

What was your inspiration in writing the book?
I heard the name Henrietta Swan Leavitt for the first time about 20 years ago, while interviewing astronomer Wendy Freedman. When I looked into Leavitt's background, I discovered she worked within a large group of women at Harvard College Observatory. The more I learned, the more intriguing the story sounded.

Was this a difficult book to research?
What made it quite difficult was the number of characters in the story and the length of time that elapsed from the hiring of Harvard's early female computers to the granting of tenure to the university's first female professor of astronomy. Diaries and letters helped me portray the individual players and put their work in the context of their lives.

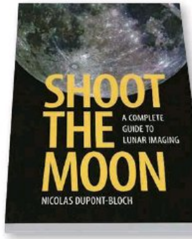
What are some of your favourite stories from the book?
I admire Williamina Fleming's rise from maid in the observatory director's residence to Curator of Astronomical Photographs, the first Harvard University title granted to a woman. I was also moved by Annie Jump Cannon's ability to befriend other astronomers all over the world, and even carry on correspondence with their children.

How can we encourage young women to choose a career in science?
I'm sure there are many ways, but the only one I know is to tell true stories so young women have real examples to follow.

DAVA SOBEL *is an author and former science reporter for the* New York Times

Shoot the Moon

Nicolas Dupont-Bloch
Cambridge University Press
£24.99 ● PB



There are many books about astrophotography, and many more about the Moon. But there are few that combine the two, and none that does it this well. This guide moves from the extremely simple (holding your smartphone up to a telescope eyepiece) through to the eye-wateringly complex, by way of sensors, image formats and processing techniques.

The author's experience shines clearly through his prose, his images and the many tips that he shares: his idea of a DIY focusing lever instead of an expensive microfocuser, for example. Another worthy suggestion is to create a negative image to better highlight ray systems. The book is littered with such observations.

Yet there is no escaping the fact that this is a rather technical book. The complexity of the content and the inclusion of numerous equations, graphs and process diagrams will no doubt appeal to experienced astronomers or astrophotographers, but will be less attractive to those just starting out.

That said, the book also provides a delightfully comprehensive overview of lunar features and phenomena, from mountains and maria to mascons and pyroclastics, which will no doubt be of interest to beginners or those looking to brush up on their lunar knowledge. There are also suggestions of specific observing targets, along with an explanation of how each of these can be imaged to best effect.

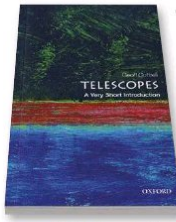
If you are new to astronomy or astrophotography, you would be better off by starting with something more basic. But if you are a keen lunar observer looking to start imaging, or an astrophotographer looking to take things to the next level, this is the book for you.

★★★★★

SIMON PERKS *is a science writer and a Fellow of the Royal Astronomical Society*

Telescopes
A Very Short Introduction

Geoff Cottrell
Oxford University Press
£7.99 ● PB



The smallness of this pocket-sized Very Short Introduction belies the depth into which it delves. *Telescopes* explores an instrument that has made us aware of the Universe around us. This historical and scientific survey of the telescope threads a path from our most basic means of grasping light – the human eye – to the giant lightbuckets millions of times more powerful that are yet to be built.

The prose is authoritative and insightful, leading readers on a remarkable 400-year journey from the earliest reflectors and refractors of the 17th century to the 'silvering' of mirrors, and on to the use of photography to manipulate light, discern far-off objects and explore the breadth of the electromagnetic spectrum.

Yet for all the technological advances made on the ground from Galileo's day, our most significant breakthrough came when we first placed a telescope above Earth's distorting atmosphere. Along with developments in charge-coupled devices, computer and software control and adaptive optics, modern astronomers now have a sturdy arsenal of tools at their disposal to peer deeper into the Universe and farther into the past than ever before.

Published four centuries after Galileo's primitive telescope left its indelible mark and made Jupiter's four large moons known for the first time, *Telescopes* brings us up to date via a glimpse through the eyepiece towards the future. It ends by wistfully whetting the reader's appetite for upcoming telescopes on the ground and in space that, like the human eye itself, will continue to evolve.

★★★★☆

BEN EVANS *is the author of several books on human spaceflight, and is a science and astronomy writer*

Exploring Space
From Galileo to the Mars Rover and Beyond

Martin Jenkins & Stephen Bietsy
Walker Books
£14.99 ● HB

Exploring Space is almost two books in one. First there's the text, which covers the technology behind humanity's exploration of the Solar System. It's interspersed with cut-away illustrations on everything from spacesuits to space stations, telescopes to Mars rovers, and communications satellites to space elevators.

The narrative starts with the Voyager spacecraft leaving the Solar System, then takes the reader back a couple of millennia to ancient observatories before speeding through the story of space exploration – past, present and future. While the language is clear, it's not oversimplified. Nor does the text shy away from important details, such as what interferometry is or why we think there's flowing water on Mars.

The graphics are the real highlight, though – refreshing in their appearance, a hand-drawn style that is not too 'cartoony'. Some are more complex than others, but the detail is almost guaranteed to encourage further reading. Some are pleasantly surprising. For example, the main rocket schematic is the Soyuz (the most launched type of rocket in the world), not the Saturn V. And it's rare to see such a detailed image of a communications satellite, which are surprisingly complicated (and important). There's bound to be something in here that's new for even the most widely read space enthusiast.

★★★★★

DR CHRIS NORTH *is Odgen Science Lecturer and STFC Public Engagement Fellow at Cardiff University*

Gear

Elizabeth Pearson rounds up the latest astronomical accessories

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3 Petzl Tactikka Head Torch

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www.trekkinn.com

Preserve your night vision with this head torch's red light mode, then switch to white light when it's time to pack up.

4 Baader Diamond Steeldrive System

Price £268.34 • **Supplier** Microglobe
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6 Alaska print swing dress

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WHAT I REALLY WANT TO KNOW IS…
Did these stars once live in a globular?

Ricardo Schiavon has discovered a new family of stars in the heart of the Milky Way that could explain how galaxies formed

INTERVIEWED BY PAUL SUTHERLAND

Sky surveys are one of the most exciting fields of astronomy today. Specialised digital cameras and spectrographs fitted to wide-field telescopes are allowing us to learn about large numbers of stars, or galaxies, at a time.

I am a member of the team that is conducting one such census, the Apache Point Observatory Galactic Evolution Experiment (APOGEE). It is one of three being carried out as part of the Sloan Digital Sky Survey IV, using a 2.5m telescope in New Mexico.

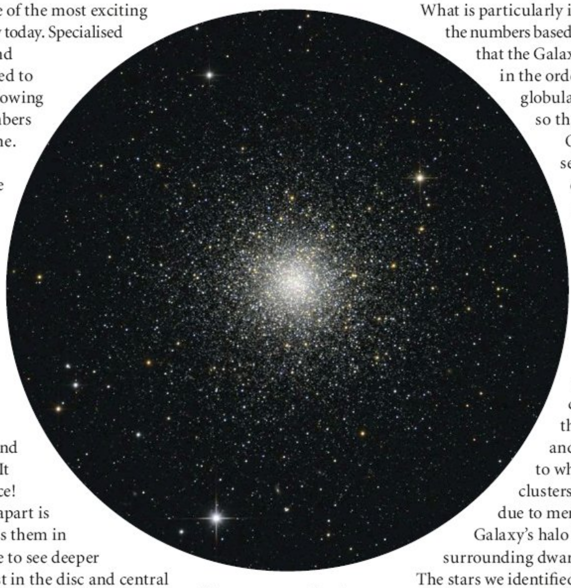
APOGEE studies hundreds of thousands of stars in the Milky Way to find out what they are made of. It can observe 300 stars at once! What sets this experiment apart is that its spectrograph studies them in infrared light, and so is able to see deeper into the vast amount of dust in the disc and central bulge of our Galaxy. Dust extinguishes optical light very efficiently, but not so much infrared light.

The first survey by this instrument, APOGEE 1, collected data on 150,000 stars, determining their velocities and chemical makeup accurately. And in doing so, we made an unexpected discovery.

Nitrogen abundance

For the first time, it was possible to collect this data for over 5,000 stars within two kiloparsecs (about 6,500 light years) of the galactic centre. And we discovered that a sizeable number of these stars contained very high levels of nitrogen. Such high nitrogen abundance is known to be a characteristic of stars found in globular clusters, those ancient concentrated collections of stars found in the halo around the Milky Way.

The reason for the existence of these stars in the centre of our Galaxy has not been established yet. But the explanation that seems most likely is that these stars actually result from the destruction of an early population of globular clusters.



BERNHARD HUBL/CCDGUIDE.COM

If the team are right, there might have been 10 times as many globulars in the past as there are today

What is particularly interesting is that, if you do the numbers based on our observations, we find that the Galaxy must have had something in the order of 10 times more globular clusters than the 150 or so that we see surviving today.

Our discovery was quite serendipitous. We weren't expecting it, though my previous research in the field of extragalactic astronomy, where I studied the cores of other galaxies, had indicated that it would be a possibility. In that early work, 10 years ago, I identified an abundance pattern in the cores of elliptical galaxies that was nitrogen enriched, and I suggested it was similar to what you see in globular clusters. And elliptical galaxies are due to mergers of galaxies, just as our Galaxy's halo was formed by absorbing surrounding dwarf galaxies.

The stars we identified have a velocity and spatial distribution that is indistinguishable from populations of other stars in the inner halo. That means they are not the result of a recent accretion process, but have been there for a long time.

I suspect they originally existed in globular cluster systems belonging to dwarf galaxies that came together in the formation of the early halo. These clusters would have been drawn by gravity into the centre of our Galaxy and got disrupted by its tidal forces.

We will follow up our findings by doing computer modelling to work out how this all happened. We will also carry out further observations using a clone of the APOGEE spectrograph fitted to the du Pont 2.5m telescope and also the European Southern Observatory's Very Large Telescope, both in Chile. It will be a lot easier to study the inner Galaxy from there as it lies in the southern part of the sky.

Studying our Galaxy helps us to learn more about galaxy formation in general because it is the only galaxy we can see in so much detail. It is also a way in which we can get a handle on our own origin. ⓢ

ABOUT RICARDO SCHIAVON
Ricardo Schiavon is based at Liverpool John Moores University's Astrophysics Research Institute, from where he seeks to solve the riddle of how galaxies came to be

THE SOUTHERN HEMISPHERE IN MARCH

With Glenn Dawes

WHEN TO USE THIS CHART

1 MAR AT 00:00 UT
15 MAR AT 23:00 UT
31 MAR AT 22:00 UT

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

MARCH HIGHLIGHTS

Comet Encke returns briefly in 2017, passing closest to the Sun early in March, then moving into the dawn sky. Located in Aquarius, it may be visible in binoculars in the third week of the month. Look for it a few degrees above the eastern horizon one hour before sunrise, or approximately 15° to the lower left of mag. +1.2 Fomalhaut (Alpha (α) Piscis Austrini). It should be around 5th magnitude at this time, fading to 8th magnitude by month end. It's likely to be a reasonable telescopic object in April.

STARS AND CONSTELLATIONS

The late evening sees two distinctive constellations near the horizon. Rising in the east is Scorpius, heralding the coming winter. At the same time, the western sky sees the summer icon, Orion, tilted on his side preparing to set. These bodies share a common legend and being on opposite sides of the celestial sphere is key to this fable. In Greek mythology, Orion was killed by the scorpion's sting. This heavenly hunter is destined to flee his deadly enemy for eternity.

THE PLANETS

Venus can be seen low in the western twilight sky in the first week of March, setting about 45 minutes after sunset. It will be a thin crescent and a 50-arcsecond disc. Mars continues its slow descent towards the Sun, setting near the end of twilight. Around this time Jupiter is rising and will be visible for the entire night, transiting (due north and highest in the sky) in the early hours. Saturn rises at 23:00 EST mid-month, leaving the whole morning to enjoy this ringed wonder.

DEEP-SKY OBJECTS

Antlia, the Pump, is an obscure southern constellation with its brightest star – Alpha (α) Antliae – only mag. +4.2. It forms a nice naked-eye double with Delta (δ) Antliae (RA 10h 29.6m, dec. –30° 36') only 0.7° to the northeast. Delta Antliae is itself a great double comprised of a mag. +5.5 yellow primary with a fainter, mag. +9.8 companion a comfortable 10 arcseconds away.

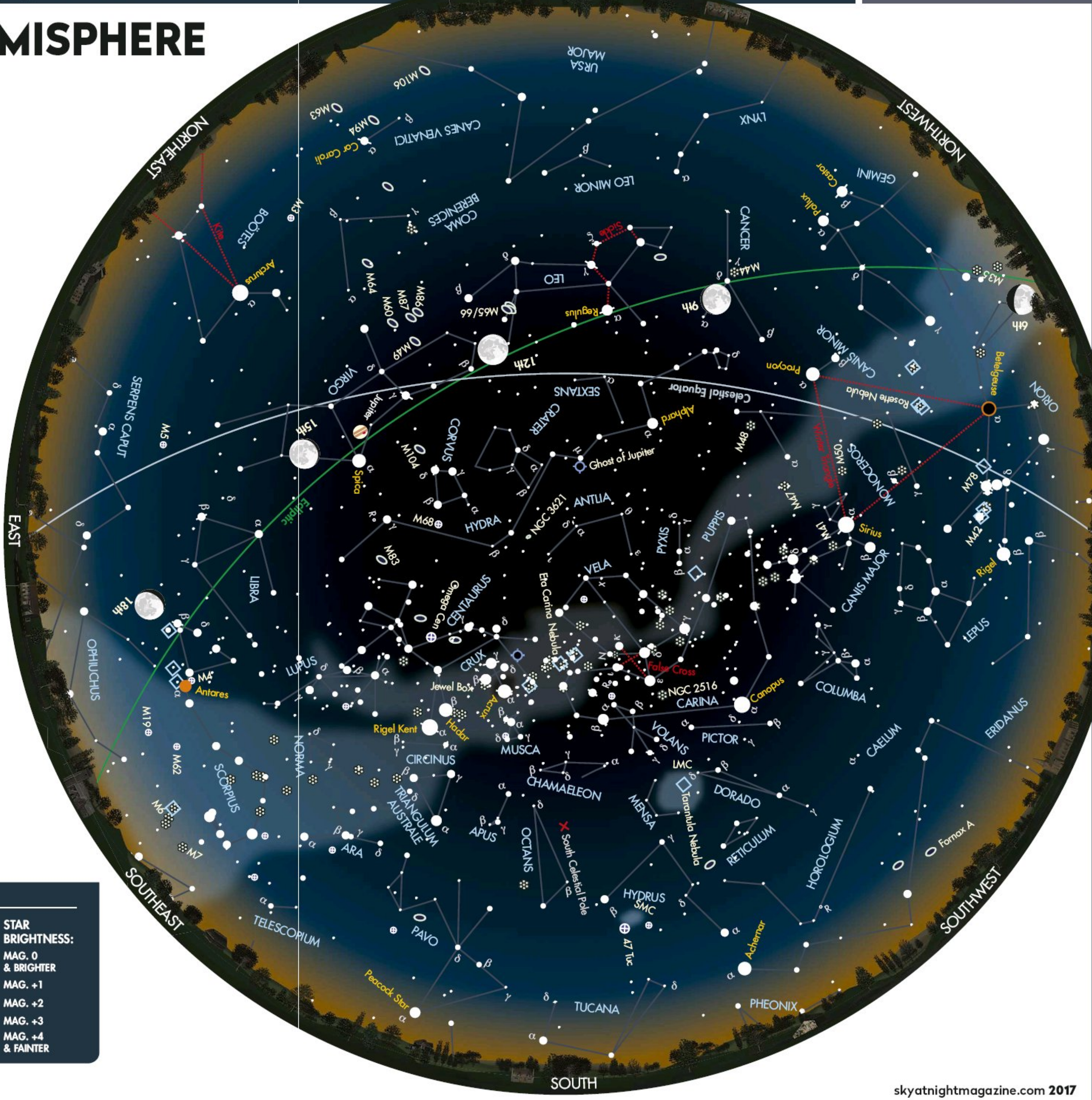
Moving 11° east (and slightly south) from Alpha Antliae is mag. +9.5 spiral galaxy NGC 3621 (RA 11h 18.3m, dec. –32° 49'; pictured). It has a bright oval core, in which some dark markings are visible. It sits within a pattern of four stars that resembles the Southern Cross, with the southern and southwestern stars (both 10th magnitude) quite prominent. The galaxy's fainter outer region fills much of this asterism.

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: BERNHARD HUBL/CHRISTOPH KALTSEIS/ WOLFGANG LEITNER/ HERBERT WALTER/CCDGUIDE.COM



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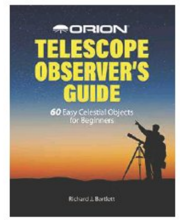

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#8715 £153

7 Orion® 1.25" Telescope Accessory Kit
This value-packed kit comes with seven accessories in a foam-lined hard carry case. Includes 20mm and 7.5mm Sirius Plössl eyepieces; Shorty 2x Barlow lens; #12 Yellow, #25 Red, and #80A Blue filters; and a neutral-density Moon filter.
#8889 £98

8 Orion® 1.25" Premium Telescope Accessory Kit
This comprehensive kit will enhance the abilities of any telescope. Includes Five Sirius Plössl eyepieces; 40mm, 17mm, 10mm, 7.5mm and 6.3mm; a Shorty 2x Barlow; five color filters; #12 Yellow, #23 Orange, #25 Red, #58 Green and #80A Blue; and a Moon filter all packed in a foam-lined hard case.
#8890 £160

1

#8241	3.5mm	£137
#8242	5mm	£154
#8243	8mm	£137
#8244	13mm	£141
#8245	17mm	£137

2

#8738	7.5mm	£36
#8736	10mm	£35
#8733	20mm	£36
#8741	25mm	£40

3

#8827	26mm	£88
#8828	32mm	£88
#8829	38mm	£88

4

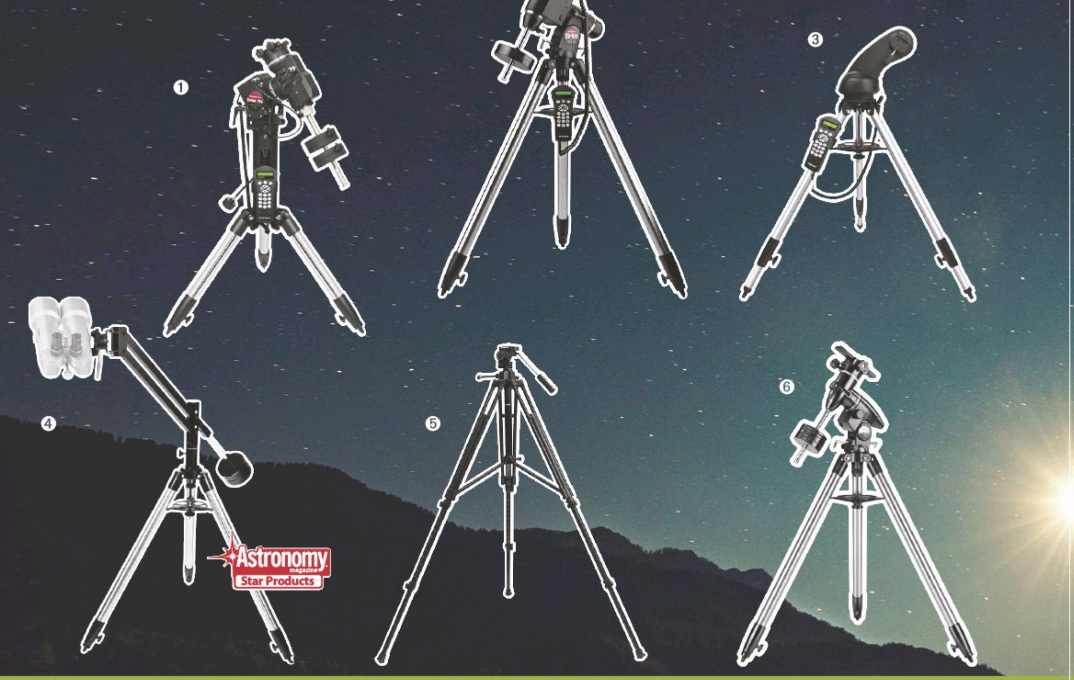
5

6

7

8

STURDY MOUNTS AND VERSATILE ACCESSORIES



ADVERTISING FEATURE

❶ Orion® Sirius™ Pro AZ/EQ-G GoTo Telescope Mount

This compact GoTo telescope mount combines astrophotography-caliber tracking precision with the ability to hold one or two mid-sized telescopes and a vast computerized database of over 42,000 night-sky targets to explore. Supports up to 30 lbs./13.6kg.

#10088 £1,258

❷ Orion® Sirius™ EQ-G Equatorial GoTo Mount

The Orion Sirius EQ-G GoTo Telescope Mount is less hefty than the Orion Atlas but with the same drive motors, electronic features, and functionality. This mount can hold up to a 30 lb./13.6kg load and allows you to select from 42,900 objects in the database.

#9995 £1039

❸ Orion® StarSeeker™ IV GoTo Altazimuth Mount & Tripod

With a telescope payload capacity of 13 lbs./5.8kg, the StarSeeker IV Mount provides an inexpensive upgrade for backyard astronomers who want to add the luxury of GoTo object location and motorized tracking to a small or medium telescope optical tube.

#13165 £377

❹ Orion® Monster Parallelogram Binocular Mount & Tripod

This parallelogram mount supports giant astronomical binoculars weighing up to 15 lbs./6.8kg with up to 100mm-diameter objective lenses. Six degrees of motion make it easy to balance and position attached binoculars easily, even when aimed at the zenith! *(Binoculars not included)*

#5752 £452

❺ Orion® Paragon™-Plus XHD Extra Heavy Duty Tripod

The Orion Paragon XHD field tripod is strong enough to hold binoculars, a camera, spotting scope, or small telescope - anything up to 10 lbs./4.5kg. Recently upgraded with easy-to-use lever locks and graduated marks for quick and easy leveling.

#5377 £138

❻ Orion® SkyView™ Pro EQ Telescope Mount

The Orion SkyView Pro Equatorial Telescope Mount is an affordable heavy duty mount that supports tubes up to 20 lbs./9.0kg. With the dual slow-motion knobs you have fine manual control or add an optional clock drive or full Go-To kit for added functionality.

#9829 £348

❶ Orion® Variable Polarizing Filter

The 1.25" Orion Variable Polarizing Telescope Filter reduces glare and brings out details. You can adjust the amount of light transmission for the perfect view.

#5560 £ 35

❷ Orion® SkyGlow™ Broadband Filter

Allows maximum transmission of hydrogen-alpha, hydrogen-beta, and doubly ionized oxygen. Great for visual use in areas of moderate light pollution.

#5660 £ 73

❸ Orion® UltraBlock™ Narrowband Light-Pollution Filter

If you observe from highly light-polluted sites, get an UltraBlock. It rejects wavelengths from incandescent and fluorescent lighting, which wideband filters can't stop.

#5654 £87

❹ Orion® Dielectric Mirror Diagonal

The 1.25" dielectric mirror star diagonal angles the eyepiece to a comfortable viewing position, while dielectric coatings give you brighter images compared to a standard star diagonal.

#8880 £ 84

❺ Orion® 9x50 Illuminated Right-Angle CI Finder Scope

The Orion 9x50 Illuminated Right-Angle CI Finder Scope features easy-to-see crosshairs, a big 50mm aperture, correct-image view and comfortable right-angle design.

#7020 £ 120

❻ Orion® 9x50 Right-Angle Correct-Image Finder Scope

The 9x50 Right-Angle Correct-Image Finder Scope shows you an upright, non-reversed image. And the right-angle design allows for comfortable viewing.

#7212 £83

❼ Orion® 45° CI Prism Diagonal

The Orion 45° Correct-Image Prism Diagonal is perfect for terrestrial viewing with a refractor or Cassegrain telescope. Fully multi-coated prisms give you superior image fidelity.

#7216 £ 48

❽ Orion® 70mm Multi-Use Finder Scope

Add a diagonal and eyepiece, imaging camera, video camera, or autoguiding device to create your own specialized aiming tool. *(All accessories sold separately.)*

#7220 £ 96

SINCE 1975 41st year

STABLE SUPPORT & SPECTACULAR SCOPES

❶ Orion® HDX110 EQ-G GoTo Mount with Tripod Pier

An observatory-class equatorial mount for dedicated amateur astronomers, the Orion HDX110 EQ-G Mount combines a huge 110 lb./49.8kg payload capacity with top-notch GoTo electronics and extremely precise tracking. Includes rock-solid pier with tripod legs.

#10011 £ 3,912

❷ Orion® Atlas™ EQ-G Equatorial GoTo Mount

The popular Atlas EQ-G mount supports up to 40 lbs./18.1kg on 2"-diameter stainless steel legs. You can select from over 42,000 objects and command the mount to find them. The Atlas EQ-G sports a dual-with dovetail attachment saddle that accepts both narrow and wide mounting plates.

#9996 £ 1,272

❸ Orion® Atlas™ Pro AZ/EQ-G GoTo Mount

This three-in-one smart mount can operate in equatorial GoTo mode with one telescope or Altazimuth GoTo & Tracking mode while holding two telescopes. Features bump-forgiving closed-loop electronics, precise belt-driven motors and a 44 lb./19.9kg capacity.

#10010 £ 1,832

❹ Orion® 8" f/3.9 Newtonian Astrograph Reflector

Our 8" aperture deep-sky specialist is an ideal choice for wide-field imaging with its 8", f/3.9 parabolic primary mirror and large, 70mm minor-axis secondary mirror. To eliminate off-axis light, the dual-speed 2" (50.8mm) Crayford focuser is installed 6.3" (160mm) from the front of the optical tube. A steel reinforcing plate eliminates focuser flexure, even with heavy imaging gear attached.

#8297 £ 475

❺ Orion® 10" f/3.9 Newtonian Astrograph Reflector

Our largest reflector optimized for imaging boasts 10" parabolic primary optics with a very fast f/3.9 focal ratio and a large 82mm minor-axis secondary for exceptional wide-field imaging performance. The dual-speed Crayford focuser lies 7.5" (19.05cm) from the front of the telescope for high-contrast performance. A rigid steel reinforcing plate eliminates flexure for trouble-free use of heavy imaging gear.

#8296 £ 661

❻ Orion® Premium 190mm f/5.3 Mak-Newt Astrograph

Our 190mm aperture "Mak-Newt" Astrograph delivers detailed images of deep-sky phenomena with its f/5.3, flat-field, coma-suppressed optics. A dual-speed Crayford focuser with 11:1 fine focus control provides ample, backlash-free support for imaging cameras and accessories. A 64mm secondary mirror provides a fully illuminated field diameter of over 22mm for bright images with minimal vignetting.

#9978 £ 1,696

ADVERTISING FEATURE

AFFORDABLE GEAR FOR AMAZING ASTROPHOTOS

Orion has a wide assortment of affordable astrophotography equipment that can help you obtain clear and sharp photos of the night sky. From sophisticated cameras and autoguider devices to vital adapters and brackets, our extensive line of imaging gear will help you capture amazing astrophotos!

Orion® 60mm Multi-Use Guide Scope with Helical Focuser
#13008 £ 199

1.25" Orion® StarShoot™ All-In-One Astrophotography Camera
#52098 £ 344

Orion® Thin Off-Axis Guide for Astrophotography
#5531 £ 136

Orion® StarShoot™ AutoGuider
#52064 £ 269

Orion® StarShoot™ Solar System Color Imaging Camera IV
#52175 £ 92

Orion® StarShoot™ G3 Deep Space Monochrome Imaging Camera
#53083 £ 398

Orion® Dual Finder Scope Mounting Bracket
#10145 £ 46

Orion® StarShoot™ AutoGuider Pro Mono Astrophotography Camera
#52031 £ 363

Orion® SteadyPix™ EZ Smartphone Telescope Photo Adapter
#5347 £ 83

ADVERTISING FEATURE

OPEN BOTH EYES WIDE

#51463

Specifications	15x70 Astro-Binocular	20x80 Astro-Binocular
Magnification/Objective lens	15x, 70mm	20x, 80mm
Field of view	4.4°	3.2°
Anti-reflective coatings	Fully multi-coated	Fully multi-coated
Eye relief	18mm	17mm
Weight	3.1 lbs/1.4kg	4.7 lbs/2.1kg

Orion® Astronomy Binoculars

Our amazingly affordable Astronomy Binoculars have been designed to provide peak viewing performance. Their large aperture mean gathering plenty of light for extensive astronomical exploration. High quality BAK-4 porro prisms and anti-reflection multi-coatings on every air-to-glass surface ensure as much light as possible reaches you so views are full of detail. Eyeglass wearers will appreciate the substantial eye-relief of both models.

The 15x70 model includes a tripod L-adapter, and the 20x80 features a built-in heavy-duty tripod adapter for easy attachment to a field tripod or binocular mount. Tripod use is highly recommended for long viewing sessions with these big astronomy binoculars.

get more & SAVE

Orion® 15x70 Binocular & HD-F2 Tripod Bundle

Buy our 15x70 Astro-Binos and Paragon HD-F2 Tripod together, and SAVE!

#21126 £ 152

get more & SAVE

Orion® 20x80 Binocular & XHD Tripod Bundle

Save a bundle with this 20x80 Astro-Bino and Paragon XHD Tripod set!

#21329 £ 231

15x70 Astronomy Binocular

#51463 £ 85

20x80 Astronomy Binocular

#51464 £125

Orion® Resolux™ Waterproof Astronomical Binoculars

Professional quality Resolux binoculars combine high-resolution, flat-field optics with mechanical construction that meets the U.S. military spec for ruggedness and the strict JTII spec for collimation. They are fully waterproof, and nitrogen purged to prevent internal lens fogging. The extra-large BAK-4 prisms and advanced multi-coatings on all optical surfaces really drink in the light. The eyepieces focus individually, which yields a sturdier mechanical design than a center-focus mechanism.

The Resolux's all-metal housing is armored with thick rubber to ensure a secure, comfortable grip. Each binocular comes with lens caps, heavy-duty tripod adapter, and neck strap. The 50mm models include a padded soft carrying case, while the 70mm models come with a foam-lined hard case.

7x50 Resolux

#9543 £ 259

10.5x70 Resolux

#9545 £ 382

15x70 Resolux

#9546 £ 382

Retail prices shown are current as of 01/02/17 from Orion. Product prices include VAT. Prices are subject to change without notice. Please check ***OrionTelescopes.co.uk*** *for the most current pricing. Dealer pricing and/or promotions may vary.*

#9545

Specifications	7x50 Resolux	10.5x70 Resolux	15x70 Resolux
Magnification/Objective lens	7x, 50mm	10.5x, 70mm	15x, 70mm
Field of view	7.5°	5°	4.4°
Anti-reflective coatings	Fully multi-coated	Fully multi-coated	Fully multi-coated
Eye relief	23mm	23mm	18mm
Weight	3.4 lbs/1.5kg	5.5 lbs/2.4kg	5.5 lbs/2.4kg

#9332

Orion® Scenix™ Binoculars

Scenix binoculars feature porro prisms made from high-grade BAK-4 optical glass – the same prisms found in binoculars that sell for as much as four times the price. You just can't beat Scenix for all-around value. Every air-to-glass surface is anti-reflection coated, and the objective lenses are multi-coated for additional light transmission. Orion doesn't use gimmicky "ruby" coatings like you find on some brands, which only serve to turn images green!

#9332 7x50 £ 90

#9333 10x50 £ 99

Specifications	7x50 Scenix	10x50 Scenix
Magnification/Objective lens	7x, 50mm	10x, 50mm
Field of view	7.1°	7.0°
Anti-reflective coatings	Multi-coated	Multi-coated
Eye relief	20mm	12mm
Weight	1.8 lbs/0.8kg	1.8 lbs/0.8kg

Orion® 10x50 Binocular Stargazing Kit

A great gift for any stargazer! The 10x50 binos will wow the whole family with 10x power views of the Moon, the Andromeda Galaxy, glittering star clusters, and so much more. Use our Star Target Planisphere year-round to see what stars and constellations will be visible, and where they can be found in the sky. Read the Star Target at night without disrupting dark-adapted vision with the included RedBeam Mini LED. Use the included Starry Night SE software download to learn more about the night sky.

#10008 £ 56

Specifications	10x50 Binocular Kit
Magnification/Objective lens	10x, 50mm
Field of view	6.5°
Anti-reflective coatings	Fully coated
Eye relief	14.5mm
Weight	1.6 lbs/0.7kg

Orion® 10x50 E-Series Waterproof Binoculars

Explore both starry skies and daytime vistas, rain or shine! Orion 10x50 E-Series Waterproof Astronomy Binoculars will give you great views without having to worry about rain or damp weather conditions. Observe comets, star clusters, the Moon and more in almost any weather. Multi-coated optics and top-quality BAK-4 porro prisms deliver a bright, 6.5° field-of-view. You won't have to worry about unexpected rain or foggy weather with Orion 10x50 E-Series binoculars thanks to their waterproof construction.

#10151 £ 74

Specifications	10x50 E-Series
Magnification/Objective lens	10x, 50mm
Field of view	6.5°
Anti-reflective coatings	Multi-coated
Eye relief	19mm
Weight	2.15 lbs/0.97kg

Orion® UltraView™ 10x50 Binoculars

UltraView binoculars combine fabulous light-gathering capability with the long eye relief and unsurpassed optical performance that have earned them their outstanding reputation. The eye relief of 22mm means eyeglass wearers can leave their glasses on and still take in the whole field of view.

UltraViews have high-index BAK-4 glass prisms, with fully multi-coated eyepiece and objective lenses to facilitate maximum light transmission and image quality. Made in Japan.

#9351 £ 162

Specifications	10x50 UltraView
Magnification/Objective lens	10x, 50mm
Field of view	6.5°
Anti-reflective coatings	Fully multi-coated
Eye relief	22mm
Weight	2.0 lbs/0.9kg

#9326 (tripod not included)

Orion® Giant View™ Large-Aperture Binoculars

It's the same night sky, all right. But with our jumbo Giant View binoculars, you'll see it like never before. Their large-aperture, fully multi-coated optics provide exceptional light gathering capability for stargazing.

The BAK-4 prisms and internal baffling ensure sharp images and pleasing contrast. The eyepieces focus individually, which affords a higher degree of focusing precision than center-focus mechanisms. Includes heavy-duty aluminum case.

#9326 25x100 £ 361

Specifications	25x100 Giant View
Magnification/Objective lens	25x, 100mm
Field of view	2.5°
Anti-reflective coatings	Fully multi-coated
Eye relief	18mm
Weight	10.1 lbs/4.5kg

#9463

Orion® Mini Giant™ Binoculars

Our Mini Giants' 63mm objective lenses deliver bright images of clusterings and other celestial lollipops in the evening sky. Of course, Mini Giants excel for daytime viewing as well. Their lenses and high-grade BAK-4 prisms are fully multi-coated to permit the highest light transmission possible. Contributing to the Mini Giants' comfort factor is their long eye relief. Even eyeglass wearers will see edge to edge. Each Mini Giant comes with a hard case, deluxe wide neck strap, and lens caps.

#9463 9x63 £ 206

#9466 15x63 £ 236

Specifications	9x63 Mini Giant	15x63 Mini Giant
Magnification/Objective lens	9x, 63mm	15x, 63mm
Field of view	5.0°	3.7°
Anti-reflective coatings	Fully multi-coated	Fully multi-coated
Eye relief	26mm	19mm
Weight	2.6 lbs/1.1kg	2.6 lbs/1.1kg

POPULAR BEST SELLERS

Explore starry skies with our popular favorites! Orion's wide variety of best-selling astronomy equipment will provide night after night of stargazing adventure for you and your family.

Orion® Mini Deluxe Pro AutoGuider Package

#20011 £456

Orion® StarSeeker™ IV GoTo AZ Mount

#13165 £377

Orion® SkyQuest™ XX16g GoTo Truss Tube Dobsonian Telescope

#8968 £3,378

Orion® StarSeeker™ IV 150mm GoTo Mak-Cass

#13166 £1,010

Orion® 180mm Maksutov Cassegrain Telescope

#9969 £1,125

Orion® StarBlast™ 6i IntelliScope® Reflector Telescope

#27191 £480

Orion® Mini Giant™ 15x63 Astronomy Binoculars

#9466 £236

Orion® SkyQuest™ XT10g Computerized GoTo Dob

#10135 £1,279

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no minimum order*

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We're here to help. Call us 00-800 8989 0123, or Live Chat with our representatives (1400-2400 GMT)

*Retail prices shown are current as of 21/09/16 from Orion. Product prices include VAT. Prices are subject to change without notice. Please check **OrionTelescopes.co.uk** for the most current pricing. Dealer pricing and/or promotions may vary.*