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Use the night sky as a clock and a calendar

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Studying the secrets of Enceladus's seawater

ALSO THIS ISSUE

1ST FOR GEAR

The HD video camera that filmed totality for Stargazing LIVE

LIFE IN THE DARK

What it's like to be in control of the world's largest observatories

UK SPACEPORT

Should Britain have its own permanent launch pad?

MAY 2015 #120
www.skyatnightmagazine.com

This month's contributors include...

HEATHER COUPER
SCIENCE WRITER

Get your head around Saturn's rings ahead of the planet coming to opposition on 23 May. *Page 82*

LEWIS DARTNELL
COSMIC CLOCK MAKER

With the help of the Sun and stars Lewis explains how you can stay on time, even if your watch has stopped. *Page 32*

WILL GATER
ASTRONOMY EXPERT

Will talks to the enthusiasts who are turning raw image data from space probes into their own astrophotos. *Page 40*

KENDRICK OLIVER
COSMOLOGY HISTORIAN

Kendrick examines the events that led to the identification of the CMB 50 years ago. *Page 62*

Welcome

Another month, another landmark anniversary in space science

Were you lucky enough to see the eclipse on 20 March? Approaching maximum eclipse, our outreach event in central Bristol was blessed with a break in the clouds. It may not have been totality, but it was still a magical experience to share with so many of you. We were also delighted to have been able to help many of those who got in touch needing eclipse glasses, and to have played a part in making the wonder of astronomy more accessible.

If you were clouded out on 20 March, you may well have watched live footage of the eclipse on *Stargazing LIVE*. On page 98 you'll find a review of the video camera that recorded that historic footage, written by the very cameraman who filmed it.

History was made 50 years ago this month too, when the *New York Times* broke the story of the discovery of the cosmic microwave background. To mark this first step on humanity's road to cosmological understanding we have two features this month. On page 62 we look back at the fascinating story of how the earliest light in the Universe was recorded and recognised, while on page 69 Chris North presents us with the most up to date picture of the CMB provided by the Planck satellite.

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Editorial enquiries
BBC Sky at Night Magazine, Immediate Media Co Bristol Ltd, Tower House, Fairfax Street, Bristol, BS1 3BN

On page 32 we explore our experience of the celestial sphere on a more human level, as Lewis Dartnell reminds us how the changing view of the night sky through the year underpins how we measure the passage of time.

Enjoy the issue!

Chris Bramley Editor

PS Next issue we celebrate our own 10-year anniversary with a special guest editor. Don't miss the on sale date, 21 May!

Sky at Night LOTS OF WAYS TO ENJOY THE NIGHT SKY...

TELEVISION
Find out what *The Sky at Night* team will be exploring in this month's episode on page 19

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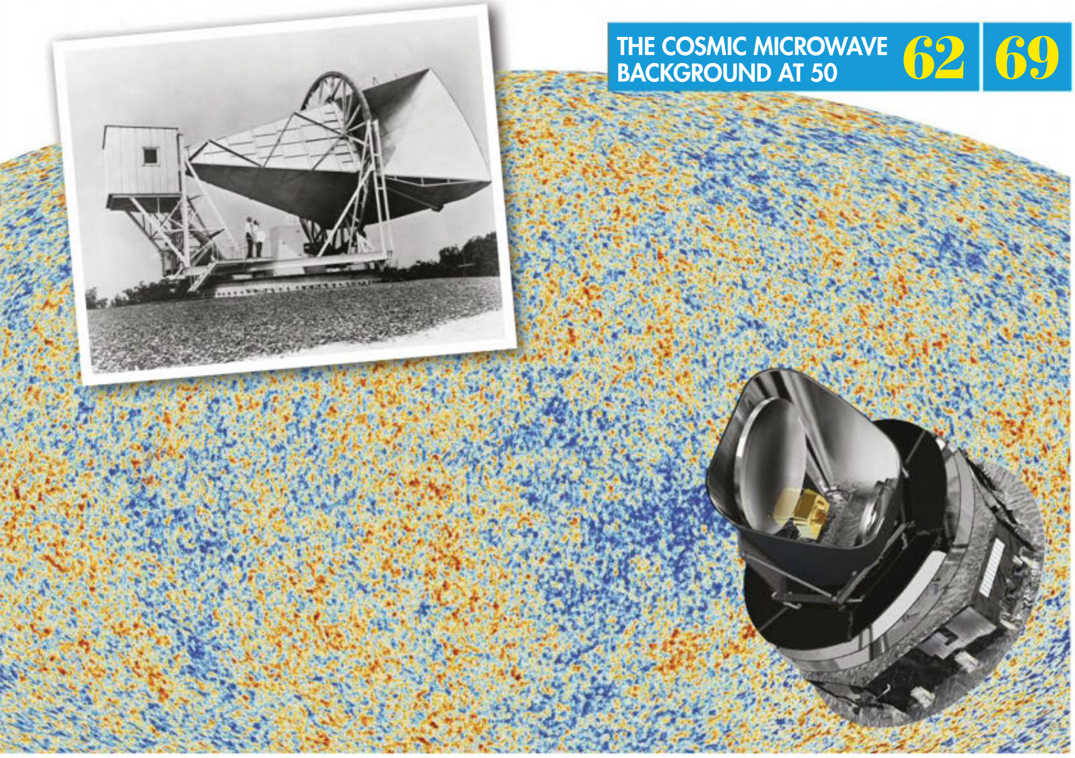
In the magazine

NEW TO ASTRONOMY?
See *The Guide* on page 82 and our online glossary at www.skyatnightmagazine.com/dictionary



REGULARS

FEATURES

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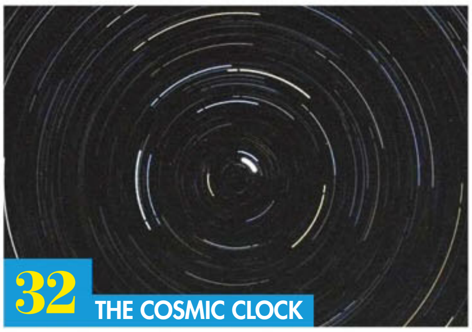

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EDITORIAL
Editor Chris Bramley
Art Editor Steve Marsh
Production Editor Kev Lochun
Staff Writer Elizabeth Pearson
Reviews Editor Paul Money

CONTRIBUTORS
Paul Abel, Maggie Aderin-Pocock, Rob Banino, Sean Blair, Mark Bowyer, Heather Couper, Adam Crute, Jon Culshaw, Lewis Dartnell, Glenn Dawes, Russell Deeks, Ian Evenden, Mark Garlick, Will Gater, Pete Lawrence, Chris Lintott, Hazel Muir, Chris North, Kendrick Oliver, Mark Parrish, Mark Payne-Gill, Steve Richards, Steve Sayers, Govert Schilling, Paul Sutherland, Stephen Tonkin, Amy Tyndall, Paul Wootton

ADVERTISING SALES
Advertising Managers Steve Grigg (0117 314 8365), Tony Robinson (0117 314 8811)
Inserts Laurence Robertson (00 353 87 690 2208)

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Production Manager Derrick Andrews
Ad Services Manager Paul Thornton
Ad Co-ordinator Emily Thorne
Ad Designers Cee Pike, Andrew Hobson
Reprographics Tony Hunt, Chris Sutch

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Head of Marketing Jacky Perales-Morris
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PUBLISHING
Publisher Jemima Ransome
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BBC WORLDWIDE, UK PUBLISHING
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Head of UK Publishing Chris Kerwin
UK Publishing Coordinator Eva Abramik
UK.Publishing@bbc.com
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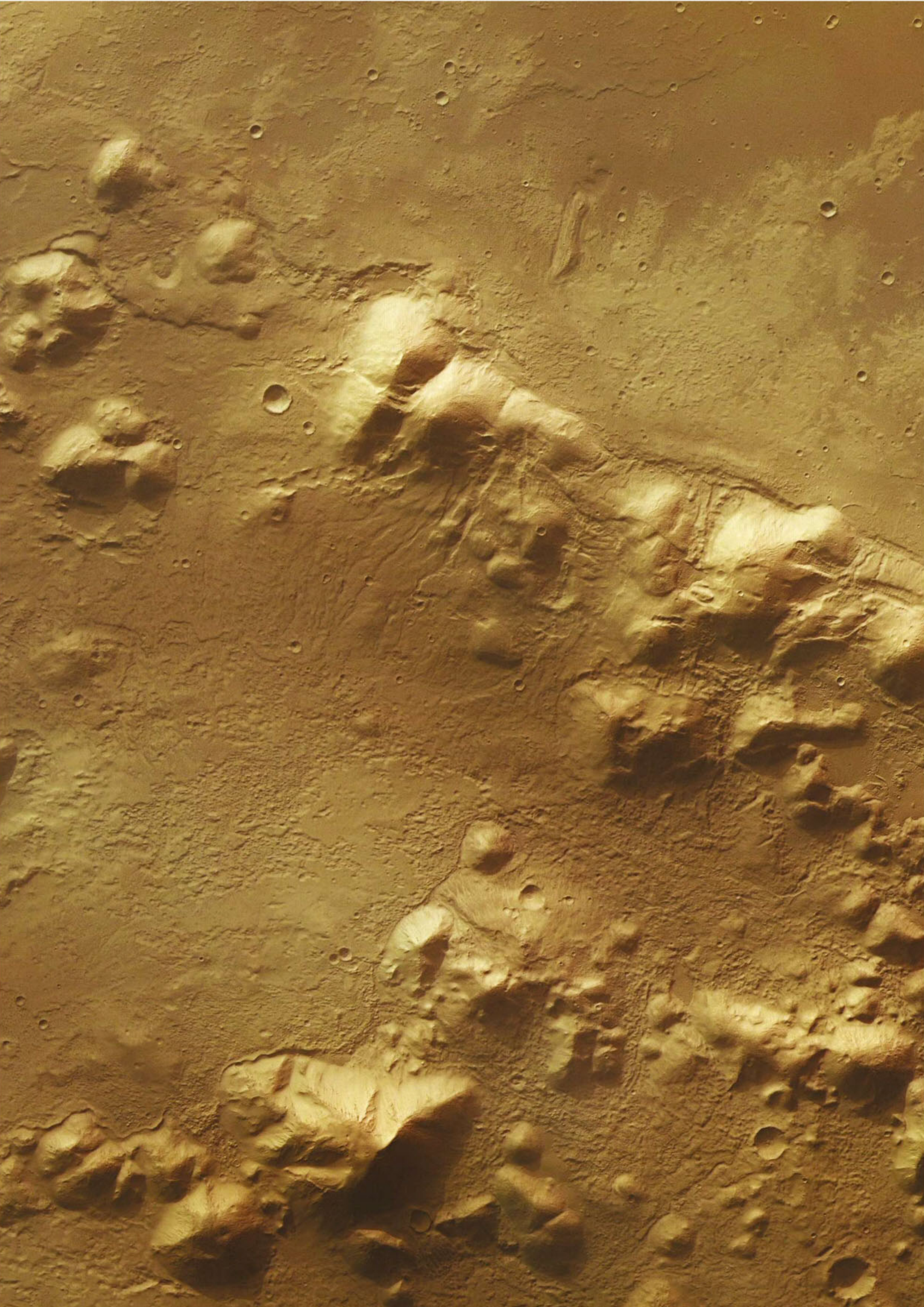
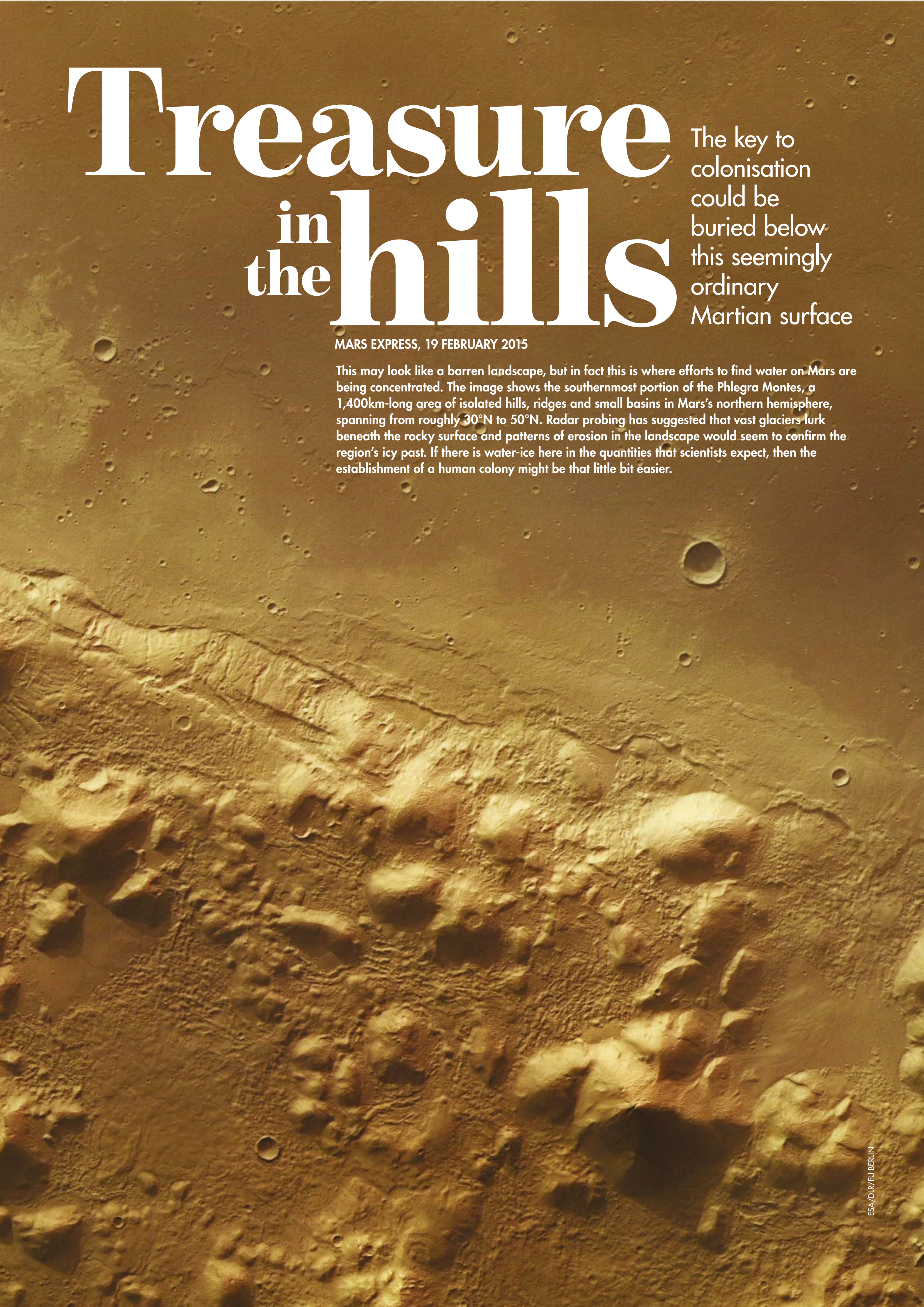


Treasure in the hills

The key to colonisation could be buried below this seemingly ordinary Martian surface

MARS EXPRESS, 19 FEBRUARY 2015

This may look like a barren landscape, but in fact this is where efforts to find water on Mars are being concentrated. The image shows the southernmost portion of the Phlegra Montes, a 1,400km-long area of isolated hills, ridges and small basins in Mars's northern hemisphere, spanning from roughly 30°N to 50°N. Radar probing has suggested that vast glaciers lurk beneath the rocky surface and patterns of erosion in the landscape would seem to confirm the region's icy past. If there is water-ice here in the quantities that scientists expect, then the establishment of a human colony might be that little bit easier.



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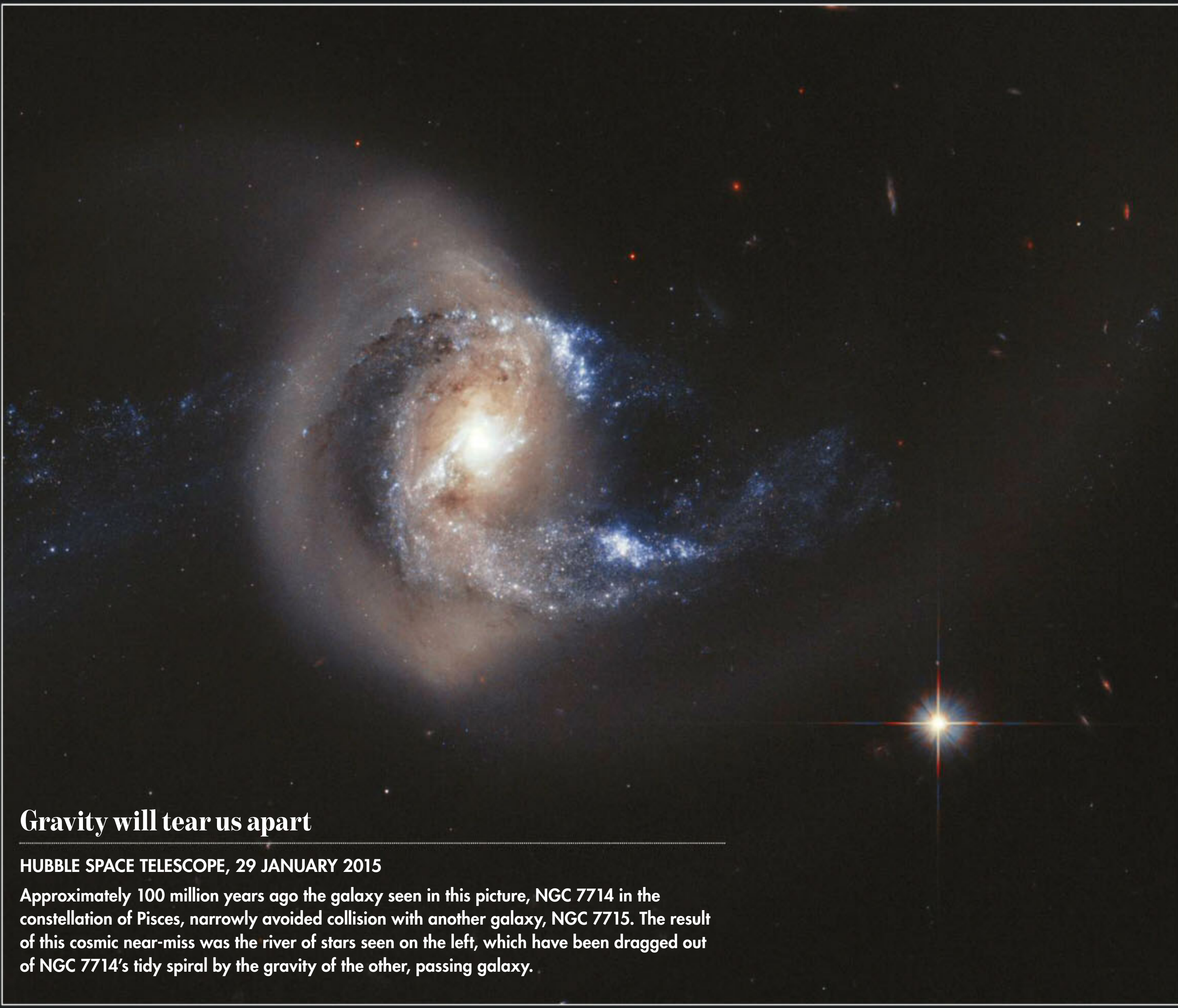


Gravity will tear us apart

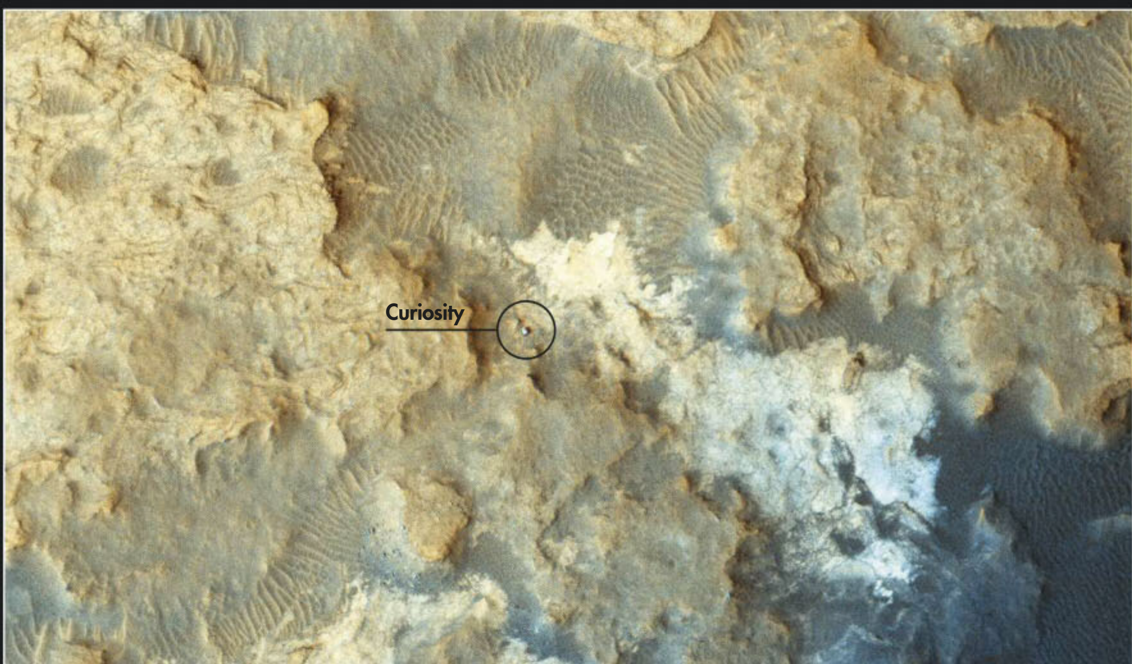
HUBBLE SPACE TELESCOPE, 29 JANUARY 2015

Approximately 100 million years ago the galaxy seen in this picture, NGC 7714 in the constellation of Pisces, narrowly avoided collision with another galaxy, NGC 7715. The result of this cosmic near-miss was the river of stars seen on the left, which have been dragged out of NGC 7714's tidy spiral by the gravity of the other, passing galaxy.

Orbital overview ▶

MARS RECONNAISSANCE ORBITER 13 DECEMBER 2014

We've seen many pictures of NASA's Curiosity rover before, but not from this angle. This image was taken by the Mars Reconnaissance Orbiter's HiRISE camera and captures Curiosity exploring the Pahrump Hills, at the base of Mount Sharp.



▼ Cosmic smile

HUBBLE SPACE TELESCOPE, 9 FEBRUARY 2015

Galaxy clusters are so massive they can warp spacetime, turning the region around them into a lens that amplifies light from distant objects. Such 'gravitational lensing' has helped astronomers make many discoveries about the Universe. Occasionally, it also produces an arc of light, known as an Einstein Ring – such as the ring that seems to 'smile' in galaxy cluster SDSS J1038+4849.

Spirit in the sky ▶

XMM-NEWTON AND HUBBLE SPACE TELESCOPE, 2 FEBRUARY 2015

Seen here is Jupiter's Ghost, a planetary nebula lying 3,000 lightyears from Earth in the constellation of Hydra. At the heart of the nebula sits a white dwarf star. Clouds of hot gas from the dying star, seen in X-ray emissions, are shown in blue; cooler gas seen in optical light is shown in green, while the red areas are pockets of even cooler but faster-moving gas.

Through the veil ▶

HUBBLE SPACE TELESCOPE 9 MARCH 2015

This image reveals the gaseous structure of part of the Veil Nebula, with oxygen shown in blue, sulphur in green and hydrogen in red. These gases were once part of a star that went supernova 5,000-10,000 years ago, giving birth to this nebula discovered by William Herschel.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Bulletin

The latest astronomy and space news written by **Hazel Muir**

PLUS CUTTING EDGE

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Our experts examine the hottest new astronomy research papers

An artist's mock up of US 708 being ejected from the Milky Way by a supernova; in reality the supernova would have faded before the star had travelled so far

ESA/HUBBLE/NASA

The great escape

A superfast star is leaving our Galaxy at breakneck speed

A STAR HAS been spotted barrelling out of the Milky Way at record speed. Astronomers reckon it's the first known example of a star destined to be evicted from our Galaxy by a supernova explosion. The compact helium star, known as US 708, is moving at a whopping 1,200km/s. "At that speed, you could travel from Earth to the Moon in five minutes," says Eugene Magnier from the University of Hawaii.

Stars like the Sun are bound to our Galaxy by gravity, and typically orbit its centre at up to a few hundred kilometres per second. Half a dozen previously identified 'hypervelocity' stars travel so fast that they'll eventually escape the Milky Way, but they were probably all propelled to high speeds by a close encounter with the supermassive black hole at our Galaxy's centre.

Now Magnier and colleagues have measured the speed of US 708 using the Keck Observatory and the Pan-STARRS1 telescopes in Hawaii, and have confirmed that it is the fastest-moving galactic star known.

"By observing the sky repeatedly over several years, the Pan-STARRS1 survey let us make a movie of the motions of the stars in the sky," says Magnier. "That enables us to study the behaviours of extremely rare and weird stars."

The trajectory alone of the star US 708 rules out the idea that it was accelerated by the gravity of the Milky Way's central black hole. Instead, it was probably kicked out of a close double-star system at enormous speed when its companion star catastrophically exploded in a supernova.

▸ See Comment, right

COMMENT
by Chris Lintott

The journey of US 708 is straight out of science fiction – it made me think of the bizarre universe conjured up by Olaf Stapledon, who wrote of intelligences powerful enough to control the path of the stars. No aliens are needed here, of course, but it's wonderful to be able to conceive of the Milky Way as a dramatic, dynamic place in which stars are flung this way and that by the vagaries of fortune.

Events like the one which expelled US 708 are presumably rare: most supernovae in such circumstances would end with a star ejected but still bound to the galaxy. Yet US 708's fate reminds us that we're going to have to get used to the idea of our Universe being in constant flux. Already it seems that planets wandering between the stars may be more common than those safely in orbit, and missions such as Gaia are bound to bring more surprises. It's a new view of the Universe, and things are moving.

CHRIS LINTOTT co-presents *The Sky at Night*

NEWS IN BRIEF

MILKY WAY IS WIDER THAN WE THOUGHT

A new study suggests that the Milky Way is actually 150,000 lightyears wide, rather than the 100,000 lightyears previously assumed. A team led by Heidi Jo Newberg from the Rensselaer Polytechnic Institute in New York looked at archived observations from the Sloan Digital Sky Survey, which revealed stars beyond the known galactic plane.

"What we found is that the Milky Way isn't just a disc of stars in a flat plane – it's corrugated," says Newberg.

FOUR STARS HOST PLANET

Astronomers have found a second example of a planet in a four-star system. A team led by NASA's Jet Propulsion Laboratory discovered the 10-Jupiter-mass planet using California's Palomar Observatory. The finding supports evidence that multiple-star systems can affect the orbits and sizes of young planets. "This strengthens the connection between multiple-star systems and massive planets," says the team's leader Lewis Roberts.

DANA BERRY, KAREN TERAMURA/UH IFA, NASA/JPL-CALTECH/UCLA/MPS/DLR/IDA, NASA/ESA AND G. BACON (STSCI), NASA/ESA AND S. RODNEY (JHU) AND THE FRONTIERSN TEAM/T. TREU (UCLA)/P. KELLY (UC BERKELEY) AND THE GLASS TEAM/J. LOTZ (STSCI) AND THE FRONTIER FIELDS TEAM; M. POSTMAN (STSCI) AND THE CLASH TEAM; AND Z. LEVAY (STSCI)), V. BELOKUROV/S. KOPOSOV (IOA, CAMBRIDGE)

The two bright spots discovered on Ceres have intrigued astronomers

The first probe to orbit a dwarf planet

Can the Dawn probe explain the mysterious white spots on Ceres?

THE DAWN PROBE became the first spacecraft to orbit a dwarf planet on 6 March. NASA's probe will circle Ceres – the largest object in the asteroid belt between Mars and Jupiter – for more than a year.

Ceres is 950km wide. "Since its discovery in 1801, Ceres was known as a planet, then an asteroid and later a dwarf planet," says Marc Rayman from NASA's Jet Propulsion Laboratory in California, chief engineer for the mission. "Now, after a journey of 3.1 billion miles [4.9 billion km] and 7.5 years, Dawn calls Ceres 'home'."

Before reaching Ceres, Dawn orbited the vast asteroid Vesta, which also lies in the asteroid belt, during 2011 to 2012. It has now become the first probe to have orbited two extraterrestrial targets.

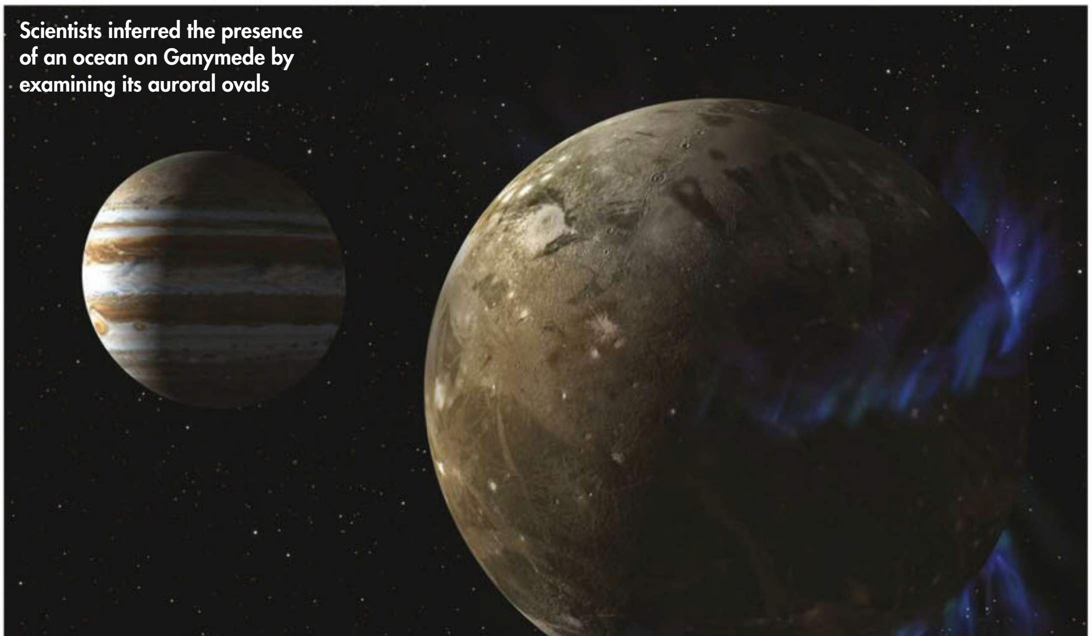
Early images from Dawn showed Ceres as a crescent, mostly in shadow. But the probe is now starting to image the sunlit side, and it will deliver ever-sharper images of the dwarf planet's surface as it gradually spirals downwards to lower orbits.

"We feel exhilarated," says Chris Russell from the University of California at Los Angeles, chief mission scientist. "We have much to do over the next year and a half, but we are now on station with ample reserves and a robust plan to obtain our science objectives."

The team hopes to gain a deeper understanding of Ceres, which is thought to have a rocky core and icy mantle, and possibly even a water ocean lying underneath its crust. Another aim is to explain the intriguing bright spots on the dwarf planet. In February, images from Dawn revealed that the brightest spot on the dwarf planet has a dimmer companion that lies in the same basin.

"This may be pointing to a volcano-like origin of the spots, but we will have to wait for [images with] better resolution before we can make such geologic interpretations," says Russell.

Dawn scientist Andreas Nathues from the Max Planck Institute for Solar System Research in Göttingen, Germany, adds that the brightest spot, although small, is peculiarly striking. "Despite its size, it is brighter than anything else on Ceres," he says. "This is truly unexpected and still a mystery to us.". www.noao.edu/kpno



Scientists inferred the presence of an ocean on Ganymede by examining its auroral ovals

New signs of Ganymede's ocean

Is the Jovian moon home to more water than Earth?

THE BEST EVIDENCE yet that Ganymede – Jupiter's largest moon – has an underground saltwater ocean has been revealed by the Hubble Space Telescope. The moon could contain more water than all the Earth's oceans combined.

Prof Joachim Saur from the University of Cologne in Germany came to the conclusion after using the Hubble Space Telescope to observe auroral light from the moon, linked to its magnetic field. The interaction between Ganymede's magnetic field and that of Jupiter creates a complex 'rocking' motion in the aurorae, which allowed them to estimate that Ganymede's magnetic field is influenced by a salty ocean that's 100km deep.

Finding liquid water would be a crucial step in the search for alien life. "A deep ocean under the icy crust of Ganymede opens up further exciting possibilities for life beyond Earth," says John Grunsfeld from NASA's headquarters in Washington DC.

www.hubblesite.org

STAR EXPLODES IN HALL OF MIRRORS

ASTRONOMERS HAVE DISCOVERED a supernova that has been gravitationally lensed into four images. The exploding star's light was bent and magnified on its way to Earth by the gravity of a massive cluster of galaxies. It is the first time the phenomenon has been observed.

"It's a wonderful discovery," says team member Alex Filippenko from the University of California, Berkeley. "We've been searching for a strongly lensed supernova for 50 years, and now we've found one. Besides being really cool, it should provide a lot of astrophysically important information."

Filippenko's colleague Patrick Kelly discovered the supernova in Hubble observations from November 2014. The stellar explosion occurred 9.3 billion lightyears away and its light was lensed by a galaxy cluster lying roughly halfway along its path to Earth. The lensing effect causes separate images from the supernova to appear at different times, depending on the path the light takes. This allows astronomers to repeatedly observe the same supernova. The team says these 'replays' will probably continue in future.

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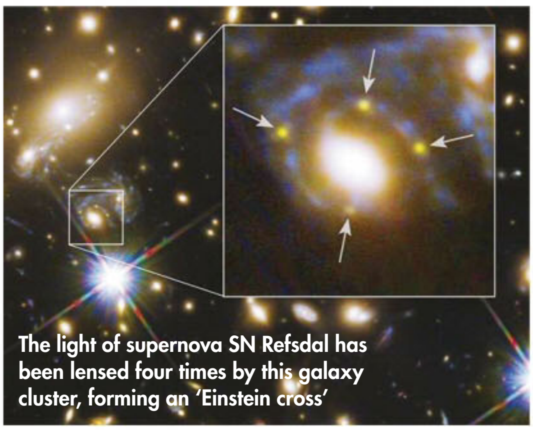


The light of supernova SN Refsdal has been lensed four times by this galaxy cluster, forming an 'Einstein cross'

NEWS IN BRIEF

NEW HAUL OF DWARF GALAXIES

Nine dwarf galaxies have been found orbiting the Milky Way – the largest group ever discovered. Using observations from Chile, astronomers from the University of Cambridge identified the new dwarf satellite galaxies.

"The discovery of so many satellites was unexpected," says team leader Sergey Koposov. It's thought the dwarf galaxies could hold clues to help us understand dark matter.

MYSTERY OF VENUS SOLVED

A presence of a giant Y-shaped cloud in the atmosphere of Venus may have finally been explained, 50 years after it was first spotted. The cloud is able to hold its shape thanks to a type of wave disturbance that's distorted by the high-speed winds that blow through the planet's atmosphere.

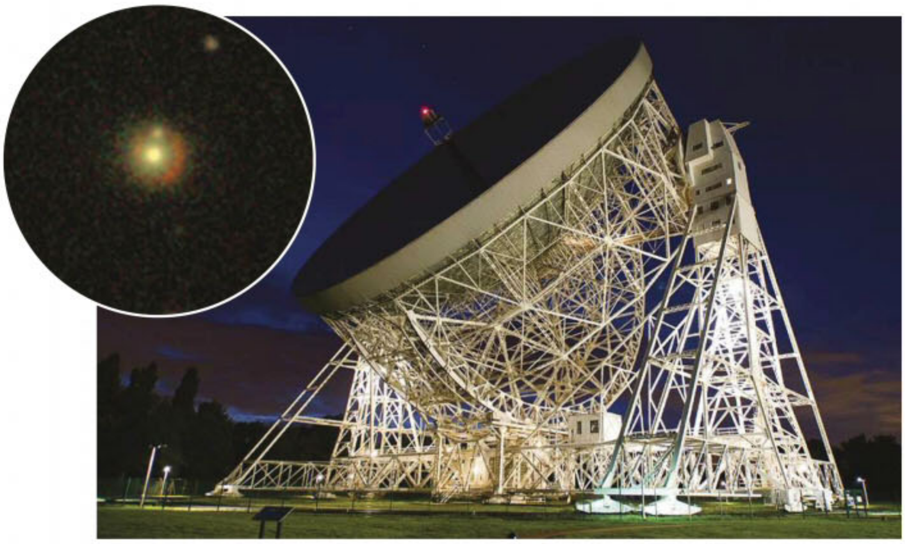
Javier Peralta and his team from the Institute of Astrophysics in Spain, were able to simulate the cloud's behaviour. However, the compound that makes the cloud dark by absorbing ultraviolet light remains unknown.

CUTTING EDGE

Our experts examine the hottest new research

Lensing LIVE

Last year, a gravitational lens was discovered live on the BBC. Now more is known about this rare object



▲ The Lovell Telescope was used to confirm the gravitational lens discovery live on air

Buried among the names at the top of a recent paper by the SpaceWarps collaboration, alongside my own, are some familiar ones – a certain B Cox and D Ó Briain. The paper reports the results of a challenge we ran in conjunction with last year's *Stargazing LIVE,* asking viewers to hunt through images in search of gravitational lenses.

These rare sights, which occur when light from a distant galaxy is bent as it passes a nearer galaxy, can be of immense value, both in understanding the objects themselves and in helping pin down what's been happening to the Universe as a whole while the light has been on its journey. We were very excited, therefore, to announce during the show that our hunt had been successful: a group of volunteers had found what appeared to be a plausible ring, the signature of a lens produced by a perfect alignment. In the rush to get more data while still on air, we made use of Jodrell Bank's enormous Lovell Telescope. Producing an image from radio data isn't easy, and the team at Jodrell worked wonders to give us something we could show viewers.

This paper, though, is the result of much work and many further observations over the last year. So what do we know about this distant galaxy?

We know how far away it is, for starters. The nearby lens is about three billion lightyears away, but the distant source behind it is at a redshift of 2.553. This means the light we receive from it has been travelling for more than 11 billion years. That, combined with its observed brightness, tells us that it must be very luminous indeed – bright enough to be what infrared astronomers call a hyperluminous source. It's bright in the radio, too. The exception is the visible spectrum, where the source is very faint.

Why is this? Two possibilities present themselves. It might be a galaxy with an old stellar population, shining brightly in the red but missing young blue stars. Or it might hide its stars from us in dust clouds, which obscure visible light but shine brightly in the infrared. The former seems unlikely, given that only a few billion years passed between the Big Bang and the epoch at which this galaxy is observed, and observations showing a strong signal of carbon monoxide support the idea of a system just beginning a burst of star formation. In time, the dust may be blown away by the winds from myriad young stars, but until then we owe our discovery of the system to the infrared.

However, star formation may not be the whole story. Radio and infrared emissions can also be associated with the nucleus of a galaxy, particularly if the supermassive black hole lurking there is in the process of accreting material rapidly. Astronomers will be keeping a close eye on the system in years to come: if what we're seeing is light from a growing accretion disc, they might expect it to vary in brightness on timescales as short as days.

"A group of volunteers had found what appeared to be a plausible ring"

It's exciting stuff, but in a world where astronomers are getting more used to dealing with large surveys and statistics, what's the point of studying a single galaxy? The key is to find those galaxies that are unusual and exciting – and that, we conclude in the paper, is why this sort of citizen science is particularly helpful. If you want to find the everyday parts of the Universe, use a computer. If you want to seek out rare objects, it's worth taking a close look yourself.

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

CHRIS LINTOTT was reading… *The red radio ring: a graitationally lensed hyperluminous infrared radio galaxy at a = 2.553 discovered through citizen science* by J E Geach et al.
Read it online at http://arxiv.org/abs/1503.05824

NEWS IN BRIEF

RED DWARF MADE CLOSE CALL

A red dwarf star made the closest known flyby of the Solar System 70,000 years ago, a new study suggests. Astronomers in South Africa and Chile, calculated the star's trajectory and showed that the star must have passed through the Solar System's outer fringe – the Oort Cloud.

"The small tangential motion and proximity initially indicated that the star was most likely either moving towards a close encounter with the Solar System or it had 'recently' come close to the Solar System and was moving away," says team leader Eric Mamajek from the University of Rochester, New York State. "We realised it must have had a close flyby in the past."

SIGNS OF LIFE ON EUROPA?

Scientists have been asked to consider ways that a spacecraft mission could search for evidence of alien life on Jupiter's moon Europa by NASA officials. The agency hopes to sample water vapour from plumes that spray out from the moon's south pole.

MICHAEL OSADCIW/UNIVERSITY OF ROCHESTER, NASA/JPL-CALTECH/SETI INSTITUTE, ZHAOYU LI/NASA/JPL-CALTECH/MISTI MOUNTAIN OBSERVATORY, ESO/M. KORNMESSER, NASA/CXC/UNIV. OF WISCONSIN/Y.BAI. ET AL

Monster black hole grew early

The discovery challenges theories about how these giants form

▲ **The quasar powered by the hugh black hole, SDSS J0100+2802, has the luminosity of 420 trillion Suns**

A MONSTER BLACK hole has been discovered at the dawn of the cosmos. Light from the collapsing star's surrounding galaxy has taken so long to reach Earth that we are seeing it as it would have looked just 900 million years after the Big Bang, which occurred 13.7 billion years ago.

Observations made using telescopes in the US, Chile and China suggest the black hole is 12 billion times more massive than our Sun and is powering the brightest quasar known to man. According to Prof Xiaohui Fan from the University of Arizona, part of the team that made the discovery, now the challenge is to find out "how a quasar so luminous and a black hole so massive formed so soon after the earliest stars and galaxies emerged."

www.arizona.edu

GIANT OCEAN SLOSHED OVER MARS

A PRIMITIVE OCEAN that once existed on Mars covered a greater portion of the planet's surface than the Atlantic Ocean and held more water than the Arctic Ocean, new studies suggest. Astronomers have come to this conclusion after using observations made with the VLT in Chile and others to help them clarify the amount of water that Mars has lost to space.

The findings hint that water pooled in an ocean covering almost half of Mars's northern hemisphere, reaching depths greater than 1.6km in some regions. "With this work, we can better understand the history of water on Mars," says team leader Geronimo Villanueva from NASA's Goddard Space Flight Center in Maryland.

www.eso.org/vlt

The long-gone ocean was not only widely spread: it would have held more water than the Arctic Ocean

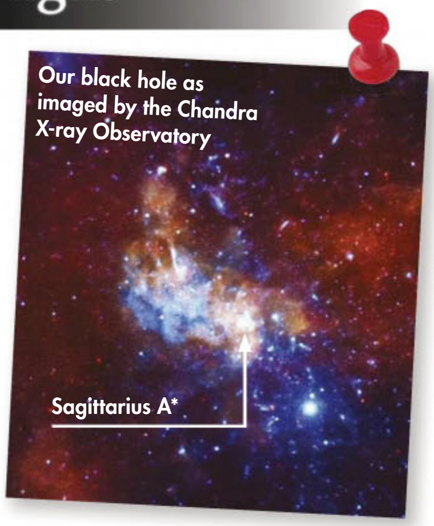
Looking back The Sky at Night

May 1980

The Sky at Night programme broadcast on 30 May 1980 discussed the possibility of there being a huge black hole in the centre of our Galaxy. The first signs of this came in 1974, when astronomers noticed a strong radio source in the middle of the Milky Way. Known as Sagittarius A*, it is thought to be a black hole 4.5 million times as massive as the Sun.

Smaller black holes can form when stars explode, leaving behind collapsed cores with such strong gravity that nothing – not even light – can escape from. But matter swirling towards them can sometimes be heated to enormous temperatures and start emitting bright radiation, giving away the black hole's presence.

However, it remains unclear how supermassive black holes at the centres of most large galaxies formed. Some of them are billions of times as massive as the Sun.

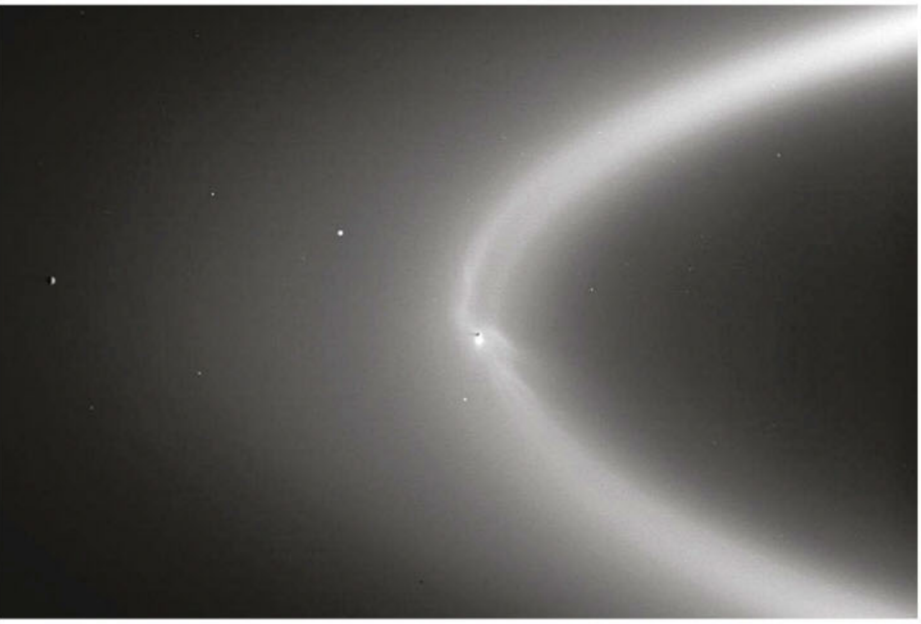


CUTTING EDGE

Our experts examine the hottest new research

Testing the water

Eruptions of water spewing out of Saturn's moon Enceladus may hold clues to primordial life



▲ Particles from Enceladus are believed to form Saturn's wispy E-Ring

NASA/JPL/SPACE SCIENCE INSTITUTE

Thinking about the moon Enceladus still boggles my mind because it is a truly astounding place. It's a tiny world, no bigger than the UK from end to end, where subsurface ocean water is erupting up into space and forming one of the rings of Saturn.

Jupiter's moon Europa is also strongly thought to hide an ocean of liquid water beneath its frozen face, but the wonderful thing about Enceladus is that it is very generously squirting its seawater out for us to study. Using the instruments aboard the Cassini orbiter, we've been able to measure several substances in the gas and particles jetting out from below the surface of Enceladus.

Planetary scientists want to work out the exact composition of the Saturnian moon's seawater. The plume is not very salty and doesn't contain much ammonia (both of which act as antifreeze) and so the ocean water in Enceladus is probably around 0°C. But the most important factor involved in determining the chemistry and composition of Enceladus's seawater is the pH. The pH scale describes how acidic or alkaline a fluid is and fundamentally relates to what substances are able to dissolve in it.

Christopher Glein at the Carnegie Institution of Washington led a team to determine the pH of Enceladus's ocean. He built a computer model of all the major substances that could be present in the seawater, and the possible reactions between them. By fixing some of the variables, such as the concentrations of substances such as carbon dioxide and sodium inferred from Cassini's measurements of the plumes, he has then solved this interacting system to find the natural equilibrium.

Glein found that the seawater is dominated by sodium-chloride salt and, in this sense, Enceladus's ocean is much like Earth's seas. However, Enceladus's ocean also contains a lot of sodium carbonate, which makes the seawater exceedingly alkaline – a pH around 12, compared to pH 8 for terrestrial seawater. Chemically speaking, the closest analogue to the subsurface water in this icy moon would not be the subglacial lakes in Antarctica, but the alkaline soda lakes in East Africa, near to where I grew up in Nairobi.

The team believe that this extremely high pH is due to a process called serpentinisation, whereby

"Scientists want to work out the exact composition of the Saturnian moon's seawater"

iron-containing minerals react with seawater to produce very alkaline fluids. This also occurs in Earth's oceanic crust, producing alkaline hydrothermal vents such as 'Lost City' in the mid-Atlantic. Indeed, such serpentinisation-driven hydrothermal vents are believed by many researchers to offer the most plausible nursery for the origin of life on the primordial Earth. Could Enceladan microbes be blooming on the chemical energy released from the moon's crust?

The big unknown, as Glein explains, is whether these vital serpentinisation reactions are still running on the Enceladan seafloor today. Enceladus has no plate tectonics or means of recycling its seabed, so all the exposed iron-containing minerals may already have reacted long ago, leaving behind an alkaline ocean containing nothing but dead hydrothermal vents. And without a continuing chemical energy source there would be no hope of finding life today in this dark ocean.

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

LEWIS DARTNELL was reading… *The pH of Enceladus's ocean* by Christopher Glein, John Baross & Hunter Waite
Read it online at http://arxiv.org/abs/1502.01946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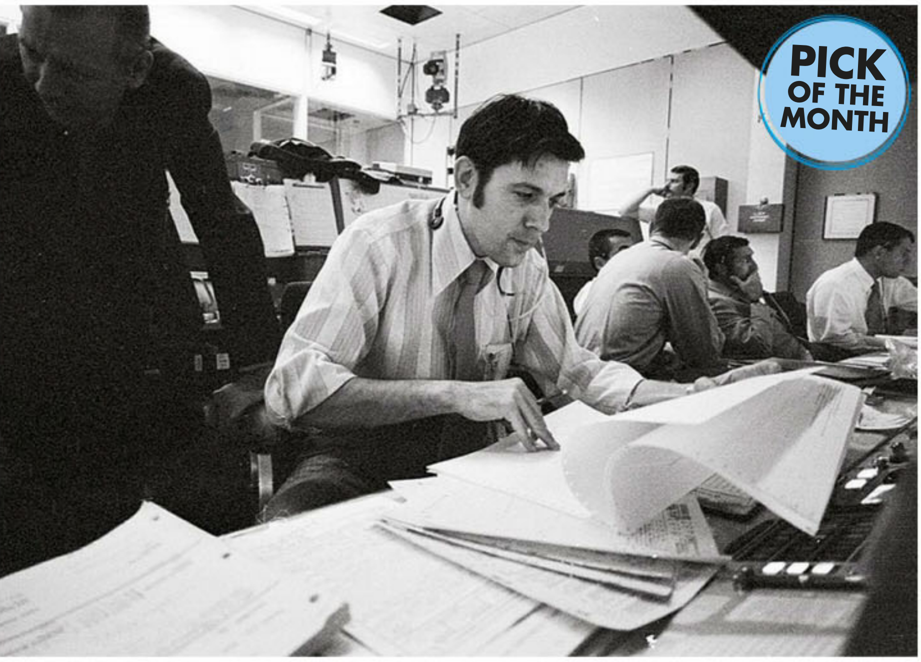
What's on

Our pick of the best events from around the UK

Apollo Flight Controller Chuck Deiterich

Something Astronomical, Sheffield Hallam University, 16 May, 1.30pm



▲ Chuck Deiterich was part of the NASA team that successfully brought back Apollo 13

Space-themed lecture event series Something Astronomical offers a rare chance to get up close and personal with a veteran of the Apollo Moon landings. Flight controller Charles 'Chuck' Deiterich was sitting in mission control for Apollo 8, 11 and 13 and was also closely involved with the Skylab and Space Shuttle programmes. He'll be presenting a talk and discussing his long and illustrious NASA career, as well as signing copies of *From the Trench of Mission Control to the Craters of the Moon*, the book he recently co-authored with the rest of the Apollo Flight Dynamics Team. Also present will be W David Woods, author of *How Apollo Flew to the Moon*, and the talk will be followed by an informal Q&A session and a rooftop barbecue. Tickets for this event cost £15.
www.somethingastro.com

BEHIND THE SCENES

THE SKY AT NIGHT IN MAY

BBC Four, **10 May**, 10pm (first repeat BBC Four, **14 May**, 7.30pm)*

ESA's Venus Express examined Earth's inhospitable twin planet for eight years

VENUS, EARTH'S TWIN

How did two such similar planets become so different? One is the crucible of life, the other an inferno scorched by acidic rain – yet they began as near-identical bodies. This month's show explains how our nearest neighbour formed and how ESA's Venus Express spacecraft has revealed the secrets of its atmosphere.

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

NASA, ISTOCK, ESA, JAMESFRANKLINGRESHAM

Anomalous X-Ray Pulsars

Plymouth Astronomical Society, Rolle Building, Plymouth University, 8 May, 7.30pm

Anomalous X-ray pulsars are characterised by a slow rotation period and very high-energy emissions. In this talk, Dr Ben King of Plymouth outlines what we know about these mysterious objects and asks, what is it that makes them 'anomalous'? Entry is £2 for visitors and free for members.
www.plymouthastro.btck.co.uk

Star-forming Galaxies

Leeds Astronomical Society, Friends Meeting House, Carlton Hill, Leeds, 13 May, 7.30pm

An in-depth talk on star-forming galaxies, given by Prof Paul Crowther, of the Astrophysics Group at the University of Sheffield, who has authored or co-authored over 130 academic papers on the subject. Entry is free, but donations are welcome.
www.leedsastronomy.org.uk

Proving Einstein Right

Nottingham Astronomical Society, The British Geological Survey, Keyworth, 7 May, 7.30pm

Prof Ian Morison, a lecturer in astronomy at both the University of Manchester and Gresham College in London, presents a talk on how modern-day scientists are testing out Einstein's 100-year-old theories about gravity. Entrance is free for all.
www.nottinghamastro.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

As Hubble marks 25 years in space, the *Sky at Night* presenter picks her five favourite images

THE HUBBLE DEEP FIELD

Described as the most important picture ever taken, the Hubble Deep Field gives us an understanding of the size and scope of our Universe. With it, the Hubble Ultra Deep Field and the eXtreme Deep Field we have been able to look at some of the earliest galaxies ever formed, some 13 billion years ago. I love to show these images to kids when I give talks, as I tell them that from this image we were able to estimate the number of galaxies in the Universe (approximately 100 billion).

V838 MONOCEROTIS

In this image lies a mystery: why did the star throw off its outer mantle and shine so brightly, then fade, in 2002? The light from the flash gets reflected from the surrounding interstellar gas and dust; this gives the impression of an object expanding faster than the speed of light, but analysis shows that this is not the case. The light echo just takes an indirect route to get to us. Observed over a number of years we can see the illumination of beautiful filaments of dust surrounding the star, probably created in a previous expulsion of material. The phenomenon looks similar to previously viewed nova expansions but with a unique extreme-red colouring. If you get a chance to see the timelapse imagery of this phenomena, it is truly breathtaking.

THE CAT'S EYE NEBULA

This nebula shows shells of material being thrown off into space at regular intervals. The pulses occur with a frequency of 1,500 years and each shell contains an equivalent mass to the planets of our Solar System. Although the shells would be spherical in nature, this view taken by Hubble give us a cross-section of the action. As well as the rings, we have material radiating outwards in the same way that the lines on a dartboard do. Approximately 1,000 years ago the regular cycle of mass loss changed, and the nebula is expanding as witnessed by Hubble through observations over an eight-year period.

COMET SHOEMAKER-LEVY 9 SMASHES INTO JUPITER

I like to think of Jupiter as our big brother in space. Having such a large mass in relative proximity to Earth is beneficial, as Jupiter attracts and absorbs objects that could otherwise be destined for Earth. With this image we were able to observe this process in amazing detail. Impacts like this are often captured by the amateur community and we now know that such bombardments happen far more frequently than we previously thought.

SUPERNOVA REMNANT 0509-67.5

This ethereal bubble is all that remains of the violence of a supernova that occurred some 400 years ago. This shell of gas is left from the shock blast wave; the red comes from the excitation of hydrogen by the blast wave. The bubble is 23 lightyears in diameter and is expanding at a rate of 5,000 km/h. It seems amazing that after a relatively short time, all that can be seen in the visible is this expanding sphere.

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

ROBERT WILLIAMS AND THE HUBBLE DEEP FIELD TEAM (STSCI) AND NASA, NASA AND THE HUBBLE HERITAGE TEAM (AURA/STSCI), NASA/ESA/HEIC AND THE HUBBLE HERITAGE TEAM (STSCI/AURA), HUBBLE SPACE TELESCOPE COMET TEAM AND NASA, NASA/ESA/CXC/SAO/THE HUBBLE HERITAGE TEAM (STSCI/AURA) AND J. HUGHES (RUTGERS UNIVERSITY)

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JON CULSHAW'S EXOPLANET EXCURSIONS

Jon pays a visit to the vast rings spinning around the brown dwarf J1407b

There's an intriguing star in the constellation of Centaurus, about 90 per cent the mass of the Sun. It glows at a magnitude of +12.3, so it is visible to a telescope from southern latitudes. This fascinating star has the name of (get ready) 1SWASP J140747.93-394542.6, a name with all the hallmarks of a complicated moment halfway through the *Shipping Forecast*. Thankfully it's usually abbreviated to a more manageable J1407.

There's something highly perplexing about this star when seen by the SuperWASP observatories. Its light is dimmed and brightened in the most astonishingly variable and complex fashion. At times 95 per cent of its light ebbs away before once again returning, emulating the tides of Earth's oceans with stellar light. What could be creating light fluctuations of such enormity?

The cause of this phenomena goes by the mercifully short name of J1407b, a foreboding companion brown dwarf surrounded by a singularly spectacular ring system, the discovery of which left astronomers slack-jawed with stupefaction. Fanning out for 145 million km and 200 times the size of Saturn's magnificent rings, you have no choice but to marvel at this system while feverishly speculating about its formation.

Settling my new ship, the Perihelion, upon the ring system's outer edge gives an awesome view of a seemingly infinite banded horizon. You feel like a microbe perched on the edge of Status Quo's *Piledriver* vinyl album. Endless, beautifully circular grooves appear together like compressed isobars on a weather map.

There are several gaps at intervals within the rings, similar to concentric Cassini divisions, cleared paths occupied by exomoons orbiting their parent brown dwarf. The view from the surface of these moons must be utterly breathtaking, with the sky dominated by the arcs of the rings and the smouldering, rusty glow of the brown dwarf hanging steadfastly above them.

The sight of this exo-ring system could easily be one of the 700 Wonders of the Universe. If the rings swapped places with Saturn's and were observed from Earth, they would span the width of about 20 apparent full Moons across our sky. Perhaps in the past there was a cataclysmic clash of planetary bodies of sufficient force to completely reduce the objects into proverbial smithereens. It seems that the wreckage settled down after a period and the gravity of the brown dwarf was enough to sustain a magnificent ring system spanning the best part of an astronomical unit.

Surveying the scene, I wonder if we're witnessing a period of planet and moon formation around the brown dwarf – quite a privilege if so. Or does the gravity of J1407b coupled with the manner of the initial clash mean that fragments of the rings and the moons are moving towards the brown dwarf and being absorbed by it, a fate similar to Phobos around Mars? If that's the case, I imagine a cosmic domino effect where eventually every fragment of the ring system becomes absorbed. Perhaps when a sufficient amount of fragments have been digested, J1407b might take on enough extra mass to reboot and upgrade from a brown dwarf to a proper star. Nothing like an exoplanet excursion to set the imagination in motion.

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

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


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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 Philip's: Heather Couper and Nigel Henbest's *Stargazing 2015*, Patrick Moore's *The Night Sky*, Storm Dunlop's *Practical Astronomy*, and *Stargazing with Binoculars* by Robin Scagell and David Frydman.

PHILIP'S

MESSAGE OF THE MONTH

Britain's youngest eclipse hunter?


Zack looking good in his eclipse glasses

In the days leading up to the solar eclipse, my son Zack and I explored how the Moon would block our view of the Sun using a torch and some small model planets. We discussed how the Moon goes around the Earth and how the Earth goes around the Sun. Our discussions were encouraged and supported by the excellent show *CBeebies Stargazing*, which has hopefully encouraged more young children to take an interest in astronomy.

On the day of the eclipse Zack was ready with his solar specs, however cloud cover blocked a lot of the view here in Salford. Thankfully we got to see the amazing sights of the eclipse later on when we both eagerly watched *Stargazing LIVE*. Thank you to the BBC for *Stargazing LIVE* and *CBeebies Stargazing*, and to your magazine for the solar specs.

Gary Pickup, Salford

It's very rewarding to know readers like you are inspiring a new generation of enquiring minds with our work, Gary. **– Ed**

SOCIAL MEDIA

WHAT YOU'VE BEEN SAYING ON TWITTER AND FACEBOOK

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

@skyatnightmag asked: Did you see the eclipse or were you clouded out? Tell us your experiences

@siobsi Perfect conditions in Leicester – a city glued to the sky.

@ozric42 Totally clouded out in Colchester, but enjoyed the temperature drop. :)

Phil Jones Fantastic in Cornwall, made up for disappointment of 1999

@KittiwakeNature Watching partial eclipse sat on my doorstep, a neighbour yelled "Oh look. It's a full Moon!"

Pam Shepherd Clear skies in Invergowrie. Drove 60 miles to get them, but your glasses worked a treat!

Eclipse chasing

We could have stayed in Bristol to see the 86 per cent eclipse there, but decided to risk going to Scotland for the opportunity of 95-plus per cent. We drove from Inverness to Balintore on the coast and set up shop, as this was the only spot that had any chance of sunny intervals in the forecast.

With no sign of the Sun we waited and waited, but missed the start of the eclipse: the blue patches of sky moving towards the Sun were going far too slowly. Finally we decided to start 'eclipse chasing', packed up, jumped in the car, and drove madly towards the nearest patch of blue sky. Suddenly we spotted sunshine on the ground and pulled over in it. There was no time to get the camera and scope out so we just watched the moment of maximum eclipse until the cloud rolled over.

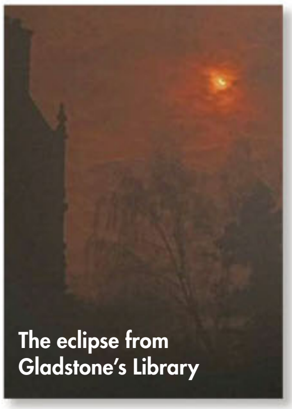
Back in the car we headed to the next area bathed in sunshine and moved on when the cloud rolled over. Six blue patches of sky later I was also able to see the moment of last contact from the middle of a muddy farm field. All in all, it was probably more fun than sitting in one place for the whole event – and not a single speed limit broken!

Julian Whitfield, via Facebook

An epic road trip, Julian. Sounds like fun! **– Ed**

Eclipse over Wales

I wanted to send you this image of the eclipse that was captured here at Gladstone's Library, which I'm sure you will agree is very atmospheric.


The eclipse from Gladstone's Library

Natalie Tomlinson, Gladstone's Library, Hawarden, Flintshire

How evocative, Natalie. Certainly a sight to make visitors to the nation's largest residential library look up from their books. **– Ed**


Free eclipse glasses meant George didn't have to shell out

Turtle eclipse

My pet tortoise George was certainly ready for the solar eclipse today!

Claire Best, via email

Was George more active in the twilight, Claire, as crepuscular animals like tortoises often are? **– Ed**

Hotshots

This month's pick of your very best astrophotos

◀ Gibbous Moon mosaic

JARROD BENNETT
MUTXAMEL, SPAIN
27 FEBRUARY 2015

Jarrod says: "This is a 17-panel mosaic of the Moon at 71 per cent illumination. Whenever there's a still night and the Moon is out, I like to grab a few panels! I've only been making mosaics for about six months and this is one of my best."

Equipment: ZWO ASI120mm CCD camera, Sky-Watcher 150PL telescope, Sky-Watcher EQ3-2 mount, Baader red CCD filter.

***BBC Sky at Night Magazine* says:** "What really stood out with Jarrod's mosaic is the sharp clarity all the way to the limb. His perfect processing results in crisp shadows and no bleached out areas."

About Jarrod: "I'm an Australian living in Spain. About five years ago my wife bought me my first telescope and I haven't looked back since. In the last two years I've started producing solar and lunar images."

◀ The Bubble Nebula

CHRIS GRIMMER
NORFOLK
5 JANUARY 2014

Chris says: "I took this image in January 2014, but struggled to process it to my satisfaction. Finally, with another year's experience under my belt, I got an image I'm happy with!"

Equipment: Starlight Xpress SXVR-H694 CCD camera, William Optics GT-81 telescope, Sky-Watcher HEQ5 Pro mount, Baader Ha, OIII and SII filters.

▲ The Baby Eagle Nebula

BOB FRANKE, ARIZONA, 28 DECEMBER 2014

Bob says: "This nebula lies about 450 lightyears from Earth in the Taurus Molecular Cloud. Beverly Lynds included it in her Catalogue of Bright Nebulae in 1965."

Equipment: SBIG STF-8300M CCD camera, Takahashi FSQ-106ED telescope, Losmandy G-11 mount, Baader LRGB filters.

▲ ISS, Moon, Venus and Mars

GRAHAM SINAGOLA, CHESHIRE, 21 FEBRUARY 2015

Graham says: "I like this image because it contains the International Space Station, which put in a surprise appearance while I was taking long exposures of the other three objects. The ISS moves quickly across the sky so there was only a short time slot in which to catch them all."

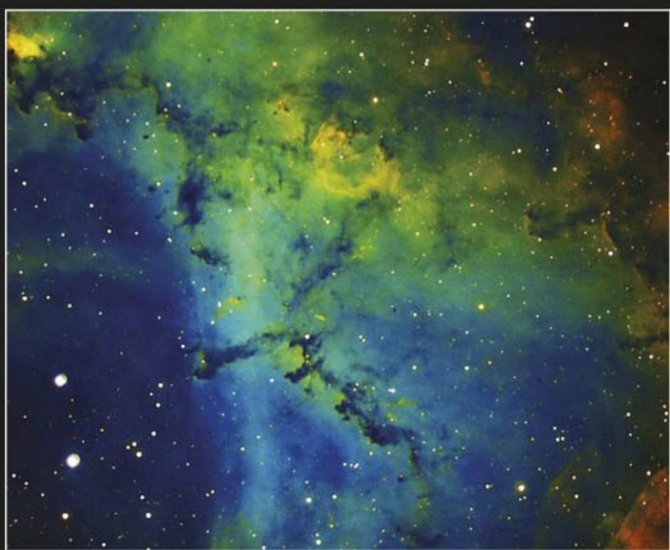
Equipment: Sony Alpha α7 DSLR camera, 18-70mm zoom lens.

Bok globules in the Rosette Nebula ▶

MARK GRIFFITH, SWINDON, WILTSHIRE, 6 FEBRUARY 2015

Mark says: "Bok globules are dense clouds of dust and gas, seen here in the Rosette Nebula. I used the Hubble palette to bring out the globules, then a Curves adjustment so as not to overpower the hydrogen and sulphur data."

Equipment: Atik 383L+ CCD camera, Celestron C11 telescope, Sky-Watcher NEQ6 Pro mount, Astronomik SII, Ha and OIII filters.



▲ The Rosette Nebula

DAVID TELFER, DOVER, 8/17 FEBRUARY 2015

David says: "I love the Rosette Nebula so I had to catch it with my new Atik. This is the first image I've taken with a CCD camera, and I'm glad I upgraded from my DSLR."

Equipment: Atik One CCD camera, Tele Vue TV-85 telescope, Sky-Watcher AZ EQ6-GT mount, Baader HA and OIII filters.

▲ Comet Lovejoy

GARY STONE, PETERBOROUGH, 25 JANUARY 2015

Gary says: "This image was created using 10 separate 90-minute exposures, stacked and processed with PixInsight. The Moon was out so I was very pleased to capture the comet's tail."

Equipment: Modified Canon EOS 450D DSLR camera, Sky-Watcher Quattro f/4 telescope, Sky-Watcher NEQ6 PRO SynScan mount, Astronomik CLS light pollution filter.

▲ The Horsehead Nebula

LEE HOUSDEN, ESSEX, 13 MARCH 2015

Lee says: "I chose the Horsehead Nebula because I'd imaged it before with a DSLR and wanted to try it with my new dedicated CCD setup. It was quite tricky to tease out the detail while not making the stars too bright, but overall I'm pleased with the result."

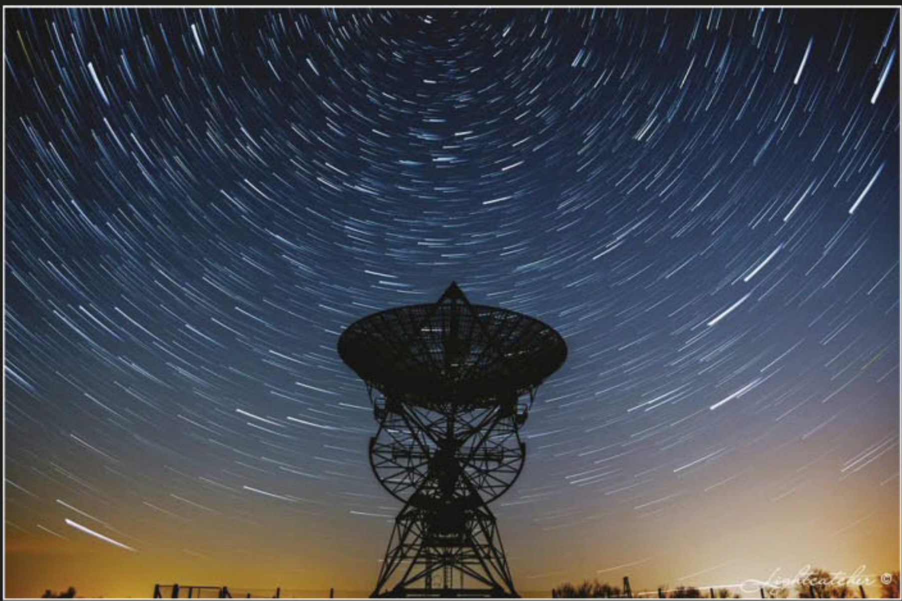
Equipment: QHY10 CCD camera, Sky-Watcher 80ED telescope, Celestron CPC 800 GPS mount, Astronomik CLS light pollution filter.

▼ Star trails

MARIUSZ SZYMASZEK, CAMBRIDGESHIRE, 4 MARCH 2015

Mariusz says: "This is one of a series of photos I took near the decommissioned One-Mile Telescope at the Mullard Radio Astronomy Observatory. While I was capturing comet C/2014 Q2 Lovejoy through my telescope, I set up my other camera for star trails."

Equipment: Pentax K-01 compact system camera, Tamron 17-50/f-2.8 lens, Velbon VEB-3 mount.



▲ Thor's helmet

NICK DE VILLIERS, CALITZDORP, SOUTH AFRICA, 20 JANUARY 2015

Nick says: "Thor's Helmet, otherwise known as NGC 2359, is an emission nebula in Canis Major. I managed to capture some of the reddish tint at the edges for the first time, so I'm pleased with the result."

Equipment: Atik 460EX monochrome CCD camera, Altair Astro 8-inch Ritchey-Chrétien telescope, Celestron CGEM mount, Astronomik RGB filters.

Comet Lovejoy ▶

DAN CROWSON NEW FLORENCE, MISSOURI 14 FEBRUARY 2015

Dan says: "This was one of several shots I managed to capture of comet C/2014 Q2 Lovejoy. The bright objects at the top-right are NGC 869 and NGC 884, also known as the Double Cluster."

Equipment: Canon EOS Rebel T2i DSLR camera, Canon EF 50mm f/1.8 lens.

ENTER TO WIN A PRIZE!

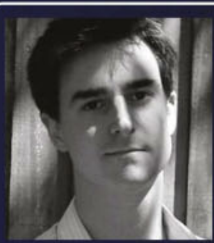
We've teamed up with the Widescreen Centre to offer the winner of next month's best Hotshots image a fantastic prize. The winner will receive an Orion StarShoot Solar System Colour Imager IV camera, designed for capturing sharp shots of the Moon and planets.

www.widescreen-centre.co.uk • 020 7935 2580

Email your pictures to us at hotshots@skyatnightmagazine.com or enter online.

THE COSMIC CLOCK

How would you tell the time if every clock on Earth were suddenly to disappear? **Lewis Dartnell** explains how astronomy can help



ABOUT THE WRITER
Dr Lewis Dartnell is an astrobiologist at the University of Leicester. His latest book, *The Knowledge: How to Rebuild our World from Scratch*, is out now in paperback.

The stars could tell you more than you might think if you suddenly found yourself alone and bereft of any way of telling the time

ISTOCK X 3

▲ Our lives are governed by time: clocks, diaries and calendars set out our lives day by day, week by week

Much of our modern lives are ruled by time – we always have one eye on the clock so we don't miss that all-important train, meeting or school play, while calendars and diaries chart our lives weeks and months into the future. Living in today's electrically lit, climate-controlled civilisation, we've become disconnected from the fundamental rhythms of the planet, and the basic reasons behind much that we take for granted.

"We've become disconnected from the fundamental rhythms of the planet"

But imagine just for a moment that you woke up tomorrow totally alone on a deserted world. How could you determine basic things like the time of day, the date in the year, or even the year itself? How many of the fundamentals that we take for granted today would you know how to work out for yourself, using only the basic principles of science and simple observations of the heavens?

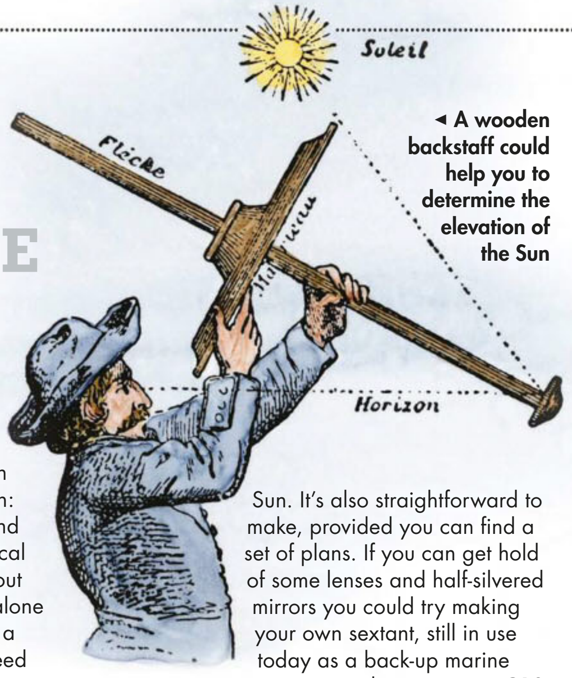
The most straightforward way of telling the local time is through an age-honoured method: plant a stick upright in the ground and the rotation of its shadow will indicate the passing of the day. This is the essence of a sundial. The time when the shadow is shortest (and points due north in the northern hemisphere) is midday, or noon. For best results, the stick should be angled directly towards the north celestial pole, which is currently located near the star Polaris in Ursa Minor.

▼ A stick in the ground is all you need to make a simple sundial

Marking days

You can divide the day into as many segments as you like. Our convention of breaking down a full day into halves of 12 hours originates with the Babylonians and may be linked to the 12 traditional signs of the zodiac: the band of constellations that the Sun and planets appear to move through in their passage across the sky, excluding Ophiuchus. In fact, this may be reason that the hands on all modern clocks turn 'clockwise'. When European machinists invented the clock, they made the hands move in the same direction the sundial shadow moves during the day in the northern hemisphere.

If you divide the time between sunrise and sunset evenly, the length of solar hours indicated by a sundial varies throughout the year: a winter hour is



◂ A wooden backstaff could help you to determine the elevation of the Sun

TELLING THE TIME

Scientific progression is often driven by the development of new and improved instruments, and this is particularly true in terms of the devices used to measure the angle of Sun and stars above the horizon: crucial for navigating around the globe and telling the local time. While you can work out some things using the eye alone and fashion a sundial from a stick; for most part you'll need a tool of some sort.

The wooden backstaff, developed in the late 16th Century, is one simple way of measuring the elevation of the Sun. It's also straightforward to make, provided you can find a set of plans. If you can get hold of some lenses and half-silvered mirrors you could try making your own sextant, still in use today as a back-up marine navigation device in case GPS fails. However, for observing Barnard's Star to work out the year, you'd need to find or fashion a small telescope.

shorter than a summer hour. Only on two days of the year are the solar hours all equal, the equinoxes in March and September.

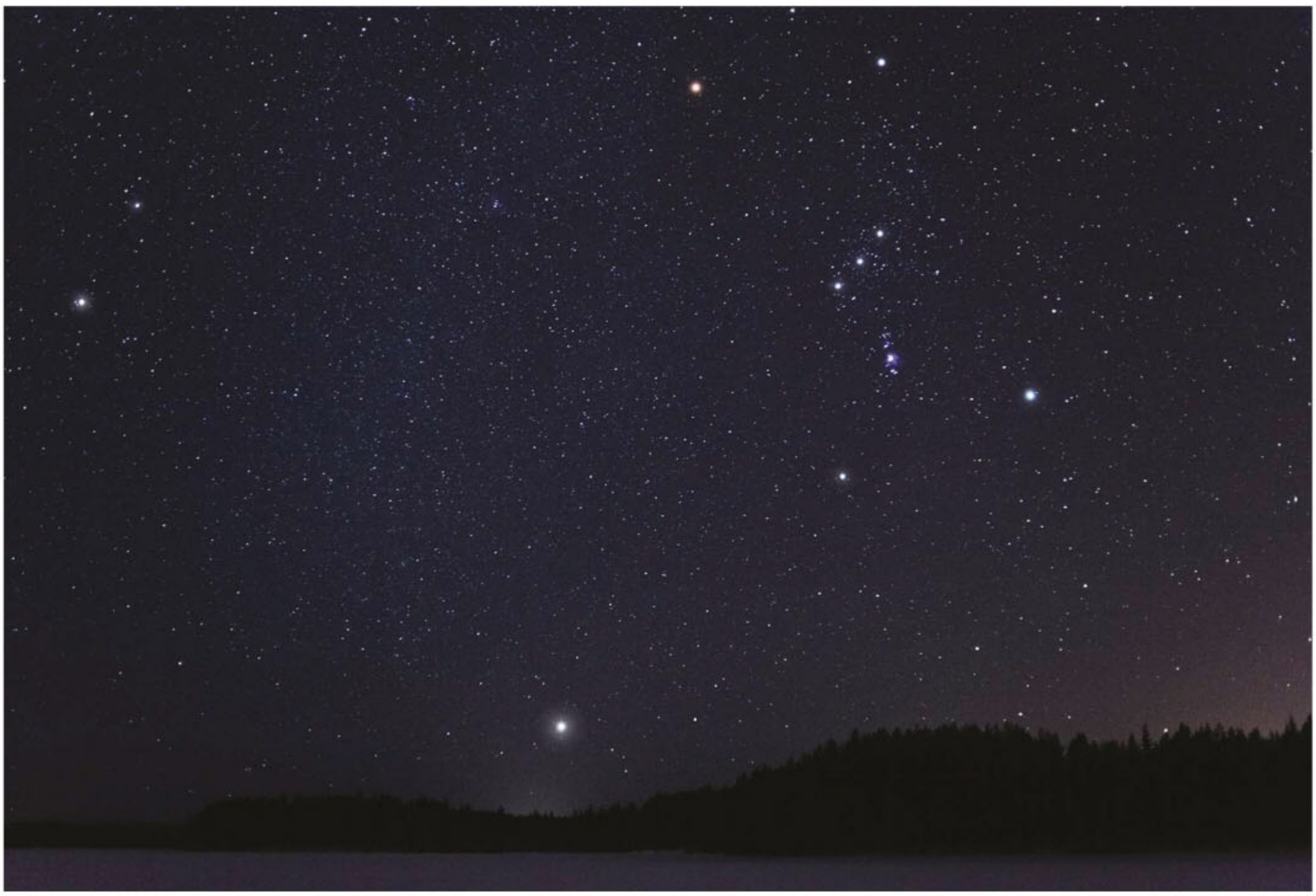
It's this standard equinoctial hour, which can be measured from a sundial using a sand timer, that mechanical clocks are set to count. But when mechanical clocks became common in our history, this created a potential source of confusion. When someone sets a time to meet, which of the two time systems do they mean: the uniform hour of machinery or solar time counting the number of hours since sunrise? This is the reason that since the 14th Century we have specified time as 'three o'clock' – the hour of the clock.

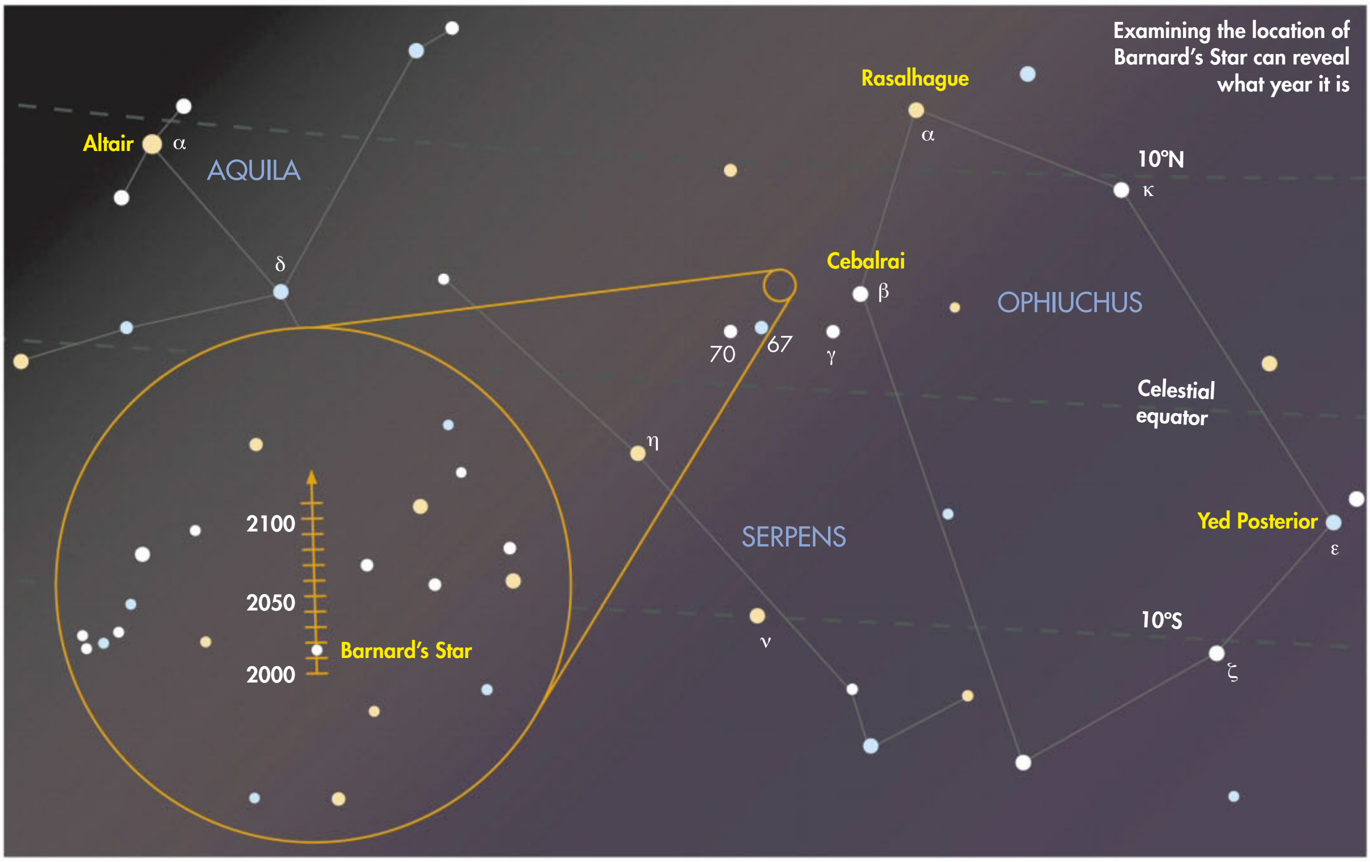
The calendar in the sky

As Earth moves along its orbit over the course of a year, particular stars lying near the horizon from a given viewpoint first become visible at night (and then become obscured again) on specific dates. By counting days between these stellar events, you can determine for yourself that there are 365 full days in the year and track your progress through the seasons. The ancient Egyptians, for example, predicted the flooding of the Nile and rejuvenation of their soil by the first appearance of Sirius in Canis Major, brightest star in the sky, which in our modern calendar equates to around 28 June.

By paying attention to the tracks of the Sun through the daytime sky you'll also notice several special days. The day that the Sun reaches highest in the sky, and then six months later skims lowest over the horizon, are the summer and winter solstices – the longest and shortest days respectively. You can measure the angle of the Sun, or other stars, above the horizon very accurately using a ▸

▾ Sirius sits just above the horizon; the ancient Egyptians were able to use it to predict flooding on the Nile



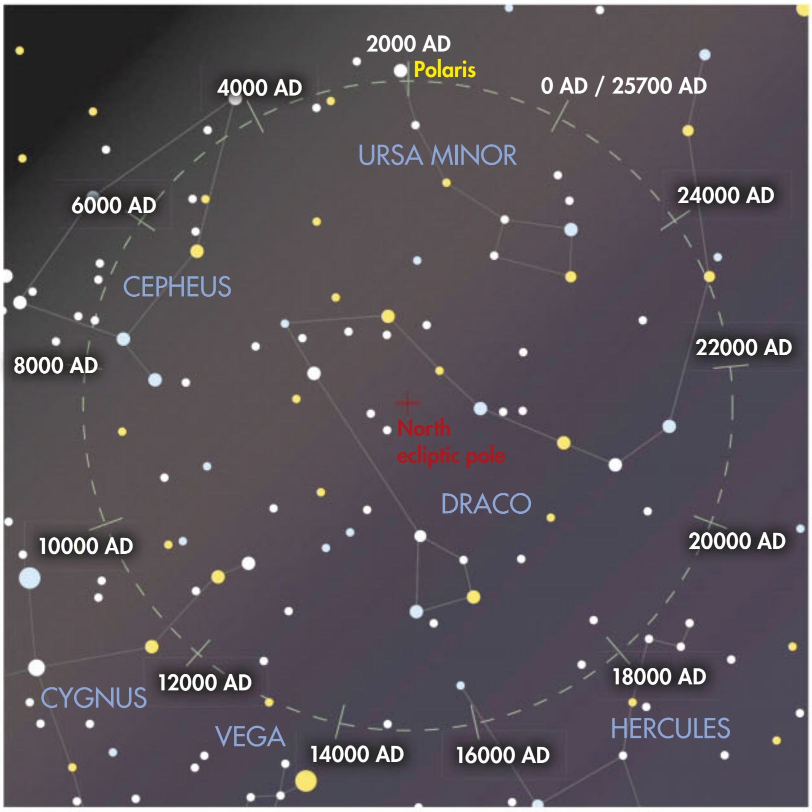


▸ backstaff or sextant (see 'Telling the time', page 35). In between the solstices, the Sun will rise from due east (at right angles to the north celestial pole) on the morning of the autumn and spring equinox. These temporal monuments can be used to fix the date: the solstices occur near 21 December and 21 June and the equinoxes fall around 22 September and 20 March. So if you wanted to, you could reconstruct the Gregorian calendar with its comfortably familiar structure of 12 months from January to December, and peg it back on to the special days you've determined from your observations.

The final part of our thought experiment is farther reaching. If you fell through a time warp into the future, how could you tell from the stars what year it was? To us, the stars seem locked into position, wheeling around the firmament in fixed configurations we call the constellations. But over timescales far longer than human experience, the stars are in fact swirling around the sky like flecks of foam on a dark ocean. This is called 'proper motion', and is due to the other stars each following their own orbital trajectory around the centre of the Milky Way.

Charting years

The star with the fastest proper motion from our point of view, and therefore the one most useful as a natural time marker, is known as Barnard's Star. This is a cool red dwarf in Ophiuchus. Despite being one of the closest stars to us it is too dim to be seen with the naked eye, but can be picked out by a modest telescope. Barnard's Star tears across the sky at almost 1/3000th of a degree every year. This may not sound like much, but compared to all the surrounding stars it's a blistering pace, and over a human lifespan it races almost half the diameter of a full Moon. So to find the date in the future, all you'd need to do in principle is observe the patch of sky shown in the chart at the top of the page, note the present location of Barnard's Star and read off the current year from the timeline.



▲ **Precession means that the pole star will change; it will take around 28,000 years for the pole to return to the same position it is today**

CHARTS SOURCE: LEWIS DARTNELL, ISTOCK X 2

Things get a bit more complicated if you were to end up more than a few centuries into the future. Earth's axis of rotation topples round in a circle gradually over time, like a giant spinning top. This 'axial precession' means that while the Polaris happens to sit directly in line with the celestial north pole today, this won't always be the case. Within 1,000 years the pole will have wandered through blank sky and passed close to other stars, and by 25,700 AD will have roamed a complete circle to return to its position at the birth of Christ.

You can check where the current north celestial pole lies by observing which point in the sky doesn't appear to move over the course of the night – the star trails smeared out by a long-exposure photograph will really help here – and compare it the star map timeline shown in the lower chart on page 36 to read off your current millennium. Or at least, how many multiples of 26,000 years you've landed in the future. Or is it the past?

▲ Capturing star trails with a long-exposure photograph will reveal where the location of the celestial pole is

In Our Time: The Measurement of Time

BBC RADIO 4

Discover how time has been measured from the first water clocks to the atomic clocks of today.
www.bbc.co.uk/programmes/b01dvw6t

WHAT'S THE POINT OF ALL THIS?

The thought experiment we've explored here may seem frivolous. As long as modern civilisation doesn't collapse, you will always be able to find the current time and date. But while telling the time and ticking off days on the calendar are mindless activities today, they were fundamental capabilities for the progression of civilisation in the first place. Through history, being able to tell the time yourself has been vital to coordinating the actions of society – the opening of market, for example. And constructing the calendar to track your progress through the seasons of the year is vital for successful agriculture. You need to know when is the best moment to sow the seeds so your crop has time to mature before winter draws in and you starve to death.


Apollo 15 commander David Scott during the mission's second EVA

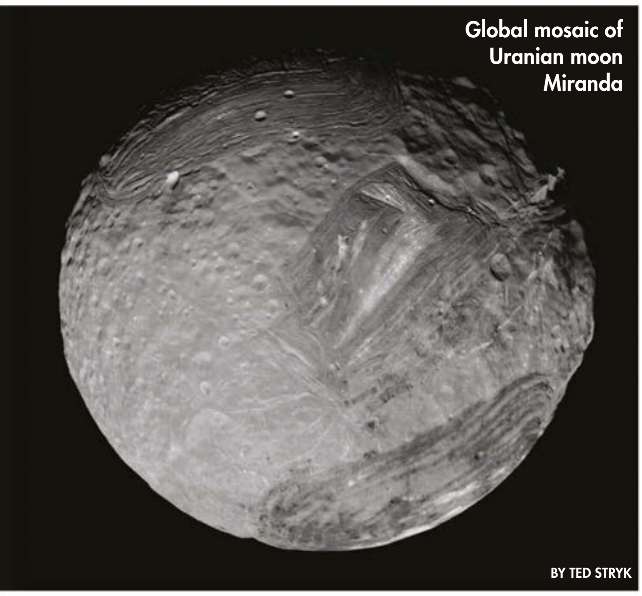
BY MICK HYDE


BY EMILY LAKDAWALLA

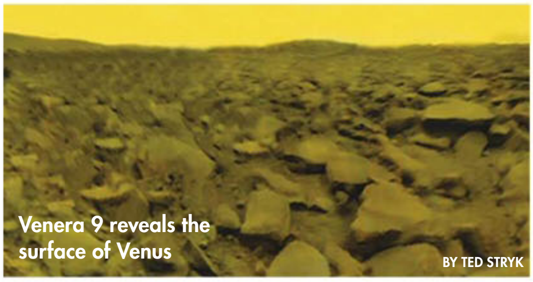
CREATE YOUR OWN IMAGES WITH SPACE MISSION DATA

Will Gater speaks to the enthusiasts creating breathtaking images using data direct from the spacecraft exploring the cosmos

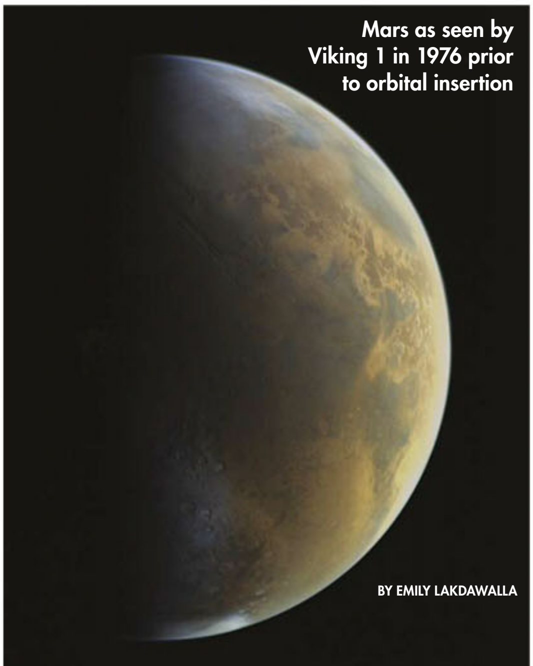
MICK HYDE X 2, TED STRYK, NASA/JPL/MSSS/EMILY LAKDAWALLA, NASA/JPL/COLOR COMPOSITE BY EMILY LAKDAWALLA


Global mosaic of Uranian moon Miranda

BY TED STRYK


Venera 9 reveals the surface of Venus

BY TED STRYK


Mars as seen by Viking 1 in 1976 prior to orbital insertion

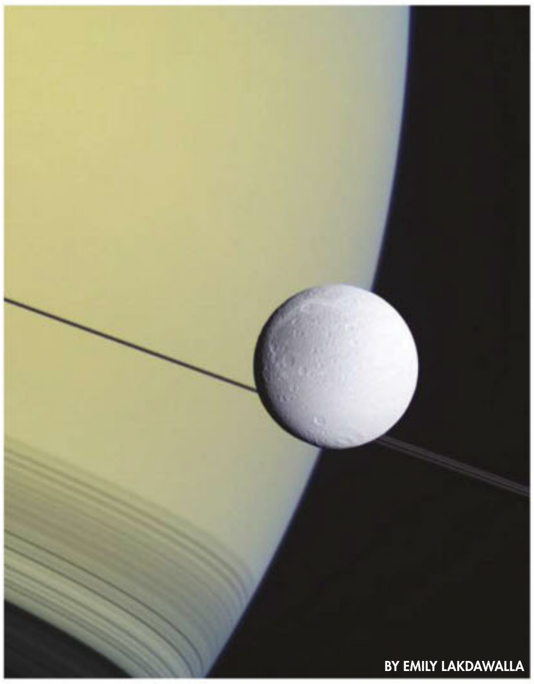
BY EMILY LAKDAWALLA


Opportunity surveys the geology of the Red Planet

BY STUART ATKINSON

YOU CAN DO IT TOO
All of the images in this feature have been processed from raw mission data by enthusiasts

Curiosity photographs itself at the waypoint dubbed 'the Kimberley' as it prepares to commence drilling work



▲ **Clockwise from top: Uranian moon Ariel; Dione and Saturn captured by Cassini in 2012; the damage to Curiosity's wheels, snapped by the rover on Sol 708; and Jupiter's Great Red Spot as seen by Voyager 1 in 1979**

Stuart Atkinson can still remember the first images from space he saw. It was the early seventies and NASA's Apollo adventure was in full swing. He and his classmates had been gathered into the hall at their primary school in Cumbria and a bulky television set had been tuned in to the coverage of the US astronauts on the lunar surface. "People in that room, other people got into football or sport, with me it was just straight away from day one I was into space," he says.

It's a similar story for Mick Hyde. Like Atkinson, it was the sight of our nearest neighbour – in his case, an astonishing oblique view of the crater Copernicus from the Lunar Orbiter 2 spacecraft – that he remembers particularly. "I owned a small reflecting telescope at the time and loved observing the Moon," says Hyde. "Copernicus was always a favourite of mine. To see it from this angle was truly amazing."

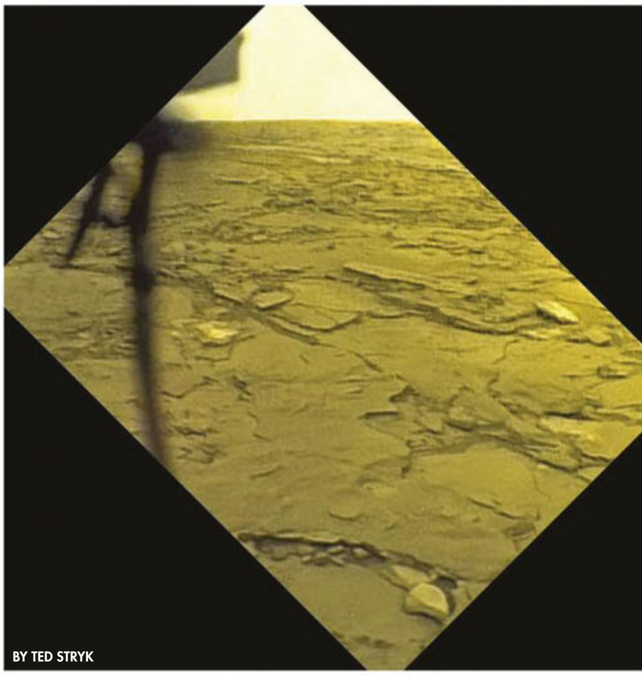
Emily Lakdawalla had been interested in science her entire life and studied geology at college before moving into teaching; yet in the 1990s, the spectacular pictures returned by missions at Mars and Jupiter prompted a career change. "It was when Galileo was sending back the first images of Jupiter's moons," says Lakdawalla. "It suddenly occurred to me to ask whether I could study geology on planets other than Earth. I talked to my geology advisor in college and she said why yes as a matter of fact you can and I went to grad school to do it."

Shared endeavours

What then, other than a passion for space, links these three together? The answer is that their interest in images from the cosmos goes far beyond just admiring them in books or online. They're part of a growing band of amateur astronomers, space enthusiasts and interested members of the public who are processing image data from missions exploring our Solar System and the Universe at large. The result: astonishing pictures of worlds and landscapes that rival the works of even the greatest painters and photographers.

Spurred by those early views of Apollo and television shows like *Cosmos* and *The Sky at Night*, Atkinson developed a keen interest in astronomy.

MICK HYDE X 3, TED STRYK X 2, NASA/JPL/SSI/COLOR COMPOSITE BY EMILY LAKDAWALLA, NASA/JPL/UA/EMILY LAKDAWALLA



▲ Clockwise from top: the terraced floor of this unnamed Martian crater is clear to see; Venera 14 glimpses Venus; and a panorama taken during EVA3 of Apollo 15

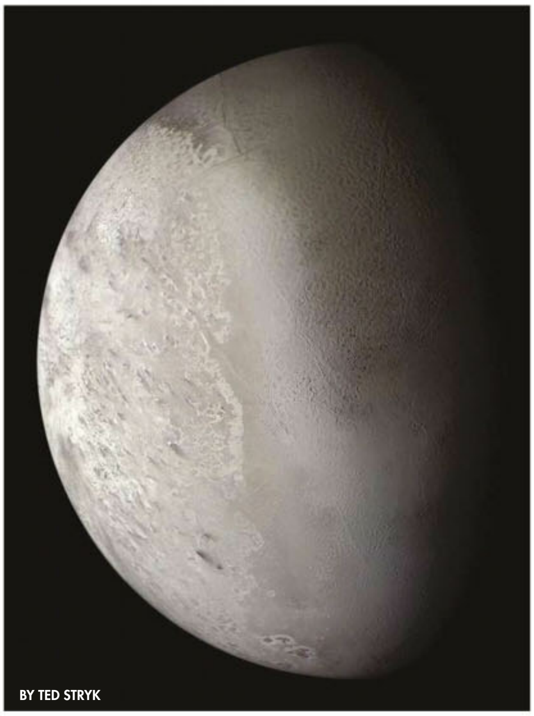
But it was the landings of the Mars Exploration Rovers Spirit and Opportunity on the Red Planet in 2004 that threw him into the world of processing space images. "That was the first time things were actually put out on the internet. Before then it was all quite a closed shop," he recalls. "I remember watching the landing of Spirit. I was on my Windows PC sitting at home watching on a 2x2-inch screen on dial up and it kept breaking up and going into this blaze of pixels then starting again."

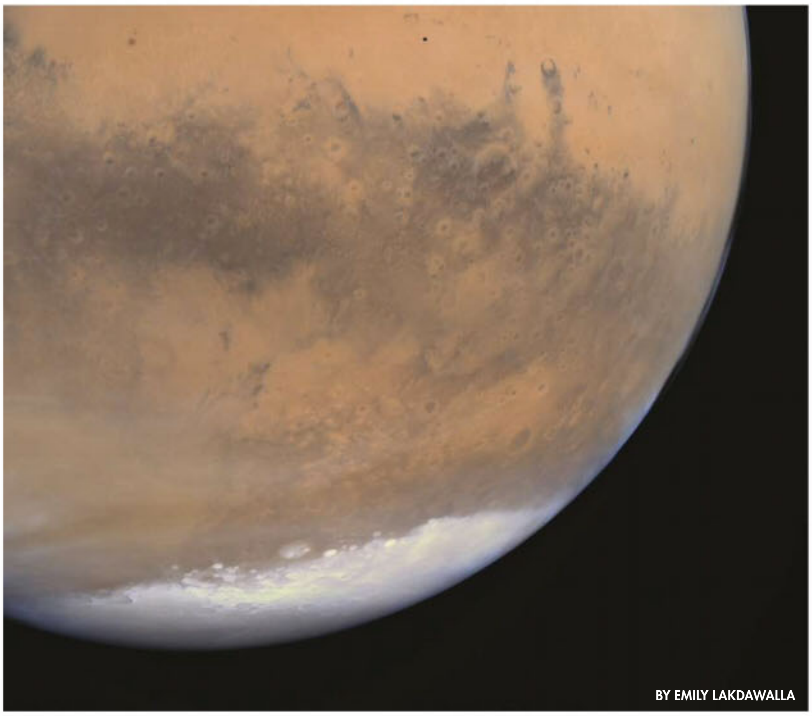
The view on his computer screen may have been shaky by today's standards, then, but that early coverage nonetheless had a profound impact on Atkinson. "Everything was online. All the photographs, the landings were live [and the] press conferences after that," he says. "It was like being on Columbus' ship with him going to America and seeing this new world for the first time."

There has been no shortage of breathtaking imagery released in recent years by the teams working on space telescopes, planetary probes and rovers. But it's the chance to process and interpret the raw image data from these missions themselves that Atkinson and his colleagues revel in. "I feel like I'm walking alongside that rover with my hand on her back seeing what she sees, saying 'look over there, look at that hill'," he says.

That sense of discovery, and of gazing upon a previously unseen vista, is echoed by Lakdawalla, who today works for the California-based Planetary Society. "Most people don't appreciate how much more data there is than gets publicly released by, say, JPL. That's not because they're hiding anything, it's just that there's only so many images that you can write captions for," she says. "It's exactly like a museum has only one per cent of its collection on display and then it has this much deeper collection in its vaults. I like finding things that people haven't really processed and appreciated before."

Today a handful of – mainly NASA – missions offer a form of raw image data on their websites alongside the numerous polished images released officially by their science teams and parent space agencies. "There are some missions that are releasing JPEG versions of all of their image data ▸





▲ **Clockwise from top: the rugged Martian landscape, from data recorded on Sol 540 of the Curiosity mission; comet-hunting Rosetta's view of Mars as it passed by in 2007; and Neptune's largest Moon, Triton**

MICK HYDE X 2, TED STRYK X 2, ESA/MPS/UPD/LAM/IAA/RSSD/INTA/UPM/DASP/IDA/PROCESSED BY EMILY LAKDAWALLA

▸ almost immediately to the web," says Lakdawalla. "They include the Mars Exploration Rover Opportunity, Curiosity and Cassini as well as the Visual Monitoring Camera on Mars Express." Older NASA data, including images from past missions like Voyager and Galileo, is stored on a vast online repository known as the Planetary Data System (see 'Data mine', page 46).

Before embarking on processing image data from your favourite mission, do make sure you are aware of any rules governing its use.

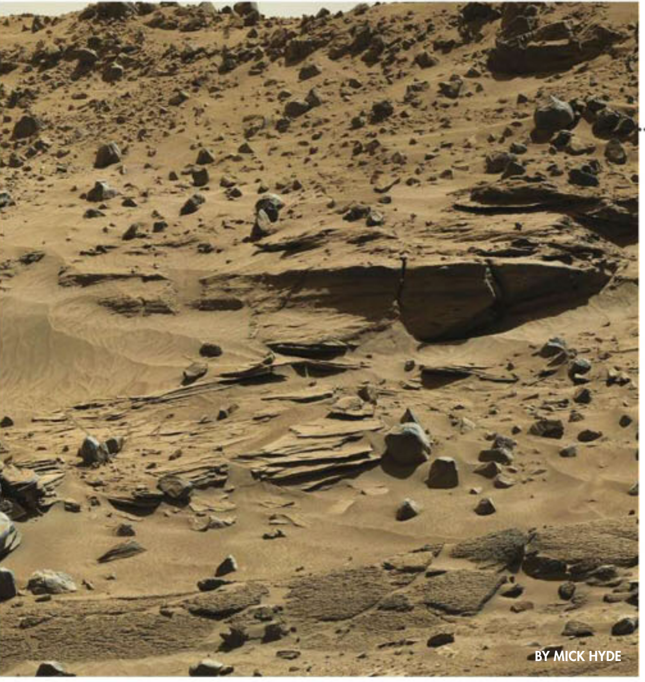
"Any data produced by any American government agency is in the public domain," says Lakdawalla. "So there are really no rules for what you can do with NASA images, you can do anything with them. ESA are different. In general they require attribution for images. So you can't just slap an image on something and claim it as yours. You have to acknowledge ESA and the different institutions whose investigators worked on that image data. Recently ESA has been releasing images with Creative Commons licences to allow them to be shared on Wikipedia, but only for certain data sets."

If you've taken pictures of the night sky before, the methods used to bring out details in professional space image data will probably seem quite familiar. "Some of the cameras that I use for imaging the Moon, planets and deep-sky objects are very similar to the ones used on remote spacecraft," says Hyde, who is an accomplished amateur astrophotographer. "Assembling large mosaics of the Moon or nebulae uses the same skills for processing spacecraft data."

From bits to Bierstadt

Just as with astrophotography, you needn't necessarily have expensive image processing software either. "You can use GIMP [free from **www.gimp.org**]," says Lakdawalla. "You can use that to do almost all of the things you need to do."

Typically, the raw image data is monochrome and may require stretching with the Levels tool to make the landscape or subject apparent on screen.



BY MICK HYDE

BY MICK HYDE

BY TED STRYK

▲ Above: the Mars Curiosity rover takes a selfie on Sol 868; and the moon Despina transits across its parent planet Neptune

TOP TIPS FOR **PROCESSING**

EMILY LAKDAWALLA, SENIOR EDITOR, THE PLANETARY SOCIETY

"The raw data sets from the Mars rovers and Cassini are converted to JPEGs and that introduces compression artefacts. I can't tell you how many conspiracist websites I've seen where people have blown up these artefacts and found dinosaur bones and who knows what else. Don't blow things up too much – respect the pixels!"
www.planetary.org/blogs/emily-lakdawalla

STUART ATKINSON AMATEUR ASTRONOMER

"You can't break anything; just download the pictures and experiment. And even if it's only saving a picture and boosting the contrast or the Curves, just see what you can do. Also, pay a visit to Emily Lakdawalla's blog on the Planetary Society website; she's got some links to tutorials on there, which are fantastic."
https://roadtoendeavour.wordpress.com

TED STRYK PROFESSOR OF PHILOSOPHY

"Start by learning the basics: how to project images, what kind of issues a particular camera has, what kind of filters it has. Learn to do this first before trying to repair damaged imagery. When you come across something unexpected, always assume it is an error on your part until you have ruled everything else out."
http://planetimages.blogspot.co.uk

MICK HYDE AMATEUR ASTROPHOTOGRAPHER

"Make sure you have a sound understanding of an image editing package such as Photoshop or GIMP, and that you can use layers and can understand what the histogram tells you. You also need to be comfortable using the Levels and Curves tools, since some data is very dark and needs stretching to bring out detail. The main thing is to have fun."
www.flickr.com/photos/mickhyde

"If you want colour pictures you have to combine three images taken through different filters into colour," explains Lakdawalla. "That's very easy for Mars rovers because the camera stays still as it takes the different pictures. But for Voyager and Cassini or Galileo, the spacecraft is moving between the pictures and so you often have to do resizing, stretching, rotation, other tricks that are more art than science in order to get the images to line up properly to make nice-looking colour pictures."

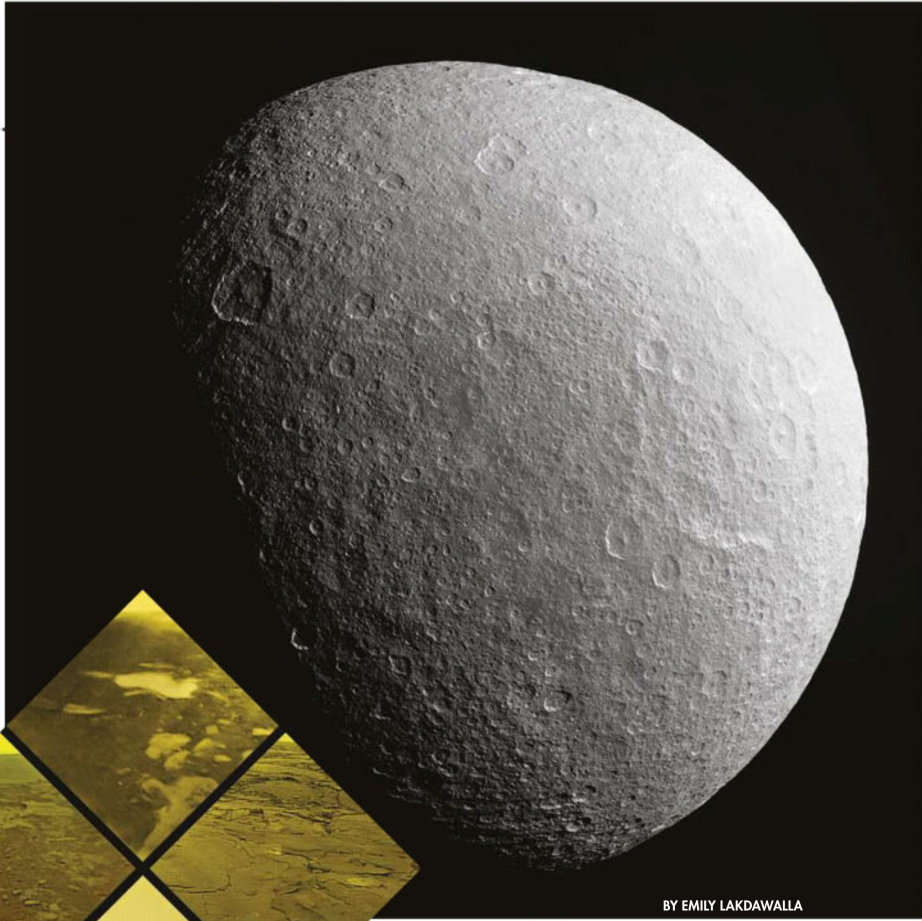
Indeed what's perhaps most interesting about the images produced by amateurs is that the same set of data may be processed in a number of different ways, with each person making their own artistic or technical decisions about how the picture should look. "Some people go for accuracy and balance these Curves and Levels and all sorts," says Atkinson. "I just try and make pretty pictures. I try and make a picture that looks like how I imagine Mars would be if I went there. I'm a big fan of people like Ansel Adams and Albert Bierstadt, these painters and photographers who took the landscapes of the American West and just made them look 'wow' gorgeous. I'm trying to do that in a little way with Mars."

Building the picture

Others use the powerful image processing software available today to breathe new life into much older mission data. Ted Stryk's work on the Venera and Voyager data has produced exquisite new renditions of the pictures returned by these pioneering spacecraft. "The Venera images are our only views from the surface of Venus," says Stryk, a professor of philosophy at Roane State Community College in Tennessee. "Yet many of the versions shown look like bad scans and in some cases might even be photocopies. So I try to combine all the data available from each lander to make the best possible product. In the case of Voyager, my particular interest has been the moons of Uranus and Neptune. Given the low illumination and high speed of the spacecraft, many images are smeared, so I have worked to de-smear them. Also, many are poorly exposed and are ▸


BY MICK HYDE


BY MICK HYDE


BY EMILY LAKDAWALLA


BY TED STRYK

▲ **Clockwise from top: a panoramic view from Apollo 9; an 11-image mosaic of Saturn's moon Rhea; four views of Venus from the Venera programme; the Curiosity rover's view of Mars on Sol 584**

▸ somewhat noisy. I have worked on stacking all available images of a target from a given angle in order to cancel out as much of this as possible."

If you have a more analytical than artistic streak, you can use some sets of spacecraft image data to carry out your own simple scientific studies. "There's a lot that people could do looking at, for instance, HiRISE data from Mars," says Lakdawalla. "There is a lot of imagery from HiRISE [a camera on the Mars Reconnaissance Orbiter] that really hasn't been looked at in very much detail." Such analyses might involve scrutinising images for signs of changes on the Martian surface, such as the appearance of fresh impact craters, rockfalls or even clouds.

Today Atkinson is the one who's inspiring the next generation of astronomers with the space images he processes. "I tell kids in my talks, you can go online when you get home from my talk, you can see pictures tonight sat in your lounge from Mars, from the Moon, from Saturn, from asteroids just by clicking," he says. "When I was growing up, you couldn't do that." His message to the mission scientists that have released their data, so that people like him can explore and enjoy it, is a simple one: "Thank you, really, for letting us join in with the adventure." Ⓢ

ABOUT THE WRITER

Will Gater (@willgater) is an astronomer, writer and broadcaster. He is the author of several popular astronomy books and presents live astronomy shows for Slooh.

DATA MINE

Start your exploration of professional image data from outer space with these weblinks

PLANETARY DATA SYSTEM IMAGING NODE

The image archives, supporting data sets, software tools and tutorials for the digital collections from NASA's planetary missions.
http://pds-imaging.jpl.nasa.gov

MARS EXPLORATION ROVER OPPORTUNITY RAW IMAGES

The unprocessed image data from the five cameras on NASA's Mars rover.
http://mars.nasa.gov/mer/gallery/all/opportunity.html

MARS SCIENCE LABORATORY 'CURIOSITY' RAW IMAGES

The unprocessed image data from the eight cameras on NASA's latest Mars rover.
http://mars.jpl.nasa.gov/msl/multimedia/raw

CASSINI SPACECRAFT RAW IMAGES

The regularly updated archive for all raw image data from Cassini at Saturn.
http://saturn.jpl.nasa.gov/photos/raw

MICK HYDE X 2, TED STRYK, NASA/JPL/SSI/EMILY LAKDAWALLA

PETE LAWRENCE

PLUS
Stephen Tonkin's
BINOCULAR TOUR
Turn to page 58 for six of this month's best binocular sights

The Sky Guide May

The Moon's rocking and rolling motion, better known as libration, brings the highly cratered southern polar region nicely into view at the beginning and end of May. This complex region is exciting to explore and will push your lunar navigational skills to the limit.

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.

Highlights

Your guide to the night sky this month

This icon indicates a good photo opportunity

PETE LAWRENCE X 6

4 ◀ **MONDAY**
The Moon's southern polar region is nicely on view until 12 May. This complex region of the Moon is covered in amazing craters.

5 **TUESDAY**
The Eta Aquariid meteor shower reaches its peak tonight. Unfortunately, an almost full Moon will spoil the show.

9 **SATURDAY** ▶
Mag. –4.0 Venus, sits 1.75° to the north of mag. +5.1 open cluster M35 in Gemini this evening. Look for the pair with binoculars as the sky darkens. The cluster will appear below and left of the planet.

14 **THURSDAY**
With the Moon out of the way, now until the 28th is a great time to try our *Deep-sky tour.* See page 56.

15 **FRIDAY**
Look out for the semi-circular constellation of Corona Borealis, the Northern Crown, which is visible about two-thirds of the way up the sky, due south around 01:00 BST (00:00 UT).

19 **TUESDAY**
Look towards the northwest horizon after the Sun has gone down and see if you can pick out mag. +2.7 Mercury very low in the darkening skies. A 3%-lit waxing crescent Moon is also present, 9° to the left of Mercury.

20 **WEDNESDAY** ▶
Late May is traditionally considered the start of noctilucent cloud season. See if you can spot an early display low down in the northwest 90-120 minutes after sunset or low in the northeast 90-120 minutes before sunrise.

23 **SATURDAY**
Look out for mag. –1.8 Jupiter and a 33% lit waxing crescent Moon, low down in the west around midnight. The Moon will be separated from the planet by around 6.5° just before it sets.

29 **FRIDAY**
The bright star 2° below the 86%-lit waxing gibbous Moon this evening is mag. +1.0 Spica (Alpha (α) Virginis), the brightest star in the constellation of Virgo.

30 **SATURDAY**
Lunar libration once again brings the Moon's southern polar region into a favourable position between 30-31 May.

31 **SUNDAY**
A hint of things to come, the apparent gap between Venus and Jupiter will have closed to just 19° by the end of May. They will now close in on one another, appearing separated by just 21 arcminutes at the end of next month.

7 THURSDAY Mercury reaches greatest eastern elongation. It can be seen approximately 40 minutes after the Sun has set, low down over in the west-northwest.

8 FRIDAY Titan, the largest moon of Saturn, is at greatest eastern elongation from the Ringed Planet.

12 TUESDAY This time of year is great if you're into globular clusters. Around midnight, magnificent M13 in Hercules is high in the sky. Also prominently on view are M3, M4, M5, M9, M10, M12, M14, and M92.

13 WEDNESDAY Both Io and its shadow can be seen transiting Jupiter's disc. Io passes onto the disc at 22:55 BST (21:55 UT), followed by its shadow at 00:11 BST on the 14th (23:11 UT). Io leaves the disc at 01:12 BST (00:12, UT) and its shadow at 02:27 BST (01:27 UT).

18 MONDAY ▶ Globular cluster M5 lies due south at 00:50 BST (23:50 UT on the 17th). At mag. +5.7 this is an easy target for a small telescope and with larger apertures is a magnificent sight.

21 THURSDAY The 16%-lit waxing crescent Moon is 9° below and left of mag. –4.1 Venus this evening. Catch the pair in darkening skies around 23:00 BST (22:00 UT), low in the west-northwest.

What the team will be observing in May

Pete Lawrence "As we approach the end of May my attention's going to shift to noctilucent cloud patrols. There's something really quite magical about catching a bright display of these incredible clouds."

Steve Marsh "Nightscape photography has become a passion of mine recently so this month I'm hoping to catch some noctilucent cloud displays – I've never managed to capture any!"

Paul Money "At the end of April and into the beginning of May I'll be looking out for Mercury – it will be close to the Pleiades cluster in Taurus, low in the evening twilight."

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'.

HOW TO TELL WHAT EQUIPMENT YOU'LL NEED

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

BINOCULARS
10x50 recommended

PHOTO OPPORTUNITY
Use a CCD, planetary camera or standard DSLR

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 your first scope.

DON'T MISS...

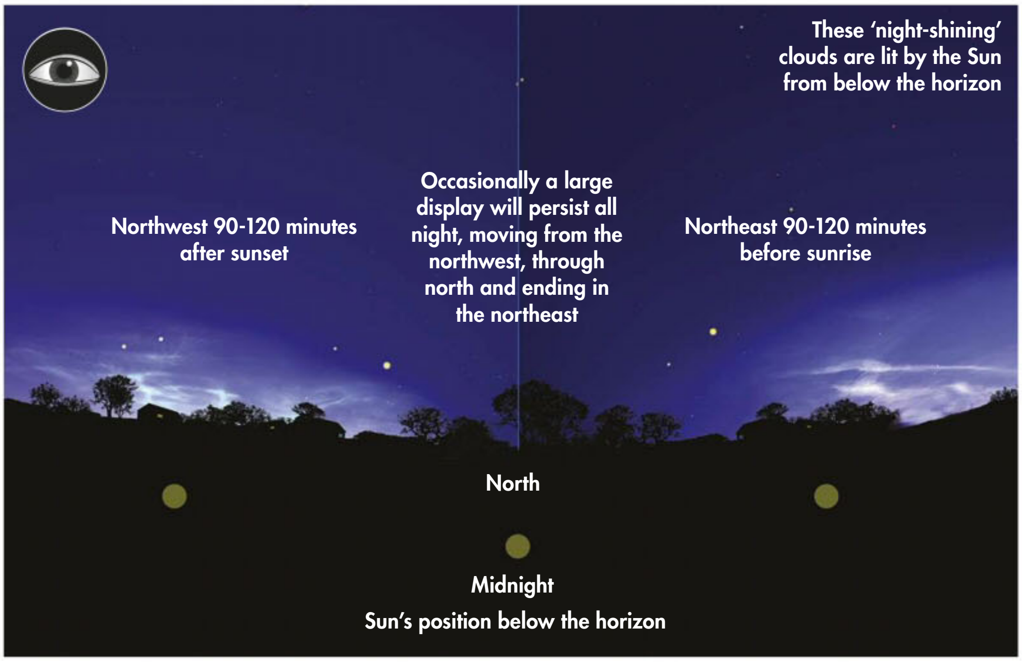
3 top sights

Noctilucent clouds

NEED TO KNOW

An object's brightness is given by its magnitude. The lower the number, the brighter the object: with the naked eye you can see down to mag. +6.0.

WHEN: Late May through to early August



THE END OF May marks the start of noctilucent cloud (NLC) spotting season. If you've never seen an NLC display before and are wondering what all the fuss is about, especially as they are technically clouds, then be prepared for a treat. If you have seen NLC's before then no doubt you'll be keen to see them again.

NLCs are the highest clouds on planet Earth, forming in the part of the atmosphere known as the mesosphere, in a narrow layer at a height of 76-85km. During the summer months in the northern hemisphere, the temperature at this altitude can plummet to below –120°C. Water vapour becomes super-cooled at this temperature, and if anything happens to be in the layer, such as fine particles left over from meteor vaporisation, the water vapour instantly freezes on contact with them. The result is a sheet of fine ice crystals typically around 100nm in size (1nm being equivalent to one-billionth of a metre).

At this height between the end of May and start of August, the Sun's altitude below the horizon at night is sufficiently shallow to still illuminate the NLC layer. This occurs when the Sun's altitude is between –6° and –16°. Even though the ground is in darkness, the clouds shine with an eerie blue glow; hence the name noctilucent, which means 'night-shining'.

There's no guarantee that NLCs will appear on any given night, but if they do they will typically put in an appearance 90-120 minutes after sunset low in the northwest or 90-120 minutes before sunrise low in the northeast. If a major display is in force, it may persist all night, moving slowly from the northwest, through north and into the northeast by dawn. This is caused by the apparent movement of the Sun below the horizon.

The low altitude of NLCs can catch people out, so it's imperative to find a lookout spot which has a very low, flat horizon in the relevant direction. A good NLC display is something that's not easily forgotten and should be visible even through light polluted skies. Some have been so bright that they've been misreported as aurorae.

NLCs tend to change shape quite slowly. They often show a bluish colour or sometimes white-yellow and often look like a patterned network across the sky. Photographs show this well.

NLCs offer an exciting opportunity. There's no substitute for keeping the evening and morning watch going for as many days as possible, and little worse than having given up hope, only to see a report of a really bright display on the night you decided to sleep in!

PETE LAWRENCE X4

Really strong NLC displays have been so bright that they have been mistaken for aurorae

Saturn at opposition

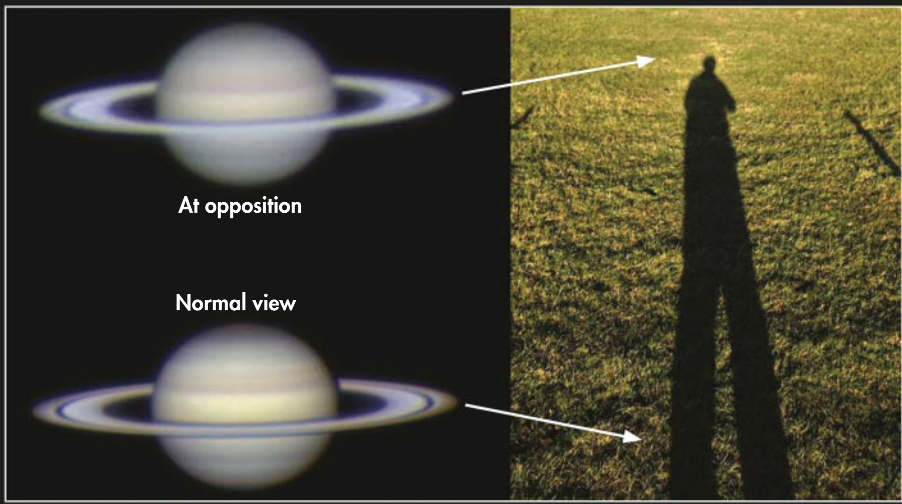
WHEN: 23 May, though Saturn is visible all month

SATURN IS AT opposition on 23 May, a time when its location in the sky is directly opposite the Sun. If you imagine a line from the Sun, through Earth and onto Saturn, although the real alignment isn't quite like this, it does serve to point out that the planet and Earth are at their closest at this time. This means that Saturn appears at its largest and brightest for the current period of visibility.

As Saturn is quite a distant world, the variation before, at and after opposition isn't as dramatic as you'd get with a nearer planet such as Mars or Jupiter, but it's still enough to make a difference.

Another interesting effect occurs when Saturn reaches opposition, because its amazing ring system appears to brighten faster than the globe. This is due to a phenomenon known as the Seeliger effect. Essentially, what's happening is that each of the particles that form the rings casts a shadow. Away from opposition, we can see the net effect of the shadows cast by the particles closer to the Sun on those behind. However, at opposition, Saturn's orientation relative to us and the Sun means that the shadows are hidden directly behind the face of the particle that's casting them. The net result is a small but tangible brightening of the planet's rings.

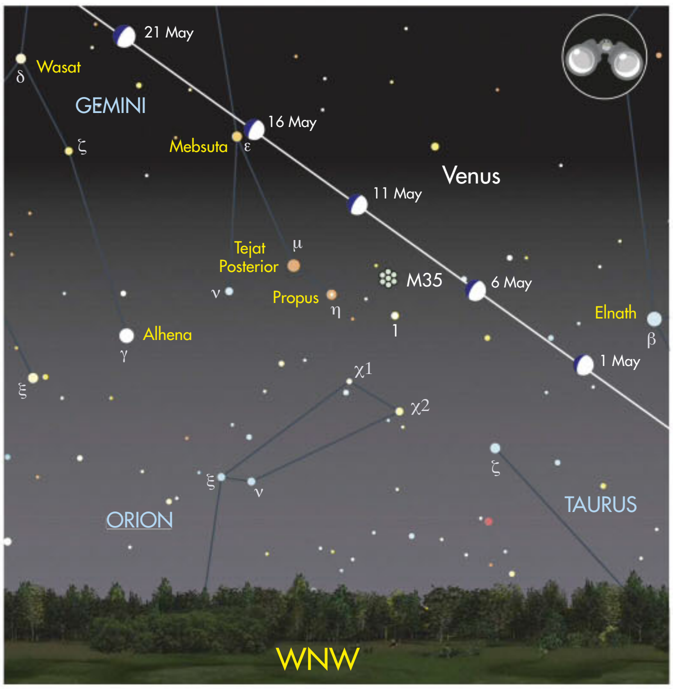
The effect can be seen for several days before and after opposition, rising to a peak at opposition itself. If you have a telescope, take a look over as many days as you can and see if you can detect the brightening. You might be surprised at how obvious it is. As Saturn is rather low down in UK skies at present, it's difficult to get a steady view. However, the Seeliger effect should be visible even if the planet is a bit wobbly in the eyepiece.



▲ The Seeliger effect can be seen in the image of a photographer's shadow on grass. Away from the camera/head position the shadow cast by individual blades of grass are visible and the ground appears darker. Around the head and in line with the Sun, the shadows are hidden behind each blade and the ground appears brighter

Venus and M35 in conjunction

WHEN: 7-11 May, 23:00-23:30 BST



IT'S DIFFICULT TO miss the brilliance of Venus as it now dominates the western sky as twilight falls. As the minutes pass after sunset, Venus will be seen against an ever darkening sky, albeit with the planet losing altitude.

From 7-11 May, it's worth keeping an eye on Venus against a darker sky because it'll be close to the lovely and somewhat understated open cluster M35, in Gemini, which is on the edge of naked eye visibility from a dark site.

Venus approaches the cluster from the southwest, passing to the north of it by just 1.6° on 9 May. Although there's no real scientific value to the meeting, it's still a lovely sight to behold through a pair of binoculars and makes a fantastic pairing to try and photograph. Of course Venus, being mag. –4.0, will completely outshine the mag. +5.1 cluster, but this is also part of the challenge for getting a good shot.

In the days after 9 May, the planet will appear to head ever eastward, passing 0.75° to the north of the third-magnitude star Mebsuta (Epsilon (ε) Geminorum) on 16 May.

NEED TO KNOW

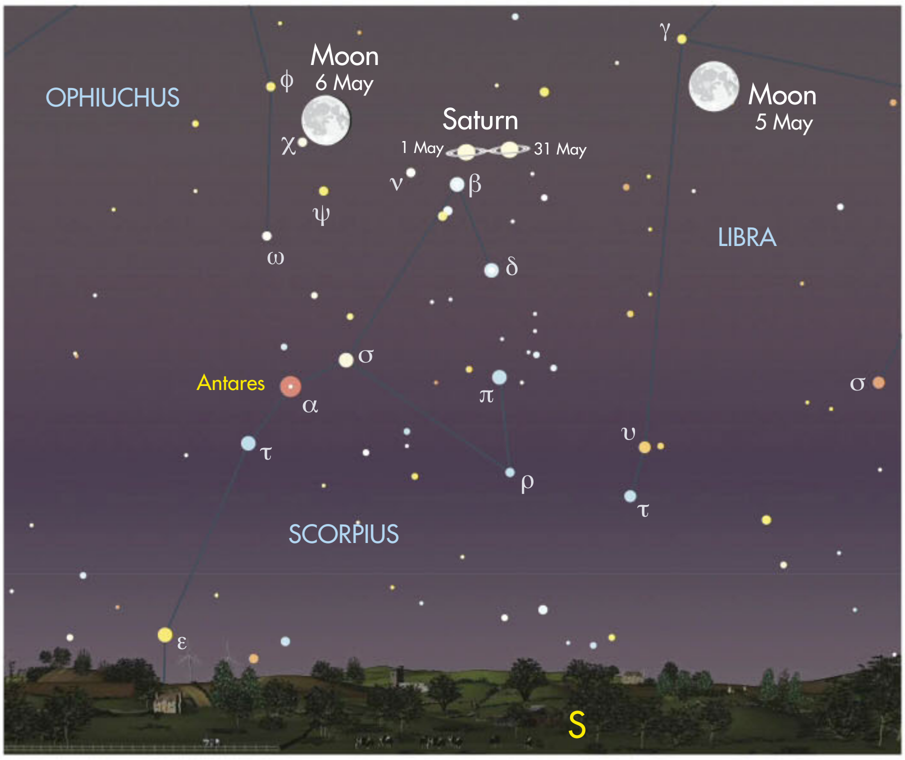
The size of objects in the sky and the distances between them are measured in degrees. The width of your little finger at arm's length spans about 1°.

The planets

PICK OF THE MONTH

SATURN

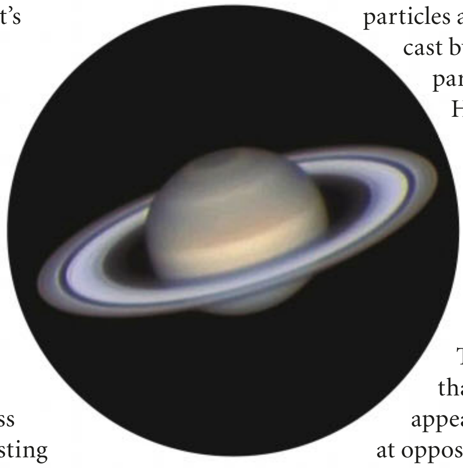
BEST TIME IN MAY:
23 May 01:10 BST (00:10 UT)
ALTITUDE: 18°
LOCATION: Libra
DIRECTION: South
RECOMMENDED EQUIPMENT:
3-inch or larger scope
FEATURES OF INTEREST:
Rings, subtle belts on globe, bright storms in the atmosphere, moons



Though Saturn is quite low down in Scorpius and Libra, it remains above the horizon all night

SATURN REACHES OPPOSITION this month, a time when it's in the opposite part of the sky to the Sun. Opposition occurs on 23 May and it's around this time that interesting things can happen.

The magnificent ring system is nicely presented through a telescope at the moment, tilted over by around 24.5°. It's the north face of the rings we're currently seeing from Earth. The rings comprise countless small particles, each casting their own shadows. Their brightness is usually an average of the bright sunlit faces of these particles and the shadows cast by them onto the particles behind. However, at opposition the shadows become hidden, meaning that we get to see mostly bright ring particle faces. The net result is that the ring system appears to brighten at opposition. This is known as the Seeliger effect; look for it for several days around opposition.


Saturn's rings are currently tilted by nearly 25°

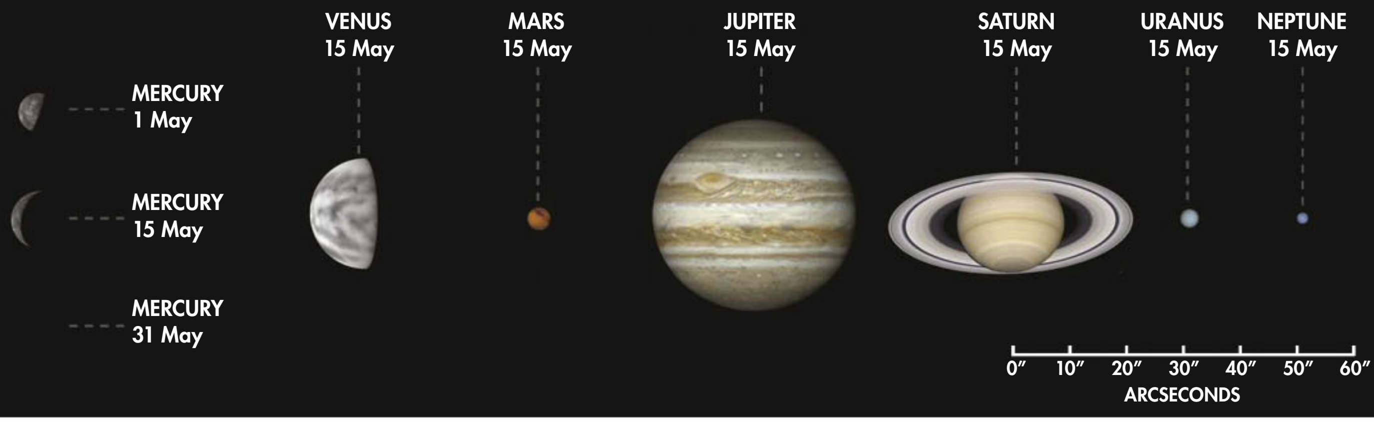
PETE LAWRENCE X 3

The planet starts the month off in Scorpius but drifts westwards into Libra on the 12th. On the 6th, a 96%-lit waning gibbous Moon sits 3.75° east of Saturn at 00:00 BST (23:00 UT on the 5th). By the 31st, the Moon will return to the vicinity with a 96% waxing gibbous Moon 11.5° to the west of the planet. Just as Saturn is at opposition in this part of the sky, so the Moon experiences the same thing. When the Moon is at opposition, it's a full Moon.

Telescopically, mag. +0.1 Saturn is a bit of a challenge from the UK as it's very low down, only managing to reach an altitude of 18° at best. However, as it's at opposition, the planet does at least have the virtue of being up all night.

THE PLANETS IN MAY

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



VENUS

BEST TIME IN MAY: 1 May 22:00 BST (21:00 UT)
ALTITUDE: 21°
LOCATION: Taurus
DIRECTION: West-northwest

Venus remains a prominent evening object, setting four hours after the Sun at the start of May and 4.5 hours by the end of the month. The planet is now very bright at around mag. –4.2 and an easy find with the naked eye; just look towards the west after sunset. Telescopically, things are starting to get interesting too as the planet is now starting to grow in apparent size quite quickly. This is due to the fact that Venus is getting closer to Earth as it travels along its orbit. At the start of May it shows an apparent diameter of 17.4 arcseconds, increasing to 21.8 arcseconds by month end.

The planet's phase decreases as it gets nearer to us and on 1 May, a telescope will show it as slightly gibbous, being 65% illuminated on this date. This decreases to 54% by 31 May.

On 9 May, Venus will be 1.6° north of open cluster M35 in Gemini. By the 16th, it will have moved further into the constellation, being 45 arcminutes to the north of Mebsuta (Epsilon (ε) Geminorum).

JUPITER

BEST TIME IN MAY: 1 May 22:00 BST (21:00 UT)
ALTITUDE: 45°
LOCATION: Cancer
DIRECTION: West-southwest

Jupiter's still looking good at the start of the month but appears to the west of south as darkness falls, losing altitude as a consequence. At mag. –2.0, it's pretty easy to pick out. The shortening nights mean that by the end of May, Jupiter will be poorly positioned, approximately 20° above the horizon as the evening starts to get dark. The planet is located on a line joining the Beehive Cluster, M44 in Cancer, to mag. +1.4 star Regulus (Alpha (α) Leonis). A 33%-lit waxing crescent Moon is 6.5° below Jupiter on 23 May.

MERCURY

BEST TIME IN MAY: 1 May 21:30 BST (20:30 UT)
ALTITUDE: 9° (low)
LOCATION: Taurus
DIRECTION: West-northwest

On 1 May, Mercury lies 2° to the left of the Pleiades, M45 in Taurus. They can be seen when low down in the northwest as the sky gets dark. The planet appears to move eastwards through the stars in the evenings that follow. Greatest eastern elongation occurs on 6 May, when mag. +0.4 Mercury is separated from the Sun by 21.2°.

The planet continues to be visible low in the northwest in the darkening evening twilight through to mid-month. Its last day of visibility will probably be 19 May. On this date, a 3%-lit waxing crescent Moon can be seen lying 9.25° left of mag. +2.7 Mercury. Both objects should be visible about 1 hour after sunset but they will be very low down.

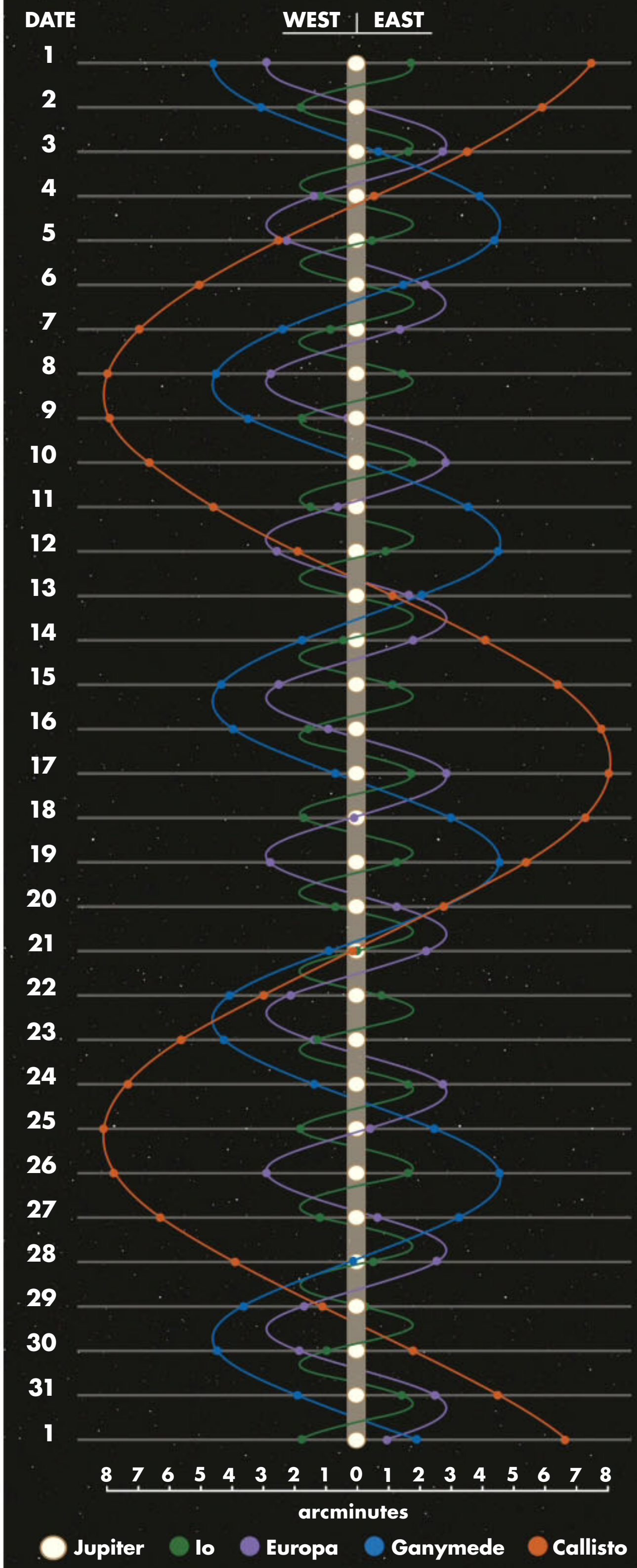
If you can get a look at Mercury with a telescope during the early part of May, its phase will decrease from 52%-lit on the 1st, to just 9%-lit on the 19th. Its size will change too, from 6 arcseconds on the 1st to 10 arcseconds on the 19th. Inferior conjunction, when Mercury lines up with the Sun on the earthward side of its orbit, occurs on 30 May.

NOT VISIBLE THIS MONTH
MARS, URANUS AND NEPTUNE

See what the planets look like through your telescope with the **field of view calculator** on our website at:
http://www.skyatnightmagazine.com/astronomy-tools

JUPITER'S MOONS
May

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.



The Northern Hemisphere

KEY TO STAR CHARTS

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

STAR BRIGHTNESS:

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

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

WHEN TO USE THIS CHART

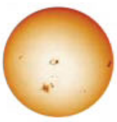
1 MAY AT 01:00 BST
15 MAY AT 00:00 BST
31 MAY AT 23:00 BST

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.

THE SUN IN MAY*



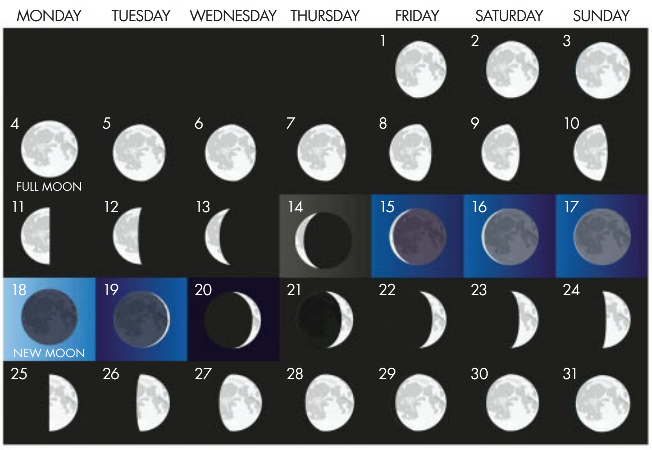
DATE	SUNRISE	SUNSET
1 May 2015	05:36 BST	20:39 BST
11 May 2015	05:17 BST	20:56 BST
21 May 2015	05:01 BST	21:12 BST
31 May 2015	04:49 BST	21:26 BST

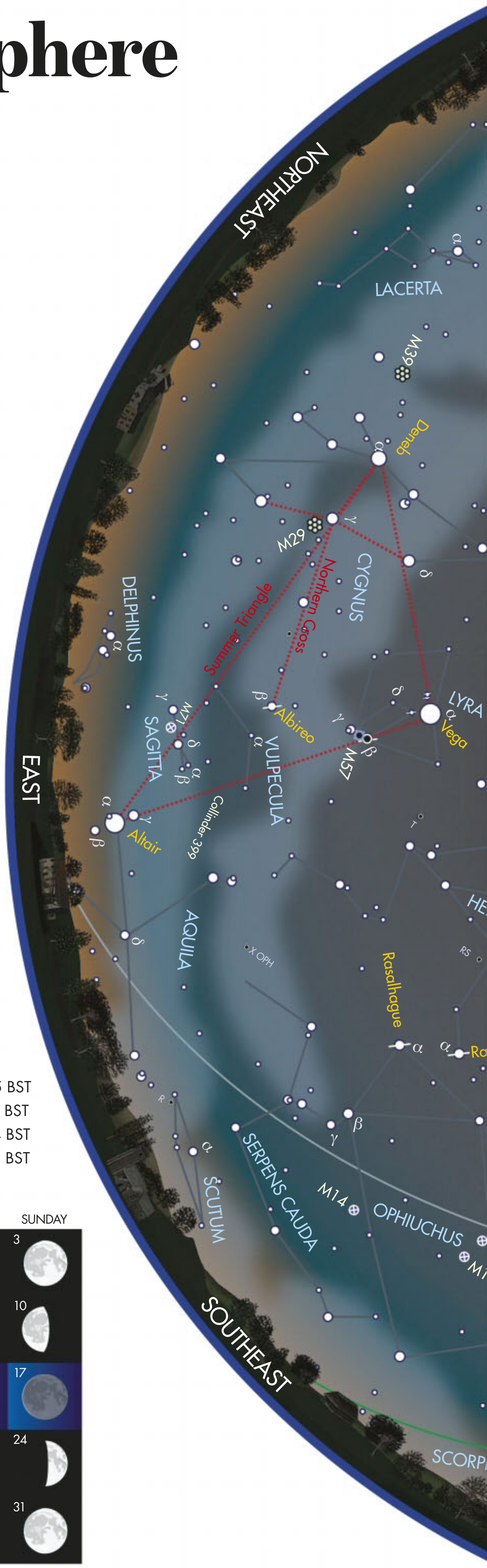
THE MOON IN MAY*

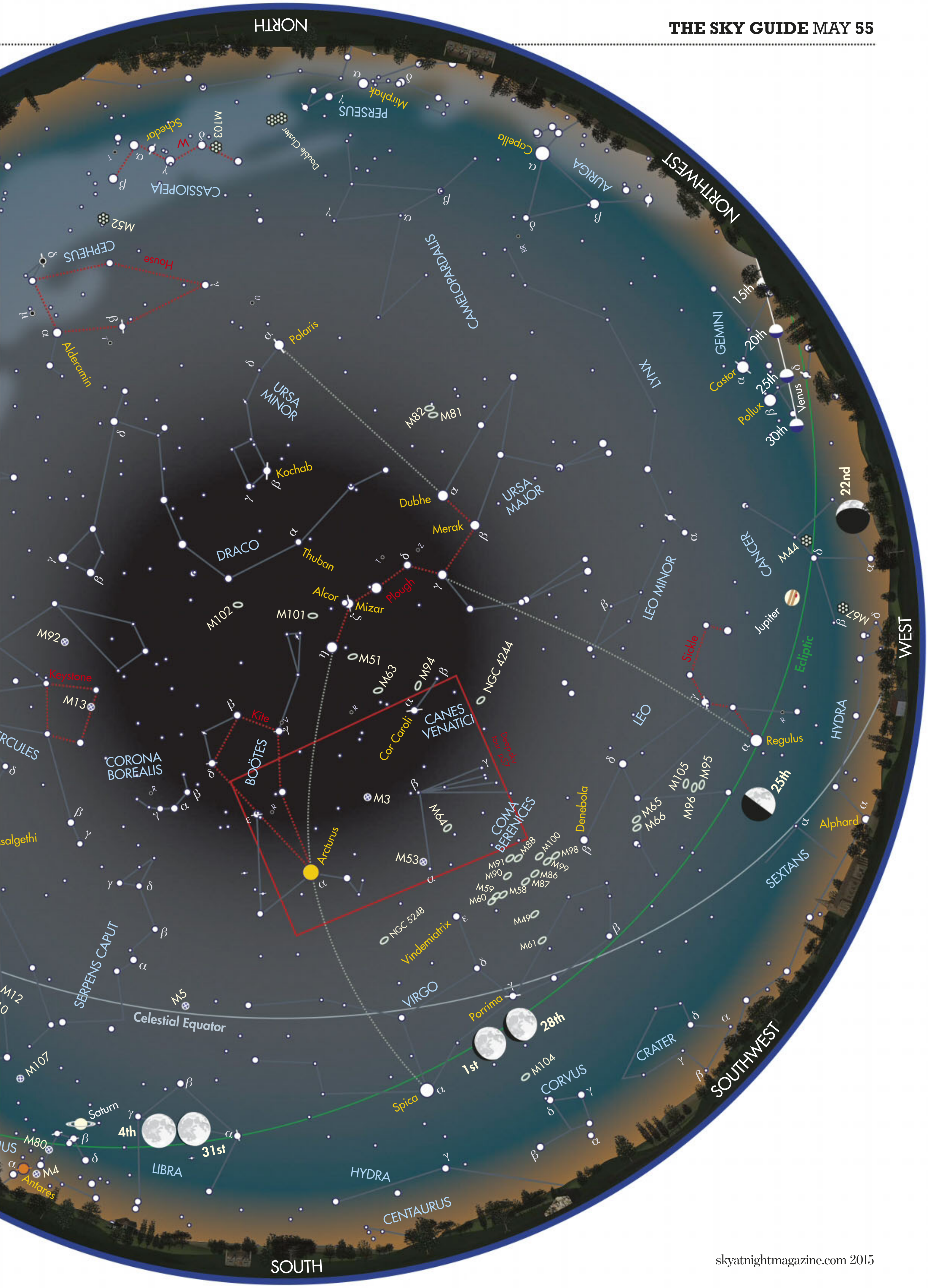
MOONRISE TIMES

1 May 2015, 17:49 BST
5 May 2015, 22:11 BST
9 May 2015, 00:53 BST
13 May 2015, 03:09 BST
17 May 2015, 05:05 BST
21 May 2015, 08:12 BST
25 May 2015, 12:24 BST
29 May 2015, 16:41 BST

*Times correct for the centre of the UK



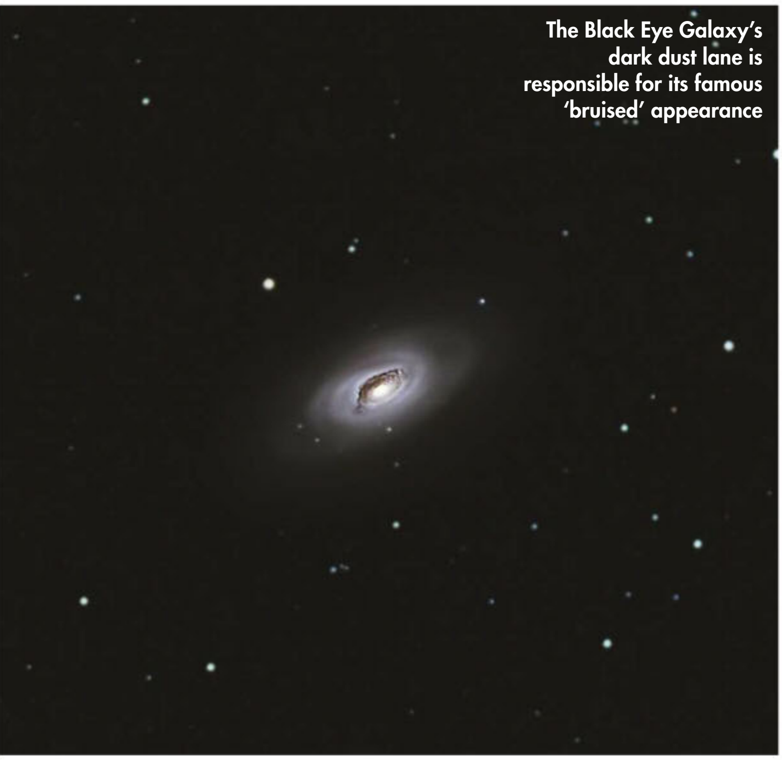



NORTH
NORTHWEST
WEST
SOUTHWEST
SOUTH
PERSEUS
Mirphak
Double Cluster
CASSIOPEIA
Schedar
W
M103
M52
CEPHEUS
House
Alderamin
Capella
AURIGA
CAMELOPARDALIS
Polaris
URSA MINOR
Kochab
GEMINI
Castor
Pollux
Venus
15th
20th
25th
30th
LYNX
M82
M81
URSA MAJOR
Dubhe
Merak
DRACO
Thuban
Alcor
Mizar
Plough
M102
M101
M92
22nd
CANCER
M44
LEO MINOR
Jupiter
M67
Sickle
Ecliptic
M51
M63
M94
NGC 4244
Keystone
M13
HERCULES
Kite
CANES VENATICI
Cor Caroli
CORONA BOREALIS
BOÖTES
LEO
Regulus
HYDRA
M3
M64
COMA BERENICES
Denebola
M65
M66
M105
M95
M96
25th
Alphard
Rasalgethi
Arcturus
M53
M100
M98
M99
M88
M91
M90
M86
M87
M59
M58
M60
SEXTANS
NGC 5248
Vindemiatrix
M49
M61
SERPENS CAPUT
M12
M10
M5
VIRGO
Celestial Equator
Porrima
28th
1st
M104
CRATER
CORVUS
M107
Spica
Saturn
4th
31st
M80
M4
Antares
LIBRA
HYDRA
CENTAURUS

Deep-sky tour

Explore the boundary region between the Herdsman and Hair of Queen Berenice

☑ Tick the box when you've seen each one



The Black Eye Galaxy's dark dust lane is responsible for its famous 'bruised' appearance

1 NGC 5466

This month's objects are all in the region where Boötes meets Coma Berenices. Our first target is a rather loose example of a globular cluster – mag. +9.0 NGC 5466. It can be found three-fifths of the way along a line from mag. +4.2 Beta (β) Comae Berenices to mag. +2.3 Izar (Epsilon (ε) Boötis); look slightly north of this point to find it. A small scope shows a 5-arcminute smudge, while a 10-inch instrument at 150x magnification or higher resolves about 20 of the main cluster stars. Larger scopes don't fare much better, the cluster appearing as an uneven mottled glow rather than having the dramatic central condensation normally associated with this type of object. ☐ **SEEN IT**

2 M3

If NGC 5466 left you wondering what all the fuss is about globulars, M3 will leave you in no doubt. This is one of the showpiece globulars visible from the northern hemisphere, but is often overlooked because it is in a region of sky that can be tricky to navigate. Imagine another line, this time from mag. +2.9 Cor Caroli (Alpha (α) Canum Venaticorum) to mag. +0.2 Arcturus (Alpha (α) Boötis) and look three-fifths of the way along it. Mag. +5.9 M3 is easy to spot in a small scope. A 6-inch instrument at 200x magnification will resolve many cluster stars. The 10x8-arcminute core has a definite flattened appearance to it, with strings of stars spreading out it. This is a lovely object that really rewards patient viewing. ☐ **SEEN IT**

3 M53

Our next target sits about 1° northeast of mag. +4.3 Diadem (Alpha (α) Comae Berenices). M53 is a mag. +7.5 globular cluster, smaller and dimmer than M3. A 6-inch scope at 200x magnification starts to resolve the core, revealing a grainy appearance that comes and goes on the edge of vision. A 10-inch scope shows upward of 100 individual stars. Look closely and the 1.5-arcminute brighter portion of the core has a definite triangular appearance to it. It's interesting to compare and contrast the enormous difference in appearance between M53 and M3. ☐ **SEEN IT**

4 NGC 5053

Our fourth and final globular this month is NGC 5053, which is 1° east-southeast of M53. Once again we have a contrast of views, here between the relatively bright and easy to see M53 and the much dimmer NGC 5053. Where M53 has a bright central core, NGC 5053's core is faint and appears virtually flat. Its surface brightness is low and this makes the whole cluster less distinctive; there is also a distracting mag. +9.7 star on its southeast border. NGC 5053 is so loose and uncondensed that it appears more akin to an open cluster than a globular. A 12-inch scope resolves a few tens of stars across the 'core'. ☐ **SEEN IT**

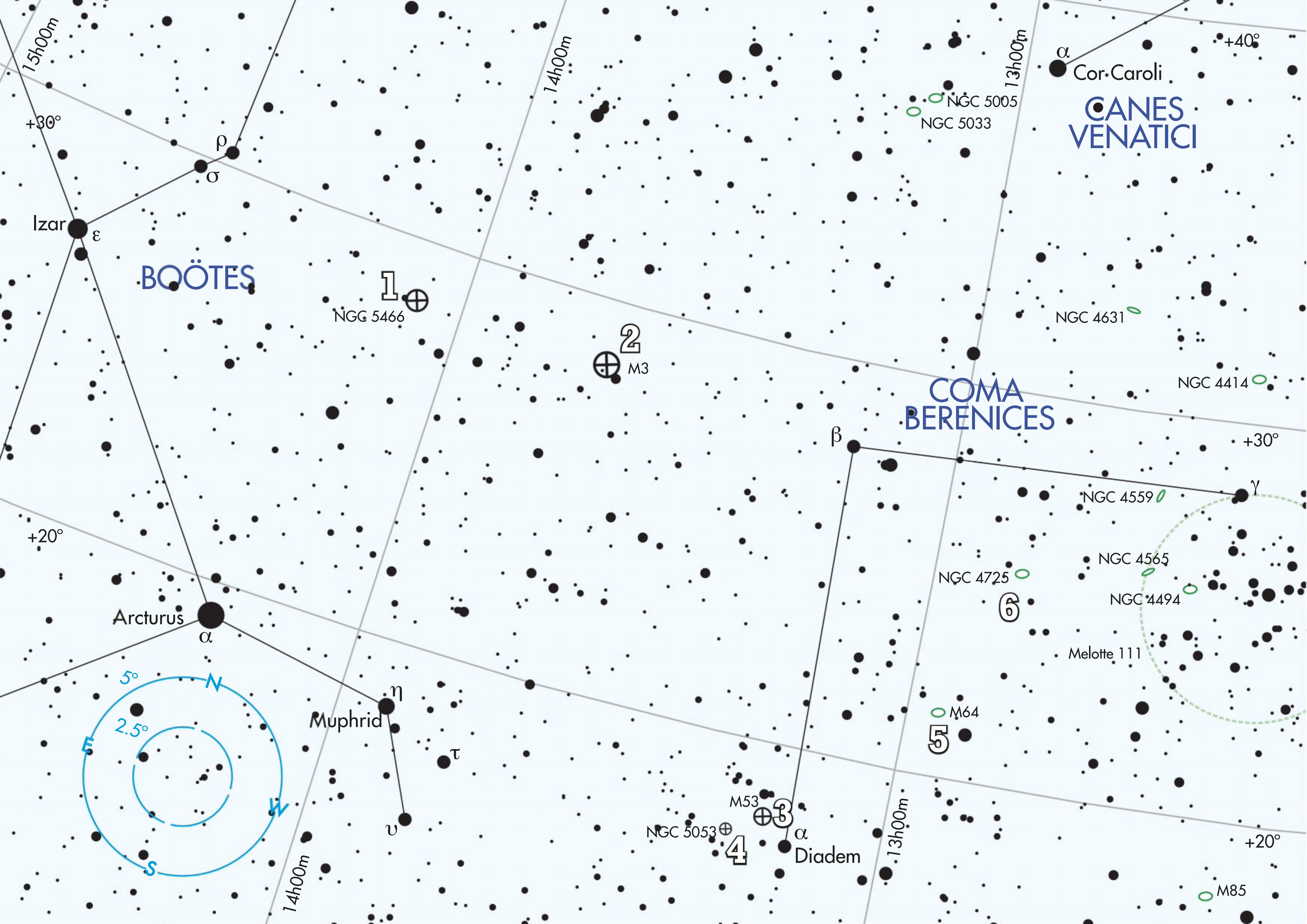
5 THE BLACK EYE GALAXY

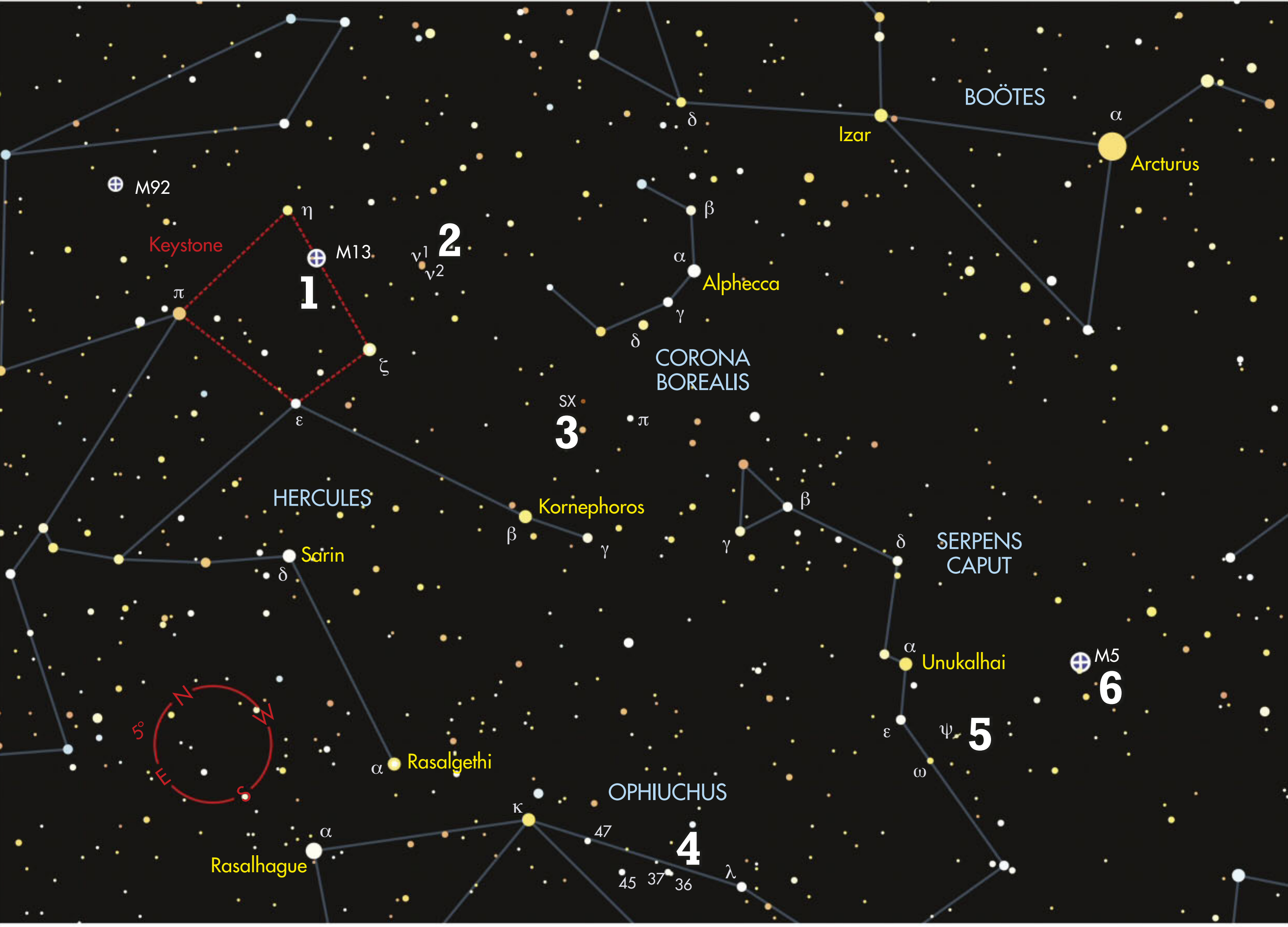
Up next is lovely spiral galaxy M64 in Coma Berenices. This object lies approximately three-fifths of the way along a line drawn from mag. +4.3 Gamma (γ) Comae Berenices to Diadem. At mag. +8.5, this is a fairly bright galaxy and an easy target for a small scope, which shows it as an elongated patch measuring 6x3 arcminutes. A 6-inch scope at 150x magnification will reveal the main characteristic of M64, a dark dust lane that curves around one side of its core. Larger instruments bring the dark region into better definition and show that it covers about half of the core. This feature gives the galaxy its unofficial name, the Black Eye Galaxy. ☐ **SEEN IT**

6 NGC 4725

We head approximately 4° north and slightly west of M64 for our last target, mag. +9.2 galaxy NGC 4725. Although fainter than M64, NGC 4725 is also fairly large, measuring 7x5 arcminutes. A 10-inch scope shows it to have an almost star-like core, with the remaining bulk of the galaxy appearing quite regular and without noticeable condensation. It is classed as an intermediate barred spiral galaxy and a type of object known as a Seyfert galaxy, characterised by having an active and very luminous central core. In the case of NGC 4725, it is likely that there's a supermassive black hole at the centre of the galaxy. ☐ **SEEN IT**

CHART: PETE LAWRENCE; PHOTO: ISTOCK


CANES VENATICI
Cor Caroli
α
+40°
13h00m
NGC 5005
NGC 5033
NGC 4631
NGC 4414
14h00m
15h00m
+30°
BOÖTES
Izar
ε
ρ
σ
1
NGC 5466
2
M3
COMA BERENICES
β
γ
+30°
NGC 4559
NGC 4565
NGC 4494
NGC 4725
6
Melotte 111
M64
5
M85
+20°
Arcturus
α
Muphrid
η
τ
υ
M53
3
NGC 5053
4
α
Diadem
13h00m
14h00m
+20°
5°
2.5°
N
E
S
W



Binocular tour

The Keystone asterism serves as a launch point for a sextet of binocular wonders

With
Stephen Tonkin

☑ Tick the box when you've seen each one

1 M13

10x50 We begin with a globular cluster located one-third of the way down the western side of Hercules's Keystone asterism. Even with small binoculars, this mag. +5.8 globular can be seen in urban skies, looking very much like a comet's coma – which may be why it appears in Charles Messier's list of objects for comet hunters to avoid. In 10×50s you should notice that it brightens towards the centre, exactly like a comet does. This ball of about 400,000 stars is 25,100 lightyears away and has a diameter of 168 lightyears. ☐ **SEEN IT**

2 NU CORONAE BOREALIS

10x50 We continue with a double star, Nu (ν) Coronae Borealis. It is easy to split in small binoculars, where it appears as a wide pair of distinctly deep yellow stars (6 arcminutes apart) shining at mag. +5.2 and +5.4 respectively. Being an optical double, the stars are not gravitationally connected, but are a line-of-sight pairing. The more northerly star, ν1, is 555 lightyears away, which is 10 lightyears further than ν2. However, they are very similar; each of them is about 2.5 solar masses, but the brighter one is about 750 million years older, making it larger and more luminous. ☐ **SEEN IT**

3 SX HERCULIS

15x70 SX Herculis is the most challenging object in this month's tour. To find it, start at mag. +4.8 Pi (π) Serpentis and navigate 2.5° north, where you will find a 7th-magnitude star. From there look 1° east-southeast, where SX is located. It is a variable star that is predicted to be near minimum (mag. +9.0-ish) as May begins. If you observe it every week or so, you should notice it brighten by at least a magnitude over the next couple of months. The star has a period of 103 days. ☐ **SEEN IT**

4 36/37 HERCULIS

10x50 You can hop to our next target, 36/37 Herculis, by starting at mag. +3.2 Kappa (κ) Ophiuchi and stopping at the 5th-magnitude stars 47 and 45 Herculis along the way. Mag. +5.8 37 Herculis is the brighter of the pair, with fainter 36 Herculis (mag. +6.9) 70 arcseconds to the southwest. Both are brilliant white and approximately 300 lightyears away. They are moving together through the Galaxy on a path that will bring them to about 45 lightyears away – and about 4 magnitudes brighter – in just over three million years time. ☐ **SEEN IT**

5 PSI SERPENTIS

10x50 Mag. +5.9 Psi (ψ) Serpentis is quite easy to locate as it is due south of mag. +2.6 Unukalhai (Alpha (α) Serpentis) and west of mag. +5.2 Omega (ω) Serpentis. Initially you should see a widely separated (5 arcminutes) pair of yellowish stars, the fainter one shining at mag +7.2. Look more carefully and you may be able to make out a third, mag. +9.0 member of the group midway between them. The stars are 48, 523 and 850 lightyears away respectively, but these distances mask their true luminosities: the one we see as brightest is about 20 times fainter than the others. ☐ **SEEN IT**

6 M5

15x70 Our final target is another magnificent globular cluster, M5. It sits adjacent to mag. +5.0 star 5 Serpentis, itself 8° due west of Omega Serpentis, and is just visible to the naked eye if the sky is dark and transparent. M5 is comparable to M13 in extent and number of stars. Both are thought to be nearly 12 billion years old, suggesting that they formed very soon after our Galaxy did. ☐ **SEEN IT**

CHARTS AND PICTURES: PETE LAWRENCE

Moonwatch

Newton

THE MOON'S LIBRATION favours the south polar region this month. A good view of this complex, highly cratered area is given at the start of May and again towards the end. Our target crater is 80km-wide Newton, which is close to the pole. This means that at some times libration makes it hard to view Newton properly, while at others it can be seen clearly. At 76.5° south, Newton always appears to us foreshortened into an ellipse and this can make locating it that little bit harder.

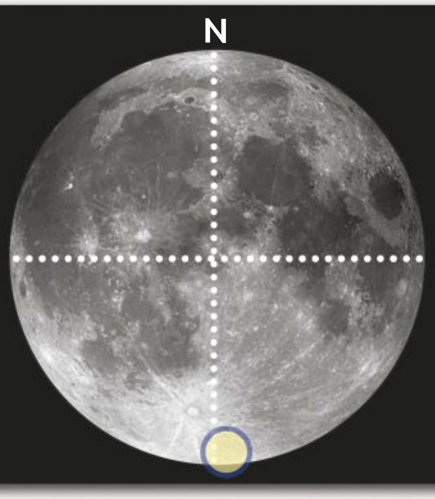
Newton lies 530km south of the giant crater Clavius (225km), a very recognisable feature. Although 530km may sound a long way, the foreshortening effect means that the apparent distance doesn't look so huge.

Immediately south of Clavius is Blancanus (106km), a well-defined crater with a flat floor. Keep going south to locate Klaproth (119km), which also has a flat floor. Overlapping the southern edge of Klaproth is Casatus (111km), the flat floor of which is interrupted by Casatus C (17km).

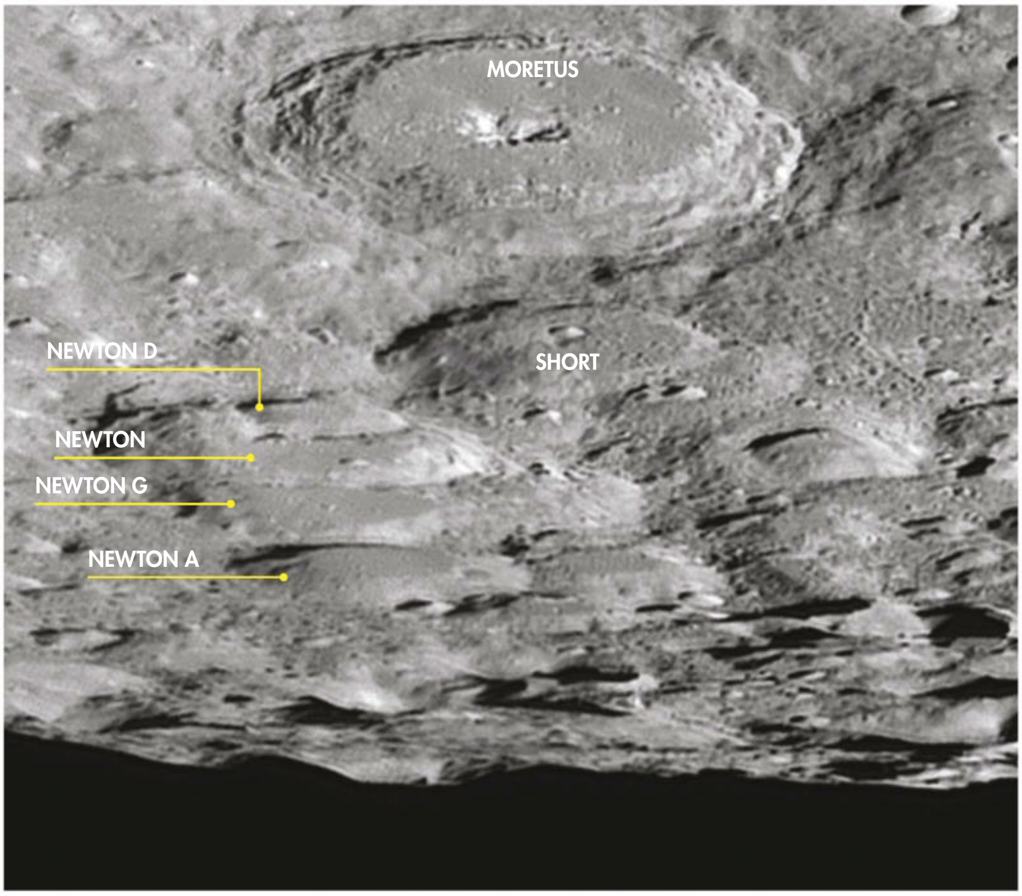
Newton lies 157km east and slightly south of Casatus. Another key locator is crater Moretus (114km); distinctive because of its impressive central mountain peak. Immediately south of Moretus lies crater Short (50km); Newton is immediately southwest of this position. The crater is named after the eminent physicist and mathematician Sir Isaac, and is regarded as the deepest crater on the Earth-facing side of the Moon. Its floor is over 6km below the rim.

STATISTICS

TYPE: Crater
SIZE: 80x80km
AGE: 3.9–4.6 billion years
LOCATION: Latitude 76.5°S, longitude 17.4°W
BEST TIME TO OBSERVE: One day after first quarter or last quarter (4-11 May or 28-31 May)
MINIMUM EQUIPMENT: 2-inch refractor



"This may be the deepest crater on the near side – its floor is 6km below the rim"



Foreshortening makes the walls of Newton and its overlapping craters appear close together

Once you've located Newton, the work really begins because this is a complicated crater to decode. The issue here it that there are three overlapping craters. If Newton was towards the centre of the Moon's disc this wouldn't be hard to work out, but under this much foreshortening it's a lot trickier.

Newton sits at the centre of the trio. A large part of its northern half is covered by the Newton D (37km). Newton itself overlaps Newton G (67km). The distances from the southern lip of G to the southern edge of Newton, then to the southern edge of D and onto the northern edge of D, are all roughly similar at around 40km.

Seen at the oblique angle presented to us here on Earth, these distances shrink to make all the walls look quite close together and it's this which causes the confusion. The situation isn't helped by the fact that there's also another unnamed old crater beneath Newton and Newton G. The remains of this feature can be seen as rough terrain immediately south of Short and due east of Newton G. Newton A (64km) can be seen prominently to the south of Newton G. As this isn't overlapped by anything else, it's surprisingly easy to pick out under favourable libration despite having a latitude of 80.1° south.

Astrophotography

The Ringed Planet and its moons

RECOMMENDED EQUIPMENT

DSLR or high frame rate camera and a telescope. If you opt for a monochrome high frame rate camera, consider a filter wheel and RGB filters

Persevere with imaging Saturn at low altitude and you'll be rewarded with a great view of its rings

BEAUTIFUL SATURN IS now in our skies, but from the UK the planet is altitude challenged. This means that its light is going to be passing through a thick and rather turbulent layer of atmosphere, which has a tendency to blur any fine detail visible on the planet or its rings.

This is a real shame and a good reason to consider taking a holiday somewhere with a more southerly latitude. The planet's rings are tilted at a good angle to Earth at present. If that's not an option you can still take great photos of this marvellous planet, but you have to take some steps to reduce the impact of the unsteady low-altitude atmosphere. If the conditions are right, it is possible to get a steady view even at such a low altitude so it's always worth ramping your telescope's magnification up to see what detail you can capture.

If the wobbles take over, then the best strategy is to reduce the image scale. This will give you a smaller image of Saturn but the wobbles that affect fine detail will also be reduced in size. So the overall effect is a reasonably crisp, albeit small, view of the planet. The smallest natural image scale your scope can provide occurs by using prime focus. This is where the camera simply replaces the eyepiece. For many instruments this will provide a sufficiently low-power view to hide any poor seeing that's present. A low-power view also gives you an opportunity to image the planet's moons too. Here, it might be necessary to employ a trick or two to get the main ones in, but this depends on your field of view. Alternatively, it's possible to widen the field further by using a focal reducer if you have one.

Basically, what you're trying to do here is to capture a beauty shot of Saturn, exposed properly for the planet. To record the moons, you'll need to increase camera sensitivity and, in the process, overexpose the planet's disc. It is important to get a balance here because a misty sky or slightly dewed optics can make Saturn's light spread over a large area. A more sensitive or longer exposure may then cause the planet's influence to spread over too large an area on the final image, so engulfing some of the inner moons. However, if you don't set the exposure correctly, the moons themselves will not show at all.

Another thing that you need to remember is that the moons themselves are not static entities, but move as they orbit the planet. The inner ones actually move quite rapidly. So taking images that are staggered by a minute or two over the course of half an hour to an hour will produce a sequence which can be animated together to produce a Saturnian moon orbit movie.

For a further challenge, it's also good fun to try and capture some of the planet's less obvious moons such as Iapetus, Hyperion and Phoebe; note that Phoebe orbits in the opposite direction to the others. These have larger orbits than the most obvious bright moons and so may take a bit of tracking down.

However you approach it, despite its low UK altitude Saturn still has some amazing sights that can be photographed. And you never know, there's also the chance that the wobbles may abate for a time, allowing a clear magnified view of this amazing world.

KEY TECHNIQUE

DEALING WITH MURK

Low-altitude objects can be tricky to image well because their light has to pass through a thicker layer of atmosphere. This introduces distortion and leads to more absorption and scattering. A prismatic effect also kicks in, misaligning component colours to produce colour fringing. Faced with such hurdles the sensible thing to do is to use a strategy that reduces the size of these effects. This is achieved by relaxing image scale. Here, we're doing just that and making use of the wider field of view offered by such an approach.

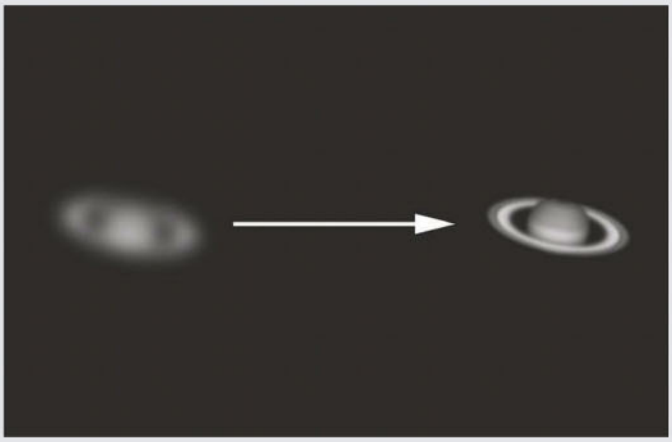
Send your image to: hotshots@skyatnightmagazine.com

ALL PICTURES: PETE LAWRENCE

STEP-BY-STEP GUIDE

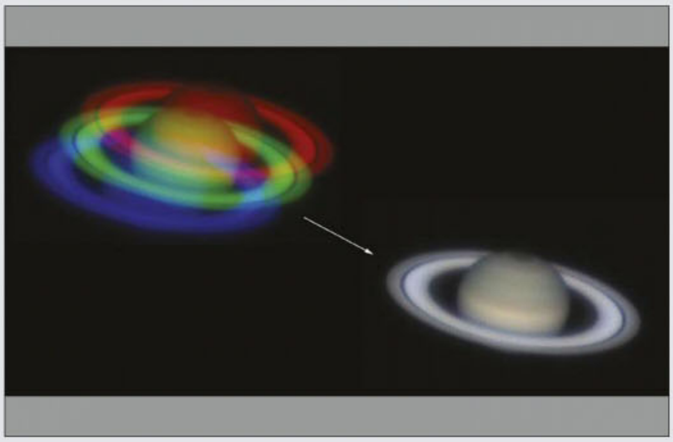
STEP 1 An RGB filtered high frame rate mono camera will produce the best results. A colour model or an interchangeable lens stills camera can also be used, but the results will be less sharp. An adaptor must be fitted to allow the camera to slot directly into the eyepiece holder of your telescope. For RGB filtering, a filter wheel is recommended.

STEP 2 Line the scope up with Saturn visually, focus roughly, then replace the eyepiece with the camera. If using an RGB filter wheel, select the red or green for the brightest image. Carefully adjust the focus to create as sharp an image of the planet as possible. Adjust the gain and exposure to brighten the image if necessary to make focusing easier.

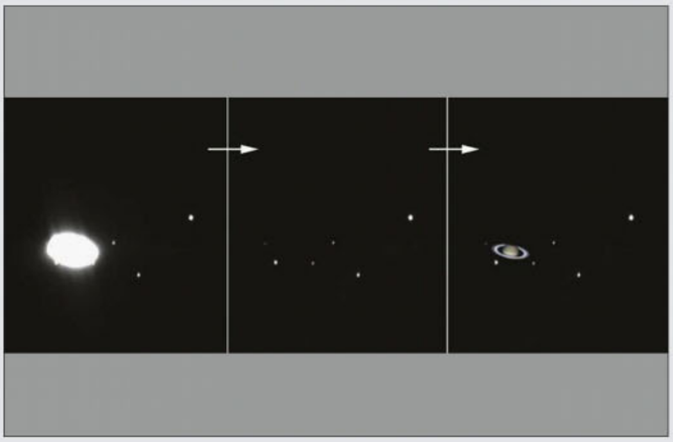


STEP 3 Adjust exposure and gain for a strong signal. If your control software has a level meter, obtain a saturation of 80-90 per cent. Keep the gain to 75 per cent or lower to reduce noise. Take an exposure. For high frame rate cameras, 1,500-3,000 frames should be fine. For RGB filter setups, make one capture for each filter, refocusing in-between.

STEP 4 Once you've captured the planet, increase the exposure until the moons begin to appear. The planet will overexpose as you do this, the level meter becoming full. Make sure that the overexposed planet doesn't cover the inner moons. If using RGB filters, switch to a clear (luminance) or red one for this step. Take a 30-second capture.



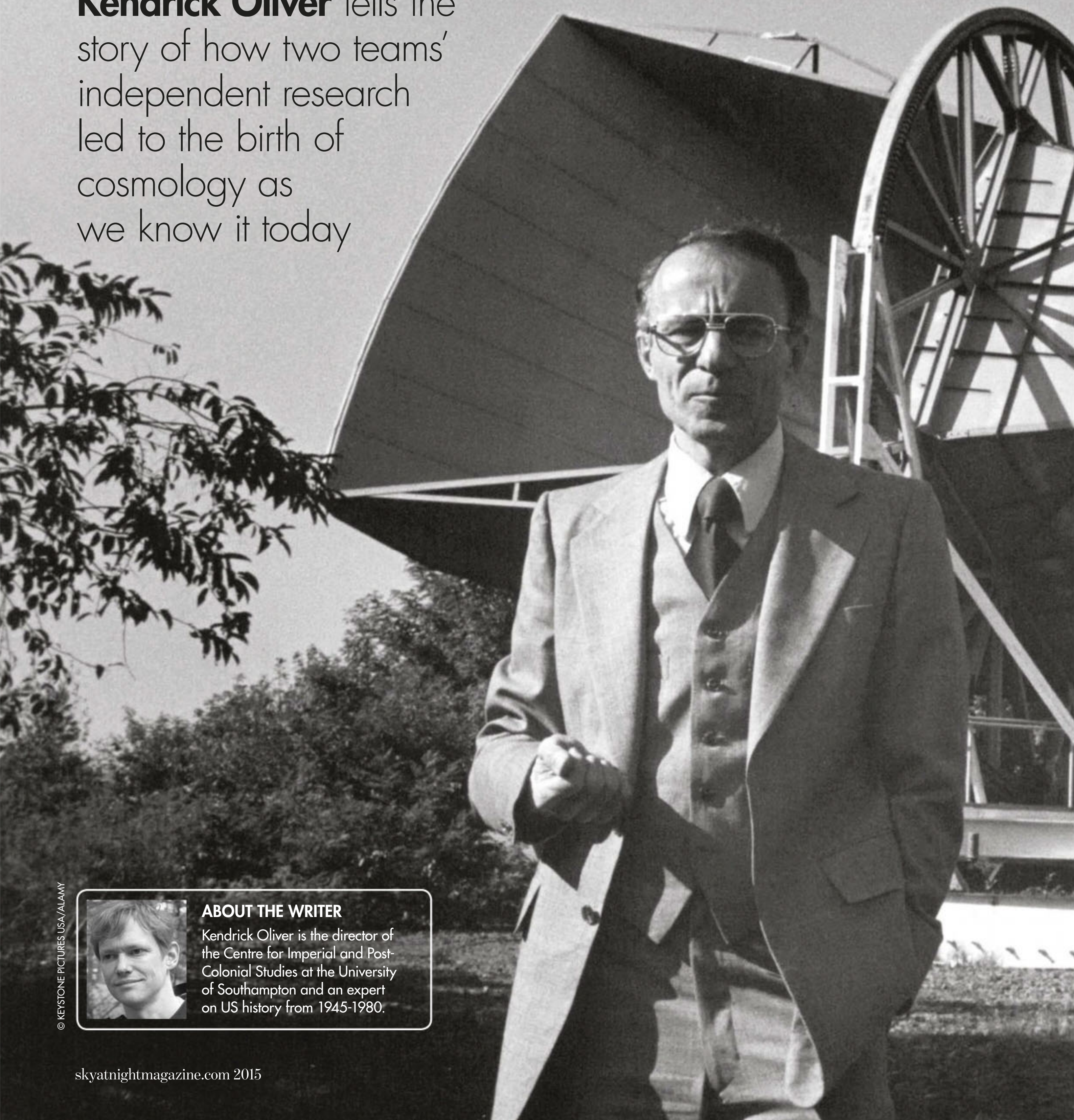
STEP 5 Use a stacking program such as the freeware RegiStax to process the planet captures into a final result. For RGB-filtered images, combine the components into a single image using RegiStax or a graphics editor that allows you to load each filtered result into its respective colour channel. Then stack the moon sequence into a still image.



STEP 6 Open your planet and moon shots in a layer-based editor, making the moons the upper layer. In the moons image, create a selection around the overexposed planet and, using the clone tool, clone in background from elsewhere. Set the upper layer's blend mode to Lighten and the planet and moon images will appear together as a single shot.

DISCOVERING creation

Kendrick Oliver tells the story of how two teams' independent research led to the birth of cosmology as we know it today



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ABOUT THE WRITER

Kendrick Oliver is the director of the Centre for Imperial and Post-Colonial Studies at the University of Southampton and an expert on US history from 1945-1980.

In mid-May 1965, Walter Sullivan, the science editor for the *New York Times*, contacted the editorial office of the *Astrophysical Journal* – the journal astronomers and astrophysicists use to report their most significant theories and discoveries. Sullivan had heard that the journal's editors were rushing an article by American astronomer Allan Sandage into print. The article was said to identify an entirely new class of 'radio-quiet' quasars. In the course of his conversation with an editorial assistant, Sullivan learned about two other submissions that had just been received by the journal.

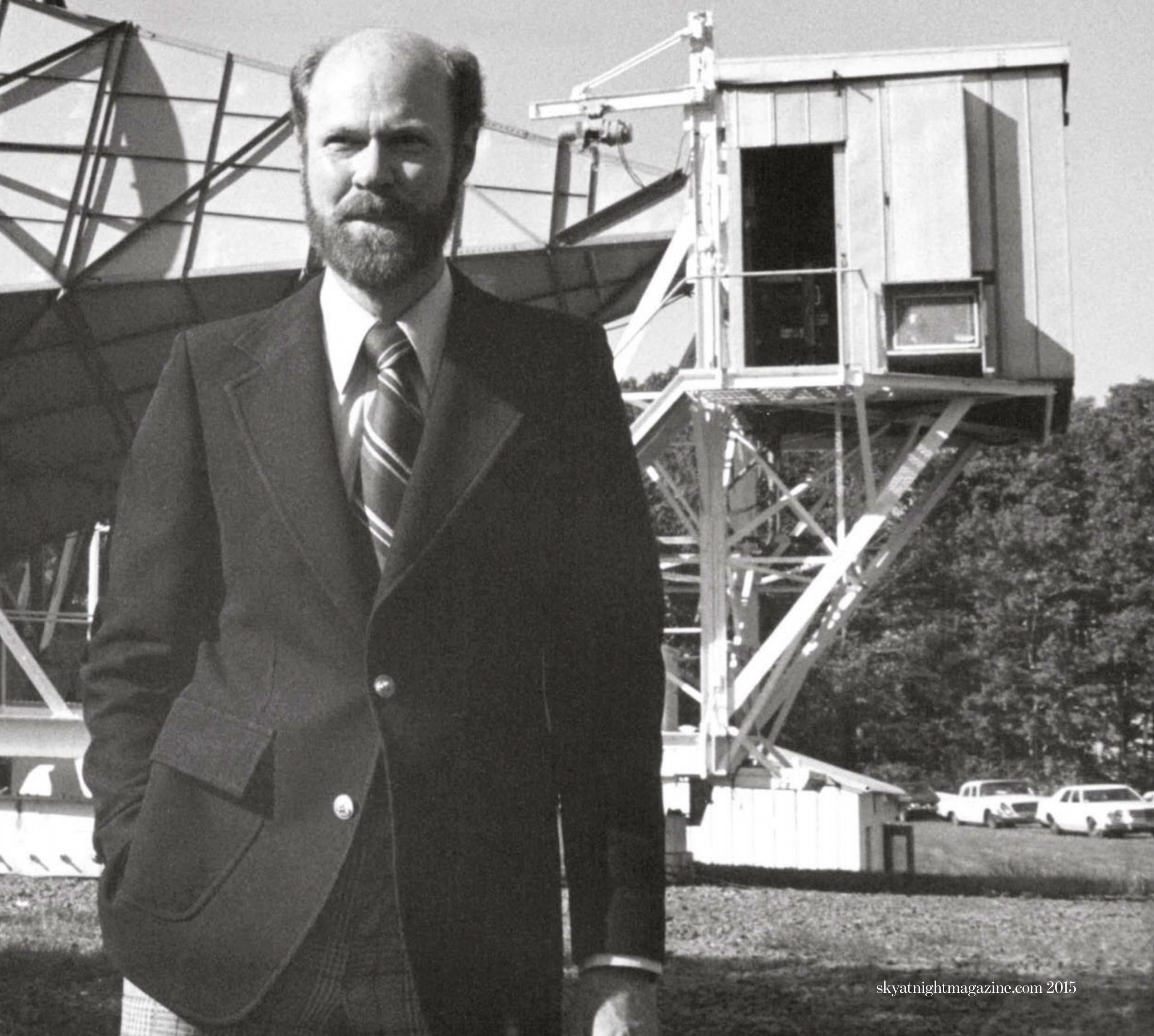
The first was one written by a couple of young radio astronomers working for Bell Telephone Laboratories (Bell Labs) at Crawford Hill, New Jersey. It reported an excess temperature measurement of 3.5K (–269.65°C) in the sky no matter where they pointed their antenna.

The second, submitted by four physicists from Princeton University, offered an explanation for the readings the pair from Bell Labs had recorded.

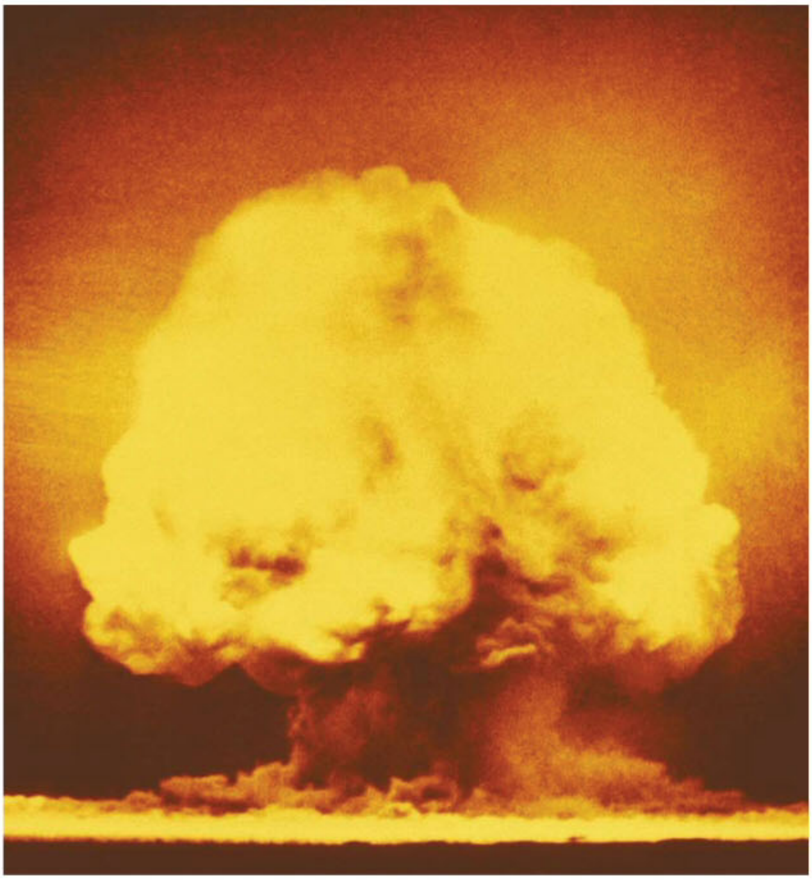
The Princeton University article suggested that if the Universe had been formed either in the 'bounce' from a prior collapsed Universe or in a singular 'big bang' it would have been exceedingly hot in the early stages of its existence. But, more importantly, it suggested that some of that heat, although cooled into microwave radiation, would still pervade the modern-day cosmos, and could provide us with clues to its distant origins.

Background to the Big Bang

After Sullivan heard about the Bell Labs and Princeton University articles, Sandage and his quasars no longer seemed quite so significant. On 21 May 1965, the *New York Times* published Sullivan's scoop on its front page under the ▸



▼ Arno Penzias (left) and Robert Wilson with the Bell Laboratories' Horn receiver with which they unknowingly detected the cosmic microwave background



► headline: 'Signals Imply a "Big Bang" Universe'. Only a few years before, the field of scientific cosmology – the study of the large-scale structure of the Universe – had not seemed a promising source of front-page headlines. But indications that the footprints of the theorised Big Bang might be detectable were changing that.

In the late 1940s, physicists Ralph Alpher and Robert Herman used data from the Manhattan Project to show that the nuclear chain reactions that would occur in the dense and hot conditions of an exploded early Universe would produce hydrogen and helium in the same quantities observable in the modern-day cosmos. As hydrogen and helium account for almost all of the ordinary matter in the Universe, this represented significant circumstantial evidence in support of the Big Bang theory. Conclusive proof remained elusive, however.

Alpher and Herman had also theorised that the residual radiation from the Big Bang would have cooled to about 5K (–268.15°C), but they could find no one in those early days of radio astronomy willing to look for it. Meanwhile, other authorities, most famously British astronomer Fred Hoyle, rejected the Big Bang hypothesis entirely, proposing that the Universe had always existed in a 'steady state'.

The stand-off between the Steady State and Big Bang theories appeared intractable. And, as the physicist Steven Weinberg recalled, complicating the situation further was the perception that in the 1950s, "The study of the early Universe was widely regarded as not the sort of thing to which a respectable scientist would devote his time."

▲ Data from the Manhattan Project provided clues as to the composition of the early Universe

▼ The implications of Oscillating Universe theory (inset) fascinated Robert Dicke, who set up a team to detect the background heat signature it would leave

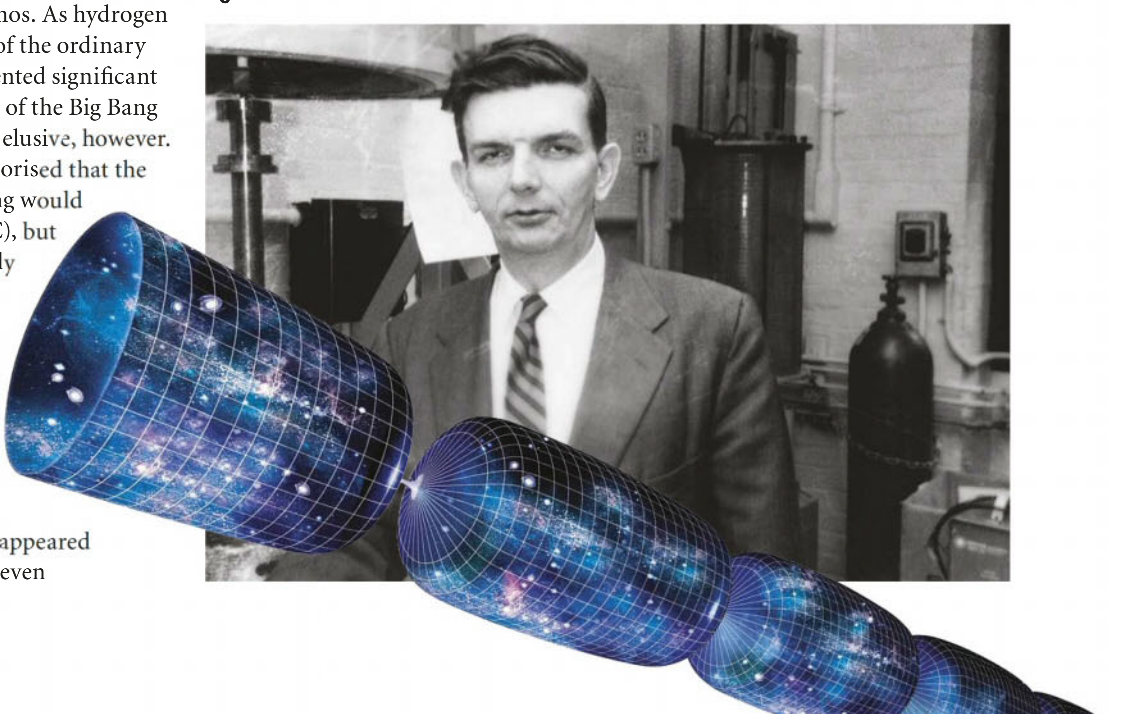
One of the few places in the US where cosmology was taken seriously was Princeton University. There, the physicist Robert Dicke – always suspicious of scientific orthodoxies – had developed an interest in testing Einstein's cosmological models. He was also attracted to the idea of an oscillating Universe, a theory which required the existence of extreme heat at the moment of 'bounce' to decompose the old Universe and allow the formation of the new.

In the summer of 1964, he persuaded three of his postdoctoral assistants to explore this theory. James Peebles would seek to calculate the likely temperature of the residual radiation, while David Wilkinson and Peter Roll would build equipment to try and detect it. Peebles had the easier task – though he did not initially consult their work, Alpher and Herman had already proved such calculations were possible a generation before.

Calibration toil

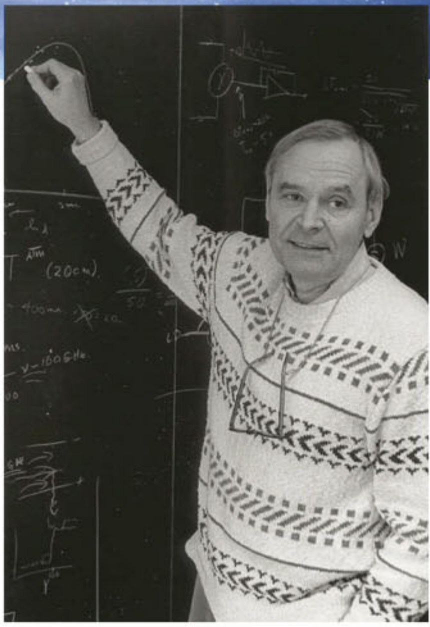
By February 1965, Peebles was already giving lectures suggesting a background temperature of 10K (–263.15°C). Wilkinson and Roll, meanwhile, were struggling. Neither of them had any background in radio astronomy. Although their supervisor Dicke had invented a radiometer earlier in his career that was still used by radio astronomers, he'd not kept abreast of technological developments in the field. Wilkinson and Roll read what they could about antenna design, worked out a specification that would meet their purposes and handed it to their laboratory's workshop to build. They then began scavenging suitable electronic equipment from surplus military hardware.

The biggest challenge was creating a reference source – a 'cold load' – to calibrate their antenna



LOS ALAMOS NATIONAL LABORATORY/SCIENCE PHOTO LIBRARY, EMILIO SEGRE VISUAL ARCHIVES/AMERICAN INSTITUTE OF PHYSICS/ SCIENCE PHOTO LIBRARY, CLAUS LUNAU/SCIENCE PHOTO LIBRARY, PRINCETON UNIVERSITY, NASA X 2 for precise low-temperature observations. If the background radiation existed it would be only a few degrees warmer than absolute zero (–273°C) and Dicke's team needed to be sure that their measurements included no heat from within the antenna system. Liquid helium, extracted from natural gas and with a boiling point of 4K (–269.15°C), had recently become available for use in such reference sources, but integrating this expensive, unstable substance into the antenna involved much trial and error. Wilkinson and Roll continued to test and refine their system through the early months of 1965, with a view to starting observations in the summer.

At the Bell Labs Radio Research Laboratory at Crawford Hill, New Jersey, only 30km away from where Wilkinson and Roll were toiling over their equipment, there already existed an antenna well-suited to the observations they wanted to make. At 15m long, with a 6x6m aperture and a horn-shaped shield to isolate its receiver from noise sources on the ground, the antenna had been constructed to receive the extremely faint radio signals bounced off the Echo 1 satellite, a large metallic balloon launched into space in 1960 as a joint Bell Labs-NASA experiment in satellite communications.



▲ David Wilkinson (above) worked with Peter Roll to build an antenna to detect the cosmic microwave background

The Crawford Hill Horn Antenna had already been used in 1962 to receive telephone and television signals from the Telstar satellite. During the course of calibrating the antenna for both Echo and Telstar, Bell Labs' engineers had found that they could not account for all of the temperature measured by their system. They attributed the excess to error margins in their measurements and then moved on. The engineers' principal concern, after all, was communication, not the cosmos. In 1964, two Soviet physicists suggested that the Bell Labs results might include the radiation leftover from the Big Bang, but their article went largely unnoticed in the West.

Repurposed technology

Meanwhile, as Bell Labs' experiments in satellite communications ended, the antenna had passed into the hands of two radio astronomers, Arno Penzias and Robert Wilson, who began adapting it for observational use. They already possessed ▸

WHAT IS THE COSMIC MICROWAVE BACKGROUND?

There are many localised sources of radiation in the Universe, including quasars, black holes, supernova remnants, ordinary stars like our Sun and individual planets. On Earth, radiation is emitted from the ground in the form of radon and produced by man-made sources such as medical X-rays or nuclear power stations. The cosmic microwave background (CMB), however, pervades the entire Universe and has an almost uniform (isotropic) character. It is pervasive because it originated with the Universe itself.

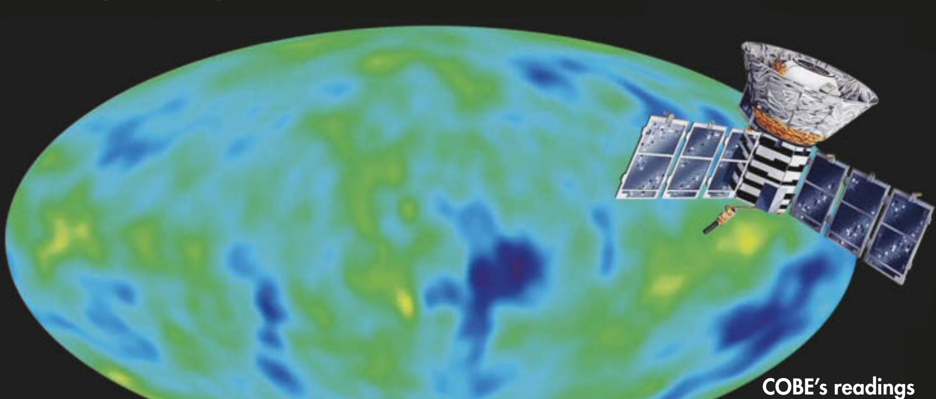
The Universe was extremely hot and dense in the first few minutes after the Big Bang, then it relaxed and cooled to an opaque plasma comprised of photons, protons, electrons and hydrogen and helium nuclei. When the Universe was around 380,000 years old, it had cooled sufficiently (to about 3,200K or 2,926°C) for hydrogen and helium atoms to form, converting the plasma into a gas and freeing the photons to move through the Universe, saturating it with light.

In the late 1940s, Ralph Alpher and Robert Herman estimated that, with the continued expansion of the Universe, this light – the cosmic background radiation – would have been stretched to microwave length and cooled to a temperature of around 5°C above absolute zero (which is –273°C). But a highly attuned antenna, capable of making precise measurements at low temperature, would be required to isolate the cosmic background from all other sources of heat – those in the sky, from the ground and in the antenna. It was such an antenna that Penzias and Wilson developed on Crawford Hill.

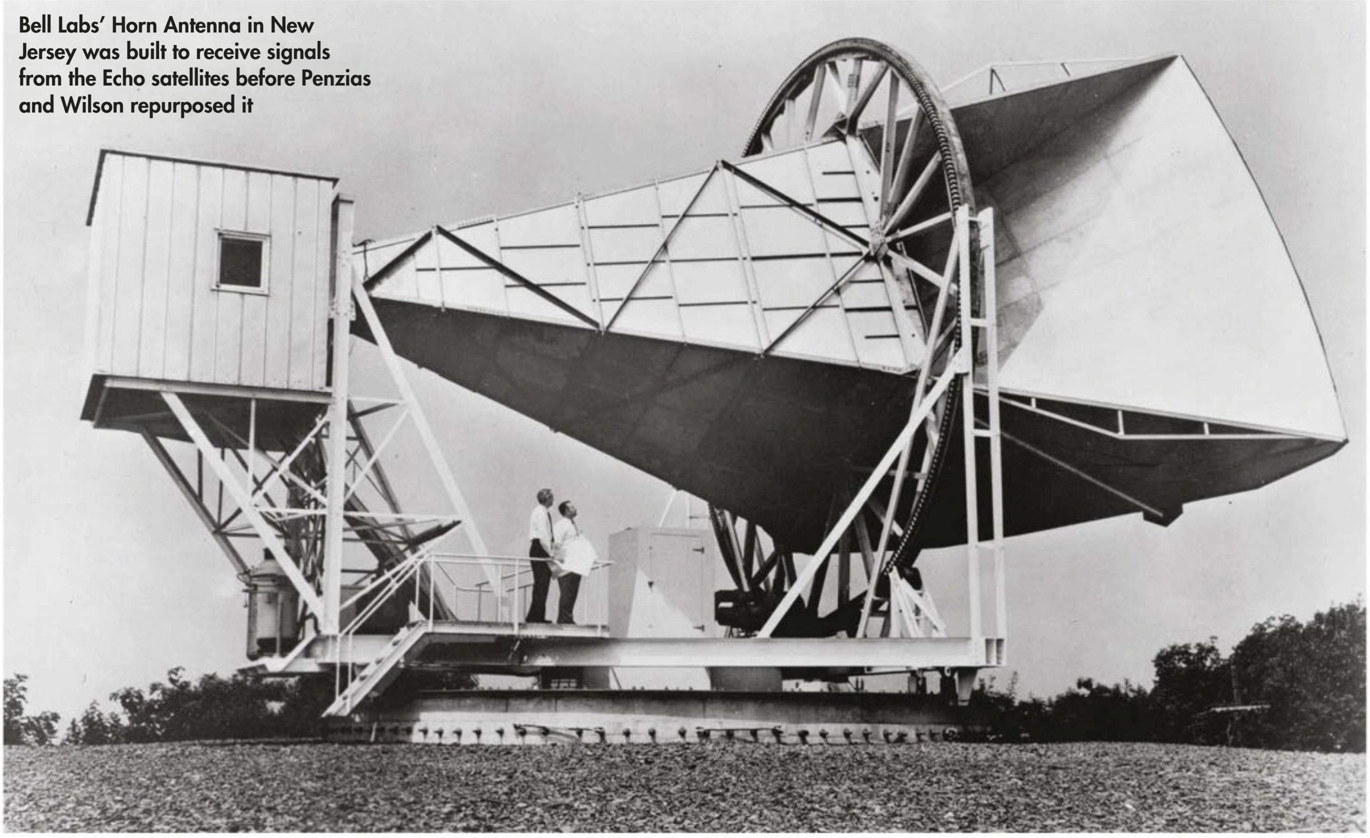
Since the 1960s, there have been two major developments in the theory of the CMB. The first involved an attempt to account for the uniform nature of the radiation; the second, a study of whether tiny variations in the radiation might explain the existence of galaxies.

In the late 1970s, the physicist Alan Guth proposed that the homogeneity of the Universe in its large-scale characteristics, such as the CMB, was caused by an extremely rapid and exponential expansion – 'inflation' – shortly after its birth. Inflation imprinted the uniformity of the early Universe, when it was small enough for its regions to even out their differences onto its subsequent, much expanded structure.

But if the Universe had been completely isotropic in its early life, how did galaxies and stars begin to form? In the 1970s, scientists began to look for evidence that the CMB was not completely homogeneous – specifically, for variations in density that gravitational forces would have eventually pulled into concentrations of gas to eventually form the first galaxies. These variations would be so minuscule that they were difficult to detect through ground-based instruments. In 1992, scientists announced that the Cosmic Background Explorer (COBE) satellite had revealed such variations.



COBE's readings showed the variations in the cosmic microwave background



Bell Labs' Horn Antenna in New Jersey was built to receive signals from the Echo satellites before Penzias and Wilson repurposed it

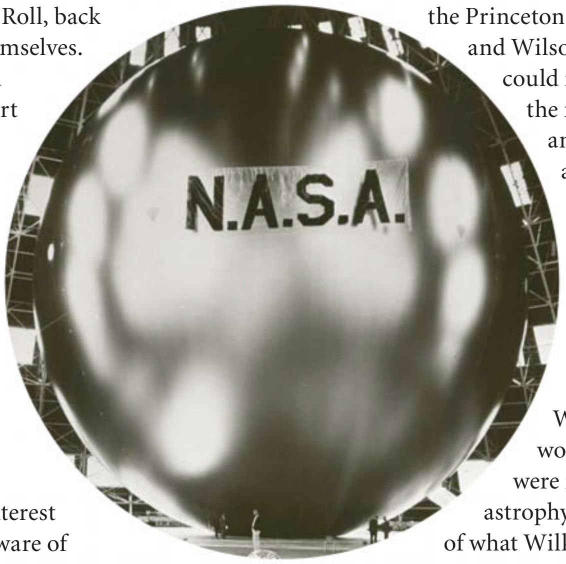
▸ the practical skills that Wilkinson and Roll, back in Princeton, would have to learn for themselves. Penzias knew how to build a helium cold load, while Wilson was adept with the sort of electronics that were key to accurate signal measurements. By May 1964, they were ready to begin observing, aiming first to prove their antenna's sensitivity by pointing it towards the halo of the Milky Way. At the 7cm wavelength, they expected to detect little or no radiation, which would confirm the precision of their readings before they moved on to other regions of the Galaxy.

Picking up heat

Neither Penzias nor Wilson had much interest in cosmology; they were completely unaware of studies that predicted the existence of a microwave background. So they were perplexed when their antenna, searching the empty sky, registered a temperature of about 7K (–266.15°C), two degrees hotter than the cold load and about four degrees hotter than the combined total of the system and atmospheric temperature sources that they knew about. Penzias and Wilson spent much of the rest of the year re-examining their equipment and sweeping the sky, hoping to isolate the source of the excess. But whatever they did and wherever they looked, a stubborn margin of around 3.5K (–269.65°C) continued to crackle through their antenna.

By the end of 1964 the radio astronomers at Bell Labs had the answer to the problem confronting the Princeton physicists, and vice versa. Penzias and Wilson had developed an antenna that could make absolute measurements of even the most faint cosmic radiation; Dicke and his associates had calculated that, assuming the correctness of either the oscillating Universe or the Big Bang theory, an antenna as sensitive as that on Crawford Hill would encounter such a faint radiation everywhere in the sky. But despite their proximity, neither party knew what the other was up to. Penzias and Wilson, as young radio astronomers working for an industrial laboratory, were not connected to the broader astrophysics networks. And although much of what Wilkinson and Roll knew about antenna design had been gathered from articles written by Bell Labs' engineers, they had neglected to visit Crawford Hill. Dicke had been invited to give a lecture at Crawford Hill in late 1964, but due to other commitments he asked for the engagement to be postponed.

It was only in February 1965 that the two groups made contact. Penzias had spoken to Bernard Burke, a radio astronomer at the Massachusetts Institute of Technology, about the mysterious 3.5K excess. When, a little while later, Burke heard about a lecture that Peebles had recently delivered predicting the existence of a background radiation, he passed the information to Penzias, who phoned Robert Dicke to find out more.



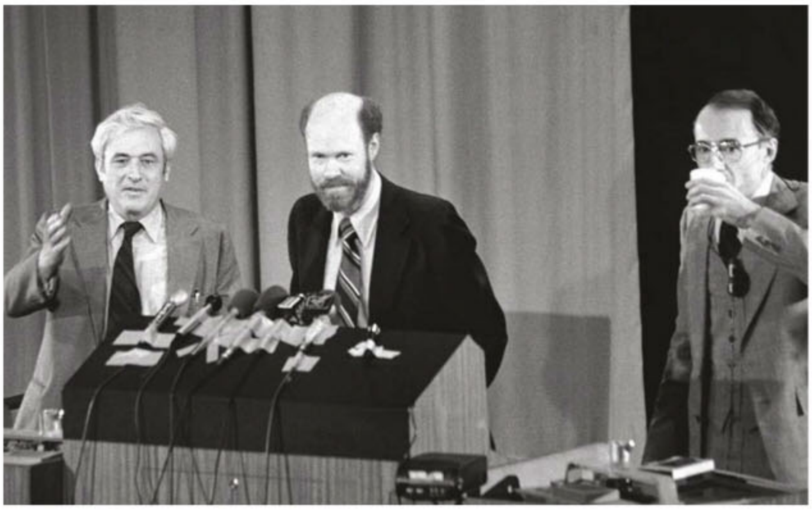
▲ Echo I was followed in 1964 by Echo 2, seen here during preflight testing

When the call came through, Dicke was in his office, meeting with Peebles, Wilkinson and Roll. As they heard Dicke mention helium loads, atmospheric radiation and the details of their own experiment, his three associates realised that the conversation was important. When the call was over, Dicke turned back to the group and said: 'Gentlemen, we've been scooped.'

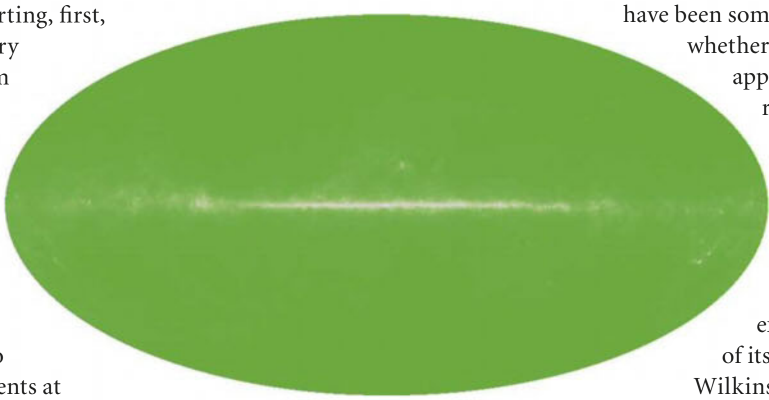
Comparing notes

Shortly afterwards, Dicke, Wilkinson and Roll drove from Princeton University to inspect the Crawford Hill antenna. It was clear to them that Penzias and Wilson had been careful in their work and that their measurement was not caused by a system fault or some other local source. Dicke then explained to Penzias and Wilson his ideas about how the heat of the early Universe would have left a 'footprint' in the form and range of the radiation they had detected. Penzias and Wilson were relieved to finally have an answer to their puzzle. The two groups agreed to submit companion articles to the *Astrophysical Journal* reporting, first, the Princeton University theory and, second, the readings from Crawford Hill.

Walter Sullivan's front-page splash in the *New York Times* covering the two journal articles was not enough to transform cosmology alone. The existence of the cosmic microwave background had to be confirmed with measurements at other wavelengths, work conducted by Penzias and Wilson at Crawford Hill and by Wilkinson at Princeton University after his antenna began operating in summer 1965. By 1967, confidence in the Big Bang theory was growing and so was the field of scientific cosmology. From that year, there began a marked and enduring increase in the number of papers on cosmology published annually in scientific journals. Advocates of a Steady State Universe dwindled to a marginal, eccentric rump.



▲ Robert Wilson (centre) and Arno Penzias (right) answer the questions from the press after receiving the Nobel Prize in 1978



▲ A simulation made by NASA of how the CMB would have appeared to Penzias and Wilson's microwave receiver

In 1978, Arno Penzias and Robert Wilson were awarded the Nobel Prize "for their discovery of cosmic microwave background radiation". There have been some who have questioned whether the award was appropriate. After all, the recipients had to be told by others what they had discovered. Perhaps Ralph Alpher and Robert Herman deserved it instead, for their original prediction of the radiation's existence and their estimates of its temperature.

Wilkinson and Roll, who did know what they were looking for, were only a few months away from making the observations before they were scooped. But Penzias and Wilson were much more than just lucky: with care and skill, they had converted a massive, complex instrument from one purpose to another, attuning it to such a degree of precision that they came to record the ancient whispers of creation. S

THE STORY OF **CREATION**

The discovery of the cosmic microwave background unlocked the history of the cosmos

1965
The measurements at the 7cm wavelength detected in 1964 are identified as the CMB by Bell Labs radio astronomers Arno Penzias and Robert Wilson, in collaboration with Princeton University physicists Robert Dicke, James Peebles, David Wilkinson and Peter Roll.

1966-67
Measurements of the CMB are made at the 3cm and 30cm wavelengths, showing it to be present across the spectrum predicted by Ralph Alpher and Robert Herman.

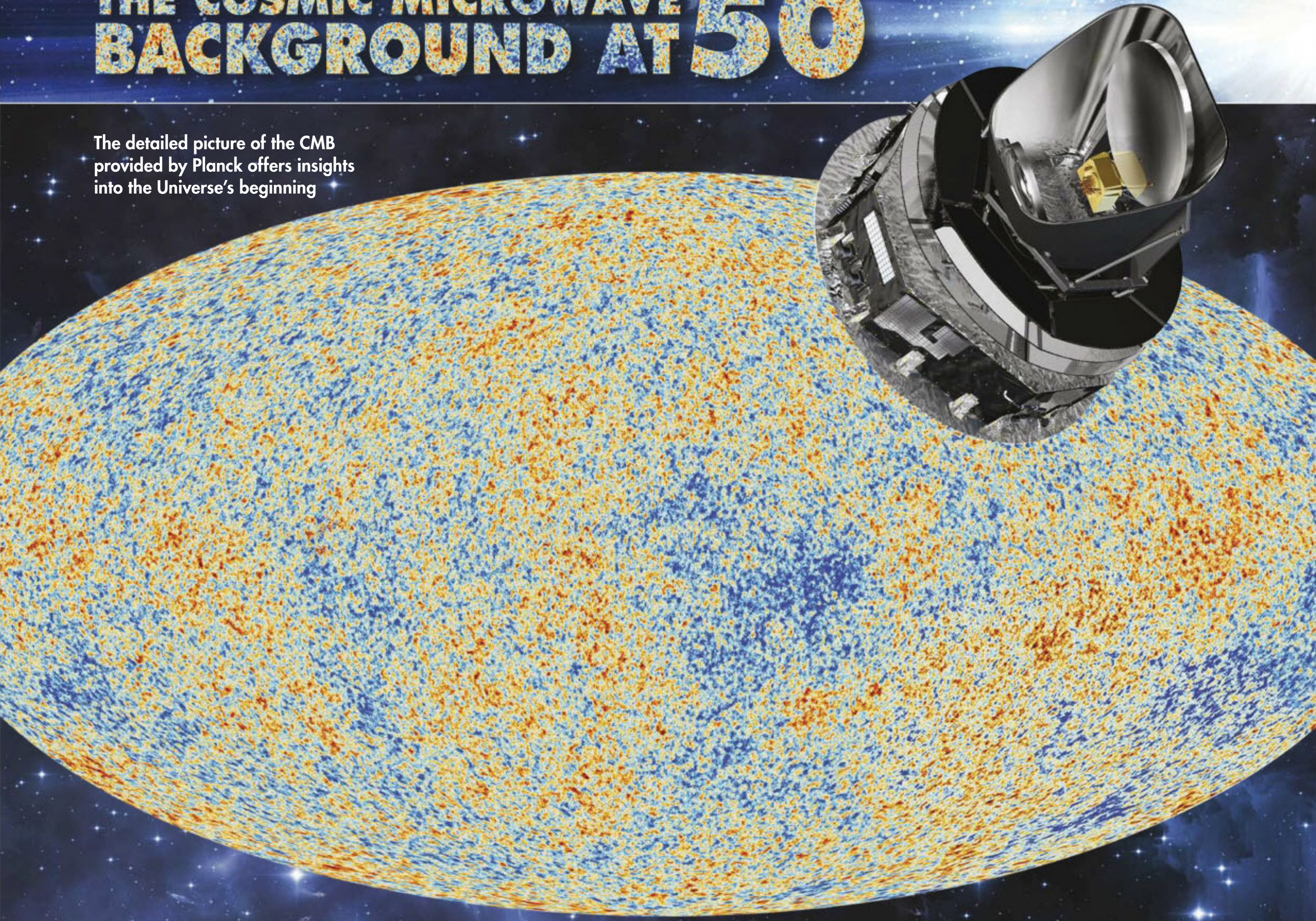
1978
The homogeneity of the CMB is attributed to a rapid inflation of the early Universe.

1992
Variations in the CMB are revealed by the Cosmic Background Explorer satellite, incorporating the creation of galaxies into the Big Bang model.

2001
The Wilkinson Microwave Anisotropy Probe is launched to conduct a more detailed survey of the CMB variations. Over the next decade, it would reveal the proportions of dark matter and dark energy in the Universe.

2009
ESA's Planck spacecraft is launched to conduct a high-resolution survey of the CMB.

2013
Planck mission scientists announced that the survey has refined estimates of the age of the Universe, and of the proportions of dark matter and dark energy.



The detailed picture of the CMB provided by Planck offers insights into the Universe's beginning

ESA AND THE PLANCK CORPORATION X 2, ISTOCK

THE UNIVERSE IN HIGH RESOLUTION

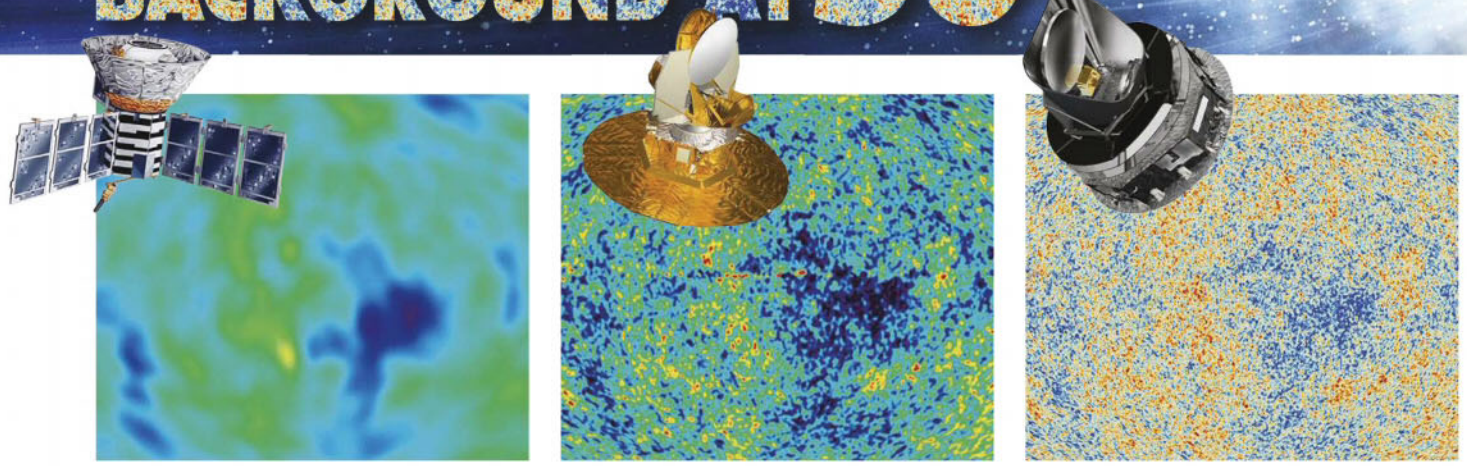
A clearer picture of the early Universe is emerging thanks to studies of the Big Bang's afterglow

As the Barenaked Ladies explain in the opening titles of *The Big Bang Theory*, our whole Universe was once in a hot, dense state. Intense light ripped apart atoms into their constituent protons and electrons, and the Universe was made of an opaque plasma – a hot sea of ionised gas. It cooled sufficiently for atoms to form about 380,000 years after the Big Bang and the light was free to travel through the Universe almost unimpeded. That light is what we measure today as the cosmic microwave background (CMB), it tells us about the state of the matter it last interacted with all that time ago – it's essentially a baby picture of the Universe.

Our understanding of the CMB leapt forwards in the 1990s, with the Cosmic Background Explorer satellite discovering tiny fluctuations in an otherwise almost-uniform afterglow, followed by higher-resolution images from balloon-borne experiments. These density variations have now been mapped over the whole sky, first by NASA's Wilkinson Microwave Anisotrophy Probe and more recently, at higher resolution, by ESA's Planck satellite.

Launched in 2009, Planck scanned the sky in nine wavelengths, or colours, of microwave light. It operated for over four years and, following its decommissioning in 2013, is now permanently switched off and in orbit around the Sun. The wealth of data it collected has been pored over by the Planck team, and is now being released ▸

THE COSMIC MICROWAVE BACKGROUND AT 50



▲ **From left: the Cosmic Background Explorer, Wilkinson Microwave Anisotrophy Probe and Planck have captured ever-sharper images of the CMB**

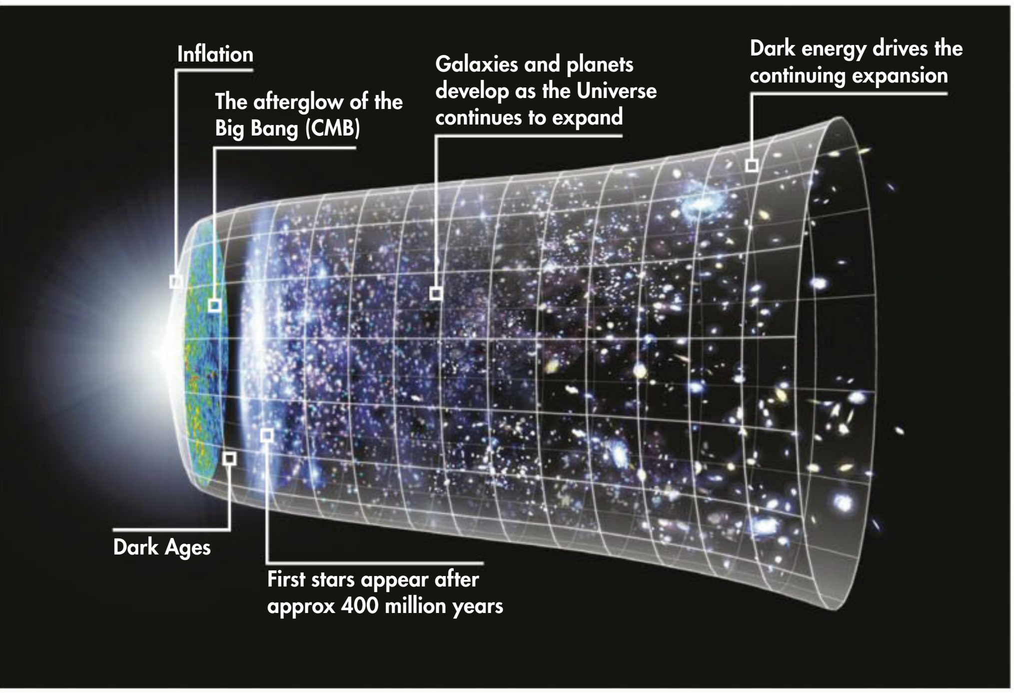
▸ to the world for other astronomers and cosmologists to study. It's allowing new insight into what cosmologists call the standard cosmological model, the picture of the composition and evolution of the Universe, starting with a primordial soup of matter and ending with the massive structures we see in the Universe today. It is thanks to gravity that the tiny temperature and density variations as small as 0.001 per cent in the early Universe – pictured as a seemingly random hodge-podge of hot and cold spots in all-sky maps of the CMB – expanded and cooled over time to become enormous groups of galaxies arranged in a cosmic web.

Signs of inflation

In a nutshell, the Universe comprises three main constituents. Only around 20 per cent of the matter in the Universe is made of the same stuff we are – atoms, molecules and so on. The rest is dark matter, which only feels the force of gravity. But even all this matter only accounts for less than a third of the energy content of the Universe. The rest – about 68 per cent – is dark energy, which acts as an anti-gravity force pushing everything apart. However, it has only dominated the Universe in the past few billion years.

One of the most counter-intuitive features of the standard model of cosmology is 'inflation': the Universe's first tiny fraction of a second (about one thousand million billion trillionth), in which it expanded by a factor of around 100 thousand billion trillion. This smoothed out the visible Universe, making it almost the same everywhere, but it also blew up tiny quantum fluctuations to a macroscopic scale. It's these fluctuations that led to the density variations in the CMB. While inflation seems like a theory of convenience, with little or no physical motivation, it does explain many of the observed properties of the Universe. It's the best theory we have at the moment, but without firm evidence we could simply be barking up the wrong tree, cosmologically speaking.

While there have been refinements to some of the numbers, the basic model of cosmology hasn't really changed at all over the last 15 years. By combining Planck's precise measurements of the CMB with other large-scale studies of the Universe, cosmologists have narrowed down the half-dozen or so basic parameters to the level of a few per cent, sometimes even less. For instance, using the latest results from Planck the age of the Universe, calculated as 13.8 billion years, can be determined to an accuracy of less than 0.2 per cent, equivalent to 30 million years.



▲ **Much of the Universe's expansion occurred a fraction of a second after the Big Bang, during inflation, and the initial positions of all the matter in the Universe are imprinted on its afterglow**

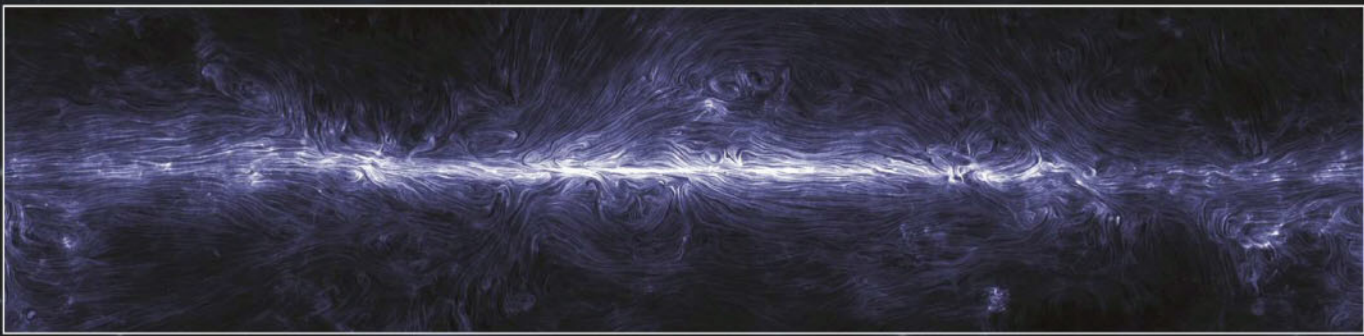
Cosmic interference

Unfortunately, for cosmologists at least, Earth is not completely isolated in the Universe, and the early Universe is not the only source of microwave light. Material in our own Galaxy, within the Solar System, and even in different galaxies emits light and confuses the picture. In fact, most of the sky is dominated by emissions from the Milky Way, so separating these 'foregrounds' is critical if we are to get a better view of the early Universe.

While the CMB looks the same at every wavelength, these other components have a specific range of colours, and so a multicolour view of the Universe can be split up into its constituent parts. Planck's most powerful tool is its nine-colour vision, which allows it to separate the cosmic afterglow from the galactic foregrounds with much greater reliability than previous missions, and refine our cosmological parameters more accurately than ever before. ▸

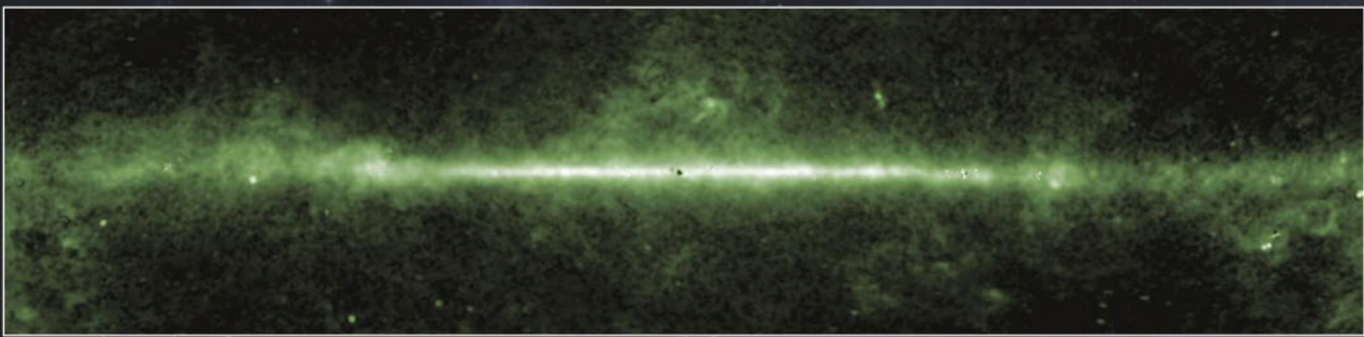
A MULTICOLOURED **MILKY WAY**

Planck's ability to observe at nine wavelengths makes its data particularly rich. Below are just four of its views of our Galaxy



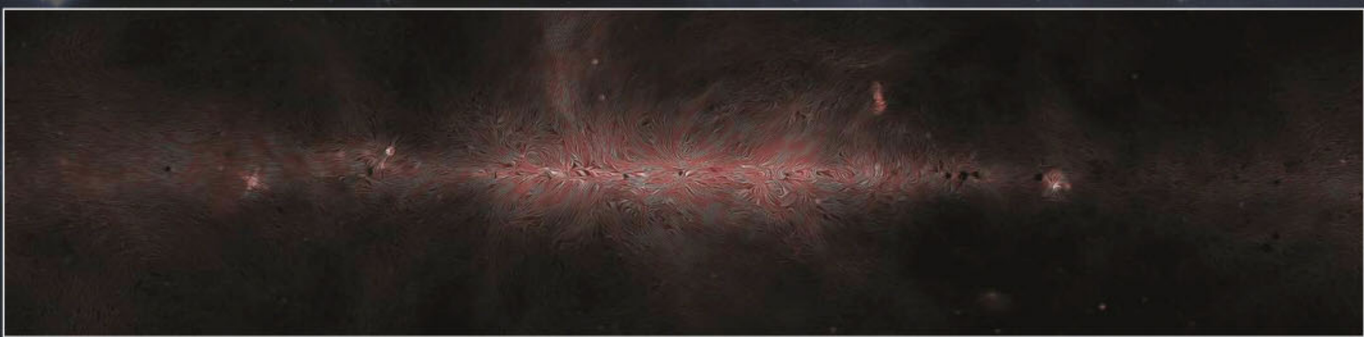
△ DUST

Interstellar dust grains in our Galaxy glow at submillimetre wavelengths and can be aligned to the magnetic field to give this polarised view.



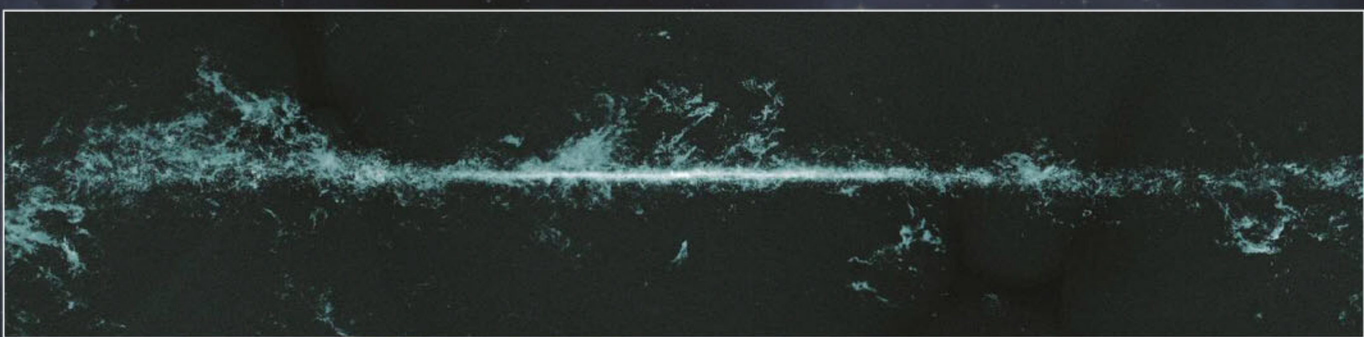
△ SPINNING DUST

Dust particles can be set spinning in the galactic magnetic field at a rate of billions of rotations per second, emitting millimetre-wave light.



△ SYNCHROTRON RADIATION

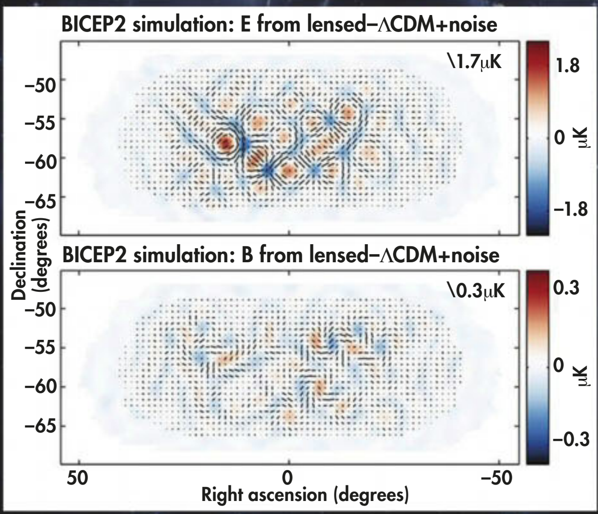
Electrons from within our Galaxy and beyond spiral round the magnetic field lines. As they do, they emit radio waves detected by Planck.



△ CARBON MONOXIDE

The coldest gas in our Galaxy can form molecules such as carbon monoxide. This shows the regions where cold gas is collapsing to form stars.

POLARISATION



Light is a wave of oscillating electric and magnetic fields travelling through space. The properties of light we see tell us about the source that emitted it. In astronomy, for example, the colour, or wavelength, of light tells us about the source's temperature and the intensity of light tells us the density of the gas or dust that's emitting it. If the source has a preferred orientation, then there can also be a preferred direction to the electric and magnetic fields we see, and so a preferred orientation of the light. We call this a polarisation. The effect can also be created when light is scattered off an object. For example, light reflected of a road is slightly polarised, which is why polarised sunglasses can block out some of the reflected glare.

Light in the early Universe was scattered off electrons and the electric field of the light caused the electrons to oscillate. If the light had been the same everywhere the electrons would have oscillated in random directions, but the distribution of hot and cold regions in the Universe (which we see as hot and cold spots in the CMB) gave the electrons a preferred direction of oscillation, polarising the scattered light. The particular structures and patterns in the CMB mean that the observed polarisation has a particular structure – a swirly pattern around hot spots, referred to as an 'E-mode'.

The distortion of space by gravitational waves would manifest itself as a subtle distortion to the polarisation pattern, adding in a different pattern of swirls, called a 'B-mode'. Unfortunately, the signature of gravitational waves is much weaker than the normal CMB polarisation pattern. It's also masked by other sources, such as gravitational lensing and polarised light from our Galaxy.

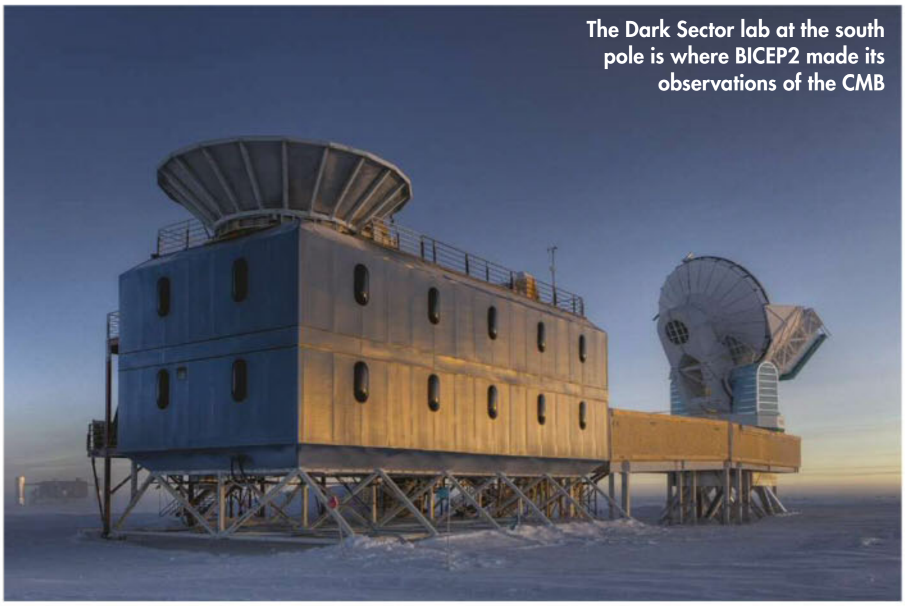
► We think of a beam of light as having a wavelength (or colour) and an intensity (or brightness). But in some situations light can also have a preferred orientation, called its polarisation. Light can become polarised if its source has a preferred direction. For example, the galactic magnetic field causes dust particles to be aligned in the same direction, and the light they emit also has this preferred orientation. Similarly, electrons spiral around the magnetic field lines and emit light with orientations that also correspond to the magnetic field. While these might be a nuisance to cosmologists, to astrophysicists they're a fascinating insight into the structure of the Galaxy and the formation of stars.

Light from the early Universe is also slightly polarised, and the pattern of polarisation provides clues as to what happened at the beginning of time, as well as more recently in cosmic history. There's little benefit looking at one spot in the CMB, as we don't know anything about the initial conditions at each point in the Universe. But by averaging them together, and looking at patterns over the sky, we can build up a statistical picture. The polarisation, or orientation, of the CMB has a very particular pattern – it looks swirly. This isn't that surprising, as the pattern of hot and cold regions on the sky leads to this swirliness.

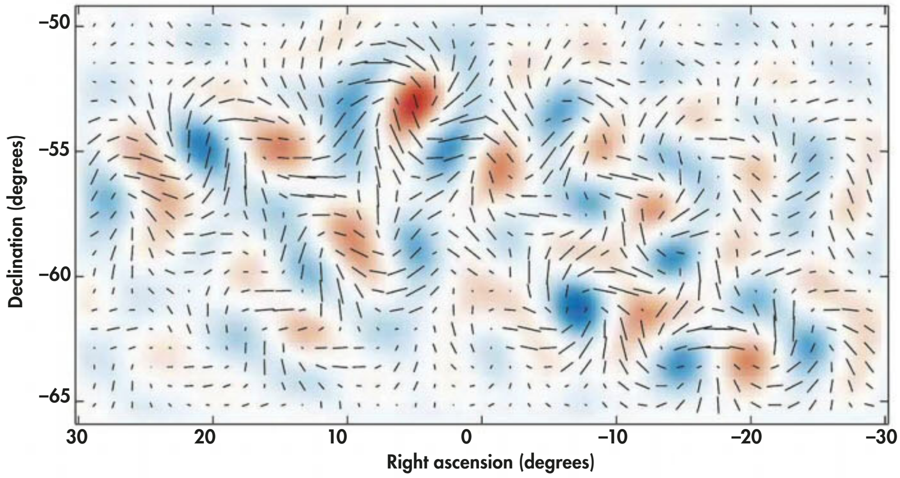
Looking for patterns

But cosmologists are hunting for a much fainter pattern in the orientation, hiding among the swirls. These so-called 'B-modes', if seen in the early Universe, would provide evidence of gravitational waves propagating through the cosmos, originating from the massive expansion of space during inflation. It is one of the only testable predictions that inflation makes, and finding them would be a huge discovery. Unfortunately, the expected signal is incredibly weak and is easily masked by a huge number of other effects. As well as polarised light coming from our Galaxy, the polarisation patterns are also distorted by gravitational lensing, which twists the orientation around and mixes up the patterns.

In March 2014 a team of cosmologists running telescopes at the South Pole reported that they may have found this B-mode signature in their maps of the sky. The cosmological community, and the rest of astronomy, was buzzing with speculation. While many were very excited about this detection of gravitational waves, others were more sceptical. The findings were made by an experiment called Background Imaging of Cosmic Extragalactic Polarization (BICEP2). It focused on one patch of sky and while it had to compete with the obscuring effects of the Earth's atmosphere it did so with a large number of detectors – in some ways making it more sensitive than Planck.


The Dark Sector lab at the south pole is where BICEP2 made its observations of the CMB

THE KECK ARRAY AND BICEP2 COLLABORATIONS 2015, AMBLE/BICEP2, STEFFEN RICHTER/HARVARD UNIVERSITY, BICEP2 COLLABORATION, ESA



▲ **BICEP2's measurements were thought to show the faint footprints of cosmic inflation**

Its Achilles' heel, however, was that BICEP2 only saw one colour of light, and so wasn't able to confidently separate out the foreground interference. The assumptions made were too optimistic, and a subsequent collaboration with Planck showed that much of what had been seen was due to dust in our Galaxy, not a signature of inflation.

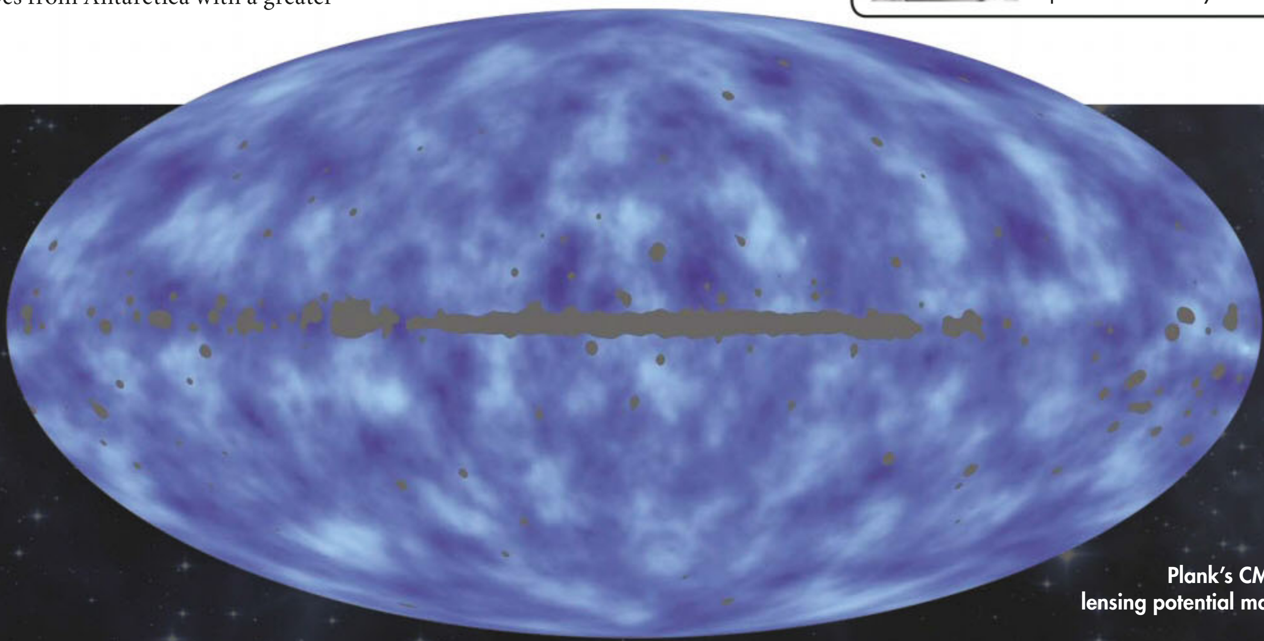
More data to gather

That's not the end of the story, though, as the same team are running more telescopes from Antarctica with a greater range of colours. Combined with Planck's maps of the galactic emissions, we may yet discover the cosmological B-modes. There are other teams involved too. A balloon-borne experiment called SPIDER recently completed a flight over Antarctica, and over the next couple of years scientists will be busily analysing its haul of data to see if there are any secrets held within.

There is a huge breadth in the scientific results possible with Planck's data. Not only from our Galaxy and the early Universe, but also much of the stuff in-between. When the first stars lit up, their intense light started stripping atoms of their electrons, re-ionising the Universe. This ionised gas scattered light travelling through the Universe, altering its preferred orientation and subtly distorting our measurements of the CMB. Planck's latest results have established that this probably happened about 500 million years after the Big Bang. This is good news for astronomers, as the stars and galaxies that caused the effect should be visible to the James Webb Space Telescope when it is launched in 2018.

There is still much to learn from Planck's observations. While almost all the data from the mission is now available, there is a lot left to understand. As well as cosmological discoveries, we are just at the beginning of exploring the polarised images of the sky, and astronomers will undoubtedly make many new discoveries about our local neighbourhood. S

ABOUT THE WRITER
Chris North is an astrophysicist at Cardiff University and the UK outreach officer for the Herschel Space Observatory.



Plank's CMB lensing potential map

GRAVITATIONAL LENSING

One of the predictions Albert Einstein made in his general theory of relativity was that large masses can bend spacetime, distorting our view of distant objects. We are used to seeing this effect with optical telescopes, with huge clusters of galaxies warping the light from more distant galaxies, creating long, curved arcs and sometimes multiple images. The light from the cosmic microwave background is similarly distorted by the masses it travels past on its way to our telescopes. While the effect is much weaker, and there are not individual objects whose light gets warped, it does distort the pattern of the hot and cold spots that we see. By searching for tiny distortions in the fluctuations of the CMB, cosmologists can map out where the massive structures are in our Universe. This is another test of the way that the structures in our Universe have formed over time.

Could a spaceport become a new hub for the UK's space industry?

SHOULD THE UK BUILD A **SPACEPORT?**

The Government has endorsed plans to build a spaceport, but is it really the best move for the UK? **Elizabeth Pearson** asks the experts

Space is big business. Today we rely on the space sector for everything from GPS and communications to medical research aboard the ISS. Having access to space is no longer a luxury for the richest nations. It is rapidly becoming a necessity of modern life.

The UK Space Agency was founded in 2010 with the pledge that in within 20 years Britain would represent 10 per cent of space products and services worldwide. Currently we only account for six per cent of the global space industry. To close the gap there are going to have be some big advances, one of which could be the building of Europe's first spaceport.

A spaceport would provide the infrastructure for commercial spaceflights to take off and land, as well as providing a hub for the space industry to base itself around. There are now several companies flying to space on a regular basis, among them SpaceX and Orbital Sciences, and the UK Space Agency is keen to attract their business to our shores.

After a three-month consultation with industry experts the Government has thrown its support behind the project. Possible sites have been suggested in Stornoway, Glasgow Prestwick and Campbeltown in Scotland, Newquay in England and Llanbedr in Wales. But not everyone is convinced that building a multimillion-pound spaceport is the right move for the UK. There are concerns that the build may be premature, or that the UK is not in the best geographical location for such a facility. There are many who think that a spaceport would just be used by the rich for space tourism flights. On the other hand, those in favour of a spaceport believe that it will be a great focal point for future space activity.

Over the page, two experts give their views on whether the UK should construct a permanent base for spaceflight. ▸

ABOUT THE WRITER

Dr Elizabeth Pearson is *BBC Sky at Night Magazine*'s staff writer, specialising in space science. She gained her PhD in extragalactic astronomy at Cardiff University.

WWW.GOV.UK

YES

Dr Malcolm MacDonald is senior lecturer in mechanical space engineering at the University of Strathclyde

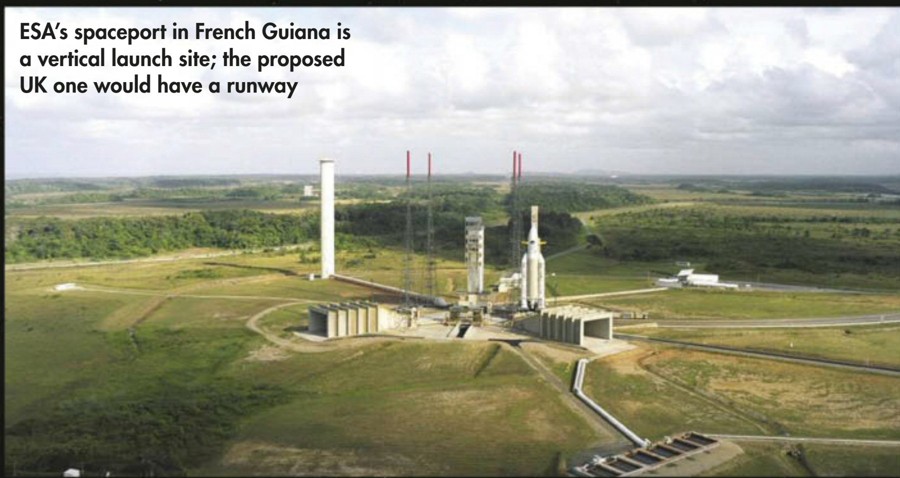
When most people think of a spaceport they think of it as something like what ESA has in French Guiana, where you can use a vertical launch vehicle. That's not what is being looked at in the UK. Here plans are around a horizontal take off, in the same way as an aircraft would on a runway, maybe using a one- or two-stage process to get into space.

The UK is a good place, geographically, to build that kind of spaceport. What you need is quiet airspace, and from Scotland northwards you have that. You want to fly over coastal areas as well, to keep the space travel away from large areas of population for safety reasons. In the US this is done by flying over the desert.

We already have lots of potential sites that could be built up. I think that approach is much more sensible than building something from scratch, and that is what the Government is planning on doing.

Economically it would be very valuable to have the European spaceport in the UK. That is what is driving the Government's interest in the whole space sector. In the short term a lot of the interest is in space tourism, but I think the scope of that could be somewhat limited compared to the capability of actually launching spacecraft into orbit.

In the UK we've got relatively good capability to build small, low-cost spacecraft, but we don't have that indigenous capability to actually get it into orbit. We still have to barter agreements, still have to pay somebody else. In the future, being able to identify a business need, build the spacecraft and launch it all within a short period of time is going to become more and more important.



ESA's spaceport in French Guiana is a vertical launch site; the proposed UK one would have a runway

The UK Space Agency has set out very ambitious targets both in the value of the space sector and the share of the global space sector that the UK wants to have. And to achieve those targets we can't simply continue doing what we are already. We have to make changes. We have to engage with sectors that aren't strong users of space technology and explain to them that actually there's new ways that we can use space.

"We have to engage with sectors that aren't strong users of space tech"

At a spaceport you'll have all of the support services nearby. Because you have a highly skilled sector, that in turn attracts other high skill areas. So a spaceport offers the chance to be a flagship to the world. Businesses will see the opportunity to bring their work here because they know they will find people with the right skills.

You can't just invest in either infrastructure or in technology. These can't be taken in isolation. A lot of places in the United States tend to look for an anchor customer who is developing technology at the spaceport that they will then launch from. But I think in the UK it will be important not to cater for a single customer, but to establish a research and development facility and run it as somewhere where customers can come and develop their technology first.

You could argue that it's premature just now, but if you wait it will be too late. If you get in early you can lose big, but you can also win big. If you get in when the technology has reached a sufficient level of maturity to know that this is definitely going to be profitable, you'll definitely receive some return on your investment, but no way near the amount as you would if you had invested earlier on.

ESA - S. CORVAJA, ISTOCK X 3, © REACTION ENGINES

NO

Dr Richard Brown is director of the Centre for Future Air-Space Transportation Technology, University of Strathclyde

"It's like building a cart and expecting someone to invent a horse"

I don't think it has yet been settled on just what is meant by a 'spaceport' and that is part of the problem. A spaceport can mean anything from a place where people who are interested in space can get together for commercial activities, through to an airport-like building where spacefaring vehicles take off on a daily basis. Somewhere in that spectrum lies what is practical within the UK.

To me, a spaceport in the UK doesn't make much sense geographically. It would be a very northerly launch site, which is only good for very specific orbital insertions. The major money is to be made in putting satellites into equatorial orbits, but they are very difficult to access from a launch site in the far north. The polar orbits that you can get into from the UK are for very specific purposes, mainly reconnaissance satellites. Unless a good business plan can be made, the UK is not a very good generic place for space access.

The timing is also a bit dubious. The technology for Virgin Galactic will be ready next year, maybe the year after, so I can see why a spaceport might seem useful. The problem is they don't really require huge infrastructure; they can operate without a dedicated spaceport. All you really need is a well-isolated runway with clear access to space to operate that kind of vehicle. And most of the UK is not like that at all. We live under a very congested set of air routes.

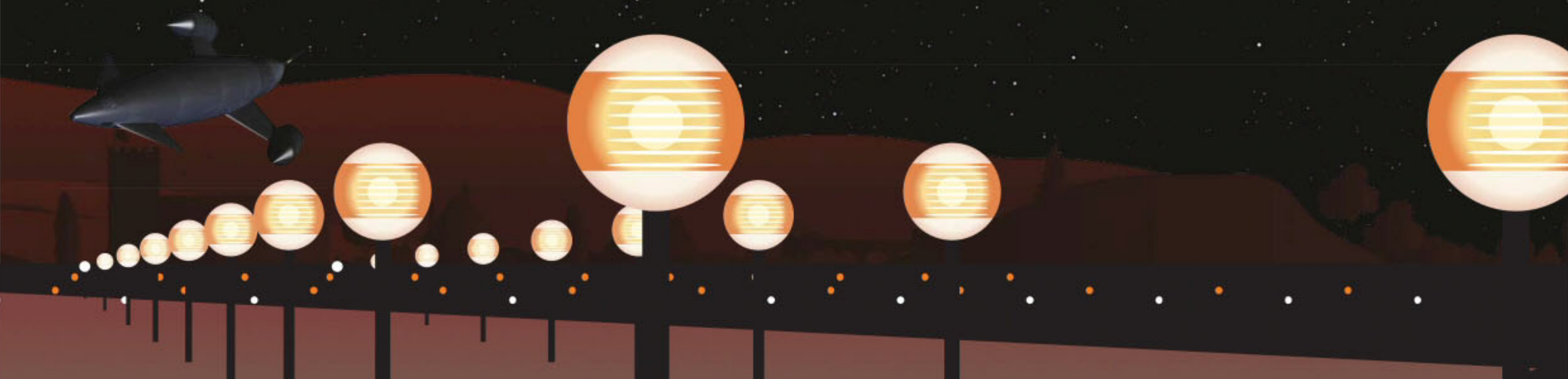
Then you have Skylon. Not only will it be another 20 to 30 years for the technology to come online, it's not the sort of technology that can launch efficiently from a UK spaceport. It's much better suited to equatorial launch sites.

What is the UK actually trying to do in space? In the 1960s we were perhaps one of the world leaders space technology, but we have lost the capability to design the technology to get rockets into space. We ended up designing the technology that would go into space. Many companies and universities are now well established in the satellite-manufacturing field. But that's almost like dressing up to go to a party and realising there are no taxis to take you. We have the means of building satellites, but no national means of getting them into space.

This idea that the UK should go it alone with an independent capability is a rather parochial approach to this issue, yet we've just missed out on getting involved in the next European launcher, the Ariane 6. Ariane 7 is just coming up for discussion, and I would hate to think we missed the boat again because we focused on a UK version of launch. I think our future should be towards full and international collaboration where we can provide our niche capabilities to a broader team of more capable players.

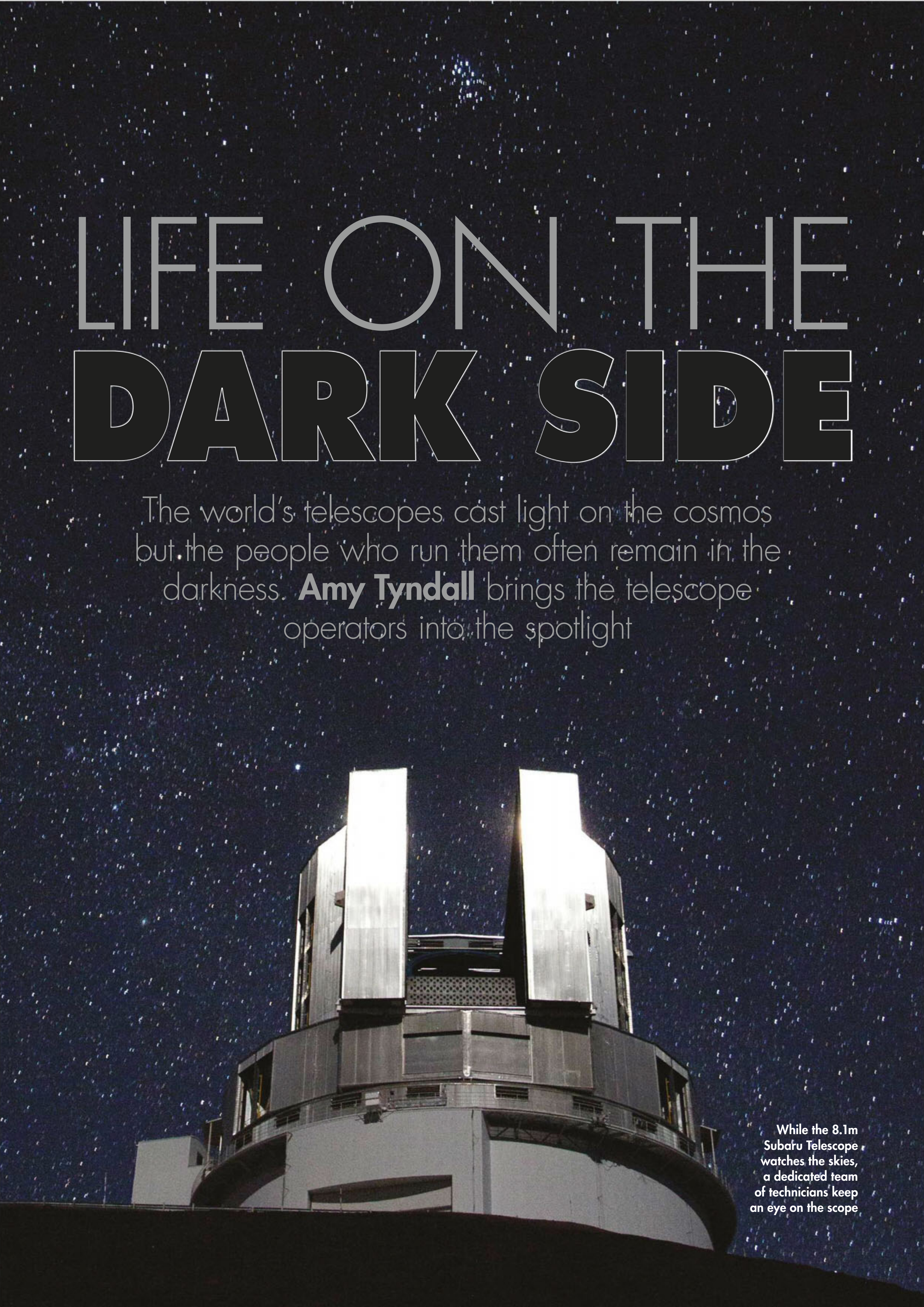
The UK is very active in the space sector, but we seem to be taking the easy bits and developing those, and hoping someone else will come along and do the hard bits. We're hoping that they will bring the technology to our doorstep and use the infrastructure that we've provided and I don't think that's really the way to go. It's like building a cart with the expectation that someone will come along and invent a horse for you. Certainly a spaceport is a very high profile way of attracting public attention to the field. I'm just not convinced that it is particularly well motivated. S

Our airspace is already congested, which is why many of the proposed sites are in the north of the UK



LIFE ON THE DARK SIDE

The world's telescopes cast light on the cosmos but the people who run them often remain in the darkness. **Amy Tyndall** brings the telescope operators into the spotlight



While the 8.1m Subaru Telescope watches the skies, a dedicated team of technicians keep an eye on the scope

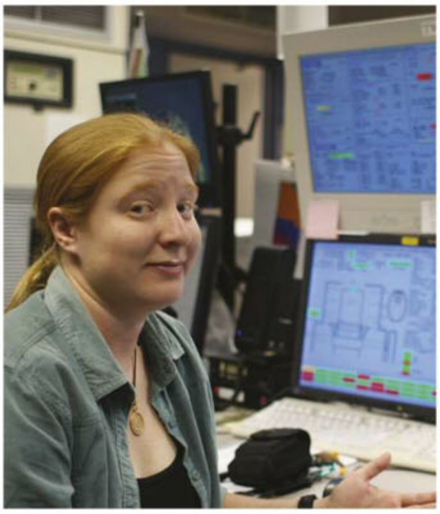
As the Sun sets on the Subaru Telescope (left) the telescope operators' work begins

"What hath night to do with sleep?" pondered John Milton in his poem *Comus*. To astronomers around the world, the answer is very little. As the Sun sets, the real work begins for these men and women – setting up the telescopes and their instruments, organising the incoming data and checking its quality. These are just a few of the tasks that have to be carried out every night in order to keep everything running smoothly.

We often hear stories in the media in which astronomers are interviewed about their latest exciting findings, but the true story behind how they got to that stage rarely sees the light of day. So let us introduce you to the people behind the scenes of a professional astronomical observatory, the people who act as the intermediaries between the research astronomers and the cosmos – the telescope operators.

Watching the watchers

The telescope operators, or TOs, often come from a wide range of academic backgrounds, from electronics to computer science, which brings an eclectic mix to the observatory environment. But what exactly is the TO's role? "To sum it up, my role as a telescope operator is to keep the telescope working and the people working on the telescope happy," says Marita Morris, TO for the 8.1m Subaru Telescope on Mauna Kea in Hawaii. "When the scope's working and the people are happy, the observers can get their data and good science can follow." ▸



▲ Above: Marita Morris in the control room operating the Subaru Telescope; and top, repairing a faulty primary mirror actuator

HOW I BECAME A **TELESCOPE OPERATOR**

Cristian Romero works at Paranal Observatory in Chile's Atacama Desert

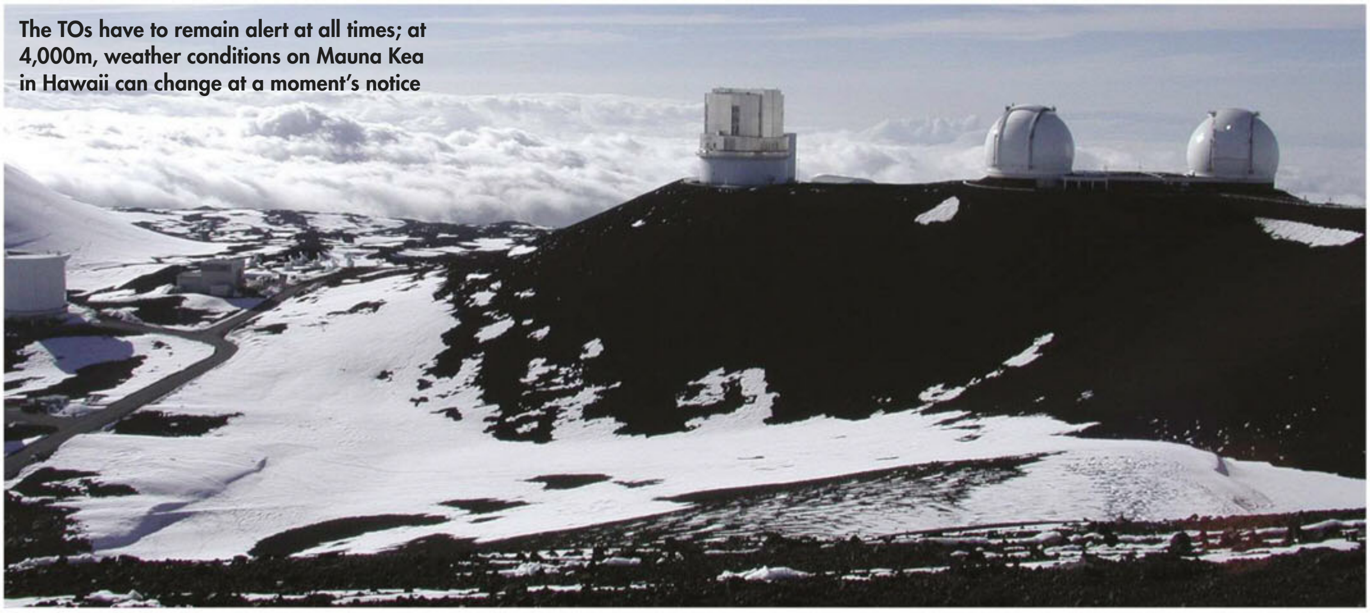
"I served as a second lieutenant in the Chilean Navy before I became a telescope operator so I'm familiar and comfortable with high-level technical training. I studied naval electronic engineering during my time in the military, which has proven invaluable in my current role.

I had more than a passing interest in astronomy before I changed paths as I had to learn some astronomical concepts and use them for oceanic navigation. The use of stars, planets and the Sun to determine the location of the vessel with a sextant was part of the training I received. Little by little, this was what got me interested in learning more about the Universe.

What motivated me to change careers and become a TO was a visit to the ESO Paranal Observatory in the Atacama Desert when I was still a naval officer. Seeing the premises, the telescopes and their instruments was extremely inspiring and I then found out that there was a chance I could join the European Extremely Large Telescope project. So a few months later I applied for the job.

What I like most about my job is being part of a highly trained and highly technical, multidisciplinary and multicultural team. Indeed, being an important link in the chain of scientific research is very motivating.

There are several tips I would give to anyone interested in becoming a TO. Firstly, you must enjoy a challenge. Secondly, you should ideally study a technical subject such as electronic or systems engineering. And be aware that it takes a lot of patience because the learning curve can be slow; learning each system with its particular function takes a long time. Finally, you must be prepared to work long hours at night without losing that all-important motivation."



The TOs have to remain alert at all times; at 4,000m, weather conditions on Mauna Kea in Hawaii can change at a moment's notice

▸ The TOs perform many duties during the night, from observing to technical maintenance, which means their full attention is required at all times. "The job basically consists of opening and closing the telescope at night, and keeping an eye on all of its systems," explains Morris. "I'm the first line of defence if something goes wrong with the telescope. I'll troubleshoot the problem and if I can fix it, I will. If not, then I'll get the right people working on it as soon as possible."

But sometimes it's nature, not mechanics, that can cause issues during a night's observing. "On Mauna Kea, rain or snow storms can move in very fast (it can go from clear to snowing in 15 minutes), and when they do we need to be ready to close the dome as quickly as possible in order to protect the telescope," Morris continues. "Water and very shiny mirrors tend not to mix well together."

Working the night shift

Life at the forefront of astronomy is often gripping and inspiring, but just as with any other job it can have its mundane side too. "We have an office in town that we occasionally use during the day," Morris says. "During this time, we are maintaining manuals, updating fault databases and basically taking care of any paperwork that goes along with telescope operations. Like any other job, it's the paperwork that's boring."

Patricia Guajardo, TO for the ESO Paranal Observatory in Chile, agrees that the daytime work can be a chore, but she chooses to see it in a different light. "I have to separate my roles from day to night because they are so different," she says. "One could say that during the day we are preparing the party, and at night we are a part of it."

What all of the TOs agree on is that working antisocial shifts (as long as 14 hours a night in winter) for up to two weeks at a time, and at altitudes of several thousand metres, presents difficult and unusual working conditions. For Guajardo, as a wife and mother, the distance it creates from her family can be hard to cope with. "It has not been easy," she admits. "It's really difficult when my young daughter is sick, for example, as I can't be there. But we installed a webcam in her room so that I can always see her when I'm on shift, and that helps a lot!"

THE CONTROL ROOM

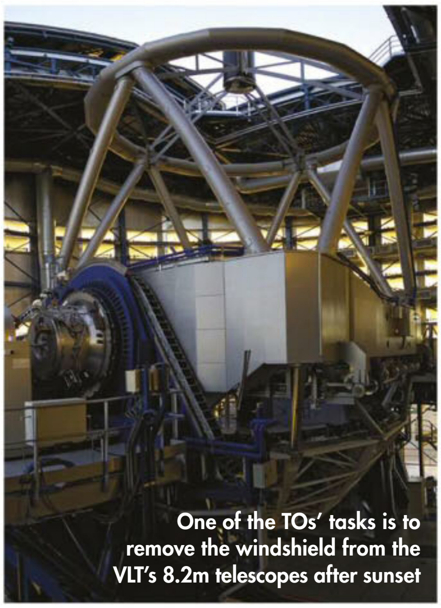
The control room is the nerve centre of any astronomical observatory, the place where the astronomers send impulses to the telescopic limb that then reaches out to touch the stars. This nerve centre is often separated from the telescope dome, and in some cases is located miles away from the mountaintop upon which the telescope sits.

Upon entering a control room, you are greeted with a seemingly endless array of monitors displaying everything from the incoming data to the position of the telescope and the weather conditions outside. These act as digital eyes for the astronomers looking up at the cosmos and making sure that conditions are optimal for observing – no longer do astronomers have to use the traditional eyepiece to peer up at the night sky. There's often a sofa for staff to sit and relax on in between observations or while they enjoy their 'night lunch', typically a packed lunch that serves as their evening meal, although it's eaten in the small hours of the morning due to their flipped work schedules.

Some control rooms are still housed underneath the telescopes, such as the Nordic Optical Telescope on La Palma in the Canary Islands. The control rooms for this telescope have been designed to rotate with the rest of the building as the telescope moves. This presents quite a bit of a plumbing challenge, so a midnight dash outside to another building is required for bathroom visits.

TOs at the VLT Interferometer in Chile prepare for the night of observing ahead

Patricia Guajardo is one of the TOs that keeps the Paranal Observatory running



One of the TOs' tasks is to remove the windshield from the VLT's 8.2m telescopes after sunset

As well as the obvious problems of separation and feelings of isolation that can come with such a job, people can also fall foul of the physical effects that result from working in such an extreme environment. And the TOs must be ready to act quickly when those effects occur.

"A big part of our job at the summit is keeping everyone safe," says Morris. "On Mauna Kea we're just over 4,000m above sea level, so the effects of high altitude on people are very noticeable, even on people who are well acclimatised. These can range from a slight headache, to fainting, to a heart attack. Since the nearest hospital is over an hour away, we're trained as emergency medical responders so that if things go wrong we know how to help."

"I really like the hands-on aspect, actually taking data and troubleshooting instead of just focusing on one task" Lindsay Magill

Lindsay Magill ensures the Gemini South Observatory stays on its intended target

Toys and telescopes

When talking to the TOs, it quickly becomes apparent that most of them have had an interest in astronomy ever since they were children. "Most girls played with dolls growing up, but I played with telescopes in the backyard," says Morris. "Later on, when I had the option to pursue another degree or apply for a job at one of the coolest telescopes in Hawaii, the choice was easy. Get paid to work with giant telescopes? Er… Yeah!"

Lindsay Magill, TO for the 8.1m Gemini South Telescope near La Serena in northern Chile, experienced a similar spark when she was younger. "I always loved optics as a child, and would use lenses from old spectacles or magnifying glasses to build make-shift overhead projectors or telescopes, though never with any real success," she laughs. "I did a PhD in astrophysics at Queen's University in Belfast and always thought I would go into research astronomy afterwards. But during my studies I had the opportunity to spend a year working at the Isaac Newton Telescope in La Palma as a student support astronomer." Over the course of the year, Magill became more interested in using the telescope and less interested in her own research, which prompted her to go on to become a TO later on. "I really like the hands-on aspect of it," she says, "actually taking data and troubleshooting instead of just focusing on one task."

But despite the incredibly long nights, the potential altitude sickness and the need to be alert and aware of the telescope systems at all times, the TOs remain dedicated to the task and passionate about what they do. "I love that I'm able to be around astronomy every night that I work," says Morris. "I love that I'm able to do it on top of one of the most interesting mountains in the world and I love that I'm able to play with some of the newest, coolest technology astronomy has to offer!" With attitudes like this, we can sleep soundly at night, safe in the knowledge that the world's telescope operators are awake and hard at work connecting us to the farthest possible reaches of Universe.

ABOUT THE WRITER

Astrophysics PhD student Amy Tyndall is currently working on a research project at the European Southern Observatory in Chile.

The Guide

Saturn: Ringworld of the Solar System

With **Heather Couper**

The sixth planet from the Sun is one of the wonders of the cosmos

Nothing prepares you for your first view of Saturn through a telescope. It looks surreal: a crisp, dazzling model of a cartoon planet out of the pages a comic. It can't be real! But it is: and the planet's glorious encircling rings would stretch nearly to the Moon if Saturn were to be plonked in the same position as Earth.

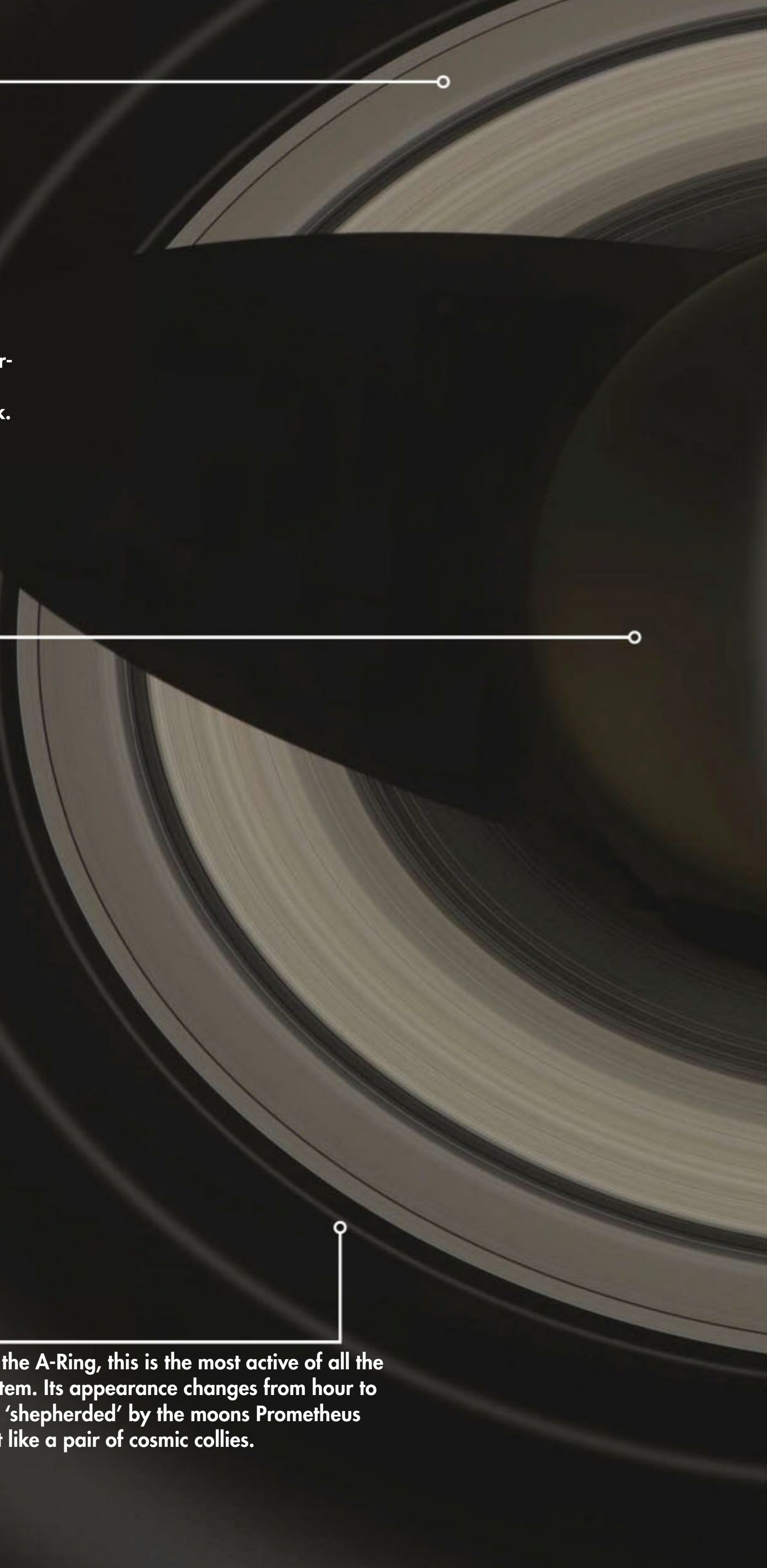
On 23 May, Saturn reaches opposition, its closest point to Earth. But 'close' is a relative word. Even at its nearest, Saturn is 1.34 billion km away. Its rings are probably the remains of an icy moon destroyed by Saturn's gravity. The particles that make them up, ranging in size from ice cubes to refrigerators, can brighten dramatically at opposition, when sunlight hits them head-on.

After Jupiter, Saturn is the second largest planet in our Solar System. A gas giant like Jupiter, it has no solid surface. It's so low in density that, were you to put Saturn in an ocean, it would float. Like Jupiter, Saturn has a ferocious spin rate: its day lasts just 10 hours and 34 minutes. And its winds roar around the planet at speeds of up to 1,800km/h.

Compared to its bigger cousin, Saturn is also a much blander planet than Jupiter. While Jupiter rejoices in bands of ochre-coloured clouds, and its famed Great Red Spot, Saturn is a much calmer beast. But at its solstices, things liven up. The somewhat shy ringworld can erupt in an outbreak of spots.

And the NASA spaceprobe Cassini, currently in orbit around Saturn, is recording lightning bolts on the planet more than 1,000 times more powerful than those on Earth. Ⓢ

Heather Couper is a science writer. This article is based on a feature from her latest book, co-authored with Nigel Henbest, *The Astronomy Bible*, published by Philip's.



A-RING

The outermost of Saturn's three bright rings, the A-Ring is crossed by a 300km-wide division called the Encke Gap, which is swept clean of ring particles by the tiny moon Pan. For all their enormous width, Saturn's rings are paper-thin. The A-Ring is no more than 10-30m thick.

SATURN'S GLOBE

Saturn doesn't rave it up like its bigger cousin Jupiter. Unlike the giant of the Solar System, Saturn is calmer and less colourful, but it can pull off a trick. In 1933, stage and screen comedian Will Hay (also an amateur astronomer) discovered an enormous white spot on the planet. You never know what to expect.

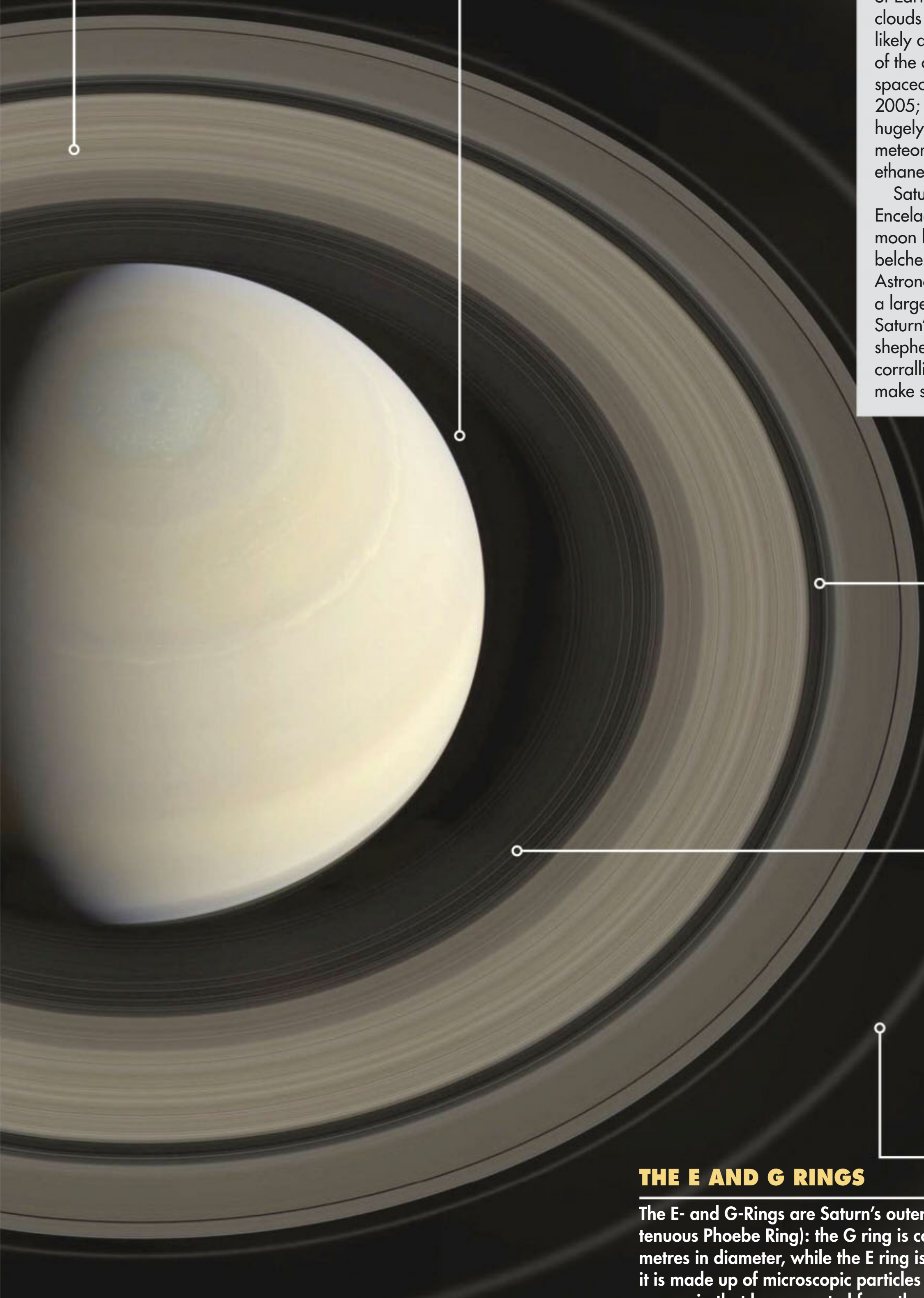
F-RING

Lying 3,000km beyond the A-Ring, this is the most active of all the rings in the planet's system. Its appearance changes from hour to hour as its particles are 'shepherded' by the moons Prometheus and Pandora, which act like a pair of cosmic collies.

THE MOONS OF SATURN

Saturn has 62 moons, the largest of which, Titan, is bigger than Mercury. It boasts a nitrogen atmosphere (unique in the Solar System with the exception of Earth) filled with orange clouds and is one of the most likely abodes of life in our part of the cosmos. The Huygens spacecraft landed on Titan in 2005; it found a world with hugely complex topography and meteorology, as well as seas of ethane and methane.

Saturn's other 'supermoon' is Enceladus. Just 500km across, this icy moon has at least 100 geysers, and belches plumes of vapour into space. Astronomers suspect that it is home to a large subsurface ocean. Many of Saturn's smaller moons provide a shepherding function, gravitationally corralling particles in the planet's rings to make sure that they behave themselves.



B-RING

The broadest, brightest and densest of Saturn's rings, the B-Ring is crossed by dark 'spokes' visible only to space probes. These are composed of fine particles of dust channelled into lines by magnetic fields.

D-RING

This is the planet's innermost ring, and it's very faint. The D-Ring shows wave-like patterns 30km apart, which may have been caused by the impact of a comet which collided with Saturn in 1983.

CASSINI DIVISION

Nearly 5,000km across, the Cassini Division is a huge chasm between the A- and B-Rings. The dramatic dark gap is caused by the moon Mimas pulling on the ring particles.

C-RING

This is the famous 'crepe ring'. It's made of darker particles than A- and B-Rings, and is an astonishingly slim 5m thick.

THE E AND G RINGS

The E- and G-Rings are Saturn's outermost (with the exception of the tenuous Phoebe Ring): the G ring is composed of particles up to a few metres in diameter, while the E ring is a flimsy affair. Although wide, it is made up of microscopic particles of water-ice, carbon dioxide and ammonia that have erupted from the moon Enceladus.

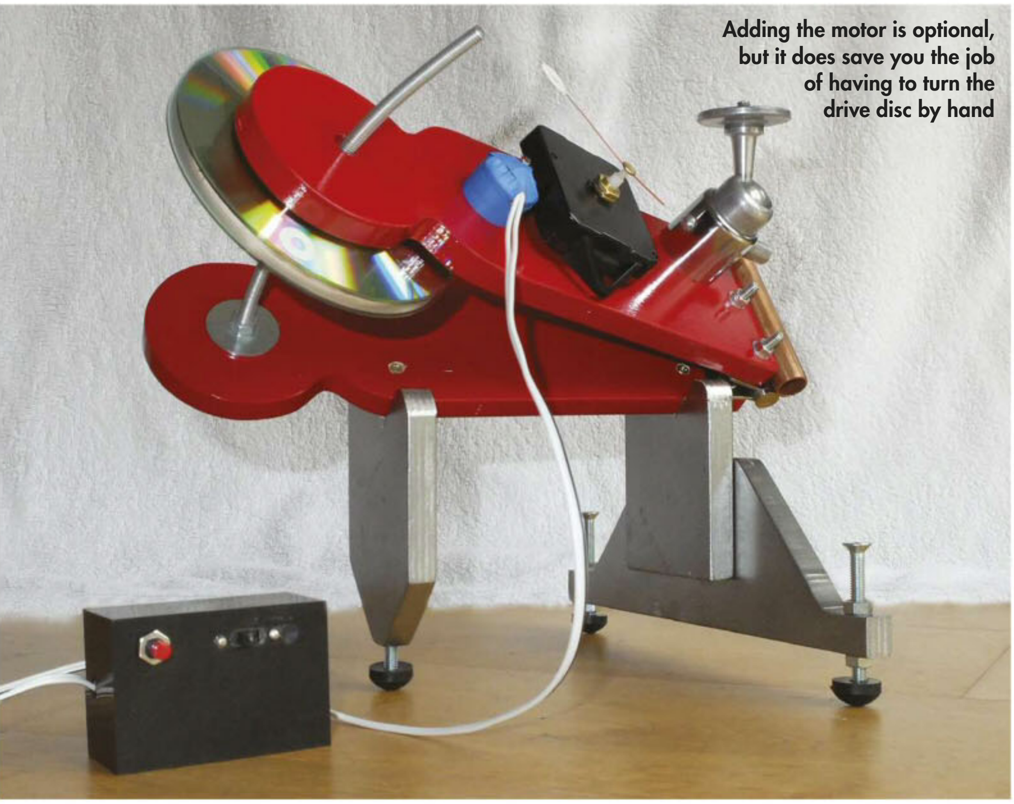
How to

PART 2

Build a tabletop tracking mount

With Mark Parrish

Add the drive mechanism and motor to finish your new mount



Adding the motor is optional, but it does save you the job of having to turn the drive disc by hand

TOOLS AND MATERIALS

FINISH
Paint or sticky labels for marking the drive disc.

ELECTRONICS
Small 6V DC motor, push-to-make switch, double pole-double throw slide switch, battery holder and connector for two AA cells, clock mechanism.

MATERIALS AND COMPONENTS
An offcut of 6mm plywood or similar for the drive disc.

SUNDRIES
Two CDs, an M6 nut, short length of 15mm copper tube, wire and solder for electronics, epoxy resin glue, elastic band for drive belt, small offcut of felt for bearing surface, small bead to fit motor spindle.

TOOLS
Coping saw, drill with bits to suit an M6 nut (11mm), sandpaper, ruler, pencil, soldering iron.

We continue our project to build a barn door tracker this month. This simple tabletop camera mount is able to track the apparent movement of the stars, allowing you to take photos with longer exposure times before star trailing becomes evident. Last month we described how to make the main elements, and we'll assume you've done so. Here, we describe the drive mechanism, optional motorisation and how to operate the mount. Diagrams and additional photos to help you with this can be found online at **http://bit.ly/trackingmount**.

The drive disc is made from a sandwich of two CDs or DVDs glued either side of a wooden disc with a slightly smaller diameter, forming a pulley. The disc has an M6 nut glued into its central hole, which runs up and down the curved drive rod in operation. The upper arm of the mount sits on the CD surface so that as the disc turns clockwise, the arm (and the camera mounted upon it) slowly descends.

We stuck a felt pad to the underside of our upper arm to provide a low friction bearing where it touches the CD and the resulting movement required is very light and smooth. With some combinations of cameras and lenses, the balance point might make it necessary to fasten an elastic band between the upper and lower arms to maintain contact between the upper arm and drive disc. A small hook or screw in the end of each arm would facilitate this.

Simplicity in motion

The beauty of this mount is that it works very effectively when hand-driven, and there is something very satisfying about the simplicity and interaction involved in moving it. To add a little sophistication you can motorise the mount, for which you need a small DC motor. We useds a 6V one, powered by two AA cells (3V) so it turns more slowly. Experiment with different rubber bands running between your motor spindle and the drive disc until it runs smoothly. The electronics couldn't be simpler – we've included a wiring diagram online to help. The circuit consists of a push-to-make button switch, with which you send short pulses to move the motor, and a slide switch, which is used to reverse the motor for 'rewinding' the mount back to its starting position. A soldering iron is needed to join the components and wires together. We used a simple plastic box to house the switches and batteries.

ALL PICTURES: MARK PARRISH

▲ The finished mount allows you to take longer-exposure photos before stars begin to trail

The drive disc doesn't need to be turned constantly – just keep the average rate at one turn per minute. We mounted a cheap clock mechanism on the upper arm, with only its second hand fitted, as a visual reference. Providing you keep within the following range of movements, your image should not show any trails:

▶ A wide-angle lens (30mm or less): half a turn every 30 seconds.
▶ A standard lens (30-70mm): one-quarter of a turn every 15 seconds.
▶ A telephoto lens (70mm or more): 1/12th of a turn every five seconds.

Put a mark on the disc; if you can keep that marking within the same quarter of the clock face as the second hand, you should be successful.

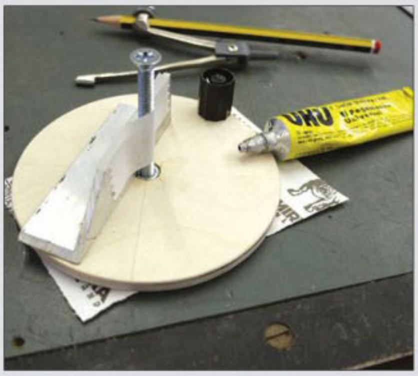
The mount is quite easy to set up. Place it on a suitable table (or skip the base part and mount it directly onto a tripod). Turn it so it is facing north and close to the table edge so you can look up through the alignment tube. Use the screw adjuster feet to sight and centre Polaris through the tube. Set up your camera, taking care not to knock the mount out of alignment. Turn the disc and start taking images! You might consider perfecting your technique on shorter exposures but it won't be long before you are trying minutes rather than seconds. Seeing conditions, camera noise, focus and exposure settings will become the major factors then… but that's the astrophotography learning curve you are now embarking on. Ⓢ

Mark Parrish is a consummate craftsman who loves making astro accessories

GO ONLINE

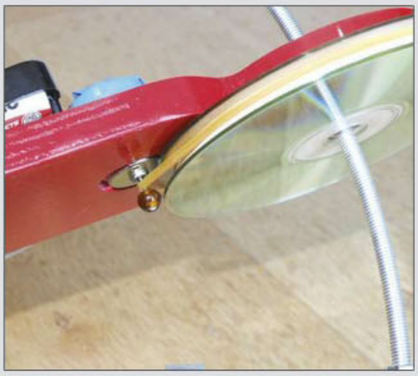
Download useful drawings, printable templates and plans for this project at **http://bit.ly/trackingmount**

STEP-BY-STEP GUIDE



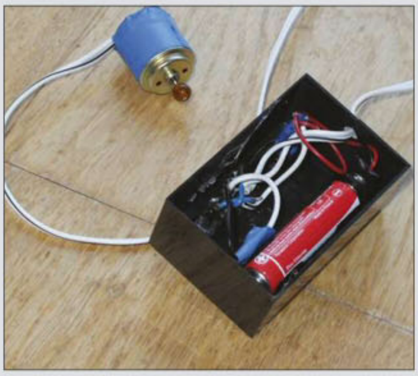
STEP 1

Cut a 110mm diameter disc from some scrap wood approximately 6mm thick. Drill an 11mm hole and press an M6 nut into it. Apply some glue (avoid the threads) and use a spare screw to check it is straight. Glue a CD to either side to complete.



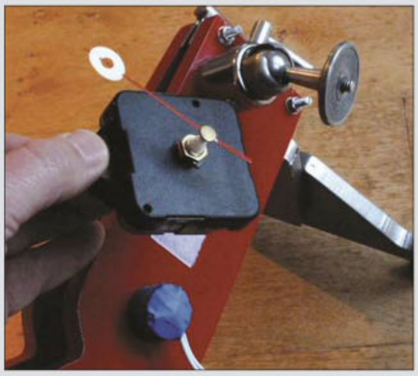
STEP 2

Wrap the motor with electrical tape so it fits tightly in its hole. Fit a suitable elastic band; a small bead glued to the motor spindle will prevent it riding off. After Step 3, check it runs smoothly in each direction, adjusting the motor position in the hole if necessary.



STEP 3

Using the wiring diagram as a guide, solder short lengths of wire between the switches and batteries. A longer pair of wires extends to the motor. Mount the switches and batteries in a suitable sturdy box. Glue or fix the switches in place.



STEP 4

Carefully remove the hands from a standard quartz clock mechanism. Stick a thin paper shape (we used a hole reinforcer) onto the end of the second hand and refit it. Use double sided tape to secure the mechanism after installing a battery.

STEP 5

Carefully glue the alignment tube between the hinge and end of the upper arm – make sure that you only apply glue to the parts of the hinge that remain still with respect to the arm. Confirm the tube is aligned with the axis and tape it in position before the glue sets.

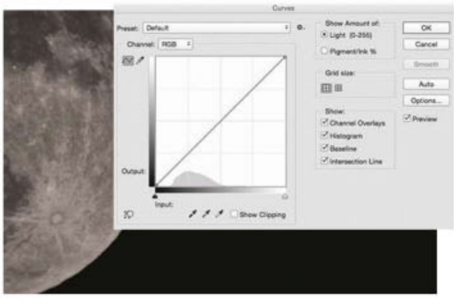
STEP 6

After checking that everything works smoothly, fix your camera mount to the upper arm, high up and close to the hinge. Check the balancing with your camera pointing in all directions. If the upper arm lifts up, a rubber band between the ends of the arms will help.

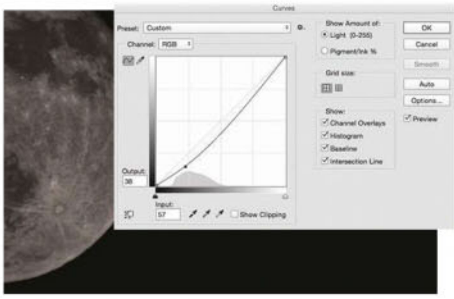
Image processing

An introduction to Curves

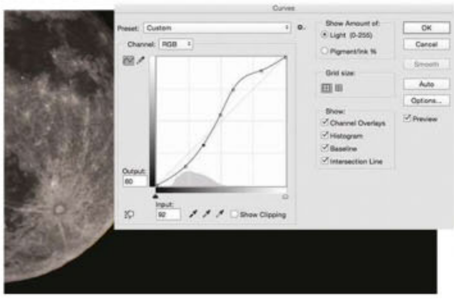
With **Ian Evenden**



▲ The Curves graph is initially linear; distorting this line brightens and darkens the image tones



▲ We started with an adjustment point near the bottom, dragging down to add contrast



▲ We added five adjustment points, but the max is 16; this is the Curve tool's great advantage

The Moon's craters and seas stand out nicely in our final image

At first glance, the Curves tool is an intimidating version of the Levels adjustment we looked at last month. They do a similar job, altering the brightness and contrast of your image. So why use Curves at all?

If you're a Photoshop Elements user you don't really have a choice: Curves only exists as an afterthought in that program. But in Photoshop or freeware alternative GIMP, it's a sophisticated tool.

Open your image –we're using the same one of the Moon as last month – then bring up the Curves window (click **Image** > **Adjustments** > **Curves**). When it first appears, you'll see an image histogram much like that of Levels, but with a graph superimposed over it. The graph will be linear: it's up to you to add the curves by manipulating the line to adjust the tones in your image. It offers up to 16 points of adjustment, its major advantage over Levels.

The X axis of the graph represents input (the tones in the image as they are at the time) with dark at the left and light at the right. The histogram shows how many pixels in the image are at a particular brightness. The Y axis is output (the tones as they will be after you confirm your changes). By moving the graph you alter the mapping between input and output tones, brightening or darkening specific tonal ranges in the image.

What this image of the Moon needs is additional contrast between its dark seas and brighter uplands, without clipping any light areas to pure white. The classic way to use Curves is to form the central line into an S shape, but on our Moon picture this pumps far too much contrast in. A shallow S with an additional point to straighten the curve in the midtones gives a better result, but we could have achieved this in Levels. Time for more points.

Starting in the bottom left of the graph, adding an adjustment point about a fifth of the way up and dragging it down with the mouse darkens the darker areas of the Moon. Higher up the graph, we add a point near the top and drag it upward to brighten the highlights. It's easy to see when highlights are clipping, as the graph flattens against the top of the window; holding Alt as you work for a more dramatic representation of unwanted pure white areas.

Adding a point halfway up the graph and moving it up, then points above and below that which are dragged up and down respectively, gives us a good contrast between the different areas of the Moon, and brings out details in the image.

Adding Curves as an adjustment layer allows you to turn the effect on and off at will, and changing the layer's blend mode to Luminosity allows you to alter brightness without messing up colour saturation. There's no reason not to experiment with these adjustments. Unless you save over your original image file you're not going to damage anything. Play around with Levels and Curves, and discover the combinations that make your images look great.

Ian Evenden is a journalist working in the fields of science, tech and photography

ALL PICTURES: IAN EVENDON

With **Steve Richards**

Scope DOCTOR

Our resident equipment specialist cures your optical ailments and technical maladies

I bought an EQ6 mount as part of my first setup, but am now having trouble polar aligning it. Can you help me?

MIKE SMITH

Like all equatorial mounts, the EQ6 SynScan must be polar aligned at the start of every observing session.

As a one-time operation, it is necessary to centre the polarscope's reticule. This is best carried out during the day by tilting your mount until the polarscope can be pointed at a fixed, distant object. Make sure that the declination axis is rotated so the hole in the fully extended counterweight shaft aligns with the polarscope exit.

Use the altitude and azimuth bolts to carefully centre the object on the crosshair of the polarscope's reticule and then rotate the right ascension axis through 180°. If the crosshair has moved off the fixed object, move the reticule by making tiny adjustments to the three Allen-head bolts that retain it until you have corrected half the error. Use the altitude and azimuth bolts to re-centre the object on the crosshair once again and repeat the process until there is no apparent movement of the crosshair on the distant object when you rotate the right ascension axis.

The polarscope can now be used to get a reasonably accurate northern hemisphere alignment. Rotate the right ascension axis until Cassiopeia and the Plough are at the correct orientation with regard to the night sky and then align the star Polaris in the tiny circle on the reticule.

The polarscope's red LED can be dimmed by selecting 'Utility Function' – 'Polarscope LED' on the handset.

Polar alignment is fiddly, but an essential step prior to observing with an EQ6

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STEVE'S TOP TIP

What is a Plössl eyepiece?

The Plössl is a good general-purpose eyepiece that usually comprises four glass elements in two groups of doublets, each doublet having a convex and a concave element sandwiched together. They can be produced reasonably cheaply, although it has to be said that some of the eyepieces bundled with beginner telescopes are of questionable quality.

The Plössl design results in an apparent field of view of around 52°, which is adequate for many observations. Its chief disadvantage is its eye relief, which is roughly 75 per cent of its focal length. This means that with short eyepieces, your eye has to be very close to the optical elements, which can be uncomfortable.

I can't get a full lunar disc image using a ZWO ASI120MC-S camera on my Celestron C8 telescope. What am I doing wrong? Would a Barlow lens help?

RON PASHLEY

You're not doing anything wrong at all. Unfortunately, your telescope's focal length and the size of your camera's sensor only produce a very small field of view.

Your camera has an Aptina AR0130-CS CMOS sensor with an imaging area that's 4.83mm wide by 3.63mm deep which, combined with your telescope's focal length of 2,032mm, yields a field of view that's just 8.2 arcminutes wide and 6.1 arcminutes deep. The angular size of the Moon is roughly 30 arcminutes so your imaging system can only capture a small portion of the Moon at any one time.

A Barlow lens would act as an amplifier, making the situation worse. What might help is a focal reducer, which would shrink the telescope's focal length and reduce its magnification. Celestron makes a 0.63x focal reducer and Meade produces a 0.33x one, but even the latter wouldn't allow you to image the whole of the Moon's disc. The solution is to purchase a second telescope – one with a focal length of 500mm or less.

The Moon's too big for a ZWO ASI120MC-S camera and Celestron C8 scope combo

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
Teleskop Service's new astrograph tackles the three-lens problem

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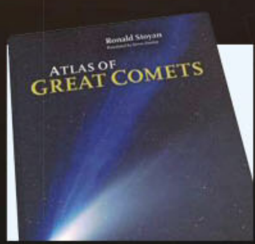
This month's reviews



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

FIRST light

See an interactive 360° model of this scope at www.skyatnightmagazine.com/ImagStar100Q

TS Imaging Star 100Q 4-inch apo astrograph

A smart approach to optics delivers a flat field straight out of the box

WORDS: STEVE RICHARDS

VITAL STATS

- **Price** €2,570
- **Optics** FPL-53 ED glass quadruplet
- **Aperture** 100mm (4 inches)
- **Focal Length** 580mm (f/5.8)
- **Focuser** 3-inch dual-speed 10:1 rack and pinion
- **Extras** Aluminium flight case
- **Length** 488mm with focuser, 588mm with focuser and dew shield extended
- **Weight** 4.53kg
- **Supplier** Teleskop Service
- **Tel** +49 891 892 870
- **www.**teleskop-express.de

WWW.THESECRETSTUDIO.NET X 5

Desirable though apochromatic refractors may be for astrophotographers, they can be very expensive, especially once you pass 3.5-inch apertures. However, Teleskop Service has released a new quadruplet apo with an aperture of 4 inches, claiming a very flat field of view, at an appealing price.

This instrument is supplied with tube rings in a well-constructed aluminium flight case, but the choice of dovetail bar is up to the owner. We used a Losmandy-style dovetail bar for this review. Similarly, although an industry standard finderscope shoe is included, you will need purchase a finderscope separately.

The telescope tube is unbaffled but flocked in black to reduce unwanted reflections and increase contrast. Likewise the dual-speed rack and pinion focuser's tube is internally ridged with a deep matt black finish to reduce reflections. As well as the now standard 2-inch eyepiece holder with 1.25-inch eyepiece adaptor (both of which make use of anti-marring brass collars) the focus tube has a removable end section.

Unscrewing the 2-inch eyepiece holder reveals a 68mm female thread, which you could use to screw in an adaptor with a male T thread and thus attach imaging equipment. The advantage of a screw-fit connection for your astrophotography gear is that there is far less risk of tilt or flexure in comparison with a push-fit connection, leading to more uniform star shapes across the field of view.

SKY SAYS... The focuser supported our camera securely with no slippage and it was easy to achieve focus

Twin dual-element optics

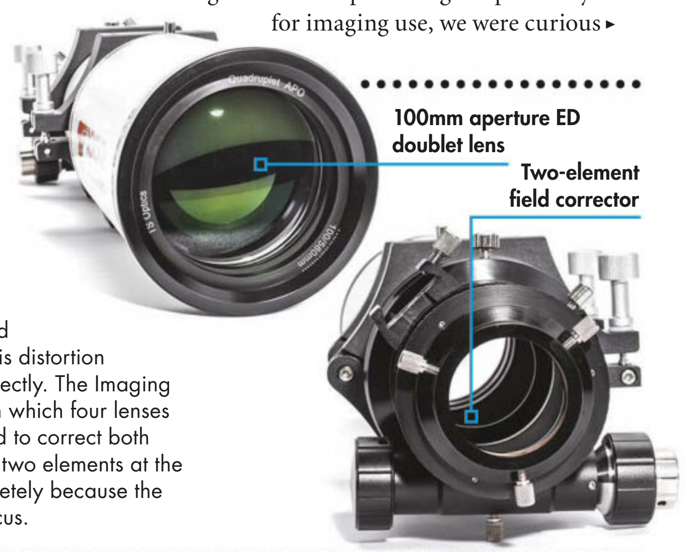
The optical elements of the Imaging Star 100Q are arranged in two groups of fully multicoated lenses, comprising a doublet primary lens with an ED (extra-low dispersion) glass element at the front and a two-element correcting lens just in the front of the focuser. The multicoating was blemish-free and evenly applied. The optics produce a focal length of 580mm (f/5.8) resulting in a generous field of view 2° and 11 minutes wide by 1° and 27 minutes deep when used with a camera with a typical APS C sized sensor DSLR cameras. To put this into some perspective, this field of view would be sufficient to capture the Witch's Broom Nebula and Pickering's Triangle, or the Rosette Nebula, in a single frame.

Although this telescope is designed primarily for imaging use, we were curious ▸

DISPENSING WITH THE TRIPLE TROUBLE

The TS Imaging Star 100Q has, as its name implies, been specifically designed with astro imaging in mind. All astrophotographers want their telescopes to have well colour-corrected optics and a flat field of view. Apochromatic refractors commonly have a triplet lens designed to produce a colour-fringe free view by ensuring that red, green and blue light are all brought to focus at the same distance from the lens.

However, triplet refractors still suffer from field curvature showing elongated stars in the corners of the image frame. External field flatteners can correct this distortion but spacing of the camera sensor becomes very critical for these to work correctly. The Imaging Star 100Q resolves these issues by implementing a quadruplet type design in which four lenses (one of which is made from FPL53 Ohara extra-low dispersion glass) are used to correct both chromatic aberration and field curvature. In this quadruplet design, there are two elements at the front of the telescope and two at the rear. Spacing issues are obviated completely because the correct spacing of 150mm is achieved automatically when the image is in focus.



RACK AND PINION FOCUSER

A substantial focuser is a prerequisite for an imaging telescope and the 3-inch rack and pinion focuser is certainly that. The focuser is very smooth in operation with 46mm of travel and a 10:1 reduction drive, yet it was capable of supporting the weight of our imaging equipment with no slippage.

RETRACTABLE DEW SHIELD

The telescope has a retractable dew shield that also impedes stray light. The interior of the shield is finished in a black flock material to reduce reflections and once extended by 100mm it can be locked in position by a single thumbscrew. The overall fit could have been a little tighter.

CNC TUBE RINGS

The supplied pair of CNC-machined tube rings have secure hinges and easy to lock fastening knobs. Threaded holes on both top and bottom surfaces allow for the attachment of a dovetail bar and other accessories.

FINDERSCOPE SHOE

A substantial finderscope shoe is attached to the focuser. This shoe held both our Synta-manufactured finderscope and our Altair Astro finder-guider very firmly, despite having just a single thumbscrew for tightening. A wide range of other finder devices, including some red-dot variants, will also fit this standard shoe.

FIRST light

ALUMINIUM FLIGHT CASE

The telescope is supplied in an aluminium flight case with a tightly sculptured interior that includes cut-outs for the two tube rings. This holds the telescope snugly, giving a high degree of protection. Externally there are two lockable clasps and a comfortable carrying handle.

SKY SAYS…
Now add these:

1. iOptron CEGM mount
2. TS Deluxe 60mm guiding-finderscope
3. TS Professional 2-inch L-RGB CCD interference filter set

▲ **Our composite of the Triangulum Galaxy, M33, from nine 600-second exposures**

▲ **Our shot of M42 consists of 18 images at 300 seconds and 11 images at 100 seconds**

WWW.THESECRETSTUDIO.NET, STEVE RICHARDS X 2

▸ to see how well it performed as an observing instrument, so we added a 2-inch dielectric star diagonal with 17mm and 8mm eyepieces. A star test showed an excellent extra-focus Airy disc, but a rather muddy intra-focus disc indicating some over-correction, although this did not seem to spoil our observations, with star shapes remaining excellent to over 90 per cent of the field of view. We enjoyed excellent views of the Pleiades open cluster in Taurus, open cluster M35 in Gemini and the Orion Nebula, but the highlight was the beautiful double star Almach with comet C/2014 Q2 Lovejoy in the same field of view. They were separated by just 49.5 arcminutes through our 17mm eyepiece.

Moving on to imaging we attached our APS C sized one shot colour CCD camera to the telescope, along with a 60mm finder-guider to perform our autoguiding. We captured a series of images of the Triangulum Galaxy, the Orion Nebula and the Rosette Nebula despite the rather murky sky conditions during the review period, and these confirmed that the Imaging Star 100Q does indeed produce a very flat field of view right into the corners of the frame when using a APS C size sensor, although very close scrutiny of the stars showed the tiniest hint of pinched optics.

The rack and pinion focuser supported our imaging camera securely with no slippage and it was easy to achieve focus using the 10:1 reduction microdrive and a Bahtinov mask. The TS Imaging Star 100Q should certainly be on the shortlist of any astrophotographer looking for a refractor that provides a very flat field of view straight out of the box. Ⓢ

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

FIRST light

See an interactive 360° model of this mount at
www.skyatnightmagazine.com/VixenSX2

Vixen SX2 equatorial mount with Star Book TEN controller

A superb hand controller and clever mount design make Vixen's SX2 a joy to use

WORDS: PAUL MONEY

VITAL STATS

- **Price** £2,447
- **Mount** Computerised EQ Go-To
- **Max capacity** 12kg
- **Controller** Star Book TEN with Advance Unit
- **Database** 272,342 objects including the Sun, Moon and planets, and the Messier, NGC and Caldwell catalogues
- **Power requirements** DC12V 0.3A~2.0A via powertank or mains adaptor
- **Extras** Polarscope, 1.9kg counterweight
- **Weight** 7kg (mount only)
- **Supplier** Opticron/Vixen UK
- **www.vixenoptics.co.uk**
- **Tel** 01582 726522

WWW.THESECRETSTUDIO.NET X 6

The SX2 equatorial mount is the latest basic model of the Vixen Sphinx series, suitable for small to medium sized telescopes up to 12kg. It is supplied with one 1.9kg counterweight, a polarscope and the Star Book TEN hand controller with Advance Unit for £2,447; an alternative package (not reviewed) without the polarscope and with the Star Book ONE controller is available for £1,449.

The SX2 mount is beautifully engineered, much as we've come to expect from Vixen. It is designed so that the RA body also acts as a counterweight with the cabling and electronics tucked away inside it, a nice feature that cuts down on the number of counterweights you need to balance your chosen telescope. Mounting the SX2 on a tripod was straightforward, and on the underside of the RA body are the ports for attaching the hand controller via a serial cable, power socket for the supplied cigarette power lead and an on-off switch. The top of the dec. axis head has a Vixen-style dovetail mounting block with a large retaining bolt, and a smaller bolt for safety when installing your telescope. For our tests we used a Sky-Watcher Equinox 80ED refractor for wide-field views and a Sky-Watcher SkyMax 180 Pro Maksutov for higher magnification views as they both have Vixen-style dovetail bars.

SKY SAYS...
The Go-To results were impressive: all of our targets were in the central 15 per cent of the view

Adjustment for latitude has a range of 0-70° and rough alignment has three main settings: high, medium and low. These have a range of 15° and for our latitude of 53°N we had to set it to the high range. To achieve polar alignment we used both the large altitude knob to fine tune the latitude using the engraved scale, and the polarscope. Azimuth adjustment was straightforward, achieved via the front two knobs. We were impressed with the polarscope as, unlike most other designs, you don't have to rotate the whole mount in RA; instead you set the time and date on the polarscope scale then adjust Polaris to the marked position in the illuminated view.

Testing the tracking

Once aligned we powered up the system and, using the easily readable display of the Star Book TEN controller, we set the scope at the home position looking due west. On the controller there are the usual basic settings for your latitude and location, and once set these are retained thanks ▸

HIGH-POWERED ADVANCES

The Star Book TEN controller is enhanced by the addition of the Advance Unit, which adds even more options via the Expansion Function menu. The unit has two 3.5mm jack ports, one for video in and one to control a DSLR camera. With a suitable cable you can attach a CCD camera, such as Vixen's C0014-3M. When activated in the menu, this enable you to use the Star Book TEN as a guiding system controlling the mount and with live on-screen views of the guide star. It also allows full screen live views of bright objects such as planets and even the brighter deep-sky objects such as M3.

The Advance Unit also has a slot for an SD card, which enables you to record the views captured for later processing. The 3.5mm jack for a camera allows you to programme the length of exposure, the interval between exposures, the number of exposures to be taken and a mirror lock function. The inclusion of a USB port provides for the possibility of further expansion with future unspecified equipment.

MOUNT PORTS

The ports on the mount appear to be limited, but all you need is here. There is a port for the Star Book TEN hand controller (a D-SUB 9-pin male plug) and a DC 12V power supply connector. An on-off switch completes the line up.

MOUNT BODY

The electronics and cabling are inside the RA housing body, which enables it to act both as a built-in counterweight and tidies up the clutter of cables that can sprout from Go-To mounts. This means that many small and lightweight scopes may not even require a counterweight.

ALTITUDE AND AZIMUTH ADJUSTMENT

The adjustment knobs for both azimuth and altitude were nice and chunky to grip and gave fine control over the adjustments. The altitude adjustment can be set from 0-70° and has three main zones, with a 15° range of adjustment per zone, as well as an engraved scale.

POLARSCOPE

Achieving accurate polar alignment is vital for ensuring accurate Go-Tos and good tracking during long exposure astrophotography. The polarscope has a bubble level, and dates and times engraved on it. This means that you just need to set the date and time to your night's viewing and then move Polaris to the required spot for polar alignment.

TRIPOD NOT INCLUDED

FIRST light

► to the in-built battery. We were able to select up to 20 stars for alignment, giving great accuracy.

For our tests we chose planetary targets such as Jupiter and the Moon, as well as deep-sky targets from Messier, NGC, IC and SAO star catalogues over a large area of the sky. The Go-To results were impressive: in our 26mm eyepiece using the Equinox 80ED, all of our chosen targets were placed in the central 15 per cent of the view; on most occasions they were virtually centred.

The Star Book TEN controller has a 5-inch LED back-lit display with 0.3 megapixel (800x480 pixels) format resolution. It is menu driven, with clear, well defined subjects. This fully featured planetarium has two chart modes, Scope and Chart. Scope points the mount directly with the control buttons to any place in the sky, while Chart enables you to explore the sky chart and choose a target.

In the end we had so much fun exploring what the Scope and Chart modes could achieve that several hours elapsed in no time at all. The Star Book TEN came with the new Advance Unit installed (see page 96) and it really enhances the controller and mount capabilities so much so that we were reluctant to part with it. S

VERDICT

ASSEMBLY	★★★★☆
BUILD & DESIGN	★★★★★
EASE OF USE	★★★★★
TRACKING ACCURACY	★★★★☆
STABILITY	★★★★★
OVERALL	★★★★★

STAR BOOK ONE

The mount is also available with a less feature-rich controller, the Star Book ONE, which has a 22,725 object Go-To database, plus tracking and slewing control.

SKY SAYS…

Now add these:

1. Vixen SXG-Hal130 tripod

2: Vixen colour CCD camera C0014-3M

3: Vixen ED81SII refractor

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STAR BOOK TEN

The Star Book TEN hand controller has a full-colour LCD screen (800x480 pixels) with a huge range of menus and functions to control the mount. It has two operational modes, an ST-4 compatible autoguider port, serial port to connect it to the mount and an expansion bay incorporating the Advance Unit.

TRIED & tested

We review well-established equipment that's stood the test of time

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

VITAL STATS

- **Price** $849.99
- **Sensor** 1/3-inch Kodak Exmor scientific grade IMX035LQR
- **Dimensions** 100x50x50mm
- **Ports** Analog & HD-SDI digital outputs, RS-485 I/F connection, power input socket
- **Weight** 300g
- **Software** Third-party control software available
- **Supplier** www.mallincamusa.com
- **Tel** +1 985 863 2165
- **www.**mallincam.net

SKY SAYS... The Mallincam Signature is a fantastic outreach tool for groups of people to experience the night sky

Mallincam Signature HD colour video camera

Bringing the cosmos to your living room live in high definition

WORDS: MARK PAYNE-GILL

Recent advances in camera technology have created exciting times in the field of video astronomy. It is now a very popular observing medium for many amateur astronomers. At the forefront of this observing revolution, Mallincam produced the first standalone, high-definition astronomical video camera, designed specifically for live solar, lunar and planetary observing and without the need for a computer. The Signature HD on review here was ahead of its time in that it used the same digital technology standards as used by the broadcast industry. But has it stood the test of time in this growing market?

Our tests took place over a few nights of excellent seeing around a first quarter Moon. We attached the camera to a 14-inch telescope and used the supplied BNC video cable to connect it to our monitor's HD input. The on-screen menu is accessed by holding down the central button on the rear of the camera body; navigating it is straightforward, using the other four menu buttons to move around and change settings. The most important settings are shutter, gain and gamma, which control exposure and contrast.

Aiming at the Moon, the monitor initially showed a washed out, overexposed image. This was soon corrected by shortening the exposure time from 1/25th of a second to 1/180th, and checking that the gain setting, which adjusts the sensor's sensitivity, was set at zero. As we fine-tuned the settings, the Moon's image snapped into perfect focus on our monitor.

Digital eye

Features along the terminator were defined with breathtaking clarity. Jagged shadows on the floor of crater Plato revealed the shape of its eastern wall, while the crater walls of Copernicus showed a wealth of detail, along with a fine daisy chain of small craters that could be seen weaving along the Moon's surface to the west of this iconic feature. Contrast was a little high as we viewed farther away from the terminator, with highlights too bright. This was brought under control by changing the gamma setting from LCD to CRT. We noticed a slightly pinkish tint, but adjusting the colour setting allowed us to correct this giving a more pleasing neutral grey. Apart from some noise visible in the shadow areas the live uncompressed HD ▸

OWNER'S OBSERVATIONS

Name Mark Payne-Gill
Location Chew Magna, Bristol
Equipment Mallincam Signature HD colour video camera
Owner since April 2011

"As a professional cameraman I became intrigued to see if it was possible to film the Moon and planets with affordable professional broadcast equipment. I discovered the Mallincam Signature was able to do exactly this. I bought my first one four years ago and now own three, which I regularly use in my role as the main specialist cameraman for *Stargazing LIVE*. This camera still stands out with its professional grade sensor and outputs. The standard definition output produces great images in its own right, but the HD signal produces an image quality that is in a different league and well worth the extra outlay for viewing on a professional HD monitor. I've found it essential to add a flip mirror system for quick object finding and centering and often use it in conjunction with a 0.5x focal reducer to give wider views not possible with the small sensor.

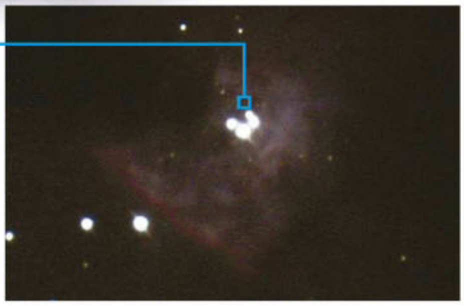
The fine detail visible during good seeing can be mind blowing and I love using the camera as an outreach tool, sharing live footage of the Moon, Sun and planets to inspire large audiences."

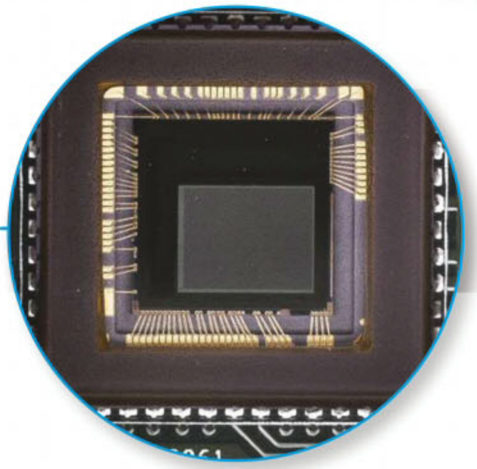
BODY OF CAMERA

The Signature is compact, lightweight and has excellent build quality. As is typical with a security style camera it has a C mount lens port and is supplied with a threaded 1.25-inch nosepiece that accepts filters.

FRAME RATE

With shutter speeds from 1/10,000th of a second to eight seconds, the Signature has dynamic exposure range and is even capable of recording the brightest deep sky objects. The heart of M42 revealed detailed nebulosity around the Trapezium cluster, although in slow shutter mode the commands take as long as the exposure time to execute.

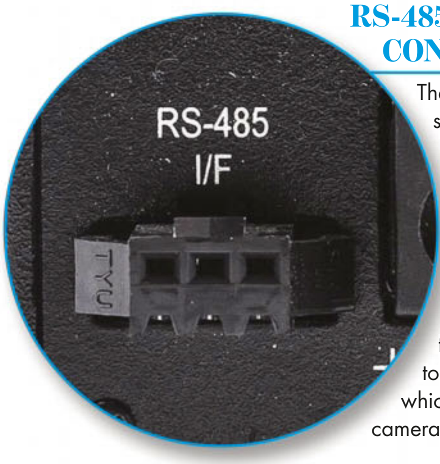




SENSOR

The Kodak Exmor IMX035LQR is a scientific grade 1/3 inch CMOS sensor at 1.49 megapixels. Its small size is the equivalent of a 7mm eyepiece, giving an ideal image scale for close-up views. It has a multitude of formats from 1080p25 to 720p50, selectable between PAL and NTSC, and outputs a professional 3G/HD-SDI signal.

TRIED & tested



RS-485 I/F CONNECTION

The Signature is designed as a standalone live video camera and as such no software is supplied. However, third party software is available for computer control via the rear RS-485 I/F connection. This has the benefit of granting access to the menu without having to reach for the rear buttons, which can cause distracting camera shake.

PORTS/CABLES

A convenient dual-shielded cable provides both separate power to a 12V input and data connection to the HD-SDI port. As well as an HD output, there is a second port that produces a standard definition signal. This is useful for connecting to a monitor for framing and focusing while simultaneously recording the HD output.

▸ image was almost equal to the eyepiece view seen with our own eyes!

We switched to a more modest 4-inch telescope to see how the Signature performed with Jupiter. We needed to increase the exposure to 1/25th of a second and added some contrast by changing the gamma back to LCD. This darkened the image slightly, so we added some 4dbs of gain to correct it, although this added some noise. The seeing had deteriorated but we could still make out some fine detail in the cloud belts and both Europa and its shadow were clearly visible crossing in front of the planet itself. We were impressed – it gave a very similar view to that through the eyepiece.

Staring at the Sun

We couldn't resist trying out our hydrogen-alpha telescope to see how the Signature could handle the Sun's subtle surface features. Adjusting the gamma setting to one, the contrast setting to its highest and fine tuning our solar scope's etalon, we saw fantastic detail with prominences around the edge of the Sun's disc, as well as filaments, fine granular surface detail and bright active regions around sunspots. It was an incredible wealth of texture and detail, live and in high definition. It looked better than our eyepiece views.

Beginners without technical video knowledge might struggle to grasp the principles not covered in the instruction manual, but even so the Signature is a great tool that could replace the eyepiece given its rewarding live views. Useful for those who find observing through an eyepiece uncomfortable, it also makes for a fantastic outreach tool for schools and star parties as groups of people can experience the night sky whatever is on show at the same time. Considering it's been around for nearly six years, the Signature is a great camera that can easily hold its own against the competition. Ⓢ

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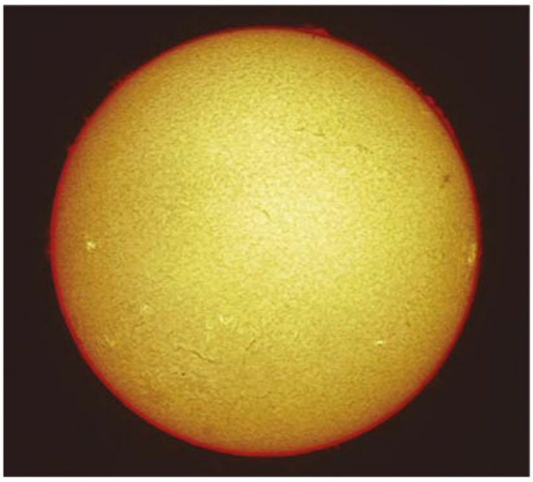
▲ The Mallincam Signature reveals great detail in the crater walls of Copernicus in this single frame; only minimal constrast tweaks have been made



◂ A single frame of the Sun in hydrogen-alpha with slight colour and contrast enhancement

VERDICT

BUILD AND DESIGN	★★★★☆
CONNECTIVITY	★★★★☆
EASE OF USE	★★★★☆
FEATURES	★★★★★
IMAGING QUALITY	★★★★☆
OVERALL	★★★★☆

SKY SAYS...
Now add these:
1. 0.5x focal reducer
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★★★★☆ Good
★★★☆☆ Average
★★☆☆☆ Poor
★☆☆☆☆ Avoid

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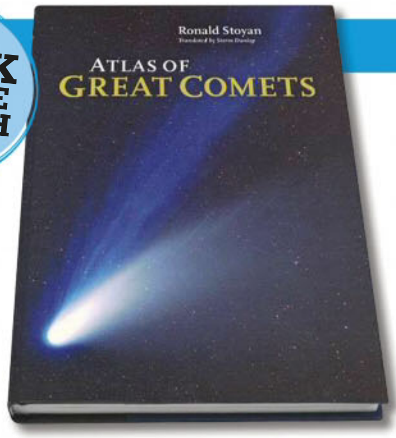
BOOK OF THE MONTH

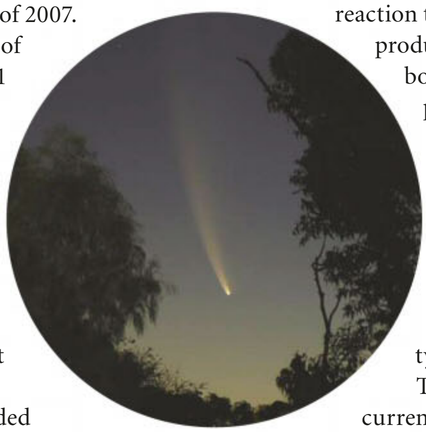
Atlas of Great Comets



Ronald Stoyan and Storm Dunlop
Cambridge
£35 ● HB

Despite the inclusion of "the fiasco of the Century" and a magnitude +12.0 comet that few people at the time ever saw, it is difficult to find anything contentious about the selection of comets for this book. After a comprehensive and thorough introduction that covers historical, mythological, cultural, literary, artistic and scientific aspects of comets, *Atlas of Great Comets* deals, in detail, with 30 icy visitors of modern times, beginning with the Great Comet of 1471 and ending with Comet McNaught of 2007.

All seven apparitions of Comet Halley from 1531 to 1986 are included, and all the comets but one were visible to the naked eye. The exception is Comet Shoemaker-Levy 9 of 1994, while the "fiasco" was C/1973 E1 Kohoutek; although it did not meet public expectations, Kohoutek greatly extended cometary science.



McNaught, the Great Comet of 2007, peaked at around mag. +5.5

ISTOCK

For each comet, important astronomical and orbital data is followed by accounts of its discovery, visibility and public reaction to its apparition. This is illustrated with a chart for each comet and numerous drawings or photographs of the comet itself. For older comets, these include reproductions from contemporaneous paintings, engravings and news broadsheets. Author Ronald Stoyan also discusses the effects of comets on human imagination, ranging from ancient superstitions to modern conspiracy theories.

Storm Dunlop's skill at translation has enabled Stoyan's detailed knowledge and understanding to shine through; you could be forgiven for thinking that the book was originally written in English. Unfortunately, the mostly German text in the broadsheet images is not translated, although the contents are summarised in the accounts of public reaction to each comet. The production quality of the book is excellent. The paper quality is good and the colours in reproductions of paintings and photographs are faithful to the originals.

There are very few typographical errors. There is no other current book of this kind. Whether you want a lavishly illustrated large format coffee-table book, a cultural history of comets, or clearly written accounts of fundamental cometary science, *Atlas of Great Comets* could give you pleasure for years to come.

★★★★★

STEPHEN TONKIN *writes our* Binocular tour *each month*

Reader price £31.99, subscriber price £29.99
P&P £1.99 Code: S0515/1 (until 22/06/15)

TWO MINUTES WITH STORM DUNLOP

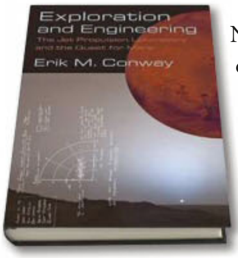
Why are comets so important historically?
In antiquity, comets were regarded as phenomena in the upper air. It was the realisation that they were beyond the orbit of the Moon that helped to bring about the recognition that the orbits of objects in the Solar System were not centred on the Earth, but on the Sun. Somewhat similarly, the work by Edmond Halley on cometary orbits, and the prediction of the return of 'his' comet – albeit after his own death – helped to confirm that Isaac Newton's theory of universal gravitation was correct. Nowadays, our interest in comets is primarily because they offer the chance of investigating material that has remained essentially unchanged since to formation of the Solar System.

What makes comets 'great'?
There are various reasons why some comets are considered 'great'. They may be spectacular, with bright heads and long, bright tails and are thus visible to large numbers of people. They may perhaps be visible for very long periods – so long that they create a great impression on even casual observers. Perhaps the most important reason is when they bring about a change in the ideas held by the general public – a change from superstition to a belief that they are an understandable natural phenomenon, for example – or when they produce a major change in scientific knowledge of comets or of the Solar System as a whole.

STORM DUNLOP *is an author and translator specialising in astronomy, meteorology and geology*

Exploration and Engineering

Erik M Conway
Johns Hopkins University Press
£22.50 ● HB



NASA's Curiosity rover is climbing Mount Sharp. Opportunity is still active, more than 10 years after its landing on Meridiani Planum. The Mars Reconnaissance Orbiter provides us with high-resolution images of the surface. With all these successes, it's easy to forget that Mars exploration hasn't always been so smooth.

In *Exploration and Engineering: The Jet Propulsion Laboratory and the Quest for Mars*, JPL historian Erik Conway delves into the history and background of every NASA Mars mission between Mars Observer (launched in September 1992) and Phoenix (August 2007). It is a great tale of ambition, mishap and recovery, building on extensive archival research and interviews with JPL managers, scientists and engineers, to deliver a detailed overview of each mission's feats and failures.

NASA's darkest year as far as Mars missions go may have been 1999, when both the Mars Climate Orbiter and the Mars Polar Lander were lost. Luckily, the book ends in a more positive tone, highlighting the Mars Reconnaissance Orbiter, the Spirit and Opportunity robotic geologists, and the Phoenix lander, although Conway worries about the diminishing funds for Mars exploration.

Exploration and Engineering is a great book for everyone seriously interested in the struggles and achievements of JPL as NASA's centre for Mars exploration. Don't expect a thrilling writing style or spectacular colour photographs, though. Other books bring you Mars as an exciting destination; this book brings you the nitty-gritty details of how hard it is to get there in the first place.

★★★★☆

GOVERT SCHILLING *is an astronomy writer and author*

Reader price £18.99, subscriber price £17.99
P&P £1.99 Code: S0515/2 (until 22/06/15)

New Space Frontiers

Piers Bizony
Zenith Press
£23 ● HB

Are the best days of space exploration far behind us, or is humankind on the verge of a whole new era? Opinion is split on the question – not least in the space industry. In his latest book, aerospace historian Piers Bizony makes a solid case for optimism, and does so in fine style.

Pointing out that there are more people-carrying spacecraft under construction today than at any time since the Space Age began, Bizony takes the reader on a wide-ranging tour of the possible shape of space to come, covering both government projects and commercial companies seeking profits from the high frontier.

Current and future manned spacecraft are detailed first, followed by 'near space' endeavours such as Virgin Galactic's suborbital space tourism and stratospheric balloons, space stations and plans for settlement on the Moon and Mars. A final chapter focuses on Earth- and space-based astronomy, our only practical means of probing the furthest reaches of the cosmos.

New Space Frontiers boasts excellent design and well-chosen imagery; almost every spread could be framed and hung on a wall. Bizony does a good job of highlighting how the space sector is changing: commercial spaceflights are already almost routine, although NASA remains their main customer for the time being. One criticism is that not enough differentiation is made between tangible, fully-funded projects, and more aspirational designs. The UK's Skylon spaceplane, for instance, has amassed impressive technical breakthroughs, but still remains several decades, and many billions of pounds, away from completion.

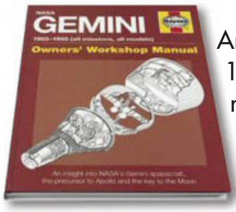
★★★★☆

SEAN BLAIR *writes for the European Space Agency website*

Reader price £18.99, subscriber price £17.99
P&P £1.99 Code: S0515/3 (until 22/06/15)

NASA Gemini Owners' Workshop Manual

David Woods and David Harland
Haynes
£22.99 ● HB



America had only 15 minutes of manned spaceflight experience when President John F Kennedy challenged the country to put a man on the Moon. With so much to do, NASA could not afford to wait until the Apollo hardware was ready to start putting theory into practice. With 10 manned launches in just 20 months, Gemini taught NASA how to operate in space.

Haynes has taken the format familiar to home mechanics and applied it to this often overlooked programme. The authors start with a short history to set the scene. America was behind the USSR in a race for space at the height of the Cold War. They then take us through each of the major systems, from ejector seats to retro rockets, as well as explaining the military interest, docking target and ill fated wing landing system, with plenty of anecdotes from those involved.

The clear illustrations and exploded views that Haynes are know for are here in force. Complex systems and concepts are broken down and leave the reader feeling that they have learnt some rocket science along with the human story. David Woods, who excels at explaining complex ideas, and David Harland, with his eye for detail, work seamlessly to tell this fascinating tale. Whether you are interested in Gemini in particular or manned space flight in general, there is much to recommend this entertaining and educational volume.

★★★★★

MARK BOWYER *is an expert in the US manned space programme*

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Elizabeth Pearson rounds up the latest astronomical accessories

[redacted]

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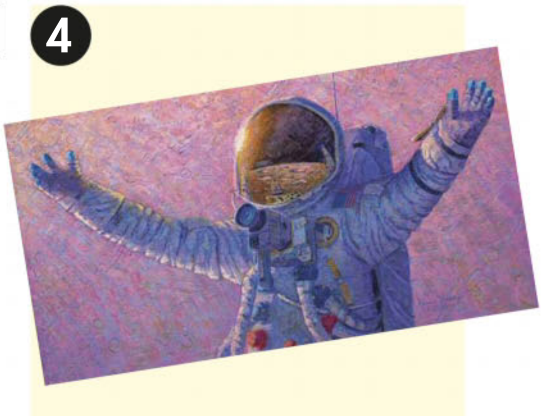

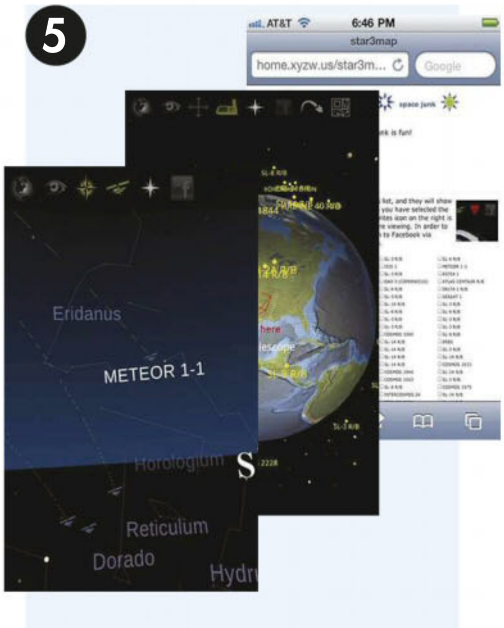

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WHAT I REALLY WANT TO KNOW IS…
Is a dark galaxy behind the Milky Way?

Sukanya Chakrabarti's detective work suggests a previously unknown dwarf companion with few stars but a lot of mass

INTERVIEWED BY PAUL SUTHERLAND

Our Milky Way has long been known to have some close companions, in particular the Large and Small Magellanic Clouds, first recorded in the 16th Century. But in more recent times, other neighbouring dwarf galaxies have been identified that are much fainter and less obvious. One, the Sagittarius Dwarf Galaxy, is nearly as large as the LMC, but was only discovered in 1994. That is because it lies just 14° from the plane of the Milky Way; it had been hidden by intervening dust and gas.

Hundreds of similar dwarf galaxies, each around a thousandth the mass of our Galaxy but dominated by dark matter, have been predicted to exist. But to date we've still confirmed fewer than 30 around our own Galaxy – though a new Dark Energy Survey has begun identifying new candidates. The Milky Way's gas and dust is a huge barrier to finding dwarf galaxies close to the plane.

Chasing ripples in a pond

The smallest dwarf galaxies found recently can have as few stars as a single star cluster, but dark matter means their total mass is large. Because they are very dim, we need a way to hunt them that doesn't rely on visible light. I found that this can be done by analysing the gravitational effects they exert – which lead to density perturbations, or 'ripples' in galactic discs.

The way we infer the presence of dark matter is by measuring the velocities of the few stars we see. It is the same technique we use to identify dark matter in spiral galaxies; we look at how objects move at different distances from the centre. Back in the 1970s, astronomers measured the rotation curves in spiral galaxies – the speed at which material circles a galaxy in relation to its distance from the centre. And they found that the rotation curve continues to be fairly flat out to large distances. If all the matter in the spiral galaxy were simply due to the visible stars alone, with no dark matter, then the rotation curve would not have been flat, it would have dropped much more steeply. This was really the breakthrough that led to the inference of dark matter.

There are large ripples in the outskirts of our Galaxy's gas disc that can't be accounted for without an interaction with a companion. In my earlier work, I was able to predict the location and mass of the perturbing dwarf galaxy that could produce these ripples. It is like looking at ripples in a pond and using them to work out how large the pebble was that produced them.

I tried to find this dwarf galaxy last year. I knew it wouldn't be easy, as it was predicted to be close to the plane of the dusty Milky Way. But I used observations from a survey made with ESO's VISTA telescope in Chile. Because VISTA sees in infrared light, it can look deeper into the otherwise opaque gas and dust. This allowed me to look for particular tracers called Cepheid variables, pulsating stars that obey a period-luminosity relationship. If you measure the period of a pulse, you can figure out how far away they are quite accurately. So they make good distance markers.

I studied a number of Cepheids, plus some luminous 'red clump' stars that also make good distance markers, and they allowed me to figure out their distance to about 300,000 lightyears, which is far beyond the disc of the Milky Way. This was the distance I had predicted back in 2009 for the dwarf galaxy, so that was really exciting.

The separation between the stars in the dwarf galaxy is small, which tells us it is part of a gravitationally large structure. Early estimates put its mass at one hundredth that of the Milky Way, suggesting it is 90 per cent dark matter. Further studies of the motions of its stars will give us a more accurate determination.

Early estimates suggest that the predicted galaxy could be 90 per cent dark matter

ISTOCK X 2

ABOUT SUKANYA CHAKRABARTI
Dr Sukanya Chakrabarti is an expert in galaxy evolution at the Rochester Institute of Technology in New York, where she looks for clues to help find our invisible cosmic neighbours.

UK Retailer Guide

Find the right one for you: buy your telescope from a specialist retailer

It is quite easy to become daunted by the vast array of equipment that is available to today's amateur astronomers. Different makes, different models, different sizes and optical arrangements – if you're new to the hobby, how do you make sense of all these details and find the telescope that will show you the Universe?

The answer lies in buying from a specialist retailer – somewhere that really knows what they're talking about. Like the retailers in this guide, they'll have the practical knowledge that will guide you towards the scope that won't end up gathering dust in a cupboard.

Today there are over 1,000 models of telescope to choose from – refractors and reflectors, Dobsonians and Newtonians, Schmidt- and Maksutov-Cassegrains. And just as important as the telescope is the mount it sits on; but do you go for equatorial or altazimuth, manual or Go-To? And what about accessories like eyepieces and finderscopes?

That's certainly a lot to consider before making a decision, but a specialist retailer will help you make that decision, taking important considerations like portability, construction and price into account.

So if you need friendly, face-to-face advice and excellent aftersales service, free from biased opinions, specialist telescope retailers are the place to go for a helping hand through the technical literature and tables of figures. They'll help you find a scope that combines quality and convenience at a price that's right.

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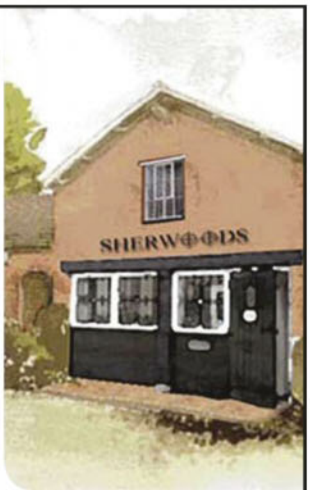

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The Southern Hemisphere in May

With Glenn Dawes

WHEN TO USE THIS CHART

1 MAY AT 00:00 UT
15 MAY AT 23:00 UT
31 MAY 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.

MAY HIGHLIGHTS

The Moon has some impressive conjunctions in the evening sky this month. On the 5th, the near-full Moon is 4° from Saturn and forms a straight line with mag. +1.1 Antares (Alpha (α) Scorpii). On the 21st, the thin crescent Moon, Venus and mag. +1.9 Castor (Alpha (α) Geminorum) are in alignment. The following night the Moon is directly above Venus. More encounters follow: our close companion passes 5° from Jupiter on the 24th and 3° from mag. +1.4 Regulus (Alpha (α) Leonis) on the 25th.

STARS AND CONSTELLATIONS

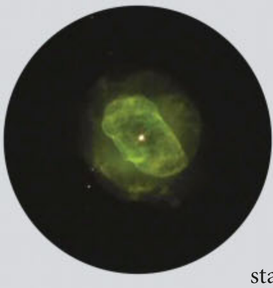
Lupus, the Wolf, is in the southeast evening sky, embedded in the Milky Way between Centaurus and Scorpius. It is a bright constellation, although the pattern formed by its 2nd- and 3rd-magnitude stars doesn't look particularly lupine. It's hard to see an obvious division between Lupus and Centaurus, and since ancient times they have been considered closely related; the centaur's spear impaling an often undefined animal. This sacrifice is being carried to the nearby altar, the constellation of Ara.

THE PLANETS

The evenings continue to exhibit the most spectacular planets. Brilliant Venus is low in the northwest as twilight ends, moving steadily through Gemini as May progresses. The next dazzling 'star' is Jupiter in the north, about 15° from mag. +1.4 Regulus (Alpha (α) Leonis). Rounding off these impressive offerings is Saturn, rising in the east and visible all night. Neptune rises at 01:00 EST mid-month and Uranus three hours later; predawn observations are best.

DEEP-SKY OBJECTS

Lupus is renowned for double stars. Start at mag. +4.4 Lambda (λ) Lupi then move 0.5° east to reach HR 5642 (RA 15h 11.6m, dec. –45° 17'). Its mag. +6.5 and +7.2 components are a comfortable 31 arcseconds apart and easily split at 50x magnification.



NGC 5882 (RA 15h 16.8m, dec. –45° 39'; pictured) is only 1.0° southeast of HR 5642. This mag. +9.5 planetary nebula is an evenly illuminated disc 15 arcseconds in diameter.

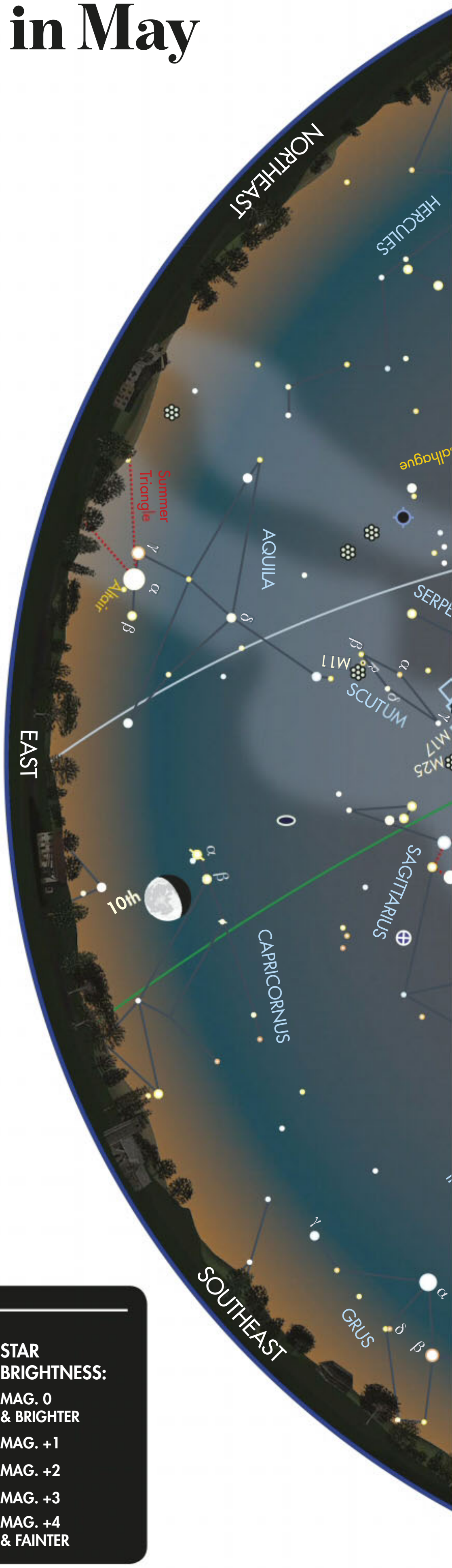
Return to Lambda Lupi and look 1.9° south-southwest to find an isolated star, mag. +4.4 Pi (π) Lupi (RA 15h 05.1m, dec. –47° 03'). This double, comprised of nearly matched white stars, is separated by only 1.7 arcseconds, so a high magnification of 100x or more is needed for this one.

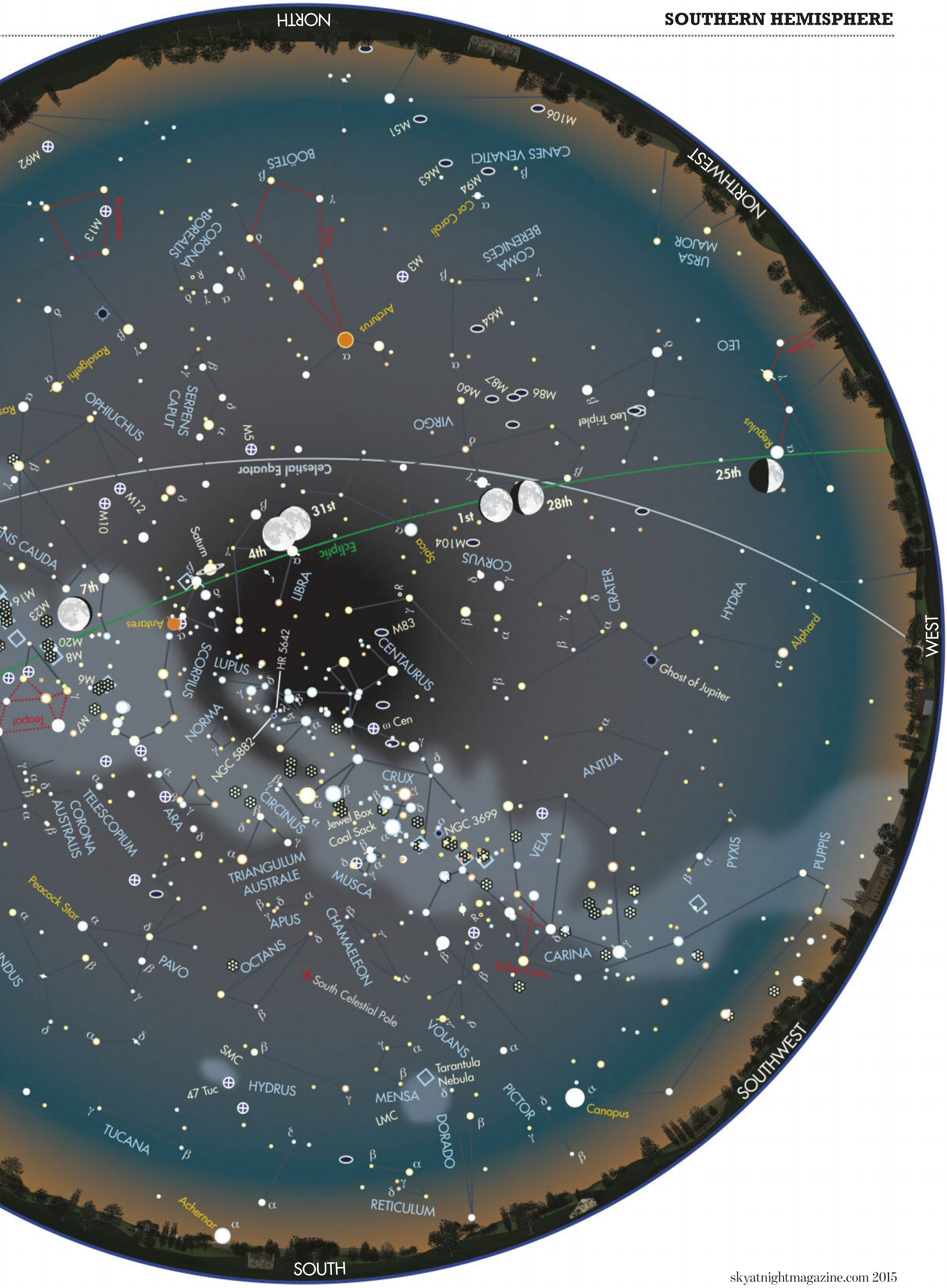
H. BOND/HST/STSCI/NASA

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





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