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Sir Patrick Moore writes for Astronomy Now!

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Rising Sun

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Astronomy NOW

Keith Cooper, Editor

I'd first like to wish all of our readers a happy and prosperous new year – what will 2011 bring us, I wonder?

Meanwhile, regular readers of *Astronomy Now* may have already noticed my interest in astrobiology and SETI. So when NASA announced a press conference in early December regarding a major astrobiology finding, I was excited. So too were the many bloggers on the Internet, and the rumour-mill went into full swing. Some of the bloggers with more nous about them suspected (correctly) that it was something to do with arsenic-loving life, based on the work of Felisa Wolfe–Simon, a NASA-funded astrobiologist. Others though proclaimed that NASA had discovered life on Titan, which began to raise expectations high, so that when the real discovery was revealed, some people felt unduly let down, ignored the discovery altogether, or felt it some cynical ploy for scientists to grab more funding.

This depressed me a great deal.

Arsenic-based life is an exciting breakthrough. Perhaps not as big as really finding life on Titan (NASA's Cassini spacecraft is not equipped to do this, it would take a future mission to accomplish such a feat) or as big as finding a shadow biosphere (a second origin of life that developed independently to our own tree of life) but it is important. Many of you may have heard talk of the possibility for silicon-based life on alien worlds; well, arsenic-based life is the same analogy. It is a different kind of life, working differently to any kind of life we have ever encountered on Earth before. It raises all kinds of possibilities of what alien life, if it exists, could be like.

So I was disappointed in the public's reaction because if this is the public's and the mainstream press' attitude to science, then why are we bothering to get up in arms about budget cuts to science, or encourage scientific outreach? What is the point if nobody cares? I do like to think however that people do care, and I hope I am right in that, and if you agree or disagree, write in and tell me!

As for how rumours start on the Internet, I think it highlights the strength of a professionally researched, written and edited magazine such as *Astronomy Now* over Internet blogs and forums. Some blogs, written by journalists or professional scientists describing their work, are great, but it is dangerous to believe everything you read on the Internet!

Finally, we're gearing up for AstroFest, with special guests such as Professor Brian Cox and Sir Patrick Moore (who writes for *Astronomy Now* this issue on page 64). Tickets are available now, so don't miss out on our annual astronomy extravaganza – see our special pullout for more details.

Our next, February issue is on sale on 20 January. Until then, clear skies!

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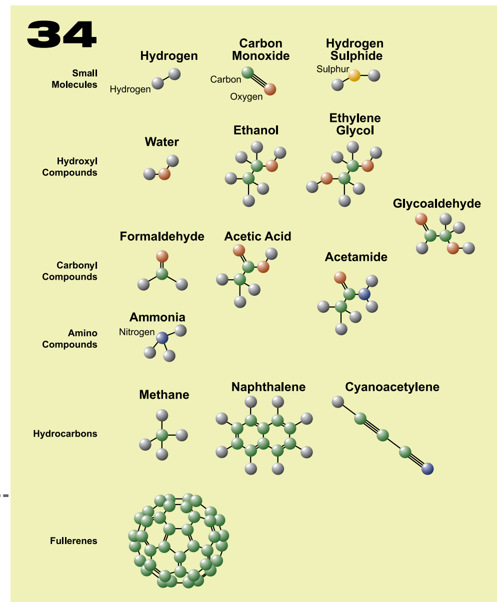

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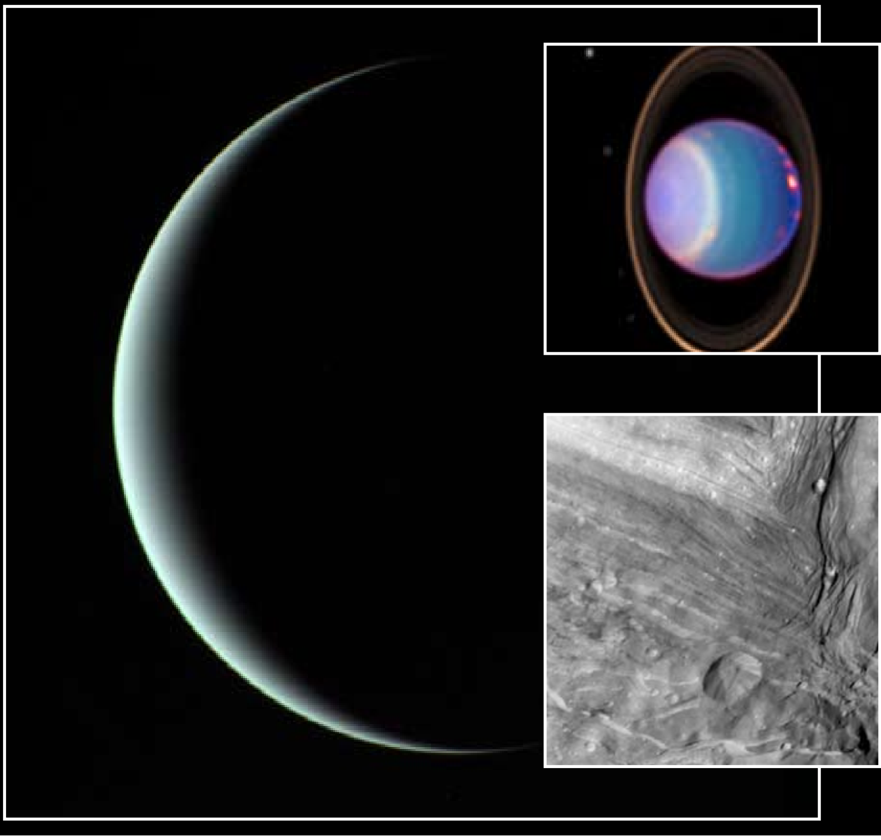

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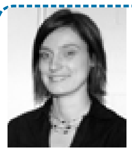

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Online this month

Things are beginning to hot up with our AstroFest preparations, which will be held in London on 4 and 5 February 2011. You can find speaker biographies and talk synopses, as well as exhibitor information and details on how to reserve your tickets, via our dedicated website at http://www.astronomynow.com/astrofest. Be the first to hear the latest AstroFest announcements via our AstroFest Facebook page too!

The end of the year and the start of a new one is a time for reflection as well as looking forward, so together with our top ten news stories of 2010 below, take a look back at the year's most stunning astro-pics from space- and ground-based telescopes alike, by enjoying our *2010 in pictures* gallery – just follow the link from our homepage. Perhaps it will inspire you to tackle that imaging project you've been meaning to do – now equipped with a Starlight Xpress HX516 colour CCD, one of my new year's resolutions is to really get stuck in to astrophotography!

What have you been reading?

As 2010 draws to a close, we count down the top ten news stories of the year:

10. Jupiter's close approach (20 September)
9. Goldilocks exoworld discovered (30 September)
8. Astronomers discover new solar system (24 August)
7. Giant star breaks all records (21 July)
6. Oceans of diamond possible on Uranus and Neptune (21 Jan)
5. Something strange is happening on Titan (10 June)
4. Mars' water went underground (29 October)
3. Rare black hole munches on white dwarf (4 January)
2. Solar blast heads for Earth (3 August)
1. Two asteroids approach Earth (7 September)

If you missed these stories you can catch up by browsing our month-by-month News Archive at http://www.astronomynow.com/NewsArchiveHomepage.html. *(Top ten based on figures as of 3 December).*

Get more online!

- Discover the latest astronomy news
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Submissions to Astronomy Now are welcomed. Please send for our writer's guide first (enclosing a stamped SAE) to Astronomy Now, PO Box 175, Tonbridge, Kent TN10 4ZY. Return of material cannot be guaranteed unless a stamped self-addressed envelope is enclosed.

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News update

'Alien' biochemistry • Galaxy collision created Magellanic Clouds • **Planet from another galaxy** Stellar explosions go unnoticed • **A steamy super-earth?** • An abundance of red dwars • **Milky Way blows giant bubbles** • Bars kill off spiral galaxies **Rhea's oxygen-rich atmosphere** • Obituaries to Brian Marsden and Allan Sandage.

'Alien' biochemistry discovered on Earth

All life on Earth needs the element phosphorus, or so we thought, but the discovery of a microbe that can grow using arsenic (As) instead of phosphorus (P) changes biology forever, and provides astrobiologists with their first glimpse of what an 'alien' biochemistry might be like. The bug, GFAJ-1, is a member of a common enough group of bacteria, but it's an extremophile, living in the hostile, highly salted, arsenic-laced, Mono Lake in California. Amazingly, bacteria that breathe arsenate (AsO_4^{3-}) are already known (they use arsenate instead of oxygen!) but GFAJ-1, in building key components of itself using arsenic, is in an altogether different league.

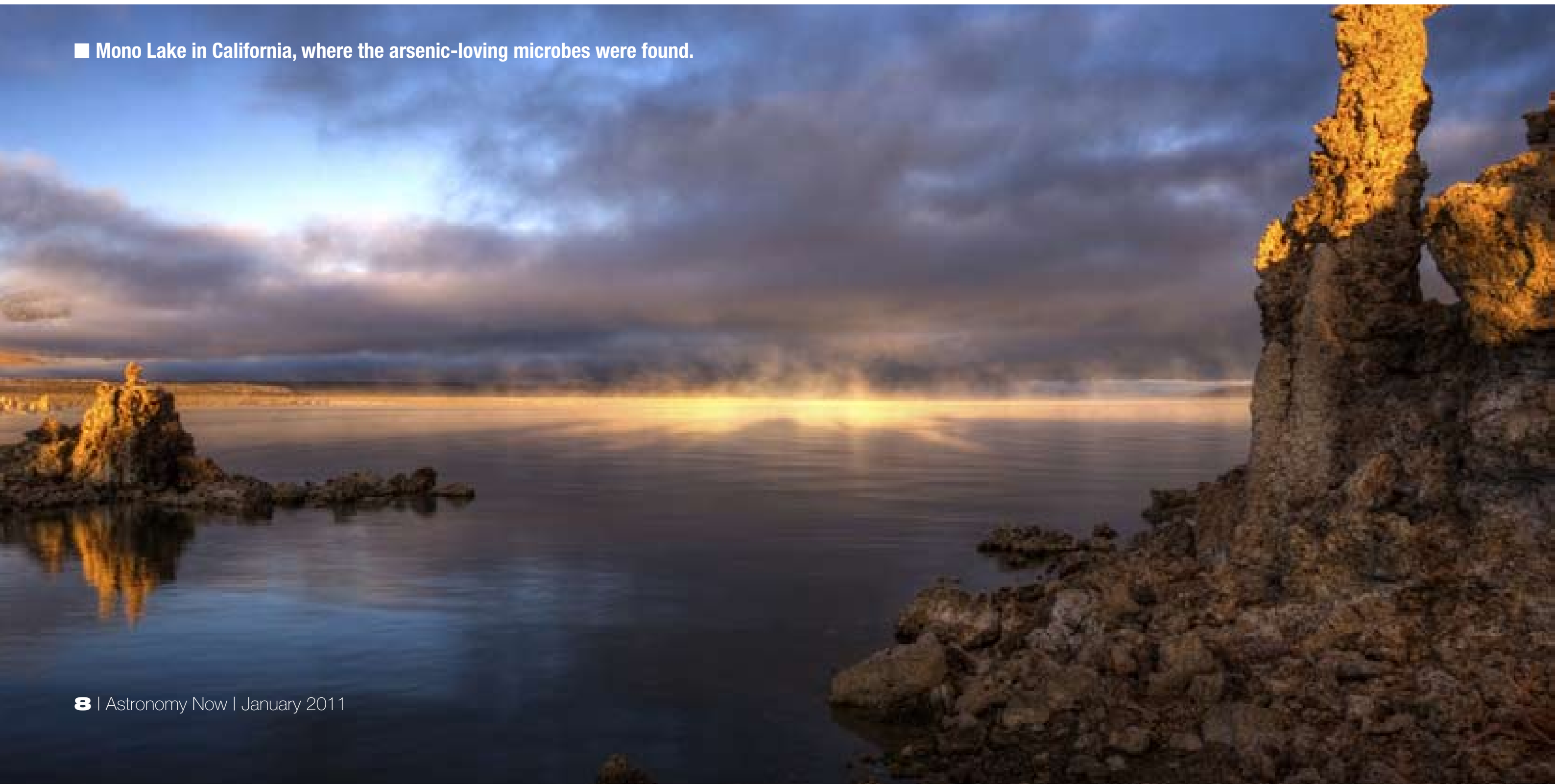
Felisa Wolfe-Simon of the NASA Astrobiology Institute and eleven colleagues from other US institutions, grew GFAJ-1 in increasingly arsenate-rich media, reducing the concentrations of phosphorus until eventually they were sure the organism could not be growing because of the phosphorus. Under these +As/-P conditions GFAJ-1 cell numbers increased 20-fold in six days. Organisms deprived of both arsenic and phosphorus (-As/-P) completely failed to grow, showing that arsenic was genuinely responsible for the growth. Next the researchers used an armoury of sophisticated biochemical techniques to find out where in the GFAJ-1 cells the arsenic was going.

It is impossible to overemphasise the critical role phosphorus plays in living cells. As phosphate (PO_4^{3-}) it helps make the backbones of DNA and RNA, the molecules that encode genetic information; it is part of ATP (adenosine triphosphate), the key energy-storing molecule that drives countless chemical processes in cells; it is present in some amino acids, the building blocks of proteins, in fats, and in the small molecules our cells use for energy (e.g. glucose phosphates). Astonishingly, GFAJ-1, substitutes arsenate for phosphate in all these places.

It can do this because arsenic, being in the same group in the periodic table, is chemically very closely related to phosphorus. Arsenic is poisonous for most life because it gets incorporated into phosphorus biochemistry, but the arsenate-containing molecules are unstable, being rapidly broken down by water. Although As-based DNA was postulated in 2008, a serious problem with the idea is that it would not last very long. However, GFAJ-1 seems to be able to stabilise As-based molecules. The organisms look different if fed on arsenic rather than phosphorus; the +As/-P bugs contained vacuoles loaded with a molecule (poly-b-hydroxybutyrate) that is thought to lower the activity of water and hence inhibit the degradation of As-containing molecules.

Let's be clear what this work shows. It does not re-define life. Moreover, GFAJ-1 has not abandoned conventional biochemistry; it actually prefers to grow on phosphorus. It is not evidence that life originated twice on Earth, although it lends some credence to the suggestion that life on Earth may originally have used arsenic rather than phosphorus, because arsenic would have been more readily accessible than phosphorus in the oceans, and hydrothermal vents release arsenic. But GFAJ-1 is proof of principle. If it's possible for a terrestrial organism to break biochemical conventions, then surely it must be so for life on other worlds.

Alan Longstaff



■ Mono Lake in California, where the arsenic-loving microbes were found.

Did the Magellanic Clouds come from the birth of M31?

An astounding new theory has proposed that the Magellanic Clouds were born out of a collision between two large galaxies that formed the Andromeda Galaxy, M31, six to nine billion years ago.

The origin of the Large and Small Magellanic Clouds (see *The unique Magellanic Clouds* in the December 2010 issue) is currently a mystery, with debate raging over whether they are true satellites of the Milky Way or just 'passing through'. However, new computer simulations by a team led by Francois Hammer of Paris Observatory depict how the Magellanic Clouds could have congealed from tidal tails emanating from a collision between two galaxies that formed the Andromeda Galaxy.

"The Andromeda Galaxy shows a lot of exceptional properties that have been discovered in the last decade," says Hammer, explaining why it was suspected that M31's origin may be different to our own Galaxy's. "There is the giant stream of old stars falling back onto the galaxy, many smaller streams, and a gigantic thick disc surrounding the thin disc [in the spiral arms]. Here we explain all these properties by a single event, a major merger."

The merger is suspected to have involved a galaxy slightly larger than our own Milky Way, and one three times smaller. Gas rich galaxies, when they merge violently, tend to form a spinning spiral galaxy rather than an elliptical galaxy. Based on estimates of the ages of stars in Andromeda that were born out of the interactions between the two progenitor galaxies, the first close encounter was nine billion years ago, and the final coalescence just under six billion years ago.

Astronomers do find gas rich dwarf galaxies like the Magellanic Clouds in tidal tails of mergers between other galaxies. "Because tidal tails of gas-rich mergers are very gas-rich in themselves, the associated tidal dwarfs should also be gas-rich," says Hammer. "Unfortunately, this is difficult to see in the local Universe because most massive galaxies are gas poor, and at larger distance we do not yet have enough resolving and collecting power to observe such faint galaxies in tidal tails."

■ Did the Andromeda Galaxy bequeath the Magellanic Clouds after it was born in a violent merger? Image: Nik Szymanek.

The planet from another galaxy

A planet orbiting a star that originally hailed from another galaxy has been discovered by astronomers at the Max Planck Institute of Technology. The finding tells us not only about the formation of planets in the distant past, but also possibly about the future of our own Solar System.

The planet, discovered by the radial velocity method using the 2.2-metre Max Planck telescope at the European Southern Observatory in Chile, has a mass one and a quarter times that of Jupiter, and orbits an ancient, dying star called HIP 13044. This star is part of the Helmi Stream of stars that originated from a dwarf galaxy that was cannibalised by the Milky Way six to nine billion years ago – hence the star and planet come from another galaxy.

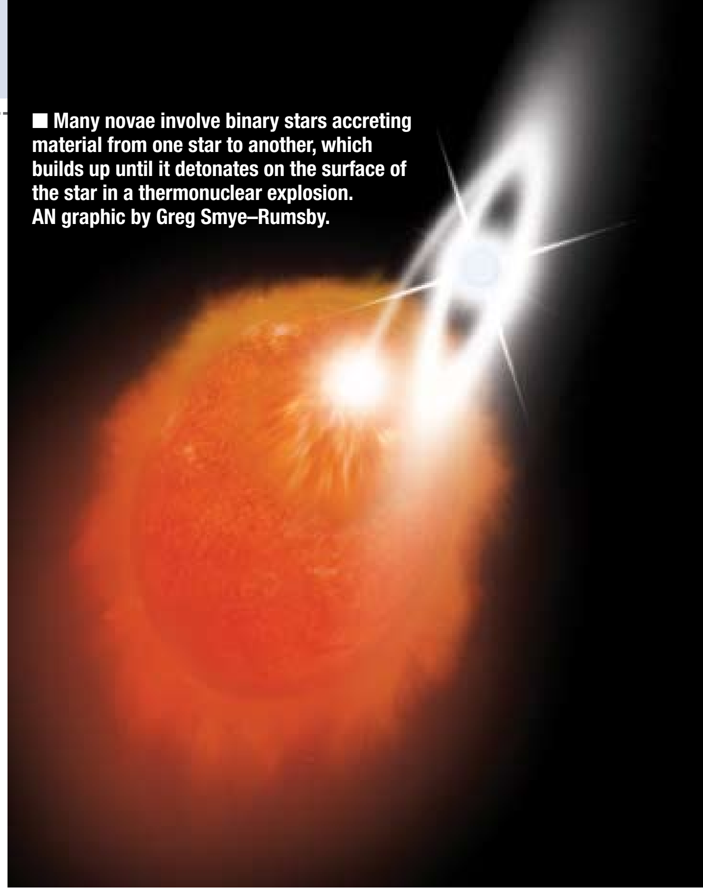
What is especially interesting is that the star is lacking in heavy elements (or metals, in astronomical parlance) one would expect are needed to make planets. Dwarf galaxies are typically representative of conditions in the early Universe, when heavy elements did not exist in large quantities. Could the Universe have started forming planets sooner than we realised?

"For example," says Rainer Klement, who was part of the team that found the planet, "could there have already been planets around the first, second or third generation of stars that formed after the big bang? I think the threshold in metallicity (and with it, age) for planets to form will be set by future observations."

The planet orbits as close as 8.2 million kilometres to the star, but Klement's team suspect it used to orbit further out, before its star turned into a red giant, causing the planet's orbit to move inwards. The star has now contracted again as the nuclear fusion of helium has replaced the nuclear fusion of hydrogen within its core. Nevertheless, the star will expand again in the future, possibly engulfing the planet. It hints at what fate may befall Jupiter in five billion years, when our own Sun dies and expands into a red giant.

■ An artist's impression of the alien star HIP 13044 and its planet. Image: ESO/L Calcada.

Stellar explosions go unnoticed



■ Many novae involve binary stars accreting material from one star to another, which builds up until it detonates on the surface of the star in a thermonuclear explosion. AN graphic by Greg Smye–Rumsby.

Many novae are being missed by both amateur astronomers and professional all-sky surveys, says new research by PhD student Rebekah Hounsell of Liverpool John Moores University.

Novae are stars that experience unpredictable outbursts, often as part of a binary system or in the run-up to a supernova. It is estimated that there are around 35 of these stellar flare-ups a year, but according to Hounsell's analysis of data from the Solar Mass Ejection Imager (SMEI) on the Coriolis satellite, many of these are not spotted. Some could even be bright enough to be seen with the naked eye, if we knew when and where to look.

"The brightest novae and in turn the most easily detected are also usually the fastest," says Hounsell. "This means that you really need to be observing the right patch of sky at the right time otherwise you will miss them."

Why is a solar imager spotting novae? SMEI scans the entire sky every 102 minutes, searching for clouds of plasma from coronal mass ejections on the Sun, and it was realised that as it does so it will pick up a lot of transient objects. Professor Allen Shafter at the San Diego State University realised the potential of SMEI to discover novae, and brought it to the attention of Hounsell and Liverpool John Moores professor Michael Bode. "We soon recognised that the SMEI dataset could contain a treasure trove of known and unknown novae, says Hounsell." Her results, which have been published in *The Astrophysical Journal*, also reveal a little more about how novae work, showing evidence for a 'pre-maximum halt' where a nova's brilliance seems to falter, which theoretical models are still struggling to explain,

Hounsell reckons that around five novae per year should be brighter than eighth magnitude, with several reaching naked eye magnitudes. So, novae-watchers, keep a close eye on the skies – there's plenty out there to be discovered!

A steamy super-earth?

For the first time the atmosphere of an exoplanet just a few times more massive than Earth has been probed, revealing a planet that is either very cloudy or a steam-covered waterworld.

Astronomers have measured the atmospheres of exoplanets before, by watching them transit in front of their star, and then studying the absorption lines in the spectrum as the starlight filters through the atmosphere. However, such measurements have previously only been achieved for the larger exoplanets. Now the atmosphere of a rocky super-earth, called GJ 1214b that has a mass of six and a half Earths and is 2.7 times as big, has been analysed in near-infrared wavelengths by astronomers using the Very Large Telescope in Chile.

The observations, conducted by a team led by Jacob Bean of the Harvard–Smithsonian Center for Astrophysics, found a near featureless spectrum. This either means that a thick hydrogen atmosphere is being veiled by a blanket of cloud or haze (as on Titan or Venus), or an ice-world where the ice has sublimated because of the heat (the planet reaches 1,000 degrees Celsius because of the proximity to its star) to form an atmosphere of steam.

"We need to make similar observations at longer wavelengths of infrared light," Bean told *Astronomy Now* when asked about how to distinguish between the two possibilities. If these observations found clouds, it would either suggest a world that is very much like a mini Neptune or Uranus, that formed further out and migrated in, or a rocky planet with giant volcanoes that have belched out sulphuric clouds. The steam world promises to be even more fascinating. "A planet with a steam atmosphere would not even really have a surface," says Bean. "As you move down through the atmosphere the hot water vapour would transition directly into an exotic form of matter known as a 'super critical fluid'."

Bean's team plan further observations, as do other groups of astronomers, making it probable that whatever mysteries this world is hiding, they won't remain secret for long.

■ An artist's impression of GJ 1214b. Image: David A Aguilar (CfA).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Dr Brian Marsden, 1937–2010

Dr Brian Marsden, Director Emeritus of the Minor Planet Center and Senior Astronomer at the Smithsonian Astrophysical Observatory, passed away on 18 November 2010 at the age of 73.

Born in Cambridge on 5 August 1937, Dr Marsden was a minor planet expert, specialising in collecting asteroid and comet data to calculate their orbits, as well as astrometry and celestial mechanics. As part of his minor planet work, he frequently came into contact with amateur astronomers who had discovered new comets and asteroids, as *Astronomy Now*'s Mark Armstrong fondly recalls:

"Brian Marsden's passing is a very sad day for the whole of the astronomical community, professional and amateur. I first heard about Brian back in 1995 from Guy Hurst, a great friend and colleague of Brian, as soon as I started to become interested in trying to discover the first supernova from the UK. Brian was the Director of the Central Bureau for Astronomical Telegrams in the USA, the official clearing-house for all discoveries. Long before I came on the scene Brian was a legend amongst the 'serious' British amateur astronomers – the *Astronomer Group* run by Guy Hurst had particularly close links with Brian, with the likes of Denis Buczynski, Nick James and Martin Mobberley benefiting from his advice and expertise in the field of discoveries, comets and minor planets.

"Guy used to feed me stories about Brian, with one of his favourites being that he regarded one discovery, whether it be a supernova, nova or comet, to be a possible fluke – you needed a second one to convince him you were 'for real'. Well that was a challenge! In October 1996 I made the first supernova discovery from the UK and was invited to give a talk at the November BAA meeting. This was a nerve-racking thing for me, being my first ever talk. Then I was informed that Brian would be attending! A couple of days before the meeting I missed seeing a pretty faint suspect on one of my images that was later confirmed as a supernova. This was very frustrating for me but I thought I'd better have a slide or two for the meeting. As I was speaking about it I could see Brian sitting in the front row grinning from ear-to-ear. I knew what he was thinking – fluke!

"I met Brian at AstroFest and other BAA and Eastbourne society meetings and he was always so supportive of and interested in my work – I know Tom Boles and Ron Arbour, fellow discoverers, felt the same way too. He played a very important part in the UK supernova discovery story and helped amateurs in so many other ways. I feel very honoured to have known him and without his help and support my supernova patrol wouldn't have been as successful or half the fun. He was a giant of a man and will be sorely missed."

■ The late Dr Brian Marsden. Image: Harold Dorwin.

■ An artist's impression of a planet orbiting a red dwarf. There could be trillions of these planets in galaxies. AN illustration by Greg Smye–Rumsby.

Red dwarf population rockets skywards

An abundance of red dwarf stars found in massive elliptical galaxies may mean there are three times as many stars in the Universe as previously thought.

Red dwarfs are faint, low mass stars a fraction of the size of the Sun. They were already known to be the most common stars in the Universe, but because of their faintness they are difficult to see beyond our Local Group of galaxies. Now the Keck Telescope on Mauna Kea in Hawaii has observed red dwarfs in distant elliptical galaxies – between 50 and 300 million light years away – and found there are many more than expected, with some elliptical galaxies containing 20 times more red dwarfs than the Milky Way.

The evolution of elliptical galaxies in clusters is heavily influenced by mergers with other galaxies, but Pieter van Dokkum of Yale University, who led the research, doesn't believe that was necessarily a factor here. "We measured the abundance of red dwarf stars in the central regions of the galaxies," he tells *Astronomy Now*. "It is thought that mergers mostly add stars to the outer parts of galaxies, building up their outer envelopes around a core that was formed very early, so mergers probably did not influence the results very much." He speculates that the high densities within the cores of elliptical galaxies may have been efficient in producing large numbers of small stars.

If elliptical galaxies contain all this extra mass in red dwarfs, does this spell the end for dark matter as the missing mass? Far from it, says van Dokkum – the results actually bring the amount of dark matter more in line with what theoretical models depict them to be. Another exciting angle of research is that having many more red dwarfs will lead to many more planetary systems around them. Red dwarfs are long lived, allowing plenty of time for life to flourish, and there could be trillions of planets orbiting them.

Professor Allan Sandage, 1926–2010

Allan Sandage, perhaps one of the greatest astronomers of the twentieth century, passed away on 13 November at the age of 84. Sandage worked with Edwin Hubble at Mount Wilson Observatory, and was subsequently influential in fully exploring the scale of the Universe and in determining the Hubble Constant, which describes the expansion of the Universe.

▼ Professor Allan Sandage. Image: Carnegie Institute of Washington.

After Hubble died in 1953, Sandage took on the torch of pushing the boundaries of the known Universe. Hubble's measurements of the distance to galaxies had been limited by the telescopic technology of the time. With the 5.1-metre Hale Telescope Sandage was able to refine these distances using standard candles such as Cepheid variables, RR Lyrae stars and supermassive stars. During one memorable presentation in 1958, when he received the American Astronomical Society's Warner Prize for outstanding achievement by a young astronomer, he announced that he had reworked Hubble's original calculations, showing that M31 was two million light years away, not 700,000, and that the Virgo Cluster was 50 million light years away, not seven.

Literally overnight Sandage had expanded the Universe to unimaginable scales. It allowed him to calculate Hubble's Constant to ever-increasing accuracy – his value of 75 kilometres per second per megaparsec is close to today's best measurement of 71 kilometres per second per megaparsec made by the Hubble Space Telescope. From this he was able to estimate the age of the Universe to be 15 billion years – not far off the true age of 13.7 billion years, derived by the WMAP probe.

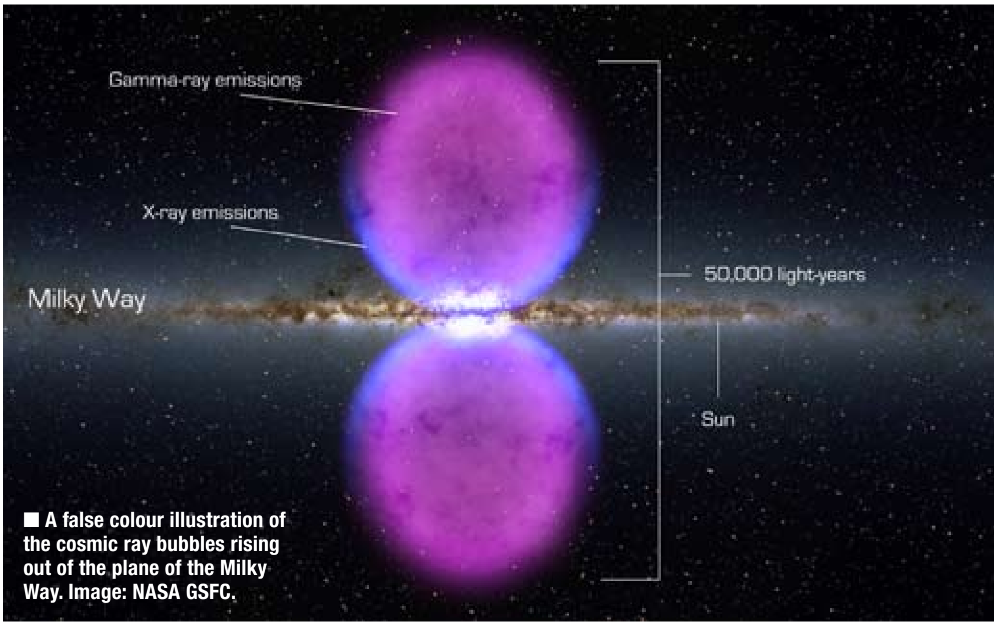
A true giant of astronomy, Sandage published more than 500 scientific papers throughout his career, and continued working at the Carnegie Observatories in California until the end – his final paper, on RR Lyrae stars, was published in *The Astrophysical Journal* in June 2010.

Giant cosmic ray bubbles from our black hole?

Giant bubbles of cosmic rays rising 25,000 light years out of the centre of the Galaxy and spanning 11,500 light years across may be the relics of a powerful outburst as strong as 100,000 supernovae from the centre of our Galaxy.

The bubbles were detected by NASA's Fermi Gamma-ray Space Telescope, hidden behind the fog of gamma rays that fills our Galaxy. The bubbles are produced by energetic cosmic rays striking lower energy photons and causing them to emit gamma rays. But where did the cosmic rays come from originally to produce these giant bubbles centred on the core of our Galaxy, and rising out to galactic north and south?

There are two possibilities, says Douglas Finkbeiner, an Associate Professor at the Harvard–Smithsonian Center for Astrophysics, who discovered the bubbles in Fermi data along with Harvard graduate students Meng Su and Tracy Slayter. One is a giant starburst – an explosion of star formation that formed the giant clusters of stars that lurk in the galactic centre. As the biggest, hottest stars formed in the starburst explode as supernovae, they can produce a torrent of radiation.



■ A false colour illustration of the cosmic ray bubbles rising out of the plane of the Milky Way. Image: NASA GSFC.

The second possibility is violent activity around the supermassive black hole at the centre of our Galaxy. Occasionally material – interstellar gas and dust, or any stars unfortunate enough to get in the way – accretes onto the 4.3 million solar mass black hole. While most plummets into the black hole, around ten percent is flung out as relativistic jets of charged particles by magnetic fields around the black hole. Our Galaxy does not have any jets to speak of today, but millions of years ago it may have, had activity in the centre been much more extreme than it currently is. "All we need is an accretion event onto the black hole, and we can get a lot of high energy particles," Finkbeiner told *Astronomy Now*. "We still have a lot of work to do before we figure out exactly what is going on, but it is fun to have a mystery!"

Bars may be killing off spiral galaxies

New research based on data collected by the interactive galaxy classification website Galaxy Zoo has discovered that the bars found in some spiral galaxies may be responsible for their eventual death.

The study, led by Dr Karen Masters of the Institute of Cosmology and Gravitation at the University of Portsmouth, worked on a large sample of galaxies to determine the fraction that displayed bar structures and establish the significance of this on galactic evolution.

Galaxies take several different forms, including spiral, elliptical and irregular. One feature present in approximately half of all spiral galaxies is that of a bar, a linear structure of stars cutting through the galactic centre. This is thought to help mass transfer throughout the galactic disc and possibly ignite star formation in the centre. It may also feed material to the central black hole, something found in almost all galaxies.

Masters found that red spirals are twice as likely to host bars as blue spirals. This is significant as the colour of the galaxy indicates the amount of star-formation occurring. A blue colour implies that the galaxy is full of hot young stars and is also forming new stars, whereas red galaxies are composed of mainly older, cooler stars.

"It's not yet clear whether the bars are some side effect of an external process that turns spiral galaxies red, or if they alone can cause this transformation," says Masters. The presence of a bar in the Milky Way indicates that it may become a passive red spiral galaxy. It is possible that satellite galaxies may also play a role in turning off star-formation.

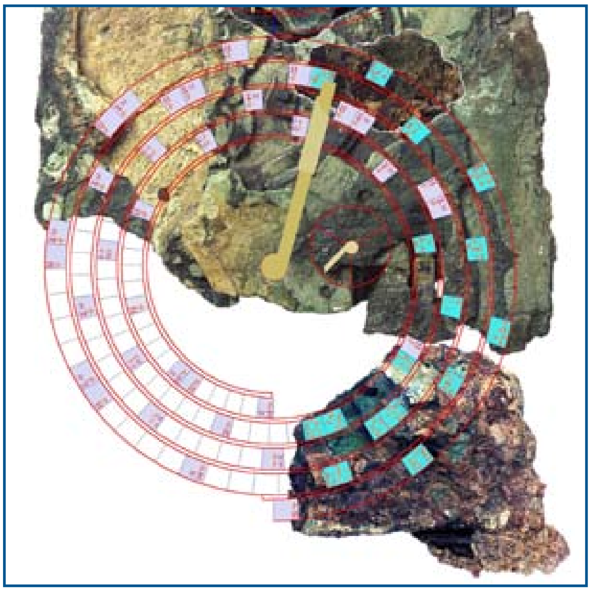
Galaxy Zoo is an interactive project founded in 2007 that invites the public to classify galaxies from home at www.galaxyzoo.org. "Pattern recognition is something that humans are just very good at – and it turns out to be hard to program a computer to do it," says Masters. "With the huge numbers of galaxies we now have images of, the best way to classify them is to involve members of the public – astronomers just can't do it alone anymore."

Nicky Guttridge

▼ Barred spiral galaxies like NGC 1300, pictured here, may be killing off their own star formation. Image: NASAE/ESA/Hubble Heritage Team (STScI/AURA).

Talking point by Alan Longstaff

The Antikythera mechanism: a cosmological model or inspiration?



▲ A representation of the Saros cycle, used to predict lunar and solar eclipses, overlaid on a fragment of the mechanism. Image: Antikythera Mechanism Research Project.

In 1900 divers discovered a Roman shipwreck off the coast of the tiny Greek island Antikythera. It contained fragmentary remains of an enigmatic bronze, geared, hand-driven device just 31 centimetres high: the Antikythera mechanism. Greek inscriptions and modern reconstructions indicate the device was a calendar that showed the positions of the Moon and Sun in the sky, lunar phases, and predicted lunar and solar eclipses.

Its front had two concentric dials. The outer one represented the Egyptian calendar of twelve 30-day months plus five intercalary days. The inner dial depicted the Zodiac; 360 degrees divided into 12 signs. A Sun pointer and a lunar pointer showed the passage of these bodies through time and the heavens against the calendar and the Zodiac. The back of the instrument had two dials, one vertically above the other. The top one instantiated the metonic cycle of 235 synodic (phases) months, which brings the same phase of the Moon back on the same date 19 years later. The bottom dial represented the Saros cycle that returns a nearly identical type of solar eclipse every 223 synodic months.

The Antikythera mechanism was built between 150 and 100 BCE, at about the same time (148–126 BCE) that Hipparchus was developing his eccentric theory to explain the irregularities in the motion of the Moon, which we now know is caused by its elliptical orbit. A reconstruction of the Antikythera mechanism, by Mike Edmunds of Cardiff University and colleagues in 2006, uses a mechanism by which one gear drives another around an off-centre axis in what seems to be an analogue model of this theory. It is equivalent in effect to the epicycles required by the Ptolemaic geocentric model of the Solar System, although the construction details could reflect Babylonian rather than later Greek algorithms for lunar motion.

Inscriptions imply that mechanisms representing the five planets known at the time were also present, but these have now vanished, except perhaps for one gear wheel (designated r1) with 63 teeth, which has no known role. Most authorities have reckoned that the Antikythera mechanism showed the positions of the planets in the Zodiac using gears that emulate epicycles.

Ancient Babylonian?

So far, so good. But a new analysis by James Evans, Christiàn Carman, and Alan Thorndike of the University of Puget Sound in the United States has led to an astonishing reappraisal of the Antikythera mechanism. Studies of an 88 degree arc of the Zodiac dial that is in a readable condition show that the degree markings are closer together than they need to be if they had been uniformly distributed around the dial. Hence part of the missing dial must have had wider spacing to compensate. The researchers suggest that the Antikythera engineer represented the varying motion of the Sun during the year (the solar anomaly) not by epicyclic gearing, but by differential spacing of the Zodiac divisions around the Zodiac and constant speed sun pointer. Intriguingly, this seems to emulate a Babylonian system for representing the Sun's motion, rather than the Greek model.

Although differential spacing meant that solar longitude was accurately represented, a consequence is that any gearing to show the correct positions of the planets in the Zodiac would need to be ludicrously complicated. So the builder of the Antikythera mechanism must have had something else in mind. Evans and colleagues reckon that the planetary dials represented the synodic period (the time for a planet to return to the same position in the sky relative to the Sun, as seen from Earth). Letters at key points around planetary dials would mark key events; greatest elongations, stationary points, etc., which may have been described in more detail in inscriptions. Unfortunately key parts of the inscriptions are missing, making it impossible to verify this idea directly. However detailed calculations show how the synodic periods of all the planets can be obtained by various gearings from a 224-tooth drive wheel that is part of the solar mechanism. In the case of Venus, based on Babylonian texts describing 720 synodic periods of 584 days as equal to 1,151 years, the calculations show that the necessary gearing would have required the mysterious r1 63-tooth wheel. This is further evidence that the cosmology of the Antikythera mechanism might have been Babylonian rather than Greek.

It seems that the Antikythera designer did not use epicyclic gearing to simulate the motion of all heavenly bodies, but he did come up with a gearing system, perhaps based on Babylonian theories, equivalent to epicycles for the Moon. Could it be that rather than a pre-existing cosmology being modelled by the Antikythera mechanism, it was the epicyclic modelling of the Moon, a mechanical solution for lunar motion, which inspired Greek cosmology?

Dr Alan Longstaff is a regular contributor to Astronomy Now *and is a freelance tutor at the Royal Observatory, Greenwich.*

▲ The main remnant of the Antikythera mechanism, which is kept in the National Archaeological Museum in Athens. Image: Antikythera Mechanism Research Project.

Saturn's moon's atmosphere of oxygen

A **thin** atmosphere of oxygen and carbon dioxide has been found on Saturn's second largest moon, 1,500-kilometre wide Rhea.

Discovered by the Cassini spacecraft's plasma spectrometer and ion and neutral mass spectrometer, the oxygen is being liberated when high-energy particles trapped in Saturn's magnetic field bombard water-ice on the surface of the moon. Cassini measured 50 billion oxygen molecules per cubic metre, which is five trillion times less dense than the oxygen content in Earth's atmosphere. The carbon dioxide's origin is less uncertain – it could be from dry ice or carbon-rich materials trapped in the surface, or irradiation processes on organic molecules on the surface.

"The new results suggest that active, complex chemistry involving oxygen may be quite common throughout the Solar System, and even the Universe," says Dr Ben Teolis, a Cassini scientist at the South-west Research Institute in San Antonio.

Jargon buster

Astronomical unit
The average distance between Earth and the Sun, which is 149.6 million kilometres.

Black hole
An object so dense and massive that not even light can escape its gravitational pull. All large galaxies contain a central supermassive black hole millions of times more massive than the Sun.

Cosmic ray
A high-energy particle moving at the speed of light that has originated from beyond the Solar System.

Elliptical galaxy
A large, amorphous galaxy, spherical or egg-shaped, with little to no star formation. They are often found in the centres of galaxy clusters where they have formed by two or more galaxies merging.

Major merger
A collision between two galaxies of similar size and mass. A minor merger involves one large galaxy and a dwarf galaxy.

Nova
An outburst on the surface of a star, usually caused by material accreting onto it and exploding. A nova does not destroy a star, but does cause it to become much brighter for a short time. Stars can experience novae repeatedly.

Red dwarf
A type of dim, cool star, that is smaller than the Sun and far more common than any other type of star in the Universe.

MISSION STATUS

Steven Young reports from Cape Canaveral on the latest spaceflight news.

Space shuttle Discovery's final voyage will now not take place before early February as NASA struggles to understand why cracks developed in its external fuel tank during a launch attempt on 5 November. That countdown was halted that day when a vent line started leaking explosive hydrogen, but engineers also discovered a crack in the foam that insulates the fuel tank. Further examination revealed the metal beneath had cracked, causing the foam to break. Two nine-inch long cracks were found in a metal stringer that provides strength to the cylindrical part of the tank that connects the lower liquid hydrogen tank and the upper portion of the tank, which stores liquid oxygen. Another pair of cracks was found adjacent to the first. Cracks in this part of the tank's aluminium-lithium alloy are not unusual during the manufacturing process but this was the first time the defect had been found at the launch pad. Technicians X-rayed other areas of the tank and found no other signs of damage beneath the foam insulation, but much of the bullet-shaped structure cannot be reached for examination at the launch pad.

The decision to delay the shuttle's launch until February was taken when engineers failed to come up with a quick explanation of why the tank cracked. "We've hit a point where there is no obvious answer as to what occurred," shuttle programme manager John Shannon said. He ordered additional tests including a fueling of the shuttle's tank once it had been wired with instrumentation and under the scrutiny of stereo video cameras. "One good test is equal to a thousand expert opinions, right?" he said, quoting Wernher von Braun, who led NASA's rocket programme in the 1960s. NASA officials said Discovery would not fly until they determine what caused the cracks and that the tank is structurally safe.

◀ Space shuttle Discovery awaits its final voyage into space, if its fuel tank can be cleared for flight. Image: Justin Ray/ Spaceflight Now.

A military mini-shuttle returned to Earth on 3 December after a top-secret 225-day mission in low Earth Orbit. The US Air Force X-37B unmanned space plane became the first American spacecraft to make a fully automated landing on a runway and only the second in history – the first being Russia's Buran shuttle in 1988 at the end of its one and only test flight. The stubby winged craft reentered the atmosphere over the Pacific Ocean and glided to a touchdown on a runway at Vandenberg Air Force Base that was original built to receive space shuttles returning from polar orbit. It launched aboard an Atlas 5 rocket from Cape Canaveral on 22 April. The X-37B's mission was classified secret but amateur satellite observers said it worked in orbits normally used by spy satellites and changed its altitude regularly, perhaps to avoid detection. The second X-37B is scheduled for launch next spring.

■ Technicians dressed in protective suits check the X-37B space plane for toxic fuel leaks after its landing in California. Image: US Air Force.

Send your letters to: Your views, Astronomy Now, PO Box 175, Tonbridge, Kent TN10 4ZY, by fax on 01732 300148, or by e-mail to: yourviews2011@astronomynow.com. We reserve the right to edit or shorten letters.

Your views

Memories of Gagarin

On 12 April 1961 Major Yuri Gagarin made mankind's first journey into space, travelling at over 17,000 miles an hour. He went around Earth in the time it takes to play a football match. After a single orbit, he landed within the Soviet Union, not far from the launch site.

Gagarin's first job was as a foundryman and, invited by the Amalgamated Union of Foundry Workers, he arrived in London on 11 July 1961, visiting Earl's Court, the Royal Society, the Tower of London, Buckingham Palace, Highgate Cemetery, Mansion House and Admiralty House. On Wednesday 12 July he was in Manchester, despite the rain, travelling in an open top Bentley to a union office in Old Trafford, Metrovicks foundry in Trafford Park and then the town hall. He was cheered on throughout by drenched but enthusiastic crowds everywhere.

Were you amongst those crowds? Perhaps you know someone who was? I am conducting a research project to commemorate the fiftieth anniversary next year. Please share your memories - get in touch with me either at www.astrotalkuk.org, e-mail me at info@astrotalkuk.org or telephone 07970 267353.

Gurbir Singh
Via email

Living with light pollution

I would like to congratulate Bob Mizon for his excellent article on urban astronomy (*AN*, October 2010, and also see this issue, pages 22–25). At last a simple, straightforward piece of writing that shows what can be seen visually from a moderately light polluted back garden. I too, to quote Bob's words, am a 'low-tech' observer and proud to be so. My main observatory houses a home-built 16-inch f/6 Newtonian on a massive fork mount driven by a 12V car windscreen wiper motor. This is controlled by a simple VFO unit. No computers, no CCDs, no GOTO system; only a decent set of eyepieces, colour filters, a light pollution filter, a copy of *Nortons Star Atlas* and a pencil and paper are usually all I need!

My observatory is less than 30 feet from an obtrusive yellow sodium streetlight that lights the yard area of an old peoples' complex. So far my request for some sort of shield or baffle has fallen on deaf ears. Also, my neighbours have an outside light that is on most nights until around 10pm. They will switch the light off when I ask them but the next night it is back on again.

It is interesting to note what affect various forms of stray lighting have on deep sky objects. For instance, the unfiltered view of M42 in Orion can look a lovely pea green colour in the streetlights' sodium glow, but a couple of hours later as it 'approaches' my neighbours' white security light it is transformed into a colourless grey mist. Albireo is a famous double star that can look a truly beautiful sight with its golden yellow primary and electric blue companion, yet some nights shows hardly any colour and is almost unrecognisable as one of the showpieces of our northern skies.

Visual observers such as myself are more prone to the effects of poorly designed and thoughtless lighting than our more modern electronic gadget brigade, but in the end we made the choice to pursue our hobby in this way, and so to some extent we have to grit our teeth and put up with the conditions. To me half the fun in observing some elusive planetary nebula or galaxy is in actually finding it, and surely by star-hopping and manually finding such objects and not relying on GOTO systems is how we come to learn our way around the night sky!

So congratulations once more to Bob Mizon, and hopefully his article will encourage young and old alike to lift their eyes up from their computer screens and actually start to look though their telescopes – who knows, they just might find the experience enjoyable!

Trevor Smith,
Ripley, Derbyshire

Key moments in **astronomy**

Birthday for a star cluster

It may be just me, but a Messier number seems always to add to the romance of an object. Yet glamour was the last thing on Charles Messier's mind. Many of the objects he recorded were already familiar to observers. Most had in fact been discovered many times and, in the absence of a unified reference system, were likely to continue being rediscovered and misidentified as comets. The catalogue aimed to reduce such confusion and eliminate, not celebrate, these wonders of the sky.

On the night of 16/17 January 1765, Messier directed his attention towards a "cluster of stars below Sirius, near rho Canis Majoris", noting "this cluster appears nebulous in an ordinary telescope of one foot [focal length]; it is nothing more than a cluster of small stars". He observed through his 'night refractor' – in modern terms a three-inch telescope with a 44x magnification – typical of the relatively modest instruments that he preferred.

M41, as the cluster became known, has an unusually rich observational prehistory. It may even be an object described by Aristotle in the fourth century BC. According to his *Meteorologica*, some "fixed stars also have tails" like comets, and "we have ourselves observed the fact. For a star in the thigh of the Dog had a tail, though a faint one. If you looked hard at it the light was dim, but it seemed brighter if you just glanced at it". This passage is also noted as the first recorded account of the averted viewing technique.

The earliest undoubted observation of the cluster was by Giovanni Hodierna, a Catholic priest, friend of Galileo and forgotten genius of early modern astronomy. It was published in his *Orbis Cometici* (1654), as part of a catalogue of non-cometary objects prefiguring Messier's work. Unfortunately Hodierna's writings were almost completely unknown outside his immediate circle and thus had no impact. M41 was independently rediscovered by John Flamsteed on 16 February 1702, but his notorious aversion to publishing observations ensured it remained in obscurity. A third rediscovery – this time by Guillaume Le Gentil in 1749 – was of little more use to astronomy at large. Messier does not appear to have known of any of these earlier observations, which itself underlines the desperate need for a systematic catalogue of the type he created. His own rediscovery ended the cycle; the cluster was included as one of 45 'nebulous objects' described in a paper submitted to the French Académie des Sciences on 16 February 1771, although not actually published until 1774.

We can reasonably assume that M41 was blissfully unaware of this attention. An open cluster in Canis Major, it shines at magnitude +4.6 and contains around 100 stars, including several red giants. Under any name or number it remains one of the many gems of the winter sky.

Ian Seymour

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▲ Beat the town lights and do some astronomy this winter. Image: Bob Mizon.

Winter Urban astronomy

Bob Mizon selects a number of winter targets for light-polluted astronomers to show that astronomy is possible from the city

In some parts of the UK, backgarden astronomers who brave the winter's cold will perhaps have already noticed that there is a little more to see in the night sky now than there was some years ago. More than twenty local authorities in Britain are now dimming or switching off streetlights after midnight, and lights on many stretches of motorway are now regularly following suit, while large-scale relighting schemes all over the UK are seeing new, better directed types being installed.

While the BAA Campaign for Dark Skies has never called for the switching off of any necessary light, it welcomes this national trend towards more responsible, energy-efficient lighting, towards which it has worked for the last twenty-one years.

Winter nights can occasionally be clear and transparent, especially when high pressure moves in. Also, the effects of residual light pollution may be mitigated, as the air above the observer becomes less turbulent now that the ground is radiating less heat. The reduction in dust and other particles after rain can also improve visibility; so profit from clear winter nights to attempt targets in those city skies that you might have thought were not worth the effort. There are some interesting planetary encounters this winter, and some fascinating stellar objects to be found, and a little lunar astronomy to be done.

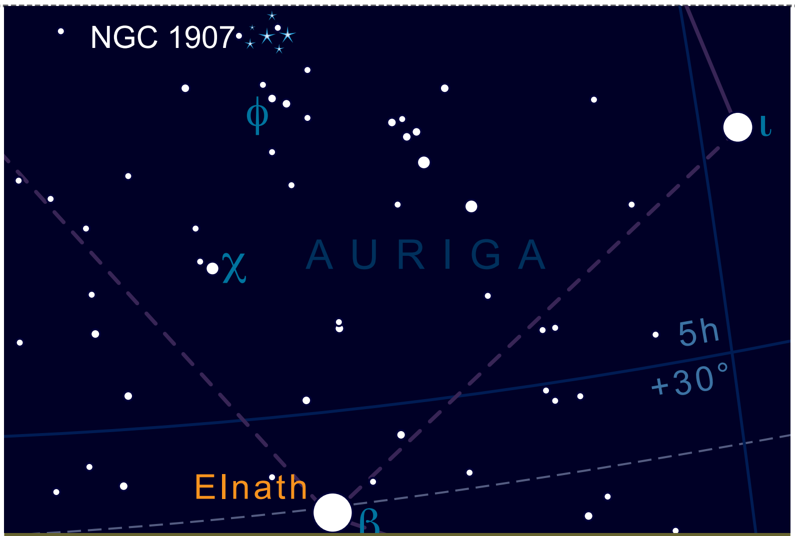
Remember, the visibility of fainter objects can be increased markedly if binoculars are firmly mounted. Just holding them is worse than useless, as even the strongest arms soon tire: the instrument magnifies not only the object to be observed, but also all the tremors of the observer's hands! Invest in a good tripod, or even better, a parallelogram mount (there are many websites describing how to construct or obtain these) – a post hammered into the ground is better than nothing to steady your binoculars.

Here is a list of ten objects, visible from northern mid-latitudes, to be discovered this winter with minimal optical aid, or even the unaided eye, in a moderately light polluted sky. Clear skies!

Bob Mizon is co-coordinator of the BAA Campaign for Dark Skies (www.britastro.org/dark-skies), author of various publications on light pollution, and operates a travelling planetarium.

NGC 1907

Dress warmly, don that woolly hat and first of all look east early on a crisp winter night to find glittering Capella, the sixth brightest star in the night sky. This is your marker for the constellation of Auriga (the Charioteer, although the ancients must have had very vivid imaginations to see this in the figure). In a moderately polluted sky, steadily-mounted binoculars will usually still be able to pick out the three brightest clusters in the constellation, strung out in a line below Capella: from east to west, they are M37, M36 and M38. Now here is a test for your instrument and your eyesight: half a degree south of the bright splash of M38 lies an interesting compact cluster, close to the galactic equator. This is NGC 1907, quite a rich cluster though without the bright stars of its three showy neighbours. Averted vision may show some of its fainter members.



Right ascension:	05h 28m
Declination:	+35° 20'
Magnitude:	+8.2
Apparent Diameter:	seven arcminutes
Distance:	~4,500 light years

Castor

Our second winter gem is not hard to find! High in the south in January and February is the glittering constellation of Gemini, and its two lead stars, Castor and Pollux, will outshine all but the most vicious light pollution Interestingly, although Castor is designated as alpha (α) Geminorum, Pollux (beta, β) is slightly the brighter of the two. Castor is truly a complicated system. This famous sextuple consists of three pairs, Castor A, B and C, 52 light years away. Castor A is magnitude +1.9, Castor B is magnitude +2.9 (the A–B separation is 3.9 arcseconds) and Castor C [YY Gem] is a variable star with a magnitude range of 8.9–9.6, 70 arcseconds away to the south.

It was the rapid 400-year orbit of Castor B around Castor A that finally convinced William Herschel of the reality of binary systems. The Reverend Thomas Webb saw A as 'greenish'. Try your highest magnifications on Castor.

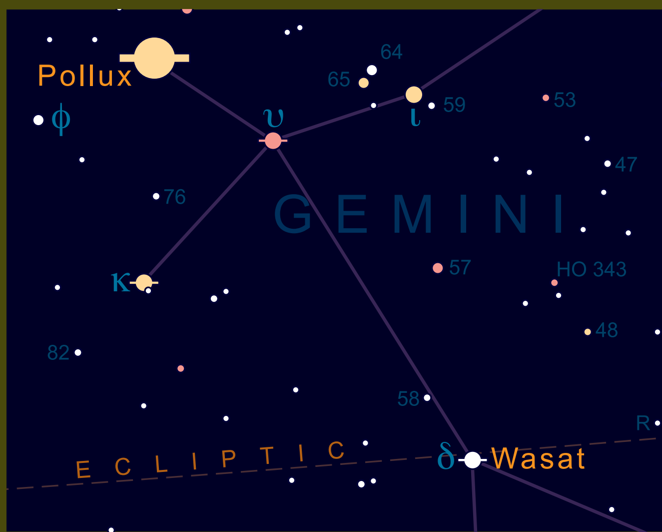
Right ascension:	07h 35m
Declination	+31° 53'
Distance:	52 light years

▲ **The constellation Gemini, with the two bright stars Castor and Pollux left of centre, rises over the winter horizon. Image: Neil English.**

Wasat

Having split Castor, locate nearby delta (δ) Geminorum, or Wasat as it is known. If you think of Gemini as a long box of a constellation, delta is the fairly bright star halfway along the bottom of the box between Pollux and gamma (γ) Geminorum. Although delta, 59 light years away, is another fine double of magnitudes +3.5 and +8.2, separated by 5.8 arcseconds (use a high-power eyepiece), aim your telescope just one degree east-south-east of it, at a point halfway between delta and another binary, 63 Gem (right ascension 07h 27m, declination +21° 27'). Nothing there? Not much, but this is a historic sky location. In January 1930, Pluto's faint image occupied this spot on a photographic plate taken at Flagstaff Observatory in Arizona and found by Clyde Tombaugh. Since that time, Pluto has completed a little less than one-third of its unconventional 249-year orbit around the Sun, and currently lies in a starry region in Sagittarius between the open cluster M25 and the Sagittarius Star Cloud, M24.

Right Ascension:	07h 20m
Declination:	+21° 59'
Distance:	59 light years

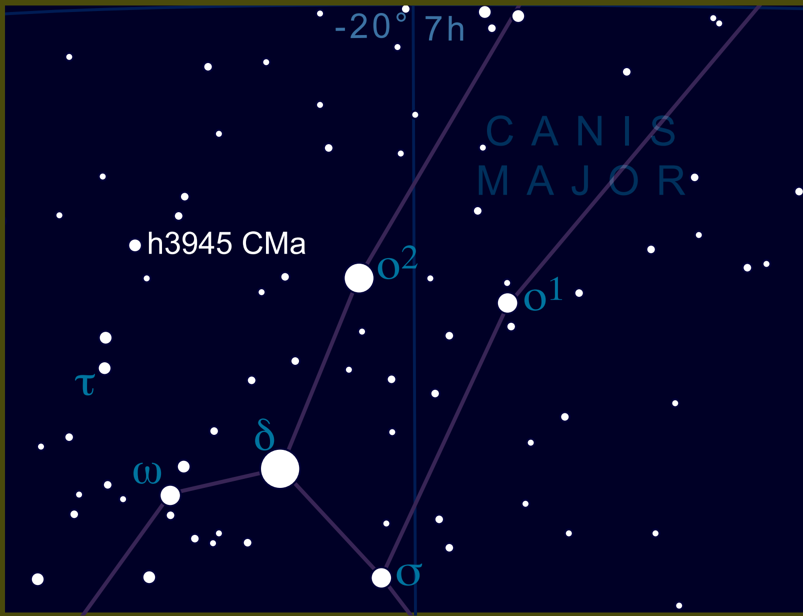


■ **All AN graphics by Greg Smye–Rumsby.**

Double star h3945 Canis Majoris

You've probably heard of, and maybe gazed in awe through the telescope at, the star representing the head of Cygnus the celestial Swan. This colourful gem is Albireo, a double system noted for its electric blue and orange-yellow components. A 'must' for summer star parties – but did you know that it has a winter equivalent in Canis Major? This fine pair is h3945 (or 145 Canis Majoris). It represents the finest colour contrast of any double star in the winter sky. Seek out h3945, orange-red and striking blue, just east of omicron² Canis Majoris and north of tau. I first saw it by chance in 1971, low in the south through the light pollution of Poole, and I was amazed that I had never heard of this celestial gem before. Easily split with moderate power, it is in fact an optical double, only a line-of-sight effect; the brighter of the two stars is 2,500 light years from us, while its 'neighbour' is only one-tenth of that distance away. 'Star-hop' to it using delta (δ) and tau (τ) as pointers. It is due south at 10pm in early February.

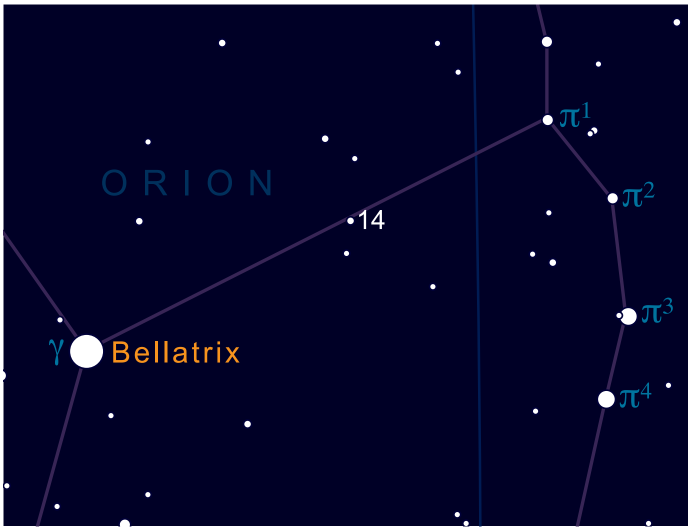
Right ascension:	07h 17m
Declination:	–23° 18'
Magnitudes:	+4.8, +6
Separation:	27 arcseconds
Distances:	2,500 light years, 250 light years



14 (OΣ98) Orionis

The celestial hunter Orion dominates the southern sky in January. Tucked in between the stars of his upraised club (designated pi¹ to pi⁶) and his shoulder star gamma (Bellatrix) is the magnitude +6 star 14 (OΣ98) Orionis. This is a close binary, and a challenge at high powers, its separation being only 0.8 arcseconds; with highest power, two fairly similar white stars (magnitudes +6 and +6.5) can be discerned. There is a delicate little double (S643) close by to the south. If you succeed in splitting it, and enjoy the prospect of a long-term observing run, then sketch or photograph 14 Orionis regularly over the next few years, and watch the position angle change. Its 160-year period means that, in the decade 2000–2010, the secondary appeared to move through more than 20 degrees in its orbit around the primary.

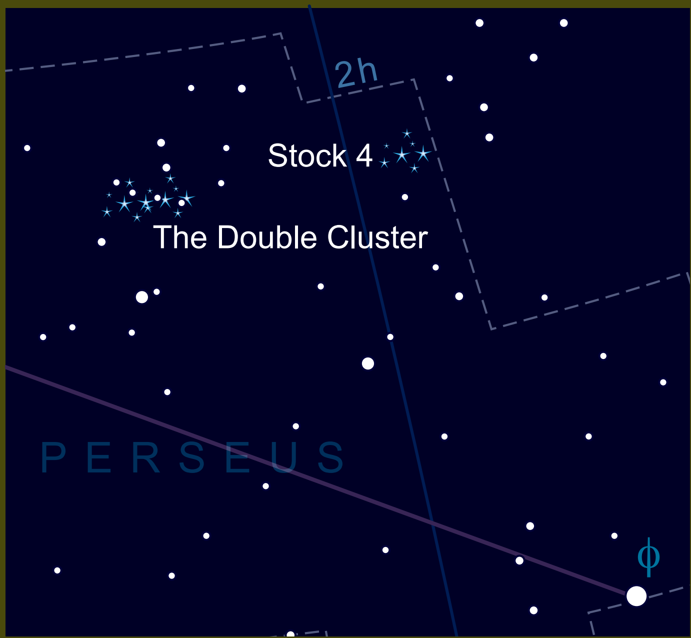
Right ascension:	05h 08m
Declination:	+08° 30'
Distance:	194 light years



Stock 4

The sparkling crowds of stars that form the Perseus OB associations, short-lived large groups that are a delight in binoculars, offer many targets for the casual astronomer, even in poor skies. Most of us have heard of and seen the glorious Perseus Double Cluster (NGC 869 and NGC 884) but spare a thought for, and allot a few minutes to observe, another cluster near at hand (preceding the Double Cluster by seven degrees). This is Stock 4, an interesting grouping in binoculars (the higher the power, the better) or at the telescope with a wide-field eyepiece. You will not find it in most atlases, and it is neglected probably because of the fame of its near neighbours. The field is scattered with faint stars, and, observing it with a low-power eyepiece through a 210mm telescope on a clear, frosty autumn night, I wrote in my notebook: 'like a rain of tiny ice crystals'.

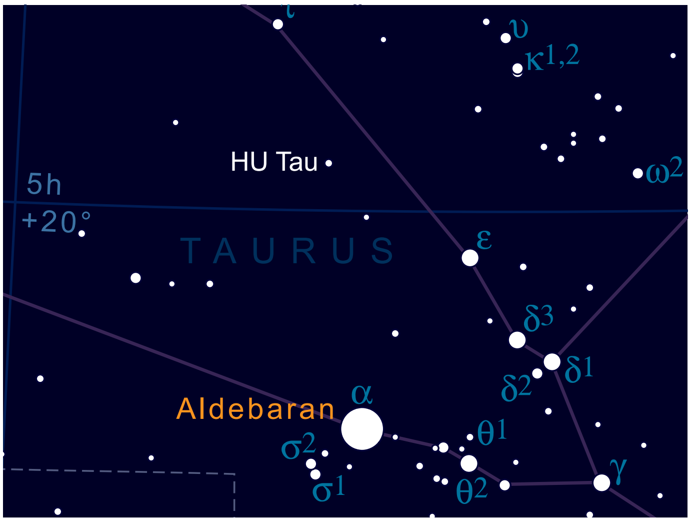
Right ascension:	01h 52m
Declination:	+57°
Magnitude:	+8
Apparent diameter:	20 arcminutes
Distance:	3,900 light years



HU Tauri

Follow the grand sweep of the stars of Perseus down to Taurus the Bull, to find a relatively bright eclipsing binary, HU Tauri. This star is normally at magnitude +6.0 and easy to locate, four degrees almost due north of Aldebaran, near the Hyades cluster, and halfway between epsilon (ε) and tau Tauri. Every two days, one hour and 21 minutes, it dims to magnitude +6.8, the whole event being well within the range of small binoculars. See www.britastro.org/vss/vsoty_hutau_2002.pdf for further information.

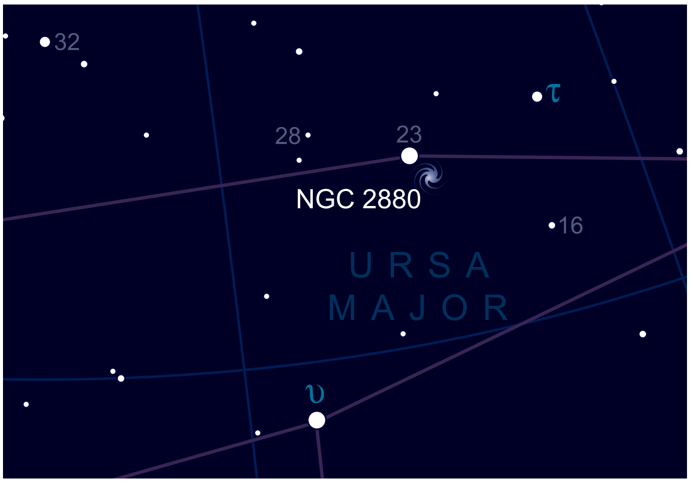
Right ascension:	04h 38m
Declination:	+20° 40'



NGC 2880

The two bright stars at the top of the 'bowl' of the Plough, delta (Megrez) and alpha (Dubhe) can be used as pointers to find 23 Ursae Majoris, a double star of magnitudes +4 and +9. But the real challenge here is to fish up the galaxy NGC 2880, just half a degree to the south of 23. For a galaxy of magnitude +11, this one looked surprisingly clear on a transparent night through a medium-power 50× eyepiece. NGC 2880 appears somewhat pear-shaped, with no pronounced nucleus and of uniform brightness right across. Yet further south along the line from 23 Ursae Majoris through the galaxy you discover a pleasing white triple star, four arcminutes away.

Right ascension:	09h 30m
Declination:	+62° 30'
Magnitude:	+11.6
Apparent diameter:	2.6 arcminutes

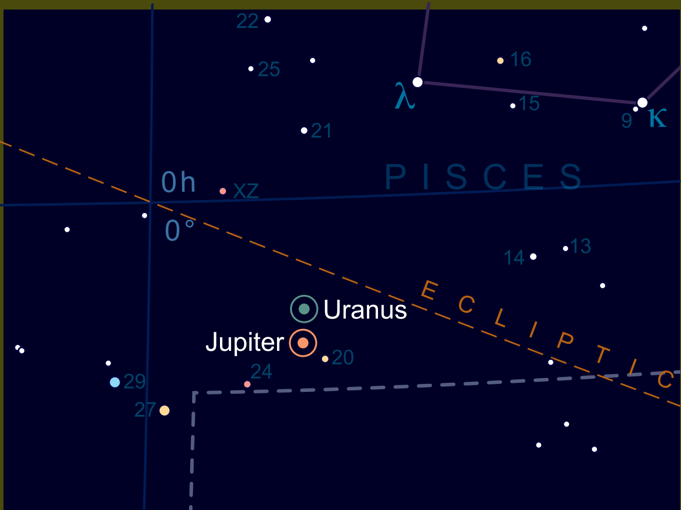


Uranus and Neptune

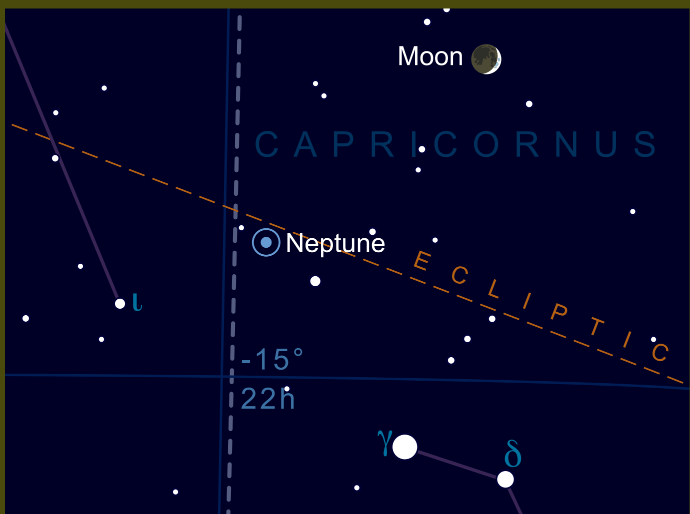
If you prefer looking at planets, you can use the Moon and Jupiter as guides to two remote gas giants this winter. Look for the crescent moon on 7 January; admire the Earthshine, the lunar equivalent of moonlight on Earth, rendering the nighttime part of the Moon a ghostly shade of its former self: perhaps not an unusual sight, but on these dates the Moon can be used to locate Neptune, a bluish magnitude +7.8 dot about five degrees to the south. Binoculars will reveal it, and a telescope view will show that it is a tiny disc and not a star-like point.

Our last winter object is another remote planet that most observers may never have seen through a telescope, because it is not always easy to pinpoint in the starfield and it is not a naked-eye object. Now is your chance to find it because of its proximity to a brighter object. Uranus, the bluish-green, tilted giant at about twenty astronomical units from the Sun, has recently been having a series of encounters with Jupiter, which was at its nearest to us for 47 years in September 2010 and therefore very bright and easy to locate. Uranus, just above and to the left (east) of Jupiter, closes slowly with it as Jupiter resumes its direct motion in the sky. On 2 January 2011, Uranus appears just over half a degree directly above its giant sibling, and a low-power eyepiece should reveal both gas planets in the same field.

▼ **Uranus close to Jupiter on 2 January. All graphics by Greg Smye–Rumsby.**



▼ **Neptune near the crescent moon on 7 January.**



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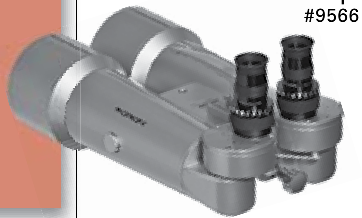

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The phantom planet?

Was the discovery of the first potentially habitable planet around another star a false alarm? Controversy rages between two crack teams of exoplanet hunters as **Keith Cooper** steps between them to learn that with this particular planet, nothing is as it seems.

▲ **An artist's impression of what Gliese 581g might look like. Image: Lynette Cook.**

On 29 September 2010 the news many of us had been waiting fifteen years for, ever since the first planets around Sun-like stars were discovered, was announced: a potentially habitable, rocky planet, in the 'Goldilocks' zone around a nearby star, had been discovered. Gliese 581g, as it is known, was the first planet beyond our Solar System where life as we know it could potentially survive. It was found by a team led by Professor Steven Vogt of the University of Santa Cruz and Dr Paul Butler of the Carnegie Institution of Washington, who used the HIRES (High Resolution Echelle Spectrometer) instrument on the ten-metre Keck telescope to detect it. This new planet was found orbiting the red dwarf star Gliese 581, 20.5 light years away, around which four other planets had already been detected. With an estimated mass of three to four times the Earth, it is definitely rocky, and at a distance of 21 million kilometres (0.146 astronomical units) it is located in the region around its cool star where water could potentially be liquid on its surface.

Initially, any controversy surrounding Gliese 581g existed in the caveat of the phrase 'potentially habitable'; without knowing the atmospheric condition of the planet (or even if it has an atmosphere) it is speculative to say that it definitely supports water. But if its atmosphere were like Earth's, there's a good chance that it would. Regardless, it was a rocky planet in a Goldilocks zone, and if one exists there will undoubtedly be many more around other stars. It is a huge leap towards finding another Earth, which is the ultimate aim of exoplanet research.

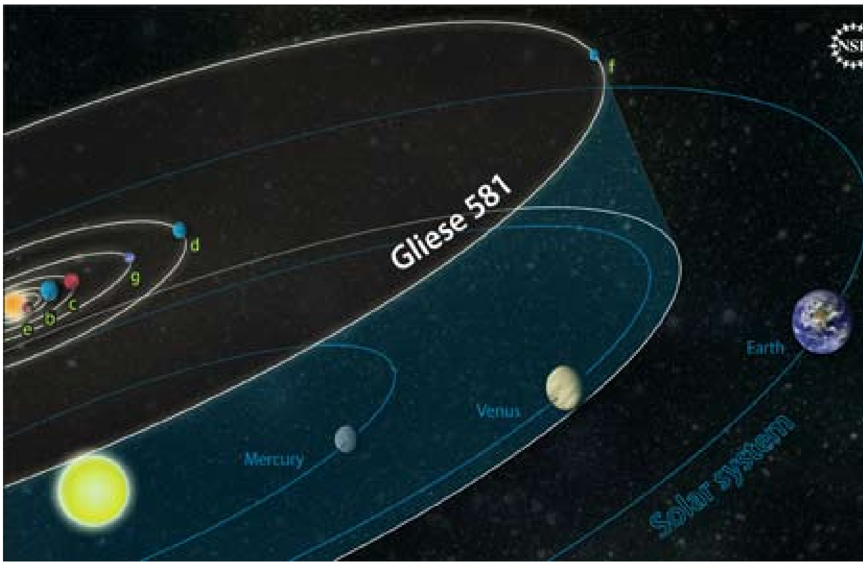
However, a spanner was thrown into the works during a conference in Turin in October, when Dr Francesco Pepe, a researcher from Geneva Observatory who is part of the team that use the HARPS planet-finding instrument at the European Southern Observatory in Chile, claimed that he could find no evidence for planet g in the HARPS data. All of a sudden, its existence was thrown into doubt. Does Gliese 581g, the first potentially habitable world in another star system, really exist?

Radial velocity

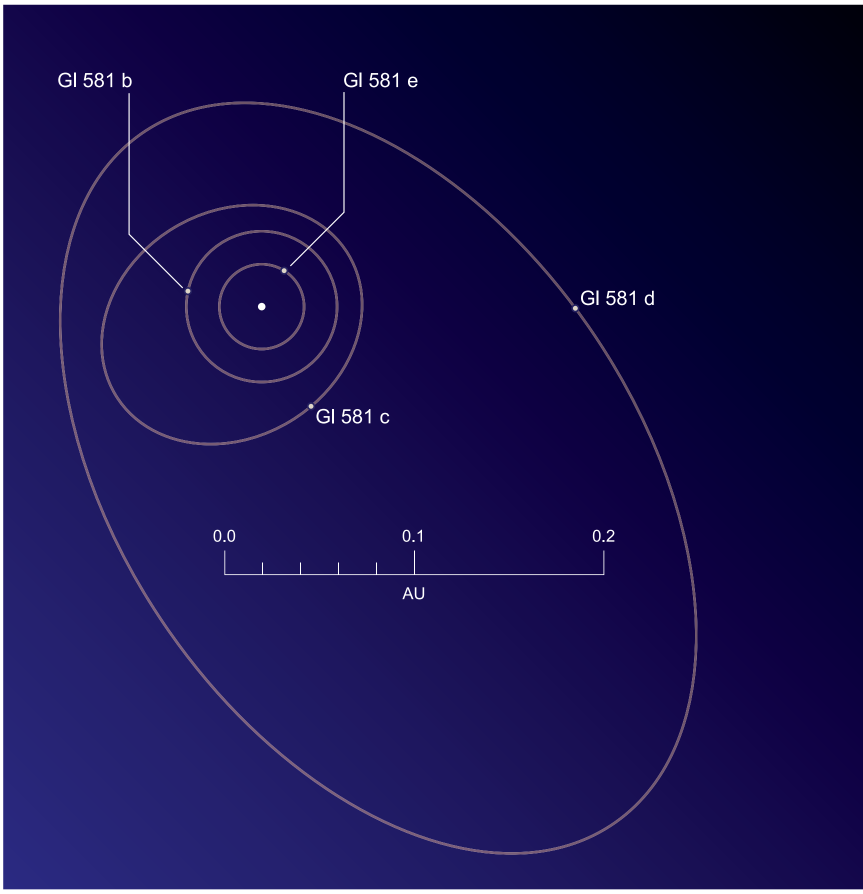
Let's begin with some background. Gliese 581 has been studied by exoplanet researchers for many years, through what is called the radial velocity measurement. As a planet orbits a star, its gravity tugs on it, causing the star to appear to wobble around their common centre of mass, perhaps at a velocity of just a few metres per second.

Sensitive spectrometers targeted at such a star can see this wobble as a slight Doppler shift in the star's light. The HARPS team (HARPS stands for High Accuracy Radial velocity Planet Searcher) has discovered four planets around Gliese 581 in this way since 2005. The first planet, 581b, is at a distance of 6.1 million kilometres from the star and has a mass similar to Uranus. Two more worlds, c and d, discovered in 2007, have masses five and seven times that of Earth, residing at 10.5 and 39.2 million kilometres from the star. In 2009, the HARPS team announced a fourth planet, e, which is one of the smallest ever found with a mass just 1.9 times that of Earth, but is baking under its star's heat at a distance of just 4.4 million kilometres. All these worlds are much closer to their star than the distance of any of the planets in our Solar System from the Sun, but because Gliese 581 is a much smaller, cooler, dimmer star than the Sun, its planetary system is scaled down accordingly. Hence its Goldilocks zone – where temperatures could be just right for liquid water – is also much closer.

"THE ONLY THING THAT WILL EVENTUALLY SETTLE THE ARGUMENT IS MORE DATA, BECAUSE THE MORE DATA YOU HAVE, THE STRONGER THE SIGNAL BECOMES AS YOU BUILD UP THE EVIDENCE"



■ **The HIRES team argue that the orbits of the planets in the Gliese 581 system are circular (seen above here compared to our Solar System) while the HARPS team argue that some of the planets have highly elliptical orbits (below). Images: Zina Deretsky (above); Greg Smye–Rumsby (below).**



Planet g, along with a sixth planet, f, (that weighs in at about eight Earth masses and is located at a distance of 113 million kilometres from the star) were the first planets around Gliese 581 to be discovered by an instrument other than HARPS. But then the real controversy set in.

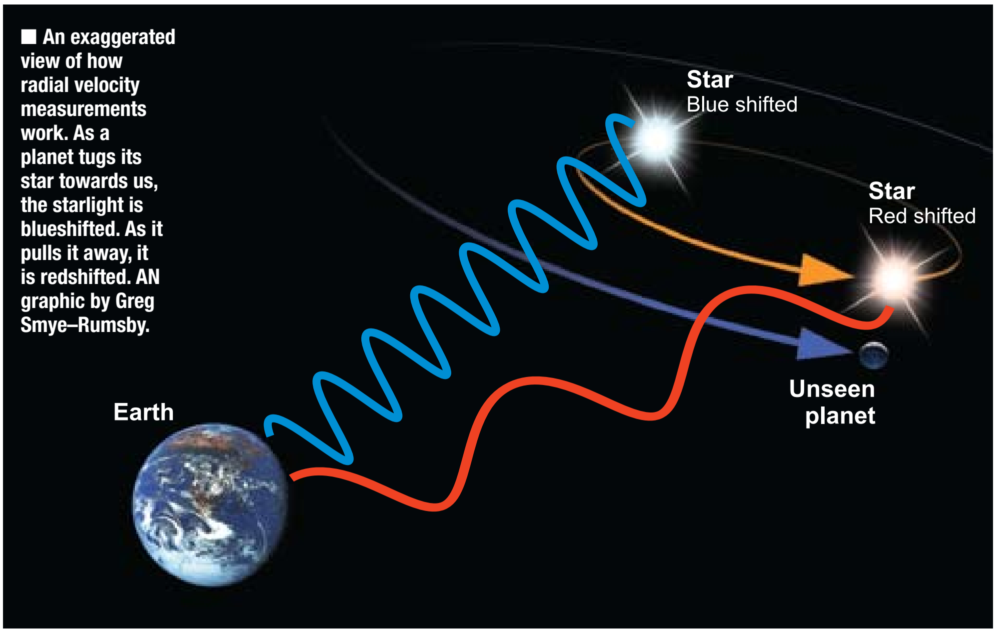
Professor Steven Vogt is bullish about his discovery, saying the planets are only detectable when one combines his HIRES observations, which were taken over eleven years, with HARPS' dataset. This is because the more observations you have, the more sensitive and reliable the results are. "I was surprised when Francesco Pepe said that they had only looked at the HARPS dataset, and not the combined dataset, when we'd made it pretty clear that you couldn't see this in the HARPS dataset alone," Vogt tells *Astronomy Now*.

This is true, responds Dr Christophe Lovis, a HARPS team member at Geneva Observatory. "What we said in Turin in October was based only on the HARPS data, because at the time that is all we had, but that included new unpublished data that increases the HARPS data by about 50 percent, and we could not see the signal of planet g," he says. "In the meantime I have also tried to combine the HARPS data with the HIRES data, but I still don't see the planet."

Both teams of astronomers are highly skilled, with scores of planet discoveries behind them, and both HIRES and HARPS are terrific instruments, currently the most sensitive in the world for radial velocity measurements. So why is there a disagreement between the two?

One problem is what astronomers call jitter. Stars are not perfectly still. They have vibrational modes, waves that reverberate throughout their interior, which can generate a Doppler shift measurement. Starspots (like sunspots) can also interfere with radial velocity measurements. This activity amounts to a background noise, and because each star is different the background noise can also differ, often in ways that we are unaware of. Instrumental noise can also add to this jitter. "At the end of the day we can have a go [at measuring jitter] but it is quite difficult to quantify to better than fifty percent," says Professor Hugh Jones of the University of Hertfordshire, who is an exoplanet researcher independent of the HIRES and HARPS teams.

Jitter can have a huge effect on results. Overestimate it and it can drown out the subtle signals of smaller planets. Underestimate it and a signal that



■ **An exaggerated view of how radial velocity measurements work. As a planet tugs its star towards us, the starlight is blueshifted. As it pulls it away, it is redshifted. AN graphic by Greg Smye–Rumsby.**

you think is a planet could just be background noise.

"My main problem with the planet g discovery is that I think they underestimate the noise," says Lovis. "We think that the data is almost too noisy to say anything about a planet, so I think they are being too optimistic."

Occam's razor

The laws of orbital motion derived by Johannes Kepler tell us that all planets have orbits that are ellipses. Nevertheless, for the planets in our Solar System the orbits are nearly circular. The HIRES team argues that the orbits of all the planets in the Gliese 581 system are similarly circular, but the HARPS team derives a highly eccentric orbit for planet d in particular. The difference comes because of a 'phase gap' in the data that allows the teams to consider the degree of orbital eccentricity a free parameter.

Draw a sinusoidal wave on a piece of paper in front of you. A planet with a perfectly circular orbit will produce a series of radial velocity measurements that you could map perfectly onto this sine wave. An eccentric planet would not follow the sine wave exactly – its curve would be more deformed. The problem is that two planets in the Gliese 581 system – planets d and g – have orbits of 67 days and 37 days respectively, which is very close to the lunar cycle, or multiples thereof. So, at roughly the same point in each of their orbits, the full moon is up in our sky, limiting observations. This means that for this particular part of the planets' orbits, we have no data – on our sine wave there is a gap where we have no measurements, and this is what we mean by a phase gap.

"If you don't have good phase coverage then you can have problems," says Jones. "It will mean that your false alarm probability will go up."

Because a phase gap exists, the eccentricity of the planets is not constrained. The HARPS team found an eccentricity of 0.4 for planet d, and although Lovis admits he does not know if that is correct, he doesn't believe it will be decisive in the debate on planet g. However, with that eccentricity Vogt was unable to get a solution that fitted well with all of the HARPS and HIRES data simultaneously and therefore he believes it to be incorrect.

"When you are determining an eccentricity, you are saying you understand the shape of the signal [the shape of the sine wave], but these signals are so weak we don't think there is any justification for trying to claim eccentricity," says Vogt. "The errors bars are so large that they are consistent with eccentricities of zero, so we took the Occams razor solution, the simplest one, which is an all-circular solution since there were no better solutions. When I moved away from the high eccentricity approach the whole thing came together very nicely."

This approach won support from Guillem Angada-Escude of the Carnegie Institute of Washington, who had written a paper early in 2010 predicting that the existence of a planet with a 37-day orbit was being masked by the postulated eccentricity of planet d, long before Vogt's team announced their discovery. He has subsequently written a new paper taking all the data – HARPS and HIRES – that suggests the weight of evidence based on the current data is in favour of planet g. However, this potentially may change with the extra sixty data points that Francesco Pepe referred

■ **The two Keck Telescopes, home to HIRES, above the clouds on Mauna Kea in Hawaii. Image: W M Keck Observatory.**

to in Turin, and which the HARPS team are currently writing a paper on. Until the paper has undergone peer review and been published, it is hard for Vogt, Jones or any other exoplanet researcher to comment in too much detail on what that data might imply. Nevertheless, Vogt has had a bash.

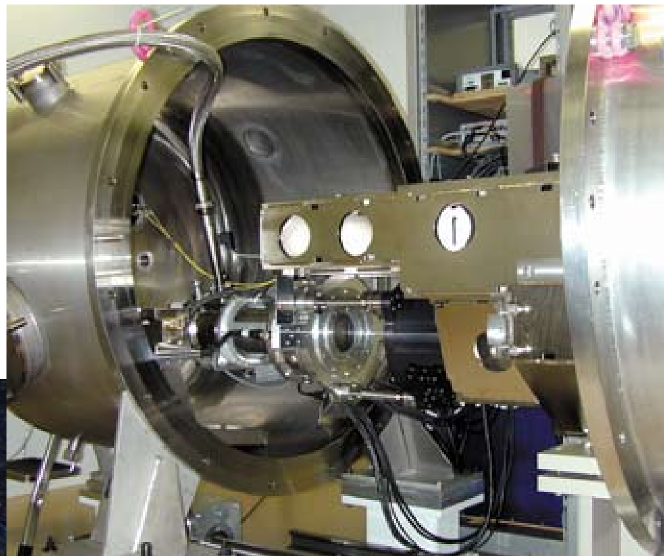
"What we did do is say, 'okay, they claim that they should have been able to see this planet with their sixty new data points', so we did a simulation where we took the HARPS data, and imagined observing it for another two seasons, sixty more points," he says. "After simulating it a thousand times, we came to the conclusion that they shouldn't have been able to see this planet with their dataset alone. So I am dubious of Pepe's statement [that they should have been able to see planet g with their additional 60 data points], and that's all we can do at this point until they publish their data for us to analyse independently."

The scientific process

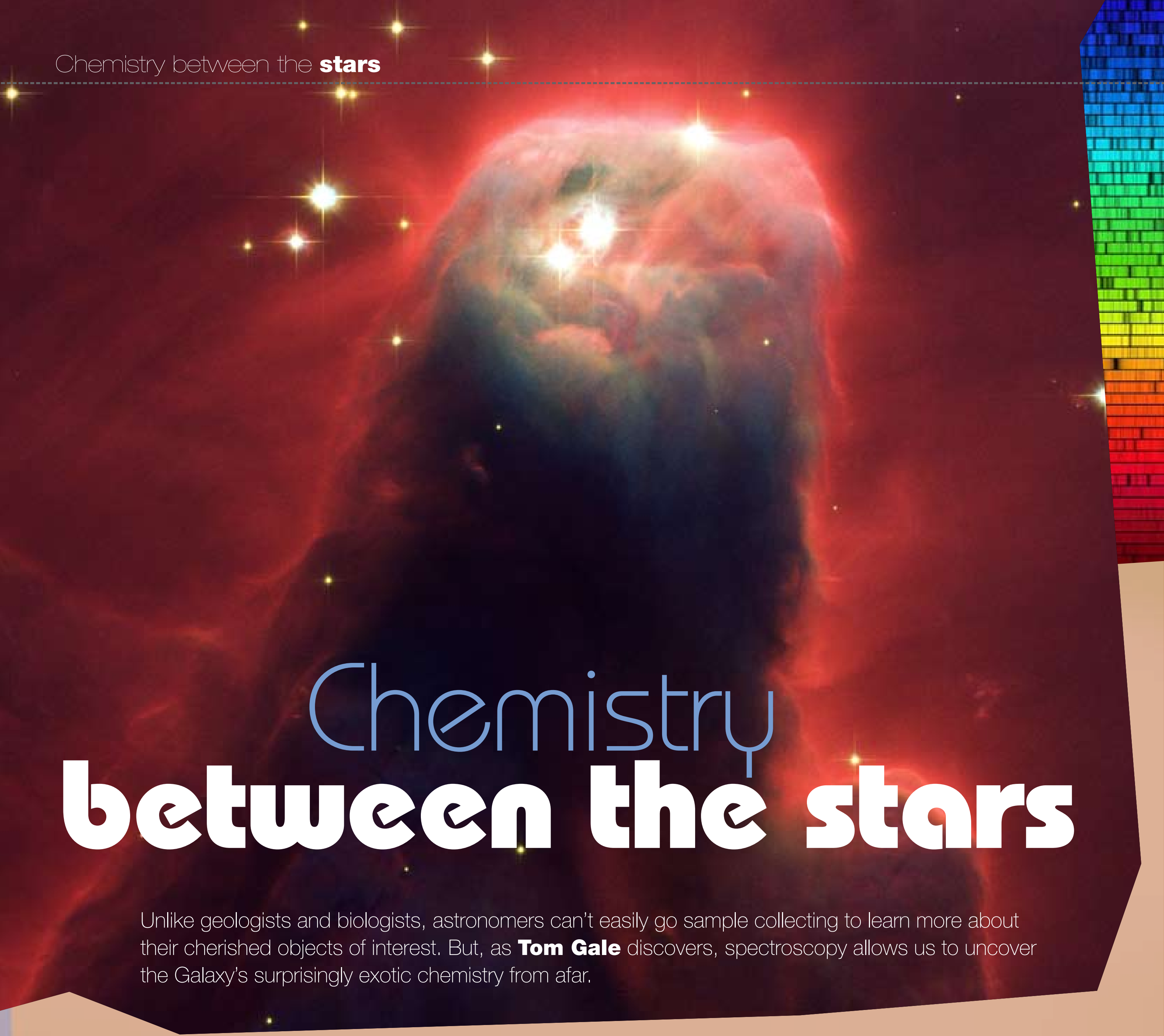
Although this all sounds acrimonious, it isn't really – it's how science works. Once a discovery has been made, rigorously peer reviewed and published, the onus is on other groups to disprove it should they disagree with it, with an open dialogue and publishing of all data to back up their assessments. The only thing that will eventually settle the argument is more data, because the more data you have, the stronger the signal becomes as you build up the evidence. Unfortunately none of the planets in the Gliese 581 system are seen to transit – the alignment between their orbital plane and our line of sight is wrong for that – so we have to rely on radial velocity measurements. Both the HIRES and HARPS teams will be targeting Gliese 581 in the coming months, while other, even more sensitive planet-finding instruments are in the works. The HARPS team is developing ESPRESSO, the Echelle SPectrograph for Rocky Exoplanet and Stable Spectroscopic Observations, for the eight-metre Very Large Telescope in Chile. Meanwhile, Carnegie's Paul Butler is currently shaking the gremlins out of the new Planet Finding Spectrometer (PFS) on the 6.5-metre Magellan Telescope, also in Chile, which should be able to measure radial velocities of less than a metre. Additionally, Vogt himself is preparing the Automated Planet Finder (APF), a robotic instrument that will search for planets every clear night of the year on the 2.4-metre telescope at the Lick Observatory in California. ESPRESSO and PFS will provide far more sensitive measurements, while APF will be a dedicated planet-finder that will dramatically increase the number of data points that we have (because telescopes such as Keck are under 'timeshare' with other astronomers also using them for various projects, not just exoplanets). So, regardless of whether Gliese 581g is real or not, many more potentially habitable worlds will soon be within our grasp. One such world may be around another red dwarf, Gliese 436, on which both the HIRES and HARPS teams are collaborating to try to tease out hints of another potentially habitable planet, should it exist. This is just one of 300 stars that HIRES is currently looking at.

The story of Gliese 581g is far from over. "If this was just another planet, nobody would care, but this one is different, people care a lot about it," says Vogt. "We thought long and hard about announcing the discovery and we are aware of all the sensitivities involved. It would be nice to have unabashed collegiality and combine our data and work really hard, because it is hard stuff, we're right at the limits of what we can do."

Keith Cooper is the Editor of Astronomy Now.



◀ **The dome of the 3.6-metre Swiss telescope at the European Southern Observatory in Chile, and inset the HARPS spectrograph that it houses. Image: Iztok Boncina/ESO.**



Chemistry between the stars

Unlike geologists and biologists, astronomers can't easily go sample collecting to learn more about their cherished objects of interest. But, as **Tom Gale** discovers, spectroscopy allows us to uncover the Galaxy's surprisingly exotic chemistry from afar.

▲ The Cone Nebula is a dark pillar of gas and dust, inside which stars are forming. It is rich in molecular hydrogen, which is the most common molecule in the Universe. Image: NASA/H Ford (JHU)/G Illingworth (USCS/LO)/M Clampin (STScI)/G Hartig (STScI)/ACS Science Team.

Space is a brutally unforgiving environment, something we easily overlook from within our planet's snug cocoon of protective gases. Venture beyond our atmosphere and we're bombarded by X-rays, cosmic rays and other ionising forms of radiation that shred molecules by ripping apart the chemical bonds between their constituent atoms. In fact, until a few decades ago astronomers considered the harsh conditions of open space too energetic for any molecules to exist at all. Much of the matter in the Universe does indeed consist of solitary atoms, dispersed across interstellar voids far more tenuous than the best vacuums our Earthly laboratories can generate. The majority of those atoms are hydrogen (90 percent by head-count or, as cosmologists prefer, 75 percent by mass). The lightest and simplest of all the chemical elements, atoms of hydrogen feature just a single electron orbiting, typically, a lone proton. Of the remaining mass in the cosmos, the bulk is contributed by the second lightest element, helium. But this overall picture of simplicity is deceptive. Thanks to a new generation of powerful radio telescopes, astronomers are discovering that certain pockets of the Galaxy are more chemically diverse than ever previously imagined.

Spectroscopy's helping hand

Many substances give away their identity at a distance by the frequency of radiation they absorb or emit, a trait that is invaluable to astronomers. Isaac Newton had been the first to demonstrate the dispersal of sunlight into a continuum of its constituent rainbow colours, but it would be more than a century before astronomers crafted spectroscopes to similarly split the feebler glow of starlight. Early pioneering spectroscopists, such as the German Gustav Kirchoff, identified chemical elements in stars for the first time by matching the frequency of their dark absorption bands to those of corresponding bright spectral emission lines seen in ground-based laboratory experiments (see box, *Emission and absorption*). More confident still, the British astronomer Sir Joseph Norman Lockyer, on seeing an unexplained line in the solar spectrum at 588 nanometres (nm), boldly announced the discovery of a new element in 1868, promptly naming it after the Greek god of the Sun,

▲ **The Sun's spectrum is covered in dark absorption lines that we call Fraunhofer bands. Image: Harvard–Smithsonian CfA.**

'Helios'. With a stroke of serendipity, the find came around the same time that Dimitri Mendeleev was drawing up his now-famous periodic table to classify the chemical elements. The Siberian chemist had ingeniously left gaps for elements that hadn't yet been found. Now helium could rightly jump in to fill the table's number two position, remarkably some ten years before it was even detected in the Earth's crust!

Before long, stellar spectroscopists could even pick out very close double stars by spotting certain families of absorption lines moving in unison. The alternate redshifting and blueshifting of these line groupings, they correctly inferred, occurred as each component star danced around the system's common centre of mass, moving towards us and away from us. But there was a puzzle: in some of these binaries, such as Mintaka (the westernmost star of Orion's Belt), certain lines refused to budge. In 1904, the German astronomer Johannes Hartmann noticed that Mintaka's calcium 'K' line (Ca^+ ion at 393.4nm) stayed put throughout the binary's week-long orbital period. The anomaly, he quickly inferred, had nothing to do with either star but was instead caused by calcium-laced nebulosity in the interstellar medium, lying somewhere along the line of sight to the star system.

Dark horses

Within a decade, improved long exposure photographic techniques allowed the American Edward Barnard to catalogue several hundred of what he termed 'dark markings of the sky', which are nebulae that only give themselves away at optical wavelengths if they happen by chance to be silhouetted against a bright patch of sky lying beyond. Famous dark nebulae of modern day deep sky observers include the challenging Horsehead Nebula (Barnard 33) in Orion and the striking dark bands trisecting the summer sky's Trifid Nebula (M20) in Sagittarius.

Spectroscopists soon noticed that starlight passing through such nebulosity became dimmed by these mysterious clouds. Typically, a bias of transmitted red colour was observed, suggesting, as we now know to be the case, preferential scattering of shorter, blue wavelengths by countless intervening microscopic dust grains. Deep space, it soon seemed, was far from empty.

Although a handful of neutral, stable gases such as carbon dioxide (CO_2) had been picked up by infrared analysis of Mars and the Venusian cloudtops, the first discoveries of interstellar molecules came as a big surprise. First came water vapour (H_2O) and ammonia (NH_3) in 1968, both detected in distant nebulae from their radio signals of wavelengths close to 1.3 centimetres. Spurred by these finds, searches over the following years quickly uncovered a whole host of other simple compounds, kick-starting a new branch of radio astronomy.

Chemists, astronomers and biologists alike are fascinated by discoveries of extraterrestrial compounds because their presence and distribution offer clues about how the Earth's first biological building blocks may have come about. All this has big implications for the origin of life on Earth, still a hotly debated topic. Until the early nineteenth century it was thought that carbon-based 'organic' molecules were generated exclusively by living organisms and couldn't be produced any other way. As a result, organic compounds were ring-fenced into a whole separate branch of chemistry quite distinct from metals, salts and minerals – the stuff of 'inorganic' chemistry. But then the German

Emission and absorption

Spectroscopy is the key to investigating the chemistry of the heavens. The Victorian English astronomer William Huggins was first to distinguish the two main types of celestial spectrum: emission spectra, which are typical of star-forming or planetary nebulae, and absorption spectra that are used to classify stars and galaxies. Emission lines are produced by gases that are ionised or in some way 'excited'. The German scholar Robert Bunsen analysed light given out from gases he had excited by electrical voltages, which pushes each atom's outlying electron up to a higher energy level. The excited atoms later lose the excess energy by simultaneously booting out a photon that carries that lost energy difference (energy is always conserved in the Universe).

Fortunately for astronomers, the amount of energy an atom or molecule has doesn't just take on any random value. Instead, as the Danishman Niels Bohr was first to mathematically explain, electron energies are quantised, meaning that they can only adopt certain values and cannot hold values in between. It's a bit like climbing up a ladder – you can't realistically stand halfway between two rungs! As a happy consequence of quantisation, Bunsen's excited gases each appeared to emit just a handful of narrow bands of characteristic frequencies, offering a handy diagnostic fingerprint for identifying each element.

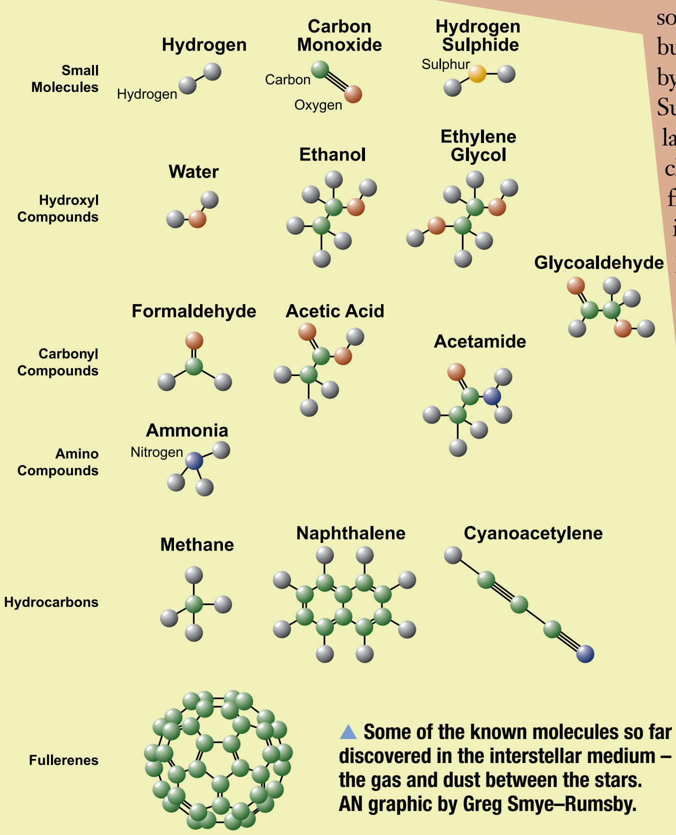
The situation is quite different for hot incandescent bodies, such as stars, galaxies, flames and domestic light bulbs that beam out a rainbow continuum of colours. In this case, any vapour sample happening to lie in front of such a light source will show up as it becomes excited by plucking out select photons from the light source beyond. The result is that same chemical fingerprint, but this time appearing as silhouetted, razor-sharp 'Fraunhofer' lines seen against the bright background – an absorption spectrum.

One of the most omnipresent spectral bands recognised by astronomers is the hydrogen-alpha emission of wavelength 656.3nm. This feature arises when an electron moves between hydrogen's second and third energy states and is cherished by solar astronomers as hydrogen's most prominent visible signature. Like all spectral lines, the hydrogen-alpha frequency is a constant of nature, retaining the same value no matter whether the gas source is trapped in a laboratory belljar or out in the remotest corner of the Tarantula Nebula.

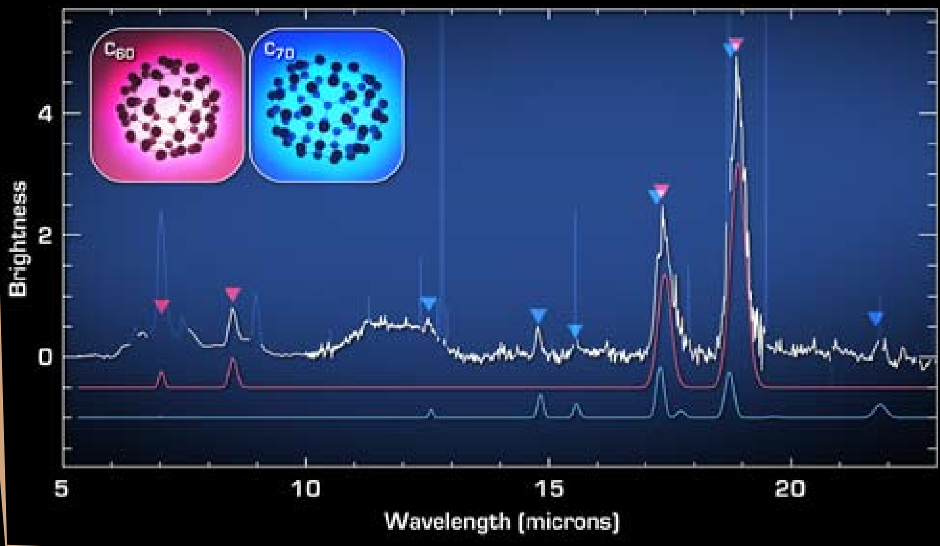
Seeing through dust

Inside the galaxy's cold molecular clouds there isn't enough energy kicking around to push electrons about, so visible spectra do not reveal much. Instead astronomers tune into the longer wavelengths of the electromagnetic spectrum. Infrared rays not only shine right through thick dust clouds but, at certain photon energies, can wobble chemical bonds, making each oscillate like a miniature spring at certain characteristic frequencies. For instance, the carbon-hydrogen (C–H) single bond, found in terrestrial fossil fuels and interstellar hydrocarbons alike, vibrates under irradiation with infrared rays of 3.4 microns wavelength. The carbonyl double bond (C=O), a key feature of many proteins, sugars and lipids, similarly soaks up radiation of 5.8 microns wavelength. The circumstellar envelopes of carbon stars offer rich pickings for molecule hunters, where absorption lines can easily be picked out against the powerful infrared source lying behind.

It is the rotation of molecules, however, that gives away their presence in even the coldest environments. Rotational energy levels are much closer together than those of vibrating chemical bonds. As a consequence, transitions between rotational quantum states involve lower energy microwaves, the radiation known to many from its use in the domestic ovens with which they are synonymous. The shortest of all radio waves, these are also the rays of radar, for which wavelengths are measured in millimetres and centimetres. Fortunately for astronomers, asymmetrical, polar molecules show particularly strong microwave signals, each glowing at a diagnostic, telltale set of frequencies. Take carbon monoxide (CO), the Galaxy's most abundant compound, for example. Infamous in a domestic context as the suffocating but dangerously odourless gas leaked out by faulty heating systems, carbon monoxide is useful to radio astronomers for whom its distinctive 2.6 and 5.6 millimetre emissions offer a handy way to map out molecular clouds. What's more, the relative intensities of these signals reveal to astronomers the density and temperature of the nebula in which the gas resides.



▲ Some of the known molecules so far discovered in the interstellar medium – the gas and dust between the stars. AN graphic by Greg Smye–Rumsby.



▲ A spectrum from the planetary nebula Tc 1, showing the fingerprints of 'buckyballs' – giant molecules of 60 and 70 carbon atoms. They have four vibrational modes that cause light to be emitted or absorbed at infrared wavelengths, seen here in this spectrum. Image: NASA/JPL–Caltech/J Cami (University of Western Ontario/SETI Institute).

chemist Friedrich Wöhler turned chemistry on its head in 1828 by showing that certain natural products could be made from inorganic salts. His synthesis of urea (the kidney's nitrogen excretion product of formula $((H_2N)_2CO))$ by simply heating 'inorganic' ammonium cyanate (NH_4NCO) not only united chemistry but threw up new quandaries regarding the chemical origin of life. Did the primordial Earth merely happen to carry the right combination of gases and minerals waiting to be fried by atmospheric lightning strikes into molecules ripe for roles in primitive biochemistry? Or perhaps the advent of terrestrial life required more cajoling thanks to deposits of pre-solar, ready-to-use complex organic building blocks that were dumped by impacts of carbon-rich comets. Such fundamental issues remain largely unresolved today, and so any chemical clues astronomers can glean from meteorite samples, comets and interstellar clouds remain highly prized indeed.

Where molecules hide out

The first exciting discoveries of molecules in space immediately prompted many theorists to wonder how they could have formed out there in the first place. The rate of chemical reactions is strongly temperature-dependant and in Barnard's cold, dark nebulae would be expected to proceed exceedingly slowly. However, here gas and dust clumps together in much higher density than other parts of the Galaxy. Take, for example, the most studied interstellar dust cloud of all, Sagittarius B2. Lying 26,000 light years away near the centre of the Milky Way, Sgr B2 packs in several thousand particles per cubic centimetre. Compare that to the Local Bubble, the nickname of the Sun's neighbourhood, which hosts a spartan one particle for every 20 centimetres cubed!

The cores of such interstellar clouds are denser still and clogged with dust that blots out destructive incoming radiation and protects newly-born molecules. Now astro-chemists, including Max Bernstein of NASA's Ames Research Center in California, are convinced that the countless sub-micron sized soot grains play another role too. His laboratory simulations of the interstellar medium show that despite the clouds' low temperatures (10–50 kelvin, between –263 and –223 degrees Celsius), atoms can come together on the ice-coated surface of dust particles. Here atoms meet and react with one another much faster than they would randomly wandering about in the three dimensions of free space. In a manner somewhat akin to the goings-on inside catalytic converters used to scrub pollutants from car exhausts, the interstellar grain surfaces provide a short cut to chemical bond formation.

Organic space

To date, astronomers have detected around 150 different molecular species in deep space and that list keeps growing year by year. So too does the complexity of the compounds they spy, some of which are the stuff of everyday life, including alcohols. It has been estimated that Sgr B2 contains enough ethanol (C_2H_5OH) to make 10^{28} bottles of whisky! Other known interstellar drifters of household notoriety include acetone ($(CH_3)_2CO$, in nail-varnish remover), acetic acid (CH_3COOH, the sourness of vinegars), naphthalene ($C_{10}H_8$, the smell of mothballs), and ethylene glycol (HOC_2H_4OH, used as engine antifreeze).

In 2001, acetamide (CH_3CONH_2) was detected for the first time. The molecule's four-atom CO–NH unit is a key find, as this is the so-called peptide bond that links all amino acids together in proteins, allowing enzymes to hold their rigid shape and act as nature's chemical catalysts. Amino acids themselves, by contrast, remain elusive in deep space, despite considerable searching. This absence is something of a headache for astro-chemists given the appearance in the Solar System of the amino acid glycine ($H_2NC H_2COOH$) in numerous carbonaceous meteorite samples and in particles collected from Comet 81P/Wild-2 by NASA's Stardust probe. Many believe, however, that as the sensitivity of microwave detectors improves, interstellar glycine will inevitably be spotted. Such hopes were given a boost in 2009, when European astronomers recorded a signal of aminoacetonitrile ($H_2NC H_2CN$) using millimetre-wave dishes sited high in the Alps and Spanish Sierra Nevada. This compound is the immediate forerunner of glycine in the well-documented Strecker synthesis pathway, the likely route to its formation in the slushy interior of comets.

Since 2004 the Green Bank Radio Observatory in West Virginia has also played a major role in the quest for interstellar biomolecules. Jan Hollis of NASA's Goddard Space Flight Center used the site's mighty 100-metre dish to discover glycoaldehyde ($HOCH_2CHO$) in Sgr B2, the first simple sugar seen in space. Scientists think that this mini-carbohydrate comes about as formaldehyde units join together, a sequence capable of generating key complex sugars such as ribose.

Since the coma gases of several comets, including Hale–Bopp, have also been shown to be rich in formaldehyde, Hollis' find suggests that comets may likewise harbour sugars. Such tantalising clues once again fuel speculation that, as prebiotic incubators of organic building blocks, comets could have played a crucial role in the origin of life.

The latest and the future

Finally, in 2010 came the finding of a molecular giant who's story has come full circle, in more ways than one. Back in the 1980s the British chemist Sir Harold Kroto collaborated with colleagues at Rice University in Texas to investigate possible carbon species puffed out by ageing red giant stars. Cool, sooty circumstellar environments were already known to be home to odd-looking carbon chain molecules such as cyanoacetylene (HCCCN), indicating quite a distinct chemistry from that of hydrogen-rich interstellar clouds. To his astonishment, Kroto's laboratory experiments sometimes produced previously unseen perfect molecular spheres of carbon, lattices of 60 or 70 atoms arranged in tessellated rings like the patches of a football. Suddenly, here was a third form of carbon (to join graphite and diamond), a find of such significance that it earned the team the 1996 Nobel Prize for Chemistry. Christened fullerenes, as their geometry resembles that of domes designed by the American architect Buckminster Fuller, the molecules were subsequently shown to be sparingly present in common candle soot. Though expected in space, carbon-60 evaded detection for 25 years – until now. Fullerenes' perfect symmetry means they don't give away any telltale microwave absorptions. However, when Jan Cami, of the University of Western Ontario in Canada, scoured data from the Spitzer Space Telescope's infrared spectrograph, he found a carbon-60 infrared emission signature for the first time, from a planetary nebula 6,500 light years away. Long awaited, this landmark find highlights how large, carbon-backboned structures could be relatively common throughout the Galaxy.

In the coming decade, new multi-dish radio observatories are set for unprecedented ultra-sensitive exploration of molecular clouds in far-flung corners of the Galaxy. Site confirmation for the immense Square Kilometre Array is imminent, while preliminary observations with the high altitude Atacama Large Millimeter Array in Chile are scheduled for 2011. The unprecedented scale of these multinational interferometry-linked arrays promises discoveries that are sure to tempt more astronomers than ever before to think as chemists and chemists, similarly, to develop newfound passions for astronomy.

Dr Tom Gale researched glycopeptide antibiotics for his doctoral thesis and is active in the Bristol Astronomical Society.

▲ A young star cluster in Serpens, imaged by the Spitzer Space Telescope. The wispy red haze is home to organic molecules called polycyclic aromatic hydrocarbons (PAHs) – on Earth you can find PAHs on your burnt toast or from car exhausts! Image: NASA/JPL–Caltech/L Allen (Harvard–Smithsonian CfA)/Gould Belt Legacy Team.

▼ The Horsehead Nebula in Orion, a famous dark nebula. Image: ESO.

Best of British

Is British telescope manufacturing really dead, as some have suggested? **Neil English** finds that claims of its demise are somewhat exaggerated.

▲ The Skylight F/15 points towards the stars of Scorpius under a Mexican Sky. Image Credit: J J Villalobos.

▼ Just one of Orion Optics' innovative products, the AG-12 Newtonian. Image: Orion Optics.

Britain has basked in the noonday brightness of a unique and illustrious astronomical tradition. Thomas Harriot used a crude spyglass to observe the Moon before Galileo. James Gregory fashioned the first reflecting telescope, and Isaac Newton re-invented the wheel, as it were, by creating his own version. The Dollond and Cooke dynasties, founded in the eighteenth and nineteenth centuries respectively, brought achromatic refractors to the world and cultivated them to new heights of sophistication well into the early years of the twentieth century.

Since then, of course, the world has changed and the amateur market today is flooded with inexpensive telescopes made in the Far East. That said, the Sun has never set on the British telescope industry, and a number of firms – both large and small – continue to grace the world with their fine instruments.

Our story begins in Louth, set at the eastern edge of the Wolds, a bustling market town with a maze of narrow streets graced by predominantly Georgian and early-Victorian architecture. This is the hometown of Barry Watts, founder of Beacon Hill Telescopes. Starting out as an amateur telescope maker (ATMer) himself, Watts learned his trade from men of the ilk of Ron Irving and Dudley Fuller, before branching out on his own. Watts has been supplying custom-made refractors, Newtonian reflectors and accessories to the amateur community for the past 28 years. Because the market is saturated with mass produced telescopes up to about 12-inches (300mm) of aperture, Watts now specialises in creating large aperture classical refractors in apertures ranging from six inches (150mm) to eight inches (200mm) as well as super large Dobsonian telescopes in the 18–24 inch (450–600mm) aperture class. He's also made the odd camera obscura or two! Where possible, he sources all of his materials from local machinists. The optics on his large Fraunhofer achromats (f/12 or above) are also made right here in the UK by John Owen of Halifax. Watts himself is no stranger to mirrors either, recently finishing two large Dobsonians of 19- and 21-inch aperture. Indeed, Watts is putting the final touches to an 18-inch reflector to be shipped to Australia, where it is to be equatorially mounted.

Celebrating prestige

Some telescope makers have resisted modernisation and continued to make high quality achromats using materials that are more at home in the nineteenth century than in the twenty-first century. Ian (I R) Poyser of Ceredigion, Wales, offers beautifully designed long focus achromats using British-made objectives mounted inside finely crafted, solid brass optical tubes. These telescopes are purposefully contrived to recreate the experience of observing in a Victorian style. The lens cell is machined from thick-walled brass and provides a secure housing for the air-spaced objective lens. Conveniently, the lens cell is detachable and so can be transported separately from the rest of the telescope. The threaded lens cell has provision provided for a screw-on brass dust cap. supplied as standard with your choice of brass finder telescope (either 7 × 50 or 10 × 50). A pair of adjustable brass rings attaches the finder telescope to the main instrument. Each ring has three adjustment screws (polished brass, of course!) that bear on the finder telescope by means of soft-lined pressure pads. Each telescope is supplied, as standard, with a brass, 35mm Plössl eyepiece. Sales for his masterful telescopes – and they don't come cheap – are divided up roughly fifty-fifty between home and overseas.

In business for over a quarter of a century, Poyser still makes specialist telescope components for customers. Indeed, his company produced brass components for the 0.72 metre refractor at the Royal Observatory, Greenwich and its 150mm guidescope. In addition, Poyser offers his own brand of brass Plössl eyepieces to complement his brazen instruments, as well as optical components such as lenses, mirrors and prisms for the budding ATMer. If that weren't enough, Poyser supplies lens kits to those students who are studying the GCSE

"The Sun has never set on the British telescope industry, and a number of firms continue to grace the world with their fine instruments"

I asked Poyser how he evaluates the optical quality of the objective lenses he fits to his brass tubes. "We do all our testing the traditional way, by conducting a high power star test," he says. "If it doesn't make the grade we won't use it."

Currently Poyser offers two brass refractors for sale: a three-inch (76mm) f/14 and a 4.7-inch (120mm) f/15. The drawtube of the telescope is moved by a single wheel, rack-and-pinion mechanism of similar design to many nineteenth century refractors I've seen or used, and which is completely contained within the body of the telescope. The drawtube has a diameter of 50mm so you'll be able to use two-inch and 1.25-inch eyepieces (with an appropriate adaptor) and a total travel of 100mm. Each telescope is Astronomy course.

I R Poyser is not the only British telescope maker that has derived inspiration from the past. Richard Day, proprietor of Skylight Telescopes, London, has designed a modern incarnation of a Victorian gentleman's Cooke refractor. A relative 'new kid on the block", Day entered the industry in 2007, selling both antique and modern classic telescopes. Sensing the need for instruments that break the mass-market mould, Day decided to re-create a thoughtfully designed classical refractor that combines the best of the old with the new. Called the Skylight f/15, Day designed a very fetching four-inch (102mm) Fraunhofer achromat with a high specification objective well above the diffraction limit.

■ Above and below: Ian Poyser's 120mm brass refractor. Image: I R Poyser (www.irpoyser.co.uk).

▼ Check out the craftsmanship on the Poyser refractor. Image: I R Poyser (www.irpoyser.co.uk).

▲ A technician operates the CNC lathe at Orion Optics, manufacturing their fine telescope tubes. Image: Orion Optics.

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While the fluted objective and brass finder would not look out of place on a nineteenth century instrument, the focuser is a state-of-the-art dual speed Steeltrack Crayford for ultra smooth focusing. Best described as 'neoclassical', the eight-kilogram black and gold Skylight f/15 is designed and assembled by hand in the UK in limited quantities. Where possible, components are sourced from within the UK, including some bespoke parts. The optical tube itself is completely hand-made in England. Because this fine telescope is hand assembled and in the case of some elements, hand-made, each example is individual and indeed, completely unique. Since launching the Skylight f/15 last year, Day has secured orders from within the UK, Canada, the United States and Mexico. The Skylight f/15 is also nowpart of the Las Cumbras Global Telescope Network.

A global success story

Orion Optics is a British telescope manufacturer based in Crewe, Cheshire. Situated near the Bentley automobile factory, the region obviously has no shortage of skilled labour. That might also have something to do with the great success story of company founder Barry Pemberton. Established in 1984, Orion Optics specialises in making certifiably high-quality optics at prices that won't break the bank. Like so many other telescope makers, Pemberton's started out from a humble arrangement in his garage, which he fitted with grinding, figuring and polishing machines, and concentrated on supplying UK telescope retailers with high quality mirrors.

Moving to new premises in 1987, Pemberton built his first complete telescope, a 150mm Schmidt–Newtonian, and the business grew from strength to strength. Sensing a change in the wind, the company invested heavily in state-of-the-art technology as well as some of the finest optical technicians anywhere in the world. To give you an idea of the attention to detail the company go to, each optical surface is tested up to 29 times as it passes through its many processes of being turned from a blank piece of glass to a highly accurate figured mirror or lens.

Today the company, which is now run by Barry's son John Pemberton, occupies a large 650 square metre site and employs a sizeable work force supplying high quality Newtonians (both Dobsonian and equatorial), Maksutov–Cassegrains and optimised Dall–Kirkhams to dealers in nearly 20 countries around the world. In addition, their products have found their way into universities and private businesses the length and breadth of the country. If that is not a success story, I don't know what is!

These are but a few of the nation's unsung success stories. The key to their collective success is a mixture of perseverance, innovation and an erudite reading of market trends. It has been said that Britain's eagerness to produce new telescopes has waned somewhat since the halcyon days of the great telescope workshops of the nineteenth century, but thanks to the efforts of the above companies, she remains a force to be reckoned with.

Neil English's new book Choosing and Using a Refracting Telescope *is published by Springer.*

▶ Mixing the old with the new, the modern two-speed focuser on the Skylight f/15. Image credit: Neil English.


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The Night Sky
January

Look to the east of Orion on January nights and, where you can see the glow of the Milky Way, you are looking at the constellation of Monoceros, the Unicorn. Trying to visualise this mythical animal amongst the dismal fourth magnitude stars that make up the constellation pattern is, to say the least, a challenge. Monoceros would be a vague constellation even away from the Milky Way, but superimposed on top of scores of fainter naked eye stars it can be an almost invisible pattern! Arguably the stellar highlight is the triple star beta (β) Monocerotis, which at magnitude +4.3 may challenge many UK observer's naked eye skills from an urban location.

To find it look first at Saiph, the bright south-eastern star marking Orion's eastern knee. From there, look eight degrees to the east-north-east where you will find gamma (γ) Monocerotis, a star some 650 light years distant and shining at magnitude +4.0. Fainter beta Mon, at –7 degrees declination, is the star three degrees east and three-quarters of a degree south of gamma. Use a small telescope with a decent magnification and it reveals itself as that splendid triple star. William Herschel thought it was one of the finest examples in the sky. All three stars (magnitudes 4.7, 5.2 and 6.1) fit inside a 12-arcsecond diameter circle and appear whitish in colour, with different observers seeing hints of blue and yellow. The stars reside some 700 light years from our Solar System.

Almost twelve degrees to the north (not that far from Betelgeuse) magnitude +4.4 epsilon (ε) Mon is a double star worth pointing a small telescope at too. In this case the system is only 130 light years away and the two stars are magnitude +4.5 and +6.5 with a 13 arcsecond separation. Epsilon lies just half a degree east of the border with Orion and two degrees west of the famous Rosette Nebula and star cluster.

The fourth magnitude star that lives roughly at the centre of Monoceros carries the designation delta (δ) and is an unremarkable object 380 light years distant. Thirteen degrees to its south-east you will find alpha (α) Mon. The fact that the alpha star is only magnitude +3.9, despite living only 140 light years away, speaks volumes about Monoceros! The one remaining constellation pattern star is magnitude +4.4 zeta (ζ), which sits just next to the border with Hydra. At almost 2,000 light years away zeta is a powerful star, but it's just too far away to be impressive.

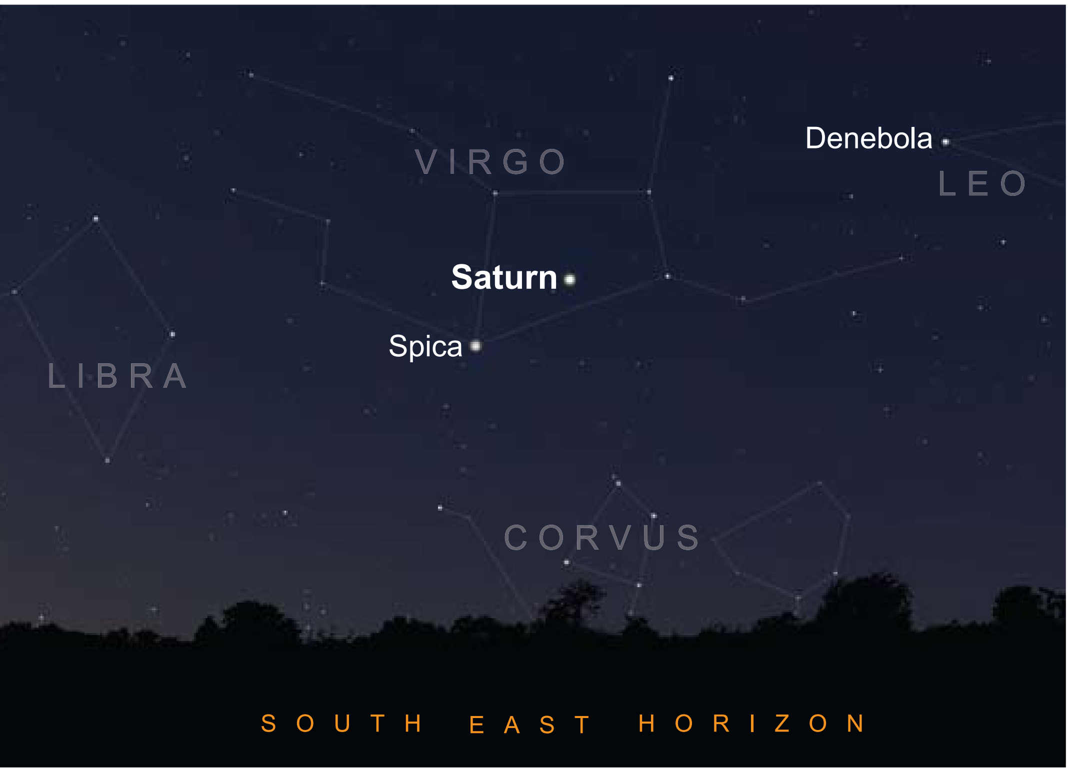
Immediately to the north-east of Monoceros lies the tiny constellation of Canis Minor, whose two principle stars put those of the Unicorn firmly in the shade. These stars are Procyon and Gomeisa. At only 11.4 light years distant the Procyon system is the thirteenth closest stellar system to the Earth and at magnitude +0.34 it is the seventh brightest star in the sky, fitting into the ranking order between the far more distant Rigel (sixth) and Betelgeuse (eighth). In comparison magnitude +2.8 Gomeisa is 170 light years away.

Martin Mobberley

▲ **The Rosette Nebula, imaged in red, green and blue with a one-shot colour Atik 4000 CCD, and additional hydrogen-alpha data. Image: Olly Penrice.**

What's up?

Jupiter's SEB resurgence has already begun, while inner planets delight before dawn and Saturn begins to return to prominence amongst the galaxy-strewn fields of Virgo.



Jupiter's belt is back!

Located in south-western Pisces, Jupiter is approaching the end of what has been a rather memorable apparition, an evening object well worth viewing and imaging. Last year we saw an almost complete disappearance of the planet's South Equatorial Belt (SEB) – a cyclical phenomenon – and a prominent Great Red Spot being passed to the south by the 'Little Red Spot'. A more recent resurgence in bright spot activity within the SEB has now marked the beginning of one of the Belt's famous revivals. Appearing late in this apparition, the SEB revival has produced a notable darkening of the belt that can be followed through relatively small telescopes, as darker clouds have flowed westward in longitude from the point of revival. At the time of writing, the SEB has revived along 100 degrees of its length, and may extend fully around the globe by the time this report is published.

In early January, Jupiter crosses the meridian at an altitude of 37 degrees as the dusk twilight deepens. The young crescent moon glides a few degrees north of the giant planet on 10 January, and passes by it again in the evening skies of 6 and 7 February. By the end of January Jupiter sets in the south-west, around four-and-a-half hours after the Sun.

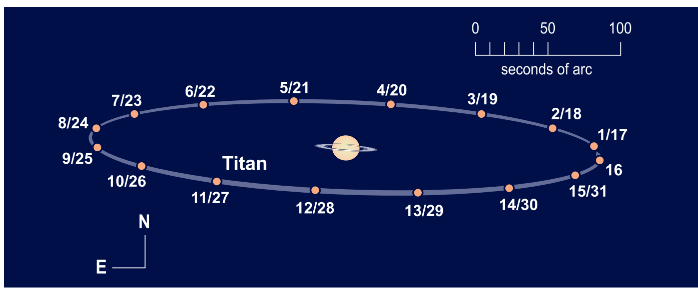
Shining prominently in mid-Virgo, Saturn lies a hand's width to the north-west of Spica (alpha – α – Virginis, magnitude +0.96). The planet's rings and numerous moons continue to delight observers. The moons include its largest moon Titan (see the accompanying chart) and Iapetus, which reaches western elongation on 4 January, when it is at its brightest of magnitude +10. By the end of the month we are seeing more of its dark leading hemisphere, and hence it appears dimmer at magnitude +11.

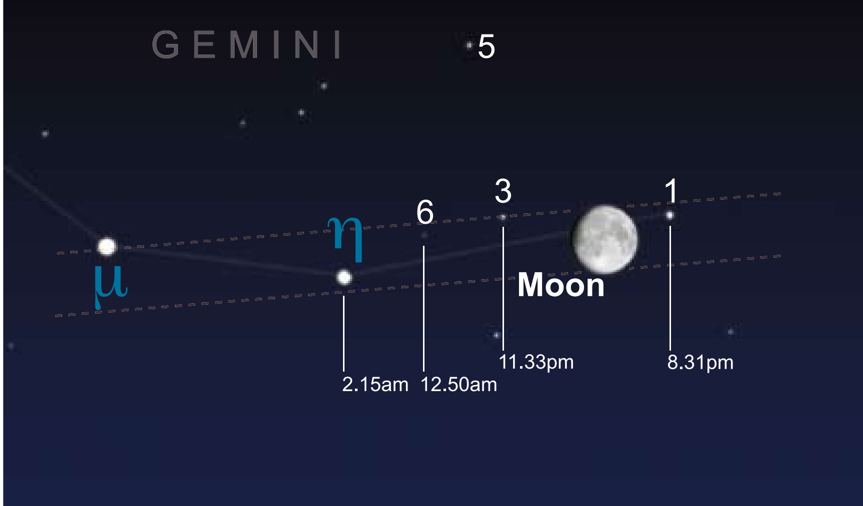
Saturn's rings are now also broadening out as the planet's north pole tilts slowly in our direction, enabling the Cassini Division to be discerned, and perhaps (with at least a 150mm telescope under excellent seeing conditions) giving a lucky few a glimpse of the narrower Encke Gap in the outer A-ring. The shadow of the globe on the rings is broad and obvious, and the shadow of the rings on the globe falls north of the rings. By the end of January Saturn rises at 11pm and transits the meridian at 4:45am, 35 degrees high; this gives around a five-hour window to view Saturn at a good height in dark skies.

Uranus, located in south-western Pisces and shining at magnitude +5.9, remains pretty close to Jupiter and is therefore easier than usual for the more inexperienced observer to locate. On 1 January Uranus lies just half a degree north of Jupiter, and both planets can be discerned as discs in the same field of a medium-power, wide angle eyepiece – say a 200mm Schmidt–Cassegrain telescope at 75×. Jupiter slowly moves east of Uranus, but during the first ten days of January the two planets are separated by less than one degree.

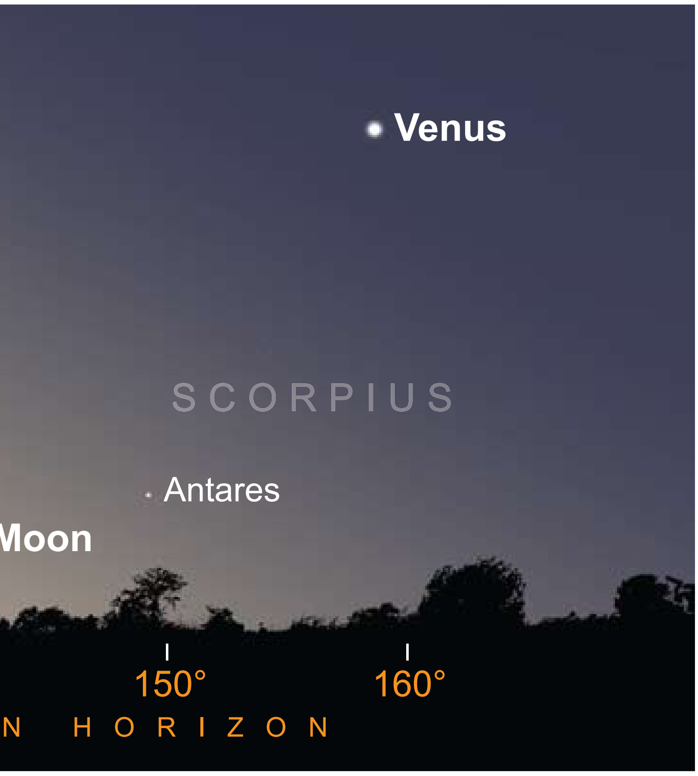
▲ Super Saturn and Spica put on a double act in Virgo throughout the first half of the year in the run-up to the opposition of Saturn in April. AN graphic by Greg Smye–Rumsby.

▼ Titan orbits Saturn once every 16 days, and at magnitude +8 is visible in binoculars or a small telescope. AN graphic by Greg Smye–Rumsby.





■ The Moon will occult several stars in Gemini, including eta, on 18 January. The times shown are for London – the occultation happens a few minutes earlier the further north you travel; in Edinburgh it begins at 2:04am. AN graphic by Greg Smye–Rumsby.



▲ Venus, Mercury and the young crescent moon are visible in dawn skies at the beginning of January. AN graphic by Greg Smye–Rumsby.

The Moon and inner planets

The brightest lunar occultation visible from the UK this month is the disappearance at the dark limb of the waxing gibbous moon (aged 12.8 days) of the star eta (η) Geminorum (magnitude +3.5) on the morning of 18 January. From London the disappearance takes place at 2:15am; from Edinburgh the star disappears at 2:04am.

Mercury is a morning object during January. A slender waning crescent moon, 27.5 days old, passes five degrees south of the planet on 2 January. Mercury reaches greatest elongation on 9 January, some 23.3 degrees west of the Sun, rising in the south-east at around 6:30am and ten degrees high by sunrise just after 8:00am. This western elongation of Mercury isn't the most favourable of apparitions for UK observers, but the planet can be followed above the pre-dawn twilit south-eastern horizon throughout the rest of January as it heads back towards the Sun.

Throughout January and February, Venus is a morning object. The planet reaches its greatest elongation west on 8 January, some 47 degrees from the Sun, rising at 4:15am. On this morning the 26.5-day old crescent moon will lie some 12 degrees east of Venus, presenting a good astrophotographic opportunity. Does the disc of Venus look at dichotomy (half-phase) at this time? The so-called Schröter effect may give rise to a later dichotomy than predicted. Venus slowly moves towards the Sun and sinks towards the south-eastern horizon as the weeks progress, although it will not be too difficult to locate because of its brightness, which is magnitude –4.3 by the month's end.

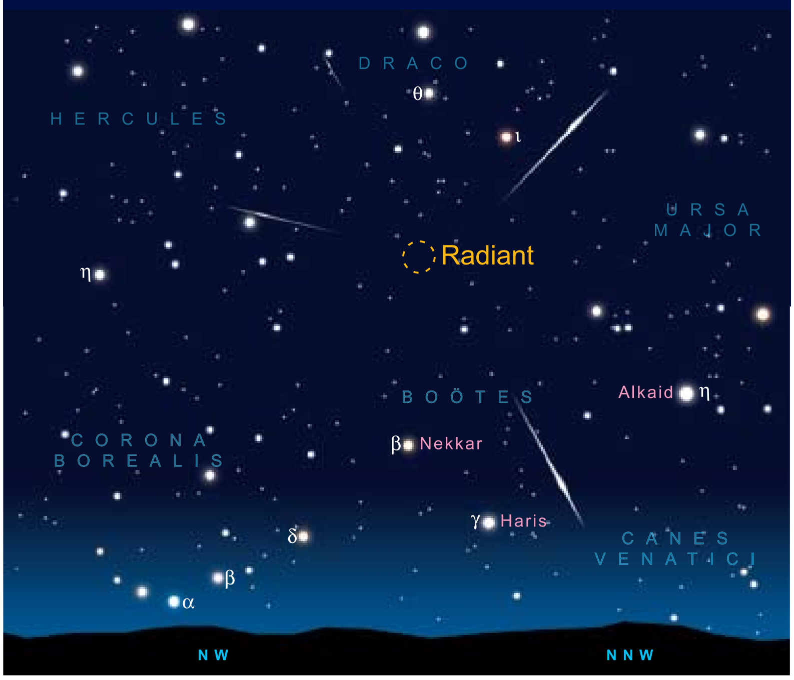
Peter Grego is the author of The Solar System Observer's Guide, *published by Philips.*

The stage is set for the Quadrantid meteors

Active between New Year's Day and 5 January, the year's first annual meteor shower is the Quadrantids, which reach their maximum at around 1am on 4 January when their circumpolar radiant in northern Boötes is at a good elevation. The shower is in favourable skies this year, as the Quadrantid radiant can be observed under Moon-free conditions. Although meteor showers usually take their name from the constellation in which their radiant is located, you won't find Quadrans on any modern star chart. The shower takes its name from a now defunct constellation – Quadrans Muralis, the Wall Quadrant – created by Jérôme Lalande in 1795 and located between the constellation of Boötes and the tail of Ursa Major.

Quadrantid observing is practical from about midnight onwards; although their Zenithal Hourly Rates (ZHRs) vary from year to year, with recent highs of around 120, maximum usually takes place over a short, sharp, time period, so observers need to be alert and vigilant. Remember, if spending any time outside to observe meteors, you need to wrap up warm. A deck chair can provide the most pleasurable viewing angle but be careful not to fall asleep in the cold, and bring a flask out with you to avoid having to go back inside and ruining your dark adapted eyes.

▼ The radiant of the Quadrantids is in a constellation that no longer exists! AN graphic by Greg Smye–Rumsby.



Rising in eclipse

A stunning partial solar eclipse rises on the morning of 4 January, providing a memorable sight for many in the morning rush hour, but remember to view the eclipse safely!

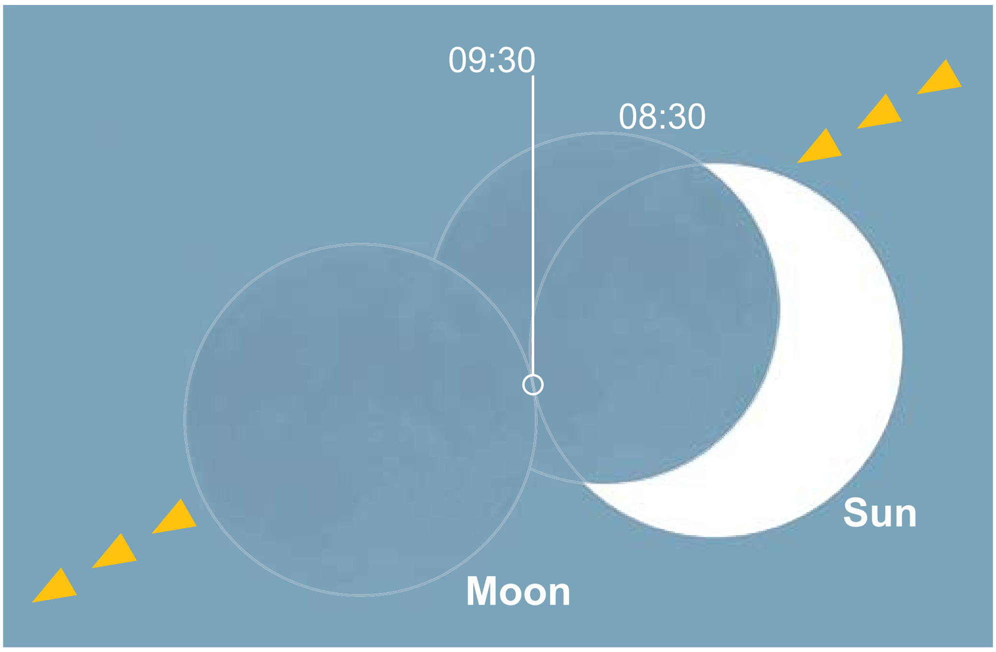
Sunrise on 4 January will appear rather special from the UK, when the crescent of a partially eclipsed Sun will emerge through the wintry haze near the south-eastern horizon. A similar sunrise partial solar eclipse took place on 31 May 2003, producing a spectacle of mystical proportions that viewers will always remember – this eclipse promises equivalent fond memories.

The eclipse begins at 7:02am, more than an hour before sunrise over the UK. Maximum is reached at 8:30am, just as the Sun rises in the south-east, when around 75 percent of the left side of the Sun will be hidden by the Moon (from London). The further north and west the viewing point from the UK, the later the rising time and less the magnitude of the eclipsed Sun will be. From Birmingham, for example, the eclipsed Sun rises at 8:20am and is 73 percent eclipsed; from Glasgow the Sun rises at 8:49am and the coverage of the Sun will be 50 percent.

Atmospheric mist and murk may be thick enough to mask the Sun for some time after sunrise, but given a generally clear sky with an unobstructed horizon there should be plenty of time to enjoy a view of the event as the Moon slowly moves off the Sun's disc (moving to the left). From London, the eclipse ends at 9:30am when the Sun has climbed to around eight degrees above the horizon.

This is the first solar eclipse of 2011, and it occurs at the Moon's ascending node in eastern Sagittarius (a point near the ecliptic when the Moon is moving northwards). Most of Europe, the Arabian Peninsula, North Africa and central Asia will be treated to a partial solar eclipse – but nowhere on Earth is a total eclipse seen. Northern Algeria is first terrestrial landfall of the Moon's penumbral shadow at 6:40am GMT/UT. The shadow moves eastward, producing a partial eclipse over Western Europe. From Madrid, 58 percent of the Sun will be covered at maximum; from Paris, 73 percent, London 75 percent and from Copenhagen 83 percent of the Sun is obscured. Greatest eclipse takes place in northern Sweden at 8:51am where there is 86 percent coverage of the Sun's disc; the centre of the Moon's shadow passes just 510 kilometres above Earth's surface over this point, meaning that any satellites in the vicinity will pass through totality. Further south, the extent of coverage will be less pronounced. From Cairo, 55 percent of the Sun will be covered at maximum, Jerusalem sees 57 percent and Tehran experiences 51 percent coverage. Central Russia, Kazakhstan, Mongolia and north-west China will see the setting of a partially eclipsed Sun. The event ends when the Moon's penumbra lifts off the Earth at 11:01am.

Many unsuspecting viewers on their way to school, college or work that morning may glimpse the spectacle through a misty sky and possibly perceive that they are viewing a rising crescent moon. Such misperceptions have often been reported. Many years ago I once received (in my capacity as SPA Lunar Section Director) a naked eye observation of the crescent moon; I had the sad task of informing the young observer that they had observed the partial phases of a total lunar eclipse, and that they had missed out on seeing a particularly lovely totality!



▼ **The path of the Moon across the Sun during the partial solar eclipse. Maximum is reached at 8:30am, and the eclipse ends at 9:30am. AN graphic by Greg Smye–Rumsby.**

Safe observing

Under normal circumstances, the Sun is a million times too bright to view directly with the unaided eye, so extreme care must be taken when observing the Sun. Because the Sun is low and its light may to some extent be reduced by the Earth's atmosphere during this event, observers may be tempted to dispense with the usual precautions when viewing this event. Even though the Sun may appear safe to view, unfiltered solar light and heat focused into the eye by any optical instrument – however small and however briefly – has the potential to cause eye damage, perhaps producing permanent injury to the retina and, at worst, irreversible blindness. One need only think of the burning power of a magnifying glass to realise what concentrated, focused sunlight might do to an unprotected eye.

Special solar viewing shades using aluminised Mylar filters can be used for viewing partial solar eclipses. If you have a pair left over from viewing a previous eclipse, only use them if they are in good condition and their silvery filters are fully intact – check them for pinholes and if in any doubt throw them away and get some new Mylar filters. Never use these shades while attempting to view the Sun directly through binoculars or a telescope – the heat of the unfiltered Sun will quickly burn through the filters and cause permanent damage to the observer's eyes. Additionally, the shades should never be taken apart and their filters used for makeshift whole aperture filters for very small telescopes such as finderscopes.

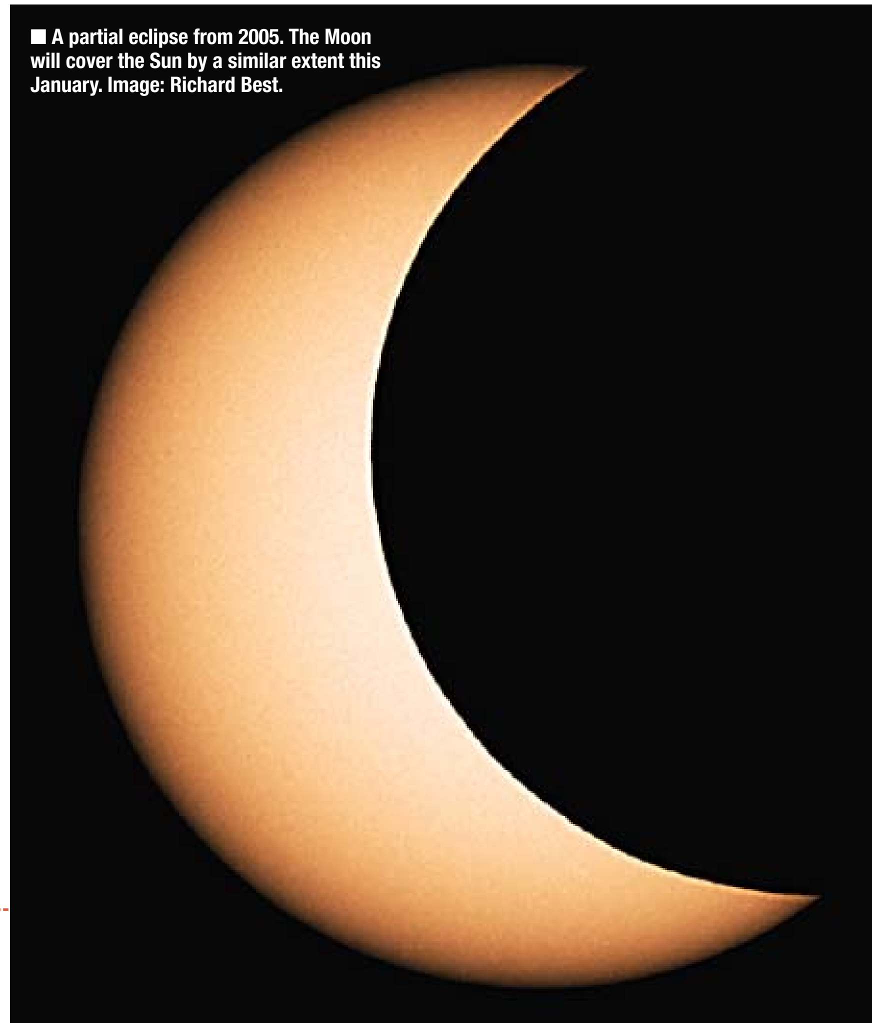
Whole aperture solar filters that cover the lens or corrector plate of the telescope allow the observer to view the Sun safely through the telescope eyepiece, enabling those with camera equipment to image using the prime focus, eyepiece projection or afocal methods. There are two main types of solar filter: aluminised Mylar filters and glass Inconel filters. Both types prevent most of the Sun's light and heat from entering the telescope by reflecting it away, permitting only a safe level of solar energy to reach the eye.

Photography

Since the eclipse will appear so low down, with the Sun partially filtered by the atmosphere, there's an excellent opportunity for the more imaginative astrophotographers among us to capture the event with a wide angle lens and frame it in a photogenic setting, complete with landscape and foreground objects. Well-known landmarks on open ground, such as Stonehenge, the Angel of the North, castles, cathedrals and far-off cityscapes have always proven evocative settings, as have more mundane foreground features like gnarled wintry trees, villages and wind farms – all in glorious silhouette against the dawn sky. Depending on the brightness of the Sun and the camera lens/setting you're using, exposure times will vary; it may be possible to capture the event using an unfiltered lens on a short exposure (say, anything from 1/125 to 1/8 second). One useful tip when producing a wide-angle image is to place the eclipsed Sun to one side of the frame, rather than at the centre; it looks more picturesque this way. It's always important to bracket your images, using a variety of exposures so that at least one of the images presses all the right buttons – and don't forget to send in your best eclipse images to *Astronomy Now*!

Peter Grego is the Director of the SPA's Lunar Section and Assistant Director of the BAA's Lunar section.

■ The rising solar eclipse will make for picturesque images. Image: Greg Smye–Rumsby.



■ A partial eclipse from 2005. The Moon will cover the Sun by a similar extent this January. Image: Richard Best.

Solar watch

Fleeting fly-bys

Observing the Sun can sometimes yield some surprising 'new' features as **Nick Howes** explains.

Solar safety

NEVER look directly at the Sun with your naked eye, and especially not through the eyepiece of an unfiltered telescope, or you risk instant and permanent blindness. The safest method by far is the projection method, or else use specialist solar telescopes like the Coronado Personal Solar Telescope (PST) or filters bought only from reputable dealers. Solar filters should always go on the front of the telescope – never use filters that can be screwed into the eyepiece – and also inspect them first to ensure there are no pinholes.

Firmly in the middle of the season between October and March where the northern lights are more commonly seen, the Sun again seems to be picking up, hopefully yielding some spectacular displays for those heading to northern climes like Norway, and possibly even some dramatic displays from the north of the UK. The Aurora Borealis, or northern lights, is caused by charged particles from the solar wind interacting with Earth's magnetic field lines, causing currents called Birkeland currents to travel towards the poles where they hit the ionosphere, colliding with atoms of oxygen and nitrogen, transferring energy as they do so. The now 'excited' atoms eventually 'relax' and re-radiate the energy back as light.

During late October and early November, our nearest star was throwing off a few medium sized flares (B-Class) in some of the active regions observed, and some dramatic prominences scattered around the limb meant that hydrogen-alpha and Calcium K-line observers had a good month. Let's keep our fingers crossed that solar activity continues to rise and produce some more good aurorae.

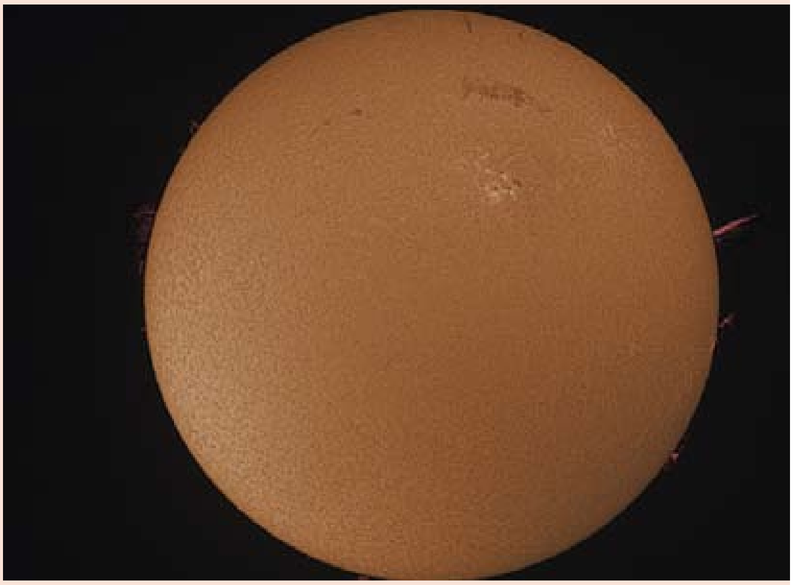
White light is still not back up to speed though, with only a few smallish sunspots gracing the disc. However, all is not lost for the white light aficionado, with some fleeting visitors making for interesting targets of opportunity as they fly across the Sun.

What do I mean? If you visit a website like www.calsky.com (which I use regularly for comet coordinates) you can find transit timings for things like the International Space Station (ISS) as it flies overhead. If you're lucky, and the clouds are playing ball, you may be in the right position on Earth to capture the largest man-made object ever put into orbit as it passes in front of the Sun. Some truly remarkable images of this have made international headlines, with one in particular showing the space shuttle, docked onto the ISS, in quite amazing detail. But even with quite normal equipment, these events (which typically last for a second or two at most, so you have to be ready and imaging with a high frame rate camera) can be caught.

Ideally set up and practice a while before the transit event, and make sure your focus is good on any solar surface features. The ISS will literally fly across the field-of-view, so unless you know precisely where on the solar disc it's going to be, the best approach is a low magnification set-up, encompassing the entire (or as close to) solar disc. In white light, the contrast of the ISS will be clear as it crosses the disc, and whilst the same is true in hydrogen-alpha and Calcium K, at these wavelengths you may be lucky enough to capture the ISS as it crosses over a large prominence, pre-contact with the solar limb. If you do manage to capture this uncommon event, then be sure to send your images in to our *Picture gallery*!

Nick Howes

▼ The International Space Station passing in front of the Sun – a tiny silhouette with the enormous disc of the Sun behind it. The image was captured 10 November 2010 at 2:50pm using a DMK41 camera at 15 frames per second with a Solarscope SV60. Image: Brian Beesley.



▶ The solar disc in hydrogen-alpha showing several prominences, imaged on 27 October 2010 with a Lunt 60 double stacked and a Skynyx 2.1 camera. Image: Sheri Lynn Karl.

Moon watch

Puncture in a pimply rash

Peter Grego explores holes in the Moon – deep pits only just discovered by NASA and Japanese spaceprobes.

Lying in western Oceanus Procellarum (Ocean of Storms) around 300 kilometres south of the Aristarchus Plateau, the Marius Hills region is unlike any other area on the lunar nearside. Marius itself (41 kilometres across) is a flooded crater, rather unremarkable in appearance. However, the terrain to its west is covered by the Moon's most extensive field of volcanic domes. Low magnification on a small telescope will show the area as an ill-defined dusky area, but a high magnification view through a 150mm aperture reveals a stunning collection of at least a hundred domes and remarkable elongated dome-like ridges spread among wrinkle ridges covering an area of about 40,000 square kilometres. One correspondent of mine likened the Marius Hills to a 'pimply rash'.

In late 2009, an entirely new kind of lunar feature was discovered. From its orbit 100 kilometres above the Moon, the high-resolution camera aboard Japan's SELENE (Selenological and Engineering Explorer) probe imaged a circular black spot in the Marius Hills. On closer examination it turned out that this spot, estimated to be 65 metres in diameter, wasn't just a dark splotch on the lunar surface; it was a hole in the surface, around 90 metres deep. It's so deep, in fact, that its interior is only illuminated by sunlight each month, at lunar midday, when the Sun is almost directly overhead of the feature. What could have caused it? Well, the Marius Hills area is known to have been a major centre of late lunar volcanic activity in which lava-formed structures abound. The hole appears to have formed – possibly through a meteoroid impact, or maybe through a natural cave-in – in the roof of a hollow lava tube, the likes of which are familiar to terrestrial geologists. Lava tubes are formed when fast-flowing lava cools at the surface and solidifies, leaving a sub-surface river of lava that creates a cavity once it has flowed along onto the surface. Scientists had long speculated that such features might exist on the Moon, but this was the first proof of their existence.

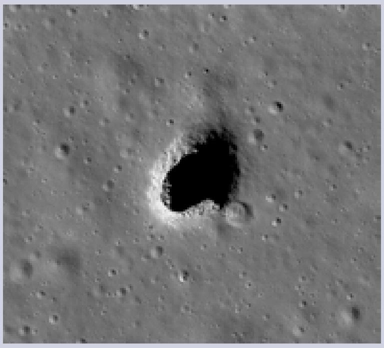
Since then, more lunar holes have been identified, including one in Mare Ingenii (Sea of Cleverness) measuring 130 metres across; oddly enough, this particular hole appears in a relatively smooth tract of mare and on the face of it is unconnected with any lava tube or mare ridge. In 1997 (in *Popular Astronomy* magazine) I wrote a speculative article about 'Endymion', a hypothetical lunar rover that came across such a feature and explored it:

"As Endymion approaches one ridge a ten metre wide cavity is noticed, as if the ridge had been struck by a meteorite and had collapsed on itself. Because the sunlight makes a narrow angle with the edge of the ridge the cavern is in deep shadow. It is essential to explore this feature, as nothing like it has been seen before. At the cavern entrance the rover's searchlight is switched on; the interior recedes into blackness, giving the impression that this ridge is hollow throughout its length! This feature could have been formed when a river of fast-flowing molten lava cooled and solidified on the outer surface yet remained hot and fluid underneath. As the source of molten lava dried up a long tubular cavity was left behind. The interior walls appear to be tightly striated. But no stalactites hang down from this cave, for such features are the result of thousands of years of fluid water depositing minerals, and the Moon is an entirely dry world.

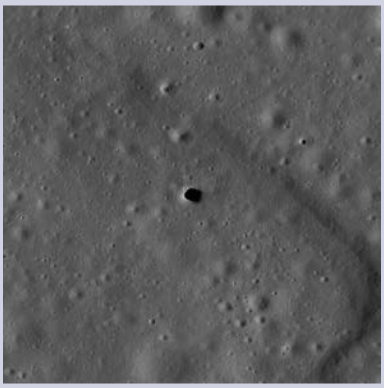
"The cavern floor is piled with sizeable blocks that had fallen from the ceiling, making it impossible to proceed any distance into the cavern. As an experiment the main lights are switched off and the ultraviolet (UV) light turned on. The cameras record signs of fluorescence as certain minerals in the rocks convert UV light to visible light. When the UV light is switched off several mineral pockets continue to emit visible light – a rarer phenomenon known as phosphorescence. As the camera pans around in the darkness an amazing image is seen low down on a smooth section of the wall – it is a clear pinhole projection of the glorious blue gibbous Earth outside. Through a tiny crack in the roof, the cavern is acting as a natural camera obscura!"

Who knows if such a sight might be viewed by robot or astronaut? The chances are that such a scene exists and awaits discovery.

Peter Grego is the Director of the SPA's Lunar Section and Assistant Director of the BAA's Lunar section.



▲ **A pit in the Marius Hills region, imaged by the Lunar Reconnaissance Orbiter. Image: NASA/GSFC/Arizona State University.**



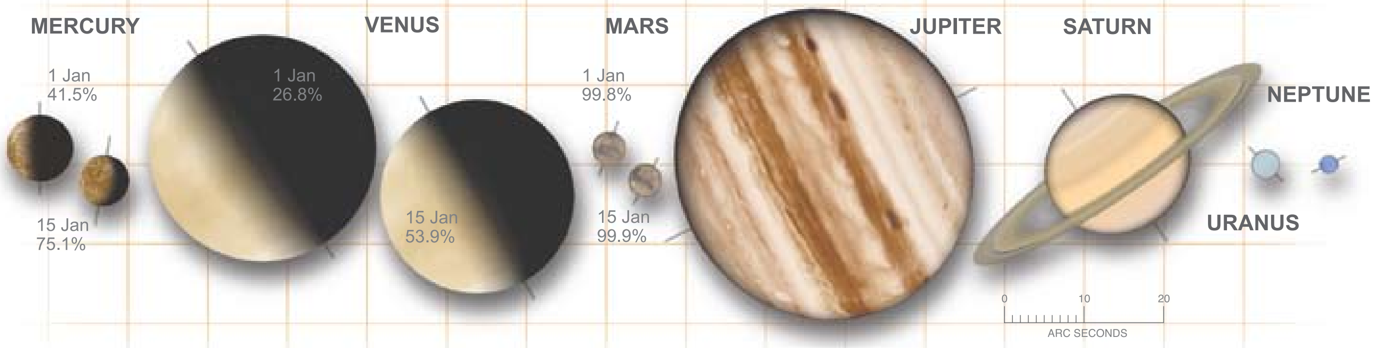
▲ **A pit in Mare Ingenii, imaged by NASA's Lunar Reconnaissance Orbiter. Image: NASA/GSFC/Arizona State University.**

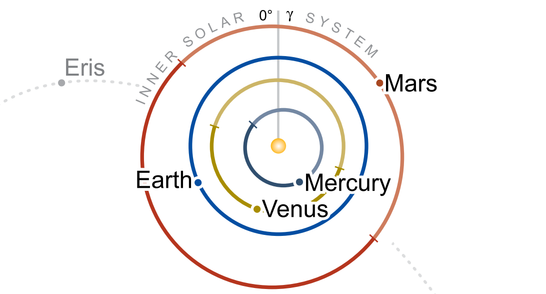
Monitor the Marius Hills

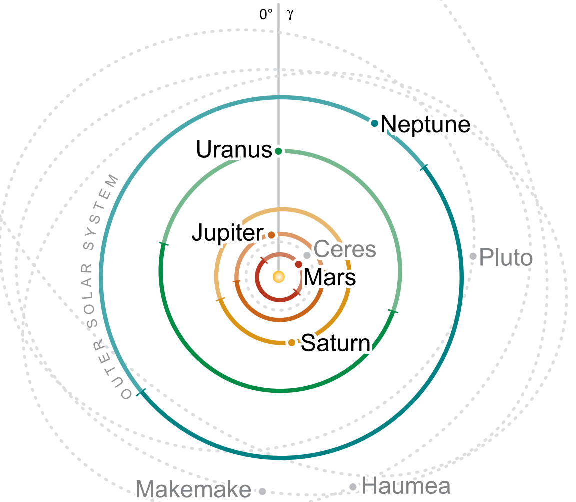
1 January (morning) – Late afternoon illumination over Marius and the Marius Hills.
16 January (evening) – Favourable morning illumination of the Marius Hills region.
31 January (morning) – Marius on lunar evening terminator.

SAT 1
SUN 2
MON 3
TUE 4 New Moon
WED 5
THU 6
FRI 7
SAT 8
SUN 9
MON 10
TUE 11
WED 12 First Quarter
THU 13
FRI 14
SAT 15
SUN 16
MON 17
TUE 18
WED 19 Full Moon
THU 20
FRI 21
SAT 22
SUN 23
MON 24
TUE 25
WED 26 Last Quarter
THU 27
FRI 28
SAT 29
SUN 30
MON 31

The Solar System







Solar System data

	Date	Mag	Size	RA	Dec	Rise	Culm	Set	Dist
Sun	5 Jan	–26.7	32'.5	19h 02.0m	–22° 40'	0804	1205	1607	0.983
	15 Jan	–26.7	32'.5	19h 45.5m	–21° 00'	0759	1209	1621	0.984
	25 Jan	–26.7	32'.5	20h 27.9m	–19° 06'	0748	1212	1637	0.984
Mercury	5 Jan	–0.2	07".3	17h 24.8m	–20° 50'	0617	1027	1438	0.921
	15 Jan	–0.3	06".1	18h 07.9m	–22° 34'	0633	1032	1431	1.112
	25 Jan	–0.3	05".4	19h 06.2m	–23° 05'	0655	1051	1448	1.252
Venus	5 Jan	–4.5	25".7	15h 44.1m	–16° 10'	0408	0847	1326	0.646
	15 Jan	–4.4	23".1	16h 26.1m	–18° 17'	0423	0850	1316	0.722
	25 Jan	–4.3	20".9	17h 11.2m	–19° 57'	0439	0856	1312	0.798
Mars	5 Jan	+1.2	03".9	19h 33.5m	–22° 43'	0838	1236	1635	2.379
	15 Jan	+1.1	03".9	20h 06.6m	–21° 19'	0822	1230	1638	2.378
	25 Jan	+1.1	03".9	20h 39.1m	–19° 32'	0804	1223	1643	2.377
Jupiter	5 Jan	–2.3	38".2	23h 51.3m	–02° 18'	1100	1652	2244	5.150
	15 Jan	–2.3	37".2	23h 57.0m	–01° 39'	1023	1618	2214	5.298
	25 Jan	–2.2	36".3	00h 03.4m	–00° 55'	0947	1545	2145	5.435
Saturn	5 Jan	+0.8	17".4	13h 05.8m	–04° 22'	0027	0608	1149	9.579
	15 Jan	+0.7	17".7	13h 06.9m	–04° 26'	2345	0530	1111	9.414
	25 Jan	+0.7	18".0	13h 07.4m	–04° 26'	2306	0451	1032	9.252
Uranus	15 Jan	+5.9	03".4	23h 51.4m	–01° 43'	1018	1612	2207	20.518
Neptune	15 Jan	+8.0	02".2	21h 58.2m	–01° 43'	0923	1419	1917	30.836
Ceres	15 Jan	+9.0	N/A	20h 32.7m	–24° 54'	0914	1256	1638	3.918
Pluto	15 Jan	+14.5	00".1	18h 23.9m	–18° 50'	0623	1045	1507	32.890
Eris	15 Jan	+18.8	N/A	01h 37.7m	–04° 19'	1218	1759	2340	96.672
Makemake	15 Jan	+17.0	N/A	12h 41.4m	+27° 24'	2015	0505	1351	51.803
Haumea	15 Jan	+17.4	N/A	13h 50.3m	+18° 10'	2229	0613	1354	50.872

Asteroids

(28) Bellona (at opposition on 14 January in Canis Minor)

Date	RA	Dec	Magnitude
5 January	07h 43.41m	+12° 19.3'	+10.2
15 January	07h 34.62m	+13° 17.5'	+10.0
25 January	07h 25.92m	+14° 24.4'	+10.2

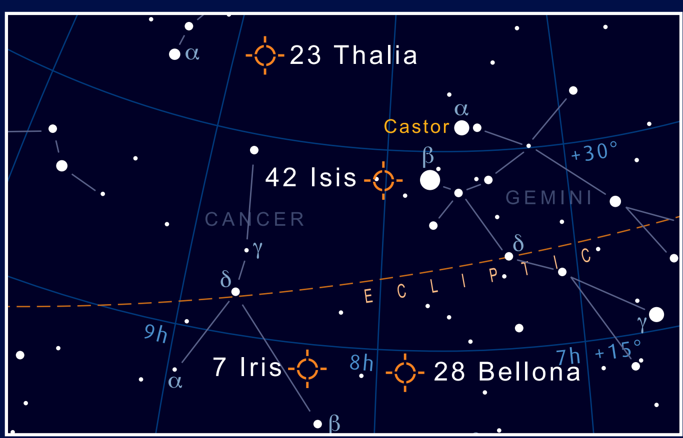
(23) Thalia (at opposition on 22 January in Lynx)

Date	RA	Dec	Magnitude
5 January	08h 47.77m	+32° 37.1'	+9.4
15 January	08h 40.67m	+34° 18.6'	+9.2
25 January	08h 31.43m	+35° 43.0'	+9.1

(7) Iris (at opposition on 24 January in Cancer)

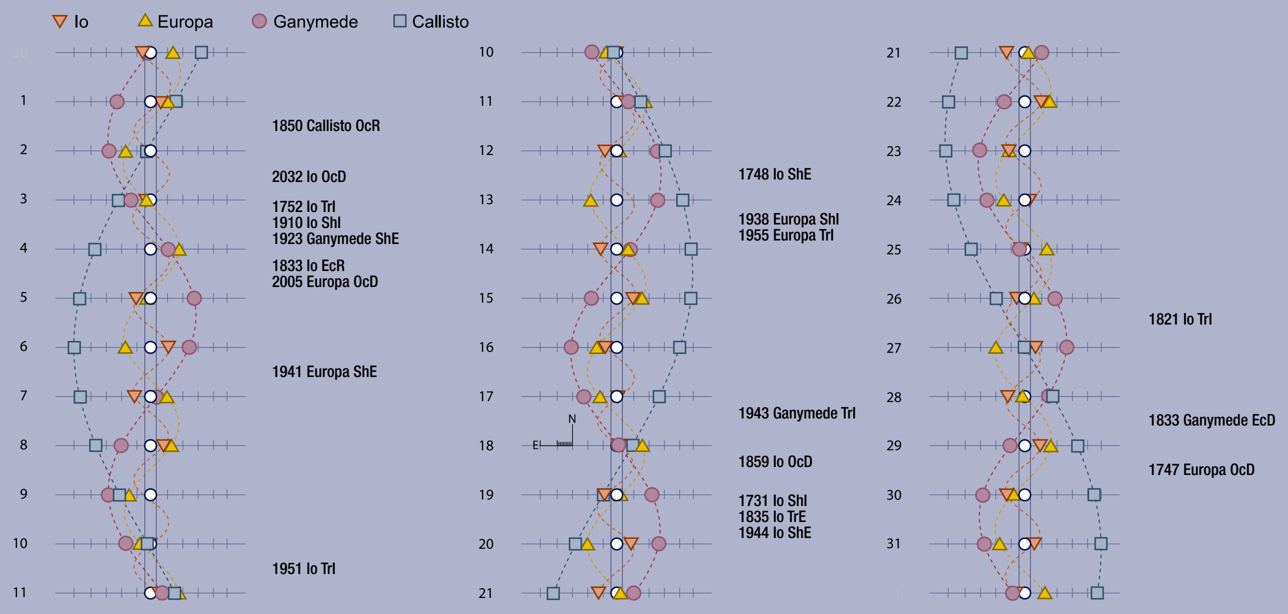
Date	RA	Dec	Magnitude
5 January	08h 38.21m	+12° 11.8'	+8.2
15 January	08h 28.08m	+12° 13.8'	+8.0
25 January	08h 17.02m	+12° 27.1'	+7.9

■ Asteroids at opposition in January. AN graphic by Greg Smye–Rumsby.



Jupiter's Galilean moons

Each of Jupiter's four largest moons – Io, Europa, Ganymede and Callisto – will at times cross in front of (transit) Jupiter, as will their shadows. The moons will also pass behind Jupiter (an occultation). Dates are marked at midnight at the start of each day. All times are GMT. Key is as follows: OcD (moon moves behind Jupiter's limb, disappears in occultation); OcR (moon moves out from behind Jupiter, reappearing from occultation); EcD (moon moves into Jupiter's shadow and is eclipsed); EcR (moon moves out of Jupiter's shadow); TrI (moon starts transit, moving across Jupiter's disc); TrE (moon ends transit); ShI (moon's shadow starts a transit, moving across Jupiter's disc); ShE (moon's shadow ends transit).



Deep sky challenge: NGC 1514

In the latter part of the eighteenth century most astronomers believed that the nebulous objects found by Messier and others were merely unresolved star clusters that would be resolved if only larger telescopes were available. Yes, aperture fever existed even then! However, there were a few nagging exceptions such as the Orion Nebula, in which changes were believed to have been seen. Then, in 1791, William Herschel discovered an object in Taurus that he described as "a most singular phenomenon". Here he saw a nebulous object surrounding a star and he had no doubt they were associated. This object, which was later catalogued as NGC 1514, was placed into his category of class IV objects, or planetary nebulae. Sometimes known as the Crystal Ball Nebula, NGC 1514 is a large faint planetary nebula about 1.5 times the size of M57. In physical terms NGC 1514 is a moderately high excitation planetary nebula and the central star seen in images is not the one that formed the nebula. The true source of the nebula must be a companion to the observed central star and hence the system must be a binary. The planetary itself consists of a number of bubbles and recent infrared observations from the WISE satellite have shown a completely unexpected pair of rings around the object visible only in infrared light.

To the visual observer with a medium-sized telescope this is quite a faint object and views will be enhanced by using a UHC or O III filter. Owners of a large telescope will be able to see quite a lot of structure in the nebula using an O III filter. The faintness and size of this object does mean that clear dark skies are required to bring the best of it out. I would also use a low or medium power eyepiece when observing it. For imagers the challenge is to bring out the faint outer halo around this object and the internal structure.

■ The planetary nebula NGC 1514. Image: Jim Misti.

Owen Brazell

Sky scene

The Moon

All times GMT/UT.

NEW	FIRST	FULL	LAST
5 January	12 January	19 January	26 January
9:03am	11:31pm	9:21pm	12:57pm
Rise: 8:07am	**Rise**: 10:20am	**Rise**: 4:15pm	**Rise**: 12:46am
Set: 4:21pm	**Set**: 12:25am	**Set**: 7:28am	**Set**: 10:07am

	Date	Time	Distance	Diameter
Apogee	10 January	5:39am	404,975km	29' 30"
Perigee	22 January	12:09am	362,794km	32' 56"

The planets

Mercury reaches greatest elongation west (23 degrees) on 9 January and this is one of the best morning apparitions for the UK.

Venus reaches greatest elongation west (47 degrees) on 8 January and is a brilliant sight in the morning sky.

Mars is too close to the Sun to be seen.

Jupiter is an early evening object setting by 9:30pm at the end of January.

Saturn is an improving morning object, rising by midnight mid-month.

Uranus is close to Jupiter all month, with a very close conjunction on 2 January.

Neptune is an early evening object that becomes a difficult proposition in the second half of the month.

Dwarf planet Pluto technically reappears in the morning sky but is really too close to the Sun to be easily seen.

Dwarf planet Ceres is in conjunction with the Sun on 31 January.

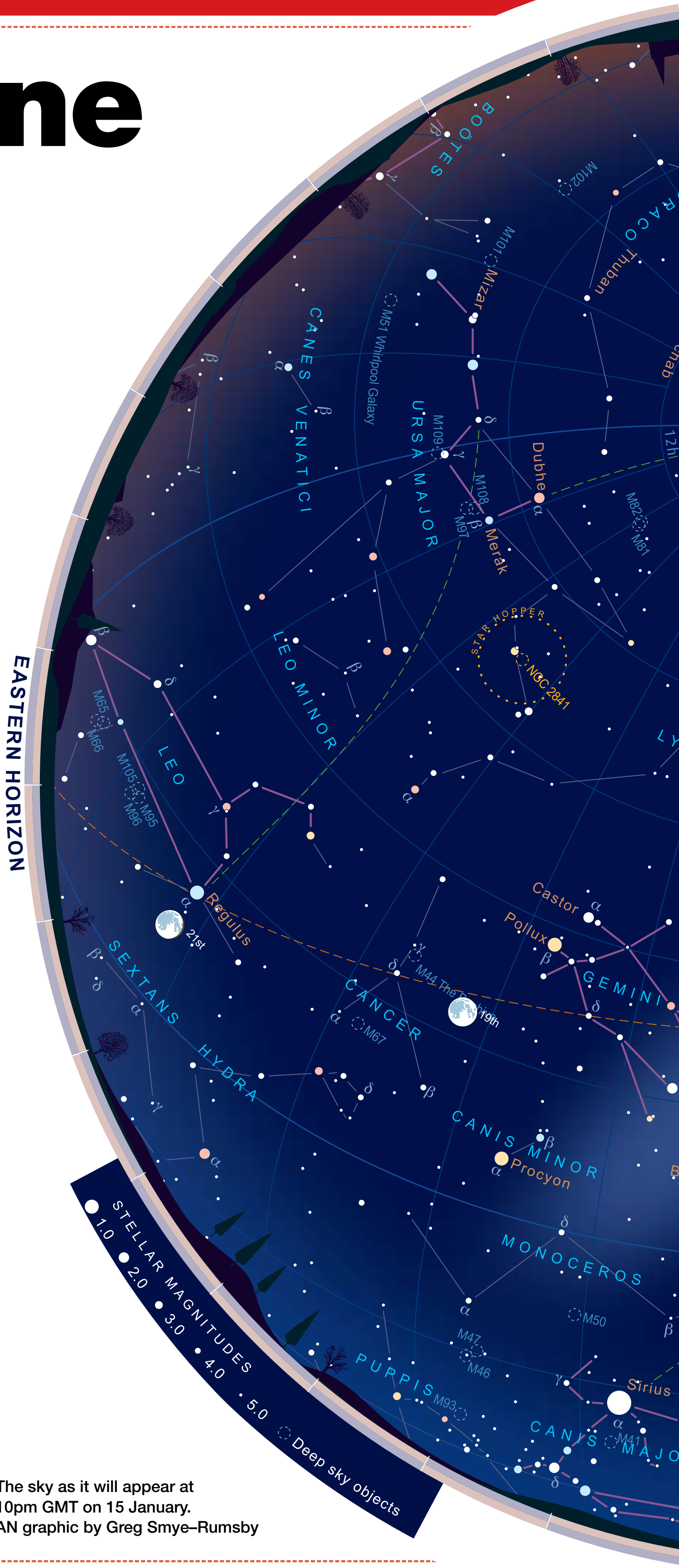
Dwarf planet Eris is an evening CCD object in Cetus.

Dwarf planet Makemake is a CCD object in Coma Berenices.

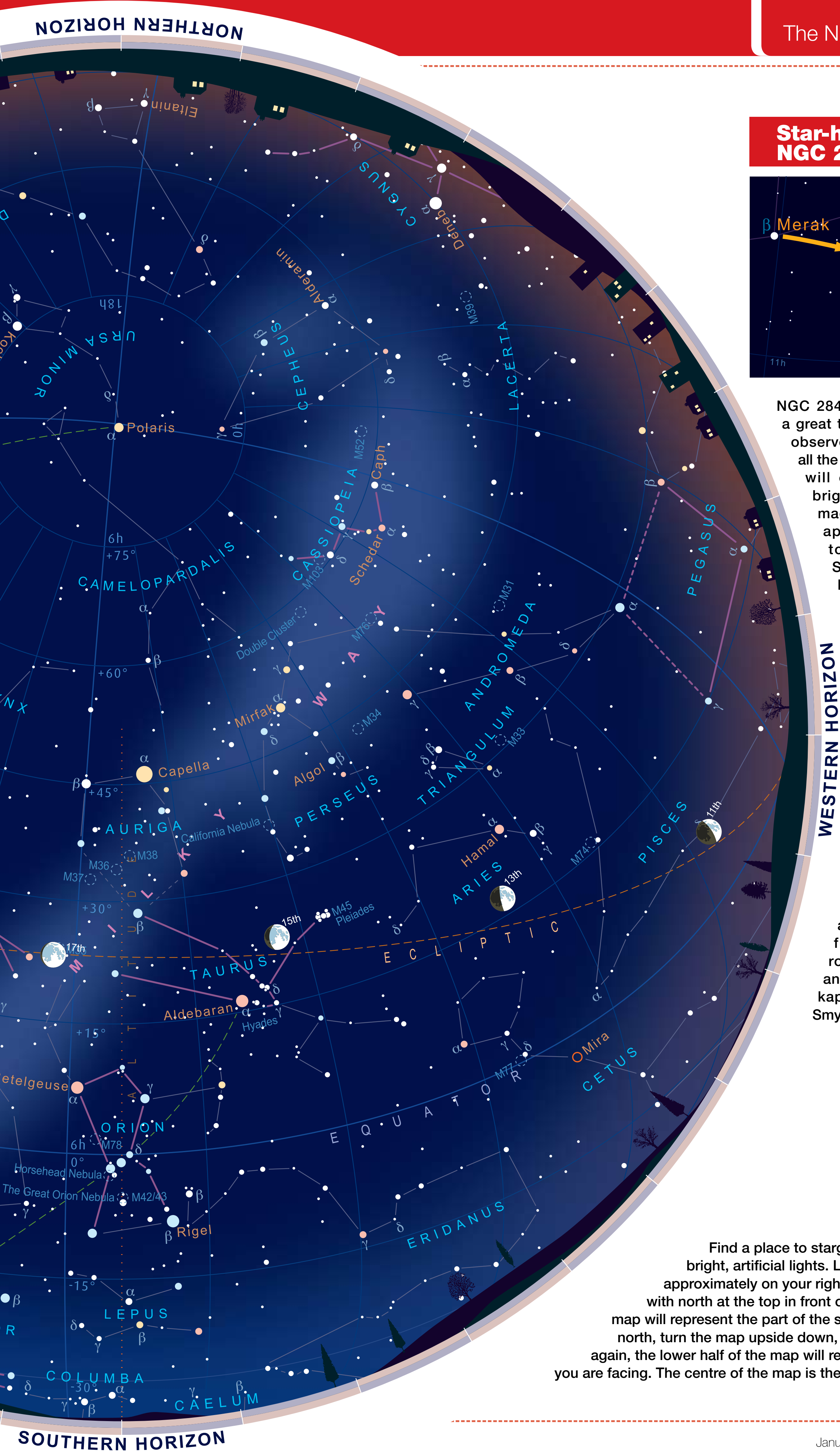
Dwarf planet Haumea is a CCD object in Boötes.

January phenomena

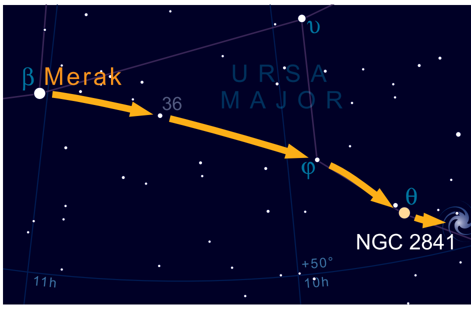
2	2pm	Jupiter is 0.6 degrees south of Uranus
	3pm	Mercury is four degrees north of the Moon
3	7pm	Earth is at perihelion
4	1am	Quadrantids meteor shower peak
	9am	Partial solar eclipse (Sun in eclipse at sunrise in UK)
	6pm	Saturn's moon Iapetus is at greatest western elongation
8	12am	Neptune is five degrees south of the Moon
	4pm	Venus reaches greatest western elongation (47 degrees)
9	3pm	Mercury reaches greatest eastern elongation (23 degrees)
10	3pm	Uranus is seven degrees south of the Moon
	5pm	Jupiter is seven degrees south of the Moon
11		NEO 2000 AZ93 (magnitude +15.8) makes a close approach of 3.4 lunar distances (0.0477 AU)
15	10pm	Venus is eight degrees north of Antares
17		Comet 9P/Tempel at peak brightness (mag +13)
22	11pm	Asteroid (3) Juno is stationary
24		Asteroid (7) Iris at opposition (magnitude +7.9)
25	10am	Saturn is eight degrees north of the Moon
27	8am	Saturn is stationary
30	4am	Venus is three degrees north of the Moon
31	1am	Ceres is in conjunction with the Moon



The sky as it will appear at 10pm GMT on 15 January. AN graphic by Greg Smye–Rumsby



Star-hopping: NGC 2841



NGC 2841 is big and bright and a great target for those pining to observe a nice galaxy amongst all the nebulae. Small telescopes will easily show the small, bright nucleus of this tenth magnitude galaxy but large apertures will be needed to see spiral structure. Start the star-hop from Merak (beta – β – UMa), the second magnitude southernmost pointer star in Ursa Major, and it's basically a sweep south-westwards to the Great Bear's forepaws, marked by theta (θ), iota (ι) and kappa (κ). Four degrees from Merak is magnitude +4.8 star 36 UMa and six degrees further on is magnitude +4.6 star 30-phi UMa. The close pairing of theta (magnitude +3.2) and 26 UMa (magnitude +4.5) is 3.75 degrees south-west from phi (φ) and almost two degrees further on is NGC 2841, roughly in between theta and the pairing of iota and kappa. AN graphic by Greg Smye–Rumsby.

Finding your way around

Find a place to stargaze, preferably away from bright, artificial lights. Look south (the Sun will set approximately on your right). By holding the star map with north at the top in front of you, the lower half of the map will represent the part of the sky you are facing. Looking north, turn the map upside down, so that south is at the top; again, the lower half of the map will represent the part of the sky you are facing. The centre of the map is the zenith (directly overhead).

Drawn to the Universe

A careful sketch of astronomical objects from different sites can reveal the depth of light pollution in your area, says **Jeremy Perez**.

▲ **Plot the star field, then use an artist's chamois to lightly shade the overall shape of the nebula. Use a blending stump to apply graphite to the brighter portions of the nebula, and then add the fainter structures. Use the star field as a guide when positioning these features.**

While the brilliant winter constellations sparkle overhead, the lights of our cities, highways and neighbourhoods compete from below. The unfortunate reality of deep sky observing is that most observers need to travel long distances from home to enjoy rich views of these delicate, distant wonders. Raw numbers can be used to quantify light pollution's effect on the night by using star counts, naked eye limiting magnitudes, sky quality meter measurements, or the Bortle dark sky scale. Photographs of the night sky comparing the dark countryside to bright urban settings can also do much to dramatically depict the effects of light pollution.

Since our eyes respond to these sights differently than a camera records them, sketching also becomes an excellent way to show how seriously our views are compromised. Drawing the same field from a dark site and again from a light polluted site, can clearly demonstrate the effect a bright sky has on these objects. Not only will such an exercise generate a reference of views from dark and light polluted sites for your own records, but you can also use those sketches to easily describe the effects to others.

To demonstrate this process, we will delve into winter's deep sky showpiece, the Great Orion Nebula (Messier 42 and 43). The sheer complexity of this nebula means that it can be a challenge to sketch. However, this intricacy and the great dynamic range it possesses make it an excellent gauge of sky brightness.

A list of suggested materials for such a sketch is as follows:

- White, acid free sketch paper
- HB and 2H graphite pencils
- White vinyl eraser and putty rubber
- Blending stump and artist's chamois
- Transfer tracing paper
- Clipboard and adjustable red observing light
- Optional digital processing with *GIMP* or *Photoshop*.

In this example, we will start with a sketch of M42 and M43 as observed from a dark observing site. Under dark, clear conditions, the Orion Nebula is a beautifully complex, mottled bowl, punctuated along its north-eastern hemisphere by bold, arching wings emerging from the brilliant box of nebulosity surrounding the Trapezium. Sketching this magnificent sight is no small task, but well worth the effort.

Field stars first

Begin by plotting the star field with HB and 2H pencils. Start with the brightest stars (HD lead), and then use these stars to estimate the position of fainter ones (2H lead). As usual, working from wider arrangements of stars to closer arrangements will help place them more accurately. Next, examine the nebula's position across this field, noting which stars it embraces and which rest just outside its enormous grasp. An artist's chamois is a great tool for defining its soft, broad, overall shape. Scribble a dark patch of graphite with your HB pencil on an unused stretch of paper. Brush the chamois in this patch to load it with graphite and then lightly apply it to the sketch to shade the nebula's overall shape.

Now that the large, soft form of the nebula is in place, switch to your blending stump. Load it with graphite from the scribbled patch you just made and begin shading some of the more crisply defined sections of the nebula. Use the field stars to guide your placement of these features. For example, the eastern wing appears to peel away from a linear trio of

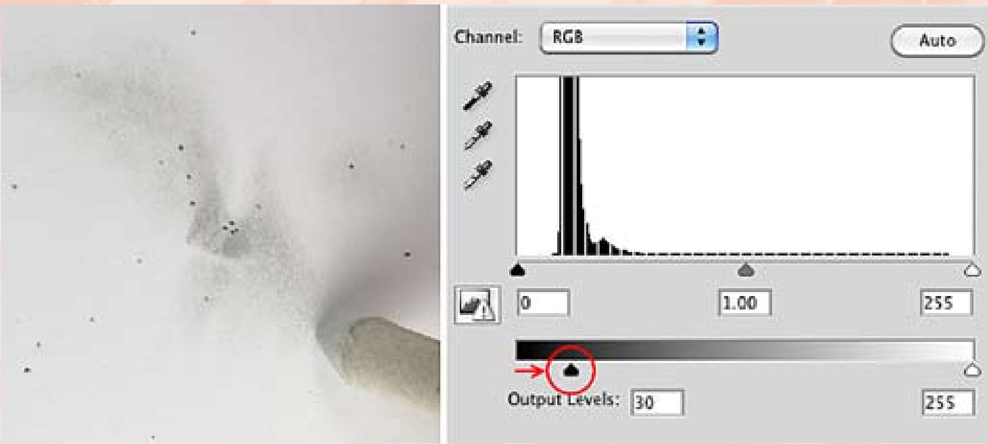
▶ **Use a 2H pencil to darken and harden the edges of the nebulosity surrounding the Trapezium. Optionally use the blending stump to lightly apply a halo of glare around the brightest stars.**

stars (Theta-2 Orionis) just east of the Trapezium and to curl around and encompass a triangular group of stars on the eastern edge of the nebula.

Finish defining the brighter features, including the comma-like shape of M43. Then work your way systematically around the nebula lightly adding the more delicate, softly defined features you encounter. Try to pick out as many details as possible so that your sketch captures all the wealth a dark sky has to offer.

Once these features are in place, you may need to refine their brightness to better convey the nebula's huge dynamic range. If necessary, apply more shading to the wings and M43. The box-like nebulosity surrounding the Trapezium is not only bright, but also possesses some very hard edges that a blending stump may not handle well. Try using your 2H pencil to darken it further. By using light, short strokes, you can darken it and give it more crisply defined edges. Look for irregularities in brightness as you do this so you can give a sense of its crumpled complexity.

Look around the star field and adjust the brightness of any stars that were dulled during the shading process. Some of the stars here are very bright. Applying a light halo around them with your blending stump can help portray that brilliance in your finished sketch. At some point during your observation, take a moment to estimate or measure the local sky brightness and include that information in your observing notes.



▲ **Trace your original star field on a new sheet of paper to make your comparison sketch. Use a blending stump to shade the nebula as it appears under more light polluted conditions. After scanning and inverting your sketch, use the 'Levels' tool to brighten the background of the light polluted sketch by moving the black 'Output Levels' slider to the right.**

Making a comparison

Before heading out to make your comparison sketch, take advantage of all the hard work you put into the star field of your original drawing. Use transfer tracing paper to trace the brighter stars from your original sketch onto a new sheet of paper and take this template with you when you make your next sketch under a brighter setting.

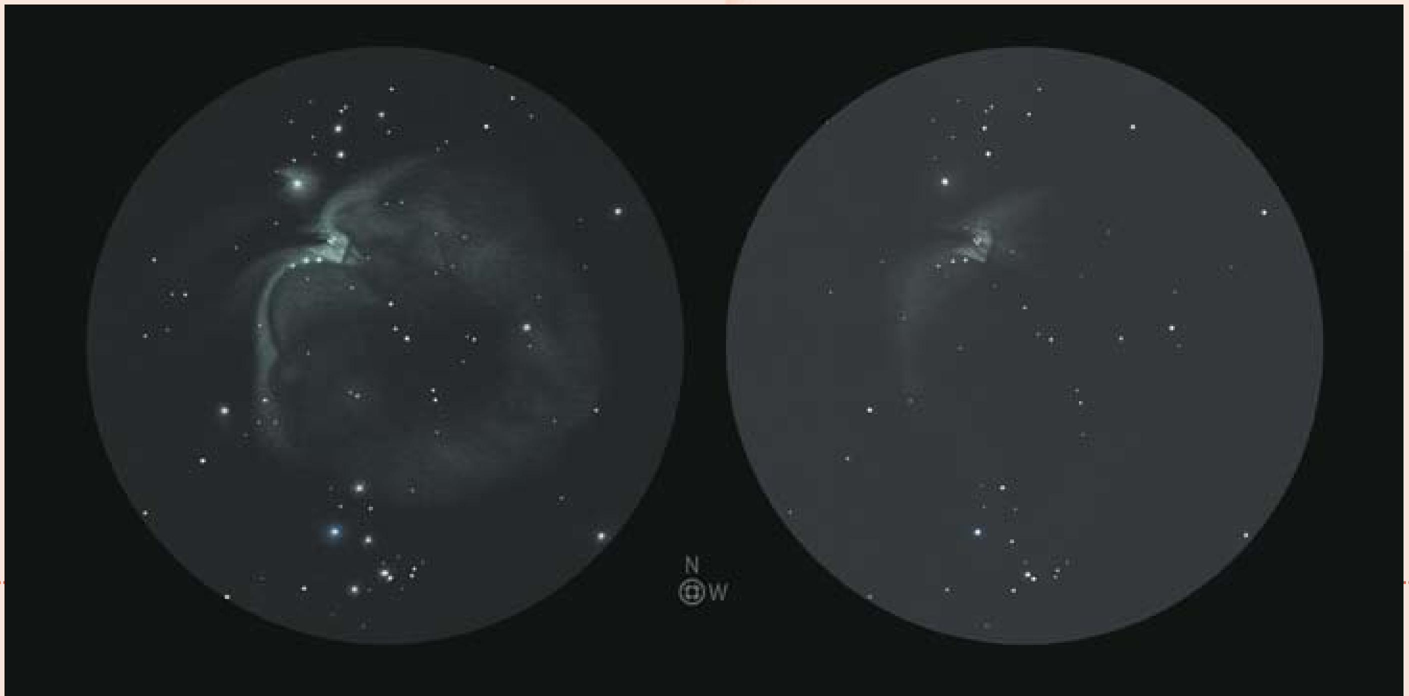
Begin your comparison sketch by plotting any stars you did not include when you made your template or erase any that you don't see in the eyepiece. Stars that appeared brilliant under a dark sky may now seem stifled by the brighter background. If so, don't plot them as boldly. When your star field is ready, take your blending stump and use the same shading process as before to create the nebula. Be sure to estimate or measure the sky quality and describe it in your notes.

If you plan to scan and invert your sketches to be displayed as positives, you can take things a step further. The 'Levels' or 'Curves' adjustment tools can be used to brighten the background of the light polluted sketch to give a better sense for how it appears in the eyepiece. If you noticed colour in either view, you can also apply that with a paintbrush set to 'Colour' mode.

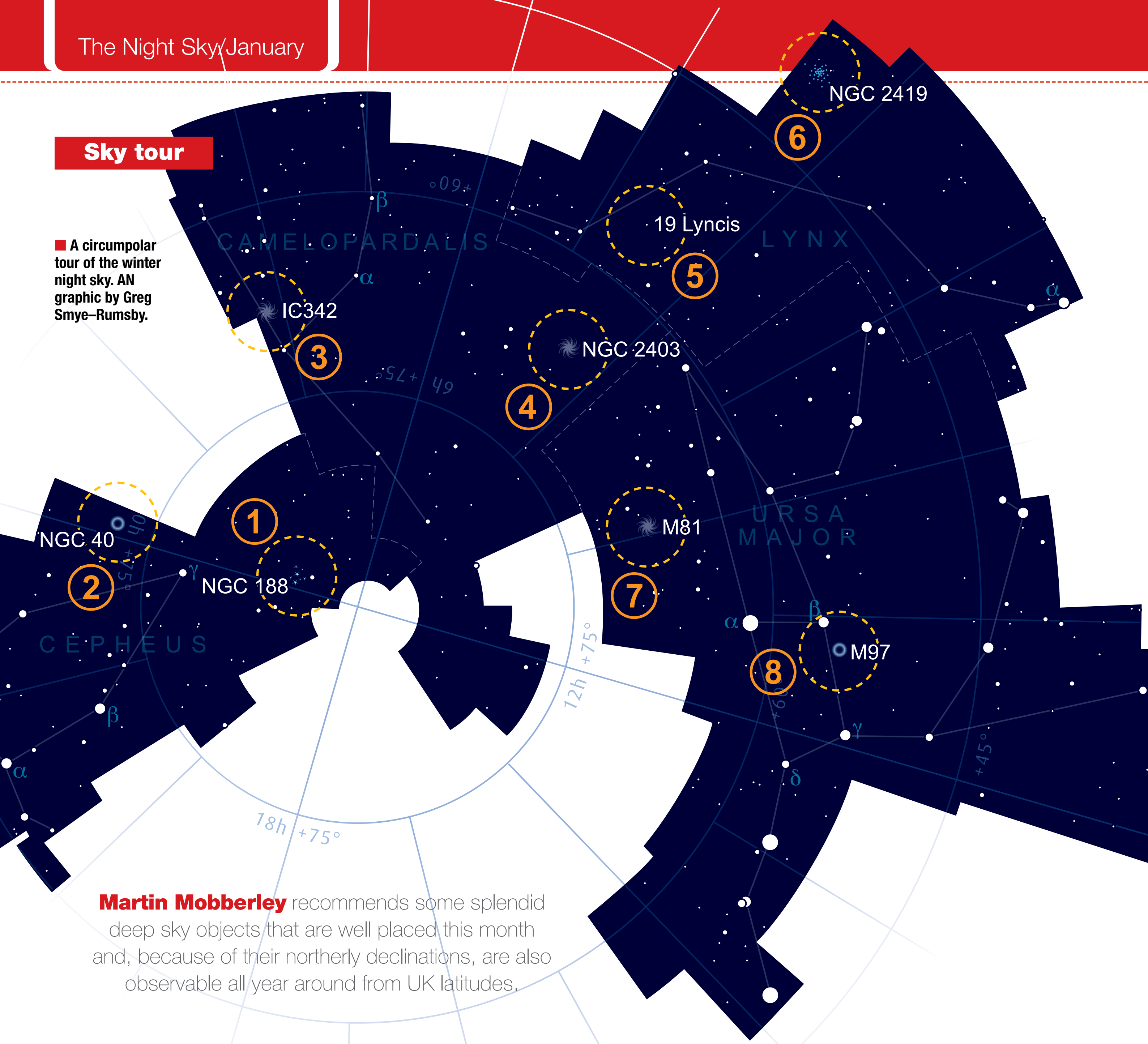
As enlightening as this process is on a personal level, your sketches can also become a helpful resource for others to see the enormous effect light pollution has on our ability to examine and enjoy the remarkable universe that surrounds us. If you create a set of comparative sketches under dark and light polluted conditions, please consider sharing them at gallery2011@astronomynow.com. Meanwhile, observers interested in completing the Astronomical League's Dark Sky Advocate Club can use this sketching process to meet one of the club's objectives to sketch five deep sky object types under three different lighting conditions. Visit www.astroleague.org for more information.

Jeremy Perez is a graphic artist from Arizona and is the co-author of Astronomical Sketching: A Step-by-Step Introduction*, published by Springer. Visit his website at www.beltofvenus.net.*

▼ **The final positive sketches of Messier 42 and 43 observed with an Orion SkyQuest XT8 (8-inch f/5.9 Dobsonian) at 37.5x. Left: As observed from Sunset Crater National Monument, Arizona (SQM 21.7 mag per square arcsecond). Right: As observed from the light polluted heart of Phoenix, Arizona (SQM 18.2 mag per square arcsecond). All images: Jeremy Perez.**



Sky tour



■ A circumpolar tour of the winter night sky. AN graphic by Greg Smye–Rumsby.

Martin Mobberley recommends some splendid deep sky objects that are well placed this month and, because of their northerly declinations, are also observable all year around from UK latitudes.

A circumpolar jaunt

Strangely, many of the far northern deep sky objects that are well above the UK horizon for the whole year (so-called circumpolar objects) are the least viewed. Maybe this is because many British amateurs make a good south-facing observatory their top priority and find a tall tree always blocking their north horizon? One seriously neglected circumpolar object is the first one on our tour, NGC 188 ① in Cepheus. This dim open cluster is rarely viewed and I'm ashamed to say that after 40 years of stargazing I only observed this ancient object for the first time in October 2008. The BAA Deep Sky Section Director Stewart Moore promptly told me that it was the only observation of it in the BAA database, which made me feel slightly better! Find Polaris first and from there glide four degrees south, towards the 'W' of Cassiopeia. At +85° 15' this is a very northerly object indeed, but one that is easily visible all year. NGC 188 is a five billion year old open cluster some 14 arcminutes across and with a magnitude of +8.1. Unfortunately it contains mainly thirteenth and fourteenth magnitude stars which will only reveal themselves well in apertures of 250mm and larger. However, the cluster does have a certain attraction, if only because it is so ancient.

Slide thirteen degrees south of NGC 188 and you will arrive at the 'Bow-Tie' nebula, also in Cepheus, and designated as NGC 40 ②. This is a planetary nebula, but don't expect it to look like Lyra's Ring Nebula, M57. At twelfth magnitude it's a faint one. It has a width of 40 arcseconds with bright arcs only at the eastern and western edges, hence the 'Bow-Tie' nickname. However, NGC 40's central star is relatively bright, at around magnitude +11.6, but it does tend

to swamp the nebula completely at low powers. A decent aperture and at least 200× will be needed to get the most out of this object, but an Ultra High Contrast (UHC) filter will enhance the nebulosity significantly.

For our next object we are heading more than three hours east, jumping over Cassiopeia and ending up in western Camelopardalis at a declination of +68 degrees. It is here that we will find the large and bright galaxy IC 342 ③, which transits around 8pm in mid-January and spans more than 20 arcminutes. The earliest known reference to it appears to be by the British comet discoverer W F Denning, in the early 1890s. You might expect an eighth magnitude galaxy to be an impressive sight, but it's not. The spiral arms are just too ghostly compared to the galaxy core, but it is still a must-see large 'faint fuzzy'.

Now for a much more impressive object: the magnificent galaxy NGC 2403 ④. Being a further four hours east in right ascension than IC 342, NGC 2403 will transit close to midnight by mid-month. At magnitude +8.4 and spanning 23 × 12 arcminutes this too is one of the larger galaxies in the northern sky, thanks to its proximity of just eight million light years. At magnitude +8.1 it's nice and bright too, and yet, strangely, NGC 2403 was not catalogued by Messier. Seven years ago the eleventh magnitude supernova 2004dj, discovered by the tireless Japanese hunter Koichi Itagaki, became one of the brightest in recorded history. Its light curve in decline is one of the best recorded by amateur astronomers. In colour CCD images a steely blue spiral structure is visible with subtle pink hydrogen regions signifying the star forming H II regions. It's a stunner!

Moving ten and a half degrees due south now, it's time for something completely different: a pretty double star, visible in small telescopes, namely 19 Lyncis or Struve 1062 ⑤. You will find this object at RA 7h 22m 52s, Dec +55° 16' 52". Lynx is not the most exciting constellation and you might regard 19 Lyncis as its high point! However, as the constellation pattern is so vague you may need setting circles or experienced star-hopping to pin it down. The star system consists of two bright Albireo-like components of magnitude +5.5 and +6.5, separated by 15 arcseconds, and with an obvious yellow/blue colour contrast. Almost four arcminutes due north of the main pair is an eighth magnitude star and one arcminute to the west-north-west a star slightly brighter than magnitude +11.0 completes the eyepiece view.

Staying in Lynx, but plunging more than 16 degrees south, will get you to the next object in this tour, the globular cluster NGC 2419 ⑥. It lies seven degrees north of Gemini's bright star Castor. At a declination of +38° 53', you may challenge my definition of circumpolar here! Well, it is circumpolar if you live north of +51° 07'! At magnitude +10.4 and with sixteenth magnitude stars this is not the most awesome globular cluster in the northern sky. M13 is a hundred times brighter! However, before you decide it's not worth a look, bear in mind it lives a staggering 280,000 light-years away. NGC 2419 is a huge inter-galactic freak: a massive globular more distant than the Magellanic Clouds! For that reason alone it's worth rooting out.

We will round off this tour with a few more Messier objects. First, let us dig out that famous galaxy duo of M81 and M82 ⑦. Living in the north-western corner of Ursa Major, some ten degrees north-west of Dubhe, you can just squeeze the two into a one degree field, with the elliptical profile of magnitude +6.9 M81 to the south and the smaller edge-on, magnitude +8.4, M81 to the north. Spanning 25 arcminutes M81 is a real treat, with spiral arms obvious in any modest telescope. Those of us who remember M81's tenth magnitude supernova 1993J of eighteen years ago will always have great memories of this splendid galaxy. Smaller M82 looks more of a ghostly splinter to the visual observer, but that violent active galactic centre, brought out in deep CCD images, is impressive and a bit spooky too.

We could gaze at that duo all night, but it's time to move on now to the planetary nebula that lives two degrees south-east of Ursa Major's bowl star Merak, namely the Owl Nebula, M97 ⑧. The Owl is one of the fainter Messier objects and for telescopes smaller than 150mm in aperture an O III filter will make the difference between it being elusive and being easy. At slightly more than three arcminutes across M97 is quite a large planetary nebula and the two dark patches give it the distinctive owl-like face. Star hopping the two degrees from Merak to M97 is easy, but no sane visual observer will fail to pause two-thirds of the way to the Owl where the fine Messier galaxy M108 also lives!

Martin Mobberley is a regular contributor to Astronomy Now. His latest book Hunting and Imaging Comets *has just been published.*

Circumpolar highlights

NGC 40
A planetary nebula listed second in the Caldwell catalogue, the central dying star has a surface temperature of 50,000 degrees Celsius. Image: Jim Misti.

IC 342
Hidden behind the dust of our own Milky Way Galaxy, IC 342 would otherwise appear much brighter. The core often takes on a fairly star-like appearance to visual observers. Image: Robert Gendler.

NGC 2403
This spiral galaxy was the first galaxy outside of your Local Group to be found to have Cepheid Variables, by the late Allan Sandage. Image: Jim Misti.

Messier 81
Visible in binoculars as a smudge of light, and in small telescopes with a granular core and mottled spiral arms, M81 is one of the best galaxies of the night sky. Image: Mark Shelley.

Double star of the month: epsilon (ε) Hydrae

Some 15 degrees following Procyon is a group of six third and fourth magnitude stars that form the head of Hydra, the huge constellation which sprawls across almost seven hours of right ascension and more than 40 degrees of declination. The most northerly of this group is epsilon Hydrae, the duplicity of which was noted by Wilhelm Struve in 1825. The companion C was four magnitudes fainter than epsilon at a distance of about 3.3 arcseconds. This pair is easily accessible today to apertures of 150mm or so, although the rather low declination means that the stars need a reasonably clear and steady air to be seen well.

The period of this pair is 990 years and at the time of writing C is 2.9 arcseconds distant from A. In 1860 Otto Struve suspected an elongation in the primary star itself and in 1888 Giovanni Schiaparelli confirmed this close companion to A at a distance of 0.2 arcseconds. This pair turns out to have a period of only 15 years and is currently approaching widest separation (0.27 arcseconds) in 2013.

Epsilon is an even more complex system, because C is a nine-day spectroscopic binary and a fainter star D (magnitude +12) some 19 arcseconds away also moves with the brighter stars forming a physical quintuple. Star A is also a BY Draconis-type variable star with a period of 71 days and an amplitude of 0.1 magnitudes, so there are several challenges here for the visual observer.

Bob Argyle

■ Epsilon Hydrae, sketched by Jeremy Perez.

Variable star scene

UU Aurigae: carbon star

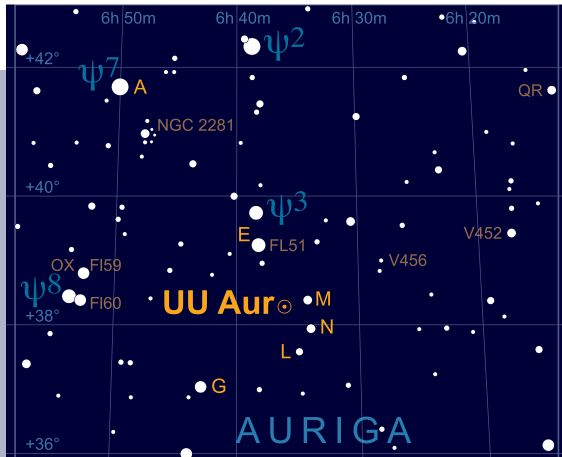
Last month I described how the variable star naming system can be confusing to newcomers. Another source of confusion can be the brightness ranges quoted for variable stars. For some stars you can expect to regularly see brightness changes over the whole quoted range; for others the quoted range merely shows the extreme limits seen over many decades.

There are many stars listed as semi-regular variables with sizable brightness ranges. Once you start observing them however, you find that some will go for years without showing much change in their brightness. The sub-division of the semi-regular class (into SRa, SRb, SRc and SRd) is only of limited help, as this tends to be based more on the spectral type of the stars involved rather than on their individual brightness variations. Whilst it is true that SRa variables tend to show the most sizable changes and SRd variables tend to be show the least, I know of quite a few SRc and SRd type variables that are more reliable than some classified as SRa or SRb.

UU Aurigae is classified as a SRb variable with an extreme magnitude range of 5.1–6.8. Some sources give the period as 234 days, whilst others quote a period around double this. My experience has shown that it is one of the more reliable semi-regular variables, often showing an amplitude of around a magnitude in individual cycles of variation.

UU Aurigae is a carbon star. Carbon stars are (relatively) cool stars with a surface temperature in the range 2,000–3,000 degrees Celsius and consequently are very red. This relatively low temperature allows simple molecules to form – the type of molecule is dependent on the ratio of carbon to oxygen in the surface layers – the spectra of those stars with more carbon being dominated by very simple carbon-based molecules. The carbon can't have originated near the surface however – the most likely explanation for its presence is that it was created by nuclear fusion in the core of the star and brought to the surface via huge convective cells that exist within such stars.

Tony Markham



▲ A finder chart for UU Aurigae with comparison stars A (magnitude +5.0), E (+5.7), G (+6.2), N (+6.7), L (+7.0) and M (+7.3). AN graphic by Greg Smye–Rumsby.

Variable alert times

Eclipse mid times (UT)

RZ Cas (Duration 4.8 hours): Jan 3d 16.7h, 4d 21.4h, 6d 2.0h, 10d 20.8h, 12d 1.5h, 16d 20.2h, 18d 0.9h, 22d 19.7h, 24d 0.3h, 28d 19.1h, 29d 23.8h.
U Cephei (Duration 9 hours): Jan 2d 1.1h, 7d 0.7h, 12d 0.4h, 17d 0.1h, 21d 23.7h, 26d 23.4h, 31d 23.1h.
Beta Lyrae (primary): 2, 15, 28 January.
Beta Lyrae (secondary): 8, 21 January.
Beta Persei (Duration 10 hours): Jan 3d 20.6h, 6d 17.5h, 18d 4.7h, 21d 1.5h, 23d 22.4h, 26d 19.2h.
RW Tau (Duration 9 hours): Jan 9d 22.8h, 12d 17.3h, 21d 0.6h, 23d 19.1h.

Binocular Mira Variables:

Rising: R Aqr, T Cep, R Dra, U Ori, R Peg, U Per, R Tri.
Maxima: R LMi (early Jan, average peak mag +7.1), V Cas (early, +7.9), V CrB (late, +7.5), chi Cyg (late, +4.8), X Cam (late, +8.1).
Fading: omicron Cet, R Gem, U Her, R Hya, X Oph, R UMa.

Early risers

Those hardy souls leaving the comfort of their warm bed around 5am for a spot of pre-dawn observing will still be able to enjoy around 90 minutes before the morning twilight interferes too much, says **Mark Armstrong**.

■ E E Barnard thought M5 was the most beautiful globular cluster in the sky. Image: Gianni Tumino and Melania Pluchinotta.

"SCANNING THE SKY WITH BINOCULARS IN THE DIRECTION OF SERPENS, YOU MAY COME ACROSS A HAZY SPOT, LIKE AN OUT OF FOCUS STAR – THE BIG, BRIGHT AND BEAUTIFUL GLOBULAR CLUSTER MESSIER 5"

For observers with a good western horizon, Betelgeuse and Aldebaran can be seen setting around 5am at the start of January, with Castor and Pollux still 40 degrees up. Turning further around to the south, Leo has crossed the meridian and the great galaxy fields of Virgo and Coma Berenices are just about to transit. Looking east it's possible to get a great preview of the early summer sky with Hercules well up as well as the bright, lead star of Lyra and principle Summer Triangle member, Vega. If you have a good northern horizon and dark skies then it should be possible to see the summer Milky Way streaming almost parallel to the horizon through Cygnus.

The early summer sky is blessed with some great globular clusters and last month we focused on the famous Herculean pair of M13 and M92. But there is a globular that is hardly inferior to M13 but suffers in comparison somewhat only because of its poorer altitude. Scanning the sky with binoculars in the direction of Serpens, close to the border with Virgo, you may come across a hazy spot, like an out of focus star. This is the big, bright and beautiful globular cluster Messier 5 (NGC 5904) – so good in fact that the great observer, Edward Emerson Barnard, thought it 'much more beautiful than M13'. Messier 5 can be found with the naked eye by eagle-eyed observers at dark sites some 25 degrees south-east of Arcturus and eight degrees west of alpha (α) Serpentis. Small telescopes reveal a distinctly elliptical shape with a bright core and resolution of the outlying stars. Moving up to telescopes in the 150–200mm class gives magnificent views, with resolution more or less down to the core at moderate magnifications. Gottfried Kirch in Berlin first recorded M5 in May 1702, Charles Messier noted it in 1764 but William Herschel was the first to resolve it in 1791. It is the equal to M13 in brightness, shining at magnitude +5.7 and has only a slightly inferior apparent size of 20 arcminutes as opposed to M13's 21 arcminutes. This gives it an actual size of 150 light years across at its distance of 26,620 light years and M5 could contain as many as half a million stars and weighs in at 800,000 solar masses.

■ Messier 10 in Ophiuchus. Image: Jim Misti.

Just less than 25 degrees east of M5 lies a nice pair of globular clusters, M10 and M12, in Ophiuchus. Towards the end of January at 6am they are well up in the south-eastern sky. Both clusters are easy binocular objects with M10 being the superior cluster physically and in terms of apparent size and magnitude. M10 shines at magnitude +6.6 and spans 19 arcminutes in images but visually is perhaps only 10 arcminutes in small to moderate-sized telescopes. It is only a modest globular of 250,000 solar masses contained in a sphere 140 light years across. M12 is two-tenths of a magnitude fainter and five arcminutes smaller than its neighbour and through even a small telescope it's obvious that M12 is a much looser globular. It lies at a distance of 20,700 lights years, about 3,000 light years closer than M10, and has an actual diameter of 85 light years.

Before packing up your gear or heading off to work, cast a final glance to the east at around 6:45am. The last of the Summer Triangle stars, Altair in Aquila, has cleared the horizon and will surely stir up thoughts of the summer delights to come.

Mark Armstrong

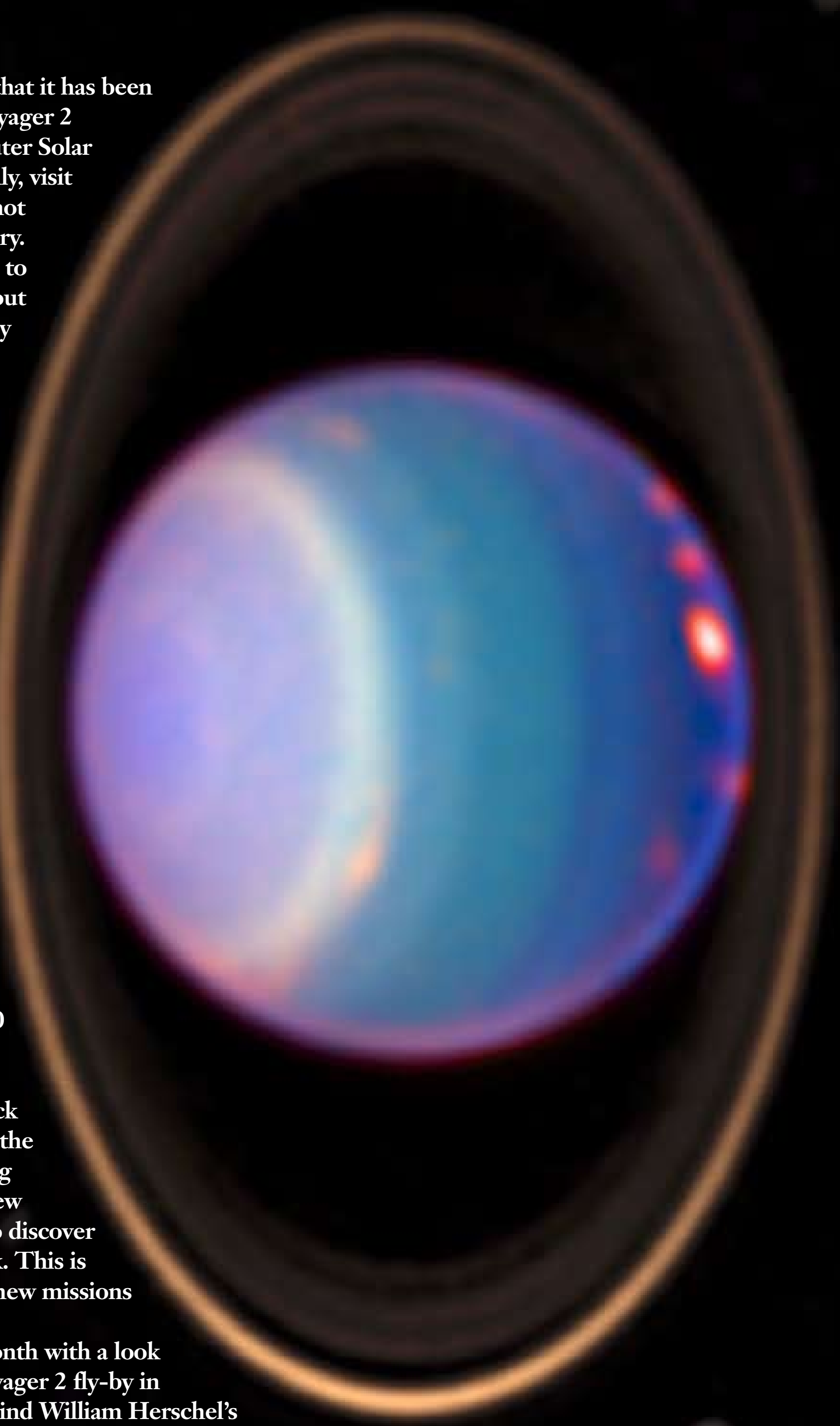
Focus Uranus

By Sir Patrick Moore, Ian Welland and Keith Cooper

How time flies! It is incredible to think that it has been a quarter of a century since NASA's Voyager 2 spacecraft, on its Grand Tour of the outer Solar System, visited Uranus. It was our first, and only, visit to this enigmatic turquoise world, and we cannot expect to return for another quarter of a century. Fifty years between visits is a long time to wait to answer some of our most urgent questions about the planet, but it is the cost of being so far away from Uranus. Closer worlds such as Mars, Jupiter and Saturn are always going to get more attention.

But that's slowly beginning to change, not least because exoplanet discoveries are showing how important worlds such as Uranus and Neptune really are. Many of the planets that we are finding are similar in mass to Uranus, and are possibly composed from the same materials. We often lazily describe Uranus and Neptune as gas giants – and in many ways they are – but it is more apt to call them 'ice giants'. These cold worlds possess atmospheres filled with icy crystals, and their interior structure are a mystery. We think they could possess a small rocky core, surrounded by layers of icy materials, topped off by a smog of hydrogen and helium laced with methane. What is the origin of Uranus' extreme tilt? Similarly, what is the source of the planet's magnetic field, and what forces act on its rings and moons? Voyager 2, speeding within 81,500 kilometres, was only able to catch a cursory glance; giant ground-based telescopes, such as the Very Large Telescope in Chile and the Keck Telescope in Hawaii, have succeeded in filling the void somewhat, being able to monitor changing weather systems on Uranus and discovering new moonlets and rings, but if we're really going to discover what secrets Uranus holds, we need to go back. This is the driving force behind proposals for several new missions by NASA and the European Space Agency.

Sir Patrick Moore begins our *Focus* this month with a look back at the history of Uranus, and the epic Voyager 2 fly-by in 1986. Next, Ian Welland looks at the story behind William Herschel's shock discovery of the seventh planet. Finally, Keith Cooper explores the scientific mysteries of the ice giant, its ring and its moons, and looks to the future of Uranian exploration.



■ A false-colour, near-infrared view of Uranus taken with the Hubble Space Telescope in 1998. Ten of its moons are visible, as are four of its rings. The bright southern collar can be seen, as can several bright clouds in the northern hemisphere. Image: NASA/JPL/STScI.

Uranus has it all – history, mystery and a fascinating retinue of icy moons. **Sir Patrick Moore** was at NASA's Jet Propulsion Laboratory in 1986 when the first close-up pictures of this enigmatic planet were beamed back to Earth from Voyager 2.

Celestial oddity

Without Voyager 2, we would still know very little about Uranus, and we are not likely to learn much more until a new probe is sent there, which may not be for a long time yet. On 24 January 1986, twenty-five years ago this month, our eyes were at last opened to this remote planet whose nature had remained largely hidden to us for the 230 years since it was first discovered.

On 13 March 1781 an amateur astronomer, William Herschel, discovered the planet we now call Uranus. He was not looking for a planet, and did not even recognise its nature; he believed it to be a comet. Its planetary nature was first recognised independently by the French amateur de Saron – later guillotined during the Revolution – and by the Finnish mathematician Anders Lexell. Lexell calculated an orbit, giving a fairly accurate value for the planet's distance from the Sun, and a period between 82 and 83 years; the actual period is 84 years.

The discovery came as a shock to astronomers. Seven is the magical number of ancient peoples, and it was right to have seven bodies in the Solar System: the Sun, the Moon, and the planets Mercury, Venus, Mars, Jupiter and Saturn. There was no room for an eighth – yet Uranus was quite definitely there. Preliminary attempts were made to put it into a different category, but these soon had to be abandoned. Uranus is a giant planet, albeit much smaller than Jupiter or Saturn, but a giant none the less; with a diameter of over 30,000 miles (51,000 kilometres) it dwarfs the Earth. We now know that it is unlike the small, solid inner planets but also unlike the gas giants Jupiter and Saturn, and is best described as an 'ice giant'.

▲ How Uranus would appear to the human eye were astronauts ever to venture out that far in the Solar System. Image: NASA/JPL.

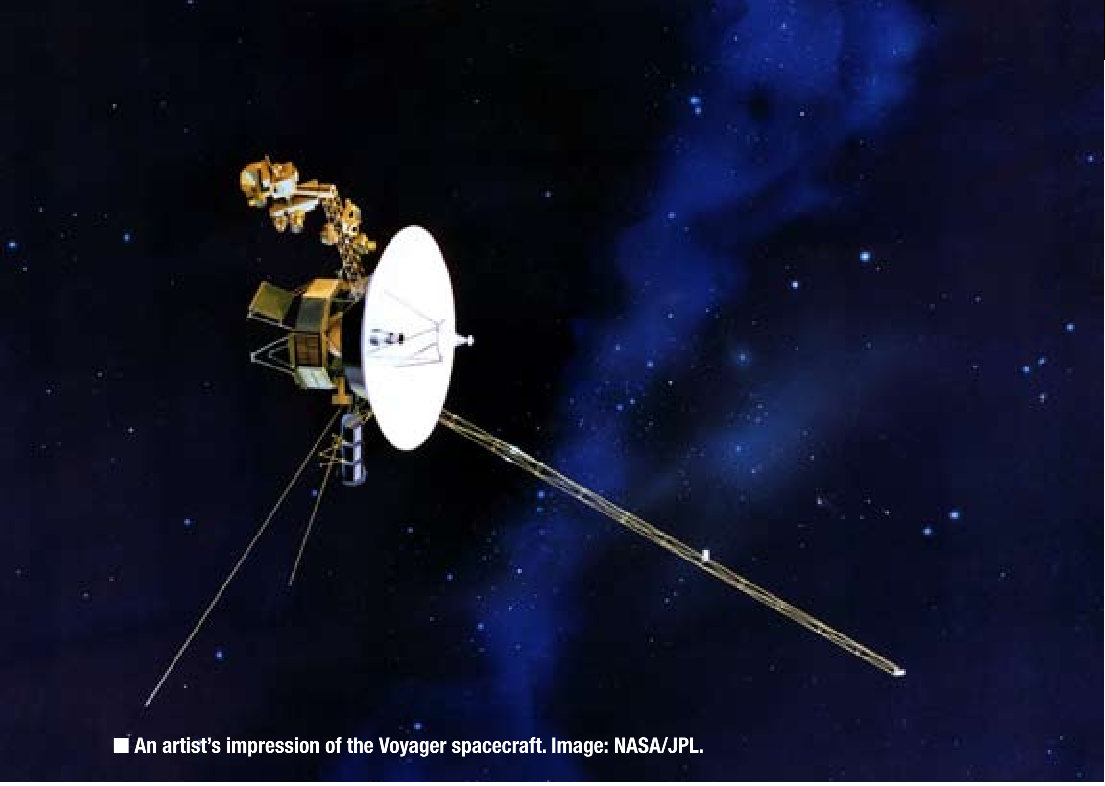
▼ Sir Patrick Moore was at JPL in California in 1986, filming for *The Sky at Night* as images of Uranus were beamed back to Earth by Voyager 2. Image: Patrick Moore.

Uranus is visible with the naked eye from a dark site (just!) and when the first Astronomer Royal, John Flamsteed, drew up a star catalogue he gave it a stellar number: 34 Tauri. Altogether there were over twenty pre-Herschel observations, but Uranus had always been mistaken for a star.

Bode's Law

There was then the question of Bode's Law, a mathematical sequence relating to the distance of the planets from the Sun. It worked fairly well out to Saturn, and Uranus fitted in neatly. Was it an important scientific relationship, or was it due to mere coincidence? Astronomers did not know, but Uranus seemed to go a long way toward disproving the coincidence idea. Little over half a century later the whole picture changed. Uranus did not move quite as it was expected to do; something was pulling it out of its predicted position, and that 'something' turned out to be a more distant planet. In France, Urbain Jean Joseph Le Verrier worked out the probable position of the planet, and from Germany two observers, Johann Galle and Heinrich D`Arrest, found it very close to the position given by Le Verrier. It was named Neptune, and was an ice giant, almost a twin of Uranus in size and mass.

Two facts were of obvious and immediate importance. First, Neptune was in flagrant disagreement with Bode's Law, and this meant that the coincidence theory was correct after all. The so-called law has been relegated to the status of a 'take-away-the-number-you-first-thought-of' game. Secondly, there are ways in which Uranus differs markedly from the other giant planets. Jupiter, Saturn and Neptune radiate considerably more heat than they would do if they depended solely upon what they receive from the Sun, so that each must have a strong internal heat-source. Uranus does not. The internal



■ An artist's impression of the Voyager spacecraft. Image: NASA/JPL.

heat-source is weak at best, and may be absent altogether.

This is not all in our list of oddities. The axial inclination is 98 degrees, so that the rotation is technically retrograde, though not generally regarded as such. The axial rotation period is 17 hours and 14 minutes, and obviously any Uranian calendar will be most peculiar (would any of our readers care to work one out?). The reason for this extreme axial tilt is unclear. It used to be thought the planet was hit by a large impactor and literally tipped over, but this does not sound very plausible, and it is more probable that the tilt was caused by interactions with the other giant planets.

Uranus does have a magnetic field, but the magnetic axis is inclined to the rotational axis by 59 degrees, and does not pass through the centre of the globe; it is offset by 5,000 miles (8,000 kilometres). If you are taking a holiday on Uranus and want too see some aurorae, go to the equator rather than the darkened pole!

Uranus has five satellites of reasonable size, all identified pre-Voyager, but they are not easy objects. With my 15-inch reflector I can make out Titania, Oberon, Ariel, Umbriel and (with great difficulty) Miranda. All these orbit more or less in the plane of Uranus' equator, so that they must be bona-fide satellites rather than captured bodies.

Encounter day

Telescopes used by amateurs show little on the pale green disc of Uranus, which was why the close encounter by Voyager was so keenly anticipated. I covered the event from NASA's headquarters in Pasadena.

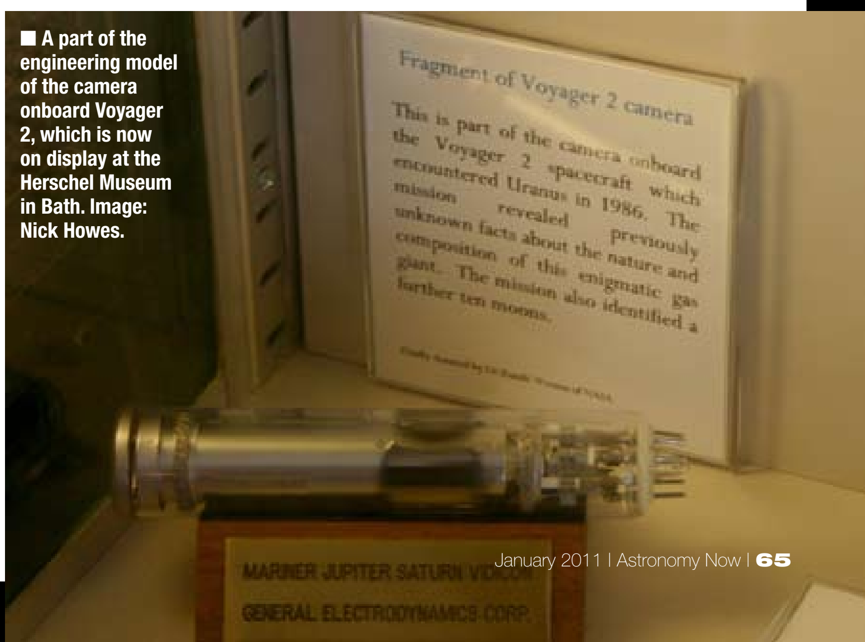
In every way Voyager 2 was an outstanding success. During its one 'encounter day', 24 January 1986, it revolutionised all our ideas about Uranus. It made a detailed analysis of the upper clouds, and enabled us to draw up a reliable model of its interior; it analysed the outer atmosphere, and made a careful study of the magnetic field, finding that, compared with Jupiter and Saturn, the magnetosphere is relatively 'empty'. It gave us our first proper views of the wraithlike rings, and found there ten altogether (in subsequent years the Hubble Space Telescope has found a further three, bringing the tally to 13 rings); they are not all alike, but as they are no more than one kilometre thick their mass is very small, and they cannot be compared with the glorious icy rings of Saturn.

Voyager also gave us our first detailed views of the satellites. Miranda has an amazingly varied landscape with several distinct types of terrain; old cratered plains, brighter areas with cliffs and scarps, and ovoids or coronae, large trapezoidal-shaped regions, one of which was nicknamed the 'race-track'. Ariel has smooth-floored valleys which look as though fluid has flowed there, but this presents problems in view of Ariel's small size; the other principal satellites really are icy and cratered. In addition Voyager discovered numerous small satellites, most of which must be captured bodies.

Compared with Jupiter, Saturn or even Neptune it seems strangely bland. Yet it is immensely interesting as well as puzzling, and in many ways Herschel's planet has to be classed as a celestial oddity.

Sir Patrick Moore is the well-known presenter of the BBC's The Sky at Night.

■ Sir Patrick with Garry Hunt on the set of *The Sky at Night*. Garry Hunt was one of NASA's principal scientific investigators for the Voyager programme, and a frequent contributor to the show. Image: Patrick Moore.



■ A part of the engineering model of the camera onboard Voyager 2, which is now on display at the Herschel Museum in Bath. Image: Nick Howes.

Herschel's Uranus

On one fateful night in March 230 years ago, William Herschel made the discovery of a lifetime that not only ensured his fame, but also vastly expanded our knowledge of the Solar System, says **Ian Welland.**

On 13 March 1781, a composer–musician discovered the planet Uranus from his back garden in Bath and at a stroke, doubled the size of the known Solar System. The feat was even more remarkable in that he was using a homemade seven-foot telescope with a 6.5-inch speculum mirror that, when tested, was confirmed as a much better telescope than those being used for serious astronomical observation at Greenwich. For William Herschel (1738–1822), the discovery of Uranus changed his life and career. The story of his discovery, however, starts on 10 May 1773 when Herschel purchased James Ferguson's *Astronomy* book shortly after he had purchased a Hadley quadrant and William Emerson's *Trigonometry*. Over the course of the next eight years, Herschel taught himself the constellations and started a project that simply would last the rest of his life: a 'review of the heavens'.

Almost from the start of Herschel's astronomical career, his sister Caroline became his secretary and it is purely down to her that the story of the discovery and indeed the full extent of Herschel's achievements can now be appreciated.

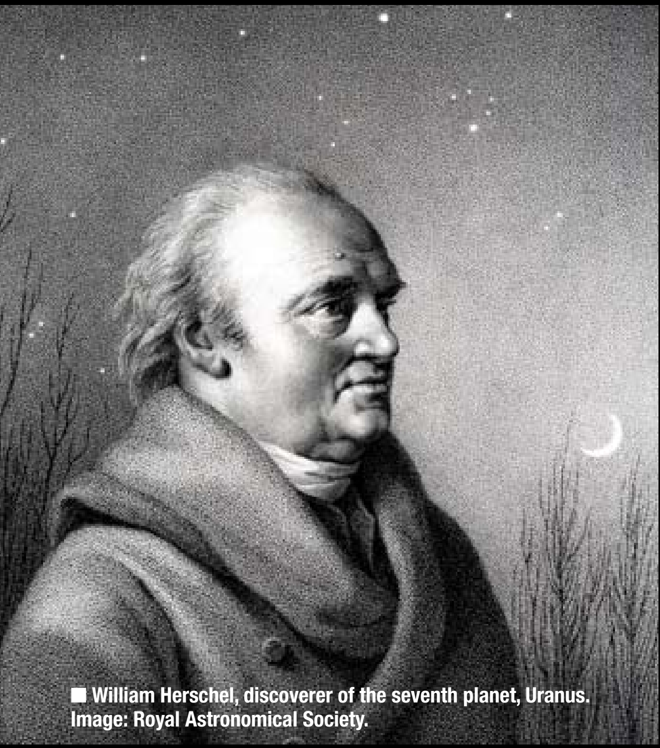
Herschel decided, from reading Ferguson's book, that there appeared to be a need to investigate stars as fixed points: resolve their properties and find out more regarding the distribution of stars. Herschel was persuaded to resolve all stars and commence counting of stars in the field-of-view (referred to as star-gauging) and as larger, more powerful telescopes came into being, he would revisit and revise his observations to arrive at accurate catalogues of double stars, nebulous objects and forecasts of proper motion and distance.

The stage is set

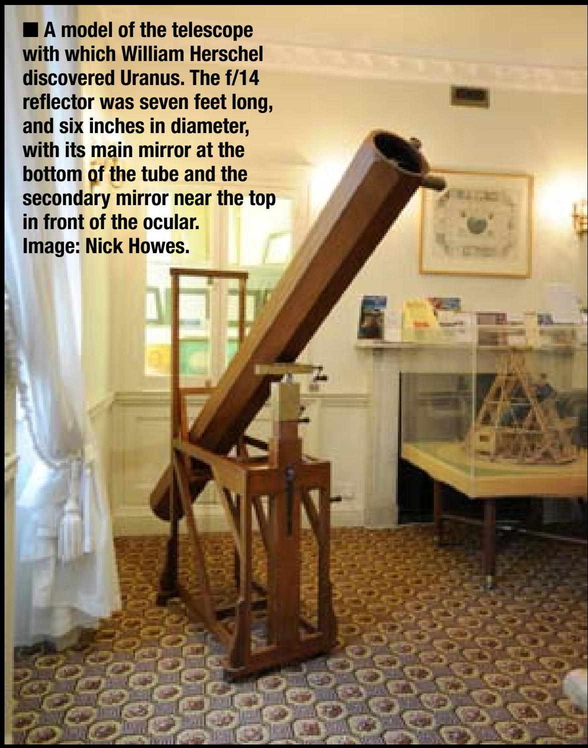
Early observations raised even more questions as Herschel noted that the Milky Way converged and forked in different areas of the sky giving way to an abundance of stars in clusters in one direction and then a more diffuse distribution in another. So the stage was set and discoveries awaited this very amateur but diligent astronomer. Such was Herschel's commitment that when concerting in Bath he was known to run through the streets to his telescope in order not to waste a single observing moment! By 1781 he was an incredibly skilled observer.

In March 1781, after several months of domestic inconvenience at 5 Rivers Street, Herschel decided to move back to New King Street and at Number 19 he found a sizable back garden suitable for astronomical observation. On 13 March his telescope was set up but unusually his sister would not be at his side to record any observations that night. Herschel duly noted his observations and subsequently published a paper with the assistance of his friend Dr William Watson entitled *Account of a Comet*, which was read on 26 April at the Royal Society. The key statement in the paper was thus:

"On Tuesday the 13 March, between ten and eleven in the evening, while I was examining the small stars in the neighbourhood of H Geminorum, I perceived one that appeared visibly larger than the rest; being struck with its uncommon magnitude, I compared it to H Geminorum and the small star in the quartile between Auriga and Gemini, and finding it so much larger than either of them, suspected it to be a comet."



■ William Herschel, discoverer of the seventh planet, Uranus. Image: Royal Astronomical Society.



■ A model of the telescope with which William Herschel discovered Uranus. The f/14 reflector was seven feet long, and six inches in diameter, with its main mirror at the bottom of the tube and the secondary mirror near the top in front of the ocular. Image: Nick Howes.

■ Replica of the furnace in which William Herschel cast the mirrors for his telescopes. The mirrors were of a metal named speculum, a hard alloy of copper and tin. On the floor

His paper created a great deal of interest. Crucial to the process were Herschel's post-discovery observations in the following weeks and months which he noted a "... very visible daily parallax". As the summer of 1781 arrived, the object was lost in the sky, but speculation grew that Herschel's comet could in fact be a planet! The Rev Dr Hornsby of Oxford and Astronomer Royal Dr Nevil Maskelyne were among a host of astronomers who took up the challenge of proving Herschel's discovery.

Herschel continued his work on fixed stars knowing that his comet was being investigated elsewhere. The Royal Society received two papers on the parallax of fixed stars and double stars (read 6 December 1781 and 10 January 1782 respectively). On 15 November 1781 however, Sir Joseph Banks, President of the Royal Society, not wishing to allow any deflection away from Herschel regarding his discovery, wrote to Herschel with the news that "Some of our astronomers here incline to the opinion that it is a planet not a comet"; and on presenting Herschel with the Society's Copley Medal, Banks went further in his public address by commenting, "Who can say but your new star, which exceeds Saturn in its distance from the Sun, may exceed him as much in magnificence of attendance?"

By spring of 1782, a Finnish astronomer, Anders John Lexell (1740–1784), was among a large number of European based astronomers who released conclusive evidence that proved not only had Herschel discovered the first planet since ancient times and by using a telescope, but that the new planet did lie beyond the orbit of Saturn.

Name of choice

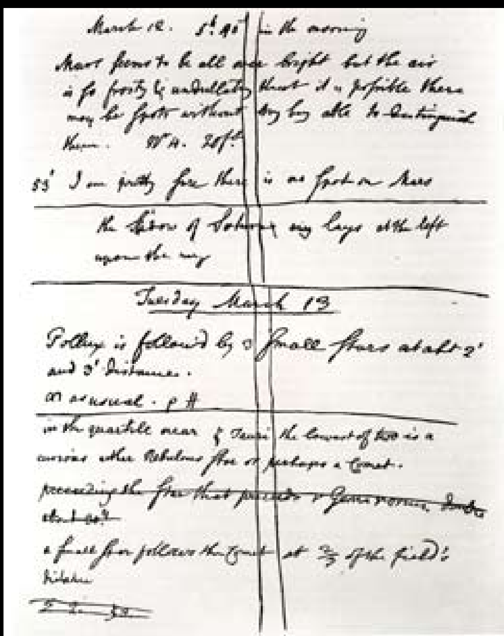
Herschel's lament now rest on the official name for this new world. Herschel was by birth a Hanoverian. The King, George III who was seriously interested in astronomy, was also Hanoverian. With advice from Banks and Maskelyne, and seeing the possibility of becoming a full time astronomer, the new world was named 'Georgium Sidus' anglicised as 'The Georgian'. Accepted in England, this name continued to be used during Herschel's lifetime, though in Europe there remained opposition. Astronomical objects were usually named in honour of gods, heroes and heroines. Johann Elert Bode (1747–1826) wrote to Herschel in July 1783 proposing a change to 'Uranus' – father of Saturn and grandfather of Jupiter. Herschel immediately wrote to Banks at the Royal Society asking Banks to intervene and communicate to Europe the patronage toward His Majesty, "...by giving the name Georgium Sidus to a star, which (with respect to us) first began to shine under His auspicious reign." The matter was finally settled by English mathematician astronomer John Couch Adams (1819–1892) who conceded in 1850 that Uranus was philosophically and scientifically appropriate.

Herschel's detection of Uranus was no accident. In 1933 his granddaughter Constance Lubbock commented in her book *The Herschel Chronicle* (p78), "If in the course of this survey (review of the heavens) a hitherto unknown planet lay in his way he was bound to discover it, as his admirable telescope at once revealed to him its difference from a fixed star". But Uranus had been seen before. There are now believed to be at least 22 pre-discovery observations of Uranus – six of which (1690, 1712, and four in 1715) belong to the first Astronomer Royal John Flamsteed (1646–1720). Flamsteed's successor James Bradley (1692–1762) missed Uranus on two occasions in 1748 and 1750. Flamsteed's errors may well have been found by Herschel's sister during her revisions and indexing in 1798 of Flamsteed's famous star catalogue.

Herschel continued to observe Uranus right up to his death on 25 August 1822. On 11 January 1787 he discovered the two outermost satellites of Uranus named Oberon and Titania; and in 1798 announced the discovery of four additional satellites of which only one – Umbriel – is now considered legitimate, being confirmed in 1851 by English astronomer William Lassell (1799–1880).

Ian Welland is an astronomical historian.

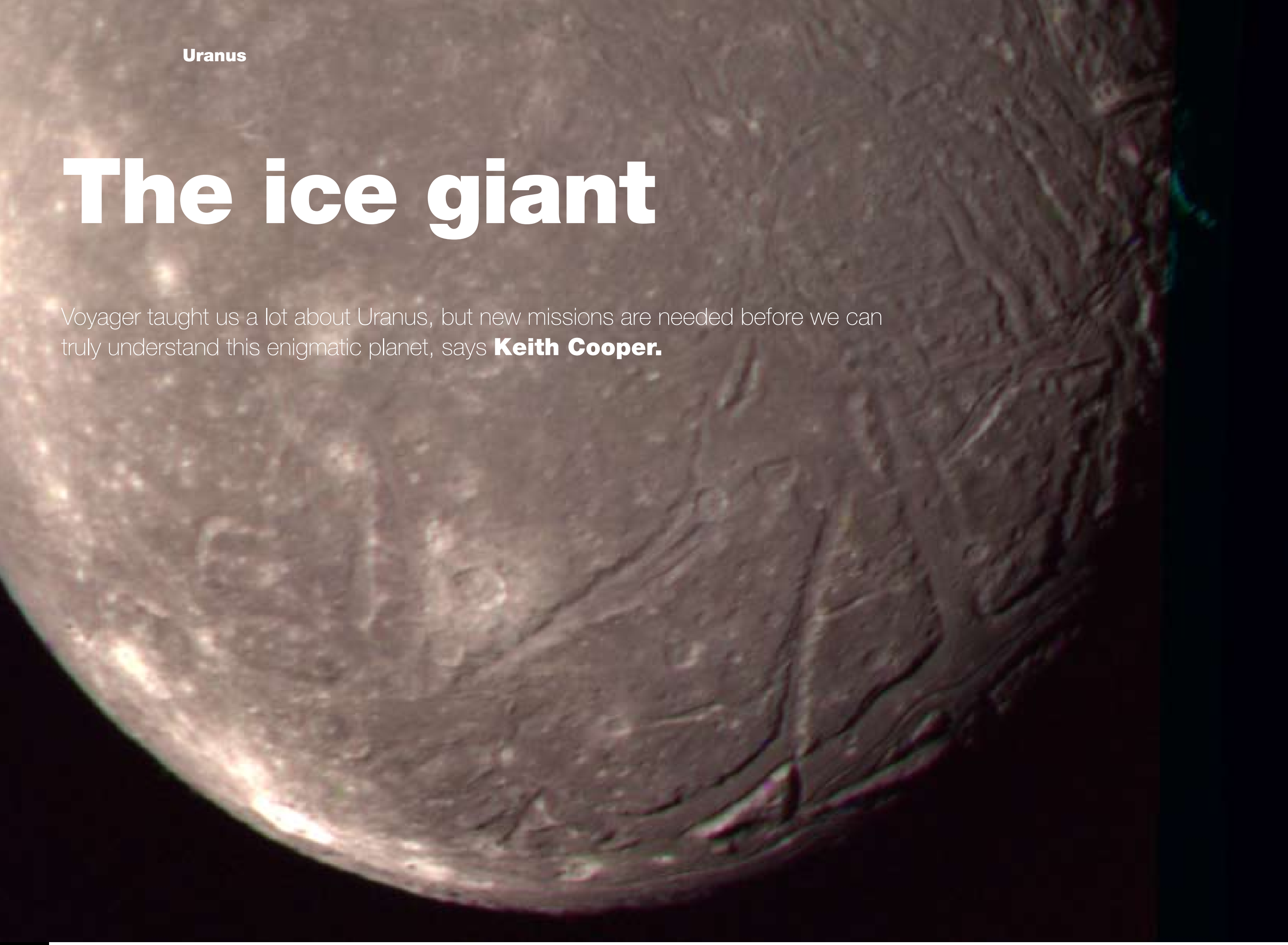
is a replica of the sort of mold Herschel would have as a cast. The flagstone floor is badly cracked – reputedly as a result of a spill of the molten metal. Image: Robin Rees.



Tuesday March 13

■ Herschel's notes from the night that he discovered Uranus. At the time he thought it was a comet: "In the quartile near zeta Tauri the lowest of two is a curious either nebulous star of perhaps a comet." Image: Royal Astronomical Society.

■ The garden of William Herschel's house, 19 New King Street, Bath, from where he identified Uranus as a planet. Image: Robin Rees.

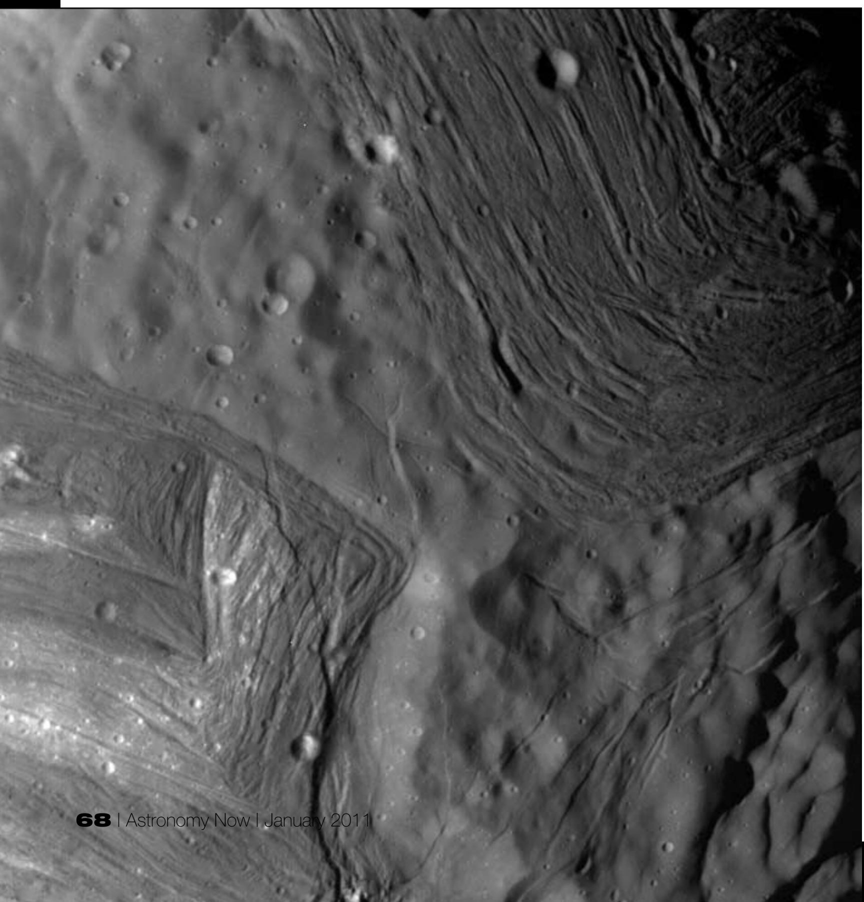


The ice giant

Voyager taught us a lot about Uranus, but new missions are needed before we can truly understand this enigmatic planet, says **Keith Cooper.**

▲ Uranus' fractured moon Ariel. The giant valleys seen on its surface are thought to be formed over depressed blocks of land called graben. Image: NASA/JPL.

▼ Miranda demands close-up attention, with its complex, half melted surface. The bright 'V'-shaped series of grooves at the bottom left is known as the 'Chevron'. Hummocky terrain is sandwiched in between grooved regions. Image: NASA/JPL.



For the blandest world in the Solar System, Uranus is hiding a lot from us. It's not an easy situation to change either. We send a regular procession of spacecraft to the likes of Venus, Mars, Jupiter and Saturn, but Uranus has met only one earthly visitor – a rapid fly-by made by NASA's Voyager 2 probe twenty-five years ago, on 24 January 1986. Our knowledge of the seventh planet of the Sun is limited to that fly-by and a few observations by the world's biggest telescopes, and so putting together the pieces of the puzzle that is Uranus has so far been difficult to say the least.

Part of the problem is that Uranus is so far away. At over three billion kilometres from the Sun during aphelion, and just under 2.8 billion kilometres at perihelion, it's not the easiest port of call in the Solar System to reach. Yet, despite the length of time since our last visit, our fascination with the enigmatic ice giant is undergoing something of a renaissance.

"There has been quite a lot of interest in Uranus and Neptune recently," says Dr Chris Arridge of the Mullard Space Science Laboratory (UCL) in Surrey. "A lot of people in the outer planets community are looking towards Uranus and Neptune as the next logical step."

Arridge is among a group of scientists assembling a proposal for a European Space Agency mission to the ice giant, while in the United States there have been three proposals made in the past year as part of their Decadal Surveys. Part of the reason for the re-emergence of Uranus and Neptune as important

"URANUS IS THE MOST SEASONALLY FORCED PLANET IN THE SOLAR SYSTEM WITH ONE POLE CONTINUALLY IN SUNLIGHT FOR HALF OF ITS 86-YEAR ORBIT"

scientific objects of study has been the explosion in the number of exoplanets discovered over the past 16 years. We're finding that many of these faraway worlds are similar to Uranus and Neptune in size and mass, albeit generally far closer to their suns than our ice giants, but we can't hope to understand these exoplanets if we don't even understand the worlds in our own Solar System properly.

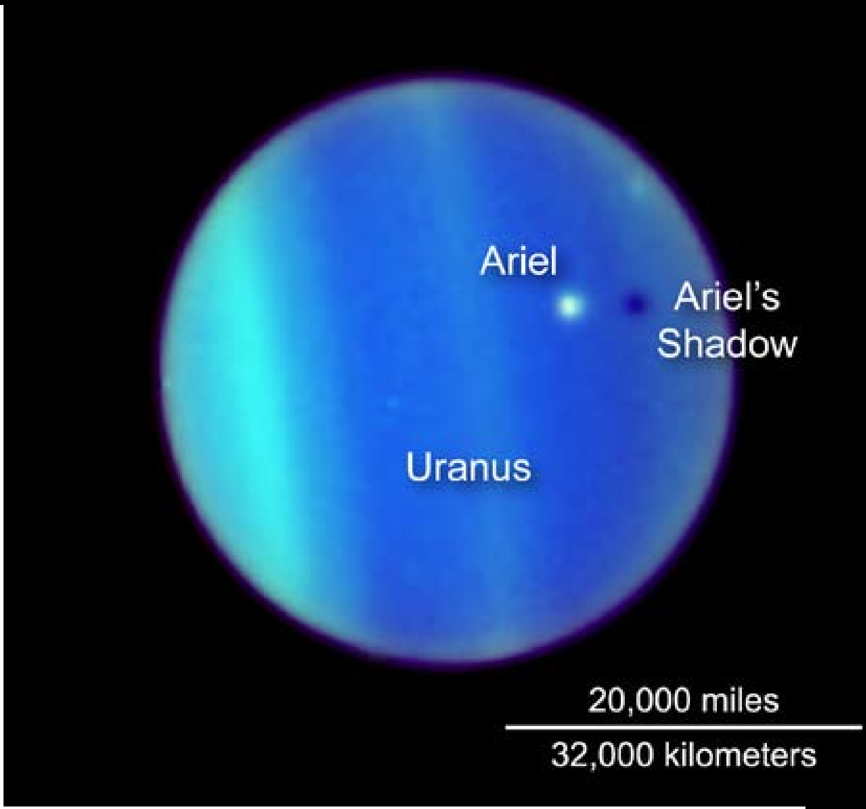
"One of the things we're particularly excited about is using observations of Uranus to represent ground truth for exoplanet observations, because the data suggests that objects similar to Uranus and Neptune might be quite common in the Universe," says Arridge. And if the mission that he is co-proposing, named Uranus Pathfinder, is chosen and launched, its aims are clearly defined. "We've divided the mission into three science questions. We particularly want to understand Uranus as an ice giant planet, and how ice giant planets work," he says. "We want to understand the origin and evolution of Uranus' rings and moons, and to try and understand how Uranus' magnetosphere works, and how its asymmetric magnetic field interacts with the Sun."

Knocked over

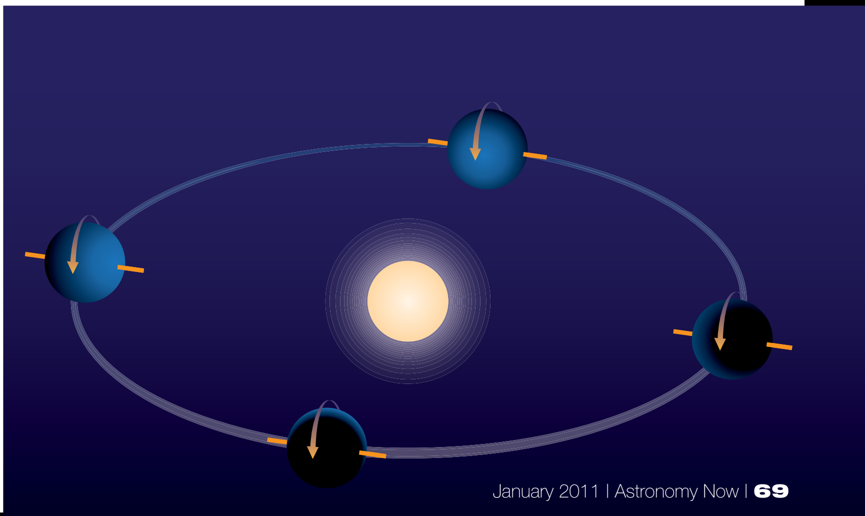
Uranus' rings were discovered in 1977 during a stellar occultation that saw the star SAO 158687 wink in and out five times as its light flittered behind the dark rings. Voyager 2 found another five rings in 1986, and the Hubble Space Telescope a further three rings in 2003. They're not as brilliantly bright or as broad as Saturn's famous rings, but they are more sharply defined than Jupiter or Neptune's vague rings. They are also tilted, along with the planet itself, by 98 degrees to Uranus' orbital plane. This is an extreme tilt – Earth has an obliquity of 23.5 degrees, and Mars shows evidence that it has wobbled by up to forty degrees and possibly more in the past, but Uranus is something different. It is effectively tipped on its side and rolling around the Sun! It couldn't have formed like this, for the rotating protoplanetary disc of gas and dust around the Sun 4.6 billion years ago would have ensured that all the planets formed rotating in the same direction. Whatever happened to Uranus, happened afterwards.

One of our best guesses is that the young Uranus got whacked by a smaller, possibly Earth-sized protoplanet in a collision with enough force to knock Uranus on its side. The moons and rings would have formed afterwards, still orbiting the planet's equator. It could also explain another mystery belonging to this blue-green world: why it produces so little internal heat. Uranus is intrinsically the dimmest planet in the Solar System – the amount of radiation it receives from the Sun (which is 1/400th of what Earth receives) almost exactly balances the amount of heat it emits from its interior. A collision very early in the planet's history could have knocked much of the leftover heat from its formation out of the planet, but alternatively the lack of heat could be down to a limited amount of seasonally forced convection from deeper within Uranus. So how to prove it?

"One way might be through the composition of Uranus," says Arridge. "If we find that it is enriched in particular elements, or that there was more rock, that would suggest it was affected by something that it absorbed." Uranus does contain more heavy elements than either Jupiter or Saturn, but so does Neptune, and this seems to be a distinguishing feature of ice giants compared to the more traditional gas giants like Jupiter. Additionally, it is thought that Uranus may have jostled for position with the other gas giants during the early days of the Solar System, eventually migrating outwards to its current location. As such, its composition may simply reflect where it has been in the Solar System during its travels, and its obliquity may be a result of gravitational interactions with the likes of Jupiter and Saturn, but at the moment this is just guesswork. "It might always be a mystery," admits Arridge.



▲ At equinox the orbital plane of the moons saw them transit the disc of Uranus, as seen by the Hubble Space Telescope. Image: NASA/ESA/L Sromovsky (University of Wisconsin)/H Hammel (SSI)/K Rages (SETI Institute).



▼ Because Uranus is on its side, it experiences extreme seasons. At its equinoxes the north and south poles take turns to point directly at the Sun, whilst light is more evenly spread over the planet at the solstices. AN graphic by Greg Smye–Rumsby.

Wonky magnetism

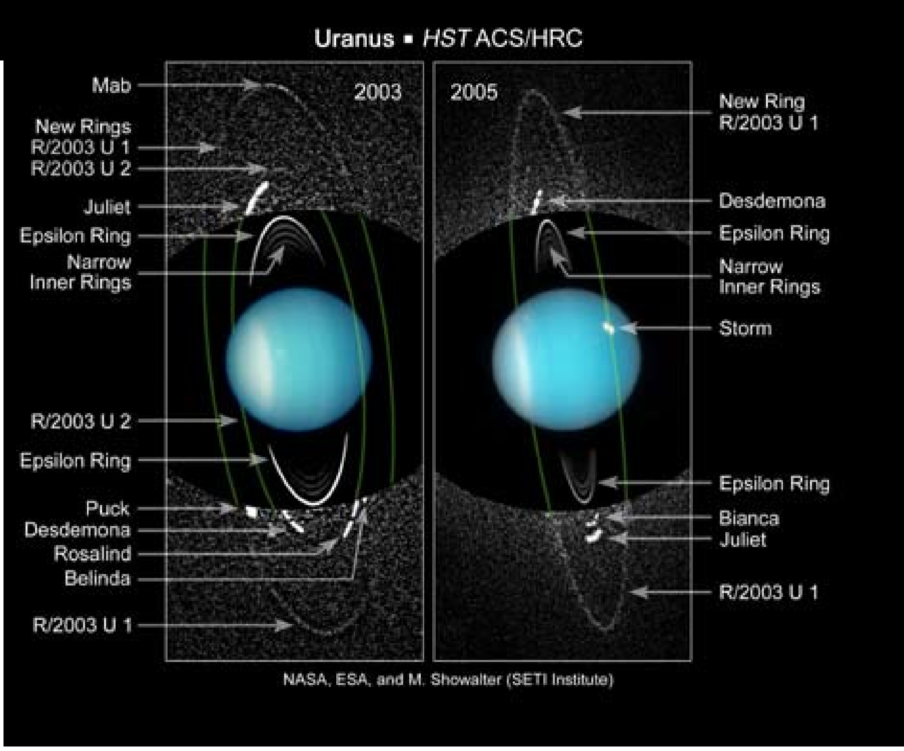
Any spacecraft approaching Uranus will first encounter the seventh planet's magnetic field. Voyager 2 came upon it five days before the probe's closest approach to the planet. It found that the magnetic field is offset from the centre of the planet by over 8,000 kilometres. Furthermore the solar wind, although weaker at the distance of Uranus, buffets against the magnetosphere so that at the time of the Uranian northern summer solstice, the magnetic field extended only 590,000 kilometres from the planet on the day side (the northern hemisphere at the time) and reached out six million kilometres on the night side (the southern hemisphere), where it is dragged into a tail by the solar wind. Strangely, Uranus' north pole also had a south magnetic polarity, and it is also tilted, but by 60 degrees rather than 98 degrees. As Uranus orbits the Sun, the orientation of the magnetic field with respect to the Sun changes, so that at times its magnetic dipole axis is aligned much like Earth's is

> "METHANE CRYSTALS, WHICH ACCOUNT FOR JUST 2.3 PERCENT OF THE ATMOSPHERIC COMPOSITION, GIVE URANUS ITS DISTINCTIVE BLUE–GREENISH TINT BY ABSORBING RED LIGHT."

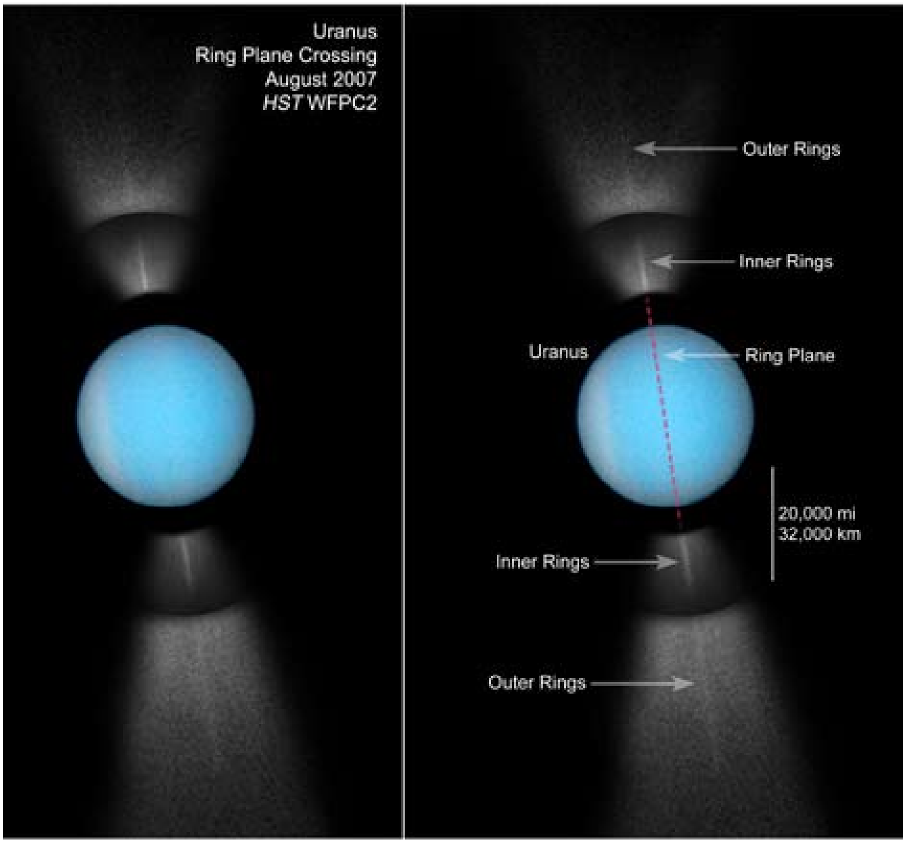
to the Sun, and at other times it is pointed directly at the Sun. As the orientation of the magnetic field changes with respect to the Sun, its interaction with the solar wind could also change, but exactly how is something that a future mission such as Pathfinder will need to determine – Voyager 2 sped by too quickly to make any meaningful measurements of changes in the magnetic field. However, Uranus' magnetic field is more than a mere scientific curiosity; it could tell us about what happens when Earth undergoes a magnetic reversal, during which the orientation of our magnetic field changes. "One of our goals is to understand how Uranus' magnetosphere and ionosphere (the electrically charged upper atmosphere) interact with and couple with the solar wind," explains Arridge. "It is important in trying to infer how Earth's paleo-magnetosphere (our magnetic field in ancient times, during the last reversal 780,000 years ago) might have worked."

Clearly, the origin of Uranus' offset, asymmetric magnetic field is a little different to Earth's magnetic field, which is generated by the dynamo of our planet's spinning molten core. Its offset nature may mean that the dynamo for the ice giant's magnetic field is not located in the planet's centre, but in an outer layer, possibly rich in vaporous water-ice.

"It's all wrapped up in the question of what is going on inside the planet," says Arridge. "And one of our top level objectives is to try and understand



▲ **Uranus, imaged by the Hubble Space Telescope in 2003, 2005 and (below) at equinox in 2007 when the rings and moons were edge-on. Many of the minor moons of Uranus are named in this diagram. IMAGE: NASA/ESA/M Showalter (SETI Institute)/Z Levay (STScI).**



the internal structure and composition of Uranus."

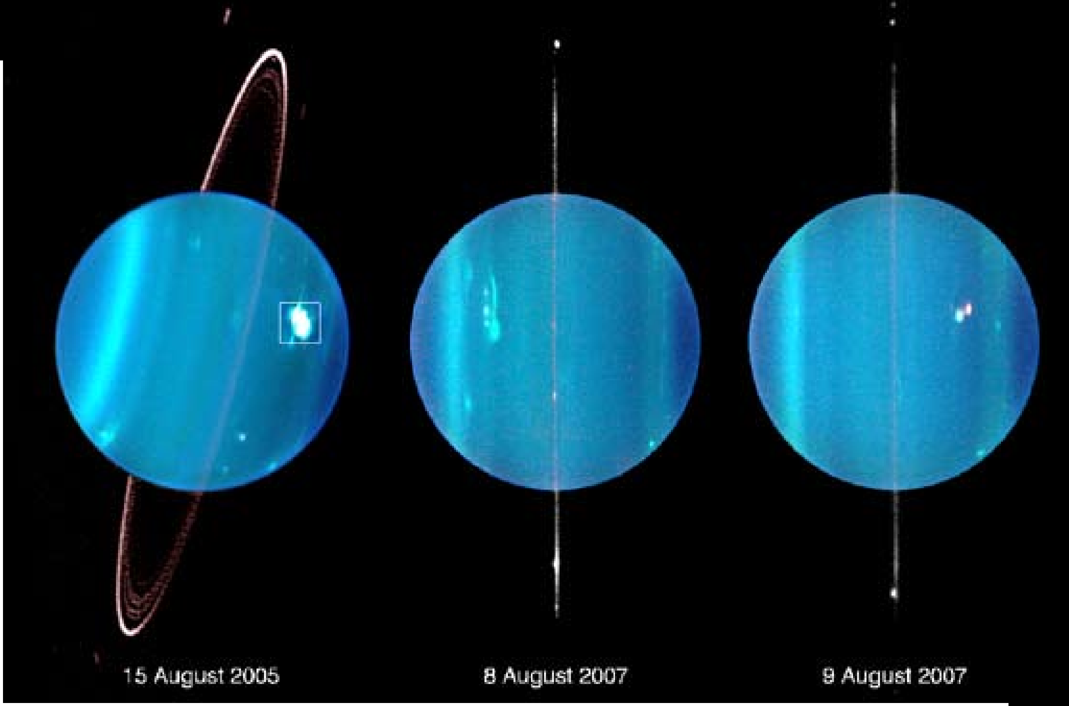
What do we know about the structure of the planet? It has over 14 times the mass of Earth, so it's pretty hefty, but it has a low density of 1.27 grams per cubic metre (only Saturn is less dense) so if it does have a rocky core it cannot be the dominant component of the planet – estimates place it at perhaps half the mass of Earth. Models of Uranus' interior then suggest a voluminous mantle, mainly of the ubiquitous gases hydrogen and helium that together make up 98 percent of the planet, but heavily laced with methane, ammonia and water. These are in the form of warm gases, but we call them 'ices' because at the cloud tops, where the temperature drops to –214 degrees Celsius, they freeze into ice crystals. Methane gas, which accounts for just 2.3 percent of the atmospheric composition, give Uranus its distinctive blue–greenish tint by absorbing red light. Part of the reason the upper atmosphere looks so bland is that ultraviolet light from the Sun reacts with the methane in the upper atmosphere, producing hazy particles that block visibility to much of the activity below. However, as Uranus reached equinox in 2007 to give us the best look at the planet since the Voyager fly-by, near-infrared observations made by the ten-metre Keck II telescope in Hawaii penetrated the haze to tease out atmospheric details, such as bands and white clouds zipping around the planet on winds of 900 kilometres per hour, and a giant, swirling vortex in the southern hemisphere between 30 and 36 degrees south.

Forcing the weather

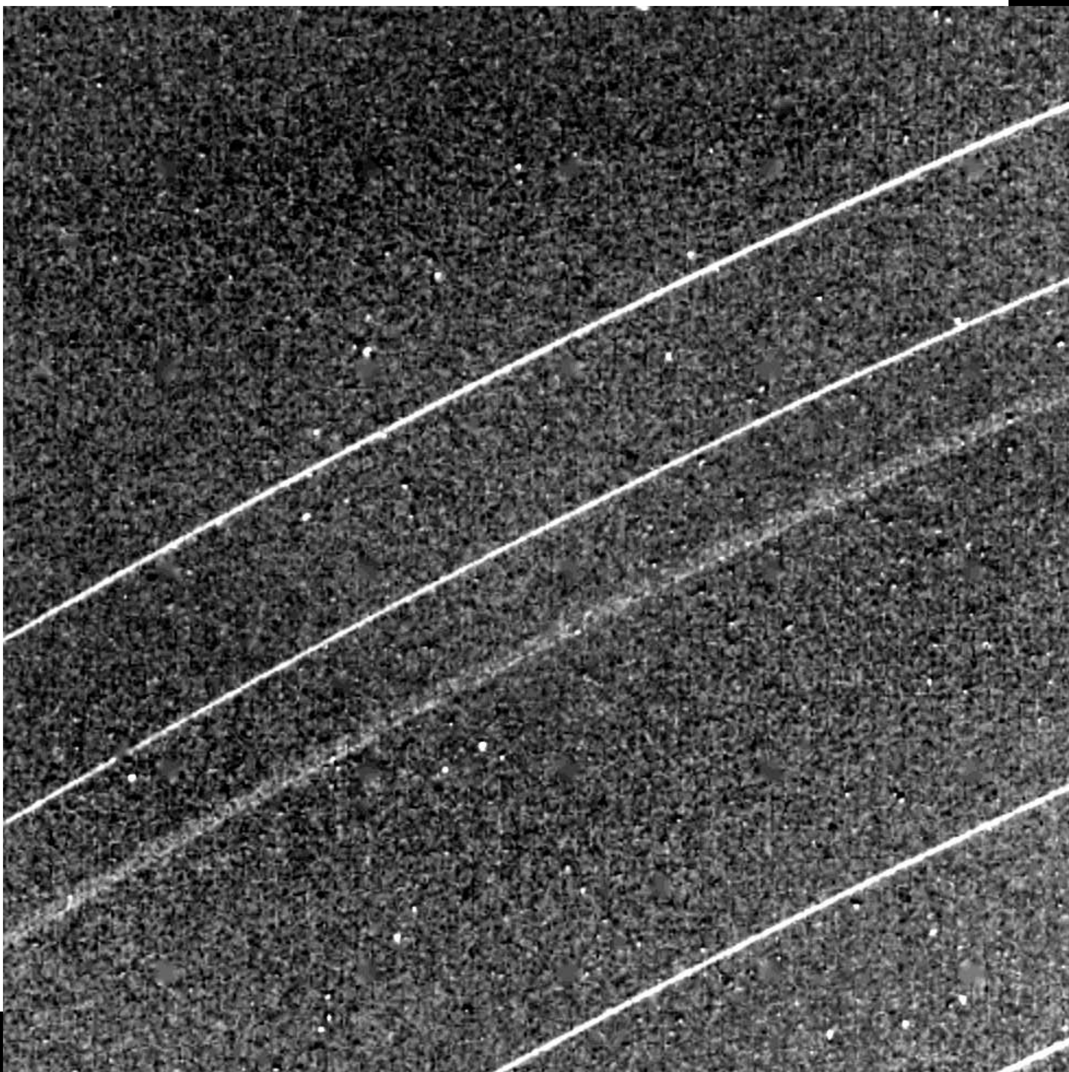
The equinox was a big event for Uranus watchers, for it showed that much had changed. When Voyager 2 flew past the seventh planet in early 1986, it was during the solstice when the planet was side-on to the Sun, and solar heat was being distributed much more evenly, leading to a much calmer atmosphere – Voyager 2 only detected ten distinct clouds on the entire planet. What it did find, visible in ultraviolet light, was a dark polar hood surrounded by concentric bright zones, possibly caused by atmospheric circulation arranging the methane haze into dense bands. One of these bands comes in the form of a 'collar' around the pole.

Come 2007 and Uranus' northern pole was directly facing towards the Sun. The southern collar had virtually vanished to be succeeded by a new, faint northern collar. Meanwhile, the weather was rapidly becoming exacerbated, with the appearance of a giant storm system in the form of a black 'spot'. Despite being over three billion kilometres (Uranus reached aphelion two years later in 2009) from the Sun, the diminished sunlight is still enough to cause seasonal variations in Uranus' climate. Rolling around the Sun on its side has a powerful effect on Uranus, on average making the poles the warmest parts of the planet and the equator the coldest (also see our Exoclimes conference report in the November 2010 issue of *Astronomy Now* for more on tilted planets). At different points in Uranus' orbit, solar heating can dramatically change how energy is distributed throughout the Uranian atmosphere – a phenomenon known as 'forcing', resulting in changes in weather from season to season. The greatest amount of forcing occurs at equinox.

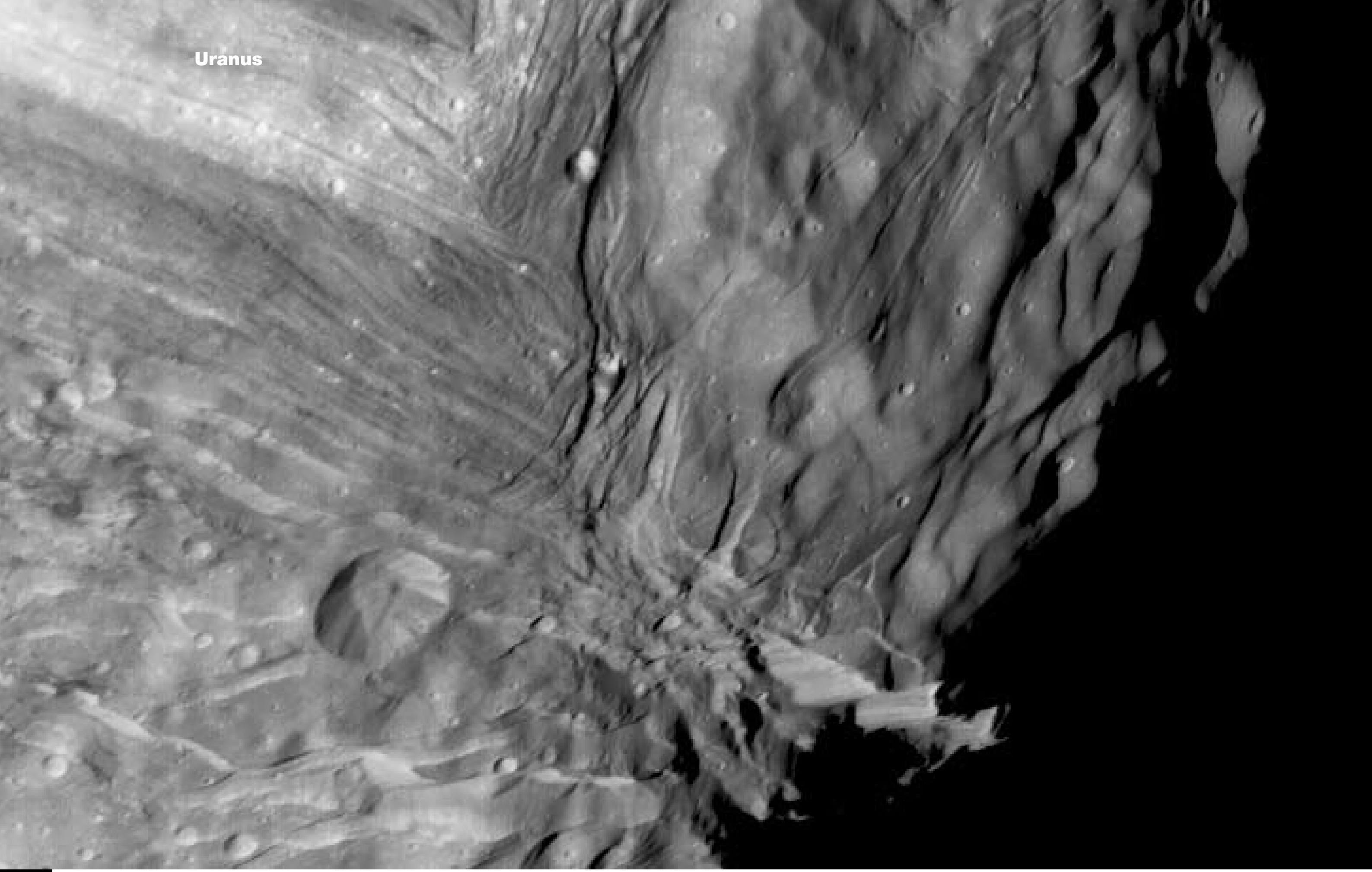
"Uranus is the most seasonally forced planet in the Solar System," says Arridge. "Not only



▲ Uranus, with its rings edge-on at equinox, imaged by the Keck II telescope. Image: Imke de Pater (UC, Berkeley)/Heidi Hammel (SSI)/ Lawrence Sromovsky and Patrick Fry (University of Wisconsin-Madison).



▼ The difference between Saturn's brilliant rings and Uranus' rings couldn't be starker. The narrow, faint rings in this image include (from top to bottom) the delta, gamma, eta, beta and alpha rings. Image: NASA/JPL.

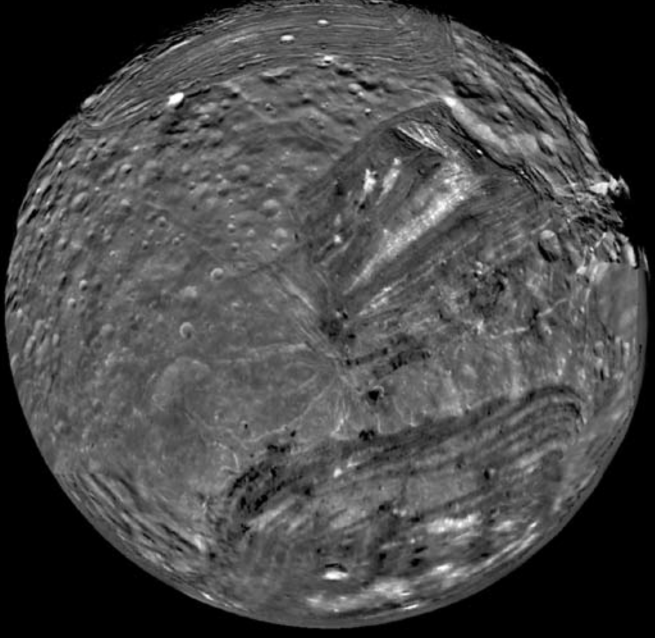


▲ A region 250 kilometres across on the surface of Miranda, showing the textured terrain. Hilly, rugged terrain is visible on the left, and striated lowlands on the right. Image: NASA/JPL.

is one pole continually in sunlight for half of its 86-year orbit, but also one half of the moons are continually in sunlight, so the whole system is very seasonally forced. There certainly seem to be unique circulation patterns on Uranus that are produced by this extreme tilt."

When Voyager 2 encountered Uranus, it was only able to image one hemisphere of each of the moons, the other hemisphere being in darkness. Although subsequent sophisticated image processing has teased out some extra details from 'Uranus-shine' on the dark hemispheres, the simple fact is that there is still plenty of new terrain on Uranus' 27 known satellites to be explored. The same can be said for the rings – Voyager 2 was unable to measure their composition, so it is still unknown whether they are made from particles of ice, or particles of silicate rock. Nevertheless, the recent equinox provided ample opportunities to learn more as the rings, and the orbital plane of the moons, moved edge-on to us. Observatories around the world, including Keck, the Very Large Telescope, Palomar Observatory and the orbiting Hubble Space Telescope, took advantage of the viewing angle to make several major new discoveries.

■ Miranda, shown in a computer-assembled mosaic of images obtained by Voyager 2. Nine images were combined to obtain this full-disc, south-polar view. The large trapezoidal region in the lower part of the image has been nicknamed the 'Racetrack'. Image: NASA/JPL/USGS.



"MIRANDA IS A PATCHWORK QUILT OF A MOON, BIZARRE BEYOND BELIEF, DISPLAYING A HODGE-PODGE OF DIFFERENT TYPES OF TERRAIN"

"The rings were observed to have changed quite markedly at equinox since the Voyager era," says Arridge. Back in 1986, the inner rings had been darker, but now, suddenly, they appeared much more prominent. Professor Imke de Pater, of the University of California, Berkeley, led observations of the rings with the Keck telescope. "People tend to think of the rings as unchanging, but the observations show that isn't the case," she says. "There are a lot of forces [such as gravity, sunlight and electrostatic forces] acting on small dust grains, so it is not that crazy to find that the arrangement of rings changes." One of the rings, called the zeta-ring, even appears to have shifted two thousand kilometres away from the planet during the intervening time.

Moon system

Uranus has 13 known rings, which are dense and distinctive, rather than being like the broad rings of Saturn. The Hubble Space Telescope discovered three new dusty rings in 2003 and 2005, as well as several new moonlets, including one diminutive satellite called Mab that may be the key to understanding how some of the rings are evolving.

Mab was discovered with its associated ring, the mu-ring, by Hubble in 2003. This ring is more diffuse than the others, and is somewhat reminiscent of Saturn's E-ring, which derives most of its particles from the spouting water-ice geysers of the frigid moon Enceladus. While Mab, which is a measly 19 kilometres wide, is too small to have dramatic geysers like Enceladus, it does seem to be the source of particles for the mu-ring. "There's clearly more than meets the eye with Mab," comments Arridge. "It's not just a chunk of ice and rock." The leading explanation is that the particles of the mu-ring originate from micrometeoroid impacts, and possibly the odd larger impact, on the icy surface of Mab, gradually whittling it away.

Moving away from Mab, there is a menagerie of other moons well worth exploring. As evidenced by Mab, they are all named after characters in the works of William Shakespeare and Alexander Pope, adding a literary flavour to the outer Solar System. While most of the moons are tiny, between about 20 and 150 kilometres wide, there are five noticeably large satellites, all visible to good amateur instruments – Miranda, Umbriel, Oberon, Ariel and Titania – and these were the only moons known of prior to 1986.

The first of the five is Miranda, a patchwork quilt of a moon, bizarre beyond belief. Three thousand kilometres across, it displays a hodge-podge of different types of terrain. One area appears ancient and cratered, another sports extensive grooves and fractures, while a third terrain appears dark and rectangular (nicknamed the Chevron). On all terrains are cliffs, ridges, fault lines and scarps, and frankly the moon is a mess. What happened to it? It appears to have partially melted, and refrozen, in different areas at different times. Computer simulations of the orbits of the moons suggest that Miranda was once trapped in a 3:1 orbital resonance with fellow moon Umbriel, which created gravitational tides that stirred up its insides, generating heat that resulted in cryovolcanism (basically volcanoes of ice rather than molten lava). Arridge likens Miranda to Enceladus, hinting at what Saturn's moon would be like were its geysers inactive. Perhaps, once upon a time, Miranda had geysers just like Enceladus does today.

Miranda, 350 kilometres across, is the closest of the five major moons to Uranus, at a distance of 130,500 kilometres – that is well within the distance between Earth and our Moon, so Miranda really is skirting the cloud tops of the planet. Fellow moons Ariel and Umbriel, at 191,800 kilometres and 267,200 kilometres respectively, could also easily fit inside the span of space between Earth and our Moon. Ariel, 1,050 kilometres across, is riddled with large, branching channels, while Umbriel, 800 kilometres across, is barren and cratered, and possibly has a ying-yang nature similar to Saturn's bright/dark moon Iapetus. The evidence for this

■ Titania, imaged by Voyager 2. Does this moon hide an underground ocean? Image: NASA/JPL.

■ Oberon's surface is marked with bright rays, similar to Jupiter's moon Callisto. On the moon's limb (bottom left) a six kilometre tall mountain can be seen climbing into space. Image: NASA/JPL.

comes from spectroscopic observations in infrared that detect water-ice, which find an abundance of it on Umbriel's leading hemisphere. Charged particles, trapped in the web of the planet's magnetic field, impact the surface more ferociously on the trailing hemisphere, where it causes particles of water-ice to be kicked off the surface and otherwise darken the ground, leaving behind a tarry carbon residue.

Titania (438,000 kilometres distant) and Oberon (586,300 kilometres) round off the large moons. Titania hosts a rather impressive fault system known as Messina Chasmata and is 1,500 kilometres long. A giant mountain, six kilometres high, was caught on camera on the limb of the moon by Voyager, and may well be the central peak of a giant crater.

The right orbit

What is particularly fascinating is the potential for some of these large moons to be 'roofed worlds'; moons with crusts of ice hiding liquid water oceans, maintained by a mixture of tidal heating from the gravitational fields of Uranus and their fellow moons, radioactive decay, and an anti-freeze substance such as ammonia. Plans to launch a mission to Jupiter to study its moons Europa, Ganymede and Callisto, which may all possess underground oceans, are already in the works, whilst Cassini is already at Saturn and inspecting its moons. Will the Uranus Pathfinder be able to find out whether any of Uranus' moons have oceans? It depends, says Arridge. "If we can get fly-bys of the moons then we will have the instrumentation to try and work out if there are oceans."

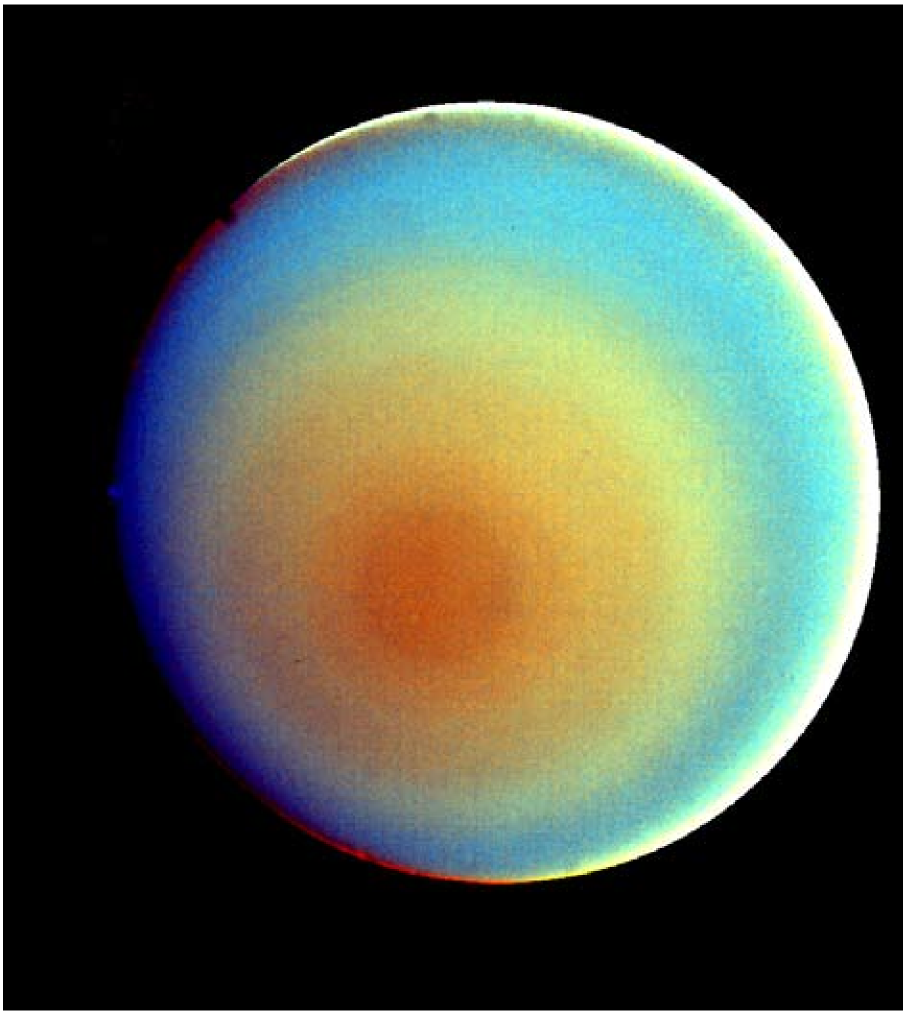
Pathfinder will have to make the best of what it can get. Being proposed as part of the European Space Agency's medium-class programme, it is limited to the launchers available for such missions. The M-type programme has a maximum budget of 470 million euros – about 398 million pounds at the time of writing – which puts the really big heavy lifters, which would make it simpler for Pathfinder to get into Uranus orbit, out of reach.

"As you can appreciate, getting out to Uranus is no easy task," says Arridge. "We were thinking that we wouldn't be able to get into orbit, but it turns out that there are some clever trajectories that will allow that. We haven't done a detailed study of a satellite tour, but we do hope to get a fly-by of at least one of the satellites."

D-day for the Pathfinder arrives in February, when the team discovers whether their proposal has made it to the final three that will go forward into the next phase. "At the moment we're in a competitive phase with up to 58 submitted proposals," says Arridge.

If chosen, Pathfinder isn't expected to launch any sooner than 2021. Even though it only took Voyager 2 nine years to reach Uranus, that was with the aid of a powerful Titan IIIE/Centaur rocket and gravitational slingshots around Jupiter and Saturn to help propel it on its way. Pathfinder will take a more direct route, and the use of a smaller launch vehicle will slow it down, making the journey last fifteen years. If everything goes to plan, we won't get our next close up look at Uranus until 2036, just six years after northern summer solstice on the planet, giving Pathfinder a mirror image view of what Voyager 2 found a quarter of a century ago.

Keith Cooper is the Editor of Astronomy Now.



▲ An enhanced image of Uranus taken by Voyager 2 through ultraviolet, violet and orange filters, showing the dark hood at the south pole, and the southern collar.

▼ Goodbye Uranus. Voyager 2's parting shot of the seventh planet, as it sped away towards a rendezvous with Neptune in 1989. Image: NASA/JPL.

Ask Alan

Freelance astronomy tutor at the Royal Observatory Greenwich, **Dr Alan Longstaff**, answers more of your questions.

Send your questions for Ask Alan to: Ask Alan, Astronomy Now, PO Box 175, Tonbridge, TN10 4ZY Or by email to: askalan2011@astronomynow.com. Please include your full name along with your address, phone number or email.

Q What shape is the Universe? Can we see the other side of it?

***Douglas McKenzie* (Aberdeen)**

There are two ways to think about this. First, what is the curvature of space locally; i.e. the observable Universe? The other is to think about the global geometry of the entire Universe. Cosmologists are fairly convinced now that locally the Universe is flat; it has the geometry we learnt as schoolchildren: parallel lines meet at infinity, internal angles of a triangle sum to 180 degrees, the circumference of a circle divided by the diameter is pi, and so on. Evidence for this comes from studying the cosmic microwave background (CMB) radiation. If the Universe is indeed flat then we need dark matter and dark energy (or some equivalent alterations to our theory of gravity) to account for the critical density of gravitating matter and energy that makes it so.

The global geometry is much harder. Now we have to ask whether the Universe is simply connected or non-simply connected, and whether it is infinite or finite (this boils down to whether it is unbounded or bounded). Let's take each of these ideas in turn.

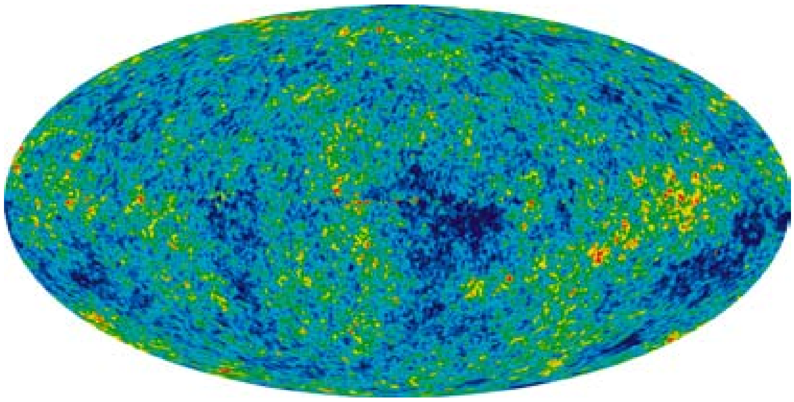
To think about connectedness imagine a sphere. This is a simply connected shape because you can place a loop anywhere on it and make the loop shrink to a point. You can't do that on a torus (doughnut shape). Lay the loop on top of the torus and as it shrinks it falls into the hole. Put it around the torus and it can't shrink without squeezing the torus. Hence a torus is non-simply connected.

A space is infinite (unbounded) if it can contain points arbitrarily far apart. A finite universe is a bounded space in the same sense that a triangle is bounded by three sides. If I remove one of its sides the space 'inside' what was the triangle is now unbounded. For most bounded universes it is possible to define a scale, a diameter or a volume; imagine the Universe as a sphere, for example. Unfortunately, for a flat universe the scale is not well defined and may or may not be detectable.

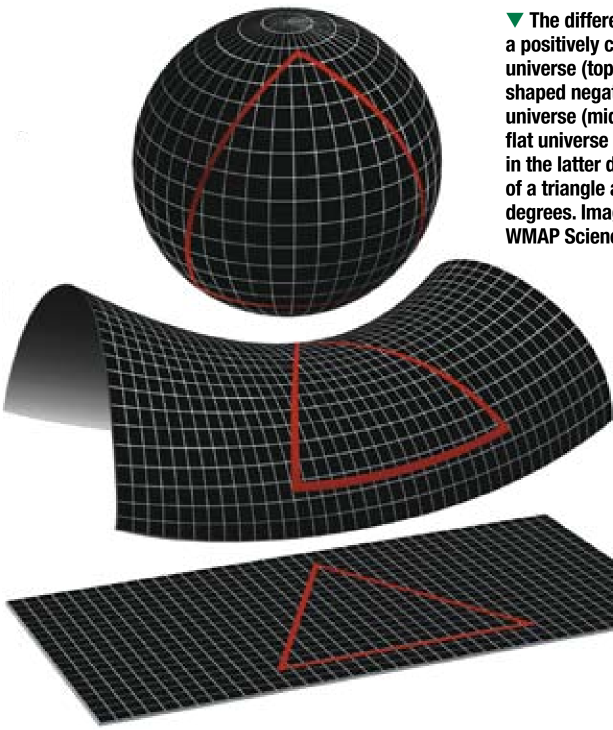
Some flat geometries are infinite (the Euclidian plane, which is simply connected), whereas others (e.g. the non-simply connected torus) are bounded. That a torus is finite seems intuitively fine, but that it is flat may sound surprising. A cylinder is flat because you can make it from a 2D sheet of paper curled up in the third dimension. Any triangle on the paper would be undistorted by this operation; its internal angles would still add to 180 degrees. Now if you bend the cylinder through a fourth spatial dimension (don't try to imagine this) you end up with a torus and the triangle remains undistorted. Now, the torus is just one of ten finite, flat, 3D spaces. The upshot of all this is we cannot tell whether our flat Universe is infinite or finite, and if it is finite and has three spatial dimensions there are ten possible shapes it might be, and we can't tell which.

We can't see across the entire Universe (even if it is bounded) but we might be able to see around it. Some of the ten potential shapes (but not the Euclidian plane) have closed geodesics, which means that there is a shortest possible path that gets you back to where you started. This is analogous to starting at the north pole and travelling along a great circle. Eventually you end up back at the north pole. Cosmologists are examining the CMB to see if there are multiple images of the same region, since this would mean that the light it emitted has had sufficient time to make a complete circuit of a bounded Universe. Such multiple images have been searched for, but not found so far.

If we are wrong about the Universe being flat and instead it has a locally spherical geometry then its global geometry could be like that of a football. If it has a local hyperbolic (saddle-shape) geometry then globally it is probably horn-shaped. If the Universe has more than three spatial dimensions I give up!



▼ **The shape of the Universe is imprinted in the cosmic microwave background radiation. Image: NASA/WMAP Science Team.**



▼ **The difference between a positively curved universe (top), a saddle-shaped negatively curved universe (middle) and a flat universe (bottom). Only in the latter do the angles of a triangle add up to 180 degrees. Image: NASA/WMAP Science Team.**

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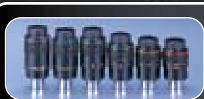

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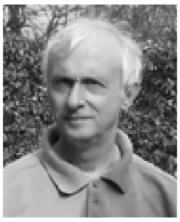


Telescopetalk

Martin Mobberley tells the tale of a splendid telescope made by 93-years-young Frank Horder.

An inspirational Dobsonian

Since the 1990s I have received e-mail queries about telescopes almost every day, but few have been as inspirational as the message I received recently from Neil Houghton of Warrington. Neil told me about a British ex-pat friend of his, Frank Horder, now living in Spain, who at the age of 93 had constructed a fine Dobsonian telescope.

Whilst living in Tenerife, Frank had enjoyed a firm friendship with Donald Dun, who was a Fellow of the Royal Astronomical Society. One day Donald told Frank that he owned a primary and secondary mirror suitable for making a 200mm Dobsonian telescope. Sadly, Donald subsequently became ill, but during Frank's twice-weekly visits to his friend's bedside they discussed plans for building a Dobsonian together, when he recovered. Unfortunately Don did not survive his illness, but he bequeathed the mirrors and his astronomy books to Frank, who was determined to see the project through to the end. Some time later Frank and his wife Jenni moved from Tenerife to Valéncia de Alcántara (a dark site near the Spanish–Portuguese border) and their new home provided the space to set up a proper engineering workshop. Shortly afterwards they met *Astronomy Now* reader Neil Houghton and his wife Jane, who visit Spain regularly, and they soon became firm friends. Neil became interested in Frank's dream of building the telescope and he searched the Internet for information on Dobsonian fabrication techniques.

First base

Frank made the bases for his Dob's azimuth and altitude bearings from 20mm plywood. The azimuth bearing consists of the usual Teflon pads and a large upper disc cut from a sheet of low friction Formica, attached to the plywood base. The azimuth pivot is a 10mm bolt. The altitude bearings were made from 160mm PVC pipe end caps fitted to a plywood box holding the tube, and the bearing side boards were machined by Frank, with craftsman-like precision, to produce the semicircular bearing cut-outs.

▼ Craftsman Frank cutting the Formica azimuth bearing.

Mirror, mirror

Frank made the telescope tube from a 250mm diameter PVC pipe and the primary mirror cell was made from two discs of plywood, fitted with bolts, springs, washers, wing nuts and three pads of cork. The mirror was held in place with three clips made from 3mm mild steel bar and blobs of silicone adhesive. Underneath the Dobsonian's base Frank attached four tiny posts, or feet, equipped with low friction sliders so that the whole telescope can slide about and be positioned on his patio. Finally, a TELRAD style of finder and a focuser were fitted. The only part that nonagenarian Frank found rather tricky was getting the telescope precisely collimated. Well, Frank, we've all been there!

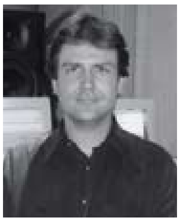
▼ Frank with the completed mirror cell, ready to be installed in the Dobsonian's tube.

First light

In September 2010 the telescope was ready for first light. To quote Frank precisely: "The first night I set it up in trepidation wondering whether I would get any results. Our friends Neil and Jane were with us at the time, as I focused, inevitably first on the Moon. Up came the craters good and clear, then Jupiter, clear with all four moons – first time – phew! Neil and I were dancing around like a couple of kids. I think that maybe you will be able to imagine my feelings at the time!"

Indeed Frank. You are surely an inspiration to us all!

▼ Frank Horder and his homemade 20cm Dobsonian on his patio.



Telescopetalk

Nick Howes pushes all the right buttons in his automated observatory.

Have you hammered out a home-made telescope? Manufactured your own mount? Dallied with a DIY dew shield? Write in and tell us about it! You can reach us at techtalk2011@astronomynow.com, or write to us at Tech Talk, Astronomy Now, PO Box 175, Tonbridge, Kent, TN10 4ZY. Don't forget to include your full name and address, and include any photographs you have of your DIY kit.

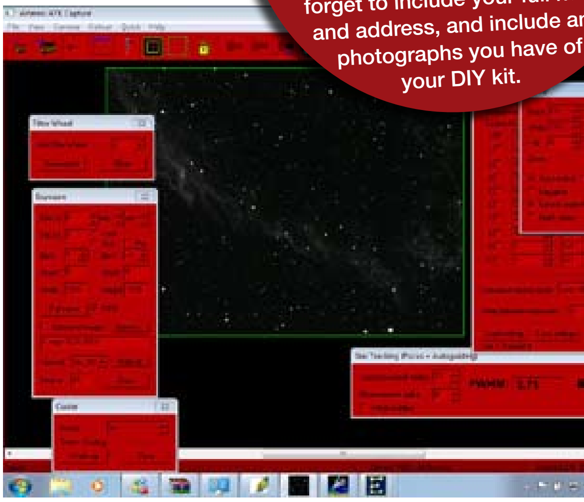
Automatic for the people

If you have ever seen the inner sanctum of a professional observatory you'll know that in almost all cases the observations are conducted from a warm control room, located either in the observatory site itself or remotely from locations literally anywhere in the world (see our *Astrophotography Techniques Focus* in the October 2010 issue, and *Gearheads* on page 84 of this issue, for more on amateur use of robotic observatories). Thanks to the UK's freezing winters and generally inclement weather, more and more people, myself included, have moved towards completely automating our own home observatories. My own drive and desire to do this additionally came from wanting to maximise family time. With young children in tow, being able to remotely control the observatory is a godsend, as after a few minutes setting up I can leave it running all night – occasionally glancing at the laptop to check sub frames and the guide graph – while remaining indoors with my family.

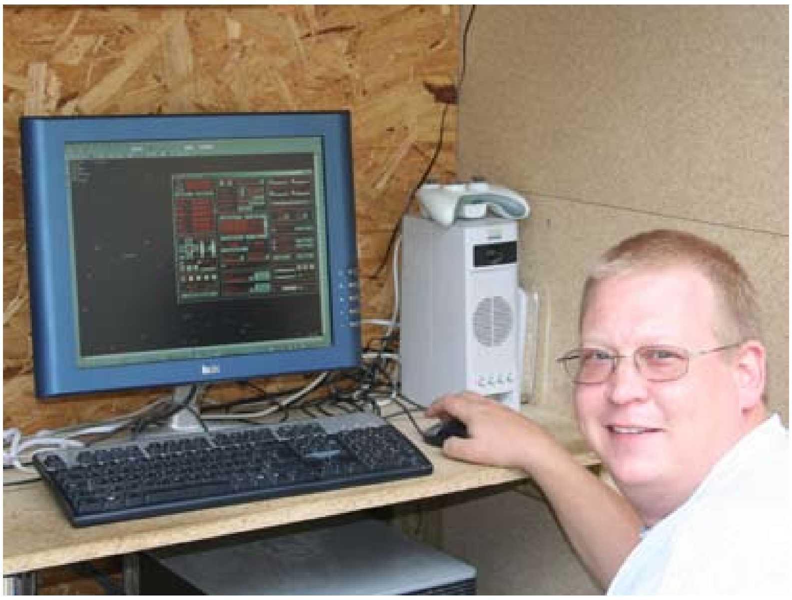
Tempted? Here are some of the steps you can take to make your observatory do all the hard work for you.

Roof on, roof off

Let's first consider the observatory itself. Many people dream of owning one – and the advantage in terms of time saved setting up and aligning equipment each night speaks for itself – but you still have to trundle out into the garden to roll back the roof or dome shutters. For the latter you also have to move it every so often to keep a clear aperture for your telescope, which can make for a chilly night in typically unheated domes. With both domes and roll-off roofs (see *Telescope Talk* August 2010 on how to make a roll-off roof observatory), you will still face the oft-unpredictable threat of a downpour, and I bet most of us have been caught out by a sudden shower, running frantically indoors with expensive kit.



▲ The author using Artemis' *ATK Capture*, a standalone program that allows you to control your Atik camera. Image: Nick Howes.

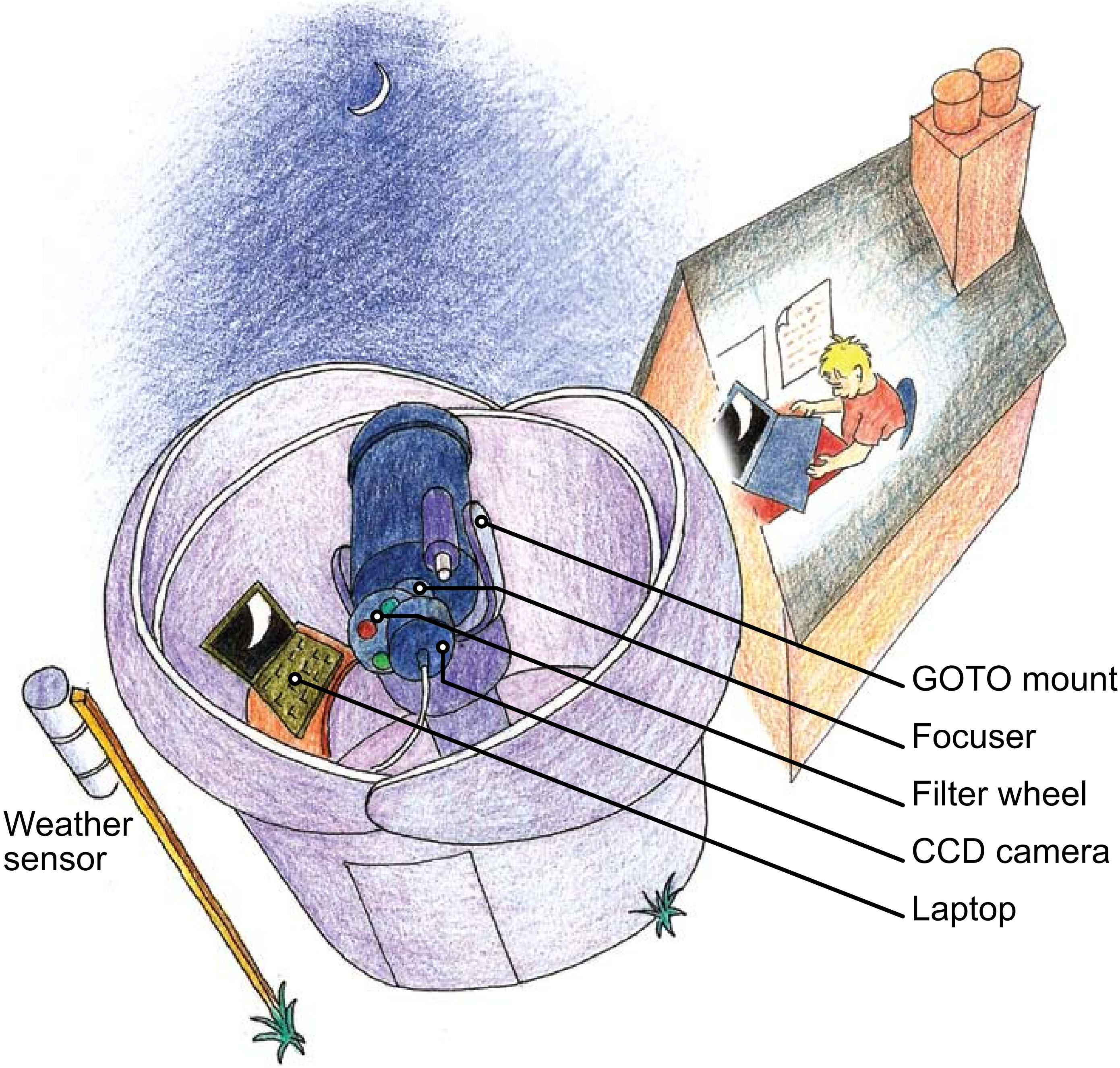


▲ Amateur astronomer Richie Jarvis using *EQMOD* and *Cartes Du Ciel* in his observatory set-up. Image: Richie Jarvis.

Given the lightweight nature of typically fibreglass dome shells, automating a dome is usually easier than automating a roll-off roof, which requires a lot more in the way of clout to get things going, even with pulleys and counterweights involved. Kits from companies like Pulsar Observatories can move a dome at a suitable rate to keep the sky in front of the telescope, and also open and close the shutters themselves. With USB and serial port control systems, the shutters can be linked into advanced weather station software and hardware like the Boltwood Cloud Sensor, or many of the homemade derivatives, which can even activate alarm buzzers linked to your house to wake you up or warn you when an impending downpour is about to happen. These sorts of systems may not be suitable for all roll-off roof observatory owners however, since automated roofs are inevitably slow-moving, potentially still leaving you with a very expensive puddle to clear up.

Mount up

Next is the mount. Many amateurs now have GOTO mounts, which are relatively easy to link to a computer – my own current set-up is a Sky-Watcher EQ6. Controlled by the free and immensely powerful software



▲ A home-automated observatory means you can be warm indoors while your telescope does the hard work for you. AN graphic by Greg Smye-Rumsby.

toolset *EQMOD*, it is also possible to map your horizon (preventing pointless imaging of objects behind a tree or house), handle the pointing accuracy, and detect when the mount needs to do a meridian flip (with an equatorial mount this is a given when objects pass over the telescope and it needs to 'flip' to avoid bashing into the mount, tripod or pier). By connecting that software, which uses the ASCOM protocol – an open standard for controlling many astronomical products – to a freeware planetarium like *Cartes Du Ciel*, you will move a big step towards automating your set-up.

Point and shoot

The range of software you can use to assist in automated imaging duties is immense. All of them, however, link from your computer in the observatory via USB and serial port connectors to your mount, camera, filterwheel, focuser and so on, to give you complete control over the essentials. I use an Atik 4000 camera that is controlled either via *Maxim DL* software, which has scripting capability and plug in support via third party applications for automating many tasks, or more simply from *Art Capture*, which again can be set up to conduct a night's worth of imaging on a single target using its sequencer control. These both control the camera and also the filterwheel. By adding to this with a product like the *Robofocus* by Technical Innovations (who also manufacture a range of other automation products), you can truly control what, how, how long for, and every other aspect of your imaging, from the comfort of your living room.

Remote login

Depending on the job, I now run *EQMOD/Cartes Du Ciel*, and *Maxim DL/Art Capture* from my living room using a low cost netbook in the observatory, which is connected via Ethernet mains links at 200mb per second to the home network. A laptop in the front room, using Microsoft's remote desktop, lets me see exactly what the netbook is doing, and allows me to control everything remotely. My cloud sensor is *PHD Guide* software's built-in 'star loss' alarm sound, which beeps over the remote link to inform me if the guide star is lost. Simple, cost effective, yet it works well.

Low cost USB controlled focusers from companies like Shoestring Astronomy and Orion can also be linked easily to your laptop, and using software you can adjust the focus until you're happy it's spot on, although using something like a Hartmann mask will still require you to pop outside to remove it. More sophisticated hardware focusing solutions link into products like *Maxim DL/FocusMax* and completely automate the focus, based on peak brightness and full-width half-maximum levels, so that temperature changes and movements in your mount/focuser can be addressed almost instantly.

Software can also assist in framing and positioning the target object, such as the excellent *T-Point*, which can model the pointing accuracy of your telescope and improve it over time (a feature which is also part of the superb *EQMOD*, where you build up a set of sync points when a star or object is dead centre in your CCD field-of-view, and the pointing accuracy of the humble EQ series mounts improves to an almost unheard of 0.4 arcsecond accuracy level). With *Maxim DL*'s plug in options however is the ability, to 'plate solve' it and correct the telescope's position based on the solved image. This is where the star positions are compared to a known positional database (either online or locally stored on your computer's hard drive) and if you're not pointing dead on at the object you have selected, the mount will be moved accordingly based on your actual position to the position you want. This becomes more critical when you're constructing large mosaic images or wishing to image fast moving objects such as asteroids, or if you're using a small but possibly very sensitive CCD for detecting supernovae in faint galaxies.

> "THANKS TO THE UK'S FREEZING WINTERS AND GENERALLY INCLEMENT WEATHER, MORE AND MORE PEOPLE HAVE MOVED TOWARDS COMPLETELY AUTOMATING THEIR HOME OBSERVATORY."

Automatic supernova hunting

As well as stacking up your own target hit-list for your telescope to work through, you can take things even further by using automation to assist in supernova searches. Such is the method of the remarkable Tom Boles who has 130-plus supernovae discoveries to his name at the time of writing – a Guinness World Record no less. Tom's use of the fantastic but expensive ACP (Astronomers Control Panel) and Orchestrate (a scripting language for moving and automating complete sessions) has yielded him almost legendary status in the astronomy world with his supernova finds, but let's not forget that a huge amount of investment both in his knowledge-base and skill-set, and also financially in the three telescopes he currently uses on world class mounts, is also the reason why he's so prolific. It's not just a matter of automating, it's

■ Tom Boles hunts supernovae from his automated home observatory. Image: Tom Boles.

DIY astronomy

Every amateur telescope maker with more than a few years in the hobby will have heard of the amazing John Wall, the inventor of the Crayford focuser and a builder of gigantic telescopes, including a 30-inch folded refractor. The original Crayford focuser was first demonstrated to the Crayford Manor House Astronomical Society by John, and then details were published in the February 1971 *Journal of the British Astronomical Association*. Since then, virtually all top range commercial focusers have dispensed with the rack and pinion system in favour of John's design where a round axle is pressed against a flat on the side of the drawtube and the drawtube presses against ball bearings for maximum smoothness.

Recently John was asked to make a huge load bearing focuser for the York Astronomical Society. It takes a 70mm diameter drawtube, with a 5mm wall thickness. The body of the focuser was handcrafted from aluminium angle sections and assembled using 2BA and 4BA screws; some parts were bonded together using epoxy resin glue. The focuser pinion is a length of precision ground high carbon steel rod, known as 'silver steel', 0.25-inches (6.35mm) in diameter. It runs in oil impregnated sintered bronze bearings, known as 'oilite bearings' which are pressed into the pinion bracket to give a tight fit. Magnificent!

■ John Wall's 70mm heavy duty Crayford focuser dwarfs one of his standard size units. Image: John Wall.

■ Palomar's 48-inch Samuel Oschin Telescope forms the backbone of the Palomar Transient Factory. Image: Nick Howes.

"IT'S NOT JUST A MATTER OF AUTOMATING – IT'S KNOWING WHY YOU'RE AUTOMATING AND TO WHAT PURPOSE."

knowing why you're automating and to what purpose. Even with some of the large sky survey systems things get missed and amateurs are still making valuable discoveries today, racking up impressive tallies of supernovae and comets using similar systems to Tom's, and conducting follow on work collaborating with professional observatories.

Target of opportunity

Not long ago I was in a meeting with the team at Mount Palomar, discussing their Palomar Transient Factory project (PTF, a fully-automated wide-field survey of the sky that hunts for supernovae, variable stars, active galactic nuclei and so on) and the potential follow on that amateur observations could offer. Getting e-mails from PTF or an orbiting space satellite about a gamma-ray burst or supernova event, and routing these via a simple ASCOM plug in (which I have been testing and is, as of time of writing, nearing completion) would alert you to the event. Linked up to planetarium software to determine if the object is in your area of sky, your telescope could automatically slew to the location to potentially do follow on observations of faint gamma-ray burst light curves or a supernova as it was developing or tailing off – a real 'target of opportunity' system. This is increasingly how the professional observatories around the world work, but also how some people with home observatories want to work, whether to just take wonderful images of the night sky or do some real scientific research. Having sat in the control room of one of the world's finest telescopes – and regularly using the professional two metre Faulkes Telescopes – there is something to be said for comfortable control, be that robotic internet telescopes or something closer to home, and the desire to do it yourself with your own equipment, and to the same kind of level, is one that has driven me to the place I am now.

If there is any downside at all to having a fully automated observatory, it is the lack of 'hands on'. Many astronomers, me included, love to be out under a beautiful night sky just looking up and collecting photons with the naked eye, but having the ability to now do both is something I enjoy and cherish, a real best of all worlds.

Nick Howes is the Equipment Consultant for Astronomy Now and Technical Consultant for the GEO Observatory in Spain and for Wiltshire Astronomical Society.

FIND OUT MORE

ACP observatory control software
http://acp.dc3.com/index2.html

Art Capture
http://www.atik-cameras.com/

ASCOM
http://ascom-standards.org/

Boltwood cloud sensor
http://www.cyanogen.com/cloud_main.php

Cartes Du Ciel
http://www.deepsky2000.com/cartes.htm

EQMOD
http://eq-mod.sourceforge.net/

FocusMax
http://focusmax.org

Maxim DL
http://www.cyanogen.com/maxim_main.php

Palomar Transient Factory
http://www.astro.caltech.edu/ptf/

California dreamin', Astronomy Now, August 2009

PHD guiding
http://www.stark-labs.com/phdguiding.html

Pulsar Optical dome observatories
http://www.pulsar-optical.co.uk/cat/observatory/dome/glassfibre.html

Robofocus
http://www.robofocus.com/

T-Point software
http://www.tpsoft.demon.co.uk/

Gearheads

R Jay GaBany is one of the world's most renowned astrophotographers, with his images gracing many magazine and websites. He tells Gearheads how he achieves his magnificent results with his remote Blackbird Observatory.

Remote **viewing**

▲ **Blackbird Observatory, nestled in the mountains of New Mexico. All images: R Jay GaBany.**

I **began** taking images from my back garden in suburban San Jose, California about six years ago after thirty years of visual observing. However, I couldn't have chosen a much worse location because my neighborhood is surrounded by over three hundred streetlights positioned about 30 metres apart. The glare from these lamps makes it possible to read a newspaper without assistance at midnight. Still, I was undeterred and determined to take pictures through my telescope. But these first images were awash with bright background gradients instead of deep space darkness. Counter-intuitively, I discovered that extremely long exposures made it easier to remove the light pollution filling my pictures during post-production. As a result, I spent most of my time trying to salvage the astronomical subjects in my photographs rather than enhancing them.

After a year of battling these local conditions, I searched and discovered a telescope located under clear, extremely dark skies in the south central Sacramento Mountains of New Mexico, USA about 1,200 miles from my home. The instrument could be remotely controlled using a common Internet browser, featured an aperture of half a metre and was available for a relatively modest hourly rental rate. After one session, I was hooked and within three months sold my back garden instruments, purchased a large block of time and began exposing pictures long distance. Within a year, I became the telescope's owner because I realised that nothing is more important to successful astrophotography than working under dark skies untainted by city lights. Without pitch black skies, everything else (seeing, telescopic aperture, photographic exposure length and even sky clarity) is irrelevant if you want to produce colorful, naturally hued, high contrast deep images of heavens.

Remote link

Operating a remote observatory is similar to using a back garden, computer controlled telescope with a few significant differences. For example, my telescope is controlled by a standard off-the-shelf computer located inside the observatory and accessible from the Internet. The telescope mount, camera, filter wheel, guider, instrument rotator, focuser and dome are connected to this computer using USB cables. A small movable IP camera faces the telescope and provides a live view of what's happening under the dome. Local weather conditions are obtained from the national weather service, satellite data, an electronic weather station mounted outside the building and a light-sensitive all-sky camera that's useful to spot rapidly changing sky conditions immediately overhead. Thus, accessing the remote computer's desktop provides much of the same control as if I were physically seated alongside my instruments.

Any back garden astro-photographer can walk over, extend their hands and adjust their instruments when needed, and cover or move their telescope inside should the weather suddenly turn inclement. This is not possible when your equipment is located hundreds or thousands of miles in the distance.

▲ Jay GaBany at work on his home computer, using the interface that controls the telescope from the comfort of his study.

So, even small situations mushroom into a crisis quickly. For example, local observatory power failures, the loss of Internet connectivity or a dome that refuses to close can lead to catastrophic conditions if the weather turns bad. Therefore, it's vital to have a ground crew nearby who's willing to provide 24/7 assistance at a moment's notice because a remote observatory might as well be located on the far side of the Moon if something unexpected breaks. Fortunately, I've received consistently responsive local support.

Robotic observatory

There are several applications on the market that literally turn a telescope into a robot. These powerful, clever tools enable the astrophotographer to script the complex steps required to obtain deep exposures. Their execution also permits the user to grab a good night's sleep confident their observatory will automatically close and protect their valuable equipment if the weather turns unexpectedly for the worse. I've used these solutions on several occasions but still prefer to remain awake and review each exposure as it downloads from the camera. I miss being able to stand by my telescope at night, gaze up and view the same sky that rivets its attention. While it's infinitely more convenient to expose images from the comfort of a warm home office, I admit my connection to the night sky has weakened over time. So, monitoring the camera's progress is one way I compensate and retain a smidgeon of that old romance with the stars.

At the end of a night's session, each exposure is downloaded and re-inspected. Since many of my imaging projects encompass multiple days or weeks it may be months before I commence my post-production processing. Working with extremely long exposure times enables the surfacing of extremely faint features with a minimum of noise. Since all of my projects are produced unbinned, the color exposures permit me to reveal small often overlooked structures, too. Typically, I'll spend several hundred hours processing the data my camera has gathered and often start from scratch at least once or twice before reaching an acceptable conclusion.

The effort I invest often produces results wholly unexpected and occasionally surprising, even to me. However, I enjoy the hours spent in post-production because it allows me to explore the places my camera has captured as if I were actually there. Unfortunately, the stars will remain physically beyond our grasp until long into the far future. So, until our forebears consider Orion the best place to spend their next vacation, astronomical images are the closest we will get.

The past few years have been quite a personal journey from my initial light saturated back garden imaging attempts. However, there are many others who have traveled a similar path to the stars and I suspect, over time as the night sky continues to brighten, many more will follow.

▲ The interior of Blackbird Observatory, with the 0.5-metre (20-inch) Ritchey–Chrétien that was manufactured by RC Optical Systems. It is mounted on a Paramount ME. Prior to 2010 Jay used an 11 megapixel SBIG STL-11000M CCD, but this has now been superceded in his observatory by a 16 megapixel Apogee Alta U16M-HC.

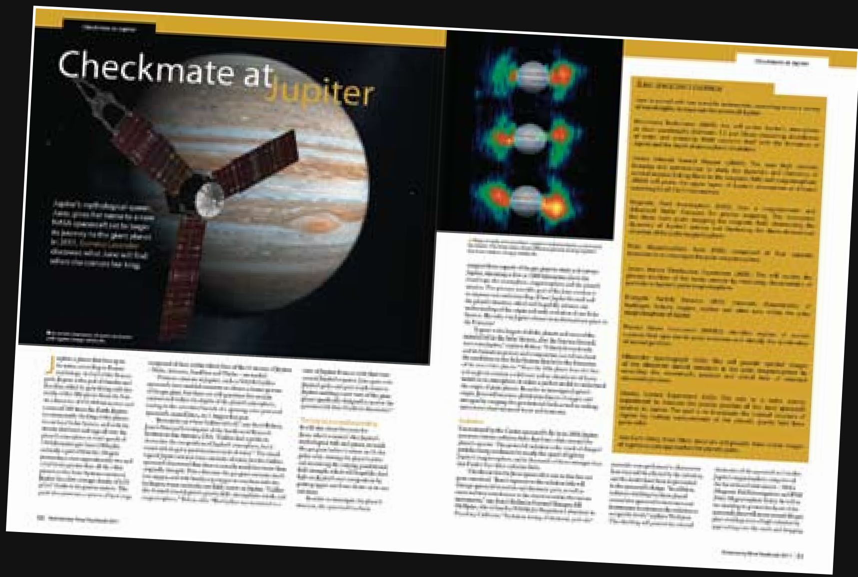
For more relating to remote-controlled observatories, see *Telescope talk* this month on pages 80–83.

R Jay GaBany is an astrophotographer living in California. His first remote observatory, the Blackbird Observatory, was located in the mountains of New Mexico. His new observatory, Blackbird Observatory 2, is relocated in California's Sierra Mountains. You can experience his wonderful astrophotography at www.cosmotography.com.

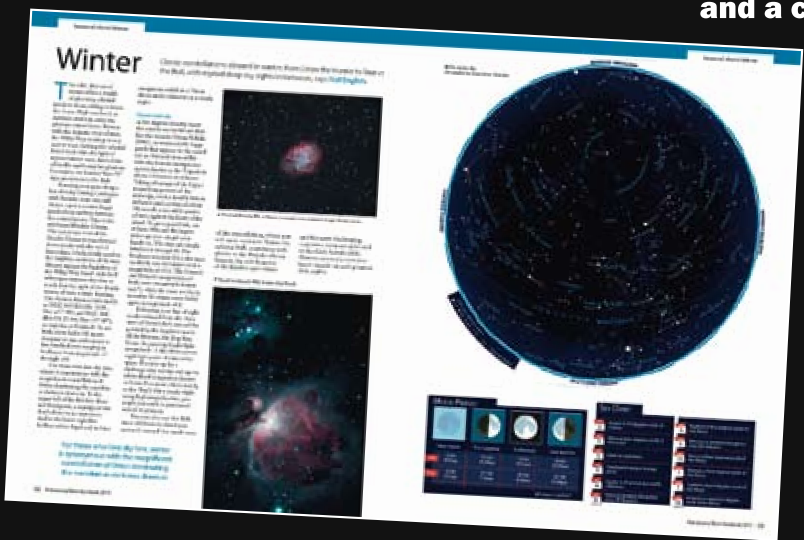
▼ The lovely spiral galaxy M106 in Canes Venatici, imaged by R Jay GaBany. The red 'arms' sprouting from the galaxy's core are caused by jets emanating from the supermassive black hole at its centre and shocking the surrounding gas. The image was captured over a total exposure time of 37-hours between April and June 2010.

Astronomy NOW

2011 Yearbook



Our latest 116-page *Astronomy Now* special edition is an extravaganza of astronomy for the year ahead. Featuring star charts for all seasons, special sky tours of galaxies, star clusters, the summer Milky Way and winter's bright stars, plus a look at what the planets are doing in 2011, the *Astronomy Now Yearbook* is the perfect catch-all guide to the night sky over the next twelve months. Plus, there's more! We introduce you to major new space missions: GRAIL, a gravity mission, is off to the Moon; Mars lander Curiosity will launch towards the red planet and Juno will commence its five year journey to Jupiter, where it will get to the bottom of the giant planet's structure, origin and evolution. We also present an epitaph for the space shuttle, and find out what the Cassini, Mercury MESSENGER and the planet-hunting Kepler spacecraft are up to. And to see you through the year's biggest observing sessions we provide an essential star party survival guide. With all this, plus a lookback at 2010 with our news review and a collection of some of that year's best astro-pictures, for just £4.99 the *Astronomy Now 2011 Yearbook* is the perfect Christmas present for all astronomers!



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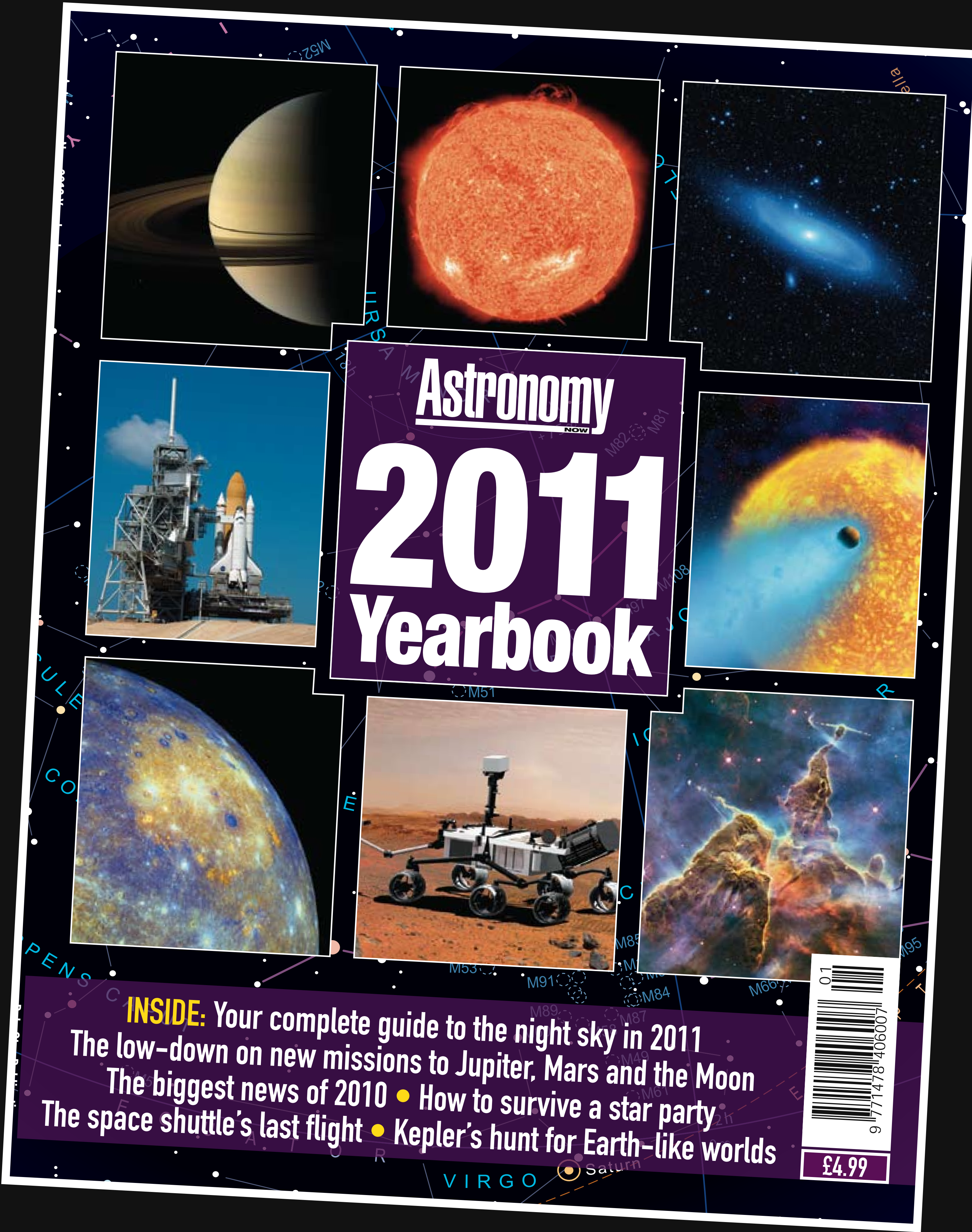

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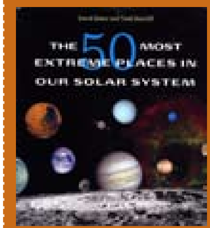
Book reviews

The 50 Most Extreme Places in Our Solar System



Authors:
David Baker and Todd Ratcliff
Publisher:
Harvard University Press
ISBN:
978-0-674-04998-7
Price:
£19.99 (Hb), 143pp

This planet on which we find ourselves is part of a larger, unforgiving and extraordinary environment; it's kind of like growing up all safe and warm but in the middle of a busy road.

There is no shortage of harsh realities out there and this book deals with many of them, such as Jupiter's enormous magnetosphere, Venus's super dense atmosphere and diamond hail on the ice giants Uranus and Neptune.

Every chapter is given to detailing each of the 50 chosen extremes and each are described in a clear and accessible manner, including up to date information from spacecraft such as Cassini at Saturn.

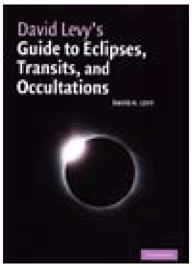
Although deemed 'extreme' it's not all volcanoes, gaping impact scars and tidal waves – many chapters deal with gentler wonders such as solar eclipses, the awe-inspiring rings of Saturn and our own planet Earth all illustrated by a multitude of high quality images.

As may be deduced from the title, this book would be of immediate interest to younger readers and their attention would easily be maintained by the tone and clarity of the writing. That said; more seasoned readers will also find it an enjoyable and fascinating look at the Solar System around us and will no doubt broaden their knowledge.

I fully recommend this book to anyone of any age with an interest in the Solar System and how much of a hostile, humbling and amazing place it is to exist.

David Powell

David Levy's Guide to Eclipses, Transits, and Occultations



Author:
David H Levy
Publisher:
Cambridge University Press
ISBN:
978-0-521-16551-8
Price:
£18.99 (Pb), 222

As the discoverer of 23 comets (eight visually) and dozens of asteroids, David Levy is one of the great amateur astronomers of our age. His co-discovery of the comet that bruised Jupiter in 1994, Shoemaker–Levy 9, ensures his immortality in the astronomical annals. In recent years Levy has turned his considerable skills to being an author and when writing about comets, Clyde Tombaugh or Gene Shoemaker, there are no greater authorities. However, his new *Guide to Eclipses, Transits, and Occultations* is obviously not about comets and with authors like NASA's Fred Espenak (and his colleagues) competing in the same field, this is a tough area to break into.

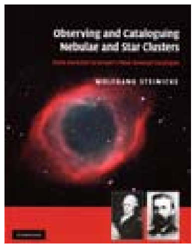
The first thing to say about this book is that it is not a heavyweight or a comprehensive tome. It consists of only 177 pages and some 60,000 words of text. Eighty percent of the book is about eclipses, mainly solar ones, with 25 pages covering eclipses of the Moon. Lunar occultations occupy nine pages and transits (of the Sun by Mercury or Venus) cover a mere seven. A scant two-thirds of a page is devoted to asteroid occultations.

Unfortunately, all of the illustrations are reproduced in a very drab monochrome. Most of the 56 photographs are uninspiring and, sadly, far too dark, hinting that the quality control at the printers was ineffective. You will certainly not gape in awe at a Miloslav Druckmüller solar corona masterpiece here!

On the positive side the book is very well written, in a friendly personal style, and therefore easy for a complete beginner to understand. However, the only part that really grabbed my attention was Chapter 17, which describes, over 14 pages, the 77 times that Levy has witnessed partial or total solar and lunar eclipses since 1959, when he was just eleven years old. Other than that section, regrettably, I found the book just a bit too basic for my taste.

Martin Mobberley

Observing and Cataloguing Nebulae and Star Clusters



Author:
Wolfgang Steinicke
Publisher:
Cambridge University Press
ISBN:
978-0521192675
Price:
£90 (Hb) 660pp

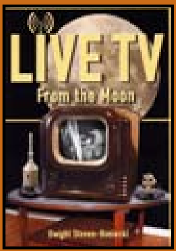
There are probably two catalogues well known to most deep sky observers; those of Messier and the New General Catalogue (NGC) of John Dreyer. Whilst the history of Messier's catalogue has been well covered in numerous books the story of the New General Catalogue is not as well known. In this large tome Wolfgang Steinicke sets out to remedy this unfortunate state of affairs. Subtitled *From Herschel to Dreyer's New General Catalogue* it sets out to chart the history of the discovery of nebulae from the pioneering catalogues of Sir William Herschel through to the last of the visual discoveries that made up the NGC. The book also touches on the contents of the two Index Catalogues (IC) as well. The main part of the book discusses the observations from all the great and not so well known observatories including those done at Birr castle with the 72-inch Leviathan and those done with small refractors from Europe.

The stories covering the discoveries and controversies around variable nebulae are well told along with the evolution of instrumentation that went from the speculum metal reflectors of the Herschels and Lord Rosse through to the silver on glass reflectors via the refractors. The book also covers the history of several of the more interesting nebulae in the NGC, such as Hind's Variable Nebula and the nebulosity surrounding the Pleiades. There is also a large section on the discovery of the spiral nature of M51 and how it fitted into the cosmogony of the time.

This is not a book to sit down and read all the way through, at least not at one sitting. It is a must for anyone interested in the history of deep sky observing and Cambridge University Press are to be congratulated in publishing what may appear to be a very niche publication. The book does contain a number of appendices and a vast bibliography for readers wishing to delve deeper.

Owen Brazell

Live TV From the Moon



Author:
Dwight Steven–Boniecki
Publisher:
Apogee Books
ISBN:
9781-926592-16-9
Price:
$25.95 (Pb) 248pp plus DVD

Television has always been associated with hysteria, no doubt because if only you can get yourself on it, you are assured of instant personal celebrity. Dwight Steven-Boniecki was born in Sydney, Australia, only months before Neil Armstrong stepped on the Moon in July 1969, but has neatly captured the spontaneous marriage between space exploration and television. They started life together and grew up by feeding upon one another.

He has spent his life working in TV, and in this book he tells reporters like me who were at Cape Canaveral and Houston watching it all happen before he could talk, things we did not know at the time. Why was it that Honeysuckle Creek in Australia got a much clearer picture of Armstrong's descent to the lunar surface than we did? I have vivid memories of my personal panic trying to understand and describe the fuzzy, black-and-white, upside-down picture we were receiving as that historic event was taking place.

What had happened was that the controller at NASA's Goldstone antenna panicked as the upside-down picture began to build on his screen, and made things worse by trying to compensate by changing the brightness and contrast settings. With a much bigger antenna than Australia's, our picture would have been much better if he had left things alone.

For the technically-minded, Boniecki describes in detail the battle between RCA and Westinghouse to provide a TV camera able to withstand the low pressurisation on the Moon - finally won by Westinghouse. For the layman it is more interesting to read how Frank Borman, the Apollo 8 commander who made history with his Christmas TV broadcast as he and his crew made the first circuit of the Moon, strongly resisted having to take the 12-pound TV camera when it necessitated leaving behind some of their meals to save weight.

That camera not only made TV stars of the crew but also convinced millions that they must rush out and buy a TV set. "I was very short-sighted," Borman confessed.

Reginald Turnill

INTERVIEW

▲ Todd Ratcliff (left and David Baker (right)
Image: Babette Sparr / David Baker.

Dr David Baker – a research scientist from NASA's Goddard Space Flight Center who explores extreme weather on Earth and other planets – and Dr Todd Ratcliff, a scientist at NASA's Jet Propulsion Laboratory – have explored the most radical, dangerous, adventurous and simply different environments of our Solar System in their exciting new book, *The 50 Most Extreme Places in our Solar System*. *Astronomy Now* caught up with them to find out how extreme the Solar System really is.

How do you define 'extreme' in the book?

By extreme, we mean things that are unique, quirky, out of the ordinary – cool stuff 'beyond the norm'. The question then becomes, what exactly is the norm? We humans are biased by our experiences here on Earth. A tiny microbe (should it exist) on cold, dusty Mars would have a completely different idea of 'normal'. In the book, we try our best to keep a broader Solar System perspective of the 'norm'.

Is there a place in the Solar System that, above all others, you would say is the most extreme?

Although it was tempting, we chose not to rank the extreme places from 1 to 50 in the book. We thought it would be more fun for the readers to decide the most extreme place in our Solar System. You can vote for your top extreme places at our website www.ExtremeSolarSystem.com and see how your opinion compares to that of other readers.

Of course, a discerning reader may be able to uncover our own opinions on the most extreme place – there are extreme clues scattered throughout the book.

What's the most 'fun' extreme location that you came across whilst writing the book?

One of our favorite sections in the book is called 'The Wack Pack'. From the 'Best Fuel Depot' to a 'One-Eyed Monster' to the 'Strangest Life-Form', this section explores some of the most bizarre places in our celestial neighborhood.

We often hear from kids of all ages that one of the most fun extreme places is Jupiter's smelly moon Io, a 'fun-ky' member of the Wack Pack. As the most volcanically active place in the Solar System, Io continually emits fresh sulphur compounds onto its surface. The colorful moon reeks like a jumbo rotten egg.

By studying extreme locations elsewhere in the Solar System, what do we in turn learn about Earth as a result?

We learn a great deal about where Earth fits in the continuum of Solar System bodies. From hellish Mercury to cold, distant Kuiper Belt objects, there's always something new that informs what we know (or think we know) about our own home planet.

We can use the other planets and moons as a kind of laboratory to test our theories about planetary formation, weather, plate tectonics, climate, and even life. One classic example is how the study of Venus' runaway greenhouse led to the development of the Nuclear Winter hypothesis during the Cold War. A more recent example is a suspected nano-fossil within a meteorite from Mars that kick-started the whole field of exobiology and the detailed study of extremophile organisms here on Earth.

Do you consider the Solar System, or the Universe as a whole, to be too extreme for life to really make a mark?

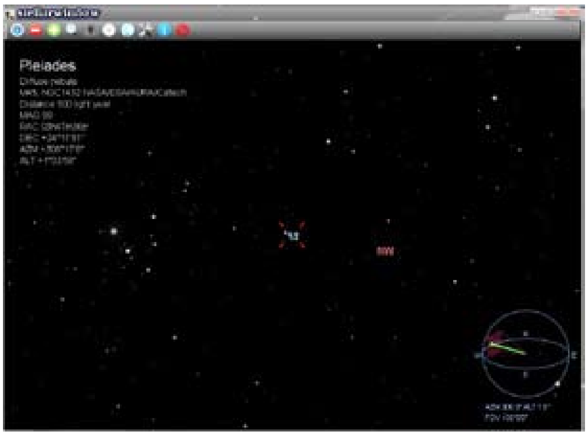
One could argue that life has already made its mark in the Solar System and beyond. Television and radio signals from Earth have been propagating through interstellar space at the speed of light for several decades. And soon, NASA's Voyager spacecraft will cross the heliopause (the boundary between our Sun's solar wind and stellar winds from other stars) into interstellar space. It's possible that life in other solar systems is leaving similar marks, but our technology is too primitive to detect them.

Is there any chance of a second book that takes us out of the Solar System and into the wider Universe?

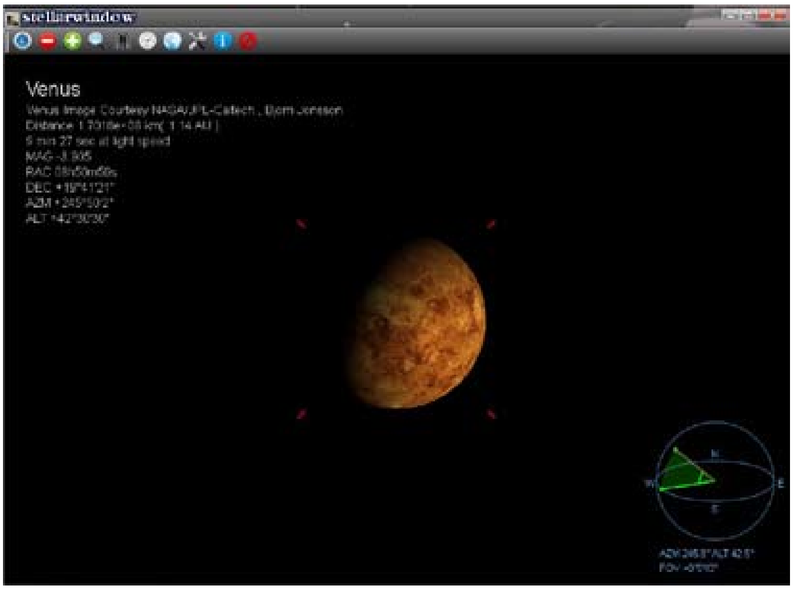
We do indeed have a couple ideas in mind for future books. Just as you suggest, one direction is to explore beyond our Solar System into the 'Extreme Universe': exoplanets, quasars, pulsars, black holes – the list goes on and on. Another possibility is a children's version of *Extreme Solar System* with roughly a dozen fun extreme places (like stinky Io) for younger kids. We are 'extremely' excited about both projects.

Opening the **stellar window**

Steve Ringwood steps out under the virtual sky as he tests a new laptop planetarium that gives real time tours of the night sky controlled by a USB sensor.



▲ ***StellarWindow* successfully finds the Pleiades. Image: Steve Ringwood.**



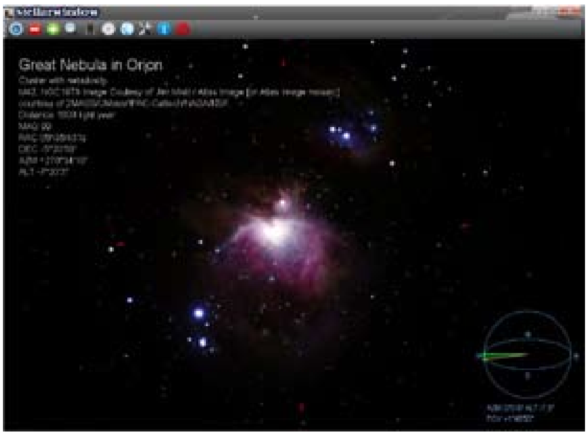
▲ **The conclusion of a search for Venus with *StellarWindow*, and subsequent magnification showing correct phase. Image: Steve Ringwood.**

Prior to the coming of the silicon chip, we had the planisphere. To this has been added the computerised power of sky-mapping software. Now, something new stirs in the wood; sky-mapping software controlled by a guiding USB sensor – capable of both identifying and seeking out celestial objects.

No larger than a couple of stacked CDs, the *StellarWindow* kit – courtesy of Japanese start-up company Fairy Devices, Inc, and supervised by Professor J Watanabe of the National Astronomical Observatory of Japan – is comprised of the software CD, the USB device, USB extension lead and user's manual. The software loaded easily on my less than top-spec laptop and in not more than 15 minutes I was ready to roll.

Remaining inside the house for my trial run, I inserted the sensor's lead into the laptop's USB port and kicked off the software. I was presented with a star map displaying realistically twinkling stars. To my astonishment, I realised the software was already obeying the sensor. The celestial co-ordinates diagram, which had appeared in the lower right of the screen, correctly showed that the current target altitude of the sensor was zero (as it was flat on the desk) and the stellar screen itself showed it pointing west – which indeed it was. I hadn't even done anything yet!

▼ **Having located the Orion Nebula, M42, the *StellarWindow* user is presented with an image, distance, RA and Dec. Image: Steve Ringwood.**



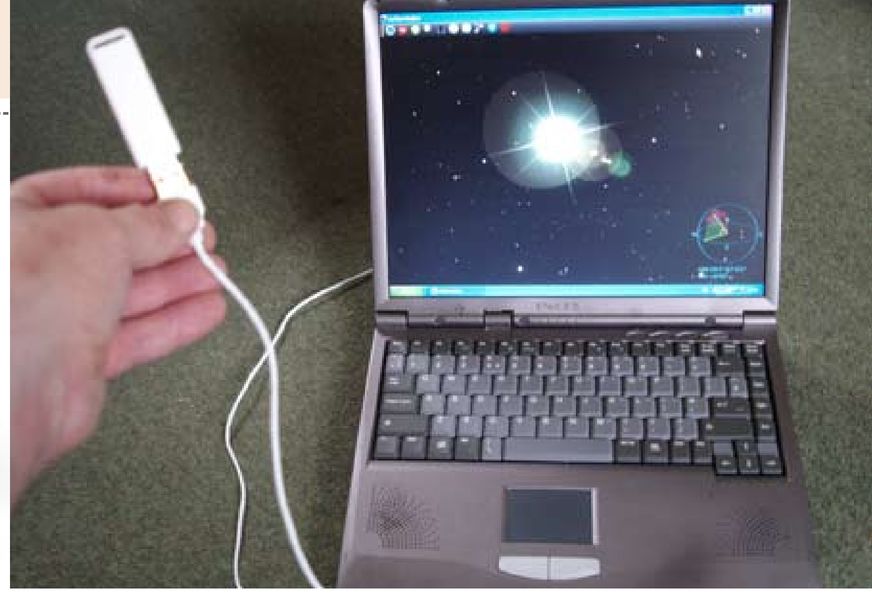
I nudged the sensor. In response, the stars on my screen moved likewise. With experiment, I found that the merest trace of movement was reflected on the screen. Fitted with the latest geomagnetic and motion detectors, this sensitive sensor has six-axis high definition awareness of its own movement and the target area to which it is being pointed.

Still inside my living room, I swung the sensor towards the ceiling. Into the virtual sky on my screen, a galaxy hove into view. Clicking my cursor on its image, the galaxy was immediately centred in a fixed screen accompanied by textual information. It seems that in my blind wanderings I had captured M31. The caption blotted its copybook somewhat by using the out-dated term 'Great Nebula in Andromeda' rather than the Andromeda Galaxy, but the functionality was impressive nonetheless. The text included information on its other designations, distance, magnitude, co-ordinates and current azimuth and altitude. Having absorbed the data, I clicked on the 'sensor-control' icon on the software's taskbar and I was happily swivelling around my internal 'sky' once more.

Get the time zone right

Before venturing outside I had a nagging concern that, with the added functionality of ongoing sensor input, would it hold up against a standalone PC sky map? Against three other well known stellar software products, I carefully compared positional accuracy of stars, planets and sky aspect and found it equal to them all. Cartographic credentials firmly established, I looked forward to using *StellarWindow* with a vengeance – in the dark.

But the stars could wait. As dusk fell, an obvious twilight target presented itself. Low in the west, Venus shone like a beacon. I set up a small table in the garden and as the turquoise evening cooled I fired up my laptop. As soon as the virtual star map appeared on the screen, I picked up the sensor and slowly brought it around towards Venus. As I did so, I could see Venus appearing at the edge of the laptop's screen. With one (sensored) arm outstretched towards the real Venus, I clicked on the virtual



Venus for the proffered data. Magnifying the planet via the screen zoom function, I found the current phase perfectly represented.

Yet it had seemed to me that when the sensor had been pointing directly towards Venus, its electronic doppelgänger had not reached the centre of the screen. Using another tack, I pointed the sensor far away to the east and then initiated a search for Venus using the 'object search' panel. A graticule appeared on the screen, illustrating the angle and distance of the desired target from the sensor's current position. Then, suddenly, a voice from the laptop began giving vocal directions towards the planet. As I moved under instruction, towards the west, the voice gave a running status as to how many degrees in azimuth and altitude remained to accomplish acquisition. As I moved the pointing sensor around, the screen graticule showed my progress towards Venus.

But before I was dead on target, the voice announced that I had arrived. I estimated I still had about 10 to 15 degrees to run. My heart sank. I had experience of similar devices that were found to have inherent inaccuracy and history seemed about to repeat itself. But it was the extent of the error that gave me the clue. It struck me that the error was about an hour's worth of sky movement. I found the software was using PC time as default – and being BST this was advanced from GMT (universal time) by an hour. I found no daylight saving switch in the software, but there is the facility to set it to any time required. I cajoled the software into GMT then repeated my tests. I am happy to report that it performed flawlessly from then on. Requesting Venus, it guided me to the fast sinking planet with uncanny accuracy. Saturn, too, albeit barely penetrating the twilight, became visible to me by sole virtue of the software's guidance.

When true darkness fell, I directed the sensor at different points in the star-washed sky and saw this represented on the screen. It did not seem to matter how fast or slow I moved the sensor; once directed, it would stabilise its new view quite quickly and stand ready for instruction. During a long and fascinating celestial sojourn, I used the screen cursor to identify stars towards which I was pointing – or in curiosity demand to be guided to unfamiliar objects. By turn it obeyed me, then I it.

When I found nebulae or galaxies, the screen enabled me to zoom in for higher definition viewing (in which photographic and computer graphic imagery are interwoven with great skill). So it was a sort of observation session, but without the telescope.

The software holds a catalogue of 2.5 million stars (Hipparcos and Tycho 2), 6,000 deep sky objects and even Earth-orbiting artificial satellites. Deployable on PCs, laptops, notepads or tablet PC devices, the *StellarWindow's* use of a USB lead means the sensor can be fitted and aligned to any optical device to turn it into a computerised GOTO instrument – be it a massive Dobsonian or pair of binoculars.

This is what a digital tutor of the sky should be – it is just a shame there is not a Mac version yet for use on the iPad. Accurate and simple – and use of a bona fide computer provides a massive screen full of detail. A joy to use. Absolutely recommended.

Steve Ringwood is a regular contributor to Astronomy Now.

▲**The USB sensor pointing towards the Sun. Image: Steve Ringwood.**

Specifications

Operating System:	Microsoft Windows XP SP2 or higher.
'Normal' operating mode laptop PC system requirements:	
CPU:	Intel Pentium 4, Xeon, Core Duo compatible or higher
Free Memory:	1GB or more
Graphic Environment:	OpenGL compatible graphics hardware
Monitor:	1280 x 1024 dots resolution or larger recommended
Hard disk space:	1.2GB or more
'Lite mode' Notebook PC system requirements:	
CPU:	Intel Celeron M 900MHz compatible or higher.
Free Memory:	300MB or more
Graphic Environment:	OpenGL compatible graphics hardware
Monitor:	800 x 600 dots resolution recommended
Hard disk space:	160MB or more
Supplier:	Altair Astro
Tel:	01263 731 505
Web:	www.altairastro.com
Price:	£199

StarSpikes **Pro**

Nik Szymanek runs the rule over a *Photoshop* plug-in that can make your astronomical images even prettier.

At a glance:

System requirements:
Windows XP, Vista or Windows 7
Compatible with all versions of Adobe Photoshop, Adobe Photoshop Elements, Corel Paint Shop Pro, and other image editors that support 8BF style plug-ins

Price: $59.95 (£38.55 at time of writing)

Available from:
http://www.ProDigitalSoftware.com/StarSpikes.html

One of my favourite and most influential books is *Colours of the Stars* by David Malin and Paul Murdin. It features many groundbreaking images taken with the Anglo–Australian Telescope, many of which show alluring and photogenic effects around bright stars including haloes and pin-sharp diffraction spikes. As CCD imaging became popular many amateurs attempted to recreate these effects (which of course are nothing to do with the actual star but rather because of the wave nature of light causing diffraction around the four supports holding the telescope's secondary mirror). By placing two threads of string over the front aperture it's possible to include these diffraction spikes in CCD images. Many modern catadioptric telescopes naturally create diffraction spikes, including my own Vixen VMC-260. Refractors, with their unobstructed light path, do no such thing, hence the use of string.

Now it's possible to purchase a *Photoshop* plug-in to include diffraction spikes during the processing stage, which offers much finer control. ProDigital Software, a US-based company, offer *StarSpikes Pro*, written by the well-known image-processing expert Noel Carboni. The plug-in can be downloaded and tried for 15 days, which is plenty of time to get used to running the software. Once installed, it's accessed under the 'Filter' menu. With your image onscreen the plug-in is launched and the software automatically detects the brightest stars in the image and displays the new diffraction spikes on them.

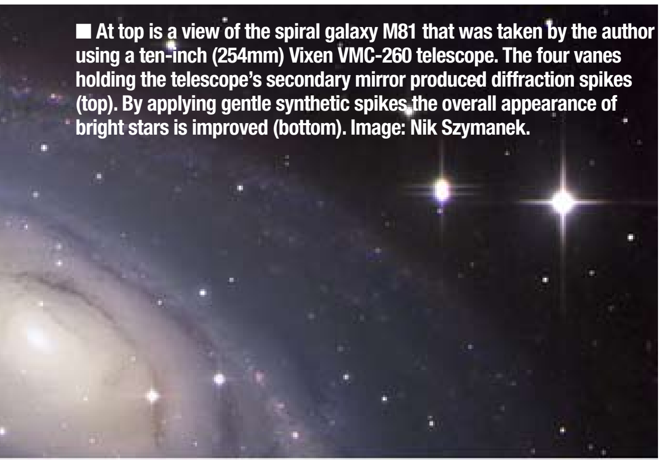
On the right hand side are the menu features that fine-tune the spikes with great levels of control. Roughly divided into three sections, the main part allows you to control the overall intensity of the created spikes as well as the length, number of points and spike sharpness. Dragging the sliders left or right decreases or increases the effect almost in real time. The second menu group contains features that would probably be of more use to traditional photographers, including rainbow intensity and colour saturation effects that are very reminiscent of the popular cross-screen filters used by many photographers. Indeed, this program is equally adept at creating pleasing effects on photos containing highlighted reflections from water and metal surfaces and offers far more control than normal photographic filters. ProDigital also offer two other plug-ins, *StarFilter Pro* and *StarFilter Light* designed for everyday photography.

The final menu group allows you to create secondary spike effects and also produce soft flare effects around the star image, further enhancing their appearances. The main menu allows you to zoom in and out in the usual way and a useful X-shaped button at top left can be used to remove the applied spikes from selected stars by clicking a cursor on the offending star. Alt-clicking brings it back and drawing a selection with this tool allows you to work on groups of stars.

Whilst part of my purist approach to CCD imaging balks at the idea of creating synthetic spikes there's no doubt that they do look nice. One aspect I really liked was that this can be used to cosmetically improve the diffraction spikes that my own telescope produces. By gently applying the effects I was able to subtly alter them until they became more photogenic. Overall I found the software easy and great fun to use.

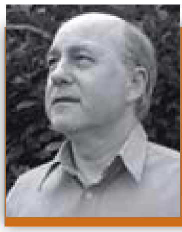
Nik Szymanek is an astrophotographer from Essex and author of Infinity Rising.

▼ A view of the *StarSpikes Pro* plug-in showing artificial diffraction spikes applied to a colour image of the Pleiades open star cluster. The right hand side of the graphic shows the sliders that are used to manipulate the overall intensity and appearance of the diffraction spikes. Image: Nik Szymanek.



■ At top is a view of the spiral galaxy M81 that was taken by the author using a ten-inch (254mm) Vixen VMC-260 telescope. The four vanes holding the telescope's secondary mirror produced diffraction spikes (top). By applying gentle synthetic spikes the overall appearance of bright stars is improved (bottom). Image: Nik Szymanek.

■ The Orion Nebula shown with synthetic diffraction spikes included on the brighter stars. In this case the spikes angle has been rotated by approximately 45 degrees. Image: Nik Szymanek.



Astroloot

Optical tube assembly • Digital Crayford focuser • **Andromeda gemstone globe** • Anti-dew heater • Compiled by **Steve Ringwood.**

Tal-125 APOLAR APO optical tube assembly

It was a revolution, in those not too distant days of the mid-eighteenth century, when the achromatic doublet telescope lens displaced the seventeenth century singlet via a murky mix of conspiracy and controversy. Now, it looks as if the doublet itself is heading for technological extinction as optical designers make full use of modern glasses and computer-assisted design. Despite the achromatic's revolutionary reduction of chromatic aberration, those remaining traces of false colour are steadily submitting to the modern onslaught of apochromatism.

Using two types of glass, the TAL-125 (five-inch, 125mm) APOLAR employs no less than six lenses (in three groups) in the light train to reduce chromatic aberration to a mere trace. As you would expect from the number of glass elements, multi-coated optics and light-baffles are harnessed to prevent internal reflections.

At f/7.5, its handy focal length of 940mm yields a potential high magnification of 375× with a 2.5mm eyepiece, yet a fathomless low power of 23× with a standard 40mm. The two-inch Crayford focuser (with 1.25-inch adapter) is accompanied by a star diagonal. Tube rings make themselves doubly useful by forming a great carrying handle.

Supplier: Optical Vision
Details at: www.opticalvision.co.uk
Price: £1,499

William Optics DDG SCT Crayford focuser

The technological advances that have recently flowed into the telescope have not left the focuser behind. Having superseded the rack and pinion that had held sway for centuries, the Crayford design has now been adorned with an LCD readout that facilitates a reproducible focus position of incredible accuracy – to two decimal places, in fact.

This high precision DDG two-inch focuser (DDG stands for Digital Display Gauge) is assisted by a 1/10th micro focuser. Pressure knobs enable accurate tension adjustment for the focusing job in hand, be it simply just an eyepiece or a heavy photographic configuration. An axial rotation of 360 degrees and smooth focusing (with zero image shift) make this unit suitable for both visual and photographic use. It will fit virtually any standard Schmidt–or Maksutov–Cassegrain telescope, (Meade and Celestron two-inch screw fittings – 24 threads per inch). And with a nice touch of inventive design, an analogue thermometer nestles inside one of the focus knobs.

Supplier: Ian King Imaging
Details at: www.iankingimaging.com
Price: £184.98

Andromeda gemstone globe

Scientific endeavour aside, astronomical observation is a pursuit that offers a limitless experience of breathtaking beauty. This extends to the instrumentation employed and the representation of its investigations. Both these aspects are often artfully encapsulated in the celestial globes whose careful designs and constructions litter the history of astronomy. No lesser man than Tycho Brahe laboured for years (reputedly decades!) on mapping a thousand stars onto a single papier-mâché globe fully six feet in diameter. It must have driven him nuts. Celestial globes therefore occupy a special place in the instrumental pantheon by being both cartographic tools and works of art.

The Andromeda gemstone globe is a fine example of this principle. The lustrous nine-inch globe is made from black agate, inlaid with 1,523 mother-of-pearl stars. Constellations (with silk screen printed nomenclature) are depicted by delicate gilded wire. With an overall height of 30.5cm (12 inches), this fantastic globe is then cradled by a brass-plated stand and meridian circle. Not only is the globe a remarkable talking point, it has a presence which will adorn any environment.

Supplier: JustGlobes
Details at: www.justglobes.co.uk
Price: 9-inch globe: £187.50 (13-inch globe also available at £306.95)

Anti-dew heater

In denying airborne moisture safe haven, dew-battling heating strips have two challenges. Firstly, the tube area benefiting from the encircling cylinder of heat can be too narrow to supply enough energy to the optics. Secondly, to the problem of conducting energy might be added that of consuming too much of it, with a heating effect disproportionately small compared to the energy required to accomplish it. In this new two stage design, an initial wrap-around 12V DC heater strip is wider and thinner, applying heat directly against a much broader swathe of the telescope wall. This 'internal' band is then enclosed in a tailored thermal blanket, ensuring that all heat energy is enclosed and directed towards the telescope. Not only is heat applied more extensively, but also uses less electrical power in the bargain. Designed to work with all forms of resistive or pulse width modulation controllers, this dew-prevention system is also unobtrusive enough to leave in place on the OTA.

Supplier: AstroScienTech
Tel: 07900 935600
Details at: www.astroscientech.co.uk
Price: Depends on tube size (e.g. 8-inch Meade £52; 14-inch Meade £84.50)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Grassroots astronomy

The grassroots level is what continues to support and maintain the astronomical community in the UK, and **Callum Potter** presents more news of the work done by societies and outreach enthusiasts.

75 years of Mills Observatory – but clouds on the horizon?

I have a particular affection for the Mills Observatory in Dundee. Back in the seventies we had trips from Kirkcaldy High School to visit the observatory where, under the supervision of resident astronomer Harry Ford, we are able to see Saturn and Mars through the fine Cooke refractor, and enjoy shows in Harry's home made planetarium. Of course this was some time after the original opening on 28 October 1935 by Professor Ralph Sampson – the fifth Astronomer Royal for Scotland. And it was therefore fitting that Professor John Brown, the tenth Astronomer Royal for Scotland, led the celebration of Mills' seventy-fifth anniversary on 28 October 2010.

The Mills Observatory was built using money bequeathed by John Mills (1806–1889), a Dundee industrialist and keen amateur astronomer. His bequest lay in a fund for many years, and the First World War saw an end to early plans to build the observatory on Dundee Law. But, after the war, Dundee's war memorial was placed on the site.

Little happened until the early 1930s, when there was much unemployment and the City Fathers decided to have the observatory built to create employment in the area. Professor Sampson recommended Dundee's Balgay Hill as the most appropriate site, being easily accessed by the citizens of Dundee, but near the edge of the city where light pollution was not a great problem.

The observatory was opened in 1935, housing a brand new 18-inch (457mm) Newtonian reflector from Grubb Parsons, but closed a few years later for the duration of the Second World War. It reopened after the war and, in 1952 following the replacement of the 18-inch with the world's first Schmidt–Cassegrain telescope designed by Professor Finlay Freundlich of St Andrews, a deal was done with the University of St Andrews whereby they took the Schmidt–Cassegrain and replaced it with an excellent ten-inch (254mm) Thomas Cooke refractor made in 1872. This proved to be a blessing because the Cooke is an ideal instrument for public viewing.

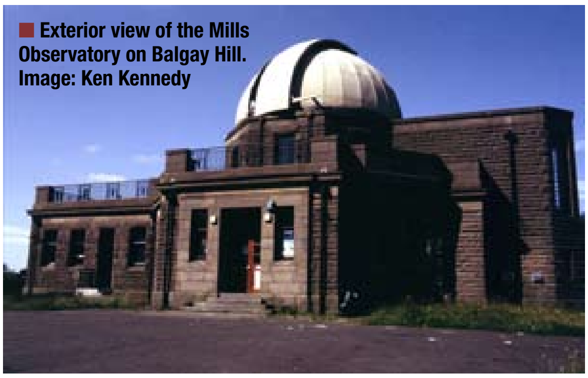
The ten-inch Cooke continues to be used every weekday evening during the winter months, and was refurbished during the summer of 2010. The anniversary celebration was attended by members of Dundee Astronomical Society, the Mills Observatory Advisory Group and representatives of Dundee City Council who continue to operate the observatory. Stuart Clarke, a member of staff at Mills, made a superb cake in the shape of the observatory building and Professor Brown did the honours by cutting the cake. Members of the public visiting the observatory that evening had the added treat of sampling the cake!

Professor Brown presented a certificate to Dundee City Council, congratulating them on the observatory's seventy-five years of resounding success.

■ The ten-inch Cooke refractor at the Mills Observatory. Image: Ken Kennedy

However, the latest news from Dundee is not so good as plans by the City Council to reduce their budgets may see the observatory sold, even though it only costs the council a mere £46,500 per year to run – a very small fraction of the £20 million savings the council has targeted. And the observatory is cost effective, only 50 pence per visitor, some ten times less than the City's Galleries.

"The Mills is a great educational resource that has inspired generations of schoolchildren to pursue a career in science," says the Astronomer Royal for Scotland, Professor John Brown. No decision has been made, but it would surely be madness to put in doubt the future of this valuable resource for encouraging the scientists and engineers of tomorrow, as I was all those years ago.



■ Exterior view of the Mills Observatory on Balgay Hill. Image: Ken Kennedy

▼ Members of Dundee Astronomical Society, the Mills Observatory Advisory Group and staff of Dundee City Council at the seventy-fifth anniversary celebration. Image: Mike Fenwick.

▲ The Dumbbell Nebula, M27. Astrophotographers now have a home at the Progressive Astro Imaging Group. Image: Nik Szymanek.

Progressive Astro Imaging Group

Imaging the night sky has really taken off in recent years, due to the ever-increasing development and availability of affordable technology. Ten to fifteen years ago, those starting out with a webcam to image the Moon and planets found it very challenging, but exciting to even just acquire an image. The processing of the images was a huge learning curve too, taking hours of time to achieve a presentable end result.

Over the years imaging has improved, helped in no small way by the growing availability of equipment and software. Thanks to the Internet, astronomy forums were also beginning to develop, providing invaluable help for those starting out, and it gave a benchmark as to what could be achieved. Growing at a rate of knots, astronomy forums both helped and encouraged people who wanted to become involved in amateur astronomy. But Roger Warner felt something new was needed. Something to get your teeth into, as a stand-alone group/forum, aimed purely at astro-imaging. There was no desire to extend beyond this subject, as other forums do an excellent job of catering for the broad field of amateur astronomy as a whole. So Roger got together with another keen astro-imager and close friend, and talked about the best way to improve their skills, and to gain a more in-depth knowledge of the theory and practice of CCD astro-imaging. They hit on the idea of an imaging only forum, or group as they prefer to call it, where they could deal with the core interest of imaging techniques and processes, and where member astro-imagers would be happy to both give and receive constructive criticism and meaningful comments of 'posted' images. The ethos of this group would be aimed at improvement and progress in both knowledge and ability, as opposed to just somewhere to display your latest image.

With this in mind they created the Progressive Astro Imaging Group (PAIG), and launched an online forum to support it. PAIG was born in July 2009, starting out with just a handful of astro-imagers. Word spread, and slowly more people joined, not just from the UK, but around the world too. This is what they wanted, a dedicated imaging group, where knowledge, techniques, and experiences could be shared among other like-minded people, in a friendly and helpful environment.

PAIG is now in its seventeenth month, and is still a relatively small community, currently with around 200 members. Among them are people at all levels of experience, from renowned astro-imaging experts, to those at the beginning of the learning curve. If you are serious about improving your knowledge and ability of astro-imaging, you would be very welcome to join the PAIG, at www.progressiveastroimaging.com.

Wirral star party

Liverpool Astronomical Society held another very successful star party on 16 October at Wirral Country Park, Thurstaton, with the kind co-operation of Wirral Ranger Services. Held as part of the society's very extensive public outreach programme, the evening was rewarded with clear skies for most of the evening.

Society members brought a wide range of telescopes and binoculars, and an estimated 150 members of the public were treated to excellent views of the Moon, the planet Jupiter, and Comet Hartley 2. A shadow transit of Jupiter's large moon Ganymede was observed by many, as were the ever changing cloud formations on Jupiter's disc. Several deep sky objects were also checked out.

Lectures on astronomy where given within the Thurstaton visitor centre, and advice was also dispensed by members on all manner of topics. All in all a very successful night and the Liverpool Astronomical Society will be repeating the event at the same venue on 12 March 2011.

More details on all their events and meetings in 2011 can be found at www.liverpoolas.org or by contacting the secretary, Gerard Gilligan on 0151 794 5356.

▲ A young astronomer experiences the night sky through a telescope at Liverpool AS' Wirral star party. Image: Jim Stacey.

Why grassroots?

Grassroots is about what's going on in your community, whether that's a traditional society or club, a science centre or local observatory, an Internet forum, or a casual meet up of like-minded astronomers. Let us know what's happening, and we'll look to publish as much as we can. Send your reports, news or photos to us at listings2011@astronomynow.com or through the post to the editorial address on page 6. To meet our production deadlines we need to receive your items three months prior to the issue date – for example material for the March 2011 issue needs to reach us by the end of December 2010, and for the April 2011 issue by the end of January.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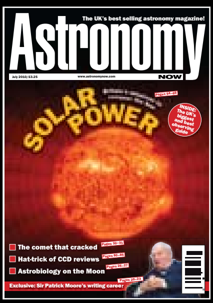

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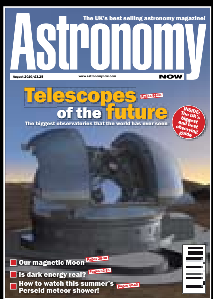

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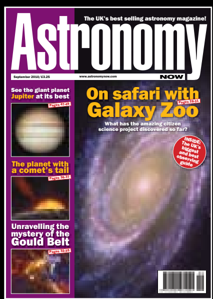

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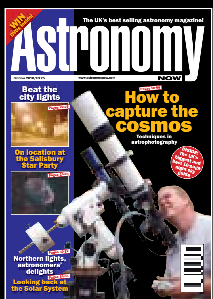

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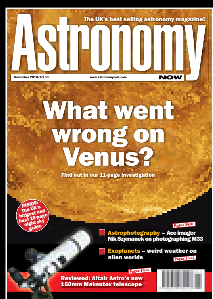

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Astrolistings

3 January

Northern Island AAS, Lecture Theatre, Ballyclare High School, Ballyclare, County Antrim, 8pm. '3D Astronomy' by Dr Brian Espey. For details visit www.niaas.co.uk.

4 January

University of Keele Observatory, North Staffordshire, 8pm. Free public observing. For more details tel 01782 734086 or visit www.astro.keele.ac.uk/~obs/.

Wiltshire AS, Pavillion, Rusty Lane, Seend near Melksham, Wiltshire, 8pm. Talk TBA. For details visit www.wasnet.co.uk.

Bolton AS, Ladybridge Community Centre, Beaumont Drive, Bolton, 7:30pm. 'Supernova Hunting' by Len Adam. For details visit www.boltonastro.org.uk.

West Yorkshire AS, Rosse Observatory, Carleton Road, Carleton, Pontefract, WF8 3RJ, 7:30pm. Public open night. £3.00. For details visit www.wyas.org.uk.

5 January

Salford AS, Salford Observatory, Chaseley Field, Chaseley Road, Salford (entrance opposite number 12), 7:30pm. Public open night. For details: tel: 0759 083 7359, or visit www.salfordastro.org.uk.

6 January

Peterborough AS, Copeland Community Centre, South Bretton, Peterborough, 7:30pm. 'Project Galileo' by Martin Hall. For details tel: 01733 761419 or visit http://peterboroughastrosociety.blogspot.com/.

Guildford AS, Lecture Theatre M, Lecture Block, University of Surrey, Guildford, GU2 7XH, 7:30pm. 'The Solar System' by James Fradgley. For details visit www.guildfordas.org/.

Cardiff AS, Department of Physics and Astronomy, Cardiff University, 5 The Parade, Newport Road, Cardiff, 7:30pm. 'Planetary Nebulae: Cosmic Butterflies or Stellar Fireflies?' by Dr Rhys Morris. For details visit www.cardiff-astronomical-society.co.uk.

Clacton and District AA, Friends Meting House, Granville Road, Clacton-on-Sea, Essex, 7:30pm. 'The International Space Station' by Colin John. For details tel 01255 429849 or visit www.clactonastronomy.co.uk.

Loughton AS, Scout Hall (off Loughton Lane), Theydon Bois, Essex, 8pm. 'A Guide to Winter Skies'. For details visit www.las-astro.org.uk.

Torbay AS, Torquay Boys Grammar School, Shiphay Manor Drive, Torquay, 7:30pm. Observational evening. For details tel 01626 367280 or visit http://torbayastro.org.uk.

7 January

Huddersfield Astronomical and Philosophical Society, 4A Railway St, Huddersfield, 7:30pm. Public lecture by Dr Alastair Gunn. Members £1.50, non-members £2. Tel 01484 307985 or visit www.huddersfieldastronomy.org.

South-East Kent AS, Blean Church car park, Tyler Hill Road, Blean, 7:30pm. Observing, weather permitting. Children welcome but must be accompanied by a responsible adult. Tel: 01227 265503 or visit www.sekas.co.uk.

Norwich AS, Seething Observatory, Toad Lane, Thwaite St Mary, sign-posted from the B1332, 7:30pm. 'The Solar System' by Mark Thompson. Entry £2.50 adults, £1.50 children. Tel: 01953 602624, or visit www.norwich.astronomicalsociety.org.uk.

Newbury AS, United Reformed Church Hall, Cromwell Place, Newbury. 7:30pm. 'The View from Saturn - Images from Cassini'. For details tel Steve Harris on 01635860047 or e-mail steveharris234@aol.com.

South Downs AS, Main Hall, Chichester High School for Boys, Kingsham Road, Chichester, West Sussex, 7:30pm. AGM followed by 'Herschel Mission' by Roger O'Brien. Free entry. For details tel 01798 865746.

8 January

Norwich AS, Seething Observatory, Toad Lane, Thwaite St Mary, 7:30pm. 'The Solar System' by Mark Thompson. Entry £2.50 adults, £1.50 children. Tel: 01953 602624, or visit www.norwich.astronomicalsociety.org.uk.

University of Keele Observatory, North Staffordshire, 1pm. Free public observing. For more details tel 01782 734086 or visit www.astro.keele.ac.uk/~obs/.

10 January

Bradford AS, Eccleshill Library, Bolton Road, Bradford, BD2 4SR, 7:30pm. AGM, followed by DVD: 'Space is the Place' in 3D. Ring Hilary on 01274 672570 or visit www.bradfordastronomy.co.uk.

Knowle AS, St George and St Teresa's Parish Centre, 337 Station Road, Dorridge, Solihull, West Midlands, B93 8TZ. 'The Last 10 Years in Astronomy/The First 10 Years of KAS'. For details tel: 01676 535941 or visit www.knowleastro.org.uk.

West Didsbury AS, William Hulme's Grammar School, Manchester, M16 8PR, 7pm. Quiz. For details visit www.wdas2.com.

Hull and East Riding AS, Room LT27, Wilberforce Building, University of Hull, 7:30pm. 'An Introduction to Active Galactic Nuclei' by Paul Reed. Visitors welcome, entrance £1.50. For details tel 01482 471119 or visit www.heras.org.uk.

St Neots AA, Visitor Centre, Paxton Pits Nature Reserve, High Street, Little Paxton, 7:00pm. 'Star Atlases and Uses' by David Roberts. Details: David Roberts, tel: 01480 212960.

Abingdon AS, Methodist Church Hall, Dorchester Crescent, Abingdon, 8pm 'Imaging' by Ian King. For details visit www.abingdonastro.org.uk.

11 January

Royal Astronomical Society, Lecture Theatre, Burlington House, Piccadilly, London, 1pm (doors open 12:15pm). Public lecture: 'Life Under Bombardment' by Dr Jane Greaves. Tel: 020 77343307, or visit www.ras.org.uk.

University of Keele Observatory, North Staffordshire, 8pm. Free public observing. For more details tel 01782 734086 or visit www.astro.keele.ac.uk/~obs/.

Astronomical Society of Glasgow, Botanic Gardens, Glasgow, 7:30pm. Stars over the Botanics, public observing evening. £4 adults, £2 children. For details tel Botanic Gardens on 0141 276 1614 or visit www.theasg.org.uk.

Lincoln AS, Lecture Hall/Observatory, Westcliffe Street, off Burton Road, Lincoln, 7:30pm. 'Images of the Universe Volume three' by Paul Money. For details tel Bill Booth on 01522 881241 or visit www.lincolnastronomy.org.

West Yorkshire AS, Rosse Observatory, Carleton Road, Carleton, Pontefract, WF8 3RJ, 7.30pm. Speaker TBA. Members £3, visitors £4. For details visit: www.wyas.org.uk.

12 January

Salford AS, Level 1 Lecture Theatre, Room 115, The Maxwell Building, University of Salford, The Crescent, Salford, 7:30pm. 'Particle Physics' by Professor Fred Loebinger. Tel: 0759 083 7359 or visit www.salfordastro.org.uk.

Hebden Bridge AS, Hope Baptist Church rooms (opposite the cinema), Hebden Bridge, West Yorkshire, 7:30pm. 'Observing the Moon' by Professor W Leatherbarrow. For details visit www.hbas.org.uk.

Leeds AS, Quaker Friends Meeting House, Carlton Hill, Woodhouse Lane, Leeds, 7pm. AGM. Free for members, visitors welcome. For details visit www.leedsastronomy.org.uk.

Hertford AG, Hatfield Cricket Club, Ascots Lane, Welwyn Garden City, AL7 4HL, 8:00pm. 'Astrium – Your Local Space Centre' by Alistair Scott. Visitors welcome. For more details visit www.hertsastro.org.uk.

Papworth AS, Vinter Room, Papworth Everard, Cambridgeshire, 7:30pm. Members' 10-minute talks to coincide with BBC Stargazing Live. For more details visit www.papworthastronomy.org.

13 January

Basingstoke AS, Cliddesden Primary School, Cliddesden Village, 7pm. Practical meeting. For details visit www.basingstokeas.org.uk.

Swansea AS, Lecture room 2, Fulton House, Swansea University, 7pm. 'Just A Handful of Stars' by Nick Hart. For details visit www.swanastro.org.uk.

14 January

Cleveland and Darlington AS, Wynyard Planetarium, Wynyard, Woodland Park, Thorpe Thewles, TS21 3JG. 'Galaxies With Proper Names' by Dave Newton. Tel: 01332 740977 or visit www.cadas-astro.org.uk.

Stirling AS, Smith Museum Lecture Theatre, Dumbarton Road, Stirling, 7:30pm. 'Latest Results from the Solar Dynamics Observatory' by Dr Lyndsay Fletcher. For details visit www.stirlingastronomicalsociety.org.uk.

Tiverton and Mid-Devon AS, Blundell's Preparatory School, Tiverton, 7:30pm. 'Controversies Over Dark Matter' by Professor Mike Disney. Free for members, visitors £2. For details visit www.tivas.org.uk.

Swansea AS open evening with telescopes, Penllergare Trust, in the grounds of the civic offices. Indoor attractions if it rains. All welcome. For more details visit www.swanastro.org.uk.

Breckland AS, Recreation Centre, Watton Road, Great Ellingham, Norfolk, 7:30pm. Planetarium show by Mike Cripps. For details contact Bob Greef on 01953 602045.

Ewell AS, Nonsuch High School, Ewell Road, Cheam, Surrey, 7:45pm. Talk TBA. For details tel: 020 8224 5818 or visit www.ewell-as.co.uk.

Mid-Kent AS, Bredhurst Village Hall, Hurstwood Road, off the Street, Bredhurst, Kent, 7:45pm. 'Constellation of the Month' by Peter Parish. For details tel 01634 232153 or visit www.mkas-site.co.uk.

15 January

University of Keele Observatory, North Staffordshire, 1pm. Free public observing. For more details tel 01782 734086 or visit www.astro.keele.ac.uk/~obs/.

16 January

North-East London AS, Park Room, Wanstead House, 21 The Green, Wanstead, London, E11 2NT. TBC. For details tel 020 8992 5751.

17 January

Worthing AS, Emmanuel United Reformed Church Hall, St Michael's Rd, Worthing, BN11 4SD, 7:30pm. 'Highlights of the Apollo Programme' by Rob Cray. Tel: 01903 505346 or visit www.worthing-astronomical-society.com.

18 January

Bolton AS, Ladybridge Community Centre, Beaumont Drive, Bolton, 7:30pm. Show and tell. For details visit www.boltonastro.org.uk.

West Yorkshire AS, Rosse Observatory, Carleton Road, Carleton, Pontefract, WF8 3RJ, 7:30pm. 'Science Fiction vs Science Fact' by Phil Coursey. Members £2, visitors £3. For details visit www.wyas.org.uk.

University of Keele Observatory, North Staffordshire, 8pm. Free public observing. For more details tel 01782 734086 or visit www.astro.keele.ac.uk/~obs/.

19 January

Gresham College Lecture, Museum of London, EC2Y 5HN, 1pm. Free public lecture by Prof Ian Morison, Gresham Professor of Astronomy: 'The Violent Universe.' Visit www.gresham.ac.uk or tel: 020 7831 0575.

Crewkerne and District AS, St Bartholomew's Church Hall, Crewkerne, 7:30pm. 'Oddities of the Solar System' by Bob Mizon. All welcome. For details visit www.cadas.net.

Wycombe AS, Woodrow High House, Amersham, 8pm. Telescope evening (members bring along and set up their equipment for discussion). For details visit www.wycombeastro.org.uk.

20 January

Cardiff AS, Department of Physics and Astronomy, Cardiff University, 5 The Parade, Newport Road, Cardiff, 7:30pm. 'Turn Left at Leo' by Colin Harris. For details visit www.cardiff-astronomical-society.co.uk.

Astronomical Society of Glasgow, Botanic Gardens, Glasgow, 7:30pm. Stars over the Botanics, public observing evening. £4 adults, £2 children. For details tel Botanic Gardens on 0141 276 1614 or visit www.theasg.org.uk.

Loughton AS, Scout Hall (off Loughton Lane), Theydon Bois, Essex, 8pm. TBA. For details visit www.las-astro.org.uk.

Torbay AS, Torquay Boys Grammar School, Shiphay Manor Drive, Torquay, 7:30pm. Mini-lectures (TBD). For details tel 01626 367280 or visit http://torbayastro.org.uk.

21 January

Crawley AS, Ifield Community Centre, Ifield, Crawley, RH11 0BT, 7:30pm. 'Making Every Photon Count' by Steve Richards. For more details visit www.crawleyas.co.uk.

Liverpool AS, Quaker Meeting House, School Lane, Liverpool, 7pm. William Lassell Lecture: 'Proving Einstein Right' by Professor Ian Morison. For details tel: 0151 794 5356 or visit www.liverpoolas.org/.

Beckington AS, Beckington Baptist Church Hall, East Somerset, BA11 6TD, 7:30pm. 'Mysteries and the Unexplained' by Mike Witt. For more details visit www.beckingtonas.org.

24 January

Bradford AS, Eccleshill Library, Bolton Rd, Bradford, BD2 4SR, 7:30pm. 'Planet Formation: The Example of Planet Earth' by Dr Maria Schonbachler. Ring Hilary on 01274 672570 or visit www.bradfordastronomy.co.uk.

25 January

University of Keele Observatory, North Staffordshire, 8pm. Free public observing. For more details tel 01782 734086 or visit www.astro.keele.ac.uk/~obs/.

West Yorkshire AS, Rosse Observatory, Carleton Road, Carleton, Pontefract, WF8 3RJ, 7:30pm. 'Astro News' by Tony Doubtfire. Members £2, visitors £3. For details visit www.wyas.org.uk.

27 January

Basingstoke AS, Cliddesden Primary School, Cliddesden Village, 7pm. Five-minute talks. For details visit www.basingstokeas.org.uk.

Heart of England AS, Furnace End, Near Shustoke, North Warwickshire, 8pm. Members' talk night. For details visit www.hoeas.org.uk.

Swansea AS, Lecture room 2, Fulton House, Swansea University, 7pm. 'Some Aspects of Particle Physics' by Carlos Nunez. For details visit www.swanastro.org.uk.

Loughton AS, Scout Hall (off Loughton Lane), Theydon Bois, Essex, 8pm. 'Resonance' by Allan Bell. For details visit www.las-astro.org.uk.

28 January

South-East Kent AS, car park opposite Walmer Castle, Deal, 7:30pm. Public observing, weather permitting. Children welcome but must be accompanied by a responsible adult. Tel: 01227 265503 or visit www.sekas.co.uk.

Stirling AS, Mayfield Centre, St Ninians, 7:30pm. Members evening, all welcome. For details visit www.stirlingastronomicalsociety.org.uk.

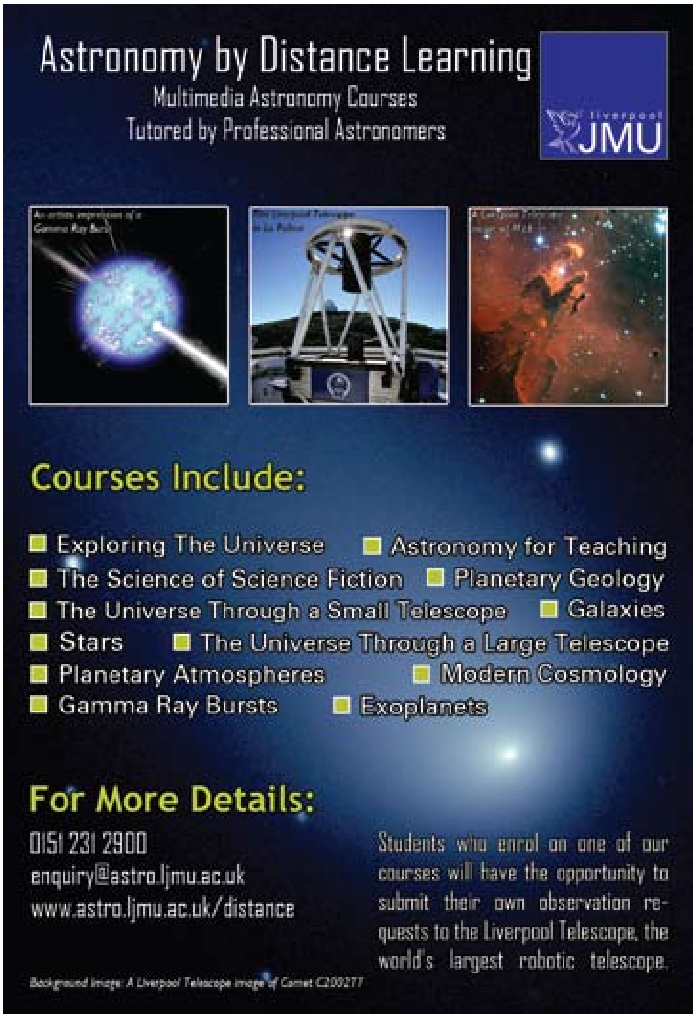
Rosliston Astronomy Group, Rosliston Forestry Centre. Rosliston, South Staffordshire, 7.30pm. 'Around the sky' talk; programme of specialist talks, public observing if sky clear. Visit www.roslistonastronomy.org.uk or call 07766 520331.

Mid-Kent AS, Bredhurst Village Hall, Hurstwood Road, off the Street, Bredhurst, Kent, 7:45pm. 'Solar Spectroscopy' by Bob Oseman. For details tel 01634 232153 or visit www.mkas-site.co.uk.

29 January

University of Keele Observatory, North Staffordshire, 1pm. Free public observing. For more details tel 01782 734086 or visit www.astro.keele.ac.uk/~obs/.

Is your society not listed? Write to us with your events diary and help us promote your society! Please send details to listings2011@astronomynow.com, or write to us at the editorial address (see page 6). Remember to allow plenty of time for our publishing schedules. We need to be notified of events for the March 2011 issue by 7 January and for the April 2011 issue by 7 February.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Picturegallery

Milky Way's balancing act • Scottish Northern Lights **Pacman, Soul and North America nebulae** • Solar prominences • **Jupiter's belt returns** • Emission nebulosity in Cepheus.

▲ Jupiter as seen on the night of 10 November 2010 by Agapios Elia in Cyprus, showing the appearance of the new Southern Equatorial Belt with Europa adjacent to it. The image was taken with a Celestron C9.25 and SPC900NC webcam fitted with an infrared block filter.

▶ Richie Jarvis collected data over several nights to produce this image of the Pacman Nebula. He used a Televue Genesis at f/5 with a Starlight Xpress SXVR-H18 camera and a Williams Optics ZenithStar 66 as a guidescope with a SX Guidehead guide camera. The image is composed of 6 × 1,200 second exposures in SII, 8 × 1,200 in hydrogen-alpha and 6 × 1,200 in OIII.

▼ Tony Rickwood captured this fantastic auroral display on 11–12 October 2010 in the Scottish Highlands using a Canon EOS 300d with a 28mm f/2.8 manual lens at 15 seconds exposure and ISO 1600.

▶ This image taken by Anthony Ayiomamitis shows the rich area of emission nebulosity in Cepheus, including a small reflection nebula in the bottom-right and a dark nebula to the east. Anthony used a Takahashi FSQ-106 at f/5, AP 1200GTO GEM, SBIG ST-10XME, and SBIG CFW10 with Baader 7nm hydrogen-alpha and SBIG LRGB filters. The image is composed of 12 × 20 minute exposures in hydrogen-alpha, and 6 × 10 minutes in each of red, green and blue.

▶ IC 1848, the Soul Nebula, imaged by Mick Hunt in October 2010 with a William Optics ZS66SD and a 0.8× reducer, a QHY2Pro camera and Astronomik SII, OIII and hydrogen-alpha filters. Mick also used an EQ6Pro mount controlled via EQMod, and a William Optics Megrez 88 and QHY5 camera for guiding. The image is made from 260 minutes in hydrogen-alpha, 385 minutes in OIII and 360 minutes in SII, combined with the hydrogen-alpha data also used as luminance.

▼ Nigel Ball composed this view of NGC 7000, the North America Nebula (bottom right) from over 11 hours of data collected with a Hasselblad 150mm lens on a QSI 583WSG camera, and an Orion SSAG guide camera on an EQ6 pro mount. Nigel stacked 14 × 900 second exposures in hydrogen-alpha, 16 × 900 seconds in SII, 16 × 900 seconds in OIII and 16 × 120 seconds in each of RGB.

▼ The Sun in hydrogen-alpha showing active regions 1123, 1124, 1125 and 1126 and several stunning prominences and filaments, taken by Sheri Lynn Karl in Aberdeen using a Lunt 60 double stack with a Skynyx 2.1 camera.

Picture of the month

▲ **This image taken by Marco Meniero shows the Milky Way sweeping across the skies of Arches Park in Utah. Marco took the image using a Canon Eos 5D MkII camera with a Canon EF 14L f/2.8 IS lens at ISO 3200.**

NIK SZYMANEK SAYS...

One of the nicest aspects of modern astrophotography is that great results can be obtained with relatively basic equipment. Digital SLRs have opened the hobby to many people that would be put off by the technical aspects of guided, long-duration imaging through the telescope. Modern DSLRs offer extreme sensitivity coupled with ease of use and the overwhelming advantage of instant results. Long gone are the days of nail-biting delays while the film was sent away for processing.

This lovely wide-field panorama by Marco Meniero has captured the grandeur of our Milky Way Galaxy rising over the 'Balanced Rock', an unusual sandstone formation in the Arches National Park in Utah, a popular location for sky-shooters. Dark skies, which allow detailed views of the summer star clouds, and dramatic foreground scenery are both captured easily by single exposures using the high ISO ratings available on today's off-the-shelf unmodified DSLR cameras.

Nik Szymanek

Win £25 for your astronomical picture

Picture of the month wins £25, all others published win £10. If you have an astronomical photograph, CCD image or sketch you want to share, please send a copy (no originals please) to: Picture gallery, Astronomy Now, PO Box 175, Tonbridge, Kent TN10 4ZY

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