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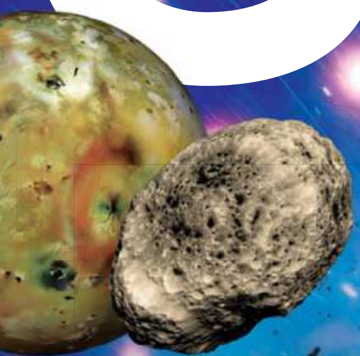

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ASTRONAUT TIM PEAKE RETURNS TO EARTH

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Meteorite Men's Geoff Notkin gives us advice on how to find a lump of space rock

Discover the wonders of the universe

If you're looking for a question that truly boggles the mind, then look no further than this issue – we've spoken to the scientists attempting to answer one of the greatest questions of all time: what happened before the birth of our universe? As expected, not all scientists agree on what's likely to have occurred before the existence of our time – some think our cosmos was made from colliding universes, while others are vouching for the notion that it has always existed. Of course, any one of these theories could be right, so I'll leave you to decide which one of the four takes your fancy over on page 16.

Elsewhere in the issue, Astronomer Royal Martin Rees tells us why we should be sending spacecraft to Alpha Centauri, our closest star system at 4.37 light years away. He's part of the recently announced Breakthrough Starshot project, alongside Facebook's Mark Zuckerberg, Stephen Hawking, astronaut Mae Jemison, author Ann Druyan and entrepreneur Yuri Milner, which will see super-fast spacecraft – no bigger than the palm of your hand – race to the distant star system at a breakneck speed of 20 per cent the speed of light. At this rate, we'd reach Alpha Centauri in under 25 years.

For those who miss the much-loved Space Shuttle that ferried astronauts to and from space between 1981 and 2011, I have some good news. They have kind of made a comeback – that is, in the form of several capsules and space planes thanks to the likes of NASA and private company SpaceX.

Last, but certainly not least, we caught up with Geoff Notkin, presenter of popular TV series *Meteorite Men*, to find out what it really takes to find a meteorite at the planet's most extreme locations, before welcoming astronaut Tim Peake back to Earth on page 34.

Gemma Lavender
Editor

Contributors

Kulvinder Singh Chadha

■ What happened before the Big Bang? Kulvinder finds out what could have existed prior to the birth of our universe according to recent research.

Jonathan O'Callaghan

■ Take a trip into space with the all-new space shuttles – the NASA, SpaceX and Boeing astrotaxis that are set to 'revive NASA's iconic spacecraft.

Giles Sparrow

■ There are some strange moons in our Solar System. Giles picks out our cosmic neighbourhood's wackiest – from Neptune's boomerang to the real-life Death Star, Mimas.

David Crookes

■ David gets the details on Project Starshot, a new venture to get us to Alpha Centauri. Turn to page 50 to discover how we will get there in about 20 years.

"Meteorites provide a snapshot of an existence before time as we know it – a Solar System or a universe that was just a dust cloud"

Geoff Notkin, presenter of *Meteorite Men* [page 64]

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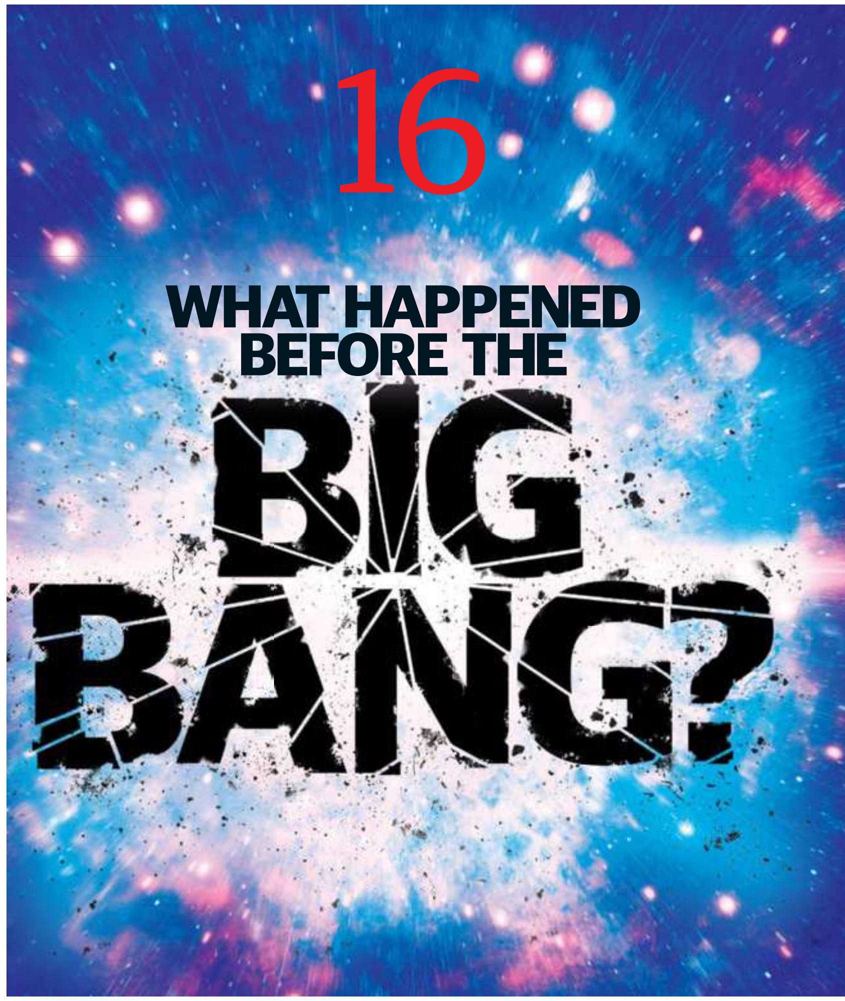
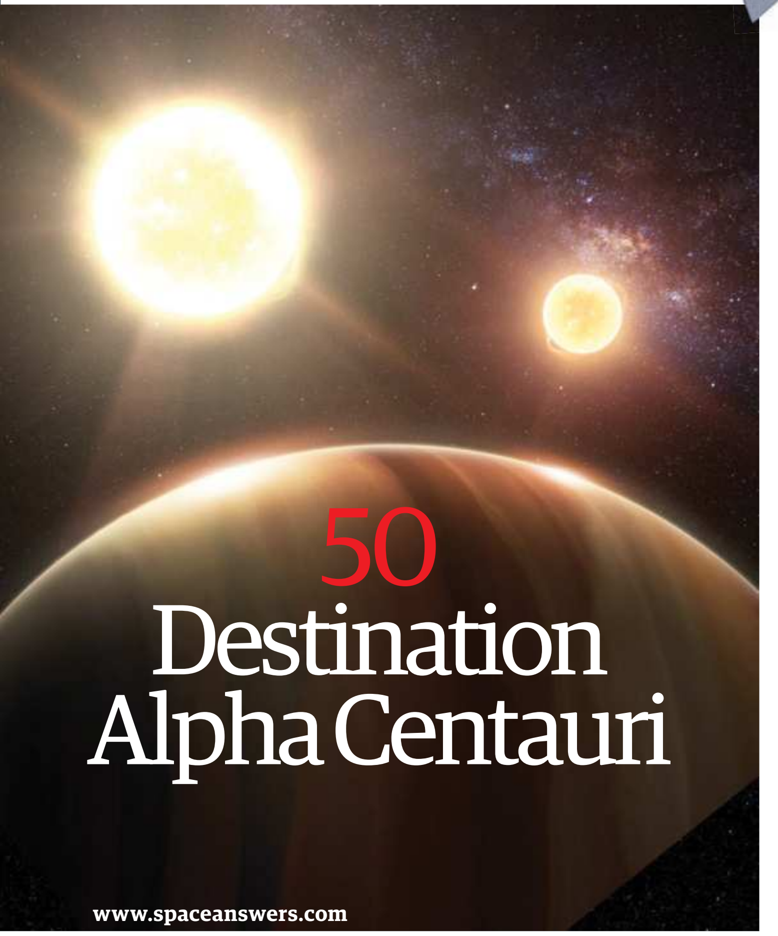


“When you see a shiny black meteorite on the ground and it’s only been on the Earth for two or three days, it’s exciting”



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Page 40

LAUNCH PAD

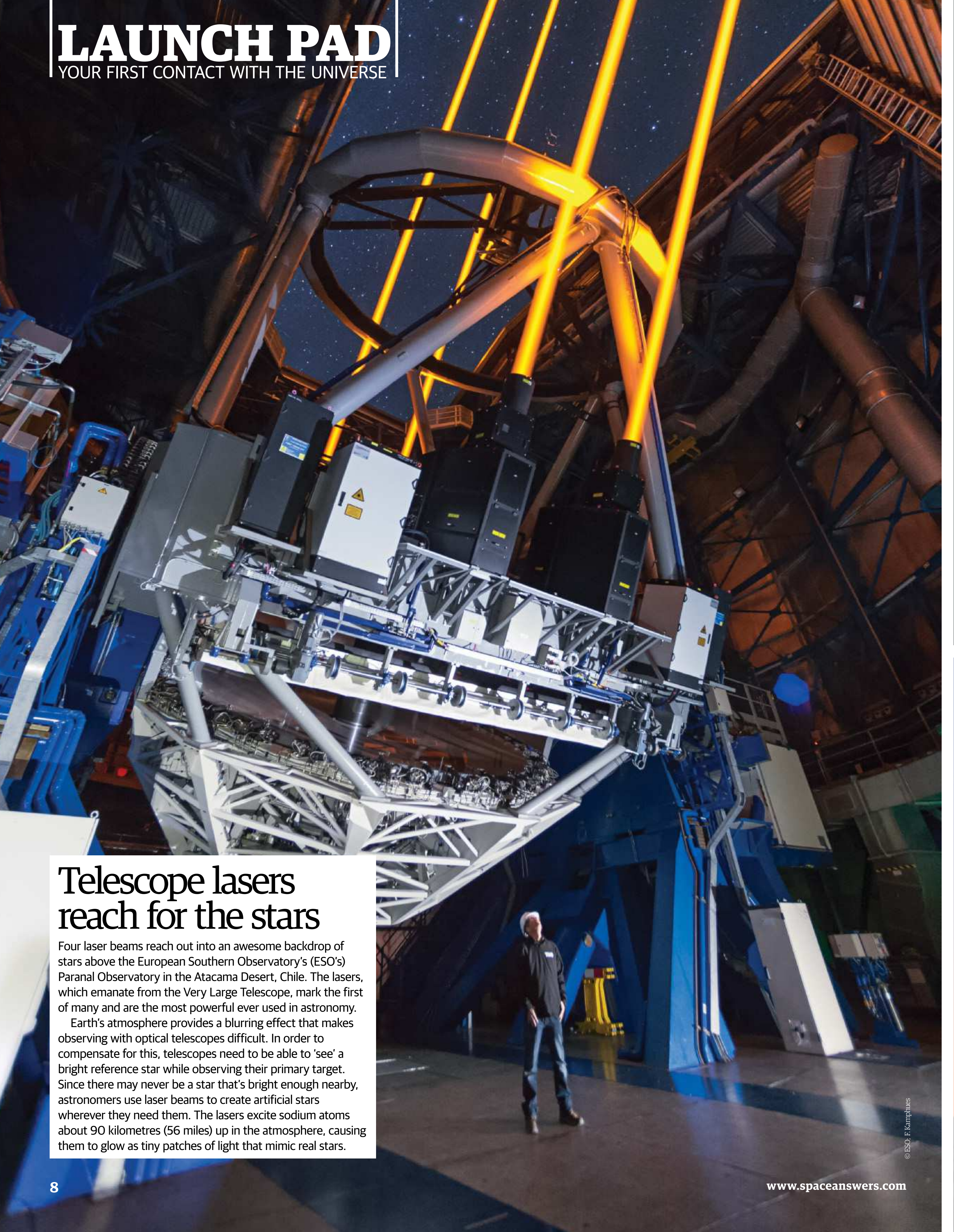
YOUR FIRST CONTACT WITH THE UNIVERSE

Curiosity's full circle from Mars' Naukluft Plateau

Using its Mast Camera, the Curiosity rover – as part of a long-term campaign to document the geology and landforms on the surface of the Red Planet – acquired a 360-degree panorama on top of Naukluft Plateau, which stands inside Gale Crater. The view that you can see combines dozens of pictures taken during the mission's 1,302nd sol, or Martian day.

The image, which is a scene dominated by remnants of a finely layered ancient sandstone deposit, is a change of pace since the rover first landed on the surface of Mars in 2012. Curiosity has traversed through terrains dominated by mudstones, some of which have contained mineral clays that suggest the ancient presence of water. However, the sandstones in this image are dominated by thick layers of windblown sand, suggesting that they were created during a much drier epoch.

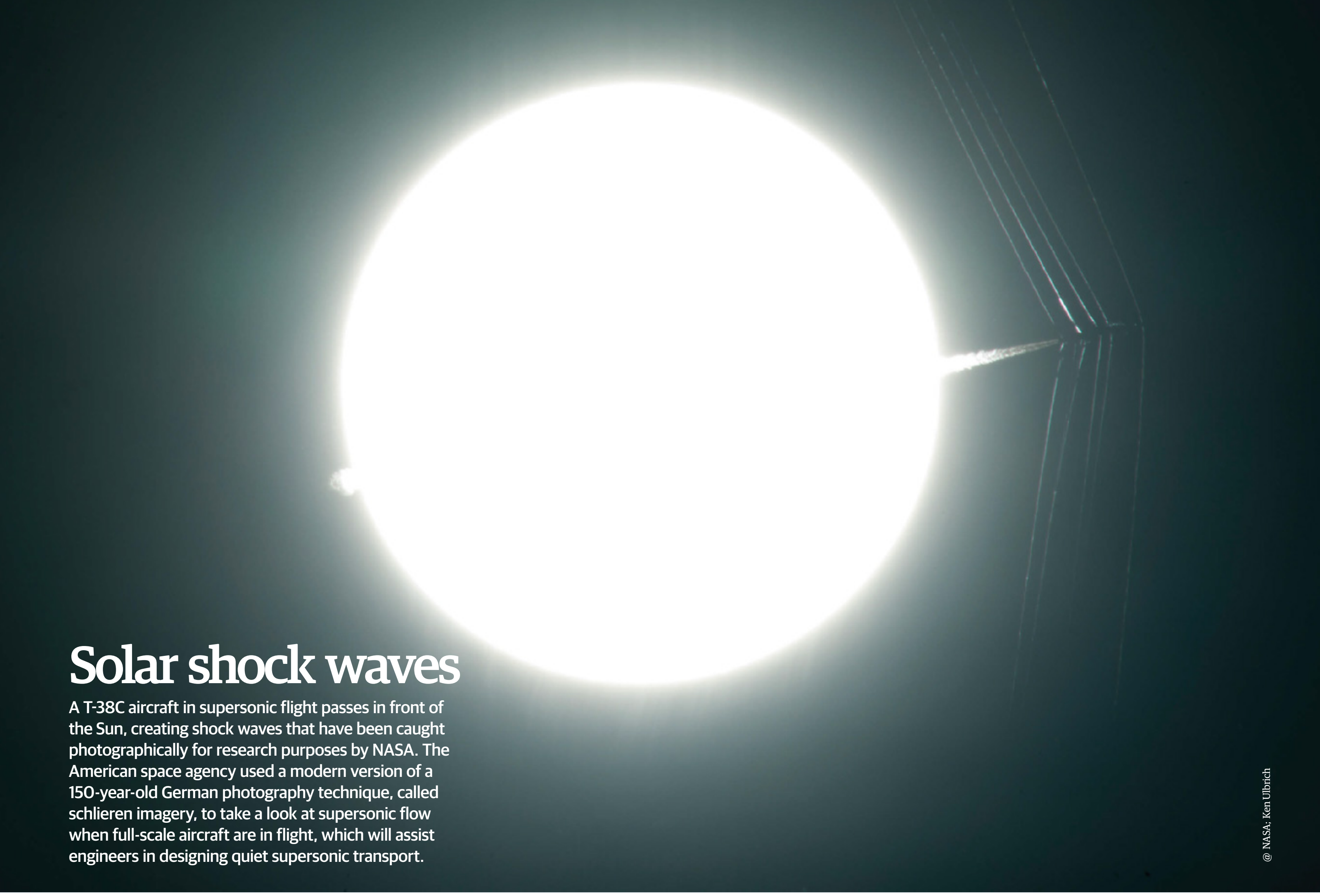

@NASA; JPL-Caltech; MSSS



Telescope lasers reach for the stars

Four laser beams reach out into an awesome backdrop of stars above the European Southern Observatory's (ESO's) Paranal Observatory in the Atacama Desert, Chile. The lasers, which emanate from the Very Large Telescope, mark the first of many and are the most powerful ever used in astronomy.

Earth's atmosphere provides a blurring effect that makes observing with optical telescopes difficult. In order to compensate for this, telescopes need to be able to 'see' a bright reference star while observing their primary target. Since there may never be a star that's bright enough nearby, astronomers use laser beams to create artificial stars wherever they need them. The lasers excite sodium atoms about 90 kilometres (56 miles) up in the atmosphere, causing them to glow as tiny patches of light that mimic real stars.



Solar shock waves

A T-38C aircraft in supersonic flight passes in front of the Sun, creating shock waves that have been caught photographically for research purposes by NASA. The American space agency used a modern version of a 150-year-old German photography technique, called schlieren imagery, to take a look at supersonic flow when full-scale aircraft are in flight, which will assist engineers in designing quiet supersonic transport.

© NASA; Ken Ulbrich

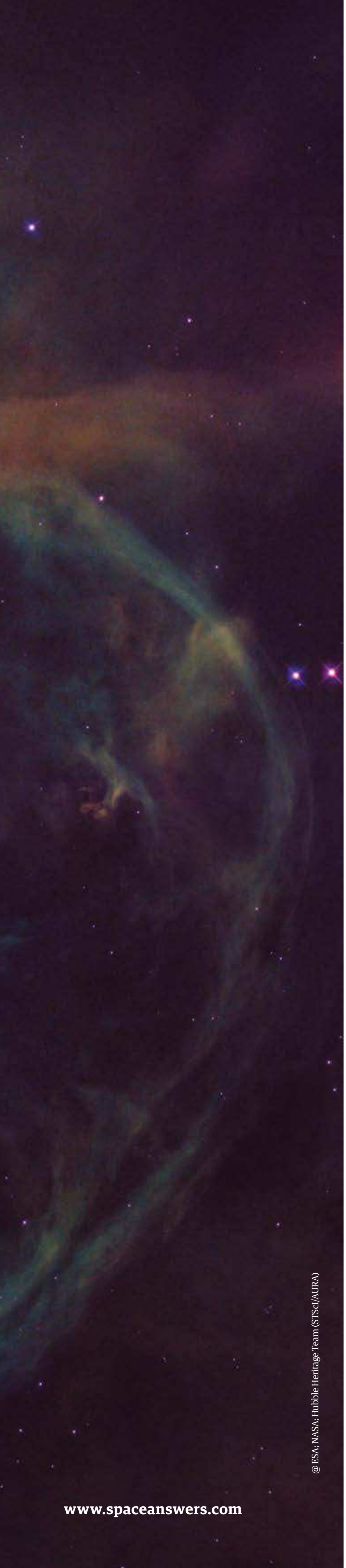
The Moon and Venus strike a sunrise pose

Two astrophotographers prepare their tripods and cameras for the superb display ahead – a crescent Moon and bright planet Venus in the superb orange shades brought about by the rising Sun. This spectacular moment was captured by ESO photo ambassador, Petr Horálek, who also brought the silhouette of the Very Large Telescope's Auxiliary Telescope into the field of view at the Paranal Observatory, Chile. Above the Chilean mountains, the full disc of the Moon is in view despite our companion in space being at its crescent phase. This is due to a phenomenon called earthshine, where the entire disc can be seen shining in the sunlight that has been reflected off the Earth.

© P. Horálek; ESO

Hubble spots a star 'inflating' its birthday balloon

NASA's Hubble celebrated 26 years in space last month and to add to the festivities, the space telescope imaged a giant space 'balloon' – an enormous bubble blown into space by a super-hot massive star. The feature is – quite fittingly – known as the Bubble Nebula and is roughly seven light years across, which is about 1.5 times the distance from the Sun to our nearest stellar neighbour, Alpha Centauri. The Bubble Nebula, which is also catalogued as NGC 7635, lies 7,100 light years from Earth in the constellation of Cassiopeia, the vain queen in Greek mythology.

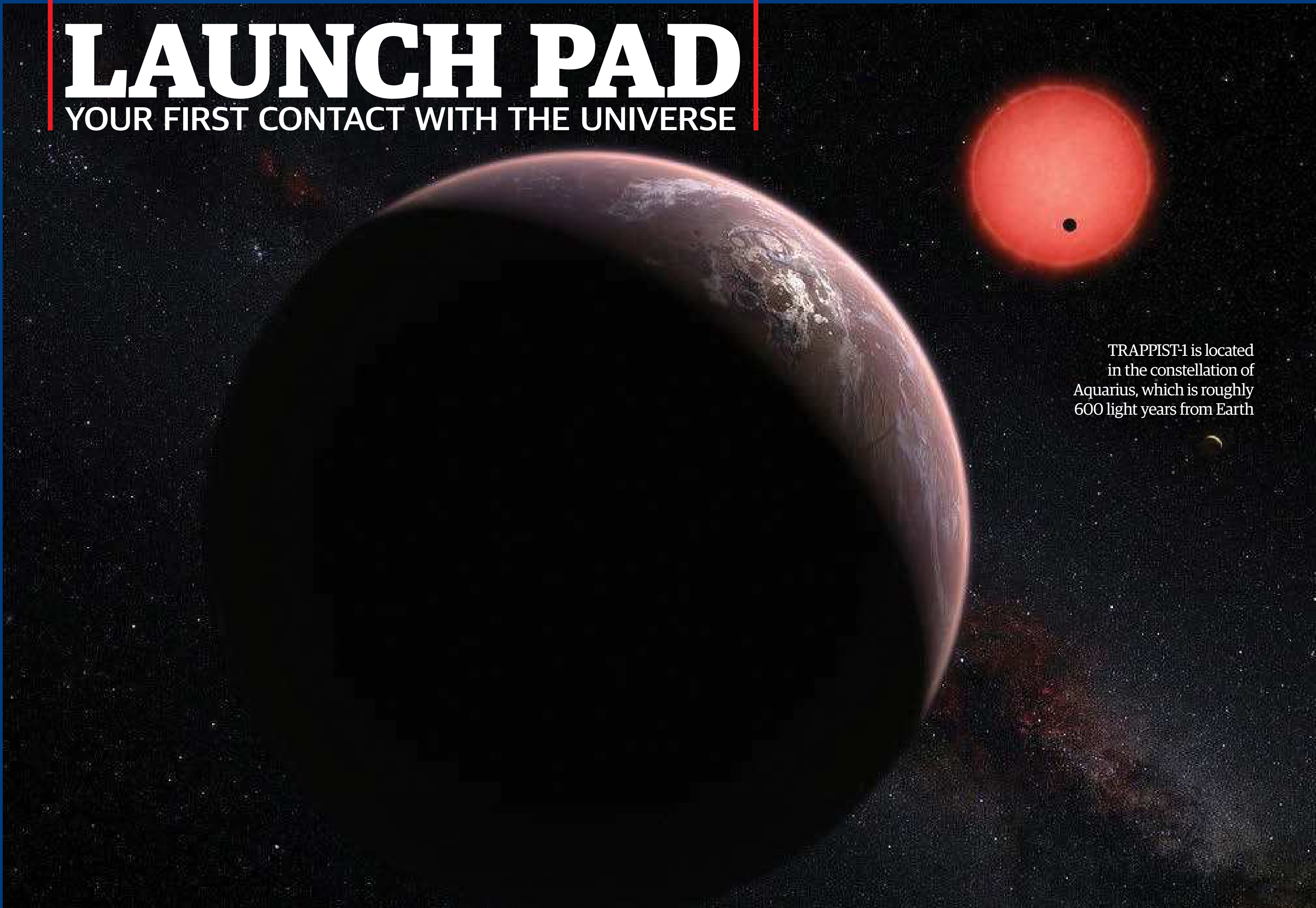


@ ESA; NASA; Hubble Heritage Team (STScI/AURA)

Under three bands of space light

Look closely at the image and you will be able to see three bands of light. The faint light that reaches up from the horizon just below the centre is known as zodiacal light, which is caused by sunlight scattering from cosmic dust along the Earth's orbit. On the lower left, a second band of light can be seen known as red airglow. This is caused by several processes occurring in our planet's upper atmosphere, including cosmic rays recombining photoionised atoms and reactions between different atoms in the Earth's atmosphere. The final band of light should be obvious – this is the Milky Way, seen high up in the sky. Billions of stars of all kinds comprise our home galaxy, many of which are hidden to the human eye behind copious layers of interstellar dust, which gives the Milky Way its mottled appearance.

@ ESO; B. Tafreshi



TRAPPIST-1 is located in the constellation of Aquarius, which is roughly 600 light years from Earth

Super-cool dwarf star yields a bounty of potentially habitable worlds

A team using the TRAPPIST telescope has revealed planets with Earth-like and Venus-like characteristics

An international team of astronomers, led by Michaël Gillon of the University of Liège in Belgium, has made a startling discovery – a cabal of previously unknown worlds orbiting an ultra-cool dwarf star. The dwarf star, TRAPPIST-1, was discovered using the European Southern Observatory's (ESO's) TRAPPIST telescope and reveals an object much redder than our Sun and around a tenth of its size. While studying the star, its luminosity dimmed at regular intervals, suggesting a number of orbiting satellites. These satellites turned out to be three full-sized planets.

"With such short orbital periods, the planets are between 20 and 100-times closer to their star than the Earth is to the Sun. The structure of this planetary system is much more similar in scale to the system of Jupiter's moons than to that of the Solar System," explains Michaël Gillon on the startling find.

Further observations with the HAWK-I instrument on ESO's eight-metre Very Large Telescope in Chile show all three planets are similar in size to the Earth. Two of the planetary discoveries have orbital periods of about 1.5 days and 2.4 days respectively, while the third one has a less well-determined orbit of around 4.5 to 73 days.

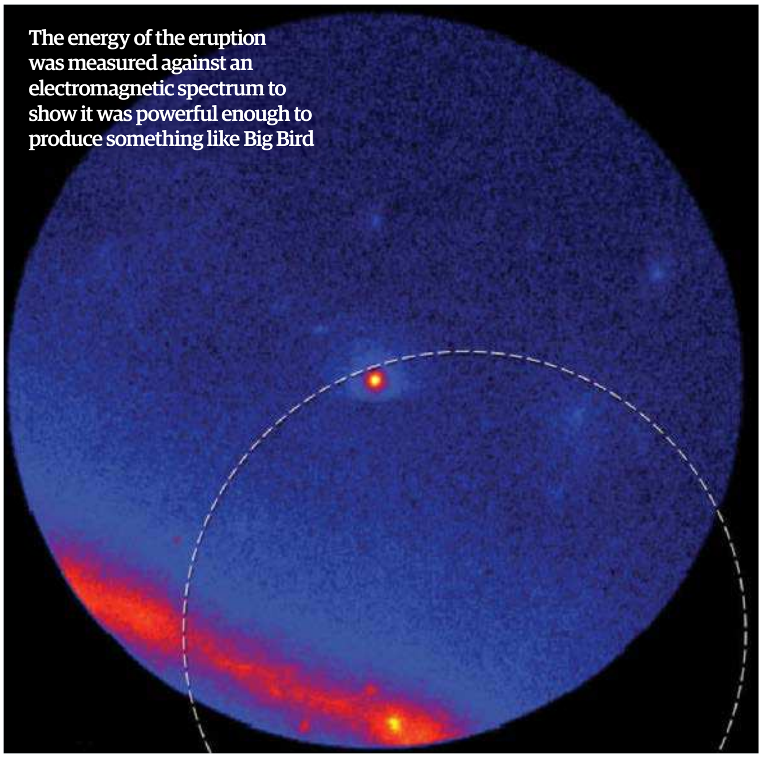
"Thanks to several giant telescopes currently under construction, including ESO's E-ELT and the NASA/ESA/CSA James Webb Space Telescope due to launch for 2018, we will soon be able to study the atmospheric composition of these planets and explore them first for water, then for traces of biological activity. That's a giant step in the search for life in the universe," says Julien de Wit from the Massachusetts Institute of Technology in the US. By a stroke of luck, two of the planets are transiting in May (a process that only happens every two years, whereby a celestial object passes partially in front of a star) so plans are already being made to study the atmosphere of these two planets and solve a few mysteries surrounding them.

NASA'S Hubble Space Telescope and K2 – Kepler's second mission – are the craft planned for these observations, with plans to release the data of these potentially Earth-like planets by May 2017. K2 will also be used to provide more data on the third planet and any other objects that may still lie hidden in the domain of TRAPPIST-1.

> "The TRAPPIST telescope revealed an object much redder than our Sun and around a tenth of its size"

Cosmic neutrino born in the heart of an ancient exploding black hole

New research has linked the 10bn-year-old Blazar Blast with a record-breaking neutrino



The energy of the eruption was measured against an electromagnetic spectrum to show it was powerful enough to produce something like Big Bird

A team of astronomers using a series of ground-based observatories, including NASA's Fermi Gamma-ray Space Telescope, have discovered a link between an exploding black hole and a neutral particle normally produced in nuclear beta decay.

Around 10 billion years ago, a black hole at the centre of a galaxy known as PKS B1424-418 erupted with a blast so powerful its light was hurled across the universe. The team behind the study has also been studying the origin of the super powerful Big Bird neutrino, with the suggestion its source could be traced back to that very explosion.

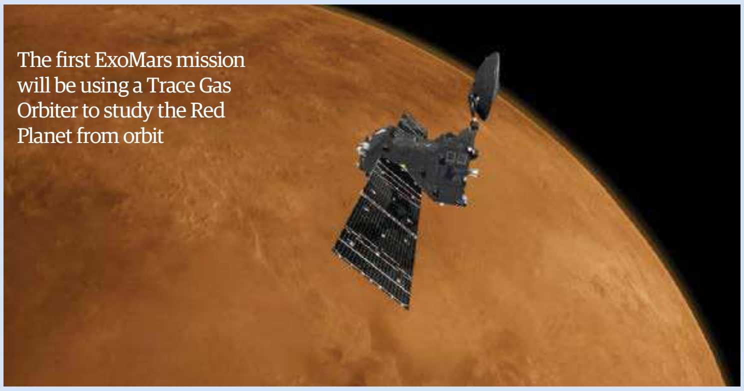
"Neutrinos are the fastest, lightest, most unsociable and least understood fundamental particles, and we are just now capable of detecting high-energy ones arriving from beyond our galaxy," says Roopesh Ojha, a Fermi team member at NASA's Goddard Space Flight Centre, Maryland. "Our work provides the first plausible association between a single extragalactic object and one of these cosmic neutrinos."

With the area of space in which Big Bird is said to have originated overlapping with PKS B1424-418, some have suggested the black hole eruption is the only plausible event that could have produced the highest energy particle on record.

"We combed through the field where Big Bird must have originated, looking for astrophysical objects capable of producing high-energy particles and light," says Felicia Krauss of the University of Erlangen-Nuremberg, Germany. "There was a moment of wonder and awe when we realised that the most dramatic outburst we had ever seen in a blazar happened in just the right place at just the right time."

New ExoMars mission set to launch for Mars in 2020

The ESA/Roscosmos partnership will renew the interplanetary team-up for second mission to Mars



The first ExoMars mission will be using a Trace Gas Orbiter to study the Red Planet from orbit

With the first ExoMars mission scheduled for a 2020 Mars arrival after launching this year, the European Space Agency (ESA) and the Russian space agency, Roscosmos, have already signed a deal to get a second underway.

The second ExoMars mission will see a Russian-led surface platform working in conjunction with a Europe-led rover. Much like the first ExoMars effort, this new mission will blast off on board a pair of Russian Proton rockets, with the Baikonur Cosmodrome, Kazakhstan, selected as a launch site.

However, recent findings have revealed the launch date for the new mission will be shifted from 2018 to July 2020. The decision was made after a Russian orientated research group (or Tiger Team) concluded that the constraints of planning another ExoMars project wouldn't be feasible within a two year time frame. The new date now gives the ESA/Roscosmos partnership more room to breathe as it juggles both missions.

ESA director general, Johann-Dietrich Woerner and Roscosmos director general, Igor Komarov made the final decision at a committee held in Moscow. The partnership between the two agencies will enable Europe and Russia to build and innovate new and existing technologies, as we edge closer to a new era of Martian study.

Space News in Brief

Moon 'tattoo' research is revealed

Studies into the swirls of light and dark on the surface of the Moon - in over 100 locations - reveals the unusual lunar phenomenon could be caused by the satellite's natural magnetic field. Some of these swirls are tens of kilometres across and as solar winds pass through this weak magnetic field, these unusual swirls are formed.

SpaceX rockets have more power

According to a series of recent tests, SpaceX's bespoke Falcon 9 and Falcon Heavy rockets are capable of lifting heavier payloads than originally expected. The new specifications state the Falcon 9 can now haul 22,800kg (50,265lb) to low Earth orbit and 8,300kg (18,300lb) to geosynchronous transfer orbit, compared to the first figures of 13,150kg (28,990lb) and 4,850kg (10,690lb), respectively.

Water may have sculpted Mars' surface

Ancient boiling waters on Mars may have helped carve slopes and envelopes on the surface of the Red Planet. The new study helps support the theory that Mars did once host liquid water, but it may also suggest these reserves were a lot smaller than scientists previously thought.

Asteroid could strike the Earth within 100yrs

NASA has revealed asteroid Bennu, discovered back in 1999, could potentially impact our planet in the 22nd century. NASA's Osiris-REX mission is planning to study the object, which is believed to be over 4,000-times bigger than the asteroid that exploded above Chelyabinsk in 2013.

Here we can see four of the galaxy clusters studied, each one in different stages of cosmological expansion




The secrets of dark energy could be found within 'Russian doll' cluster

An array of ground- and space-based telescopes hope to shed light on the force that's driving the universe's expansion

A team of astronomers have used data collected from NASA's Chandra X-ray Observatory, ESA's Planck satellite and a large list of optical telescopes to conduct the most thorough investigation into dark energy yet.

Dark energy, an unknown 'force' that permeates all of space, still remains a mystery. This new drive has seen the team of researchers focus on data collected from distant galaxy clusters. - the largest objects in the known universe to be held together by gravity.

"In this sense, galaxy clusters are like Russian dolls, with smaller ones having a similar shape to larger ones," says Andrea Morandi of the University of Alabama, lead scientist of the study into the relationship between galaxy clusters and dark energy. "We're able to compare them and accurately determine their distances across billions of light years."

The clusters are being used as distance markers to measure how quickly the universe expanded after the Big Bang. With Einstein's theory of general relativity in mind – where the size of the universe is determined by combining the amount of known matter in the universe with the added properties of dark energy – we can theoretically measure this cosmological expansion.

Recent results from the study suggest that while the universe is expanding, the amount of dark energy is not – it remains a 'cosmological constant'. "Although we've looked hard at other explanations," adds Ming Sun, also of the University of Alabama, "it seems dark energy behaves just like Einstein's cosmological constant."

A new kind of tailless rocky comet has been discovered, which could have originated from our Solar System

Tailless comet may have come from Earth

Cosmic oddity could well trace its source back to our corner of the galaxy

A new kind of comet has been discovered, one that travels through space without a tail or ice and dust particles. Nicknamed Manx after the tailless breed of cat, comet C/2014 S3 is comprised of rocky elements rather than the traditional frozen detritus, meaning it's less likely to have originated in the Oort Cloud, a shell of gas and dust that surrounds the Solar System.

So where did it come from? The rocky nature of its topography suggests it likely came from the same corner of space that we currently inhabit. However, it's been floating around beyond our Solar System for so long it's been frozen, essentially preserving the characteristics it originally had when it was sent hurtling out beyond our space.

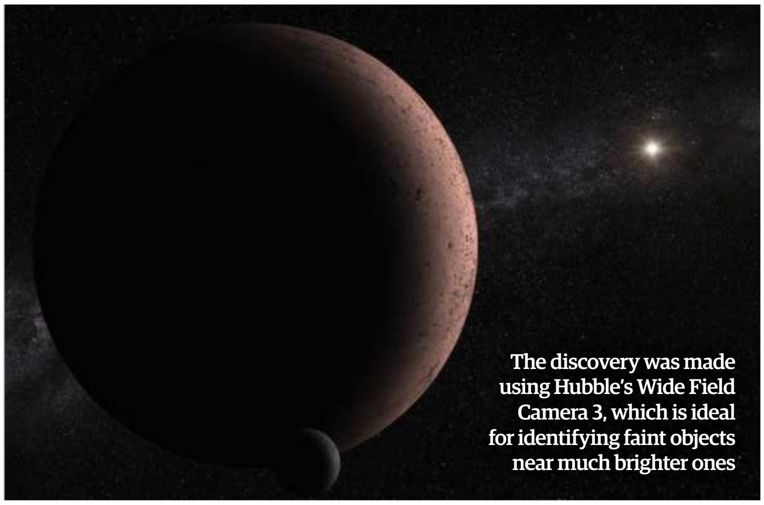
Since most comets melt as they approach the Sun – hence the tail of dust and moisture we typically see behind them – this could mean C/2014 S3 was formed from debris created in the Solar System, and the Earth itself, meaning it could hold a treasure trove that relates to our cosmological history.

Moon discovered around dwarf planet Makemake

NASA's Hubble has spied a natural satellite orbiting the small world

New images from NASA's Hubble Space Telescope have found an unsurprising feature of distant icy dwarf planet Makemake: a moon. Nicknamed MK 2, the moon is 1,300-times fainter than Makemake and was spotted around 20,900 kilometres (13,000 miles) from the dwarf planet. NASA estimates its size to be 160 kilometres (100 miles) across. By comparison, Makemake is 1,400 kilometres (870 miles) across.

Makemake, discovered in 2005, is no forgettable celestial body either. Second only to Pluto, Makemake is the second brightest dwarf planet in the Kuiper Belt, a vast reservoir of frozen detritus formed 4.5 billion years ago. While other satellites have been detected around dwarf planets, this is the first to be discovered around the small world.



The discovery was made using Hubble's Wide Field Camera 3, which is ideal for identifying faint objects near much brighter ones

"Our preliminary estimates show the moon's orbit seems to be edge-on, so often when you look at the system, you will miss the moon as it gets lost in the bright glare of Makemake," says Alex Parker of Southwest Research Institute, Boulder, who led the image analysis.

The discovery, made in April 2015, is just another detail linking the characteristics of Makemake and Pluto, including the fact both are covered in a sheet of frozen methane. Plans are already in motion to study Makemake in more detail to see just how closely tied these icy dwarf planets are.

"Makemake is in the class of rare Pluto-like objects, so finding a companion is important," says Parker. "The moon's discovery has given us an opportunity to study Makemake in far greater detail than we would have been able to without the companion."

WHAT HAPPENED BEFORE THE BIG BANG?

Could there have been a time before the birth of the universe?

Written by Kulvinder Singh Chadha

What happened before the Big Bang?

Here's an astounding thought – one that questions the beginning of existence itself: could there have been a time before the Big Bang? In other words, could the universe have existed before we thought it had even started? May there have even been previous universes? Such ideas, once the preserve of high-concept science fiction and philosophical debates, are gaining a new scientific credibility in the 21st century.

Some cosmologists are wondering if the Big Bang was merely an intermediate phase and not the true start of the universe at all. Theories such as the ekpyrotic universe, 'big bounce' models and cyclic cosmology have all been around for a while, but new data from sensitive space probes could put some of these on a firmer footing. But what exactly was the Big Bang anyway and why are some scientists now changing their minds about it?

The widely accepted standard cosmological model states that the universe came into being from a super-hot, super-dense state that was no bigger than an atom and made of pure energy. Not much about that is contentious but things get precarious with what happens next. This object, known as the 'initial singularity', is thought to have been timeless and dimensionless; there was nothing 'outside' of the singularity to speak of. Then 13.82 billion years ago (a figure obtained from NASA's Wilkinson Microwave Anisotropy Probe (WMAP) and ESA's Planck satellite), this microscopic singularity expanded rapidly to the size of a football. This was the 'Big Bang'. And despite lazy descriptions, it wasn't an explosion. The universe never exploded into being. Rather, this initial expansion from microscopic quantum fluctuations birthed space and time and seeded the large-scale structure of the universe. This 'Big Bang' model has served cosmology well for over 80 years, but there have always been unanswered questions.

Despite the Big Bang being the cornerstone of cosmology, a theory called cosmic inflation was proposed in the 1980s to address some of the problems with the original model, such as the horizon problem (i.e. how has the universe 'homogenised' on the largest scales when it hasn't existed for long enough to do so, given its enormous size?). Cosmic inflation theory proposes an extremely rapid initial expansion rate of 10^{-32} seconds. The universe would then have continued expanding in line with the Big Bang theory.

As the universe expanded it also cooled, which resulted in energy condensing into matter known as subatomic particles. This transformation of energy into matter, predicted by Einstein's theory of special relativity, is described by the most famous equation in science: $E=mc^2$. The universe (still seething and hot) was then a dense morass of quarks and electrons, with photons of electromagnetism, including those of visible light, trapped within it.

After 380,000 years this still-expanding universe cooled enough for the first chemical elements (hydrogen, helium and lithium) to form. The morass of quarks turned into the protons and neutrons of atomic nuclei and captured free-travelling electrons in the process to make fully-fledged atoms. This was the point at which all of the trapped photons of the electromagnetic spectrum could now travel unhindered. In other words, the universe became transparent. But it was still dark; it took another 400 million years for the first stars and galaxies to form.

Dense hydrogen and helium gas clumps collapsed under gravity (possibly collecting within a large 'dark matter halo'), until atomic nuclei in their cores began fusing together, known as thermonuclear fusion, which released large amounts of energy as the first stars came alight. Galaxies of such stars formed within these haloes.

It's strange to think that our universe could have existed before any of these events, but the Big Bang wasn't always accepted. The eminent British astronomer Sir Fred Hoyle, who coined the term 'Big Bang' in a BBC radio interview in 1949, actually hated the idea himself. So why did it take such a hold in cosmology?

In 1912 the American astronomer Vesto Slipher saw that the spectra of galaxies were Doppler-shifted towards the red end of the electromagnetic spectrum. This showed they were moving away from us at speed. Then in the 1920s, Alexander Friedmann, a mathematician in the Soviet Union, and Belgian astronomer Georges Lemaître both independently proposed the idea of an expanding universe, which could explain Slipher's observations. But reception to Friedmann and Lemaître's idea was lukewarm. Even Albert Einstein – upon whose general theory of relativity their hypothesis was based – didn't accept the idea at first.

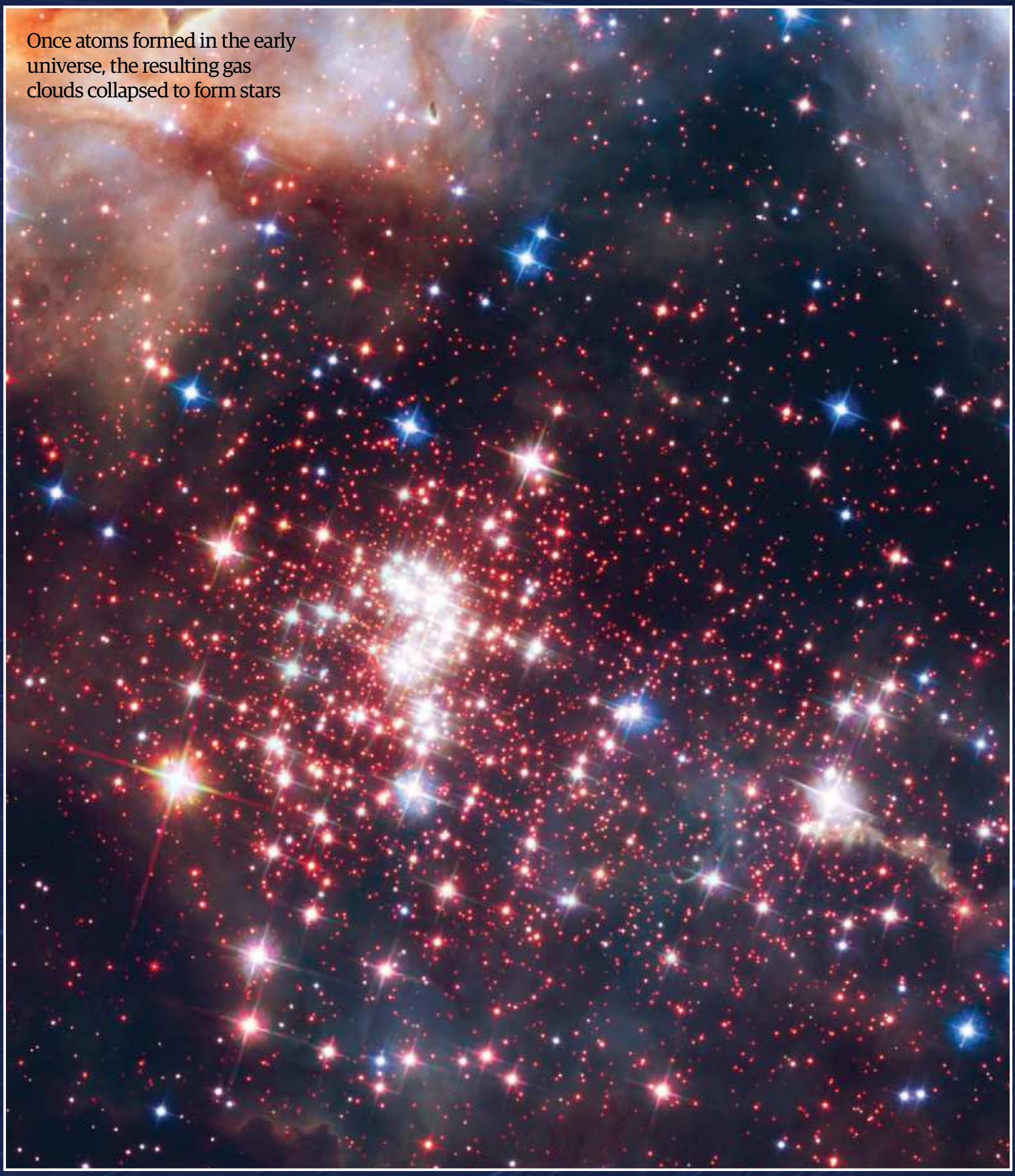
But in 1929, Edwin Hubble showed that the recession speeds of the galaxies actually increased with their distance from Earth. This meant that if the universe was a movie played backwards, then all galaxies would have once 'existed' at the same point in space and time. Friedmann and Lemaître were vindicated and the speed-distance relationship became known as 'Hubble's law'.

In light of all this, English astronomer Arthur Eddington invited Lemaître to speak in London (Friedmann having died four years earlier), calling his solution "brilliant". Lemaître posited the idea of a universe expanding from a single point, which he described as a 'primeval atom' or an 'exploding cosmic egg'. This is what cosmologists now call the initial singularity, the point of the Big Bang – although it wasn't actually an atom (or an egg). Einstein conceded his mistake (even when his own calculations had shown an expanding universe) and accepted Friedmann and Lemaître's ideas.

Unlike Einstein and others, Hoyle actually had no problem with an expanding universe. What he hated was the idea of a 'beginning'. As an avowed atheist, Hoyle couldn't accept a point of creation and thus a potential 'creator'. He clung doggedly to the steady state theory: the idea that the universe had always existed and was perpetually creating and destroying. But Hoyle was on the losing team. In 1948, American cosmologists Ralph Alpher and Robert Hermann predicted a background radiation to space – the residual heat 'echo' just before the universe became transparent 380,000 years after the Big Bang. As space had expanded for billions of years since, this radiation's wavelength should have been stretched into the microwave region. Just 14 years later it was finally discovered by physicists Arno Penzias and Robert Wilson, using the Holmdel Horn Antenna. Initially believing it to be caused by bird droppings, they soon saw that the spectrum of this Cosmic Microwave Background (CMB) matched the predictions of the Big Bang model. The steady state theory had no explanation for the CMB and was therefore royally defeated. Alongside the work of Slipher, Friedmann, Lemaître and Hubble, Penzias and Wilson's evidence showed that the universe did have an origin after all and had been expanding. The Big Bang theory was king.

And yet, despite its enormous success, there has always been something that scientists have never liked about the Big Bang: it doesn't explain the initial singularity itself. Where did it come from? Why is it simply assumed to have been timeless, dimensionless and infinitely dense? Scientists hate assumptions, especially regarding the big questions. Even cosmic inflation theory (developed by physicists Alan Guth, Andrei Linde and Paul

"If the universe was a movie played backwards, all galaxies would have existed at the same point in space-time"

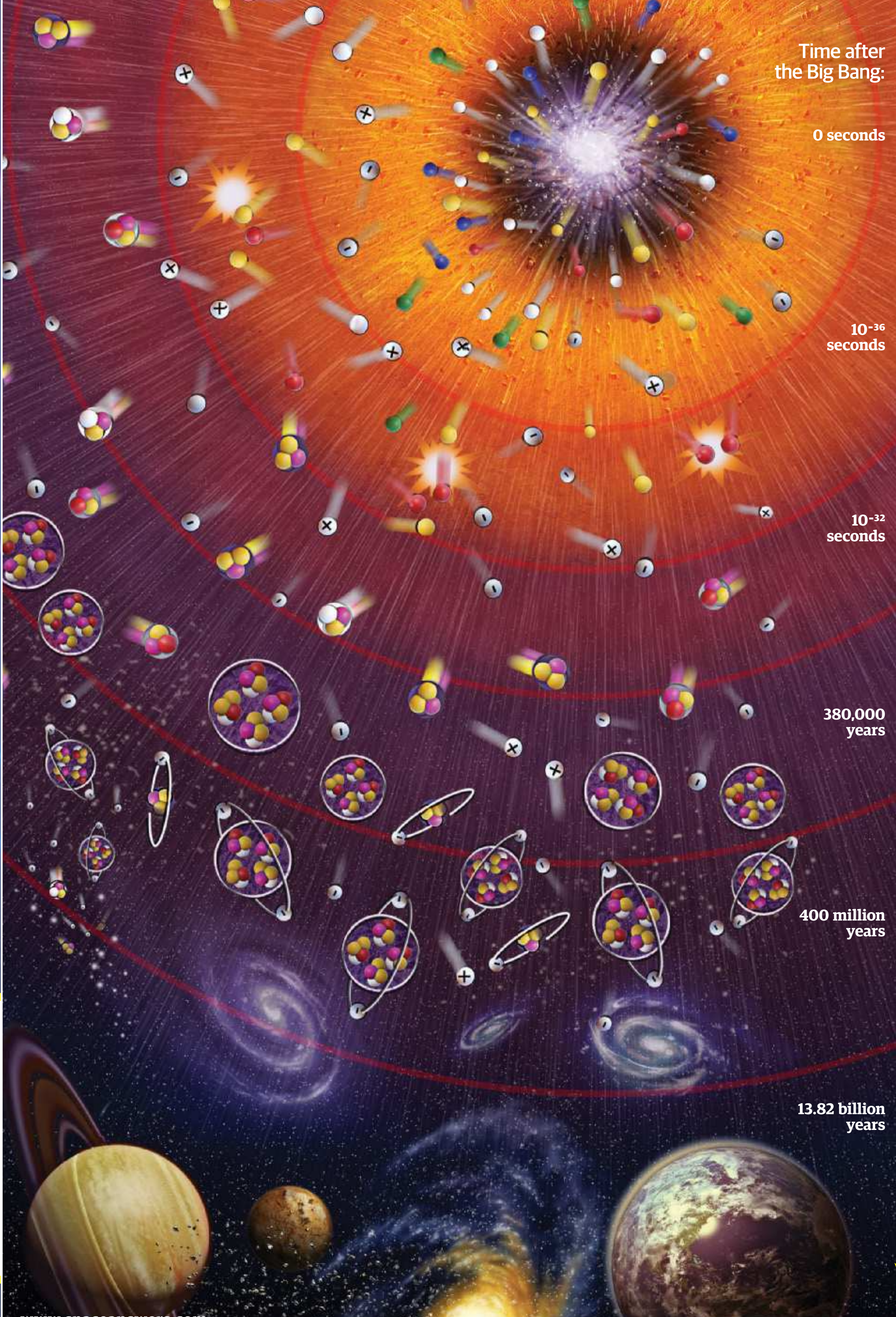


Once atoms formed in the early universe, the resulting gas clouds collapsed to form stars

What is a singularity?

Singularities are regions of space and time with extreme gravity (not even light can escape) and infinite density. They are thought to exist inside black holes, and our universe is thought to have started from one, too. Although predicted by the general theory of relativity, neither that or quantum mechanics can explain singularities. They remain truly mysterious to science.

What is the Big Bang?



The beginning
The absolute beginning of our universe (according to the Big Bang theory), which starts out as a dense, hot, timeless, dimensionless singularity.

Cosmic inflation
A rapid expansion phase after the Big Bang increases the size of the universe from that of an atom to a football. The universe is made of pure energy.

Cooling and quarks
After inflation ends, the universe cools enough for subatomic quarks, electrons and other particles to form from the available energy.

Atoms form
Further expansion and cooling means subatomic particles form into atoms. Hydrogen, helium and lithium fill the universe, which now becomes transparent as a result.

First stars and galaxies are born
Hydrogen and helium gas clumps collapse under gravity to form the first stars. They form inside galaxies, which lie in dark matter haloes.

Present day
Several generations of star formation and destruction creates and spreads chemical elements throughout space. That in turn creates planets with complex chemistry and even life.

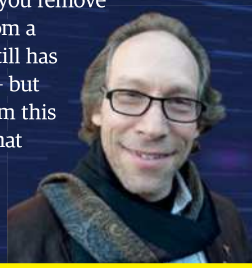
What caused the birth of the universe?

Many scenarios illustrate how our universe may have come into being

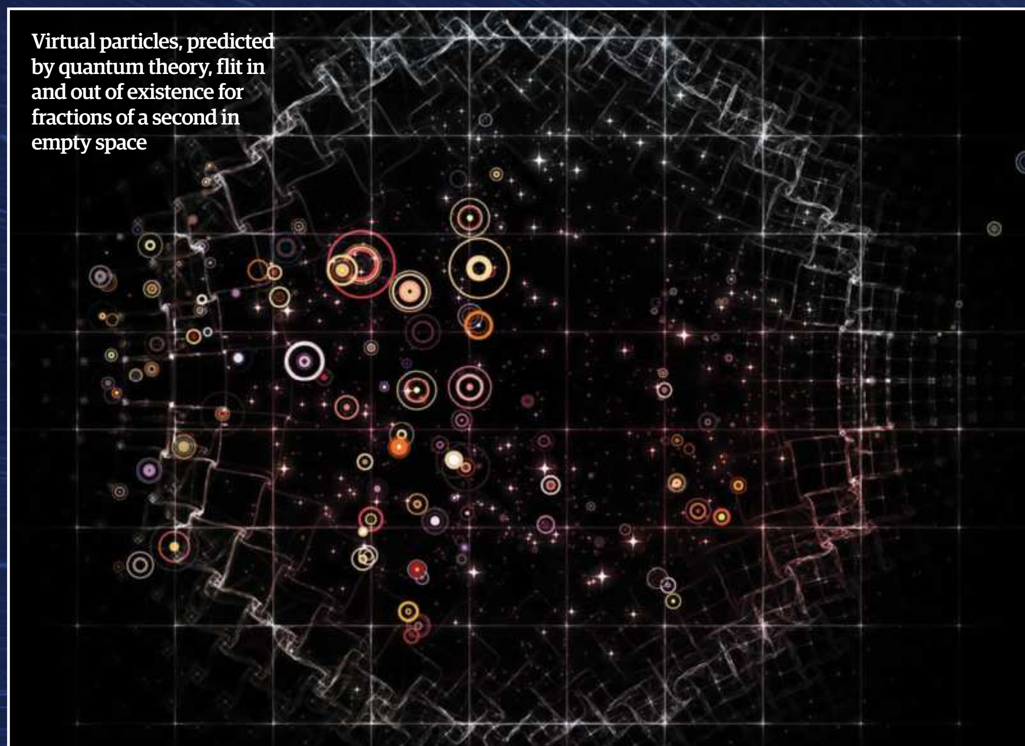
1 There was nothing

Strictly speaking, no scientist believes that our universe started from literally nothing. There always has to be something to cause another action to occur. However, many cosmologists are not yet convinced that there was anything before the Big Bang. Lawrence Krauss is one such scientist and he's developed a theory of 'quantum nothingness' from which the universe could have originated.

The theory involves so-called 'virtual particles', which flit in and out of existence for fractions of a second in empty space. They are predicted by quantum theory and their effects can be observed. Krauss says that if you remove virtual particles from a region of space it still has an energy density – but it shouldn't. It's from this form of 'nothing' that our universe could have started.



BACKED BY
Professor Lawrence Krauss
Arizona State University



Virtual particles, predicted by quantum theory, flit in and out of existence for fractions of a second in empty space

2 There was another universe before ours

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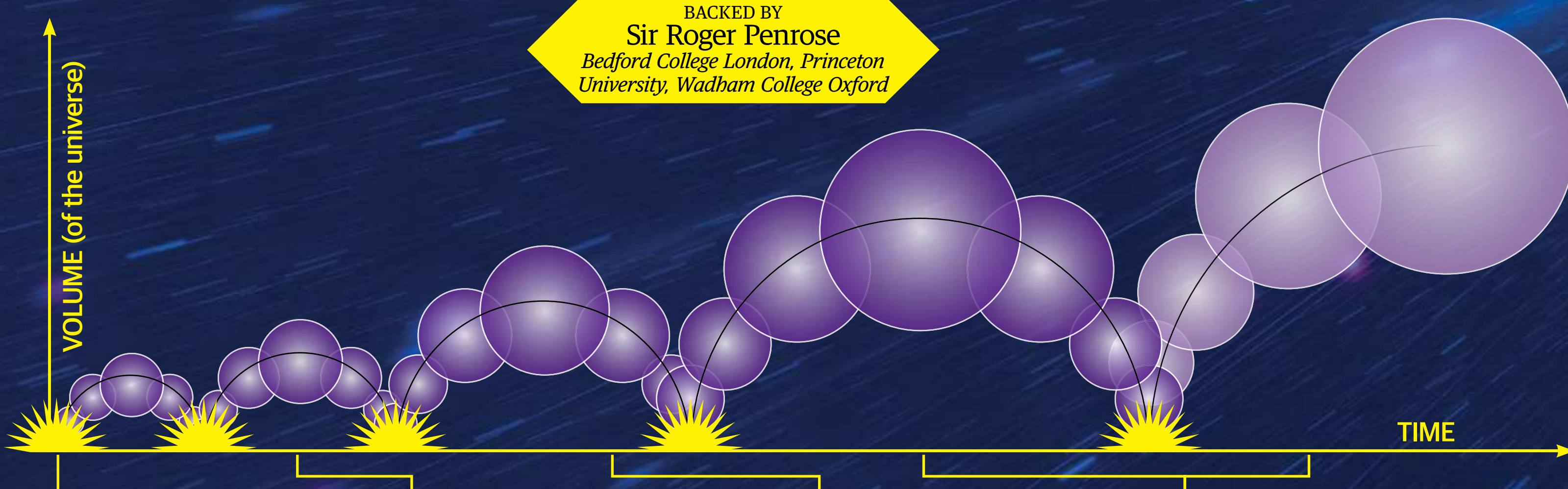
Bedford College London, Princeton University, Wadham College Oxford



Big Bang and expansion
In the cyclic model, a universe may have a true origin as normal and go through an inflation and expansion phase.

Everything now stalls
In a cyclic universe the cosmos may expand to a point and then stall. This may happen from the gravitational effect of the matter within it.

Universe in reverse
Gravity takes over and the universe now contracts, with galaxies moving towards one another instead of further away.

Big bounce and next phase
Inevitably, the universe can only contract so far. A 'big bounce' initiates the next expansion phase. The process continues, with each phase getting larger and slower.

3 It's always been there

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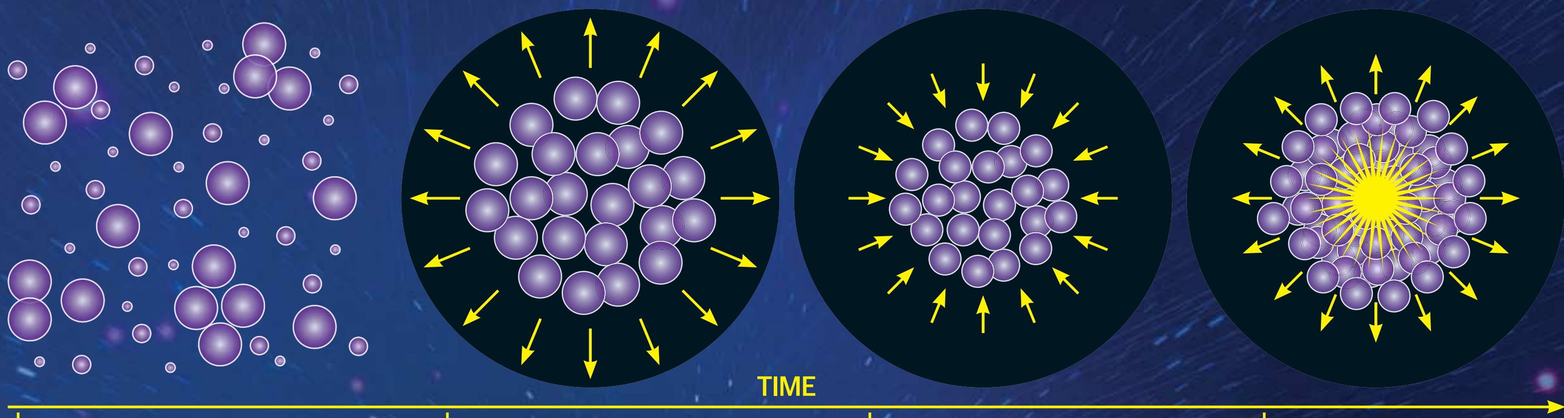
CERN and Collège de France



An empty infinite universe
In this scenario, the universe has existed forever and was nearly empty for that time. Then gravity took over and matter started to clump together.

Expanding internal region
The density of matter is such in some regions that it forms an incredibly massive black hole, the internal region of which experiences an expansion.

A big crunch
Inside the huge black hole, matter again collapses under the intense gravity and increases in density up to a limit imposed by physics.

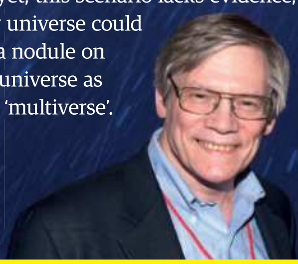
The Big Bang
When it can't stand any more, quantum fluctuations cause the matter to expand outwards in a typical Big Bang scenario within its black hole universe.

4 It is one universe of many

Eternal inflation theory was proposed in 1983 by physicist Paul Steinhardt as an extension of the cosmic inflation and Big Bang theories. Alan Guth, Andrei Linde and Steinhardt originally developed cosmic inflation theory to explain some problems with the Big Bang model, and it involved an exponential but rapid expansion of our universe.

The cause of cosmic inflation still remains somewhat vague, but for eternal inflation, Guth proposed in 2007 the existence of a 'false vacuum' or region of space with a positive energy density – similar to expanding bubbles forming in a boiling liquid. In this manner, certain regions of space-time (or 'universes') would be affected by their own form of cosmic inflation, before the positive vacuum moved on to another region.

As of yet, this scenario lacks evidence, but if true, then our universe could exist as a nodule on another universe as part of a 'multiverse'.



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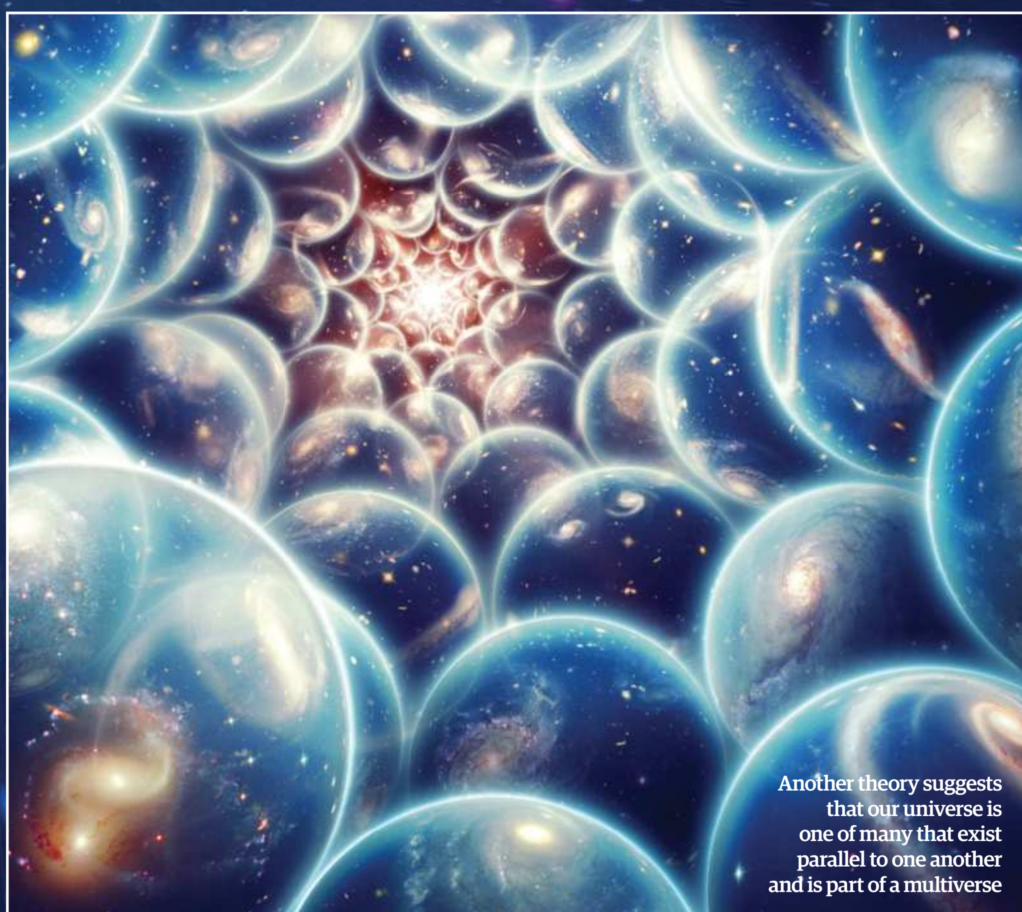
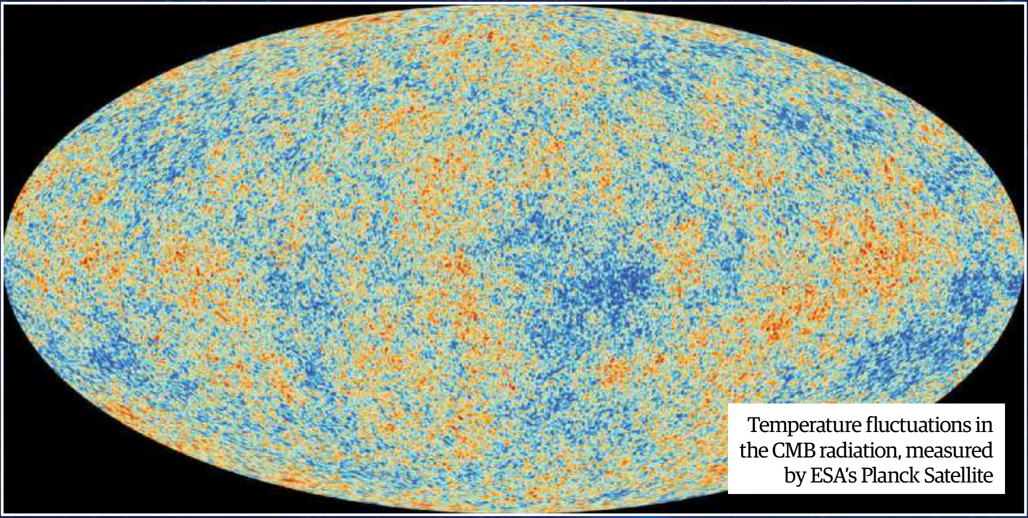
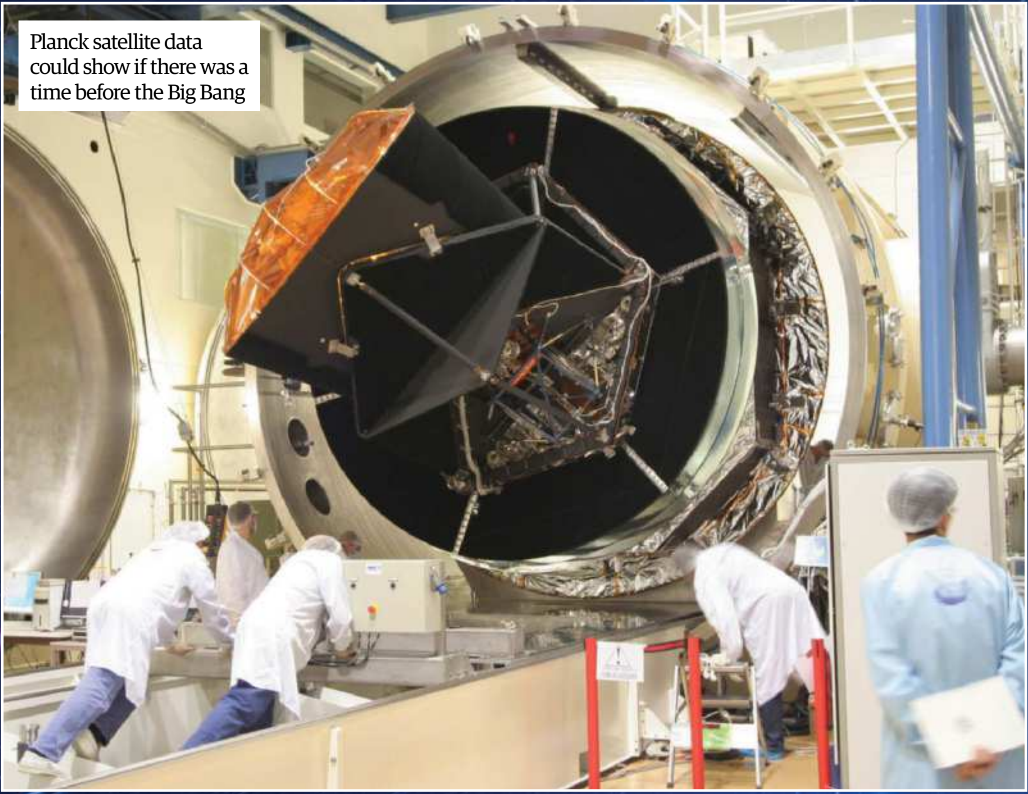
Professor Alan Guth
Massachusetts Institute of Technology



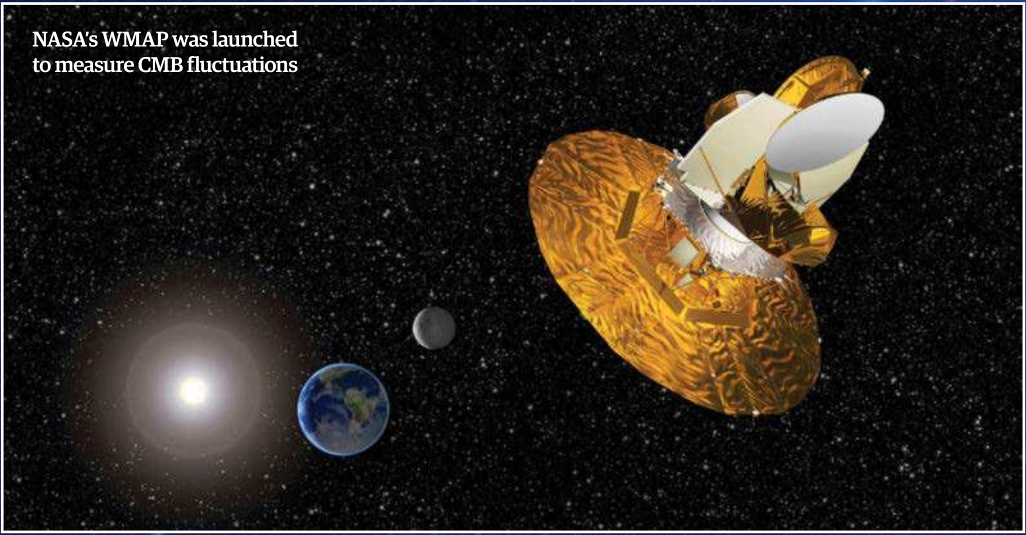
Another theory suggests that our universe is one of many that exist parallel to one another and is part of a multiverse



Temperature fluctuations in the CMB radiation, measured by ESA's Planck Satellite



Planck satellite data could show if there was a time before the Big Bang



NASA's WMAP was launched to measure CMB fluctuations

Steinhardt), which successfully ironed out some of the problems of the Big Bang, couldn't explain the singularity. As a result, alternatives to these cosmological cornerstones have been proposed and it's from this that the idea of a pre-Big Bang existence has arisen. Strangely, these ideas may even be supported by the very same CMB data that supports the Big Bang theory.

In 2001 Steinhardt worked with Neil Turok, Justin Khoury and Burt Ovrut on the 'ekpyrotic' model of the universe; an alternative to inflation. In their original hypothesis the universe was birthed from a collision between two multidimensional membranes (or 'branes') floating through a higher dimension of space, as opposed to our three dimensions (imagine a pair of flat, rippling ocean surfaces meeting along a third dimension). After the universe was created from the collision of the branes, the ekpyrotic phase would occur. This would also apply to a contracting brane. Imagine a prolonged contraction of a previous universe eventually collapsing back into a singularity, before restarting again as our present universe in a typical 'Big Bang' scenario. The conditions for our universe (its fundamental laws and seeds for a future large-scale structure) would have been set in the previous universe, and not by inflation. This scenario involving branes and multidimensions seems quite exotic, but more up-to-date forms of the ekpyrotic model mostly do away with these multidimensional branes and other exotica. The newer models simply apply the physical constraints of the Big Bang theory.

A researcher working with one such form of the ekpyrotic scenario is Dr Yifu Cai of McGill University in Canada. He says, "Since Neil, Paul, et al proposed their original scenario, the physical picture is very clear. Their cosmological model is able to dilute unwanted relics [of the Big Bang] via the 'ekpyrotic phase'. But the universe is still expected to pass directly through the singularity from the contracting to expanding phases without that being removed." What he means is that in the multidimensional scenario, although ekpyrosis can 'smooth out' some problems like cosmic inflation can, the singularity is still present and the physics surrounding that are as vague and problematic as ever. But Dr Cai's work, performed with Professor Robert Brandenberger – head of McGill's High-Energy Theory Group – does away with singularities entirely.

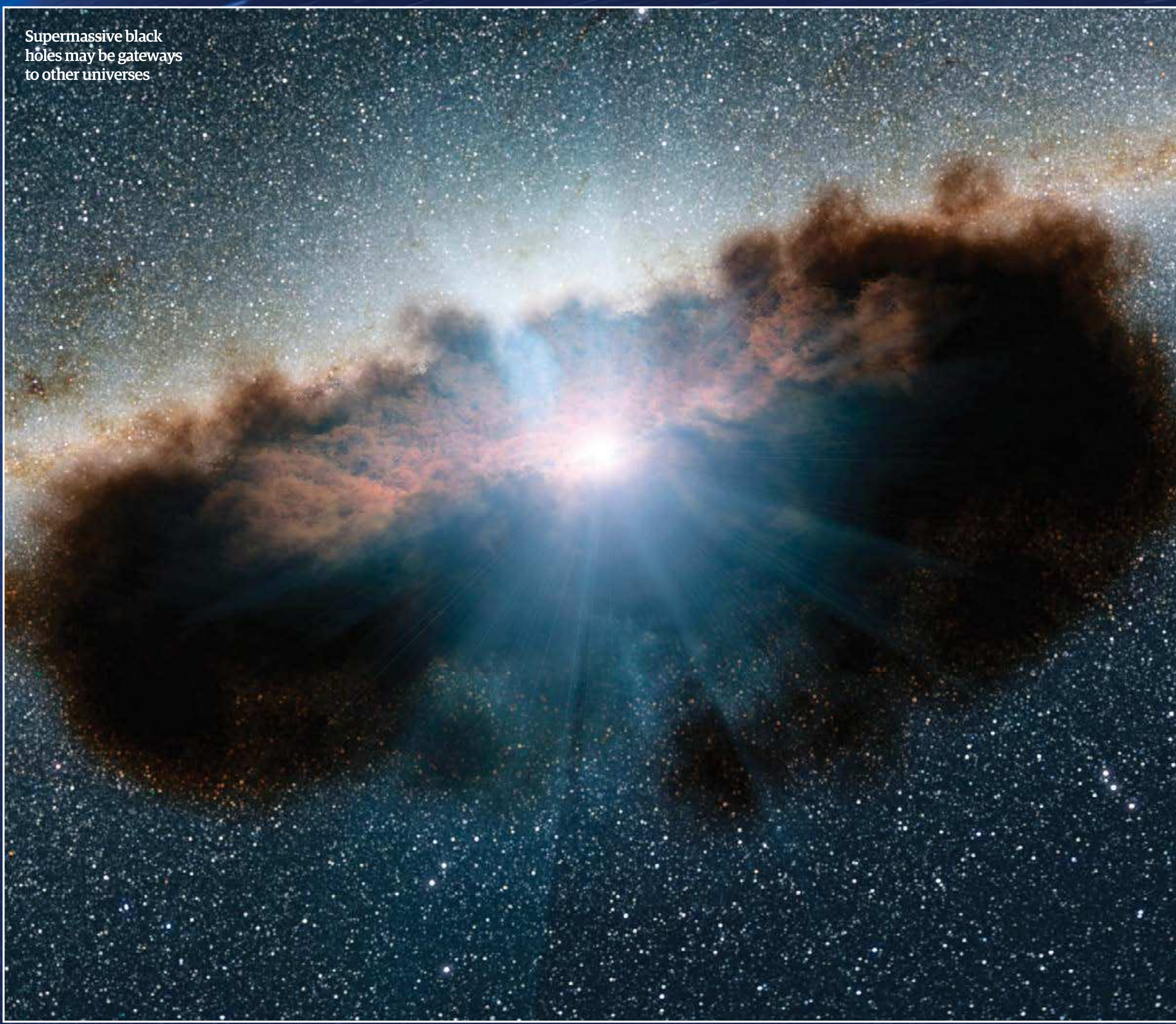
In their model a previous universe collapsed until it could go no further and then 'bounced' out as a new universe. "In our scenario, the whole of cosmic evolution then becomes smooth. The physics around the bounce, including the background [CMB] and perturbation, are well controlled and calculable," he says. By removing the singularity, a lot of associated problems (such as infinite densities and zero dimensions – which have little support in physics) are also removed. Cai and Brandenberger's work also predicts the existence of the CMB and the microscopic perturbations that grow to become the universe's large-scale structure. This is even consistent with the latest data from the WMAP and Planck probes. So could the CMB contain hints of a previous universe that we could detect?

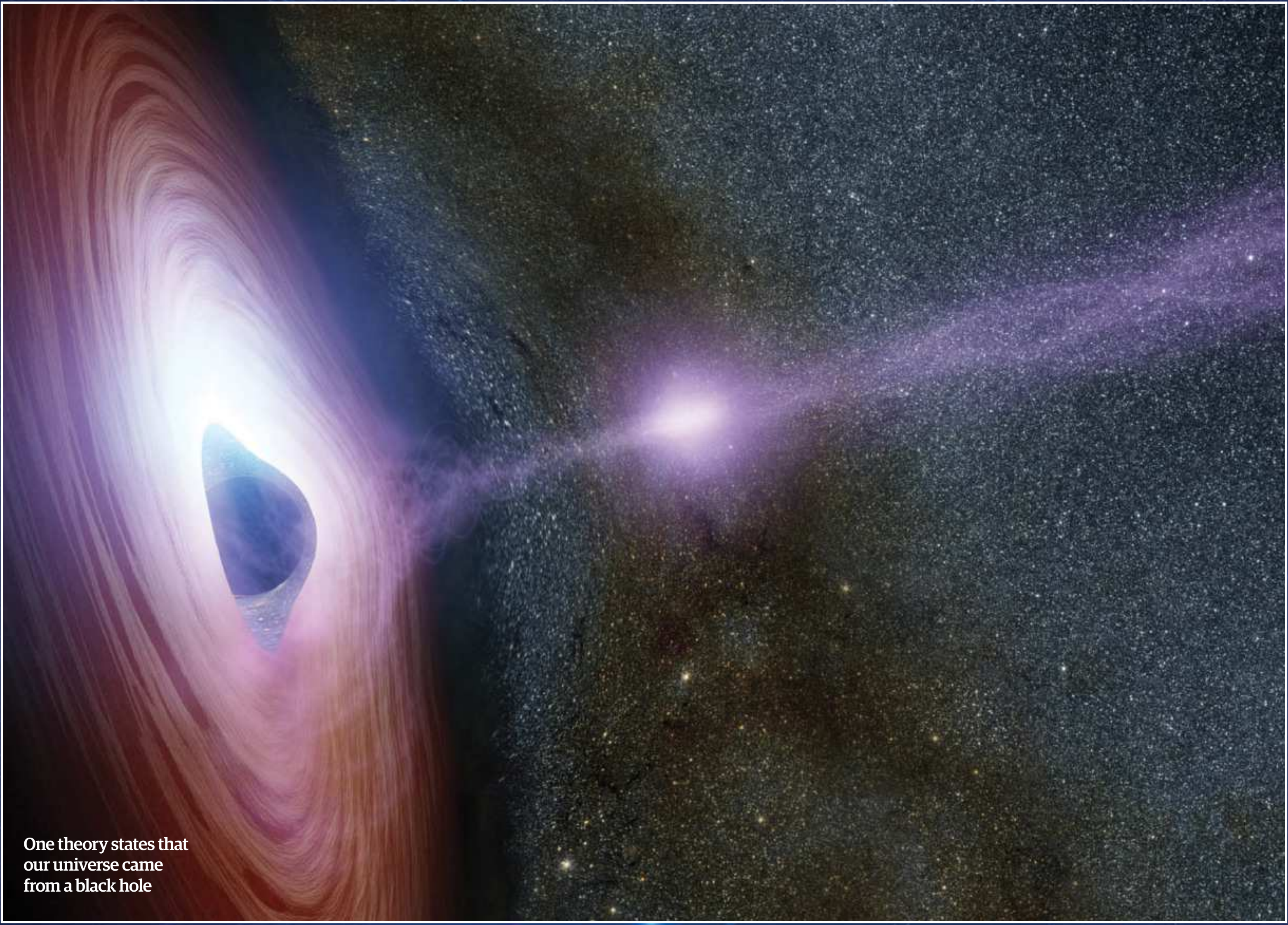
Many cosmologists have asked themselves that very question. One scenario that has an answer is a cyclic model of cosmology. With their concept of universes perpetually oscillating between expanding and contracting phases, cyclic cosmological theories have a lot in common with the 'big bounce' models (and in fact, there is a lot of overlap). The idea has been around since at least the 1920s and one variant was even proposed by Einstein in 1930 after accepting Hubble's observations supporting an expanding universe. Generally speaking in the cyclic scenario, after an expansion phase the universe would slow, then stall, and would then contract back due to the gravitation of all the matter within it. This would culminate in a 'big crunch' or a 'big bounce', which would then be followed by a new expansion phase, and so on. Einstein thought that this cyclical scenario could be a better, more long-term alternative model to the simpler idea of an expanding universe with a single origin point.

But in 1934 American physicist Richard Tolman showed that such cyclic models (Einstein's included) couldn't work the way people wanted them to because of the second law of thermodynamics. Over time, the amount of disorder (entropy) in an oscillating universe would only ever increase and the amount of usable energy within it would only ever decrease. Every expansion would be slower and larger than the previous one, as each contraction phase would only go back so far and less energy would be available for each new expansion phase. Conversely then, previous phases would have started out smaller and smaller until you eventually returned to a 'big bang' scenario again anyway.

But in the age of WMAP and Planck, the idea of cyclic, oscillating universes has re-emerged. One such example, Conformal Cyclic Cosmology (CCC), was developed by English physicist Sir Roger Penrose and Armenian mathematician Vahe Gurzadyan in 2010, and is based on the theory of general relativity. Using data from both

"Our universe could be the interior of a black hole that exists in another universe" **Nikodem Popławski, University of New Haven**


Supermassive black holes may be gateways to other universes



One theory states that our universe came from a black hole

WMAP and Planck and also the BOOMERanG (Balloon Observations of Millimetric Extragalactic Radiation and Geophysics) experiment, Penrose and Gurzadyan published results that purported to show extremely faint concentric rings from previous cosmic cycles in the CMB fluctuations – similar to ripples spreading outwards when you throw a stone into a pond. According to CCC, what we think of as the universe (the region that we can observe, anyway) is simply an 'aeon' – or domain – within an infinitely larger space-time.

Eventually, far into the future, once all the stars and galaxies have died out, all matter has dispersed and the supermassive black holes (that lay at the centres of galaxies) have evaporated, our aeon will have become completely smooth. But it will continue to expand and birth a new, larger-scale aeon. The CCC theory (which unlike previous cyclic models has no contraction phases) states that what we think of as inflation is simply the accelerating expansion of a previous aeon. Other cosmologists looking for concentric rings in the CMB haven't found anything significant yet. This may be because they used standard simulations to check against, whereas Penrose and Gurzadyan adopted a nonstandard approach.

"The Big Bang picture is too firmly grounded in data from every area to be proven invalid in its general features"

Cyclic models like CCC remain controversial and the Big Bang theory itself still has support. Physicist Lawrence Krauss wrote in 2012, "The Big Bang picture is too firmly grounded in data from every area to be proven invalid in its general features." So could it be the true picture of the universe after all?

Nikodem Popławski, a physicist at the University of New Haven, Connecticut, has developed a theory stating our universe originated from a black hole. Such extraordinary hypotheses have been a topic of speculation for years. Popławski says, "Our universe should obey the same laws as the parent universe in which the black hole exists." He adds that it should be possible to determine the size of the parent black hole by measuring temperature fluctuations in the CMB. "I published a paper that shows consistency (of the black hole scenario) with Planck's observations of the CMB. It also shows they aren't too sensitive to the black hole's initial size," he says.

And Popławski is now working on finding evidence for a black hole origin scenario. "If our universe was formed by a 'big bounce' in a black hole, then its early expansion has specific dynamics that can be tested by measuring temperature fluctuations in the CMB from all directions in the sky," he says. Intriguingly, predictions that Popławski and his colleague Shantanu Desai of Garching, Germany, made of CMB fluctuations are consistent with the latest Planck data. And black holes rotate, so if our universe really was birthed from one, Popławski expects to see those effects, too.

Finally, echoing cosmologist Stephen Hawking, he says, "Our universe could be the interior of a black hole existing in another universe. Black holes forming from stars and galaxies in such a universe create new universes. And so a universe can parent billions of baby universes, which are formed through black holes."

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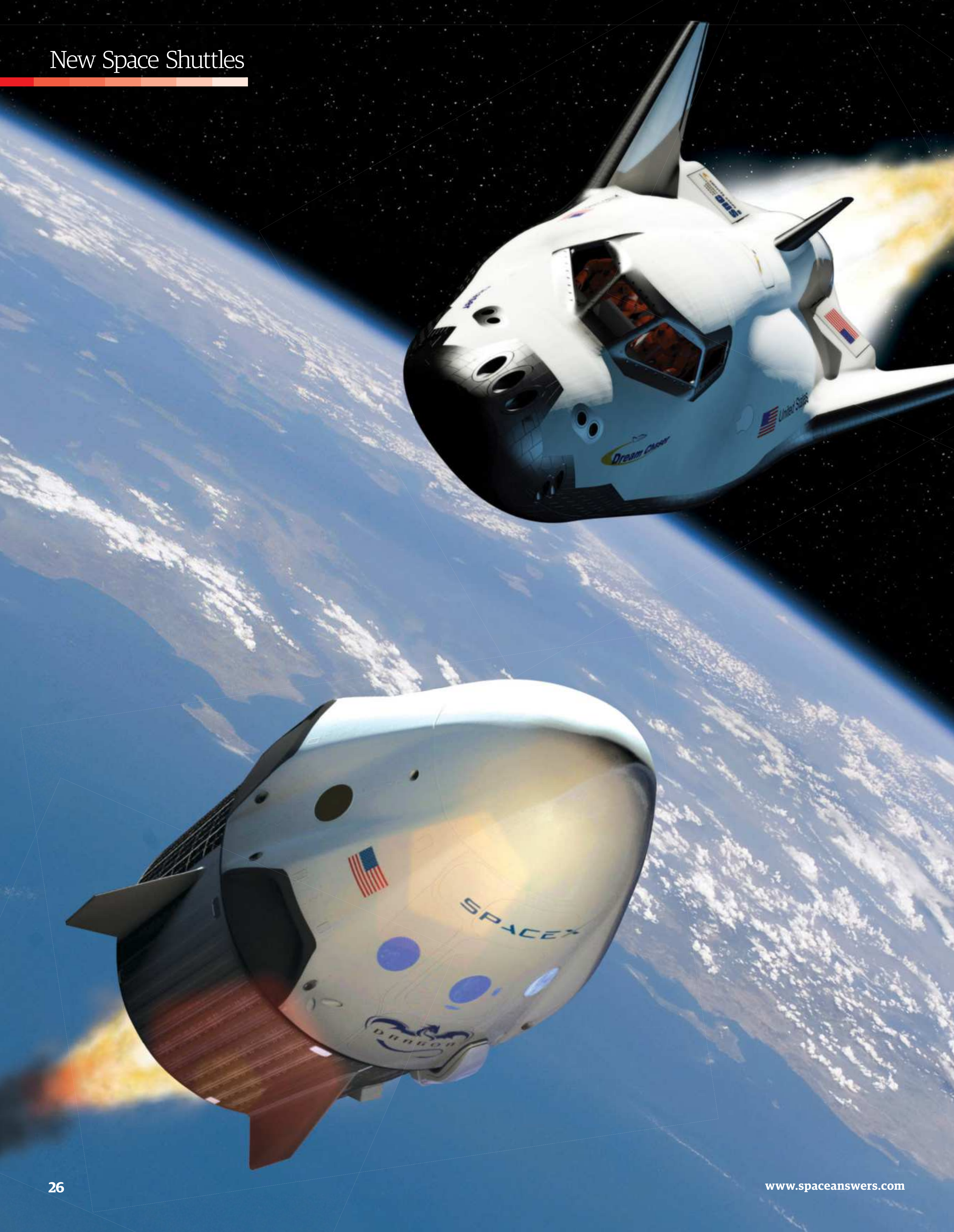
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NEW SPACE SHUTTLES

A new age of space travel is about to begin

Written by Jonathan O'Callaghan

When the Space Shuttle was retired in July 2011, many questioned the decision. Why, people asked, was the US scrapping the only method it had of reaching space? Well, we are about to find out. It may have taken five years, but the long-term goal for manned American spaceflight is finally taking shape, and it involves the extensive use of private spacecraft. On the next few pages, you'll see the various vehicles that have been funded to replace the Space Shuttle – and take us further into the cosmos than ever before.

"The private space age is well underway," Mark Sirangelo, corporate vice president of one of those private companies, Sierra Nevada Corporation's (SNC's) Space Systems, tells **All About Space**. "Today, the private space industry is entering into the next phase of development, where companies are flying real hardware for commercial missions on a consistent basis."

The problems with the Space Shuttle programme were numerous. It was expensive; each launch cost an estimated £310 million ($450 million), with the common joke being that it was cheaper to build and launch a new Hubble Space Telescope than it was to send the Space Shuttle on missions to repair it.

The spacecraft was also stuck in Earth orbit. To venture beyond, to the Moon or ultimately to Mars, the Space Shuttle was useless because it simply didn't have the muscle. It was originally conceived as a cheap means to go to and from space, with its design intended to showcase how a reusable space plane (although the booster that took it to space was not reusable) could be affordable. Alas, this did not turn out to be the case.

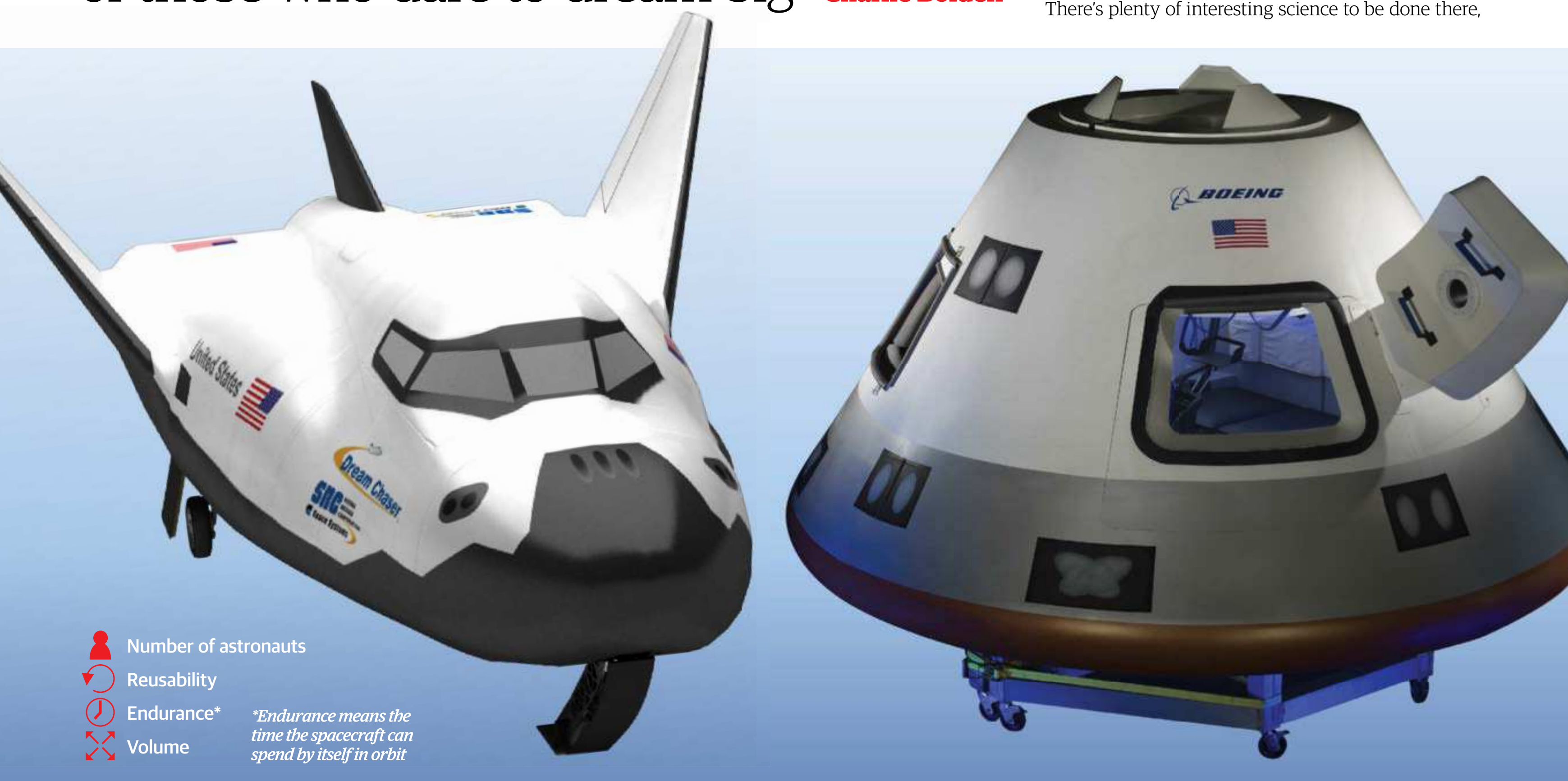
And, perhaps biggest of all, it was unsafe. A total of 14 people lost their lives in two tragedies, both the result of the Space Shuttle not having any means for the crew to exit the craft quickly and safely, in addition to a rather risky launch problem where the giant booster that took it to space would often expel bits of foam. It was one of these pieces of foam that tore a hole in Columbia, causing it to burn up on re-entry in February 2003.

The Space Shuttle was arguably born out of a desire to have reusable space planes fly to and from space. The old wives' tale that is often told is that President Richard Nixon, on seeing space planes in *2001: A Space Odyssey*, wanted that fiction to become a reality. But the harsh reality is that the capsule design, perfected on the prior Apollo, Mercury and Gemini spacecraft, is more than sufficient for human spaceflight. It's the perfect shape for a launch, while the flat design at the base means it can re-enter the atmosphere and parachute to safety on the ground – or even, one day, land by its own accord. Would you drastically redesign the shape of the car or the plane in order to improve road or air travel?

With the Space Shuttle, NASA was stuck performing missions in low Earth orbit. But they wanted something grander. It's no secret that the agency wants to ultimately send humans to Mars, possibly with a return to the Moon thrown in between. And it will do this with its upcoming Orion spacecraft and the huge Space Launch System rocket. The two are expected to launch on their first mission together by 2021.

But we can't just leave Earth orbit unoccupied. There's plenty of interesting science to be done there,

> "The best days in space exploration are ahead of us thanks to the determination of those who dare to dream big" **Charlie Bolden**



Number of astronauts
Reusability
Endurance*
Volume

**Endurance means the time the spacecraft can spend by itself in orbit*

Dream Chaser

Exclusive feature: Lands horizontally
Destination: Earth orbit (incl. ISS)
Launch date: Unknown
Organisation: Sierra Nevada Corporation
Use: Cargo transportation

Number of astronauts	0
Reusability	15 missions
Endurance	Unknown
Volume	Unknown

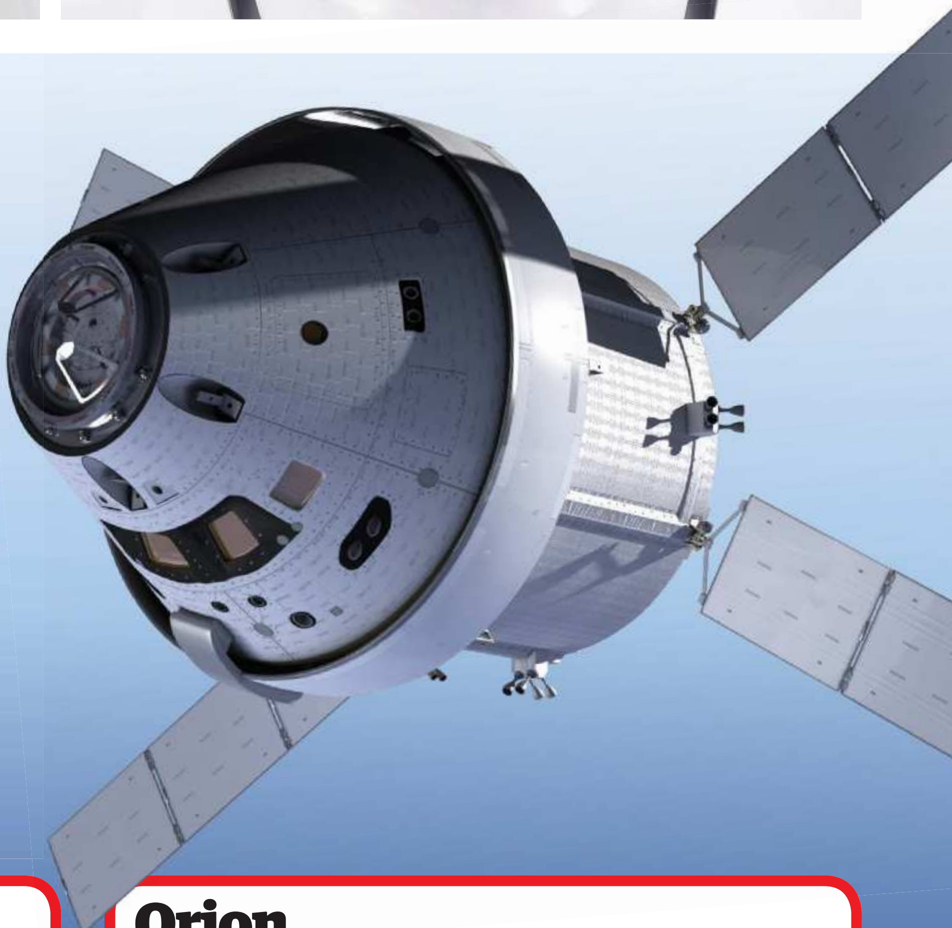
CST-100 Starliner

Exclusive feature: Can launch on multiple rockets
Destination: Earth orbit (incl. ISS)
Launch date: 2017
Organisation: Boeing
Use: Crew and cargo transportation

Number of astronauts	7
Reusability	10 missions
Endurance	7 months
Volume	Unknown

Astronauts testing flight suits in a fully outfitted test version of Boeing's CST-100 spacecraft


Dragon V2 will ultimately take up to seven people into space



Dragon V2

Exclusive feature: Powered landing
Destination: Earth orbit (incl. ISS) and Mars
Launch date: 2017
Organisation: SpaceX
Use: Crew and cargo transportation

7
10 missions
2 years
10m³ (350ft³)

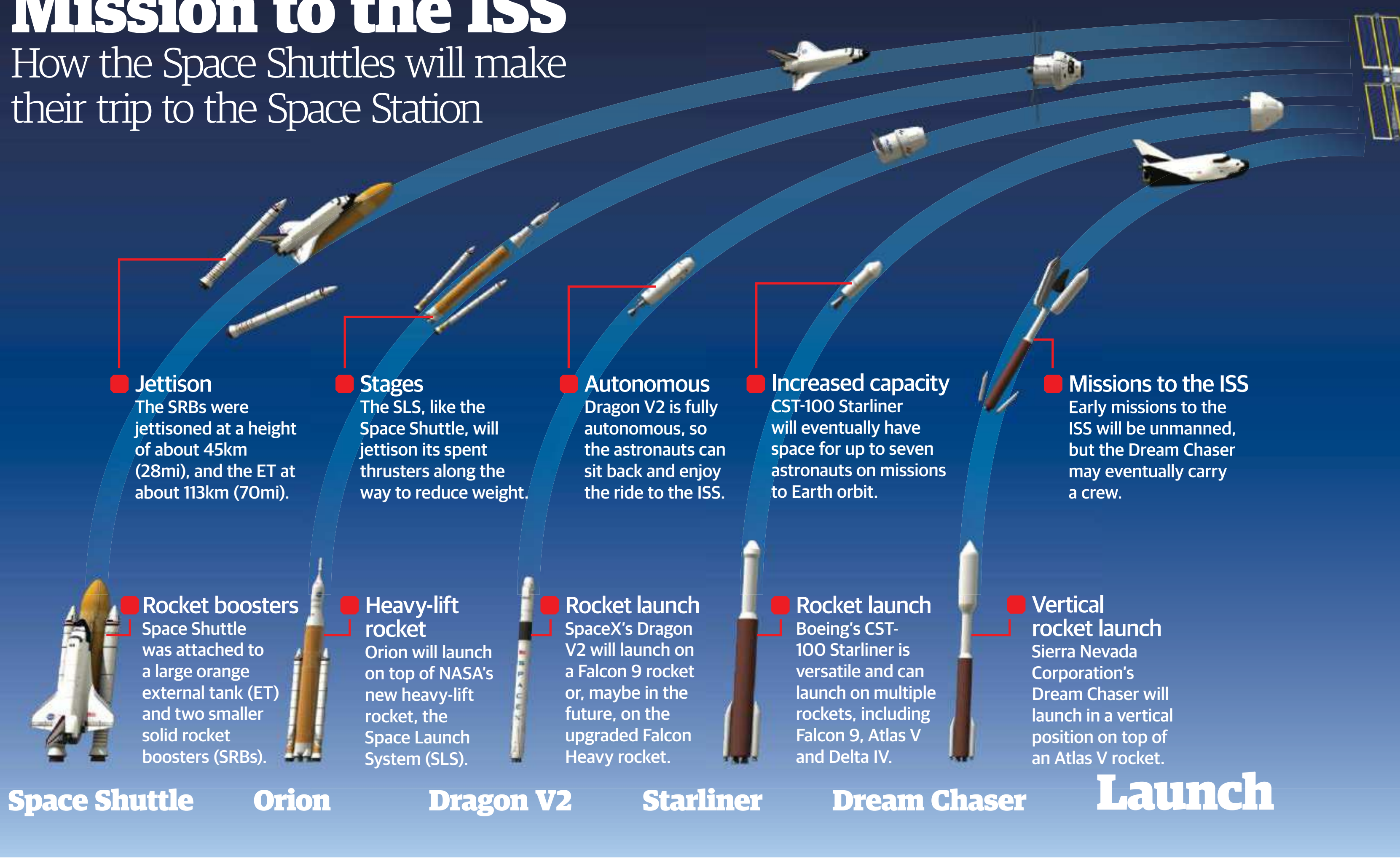
Orion

Exclusive feature: Deep space design
Destination: Earth orbit (incl. ISS), Moon, Mars and beyond
Launch date: 2021
Organisation: NASA
Use: Missions beyond Earth orbit

6
Unknown
21 days
20m³ (691ft³)

Mission to the ISS

How the Space Shuttles will make their trip to the Space Station



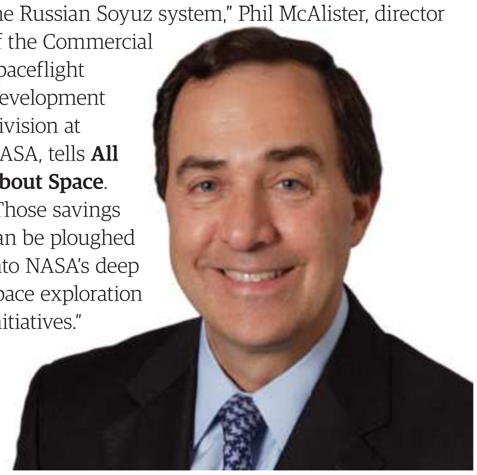
and it's a proving ground for these grander missions. So instead, the decision was made to outsource missions to Earth orbit to private companies. Some, like Boeing, were already established. Others, like SpaceX and SNC, were rapidly becoming major players. And now, five years later, these companies are ready to take up the mantle of the Space Shuttle. Their respective spacecraft will be used to ferry crew and cargo to orbit, while NASA is free to focus on missions beyond. Of course, some companies like SpaceX have their own dreams of missions to Mars. But that's a story for another day.

"America's best days in space exploration are ahead of us thanks to the grit and determination of those in government and the private sector who dare to dream big dreams and have the skills to turn them into reality," NASA chief Charlie Bolden said in November 2013. "The commercial space industry will be an engine of 21st century American economic growth and will help us carry out even more ambitious deep space exploration missions."

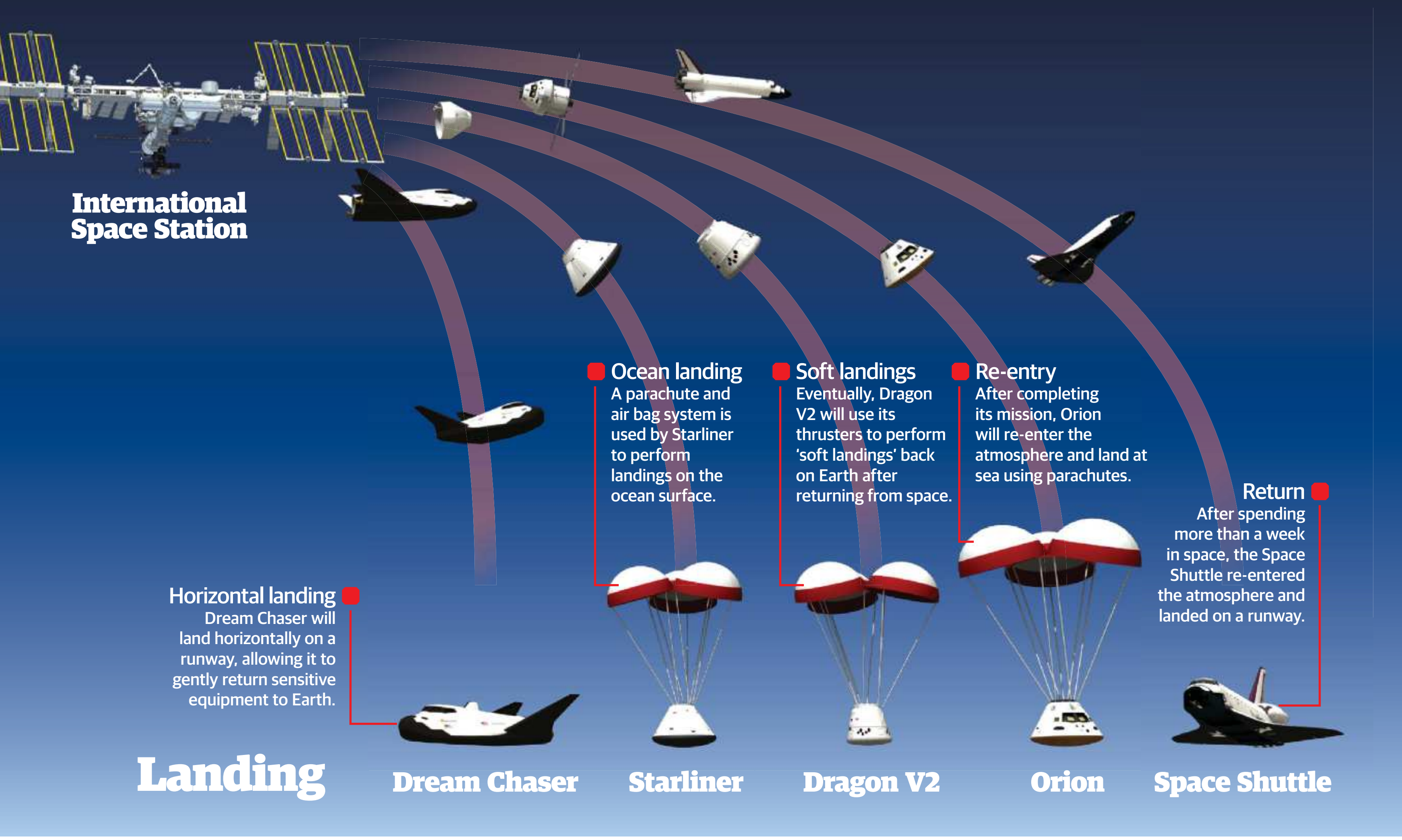
To accelerate the growth of the private sector in spaceflight, NASA began awarding lucrative contracts at the turn of the decade to several companies as part of their Commercial Orbital Transportation Services and Commercial Resupply Services (CRS) programmes. By 2011, SpaceX and Orbital Sciences (now Orbital ATK) had received several billion dollars in funding between them to send unmanned cargo spacecraft to the International Space Station (ISS). By 2013, both had been successful with their Dragon and Cygnus vehicles. Dragon has performed multiple successful missions and is also able to return cargo to Earth - just like the Space Shuttle could. Cygnus, meanwhile, offered yet another way to ferry valuable cargo to the ISS, alongside spacecraft from Russia, Japan and Europe.

But it's the next era of spacecraft that should really have you excited. If all goes to plan, by next year we will have two new spacecraft - SpaceX's Dragon V2 and Boeing's CST-100 Starliner - that can launch astronauts to space from American soil, again funded by multibillion dollar NASA contracts as part of the Commercial Crew Development (CCDev) programme. They will join Russia's Soyuz and China's Shenzhou as the only spacecraft that can transport humans currently in operation.

Both companies are now just a year from sending astronauts to the ISS. This will return human spaceflight to American soil for the first time since Space Shuttle's retirement, and the increased capacity of both - four crew will travel onboard at first, compared to three on Soyuz - will allow the capacity of the ISS to be raised from six to seven. "Every time we launch a commercial crew spacecraft, we will be saving money over paying for transportation on the Russian Soyuz system," Phil McAlister, director of the Commercial Spaceflight Development Division at NASA, tells **All About Space**. "Those savings can be ploughed into NASA's deep space exploration initiatives."



> "The ultimate goal for Dream Chaser is to provide low-cost access to low Earth orbit for all" **Mark Sirangelo, Sierra Nevada Corporation**



Perhaps though, you still yearn for a spacecraft more similar in design to the Space Shuttle. Well, if that's the case, we've got you covered. With the help of funding from NASA, the SNC are currently hard at work on the Dream Chaser, a space plane that will launch into orbit on a rocket, perform operations in space, and then return to Earth on a runway - just like the Shuttle.

SNC missed out on funding in the CCDev programme, but was awarded a contract in NASA's latest round of cargo missions, named CRS2, alongside SpaceX and Orbital ATK. This means that, at first, Dream Chaser will be unmanned. But the goal for the company was always to launch a human-rated version. Perhaps, one day, astronauts will soar into the skies on a vehicle that both looks and acts almost identical to a Space Shuttle, alongside other successful vehicles funded since its retirement.

"The ultimate goal for SNC's Dream Chaser programme is to be able to provide low-cost access to low Earth orbit for governments, commercial customers and academia," says Sirangelo. "We are thrilled to have been selected by NASA to provide cargo transportation services to the ISS and look forward to joining the existing fleet of providers."

Don't be fooled into thinking that cargo and crew missions for NASA is all these spacecraft will be used for, though. NASA was more than aware that by providing the funding for these spacecraft, they


SpaceX's goal is to send an upgraded Dragon spacecraft to Mars

would be moving us towards an age where space travel was not a rarity, but a regular occurrence. In just a few years, we'll have an impressive array of spacecraft capable of going to orbit. And they won't just be going to the ISS.

Already, other organisations – from satellite operators to research institutions – are eyeing up the opportunities that will be available to them with these new spacecraft. And perhaps more excitingly, there are plans afoot to begin construction on a private space station – a space hotel if you will – that these private spacecraft can go and visit. A Las Vegas-based company called Bigelow Aerospace is leading this venture. And in April this year, they attached one of their fledgling inflatable modules to the ISS. Called BEAM (Bigelow Expandable Activity Module), it is basically a large room that launches in a compact form and then expands in space to create a room by being pumped full of gas.

By 2020, they are hoping to launch a larger version known as the B330, and by joining several of these together they hope to one day create a privately run orbiting research laboratory that can be used not only by organisations, but by paying space tourists as well. Yes, the age of true space travel is nearly here, and it's much closer than you think. "I hope space travel in 50 years will be close to the experience of buying a ticket on a commercial airplane," McAlister says. "I hope to be able to see that day and buy a ticket!"

The Space Shuttle had its moments. But the array of capabilities offered by these new spacecraft opens up a whole new realm of possibilities. Rather than banking everything on one vehicle, we are now just years away from a fleet of private spacecraft taking off regularly, all of which has been made possible by the funds freed up from scrapping the Space Shuttle. Of course, all of this leads to the much grander goal of one day expanding humanity out into the universe from this relatively small ball of rock.

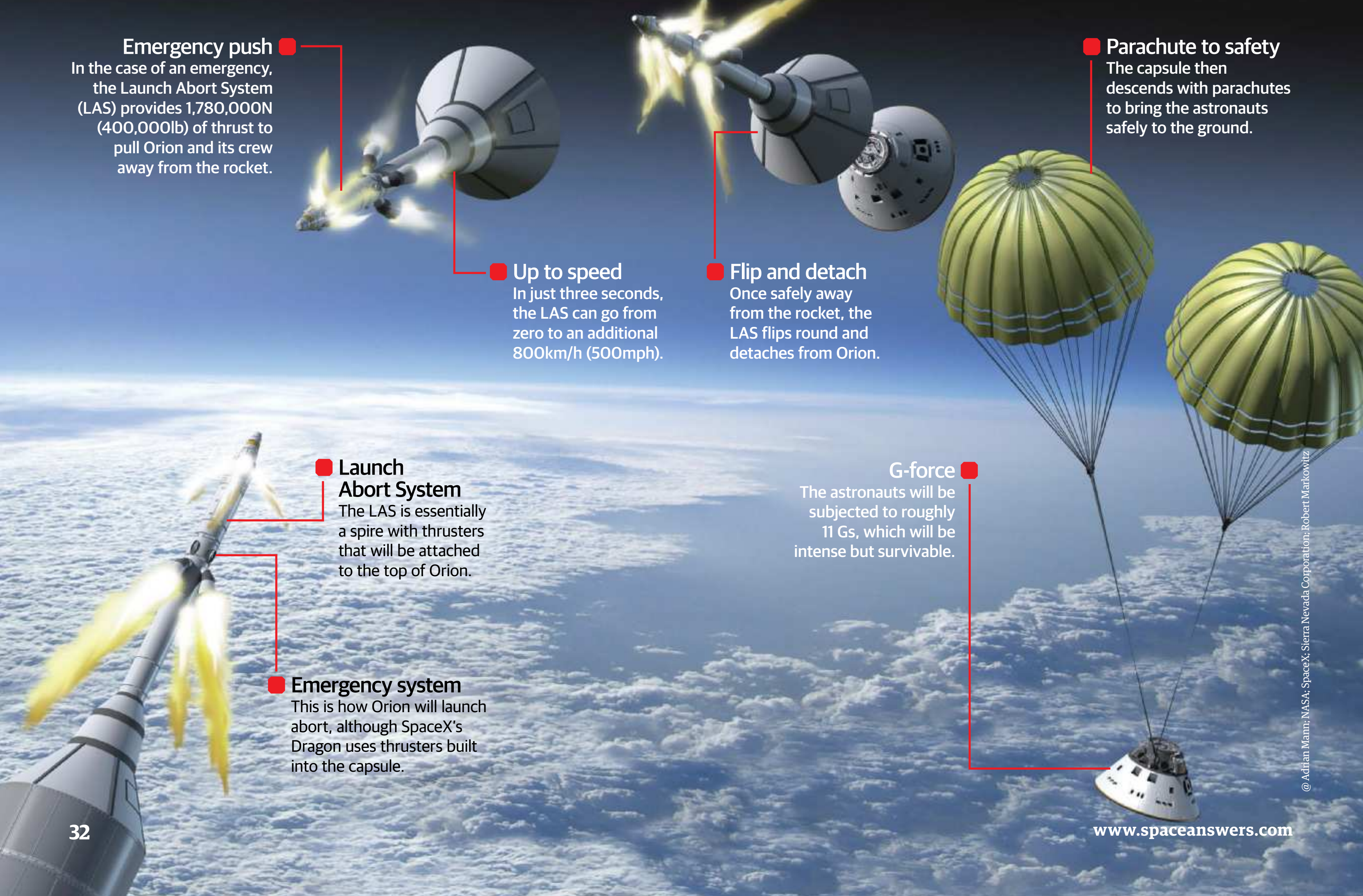
It's often said that in order for us to survive long into the future, humanity will need to colonise other worlds in the Solar System. Although it's extremely early days at the moment, developing spacecraft that can launch humans into space is an important step towards establishing civilisations on the Moon and Mars, or even elsewhere in the Solar System. And it would open up endless possibilities for human exploration of space.

For NASA, it allows the agency to focus on the more immediate goal of simply getting boots on the Martian surface, with a tentative date in the 2030s currently being worked towards. But it's not inconceivable to think that, by the end of the century, we could have astronauts regularly travelling to destinations beyond Earth, not just to conduct research but also to live permanently. And it will all have been thanks to developments in the modern era that got us there. If you still long for the days of the Space Shuttle, you might want to think again, because space travel is about to get a whole lot more exciting – and we're all coming along for the ride. ●

> "I hope space travel in 50 years will be close to the experience of buying a ticket on an airplane" **Phil McAlister, NASA**

Permission to abort

How to save your crew if there's an emergency



Welcome home, Tim Peake!

After six months of adventure among the stars, the British astronaut is finally ready to make his return trip to Earth

Written by Dominic Reseigh-Lincoln

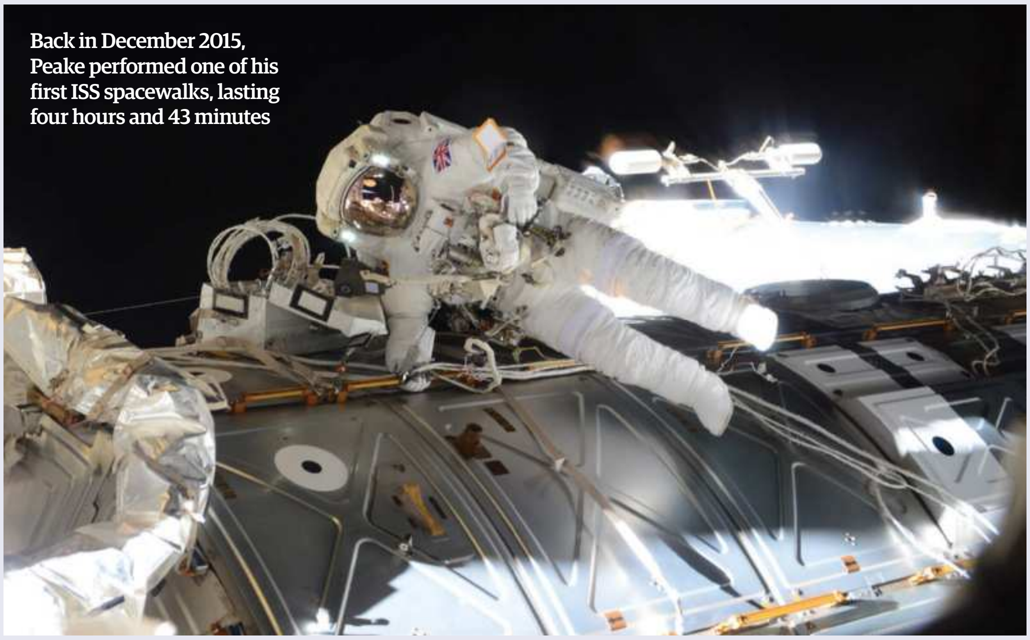
After six months orbiting the Earth onboard the International Space Station (ISS), British astronaut Tim Peake is preparing to make his return to terra firma. It only seems like yesterday that the 44-year-old beat 8,000 other candidates to become the first UK astronaut to head into space without a private contract. Ever since he was propelled out of our atmosphere from Baikonur Cosmodrome, Kazakhstan we've followed Peake's journey, from his arrival at the ISS to the final weeks of his mission (and every awe-inspiring photo and wry tweet in between).

To celebrate Peake's imminent return next month we're taking a look back at his time onboard the ISS, the aims and goals of the Principia mission, and his road home after half a year of space experiments, achievements and unforgettable moments.

Despite a long career in the Royal Air Force as a platoon commander and a helicopter pilot, as well as stints as an aquanaut during the NEEMO 16 underwater exploration mission, Peake had to pass a series of rigorous fitness tests, lengthy interviews and academic assessments to beat all of those other applicants and secure his place on the European Space Agency's (ESA's) brand new astronaut training programme.

For over six years he trained for the monumental trip that awaited him, and it was during that time Peake chose the name for the mission he was going to head up from more than 4,000 publicly submitted entries: Principia. Named after Isaac Newton's seminal work on physics, *Philosophiæ Naturalis Principia Mathematica*, the new mission would study the effects of space on human biology, the effects of radiation in a vacuum, whether life can survive in space and so much more.

> "In space, if it isn't fixed down it will float away, and that includes ourselves, so if 'you stop, you drop' [a tether]" **Tim Peake**


Back in December 2015, Peake performed one of his first ISS spacewalks, lasting four hours and 43 minutes

It's an incredibly ambitious project and one that's seen Peake involved in several experiments, with many of them as the proverbial 'guinea pig'. In fact, Peake's first experiment as a crew member of the ISS began just a few days into his mission as he began testing the effects of radiation on samples of human bone marrow. The project, rather imaginatively entitled 'Marrow', was conducted on behalf of the Canadian Space Agency and was one of many tests Peake was involved in as an astronaut.

Of course, just because you're in space it doesn't mean you're living the high life. Peake's duties are like any ISS crew member, meaning that for every experiment or run on the ARED treadmill, there's plenty of cleaning to be done. Peake and the rest of the team spent a large proportion of each Saturday removing the build up of dust and other detritus that floats into every nook and cranny in the weightlessness of the station. Two weeks into his mission aboard the ISS, Peake even had to collect together all the crew's urine for disposal – it might not sound particularly glamorous, but getting stuck into the slightly less appealing tasks didn't seem to phase Peake one bit.

Around two months into his time on the space station, Peake was finally ready for his very first spacewalk around the hull of the ISS. He had been training for years to reach this moment, drilled endlessly in underwater test facilities and having had weightless training exercises in reduced gravity aircraft. And on the 14 January – the eve of the spacewalk – Peake was musing on those hours of training: "I can hear my trainers at the European Astronaut Centre and their constant drilling in my ears," says Peake in an official Principia blog post.

"'You stop, you drop' meaning that as soon as you stop moving from A to B you 'drop' a tether – a short strap securing you to the nearest handrail. In space, if it isn't fixed down it will float away, and that includes ourselves. As we move to the furthest edge of the ISS we will be attached to an anchor point by a thin steel wire on a reel, called a Safety Tether. These thin steel wires are a double-edged sword, however, as we must remain vigilant to not get them tangled up," adds

Tim Peake is the first British astronaut to go to space without a private contract

"Peake and the rest of the ISS crew have been conducting experiments on almost every day of their mission"

Peake. Despite all of those understandable concerns, Peake's spacewalk went ahead without a hitch, although they had to cut the six-hour expedition short by a couple of hours when NASA astronaut Tim Kopra noticed an unusual build-up of moisture in his helmet. Such reactions may sound over the top, but when you're operating in something as dangerous as the vacuum of space, being overly cautious becomes second nature. And we all got to follow him, with the Twitter hashtag #SpaceWalk trending across the world while he was out on manoeuvres.

Like many of the astronauts aboard the ISS, both past and present, Twitter and other social media platforms have proved a fantastic way to give us a closer insight into life onboard a space station for Peake and the rest of the current crew. We've had images of spacewalks in action, the crew watching the Six Nations tournament and many of the experiments currently being conducted, but none have captured the imagination quite as much as his regular photos of Earth from above. We have seen volcanoes bursting into life in Russia, clouds of dust passing over Spain and the majestic twinkle of night-time Europe, its plethora of lights glittering like a web in the dark. These shots have brought an added intimacy to Peake's journey and further strengthened our shared affinity for the world we all inhabit.

Peake and the rest of the crew have also been conducting experiments on almost every day of their mission onboard the ISS, though some have been a little grander in scale than others. Take the Airway Monitoring experiment, for example, - one of many running tests - which evaluates the respiratory functions of each crew member in relation to the amount of dust present onboard.

"One area researchers are looking at is my lungs - astronaut's lungs may become easily irritated or inflamed if we inhale dust particles (thankfully, I haven't had any problems so far)," Peake reveals in another official blog post direct from the ISS. "For the Airway Monitoring experiment, Tim [Kopra] and I will breathe into a specially developed mask that

All About Peake's mission: Principia

While onboard the ISS, Tim Peake conducted a series of experiments to explore the effects of space on the body

- **Airway Monitoring**
  Studying the effects of dust particles and other detritus on the human respiratory system in a weightless environment.
- **Brain-DTI**
  Testing and understanding how an astronaut's brain reacts and functions when processing information and commands while they are weightless in the zero gravity of space.
- **Circadian rhythms**
  Testing the levels of melatonin in the body and seeing how a drastically different day cycle affects Peake's sleep patterns.
- **Space headaches**
  Living in a highly pressurised chamber can cause serious headaches, so Peake and the crew will fill out questionnaires each day to determine the severity and cause of these space headaches.
- **Muscle biopsy**
  This study will determine the effect that being weightless for six months has on Peake's muscles, both during and after his time onboard the ISS.
- **Energy levels**
  Peake and the rest of the crew onboard the ISS will provide the ESA and NASA with data on how many calories an astronaut needs to function to the required standard.
- **Cartilage and osteoporosis**
  Peake will be closely monitored to see how the reduction of cartilage affects his bone density and the potential development of osteoporosis while weightless.
- **Skin degradation**
  The first ever space-based experiment focused on skin will monitor the faster rate at which astronauts shed skin cells and examine the biological processes behind this.
- **Plasma**
  Conducting tests on the 'fourth state' of matter – an ionised gas known as plasma – as it is only possible for this fourth state (after solids, liquids and gas) to exist in space.
- **Radiation**
  To test the effects of radiation on the human body in a weightless environment, the ISS crew will be exposing material such as bone marrow to radiation and monitoring the results.

measures the nitric oxide we exhale, which is a good indicator for inflammation of the lungs."

The experiment has had varying results so far, but it has shown that varying levels of dust particles in the air can have an adverse effect on individuals. Testing his lungs wasn't easy either, as Peake explains: "On Earth doctors would use an X-ray or CT scan to test whether a patient's lungs are inflamed but in space these large machines are not an option – so necessity breeds creativity," he adds. "The researchers of the Airway Monitoring experiment devised this 'simple' nitric oxide test and Tim [Kopra] and I are part of the study to see if it works in space."

Not long after his inaugural spacewalk, Peake also began work on another experiment – NASA's ACE-H2 experiment (Advanced Colloids Experiment-Heated-2). The project, which focuses on self-assembling materials that use colloids (small particles suspended in liquid) to form, was performed in zero gravity because the strong pull of gravity on Earth tends to interfere with the process. While performing the test, Peake was able to witness the colloids settle into place thanks to the lack of gravity.

> "Peake manoeuvred an Earth-based rover across a tricky desert-style assault course all the way from space"

Alongside this experiment and the many others related to weightlessness on the human body (including its effects on muscle and bone density), Peake has also been involved in some other unusual tasks, such as controlling an Earth-based rover all the way from space. In order to simulate whether future astronauts could manually navigate a rover, Peake was asked to manoeuvre the vehicle across a tricky desert-style assault course with just two laptops. Peake was able to locate the cave within the test area, identify a series of objects and leave without an issue.

Since it would normally take 20 minutes for commands from Earth to reach a Mars-based rover, the success of Peake's performance adds more credence to the concept of controlling rovers manually from a craft orbiting the Red Planet.

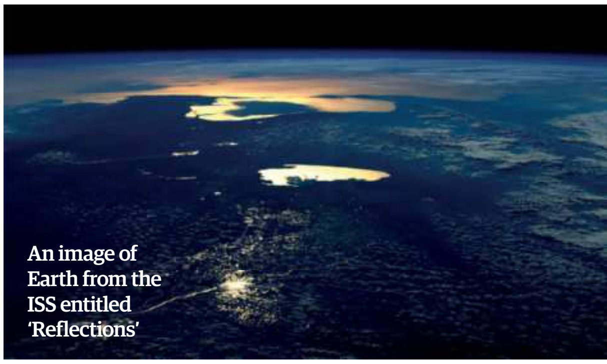
On 25 April, Peake ticked off another achievement by being only the second person to ever run the distance of a marathon in space (NASA astronaut Sunita Williams was the first, competing in the 2007 Boston Marathon). Not to let 400 kilometres (249 miles) of distance from the Earth and a lack of gravity stop him, Peake instead began his 42.19-kilometre (26.21-mile) official run of the London Marathon from the comfort (we use that word lightly) of one of the specially designed treadmills the crew use to help fight off muscle atrophy while weightless for months on end. And his attempt started off pretty well, although the feat of running that kind of distance wasn't free of its challenges.

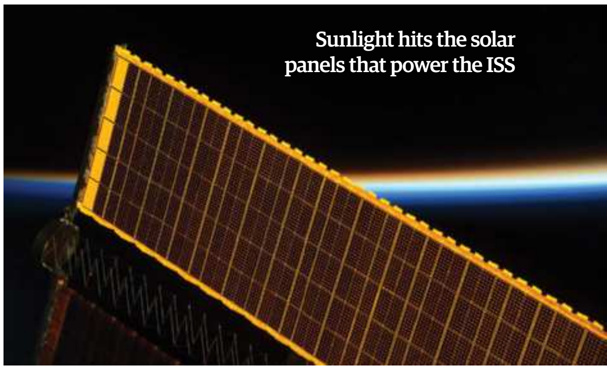
"The run went better than expected," says Peake on his official Principia blog. "I thought I'd stick to a

Tim Peake's top 10 space images

From the lens of the astronaut's camera (and the ones onboard the ISS), here's some of the best photography from Low-Earth Orbit

When Peake attempted to take a shot of The Palms in Dubai, the Dragon capsule photobombed his effort


An image of Earth from the ISS entitled 'Reflections'


Sunlight hits the solar panels that power the ISS


Taken by Peake as the ISS passed through a thick green fog of eerie aurora above the Earth

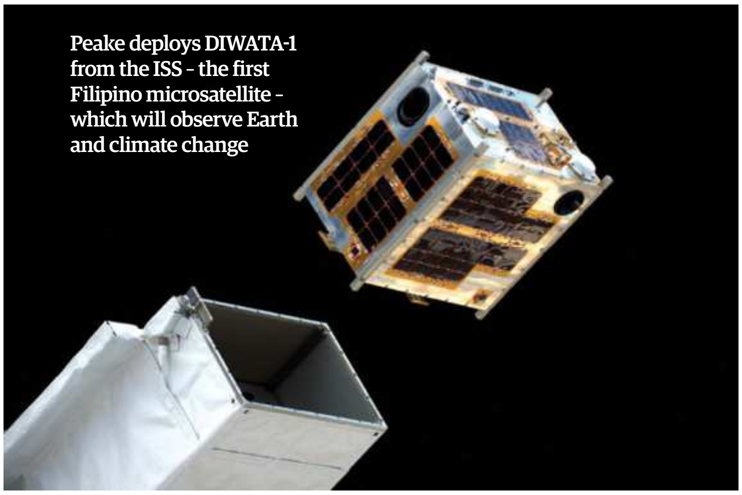

Sunrise as seen from the International Space Station

steady 12 kilometres (7.5 miles) per hour, but when I got to 16 kilometres (ten miles) my legs were feeling okay but my shoulders were beginning to hurt, so I needed to finish the run quicker than planned and running faster didn't seem to hurt the shoulders any more – in fact, I think the longer stride made it less painful on the shoulders." As a result, Peake ran the next 16 kilometres (ten miles) at a speed of 12.9 kilometres (eight miles) per hour before tackling the last ten kilometres (6.2 miles) at a higher pace of 14 kilometres (8.6 miles) per hour. Peake noted that he was having a strong race by the time he passed his own finish line (his final time was a respectable three hours, 35 minutes and 21 seconds), but in reality he was thankful to be out of the weighted harness that kept him rooted to the treadmill.

"Watching the live marathon on the BBC was a huge encouragement – I had thought I would watch a movie (*2001: A Space Odyssey* was ready to go) or listen to my #Spacerocks playlist, but it was extremely motivating watching the live coverage of the event and hearing the stories of some of the 33,000 people taking part," comments Peake.


The Airway Monitoring experiment took place in the Quest airlock onboard the ISS

After nearly six months as a crew member of the ISS, Peake's time in space is finally coming to a close. And while his name will always be famous as the first British astronaut to join the ISS in its long history, his involvement in the study of spaceflight on the human body, as well as the ongoing tests involving plasma and space-affected metals, will help further our understanding of space and our future endeavours among the stars. So, as he prepares for the four-hour return journey from the ISS to a steppe in Kazakhstan in a Soyuz TMA-19M spacecraft alongside Russian commander Yuri Malenchenko and NASA astronaut Tim Kopra, Peake can set foot back on his home planet safe in the knowledge he's already inspired a new generation of scientists and space explorers. Welcome home, Tim Peake!


Peake deploys DIWATA-1 from the ISS – the first Filipino microsatellite – which will observe Earth and climate change


While passing over Europe, we were treated to a night-time shot that captured the continent in all its electrified beauty


"I was looking for Antarctica – hard to spot from our orbit. Settled for a moonset instead," writes Peake


An incredible view of London and its web of lights

The Sinai peninsula squeezed between Soyuz (left) and Cygnus (right) spacecraft

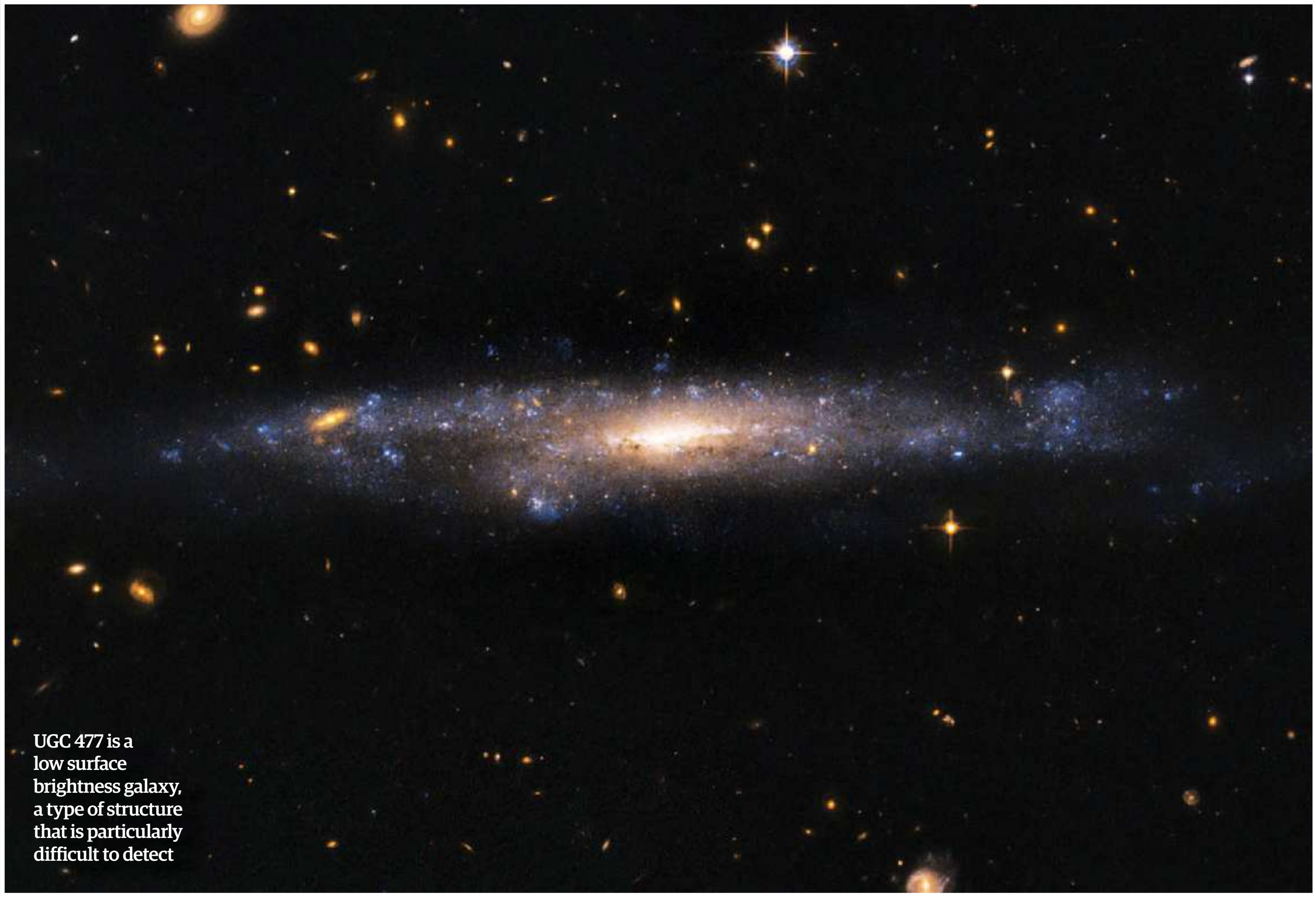
Hubble finds a hiding galaxy

Located just over 110 million light years away, the space telescope has uncovered one of the most elusive galaxies

Initially proposed by astrophysicist Mike Disney back in 1976, this striking galaxy known as UGC 477 was recently uncovered in the constellation of Pisces. UGC 477 belongs to a class of galaxies known as low surface brightness (LSB) galaxies, which are much more diffusely distributed than Andromeda and the Milky Way.

With a brightness up to 250-times fainter than the night sky, these structures are considered to be incredibly challenging to detect – this is because LSB galaxies contain a great deal of hydrogen gas rather than stars. As they are in a region devoid of galaxies and are therefore unable to merge with other structures, they have nothing to kick-start star formation.

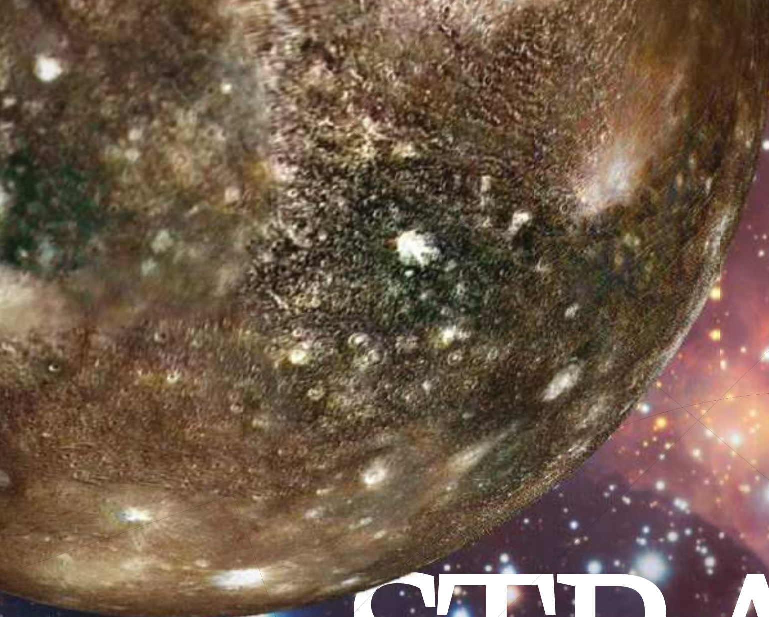
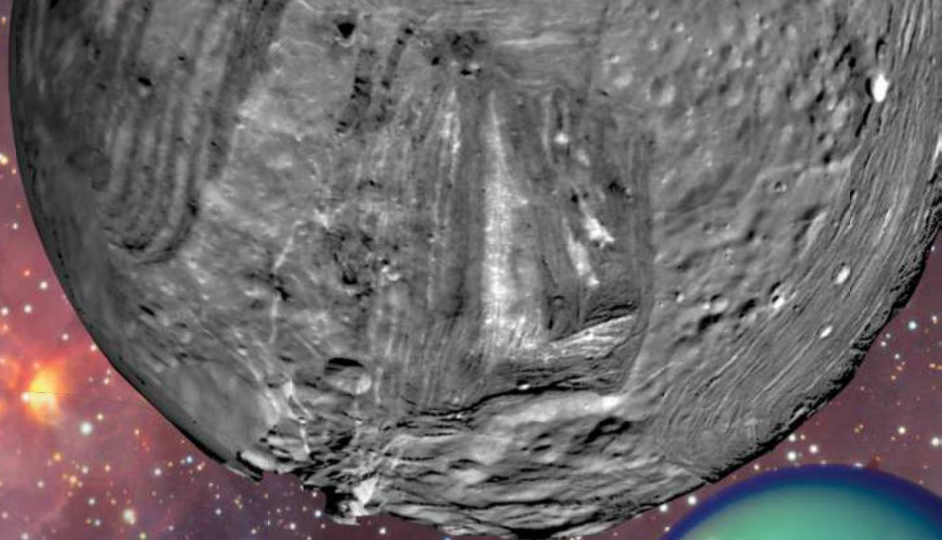
Instead – and UGC 477 is of no exception – these dim galaxies are mostly comprised of dark matter, making them excellent targets for understanding more about one of the most elusive 'substances' in the universe.



UGC 477 is a low surface brightness galaxy, a type of structure that is particularly difficult to detect

The Hubble Space Telescope has now been in operation for 26 years

© NASA

STRANGEST MOONS IN THE SOLAR SYSTEM

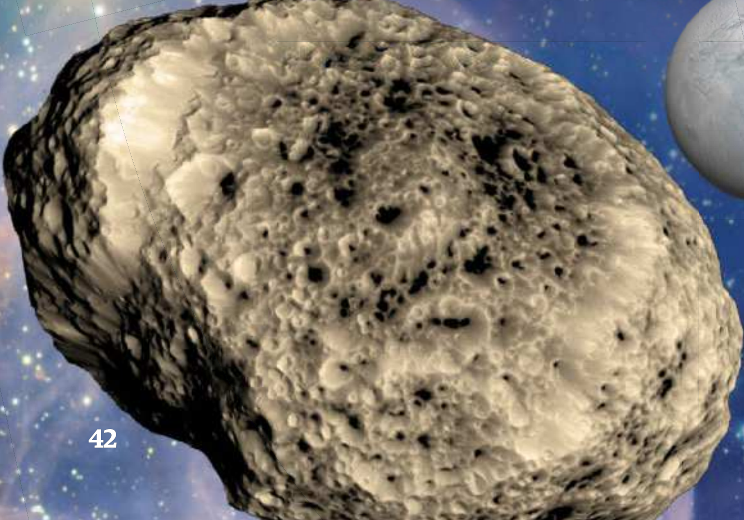
Some of the most fascinating worlds in our cosmic neighbourhood are not planets, but the moons that orbit around them

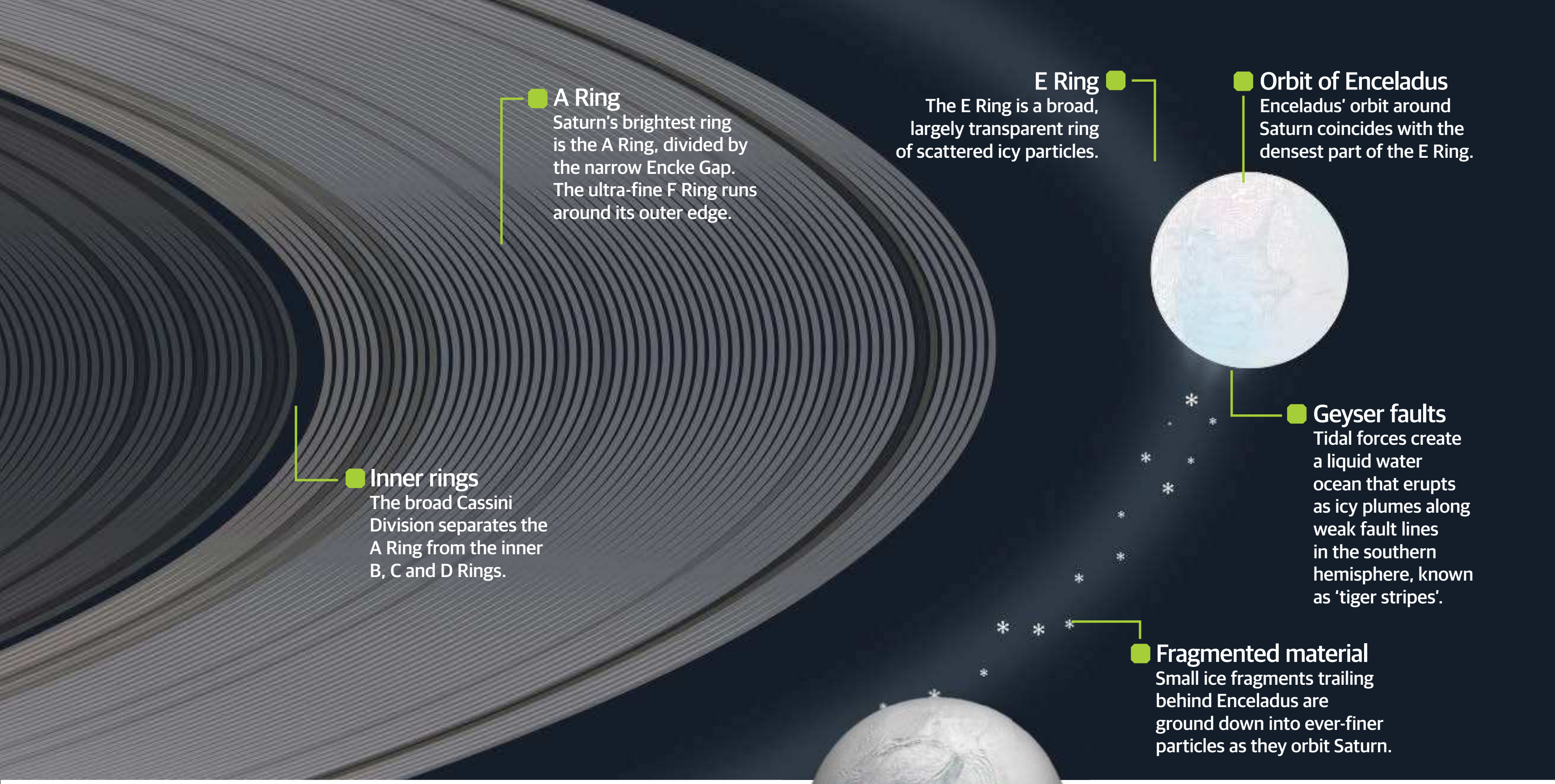
Written by Giles Sparrow


All but two of our Solar System's planets have satellites of one sort or another. Earth's own Moon, a beautiful but stark, dead world shaped by ancient volcanoes and countless impact craters, is undoubtedly the most familiar, but it's far from being the most interesting – each of the outer Solar System's giant planets is accompanied by a large retinue of satellites, many of which formed at the same time and from the same ice-rich material as the planets. Although far from the Sun and starved of solar heat and light, they nevertheless show as much variety as the planets themselves.

All About Space takes a trip to visit some of the strangest and most exciting of these astonishing worlds. Some, such as Jupiter's Callisto and Saturn's Mimas, have been frozen solid for billions of years but bear extraordinary scars from exposure to bombardment from space. Others, such as Saturn's shepherd moons Pan and Atlas and Neptune's lonely Nereid, have been affected throughout their history by interactions with their neighbours.

Most excitingly, some have been heated by powerful tidal forces from their parent planets, triggering phases of violent activity like those which shaped Miranda, Uranus' Frankenstein moon. In some cases, these forces are still at work today, creating fascinating bodies such as Jupiter's tortured Io and Saturn's icy Enceladus, whose placid exterior may even hide the greatest secret in the Solar System: extraterrestrial life itself.





1 Enceladus
The ring bearer

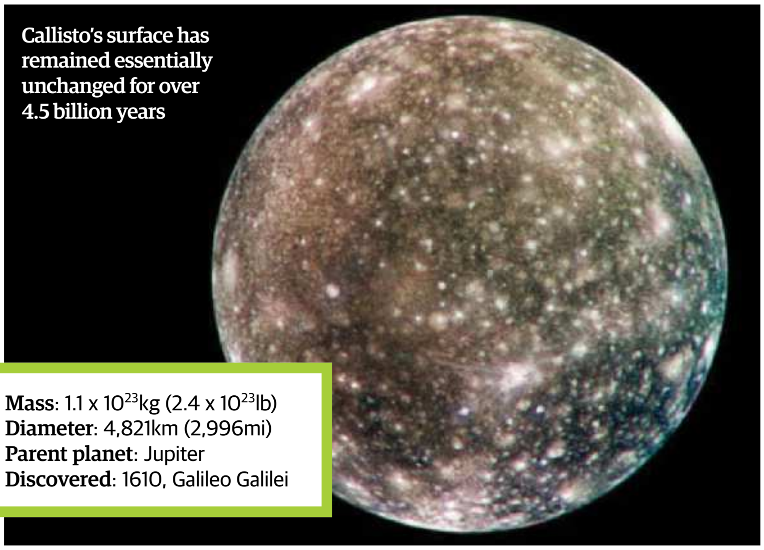
Mass: 1.1 x 10^{20}kg (2.4 x 10^{20}lb)
Diameter: 504km (313mi)
Parent planet: Saturn
Discovered: 1789, William Herschel

Since NASA's Cassini probe arrived at Saturn in 2004, the ringed planet's small inner satellite, Enceladus, has become one of the most intensely studied and debated worlds in the entire Solar System. It owes its new-found fame to the discovery of huge plumes of water ice erupting into space along fissures in its southern hemisphere - a sure sign of liquid water lurking just beneath the moon's thin, icy crust.

The strange activity of Enceladus was suspected before Cassini's arrival thanks to earlier images that showed the moon has an unusually bright surface and craters that look like they are blanketed in snow. Nevertheless, the discovery of the ice plumes (initially made when Cassini flew straight through one) was a spectacular confirmation that Enceladus is an active world.

With a diameter of 504 kilometres (313 miles) and a rock/ice composition, Enceladus should have frozen solid billions of years ago, like many of its neighbours in the Saturn system. But tidal forces caused by a tug of war between Saturn and a larger moon, Dione, keep the moon's interior warm and active, making it a prime target in the hunt for life in the Solar System.

While much of the water ice falls back to cover the surface, a substantial amount escapes from the weak gravity and enters orbit around Saturn. Here, it spreads out to form the doughnut-shaped E Ring - the outermost and sparsest of Saturn's major rings.



Callisto's surface has remained essentially unchanged for over 4.5 billion years

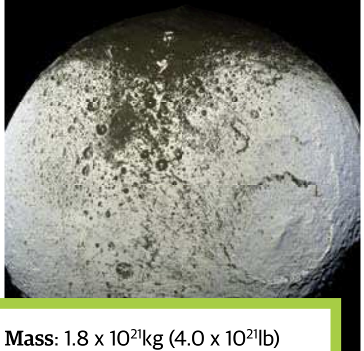
Mass: 1.1 x 10^{23}kg (2.4 x 10^{23}lb)
Diameter: 4,821km (2,996mi)
Parent planet: Jupiter
Discovered: 1610, Galileo Galilei

2 Callisto
The most cratered world

The outermost of Jupiter's Galilean moons, Callisto is the third largest moon in the Solar System and is only slightly smaller than Mercury. Its main claim to fame is the title of most heavily cratered object in the Solar System; its dark surface is covered in craters down to the limit of visibility, the deepest of which have exposed fresh ice from beneath and scattered bright 'ejecta' debris across the surface.

Callisto owes its cratered surface to its location in the Jupiter system - the giant planet's gravity exerts a powerful influence, disrupting the orbits of passing comets and often pulling them to their doom (most spectacularly demonstrated in the 1994 impact of Comet Shoemaker-Levy 9).

Jupiter's larger moons are directly in the firing line and end up soaking up more than their fair share of impacts, but Callisto's inner neighbours - influenced by greater tidal forces from the planet - have all experienced geological processes that wiped away most of their ancient craters. Callisto's surface, however, has remained essentially unchanged for more than 4.5 billion years, developing its dense landscape of overlapping craters over aeons of time.


A Cassini photomosaic of Iapetus reveals its bizarre two-tone surface

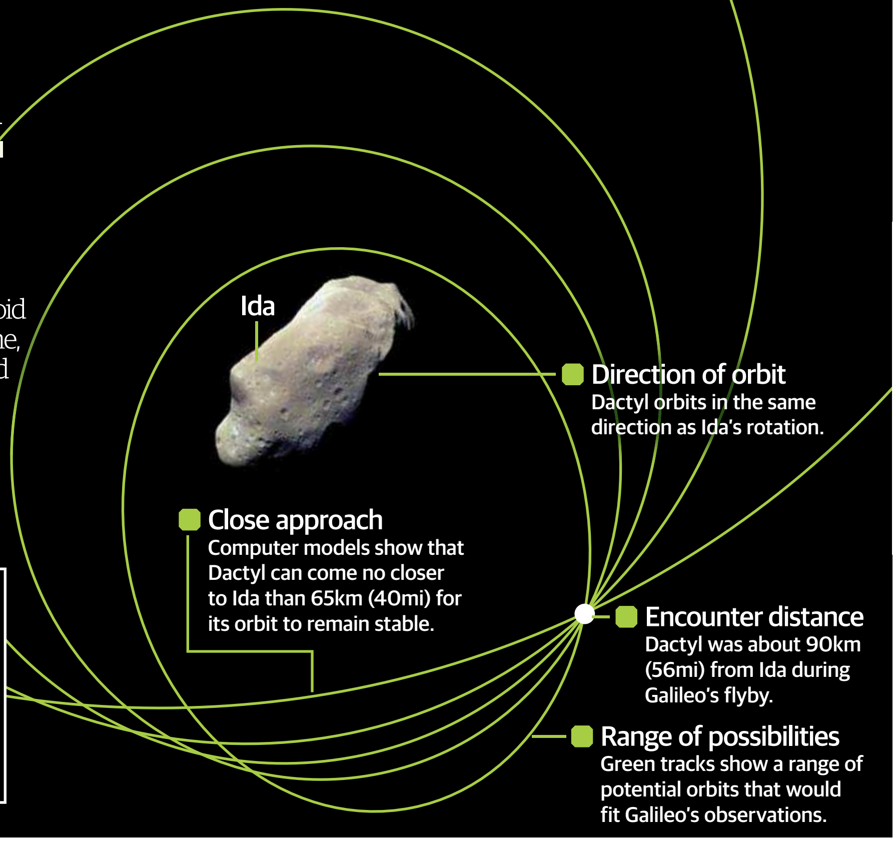
Mass: 1.8 x 10^{21}kg (4.0 x 10^{21}lb)
Diameter: 1,469km (913mi)
Parent planet: Saturn
Discovered: 1671, Giovanni Cassini

3 Iapetus
The walnut

The outermost member of the large family of moons that orbit Saturn, Iapetus has two distinct claims to a place in any list of weird satellites. The first became obvious when it was discovered in 1671 - the satellite is much dimmer when seen on one side of its orbit compared to the other. Iapetus, like most moons, keeps one face permanently towards its parent planet. Its leading hemisphere (the half that faces 'forwards' as it orbits Saturn) is dark brown, while its trailing hemisphere is light grey. One early theory to explain the colour difference was that the leading side is covered in dust, which is generated by tiny meteorite impacts on small outer moons, and spirals towards Saturn.

However, images from Cassini reveal a more complex story - most of the dark material seems to come from within Iapetus, left behind as dark 'lag' when dust-laden ice from the moon's surface sublimates (turns from solid to vapour). The process was likely started by dust from the outer moons accumulating on the leading hemisphere, but once it began, the tendency of the dark surface to absorb heat has caused a runaway sublimation effect.

As if this weren't strange enough, Iapetus is ringed by a mountainous equatorial ridge that is 13 kilometres (eight miles) high and 20 kilometres (12 miles) wide, giving the moon its distinctive walnut shape. The origins of this ridge are puzzling - some theories suggest it is a 'fossil' from a time when Iapetus span much faster and bulged out at the equator, while others think it could be debris from a ring system that once encircled the moon and collapsed onto its surface.




The most detailed view of Dactyl available

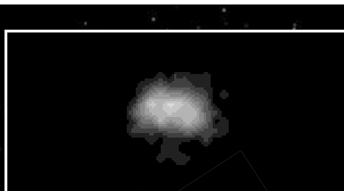
4 Dactyl
The asteroid moon

Mass: Unknown
Diameter: 1.4km (0.87mi)
Parent planet: Asteroid 243 Ida
Discovered: 1993, Galileo space probe

The idea that small objects can have their own moons was brought home when NASA's Jupiter-bound Galileo probe flew past the 60-kilometre (37-mile) long, potato-shaped asteroid 243 Ida in 1993. Several images sent back from the asteroid belt showed a small, egg-shaped object positioned near Ida - a satellite soon named Dactyl.

Ida's moon is tiny, at just 1.6 kilometres (0.99 miles) on its longest axis. Thanks to the larger asteroid's weak gravity, Dactyl is unlikely to be an object captured into orbit, but the alternative - that Ida and Dactyl formed alongside each other - raises as many questions as it answers. Ida is a major member of the Koronis family of over 300 asteroids, all of which share similar orbits. The family is thought to have formed 1 or 2 billion years ago during an asteroid collision. A simple explanation is that Dactyl could be a smaller fragment of debris from the collision that ended up in orbit around Ida, but there is a problem - computer models suggest Dactyl would almost certainly be destroyed by an impact from another asteroid. So how can it be over a billion years old?

One theory is that the Koronis family is younger than it appears, and Ida's heavy cratering is due to a storm of impacts triggered in the original break-up. Another theory is that Dactyl has suffered a disrupting impact, but has pulled itself back together in its orbit - which might explain its surprisingly spherical shape.


Voyager 2's only glimpse of Nereid showed it as a distant blur of pixels

5 Nereid
Neptune's boomerang

Discovered by astronomer Gerard Kuiper in 1949, Nereid was the second moon found to orbit Neptune, and its claim to fame arises from its extreme orbit. Nereid's distance from Neptune ranges between 1.4 million and 9.7 million kilometres (850,000 and six million miles). This orbit is usually typical of captured satellites - asteroids and comets swept up into highly eccentric orbits by the gravity of the giant outer planets - but Nereid's unusually large size suggests a rather more interesting story.

Mass: 3.0 x 10^{19}kg (6.6 x 10^{19}lb)
Diameter: 340km (211mi)
Parent planet: Neptune
Discovered: 1949, Gerard Kuiper

Neptune is striking as it does not have a normal family of satellites - a system of moons that formed in orbit around it and which circle in the same 'prograde' direction as the planet's rotation. Instead though, a handful of small satellites survive in and around the planet's rings and the system is dominated by a single large moon, Triton, which orbits in the wrong 'retrograde' direction. Evidence from Voyager 2's 1989 flyby suggests that Triton was captured into orbit from the nearby Kuiper Belt (the ring of icy objects beyond Neptune).

Triton would have disrupted the orbits of Neptune's original moons, ejecting many of them. But many astronomers believe Nereid could be a survivor, clinging on at the edge of Neptune's gravitational reach.

6 Io
The cold inferno

Mass: 8.93 x 10^{22}kg (1.97 x 10^{23}lb)
Diameter: 3,643km (2,264mi)
Parent planet: Jupiter
Discovered: 1610, Galileo Galilei

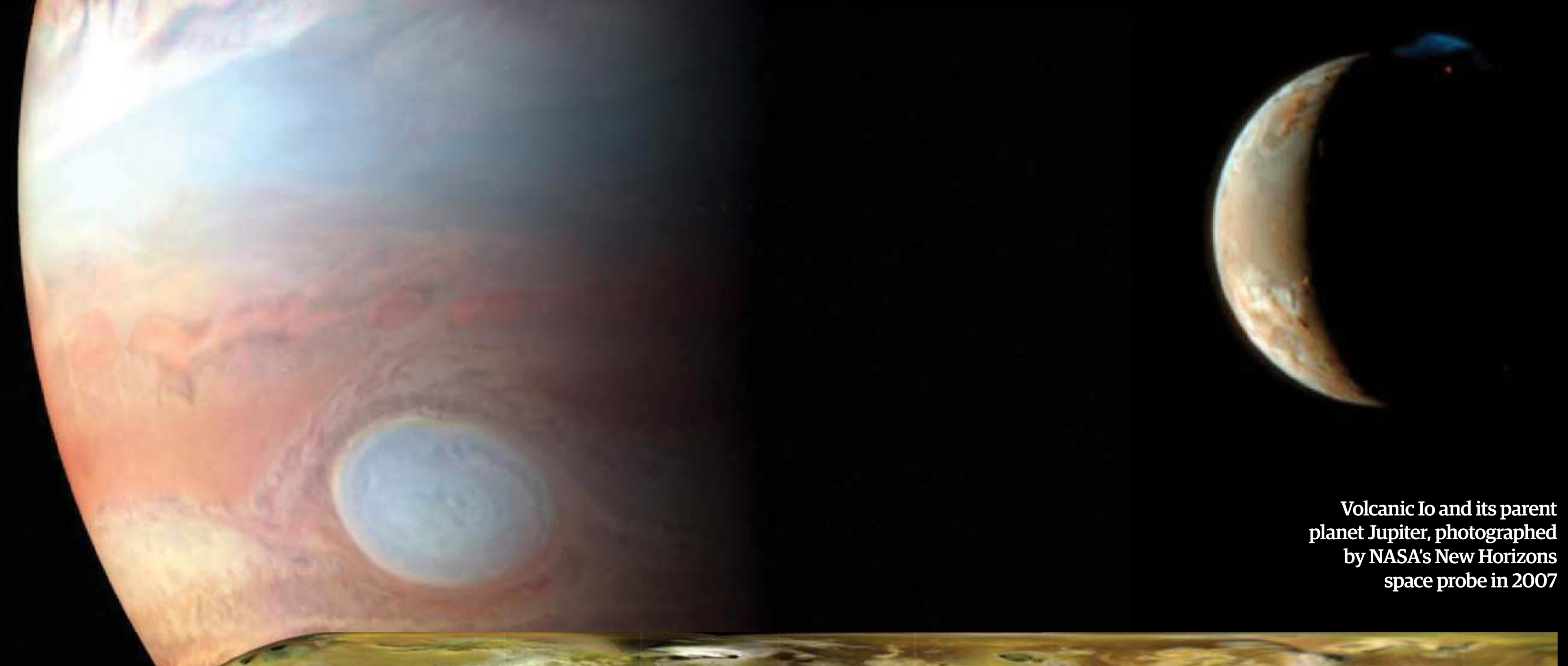
Io is the innermost of the four giant Galilean moons that orbit the Solar System's largest planet, Jupiter. But while the outer three are (at least outwardly) placid frozen worlds of rock and ice, Io's landscape is a virulent mix of yellows, reds and browns, full of bizarre and ever-changing mineral formations, created by sulphur that spills onto its surface in many forms. In fact, Io is the most volcanic world in the Solar System.

Io's strange surface was first observed during the Pioneer space probe flybys of the early 1970s, but its volcanic nature was only predicted weeks before the arrival of the Voyager 1 mission in 1979.

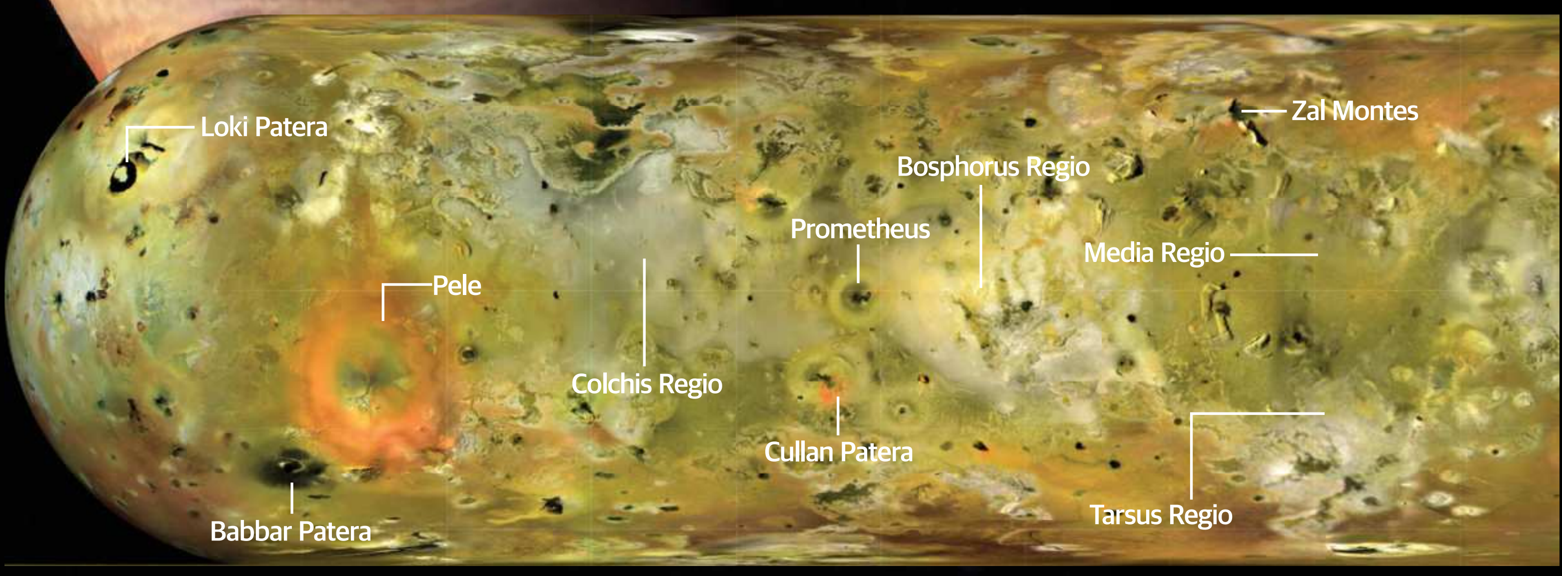
The moon is caught in a gravitational tug of war between its outer neighbours and Jupiter itself, and this prevents its orbit from settling into a perfect circle. Instead, small changes in Io's distance from Jupiter (less than 0.5 per cent variation in its orbit) create huge tidal forces that pummel the moon's interior in all directions. Rocks grinding past one another heat up due to friction, keeping the moon's core molten and creating huge subsurface reservoirs of molten magma.

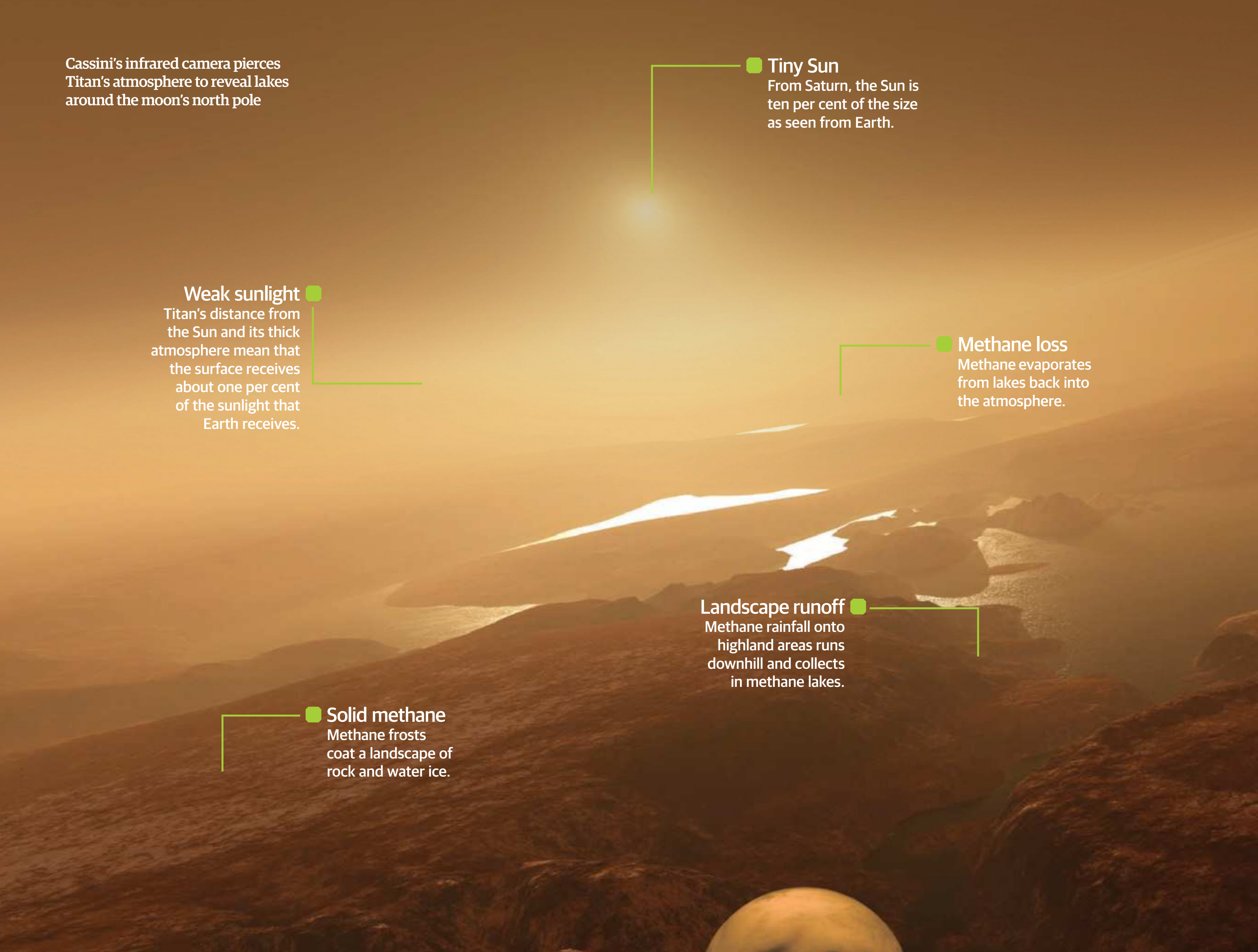
While the majority of Io's rocks are silicates similar to those on Earth, these have relatively high melting points and so are mostly molten in a hot magma ocean that lies tens of kilometres below the surface - most of Io's surface activity, in contrast, involves sulphur-rich rocks that can remain molten at lower temperatures.

Together, these two forms of volcanism have long since driven away any icy material that Io originally had, leaving a world that is arid and iceless despite an average surface temperature of -160 degrees Celsius (-256 degrees Fahrenheit).



Volcanic Io and its parent planet Jupiter, photographed by NASA's New Horizons space probe in 2007





Cassini's infrared camera pierces Titan's atmosphere to reveal lakes around the moon's north pole

7 Titan
The second Earth

Mass: 1.3 x 10^{23}kg (2.9 x 10^{23}lb)
Diameter: 5,150km (3,200mi)
Parent planet: Saturn
Discovered: 1655, Christiaan Huygens

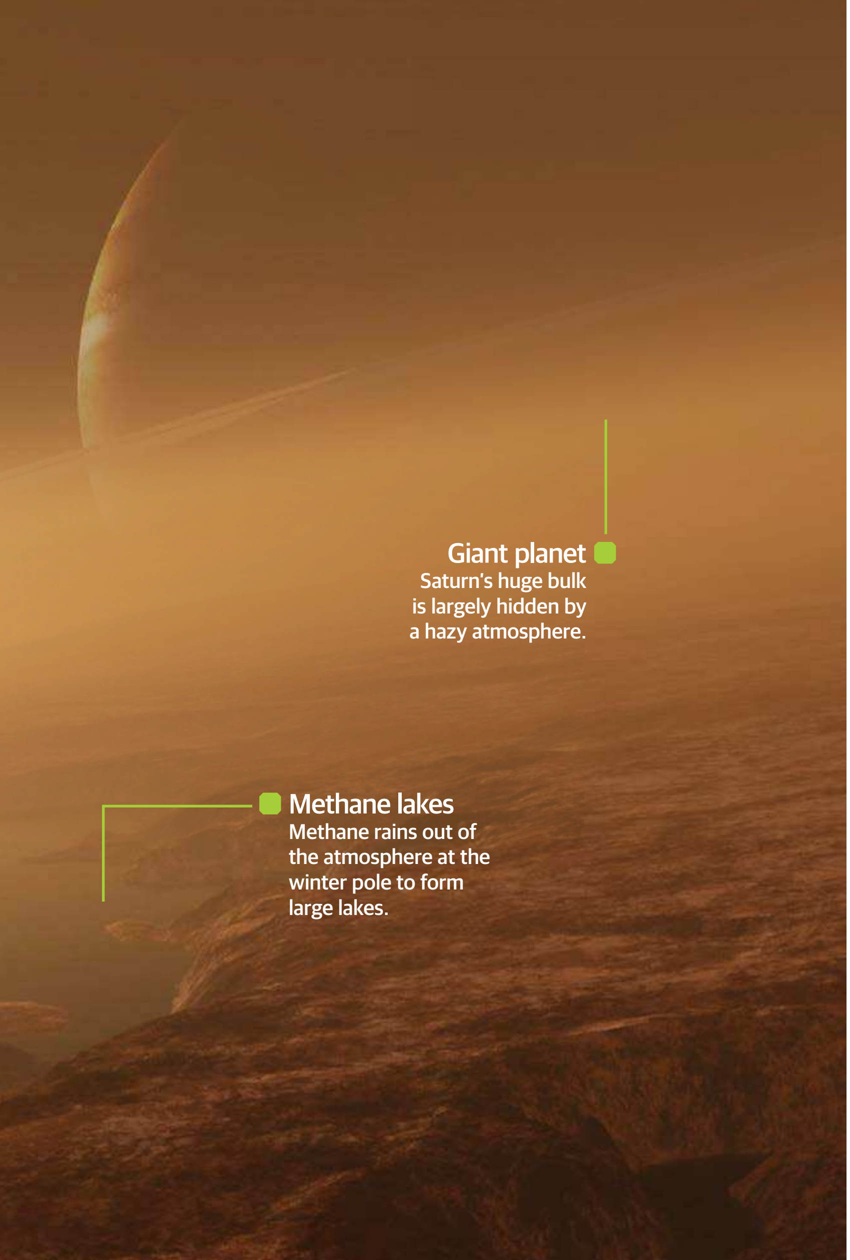
Saturn's largest moon, Titan, is unique in the Solar System as the only satellite with a substantial atmosphere of its own - a discovery that frustrated NASA scientists during the initial flybys of the ringed planet, when images from the Voyager space probes revealed only a hazy orange ball. The Cassini orbiter, however, was fitted with infrared and radar instruments that pierced the opaque atmosphere for the first time, revealing a softened landscape of rivers and lakes that is unlike any other world in the Solar System except for Earth itself.

Despite being larger than the planet Mercury, Titan can only hold onto its thick atmosphere because of the deep cold found some 1.4 billion kilometres (0.9 billion miles) from the Sun (the moon's average surface temperature is a freezing -179 degrees Celsius, or -290 degrees Fahrenheit).

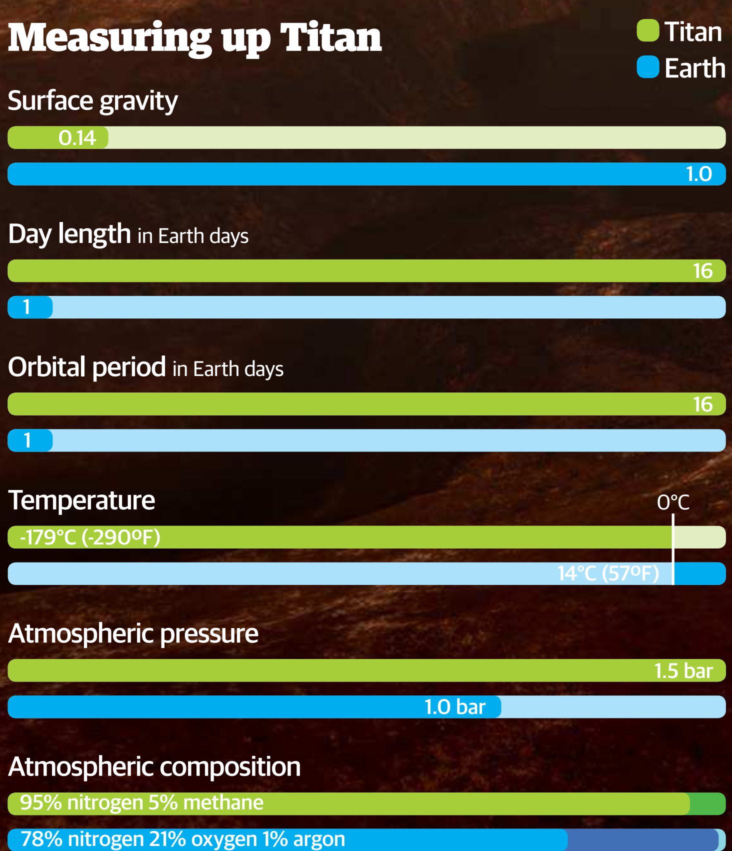
Titan's atmosphere is dominated by the inert gas nitrogen (also the major component of Earth's air) but it gets its distinctive colour, opaque haze and clouds from a relatively small proportion of methane (CH_4). Amazingly, conditions on Titan are just right for methane to shift between gaseous, liquid and solid forms, generating a 'methane cycle' rather similar to the water cycle that shapes Earth's climate; in cold conditions, methane freezes onto the surface as frost and ice; in moderate temperatures, it condenses into liquid droplets and falls as rain that erodes and softens the landscape, before accumulating in lakes; while in warmer regions it evaporates and returns to the atmosphere.

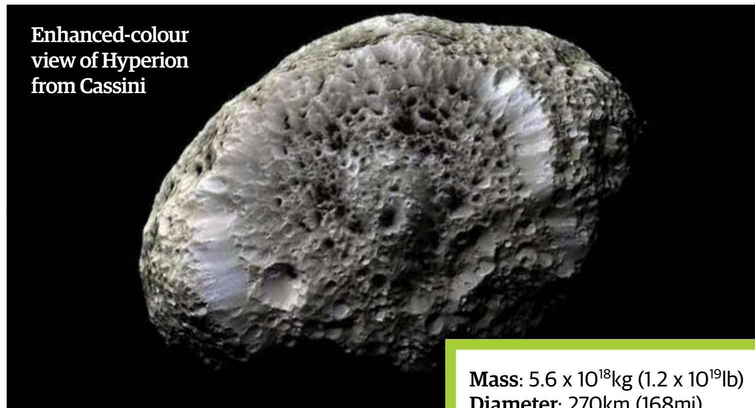
Titan experiences changing seasons very similar to those on our planet (though its year is 29.5 Earth years long), and the temperatures at the winter pole seem to favour rainfall, so the lakes migrate from one pole to the other over each Titanian year.

With all this activity, Titan is an intriguing target in the search for extraterrestrial life, though most biologists find it hard to envision organisms that could exist in such harsh and chemically limited conditions, and most agree that Titan's watery inner neighbour Enceladus offers more promising prospects for life.



Measuring up Titan




Enhanced-colour view of Hyperion from Cassini

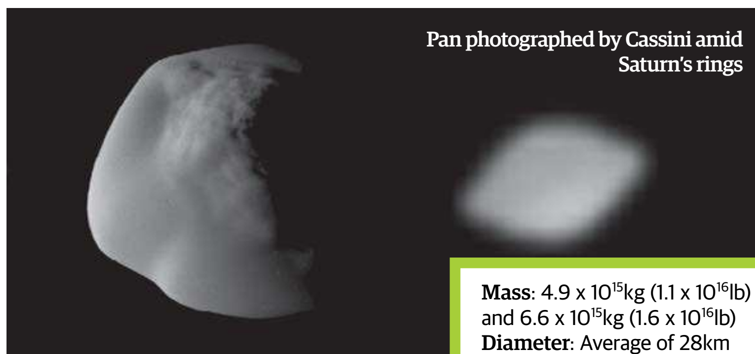
Mass: 5.6 x 10^{18}kg (1.2 x 10^{19}lb)
Diameter: 270km (168mi)
Parent planet: Saturn
Discovered: 1848, William Bond, George Bond and William Lassell

8 Hyperion
The spongy satellite

Hyperion is the strangest looking satellite in the Solar System, its surface resembling a sponge or coral with deep, dark pits rimmed by razor-sharp ridges of brighter rock and ice. But that's not the only thing that's strange about Hyperion; it was the first non-spherical moon to be discovered and has a distinctly eccentric orbit.

Rather than matching its rotation to its orbital period, it spins in a chaotic pattern, with its axis of rotation wobbling unpredictably. Like all moons in the outer Solar System, it's mostly made of water ice but its surface is unusually dark. When Cassini flew past it measured its density to be 55 per cent that of water - its interior is mostly empty space.

One popular theory to explain these weird features is that Hyperion is the surviving remnant of a larger satellite that once orbited between Titan and Iapetus, and which was largely destroyed by a collision with a large comet. Material that survived in a stable orbit then came together again to create Hyperion as we know it.


Pan photographed by Cassini amid Saturn's rings

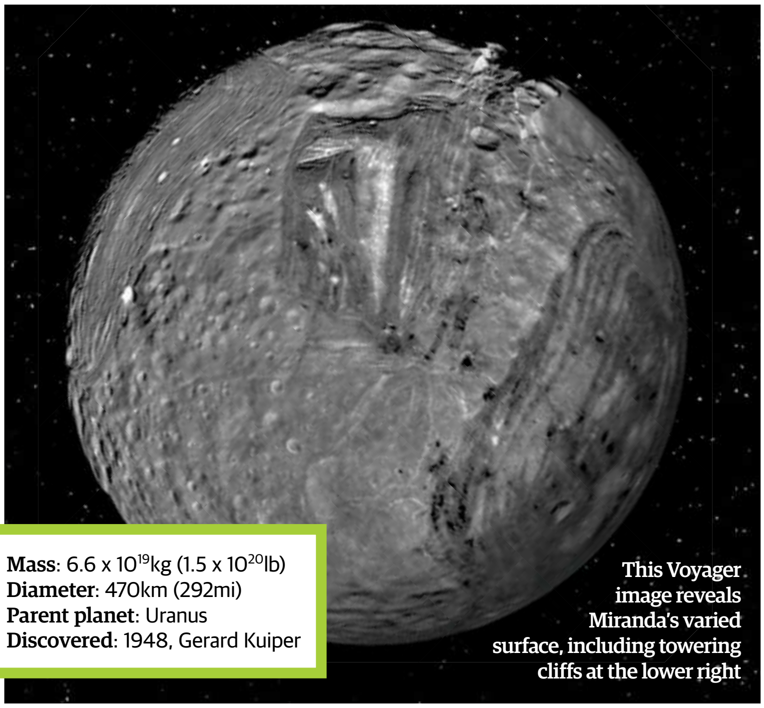
Mass: 4.9 x 10^{15}kg (1.1 x 10^{16}lb) and 6.6 x 10^{15}kg (1.6 x 10^{16}lb)
Diameter: Average of 28km (17mi) and 30km (19mi)
Parent planet: Saturn
Discovered: 1990 and 1980, Voyager 2

9 Pan and Atlas
The flying saucers

Saturn's moons Atlas and Pan are the smallest moons in the Solar System. But despite their size, their influence can be seen clearly from Earth in the form of the prominent 'gap' they create in the planet's ring system.

These two worlds are perhaps the best-known examples of shepherd moons - small satellites that orbit in or around the ring systems of the giant planets. As their name suggests, when coupled with the influence of distant outer moons, such satellites help to herd the particles orbiting in the ring system together, while 'clearing out' others. Pan is responsible for creating the Encke Gap, a prominent division in Saturn's bright A Ring, while Atlas orbits just outside the A Ring.

But the most intriguing property of both worlds is their smooth shape, resembling a walnut or a flying saucer. Experts believe the moons are blanketed in small particles swept up as they keep the space between the rings clear. As most of the particles orbit in a plane one kilometre (0.6 miles) thick, they tend to pile up around each moon's equator, building up a distinctive equatorial ridge.



Mass: 6.6 x 10^{19}kg (1.5 x 10^{20}lb)
Diameter: 470km (292mi)
Parent planet: Uranus
Discovered: 1948, Gerard Kuiper

This Voyager image reveals Miranda's varied surface, including towering cliffs at the lower right

10 Miranda
The chiselled satellite

The smallest of five satellites known to orbit Uranus before the Voyager 2 flyby of 1986, Miranda is one of the strangest worlds in the Solar System. Voyager images revealed an extraordinary patchwork of terrains, seemingly put together at random. Some parts are heavily cratered, some relatively uncratered (indicating their youth as they have been less exposed to bombardment from space). One prominent feature is a pattern of concentric ovals resembling a racetrack while, elsewhere, parallel V-shapes form a chevron-like scar.

An early theory to explain Miranda's jumbled appearance is that it is a Frankenstein world – a collection of fragments from a predecessor moon that coalesced in orbit around Uranus. Astronomers wondered whether Miranda's predecessor might have been shattered by an interplanetary impact, and whether this cataclysmic event might somehow be linked to Uranus' own extreme tilt. Further studies, however, have shown that such a theory comes up short when trying to explain Miranda's mix of surface features, and the right kind of impact is unlikely. Instead, it seems plausible that tidal forces are to blame.

Today, Miranda follows an almost circular orbit, but in its past its orbit was in a 'resonant' relationship with larger moon Umbriel. This brought the two moons into frequent alignments that pulled Miranda's orbit into an elongated ellipse that experienced extreme tidal forces. Pushed, pulled and heated from within, its surface fragmented and rearranged itself before the moons moved again and Miranda's activity subsided.

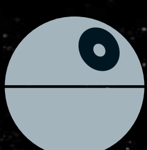
11 Mimas
The real-life Death Star

Mass: 3.8 x 10^{19}kg (8.4 x 10^{19}lb)
Diameter: 396km (246mi)
Parent planet: Saturn
Discovered: 1789, William Herschel

When NASA's Voyager space probes sent back the first detailed images of Mimas in the 1980s, scientists and the public were shocked by its resemblance to the Death Star space station from the hugely successful *Star Wars* films. A huge crater (named after William Herschel, who discovered the moon in 1789) dominates one hemisphere and is almost the exact size and shape of the planet-killing laser dish dreamt up by George Lucas many years before. But Mimas has more to offer than pop cultural references.

Mimas is the innermost of Saturn's substantial moons (orbiting closer than Enceladus, but further out than Pan and Atlas), and with a diameter of just 396 kilometres (246 miles), it's the smallest object in the Solar System known to have pulled itself into a spherical shape from its own gravity. Some larger Solar System objects haven't quite managed this, and most astronomers agree that it's only possible for Mimas because of the moon's low density (just 15 per cent greater than water).

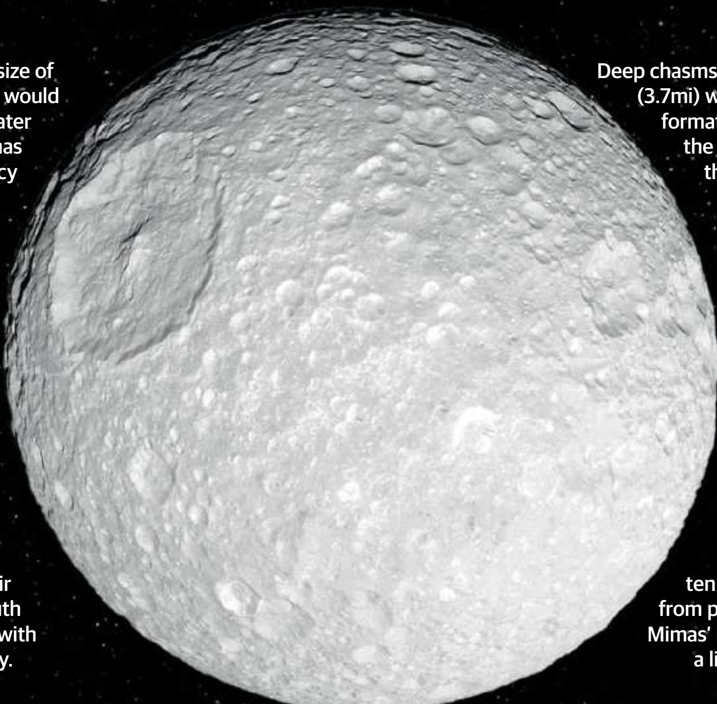
In fact, Mimas has such low density that the formation of Herschel shook it to the core – the giant crater is one-third the diameter of Mimas, and the impact which formed it would have been as violent as it could get without smashing the moon to pieces.

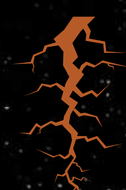


Death Star crater
If Mimas was scaled up to the size of Earth, its giant crater Herschel would be as wide as Australia. The crater was originally far deeper, but has slumped over time as Mimas' icy surface has slowly levelled off.

Towering peak
Herschel's central peak rises 6km (3.7mi) above the crater floor – it's as high as Mount Kilimanjaro in Africa and taller than any European mountain.

Crater variation
Mimas' surface is saturated with craters, but those around its south pole are half the size of those elsewhere (about 20km, or 12.4mi, at their biggest). This suggests the south pole was probably resurfaced with fresh ice early in Mimas' history.





Cracked surface
Deep chasms 100km (62mi) long and 6km (3.7mi) wide were likely created in the formation of Herschel. Scaled up to the size of Mars, they would rival the Red Planet's famous Valles Marineris canyon.

Colour changes
Enhanced-colour images show slight variations in Mimas' surface – a slightly greenish hue overlaid with blue in the area around Herschel.

Rugby ball moon
Tidal forces pulling on Mimas have given it an ellipsoidal shape, with the axis pointing towards Saturn ten per cent longer than the axis from pole to pole. Slight wobbles in Mimas' long axis suggest it may have a liquid water layer deep inside.

PROJECT STARSHOT

Destination Alpha Centauri

Some of the world's top scientists are looking to reach for our nearest stars

Written by David Crookes

If you gaze into the night sky from Earth's Southern Hemisphere – anywhere from below 29 degrees North – you should be able to catch sight of our nearest star neighbour, Alpha Centauri. It appears to the naked eye as a single, brightly glowing celestial object and has long been a source of fascination for astronomers. Our knowledge of this body dates back as far as the ancient Egyptians and it was labelled 'Second Star of the Southern Gate' by ancient Chinese civilisations, yet it still remains alien to us.

Alpha Centauri was discovered to be a binary star system in 1689, made up of Alpha Centauri A and Alpha Centauri B, and in 1915 a fainter star called Proxima Centauri was observed relatively close by. However, there has been some doubt cast over more recent theories about the star system. In October 2012, a team of European observers claimed to have evidence of an exoplanet orbiting Alpha Centauri B and yet, almost exactly three years later, the theory was dismissed by a group of astronomers at Oxford University. Other theories relating to exoplanets within the star system are similarly up in the air.

The key issue with Alpha Centauri is that it is 4.37 light years away and, while Proxima Centauri is closer, it is still distant by a just-as-daunting 4.24 light years. To put that into perspective, travelling to the star system would entail a journey of some 40 trillion kilometres (25 trillion miles) and, with current spacecraft speeds, you'd have to be travelling for more than 30,000 years to reach it. It's no surprise, then, that given such long journey times, so few have seriously considered launching a craft that would, quite literally, reach for the stars. And yet that is just what a group of some of the world's most respected scientists and engineers are now hoping to do in their bid to vault into the interstellar age. Advances in technology, combined with the financial backing of Russian entrepreneur and physicist Yuri Milner, are set to place what was felt to be the impossible very much on the table of possibility. "The problem is, space travel as we know it is slow," says Milner. "If Voyager had left our planet when humans first left Africa, travelling at 18 kilometres (11 miles) per second, it would be arriving at Alpha Centauri just about now. So how do we go faster and how do we go further? How do we make this next leap?"

Last year Milner and Professor Stephen Hawking created the privately funded company, Breakthrough Initiatives. Almost immediately, it launched a programme called Breakthrough Listen, which heralded a cash-rich search for alien life beyond the Solar System. Now, with Facebook founder Mark Zuckerberg also on board, it has unveiled a new project: Breakthrough Starshot. Its aim is to develop a craft and propellant system capable of reaching Alpha Centauri just 20 years after launch.

The central idea of Starshot is to send a fleet of tiny probes called nanocrafts deep into the more remote regions of space. It would involve shooting a powerful laser beam to propel them to one fifth of the speed of light. When they reach their destination, the probes will be able to take photographs of the celestial bodies they encounter and gather other scientific data before sending the information back down to Earth. It's a jaw-dropping proposal that would, if successful, allow for a visit to our nearest star system within a generation. And the research and engineering programme would enable many of today's scientists to search for extraterrestrial life, seek exoplanets and maybe even discover an Earth-like body in a habitable zone. But more than that, it would prove useful in quickly exploring planets and other bodies far closer to home. The potential is huge.

So why has this possibility only just emerged? The answer lies in many of our pockets: within our smartphones and tablets. Moore's law has meant that the size of microelectronic components has vastly decreased thanks to nanotechnology advances and the incredible demand for smaller, smarter consumer devices. If you pulled apart an iPhone, for example, and discarded the screen and casing, you would see that the basic driving force behind the technology is not only light in weight but small in size.

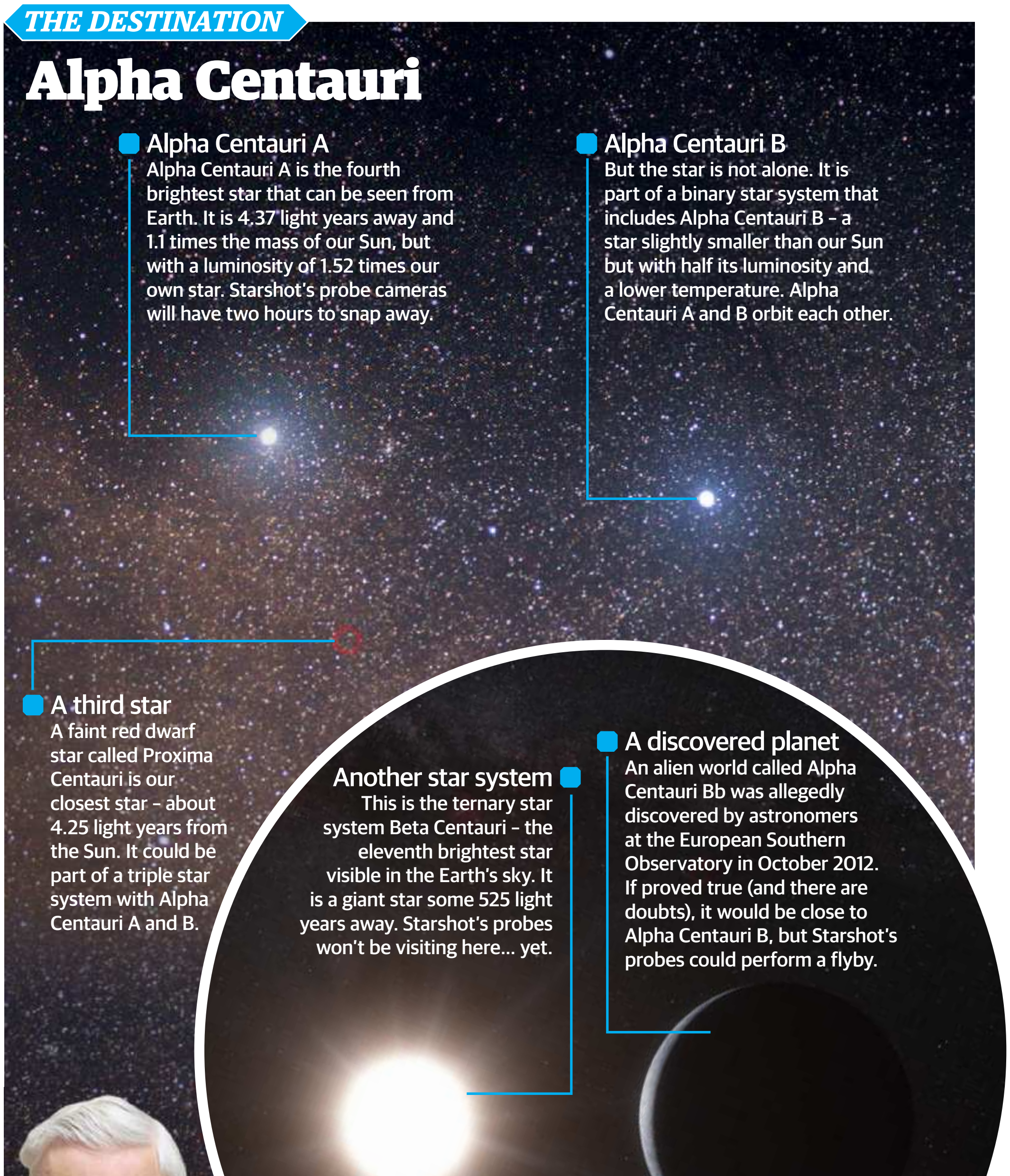
It's on this principle that the nanocrafts will be built. The so-called StarChip will be a small 'wafer' of around 25 millimetres (0.9 inches) in size and will weigh less than one gram (0.04 ounces). Yet it will be capable of carrying the key components of a robotic probe; that is a camera (or indeed four), power supply, thrusters and both navigation and communication equipment. They will be so tiny and eventually so relatively inexpensive to make, that hundreds or maybe thousands of them are intended to be placed within a mothership and rocketed into space. The sheer numbers will allow for a large margin of error, ensuring that at least some of them will succeed in reaching their target. It

> "With the lightest spacecraft ever built, we can launch a mission to Alpha Centauri within a generation" **Stephen Hawking**

Some of the best individual brains in science, engineering and aerospace are working on the Breakthrough Starshot project

THE DESTINATION

Alpha Centauri



Why should we go to Alpha Centauri?

We asked British Astronomer Royal, Martin Rees, his thoughts on studying the star system in greater detail

Is there anything special about Alpha Centauri?
It's a binary star where the separation is about the distance between the Sun and Neptune. But I think for most astronomers, it's the study of exoplanets that is especially interesting because that's a new thing that has only opened up in the last ten or 20 years. The question is whether Alpha Centauri has any planets or not.

Why is there interest in Alpha Centauri?
Some of us want to study the stars and some of us want to get detailed images of planets around stars. The main scientific goal is to find Earth-like planets. We didn't know until five years ago that most stars have planets around them and that makes it more interesting. At least we know where to look.

Could it be that the focus will have moved away from Alpha Centauri once the Starshot project is ready to launch?
Long before we launch these probes, I suspect we'll have learned enough about all of the nearby stars to know which ones have the most interesting planets around them. Before it's possible to launch anything, we would know if Alpha Centauri was the best target or not. We would have enough information to make that decision from ground-based observations.

sounds throwaway, but having more than one device flung into space also opens up the possibility of having different instruments on different StarChips, widening the scope of the collectable data. In all of this, Breakthrough Initiatives says it is bringing "the Silicon Valley approach to space travel" and it is hard to argue against that.

But it's only part of the story. Although work has already begun in prototyping the miniaturisation of the spacecraft – notably by researcher and aerospace engineer Zac Manchester – the rest of the programme hinges on having something that can not only create forward propulsion, but also get the probes to the desired speed. For this, an extremely thin, one square metre (10.8 square foot) sail will open shortly after the nanocrafts have been launched from their mothership. The StarChips will then literally sail to their destination.

Using sails in space is not a new idea. Johannes Kepler wrote to Galileo about this very concept in 1610 and, exactly 400 years later, the Japanese spacecraft IKAROS became the first to successfully use a solar sail that unfolded slowly to an area of 32 square metres (344 square foot). Sails can take advantage of the Sun's wind to propel a spacecraft forward with a push of photons. Indeed, so well-known is the power of photons that they were even used to balance the Kepler Space Telescope.

Here though, the idea begins to sound like it has been ripped from the pages of a science-fiction novel (there is mention of something similar in David Brin's 2012 book, *Existence*). The problem with relying on the Sun to produce the required force to propel the StarChip to one fifth of the speed of light is that our star isn't forceful enough to do this. So the Starshot scientists are looking to use a powerful laser beam instead. The beam will shoot out towards the probes and hit their light sails with a torrent of photons. It is this that will cause them to accelerate to a blistering speed in the microgravity vacuum of space. Within two minutes, the nanocrafts will be as far as 965,600 kilometres (600,000 miles) from home and well on their way to their target. "With light beams, light sails and the lightest spacecraft ever built, we can launch a mission to Alpha Centauri within a generation," says Professor Hawking.

But that's not to say any of this will be straightforward. It could take a decade, maybe two, to even get the technology to a stage where a launch is actually possible. "It's a very complex programme," Professor Philip Lubin of the University of California, Santa Barbara tells us. "You don't want to go into this assuming everything is simple because it's not. We know how to do many of the things but there are many things we don't. Some will require development over years, which is why we're going into a long-term development programme." This part of the programme relies heavily on advances in photonics (the science of light generation, detection and manipulation). Professor Lubin is at the forefront of this study and it was he who detailed how photonics would play its part in spacecraft propulsion in a 66-page academic paper written in 2015 called *A Roadmap To Interstellar Flight*. The paper forms the basis of Starshot and it says scientists and engineers need to fundamentally change their thinking of both propulsion and what a spacecraft is. It also says that

THE PEOPLE

Who's involved?

The Breakthrough Starshot project has some of the best and most influential figures from science, engineering and aerospace working on the spacecraft that will reach further than ever before

Prof Stephen Hawking

Director of Research at the University of Cambridge

Notable achievements: One of the greatest scientists of all time, he helped to advance the Big Bang theory. His well-known book, *A Brief History Of Time*, has sold over 10 million copies.
Involvement in Project Starshot: Board member of Breakthrough Initiatives.

"Sooner or later, we must look to the stars. Starshot is an exciting first step on that journey."

Yuri Milner

Founder of DST Global

Notable achievements: The Russian entrepreneur and physicist has invested in numerous tech businesses such as Facebook, Twitter and Spotify.
Involvement in Project Starshot: Funding Breakthrough Initiatives.

"The human story is one of great leaps - 55 years ago, Yuri Gagarin became the first human in space. Today, we are preparing for the next great leap - to the stars."

Ann Druyan

Author, producer and specialist in science communication

Notable achievements: Selected the music included with Voyager 1 and 2. Co-writer of the 1980 PBS documentary series *Cosmos*, and producer and writer of *Cosmos: A Spacetime Odyssey*.
Involvement in Project Starshot: Member of the Breakthrough Starshot Management and Advisory Committee.

"This kind of thinking that looks at a horizon 20, 35 or 50 years away is exactly what is called for now."

Mark Zuckerberg

Founder and CEO of Facebook

Notable achievements: Creation of the world's largest online social network.
Involvement in Project Starshot: Board member of Breakthrough Initiatives.

"Our nearest star, Alpha Centauri, is 4.3 light years or about 25 trillion miles away. Even with today's fastest spacecraft, it would take 30,000 years to get there. That's too long."

Avi Loeb

Professor of Science at Harvard University

Notable achievements: Author of over 500 scientific papers and three astrophysics and cosmology books. One of the 25 most influential people in space according to *TIME* magazine.
Involvement in Project Starshot: Chairman of the Breakthrough Starshot Advisory Committee.

"There is a big difference between physically exploring space regions and looking at them from a distance."

Mae Jemison

Principal of the 100 Year Starship organisation

Notable achievements: Former NASA astronaut onboard Space Shuttle Endeavour in September 1992.
Involvement in Project Starshot: Member of the Breakthrough Starshot Management and Advisory Committee.

"Collectively we are, as humans, at a point in which, technologically, there is at least one feasible path to getting us to another star within our generation."

Zac Manchester

Researcher and aerospace engineer; founder of KickSat project

Notable achievements: A graduate researcher in aerospace engineering at Cornell University with a number of scientific interests. He also created the world's smallest satellite.
Involvement in Project Starshot: Assisting on prototype StarChip.

"Moore's law is making the sensors, tiny computers, radios and all the components we need to build the spacecraft available."

Philip Lubin

Professor of physics at the University of California

Notable achievements: His scientific paper, *A Roadmap To Interstellar Flight*, details the feasibility of a gram-level spacecraft travelling at one fifth of the speed of light.
Involvement in Project Starshot: Working on directed energy propulsion.

"Using the technology we're speaking about, we can get to Voyager, which has been travelling for 38 years, in a day or so."

Martin Rees

Astronomer Royal

Notable achievements: Master of Trinity College, Cambridge, president of the Royal Society, and cofounder of the Centre for the Study of Existential Risk.
Involvement in Project Starshot: Member of the Breakthrough Starshot Management and Advisory Committee and leader of Breakthrough Listen.

"We'd all like to find ET in our lifetime - it would be the greatest discovery of all time."

Freeman Dyson

Professor emeritus at Princeton Institute for Advanced Study

Notable achievements: Known for his work in quantum electrodynamics, solid state physics, astronomy and nuclear engineering.
Involvement in Project Starshot: Member of the Breakthrough Starshot Management and Advisory Committee.

"This is part of the whole process of exploring the universe, which is something that we are pretty good at."

Pete Worden

Executive director of Breakthrough Starshot

Notable achievements: Former director of NASA's Ames Research Centre and author of more than 150 scientific papers.
Involvement in Project Starshot: Leading the Starshot programme.

"We take inspiration from Vostok, Voyager, Apollo and the other great missions. It's time to open the era of interstellar flight, but we need to keep our feet on the ground too."

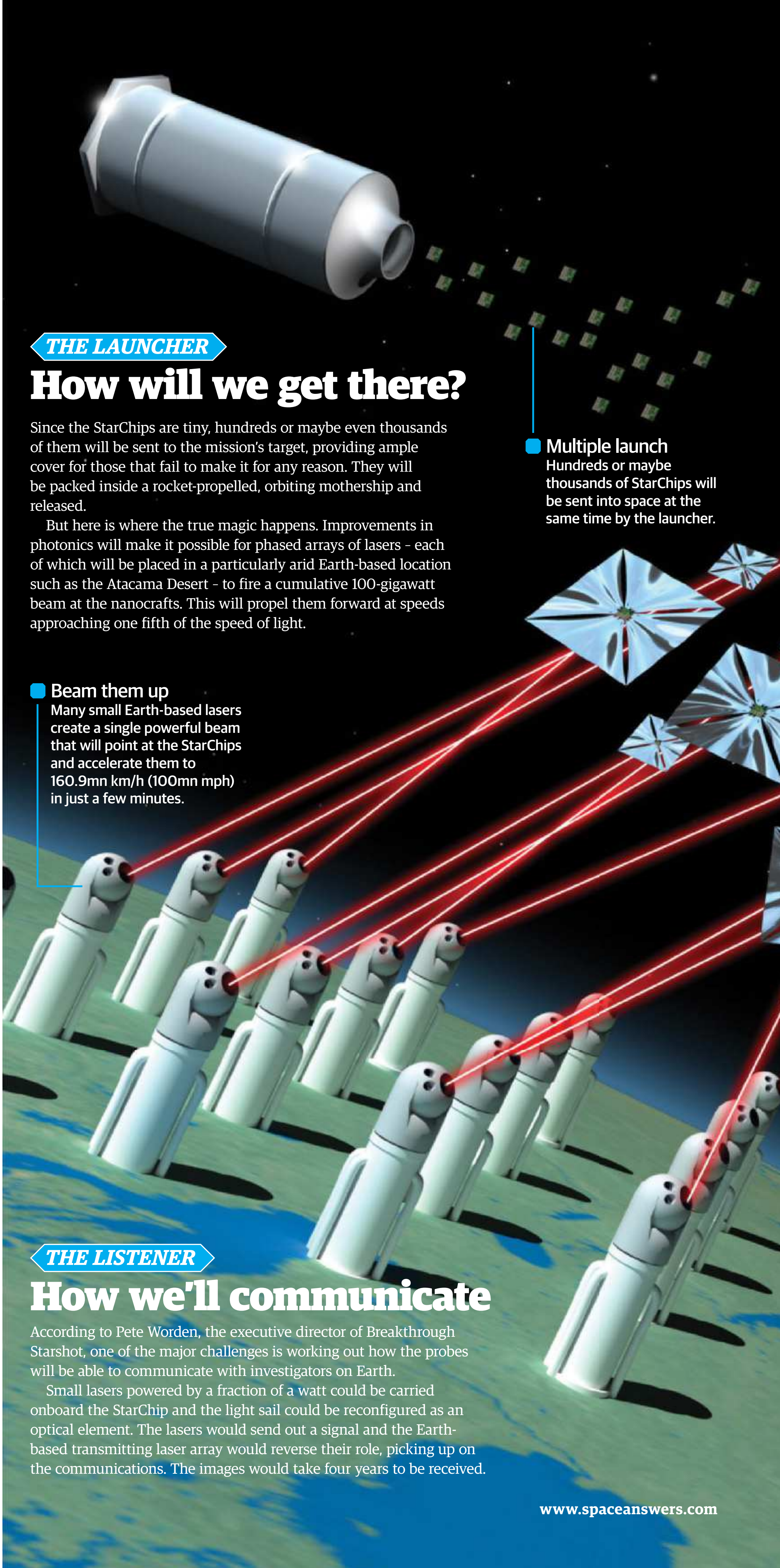
changes in directed energy technology means that the idea of photon propulsion is no longer fantasy. The potential rewards are great.

Professor Lubin points out that there is a rich environment to explore with more than 150 stars within 20 light years of the Sun. He says at least 12 of them appear capable of supporting planets that could contain life. But the scale of the task is immense. Rather than build a single laser, the idea is to create an array of phased light beams – numerous small lasers forming a single powerful light stretching more than 0.8 kilometres (0.5 miles). There are two reasons for this. First, to be effective, the beam would ideally have to scale to 100 gigawatts and, as Professor Lubin tells us, "We don't know how to make a single 100-gigawatt laser." Second, as he continues, "Even if we did, there are reasons you wouldn't want to do that – you'd still need a beam director and a large area." For this reason, it makes sense to spread it out. "Even if someone handed you a 100-gigawatt laser that you could hold in your hand, you'd still need a large one-kilometre (0.6-mile) telescope to couple it to, because you have to form a spot at long distances with a large aperture," Lubin explains. Yet, he adds, "No-one has ever built an array like that of this size and there are a lot of issues relating to it which we will have to discover along the way."

But there are some clear benefits of using this system of propulsion. There would be no need for the nanocrafts to have fuel on board (which helps to keep them light) and the lasers can be recharged (whereas rocket fuel is spent). Engineers would seek efficiencies, so steps would be taken to make optimum use of the laser beams, too: adaptive optics in the form of deformable mirrors would attempt to combat any atmospheric blurring caused by the dispersal of light and the array would be positioned in a location to give it a better 'view' of the probes.

"There will be a large element in the first decade to work out a lot of the risk," Lubin continues. "And there will be a lot of political issues." Not to mention costs: "$100 million (£69 million) will get us to prototype stage but not to a system," he adds. Some figures suggest $100 billion (£69 billion) will eventually be needed to see the programme to fruition and that could be a sticking point in the future. But there are some persuasive arguments for going ahead with it. As well as being able to boldly go where no man-made object has gone before, the bonus of having such powerful lasers projecting into space, even for the mere minutes they'll be in operation, is that the light from the lasers will be detectable all across the universe. If intelligent life is out there, a civilisation may well spot it and respond.

Even so, some astronomers – including those heavily involved in the search for extraterrestrial life – do have their reservations. "I personally think that it's very ambitious and I wouldn't bet high horses that it will ever be done," British cosmologist, astrophysicist and Astronomer Royal, Martin Rees, tells us. "All that has been done at the moment is to explore the feasibility of something that would cost many billions of dollars to actually do." Lord Rees questions whether the money might be better spent building huge telescopes in space, and he also raises two problems the Starshot team will be keen to resolve. "With the huge array, you can send



THE LAUNCHER

How will we get there?

Since the StarChips are tiny, hundreds or maybe even thousands of them will be sent to the mission's target, providing ample cover for those that fail to make it for any reason. They will be packed inside a rocket-propelled, orbiting mothership and released.

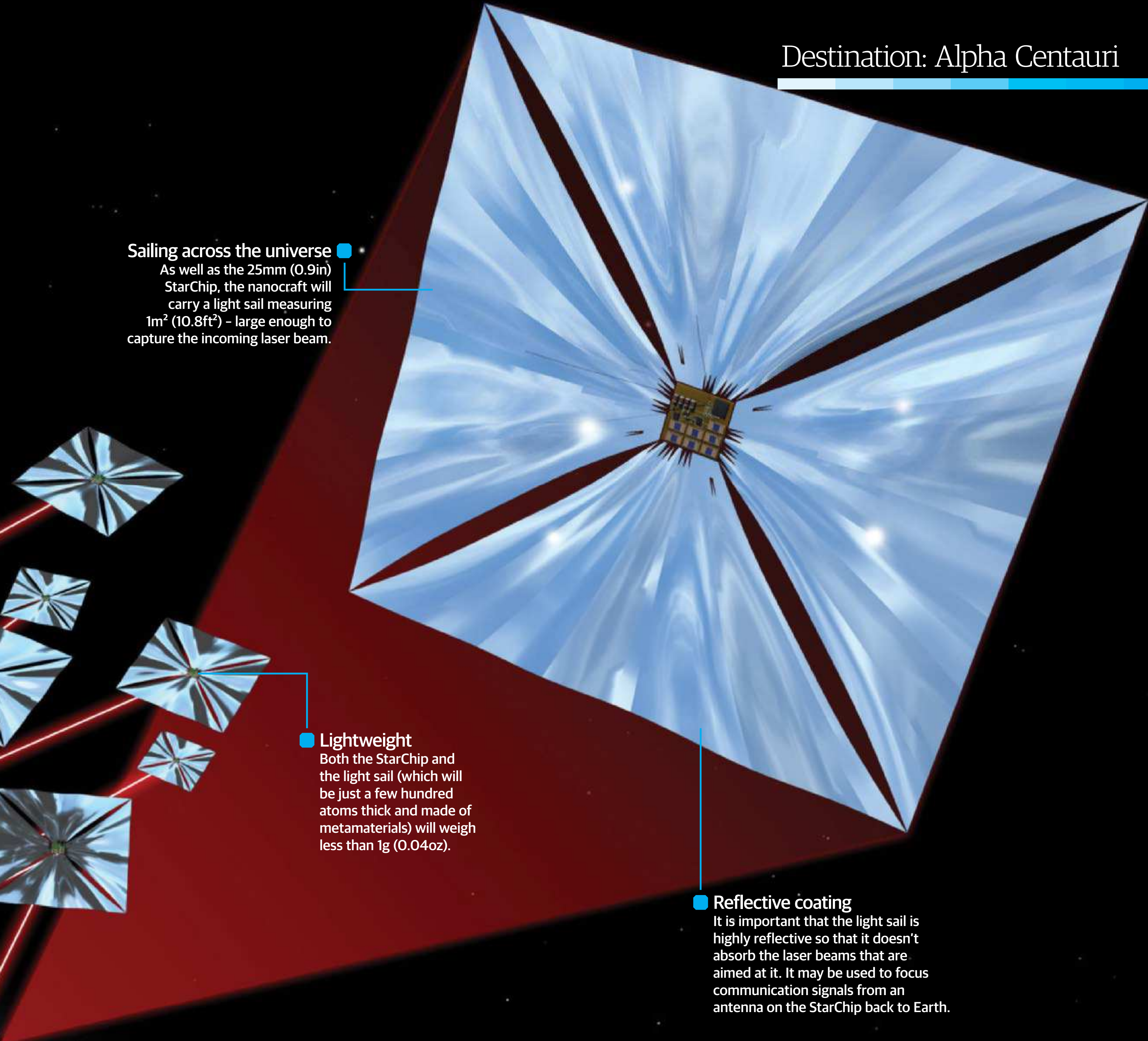
But here is where the true magic happens. Improvements in photonics will make it possible for phased arrays of lasers – each of which will be placed in a particularly arid Earth-based location such as the Atacama Desert – to fire a cumulative 100-gigawatt beam at the nanocrafts. This will propel them forward at speeds approaching one fifth of the speed of light.

THE LISTENER

How we'll communicate

According to Pete Worden, the executive director of Breakthrough Starshot, one of the major challenges is working out how the probes will be able to communicate with investigators on Earth.

Small lasers powered by a fraction of a watt could be carried onboard the StarChip and the light sail could be reconfigured as an optical element. The lasers would send out a signal and the Earth-based transmitting laser array would reverse their role, picking up on the communications. The images would take four years to be received.



Sailing across the universe
As well as the 25mm (0.9in) StarChip, the nanocraft will carry a light sail measuring $1m^2$ ($10.8ft^2$) – large enough to capture the incoming laser beam.

Lightweight
Both the StarChip and the light sail (which will be just a few hundred atoms thick and made of metamaterials) will weigh less than 1g (0.04oz).

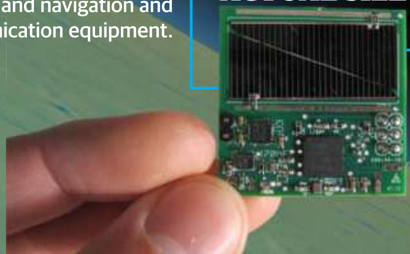
Reflective coating
It is important that the light sail is highly reflective so that it doesn't absorb the laser beams that are aimed at it. It may be used to focus communication signals from an antenna on the StarChip back to Earth.

THE NANOCRAFT

What is StarChip?

The StarChip
The StarChip will be a wafer – or thin slice of semiconductor material – carrying four miniature 2MP cameras, photon thrusters and navigation and communication equipment.

ACTUAL SIZE



Power point
The StarChip will also contain a power supply. At this stage, americium is being considered – an artificially produced yet slowly decaying radioisotope used in smoke detectors.

Space Answers

Have your say...
Do you think Project StarShot is feasible?

Yes 72%

No 28%

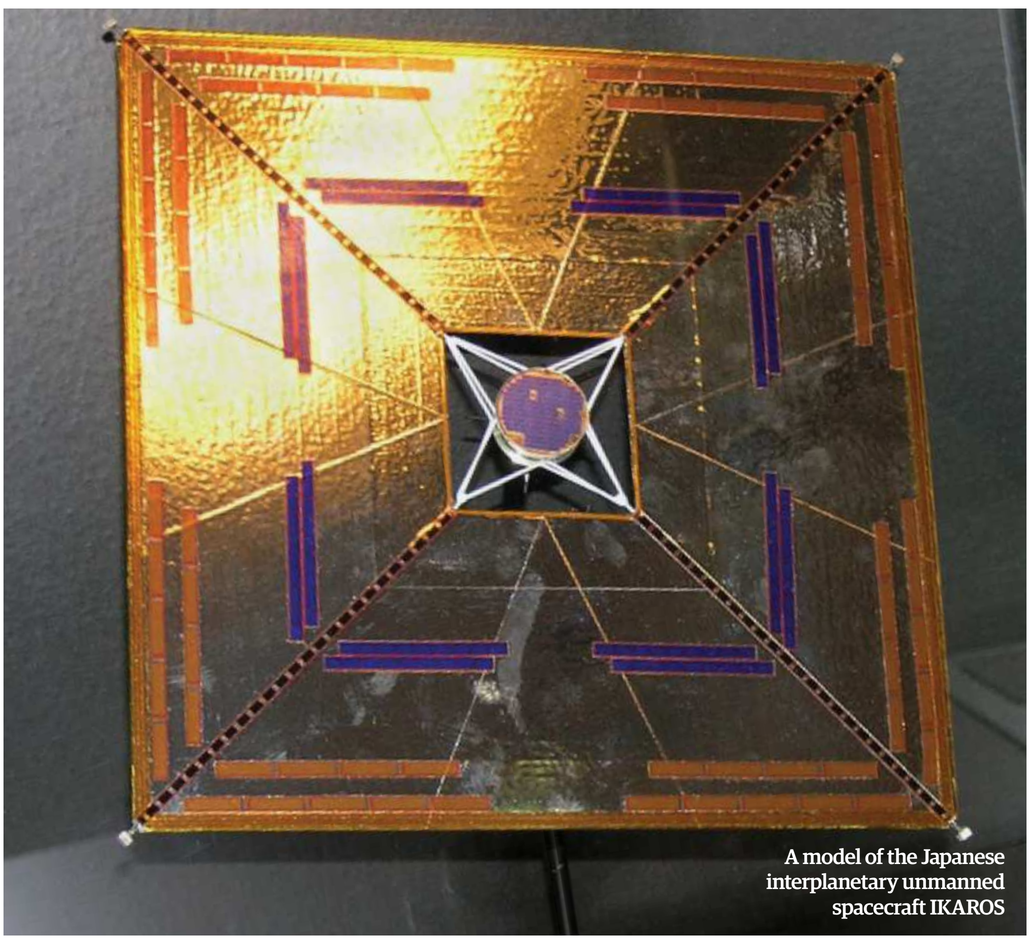
something to the nearest star in 20 years but the probes can't slow down when they get there. They just fly past," he says. "This is a constraint and I think that is something we have to clarify. The whole thing also weighs less than one gram (0.04 ounces) so how would it be able to transmit the data back?"

According to Pete Worden, who is directing the project, these issues will be addressed. The current thinking is that lasers could be fitted onboard the probes to beam images back to the laser array, which could be turned into a receiver. But as Lord Rees says: "The Pluto flyby was slower and not nearly as far away but it took a year to transmit photos back. I would have thought that the issue of how good the pictures are and the rate of data transmission back, given a very low power, will pose a big challenge."

All of this, however, is why the project is likely to take so long to figure out and the programme is not looking to hide the challenges. It points out the risk of interstellar dust collisions, for instance, and highlights issues in focusing the light beam on the light sail to accelerate individual nanocrafts. At the same time, new technologies will emerge that enhance techniques in communication and optics and will be of wider benefit to the space industry. But despite the challenges, the programme appears in good hands. As well as having some of the best individual brains in science, engineering and aerospace on the job, universities and research centres are involved too. Breakthrough Starshot is also throwing the doors open to the public and will be encouraging scientific investment with research grants. The team wants the process to be open and transparent and Breakthrough Initiatives is strictly non-profit. In the longer term, Milner hopes to work with NASA and ESA, both of which have been briefed and will inevitably look closely at the progress being made (Dr Lubin and Dr Manchester's work was funded by NASA, Worden says, so they appear already tuned into the idea). If nothing else, the sums involved make it odds-on that NASA would have to become involved for it to be financially viable.

Ultimately, it comes down to the mantra of nothing ventured, nothing gained. There are more benefits to be had in trying: "If this mission comes to fruition, it will tell us as much about ourselves as about Alpha Centauri," Milner says. "Only by challenging ourselves can we find out if we, like the pioneers before us, have the ability and ambition to succeed. For the first time in human history we can do more than just gaze at the stars, we can actually reach them. It's time to launch the next great leap." ●

"For the first time in human history we can do more than just gaze at the stars, we can reach them" **Yuri Milner, DST Global**



A model of the Japanese interplanetary unmanned spacecraft IKAROS

THE JOURNEY

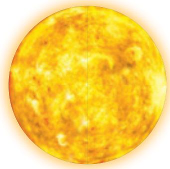
Space check points

StarChip will hit a variety of celestial targets on its way to Alpha Centauri

1 min

The Moon
Distance: 384,400km (238,855mi)
Times around the world: 9.6

41 mins



The Sun
Distance: 149.6mn km (92.9mn mi)
Times around the world: 3,732

1 hour

Mars
Distance: 54.5mn km (33.9mn mi)
Times around the world: 1,361

1 day

Pluto
Distance: 4.3bn km (2.6bn mi)
Times around the world: 106,823

4 years

The Solar System's edge
Distance: 7.4tn km (4.6tn mi)
Times around the world: 185mn

20 years

Alpha Centauri
Distance: 40.2tn km (25tn mi)
Times around the world: 1,004mn

Need for speed

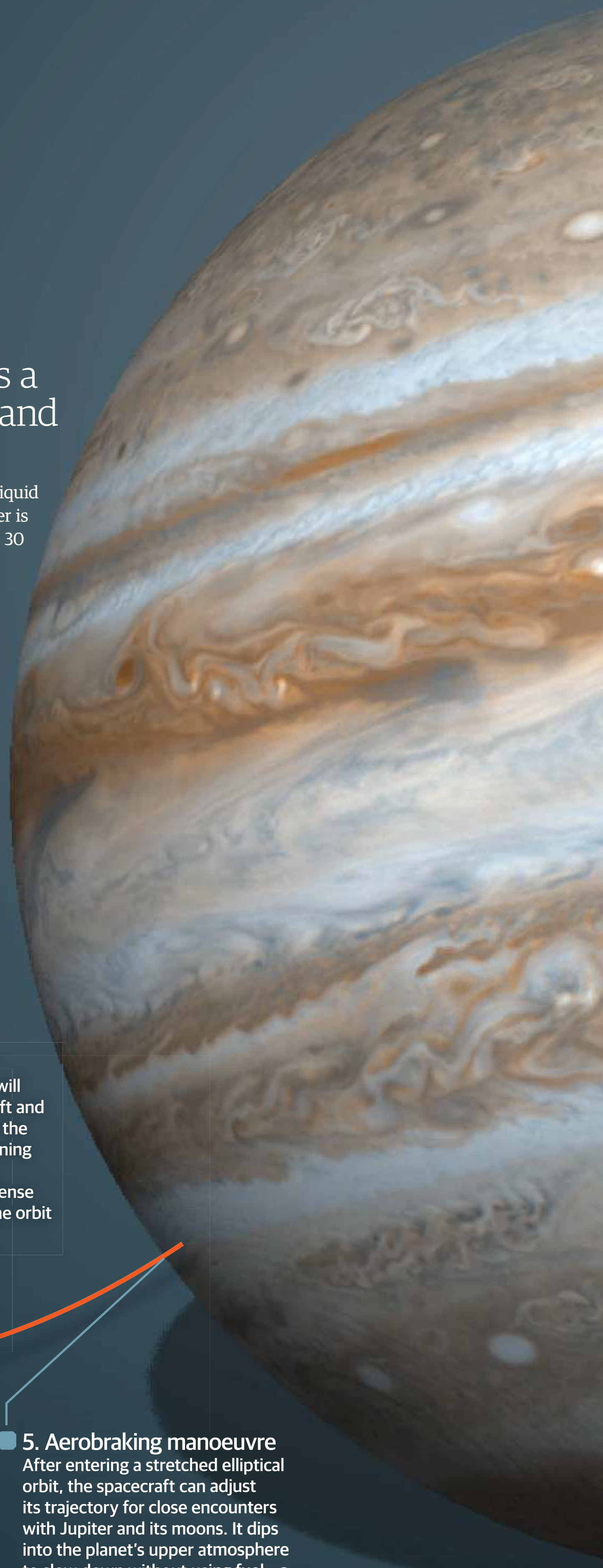
StarChip
Speed: 160.9mn km/h (100mn mph)
Mass: Less than 1g (0.04oz)
Time to edge of the Solar System: 4 years

New Horizons
Speed: 58,536km/h (36,373mph)
Mass: 470kg (1,036lb)
Time to edge of the Solar System: 10 years

Voyager 1
Speed: 61,000km/h (38,000mph)
Mass: 733kg (1,616lb)
Time to edge of the Solar System: 35 years

Explorer's Guide
Jupiter

The largest planet in the Solar System, Jupiter is a colourful gas giant wracked with violent storms and wreathed in deadly radiation belts



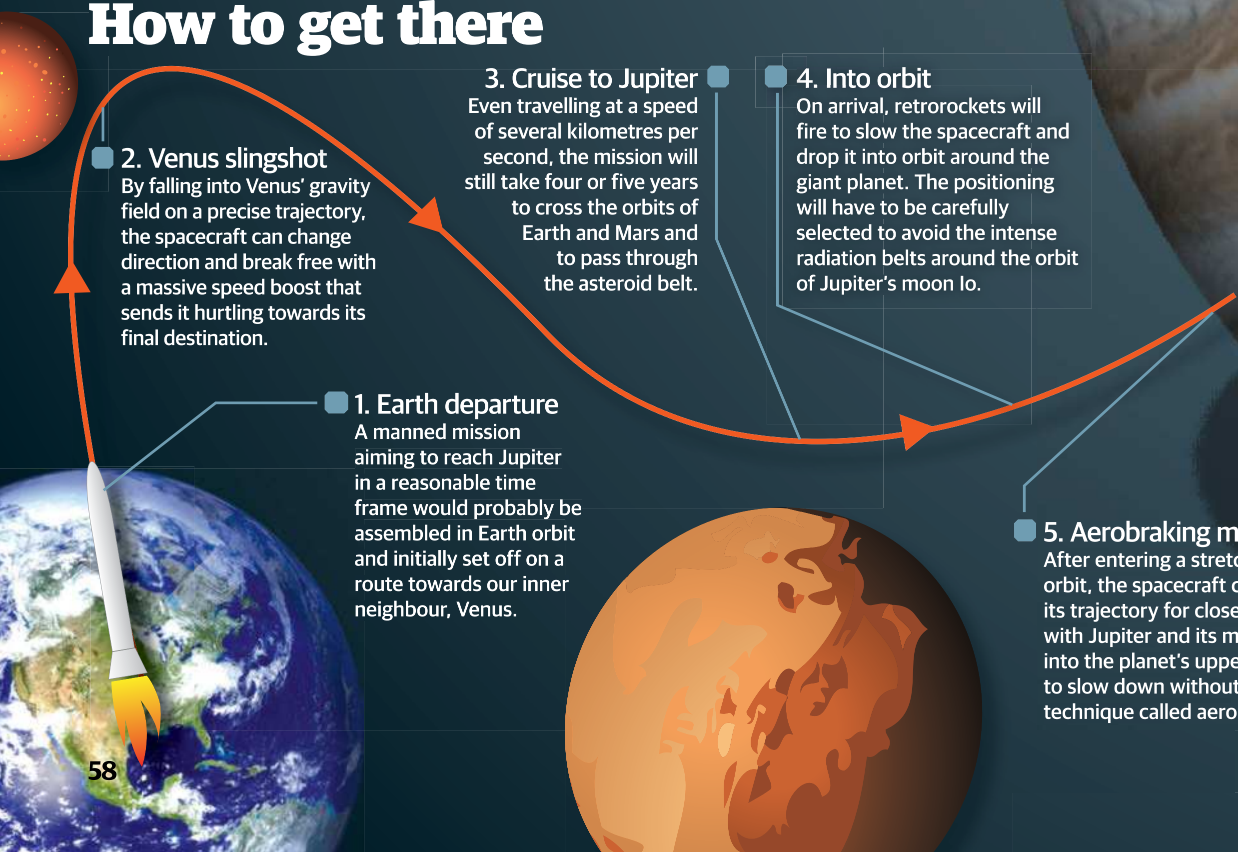
Jupiter is an unmissable sight in Earth's night sky – shining brighter than any star, it is beaten only by our nearest planetary neighbour, Venus. But while Venus is relatively small and nearby, Jupiter is a distant monster – large enough to swallow up all the other planets in our Solar System with room to spare.

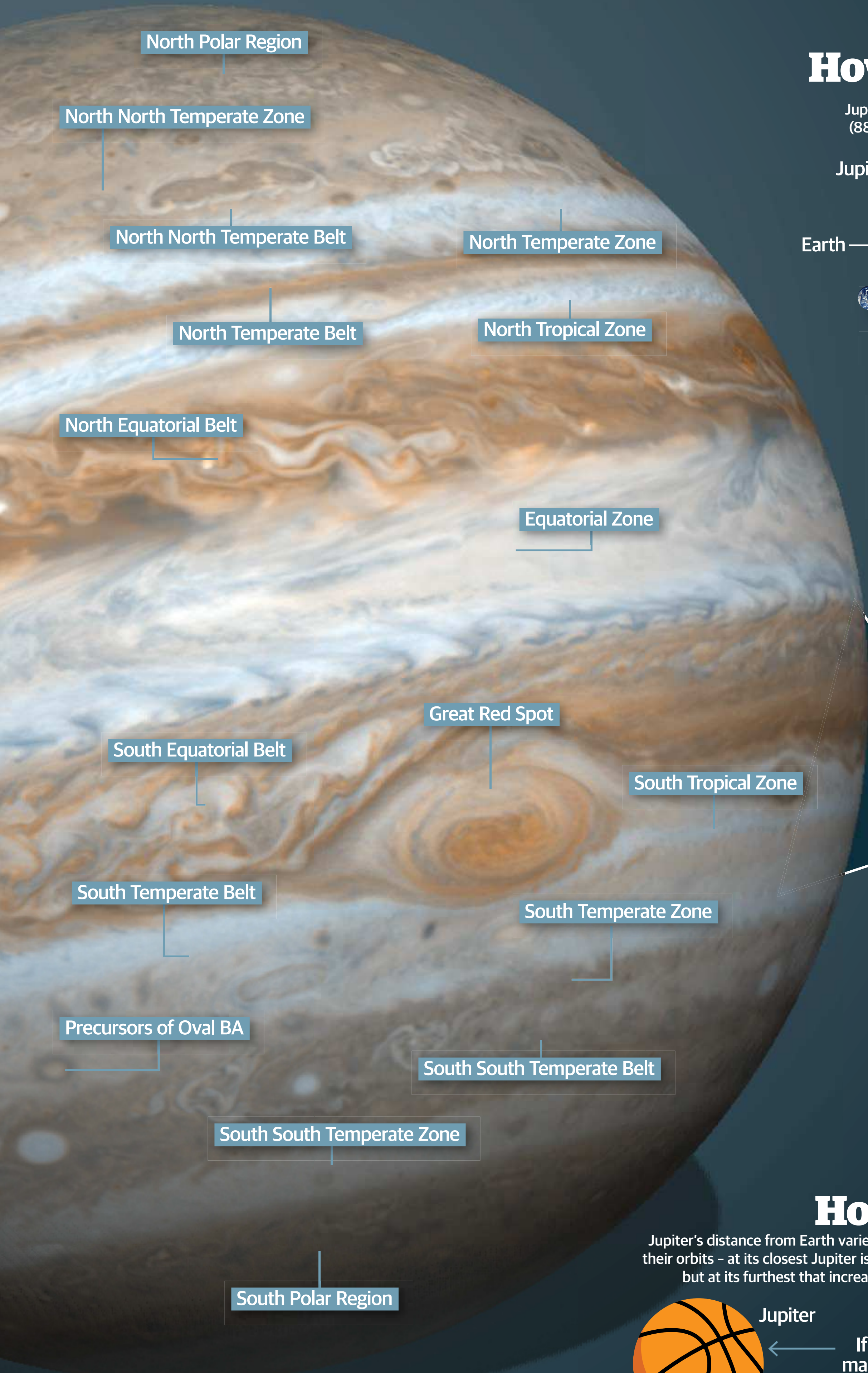
Jupiter is the closest of the gas giants – worlds formed largely out of the light elements hydrogen and helium. Despite being the lightest element of all, hydrogen accounts for 75 per cent of the planet's overall mass, with nearly all the rest being helium, and only a small proportion of heavier elements. While the upper atmosphere is dominated by molecular hydrogen gas (H_2), Jupiter's hydrogen changes its state and behaviour deep below the surface as it is compressed under the weight of the overlying layers.

About 1,000 kilometres (621 miles) beneath the cloud tops, the gas makes a smooth transition into an ocean of liquid molecular hydrogen. Deeper still, the pressure is so great that hydrogen molecules break apart to form a sea of electrically charged 'liquid metallic' hydrogen. At its very centre, Jupiter is thought to hide a solid core, which is about 30 times the mass of Earth.

Powerful currents are generated as the metallic ocean swirls inside the planet, creating an intense magnetic field that emerges from the planet's poles. Jupiter's magnetism is the strongest of any planet in the Solar System, with an influence that can be felt as far away as Saturn. Particles blowing across space on the solar wind are swept up in it and channelled down into the upper atmosphere above the poles, creating intense aurorae. Others become trapped in the magnetic field, ricocheting back and forth with increasing speed and energy. This produces intense and dangerous radiation belts that are at their most deadly around the orbit of Jupiter's volcanic inner moon, Io.

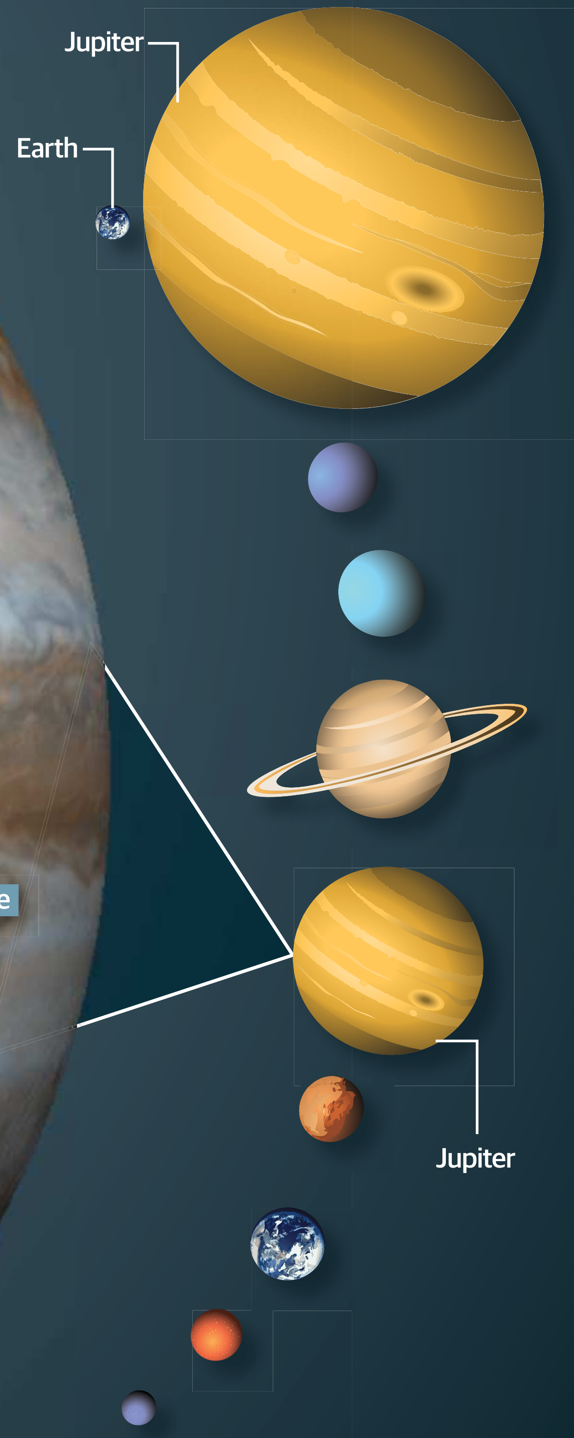
How to get there





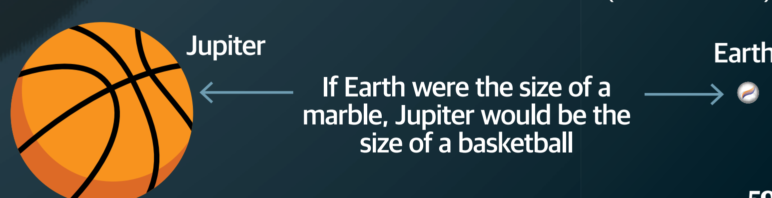
How big is Jupiter?

Jupiter's equatorial diameter of 143,000 kilometres (88,856 miles) is over 11 times greater than Earth's.



How far is Jupiter?

Jupiter's distance from Earth varies hugely depending on where the planets are on their orbits – at its closest Jupiter is 588 million kilometres (365 million miles) away, but at its furthest that increases to 968 million kilometres (601 million miles).



Top sights to see on Jupiter

Even though its upper atmosphere is in a state of constant change, Jupiter has several spectacular features that are more or less permanent. Despite its enormous size, the planet rotates in just nine hours and 55 minutes, creating powerful forces that wrap Jupiter's weather systems into horizontal bands parallel to its equator. Alternating regions of low and high pressure create darker bands known as belts, and lighter ones known as zones.

Clouds in the light zones are formed mostly of ammonia ice crystals that condense as they rise, while those in the dark belts are mostly made of ammonium hydrosulphide, with a complex mix of chemicals giving rise to their colour. High-speed winds similar to Earth's jet streams flow along the edge of the bands in alternating directions, tearing the clouds into ragged patterns known as festoons.

In places, the alternating jets isolate sections of the atmosphere and spin them into clockwise or anticlockwise rotating vortices or storms. Most famous of these is the Great Red Spot (GRS), an anticlockwise-spinning oval storm that is as tall as Earth and twice as wide. But it has shrunk steadily over the past century or so, and its colour can change dramatically - at times it is a deep scarlet-red, but at other times it forms only a pallid "hollow" in the surrounding South Equatorial Belt. Its more intense colours are probably the result of light-sensitive chemical reactions triggered as chemicals from deep inside the planet are dredged to the surface.

In general, Jupiter's clockwise-spinning vortices tend to give rise to small white spots, while anticlockwise storms tend to be larger, deeper and longer lasting. A complex exception to this rule is Oval BA, or Red Spot Junior. This storm system, about one-third of the size of the GRS, began life as three separate white ovals that developed within the South Temperate Zone during the 1930s and merged in 1998-2000, before suddenly turning red in 2005.

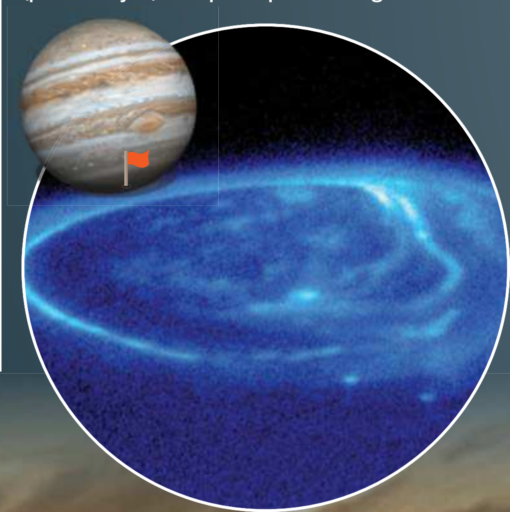
Some have speculated that Oval BA's growth is linked to the decline of the GRS, or that the two spots may ultimately collide and merge, rejuvenating the GRS. Certainly, the GRS has been seen to cannibalise smaller storms in the past, so it's worth tracking down Oval BA while you still have the chance!

Impact bruises

Jupiter's huge gravity makes it a prime target for asteroids and comets – 'bruises' in the clouds can last for weeks, dredging up chemicals from deep down.

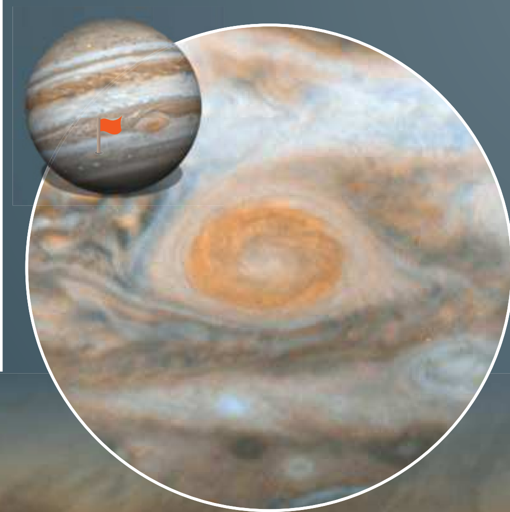
Intense aurorae

Tracks in the bright aurorae at Jupiter's North and South Pole are produced as orbiting moons (particularly Io) disrupt the planet's magnetic field.



Oval BA

Jupiter's smaller red spot has grown in size and intensity over recent years – at 12,000km (7,456mi) across it is now about half the width of the GRS.



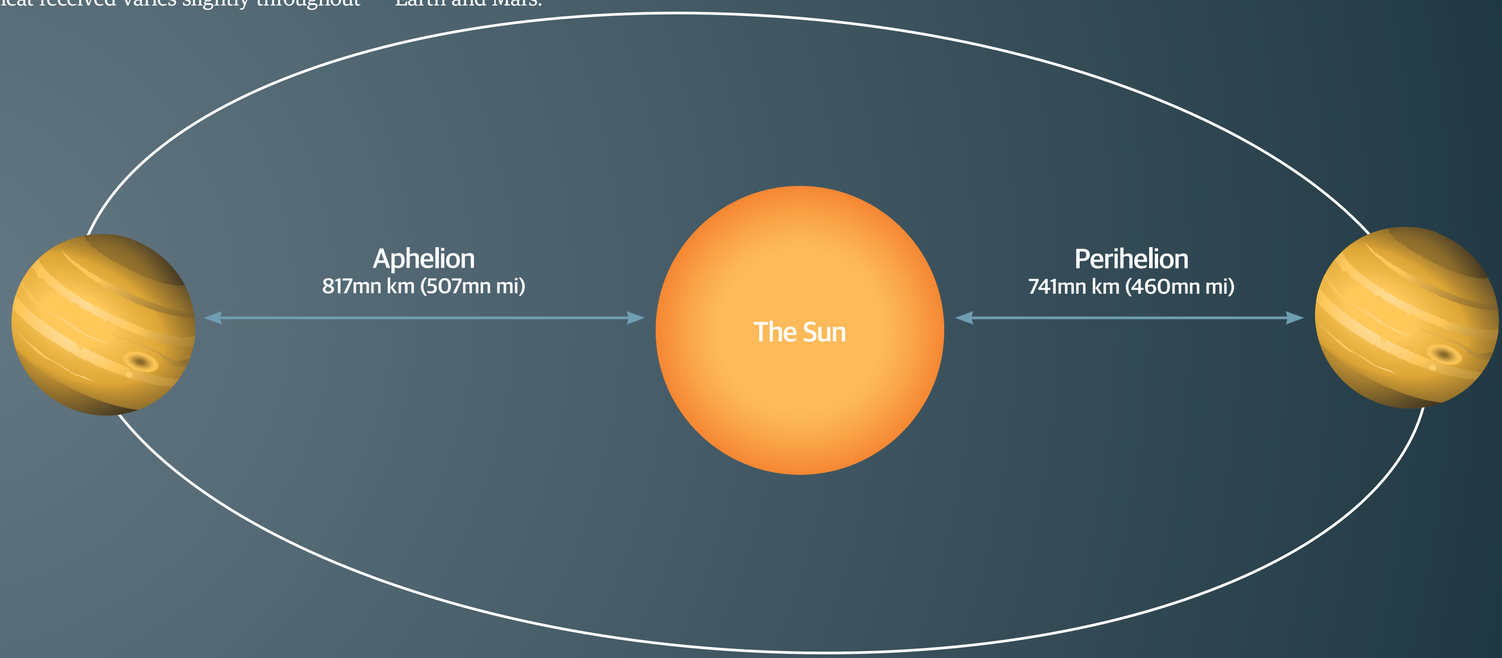
Great Red Spot

Wind speeds around the edges of Jupiter's most famous weather system can reach up to 430km/h (267mph)

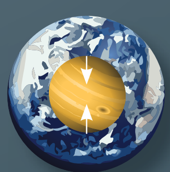
Jupiter's orbit

Jupiter takes 11.86 years to complete one trip around the Sun. Its orbit ranges between 741 and 817 million kilometres (460 and 508 million miles) from the Sun, so the amount of solar heat received varies slightly throughout the year. However, because Jupiter sits almost bolt upright in its orbit (tilted by a mere 3.1 degrees) it does not experience a cycle of seasons like those seen on other tilted planets such as Earth and Mars.

1 Earth year = 885 Jupiter days
1 Jupiter year = 4,331 Earth days



Jupiter in numbers



1.326
Jupiter's average density in gram per cubic centimetre – one quarter of Earth's

35,700°C
Estimated temperature at the boundary between Jupiter's metallic ocean and core

143,000km
Jupiter's equatorial diameter – including a substantial bulge caused by its rapid spin

Weather forecast

-110°C
-166°F

Jupiter's weather systems are driven partly by circulation of air heated by the Sun from the warmer equator to the colder poles (as on Earth), but the real reason its weather is so violent is that the planet has a powerful internal heat source; gradual contraction of Jupiter's interior pumps out as much heat as the planet receives from the Sun.

1,321
Number of Earths that could fit into Jupiter's interior

67
Current number of moons known to orbit Jupiter

59.5km/s
Escape velocity needed to leave Jupiter's gravity (over five times Earth's)

9.9hrs
Length of a day on Jupiter

Solar flapper

To explore another planet faster than a rover and in more detail than a satellite, we need to fly, and the best way to do it may be to copy birds

When we first started to build flying machines, we understandably began by copying natural flyers: birds. In the initial stages of human flight, numerous people tried jumping from high places with poorly designed wings, leading them to fall to their deaths - the earliest account of this is of a man named Armen Firman trying this out during the 9th century. Despite this, attempts at flapping wing flight continued into the machine age, typifying the early films of hopelessly eccentric airplanes flapping themselves to pieces on the ground.

It wasn't until 2010 that a team from the University of Toronto, Canada, made the first successful flight of a piloted, engine-powered ornithopter, a craft that 'flaps' its wings. While fixed wings combined with a separate source of propulsion finally took us into the air, flapping wing flight has a lot of potential benefits - it's just really hard to do. But now, if a study presented to the NASA Institute of Advanced Studies comes to fruition, then these remarkable, solid state, solar-powered ornithopters could be flying on other planets sooner than we think.

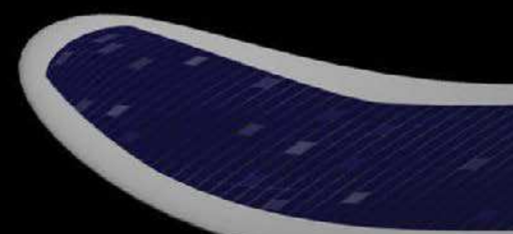
The Solid State Aircraft (SSA) study has been led by Anthony Colozza of the Ohio Aerospace Institute, with contributors from universities across the United States. With their unique aircraft concept, they are looking to combine thin film solar cells and thin film batteries with an electrically responsive synthetic muscle material to create an airplane with no moving parts. Designed as a rectangular flying wing with no tail, solar energy would be collected by flexible photovoltaic cells at just a thousandth of a millimetre thick. Despite their thinness, they can convert 10 per cent of the light falling on them into electricity, while still being able to flex with the wing. This energy would then be stored in thin film lithium-ion batteries, which are of a similar chemistry to the batteries used in smartphones and computers. However, they are produced by spraying the layers that make up the battery, such as the electrical contacts and the electrolyte - the substance that allows the charge to flow - in thin layers onto a flexible backing. This backing could then be used as the back of the solar cells.

The power supply could then be used to drive the Ionic Polymer-Metal Composite (IPMC) - this is material that acts like a muscle, flexing when electricity is applied. It is made of a substance called ion exchange membrane, which is coated with metal layers. When electricity is applied to the metal layers it causes molecules of water and sodium in the membrane to cluster at the negative terminal. This makes the negative side expand and the positive side contract, bending the membrane and flexing the wing. The IPMC could be incorporated as skeleton-like strips into the wing, or indeed spread out over the whole wing, with the pattern of the electrodes determining how it flexes. Given the combination of power supply, storage and propulsion into these thin films and the availability of miniaturised computing and sensors, the SSA could be an intelligent flying plastic sheet.

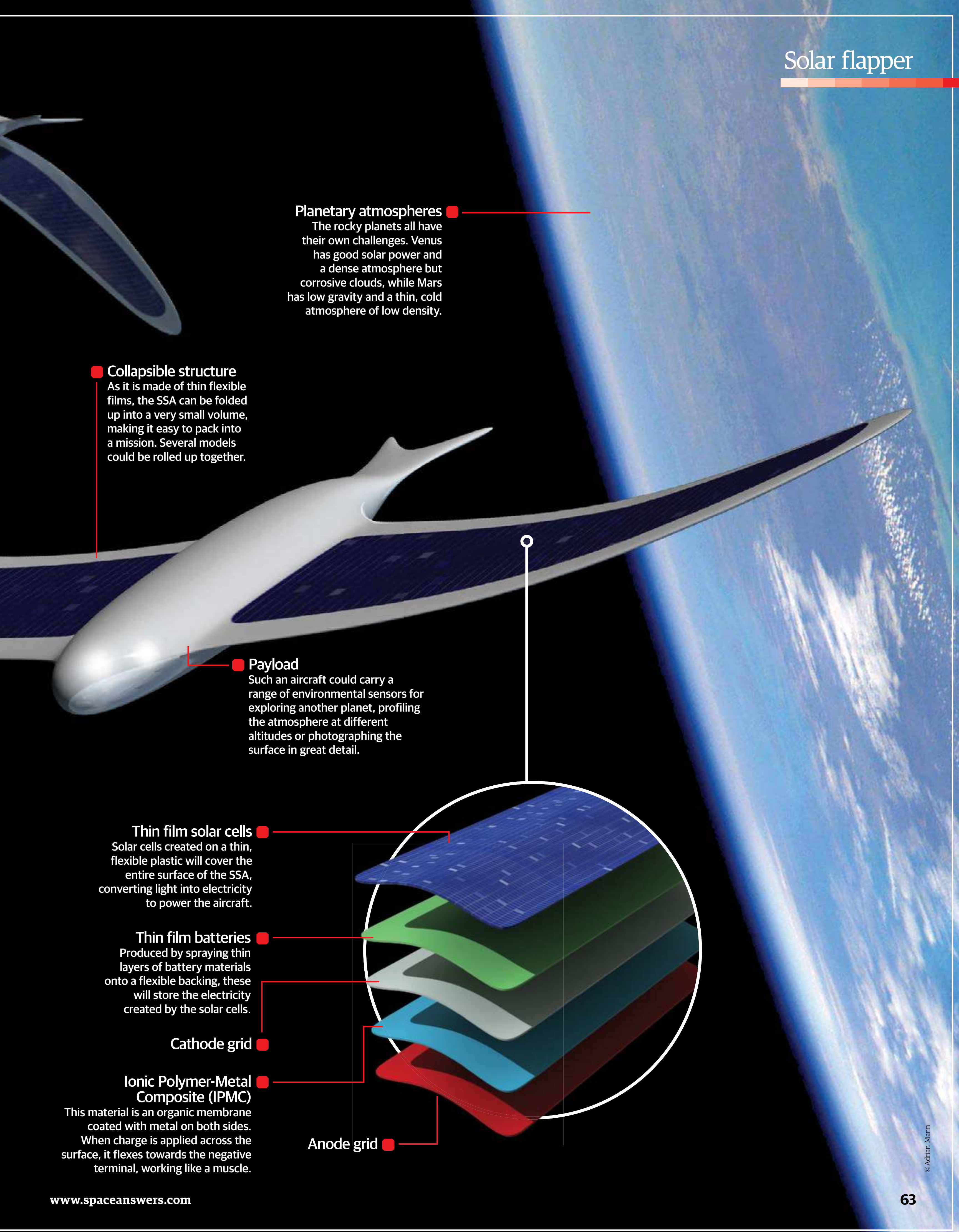
The SSA's incredible simplicity and low mass would be great advantages for missions exploring other planets, where every kilogram (or pound) costs millions of pounds to send and there is no chance of making repairs. Flapping is the most efficient form of flight, with the SSA making it possible to cruise around Venus indefinitely or grasp a hold in Mars' tenuous atmosphere - we can finally fly like the birds and soar to other planets, too.

> "The SSA's low mass would be a great advantage for missions exploring other planets, where every kilogram costs millions of pounds to send"

Flapping wing flight
The IPMC material acts like the muscles of a bird, working to flap the wings. This is a very efficient form of flight, providing lift, control and propulsion from a single structure.



Flying wing form
The SSA is able to flex its wing like a bird. This provides all flight control, without the need for a separate tail or flaps.



Planetary atmospheres
The rocky planets all have their own challenges. Venus has good solar power and a dense atmosphere but corrosive clouds, while Mars has low gravity and a thin, cold atmosphere of low density.

Collapsible structure
As it is made of thin flexible films, the SSA can be folded up into a very small volume, making it easy to pack into a mission. Several models could be rolled up together.

Payload
Such an aircraft could carry a range of environmental sensors for exploring another planet, profiling the atmosphere at different altitudes or photographing the surface in great detail.

Thin film solar cells
Solar cells created on a thin, flexible plastic will cover the entire surface of the SSA, converting light into electricity to power the aircraft.

Thin film batteries
Produced by spraying thin layers of battery materials onto a flexible backing, these will store the electricity created by the solar cells.

Cathode grid

Ionic Polymer-Metal Composite (IPMC)
This material is an organic membrane coated with metal on both sides. When charge is applied across the surface, it flexes towards the negative terminal, working like a muscle.

Anode grid

The Meteorite Man

Geoff Notkin, a world expert on meteorites and presenter of award-winning adventure TV series *Meteorite Men*, talks of his ongoing search for space rocks

Interviewed by David Crookes

Geoff Notkin was lucky enough to find his first meteorite on his first adventure into the desert. He has not stopped searching for them since

INTERVIEW BIO

Geoff Notkin

Geoff Notkin wears many hats; the former punk rock musician is a science writer, photographer, traveller and businessman. But most of all, he is a meteorite specialist who has appeared in programmes for some of the world's top broadcasters such as the BBC, National Geographic and PBS. He is best known for co-hosting the hugely popular Science Channel programme, *Meteorite Men*, with Steve Arnold. As well as presenting the educational series *STEM Journals*, writing several books and founding the recovery and research company Aerolite Meteorites Inc, he recently began offering guided meteorite hunting expeditions to the public at **meteoritebootcamp.com**.

"When you see a shiny black meteorite on the ground and it's only been on the Earth for two or three days, it's exciting. After all, it's the newest extraterrestrial arrival to Earth"

When did you first develop a passion for space and meteorites?
I was mad about science from a very early age. My dad was a keen amateur astronomer who was always setting up his telescope, often fruitlessly, in Surrey, and one of my earliest memories was of my dad waking me up in the middle of the night, wrapping me in a blanket and carrying me out to the lawn to look at the Moon and Jupiter through the telescope. I had a cosmic aspect instilled into my childhood almost from the beginning and my unconventional parents supported my growing passion.

Did you often go hunting for meteorites?
I saw meteorites for the first time at the Geological Museum in London, which is now part of the Natural History Museum, and I would love to blame it for my very unusual life. I would implore my mother to let me skip school and go there, which we did frequently, and I remember on my second visit entering a small, dark, moody area that was almost foreboding. There were these giant meteorites and I remember thinking they had to be models because they were so big. I couldn't believe they had real meteorites from space just sitting there on a display column. But, of course, they were all real and that sparked a lifetime of fascination. I was always rockhounding out in the Surrey chalk quarries and going down to Dorset to look for fossils.

How did you go from that to hunting for meteorites as a way of life?
Well, that's where it gets complicated. Meteorites fascinated me throughout my childhood and through my teens and 20s. But I'm a musician as well and I became very involved with the punk rock scene in London in the 1970s and then I moved to the United States and played professionally for many years, so I was somewhat distracted by rock and roll. But I still always had a fascination for meteorites and astronomy and whenever I was travelling and touring I always wanted to go to a planetarium or museum. In my early 30s, I said enough is enough: I must have a meteorite. I went, as a complete novice, out into the desert and I was lucky enough to find one on my first adventure. I thought, "That was easy – I'm always told how rare they are and how difficult they are to find." It took me two years to find my second, which brought me back down to Earth.

When did you meet Steve Arnold, your co-host on *Meteorite Men*?
It was in 1996. He sent me an email after doing a global online search to see who had mentioned meteorites in their profile. He said he found seven people in the world and had spammed all of them but I was the only one who had replied. He was doing meteorites full time, recovering them as a career, and he was the only person I knew other than me who was interested in them. He was already quite an experienced meteorite hunter and he'd travel around to farms in the Midwest, contact farmers, locate meteorites and trade them with museums and collectors on behalf of the finders.

Did you instantly click with each other?
The first time we met was when Steve told me he was going to the Atacama Desert in Chile on this big meteorite hunting expedition and asked if I wanted to go. I went with a complete stranger to one of the most dangerous deserts on Earth and my friends said that I was completely insane – what if he was a serial killer? I love classic movies and I'm a big fan of *The Treasure Of The Sierra Madre* with Humphrey Bogart. It's a movie about gold prospectors in the West in the 1800s and how they were very successful in finding this gold but started going crazy. Will they kill each other? That's the first thing I thought of: "Oh no, what if this is a *Treasure Of The Sierra Madre* situation, and we find valuable meteorites and Steve hits me over the head with a shovel, buries me in the desert and I'm never seen again?" So I asked him if he had seen that movie and he said, "No I haven't, should I watch it?" And I said, "No, no, don't watch it until after we get back."

But it went well?
We had an amazing expedition: three weeks across the Atacama, finding many meteorites. That was the beginning of a long friendship and I never really came back to Earth after that, no pun intended. It was fascinating seeing the beautiful country of Chile and traversing the extraordinary desert where NASA sent its early Mars rover to test because it was the environment most similar to Mars on Earth.

Steve and I formed a hunting partnership and we had many adventures starting in 1997. We'd go on expeditions together and alone all over the US and Europe. I went to Siberia in search of meteorites and meteorite-related impact types. It went from being a childhood obsession, to a mad hobby, to my entire life and then we were contacted by a big production company in California and were asked if we would be interested in doing a show. I'd done a lot of television, been a guest on astronomy shows, and Steve and I had done three one-off shows for National Geographic, Travel Channel and Discovery, so we were very keen to do more. Our one caveat was that we wanted it to be real. We didn't want to plant meteorites or have fake drama. We wanted a real adventure show. I said I would deliver as much adventure as they could handle.

Is meteorite hunting part science, part treasure hunt for you?
I grew up on things like *Journey To The Centre Of The Earth* and *King Solomon's Mines*. I loved those classic adventures and I always wanted to do that, wear the adventure hat and be out in the desert doing great deeds. When I started searching for meteorites in wild places, we had this fantastic gear and strange vehicles taking us to remote places and we'd meet weird and fascinating people. I love to hunt and I love metal detecting but I love the vistas too, and I'm always stopping and saying, "Look at this lizard and petrified wood." Steve is all about recovering as many meteorites as he can, and he's a good-natured guy who will roll his eyes. But I have this odd tendency to save what we call meteor-wrongs – belt buckles, plough blades, shell cases, horse shoes and so on.

So it's not just about cashing in?
Well, not for me. I didn't get into it because I saw it

The Science Channel show *Meteorite Men*, hosted by Geoff Notkin and Steve Arnold, has proven to be incredibly popular

Some meteors create huge impact craters when they smash into the Earth, such as this one

The CR2 carbonaceous chondrite known as NWA 10256 has proven to be scientifically important

"In studying meteorites, we are looking at a snapshot of an existence before time as we know it; a Solar System or universe that was just a dust cloud"

as a good way to make money. Steve did – for Steve it was always about the business and there is nothing wrong with that. He's a sharp businessman and he loves the adventure and thought it was a promising way to make a living. But I got into meteorite hunting because I wanted more meteorites for my collection and over time I realised going around the world renting vehicles and buying high-tech equipment was expensive so I started a company, Aerolite Meteorites Inc. It's the largest meteorite company in the world with our headquarters in Tucson, Arizona, and a new European division in the UK. I felt that meteorites are everywhere and they represent travel through the Solar System and space, so we [the company] should be accessible worldwide.

Are any meteorites expensive? You mentioned the Tucson Ring Meteorite on one of your shows…

You can find a meteorite of almost any value, so they start from a few pennies but there is almost no limit to how high the value can go. There are some meteorites in museum collections and on display in the spot where they fell and you couldn't even calculate the value – I don't think the Smithsonian would sell the Tucson Ring for £1 billion [$1.4 billion]. It's one of the most iconic and beautiful examples of an extraterrestrial visitor and one of the cornerstones of their collections; it's one of the greatest pieces in the world. But it's important to note that their value is not just monetary. My initial drive and fascination with this field was the wonder of meteorites and that has never changed. I founded the company and became a commercial vendor so that I could find more specimens and make them more available to collectors and universities and educate the public. That's a huge part of our work.

Did *Meteorite Men* help you in your work?

Meteorite Men has been seen by tens of millions of people all over the world. It aired on Discovery networks and other stations for years worldwide and I cannot even estimate how many new meteorites have come to light because of it: I can think of at least ten off-hand that we acquired because people called and said, "Hey, we saw your show and my dad found a meteorite in the 1950s and we still have it." And some of these meteorites were completely new to science. So in an era where there is so much cheap reality television, it was important to educate and delight people. The show helped to make meteorite collecting an international phenomenon.

What scientific value do meteorites have?

I would like to give you a concrete example that is fascinating to me. We have recently acquired a meteorite called Northwest Africa (NWA) 10256. If you're not aware of the naming conventions, most meteorites are named after the nearest town to where they were found. If they are found in Antarctica or the deserts of Northwest Africa and there are no towns or features nearby, they are given a number. So this one means it was the 10,256th meteorite found in the Northwest African deserts since people began to discover them there in the 1990s. One may be a little scrap or one may be 100 kilograms [220 pounds] – there are that many different finds.

So last year I met with a gentleman who showed me five little pebble-like rocks, each about the size of an egg, which he had acquired in Morocco. They're definitely meteorites and I thought there was something unusual about them, so I sent them to a highly respected institution here in the United States where they removed a slice and examined it under a microscope. It was determined to be an extremely rare type that we've never had on sale in our career.

What makes it so rare?

It is largely made up of carbonaceous chondrite material of type CR2 and the reason these chondrites are so interesting to science is that they are virtually unchanged since the very beginning of the Solar System, so they are made entirely of chondrules, which are believed to have formed in the solar nebula. When we find something like this and examine it, we are looking at a snapshot of an existence before time as we know it; a Solar System or universe that was just a dust cloud.

These meteorites are rich in carbon and some contain water and salt and there is a popular theory that meteorites may have brought water and maybe the building blocks of life to Earth. I had a PhD candidate come over from the UK to look at them and take some back to Leicester for research. For me, it's about adding something meaningful to the body of knowledge about meteorites. Something we found and recognised and classified is going into the literature for all of time and is being studied by scientists now, and maybe by future generations.

Is there anywhere that you know will contain lots of meteorites but you haven't been able to get to?

When we were producing *Meteorite Men*, Steve and I typically came up with a list of places that we would love to go to at the start of each season, and the production team would allow us to do five international episodes and three US to fit with the budget. There were places we wanted to go but couldn't because it was too expensive, too dangerous or there were legal restrictions. But Antarctica would be top of the list; thousands of meteorites have been found there. We also know that giant iron meteorites have been found in Cape York, Greenland, and that the Namib Desert in Namibia is a fantastic, famous meteorite site. But there are strict government regulations in West Africa about moving or removing meteorites and as we always do everything above board, we wouldn't do what some dodgy people do and smuggle them out. That's wrong for numerous reasons: it means cultural property disappears and important meteorites are not available to academia.

Is there a black market in meteorites, then?
There is a black market in meteorites but we don't deal with that, we don't condone it and I hope we set a better example. We're always respectful. There were a couple of places where we were virtually certain we would make big discoveries but the government didn't want anyone even looking. In several episodes of the show, we went to protected sites with the very clear understanding that anything we found would be donated to the Park Service in the US or to the appropriate university, and in some instances we had to leave behind meteorites that we found.

When the Chelyabinsk meteorite fell on Russia, did you go out to it?
That was in February 2013 but I didn't go. I was committed to a project with NASA and I am also of half-Russian heritage: my father's parents were Russian. There were 1,200 people injured, some of them seriously, and I didn't think it was appropriate to show up at a disaster area, especially with people I am descended from. But the Russians are very industrious and adaptable people and they immediately went to work harvesting meteorites, selling them on eBay or to commercial global dealers. I was glad the people benefitted and, since then, we have acquired numerous specimens from our colleagues in the Russian Academy of Sciences.

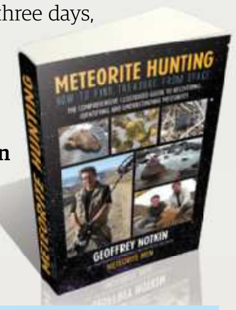
How did Chelyabinsk compare to the size of other meteorite events in history?
The Chelyabinsk fireball stands out from all other meteorite events due to the extraordinary amount of footage we have of it. Usually, a bright meteor lasts just a few seconds and there often isn't enough time to get a camera. But the Chelyabinsk fireball was of an extraordinarily long duration with a shallow angle of entry, so its burn time was very long, and in Russia it is common to have video cameras on the dashboard of your car because there is so much fraud and so many accidents on the highway. That is why we have so much footage and why Chelyabinsk is the clear winner in terms of being the most documented and spectacular fireball we've seen. It was a tense wake-up call for Earth but in the scheme of meteorite impacts, it was tiny; it's not even in the top 100.

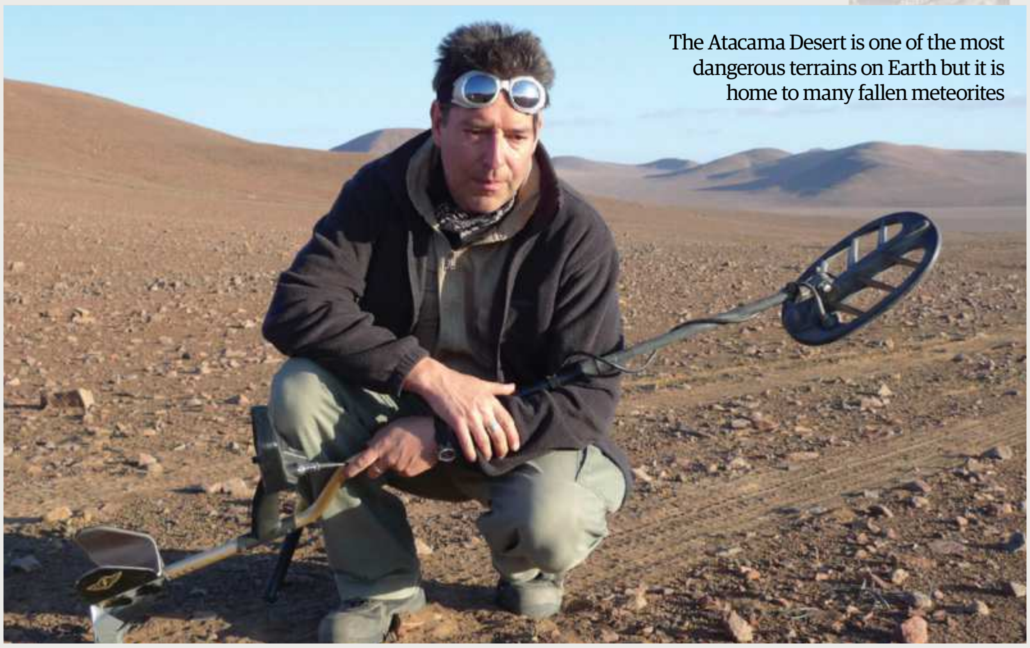
It led to calls to do something about the dangers of falling meteorites. Was that a knee-jerk reaction?
There was significant human injury as a result of the event but it's important to note that no one was actually hit by falling meteorites. The explosions that caused the resulting shock wave occurred many miles away from the city of Chelyabinsk and it was the shock waves hitting the town that injured people. Until February 2013, we had almost no documented instances in recorded history of humans being hit by meteorites. There was a woman in Alabama who was hit in 1954 by the Sylacauga meteorite that came through her roof and hit her on the thigh, leaving an enormous bruise on her leg. But the stories of people and dogs being hit by meteorites are largely apocryphal and we have no solid evidence.

So we're pretty safe?
I'm certain that in the prehistoric period, many humans were injured or killed by large meteorite impacts. We do need to be aware of asteroid impacts but it's not something that will happen today, this year or even this century. We were lucky with Chelyabinsk – it wasn't very dense and it exploded several times on the way through the atmosphere, so most of the pieces that landed were small. But if that had happened over the city, or if it had been an iron meteorite, damage and loss of life could have been catastrophic.

Do witnessed fireballs make hunting more exciting?
We did three *Meteorite Men* episodes about a recent fireball and investigated two historic ones from the 1800s. There was a sense of urgency about the recent falls because we wanted to get the meteorites to academia quickly. That way they would be far less contaminated by our oxygen and by whatever they landed in. But we knew others would want to get there too, and that's partly our fault because of the interest generated by the show. We also know that the bigger the fireball and the longer lasting it is, the less material there will be on the ground, because the incoming rocks are superheated and material is melted away. But it's exciting. It feels almost like a car chase and we're using radar, video footage and eyewitness accounts to find it first. When you see a shiny black meteorite on the ground and it's only been on the Earth for two or three days, it's exciting. After all, it's the newest extraterrestrial arrival to Earth. ■

As well as presenting, Notkin has also written several books such as *Meteorite Hunting: How To Find Treasure From Space.*




The Atacama Desert is one of the most dangerous terrains on Earth but it is home to many fallen meteorites


A full slice of the iron meteorite Northwest Africa 8302. The parallel lines are Neumann lines, which are an impact feature


Notkin continues to travel the world in his ongoing search for meteorites

YOUR QUESTIONS ANSWERED BY OUR EXPERTS

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

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Science Writer
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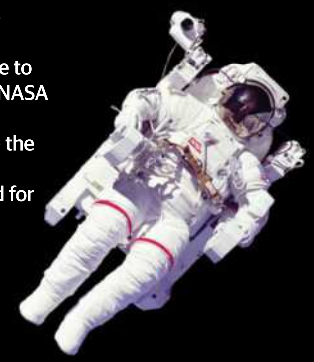
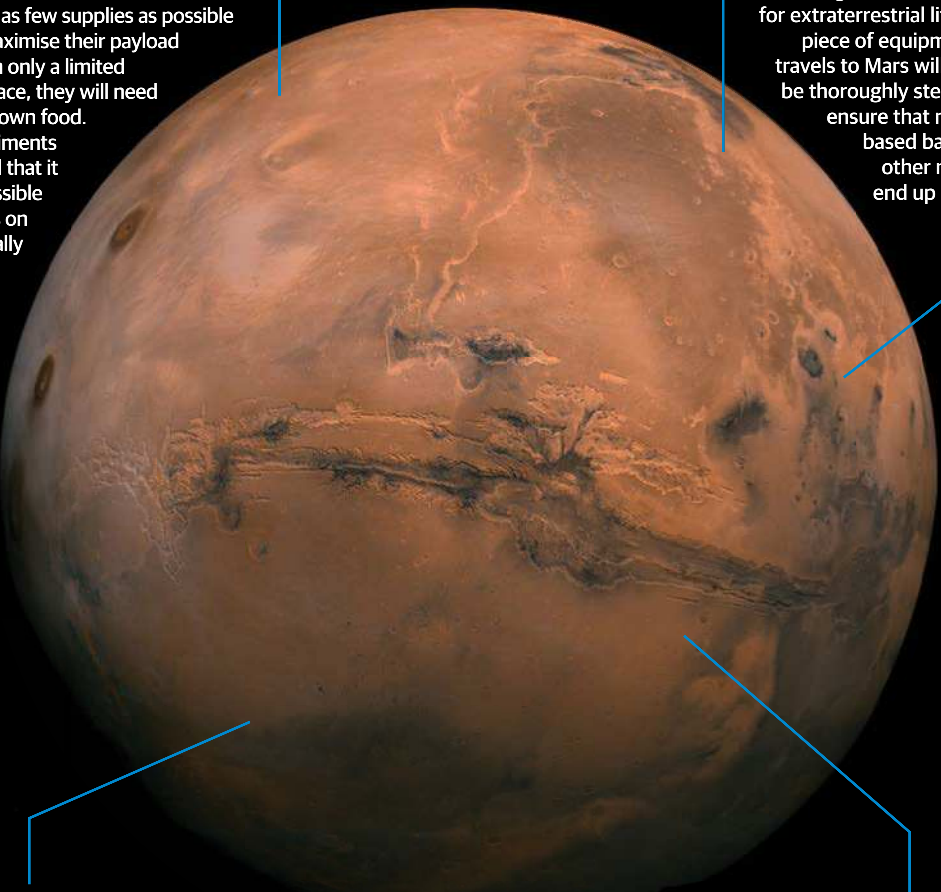
SPACE EXPLORATION

What are the challenges of a mission to Mars?

Lawrence Fox





Equipment failure

It's considered a disaster if astronauts are several days into their mission and their equipment fails, as the crew will be unable to get a replacement from Earth. Currently, NASA are testing out a solution to this problem onboard the International Space Station – the 3D printer, which can be used on a Mars mission to print any tools or parts needed for astronauts' survival on the Red Planet.

Growing food

When they reach Mars, astronauts will want to carry as few supplies as possible in order to maximise their payload capacity. With only a limited amount of space, they will need to grow their own food. Recent experiments have revealed that it should be possible to grow crops on Mars in specially designed greenhouses.

Avoiding contamination

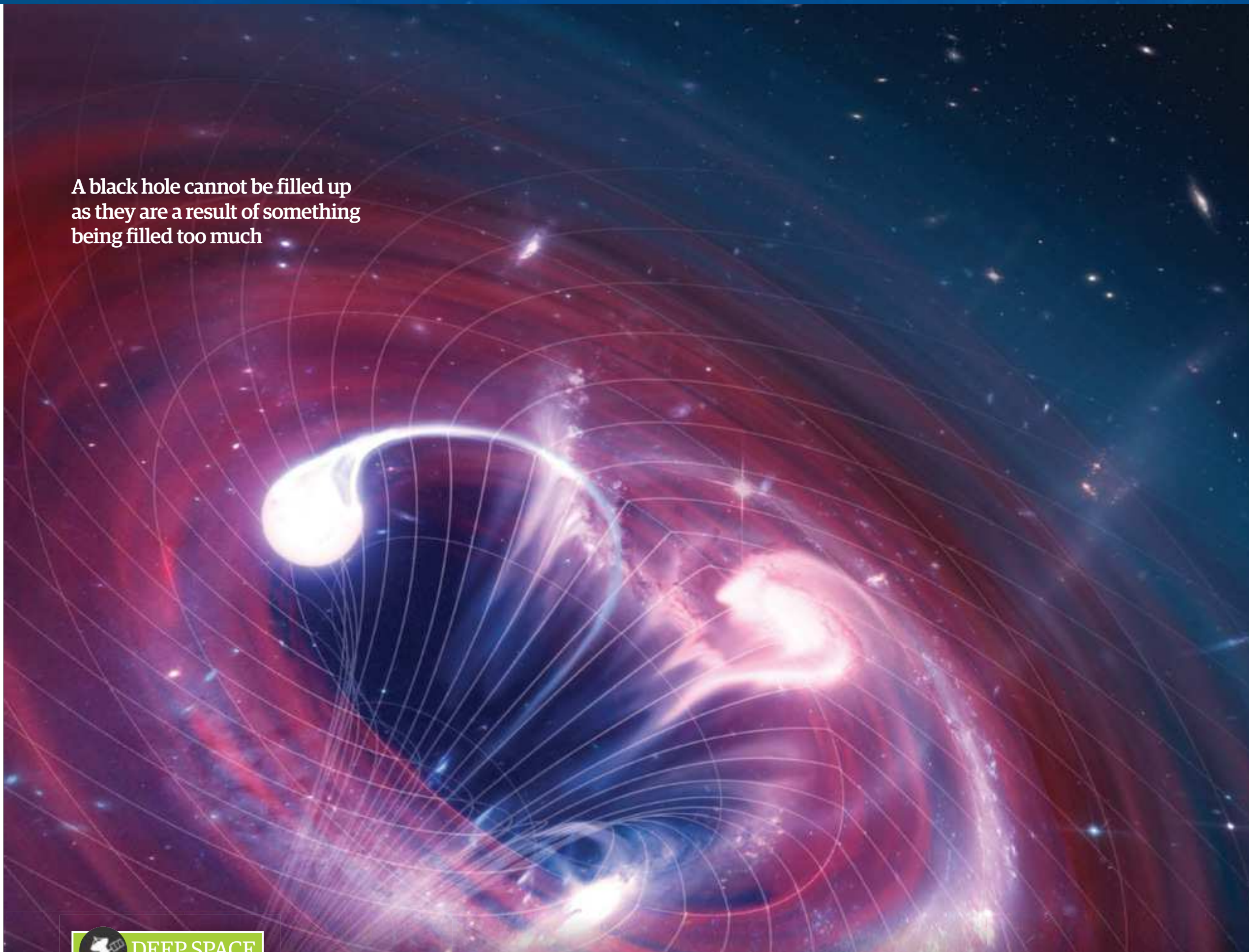
Any mission to another world brings with it the worry of contaminating it and seeding its soil with life, which could create false readings in the future hunt for extraterrestrial life. Every piece of equipment that travels to Mars will need to be thoroughly sterilised to ensure that no Earth-based bacteria or other microbes end up on Mars.

Keeping fuel amounts low

Large spacecraft capable of carrying humans require a lot of fuel to travel through space, so in order to carry out an efficient mission, the amount of fuel used needs to be kept as low as possible. To aid this, it may be possible to use an alternative source of fuel to chemical engines – such as solar electric power or ion propulsion. Once at Mars, it may be possible to make fuel from any Martian water and carbon dioxide.

High cost

One of the major drawbacks of sending humans to Mars is the cost, with estimates of a 20-year programme ranging from £52 to £62 billion ($80 to $100 billion). However, given that NASA currently spends £2.6 billion ($4 billion) a year on its human exploration programmes and a similar amount on the International Space Station, some experts think that the cost of getting to Mars might not be that insurmountable.



A black hole cannot be filled up as they are a result of something being filled too much

DEEP SPACE

Could a black hole be filled up?

Neville Shane

No, in fact they are a result of something being filled too much. Black holes form when a colossal amount of material gets crammed into a space much too small for it to exist in. At this point it collapses into something called a singularity. This infinitely small point contains all the mass and the subsequent gravity.

Because of the huge amount of mass, close to the black hole the gravity is so strong that nothing can escape. As this strong gravity pulls material close to it and into the black hole, it will consume everything until there is nothing left around it.

Once it has cleared out the area around it, the black hole may eventually evaporate away in a process taking billions of years. **JB**

ASTRONOMY

A Herschel prism refracts light away from the optical path

What is a Herschel prism used for?

Thomas Cox

Also known as a Herschel wedge, these prisms are used by astronomers for safe observations of our Sun by affixing them to a telescope. Remember, it is very dangerous to observe the Sun without the right eye protection.

The prism was originally proposed in the 1830s by astronomer John Herschel and acts by refracting – or bending – blinding light rays away from the optical path that leads to the observer's eye. The prism's surface works in much the same way as a standard diagonal mirror, reflecting a small amount of incoming light into the eyepiece. The remaining light is then gathered by the prism's trapezoidal shape, directing it safely away from the astronomer's eye. **GL**

SPACE EXPLORATION

How do astronauts get rid of waste?

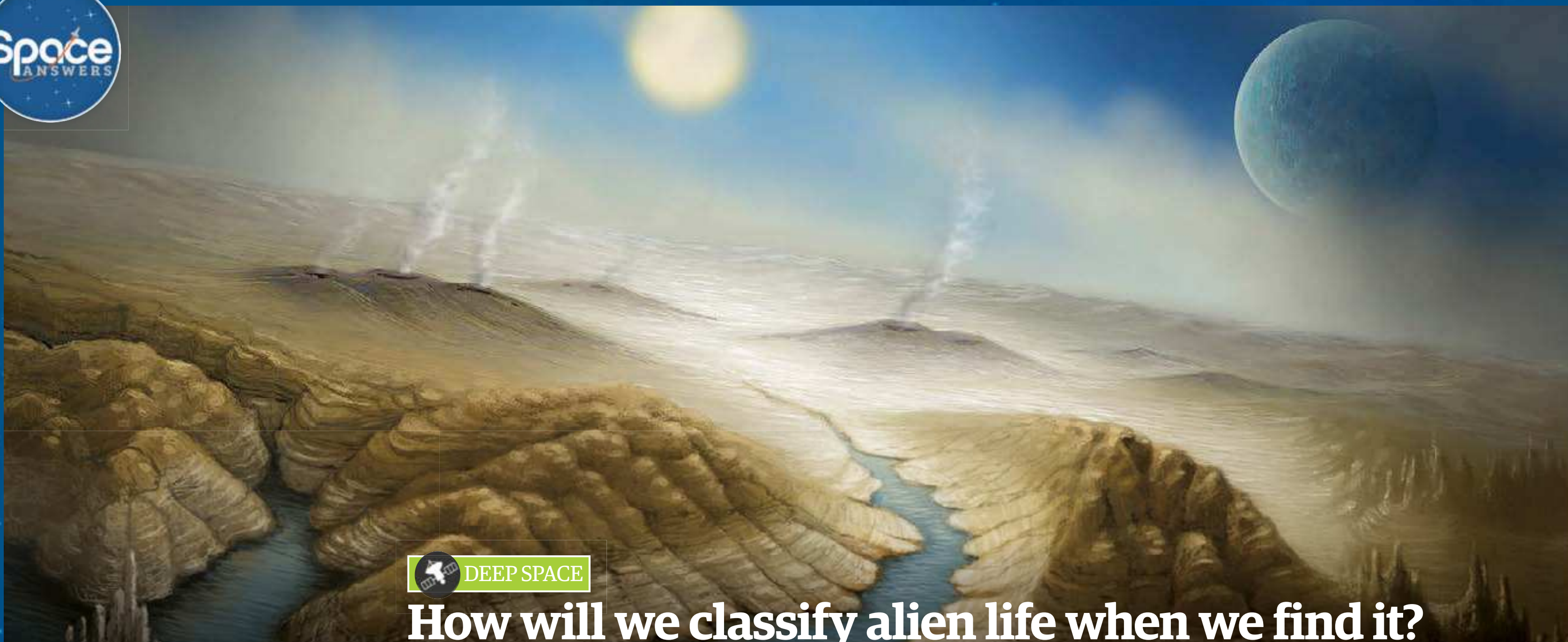
James Kinsella

It gets ejected into space. Next time you see a shooting star, it might not be a piece of space dust burning up in the Earth's atmosphere. Believe it or not, it could actually be human excrement!

Astronauts on the International Space Station (ISS) flush their waste out into space, where it orbits Earth for a while before eventually burning up in the atmosphere as a shooting star. NASA astronaut Scott Kelly produced 80 kilograms (176 pounds) worth of 'smelly' shooting stars during his recent year-long stay on the ISS.

Meanwhile, regular rubbish is brought back down to Earth onboard the frequent supply vessels that stop at the Space Station. **JB**

Astronauts flush their waste out into space, where it orbits Earth for a while



Alien life, which could exist on Earth-like worlds outside of our Solar System, may be difficult to classify

DEEP SPACE

How will we classify alien life when we find it?

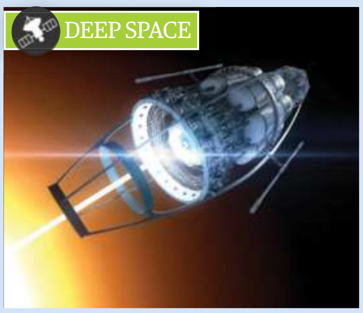
Gordon Barnett

It'll be tricky. The temptation might be to put alien life in the same categories as we do on Earth - plant, reptile, mammal- but alien life forms could surprise us by being completely beyond our expectation.

It is difficult to say exactly what alien life will be like because it will not necessarily have evolved in the same way life has on our own planet. However, there are several broad categories that alien life might fit into. The simplest categories are microbial life and more complex life forms, which may have varying degrees of intelligence. Beyond that, astrobiologists tend to look for planets that may have an oxygen-rich atmosphere, but alien life could have different chemistries and breathe different gases instead - for instance, if there were life on Saturn's moon Titan, it would be methane-based.

Plus, there's always the possibility that alien life might be so alien that we don't recognise it as being alive! **GL**

DEEP SPACE



What could antimatter look like?

Tony Fisk

Theoretically, it's thought that something made of antimatter would look no different to its counterpart made of matter but as of yet, we don't know for sure. Following the particle physics theory, antimatter is made of the antiparticles of its matter equivalent. Antiparticles are the same as their counterparts but hold the opposite charge.

So far we have only been able to create very simple forms of antimatter, such as an anti-hydrogen atom and an anti-helium nucleus. The problem with finding out what this antimatter would look like is that any exposure of antimatter to matter causes both to be annihilated. Due to this we've only been able to observe just a few particles of antimatter for a few minutes at a time. **SA**

SOLAR SYSTEM

Is the Sun really burning?

Michael Watts

No, it isn't. Fire needs three things to survive: fuel, heat and oxygen. The Sun has fuel as it is composed mainly of hydrogen and helium gas. Helium is inert and does not burn, but hydrogen is highly flammable. The Sun also has heat, its surface is an Earth-melting 5,050 degrees Celsius (9,940 degrees Fahrenheit). But there is no oxygen in space, so the fire triangle is incomplete.

In reality, the Sun isn't actually on fire and instead, the heat and light that it produces are the result of nuclear fusion. Inside the hot, high-pressure environment of our star, high-speed hydrogen atoms come within one femtometre of each other (that's 0.000000000001 millimetres, or 0.00000000000004 inches). A collision at this distance allows the two nuclei to fuse, forming helium and releasing huge quantities of energy as gamma rays. Every second inside the Sun, 700 million tonnes of hydrogen smash together to form 650,000 tonnes of helium, which triggers more fusion reactions and keeps the nuclear reactor going. **JB**

Despite its fiery appearance, our Sun isn't actually burning

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

SOLAR SYSTEM

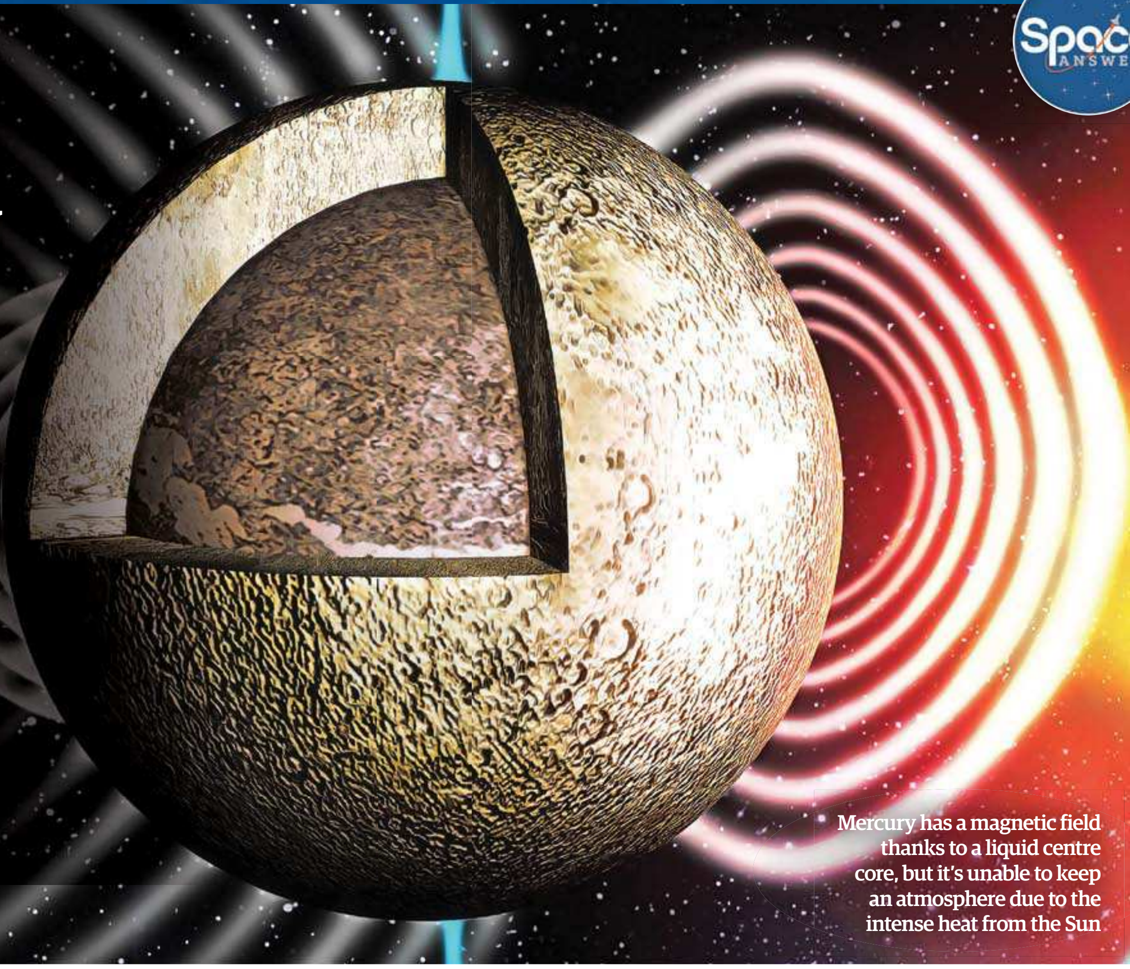
Why don't Mercury and Mars have atmospheres?

Hannah Howells

The short answer is Mercury is too hot and Mars has no magnetic field to shield it from the high-energy radiation from space and the Sun. As they are small planets, Mercury and Mars have a low surface gravity so particles that would create an atmosphere can escape if they have enough energy.

In the case of Mars, the main factor which contributed to the loss of its atmosphere is the lack of a magnetic field. These fields, which are generated by a moving molten-iron core, deflect highly charged particles, which are harmful to delicate life forms. As Mars cooled much faster than Earth, the Red Planet lost its magnetic shielding, which enabled the solar wind to strip away the atmosphere over time.

Mercury does have a magnetic field, but its low surface gravity and high temperatures make it impossible for the planet to hold on to a substantial atmosphere. **SA**



Mercury has a magnetic field thanks to a liquid centre core, but it's unable to keep an atmosphere due to the intense heat from the Sun

DEEP SPACE

What types of exoplanet have we discovered?

Ciaran Nilan

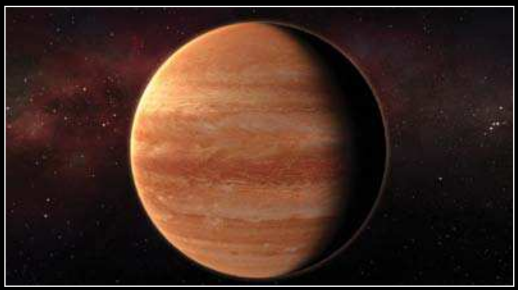
We have found a number of exoplanets ranging from hot to cold and gaseous to metallic, and have even found rogue planets wandering the galaxy alone

Rogue planet

Rogue planets appear to wander space alone, as they are not orbiting a star. Instead, they orbit the centre of the galaxy directly, still warmed by their molten cores but often encased in ice.

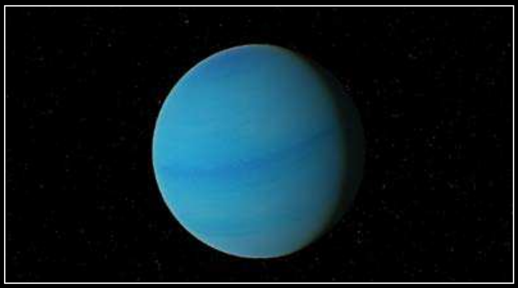
Super-Earth

These planets have a mass that's greater than Earth but they are lighter than Neptune. Despite the name, not all super-Earths are Earth-like – some are blisteringly hot, while others are frozen!



Gas giant

These enormous worlds are just like Jupiter and Saturn, with masses several times that of our own planet. They are comprised mostly of gas, possibly with a molten, rocky or metallic core.



Hot Neptune

These Neptune-sized planets orbit closely to their stars and, due to their size, are easy to detect by Earth- and space-based telescopes. A year on their surface passes quickly, as their orbits tightly hug their parent stars.

Water world

These ocean planets are composed mostly of water. Some are thought to have thick atmospheres, supporting liquid water on the surface, but others are hot, steamy and unstable.

Hot Jupiter

These gas giants orbit close to their parent stars and block the light as they pass in front, making them easy to detect. They are physically similar to Jupiter but orbit so close to their star that their atmospheres are roasted.

SOLAR SYSTEM

How big are the planets' natural satellites?

Our Moon is one of 181 known natural satellites in the Solar System, which range from tiny to ginormous

Amy Moss

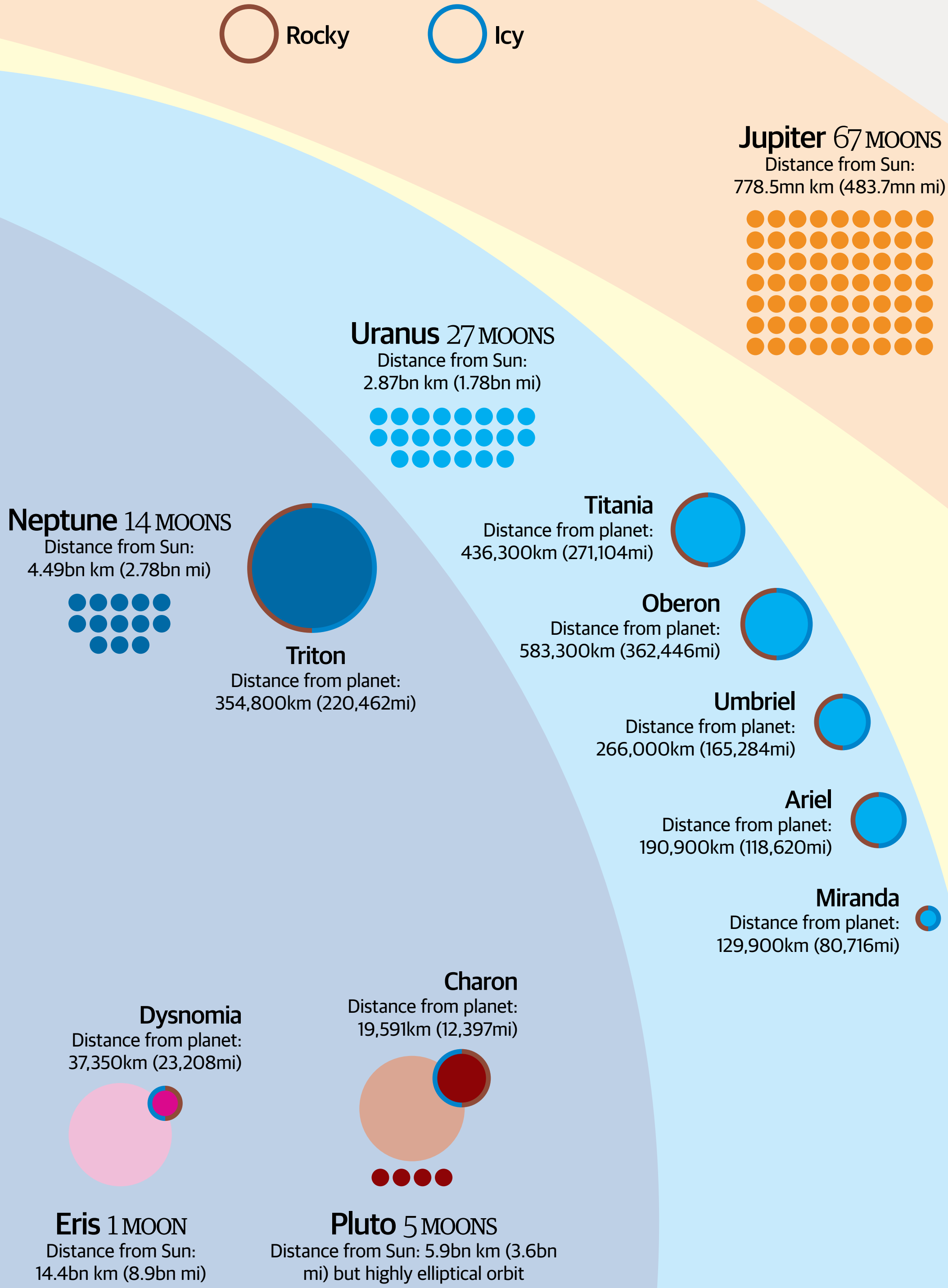
Our Moon is a familiar companion that humanity has known since it evolved; in fact, it probably helped us evolve by stirring the sea around twice a day. But it was not until 1610 that we first discovered moons around another planet, when Galileo pointed his telescope at Jupiter. At first he thought he had found three small stars, but as he observed them over a few months he realised they were in fact small bodies orbiting the planet. This was important evidence against the popular theory of the time, which said that the Earth was at the centre of the universe with everything going around it.

All of the planets except Mercury and Venus have moons. Our own Moon is unusually large at one-sixth the size of its parent planet. As it is so big - 3,474 kilometres (2,159 miles) in diameter - and so comparatively close at 384,400 kilometres (238,600 miles) away, it is tidally locked to Earth, rotating at the same rate it revolves around us - which is why the same side always points towards us. The closest moons to Earth - other than our own, that is - are Mars' moons Phobos and Deimos, their names meaning fear and dread. They are small and irregular, and are likely to be captured asteroids at 23 kilometres (14 miles) and 12 kilometres (seven miles) respectively. Out of the 181 moons, only 19 are large enough that their gravity has pulled them into a sphere.

Jupiter has the most moons with a total of 67, including the four planet-sized moons discovered by Galileo; the largest Ganymede, ice worlds Callisto and Europa, and Io, the most volcanically active body in the Solar System. The other 63 are all irregular and range from one to 166 kilometres (0.6 to 103 miles) wide.

Saturn's biggest moon, Titan, is the only moon with an appreciable atmosphere. It's also the only surface outside of Earth you could stand on without a pressure suit (just an oxygen mask and warm clothing), and it appears to have methane snow, rain, rivers and sea; it's like a frozen version of Earth. Other notable Saturnian moons include Enceladus, whose subsurface ocean produces 500-kilometre (311-mile) tall geyser jets, and Mimas, which looks like the Death Star from *Star Wars*!

Uranus has five spherical moons, the largest being Titania at 1,578 kilometres (981 miles) in diameter, and 22 smaller, irregular moons, which are all named after characters from the writings of William Shakespeare and Alexander Pope. The last planet-sized moon is Neptune's Triton, and at 2,705 kilometres (1,681 miles) wide it is bigger than Pluto and is thought to have been a dwarf planet that was captured by Neptune. Discovered only 17 days after Neptune, Triton is the only large moon to orbit opposite to the spin of its planet (retrograde). It is also geologically active with geysers of nitrogen and dust observed by Voyager 2; it is thought that this may be due to solar heating, despite its great distance from the Sun. **RH**



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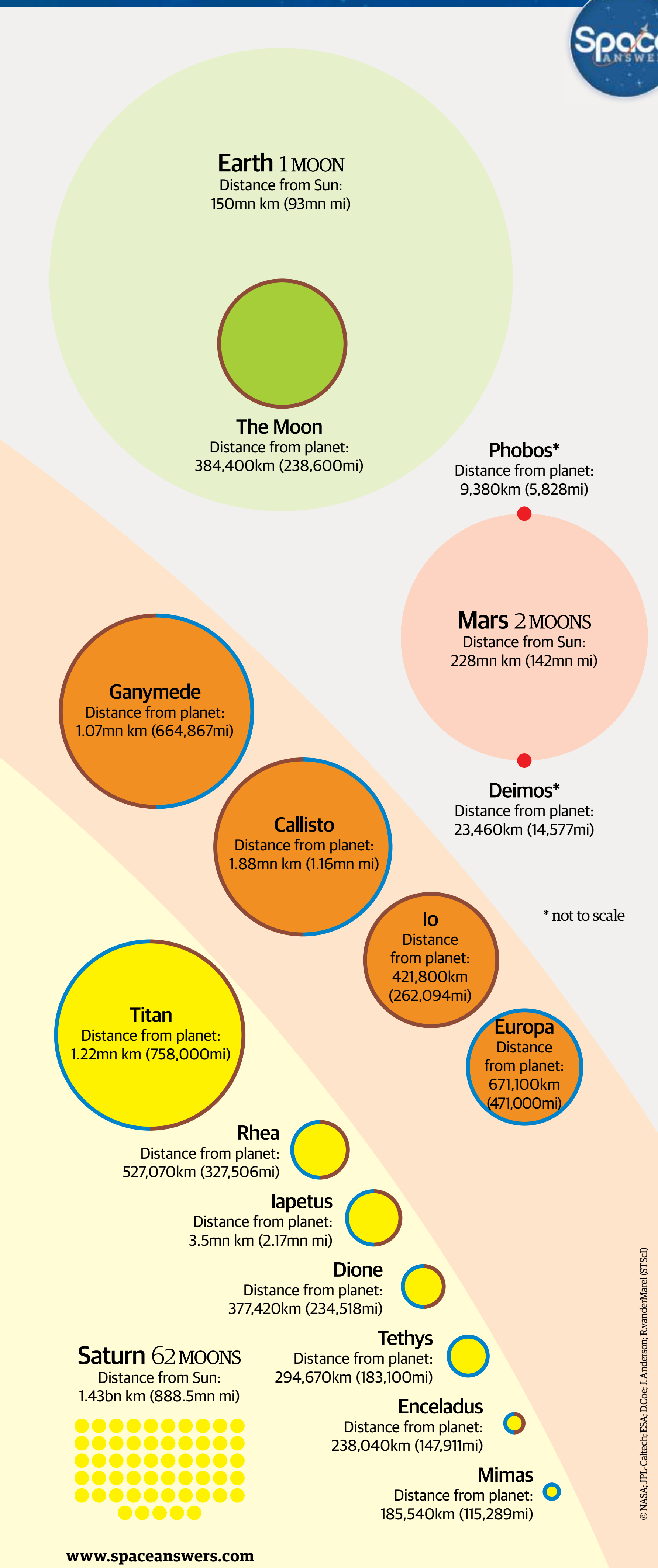


Next Issue

JUNO ARRIVES AT JUPITER

Find out how the spacecraft will unlock the secrets of the gas giant

WHY SPACE IS SIX-TIMES LOUDER

...Plus 10 other discoveries that'll change how you see the universe

SAVING EARTH FROM ASTEROIDS

Uncover the masterplan to protect our planet in time for Asteroid Day

In orbit 23 June

+

TURNING A SPACE ROCK INTO A SPACECRAFT

INTERVIEW WITH ROBIN INCE

ELON MUSK ON HIS PLANS TO GET US TO MARS BY 2018

STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

What's in the sky?

In this issue...

Red light friendly

In order to preserve your night vision, you should read our observing guide under red light

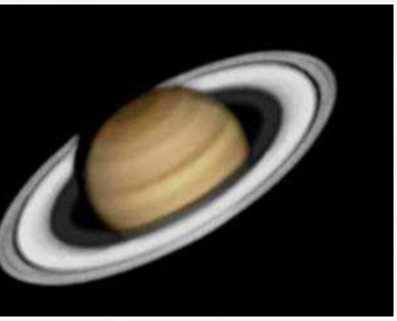
01 JUN Conjunction between the Moon and Uranus in Pisces

03 JUN Saturn reaches opposition in Ophiuchus

10 JUN Ophiuchids reach their peak at five meteors per hour

20 JUN Ophiuchids reach their peak at five meteors per hour

20 JUN June solstice



05 JUN

Mercury at greatest elongation west in the dawn sky

11 JUN

Conjunction between the Moon and Jupiter in Leo

19 JUN

Conjunction between the Moon and Saturn in Ophiuchus

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

Jargon buster

Conjunction
A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Magnitude
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object will be. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we are able to see different parts of the sky throughout the night.

Declination (Dec)
This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

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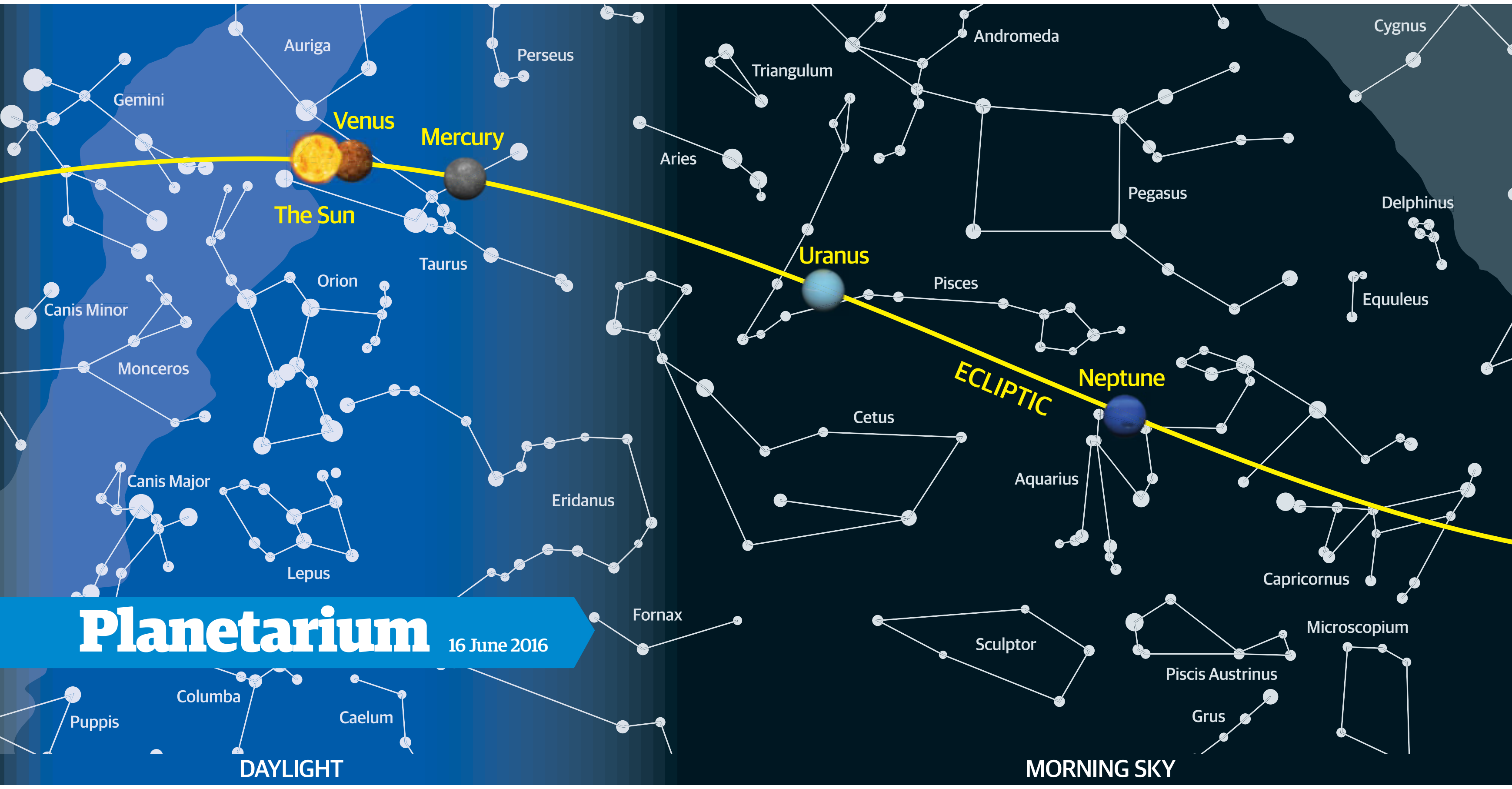


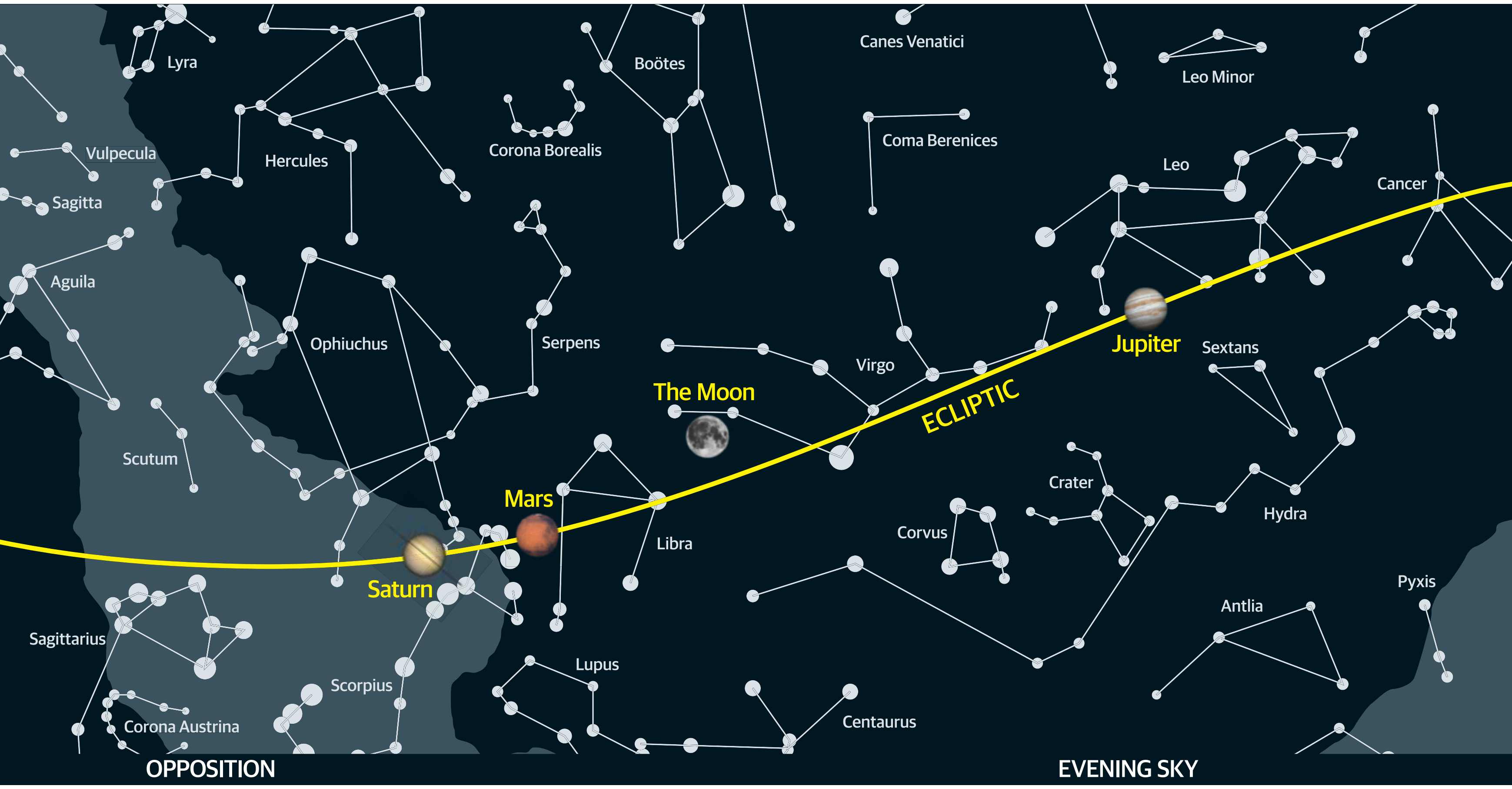
Moon phases

26 MAY		82.9%	Moonrise --:-- / Moonset 09:03
27 MAY		74.2%	Moonrise 00:30 / Moonset 10:08
28 MAY		64.1%	Moonrise 01:05 / Moonset 11:17
29 MAY	LQ	53.0%	Moonrise 01:36 / Moonset 12:29
30 MAY		41.5%	Moonrise 02:05 / Moonset 13:43
31 MAY		30.1%	Moonrise 02:33 / Moonset 15:00
1 JUN		19.6%	Moonrise 03:01 / Moonset 16:18
2 JUN		10.8%	Moonrise 03:31 / Moonset 17:38
3 JUN		4.3%	Moonrise 04:05 / Moonset 18:57
4 JUN		0.8%	Moonrise 04:45 / Moonset 20:12
5 JUN	NM	0.4%	Moonrise 05:32 / Moonset 21:21
6 JUN		3.1%	Moonrise 06:26 / Moonset 22:20
7 JUN		8.4%	Moonrise 07:27 / Moonset 23:09
8 JUN		15.7%	Moonset 08:33 / Moonrise 23:50
9 JUN		24.5%	Moonrise 09:40 / Moonset --:--
10 JUN		34.2%	Moonset 00:23 / Moonrise 10:48
11 JUN		44.2%	Moonset 00:52 / Moonrise 11:54
12 JUN	FQ	54.3%	Moonset 01:17 / Moonrise 12:59
13 JUN		63.9%	Moonset 01:40 / Moonrise 14:02
14 JUN		73.0%	Moonset 02:03 / Moonrise 15:05
15 JUN		81.1%	Moonset 02:26 / Moonrise 16:07
16 JUN		88.1%	Moonset 02:50 / Moonrise 17:09
17 JUN		93.7%	Moonset 03:18 / Moonrise 18:11
18 JUN		97.6%	Moonset 03:49 / Moonrise 19:11
19 JUN		99.5%	Moonset 04:25 / Moonrise 20:08
20 JUN	FM	99.6%	Moonset 05:08 / Moonrise 21:02
21 JUN		99.5%	Moonset 05:59 / Moonrise 21:50
22 JUN		97.2%	Moonset 06:56 / Moonrise 22:32
23 JUN		92.7%	Moonset 07:59 / Moonrise 23:08

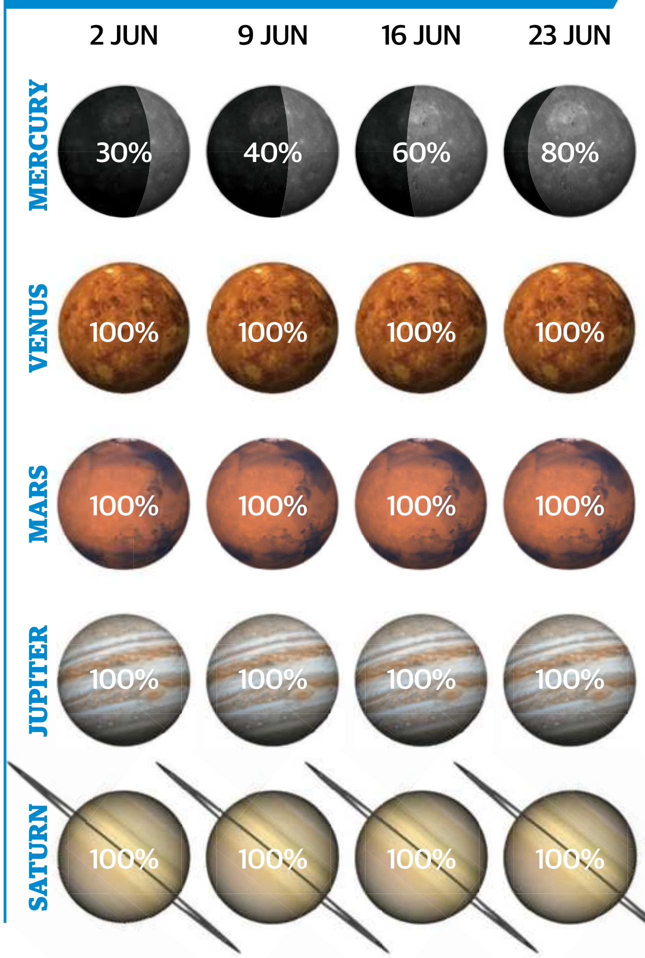
% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage



Planet positions

All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	26 May	02h 52m 42s	+12° 47'18"	Aries	+1.6	04:25	18:45
	02 Jun	03h 06m 53s	+13° 37' 20"	Aries	+0.8	04:07	18:37
	09 Jun	03h 32m 59s	+15° 48' 40"	Taurus	+0.3	03:53	18:48
	16 Jun	04h 10m 19s	+18° 45' 08"	Taurus	-0.3	03:44	19:15
	23 Jun	04h 59m 14s	+21° 43' 55"	Taurus	-0.9	03:46	19:56
VENUS	26 May	03h 58m 57s	+20° 02' 52"	Taurus	-3.9	04:47	20:35
	02 Jun	04h 35m 02s	+21° 48' 01"	Taurus	-3.9	04:44	20:55
	09 Jun	05h 11m 54s	+23° 03' 16"	Taurus	-3.9	04:45	21:13
	16 Jun	05h 49m 17s	+23° 46' 00"	Taurus	-3.9	04:49	21:28
	23 Jun	06h 26m 54s	+23° 54' 32"	Gemini	-3.9	04:58	21:39
MARS	26 May	15h 51m 25s	-21° 31' 37"	Scorpius	-2.0	20:26	04:41
	02 Jun	15h 41m 01s	-21° 20' 00"	Libra	-2.1	19:47	04:04
	09 Jun	15h 31m 51s	-21° 08' 02"	Libra	-2.0	19:09	03:29
	16 Jun	15h 24m 50s	-20° 59' 02"	Libra	-2.0	18:33	02:56
	23 Jun	15h 20m 27s	-20° 55' 43"	Libra	-1.9	18:01	02:24
JUPITER	26 May	11h 00m 58s	+07° 43' 08"	Leo	-2.1	12:59	02:29
	02 Jun	11h 02m 27s	+07° 32' 23"	Leo	-2.1	12:34	02:02
	09 Jun	11h 04m 26s	+07° 18' 35"	Leo	-2.0	12:09	01:35
	16 Jun	11h 06m 52s	+07° 01' 58"	Leo	-2.0	11:46	01:09
	23 Jun	11h 09m 44s	+06° 42' 44"	Leo	-1.9	11:23	00:42
SATURN	26 May	16h 49m 21s	-20° 37' 16"	Ophiuchus	+0.8	21:18	05:45
	02 Jun	16h 47m 09s	-20° 33' 49"	Ophiuchus	+0.8	20:48	05:15
	09 Jun	16h 44m 57s	-20° 30' 24"	Ophiuchus	+0.8	20:18	04:46
	16 Jun	16h 42m 48s	-20° 27' 08"	Ophiuchus	+0.8	19:48	04:17
	23 Jun	16h 40m 45s	-20° 24' 06"	Ophiuchus	+0.8	19:18	03:47

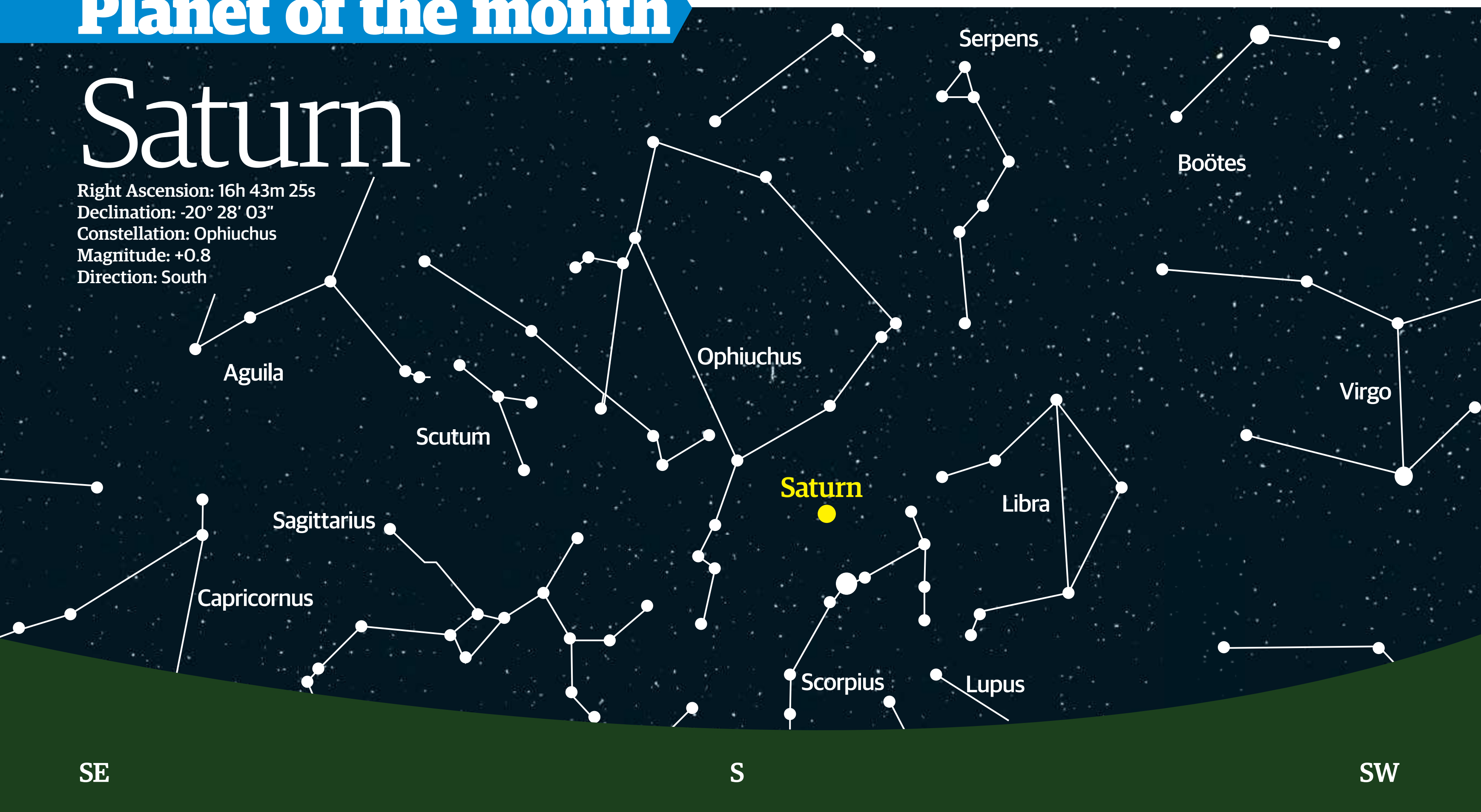
This month's planets

Mars, Jupiter and Saturn are easily visible in the night sky throughout the warmer nights of June

Planet of the month

Saturn

Right Ascension: 16h 43m 25s
Declination: -20° 28' 03"
Constellation: Ophiuchus
Magnitude: +0.8
Direction: South



00:30 BST on 14 June

Having been visible for several months in the morning skies, the ringed planet Saturn has slowly edged ever west of the Sun, gradually brightening in apparent magnitude and gaining in apparent diameter.

As far as UK-based observers are concerned, this is not exactly the most favourable of Saturnian oppositions as the planet will be rather low above the southern horizon at best - an occupant of the southern regions of the constellation of Ophiuchus (the 'Serpent Bearer'). And what's more, Saturn will continue to travel through the most southerly zodiacal constellations for several more years to come. The upcoming opposition of Saturn takes place on 3 June, and it (as well as the weeks surrounding opposition) represents the last opportunity for UK-based astronomers to view the planet at a reasonable altitude in fairly dark skies until 2020.

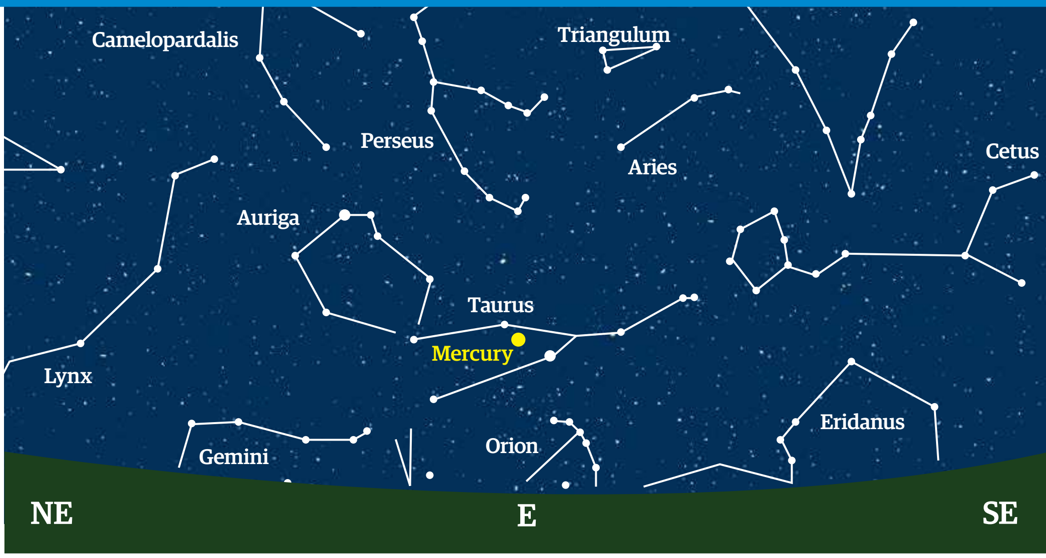
On the date of opposition, Saturn, shining at magnitude +0.8, will first become visible at around 10pm at an altitude of eight degrees above the southeastern horizon. As the evening twilight grows darker, the planet reaches its highest point in the sky, some 19 degrees above the southern horizon at around 1am. It then begins to sink ever westward until it is lost in the brightening morning twilight at around 4am.

Under good seeing conditions and when viewed through a 100mm telescope under a magnification of at least 100x, Saturn and its rings and numerous moons present a beautiful sight. The planet's famous ring system is wide open. The difference in brightness between the dusky outer A Ring and brighter inner B Ring; the darkening of the inner part of the B Ring; and the black Cassini Division (separating the A and B Rings) can easily be resolved.

Encke's Gap in the outer A Ring should make its presence known to users of larger instruments, and experienced observers may be able to make out the translucent C Ring (known as the 'Crepe Ring') that lies inside the B Ring, particularly where it crosses the disc of Saturn itself as it produces a broad dusky area.

Saturn's north polar region is tilted towards Earth at present. Its North Equatorial Belt is presented nicely, appearing very broad and it is more sharply delineated against the brighter Equatorial Zone. Banding parallel to the planet's equator may be observed further north, and the North Polar Area appears dusky and well defined along its southern margin. Short-lived bright spots, dark knots and irregularities in the planet's belts and zones can be seen, but they are usually pretty muted in their visual appearance.

Mercury 05:00 BST on 20 June



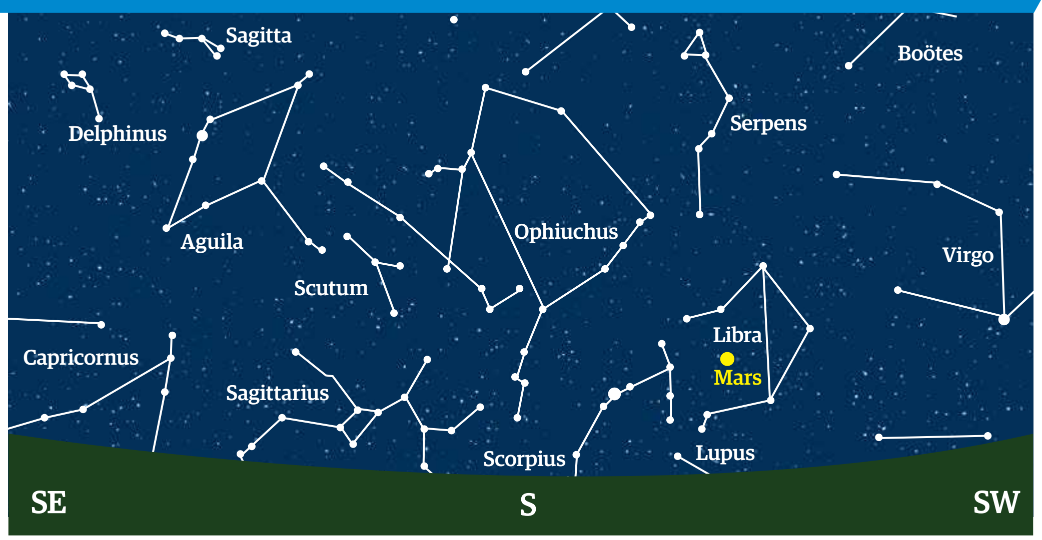
Right Ascension: 04h 36m 49s
Declination: +20° 30' 18"
Constellation: Taurus
Magnitude: -2.3
Direction: East

Mercury is a morning object in June, which is unfavourable for UK observers as it sits just a few degrees above the dawn horizon in the east at sunrise. Eager sky-watchers may find the planet before sunrise using binoculars though. Mercury comes to its greatest elongation west of the Sun on 5 June, where it is 24 degrees from the Sun and shining at magnitude +0.6 some six degrees high at sunrise. Although the planet then moves towards the Sun, observing conditions improve as its brightness increases. On 23 June, lying 16 degrees west of the Sun, it is seven degrees high at sunrise and shines at magnitude -0.9. It may just be visible low to the horizon with the unaided eye 30 minutes before sunrise.

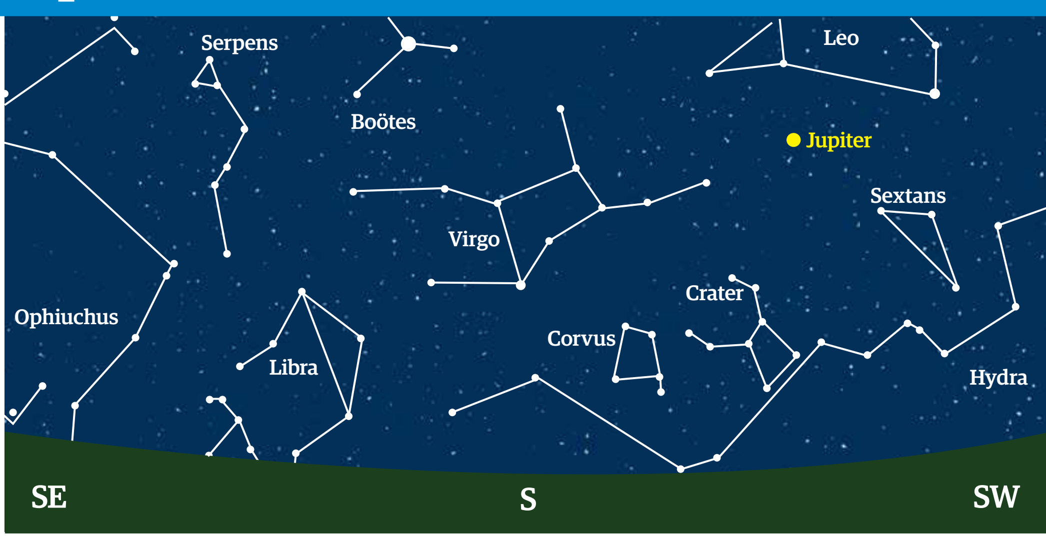
Mars 00:30 BST on 15 June

Right Ascension: 15h 21m 41s
Declination: -21° 00' 01"
Constellation: Libra
Magnitude: -2.0
Direction: South-South West

Mars was at opposition on 22 May, shining at magnitude -2.1. On 26 May the Red Planet is at magnitude -2.0 and located in northwestern Scorpius; rising at 8.30pm, it is due south at 12.45am and has climbed to an altitude of 18 degrees. Through a telescope the planet presents a disc almost 100 per cent illuminated and 19 arcseconds across. Mars continues to move west through the sky and by 23 June is located in southern central Libra. By now it shines at magnitude -1.9 and presents a disc some 17 arcseconds across. Considerable detail may still be observed on the face of Mars, including the broader dusky desert markings and the north polar ice cap.



Jupiter 20:00 BST on 23 June



Right Ascension: 11h 09m 44s
Declination: +06° 42'44"
Constellation: Leo
Magnitude: -1.9
Direction: South West

Jupiter is now a firm evening object, visible as a brilliant white point above the western horizon. On 26 May the planet is some 23 degrees high by the time astronomical night begins at midnight. Through a telescope it appears as a disc some 38 arcseconds across – sizeable enough to be discerned as a distinct planet through binoculars and whose atmospheric surface detail remains clear enough to view through relatively small telescopes. Jupiter continues to move ever closer to the Sun, and on 23 June it first becomes visible with the unaided eye at around 11.30pm, shining at magnitude -1.9 some 12 degrees above the western twilight horizon.

How to…

Get the best views of Saturn

The ringed planet comes to opposition in June. Here's how to get the best sights of it with your telescope…

You'll need:

- ✔ Telescope
- ✔ Camera
- ✔ Medium power eyepiece
- ✔ Low power eyepiece
- ✔ Driven telescope mount

The beautiful planet Saturn, famous for its amazing ring system, comes to opposition on 3 June 2016. Opposition means that it is directly opposite the Sun in our skies and is also usually about as close as it can get to us in our respective orbits. This means that it will appear relatively big and bright in the night sky.

At this time, Saturn will be in the constellation of Ophiuchus the Serpent Bearer. This constellation can be considered the thirteenth sign of the Zodiac, as the Sun, Moon and planets all pass through it at some point in the year. From the Northern Hemisphere, Saturn will be quite low in the sky, but from the Southern Hemisphere it will be riding high, so those of you in the antipodes will have the best views. That being said, Saturn will still look good for those of you located north of the equator. An interesting phenomenon occurs during the opposition of Saturn, known as the 'Seeliger effect'. Because Saturn's rings are not solid but made of particles, they usually cast shadows on each other, making them appear duller.

During opposition, the Sun, Earth and Saturn lie in a straight line, so the particles are illuminated in such a way that their shadows are cast behind them from our point of view. This means that for a few days either side of and during opposition, the rings look brighter than usual. German astronomer, Hugo von Seeliger, first noticed this effect, which has since been named after him. The rings are also tilted towards us and are nicely open, so the view should be great!

You will need a telescope to see Saturn, as it is too far away to be resolved with binoculars, but even a modest telescope should show the rings clearly. Not only that, but you should also be able to pick out a few of the planet's moons. The largest of these is Titan, but there are four or even five others that are discernible in an amateur telescope.

It is possible to photograph Saturn if you have the right equipment. You may even be able to capture a shot of it using a smartphone camera through the eyepiece of your telescope. A DSLR camera attached directly to the telescope would be even better, but you'll need a driven telescope mount and other more specialist equipment to do this successfully. Whichever way you choose to observe this wonderful planet, enjoy the view! ■

Tips & tricks

Employ a small telescope
A small telescope on a sturdy driven mount with a finder telescope is all you need to view Saturn.

Use your smartphone camera
You can use a smartphone camera to image Saturn by holding it over the eyepiece of your telescope.

High magnification
Saturn usually looks good under high magnification but this depends on atmospheric conditions.

A coloured filter will reveal greater detail
Using a coloured filter can help to enhance the view of Saturn in your field of view. A deep blue filter will work well to reveal Saturn's rings.

Use a low power eyepiece to find Saturn
In order to locate Saturn in the night sky, use a low power eyepiece. Once you have found it, swap to a medium power eyepiece to look for detail.

Viewing Saturn at opposition

How to snap the best views of the ringed giant with your smartphone

Because Saturn is quite low in the sky for UK observers - barely 18 degrees above the horizon at best - you will need to find an observing site with a clear horizon and preferably away from artificial lights or light pollution. Make sure that the finderscope is well aligned with the main telescope, as this will help to get the planet in the middle of the field of view in your eyepiece. An electric or computer driven mount is helpful to keep your telescope tracking the planet, but this isn't essential. Don't overdo the magnification; if Saturn looks fuzzy then you will get a much better view using a low power eyepiece.

Send your photos to
photos@spaceanswers.com

1 **Align the finderscope**
Line up your finderscope with your telescope in daylight. Make sure that what you see in the telescope eyepiece is also on the crosshairs of your finderscope.

2 **Get into focus**
Take the time to get a sharp focus on your telescope. It will make all the difference to seeing the detail of the planet, especially Saturn's rings.

3 **Know when to look**
The ringed planet will cross your local meridian, or be due south, at 1am BST and will be at its highest in the sky. This is the best time to view Saturn.

4 **Find Saturn with a low power eyepiece**
Always start with a low power eyepiece to centre the ringed planet in your field of view. Then increase the power a step at a time to see more detail.

@ Rochus Hess

5 **What to look for**
Once Saturn is located you can look for details. Saturn's rings will be bright. See if you can pick out the Cassini Division, a dark gap between the rings.

6 **Start photographing**
Try taking a few pictures of Saturn with your smartphone camera by simply holding it over the eyepiece. A driven mount will make this easier.

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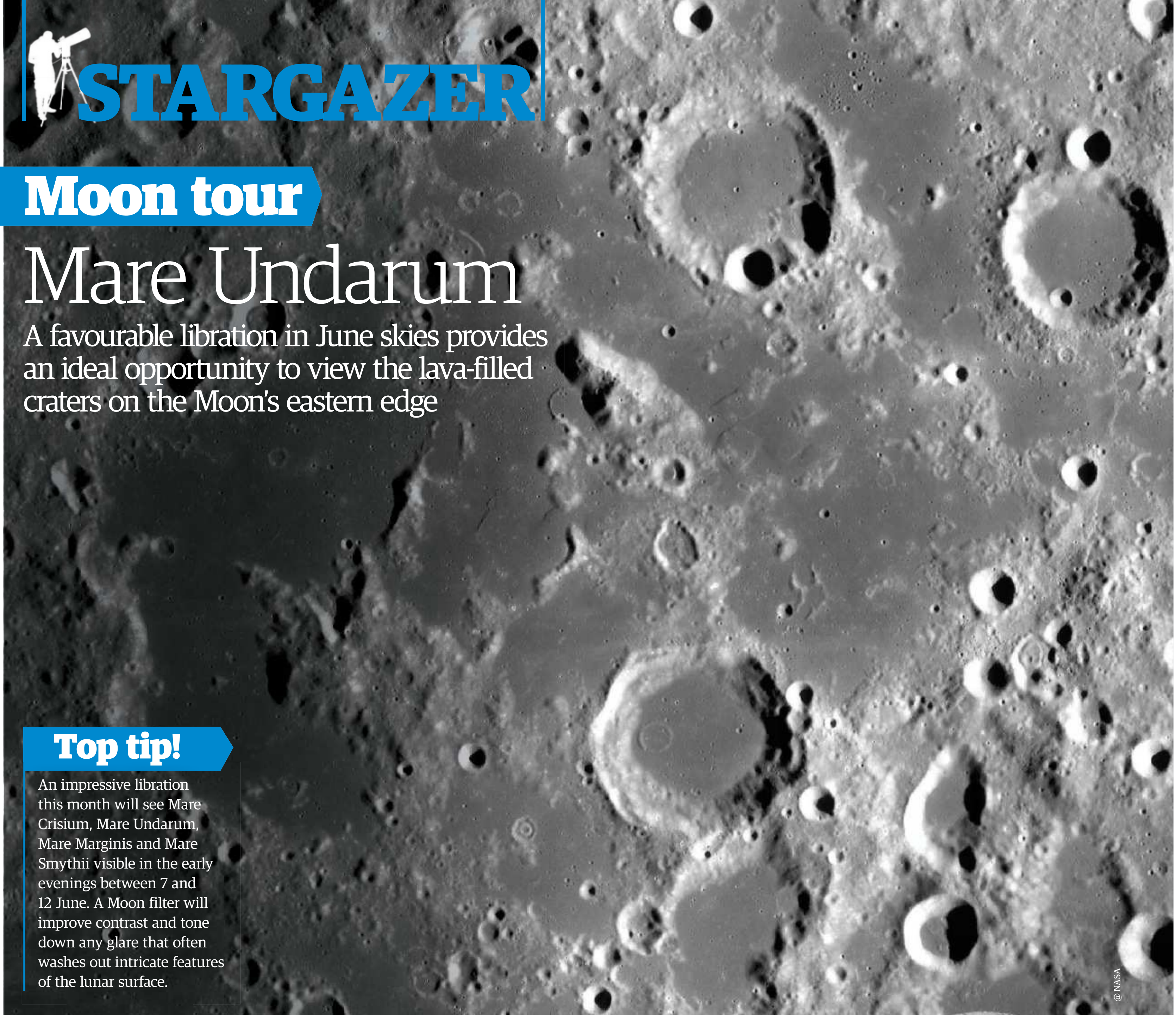
Moon tour

Mare Undarum

A favourable libration in June skies provides an ideal opportunity to view the lava-filled craters on the Moon's eastern edge



@ NASA

Top tip!

An impressive libration this month will see Mare Crisium, Mare Undarum, Mare Marginis and Mare Smythii visible in the early evenings between 7 and 12 June. A Moon filter will improve contrast and tone down any glare that often washes out intricate features of the lunar surface.

Last month we took a look at Mare Crisium (the Sea of Crises), a vast oval-shaped dark plain near the Moon's northeastern edge – a lunar sea (or maria in Latin) so sizeable that it can easily be seen with the keen, unaided eye as a dusky spot near the lunar limb. Mare Crisium may be looked at as a very large impact crater, whose central plains have been covered by lava that welled-up from beneath the lunar crust at some point in time after impact.

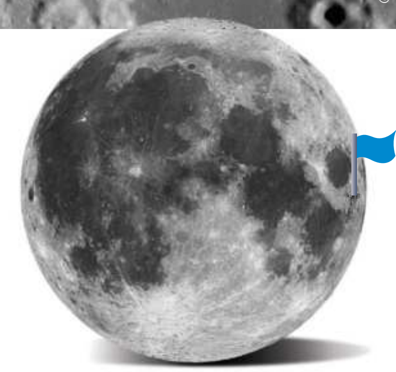
A phenomenon known as libration – an apparent slight rocking of the Moon from side to side during the month – enables Mare Crisium to appear more prominent from time to time. However, Mare Crisium lies entirely on the Moon's nearside and its oval shape can always be observed when the area is illuminated. But there also exists a cluster of smaller lunar seas also visible, which are located to the east of Mare Crisium. None of these seas take the classic oval form of Mare Crisium, for each is somewhat patchy and irregular in outline.

Located around 100 kilometres (62 miles) southeast of Mare Crisium lies Mare Undarum (Sea of Waves), which is a collection of lava-filled craters. Like Mare Crisium, Mare Undarum is positioned firmly on the Moon's nearside and it therefore always remains visible whenever it is illuminated, despite the effects of libration. Mare Undarum's outline is rather irregular, roughly 100 kilometres (62 miles) from north to south and 200 kilometres (124 miles) from west to east. Even at the extreme of libration, Mare Undarum can be seen in its entirety – although foreshortened to some degree – near the Moon's edge.

However, two eastern seas lie much further east than Mare Crisium on the lunar disc, both of which are sizeable lunar marias that actually straddle the line of 90 degrees east – which separates the mean nearside and farside of the Moon. These features are Mare Marginis (the Border Sea) and Mare Smythii (Smyth's Sea).

Mare Marginis lies due east of Mare Crisium. Irregular in outline and measuring 360 kilometres (224 miles) from east to west, it occupies the libration zone. Extreme librations see the mare disappear around the limb nearly completely, but it can usually be glimpsed as a narrow elongated dark area on the eastern limb during the first half of the lunation up to Full Moon.

Located on the eastern limb, Mare Smythii is around 200 kilometres (124 miles) across and viewed from above it assumes a roughly circular (though poorly-defined) outline. Although the whole of Mare Smythii is presented towards the Earth during a favourable

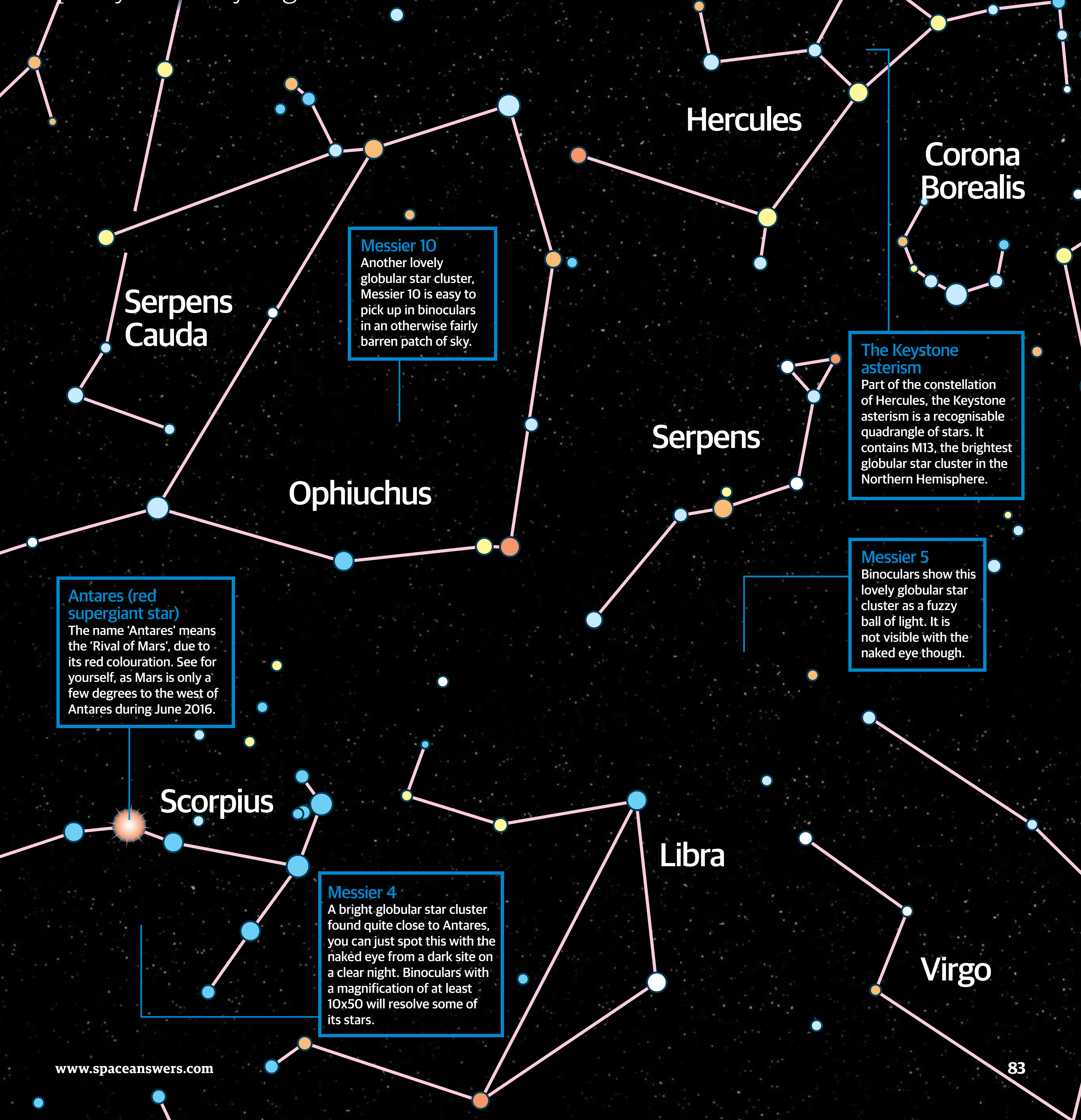


libration, its near limb position makes it appear very foreshortened. Like Mare Marginis, the sea comprises of many large, lava-filled craters and it can disappear beyond the eastern limb during an unfavourable libration.

This month, libration favours the visibility of Mare Crisium, Mare Undarum, Mare Marginis and Mare Smythii in the early evenings between 7 and 12 June.

This month's naked eye targets

Nights are getting shorter, but there's still plenty to see if you go out and look for it



Messier 10
Another lovely globular star cluster, Messier 10 is easy to pick up in binoculars in an otherwise fairly barren patch of sky.

The Keystone asterism
Part of the constellation of Hercules, the Keystone asterism is a recognisable quadrangle of stars. It contains M13, the brightest globular star cluster in the Northern Hemisphere.

Messier 5
Binoculars show this lovely globular star cluster as a fuzzy ball of light. It is not visible with the naked eye though.

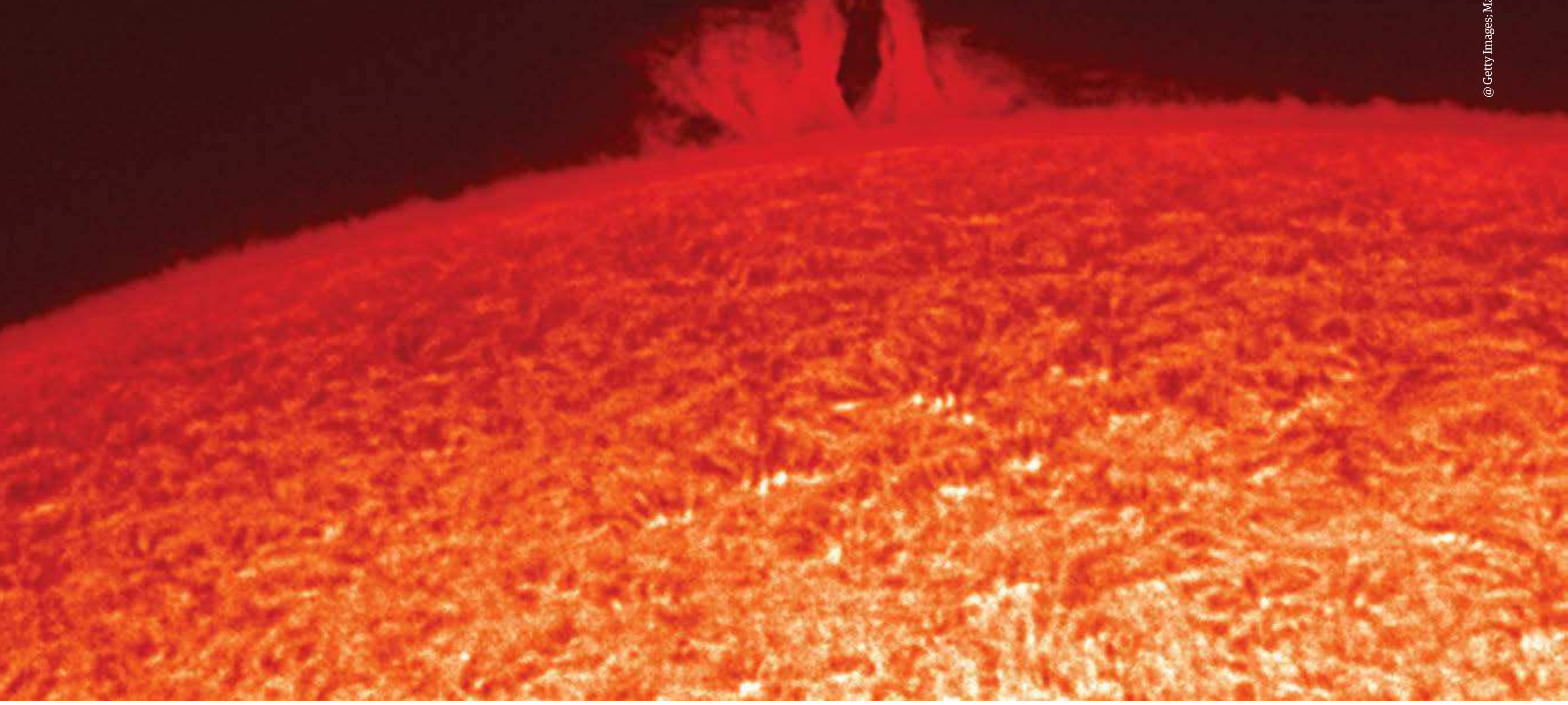
Antares (red supergiant star)
The name 'Antares' means the 'Rival of Mars', due to its red colouration. See for yourself, as Mars is only a few degrees to the west of Antares during June 2016.

Messier 4
A bright globular star cluster found quite close to Antares, you can just spot this with the naked eye from a dark site on a clear night. Binoculars with a magnification of at least 10x50 will resolve some of its stars.

How to…

Capture a solar flare

We've all seen those amazing images of huge prominences and flares bursting from the Sun, but how do you shoot them?



@ Getty Images; Malcolm Park

You'll need:

- ✔ H-alpha solar telescope
- ✔ Tracking mount
- ✔ DSLR camera
- ✔ Camera attachment

The Sun ejects matter regularly in the form of solar flares and huge explosions erupting from its surface, as well as prominences, which are slightly less energetic but nonetheless just as impressive.

However, because the solar disc is so bright, it is very hard to see these events, even with filters that block the glare. But there are specialist filters that enable us to see these amazing spectacles more easily and in perfect safety. These prominences occur on a layer of Sun called the chromosphere, which is above the level of the disc we can see in white light.

The hydrogen-alpha filter (H-alpha) is a very narrow-band filter, which blocks out all of the radiation from the Sun except for a tiny portion near the red end of the spectrum, known as the hydrogen-alpha line. These filters have to be made very carefully and are therefore not a cheap addition to your kit! However, modern technology has brought the price into the range of the enthusiast and certainly astronomical clubs and societies.

Telescopes such as the Coronado Personal Solar Telescope (PST) can show all kinds of detail never before seen on the solar disc. Prominences in particular catch the eye. Without such technology, you could only ever see these at one time - during a total solar eclipse, when the Moon blocks the dazzling light of the Sun but allows us to see what is going on around the rim of the solar disc.

You can, of course, photograph what you see through the eyepiece of your telescope and many people have had successful results by holding a smartphone camera over the eyepiece and taking a shot.

If you would like something a little more professional looking though, you will need to use a DSLR camera attached to the solar telescope, or even better, use a webcam or dedicated astro-video camera. The video camera frames can then be analysed and stacked in software such as Registax, which is 'freeware'. This has the advantage of increasing the contrast of the overall image and, through image processing, will allow you to tease out detail in the picture. In order to use this type of camera successfully though, you will need a tracking telescope mount.

There is a learning curve to all of this, but it is worth the effort, especially when you can amaze your friends and family with spectacular images of the Sun in all its glory. ●

Tips & tricks

Employ a solar telescope
To see the prominences of the Sun you'll need a specialist solar telescope, such as the Coronado PST.

Use a driven telescope mount
To get the best results, you'll need a telescope mount with a drive in order to follow the Sun across the sky.

Low-magnification eyepiece
Use an eyepiece that provides a low-to-medium magnification in order to see the whole disc of the Sun.

Try your smartphone
Hold your smartphone camera lens steadily over the telescope's eyepiece and click away for easy shots.

Attach a DSLR camera
You'll get better results with a DSLR attached to the telescope. Even better, use an astro-video camera or webcam.

Filming a solar flare

Safely catch the details and prominences of the Sun's surface

Without a doubt, a video camera is the best piece of kit to use to get really amazing images of the Sun in H-alpha. You'll need to focus it carefully and have enough memory and storage to save the video file. Shoot 200 frames or so and then open the video file in computer software such as Registax.

Follow the processing instructions and you should get some amazing results. Don't forget, the Sun can be quiet at times, so you aren't guaranteed a good prominence or solar flare every time you film it - be patient. Remember to always take care when using an optical aid to view or image the Sun.

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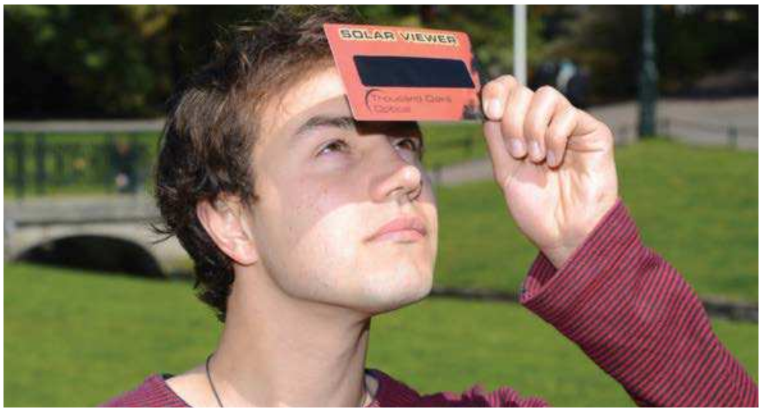
photos@spaceanswers.com



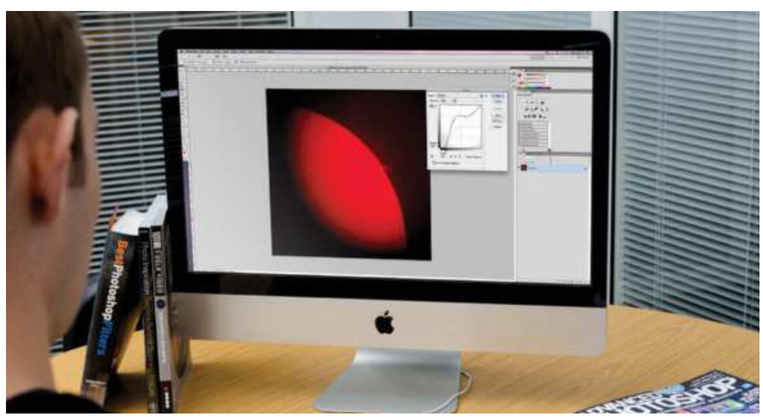
1 **Observe the Sun safely**
Always make sure that you keep safe when viewing or shooting the Sun. Viewing the Sun directly can cause irreversible damage to your eyesight.

2 **Set up the telescope mount**
Make sure your telescope mount's drive is on and tracking well. Polar align your mount if necessary to improve tracking of the Sun across the sky.

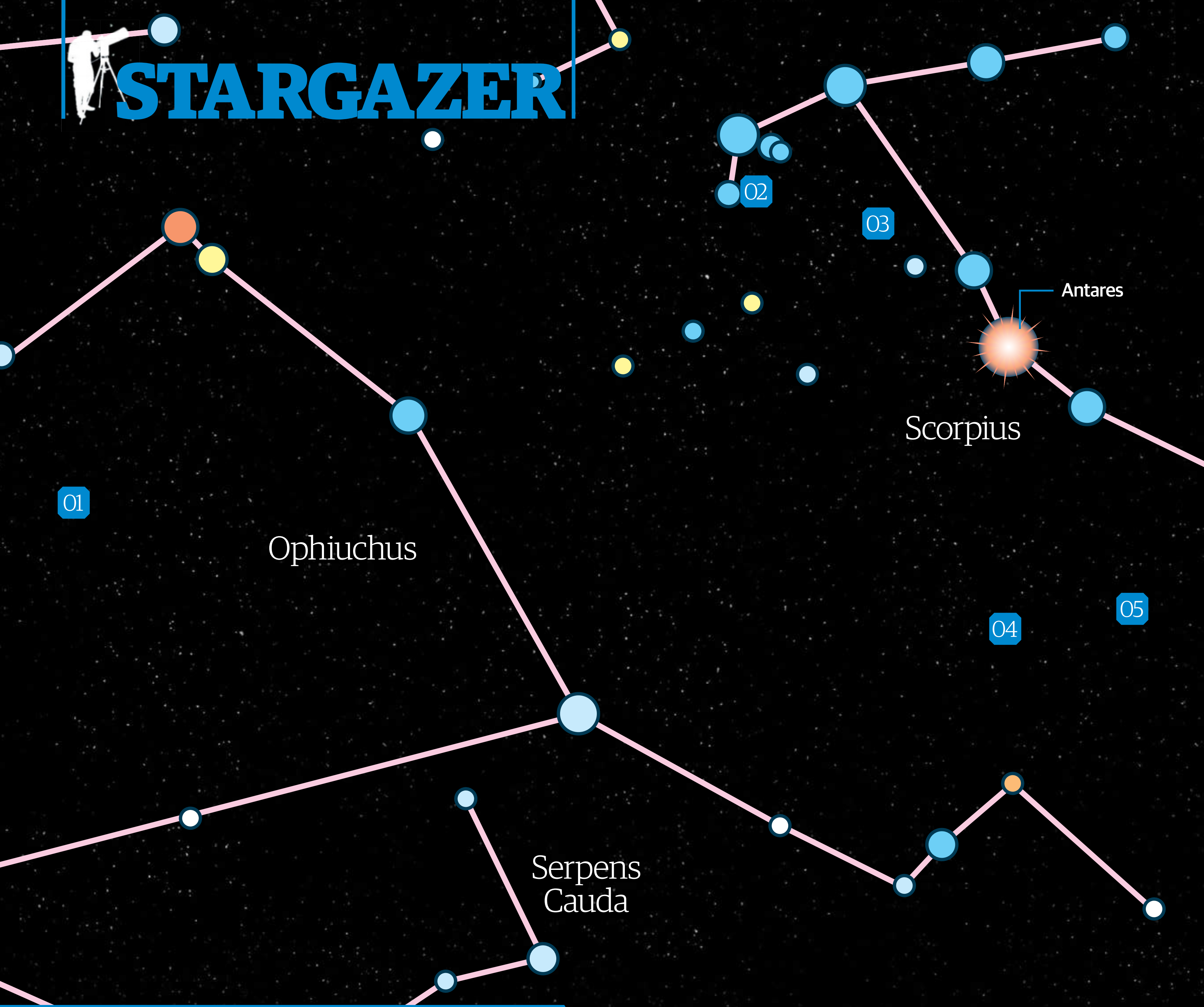
3 **Focus your camera and telescope**
Get as sharp a focus as you can on the recording device and the telescope itself. It will make all the difference to getting clear and crisp images.

4 **Set the exposure time**
Aim to capture between 200 and 300 frames for good results. Take several shots like this to increase your chances of capturing a flare or prominence.

5 **Process your video file and images**
Download the software Registax to your computer or laptop and open up your video files for processing. Follow the instructions carefully for optimum results.



6 **Final processing with Photoshop**
Once you've selected the best frames from your video, tweak your images in Photoshop or any other image editing software for spectacular results.



Deep sky challenge

The Rho Ophiuchi cloud complex

There are star clusters galore and the occasional nebula to see during this month's shorter nights

Even though the nights are short during June in the Northern Hemisphere, there are many globular star clusters within reach of a backyard telescope. These balls of ancient stars, some of the oldest in the universe, orbit around the Milky Way. Some are easier to spot than others – you may even be able to make out some of the individual stars in the groups.

There are some nebulae to be observed, too, although they are clustered around Scorpius and can be tricky to spot in June skies. These nebulae form part of a vast cloud of dust and gas known as the Rho Ophiuchi complex. But each nebula can be considered an individual in its own right. They are not very impressive visually, but long-exposure astroimaging will help to show their true grandeur.

1 Messier 12
You will need a telescope of at least 200mm or eight-inches in aperture to resolve any of the stars in this globular cluster. Otherwise, Messier 12 may look like a starless nebula.

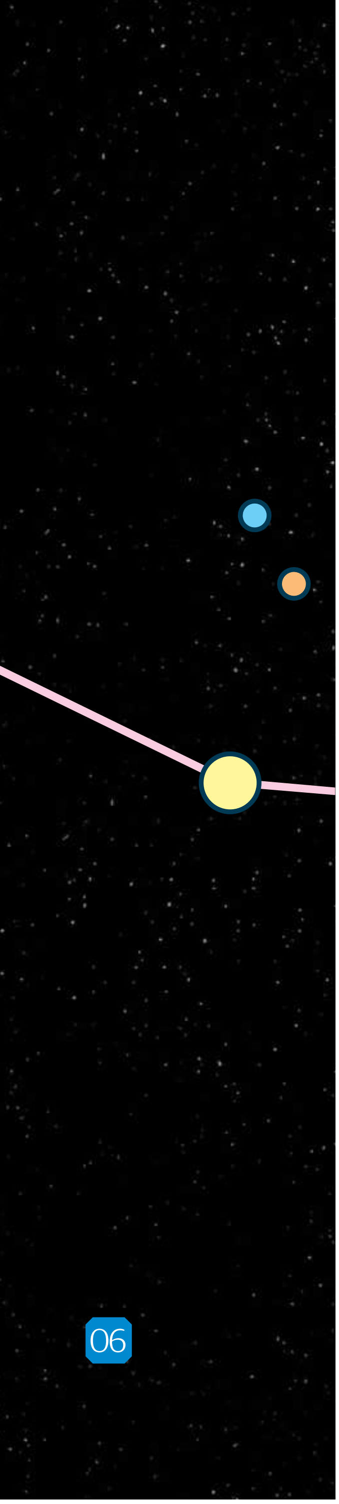
2 Nebula IC 4592
This is a reflection nebula, sometimes known as the 'Blue Horsehead' Nebula. It is dust reflecting the light of nearby star Nu Scorpii.

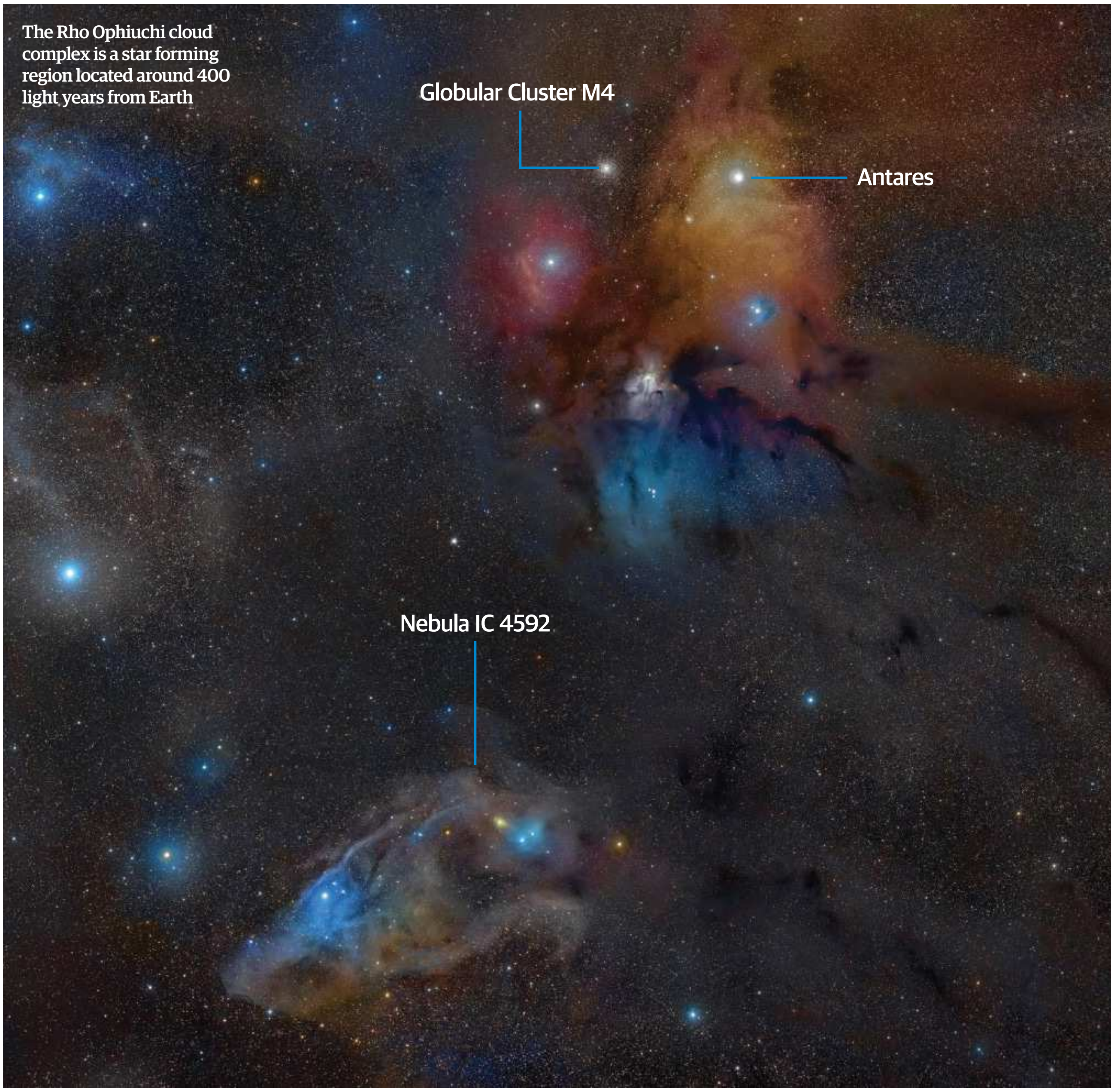
3 Messier 80
This is a dense globular star cluster with a mottled look. Larger aperture telescopes should resolve the outer stars quite easily.

4 Messier 19
Here is a slightly unusual globular cluster. It looks flattened on one side, but this is probably due to some gas blocking light from some of the stars.

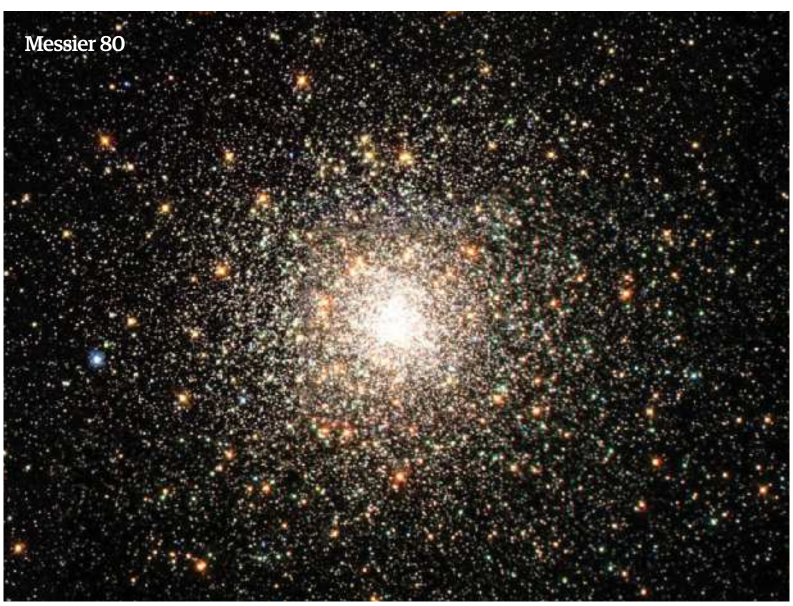
5 Messier 62
Being very low down for mid-northern latitude observers, this globular cluster is quite hard to find. It looks like a tight ball of stars in a telescope.

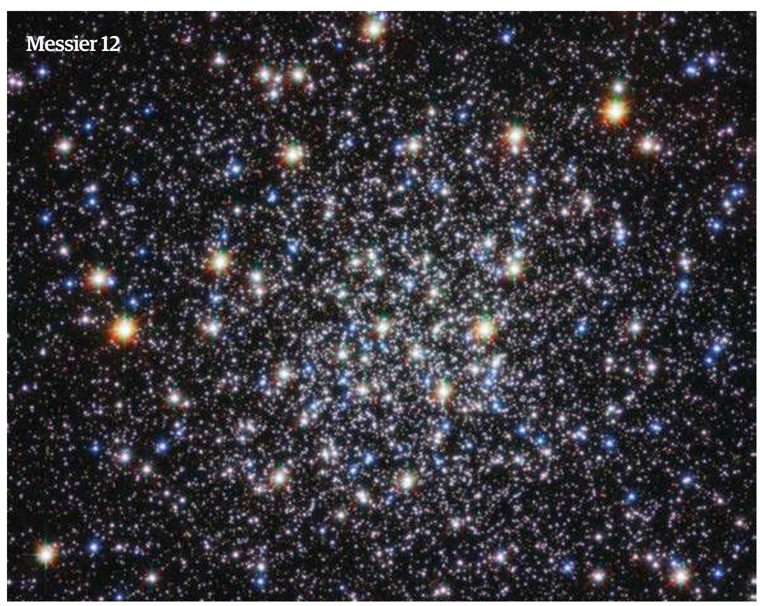
6 The Butterfly Cluster (M6)
The sixth entry in Messier's catalogue is an open star cluster in Scorpius. Its shape looks vaguely like a butterfly, hence its nickname. Use a low power eyepiece to fit it all in the field of view.





The Rho Ophiuchi cloud complex is a star forming region located around 400 light years from Earth


Messier 80


Messier 12

STARGAZER

The Northern Hemisphere

Late night astronomers are treated to an array of deep-sky objects during the warmer months

Summer is officially here, with the solstice falling on 20 June. The short summer nights are warm but leave little time for observing. Still, this shouldn't put you off as there's still plenty to see. The constellation Boötes rides high with Arcturus (magnitude -0.05), the brightest star in the northern celestial hemisphere, and is high to the south after sunset. Look out for the brilliant star Vega in the constellation Lyra, not far from the celebrated Ring Nebula (M57) – a planetary nebula that looks like a smoke ring through a small telescope.

Towards the southern horizon are the constellations of Sagittarius and Scorpius where the centre of our galaxy is located. Here, the Milky Way is at its densest with many stars and star clusters for you to spot, such as Messier 4, 6, 7 and 25.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

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.

Magnitudes

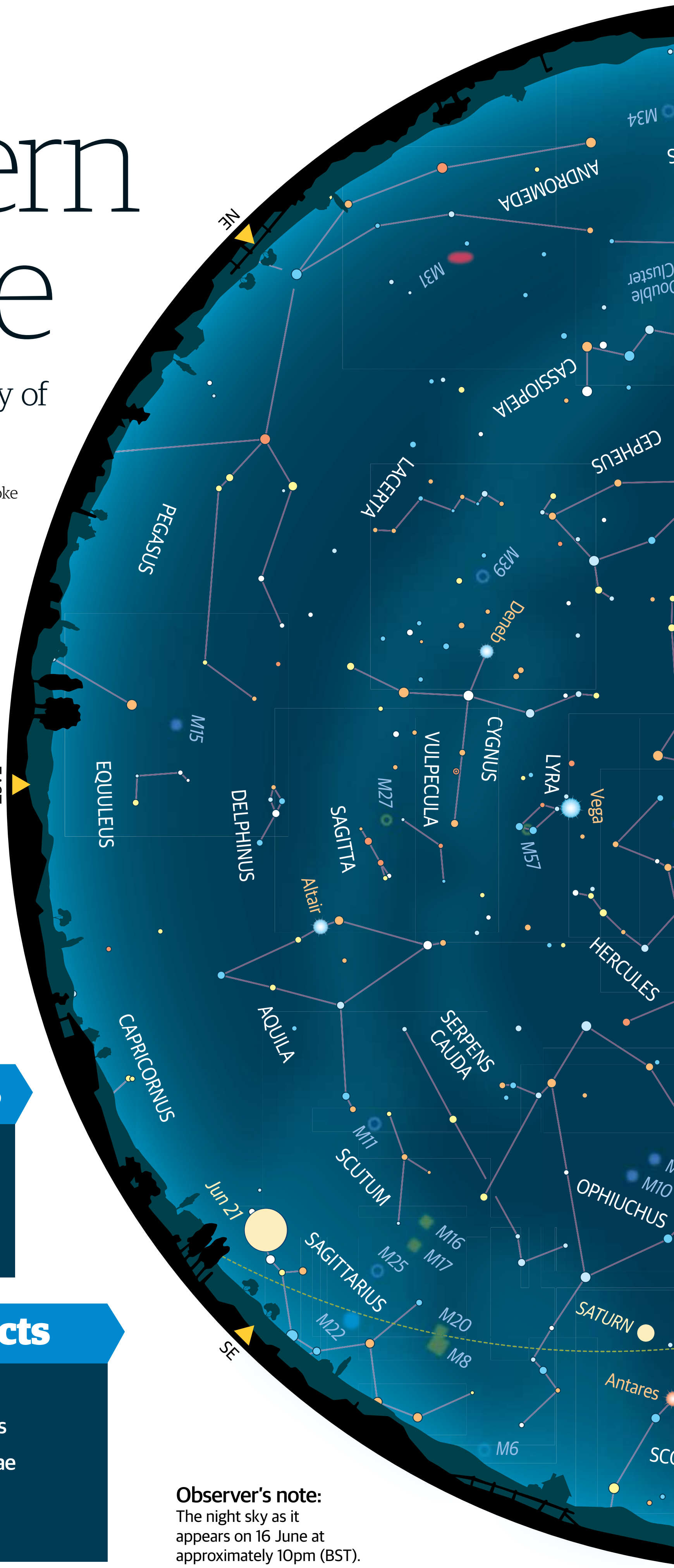
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

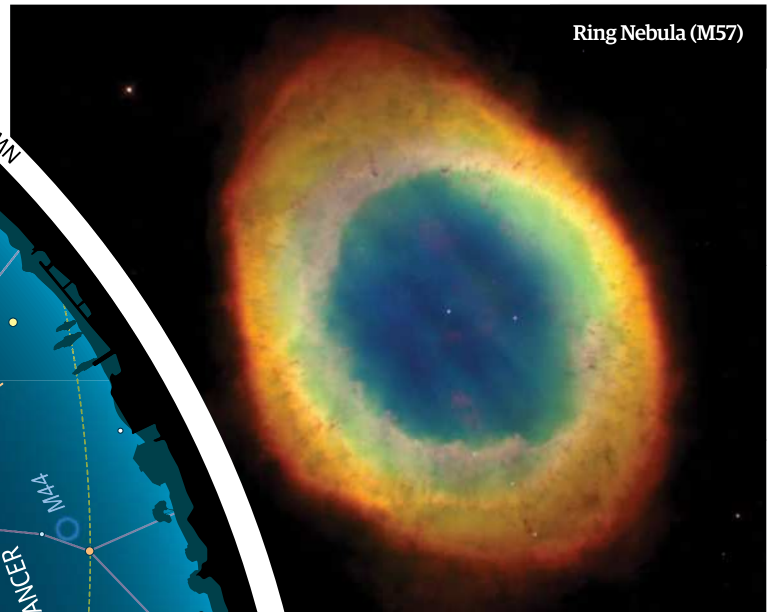
- O-B
- A
- F
- G
- K
- M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note: The night sky as it appears on 16 June at approximately 10pm (BST).


Ring Nebula (M57)


Messier 4


Messier 7

Me & My Telescope

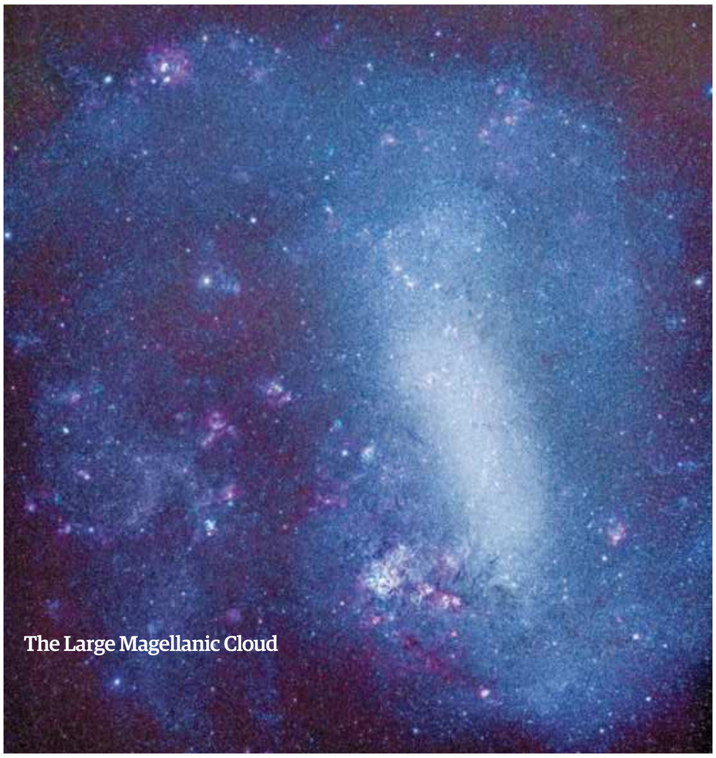
Send your astrophotography images to **photos@spaceanswers.com** for a chance to see them featured in **All About Space**

Alan Dyer

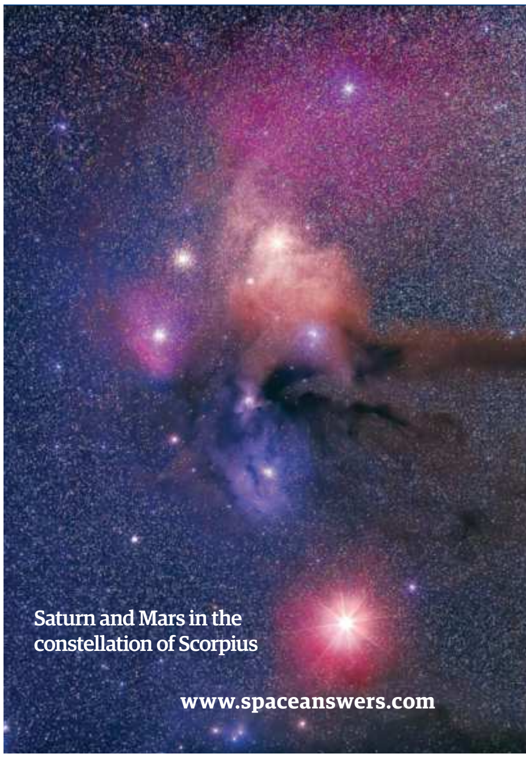
Alberta, Canada
Telescope: Borg 77mm f/4 Astrograph

"While my home in rural Alberta in western Canada presents fine opportunities for photographing the night sky, I love heading south as often as I can to visit sites below the equator and take in the wonders of the Southern Hemisphere sky. Only from 'down under' can you get the best views of the Magellanic Cloud and southern Milky Way sights such as the Carina Nebula.

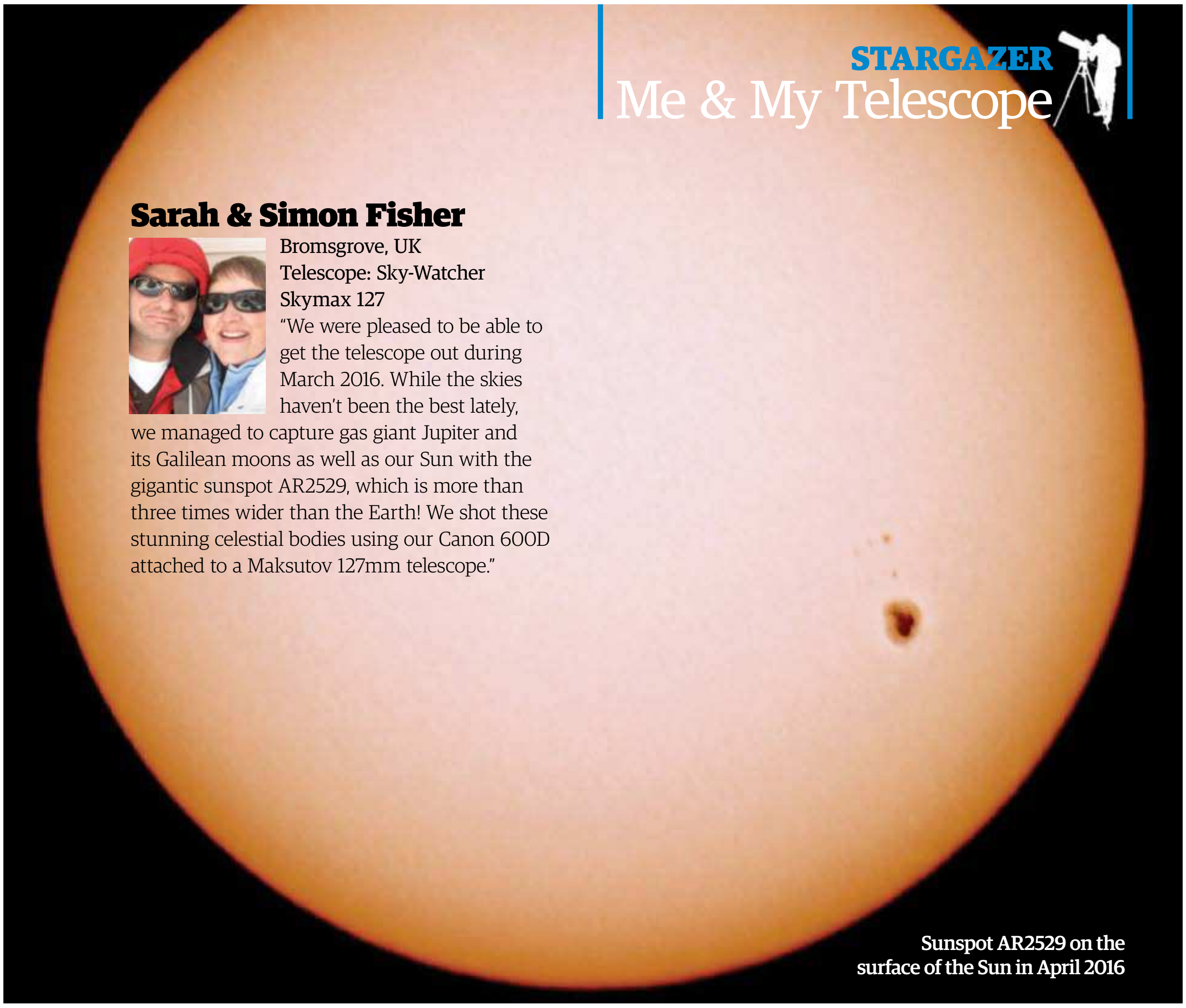
To capture these spectacles, in April 2016 I spent two weeks under clear night skies near Coonabarabran, New South Wales, billed as the 'astronomy capital' of Australia. Most nights were perfect for astronomy - clear, dry and mild, with no wind, bugs or dew. It was heaven on Earth for stargazing, under the finest skies you'll find anywhere."



The Large Magellanic Cloud



Saturn and Mars in the constellation of Scorpius



Sarah & Simon Fisher

Bromsgrove, UK
Telescope: Sky-Watcher Skymax 127

"We were pleased to be able to get the telescope out during March 2016. While the skies haven't been the best lately, we managed to capture gas giant Jupiter and its Galilean moons as well as our Sun with the gigantic sunspot AR2529, which is more than three times wider than the Earth! We shot these stunning celestial bodies using our Canon 600D attached to a Maksutov 127mm telescope."

Sunspot AR2529 on the surface of the Sun in April 2016

Star trails over Tibuc Cottage, New South Wales, Australia

Jeff Johnson

Las Cruces, New Mexico
Telescope: Borg 77mm f/4 Astrograph

"I have a long love of astronomy, which began when my dad gave me a book simply entitled *Astronomy*. Years later, I found myself observing the night sky with binoculars and a small telescope. When I was still in high school, I often went camping in the mountains with friends in the summer. I would take my binoculars out at night, point to a dense star field in the Milky Way and ask my friends to take a look - seeing their amazement was very satisfying."

Reflection Nebula Messier 78

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Meade Infinity 102 AZ

A beginner's scope that boasts versatility, this refractor is ideal for those on a budget looking for an introduction into several aspects of astronomy

Telescope advice

Cost: £250
From: Hama UK Ltd
Type: Refractor
Aperture: 4"
Focal length: 23.7"

Best for...

- Beginners
- Small budget
- Terrestrial viewing
- Planetary viewing
- Lunar viewing
- Bright deep-sky objects

Meade Instruments has built the Infinity 102 AZ with the entry-level astronomer in mind. By keeping the cost of the telescope down, while still providing the necessary attributes that a beginner astronomer will require, the manufacturer has done an impressive job on the whole – a relatively sturdy tripod setup, red-dot finder, two eyepieces and a 2x Barlow lens are combined in the package.

We were also pleased to see that Meade doesn't make any outlandish claims – for example, no Hubble Space Telescope images are splashed across the box and it simply states that it's best used for observing the Moon's surface and the planets, as well as terrestrial views. An instruction booklet, which is easy to follow, is supplied along with a copy of the AutoStar Suite planetarium programme for Windows.

The mount and the tripod are fully assembled and we found that putting the Infinity 102 together is extremely intuitive, with a simple Vixen dovetail employed to fit the telescope tube to the mount. What's more, it's very simple to adjust the tripod leg with easy-to-use outside tabs to lock them in place. A small Phillips head screwdriver and wrenches are also supplied to tighten the Infinity 102's thumbscrews on the fine adjustment control knobs, in order to get them acceptably tight on the shafts that protrude from the mount.

Measuring the objective lens, it is roughly ten centimetres (four inches) across, with additional glass to secure the lens in place. The lens, which features a bluish-green anti-reflective coating, appears to be even. Looking down the tube, the Infinity 102 AZ features three evenly spaced separation pads, commonly associated with refractors with air-space doublet objectives. The dew shield and the lens cells are comprised of tough black plastic and both inside and outside of the tube are well painted. As with all of Meade Instruments' telescopes, we appreciate the striking blue tube that certainly makes it stand out from the standard black and white tubes often supplied by other telescope manufacturers.

The Infinity 102 AZ's focuser does the job well and is well-built for an entry-level telescope. The red-dot finder, on inspection, appears to be substantial for a beginner's instrument – be aware that these finders can use up their batteries quite quickly, so be sure to switch it off once you have located your target.

The supplied eyepieces (with focal lengths of 6.3mm, 9mm and 26mm) feel strong but very light in weight and ensure that the scope isn't too 'back heavy' when the eyepieces are slotted into the holder. The 2x Barlow lens is suitable for an entry-level telescope; however, we think that the eyepieces may benefit from a bit more protective packaging. The star diagonal is also pleasant to use, however, as we were unable to get crisp views across the

The refractor comes with three eyepieces and a 2x Barlow lens

The lens, which features a bluish-green anti-reflective coating, appears to be even and provides bright and clear views of the night sky

The alt-azimuth mount is already attached to the tripod, making the Infinity 102 AZ a breeze to set up

"The Infinity 102 AZ provides a full package for those looking for their first scope"

entire field of view while using the 26mm eyepiece, we realised that the prism is too small. But this isn't a huge problem for entry-level scopes that are aimed at those looking to spend very little on purchasing an instrument.

Weighing in at 5.4 kilograms (12 pounds), the Infinity 102 AZ is portable and we had no difficulty in carrying the telescope to a suitable location for observations. With Ursa Major directly overhead, we were keen to split double stars Alcor and Mizar. Using the mount to angle the scope's tube upwards, we did notice that the mount's handle swings downwards, covering the closest eyepiece hole in the accessory tray - this is a small issue that can be overcome by simply not putting an eyepiece in this part of the tray.

With a Waxing Crescent Moon just after sunset, we turned the scope to the lunar surface. The refractor provided pleasing views of the Moon's surface for an entry-level instrument, with barely any problems with glare and a very good degree of contrast using the 6.5mm eyepiece. Observing the Moon during its almost-full phase, we detected a small amount of colour fringing around the lunar edge.

We waited until later on in the evening to observe Saturn, which was heading for opposition. The refractor was able to pick out the planet's rings but the Cassini Division - the most obvious gap in the rings - could only just be made out as very slight darkening. Shifting the planet's rings to the centre of the field of view, the rings took on a light red colouration, while moving them to the outer edge of the field of view, we could detect a cooler blue colouring - more evidence of chromatic aberration, or colour fringing, which was noticeable but didn't spoil the view.

Slewing the telescope to Jupiter, we were able to pick out the gas giant's equatorial bands and its Galilean moons as points of light. And when pushed to its limit, the Infinity 102 AZ managed to pick up the brighter region of the Lagoon Nebula (M8) in the constellation of Sagittarius and the Ring Nebula (M57) in Cygnus as a fuzzy spot in the night sky. We do recommend this telescope for brighter deep-sky objects.

The Meade Infinity 102 AZ is an excellent beginner's scope that is capable of providing an introduction into several aspects of astronomy, while proving to be a full package for those looking for their very first telescope. The refractor can easily be accessorised, especially if the astronomer is looking to upgrade the mount. Overall, Meade provides excellent value for money - this impressive instrument certainly gets the thumbs up from us! ●

The Infinity 102 AZ boasts a sturdy, portable setup

WIN ASTRONOMY KIT

WORTH OVER £550!

Courtesy of David Hinds Ltd, we've got a Celestron telescope and accessories to give away this month

Celestron AstroMaster 102 AZ

If you're looking for a telescope that provides views of both the night sky and terrestrial targets, then this dual-purpose telescope is the one for you. Supplying bright and clear images of the lunar surface and naked eye planets, the AstroMaster 102 AZ is the perfect beginner's telescope to find Jupiter's moons and gaze upon Saturn's rings.

Celestron Observer's Accessory Kit

Enhance the performance of your telescope with this eight-piece accessory kit, which includes two high-quality 1.25" Plossl eyepieces, a 2x Barlow lens, filters (including Moon, blue and red) and a hard plastic carry case to keep your accessories safe in a foam-lined interior.

Celestron Cometron 12x70 binoculars

Featuring 70mm objective lenses with impressive light-gathering capabilities, the Celestron Cometron 12x70 binoculars have the ability to showcase comets, stars, the craters of the Moon and dim nebulae in crisp clarity.

Celestron Sky Maps

Find your way around the night sky with *Celestron Sky Maps*, whatever the season! Featuring a planisphere on the front cover, allowing you to get a view of the night sky in the past, present and future, the *Celestron Sky Maps* include a collection of star charts for each of the four seasons.

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

How many potentially habitable planets have been found around ultra-cool dwarf star TRAPPIST-1?

A: 8

B: 3

C: 1

Celestron Night Vision Flashlight

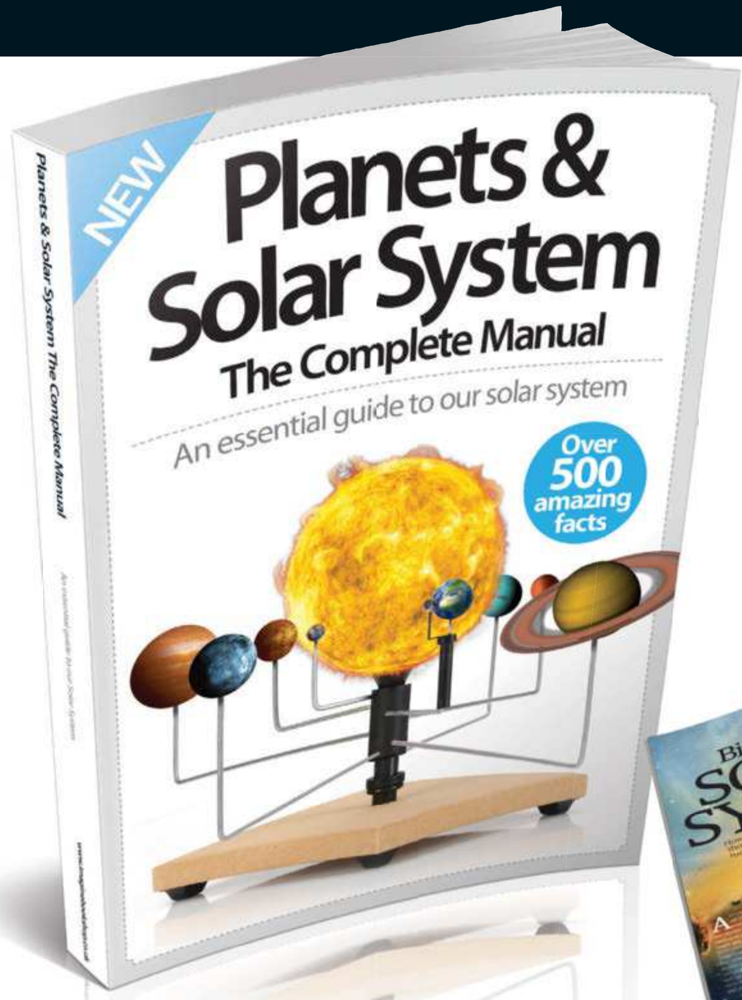
One of the most beneficial accessories to an astronomer, the Celestron Night Vision Flashlight effectively preserves your night vision, allowing you to see star charts, find an eyepiece in your accessory case, or navigate your way over telescope cables and other obstacles in the dark, without affecting your dark-adapted vision.

Celestron LensPen

Ensure that your observing sessions are crystal clear with Celestron's LensPen, a two-in-one cleaning tool – one end contains a soft brush for removing dust from any optical surface, while the opposite end takes care of the smudges and spots that can't be brushed away.

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

From the makers of All About Space

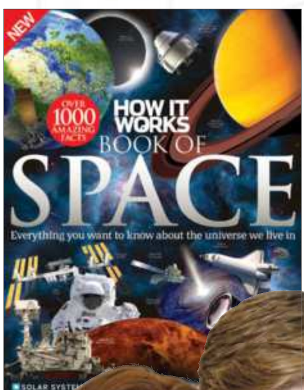


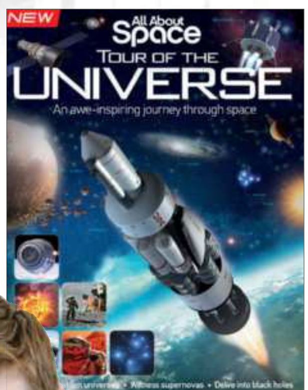
Planets & Solar System

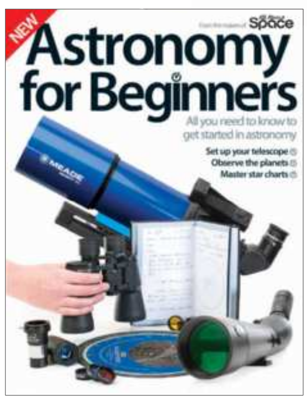
The Complete Manual

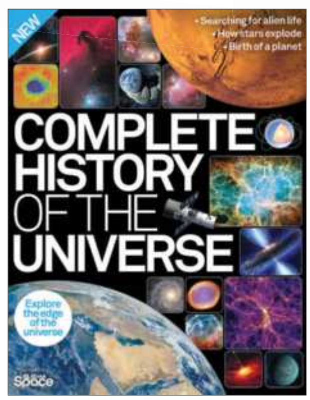
Discover Earth's place in the Solar System and how it compares to its neighbouring planets in this pocket-sized guide. Learn all you need to know about each planet from Mercury to Neptune, and even gain an understanding of Pluto.

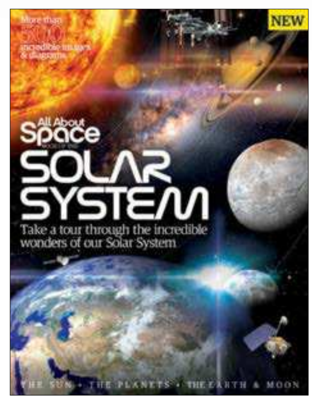
Also available...











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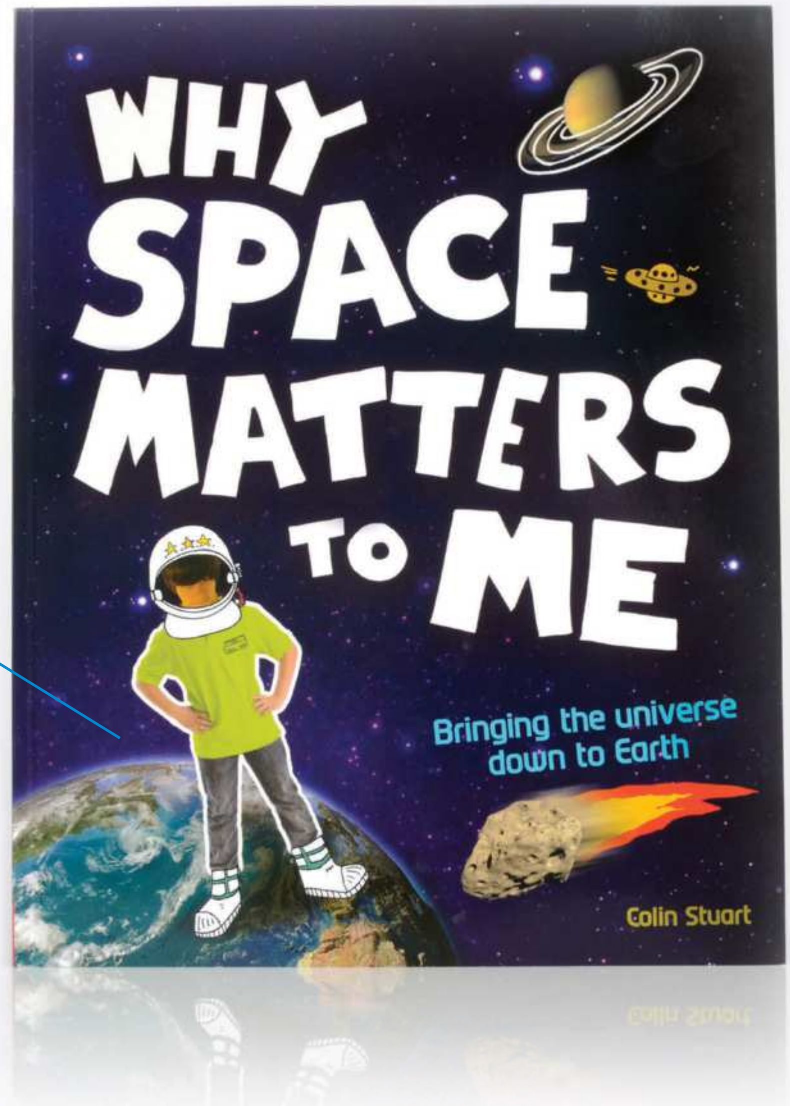

Book
Why Space Matters To Me

Cost: £6.99 / $12.99
From: Red Shed

Written by astronomer Colin Stuart, this accessible children's book provides an insight into how the universe affects us here on Earth. Vividly illustrated by Nick Chaffe, *Why Space Matters To Me* covers a wide range of topics guaranteed to excite youngsters, including the weather, the seasons and stardust, and it delivers them in a captivating way - even those of us in the **All About Space** office couldn't put this book down!

Leafing through the pages, *Why Space Matters To Me* still manages to be clear and comprehensive in the few pages required to maintain the short attention span of a young age. The 'headers' for the facts on each spread, combined with the bright colours splashed across each page, are engaging enough to grab the attention of the reader, whatever their age. The illustrations are quirky, adding to the fun and liveliness only expected from a children's book. *Why Space Matters To Me* is an excellent taster to space - we can guarantee it'll enthuse the next generation of astronomers.

Software
SkyGazer 4.5

Cost: $49.00 (approx. £32)
From: Carina Software & Instruments Inc

Carina Software's SkyGazer 4.5 offers all of the necessary information to make touring the night sky a breeze and is an ideal programme for budding astronomers who are running either Windows or Mac OS X systems. We enjoyed the close-up three-dimensional views of the planets in our Solar System, along with the database that contains digestible information on these worlds and their moons, as well as thousands of asteroids and comets. A fun feature allowed us to recreate historical sky simulations, such as Mars appearing to pass in front of Jupiter back in 1170 AD. We were also able to download the latest orbital data for asteroids, comets and spacecraft.

SkyGazer 4.5 does lack interactive tours, but there are animations that teach the user about astronomical concepts such as eclipses, why a change in seasons occurs, as well as the motions of the planets. What makes this software stand out is the implementation of NASA's Jet Propulsion Laboratory's planetary ephemeris, which can compute the positions of the planets much more accurately than ever before and allows the user to track their positions in the real night sky with ease.

Ideal for those looking to learn the basics of the night sky without the need to spend an enormous amount of money, SkyGazer 4.5 has it all - a great purchase for those looking to break into viewing the Solar System or for astronomers wishing to peer into the depths of deep-sky observing.

Binoculars
Meade 15x70 AstroBinoculars

Cost: £64.42 / $N/A
From: Hama UK Ltd

If you're looking for a pair of binoculars that do exactly what they say on the tin without having to pay a fortune, then these are most certainly the binoculars for you. What's more, they are ideal for those wishing to observe night-sky targets as well as for those who enjoy nature watching during the day.

Despite their size, the Meade 15x70 AstroBinoculars are surprisingly lightweight and are comfortable enough for sweeping across the night sky in short bursts of time. However, when we chose to observe targets in detail for longer periods, we did, as expected, find that our hands began to shake and the viewing was not so steady. A tripod for steadier observing is a must.

While the build of these 15x70s isn't the best we have felt, they are rugged and certainly promise to last for many observing sessions to come, thanks to a sturdy outer casing. The optical system though, is very good - supported by a porro prism design with BAK4 prisms, light transmission is superb with eye-wateringly clear and crisp high contrast views of star clusters and the Moon's craters, lunar maria and valleys. With no ghosting or colour fringing in sight, the Meade 15x70 AstroBinoculars are a worthy purchase.

App
SkySafari 4 Pro

Cost: £29.99 / $59.99
From: iTunes / Google Play

We have never been more impressed with an astronomy app than we are with SkySafari 4 Pro, which features 25 million stars from Hubble Guide Star catalogues, over 740,000 galaxies all of the way down to 18th magnitude, as well as 630,000 Solar System objects.

With impressive detail and simulation quality, SkySafari 4 Pro simulates the view from anywhere in the Solar System (including from locations on Earth) and beyond, as well as into the universe's past or future. Even more impressive is that you get a real-time review of the rotation of the planets as well as a Telescope Equipment setting, which enables you to enter a list of your telescope equipment and get automatic field of view.

Its high price will likely put many off, but it's compatible with iPad, iPod Touch and iPhone, as well as Android 4.0 and above. Being so useful to all levels of astronomer, we felt that it was worth every penny. There is also the option of purchasing the less-involved SkySafari 4 and SkySafari 4 Plus, depending on your budget. Whether you're a serious astronomer who wants to control a telescope or a novice who's finding their way around the night sky, we couldn't recommend this app enough.

Volkov, Dobrovolski and Patsayev (from left to right) inside the spacecraft simulator in 1971

@ Getty Images

Soyuz 11

The tragic mission that changed spaceflight forever

To date, more than 500 people have gone to space, but only three have ever died in space itself. They were the crew of the Soviet Union's Soyuz 11 mission, and their story is one of both accomplishment and tragedy.

The three crew members of Soyuz 11 were Georgi Dobrovolski, Vladislav Volkov and Viktor Patsayev, but they were not supposed to have been. Originally, the crew consisted of Alexei Leonov (the first man to walk in space), Valeri Kubasov and Pyotr Kolodin. But just four days before launch in 1971, a medical X-ray revealed a risk of tuberculosis in Kubasov. Although this was later found to be a misdiagnosis, the entire crew was grounded, as was the rule in those days, and the backup crew took their place. Leonov and Kolodin were both livid with the decision.

But on 6 June 1971, Soyuz 11 took off with its back-up crew on what was to be a ground-breaking mission in space. The three cosmonauts would be the first – and only – crew to enter Salyut 1, the first ever space station to orbit Earth. Alongside this achievement, they also spent more than three weeks in space – more than any other astronauts or cosmonauts before them.

When the time came to undock and return to Earth on the evening of 29 June, spirits were high. But several hours later, in the early hours of the morning on 30 June, it was obvious something was wrong. Ground control was receiving no communication from the crew. The landing was entirely automated, so the capsule passed through the atmosphere and landed using parachutes in Kazakhstan by itself. As a recovery team made their way to the capsule, they were unaware of the horror inside. All three of the crew were mysteriously dead. Attempts were made to resuscitate them, but to no avail.

Owing to the huge amount of secrecy in the Soviet space programme, the strange deaths of the cosmonauts sent shock waves not only through the Soviet Union, but through America, too. NASA, in the midst of its lunar missions, was unsure if prolonged spaceflight might have been the cause of death. The true cause would transpire later, though.

At an altitude of 130 kilometres (80 miles) and at around 1.47am Moscow time, the descent module that housed the astronauts of Soyuz 11 had separated from its orbital module. But somehow, the short procedure had ripped open an air valve on the descent module. The result was depressurisation. Air would have rushed out of the spacecraft and in a matter of seconds the three cosmonauts – who were not wearing spacesuits, as was procedure at the time – were exposed to the harsh, airless vacuum of space.

It's thought that the cosmonauts may have tried to locate the valve and close it. But within just 13 seconds, they would have lost any useful form of consciousness. After a minute, they would have been unconscious, coupled with a huge loss of blood, and death quickly followed. Alexei Leonov later demonstrated that closing the valve took 52 seconds, far longer than the cosmonauts had to act. The deaths of all three cosmonauts shocked the world, but no more so than in the Soviet Union where they had been lauded daily as heroes during their time in space.

A consequence of the mission is that all astronauts and cosmonauts now launch wearing a pressure suit, which can cope with depressurisation, although no such event has ever occurred since. A lasting memorial remains to the three space heroes on Pluto, where a group of hills was named Soyuz Colles in their honour. Dobrovolski, Volkov and Patsayev remain the only three humans to die in space. But their legacy, proving that long-duration spaceflight was possible, lives on. ■

All About Space

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