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21

THINGS YOU NEVER KNEW ABOUT ASTRONOMY



**ASTRONOMY
PHOTOGRAPHER
OF THE YEAR 2014**

The winning pictures revealed

THE PLANET OF MYSTERY

10 reasons we need a mission to Uranus

SECRETS OF THE CRAB

Why the most familiar of nebulae still surprises



**ALSO IN
THIS ISSUE**

1ST FOR GEAR

Vixen's new VSD 100 f/3.8:
the holy grail of astrographs?

HUBBLE IMAGING

How scientists turn data into the
space telescope's iconic images

FRONTIER FIELDS

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OCTOBER 2014 #113

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This month's contributors include...

MAGGIE

ADERIN-POCOCK

SKY AT NIGHT PRESENTER



The space scientist looks at how far we've come in predicting the existence of alien civilisations. *Page 21*

NICKY JENNER

ASTRONOMY WRITER



Nicky assembles the weirdest and most wonderful

facts about Earth, the Solar System and beyond. *Page 32*

PETE LAWRENCE

SKY AT NIGHT PRESENTER



Pete won a Royal Photographic Society award

for services to digital imaging last month. Get his top tips on *page 60*.

PAUL SUTHERLAND

SCIENCE WRITER



No probe ever launched has been free from germs. Paul

wonders then, could we avoid contaminating a planet like Mars? *Page 106*

Welcome

The winners of Astronomy Photographer of the Year 2014 revealed



First of all, a thank you to all readers who sent in their images of the conjunction of Saturn and the Moon on 31 August. It was wonderful to see so many had obviously enjoyed the dramatic sight of the Ringed

Planet and the Moon so close together. The good news is that these two bodies will be even closer on 25 October when Saturn disappears behind the lunar limb in an occultation. Turn to pages 50 and 60 for details of this dramatic event and how to image it.

There's some really stunning imagery in the mag this month, as we present the winning images from the Astronomy Photographer of the Year 2014 competition. We judges had it tough this year – such was the quality of the 2,500 entries – but this has meant that this winning photographs are really outstanding. See them for yourself on *page 39*.

As well as these inspirational examples of astro imagery, we also have a unique insight into the art of image processing. On *page 74*, Rob Banino lifts the veil on the digital darkroom at the Space Telescope Science Institute. This facility in Baltimore, US, is where astronomers turn the raw data collected by the Hubble Space Telescope into the outstanding images that have opened up the Universe to so many people.

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Our cover feature on *page 32* really shows how amazing and unexpected our Universe is. Who would have guessed that there's some part of the Milky Way that smells of raspberries or that the Sun is so vast that it can lose an avalanche's worth of mass a second and still have fuel to shine for another five billion years?!

Enjoy the issue.

Chris Bramley Editor

PS Next issue goes on sale 16 October.

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 78 and our online glossary at www.skyatnightmagazine.com/dictionary

ON THE COVER



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Find out how Hubble data is turned into iconic images, and why Photoshop is a blessing.

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Can humans avoid contaminating Mars?

BBC

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MAGAZINE



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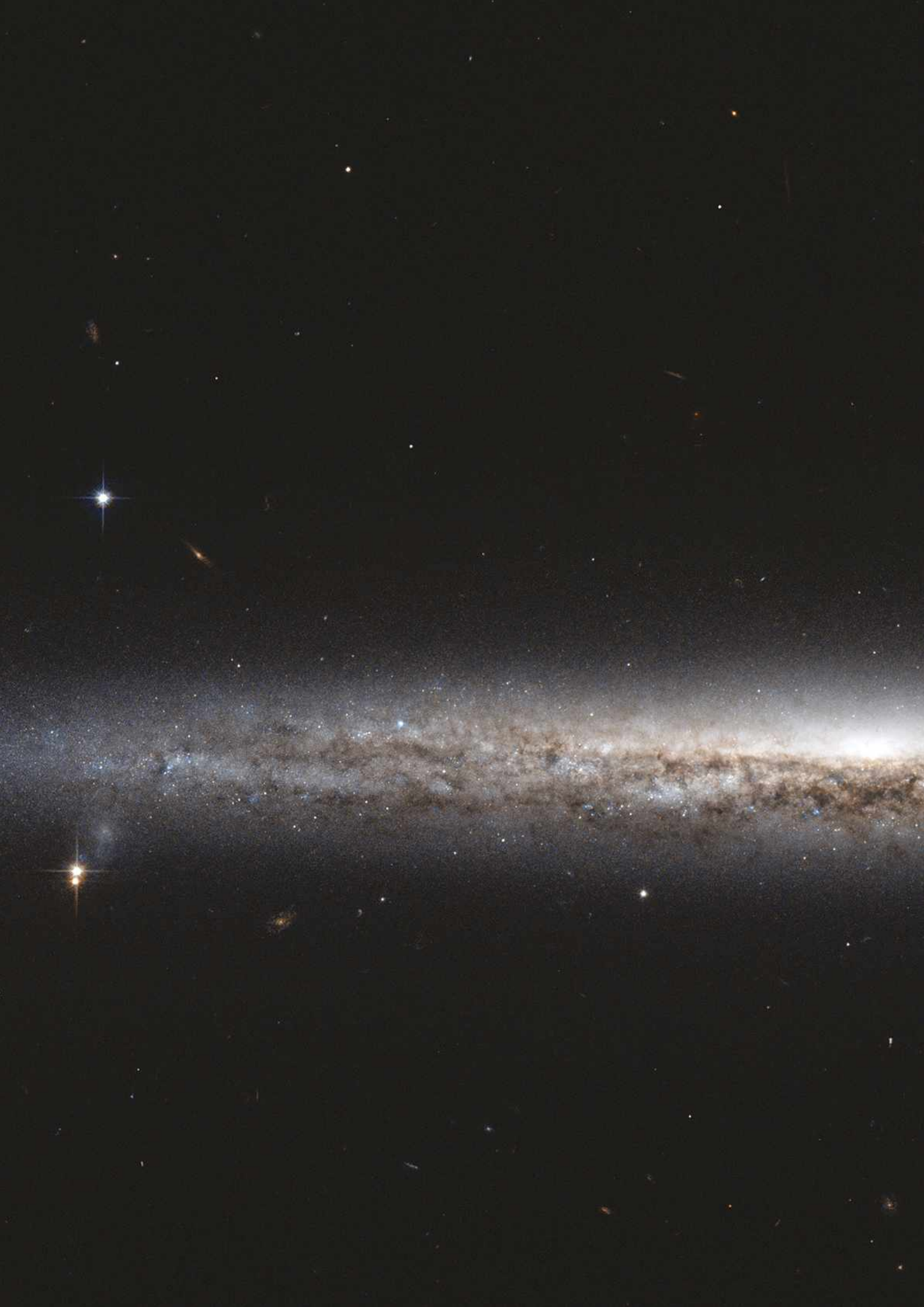
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TAP HERE TO FIND OUT MORE



Side on Spiral

Hubble Space Telescope, 21 July 2014

Captured edge on by Hubble, the vast galaxy NGC 3501 hints at its true shape, that of a spiral

From this perspective it is impossible to make out the galaxy's arms that emanate from its centre. There is however a clue to NGC 3501's true shape in the form of its companion galaxy NGC 3507. Out of frame in this image, NGC 3507 is a far more

recognisable spiral galaxy, its arms visible to us as it appears face on from our position in space. Dust lanes surround the bright gas and stars in this image of NGC 3501, a sure sign of a spiral arm, pointing to the true nature of the galaxy.



◀ Target in sight

ROSETTA SPACECRAFT, 24 JULY 2014

Comet 67P/Churyumov-Gerasimenko appears tantalisingly close in this image from ESA's Rosetta spacecraft, taken just 130km from the space rock. The probe reached its target on 6 August, after a 10-year trek through the Solar System that covered more than 6 billion km.

▼ Unstable structures

MARS RECONNAISSANCE ORBITER
10 JULY 2014

They may appear to represent a series of static geological features, but the Martian gullies captured here are surprisingly dynamic. By comparing this image with earlier ones, scientists have noticed rapid change. It seems that during winter and early spring, carbon dioxide frost is shifting the structure of these landforms.



▲ Stars in the making

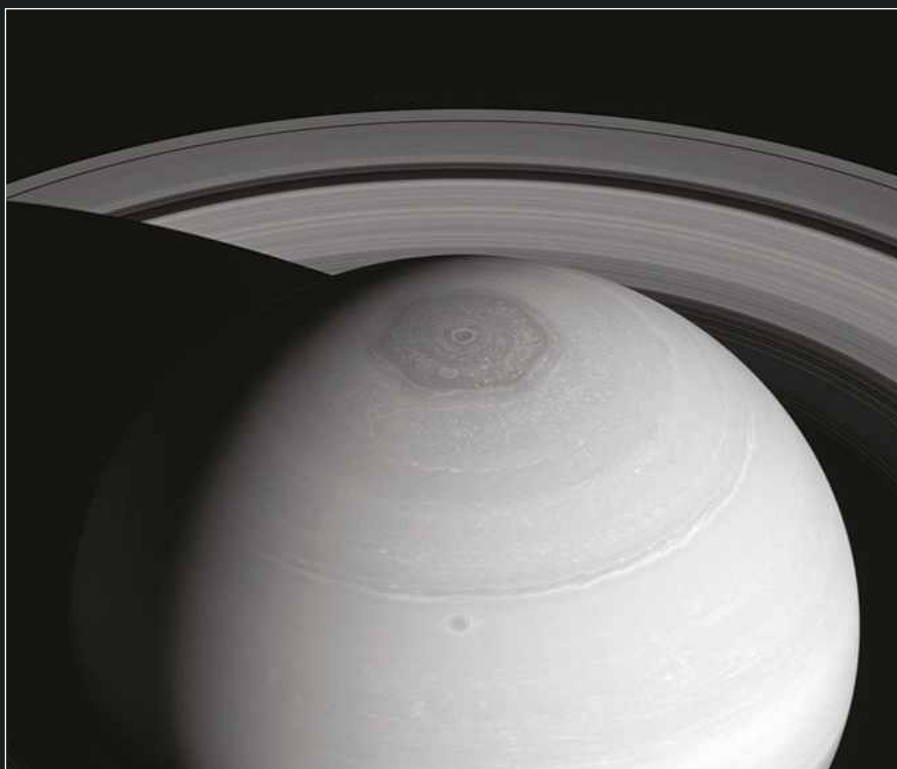
EUROPEAN SOUTHERN OBSERVATORY
23 JULY 2014

Star cluster NGC 3293 only began to form around 10 million years ago. Prior to this vast clouds of gas and dust, the remnants of which can be seen framing the stars in this image, would have populated the region.

Saturn's super storm ►

CASSINI SPACECRAFT, 7 JULY 2014

The vast hexagonal storm raging at Saturn's north pole is wider than two Earths. This amazing view was captured by NASA's Cassini spacecraft from a distance of almost 2.2 million km.



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Bulletin

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

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CUTTING

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EDGE

Our experts examine the hottest new astronomy research papers

The Andromeda Galaxy is the largest member of the Local Group

Milky Way less mighty than expected

Our Galaxy is only half as beefy as the giant spiral M31

THE MILKY WAY is less massive than astronomers previously thought, a new study suggests. Despite being a magnificent spiral type, our Galaxy is just half as massive as the only other giant spiral in our cosmic backyard, the Andromeda Galaxy, M31.

The Milky Way and the Andromeda Galaxy, which lies about 2.5 million lightyears away, are the two largest members of a cluster of galaxies called the Local Group. Estimates suggest they both contain several hundred billion stars, and M31 contains the most.

However, the relative masses of the two galaxies have been difficult to compare. That's partly because they both contain vast amounts of 'dark matter', an invisible and unidentified substance that makes up most of the matter in the Universe.

Now astronomers have analysed the relative velocities of the two galaxies – due to gravitational forces and the competing expansion of the Universe – to calculate their masses. This showed that dark matter makes up around 90 per cent of both galaxies and that M31 is twice as massive as our own Galaxy.

"We always suspected that M31 is more massive than the Milky Way, but weighing both galaxies simultaneously proved to be extremely challenging," says Jorge Peñarrubia from the University of Edinburgh. "Our study combined recent measurements of the relative motion between our Galaxy and M31 with the largest catalogue of nearby galaxies to make this possible."

M31 and the Milky Way are expected to collide around four billion years from now.

► See Comment, right



COMMENT by Chris Lintott

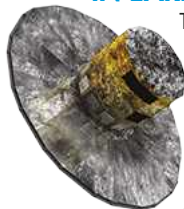
Everyone wants to believe that their home is special, so what consolation can we seek given this latest blow to our sense of cosmic self importance? Well, according to a paper published last year the Milky Way is, for a spiral galaxy, unusually green, a consequence of a larger than expected population of older stars. What's more, for a galaxy of its type, its black hole is surprisingly quiet – for now at least.

A recent discovery made by the Fermi satellite, of enormous bubbles stretching up and away from the Milky Way's main disc, suggests that this might not always have been the case. With an ageing population and a more hospitable neighbourhood than it might have been just a few tens of thousands of years ago, there's plenty about the Milky Way for a galactic estate agent to get stuck into. Even if we're not quite keeping up with the neighbours.

CHRIS LINTOTT co-presents
The Sky at Night

NEWS IN BRIEF

GAIA BEGINS IN EARNEST



The largest camera ever launched into space has reached its destination 1.5 million km from Earth. ESA's

Gaia satellite, which lifted off in December 2013, has begun a five-year mission to locate and analyse around a billion stars, mapping our Galaxy more precisely than ever before.

After several challenges, including problems with water freezing on the optics, scientists say they're confident they can scan each star 70 times, accurately measuring their positions, brightness and chemical composition.

ENCELADUS GEYSERS HAVE DEEP ROOTS

NASA's Cassini spacecraft has identified more than 100 distinct geysers erupting on Enceladus – suggesting that liquid water reaches the surface from the moon's underground ocean, thought to lie at least 30km beneath the surface.

Scientists thought that heating from tidal forces caused the geysers to blow. "Once we had these results, we knew right away heat was not causing the geysers," says Cassini scientist Carolyn Porco from the Space Science Institute in Colorado.



NASA/JPL/Caltech/Space Science Institute, ESA, ESA/Rosetta/NAVCAM, NASA/ESA/C. McCully and S. JHA (Rutgers University), R. Foley (University of Illinois) and Z. Levay (STScI), NASA's Goddard Space Flight Center, NASA/ESA/K.-V. Tran (Texas A&M University) and K. Wong (Academia Sinica Institute of Astronomy & Astrophysics)

Rosetta has revealed that the comet has two distinct parts

Rosetta meets its target

The comet hunter is preparing to deploy its lander in November

IN AUGUST, AFTER a decade-long journey, ESA's Rosetta spacecraft became the first one in history to orbit a comet. It will accompany comet 67P/Churyumov-Gerasimenko for more than a year as it swings around the Sun.

"After 10 years, five months and four days travelling towards our destination, looping around the Sun five times and clocking up 6.4 billion km, we are delighted to announce finally 'we are here'," says Jean-Jacques Dordain, Director General of ESA.

The comet has a 6.5 year orbit, taking it from beyond Jupiter to between the orbits of Mars and Earth at perihelion. Since its launch in 2004, Rosetta made three gravity-assist flybys of Earth and one of Mars to reach its rendezvous with the comet.

Images beamed back by Rosetta between late April and early June showed that the comet's activity has been variable. Its 'coma' – the extended envelope of gas and dust around it – became rapidly brighter then died down again over the course of six weeks.

Meanwhile, the spacecraft's measurements suggested that 67P/Churyumov-Gerasimenko's

average temperature was about -70°C , and that it has a dark and dusty surface. Other observations indicated it was losing water vapour into space at about 300ml per second.

Images taken more recently – from a distance of about 12,000km – showed the comet's nucleus has two distinct segments joined by a 'neck', giving it a duck-like appearance. "Is this double-lobed structure built from two separate comets that came together in the Solar System's history, or is it one comet that has eroded dramatically and asymmetrically over time?" says Matt Taylor, ESA's Rosetta project scientist.

Rosetta will drop its lander, Philae, onto the comet, the timeline for this to be confirmed by mid-October. "We have come an extraordinarily long way since the mission concept was first discussed in the late 1970s and approved in 1993," adds Alvaro Giménez, ESA's director of science and robotic exploration. "Now we are ready to open a treasure chest of scientific discovery that is destined to rewrite the textbooks on comets." <http://sci.esa.int/rosetta>

What caused a weak supernova?

It could be linked to the creation of a 'zombie star'

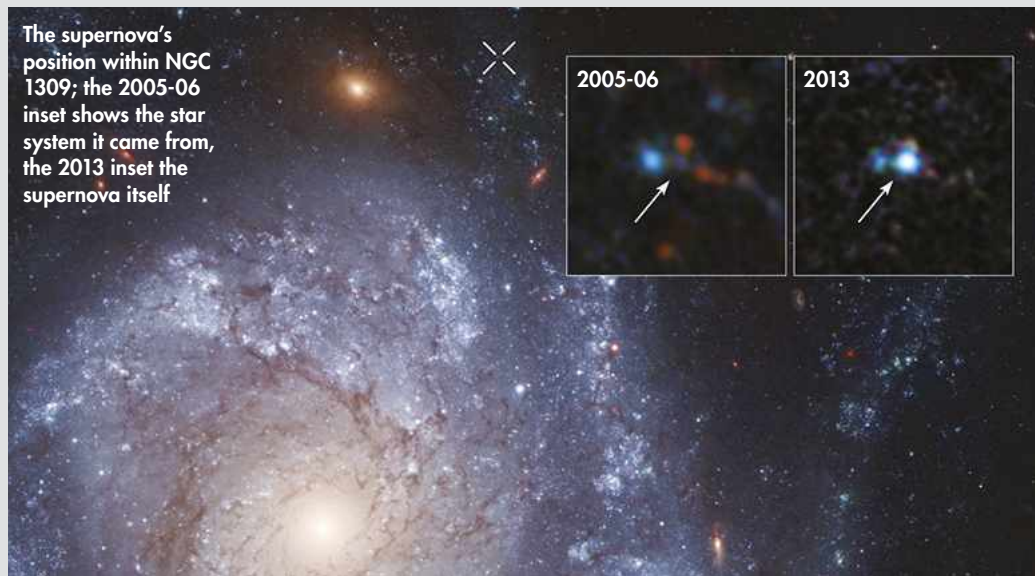
THE STAR SYSTEM that later produced an unusual supernova explosion has been revealed by Hubble observations. The curiously weak blast occurred when a blue star dumped matter onto a white dwarf.

White dwarfs are the shrunken remains of Sun-like stars that ran out of fuel. If they amass material from a companion star, they can become unstable and explode. A weak supernova, dubbed SN 2012Z, was discovered in January 2012 and

now a team led by Curtis McCully from Rutgers University, New Jersey, has identified the progenitor star system in earlier Hubble images. "We expected it would be too faint to see," says McCully. "It's exciting when nature surprises us."

Possibly, the explosion occurred when the white dwarf wasn't destroyed completely, but came 'back to life', earning it the nickname 'zombie star'.

www.hubblesite.org

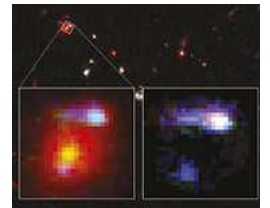


NEWS IN BRIEF

FARTHEST COSMIC LENS DISCOVERED

Astronomers have discovered the most distant cosmic 'magnifying glass' ever seen. The giant elliptical galaxy is a gravitational lens that distorts light from objects directly behind it. It is so far away that its light took 9.6 billion years to reach Earth, and breaks the previous record by 200 million years.

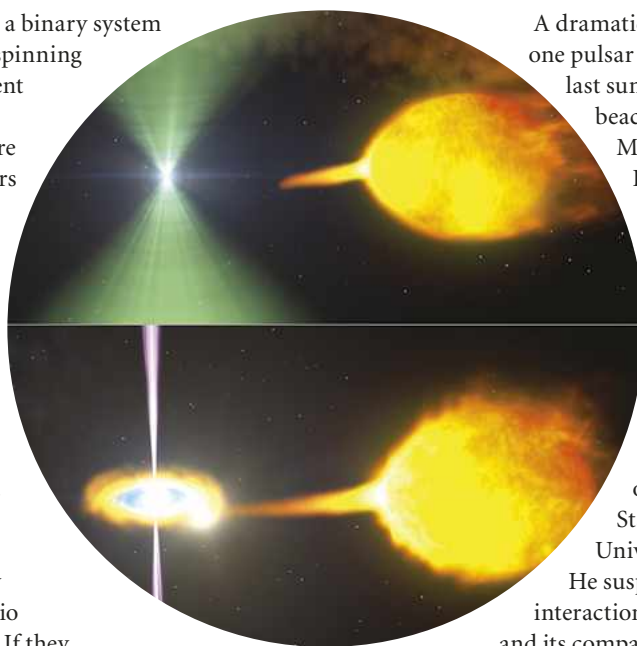
"There are hundreds of lens galaxies that we know about, but almost all of them are relatively nearby, in cosmic terms," says Kenneth Wong of Academia Sinica Institute of Astronomy & Astrophysics in Taipei, Taiwan.



FERMI FINDS PULSAR WITH SPLIT PERSONALITY

IN LATE JUNE 2013, a binary system containing a rapidly spinning neutron star underwent a dramatic change in behaviour never before observed. Astronomers say it should serve as a unique laboratory for understanding how pulsars form and evolve.

A pulsar is a neutron star that can form when a massive star explodes and its core collapses. The collapsed core, typically about 15km wide, spins extremely rapidly and emits radio beams from its poles. If they sweep across Earth as the neutron star rotates, astronomers observe regular radio pulses.



▲ Top: The pulsar emitting radio waves as usual; below: after the gamma-ray increase

A dramatic change occurred in one pulsar system called J1023 last summer, when its radio beacon vanished.

Meanwhile, NASA's Fermi space scope showed the system also brightened five-fold in gamma rays. "It's almost as if someone flipped a switch, morphing the system from a lower-energy state to a higher-energy one," says Benjamin Stappers from the University of Manchester.

He suspects a sudden, erratic interaction between the pulsar and its companion star involving mass transfer triggered the rare transitional phase.

www.nasa.gov/fermi

STARDUST FROM BEYOND THE SOLAR SYSTEM?

Scientists have discovered seven particles of what may be interstellar dust in samples brought back to Earth in 2006 by NASA's Stardust probe.

The dust motes have diverse chemical compositions and structures; nor are they all the same size. Some of the larger ones are surprisingly fluffy textures, similar to snowflakes. It is possible that they could have been created in a supernova explosion millions of years ago. "They are very precious particles," says Andrew Westphal from the University of California, Berkeley.

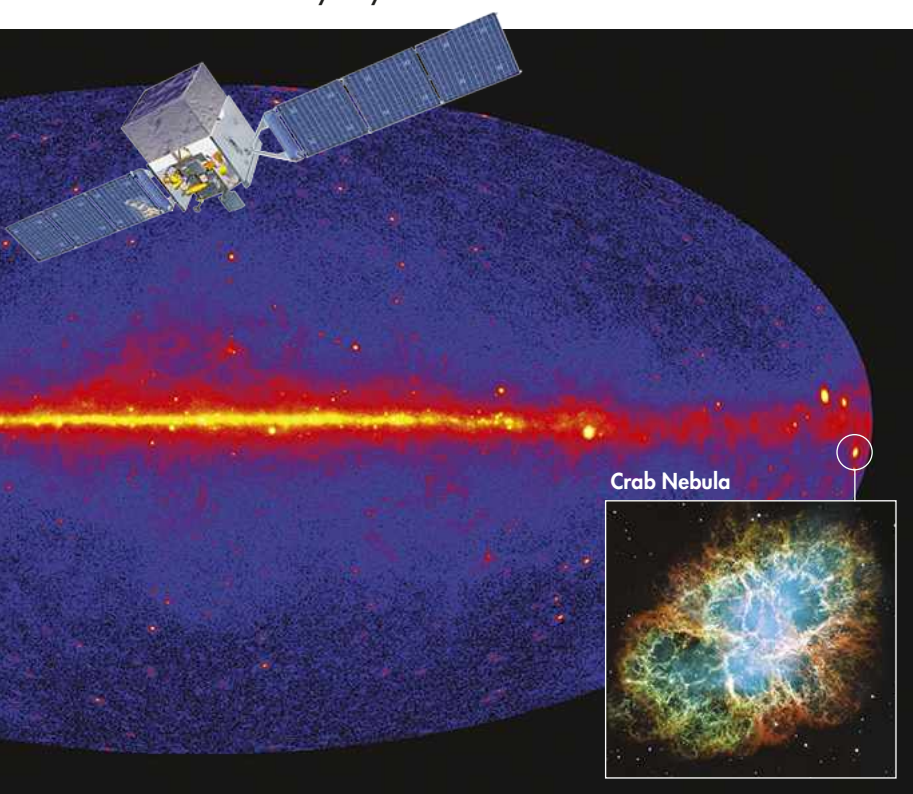
CUTTING

Our experts examine the hottest new research

EDGE

The curious Crab

Though a familiar sight to many, the Crab Nebula still holds many mysteries for astronomers



Crab Nebula

Created by the death of a massive star in a supernova observed nearly a millennium ago, the glowing gas of the Crab Nebula has probably been the subject of more research than any other object in the sky. As each generation of telescopes and instruments appears, astronomers have hurried to point them at the Crab to find out what they can about an object that continues to surprise.

A recent review of research into the object by Rolf Buehler and Roger Blandford highlights two new problems. New telescopes have allowed astronomers to detect the most energetic radiation and, surprisingly, extremely high-energy gamma rays are being generated somewhere in the nebula. At slightly shorter (but still gamma ray) wavelengths, dramatic flares make the Crab suddenly brighten and then fade again.

The key to both mysteries is to think of the Crab as an active object. The material that makes up the nebula is indeed a supernova remnant, but the light we receive today isn't the afterglow of that explosion.

▲ The radiation picked up by Fermi could mark the Crab Nebula's true power source



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.

Instead, it's the result of a powerful wind of particles driven by the pulsar at its centre, which excites the material that it encounters.

That the pulsar should have such a strong effect on its surroundings might seem mysterious, as you could expect this rapidly spinning core of the Crab's progenitor to sit quietly amongst the supernova's debris. The powerful magnetic field associated with the spinning pulsar drives its wind – we can even tell how much energy the pulsar is losing to this outflow because we can observe it slowing down. The wind itself is invisible until it slams into dense material, so you can think of the Crab as having three parts: the pulsar and its immediate environment, the region with a quiet flowing wind and then the bright nebula itself.

We shouldn't conclude that the quiet region isn't important, though, as what happens here determines the structure and the behaviour of

“The nebula is indeed a supernova remnant, but the light we see today isn't the afterglow”

the rest of the nebula. That's why the recently discovered high-frequency radiation, picked up by the Fermi satellite, is so interesting. The radiation may get to be so energetic because of the scattering of light by particles in the wind. If that proves to be the case, then what Fermi is observing is the first real evidence for the presence of the main power source for the nebula.

Not all the details are quite tied up, and there remains that second mystery, of the sudden gamma-ray flares that have been observed. Six have been seen so far, each lasting about a week, and the fact they come and go so quickly suggests that they are the result of activity in a small region within the Crab somewhere. Further study will help, but in the meantime it's nice to know that there are still mysteries in this most familiar of objects, and therefore a reason to turn the next generation of telescopes to the Crab once again.

CHRIS LINTOTT was reading... *The surprising Crab pulsar and its nebula: a review by Rolf Buehler and Roger Blandford*

Read it online at <http://arxiv.org/abs/1309.7046>

How planets get odd orbits

Unusual conditions in binary stars systems could hold the secret



HK Tauri sits 450 lightyears away, its two stars 58 billion km apart – that's 13 times the Sun-Neptune distance

TWO WILDLY MISALIGNED planet-forming discs have been discovered surrounding a pair of stars in binary system HK Tauri. Studying them could help to explain how exoplanets come to have strange orbits.

Scientists used ALMA observations to calculate that the protoplanetary discs are out of alignment by 60°. This means that one of them is likely to be misaligned with the orbits of the stars themselves – and when this happens, you can end up with planets with eccentric or tilted orbits.

“Although there have been earlier observations indicating that this type of misaligned system existed, the new ALMA observations of HK Tauri show much more clearly what is really going on in one of these systems,” says Rachel Akeson of the NASA Exoplanet Science Institute at the Caltech. www.almaobservatory.org

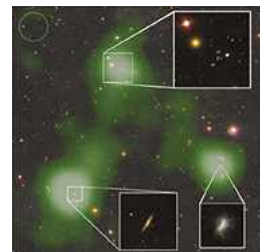
NEWS IN BRIEF

GIANT GAS STREAM DISCOVERED

Astronomers have discovered the longest known bridge of atomic hydrogen using the Arecibo telescope in Puerto Rico. The chain stretches for 2.6 million lightyears between several galaxies.

“This was totally unexpected,” says team leader Rhys Taylor from the Czech Academy of Sciences. “To find something this long and not in a cluster is unprecedented.”

Estimates suggest the mass of the gas stream is around 15 billion times the mass of the Sun – much more than in the Milky Way and Andromeda galaxies combined.



ALIEN WORLD SIZED UP

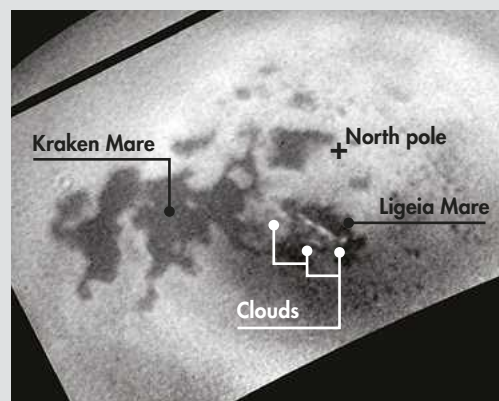
The size of an alien planet has been determined more precisely than ever. NASA's Kepler and Spitzer space telescopes have shown that planet Kepler 93b, which orbits a star 300 lightyears away, is 18,800km wide with an error margin of just 238km.



SUMMER STORMS COMES LATE TO TITAN

INTRIGUING IMAGES OF clouds moving across the northern hydrocarbon seas of Saturn's giant moon Titan have been beamed back by NASA's Cassini spacecraft. This renewed weather activity, which scientists say is unexpectedly late, could finally signal the onset of summer storms that atmospheric models of the moon have predicted.

Cassini snapped the cloud movements in late July as the spacecraft moved away from Titan after a close flyby. “We're eager to find out if the clouds' appearance signals the beginning of summer weather patterns, or if it is an isolated occurrence,” says Cassini scientist Elizabeth Turtle from the Johns Hopkins University in Maryland. www.nasa.gov/cassini



The clouds seen over Titan's hydrocarbon seas had been expected to return much sooner

Looking back The Sky at Night

October 1959

On 26 October 1959, *The Sky at Night* broadcast discussed Soviet images of the far side of the Moon. Until then, little was known about it because a gravitational effect called 'tidal locking' means that approximately, only one side of the Moon

◀ One of the first shots of the lunar far side, returned by Luna 3; though it is noisy and lo-res, several features are clearly visible

permanently faces the Earth.

But in October 1959, the Soviet probe Luna 3 took photos of the lunar far side for the first time. Later Soviet and American probes with much better resolution revealed vast chains of craters on the Moon's far side, which is now known to be densely cratered, battered and bruised by impacts, possibly because it didn't experience many lava flows, which smoothed out the Moon's near side.



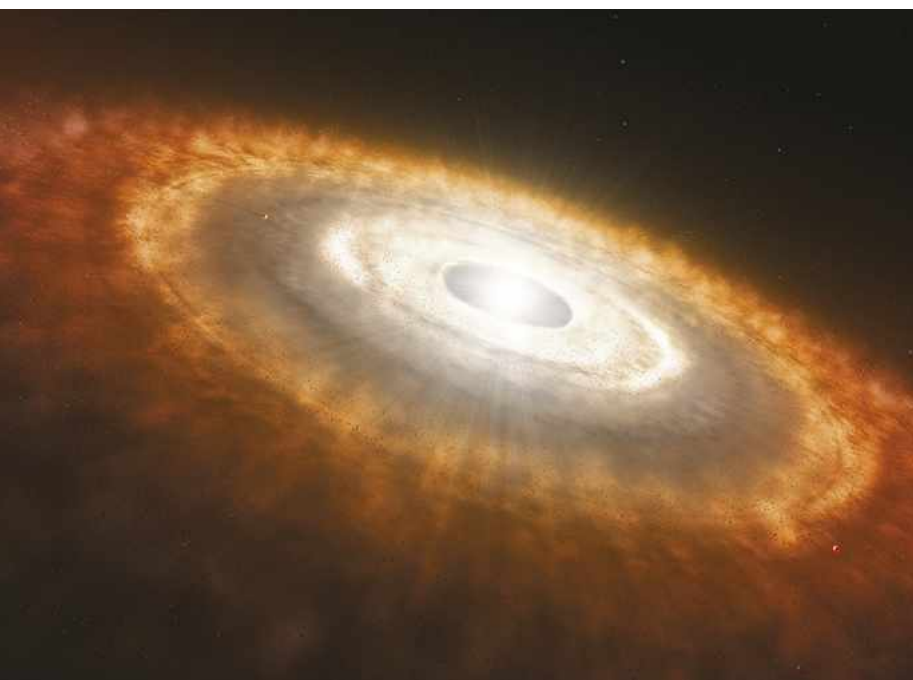
CUTTING

Our experts examine the hottest new research

EDGE

The scopes of the future

Two new instruments could change the way we examine and find alien worlds around far-flung stars



Since 1609, the core tool of astronomy has been the telescope. In the past 400 years the instrument has progressed from a series of lenses to one of the most advanced pieces of technology on – or off – the planet. And this past month alone has seen two new developments in the march of telescopic progress.

The first project, led by Nicholas Law at the University of North Carolina, promises something fantastic: an instrument that captures the entire visible sky with each exposure every few minutes throughout the night. Law has named this new device the Evryscope, meaning wide seeing. It is made up of 23 separate 2.75-inch telescopes, all mounted in a hemispherical dome, which also contains all the computer equipment and cooling systems required. The dome is itself sited on an equatorial mount, which will rotate the dome so that each telescope tracks exactly the same portion of the sky, with pixel precision. The array of cameras (providing almost a gigapixel in total) have overlapping fields of view, and so in combination offer continuous coverage of over 10,000 square degrees of sky. The diverse applications include extremely wide-field exoplanet transit surveys,

▲ The Planetary Formation Imager will (in theory) capture worlds as they coalesce



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)

real-time monitoring of transient phenomena such as microlensing events, and – because the whole sky is covered and the regular images stored afterwards – the Evryscope will also be able to provide a pre-image of unexpected events such as supernovae or gamma-ray bursts picked up by other surveys.

The Evryscope concept is currently in the development stage; the team hopes to have a first prototype of the whole design working by early 2015. While it will be a super wide-angle instrument working in the visible, another newly proposed instrument will operate in the mid-infrared range of warm dust. It's still something of a mystery exactly how planets form out of the swirling disc of dust and ice around a young star. The process can be explored theoretically using computer models, but at the end of the day you really want to be able to root your understanding in actual observational evidence.

The problem is that even upcoming telescopes like the completed ALMA won't be able to see the

“Even the completed ALMA won't be able to see the minute detail of a coalescing planet”

minute detail of a coalescing planet itself. This could be solved with the ambitious Planetary Formation Imager, which proposes to offer this unique view on the Universe. Project scientist Stefan Kraus of the University of Exeter is aiming to build an array capable of delivering an unprecedented resolution of around 0.1 milliarcseconds in the mid-infrared, meaning that it will be able to reveal this crucial period of world building.

The plan would be to image around 100 planetary-formation discs at different stages in the first 50-100 million years of their development. While the Planetary Formation Imager is still very early days in its proposal of this instrument, Kraus and his colleagues hope that the PFI could be scheduled for deployment sometime after the late 2020s.

LEWIS DARTNELL was reading... *The Evryscope: the first full-sky gigapixel-scale telescope* by Nicholas M. Law et al and *The Science Case for the Planet Formation Imager (PFI)* by Stefan Kraus
Read them online at <http://arxiv.org/abs/1407.0026> and <http://arxiv.org/abs/1407.7033>



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October Events - Join us at

Wycombe Astronomical Society on 4th Oct

See www.wycombeastro.org for details

North West Astronomy Festival 11/12 Oct

Visit www.theknowledgeobservatory.co.uk for tickets

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What's on

Our pick of the best events from around the UK

Peak Star Party 2014

Shallow Grange, Buxton, Derbyshire, 17-20 October

**PICK
OF THE
MONTH**

Resident astronomers will be able to help you explore the October night sky



It's one of the biggest annual astronomy gatherings in the country and – with 200 resident astronomers in attendance – this year's Peak Star Party in Buxton promises to be better than ever. No matter what your level of experience, help will be on hand so you can navigate the wonders of the October night sky with ease.

Alongside the astronomers there will be guest speakers talking on a range of topics, practical workshops and family

friendly space-themed activities including a bottle rocket competition and telescope making. You may even be able to pick up a bargain at one of the trade stands offering a variety of telescopes and equipment.

Weekend tickets start at £49 for a standard tent pitch without electricity; 24-hour tickets are also available on the day for £5 per person. Full details and a programme are available online. www.peakstarparty.co.uk

BEHIND THE SCENES THE SKY AT NIGHT IN OCTOBER

BBC Four, 12 October, 10pm (repeated **BBC Four**, 16 October, 7.30pm)*



Both Uranus and Neptune are well placed for observation right now; see pages 52-53

ICE GIANTS

The giant planets Uranus and Neptune are at their brightest in the night sky in October, making this month a great time to explore these enigmatic worlds. From the most powerful winds in the Solar System to their exotic atmospheres, find out what makes these distant planets so unique.

*Check www.radiotimes.com as times may vary

Telescope Workshop

National Museum Cardiff, Cardiff, 4 October, 10am



Join Cardiff Astronomical Society at the National Museum Cardiff this month for top tips on getting the best from your telescope. Whether you are planning to buy a new instrument or just need a little help finding your way

around the scope you already have, there will be experts on hand all day to help. The event is free to all.

www.cardiff-astronomical-society.co.uk

Lights in the Northern Sky

Strathclyde University, Glasgow, 16 October, 7.30pm



This month, the Astronomical Society of Glasgow invites Ken Kennedy, director of the British Astronomical Association's Aurora Section to discuss the Northern Lights.

Don't miss out on this great opportunity to find out more about this celestial phenomenon for free.

www.theasg.org.uk

The Next 50 Years of Space Exploration

Bath Royal Literary and Scientific Institution, Bath, 3 October, 7.30pm



This joint lecture from the William Herschel and British Interplanetary Societies will see former NASA scientist Dr David Baker discuss the next 50 years of Solar System exploration, both robotic and human. Entry costs

£2 for members and students, £4 for non-members.

www.williamherschel.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.



North West Astronomy Festival 2014

The Heath - Runcorn - Cheshire

Sat 11th - Sun 12th October



Will Gater



Damian Peach



Helen Keen



Philippa Browning



Nick Howes

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A PASSION FOR SPACE



with **Maggie Aderin-Pocock**

Maggie investigates whether a 1960s equation to predict advanced life in our Galaxy still holds water

Two years ago, researchers asked 2,000 people what scientific question they would most like answered. Top of the list was: are we alone in the Universe? I was surprised (and quite heartened) by the fact that so many people thought this question was important, as it has always intrigued me too. But are we to getting any closer to an answer?

In 1961 American scientist Frank Drake tried to quantify the problem by looking at probabilities, laying down the parameters that would affect the numbers of active, communicative civilisations in our Galaxy. He came up with the calculation below, which came to be known as The Drake Equation:

$$N = R^* \times fp \times fg \times ne \times fl \times fi \times fc \times L$$

When Drake first considered the equation some 53 years ago, only the first term, R^* – the rate of yearly star formation in the Galaxy – was known with any confidence. But with increasingly sophisticated equipment, we've gleaned more and more information from our observations. Our estimate of fp , the fraction of stars with planets orbiting them, has greatly improved since the discovery of the first exoplanet in 1992. Values for fg , the fraction of stars that could support habitable planets, is



We found plenty of alien worlds since 1961, but still no civilisations

also better understood today, although our definition of habitable is limited to the one example we have – Earth – and so hinges on the availability of liquid water.

The next parameter, ne , the number of planets that can potentially support life (per star with planets), has driven our search for Earth-like planets rather than the larger, easier to detect Jupiter-like worlds that earlier searches revealed.

Back to conjecture

At this point we reach a bit of a boundary, and we have to resort to guesstimation rather than estimation to fill out the rest of the parameters. We are on the cusp of being able to measure the initial signs of fl , the fraction of planets that actually develop life at some point, using spectral analysis.

Life as we know it leaves chemical signatures in a planet's atmosphere, which could be detected by analysing light absorption through it.

It may even be possible to get a feel for fi , the fraction of planets that will develop intelligent life, using a similar method. Some chemicals do not occur naturally, so if we detect them on an exoplanet it is likely that its population has made technological advances. The final two terms

prove to be even harder: fc , the fraction of civilisations that emit detectable signs of their presence, and L , the average length that a civilisation exists, are very hard to judge when you have a sample of just one, us.

As a result of the nebulous nature of these latter terms, estimates for the value of N – the number of civilisations in our Galaxy which we may be able to communicate with – can vary by more than 10 orders of magnitude. This could be seen as a problem, but that might perhaps be missing the point of the Drake Equation, as it should not be seen as less of an estimating tool and more of a blueprint for how to go about searching for life in the Galaxy. **S**

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

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"...the 115 gave exquisite views of the kind refractor buffs love... stars appeared absolutely perfect across the entire view." (July 2011, Astronomy Now Magazine).

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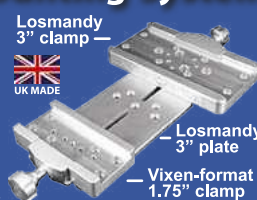
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JON CULSHAW'S EXOPLANET EXCURSIONS

Jon heads into the Milky Way's bulge, to a region where the stars are legion

One of my greatest astronomical fascinations is imagining the kind of night sky visible from the centre of our Galaxy, that massive sphere of densely packed stars called the 'galactic bulge'. How would such an unfathomable plethora of stars appear to our eyes.

A good exoplanet to provide this kind of saturated starlit view has the catchy name of MOA 2011 BLG 293 Lb. I'll call this planet 'Meridanis', if I may, to reflect its central position in the Milky Way. This was the first planet to be discovered in the habitable zone of a star in this most crowded part of the Galaxy. This particular star is G Class and reassuringly similar to our Sun, though a modicum smaller.

Upon reaching Meridanis, there's a Mars-sized exomoon in orbit, which will be the perfect place to settle and make our observations. At the time of landing, there's an hour until the parent star sets.

A sunset in the galactic bulge promises to be quite unlike any view yet witnessed on our excursions. The sky here has a purple hue and such is the staggering number of stars present they appear with

a blurry iridescence even when the daylight of the parent star dominates. It's a beautiful marbled effect similar to an opalescent paint finish on a hairdresser's car.

As the star continues setting there isn't a gently deepening dusk. In Earth skies, planets and stars appear individually and gradually: Venus, Jupiter, Arcturus and so on. The stars appear in a dramatically different way here. Over Meridanis, a huge swathe of stars appear with a rapid, mesmeric glow, which reminds me of the Sun's corona searing into view during the totality of a solar eclipse.

Every square inch of sky is compacted with pin points of stelliferous light, stars so close together they're affected by one another's gravity. As well as stars, garlands of nebulae glow in deep orange, blue and indigo.

Here, there isn't a night-time light we'd be familiar with. Such a colossal number of stars generate a glow evocative of an artificial electric light on the grandest scale; a silvery monochrome illumination casting shadows in

innumerable directions. By starlight alone, I can read my *Observer's Book of Astronomy* really quite easily.

The gas giant Meridanis is itself an incredible, ominous sight, visible from my position in its 'new' phase. It occupies about a quarter of the sky, a solid, lightless black hole amid the infinite density of stars. Only its thin ring system shimmers, like the famous image of the backlit Saturn.

One drawback here is how tricky it is to conduct any kind of astronomy. A sky so awash with light makes it extremely challenging to study objects in much detail. We can consider ourselves very lucky that our Solar System is akin to Kielder or Sark – a precious dark-sky site tucked away in a backwater of a spiral arm of the Milky Way. The opposite extreme, our journey to the centre of the galaxy to witness the overpowering splendour of the Meridanis sky, has been spectacular indeed.

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



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

The 'Message of the Month' writer will receive four top titles courtesy of astronomy publisher Philip's. Heather Couper and Nigel Henbest's *Stargazing 2014* is a month-by-month guide to the year and you'll be able to find all the best sights with Patrick Moore's *The Night Sky*. *Stargazing with Binoculars* by Robin Scagell and David Frydman contains equipment and observing guides, and you'll be viewing planets, galaxies and more with Storm Dunlop's *Practical Astronomy*.

PHILIP'S



MESSAGE OF THE MONTH

If you don't ask you'll never know

My name is John Cave and I have been an observational astronomer from my home on the outskirts of Liverpool for the past 30 years. I have a superb view of the night sky considering the fact that I live in Liverpool.

Recently I received a letter from my local council informing me that we were about to get an upgrade to the street lighting system, changing from the yellow sodium lighting to a new more economical white light system. We all know what kind of damage white light does to adapted night vision and so I wrote to the lighting officer to see whether there was a way out of the problem. She very kindly wrote back and said that, while there was nothing she could do to stop the white lights being fitted, she would get the lighting engineers to fit black light shields to the offending lamp posts. She asked how many lampposts there were and to which direction I wanted the shielding to face.

I was surprised at the brilliant help that I received and thought that anyone else out there who is about to get these lights fitted in their area should write to their lighting officer to get these shields fitted too.

John Cave, Merseyside

A very encouraging story John, it just goes to show you don't always have to head to dark skies to enjoy the wonders of the cosmos. – Ed



▲ The black light shields certainly help to cut down the intrusive white light that ruins adapted night vision

Another convert

I would like to thank *BBC Sky at Night Magazine* and Paul Hyde for the two-part 'How to... Use radio signals to catch meteors' article from the June and July issues. I am now the proud owner of a fully working system and am already detecting sporadic meteors! I can easily see how this will occupy cloudy nights when I can't get out to use my binoculars and I am also looking forward to covering the

◀ Inspired by all the meteor hunters featured here in recent months? Check out our back issues and you can have a go yourself

next expected meteor shower. The aerial is positioned 3.5m off the ground and uses a shed as a convenient mounting platform. I used Google Earth to align the aerial to Dijon in France. To lessen any visual impact on neighbours I installed the aerial horizontally.

Steve Nickolls, via email

We've had a fantastic response to this How to... article. You are one of many stargazers now experimenting with the branch of our hobby that can be done under thick cloud – Ed

Eerie blue tendrils?

I've been watching the skies over recent nights. When finishing work at 3am for three consecutive



SOCIAL MEDIA

WHAT YOU'VE BEEN SAYING ON TWITTER AND FACEBOOK

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

@skyatnightmag asked: What creature comfort would you want on board the ISS?

@jenglshesq Jelly beans!

Chris White I'd miss nice fresh coffee, but I believe that's getting sorted.

Alan Bickerstaff You'd have a job getting me out of the Cupola, but if there was a nice comfy centrifugal bed available, that might work.

@WholesomelySpun Artificial gravity, maybe through engineering (like the 1970s models on centripetal/centrifugal forces in a rotating vessel).

@moohalaa A high-back leather chair to admire Earth from the Cupola!

Mongolian Bograt I'd want to take my bongos!

@UK_Science A McDonald's drive-through.

@sjb_astro A fully stocked wine cellar!

@cosmic beach My iPod of course. Great views along with great music, what more could one ask for.

nights – 5-7 July – there has been a spectacular show of what I believe to be noctilucent clouds. I took a quick photo on my smartphone in the hope that someone on the team could confirm what I saw. I took the photo from central Dorset at 3.15am and the clouds were seen to be to the north-northeast to northeast. I based the direction on the fact that Cassiopeia was high above and to the right, with Capella in between. Sunrise locally is approximately 5am and I could only draw on noctilucent clouds as being the solution. Could you confirm my suspicions?

Tom Martin, Yeovil

It's been a great summer for noctilucent clouds and yes, Tom, you have caught a spectacular display here. – Ed



Praise from afar

Thank you so very much for such a wonderful magazine. I eagerly wait for each month's issue to arrive in my mailbox by mid-month. I'm never disappointed in the articles, newsbits, the month's seeing guides, the treasured CD with all of the wonderful things on it like the previous month's TV show that isn't available in the States, vintage *The Sky at Night* shows – which I dearly love – and the humorous and informative planetarium. Even though I'm the Pacific Northwest of the US, I really love the ads! Thanks again for your magazine!

Jim Bray, US

Thank you Jim, it's great to hear you enjoy the magazine and that astronomers across the pond are benefitting from our content. – Ed

A visitor in Perseus

Comet C/2014 E2 Jacques was quite bright and high in Perseus in mid August. It's quite a thrill to scan the sky at low power and find a bright visitor to our Solar System.



Here's a quick sketch of a lovely encounter.

Nicholas Cox, Derbyshire

Though it lacked a long tail, the comet's compact coma was a treat to observe over the summer. – Ed

Sky at Night MAGAZINE

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BBC

Sky at Night

MAGAZINE

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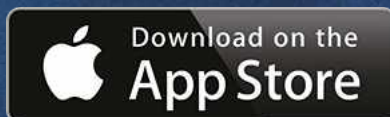
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BBC
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MAGAZINE

Hotshots

This month's pick of your very best astrophotos



PHOTO
OF THE
MONTH

▲ The Milky Way

JUSTIN NG, MERSING, MALAYSIA, 28 JUNE 2014

Justin says: Knowing that the sky would clear after sunset, I led a group of photographers to this location to film a timelapse of the rising Milky Way above a lonely boat, but what happened soon after we started shooting was amazing. We were treated to a spectacular lightning display for about an hour, before the clouds caught up with the rising Milky Way and eventually dominated the skies.

Equipment: Canon EOS 5D MK II DSLR camera, 16-35mm f/2.8 lens, Gitzo tripod with Manfrotto ball head.

BBC Sky at Night Magazine says: In this fantastic image Justin has managed to combine the bright outburst of lightning here on Earth with the subtle glow of the Milky Way, capturing a truly elemental scene. The contrast between the serene constancy of our home

Galaxy as viewed from Earth and the evanescent flash of lightening is very satisfying to contemplate.



my first astronomy tool before I started imaging deep-sky objects in August 2013. I am now pursuing an 'astro-cityscape', an unprecedented genre, in Singapore, by attempting to unveil the beautiful Milky Way obscured by extreme light pollution at locations where people don't look up.

About Justin: I started my astrophotography journey by finishing my first timelapse video in Mount Bromo, one of the active volcanoes in East Java, Indonesia, in 2012. I then spent two months from May to July 2013 developing



▲ The Bubble Nebula

CHRIS HEAPY, MACCLESFIELD, 17 JULY 2014

Chris says: The Bubble Nebula in Cassiopeia is an emission nebula created by the stellar wind from a massive hot star at its centre. Radiation from the star also illuminates the surrounding gas cloud causing it to glow.

Equipment: Atik 490EX CCD camera, 5-inch Tele Vue NP127is refractor, Losmandy G11 mount.



▲ Noctilucent clouds

GORDON MACKIE, CAITHNESS, 7 JULY 2014

Gordon says: I took this just before 2am on the night of 6-7 July. It shows a bright display of noctilucent clouds reflected in the still waters of Loch Calder, Caithness. It was a wonderfully bright and intricate display, and clear skies meant I was able to observe how the structure of the clouds evolved during the few hours of twilight that my latitude experiences in the middle of summer.

Equipment: Canon EOS 650D DSLR camera.



◀ Saturn

TOM HOWARD, SUSSEX, 17 JUNE 2014

Tom says: This was my last image of Saturn during what proved to be a challenging apparition, due to the planet's low altitude. Despite these difficulties, some detail was still available on good nights.

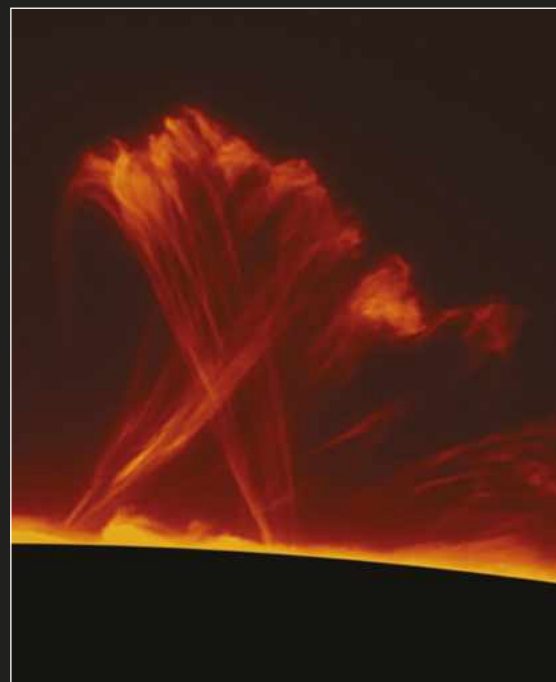
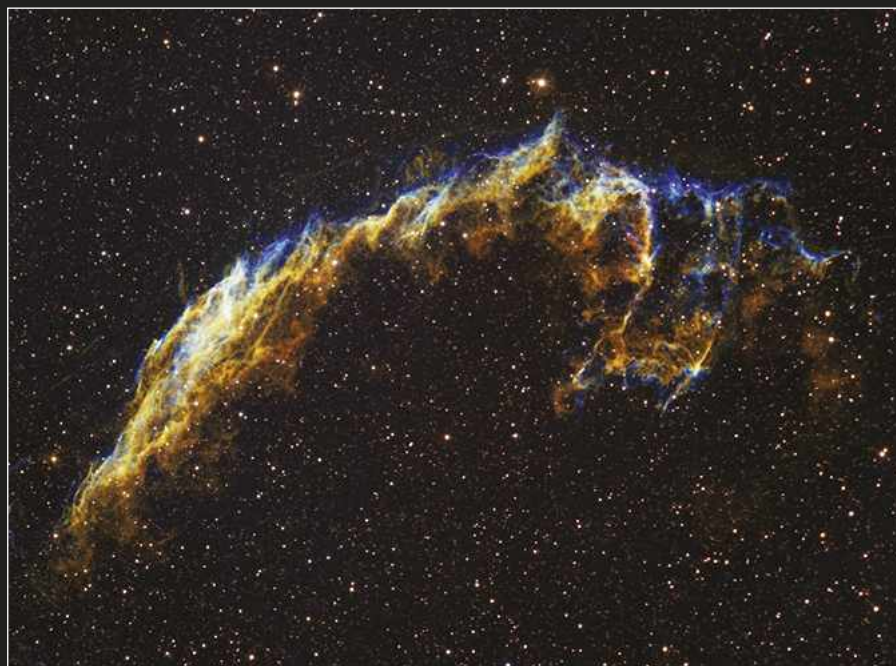
Equipment: Celestron Skyris 618C CCD camera, Celestron C11 telescope.

▼ The Eastern Veil Nebula

MARK GRIFFITH, SWINDON, 30 JUNE 2014

Mark says: This image of the Eastern Veil Nebula uses data collected over three nights in June and July 2014. I used narrowband filters to capture the delicate filaments and the Hubble palette to highlight the detail further.

Equipment: Atik 383L+ CCD camera, Teleskop-Service 8-inch Boren-Simon Power Newtonian, Sky-Watcher NEQ6 Pro mount.



▲ The Sun

PAOLO PORCELLANA
ASTI, ITALY, 31 DECEMBER 2013

Paolo says: This loop prominence was created after a few flares on New Year's Eve. The multi-crossed loop showed up for several minutes; the solar disc was masked to make it easier to see the details.

Equipment: Canon EOS 650D DSLR camera.

▼ The Lagoon and Trifid Nebulae

TERRY HANCOCK, MICHIGAN, 6 JULY 2014

Terry says: Many fine celestial objects of differing types are visible in this image, the most prominent being the Lagoon and Trifid Nebulae.

Equipment: QHY11 Monochrome CCD camera, Takahashi E-180 telescope, Paramount GT-1100S German equatorial mount.



◀ NGC 6397

DAVID TROTTER, AUSTRALIA, 18 JULY 2014

David says: This is a dense cluster in the constellation of Ara, so packed that stars are separated by lightweeks. When collisions occur new blue stars form.

Equipment: SBIG STL6303e CCD Camera, GSO RC8 telescope.



▲ The Running Chicken Nebula

KFIR SIMON, NAMIBIA, JULY 2013

Kfir says: In a closer look at the Running Chicken Nebula (IC 2944) you can see a series of black clumps dotted against the background – these are known as Bok globules. Dark Bok globules absorb the light from their more luminous background. These globules are potential sites for the condensation of newborn stars.

Equipment: Apogee Alta U-16M CCD camera, 16-inch f/3.75 Dream astrograph.

The Moon ▶

DAVE WALKER
WIGAN, 13 JUNE 2014

Dave says: It was far too cloudy here in Wigan to get any surface detail, so I went for the more atmospheric shot as the Moon rose through the heavy cloud cover.

Equipment: Canon EOS 600D DSLR camera.



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.

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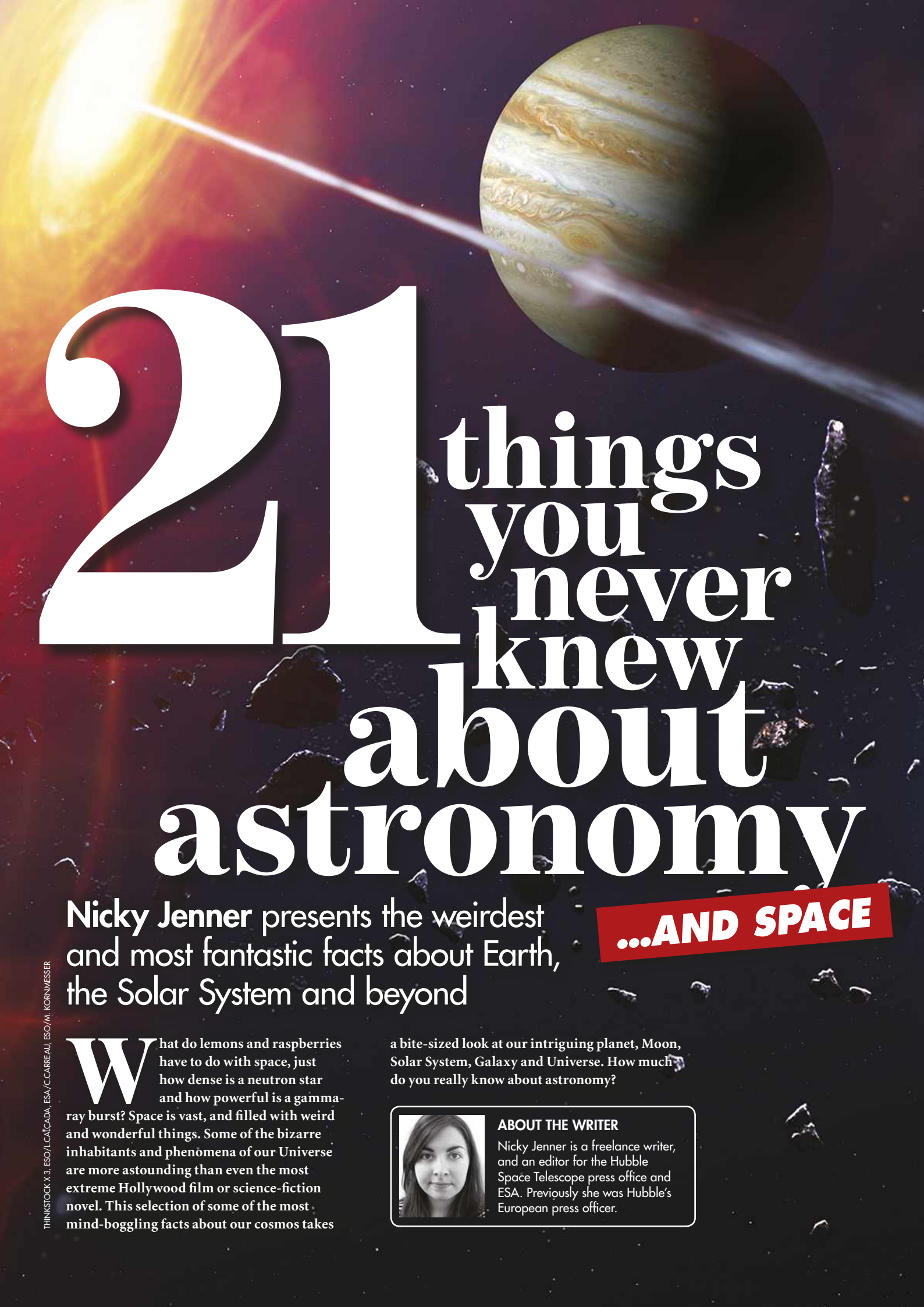
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21 things you never knew about astronomy

...AND SPACE

Nicky Jenner presents the weirdest and most fantastic facts about Earth, the Solar System and beyond

What do lemons and raspberries have to do with space, just how dense is a neutron star and how powerful is a gamma-ray burst? Space is vast, and filled with weird and wonderful things. Some of the bizarre inhabitants and phenomena of our Universe are more astounding than even the most extreme Hollywood film or science-fiction novel. This selection of some of the most mind-boggling facts about our cosmos takes

a bite-sized look at our intriguing planet, Moon, Solar System, Galaxy and Universe. How much do you really know about astronomy?



ABOUT THE WRITER

Nicky Jenner is a freelance writer, and an editor for the Hubble Space Telescope press office and ESA. Previously she was Hubble's European press officer.



THE MOON IS LEMON-SHAPED

Despite its appearance in the night sky, our natural satellite is nowhere near round. In fact, the Moon is shaped like a lemon, with flattened poles and bulges on both the near and far side around its equator. This strange shape is thought to have been created during interactions with Earth soon after its formation.

What amazes me

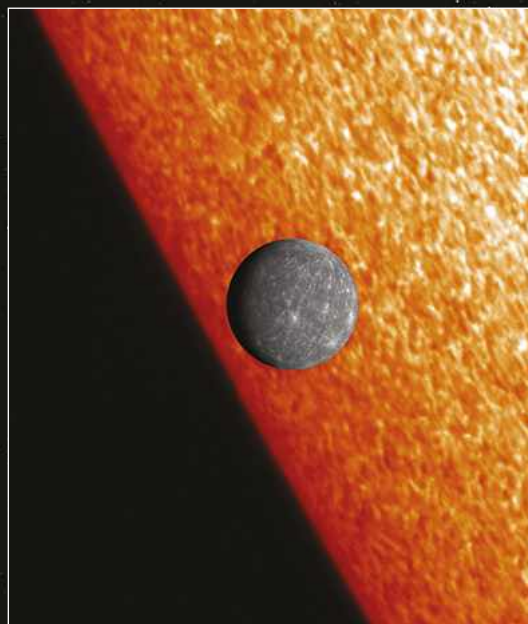


Chris Lintott, *The Sky at Night*
Space is empty. Really, really empty. Especially if you get out of our local galactic neighbourhood. If you set off from the Milky Way with your hand held out, by the time you reach the edge of our observable Universe you will have collected nothing but a few kilograms of hydrogen.

CLOUDS AT THE CENTRE OF THE MILKY WAY SMELL OF RUM, TASTE OF RASPBERRIES AND ARE PACKED WITH BOOZE

In 2009, astronomers exploring a giant cloud of gas and dust at the centre of the Milky Way made a surprise discovery – the cloud was packed full of a chemical known as ethyl formate, which has a couple of intriguing properties: it is responsible for giving raspberries their flavour, and has the smell of rum. Another nearby region is also notable as it's full of ethyl alcohol, or ethanol, the type we use to make alcoholic beverages. It

contains enough alcohol to supply every person on the planet with 300,000 pints of beer per day for the next billion years! If bottled at the source, the proof for this beer would be very low, with an alcohol content of less than one per cent, but as the cloud also contains plenty of other nasty chemicals, among them carbon monoxide and hydrogen cyanide, it would still leave you with quite a headache the next morning.



ON MERCURY, A DAY LASTS TWICE AS LONG AS A YEAR

Technically, one Mercurian day lasts 59 Earth days, while a year lasts 88. However, due to Mercury's very eccentric orbit and alignment with the Sun, the length of time from sunrise to sunrise, known as a 'solar day', is equal to 176 Earth days — twice as long as a Mercurian year.

IF YOUR SPACESUIT STARTED LEAKING, YOU COULD SURVIVE FOR A COUPLE OF MINUTES

Although films such as *Total Recall* show instant explosions and rapidly puffed-up spacesuits, the effects of being exposed to space are slightly less dramatic. Although it would definitely be unpleasant, you could survive for a couple of minutes.

After around 10 seconds, you would lose consciousness. The lower pressure of the vacuum would cause your blood to boil, along with other body fluids (the moisture on your tongue, for example) – but this boiling alone would not be fatal due to the pressure maintained by our blood vessels themselves. Gas bubbles



would form in your bodily fluids, causing your body to swell up and bloat. The low humidity of space would cause you to cool down rapidly, and your eyes may freeze over. Within one to two minutes, the lack of oxygen would be deadly.

The stress of the situation may make these symptoms worse – you would become oxygen-deprived more quickly. A rapid decompression would cause damage to your lungs, eardrums and sinuses, along with bruising and bleeding from soft tissues.

GAMMA-RAY BURSTS CAN RELEASE MORE ENERGY IN 10 SECONDS THAN OUR SUN WILL IN ITS ENTIRE LIFE

Nothing in the Universe rivals the power unleashed during a gamma-ray burst, a brief but incredibly intense flash of high-energy radiation. There are many types of GRB: some are thought to form when a massive star implodes; others when two neutron stars merge together.



THERE ARE STARS WE WILL NEVER BE ABLE TO SEE

Ever since the Big Bang, most objects in space have been moving away from one another. In fact, cosmic expansion is actually accelerating. As regions of space are whizzing away from one another at an ever-increasing rate, the first population of stars to form in the Universe are now too far away for us to ever hope of spying them – even using the best present or future telescope. Hope is not lost; we can attempt to spot them indirectly via the energetic bursts of radiation they emit at the end of their lives.

ONE TEASPOONFUL OF NEUTRON STAR WOULD WEIGH THE SAME AS THE ENTIRE HUMAN POPULATION

A neutron star's density is mind-boggling. These stars are composed almost entirely of neutrons packed together in a tiny radius. Just a teaspoonful of this material would weigh over a trillion kilograms — more than the weight of the entire human population (which reaches a few hundred billion kilograms). To make something as dense as a neutron star, the whole of humanity would need to be crammed into a space the size of a sugar cube.



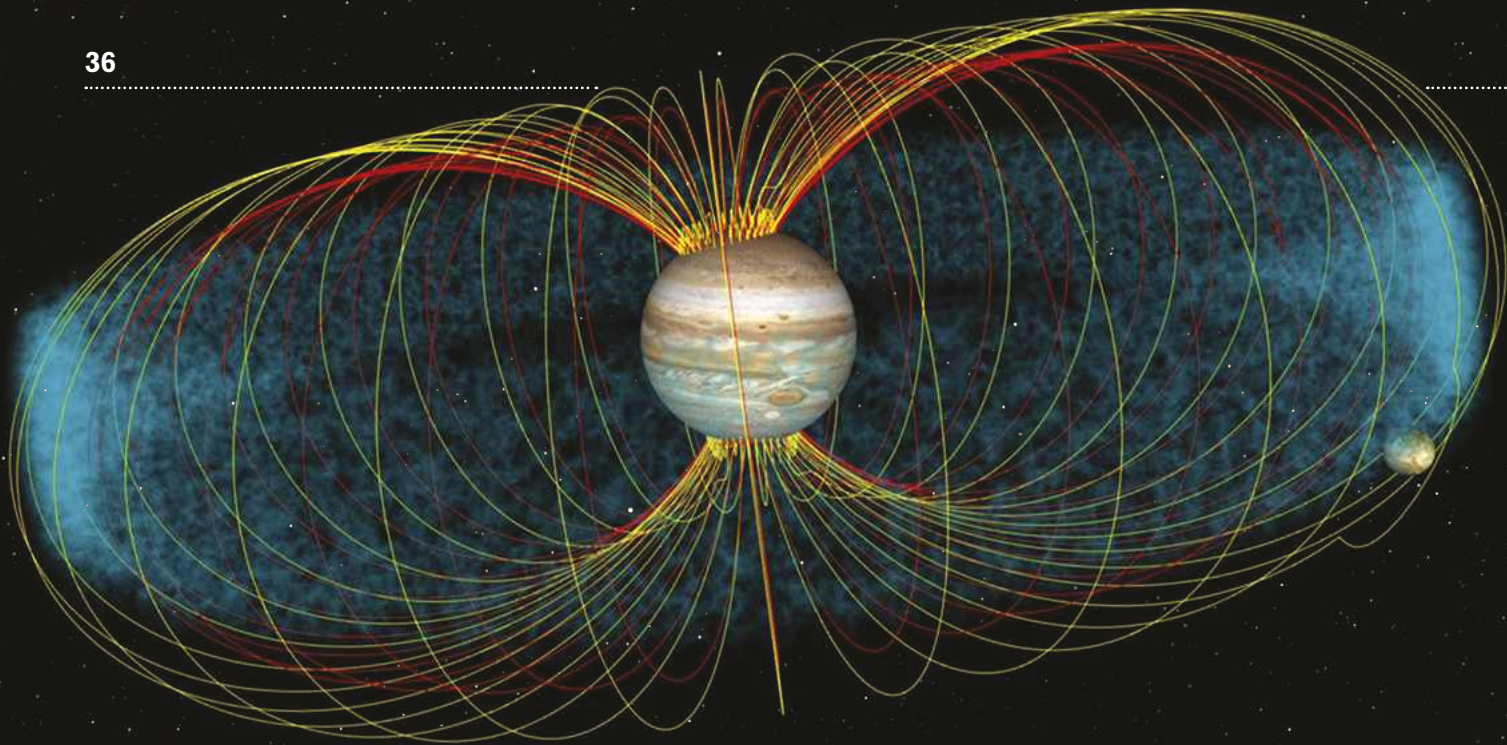
BLACK HOLES HAVE THEORETICAL OPPOSITES KNOWN AS WHITE HOLES

Black holes are known for their voracious appetites; their influence is so strong that even light can't escape their gravity. But they have a theoretical converse – white holes. They are effectively the opposite of their dark relatives, spitting out light and matter instead of trapping it. So far, they are purely hypothetical objects; astronomers are contemplating how they could form in reality.

What amazes me



Marek Kukula, Public Astronomer at the Royal Observatory Greenwich
The Moon is thought to have formed after a collision between Earth and a Mars-sized body 4.45 billion years ago. The debris probably took less than a century to coalesce into the Moon; initially it would have been just a few Earth radii away, filling the sky and raising colossal tides.



NEPTUNE HAS ONLY COMPLETED ONE ORBIT AROUND THE SUN SINCE ITS DISCOVERY

Neptune takes a whopping 165 years to complete one full orbit around the Sun. Since it was discovered in 1846, Neptune only recently finished its first full post-discovery orbit in 2011. Demoted planet Pluto has yet to match this – it is not even close to completing one full, 248-year orbit since its discovery in 1930.

What amazes me



**Sir Martin Rees,
Astronomer Royal**

Pulsars are amazingly precise clocks. If a pulsar's speed towards us altered, we could detect this within a year or two, even if the change was no bigger than the speed of the hour hand on your watch, despite the huge distances involved; even the closest pulsar to Earth is 280 lightyears away.

IF JUPITER'S MAGNETIC FIELD WERE VISIBLE, IT WOULD APPEAR BIGGER THAN THE MOON IN THE NIGHT SKY

The region of space in which a mass's magnetic field dominates is known as its magnetosphere. These regions surround planets, pulsars and even our Galaxy. The planets in our Solar System have magnetospheres that interact with and are shaped by the charged particles in the wind streaming from our Sun.

The largest magnetosphere in our Solar System surrounds Jupiter. Jupiter rotates very fast and has a very strong magnetic field, and

its magnetosphere is filled with plasma from its volcanically active moon, Io. These features, coupled with the fact that the solar wind is slower and less dense at Jupiter than at Earth, lead to a very sizeable Jovian magnetosphere. It is easily big enough to contain a body the size of our Sun and, if visible, would be larger than the Moon in our night sky; quite an achievement considering that it is over 1,500 times farther away.

PLANETS CAN WANDER THROUGH SPACE WITHOUT A PARENT STAR

Not all planets form and stay around stars: astronomers estimate that there could be more than 200 billion of them floating free and drifting through our Galaxy. These 'rogue' planets were thought to have been kicked out of their home systems. While this is true for some, other planets may have formed completely independently of an accretion disc (as was the case for our Solar System) instead forming from the collapse of tiny, cold clouds known as globulettes.



THE SUN LOSES A BILLION KILOS PER SECOND

Particles in the Sun's upper atmosphere are so hot and energetic that they speed out into space as part of the solar wind. Our star sheds around 1.3 trillion trillion particles every second. This equates to roughly one billion kilograms of matter per second, or one Earth every 185 million years.

What amazes me



Maggie Aderin-Pocock,
The Sky at Night

The Sun is so vast you can squish 1.3 million Earths inside. Its mass makes up nearly 99.9 per cent of the Solar System and its colossal power output is around 400 billion billion megawatts – put another way, the equivalent energy of 100 billion nuclear bombs every second.

VAST AMOUNTS OF WATER HAVE BEEN FOUND IN SPACE

Earth's oceans may not be that unique. Three of Jupiter's moons (Europa, Ganymede, and Callisto) and two of Saturn's (Enceladus and Titan) are thought to have underwater seas. Europa's ocean may contain over twice the volume of water found on Earth. However, the most water ever discovered surrounds a black hole some 12 billion lightyears away. This region contains vast amounts of water vapour, the equivalent of 140 trillion times the volume of water in Earth's oceans.

THERE IS GRAVITY ON THE ISS

Footage of astronauts on the ISS may give the impression of a gravity-free environment, but onboard gravity is actually only 10-11 per cent weaker than it is on Earth's surface. Astronauts float freely due to the ISS's continual state of free-fall, the same effect experienced by skydivers. The difference with the ISS is that it also has horizontal motion. As the ISS moves 'sideways' and falls towards Earth, the horizon curves away beneath it at the same rate, keeping the ISS in orbit and simulating a feeling of weightlessness for anyone on board.

MOST OF THE SUN-LIKE STARS IN OUR GALAXY ARE IN MULTIPLE STAR SYSTEMS

Our Sun may be a single star, but it is in the minority. Over half of the Sun-like stars in the Milky Way are part of multiple star systems, binaries or

triplets, with stars orbiting around a common centre of mass. Most lower-mass stars like red dwarfs, however, live alone without a companion.



OUR DAYS ARE GETTING LONGER

Earth's spin speed is slowing; every year, it takes our planet a little longer to complete one full revolution on its axis. The change is miniscule, however. Every century, Earth slows by 1/500th of a second; 1,000 years from now, one day will be two hundredths of a second longer than today.

...AND THE MOON IS GETTING FARTHER AWAY EVERY YEAR

The Moon exerts a pull on Earth, causing our planet to be slightly egg-shaped. It affects water even more, creating tides and causing the oceans to pile up towards one side of the planet, forming a 'tidal bulge'.

This bulge is dragged around with the Moon as it orbits. As Earth rotates faster than the Moon – 24 hours versus 27.3 days – the bulge moves slightly ahead of the

Moon's position in orbit. The Moon pulls back on it, effectively trying to slow it down and causing Earth's rotation rate to gradually slow down over time as a result.

As the two bodies interact through gravity, this tugging causes Earth to lose energy while the Moon gains energy. Because of this energy boost the Moon is slowly spiralling outwards, moving away from us by 3.8cm per year. **S**





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FREE 2015 CALENDAR

Inside the December issue of *BBC Sky at Night Magazine* you'll receive a free 2015 calendar featuring great images from the Astronomy Photographer of the Year 2014 competition. It's on sale from **20 November**.



The winning images will go on display at the Royal Observatory Greenwich



ASTRONOMY PHOTOGRAPHER OF THE YEAR 2014

We reveal the winners of the world's largest astro imaging competition

NATIONAL MARITIME MUSEUM

With a record 2,500 entries from over 50 countries, the judges of 2014's Astronomy Photographer of the Year competition had a tough job deciding the winners. The standard of entries to the contest, organised by the Royal Observatory Greenwich and supported by *BBC Sky at Night Magazine*,

was incredibly high, with images ranging from stunning deep-sky portraits of distant nebulae to artistic shots that included landmarks on Earth. This year even saw the first submission taken from the edge of space on a weather balloon.

Entries were judged in seven categories: the four main ones – Earth and Space, Deep Space, Our Solar System and Young

Astronomy Photographer of the Year; and the three special prizes also awarded – People and Space, Robotic Scope Image of the Year and the Sir Patrick Moore Prize for Best Newcomer. Take a look at the winners on the following pages, and see them at the Royal Observatory Greenwich's free exhibition, which runs until 22 February 2015.

www.rmg.co.uk/astrophoto

THE JUDGES



Chris Lintott
Presenter,
The Sky at Night



Chris Bramley
Editor, *BBC Sky at Night Magazine*



Marek Kukula
Public Astronomer,
Royal Observatory
Greenwich



Melanie Vandenbrouck
Curator of art, Royal
Museums Greenwich



Pete Lawrence
Presenter,
The Sky at Night



Will Gater
Astronomy journalist
and author



Maggie Aderin-Pocock
Presenter,
The Sky at Night



Melanie Grant
Picture editor,
Intelligent Life



▲ DEEP SPACE

THE HELIX NEBULA (NGC 7293)

David Fitz-Henry

Bowen Mountain, New South Wales, Australia

Equipment: STL-11000M CCD camera, home-built Newtonian telescope, Paramount ME mount, 12.5-inch mirror lens, 15-25mm f/4.8 lens.

Judge's verdict: "I gasped the first time I saw this picture. What an explosion of colour, almost like the eye of the Universe is staring right at you." – Melanie Grant, *Intelligent Life*.

EARTH AND SPACE ►

WIND FARM STAR TRAILS

Matt James

Lake George, Bungendore, New South Wales, Australia

Equipment: Sony A99 DSLR camera, Sony 70–200mm f/2.8 lens, RRS tripod.

Judge's verdict: "A deceptively simple monochrome picture with a very graphic quality. It looks like a shower of stars falling onto a field of man-made dandelions." – Melanie Vandenbrouck, Royal Museums Greenwich.



YOUNG ASTRONOMY PHOTOGRAPHER OF THE YEAR ►

NEW YEAR OVER CYPRESS MOUNTAIN

Emmett Sparling, Bowen Island, British Columbia, Canada

Equipment: Canon EOS 7D DSLR camera, 18mm f/1.8 lens.

Judge's verdict: "It reminds me of the work of some of the greatest contemporary photographers, in how the soft urban lights and delicate star trails shine against the atmospheric mist." – Melanie Vandenbrouck, Royal Museums Greenwich.



▲ OUR SOLAR SYSTEM

BEST OF THE CRATERS

George Tarsoudis, Alexandroupolis, Evros, Greece

Equipment: Unibrain Fire-1 785 monochrome camera, Sky-Watcher BK DOB 14-inch collapsible telescope, Sky-Watcher AZ EQ6 mount.

Judge's verdict: "This makes me feel as though I'm rushing over the lunar surface in a spacecraft. We're lucky to live in a time when we can see the Moon in such amazing detail." – Marek Kukula, Royal Observatory Greenwich.



▼ PEOPLE AND SPACE

LOST SOULS

Julie Fletcher

Kati Thanda-Lake Eyre National Park, South Australia

Equipment: Nikon D800 camera, 14mm f/2.8 lens.

Judge's verdict: "This picture captures for me what it feels like to stand in solitude under a majestic night sky: that as individuals we are a fleeting impression within the vastness of space and time." – Chris Bramley, *BBC Sky at Night Magazine*.





▲ PEOPLE AND SPACE

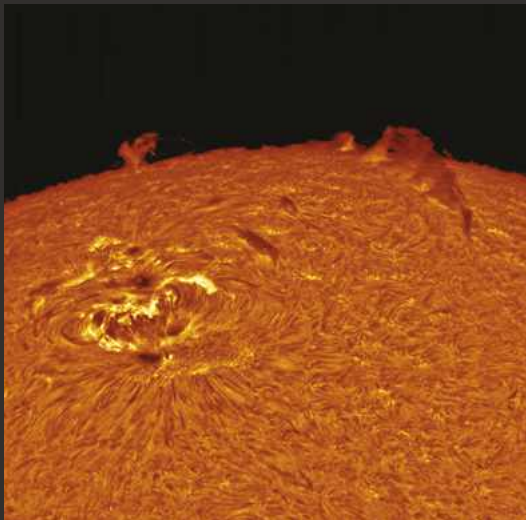
HYBRID SOLAR ECLIPSE 2

Eugen Kamenew

Turkana County, Rift Valley, North Kenya

Equipment: Canon EOS 5D Mk II DSLR camera, 700mm f/22 lens.

Judge's verdict: "An eclipse is magical enough, but with the silhouetted figure an iconic image is created." – Maggie Aderin-Pocock, *The Sky at Night*.



▲ OUR SOLAR SYSTEM

RIPPLES IN A POND

Alexandra Hart, Holmes Chapel, Cheshire, UK

Equipment: PGR Grasshopper 3 camera, TEC140 refractor, EQ6 Pro mount, Solarscope DSF 100mm f/18 lens.

Judge's verdict: "The textures in this image are incredible. You really get a sense that there are vast looping arcs of plasma leaping up and around the active region on the left." – Will Gater, astronomy journalist.



▲ DEEP SPACE

THE HORSEHEAD NEBULA (IC 434)

Bill Snyder, Heaven's Mirror Observatory at SRO, California, US

Equipment: Apogee U16 CCD camera, Planewave 17-inch telescope, Paramount mount, f/6.8 lens.

Judge's verdict: "A really unusual view of a famous object: the swirling structure at the base of the head is unusually well seen here." – Chris Lintott, *The Sky at Night*.

▼ YOUNG ASTRONOMY PHOTOGRAPHER OF THE YEAR

THE HORSEHEAD NEBULA (IC 434)

Shishir and Shashank Dholakia, Lake San Antonio, California, US

Equipment: SBIG ST-8300M CCD camera, Astro-Tech 4.4-inch f/7 triplet refractor, Orion Atlas EQ-G mount.

Judge's verdict: "The star colours are beautifully controlled in this image. The detail in the horse's head and the Flame Nebula are particularly good, too." – Will Gater, astronomy journalist.



▼ THE SIR PATRICK MOORE PRIZE FOR BEST NEWCOMER

COASTAL STAIRWAYS

Chris Murphy, Wairarapa, New Zealand

Equipment: Nikon D600 camera, 14–24mm f/2.8 lens.

Judge's verdict: "The riot of stars dancing above this rocky canopy fall within a sumptuously photographed sky. A triumph." – Melanie Grant, *Intelligent Life*.



▼ ROBOTIC TELESCOPE

NGC 3718

Mark Hanson

Rancho Hidalgo, New Mexico, US

Equipment: Apogee U16M CCD camera, RCOS 14.5-inch f/8 Ritchey-Chretien telescope, Paramount ME2 mount.

Judge's verdict: "The unusual structures in the blue arms of NGC 3718 convey complex gravitational forces shaping this warped spiral galaxy. The contrast between the warm colours of the core and the outer arms is very beautiful." – Pete Lawrence, *The Sky at Night*.



ASTRONOMY
PHOTOGRAPHER
OF THE YEAR 2014

OVERALL WINNER



EARTH AND SPACE WINNER

Aurora over a Glacier Lagoon

James Woodend, Jökulsárlón, Vatnajökull National Park, Iceland

Equipment: Canon EOS 5D Mk III camera, 33mm f/3.2 lens.

Judge's verdict: "Breathtaking shot! With its surreal colours and majestic aura, it could be the landscape of a fairytale. I love the sense of depth, the sharpness of the turquoise ice, the structured symmetry, but, above all, its ethereal feel." – Melanie Vandenbrouck, Royal Museums Greenwich.

Judge's verdict: "This beautiful image captures what it's really like to see a good aurora – the landscape, with the reflections that seem almost sharper than the shapes in the sky, is a terrific bonus too!" – Chris Lintott, *The Sky at Night*.

Judge's verdict: "I absolutely love the colours and auroral symmetry in this image as well as the contrast between the serene floating ice and the dramatic light display above. The blue ice is exquisite and the overall composition is mesmerising. The true beauty of planet Earth captured by camera." – Pete Lawrence, *The Sky at Night*.



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ASTRONOMY PHOTOGRAPHER OF THE YEAR 2014

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The Sky Guide October



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.

On 25 October, the planet Saturn will be occulted by the Moon. Disappearance occurs with the Sun still above the horizon, making the event that bit trickier to see. Reappearance occurs just after sunset in the evening twilight.

Highlights

Your guide to the night sky this month



This icon indicates a good photo opportunity

6

MONDAY

Dwarf planet Ceres will be 25 arcminutes above Saturn. Both objects will be very low in the twilight sky as darkness falls. At mag. +9.0, Ceres is a challenging spot.



7

TUESDAY

Uranus is at opposition today. The mag. +5.7 planet can currently be found in Pisces to the south of the line formed between mag. +4.3 Epsilon (ε) and mag. +4.4 Delta (δ) Piscium.

11

SATURDAY

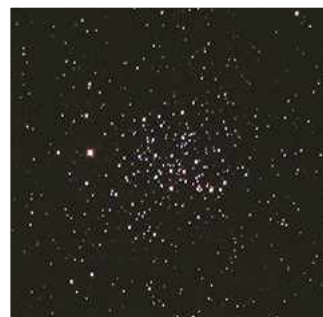
The waning gibbous Moon (85% lit) is just to the west of the V-shaped Hyades cluster and 9° south of the Pleiades (shown here) this evening.



17

FRIDAY

At around 02:00 BST (01:00 UT) the waning crescent Moon (37% lit) is 7° south of the Beehive Cluster in Cancer and 12° southwest of mag. -1.8 Jupiter. A wide-field shot may also reveal mag. +6.9 open cluster M67, 4° east of the Moon.



20

MONDAY

This is a great time to try and find your way around our *Deep-sky tour* on page 56. This month, we're wandering around some of the objects that can be seen in the constellation of Cassiopeia.

21

TUESDAY

Tonight sees the peak of the annual Orionid meteor shower. This year's display should be a good one because the Moon will be mostly out of the way – see page 51.



22

WEDNESDAY

Look out for a slender waning crescent Moon (2% lit) visible low in the east-southeast at around 07:00 BST (06:00 UT). See page 52 for a chart showing its position relative to morning planet Mercury.

23

THURSDAY

Today's new Moon makes this a great time to enjoy the wonders of the October night sky. Don't miss the wonderful Andromeda and Triangulum Galaxies, M31 and M33, both due south and highest in the sky around midnight.



24

FRIDAY

You can catch Galilean moons Europa and Callisto close together this morning; Europa's disc will actually clip that of Callisto. The partial occultation occurs between 06:08 BST and 06:11 BST (05:08 UT and 05:11 UT).

26

SUNDAY

The clocks go back an hour at 02:00 BST this morning, marking the end of daylight saving time for 2014 and a return to Greenwich Mean Time. Greenwich Mean Time is the same as UT.

27

MONDAY

This is a good time to spot the tiny planet Mercury in the dawn sky. Turn to page 52 to find out how to locate it before sunrise.

28

TUESDAY

Two of Jupiter's Galilean moons have a close encounter this morning. Between 05:32 UT and 05:39 UT, Europa will appear to partially occult Ganymede.

30

THURSDAY

The setting Moon will occult the third-magnitude star Beta (β) Capricorni at around 22:00 UT.

8 WEDNESDAY ▶
Eclipsing variable star Algol (Beta (β) Persei) reaches its minimum brightness of mag. +3.4 at around 02:10 BST (01:10 UT) this morning.



18 SATURDAY ▶
The waning crescent Moon (28% lit) is just under 6° south of mag. -1.8 Jupiter as it rises at around 02:00 BST (01:00 UT).

19 SUNDAY ▶
Mars and 9th-magnitude comet C/2013 A1 Siding Spring are at their closest today. See page 51.



25 SATURDAY ▶
A lunar occultation of Saturn occurs this evening. Disappearance occurs in daylight around 17:00 BST, with the planet reappearing from behind the Moon about an hour later in the darkening twilight. See page 50.

Venus is at superior conjunction today.



What the team will be observing in October



Pete Lawrence "My scopes will be trained on Saturn for the tricky lunar occultation on the 25th. The event starts in daylight and ends in darkening twilight – challenging, but I've caught it in similar conditions before."



Stephen Tonkin "I'll need a good southern aspect in order to catch one of the most rewarding binocular galaxies, NGC 253 or the Sculptor Galaxy, when it briefly shows its beautiful glow above the horizon murk."



Paul Money "I'm aiming to image Uranus at opposition with my 8-inch Maksutov-Cassegrain – hopefully I'll be able to capture its four brightest moons as well."

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

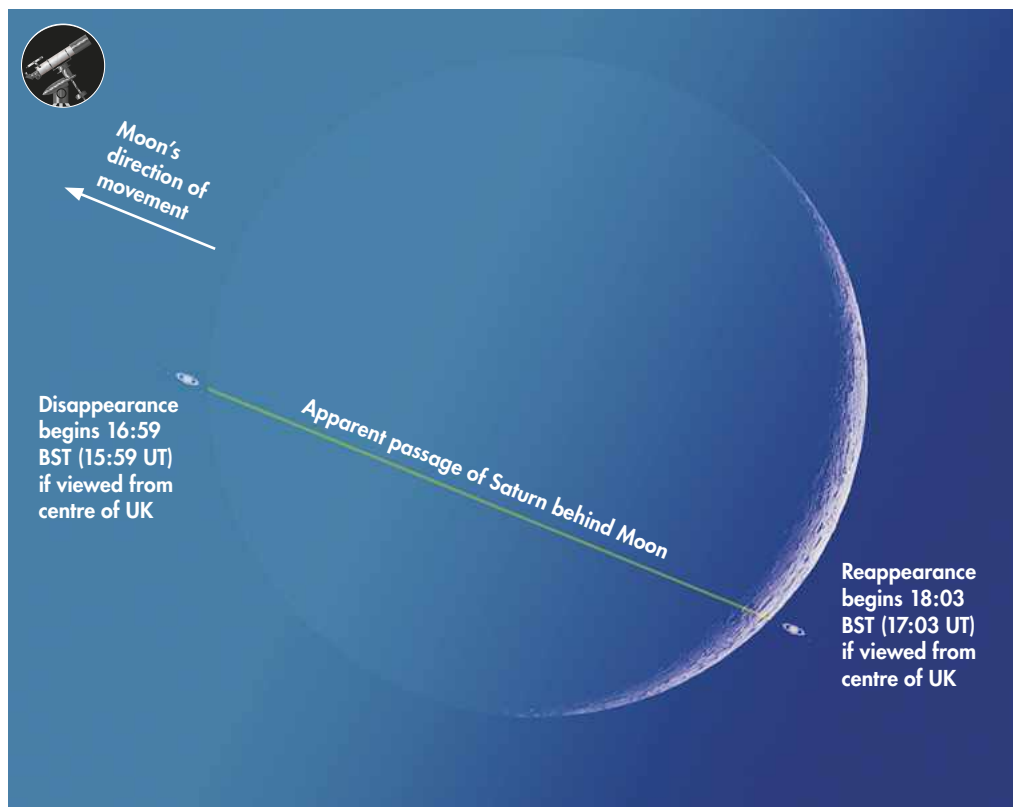
If you're new to astronomy, you'll find two essential reads on our website. Visit http://bit.ly/10_Lessons for our 10-step guide to getting started and http://bit.ly/First_Tel for advice on choosing your first scope.

DON'T MISS...

3 top sights

Occultation of Saturn

WHEN: 25 October from 16:40 BST to 18:20 BST (15:40 UT to 17:20 UT)



Saturn will disappear behind the Moon's disc in daylight, appearing just after sunset around an hour later

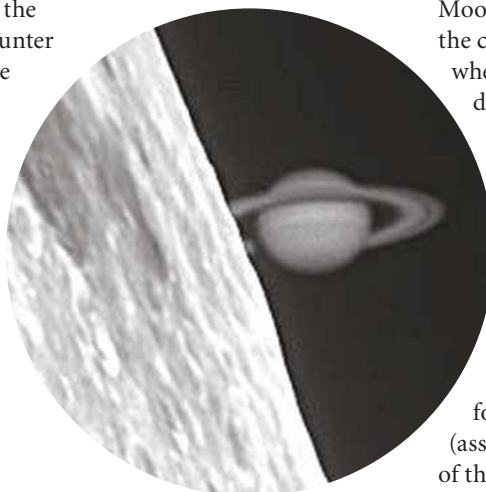
A RARE AND wonderful occultation occurs on the 25th, when the 3%-lit waxing crescent Moon passes in front of the planet Saturn. As usual there's a catch: this time it is that the event begins in daylight and ends as the sky is getting darker just after sunset. Tricky then, but all the more rewarding for it.

Saturn isn't the brightest of the planets, and at the time of the occultation will be at mag. +0.9. As the Moon moves

eastwards in front of the background stars (or background blue sky in this case) it's the dark edge of the Moon that will first encounter the planet. Disappearance begins around 16:59 BST (15:59 UT) if viewed from the centre of the UK. As the exact time varies with your location, it is best to locate Saturn at least 15 minutes before this to make sure you don't miss it.

It takes just 80 seconds for the whole planet to disappear. Saturn will reappear 64 minutes later, so 18:03 BST (17:03 UT), if seen from the centre of the UK.

Again, this will vary slightly depending on your location, so it pays to be



The Ringed Planet will emerge from the waxing crescent Moon's bright, trailing edge

ready at least a quarter of an hour beforehand.

Reappearance will be easier to see than disappearance. This is because Saturn will emerge from the bright limb of the Moon with the Sun 2° below the horizon – though that's still not very much at all and the sky will actually be quite bright. Another factor to take into account is the Moon's altitude. At disappearance it will be 12° up, but it will have dropped to just 6° above the horizon at reappearance.

The key to locating Saturn is to first locate the Moon. If you have a Go-To system and can set it up the night before the occultation, that would be a big bonus. If not it's still perfectly possible to find the Moon – it will be a little over an outstretched hand width to the left and up from the Sun. At 3% illumination, the waxing crescent itself may be a tricky to spot in the bright blue sky.

Once you've located the Moon, focus accurately on the crescent and then look at where you think the invisible dark limb extends to the east (left). Saturn will be close to this point at 16:45 BST (15:45 UT). It goes without saying that the planet will be hard to spot against the blue daylight sky.

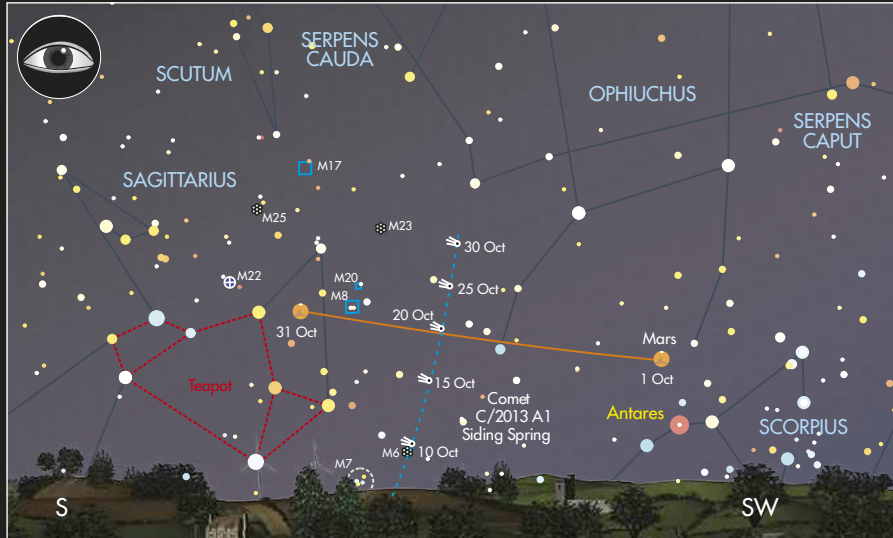
Reappearance occurs approximately at the four o'clock position (assuming the upper cusp of the crescent represents 12 o'clock). If you'd prefer to image the event, turn to page 60 for our top tips.

! 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.

Mars and comet C/2013 A1 Siding Spring

WHEN: 18-22 October, around 19:30 BST (18:30 UT)



The comet's path in October; constellation positions are correct for 05:00 BST on the 20th

IT'S OFTEN THE case that a conjunction between two celestial bodies occurs simply because they look close together in the sky, the truth being they are a significant physical distance apart. However, this month we have a conjunction between two Solar System objects that are both

apparently and physically close at the same time.

The objects in question are Mars and comet C/2013 A1 Siding Spring. On 19 October at 19:30 BST (18:30 UT), the nucleus of the comet will pass the centre of Mars by around 132,000km with a small uncertainty of a few thousand

kilometres. Arrangements have been made for some of the missions currently on or in orbit around Mars to observe this close encounter. It can also be seen from the UK too, but for us Mars and the comet will be very low in the southwest.

It would be a good idea to look for Mars a few days before the 19th and try to identify the comet so you know what to look for. C/2013 A1 Siding Spring will be around mag. +8.5 at this time, so seeing it will be a balancing act between waiting for the sky to get sufficiently dark and not letting the comet get too low.

On the 19th at 19:30 BST (18:30 UT), the apparent separation of both objects will be a little over 1.5-arcminutes – an easy fit within a telescope field of view even with a decent magnification. We'd recommend starting off at low magnification and increasing the power as you become more confident with what's being presented.

The encounter will be pretty good between 18-22 October so if the key date of the 19th is clouded out, at least there are other opportunities. The best view of course will be from the surface of Mars.

The Orionids

WHEN: 17-23 October, 01:00-06:00 BST (00:00-05:00 UT)

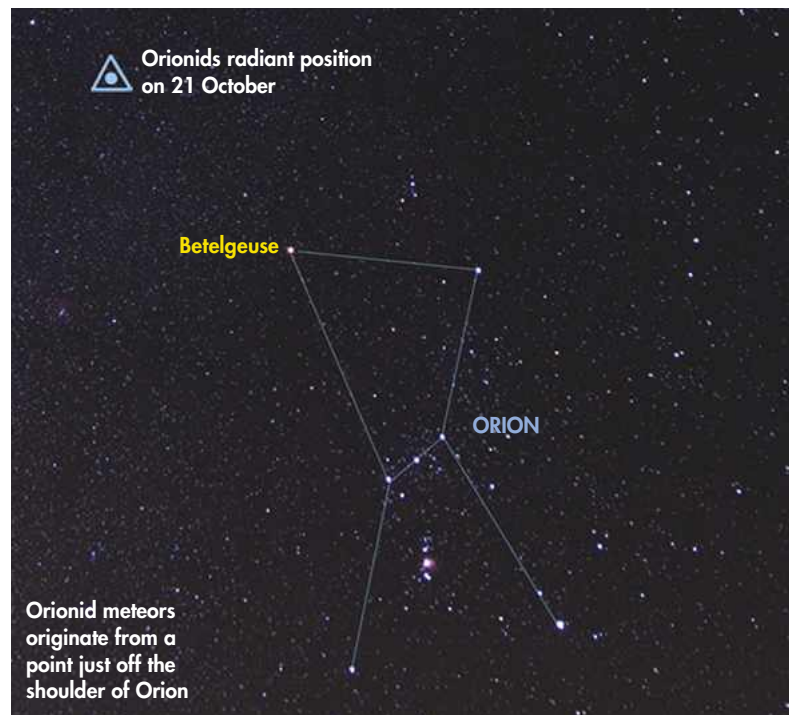
THE ANNUAL ORIONIDS meteor shower reaches its peak on 21 October and – being close to new Moon – the display is likely to be a good one. That's as long as the clouds stay away of course.

The Orionids occur when Earth passes through the debris stream left around the orbit of that most famous of periodic comets, 1P/Halley. It is the second encounter with the stream that occurs each year. The first gives rise to the Eta Aquariid

meteor shower, which peaks on 6 May.

Orionid meteors appear to emanate from a location off the shoulder of Orion, not too far from mag. +0.5 red supergiant Betelgeuse (Alpha (α) Orionis). The shower is active from 2 October until 7 November. At its peak on 21 October it will typically produce a zenithal hourly rate (ZHR) of 25 meteors per hour, although estimates suggest a slightly lower peak of 20 meteors per hour in 2014.

The shower is known to produce several sub-peaks in activity and these help to keep things interesting over a few nights. In particular watch out for one sub-peak that may



produce a ZHR of 20 meteors per hour on the night of 17/18 October. We'd recommend

observing from 01:00 BST until 06:00 BST (00:00 UT to 05:00 UT) for the best views.



NEED TO KNOW

The zenithal hourly rate of a meteor shower is the expected number of meteors seen under perfect conditions with the radiant point of the shower overhead.

The planets

PICK OF THE MONTH

MERCURY

BEST TIME OCTOBER:

31 October, 06:00 UT

ALTITUDE: 6° (low)

LOCATION: Virgo

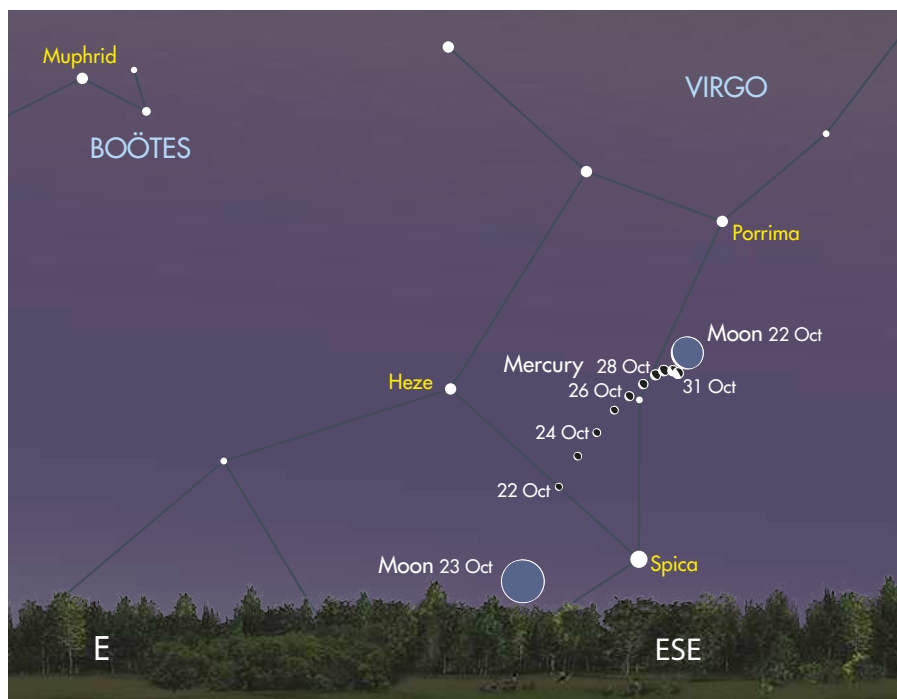
DIRECTION: East-southeast

RECOMMENDED EQUIPMENT:

3-inch or larger telescope

FEATURES OF INTEREST:

Phase, colour and possible surface shadings under good seeing conditions

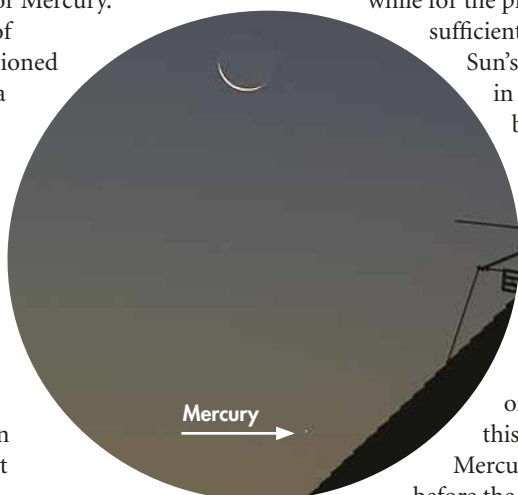


Opportunities to view Mercury vastly improve once in returns to the pre-dawn sky

THE MONTH DOESN'T start particularly well for Mercury.

At the beginning of October, it is positioned so that it sets just a little after the Sun has gone down. It starts off at mag. +0.6 but gets dimmer with each passing day until it reaches inferior conjunction on 16 October, lining up with the Sun on the part of its orbit closest to Earth.

Things are a little different after this date, when Mercury reappears in the morning sky. It takes a



Mercury sits close to the thin crescent Moon on the 22nd

while for the planet to move sufficiently away from the Sun's glare to be seen in the dawn twilight, but as it does so it also gets brighter, which will make it somewhat easier to spot.

There's a chance it'll be visible again just before sunrise on 22 October. On this date, mag. +2.1 Mercury will rise an hour before the Sun. As an added bonus, there's a lovely waning crescent Moon (2% lit) above and to the right of the planet.

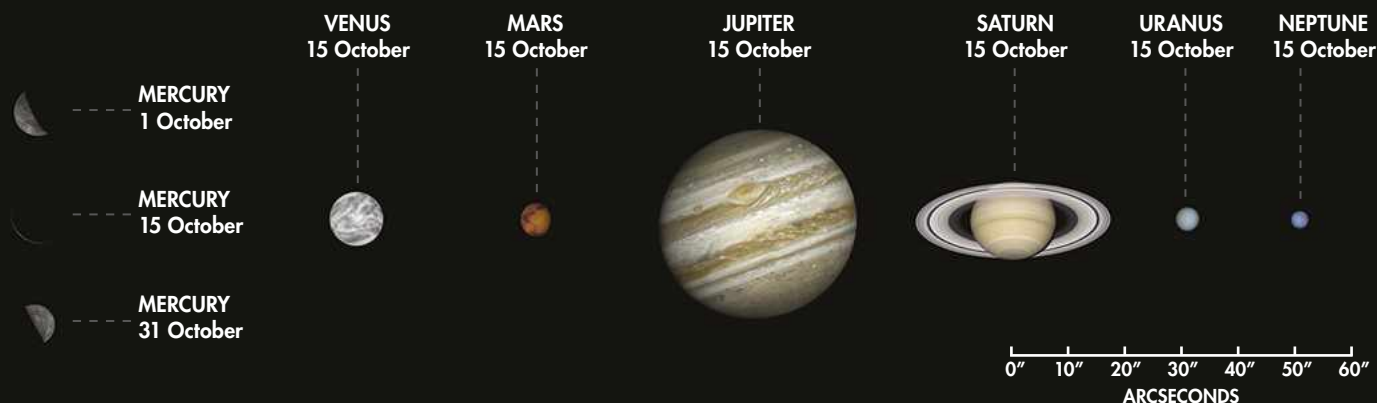
On 23 October, mag. +1.6 Mercury rises approximately 75 minutes before the Sun. If you can get a look at it through a telescope, it'll be showing a delicate 13%-lit crescent measuring 8 arcseconds across.

The planet's position continues to improve over the next few days, and by the 27th it can be seen popping up over the east-southeast horizon one hour and 40 minutes before sunrise. Shining at mag. +0.3, its phase will have increased to 32% on this date with a slightly smaller apparent diameter of 7 arcseconds.

On 31 October, Mercury will be mag. -0.4, an easy object to spot against the fairly dark twilight background – look at 05:45 UT. At this time the phase will have reached 51%, so it'll appear as a small half circle when viewed through a telescope.

THE PLANETS IN OCTOBER

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



URANUS

BEST TIME IN OCTOBER:

7 October, 01:00 BST
(00:00 UT)

ALTITUDE: 42°

LOCATION: Pisces

DIRECTION: South

Uranus reaches opposition on the 7th and will be visible all night long at the start of the month. This distant world remains at the threshold of naked-eye visibility from a site with dark skies, but is an easy spot in binoculars.

The planet has an apparent diameter of 3.7 arcseconds at the moment. Due to a relatively uniform atmosphere in visible light, it doesn't really give up its secrets that easily through amateur telescopes. What is lovely though is its greenish hue.

The full Moon sits 6° west of Uranus on the 8th. By the end of the month, the planet is above the eastern horizon as darkness falls, but remains visible for the rest of the night.

JUPITER

BEST TIME IN OCTOBER:

31 October, 05:30 UT

ALTITUDE: 48°

LOCATION: Leo

DIRECTION: South-southeast

Jupiter is becoming prominent once more. At the start of the month the planet is a bright mag. -1.8 and lies roughly one-third of the way along a line joining M44 in Cancer to mag. +1.4 Regulus (Alpha (α) Leonis). It manages to get to an altitude of 35° as the morning sky starts to lighten. By month end Jupiter is a slightly brighter mag. -1.9, and its 33-arcsecond disc will show a wealth of detail through a telescope.

NEPTUNE

BEST TIME IN OCTOBER:

1 October, 23:00 BST
(22:00 UT)

ALTITUDE: 27°

LOCATION: Aquarius

DIRECTION:

South
Neptune is currently in Aquarius, not too far from mag. +4.8 Sigma (σ) Aquarii. The planet appears as a mag. +7.8 dot, too dim for naked-eye viewing but a relatively easy catch for binoculars. It reaches its highest point in the sky in darkness all month, but sets by 01:00 UT by the end of October.

MARS

BEST TIME IN OCTOBER:

18-21 October, 19:00 BST
(18:00 UT)

ALTITUDE: 7° (low)

LOCATION: Ophiuchus

DIRECTION: South-southwest

Mars is in Ophiuchus and visible low in the southwest as darkness falls. Telescopically it's pretty small, with a disc measuring around 5 arcseconds.

At the start of October, Mars is just over 3.5° northeast of Antares (Alpha (α) Scorpii), also known as the 'Rival of Mars'. With Mars shining at mag. +0.8 and Antares at mag. +1.0, this is a good time to compare their likeness.

Mars moves eastwards during October, passing mag. +3.3 Theta (θ) Ophiuchi by 20 arcminutes on the 14th. On the 27th Mars – now in Sagittarius – passes just below the Lagoon Nebula, M8. The most exciting encounter, however, will be when it meets comet C/2013 A1 Siding Spring on 18-21 October. See page 51.

SATURN

BEST TIME IN OCTOBER:

25 October, 18:00 BST
(17:00 UT)

ALTITUDE: 5° (low)

LOCATION: Libra

DIRECTION: Southwest

Mag. +0.9 Saturn is too low for serious observation, but will be occulted by the Moon on the 25th. See page 51.

NOT VISIBLE THIS MONTH

VENUS



JUPITER'S MOONS October

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 midnight.



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>

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
- ASTERISM
- PLANET
- QUASAR
- STAR BRIGHTNESS:**
- MAG. 0 & BRIGHTER
- MAG. +1
- MAG. +2
- MAG. +3
- MAG. +4 & FAINTER
- COMPASS AND FIELD OF VIEW
- MILKY WAY

WHEN TO USE THIS CHART

1 OCTOBER AT 01:00 BST

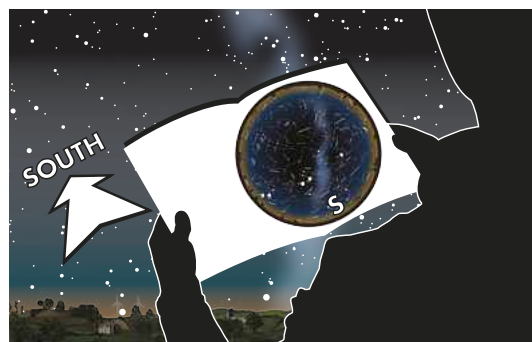
15 OCTOBER AT 00:00 BST

31 OCTOBER AT 22:00 UT

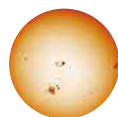
On other dates, stars will be in slightly different places due to Earth's orbital motion. Stars that cross the sky will set in the west four minutes earlier each night.

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 OCTOBER*



DATE	SUNRISE	SUNSET
1 Oct 2014	07:11 BST	18:47 BST
11 Oct 2014	07:29 BST	18:23 BST
21 Oct 2014	07:47 BST	18:00 BST
31 Oct 2014	07:06 UT	16:39 UT

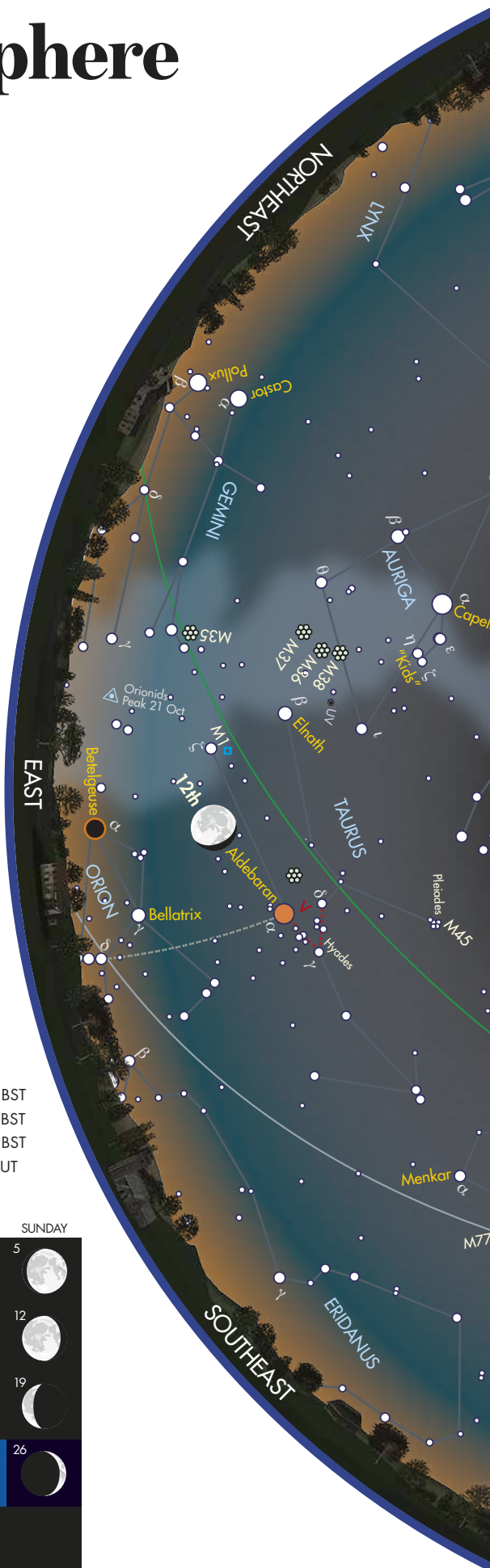
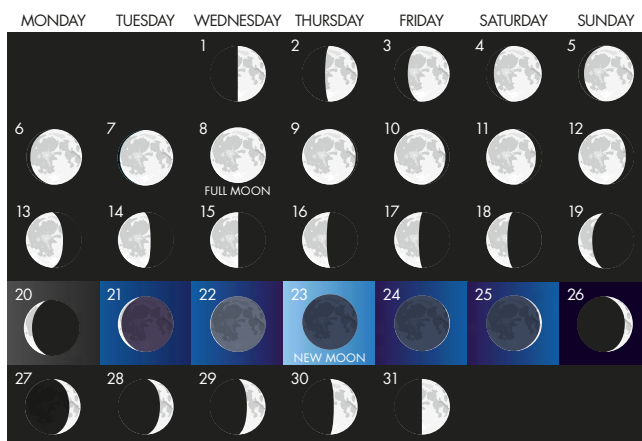
THE MOON IN OCTOBER*

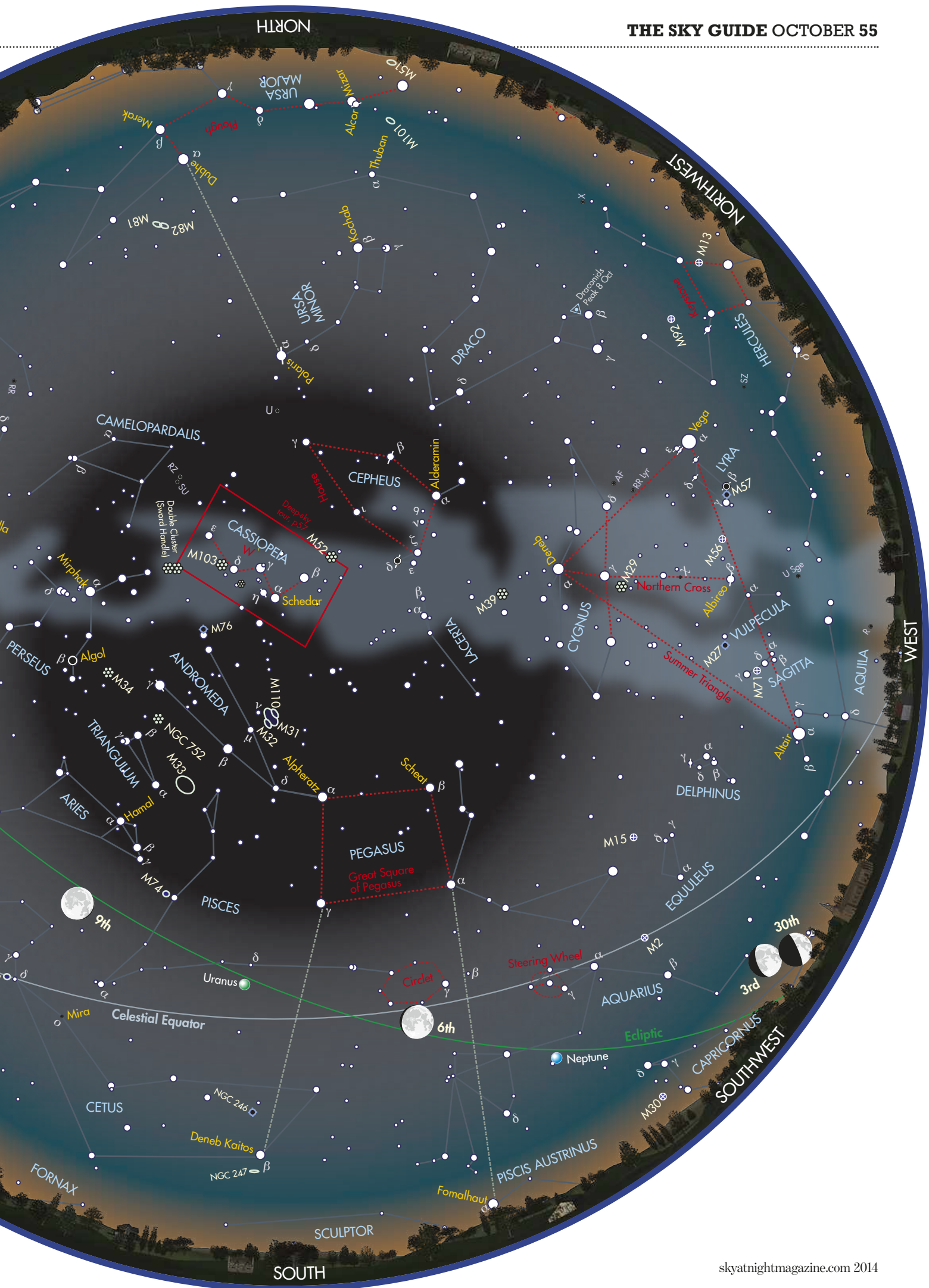


MOONRISE TIMES

1 Oct 2014, 14:37 BST	17 Oct 2014, 00:42 BST
5 Oct 2014, 17:08 BST	21 Oct 2014, 04:58 BST
9 Oct 2014, 19:02 BST	25 Oct 2014, 09:29 BST
13 Oct 2014, 21:48 BST	29 Oct 2014, 12:23 UT

*Times correct for the centre of the UK





Deep-sky tour

Explore the lesser-known sights in the sky surrounding Cassiopeia's famous 'W'

☑ Tick the box when you've seen each one



The Pac-Man Nebula seems to eat stars rather than ghosts

1

A CONCLAVE OF CLUSTERS

Our first target is not one but six open clusters, five of which form a straight line 2.5° northeast of mag. +2.3 Caph (Beta (β)) Cassiopeiae. The southern end of the line is marked by mag. +9.7, 5-arcminute-wide Berkeley 58. A 10-inch scope at medium to high magnification should reveal 35 stars of mag. +12.0 or fainter. Next in line is NGC 7790, which has a similar size but is less dense than Berkeley 58. Mag. +9.4 NGC 7788 is next and shows about a dozen members in a 10-inch scope. The line of five rounds off with ninth-magnitude Harvard 21 and 10th-magnitude King 12. Ninth-magnitude Frolov 1 lies 0.25° north of NGC 7788. ☐ **SEEN IT**

2

IC 10

We're going to head outside the Milky Way for our second target, a galaxy known as IC 10. This is believed to be part of the Local Group of Galaxies, members of which include the Andromeda and Triangulum Galaxies as well as our own. IC 10 lies 1.5° east of Caph and requires an 8-inch or larger instrument to pick out from the background sky. Unlike what you'd normally expect to see from a galaxy, IC 10 doesn't have a central condensation as such. Instead, it rather resembles a subtle granular lightening of the background sky spanning 5 arcminutes. Despite its rated magnitude of +10.3, IC 10 has a low surface brightness, which makes it a bit of a challenge. Low to medium magnification is recommended. ☐ **SEEN IT**

3

THE PAC-MAN NEBULA

Our next object is known as the Pac-Man Nebula because it resembles the famous videogame character of the same name in long-exposure photographs. Formally designated NGC 281, the nebula can be found 1.6° east of mag. +2.2 Schedar (Alpha (α)) Cassiopeiae. A 6-inch scope shows a faint glow surrounding the small open cluster IC 1590. One of the brighter stars at the centre of the region is mag. +7.8 HD 5005 – some of the members of this quintuplet system will appear at magnifications of 100x or higher. The true shape of the nebula is difficult to make out visually due to its low surface brightness; in a 10-inch scope it has a size of 15 arcminutes, which is half the apparent diameter of the full Moon. ☐ **SEEN IT**

4

THE OWL CLUSTER

Just 2° south and slightly west of mag. +2.7 Ruchbah (Delta (δ)) Cassiopeiae is the Owl or ET Cluster, designated NGC 457. It gets these names partly because of two brighter foreground stars, mag. +4.9 Phi (ϕ) Cassiopeiae and mag. +7.0 HIP 6229, which give it the appearance of having eyes. A line of ninth- and 10th-magnitude stars form the wings (or arms); a line of 10th-magnitude stars create the body. This is a really impressive object, showing around 100 member stars in a 8-inch scope. A splash of colour is provided by mag. +8.7 star HIP 6231, which marks the start of the right-hand wing. This star sits to the north of Phi Cassiopeiae ☐ **SEEN IT**

5

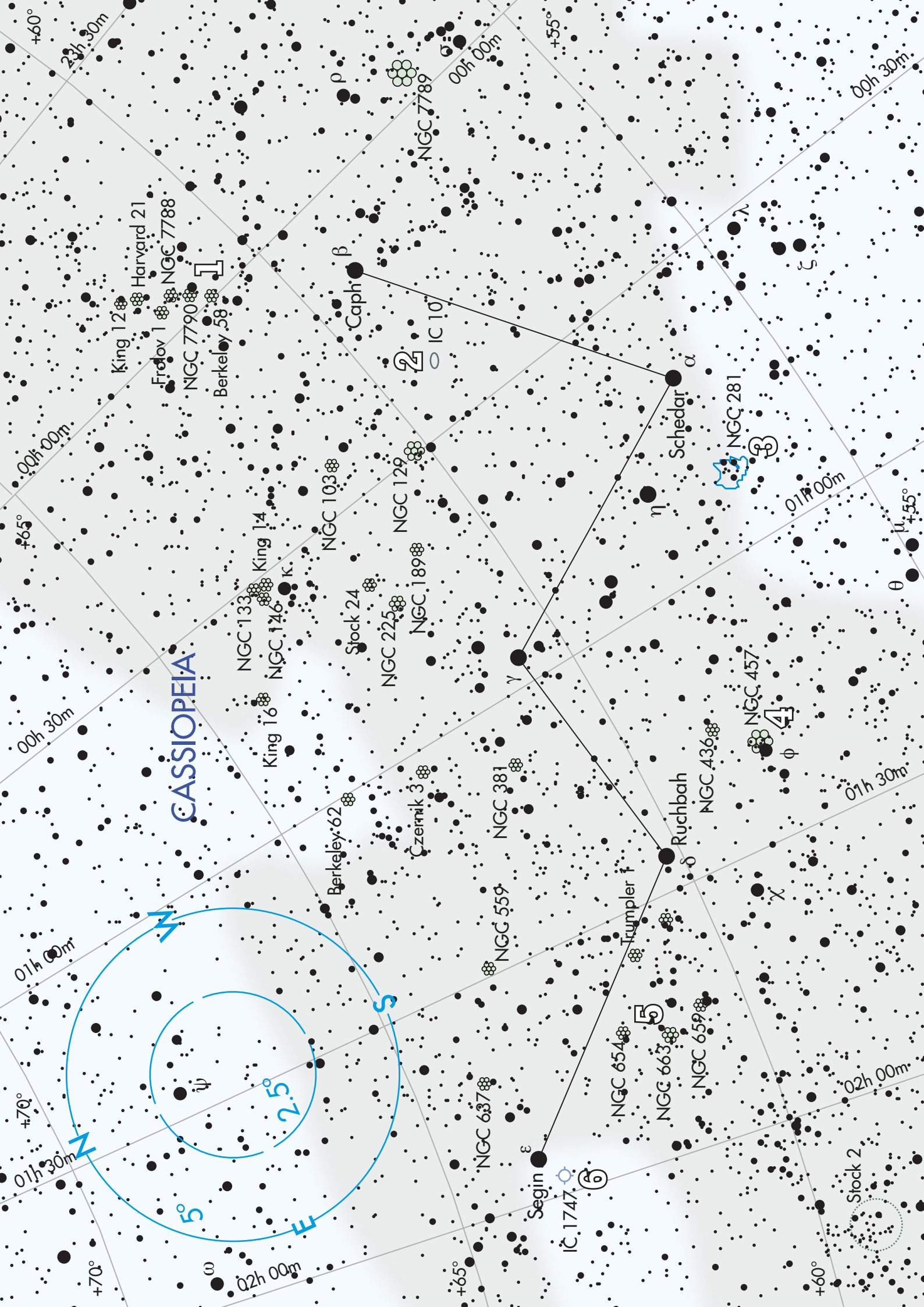
NGC 663

Imagine a line from Ruchbah to mag. +3.4 Segin (Epsilon (ϵ)) Cassiopeiae. Drop your gaze south of the midpoint of this line and you will come to young open cluster NGC 663. It's the largest of several clusters in this area, measuring 15 arcminutes across, and is a relatively easy find. A 6-inch scope reveals around 30 stars, the fainter members being surrounded by a number of brighter stars arranged in pairs. Increased apertures bring more stars, with a 10-inch scope doubling the number seen. Look slightly to the south of the cluster to see a distinctive pair of red stars shining at mag. +8.3 and +8.9. ☐ **SEEN IT**

6

IC 1747

We end this month's tour having passed across the entire W of Cassiopeia: our final stop, IC 1747, sits 0.5° southeast of Segin. It is a tiny, 12th-magnitude planetary nebula, measuring just 15 arcseconds across. At 100x magnification it looks like a star that refuses to focus properly. Increasing the power to around 400x shows the nebula to have a square, box-like appearance. Under good conditions, it should be possible to see a hole in the centre of the nebula. Although it's not uncommon for planetaries to have such a feature, this one is particularly evident. ☐ **SEEN IT**



Moonwatch

Montes Carpatius

THE GIANT IMBRIUM Basin dominates the northwest quadrant of the Moon's Earth-facing side. It measures around 1,000km in diameter, with edges marked by dramatic features. The Montes Carpatius is one of these, a mountain range that lies on the southern shore of the Mare Imbrium just northwest of ray-crater Copernicus.

Copernicus is little more than 100km south of the eastern end of the range, so close that the Montes Carpatius sits well inside the ejecta material flung out when the crater was created. During fuller phases, it can make the mountains harder to see.

Through a low-power eyepiece, the mare's east and southeast borders are clearly defined by the Apennines, which peter out just north of 60km-wide crater Eratosthenes. A few small peaks litter the region northwest of the crater, before giving way to smooth lava. The smoothness continues west for about 90km, interrupted by little more than a few chains of craterlets before reaching the foothills of Montes Carpatius.

The mountains are well defined but heavily interrupted by Imbrium lava. Where this has flowed into gaps between the peaks, it frames the mountains within perfectly. At the eastern end of the range, the first major peaks lie to the north of the younger crater Gay-Lussac (27km wide). The crater has a level floor and appears to have been stamped into the older mountain range below. Gay-Lussac A (14km) is a little south.

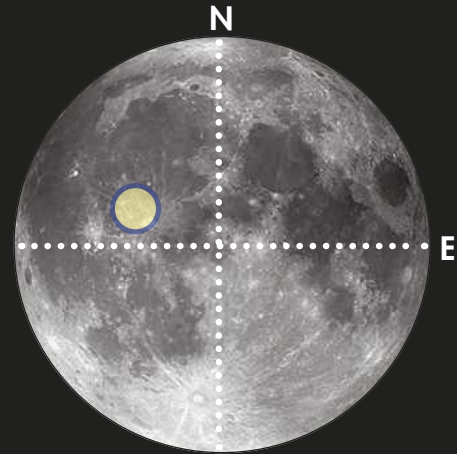
The range really starts to get going as it moves west. Large peaks tower over Imbrium's flat lava floor to the north, appearing chiselled into sharp points. To the south, the terrain is more chaotic, due to debris

from younger Copernicus. The thickest and most rugged part of the Montes Carpatius lies to the west, just before the range comes to an end close to the crater T Mayer (34km).

As with any lunar mountain range, the best views are to be had when the Sun is low in the lunar sky and the terminator nearby. At such times the range's lofty peaks – rising to about 2.4km above the floor of the Imbrium Basin – cast dramatic shadows. T Mayer, T Mayer A (16km) and T Mayer P (35km) are obvious at such times. Despite a heavily broken rim and lava

STATISTICS

TYPE: Mountain range
SIZE: 300km long and 100km wide
AGE: 3.2-3.9 billion years old
LOCATION: Latitude 14.6°N, Longitude 23.7°W
BEST TIME TO OBSERVE: Two days after first quarter or one day after last quarter (3-4 October or 16-18 October)
MINIMUM EQUIPMENT: 2-inch telescope

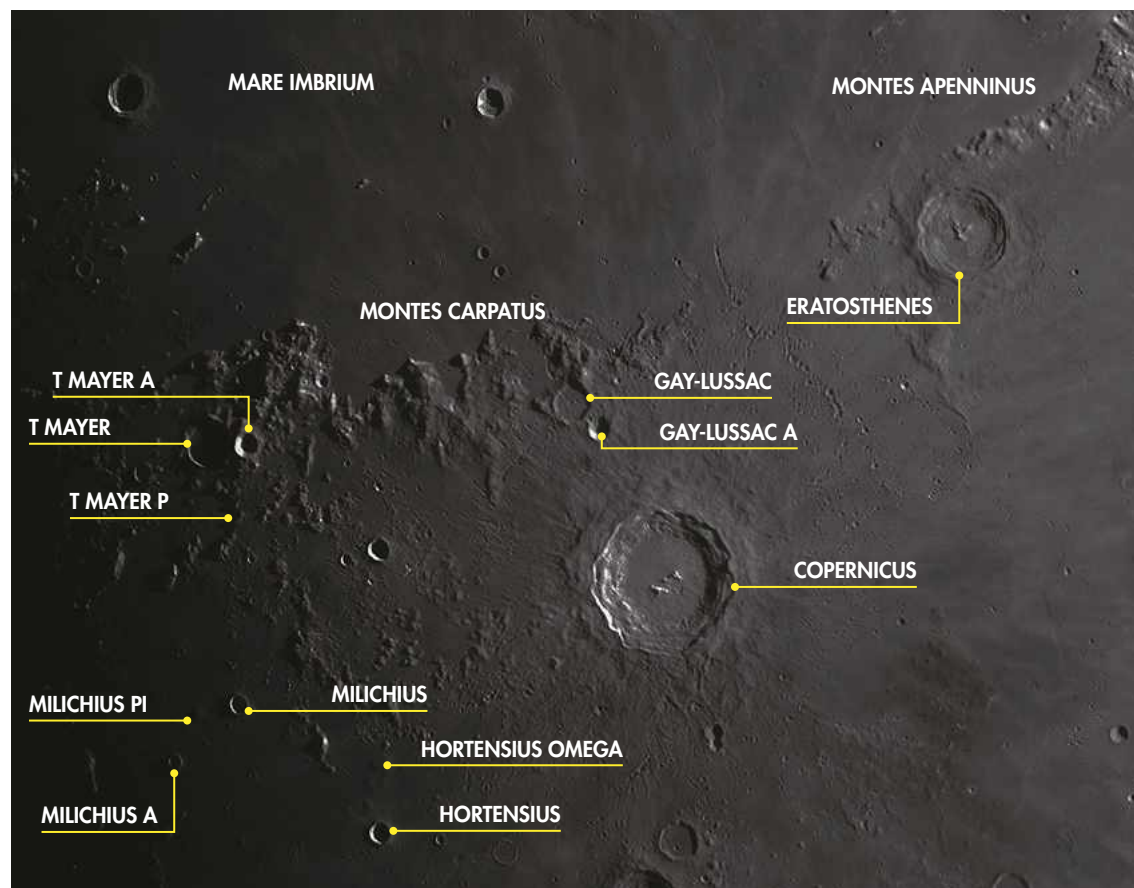


flooded floor, P comes alive when the Sun lights it obliquely from either the east or west. It sits south of T Mayer.

Located 125km south of P is small yet well defined crater Milichius (13km). Look 60km southwest of it and you'll find Milichius A (9km). When the lighting is right for the Montes

Carpatius, it can also be a good time to look for a number of volcanic domes in this region. Milichius Pi is slightly northwest of the midpoint between Milichius and Milichius A, while just north of crater Hortensius (15km) is the Hortensius Omega dome field, containing no fewer than six domes.

“Large peaks tower over the lava floor, appearing chiselled into sharp points”



The Montes Carpatius sit on the southern shore of the Mare Imbrium, close to bright ray-crater Copernicus

Astrophotography

The lunar occultation of Saturn



RECOMMENDED EQUIPMENT

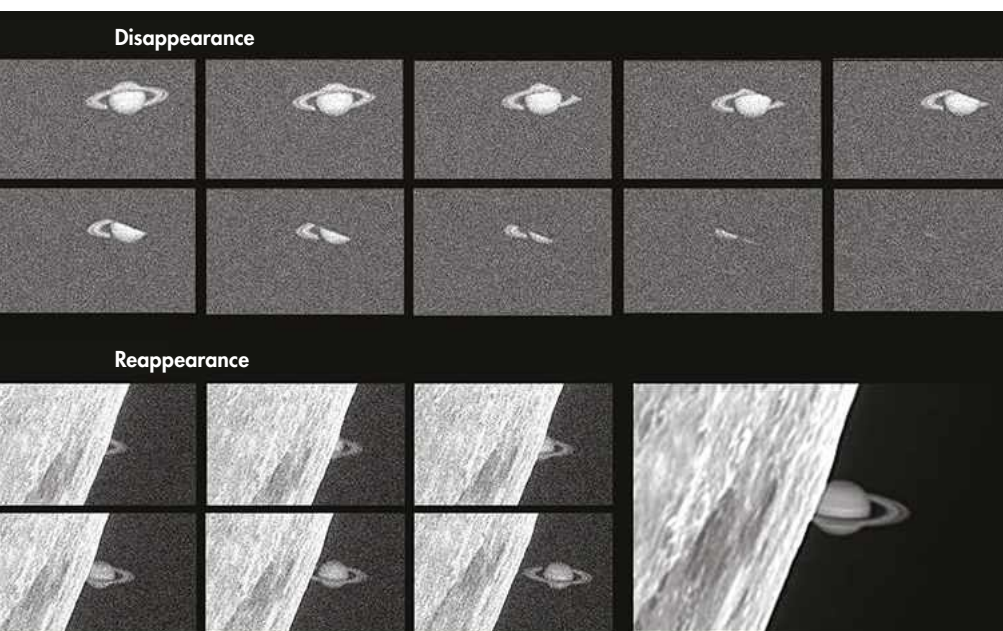
High frame rate monochrome imaging camera, equatorially mounted and driven telescope with a focal length of 700mm or more, red or infrared-pass filter

attempt to locate Saturn. This is where the red or infrared-pass filter will really help, allowing you to up the camera's sensitivity almost to saturation without too much interference from the blue sky. Even so, expect the planet to have low contrast with limited detail on view. It's a good idea to make an early, non-occulted capture of it to make sure you have the full planet recorded.

It will take about 80 seconds for the planet to fully disappear and reappear at the Moon's edge. At the time of occultation, you have two choices: capture disappearance and reappearance as a movie; or take short capture bursts and process each one. Doing the latter will give you a smoother result but at the expense of the Moon's limb.

This is an interesting quandary and one that can open a can of worms. A movie sequence will contain a frame-by-frame account of the event, but each frame will be noisy with a poor quality image of the planet. A full planet, captured and processed earlier, will appear smoother and less noisy.

Combining both results will produce a smooth representation of the occultation. To keep the purists happy, it's a good idea to include both versions on your final presentation just to be clear about what you've done.



The top sequence shows a number of stills from a movie sequence captured during a past occultation; below it is a composite of Saturn and the Moon recorded before the occultation and assembled using a still frame from the movie for correct positioning.

THIS MONTH WE have a rare and spectacular lunar occultation of Saturn. However, as ever in the universe of astrophotography, things are far from straightforward. The event starts with Saturn disappearing behind the Moon's dark limb in daylight. Reappearance, from behind the Moon's bright limb, occurs as the sky is getting darker, but still something of a challenge.

The Moon is key here, as it'll act as a guide to locating the planet. The event occurs on 25 October (see page 50), when the Moon will be a 3%-lit waxing crescent. Although the Moon will be obvious in the darkening twilight sky, it will be a reasonable challenge in itself to locate in daylight. It will be 20° east of the Sun, or a little more than an outstretched hand at arm's length to the left and up a bit.

It's best to use a high frame rate camera combined with a red or infrared-pass filter to capture the event. You can still

use another type of camera such as a DSLR, but you may find it hard to pull Saturn out from the daylight sky.

Your first job is to locate the Moon. Once found, place the Moon's crescent, or part of it at least, in the frame and focus as accurately as you can. If you are able to locate the Moon fairly early on, say at 16:00 BST (15:00 UT), it's a good idea to capture overlapping sections of the crescent to put together as a mosaic later on. Of course, if your setup has a low enough image scale to allow you to capture the Moon's disc in one go, then one capture is all you need.

Once you're familiar with the Moon's bright crescent it should be possible to guess where the dark outline will run, even though you can't see it. Once you've done this, use the chart on page 50 to

KEY TECHNIQUE

KNOWING THE LIMITS

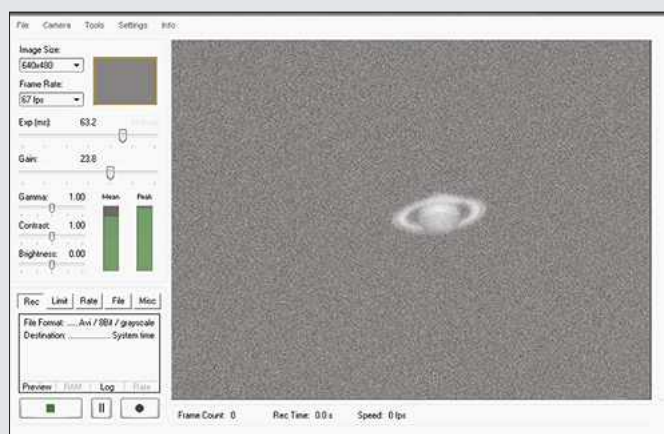
This month's imaging project presents an age-old image processing dilemma: how far can you go to manipulate a photograph, and should you? If you follow the capture instructions in our mini guide, you'll have separate smooth images of the lunar crescent and Saturn together with a sequence of noisy and distorted images of the occultation. Here, we'll show you how to combine both images to produce a stunning representation of the event. The key is being honest about the processes involved.

✉ Send your image to: hotshots@skyatnightmagazine.com

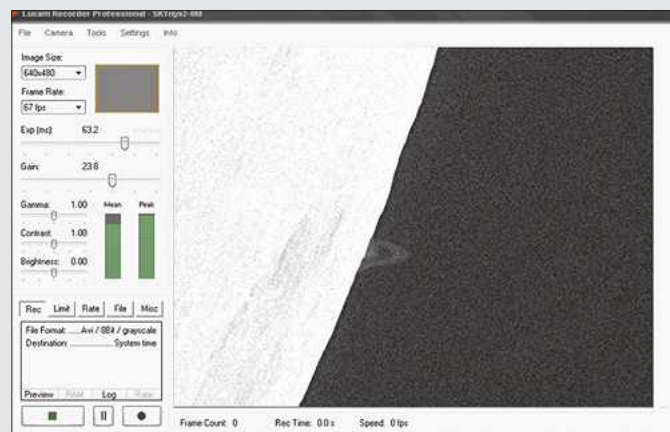
STEP-BY-STEP GUIDE

STEP 1

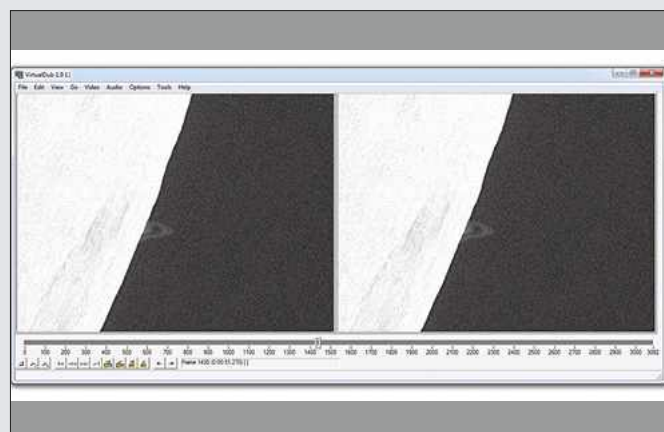
The first task is to locate the Moon and get an image of it. A high frame rate monochrome camera is the ideal tool, with a red or infrared-pass filter highly recommended to dim the blue sky and increase contrast. Make sure you take several captures around the suspected part of the limb where reappearance is due to occur. Then, using the Moon and our graphic on page 50, attempt to locate Saturn.



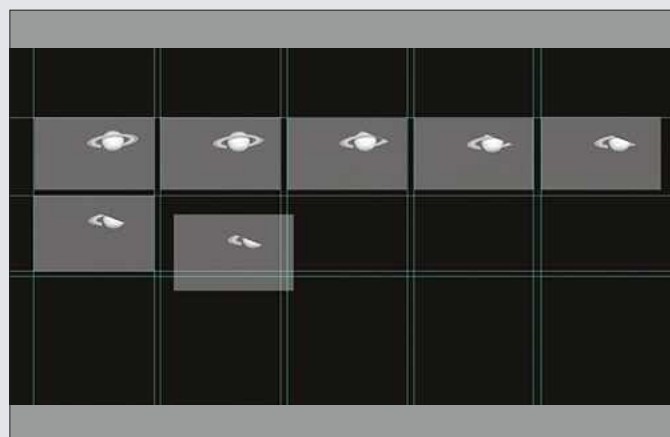
STEP 2 If using an aligned Go-To mount, it may be possible to synchronise on the Moon's centre and slew to Saturn. The planet will appear faint with low contrast, so turn camera sensitivity up to almost saturation point on the sky before looking for it. Once found, readjust sensitivity so the planet isn't overexposed.



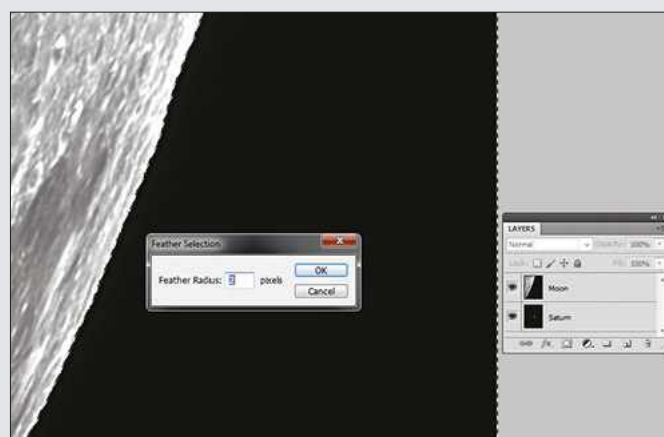
STEP 3 Capture Saturn and the Moon separately 30 minutes or so before the occultation. As disappearance approaches, record a video centred on Saturn. When disappearance starts, keep recording until the planet has totally vanished. Reposition so you are aimed at the portion of the Moon that Saturn will emerge from.



STEP 4 Start recording prior to reappearance with the same settings as before. After the event, open your two movies in a video editor such as the freeware VirtualDub (www.virtualdub.org). Step through each frame using the cursor keys; copy and paste the good frames into a grid created using your favourite graphics editor.



STEP 5 Populate the grid with frames separated by roughly the same frame count. To create a high dynamic range image, copy a good reappearance frame and create a new image from it. Take the processed Moon capture from Step 1 and place it over the overexposed Moon's edge as a new layer. Select the sky around the Moon and feather by two pixels.



STEP 6 Invert the selection, copy and paste as a new layer. Insert the processed Saturn image from Step 2 as new layer below the cut out Moon's surface. Adjust Saturn's position using the reappearance frame for reference. If necessary, use the eraser tool at 10 per cent strength and two pixels in size to tweak and remove dark fringing at the Moon's edge.

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Out of the darkness

Paul Abel puts forward the case for returning to one of the Solar System's most mysterious planets

A bold and exciting new space mission is being devised by planetary scientists, a mission that – if successful – would see a spacecraft sent to explore one of the most mysterious worlds in our planetary neighbourhood. For well over 200 years, the ice giant Uranus has lurked in the quiet outer darkness of the Solar System. It has remained an elusive oddity, largely overlooked by both amateur and professional astronomers. In January 1986, Voyager 2 briefly surveyed the Uranian system and uncovered a plethora of mysteries. To date, it has been the only emissary we have sent to the planet.

In 2010, Dr Chris Arridge of University College London, along with a number of other scientists, proposed the Uranus Pathfinder (UP) mission to ESA. Its aim was to undertake a complete survey of Uranus, its rings and satellites.

At a cost of €500 million (making it a medium- or M-class mission in ESA terminology), UP would have been launched in 2021 and arrived in the vicinity of Uranus sometime around 2036 or 2037. But it was not to be – the mission bid was unsuccessful. Not to be deterred however, Arridge and his colleagues intend to try again with ESA's call for missions starting in August 2014. What better way to mark Uranus coming to opposition this month than looking at the Uranian mission that never was, yet might still come to pass? >

MARK GARLICK/SCIENCE PHOTO LIBRARY

It would take a probe around 17 years to reach the pale green ice giant

► A mission to the outer Solar System comes with many challenges. The actual mechanics of getting a spacecraft out to Uranus is not difficult, although the journey is long, taking some 17 years to complete. The real problem lies in operating a spacecraft in the icy darkness where the planet resides. Space probes are usually powered via solar panels but, out at Uranus, a probe would receive just three per cent of the sunlight it would get here at Earth. "We would need solar panels between one and two IMAX screens in length," says Arridge. A more realistic possibility is using a nuclear element that stays warm as it decays. The heat could be used to generate electricity and power the spacecraft.

▲ Voyager 2 found a cold featureless world when it passed by Uranus in 1986

Once at Uranus, it's important that a probe is able to transmit the data it collects back to the scientists on Earth. Compared to some other space missions, the amount of data that UP could transmit back would be quite small. These problems are challenging, but not impossible to overcome.

The right tools

Deciding on what instrumentation to include on a spacecraft is rather like going into a massive sweet shop full of expensive chocolates, only to find you have a few pence in your pocket. Space is at a premium on UP, and only instruments that can be employed across a number of investigations are going to make the final cut.

First of all, a camera is essential.

A picture tells a thousand words and a high resolution camera will provide us with

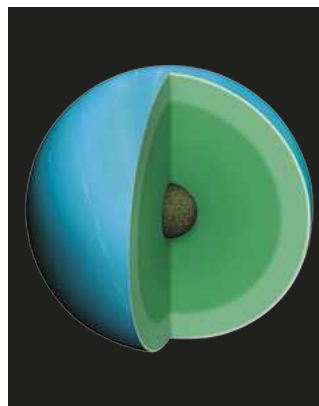
THE TOP FOUR MYSTERIES OF URANUS

Uranus and its moons present us with many bizarre riddles we have yet to solve



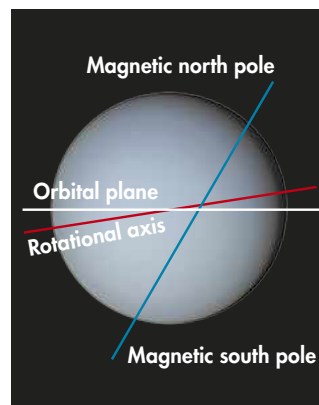
STRANGE AXIAL TILT

Many planets in the Solar System have an axial tilt. Earth's is 23.5° and this is what gives rise to our seasons. Uranus, on the other hand, has an axial tilt greater than a right angle, a whopping 98°. This means the days and seasons on Uranus are very strange, with each pole experiencing 42 years of darkness followed by 42 years of sunlight.



LACK OF INTERNAL HEAT

Most planets have an internal heat source. On Earth it is what drives our plate tectonics and volcanism. The gas giants have greater internal heating and give out much more thermal energy than they receive from the Sun, as does Neptune. Strangely Uranus appears to have very little internal heating.



STRANGE MAGNETIC FIELD

The magnetic field of Uranus is strange in two ways. First, it does not pass straight through the centre like other planetary magnetic fields. As a result, the magnetic field in Uranus's northern hemisphere is stronger than in it is in the south. Furthermore, the field is inclined by some 59° from the axis of rotation. Why this is the case is still not certain.



BASHED UP SATELLITES

Many of Uranus's satellites show a high degree of cratering and impact scars. Indeed, Miranda (pictured above) has a surface that resembles a 'patchwork quilt' of different terrains. The favoured explanation is that Miranda may have been broken up and reformed several times during its history. Quite why there is so much impact scarring on the Uranian moons is still unclear.

Titania and Oberon, the third and fourth moons from the top, may also have subsurface oceans

stunningly detailed images of the Uranian atmosphere and its rings, while allowing us to map and scrutinise its moons. Looking at Uranus in the infrared will provide us with more concrete details about the composition of the atmosphere at various depths, and allow scientists both to look for aurorae – we already know they exist – and establish how they are generated.

A magnetometer (a device for studying magnetic fields) is another must-have. Magnetic fields can give us a window into the interiors of a world, since planets generate magnetic fields in a variety of ways, depending on their composition and size. Uranus's field is one the strangest of them all (see 'Top four mysteries', page 64) and working out how it is generated will tell us a lot about its hidden depths.

The magnetometer could also be deployed to help investigate the ice giant's moons, and Arridge alludes to another exciting idea: the search for subsurface oceans under the icy crusts of the two largest satellites, Titania and Oberon. The idea that moons this far out from the Sun may have liquid oceans is not as far fetched as it seems. Both moons seemed to be composed of equal amounts

of rock and ice, and infrared spectroscopic observations have revealed crystalline water on the surfaces of each of them. If such a discovery is made, it will have implications on how habitable a planetary system can be.

Moving beyond guesswork

The team would like to see other tools on the spacecraft. A microwave instrument would help scientists to fathom the planet's interior workings and composition, and another to measure

Uranus's temperature and luminosity would also be very helpful. Uranus has the lowest self-luminosity of all the planets in the Solar System, and its cold temperature would imply that it is some three billion years older than it is thought to be.

"There is only so much we can do from the ground and a mission like this would really help to answer questions that have puzzled us for decades," says Arridge. The Voyager 2 encounter raised new

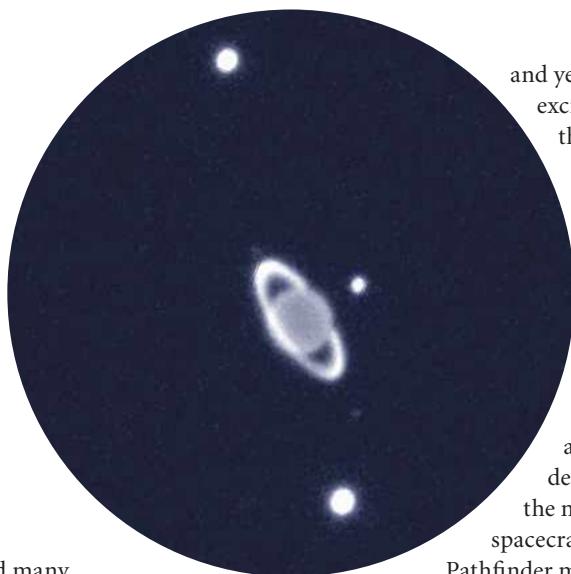
questions beyond the reach of Earth-bound telescopes. For example, Uranus's strange magnetic field seems to reconfigure itself every eight hours as the planet rotates. Why this happens is still unknown.

UP will also allow us to answer more fundamental questions regarding the formation of the Solar >

"A mission like this really would help to answer questions that have puzzled us for decades"

► System and how it came to be in its current configuration. Ice giants like Uranus and Neptune are in a class of their own, being suitably different from the inner rocky planets or the gas giants. They have their own story to tell about how planetary systems form and evolve. Understanding their nature also has wider ranging implications: as Arridge explains, the majority of exoplanets we're finding appear to be of similar size to Uranus and Neptune. If we hope to understand these exoplanets, we need to work out how the ones in our own Solar System work first.

No doubt the Uranian system will hold many surprises. It may turn out that the planet and its rings are far more dynamic than we ever believed. Arridge points to the satellite Mab within Uranus's μ -ring, which is similar to Saturn's E-Ring. The Cassini Mission has shown that Enceladus creates the E-Ring: its majestic fountains dump water ice into the system. Mab is tiny – just 50km across – and so it seems most unlikely that a moon so small could have any internal activity,



▲ Infrared images of Uranus from afar reveal little of the planet; we need to get closer

and yet if it did this would establish exciting new boundaries as to what we thought might be geologically possible.

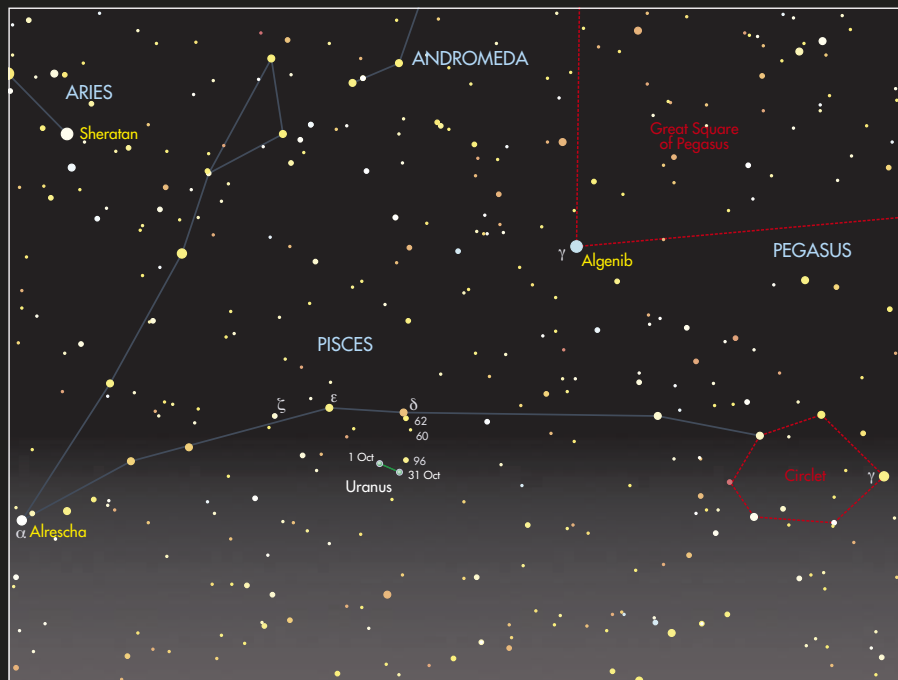
Arridge and his team have started a new version of UP ready for M4, the next round of M-class missions, and they aim to have a revised mission proposal ready before the deadline of January 2015. "Uranus and its family of satellites have been neglected for too long. The planet stands out as a massive puzzle; an outlier that deserves closer scrutiny," he says. After the many thrilling discoveries the Cassini spacecraft made at Saturn, a revised Uranus Pathfinder mission is sure to reveal just as many wonders and establish new scientific frontiers. **S**



ABOUT THE WRITER

Dr Paul Abel is an astronomer based at the University of Leicester. A keen visual observer, you can listen to him on our Virtual Planetarium each month.

OBSERVING URANUS



▲ Uranus is in Pisces just below the midpoint of a line between Delta (δ) and Epsilon (ε) Piscium

Uranus comes to opposition on 7 October. At mag. +5.9, the planet will be just about visible to the naked eye in a really dark sky. It can be found shining with its customary greenish hue amid the stars of Pisces, and opposition is the best time to look for it as this is when Uranus is at its brightest. You can use the chart above to find it during the course of the month.

Although Uranus is a large world, being so far away means it has a small apparent diameter, typically around 3.5 arcseconds. Binoculars will show Uranus as a greenish star, while small- to medium-sized telescopes will show it as a small pale green planetary disc. If you use a low-power eyepiece, you can watch it as it moves against the background stars of Pisces over the course of a few nights.

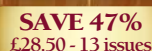


▲ Uranus's moons are dim, but not invisible – and, by overexposing the planet, they can even be imaged using amateur telescopes

Larger telescopes will reveal some subtle details – through an 8-inch reflector, it is possible to glimpse vague belts and zones. These features seem to come and go, and further observation is needed to establish their validity. Observing these details requires a high magnification of typically 350x or more and a transparent sky.

The five main moons of Uranus are faint, but if you have access to a larger scope, they will be within reach. The largest and brightest are Titania and Oberon – again, both are visible in an 8-inch reflector. Ariel and Umbriel are fainter at mag. +14.4 and +14.5 respectively and will require at least a 10-inch scope, while the faintest, Miranda, shines at mag. +15.8 and will probably require a 16-inch telescope. Miranda and Ariel are quite close to Uranus, so the glare from planet can make observing these satellites tricky.

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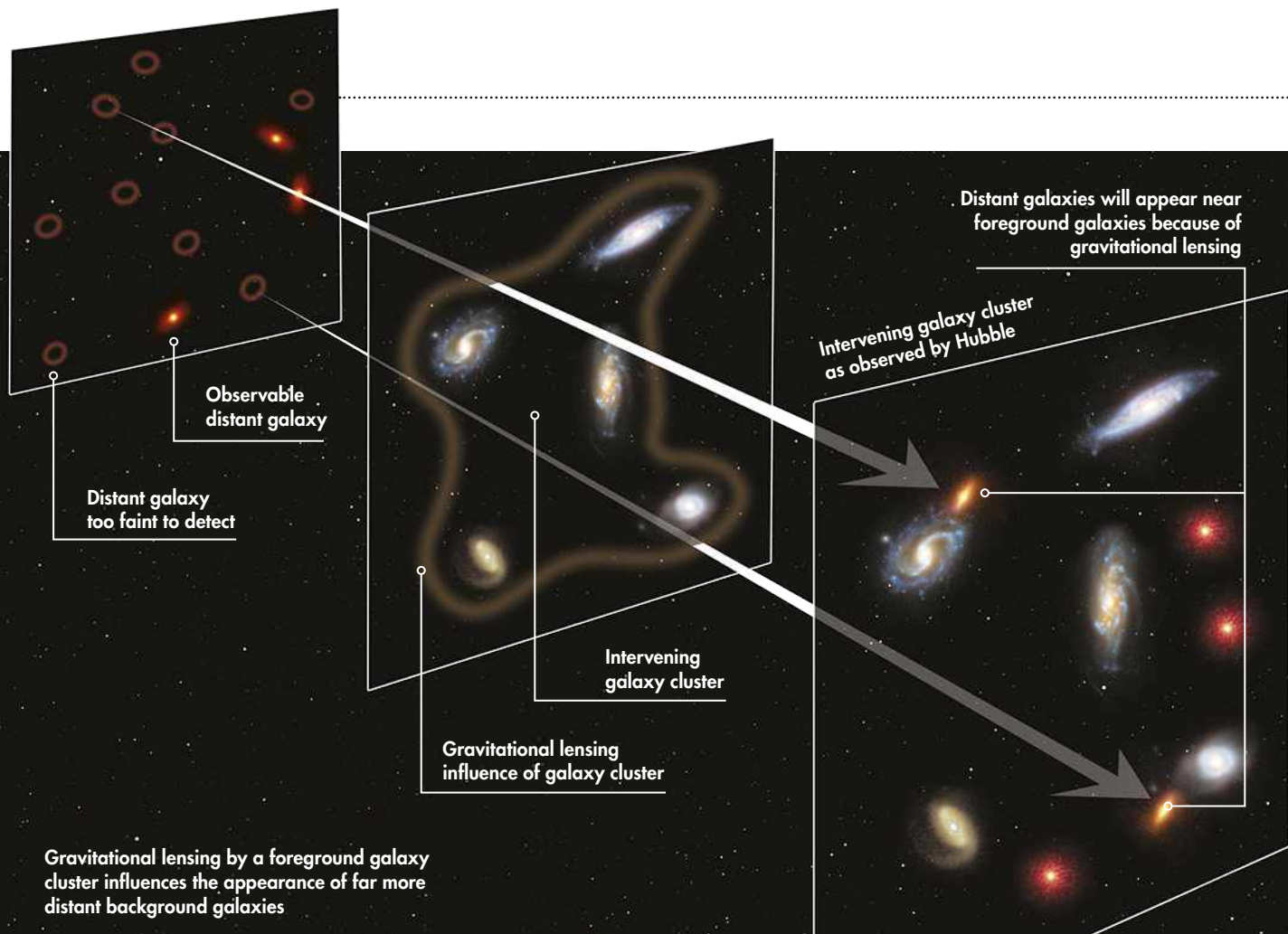
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The far frontier

Will Gater investigates a ground-breaking Hubble project that will take the space telescope farther than it has ever gone before



Two years ago astronomers working with the Hubble Space Telescope sat down and looked to the future. Hubble had been in orbit for well over two decades. In that time it had transformed modern astronomy and peered farther into the abyss than any other telescope before it.

Yet despite its many successes, Hubble was facing the fate that we must all experience eventually – it was nearing the end of its life. In NASA's enormous cleanrooms its successor, the James Webb Space Telescope, was already rising from the drawing board, preparing to carry Hubble's legacy into the coming decades. What, then, could the veteran space scope offer in its final years?

"We thought for a long time," says Jennifer Lotz, a Hubble astronomer at the Space Telescope Science Institute in Maryland. "Were there questions, particularly about the very distant Universe, that Hubble could still provide interesting answers to?" The proposal the committee settled on was bold. It would take Hubble to its very limits. By drawing on one of the most remarkable phenomena in astrophysics, Hubble was about to explore the far frontier.

The Frontier Fields, as the plan came to be known, followed a long line of grand Hubble projects that peered into the distant, early Universe. The Hubble Deep Field had

started it all, in 1995, with its now legendary view of a snowstorm of distant galaxies in Ursa Major. And in 2012 Hubble completed its eXtreme Deep Field observations of a tiny patch of sky in Fornax; those images had shown a galaxy as it was 450 million years after the Big Bang. The Frontier Fields would be different though. They would go beyond simply staring at a region of sky for long periods, to gather the faint light from this far away realm. They would also employ what Lotz calls "nature's telescopes" – gravitational lenses.

"These are very massive clusters of galaxies," she says. "They are so massive

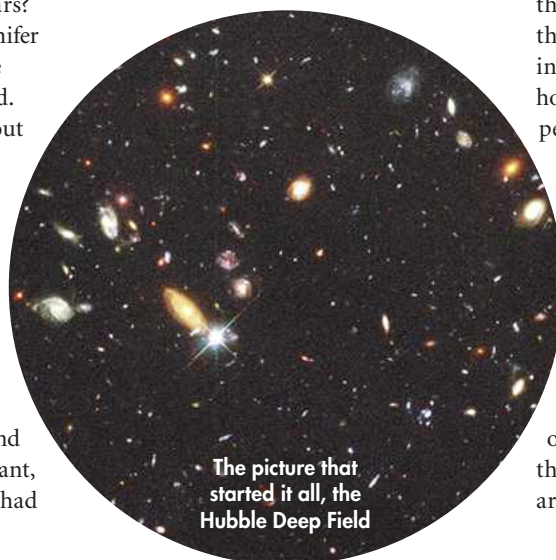
that they bend light from objects that are behind them and magnify that light." In some of these clusters hundreds of galaxies swirl together – often interacting and merging – among vast, invisible clouds of dark matter. "Their total masses are like a thousand Milky Ways or more," says Lotz, "10¹⁵ solar masses of galaxies all crammed into a megaparsec." That's just over three million lightyears.

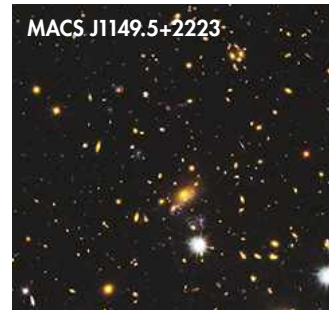
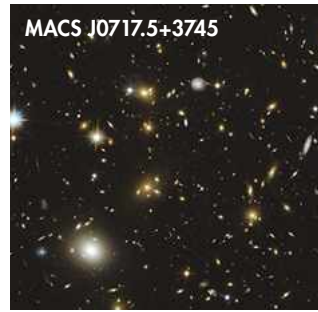
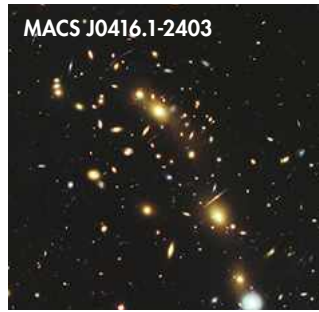
Through the looking glass

With the aid of these gravitational lenses, Hubble could see farther than any of its previous deep-field observations – allowing the Frontier Fields team to observe some of the most distant, and thus earliest, galaxies in the cosmos. In doing so the astronomers hope to learn about a significant, formative period in the Universe's history.

"We want to know when the lights came on," explains Lotz. "We have not yet seen the very first stars or the very first galaxies. Right now we are able to see stars that formed 450 million years or so after the Big Bang, but we're pretty sure those weren't the first."

Previous deep-field observations have given scientists at least a glimpse of what those early galaxies were like though. "The ones that we've seen so far are very small, they're very compact," says





▲ Four of Frontier Fields' target galaxy clusters; Hubble will study six in total, with its observations set to be completed in mid 2016

Lotz. "We think they're forming stars quite rapidly. But when you look at them in the images they're just teeny tiny little dots. They're factors of a hundred or more smaller than our own Milky Way. Yet the ones that we can see at this distance are really the tips of the iceberg – they were the biggest things out there at that time."

By studying six separate gravitational lensing clusters, Lotz says they hope to uncover fainter, more distant galaxies that are more representative of those found in the early Universe. Finding these tiny smudges of light is far from easy however. For one thing, the gravitational lens needs to be aligned with the background galaxy in a certain way. If it is, then the lens can bring

into view objects that are between 10 and 100 times fainter than those Hubble picked up in its eXtreme Deep Field.

"The trick is that it's only over very small parts of the image that we would get that magnification, so we have to be a little bit lucky and hope that there is a galaxy right in that place," says Lotz. "That's one of the reasons why Frontier Fields is looking at six lensing clusters instead of just one."

Hubble makes its Frontier Fields observations by capturing long-exposure images of the galaxy clusters through a variety of filters, including those that transmit infrared radiation. That's vital because the farthest galaxies Hubble can detect are all infrared objects. "The

light from those galaxies is redshifted because the Universe is expanding," explains Lotz. "They are actually completely invisible in optical light."

It will take Hubble until summer 2016 to complete its study of all six clusters and their gravitational lenses; the first observations – of the Abell 2744 cluster – were unveiled in January of this year. And while there is still more work to be done in analysing the data, it's already thrown up a few interesting results. These include the possible identification of a galaxy at a redshift of 10 – that is, Hubble sees it as it was just under 500 million years after the Big Bang. "It's very early days," cautions Lotz. "We have detected ▶

WHAT IS A GRAVITATIONAL LENS?

As part of the Frontier Fields project, Hubble will use several vast gravitational lenses to look far into the Universe, revealing extraordinarily distant galaxies. But how does this remarkable natural phenomenon come about?

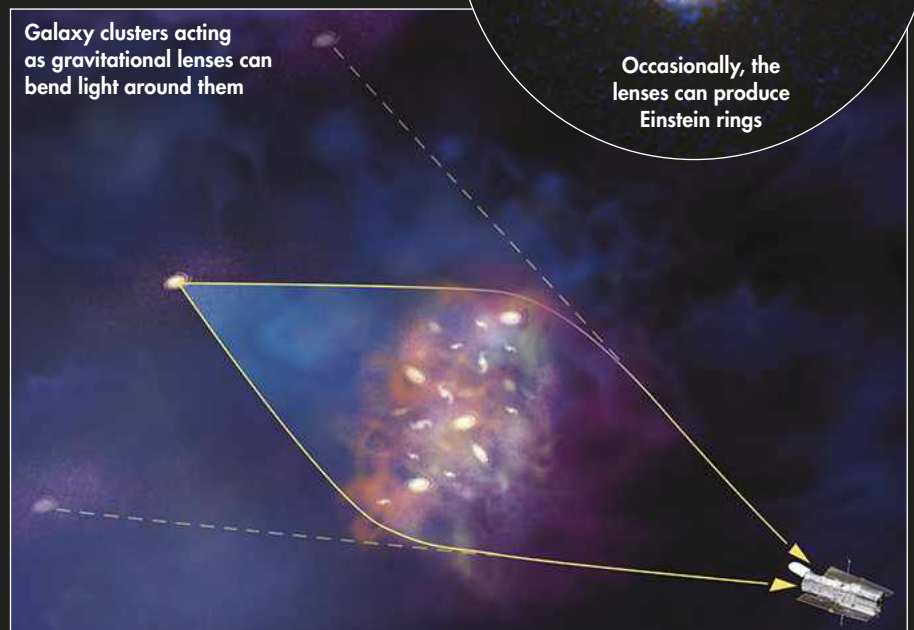
"It's actually something that Albert Einstein predicted with his theory of general relativity," says Hubble astronomer Jennifer Lotz from the Space Telescope Science Institute in Maryland. "A massive cluster of galaxies actually bends space and time around it," she explains. "This means that light travelling close to it doesn't travel in what we might think of as a straight line, but it actually gets bent around the cluster."

This has the remarkable effect of working like a telescope would, says Lotz. "It actually acts much in the way a glass optical lens works. It will take rays of light from a distant galaxy behind the cluster and focus them. It makes that distant galaxy appear larger and brighter than it would if there were no intervening cluster."

Gravitational lenses can create all manner of unusual 'images' of the objects beyond them, from huge arcs of light around the cluster to strange multiple views of a single far-off galaxy (see 'Staring into the deep', overleaf). In fact it's not just massive galaxy clusters like the ones studied in the Frontier Fields project that can create these cosmic mirages. Hubble has observed many individual massive galaxies that also act as gravitational lenses. Some of

these galaxies exhibit a particularly beautiful type of gravitational lens image known as an 'Einstein ring'. Here, the light from a far-flung background galaxy is distorted in such a way as to produce a perfect, glowing ring of light floating against the blackness of space.

Galaxy clusters acting as gravitational lenses can bend light around them



Occasionally, the lenses can produce Einstein rings

STARING INTO THE DEEP

ABELL 2744

Most of this image, from Hubble's Advanced Camera for Surveys and Wide Field Camera 3, is filled with galaxies in the Abell 2744 galaxy cluster some four billion lightyears away

DISTANT GALAXIES

These tiny smudges of light are galaxies that lie much farther away from us than the foreground galaxy cluster. Some of them are likely to appear yellowy-red because of their immense distance.

FOREGROUND STARS

Some of the objects in this Frontier Fields image are much closer to home than the cluster. These faint stars reside in our own Galaxy, the Milky Way.

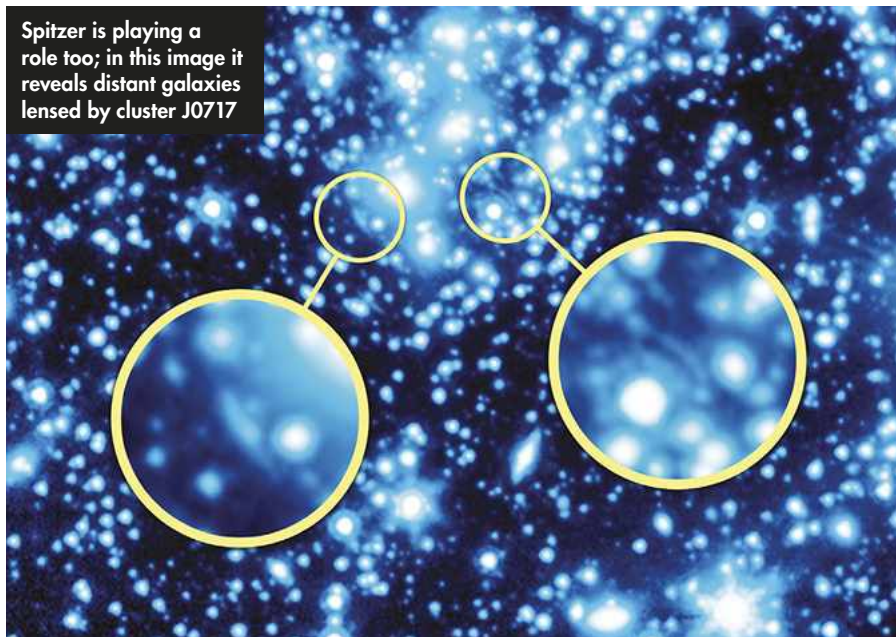
GRAVITATIONAL LENS ARCS

Galaxies far beyond Abell 2744 can become so distorted by the cluster's gravitational lens that they become sharp streaks of light like those seen spread throughout this image.

DISTORTED VIEWS

The gravitational lensing effects of Abell 2744 can do strange things to the views of objects beyond the cluster. Here we see a warped triple image of a far away galaxy.

Spitzer is playing a role too; in this image it reveals distant galaxies lensed by cluster J0717



► a number of distant galaxy candidates. But we really didn't find as many as we expected we would based on the results from the eXtreme Deep Field. We'll have to see if that stands up, but it suggests that in the very early Universe the distribution of those first galaxies is not very uniform. So you could get a lot in one place and not very many in another. That kind of argues for looking along many lines of sight in the Universe to get more of a statistical picture of what's going on."

An extra pair of eyes

Indeed, as Hubble makes its observations of the Frontier Fields clusters, its 'spare' camera will simultaneously capture deep images of six regions of sky near them.

"If we're going to stare at one part of the sky for a long time we might as well turn both cameras on," says Lotz. These images, known as the 'parallel fields', won't necessarily be used in the search for extremely distant galaxies – Lotz and her colleagues envisage that they will be used by researchers to study other phenomena – but they may still prove useful to the Frontier Fields team. "I think the parallel fields will give us a little bit of a sanity check on the results that we're getting from the lensing in the clusters," she says.

While the Frontier Fields images will be scrutinised for even more distant galaxy candidates, astronomers are also using the data to learn more about the clusters creating the gravitational lenses themselves. "We're using them as natural telescopes, but we don't really understand the optics very well, without developing a model," says Lotz. "The strength of the lensing depends on the distribution of matter in

the clusters – not just the galaxies, the light that we can see, but also the dark matter." By studying distorted background galaxies and their positions, astronomers will be able to get a sense of where the mass is located in these vast gatherings of galaxies.

Hubble's Frontier Fields observations are being supported by some of NASA's other orbiting telescopes. "Because these are clusters and clusters also have X-ray emitting gas, many of them have already been studied with the Chandra X-ray Observatory," says Lotz. "Those X-rays also help us understand the total masses of the clusters."

In the coming months, Chandra will be making further observations of the Frontier Fields clusters, as will the Spitzer Space Telescope, which studies

the infrared light. Its images will help the Hubble astronomers pin down just how far away the objects they're detecting are.

"Spitzer looks in wavelengths that are redder than those Hubble can see," says Lotz. "This is really crucial for trying to constrain whether that galaxy that you think might be at redshift 10 is really a redshift 10 galaxy or whether it's a lower redshift one. If you see it in Spitzer, it's probably not a redshift 10 because Spitzer isn't really sensitive enough to see them."

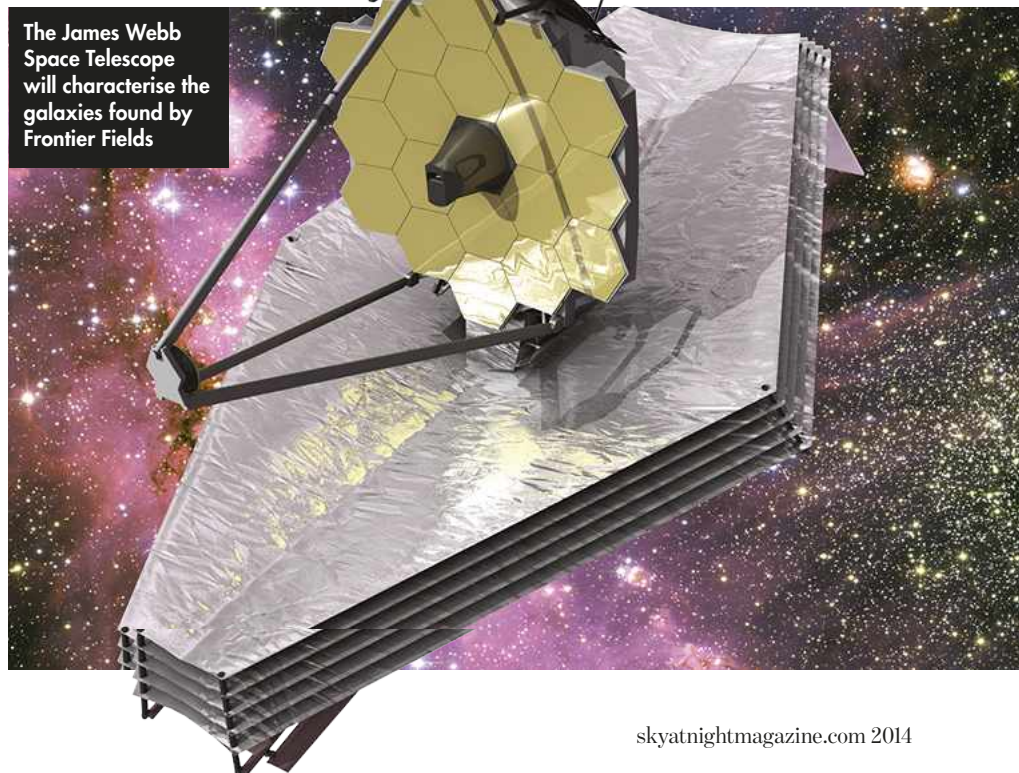
With such a formidable orbiting team working together, the Frontier Fields project promises some exciting science over the next few years. Yet in some ways it is also setting the scene for a new era in modern astronomy – that of the James Webb Space Telescope, an orbiting infrared observatory with a 6.5m mirror. By observing at longer infrared wavelengths, it'll be able to see far deeper into the cosmos than even Hubble can. "Building up our picture of what's happening in those first few hundred million years or so will really help us plan the kinds of observations that James Webb will do to follow up and characterise those galaxies in those populations," says Lotz. With the James Webb team aiming for a launch in 2018, that far frontier could soon be shifting even farther back. **S**



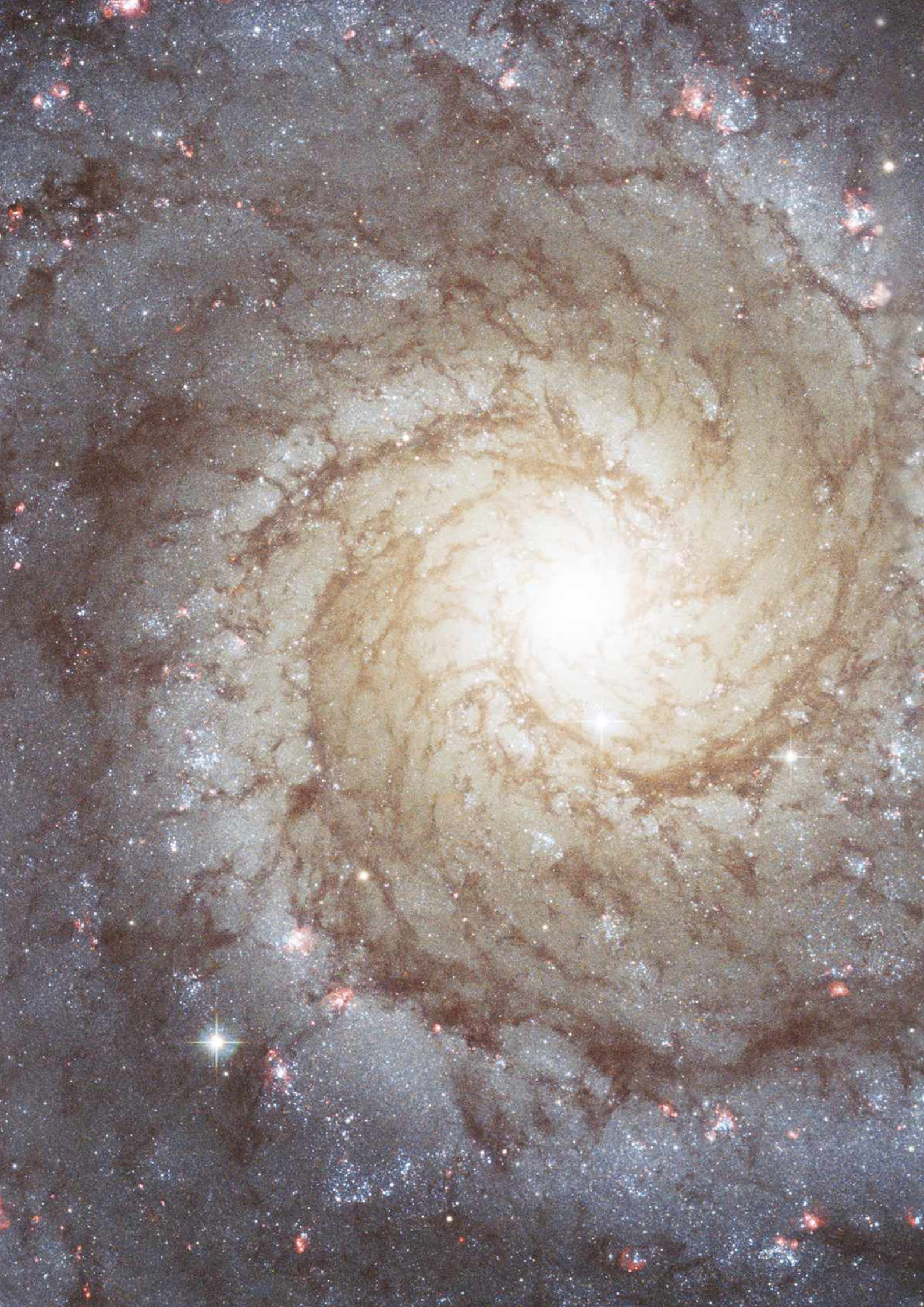
ABOUT THE WRITER

Will Gater is a journalist and the author of several astronomy books; he also appears on TV and radio to talk about space. Find him on Twitter: @willgater

The James Webb Space Telescope will characterise the galaxies found by Frontier Fields



NASA/ESA AND J. LOTZ, M. MOUNTAIN, A. KÖRNER AND THE HFF TEAM (STSCI), NASA/JR-CALTECH/P. CAPAK (CALTECH), ESA (C. CARREAU)



Hubble shots can be huge,
spanning several metres if
printed out at full size



THE ART OF SPACE IMAGING

It takes a lot of painstaking work to turn data from the Hubble Space Telescope into the images we all know, as **Rob Banino** discovers

Magnificent celestial sights are what attract many people to astronomy. And while it's true that breathtaking views await anyone who looks up into the night sky, the human eye in its natural state is ill-equipped to fully appreciate the views that are out there. Whether it's the sheer distances involved or the fact that visible light makes up only a tiny portion of the electromagnetic spectrum, there is a staggering amount that remains hidden from us.

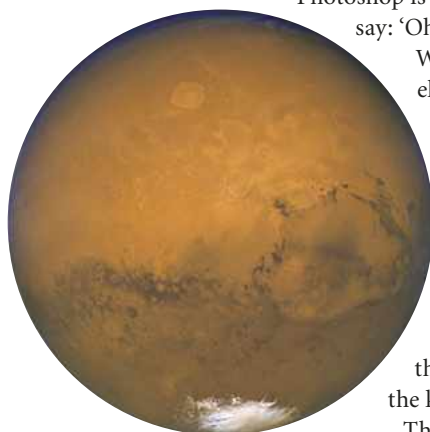
The biggest, most advanced telescopes enable us to overcome those obstacles, but they don't actually show us the spectacular objects inhabiting the heavens. They're the means by which we detect those objects, and although it's light – both visible and invisible – that is picked up, the observations come to us in the form of digital data. This data that must then be translated into something our eyes are capable of seeing.

Exactly how that translation is done varies according to what is being observed and which telescope is making the observation. In the modern age, visible light is no longer the professional astronomer's main tool for studying the Universe, yet a picture still paints a thousands words. Here, we're going to look at how an optical telescope like Hubble does just that. ▶



ABOUT THE WRITER

Rob Banino has spent the last 12 years working as a journalist and editor. He has also worked for *BBC Sky at Night Magazine's* sister science title, *BBC Focus*.



But it doesn't end there, says Villard. "There's a lot of image processing that then has to be done. For a start, you've got a wide dynamic range – there are extremely bright objects against a black sky. You have to play with the greyscale values so that it all fits into a range that represents most of what's in the picture. You also have to remove cosmic rays that hit the detector and add noise to the picture."

The new darkroom

Almost all of this processing is done using Adobe Photoshop, which can raise eyebrows. "Photoshop is ideal for what we're doing," points out Villard. "But the problem is that in today's popular culture, Photoshop is synonymous with trickery. People say: 'Oh, that image was Photoshopped.'"

Well, yeah. But Photoshop is just an electronic darkroom. In the old days of darkrooms people made the same decisions: how long am I going to expose the paper, what contrast filters am I going to use, what's my balance going to be and so on... I say Photoshop and people go: 'Oh, you're making stuff up.' No, we're being as faithful as we can to what the object really looks like in terms of the kinds of radiation it's putting out."

The people processing Hubble data have to be faithful to what's really there because the images are an important resource. "Astronomers can glean what they want from working with the greyscale image but the colour image can yield information too," says Villard. "Frankly, an attractive picture with the proper tonal and colour scales yields a lot of information. So they have a scientific value as well as an aesthetic value for the public."

That aesthetic value is why Villard believes Hubble's images have proved so popular. "They appeal at an emotional level and you don't need a science degree to appreciate them. They have a sense of mystery and go beyond what we thought was out there. Hubble, more than any other telescope, has opened up the Universe in ways never before imagined." 

▲ **Top: Photo illustration of M106 made by combining Hubble data and ground-based observations**

Above left: Hubble's 17th anniversary image of a 50-lightyear swathe of the Carina Nebula

Above right: This sharp, natural colour shot shows Mars at its closest to us in 60,000 years

Below: Star cluster NGC 3603 in Carina looks like an exploding firework



► From its position about 568km above Earth's surface the Hubble Space Telescope has a clearer view of the Universe than any ground-based instrument. Without the distorting effect of our atmosphere, Hubble can peer deep into space and produce astounding pictures of the objects it is able to see.

But although it has mirrors like any other telescope there are no eyepieces or astronomers on board. So all Hubble's observations have to be converted into digital information and transmitted to Earth before they can be seen.

"Exposures are taken and that data is collected electronically, stored on board and then sent back as a radio signal to the Goddard Space Flight Centre in Greenbelt, Maryland and then onto us in Baltimore," explains Ray Villard of the Space Telescope Science Institute. That's where the imaging work really begins.

"Each number in that digital data represents a greyscale value from which you can make a monochrome picture. Colour pictures have to be assembled from exposures taken through different colour filters. Those exposures are put together and coloured according to what filter the exposure was taken through."

Put another way, the shades of grey in a monochrome image taken through either a red, green or blue filter indicate the different intensities of those colours in the image. By assigning the appropriate shade of red, green or blue to each image and then combining them, a full-colour picture is arrived at.

NASA/ESA/THE HUBBLE HERITAGE TEAM (STSC/AURA) AND R. GENDER (FOR THE HUBBLE HERITAGE TEAM), NASA/ESA/N. SMITH (UNIVERSITY OF CALIFORNIA, BERKELEY) AND THE HUBBLE HERITAGE TEAM (STSC/AURA), NASA/J. BEL (CORNELL U.) AND M. WOOLF (SSI), NASA/ESA/R. O'CONNELL (UNIVERSITY OF VIRGINIA), F. PARESCE (NATIONAL INSTITUTE FOR ASTROPHYSICS/BOLOGNA, ITALY) E. YOUNG (UNIVERSITIES SPACE RESEARCH ASSOCIATION/AMES RESEARCH CENTER) THE WFC3 SCIENCE OVERSIGHT COMMITTEE AND THE HUBBLE HERITAGE TEAM (STSC/AURA)



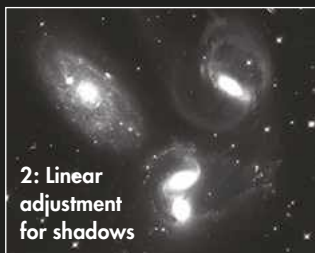
HOW HUBBLE'S IMAGES ARE PROCESSED

Zoltan Levay is imaging group lead at the Space Telescope Science Institute

"We start with data from the Hubble Space Telescope archive, the same data used by astronomers for analysis. Data has been calibrated, geometrically corrected, multiple exposures combined, mosaiced and registered. The cameras

produce monochrome images only, which contain no colour information other than what is known about any filter in the camera. Multiple images from different filters may be used to reconstruct a colour image. This

applies to almost any imaging data, whether visible or invisible. How close we get to something we might see with the human eye depends on the nature of the subject and the technology of the imaging device."



▲ STEP 1

The brightness in each image is adjusted, often using different methods. Here, Image 1 is adjusted to preserve detail in the highlights but sacrifices detail in the darker areas (shadows). Image 2 is adjusted to show details in the shadows but sacrifices the highlights. Image 3 is adjusted for highlights and for shadows, and preserves tonal range throughout. This is all done with specialised software that recognises the format used for astronomical data (FITS) before converting it into a more standard format (TIFF).



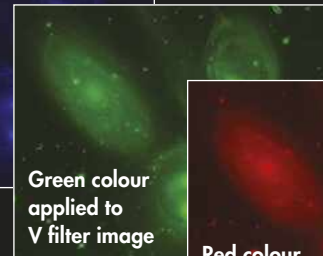
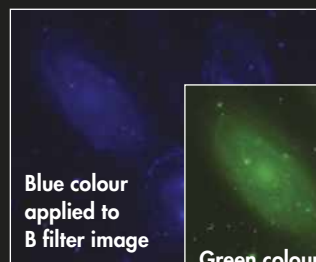
STEP 2 ▲▶

The same adjustment is applied to three filters that sample different bands of colour wavelengths. Most commonly we use three filters. Sometimes datasets from several different filters may be combined to give us three channels that can be combined in colour.



▼ STEP 3

Next we apply a primary colour appropriate to each input filter in wavelength order (reddest filter in red, bluest in blue, and so on). The applied colour need not be the actual visible colour of the filter. This and the remaining processing is done in standard photo-editing software.



◀ STEP 4

A composite is created by layering the coloured images.



STEP 5 ▼▶

Finally, adjustments to improve tonality, colour and contrast are applied, followed by retouching to remove instrument artifacts and any finishing tweaks.





The Guide

The stars we've yet to find

With Elizabeth Pearson

There may be dozens of strange stellar objects still left to discover in the Universe

A Thorne-Zytkow Object:
a neutron star trapped
inside a red giant

Often in astronomy it is a new telescope that finds some strange object in space, leaving theorists to scramble for an explanation, but sometimes the theorists get there first.

In 1975, two physicists suggested a new type of hybrid star, a red giant with a neutron star hidden inside it, which they named a Thorne-Zytkow Object. In June 2014, nearly 40 years later, a group of scientists researching red giants using the Las Campanas Observatory in Chile discovered what they believe might be one of these strange stellar bodies.

Scientists have spent many years wondering about what the first stars were

like, and what will happen to the last ones several trillion years from now, coming up with many hypothetical celestial objects in the process. Some, like Thorne-Zytkow Objects, originate in thought experiments, and it can be decades before they are found – if, indeed, they ever are. There have been several stars that were thought to exist, only to later be proven impossible as we came to better understand the laws

that govern the Universe. Others turn out to be something else entirely. In 1784, it was suggested that some stars could be so massive that they would have enough gravity to stop light from escaping. It wasn't until Einstein proposed the general theory of relativity in 1915 that the idea of such stars was superseded by black holes.

With more powerful telescopes and new technologies it might one day be possible to find some of these exotic stars, which, perhaps, really do exist. On the opposite page we take a look at some of the prime candidates – past, present and future. **S**

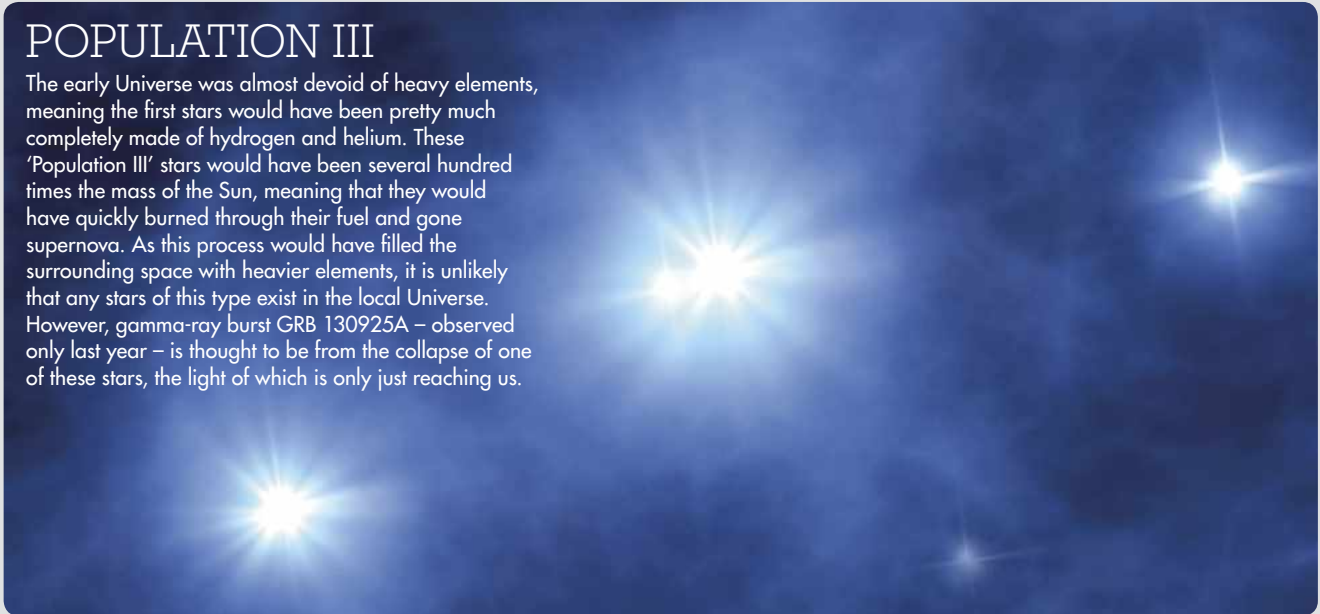
Dr Elizabeth Pearson is BBC Sky at Night Magazine's staff writer

THE HYPOTHETICAL HEAVENS

Five of the more plausible posited stellar objects that might exist, yet remain unseen

POPULATION III

The early Universe was almost devoid of heavy elements, meaning the first stars would have been pretty much completely made of hydrogen and helium. These 'Population III' stars would have been several hundred times the mass of the Sun, meaning that they would have quickly burned through their fuel and gone supernova. As this process would have filled the surrounding space with heavier elements, it is unlikely that any stars of this type exist in the local Universe. However, gamma-ray burst GRB 130925A – observed only last year – is thought to be from the collapse of one of these stars, the light of which is only just reaching us.



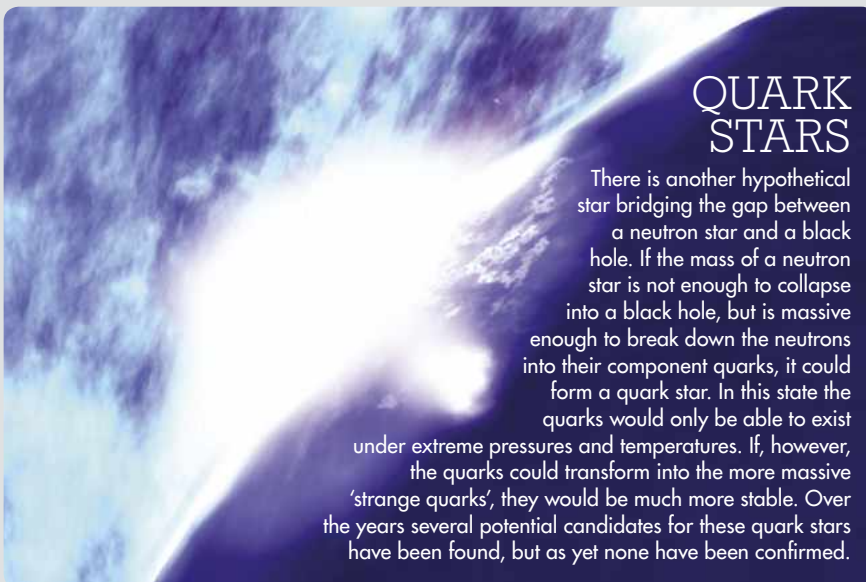
DARK STARS

Another of the Universe's earliest stars may have been a more unusual breed. As galaxies began to form, dark matter congregated at their centres, and stars born in the region may have been created with dark matter making up as

much as 10 per cent of their mass. This extra matter would have allowed the stars to grow to several million times the mass of the Sun, and a billion times brighter, but they would have been short lived. Soon the dark matter fuel would have run out, collapsing the star. This may even be how supermassive black holes form: the James Webb Space Telescope will be looking for evidence when it launches in 2018.

BLITZARS

Even in the current Universe there are stars waiting to be found, among them the blitzar. Dying stars only go supernova and collapse into black holes when they are above a certain mass; otherwise they will form a neutron star. Blitzars are neutron stars with masses above the supernova threshold, but held together by a rapid spin speed. Over time, the spinning slows and eventually the star will collapse into a black hole, releasing an incredible amount of energy. It's thought that this collapse might be responsible for intense, milliseconds-long 'fast radio bursts' detected in July.



QUARK STARS

There is another hypothetical star bridging the gap between a neutron star and a black hole. If the mass of a neutron star is not enough to collapse into a black hole, but is massive enough to break down the neutrons into their component quarks, it could form a quark star. In this state the quarks would only be able to exist under extreme pressures and temperatures. If, however, the quarks could transform into the more massive 'strange quarks', they would be much more stable. Over the years several potential candidates for these quark stars have been found, but as yet none have been confirmed.



BLACK DWARFS

The ultimate fate of our own Sun is a question that many astronomers have tried to answer. In five billion years time the Sun will have burned itself out, shrinking to a white dwarf, as will many other stars like it. Instead of generating its energy through fusion, all its light will come from its intense heat radiating away. Over time, the star will dim and cool, until all that is left behind is a cold black dwarf. How long this will take is not very certain, but even the shortest estimate states that it will take over a quadrillion (one thousand million million) years to reach this phase, so it will be a while until anyone can observe one.

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With Mark Parrish

How to Build an accessories case

Keep the essentials clean and ready for use wherever you are



▲ Moveable dividers mean that you can adapt your case to whatever accessories you have

Amateur astronomers don't take very long to accumulate stacks of eyepieces, while astro imagers often end up with an additional stockpile of filters, connectors, extension tubes and more. To be useful, all of these items need to be easy to find and kept clean, ready for use – which is why this month we're looking at how to make a storage case of your own.

Why make one? It is possible to buy specially designed accessory cases for this purpose after all, but as well as being expensive, these are often quite bulky. The interiors of many of these cases are lined with foam rubber that has been die-cut to

provide space for a number of 1.25-inch or 2-inch cylindrical accessories, but if you wish to vary the contents, you need to become rather adept at modifying the foam with a sharp knife, which isn't always very successful or neat.

Our case is going to be of wooden construction with internal dividers that you can position to suit your particular contents. We have designed it so that it can accommodate a collection of assorted accessories and – importantly – it can be built with minimal woodworking skills from stock-sized materials.

We realise that there are some very skilled joiners and craftspeople out there,

TOOLS AND MATERIALS



FINISH

Exterior quality gloss paint or varnish.

MATERIALS

Fine quality 3mm plywood for lid and base panels, 15mm softwood for the remainder of the box and the dividers, two or three cheap carpet mats.

SUNDRIES

One-inch long No.8 brass woodscrews, case handle and fittings, catches, PVA wood glue, staples, contact adhesive and self-adhesive hook tape.

TOOLS

Hand saw, drill with bits for screws and countersink bit, sand paper, ruler, pencil, scissors, staple gun, craft knife, screwdriver.

but even if you are just enthusiastic and willing to try, you should still find this a very straightforward build whatever your skill level. There are no tricky joints to make or even any hinges to fit; all you need to do is drill some holes then glue and screw the parts together. There are plans and additional photos on the coverdisc to help you with the build, as well as a cutting list for the wood, which you can give to your local timber merchant.

Inherent flexibility

The lining for the box and the moveable dividers is made from inexpensive carpet mats, which we found in a DIY store, where ▶



▲ The finished accessories case is much slimmer than many that are available to buy

► we also bought a handle and a couple of catches to keep the case closed. The dividers have Velcro-type hook tape on the underside so you can change their position within the case as needed. We used foam from a pack of cheap dishwashing sponges to raise up and separate smaller accessories so they don't rattle around when in transit.

The standard case we built is quite compact and finished with a clear varnish to bring out the grain of the wood, but with a little ingenuity you could scale up the design to house larger accessories such as cameras and lenses, or even small telescopes. You could also change the finish – perhaps painting the outside to match existing equipment.

As a finishing touch, we added a removable red LED unit to the inside of the lid, which provides just enough light to read the markings on eyepieces without spoiling your night vision. This is made from a few basic components, which are mounted inside a plastic box that once held mints. Again, Velcro-type hook tape means it can be repositioned as necessary, or even removed from the inside of the lid to use as a torch. Details of the simple circuit and construction for this light can also be found on the coverdisc.

This case is rewarding to build and should provide years of service. Other features you could add include internal pegs for coiling cables tidily, lift-out or built-in racks for eyepieces currently being used or a 'push-to-break' switch so the LED light comes on automatically when you open the case, rather like a fridge door. We estimate that you can build our case for about a third of the cost of a commercially made one, and if you already have some offcuts of timber or fittings, it's a very inexpensive prospect indeed. ●

Mark Parrish is a consummate craftsman who loves making astro accessories

STEP-BY-STEP GUIDE



STEP 1

Use the plans to mark and cut out the plywood panels for the top and base, and the softwood for the sides. If you are lucky enough to have a timber merchant who can do this for you, all you need to do is sand the edges so that they are smooth.



STEP 2

Tape paired parts together before marking out the screw holes. This will ensure that the holes line up after drilling – not to mention saving you time. Remember to countersink the holes so the screw heads lie flush with the wood's surface.



STEP 3

Assembly is simply a case of screwing the softwood sides together, though it is a good idea to apply waterproof wood glue to the joint before tightening the screws. Screw the sides together on top of the respective plywood panel so you can see if it is square.



STEP 4

Fix the plywood panels to the softwood sides with glue and pins, then rub down with sandpaper for a smooth finish. Temporarily fit a carpet lining to the lid and attach it to the box with a screw each side. Check it opens and closes properly before varnishing.



STEP 5

When the finish is dry, cut the carpet to line the inside of the lid and main box. Use contact adhesive to bond it in place. Make dividers from 48mm-wide strips of softwood wrapped with the carpet (secure this with staples), fixing hook tape to the bottom of each one.



STEP 6

Attach the lid, using screws as the pivots. Now assemble the handle and catches on a raised strip of wood so they sit flush with the projecting lid. Then you need to screw this in place with the lid closed so you can check the catches snap shut properly.

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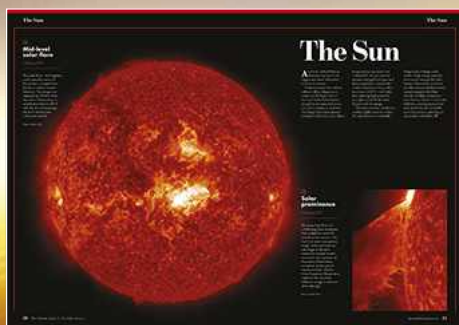
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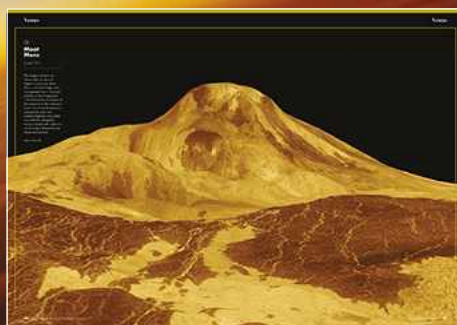
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Sketching

Hansteen and Billy

With Carol Lakomiak

NEED TO KNOW

NAME: Hansteen and Billy

TYPE OF OBJECT:

Lunar craters

CONSTELLATION: The

Moon is in Aquarius on the suggested sketching night

RA: n/a

DEC: n/a

EQUIPMENT:

8-inch reflector; HB, 2B and 4B graphite pencils; small piece of sandpaper; hard art eraser

BEST TIME TO SKETCH:

5 October, all night

FIELD OF VIEW SHOWN:

Approximately 418km;
400x magnification



STEP 1

Use an HB pencil to outline the main features along with any others you want to include, then fill their shadows with a 4B pencil. It's best to add the shadows now, because they're constantly on the move and won't look exactly the same by the time your sketch is finished.



STEP 2

Soften the outline of Mons Hansteen with a blending stump, and then coat the tip of the stump with 2B graphite. Darken the crater floors with the stump by using small circular motions, applying more graphite to the darker areas. Then use the stump to add Billy's outer slope.



STEP 3

Use the 2B graphite coated stump to evenly shade the surrounding area. Clean the stump on sandpaper and then use it to blend Step 1's basic outlines. Coat the stump with 4B graphite and add the darker areas around the craters – as seen in the main image.

Located on the southwest shore of the Oceanus Procellarum are two very different looking craters: Hansteen and Billy. Hansteen is named after Christopher Hansteen (1784-1873), the Norwegian physicist, astronomer and geophysicist who mapped the Earth's magnetic field. Hansteen is the brighter of the two craters and contains internal terraces, curved ridges and small hills.

South of Hansteen is Billy, which takes its name from French Jesuit astronomer and mathematician Jacques de Billy (1602-1679). Its floor is smooth and dark save for two light-toned craterlets on its southern end. The western one is plainly seen in our sketch, but the eastern one is hidden by the shadow on Billy's floor. Another interesting feature you'll be sketching is Mons Hansteen, nicknamed the Arrowhead. It's a bright, bumpy triangular mountain located northeast of the craters.

Because the Moon is covered with so many fascinating features, it's easy to get lost in their details. So before you begin, study the area surrounding your main target and decide which details to include and which ones to ignore.

The main thing to concentrate on during Step 1 is accuracy. For example, notice where

the craters lie relative to one another by imagining a clock face superimposed on the sketch area. Hansteen is located at 11 o'clock while Billy is at 5 o'clock. Also notice their shapes: both are basically oval, but Hansteen's upper tip is sharply pointed whereas Billy's southern tip is softly pointed. The heart of Mons Hansteen is both centred above Billy and in line with the bottom of Hansteen.

We need to use a blending stump for this sketch. This is simply a tightly rolled, pencil-shaped piece of paper that gently 'pushes' the graphite into the paper's texture, producing a soft, smooth look. Graphite can be applied to the tip of the blending stump in two ways: by applying it directly to the stump with a pencil, or by scribbling a patch of graphite onto a small piece of paper and rubbing the stump on it. Use whichever method works best for you.

No matter how careful you are, graphite always manages to make its way onto areas of the sketch where it shouldn't be, like the crater rims and the sunlit sides of the small elevated features. To clean and brighten these areas, use a hard art eraser that's been cut to a sharp edge.

Carol Lakomiak is *BBC Sky at Night Magazine's* sketching expert



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With **Steve Richards**

Scope DOCTOR

Our resident equipment specialist cures your optical ailments and technical maladies

What kind of telescope is good for deep-sky observing if my budget is £500 to £750?

JOGINDER SINGH FOLEY

Many deep-sky objects are relatively dim, so aperture is the most important telescope attribute for observing these wonderful objects.

Your proposed budget of between £500 and £750 places you at a little bit of a crossroads, as you could consider both larger telescopes on manual mounts and smaller telescopes on Go-To mounts. With your preference for observing deep-sky objects though, we would suggest steering clear of the otherwise very attractive Schmidt-Cassegrains available on altaz Go-Tos because of their relatively small main lenses – around 5 inches at the top of your budget.

The biggest aperture for your money will come from buying a Dobsonian. You should consider the Revelation 10-inch f/5 M-CRF Premium Dobsonian at £478, its 12-inch counterpart at £550 or the Sky-Watcher Skyliner 250PX 10-inch Dobsonian at £435. Each of these will give great views of a wide range of deep-sky objects while leaving you with funds available to buy additional eyepieces.

However, these are large instruments and if you need to be able to transport them some distance to, say, a site with darker skies, you should also consider the Sky-Watcher Skyliner 250PX FlexTube 10-inch Dobsonian at £529, as this scope folds

down to a more manageable size. At the higher end of your budget, a good balance between aperture and Go-To capabilities would be the Sky-Watcher Explorer 200P EQ5 Go-To, an 8-inch Newtonian reflector for £706.



◀ The Skyliner 250PX FlexTube is best if you need to take the scope places

STEVE'S TOP TIP

What the best way to discover a celestial object's right ascension and declination?

The positions of celestial objects (excluding Solar System objects) in the night sky are defined by their right ascension (RA) and declination (dec). To all intents and purposes, these numerical locations are unchanging and can be found by reference to a good star chart. However, the easiest method of obtaining this information is by the use of free planetarium software like Cartes du Ciel or Stellarium, which are available for both Windows and Mac OS X operating systems. For ultra portability, planetarium apps such as SkySafari, Distant Suns and Star Walk are available for iOS and Android smartphones.

What type of optical finder is best for a Newtonian? SALLY WHITE

Red-dot finders are often supplied with new telescopes as they are a cost effective and intuitive way of locating brighter celestial objects. However, they do not give any magnification or increase in light grasp over the naked eye. A good optical finder can, therefore, make the task of locating objects a bit more straightforward.

There are two main types of optical finder, those with a straight-through view and those with a right-angled view. Since Newtonian reflectors have the observing eyepiece on the side of the optical tube close to the front of the telescope, a right-angled finder is by far the most comfortable to use – if you were to use a straight-through finder, you would have to angle your face down the side of the telescope to see through it.

An illuminated crosshair makes it so much easier to centre objects. Both the Celestron illuminated RACI 9x50mm finderscope or the Altair 10x60mm right-angled illuminated finderscope should be on your shortlist.

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



▲ Right-angle finders are better for Newtonian reflectors

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Sky at Night
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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

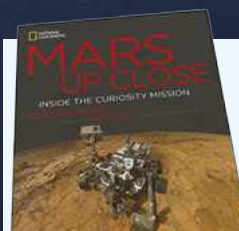
90

We test the prowess of the Vixen VSD 100's five-element optical arrangement



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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/vixvsd100



Vixen VSD 100 f/3.8 astrograph

A small imaging refractor that eradicates misshapen stars

WORDS: STEVE RICHARDS

VITAL STATS

- **Price** £5,199
- **Optics** Quintuplet in five groups
- **Aperture** 100mm (4 inches)
- **Focal Length** 380mm (f/3.8)
- **Focuser** Helical with vernier scale
- **Extras** Flight case
- **Length** 497mm
- **Weight** 4.5kg
- **Supplier** Opticron
- **Tel** 01582 726522
- **www.vixenoptics.co.uk**

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SKY SAYS...

Vixen has produced a short focal length instrument with a truly excellent flat field

If there is one thing that causes angst among astrophotographers, it is the appearance of misshapen stars at the periphery of the field of view in deep-sky images. The Vixen VSD 100 f/3.8 astrograph tackles this issue head on with a new optical design comprised of five individual lens elements.

The VSD 100 is supplied in a substantial flight case, the diminutive dimensions of which are a bit of a surprise when you first open the outer packaging, but this telescope is small for a very good reason. The clue is in the extremely low focal ratio of f/3.8 which, with an aperture of 4 inches, translates into a very short focal length of just 380mm.

Objects such as emission nebulae can extend across a surprising amount of sky: capturing these objects in their entirety requires a wide field of view, which dictates a short focal length. The VSD 100 has been specifically designed to cover a very wide yet flat field of view.

Vixen has not merely considered the optical requirements for this type of photography, as it has also included a very different type of focuser

to normal refractors. The helical focuser supplied is beautifully engineered and held our imaging equipment very solidly indeed – there was absolutely no chance of any slippage while imaging near the zenith. The action is firm but smooth and produced no image shift when changing focus direction.

The focuser has a vernier scale rather than a simple, graduated one, and this allows the focus position to be read to an accuracy of 0.02mm. If you are not used to reading a vernier scale this can take a little getting used to, but for logging the start position for various camera and filter combinations, it can be invaluable.

Small but powerful

Supporting the optics and focuser is a white, high gloss tube and dew shield. Fit and finish are exemplary, with the micro-baffling and extremely matt black internal surfaces with absolutely no reflective areas showing great attention to detail. The various components have been engineered to very close tolerances and the main adaptor that slides into the focuser drawtube was such a perfect fit that it blew the dust cap off the rear of the telescope when inserting it. ▶

A FIVE-FOLD FLATNESS FIX

All refractors suffer from field curvature to some extent. Although this can be tolerated when using eyepieces, the flat nature of a camera's sensor highlights the issue. Images captured through a normal refractor show elongated stars at the edges of the field of view because a curved plane of focus projected onto a flat surface results in just the centre of the field achieving focus. These abnormal star shapes detract from the appearance of the view – which is why astrophotographers go to great lengths to eliminate them by installing external field flatteners.

Some manufacturers use a four-element optical configuration based on the original Petzval design in an attempt to combat field curvature, with some success. However, the single most important design feature of the Vixen VSD 100 is its five-element, five-group optical configuration. Vixen has resolved the flat field issue by using a pair of lenses at the front of the telescope to focus the incoming light and a set of three additional lenses at the rear of the telescope to correct the field curvature, resulting in a very flat field of view.



INTERNAL BAFFLES AND BLACKENING

Keeping light reflections to a minimum is important to maintain good contrast and the VSD 100 tackles this in two ways. First, the internal surfaces are coated in a very matt black finish; complementing this, there are a series of baffles within the tube to further absorb unwanted reflections.



DEW SHIELD

The fixed dew shield extends 98mm past the front of the telescope and provides excellent protection from stray light and the effects of dewing. The push-in dust cap is made of aluminium and is retained in a rubberised holder, providing a very simple but extremely effective barrier.

58MM FILTER HOLDER

The push-fit adaptor that couples directly with the focuser's drawtube has an internal thread for holding a standard 58mm filter. This feature allows a light pollution filter to be installed for use with a one shot colour camera such as a DSLR.

HELICAL FOCUSER AND VERNIER SCALE

Unusually, the VSD 100 is supplied with a helical focuser, which operates in the same manner as a camera lens – adjustment is made by turning a focusing ring. The Vixen version is very substantial indeed, easily supporting our imaging gear with a superb focus action and a vernier scale for logging focus positions.



FIRST light

► Daytime imaging tests with a Canon EOS 450D DSLR camera indicated good colour correction. In fact, this telescope would be excellent for capturing high-quality wildlife images, especially as its handling has much in common with a camera lens. However, under the much more demanding spotlight of deep-sky imaging using a one shot colour CCD camera, we found it tricky to achieve best focus. Our Bahtinov mask and confirmation of correct focus using MaxIm DL's FWHM tool resulted in images that were not quite as sharply focused as we would have hoped for.

Switching to a monochrome CCD camera, we again noted that luminance data was not as critically sharp as we had expected, with a little bloating to brighter stars. However, capturing narrowband data using our 7nm hydrogen-alpha (Ha) and oxygen III (OIII) filters produced extremely finely focused results, indicating that the optics are not entirely apochromatic.

We were very impressed with the flatness of the field of view. Capturing consistently well-formed stars right to the edges of the field of view with such a short focal length instrument is quite an achievement bearing in mind the actual sensor sizes involved. With our one shot colour CCD camera the field of view was 3° and 31 arcminutes by 2° and 21 arcminutes, while with our monochrome CCD camera it was 2° and 42 arcminutes by 2° and 2 arcminutes. There



▲ The Veil Nebula, imaged using Ha and OIII filters

was some vignetting, but this was easily removed by applying flat frames.

Vixen has succeeded in producing a short focal length instrument with a truly excellent flat field ideal for many deep-sky imaging applications. Narrowband imagers will be very satisfied but one shot colour camera users and LRGB imagers may be a little disappointed with the sharpness of their images. **S**

VERDICT

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

SKY SAYS...

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1.25-INCH EYEPIECE HOLDER

Although designed primarily for astrophotography, the VSD 100 is packaged with a basic 1.25-inch eyepiece holder. There isn't sufficient backfocus to allow the use of a star diagonal, so observations must be made in a straight-through manner, which is quite typical of other Japanese telescopes.

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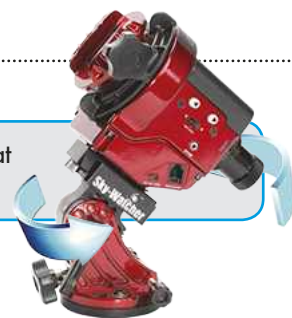
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FIRST light

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



Sky-Watcher Star Adventurer DSLR mount

A portable tracking mount that offers flexibility as well as accuracy

WORDS: PAUL MONEY

VITAL STATS

- **Price** £299
- **Payload capacity** 5kg
- **Latitude adjustment** 0°-75°
- **Tracking rates** Sidereal, 0.5x sidereal, lunar, solar for northern and southern hemispheres
- **Timelapse settings** 12 hours, four hours and two hours per revolution
- **Polarscope** Illuminated with 7° field of view
- **Power requirements** 4x AA batteries (not supplied), external power via mini USB DC 5V
- **Extras** Fine-Tuning Mounting assembly, 3/8-inch ball head adaptor, equatorial head, counterweight, camera shutter cable
- **Weight** 1kg
- **Supplier** Optical Vision
- **www.opticalvision.co.uk**
- **Tel** 01359 244200

SKY SAYS...

We captured five-minute exposures of the Double Cluster with only the slightest hint of trailing

Capturing the majesty of the night sky in wide vistas using a DSLR camera is a rewarding experience, especially if you can take long enough exposures to bring out the subtler features present: the vast clots of dust and nebulae peppered with stars. Doing so used to entail piggybacking your camera on a telescope and using the scope's motor drive to compensate for the rotation of the heavens. Today, there are a plethora of small mounts designed for this purpose. Sky-Watcher has now entered the arena with its Star Adventurer DSLR mount, and a great looking thing it is too.

Our review covers the 'astrophotography bundle', which comprises the main unit, an equatorial wedge, counterweight bar including a 1kg weight, 3/8-inch ball head adaptor, Fine-Tuning Mounting (FTM) assembly and a polarscope illuminator. Also included is a DSLR shutter control cable, for which you specify your camera make and model before ordering to get the right cable. Unlike some similar mounts on the market, this one doesn't come with its own tripod.

Inherent potential

We found assembly and use was reasonably straightforward. For the most basic setup, all you need to add is your camera with a lightweight lens, on a ball head mount (not supplied). A spirit level on the equatorial wedge allows you to level the system before performing the polar alignment. Alignment was easy to achieve – we did so by using an app on our smartphone to show exactly where to place the pole star in the illuminated field of view of the polarscope. Alternatively, you can set the date and time dials on the polarscope to place the pole star in the correct position for alignment.

For wide-field astrophotography our Canon EOS 50D DSLR with an 18-55mm lens was fixed on a ball head, which was then attached to the supplied ball head adaptor with its Vixen-style bar. However, before attaching the camera to the main unit you need to perform the polar alignment using the built-in polarscope. We did note that you ▶

A REAL 'STAR' TRACKER

With our basic setup and camera lens set at 31mm, our 20-minute exposures of Cygnus showed nice sharp stars and no sign of trailing. We swapped to our 70-300 mm lens – as you increase the lens size, you also magnify the effects of star trailing. Setting the lens to 300mm and aiming at the Double Cluster in Perseus, we managed to capture five-minute exposures with only the slightest hint of trailing. Switching to our heavier Canon EF 100-400mm lens (and adding the Fine-Tuning Mounting assembly for greater stability), we set the lens to 100mm and captured good five-minute exposures of the Andromeda Galaxy region. Finally we pushed the lens to 400mm, aimed at the Double Cluster and got exposures of two minutes before significant trailing. Take a lot like that and you'll be a happy snapper. The weather beat us during our time using the Star Adventurer so we were unable to test out the guider port, but even so the Star Adventurer is really a 'star' tracker for wide-field imaging without it.



Our five-minute exposure of the Andromeda Galaxy, imaged using a 100-400mm lens at 100mm



Our five-minute exposure of the Double Cluster in Perseus, imaged using a 70-300mm lens at 300mm

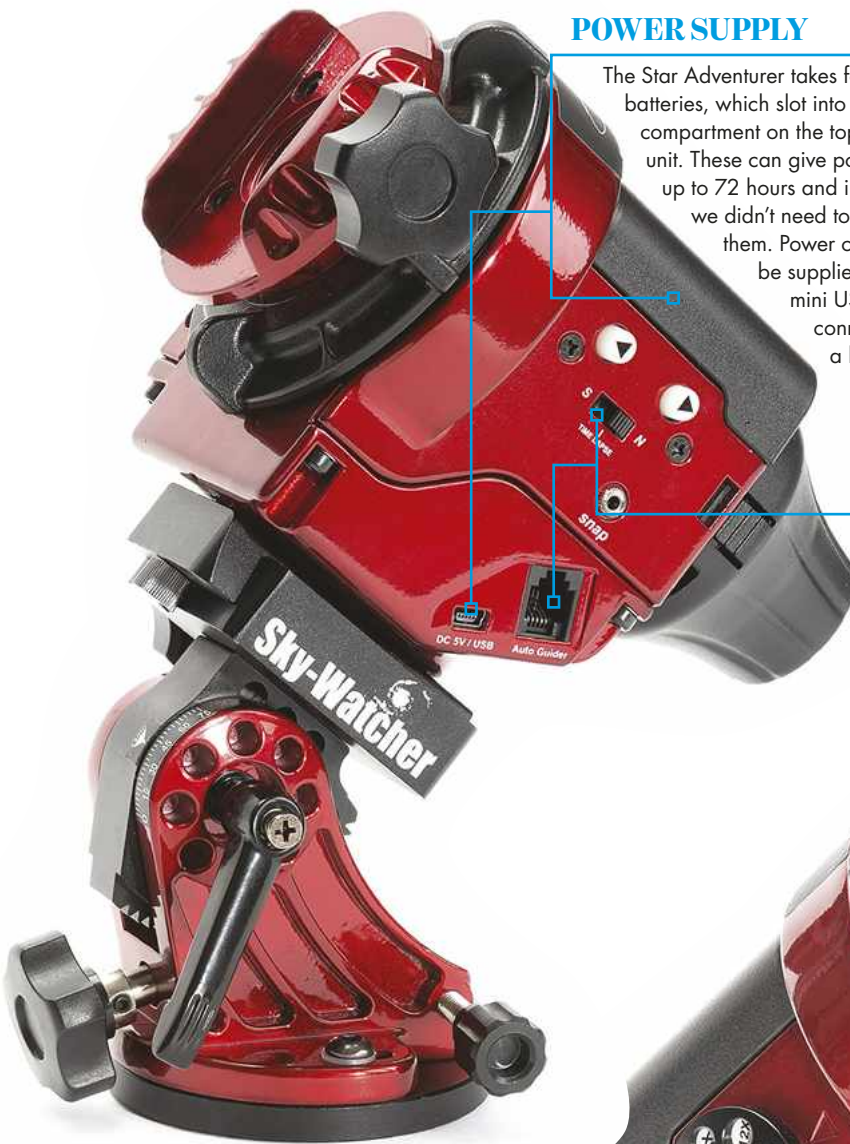
POWER SUPPLY

The Star Adventurer takes four AA batteries, which slot into a compartment on the top of the unit. These can give power for up to 72 hours and in our tests we didn't need to change them. Power can also be supplied via a mini USB 5V lead connected to a laptop.



SWITCHES AND GUIDE PORT

On one side is the main selector knob, which allows you to choose sidereal, lunar and solar rates, an 'off' position, plus settings for timelapse photography. On the other side are left and right buttons, the northern/southern hemisphere selection switch, camera snap port, autoguider port and mini USB socket.



POLARSCOPE

The Star Adventurer has a built-in polarscope usable in both northern and southern hemispheres, which we found worked without any extra calibration. The polarscope illuminator is a little fiddly but does its job, however it does need to be removed before adding a camera.



EQUATORIAL WEDGE

The equatorial wedge can be set from 0° to 75° latitude for either hemisphere with an easy to use adjustment knob and locking handle. Longitude adjustment via two adjustable bolts helped in fine tuning the alignment. We found it very stable once attached to our tripod.



FIRST light

► cannot leave the polarscope illuminator in position after doing this – it must be removed before attaching the camera gear. Ensure you are happy with the polar alignment and lock the position securely before you do so.

Installing the Fine-Tuning Mounting assembly before the camera increases the mount's flexibility, as it allows you to attach a second ball head adaptor. This means you can attach another camera, creating a dual-imaging system – especially useful in meteor photography – or a lightweight scope, either to use for direct observation or as a guidescope. The mounting also allows you to attach the supplied counterweight shaft and counterweight, should you need them to balance the setup.

The mount offers several options, including northern or southern hemisphere tracking and timelapse. A rotating dial allows you to select from a normal sidereal (star tracking) rate, 0.5x sidereal, lunar and solar rates, the last two being useful for imaging eclipses. The 0.5x rate allows for wide-field exposures that have semi-sharp foreground objects (such as trees or distant mountains) while giving reasonably sharp stars as well. Three further options are for timelapse photography.

Using our Canon DSLR and a range of lenses we took a series of exposures of varying lengths to get an idea of how well the mount tracked (see our outstanding feature, page 94). Overall we were pleased with our results, considering the Star Adventurer is a fairly light 1kg without its extras. This means it is ideal for solar eclipse or astrophotography trips involving air travel, when weight can be an issue. Add to that its stylish design and it's a piece of kit you'll like to show off while on holiday as you capture the grandeur of the night skies. **S**

FINE-TUNING MOUNTING ASSEMBLY

The Fine-Tuning Mounting assembly allows for a small telescope to be attached either for visual or guiding use, and has its own declination manual slow motion control. A second ball head adaptor can also be added, allowing you to create a dual-imaging setup.

VERDICT

ASSEMBLY	★★★★★
BUILD & DESIGN	★★★★★
EASE OF USE	★★★★★
FEATURES	★★★★★
TRACKING ACCURACY	★★★★★
OVERALL	★★★★★

SKY SAYS...

Now add these:

1. Sturdy tripod
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3. Skymax 90 telescope tube



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FIRST light

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



Daystar Quark hydrogen-alpha eyepiece filters

We don't use the term 'game changer' lightly...

WORDS: PETE LAWRENCE

SKY SAYS...

If you think an £850 hydrogen-alpha eyepiece would produce a compromised view, then you'd be wrong

VITAL STATS

- **Price** £799 (introductory price; usually £849)
- **Barrel size** 1.25- or 2-inch telescope fitting with 1.25-inch output barrel
- **Tuning range** 6,562.8Å with maximum tuning shift of $\pm 0.5\text{Å}$ in 0.1Å increments
- **Bandpass** 0.3-0.5Å (chromosphere), 0.6-0.8Å (prominence)
- **Extras** Power supply, dust caps
- **Weight** 400g
- **Supplier** The Widescreen Centre
- **Tel** 020 7935 2580
- **www.widescreen-centre.co.uk**

Interest in solar observing has developed at an amazing pace over recent years. A large reason for this is the introduction of affordable hydrogen-alpha solar filters, a category the Quark filters from Daystar certainly fit into.

Hydrogen-alpha filters give amazing views of the layer of hot hydrogen above the Sun's visible white light surface, or photosphere. A hydrogen-alpha filter shows magnetically contorted hydrogen plasma mainly located in a layer known as the chromosphere.

Cooler 'clouds' of hydrogen can sometimes be seen above the chromosphere. Witnessed against the Sun's disc, they appear as dark snaking filaments. As the Sun rotates, filaments are brought to the Sun's edge where they appear to protrude into space as beautiful prominences.

To reveal all this majesty, a hydrogen-alpha solar filter needs to be manufactured to exacting tolerances. The filter must pass the hydrogen-alpha wavelength at 6,562.8 Ångströms (Å), with just a tiny wavelength range either side, known as the filter's bandpass. This finesse is expensive to achieve but the introduction of the Coronado PST roughly a decade ago for around £500 changed the game. Even

today though, moving to larger apertures tends to require deep pockets, and it is easy to stretch into five figures.

A surprise package

Enter the Daystar Quark. Unlike a typical hydrogen-alpha solar setup, the Quark does all the filtering at the eyepiece end and so, in theory, can be used with any size of aperture. As the Quark costs around £850, it's quite an exciting prospect.

The Quark is designed to work with refractors and it's recommended that any instrument with an aperture over 3 inches should have an energy rejection filter (ERF) fitted over the front lens, at extra cost. Daystar provides an ERF configuration wizard online at visit www.daystarfilters.com/Wizard. This accessory is extremely simple to use. Insert it, power up and wait for the filter to get to operating temperature. A status LED turns green to show this has happened – for us, it took about 10 minutes.

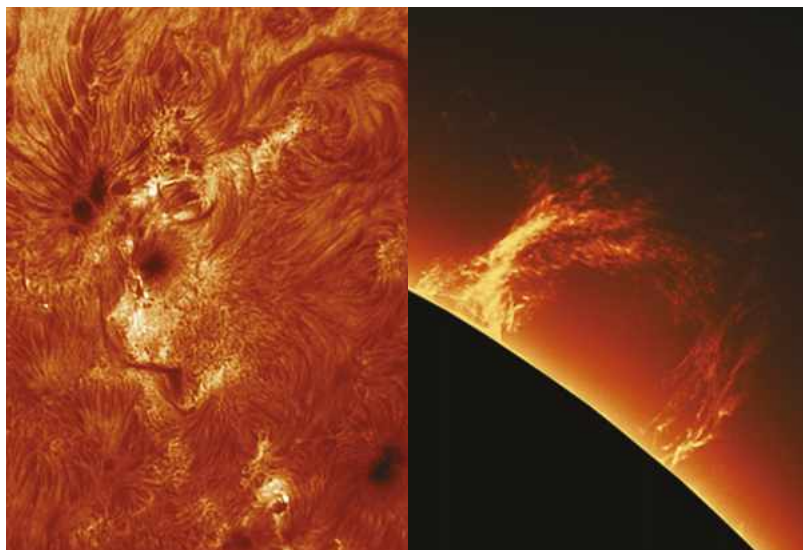
Hydrogen-alpha filters are defined by their bandpass: wider bandpasses are suitable for prominences, while narrower ones show the finer ▶

OPTIMISED TO PERFECTION

The small wait for each filter to get to temperature fills you with anticipation and your eventual opportunity to look through the eyepiece or via a camera certainly doesn't disappoint. Despite the diminutive (in hydrogen-alpha terms) price tag, both models perform impressively.

The chromosphere-optimised version shows plenty of fine detail, from dark fibrils, filaments and plage to intricate magnetic maelstroms surrounding active regions. Despite its optimisation, this version can also show limb detail including prominences and the short-lived jets of gas known as spicules. The field of view has great contrast and is without gradients or noticeable sweet spots.

Switching from the chromosphere to the prominence model delivers a whole new experience. Seeing prominences via the chromosphere filter leads you into the false sense that the prominence filter view isn't going to be that much better. However, it is. Prominences appear bright and detailed against a jet black background sky again with no sweet spot issues.

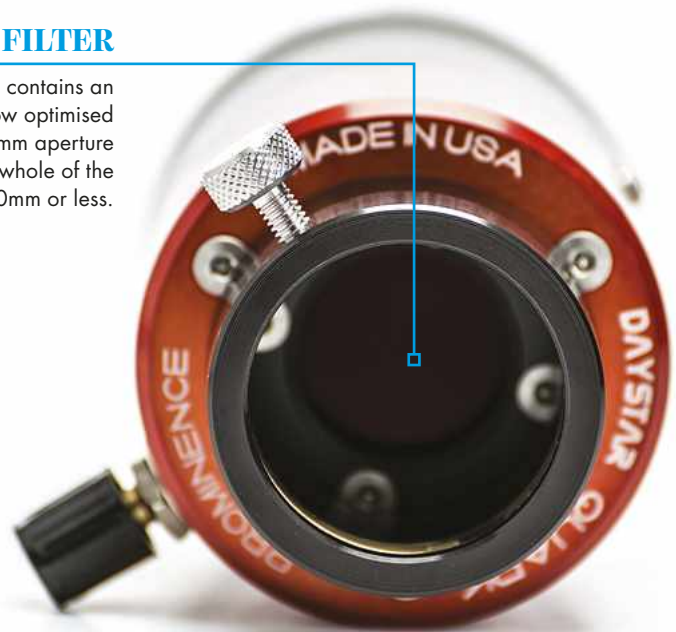


▲ A wealth of fine solar details, captured with the chromosphere eyepiece filter

▲ Not to be bettered, the images taken with the prominence variant are as impressive

HYDROGEN-ALPHA FILTER

All the optics are fully enclosed in a solid body. This contains an integrated and fully baffled, two-element telecentric 4.3x Barlow optimised for the hydrogen-alpha wavelength. The filter has a clear 21mm aperture and is fitted with a 12mm blocking filter. It's possible to view the whole of the Sun's disc through a telescope with a focal length of 450mm or less.



STATUS LED

A status LED provides basic filter information. When initially powered up the light is an orange colour, but this changes to green when the filter temperature reaches the point where it's centred on the target wavelength.

POWER

The Quark requires a 5V, 1.5A power feed for operation. The input port for this uses a micro USB plug (Micro B). A mains adaptor with plug fittings for different countries is supplied as standard, including one for the UK. An optional eight-hour battery pack is also available, should you want to make the Quark portable.



TUNING KNOB

A small knob retunes the filter to operate in the narrow wings either side of the central hydrogen-alpha wavelength of 6,562.8Å. The knob clicks in increments of 0.1Å, providing maximum variation from the central wavelength by $\pm 0.5\text{Å}$. Retuning allows you to follow fast-moving material that is heading away or towards you and so appears slightly redshifted or blueshifted as a consequence.

FIRST light



2- OR 1.25-INCH OUTPUT BARREL

Quark eyepieces fit between your telescope and your regular eyepiece or camera. The telescope end can fit into a 2- or 1.25-inch eyepiece barrel. At the other end, a 1.25-inch compression ring barrel is provided. Optional 2-inch and Schmidt-Cassegrain fittings are also available. The compression ring grips securely when the thumbscrew is tightened and prevents damage to whatever's been inserted.

SKY SAYS...

Now add these:

1. Tele Vue Plössl 32mm or 40mm eyepiece
2. Tracer lithium polymer 8Ah rechargeable battery pack
3. William Optics ZenithStar 71 ED doublet refractor

► details of the chromosphere. Daystar produces two Quarks; one for prominences (bandpass 0.8-0.6Å) and one for the chromosphere (0.5-0.3Å).

The host refractor needs a focal ratio between f/4 and f/9. The Quark design incorporates an hydrogen-alpha optimised 4.3x telecentric Barlow, giving a magnification 4.3x higher than prime focus. So an f/9 telescope would operate effectively at f/38.7.

If you think that an £850 hydrogen-alpha eyepiece advertised as "Quick, cheap, easy and fun" produces a compromised view, then you'd be wrong. The views through both versions of the Quark eyepiece were superb. As you'd expect, larger apertures delivered the most impressive results.

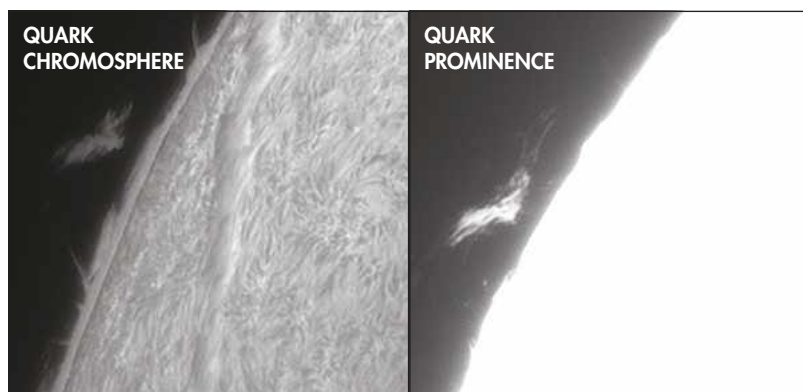
The Quark Chromosphere delivered sharp, fine detail with excellent contrast, while the dramatic rendition of hydrogen-alpha detail around active regions was breathtaking. The filter's temperature

can be adjusted slightly, which causes the Quark to go off-band. This is used to study material moving at high speed towards or away from you, which may be slightly blue- or redshifted. It's necessary to give the filter about 10 minutes to reach optimum temperature after each retune. Where the chromosphere is seen at the Sun's limb, short-lived columns of plasma measuring 500km across and thousands of kilometres high can be seen. Called spicules, both Quarks revealed these with ease during our tests.

The Quark Chromosphere shows prominences, but isn't optimised for them. That's the job of the Quark Prominence, which also shows the chromosphere. We were impressed at the difference between views of the same feature when swapping versions. If you were thinking of getting just one Quark, we'd recommend the chromosphere version simply because of the variety of features it can reveal.

A camera can be used with both Quarks. Our recommendation would be to use a high frame rate monochrome one; during our tests, we achieved some excellent imaging results with the filters.

Daystar has been producing eyepiece-based solar filters for years, but this is its first budget model. The good news is that it appears they've got the product developed right and as it stands the Quark has the potential to be something of a game changer. The ability to experiment with different apertures and configurations all for £850 is very attractive indeed. **S**

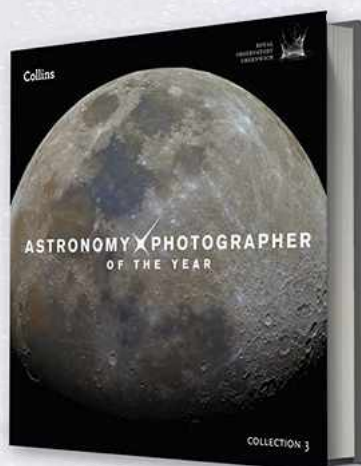


▲ One Quark variant is optimised for the chromosphere, the other for prominences

VERDICT

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

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RATINGS

★★★★★ Outstanding

★★★★☆ Good

★★★☆☆ Average

★★☆☆☆ Poor

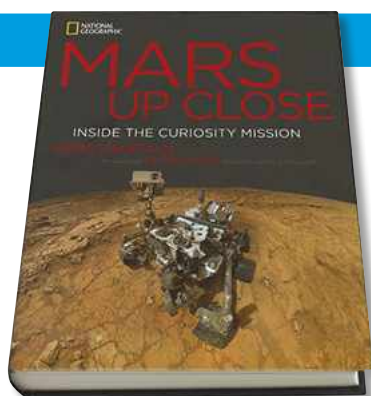
★☆☆☆☆ Avoid

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Mars Up Close Inside the Curiosity Mission

Marc Kaufman
National Geographic
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BOOK
OF THE
MONTH



In its way, NASA's Curiosity rover is like something out of a 1950s sci-fi novel: a nuclear-powered, laser-armed car, trundling its way around the Red Planet. Except if it were a product of the 50s, Curiosity would of course be driven by an astronaut, perched atop it. As it is, the rover is overseen remotely by a team of hundreds of people sat an average 225 million km away. With every turn of its wheels Curiosity stamps the identity of its controllers afresh onto Martian regolith: the wheel rims are etched with Morse symbols spelling out 'JPL'.

Journalist Marc Kaufman spent months embedded with the Curiosity team; this lavishly produced volume is the result, taking the reader from the famous seven minutes of terror that was the Curiosity landing through to the rover's careful turn on and early exploration, its exciting initial discoveries, followed by its continuing odyssey through Gale Crater towards Mount Sharp. Kaufman's main narrative is interspersed with brief profiles of key team members, highlighting the rich mix of disciplines required to bring this mission to life.

It hasn't always been an easy drive: the book describes one software anomaly that might have left the rover a day from a mission loss and arguments by mission

scientists on the best way forward. Completion of Curiosity's mission is still several years away, across progressively harder, higher terrain. Team members also note that all the work done by the rover to date could have been achieved by a human astronaut within a few days – but getting people safely to Mars and back remains a technical hurdle too far.

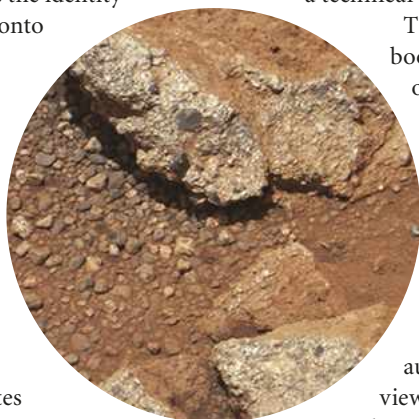
This richly illustrated book shows predictions of the death of print are premature; it'll be a long time before online equivalents can replicate such an authoritative feel. Additional online content is offered however, including augmented reality 3D views. The only criticism that might be levelled is that there is a lack of analysis of how Curiosity fits within the wider context of Martian

exploration – perhaps because its cost overruns helped scupper NASA's follow-on plans, with Curiosity's successor not due to reach Mars until the end of this decade.

★★★★★

SEAN BLAIR writes for the European Space Agency website

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Curiosity has made amazing discoveries on Mars, such as this ancient riverbed



TWO MINUTES WITH MARC KAUFMAN

What inspired you to write the book?

The Curiosity mission seemed to be a clear and major step forward in many aspects of planetary exploration and research. I became excited about telling the story of its travels to and across Mars, its discoveries and some of its key science and engineering masterminds.

What new insights has Curiosity given us about Mars?

First off is the confirmation of satellite-based theories that water ran on the Martian surface is much greater abundance and for a longer time than previously imagined. This leads to the second major insight: That Gale Crater, and potentially many other regions of Mars, were indeed once 'habitable'.

What lies in store for Curiosity?

The rover is headed now for what was going to be its first destination – Mount Sharp. The lower section of the mountain should contain layers upon layers of minerals. These layers can and will be read by planetary geologists and the early history of Mars will become much better understood. If the rover makes it up the mountain, then we will no doubt see spectacular images of the planet.

Is it still worth going to Mars?

Definitely. Curiosity has taught us much about Mars, and will definitely teach us much more. If further exploration were to prove that life did once exist on Mars (or elsewhere), I believe it would be perhaps the greatest scientific discovery of all time.

MARC KAUFMAN is a journalist at The Washington Post

Gear

Elizabeth Pearson rounds up the latest astronomical accessories

1



1 Meade Astro Rucksack

Price £67 • **Supplier** Telescope House
01342 837098 • www.telescopehouse.com

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2 Cave Collimator

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3 Baader T-2 Quick Changer

Price £62.40 • **Supplier** 365Astronomy
020 3384 5187 • www.365astronomy.com

Alternate between eyepieces and cameras using this quick changer ring. Use your eyepiece to centre your target, then switch to a camera to take your shot.

4 Sky-Watcher Planetary 58° UWA 1.25-inch Eyepieces

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IEQ45-PRO & PRO-AZ GOTO

new 2014 model with stepper motors, this GOTO mount delivers for imaging or visual observing. **20kg payload** and a head-weight of **only 11.4kg**. A class leader for portability and setup time. Field-piers or permanent observatory piers available.

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WHAT I REALLY WANT TO KNOW IS...

Can humans avoid contaminating Mars?



John E Hallsworth is using his expertise on microbial life to help NASA and ESA keep the Red Planet free of Earth bugs

INTERVIEWED BY PAUL SUTHERLAND

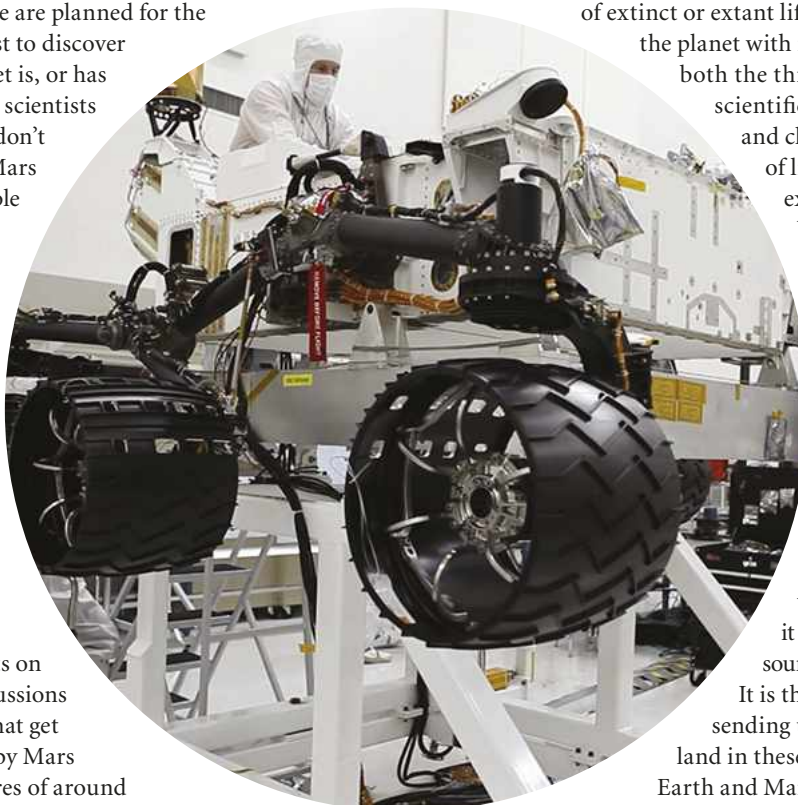
Several space probes have already landed on Mars and more are planned for the future in the quest to discover whether the planet is, or has ever been, home to life. But scientists remain concerned that we don't accidentally contaminate Mars by sending microbes, capable of multiplying on the Red Planet, as hitchhikers on spacecraft. I have joined a NASA team that is taking a serious look at the latest data on the limits of life on Earth, and conditions on Mars, to determine whether any such stowaways would be able to thrive there.

My contribution is based on my research into simple life forms in some of the most extreme environments on Earth. I'm involved in discussions to identify areas on Mars that get moist and relatively warm by Mars standards, with temperatures of around -40°C to -60°C , which is enough for such life to thrive. We call them 'Special Regions'.

You might think that, with spacecraft prepared in scientific cleanrooms, they would be free of bugs. But despite all best efforts so far, there has never yet been a microbe-free spacecraft produced. It is plausible, therefore, that microbes from Earth have already reached Mars, though contamination of the planet would necessitate the microbes multiplying either on the Martian surface or within the subsurface, which is highly unlikely.

Future dangers

However, we cannot disregard the dangers of contaminating Mars in the future. Some microbial cells are, or can produce, highly resilient structures capable of surviving temperatures well below freezing, and even below those found on Mars. And any microbes that fell into cracks in the Martian soil, or which found themselves beneath a spacecraft or robotic rover, would be shielded from exposure to ultraviolet light. Again, the critical question is whether they would be able to multiply.



Despite our best efforts, a microbe-free spacecraft remains wishful thinking

ABOUT DR JOHN E HALLSWORTH

Dr John Hallsworth, of the Institute for Global Food Security, School of Biological Sciences at Queen's University Belfast, is working with other international scientists in the Mars Exploration Program Analysis Group (MEPAG)'s second-ever Special Regions-Scientific Analysis Group.

In the event that there are any biosignatures of extinct or extant life on Mars, contaminating the planet with microbes would eliminate both the thrill and an invaluable scientific opportunity to discover and characterise life, or evidence of life forms, in a pristine extraterrestrial environment.

What's more, human habitation of Mars may occur in future, and contamination of the planet, including natural water resources, may act as an impediment to developing of a sustainable human base.

If any future spacecraft were to crash-land in one of the Special Regions that we are currently identifying, it could potentially act as major source of microbial contaminants.

It is therefore important to avoid sending unsterilised missions to land in these areas.

Earth and Mars may have exchanged material in the past, in the form of meteorites. As many microbes on Earth live within rocks, and as we know that microbes can survive a trip through space, it is possible that microbes from Earth have travelled to Mars at various times during the existence of life on Earth. I am not an expert in the possibility of Martian life on early Mars. However, I am sure that Mars today is a very extreme environment for life as we know it on Earth, and it is unlikely that there is a highly active, hidden ecosystem there. This said, I am not convinced that there is no microbe on Earth that could manage to multiply somewhere on Mars and so I believe that planetary protection considerations are important.

More work is needed to find ways to sterilise spacecraft and characterise the parameters that limit life on Earth. We know a vast amount about the stress tolerances of some microorganisms. However we are currently able to cultivate less than one percent of microbes that live on Earth and so know remarkably little about whether they might be able to cope with Martian conditions. **S**

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All prices correct at time of press. Subject to change. Errors and omissions excepted.

The Southern Hemisphere in October



With Glenn Dawes

WHEN TO USE THIS CHART

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

OCTOBER HIGHLIGHTS

On the 8th there is a total lunar eclipse visible across Australia, although from Perth the Moon rises already in totality. The eastern states see the partial phases commence just before the end of twilight (19:15 EST). Totality lasts from 20:25 EST to 21:25 EST with greatest eclipse at 20:55 EST. The Orionid meteor shower is active from 2 October to 7 November, with maximum around the 21st. It's best to look from late evening to dawn; the radiant is a few degrees north of Betelgeuse (Alpha (α) Orionis).

STARS AND CONSTELLATIONS

From Earth's perspective our Galaxy is edge-on with its flattened disc now close to the horizon around midnight. Its centre, near the teapot of Sagittarius, is getting low in the west. The south galactic pole is high in the sky in the faint southern constellation of Sculptor. Near this imaginary point lies another edge-on galaxy called NGC 55, some seven million lightyears away. Any residents of NGC 55 looking in our direction would see a magnificent face-on barred spiral galaxy spanning a degree – our Milky Way.

THE PLANETS

Mercury is visible briefly in the twilight sky but lost to the Sun's glare by mid month. No doubt the highlight of the evening is Saturn, low in the western sky just after dusk. Mars, with its 'rival' star Antares (Alpha (α) Scorpii), is above

this ringed world setting around 23:00 EST. Once the Red Planet departs only Neptune and Uranus remain until Jupiter's arrival. This king of the planets can't be missed, appearing as a beacon appearing above the eastern horizon around 03:00 EST.

DEEP-SKY OBJECTS

In the northern evening sky is the small, faint constellation of Delphinus, recognised best by four 4th-magnitude stars arranged in a diamond shape called Job's Coffin. The most easterly member is Gamma (γ) Delphini (RA 20h 46.6m, dec. $+16^\circ 07'$), a brilliant double star with mag. +4.3 and +5.1 components – orange and yellow – a comfortable 9 arcseconds apart.



Moving 11° east-southeast will take you into Pegasus and to globular cluster M15 (RA 21h 30.0m, dec. $+12^\circ 10'$; pictured). It's visible in binoculars as a hazy looking star. This is a true gem, being one of the brighter and most compact globulars, shining at mag. +6.2 and with a 4 arcminute core that quickly drops into a diffuse halo. A 6-inch scope resolves faint stars in curving lines across its disc.

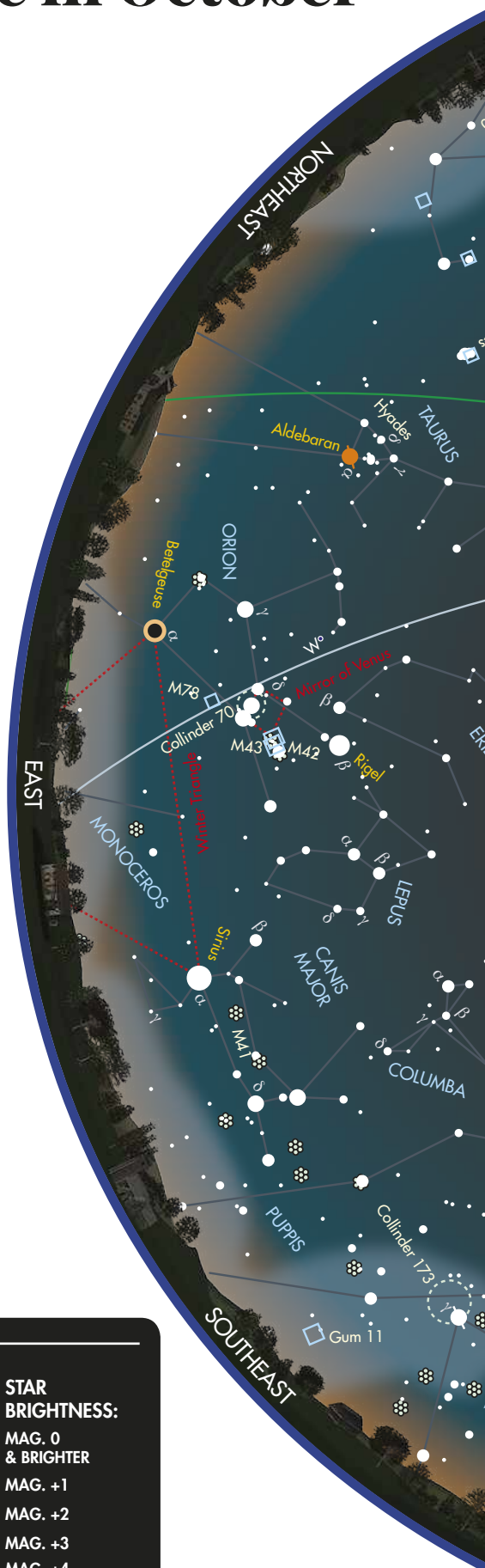
CHART KEY

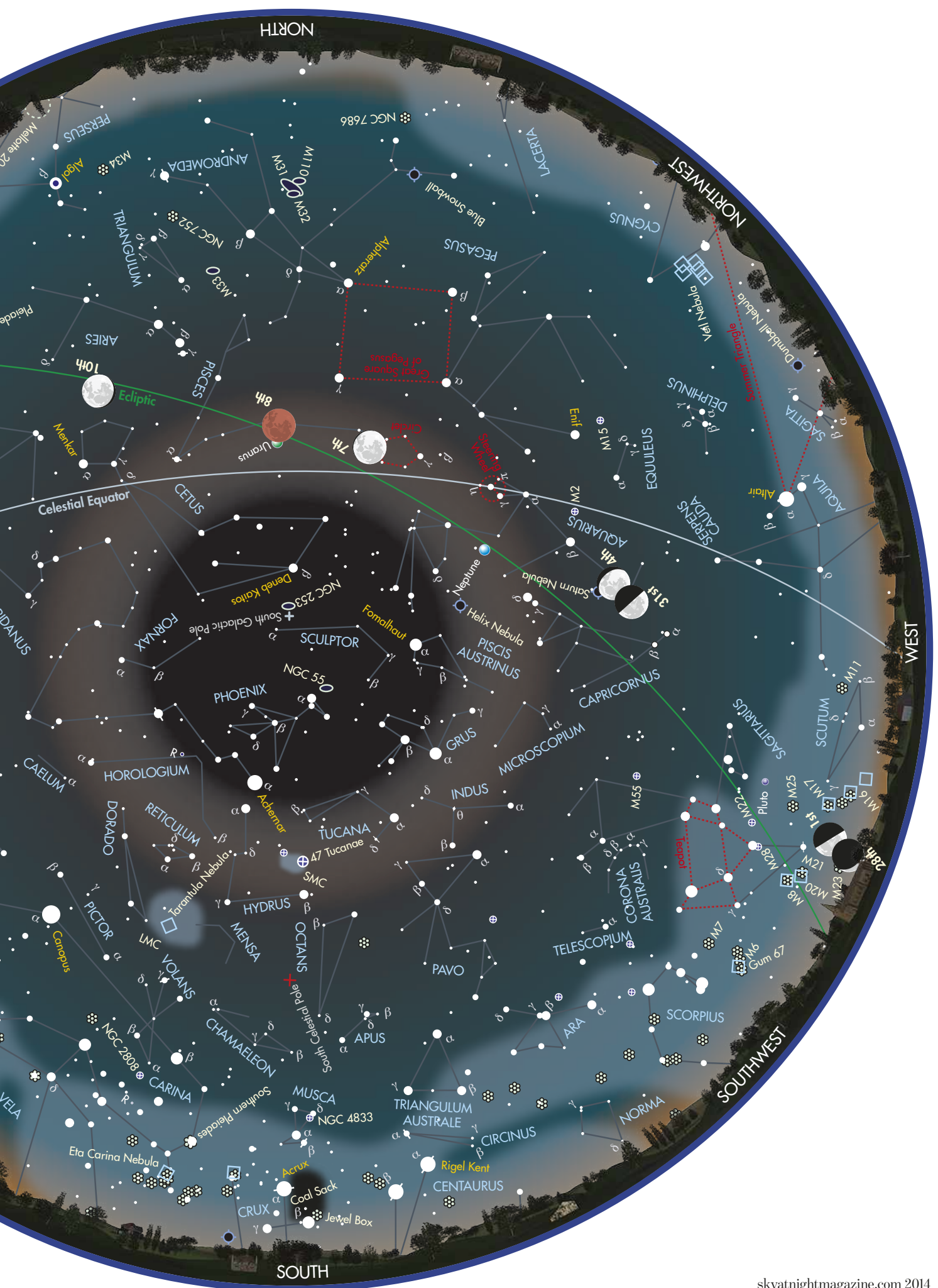
GALAXY
 OPEN CLUSTER
 GLOBULAR CLUSTER
 PLANETARY NEBULA

DIFFUSE NEBULOSITY
 DOUBLE STAR
 VARIABLE STAR
 COMET TRACK

ASTEROID TRACK
 METEOR RADIANT
 QUASAR
 PLANET

STAR BRIGHTNESS:
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 MAG. +1
 MAG. +2
 MAG. +3
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BBC Sky At Night Magazine (July '09 Issue)



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OTA SRP £199
EQ3-2 SRP £189

EXPLORER-150PL (EQ3-2)

150mm (6") f/1200
PARABOLIC NEWTONIAN REFLECTOR

Standard Specification

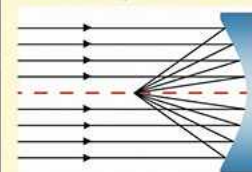
- Magnifications (with eyepieces supplied) x48, x96, x120, x240
- Highest Practical Power (Potential) x300
- Diameter of Primary Mirror 150mm
- Telescope Focal Length 1200mm (f/8)
- Eyepieces Supplied 10mm & 25mm
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