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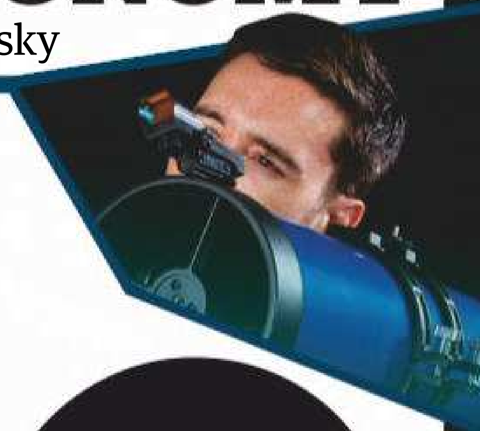

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Water worlds seem a lot more common than first thought

Welcome

As I write this, the south coast of the UK is blanketed in wall-to-wall cloud - I'm sure I speak for all fellow astronomers, who are looking forward to a night under a selection of Solar System and deep-sky objects, when I say our planet's coverage is a constant source of annoyance. That is, alongside light pollution.

That's why I'm extremely pleased to reveal that, this issue, **All About Space** presents the best tips and tricks so you can still make the most of astronomy even when it's cloudy outside. While you need some patience for some of our suggestions, we've ensured that there's something for everyone - you'll never have to put your hobby on hold ever again! If you're clouded out this month, then make sure you turn to page 70. On the flipside - for when we're treated to stunningly clear skies - don't forget to take a look at our following feature where we show you how to get the most out of observing without breaking the bank. We've got something to suit all budgets.

It wouldn't be an issue of **All About Space** if we didn't look into the most mind-bending theories of the universe - and this issue doesn't disappoint; does space have a final dimension? Over on page 16, astrophysicists are considering if there's ten or even 26 dimensions beyond what we perceive to be space and time.

Enjoy the issue!

Gemma Lavender
Editor

Our contributors include...

Colin Stuart
Author & astronomer
Could the universe really have a final dimension beyond space and time? Colin chats to the astrophysicists with conflicting answers... and the ultimate test.

Lee Cavendish
Astronomer & Staff Writer
Lee headed to Budapest to get a behind-the-scenes look at Nat Geo's next instalment of *MARS*. Turn to page 28 to get an exclusive sneak peek.

James Romero
Space science writer
It's a mystery within a mystery – could perplexing 'misfit galaxies' be explained by the equally mysterious dark matter? James has the details on page 38.

Jamie Carter
Astronomer
Stuck for what to do on a cloudy night? Jamie reveals the tips and tricks you need to make the most of the night sky – even when it's overcast.

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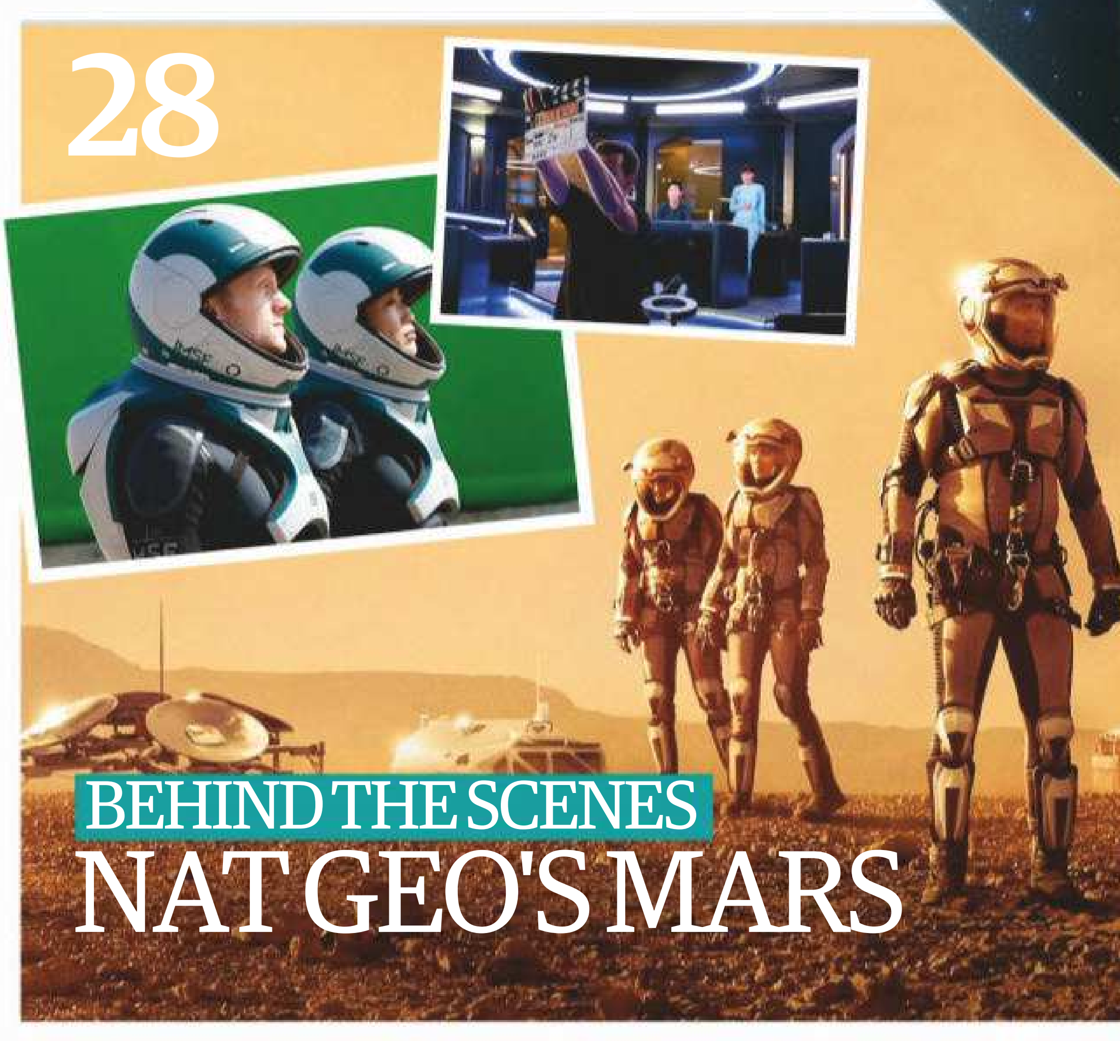

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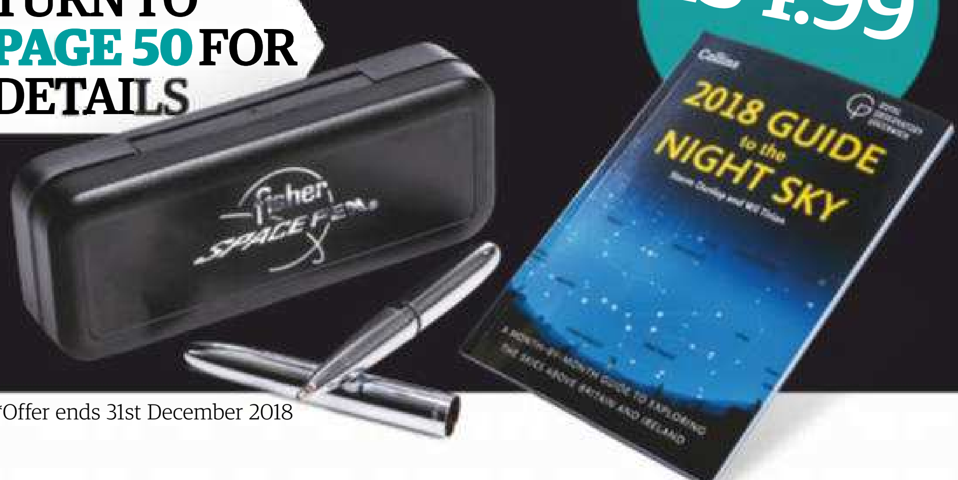

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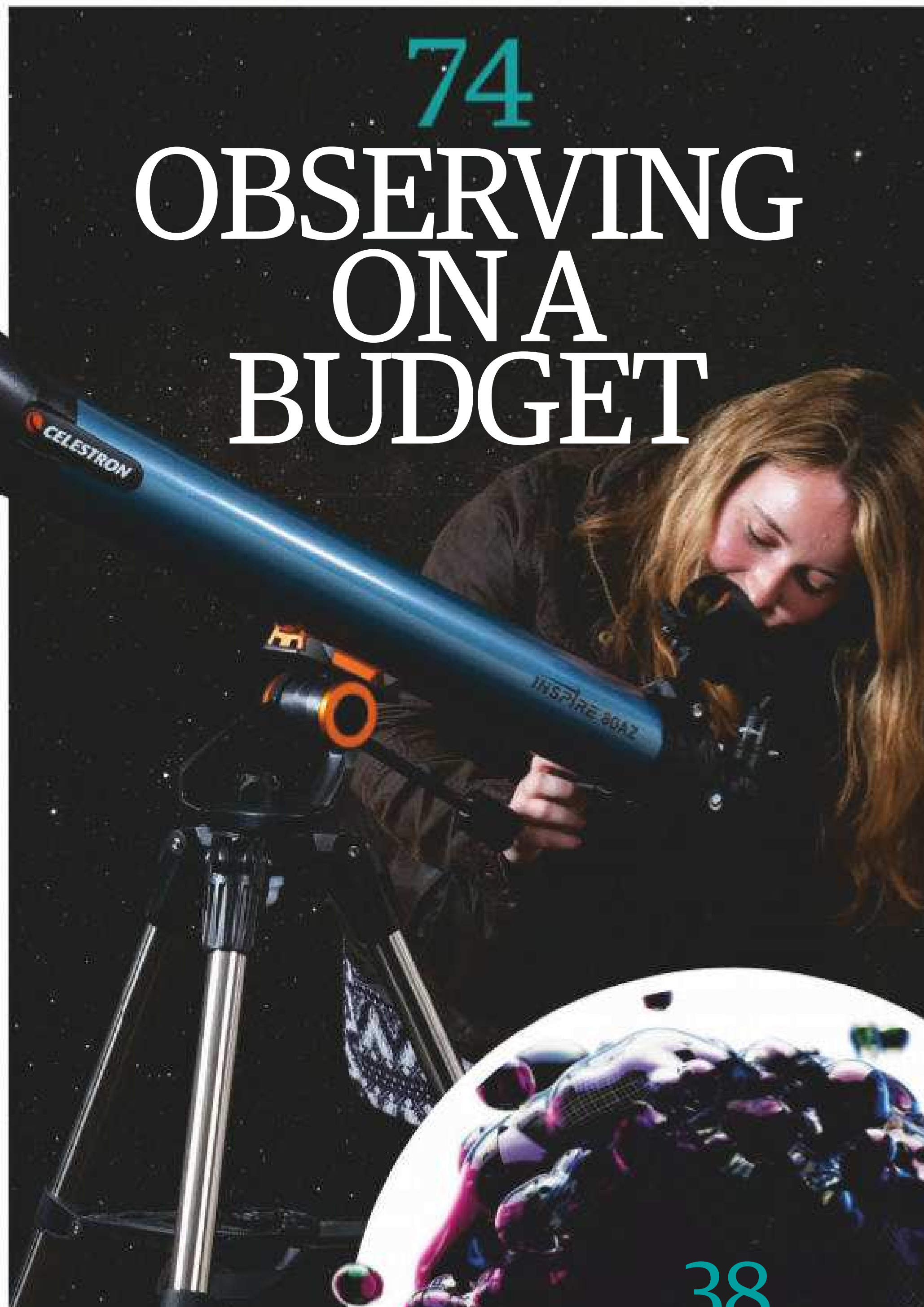

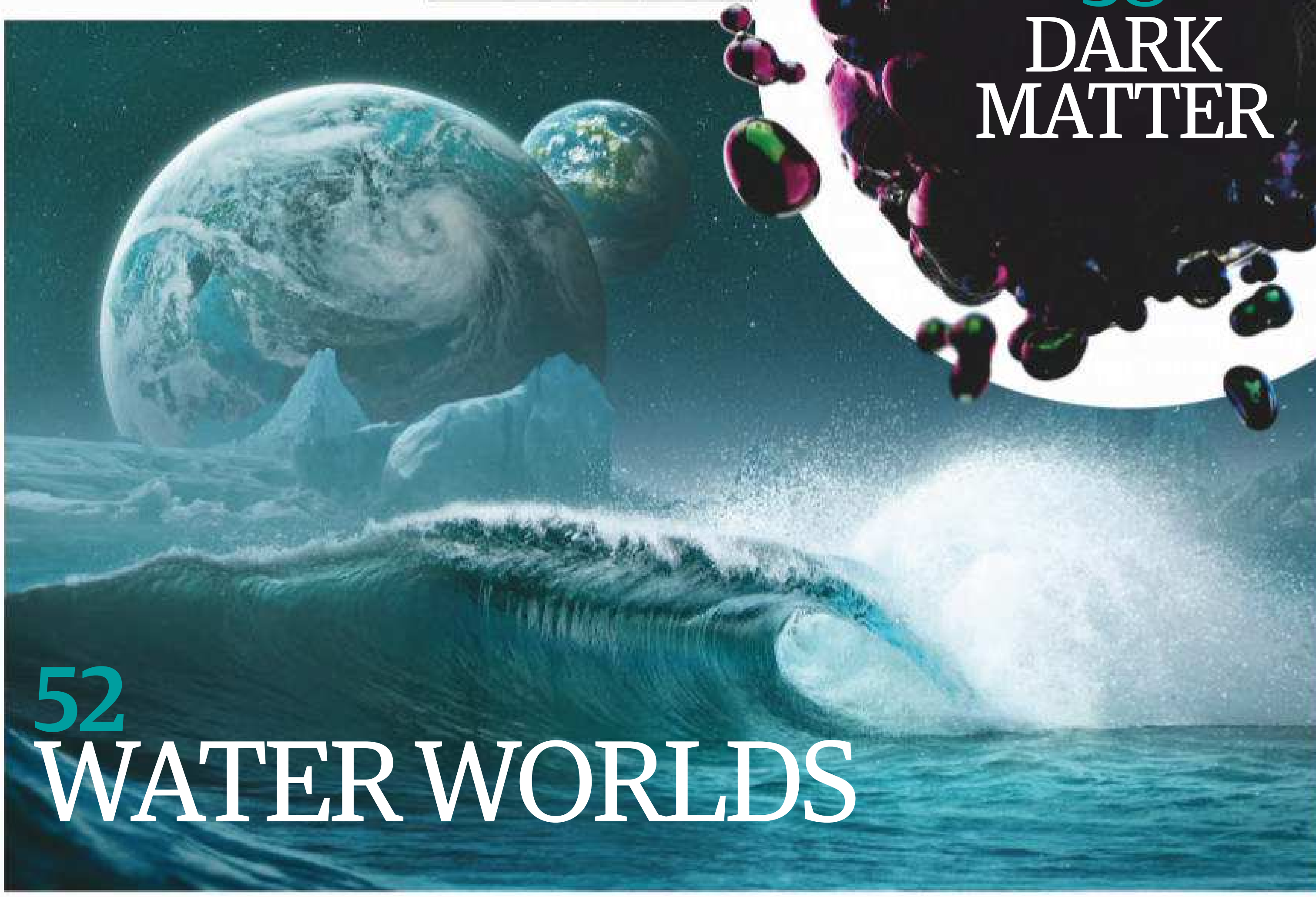

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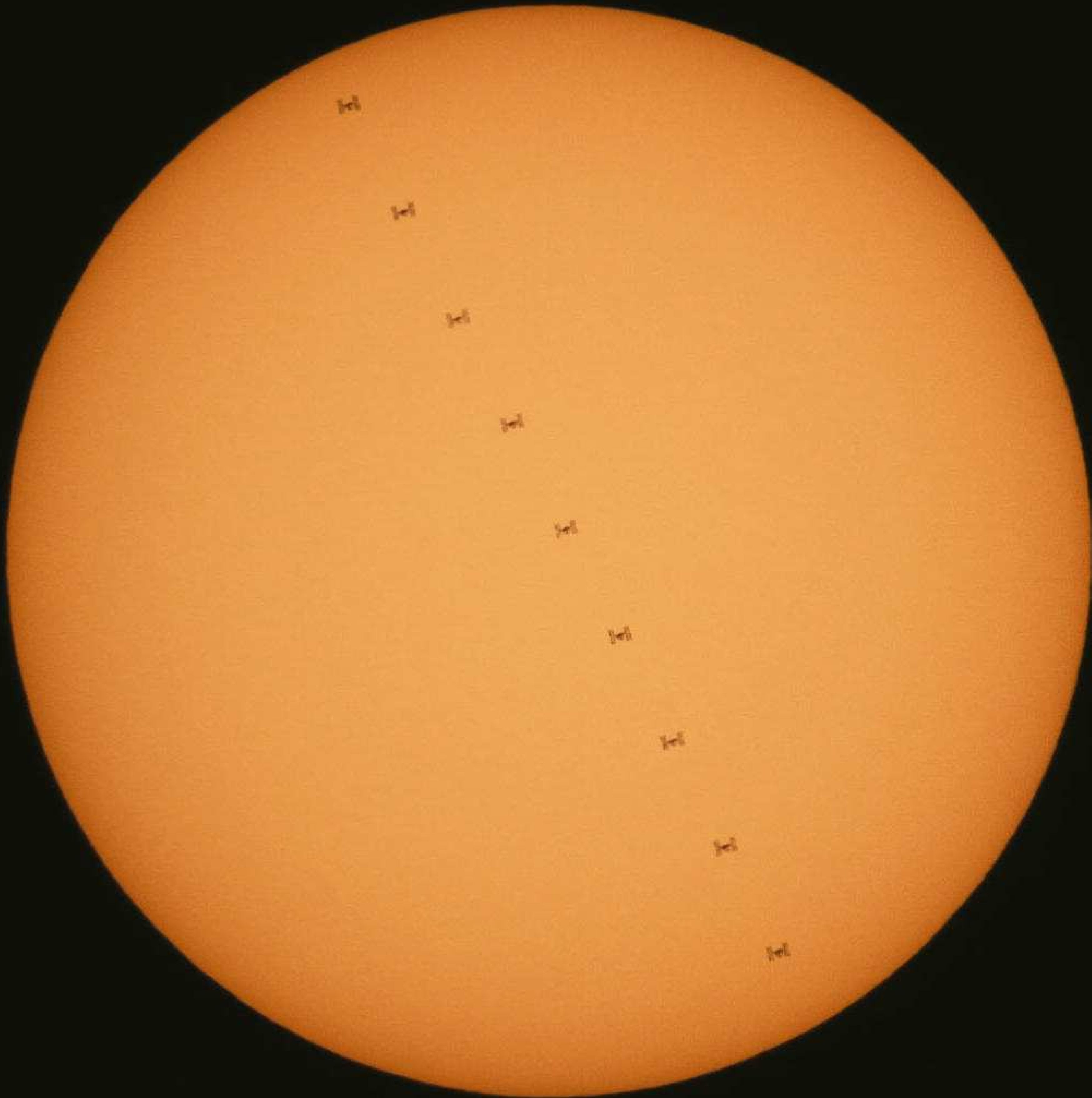


Space station silhouette

Seen here cruising across the Sun is the much-loved International Space Station (ISS), travelling at roughly eight kilometres (five miles) per second. This didn't leave much time for the photographer to capture the nine frames that were needed to capture the station's silhouette.

On board at the time were just three astronauts, NASA's Serena Auñón-Chancellor, Roscosmos' Sergey Prokopyev and commander, ESA's Alexander Gerst. While in Earth orbit, the commander has helped install a new life-support system (inset) - the Advanced Closed Loop System (ACLS) will recycle more carbon dioxide into oxygen, allowing more room on the supply missions and saving as much as 400 litres of water per year.

The glow of the early universe

Hidden in the sky is light that's invisible to our eyes. To the human eye, galaxies and stars shine bright on a black canvas in visible light, but now the MUSE spectrograph on the European Southern Observatory's Very Large Telescope has revealed the otherwise discreet diffuse glow of Lyman-alpha emission.

Lyman-alpha emission is essentially hydrogen emission from distant clouds of the most primitive element. By viewing the Lyman-alpha clouds present in such a small section of the sky, it is remarkable witnessing how much emission there is originating from the early universe.

Back in time with a cosmic hourglass

The hourglass-shaped remnant of CK Vulpeculae, first observed on 20 June 1670 by French monk and astronomer Anthelme Voituret, has been a mystery for centuries, but now astronomers believe they've found an answer to its origins.

CK Vulpeculae was originally thought to be a nova, which is the continuous explosive behaviour observed by two close stars in a binary system. Now, by using the Atacama Large Millimeter/submillimeter Array (ALMA) to study the debris, it is thought to be the merger of a brown dwarf and white dwarf star.

Herschel's view of our galaxy

Gas and dust block our view of the centre of the Milky Way, but it is this same material that provides the vast streak of faint light that divides the sky above us. In this image, the European Space Agency (ESA)'s defunct Herschel space observatory snapped a shot of the galactic centre in far-infrared.

The blue within the image dictates warmer, denser gas and dust towards the centre of the galaxy. In comparison, the yellow represents colder, more diffuse gas and dust. The infinity-shaped loop you can see in this image holds a mind-boggling mass equivalent to 30 million-times the mass of our Sun, also known as a solar mass.

Lighting up Los Angeles

On 7 October 2018 at 7:21pm PDT (8 October 2018 at 2:21am GMT), SpaceX lit up the night sky of southern California, United States, as it launched the SAOCOM 1A satellite from Vandenberg Air Force Base.

This time-lapse shows the difference in main engine ignition of the Falcon 9 rocket, as it climbs into space with a striking orange-hued blast. At an altitude of around 90 kilometres (56 miles) the main engine separates, and the ignition of the second stage to carry it into low-Earth orbit begins (inset).

Sunrise from above

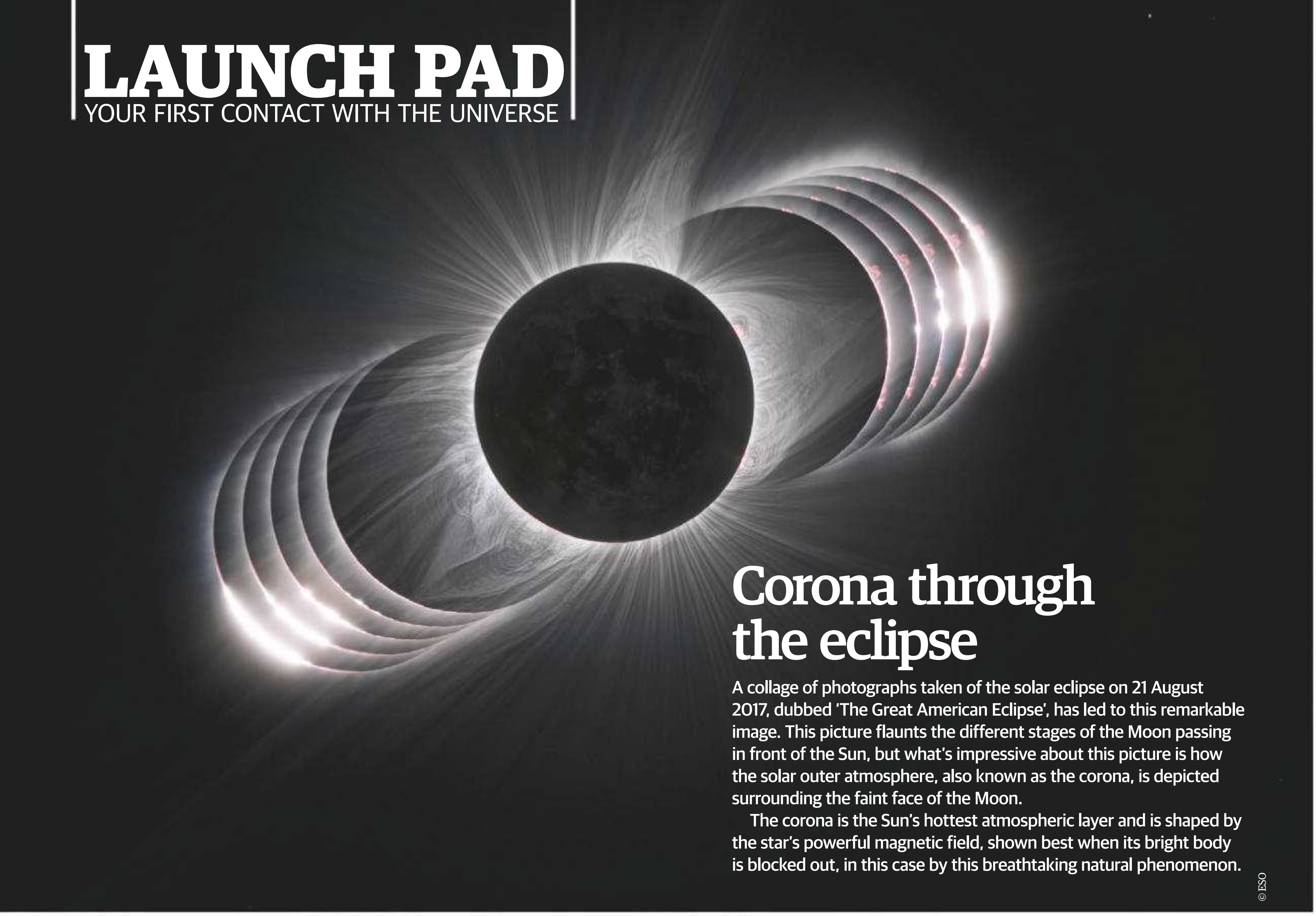
This is not a still from Disney's *The Lion King*; this is actually a picture taken by ESA astronaut Alexander Gerst captured from the International Space Station. He posted this image on social media along with his thoughts: "I don't know any words, in any language, to match the beauty of an orbital sunrise."

Watching the sunrise on top of the atmosphere is an experience only few in this world have had the privilege to see. On Earth, you can watch the sky turn from black to red and eventually to blue as the Sun rises, but it is extremely rare to see all three phases in the same shot.

Battling space junk using satellites

Space junk is littered throughout low-Earth orbit. From leftover satellites to seemingly insignificant specks of debris, any piece of junk hovvering above our atmosphere is harmful to anyone on the ground because of its unpredictability should it fall from space.

This is why space agencies are finally starting to take the removal of space junk seriously and, on 20 June 2018, the Space Station released the NanoRacks-Remove Debris satellite from the Japanese Kibo laboratory module. The satellite's aim is to map the location and speeds of debris using its 3D camera in order to understand any problems ahead.



Corona through the eclipse

A collage of photographs taken of the solar eclipse on 21 August 2017, dubbed 'The Great American Eclipse', has led to this remarkable image. This picture flaunts the different stages of the Moon passing in front of the Sun, but what's impressive about this picture is how the solar outer atmosphere, also known as the corona, is depicted surrounding the faint face of the Moon.

The corona is the Sun's hottest atmospheric layer and is shaped by the star's powerful magnetic field, shown best when its bright body is blocked out, in this case by this breathtaking natural phenomenon.

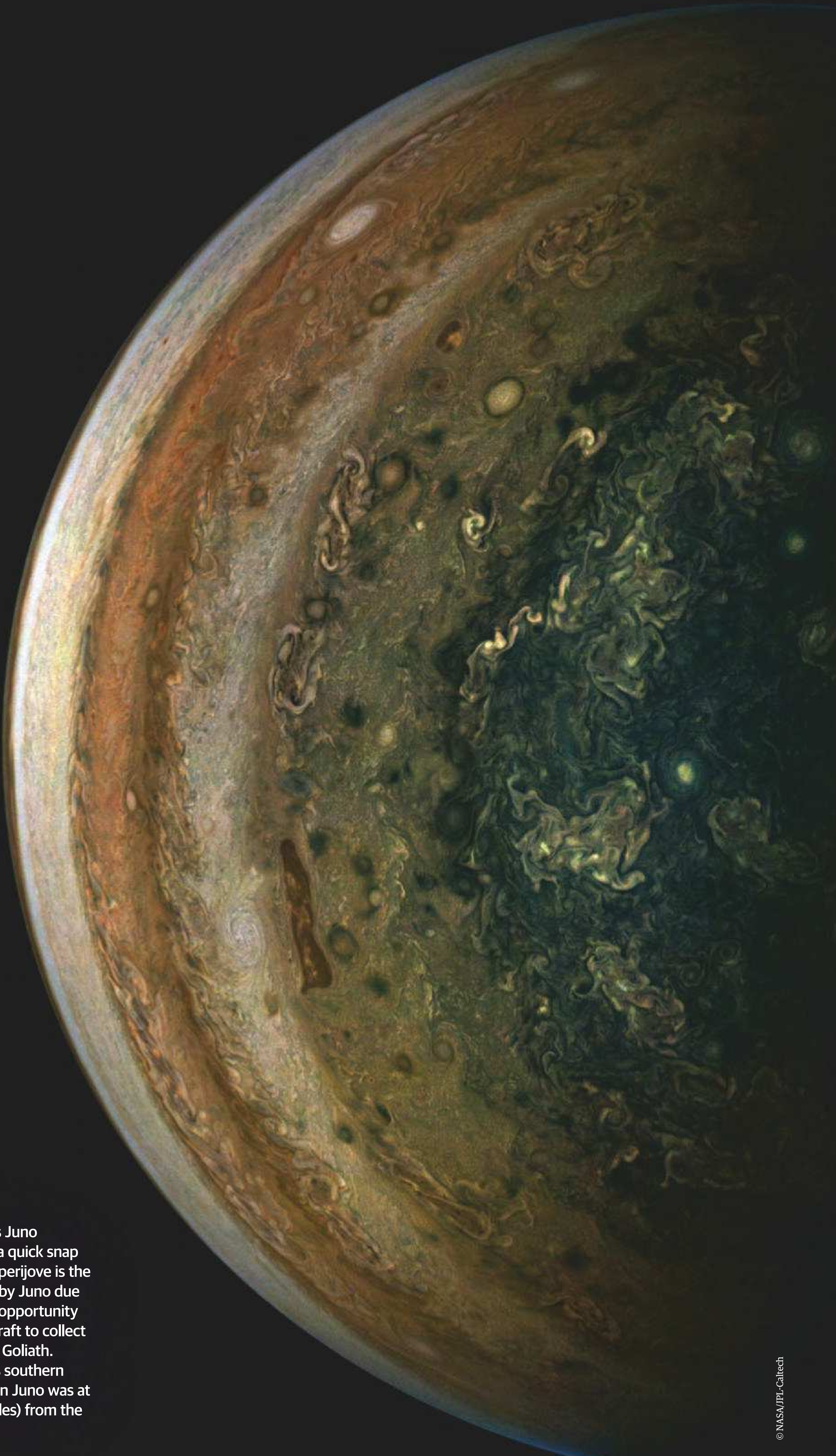
© ESO

MASCOT's descent to Ryugu

Hayabusa2's recent arrival has been well celebrated throughout the scientific community as it marks an impressive milestone in the mission to sample and study a distant asteroid. Ryugu, the targeted space rock located roughly 300 million kilometres (190 million miles) away from Earth, has recently had three visitors in the form of Hayabusa2's two MINERVA-II rovers and the MASCOT rover.

This image was taken only a few minutes after MASCOT's separation from the main spacecraft, and if you look to the top-right of the image, the shadow of MASCOT can be spotted on the asteroid's rocky surface.

©JAXA/MASCOT



"One more before I go"

With 15 notches on the perijove tally, NASA's Juno spacecraft decided to look back and snatch a quick snap before it heads away for another 53 days. A perijove is the name given to a close flyby of Jupiter made by Juno due to its eccentric orbit, providing a window of opportunity lasting only a matter of hours for the spacecraft to collect valuable scientific data of the Solar System's Goliath.

This colour-emphasised image of Jupiter's southern region was taken on 6 September 2018 when Juno was at a distance of 89,500 kilometres (55,600 miles) from the swarming, banded clouds.

Soyuz launch failure: NASA insists 'troubled rocket' will fly again

But there are concerns that the schedules for SpaceX and Boeing alternatives are too tight

NASA's administrator Jim Bridenstine is confident American astronauts will fly again on a Soyuz rocket and that the next launch will be on schedule. Speaking in the wake of the booster failure which forced the crew of Soyuz flight MS-10 to dramatically abandon their trip on 10 October, he said NASA had a "really good idea of what happened" and that it won't ultimately end up leaving the International Space Station bereft of a crew, albeit temporarily.

Believing the relationship with Russia in space continues to be strong, "despite our political differences", Bridenstine also spoke about the need for alternative transportation systems. Currently the Russian-operated Soyuz is the only vehicle able of transporting crews to the ISS, but Boeing and SpaceX are working on commercial crew vehicles that are due to be launched early next year which would ensure better continuity of service.

Even so, it isn't without worry. Members of the independent Aerospace Safety Advisory Panel are concerned that Boeing and SpaceX are pursuing unachievable schedules, saying many technical issues are yet to be resolved. They are particularly keen for both companies to push recent events out of their minds and not accelerate plans for their vehicles to plug any gaps that the Soyuz failure may cause.

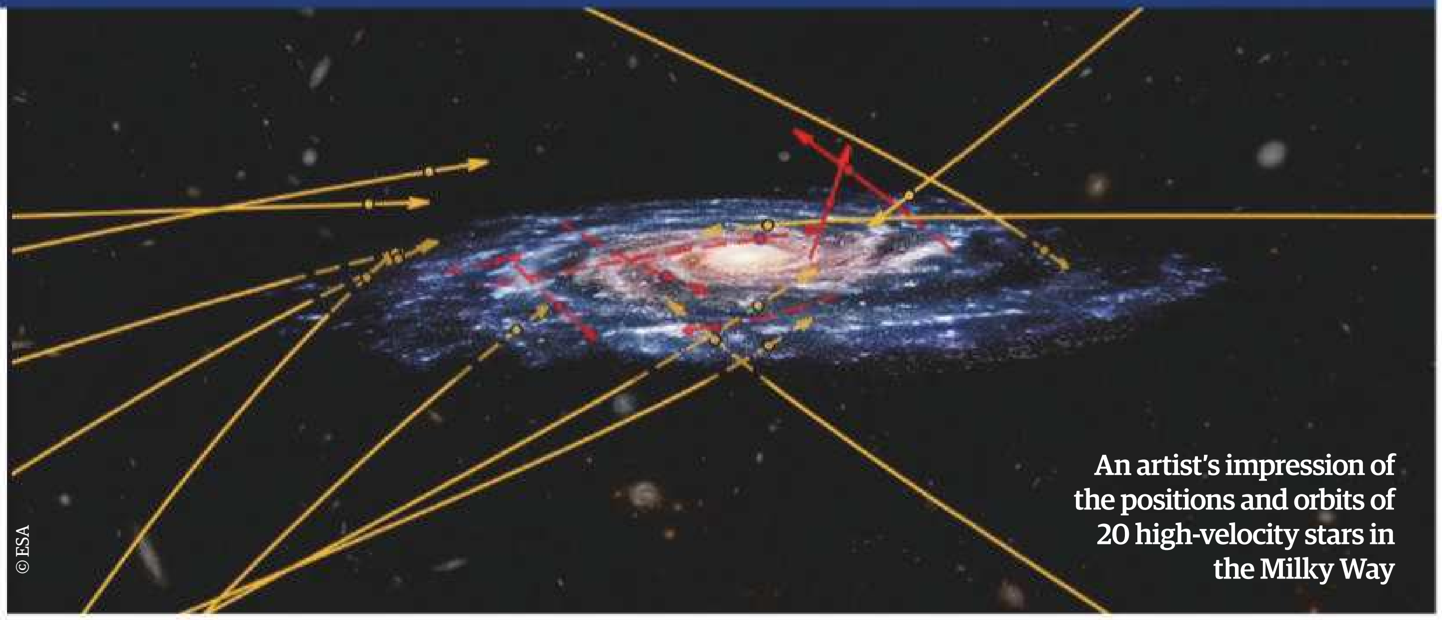
"The panel believes that an over-constrained schedule driven by any real or perceived gap in astronaut transport to the ISS… poses a danger that sound engineering design solutions could be superseded, critical programme content could be delayed or deleted and decisions of 'good enough to proceed' could be made on insufficient data," says Dr Patricia Sanders, chair of ASAP.

Problems raised include the reasons why a composite overwrapped pressure vessel caused a Falcon 9 to explode on its pad in September 2016 and issues with the parachute system on the Dragon. Even so, both Boeing and SpaceX say they are certain they'll meet their current schedules and stressed they would never sacrifice safety just to be on time. Currently, SpaceX is expected to be testing an uncrewed flight in January, with Boeing following in March. Crewed flights are due in June and August respectively.

Russia continues to investigate its failed Soyuz launch which affected the flights of NASA astronaut Nick Hague and Russian cosmonaut Aleksey Ovchinin. Neither was injured following the emergency landing, but it put paid to their six-month stay on the ISS. It has, however, left current ISS crew members with an uncertain departure date, although they have enough fuel, oxygen, water and food for six months, Russian officials say.

"The relationship with Russia in space continues to be strong, despite our political differences"

Left: The Soyuz MS-10 spacecraft encounters a problem, forcing the climb to be aborted



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An artist's impression of the positions and orbits of 20 high-velocity stars in the Milky Way

Fast stars may be joining us from other galaxies

Gaia has helped astronomers spot hypervelocity stars that appear to come from outside the Milky Way

Scientists studying stars travelling at high speeds within the Milky Way believe a good number of these celestial objects could actually be on a journey from another galaxy. Research using data from the European Space Agency's Gaia mission shows that most observed hypervelocity stars are rapidly moving towards the galactic centre. It had previously been thought such stars moved outwards.

The fresh findings have been reported by scientists at Leiden University in the Netherlands following observations made by the Gaia spacecraft between 25 July 2014 and 23 May 2016. By looking at the positions, distance indicators and motions of some seven million stars with full 3D velocity measurements, the researchers found 20 were fast enough to eventually escape the Milky Way.

In the past such behaviour has been pinned on the black hole at the centre of our galaxy propelling these stars towards the Milky Way's edge. Here, however, something unusual was happening. "Rather than flying away from the galactic centre, most of the high-velocity stars we spotted seem to be racing towards it," explains study co-author Tommaso Marchetti. "These could be stars from another galaxy, zooming right through the Milky Way."

One possibility is that the hypervelocity stars have come from a relatively small galaxy orbiting the Milky Way called the Large Magellanic Cloud. "Stars can be accelerated to high velocities when they interact with a supermassive black hole," says co-author Elena Maria Rossi. "So the presence of these stars might be a sign of such black holes in nearby galaxies."

Alternatively, the stars may have been part of a binary system, flung towards the Milky Way when their companion star exploded as a supernova. "Studying them could tell us more about these kinds of processes in nearby galaxies," Rossi concludes.

More evidence for Ceres' ancient global ocean

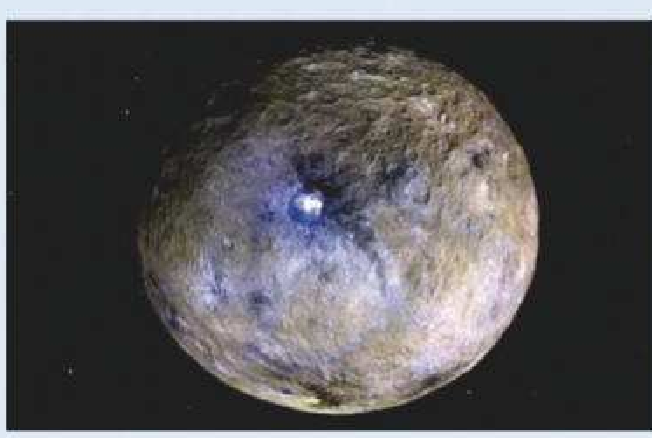
A wandering polar region on the dwarf planet has shed some substantial light on the world's past

New research is suggesting that the dwarf planet Ceres experienced a polar shift at some point in the past, causing the pole to move from its original position before stabilising. Scientist Pasquale Tricarico from the Planetary Science Institute believes there may have been an indirect polar reorientation of approximately 36 degrees at some point in the past. He says it would explain topographical irregularities on Ceres' crust, among them an overly dense equatorial region.

It has long been thought that Ceres' crust may be frozen, and Tricarico used that as the basis of his team's study. Using data from NASA's Dawn mission - which launched in 2007 with the intention of studying Vesta and Ceres - he found evidence of an ancient equatorial ridge in a different location to the current equator. It suggests Ceres underwent true polar wander where the outer layers drifted before settling.

"A multi-step reorientation could mean that the equatorial density anomaly was still evolving during the reorientation, and this could be because the crust and mantle were weakly rotationally coupled, allowing the crust to start reorienting while the mantle would lag behind," Tricarico said in a statement.

This, he says, could indicate a layer of reduced friction between crust and mantle, something which points towards a potential ancient ocean. "One of the possible mechanisms to reduce friction could be an ancient water ocean beneath the crust," Tricarico affirms.



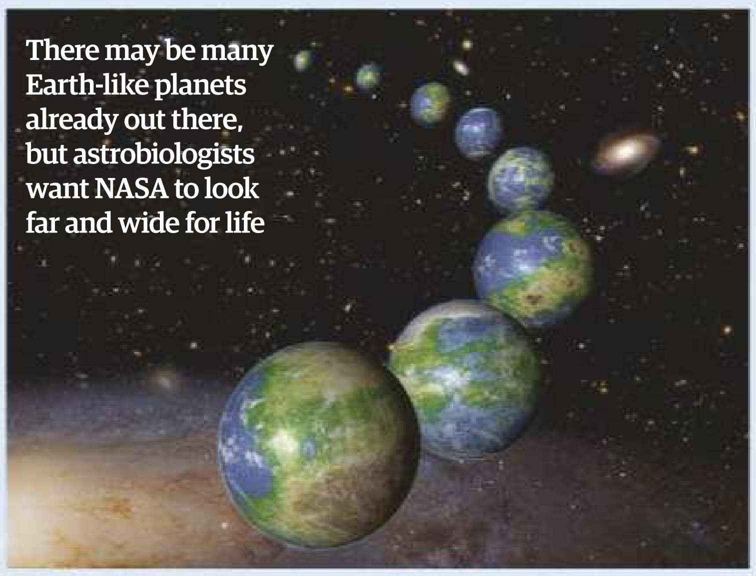
© NASA/JPL-Caltech

Ceres appears to have had a wandering crust - perhaps because of an underlying ancient ocean

Make search for alien life integral to NASA, says report

Astrobiologists say their scientific discipline should be more deeply considered when plotting future missions

A recently published congressionally mandated report has called upon NASA to ramp up its efforts in the ongoing search for life on other worlds. Astrobiologists working with the National Academies of Sciences, Engineering and Medicine hope to influence NASA's decision making on projects and missions and they want America's space agency to put astrobiology at the forefront of its research.


There may be many Earth-like planets already out there, but astrobiologists want NASA to look far and wide for life

Among the recommendations is a call for ever more powerful telescopes and instruments that can block sunlight to allow for better views of exoplanets. The paper is also keen to make the question of habitability less binary. "Planetary environments that may be habitable today or in the past are not necessarily the same as those that could have fostered the emergence of life," the report suggests. "Evidence from major transitions in environmental conditions from early Earth to today, and an understanding of how they occurred, is critical for the search for life."

New discoveries about our own planet are behind this renewed drive. Scientists have realised that life could exist in circumstances that were once thought near-impossible, such as below the Antarctic ice or within deep-sea vents, and they want future space research to consider that.

As such, the report calls for wider thinking about where life could exist in the universe, and it also places great emphasis on being able to accurately discover and interpret biosignatures – substances such as elements, molecules, isotopes or phenomenon that scientifically indicate past or present life. The National Academies would also like to see the search for extraterrestrial intelligence become part of mainstream research.

Changes planned for NASA's biggest rocket

The Space Launch System's upper stages are being altered by Boeing

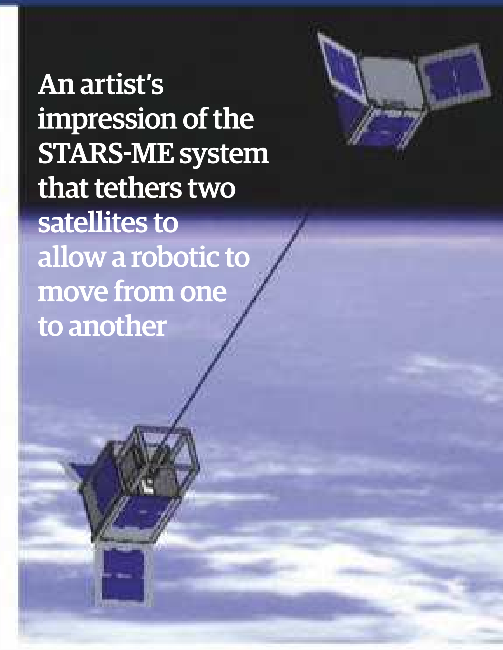
Boeing is working on improvements to the upper stage of the Space Launch System, set to be the world's most powerful rocket when it eventually launches.

NASA is seeking better performance and an increase in capacity, with the aerospace company saying it will be boosting the amount of payload the Exploration Upper Stage (EUS) can carry while looking at ways to lighten its weight. This will include modifying the stage so that it can carry up to two extra tons of co-manifested payload.

When complete it will carry modules of NASA's Lunar Orbital Platform Gateway – a proposed lunar-orbit space station that will be part science lab, part habitation module and part communications hub. "We're actively working through additional design opportunities to lighten the stage and increase its performance and take even more out to the lunar area so that the Gateway can be built and we can get human boots back on the surface of the Moon," said John Shannon, vice president and programme manager for the Space Launch System.

The news follows NASA's decision to slow the introduction of the EUS. It is now due to launch in 2024, four years later than originally envisaged.


Boeing has the contract to manufacture the Space Launch System


An artist's impression of the STARS-ME system that tethers two satellites to allow a robotic to move from one to another

Space elevator prototype tested in space

People and payloads may be shuttled back and forth through space via cable at some point in the future

Researchers at Shizuoka University in Japan are testing the concept of a space elevator. They sent a pair of satellites to the ISS which were then deployed into free space. Connected by a tightly stretched ten-metre cable, the idea is that a robotic 'climber' will travel from one satellite to another.

In this instance the satellites are called Space Tethered Autonomous Robotic Satellite Mini Elevator (STARS-ME), but there is one eye on tethering from a planetary surface to an object in space – a dream that, in truth, remains some way off.

At the very least the cables would need to be able to withstand high-energy cosmic rays, and they'd need to avoid collisions with space debris and satellites. The cables would also need to be strong enough to support their own weight. But the wider plans are nothing if not ambitious.

The LiftPort Group, for instance, wants to construct a space elevator using carbon nanotubes that would tether the Moon to a balance point of cislunar space. Meanwhile Obayashi, which constructed the Japanese space elevator, wants to produce a system that can transport people from Earth to a geostationary earth orbit station located 36,000 kilometres (22,369 miles) away. It plans to build this by 2050.

DOES SPACE HAVE A FINAL DIMENSION?

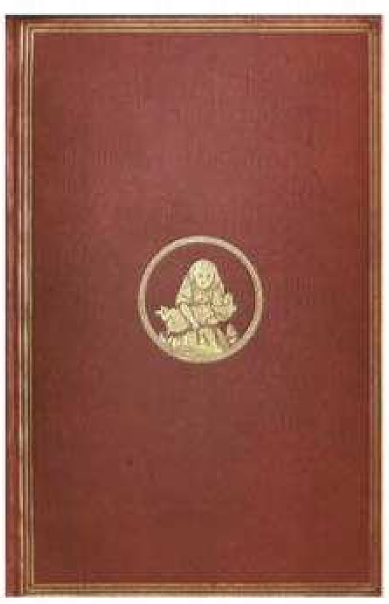
There could be more to the universe than meets the eye with extra facets beyond space and time

— Reported by Colin Stuart —

"Curiouser and curiouser!" cried Alice. In Lewis Carroll's surreal Victorian story the eponymous character goes on adventures in Wonderland. There she meets a cast of quirky characters in a world that's so alien it defies belief and common sense. To reach this otherworldly place she disappears down a rabbit hole and into another dimension.

As wonderful and wacky as *Alice in Wonderland* is, some physicists believe something similar might be at play in our universe. "It all starts with the hierarchy problem," says Kris Pardo from the Department of Astrophysical Sciences at Princeton University. Gravity, it seems, doesn't play by the rules, particularly when you compare it to the other major forces. "It's just so much weaker," says Pardo. It's ten thousand trillion trillion trillion-times feebler than the strong nuclear force that helps bind atomic nuclei together, for example. To see just how weak gravity really is, remember that you can jump into the air and temporarily overcome the collective gravitational pull of six trillion trillion kilograms of the Earth beneath your feet.

The puzzle of why gravity is so puny compared to its sibling forces is one of the greatest mysteries in physics. It has led some researchers to suggest that gravity must do the astronomical equivalent of Alice and disappear down a celestial rabbit hole. What if gravity isn't really weaker – we only perceive it that way because it leaks into additional dimensions? If you could be an all-seeing eye, capable of observing every dimension at once, you wouldn't encounter a hierarchy problem at all. Such an idea might sound far-fetched but, thanks to recent breakthroughs, Pardo has been able to test it.



Gravity may disappear into extra dimensions, just as Alice disappeared down the rabbit hole in *Alice in Wonderland*

In 2015, physicists detected gravitational waves for the first time. These ripples in the very fabric of space were predicted by Albert Einstein 100 years earlier. Calamitous events in the universe send out rolling waves, much like those created when a stone is dropped into a pond. When the waves pass through the Earth they can be detected by experiments like the Laser Interferometer Gravitational-Wave Observatory (LIGO) in the US. Its four-kilometre (2.5-mile) arms are sensitive to changes in space equivalent to one-ten-thousandth the width of a proton. The discovery was so monumental that the Nobel Prize in Physics was awarded to the founders of the facility in 2017.

The first gravitational waves detected by LIGO came from the collision of two black holes about 1.3 billion light years away. But in August 2017 another type of collision was picked up: two neutron stars smashing together 130 million light years away. This event – known as GW170817 after the date it was first detected – presented a unique opportunity to test the idea of gravity leaking into extra dimensions. That's because a neutron star merger produces a searing flash of light in the form of gamma rays along with the gravitational waves. Black holes, on the other hand, famously gobble up light. So GW170817 became the first event ever detected to emit both light and gravitational waves.

Pardo and his colleagues were able to compare the flash of gamma rays with the gravitational waves. "We think we know how much energy is released in the form of gravitational waves after an event like the one that we saw," Pardo says. "And we think we know how much of that energy is going to be lost as the wave travels from the source to us." The light from the collision also fades as it makes its way here. If you know how much energy was released, and how much energy you detect once it reaches Earth, you can work backwards to figure out how far away the collision occurred. The more it has faded, the further it has travelled across space to get here. Crucially, a neutron star merger allows you to compare two independent measures of distance - light and gravitational waves - in a way that a black hole merger cannot.

If gravity really is leaking into extra dimensions then some of the gravitational wave energy will seep into them en route to Earth. Light doesn't leak, so the two measures would disagree on the distance travelled. "It would seem like the gravitational waves were coming from further away," says Pardo. Back in July 2018, Pardo and his colleagues released a scientific paper with their findings. "The gravitational waves weakened in the way we expected," he says. In other words, he found no evidence of gravity leaking into other dimensions.

It sounds like a hammer blow, but Pardo adds an important caveat: "There are some theories of extra dimensions that you can't probe with the large scales that we worked with," he says. "To test ideas like string theory, that have very small extra dimensions, you need to be looking at much higher energy events than the ones we looked at."

Albert Einstein predicted the existence of gravitational waves in his 1915 General Theory of Relativity

String theory is notorious and probably the best known example of a theory that invokes the presence of extra dimensions. It also has its origins in the study of gravity. Physicists would love to combine Einstein's General Theory of Relativity - the theory of gravity that predicted the existence of gravitational waves in the first place - with quantum physics, which describes interactions in the sub-atomic world. Except these two theories stubbornly refuse to play nicely together. Attempts to combine them lead to discrepancies even more absurd than the weird world described in the pages of *Alice in Wonderland*. For example, the probabilities of some events happening turns out to be more certain than certain - a sure sign something is wrong. String theorists attempt to get around this problem by invoking the presence of extra dimensions. Add them in and the maths works beautifully.

"If gravity really is leaking into extra dimensions then some of the gravitational wave energy will seep into them"

Dimensions of the universe

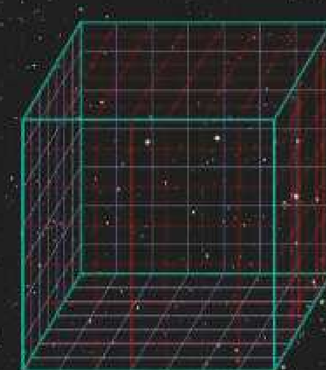
How do they differ from the ones we can observe?

First dimension

The first dimension is often thought of as a line – an object's position within one-dimensional space can be described by a single measurement. However, a single dimension need not necessarily be limited to straight lines – it may encompass a position on a circle such as compass points, or azimuth in the night sky.

Second dimension

A two-dimensional object is described by two separate measurements – the simplest example is a flat plane in which any position can be defined on a grid of x and y coordinates that are at right angles to each other. However, there are many other objects, such as spherical and cylindrical surfaces, that are also two dimensional.



Third dimension

The space we perceive in everyday life is three dimensional – we can define the position of any object within it by a set of three numbers, such as x, y and z coordinates at right angles to one another, or a set of celestial coordinates plus a distance from Earth. However, our perception is far from the whole story.

Seventh dimension

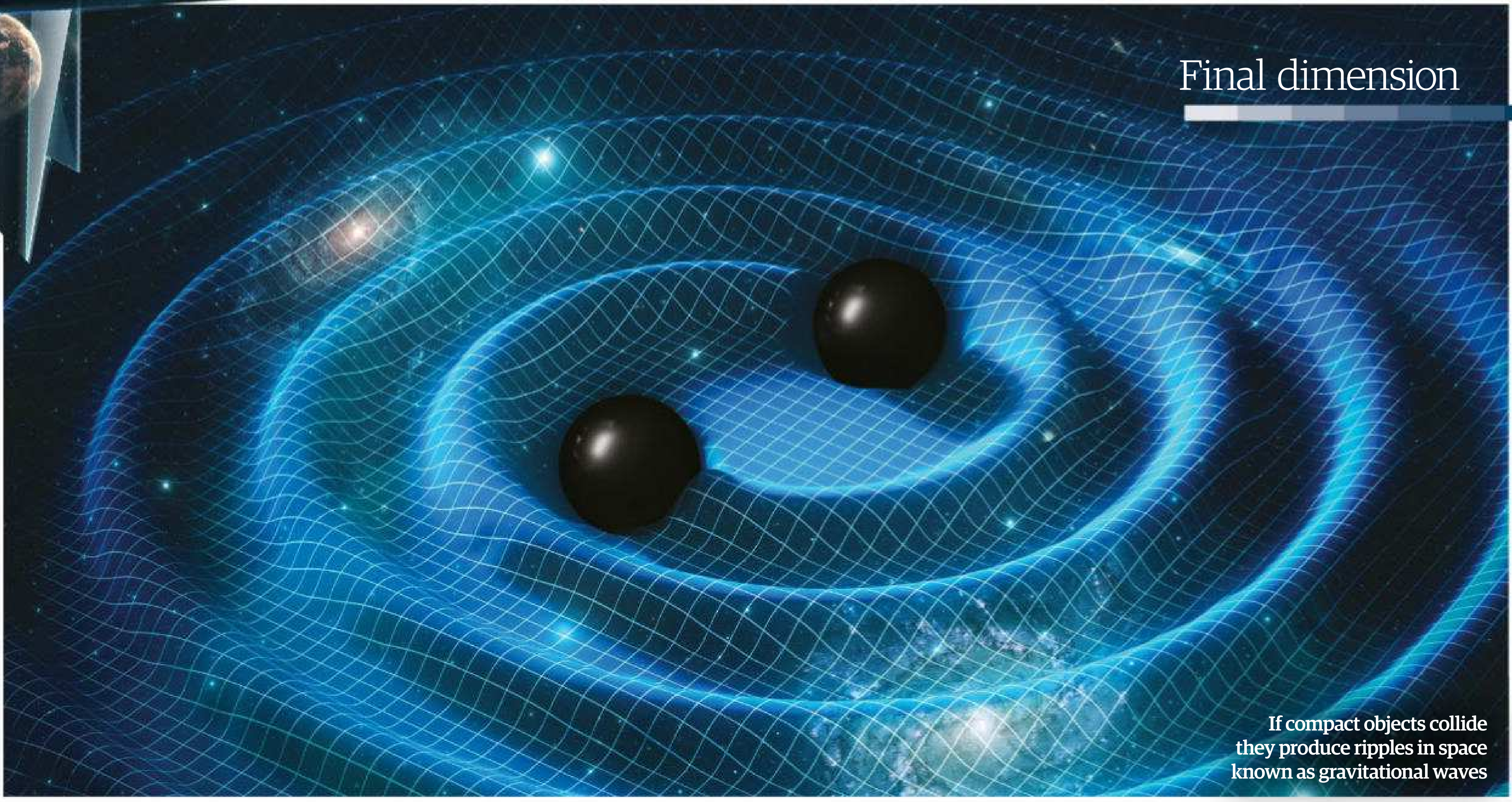
In the seventh dimension, and unlike the sixth dimension, possible worlds are born out of various starting conditions. What's more, everything is different from the very beginning of time.

Eighth dimension

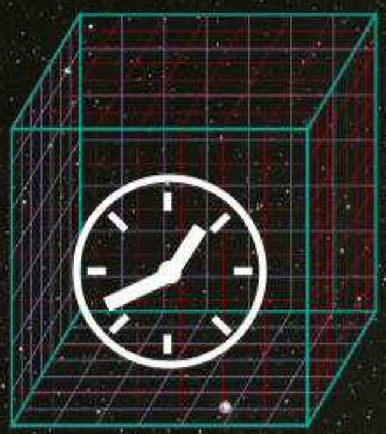
Just like the seventh dimension, the eighth presents a plane of possible histories of the universe, each of which begin with a variety of starting conditions – all of which branch out infinitely.

Ninth dimension

It's not just all of the possible histories of the universe that are different in the ninth dimension – the laws that we understand to govern the cosmos also vary.



If compact objects collide they produce ripples in space known as gravitational waves



Fourth dimension

So far as we know, movement along the time dimension happens in a single direction and we can never revisit the past. Just as importantly, the dimensions of time and space are bound together in a four-dimensional continuum that allows each to vary in extreme conditions, as described by Einstein's theories of relativity.

Fifth dimension

In this dimension you'll find another world that's slightly different to ours – we could measure similarities and differences to our own planet. A fifth dimension with similar properties to those of the three known space dimensions would be capable of giving rise to objects with four space dimensions, such as the well-known tesseract.

Sixth dimension

All possible worlds and universes start in the same way. You could easily travel backwards in time or go to different futures. If superstring theory is correct, then a linear fourth dimension of space perpendicular to the others does not exist, but there are at least six higher dimensions in which superstrings can oscillate.

Tenth dimension

Superstring theory combines string theory and supersymmetry. It manages to escape mathematical inconsistencies when combining gravity and quantum physics, but only by invoking a total of ten dimensions.

It suggests that particles are made of tiny vibrating strings that resonate across dimensions.

11th dimension

There are five different versions of superstring theory, but M-theory attempts to combine them into just one model. In M-theory the five superstring theories form a membrane which provides an extra dimension, hence why M-theory has 11 dimensions to superstring theory's ten.

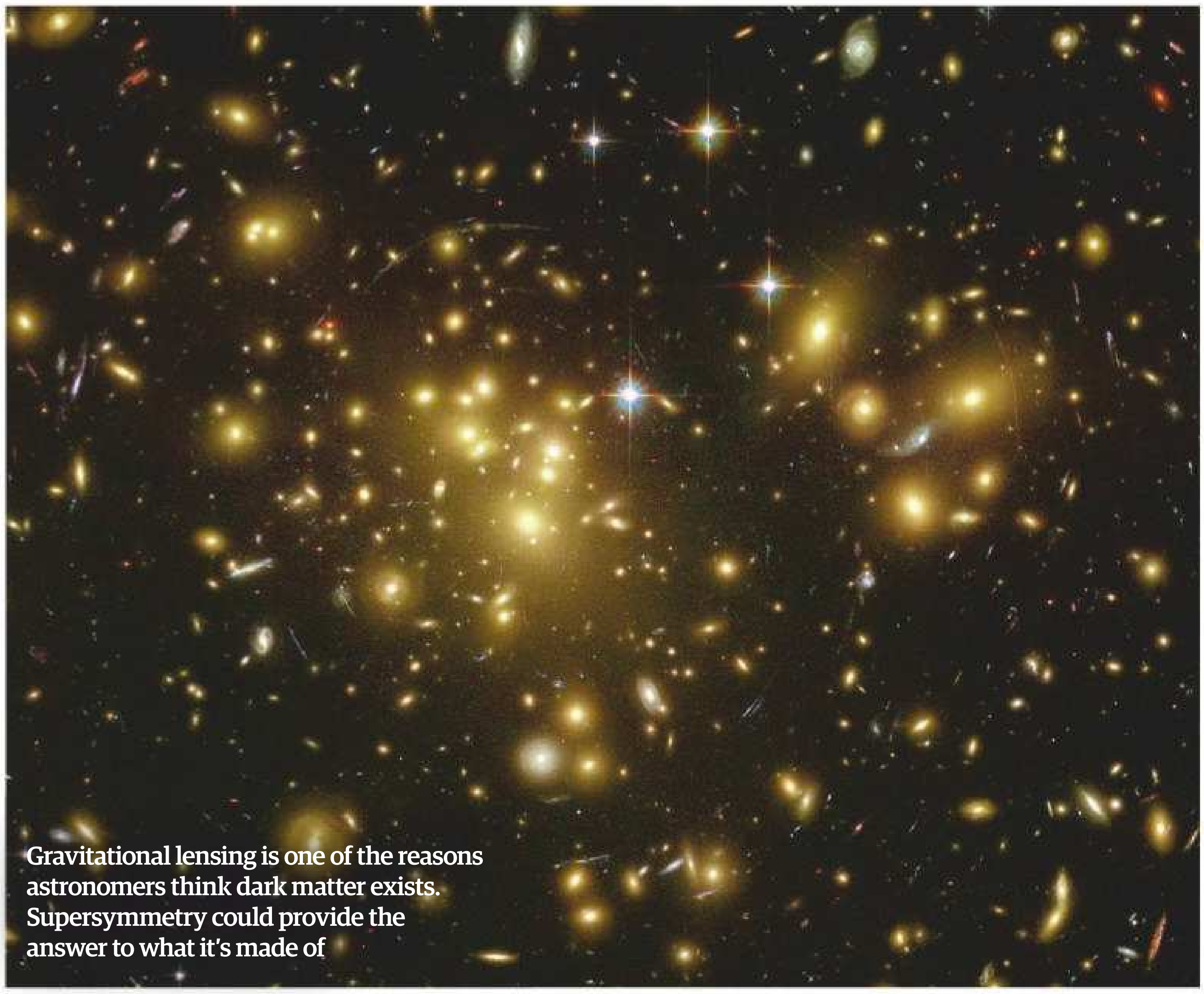
26th dimension

Bosonic string theory, devised in the 1960s, suggests reality actually has 26 dimensions. It has a major problem, however. As its name suggests it only deals with particles called bosons – like the famous Higgs boson. It doesn't account for particles called fermions. It was largely superseded by superstring theory.

The problem is we don't see evidence of any extra dimensions in our daily lives or in existing physics experiments like those conducted by Pardo. So if they're really there they must be curled up incredibly small so as to remain out of sight. Picture it this way. Look at a tree from a distance and it looks two dimensional - like it is painted onto a flat 2D canvas. But to an ant crawling on a branch, the tree would obviously be three-dimensional - it can crawl along, across and around the bark. It's all about scale. Could our universe appear painted on a three-dimensional canvas when actually there are more dimensions, hidden to all but those who live in the realm of the sub-atomic world?

The trouble with string theory is that it is famously hard to test. It says that particles such as electrons are made up of tiny vibrating strings. Just as you can play strings on a violin in different ways to produce different notes, so nature is creating a sub-atomic symphony of its own. But the number of different versions of string theory runs to 10^{500}. We don't yet know which configuration - if any - applies to our universe, and until we do we cannot perform an experiment to validate the idea. So what else can be done?

Enter the Large Hadron Collider (LHC) at CERN, near Geneva in Switzerland. The huge 27-kilometre (16.8 mile) particle race track was made world famous after its discovery of a particle called the Higgs boson in 2012. The Higgs was the last piece in a sub-atomic puzzle known as the Standard Model. This framework describes the particles that make up everything around us and their interactions with each other. Gravity, however, stubbornly refuses to be incorporated by it. That's just one of the many reasons why physicists



Gravitational lensing is one of the reasons astronomers think dark matter exists. Supersymmetry could provide the answer to what it's made of

> "Just as you can play strings on a violin in different ways, so nature is creating a sub-atomic symphony of its own"

Ask an astrophysicist: The multidimensional universe

Matt Kleban is an American theoretical physicist who works on string theory and theoretical cosmology. He is a professor of physics at New York University and director of the Center for Cosmology and Particle Physics

Why aren't we aware of other dimensions?

"In all the reasonable theories that require extra space dimensions, there's either a reason why we're stuck onto a three-dimensional subspace – in which case we simply don't notice the extra dimensions because we can't have move in those directions – or they're what we call compact. That means that if you go in that direction for a certain distance, you'll come back to where you started – a bit like if you go in a straight line on the surface of the Earth, and eventually circle the planet. Most people think that if there are extra dimensions, they must be compact on a very small scale so that we haven't noticed them."

How can we see these extra dimensions?

"The extra dimensions can play an important role in the early universe, and leave traces that we can detect. One example is a theory I've developed where inflation [the sudden burst of expansion that happened an instant after the Big Bang itself] relies on the extra dimensions. It's something moving around in an extra dimension that's causing inflation to happen, and that has implications for the structure of galaxies and galaxy clusters in the universe today. It wouldn't be a very direct detection, and there would be a lot of argument as to whether it really showed that there were extra dimensions, but in principle, with enough data and some luck, you could discover them that way."

Bluffer's guide to string theory

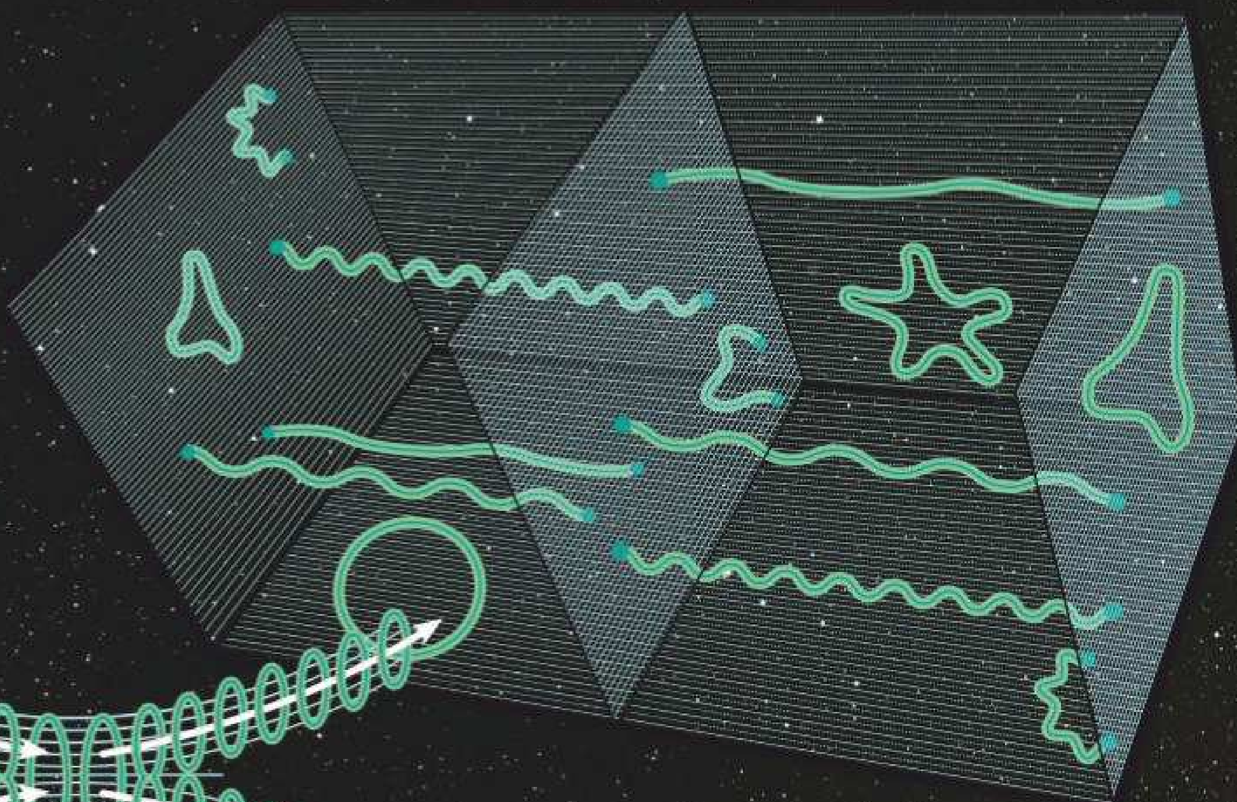
Your quick and easy guide to the ins and outs of superstring theory

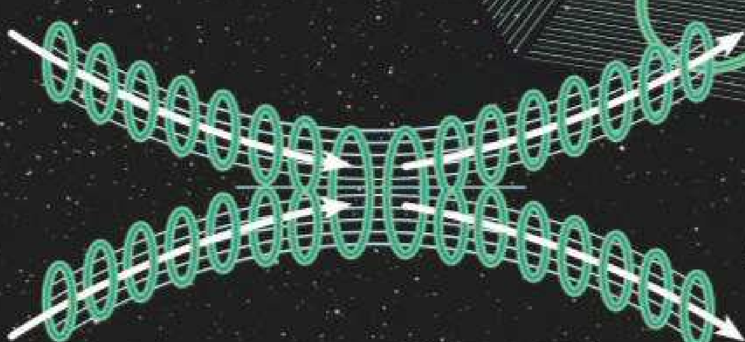
Gravity versus quantum

Physics appears divided. You need gravity to explain the large-scale universe and quantum physics to describe the sub-atomic world. Try and combine them together and the result is often nonsense. Unless, that is, you invoke extra dimensions.

How does string theory help?

By replacing particles with tiny strings that vibrate across multiple dimensions you can, at least on paper, solve many of these otherwise intractable problems. If ultimately successful it could shed light on the bottom of black holes and the beginning of the universe.





What do you mean by extra dimensions?

Our lives play out across four dimensions. To tell someone else where an object is you can give three co-ordinates to locate it in space and one to anchor it in time. Superstring theory says there are six additional dimensions that we don't experience or have access to.

Fermions versus bosons

Sub-atomic particles fall into two categories called fermions and bosons depending on a property called spin. Bosons are the force carriers, but no boson for gravity has yet been found. Gravity is also considerably weaker than the other three fundamental forces.

Is it testable?

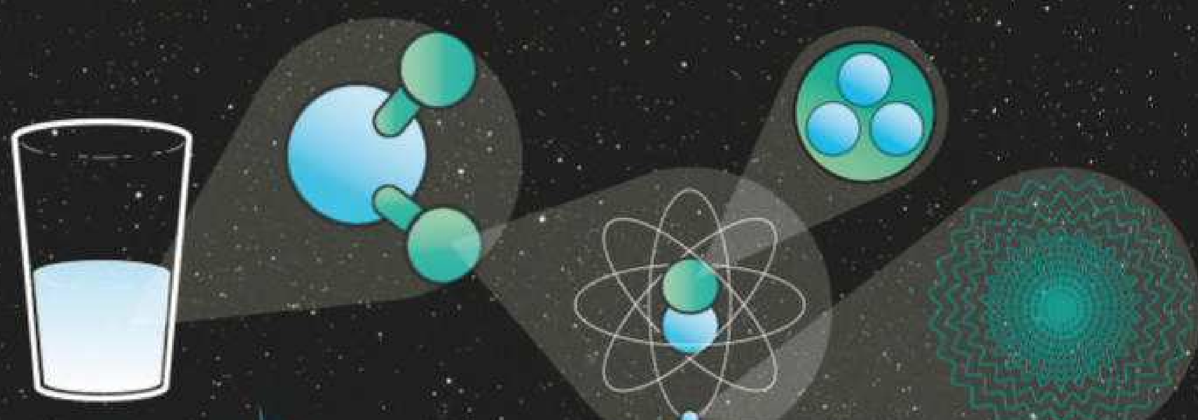
This is the major accusation levied at string theorists. At the moment it isn't falsifiable through experiment, leading some to question whether it's even science. Even finding evidence of supersymmetry wouldn't prove superstring theory correct.

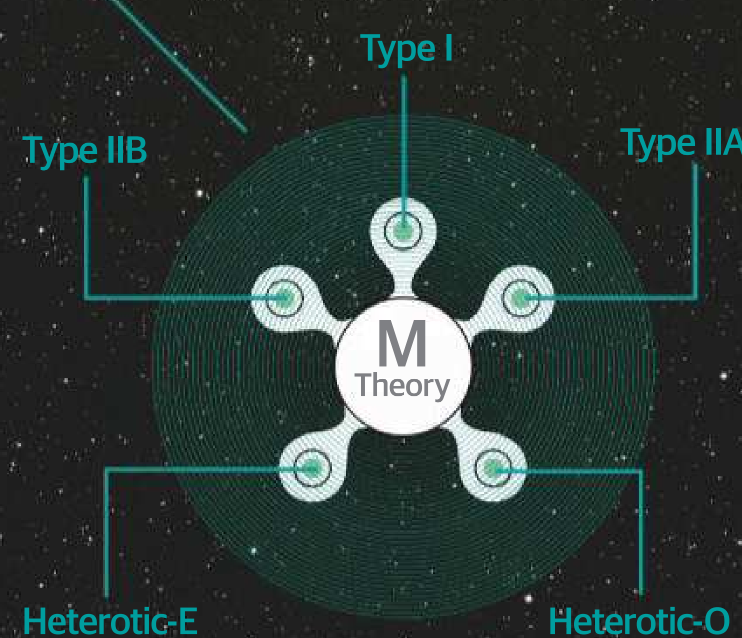
What's the super about?

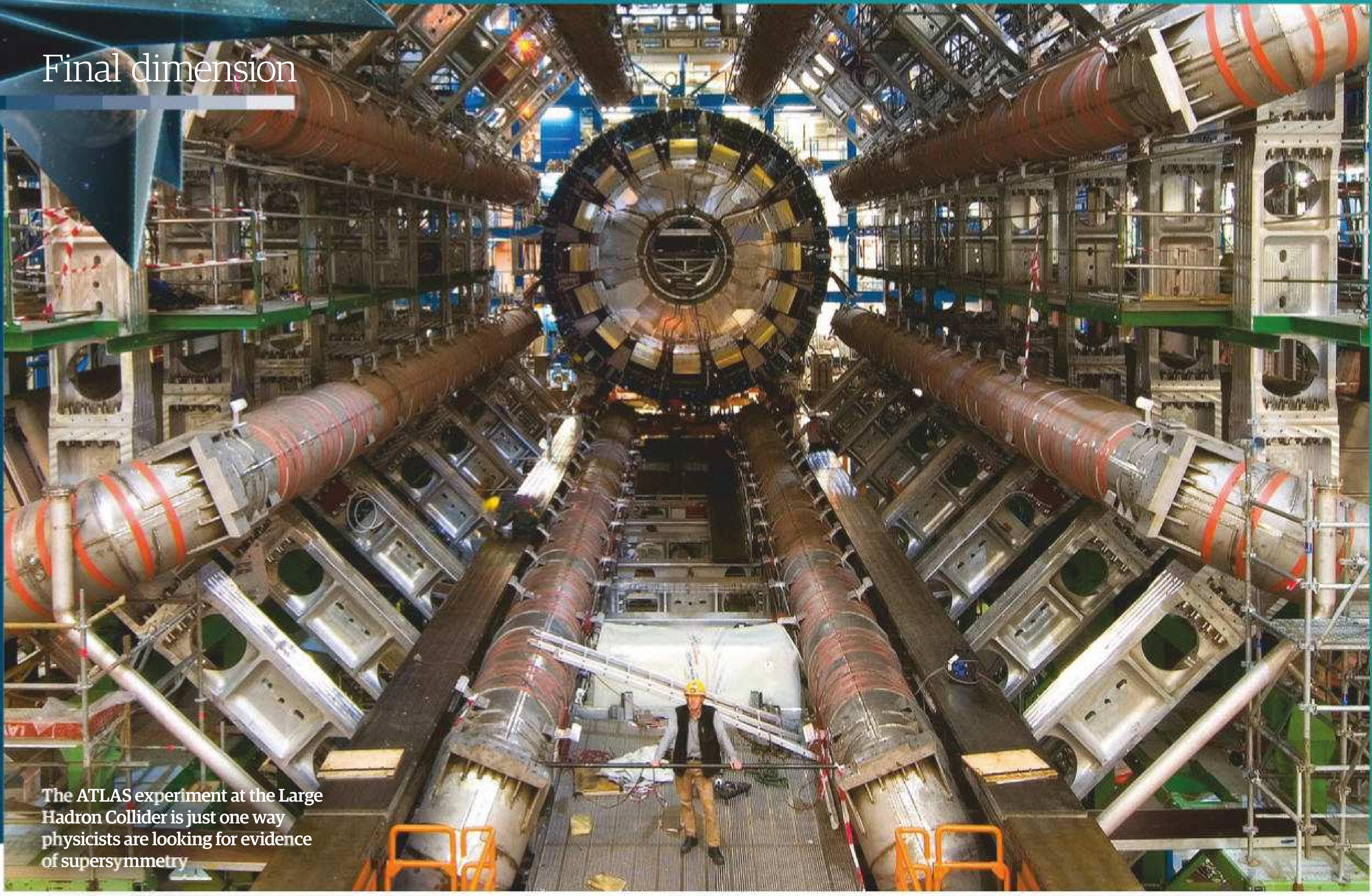
It comes from a theory called supersymmetry, which aims to find physics beyond the Standard Model. Superstring theory is an improvement on plain old string theory because it accounts for both bosons and fermions.

What about M-theory?

There are five different versions of superstring theory, but they might all be manifestations of the same thing: M-theory. It introduces an additional dimension, taking the total to 11.







The ATLAS experiment at the Large Hadron Collider is just one way physicists are looking for evidence of supersymmetry

around the world are looking for physics beyond the Standard Model. Another is the search for dark matter, the mysterious shadowy entity that acts like a glue holding large structures in the universe together. "There's nothing in the Standard Model to explain that," says Tina Potter from the University of Cambridge, UK.

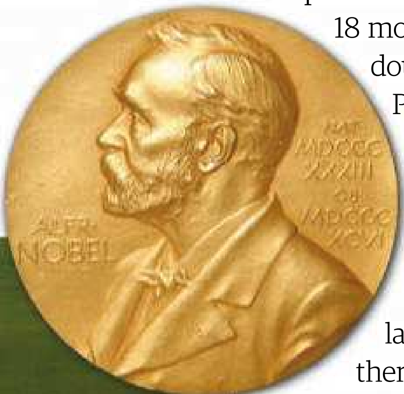
She is working on the ATLAS experiment at the LHC in the hope of finding evidence of a theory called supersymmetry – the most popular theory of physics beyond the Standard Model. It says that every particle in the Standard Model has an as-yet-undiscovered partner. That instantly doubles the number of particles physicists are searching for. "Some of these particles are fantastic candidates for dark matter – so if we find them it would plug one of the big holes in our knowledge about the universe," Potter says.

It isn't the theory's only appeal – some versions of string theory also rely on supersymmetry being true. Those that do are called supersymmetrical string theories – or superstring theories. There are five versions in total. However, in order to get the maths to work, all five superstring theories require there to be ten dimensions. That's the three of space and one of time we experience, plus six so-called 'hyperspace' dimensions that we don't. Those hyperspace dimensions would be small enough to remain out of sight. An alternative theory known as M-theory suggests that all five superstring theories are variants of an 11-dimensional reality. These superstring theories became fashionable in the 1980s and overtook the original version of string theory in popularity. That's called bosonic string theory, and it suggests the strings vibrate across a staggering 26 dimensions!

> "There are some theories of extra dimensions that you can't probe with the large scales that we worked with" **Kris Pardo**

Finding evidence of supersymmetry won't in itself confirm superstring theory, but a failure to do so would make the whole idea even harder to stomach. In that regard the LHC may be able to help. It has just reached the end of its latest run of particle-smashing experiments, producing a swarm of important data for physicists to pick over.

"We are hoping to find something there," says Potter. "It's all hands on deck to analyse it as quickly as possible." Meanwhile, the LHC will be shut down in December 2018 and upgraded ready to produce even more energetic collisions in around 18 months' time. "Next time we turn on we'll double the amount of data we have now," Potter says. "Any hints of supersymmetry we see in this dataset will be confirmed in the next one."



So slowly but surely physicists are making headway. Larger additional dimensions appear ruled out by the latest gravitational wave discoveries, but there remains hope that experiments such as the Large Hadron Collider could confirm supersymmetry and bolster the somewhat flimsy circumstantial case for string theory with its smaller hyperspaces. As always in physics, more experiments and better data bring sharper insights. They could one day prove that Nature paints on a canvas of many more dimensions than meet the eye. Curiouser and curiouser indeed.

A neutron star merger known as GW170817 was picked up by the LIGO detector in 2017

MISSION PROFILE

Hayabusa2

This innovative mission will visit the distant asteroid Ryugu and collect pieces of it to answer some of the Solar System's most pressing questions

Mission type
Space probe
Operator
JAXA
Launch date
3 December 2014
Target
162173 Ryugu
Arrival at Ryugu
27 June 2018
Primary objective
Survey the C-type asteroid, and collect and return a sample
Status
Active

Professor Sei-ichiro Watanabe
Project scientist
Watanabe is a professor in the Department of Earth and Environmental Sciences of the Graduate School of Environmental Studies at Nagoya University in Japan. He has been part of the Hayabusa2 mission for seven years and his areas of expertise are the planet formation theory, simple modelling of climate systems and the coevolution of life and Earth.

The successor to Hayabusa is currently in the depths of the Solar System spying on another asteroid, with plans to steal a sample away for Earth-based analysis. Both Hayabusa missions had a common goal: to understand these ancient time capsules that are dotted throughout the Solar System. However, the Japan Aerospace Exploration Agency (JAXA) wanted to sample another type of asteroid for its second attempt to further understand their differences.

Asteroids were formed along with the planets over 4 billion years ago, and since then they have been floating around space, orbiting the Sun. Hidden within these frozen pieces of rock are the early chapters of the story of the Solar System. However, asteroids are not as black and white as thought by some; there are many types of asteroids that exhibit different features. Hayabusa visited the small near-Earth asteroid 25143 Itokawa in 2005, and successfully returned samples of the S-type (siliceous-type), 540-metre (1,772-foot) rock (at its longest dimension).

On 3 December 2014 Hayabusa2 was successfully launched on board the H-IIA launch vehicle from the Tanegashima Space Center in Minamitane, Japan. This updated version of Hayabusa includes exciting new features and landers. Onboard instruments include optical navigation cameras, a near-infrared camera and a thermal-infrared camera, but there are also deployable payloads. Where Hayabusa only had the MIcro-Nano Experimental Robot Vehicle for the Asteroid (MINERVA) minilander, which unfortunately did not go to plan due to a error in deployment, Hayabusa2 has three rovers and one main lander. MINERVA-II-1 and MINERVA-II-2 were designed to hop along the surface to conduct probes. The Mobile Asteroid Surface Scout (MASCOT) lander will use four internal instruments to examine the surface up close while jumping from one spot to the next.

So what asteroid did JAXA choose, having already sampled an S-type asteroid. "The primary objective of Hayabusa2 is to elucidate the formation, dynamical and material evolution and impact history of a carbonaceous [C-type] asteroid," says Watanabe. A C-type asteroid is a more primitive asteroid compared to an S-type, so astronomers are hoping to delve deeper into the past. "We can understand the evolution of building blocks of planets [planetesimals] around the 'snow line' - the boundary between the inner and outer Solar System," says Watanabe. "We can also identify possible sources of water and organic materials delivered to the early Earth."

The chosen destination was 162173 Ryugu. Not much was known about the asteroid until Hayabusa2's arrival on 27 June 2018. Before Hayabusa2's eyes, Ryugu began to take shape. The most striking thing is the almost diamond-like shape to it, with a mean diameter of almost one kilometre (0.6 miles). Scientists also noticed that its surface shares some similarities with Itokawa in that there are many boulders and a grooved terrain. What's more noticeable about Ryugu though is that there are more noticeable impact features - dents in the surface.

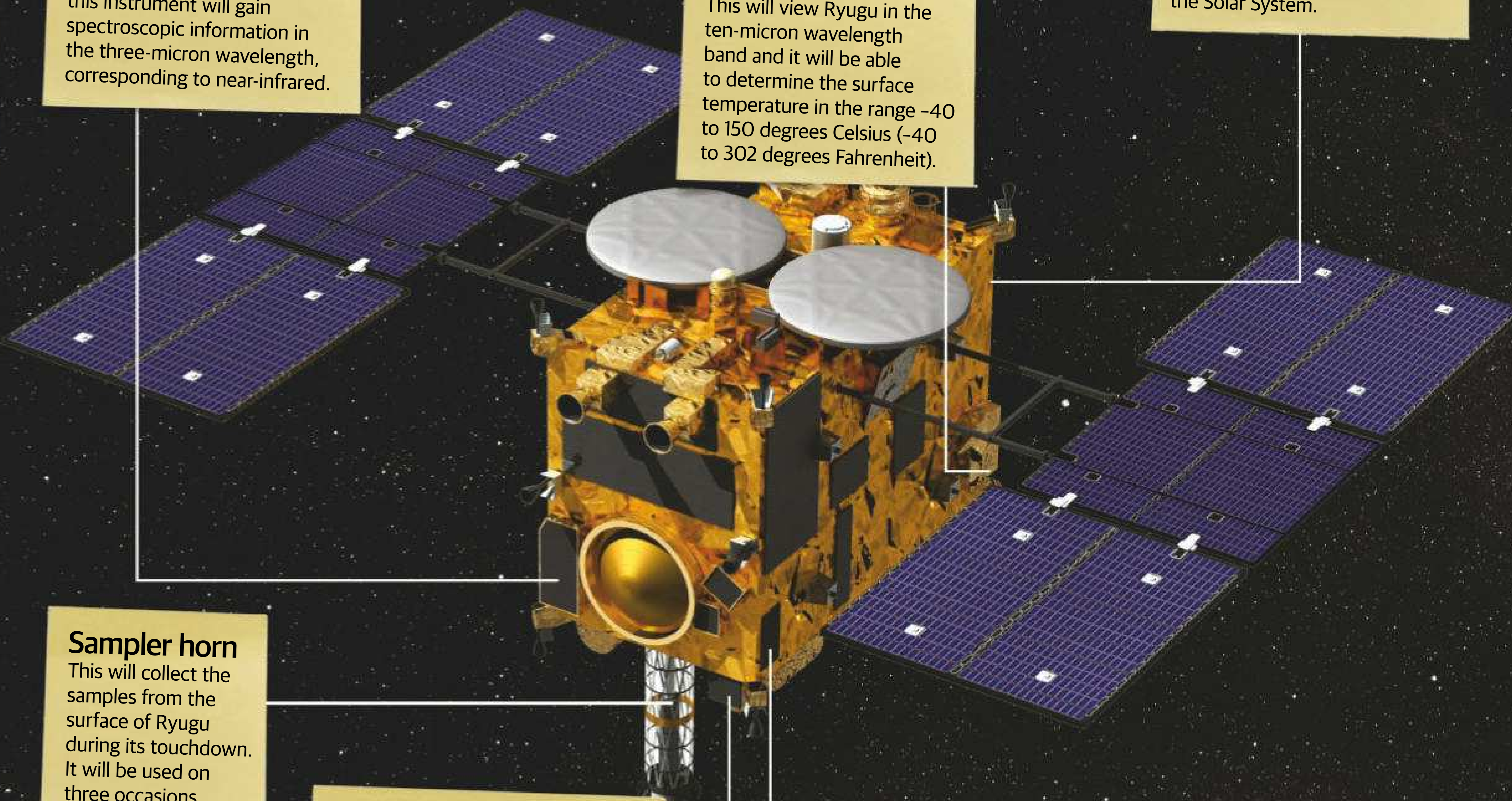
In September and early October 2018 the Hayabusa2 team decided to release the rovers and landers. The two MINERVA-II-1 rovers, Rover-1A and Rover-1B, were the first to touch down on the mysterious asteroid, skimming across the surface and providing some magnificent images as they did so. The next to follow was the MASCOT lander, which was deployed in the opening days of October 2018. In the closing days of October the mission will begin its most exhilarating feat of scientific and engineering brilliance as Hayabusa2 conducts its first touchdown onto Ryugu and collects its first sample of interstellar rock.

> "Sampling surface material is the most challenging task"
> **Professor Sei-ichiro Watanabe**

"Sampling surface material of the target asteroid is the most important and challenging task for the Hayabusa2 mission. A sampler horn is extended beneath the spacecraft to conduct surface materials to a sample catcher inside the main body of Hayabusa2," explains Watanabe. "The sampling will be performed within a few seconds, during which only the flexible sampler horn touches the asteroid's surface, before the firing of the thrusters for ascent. Exactly speaking, the sequence is not a landing but a touch-and-go, and we call it a 'touchdown'."

After two touchdowns Hayabusa2 will release its impactor between March and April 2019. Its artificial surface-destroyer will plunge into Ryugu, unmasking rock that hasn't been exposed to space in billions of years. After this impact Hayabusa2 will collect its third and final sample, after which the remaining MINERVA-II-2 rovers will be deployed. This concludes Hayabusa2's stay at Ryugu, and in late 2019 the craft will head back to Earth with a stocking not full of coal, but rare asteroid samples to help explain how our Solar System evolved.

Hayabusa2's toolkit



Near-Infrared Spectrometer
Just one of the spectrometers on board the spacecraft, this instrument will gain spectroscopic information in the three-micron wavelength, corresponding to near-infrared.

Thermal-Infrared Imager
This will view Ryugu in the ten-micron wavelength band and it will be able to determine the surface temperature in the range -40 to 150 degrees Celsius (-40 to 302 degrees Fahrenheit).

Ion engine
This improved electric propulsion will convert xenon into plasma ions, generating the speeds needed for Hayabusa2 to travel around the Solar System.

Sampler horn
This will collect the samples from the surface of Ryugu during its touchdown. It will be used on three occasions.

Laser altimeter
This instrument is key in maintaining a certain altitude from the asteroid, while acquiring important data about the asteroid's topography, gravity and albedo, between 30 and 25,000 metres (100 and 82,000 feet).

Optical Navigation Camera-Wide
Multiple cameras comprise this instrument, including telescopic and wide-angle cameras which are dedicated to scientific observations and navigation of the spacecraft.

Deployable parts

MINERVA-II-1 rover
Demonstrates the movement mechanism. Two small rovers are equipped with cameras, a temperature sensor, accelerometer and more.

MINERVA-II-2 rover
Built as a collaborative effort between different universities, it will provide another opportunity to study the surface up close.

MASCOT lander
MASCOT weighs approximately 10 kilograms (22 pounds) and carries four instruments on board. It will travel across the surface by jumping around.

Impactor
The Small Carry-on Impactor (SCI) will collide into the surface and reveal internal rock that hasn't been contaminated by space radiation or other environmental effects.

Deployable Camera 3
DCAM3 will image the SCI and the asteroid as it impacts into the surface to carefully study the whole event and the ejecta released.

Re-entry capsule
This will contain the collected samples. It's heat shield must be able to withstand 3,000 degrees Celsius (5,400 degrees Fahrenheit) to keep the sample intact.

MISSION PROFILE

Progress report

Since its arrival at Ryugu, Hayabusa2 has been busy. It is testament to the whole Hayabusa2 team that they have not only sent a space probe to Ryugu - which is extremely difficult given the asteroid's minute gravity - but they have also successfully released the MINERVA-II-1 rovers and the MASCOT lander. Watanabe provided us with an update of the mission, saying: "We have done global mapping of Ryugu using an optical camera with seven-band filters, the Near-Infrared Spectrometer, the Thermal-Infrared Imager and a laser altimeter. Several descent observations, including gravity measurement, were also done. We deployed two rovers, MINERVA-II-1A, and -1B, in September, and lander MASCOT today [3 October 2018]."

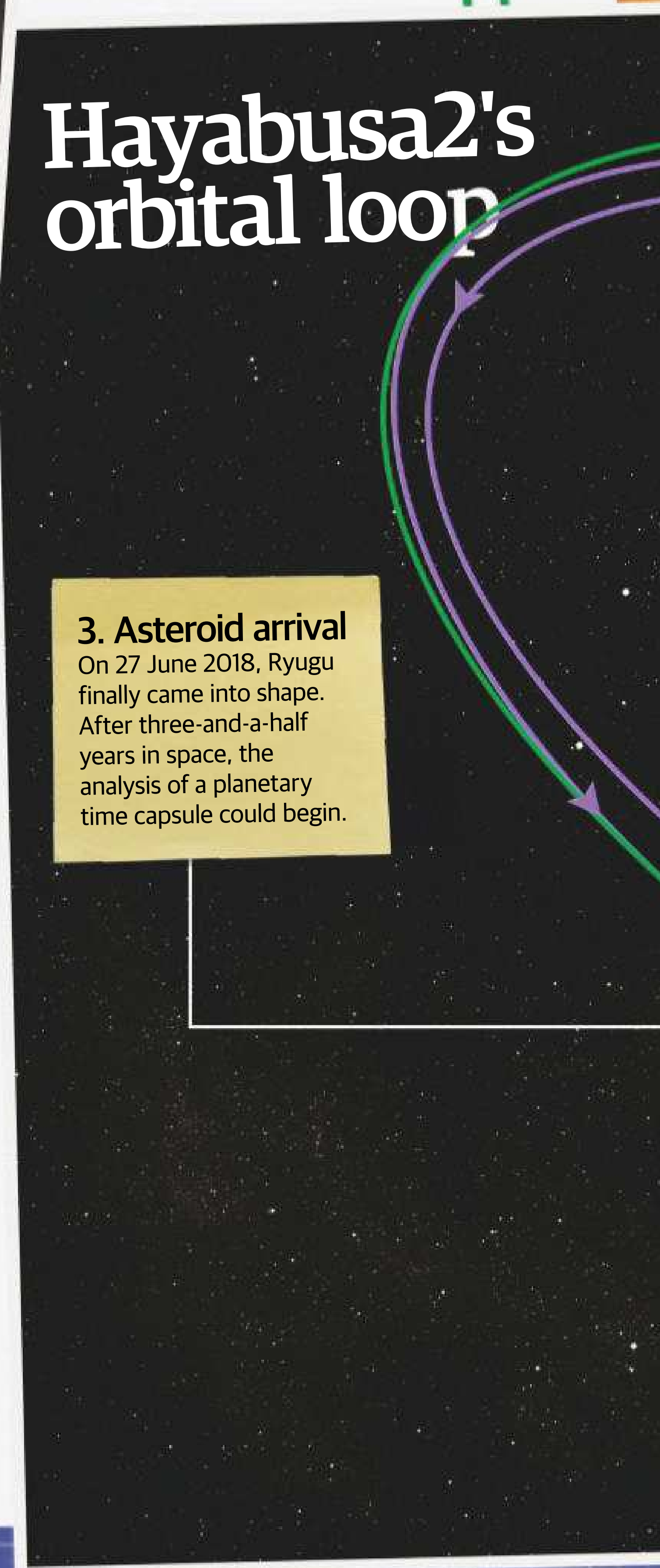
The inflation in worldwide news concerning Hayabusa2 has come because of its impressive accomplishment, and also the pictures it has produced. The two MINERVA-II-1 rovers, known as Rover-1A and Rover-1B, have been sent skimming along the surface due to the asteroid's low gravity and have revealed its rocky nature using their wide-angle and stereo imaging systems.

As for the deployment of the MASCOT lander, this will provide a more comprehensive analysis of the rock beneath its figurative feet. Created by the German Aerospace Center (DLR) and the French National Centre for Space Studies (CNES), four instruments were fitted onto the lander; these include a wide-angle camera, a hyperspectral microscope, a thermal radiometer and a magnetometer.

But what's next? As mentioned previously, the next step is sampling the surface with a controlled descent. "Ryugu is a castle of boulders. We should manage to touch down on narrow vacant land without boulders greater than 0.5-metres (1.6-feet). It is a difficult challenge so we will do rehearsals to assure the needed precise navigation of the spacecraft," explains Watanabe. Then, between March and April 2019, scientists will await the crater generation via a explosive impactor.

The surface of Ryugu photographed using the Optical Navigation Camera

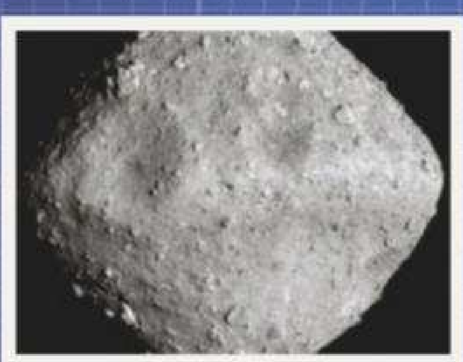
"We have done global mapping of Ryugu and several descent observations, including gravity measurement were also done" **Professor Sei-ichiro Watanabe**



Retrieving a sample from an asteroid

Arrival at Ryugu
27 June 2018

After a three-and-a-half-year journey, Hayabusa2 finally arrives at Ryugu and is inserted into a delicate orbit that remains in relatively close proximity to the asteroid.



Surveying the surface
July 2018 to February 2019

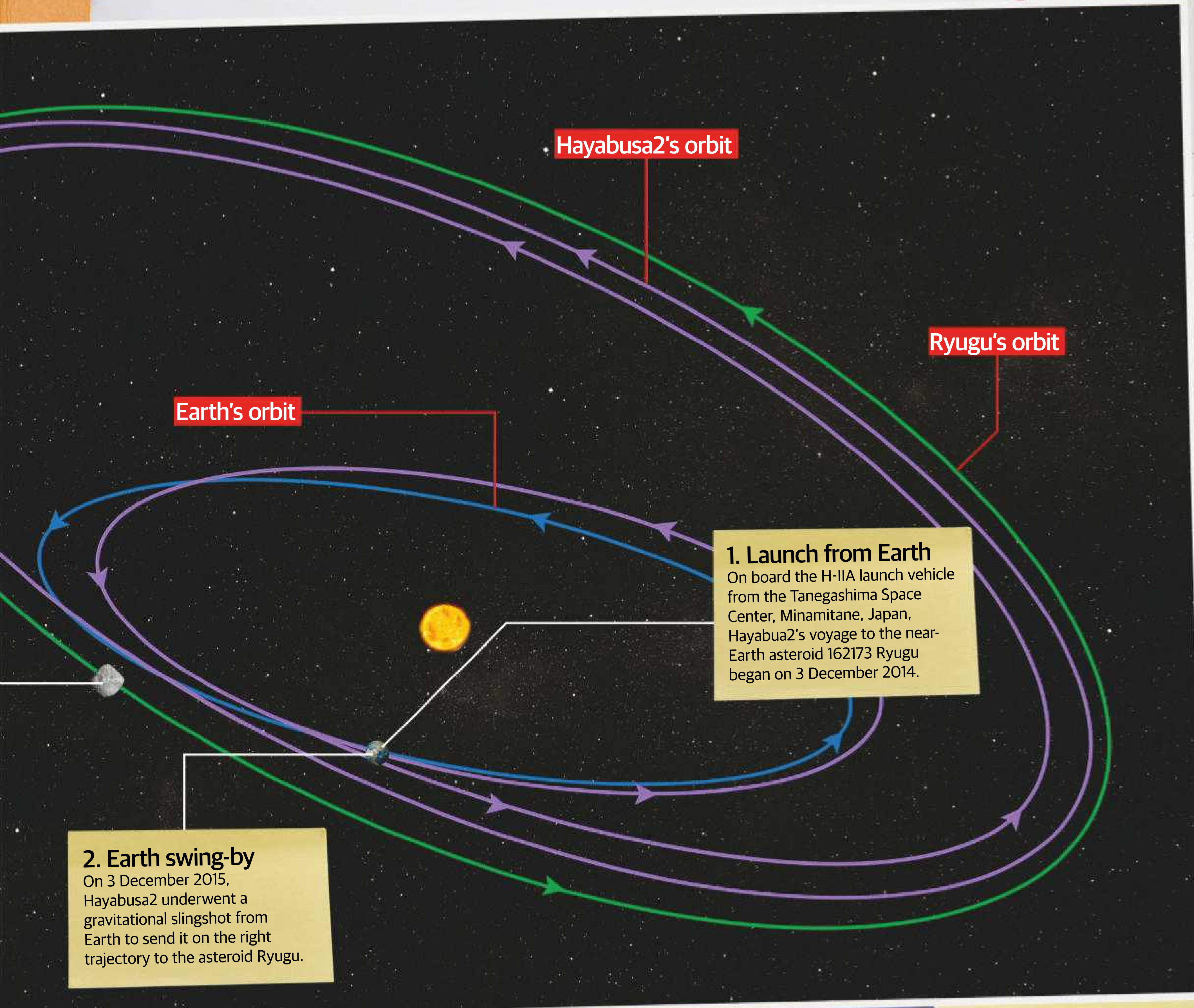
The following months provide in-depth analysis of the surface, including deployment of rovers and a lander, in order to gather information to evaluate sample collection sites.

Impactor inbound
March–April 2019

Hayabusa2 will release the SCI, the explosive impactor that will thrash the surface of Ryugu and generate a crater in order to uncover the ancient, rare subsurface rock.

Making touchdown
April–May 2019

After the site has been deemed clear with no potential debris interference, Hayabusa2 will perform another touchdown, descending onto the explosion site.



1. Launch from Earth

On board the H-IIA launch vehicle from the Tanegashima Space Center, Minamitane, Japan, Hayabua2's voyage to the near-Earth asteroid 162173 Ryugu began on 3 December 2014.

2. Earth swing-by

On 3 December 2015, Hayabusa2 underwent a gravitational slingshot from Earth to send it on the right trajectory to the asteroid Ryugu.

Pinching a sample

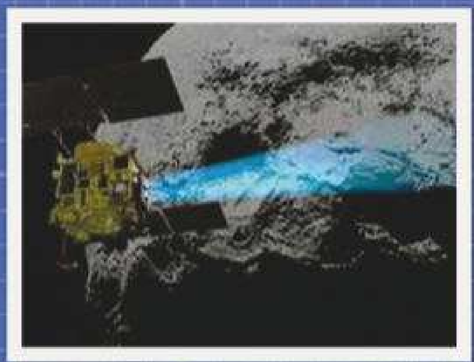
April–May 2019

Hayabusa2's sampler horn will gather a piece of this rock and seal it using a newly developed metal seal system so that volatile gases can be brought back safely.

Evacuating the premises

November–December 2019

At the end of its scientific operations at Ryugu, Hayabusa2 will start its return to Earth, using its ion engine to put it in a trajectory orbit back home.



Re-entry to Earth

December 2020

The spacecraft will release its re-entry capsule containing the samples. As it is fitted with a heat shield, it will be able to withstand the temperatures caused by atmospheric friction.

Main objectives

Understand the Solar System's origins

Not only can asteroids tell astronomers about the origins of the Solar System, they could also hold the answers to how the Earth received its water and organic materials.

Continuing unique deep-space exploration

Asteroid-sampling missions are a new category of space exploration mission, and Hayabusa2 is dedicated to making this type of mission more reliable and successful.

Benefits for the scientific community

With new missions come new technologies. The new technologies will benefit the scientific community as well as the improved knowledge on potentially hazardous near-Earth asteroids.

MARS SEASON 2

BEHIND-THE-SCENES EXCLUSIVE

The National Geographic show about Martian exploration is back, and **All About Space** got a sneak peak at what's to come from Budapest

Reported by Lee Cavendish

Behind the scenes with *MARS* Director Stephen Cragg

Optimism and excitement are the feelings that permeate all around the set of National Geographic's highly anticipated second season of *MARS* at Korda Studios in Budapest, Hungary. The first season gave its audience six exciting episodes with an innovative viewing experience, with half of the season being a documentary and the other being a drama series of a group of astronauts undertaking the incredible journey to colonise Mars.

Now everyone is reunited again for season two, along with some new faces to the cast and crew for an even bigger adventure. **All About Space** got the chance to get the full tour and sit down and talk with most the team. Watching everyone at work was incredible and exciting. Everyone at Korda Studios is working hard to create a show that will inspire and inform the public about what is to come from the future of Martian exploration. With organisations such as SpaceX and NASA emphasising their desire to take the next step to uncharted territory, this show is a glimpse into the future.

This season doesn't pick up straight from season one, which was set in 2033, as it leaps into the future even further and reveals the scene in 2042. The International Mars Science Foundation (IMSF) crew have finally settled on the Red Planet and constructed their home base, known as Olympus Town. However, the need for funds has brought in a private sector to satisfy the financial demand. This private organisation, Lukrum Industries, has now come to Mars to mine its resources, inadvertently creating some tension in the process.

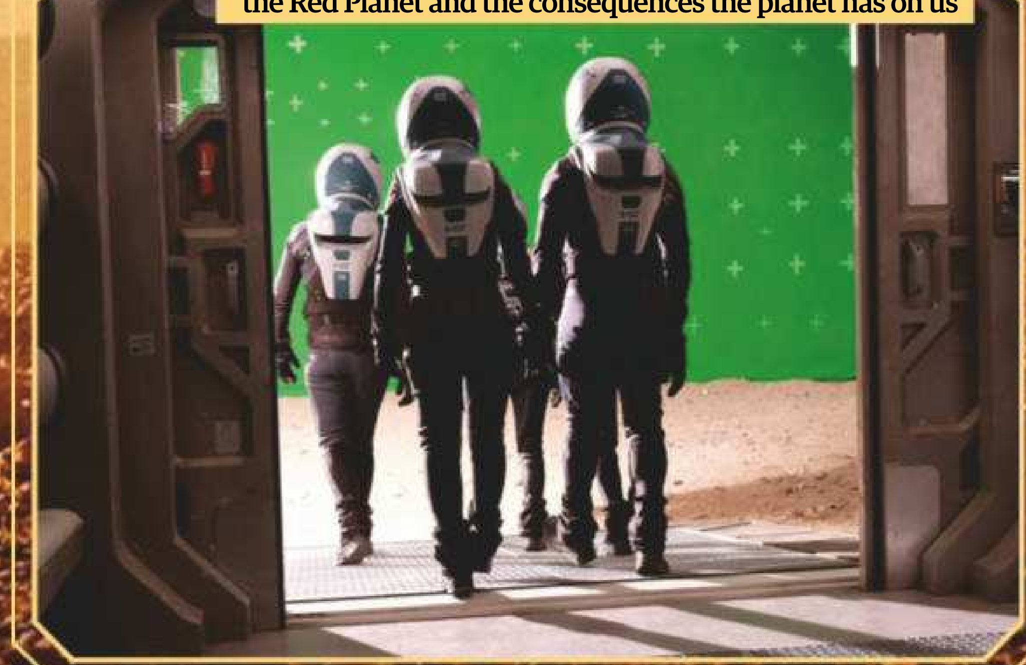
"In season one it was very much about the journey and surviving the journey. That was really exciting and good, but now they're there. So I think the interesting thing for all of us [*MARS* production team] to think is, 'how does one live there?' Not just get there, but live there for a long period of time," says Dee Johnson, the new showrunner on *MARS*, having previously worked for shows such as *Nashville* and *ER*. "This season takes us literally into new territory. With no laws, no government and no safety nets of any kind, what is it like to be among the first settlers of Mars? Not only do we explore dangers and mysteries of this brand-new world, but we also explore what it means to be human in a place where so few exist."

Being on a planet over 55 million kilometres (34 million miles) from home can't be easy. The show is a portrayal of these astronauts that have essentially left everything behind for the cause and now have to create a life and do their

IMSF crew mates Gunnar Cauthery (as Mike Glenn) with Jihae Kim (as Hana Seung) on the exterior set in front of a green screen

FILMING THE LANDSCAPE

A lot of the landscape shots of *MARS* were filmed outside, with production creating the rocky surface as similar to the Red Planet as possible, and a huge green screen behind the astronauts.



Having established humankind as an interplanetary species, *MARS* examines the impact that humans have on the Red Planet and the consequences the planet has on us

The six-part arc jumps ahead several years into the future after the Daedalus astronauts have built a fully fledged colony, Olympus Town

> "This seems like a whole new genre, with it being called science future rather than science fiction" **Akbar Kurtha**

The Lukrum team connecting the pipeline on the 'surface of Mars'

LUKRUM CONSTRUCTION

Lukrum construction scenes were filmed at night to create the illusion of underground assembly. The Lukrum suits are essentially the same as the IMSF crew's, the only difference is the colour

The original cast are joined by new faces for the second season

Jihae as Joon Seung in the SAGA 4 mid deck

The Lukrum Crew celebrating connecting to Olympus Town

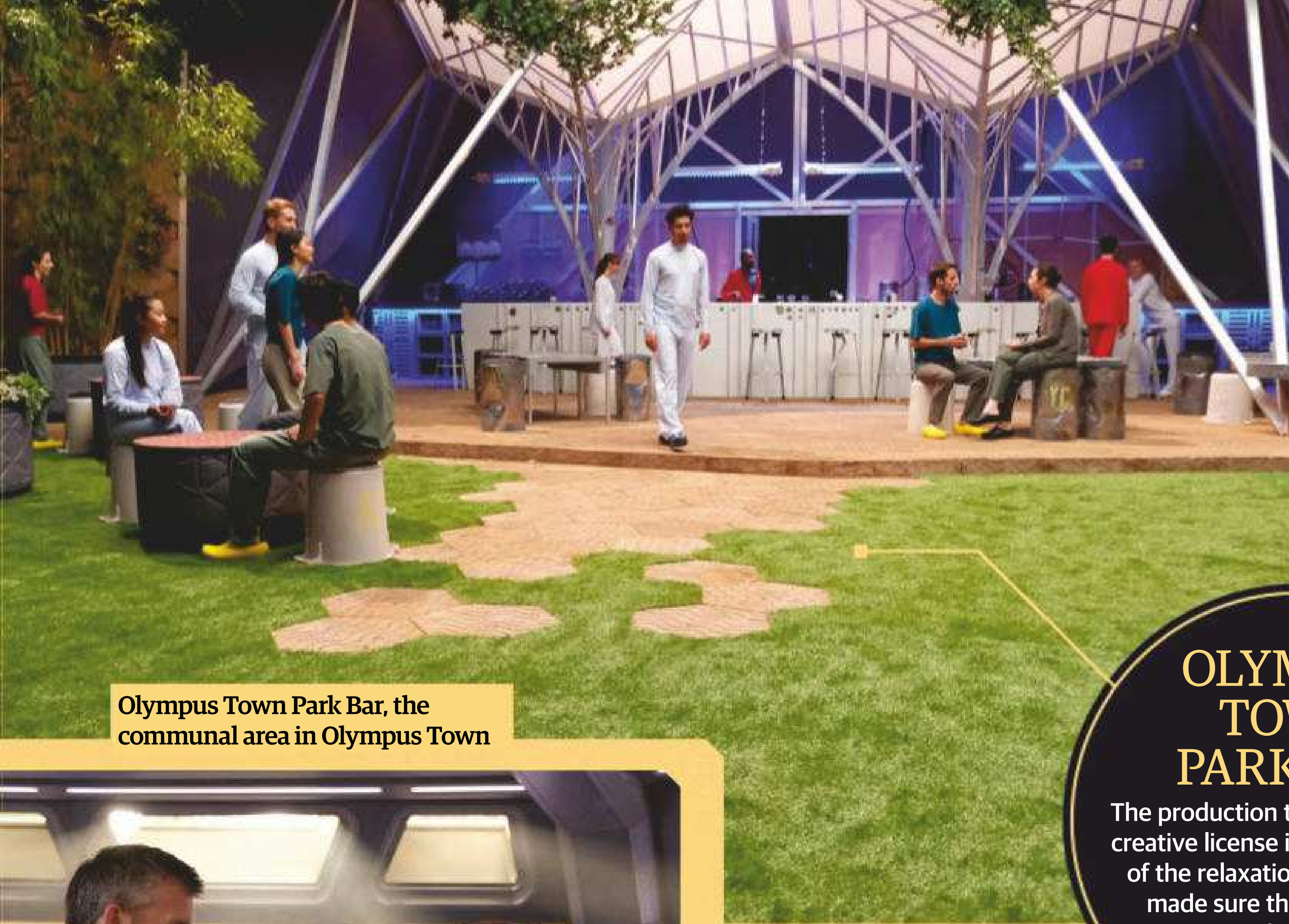
duty on the Red Planet. The returning crew will include Jihae as both Hana and Joon Seung, Sammi Rotibi as Robert Foucault, Clémentine Poidatz as Amelie Durand, Alberto Ammann as Javier Delgado, Anamaria Marinca as Marta Kamen and Cosima Shaw as Leslie Richardson. All of them are extremely excited to see their characters and the show evolve from the first season, and particularly the interesting development in crew tensions between IMSF and Lukrum. When we spoke with Sammi Rotibi, he told us what he thought of the tension from the point of view of a IMSF crew member: "You've been there [Mars] for nine years. Then you have a private entity coming in with their power and money," says Rotibi. "Are they coming to be a part of advancement of the human race or is it just for their own greed?"

This storyline is intriguing for many reasons as it plays on the current theme of the modern privatisation of space. There is always news coming out about private industries becoming involved in space travel, most notably Elon Musk's SpaceX, but there is also NASA's newly announced Commercial Crew and the space tourism organisation known as Space Nation. This is just a sign of the times in that space is becoming more accessible to everyone, including private industries that hope to make a profit from it. What *MARS* second season seems to show is that this could well be the case for Mars in real life, too.

> "We also explore what it means to be human in a place where so few exist"
>
> **Dee Johnson, season two showrunner**

However, the conflict between the show's two companies does not spill into the crew off-screen, as everyone has nothing but good words to say about their team. The newly assembled 'Lukrum' crew consists of Jeff Hephner as Kurt Hurrelle, Gunnar Cauthery as Mike Glenn, Esai Morales as Roland St. John, Levi Fiehler as Cameron Pate, Roxy Sternberg as Jen Carson, Evan Hall as Shep Marster and Akbar Kurtha as Dr Jay Johar. "I was a little nervous flying over. I got the job and 24 hours later I was flying over here. It's kind of nerve-wracking going into an already established thing. You feel like the new kid on the first day of school. Fortunately I met all of the original cast and they were all really welcoming," explains Levi Fiehler.

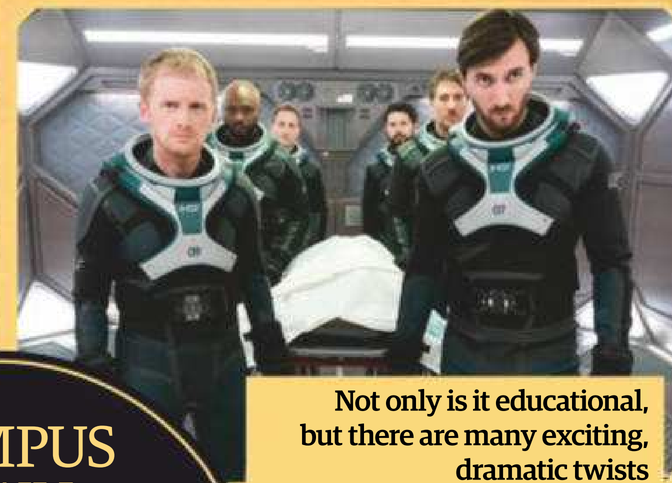
After asking the actors and actresses about their knowledge and interest in space exploration before and after being a part of this series, it became clear that this show has also inspired them. As



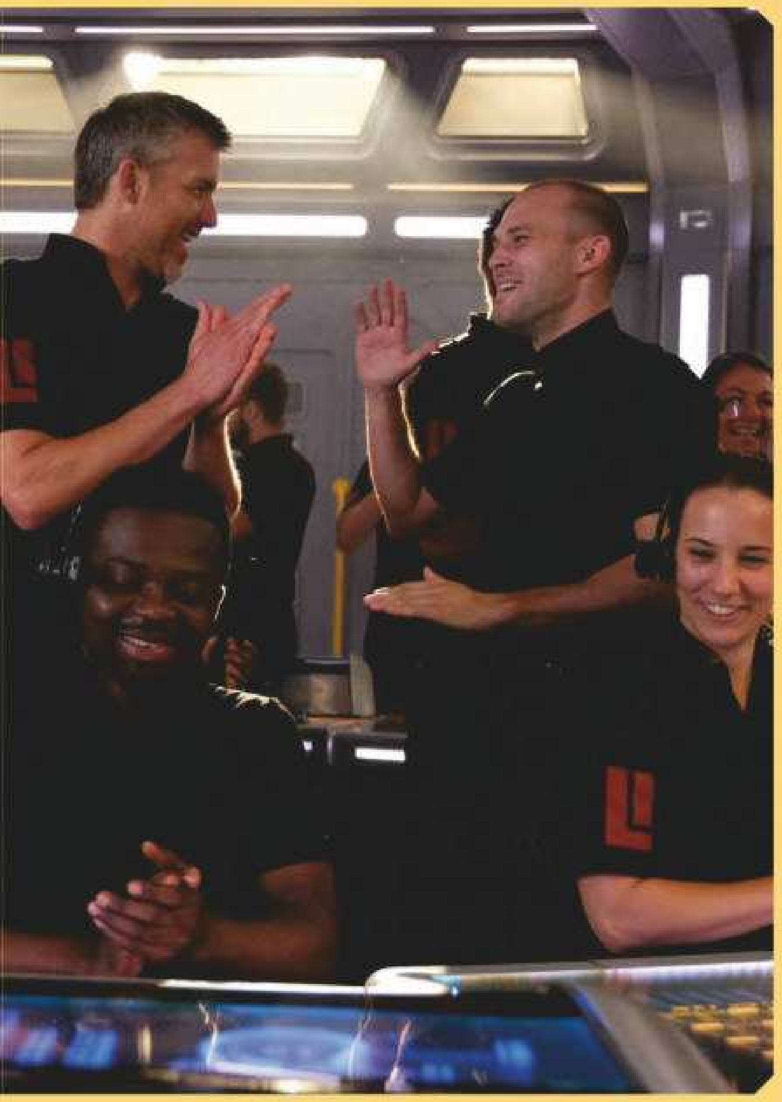
Olympus Town Park Bar, the communal area in Olympus Town

OLYMPUS TOWN PARK BAR

The production team were allowed creative license in the construction of the relaxation area. The team made sure that the area was constructed using left-over items and scrap metal.



Not only is it educational, but there are many exciting, dramatic twists



On the *MARS* Olympus Town control room set

Lukrum constructs their own structures on Mars, much to the dismay of the IMSF crew

Alberto Ammann (as Javier Delgado) is cleaned in the 'CLEEN ROOM'

Gunnar Cauthery says, "I would say I had sort of a normal level of interest [in space exploration before filming *MARS*]. Like when there's an exciting story in the news, for example, like when we launched the Mars rovers. When there were stories in the news, it would pique my imagination; other than that I wouldn't say I was searching for it. But I am now."

Another exciting aspect of the second season is the perceived terraforming and technologies of 2042. The design team showed us around their quarters, and we were amazed at how much detail went into the equipment and technologies. They explained how the astronaut suits were given a complete revamp, how Olympus Town's living quarters were carefully constructed and even how they anticipate the practicality of 3D printers in any eventual Mars colonisation.

This isn't like anything from science fiction where they erupt weird new technologies based on imagination – these are all ideas based on the evolution of technology. Akbar Kurtha puts it nicely, explaining, "What *MARS* is asking of us and asking of its audience is to be more intelligent and invested in different ways [from science fiction films]. What's interesting for us as actors is that this seems like a whole new genre, with it being called science future rather than science fiction." However, there were some things that were inspired by science fiction, with the main IMSF control room looking recognisably similar to the control room from *Star Trek*.

Educating is a key aim for this show, and this is why the episodes will include a documentary running alongside. After speaking to the production team it appears there will be more drama to this season than the first and less of the documentary – most possibly a 70/30 split. However, the show has still assembled some of the smartest minds to talk about space and the exploration of Mars. These names include SpaceX's Elon Musk; popular science communicator Bill Nye; former NASA chief scientist Ellen Stofan; theoretical physicist and futurist Michio Kaku; author of *The Martian*, Andy Weir; former NASA astronaut Leland Melvin and author of *How We'll Live on Mars*, from which the series was based, Stephen Petranek.

It is clear that every department in this National Geographic production of *MARS* season 2 is working hard to manufacturer a uniquely informative drama series with a documentary running shoulder-to-shoulder. This different kind of project has been a clear motivator for everyone involved and, having seen what is to come from this season, we at **All About Space** can't wait to see it all come together on screen on 11 November 2018 and the weeks that follow.

***MARS* returns on 11 November 2018 at 8pm GMT on National Geographic**

MISSION TO THE TROJAN ASTEROIDS

This new NASA mission will search the uncharted chunks of space rock within the orbit of Jupiter

In the first mission of its kind, NASA will venture to Jupiter's mysterious Trojan asteroids. These space rocks orbit in two groups – one ahead and one behind the gas giant – in a gravitational balancing act that occurs between the Sun and Jupiter, also known as a Lagrange point. The mission, named Lucy, was announced in January 2017 as the 13th mission of NASA's Discovery Program, following such missions as InSight, Kepler and MESSENGER. This particular mission will be operated by NASA's Goddard Space Flight Center in Greenbelt, Maryland, United States and the Southwest Research Institute in San Antonio, Texas.

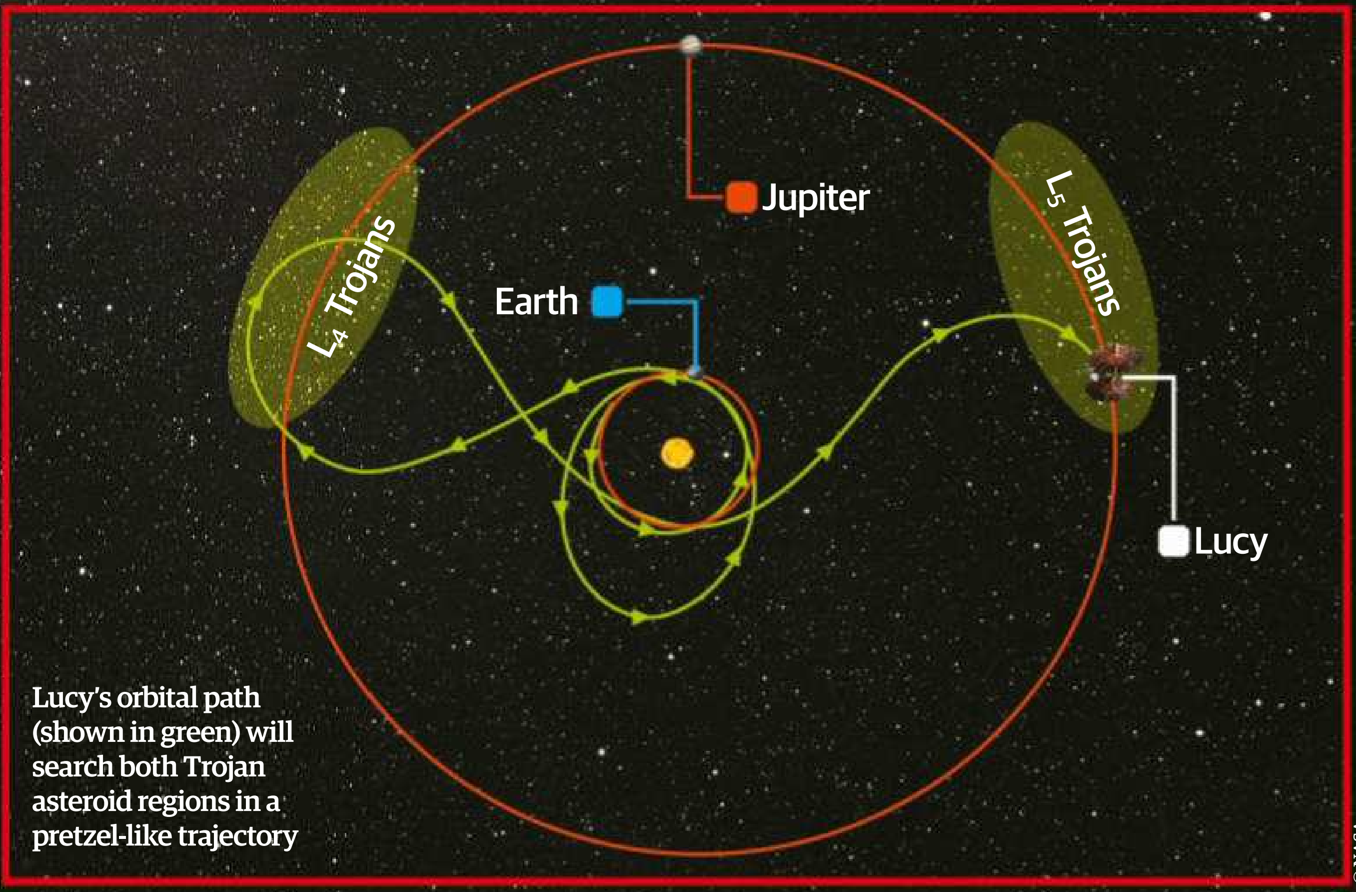
Although the mission is still in its preliminary design phase the spacecraft will include a fine tuned remote-sensing instrument suite that will carefully study the geology, surface composition, thermal and physical properties, such as the masses and densities, of the Trojan asteroids. The suite will include three sets of instruments including imaging and mapping instruments with a colour imaging and infrared mapping spectrometer, a high-resolution visible imager and a thermal infrared spectrometer, designed and built by Goddard, Johns Hopkins University Applied Physics Laboratory in Laurel, Maryland, United States and Arizona State University in Tempe, United States, respectively.

Once launched in October 2021, Lucy will undergo a 12-year mission dedicated to studying these primitive bodies, as scientists believe they hold the key to understanding the early years of the Solar System and how the planets formed and evolved, and possibly even the origin of life on Earth. The mission was named after the discovery of the remains of a 3.2-million-year-old female hominid as both have the same common goal – to understand our past. Whether by understanding human evolution or understanding the evolution of the Solar System, humanity strives to understand its past in order to influence its future.

Between the years of 2025 and 2033 Lucy will get up close to seven different asteroids, the first of which is in the main asteroid belt, and then make its way out to the Trojan asteroids before finishing the mission by observing a rare binary asteroid system. Asteroids are commonly categorised under different 'types', such as C-types, P-types, D-types and many others, based on their observed characteristics and compositions. The types specified above are the ones Lucy will study, providing a fine spectrum of analysis and allowing scientists to ascertain whether each type was formed in the main asteroid belt between Mars and Jupiter or whether it was originally created in the distant Kuiper belt beyond the orbit of Neptune more than 4 billion years ago.

This spacecraft will do what no other mission before it has done in gaining valuable data on multiple destinations in independent orbits around the Sun and revealing the diversity of the ancient rocks that are residing in the very depths of the Solar System.

> "Once launched Lucy will undergo a 12-year mission dedicated to studying these primitive bodies"



Lucy's orbital path (shown in green) will search both Trojan asteroid regions in a pretzel-like trajectory

INTERVIEW BIO

Wally Funk
Funk was a 22-year-old aviator when she volunteered to be part of the Women in Space Program. Having undergone the same tough, physiological screening as the astronauts who had been selected for Project Mercury, she was one of 13 who passed. She and the others suffered a major blow as funding was pulled, leaving her dream to become an astronaut in tatters.

Although she then became a Goodwill Ambassador and a flight instructor, Funk's desire to go into space has never left her.

"I don't get angry. I was disappointed. I threw it a fish"

Wally Funk's Mercury 13

In 1961, Wallace "Wally" Funk hoped to become one of the first women in space. Now aged 79, she's determined to embark on a journey of a lifetime aboard Virgin Galactic

When did you first become interested in space and what was it that caught your imagination?
First I was interested in flying. I jumped off the barn trying to fly when I was four years old wearing a Superman cape. Luckily I'd made sure there was a hay bale down there.

What steps did you take to become an astronaut as a teenager?
I didn't think about going into space for real until I was 21. But luckily all the things I did as a teenager were what you needed to become an astronaut. I was fit and did everything at altitude because I lived in Taos. That's where I was born and raised, in Taos, New Mexico, at 7,000 feet [2,134 metres]. I am used to altitude. I skied at 13,000 [3,962 metres].

So, as a youngster, I was able to do anything I wanted to do: bike, shoot, ride, ski. I was never told no. If I hurt myself I licked my wounds and went about my business. I was totally brought up differently from most girls. I had a Wild West costume as a child because I wanted to be a cowboy. A cowgirl. My mother got chaps for me, and boots. I had my gun and my belt, and I rode a palomino horse, Victor. I made model aeroplanes and liked space.

How did it feel to complete your first solo flight at the age of 16, and what did the aviation programme at Stephens College teach you?
When I first got to Stephens I didn't think I was going to like it. The girls had long hair and I had a short haircut. I was dressed well but I didn't fit in. They were frou-frou. About the second day, I called home and said, "I don't know if this is the right place for me." I was a tomboy. I did mostly sports. Mother spoke to my adviser and asked him if they had an airport, and Stephens had started an aviation programme in Columbia Municipal Airport. Mother told him to get Wally out there and I started flying.

I passed my solo license. It was great and I took mother up as my second or third passenger. I was thrilled and she was thrilled to go up. A dream had come true for her because she had always wanted to be a pilot, but she didn't tell me that until I was older.

I joined the Stephens Susies flight team, and in my last year I was super-qualified to go to NIFA [National Intercollegiate Flying Association] air meets in the United States. I'd have a co-pilot and she would navigate and I'd fly races and sometimes I'd win them. So it taught me how to fly and how to win races.

What drove you to volunteer to be a part of the Women in Space Program in 1961 and how important was it for you to try and become one of the first women in space?
I was working at Fort Sill military base in Oklahoma training pilots. I was a civilian and their first woman flight instructor. The year before I saw an article about Jerrie Cobb in *Life* magazine. She was a pilot, like me, and the first woman to pass the same tests as the Mercury 7 astronauts. It said she had complained less than the men had.

So I wrote to Jerrie and Dr William Randolph Lovelace - he was in charge of the tests - and volunteered as part of the Woman in Space Program. They only wanted women pilots and, same as the men, I took the astronaut tests in February 1961 in Albuquerque, New Mexico, at the Lovelace Clinic. I was the youngest to pass the tests. I was 22 years old - my parents had to sign permission for me to do them - and I excelled. In some of the tests, I beat the guys.

How gruelling were the physical and psychological tests - what were the most testing?
I swallowed three feet [0.9 metres] of rubber hose, I had barium enemas and had to place my hands

Wally was determined to become one of the first women in space, and she took part in rigorous training


No Man In Moon

Stephens Graduate Trains To Be Female Astronaut

Wally is ensuring she is well prepared for a trip into space by putting her body through the conditions she will experience, such as zero graviy

and feet in ice water for three minutes. All kinds of needles and electrodes were stuck in our bodies, not the kind that are plastered on today. They were sort of painful, but pain was not a situation with me. I would do anything. On the exercise bike test, measuring our lung capacity, you had to ride until you were exhausted.

A clock was right in front of you. It was a psychological factor, I'm sure, and you would pedal to the speed of a metronome. It was ticking, going back and forth in a room full of doctors and nurses. I wanted to break the barrier on that test and go for 11 minutes because ten was all they expected. It was pretty easy going until nine and a half, ten minutes, so I gritted my teeth, closed my eyes and felt my second wind coming, and I did it. All the electrodes were taken from me and they said, "Wally. I think we better help you." And I said, "No, I'm fine" and then I fell right down.

The worst test was when they injected ice water in your ear. It makes you go crazy and you lose control of your body. But mother said when I was four or five, when I had my horse Victor, if you fall off your bike or horse, you lick your wounds. Don't come back running home crying. They taught me to look after myself. When I was at Lovelace I took care of myself and I never complained. Only 13 of us passed these phase one tests – the same as the Mercury 7 astronauts.

You became one of the Mercury 13, yet a week before the final phase of training, the programme was cancelled: how disappointed and angry were you, and did you feel cheated?
I don't get angry. I was disappointed and I threw it a fish.

"I jumped off the barn trying to fly when I was four"

Did you consider giving up at this stage? Was there a feeling that you were facing a very unfair, uphill battle?
No. I decided to do the rest of the tests myself and find other places where I could get more testing. That's why I'm the only girl to have done all three phases of the astronaut training.

I had already taken some optional tests after phase one – psychological and evaluated stress response – with Rhea Hurrle [another member of the Mercury 13] before they'd cancelled. This was the isolation test where I stayed in an isolation tank, with water and air the same temperature as my body, in complete darkness for ten hours and 35 minutes. I beat all the guys on that one, including John Glenn. It makes most people go a little loopy, but not me.

So I decided to do all the remaining phase two and three tests by myself. I wrote to all the institutions and got in and did them. I did a centrifuge test at the University of Southern California and the Martin-Baker seat-ejection test at El Toro Marine Corps Air Station in California.

How did you feel in 1969 watching Neil Armstrong become the first to set foot on the Moon?
It was great. But there should have been a woman up there. We were ready to be astronauts. I was ready to be an astronaut and to go to the Moon.

Following the disappointment, you became a Goodwill Ambassador and America's first female aviation inspector. How much of a triumph, personally and historically, was this?
It was a great job and I loved it. After that I became an NTSB air-crash investigator, the first woman to do that too in the United States. I loved those jobs.

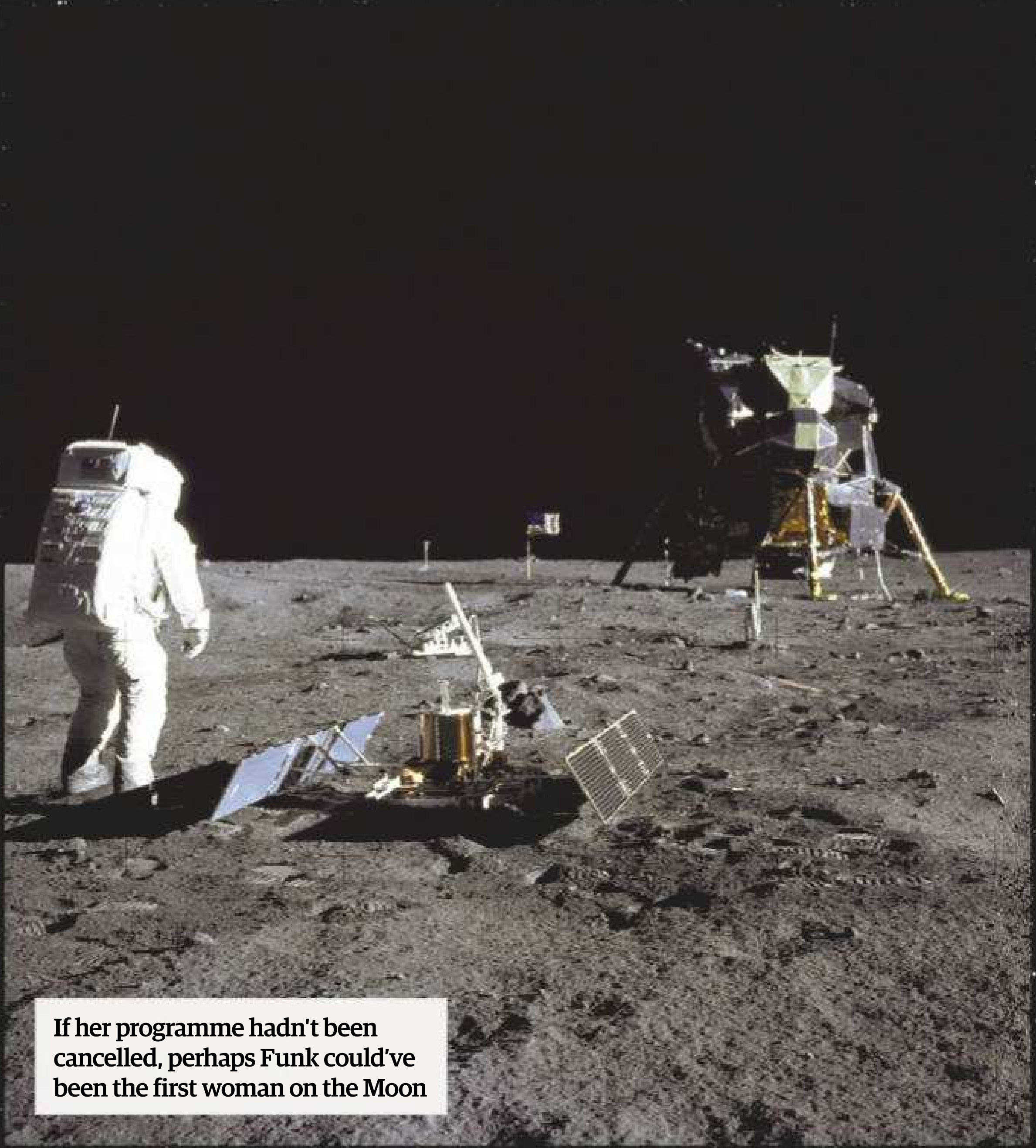
Despite your successes, your dream of becoming an astronaut has never wavered. How excited are you to have a place on a Virgin Galactic spaceplane?
I'm thrilled but I want to go up real soon. I'm going to be sat on the right-hand side, right behind the first officer.

What are you hoping to achieve during your spaceflight, and how are you preparing for it?
I keep real fit. I do exercises every day and take some vitamins. And I go flying every weekend.

How much has changed over the years? Is it now much easier for women to become astronauts or is more work still needed?
Nowadays the girls do just as well as the guys. My friend Eileen Collins [NASA astronaut] was the first girl to pilot the Space Shuttle. She's great. I met Samantha Cristoforetti [ESA astronaut] and she flew fighter jets in the Italian airforce and speaks five languages. These women are outstanding.

Do you dream that space travel will one day be open to us all?
Absolutely.

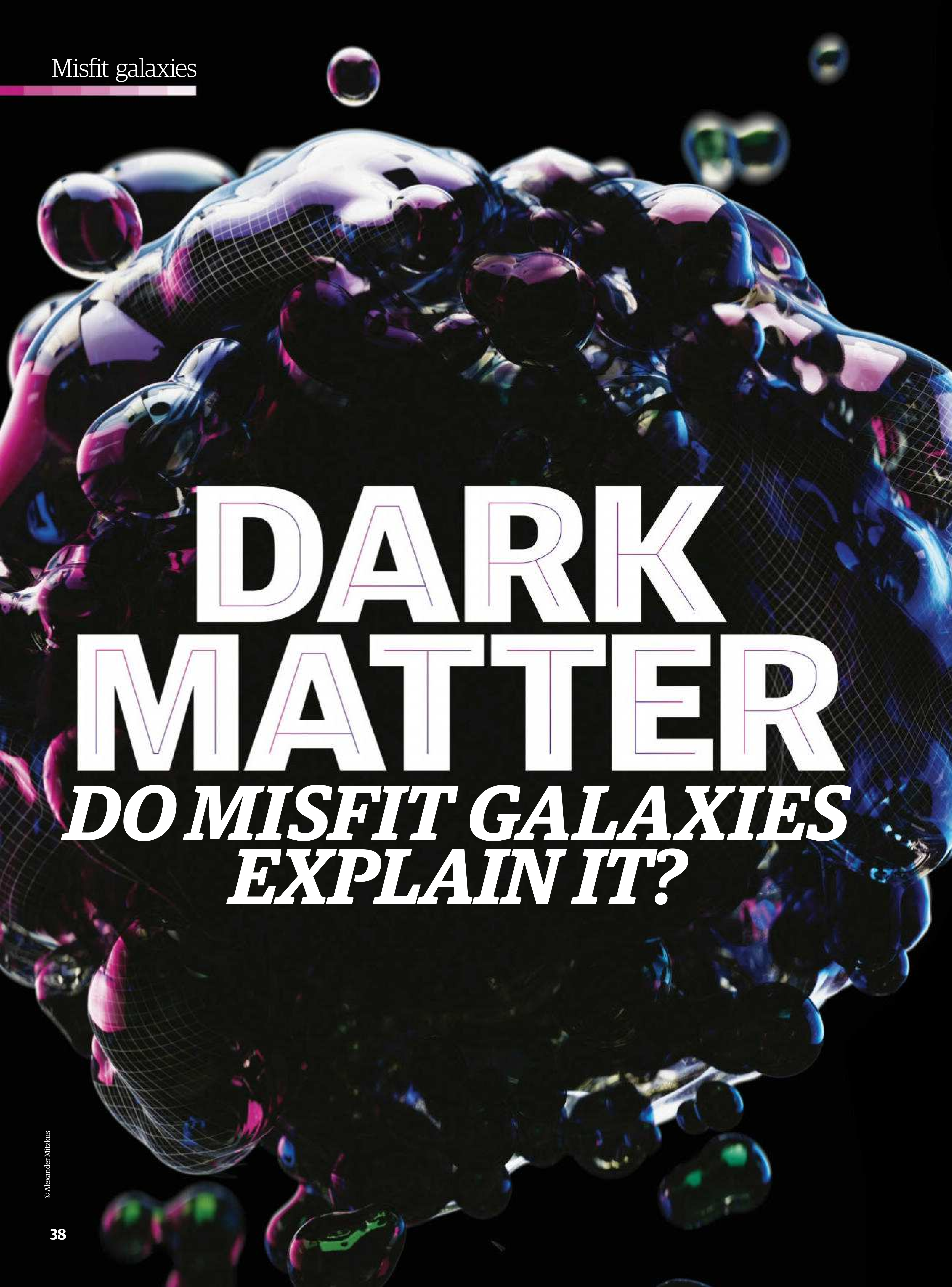
***Wally Funk's Race for Space* by Sue Nelson is published by Westbourne Press**



If her programme hadn't been cancelled, perhaps Funk could've been the first woman on the Moon

Funk has met Italian ESA astronaut Samantha Cristoforetti who holds the record for the longest uninterrupted spaceflight of a European, at 199 days and 16 hours

From left: The Mercury 13's Gene Nora Jessen, Wally Funk, Jerrie Cobb, Jerri Truhill, Sarah Rutley, Myrtle Cagle and Bernice Steadman



DARK MATTER

DO MISFIT GALAXIES EXPLAIN IT?

© Alexander Mitzkus

Misfit

How the smallest galaxies in the universe could shine a light on the invisible stuff that makes up almost everything in the cosmos

Reported by James Romero

We have no idea what 85 per cent of the stuff in the universe is. However, that hasn't stopped scientists using mysterious 'dark matter' to explain everything from waltzing galaxies to the evolving structure of the entire universe. Now the first observational evidence of it being pushed around by violent star explosions could solve a 30-year mystery inside tiny dwarf galaxies.

The earliest evidence of dark matter came from 1930s studies into the motion of galaxies in clusters. The relative speeds of these galaxies as they moved around each other were too high for the estimated gravitational forces at play to stop them flying apart. The additional gravity-inducing, but invisible mass was labelled dark matter.

"Back then it was a curiosity. No one believed it was something exotic," says Professor Justin Read, an astrophysicist at the University of Surrey. "It was thought to be just gas which was harder to detect." By the 1980s it was clear you needed this missing mass everywhere in the universe, and by the 1990s cosmologists were using it to explain the structure of the universe itself. We still don't know what this invisible mass matter is, but we have realised a few odd things about it.

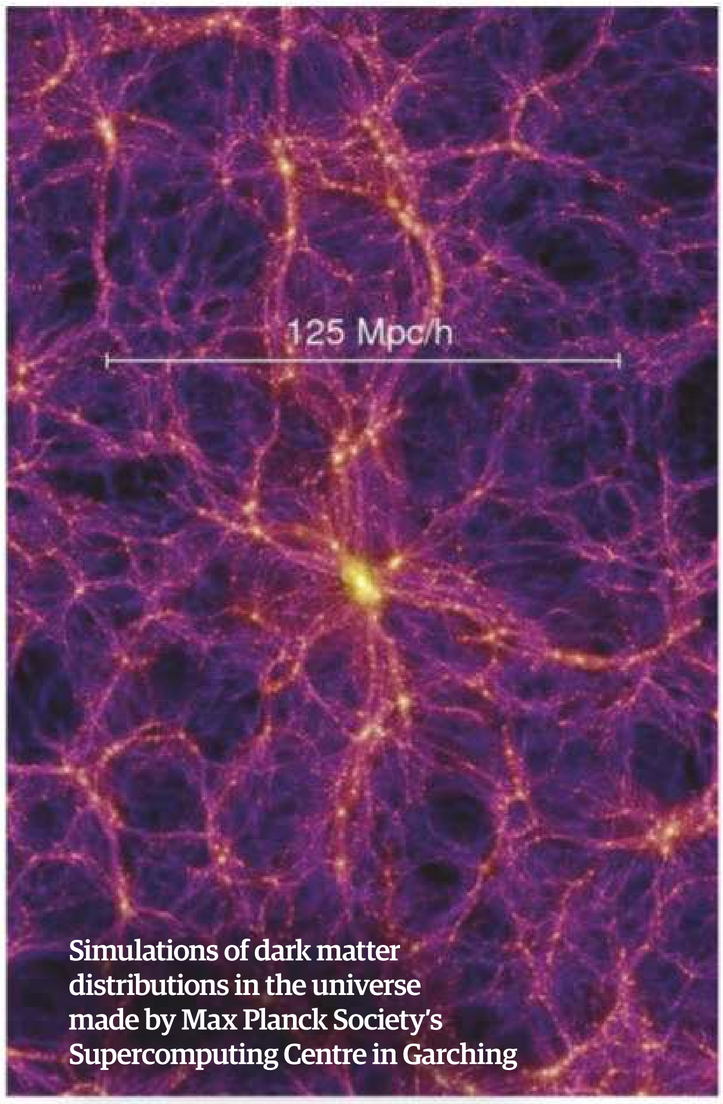
Most obviously it had to interact with normal matter via gravity, but not with light, otherwise we would have spotted it. It also didn't seem that bothered about its own kind: 'collionlessness' describes a ghostly behaviour where pouring dark matter onto other dark matter flows right through.

However, just because you don't understand something entirely doesn't mean it's not useful. The cold dark matter cosmological model, which takes Big Bang physics and incorporates what we know about dark matter and dark energy, the theoretical energy force working against gravity, provides a remarkable description of the evolving structure of the universe.

Yet on the scale of individual galaxies tensions arise, as theory clashes with observation. The oldest

Abell 1689 is an immense cluster of galaxies imaged here by NASA's Hubble Space Telescope. The relative speeds of galaxies in clusters like this one as they move around each other is too high to stop them flying apart

"Dark matter is usually the biggest beast in town, but this heating is an example of the tail wagging the dog" **Professor Justin Read**



Simulations of dark matter distributions in the universe made by Max Planck Society's Supercomputing Centre in Garching

and most notable of these is the cusp-core paradox, which looks at where dark matter likes to live inside some of the smallest galaxies in the universe. Standard models predict galaxies to be surrounded by a three-dimensional halo of dark matter with a dense 'cusp' at the centre. However, gas rotation measurements in the centre of dwarf galaxies found far less dense dark matter than predicted.

New dark matter properties were proposed to account for this discrepancy, given names like 'warm', 'fluid' or 'fuzzy'. Some researchers even used this conflict to reject dark matter altogether. So-called 'alternative gravity' theories suggest normal matter can account for any missing gravitational force, and all those discrepancies arise from our incomplete understanding of gravity.

However, many in the community sought a more straightforward explanation and pointed to problems in the dark matter models themselves. These complicated simulations were limited by computing power of the time, so shortcuts were required. In particular they assumed the universe contained only dark matter. "This is obviously wrong, but it was deemed a decent approximation," says Read. "By far the majority of mass in the universe is dark matter, and it only interacts with normal matter via the very weak force of gravity."

So, what difference could it make? Well, Isaac Newton's famous third law – that for every action, there is an equal and opposite reaction – demands normal matter must also push and pull dark matter around. It's the same often-overlooked reciprocal arrangement that sees the Earth exert a small degree of wobble on the Sun during its orbit. Given sufficient time, and in dwarf galaxies at least, Read's calculations suggested this could account for the missing dark matter.

To understand how, let's build a galaxy. First imagine a dark matter blob, inside of which our galaxy will form. The first step sees hydrogen gas cooling down at the centre. Even though the total mass of gas is comparatively tiny, its increasing concentration has enough gravity to raise the dark matter density in the centre.

Thus far we have succeeded in making the cusp-core paradox even worse by concentrating more dark matter in the core. However, the accumulating hydrogen gas doesn't just tug on dark matter. It continues to collapse, forming the first stars. When the largest of these die in violent supernovae they push gas outward through galaxy-scale winds.

As the gas flows out the gravitational field in the centre weakens, and the dark matter expands outwards. This process, known as 'dark matter heating', can be enhanced during 'starbursts', where high rates of star formation create lots of supernovae at the same time. Again the effect is small, but Read showed back in 2005 that through several cycles of star formation and death, such heating can push out enough dark matter to provide the density profiles observed. "Dark matter is usually the biggest beast in town, but this heating is an example of the tail wagging the dog," says Read.

While nice on paper, the work of Read and others represented only circumstantial evidence. Some still doubted the heating process existed. This is why Read was so excited when given the chance to test the theory. "This was my white whale. I wanted to make this sort of measurement for a long time."

The key to Read's test lies in those repeating star formation cycles. The need for them suggests galaxies who have experienced fewer years of star formation would have less time to push out their dark matter than those with long histories of forming stars. "If you strangle star formation you end the process that spreads dark matter out, and a galaxy should therefore retain a higher density centre," he explains.

So what could cause such strangling? One mechanism affecting our nearest dwarf galaxies occurs when they fall into our Milky Way through its surrounding corona of gas. Infalling galaxies' own gas is quickly pushed out by the corona, which is too hot to condense onto the stripped-bare dwarf, and star formation collapses.

In a new paper Read and his colleagues measured the central dark matter density in 16 dwarf galaxies of comparable masses around our Milky Way. Their sample included both fallen and gas-free galaxies, and those that had avoided such a fate.

Measurements of gas cloud rotation speed at various distances from the galactic centre were used for galaxies with gas clouds. For the gas-free fallen galaxies, the team calculated the velocities of hundreds, or even thousands, of individual stars.

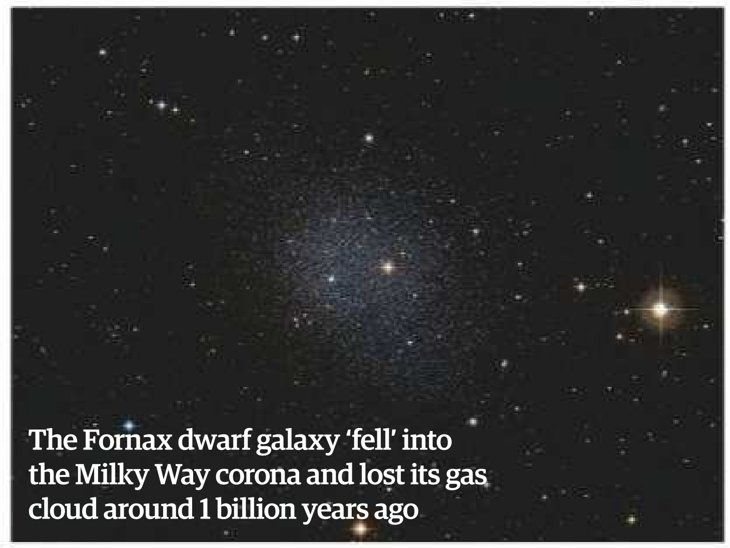
As well as dark matter profiles, detailed histories of star formation for each galaxy were also required. Fortunately the evolution of any star is predictable, following a well-known story of formation, relatively calm life and often violent death, which is told in the luminosity and colour of light they give out.

As a result Read's team were able to plot the entire stellar populations of these nearby dwarf galaxies and read off their history. They found a particularly strong indicator in the big, blue, luminous stars that burn through their hydrogen quickly before becoming our supernovae dark matter heaters. Lasting as little as 10 million years, their youthful presence shows star formation is still happening, up until very recently at least.

Combining the star formation histories and dark matter profiles, Read's sample revealed wide variation, from gas-poor dwarfs whose star formation ceased shortly after the beginning of the universe to those that shut down only very recently, to gas-rich dwarfs still forming stars today. Despite this variety the 16 dwarfs formed two clear groups which provided excellent agreement with the predicted mechanism of dark matter heating. As a rule, those that stopped forming stars over 6 billion years ago favoured greater central dark matter densities, while those with more extended star formation favoured much lower central densities.

"The findings were almost too good to be true, so we spent a lot of time convincing ourselves we


The remnants of a supernova called G299.2-2.9 (or G299 for short) located within our Milky Way galaxy


The Fornax dwarf galaxy 'fell' into the Milky Way corona and lost its gas cloud around 1 billion years ago

Different kinds of galaxies

They come in a range of shapes and sizes, but their dark matter compositions can vary even more

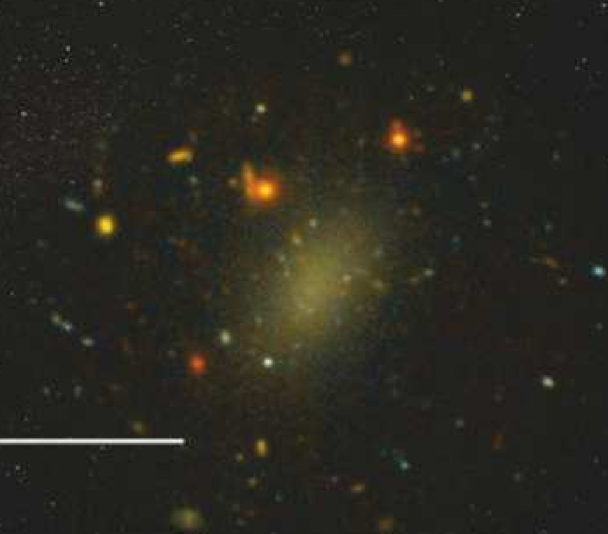
Dwarf galaxy 90 to 100%
Containing hundreds of millions of stars, they are often found near larger galaxies, heavily influencing their activity and star formation.

Spiral galaxy 50%
Like Katherine wheels, spiral galaxies consist of a bright central bulge and spiral arms where stars, gas and dust are concentrated.

Barred-spiral galaxy 50%
Around half of all spiral galaxies have a large rectangular central structure, including our own Milky Way.

Star cluster 0%
Groups of only a few hundred or a few thousand stars that form from dense gas inside larger galaxies.

Elliptical galaxy 50%
Unlike relatively flat spirals ellipticals are relatively structureless, three-dimensional ball-shaped galaxies.



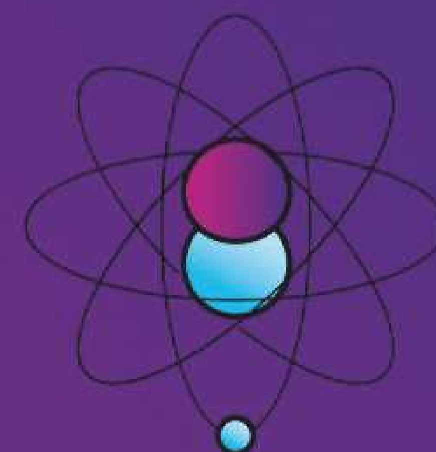
Dark galaxy/low-surface-brightness galaxy 95%+
A theoretical galaxy with no, or very few stars. Dragonfly 44 is the best candidate, with initial calculations suggesting it could be 99.99 per cent dark matter.

What is DARK MATTER?

We have no idea, despite it making up 85 per cent of the stuff in the universe.

There is six-times the amount of dark matter as all the planets, stars, gas clouds and galaxies added together in the universe.

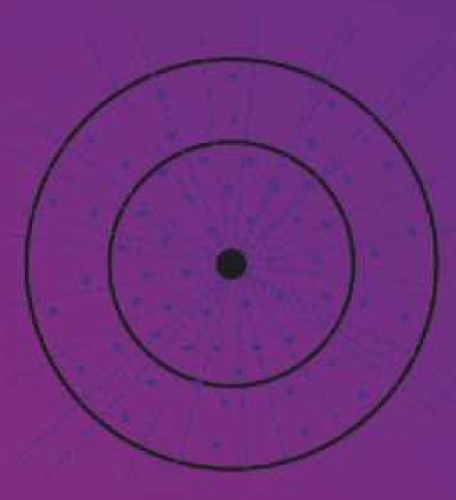
We don't know what it is or what it is made of?



The favourite theory is a hypothetical weakly interacting particle beyond the Standard Model of particle physics, similar to neutrinos but heavier.

Whatever it is made of we need it and use it to explain the structure of galaxies, clusters of galaxies and even the universe as a whole.

Every galaxy is surrounded by a halo of dark matter.



It provides the extra gravitational attraction that keeps galaxies, galaxy clusters and the universe from flying apart.

The term 'dark matter' was introduced in the 1930s to refer to missing normal gaseous matter hidden from view.

Timeline

1930s – 1940 – 1950 – 1960 – 1970 – 1980 – 1990

- 'Dark matter' coined to describe missing matter in galaxy clusters.
- Measurements of the spin of gas within individual galaxies' outer discs needed the same missing mass to make any sense.
- Vera Rubin and Kent Ford surveyed hundreds of galaxies and found all were surrounded by dark matter.
- It was clear you needed this missing mass everywhere in the universe.
- Cosmologists were using it to explain the structure of the universe itself.

What we do know about dark matter:

Interacts with normal matter via gravity

Doesn't interact with light

Displays ghostly 'collionlessness' which sees it flow through itself

Scientists have proposed many varieties of dark matter with names like warm, hot, fluid and fuzzy

The spin of gas in the outer discs of galaxies like our neighbour Andromeda make no sense without some form of invisible missing mass

weren't seeing what we wanted to see," says Read. Rather than anything more exotic, Read believes his results show dark matter is most likely a cold, collionless fluid, but one that can be 'heated up' and moved around by normal matter.

Two particular Milky Way dwarfs with very different dark matter density profiles struck a particular blow to alternative-gravity theories. Draco and Carina were measured to have very similar stellar masses, half stellar mass radii, distances from the Milky Way and orbits, but for Draco star formation had pretty much ended 10 billion years ago. So similar in every other way, Read believes it's unlikely anything other than different exposure to heating is the cause of their different dark matter profiles. "It shows dark matter must be real stuff. It really is a substance."

"I like the article," agrees Fabio Governato from the University of Washington. "It surely reconfirms, but with new observational data, the prediction that rapid gas outflows transfer energy to the dark matter, lowering its central density and reconciling observations with recent predictions of the 'cold dark matter model'."

However, not everyone is convinced that a lack of central dark matter is definitive evidence of recent star formation, or that significantly long periods of heating are required to account for their modern-day profiles. "A galaxy that had a violent event a while ago could easily have a core today," says Professor Julio Navarro from the University of Victoria, who proposed the basic mechanism of dark matter heating back in 1996. While there are ways of 'rebuilding' central dark matter density after its removal, perhaps through the accretion of more normal matter or through galactic mergers, there is no reason every dark galaxy has to experience these. "If a dwarf galaxy after a major outburst event manages to avoid both of those occurrences, then they should still have cores today," Navarro continues.

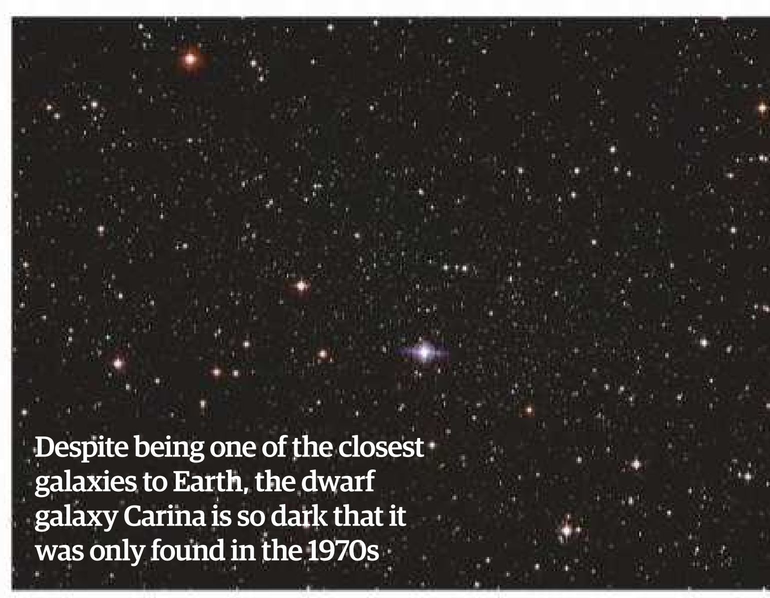
"We have direct observational evidence that dark matter really is heated up and pushed around by normal matter" **Justin Read**

Read is aware of some limitations to the study. It is certainly not ideal that they had to use two separate techniques to calculate the density profiles, though fears this may have introduced the correlation observed are countered by another of the dwarfs in their study.

Fornax is a fallen dwarf with no gas cloud that met its fate around 1 billion years ago, according to the current make-up of its star population. As a result it formed stars for almost the entire length of the universe. With no gas, the team used the star relative velocity technique to investigate Fornax and found a low-density centre profile – an anomaly, but enough to rule out measurement bias.

"What we have here is direct observational evidence that dark matter really is heated up and pushed around by normal matter," says Read, who believes his models could test the 'warm', 'fluid' and 'fuzzy' varieties of dark matter proposed. Each makes distinct predictions in terms of the distribution of dark matter within dwarf galaxies, which can now be tested and ruled out to narrow down on what dark matter really is. "These tiny little dwarf galaxies are fascinating little beasts."

An artist's impression of the Milky Way galaxy



Despite being one of the closest galaxies to Earth, the dwarf galaxy Carina is so dark that it was only found in the 1970s

DID NASA DESTROY EVIDENCE FOR LIFE?

NASA's Viking landers were sent to find carbon-based compounds. However, they did quite the opposite… they incinerated their findings

The first set of landers to ever land on the red, barren surface of Mars were NASA's highly anticipated Viking landers: Viking 1 and Viking 2. The aim of the mission was to successfully touch Martian ground, collect rock samples and heat them up to extreme temperatures to release any presence of carbon-based organic compounds hidden within. This would paint an ancient picture of Mars and show us if there was any possibly of the world once being hospitable; a tantalising thought.

Unfortunately, after collecting four rock samples and heating them up in Viking's onboard oven to temperatures up to 500 degrees Celsius (932 degrees Fahrenheit), there was no sign of these volatile organic compounds. This was not what scientists were hoping to see. However, more recently the presence of such compounds did get discovered on Mars with the help of NASA's Curiosity rover. Though this begs the question: why didn't the Viking landers detect it roughly 40 years prior?

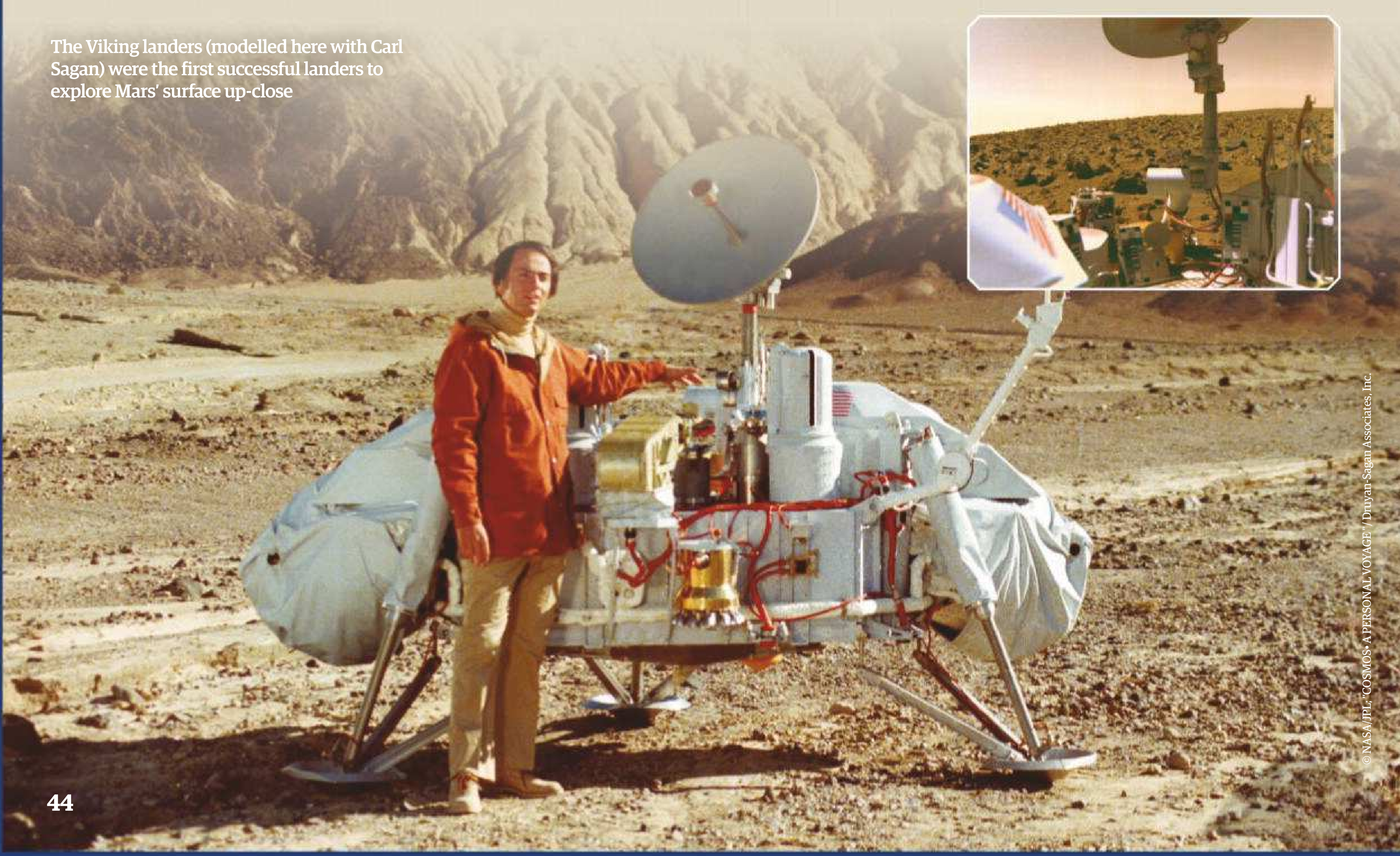
Scientists from NASA's Ames Research Centre in California, United States and the Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS) in France have now discovered the most likely answer. Viking unknowingly overcooked it. According to the scientists that conducted this study there was a hidden ingredient in the soil, a hyper-flammable fuel that, when heated, incinerated the carbon compounds, along with the chance to make the discovery a long time go.

This realisation comes from the work of another NASA lander on Mars: Phoenix. Some may recognise the appearance of this craft, as its design has been reused for the InSight lander, scheduled to make its touchdown on the Martian surface on 26 November 2018. A decade before InSight is due to land, Phoenix dropped onto Mars, in the process finding an unusual salt called perchlorate.

Scientists know that ancient microorganisms on Earth used this salt as an energy source, but they also know it to be extremely flammable as it is used in rocket fuel. If this salt was ignited it would undoubtedly have destroyed the sample, which is believed to be what happened in Viking's oven.

If this did indeed happen, the evidence should be found in the ashes. When carbon is burnt with perchlorate, the resulting molecule would be chlorobenzene, a mixture of carbon, hydrogen and chlorine that can survive for months in the soil. In 2013, Curiosity found traces of chlorobenzene in Martian soil, solidifying the claims ever further.

Scientists have also delved back into the archival Viking data, finding small amounts of chlorobenzene among Viking 2's samples. This concludes that Viking 2 had organics in its grasp. Although several planetary experts argue that this may be due to accidental contamination, more than most agree that this is definitive proof that these intriguing organic samples can be found all over the Martian landscape.



The Viking landers (modelled here with Carl Sagan) were the first successful landers to explore Mars' surface up-close

PLANETS

Why does Mars have virtually no atmosphere?

Mars has an atmosphere about one per cent as dense as Earth's, but 4 billion years ago Mars could have had the more massive atmosphere. Mars' deficit in air can be traced to its lower gravity, minimal magnetic field and quicker downshift in volcanic activity during its history. Mars' lower gravity makes it easier for light gases like hydrogen to launch away from Mars like a rocket and sometimes drag heavier gases with them. Mars' minimal magnetic field makes it easier for the solar winds to catch charged particles in the Red Planet's atmosphere and strip them away. After volcanic activity dropped to the minimal level observed today, the atmosphere could not be renewed by gases from Mars' interior.

Our knowledge of the Earth adds another wrinkle. The vast majority of the past atmosphere of our planet is not in the atmosphere now. Some is in the oceans, and 50 atmospheres (five million pascals) or so is in rocks like limestone. Gases dissolving in water along with some help from living organisms has stored the past atmosphere below ground. Only by probing or drilling Mars can we be sure how much of Mars' atmosphere has been lost to the rocks on its surface.

Dr Nicholas Heavens is a research assistant Professor at Hampton University's Center for Atmospheric Sciences, Virginia

"Mars' deficit in air can be traced to its lower gravity and minimal magnetic field"

One aim of NASA's space program is to understand the Martian atmosphere

ASTROPHYSICS

What is dark energy doing to our universe?

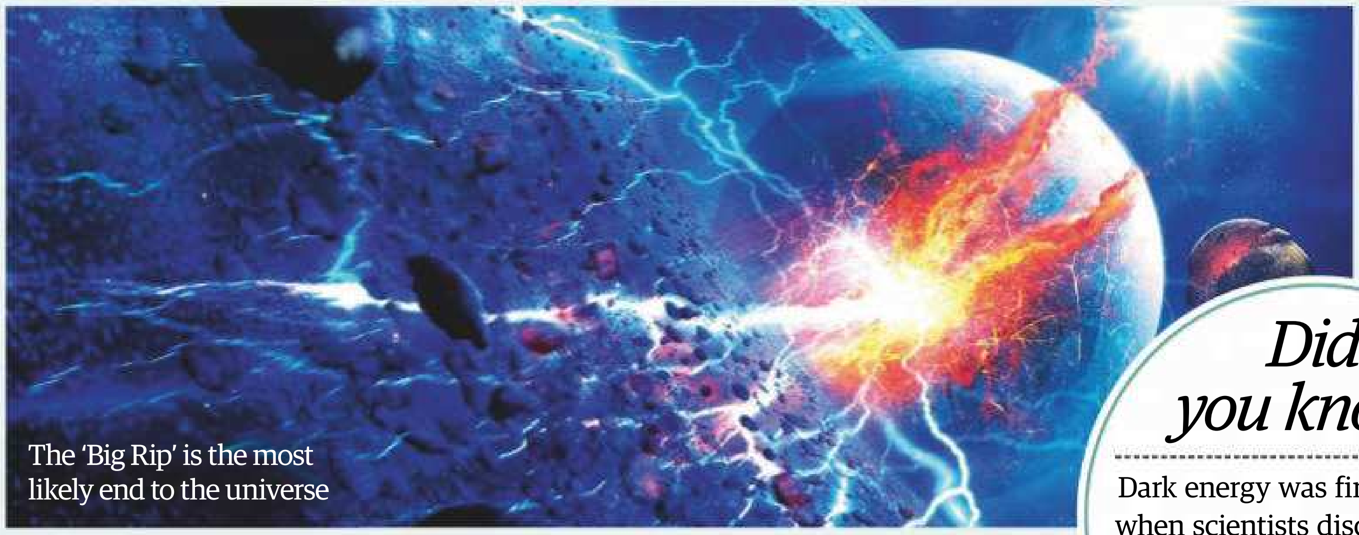
Dark energy remains perhaps the greatest unsolved mystery in cosmology, aside from the question of how the universe got started in the first place!

Currently dark energy has mostly benign effects, causing the universe to expand at a moderate, though accelerating pace. If dark energy's properties remain stable in the future, or if dark energy is similar to Einstein's famous 'cosmological constant', the universe will expand indefinitely.

There are, broadly speaking, two other possible alternative scenarios where dark energy's density changes over cosmic time. Neither scenario is particularly hopeful. In one, dark energy loses its power, decaying to zero and causing the acceleration to stop. In some models, the decay of its strength can lead to a 'Big Crunch', the collapse of all the matter in the universe, perhaps leading to a 'bounce' that causes another Big Bang.

In the second alternative scenario, in the extremely deep future, dark energy's strength increases with time, possibly causing the so-called 'Big Rip' where the force associated with dark energy's acceleration dominates over all other forces, including the chemical bond forces that hold atoms in our bodies together. But don't worry - that would not happen for another 70 billion years or more… so keep paying your taxes!

Professor Brian Keating is the professor of physics at the University of California, San Diego, CA



The 'Big Rip' is the most likely end to the universe

Did you know?

Dark energy was first theorised when scientists discovered that the expansion of the universe was speeding up - not slowing down - with the effect of gravity.

ASTROPHYSICS

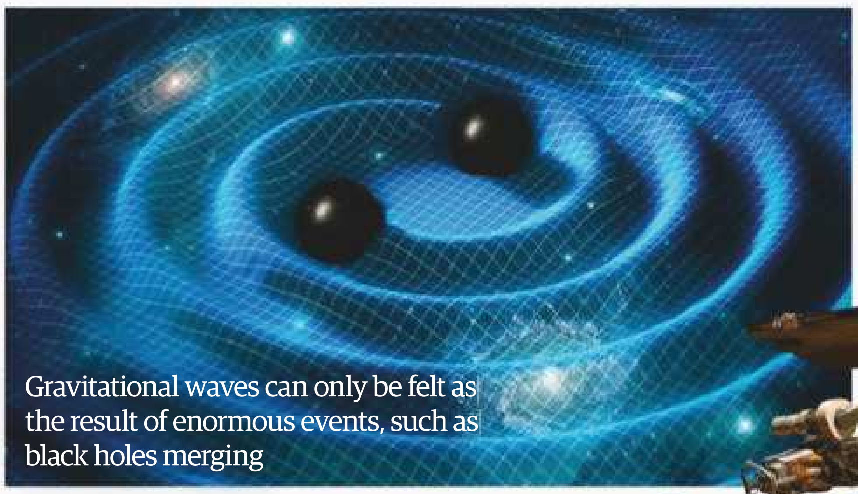
What creates gravitational waves and can we feel them?

Gravitational waves are vibrations in space-time itself. They are emitted by almost anything that moves, like planets orbiting or even your hands. However, only the most extreme phenomena in the universe can produce gravitational waves strong enough to be perceived. So far we have only detected extreme objects like black holes, and only when they are orbiting each other closely or merging.

As gravitational waves pass they cause minute distortions in relative distances between objects. To feel this event in our body we would need to be quite close to the black holes. Instead we can use technology to record fainter signals from distant galaxies.

The Laser Interferometer Gravitational-Wave Observatory (LIGO) and Virgo detectors have lasers and mirrors arranged to measure a relative stretch or contraction of minuscule amounts - less than the size of a proton over the four kilometre (2.5 mile) length of the arms. It is no surprise that the first detection took a century since Einstein first predicted them!

Dr Miguel Zumalacarregui is a Marie Curie global fellow at the Berkeley Centre for Cosmological Physics



Gravitational waves can only be felt as the result of enormous events, such as black holes merging

SPACE EXPLORATION

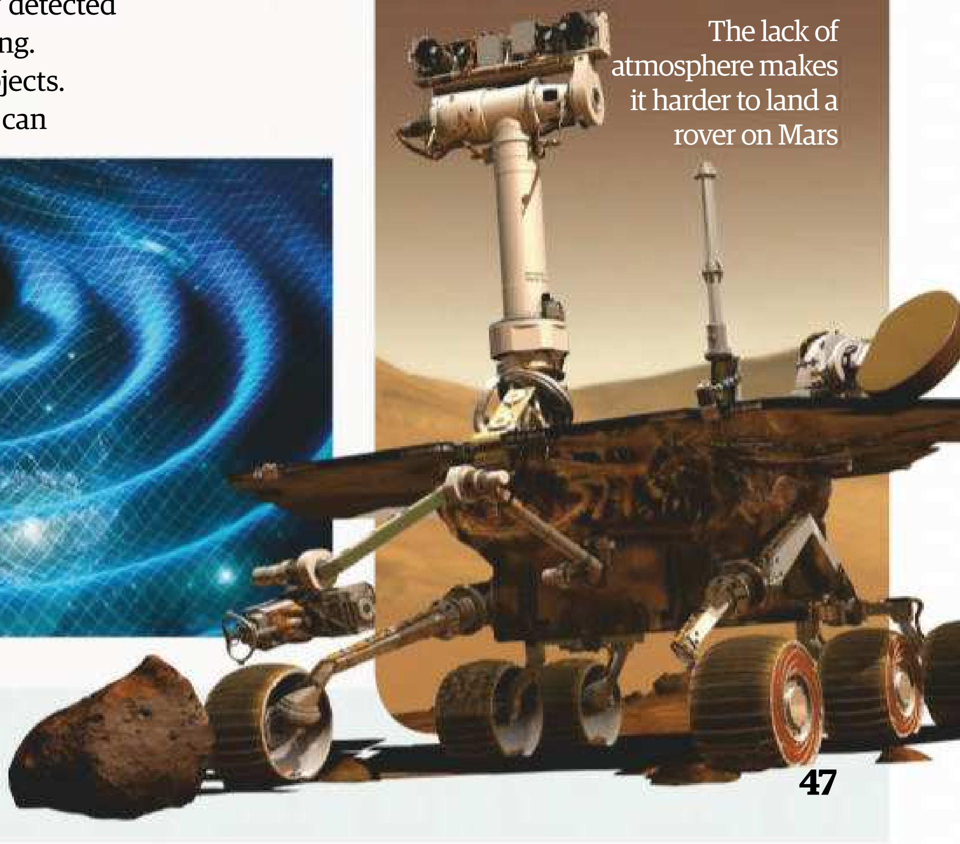
How hard is it to land a rover on Mars?

Landing a craft on Mars is difficult because it must slow itself from a high velocity to a stop on the surface in less than ten minutes - commonly known as the 'seven minutes of terror'. In that time, a large number of critical events must occur perfectly autonomously or the spacecraft will fail. Due to the time delay for information to travel to Earth, scientists don't know what has happened until the rover has landed or crashed.

Most landers use the friction of the atmosphere behind an aeroshell to initially slow the spacecraft. The aeroshell can heat up to 1,600 degrees Celsius (2,900 degrees Fahrenheit). Next the aeroshell is jettisoned and a parachute is inflated to further slow the lander.

A radar altimeter measures the closing velocity with the surface and retrorockets are fired to slow the vehicle further. Some landers inflate air bags and bounce to a stop, which is what was used for the Spirit and Opportunity rovers. Others use their thrusters to come to a landing, which was used to land the Curiosity rover.

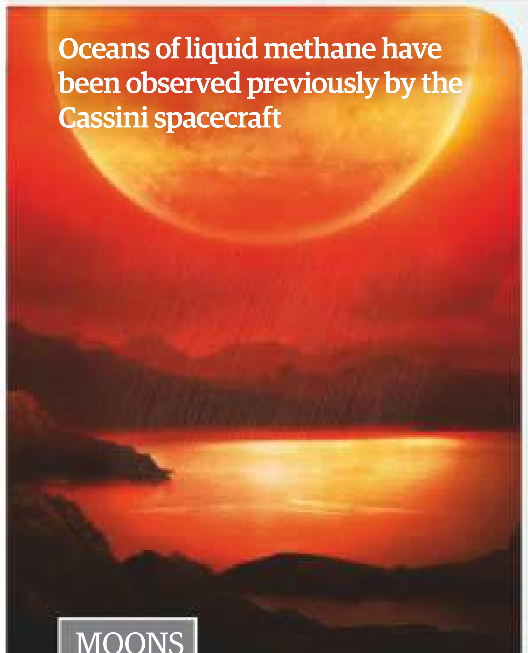
Dr Matthew Golombek is a senior scientist at the Jet Propulsion Laboratory, California



The lack of atmosphere makes it harder to land a rover on Mars

ASK Space

Our experts answer your questions



Oceans of liquid methane have been observed previously by the Cassini spacecraft

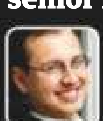
MOONS

How did Titan get oceans of liquid methane?

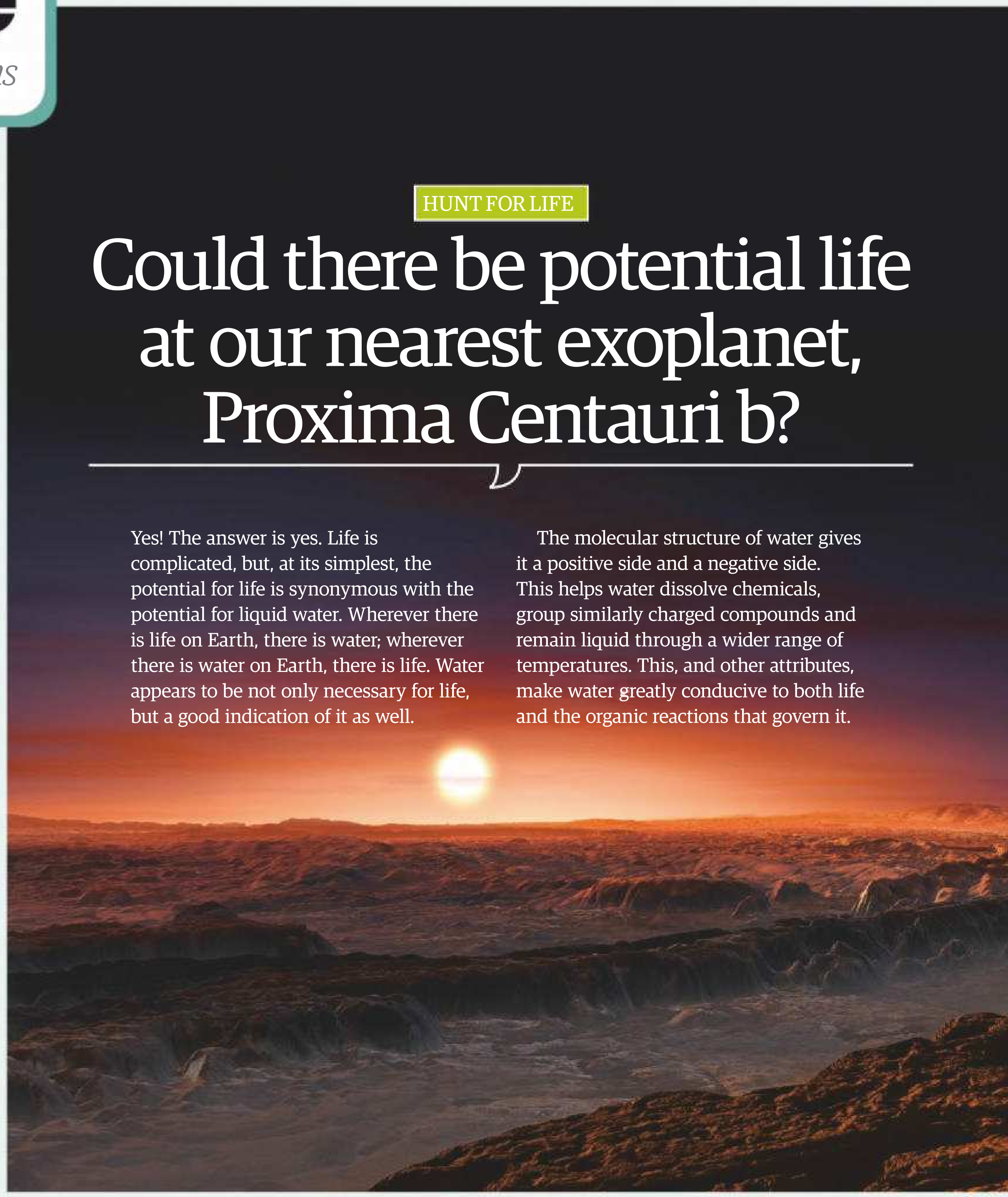
Titan has methane because it is a relatively big moon that exists in the cold outer Solar System. Being big provides enough gravity to make it difficult for methane molecules to leak into space. Cold temperatures also inhibit escape by slowing molecules down. It turns out that Titan's surface temperatures (around -180 degrees Celsius or -290 degrees Fahrenheit) are just right for methane to liquefy.

The cold temperatures also serve another purpose - they keep water frozen at Titan's surface, preventing a large number of oxygen atoms from entering the atmosphere. If that were to occur the carbon in Titan's methane would be combined with oxygen, and Titan would have a carbon dioxide-rich atmosphere similar to those of the warmer inner planets Venus and Mars.

There might also be a vast subsurface reservoir of methane-rich ice that is tapped by cryovolcanoes, which may have delivered fresh supplies of methane to the surface in the geologically recent past.



Dr Christopher Glein is a senior research scientist at the Southwest Research Institute in San Antonio, TX



HUNT FOR LIFE

Could there be potential life at our nearest exoplanet, Proxima Centauri b?

Yes! The answer is yes. Life is complicated, but, at its simplest, the potential for life is synonymous with the potential for liquid water. Wherever there is life on Earth, there is water; wherever there is water on Earth, there is life. Water appears to be not only necessary for life, but a good indication of it as well.

The molecular structure of water gives it a positive side and a negative side. This helps water dissolve chemicals, group similarly charged compounds and remain liquid through a wider range of temperatures. This, and other attributes, make water greatly conducive to both life and the organic reactions that govern it.

SPACE EXPLORATION

How does artificial (AI) intelligence benefit astronomy?

AI benefits astronomy by making it possible to analyse the rapidly increasing observational data and compare it with improving theoretical simulations. For example, the shapes of galaxies in telescopic images have long been analysed by visual inspection by astronomers, and more recently by nearly a million citizen scientists in the Galaxy Zoo project. But the billions of galaxy images that will come from the Large Synoptic Survey Telescope (LSST) can only be analysed by computers.

Since about 2012, the AI methods of 'deep learning' using neural networks have become increasingly effective at image analysis. My collaborators and I have been using deep learning to classify galaxy images and compare them systematically with galaxy images from high-resolution simulations. This helps to tell how well the simulations agree with observations, and to interpret the observations when they do agree.

Telescopes produce galaxy spectra in addition to images, and AI will become increasingly important to help us understand the complex combined information across many wavelengths. We are already seeing that deep learning and related methods such as generative adversarial networks (GANs) can reveal much more than can be obtained from inspection even by the most experienced astronomers.

Dr Joel Primack is a Distinguished Professor of Physics Emeritus at the University of California, Santa Cruz

Proxima Centauri b orbits in what is known as the 'habitable zone', or the distance away from its host star a planet must be to maintain liquid water on its surface. That alone means Proxima Centauri b carries the potential for life.

Whether there really is life there depends on any number of other properties of the planet and of life, both of which remain uncertain. A definitive answer hangs on work done by astronomers, biologists and chemists alike, as well as increasing observational capabilities, such as the planned James Webb Space Telescope.

Lily Zhao is a graduate student at Yale University, Connecticut, and a National Science Foundation graduate student fellow

ASTROPHYSICS

Why don't all stars eventually turn into a black hole?

It's all to do with mass. During its life a star exists in a balance between the force of gravity, which pulls its material towards its centre, and the outward pressure that material exerts when compressed. Towards the end of a star's life, the balance between these two forces shifts in favour of gravity. This often happens because the star runs out of nuclear fuel, resulting in less outward radiation pressure and less gas pressure.

However, as gravity becomes more important, it compresses the material at the centre, heating it and increasing the outward pressure once more. In the more massive stars, gravity ultimately wins and compresses the star until it is as dense as physically possible, resulting in a black hole. On the other hand, less massive stars have weaker gravitational pulls, and in the end a new balance is struck which allows these stars to support themselves against gravity indefinitely as a dead ball of nuclear ash.

Occasionally, something even more unusual happens. For stars in a certain mass range no new balance is struck, but no black hole is formed. In these cases, the star explodes entirely, scattering its matter in all directions and leaving absolutely nothing 'stellar' behind.

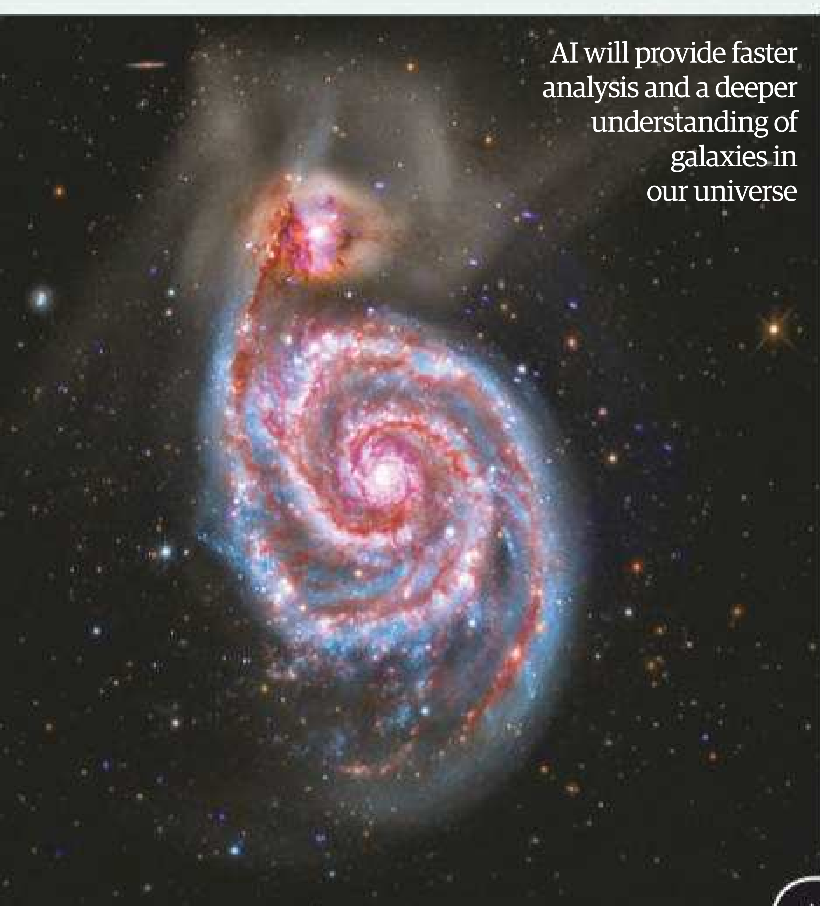
Dr Adam Jermyn is a postdoctoral scholar at the Kavli Institute for Theoretical Physics at the University of California

Did you know?

There's a supermassive black hole approximately 26,000 light years away at the centre of our galaxy, named Sagittarius A*, which is roughly 4 million-times the mass of our Sun.

The deciding factor in a star's future is its mass

"In the more massive stars gravity ultimately wins and compresses the star"



AI will provide faster analysis and a deeper understanding of galaxies in our universe

They may be plentiful in the Milky Way galaxy, but scientists now think that they may not be suitable for life

Reported by Lee Cavendish

WATER WORLDS

Imagine a world covered entirely in water – no land separating vast oceans. A recent discovery announced at the Goldschmidt Conference in Boston, Massachusetts, United States, has found that these 'water worlds' are more common than previously thought. This discovery comes courtesy of data collected by two very diligent missions that have studied the cosmos for years now – the European Space Agency's Gaia and NASA's Kepler. Of the 4,000 confirmed or candidate exoplanets, 35 per cent were found to be water worlds.

The first discovery of exoplanets was announced in 1992 with the planets PSR B1257+12c and 12d. They were found to be orbiting a pulsar 2,300 light years away in the constellation of Virgo. A third planet, PSR B1257+12b, was found orbiting the same pulsar in 1994. Over two decades later the search for exoplanets continues, with new discoveries

coming in fast, offering tantalising possibilities for life beyond our Solar System. With all the stars that twinkle in the sky, think of how many planets are in orbit around them. Surely there should be another planet with life, even if it is in its simplest form – microbial life.

NASA's Kepler mission, now also referred to as 'K2' as it undergoes its secondary mission, has been spotting exoplanets in the night sky since 2009. At the time of writing the current tally for confirmed exoplanets sits at 2,652, with a further 2,737 potential candidates. Throughout the years astronomers have been able to make exciting discoveries from this dataset, introducing new planetary genres into the mix that include hot Jupiters, super-Earths, mini-Neptunes and, of course, water worlds. These planets are mainly characterised based on their radius, density and orbital parameters. If a planet is similar to the size and density of Jupiter, but closer to its host star than Jupiter is to the Sun, then it is normally characterised as a hot Jupiter. As for super-Earths, they are planets more massive than Earth but less massive than Uranus, which is around 14.5-times the mass of the Earth.

Although Kepler is currently reaching the end of its days as it is running out of fuel, its legacy will live on. It has been instrumental in discovering thousands of planets and, as of recently, even the possible detection of the first moon found outside our own Solar System. With this Kepler data, along with analyses from the star surveyor, Gaia, astronomers are getting a clearer picture of the composition and state of different stellar systems throughout the Milky Way. Gaia's main objective is to survey more than 1 billion stars in our galaxy, and its latest data release lists the three-dimensional positions and two-dimensional motions of over 1.3 billion stars, as well as their colour, surface termperatures, radii and brightnesses. By combining the two datasets astronomers have revealed the presence of more water worlds than anyone would have expected were out there. "It was a huge surprise to realise that there must be so many water worlds," says Dr Li Zeng, a Simons Collaboration on the Origins of Life postdoctoral fellow at Harvard University, Cambridge, Massachusetts.

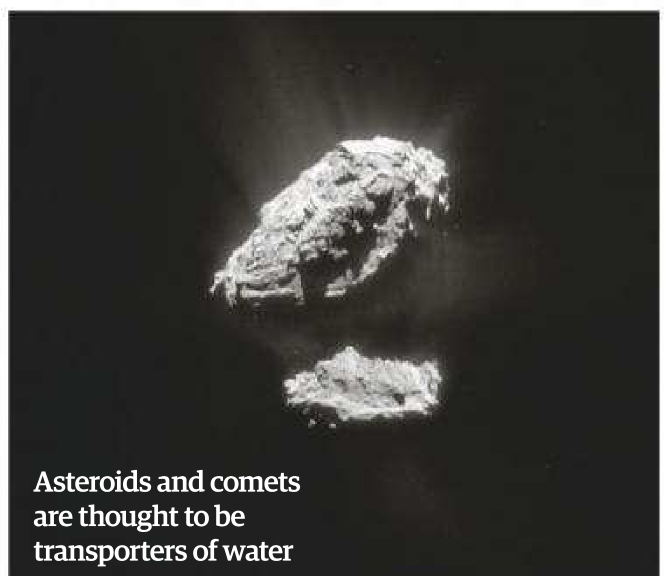
Zeng's current research focuses on the formation, evolution and chemistry of exoplanets

At the Goldschmidt Conference, an internationally renowned conference held every year to present the latest advancements in many areas of science, held this year in August, Zeng announced that the galaxy is full of water worlds. However, there are more precise constraints to these planets than just 'a planet covered in water'. These exoplanets are, on average, two-and-a-half-times the radius and ten-times the mass of Earth. Anything less – in this instance one-and-a-half-times the radius and five-times the mass of Earth – are rocky planets, which resemble the inner four planets of our Solar System: Mercury, Venus, Earth and Mars. Anything above the water world constraints will most likely be a gas giant, which are planets similar to the outer Solar System planets – Jupiter, Saturn, Uranus and Neptune. "This reflects the cosmic element hierarchy of three major planet-building materials: rock, ice and gas," says Zeng. "Therefore, this natural ladder is reflected in planets. As you go from small to large planets you expect the correlation between the mass, or the size, of planets with their composition, and thus also with the cosmo-chemical sequence."

The new research claims that these planets could be made up of as much as 50 per cent water, which is significantly higher when compared to the Earth's mere 0.02 per cent by weight. However, Zeng is clear to point out that this is not water as we find it on Earth. "Their surface temperature is expected to be in the 200 to 500 degrees Celsius (392 to 932 degrees Fahrenheit) range. Their surface may be shrouded in a water-vapour-dominated atmosphere, with a liquid-water layer underneath. Moving deeper, one would expect to find this water

"Their surface may be shrouded in a water-vapour-dominated atmosphere, with a liquid-water layer underneath" **Dr Li Zeng**

ESA's Gaia spacecraft provides important information about the stars in our galaxy



Asteroids and comets are thought to be transporters of water

What makes up a water world?

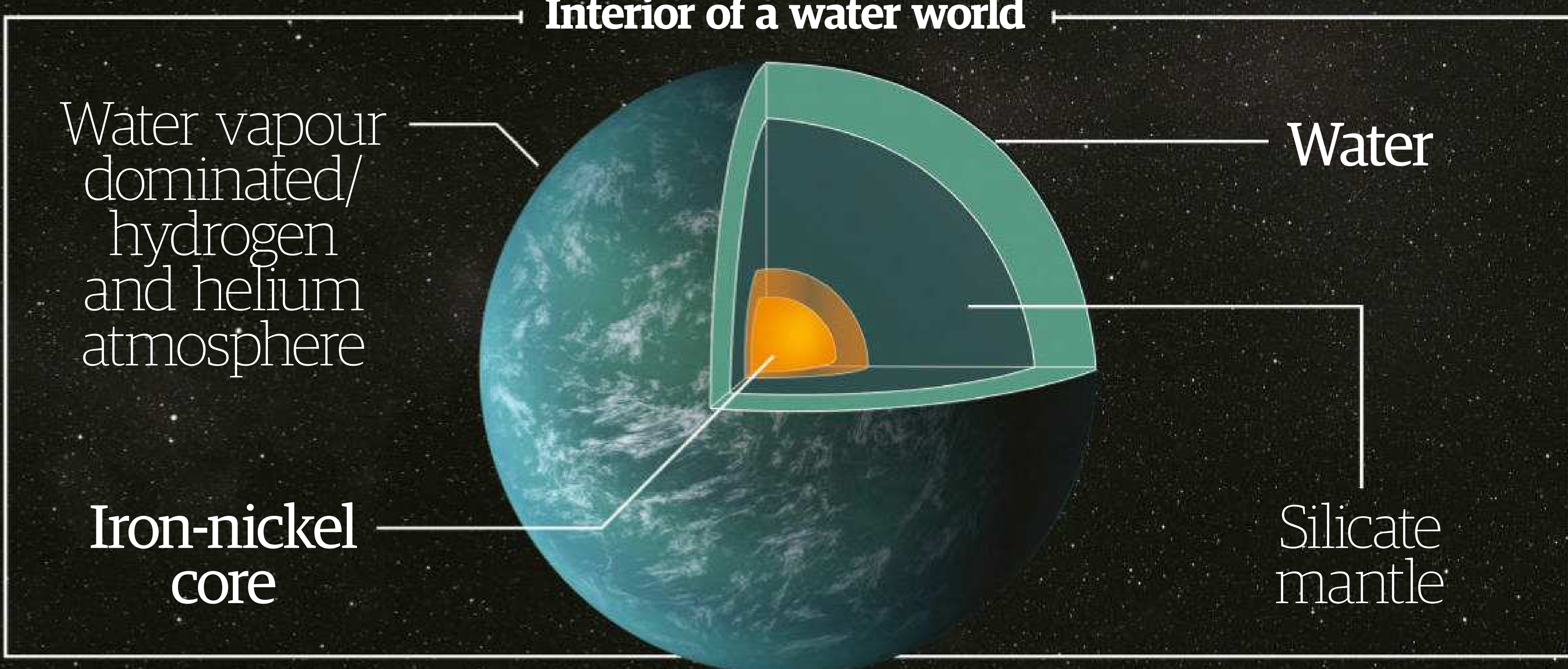
Meet some of the most common planets spread throughout our galaxy

Rocky planets
On average these planets are 1.5-times the Earth's radius and are composed primarily of rocks or metals.

Water worlds
They are between two- and four-times the radius of Earth and contain large amounts of water.

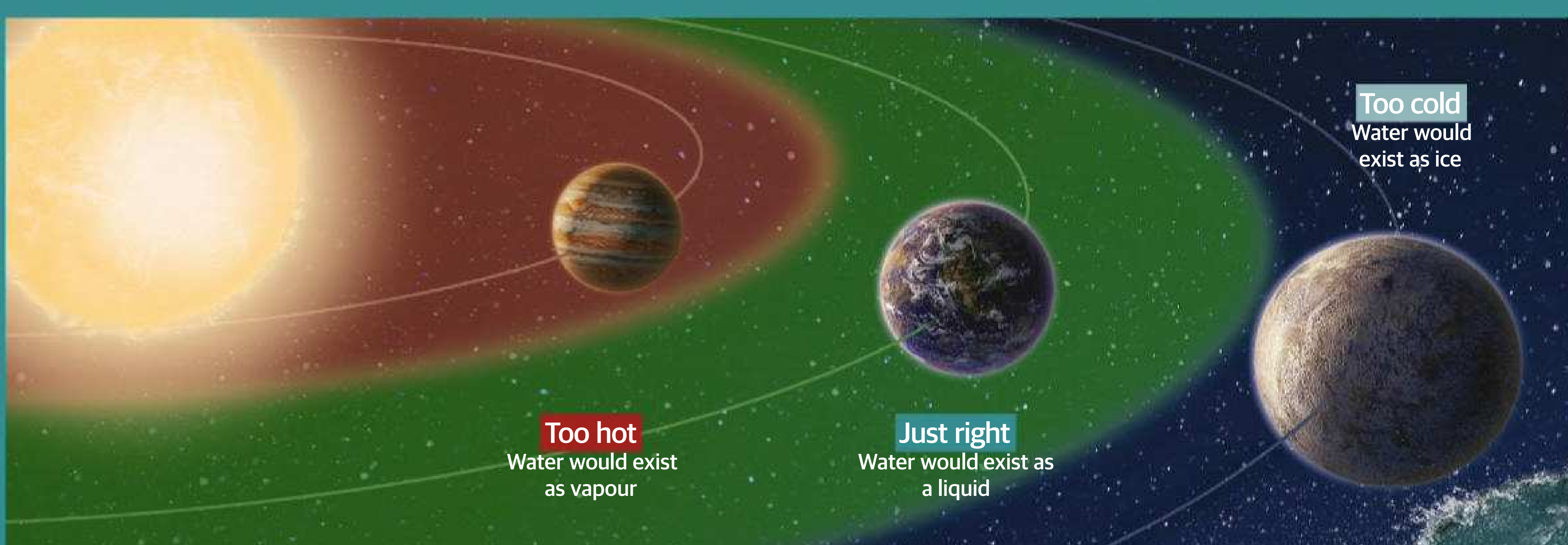
Gas giants
Much larger and much more massive planets are gas giants, composed primarily of hydrogen and helium with a small rocky core.

Interior of a water world



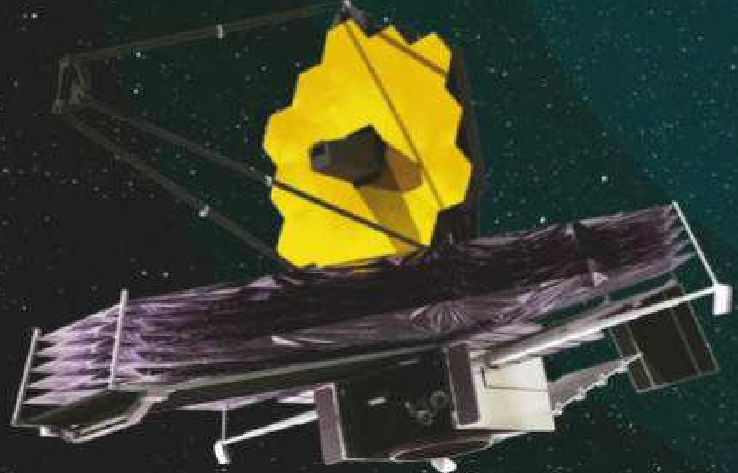
The habitable zone

The optimum distance from a star, where water could exist as a liquid



The future of exoplanet exploration

The pair will hunt down any exoplanets that could be hospitable for life, including water worlds



JWST

Transit spectroscopy
The NIRSpec (Near-Infrared Spectrograph) will be able to dissect the incoming light as an exoplanet passes in front of its host star. This will reveal the atmosphere's chemical composition, structure and temperature.

Coronagraph
Using the JWST's NIRCam (Near-Infrared Camera) coronagraph, exoplanets will be able to be directly imaged by blocking out the star's light. Although they will only appear as a dot, a lot can be learnt through spectroscopy.

TESS

Transit watchers
TESS is fitted with four CCDs that collectively create a 4,096 x 4,096-pixel detector. This is a masterpiece of exoplanet detection that will watch out for the transits of exoplanets, specifically Earth-like and super-Earth exoplanets.

Data handing
TESS' DHU (Data Handling Unit) does all the hard work; it is responsible for the hardware, software and firmware for data processing, storage, communications with the ground and spacecraft avionics.

Oxygen could join with hydrogen in nebulae in order to produce interstellar water

> "It's amazing to think that the enigmatic intermediate-size exoplanets could be water worlds" **Professor Sara Seager**

transforms into high-pressure ices before we reach the solid rocky core," explains Zeng.

But it is not just the Kepler and Gaia data that made this result possible; a model developed by the Harvard team was also a big factor. This 'growth model' takes into account the formation and evolution of planets based on meteorite analysis and simulations of a protoplanetary disc. "The first direct constraint comes from our understanding of the chemistry of the Solar System, which comes from our understanding of meteorites in our own Solar System," says Zeng. "Secondly, all planets in the Solar System orbit near the same plane. This well-defined plane is the evidence that all planets formed within a disc surrounding the central host star." The most defining region in this model of the protoplanetary disc is the 'snow line'. This is the region where volatile compounds such as water, ammonia and methane are cold enough to freeze into ice, and this is thought to contribute heavily to the creation of the gas giants.

In the snow line rock and ice is thought to clump together, making up the cores of the gas giants we know today, before they are enveloped by hydrogen and helium. However, in the case of water worlds, they developed the rocky/icy core like the gas giants, but instead fell inward towards the host star and never developed their gaseous outer layers. So if anyone asks why we don't have any water worlds in our own Solar System, the short answer is that our system had a different evolution. Without the evolution of our Solar System panning out like it did, we never would of had life on Earth. But does that mean life is still able to evolve on exoplanets such as this with a different past?

Life is a complicated thing; there are many factors to take into account, and unfortunately modern science and technology just isn't good enough to be able to make a unambiguous detection of a world able to support life just yet. "A water world isn't just an Earth that we poured water on, it's a different planet and there's no reason to suppose the geology would be identical to ours," adds Elizabeth Tasker, an astronomer at the Japan Aerospace Agency in Tokyo. "You really need to build up from basic physics and chemistry, rather

Natalie Batalha is an astrophysicist at the NASA Ames Research Center and the project scientist for NASA's Kepler mission

than relying on Earth's analogy in order to tackle [complex] exoplanet problems."

What astronomers do know is that water is a necessity for life as we know it, and the universe is full of it. Hydrogen is the most abundant element in the universe and oxygen is third - with helium sitting in-between - and if you put both of those together you get water. "Whenever conditions are appropriate, such as on dust grain surfaces in cold nebulae, the oxygen atom will readily combine with the hydrogen atoms to form the water (H_2O) molecule," says Zeng. "Here we have found a population of exoplanets corresponding to these water worlds."

And still, there are many different factors to take into account when determining if life is possible in another system. For instance, there needs to be a manageable pressure, surface temperature and the right chemical composition allowing some sort of energy source. If one of these worlds resides within the star's habitable zone - the region surrounding the star where water can exist as a liquid - the temperatures possible high up in the atmosphere could be hospitable. Unfortunately this is all speculation until astronomers can intensely study the planets' atmospheres.

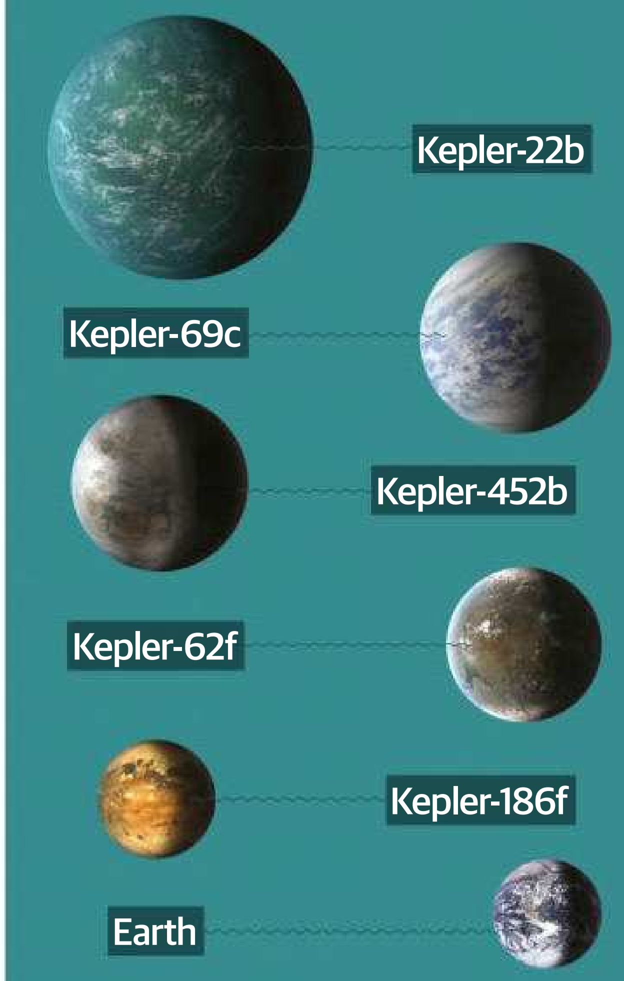
With the introduction of two space missions, NASA's James Webb Space Telescope (JWST), which is currently due to launch in 2021, and the already-launched Transiting Exoplanet Survey Satellite (TESS), the search for water worlds will intensify dramatically. TESS will provide in-depth analysis of Earth-sized and super-Earth worlds using its four top-quality CCD cameras. These cameras will watch out for the dimming of light from nearby stars, unveiling the presence of any exoplanets and revealing their physical parameters such as radius, mass and so on. "It's amazing to think that the enigmatic intermediate-size exoplanets could be water worlds with vast amounts of water. Hopefully atmosphere observations in the future - of thick steam atmospheres - can support or refute the new findings," says Professor Sara Seager, professor of planetary science at the Massachusetts Institute of Technology (MIT), United States, and deputy science director of the recently launched TESS mission, currently scouting the cosmos.

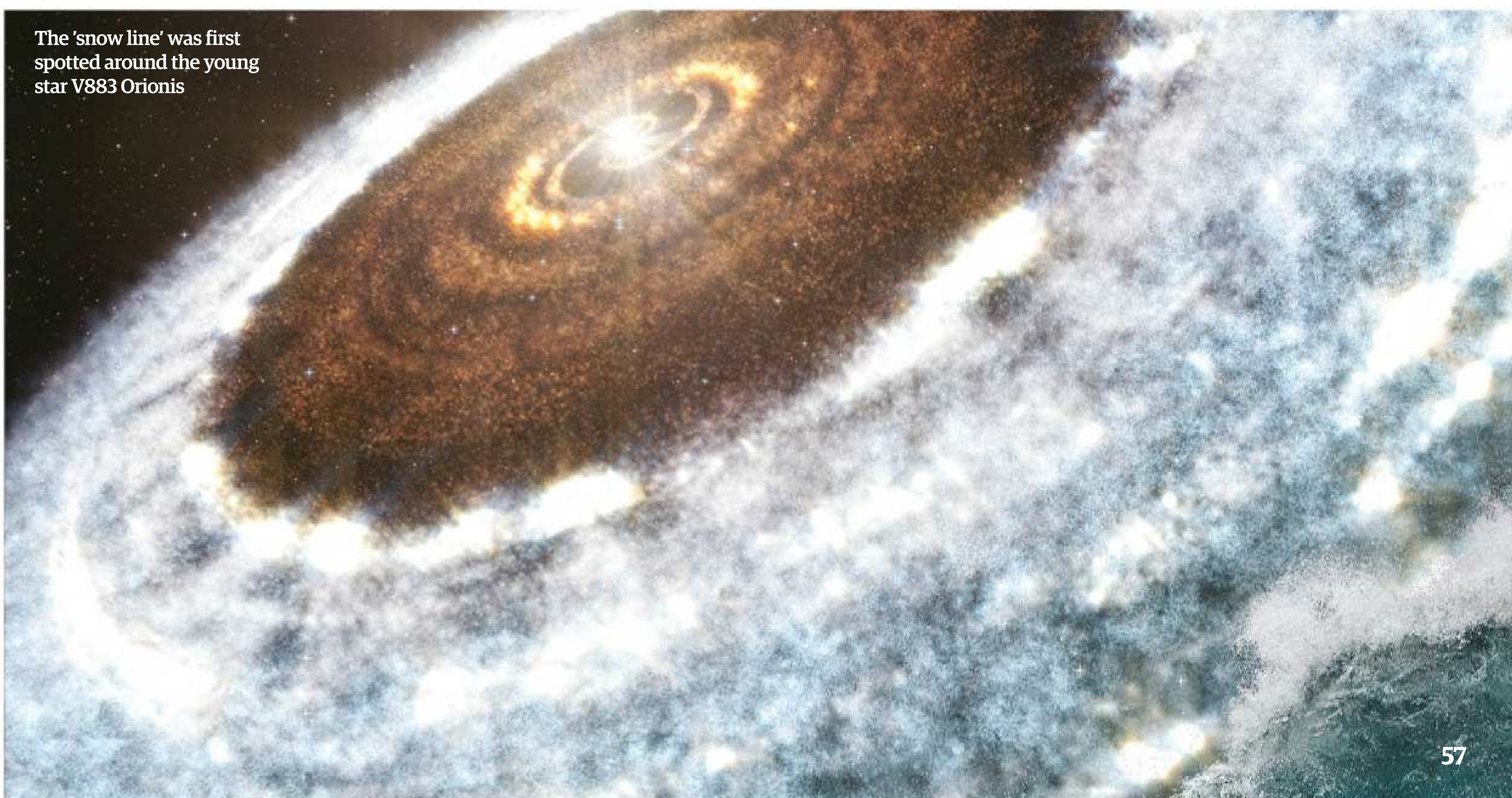
Such observations of exoplanets' atmospheres will come from the JWST and its incredible infrared capabilities. As starlight passes through the exoplanet and reaches the JWST its spectrometers will be able to detect molecules such as water, carbon dioxide and carbon monoxide in the atmosphere, painting a much clearer picture. "Our team's goal is to provide critical knowledge and insights to the astronomical community that will help to catalyse exoplanet research and make the best use of Webb in the limited time we have available," says Natalie Batalha of the NASA Ames Research Center, California, United States, project scientist for Kepler and principal investigator to a project which will observe gas giants in early JWST operations.

With all of this to look forward to, the thought of water - and possibly even life - beyond the boundaries of our Solar System is becoming more and more exhilarating. With ever-improving technologies added to spacecraft, even more interesting discoveries are right around the corner.

Kepler's Earth-like exoplanets

These planets are the closest matches to Earth, but is it possible they could also be filled with water?





The 'snow line' was first spotted around the young star V883 Orionis

Failure to launch

10 MISSIONS THAT *NEVER* MADE IT

Space is a challenging environment but often Earth-based tribulations can kill a spacecraft before it even gets off the launch pad

— **Written by Kulvinder Singh Chadha** —

Megaroc

Design submission date: *23 December 1946* ***Mission duration:*** *A few minutes*

Heavily based on Wernher von Braun's V-2 rockets, Ralph Smith submitted a proposal to Britain's Ministry of Supply for a rocket that would carry a man into space. At 17.5 metres (57.4 feet) in height and 21.2 tonnes in mass, Megaroc would have been 3.5 metres (11.5 feet) taller and 8.7 tonnes heavier than a V-2. Its girth was also slightly wider to accommodate the occupant.

The Ordnance Office's Rocket Section had already test-fired three V-2 rockets in October 1945 as part of Operation Backfire. The most successful managed to reach a height of 69.4 kilometres (43.1 miles). The plan was to launch the craft on a parabolic trajectory some 300 kilometres (186 miles) above the Earth. Once in space the nosecone would jettison, revealing the pressurised cabin inside the rocket. The occupant inside would then have had a few minutes to perform observations of the Earth, the Sun and radio tests of the ionosphere before landing safely to Earth via compressed gas-assisted parachutes. Britain was nearly bankrupt after the war, but had the Ministry of Supply chosen to fund the project, Earth's first astronaut may well have been British.

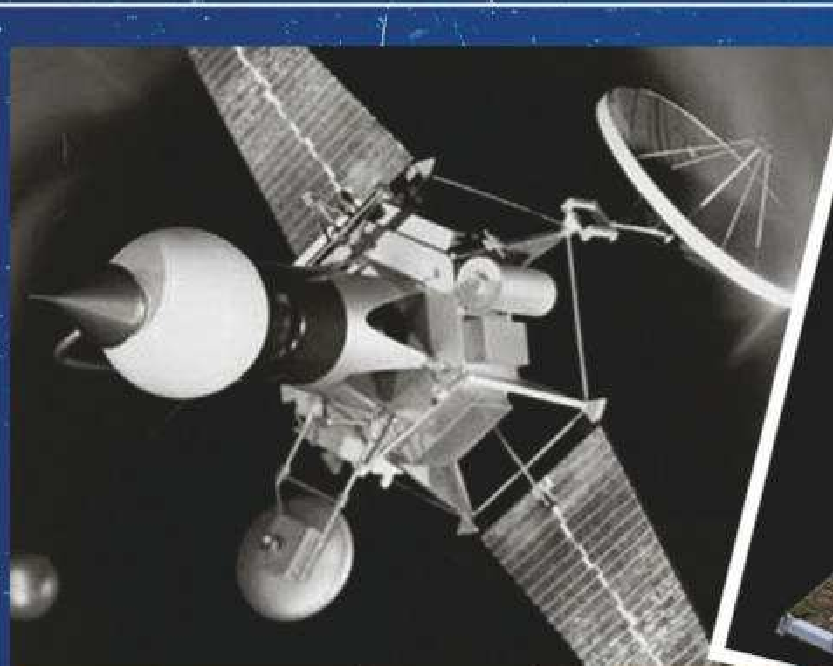
***A loss of expertise**

The workforce may become redundant or retire. Over time the skills needed to sustain a particular mission can dissipate.

*** Why missions get cancelled**

***Because they're no longer financially viable**

Missions often live and die by budgets. Either concepts aren't viable any more, or existing missions become a drain.

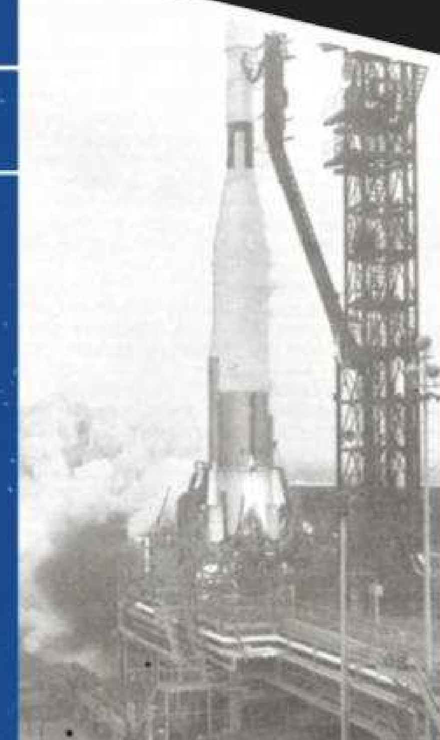


Ranger 3, 4 and 5

Launch dates: *26 January, 23 April and 18 October 1962*
Mission duration: *48, 64 and 64 hours*

Of the nine missions launched by the US to study the Moon's surface, Ranger 7 was the first successful one, while 1 and 2 failed to leave Earth's orbit. Rangers 3, 4 and 5 were part of the 'Block 2' missions. Each probe had an array of instruments including a vidicon television camera, gamma-ray spectrometer, radar altimeter and a seismometer that would detach and land on the surface.

The guidance system for Ranger 3's rocket stopped responding 49 seconds after liftoff, putting the spacecraft off course. After a perfect launch, fluctuating radio signals showed that Ranger 4 was rolling uncontrollably. Attempts to manoeuvre it back to normal were thwarted by a malfunctioning computer timer. It crashed into the Moon on 26 April 1962, making it America's first craft to land on another world. After a successful launch Ranger 5 too stopped functioning. After passing 725 kilometres (450 miles) above the Moon's surface and operating normally for 15 minutes, it flew towards the Sun, never to be heard from again.



Roton

Proposed launch date: *2000*
Mission duration: *72 hours*

With the founding of the Rotary Rocket Company, Gary Hudson and Bevin McKinney planned to make the Roton: a cone-shaped vehicle powered by rocket-tipped helicopter blades that could reach a maximum orbit of 300 kilometres (186 miles). The idea was that the rotors could propel the craft into orbit. The rotors would then act as a turbopump for the fuel system before slowing Roton down during its descent and re-entry stages.

The company's studies showed that rotors wouldn't be enough to get to space, however, so conventional rocket engines would be used for takeoff and ascent. The rotors would then be used for descent only – slowing the craft down on its way back to the ground. In the first test flight the pilots 'hopped' the vehicle some 2.4 metres (eight feet) above the ground and found controlling it extremely difficult. The rotor blades made the vehicle turn in the opposite direction, which had to be counteracted manually. Two more tests were made before the company ran out of funds. Roton had been funded by wealthy investors, but there were criticisms of its whole design concept from the start.

The rocket can be seen on display at Mojave Spaceport

The new design would have advanced the Shuttle program

Shuttle II

Proposed launch date: *2000* ***Mission duration:*** *Up to a week*

Although designed to be reusable, the Shuttle still had to discard its external fuel tank after each launch – 135 in total. The side boosters and orbiter required a lot of maintenance, and each mission cost $775 million (£595 million) to prepare and launch. President Reagan had already approved plans for the Shuttle's replacement in 1985. The Langley Research Center was commissioned to conceptualise the new shuttle, which would be one of a 'family' of orbital vehicles.

Langley's design comprised of an orbiter and a large external booster, both of which were winged and reusable. They would detach and glide back to Earth separately. The orbiter's fuel tanks were internal, with crew and payload bays sitting atop. Shuttle II was superseded by other design studies and never got off the ground.

N1 (H1)

Launch dates: *21 February and 3 July 1969, 26 June 1971 and 23 November 1972*
Mission duration: *Telemetry data until 110 seconds*

The N1 rocket – overseen by rocket engineer Sergei Korolev – was the Soviet Union's equivalent of America's Saturn V. With a thrust of 34.5 million Newtons, Saturn V was constructed for the Apollo missions. A rocket of that size and power was needed to get astronauts, Lunar craft and equipment well beyond Geostationary Earth Orbit (GEO) and towards the Moon.

The Politburo in Moscow decided that the N1 should have the same goal. But, instead of five large engines like the Saturn V, N1 had 30 smaller ones arranged in two rings. At first this seemed like a good idea, as the rocket could easily be steered by throttling the engines. But in the politico-economic environment of the Soviet Union, the engines weren't tested properly. Their multiplicity and complex design meant that if one went wrong, they all did. After four failed launches and four years after the last Apollo astronaut returned to Earth, the N1 programme was officially cancelled.

* Other missions are a priority

Space agencies often have to choose missions carefully to maximise scientific returns. Even promising missions are sometimes abandoned.

JIMO

Proposed launch date: *May 2015 to January 2016*
Mission duration: *About 10 years*

Europa is a prime candidate in the search for life in our Solar System. There's strong evidence that Jupiter's ice-encrusted moon has liquid oceans beneath. NASA's Jupiter Icy Moons Orbiter (JIMO) was planned to study Europa, and also Ganymede and Callisto. The 36-tonne craft was to be propelled by eight ion engines and powered by a fissile nuclear reactor at the front. A fissile reactor would have given JIMO a thousand-times the power of standard radioisotope thermoelectric generators used on other deep-space probes. This would have allowed for subsystems such as a powerful ice-penetrating radar, and there were even plans for a Europa lander to be attached. However, because of the nuclear reactor and because JIMO was to be assembled in space, it was deemed too ambitious. The project was defunded in 2005. Of all the cancelled or unsuccessful missions in this feature, JIMO is the most hopeful: its mission ethos lives on in the European Space Agency's Jupiter Icy moons Explorer (JUICE), which is slated for launch in 2022.

JIMO would have explored the icy Jovian moons

*** It's technologically far too challenging**
The design concepts can be unfeasible with current technology, because of the available budget or required scientific breakthroughs.

"NASA's Jupiter Icy Moons Orbiter (JIMO) was planned to study Europa, and also Ganymede and Callisto"

Mars Telecommunications Orbiter

Proposed launch date: *September 2009*
Mission duration: *11 years*

The Mars Telecommunications Orbiter (MTO) would have been placed in a high orbit around Mars and relayed information from various Mars missions back to Earth using radio and microwave relays, and also near-infrared lasers. This latter, optical link could have provided an information density 10,000-times that of microwaves. This would have been ideal for high-quality video data, but the MTO project was scrapped in 2005. The need to fund a Hubble servicing mission, an Earth observation satellite and, ironically, the Mars Science Laboratory and Mars rover Spirit and Opportunity's extended missions took precedent.

The Mars Reconnaissance Orbiter and Mars Express have shown that communications from Mars are fine, and dedicated missions like MTO may be unnecessary. However, laser communication has been tested between the Earth and the Moon with NASA's Lunar Atmosphere and Dust Environment Explorer.

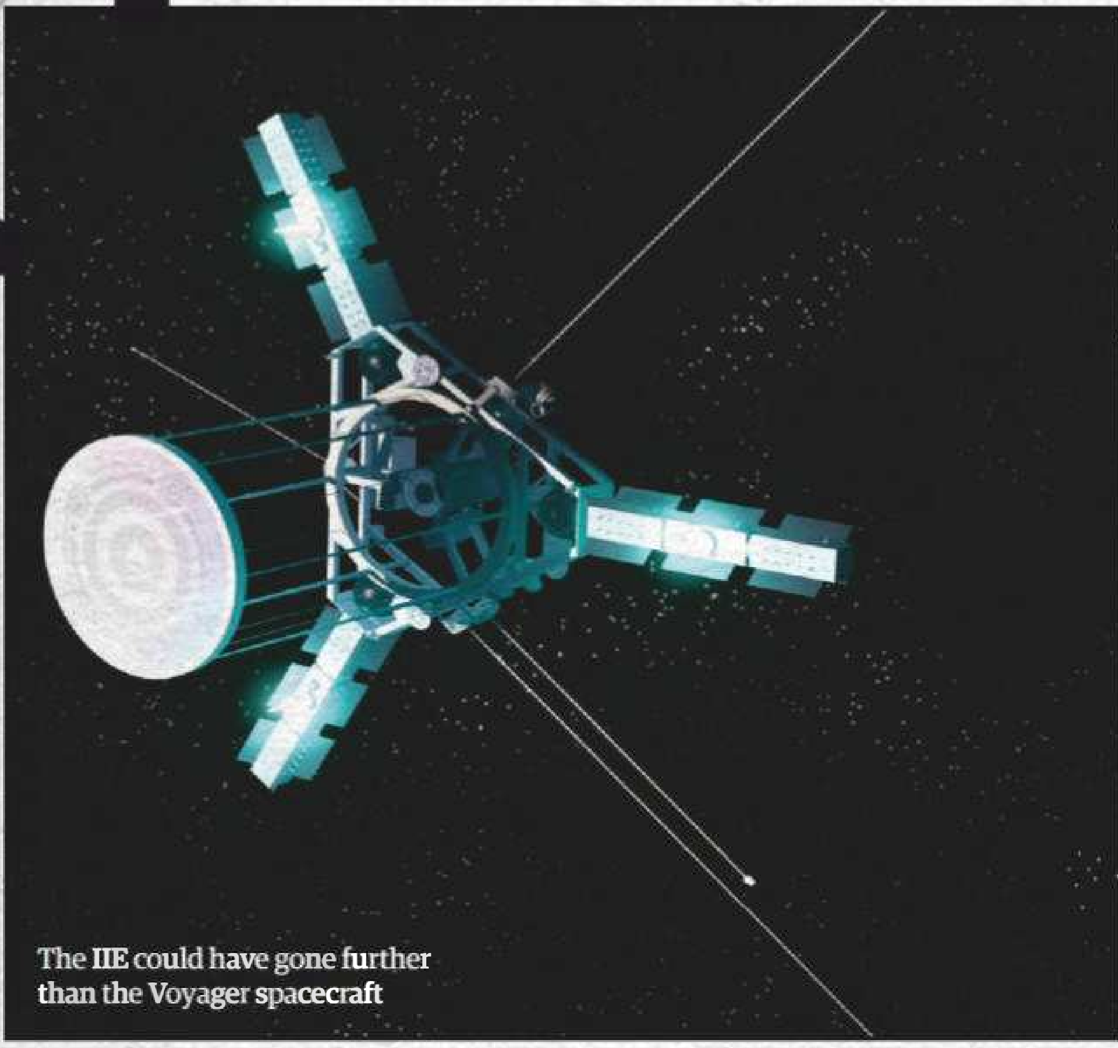
*** It's been hobbled by politics**
Aside from government budgets, politics can often have a direct effect on a spacecraft's design. Eventually it can become unworkable.

Manned Venus flyby

Proposed launch date: *31 October 1973*
Mission duration: *396 days*

The Apollo Applications Program was set up to utilise Apollo hardware for manned missions after the Moon landings, with a strong emphasis on science. A flyby of Venus was one such consideration, and it didn't lack ambition. During the flyby the astronauts would have launched probes to six locations in Venus's atmosphere, four weather balloons and four surface probes with the aim of photographing the surface. In 1968 the Apollo Applications Program had its $455 million budget cut by 73 per cent. Humanity's first flyby to another planet wasn't to be.

Humans could have flown past Venus and launched probes



The IIE could have gone further than the Voyager spacecraft

Innovative Interstellar Explorer

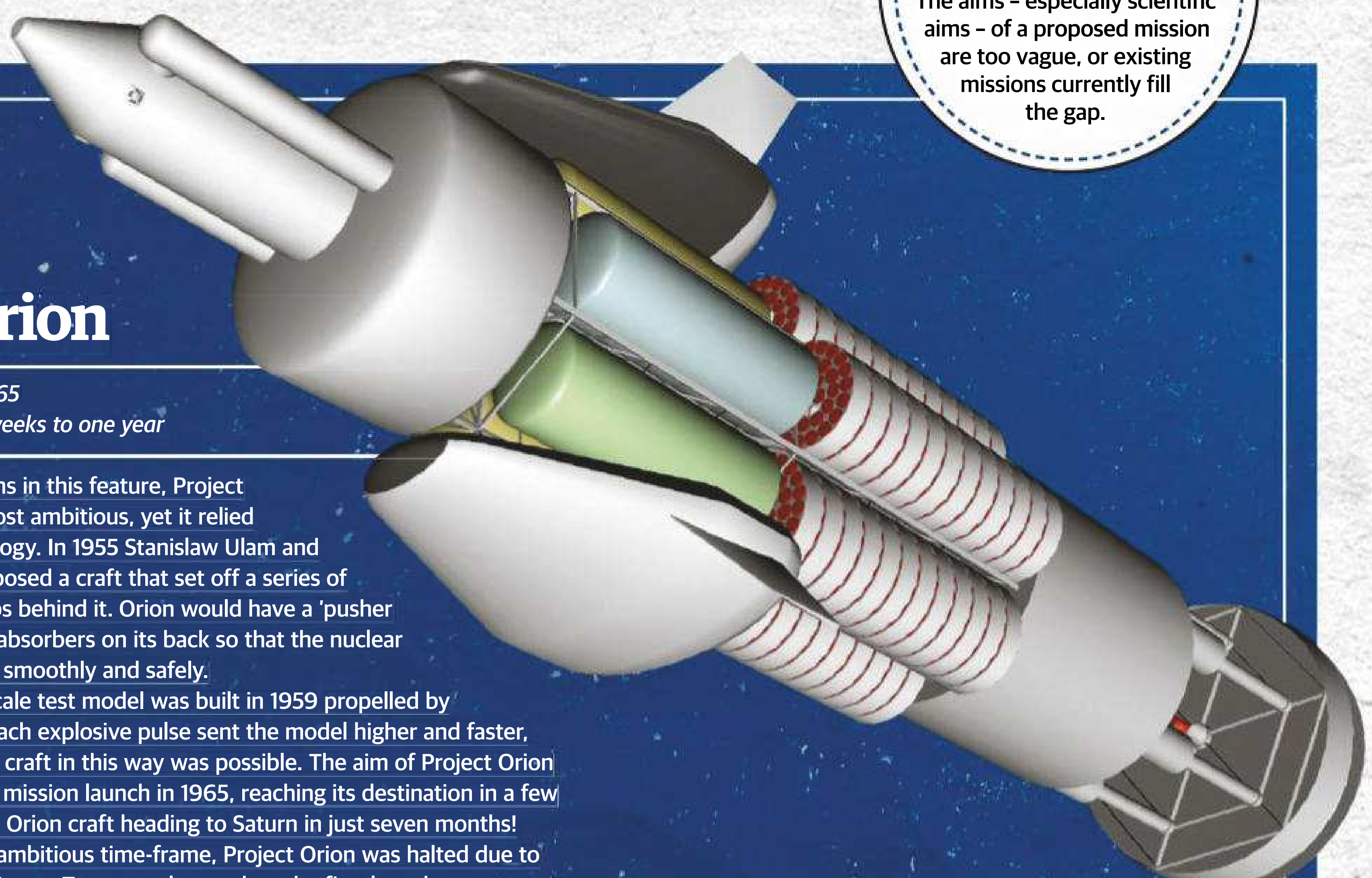
Proposed launch date: *2014*
Mission duration: *100 years plus*

The Innovative Interstellar Explorer (IIE) study, funded by NASA in 2003, focused on a mission to travel into interstellar space. It would be powered by a fissile nuclear reactor and propelled by efficient ion engines that would get it beyond 200 astronomical units (AU), or 200-times the distance between the Earth and Sun, in 17 years. It's taken Voyagers 1 and 2 41 years to reach roughly 144 and 119 AU respectively. Like the Voyager interstellar mission, IIE would have studied the interstellar medium, the structure of the heliosphere, galactic cosmic rays and other science targets. The probe itself would have been accurately tracked to look for gravitational waves, a possible cosmological constant or other forces. Even the data downlink signals would have been studied to probe whether space itself had polarising effects. If the craft survived into the 22nd century it could reach 1,000 AU. The IIE wasn't without inspiration: the Thousand Astronomical Unit (TAU) study in 1987 had almost identical aims. It planned to reach 1,000 AU in 50 years and even had a laser data link.

"IIE would have studied the interstellar medium, the structure of the heliosphere, galactic cosmic rays and other targets"

*** The mission has limited value**

The aims – especially scientific aims – of a proposed mission are too vague, or existing missions currently fill the gap.



Project Orion

Proposed launch date: *1965*
Mission duration: *A few weeks to one year*

Of all the cancelled missions in this feature, Project Orion was probably the most ambitious, yet it relied heavily on existing technology. In 1955 Stanislaw Ulam and Cornelius Everett first proposed a craft that set off a series of small thermonuclear bombs behind it. Orion would have a 'pusher plate' connected to shock absorbers on its back so that the nuclear explosions would propel it smoothly and safely.

A 2.1-metre (6.9-foot) scale test model was built in 1959 propelled by conventional explosives. Each explosive pulse sent the model higher and faster, proving that accelerating a craft in this way was possible. The aim of Project Orion was to have a Mars-bound mission launch in 1965, reaching its destination in a few weeks, with other manned Orion craft heading to Saturn in just seven months! Apart from the extremely ambitious time-frame, Project Orion was halted due to the 1963 Partial Test Ban Treaty. Two years later, when the first launch was meant to occur, the US Air Force ceased its funding.

Project Orion was quite an explosive proposal

What's in the sky?

In this issue...


©Giuseppe Donatiello

8 NOV
Conjunction between the Moon and Jupiter in Libra

16 NOV
Asteroid 3 Juno is at opposition in Eridanus

17 NOV
The Leonids will reach their peak of 20 meteors per hour

27 NOV
The Moon and M44 make a close approach, passing within 0°25' of each other in Cancer


©Nicholas Jones

3 DEC
Conjunction between the Moon and Venus in Virgo

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

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.

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 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.

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. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

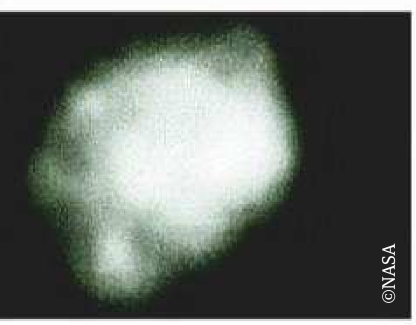
Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

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.

9 NOV
Conjunction between the Moon and Mercury in Ophiuchus

16 NOV
Conjunction between the Moon and Mars in Aquarius

16 NOV
The Moon and Mars make a close approach, passing within 0°57' of each other in Aquarius


©NASA

17 NOV
The Pleiades (M45) is well placed for observation in Taurus


©NASA/ESA

28 NOV
Comet C/2016 N6 (PANSTARRS) reaches its brightest at a predicted magnitude of 12.2

30 NOV
Venus is well placed for observation in the dawn sky, shining brightly at magnitude -4.7

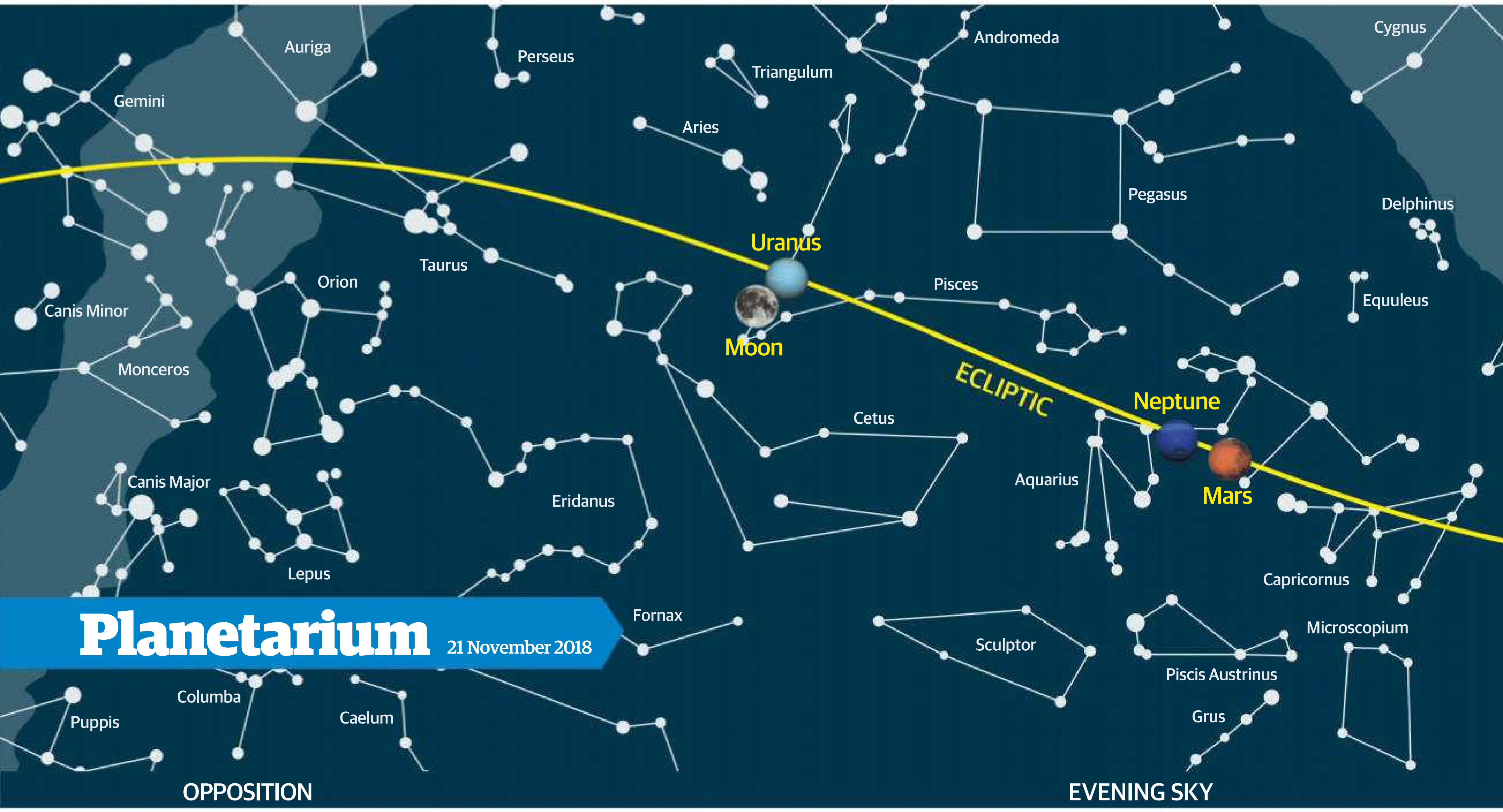
2 DEC
Comet 69P/Taylor is due to reach its brightest at a predicted magnitude of 11.9 in Eridanus

3 DEC
The Moon and Venus make a close approach, passing within 3°23' of each other in Virgo


©NASA

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

Planetarium 21 November 2018



Moon calendar

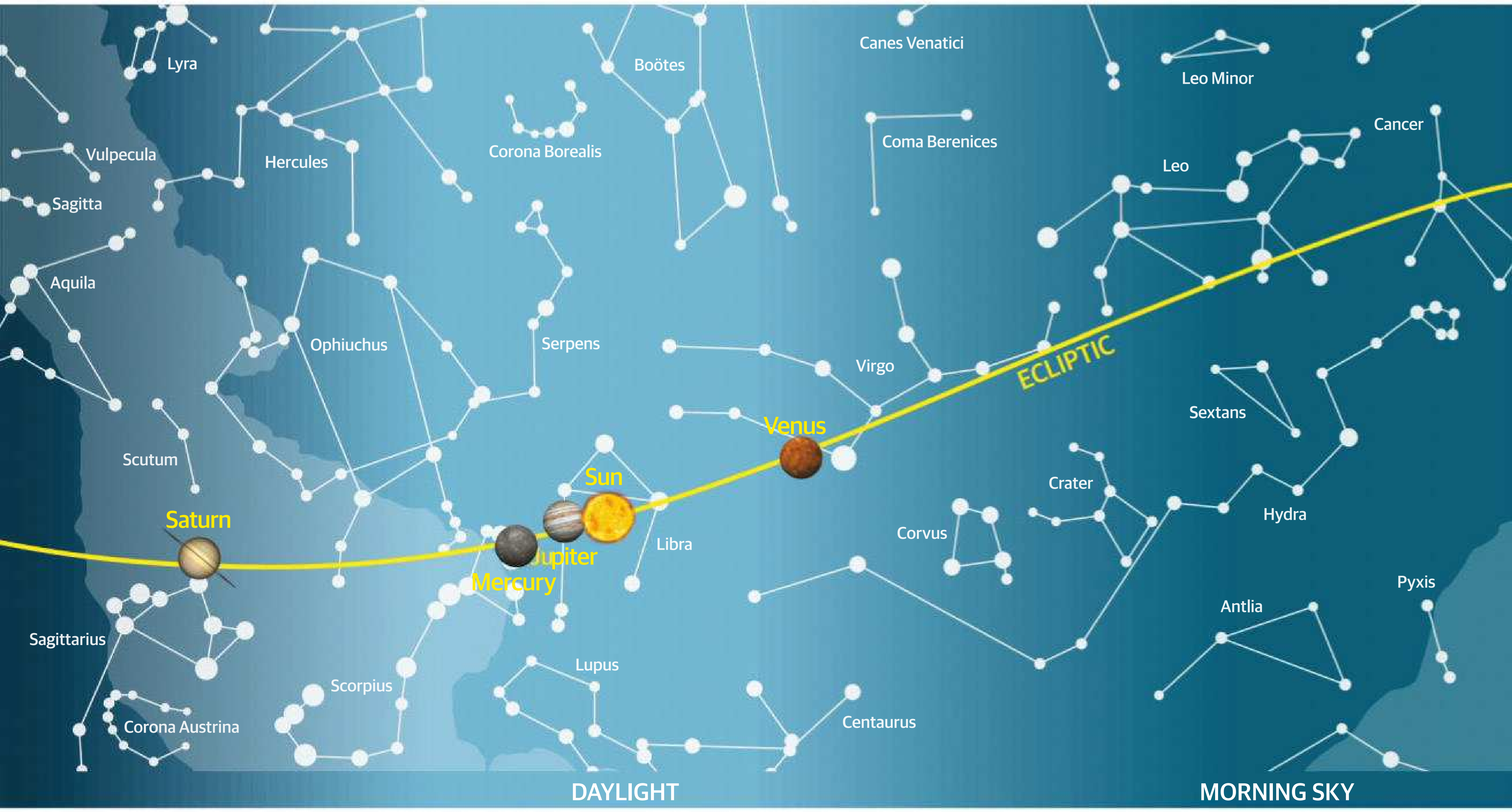
* The Moon does not pass meridian on 23 November

Date	Phase	Illumination	Moonrise	Moonset
8 NOV		1.0%	07:36	17:17
9 NOV		4.0%	08:46	17:49
10 NOV		9.0%	09:52	18:27
11 NOV		15.7%	10:51	19:11
12 NOV		23.6%	11:41	20:02
13 NOV		32.4%	12:24	20:59
14 NOV		41.8%	12:59	22:00
15 NOV	FQ	51.4%	13:29	23:04
16 NOV		61.1%	13:54	--:--
17 NOV		70.5%	14:16	00:09
18 NOV		79.3%	14:37	01:16
19 NOV		87.1%	14:57	02:24
20 NOV		93.4%	15:18	03:34
21 NOV		97.8%	15:41	04:47
22 NOV		99.8%	16:08	06:03
23 NOV	FM	--:--*%	16:41	07:19
24 NOV		99.1%	17:23	08:35
25 NOV		95.6%	18:15	09:46
26 NOV		89.3%	19:17	10:48
27 NOV		80.8%	20:29	11:40
28 NOV		70.4%	21:46	12:21
29 NOV		59.0%	23:04	12:53
30 NOV	FQ	47.3%	--:--	13:21
1 DEC		35.9%	00:22	13:45
2 DEC		25.4%	01:38	14:07
3 DEC		16.3%	02:53	14:29
4 DEC		9.0%	04:07	14:52
5 DEC		3.8%	05:20	15:18
6 DEC		0.9%	06:31	15:47

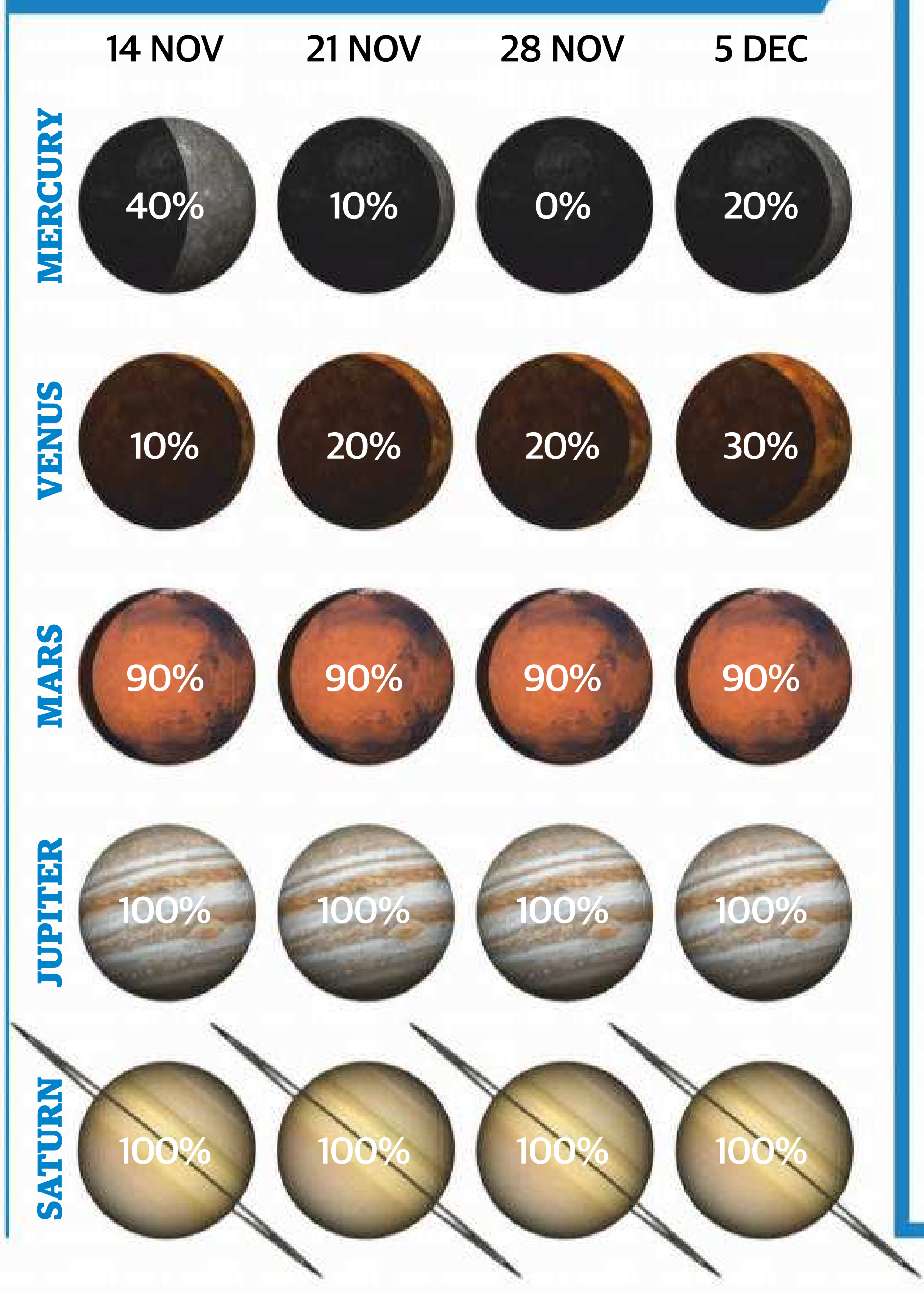
% Illumination
Moonrise time
Moonset time

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 GMT

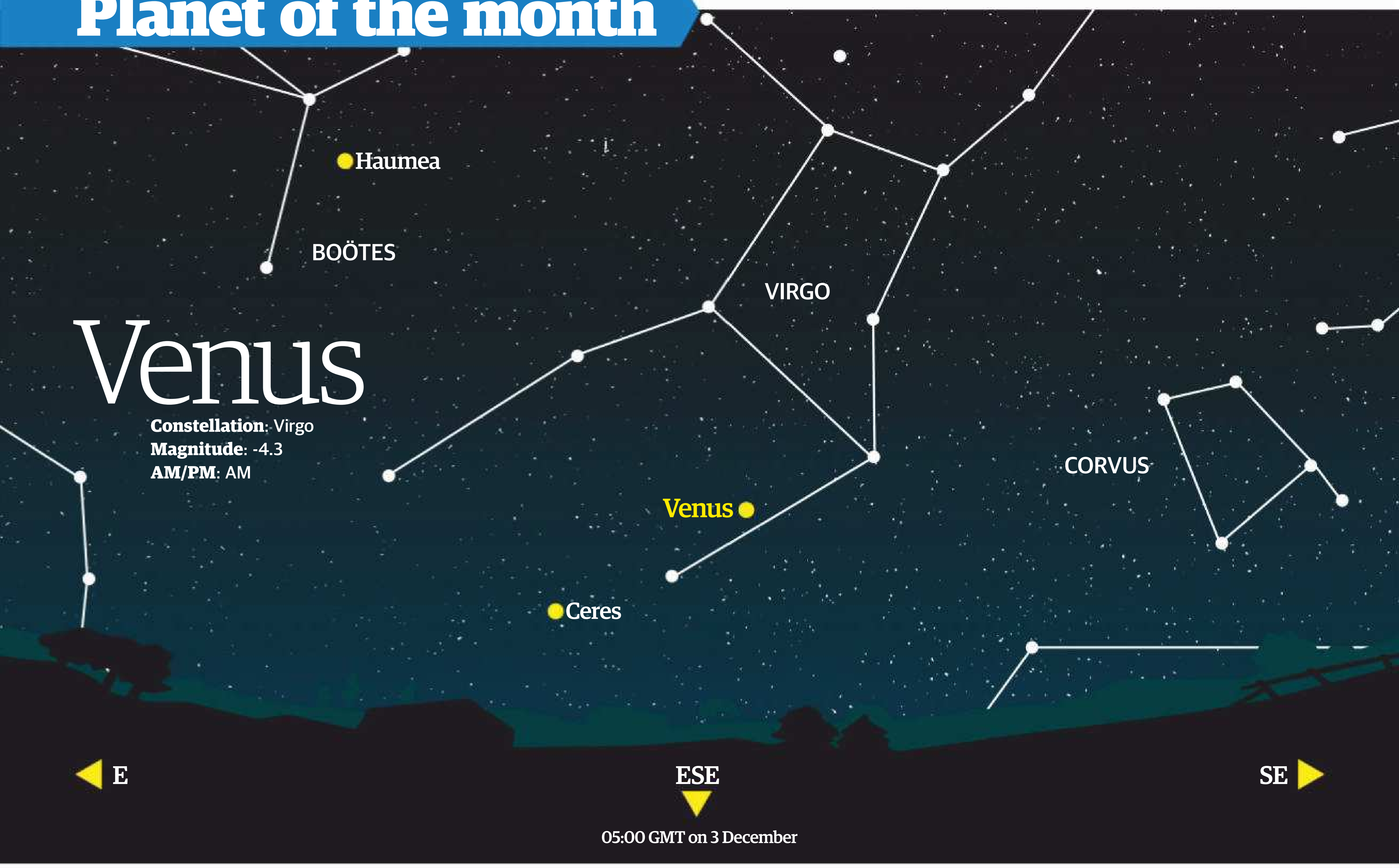
	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	08 Nov	16h 24m 35s	-24° 27' 02"	Ophiuchus	-0.3	09:33	17:13
	14 Nov	16h 43m 02s	-24° 45' 01"	Ophiuchus	0.0	09:30	17:06
	21 Nov	16h 41m 05s	-23° 21' 59"	Ophiuchus	1.5	08:51	16:46
	28 Nov	16h 08m 43s	-19° 50' 45"	Scorpius	5.8	07:29	16:09
	5 Dec	15h 42m 40s	-17° 02' 17"	Libra	0.8	06:19	15:32
VENUS	08 Nov	13h 33m 00s	-13° 22' 44"	Virgo	-4.4	05:36	15:29
	14 Nov	13h 30m 11s	-11° 30' 06"	Virgo	-4.5	04:59	15:12
	21 Nov	13h 33m 35s	-10° 09' 24"	Virgo	-4.6	04:28	14:55
	28 Nov	13h 43m 22s	-09° 43' 41"	Virgo	-4.7	04:08	14:39
	5 Dec	13h 58m 19s	-10° 04' 17"	Virgo	-4.6	03:57	14:25
MARS	08 Nov	21h 51m 45s	-15° 04' 58"	Capricornus	-0.5	14:02	23:37
	14 Nov	22h 05m 22s	-13° 37' 16"	Aquarius	-0.3	13:44	23:35
	21 Nov	22h 21m 31s	-11° 50' 26"	Aquarius	-0.2	13:23	23:33
	28 Nov	22h 37m 53s	-09° 59' 26"	Aquarius	-0.1	13:03	23:31
	5 Dec	22h 54m 25s	-08° 04' 59"	Capricornus	0.0	12:42	23:30
JUPITER	08 Nov	15h 50m 22s	-19° 24' 08"	Libra	-1.7	08:26	17:12
	14 Nov	15h 55m 50s	-19° 41' 16"	Libra	-1.7	08:10	16:52
	21 Nov	16h 02m 19s	-20° 00' 31"	Scorpius	-1.7	07:51	16:29
	28 Nov	16h 08m 51s	-20° 18' 52"	Scorpius	-1.7	07:32	16:06
	5 Dec	16h 15m 24s	-20° 36' 13"	Scorpius	-1.7	07:13	15:43
SATURN	08 Nov	18h 22m 54s	-22° 46' 01"	Sagittarius	0.6	11:20	19:23
	14 Nov	18h 25m 18s	-22° 45' 18"	Sagittarius	0.6	10:58	19:02
	21 Nov	18h 28m 17s	-22° 44' 07"	Sagittarius	0.6	10:34	18:37
	28 Nov	18h 31m 26s	-22° 42' 33"	Sagittarius	0.6	10:09	18:13
	5 Dec	18h 34m 43s	-22° 40' 36"	Sagittarius	0.6	09:45	17:49

STARGAZER

This month's planets

Venus, Mercury and Jupiter are the perfect targets for early risers this November and through to December

Planet of the month



Venus

Constellation: Virgo
Magnitude: -4.3
AM/PM: AM

Venus is now shining brightly in the east before sunrise as a 'Morning Star', far, far brighter than any of the many stars around it. At the start of our observing period the second planet from the Sun rises at 6am, and by early December is rising at 4am, long before the Sun. Each morning through November and into December it will be a little higher, a little brighter and a little easier to see, very obvious to the naked eye as a bright silvery-white 'star'.

Our best views of Venus for this period will come in early December when it will be so bright that not even the light pollution blighting your town or city's sky will prevent you from seeing it; your naked eye will pick it out very easily, and the view through a pair of binoculars or a small telescope will be beautiful, too.

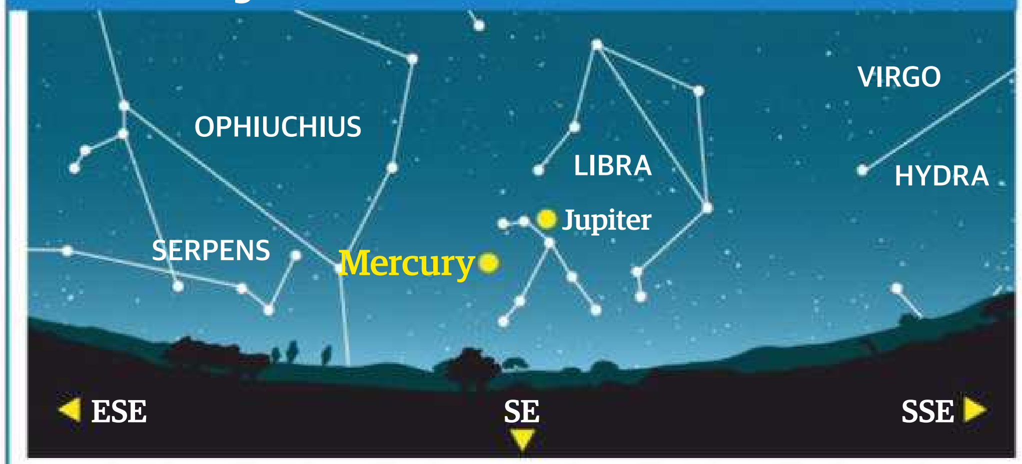
In early December Venus will have company in the sky. Before dawn on 3 December a thin waning crescent Moon will shine just eight degrees to the planet's upper right. The following morning the Moon will have moved on and will be a very thin crescent shining to the lower left of Venus. You should try to look at this gathering through a pair of binoculars to ensure you appreciate the contrasting colours of the Moon and Venus, and their different brightnesses too. On either of those mornings you might also see the dark part of the Moon's face glowing with the soft purple-pink glow of Earthshine.

Although it doesn't actually rain great plopping drops of skin-scorching acid on Venus, as some would have you believe, it does have clouds of highly corrosive sulphuric acid in its atmosphere. However, the temperature down on its surface would be equally as lethal to anyone who went there without adequate thermal protection: daytime temperatures on Venus can reach 470 degrees Celsius (878 degrees Fahrenheit).

With all that in mind it's unlikely that astronauts will visit Venus any time soon, but when they eventually do make the long journey from Earth the first team to land on Venus will be inside a spacecraft constructed with a thick, protective hull made out of special materials resistant to the planet's crushing pressures, lethal heat and poisonous air - something more like a diving bell than a lunar lander. That won't be for many years though, so you should get out there on these chilly, clear mornings and enjoy the sight of Venus blazing in the sky as a beautiful Morning Star.

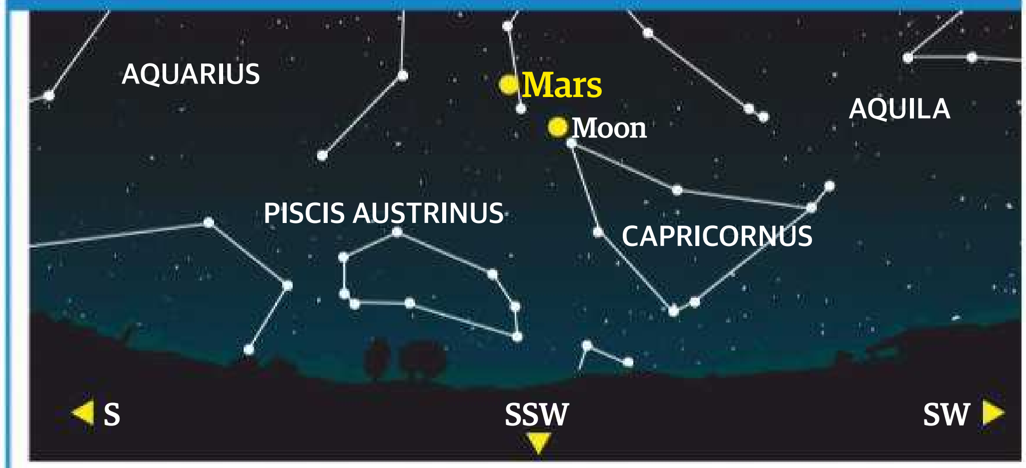
This month's planets

Mercury 09:00 GMT on 24 November



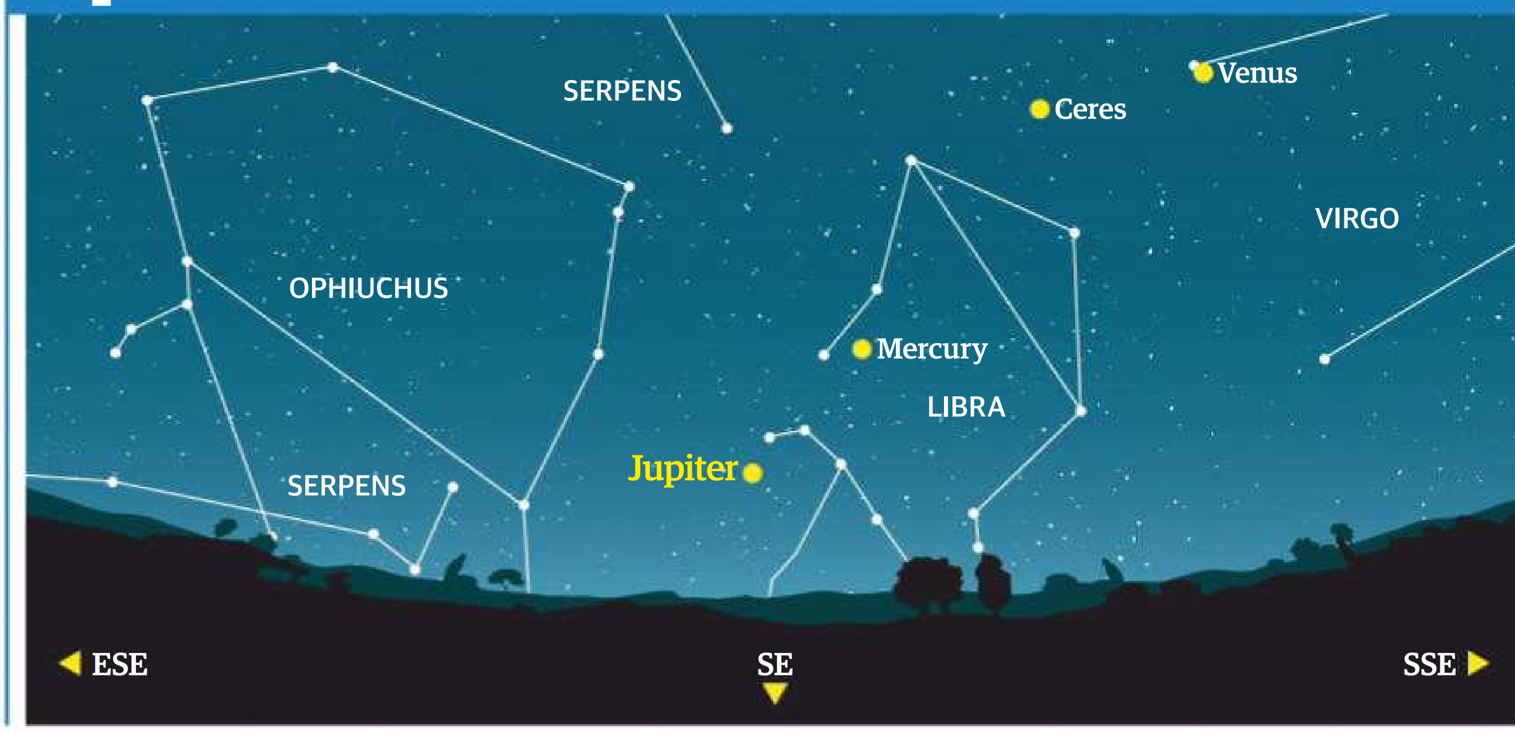
Constellation: Libra
Magnitude: -0.2
AM/PM: AM
Mercury is too close to the Sun to be seen at first, but by late November it might be visible in your binoculars or small telescope low in the southwest after sunset, just as long as you have no trees, buildings or hills blocking your view in that direction. After 20 November Mercury will begin to approach the Sun again.

Mars 20:00 GMT on 15 November



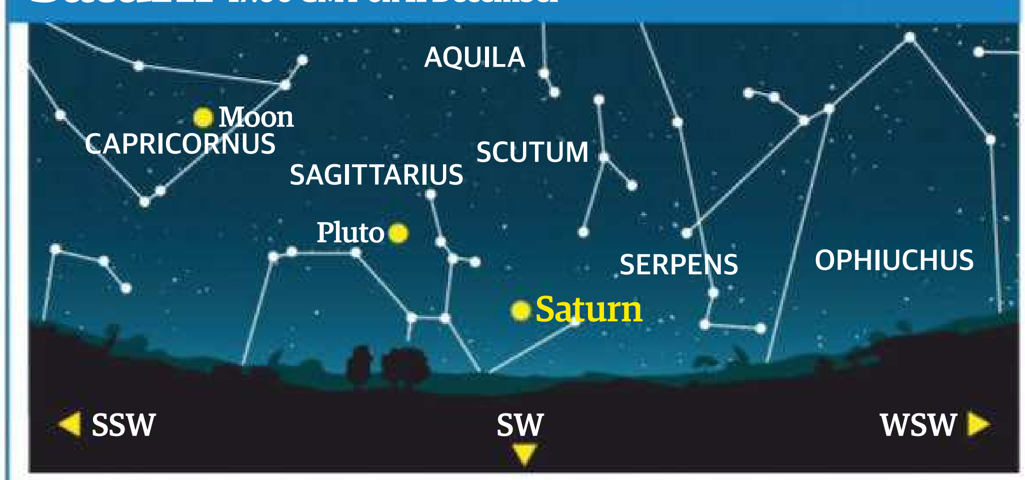
Constellation: Aquarius
Magnitude: -0.6 fading to 0.1
AM/PM: PM
Mars is really winding down for 2018 now. A bright, striking object in the summer, it is now little more than an orange-coloured 'star' shining among the fainter stars of Aquarius after sunset – and it is fading fast itself. At the start of our observing period it shines at a respectable magnitude -0.6, but this will dim as days pass.

Jupiter 08:00 GMT on 10 December



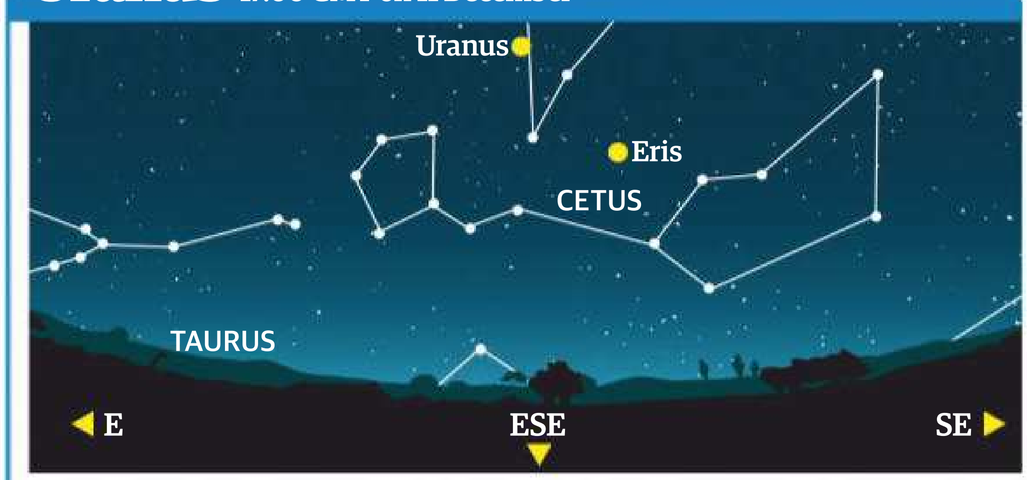
Constellation: Scorpius
Magnitude: -1.7
AM/PM: AM
There's no easy way to dress this up – this is going to be a really poor month for observing Jupiter. It will be so close to the Sun during all of November that it just won't be visible, and when it reappears in the morning sky at the start of December it will still be so close to the Sun that it will be all but lost in its glare for the 40 minutes that will pass between it rising and the Sun rising behind it. So if you want to see Jupiter this month your best bet is to go to the website of NASA's Juno mission (**missionjuno.swri.edu**) and take a look at the amazing images being returned by its camera.

Saturn 17:00 GMT on 11 December



Constellation: Sagittarius
Magnitude: 0.6
AM/PM: PM
After being a pleasing sight all through the summer months, Saturn is now fading and becoming less and less impressive and even less interesting to look at. At the start of our observing period it is already visible low in the southwest as darkness begins to fall, but will be setting mid-evening, around 7pm.

Uranus 17:00 GMT on 11 December



Constellation: Aries
Magnitude: 5.7
AM/PM: PM
Huge, distant, lonely Uranus will be visible all through the evening right through our observing period. As darkness falls on any clear night you'll find Uranus low in the east as dusk falls, and it will remain visible until the early hours of the next morning. At magnitude 5.7 it is technically a naked-eye object.

CLOUDY NIGHT ASTRONOMY

There are lots of things you can do when the weather doesn't cooperate

Written by Jamie Carter

Clear skies allowing – a phrase every stargazer and amateur astronomer should have as their personal motto to remind them that astronomy can be a fickle friend. In fact, during the cold winter months and into spring the chance of clear nights drops dramatically in the Northern Hemisphere. Even when it's been clear all day a cold front can arrive quickly and produce thick cloud just after telescopes have been set up. Should you wait it out and hope for a gap in the clouds? Pack up and head indoors? Try again at 4am? Or abandon the idea altogether and come up with a Plan B?

If you're just starting out as a stargazer, it's perhaps better to suspend your plans if it's cloudy at dusk. After all, at the start of your career you're after a big wide-eyed view of a clear sky where you can take in the enormity of the universe. For more experienced stargazers and telescope owners, why not draw up a list of targets for your next observing session? Either way, keep calm about the weather – getting annoyed won't get you anywhere – and follow our tips for making the best of bad weather.

Why not log on to a telescope above the clouds in La Palma in the Canary Islands?

Use an online observatory

If you're under the kind of stubborn cloud that seems to last forever and you can't get yourself to clear skies, have them come to you via the internet. Thanks to a worldwide observatory network of automated telescopes situated under some of the planet's clearest skies, you can now discover the universe with nothing more than a web browser. The best choice for beginners is Slooh (slooh.com), which has seven telescopes in the Canary Islands and Chile, as well as occasional feeds from 25 others. As well as looking at a live feed, as an 'apprentice' member you can look at 500 popular objects in the night sky, and even take control of the telescopes to create images. Remote astrophotography is also possible via the more advanced iTelescope (itelescope.net) platform, which has a network of remote telescopes around the globe.

Get a stargazing forecast

Although you can easily consult weather apps and websites for a general overview of conditions in your area, it's now possible to get a forecast not only specific to your exact location, but also created especially for amateur astronomy. One of the best apps is Egg Moon Studio's Scope Nights **(eggmoonstudio.com)**, which provides stargazing weather reports for anywhere in the world. Designed to be a planning aid, it gives details for up to ten nights ahead using the Met Office DataPoint. It also sends clear period notifications before sunset so you can confidently set up. Another option is the Dark Sky **(darksky.net/app)** app, which gives detailed hour-by-hour hyperlocal weather information and provides a real-time satellite map showing cloud cover. With a little luck you should be able to spot a gap in the weather.

Don't shout at clouds!

If you've planned an observing session and made an effort to get somewhere remote - perhaps even somewhere abroad known for its dark, clear skies - stepping outside to cloud can be devastating. Don't get annoyed. There's no point. A good stargazer knows how to get excited about the night sky, but equally knows not to start shaking their fists at clouds. A large part of the attraction of amateur astronomy is the sense of perspective you get when looking at the night sky, and the sense of peace it can bring. It would be a shame if some condensed watery vapour changed all that. Consider what late Apollo 12 Lunar Module pilot Alan Bean - the fourth person to walk on the Moon - said about his experience on the desolate lunar surface: "Since that time I have not complained about the weather one single time... I'm glad there's weather." The weather might be bad sometimes, but without it we wouldn't be here.

Mind the gaps

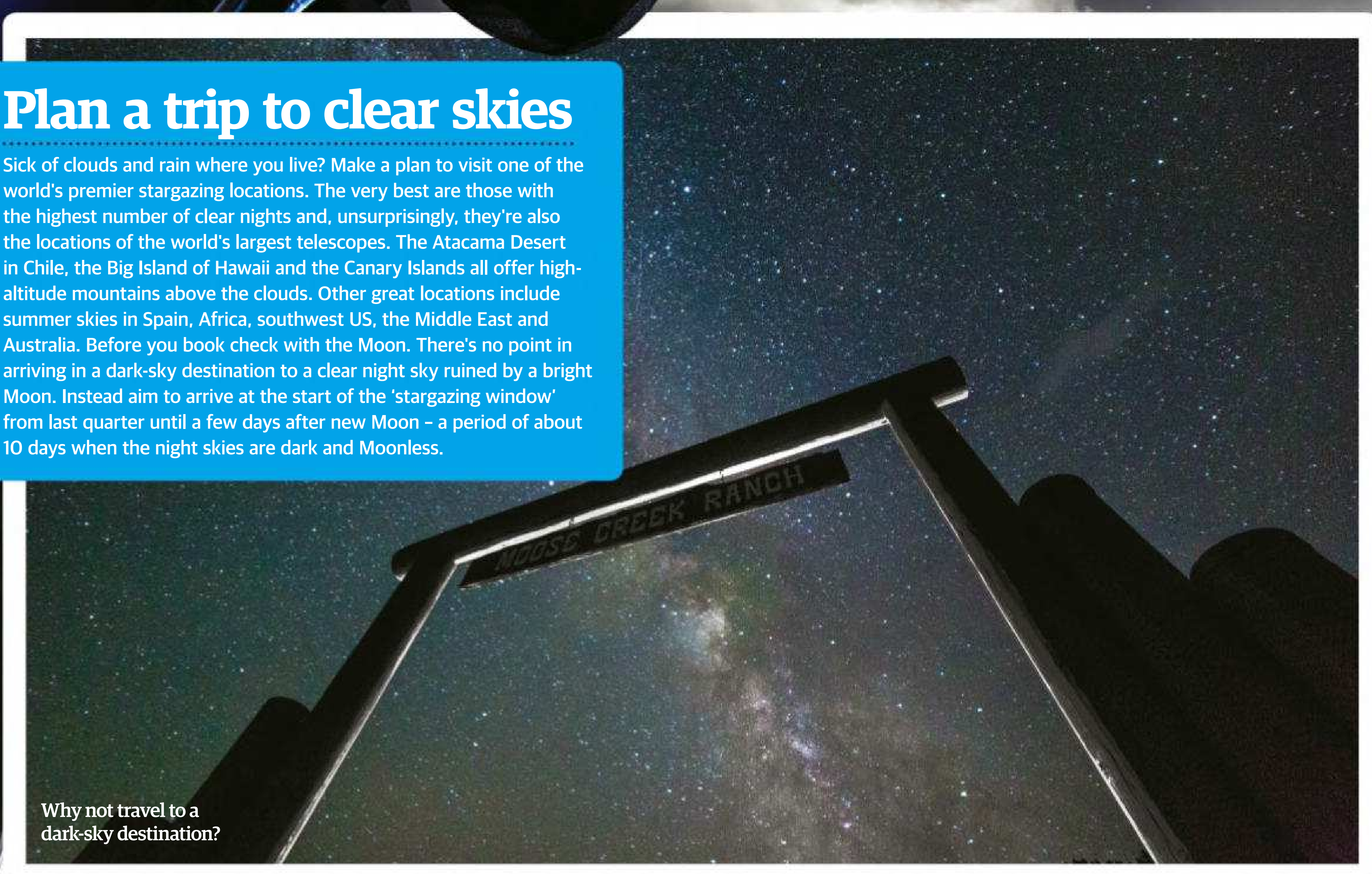
Most stargazers learn the night sky by star-hopping. For example, it's easy to find Polaris, the North Star, if you can identify The Big Dipper; its bowl's outer two stars, Dubhe and Merak, point straight at Polaris. Other popular star-hops include using Orion's Belt not only to point downwards in winter to Sirius, the Dog Star – and the closest star that Northern Hemisphere dwellers can see – but also up to the constellation of Taurus and the Pleiades star cluster beyond. With clouds covering most of the stars you use to navigate, can you still find Sirius in gaps in the cloud cover? What about the Pleiades?

Learning how to recognise stars, parts of constellations and star clusters without any visual prompts is great practice if you're trying to learn the night sky. That kind of knowledge can make it much easier to aim a manual telescope.

Can you find the Pleiades in gaps in the clouds?

Plan a trip to clear skies

Sick of clouds and rain where you live? Make a plan to visit one of the world's premier stargazing locations. The very best are those with the highest number of clear nights and, unsurprisingly, they're also the locations of the world's largest telescopes. The Atacama Desert in Chile, the Big Island of Hawaii and the Canary Islands all offer high-altitude mountains above the clouds. Other great locations include summer skies in Spain, Africa, southwest US, the Middle East and Australia. Before you book check with the Moon. There's no point in arriving in a dark-sky destination to a clear night sky ruined by a bright Moon. Instead aim to arrive at the start of the 'stargazing window' from last quarter until a few days after new Moon – a period of about 10 days when the night skies are dark and Moonless.



Why not travel to a dark-sky destination?

Photograph the Moon

If there is any kind of gap in the cloud, or even if there's just a thin layer of cloud, Moon-watching may still be possible. It's also a great time to photograph the Moon. Although they are annoying clouds can make images of the Moon more interesting. A cloud drifting over its face, or a cloud nearby reflecting some of its light can look effective in terms of composition and framing. As a starting point, in manual mode set your camera to ISO 100 or ISO 200, the aperture to between f/5.6 and f/11 and the shutter speed to between 1/125sec and 1/250sec. Then use autofocus on the Moon. Take some test shots, and if they're reasonable zoom in to see if the results are sharp (a tripod helps). If the Moon is waxing towards full, or just past full then it's probably too bright to look at anyway. By blotting out some of its glare, a thin layer of cloud can sometimes make it easier to Moonwatch.


The appearance of the Moon can actually be improved by the presence of some cloud

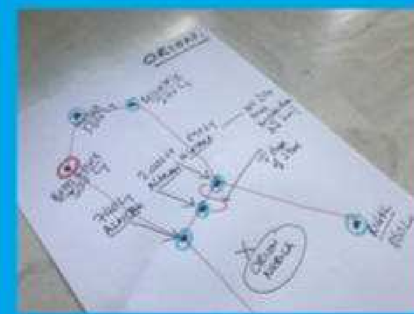
Go planet-spotting

Why not focus on finding planets among the clouds using a telescope or binoculars? What planets you can see will depend on where they are on their orbital path in the Solar System in relation to where Earth is. However, since the Solar System is flat and all the planets orbit the Sun in the same plane, there's a path through the night sky stretching from east to west – the same as the Sun's apparent path – where all planets can be found. That's called the ecliptic, and it's where you'll find Jupiter, Mars, Saturn, and Venus, which are the biggest, brightest planets in the night sky, and easiest to observe.

> "Stargazing is about learning not just the contents of the night sky, but how it changes"

Go virtual stargazing

Stargazing is about learning not just about the contents of the night sky, but how it changes. So even if you can't see the stars themselves, it's useful to know what's up. By waving an augmented-reality planetarium smartphone app at the heavens you can see what's 'up' that night. It's not ideal, but if you have a look at what's behind the clouds at, say, 8pm, you can come back the next day and – if it's clear – you'll know exactly what to expect. Good examples of planetarium apps include Stellarium Mobile Sky Map, Night Sky and Star Walk 2. Your phone's accelerometer, compass and GPS sensors will give you a live view of the night sky as you move it around. Whether the sky is cloudy or clear is irrelevant.

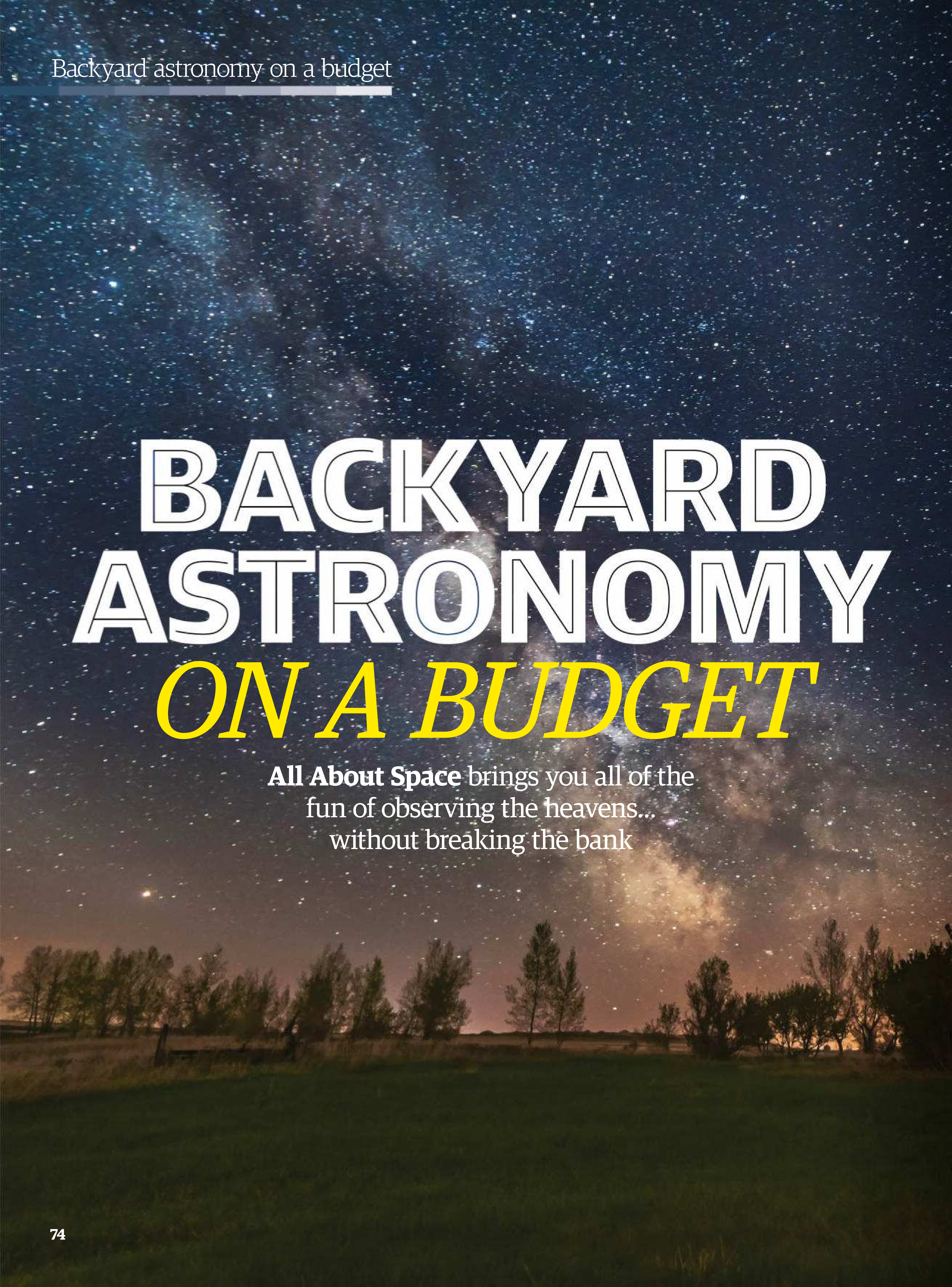


Make constellation cards

You may know how to find dozens of constellations, but how well do you know their constituent stars and the deep-sky gems that lay within? If it's cloudy pick a constellation that you know would otherwise be visible and use an app, astronomy book or the internet to make a rough sketch of it on a piece of card. First plot its main stars, then beside each write its name and its distance from the Sun. Then add the position and names of any double stars, interesting shapes, asterisms and deep-sky objects that you can later check out with your binoculars or telescope.

Check your equipment

If you're using binoculars, a telescope or a camera for observing it's likely they could do with a check up for dirt and dust. It's best not to touch and clean lenses, eyepieces, filters and telescope mirrors unless it's unavoidable, but now is the time to check. If you have a Newtonian or Schmidt-Cassegrain reflector telescope it may need collimating (aligning). Cloudy weather is also a good time to accessorise. Go looking for more powerful binoculars, a better finderscope or a new wide-angle lens for when clear skies return. Clean and upgraded equipment means next time you're faced with a starry sky you can get straight down to stargazing.



BACKYARD ASTRONOMY *ON A BUDGET*

All About Space brings you all of the fun of observing the heavens… without breaking the bank

When it comes to first choosing and purchasing equipment to observe the night sky, there's a lot to take in. "Which telescope should I get?" "Which magnification is best for my first pair of binoculars?" "Do I need to buy extra eyepieces?"

These are possibly just some of the questions that you may have found yourself puzzling over. It may be that the daunting task of selecting a telescope or pair of binoculars has put you off pursuing a hobby in astronomy. Maybe you bought a telescope that doesn't meet your requirements or is too complicated for you to use. If you took the plunge before you were ready, it has most likely left you feeling frustrated and disappointed, with nothing to show for your efforts other than a piece of equipment gathering some dust in some rarely visited corner of your home.

Blunders like this aside, it certainly is possible to take part in backyard astronomy without having to spend an incredible amount. The trick is to do your research; that could involve reading up on your hobby in stargazing books, or getting some advice from a seasoned amateur astronomer at your local astronomical society before you make your first purchase. It is also essential that you shop around to compare prices, making sure that there is a satisfactory trade-off between how much you can afford and what your potential piece of equipment can actually offer in terms of observational performance. Lastly, you should always think ahead – will your equipment still be usable a year into your backyard astronomy hobby?

Where first-time astronomers often get lost is not being able to figure out what they should be looking for in an ideal piece of equipment, and thinking that bigger and more expensive is better. This is not always the case. It is always down to the individual, and a telescope that allows you to do what *you* want at a reasonable cost is definitely a step in the right direction.

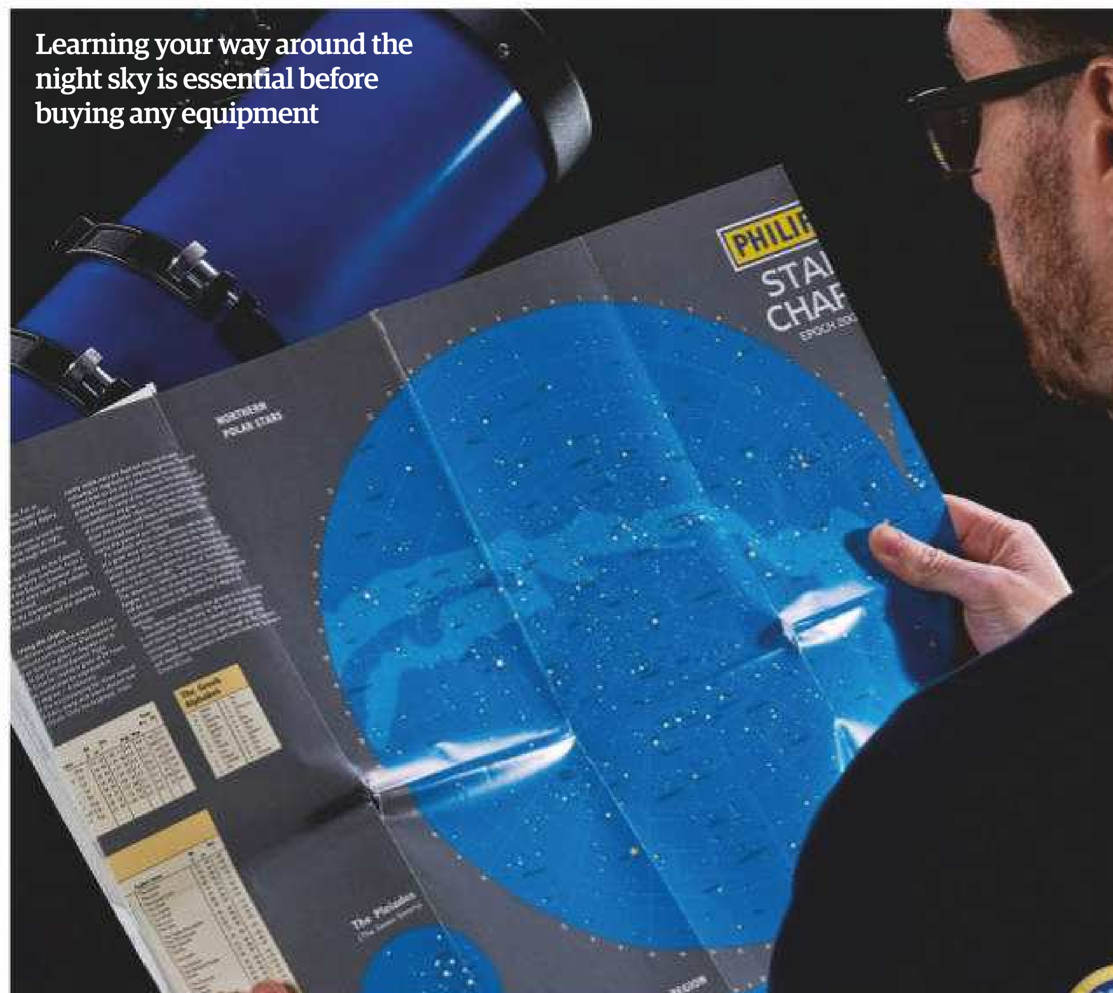
Still at a loss? We've put together this guide to ensure that you get the experience that you want with minimum fuss.

"It is also essential that you shop around to compare prices"

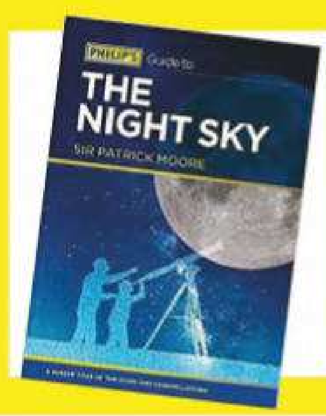
Choosing your night sky guide, map or planisphere

Getting a good idea of the constellations and identifying naked-eye objects such as planets, star clusters and prominent stars will help you to find objects with the equipment that you might be intending to buy later on. These objects can act as signposts in the night sky, pinpointing hidden treasures that you could have the chance of meeting further into your hobby.

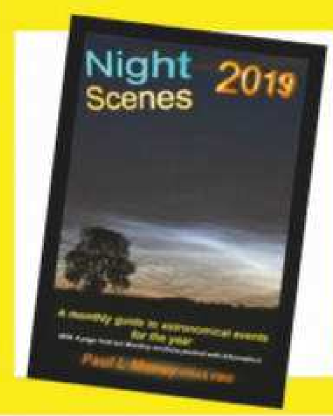
If you're very unfamiliar with what's out there and you're unsure of prime targets in the winter, summer, autumn and spring skies then you should certainly invest in a planisphere or a guide to the night sky; it will not only show you where everything is, but what objects you can observe throughout the year. Many guides are less than £10 (~$16), which means that you wouldn't have to spend too much if you do change your mind about your hobby. Alternatively, stick with it and it will be a guide that you can use over and over again. Remember, there's no time limit to how long you should spend partaking in naked-eye astronomy, so take your time in getting acquainted with the heavens.


Learning your way around the night sky is essential before buying any equipment

Philip's Guide to the Night Sky (Sir Patrick Moore)
Cost: £5.99
www.amazon.co.uk



Nightscenes 2019: A Monthly Guide to the Astronomical Events for the Year (Paul Money)
Cost: £6.00
www.astrospace.co.uk



Philip's Planisphere (Classic 11.5")
Cost: £9.99
www.amazon.co.uk

© Alan Dyer / VWPics / Alamy Stock Photo

Pay close attention to the magnification of your potential binocular purchase

Selecting your binoculars

Without a shadow of a doubt, a pair of binoculars is the way to go when it comes to using your first piece of equipment. Not only do they promote minimum fuss and can be turned to any object with ease - unlike a telescope which will need polar alignment - but the pair that you're likely to be using don't require any setting up. Additionally you have much more freedom of movement, magnifying objects without spending a great deal of money.

If your budget is less than £100 then it may be worth your while investing in a very good pair of binoculars rather than a low-quality telescope. Also remember that your binoculars can be doubled-up as sight-seeing aids on holiday, as well as for nature-watching, providing a multitude of purposes in one hit.

You'll find that binoculars are usually marked with figures such as 8x40, 7x50 or 10x50 - here the first figure is the magnification, while the second is the aperture of the lenses built into the binoculars in millimetres. For casual observing your best bet is to go for 7x50 or 10x50 binoculars, since they are both equally useful. Remember that the greater the aperture, the heavier the binoculars, so if you find that 50mm is too heavy for you to hold steady, opt for 40mm or even 30mm models. Alternatively, when it comes to the compromise between weight and power, many go for 8x32 or 8x42 binoculars. Remember that the heavier they get, the more likely you'll need a tripod - it will be very difficult to observe any objects when your arms are shaking under the weight, so make sure you choose wisely!

"You have much more freedom of movement, magnifying objects without spending a great deal of money"

Meade 10x50 Binoculars
Cost: £38.99
www.meade.com

Nature 8x42 Porro Binoculars
Cost: £74.99
www.harrisontelescopes.co.uk

Elinor 10x50 Binoculars
Cost: £199.99
www.opticalhardware.co.uk

EDITOR'S CHOICE

Avoid...

- Magnifications greater than 12x – unless you have a particular need for specialist binoculars.
- Binoculars that are too heavy for you to hold – they will be difficult to hold steady without the additional cost of a tripod.
- Zoom binoculars – they have narrow fields of view and poor optics.

Go for...

- Binoculars with coloured coatings on their optics – these will improve image brightness.
- Binoculars that strike a good balance between light-gathering capacity (the aperture or diameter of the object lens), magnification, weight and cost.
- Good build quality – you want a pair either made of polycarbonate resins and plastics or magnesium alloys.
- Waterproof binoculars that are environmentally sealed and filled with an inert gas such as nitrogen.
- Porro or BAK-4 prisms that offer 8x magnification and reasonably large object lenses of 42mm or above.

Upgrading to a telescope

At this stage you might be looking to upgrade your binoculars to look deeper into the night sky. Before you purchase a telescope there are a few things that you should consider; firstly, consider if you're familiar enough with the night sky and, secondly, ensure that buying a telescope will improve your observing experience. There is little point in spending more money on a telescope when it doesn't give much more magnification than your binoculars or if it's likely to end up gathering dust in your home. So before buying, it is always best to consider these factors.

Choosing your telescope can be a challenge when you don't know what you're looking for, so once again it is important to know how much you're willing to spend and what capabilities you're wanting your telescope to have. It's said that refractors are best for checking out the craters on the Moon and the planets, while a reflector – capable of collecting more light – is best for the fainter, more diffuse nebulae and galaxies.

However, at this stage it is best not to limit yourself and to go for an all-round telescope that can show you a wide range of night-sky gems. These are often referred to as Newtonian, or the hybrids Schmidt-Cassegrain, Maksutov-Cassegrain or catadioptric telescopes. It may be tempting to opt for a GoTo telescope which can just point you to any object that you wish. However, these can be difficult and time-consuming to set up. Many beginners are attracted to what a dobsonian telescope (a type of Newtonian telescope) has to offer in the trade-off between price and performance.

A good, sturdy Newtonian telescope should cost you around the region of £200, while a good refractor could be as little as £300. Most come with a tripod and eyepieces to start you off. Also ensure that you buy from a well-respected telescope dealer, or perhaps someone experienced at your local astronomical society, and you can't go wrong.

A refractor is one of the most recognisable types of telescope for beginners

Visionary Mira Ceti 1400/150 telescope
Cost: £299.99
www.opticalhardware.co.uk

Vixen Space Eye 70 telescope
Cost: £129
www.vixenoptics.com

Skywatcher Skyliner-150P telescope
Cost: £223 ($295)
www.skywatcher.com

All About Space EDITOR'S CHOICE

Top tip!

You'll see Linné's central crater pit at its best when it is close to the terminator, the line between night and day.

Moon tour

Linné

Track down one of the most infamously mysterious craters on the lunar surface

After centuries of intensive study with the naked eye, through telescopes and more recently using the amazingly powerful cameras of orbiting satellites, we're pretty clear on how the craters we see spattered across the face of the Moon formed - and it's really not rocket science. Over millennia countless thousands of big rocks have come barrelling in from space, slamming into the Moon and blasting great big holes out of it.

Some of these craters are huge, measuring hundreds of kilometres across; others are barely one kilometre from side to side. Some are surrounded by beautiful, bright rays - dust that sprayed away from the impact and then splashed back down across the Moon's surface. Most of the Moon's craters have changed in some way since they were formed. Subsequent impacts nearby have shook them up and even altered their shapes, causing their walls to slump or collapse. Many craters have vanished since they were formed, either buried beneath the debris thrown out by the younger impact or covered by tsunamis of glowing, bubbling lava.

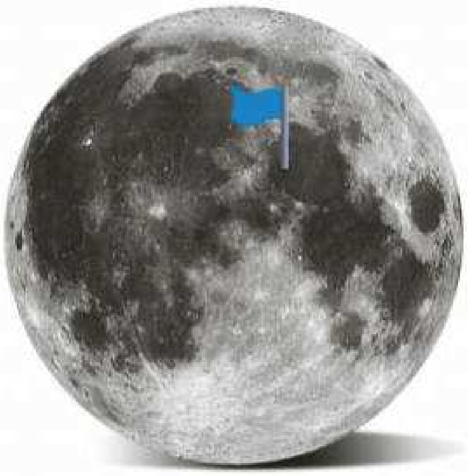
Here and there we can see craters that have somehow managed to survive unscathed since they were formed. These are useful to planetary scientists because they allow them to study the process of crater formation very accurately. One such crater is our target for this month.

Linné is a tiny crater on the western side of Mare Serenitatis. Barely two kilometres (1.2 miles) across and just 600 metres (0.37 miles) deep, it stands alone on the Sea of Serenity with no other features nearby, and has not been shaken, broken or destroyed by any other impacts close to it. It is very young, perhaps only 10 million years old, so it formed when the major bombardments of the Moon had ended, and it has managed to avoid being smashed up by any impacts since then. So, although Linné is unimpressive physically, its youthfulness and almost pristine condition makes it a perfect study subject for scientists wanting to understand how craters form and change over time.

Linné was discovered by Giovanni Riccioli in the 17th century. After that it was observed frequently by others, but in 1866 Johann Schmidt made a startling claim - Linné had vanished! All he could see, he said, was a bright mound where the crater had once been. Other observers looked, and they too could not see the crater any more. By 1868 observers could see the crater again very clearly, and it has remained in clear view ever since. So what happened?

One theory is that Linné was leaking gas from beneath its surface in 1866, which glowed in the sunlight and obscured the crater itself from view. This idea was very controversial for a long time, but today is widely accepted; astronomers call it 'transient lunar phenomenon', or TLP. It has been seen in or close to other lunar features, including the large crater Alphonsus.

So how can you see this strange little crater? Linné is so small it can't be seen with the naked eye, and even a pair of binoculars shows it as just a tiny white spot to the right of the Appennines, without any hint of the small crater pit at the centre. Small telescopes show it as a bright splash of white on the grey surface of the Moon, like the mark a piece of chalk would leave on a grey slate, and might pick out the crater at high magnification. It takes a large telescope to show the crater properly, in the centre of its bright splash of ejecta rays.

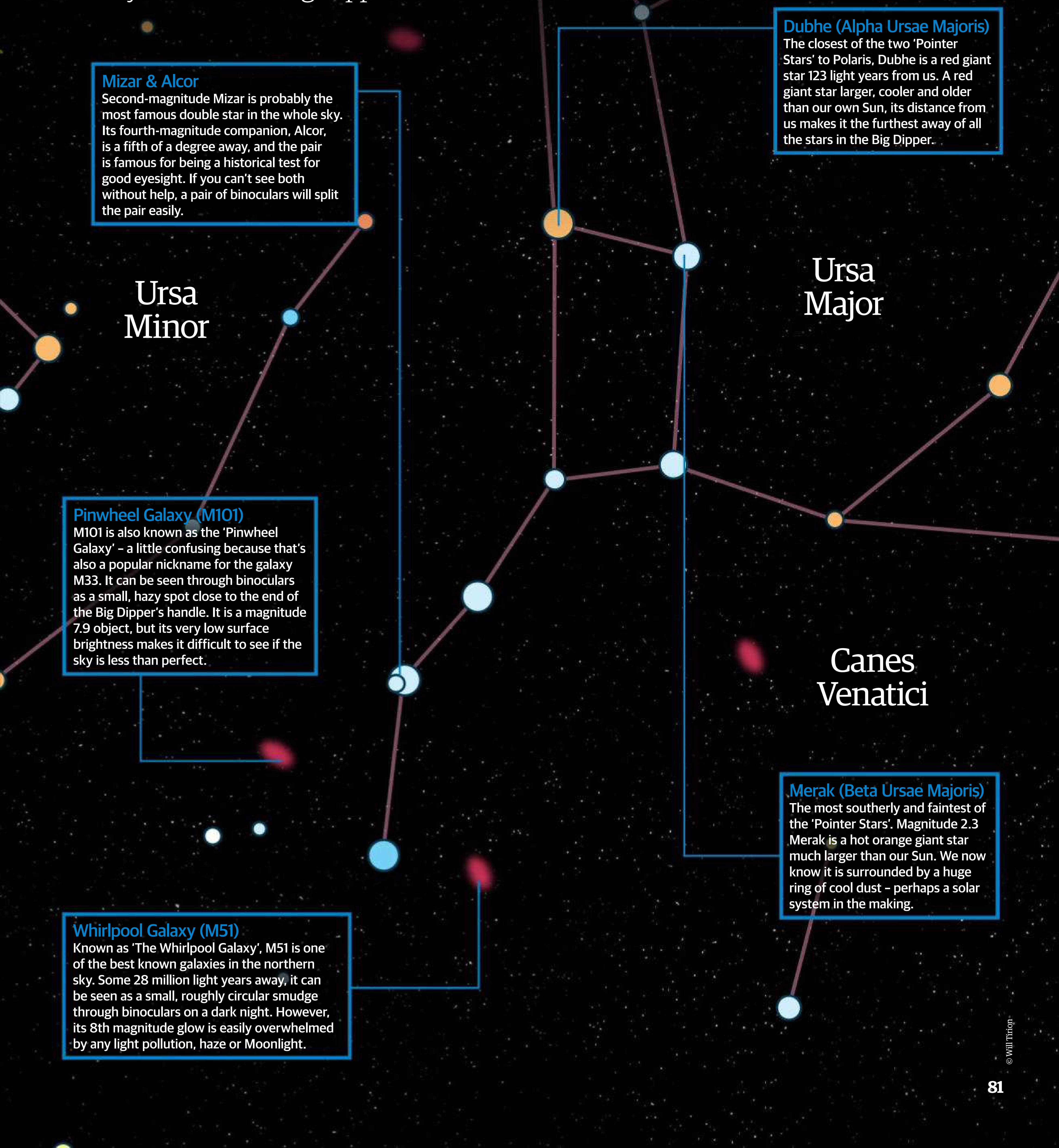


So when can you see it? The bright splash of ejecta surrounding Linné can be seen at virtually any phase of the Moon when Mare Serenitatis is illuminated, but you will only have a chance of seeing the actual crater pit when it is close to the terminator and illuminated at a low angle.

Luckily Linné will emerge from the darkness on 14 November, as the terminator sweeps over it. Through a telescope at high magnification you should be able to see the crater. After that, as the Sun climbs higher in the sky, Linné will appear as a bright spot on the Moon, standing out starkly against the dark sea until the terminator rolls towards it again. By 28 November it will be illuminated at a very low angle again, and its crater pit should be visible briefly before it is plunged into the darkness of the long lunar night once more.

This month's naked eye targets

Winter's frosty nights are perfect for exploring the sky around the Big Dipper...



Mizar & Alcor

Second-magnitude Mizar is probably the most famous double star in the whole sky. Its fourth-magnitude companion, Alcor, is a fifth of a degree away, and the pair is famous for being a historical test for good eyesight. If you can't see both without help, a pair of binoculars will split the pair easily.

Dubhe (Alpha Ursae Majoris)

The closest of the two 'Pointer Stars' to Polaris, Dubhe is a red giant star 123 light years from us. A red giant star larger, cooler and older than our own Sun, its distance from us makes it the furthest away of all the stars in the Big Dipper.

Pinwheel Galaxy (M101)

M101 is also known as the 'Pinwheel Galaxy' – a little confusing because that's also a popular nickname for the galaxy M33. It can be seen through binoculars as a small, hazy spot close to the end of the Big Dipper's handle. It is a magnitude 7.9 object, but its very low surface brightness makes it difficult to see if the sky is less than perfect.

Merak (Beta Ursae Majoris)

The most southerly and faintest of the 'Pointer Stars'. Magnitude 2.3 Merak is a hot orange giant star much larger than our Sun. We now know it is surrounded by a huge ring of cool dust – perhaps a solar system in the making.

Whirlpool Galaxy (M51)

Known as 'The Whirlpool Galaxy', M51 is one of the best known galaxies in the northern sky. Some 28 million light years away, it can be seen as a small, roughly circular smudge through binoculars on a dark night. However, its 8th magnitude glow is easily overwhelmed by any light pollution, haze or Moonlight.

How to...

Choose binoculars for astronomy

They're great for sky-watching and stargazing, but with so many different models available which should you buy?

With Christmas around the corner, no doubt many of you will be wondering what to buy that special someone. If they are interested in astronomy the obvious gift would be a telescope, right? Wrong! They might not be ready for something as powerful and as complicated as that, especially if just starting out in the hobby. A great alternative is a pair of binoculars - they're not so powerful that they can't be used by an absolute beginner, and they're cheaper and less complicated to use than a telescope too. But which pair to buy?

The good news is that it is really easy to identify a pair of binoculars that will be suitable for astronomy use; all you have to do is hold them, take a look at and through them and work out a very simple sum using the numbers printed on them.

First of all, weight is very important. If a pair of binoculars is too large and heavy for them to be held and supported by hand they will quickly become a chore to use. If you can't support them properly everything you look at through them will shudder and shake. You can mount larger pairs of binoculars on a tripod with an adaptor, but that makes it harder to aim them at their targets. Avoid that for an absolute beginner. On the other hand, a pair of binoculars that is very small and lightweight will offer poor magnification and a very narrow field of view, so beware those too.

There's no substitute for actually looking through a pair of binoculars, and a good retailer will have no problem with you taking your prospective purchase to their shop door and trying them out. If the image you see after focusing is still blurry, has colour fringes or is even split into two parts, that pair is no use. Look at the colours of the front lenses too. Ones that are coated orange, red or green are designed to cut down contrast - useful for daytime activities, but not for astronomy because you want as much contrast as possible.

Every pair of binoculars has two numbers on it - 7x35, 10x50, 25x50 and so on. These stand for the power of magnification and the aperture of their front lenses. To be good for astronomy the second number divided by the first should give you a value of five or higher. This figure represents how much light comes out of the binoculars and goes into your eyes. A figure of five is ideal.

> "There's no substitute for actually looking through a pair of binoculars"

Tips & tricks

Don't panic
It's not as hard to pick a good pair of binoculars as you might think. It just takes a little time and comparison.

You get what you pay for
Don't be tempted by budget or cheap binoculars. It's well worth paying a little extra for equipment that will last.

Don't be afraid to ask
A good retailer won't mind you asking if you can test outside their shop if it helps you buy the right equipment.

Crunch the numbers
Doing a simple sum will save you buying the wrong binoculars; don't just assume the pair you like the look of will work.

Avoid shake, rattle and roll
If you feel you need to put your binoculars on a tripod, go ahead. If your hands are shaking you won't be able to see a thing through them.

Making the right choice

Follow our step-by-step guide to ensure you've got the perfect binoculars

The right pair of binoculars will reveal the wonders of the universe. Obviously without the light grasp and high magnification of a telescope they won't reveal famous features such as Mars' ice caps, Jupiter's Great Red Spot or Saturn's rings, but they will allow you to see Venus as a crescent, the craters and mountains of the Moon and countless hundreds of galaxies, star clusters and nebulae.

Send your photos to
space@spaceanswers.com

1 Avoid shopping online

Although shopping online for binoculars is easy and convenient, you can't beat seeing and holding a real pair. There'll be a photographic retailer near you with a wide selection.

2 Handle and compare

Try handling a few different pairs. Some will be too heavy to support with just your hands, and smaller ones won't give as good a view. Find a pair a comfortable weight for you.

3 Pay attention to the magnification

Look at the numbers on the binoculars and divide by second number by the first. If the answer is five those binoculars would be greatly suited for astronomy.

4 Take them for a test run

Test the binoculars outside the shop - a good retailer won't mind. Avoid any binoculars which offer you views spoiled by coloured fringing or double images.

5 Check if you need a tripod

If you choose a large pair of binoculars you will need a tripod and a special bracket to connect them together - using just your hands will be too shaky on a larger pair.

6 Hunt for deep-sky targets

The right binoculars will show you amazing things in the night sky, especially in dark-sky areas - the misty tails of comets, glittering star clusters and cloudy nebulae.

Deep sky challenge

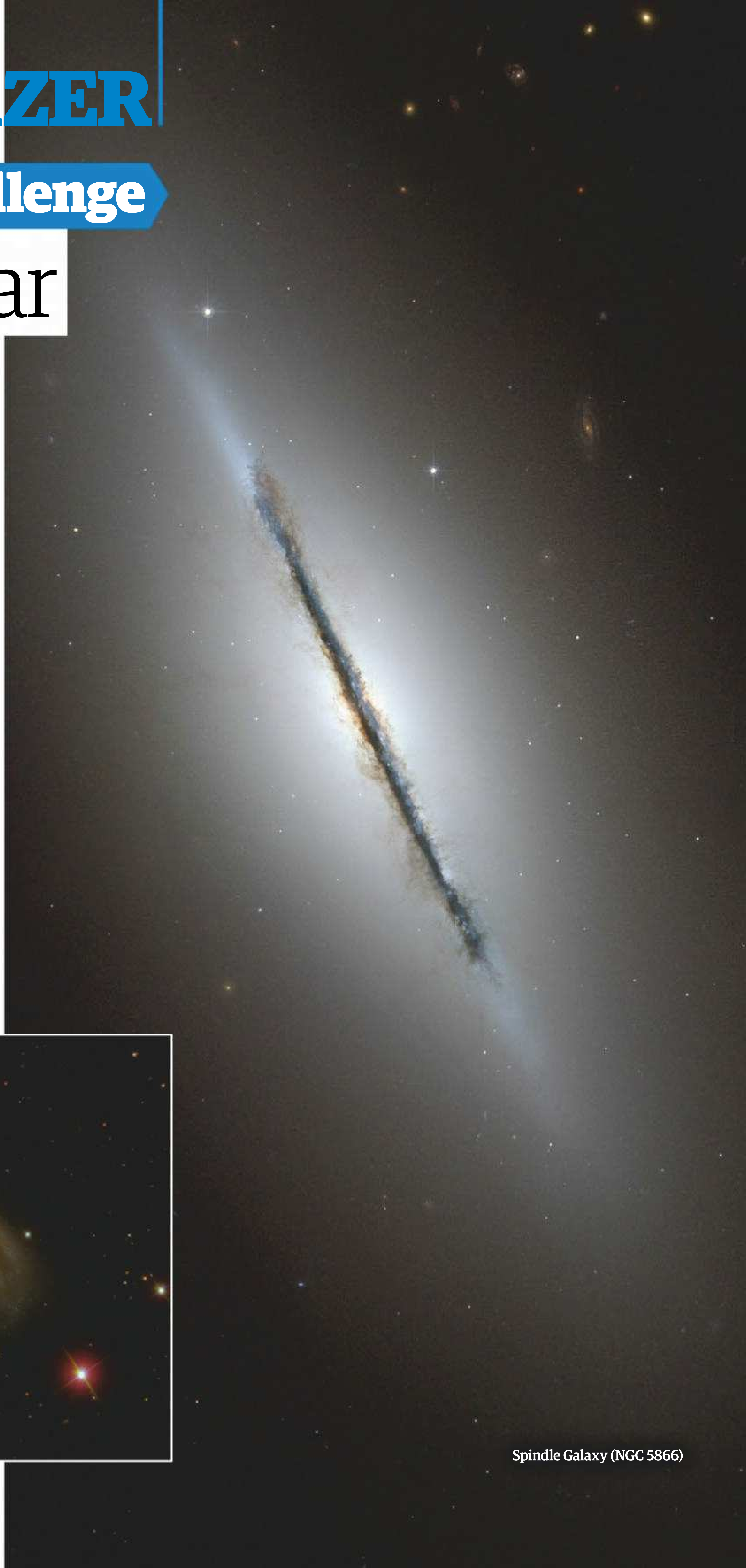
End-of-year delights

The Dragon and the Great Bear hide some lesser known deep-sky targets

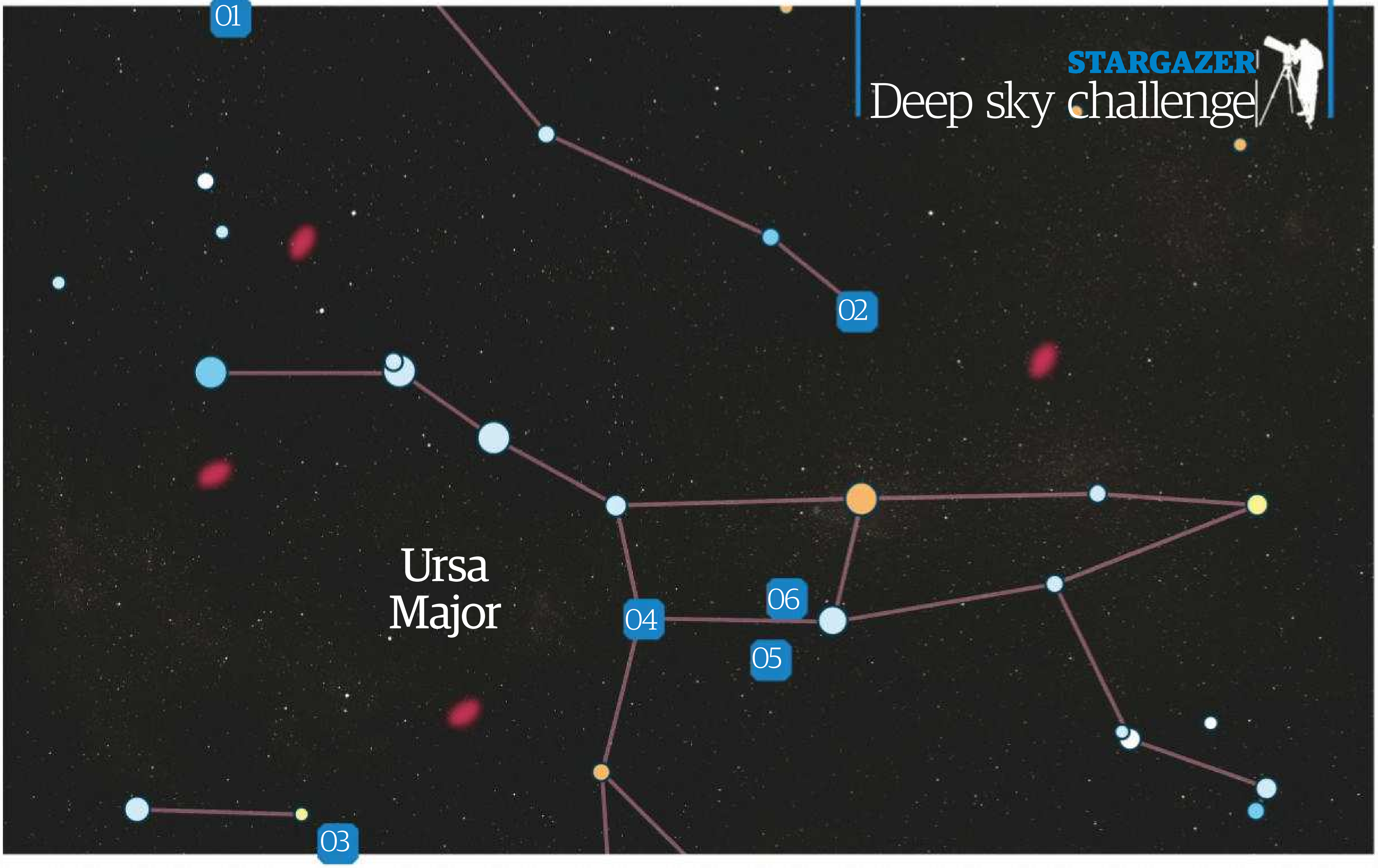
As the year draws to a close and sparkling, frosty nights lure you outside, it's only natural to aim your beloved refractor or reflector at the bright and colourful deep-sky delights of Orion, Taurus and Gemini. The sky around the Big Dipper - within the larger borders of the Great Bear, Ursa Major, and his draconian neighbour, Draco - is generously populated with popular and easily found deep-sky objects: bright galaxies, clusters and even a nebula or two. If you're prepared to work a little harder and prowl carefully around the sleeping bear you will be rewarded with fascinating views of some less known objects.

This month we have objects for owners of small telescopes and larger instruments alike to track down. We'll help you find an ancient planetary nebula that looks like the face of a wide-eyed owl, a faraway galaxy that - some say, you might disagree - looks like an old-fashioned weaver's spindle and another galaxy most honestly described as a 'mottled mess'. None of this month's objects could claim to be classically beautiful, but they're all fascinating in their own right, and deserve better than to be ignored. So what are you waiting for? Start hunting!

Messier 109



Spindle Galaxy (NGC 5866)



1 **The Spindle Galaxy (NGC 5866)**
Large 'scopes show this magnitude 10 lenticular galaxy, seen edge-on, as a bright streak cut in half by a narrow, dark dust lane. Only its bright core will be seen through a small 'scope.

2 **NGC 4236**
This magnitude 9.7 barred-spiral galaxy is part of the M81 Group, but it has been seen by very few observers; its very low surface brightness makes it hard to pull out from the background sky, so large telescopes are needed to glimpse it.

3 **NGC 4449**
This irregular galaxy is 12 million light years away, and in both shape and size closely resembles the Large Magellanic Cloud. 8" or larger telescopes are needed to see this object clearly.

4 **Messier 109**
This barred-spiral galaxy lies just 40' southeast of Phecda. Small telescopes will struggle to pick it out, but 8" and larger instruments will show its bright centre and extended bar.

5 **The Owl Nebula (M97)**
This planetary nebula's disc is visually as large as Jupiter's, but it is very faint at just magnitude 9.8. You might glimpse it as a smoky dot through 4" telescopes, but 8" and larger are needed to see its dark 'owl eyes'.

6 **Messier 108**
A barred-spiral galaxy oriented edge-on from our viewpoint, magnitude 10 M108 needs a 6" or larger telescope to see it. At high magnification it resembles M82, a mottled mess of light and dark patches with a bright centre.

> "Prowl carefully around the sleeping bear and you will be rewarded with fascinating views of some less known objects"


The Owl Nebula (Messier 97)

How to...

Take winter sky portraits

The stars and constellations are beautiful to look at - and even more stunning to photograph. Here's how to take your very own portraits of Orion and his sparkling neighbours...

You'll need:

- ✔ Warm clothes
- ✔ Suitable observing site
- ✔ DSLR camera on tripod
- ✔ Wide-angle lens
- ✔ Cable release
- ✔ Photo-processing software on home computer

As autumn ends and the misty star clouds of the Milky Way sink beneath the horizon, winter offers observers a sky full of glittering wonders. Chilly days are often followed by perfectly still, frosty nights where the colourful stars of Orion, Gemini and Taurus sparkle and flash like finely cut jewels scattered across a cloak of black velvet, so it's only natural that many stargazers reach for their cameras. Here's how you can make sure your photos are faithful portraits of the winter sky and not just hasty snaps.

Usually astrophotographers seek out somewhere really dark with as little light pollution as possible and as few things on the horizon as possible; collecting as much starlight and capturing the faint glow of galaxies and nebulae is their aim. However, the point of a sky portrait is to show the sky as the eye sees it and portray its natural beauty, so the best sky portraits will have things on the horizon for contrast. Find somewhere with interesting trees, hills or even buildings in the landscape.

It's then just a matter of setting up your DSLR camera on its sturdy tripod and setting it up to take photos. You should use a wide-angle lens if you have one - if not your standard 50mm lens will be fine - set at its widest aperture. With your camera set to manual mode, set its ISO to 800 - at first, you will be experimenting with that later - and the exposure length to as long as you can get away with without the stars trailing on your images - up to 20 seconds for a wide-angle lens, five seconds for a 50mm. Fit the camera with a cable release - essential for helping reduce vibrations - and then aim the camera at the sky. Obviously the stars of Orion will be calling out to you, dominating the sky, so start with that constellation, but position yourself somewhere so it is shown above an interesting feature in the landscape, not just a flat, boring horizon. Walk around your site until Orion is looming over some trees, or a hill, and it will look stunning.

Finally, with Autofocus turned off, manually focus your camera sharply on either Rigel or Sirius, and shoot!

> "Winter offers observers a sky full of glittering wonders"

Tips & tricks

Bring gloves and a hat
You'll be spending long periods standing still in the cold, so dress warmly; you won't be able to use your cable release or focus your camera if your fingers are numb.

Think like a photographer, not an astronomer
Choose your photoshoot location as much for its own beauty as for the darkness of its sky. You want an interesting foreground.

Focus carefully
Focus your camera on either a very bright star or a distant light on the horizon – check your focus regularly so you're not taking blurry images without knowing it.

Keep everything steady
Reduce vibrations to an absolute minimum by tightening up everything on your tripod and using a cable release to begin your exposures.

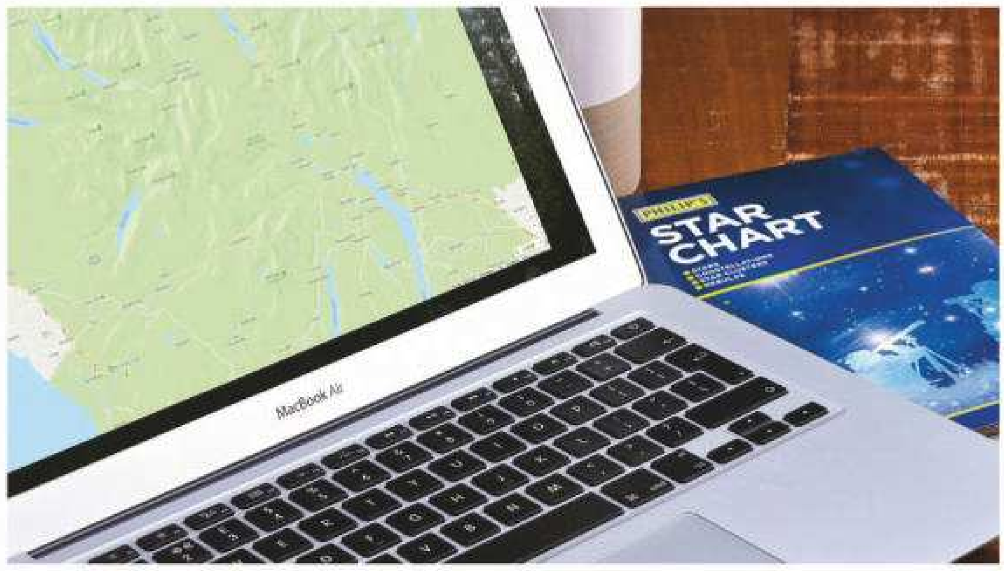
Getting the right settings

Obtain the best photo results through trial and error

Take a look at your first image and change your settings if it's not quite right: increase the ISO if it's too dark, or reduce the exposure time if the stars have trailed. Experiment and have fun! Wander around your chosen site trying different viewpoints and photographing different constellations, too. Eventually you'll find a perfect spot from where you can take portraits of the sky to be proud of.

Send your photos to
space@spaceanswers.com

1 **Wrap up warm**
Make sure you dress for the cold. Gloves are vital to stop your fingers freezing, which will hinder you changing your camera's focus and settings.



© Google Maps

2 **Seek a good location**
Choose somewhere that will give your star portraits an interesting and attractive foreground, such as trees, hills and even tall buildings.

3 **Make use of a tripod**
Mount your camera on its tripod. This will steady your images and keep them aligned on the stars you choose to photograph.

4 **Take test shots**
Using a cable release, take a test frame. Too dark? Increase the ISO number. Too bright? Reduce the exposure length.

5 **Tweak your settings**
To take star trails reduce the ISO to 400 and set your exposure to B, or 'bulb'. Use the cable release to take exposures of a minute or longer.

6 **Use photo-processing software**
Use photo-processing software on your computer to change your images' contrast, saturation and levels until they look how you want them to.

The Northern Hemisphere

The darker, longer nights are officially here, offering a splendour of night sky objects for astronomers

Andromeda, Cassiopeia and Sculptor are just some of the constellations offering a selection of targets for telescope and binocular-wielding astronomers this month. With the Sun dipping below the horizon at approximately 4pm (GMT), those wanting to catch new or favourite targets don't have to wait long for dark skies to boast these treasures.

Head over to Andromeda and you'll be rewarded with not just its spiral galaxy M31, but also its dwarf elliptical galaxies M32 and M110. While the parent galaxy is easy to spot, you'll need at least a medium-sized telescope to spot Andromeda's satellites. Star clusters are a joy to behold in the constellation of Cassiopeia, which can be spotted with ease by its "W".

Using the sky chart

This chart is for use at 10pm (GMT) 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

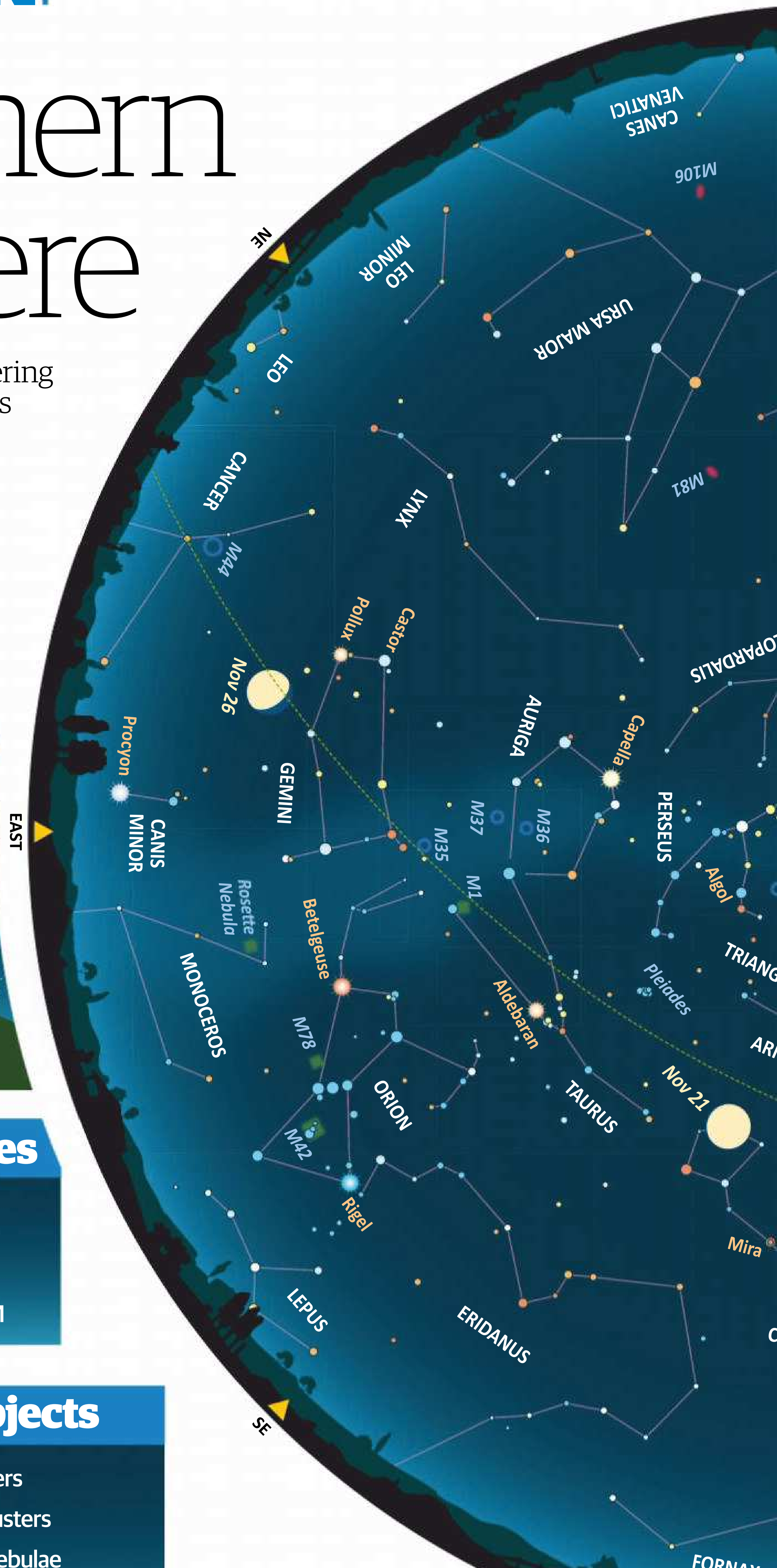
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

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

Deep-sky objects

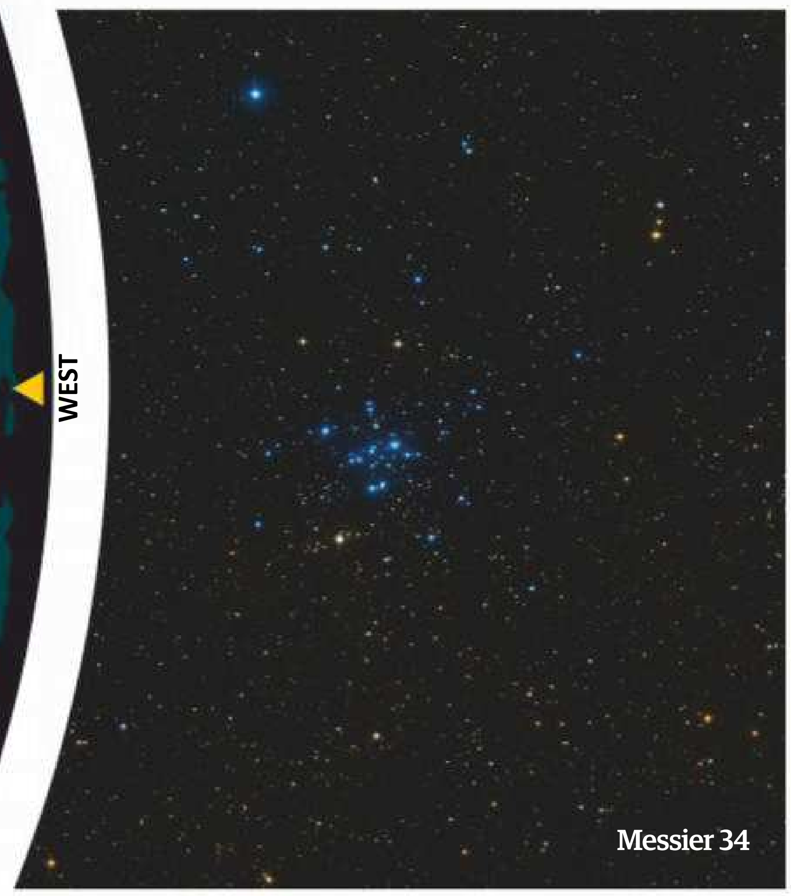
- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



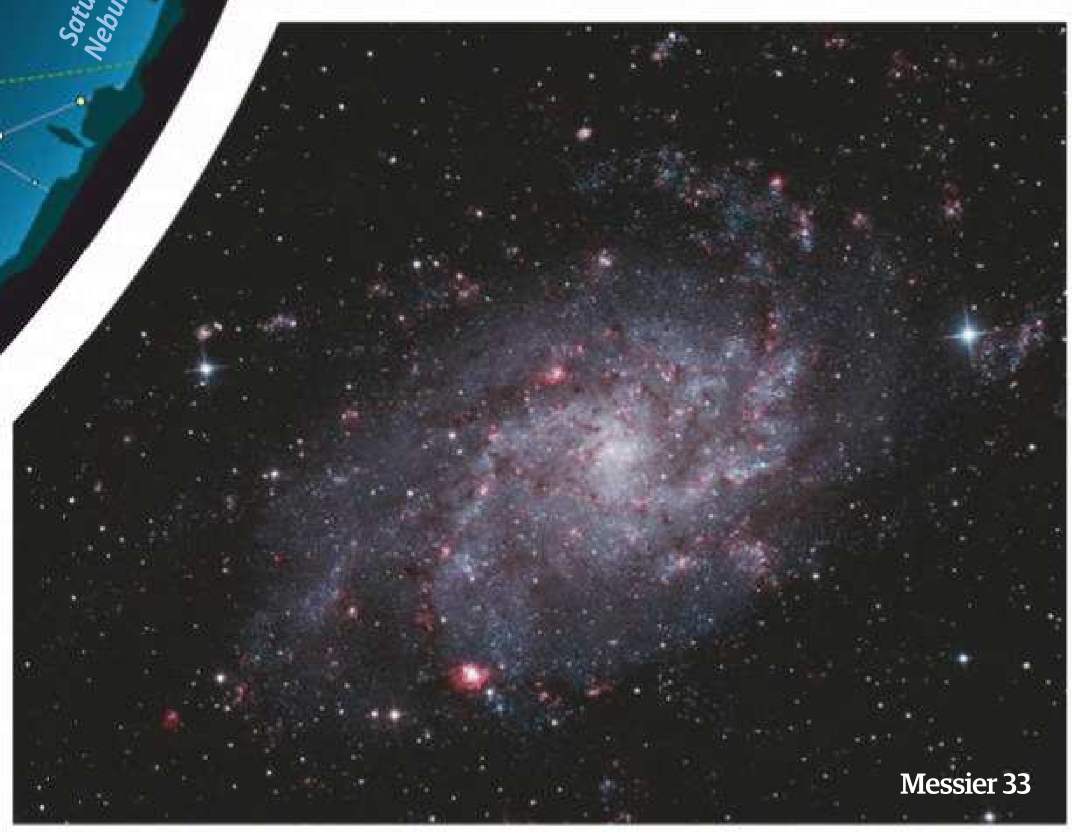
Observer's note:
The night sky as it appears on 16 November 2018 at approximately 10pm (GMT).

The Northern Hemisphere

Flaming star Nebula (IC 405)



Messier 34

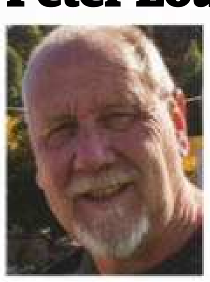


Messier 33

Astroshots of the month

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

Peter Louer



Teide National Park, Tenerife

"I retired to the beautiful island of Tenerife back in 2013. One of the top sites in the world for astronomy, the Caldera in Teide National Park is at an altitude of over 2,000 metres [6,562 feet]. With a dry atmosphere and limited light pollution it has proved to be the ideal location to combine my hobbies of photography and astronomy – here are a couple of shots of our Milky Way galaxy a true pleasure to image at such a fine location, completely free of light pollution."

Antoine & Dalia Grelin

Nelson's landing, Nevada

"Myself and my wife Dalia took our first evening trip into the desert and were completely astonished by how many stars were visible. Las Vegas might be one of most light-polluted cities in America, but it is surrounded by land untouched by light pollution.

"That night we took a couple of photos with our point-and-shoot camera, which of course were not great, but we could see the Pleiades (M45) in one of them - it was from that point that we immediately fell in love with photographing the night sky.

"We now have enough experience to capture beautiful deep-sky objects using our DSLR and our telescope and enjoy teaching astrophotography to others. As a result, we created a YouTube channel, Galactic Hunter, where we make mini-films and tutorials about photographing deep-sky objects in the hope of assisting as many amateur astrophotographers as possible."

Barnard's Loop (Sh 2-276)

Matt Dieterich

Montana, US

"This high-elevation location - around 6,000 feet or 1,828 metres - in northern Montana makes the night sky a lot more clear and free from atmospheric distortion and pollution.

Being out under the stars is a relaxing experience that we as humans can all relate to. You can take these photos to help protect our night sky with nothing more than a camera, lens and tripod. National Parks are incredible resources, especially for stargazing. Parks conserve the night sky just as they protect the forests, meadows and wildlife."

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

Meade Infinity 76

Perfect as an introduction to astronomy, this beautifully finished telescope is suitable for observing the lunar surface and the planets

Telescope advice

Cost: £119 (approx. $115)
From: Currys/ Hama UK
Type: Reflector
Aperture: 2.99"
Focal length: 27.56"

Best for...

- Beginners
- Small budget
- Planetary viewing
- Lunar viewing
- Family
- Basic astrophotography

Starting out on the right foot is essential in astronomy, and this introductory telescope from Meade ensures that the beginner is fully equipped for their first night under the stars. It comes complete with a low-power 9mm and high-power Plössl 20mm eyepiece for a variety of viewing situations, providing magnifications of 78x and 35x. For those wanting to get started in basic astrophotography, there's a bonus feature in the shape of a smartphone holder, as well as a carry bag for those nights where the observer is looking to travel further afield.

We are pleased to see that a red dot finder - rather than an optical finderscope - is supplied for effective touring of the night sky. This ensures that fainter stars can be used for star-hopping with ease, meaning that the observer doesn't need to stick to the brighter stars in areas with less-than-ideal observing conditions. Their optical counterparts often struggle on this account, especially when they have a modest magnification, making navigation quite difficult and cumbersome.

We are also pleased to see that Meade is realistic and honest about the Infinity 76's capabilities - many a time we have seen Hubble Space Telescope images splattered across packaging of telescopes by the telescope manufacturer: beginners can often be fooled into thinking that they'll get NASA space telescope views through an amateur instrument.

Due to its modest aperture, the Infinity 76 is best used for observing the rugged lunar surface, the planets - namely Saturn, Jupiter, Mars and Venus - and, provided seeing conditions are good, some of the brighter deep-sky objects. Setting up of the refractor is extremely intuitive, however, an easy-to-follow instruction manual is provided along with a copy of the AutoSuite planetarium program. At present, this software can only be run on Windows.

The alt-azimuth mount and tripod already come fully assembled out of the box and the overall set-up is impressive for a telescope in such a low price range. The tripod legs are easy to adjust with easy-to-use tabs to lock them in place. If you're not fully satisfied with the sturdiness of the telescope then a small Phillips head screwdriver and wrenches are supplied for tightening up those loose areas.

The Infinity 76's mirrors are also beautifully finished. As with all of Meade's telescopes, a substantial dew shield has been manufactured and, similar to the lens cells, is comprised of tough black plastic. Both the inside and outside of the tube are well painted, and we are certainly appreciative of the exquisite blue finish, certainly making it stand out from the much more common black or white tubes often manufactured by telescope makers.

The previously mentioned red dot finder is ideal for any beginner's instrument; be aware that these finders can run batteries low quite quickly, so be sure to switch it off when you have located your target. The build of the eyepieces is sufficient and, when slotted into the 1.25" holder, ensure that the 'scope isn't too 'back heavy'. Using the star diagonal is a pleasant experience, angled in such a way that peering through the eyepiece is comfortable. Using the 26mm eyepiece during the day and on a line of trees, we noted that the field of view isn't entirely crisp - a flaw that comes about from using a prism that's too small for a telescope's optical system. However, given that the Infinity 76 is aimed at those new to the hobby, this isn't a huge problem for basic observing.

Early November brought thick clouds and an enormous amount of rain, meaning that we were forced to look for gaps in the cloud to test the Infinity 76's mettle. We were rewarded with views of Mars and the Moon as they hung close together in a cloud-free horizon during the early evening. Views of the lunar

We were delighted to see that a red dot finder was included with the telescope

The Infinity 76 features an alt-azimuth mount with slow motion control rod for tracking celestial objects as they move across the night sky

For those wanting to get started in astrophotography, Meade has included a smartphone holder that can be affixed with ease to the eyepiece holder

© Rdenton

> "Due to its aperture the Infinity 76 is best used for observing the rugged lunar surface and the planets"

surface are good through this telescope and, on the whole, are wonderfully crisp and clear. Craters stand out beautifully, with the terminator in particular causing their walls and details to stand out in both light and dark.

We are delighted to see that there is hardly any problems with glare during our observations through the optical system. We also advise using a Moon filter when the Moon is full to lessen the intensity of light coming through the telescope. Meanwhile, turning our observations to Mars were good through the Infinity 76 as it appeared as a featureless salmon-pink disc in our field of view.

With Ursa Major directly overhead, we were keen to split double stars Alcor and Mizar. Views of the Pleiades star cluster, also known as Messier 45, in the constellation of Taurus are pleasant, with the optics revealing the member stars as clear blue-white points of sparkling light.

A robust telescope that's ideal for the whole family, the Infinity 76 is ideal for those looking to get started in stargazing without breaking the bank - for more seasoned astronomers, the Infinity may be worth a look if you're looking for a minimum-fuss instrument for casual observing of the night sky.

The Infinity 60AZ features a beginner-friendly mount that comes attached to the tripod for easy setting up

Christmas gift guide

With the holiday season just around the corner, **All About Space** selects the space gifts sure to delight any fan of the universe

Telescope Meade Infinity 76

Cost: £119 (~€136/$155) **From:** currys.co.uk

Give someone the gift of infinity this Christmas and take them on an out-of-this-world journey through the wonders of the night sky. Easy to assemble, the Infinity 76 comes with everything you need to get started in one box, allowing both beginners and more advanced users to get set up and viewing within seconds. Know a budding astrophotographer? Perfect! Meade has exclusively included a universal smartphone mount to permit the capture and sharing of stunning celestial snapshots via most modern phones. Smooth tracking controls and the navigationally useful red dot finderscope mean there will never be a shortage of subjects to locate and discover… the sky is the limit! Portable and lightweight, both telescope and tripod swiftly collapse down into the equally exclusive vivid-blue Meade travel bag for convenient transportation and storage of the telescope plus accessories between viewing locations. So follow that star!

Book
Seeing Stars: A Complete Guide to the 88 Constellations

Cost: £17.95 (€19.95/$24.95) **From:** Phaidon Press Ltd

A graphically stunning, comprehensive introduction to the constellations. This artful and accessible introduction to constellations equips readers with the information they need to locate, name and explain all 88 internationally recognised constellations. Each cluster of stars is featured alongside the story – mythological or historical – behind its naming, tips on how to find it, what times of year it is visible and key stars and asterisms within its grouping. Complete with star maps and a glossary, this keepsake volume of visual reference and beauty is perfect for inquisitive young stargazers. Colours are brighter than they appear – printed in pure Pantones. Book jacket features foil stamping and laser-cut pinholes.

Binoculars
Celestron SkyMaster binoculars

Cost: £89 (~€101/$116) **From:** www.celestron.com
Celestron's SkyMaster series of large-aperture binoculars are phenomenal value for high-performance and are ideal for astronomical or terrestrial use, especially over long distances. Each SkyMaster model features high-quality BAK-4 prisms and multi-coated optics for enhanced contrast. Designed and engineered to exquisite quality, SkyMaster meets the special demands of extended astronomical viewing sessions with large objective lenses and high magnification in a reasonably lightweight configuration. Comes in a variety of magnifications including 25x70, 25x100, 20x80 and 15x70.

"Celebrate the Apollo 11 mission's 50 anniversary with Buzz Aldrin's *To the Moon and Back*"

Book
To the Moon and Back

Cost: £25 (~€28/$32) **From:** harpercollins.co.uk

Celebrate the Apollo 11 mission's 50th anniversary with *To the Moon and Back* and experience the awe and excitement of humankind's first steps on the Moon! In this exclusive, exquisite pop-up adventure, readers follow astronaut Buzz Aldrin's story as he encounters the "magnificent desolation" of Earth's satellite first-hand. Available to buy now in all good bookshops and online.

Planetarium Universe2go

Cost: £44.90 (~€51/$58) **From:** astroshop.co.uk
You have never seen the night sky like this! Have you ever stood under the starry cosmos and wondered what exactly it is you are looking at up there? Or are you an amateur astronomer who has only peered into space through a telescope? Whatever the answer, Universe2go will fascinate you – because you have simply never experienced the night sky in this way before! Universe2go is an augmented-reality star viewer and app, combining stargazing with history, mythology and lasting impressions otherwise solely experienced in a planetarium. Using your smartphone, this planetarium superimposes a digital picture over your view of the night sky, offering a revolutionary perspective of the universe and the chance to explore the cosmos with astounding precision and ease.

HEROES OF SPACE

Jocelyn Bell Burnell

The discoverer of the exotic cosmic lighthouses, pulsars, who was overlooked for the Nobel prize

Bell Burnell's discovery revolutionised the field of radio astronomy, tapping its potential for knowledge

Over half a century since her amazing discovery, Dame Jocelyn Bell Burnell has been recognised for her achievements in astronomy with a lucrative prize that she has decided she will donate to 'minorities in science'.

Born on 15 July 1943 in Lurgan, Northern Ireland, Bell Burnell has been educated by many institutions in the art of astronomy. She gained her Bachelor's degree from the University of Glasgow, Scotland, in 1965. Four years later she had received her doctorate in radio astronomy from the esteemed University of Cambridge, England. It was during her doctorate years that Bell Burnell made the discovery that would change our understanding of the universe. She did this by introducing a whole new type of stellar object: the pulsar.

During her years at the University of Cambridge she was studying under the tutelage of Antony Hewish when they built and used a new radio telescope. Upon taking data, Bell Burnell noticed a highly unusual and notably frequent detection of radio pulses. She'd chanced across the pulsar; stars which have incredible masses squeezed into tiny spheres, rotating in a way that releases energy over all wavelengths in every direction in bursts. However, due to their enormous distances from Earth they are commonly seen in the radio end of the electromagnetic spectrum.

Confused, they spent much time trying to explain the signal, eliminating any outside interference in the process. It wasn't until she observed the second, third and fourth pulsars that she could undoubtedly announce the discovery of a brand-new type of star. Controversy stemmed from this finding unfortunately, as Bell Burnell was overlooked for the Nobel prize in 1974, which was instead awarded to Hewish and fellow astronomer Martin Ryle. This brought on accusations of sexism in science, and in particular physics, which Bell Burnell has been trying to fight ever since.

Most recently, Bell Burnell was awarded the Breakthrough Prize, which has also been given to prestigious individuals such as Stephen Hawking, CERN scientists that played a role in the discovery of the Higgs Boson and the LIGO team that detected gravitational waves. Part of this award was also a handsome £2.3 million ($3 million) prize. The award recognises the stupendous work Bell Burnell has achieved for the scientific community in discovering this exotic star type that takes us another step closer to understanding the vast and mysterious universe.

In the fight against the 'unconscious bias' that still resides within physics-based research jobs, Bell Burnell has recently donated her share from the Breakthrough Prize to fund the minorities in science, such as woman, refugee students and under-represented ethnic minorities, to boost their chances in forging a career in physics. The incredible work Bell Burnell has achieved in science continues to amaze and strives to see positive changes in the physics community. With this recent prize win, that dream becomes that bit more viable.

"The incredible work Bell Burnell has achieved in science continues to amaze"

© Roger W Haworth; Conor McCabe

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