EXCLUSIVE INTERVIEW WITH ASTRONAUT TIM PEAKE

All About Space

DEEP SPACE | SOLAR SYSTEM | EXPLORATION

WIN! £1100 ASTRONOMY KIT

THE LOST ICE GIANT

Searching for the frozen planet that was kicked out of our Solar System

JOURNEY TO AN ASTEROID

+10 other upcoming space missions

WHY WE LIVE IN A MULTIVERSE

...and what it means for the fate of the universe and humanity

STARGAZING DIARY 2016

Everything you need to know for the best night sky events

www.spaceanswers.com
ip IMAGINE PUBLISHING
DigitalEdition
GreatDigitalMags.com
ISSUE 046

WORLD'S BIGGEST ROCKET

How the most powerful booster in history will get us to Mars

+ SOHO SOLAR OBSERVATORY ■ VIEW MERCURY ■ MILKY WAY ■ VENUSIAN SPACE PLANE ■ EXOPLANETS


Sky-Watcher®
Performance, Precision and Value
Sky-Watcher astronomical telescopes perfectly integrate modern optical technology with precision mechanical engineering, resulting in designs of superb functionality, versatility and uncompromising levels of performance. The Sky-Watcher EXPLORER range of Parabolic Newtonian Reflectors cater superbly for astronomers of all levels. Whether your interest is Deep-Sky Observations, the Moon and Planets, or a combination of both, the EXPLORER range offers excellent all round Diffraction-Limited performance.
EXPLORER-200P (EQ5)
200mm (8") f/1000 PARABOLIC NEWTONIAN REFLECTOR
Prod.Code 10923/20464
OTA SRP £279
EQ5 SRP £279
SRP £499
Standard Specification
• Magnifications (with eyepieces supplied) x40, x80, x100, x200
• Highest Practical Power (Potential) x400
• Diameter of Primary Mirror 200mm
• Telescope Focal Length 1000mm (f/5)
• Eyepieces Supplied 10mm & 25mm
• x2 Deluxe Barlow Lens • 6x30 Finderscope
• Parabolic Primary Mirror
• 0.5mm Ultra-Thin Secondary Mirror Supports • Fully GO-TO Upgradeable
• EQ5 Equatorial Mount with Stainless Steel Tripod
• 77% more Light Gathering than 150mm
'The Explorer-200P passed all our tests with flying colours and was a delight to use both optically and mechanically"
BBC Sky At Night Magazine (July '09 Issue)
Sky at Night MAGAZINE GROUP TEST WINNER 93%
EXPLORER-150P (EQ3-2)
150mm (6") f/750 PARABOLIC NEWTONIAN REFLECTOR
Standard Specification
• Magnifications (with eyepieces supplied) x30, x60, x75, x150
• Highest Practical Power (Potential) x300
• Diameter of Primary Mirror 150mm
• Telescope Focal Length 750mm (f/5)
• Eyepieces Supplied 10mm & 25mm
• 6x30 Finderscope • Fully GO-TO Upgradeable
• x2 Deluxe Barlow Lens • Parabolic Primary Mirror
• 0.5mm Ultra-Thin Secondary Mirror Supports
• EQ3-2 Equatorial Mount with Aluminium Tripod
• 33% more Light Gathering than 130mm
"Good for advanced observing"..... "Saturn was a stunning sight"
BBC Sky At Night Magazine
Prod.Code 10912/20448
SRP £359
OTA SRP £199
EQ3-2 SRP £199
Prod.Code 10949/20448
SRP £329
OTA SRP £199
EQ3-2 SRP £199
EXPLORER-150PL (EQ3-2)
150mm (6") f/1200 PARABOLIC NEWTONIAN REFLECTOR
Standard Specification
• Magnifications (with eyepieces supplied) x48, x96, x120, x240
• Highest Practical Power (Potential) x300
• Diameter of Primary Mirror 150mm
• Telescope Focal Length 1200mm (f/8)
• Eyepieces Supplied 10mm & 25mm
• x2 Deluxe Barlow Lens
• 6x30 Finderscope
• Parabolic Primary Mirror
• 0.5mm Ultra-Thin Secondary Mirror Supports
• Fully GO-TO Upgradeable
• EQ3-2 Equatorial Mount with Aluminium Tripod
• 33% more Light Gathering than 130mm
"Verdict: a reborn classic that I can't recommend highly enough for the price.."
Ade Ashford, www.scopetest.com
ADVANCED FEATURES All Sky-Watcher f/4 & f/5 Newtonian Reflectors feature high quality Paraboloidal primary mirrors to eliminate spherical aberrations, producing sharp, contrasty images, which are full of detail. In addition they feature 0.5mm Ultra-Thin secondary mirror supports to reduce diffraction spikes and light loss. All Sky-Watcher reflectors are Multi-Coated with Silicon Dioxide as standard for Optimum Durability and Long Term Performance.
HERITAGE-76
76mm (3") f/300 MINI DOBSONIAN
Prod.Code 10212
SRP £54.99
HERITAGE-100P
100mm (4") f/400 PARABOLIC DOBSONIAN
Prod.Code 10245
SRP £105
SRP £159
Prod.Code 10213
HERITAGE-130P FlexTube™
130mm (5.1") f/650 PARABOLIC DOBSONIAN
76 Page Colour Catalogue
Order Your FREE Copy Today
FAX: 01359 244255
EMAIL: info@opticalvision.co.uk
Sir Patrick Moore Endorsed Sky-Watcher Telescopes
"I have used a great number of telescopes; some are good, some mediocre and some bad. To me the Sky-Watcher range of instruments are very good indeed, & suited to amateurs of all kinds - and they are not priced out of the market! Excellent value. Use them and enjoy them."
Sir Patrick Moore CBE FRS (1923-2012)
Our Products are Available from Dealers throughout the UK
OVL
Please contact us, or Check our Website for your Nearest Stockist
OPTICAL VISION LTD
UNIT 3, WOOLPIT BUSINESS PARK
WOOLPIT, BURY ST. EDMUNDS
SUFFOLK IP30 9UP
OPTICAL VISION LIMITED
www.opticalvision.co.uk
www.barrandstroud.com
Importers and Distributors of Sky-Watcher Astronomical Telescopes, Helios, Acuter, Barr and Stroud Binoculars & Spotting Scopes and 'Zenith' Microscopes.

We caught up with astronaut Tim Peake, who will be making his way into space this month.

Discover the wonders of the universe

Try to imagine the size of the universe and you'll find it hard. We suspect that the very edge of the observable cosmos is 46 billion light years away, but how much further beyond that boundary does it extend? It's difficult to say. Some - and I have to admit, I'm in this camp - think that we're just one of many universes, a so-called multiverse, where it's possible that an alternate you and I exist, where every moment of our lives, every decision we make, is causing a split into an infinite number of future selves. But how can we know for sure if we're living in a multiverse? We meet the physicists mounting up the evidence over on page 16.

If the idea of a multiverse boggles your mind, we also found out that there could have been a fifth gas planet in the Solar System - or more specifically, an ice giant that probably didn't look too dissimilar to eighth-world-from-the-Sun Neptune. We got the details of why this planet is no longer a member of our Sun's neighbourhood and where it could be in our galaxy right now, this issue.

With the end of the year fast approaching, we look ahead to 2016 for a run down of the next big missions the other side of Christmas. The highlights include Juno's arrival at Jupiter, the launch of asteroid-sample mission OSIRIS-REx, along with the launch of Mars missions ExoMars and Insight. We really can't wait!

Speaking of missions, we caught up with Tim Peake who will be making his way to the International Space Station for Expedition 47 this month. He filled us in on his training so far and what he'll be doing during his six-month mission. Enjoy the issue and, from all of us at **All About Space**, Merry Christmas!

Gemma Lavender
Features Editor

Contributors

Giles Sparrow

■ Giles goes on the hunt for evidence that we live in a universe of many this issue. Find out what he discovered on page 16.

Dominic Reseigh-Lincoln

■ Dominic got up close to the biggest rocket in history and why it's such a huge step in space exploration this issue.

David Crookes

■ It is thought that another ice giant once existed in our Solar System. David met the scientists uncovering what happened to it over on page 38.

Peter Grego

■ Seasoned astronomer Peter presents his pick of stargazing sights all ready for you to observe in the New Year.

> "The thing that I am most looking forward to is the view of Earth, without a doubt, as well as living in microgravity"
> **Tim Peake [page 44]**

Keep up to date

Online
www.spaceanswers.com

Facebook
/AllAboutSpaceMagazine

Twitter
@spaceanswers

CONTENTS

www.spaceanswers.com

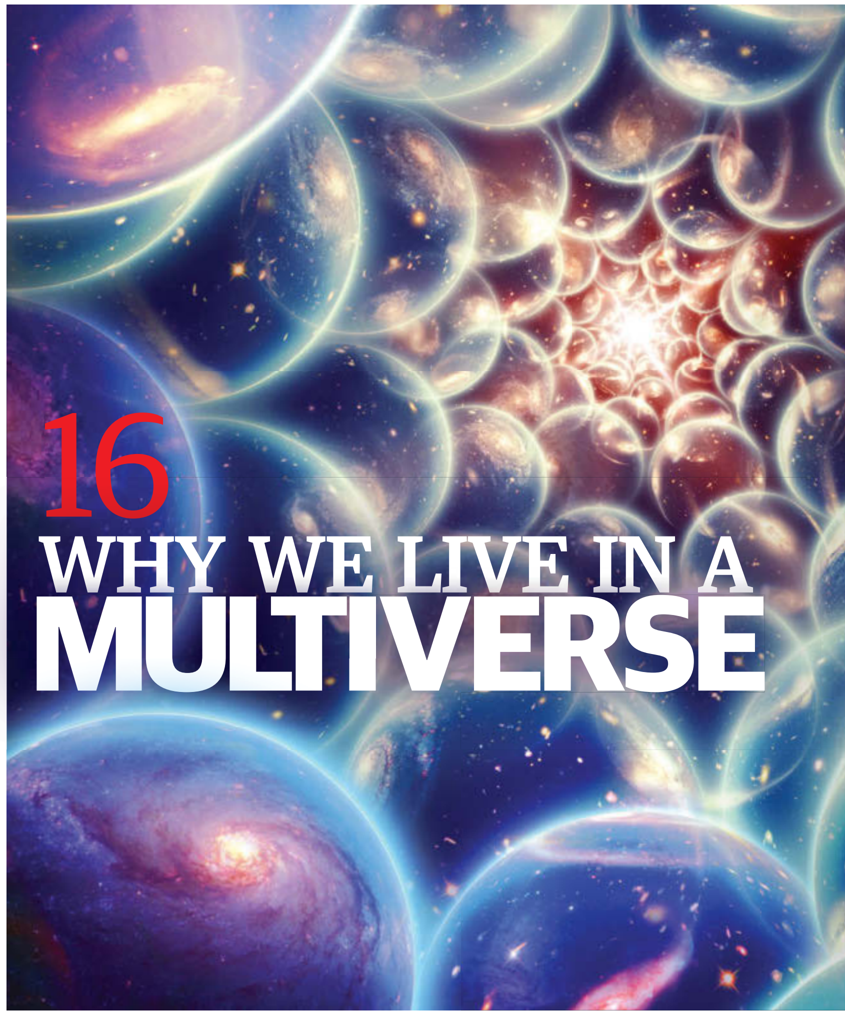
TWEET US
@spaceanswers

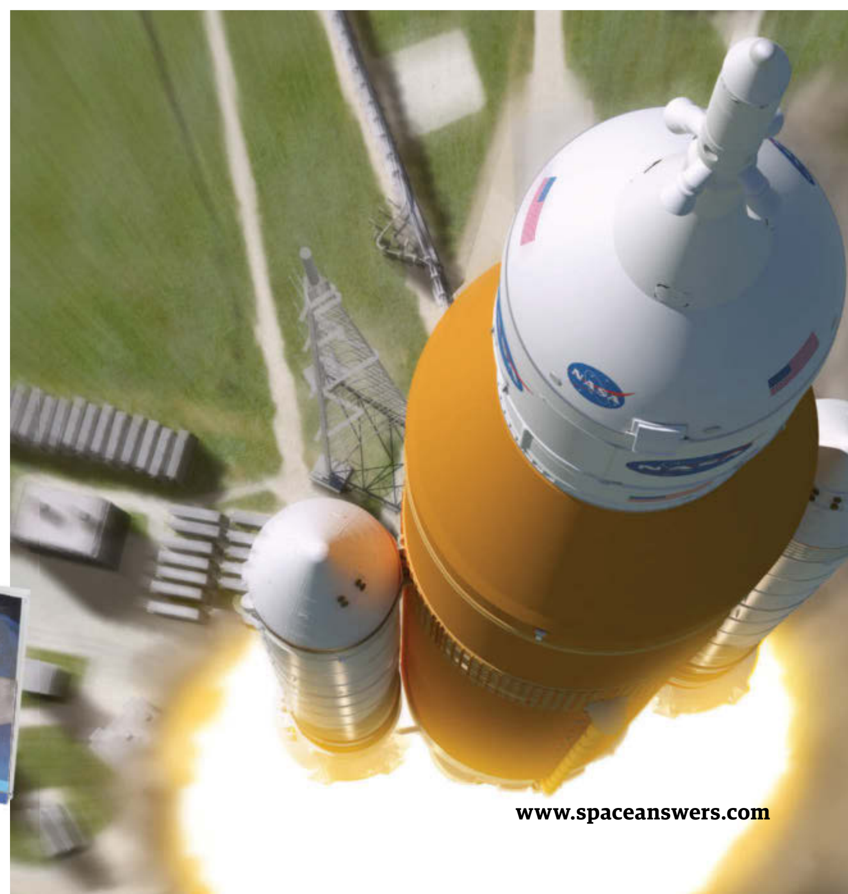
POST ON FACEBOOK
/AllAboutSpaceMagazine

SEND US AN EMAIL
questions@spaceanswers.com

LAUNCH PAD
YOUR FIRST CONTACT WITH THE UNIVERSE

FEATURES



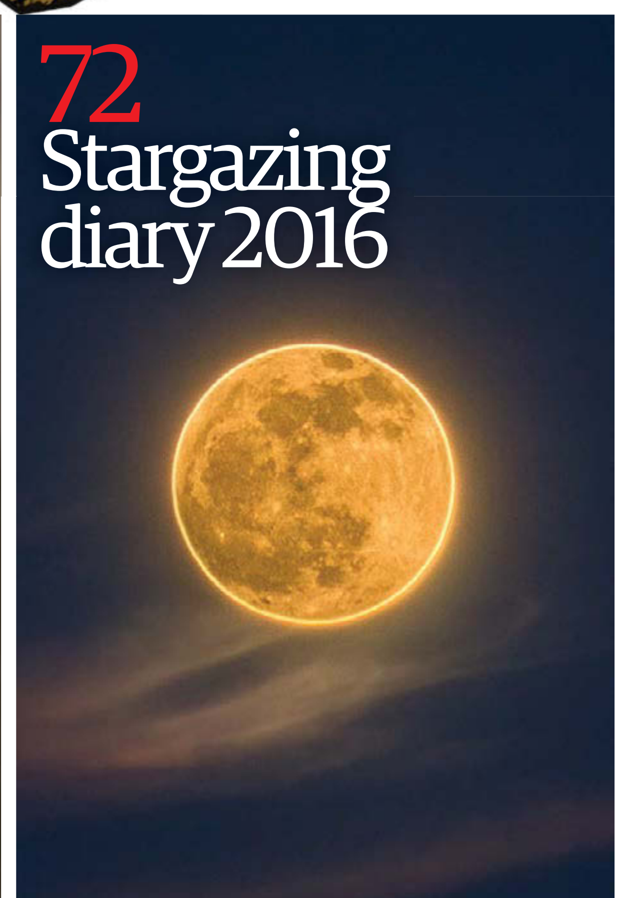


"There are about 263 experiments that will take place across the entire mission - about 25 on myself - so there will be a lot going on!"

44 Major Tim Peake
European Space Agency Astronaut

STARGAZER

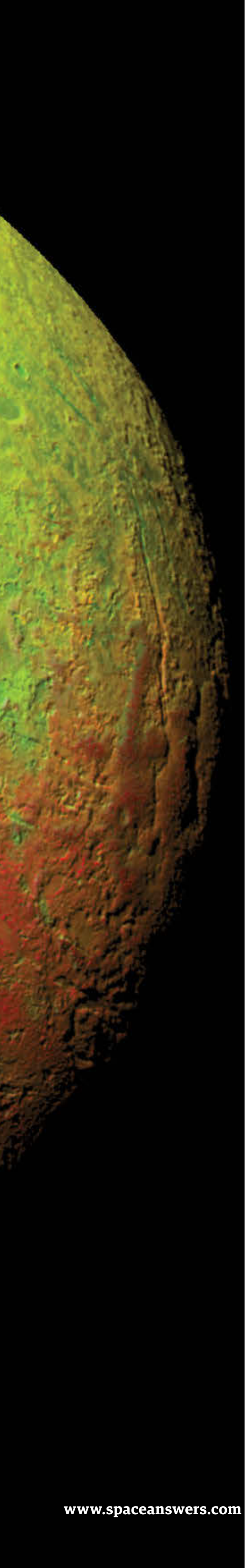
Top tips and astronomy advice for beginners



Page 48

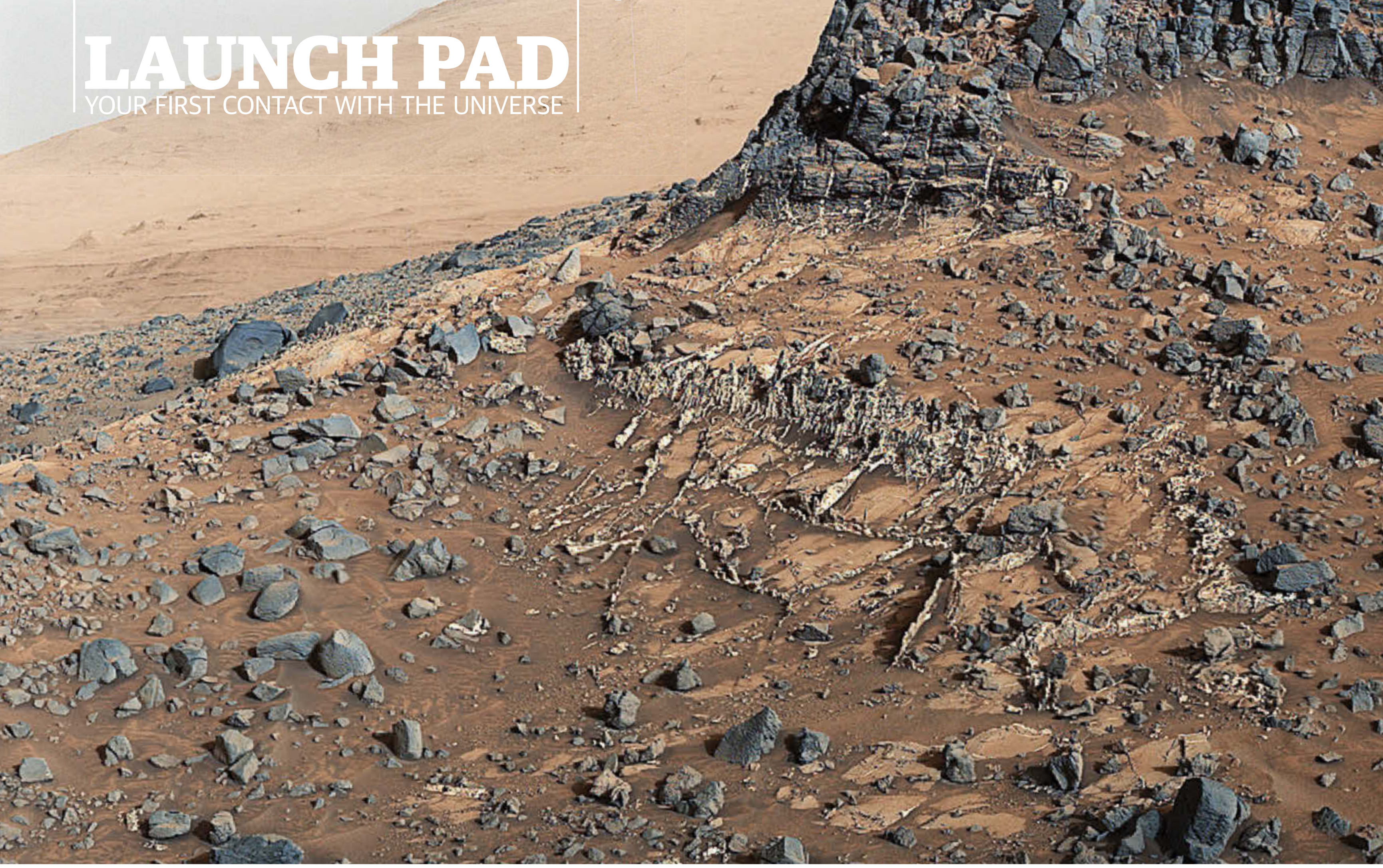
Psychedelic Pluto

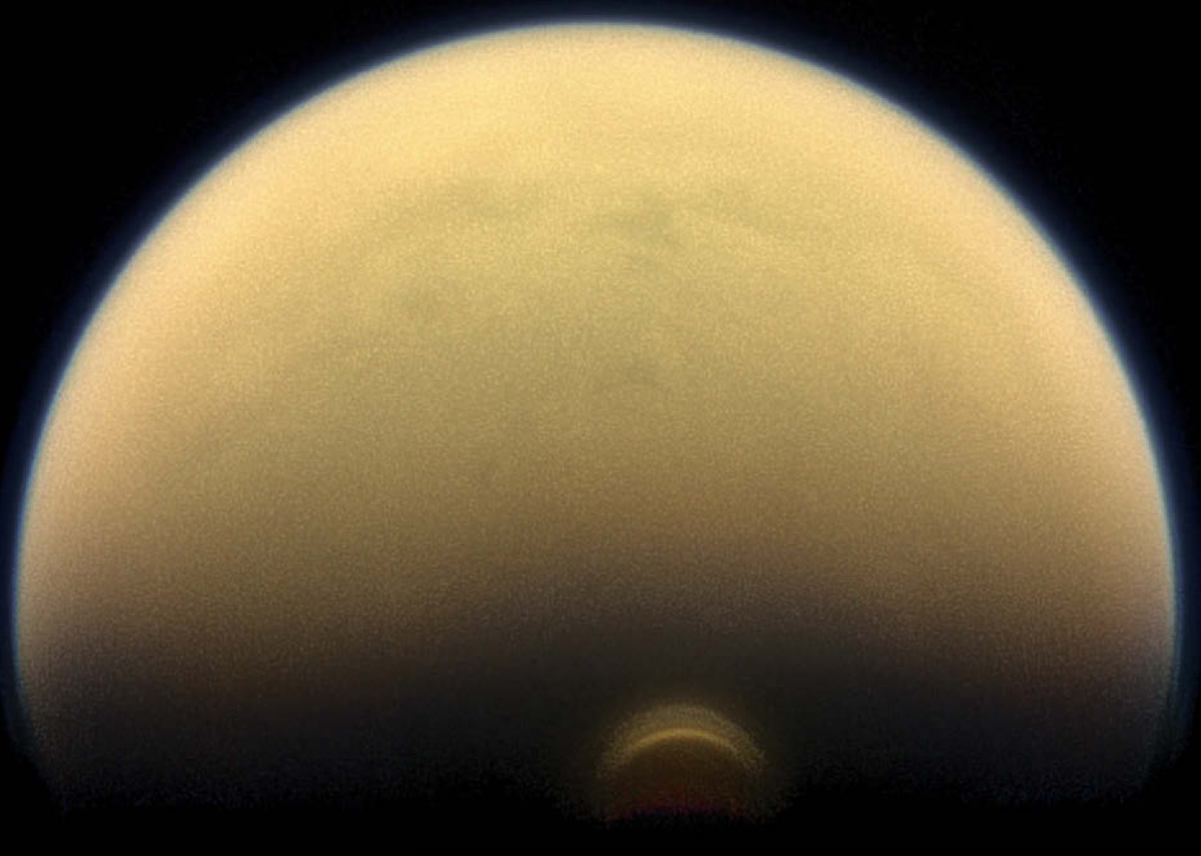
The New Horizons mission has not only been shedding new light on Pluto following its successful nine-year journey to the dwarf planet, but it has been giving it a few splashes of colour too. Scientists have used a technique called principal component analysis to create this enhanced colour image, which highlights the subtle differences in composition and texture on Pluto's surface. They are now eagerly trying to identify the different regions to "unravel the processes that put them where they are," according to Will Grundy, a New Horizons co-investigator. The image uses data taken from a distance of 35,000 kilometres (22,000 miles) by the spacecraft's Ralph/MVIC colour camera and its release follows the likely discovery of recently active ice volcanoes on Pluto. The surface is also shown to vary with age, with both crater-ridden ancient areas and relatively young, smooth environments such as Sputnik Planum.



Spooky aurora

This startling scene is the result of one of the Sun's most spectacular displays: an ejection of up to one billion tons of matter containing electrons and protons from our star's outer atmosphere. Called Coronal Mass Ejections (CME), the Sun's particles make the 149 million-kilometre (93 million-mile) journey to our planet in just a few days, but they then get caught in the Earth's magnetosphere. When they interact with molecules in our atmosphere, energy is released in the form of light, producing beautiful displays such as this one above Grotfjord, Norway. The colour of an aurora depends on which particles are hit in the Earth's atmosphere. As well as green, they can mix into orange, yellow, pink and purple.





Titan's huge ice clouds

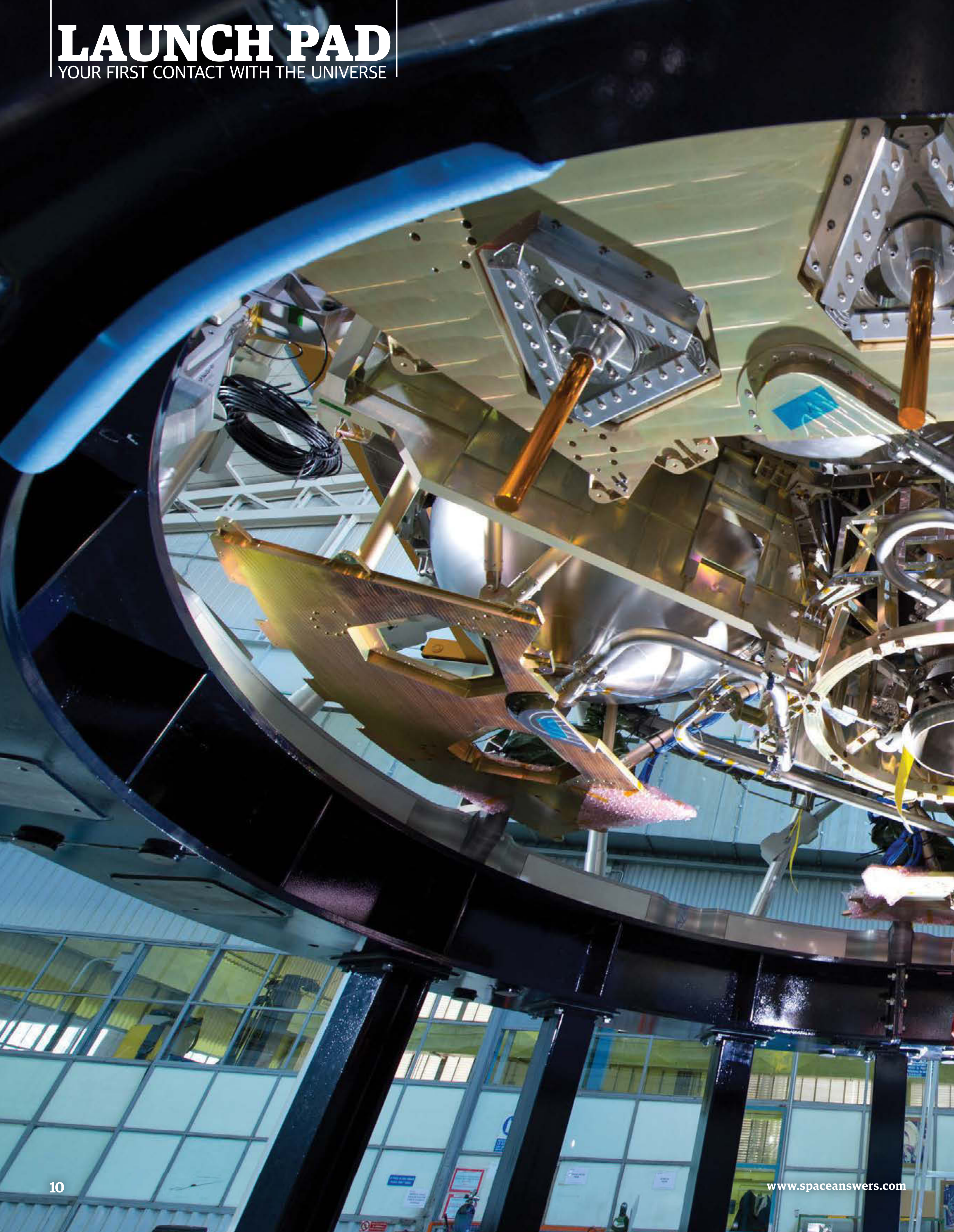
If you think it's cold wherever you are right now, then imagine if you found yourself living on Saturn's moon, Titan: winters here last more than 7.5 years, so spring is seldom around the corner. NASA's Cassini has been monitoring the seasons using its infrared instrument, which profiles Titan's atmosphere at invisible thermal wavelengths, and now scientists have found a massive cloud of frozen compounds in the low-to-mid-stratosphere of the south polar region. When large clouds of gas, consisting of mainly nitriles and hydrocarbons, fall through the moon's atmosphere they condense, creating the huge frozen ice clouds that we can see. Scientists claim that temperatures here can plunge as low as -150°C (-238°F).

Mars' Garden City

The Curiosity rover's Chemistry and Camera instrument (ChemCam) has been helping astronomers to better examine a site on Mars that is crisscrossed with protruding mineral veins – Garden City. By upgrading the rover so that it can now recognise more than three times the number of geochemical samples, the ChemCam has found a strong indication that multiple sources of groundwater passed through during different periods of time. The protruding mineral veins – which are a couple of finger widths above the fractured bedrock on lower Mount Sharp – are formed when fluids move through it and deposit minerals that affect the chemistry of the surrounding rock. Samples have been recorded using Curiosity's ChemCam, which fires lasers at an object and analyses the sparks it produces.

Illusion of a Saturnian moon

Epimetheus is just one of the 62 moons known to orbit Saturn but why is it above the planet's rings in this image? The answer is that it is not – it is an illusion due to the viewing angle at which the image was taken. This image was captured by the Cassini spacecraft in visible light from a distance of around 800,000 kilometres (500,000 miles) away. The moon is one of Saturn's inner satellites and completes its orbit around the gas giant in less than 17 hours, sharing a near-identical orbit with neighbouring Janus. It is also phase locked with Saturn, which means one side always faces towards it.



A new era of manned space exploration

NASA continues to work on its new spacecraft, Orion, which hopes to take humans further than ever before, with journeys to Mars in the planning stages. A contract was signed between the ESA and the Airbus Defence and Space division to develop and build the European Service Module for Orion and NASA is hoping that it will be ready in time for an unmanned test flight in 2018. It's an impressive 2.7-metre (8.85-foot) long cylindrical design with a 4.5-metre (14.8-foot) diameter and has four solar array wings of 18.8 metres (61.8 feet). Pictured is a carbon copy, non-functional, structural test model that is due to be tested at NASA's Plum Brook Station test centre in Ohio, USA.

New dwarf planet discovered at Solar System's edge

The edges of the solar neighbourhood could stretch even further thanks to the discovery of a new celestial body beyond Pluto

A brand new alien world less than half the size of Pluto has been found, setting a new record for the most distant dwarf planet in the Solar System. This discovery also hints that similar worlds could exist within the confines of the solar neighbourhood.

The trans-Neptunian object, designated V774104, is located around 15.4 billion kilometres (9.6 billion miles) from the Sun, around 2.6-times farther than Pluto. Lead scientist Scott Sheppard from the Carnegie Institute for Technology, and Chad Trujillo of the Gemini Observatory in Hawaii, made the discovery using observations made by Japan's Subaru telescope. However, since it is so far away the team haven't yet been able to study its motion, trajectory, or orbit. Looking to the furthest edges of our Solar System is not just driven by a desire to extend astronomical records, but also by a curiosity to learn more about the outer composition of the Milky Way and the orbital behaviour of its contents. The dwarf planet Eris, which was previously thought to be the furthest object in our galaxy, has an inward trajectory that sweeps it onto a path back into the Solar System, but does V774104 share the same behaviour?

Considering the dwarf planet was only discovered at the beginning of November it's still early days, but Sheppard, Trujillo and the rest of the team behind the discovery are confident the Subaru telescope will help them get to know V774104 a little more intimately.

The new dwarf planet's position beyond the reaches of Neptune places it within a community of icy objects known as the Kuiper Belt. V774104 is located 103 astronomical units (roughly 103 times the distance between the Sun and Earth) from the Sun and its locality suggests it could even pass into the Oort Cloud - a gathering of icy objects at the edge of the Solar System. Should this be the case, its positioning could add weight to the theory that these distant objects weren't born in our Solar System but were pulled in later by gravitational forces.

Solar storms stripped early Mars of 'habitable environment'

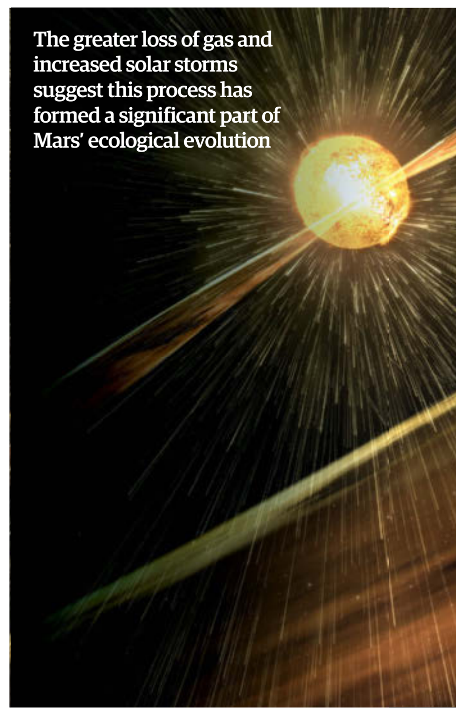
The Red Planet's upper atmosphere is being stripped by the Sun, which has played a key role in the planet's ecological history

Mars has long been an arid planet, known for its rocky landscape and cold environment, but it wasn't always that way. In the distant past, our Martian neighbour was warm and wet and may well have supported life at one point in its existence. But a new study by NASA's Mars Atmosphere and Volatile Evolution (MAVEN) mission reveals the planet is slowly being robbed of its nutrient-rich exosphere.

Data gathered by the MAVEN mission has shown this degradation continues at a gradual pace in normal conditions, but increases substantially when the planet is battered by solar storms. These winds cause ion-rich pockets of gas to seep out of the planet's grasp and into space.

"Mars appears to have had a thick atmosphere warm enough to support liquid water, which is a key ingredient and medium for life as we currently know it," comments John Grunsfeld, former astronaut and current associate administrator for the NASA Science Mission Directorate in Washington. "Understanding what happened to the Mars atmosphere will inform our knowledge of the dynamics and evolution of any planetary atmosphere. Learning what can cause changes to a planet's environment - from an environment that could host microbes at the surface to one that doesn't - is important to know, and is a key question that is being addressed in NASA's journey to Mars."

Data collected by the spacecraft suggests that the solar winds strip away gas from the top of Mars's atmosphere at a rate of around 100 grams (3.5 ounces) every second. A series of dramatic solar storms ravaged the Red Planet back in March of this year, and MAVEN observed this process accelerate rapidly throughout the period.



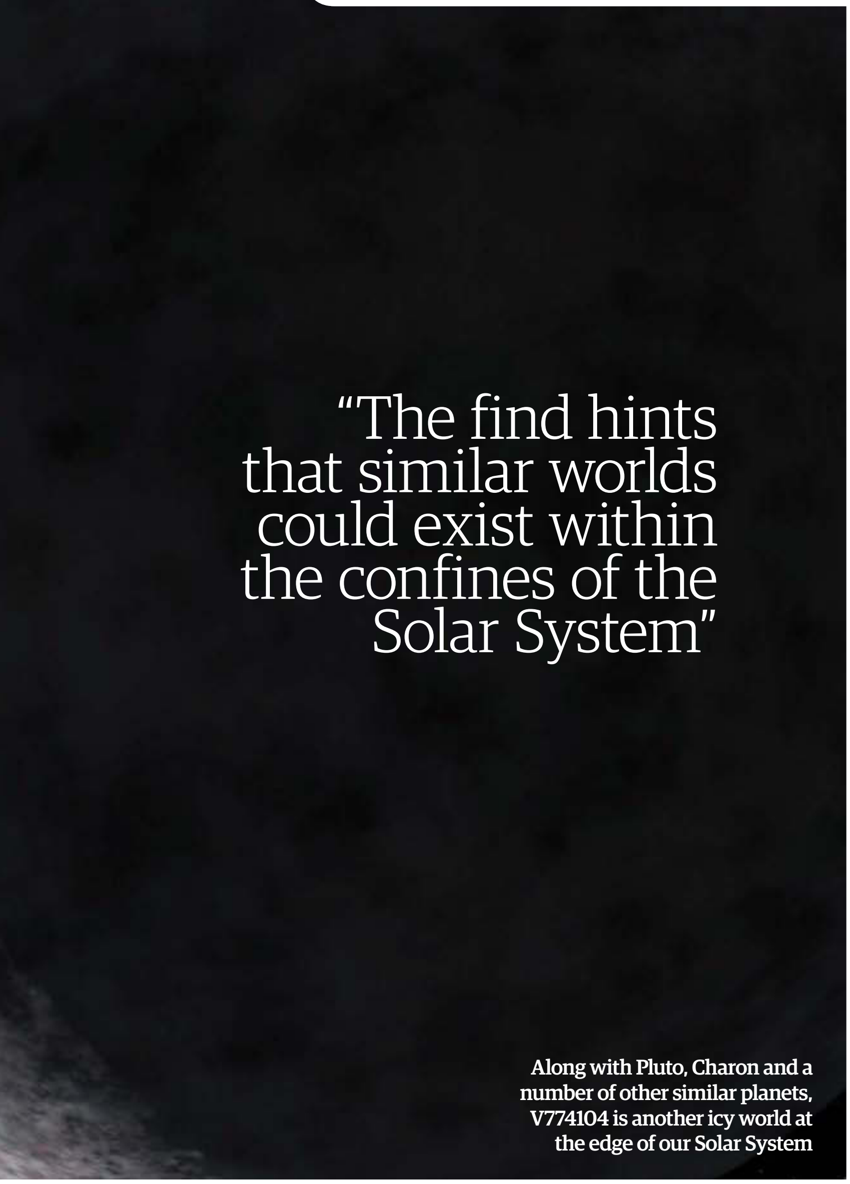
The greater loss of gas and increased solar storms suggest this process has formed a significant part of Mars' ecological evolution

Stay up to date...

www.spaceanswers.com
Fascinating space facts, videos & more

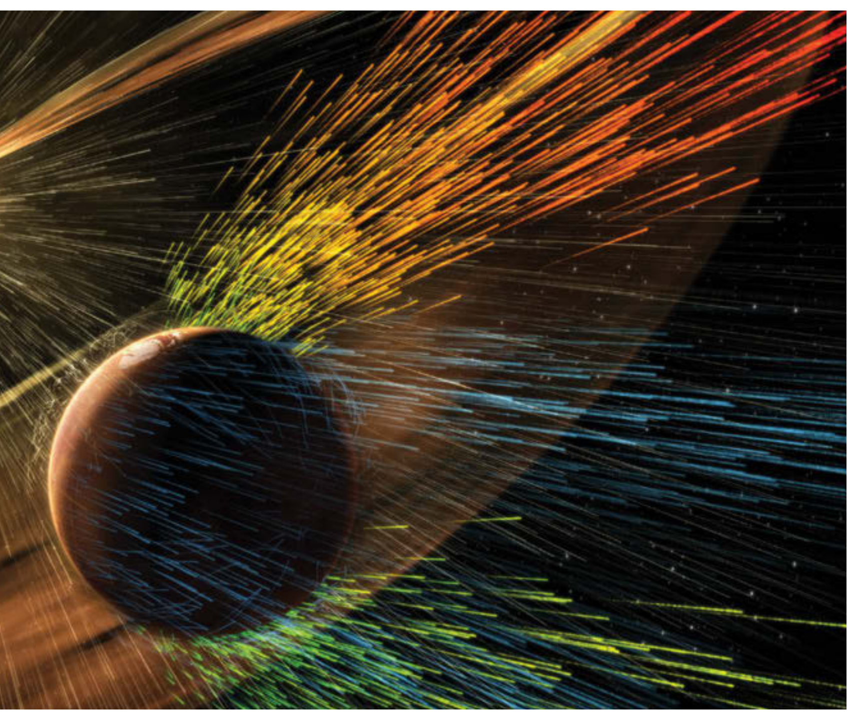
Twitter
@spaceanswers

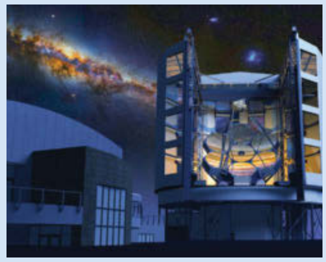
Facebook
/AllAboutSpaceMagazine



"The find hints that similar worlds could exist within the confines of the Solar System"

Along with Pluto, Charon and a number of other similar planets, V774104 is another icy world at the edge of our Solar System





A number of high-profile institutions are contributing to the multinational telescope project

Construction of giant next-generation telescope gets underway

The Giant Magellan Telescope will boast a light-collecting surface twice as large as other telescopes in operation

The construction of one of the world's biggest telescopes is now underway in the remote Atacama Desert in Chile. Billed for completion in 2025, the $1 billion (£657 million) Giant Magellan Telescope (GMT) is set to be one of the most ambitious and ground-breaking space telescopes ever constructed. Based at the Las Campanas Observatory, the GMT is the fruit of a multinational partnership between NASA and the space agencies of Australia, Brazil and South Korea.

"The GMT will revolutionise our view and understanding of the universe," comments Taft Armandroff, chair of the Giant Magellan Telescope Organization, during the project's grand opening ceremony at the observatory. "It will be remembered in the science textbooks written hundreds of years in the future."

Those claims may sound bold, but the GMT aims to be the most powerful Earth-based telescope at our disposal - in fact, on completion the site will offer a resolving power ten-times greater than the Hubble Space Telescope. It will also use seven of the world's largest mirrors in order to stare deep into the fathoms of space - each mirror at a monumental 8.4 metres (27.6 foot) in diameter. ●

Space News in Brief

Martian moon found to be falling apart

According to a new study by Terry Hurford from NASA's Goddard Space Flight Center and his colleagues, the largest and innermost moon of Mars is slowly being wrenched apart by the gravity forces of the Red Planet. The long linear grooves visible on Phobos's surface suggest that it could be eviscerated in the next 30 to 50 million years, possibly leaving Mars with a ring system.

Brightest and most-distant pulsar detected

The most luminous pulsar ever discovered, blasting out huge quantities of gamma rays in a galaxy beyond our own, has been detected. Based in the Large Magellanic Cloud, the rays were found in a star-forming region known as the Tarantula Nebula, which houses the bright object.

Electric sails tipped to propel future spacecraft

Researchers at NASA are working on a prototype robotic craft that will use solar winds to navigate space at unprecedented speeds. Using a large 'e-sail', the craft would ride charged particles that travel up to 1.6 million kilometres (1 million miles) per hour.

NASA opens up applications for new astronauts

After a four-year hiatus, NASA is now accepting astronaut applications. Applicants must: be US citizens; hold a degree in physical or biological science, engineering or mathematics; and have three years' professional experience, or 1,000+ flight hours.

GJ1132b is 'tidally locked' meaning one side of the planet is permanently bound in daylight throughout its 'yearly' orbit - an orbit that actually takes 1.6 Earth days to complete

Venus-like planet hailed as 'most important' discovery

Found orbiting a red dwarf star less than a quarter of the diameter of our Sun, GJ1132b is just a stone's throw away

NASA's search for alien worlds has reached a new milestone with the discovery of GJ1132b - a planet that not only shares a variety of Earth-like and Venus-like characteristics but is also located less than 40 light years away from Earth. This makes it the closest planet of its kind in proximity to our home planet.

Detected using the MEarth-South array, a group of eight 40-centimetre (15.7-inch) robotic telescopes at the Cerro-Tololo Inter-American Observatory in Chile, GJ1132b is one of the most intriguing discoveries in recent years and could even help astronomers identify other worlds with the potential to support life.

"If this planet still has an atmosphere, then we might find other, cooler planets that also have atmospheres and orbit small stars. We can then imagine interrogating the atmospheres for molecules that come from life," says Zachory Berta-Thompson from the MIT's Kavli Institute for Astrophysics and Space Research. And while it may share a number of characteristics with the Earth - including the fact its locked to one star, has a mass 1.6 times that of our planet and is around 1.2 times larger in size than our own - GJ1132b is even closer in terms of composition to Venus.

The planet's surface is far too hot to sustain liquid water but not so hot that it burns away its atmosphere. It has become such an exciting prospect, the team have requested the Hubble and Spitzer Space telescopes point themselves towards the alien world.

It's likely that Earth's water was carried on a dust disc that existed around our Sun before the planets were formed

Earth's waters are likely to have been home-grown

New study suggests the origin of Earth's water was less reliant on space rocks and other such celestial bodies

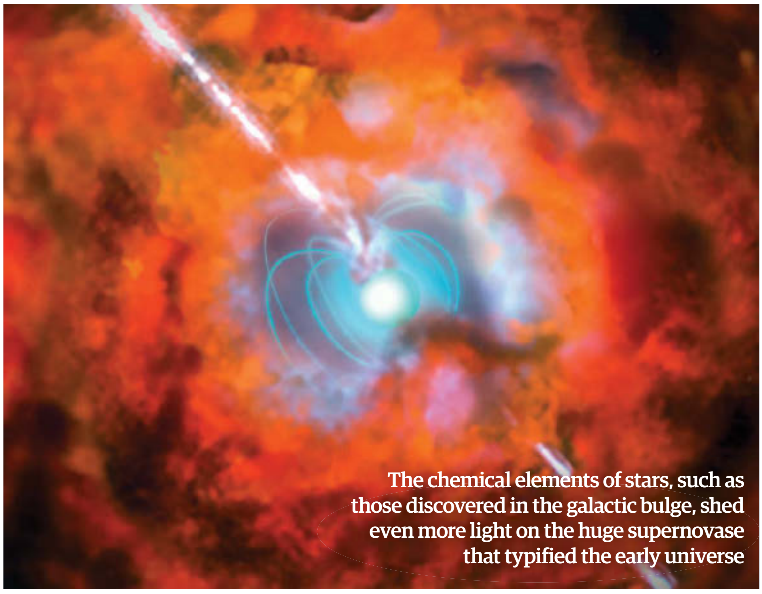
It's one of the eternal topics of contention in the scientific community - did Earth's water originate from its own formation or was it built up from the impact of alien bodies such as asteroids and moisture-rich dust clouds?

A new report from the University of Glasgow claims the Earth's waters are very much a home-grown affair. The paper focuses on rock samples collected 20 years ago in the Canadian territory of Baffin Island, and claims these samples were never affected by the sedimentary input from the crustal layers above them, providing a blueprint of Earth-formed water sources.

"The water had very little deuterium, which suggests it was not carried to the Earth after it had formed and cooled," says Dr Lydia Hallis, who led the research. "Instead, water molecules were likely carried on the dust that existed in a disc around our Sun before the planets formed. Over time this water-rich dust was slowly drawn together to form our planet." Much of this water evaporated during the formation process, but enough managed to survive to form the world's water.

Oldest stars detected were created 300 million years after Big Bang

The oldest stars, dating from before the Milky Way formed, have been found in our galaxy



The chemical elements of stars, such as those discovered in the galactic bulge, shed even more light on the huge supernovase that typified the early universe

A group of astronomers based in Australia has discovered the oldest known stars in the universe close to the centre of the Milky Way, at about 34,000 light years away from Earth. The ancient celestial group was picked up by the Australian National University's SkyMapper telescope and provides astronomers with a startling insight into the blueprints of our galaxy's birth.

The stars formed in the universe's infancy are normally metal-poor - if a star lacks heavy metals it was likely formed right after the universe was born, before stars began producing iron. One of the ancient stars, which is one of 5 million stars observed with the SkyMapper, has an iron-to-hydrogen ratio that is so pure - around 1/9,000th that of our Sun - it stands as the most pristine star located in the galactic bulge.

Astronomers at the National Australian University have been studying the chemical composition of each star's atmosphere to better understand which elements were most prevalent during the 'cosmic dawn' of the universe. Interestingly, many of these stars contain alpha elements, which are formed in the nuclear fusion of a star's earliest years, such as silicon, calcium, titanium and magnesium. A particular candidate also contains traces of carbon - suggesting it was born in a single supernova before emerging through an element-rich dust cloud.

WHY WE LIVE IN A MULTIVERSE

Could our entire universe be just one small part of many? The evidence is mounting up…

Written by Giles Sparrow

Have you ever wondered how different your life would be if you had made different decisions to the ones that you had? If you had turned right instead of left? You may never know what may have been, but incredibly, all those 'what if' scenarios may have played out somewhere. That's because over the past few years support for the idea that we live in a 'multiverse', in which our universe is just one tiny bubble among countless others, has been gaining strength. How would a multiverse arise - and just how similar, or different, would the many universes within it be?

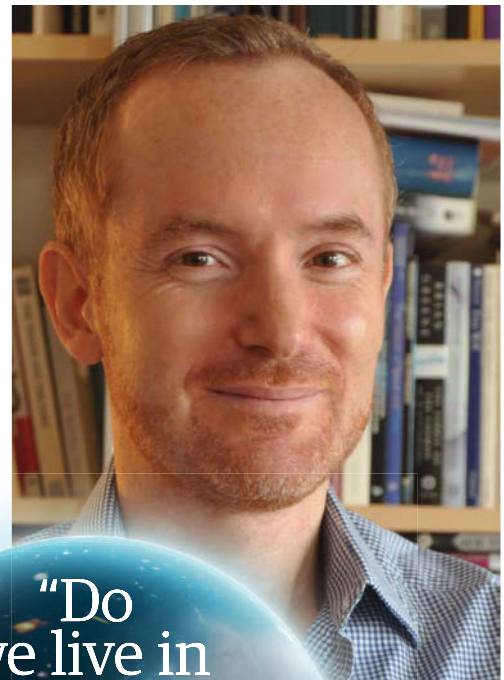
For a lot of people, the term 'multiverse' conjures up pictures of parallel realities, some perhaps with just a slight difference from our own. And in fact, that sort of multiverse is indeed predicted by the 'many worlds' interpretation of quantum mechanics - the strange but highly successful model of how the universe works on the smallest scales - wherein every possible quantum state branches off into a new universe. In other words, every action that is physically possible - every choice that can take place - can happen and will happen, somewhere.

Such parallel universes might exist, and evidence for this 'many worlds' interpretation of quantum mechanics that invokes them might one day be found, but they would be forever unobservable, and separated from our universe in ways we can hardly comprehend. Cosmologists like Matthew Kleban are instead interested in a more concrete form of multiverse - something beyond the realm of our current universe, but which we might nevertheless learn about.

"We have a horizon in cosmology that's a lot like the horizon on Earth," explains Matthew Kleban, associate professor of physics at New York University and a leading multiverse theorist. "If you're on an island in the ocean and climb to the highest point, there's a finite distance you can see, and you don't know what's beyond that horizon by directly seeing it. But you still might be able to get information about it, like say a log comes floating up to your island, with some plants growing on it. You can learn things from over the horizon because signals of various sorts can reach you from beyond it."

In the case of our universe, the horizon is a lot further away than a horizon on Earth - in fact it's about 46.5 billion light years away from us, in every direction. This apparent 'edge' to the universe is caused by the limited speed of light, and the fact that the universe is expanding rapidly from the Big Bang - the hot, dense state in which it originated. According to the best current measurements, the

Associate professor of physics at New York University, Matthew Kleban believes that it is highly likely that we live within a multiverse



"Do we live in a 'multiverse' in which our universe is just one tiny bubble among countless others?"

There is growing evidence that we live in a multiverse, with multiple Big Bangs bringing other universes into existence

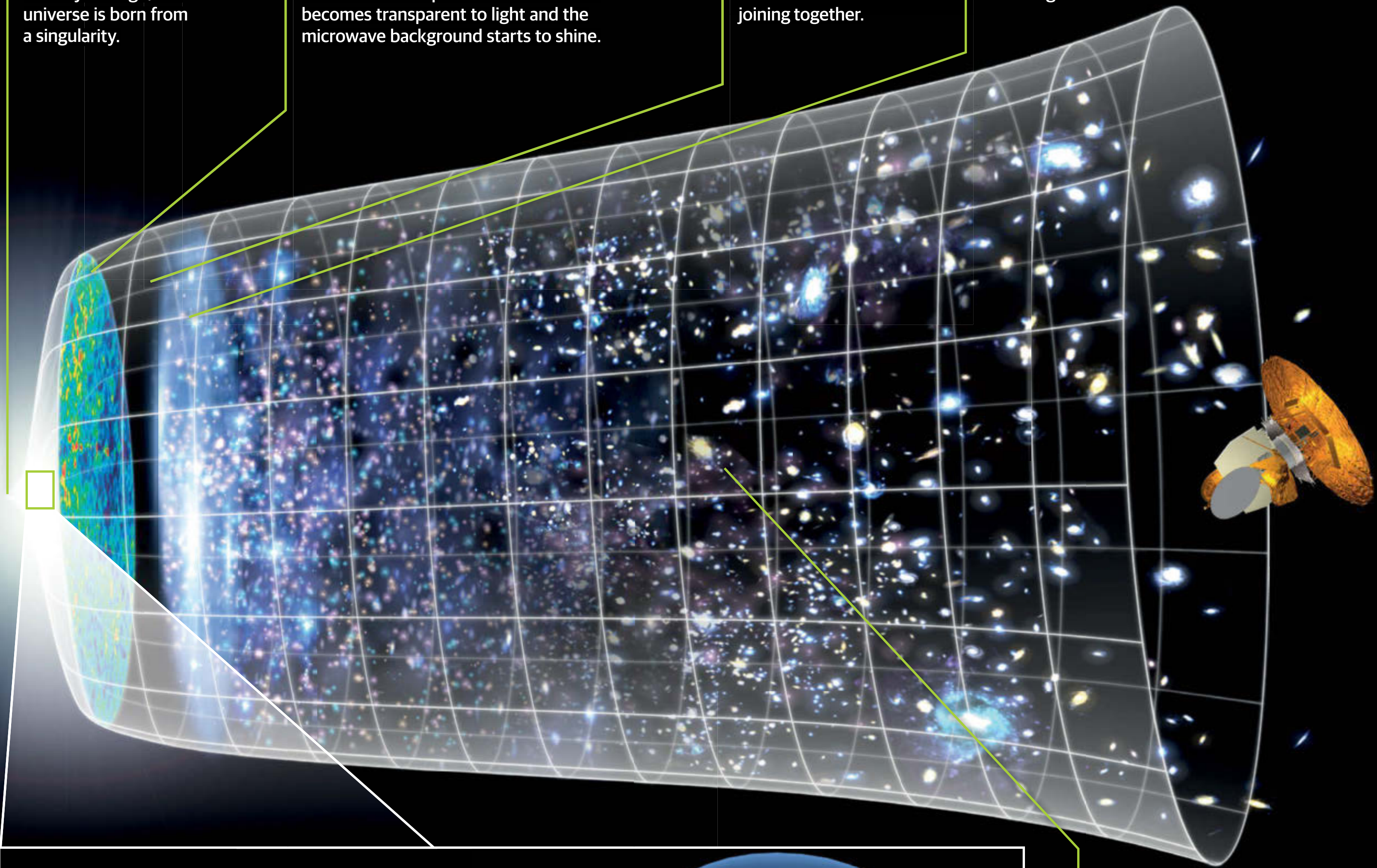
Inflation: proof for a multiverse?

Big Bang
In an infinitely dense moment some 13.8 billion years ago, our universe is born from a singularity.

Cosmic Microwave Background
After about 380,000 years, subatomic particles known as electrons cool enough to combine with protons. The universe becomes transparent to light and the microwave background starts to shine.

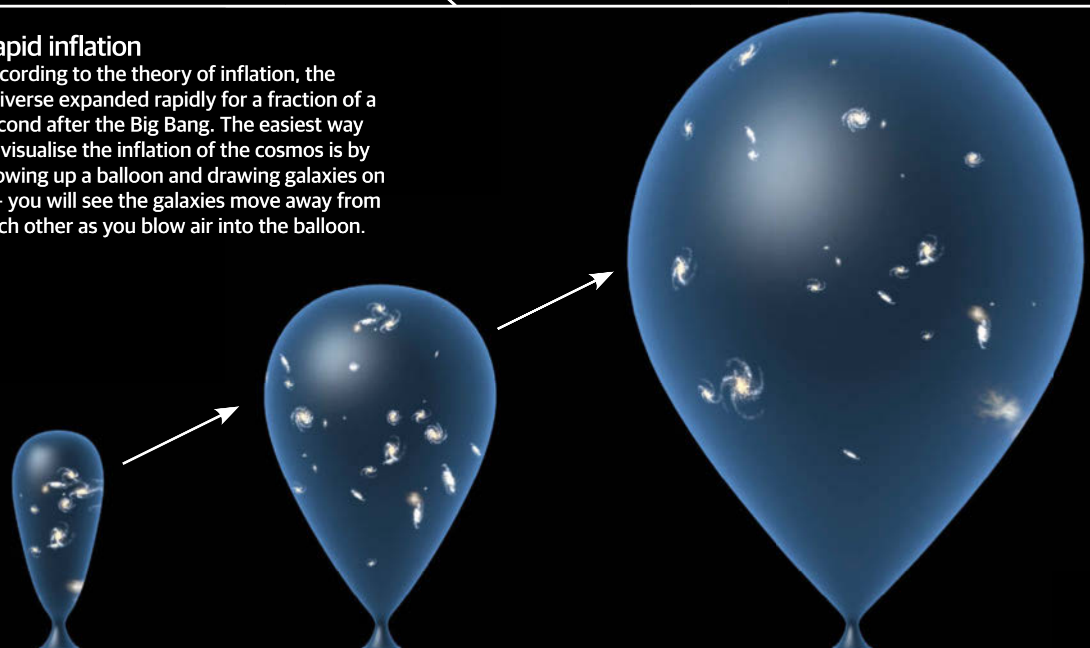
Dark ages
Clouds of dark hydrogen gas cool before joining together.

First stars
Gas clouds collapse and fusion of the stars begins.



Galaxy formation
Gravity causes galaxies to form, merge and drift. Dark energy accelerates the expansion of the universe, but at a much slower rate.

Rapid inflation
According to the theory of inflation, the universe expanded rapidly for a fraction of a second after the Big Bang. The easiest way to visualise the inflation of the cosmos is by blowing up a balloon and drawing galaxies on it – you will see the galaxies move away from each other as you blow air into the balloon.



Big Bang happened 13.8 billion years ago, and so we can only ever see objects whose light, travelling at 299,792 kilometres (186,282 miles) per second, has had time to reach us.

In fact, because the very early universe was so dense, it formed a brilliant opaque fireball that only became transparent after about 400,000 years. Light from that fireball – transformed into invisible microwave radiation in its long journey across expanding space – is the most distant thing we can directly observe, and as we'll see, this 'Cosmic Microwave Background Radiation' (CMBR) has a key role to play in the search for evidence of a multiverse. Its true distance is estimated at 46.5 billion light years because, although the most distant light has been travelling for 13.8 billion years, the space it has been moving through has been expanding during that time.

"We don't know what's beyond the horizon," continues Kleban, "but what we can do is extrapolate from what we can see. On those large scales, the universe is pretty much homogeneous and isotropic, meaning it's pretty much the same in all directions and as far as we can tell the same in every place. So there's definitely a wider universe that's much bigger than what we can see, but it may not be very interesting. That's a basic assumption of modern cosmology, that we call the cosmological principle."

Quite how far these distant reaches of spacetime stretch is an intriguing question – and one that depends on the shape of space itself. Estimates range from about 250 times the size of the observable universe (for a 'closed' and finite universe in which space curves inwards like a sphere), to infinite (if space is flat or 'open', curving outwards like a saddle). However far space stretches, though, we'd expect parts of this wider universe to be essentially similar to our own. In fact, if the universe really is infinite, or close to it, we'd expect there to be parts of the universe, far, far away from us, that are exactly like our own observable universe.

How far away would these replica 'universes' – and the replicas of ourselves that would live in them – be? Our observable universe, with its radius of 46.5 billion light years, has enough room for 10^{118} particles. Try to imagine all the different ways these particles can be arranged – mathematics tells us that there are 2 to the 10^{118} different arrangements of all these particles and that we would have to cross 10 to the 10^{118} metres – that's 10 to the power of 10 with 118 zeroes after it – before we encountered another duplicate universe with duplicate versions of us and our friends, living out parallel existences. That is a long, long way – in comparison, our observable universe is just 8.8 x 10^{26} metres across – but if the universe is infinitely big, then there is enough room for the particular arrangement of particles making up our universe to be repeated again and again.

What if there's another type of multiverse – one in which universes pop into existence like bubbles and have the potential to be radically different from our own? That's the intriguing possibility that fascinates Matt Kleban and many of his colleagues and at its heart lies a concept called 'eternal inflation'.

"In everyday life we're familiar with the phases of matter – if you think about a water molecule, for example, that can be liquid water, ice or steam. But

The different types of multiverse

From unseen regions of spacetime to complex structures, there are four distinct levels

Level 1

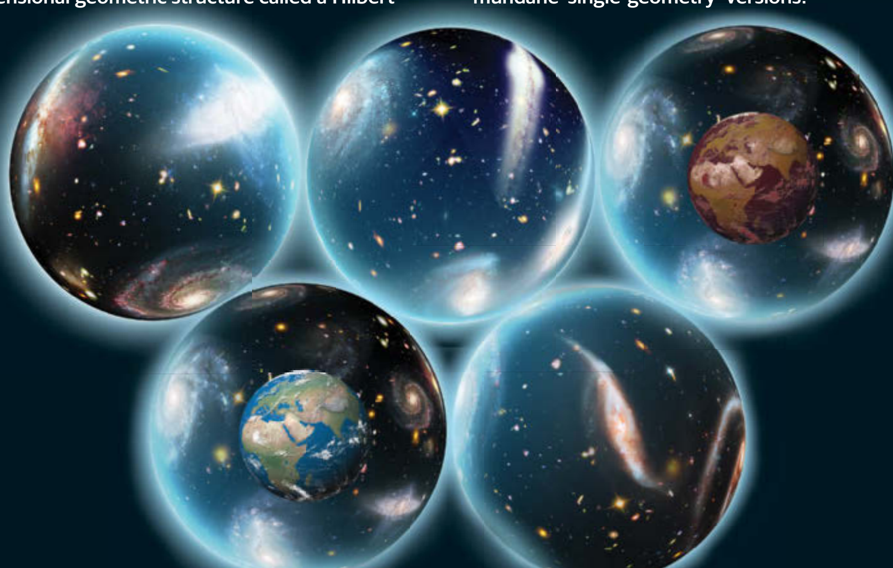
Where an identical Earth exists

The simplest multiverse is one that most certainly exists – the Big Bang model of cosmic origins predicts that every point in the universe has a 'Hubble volume' around it, limited by the expansion of the universe and the distance light has been able to travel in the 13.8 billion years since the infant universe became transparent. In practice, this means our Hubble volume is a sphere 93 billion light years across, but there are many more Hubble volumes extending far beyond what we can see. If the universe has a closed geometry, the number is limited as space curves back around on itself, but if the universe is open (as seems most likely), there may be an infinite number of Hubble volumes, each containing a universe, meaning that somewhere out there, other planets virtually identical to Earth exist.

Level 3

Where your future self exists

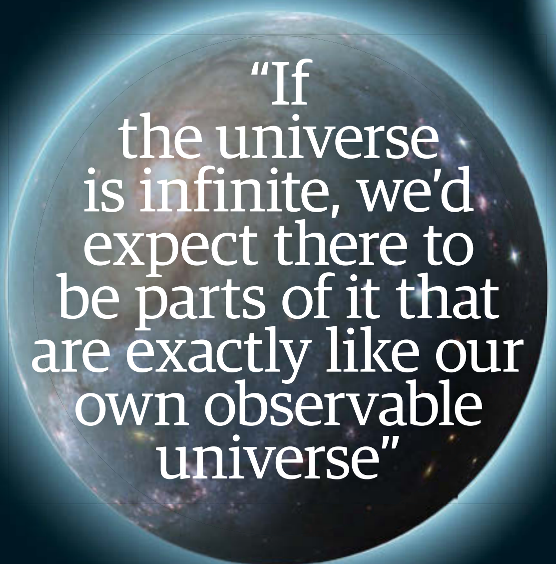
According to the so-called "many worlds interpretation" of quantum mechanics, every decision point between alternative outcomes – even on the tiniest microscopic scale – sees the universe branch into two mutually unobservable realities. This astonishing idea would involve the creation of multiple universes not in the few-dimensional space described by string theory, but in an infinite-dimensional geometric structure called a Hilbert space. Although you might imagine the many worlds interpretation giving rise to a more varied multiverse than an extended or bubble model, the reality is that since all three are infinite, the same variety will play out across all types. What's more, some physicists have even argued that if quantum mechanics works in a certain way, then the many worlds version of the multiverse could be formally equivalent to the more mundane 'single-geometry' versions.



Level 2

The expanding universe we can't reach

String theory, a potential grand unified theory that aims to explain the fundamental laws of particle physics, suggests that spacetime has at least ten dimensions, of which we experience just four (three dimensions of space, plus time) in our own universe – the others are tightly curled around each other so we don't perceive them. But our arrangement of dimensions, or phase, is just one among many possible phases – given the right conditions, new ones can pop into existence within a pre-existing phase and then expand rapidly at the speed of light, meaning that they are completely unreachable. This theory of eternal inflation gives rise to a potentially infinite number of bubble universes with different dimensions and laws of physics.



"If the universe is infinite, we'd expect there to be parts of it that are exactly like our own observable universe"

Level 4

The strangest universe of all

As if the ideas of a multiverse as an extension to our own universe, a series of interconnected bubbles, or a branching structure of infinite dimensions weren't strange enough, cosmologist Max Tegmark of the Massachusetts Institute of Technology, argues that all of these "lower-level" multiverses are simply limited examples of an overarching mathematical multiverse called the "Ultimate ensemble." This encompasses all possible multiverses that can be abstracted from the messy details of terminology into a purely mathematical description, and therefore includes all the lower-level multiverses, plus any other types that still remain to be discovered. This, however, is merely part of Tegmark's semi-philosophical argument that the entire multiverse is a mathematical structure within which conscious entities perceive a physically "real" world.

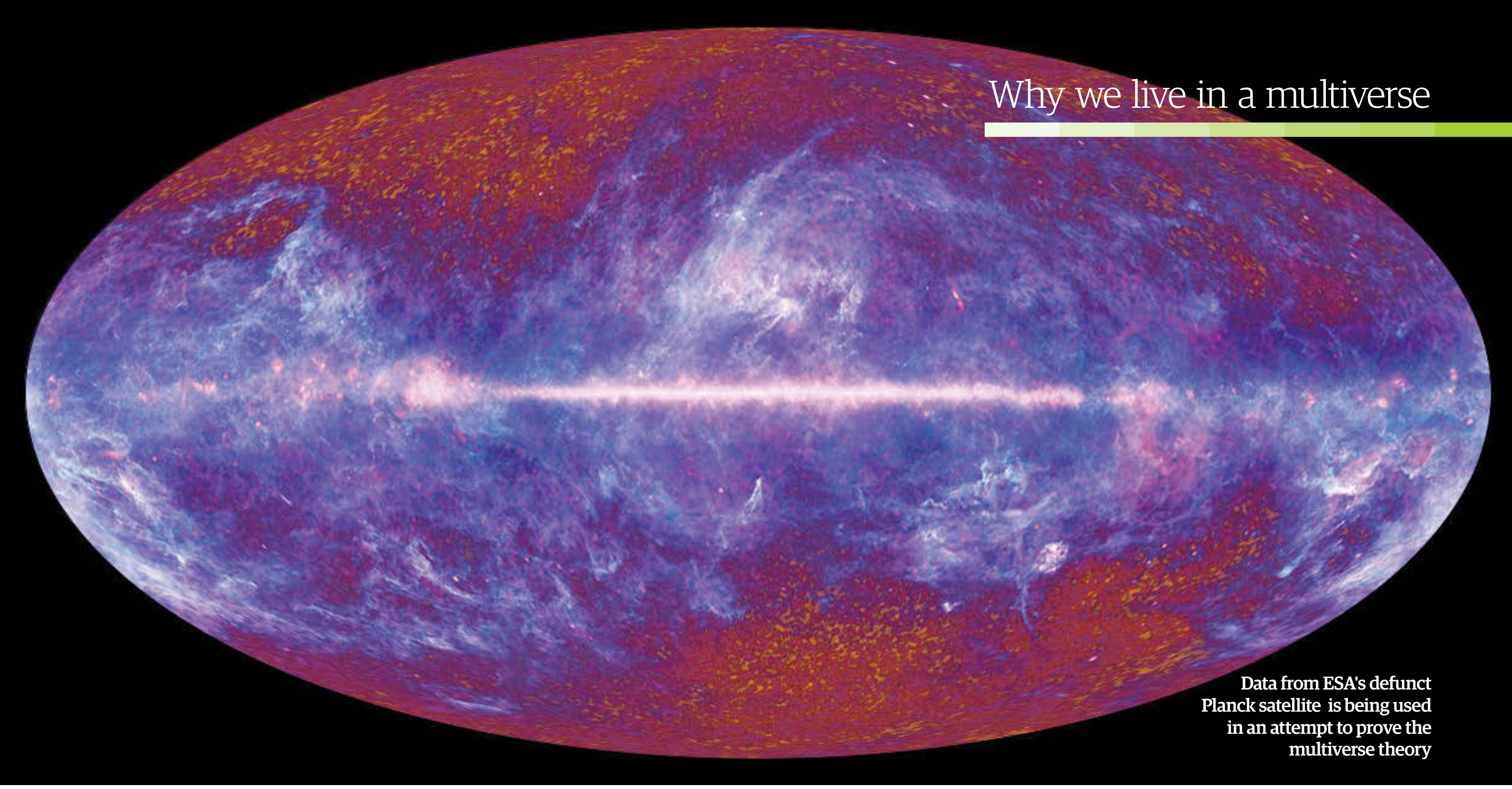
The Planck telescope being prepared for tests at ESA's European Space Research and Technology Centre (ESTEC) in the Netherlands

in fundamental physics it's not just substances that have phases, but everything around us – space and time themselves. Theories like String Theory [the leading theory of high-energy theoretical physics] predict a large number of phases, differing a lot more than ice differs from water. They would have different laws of physics: for instance the fundamental particles of the cosmos, such as electrons and quarks, might not exist in some other phase, or they might have some different form, or different properties like electrical charge and mass. These phases are kind of a generic feature of most modern cosmological theories."

> "Eternal inflation would explain one of the biggest mysteries about our cosmos"
> **Matthew Kleban**

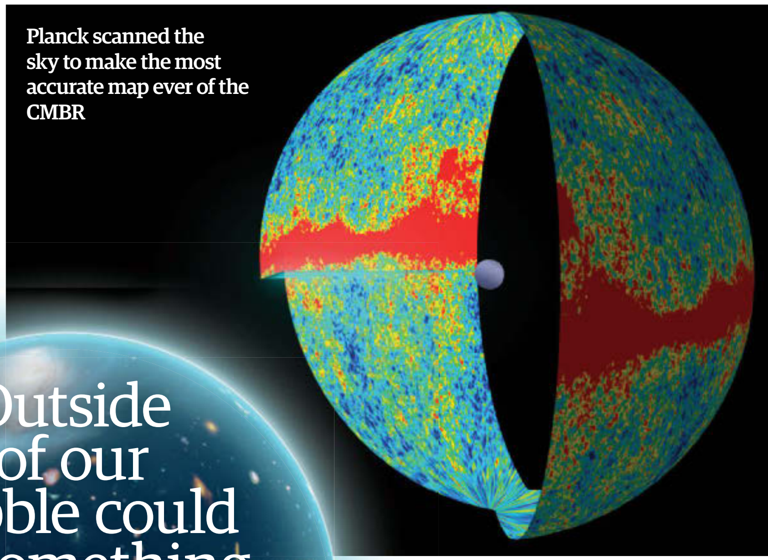
Among the various properties that could change from one phase to another is the strength of the 'vacuum energy' that permeates empty space. In the past couple of decades, astronomers have discovered strong evidence that a small amount of this energy in our universe – better known as 'dark energy' – drives the expansion of the cosmos to accelerate when it should be slowing down, but in other phases it might be nonexistent, much stronger, or even have a negative value. This, it turns out, is key to creating new universes in this kind of multiverse. If all these different phases can exist, of course, then there should be transitions between them, just as there are between ice, water and steam.

"You could have a universe that at some initial time has a single phase everywhere," Kleban explains, "but bubbles of different phases will inevitably appear more or less at random, like bubbles appearing in champagne. It's sort of a coin flip whether a given phase would have positive or negative vacuum energy, but at least some of them will be positive, and if the vacuum energy is large, then the bubble expands exponentially, doubling in a fraction of a second, doubling again after that, and so on. So the volume will just explode in those regions. And if those phases are themselves unstable, then bubbles will appear inside them – that's what we call eternal inflation." It's a fairly mind-blowing concept, as Kleban admits: "If all this is correct, then we may be inside one of these bubbles, and outside of it is something that's probably extremely exotic, most likely very rapidly inflating, and has different laws of physics – perhaps even different numbers of dimensions. Once you go beyond the wall of our



Data from ESA's defunct Planck satellite is being used in an attempt to prove the multiverse theory

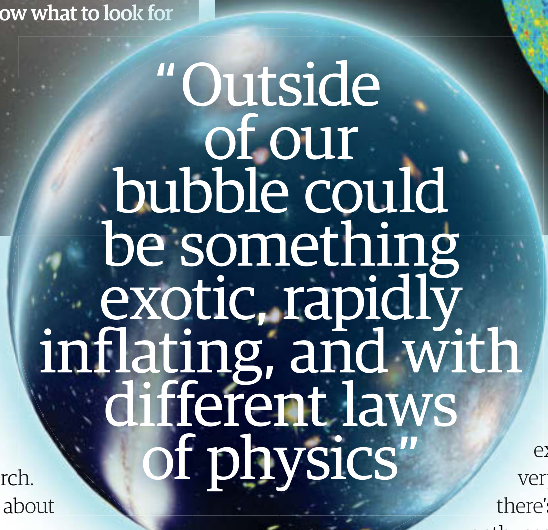
Working out what we would see if a multiverse exists will help us to know what to look for



Planck scanned the sky to make the most accurate map ever of the CMBR

bubble, the multiverse isn't at all boring and isotropic after all." Eternal inflation would explain one of the biggest mysteries about our cosmos. The properties of the universe seem suspiciously fine-tuned for life. For example, if the gravitational constant were a little stronger, or the charge of an electron a little smaller, or the force that binds particles together weaker, then stars and planets would not be able to form and we would not be here. Everything is 'just right', like Goldilocks' porridge, and so far no one has been able to explain why. However, if there are an infinite number of bubble universes, all with slightly different properties, then there is bound to be a universe – our own – where the properties are just right, which would explain why we can exist.

One of the big questions, of course, is whether we could ever hope to find evidence that would prove the theory – or at worst, prove that this cannot be the case (a key test of whether a theory is truly scientific – technically referred to as 'falsifiability'). The idea that the multiverse theory cannot be proved or disproved has been a common criticism from sceptics, and it's an area where Matt Kleban has been concentrating much of his work and research.



"What's nice about the theory is there are observational consequences – if other bubbles form close enough to us, then they'll collide with our own bubble. Detecting the consequences with our current technology is a long shot, but it's not impossible, and you can actually work out what you would see, and therefore know what to look for. So the theory makes testable predictions, and it also makes falsifiable predictions – it predicts that our bubble would need to have an open spatial geometry – if we measure the geometry of our universe and it turns out to be closed, then that would falsify the whole thing."

So what traces would a collision with another bubble make on our universe? As you might expect, a collision between two universes is a highly energetic event.

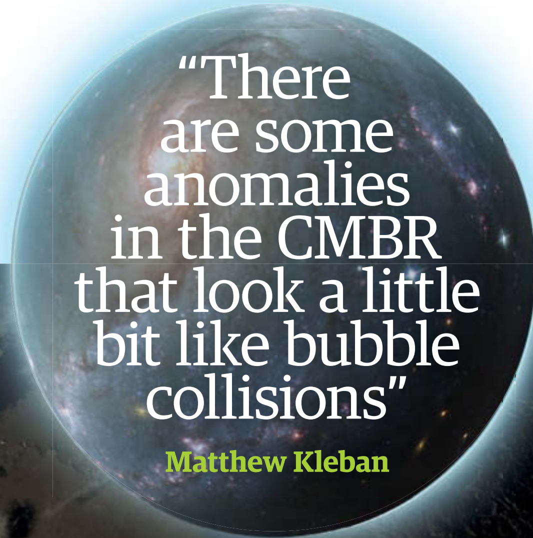
"The walls of these bubbles are extremely rigid, and moving at speeds very close to the speed of light, because there's a force that drives their expansion," enthuses Kleban. "The bubble naturally wants to expand and 'eat up' the vacuum energy around it. That gets converted into the kinetic energy of the wall, so these things accelerate, going faster and faster, until they collide. The result is a wave of energy injected into our own bubble, and this propagates across our universe in what we call a 'cosmic wake'. All sorts of things are affected, but the most important is the Cosmic Microwave Background Radiation. That's what we want to look at, because it's the oldest and most distant radiation, so it's had the most time to be affected by this sort of event."

According to most simulations, a collision between universes would show up as a ring of slightly higher temperature amid the otherwise more or less random variation of the CMBR, and also as a polarisation pattern within the radiation – instead of the microwaves vibrating in random planes, their oscillations would be aligned in specific directions.

"So far astronomers haven't found any strong evidence for such collisions, but there are some anomalies in the CMBR that look a little bit like bubble collisions. I don't take them very seriously, but imagine there really was something there on the verge of detectability – it would produce an anomaly of marginal significance and at first no one would take it seriously, so I guess that you can't rule it out. Currently we're waiting on a major new piece of data in the form of an all-sky polarisation map from the Planck satellite. That's a partially independent piece of data from the temperature maps, and certain types of bubble collisions would have a very distinct signature in the polarisation."

If our universe does turn out to be just one among, perhaps, infinitely many in a multiverse, the implications for cosmology would be huge. No longer would we imagine space and time as being created in a single event 13.8 billion years ago – that would simply mark the point when our particular phase popped into existence and began to expand. It would at last be meaningful to ask what came before the Big Bang, but in the process we would be forced to exchange our current view of a relatively young universe with a specific beginning for a multiverse, whose origins, if indeed their were any, lay in the unknowable distant past.

But as Matt Kleban is keen to point out, the study of our potential multiverse is still very much in its infancy. "We focus on certain types of collision because it seems like those would be the ones we'd have the best chance of observing, but there could be something that we have missed. And the other possibility is an entirely different type of observation that we can't yet do, or haven't thought of. The important thing is that it is possible to detect the multiverse, and once something's possible, we may discover a clever way to do it. We're really still at the beginning." ●



"There are some anomalies in the CMBR that look a little bit like bubble collisions"

Matthew Kleban

Life in the multiverse

Confirmation of a multiverse could raise some intriguing questions about the origins of life and our own place in the cosmos. According to our current understanding, the physical laws of our universe are suspiciously fine-tuned for life to arise – a tiny difference in any one of several physical constants might make liquid water much rarer, render complex organic chemistry unworkable, or leave matter itself unable to hold together. The usual scientific solution to this problem, called the 'weak anthropic principle', simply states that if the laws of the universe did not have the particular behaviours we observe, then we would not be around to see them – so we shouldn't be so surprised. Various 'strong anthropic principles', meanwhile, take things a step further with the assumption that for some reason or other, the universe has to give rise to something like its present set of life-friendly parameters (perhaps even because, borrowing an idea from quantum theory, the existence of conscious observers is a requirement for the universe to exist).

If this universe is just one within an infinite multiverse (particularly an 'eternal inflation' or 'many worlds' multiverse), this could significantly change the terms of the debate. The odds of a universe arising with our own parameters would rise from highly improbable to a locked-in certainty, but at the same time so would the odds of any other combination of parameters. So could life exist in these other universes? According to some researchers, it may be far more robust than previously realised – using computer simulations to study the evolution of universes with various fundamental constants, they have found that stable forms of matter and carbon chemistry can arise in a surprising variety of situations.

The physical laws of our current universe are suspiciously fine-tuned for life to exist

Venusian plane

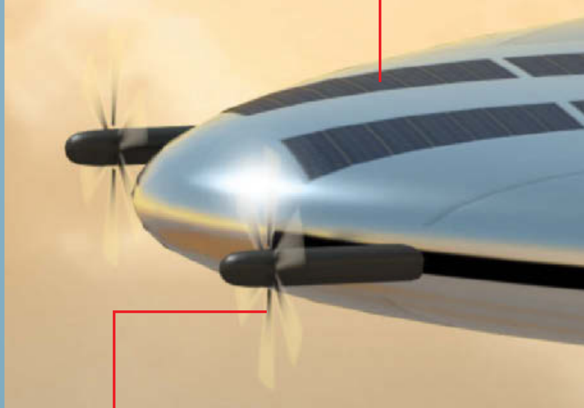
An American aerospace giant aims to send an inflatable flying wing to Earth's evil twin

Distinguished aerospace firm Northrop Grumman has a thing about flying wings. If you've ever seen pictures of an amazing 1940s silver flying wing bristling with propellers, that was them, as too is the current B2 Stealth Bomber. Now in a move that would surely thrill company founder and flying wing enthusiast Jack Northrop, the firm may be sending one to the second planet from the Sun.

Venus' atmosphere makes the planet the most difficult place to explore in the Solar System - dominated by carbon dioxide, it has a runaway greenhouse effect that gives it an average surface temperature of over 400 degrees Celsius (752 degrees Fahrenheit). Carbon dioxide is also much denser than air, making the surface pressure 90 times that of Earth's; added to which sulphuric acid rains out of a dense, planet-wide cloud cover. However, there is increasing interest in exploring and even colonising Venus' upper atmosphere because the same mechanisms that make the surface so inhospitable produce a one bar, 15 degrees Celsius (59 degrees Fahrenheit) environment at 50 kilometres (31 miles) altitude. The Venus Atmospheric Manoeuvrable Platform (VAMP) is a 900-kilogram (1,984-pound) inflatable flying wing, with a 55-metre (180-foot) wingspan, which Northrop hope to enter into NASA's New Frontiers Solar System exploration competition. It will take advantage of this sweet spot on Venus, flying between 52 and 68 kilometres (32 and 42 miles) high, whilst sampling the atmosphere and scanning the surface far below. But the first remarkable thing it does will be in space.

VAMP's designers hope to be able to save considerable payload mass for experiments by entering Venus' atmosphere in a novel way. Atmospheric entry, generally known as "re-entry" on Earth, is difficult because spacecraft in orbit are travelling at around 7.8 kilometres (4.8 miles) per second, and when heavy, blunt spacecraft enter the atmosphere, they plunge straight down into denser air. As they collide with the air molecules, their speed is converted into tremendous heat, which can interrupt communications with the spacecraft as it creates a shield of plasma around the vehicle - such heating even led to the tragic loss of the Space Shuttle Columbia in 2003 after its shielding was damaged. But VAMP will be inflated in space when it first arrives in Venus' orbit. Because VAMP will be a large, diffuse wing-shaped balloon, it will be affected by the atmosphere much higher up, and will therefore be able to slow down gradually, so it won't need a heavy heat shield. It will still experience 1,200 degrees Celsius (2,192 degrees Fahrenheit) on the leading edge of the wing, but the wing will be protected by a woven ceramic fabric called Nextel.

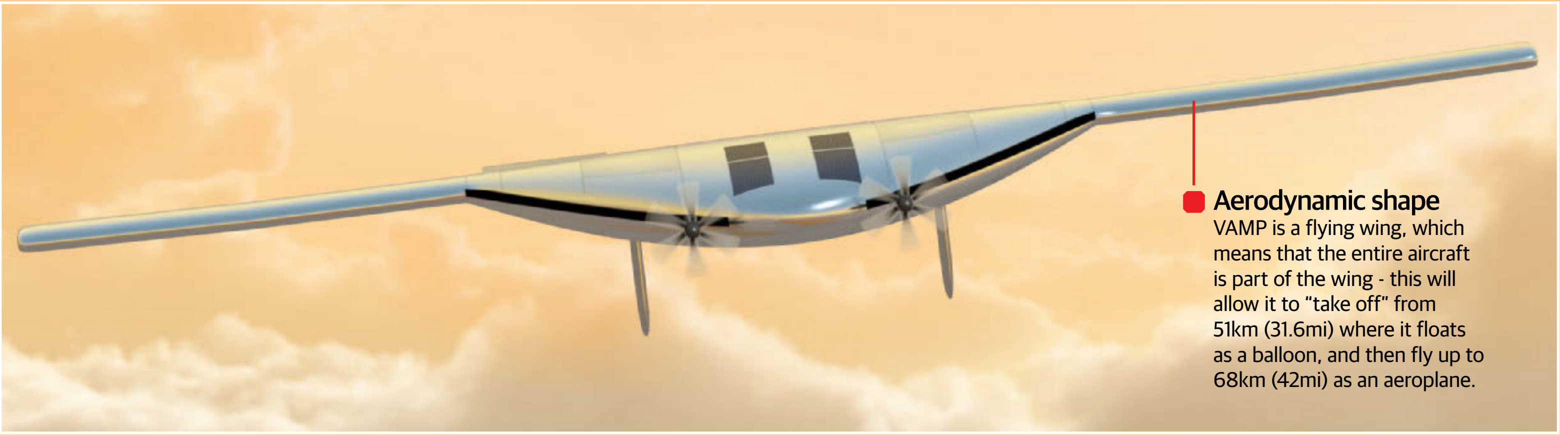
Since VAMP will be filled with hydrogen gas before it even enters the atmosphere, it will never have to land. Indeed even with no power at all, it will be 100 per cent buoyant at 51 kilometres (31.6 miles) altitude. But VAMP will also have electrically driven propellers, powered by eight kilowatts of solar panels and a battery storage system. These, and the VAMP's wing shape, will enable it to fly up to 68 kilometres (42 miles) altitude, where 91 per cent of its lift will be aerodynamic rather than from balloon lift. Then at night, when there is insufficient power to sustain level flight, it will sink back down to 52 kilometres (32 miles) to wait for sunrise. VAMP will be able to continue doing this as long as there is enough gas remaining in the balloon envelope, possibly as long as a year. Flying along at a very speedy 30 metres (98 feet) per second while Venus' winds carry it around the planet every six to seven days, VAMP will be able to extensively explore our nearest neighbour's upper atmosphere, while providing an unrivalled vantage point for scanning the surface far below.

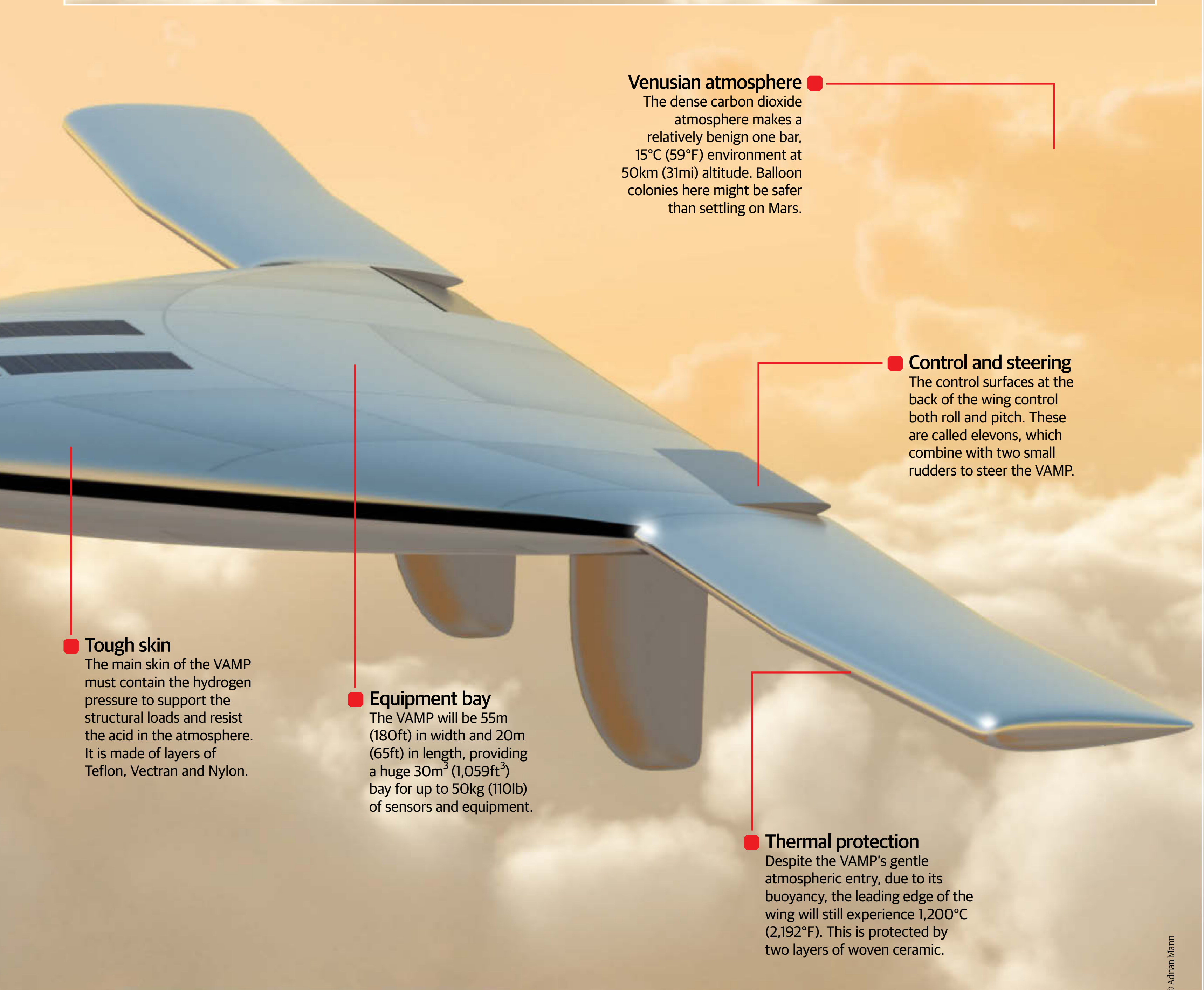


Solar panels
The aircraft will be equipped with solar panels to provide up to 8kW of power, while surplus energy will be stored in lithium-ion batteries.

Propulsion system
The VAMP has two propellers with a diameter of 2.4m (8ft). They are driven by electric motors, producing 45kgf (100lbf) of thrust, letting the VAMP achieve speeds of up to 30m/s (98ft/s).

"VAMP will be filled with hydrogen gas before it enters Venus' atmosphere. It will never land and, even with no power, will be 100 per cent buoyant"


Aerodynamic shape
VAMP is a flying wing, which means that the entire aircraft is part of the wing - this will allow it to "take off" from 51km (31.6mi) where it floats as a balloon, and then fly up to 68km (42mi) as an aeroplane.


Venusian atmosphere
The dense carbon dioxide atmosphere makes a relatively benign one bar, 15°C (59°F) environment at 50km (31mi) altitude. Balloon colonies here might be safer than settling on Mars.
Control and steering
The control surfaces at the back of the wing control both roll and pitch. These are called elevons, which combine with two small rudders to steer the VAMP.
Tough skin
The main skin of the VAMP must contain the hydrogen pressure to support the structural loads and resist the acid in the atmosphere. It is made of layers of Teflon, Vectran and Nylon.
Equipment bay
The VAMP will be 55m (180ft) in width and 20m (65ft) in length, providing a huge 30m³ (1,059ft³) bay for up to 50kg (110lb) of sensors and equipment.
Thermal protection
Despite the VAMP's gentle atmospheric entry, due to its buoyancy, the leading edge of the wing will still experience 1,200°C (2,192°F). This is protected by two layers of woven ceramic.


Scale
93m
Statue of Liberty
111m
SLS block 2 configuration

The world's BIGGEST ROCKET

A marvel of modern space engineering, the Space Launch System is set to take humanity further into space than ever before

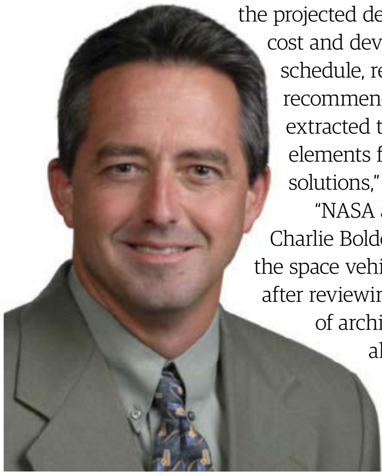
Written by Dominic Reseigh-Lincoln

Ever since the launch of the Juno I - the rocket which sent the United States' first satellite, Explorer 1, into orbit in 1958 - American astronomers, engineers and astronauts have been looking far beyond our atmosphere and further than our own lone lunar satellite – the eyes of the space engineering industry have been firmly set not just on our Moon, but toward Mars and distant asteroids.

However, in order to travel those incredible distances, you need an equally incredible feat of engineering to take you there – a launch vehicle with the thrust and capacity to take humanity distances that only probes and unmanned spacecraft have traversed before. Distances that are normally covered in slow, steady states of hibernation. The answer to that dream lies in a $35-billion (£23-billion) planned mission, powered by the most powerful rocket ever created – the Space Launch System.

So how did it all come together? The origin of the SLS can be traced back to the NASA Authorization Act of 2010, which called for the development of a brand new heavy-lift rocket. The Saturn V, the last heavy-lift rocket used by NASA, was taken out of service in 1973 and since then nothing in the American space agencies' fleet could match its incredible power and capacity.

"The original concept was a capability which the US and its international partners will rely on to enable exploration beyond low-Earth orbit for the better part of the 21st century," reveals Jay Onken, deputy chief engineer of the SLS. "The NASA team completed a series of studies as part of a Requirements Analysis Cycle (RAC), in parallel with 13 complementary studies conducted by private industry, under Broad Agency Announcement (BAA) contracts. The results of these efforts converged on a Mission Concept Review (MCR) in the spring of 2011." These activities helped to determine the feasibility of meeting top-level missions with the launch vehicle set ups available in the US at the time. The NASA planning team used these different trade studies to evaluate alternative options to meet the NASA's 'Human Exploration' goals. "These studies, which included independent reviews of the projected development cost and development schedule, resulted in a recommendation that extracted the 'best' elements from possible solutions," adds Onken.



"NASA administrator, Charlie Bolden selected the space vehicle's design after reviewing the various of architectures and alternatives." And with that, the Space Launch System (SLS) was born.

"It will offer game-changing benefits, making manned space exploration missions possible" **Jay Onken, SLS deputy chief engineer**

The SLS incorporates components from the Space Shuttle program

The SLS is the first heavy-lift operation to be designed and constructed by NASA since the Saturn V in the Sixties and Seventies

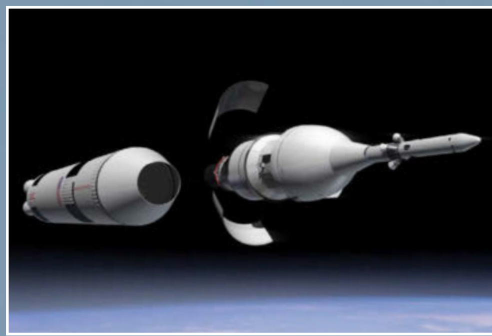
Block 1, used for EM-1 and EM-2, will have a lift capacity of around 70 metric tons

Rocket of the future

From its three planned missions to some of the biggest of its proposed journeys, these are the voyages of the SLS

Exploration Mission-1

Set to launch in November 2018, the first mission will take an unmanned Orion capsule around the Moon and back to test the in-space capabilities of the SLS.

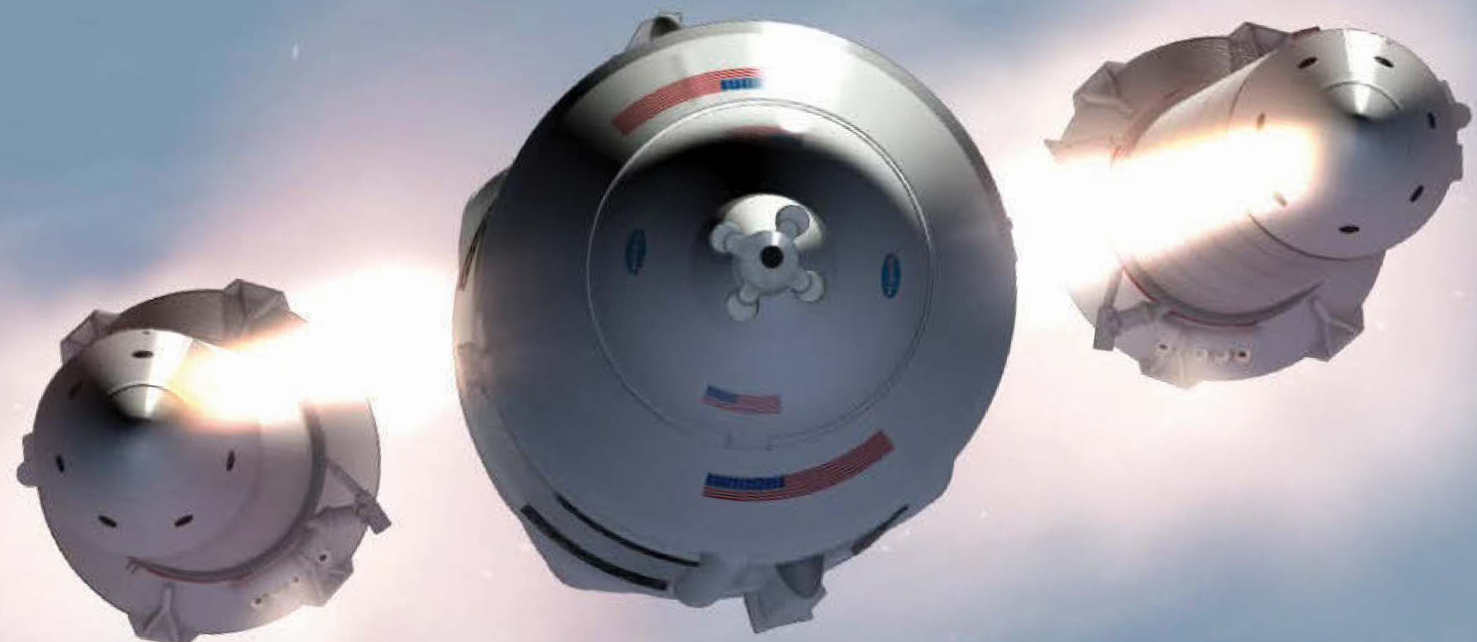


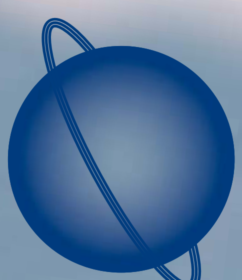
Exploration Mission-2

The second mission, EM-2, is planned to launch sometime between 2021 and 2023, carrying a crew of four people on a retrograde lunar orbit.

Exploration Mission-3

EM-3, the third and final mission on the officially planned list, will launch in 2026, sending another four-man crew to a robotically-captured asteroid.





Uranus orbiter and probe

Airplane multinational Boeing has proposed that the SLS be used as a launch vehicle for a probe bound for Uranus.

Strategic timeframe design reference missions to the Moon

Alongside a series of lunar probes that will hopefully lead to a lunar base, NASA will dual-launch crafts to geostationary orbits.

ISS back-up crew delivery

Should the other vehicles that normally ferry astronauts to the International Space Station fail or become unavailable, the SLS will temporarily take on their role.

Five NEA missions

Proposals for five separate Near-Earth Asteroid (NEA) missions that will aim to visit, study and potentially capture asteroids passing close by to Earth.

The question is, why did it take over four decades for NASA to finally design and construct a heavy-lift system to replace the Saturn V program that ran during the 1960s and 1970s? The answer is simpler than you might imagine. After the Cold War driven Space Race to the Moon, NASA realised it was attempting to reach out into the stars without truly understanding the environment in which they were working. "After the Saturn V was retired in the 1970s, President Richard Nixon directed NASA to focus on building the Space Shuttle for more routine access to low-Earth orbit," explains Onken, in regards to the phase that would eventually lead NASA back to heavy-lift operations.

"America's first Space Station, Skylab, was launched, and Americans broke world records for time spent in space on those missions," he adds. "NASA learned a lot about how people and materials were affected by microgravity and the space environment, and before longer space missions to the Moon and Mars could be planned, these questions needed to be answered. The Space Shuttle and the International Space Station, which has been occupied by humans continuously since 2 November 2000, allowed NASA to learn a great deal about living and working in space."

The now defunct Space Shuttle program would also play a major role in the future of the SLS, mainly due to the inclusion of the Space Shuttle's own booster rockets in the new mega vehicle's design. So what was the reasoning behind the use of components first used at the start of the 1980s? It all comes down to keeping the elements that proved the most successful and durable from past endeavours.

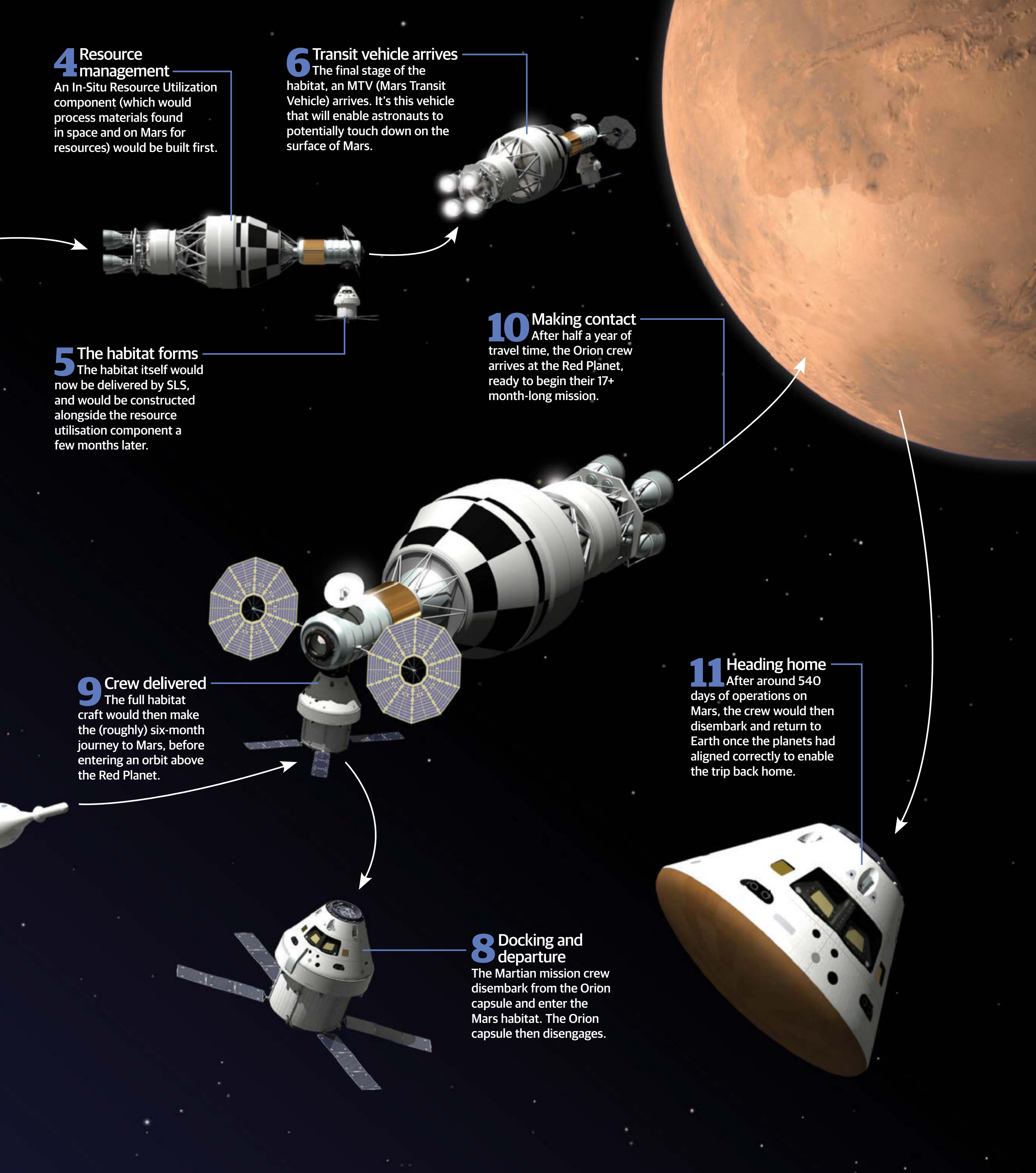
"The SLS incorporates components from the Space Shuttle program because of the reliability of these systems and to provide an affordable means to start the program," adds Onken. "For example, developing a new engine tends to be the most expensive part of any program – we are starting with a very proven, reliable engine and therefore do not have the added expense of designing, developing, testing and manufacturing the engine."

The Space Launch System aims to take all those existing technologies and create the most powerful rocket ever constructed. It's more than double the size of any space vehicle currently in operation and will offer 15 per cent more thrust than the decades old Saturn V. Unlike any other rocket in NASA's history, the SLS will be split into three separate designs, each one tailored for specific missions at distinct distances from the Earth. The first, Block 1, will have a lift capacity of around 70 metric tons and will be used for Exploration Mission-1 (EM-1) and Exploration Mission-2 (EM-2).

Exploration Mission-1, set for launch in November 2018, will carry the unmanned Orion spacecraft, as well as 13 secondary science payloads. These payloads include; the Lunar Flashlight, a spacecraft with a solar sail that will determine the presence (or indeed the absence) of water ice at the lunar south pole; the BioSentinel, an astrobiology device that will use something as commonplace as yeast to study the effects of deep space radiation on living organisms; and the Near-Earth Asteroid Scout, another solar sail powered craft, this time focused on studying spacefaring bodies passing near our planet's

Mission to Mars

Perhaps the most ambitious of the proposed space missions, the SLS plans to carry a crew of four-to-six astronauts to a habitat on the Red Planet



4 Resource management
An In-Situ Resource Utilization component (which would process materials found in space and on Mars for resources) would be built first.

5 The habitat forms
The habitat itself would now be delivered by SLS, and would be constructed alongside the resource utilisation component a few months later.

6 Transit vehicle arrives
The final stage of the habitat, an MTV (Mars Transit Vehicle) arrives. It's this vehicle that will enable astronauts to potentially touch down on the surface of Mars.

8 Docking and departure
The Martian mission crew disembark from the Orion capsule and enter the Mars habitat. The Orion capsule then disengages.

9 Crew delivered
The full habitat craft would then make the (roughly) six-month journey to Mars, before entering an orbit above the Red Planet.

10 Making contact
After half a year of travel time, the Orion crew arrives at the Red Planet, ready to begin their 17+ month-long mission.

11 Heading home
After around 540 days of operations on Mars, the crew would then disembark and return to Earth once the planets had aligned correctly to enable the trip back home.

atmosphere. All of them will operate in different areas, all of them powered by the thrust of the SLS.

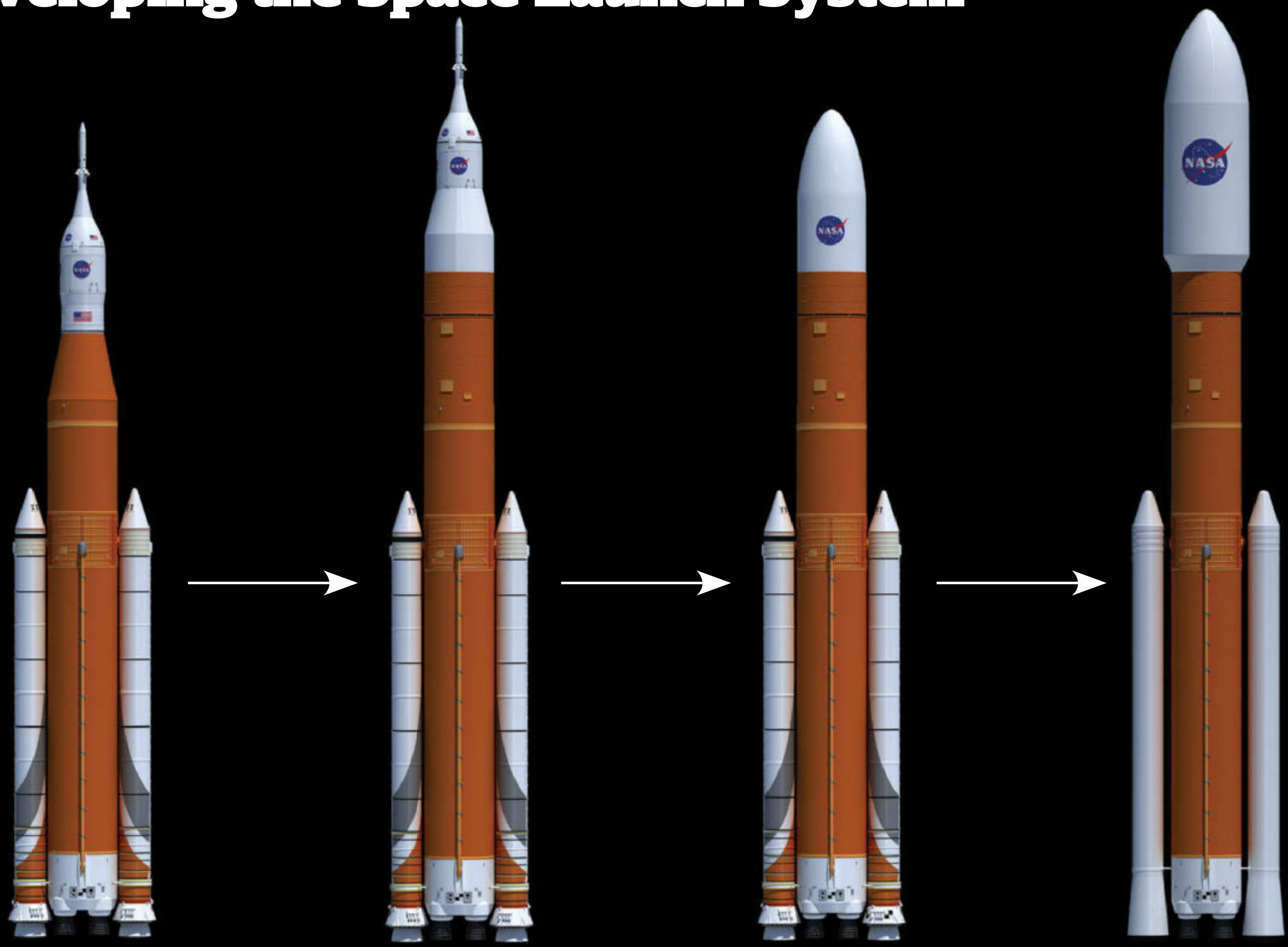
That first design will be powered by two five-segment Solid Rocket Boosters, four RS-25D engines (previously used as part of the Space Shuttle program), and an Interim Cryogenic Propulsion Stage, which is based on the payload motor used by the Delta IV evolved expendable launch vehicle. On lift off, the Block 1 variation will produce nearly 4 million kilograms (8.8 million pounds) of thrust, which is equivalent to an incredible 31 times the thrust of a Boeing 747 jet. The Block 1 SLS also weighs a staggering 2.6 million kilograms (5.75 million pounds), the equivalent of eight fully-loaded 747s. It will also be one of the tallest rockets ever constructed at 98 metres (322 feet) tall – essentially a skyscraper that will blast into space.

"We are starting with proven high-performance RS-25 core stage engines from the Space Shuttle inventory," says Onken on some of the new innovations being used to make the Space Launch System a reality. "Building on 30 years of experience and engine success, which reduces both risk and cost, we now have 16 RS-25 engines – enough for the first four flights – currently in inventory at the Stennis Space Center. Testing on a RS-25 development engine finished in August 2015 and work is underway to begin testing on flight RS-25 engines." Other enhancements are currently in progress for the engines. For example, NASA is working with Aerojet Rocketdyne on plans to restart production of a more affordable variant of the RS-25 engine that is tested and certified for flight at a higher thrust level. This future engine will implement a much more simplified design and new manufacturing and inspection technologies and processes. These will reduce handling and support labour, hardware defects and production time – in other words, it's a design that works at a price that's far more affordable.

The second variation of the Space Launch System, Block 1B, will provide even more power with a lift capacity of around 105 metric tons. It will be even bigger than the Block 1 iteration, more

"This giant rocket's incredible thrust will be about 31 times that of a Boeing 747 jet engine"

Developing the Space Launch System



SLS Block 1
November 2018
The SLS is designed to make passes around the Moon and return to Earth. It will utilise solid rocket boosters, an Interim Cryogenic Propulsion Stage (all it needs to make this relatively short test flight) and the Orion spacecraft.

SLS Block 1B Crew
2021-2023
If the SLS Block 1 tests with an unmanned crew are successful, the Block 1B model will then be launched. It will conduct exactly the same mission as the Block 1 rocket but this time with a crew of four astronauts.

SLS Block 1B Cargo
2030
The next stage of the Space Launch System's evolution is using the Block 1B to carry heavier payloads to low-Earth orbits and beyond, such as the components for the proposed Forward Work Mars Landing mission.

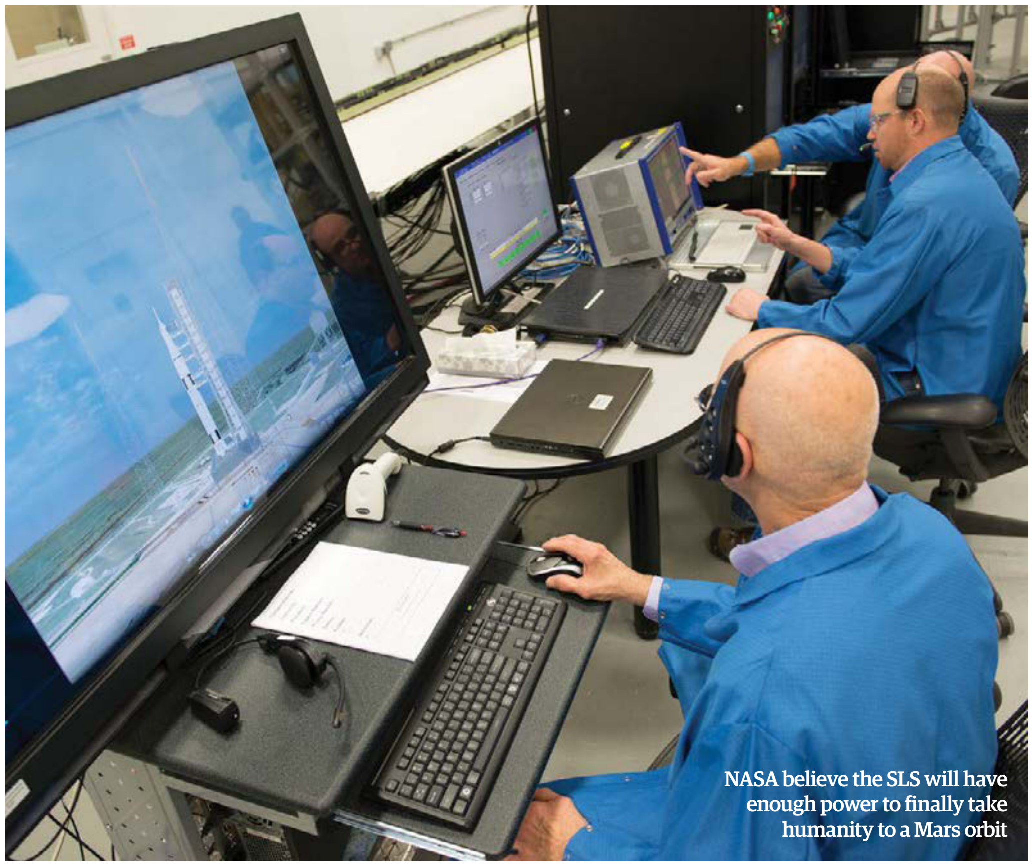
SLS Block 2 Cargo
2033-2045
The ultimate goal is to launch the final stage of the evolved SLS – larger and more powerful than its previous incarnations, the Block 2 would transfer crews and large cargo payloads to Mars and nearby passing asteroids.

or less matching the height of its predecessor the Saturn V at a huge 110.9 metres (364 foot) tall. That additional height and weight all comes from an extra component that will distinguish this phase from others in the SLS design: the Exploration Upper Stage. Forming a key part of Exploration Mission-2, the Exploration Upper Stage will replace the Interim Cryogenic Propulsion Stage and serve as the basis for more ambitious crew and science missions to the proving ground of space, near the Moon and beyond, where NASA will test systems for Mars missions.

The third and, currently, final stage of the Space Launch System will be Block 2 and, like Block 1B, it will be designed to take both manned and unmanned cargo further than ever before. It's this variation of the SLS that will aim to take humans to the Moon, to asteroids for the first time, and even out to Mars in the not too distant future. Every element of the Block 2 will break records in space engineering and space-based flight. At 111.2 metres (365 foot) tall it reaches higher than a 30-story building, while its weight of 2.9 million kilograms (6.5 million pounds) weight is as heavy as ten fully-loaded 747 jets! The SLS will be NASA's first exploration-class vehicle since the Saturn V took American astronauts to the Moon more than 40 years ago, and will expand our reach in the Solar System, launching crews of up to four astronauts aboard the new Orion spacecraft to explore multiple, deep-space destinations. Outside of its three main Exploration Missions, the SLS stands as a platform for humanity's endeavours beyond the low-Earth orbits that have categorised spaceflight for the last three decades.

"In addition to making human exploration missions possible, the SLS offers game-changing benefits for potential robotic science missions and other payloads," adds Onken. "Its lift capability enables the launch of larger payloads than any other rocket; its high performance decreases the time it takes for robotic spacecraft to travel through the Solar System, and by extension, cost and risk; and its ability to carry larger payloads provides volume to fly unique science missions that are otherwise too large to fly on commercial rockets."

Perhaps most important of all, the SLS will be the vehicle with the power to finally take humanity to a Mars orbit. The Block 2 variation will, if the planned Forward Work Mars Landing program goes ahead, be the rocket that finally reaches that Martian milestone. The proposal aims to take a crew of four-to-six astronauts 54.6 million kilometres (33.9 million miles) away to the Red Planet (a journey of roughly six months) aboard a pre-constructed orbital habitat. Of course, such a ground-breaking construct wouldn't arrive with the crew – in fact it will take a total of seven Block 2 rockets. Each one will be powered by nuclear propulsion modules, and will be constructed in-orbit before being made habitable. The crew will spend roughly 540 days onboard the habitat while the planets align again, thus enabling them to make the six-month return journey home. It's an incredible feat and one that's still decades away – the project team behind the proposal hopes to use the Space Launch System to blast off for Mars between 2033 and 2045 – but it's still just one more landmark clinging to the fuselage of the world's most ambitious space rocket ever to launch. ■



NASA believe the SLS will have enough power to finally take humanity to a Mars orbit

The SLS' rocket boosters (shown here during a test) are the most powerful ever built

The Block 2 configuration will be over 30-stories tall at 111m (365ft)

The Block 1 and Block 2 will produce 15 and 20 per cent more thrust than Saturn V respectively

Gemini Observatory's Exoplanet Hunter

It's the world's freshest eye on the sky and it's making great strides in the hunt for alien worlds

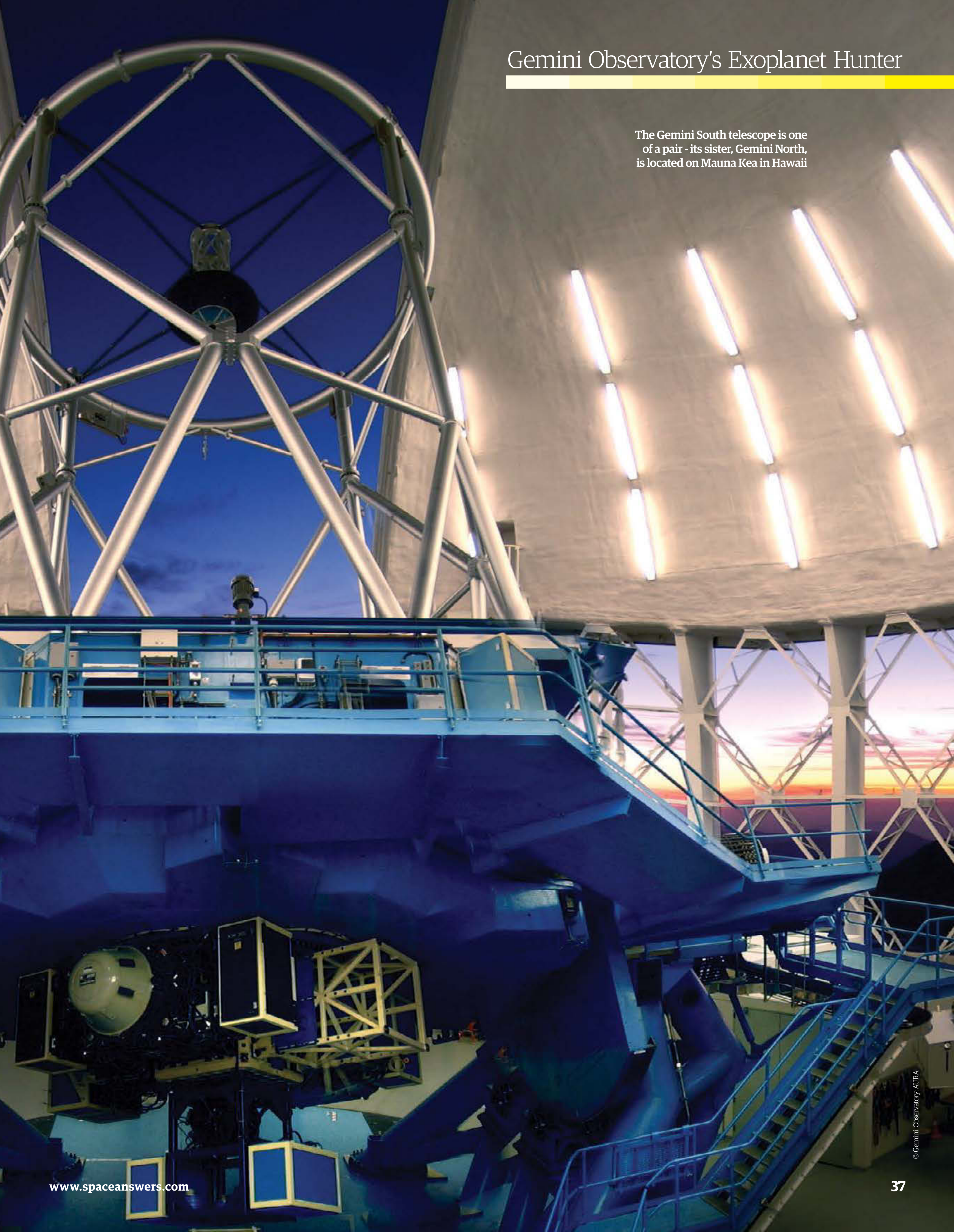
Built on top of the 8.1-metre (26.6-foot) Gemini South Telescope in Chile, the Gemini Planet Imager (GPI) was built to detect and uncover Jupiter-like exoplanets and it certainly hasn't disappointed in its first full year of operation.

Within just a few months, the Gemini Planet Imager had discovered a young planetary system with a bright ring of dust around a nearby star and, a short while later, it spotted a low-mass exoplanet named 51 Eridani b, located 100 light years away. Remarkably, 51 Eridani b is twice the mass of Jupiter but is also the smallest exoplanet ever to be directly seen by a telescope.

Finds such as these underline Gemini South Telescope's importance in furthering our understanding of how planets form in the universe, not least because the distance between the discovered dust and the star is roughly the same as that between the Kuiper Belt and the Sun in the Solar System - this allows parallels to be drawn. Meanwhile, the 'alien' Jupiter is only 20 million years old and appears to have water and strong methane within its composition. Could it be an indicator of Jupiter's past?

Such discoveries show the importance of the GPI. By directly looking for signs of light from large planets - each of which, like our own gas giants, are some way away from their stellar parents - it has already picked up on 100 planetary bodies orbiting young stars and will certainly uncover more.

The Gemini Planet Imager is located at the Cassegrain focus of the Gemini South Telescope, Chile

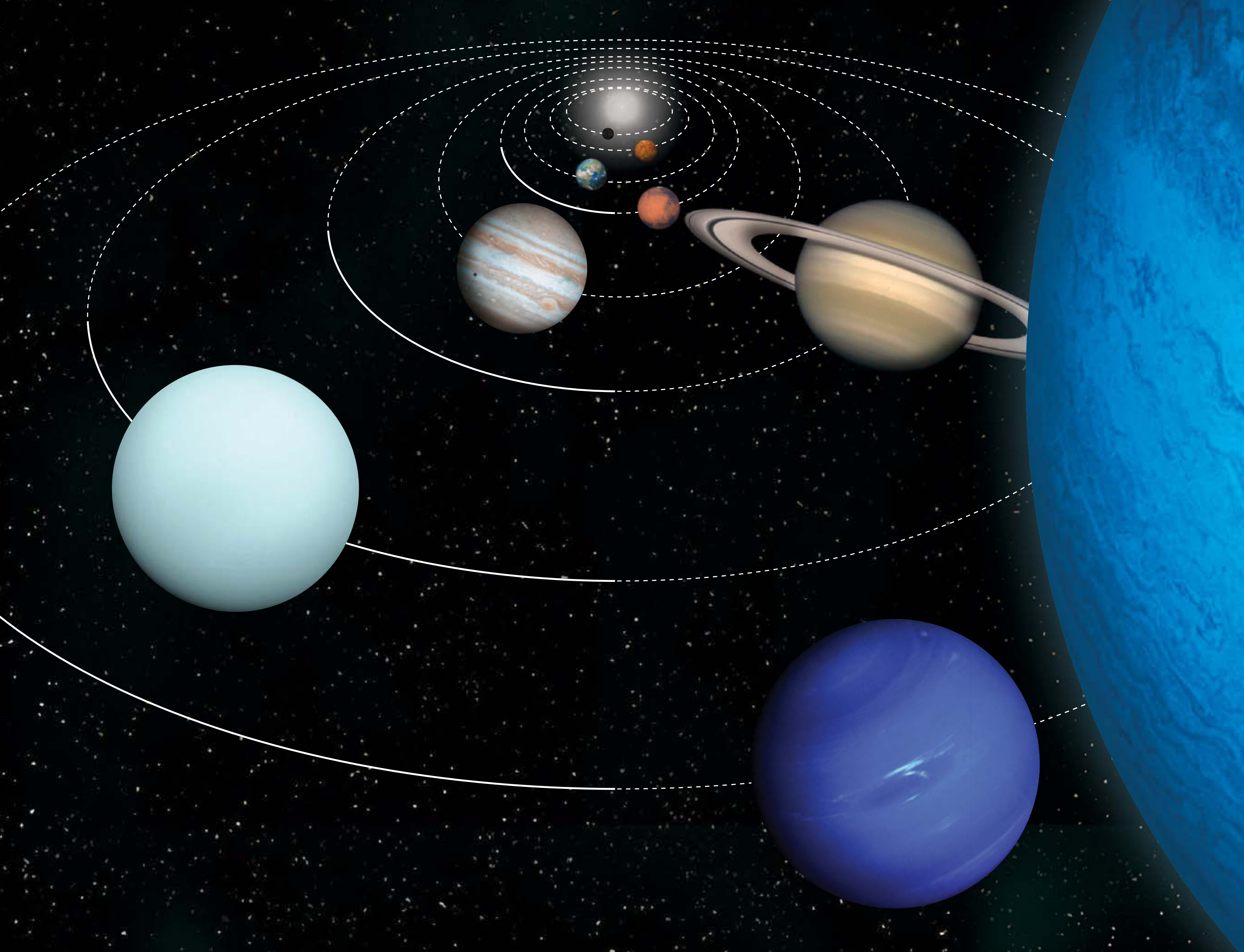


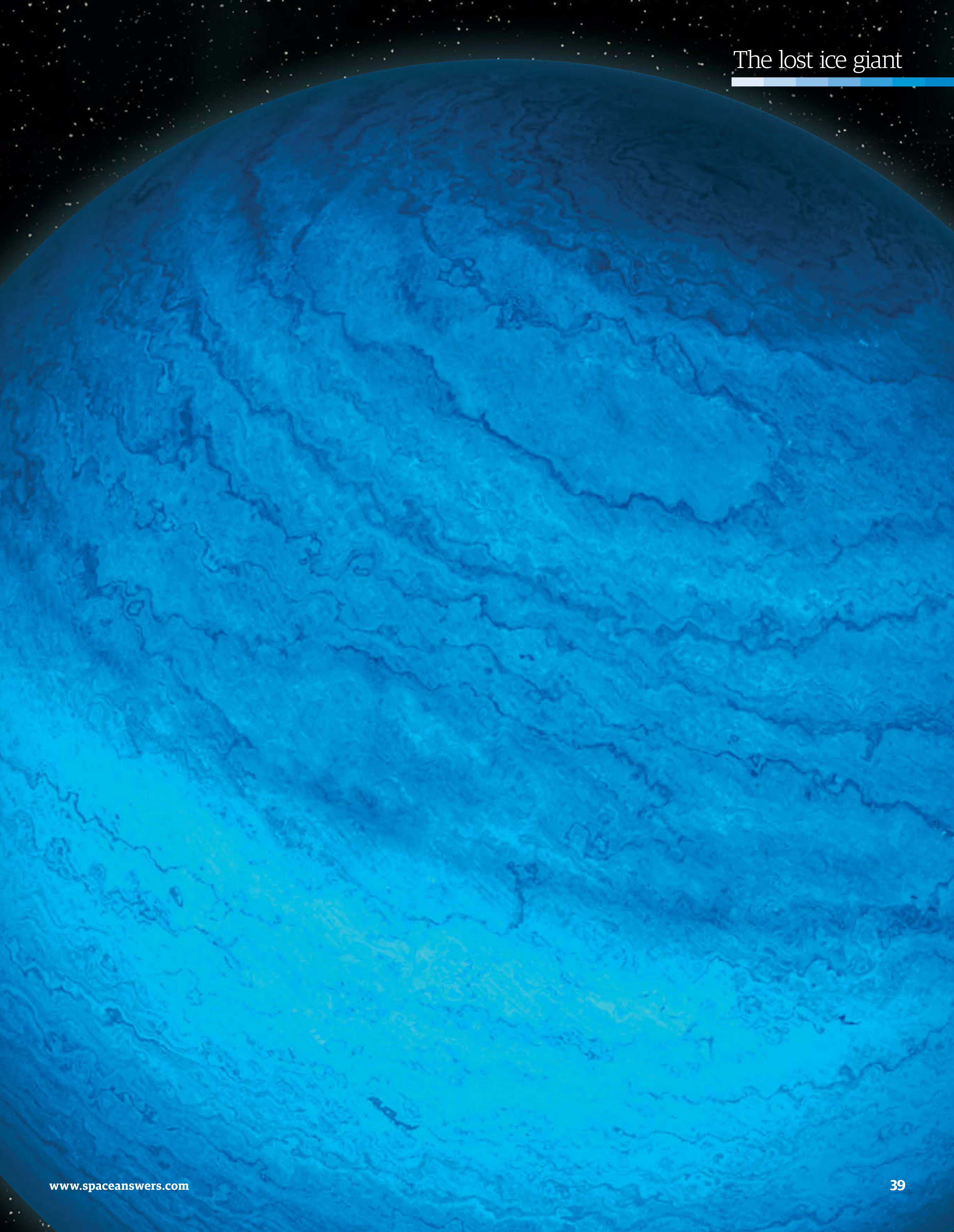
The Gemini South telescope is one of a pair - its sister, Gemini North, is located on Mauna Kea in Hawaii

THE LOST ICE GIANT

Imagine being frozen out of a tight knit family – if the Solar System ever had a fifth giant planet, this was its likely fate

Written by David Crookes





Somewhere, out there, deep in interstellar space, in the darkness far away from our Sun, is a lonely planet believed to be wandering the galaxy. Rich in icy matter, roughly the same mass as Neptune and with an atmosphere to match, it is a free-floating world untethered to any star, set adrift in a perpetual night. But it has never been seen and no astronomer is able to pinpoint its precise whereabouts in the abyss of space. It may be big but it remains one of the universe's most mysterious bodies.

Or at least that is what some astronomers think. As it stands, this intriguing giant planet is hypothetical but there is compelling evidence that it does exist. After all, there are likely to be billions of free-floating planets in the universe, each of them alone and abandoned and left to fend for themselves. The difference with this particular orphan planet is that it forms part of a theory that could have important ramifications for the formation of the Solar System. For according to one astronomer, it may have started its life much closer to home.

Scientist David Nesvorny of the Southwest Research Institute in Boulder, Colorado, believes the Solar System originally had five giant planets and not merely the four that we know of today. He says the fifth planet would have been created alongside Jupiter, Saturn, Neptune and Uranus during the very early years of the Solar System's formation. Created in close proximity to each other, they would have fed off the same supply of gas and dust. But as they began to spread out, the fun and games began. Nesvorny's simulations have found that one of them just had to go.

"My findings were based on the Nice model theory which was published in 2005," he explains. The theory put forward by four international scientists claims the giant planets migrated out from a compact configuration that was initially closer to the Sun. Nesvorny continues, "The model assumes that the Solar System is evolving and that the planets can become unstable at some point, so I began to run thousands of simulations. I wanted to test the likelihood of this dynamic instability and see how it could produce the Solar System that we know today."

When Nesvorny initially carried out his simulations, he – like many others before him – based them on the Solar System having four giant planets. In each case either Neptune or Uranus was banished and that left just three. This obviously caused a major headache because it didn't correspond to reality. "The problem with these simulations is that the chances of preserving the four giant planets has been tiny," he says. "None of the simulations I ran would provide them – in the best cases either Uranus or Neptune would be expelled so I started to think about how to resolve this."

Such simulations have been fascinating astronomers for many years, as they are keen to work out just how the planets ended up in their current state. Theoreticians are often baffled that the planets of the Solar System formed in a far more orderly fashion than has been seen in other planetary systems. Many giant planets are much closer to the Sun than our own, for example – some are actually nearer to their stars than even our terrestrial planet, Mercury, is to our Sun.

Aside from that, many of the planetary bodies from other systems have highly elliptical orbits too, whereas – Pluto aside – ours have low eccentricities. But what these anomalies have shown is that the boundaries of possibility are far wider than was once thought. Having a fifth planet involved is not something that can be dismissed out of hand.

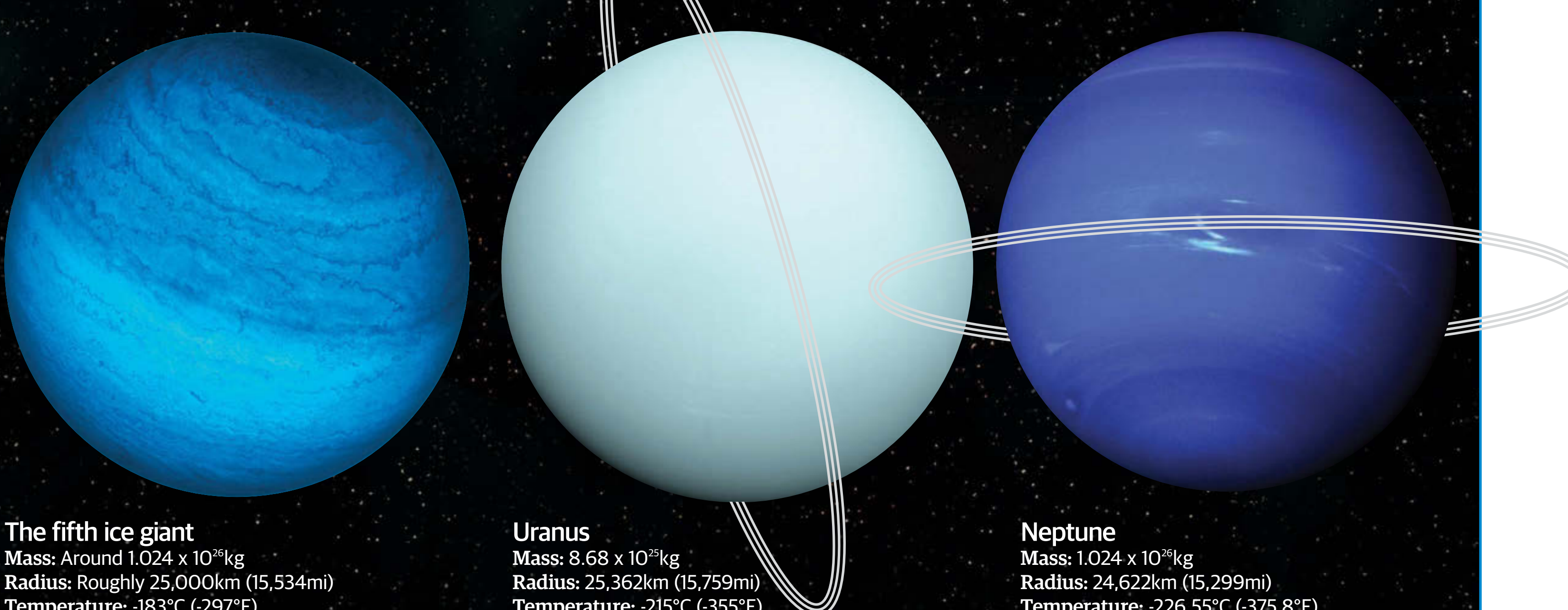
"I initially increased the mass of the protoplanetary gas disc to 50 or 100 Earth masses, which saved those two planets but produced other results that were not plausible," says Nesvorny of his ongoing investigations. "Every time, I ended up with a Solar System that didn't look like the current one. But that changed when I added an extra planet."

Dr Nesvorny experimented with the additional planet, altering its mass and position. The model

"There are likely to billions of free-floating planets in the universe, each of them left to fend for themselves"

The lost world

How would the fifth planet measure up to the other ice giants?



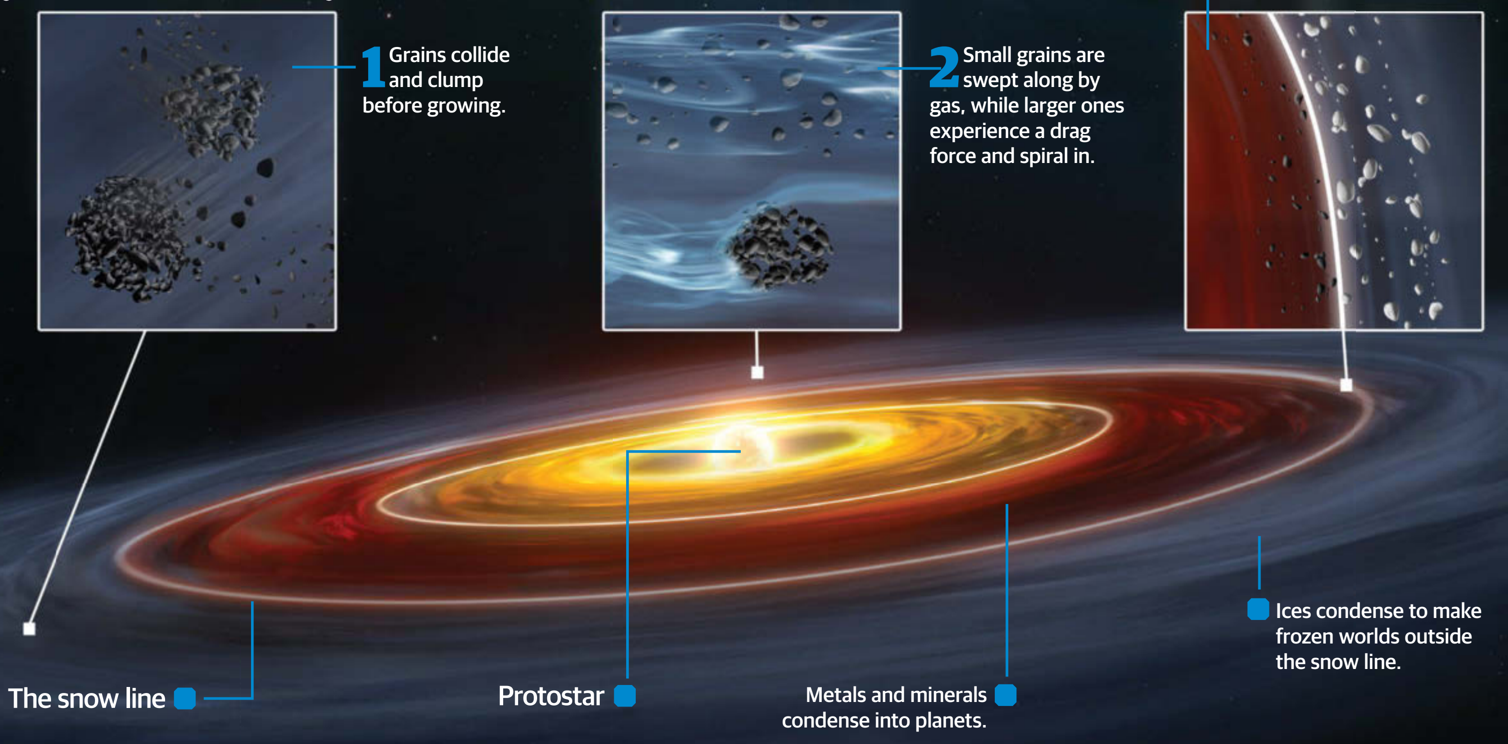
The fifth ice giant
Mass: Around 1.024 x 10^{26}kg
Radius: Roughly 25,000km (15,534mi)
Temperature: -183°C (-297°F)
Composition: Mostly rock and ice, with ten per cent atmosphere
Characteristics: Moons would have been removed during the ejection process
Colour: Similar to Neptune

Uranus
Mass: 8.68 x 10^{25}kg
Radius: 25,362km (15,759mi)
Temperature: -215°C (-355°F)
Composition: Hydrogen, helium, methane, water and ammonia ices with a rocky core
Characteristics: Planetary rings and 27 moons
Colour: Blue-green due to atmosphere

Neptune
Mass: 1.024 x 10^{26}kg
Radius: 24,622km (15,299mi)
Temperature: -226.55°C (-375.8°F)
Composition: Hydrogen, helium, water and methane, with a core of iron, nickel and silicates
Characteristics: Planetary rings and 14 moons
Colour: Blue tint due to cloud cover

How to make a frozen planet

Beyond the snow line, icy worlds form



he ended up with consisted of Jupiter and Saturn alongside three ice giants: the two that we know of – Uranus and Neptune – and the extra planet. It cemented the theory of a five-planet system, which was a striking claim and one that is still very much in the early days, with even Nesvorny keeping an open mind. But compelling evidence is building in support of this theory, leading to some tantalising clues as to what the planet would have been like – and how it would appear today.

For a start, it would certainly have had to be an ice giant. "Gas giants are much more massive than Uranus and Neptune and they would not work because they would cause wild instability," Nesvorny says. "It would also lead to an eccentric orbit for Jupiter that we don't have either." It also had to be of a mass roughly equal to Neptune. "If I added an Earth-sized planet or if I increased the mass to one-and-a-half times Neptune's mass or half of Neptune's mass, the simulation wouldn't work," he continues.

What's more, the fifth giant planet would also have been placed between Saturn and Uranus. "The best results came when I added the planet between those initial orbits, so somewhere between ten and 15 Astronomical Units [one AU is the distance from the Earth to the Sun]. This location wasn't clear at the beginning but it worked best there." As for the planet's colour, "it would most likely have the same colour and temperature as Neptune – it's the best guess judging by how the other planets formed."

The fifth planet, which some people have called Hades after the Greek god of the underworld, would certainly have formed in the same way as Neptune. "It is not a problem to imagine how this fifth planet formed because if you look at the theories of planet formation, they frequently give you more than two ice giants in the outer Solar System," says Nesvorny. "It's not a big deal having an extra ice giant and there is really nothing in the current understanding that says there were only two ice giants in the outer Solar System. It was formed by the same mechanisms as Uranus and Neptune – the favoured theory is of planetary accretion, where the planets started accreting boulders of roughly a metre in size."

Certainly, the simulations have supported the existence of an extra giant: with the fifth planet added to the simulations, today's Solar System is subsequently recreated more than half of the time. In each of those cases, it would ultimately lead to a Solar System consisting of four planets – Jupiter, Saturn, Uranus and Neptune – in the orbits they enjoy today. For Nesvorny, such findings cannot be overlooked and deserve greater study.

All of which leads to the inevitable question: how does adding a fifth giant planet lead to four giant planets in the Solar System? Where does that fifth body go? The answer is startling: by having Jupiter tussle with the other planets, the fifth giant planet – rather than Uranus or Neptune – is violently hurled into interstellar space. It effectively means Jupiter becomes the big bully and the additional planet assumes the role of the fall guy. "Without this fifth planet, Neptune and Uranus would have been ejected because at least one ice giant has to be thrown out of our Solar System," Nesvorny explains.

"Jupiter is a much bigger planet than Uranus and Neptune – it does not care too much," he laughs. "The typical outcome is that Jupiter, after several encounters, increases the semi-major axis of this additional ice giant and so it's always further and further away from the Sun. It gives the planet a greater increasing elliptic orbit, which continues until the speed exceeds the escape velocity from the Solar System. At that point, the ice giant gets ejected into interstellar space."

Interestingly, the speed at which this fifth giant planet is travelling is relatively slow. Nesvorny's simulations show it moving at just one kilometre (0.6 miles) per second. That may sound fast but compared to the 30 kilometres (18.6 miles) per second at which the Earth orbits the Sun, it is not a huge speed. "It is walking speed in astronomical terms," he says. "But this happened a long, long time ago, so when you

> "Without the fifth planet, Neptune and Uranus would have been ejected from our Solar System" **David Nesvorny, SwRI**

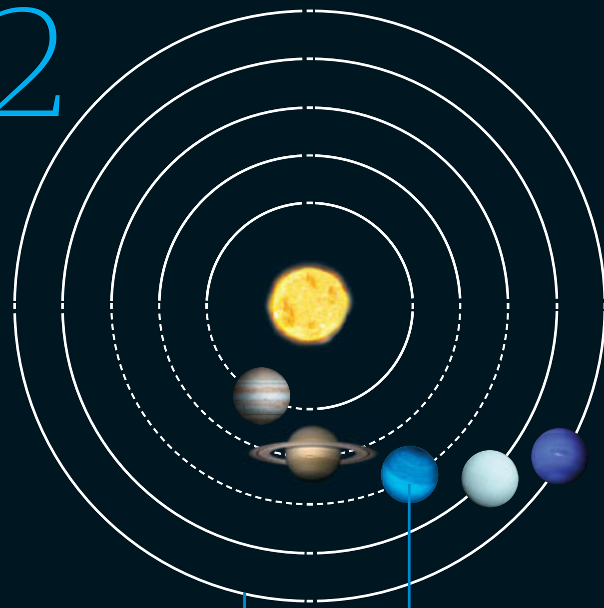
How the Solar System lost a planet

The lone wolf may well be out there somewhere, but how was it ejected?

1

The giant planets are created
Giant planets form in the protoplanetary gas disc and they begin to migrate due to a gravitational interaction with the disc.

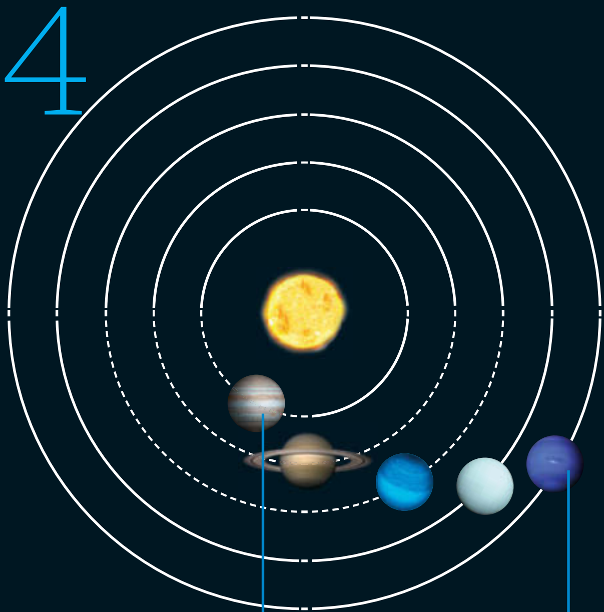
2



A short period of stability
When the gas disc dispersed, the planets found themselves in a compact and resonant configuration, with Neptune at around 20 AU from the Sun.

The ice world's location
The fifth planet was probably at around 10 AU, which would have placed it between the original orbits of Saturn and Uranus.

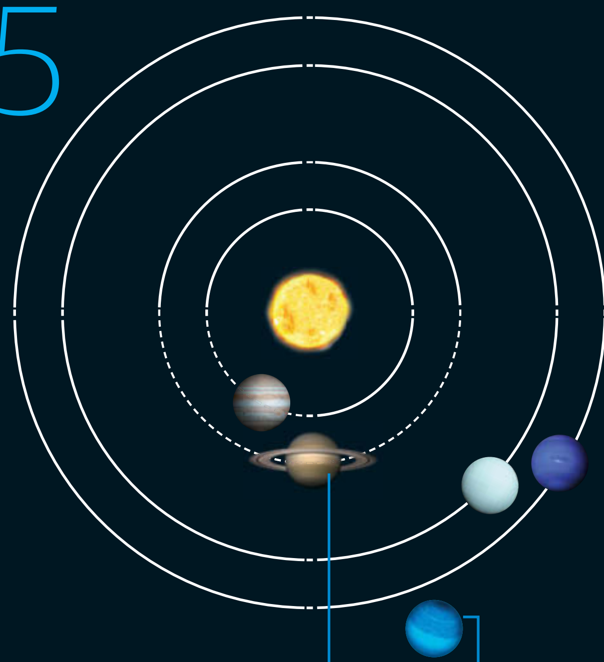
4



Jupiter gets involved
Jupiter's semi-major axis changes discontinuously during its own encounters. Jupiter Trojan asteroids are captured and Jupiter's orbital eccentricity is established at 0.05.

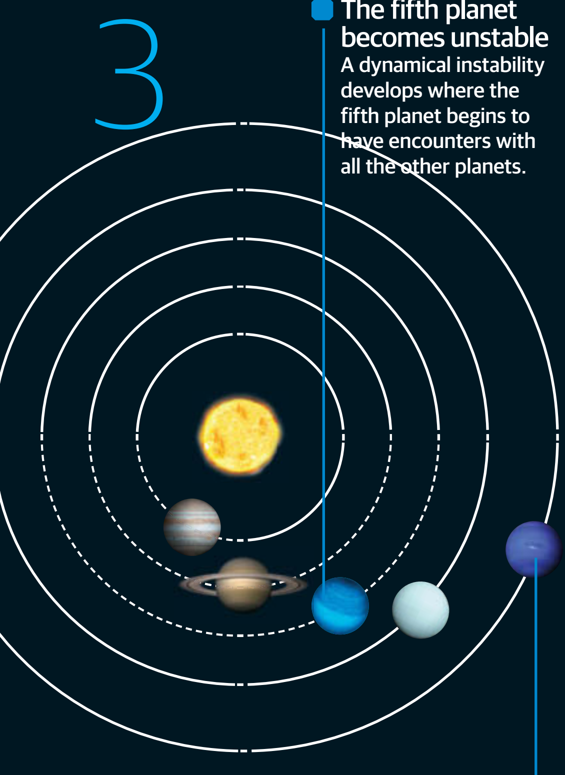
Neptune takes a giant leap forward
When the fifth planet encounters Neptune, it causes Neptune to jump and this potentially provides an explanation for the Kuiper belt kernel.

5



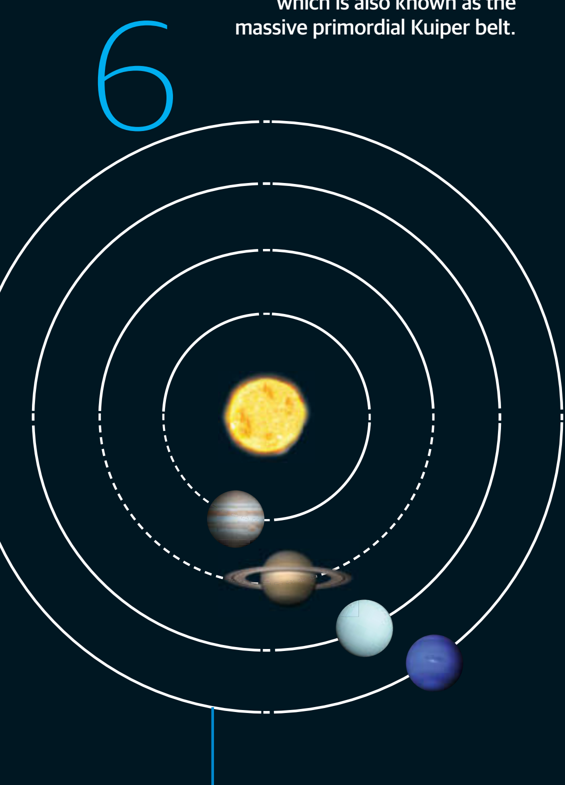
The other planets carry on moving
All of the remaining planets continue to migrate to their current locations. The outer cometary disc is dispersed and gradually eliminated.

The fifth planet is violently ejected
The fifth planet is ejected from the Solar System at a terminal speed of roughly 1km/s (0.6mi/s).



The fifth planet becomes unstable
A dynamical instability develops where the fifth planet begins to have encounters with all the other planets.

Neptune begins to migrate outward
Neptune migrates outward into outer planetesimal disc primordial, which is also known as the massive primordial Kuiper belt.



The four planets take their position
After the terrestrial planets are bombarded with debris, planetary migration slows down and practically stops, with the major four planets at 5, 10, 20 and 30 AU.

think of a body moving at one kilometre (0.6 miles) every second for billions of years, you realise that it has travelled a very large distance. The planet will be relatively far out in the galaxy at this point." Indeed, the suggestion is that the fifth giant planet was cast aside and forced on its lonely journey some four billion years ago.

The addition of the extra planet in the early years of the Solar System helps to explain how the four planets we know of ended up settling in their orbits. But it also goes some way to showing how the Earth's Moon gained most of its craters (the Earth also suffered heavy bombardment but since the Moon is geologically inactive, the craters are still visible). At the time when Jupiter was bulldozing its way through the universe and the other planets were seeking to find their final resting orbits, the Kuiper belt – a region of the Solar System beyond the orbit of Neptune which has many comets, asteroids and small ice bodies including the dwarf planet Pluto – would have been disturbed.

The Kuiper belt was still forming at this time in the universe's history and the result of the reshuffling would have knocked much of the debris towards the Sun. As these rocks travelled at high speed toward the inner Solar System some 4.1 to 3.8 billion years ago, it would have collided with the early terrestrial planets and the moons. This theory formed part of the Nice model but it fits perfectly with the five-planet hypothesis too. What's more, having five initial giant planets also helps to explain how a cluster of icy objects in the Kuiper belt was able to form.

"There is a strange concentration of icy objects within the Kuiper belt at 44 AU, which is called the kernel," says Nesvorny. "It has low inclination and low eccentricities and people initially thought this may be the result of a collision in the Kuiper belt, causing fragments to be ejected in order to form this concentration. But this is problematic as the typical ejection speeds are hundreds of metres, or foot, per second, which would cause the fragments to be dispersed over a very large orbital region. It certainly didn't account for something as concentrated as the kernel."

In 2015, he put forward the idea that the cluster was once within the gravitational pull of Neptune. But as the fifth giant planet had a gravitational encounter with Neptune while it was on its migration outwards in the Solar System, the cluster and Neptune were separated from each other. For this to happen, Neptune had to make a giant leap forward but it meant the cluster escaped Neptune's gravitational pull because it could not keep up, causing the objects to effectively became abandoned. The gravitational encounter forced the fifth planet further outward until its ejection was complete.

"I began to run simulations with the Kuiper belt included, factoring in a slow migration of Neptune," Nesvorny says. "I then introduced a jump which would have been caused when the fifth planet interacted with Neptune, which took it from 28 AU to 30 AU. After that had happened, Neptune slowly migrated again, but its orbit had shifted. The resulting mean motion was like being hit by a bulldozer but, more than that, the interaction of the fifth ice planet with Neptune could potentially explain this Kuiper belt kernel. It has been puzzling people for a decade or so, but it could be indirect evidence for Neptune having encounters with an ice giant."

And yet did this really have to happen? Could the fifth giant planet have not remained within the Solar System so that today it and the other four would all be orbiting around the Sun? "Yes, that could have happened," says Nesvorny. "It just depends on the initial state. If the outer cometary disc, which was driving planetary migration, had been missing or much lighter for some reason, the migration would not have happened and the planetary system would not have been de-stabilised.

"In that circumstance, we would have had five outer planets and it would not have been surprising for us. We would have had two Neptunes, one Uranus and a Jupiter and a Saturn, and today we would be trying to understand how that formation happened. But as it stands, the addition of a fifth giant planet is one of the ways to explain the reality of what we have in the Solar System right now. It's certainly an interesting concept." ●

Jumping Jupiters

How a giant leap could have had an effect on the fifth planet

Jupiter, unlike all other planets, migrated inward and not outward when interacting with the scattered objects from the outer cometary disc. Since it is also massive enough to be capable of ejecting bodies from the Solar System (again unlike other planets) it is said to have caused the bodies it encountered to be ejected outward. The Jumping Jupiter theory says Uranus and Neptune caused the gas giant to jump and allowed it to assume its current orbit. The problem is, under simulation, either Uranus or Neptune end up being ejected. With a fifth planet introduced, this does not happen. According to Dr David Nesvorny, the Jumping Jupiter theory is therefore a natural consequence of the five-planet system.

> "Having five initial giant planets might explain how a cluster of icy objects in the Kuiper belt formed"

Astronaut Timothy Peake

Due to launch to the International Space Station this month, the British astronaut tells **All About Space** about his exciting six-month mission

Interviewed by **Gemma Lavender**

You're the first Briton to be selected by the European Space Agency, what does that mean to you?
I'm really delighted. First, I'd like to pay tribute to Helen Sharman, who was the first British astronaut to fly to the Mir space station in 1991. I've met with her several times, she's a great lady and has given me lots of good advice about the upcoming mission. But what is different and important about this mission is it's the first time the UK government has actually subscribed and become involved in human spaceflight. That opens up human spaceflight to our science community, to the UK industry and also to children, in terms of outreach and education, which is going to be a really important part of my mission. So, I'm really delighted that the UK is now involved in human spaceflight.

You've completed quite a bit of extensive training in preparation for your mission. Could you tell me a bit more about what was involved and how challenging it was?
[Laughs] Yes, training for a six-month mission to space is very involved these days, namely because there are a lot of elements to it. We've got to get [into space] and we've got to be able to get back safely, so that means we [the crew] have to know everything about the spacecraft we are flying.

For us, that is the Russian Soyuz spacecraft. Training as a crew of three – with myself, Tim Kopra, my NASA crewmate, and Yuri Malenchenko, my Russian commander of the Soyuz – has taken a lot of time and commitment, but then we have also had to get to know everything about the Space Station where we will be living and that includes knowing about the various different modules – the Russian segment, the American laboratories, the European laboratories, the Japanese laboratories, and the various other modules that we will be using up there.

We also have to know how to maintain the Space Station and keep it running safely, and we need to be able to do certain tasks such as robotic operations, which involves using the Canadian robotic arm to grab visiting vehicles and dock them to the Space Station – that's how we keep the ISS supplied. That is a big task that astronauts have to be able to do, as well as the possibility of doing spacewalks in order to complete any maintenance outside of the ISS.

What different medical tests did you have to undergo, and do you have to be as fit as, let's say, an athlete, to be able to become an astronaut?
You don't have to be as fit as an athlete but it does help to be in good shape because the better the shape you're in, the easier life will be for you in space. Your body is going to undergo a dramatic change in weightlessness and it's probably going to take a

Intensive astronaut training has taught Peake everything he needs to know for his mission to the ISS

INTERVIEW BIO

Major Tim Peake

Tim Peake is the first British citizen to be selected as an astronaut by the European Space Agency. He began his intensive astronaut training course in September 2009 before graduating in November 2010. A former British Army Air Corps officer, Peake holds a degree in flight dynamics and evaluation. He is scheduled to launch for the International Space Station for six months this December for Expeditions 46 and 47, flying under the mission name of Principia.

Astronauts need to know everything about the Space Station in order to maintain it and keep it running safely

good three to four weeks to go through that process. Various things happen – all of the fluid that normally pulls in your legs here in Earth's gravity is shifted upwards in [microgravity], so you actually get puffy-faced and get higher intracranial pressure as your brain is trying to get rid of all of that excess fluid (or at least, it thinks it's excess fluid). As your body starts to get rid of that fluid you will begin to lose calcium and lose muscle mass because your body is not getting the stimulus that it does here in gravity – it doesn't need those muscles or that bone density, so it loses them.

In fact, the body is such a brilliant machine that it adapts too well to its new environment, which would be great if all we were going to do was fly into space but – of course – we need to come back to Earth and be healthy for our return. If we did not do all of the exercise that we do in space, then we would be in very poor shape when we came back to Earth, so that's really why we stay fit and healthy, so that we're in a good shape for when we return. Also, in terms of medical history, ESA needs to pick astronauts who are at a low risk of having any medical problems when they are on board the ISS, so that's really what the [European Space Agency] looks for in an astronaut – a person with a low-risk medical history.

You've had a fairly long career in the army, at what point did you decide that you wanted to become an astronaut?

It was fairly late on actually, and only when I saw the advertisement in 2008 from the European Space Agency, which said: 'New call of astronauts wanted, apply here'. I was a test pilot at the time. I saw it and I was just in the process of leaving the British army after many years of a great and fun career with them.

It was just about timing really – I was at the right time and the right place and had the right qualifications, so I decided to apply. It was really a no-brainer from my point of view. The opportunity

"There are 263 experiments taking place across the entire mission, from human physiology to engine design"

Peake (left) with crewmates Yuri Malenchenko (centre) and Tim Kopra (right) to go from being a test pilot to an astronaut is something that most test pilots would jump at - and I certainly did!

What other training tests did you have to complete in the final months before the big day?
Two big tests [which we did were] on the Russian segment, just to make sure that we are competent to work and operate on board the Space Station. But really the main one was an eight-hour simulation in the Soyuz spacecraft. This [happened] just before we went to Baikonur [Kazakhstan] for quarantine, and that was our final big test to make sure that we know what we're doing in the Soyuz, and to ensure that we can handle all of the emergency situations that might arise during our time in space.

When you reach the International Space Station, what sort of experiments will you be doing?
There's a whole platter of experiments that are planned over the entire mission. There are about 25 experiments that are going to be conducted on myself - I signed up for them - which are human physiology experiments. In fact a lot of my time [during one week of training] was spent gathering all of the baseline data for those medical experiments.

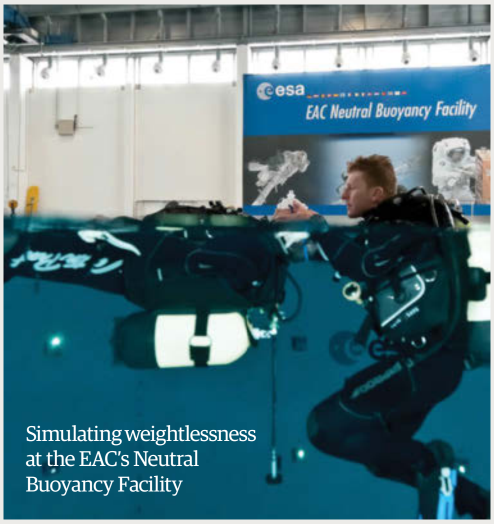
So, for example, I've had muscle biopsies, a number of different MRI scans and X-rays on various parts of the body, and I have also had daily blood tests and urine samples. I will also have my immune system and my vision studied before launch, and I will get an ultrasound of my eyes, heart, arteries and my cardiovascular fitness. So, just the human physiology experiments alone are very wide reaching. Since the body changes so much in microgravity, there's an awful lot that we can learn about the human body by monitoring those changes and that really has knock-on effects for people on Earth - especially when you have things like the immune system, osteoporosis and muscle mass.

Microgravity is a good environment for studying things in general, such as material science, and we have a number of great experiments going on where we're studying metal alloys - we're actually designing and making new materials with some great properties that we couldn't possibly make on Earth, and ultimately this is to try and improve our efficiency in things like engines - aeroplane engines, car engines and that kind of thing. We're looking at flame combustion, but we're also looking at growing proteins for medical research so that we can improve the drugs and vaccinations back here on Earth. There are about 263 experiments that will take place across the entire mission, so there will be a lot going on!

What are you most looking forward to during your time in space?
I'm most looking forward to the view [of Earth] without a doubt and the mission itself, just living in microgravity and getting used to that whole new environment. Eating, sleeping and working in weightlessness is just going to be brilliant. I want to take as many photos as I can and call friends and family from the Space Station. I'm also looking forward to the educational outreach programs that I've got planned - so lots of competitions with kids - and I hope to share the mission as much as possible.

What's your biggest piece of advice for someone who wants to become an astronaut?
My biggest piece of advice is to definitely work out what you want to do and what you enjoy. If you want to become an astronaut, you can become an astronaut by being an engineer, a doctor, a scientist, a school teacher or an army pilot like myself. Don't focus on the astronaut bit just yet, focus on what you are good at and what you enjoy. By tying those things together you will find your path. ■


Helen Sharman was the first British astronaut to go to space in 1991



Simulating weightlessness at the EAC's Neutral Buoyancy Facility


Peake during a water survival training session near Star City, Russia, during 2014

SUBSCRIBE TO ANY MAGAZINE FOR JUST £29.99

- Exclusive **Christmas offer**
- Save **up to 50%** on the shop price*
- Never miss an issue of your **favourite magazine**
- **Free delivery**, direct to your door
- **Ideal Christmas gift** - that lasts all year!
- **Free e-card** to send when you buy as a gift

BUY AS A GIFT OR TREAT YOURSELF!

Use code **XMAS151** for this extra-special price.

Order by 2nd December to start your subscription the first issue after Christmas.

** Calls will cost 7p per minute plus your telephone company's access charge.

BY POST

Send your completed form to:
Imagine Subscriptions, 800 Guillat Avenue, Kent Science Park, Sittingbourne, Kent ME9 8GU

YOUR DETAILS

Title________ First name________

Surname________

Address________

Postcode________ Country________

Telephone number________

Mobile number________

Email address________

This subscription is ☐ for me ☐ a gift

DELIVERY DETAILS (IF DIFFERENT FROM ABOVE)

Title________ First name________

Surname________

Address________

Postcode________ Country________

Telephone number________

PAYMENT DETAILS

UK £29.99 Magazine name________

FOR MULTIPLE ORDERS PLEASE CALL THE ORDER HOTLINE **0844 856 0644****

CHEQUE

☐ I enclose a cheque for £________

(made payable to Imagine Publishing Ltd)

CREDIT/DEBIT CARD

☐ Visa ☐ Mastercard ☐ Amex ☐ Maestro

Card number ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐ ☐☐

Expiry date ☐☐ ☐☐

Issue number (Maestro) ☐☐

Signed ________

Date ________

All subscribers receive a monthly e-newsletter of news and offers.

Please tick if you would prefer not to receive any promotional material from Imagine Publishing:

by post ☐ by telephone ☐ by email ☐

Please tick if you would prefer not to receive any promotional material from other companies

by post ☐ by telephone ☐ by email ☐

Please tick if you DO wish to receive such information by email ☐

TERMS & CONDITIONS

* Titles are priced at £29.99 saving up to 50% on the shop price. For the full list of titles and issue details please visit **www.imaginesubs.co.uk/XMAS151.** This is a UK-only offer, for overseas offers please visit **www.imaginesubs.co.uk/XMAS151** or call **+44 (0)1795 592 869.** Gift subscriptions ordered by 2nd December will begin with the first issue on sale January 2015 – orders after this date will start with the following issue. You have the option of sending a digital gift card so please include your email address in the form above. Non-gift subscriptions will start with the next available issue.
Offer ends 31st December 2015. Promo code XMAS151

MISSION PROFILE

Solar and Heliospheric Observatory (SOHO)

This Sun-watching spacecraft has been unlocking secrets at the heart of our star for over 20 years

Mission type:
Space observatory

Operator:
ESA/NASA

Launch date:
2 December 1995

Target:
Earth-Sun L1 point

Arrival in orbit:
February 1996

Primary objective:
To study the Sun's composition and behaviour

Status:
Operational

INTERVIEW BIO

Dr Joseph B Gurman
NASA project scientist for the SOHO observatory
After graduating from Harvard College, Dr Joe Gurnam recieved his PhD from the University of Colorado in 1979. His career began as a research associate at the Applied Research Corporation at NASA Goddard before becoming an astrophysicist, working on some of NASA's most prolific missions since the 1980s.

After over 20 years in operation, the Solar and Heliospheric Observatory (SOHO) remains one of NASA's most influential spacecraft. While other missions set their sights on the deeper reaches of our Solar System, the SOHO had a very different destination: the Sun. The data it has gathered has radically changed our understanding of our star's composition and how its solar flares and winds interact with the Earth.

From the late 1970s through to the early 1980s, Europe placed its focus on GRIST (Grazing Incidence Solar Telescope) and DISCO (Dual Spectral Irradiance and Solar Constant Orbiter) proposals, while NASA intended to contribute a solar probe to the International Solar Probe Mission (ISPM). Sadly, all of these projects were scrapped, but they brought all the right people together. In November 1982 a group of ESA scientists proposed the idea of a cost-effective observatory that would operate from Lagrange point, L1 – a region in space between Earth and the Sun where gravitational forces are balanced. The following year a deal was struck, with the European Space Agency (ESA) agreeing to fund and organise the craft's development and construction, while NASA would control its launch and future operation. It took another 12 years for SOHO to finally launch from Cape Canaveral in December 1995, but as it took off, we were one step closer to unlocking the Sun's secrets.

"When the spacecraft was launched, the primary scientific goals centred on three long-standing puzzles, each going back decades," says SOHO project scientist Dr Joseph Gurman. "We wanted to find out what goes on deep in the interior of the Sun and near the surface, where the magnetic fields that drive solar activity are generated.

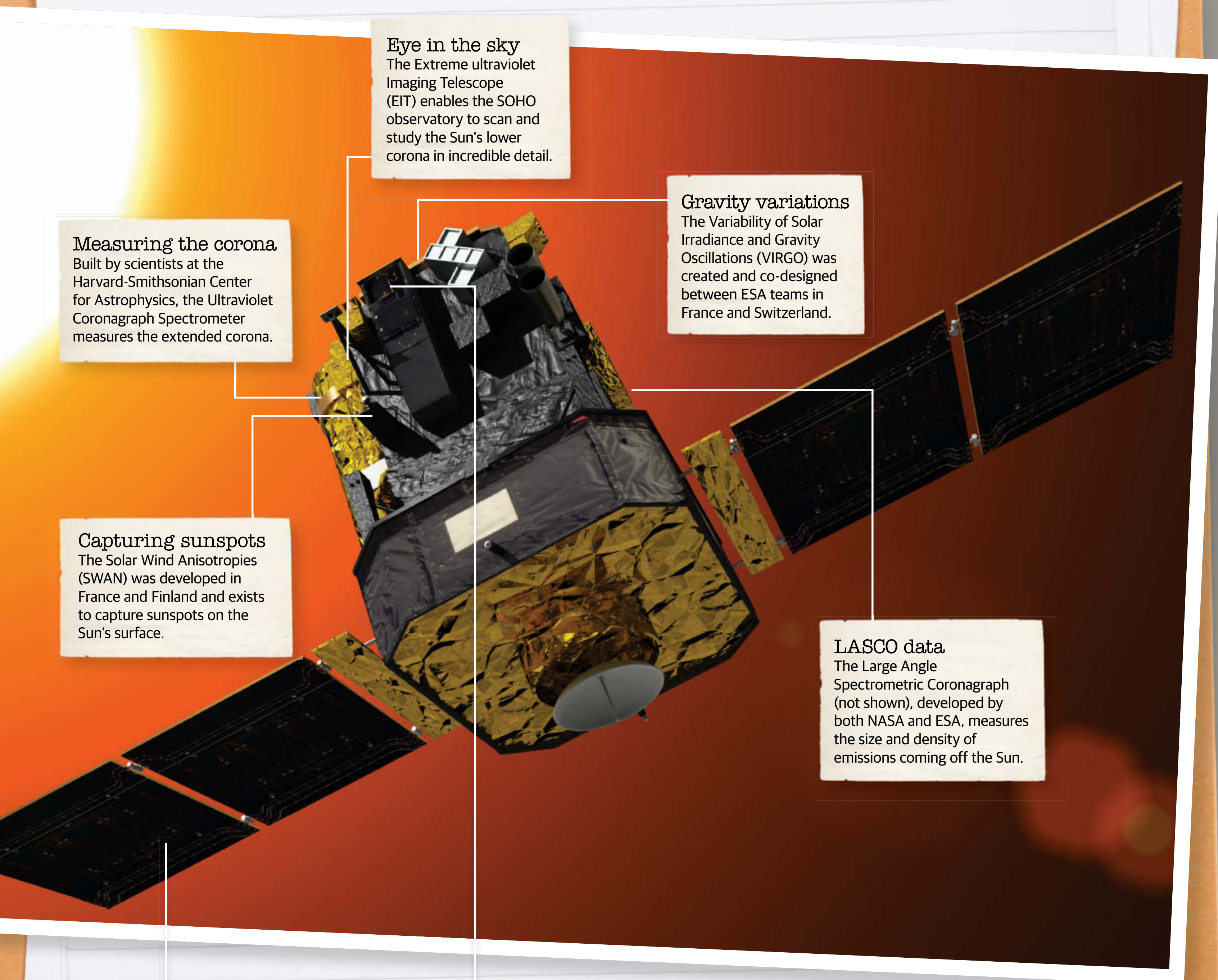
"We also wanted to understand how the corona, the tenuous, outermost part of the Sun's atmosphere, could be heated to temperatures of about 2 million degrees Celsius (3.6 million degrees Fahrenheit), when the visible surface of the Sun is only about 6 million degrees Celsius (10.8 million degrees Fahrenheit). If magnetic fields are key, how do they organise themselves into the conditions necessary for solar activity? We also wanted to learn how solar winds, the outflow of ionized gas from the Sun, were driven. What physical mechanism(s) were responsible, and why the wind from coronal 'holes' is faster than that from the 'quiet' and 'active' parts of the solar surface?"

Since its arrival at the L1 point in 1996, the SOHO observatory has uncovered some intriguing new data. SOHO revealed the first ever images of the Sun's convection zone (the name of its turbulent outer shell), as well as the structure and composition of the sunspots beneath the surface. It's also provided invaluable information on the precise measurements of its temperature structure, its interior rotation and the flow of gas within said interior. "We were also able to demonstrate that the small-scale, ubiquitous magnetic field at the visible solar surface was replaced in one to two days," adds Gurman. "Confirming what had been conjecture up until that point: that there was more than enough energy (in fact, a thousand times more than enough energy) in that magnetic field to heat the corona – though we're still trying to determine exactly how the energy is transferred."

> "SOHO revealed the first images of the Sun's convection zone and the composition of its sunspots"

SOHO has also, rather serendipitously, provided the opportunity to study thousands of comets in greater detail, due to the sheer number that have passed it. "Based on coronagraphs in the 1970s and 80s (on the P78-1 and Solar Maximum Mission spacecraft), we thought we'd see a dozen or so sungrazing comets over SOHO's maximum expected lifetime of five years," comments Gurman. "Instead, we've been able to detect thousands, simply because we had a coronagraph with superb stray light properties and a detector with much greater dynamic range than previous instruments. The result was startling."

SOHO AT WORK



Eye in the sky
The Extreme ultraviolet Imaging Telescope (EIT) enables the SOHO observatory to scan and study the Sun's lower corona in incredible detail.

Gravity variations
The Variability of Solar Irradiance and Gravity Oscillations (VIRGO) was created and co-designed between ESA teams in France and Switzerland.

Measuring the corona
Built by scientists at the Harvard-Smithsonian Center for Astrophysics, the Ultraviolet Coronagraph Spectrometer measures the extended corona.

Capturing sunspots
The Solar Wind Anisotropies (SWAN) was developed in France and Finland and exists to capture sunspots on the Sun's surface.

LASCO data
The Large Angle Spectrometric Coronagraph (not shown), developed by both NASA and ESA, measures the size and density of emissions coming off the Sun.

Solar operation
These two solar panels, which reach 9.5m (31ft) when fully extended, provide SOHO with all the energy it needs to operate.

Detecting radiation
The Coronal Diagnostic Spectrometer has been designed to detect solar extreme ultraviolet radiation in and around the Sun.

> "The mission provided precise measurements and details of the Sun's temperature structure, which are invaluable"

Progress report

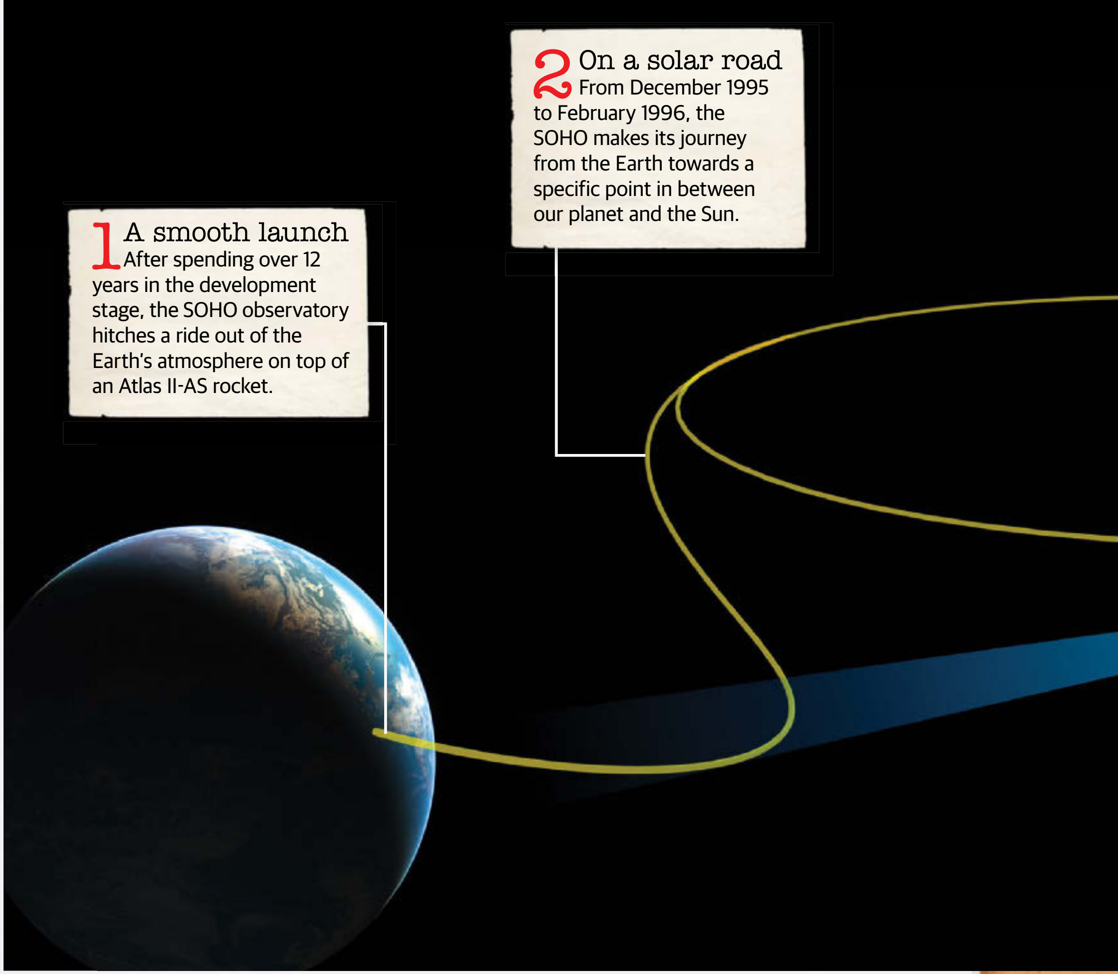
Despite its many years of service, the SOHO observatory is still going strong. "The spacecraft is in great shape, with decades of hydrazine propellant still on board," reveals Gurman. However, the NASA team know that every craft has a shelf life and SOHO will eventually be retired and directed into the Sun. "Thanks to SEPs (solar energetic particles) and EUV (extreme ultraviolet) radiation, the solar panels are ageing," he says. "And at some point in the next decade, but hopefully not any time soon, we expect to see a charge-voltage relationship change in a matter of weeks that will result in loss of power."

It's also easy to forget that after almost two decades of operation, some of the instruments and procedures used on SOHO are now out of date or simply worn out. For instance, the Solar Dynamics Observatory (SDO), launched by NASA in 2010, has instrumentation that performs to a much higher standard and efficiency than SOHO's MDI and EIT devices.

So what does the future hold for SOHO? The project has been scheduled to run until 2018 with a preliminary review pencilled in for December 2016, so it's safe to say the elderly craft is far from done. "We continue to operate in order to provide space weather information, specifically on coronal mass ejections," Gurman adds. "The President's budget request for NASA for the last two years has cited SOHO's LASCO coronagraphs as 'a unique instrument resource on the Sun-Earth line that's critically important to the nation's space weather architecture.'"

Gurman reveals that a number of SOHO's on board tools are still operational, but the craft itself is no longer the subject of major operations. "We no longer fund scientific research through SOHO but our data supports other NASA research programs. And five European instruments continue to give us valuable information on the solar interior, solar radiative output, solar energetic particles, and the interstellar wind." ●

> "The SOHO spacecraft is still in great shape, with decades of hydrazine propellant still on board"



SOHO'S JOURNEY FROM EARTH TO SPACE

December 1982

Operation first proposed

The concept for a craft that would study the Sun in minute detail was first presented by six scientists in 1982, following the ESA's Call for Mission Proposals initiative.

Summer 1983

Working together

With a similar project canned by NASA a few years earlier, the two space agencies eventually agreed to co-fund, co-design and co-operate the spacecraft.

May 1984

Becoming a Cornerstone

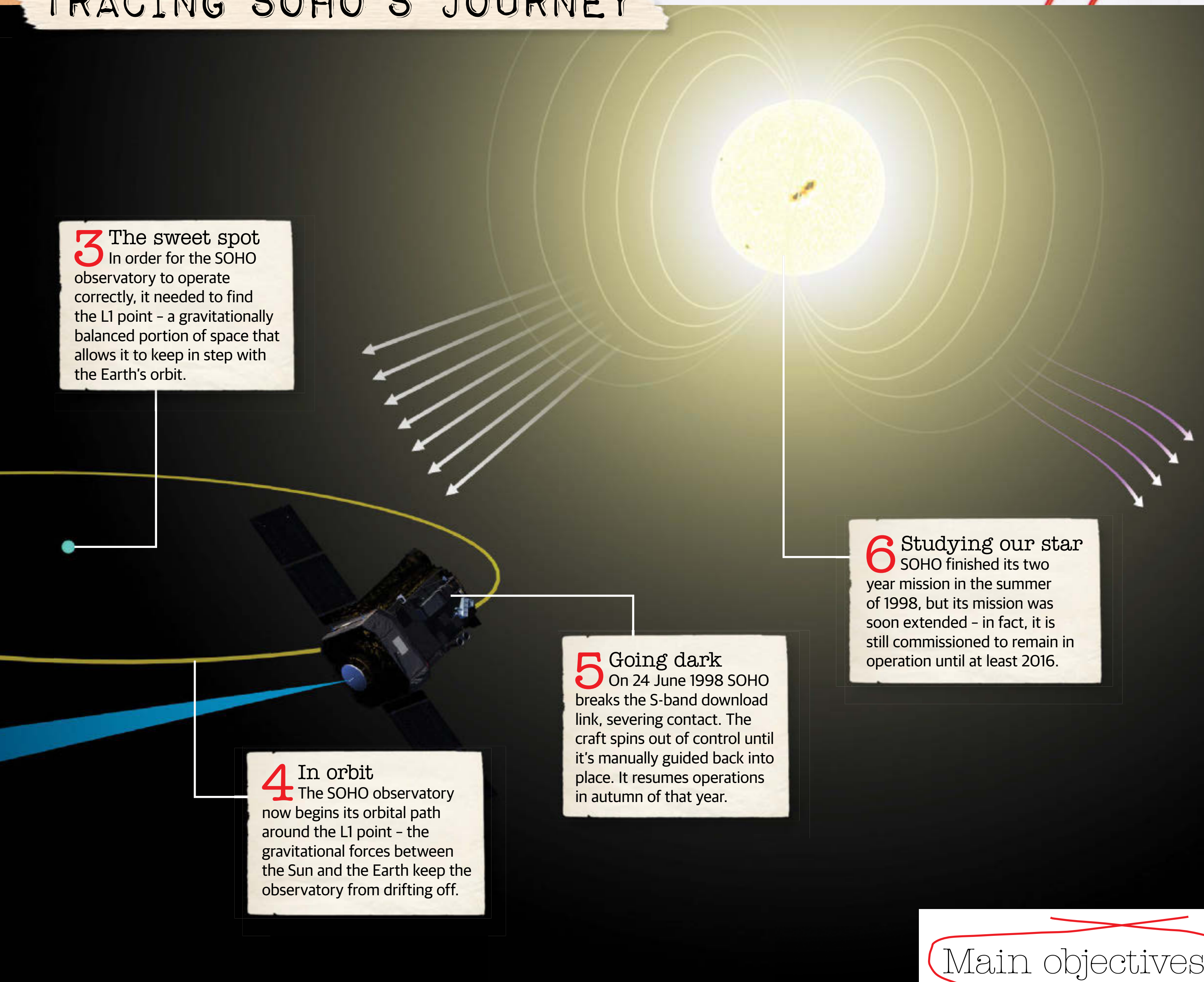
Just two years after its initial proposal, the plan for what would become SOHO was incorporated into the ESA's Horizon 2000 Cornerstone program.

November 1995

Delayed launch

SOHO was originally intended to launch in November 1995, but it was delayed due to an issue with the precision regulator, which is linked to the Atlas' rocket boosters.

TRACING SOHO'S JOURNEY



3 The sweet spot
In order for the SOHO observatory to operate correctly, it needed to find the L1 point – a gravitationally balanced portion of space that allows it to keep in step with the Earth's orbit.

4 In orbit
The SOHO observatory now begins its orbital path around the L1 point – the gravitational forces between the Sun and the Earth keep the observatory from drifting off.

5 Going dark
On 24 June 1998 SOHO breaks the S-band download link, severing contact. The craft spins out of control until it's manually guided back into place. It resumes operations in autumn of that year.

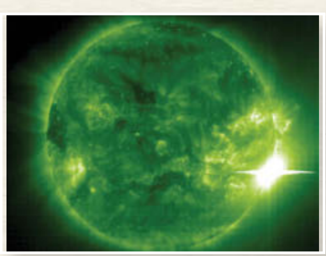
6 Studying our star
SOHO finished its two year mission in the summer of 1998, but its mission was soon extended – in fact, it is still commissioned to remain in operation until at least 2016.

December 1995

Taking off
The SOHO observatory takes off from Cape Canaveral in Florida on board a Lockheed Martin Atlas II-AS rocket. The rocket and payload launch without incident.

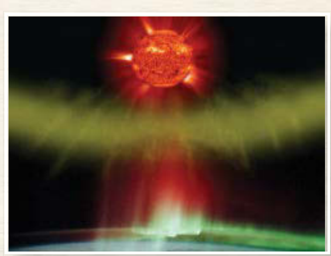
Early 1996

The team grows
With SOHO on its way, more and more scientists prepare for its imminent arrival at the L1 point – by this stage around 1,500 individuals from 20 countries are involved.



February 1996

The mission begins
After several weeks of transit from Earth, the SOHO observatory finally arrives at its destination – the L1 point. This point in space orbits the Sun every 12 months.



Main objectives

Study the Sun's composition
The main crux of SOHO's mission is to study the internal structure of the Sun, including the depth of its corona and the level of radiation it emits.

Shed more light on solar winds
Broadly referred to as 'space weather', SOHO also focuses its attention on understanding the gravitational relationship between the Sun and the Earth, and how solar winds are swept between the two.

Further studies of comets
Its positioning at the L1 point – whose orbit enables SOHO to keep in step with the Earth's own path – provides the opportunity to study the many comets that pass through our Solar System.

5 AMAZING FACTS ABOUT

The Milky Way

Our galaxy s a barred spiral and is about 100,000 light years across. It's thought to contain over 200 billion stars

Unusual baby stars are at its centre

Up until October this year, it was thought that the bulge at the centre of the Milky Way only contained old stars. But scientists have also discovered a new disc of 35 younger stars less than 100 million years old. By comparison, our Sun is 4.5 billion years old.

It's very dusty

The space between the stars - the interstellar medium (ISM) - is comprised of gas and dust. Despite making up just a tiny percentage of the ISM, these cosmic dust grains are what planets are made of. These miniscule particles of solid material can be a nuisance to astronomers, as they obstruct our view of the universe.

It's bigger than we think

The galaxy is more than 100,000 light years across and there are around 200 billion stars within it. Yet when astronomers at Ruhr-Universität Bochum in Germany spent over five years creating a 46 billion pixel image of the Milky Way, they interestingly also uncovered 50,000 new stars and other variable objects.

It's home to a monstrous black hole

A supermassive black hole is located at the centre of the Milky Way within a site called Sagittarius A. It emitted bright X-ray flares in August 2014 and NASA's Swift satellite monitors it daily. There are about 100 million black holes in our galaxy.

It has more star-forming material than we thought

Dr Peter Barnes of the University of Florida says stars could be formed for another six billion years rather than just two billion years as had previously been assumed. There may be three times as much star-forming material than we imagined.

All About Space presents some of the most exciting launches and missions scheduled for the New Year

Journey to an Asteroid

+10 other upcoming space missions

Written by Laura Mears

This year has been prolific for space exploration. The Hubble Space Telescope celebrated its 25th birthday, the International Space Station commemorated 15 years in orbit, NASA's New Horizons captured breathtaking images of Pluto, and scientists published evidence that liquid water flows on Mars. But the best is yet to come.

Next year, we will see space exploration entering an exciting new phase, and several missions will seek to answer questions about the origins of Earth and the universe - Juno will arrive at Jupiter to find out how the planet formed, InSight will set off to examine the internal structure of Mars, and NASA's ambitious OSIRIS-REx will start its mission to retrieve a sample of an asteroid that could be carrying the building blocks of life.

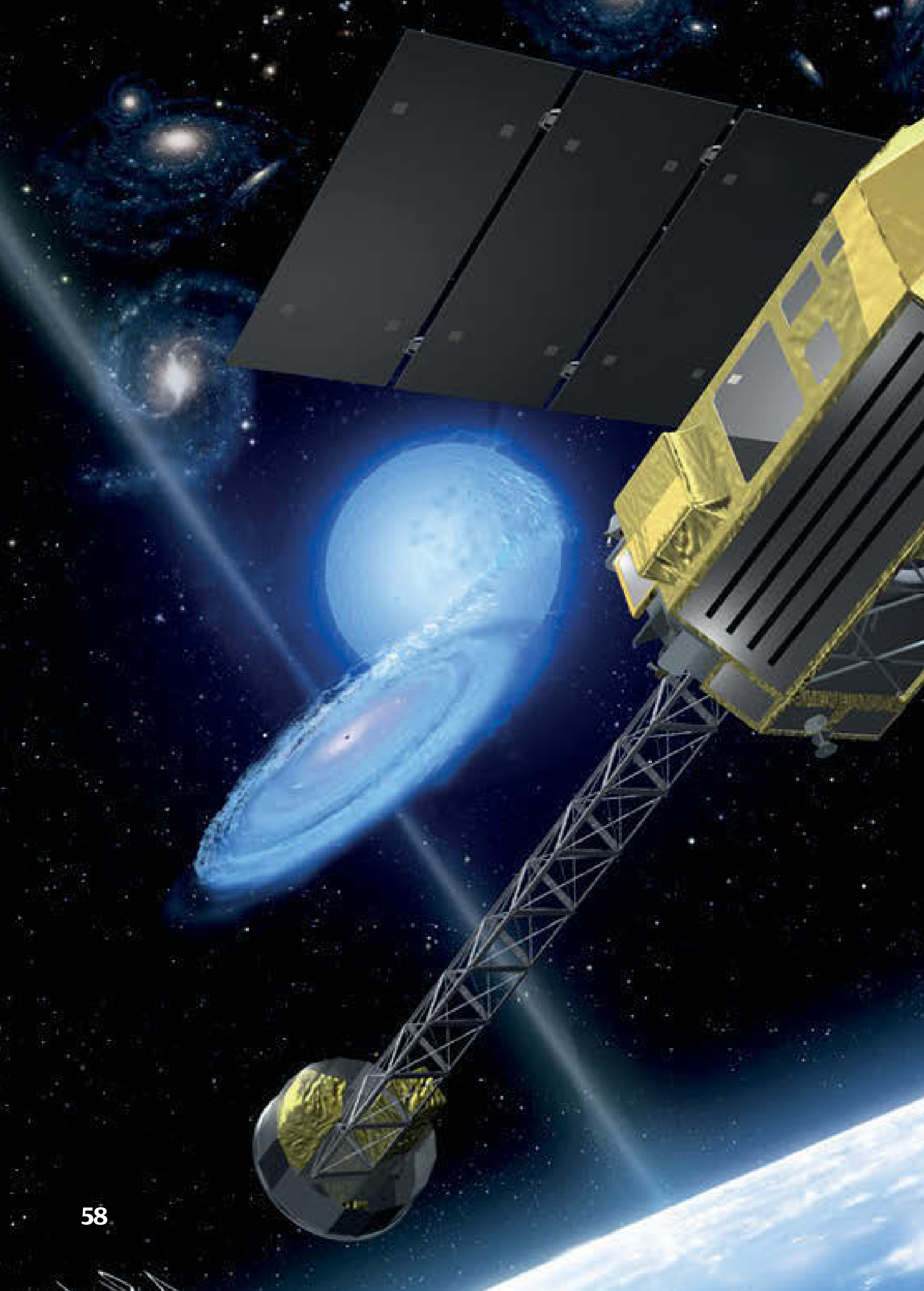
Meanwhile, the European Space Agency (ESA)'s ExoMars mission will begin to search for signs of life on Mars, a deep-space observatory will begin unravelling the history of the universe, and a precision atomic clock will be tested for use in future exploration missions. **All About Space** takes a look at the missions that will define the next year of space exploration.

1 Searching for giant black holes

The Japan Aerospace Exploration Agency (JAXA) is preparing to launch a new orbiting observatory that will investigate some of the highest energy objects in the universe.

The Astro-H observatory was developed as part of an international collaboration involving more than 160 scientists from Japan, the USA, Canada and Europe. It is equipped with four X-ray telescopes, each with different detectors, and will examine some of the most extreme phenomena in the universe.

Astro-H will watch matter as it drops into black holes and probe the chemical contents of supernova remnants, helping to answer questions about the origins of different elements. It will also use its sensitive equipment to explore clusters of galaxies, examining shock waves, investigating jets and collecting information about the evolution of the universe. Its instruments have been significantly upgraded in comparison with its predecessor, Suzaku (Astro-EII), allowing the observatory to see more than ever before. The ESA claims the sensitivity of the hard X-ray imaging will be 100-times higher, enabling it to search for supermassive black holes currently hidden in the background noise of the energetic universe.



Astro-H

DATE OF LAUNCH:
Early 2016

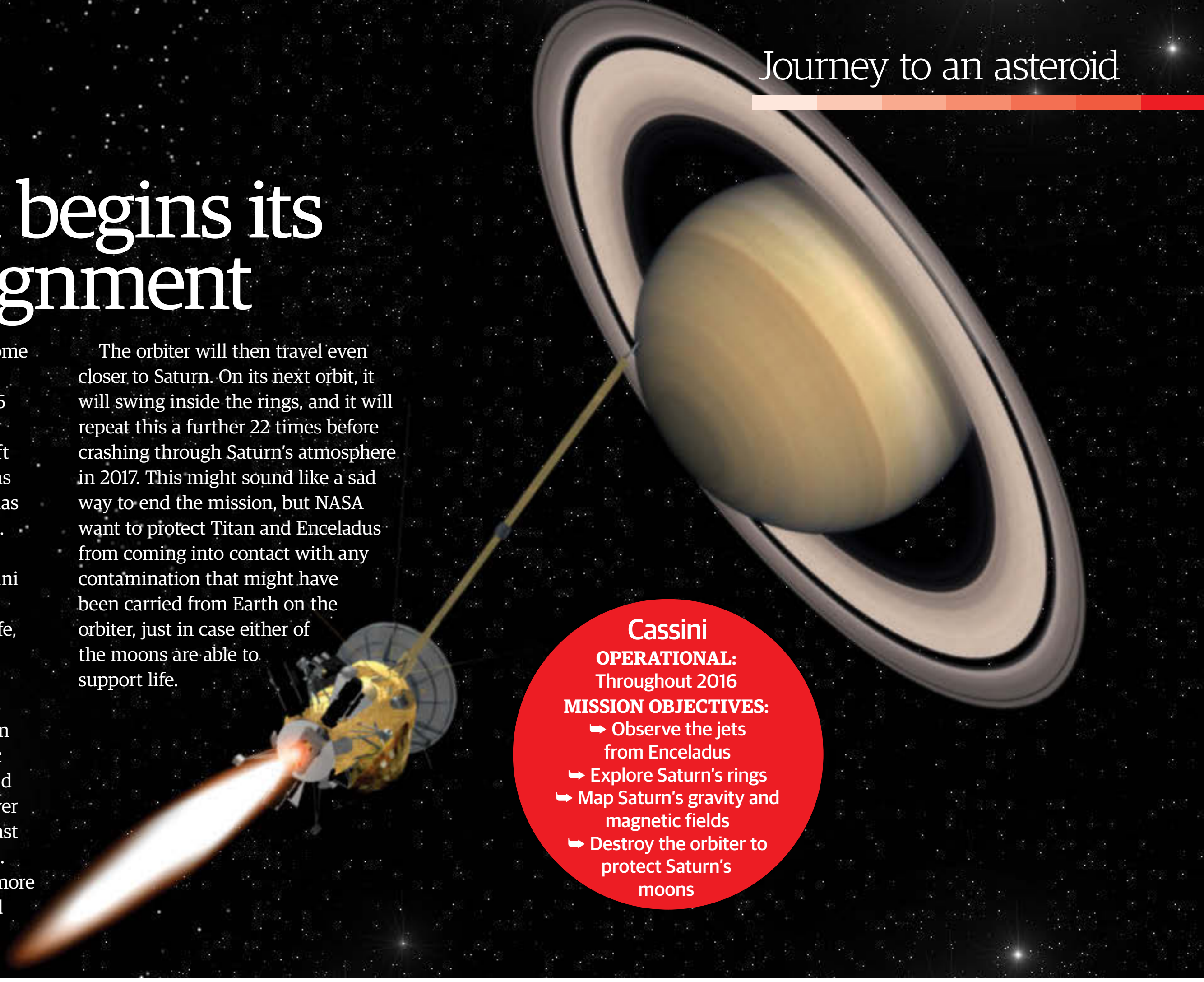
MISSION OBJECTIVES:
- Start to explore the structure of the universe
- Investigate how matter behaves in extreme gravity
- Determine the spin of black holes
- Investigate jets in various galaxies

2 Cassini begins its final assignment

NASA's Cassini orbiter captured some stunning images of Titan, Dione and Enceladus in 2015, but in 2016 its mission will take a much more dramatic turn, when the spacecraft will make many more observations of the Saturnian system. Cassini has been exploring Saturn since 2004. It completed its main mission in 2008, finished the extended Cassini Equinox mission in 2010, and it is currently in the last phase of its life, the Cassini Solstice Mission.

Towards the end of the year, Cassini will begin to undertake its "final assignment", which has been named the Grand Finale by public vote. The orbiter will sweep around Saturn in orbits that circle high over the north pole, before whizzing past the edge of the bright outer F-ring. From here, it will be able to look more closely at the jets of water emitted from Saturn's moon, Enceladus.

The orbiter will then travel even closer to Saturn. On its next orbit, it will swing inside the rings, and it will repeat this a further 22 times before crashing through Saturn's atmosphere in 2017. This might sound like a sad way to end the mission, but NASA want to protect Titan and Enceladus from coming into contact with any contamination that might have been carried from Earth on the orbiter, just in case either of the moons are able to support life.



Cassini
OPERATIONAL: Throughout 2016
MISSION OBJECTIVES:
- Observe the jets from Enceladus
- Explore Saturn's rings
- Map Saturn's gravity and magnetic fields
- Destroy the orbiter to protect Saturn's moons

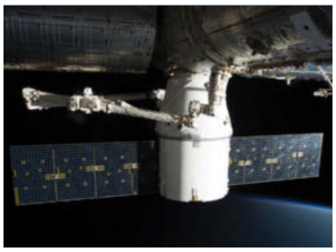
InSight
DATE OF LAUNCH: March 2016
MISSION OBJECTIVES:
- Understand the evolution of rocky planets
- Investigate Mars' interior
- Monitor tectonics and asteroids

3 Peering into the Red Planet's core

2016 will see NASA return to Mars, this time with a probe capable of drilling deep into the planet. InSight, (Interior Exploration using Seismic Investigations, Geodesy and Heat Transport) is a lander that will look below the surface of the Red Planet for information about how it and other rocky planets were formed. The interior of the Earth is stirred by convection and plate tectonics disrupt the geological record, but Mars' interior is still, giving a clearer view of the past.

The lander is based on the same design as NASA's Phoenix, which was used to probe the ice at Mars' north pole, but the equipment on board will be different. InSight will measure the temperature inside the Red Planet, its seismic activity, and how it responds to changes in gravity as it orbits the Sun, and as it is orbited by its moons. NASA describes this as a "check-up" for Mars, testing its temperature, pulse, and reflexes. They will look at the structure of each of the layers of the planet and investigate how rapidly it loses heat in order to unlock the secrets of Mars.

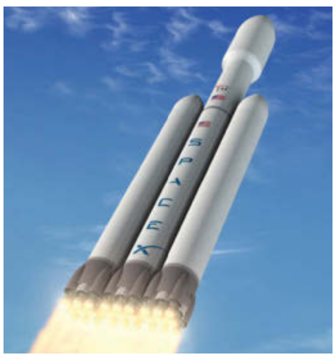
4 Rocket launches



SpaceX CRS8

DATE OF LAUNCH:
January 2016

The three-times delayed Dragon spacecraft carrying supplies to the International Space Station is due to launch in January 2016 using a SpaceX Falcon 9 rocket.



SpaceX Falcon Heavy Demo

DATE OF LAUNCH:
April-May 2016

SpaceX are testing their new heavy rocket, which they say is capable of lifting the equivalent weight of a fully loaded and fuelled Boeing 737 into space.

GOES-R weather satellite

DATE OF LAUNCH:
October 2016

An Atlas 5 rocket will be used to launch a 'next generation' geostationary weather satellite into orbit that will be used by NASA and NOAA to monitor weather across the United States.

ExoMars

DATE OF LAUNCH:
March 2016

MISSION OBJECTIVES:

- Test technologies for landing on and exploring Mars
- Access samples from beneath the ground
- Examine the Martian atmosphere
- Search for signs of life

5 Hunt for life on Mars

After the NASA announcement that there is liquid water still on Mars, the ESA's ExoMars mission is set to be exciting. In collaboration with the Russian space agency, Roscosmos, the ESA are sending a Trace Gas Orbiter to the Red Planet in early 2016, along with a lander called Schiaparelli. They will travel together until they reach Mars in October 2016, at which point Schiaparelli will be ejected, allowing the orbiter to get into position.

As its name might suggest, the Trace Gas Orbiter will be scouring the Martian atmosphere for traces of gas that could be a sign of life. Scientists are particularly interested in methane, which is produced by living organisms (among other things) and has been detected on Mars before. This is an exciting mission in itself, but the orbiter also has another role. The lander, Schiaparelli, will test the ESA's descent technologies in preparation for landing a rover on Mars in 2018, at which point the Trace Gas Orbiter will become a relay station back to Earth.

Schiaparelli will run on batteries alone, and won't have long on the surface before its power fails, but it will carry with it a selection of scientific instruments, including a number of different atmospheric sensors which will feed information back to Earth about humidity, pressure and, for the first time, electrical fields.

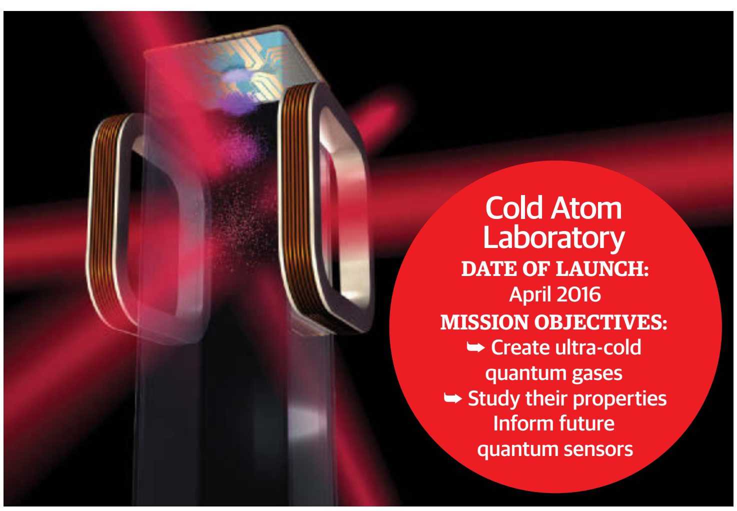
6 ISS Expeditions 47, 48 and 49

There will be three Expeditions to the International Space Station in 2016, carrying nine astronauts, cosmonauts and experiments to the orbiting laboratory. When the first Expedition arrives, it will mark the end of the 'Year in Space' mission, which began in 2015 with NASA astronaut Scott Kelly and Russian cosmonaut Mikhail Kornienko. The pair will have spent almost a whole year away from Earth - double the amount of time usually spent on board the ISS.

They have been monitored during their time on the Space Station and will be tested again once they return to Earth, helping researchers to understand more about the effects of long-term space travel on the body.

According to NASA, this multi-record breaking mission is another step towards crewed deep-space exploration missions. Expedition 47 will bring three new members of crew to the ISS, allowing Kelly and Kornienko to return to Earth in March with Sergey Volkov.

The first British astronaut on the ISS, Tim Peake, will stay in orbit on the Space Station until September 2016. It has been over 20 years since the last British astronaut went to space, so 2016 is an exciting year for the UK.



7 Cold laboratory goes into space

In 2016, part of the International Space Station (ISS) will become the coldest spot ever observed in the universe. NASA are sending the Cold Atom Laboratory (CAL) into orbit to study quantum physics in a way that is just not possible here on Earth.

As temperatures drop to absolute zero, something strange happens; atoms start to synchronise and overlap, forming a new state of matter known as a Bose-Einstein condensate. Gravity disrupts the condensate, but in microgravity they should stay synchronised for longer. In orbit on the Space Station, CAL will cool rubidium and potassium atoms to temperatures as low as one picokelvin - just one trillionth of a degree above absolute zero. This has never been done in space before, and scientists hope these conditions will allow the condensate interactions to remain stable for up to 20 seconds, enabling the quantum world to be examined more closely.

When CAL is switched on for the first time it will achieve a long list of scientific firsts. It has attracted global attention amongst scientists, with the seven CAL teams funded by NASA's Physical Science Research Program featuring three Nobel Prize winners.

8 Juno arrives at Jupiter

NASA's Juno is on a mission to understand the origins of Jupiter. The gas giant is composed of the same gases as the Sun, and was formed in the early days of the Solar System, but we don't know exactly how. According to measurements taken from the ground, Jupiter is much heavier than it looks, and scientists want to know what is hidden beneath the cloudy atmosphere.

Juno's payload includes; a gravity science system, equipment to measure the composition of the atmosphere, particle detectors, ultraviolet and infrared imagers, and instruments to detect magnetic fields. It has been travelling to Jupiter since 2011 and is due to arrive in July 2016.

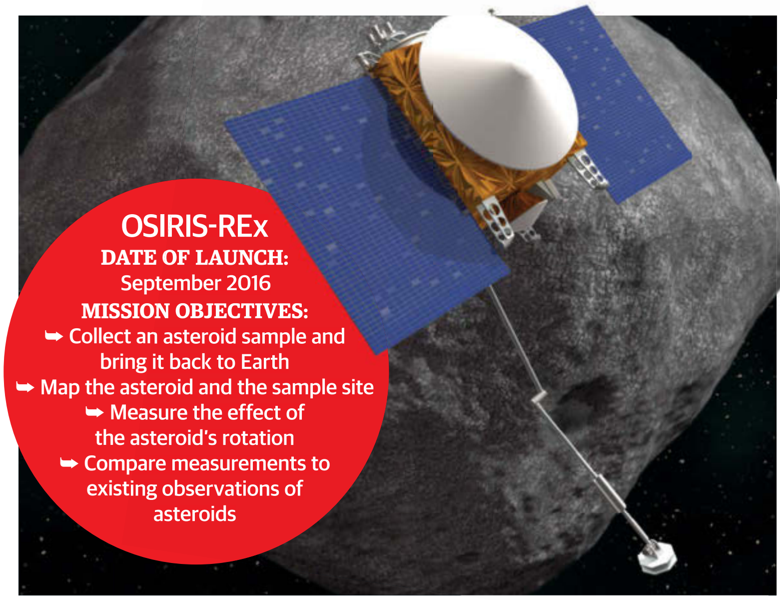
Juno will orbit the gas giant just 37 times over the course of two years, and will use its on-board instruments to probe Jupiter's atmosphere to understand how the planet was formed. It will examine magnetic fields to find out whether Jupiter has a solid core underneath all that gas, and it will determine the amount of water and ammonia in the atmosphere. It will also look at the planet's gravitational field, and will examine the northern and southern lights at the poles to learn more about Jupiter's magnetic fields.

Juno

ARRIVAL AT JUPITER: 4 July 2016

MISSION OBJECTIVES:
- Measure how much water is in Jupiter's atmosphere
- Measure atmospheric temperature, composition and weather
- Map Jupiter's magnetic field and gravity
- Observe Jupiter's northern lights and southern lights

9 Sample return mission heads to asteroid Bennu



OSIRIS-REx

DATE OF LAUNCH: September 2016

MISSION OBJECTIVES:
- Collect an asteroid sample and bring it back to Earth
- Map the asteroid and the sample site
- Measure the effect of the asteroid's rotation
- Compare measurements to existing observations of asteroids

At the end of 2014 the Philae lander made history when it touched down on the surface of a moving comet, but in 2016 NASA will go one step further. OSIRIS-REx will visit an asteroid known as Bennu, collect a sample, and bring it back to Earth.

Bennu passed close to the Earth in 2013 and measures 492 metres (1,614 feet) across - about four and a half football pitches. It's in an orbit that brings it closer than the Moon once every six years, and NASA predicts that there's a tiny chance it may collide with Earth in 2182, but before then they want to take a closer look. Bringing back a sample will not only be useful in planning how to avoid a future collision, but it could also hold some of the secrets to our origins. Bennu is thought to have formed 4 billion years ago in the early Solar System and contains ancient carbon-based compounds that could be similar to the ones that enabled life on Earth.

OSIRIS-REx is expected to reach Bennu in October 2018, but it will not be ready to take sample until late the following year. It will not land but will instead use a robotic arm to snatch a sample of surface rocks as it passes close to the asteroid, using a puff of gas to blow the rocks loose.

Deep Space Atomic Clock
DATE OF LAUNCH: Late 2016
MISSION OBJECTIVES: ➥ Technology demonstration of an ultra-precise deep-space atomic clock

10 Launch of an atomic clock

NASA's Deep Space Atomic Clock (DSAC) aims to push the boundaries of precision space navigation further than ever before. It has been in development for 20 years at the Jet Propulsion Laboratory (JPL) in California, and is due to be tested in orbit in 2016.

Atomic clocks keep time by measuring the oscillations of atomic nuclei and their electrons – instead of having a pendulum like a normal clock, they track the regular ups and downs of the energy absorbed and released by electrons. This creates a clock that is much more precise, keeping time to within fractions of a second over millions of years.

Atomic clocks are already used in navigation, both on Earth and in space, but the DSAC will take the technology further. It is described as a "miniaturised, ultra-precise mercury-ion atomic clock"; smaller than the best current atomic clocks and 50-times more accurate.

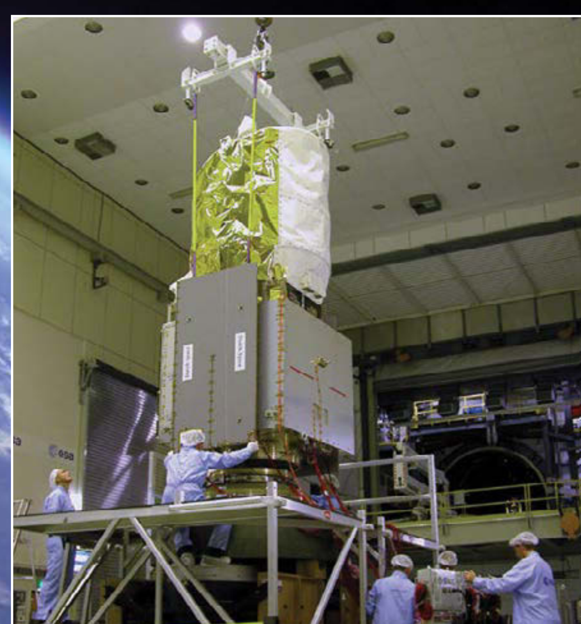
The DSAC will spend around a year in orbit, and will use GPS signals to demonstrate its time keeping abilities. Scientists at JPL will then tweak and refine the design to improve it even further. In the future it could provide the basis for highly sophisticated space navigation systems, guiding spacecraft around the Solar System and out into deep space.

11 Monitoring the Earth from space

ADM-Aeolus is the fourth in a series of Earth observation satellites launched by the European Space Agency (ESA) under the 'Living Planet Programme.' The name was chosen for its meaning in Greek mythology; Aeolus was the 'keeper of the winds', and the satellite's main objective will be to observe wind in the atmosphere, helping with both weather forecasting and climate monitoring.

Aeolus will be equipped with just one instrument, known as ALADIN (Atmospheric Laser Doppler Instrument). ALADIN will send bursts of light into the atmosphere, which will scatter as they crash into the gas, dust and water droplets. If the particles are moving when the light hits them, the wavelength of the scattered light will change slightly, allowing scientists to calculate the speed and direction of the wind. This is the first time such measurements will ever have been recorded from orbit, and once the satellite is up and running it is expected to be able to produce 120 wind profiles every hour. The information will be fed to the ESA's ESTRACK ground station in Kiruna, Sweden, or to the SG-3 antenna in Svalbard.

Aeolus will be able to reach the furthest corners of the Earth's atmosphere, beyond the reach of our weather monitoring systems here on the ground, providing an unprecedented view of the winds and the climate across the entire globe.



ADM-Aeolus
DATE OF LAUNCH: Autumn 2016
MISSION OBJECTIVES: ➥ To monitor Earth's atmosphere and weather systems

WANT MORE?

Go to **GreatDigitalMags.com** and get great deals on brilliant back issues & exclusive special editions

INSTANT ACCESS TO BACK ISSUES

PLUS SAVE EVEN MORE IF YOU SUBSCRIBE

EXCLUSIVE
BOOKS & SPECIAL EDITIONS
GO TO GREATDIGITALMAGS.COM NOW
All About Black Holes
MOST MASSIVE
OUR NEAREST
EDITOR'S PICK
NEW
All About Space
TOUR OF THE UNIVERSE
An awe-inspiring journey through space
Explore alien worlds • Discover stunning supernovas • Delve into black holes
NEW
• Hubble's great discoveries
• Birth of a planet
• The Big Bang
COMPLETE HISTORY OF THE UNIVERSE
Over 750 amazing images
THE SUN • THE EARTH & MOON • BEYOND EARTH
NEW
All About Space
SOLAR SYSTEM
Take a tour through the incredible wonders of our Solar System
NEW
Includes star chart guides
All About Space
BOOK OF THE
NIGHT SKY
MONTH BY MONTH
Your complete guide to viewing the night sky
International Space Station
The Complete Manual
SATURN
THE SEARCH FOR
ALIEN WORLDS
ALL AVAILABLE TODAY ON
GREATDIGITALMAGS.COM

Exploring the universe will help to ensure the survival of humanity

YOUR QUESTIONS ANSWERED BY OUR EXPERTS

In proud association with the National Space Centre *www.spacecentre.co.uk*

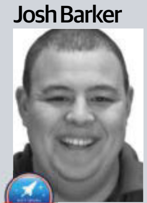
Sophie Allan

National Space Academy Education Officer
■ Sophie studied astrophysics at university. She has a special interest in astrobiology and planetary science.

Zoe Baily

Space Communications Officer
■ Zoe holds a master's degree in Interdisciplinary Science. She has an interest in space since it unites various disciplines.

Josh Barker

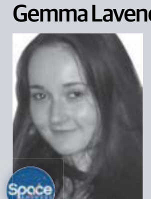


Education Team Presenter
■ Having earned a master's in physics and astrophysics, Josh continues to pursue his interest in space at the National Space Centre.

Robin Hague

Freelance Science Writer
■ Robin has a degree in physics with space technology and a master's in hybrid rocket engine design. He contributes regularly to All About Space.

Gemma Lavender



Features Editor
■ Gemma holds a master's in astrophysics, is a Fellow of the Royal Astronomical Society and is an Associate Member of the Institute of Physics.

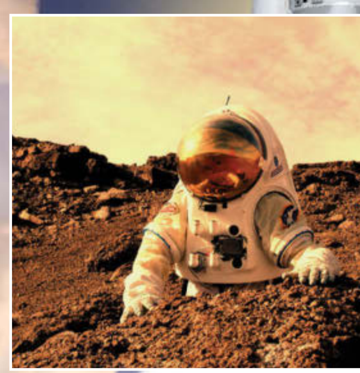
SPACE EXPLORATION

What are the benefits of going to the Moon, Mars and an asteroid?

Harold Carrion
Each of these space objects have their separate benefits and each potentially provides information that satisfies our need to explore space. Exploring the universe and sending missions to a variety of different worlds doesn't just further our knowledge of space, but it also enhances our quality of life and helps to ensure the survival of humanity beyond our planet. **JB**

The Moon is a stepping stone

Our Moon has a vast abundance of resources and is only four days away. Utilising the Moon allows the potential to build a Moonbase. While we were there, we could explore its surface to work out the formation of the Earth-Moon system, along with details of the Solar System's heavy bombardment phase. We could also set up telescopes to scan the night sky to new depths.



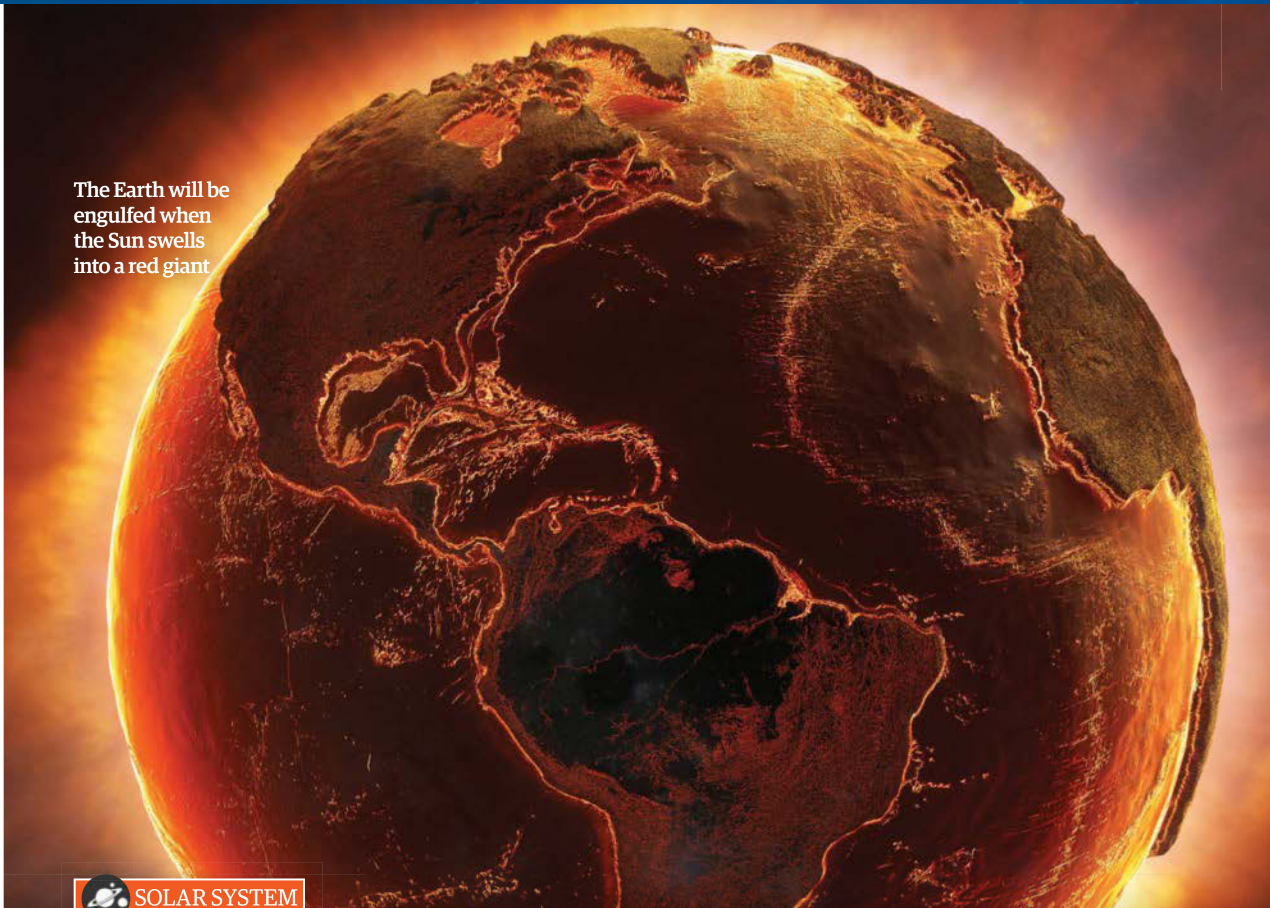
Mars could be a place to live

Science needs to be achieved on Mars so that we can work out how to enable humans to live there. Most science, admittedly, could be achieved with robots, but humans could carry out the same scientific experiments and studies much faster. That's why we have sent missions to Mars and are working towards a manned mission to the Red Planet.

Learn how to avoid asteroids

While asteroids contain resources that we can mine, such as organic compounds, these racing lumps of space rock pose a threat to life on Earth. Sending a mission to an asteroid would allow us to gather information about the birth of our Solar System and to implement a planetary defence project – to intercept any dangerous asteroids before they hit Earth.

Make contact: @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com



The Earth will be engulfed when the Sun swells into a red giant

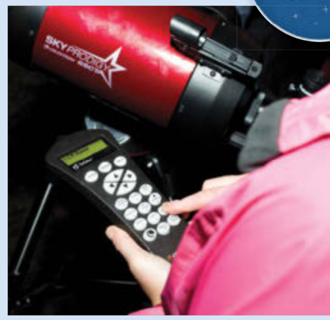
SOLAR SYSTEM

What will be the Earth's fate?

John Matthews

The fate of our planet is very likely to come from within it - whether it is the result of nuclear war, climate catastrophe or the collapse of civilisation. This is why civilisation should establish a second biosphere - to safeguard mankind, culture and technology - by attempting to colonise other worlds. Another fate of our planet is when the Sun turns into a red giant and boils our oceans away. However, hopefully, we will be out of the Solar System by then or, at least, beyond the Sun's swollen limbs and near Saturn as the habitability zone shifts.

Before the evolution of our Sun, it is possible that our planet will be hit by an asteroid or comet, perhaps at the same scale as that of 65 million years ago, which wiped out the dinosaurs. In reality, there are several fates that can befall our planet - something that we'll only find out with time - it may be predictable in the death of the Sun, or unpredictable in the collision with a wandering chunk of space rock. **GL**



GoTo telescopes have an integrated database of astronomical objects

ASTRONOMY

Are GoTo telescopes easy to use?

Drew Ellis

Yes - GoTo telescopes are ideal for helping beginners find their way around the night sky. These telescopes have an integrated computer with a database of astronomical objects visible in the sky, including Solar System planetary targets and deep-sky objects such as star clusters, nebulae and galaxies. GoTo telescopes can point themselves at a chosen target without the user having to turn the tube manually. Many GoTo telescopes do have a database of thousands of objects, but depending on the instrument's aperture (the diameter of the objective lens), it's unlikely that you'll be able to see all of the objects in it. Despite this, GoTo telescopes have revolutionised amateur astronomy. **SA**

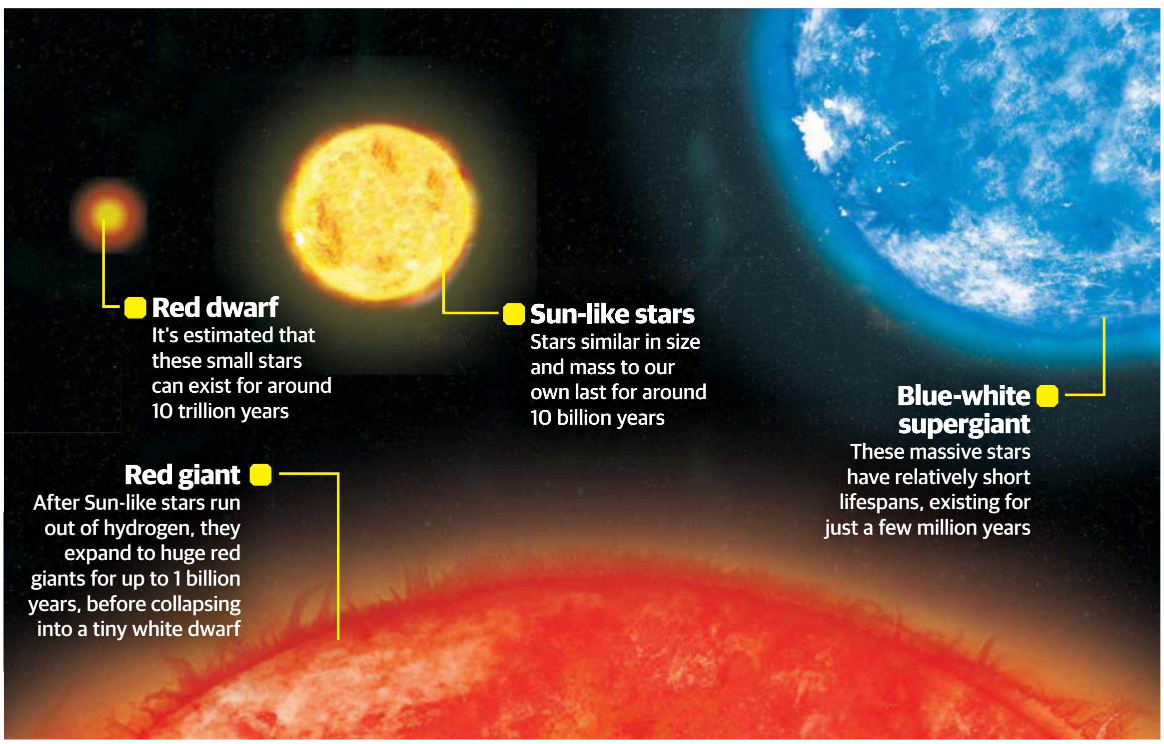
DEEP SPACE

Will all of the stars in the universe die out?

Marie Cunningham

Yes, but not for around 100 trillion years or so when there's not enough material to form new stars. At this time, stars will stop being born and the universe will eventually go dark. Not all of the stars in the universe will die at the same time though, as many are at different stages in their lifetimes. The Sun, for example, has been around for roughly 5 billion years and will live for another few billion before it runs out of fuel and will swell into a red giant star, where it's thought that it will engulf most of the inner planets.

Stars that are heavier than the Sun, meanwhile, often die out in a supernova explosion. While some stars in the universe will run out of fuel and die, there are many others that are being born in dusty galaxies to 'replace' them. **GL**



The Chelyabinsk meteor explosion released 30-times more energy than the Hiroshima atomic bomb

SOLAR SYSTEM

Why did the Chelyabinsk meteor make a shock wave?

Sherwin Atkins

The Chelyabinsk meteor, which made its way through the Earth's atmosphere in February 2013, had gas trapped inside of it, which caused it to make an airburst rather than hit our planet's surface as a whole piece.

An airburst occurs when a gas-laden piece of rock is heated up on entry into the Earth's atmosphere. This causes the meteor to expand. If there is enough gas inside of the rock, it can expand so much that the rock explodes, which creates a shock wave.

The Chelyabinsk meteor explosion released approximately 30-times more energy than that released in the atomic bomb that devastated Hiroshima in August 1945 - but, luckily for us, it exploded in the air, meaning that the brunt of the explosion was absorbed by the Earth's atmosphere.

However, that being said, the shock wave was powerful enough to shatter windows on the ground, despite the explosion taking place 23 kilometres (14 miles) above the Earth's surface. **SA**

SPACE EXPLORATION

Since there is no air in space, the burning of fuels and oxygen by the jet pack propels the user forward

Is it possible to use a jet pack in space?

Jack Simmons

Yes, it is. The physics behind how a jet pack works is the same physics that's behind how a rocket is able to launch from Earth and into space. This principal is known as Newton's Third Law, which states that if you put a force on an object, the object pushes back with an equal but opposite force.

As a result of this physics, if a rocket or jet pack throws out particles - that result from the burning of fuels and oxygen - behind it, those same particles exert an equal and opposite force. As there's no air in space, the user is propelled forwards. As long as a jet pack has a supply of fuel and oxygen, it's possible to use it in space. Astronauts currently use the SAFER (Simplified Aid for EVA Rescue) system - essentially jet packs - in case of emergency during a spacewalk. **SA**

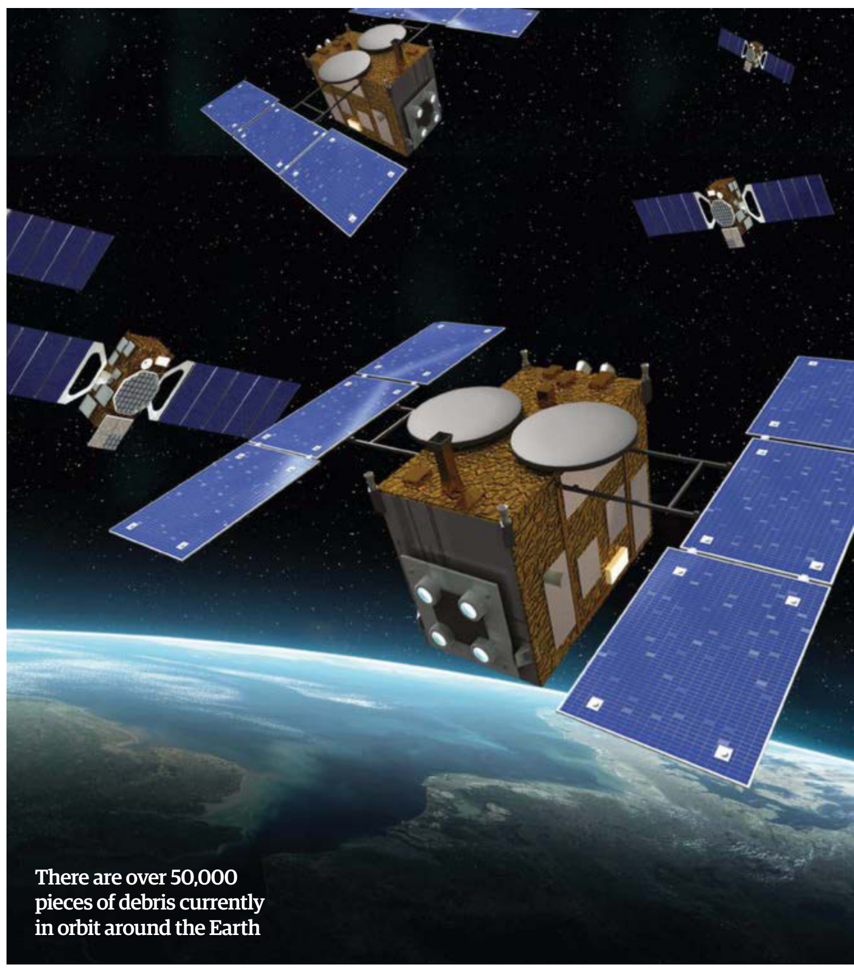
ASTRONOMY

If there is so much debris in Earth-orbit, why can't we see it?

Darren Fox

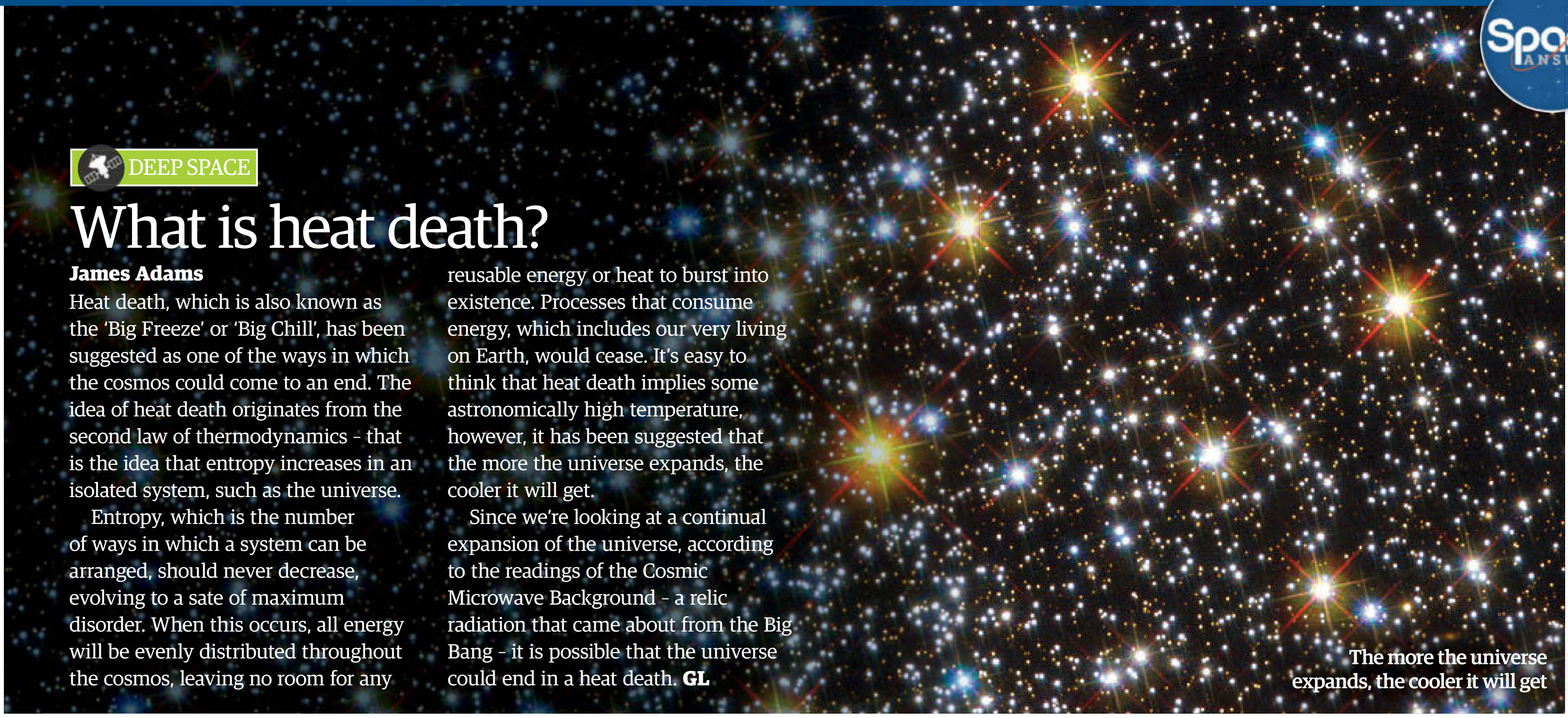
It's incredibly tricky to see all of the satellites and pieces of space junk that are in orbit around our planet - even if there are over 50,000 pieces of debris. It is particularly difficult because these satellites orbit the Earth between 300 to 36,000 kilometres (186 to 22,369 miles) above its surface, meaning that the majority are just too faint for us to see with the naked eye alone. It's similar to trying to spot a car in Paris from London.

The most famous visible satellite from Earth is the ISS during the times it's in low orbit and when it passes over areas of land on Earth. Not only is the Space Station the largest man-made structure in orbit around us, its massive solar panel array reflects the Sun, meaning that it is visible to the naked eye as it reaches a magnitude of a stunningly bright -5.9. **JB**



There are over 50,000 pieces of debris currently in orbit around the Earth

Questions to... @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com



DEEP SPACE

What is heat death?

James Adams

Heat death, which is also known as the 'Big Freeze' or 'Big Chill', has been suggested as one of the ways in which the cosmos could come to an end. The idea of heat death originates from the second law of thermodynamics - that is the idea that entropy increases in an isolated system, such as the universe.

Entropy, which is the number of ways in which a system can be arranged, should never decrease, evolving to a sate of maximum disorder. When this occurs, all energy will be evenly distributed throughout the cosmos, leaving no room for any reusable energy or heat to burst into existence. Processes that consume energy, which includes our very living on Earth, would cease. It's easy to think that heat death implies some astronomically high temperature, however, it has been suggested that the more the universe expands, the cooler it will get.

Since we're looking at a continual expansion of the universe, according to the readings of the Cosmic Microwave Background - a relic radiation that came about from the Big Bang - it is possible that the universe could end in a heat death. **GL**

The more the universe expands, the cooler it will get

SOLAR SYSTEM

What does the Sun look like in different wavelengths?

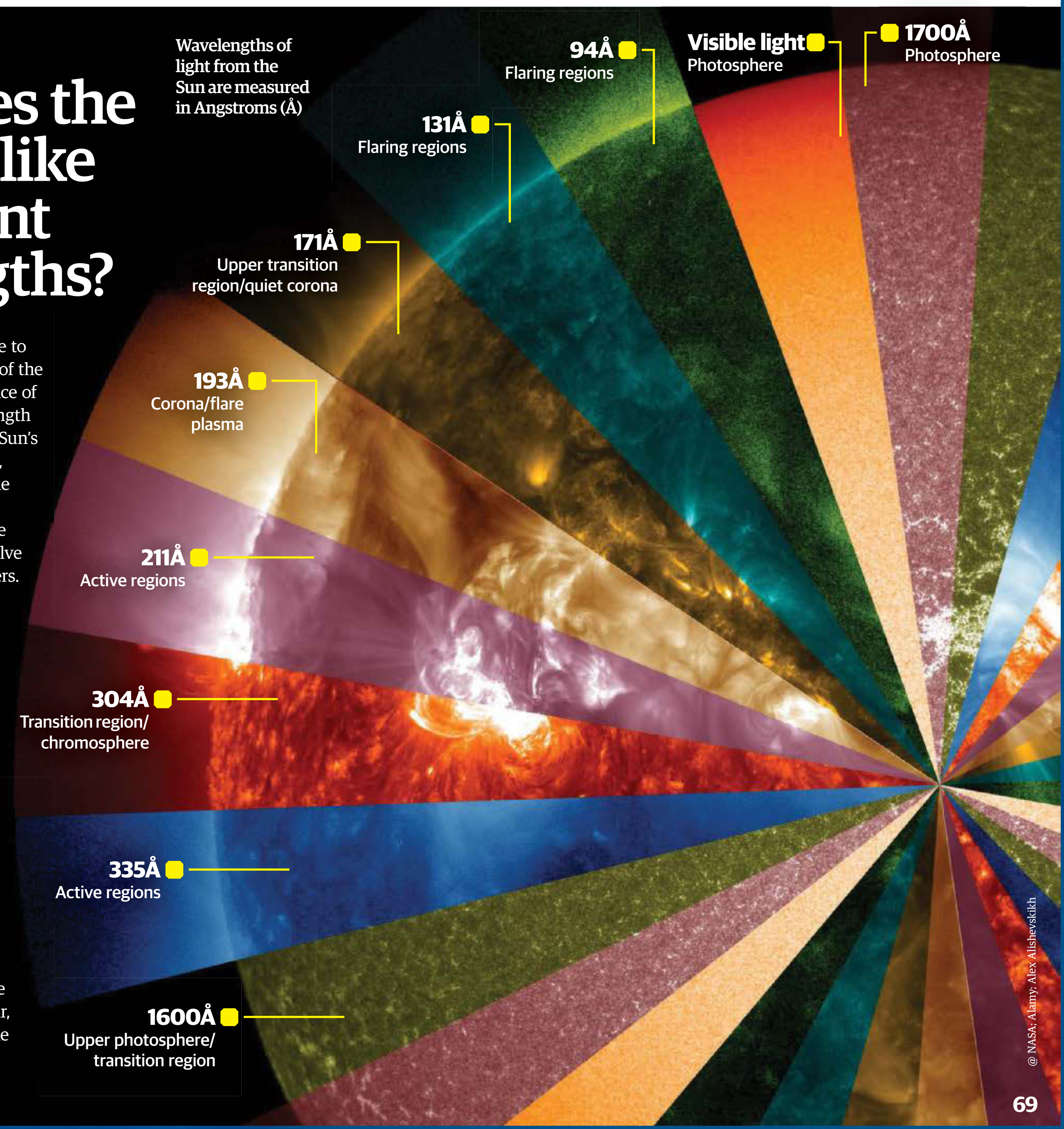
Shannon Lewis

In wavelengths that are invisible to the naked eye, we can see a lot of the activity that occurs on the surface of our Sun. For example, a wavelength of 4,500 angstroms reveals the Sun's face, known as the photosphere, and its sunspots with ease, while a wavelength of 94 angstroms will reveal flaring regions. These wavelengths also allow us to delve deeper into the Sun's many layers.

Space telescopes, such as NASA's Sun-staring Solar Dynamics Observatory (SDO) is able to observe what we're unable to see with the naked eye, as well as being able to view its angry, bright surface up close. What we are left with, after these wavelengths are assigned a colour to tell them apart and make them visible to the naked eye, is our Sun in a rainbow of colours that tells us a lot about our star.

In the case of the Sun, the wavelengths of light are measured in angstroms, with longer wavelengths showing the cooler regions of our nearest star, while shorter wavelengths tackle the hotter phenomena. **GL**

Wavelengths of light from the Sun are measured in Angstroms (Å)



How are galaxies made?

Sonia Gill

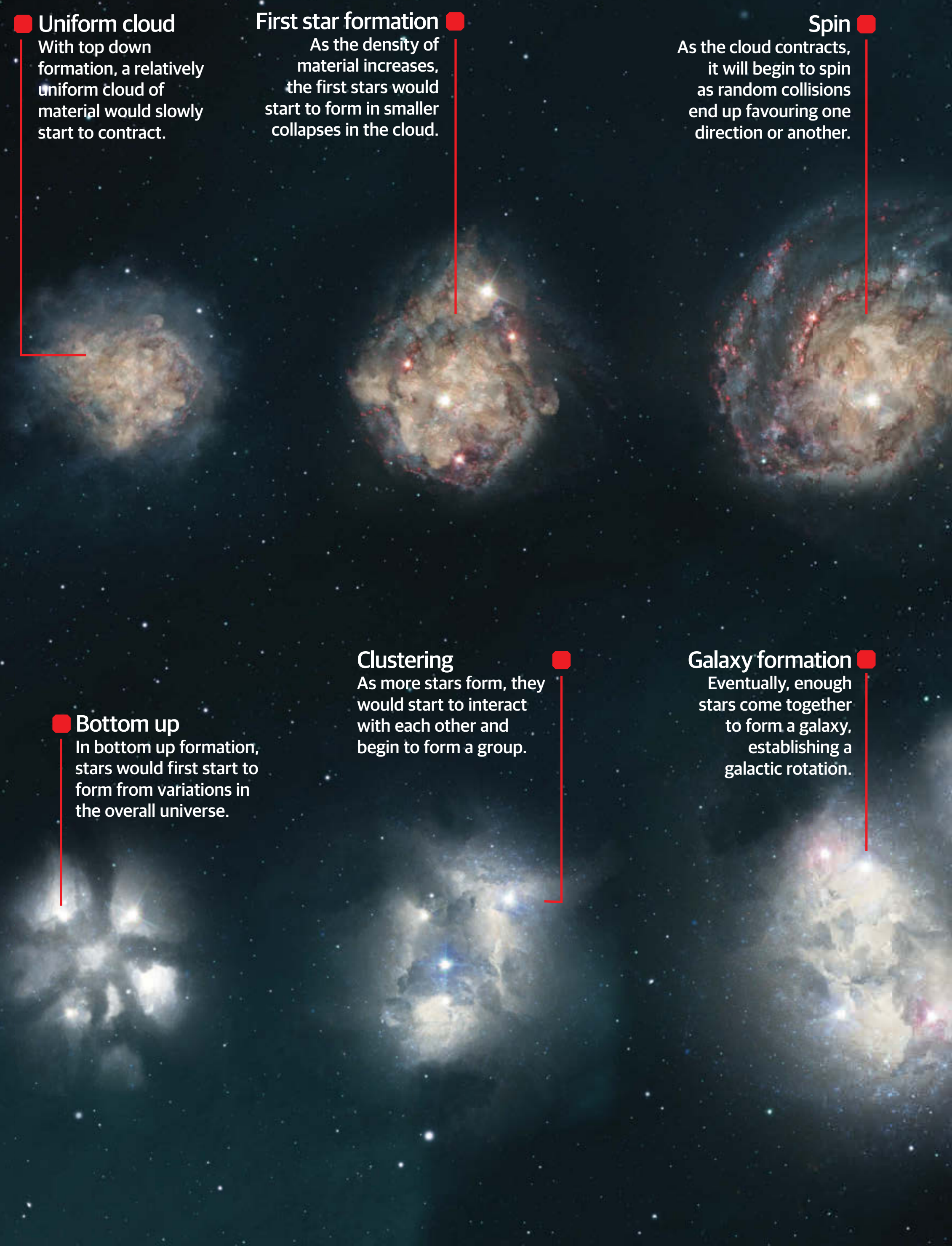
Galaxies are tremendous clusters of billions to trillions of stars, and indeed where the majority of stars reside. If you are fortunate enough to have a dark night sky you will be able to see the section of our own galaxy, the Milky Way, as a ribbon of stars stretching across the sky. The Milky Way is estimated to be roughly 100,000 light years across, containing some 100 billion stars, and is probably a barred spiral shape rather than the classic swirl we think of as a galaxy. Our nearest galactic companion, the Andromeda Galaxy, is even bigger, containing up to a trillion stars, so how do these massive structures come to form?

Opinion is divided, and there are two major shapes that a galaxy can form. Elliptical galaxies are fuzzy clouds of stars, whereas spiral galaxies are the classic image of a galaxy, with a number of arms wrapped around a centre. So different mechanisms may be at play in the different shapes, but broadly the theories are either "top down" or "bottom up."

Top down formation would be very similar to the way we believe stars form – a large, cold cloud of gas and dust starts to contract, warming up and starts to spin as it does so. Once the centre of the cloud gets dense enough, stars would start to form as smaller versions of this process, with their own small eddies forming planets around them.

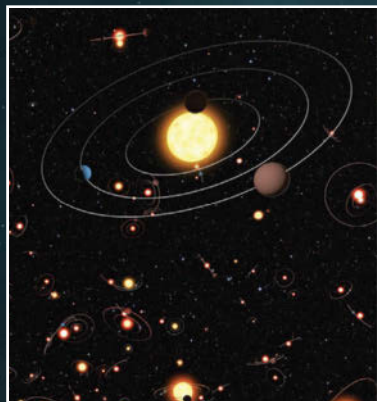
In bottom up formation, stars would form first from the general background material of the Big Bang. As the first ones become established, their presence would start to attract other stars, and indeed set off the formation of other stars as the density of material increases. It may be that elliptical galaxies form one way and spirals form another, or that ellipticals began with clouds that were spinning slowly and spirals with clouds spinning quickly.

Another factor that we know from observation effects the development of galaxies is collision. Despite the massive distances between them, proportionately, galaxies are closer together than stars are. As a result we can see a number of galactic collisions currently occurring in the universe, and it is believed our own Milky Way has collided with other smaller galaxies. Although there is a huge amount of matter in galaxies, these collisions aren't actually impacts. Because there is so much space in between stars, meeting galaxies actually pass through each other, and it is the gravitational interaction of their matter that can mingle them together into a new whole. Galaxies themselves are not randomly scattered through space, but are grouped together into long filament like clusters, these are the largest structures we have identified and probably indicate variations in density in the very early universe. **RH**

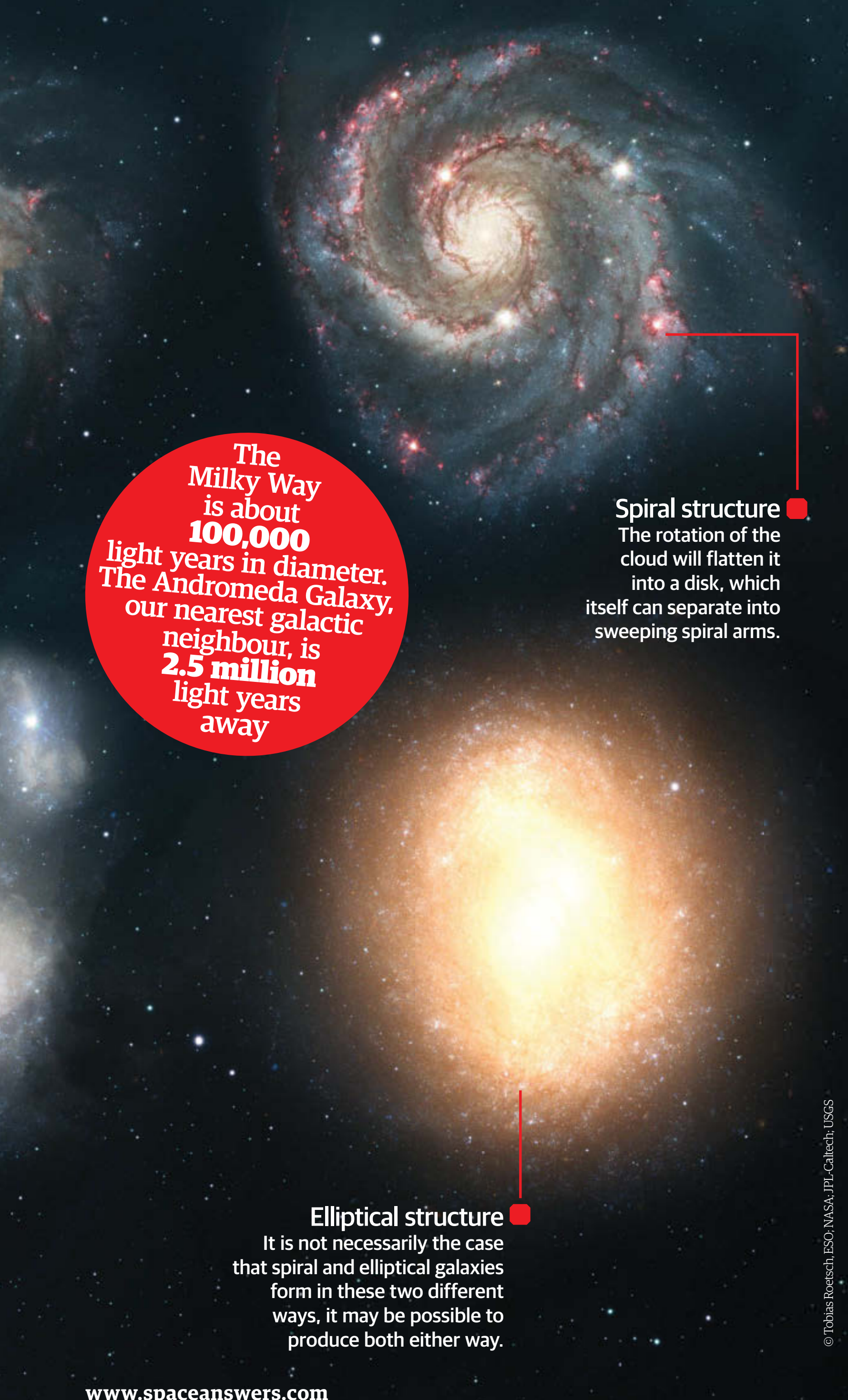


Questions to... @spaceanswers /AllAboutSpaceMagazine questions@spaceanswers.com

Spread of life



Only 20 years ago we were unsure if there were planets around other stars, now we have found thousands of them and they're just the ones that are easiest to find. A study by NASA, based on data from the Kepler planet-hunting telescope, estimates that there could be around two billion planets like Earth in the Milky Way alone. So if the 50 billion galaxies we can see have the same concentration, there could be 100 quintillion Earths out there.



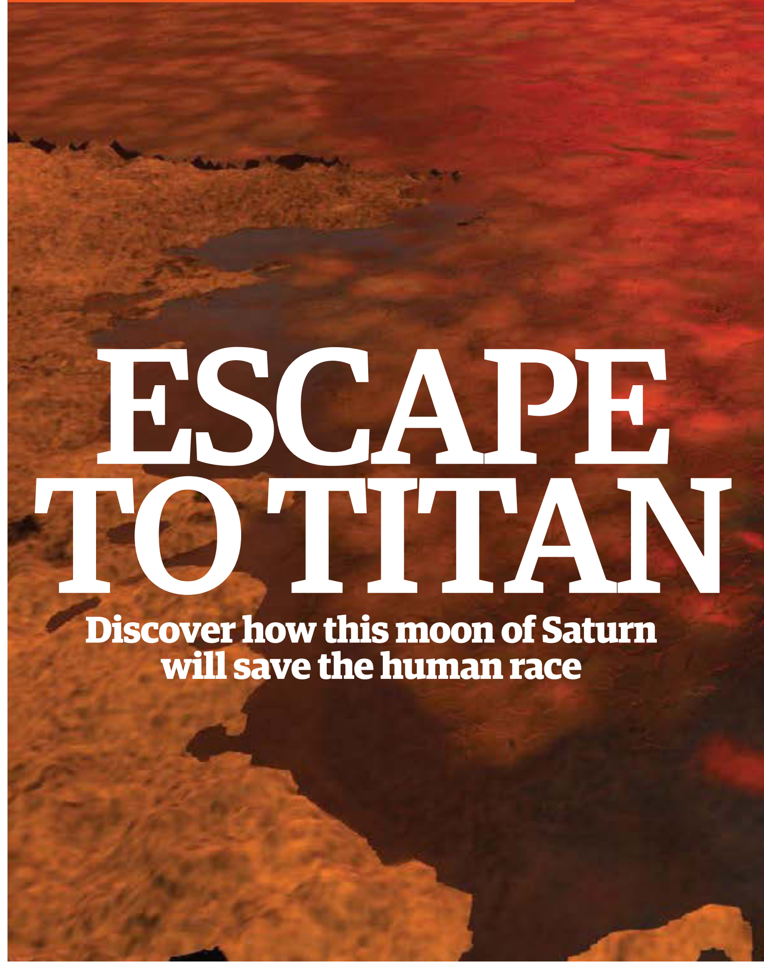
The Milky Way is about 100,000 light years in diameter. The Andromeda Galaxy, our nearest galactic neighbour, is 2.5 million light years away

Spiral structure
The rotation of the cloud will flatten it into a disk, which itself can separate into sweeping spiral arms.

Elliptical structure
It is not necessarily the case that spiral and elliptical galaxies form in these two different ways, it may be possible to produce both either way.

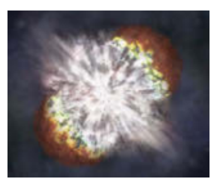
© Tobias Roetsch; ESO; NASA; JPL-Caltech; USGS

Next Issue

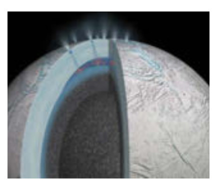


ESCAPE TO TITAN

Discover how this moon of Saturn will save the human race



WEIRDEST STARS IN THE GALAXY
The members of the Milky Way that you wouldn't believe exist



HUNT FOR LIFE IN THE SOLAR SYSTEM
All About Space meets the scientists finding out if we're alone

NEXT-GENERATION SPACE PLANES
Come on board the craft that will get you into space in the near future

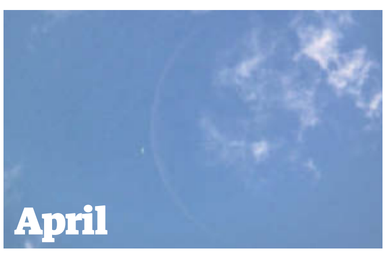
FUTURISTIC SPACE ARKS
GUIDE TO THE NIGHT SKY
HOW THE SUN LOOKS FROM OTHER WORLDS
YOUR SPACE QUESTIONS ANSWERED

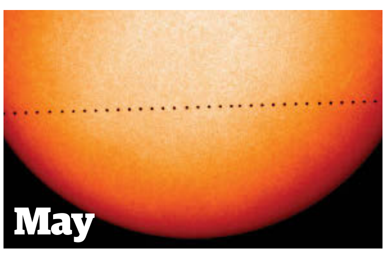
In orbit 07 Jan 2016

In this issue...

Stargazing diary 2016

A roundup of the major astronomical events observable from your location throughout next year





Star parties and astro-events

Kelling Heath Spring Star Party
Thursday 7 to Monday 11 April 2016
Main Weekend: 9 to 10 April
Kelling Heath, Norfolk
www.starparty.org

British Astronomical Association (BAA) Summer Meeting
Saturday 2 July 2016 from 10am to 6pm
Priory Street Centre, 15 Priory Street, York, YO1 6ET
www.britastro.org/meetings

16th Annual Starfest
Thursday 4 to Sunday 7 August 2016
Dalby Forest, North Yorkshire
www.scarborough-ryedale-as.org.uk/saras/starfest/starfest-2016

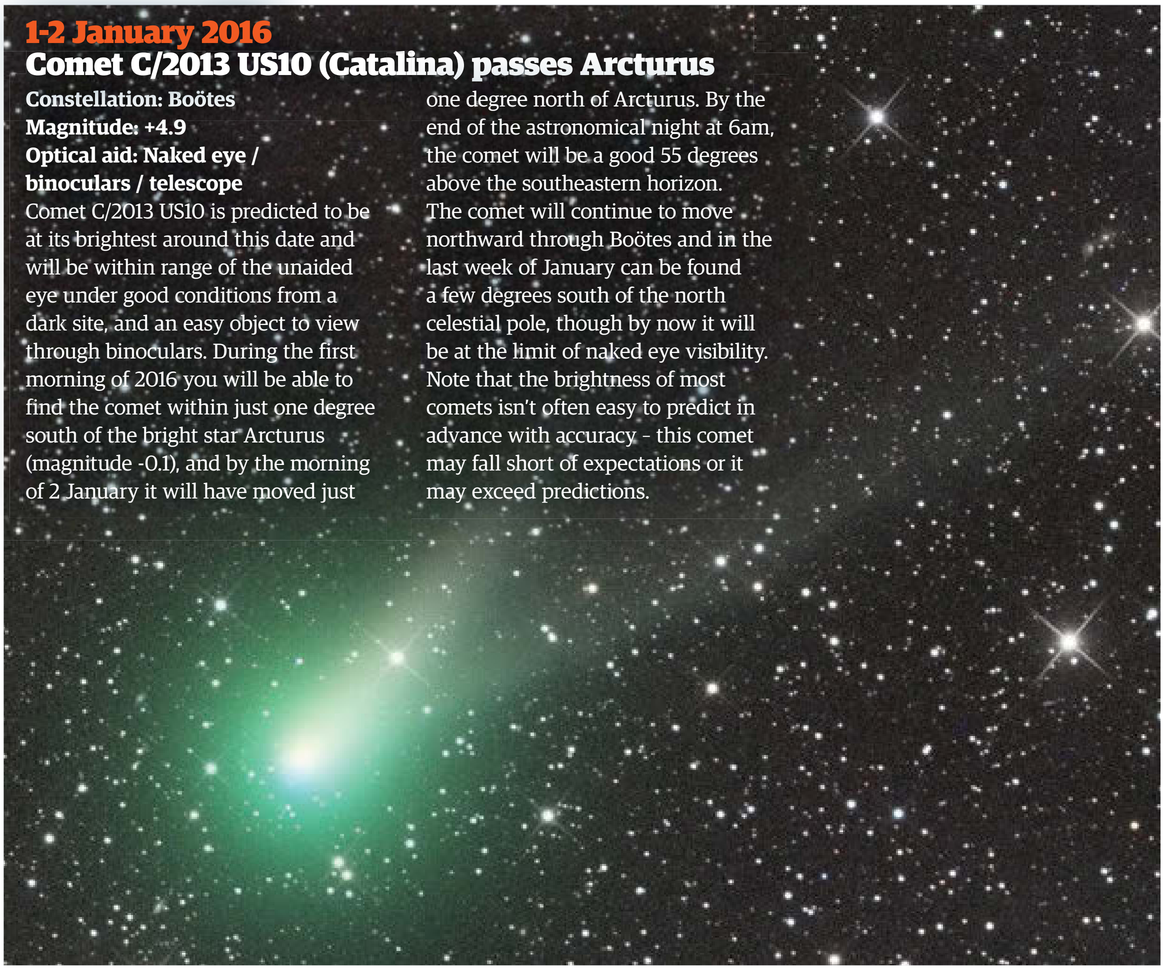
Spring Brecon Astrocamp
Saturday 7 to Tuesday 10 May 2016
Brecon Beacons, Wales
www.astrocamp.org.uk

Autumn Brecon Astrocamp
Saturday 24 to Tuesday 27 September 2016
Brecon Beacons, Wales
www.astrocamp.org.uk

Kelling Heath Autumn Equinox Sky Camp
26 September to 7 October 2016
Main Weekend: 30 September to 3 October
Kelling Heath, Norfolk
www.starparty.las-astro.org.uk

Kielder Forest Star Camp
Wednesday 14 to Sunday 19 October
Kielder Forest, Northumberland
www.kielderobservatory.org/events/

JANUARY



1-2 January 2016
Comet C/2013 US10 (Catalina) passes Arcturus

Constellation: Boötes
Magnitude: +4.9
Optical aid: Naked eye / binoculars / telescope

Comet C/2013 US10 is predicted to be at its brightest around this date and will be within range of the unaided eye under good conditions from a dark site, and an easy object to view through binoculars. During the first morning of 2016 you will be able to find the comet within just one degree south of the bright star Arcturus (magnitude -0.1), and by the morning of 2 January it will have moved just one degree north of Arcturus. By the end of the astronomical night at 6am, the comet will be a good 55 degrees above the southeastern horizon. The comet will continue to move northward through Boötes and in the last week of January can be found a few degrees south of the north celestial pole, though by now it will be at the limit of naked eye visibility. Note that the brightness of most comets isn't often easy to predict in advance with accuracy - this comet may fall short of expectations or it may exceed predictions.

3-4 January 2016
Quadrantid meteor shower at maximum

Radiant: Boötes
Meteors per hour: Up to 80

Active between 1 to 5 January, the Quadrantid meteor shower peaks on the night of 3 January and the morning of 4 January. The shower's radiant, located in the constellation of Boötes (near the handle of the 'Plough' asterism), will climb high above the northeastern horizon at midnight. Some interference will come from the light of the waning crescent Moon, which will rise on the eastern horizon at 2.20am, but good rates may be observed at the shower's peak.

7 January 2016
Appulse of Venus, Saturn and the Moon

Constellation: Ophiuchus
Optical aid: Naked eye / binoculars

A beautiful get-together of Venus (magnitude -4.0), Saturn (magnitude +0.5) and the waning crescent Moon (26.8 days old) will take place low above the southeastern horizon before dawn. All three objects will be seen in the same field of view of 10x50 binoculars, and the earthshine glow on the Moon's unilluminated side will further enhance the scene. This will be a good astrophotographic opportunity for anyone armed with a camera and zoom facility.

9 January 2016
Conjunction between Venus and Saturn

Constellation: Ophiuchus
Optical aid: Naked eye / binoculars / telescope

Venus (magnitude -4.0) will pass a mere eight arcseconds to the east of Saturn (magnitude +0.5) on the morning of 9 January - that's less than one-third the apparent diameter of the Moon. Through a telescope both planets will be seen in the same field of view, even at a magnification of around 200x. Saturn's biggest moon Titan (magnitude +8.8) will be visible to the west, and larger instruments will show the Saturnian moons Rhea (magnitude +10.3) and Dione (magnitude +10.9) immediately east of the ringed planet. This will be a good opportunity to compare Venus and Saturn as the contrast between Venus' brilliant white and Saturn's dull yellowish tones will be striking. The planets are of similar apparent size, too, both around 15 arcseconds across.

20 January 2016
Lunar occultation of Aldebaran

Constellation: Taurus
Magnitude: Aldebaran (+0.8)
Optical aid: Naked eye / binoculars / telescope

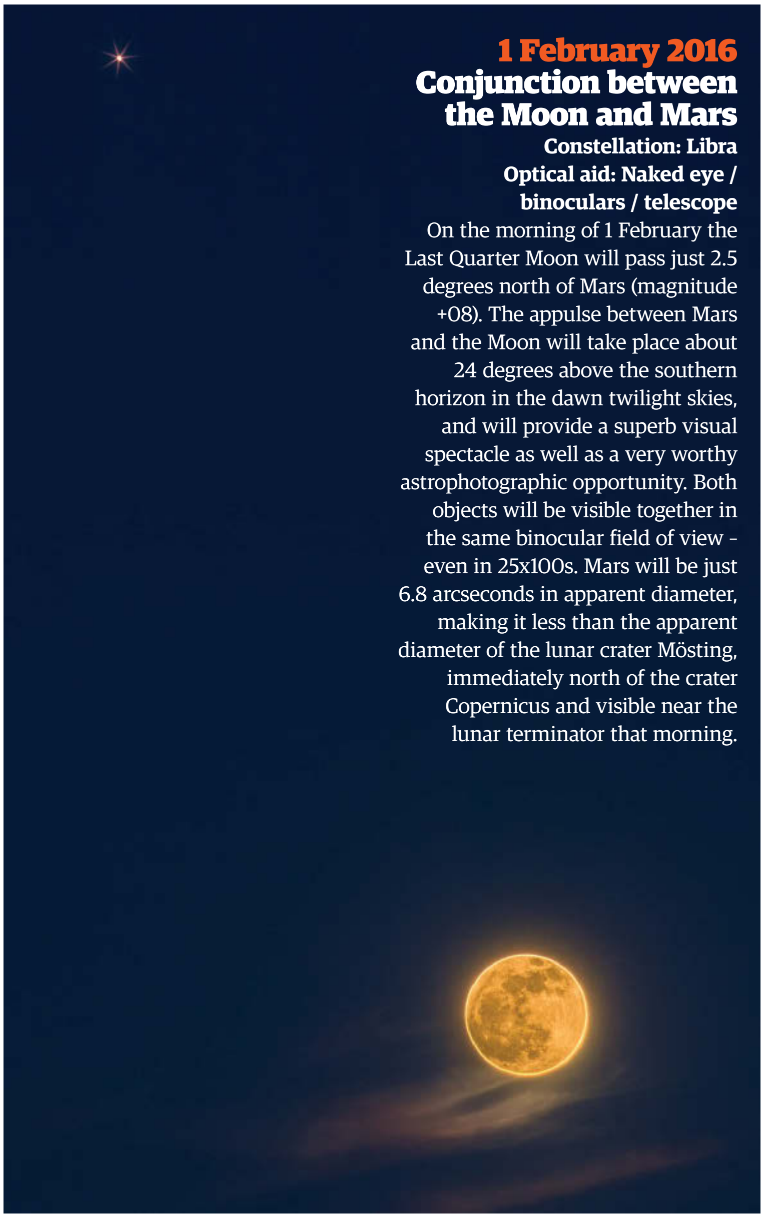
Aldebaran, the brightest star in Taurus, will be occulted by the waxing gibbous Moon (11 days old) on the morning of 20 January. The bright star will be hidden by the dark northwestern lunar limb at around 3.25am when the Moon is about eight degrees above the northwestern horizon. Aldebaran will emerge from the bright lunar limb at around 4am, when the Moon will have sunk to just a few degrees above the horizon.

28 January 2016
Conjunction between Jupiter and the Moon

Constellation: Leo
Optical aid: Naked eye / binoculars / telescope

In the early hours of 28 January, the waxing gibbous Moon (18.5 days old) will pass less than two degrees south of Jupiter (magnitude -2.3), with the two being at their closest just after midnight when the Moon will be 28 degrees above the southeastern horizon. This close conjunction can be enjoyed with the naked eye, while binoculars (ranging from 7x50s to 25x100s) will show both objects in the same field of view. Binoculars and telescopes will reveal the 42 arcsecond diameter disc of Jupiter - which is about the same apparent diameter as the crater Aristoteles (visible near the northern lunar terminator).

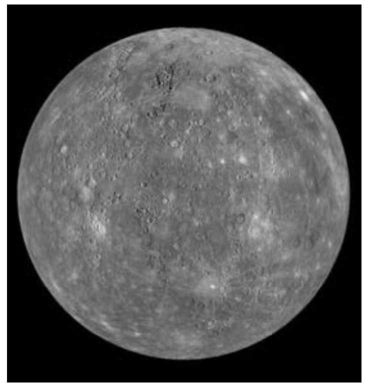
FEBRUARY



1 February 2016
Conjunction between the Moon and Mars

Constellation: Libra
Optical aid: Naked eye / binoculars / telescope

On the morning of 1 February the Last Quarter Moon will pass just 2.5 degrees north of Mars (magnitude +08). The appulse between Mars and the Moon will take place about 24 degrees above the southern horizon in the dawn twilight skies, and will provide a superb visual spectacle as well as a very worthy astrophotographic opportunity. Both objects will be visible together in the same binocular field of view – even in 25x100s. Mars will be just 6.8 arcseconds in apparent diameter, making it less than the apparent diameter of the lunar crater Mösting, immediately north of the crater Copernicus and visible near the lunar terminator that morning.



7 February 2016
Mercury at greatest western elongation

Constellation: Sagittarius
Magnitude: -0.0
Optical aid: Naked eye / binoculars / telescope

The first of Mercury's 2016 elongations, 7 February will see the innermost planet at its greatest distance west of the Sun (by 25.6 degrees), making an appearance in the dawn skies. Although it will be visible with the unaided eye, this particular elongation isn't very favourable as viewed from the UK because the planet is only a few degrees above the southeastern horizon in the dawn twilight. A good signpost for Mercury is Venus – a brilliant magnitude -4.0 and just 4.5 degrees west of Mercury. Binoculars will show both Mercury and Venus in the same field of view.

Caution: never attempt to sweep for Mercury when the Sun is visible above the horizon – even the briefest magnified glimpse of the Sun through an unprotected optical aid could permanently damage your eyesight.

12 February 2016
Conjunction between the Moon and Uranus

Constellation: Pisces
Optical aid: Binoculars / telescope

On the evening of 12 February, the waning crescent Moon (4.7 days old) will pass just 2.5 degrees east of Uranus (magnitude +5.9). At the darkening of the evening twilight sky, at around 7.15pm, the Moon will be just 29 degrees above the southwestern horizon. Both Uranus and the crescent Moon will be seen in the same field of view afforded by small binoculars up to 15x70s. Note the presence of the star 80 Piscium (magnitude +5.5) directly between Uranus and the Moon at this time. This will also be a good opportunity to find Uranus if you have never seen it before.

24 February 2016
Conjunction between the Moon and Jupiter

Constellation: Leo
Optical aid: Naked eye / binoculars / telescope

The morning of 24 February will see the waning gibbous Moon (16 days old) pass just 2 degrees south of Jupiter (magnitude -2.5), a sight that can be enjoyed without optical aid. At 4am the Moon will be more than 30 degrees above the southwestern horizon. Both Jupiter and the Moon can be seen in the same field of view of binoculars up to 15x70s – it will even be possible to see both objects in the field of a long focal length ultra-wide eyepiece on a rich-field telescope.

MARCH

8 March 2016
Jupiter at opposition

Constellation: Leo
Magnitude: -2.5
Optical aid: Naked eye/ binoculars/telescope

The Solar System's largest planet, Jupiter, will be near to its closest approach to Earth this apparition. The gas giant will rise due east at around 6pm in the evening twilight, where it will climb to 45 degrees above the southern horizon at 12.30am. It will be 19 degrees above the western horizon at the end of the astronomical night at around 5am in the morning of 8 March. The planet will therefore be clearly visible at a good altitude and against a dark sky background with little light pollution for around nine hours – that's just an hour short of a full rotation of Jupiter. A medium-sized telescope will reveal a good amount of detail in Jupiter's atmospheric bands, and the planet's famous Great Red Spot will be visible crossing the central meridian of the Jovian disc just before midnight on 8 March.

20 March 2016
Vernal equinox (Northern Hemisphere)

Constellation: Pisces
Optical aid: Naked eye

The Sun, moving northward, will be located precisely on the celestial equator, meaning that the duration of day and night across the Earth will be equal – 12 hours apiece. This day will mark the first day of spring in the Northern Hemisphere and the first day of autumn in the Southern Hemisphere. Equinox actually means 'equal nights'.

APRIL

6 April 2016
Lunar occultation of Venus (daytime)

Constellation: Pisces
Magnitude: -3.9
Optical aid: Binoculars / telescope

Being able to locate Venus in full daylight may seem like a daunting task, but the planet will present as a fairly bright target through an optical aid in the daylight, providing you know precisely when and where to look. The fact that Venus will lie very close to the bright edge of the waning crescent Moon (28.2 days) on the morning of 6 April will make the lunar occultation observable through both binoculars and telescopes. Venus will be hidden behind the Moon at around 8.30am (BST); however less than half an hour later Venus will emerge from the dark lunar limb, when the Moon will be more than 20 degrees above the southeastern horizon. The Sun will be just 16 degrees east of the Moon at this time, so please take extra care when viewing to avoid inadvertently catching a glimpse of the Sun through unprotected optical instruments.

18 April 2016
Mercury at greatest eastern elongation

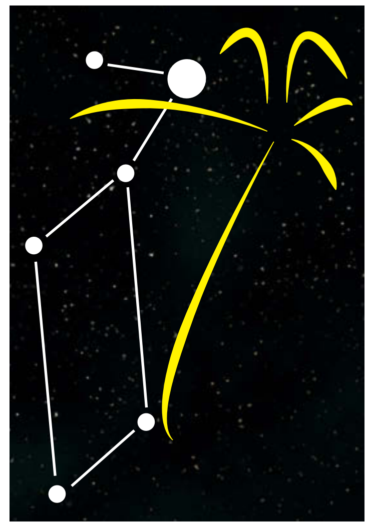
Constellation: Aries
Magnitude: +0.2
Optical aid: Naked eye / binoculars / telescope

Mercury will reach its greatest eastern elongation on 18 April, at 19.9 degrees east of the Sun. One of the planet's most favourable showings during 2016, it will be 17 degrees above the sunset horizon at 7.15pm, and by the time civil twilight sets in an hour later, Mercury will be 12 degrees high. At this point the planet may be spotted with the unaided eye and transparent skies above the clear western horizon, and binocular views will certainly capture Mercury at this time. Through a telescope, Mercury will appear as a 7.8 arcsecond disc, a wide crescent phase some 38 per cent illuminated.

22-23 April 2016
Lyrids meteor shower at maximum

Radiant: Lyra
Meteors per hour: Around 10

The presence of the Moon - bright and full on 21 April and a waning gibbous phase in Virgo during the shower's maximum - will significantly affect the number of Lyrid meteors observed. Usually producing a peak of 20 meteors per hour, with individual meteors leaving bright dust trails that last for several seconds, all except the brightest Lyrids will be seen. But, if you set up in a dark location with the Moon out of view, a reasonable number of meteors may be seen.

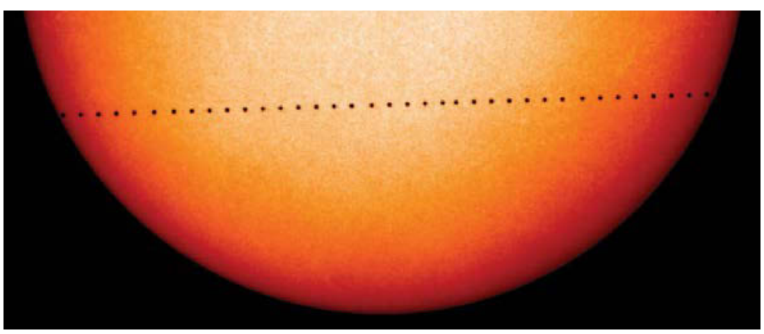


MAY

6-7 May 2016
Eta Aquarids meteors at maximum

Radiant: Aquarius
Meteors per hour: Up to 40

Active between 19 April and 28 May, the Eta Aquarid meteor shower will peak on the night of 6 to 7 May. The shower's radiant in northern Aquarius will rise in the east well after midnight and will only reach a few degrees high by the onset of dawn twilight at around 2.20am. However, meteors may be seen in any part of the sky radiating from this point. This year's maximum is very favourable because the Moon is new and will not present any light interference.



9 May 2016
Transit of Mercury across the Sun

Optical aid: Telescope (only with adequate solar radiation protection)

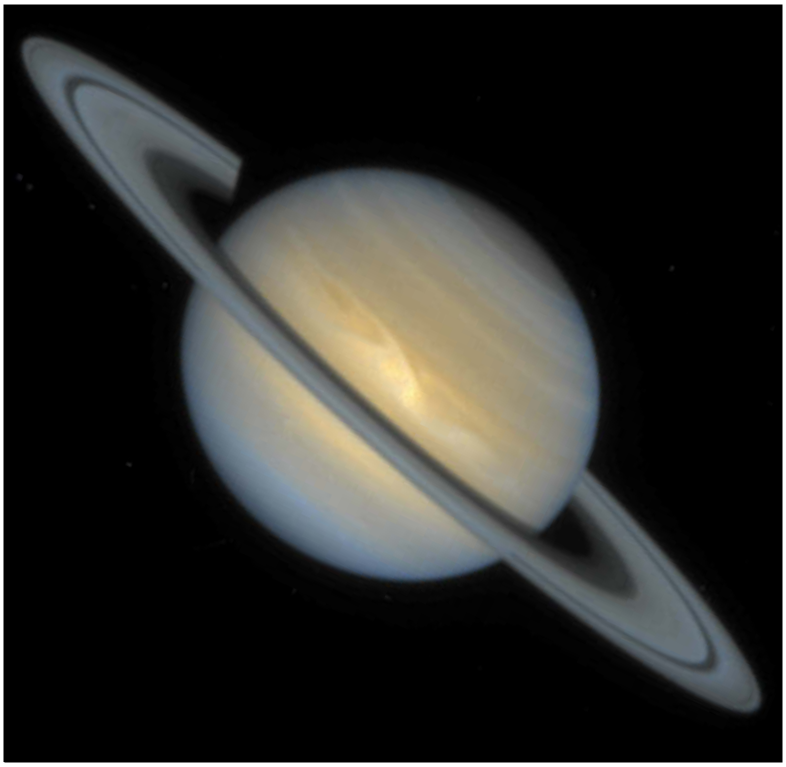
The innermost planet Mercury will cross the Sun on the afternoon of 9 May. Given co-operative weather conditions, the entire 7.5 hour long event can be followed from the UK. When in transit, Mercury will appear as a tiny black dot, just 12 arcseconds in apparent diameter. It will first appear at the Sun's edge at 12.12pm and will slowly cross the Sun's disc (moving from west to east) and reach its mid-point at 3.57pm. The event will end at 7.42pm with Mercury's exit at the Sun's edge. **Caution:** only view this event using a filtered telescope or via eyepiece projection onto a shaded white card. Any inadvertent glimpse of the Sun through an unprotected optical aid will cause permanent eye damage. Only one more transit of Mercury will be seen this decade, in 2019. The next won't be until 2032.

22 May 2016
Mars at opposition

Constellation: Scorpius
Magnitude: -2.1
Optical aid: Naked eye / binoculars / telescope

On the evening of 22 May the planet Mars will reach opposition. The Red Planet will be near its closest approach to Earth this apparition, shining as a distinctly orange ember just a hand's width above the southern horizon at around 1am. Mars will lie just 1.5 degrees northwest of Delta Scorpii (magnitude +2.3) and makes for a prominent naked-eye beacon above the southern horizon. If you are viewing through binoculars, the Scorpius star field surrounding Mars will be star-packed. If you are viewing the event through a telescope, Mars will present as a disc some 18 arcseconds across in diameter - easily large enough to make out many of the planet's dusky desert features and its bright north polar ice cap.

JUNE



3 June 2016
Saturn at opposition

Constellation: Ophiuchus
Magnitude: +0.0
Optical aid: Naked eye / binoculars / telescope

Having become an increasingly familiar sight in the early morning skies throughout the first half of 2016, Saturn will finally come to opposition in southwestern Ophiuchus, where it will be 19 degrees above the southern horizon at midnight. Directly opposite the Sun and at its closest to Earth, the planet will shine at magnitude +0.0. The scene will be further enhanced by the presence of brilliant Mars (magnitude -2.0) just 15 degrees west of Saturn. A medium telescopic magnification will reveal that Saturn's magnificent ring system is wide open, and several of the planet's brighter moons will be on show, including the brightest, Titan (magnitude +8.5), which can easily be found to the west of Saturn on this date (Titan will even be visible through binoculars).

5 June 2016
Mercury at greatest western elongation

Constellation: Aries
Magnitude: +0.6
Optical aid: Binoculars

Mercury will reach its greatest western elongation on 5 June, some 24 degrees from the Sun. For UK-based observers, this will be an unfavourable elongation of the innermost planet; it will be something of a challenge to spot since it will rise above the brightening eastern horizon less than an hour before the Sun. Only attempt to view Mercury before sunrise - never sweep for Mercury when the Sun is on view.

11 June 2016
Conjunction between the Moon and Jupiter

Constellation: Leo
Optical aid: Naked eye / binoculars / telescope

The evening of 11 June will see the first quarter Moon pass just two degrees south of Jupiter (magnitude -2.0). The conjunction will make a pleasant naked-eye spectacle (and a great astrophotographic opportunity), and both the Moon and Jupiter may be seen together in the field of view of binoculars or in a rich-field telescope, using a low-magnification and a wide-angle eyepiece.

20 June 2016
Summer solstice

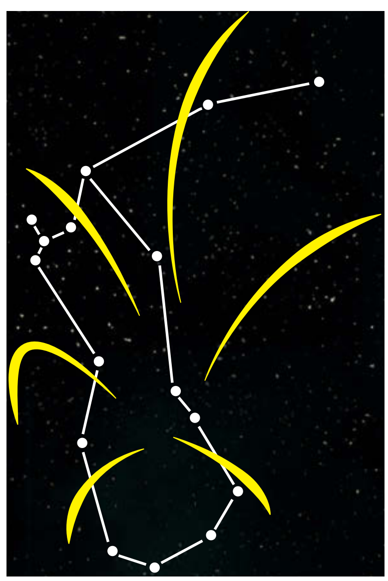
This will be the longest day of the year for the Northern Hemisphere. Earth's north pole will be tilted at its maximum towards the Sun, which means that the Sun reaches its most northern position in the sky (actually in eastern Taurus). From London there will be 16.5 hours of daylight (17.5 hours in Edinburgh) and the sky will have a deep twilight glow - even at midnight.

JULY

8 July 2016
Capricornid meteors at maximum

Radiant: Capricornus
Meteors per hour: Up to five

This annual meteor shower will be active in July and August, and although it will by no means be a prolific shower, it could produce the occasional bright yellow and bright blue meteor. The radiant will be low above the southeastern horizon at midnight, so it is worth keeping an eye out in the early hours as the radiant climbs. The Moon will be well out of the way this year, so the shower is expected to have a favourable viewing.



28-29 July 2016
Delta Aquarid meteors at maximum

Radiant: Aquarius
Meteors per hour: Up to 20

The Delta Aquarid shower is active between 15 July to 20 August. The shower has two radiants in Aquarius, and each has a peak date. The southern Delta Aquarid radiant will peak on the night of 28 to 29 July and will produce higher rates, but most meteors from this shower will be on the faint side. The presence of a waning crescent Moon in Taurus (24.5 days old) will interfere with the visibility of fainter meteors, but you should be able to spot a few if you are viewing from a good dark location after midnight.

AUGUST

2 August 2016
Alpha Capricornid meteors at maximum

Radiant: Capricornus
Meteors per hour: Up to five

Not to be confused with the Capricornids of July, the Alpha Capricornids will be active between 15 July and 20 August. This will be another low-rate shower at maximum, producing just a handful of meteors; however, slow, long-duration fireballs can sometimes be produced by this shower, so it's worth watching after midnight, particularly as the Moon will be well out of the way.

16 August 2016
Mercury at greatest eastern elongation

Magnitude: +0.3
Optical aid: Binoculars

Mercury will reach its furthest distance east of the Sun at an angle of 27 degrees, and will be visible in the evening skies, low above the western horizon after sunset. This will not be a favourable elongation to view from the UK, as Mercury will not be very bright and can only be seen in bright evening twilight skies after sunset - but only by scanning the dusk horizon after sundown. **Caution:** never sweep the skies for Mercury when the Sun is above the horizon.

20 August 2016
Pallas at opposition

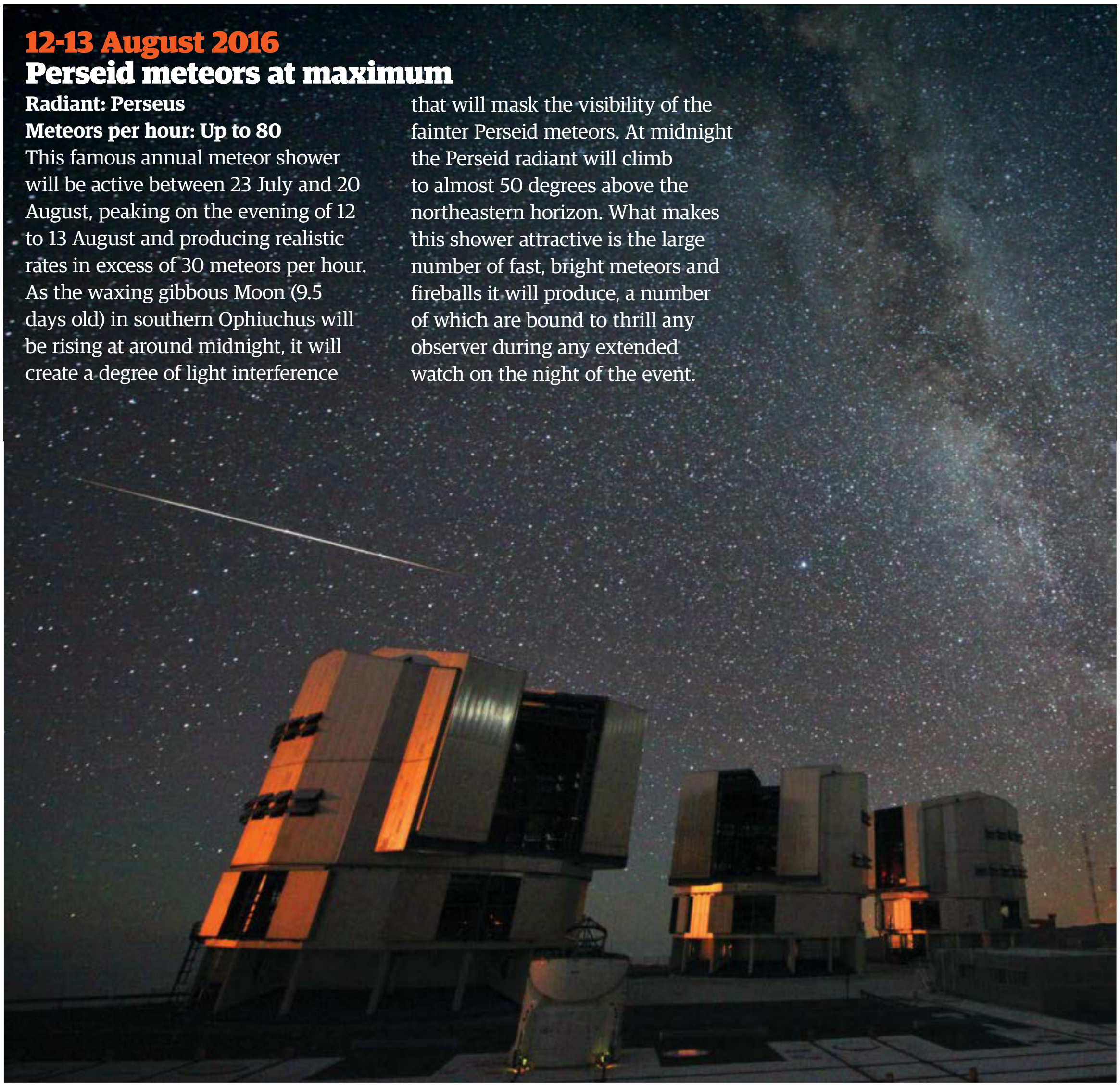
Right ascension: 21hr 27min 39sec
Declination: +9 deg 58min 38sec
Magnitude: +8.6
Optical aid: Binoculars

After taking a curving path through southwestern Pegasus, minor planet Pallas will come to opposition just four degrees west of the star Epsilon Pegasi (magnitude +2.4) and a little over two degrees south of the globular cluster M15 (magnitude +7.5). The minor planet will be a good 48 degrees above the southern horizon at midnight, but it will by no means be a conspicuous object - at magnitude +8.6 it will be well below naked eye visibility and will require a good star chart to identify it among the brighter stars that neighbour it. But it can be seen this opposition through 10x50 binoculars in the same field of view as Epsilon Pegasi and star cluster M15.

12-13 August 2016
Perseid meteors at maximum

Radiant: Perseus
Meteors per hour: Up to 80

This famous annual meteor shower will be active between 23 July and 20 August, peaking on the evening of 12 to 13 August and producing realistic rates in excess of 30 meteors per hour. As the waxing gibbous Moon (9.5 days old) in southern Ophiuchus will be rising at around midnight, it will create a degree of light interference that will mask the visibility of the fainter Perseid meteors. At midnight the Perseid radiant will climb to almost 50 degrees above the northeastern horizon. What makes this shower attractive is the large number of fast, bright meteors and fireballs it will produce, a number of which are bound to thrill any observer during any extended watch on the night of the event.



27 August 2016
Conjunction between Venus and Jupiter

Constellation: Virgo
Optical aid: Naked eye/ binoculars / telescope

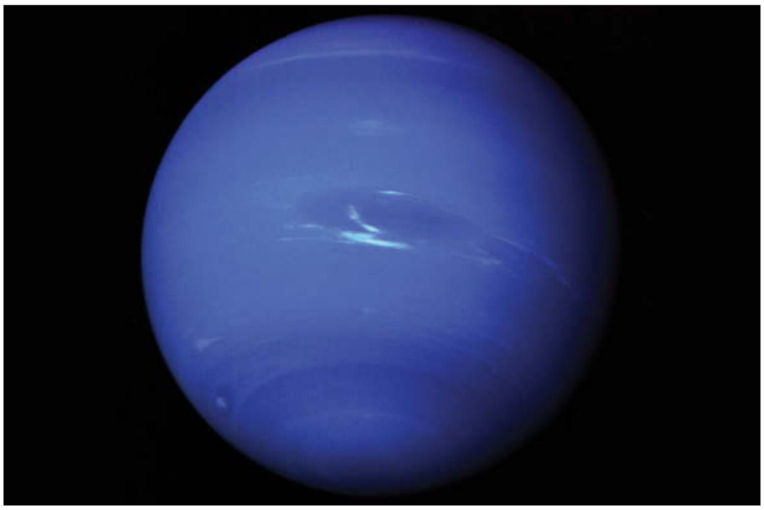
Low above the western horizon after sunset, there will be a wonderful close encounter between Venus (magnitude -3.9) and Jupiter (magnitude -1.7). This dusk spectacle will see the two planets separated by just eight arcminutes - around a quarter the apparent diameter of the Moon. Binoculars will show the conjunction nicely, and if you're quick enough to train your telescope on the event before the planets set, you'll be able to compare them closely - Jupiter's creamy white disc will make a splendid contrast with Venus' dazzling white gibbous disc.

SEPTEMBER

3 September 2016
Neptune at opposition

Constellation: Aquarius
Right ascension: 22hr 48min 48sec
Declination: -8 deg 29min 52sec
Magnitude: +7.8
Optical aid: Binoculars / telescope

Neptune will finally reach opposition on 3 September, where it will be directly opposite the Sun and near its closest position to Earth this apparition. Shining at magnitude +7.8, the distant giant planet will be located just one degree southwest of Lambda Aquarii (magnitude +3.7), and will be fairly easily seen through binoculars and within the field of view of a wide-angle eyepiece on a rich-field telescope. Even viewed at high power on a telescope, the apparent 2.4 arcsecond diameter of Neptune will appear as a little bluish dot.



15 September 2016
Neptune occultation

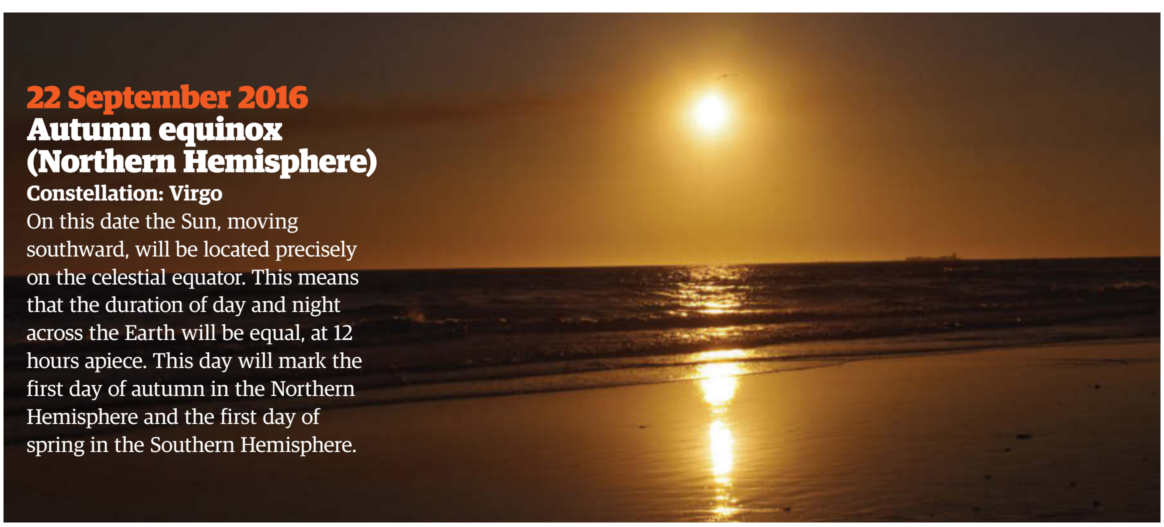
Neptune occultation
Time/best visible: 8.02pm and 8.50pm (BST)

On the evening of 15 September the planet Neptune will be hidden by the waxing gibbous Moon (13.7 days old). From southern England, Neptune will start to be hidden by the Moon's dark southwestern limb at around 8.02pm and the planet's 2.4 arcsecond disc will take around six seconds to disappear. At this time, the Moon will be around eight degrees above the southeastern twilight horizon. Neptune will then reappear at the Moon's bright southeastern limb at 8.50pm, when the Moon will have risen to 15 degrees in the darkening twilight skies.

16 September 2016
Penumbral lunar eclipse

Time/best visible: 7.30pm to 9.50pm (BST)

A penumbral lunar eclipse will take place on 16 September. This event occurs when the Moon passes through the Earth's partial shadow, or penumbra; this kind of eclipse sees only a slight darkening of the full Moon, so it will by no means be a spectacular visual event. From southern England the Moon, located in eastern Aquarius, will rise in the southeast at around 7.30pm, around an hour and a half after the penumbral eclipse begins. At maximum eclipse at 7.54pm, the Moon will be almost completely covered by Earth's faint penumbral shadow and will lie just three degrees above the horizon. The eclipse will end at 9.54pm.



22 September 2016
Autumn equinox (Northern Hemisphere)

Constellation: Virgo

On this date the Sun, moving southward, will be located precisely on the celestial equator. This means that the duration of day and night across the Earth will be equal, at 12 hours apiece. This day will mark the first day of autumn in the Northern Hemisphere and the first day of spring in the Southern Hemisphere.

28 September 2016
Mercury at greatest western elongation

Constellation: Leo
Magnitude: -0.4
Optical aid: Naked eye / binoculars / telescope

Mercury will reach its greatest western elongation from the Sun in the morning skies of 28 September, some 17.9 degrees from the Sun. The planet will rise in the east at around 5.30am (BST) and will climb to an altitude of 14 degrees by sunrise, more than an hour and a half later. This favourable morning apparition of the innermost planet will make it relatively easy to spot in the predawn skies.

OCTOBER

1 October 2016
Jupiter occultation

Time/best visible: 5.55am and 6.55am (BST)

On the morning of 1 October the planet Jupiter will be hidden by the almost-new Moon (29.3 days old). From southern England, Jupiter will be hidden by the lunar limb at around 8.02pm, the planet's 2.4 arcsecond disc will take around six seconds to disappear. At this time the Moon will be around eight degrees above the southeastern twilight horizon. Jupiter will reappear at the Moon's bright southeastern limb at 8.50pm, the Moon by then having risen to some 15 degrees above the southeastern horizon in darkening twilight skies.

12 October 2016
Uranus at opposition

Constellation: Pisces
Magnitude: +5.7
Optical aid: Telescope

The blue-green planet, Uranus, will be at its closest approach to Earth and its face will be fully illuminated by the Sun. The planet will appear brighter than any other time of the year and will be visible all night long on the night of 15 October. This will be the best time to view Uranus. Due to its distance, the planet will only appear as a tiny blue-green dot in all but the most powerful telescopes.

16 October 2016
Supermoon

Constellation: Cetus
Optical aid required: Naked eye

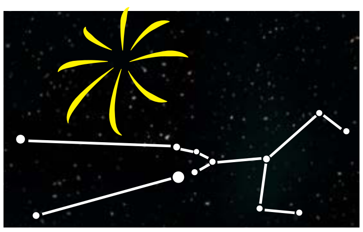
The full Moon on the evening of 16 October will take place only 19 hours before perigee, when the Moon is at its closest point in its orbit of Earth. Known as a 'supermoon', the full Moon (in northeastern Cetus) will rise in the east at around 7pm. The Moon will appear somewhat larger than the 'normal' full Moon, with an apparent diameter of 33.37 arcminutes. This will be the first of two consecutive supermoons in 2016.

21-22 October 2016
Orionid meteors at maximum

Radiant: Orion
Meteors per hour: Up to 25

The Orionid meteor shower will be active between 16 and 30 October, peaking on the night of 21 to 22 October. At midnight the radiant will be nearly 30 degrees above the eastern horizon, and the presence of a last quarter Moon (22 days old) in Cancer may well restrict the visibility of any fainter Orionids. However, many Orionid meteors are fast and pretty bright, so a vigilant observer in a dark-sky location after midnight could expect to view around ten or more meteors per hour.

NOVEMBER



4-5 November 2016
Taurid meteors at maximum

Radiant: Taurus
Meteors per hour: Up to ten

The Taurids shower runs annually from 20 October to 30 November, peaking this year on the night of 4 November. The shower, characterised by slow meteors with occasional bright examples, will be fairly favourable because the first quarter Moon will set just after midnight, so dark skies will be available for viewing in the morning, with a radiant high above the southeastern skies.

14 November 2016
Supermoon

Constellation: Taurus
Optical aid: Naked eye

The full Moon will take place only two hours after perigee, when the Moon is at its closest point in its orbit of Earth. Known as a 'supermoon', the full Moon (in western Taurus) will rise in the east at around 5pm. It will appear somewhat larger than the 'normal' full Moon, with an apparent diameter of 33.6 arcminutes. This will be the second supermoon in 2016.

17-18 November 2016
Leonid meteors at maximum

Radiant: Leo
Meteors per hour: Up to 20

With an annual limit of activity between 15 and 20 November, the Leonid meteors will peak on the 17 to 18 November. Leonids are very swift and bright meteors, leaving persistent trails. This year the waning gibbous Moon (18.6 days old) will rise at 7.45pm and its light may prevent many fainter Leonids from being detected. However, a vigilant watch from a dark-sky location is likely to reveal up to ten Leonids per hour. The meteor radiant will rise after midnight to more than 50 degrees, as dawn twilight sets in.

DECEMBER

6 December 2016
Occultation of Neptune

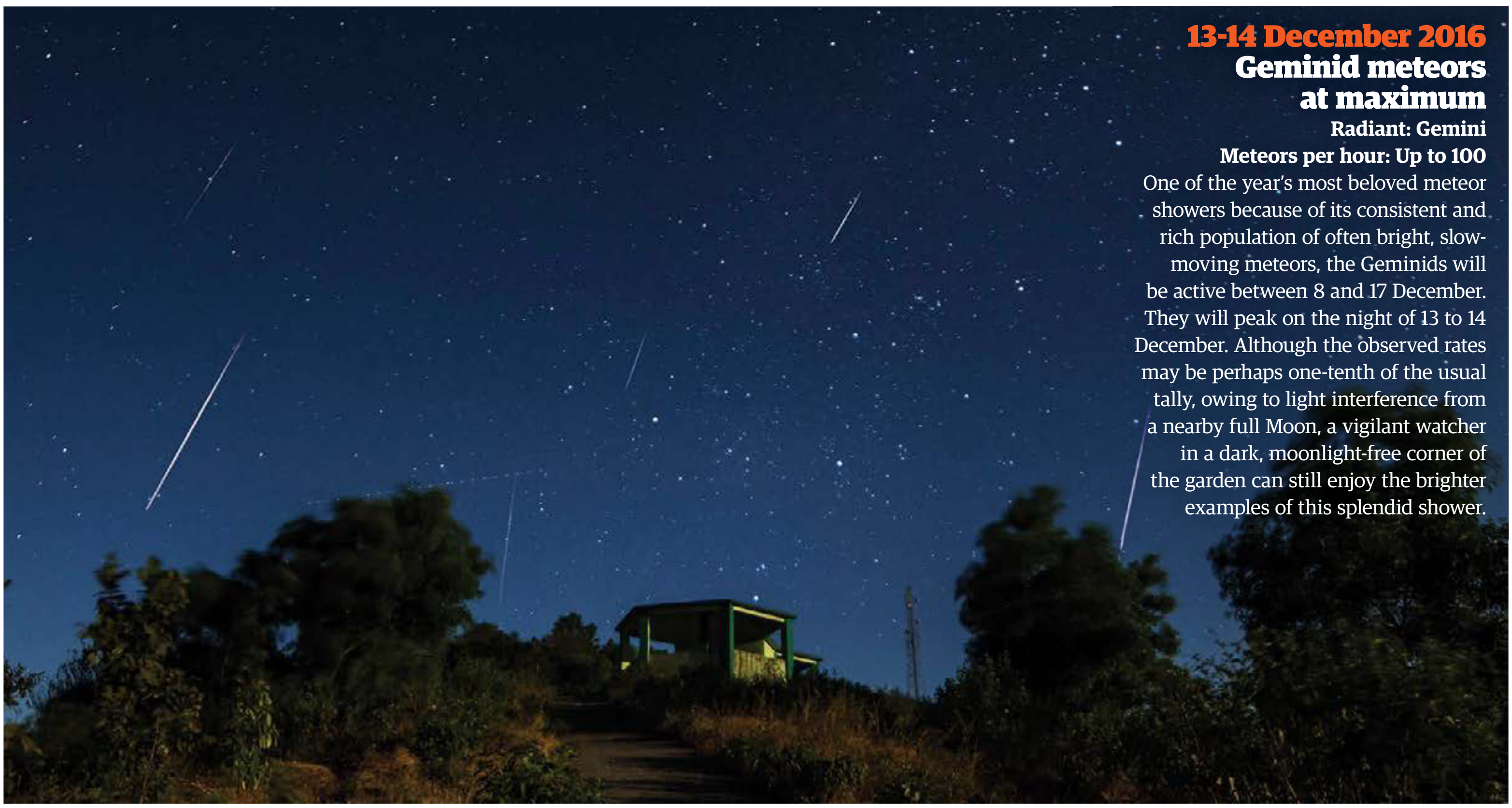
Constellation: Aquarius
Magnitude: +7.9
Optical aid: Binoculars / telescope

On the late evening of 6 December, the planet Neptune will be hidden by the dark western limb of the waxing crescent Moon (6.9 days old) at around 10.38pm. At this time, the Moon will be around five degrees above the southwestern horizon, so this will present quite a challenge for keen observers. Unfortunately, Neptune's later emergence from the bright lunar limb will not be visible in UK skies because the Moon will have set long beforehand.

11 December 2016
Mercury at greatest eastern elongation

Magnitude: -0.4
Optical aid: Binoculars / telescope

Mercury will reach its greatest eastern elongation from the Sun at 20.8 degrees. An evening object, the innermost planet will be just seven degrees above the southwestern horizon at the time of sunset at 4.15pm, shining at magnitude -0.4. This will not be the most favourable of UK apparitions of Mercury owing to the planet's low altitude, but the planet may be seen low to the horizon through binoculars or telescopes after sunset.



13-14 December 2016
Geminid meteors at maximum

Radiant: Gemini
Meteors per hour: Up to 100

One of the year's most beloved meteor showers because of its consistent and rich population of often bright, slow-moving meteors, the Geminids will be active between 8 and 17 December. They will peak on the night of 13 to 14 December. Although the observed rates may be perhaps one-tenth of the usual tally, owing to light interference from a nearby full Moon, a vigilant watcher in a dark, moonlight-free corner of the garden can still enjoy the brighter examples of this splendid shower.

13 December 2016
Occultation of Aldebaran

Magnitude +0.9
Optical aid: Binoculars / telescope

The brightest star in Taurus, Aldebaran will be hidden behind the dark northwestern edge of the waxing gibbous Moon (13.8 days old) at 5.20am on 13 December 2016. The occultation will take place some 13 degrees above the western horizon and will be visible to keen observers from dark-sky locations. Aldebaran will reappear at the bright northeastern lunar limb at around 5.58am, when the Moon will be visible at just seven degrees above the horizon. The sudden disappearance and later reappearance of Aldebaran can be enjoyed through binoculars or telescopes. Aldebaran is also known as the bright 'Eye of Taurus'.

21 December 2016
Winter solstice (Northern Hemisphere)

Constellation: Sagittarius

Winter December solstice will see the Sun reach its most southerly point along the ecliptic. Earth's south pole will be tilted toward the Sun, giving those in the Northern Hemisphere the shortest day and longest night of the year – London will see less than eight hours of daylight.

STARGAZER

Catch the International Space Station

Observe the ISS as Tim Peake, Yuri Malenchenko and Tim Kopra make their way to the artificial platform this month

The International Space Station (ISS) is a frequent feature in our skies. It's usually quite bright and is easily seen with the naked eye. It travels fast though, making it easy to miss unless you know when to expect it and where to look.

In orbit since 1998, the ISS is by far our largest artificial satellite and is crewed with up to six people from various nations, studying and experimenting in the microgravity environment of low-Earth orbit. Travelling at a blistering 27,600 kilometres (17,150 miles) per hour, it can appear and then disappear for an observer on the Earth's surface in a matter of minutes. In fact, it takes the ISS about 92 minutes to do one complete orbit of the Earth. How then can you spot the ISS, and what will it look like?

The ISS can look like a very bright, fast-moving star and can even be mistaken for an aircraft, although it has no navigation or other flashing lights. It will always seem to appear from the west and, depending on your location, will be seen to cross the sky low down near the horizon, or high overhead - or any place in between!

It can pass into the Earth's shadow, in which case it seems to fade out, or a good pass can mean it is visible from horizon to horizon. Since it is moving so quickly, you may be lucky enough to see two or even three passes in the course of an evening or early morning. This of course depends on the path the ISS is taking, where you are on the Earth in relation to it, and even the clarity of the sky above you. The orbital track, or path, of the ISS changes regularly so you won't see it every night, but you should get good visible passes approximately every six weeks if you stay in one location. Occasionally, you may get the chance to witness the ISS being joined by a Soyuz capsule carrying more crew to man the space station, or perhaps a re-supply vehicle. If this happens you will see two bright points of light closing in on one another, sometimes minutes apart or even very close together before they dock or separate.

In order to see the ISS, the first thing you need to know is when it will appear in the sky above you. This information is available from various websites and there are even some apps for smartphones and tablets that you can download, which will give you up to the minute information as to when the ISS will be viewable and where in the sky you should look in order to see it. You are going to need a clear night sky, or at least a minimal amount of cloud cover, if you are going to see it clearly.

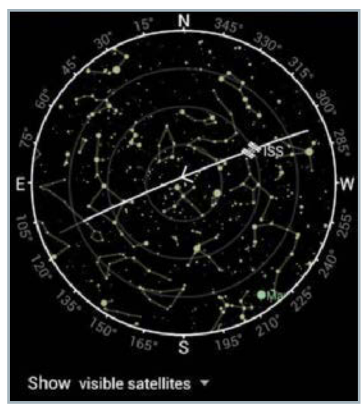
You will also need to make sure that you are out and observing for a good few minutes before it is due to appear. Don't forget to wrap up warm, even if you are only outside for a few minutes, and be patient - the ISS might not be visible at the exact time stated. It may be coming out of the shadow of the Earth, or it may need to climb above local obstructions such as mountains or even trees before it becomes visible to you. Seeing the ISS is great fun. Remember that there are people on board that tiny fast-moving point of light as it glides across the sky, so don't forget to wave!

Free ISS pass apps

ISS Detector Satellite Tracker
Available for: Android
Cost: Free

ISS Spotter
Available for: iPhone and iPad
Cost: Free

GoISSWatch
Available for: iPhone and iPad
Cost: Free



Heavens-Above
Available for: Android
Cost: Free

How to be prepared for the next ISS pass

Preparation is key for enjoyable observations of the International Space Station

1 Check the timings

Refer to a suitable website or app for the specific time that the ISS will pass over your region. The sky will need to be dark for you to be able to see it, so check the times of twilight if you need to as well.

2 Check the weather

The weather and cloud cover will be critical in determining whether you get a good observation of the ISS. A little cloud is okay but, of course, clear skies are much better!

3 Plan and prepare

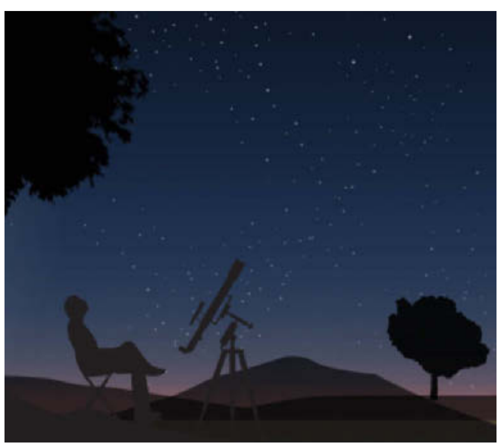
You'll find that observing the ISS is much more relaxed if you are well prepared. Dress appropriately and wrap up warm - it's surprising how cold you can get in just a few minutes.

4 Give yourself time

Go outside at least five minutes before the expected time of the ISS appearance. This will give you time to orientate yourself and will let your eyes adapt to the dark.

5 Find the right direction

You need to know which direction to face in order to see the ISS rise over the horizon. A compass will help if you are unsure of which way to look from your location.



6 Be patient

As the ISS sometimes has to climb over local landmasses, or perhaps even trees, you may need to wait a little longer than planned to see it. Don't worry, if everything else is right, you'll see it.

7 Enjoy and wave!

If you're seeing the ISS for the first time, or even if you have seen it 20 times, you'll probably never get over the thrill. It's especially exciting if you are observing it with children. Remember to wave!

Must-see Space Station passes

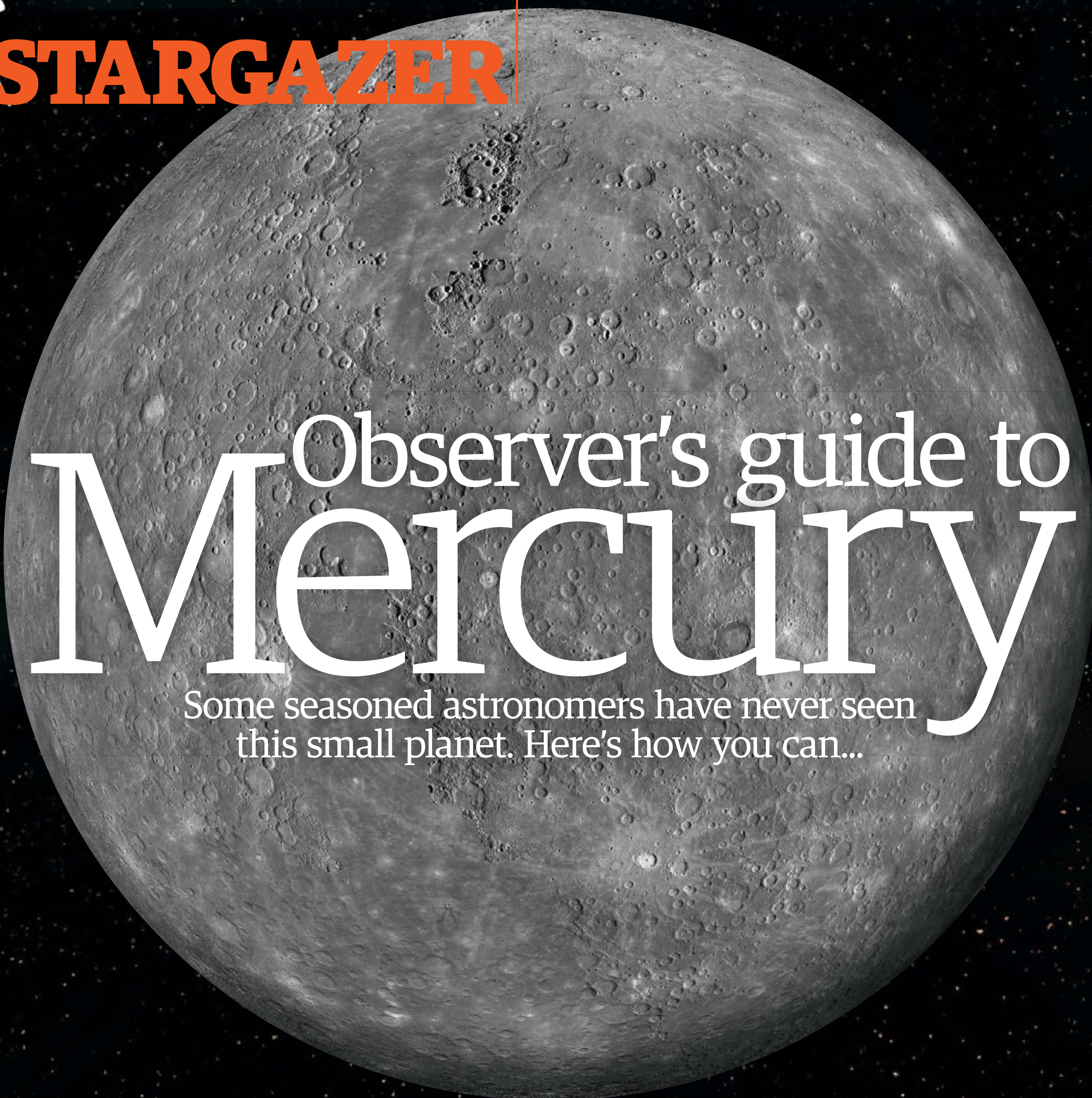
Northern Hemisphere (London)

Date	Start time	Direction
9 December 2015	17.58 GMT	SW
10 December 2015	17.50 GMT	WSW
11 December 2015	18.41 GMT	SW
12 December 2015	16.58 GMT	SSW
12 December 2015	18.33 GMT	W
13 December 2015	17.41 GMT	WSW
14 December 2015	16.47 GMT	WSW
14 December 2015	18.24 GMT	W
15 December 2015	17.33 GMT	W
16 December 2015	16.40 GMT	W
16 December 2015	18.16 GMT	W
17 December 2015	17.24 GMT	W
18 December 2015	18.08 GMT	W
19 December 2015	17.15 GMT	W
20 December 2015	17.59 GMT	W
21 December 2015	17.07 GMT	W
22 December 2015	17.52 GMT	SW
23 December 2015	16.59 GMT	WSW
25 December 2015	16.51 GMT	SSW

Southern Hemisphere (Darwin)

Date	Start time	Direction
3 December 2015	05.20 ACST	NNE
5 December 2015	05.11 ACST	NNW
6 December 2015	04.21 ASCT	ENE
7 December 2015	05.04 ACST	WSW
8 December 2015	04.14 ACST	SE
27 December 2015	20.19 ACST	NNW
29 December 2015	20.11 ACST	W
31 December 2015	05.09 ACST	S

Please note: Timings are approximate.
Please check for local information.



Observer's guide to Mercury

Some seasoned astronomers have never seen this small planet. Here's how you can...

In Greek mythology, Mercury was the messenger of the gods and was quick and elusive. This is probably where the nearest planet to the Sun got its name, orbiting the Sun in just 88 days. Because of this, it is never very far from the Sun in our skies and regularly shifts its location from either the east side or the west side of the Sun. The furthest point east or west, known as an elongation, is therefore the best time to try to see the planet.

To further complicate matters, the altitude above the horizon, above which Mercury can be seen, can also change, and so not every elongation is favourable for viewing it. This is due to the angle of the ecliptic path - the path that the Sun and planets appear to take across the sky - changing as we in turn orbit the Sun. When the ecliptic path has a steep angle to the horizon, then we usually get favourable elongations of Mercury and therefore stand a much better chance of seeing it.

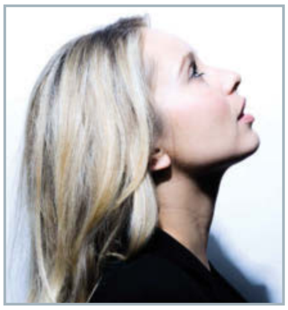
Because of all this, Mercury is only ever visible in twilight skies, either just after sunset or just before dawn, depending on whether it is going through an eastern or western elongation. Above all else, if you hope to see this little and elusive planet, you will need to have very clear skies and a clear horizon, with no trees or buildings in the way. Twilight, of course, makes it all the harder to spot, but it is not too difficult if you know where you should be looking.

But a warning needs to be issued here. Do not attempt to go looking for Mercury with any optical aid, such as binoculars, a telescope or even a camera, until after the Sun has fully set or a minute or two before dawn, as it would be very easy to accidentally catch the sunlight in your optics, with all the inherent risks to your eyes that may bring. Desktop planetarium software such as *Stellarium*, will give you a good indication of where you should be able to find the planet on any given date or time, which should help considerably.

To the naked eye, Mercury will look like a moderately bright star, glowing in the twilight with a pinkish hue. Binoculars will show it as something non-stellar, although it will take more magnification than binoculars can usually give to show it as an appreciable disc. Binoculars though, are very helpful in actually locating the planet. Scanning the area in slow steady lines, sometimes called 'sweeping', is an effective method of picking up Mercury in the twilight sky. Once it's located, it is much easier to find it again. A small telescope will show its true nature. Mercury will be seen as having distinct phases, like that of the Moon, depending on how far along it is into its orbit around the Sun. This will change over the few days that Mercury will be viewable. At its greatest elongation, the point that it is furthest from the Sun from our point of view, it will show a half phase. In other words, half the disc will be illuminated. It will also be at its brightest.

Larger telescopes with higher magnification will show a larger disc of the planet and the phase will be easier to see. But the blurring effects of our atmosphere will make imaging Mercury a challenge through a telescope. Unfortunately, Mercury is just too small and far away to show any features other than its phase in amateur telescopes, but don't let that put you off taking a look. This fascinating world has many secrets yet to be revealed and surprisingly few amateur astronomers have laid their eyes on it. ■

What can I expect to see?



Naked eye
Not far above the horizon and just after sunset, you should see a moderately bright star.

10x50 binoculars
Binoculars will make it easier to spot Mercury, which looks like a tiny version of the Moon.

Small telescope
A small telescope will enable you to view the phase of Mercury quite clearly.

Medium telescope
A medium-sized telescope will show the disc of Mercury quite well, as well as its phase.

Large telescope
Mercury appears very bright through a large aperture scope, with a distinct phase.

Mercury is found quite near to the Sun in our skies. It is only ever visible in twilight skies, just after sunset or just before dawn, depending on whether the planet is going through an eastern or western elongation

What's in the sky?

With the arrival of the long winter nights, now is the perfect opportunity to observe a variety of night-sky treasures

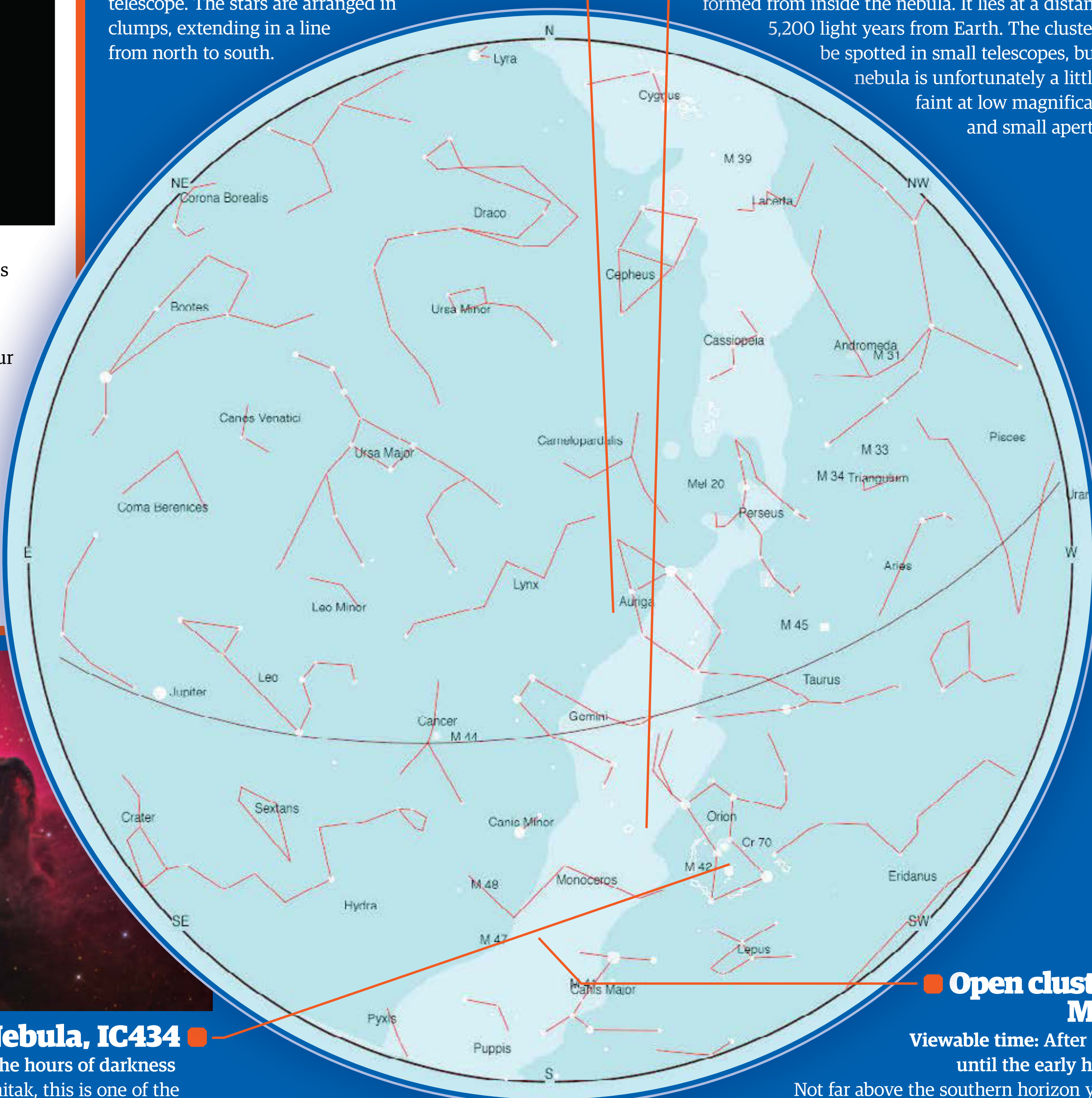
Using the sky chart

Please note that this chart is for midnight mid-month and is set for 45° latitude north or south respectively.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.



Northern Hemisphere

Open cluster, NGC 2281

Viewable time: After dark until just before dawn

A medium-sized but not well-defined open cluster found in the constellation of Auriga the Charioteer. It's just detectable with the naked eye from a clear dark site and shows up in binoculars or a small telescope. The stars are arranged in clumps, extending in a line from north to south.

Open cluster, NGC 2244

Viewable time: All through the hours of darkness

NGC 2244 is the star cluster that resides in the Rosette Nebula in the constellation of Monoceros the Unicorn. It's believed to be a relatively young cluster of only around five million years old, with the stars having formed from inside the nebula. It lies at a distance of 5,200 light years from Earth. The cluster can be spotted in small telescopes, but the nebula is unfortunately a little too faint at low magnifications and small apertures.

The Horsehead Nebula, IC434

The Horsehead Nebula, IC434

Viewable time: All through the hours of darkness

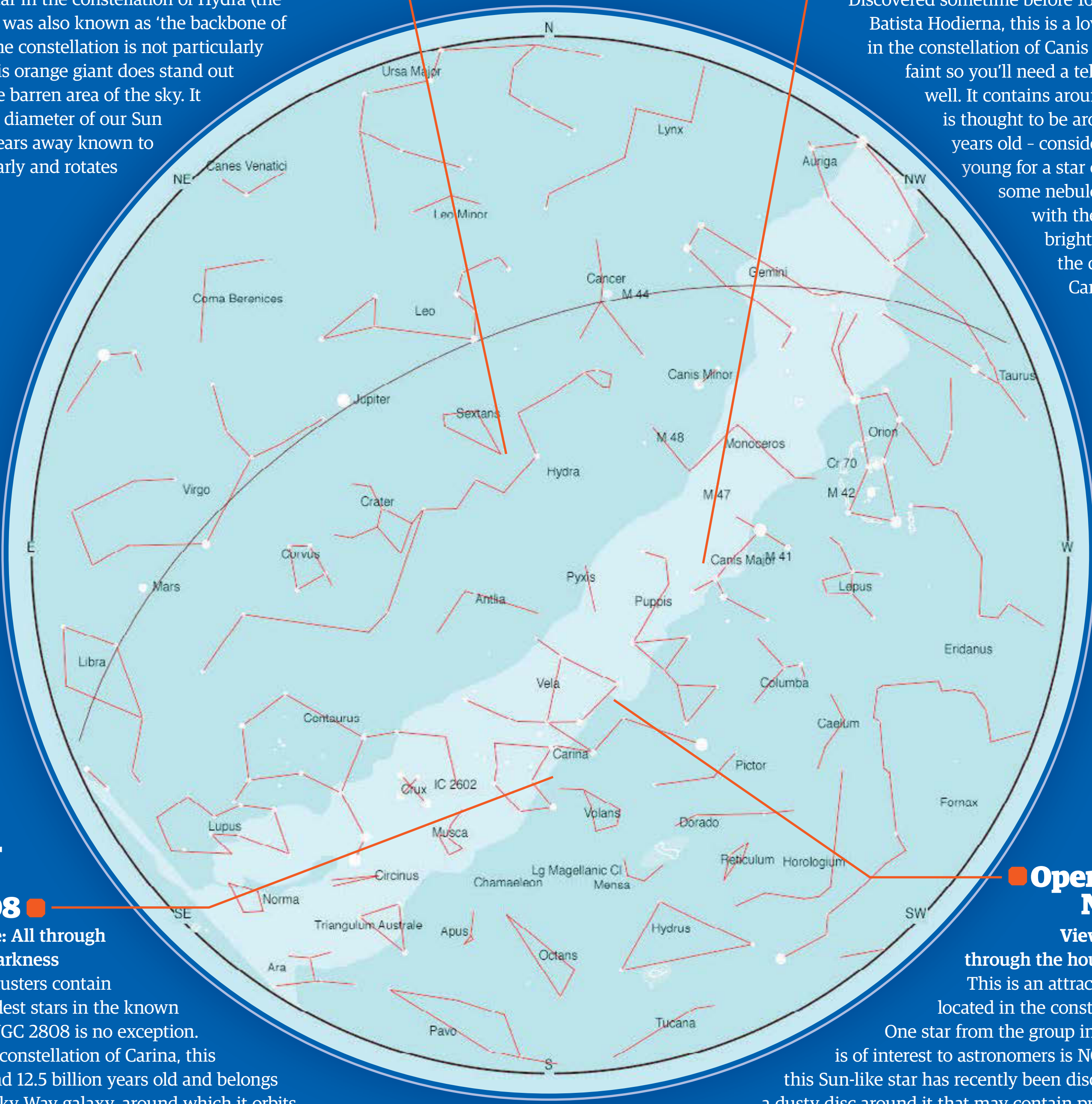
Found near the bright star Alnitak, this is one of the most famous nebula in the night sky and one of the most difficult to see. It's 'dark' nebula, silhouetted against an already faint nebula further away. You'll need a large aperture telescope to see it, and a H-Beta filter. It shows up well in long-exposure astrophotographs.

Open cluster, M47

Viewable time: After dark until the early hours

Not far above the southern horizon you'll find the constellation of Puppis., which was once part of a very large constellation known as Argo Navis, the ship of Jason and the Argonauts. The cluster was discovered in 1771 by Charles Messier, whose catalogue number it now bears. It can be seen as a faint misty patch.

Southern Hemisphere



Alpha Hydrae (orange giant star)

Viewable time: All through the hours of darkness

Alphard, meaning the 'solitary one' in Arabic, is the brightest star in the constellation of Hydra (the Watersnake). It was also known as 'the backbone of the serpent'. The constellation is not particularly notable, but this orange giant does stand out in an otherwise barren area of the sky. It is 50 times the diameter of our Sun and 177 light years away known to pulsate irregularly and rotates on its axis.

Star cluster, NGC 2362

Viewable time: All through the hours of darkness

Discovered sometime before 1654 by Giovanni Batista Hodierna, this is a lovely star cluster in the constellation of Canis Major. It's fairly faint so you'll need a telescope to see it well. It contains around 60 stars and is thought to be around 25 million years old - considered to be quite young for a star cluster. There is some nebulosity associated with the cluster too. Its brightest star is given the designation Tau Canis Major and is visible to the naked eye.

Globular cluster, NGC 2808

Viewable time: All through the hours of darkness

Globular star clusters contain some of the oldest stars in the known universe and NGC 2808 is no exception. Located in the constellation of Carina, this cluster is around 12.5 billion years old and belongs to our own Milky Way galaxy, around which it orbits. It rests some 31,300 light years away from Earth and is bright enough to be seen in binoculars. A small telescope will resolve many of the outer stars in the group.

Open cluster, NGC 2547

Viewable time: All through the hours of darkness

This is an attractive star cluster located in the constellation of Vela. One star from the group in particular that is of interest to astronomers is NGC 2547-ID8, as this Sun-like star has recently been discovered to have a dusty disc around it that may contain protoplanets. It is thought the dust was created by asteroid collisions. Studying this cluster, which is located about 1,200 light years away, can help us understand the formation of our own Solar System.


Globular cluster, NGC 2808


Open cluster, NGC 2547

Me & My Telescope

Send your astronomy photos and pictures of you with your telescope to **photos@spaceanswers.com** and we'll showcase them every issue

Warren Keller

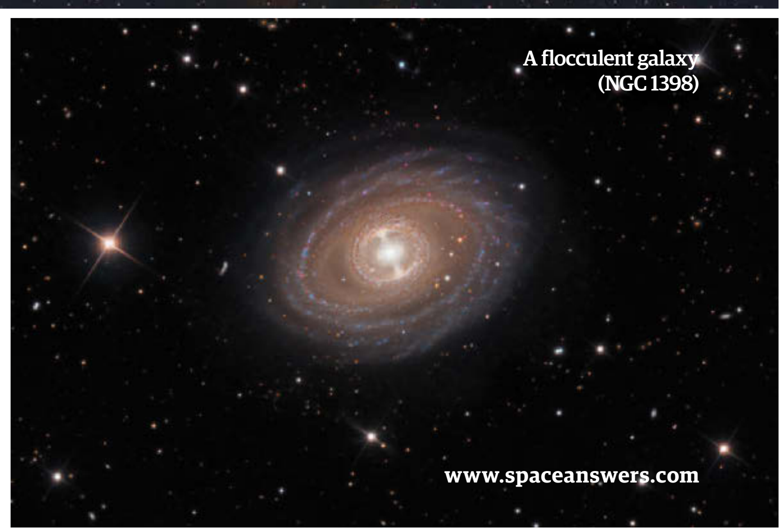
West Virginia, USA
Telescope: 16" RCOS Ritchey-Chrétien (University of North Carolina owned)

"A child of the 1960s, *Star Trek*, *2001: A Space Odyssey*, I boldly went with my heroes 'where no man [has] gone before', and I never really touched-down again. I began exploring the night sky at 15 years old with an 8-inch Newtonian and I knew from the moment I received Fred Hoyle's book entitled *Astronomy*, that I would someday photograph the wonders of the skies above.

"I started out using film in 1998 and then I switched to a charged-coupled device (CCD) in 2003. I am artistic by nature, so for me it's less about the cosmology and more about the thrill of the hunt for the myriad of beautiful shapes and colours throughout the universe."

Rosette Nebula (NGC 2237)

Horsehead Nebula (Barnard 33)



A flocculent galaxy (NGC 1398)

Terry Hancock

Michigan, USA
Telescope: 12" Ritchey-Chrétien reflector & Takahashi E180 Astrograph

"My interest in astronomy and photography began some 40 years ago in Australia. Inspired by the late Sir Patrick Moore, my first telescope was a 4.5-inch Newtonian and I enjoyed many nights in the pollution-free, dark southern night skies of the hot Australian outback. It was often so dark that the Milky Way cast a shadow on the ground.

"The skies are mediocre in western Michigan where I now observe from in the evenings. I pride myself in taking really long exposure astrophotographs of deep-sky objects and always try to maintain a natural look to my images."

The Cygnus Wall and North America Nebula (NGC 7000)

A large solar prominence lifting off the limb of the Sun

Samuel Bleyen

Dublin, Ireland
Telescope: Solarscope SV-60 Solarview H-alpha

"My personal interest in astronomy began when I was a teenager. Although I do a great deal of astronomy during the night - observing galaxies, nebulae, star clusters, planets and various constellations - my real passion for the subject lies with solar observing. Using my solar telescope, and a Canon EOS 600D DLSR camera, I photographed a large prominence lifting off the solar limb back in July. The Sun was just about to set behind the rooftops and some clouds were gathering in the western horizon as well. The prominence lifted off quite suddenly and it was over in a few minutes - luckily I was in the right place at the right time."

Send your photos to... @spaceanswers photos@spaceanswers.com

STARGAZER

Stargazing stories

Tell us the story of how you got started in astronomy by emailing us at **photos@spaceanswers.com** for a chance to feature in **All About Space**


"Circumpolar star trails capture the rotation of the Earth with a long exposure and sturdy tripod"

Ronald Zincone

Location: Richmond, Rhode Island
Twitter: @ronaldzincone
Info: Astronomer for over 40 years
Current rig
Telescope: Meade 16-inch LightBridge Dobsonian
Mount: Alt-azimuth
Other: Canon EOS 60Da, ZWO ASI120MC CMOS camera

"Growing up, my real passion was photography with an interest in astronomy. One Christmas morning I received a Tasco 50X (variable power) #4VTE telescope. My Tasco took me on a never-ending cosmic journey. I have many fond memories of my older brother, Ray, and I observing the Moon and planets from our light-polluted neighbourhood. This sparked my passion for astronomy and my love for the Solar System grew.

"Fast forward to 1999 when my wife and I built our home in Richmond, Rhode Island - a rural dark-sky area away from light pollution, and where my passion for amateur astronomy was reignited. My next telescope and my first serious beginners scope was a Meade 4500 reflector. It had a 4.5-inch mirror on an equatorial mount. That same year, I took my first step into astrophotography, combining my two passions. I started capturing celestial subjects, first using black and white film, then on to colour film, before settling on chrome film. Several telescopes - such as an astronomy society-made 10-inch Dobsonian, an 80mm ED Orion doublet refractor, a Meade 12-inch LightBridge, a Sky-Watcher 120mm ED APO and several cameras have passed through my hands. And, then I finally took the plunge and switched to digital in 2006. I never looked back.

"Today, my passion for astronomy and astrophotography still centres on the Moon and planets. After reading more than 50 books and spending countless hours in the field learning my craft and networking, I can say that it has paid off. I don't just mean the technical and artistic rewards, but also the enjoyment of experiencing the greatest hobby in the world!"


"Silhouetted trees under the northern lights"


"A single shot of the Moon taken at prime focus"

Ronald's top three tips

1. Find a dark sky
Visual astronomy and astro-imaging require a dark-sky location away from city light pollution - especially when imaging deep-sky objects such as galaxies and nebulae.

2. Start at the basics
If you are new to astrophotography, start with the basics. Mount your DSLR camera onto a photo tripod, remove shutter release and use a 24mm to 50mm lens.

3. Practice!
Astrophotography is a science and an art - to master it involves a steep learning curve. There is no substitute for hands-on learning, so get under the sky and practice.

"Photography and astronomy lovers can combine their two passions with the right equipment"

Send your stories and photos to... @spaceanswers photos@spaceanswers.com

"Zodiacal light over Tenerife – I like to connect the sky with a landscape"

"A panoramic image of the Milky Way over Tenerife"

Stephen Cheatley

Location: Blackpool, Lancashire
Twitter: @StephenCheatley
Info: Astronomer for 4 years
Current rig
Telescope: Altair Wave 115ED Triplet refractor
Mount: Equatorial
Other: Nikon D800E camera

"I always had a little more than a passing interest in astronomy, although I knew very little about the night sky. However, it wasn't until after I'd watched – with great interest – the first series of *Stargazing Live* shown in 2011 that I decided to take my passion further and join my local astronomy club, the Blackpool and District Astronomical Society.

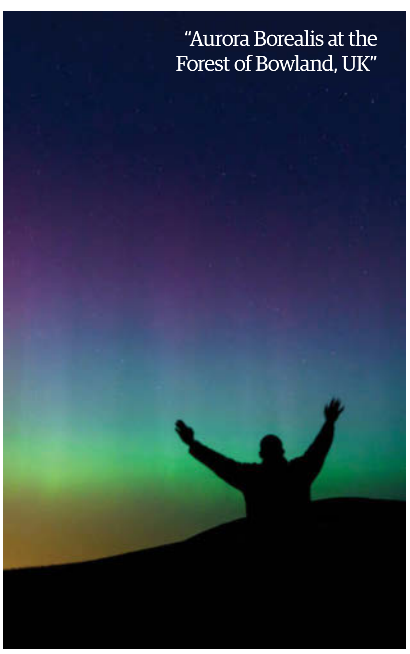
"Already having very good experience with photography, I was to find imaging the night sky a whole different ball game, but after a couple of years with the astronomy society I started to get to know good local dark-sky sites. My early astrophotography was poor, but it was a combination of my inexperience of the night sky, and not using the correct settings. As I progressed I even started to book holidays specifically for astronomy and astrophotography, travelling to places like Arizona, Tenerife, the Isle of Man and Cornwall – booking the trips around the times of new Moon phases, which wouldn't have ever crossed my mind previously.

"One of my most memorable holidays was to Sutherland in South Africa. I had seen it featured on the second series of *Stargazing Live* and I got to see amazing things like Omega Centauri, the Southern Cross and the Magellanic Clouds for the first time. They looked every bit as stunning as I thought they would.

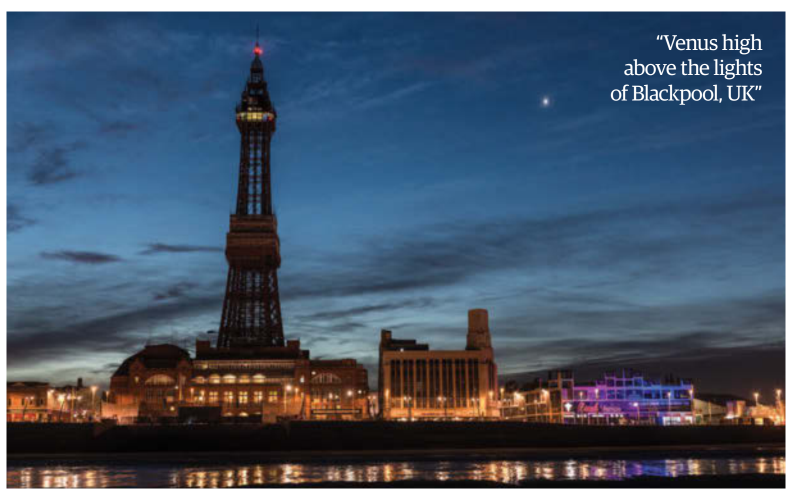
"One of my aims of DSLR astrophotography is to connect the sky with a landscape, or landmark. I always think that a popular, or well-known ground subject adds to the image because many people will relate to it better. Recently I was lucky enough to witness and capture the Aurora Borealis for the third time in 18 months from my local dark-sky site, just 30-minutes from Blackpool. Now my images regularly appear in publications and I have featured on national television twice this year talking about my astrophotography.

"The list of objects and rare events which I have seen in the last four years is very long. Things like the Aurora, solar and lunar eclipses, meteors and fireballs, distant galaxies and many more. I'm certainly hoping to visit the USA for the total solar eclipse in 2017. I can only look forward to seeing more astronomical events in the future and will continue to try and think of unique ways in which to capture them. I will certainly never tire of it."

"A Lunar eclipse at Blackpool tower, UK"



"Aurora Borealis at the Forest of Bowland, UK"



"Venus high above the lights of Blackpool, UK"

Celestron Ambassador 80AZ

Ideal for observing the lunar surface and bright night-sky targets, this stunning brass refractor is sure to impress casual astronomers

Telescope advice

Cost: £975 / $1471
From: David Hinds Ltd
Type: Reflector
Aperture: 3.15"
Focal length: 31"

Best for...

- Intermediate
- High budget
- Planetary viewing
- Lunar viewing
- Bright deep-sky objects

Without a doubt, the Celestron Ambassador 80AZ is one of the most beautifully crafted telescopes we have had the chance to review in **All About Space** – almost entirely made of brass, polished to a high finish and affixed to a mahogany tripod.

Due to the stunning appearance of the telescope, which also features a brass star diagonal eyepiece barrel, as well as brass-finished lens caps, it seems a shame to pack it away after use – if you have the room, the Celestron Ambassador 80AZ doubles up as an ornament for your home and will certainly be a conversation starter. While its appearance does look old-fashioned, this refractor is versatile in that it accepts the standard 1.25-inch astronomical eyepieces and, given our daytime views, we found that the optics are of good standard, providing decent clarity and contrast.

Setting the Ambassador 80AZ up was nothing short of a breeze, however, we did take extra care in putting the refractor together given its more 'unusual' materials. The tripod is sturdy, thanks to an accessory tray affixed securely to the legs using washers, wing nuts and machine screws. However, once we had set everything up and began moving the telescope out for a night of observations, it became quite awkward to carry, forcing us to remove the accessory tray and only attach it to the tripod once we had reached an observing spot. This made the set-up that little more time-consuming – due to fiddly washers – and we had to take special care in setting it up under very minimal light. Slewing the telescope across various sections of the sky, we noted that its mount operated smoothly in its altitude movement but, at first, we found that the azimuth direction was a tad stiff until we loosened the nut on the underside of the mount head.

> "An ideal refractor for casual observing and a beautiful brass ornament for the home"

We did also find that the mount on this telescope makes it difficult to observe any higher than half way up in the night sky (about 45 degrees to the zenith), so we were limited to what we could observe with this telescope and with the included 25mm eyepiece. Many may be used to using a Crayford focuser to bring views through a telescope into focus, however, the Ambassador 80AZ sharpens sights of targets using a Rack-and-Pinion focuser that works well, but may take some getting used to if you are unfamiliar with using one.

Given its location in the sky, a first quarter Moon, with a 53 per cent illuminated surface was an ideal target to observe with the Ambassador 80AZ. Views of the lunar seas such as Mare Crisium (Sea of Crises), Mare Fecunditatis (Sea of Fertility) and Mare Tranquillitatis (Sea of Tranquillity) looked beautiful through the refractor, with very good resolution and high contrast, as did the craters that stood out along the terminator. The craters Aristoteles, Janssen, Piccolomini and Theophilus in particular caught the Sun's light very well and were a pleasure to observe through the telescope's optics. During our observations, we noted the sturdiness of the mahogany wood tripod, which seemed to resist any shaking as we brought lunar surface features into view using the focuser. Sadly, as with many refractors, we experienced a degree of colour-fringing – also known as chromatic aberration.

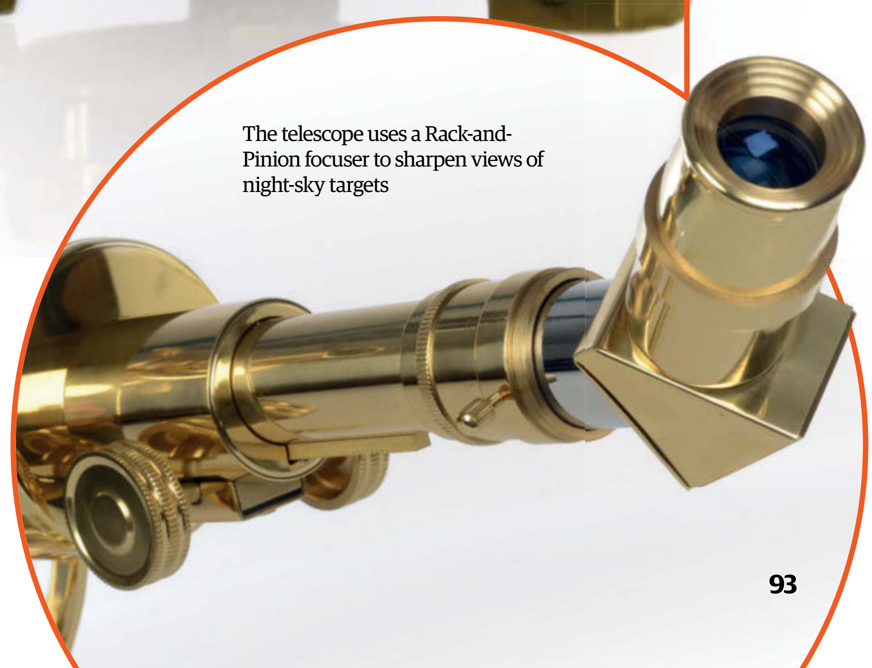
The Celestron Ambassador 80AZ is ideal for casual observing as well as serving as a beautiful ornamental piece. While the optics of this refractor are very good compared to other brass telescopes that we have used, we wouldn't recommend this

The Ambassador 80AZ is supplied with a beautifully coated 25mm eyepiece, which is optically sound

The optical capacity of this refractor is good for casual observing of the night sky

With its polished brass appearance, the Ambassador 80AZ makes for a stunning ornamental piece

The telescope's mount operated smoothly in the altitude direction but, at first, the azimuth direction was quite stiff



The telescope uses a Rack-and-Pinion focuser to sharpen views of night-sky targets

telescope for those just starting out in astronomy since it doesn't have the light gathering capacity of many instruments on the market.

The 1.25-inch eyepiece holder offers versatility in terms of increasing the magnification of the telescope, but we found that we had to be careful in how high we pushed the instrument to its limit - too high and we received blurry views of the lunar surface. The telescope promises to last for many observing sessions to come, however, only if lightly used. Since it is mainly comprised of brass, low temperatures will cause the brass to shrink, so we advise being selective of when and where it is used - it would be best to have a 'sturdier' telescope to hand if you are looking to observe a variety of objects in the Solar System and deep-sky categories for hours on end.

WIN ASTRONOMY KIT

Courtesy of: OPTICAL HARDWARE

WORTH £1100!

Keen to get started in astronomy?
We have the ideal competition for you!

Visionary FirstView table top telescope
From: Optical Hardware Ltd
Cost: £49.99 (approx. $75)
Already preassembled, the FirstView is ideal for touring the Moon's surface and the brightest planets with its 76mm aperture.

Olivon ED eyepieces
From: Optical Hardware Ltd
Cost: From £89.99 (approx. $136) each
Ideal for use with the Olivon T800 spotting scope, the 1.25" Olivion ED eyepieces (5mm, 12mm and 18mm) allow for excellent viewing of a selection of night-sky and deep-sky targets, and this range from Olivon are suitable for use with a wide range of telescopes.

Visionary Mira Ceti 150 1400 telescope
From: Optical Hardware Ltd
Cost: £299.99 (approx. $463)
With its six-inch aperture, this is the perfect companion to observe various night-sky and deep-sky targets. Complete with 25mm and 6.5mm eyepieces, as well as a Barlow lens and Moon filter, this compact and light Newtonian offers excellent portability.

Visionary Nature Detective 10x50 binoculars
From: Optical Hardware Ltd
Cost: £35 (approx. $52)
The Visionary Nature Detective binoculars offer excellent light-gathering ability in order to pick out objects, from star clusters to the brightest planets. The 10x magnification also allows these binoculars to be used as an aid for nature-watching during daylight hours.

Olivon Spotting Scope T800 20-60x80
From: Optical Hardware Ltd
Cost: £349.99 (approx. $530)
Featuring a multi-coated, high-resolution 20-60x80 zoom eyepiece, as well as with BAK4 prisms for exquisite, crisp and clear views of bright night-sky objects, the T800 is ideal for those just breaking into astronomy. With a fully waterproof and fog-resistant design, the T800's rugged build promises to last for years of observations.

Philip's Guide to The Night Sky
From: Waterstones
Cost: £5.99 (approx. $9)
Phillip's Guide to The Night Sky is a complete guide for a newcomer to astronomy. The late Moore explains how to find the most famous constellations and the brightest of stars and when to look out for them. Clear star maps, which show the stars visible to the naked eye, assist with navigating the night sky in Britain. Ireland, northern Europe and Canada.

To be in with a chance of winning, all you have to do is answer this question:

What does E-ELT stand for?

A: European Extremely Large Telescope

B: Eurasia's Even Larger Telescope

C: ESO's Extremely Large Telescope

Enter online at: **spaceanswers.com/competitions** Visit the website for full terms and conditions

Astronomy kit reviews

Stargazing gear, accessories and books for astronomers and space fans alike

Book

Insight Astronomy Photographer of the Year: Collection 4

Cost: £25 (approx $38)
From: Harper Collins

You don't need to have any technical appreciation of photography or astronomy to be blown away by the night-sky images printed in this book, which are the result of the Astronomy Photographer of the Year – the biggest international competition of its kind – and in association with Royal Observatory Greenwich.

Featuring a foreword from comedian, impersonator and amateur astronomer Jon Culshaw, we're taken on a tour of a variety of night-sky views – from the spectacular Milky Way to the breath-taking aurorae and this year's total solar eclipse – from different locations all over the world. Given the vibrancy and detail of these images, you might be surprised to learn that some of the astronomers who took them are relatively new to astrophotography. With every page featuring a glossy finish, this coffee table book certainly doesn't disappoint and it was a pleasure to read about how the photographer captured the image along with their thoughts on the view from behind the camera lens. A simple yet impressive collection, contributed by amateur astronomers of various levels, with a fair price. We highly recommend this fourth instalment of *Insight Astronomy Photographer of the Year.*

Magnifier

Celestron 10x illuminated magnifier

Cost: £37 (approx $55)
From: David Hinds Ltd

The Celestron 10x illuminated magnifier is aimed at a variety of hobbyists, whether you enjoy studying stamps, coins, plants, rocks or insects. However, we think that this handy device also has some uses for astronomers too. Namely for quality control of kit such as telescopes and binoculars and getting better views of sky maps. Once we had plugged in a pair of AA batteries, we were good to go and began observing sections of maps and charts.

The multi-coated glass triplet lens combined with the bulb illumination worked very well, increasing light transmission and delivering bright images with a pleasing amount of detail. If your eyesight isn't brilliant, or you are trying to read a map in a low-lit area, then this magnifier is ideal. What's more, it fits comfortably in the hand and is light enough to use for long periods of time.

Star diagonal
Altair Astro 1.25" diagonal

Cost: £49.99 (approx $75.50)
From: Altair Astro

With its sleek finish, the Altair Astro 1.25" diagonal from Altair Astro is pleasing to the eye and sturdy to the touch. The barrels are of high quality, promising a long life and many observing sessions to come. Removing the 1.25" attachment, we were disappointed to find that there was a mass of sticky residue where the optical system has been stuck together.

This didn't affect the functionality of the diagonal and we achieved pleasing and comfortable views through this piece of kit, combined with our in-house telescope's excellent optical system. We were able to slot our eyepieces in with ease and without damaging their barrels, however, we were quite disappointed with the price of the diagonal, especially since you can buy other diagonals that do the same job, and to a high standard, elsewhere on the market.

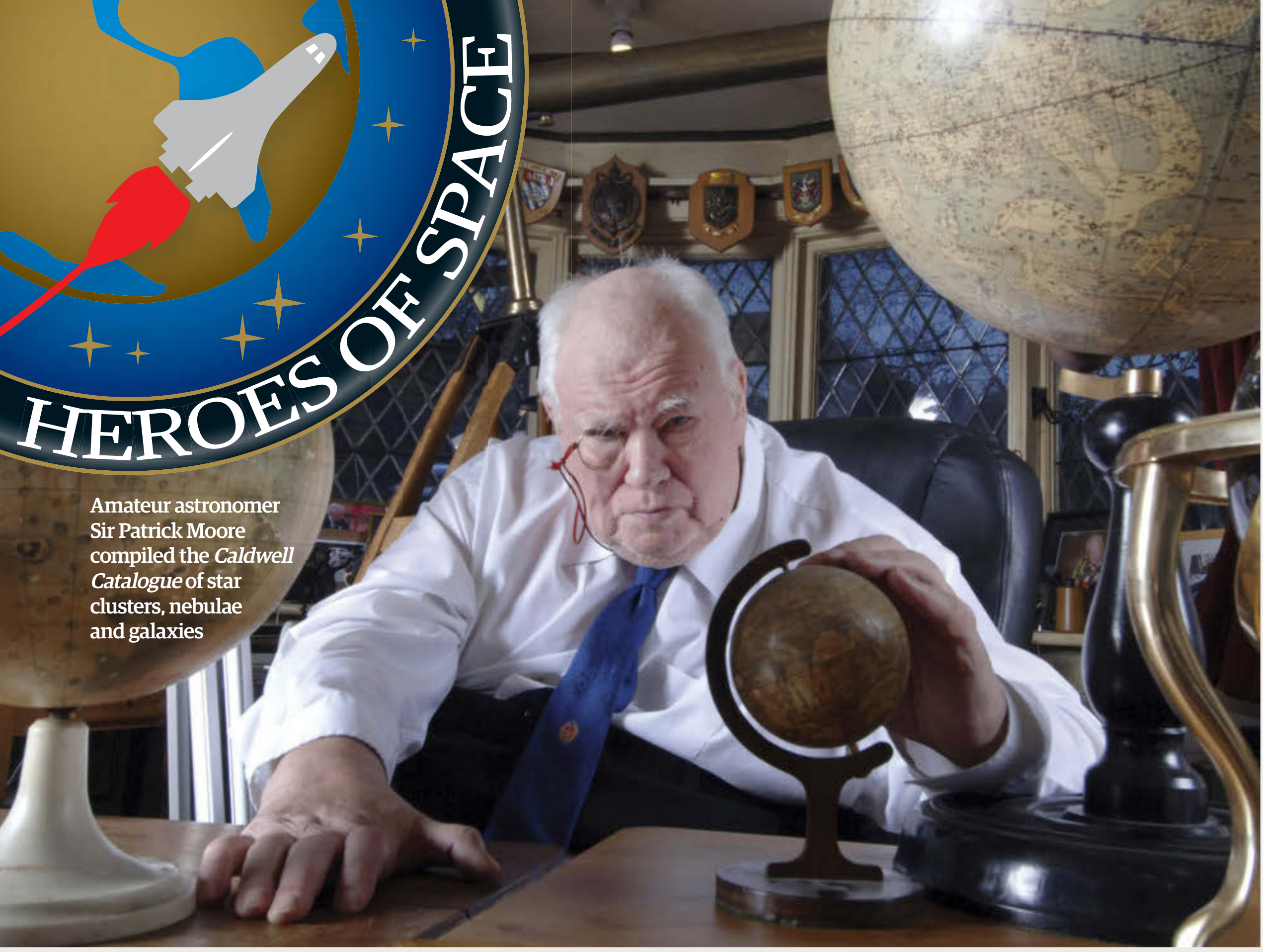
Tripod
Celestron CPC 800

Cost: £487 (approx $735)
From: David Hinds Ltd

As we anticipated from Celestron, the CPC 800 certainly lived up to our expectations. Beautifully manufactured and extremely strong, this heavy-duty tripod provides a superb foundation for astrophotography and general observing.

In order to test it to the maximum, we observed the night sky during a breezy evening. Attaching the mount and tube of the Celestron NexStar 8SE and training the telescope on the +0.03 magnitude star Vega, we stepped away from the instrument and examined its resilience to a mildly buffeting wind. Pleasingly, the tripod didn't shake or wobble during this time. Additionally as we got the mount's motor up and running, slewing it from one target to the next, we noticed only mild shaking as Vega vibrated in the field of view. We imagine that this exquisite mount safeguards from clumsiness, however, we wouldn't put this to the test!

As expected, the mount is heavy and gets even heavier when attached to a GoTo. The central eyepiece holder is also quite precarious if it isn't carefully put in place.



Amateur astronomer Sir Patrick Moore compiled the *Caldwell Catalogue* of star clusters, nebulae and galaxies

Sir Patrick Moore

The stargazing television presenter with an idiosyncratic style, whose fascination with space was infectious

As the presenter of the *BBC*'s *The Sky At Night* programme, Sir Patrick Moore was the voice and face of space in the UK for 55 years, an impressive feat which not only earned him a spot in the *Guinness World Records,* but the admiration of some of the world's best known astronomers.

He began his on-air duties on 24 April 1957, quickly gaining an eccentric reputation, not least in part for his trademark monocle, boundless energy, great humour and unique machine-gun way of imparting his knowledge. His strength was an amazing ability to effortlessly explain complex subjects to audiences: one of his best moments being the comparison of the Milky Way to a fried egg. He would also frequently exclaim, "we just don't know," serving a timely reminder that there was still so much to learn.

Such an approach was infectious and Sir Patrick's on-screen longevity – he missed just one episode due to illness in July 2004 – meant that he was ideally placed to witness and enthusiastically commentate on some of the most important moments of space exploration in the 20th century. Six months after the show began, for instance, the world's first artificial Earth orbiting satellite, Sputnik, was launched. It was very well timed and it helped to usher in the modern space era. Sir Patrick was therefore around for every high and low of the following decades of space exploration. He would go on to be one of the *BBC* commentators of the Moon landings in 1969 and his show attracted guests including astronauts Neil Armstrong and Buzz Aldrin. The stargazer gained the confidence of the unlikeliest of people: the Russians allowed him to show photographic results from their Luna 3 probe in 1959 – a time when the Soviet Union was deemed the enemy. He also gripped viewers in 1986 during the approach of Halley's Comet.

Yet for all of his vast astronomical science knowledge and enthusiasm, Sir Patrick was actually a fiercely proud, self-taught amateur. Born in Pinner, Middlesex on 4 March 1923, the stargazer had become interested in space at the age of six after his mother handed him a copy of *The Story of the Solar System* by G F Chambers. By the age of 11, he had learned enough to become the youngest ever member of the British Astronomical Association and he delivered his first paper to members two years later. But rather than attend Cambridge University, he lied about his age and joined the Royal Air Force during World War II. After he left the RAF in 1947, he became a freelance writer. Yet by concentrating on books about astronomy, he built his reputation. He would go on to write more than 70 astronomical books, including text books and tomes about the Solar System. Much of his work would be crucial to furthering human understanding of space.

Not only was he the editor of the *Yearbook of Astronomy* from 1962 to 2011, Sir Patrick had a passion for the Moon and noted many features on the far side that would add a great deal to astronomical knowledge. Together with H P Wilkins, the director of the Lunar Section of the British Astronomical Association, he mapped the Moon with observations made by himself and others which were used by NASA. He wasn't averse to science fiction, though: he wrote novels under the pen name R T Fishall. And some children better knew him for his role as *GamesMaster* in the *Channel 4* programme of the same name.

But space is what he will be most remembered for. Without Sir Patrick – the reluctant teacher as he called himself – many people may not have been inspired to turn their thoughts skywards. He was appointed OBE in 1968, CBE in 1988 and was knighted in 2001 but his election as an honorary fellow of the Royal Society touched him most. He died peacefully at home on 9 December 2012 following a battle with an infection, aged 89.

All About Space

Imagine Publishing Ltd
Richmond House, 33 Richmond Hill
Bournemouth, Dorset, BH2 6EZ
☎ +44 (0) 1202 586200
Web: www.imagine-publishing.co.uk
www.greatdigitalmags.com
www.spaceanswers.com

Magazine team

Features Editor **Gemma Lavender**
gemma.lavender@imagine-publishing.co.uk
☎ 01202 586209

Editor in Chief **Dave Harfield**
Designer **Jo Smolaga**
Assistant Designer **Briony Duguid**
Production Editor **Amelia Jones**
Research Editor **Jackie Snowden**
Photographer **James Sheppard**
Senior Art Editor **Duncan Crook**
Publishing Director **Aaron Asadi**
Head of Design **Ross Andrews**

Contributors
Ninian Boyle, David Crookes, Peter Grego, Robin Hague, Laura Mears, Dominic Reseigh-Lincoln, Giles Sparrow

Cover images
Tobias Roetsch, NASA, Robert Markowitz

Photography
Adrian Mann, Airbus Space and Defence, Alamy, Alex Alishevskikh, AURA, Boeing, B. Tafreshi, Celestron, CfA, Dana Berry, Department for Business, Innovation and Skills, ESA, ESO, F. Char, Gemini Observatory, IUCAA, Ivan Eder, JAXA, JPL-Caltech, MSFC, NASA, Orbital ATK, Rex Features, Robert Markowitz, Roscosmos, Samir Dhurde, Skyworks Digital, SOHO, Space Science Institute, SpaceX, SPL, S. Guisard, Tobias Roetsch, University of Arizona, USGS, WMAP Science Team

Advertising
Digital or printed media packs are available on request.
Head of Sales Hang Deretz
☎ 01202 586442
hang.deretz@imagine-publishing.co.uk
Account Manager Lee Mussell
lee.mussell@imagine-publishing.co.uk
☎ 01202 586424
Account Manager Jennifer Galvin
jennifer.galvin@imagine-publishing.co.uk
☎ 01202 586436

International
All About Space is available for licensing. Contact the International department to discuss partnership opportunities.
Head of International Licensing Cathy Blackman
☎ +44 (0) 1202 586401
licensing@imagine-publishing.co.uk

Subscriptions
☎ 0844 826 7321
Overseas +44 (0)1795 414 836
Email: allaboutspace@servicehelpline.co.uk
13 issue subscription (UK) – £46.25
13 issue subscription (Europe) – £56
13 issue subscription (USA) – £56
13 issue subscription (ROW) – £68

Circulation
Head of Circulation Darren Pearce
☎ 01202 586200

Production
Production Director Jane Hawkins
☎ 01202 586200

Finance
Finance Director Marco Peroni

Founder
Group Managing Director Damian Butt

Printing & Distribution
Wyndeham Peterborough, Storey's Bar Rd, Peterborough Cambridgeshire, PE1 5YS
Distributed in the UK and Eire by: Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
☎ 0203 787 9060
Distributed in Australia by: Network Services (a division of Bauer Media Group), Level 21 Civic Tower, 66-68 Goulburn Street, Sydney, NSW 2000
☎ + 61 2 8667 5288
Distributed in the Rest of the World by: Marketforce, 5 Churchill Place, Canary Wharf, London, E14 5HU
☎ 0203 148 8105

ISSN 2050-0548