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CHRIS HADFIELD EXCLUSIVE
LIFE AFTER SPACE

All About Space

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Astrophysicists are asking...

DARK MATTER IS IT REAL?

Hard-hitting evidence that could end the hunt for the missing universe

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Future
ISSUE 072

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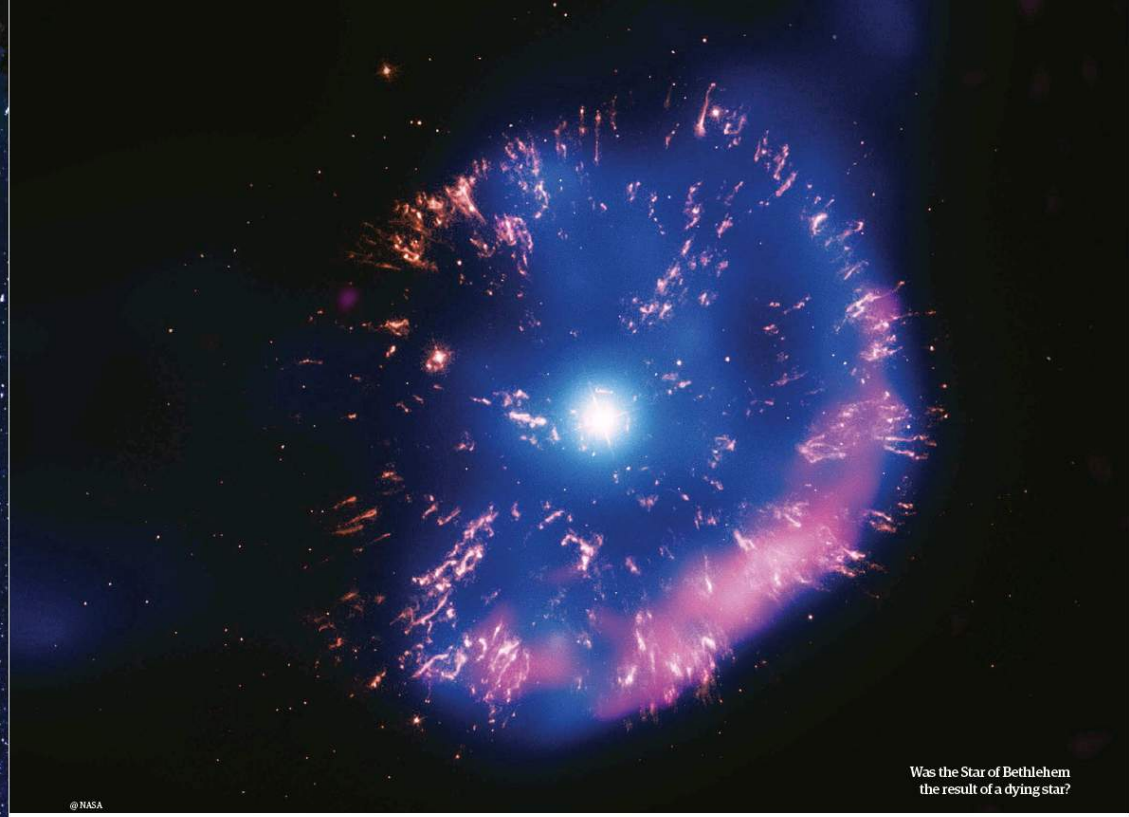

Was the Star of Bethlehem the result of a dying star?

@ NASA

Welcome to issue 72!

Well, this is our final issue of 2017 - and what a year it's been! We've found out if the 'God Particle,' aka the Higgs boson, will destroy the universe, gone on a hunt for white holes, discovered what it'll be like on the surface of our planet before it falls into the Sun, lifted the lid on what really happened the day we landed on the Moon with an Apollo 11 exclusive and chatted to Brian Cox and Dara Ó'Briain about the top stargazing sights you need to observe. We also spoke to astrophysicist Neil deGrasse Tyson about his thoughts on the cosmos (and, of course, why far-flung Pluto is not a planet!).

This month, we round off the year with an eclectic mix of revelations, probe into some terrestrial worlds, give you some more advice on what you can observe this December and look ahead to some unmissable space events in 2018. We meet the astrophysicists who believe dark matter doesn't really exist and that alternative theory MOND (that's Modified Newtonian dynamics) is our best chance of understanding the universe, get a look at the dark side of Venus and discover what the star of Bethlehem really was - just in time for Christmas. We also reveal the results of our image survey, which you, our readers, took part in - thank you for voting! Turn to page 48 for the results and let me know if your favourite hit the top spot?

Merry Christmas and Happy New Year - see you in January!

Gemma Lavender
Editor

"You can't follow a star from Baghdad to Jerusalem to Bethlehem. Stars don't do that"
David Weintraub, page 65

Our contributors include...

Giles Sparrow
Astronomer & author
Dark matter may not be real - that's according to the astrophysicists that Giles spoke to this month. Head to page 16 for a theory that could signal its end.

Abigail Beall
Science and technology journalist & writer
Abigail reveals an entire calendar of events for 2018 this month - including the launch of a new Mars mission and two exoplanet hunters.

Paul Cockburn
Science and technology journalist
What's going on on the dark side of Venus? Paul has the details, as astronomers find out some new information about Earth's 'evil twin'.

Nick Howes
Astronomer & science writer
Nick has the astronomy apps you shouldn't live without. Whether you need help navigating the night sky or want to track the ISS - they're all there!

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Canadian astronaut and social media sensation

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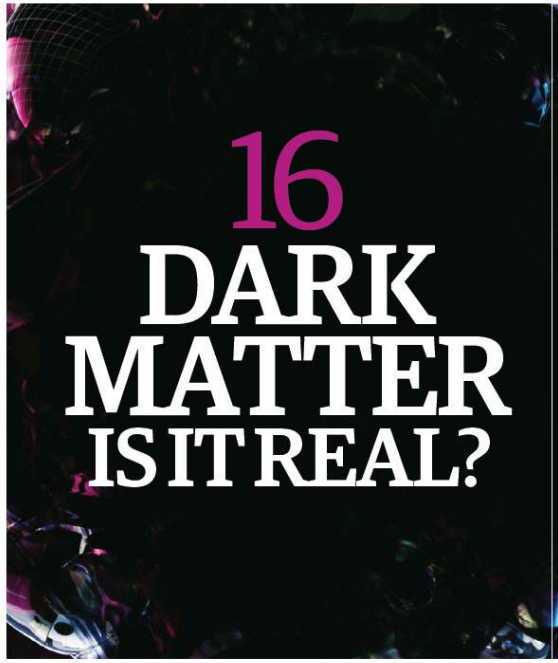

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LAUNCH PAD
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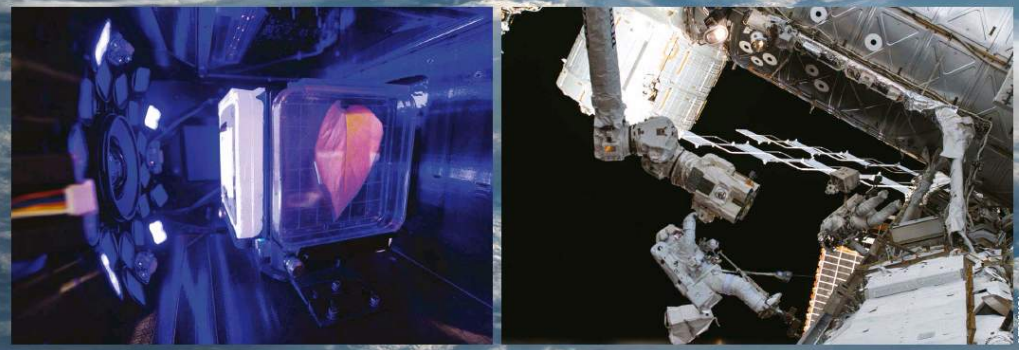
Orbiting above the clouds tops

The International Space Station offers some of the best views a human can see in their lifetime. The European Space Agency (ESA)'s Paolo Nespoli, who serves as a flight engineer on Expedition 53, is one of the few people to know this feeling all too well, and shared this incredible image of our planet's clouds swirling underneath them.

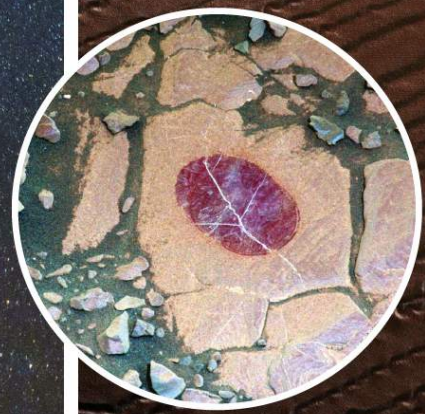
As well as taking in the breathtaking views, these astronauts are always hard at work. NASA astronauts Joe Acaba (second inset, left) and Randy Bresnik (second inset, right) completed a spacewalk totalling almost seven hours. They're also working hard on the Spectrum project, which focuses on how living organisms could survive long-duration space flight (inset 1).



Magnificent astronomical sights of the Chilean desert

Taken atop Cerro Paranal in the Atacama Desert, Chile, home to the European Southern Observatory (ESO)'s industrious Very Large Telescope (VLT), one of four auxillary telescopes, which can simultaneously form the Very Large Telescope Interferometer (VLTI), is visible. One of these telescopes is approximately 1.8 metres in diameter.

Sparkling above the landscape is a magnificent fusion of bright, blue stars studding the dusty trail of our galaxy's plane, which is dotted with bright regions of hot gas. The bright star to the top left corner of the image is Antares, the brightest star in the constellation of Scorpio and the fifteenth most-luminous star in the night sky.



Squiggles on the Red Planet

Despite having spent over 20 years studying the surface of Mars, our observations are never done. With multiple landers, rovers and orbiters currently at our planet's neighbour, we can gain extensive images of the Red Planet's landscape, as well as up-close views of specific rocks.

NASA's Mars Reconnaissance Orbiter (MRO) created this widespread view of Hellas Planitia and its distinguishable 'scratch marks', which are linear gullies heading down the impact basin. While on the surface, NASA's Curiosity rover revealed the presence of hematite, an iron-oxide mineral, on a rock called the 'Christmas Cove', highlighted in purple (inset image, above).

Into the Fornax Cluster's furnace

The leavings of a violent galaxy that shreds its neighbours and throws out their remains, can be seen in the most detailed picture ever taken of the Fornax Cluster, which is one of the closest galaxy clusters to the Milky Way. The cluster is comprised of 58 galaxies and it's the black hole at the centre of member Fornax A that's responsible for siphoning material from neighbouring galaxies, ejecting their stars into the void.

This image, which is one of the largest images the European Southern Observatory (ESO) has ever released at an enormous 2.3 gigapixels, is courtesy of the Very Large Telescope array at Paranal Observatory in the Atacama Desert of Chile.

Testing rovers in a quarry

The European Space Agency (ESA) tested a prototype rover by guiding it into the Saint-Alphonse-de-Granby quarry in Quebec, Canada. This rover, shown in this virtual reality impression, had to drive in and sample the quarry, in order to simulate a mission on the lunar surface.

This all comes as part of the ESA-led HERACLES initiative, which also incorporates the Canadian Space Agency and Japanese space agency JAXA. This rover is a key component on this programme, as it aims to take advantage of technological advances that can be used for space exploration. In this case, they hope to use a similar 'buggy' to explore the untouched far side of the Moon.

ESO's Very Large Telescope prepares to stargaze

The observing party doesn't start until the lights are out, but while the astronomers wait, there's always time to get a picture showing off the mechanical distinction of ESO's Very Large Telescope (VLT).

Situated at the Paranal Observatory, Chile, the VLT is made up of four individual telescopes, each with an 8.2-metre primary mirror. To keep the VLT at maximum efficiency, each telescope must be sheltered from winds and kept at freezing temperatures. This means that the telescope's 'dome' is equipped with a vast air-conditioning system, creating the perfect conditions for unlocking the secrets of the universe.

An artist's impression of a massive star reaching the end of its life

Ground telescope finds 'zombie star' that refuses to die

Astronomers are amazed to find a supernova isn't playing by the rules – getting brighter rather than fading away

Long-held wisdom that supernovae shine for months as they explode has been turned on its head following the discovery of a 'zombie star' that's still shining bright years later. Astronomers at Las Cumbres Observatory, California have been startled to discover that the supernova known as iPTF14hls has not merely peaked and faded over the course of 100 days as expected, but has actually been growing dimmer and brighter for two years.

Scientists are now seeking to confirm and explain the observation which, as it stands, defies their understanding of how stars evolve and die. First detected on 22 September 2014 by a telescope in San Diego, it appeared to be a typical example of a Type II-P supernova, but, five months later, they noticed that it had become brighter. What's more, after two years it looked like it was just 60-days old, and it remains bright to this day.

"The supernova offers astronomers their greatest thrill: something they do not understand," says Stan Woosley, director of the Center for Supernova Research at the University of California, Santa Cruz. Certainly there is no existing model or theory to explain the observation, and scientists are not even sure what will happen next. It could fade, grow brighter or suddenly disappear, but what is even more intriguing is that the supernova – which is 500-million-light-years from Earth in the constellation Ursa Major – is in the same spot as another supernova spotted in 1954. There's a 95 to 99 per cent possibility that the supernova has been undergoing this event for at least 63 years.

But even that is not the end of it. Woosley says the supernova has varied in brightness by as much as 50 per cent, so it could be going through a cycle of exploding, fading and exploding again. One potential explanation is the 'pulsational pair-instability model' which states a star with a mass of more than 100 Suns is able to explode multiple times before dying. Blasts send material rushing from the star and it can collide with older material, producing a bright flash of light.

Woosley says the model isn't able to account for the huge amount of energy released by iPTF14hls, though. There is also no observation of this model in action, so no-one knows for certain if it does exist. In the meantime, scientists have moved to using larger instruments as they continue to monitor the supernova. They are also seeking to look at it with the Hubble Space Telescope in a bid to shed more light on the mystery.

"The supernova offers astronomers their greatest thrill: something they do not understand"

© European Southern Observatory/M. Kornmesser

Virgin Galactic's SpaceShipTwo is pictured embarking on its third powered flight

Virgin promise: Fly from UK to Australia in two hours – via space

Forget reviving Concorde. Virgin Galactic wants even faster travel

Virgin Galactic – which bills itself as the world's first commercial spaceline – is looking at plans to revolutionise flights around the globe. It wants to eventually provide superfast point-to-point passenger flights that would slash flight times to even the most far-flung locations to a couple of hours.

Those on board would end up taking off in space, with a plane taking the spacecraft skywards, dropping it in mid-air and allowing it to power up and jet away.

In doing so, the spacecraft could reach anywhere between Mach 3 (3,704kph/2,302mph) and Mach 5 (6,174kph/3,836mph), according to Virgin Galactic's CEO George Whitesides. It would also be something of a long-term victory for founder Richard Branson, who was thwarted in his attempts to buy Concorde from British Airways a decade ago. If it gets off the ground it would potentially compete with SpaceX, which is also considering the possibilities of using its technology for point-to-point travel.

Still, that is not likely to deter Virgin Galactic whatsoever, and it says all possibilities are on the table. "We don't have to accept the status quo. We can imagine a vehicle using liquid oxygen or liquid hydrogen to get us across the Pacific in an hour. You could do that," says Whitesides. Quite how much a ticket would cost, however, is an entirely different question.

Universe's elusive quark particle has been proven to exist

Two physicists have made a breakthrough in the long-running search for confirmation of the tetraquark

For half a century, physicists have been fascinated by quarks – those tiny elementary particles which combine in groups of three to form hadrons such as protons and neutrons. They've also been obsessed with trying to prove whether or not four quarks can stably combine to create a tetraquark. But now it seems there is confirmation that they can.

Physicists Marek Karliner of Tel Aviv University and Jonathan Rosner of the University of Chicago have been calculating the outcome of different quark combinations. They knew that the heavier quarks – those termed 'charm', 'top', 'strange' and 'bottom' (as opposed to the lighter ones, 'up' and 'down') – are better able to bond into hadrons. They were also aware that doing so in groups of three leads to stability, whereas four causes potential instability, mainly because of issues with the strong forces which help hold them together.

However, they have found that one combination does appear to work. By putting a doubly charmed baryon (a hadron made of two charm quarks and a lighter quark) together with a double-bottom baryon they found that – theoretically at least – a stable quark emerges. It is also likely that this true tetraquark can be generated using CERN's Large Hadron Collider (LHC). "The upshot of all this is that we now have a robust prediction for the mass of this object which had been the holy grail of this branch of theoretical physics for quite some time," Karliner concludes.

The hope is that the Large Hadron Collider will eventually find a tetraquark

© Dominguez, Daniel; Price, Maximilien

Space News in Brief

Private team seeks life on Saturn's moon

Breakthrough Initiatives is looking to launch a mission through the plume of water vapour coming off Enceladus in a bid to find signs of life. The program, funded by Russian entrepreneur Yuri Milner, would seek to achieve what Cassini couldn't, since it didn't have life-detection devices.

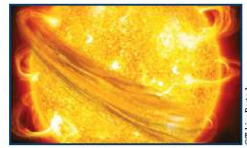
©NASA/JPL-Caltech

E. coli launched into space

The bacterial pathogen E. coli, which is responsible for foodborne illnesses and urinary tract infections, has been sent to the International Space Station for a study into antibiotic resistance. Scientists want to see how microgravity affects its ability to thrive while exposed to antibiotics.

Dinosaurs suffered terrible weather

Temperatures on Earth in the wake of the asteroid strike that led to the extinction of the dinosaurs were far lower than suggested. A study shows greater amounts of sulphur vaporised into the atmosphere, which absorbed the Sun's rays and may have led to a 26-degree Celsius drop.



©Tobias Roetsch

NASA bid to tackle aerosol hazards

NASA is looking for a winning aerosol sensor so that it can better monitor the air astronauts breathe on the ISS. It has launched a competition asking for designs and development on specialised sensor technology. You can find out more about this by visiting **earthspaceairprize.org.**

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Whirlpool of plasma spotted on the Sun

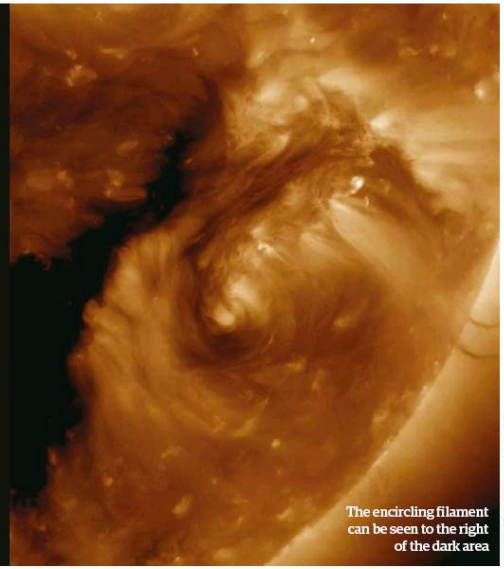
NASA has observed a rare circular pattern streaming at top speed from the Sun

A rarely observed encircling filament on the Sun has been captured by a NASA spacecraft. The space agency has released an image which shows a dark filament encircling an active region on the solar surface, and while it admits it "may have no major scientific value" it is, nevertheless, rather intriguing.

Photographed by NASA's Solar Dynamics Observatory (SDO) between 29 and 31 October, the pattern is understood to be streaming at close to 11,200kph (7,000mph), and is a cloud of charged particles that hover over the Sun's surface. Invisible magnetic fields keep it in place, but the curious thing is that they tend to be stretched like a strand, rather than circular.

"[It is] an oddity that the spacecraft has rarely observed before," said a statement put out by NASA. "Only a handful of times before have we seen one shaped like a circle." It further explains that the black area to the left of the active region is a coronal hole, a magnetically open region of the Sun, and that the still was taken in a wavelength of extreme-ultraviolet light.

The SDO has been observing the Sun since 2010, and it hopes to give a greater understanding of the influence the Sun has on the Earth and near-Earth space. It stares at our nearest star to record solar weather in many wavelengths simultaneously. Solar filaments, meanwhile, tend to last for a few weeks or months, although their birth and death is something scientists are continuing to study.



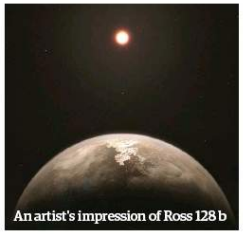
The encircling filament can be seen to the right of the dark area

©NASA/GSFC/Solar Dynamics Observatory

Temperate Earth-sized world discovered 11 light-years away

The exoplanet was detected by ESO's Extremely Large Telescope orbiting a quiet star

A potentially life-bearing world boasting a mild surface temperature similar to our own has been discovered just 11 light years from the Solar System. Designated Ross 128 b by the observational team, the low-mass exoplanet has been found to orbit the red dwarf star Ross 128 every 9.9 days. Scientists say it is the "quietest" nearby star to host such a temperate world.



An artist's impression of Ross 128 b

The discovery was made by a team at the La Silla Observatory in Chile using the European Southern Observatory's planet-hunting HARPS instrument. It is the second-closest temperate planet to be detected after Proxima b, and the closest to be discovered orbiting an inactive red dwarf star.

The researchers say this increases the likelihood that the planet is able to sustain life. "This discovery is based on more than a decade of HARPS intensive monitoring, together with state-of-the-art data reduction and analysis techniques," says the study's Nicola Astudillo-Defru, of the Geneva Observatory at the University of Geneva. What's more, it is getting closer to the Earth: it will be our nearest stellar neighbour 79,000 years from now.

Other facts gathered show Ross 128 b orbits 20-times closer than the Earth orbits the Sun, yet it only receives 1.38-times more irradiation. Its equilibrium temperature is also estimated to be between minus 60 and 20 degrees Celsuis, thanks to the red dwarf having just over half the surface temperature of the Sun.

Further studies will shed light over whether the planet is inside, outside or on the cusp of the habitable zone, potentially pointing to the existence of liquid water on the surface.

©ESO/M.Kornmesser

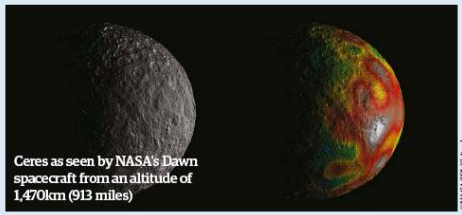
Dwarf planet Ceres probably had an ancient ocean

Minerals containing water suggest geologic activity and a lot of past liquid water

Two insightful studies into the dwarf planet Ceres have found evidence to suggest it may have once had a global ocean. According to the team working on NASA's Dawn mission, which is studying two of the three known protoplanets of the asteroid belt, Ceres' crust is a mixture of ice, salts and hydrated material that were subject to past and possibly recent geologic activity – and that the crust represents most of the ancient ocean.

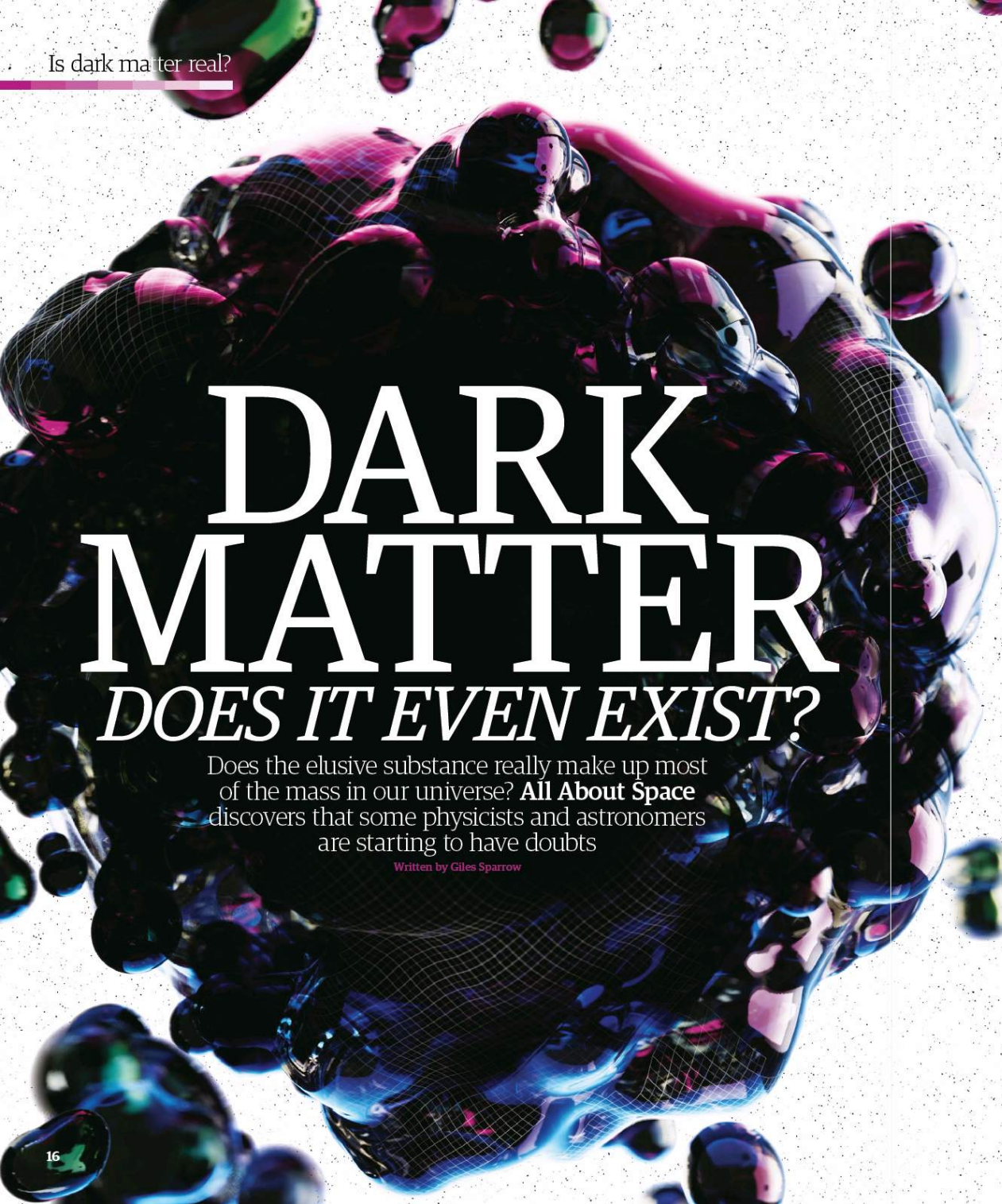
In a statement, the team goes on to claim that a second study has also shown there is a softer, easily deformable layer beneath its rigid surface crust, which they say is another indicator of residual liquid from the past ocean. "More and more, we are learning that Ceres is a complex, dynamic world that may have hosted a lot of liquid water in the past, and may still have some underground," said Julie Castillo-Rogez, Dawn project scientist and co-author of the studies, based at NASA's Jet Propulsion Laboratory in California.

The researchers believe most of the ancient ocean is now frozen and bound up in the crust, and that it has been that way for more than 4 billion years, albeit with some residual liquid underneath.



Ceres as seen by NASA's Dawn spacecraft from an altitude of 1,470km (913 miles)

©NASA/JPL/Caltech



DARK MATTER

DOES IT EVEN EXIST?

Does the elusive substance really make up most of the mass in our universe? **All About Space** discovers that some physicists and astronomers are starting to have doubts

Written by Giles Sparrow

Is dark matter real?

For almost a century, astronomers have believed that our universe is dominated by something we cannot see – a type of matter that neither emits nor absorbs light and other forms of electromagnetic radiation, and which reveals itself only through the influence of its gravity on objects we can directly observe. This 'dark matter' is thought to vastly outweigh the 'normal matter' that emits and interacts with light – it makes galaxies and larger cosmic objects behave as if they have, on average, about six-times the mass suggested by their visible stars, gas and dust. And yet, decades of attempts to directly detect this mysterious matter have failed to produce any

The speedy motion of stars in the outer reaches of spiral galaxies is strong evidence that something is wrong with our simplest models of the universe

"The stars were moving faster than predicted by Newtonian gravity"
Margot Brouwer

evidence of their existence.

So is the 'dark matter paradigm' an accurate way of looking at our universe? Support for alternative theories, which instead rewrite long-standing laws of physics, is growing – and a recent astronomical study has offered the first observational evidence that one of these rebel theories is a remarkably good match for reality. Is dark matter living on borrowed time?

"The story started decades ago," explains Margot Brouwer of the University of Leiden, whose recent research has helped fuel the debate. "In the early 1930s, Dutch astronomer Jan Oort was studying how fast the stars in our Milky Way galaxy were moving. When he compared that to calculations based on Newton's laws of gravity, he found that they weren't moving in the way he expected – they're actually moving too fast."

Isaac Newton's laws of motion and gravity, published in 1687, describe how objects move under the influence of forces, including gravity. One of their most important consequences is that the speed of a small object orbiting a more massive one is related to both the distance between them, and the mass at the centre. The heavier the central mass, the faster the orbiting object must move at a given distance, so faster orbits for stars in the outer reaches of the galaxy implied more mass in the centre. The only problem was that the measurable amount of stars, gas and dust in the galactic core was only a small fraction of that required to produce such orbits.

"Later, lots of other scientists started to see the same thing," continues Brouwer. "In 1933, Swiss astronomer Fritz Zwicky was studying the speed of galaxies moving in large clusters, and he found they were also moving too fast. And then, in the 1970s, US astronomer Vera Rubin measured how fast galaxies were rotating around their centre, and she also found that the stars were moving faster than predicted by Newtonian gravity."

Rubin's work on what became known as the 'galaxy rotation problem' finally convinced most astronomers to take the issue seriously. Most agreed that the unexpected orbits really were due to the gravity of undetected matter (which Zwicky had named 'dark matter' as early as 1933). "If you look at the entire universe," explains Brouwer, "there has to be about five times as much of this 'dark matter' as the normal matter we can see, in order to make our calculations work using the framework of Newton and Einstein's gravity."

© European Space Agency & NASA; NASA, ESA, D. Harvey

Colliding galaxy clusters are a big challenge for MOND – lensing seems to show their mass in different areas from their visible galaxies

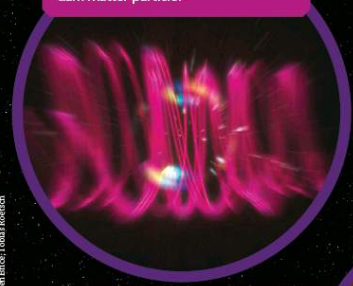
The problem with dark matter

If we can't prove it's there, how do we know it exists?

Dark matter isn't 'normal'
Even when the mass of cold interstellar gas and dust, and compact, dark bodies such as the burnt-out cores of stars are taken into account, there's only enough normal matter to account for 1/6th of large-scale gravity.

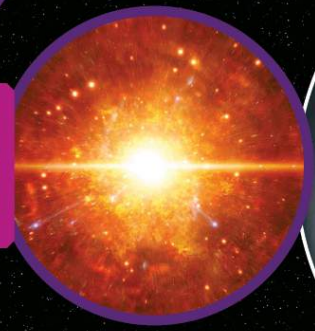
Why haven't we detected it?
If the universe is really dominated by strange particles that carry mass but don't interact with light, then why haven't underground particle detectors found any trace of them?

Why haven't we created it?
If dark matter is so abundant, why haven't experiments in particle accelerators, which specifically aim to create new subatomic particles, generated anything that looks like a dark matter particle?



Why are rotation curves so uniform?
A 2016 study comparing the rotation speeds of galaxies to the mass of their visible matter appeared to show a strong link that's hard to explain if the proportion of dark matter varies from one galaxy to the next.

Troubles with the Big Bang
Even if we could find another way of explaining, we would still need something like dark matter to explain the balance of mass and energy created in the Big Bang, and the way that gravity rapidly took control of the early universe.



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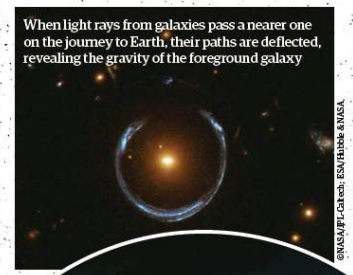
"Of course there's still a hope that one day they'll track down dark matter particles"
Margot Brouwer

But what exactly was this matter? Many astronomers hoped it would turn out to be unseen normal matter – compact objects such as rogue planets and burnt-out stellar cores that could hold a lot of mass while rarely interfering with the light from other objects. But prolonged searches in and around our own galaxy found very few of these objects, and instead, most scientists reluctantly concluded that dark matter must be something very strange indeed – vast clouds of particles that permeate the universe but are somehow immune from all interactions with light.

The search for dark matter particles has continued for decades, but so far no suitable candidate has been directly detected. Astronomers have found supporting evidence for the influence of particle dark matter in collisions between galaxy clusters, and even the formation of large-scale cosmic structure in the early universe, but the particles themselves remain elusive.

Even as early as the 1970s, however, there was a minority view that missing forms of matter were not the only answer to the galaxy rotation problem.



When light rays from galaxies pass a nearer one on the journey to Earth, their paths are deflected, revealing the gravity of the foreground galaxy

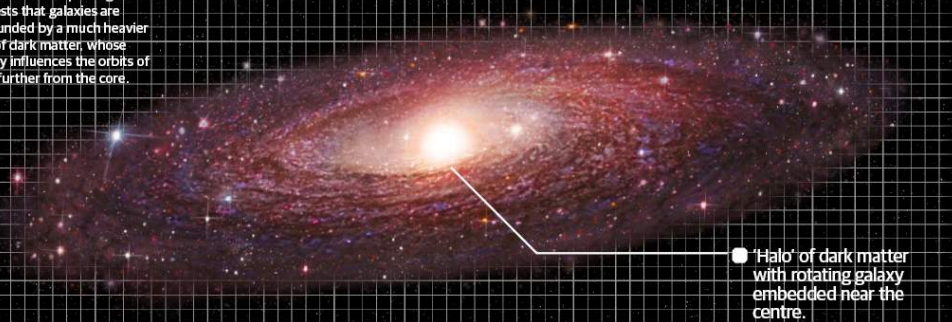
©NASA/JPL-Caltech; ESA/Hubble & NASA,

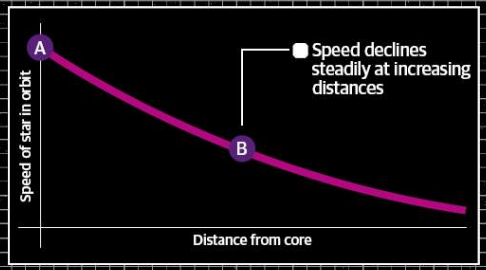
Could dark matter be explained by small, dense objects in the halos of galaxies? According to studies of the Milky Way, there just isn't enough of these objects to make a difference

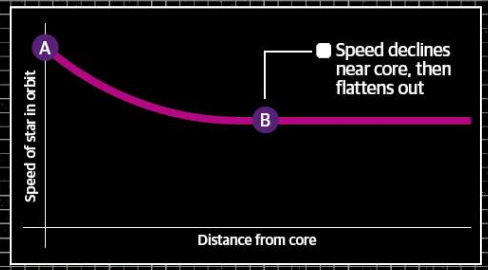
Dark matter replacement: MOND

MOND and dark matter both aim to explain a key pattern identified by Vera Rubin in the 1970s – the 'flat' rotation curves in the outer reaches of galaxies

1. Dark matter solution
The 'dark matter paradigm' suggests that galaxies are surrounded by a much heavier halo of dark matter, whose gravity influences the orbits of stars further from the core.

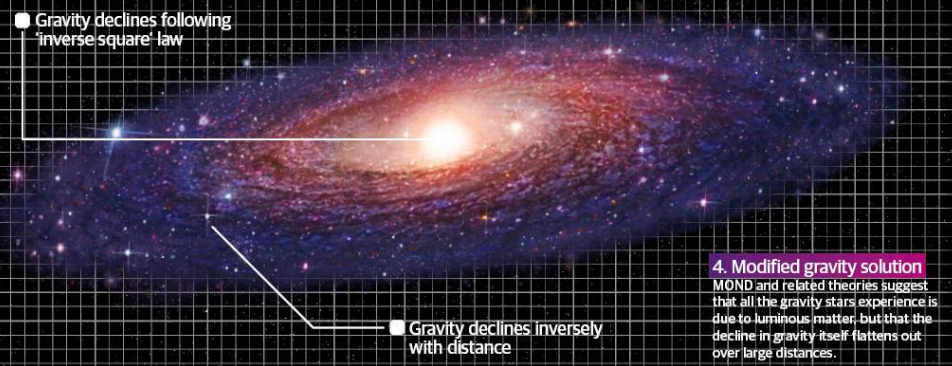






2. Expected motion
If a galaxy's mass matched its distribution of luminous matter, then Newtonian gravity suggests that stars should orbit more slowly at greater distances from the core.

3. Real orbits
Measurements by astronomers show that, beyond a certain distance from the core, stars all tend to orbit at a certain speed, suggesting they are experiencing unexpectedly strong gravity.



4. Modified gravity solution
MOND and related theories suggest that all the gravity stars experience is due to luminous matter, but that the decline in gravity itself flattens out over large distances.

What if, some argued, the laws of Newtonian gravity were not as rock-solid as generally thought? In 1983, Israeli physicists suggested that the problem would disappear with a relatively simple tweak to the puzzlingly way that gravity tails off over the largest of cosmic distances.

Newton's equations suggest that the strength of gravity declines according to an 'inverse square law' – doubling the distance between two masses reduces the gravity between them to a quarter of its former strength. Milgrom's 'modified Newtonian dynamics' (MOND) theory suggested that at great distances, when the acceleration due to gravity becomes 100-billion-times weaker than we experience on the surface of the Earth, its decline becomes a simple inverse relationship (where doubling the distance halves the strength). If one relationship changed gradually to the other on scales of tens of thousands of light years, then gravity above these scales would be much stronger than Newtonian predictions, explaining why stars in the outer reaches of galaxies move so fast.

However, MOND itself is simply a 'paradigm' – a framework for thinking about the problem. Over the following years, Milgrom and his colleague Jacob Bekenstein worked to develop it into a complete theory where the equations match up precisely to the evidence observed from galaxy rotation curves.

Developing a form that can work even in the extreme situations of general relativity took considerably longer, but in 2004, Bekenstein produced 'tensor-vector-scalar gravity' (TeVeS) theory, a model of gravity that can, at least in theory, replace both Newtonian gravity and general relativity.

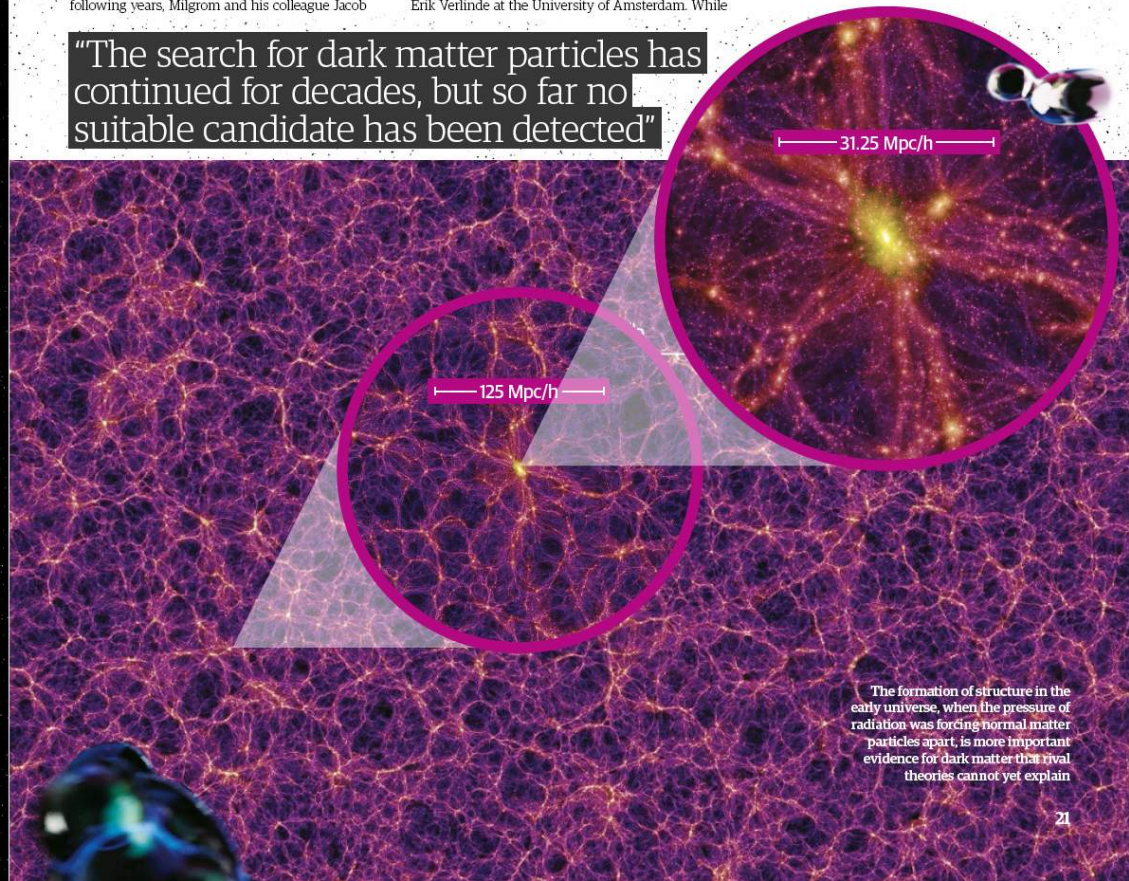
But, despite these advances, MOND remained on the fringes while most astronomers chased after dark matter. Supporters picked away at areas where the dark matter paradigm seemingly failed to match observations of the real universe, but MOND was also vulnerable to such criticisms. And even when TeVeS emerged as a possible description of how gravity might work, it didn't really explain why it would work that way.

In the past decade, however, that has changed with the emergence of a new theory called 'emergent gravity', pioneered by theoretical physicist Erik Verlinde at the University of Amsterdam. While previous theories were driven by the need to explain galaxy rotation curves, Verlinde's work started out as a way of looking at the biggest problem in modern science.

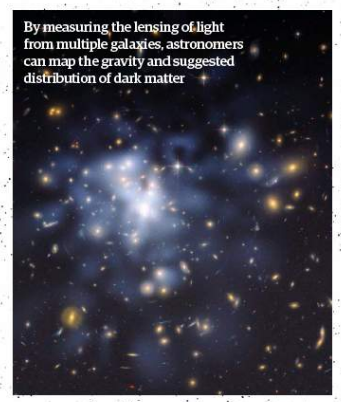
"In physics we have two great theories, explains Margot Brouwer, "Einstein's general relativity explains everything on large scales, and quantum mechanics works to explain the very small scales of atomic nuclei and elementary particles. But, when we try to combine the two scales, the equations don't work out, and so far nobody's been able to make a theory that combines general relativity with quantum mechanics."

Verlinde's theory is too complex to explore here in detail, but at its heart is a description of how complex quantum phenomena link separated areas of space-time to create the 'emergent force' that we experience as gravitation. On relatively small scales, gravity in Verlinde's theory behaves just like that of Newtonian physics and general relativity – the only significant difference is that, as the strength of

> "The search for dark matter particles has continued for decades, but so far no suitable candidate has been detected"



The formation of structure in the early universe, when the pressure of radiation was forcing normal matter particles apart, is more important evidence for dark matter that rival theories cannot yet explain



By measuring the lensing of light from multiple galaxies, astronomers can map the gravity and suggested distribution of dark matter

Motion of galaxies in the Coma Cluster led Zwicky to suggest the existence of dark matter weighing at least 400-times more than estimated calculations

gravity trails off over huge distances, the pattern of its decline changes from an inverse-square law to a simple inverse relationship – the same pattern used by MOND theories.

A key test for any truly scientific theory is that it should make predictions that can be tested, and for Brouwer, Verlinde's prediction was too tempting to ignore. Fortunately, her research interests provide her with an ideal situation in which to test it. "My main research topic is studying the distribution of gravity around galaxies, and the way that we do this uses a phenomenon called weak gravitational lensing. Einstein's general relativity shows that gravity is essentially the same as curvature of space-time, so when light from a distant galaxy passes through space-time that is curved by the mass of another galaxy, the light from the more distant galaxy will get distorted."

Brouwer's work involves measuring the distortion of light from many different background galaxies, as it passes a single foreground system. This allows her to map the distribution of mass and gravity, but means taking dark matter into account: "In the dark matter paradigm you would have the galaxy surrounded by a cloud of dark matter – you can approximately know the mass of the visible galaxy, but it's not easy to predict the mass of the dark matter cloud – often that's what we're trying to figure using the gravitational lensing method."

Verlinde's ideas, however, provide an opportunity to turn Brouwer's usual methods on their head. "The theory gives a prediction for how the gravitational distortion around a galaxy will be distributed based on the mass of visible stars and gas in that galaxy. Dark matter does not exist, so all the gravity originates from the normal matter, and we can work out the distribution of gravity around the galaxy and the space-time distortions arising from that. That's what I calculated, and when I compared that to measurements of the gravitational lensing effect, to my surprise they were in fact an exact match."

When the findings were published last year, some observed that traditional dark matter models could also produce a good match for the observed lensing effects – but Brouwer explains that's missing the point. "In the dark matter model you can change the percentage of dark to visible matter for each individual galaxy, which makes it easier to adjust the gravity and match perfectly with the lensing effects you detect. Verlinde's model makes a more direct prediction with none of these 'free parameters', and the fact that it matches so well immediately grabbed my attention."

But while the Verlinde theory may have cleared this first hurdle in style, there are still many problems in thinking that some form of MOND could easily replace dark matter. As mentioned above, the dark matter paradigm is supported not just by galaxy rotation, but in complex situations such as galaxy cluster collisions (where dark matter appears to separate from the luminous matter) and the early days of the universe (where dark matter began to clump together and form the beginnings of today's web-like cosmic structure while luminous matter was still in chaos).

Unfortunately, it's just too early to know whether emergent gravity might have its own solutions to these sorts of observations, as Margot Brouwer explains. "One of the main criticisms of Verlinde's theory from an observational point of view is that it can only make fairly rudimentary predictions for spherically symmetric, static and isolated mass distributions. Because I was studying lensing around individual galaxies that aren't doing too much crazy stuff, I was able to test Verlinde's theory for this particular case. But, so far, the theory can't make predictions for more 'messy' situations."

Erik Verlinde is now working on extensions of the theory that could explain how gravity works in more complex conditions, but it could be many years before that work comes to fruition. In the meantime, as Brouwer points out, the case is far from proven. "Just because I worked on Verlinde's theory, that certainly doesn't mean I don't believe in dark matter. There are a lot of challenges still, and of course there's still a hope that one day they'll track down dark matter particles (though they've been looking for a very long time!). "There are all kinds of strange things going on in the universe where we absolutely seem to still need it, so I certainly wouldn't say that dark matter is dead."

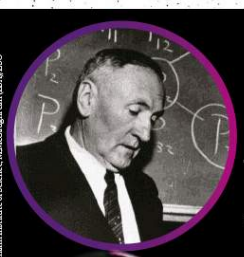
For now we can only wait for theorising and testing to be done.

> "So far nobody's been able to make a theory that combines general relativity with quantum mechanics" **Margot Brouwer**

Is dark matter real?

Some astronomers claim that the orbits of small satellite galaxies around the Milky Way are better explained by MOND than by dark matter

For dark matter



Fritz Zwicky (in Helvetica Physica Acta, 1933)
"If [my estimate of the Coma Cluster's mass] is true, then the surprising result would be that dark matter is present in much greater density than glowing matter."

Michio Kaku, City College of New York
"I hope we find evidence of dark matter in the lab and in outer space. This would go a long way to proving the correctness of string theory, which is what I do for a living."

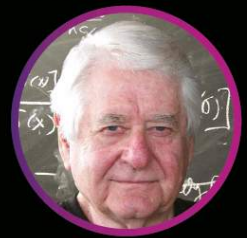
Chamkaur Ghag, University College London, chair of the Dark Matter UK consortium
"Theory indicates we have a really good chance of finding dark matter particles. This is certainly not the time to talk of giving up. Are we just going to say 'OK, we have no idea what makes up 85 per cent of the universe just because we are finding it all a bit hard'? That's not realistic."

Kathryn Zurek, Lawrence Berkeley National Laboratory
"As evidence for dark matter, [galactic rotation curves are] only one very small part of the puzzle. Dark matter explains a whole host of observations from the time of the cosmic microwave background when the universe was just a few-hundred-thousand-years old, through structure formation all the way until today."

Against dark matter

Vera Rubin in *One Hundred Years of Rotating Galaxies* (Astronomical Society of the Pacific, 2000)
"Surprisingly, we cannot yet rule out a modified gravitational potential, rather than dark matter, as the explanation of our observations. We have learned much about galaxies in the last 100 years. I think that we still have major surprises to uncover."

Pavel Kroupa, University of Bonn
"The existence of dark matter particles can never be disproven by direct experiment because ever lighter particles, and/or ever smaller cross sections just below the current detection threshold may be postulated for every non-detection. There exists no falsifiable prediction concerning the DM particles."



John Moffat, University of Toronto, in his book *Reinventing Gravity*
"It may be that ultimately the search for dark matter will turn out to be the most expensive and largest null-result experiment since the Michelson-Morley experiment [an 1887 experiment that failed to find the hypothetical ether substance supposed to fill space]."

Mordehai Milgrom Weizmann Institute of Science, Israel
"Recent years have seen the advent of several relativistic formulations of MOND. These account well for the observed gravitational lensing, but do not yet provide a satisfactory description of cosmology and structure formation... [I]t may well be that none of them point to the correct MOND theory."

"In space, both your eyes going blind is just a small thing to deal with"

Astronaut Chris Hadfield chats to **All About Space** about what really happened on board the International Space Station and life after space

Interviewed by Lee Cavendish

Your first time in space was on board the STS-74 mission. Could you explain what it's like being on a Space Shuttle leaving Earth?
It starts years in advance to that moment of course. I decided to be an astronaut when I was nine years old, and it was 26 years later I was on board a spaceship. So it's a continuation of an immense amount of lifetime work, but you also recognise that today is the major event. You know you're doing something extremely dangerous too. We know that the odds of not making it to orbit that day were about one in 38. So you're facing up to something with tremendous risk, but you're also immensely prepared already, because of a lifetime of work. So you're not at all irrationally scared; you're properly respectful, ready, competent and eager to go.

In fact, your biggest concern isn't the worry about the spaceship – your main worry is that they're not going to let you go. We were supposed to go 11 November 1995; it was a beautiful day in Florida, but we didn't have an overseas abort site in Africa, Spain or France. So we had to abort on the 11th, making the 12th our second try.

You're wearing clothing designed after the Challenger accident. These are big, heavy, protected, pressurised suits called the Launch Entry Suit, and it's orange, so we also called it the Pumpkin Suit.

You've gone through all of the work, and you've ridden up to the vehicle and you're lying on your back in the spaceship. A team of people have made sure you have all the right gear, and you're strapped in with a five-point harness. You're going through all the checks and you're excited but focused. So it's like the hardest test you've ever written, and you think you know the answers to every question.

You don't actually let yourself count on going, as you're still very much expecting that one of the thousands of things that will keep you from going is going to happen, and they [mission control] are going to say "not today". But with every tick of the clock, the probability of actually going improves. So your anticipatory excitement is climbing, and you get to five minutes before – you're in the final count – you start to let yourself go, "Wow! We're really going to go today!"

Some 30 seconds prior to launch the vehicle takes over from the ground launch sequencer and is autonomously getting ready to launch itself into space. Then, six seconds before launch, the engines start to light, so you're watching things like a hawk. Then at T-0 [moment of launch], the two solids light and you suddenly have an irresistible amount of force, and the vibration is huge.

The Soyuz TMA-07M was launched from Kazakhstan, transporting Chris Hadfield, Roman Romanenko and Tom Marshburn

It takes four people to fly a space shuttle, so the four of you on the flight deck are doing all your various tasks. The vehicle then rolls to align itself from the orientation of the launch pad to the orientation of your flight [to the destination]. So we rolled, and then I noticed about a little over a minute into the flight that my face was hurting. It was way in the periphery of my perception. Finally, when I had a free moment in my head, I wondered, "why is my face hurting?" I realised it was because I was smiling so broadly that my cheeks were cramping up!

So you're all watching everything, and after two minutes, the solids have done their job and got you above the air and they start to tail off. The mantra that's going through your head the entire time is, "What's the next thing that's going to kill me? What's it going to look like?"

It's not a negative thing; it's positive because it keeps you focused. The solids explode off and it's nice to be rid of them because they're big, rough and primitive. So you're up about 160,000 feet and going six-times the speed of sound and they tumble down to the ocean.

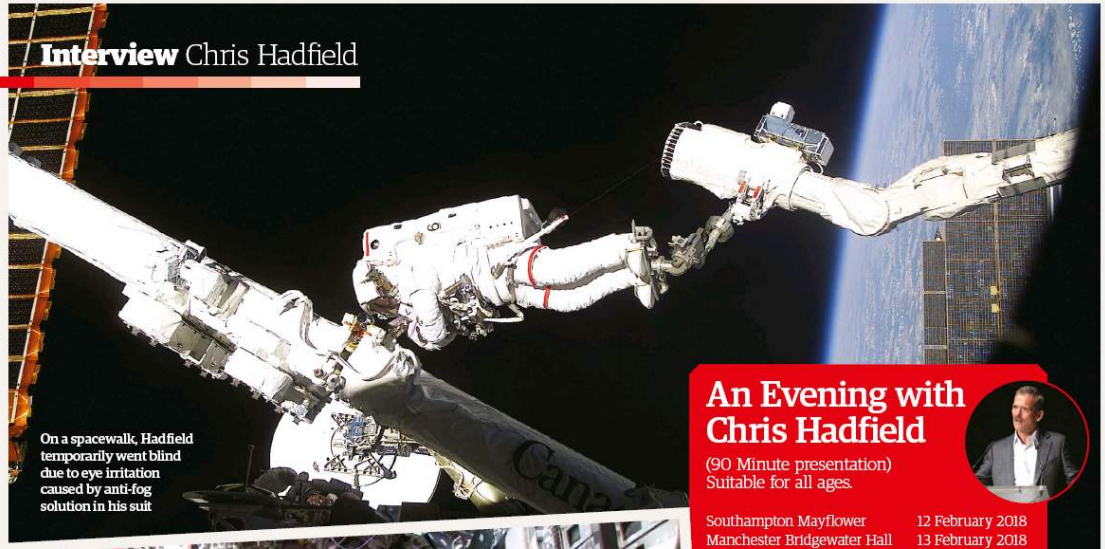
At eight minutes and 40 seconds or so after an incredibly intense ride, we can put the throttles to idle. The engines are shut off, we manually check everything and we have just stopped being a rocket ship and started to turn ourselves into a spaceship.

At the end of it, you've got all sorts of stuff to do, as you've got immediate tasks to do. However, there's a great sense of relief because you're there, and no one could ever take that away from you. You've made it, and all of the training paid off.

INTERVIEW BIO

Chris Hadfield
Hadfield is a retired Canadian astronaut. He flew on two Space Shuttle missions to help construct the International Space Station (ISS), and was also included in Expedition 34/35. He commanded the ISS for a proportion of Expedition 35, where he maintained the Station on spacewalks and conducted scientific experiments in the microgravity laboratory. Hadfield gained large amounts of popularity due to his social media activity while in space, including a cover of David Bowie's *Space Oddity*. The rendition has since gained over 37-million views on YouTube.

Hadfield clocked up 166 days in space and completed two spacewalks in the process



On a spacewalk, Hadfield temporarily went blind due to eye irritation caused by anti-fog solution in his suit

Hadfield (left) became the first Canadian commander of the ISS after Kevin Ford (right) handed it over for Expedition 35

Would you say, because that was your first time going into space, that was the hardest, or most emotional mission for you out of all the missions you have completed?
No, neither. The complexity doesn't decrease; your awareness of it increases. They were all equally hard. And Emotionally? No.

I think the first flight, you don't know what to expect as much on the second or third subsequent launches, so I think you appreciate the second and third ones more. It's like saying: do you appreciate your second visit to the Mona Lisa more than the first? You might appreciate the second one more, especially because you know what to look for. You see the nuance of it, and see the real beauty and amazing parts of it.

This is a career with thousands of applicants each year. What do you think are the fundamental characteristics needed for someone to become a successful astronaut?
Some of the simple things are an outrageously healthy body, because you have to be able to pass the hardest physical in the world to be deemed safe to send to the space station, and the second is a proven ability to learn complicated things. We tend to choose folks who have an advanced university degree, because if you have a PhD in polymer chemistry, then you've shown you can learn complicated things.

The third is a proven ability to make good decisions when the irreversible consequences are high. So how do you choose someone who has shown that they're not only a healthy student, but also someone who can react appropriately and make good calls in a highly stressful, high-threat environment.

But, that just gets you down to the hundreds of applicants, and then you're looking for life experiences. After that there are some of the subtle aptitudes, such as three dimensional visualisation and mental acuity.

Then, to a large part, is psychology: what type of person are they? Is this someone I'd want to fly in space with? Would I trust this person with my life? And would I want to be on board a spaceship for six months with them? So that's the list of things we're looking for.

What's the most dangerous situation you've been put in as an astronaut?
Launch. Launch by far. For example, Peggy Whitson holds the all-time record for American space flight. She's the most experienced American astronaut ever, commanded the space station twice and was NASA's chief astronaut. But 50 per cent of all the risks she has ever faced in her life were during the eight minutes of launch.

...so that wouldn't have been the time you went blind on your spacewalk in 2001?
No, that wasn't risky. It was just a problem to deal with. One of thousands of problems to deal with, and some of them will kill you instantly, or kill you within a few seconds or kill you in one breath. Things where there's just a problem to deal with are not necessarily risky; it's just an operational consequence. I might have been struck blind permanently. In fact, some of the chemicals in the suit are toxic enough that they could permanently damage the mucous membrane, so that could have been very bad. But it wasn't, it was something much more minor. Just because something makes you feel vulnerable and uncomfortable doesn't mean it's necessarily dangerous or risky.

The key moments of launch, docking and re-entry into the atmosphere are the most action-packed and dangerous things. We definitely increase our level of danger by going outside on a spacewalk, as we have fewer layers of protection and systems around us keeping us alive if things go wrong. So you don't go outside recreationally, because the risk is high. We go outside very deliberately, with purpose and a great amount of practise and preparation, so that something as little as both your eyes going blind is just a small thing to deal with.

What do you miss about being in space?
I'm not the type of guy who spends much time missing things. To me, 'missing' means you've stopped and looked backwards. I mean, I used to be a downhill ski racer, I used to be a fighter pilot and I used to be a test pilot. Those were all fascinating, complex, heavily engrossing, demanding and interesting things. But I don't spend my time wishing it were the past by missing things. It allows me to be who I am today and still have the understanding and perspectives that I have, so I don't miss it.

Is there an aspect of being in space that you enjoyed most of all?
That's a big list, that's like saying is there an aspect on Earth you enjoy more then others? It's a big question.

Weightlessness is very joyful, fun, delightful, freeing and three-dimensionally magical. Having the whole world go by your window in 92 minutes is incredibly instructional, revelational and beautiful. There's just the level of business of getting a million things done everyday, the pace of work is fascinating and fun. Doing something you've trained your whole life for, and doing it well, is very satisfying and fun. All those things are great, and they are a great part of the pleasure of being an astronaut.

How important do you think it is for astronauts on the International Space Station to inspire a generation?
The importance of that hasn't changed since it began among all the original astronauts. I think there's very much a distorted view of it, because typically the only time you can see what an astronaut is doing is when they're doing outreach. So you tend to think that that's the only thing they're doing.

[Laughs] It's kind of funny, 99 per cent of what you do is operating the spaceship, running the 200 experiments on board, fixing the things that are broken and studying and preparing for the next day. It's a vast tranche of work, that's what you're doing up there. Then, once in a while, you try and squeeze in a chance to share the experience with other people and let them see it.

Also, technology has improved so drastically over the last ten years to make it easier and more effective, so it's really improved. On my first flight I worked really hard to do everything, including sharing it, but all I had was a ham radio and a film camera. You can't show anybody anything, and a ham radio is in no way an effective widespread communications means. So I think it's always been important, as we're exploring the rest of the universe. If you want to try and understand the Earth, it's very difficult to measure anything from one small location on the planet. So it [the ISS] gives us a perspective and an insight both at a technical level as well as a personal level that is kind of new to the human experience.

So I think it's important to share, but I also think the public perception of what an astronaut is actually doing in space is drastically distorted, because they only see the astronaut when they're deliberately communicating with the ground.

You're heading to the United Kingdom in February 2018. Could you tell us a bit what you'll be doing there?
I'm speaking in four cities and very much looking forward to it. I'm speaking in Belfast, Glasgow, Southampton and Manchester.

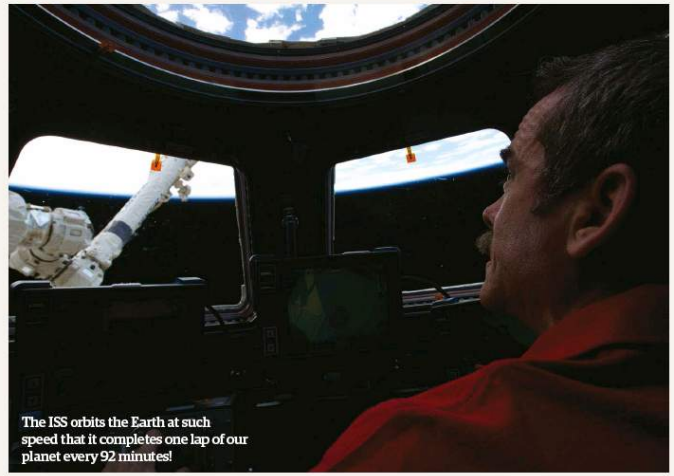
There's an immense inspirational side to exploration, especially at this stage in human development and space exploration. So there's a large public interest in it - this is reflected in movies and all sorts of popular media. This is a chance to meet people, talk to them, get up and talk on stage about some of the experiences and where it's going and what it means for us as people. Also, what it means to us individually, how can we learn some things from this crazy astronaut experience that could be useful in normal life?

I'll be talking about that, interacting with the crowd, doing lots of Q&A and playing a little bit of music as well. I may even include some of the candidates off of the BBC series *Astronauts: Do You Have What It Takes?* also. The only complaint I seem to get on social media is that it's only four cities!

"There's a great sense of relief because you're there, and no one could ever take that away from you"

The ISS provides a laboratory of microgravity magnificence, inspiring people back on Earth

Conducting experiments is just one of the many important activities astronauts carry out on the ISS

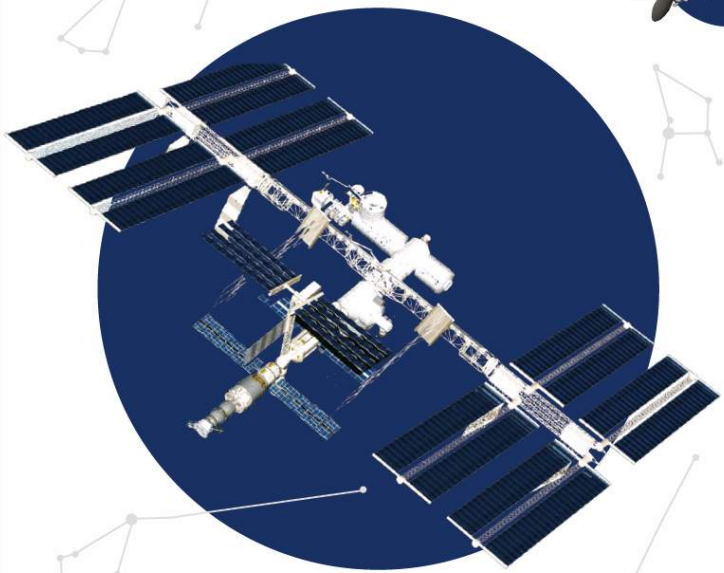


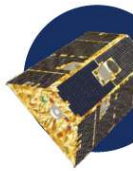
The ISS orbits the Earth at such speed that it completes one lap of our planet every 92 minutes!

UNMISSABLE SPACE EVENTS 2018

Written by Abigail Beall

The mission launches, flybys and stargazing spectacles you shouldn't miss

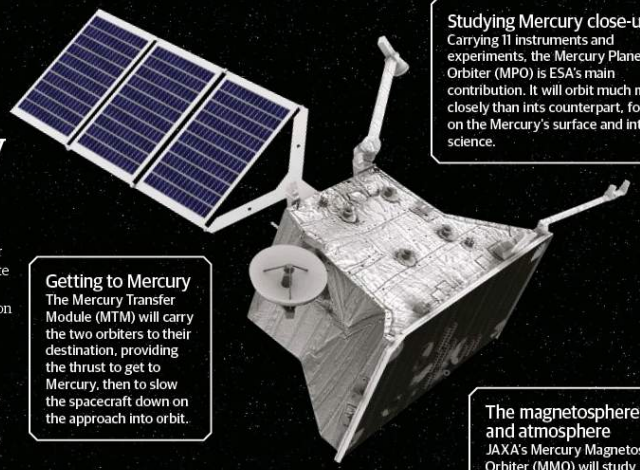




October 2018

BepiColombo heads for Mercury

A joint mission between Europe and Japan's space agencies, ESA and JAXA, BepiColumbo will head where no other European missions have been before; an adventure towards the Sun. BepiColumbo is made up of two orbiters and after a seven-year journey to Mercury, they will separate and orbit the Solar System's smallest and least understood planet. At an average of only 58 million kilometres (36 million miles) from the Sun, once they arrive the orbiters will endure temperatures of over 350 degrees Celcius as they try to gather information about Mercury's composition, atmosphere and magnetosphere to piece together the history of the planet closest to our star. The biggest challenge facing the mission will be these extreme temperatures, making Mercury such a harsh environment to study. Battling against the heat, BepiColombo will study what lies at Mercury's poles, look closely at the planet's surface craters and use its precise instruments to test general relativity. This mission is expected to last one year from its arrival in 2025, but there will be an option to extend it by another year.



Studying Mercury close-up
Carrying 11 instruments and experiments, the Mercury Planetary Orbiter (MPO) is ESA's main contribution. It will orbit much more closely than ints counterpart, focusing on the Mercury's surface and interior science.

Getting to Mercury
The Mercury Transfer Module (MTM) will carry the two orbiters to their destination, providing the thrust to get to Mercury, then to slow the spacecraft down on the approach into orbit.

The magnetosphere and atmosphere
JAXA's Mercury Magnetospheric Orbiter (MMO) will study Mercury from a wider perspective by looking at the solar wind, electric fields and radiation, interplanetary dust and Mercury's atmosphere.

Protection from the Sun
The MMO Sunshield and Interface Structure (MOSIF) will protect the MMO from the Sun's heat, and will work as an interface for mechanical and electrical signals between the MMO and the MPO.

July and August 2018

Hayabusa and OSIRIS-REx: Rendevous with an asteroid

Proximity to Earth
When Bennu was selected as the target there were over 7,000 known near-Earth objects orbiting within 1.3 AU of Earth.

Composition
An old, rare B-type asteroid, Bennu is expected to contain carbon and water-rich minerals.

Size
A diameter bigger than 200m prevents an asteroid from rotating too rapidly allowing a spacecraft to approach and collect a sample.

© NASA, ESA, JAXA / Andrew Basiuk

Why asteroid Bennu?

Asteroids are the rocky debris left over from the creation of the Solar System, so understanding them can give us an insight into our planet's history. Two separate missions will see spacecraft approach asteroids and return samples to Earth during 2018. The first of these will be JAXA's Hayabusa 2, launched in December 2014. The spacecraft will reach its target, the carbonaceous asteroid 162173 Ryugu, in June or July. Its aim is to bring back asteroid samples to Earth in order for scientists to study their composition and compare it with Earth to unravel the mysteries of the origin of life. The spacecraft is expected to stay around the asteroid for a year and a half, before leaving in 2019 and reaching Earth at the end of 2020. Meanwhile, NASA will be attempting something similar.

Having launched in September 2016, NASA's Origins Spectral Interpretation Resource Identification Security - Regolith Explorer (OSIRIS-REx) will reach its target asteroid, Bennu, in August 2018. Two months after it arrives, the spacecraft will start a year-long detailed survey of the asteroid, during which time it will carefully select a site to recover a sample from. In a five-second contact with Bennu, a sample of at least 60 grams (2.1 ounces) will be taken from its surface, by releasing a burst of nitrogen gas that will break up the rock and soil, allowing it to be captured. The spacecraft has enough gas for three of these attempts. In March 2021, the spacecraft will leave the asteroid and begin its two-and-a-half-year journey back home, where the sample capsule will separate from the spacecraft and enter the Earth's atmosphere.

What OSIRIS-REx will do

- ☑ Reach the asteroid Bennu in 2018 and study it for at least a year, choose a sample site before taking a sample of 60 grams from the asteroid's surface, and returning it to Earth.
- ☑ Help astronomers to learn about the composition of asteroids like Bennu, to understand what the early Earth was like and where life may have originated from.
- ☑ Allow scientists to develop ways of studying asteroids and predicting their orbits, in the hope of being able to protect us from the threat of an asteroid hitting our planet.

© Pitre

March to April 2018

Spektr-RG revived

Russia's next generation of high-energy astronomy observation is expected to go into an elliptical orbit around the Earth in spring 2018. While in orbit, it will study the universe using five telescopes that range from the far ultraviolet to the X-ray part of the electromagnetic spectrum, plus an all-sky monitor. The focus of Spektr-RG, a follow-on mission from Russia's first Spektr-R satellite, will be to study black holes, galaxies and interplanetary magnetic fields. It is hoped the satellite will be able to produce a catalogue of X-ray sources, and possibly even detect hot gas from dark matter sources. Its development has faced a series of delays after the original idea took off in the mid 1990s, was cancelled in 2002 and then picked up again in 2005. Progress has been aided by international collaboration, including the University of Leicester, who constructed one of the X-ray telescopes, and an ultraviolet telescope built by Tel-Aviv University.

> "The focus of Spektr-RG will be to study black holes, galaxies and the magnetic field between the planets"

Scientific objectives

- ☑ Study the asteroid's surface topography and chemistry in detail
- ☑ Collect, return and analyse a sample
- ☑ Help determine the chemical make-up of the asteroid's soil
- ☑ Measure the orbit of Bennu and its deviation from non-gravitational forces
- ☑ Compare the asteroid to observations from ground-based telescopes

Mission timeline

2016 The spacecraft started its journey

2018 It will spend over a year studying the asteroid

2020 OSIRIS-REx will have three attempts to collect a sample

2023 The sample will be returned to Earth

Rocket launches

18 January
Atlas 5 rocket for missile detection
The rocket will carry the fourth US Space Based Infrared System Geosynchronous satellite (SBIRS GEO 4).

18 January
Two new communications satellites
An Ariane 5 ECA rocket will launch the SES-14 and Al Yah 3 satellites from Kourou, French Guiana.

9 February
SpaceX Falcon 9 delivers to ISS
The Dragon CRS-1 spacecraft will launch from Cape Canaveral Air Force Station in Florida.

13 February
A Russian ISS cargo delivery
A Soyuz rocket will launch the 69th Progress mission, a cargo delivery mission to the ISS.

1 March
A new US weather satellite
NASA and NOAA will launch an Atlas 5 rocket from Cape Canaveral.

20 March
Hunting exoplanets with SpaceX
A Falcon 9 rocket will launch NASA's Transiting Exoplanet Survey Satellite (TESS) from Cape Canaveral.

18 April
A US Air Force mission
An Atlas 5 Rocket will launch the AFSPC 11 from Cape Canaveral.

30 April
SpaceX to launch a US Air Force mission
The Space Test Program 2 will involve a cluster of satellites for military and scientific research.

1 May
Cygnus cargo to the space station
An Orbital ATK Antares rocket will launch a Cygnus cargo spacecraft from Virginia.

31 July
NASA's mission to touch the Sun
The Parker Solar Probe will be launched with a Delta 4-Heavy rocket from Cape Canaveral.

Autumn
NASA's Space Launch System
The mission will send an unmanned Orion capsule into orbit around the Moon.

October
Europe's mission to the Sun
A NASA-provided launch vehicle will send ESA's Solar Orbiter on its journey to the Sun.

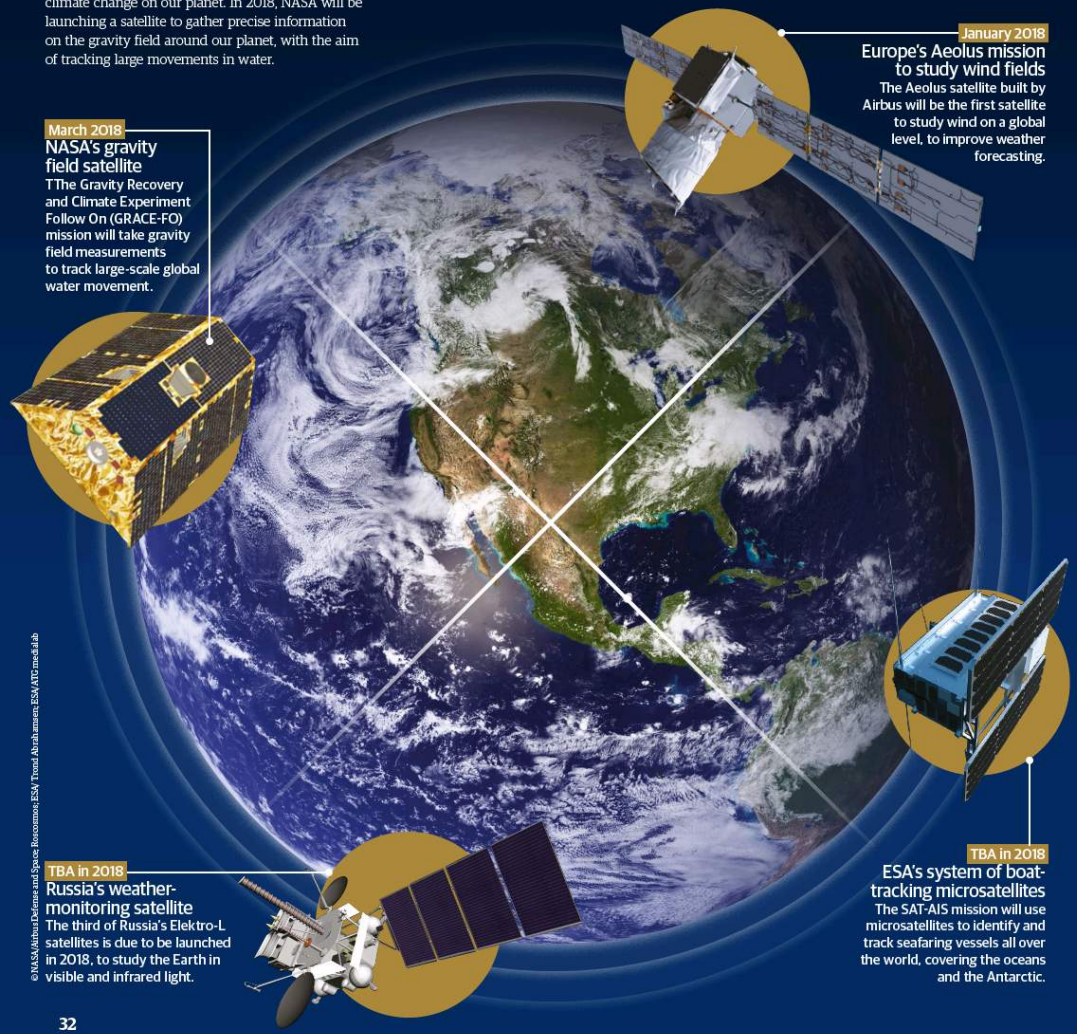
© Adrian Mann

Earth observation

Space missions are not all about looking outward. Many of the satellites that will be launched in 2018 will be aimed at studying our own planet. From monitoring the Earth's weather to the way large ships move, satellites provide a unique perspective, which would otherwise be impossible to get using ground-based observational techniques. Many of the satellites studying the Earth monitor its climate, with the hope of improving weather and climate forecasting techniques and studying the effect of climate change on our planet. In 2018, NASA will be launching a satellite to gather precise information on the gravity field around our planet, with the aim of tracking large movements in water.

ESA will launch two Earth-monitoring satellites, observing wind patterns on a global scale and using a new microsatellite network to study ships around the world. Russia will also launch its third weather-monitoring satellite, Elektro-L. It will use both the infrared and visible light to study the Earth, with a particular focus on climate change data, and monitoring the sea and oceans. It is hoped the third satellite will help improve the accuracy of Russia's weather forecasting.

"Satellites provide a unique perspective, which would be otherwise impossible to get"



January 2018
Europe's Aeolus mission to study wind fields
The Aeolus satellite built by Airbus will be the first satellite to study wind on a global level, to improve weather forecasting.

March 2018
NASA's gravity field satellite
TThe Gravity Recovery and Climate Experiment Follow On (GRACE-FO) mission will take gravity field measurements to track large-scale global water movement.

TBA in 2018
Russia's weather-monitoring satellite
The third of Russia's Elektro-L satellites is due to be launched in 2018, to study the Earth in visible and infrared light.

TBA in 2018
ESA's system of boat-tracking microsatellites
The SAT-AIS mission will use microsatellites to identify and track seafaring vessels all over the world, covering the oceans and the Antarctic.

June and the 'end' of 2018

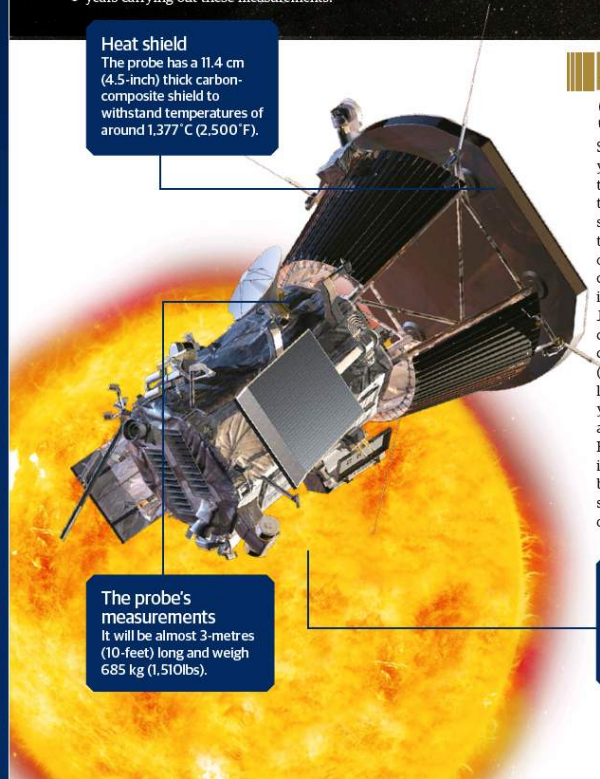
Exoplanet missions: CHEOPS and TESS

The year 2018 will see two important missions dedicated to the search and study for exoplanets: NASA's Transiting Exoplanet Survey Satellite (TESS) and ESA's Characterising Exoplanets Satellite (CHEOPS). Launching in June, TESS will spend two years peering into the distance and scanning every part of the sky. It will study the brightness of over 200,000 stars, searching for signature drops in brightness that could point towards a planet passing in front of the star. It is expected to find 2,000 planets, looking for Earth-sized planets, super-earths and tiny rocky, gas and icy worlds. The mission is also expected to determine the planetary atmospheres, studying the changes in light from the star when the planet transitions in front of it.

Launching at the end of the year, Europe's answer to TESS is CHEOPS, a space telescope also searching for exoplanets. It will study planets we have already spotted using ground-based telescopes, for which we already have mass estimates. Its mission will be to accurately measure the mass and density of the exoplanets building upon previous missions. To do this, it will study the photometric signals, and focus on planets ranging from a few times the size of Earth to the size of Neptune. Powered by solar panels, the satellite is expected to spend three and a half years carrying out these measurements.

Characterising Exoplanets Satellite (CHEOPS)

Transiting Exoplanet Survey Satellite (TESS)



Heat shield
The probe has a 11.4 cm (4.5-inch) thick carbon-composite shield to withstand temperatures of around 1,377˚C (2,500˚F).

The probe's measurements
It will be almost 3-metres (10-feet) long and weigh 685 kg (1,510lbs).

July and October 2018

Solar missions

Solar winds bombard Earth every day, yet we do not exactly know where these particles are created or how they are accelerated. Next year will see two groundbreaking missions to the Sun - where over 99 per cent of the mass in the Solar System is contained. NASA's Parker Solar Probe is expected to launch at the end of July, with its spaceship due to fly closer to the Sun than ever before; coming within 6.2 million kilometres (3.9 million miles) of its surface. After launch, it will spend nearly seven years heading through the Sun's atmosphere, with Venus' assistance. By battling into the dangerous corona it is hoped that we will be able to begin unravelling the mysteries of our star, which have eluded scientists for decades. Its main aims are to trace how energy and heat move through the solar corona, and explain what accelerates the solar wind.

While the Parker probe is on its way, ESA will launch its own mission to study the Sun: the Solar Orbiter now due to launch in October 2018. Carrying ten instruments, the orbiter will study the surface of the Sun, the changing solar wind flows and the cause of the 11-year solar cycle. It will reach its orbit, 43 million kilometres (26.7-million-miles) from the Sun - even closer than Mercury - three and a half years after its launch, where it will spend approximately three more years in orbit.

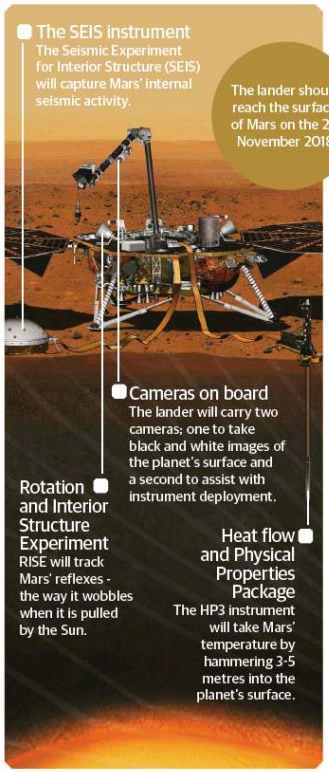
The Sun's corona
The probe will carry four instrument suites, to study magnetic fields, plasma and energetic particles, and image the solar wind.

- Launch will be between 31 July and 19 August 2018
- The probe will reach the closest point to the Sun in 2024
- Mission is scheduled to end in 2025

5 May 2018

InSight launches for Mars

Launching in May, the NASA Interior Exploration using Seismic Investigations, Geodesy and Heat Transport (InSight) mission to Mars is expected to land on the red planet at the end of November 2018. A lander will explore the surface of the planet to study its interior composition in more detail than ever before. The lander's mission is to learn more about the formation of the rocky planets, the innermost planets, in our Solar System over 4-billion-years ago. InSight will use its instruments to peer beneath the surface of the red planet, using seismology, a heat flow probe and communication technology to learn more about what is going on underneath the surface. It will measure the size, composition and state of the Martian core, the thickness of its crust and the patterns of seismic activity on the planet. It will also study the rate of impacts on the planet's surface. InSight will carry three instruments to Mars' surface to help piece together the history of our Solar System.



9 February
The year's first ISS cargo mission
The Dragon CRS-1 spacecraft will go on a cargo delivery mission to the International Space Station, launched on a SpaceX Falcon 9.

Trips to the International Space Station

27 June
Another Russian cargo delivery
The 70th Progress cargo ship will launch on a Russian Soyuz rocket carrying cargo to the Space Station.

TBA in August
Boeing's first ISS mission
An Atlas 5 rocket will launch Boeing's CST-100 Starliner, carrying two astronauts, to the ISS.

13 February
A Russian ISS cargo delivery
A Soyuz rocket will launch the 69th Progress mission, taking the second cargo delivery of the year to the ISS.

10 March
The first crew of the year to the ISS
A Russian Soyuz rocket will take a Soyuz spacecraft to the space station, carrying Expedition crew 54.

25 April
Another Russian cargo delivery
A Russian Soyuz rocket will take the next members of the ISS crew, Expedition 55, to the Space Station.

January to December 2018

Missions to the Moon

Our natural satellite has inspired wonder in humans for thousands of years. We can see the bright man in the Moon, yet the mysterious dark side of the Moon has been a source of suspicion for centuries, but soon this may no longer be the case. One 2018 mission to the Moon involves landing a rover on the Moon's far side. A Chinese mission, the Chang'e 4 rover, aims to become the first nation to achieve this. This is China's second lunar rover, after Chang'e-3 with its lander 'Jade Rabbit'. India's second Moon mission; approximately 10-years after its first, Chandrayaan-2, is scheduled to launch in March and will include a Moon orbiter, lander and a rover. Developed by the Indian Space Research Organisation, the orbiter aims to track lunar dust, feeding data back to Earth. SpaceX also plans to send two private citizens to the Moon on-board their Dragon V2 crew capsule. US mission, NASA's TESS, will perform a flyby of the Moon. New German-based private space company, PTScientists, aim to send two Audi lunar rovers to revisit the landing site of Apollo 17. Additionally, the Google funded Lunar X Prize have selected five teams to launch their spacecraft to our nearest space neighbour.

Stargazing highlights

31 January
Blue blood Moon
A blue Moon will occur at the same time as a total lunar eclipse, also known as a blood Moon.

15 February
Partial solar eclipse
Those in parts of Chile, Argentina and Antarctica will be able to see the Moon partially block the Sun.

22 to 23 April
Lyrid Meteor Shower
The shower, produced by comet C/1861 G1 Thatcher will produce around 20 meteors per hour when it peaks on the night of 22 April.

29 April
Best time to spot Mercury
The planet will be at its highest point above the horizon, known as greatest western elongation, making it easy to spot.

27 July
Total lunar eclipse
The Moon will gradually get darker and then turn rusty red, viewable between Europe and West Australia.

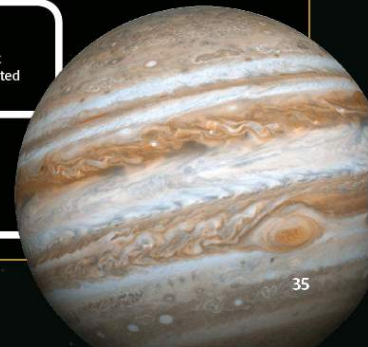
27 June
Saturn at opposition
This will be the best time to spot the ringed planet, when it is brighter than any other point in the year.

9 May
Jupiter at opposition
The gas giant will be at its closet point to Earth, and fully illuminated by the Sun on this date.

12 to 13 August
Perseid meteor shower
The Perseids will see up to 60 meteors per hour at its peak, on the night of the 12 August.

8 October, 21 to 22 October
Draconid and Orionid showers
The minor Draconids appear at the start of the month, followed by the more active Orionids towards the end.

13 to 14 December
Geminid meteor shower
With up to 120 multicoloured meteors per hour, the Geminids will be a great end to the year.



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Dark Venus

THE DARK SIDE OF VENUS

Earth's 'evil twin' continues to surprise us, and shining light on its chaotic dark side has forced astronomers to rethink some of their ideas about the planet

Written by Paul F Cockburn

Venus, the second planet out from the Sun, has long had our attention, and this is hardly surprising; it's by far the brightest astronomical body in the sky after the Sun and the Moon - a world that's hard to miss.

The most brilliant of the five planets known to ancient astronomers, clearly visible to the naked eye at both dawn and dusk, Venus has been admired for millennia. The ancient Greeks associated the world with their goddess of love and beauty, Aphrodite, while the Romans counterpart if the goddess Venus – confirming it as the only planet in the Solar System named after a woman!

To the ancient Mayans, however, the planet was linked with the feathered serpent Kukulkan, the patron of war, while in early Christians sometimes referred to the bright 'morning star' as Lucifer, the 'light-bringer'. As we've since discovered during the last few decades, the latter is certainly more apt: the name given to Satan before he rebelled and fell from heaven is particularly appropriate for the hellish environment on the planet today.

Venus is often referred to as Earth's sister or twin, given that the planet is almost the same size – and has a similar mass, density, composition and gravity. Some early science-fiction writers even imagined it to be a lush, bountiful paradise, full of wondrous life. It wasn't until 14 December 1962, when NASA's Mariner 2 spacecraft flew within 34,760 kilometres (21,600 miles) of the planet, that we truly began to get a real sense of just how different Earth's so-called twin actually is.

For starters, Venus is far warmer – in fact, it's the hottest world in the Solar System. Small, rocky Mercury may be physically closer to the Sun, orbiting between 47 and 70 million kilometres (29 to 43 million miles) away, but Venus – with its relatively circular orbit some 107 to 109 million kilometres (67 to 68 million miles) from the Sun – is covered by a dense atmosphere of clouds that refelects sunlight. It's this covering which ensures Venus is the brightest of the planets as seen from Earth, as it reflects around 70 per cent of the light striking it.

Those thick clouds also trap whatever energy reaches the surface, in a runaway 'greenhouse effect'. Temperatures on the dimly illuminated surface can reach an estimated 471 degrees Celsius (880 degrees Fahrenheit), which is more than enough to melt lead. When the Russian lander Venera 13 landed on the Venusian surface on 1 March 1982, transmitting back colour pictures of its rocky surface for the first time, scientists were surprised that the probe functioned for more than two hours – they had assumed it would last only 30 minutes on the harsh surface.

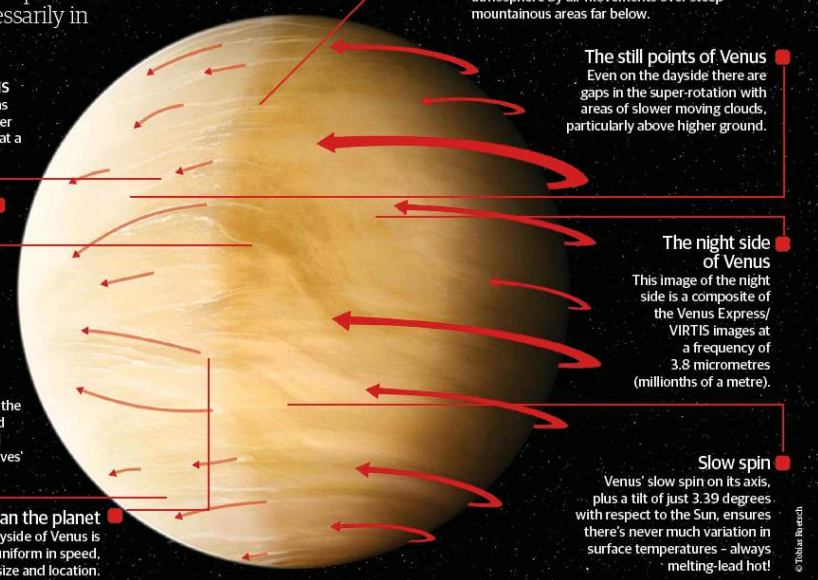
It's not just the high temperature that any visitor to Venus has to contend with. The ultra-dry surface of the planet is littered with thousands of volcanoes, active volanoes, which have likely contributed to Venus now having an atmosphere primarily made up of suffocating carbon dioxide, ozone and eroding sulphuric acid. Just to add to the fun, much of the atmosphere cloaking the planet is so thick that the 'air' pressure at the surface is an oppressive 90-times greater than you'll experience at sea level on Earth.

Admittedly, it's likely that Venus wasn't always like this. In 2016, NASA researchers at the Goddard Institute for Space Studies published their results from computer models which suggested that, during the first 2 billion years of its existence, the planet could well have been habitable – with a shallow ocean of liquid water, cooler surface temperatures and a thinner, Earth-like atmosphere. This contradicted Cornell University theoretical

> "The winds and the cloud composition are somehow connected to the properties of Venus' surface itself" **Jean-Loup Bertaux**

Dark versus light

The terrestrial world is a planet of contrasts, but not necessarily in the ways you'd think



The daytime side of Venus
This image of daytime Venus was taken using the Ultraviolet Imager (UVI) on Japan's Akatsuki craft, at a frequency of 360 nanometres.

The unexpected winds of change
The super-rotation observed on the night side of Venus is noticeably more irregular, unpredictable and features unmoving phenomena.

Unexpected night-time structures
High-velocity filaments seen on the upper clouds of Venus, triggered by unmoving phenomena called 'stationary waves' or 'gravity waves' over steep mountainous areas.

Winds faster than the planet
The super-rotation on the dayside of Venus is observably strong and largely uniform in speed, size and location.

Clouds anchored in the atmosphere
'Stationary waves', also known as 'gravity waves', are apparently triggered in the upper atmosphere by air movements over steep mountainous areas far below.

The still points of Venus
Even on the dayside there are gaps in the super-rotation with areas of slower moving clouds, particularly above higher ground.

The night side of Venus
This image of the night side is a composite of the Venus Express/ VIRTIS images at a frequency of 3.8 micrometres (millionths of a metre).

Slow spin
Venus' slow spin on its axis, plus a tilt of just 3.39 degrees with respect to the Sun, ensures there's never much variation in surface temperatures – always melting-lead hot!

© Tibkat Rateich

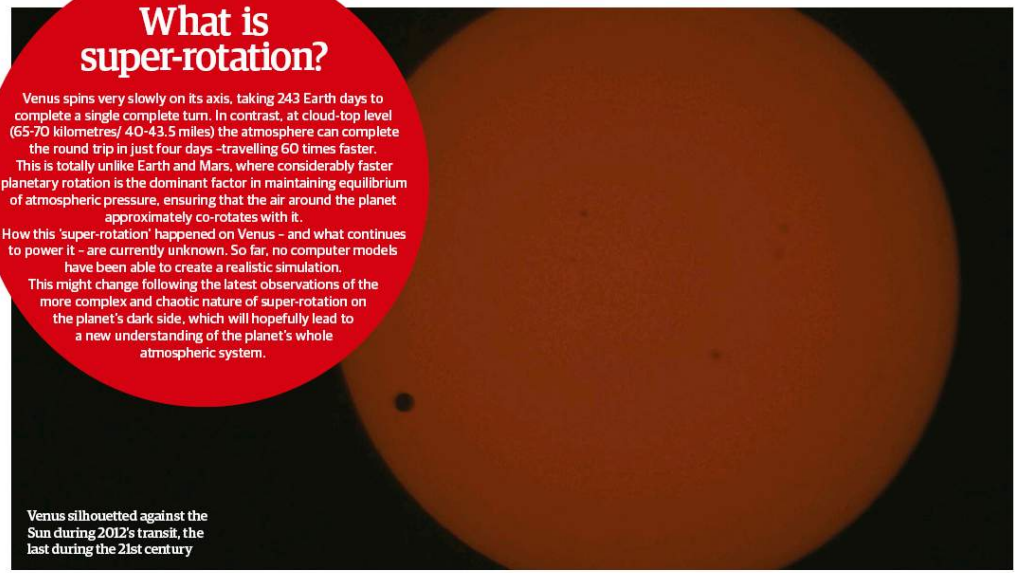
What is super-rotation?

Venus spins very slowly on its axis, taking 243 Earth days to complete a single complete turn. In contrast, at cloud-top level (65-70 kilometres/ 40-43.5 miles) the atmosphere can complete the round trip in just four days –travelling 60 times faster.

This is totally unlike Earth and Mars, where considerably faster planetary rotation is the dominant factor in maintaining equilibrium of atmospheric pressure, ensuring that the air around the planet approximately co-rotates with it.

How this 'super-rotation' happened on Venus – and what continues to power it – are currently unknown. So far, no computer models have been able to create a realistic simulation.

This might change following the latest observations of the more complex and chaotic nature of super-rotation on the planet's dark side, which will hopefully lead to a new understanding of the planet's whole atmospheric system.



Venus silhouetted against the Sun during 2012's transit, the last during the 21st century

physicist Dima Bolmatov's who, in 2014, proposed that if there were early oceans, they were more likely to have consisted of liquid carbon dioxide.

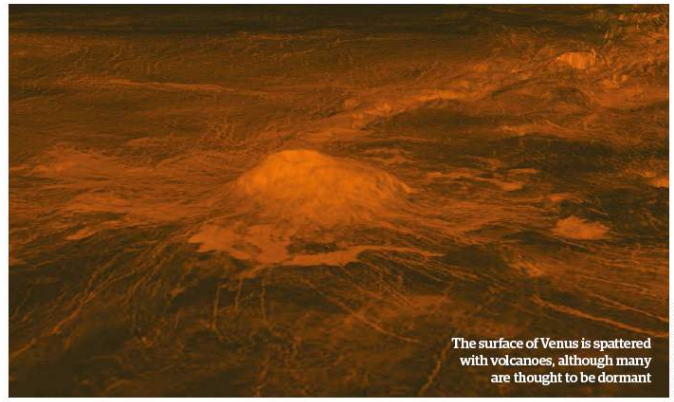
Clearly, neither is the case today, but that hasn't stopped a few NASA researchers proposing that we could still explore Venus, or at least its upper atmosphere. After all, on average at their closest approach, Venus and Earth are 'just' 40-million-kilometres (25-million-miles) distant, which is considerably closer than Mars and the closest that any planet comes to Earth. Chris Jones, of Langley Research Center in Virginia, was part of a team behind the High Altitude Venus Operational Concept (HAVOC), suggesting that the use of helium-filled airships could even lead to permanent settlements, floating where atmospheric conditions are likely to be far more congenial, some 50 kilometres (31 miles) above the Venusian surface.

Certainly, the most recent human-built visitors to Venus have gone nowhere near ground-level. Much of what we now know about the planet comes from decades of observations made from orbit. For example, the first successful Venusian orbiter, NASA's Magellan spacecraft, used radar to generate relief maps of 98 per cent of the planet's surface – showing details of features as small as 100 metres (328 feet) across – before radio contact was lost in October 1994.

Until December 2014, the European Space Agency's Venus Express spent eight years orbiting Venus, with a variety of instruments to gain a deeper understanding of her. Among its many findings, it confirmed the presence of lightning within the Venusian clouds, and also detected a surprising strong electric field that may well have helped deplete the planet's upper atmosphere of oxygen, one of the components of water.

Currently, Japan's Akatsuki spaceship has been in orbit of Venus since 2015. Among its most fascinating discoveries so far was an enormous bow-shaped bright region stretching for 10,000 kilometres (6214 miles) across the upper atmosphere – a region where clouds usually move at about 100 metres (328 feet) per second in relation to the planet's surface. Makoto Taguchi and his colleagues at the Japan Aerospace Exploration Agency (JAXA) suggested that this phenomenon, which was hotter than the surrounding atmosphere, was similar to the 'gravity waves' generated in the lower atmosphere by air passing over mountains on Earth. (These should not be confused with the recently-detected 'gravitational waves', which are ripples in space-time!)

While ESA's Venus Express mission ended in 2014, the huge amount of data it collected during its eight years in orbit is still being analysed, with some of its findings seemingly supporting Taguchi's suggestion. A study published in July 2016 suggested that some of the more extreme wind patterns seen in the planet's 20-kilometre- (12.4-mile) thick cloud layer, which sits between 50 and



The surface of Venus is spattered with volcanoes, although many are thought to be dormant

© NASA/JPL-Caltech/ESA

70 kilometres (31 and 43.5 miles) above the surface, might indeed be at least partially influenced by the topography of the land underneath.

"We used observations from Venus Express spanning a period of six years, from 2006 to 2012, which allowed us to study the planet's longer-term weather patterns," explains Jean-Loup Bertaux of Laboratoire Atmosphères, Milieux, Observations Spatiales (LATMOS) near Versailles, France. "Our results showed that all of these aspects – the winds, the water content, and the cloud composition – are somehow connected to the properties of Venus' surface itself."

Bertaux and his colleagues used observations in the infrared part of the spectrum to track the absorption of sunlight by the very small amounts of water vapour which exist in the Venusian atmosphere, enabling them to detect how much was present in each location at cloud-top level. They found that one particular area, near the planet's equator, contained more water vapour than its surroundings. This was located above a 4,500 metre (14,764 feet) mountain range, called Aphrodite Terra, suggesting that water-rich air was being forced upwards in a way similar to the gravity waves seen on Earth.

As well as helping us understand more about Venus, these findings have consequences for more general theories about climate. Håkan Svedhem, ESA project scientist for Venus Express, says: "While our current general circulation models do acknowledge a connection between topography and climate, they don't usually produce persistent weather patterns connected to topographical surface features. This is the first time that this connection has been shown clearly on Venus – it's a major result."

Results of the Venus Express are still being released including the results of wind and upper-cloud patterns on the night side of Venus. The new study, published this summer in the journal *Nature Astronomy*, showed that the atmosphere on the planet's night side behaves very differently to that on the side of the Venus facing the Sun.

One of the unique features of Earth's 'twin' is that, unlike most other planets in the Solar System, Venus spins on its axis in the opposite direction to that in which it orbits the Sun. Another is that it does so very slowly: it takes 243 Earth days for Venus to spin once on its axis – what's called the sidereal day – compared with just 225 Earth days to complete one solar orbit. This means that on Venus, a day is technically longer than a year.

Just to confuse matters, however, the planet's retrograde rotation means than a Venusian solar day – the time between one sunrise and the next – is actually only approximately 117 Earth-days long.

In contrast to these lethargic speeds, however, winds in the upper Venusian atmosphere sweep around the planet in around four Earth days; a process termed 'super-rotation'. Until this summer, it was assumed to be essentially uniform on both the 'day' and 'night' sides of Venus, although an inability to successfully model those observed on the day side suggested that "we might be missing

IR2: The 2 micrometre camera
What it discovered/observed:
Equatorial jet
Observed lower-altitude clouds by observing their silhouettes against the heat rising from the lower surface, and detected a high-speed jet near the equator.

UVI: Ultraviolet imager
What it discovered/observed:
Sulphur dioxide distribution
The UVI is designed to study distribution of specific atmospheric gases in ultraviolet wavelengths, and also the wind speed of the cloud tops.

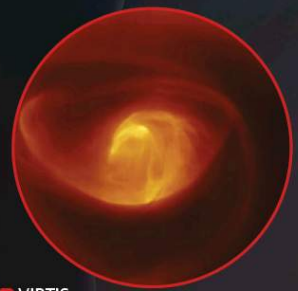
LIR: Long-wave infrared camera
What it discovered/observed:
Gravity waves
The LIR first observed the near-stationary, 10,000 kilometre (6,213 mile) bow-shaped feature in the cloud layer above the highlands of Aphrodite Terra.

High Gain Antenna
What it discovered/observed:
Nothing, but without it...
The 1.6 metre (63 inch) antenna was the spacecraft's main transmitter of data back to Earth. It was flat to prevent heat building up.

IR1: the 1 micrometre camera
What it discovered/observed:
Dark side of Venus
Designed to study heat radiation from the lower Venusian atmosphere IR1 provided the most detailed global view yet of the planet's night side.

What we've found out about Venus

It may have a thick atmosphere, but spacecraft have been able to tease out some important information about the planet

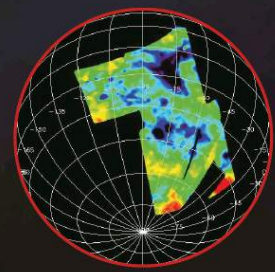


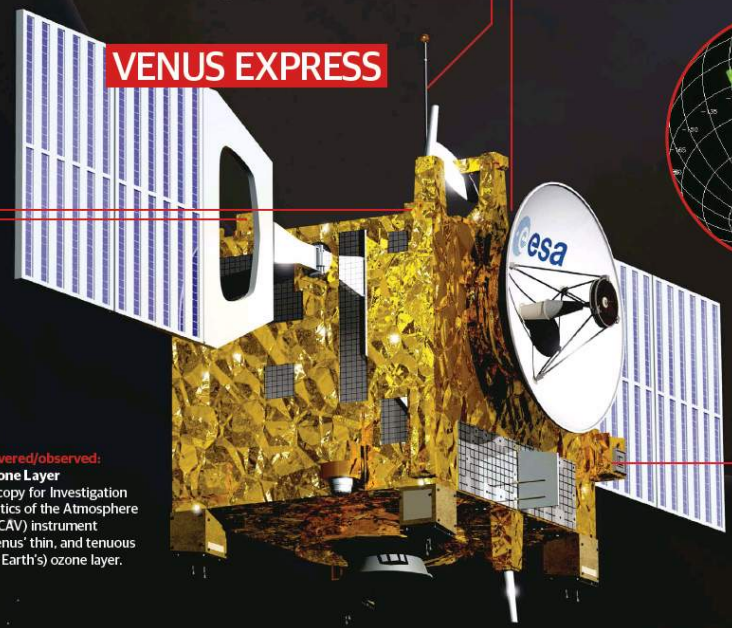
Fluxgate Magnetometer (MAG)
What it discovered/observed:
Lightning on Venus?
MAG detected very brief electromagnetic waves – which last less than half a second – with frequencies near 100 Hz, consistent with wave signals generated by lightning discharges.

VIRTIS
What it discovered/observed:
Complexity of solar vortices
While the existence of solar vortices was well known, VIRTIS showed the vortices at the south pole were far more complex than expected.

"The atmosphere on the planet's night side behaves very differently to that on the side of the Venus facing the Sun"

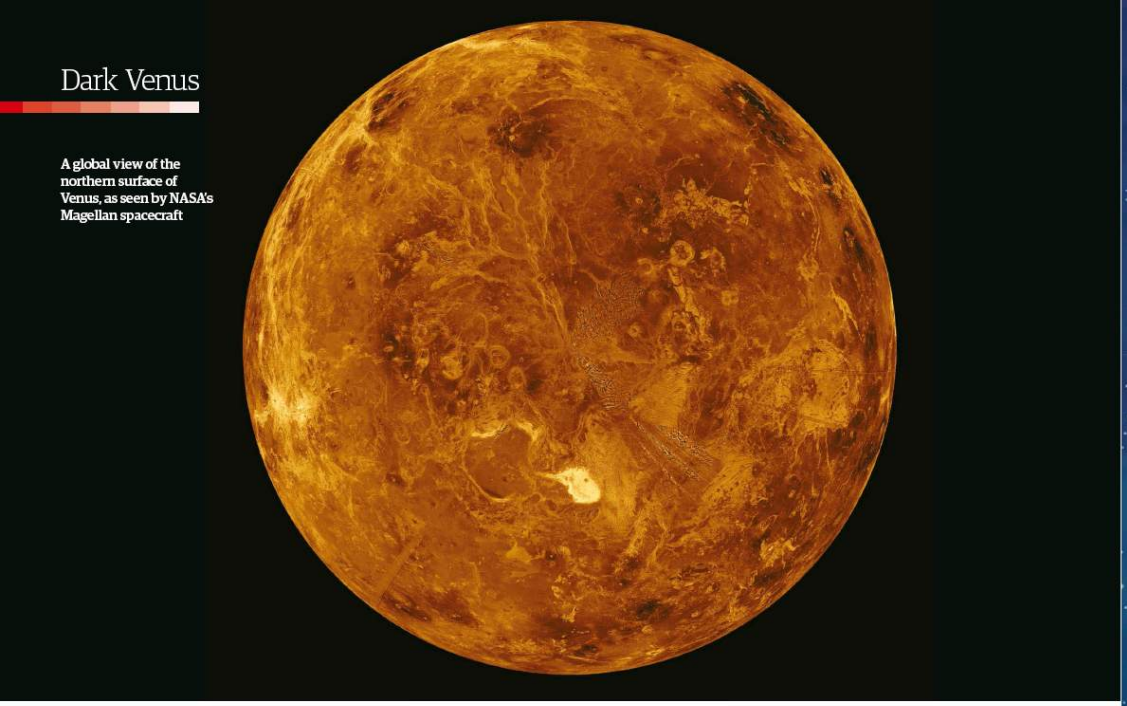
Venus Monitoring Camera (VMC)
What it discovered/observed:
Potential evidence of volcanic activity
VMC detected bright, transient features – including an apparent hot spot in the Ganiki Chasma region – that could have been an eruption or fresh lava flow.





SPICAV
What it discovered/observed:
Venusian Ozone Layer
The Spectroscopy for Investigation of Characteristics of the Atmosphere of Venus (SPICAV) instrument discovered Venus' thin, and tenuous (compared to Earth's) ozone layer.

ASPERA
What it discovered/observed:
Rapid loss of hydrogen and oxygen
The Analyser of Space Plasma and Energetic Atoms instrument discovered rapid loss of hydrogen and oxygen—split from water by the solar wind—on the planet's night side.



A global view of the northern surface of Venus, as seen by NASA's Magellan spacecraft

"While the dayside has been extensively explored, there was still much to discover about the night side" **Javier Peralta**

some pieces of this puzzle", according to Javier Peralta of the Japan Aerospace Exploration Agency.

"While the atmospheric circulation on the planet's dayside has been extensively explored, there was still much to discover about the night side," said Peralta. "We focused on the night side because it had been poorly explored. We can see the upper clouds on the planet's night side via their thermal emission, but it's been difficult to observe them properly because the contrast in our infrared images was too low to pick up enough detail."

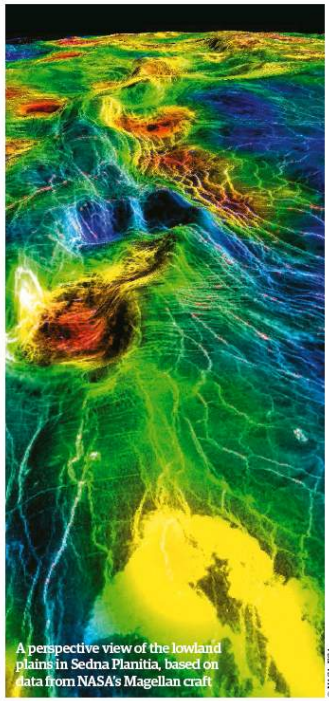
By capturing a 'cube' of hundreds of images taken simultaneously at different wavelengths – therefore creating much sharper images than previously – the Visible and Infrared Thermal Imaging Spectrometer (VIRTIS) on the Venus Express enabled Peralta and his colleagues to observe the clouds on the night side for the first time. Their findings were ruled to be "unexpected and surprising".

Simply put, super-rotation seems to be more irregular and chaotic on the night side, with the upper clouds forming different shapes and forms than those seen on the dayside: large, wavy, patchy, irregular and filament-like patterns. Also, supporting the earlier Akatsuki discovery, the cloud patterns were dominated by unmoving phenomena, referred to as stationary waves.

"Stationary waves are probably what we'd call gravity waves. In other words, rising waves generated lower in Venus' atmosphere that appear not to move with the planet's rotation," explained planetary scientist Agustín Sánchez-Lavega, of University del País Vasco in Bilbao, Spain. "These waves are concentrated over steep, mountainous areas of Venus, which suggests that the planet's topography is affecting what happens up above in the clouds."

So what of the future? NASA and the Russian Academy of Sciences' Space Research Institute (IKI) possible collaboration on the Institute's planned Venera-D mission, a successor to the series of probes launched to Venus between 1961 and 1983. The new mission – which would include an orbiter, a lander and potentially a solar-powered airship to explore the atmosphere. The proposed launch date is around 2025.

Meanwhile, NASA continues to fund a range of very-early-stage mission ideas as part of its Innovative Advanced Concepts programme. These range from HAVOC's helium-filled crewed airships in the more temperate regions of Venus' atmosphere, to a 'steampunk' rover which would pass on using the electronics that fry in the planet's environment. Their development and success are by no means guaranteed, but it's clear that our interest in our closest planetary neighbour continues. Just as well, too. If history teaches us anything, the more we learn about Venus, the stranger still the second world from the Sun becomes.



A perspective view of the lowland plains in Sedna Planitia, based on data from NASA's Magellan craft

© NASA, ESA

Microwave spacecraft

Thales Alenia Space has proposed a radical way to launch small satellites on a beam of microwaves

Imagine taking a flight where the airliner jettisoned a batch of fuel tanks and possibly an engine or two; flights would be rather unnerving, and a lot more expensive! But this what we have to do to launch stuff into space. We don't need to do this with aeroplanes, both because they need much less energy, and because they can use the air to create lift, as a reactive mass to create thrust and to provide oxygen for the engines. Launch vehicles, however, are travelling to an environment where they must take all their oxygen and reactive mass with them.

Rocket engines are presently the only propulsion we have that can provide a big enough thrust, travel from sea level into vacuum and from a standstill to orbital velocity (at least 28,164 kilometres/17,500 miles per hour). But rockets are limited by the chemical energy that is available from their propellants. This is why launch vehicles are built in stages, so they can leave behind any tanks or engines as they are emptied.

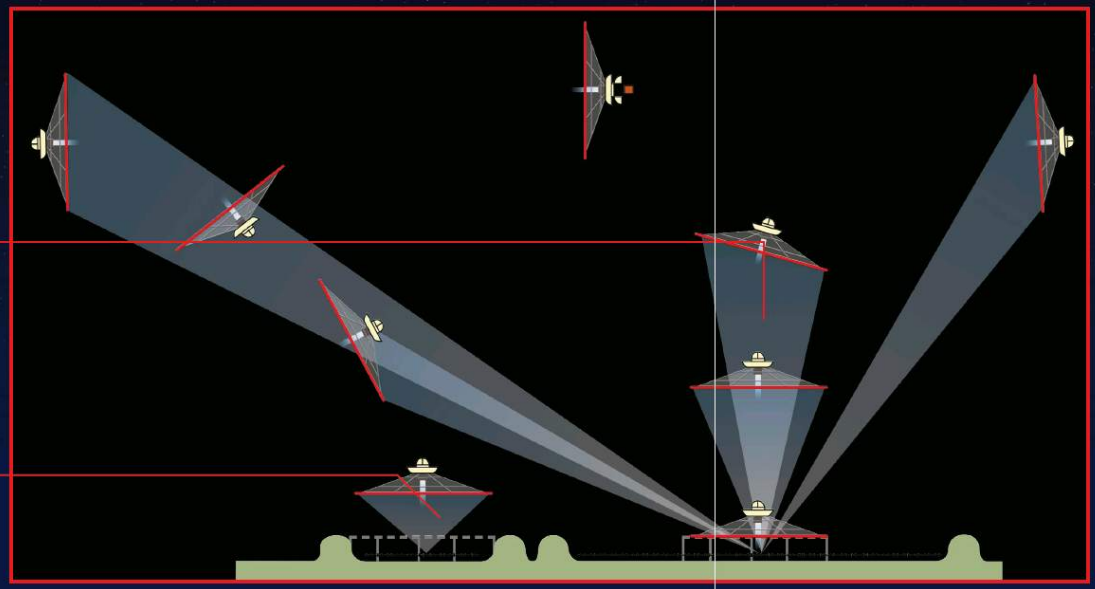
The staging of rockets and the limitations of chemical propellants contribute to the difficulty and expense of accessing space. US- based SpaceX have built a rocket which can land vertically to return to base allowing multiple uses, while UK's Reaction Engines are hoping to create Skylon, a spaceplane using a Synergetic Air-Breathing Rocket Engine (SABRE), a hybrid jet engine and rocket, to take off and land like an aeroplane.

Recently, the UK arm of aerospace prime, Thales Alenia Space (TAS), have just completed a study, funded by the UK Space Agency's National Space Technology Programme, of a radically different approach; the MicroLaunch Rectenna. Its aim: to launch small satellites from the ground via a microwave beamed propulsion system.

Chemical rocket engines work by releasing chemical energy via a combustion reaction between a fuel and oxygen, which also releases heat. This heat is transferred to the exhaust where the increase in pressure causes the hot gases to squirt out from the rocket nozzle as thrust. MicroLaunch TAS aims to break the link between these traditional sources of energy and reactive mass, and ultimately keep the source of energy firmly grounded.

The MicroLaunch vehicle would look like the canopy of a wire-mesh umbrella, with a small bullet-shaped pod at the top. This metal canopy is the rectenna (rectifying antenna), that transforms microwave beam energy transmitted from a ground station into a direct electric current (that is the rectifying part). This electricity can then be used to power an ingenious engine called a Hybrid Plasma Thruster (HPT). This electrically heats either neutral air or an on-board supply of nitrogen to use as a reactive mass. Rocket engines are theoretically more efficient at a higher temperature and because the HPT is not limited to a combustion temperature (verses chemical propellants) it can theoretically run hotter and produce more thrust per mass expelled. In addition, because its power source is a transmitter based on the ground, it can take off much more gently (such a vehicle could hover indefinitely in the atmosphere), reducing vibration and enabling the structure to be lighter.

The transmitter need only be a large, flat field of aerials – rather than some big dish – as a highly directional beam is used to transmit microwave power from the ground to the rectenna and track the MicroLaunch as it climbed and pitched over into orbit. These novel developments in the ever advancing world of space travel promises to meet the needs of post-2025 space industry allowing us to continue exploring the mysteries of our universe.



Return from orbit
The same system can return the MicroLaunch to Earth, initially pushing it out of orbit before a benign re-entry, and then making a vertical landing over a smaller transmitter.

Phased array
The transmitter can be built as a flat, stationary installation because the beam can be steered electronically by pulsing the antenna elements in waves.

Subsonic resealable fairing
Instead of a payload fairing which must be discarded to save mass, Microlaunch can have a resealable cover that could safely bring satellites or debris back to Earth.

Air-breathing variable intake
One advantage of MicroLaunches is being able to use the air as a reactive mass (like an aeroplane) during atmospheric flight.

Liquid nitrogen fuel tank
When in space, Microlaunch would use a supply of liquid nitrogen, heated and expelled as a reactive mass. its also safer reducing costs and time.

Hybrid Plasma Thruster
The HPT uses electrical power to directly heat a gas, instead of drawing energy from burning propellants. Once in space, it can further accelerate its exhaust electromagnetically.

Rectenna
This canopy is made of multiple antennae that collect the microwave energy and then convert it from rapidly alternating current to direct current to wirelessly power the MicroLaunch.

> "The limitations of chemical propellants contribute to the difficultly and expense of accessing space"

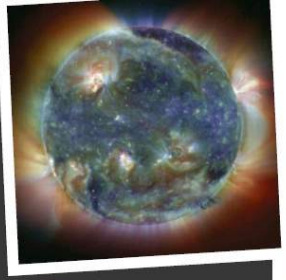
VOTED BY YOU...

THE BEST SPACE IMAGES OF ALL TIME

Written by Lee Cavendish

Space has continuously amazed everyone with its ever-changing scenery and medley of assorted celestial objects, and we have given our readers the opportunity to decide which image of our elusive universe reigns supreme. Now that the votes are in, **All About Space** can reveal your favourites. We wouldn't have any of these fantastic images without the current capabilities of telescopes, which have improved exponentially in the last quarter of a century. This is complimented by the continuous development of space and ground-based observatories. To think we have gone from the Apollo astronauts taking a truly humbling photograph with a mediocre 70-millimetre camera in 1972, to NASA and the European Space Agency's (ESA) Hubble Space Telescope producing stunning images of the universe every year with its 2.4-metre (7.9-foot) primary mirror.

It's not just Hubble that's been hard at work though, as there is a network of worldwide and interplanetary observatories that have provided us with jaw-dropping, heavenly and captivating pictures. There have also been wonderful images sent back to Earth from the pioneering spacecrafts - such as Juno, Cassini and New Horizons. Which one will prevail as the greatest space image of all time though? Let's begin the countdown!



30 The Sun in ultraviolet

You have to start somewhere, and much like the Solar System, it all originates from the ever-bright sphere of gas that is the Sun. When NASA and ESA launched the Solar and Heliospheric Observatory (SOHO) 22 years ago, it was a revelation in understanding solar behaviour. It has continued to provide a wide range of images showcasing the Sun's erratic behaviour. The standout of which was taken with SOHO's Extreme Ultraviolet Imaging Telescope (EIT), as it merges images from three different wavelengths. By colour coding the three wavelengths, which correspond to 17.1, 19.5 and 28.4 nanometres (a unit of length that is equivalent to one billionth of a metre) and combining them, the highly ionised iron in the Sun's corona can be studied.

28 The cosmic dance reshaping Arp 273

Halton Arp first listed this pair under the Atlas of Peculiar Galaxies in 1966, because of this the interacting galaxies are now commonly referred to as Arp 273.

The larger of the two galaxies, UGC 1810 - from the Uppsala General Catalogue - has been distorted into a mesmerising rose-like shape by the gravitational forces of its smaller companion, dubbed UGC 1813. The smaller galaxy is thought to have rapidly dived through UGC 1810 and lost a large amount of material in the process.

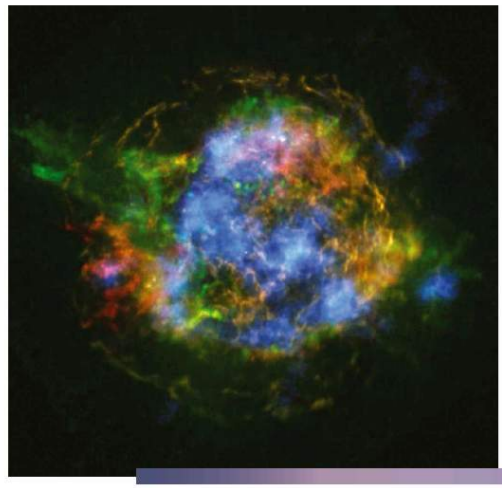
When UGC 1810 collided with its galactic sibling, this kick-started a new era of star formation in both galaxies, producing millions and millions of new stars.

29 The core of NGC 2841

There was a large selection of galaxy snapshots to choose from within this list, but none of them show the core of a galaxy quite as well as this one. NGC 2841 - a member of the New General Catalogue - is known as an abnormal spiral galaxy, primarily due to relatively low levels of star formation in its spiral arms compared to other spiral galaxies. That's not to mean there isn't an abundance of young, new, vital stars, shown by the blue sparkles. These young stars illuminate all of the surrounding gas with ultraviolet radiation, creating the coruscating spiral arms that are interrupted with darkened streaks of dust absorbing the visible light.

It is within these spiral arms that star formation is at its most prominent. By getting a closer view of the galactic habitat, astronomers can better understand the driving force that powers the birth of these enormous, radiating balls of gas. This is why astronomers decided to employ Hubble's Wide Field Camera 3 (WFC3) towards this intriguing environment in 2011, thus creating the incredible display shown before you.

"[It's] known as an abnormal spiral galaxy, due to relatively low levels of star formation"



27 Remains of Cassiopeia A

The remains of a supernova that occurred 11,000-light-years from us, it is best known for being an incredibly bright radio source. This is the consequence of a relatively recent stellar explosion, as astronomers have estimated that the first light from this supernova explosion reached Earth about 300 years ago. Now the leftover material can be studied in previously unregistered detail using NASA's Nuclear Spectroscopic Telescope Array (NuSTAR), which mapped the remnant's high-energy X-ray emissions. "This is a beautiful image, and one of the things we built NuSTAR to do - to make the first-ever map of emission from radioactivity in the remnant of an exploded star," said Fiona Harrison, principal investigator of NuSTAR.

26 Martian pits

NASA's Mars Reconnaissance Orbiter (MRO) arrived at the Red Planet on 10 March 2006 with the sole purpose of searching for water on Mars. This question has frustrated scientists for years, as Mars appears to show signs of previously existing surface water, but no current signs. It is thought that there once was a respectable atmosphere on Mars, one that could protect and preserve the surface, until the atmosphere dwindled away. The runaway effect caused the Martian atmosphere to virtually disappear, and thus began an era of heavy bombardment from the Sun's harmful radiation. This radiation has left the surface essentially uninhabitable and caused all its water to evaporate, but that doesn't stop scientists from searching.

The search continues with the MRO imaging the surface constantly with its High Resolution Imaging Science Experiment (HiRISE) camera. MRO's snapshot of Mars' southern hemisphere paints an unusual picture, one that resembles a type of cheese. The silver material creating this outlandish terrain is carbon dioxide ice. The larger depression in the corner of the picture penetrates through this ice and dust, but astronomers do not fully understand its perceived origin. The thoughts are that this is either an impact crater or a collapsed pit. Either way, it makes for a pleasing picture.

"Mars' southern hemisphere paints an unusual picture"

25 Forever blowing bubbles

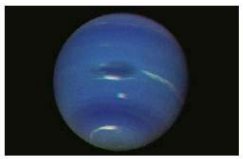
NGC 7635, appropriately nicknamed the Bubble Nebula, resides 8,000-light-years away in the constellation Cassiopeia. This depiction was chosen to represent Hubble's 26th anniversary. The bestowed picture of the Bubble Nebula combines four images taken with Hubble's WFC3 to create the mosaic masterpiece that brings not only new scenery, but fresh information for astronomers to study.

Astronomers understand that the almost-symmetrical shell of gas is being shoved away from the enormous star residing at its centre. The star heats up any surrounding gas that dares to enter its confines, which is then carried away at very high speeds aboard the stellar winds. The resulting stellar pulsation created the circular structure that spans seven-light-years across.

24 Voyager's view of Neptune

Voyager 2 flew past the ice giant Neptune in 1989 for our first views, and no camera has returned to the planet since. During this fly-by, the Voyager 2 spacecraft captured the blue-green atmosphere of Neptune from a distance of about 16 million kilometres (10 million miles), showing a wealth of complex features.

At the centre of the planet is the Great Dark Spot (GDS), which is a circulation of wind around an area of high pressure – opposite of a cyclone, ushering in the term anti-cyclonic – extending 13,000 by 6,600 kilometres (8,078 by 4,101 miles) across the surface. The brighter clouds around the Spot have an unknown origin and exhibit rapid changes, but they are known to exist at a higher altitude than storms related to the GDS.



Less than 1% of you chose ESO's picture of the Helix Nebula as the best space image of all time

23 The Helix Nebula

Planetary nebulae are some of the most spectacular, striking and alluring sights in the night sky. They occur when a star of roughly 0.8-to-eight-times the mass of our Sun depletes its source of nuclear fuel and expels its outer layers in a spectacular fashion. What is left behind is the core of the star, also known as a white dwarf, and different layers of diffuse gas hurtling through the cosmos.
In the case of this planetary nebula, labelled the Helix Nebula or NGC 7293, it's the brightest planetary nebula around, and for this reason it has been a firm favourite among observational astronomers. Although it can be seen with a beginner's telescope on a clear night, to reveal the true intricacy of the system, the European Southern Observatory's 2.2-metre telescope at the La Silla Observatory in Chile gained this amazing image.
It is apparent that the exploded layers of gas have caused an uncanny resemblance to an eye, encouraging people to refer to it as the 'Eye of Sauron' from the popular J.R.R. Tolkien book *The Lord of the Rings*. The blue-green glow of the inner circle is due to the emission of ionised oxygen. At the outer ring, hydrogen and nitrogen collide with the interstellar medium and are slowed down, reducing energy and emitting at a redder wavelength.

22 The Butterfly Nebula

Every now and again, the Hubble Space Telescope needs a service. This is a situation similar to updating the software on your computer or smartphone. This update was a more complicated process, though, as it required a team of NASA astronauts spending over 12 days in space to carry out the task.

Servicing Mission 4 was a success, and the newly fitted WFC3 began its duties of probing the universe. To celebrate the cameras arrival, Hubble took this snapshot of the Butterfly Nebula, also known as NGC 6302.

The explosive nebula falls under the category of planetary nebulae, as this particular deep-sky object is the result of a final eruption of a star. The eruption that caused NGC 6302 cast the outer layers away at a speed of 950,000 kilometres per hour (590,300 miles per hour), which is over 765-times the speed of sound.

Even though the dark dust trail has obstructed our view of the central star, scientists were still able to estimate the surface temperature of the star as being over 220,000 degrees Celsius (396,032 degrees Fahrenheit). This scorching temperature makes it one of the hottest known stars in our galaxy – it's almost 40-times the temperature of our Sun's surface. This dust trail also constrains the movement of the escaping ionised gas, which is what brings rise to bipolar outflow motion within the structure.

21 A portrait of Stephan's Quintet

In 1877, Édouard M. Stephan discovered this as the first compact galaxy group ever, visible in the constellation of Pegasus. It remains the most studied compact galaxy group. 132 years after its discovery, Hubble and the WFC3 saw it in unparalleled detail. The image here was taken at roughly the same time as the Butterfly Nebula previously mentioned. This was another one of the wonderful spectacles produced to toast the success of the Hubble Servicing Mission 4 and its camera.

Stephan's Quintet is one of the most aesthetically pleasing galaxy groups around, but there is one outsider in the group. Out of the five galaxies that make up this cosmic club, four of them are gravitationally bound. The spiral galaxy in the top left of the image, NGC 7320, lies 40-million-light-years from us. The other members of the team lay a further 260-million-light-years away. The four that make up the galactic family – NGC 7319, 7318A, 7318B and 7317 – have been in a constant galactic tug of war because of each other's interacting gravities. This has caused much distortion among the group, including the elongated tails and misshapen loops. However, NGC 7317, bottom left, is less affected by these interactions. It is also predicted that these four galaxies will someday merge.

20 The famous Orion Nebula

The Orion Nebula, also dubbed M42, is one of the most photogenic and recognisable celestial objects throughout the astronomical community. M42 is categorised as a 'diffuse nebula', which is essentially a cloud of the most primitive molecules, such as hydrogen and helium. This molecular gas cloud is the field in which new stars emerge. When a fragment of the cloud collapses and forms a highly energetic star, its fierce ultraviolet radiation illuminates the surrounding gas. Although astronomers have spent centuries staring at this wonderful entity, Hubble's ACS was able to observe the nebula showing off more than 3,000 stars, 1,500 light-years away.

19 Hubble's Ultra-Deep Field

One of the primary reasons why the Hubble Space Telescope was built was to explore the deepest, darkest segments of our universe in an attempt to find its origins. To do this, Hubble used its ACS to gather 800 exposures, over 400 Hubble orbits totalling 11.3 days of exposure time. This produced the grand finale of images called the Hubble Ultra-Deep Field.

This view includes roughly 10,000 galaxies that range in sizes, shapes, colours and orientations. However, the Ultra-Deep Field provides us with more valuable information than meets the eye. For instance, the smallest and reddest galaxies in this image are among the most distant galaxies known in the universe.

2% of our readers think New Horizon's fly-by snapshot of Pluto is the best space image of all time

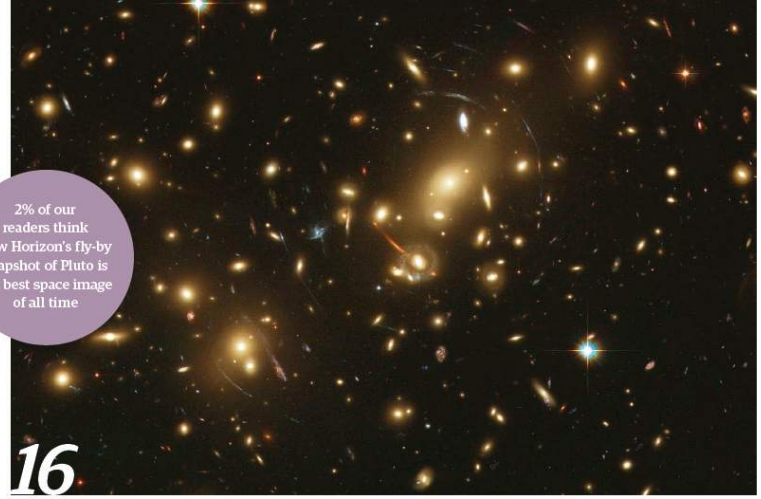
18 Fly-by of Pluto

Upon New Horizon's 2015 arrival at Pluto, the space probe began working hard to gather important information about its surface and interior, hoping to explain Pluto's (and its moons) place in the Solar System. One image most admired by the public was a high-resolution, global image of Pluto taken with the Long Range Reconnaissance Imager (LORRI).

This picture was captured at a distance of 450,616 kilometres (280,000 miles) away, showing features as small as 2.2 kilometres (1.4 miles). People's hearts were captured by the heart-shaped feature – also known as the Tombaugh Regio after the discoverer of Pluto, Clyde Tombaugh.

17 Collaboration for the Crab Nebula

Collaboration is key in science; when institutions and telescopes concentrate their efforts, we get the finest and most impressive results. To create this composite picture, five telescopes were used to observe the Crab Nebula, otherwise called Messier 1, across most of the electromagnetic spectrum, giving it a multi-coloured appearance here. The Crab Nebula is the consequent of a colossal supernova explosion which spans 11-light-years across and continues to grow at a rate of over 1 billion kilometres per day. This event is believed to have occurred in 1054, and was observed by ancient Chinese astronomers at the time.



16 Understanding dark matter

Dark matter is arguably the most elusive and misunderstood element of the universe, as we can see how it interacts and shapes the universe, but we can't physically see the matter itself. One way in which we can see dark matter warping spacetime is the formation of Einstein rings. These rings occur from a phenomenon known as 'gravitational lensing', which is the bending of light – similar to how the lenses on a pair of glasses bend light to focus on our eyes – on a universal scale.

This means that light from a distant galaxy travelling towards Earth encounters a tremendously heavy cluster of galaxies, but the cluster's mass isn't purely down to the visible mass we see, as it is also dark matter that contributes greatly to it. Getting back to the point, the light encounters the galaxy cluster and its huge mass, and consequently huge gravitational attraction, which bends the path of the light. This refraction of light reaches Earth and causes the Einstein rings you see before you.

The Hubble Space Telescope has observed this phenomenon on several occasions now, but this is one of the images that has become most popular amongst the public. The fan favourite is the galaxy cluster Abell 2218 that lies roughly 2.1-billion-light-years away from us.

15 The Sombrero Galaxy

Now we have reached the halfway point for this countdown, so let's see what you've voted as the better half! This begins with another member of the Messier Catalogue, the spiral galaxy M104. This galaxy holds a total mass of about 800 billion Suns, which brings the uncommonly large and luminous core to prominence. The cause for this extensive and diffuse glow at the centre of the galaxy is the presence of billions of old stars. The galaxy's orientation towards the Earth causes the dust trails in the galactic plane to obstruct the light, and because of this structure, astronomers have given it the nickname the 'Sombrero Galaxy'. This cosmic hat fits comfortably in the Virgo galaxy cluster 30-million-light-years away, and is only half the size of the Milky Way.

This galactic snapshot was taken as part of the Hubble Heritage Project, which was founded in 1998 by a team of astronomers aiming to educate and inspire the public with fantastic pictures from the Hubble Space Telescope. This is one of the space observatory's younger photos, as it was taken in 2003 to mark five fruitful years of Hubble in space.

14 Beautiful bars of NGC 1300

NGC 1300 is the only barred spiral galaxy in this countdown, which brings a refreshing outlook to the selection of galaxies. What makes a 'barred spiral' different from a regular spiral galaxy is the presence of a distinct 'bar' running through the galactic centre, which are connected to its spiral arms at the ends. Galactic bars arise when the orbits of multiple stars within the spiral arms become unstable, causing them to drift astray from the circular path. Once more and more stars are caught up in this elliptical orbit around the galaxy, the bars become more pronounced.

Astronomers were able to detect the star forming within the spiral arms as well as the older population of stars closer to the core.

13 25 years of Hubble

Within this stellar population lies some of the brightest and hottest stars known throughout the galaxy. Westerlund 2 is located 20,000-light-years away in the constellation of Carina, and contains roughly 3,000 stars. This is a young star cluster - aged between 1-2 million years - stars who have not yet ignited their hydrogen. The red dots are forming stars wrapped in a cocoon of dust and gas. The blue dots are in the foreground and not part of the cluster. Ultraviolet and stellar winds from the stars are responsible for reshaping the nebula landscape and creating new stars. When these stellar winds hit the gas in the area, they create shockwaves, which also birth a new generation of stars.

This image honours Hubble's quarter of a century in space. "Hubble has completely transformed our view of the universe, revealing the true beauty and richness of the cosmos," said John Grunsfeld, astronaut and associate administrator of NASA's Science Mission Directorate. "This vista of starry fireworks and glowing gas is a fitting image for our celebration of 25 years of amazing Hubble science."

12 Rosetta's comet up close

ESA's Rosetta space probe became the linchpin of chasing down, orbiting and landing on a comet. The Rosetta spacecraft was launched in 2004, and after a decade of travelling through the Solar System it finally reached the 'dirty snowball' Comet 67P/Churyumov-Gerasimenko. This was a monumental occasion, representing great scientific ambition and knowledge in designing a spacecraft to travel to a small fast-moving object compared to a planet, but to also enter an orbit around it and successfully park a lander on its surface.

Before the Philae lander grounded on the comet's surface in 2014, after a difficult landing, made contact with the orbiter in June and July 2015. After a series of sketchy messages, Rosetta observed Philae's position, finishing its mission by crashing into Comet 67P. This image was taken by Rosetta at a distance of 86 kilometres (53 miles) from the comet's centre.

11 The ancient stars of Omega Centauri

The Omega Centauri, also known as NGC 5139, is a collection of long-lived stars gravitationally bound together in a group referred to as a globular cluster. This particular cluster is an impressive celestial specimen, as it's the brightest and largest globular cluster visible from Earth, shining at an apparent magnitude of 3.9 and 17,000 light-years from Earth in the constellation of Centaurus. This army of ancient stars is also the largest globular cluster associated within the Milky Way, with a combined mass of 4-million-times the mass of our Sun. However, further studies of NGC 5139 have shown that these stars have a variety of ages, begging the question, is Omega Centauri a remnant of a small galaxy that used up all its star forming gas?

ESO's 2.6-metre (8.5-foot) VLT Survey Telescope (VST) released its first images on the 8 June 2011, after an assiduous construction period. The Omega Centauri globular cluster was one of the first images released, utilising the recently developed OmegaCAM. From this, astronomers were able to detect the faintest outer regions, culminating in this view that includes roughly 300,000 stars.

"It's the brightest and largest globular cluster visible from Earth"

10 Panorama of the Milky Way

3% of our readers voted this panoramic shot of the Milky Way's galactic plane as the best space image of all time

This is a sight that many astronomers who have braved the cold nights in a dark-sky area will be familiar with; or at least a segment of this. The Milky Way illuminates the background of the night sky in one humongous strip that encircles the Earth within its galactic plane.

This fulfilling image includes both the northern and southern hemisphere to produce a full panoramic masterpiece. All the best features of the Milky Way are present within this image. Some of the key aspects include the satellite galaxies that are gravitationally bound to the much superior Milky Way, the central bulge of light that hides away our central supermassive black hole and the streaks of blackness, which are caused by the intergalactic dust.

To see the plane of the Milky Way appear across the night sky is a truly submissive and self-effacing experience. There are over 200 billion stars within our galactic home, and the light seen has travelled thousands of light years to reach us. Within all this mayhem, we sit roughly 25,000 light years from the centre in the Orion Arm.

9 Curiosity on Mars

A Martian selfie is a rare event, and nothing else has done it other than NASA's Curiosity rover. After arriving on Mars on 6 August 2012, Curiosity has been searching for signs of life while analysing the geology of our planetary neighbour. All the information gathered by this extraterrestrial rover will lay the foundations for future exploration missions, such as the InSight lander, due to launch in May 2018.

Curiosity was able to use its Mars Hand Lens Imager (MAHLI) camera to take the self-portrait, which occurred on its 1,126th Martian day, or sol, which is 2.8 per cent longer than an Earth day. The picture was originally taken to check on the Chemistry and Camera (ChemCam) instrument on top of the rover. At the time of the image, Curiosity was also busy at work searching the 'Big Sky' site, where the rover's drill took a fifth sample of Mount Sharp.

The Curiosity rover continues to troll along the Martian surface all alone, and at the time of writing has clocked an impressive 17.75 kilometres (11.03 miles).

"Curiosity was able to use its MAHLI camera to take the self-portrait"

8 The Cigar Galaxy

M82, or the Cigar Galaxy, is a classification of galaxy known as a starburst galaxy. Located 12-million-light-years away in the constellation Ursa Major (the Great Bear), the Cigar Galaxy, much like other starburst galaxies, is incredibly busy when it comes to birthing new stars. For instance, the central region in M82 is producing stars at a rate that is ten-times faster than our own Milky Way.

This heavily influences the movement of gas and dust already travelling around the galaxy. When new stars are born, they produce a powerful stellar wind that permeates through the galaxy, and as more stars are born, these stellar winds combine to form a galactic superwind.

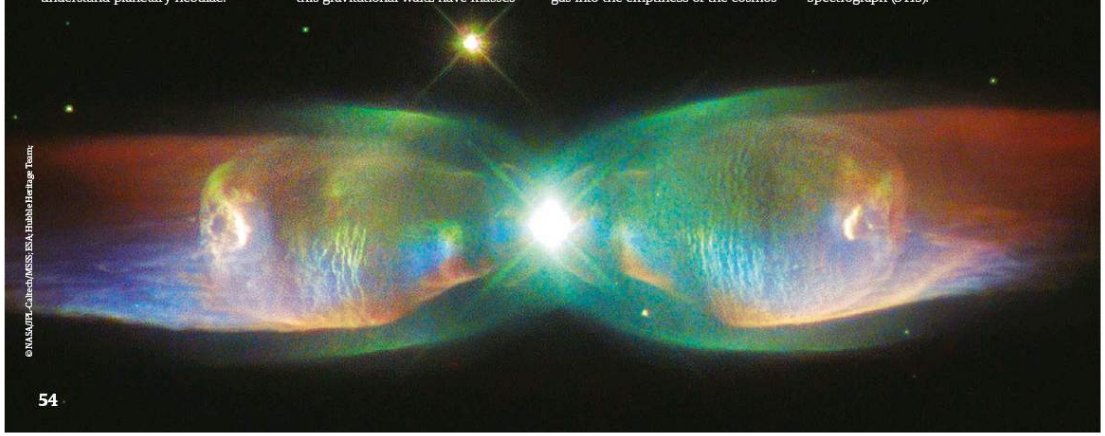
7 The Twin Jet Nebula

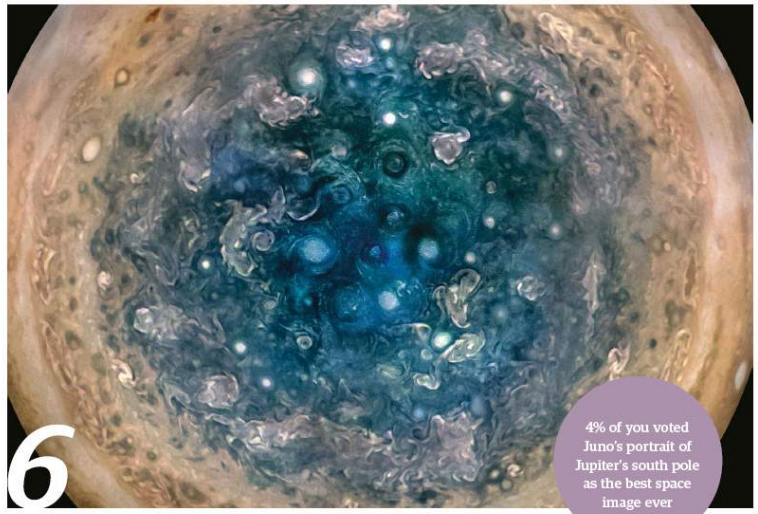
The complexity of the Twin Jet Nebula, otherwise called Minkowski 2-9, is a remarkable sight to behold. The mixture of vibrant colours across different layers and its obvious bipolar nature is visually stimulating, and this has made astronomers intensely examine it in an attempt to understand planetary nebulae.

Many planetary nebulae, much like the Helix Nebula, tend to have their material eluding one central white dwarf star in a uniform fashion. To create these bipolar outflows, they must originate from two stars caught up in a binary star system. The two stars that are involved in this gravitational waltz have masses similar to the Sun, with the smaller star having between 0.6 and one solar masses – the mass of our Sun being one solar mass – and its companion between one and 1.4 solar masses.

Astronomers suggest that the larger sibling is approaching the end of its life and is expelling its outer layers of gas into the emptiness of the cosmos to be recycled, whereas the smaller has evolved into a white dwarf star.

Hubble first imaged the Twin Jet Nebula using its Wide Field Planetary Camera 2 in 1997. 18 years later, this updated image incorporates more recent observations using the Space Telescope Imaging Spectrograph (STIS).





4% of you voted Juno's portrait of Jupiter's south pole as the best space image ever

6 Southern storms of Jupiter

Since NASA's Juno spacecraft entered Jupiter's orbit in July 2016, scientists have grasped at every piece of data collected by such a rare and exhilarating mission. Unfortunately, due to an issue with the engine burn, Juno was forced into a highly elliptical orbit that only makes a close approach to Jupiter every 52 days. This approach – also known as a perijove – is when Juno's instruments are working at their hardest; obtaining any information they can as Juno swoops from the north to the south.

In this case, Juno's only imaging camera on board, JunoCam, captured some unusually intriguing images of Jupiter's south pole. The images that Juno sent back to Earth were then released to the public and visually emphasised by citizen scientists, unveiling the exotic nature of the Jovian poles. It clearly shows there is an unknown, tempestuous and enormous flurry of Earth-sized cyclones covering the south pole.

It is common knowledge that Jupiter exhibits an atmospheric imbalance, which is shown by its zonal bands, but the configuration of cyclones at the poles has risen more questions. This confusion from the spacecraft's observations has become a theme for many of Juno's results. It appears Jupiter is a lot more complex and fascinating then we first thought.

4 Pillars of Creation

In 1995, Hubble captured one of its most memorable images in the form of the Eagle Nebula's (Messier 16) Pillars of Creation. Fast-forward 20 years, and Hubble returned. Using the WFC3, this visible-light image has dethroned the 1995 image. Everything from the rust-coloured clouds to the dark dust has provided astronomers with a sharper and wider view. Within the colourful gas clouds are glints of light escaping from the cosmic pillars: these are newly born stars emerging from their stellar incubator. These massive new stars will continue to erode the pillars with their intense radiation and stellar winds, changing their structure over time.

5 The stellar nursery IC 2944

ESO's Very Large Telescope (VLT) is one of the company's crowning jewels. It consists of four individual telescopes, each with an 8.2-metre-diameter primary mirror, making it the world's most powerful optical instrument. This gives it a great amount of responsibility though, which is what also what makes it one of the most productive astronomical facilities in the world.

The VLT snapped this flamboyant picture of the stellar nursery IC 2944 as part of its 15th anniversary. This celestial beauty is located within the same constellation as Omega Centauri, although this celestial object hosts a much younger group of stars. The pale pink background is the cloud of gas illuminated by the ultraviolet radiation of the new hot stars; with too much intense radiation from these stars, the darker blobs form. These darker blobs are known as Thackeray globules, and they occur when intense radiation from new stars causes them to be eroded away and are eventually destroyed before they can collapse to form new stellar siblings.

3 Our Earth, the Blue Marble

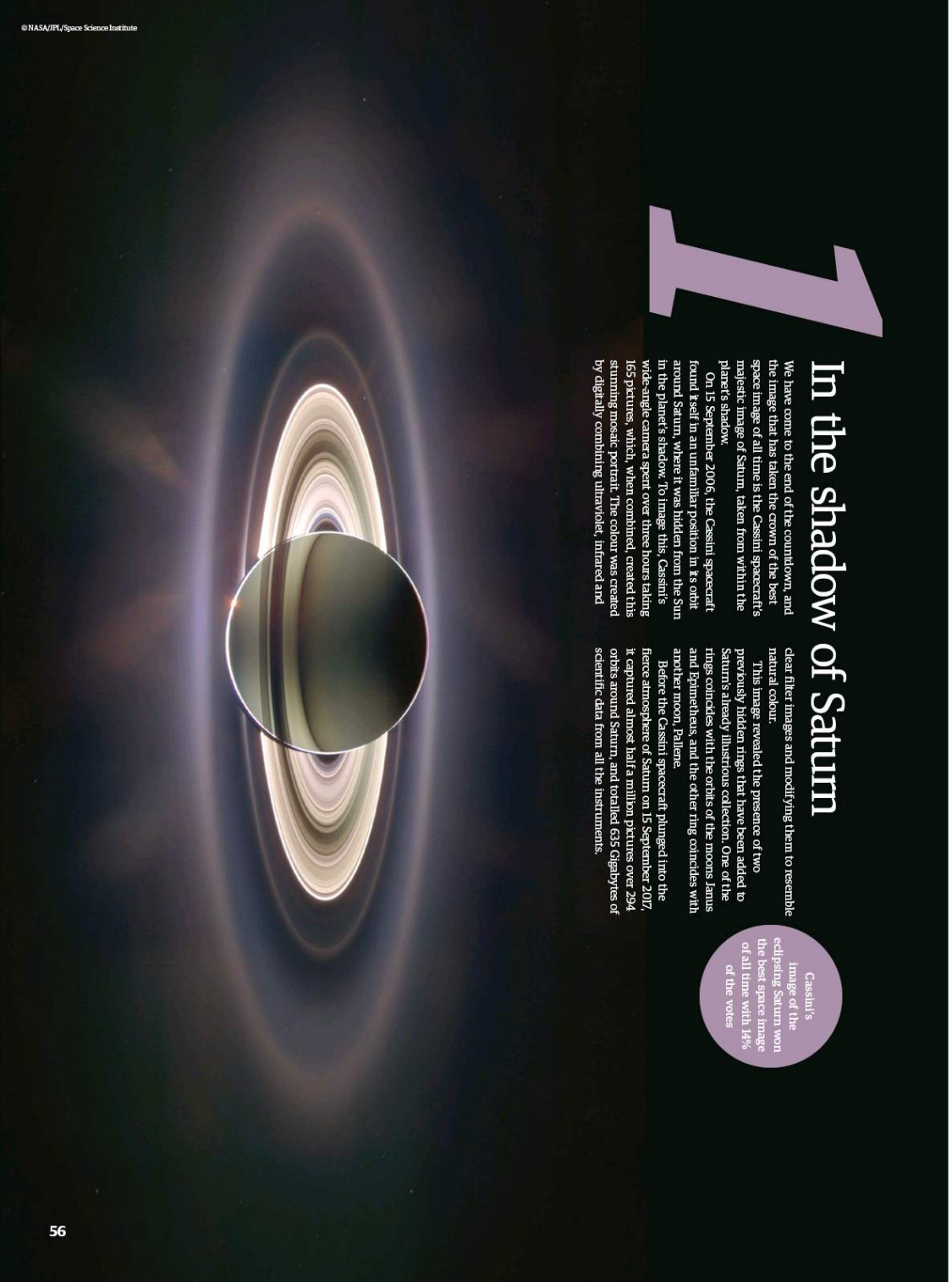
On 7 December 1972, the Apollo 17 crew, consisting of Commander Eugene Cernan, Command Module pilot Ronald Evans and Lunar Module pilot Harrison Schmitt, captured this iconic image of Earth. It has since then been famously referred to as The Blue Marble.

45 years ago this image was taken, and it is still one of the most widely reproduced photographs of all time. Simply by using a 70-millimetre Hasselblad camera with an 80-millimetre Zeiss lens, the Apollo 17 crew were able to capture a photograph that showcases the unique environment we call our home planet.

2 Hubble's Horsehead Nebula

In 2013, Hubble looked towards the Horsehead Nebula, or Barnard 33. Its dark pillars of dust create the illusion of a horse's head in front of a background of illuminated gas.

To delve deeper into the nebula and uncover the internal intricacies, Hubble imaged the nebula in infrared light. Infrared light has a longer wavelength than visible light, and is undetectable by human eyes. By seeing the structure's infrared emission, we can pierce through the dust that generally cloaks the inner areas. The conclusive picture shows many delicate and elegant layers of gas, which is incredibly different to the gloomy, dark structure that is seen in visible light.



1 In the shadow of Saturn

We have come to the end of the countdown, and the image that has taken the crown of the best space image of all time is the Cassini spacecraft's majestic image of Saturn, taken from within the planet's shadow.

On 15 September 2006, the Cassini spacecraft found itself in an unfamiliar position in its orbit around Saturn, where it was hidden from the Sun in the planet's shadow. To image this, Cassini's wide-angle camera spent over three hours taking 165 pictures, which, when combined, created this stunning mosaic portrait. The colour was created by digitally combining ultraviolet, infrared and clear filter images and modifying them to resemble natural colour.

This image revealed the presence of two previously hidden rings that have been added to Saturn's already illustrious collection. One of the rings coincides with the orbits of the moons Janus and Epimetheus, and the other ring coincides with another moon, Pallene.

Before the Cassini spacecraft plunged into the fierce atmosphere of Saturn on 15 September 2017, it captured almost half a million pictures over 294 orbits around Saturn, and totalled 635 Gigabytes of scientific data from all the instruments.

Cassini's image of the eclipsing Saturn won the best space image of all time with 14% of the votes

Explorer's Guide

Ganymede

The largest moon in the Solar System presents a labyrinth of dark, bright and cratered features

Ganymede is not only Jupiter's largest moon, but the largest natural satellite in the entire Solar System. With a diameter of 5,262 kilometres (3,270 miles), this moon is bigger than the dwarf planet Pluto, and even the planet Mercury. The discovery of Ganymede and the other Galilean moons – Io, Europa and Callisto – caused much controversy in the year 1610. Galileo Galilei had discovered that moons orbit other planets, but this new model, at the time, strongly disagreed with the idea that the Earth was at the centre of the Solar System. Instead, this made astronomers propose the heliocentric model, realising that the Sun is at the centre, and we are not as special as we thought.

After a series of flybys, including Pioneer 10 and 11, Voyager 1 and 2 and also the Galileo spacecraft, the true identity of the massive moon has proved to be more complex that anything they could have imagined. These flybys have shown that Ganymede has an unusual combination of young and old terrain. The older surface covers 40 per cent of the surface and is much darker and is very heavily cratered, with analysis showing it formed around 4 billion years ago. However, the younger terrain has a significantly smaller amount of craters, and more grooves and ridges.

These grooves are compelling evidence for the idea that there was tectonic activity replenishing the surface, making this surface seem younger. The driving force behind this activity is most likely the combination of the metallic iron and iron-sulphide core and a thick outer sub-surface saline ocean (and water ice). The metallic iron core also explains why Ganymede is the only moon to have its own magnetosphere, which provides a surrounding protective sphere of magnetic fields.

Ganymede shows some similarities to its Jovian sister, Europa, as Ganymede has a flimsy, oxygen-filled atmosphere. Scientists also believe that the atmosphere was formed by the radiolysis of water, which is the separation of hydrogen and oxygen via interaction with ultraviolet.

How to get there

1. Packing light but appropriately
As this journey will take the best part of a decade, packing efficiently is key in order to optimise your fuel usage and it's essential to only take the necessities.

2. Launch from Earth
As many probes have done before, this mission will be launched from Earth via a high-power rocket, sending it on an escape trajectory in a heliocentric orbit.

3. Gravitational slingshots
This heliocentric orbit leads on to a series of flybys past the terrestrial planets (minus Mercury) in order to increase speed, which is proven by Kepler's second law of planetary motion.

4. Final slingshot
After the spacecraft has built up enough speed, it will then travel through the asteroid belt. If all goes correctly, it will be directed into the orbit of Jupiter.

5. Arrival at Jupiter and Ganymede
The spacecraft will then arrive at Jupiter and enter its orbit after an insertion burn of the thrusters. This orbit around Jupiter will take it to its final destination of Ganymede.

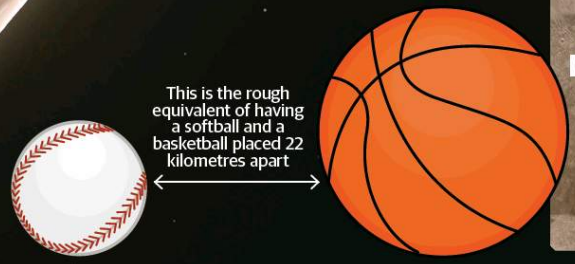
How big is Ganymede?

Ganymede has a diameter of 5,262 kilometres (3,270 miles), making it over twice the size of Pluto.

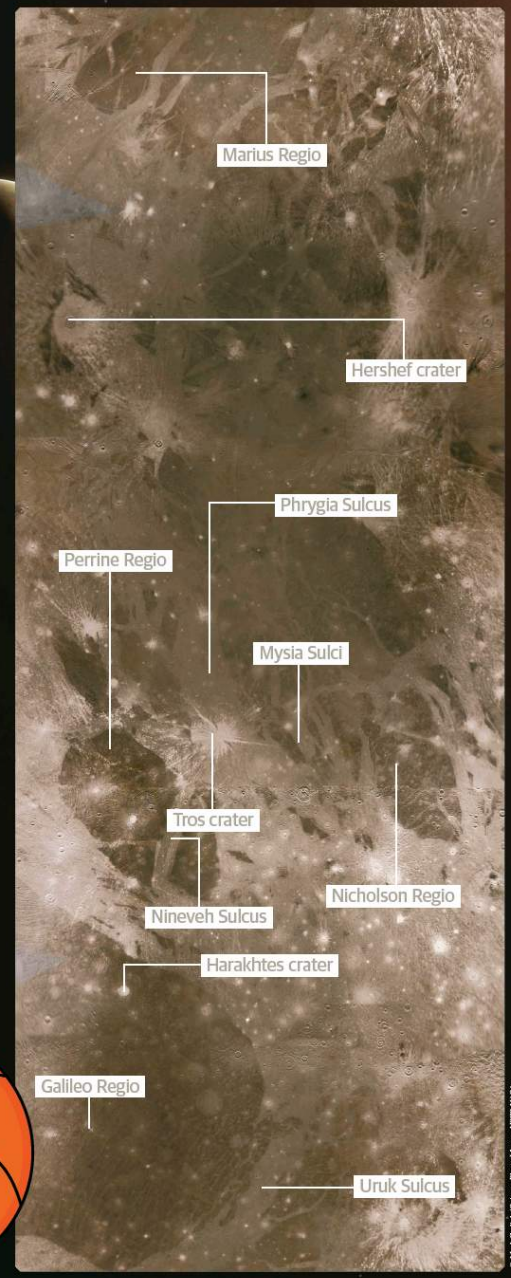
"Flybys have shown Ganymede has an unusual combination of young and old terrain"

How far is Ganymede?

As Ganymede trails Jupiter, the distance from Earth is forever changing in their respective orbits. The closest approach between the two is 588 million kilometres (365 million miles).



This is the rough equivalent of having a softball and a basketball placed 22 kilometres apart



Top sights to see on Ganymede

There is a huge contrast on the surface of Ganymede, as there are two distinctly different types of terrain. Covering 60 per cent of the Jovian moon is a relatively young, bright surface, covered by an array of ridges and grooves. Conversely, Ganymede also exhibits an old, dark, heavily cratered terrain. After investigating the density of the craters, scientists suggest that the oldest craters formed around 4 billion years ago.

Scientists believe that this contradicting terrain is a result of tectonic plate activity replenishing the surface, much like we see on Earth. In this case, it's most likely that the newer surface originated from a subsurface ocean, which had been indirectly confirmed by the Hubble Space Telescope in 2015. It is this internal saline ocean that has led to the intriguing and fascinating surface, and also the moon's magnetosphere. It is because of the plate tectonics that a lot of ancient craters have been lost below the surface.

The older regions, – also be referred to as Regiones – have the orignal craters from the intense bombardment in its early history. These are much darker regions, as they have more contaminated water ice from the interior, causing it to have a lower albedo - a measurement of reflectivity.

> "It is because of the plate tectonics that a lot of ancient craters have been lost below the surface"

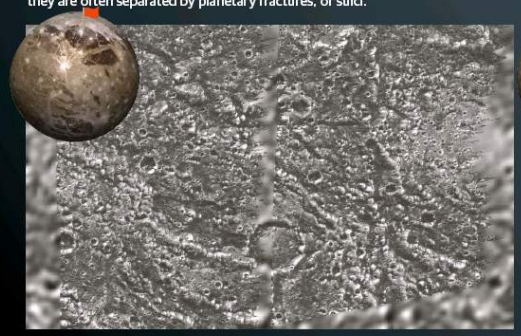
A peculiar aspect of the craters is the lack of a central depression. When a crater is mentioned, most people will automatically think of a ring in the ground with the surface declining as you reach the centre of it. However, this is not the case for Ganymede's craters, they have almost no height and are flat. This is thought to be down to the slow adjustment to the icy surface, and this can also be referred to as a palimpsest.

Over time, the surface of Ganymede has been stretched and ripped apart. This could be due to plate tectonics or the release of internal water, creating a series of grooves and ridges, which can be cited as a sulcus. These sulci – named after their resemblance to our brain's grooves – individually extend for thousands of kilometres all across the surface. Because of fresh water dispersing from the moon's interior and immediately freezing because of the cold temperatures, this creates a newer, shinier surface.

It's because of these features astronomers are constructing JUICE (Jupiter Icy Moons Explorer), a spacecraft to examine Ganymede, Europa and Callisto, in an attempt to understand the oceans under their icy and cracked surfaces. This could potentially reveal a habitable environment, which would be ground-shattering news in the astronomical community.

Older, cratered terrain
These heavily cratered regions tell us a lot about the moon's ancient history, but they are often separated by planetary fractures, or sulci.

Young, groovy surface
The lighter material on the surface of Ganymede is filled with a beautiful series of grooves and ridges, which appear to have replenished the moon's surface.



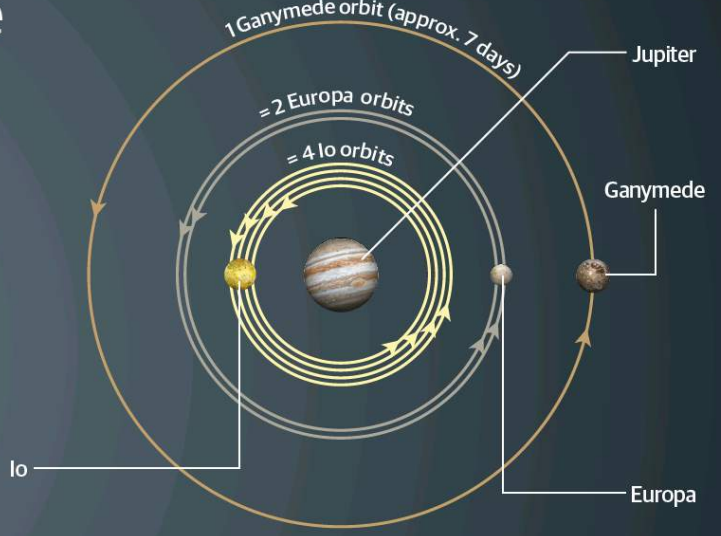
Galileo Regio
The largest area on Ganymede with a diameter of 3,200 kilometres (1,988 miles). The lighter material appears to enclose this timeworn, dark region.

Crater chain
Across the surface are a series of crater chains, known as catenae. These lines of closely spaced craters may originate from comet or asteroid fragments.

Ganymede in orbit

Ganymede orbits Jupiter at an average distance of 1.07 million kilometres (665,000 miles), taking only 7.1 Earth days to complete one orbit. Three out of the four Galilean moons have oddly organised orbits, also known as an orbital resonance.

In this case, for every orbit Ganymede completes, Europa completes two orbits around the gas giant and Io completes four orbits around Jupiter simultaneously.



Ganymede in numbers

1610
The year Ganymede was discovered by Galileo Galilei

5,262 km
The diameter of Ganymede, making it the largest moon in the Solar System

1,070,400km
The distance of Ganymede's orbit around Jupiter

2022
The year the JUICE spacecraft will be launched to study Ganymede up close

0.15
The strength of Ganymede's gravity relative to Earth's

Ganymede's weather

-113°C
-171°F

In the daytime, Ganymede's freezing surface temperature ranges from -113ºC (-171ºF) to -183ºC (-297ºF). When night-time falls on Ganymede, the surface temperature reaches a freezing -193ºC (-315ºF)!

0.025
The mass of Ganymede relative to the mass of Earth

Star of Bethlehem

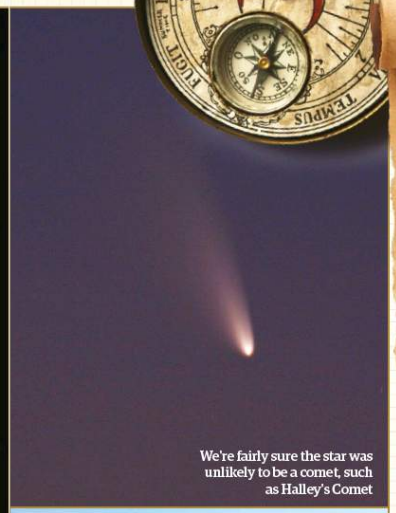
What was THE STAR OF BETHLEHEM?

An event that supposedly occurred thousands of years ago is suspected to be a planetary conjunction, rather than a star, that guided three wise men to a stable

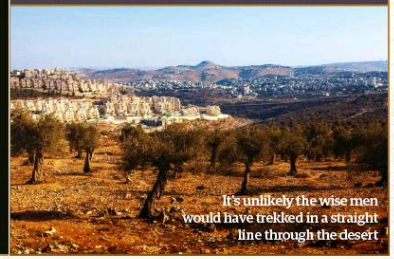
Written by Jonathan O'Callaghan

Star of Bethlehem

A supernova has mostly been ruled out as the cause of the event



We're fairly sure the star was unlikely to be a comet, such as Halley's Comet



It's unlikely the wise men would have trekked in a straight line through the desert

© Nicholas Forder; Astronomy Education Services/Giegin Observatory; NASA/CXC/JHU/D.Patnaude et al.; AlaskyStock/Photo; STOCKFOLIO® / Alamy Stock Photo

We all know the story. Approximately two millennia ago, three Magi – or wise men – followed the Star of Bethlehem to Jerusalem. After consulting with King Herod of Judea, they locate the birth of a baby boy in the little town of Bethlehem, claimed to be the baby Jesus. Whether such an event really happened in history is difficult to prove, but if it did, what might that 'star' have been?

This is a question scholars have long pondered, not just from a religious perspective, but from a scientific one too. Plenty of theories have been proposed, from an astronomical event to an astrological horoscope, and thanks to our modern knowledge of astronomy, we now think we're getting closer to an answer.

"If what is in the New Testament is a historical account of something, then that historical account requires an explanation," David Weintraub, Professor of Physics and Astronomy at Vanderbilt University in Tennessee tells **All About Space**. "As an astronomer, you want an astronomical explanation."

And that is exactly what astronomers have tried to do over the years. The Star of Bethlehem only appears in one book of *The Bible*, the Gospel of Matthew. While this means the amount of information on the event is limited, we do gain a few tidbits from *The Bible*, and piecing these together with our knowledge of science gets us close to an answer.

> "If what is in the New Testament is a historical account of something, then that requires an explanation" **David Weintraub**

We know that Halley's Comet was visible in the sky in 12 BCE. As the Magi trekked towards Jerusalem and on to Bethlehem, it seems unlikely they were following a comet, because its position would have changed as the Earth rotated. It would not have led them in a single direction. What's more, in the ancient world, comets were regarded as bad omens, indictaing death, disaster, doom or even disease.

"For Christmas cards, it makes a nice picture having a comet and a tail," Grant Mathews, Professor of Theoretical Astrophysics and Cosmology at the University of Notre Dame in Indiana, tells **All About Space**. "But in those days comets up in the sky were usually a harbinger of impending disaster."

For similar reasons, we can rule out various novae and supernovae around 5 BCE. Thanks to Chinese astronomers, we know that several such exploding stars occurred but these events would not point in one direction in the sky. Had the Magi followed one, they would essentially have walked in a circle. Furthermore, star death would have resulted in a detectable supernova remnant, but astronomers have not found anything that might date back to this time. "You can't follow a star from Baghdad to Jerusalem to Bethlehem," says Weintraub. "Stars don't do that. They rise and set, and they don't sit in the sky."

Such an event would surely have been seen by others at the time, too. Although novae are reportedly quite rare, you'd still expect some more historical accounts of a large, bright event in the sky, but aside from the Gospel of Matthew there isn't really anything. The same argument, if you needed it, seems to rule out this being a miracle. Had the Angel of the Lord come down, wouldn't others have seen it?

Other theories suggest a hypernova in the Andromeda Galaxy as the cause. Although it is possible to see the galaxy, it isn't possible to see a star going supernova and exploding within it, even with the help of a telescope.

This leads us to one of two possibilities. The first is that the Magi were making an astrological interpretation of the sky. Due to a particular alignment of planets and stars, they may have read a hidden meaning among the stars, leading them to King Herod. The fact that they needed to ask Herod for directions when they arrived suggests they were not being led to their final destination by a single bright object.

The other, more astronomical, explanation is that there was indeed a bright object in the sky – a conjunction between planets and stars. A conjunction occurs when two celestial bodies appear to meet in the night sky from our location

Some suggestions...

A comet

We know that Halley's Comet made an appearance in the night sky in 12 BCE. However, there are two key reasons the Star of Bethlehem is unlikely to be a comet. First, it would have appeared to change position in the sky as Earth rotated, so it wouldn't have led the wise men in a straight line to Bethlehem, but in a circle. Second, comets were seen as an evil omen, making it unlikely they would have followed it.

Planetary conjunctions

A planetary conjunction, or some sort of occultation, is our best bet. A conjunction between Jupiter, Saturn, the Moon and the Sun on 17 April in 6 BCE looks particularly promising. Not only is the date around the right time, but Jupiter's retrograde motion in the sky would have seen it move to the West – possibly leading the wise men to Bethlehem.

An exploding star

While a number of various novae and supernovae were reported around the time of Jesus' birth, it's unlikely one of these was the Star of Bethlehem. For one thing, it would be odd that the wise men were the only ones to see this event, with no other historical records. Also, like the comet, the exploding star would have moved across the night sky, so the wise men would not have been led in a straight line.

Heliacal rising

A heliacal rise is when a star becomes visible above the horizon, having not been visible before. Such an event, perhaps coupled with a planetary conjunction, could explain the Star of Bethlehem. We know of a conjunction involving the star Regulus that could be a good bet, or perhaps the rising of another star carried astrological implications. This is supported by the wise men seeing the star rise in the east, and move west.

Astrological event

There is a good chance that the Star of Bethlehem was simply an astrological event, given supposed significance by the wise men. In the modern day astrology is mostly scorned, but 2,000-years ago it was very much favoured, with people often looking for meaning in the stars. The reference to a literal star may in fact refer to a particular alignment that simply seemed to suggest to the wise men the birth of the Messiah.

Regulus, Jupiter and Venus

There is another conjunction that looks promising, and that's one between Jupiter, Venus and the star Regulus in the constellation of Leo on 17 June, 2 BCE. However, it doesn't quite match up with the clues we have in the New Testament, and it also seems to occur a bit too late in the year. A conjunction between Jupiter, Saturn and Mars in February of 6 BCE is also a possibility.

on Earth, such as two planets passing close to other, and this can result in them appearing especially bright. These events can continue every night in a similar location for days or weeks. If one were to follow the moment of conjunction, it's possible they could be led in a particular direction.

A important book by former Rutgers University astronomer Michael Molnar in 1999, called *The Star of Bethlehem*, first suggested one of these theories might be correct. If the conjunction idea is true, though, and this historical event did really happen, then there are a number of different alignments that could be the culprit.

Perhaps the most promising, and the one favoured by Mathews, is an alignment of Jupiter, Saturn, the Moon and the Sun in the constellation of Aries on 17 April, 6 BCE. It seems to line up pretty well with the story. For one thing, the New Testament notes they saw the star rising, suggesting it was a morning star – which this conjunction was.

They also reportedly lost sight of the star, before seeing it come to rest in the place where the child was. This could have been the result of the retrograde motion of Jupiter, which means that it appears to change direction in the night sky as Earth's orbit overtakes it. "Normally, planets move eastward if you're following them in the sky," says Mathews, "but when they go through retrograde motion, they turn around and go in the direction that the stars rise and set at night [the west]."

Two other conjunctions around a similar time also look promising. One is the meeting of Jupiter, Venus and the star Regulus in the constellation of Leo on 17 June, 2 BCE. To most people, the two planets would appear as a single 'star', brighter than Venus and Jupiter individually. Another is in 6 BCE, between, Jupiter, Saturn and Mars in Pisces, but, neither of these as closely match the description in the New Testament as the conjunction on 17 April – coincidentally just before Passover.

The Andromeda Galaxy is too far away to have been the cause of such a bright star

There is the chance, of course, that they weren't following a literal star at all. They may instead have been reading signs from the stars themselves, using astrology to pinpoint the location of the Messiah's birth. Astrology was widely used at the time, and with the Magi coming from Babylon, its plausible that they were astrologers. Jupiter's display could have been of great significance here too, as astrology associated the planet Jupiter with royalty, so the Moon passing it in Aries on 17 April 6 BCE could have heralded the birth of Christ.

"Modern astronomers don't put any credence in astrology, but 'modern' is important in this context," says Weintraub. "What's important is what people thought 2,000-years ago. Astrology was a big deal back then. The explanation I have found that makes the most sense is that it was astrological."

It's unlikely we will ever know for sure whether this event actually happened, or what caused it, unless we make an unexpected archaeological finding. But it's a question that comes up year after year, and while we haven't got a concrete answer, we can certainly rule out a few ideas at the very least. "Nothing in science is ever case closed, nor is it in history," says Mathews. "We may never know if the Star of Bethlehem was a conjunction, astrological event or a fable to advance Christianity. Maybe it was simply a miracle."

"In those days comets up in the sky were usually a harbinger of impending disaster" **Grant Mathews**

A planetary conjunction may be one of our best explanations

What's in the sky?

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

7 DEC The Moon and the Beehive Cluster (M44) pass within 2°23' of each other in Cancer

8 DEC Conjunction between the Moon and dwarf planet Ceres in Leo

12 DEC Conjunction of the Moon and dwarf planet Makemake in Virgo and Coma Berenices

13 DEC The Moon and Mars make a close approach, passing within 3°56' of each other in Virgo

13 DEC Conjunction between the Moon and dwarf planet Haumea in Boötes

13 DEC The Geminids reach their peak of around 100 meteors per hour

13 DEC Open cluster NGC 1981 is well placed for observation in Orion

14 DEC The Moon and Jupiter make a close approach, passing within 4°03' of each other in Libra

17 DEC Asteroid 20 Massalia will be well placed for observation in the constellation of Taurus

18 DEC Conjunction between Mars and dwarf planet Haumea in Virgo and Boötes

21 DEC December solstice, marking the shortest day and longest night in the Northern Hemisphere

21 DEC The Ursids reach their peak of around ten meteors per hour

26 DEC Open cluster NGC 2232 is well placed for observation in Monoceros

27 DEC Conjunction between the Moon and dwarf planet Eris in Pisces and Cetus

28 DEC The Rosette Nebula (NGC 2244) is well placed for observation in Monoceros

1 JAN Open cluster Messier 41 is well placed for observation in Canis Major

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

In this issue...

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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.

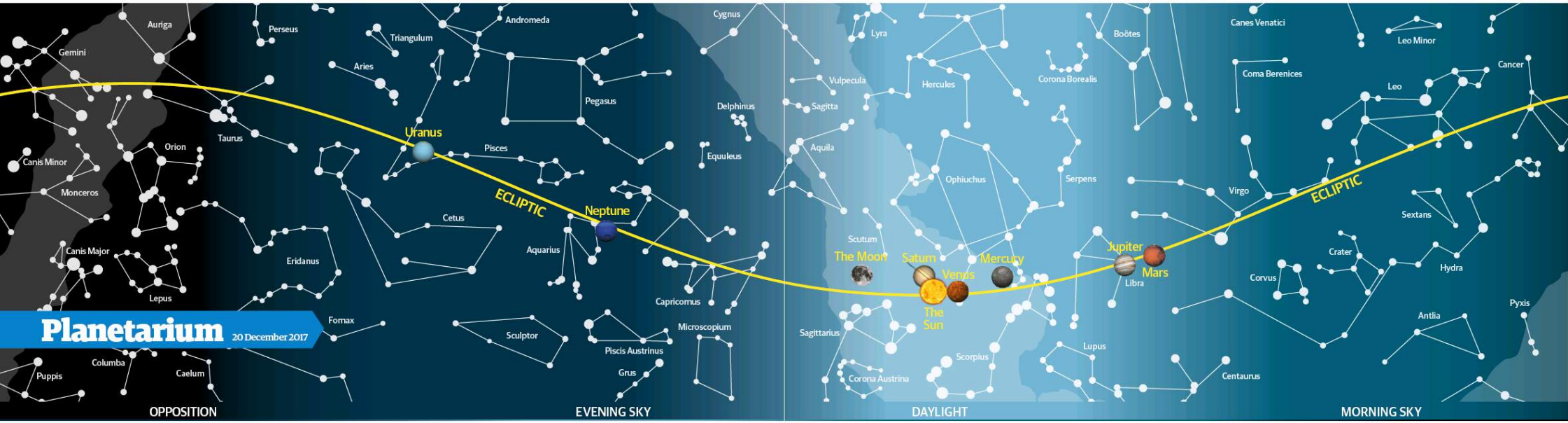
Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

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.



Planetarium 20 December 2017

Moon calendar

* The Moon does not pass meridian on 2 January

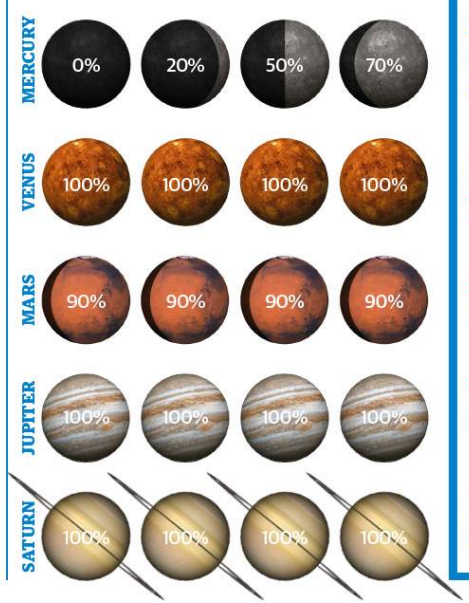
7 DEC 82.9% ▼11:10 ▲20:35	8 DEC 73.0% ▼11:48 ▲21:51	9 DEC 62.1% ▼12:18 ▲23:05	10 DEC LQ 50.9% ▼12:45 ▲--:--			
11 DEC 40.1% ▲00:17 ▼13:08	12 DEC 30.1% ▲01:26 ▼13:31	13 DEC 21.1% ▲02:34 ▼13:53	14 DEC 13.5% ▲03:41 ▼14:17	15 DEC 7.5% ▲04:46 ▼14:43	16 DEC 3.2% ▲05:49 ▼15:13	17 DEC 0.7% ▲06:50 ▼15:47
18 DEC NM 0.2% ▲07:46 ▼16:28	19 DEC 1.5% ▲08:37 ▼17:14	20 DEC 4.7% ▲09:22 ▼18:07	21 DEC 9.6% ▲10:01 ▼19:05	22 DEC 16.2% ▲10:35 ▼20:07	23 DEC 24.1% ▲11:03 ▼21:11	24 DEC 33.3% ▲11:29 ▼22:18
25 DEC 43.4% ▲11:53 ▼23:27	26 DEC FQ 54.1% ▲12:16 ▼--:--	27 DEC 65.0% ▼00:38 ▲12:39	28 DEC 75.5% ▼01:51 ▲13:05	29 DEC 85.0% ▼03:07 ▲13:34	30 DEC 92.7% ▼04:26 ▲14:10	31 DEC 97.9% ▼05:45 ▲14:54
1 JAN 99.9% ▼06:59 ▲15:48	2 JAN FM* ▼08:05 ▲16:54	3 JAN 98.6% ▼08:59 ▲18:08	4 JAN 94.2% ▼09:43 ▲19:26			

% 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

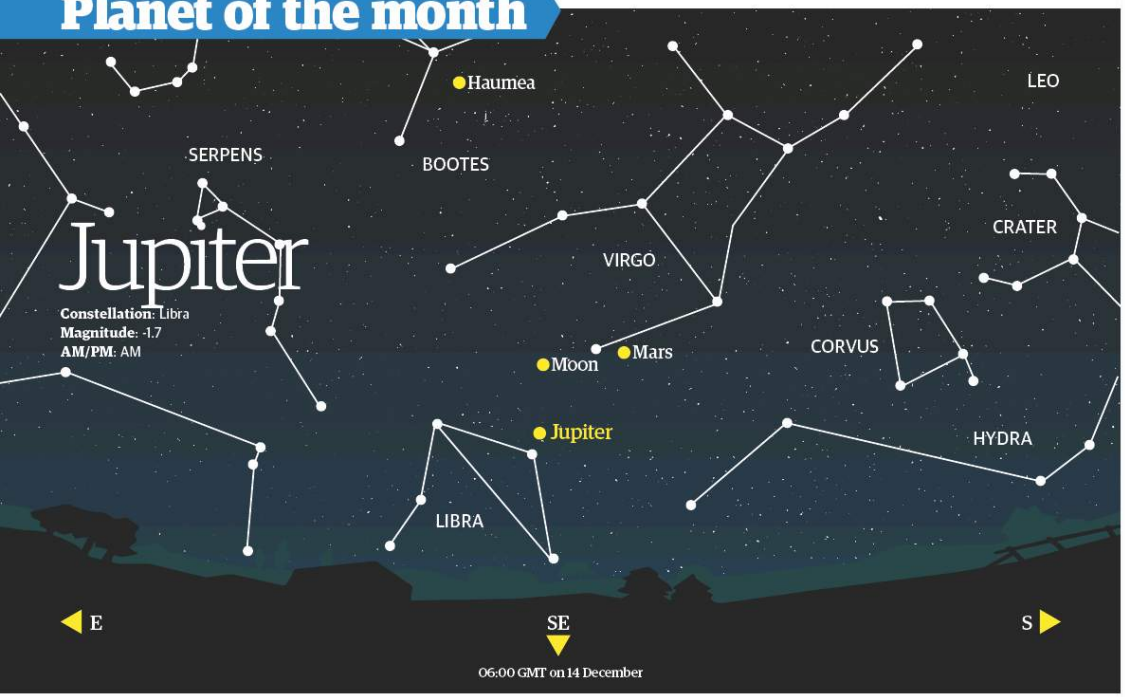
All rise and set times are given in GMT

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	7 Dec	17h 50m 32s	-23° 40' 45"	Sagittarius	1.5	09:01	12:55
	13 Dec	17h 21m 41s	-21° 26' 24"	Ophiuchus	5.9	07:54	16:11
	20 Dec	16h 50m 13s	-19° 30' 26"	Ophiuchus	1.1	06:43	15:24
	27 Dec	16h 51m 21s	-19° 50' 47"	Ophiuchus	-0.2	06:18	14:56
	3 Jan	17h 15m 56s	-21° 19' 35"	Ophiuchus	-0.4	06:25	14:43
VENUS	7 Dec	16h 20m 19s	-20° 56' 22"	Scorpius	-3.9	07:13	15:36
	13 Dec	16h 52m 19s	-22° 14' 36"	Ophiuchus	-3.9	07:30	15:36
	20 Dec	17h 30m 18s	-23° 15' 42"	Ophiuchus	-3.9	07:47	15:40
	27 Dec	18h 08m 43s	-23° 42' 02"	Sagittarius	-3.9	08:00	15:48
	3 Jan	18h 47m 11s	-23° 32' 29"	Sagittarius	-3.9	08:10	16:00
MARS	7 Dec	13h 46m 31s	-09°53' 43"	Virgo	1.7	03:37	14:05
	13 Dec	14h 00m 51s	-11° 14' 16"	Virgo	1.6	03:35	13:49
	20 Dec	14h 17m 42s	-12° 44' 43"	Virgo	1.6	03:32	13:30
	27 Dec	14h 34m 43s	-14° 10' 52"	Libra	1.5	03:29	13:12
	3 Jan	14h 51m 54s	-15° 32' 13"	Libra	1.5	03:26	12:54
JUPITER	7 Dec	14h 46m 42s	-14° 28' 36"	Libra	-1.7	04:55	14:34
	13 Dec	14h 44m 23s	-14° 49' 46"	Libra	-1.7	04:38	14:13
	20 Dec	14h 49m 39s	-15° 13' 03"	Libra	-1.8	04:17	13:49
	27 Dec	14h 54m 42s	-15° 34' 39"	Libra	-1.8	03:57	13:24
	3 Jan	14h 59m 29s	-15° 54' 29"	Libra	-1.8	03:36	13:00
SATURN	7 Dec	17h 52m 15s	-22° 29' 59"	Sagittarius	0.5	08:55	16:58
	13 Dec	17h 55m 17s	-22° 30' 55"	Sagittarius	0.5	08:34	16:37
	20 Dec	17h 58m 51s	-22° 31' 41"	Sagittarius	0.4	08:10	16:13
	27 Dec	18h 02m 26s	-22° 32' 04"	Sagittarius	0.5	07:46	15:49
	3 Jan	18h 05m 59s	-22° 32' 05"	Sagittarius	0.5	07:22	15:25

This month's planets

The king of the Solar System reigns supreme again in the early hours, while the Red Planet serves as an easy target for astronomers

Planet of the month



As long as you don't mind getting up early or staying up late, this is a great month for you if you're a Jupiter observer. The largest planet in our Solar System – so huge it could contain a thousand Earths with room to spare – rises well before the Sun and dominates the pre-dawn sky. It will be shining very brightly in the south east, much brighter than anything else in that part of the heavens.

From a location that's truly unaffected by light pollution, it will look like a distant blue-white lantern, and even if you're looking at the sky from your garden in a light-polluted town or city it is so bright you simply won't be able to miss it.

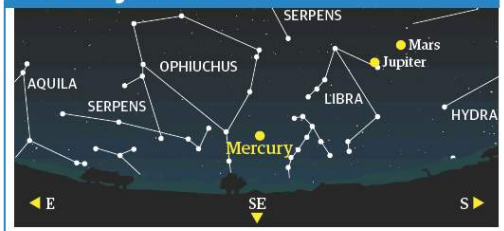
Jupiter has been visited by quite a few space probes now. The early Pioneers, and then the Voyagers, flew past the planet without going into orbit, but as they swept past they took hundreds of photographs, which gave us our first truly detailed views of its clouds and many of its moons. The more advanced Galileo and Cassini missions followed, each of those unmanned probes returning even more detailed views of the Jovian system, which many astronomers think of as a miniature Solar System in its own right, with Jupiter taking the place of a star.

Now the Juno probe is orbiting Jupiter, and although its polar orbit does not send it swooping past any of the gas giant's extended family of 64 moons, it is sending back stunningly detailed views of the planet's churning, curdled clouds as it flies over its poles. You can view those images for yourself every day, for free, on the Juno mission website.

All through this month, the planetary king will be close to Mars in the sky. As this month progresses the distance between the pair will decrease until they are less than six degrees – 12 Moon widths – apart on Christmas Day morning, and only two and a half degrees, or five Moon widths apart, at dawn on New Year's Day. If you go for an early morning walk on Boxing Day, hoping to burn off some of your Christmas dinner's calories, you'll see the two planets shining just five degrees apart. You won't need binoculars or a telescope to see the close approach either - it will be clearly visible to the naked eye.

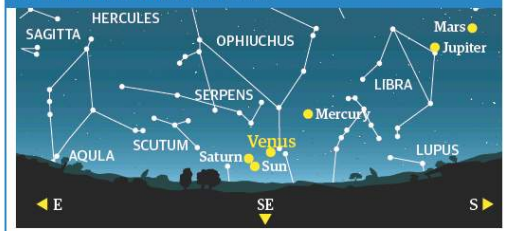
This month Jupiter also has a fascinating close encounter with the Moon, which will be both fun to watch and great to photograph. If your sky is clear on the morning of 14 December, look for the waning crescent Moon shining to Jupiter's upper right in the hours before dawn. Roughly 20 hours later, the Moon will have moved far enough along its orbit around the Earth, placing it to Jupiter's lower left.

Mercury 07:30 GMT on 23 December



Constellation: Sagittarius, Ophiuchus
Magnitude: 0.5
AM/PM: AM
This will be what can best be described as a challenging month for would-be Mercury observers. Best to wait until the closing days of the month, the morning sky will still be bright, but at magnitude 0.5 Mercury should be visible with the naked eye. Best chance to see it is around 7am on 23 December, at its furthest elongation.

Venus 08:30 GMT on 20 December

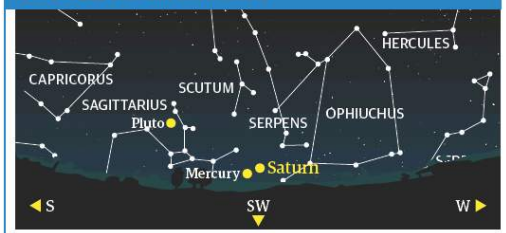


Constellation: Scorpius
Magnitude: -3.9
AM/PM: AM
At the start of December Venus will be very low in the southeast before dawn, rising barely 45 minutes before the Sun. Even though it will be shining at almost magnitude -4 it will be extremely hard to see. Venus will be lost in the Sun's glare from around 20 December, and will remain out of view for the rest of this period.

Mars 06:30 GMT on 13 December

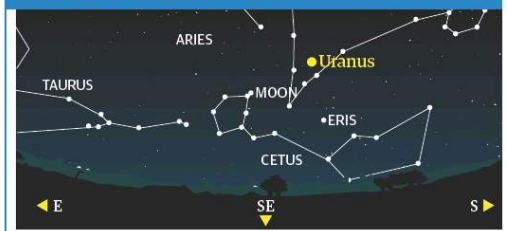
Constellation: Virgo into Libra
Magnitude: 1.6
AM/PM: AM
Shining at a magnitude of 1.6 – brighter than the stars of Orion's Belt, or the Big Dipper – Mars is an easy naked-eye object this month. Through this observing period Mars will rise around 3.40am, and it climbs into the south-eastern sky looking like an orange-red 'star' to the upper right of much brighter Jupiter. Before dawn on 13 December the waning crescent Moon will be above and to the right of the Red Planet. The next morning the Moon, now a very slender crescent, will glow directly to the planet's left. On the morning of the 15th, the thin crescent Moon will lie to the lower left of Mars, close to Jupiter.

Saturn 16:30 GMT on 3 December



Constellation: Sagittarius
Magnitude: 0.5
AM/PM: PM
This must be the worst month for trying to observe Saturn for a long time. At the start of December it might be visible briefly after sunset, but as the short, chilly days pass Saturn drops lower and drifts closer to the Sun, until it is lost from view. We'll have to wait until the spring to see the beautiful ringed planet again properly.

Uranus 17:30 GMT on 28 December



Constellation: Pisces
Magnitude: 5.7
AM/PM: PM
Out of all the planets on view this month, Uranus is above the horizon for the longest. At magnitude 5.7, the seventh planet from the Sun can be spotted as a very faint, slightly greenish 'star' inside the 'V' of the constellation Pisces. The Moon approaches and passes Uranus between 25 and 28 December.

Top tip!

To find Eddington crater, use Oceanus Procellarum as your guide. The impact is a bay within this lunar mare, with the more prominent crater Seleucus resting east-southeast of it.

Moon tour

Eddington crater

Challenge yourself this month by locating one of the trickiest impacts on the lunar surface

Usually the lunar features we profile here are very easy to find, if not with the naked eye then at least through a pair of binoculars or a small telescope. They are large, bright craters, wide, dark seas or towering sunlit mountain ranges. This month's target is going to provide you with much more of a challenge: it is small, tucked away almost on the Moon's limb and so tricky to spot you probably won't find it the first time you look...

Eddington crater is named in honour of British astronomer Sir Arthur Eddington, one of the first astronomers to figure out the nuclear processes that take place in the hearts of stars. Born in the picturesque Lake District town of Kendal, Eddington was a contemporary of Albert Einstein, with the great physicist calling Eddington a "genius". The author of many popular astronomy books, and a regular radio broadcaster, Eddington spent a lot of time doing what we refer to now as outreach – it could be said that he was the 1920s and 1930s version of Professor Brian Cox.

He is perhaps best known for travelling to the island of Principe, off the coast of Africa, in May 1919 to observe a total solar eclipse. During totality, Eddington observed stars which popped into view around the eclipsed Sun. By measuring how much their positions appeared to have shifted as their light was bent around our star, Eddington helped prove Einstein's famous General Theory of Relativity to be accurate.

Eddington crater is an impressive 125-kilometres (77-miles) wide, and over a kilometre deep. If it was near the middle of the Moon's disc, it would be very easy to see, appearing larger than 'impact celebrities' Copernicus and almost as large as Ptolemaeus. However, because it is very close to the lunar limb as seen from Earth, it is greatly foreshortened. It is also affected badly by libration, the rocking backwards and forwards of the Moon as it orbits the Earth: sometimes it is pushed towards us, and appears larger, other times it is pulled backwards and shrinks in size.

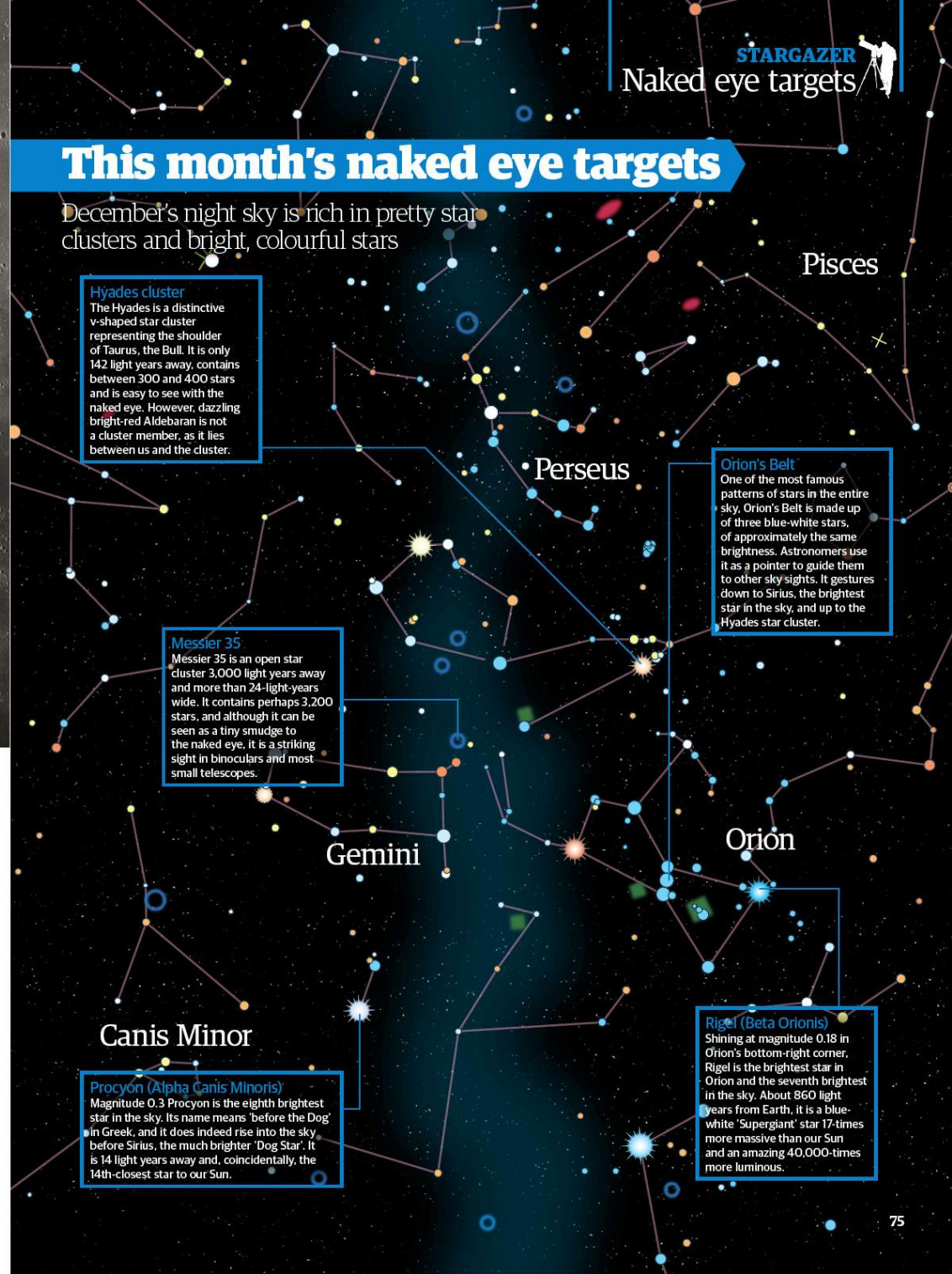
Whenever you look for Eddington, you'll see it looks more like an incomplete ring than a full circle, like most craters do. This is because it was flooded by a tsunami of molten lava many millennia ago. As the tidal wave rolled up Eddington's southern rim and spilled down into it. This flooded the crater, burying its southern walls and any central mountain peak it might once have had, leaving behind a horseshoe-shaped remnant with a flat, dark floor. Only a handful of small craters now pock that dark floor, the largest of which is Eddington P, a mere 12-kilometres (7.5-miles) across.

To see Eddington this month you will almost certainly need a telescope, as only really powerful binoculars will spot it. Through a telescope's eyepiece, Eddington will look like a vertically stretched, grey-white horseshoe against the darker lunar surface, very close to the Moon's curved limb. Eddington is not far from the much brighter and much more obvious rayed crater Aristarchus.

Being so close to the western limb, Eddington can only be seen when the Moon is at, or past, full. At the start of December, it is fully illuminated as the Moon rises in the evening sky. As the month progresses and a waning lunar phase slips into the morning sky, the terminator – the line between night and day – will sweep relentlessly towards the crater, covering it on the morning of the 16 December. The impact will then remain unobservable until New Year's Eve, when it will be bathed in the Sun's rays once more.

This month's naked eye targets

December's night sky is rich in pretty star clusters and bright, colourful stars



Hyades cluster

The Hyades is a distinctive v-shaped star cluster representing the shoulder of Taurus, the Bull. It is only 142 light years away, contains between 300 and 400 stars and is easy to see with the naked eye. However, dazzling bright-red Aldebaran is not a cluster member, as it lies between us and the cluster.

Orion's Belt

One of the most famous patterns of stars in the entire sky, Orion's Belt is made up of three blue-white stars, of approximately the same brightness. Astronomers use it as a pointer to guide them to other sky sights. It gestures down to Sirius, the brightest star in the sky, and up to the Hyades star cluster.

Messier 35

Messier 35 is an open star cluster 3,000 light years away and more than 24-light-years wide. It contains perhaps 3,200 stars, and although it can be seen as a tiny smudge to the naked eye, it is a striking sight in binoculars and most small telescopes.

Procyon (Alpha Canis Minoris)

Magnitude 0.3 Procyon is the eighth brightest star in the sky. Its name means 'before the Dog' in Greek, and it does indeed rise into the sky before Sirius, the much brighter 'Dog Star'. It is 14 light years away and, coincidentally, the 14th-closest star to our Sun.

Rigel (Beta Orionis)

Shining at magnitude 0.18 in Orion's bottom-right corner, Rigel is the brightest star in Orion and the seventh brightest in the sky. About 860 light years from Earth, it is a blue-white 'Supergiant' star 17-times more massive than our Sun and an amazing 40,000-times more luminous.

18 SPACE APPS YOU'VE GOT TO DOWNLOAD

From planetariums to telescope control, be prepared for all things space and astronomy-related - simply from the touch of a button

Written by Nick Howes

Apps on our mobile devices have transformed the way we work and live. From opening doors in our cars, to ordering shopping from our supermarket or shops, the ability to access the entire internet with a computer, several-million-times more powerful than the one that sent humans to the Moon, residing in your pocket has been a revelation over the past decade or so.

For astronomers, the 'giant leap' this has enabled means that you no longer have to lug out cumbersome star maps the size of a broadsheet. Learning your way around the sky using augmented reality makes astronomy - especially for younger people - more exciting than ever. Some may argue that 'traditional' methods are still the best, and that may be true to become a real expert, but the helping-hand apps which can give you a head start in your observing are here to stay, and used by millions of people - even those with only a casual interest in the sky. Now, with several low-cost virtual reality headsets in many high-street stores that you can easily clip your phone into, the options to observe and identify millions of objects have never been better.

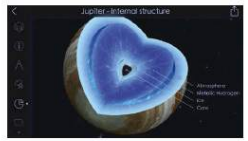
Apps for astronomy though, are not just confined to planetariums in your pocket. Over the past few years, apps have enabled remote control of telescopes, quite advanced scientific analysis and a whole lot more. Here, we dive into just a few of the ones we think are the must-have apps for your Android or iOS device.

Planetarium Apps

SkyView

Operating System: Android/iOS
Best for: Augmented reality views of the night sky and satellites flying over
Level of astronomer: Beginner and upwards
Cost: Free/£1.23 for the upgraded 'Explore the Universe' version

This free application really packs a punch when it comes to touring the night sky. With a huge integrated database of all the popular objects, it has a night-vision mode to preserve your dark adaption and a time-travel function to allow you to jump forwards and backwards, planning your observations for the whole year. The star of this show is its augmented reality feature, which allows you to point your camera at the sky and let it overlay (once it knows your position via GPS) detailed information on the objects you're looking at, as well as constellation overlays and beautifully rendered graphics of objects. Zoom in and out to get even more information. This is a great way to introduce young children to the delights of the night sky.



Star Walk - Sky View: Explore the Stars

Operating System: Android/iOS
Best for: Beautiful graphics, and engaging young people in the night sky
Level of astronomer: Beginner and upwards
Cost: £2.29 Android/£4.99 iOS/£1.89 Windows Phone

Augmented reality comes back with this multi-platform app. The level of detail in some of the rendered images of planets and the comprehensive look at our Solar System's objects in general is a delight. What makes this app stand out is the rendered graphics of the planets. It enables kids and adults alike to view details that their telescope may never show them, in a way that is really engaging. Not only does it show the planet you may be interested in's surface, but it adds real scientific data and understanding to how the planet works and was formed. It asks questions and then presents the answers in a way that educates and informs, without being too technical or scary for younger audiences.

Stellarium Mobile Sky Map

Operating System: Android/iOS/Windows Phone
Best for: Comprehensive database of objects, and one of the original and best planetarium apps
Level of astronomer: Beginner and upwards
Cost: £2.19 Android/£2.99 iOS/£1.49 Windows Phone

A favourite among many astronomers and outreach observatories, this app, which is also available on PC and Mac as well as Linux machines, has one of the best databases of objects of any planetarium. With plug-ins and upgrades galore, its 600,000+ object database will teach you more about night-sky objects than you could probably ever want to know. With in-app purchasable updates, you can add additional data for comets and much more. The photo-realistic views really do help make this a delight to work with.

As with most planetarium apps, it has a night-vision mode, overlays of constellations - including some beautifully created graphics depicting different star lores and cultural influences, satellite tracking so you can observe Hubble or the ISS flying over (plus thousands more) and as with others, it uses your mobile device accelerometers and GPS to track your movements if you wish.

SkEye Pro

Operating System: Android
Best for: Vast NGC and star map database, comet information and virtual DSC mode
Level of astronomer: Advanced
Cost: £4.69

A personal favourite app of the author, having used it extensively when taking tourists on stargazing holidays in Oman and Tanzania. This brilliant piece of software has a very detailed list of stars/objects and information, as well as an extensive and updateable TLE and comet database. But, the killer feature with this is the virtual DSC (Digital Setting Circles). Strapping your phone or tablet to a telescope and using the object locater to guide you to the thing you wish to see turns any standard non-GoTo scope into something a lot more powerful. It's not as accurate as precision GoTo systems, but with a wide-field eyepiece in, on a big Dobsonian, it's brilliant and more than accurate enough.

Planetarium VR

Operating System: Android
Best for: Use with VR headsets
Level of astronomer: Beginner
Cost: Free

While many apps support augmented reality modes and overlays, Planetarium VR takes this a step further, with full 3D support for low-cost VR headsets. A relatively limited object database compared to others does not detract from the fun. They have also added standard 'swipe' mode, but this app is really at its best when used with a VR headset. Other apps are adding this functionality, like Star Chart VR and Star Tracker VR, but this one is just a whole heap of fun.

Lunar/Planetary Observation and Exploration Apps

Moon Atlas 3D

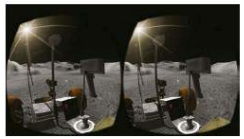
Operating System: Android
Best for: Detailed lunar observations
Level of astronomer: Beginner to advanced
Cost: Free

The late, great Sir Patrick Moore spent a lifetime learning about and mapping the Moon. The level of detail he went to was so good, it helped the Apollo mission planners. We can only imagine how much an app like this would have enthralled him to see, with a high-resolution lunar surface map, over 8,000 craters labelled and detailed, all of the Apollo landing sites marked as well as the lunar phase and shadows rendered in stunning detail. Add to this telescope mode, and you have the perfect companion for lunar viewers.

Apollo 15 Moon Landing VR

Operating System: Android
Best for: Fun way to explore the Moon like the Apollo astronauts did
Level of astronomer: Beginner
Cost: Free

Most of us would love to be an astronaut, and no greater achievement in human spaceflight occurred than in the late 1960s and early 1970s with the Apollo missions. The first Apollo mission to take a rover, and one of the most important scientifically, was Apollo 15. This wonderful app, which is almost like a game in how it runs, takes you on that journey from launch to touchdown, and then, using Google cardboard or any low-cost 3D headset, puts you in the shoes and driving seat of Dave Scott and Jim Irwin as they explore the Hadley rille landing site. Immense fun if nothing else.



Lunar Map HD

Operating System: Android
Best for: Geological survey data of the lunar surface
Level of astronomer: Intermediate to advanced
Cost: £1.39

This is a true hardcore lunar fan app that will take you places you'd never imagined. Using data from the United States Geological Survey to give you a true three-dimensional relief map of the lunar surface, augmented with the Lunar Reconnaissance Orbiters wide-angle camera data, this app - with close to 9,000 craters and lunar surface features mapped - goes above and beyond what any other lunar app does. It has colour-coded topographical maps for those who wish to understand the true shape of the lunar surface, combined with links to online databases for yet more information. It comes in both a pro and lite version, but for the few pounds that the HD version costs, it's well worth every penny.

Solar System Explorer 3D

Operating System: Android
Best for: Pretending you're Voyager 2
Level of astronomer: Beginner
Cost: Free

The Voyager grand tour took robotic exploration to locations no other spacecraft in history has since matched. But, as it's now almost 30 years since the last flyby of Neptune, we're left only with memories and Hubble images. This app takes you not only to the vast gas outer planets visited by Voyager, but inwards towards Venus and Mercury and across the asteroid belt, too. Data for the high-resolution images comes from a plethora of NASA missions, and is augmented by ground-based data where parts are perhaps missing. You can also swing to the moons of Jupiter, Saturn and beyond, as well as Ceres and Vesta. The music can be jarring, but can easily be turned off if it becomes too much of a distraction. One thing, it's not been updated for a while, so Pluto data is not from New Horizons.

Mars Globe

Operating System: iOS
Best for: Superb app for fans of the Red Planet
Level of astronomer: Beginner to advanced
Cost: £0.99

Until we get boots on the ground of the Red Planet, humankind will rely totally on the work of robotic landers, rovers and orbiters to send us detailed images of what it may be like to visit Mars. This app for iOS devices allows you to have a fly-through tour of the Martian surface, using very high-resolution orbiter data overlaid with topographic data to give it accurate and outstanding relief feature visualisations. With over 1,500 surface features annotated and linked, this is a real gem of an app, taking you to Mars in a way that most likely won't be possible for at least a decade or more.

Telesccope interface and control apps

Sky Safari 5

Operating System: iOS/Android.
Best for: Scope control and planetarium
Level of astronomer: Beginner to advanced
Cost: £0.89 (Basic - has no scope control) / £6.49 (Plus) / £17.99 Pro (Android/iOS)

With one of the largest star databases of any app (over 25 million stars and 740,000 galaxies), this will map down to magnitude 18 in the pro version. It integrates support for DSS image downlink, has the Abell and Hickson galaxy cluster catalogues as well as the full NGC and Messier catalogues, integrated DSC support with multi-star alignment and, best of all, full telescope control for Meade, Celestron, Skywatcher and more, via interfaces that work over SkyFi and SkyWire interfaces (which they also sell). A real one stop shop for pretty much everything.

Satellite Observation Apps

ISS HD Live: View Earth Live

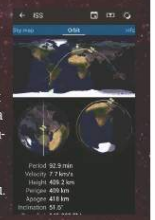
Operating System: iOS/Android
Best for: Seeing the Space Station from the ground up and looking down from Earth orbit
Level of astronomer: Beginner to advanced
Cost: Free

This app gives you a handy heads up as to when the ISS will be passing overhead. It also links in to the live HD cameras which are pointing down at us from the Station. Being able to see aurora displays from orbit, the lights of major cities and much more is a real thrill, and this app links up all the components better than most.

Heavens Above

Operating System: iOS/Android
Best for: Satellite spotting and viewing Earth from satellite feeds
Level of astronomer: Beginner to advanced
Cost: Free

Containing data for thousands of satellites, you can look out for iridium flares and uplink and downlink information for radio satellites to enable radio ham operators to listen in or, in the case of the ISS, sometimes even make voice calls to and from the station. Also a great way to impress friends when you say "Look up now" and a bright Iridium-flare flash occurs in the sky above you.



General Astronomy Applications

NASA Visualization Explorer

Operating System: iOS/Android
Best for: Getting the latest information at your fingertips on the activities of the world's leading space agency
Level of astronomer: Beginner and up
Cost: Free

What could be better than an app that delivers all the latest cutting-edge research from the world's foremost space agency? The visualization explorer is updated every day with news, information, science facts, videos and much more. This app will keep you on top of the latest work being conducted at all of the NASA centres, and with the recent upturn in spaceflight activities moving towards the hopeful 2019 launch of both the JWST and the Orion/SLS, it'll be one space-based app you'll not wish to be without.

Light Pollution Map – Dark Sky & Astronomy Tools

Operating System: iOS /Android
Best for: Finding the perfect observing or imaging location
Level of astronomer: Beginner to advanced
Cost: Free (Pro version available at $9.99)

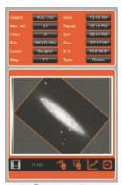
With light pollution an ever-increasing problem for many amateur and professional astronomers, an app that gives you a handy guide to where the best locations are to avoid the sodium curse is a godsend. This app not only manages that well, but gives you data on the aurora, meteor showers, eclipse alerts, Moon phases and more. It's like a pocket Swiss army knife for astro imagers and observers alike.

Astro Imaging and Support Apps

Telescope Flashlight

Operating System: Android
Best for: Helping you find your equipment in the dark
Level of astronomer: Beginner to advanced
Cost: Free

The number of times that every astronomer has wished they had a red-light torch and found that the batteries were dead, or that they'd lost or left it somewhere is huge. Having a phone or tablet in your pocket that can light up that dark field and not destroy your night vision would be ideal. The only issue with this is that if you have to turn your phone on first to launch the app, the glaring-white screen may have killed it anyway.



Telescope Calc

Operating System: Android
Best for: Helping astronomers work out parameters for their scopes and eyepieces
Level of astronomer: Beginner to advanced
Cost: Free

Again, one of those handy little apps that does a lot and very simply. This app is one pretty much every astronomer could use, with options to set up optimal eyepiece and telescope combinations for specific observations. If you want to know the magnification or field of view your eyepiece will deliver in the scope you add it to, this is a very handy app to have.

Field of View Calculator

Operating System: iOS
Best for: Helping CCD imagers (especially those with Atik Cameras) work out their imaging options
Level of astronomer: Intermediate to advanced
Cost: Free

Atik are renowned for making superb cameras and intuitive imaging software. This is a nice, free app for iOS devices that calculates the field of view for many popular objects relative to your telescope, its optical configuration and the CCD you are using. Knowing the spec of the CCD, this app could be used to support many other cameras setups too.

©iStock/ Alamy Stock Photo

How to...

Make the most of the Geminid meteor shower

Don't miss one of the greatest spectacles of the year – provided you have fair observing conditions, here's how to ensure optimum viewing

You'll need:

- ✔ Warm clothing
- ✔ Red torch
- ✔ Notebook
- ✔ Compass

Shooting stars are, without a doubt, some of the most spectacular events we can see in the night sky. Where on any given night we might see an occasional flash of light dart across the heavens, there are several well-known 'showers' of meteors that occur on specific nights every year. The Geminids are one of these, and can often produce bright, fast-moving streaks of light of up to 100 or so meteors an hour on a favourable night. You'll need favourable conditions in order to witness the event - you'll need to make sure there are no sources of artificial light around that will wash out the fainter meteors, and you will need to observe on a Moonless night. This year, our lunar companion will be out of sight, so the chances of seeing meteors greatly increases.

Asteroid 3200 Phaethon is the source of the Geminids, which leaves a stream of dust as it orbits the Sun. Every year in December, the Earth passes through this dust tail and some of the particles enter our atmosphere, burning up as they fall towards Earth. From our perspective, they appear to come from one point in the sky - this is known as the radiant, and its position varies from shower to shower. Unsurpisingly, the radiant for the Geminids appears to be in the constellation of Gemini, and is close to bright star Castor in that star pattern.

There is no best place to look for the meteors, although, in fact, looking towards the radiant is probably not the best place, as the 'shooting stars' don't start out very bright at this point. Just look up and around and you will almost certainly see some Geminids if you are patient, ensuring that your eyes are well adapted to the dark. Also, if you are staying outside for any length of time on a December night, be sure to wear warm clothes

Your best chance of catching the Geminids is after midnight and around 2.00am on the morning of the 14 December. You should also watch out for any meteors during the evening of the 13th and around these dates - you may be lucky and catch some strays around the peak!

"Your best chance of catching them is after midnight and around 2.00am"

Tips & tricks

Seek dark skies
Try to keep away from sources of artificial light. If you can, turn your back to any street or house lights.

Wrap up warm
Ensure you wrap up warm, especially late at night. Keeping your hands and feet warm will make observing much more comfortable.

Record your observations
Jot down the time, how bright you think the meteor was and its direction of travel. This will help you to be sure you saw a Geminid.

Use a red torch
Use a dim red torch to make your notes by, ensuring that you preserve your night vision.

Don't focus on the radiant
If you look around 30-degrees away from the radiant point in any direction, this will improve your chances of seeing meteors.

Spot over 100 meteors per hour this December!

Good preparation is key, so follow this guide to get the best out of the event...

Good preparation can make all the difference to having an enjoyable experience. Meteor showers, like everything else in nature, can spring surprises, both good and not as good. On a poor night observing the Geminids, you may see only a handful of shooting stars in an hour, but sometimes they can put on a real show - you won't know unless you get out there and look.

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

1 Keep an eye on the weather
Check the weather, as it is always an issue for any kind of observing, but don't be put off. Even if it's a little cloudy there will still be areas of the sky you can watch at times.

2 Wear warm clothes
Dress warmly. Several layers are good, and thick socks and gloves can make all the difference. Maybe even a blanket and a hot water bottle just to make sure you're toasty!

3 Observe for as long as you can
Stay out as long as you can. It can take 20 minutes to adapt to the dark, so be prepared to stay out at least this length of time. The longer you watch, the more meteors you are likely to see.

4 Use a compass to ensure you're looking in the right direction
Familiarise yourself with the compass points at your observing location. This will help when making notes.

5 Work out meteor brightness
If you see a Geminid, try to estimate how luminous it was. To help you, you should use bright stars for comparison - a star chart will assist with naming them.

6 Record the Geminids you see
Note down the time, direction of travel and brightness in your notebook. Be sure to use a red torch to preserve your night vision, or you might miss some fainter meteors.

Deep sky challenge

Tackle the great treasures of Orion

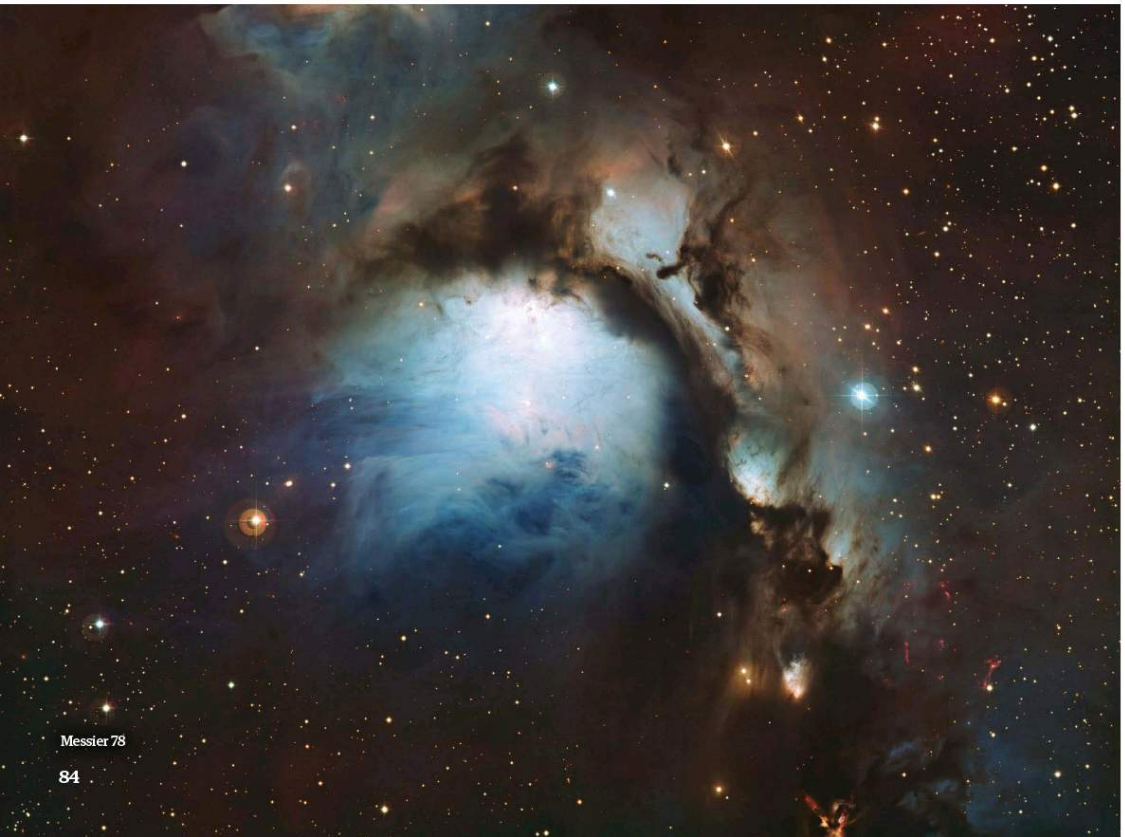
Turn your telescope to the Hunter this winter and you'll be rewarded with a splendid selection of deep-sky targets. Some are easy, but some a little harder to spot...

The constellation of Orion 'the Hunter' is littered with deep-sky objects to explore. There are star clusters and nebulae, and that's not including one of the most famous star-forming regions: the Orion Nebula (M42).

Orion is a treasure trove for those interested in seeking out challenges for eye and telescope alike. The Great Orion Nebula is easy to spot as one of the brightest nebulae, and is even discernible to the naked eye under even the most mediocre of observing conditions.

Nearby, another well-known nebula rests, which is a lot trickier to spot, and really needs a filter to help make it out: Barnard 33, dubbed the Horsehead Nebula for its equine silhouette and of which is created by pillars of gas and dust.

De Mairan's Nebula (Messier 43)



Messier 78

1 The Orion Nebula (M42)

Using your telescope or decent binoculars, look for the four bright stars at its heart - the Trapezium Cluster. Small telescopes at higher magnifications will reveal four of the cluster's brightest stars.

2 De Mairan's Nebula (Messier 43)

This nebula sits on top of the much larger Messier 42, and can be resolved using a medium-powered eyepiece. The object appears separated by a dark dust lane in the foreground, the nebula is bursting with a wealth of star formation.

3 Running Man Nebula (NGC 1977)

Also known as NGC 1977, the beautiful object is a combination of a reflection nebula and HII region - you will need a medium-sized telescope and filters to truly play up the layers of gas and dust.

4 Horsehead Nebula (Barnard 33)

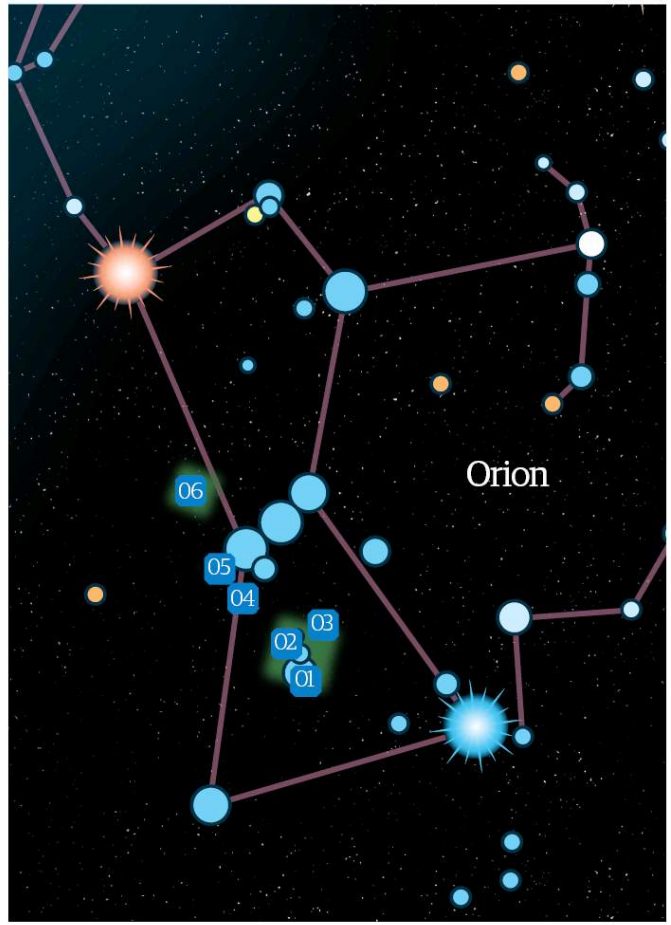
A difficult object to see visually due to its low contrast, the Horsehead Nebula requires a medium-to-large aperture telescope and a H-beta filter in order to pick out its structure. Imaging can bring out its pink glow, caused by the hydrogen gas.

5 Flame Nebula (NGC 2024)

NGC 2024 is also known quite fittingly as the Flame Nebula. Alnitak, the brightest star in Orion's Belt, shines ultraviolet light into the Flame Nebula to give it its stunning glow. Filters will help you to play up the object's true splendour.

6 Messier 78

There is a star embedded in this nebulosity which reflects its light and allows observers to make out the tenuous gas, even with a small telescope. Two stars - HD 38563A and HD 38563B - are responsible for making the cloud of dust.

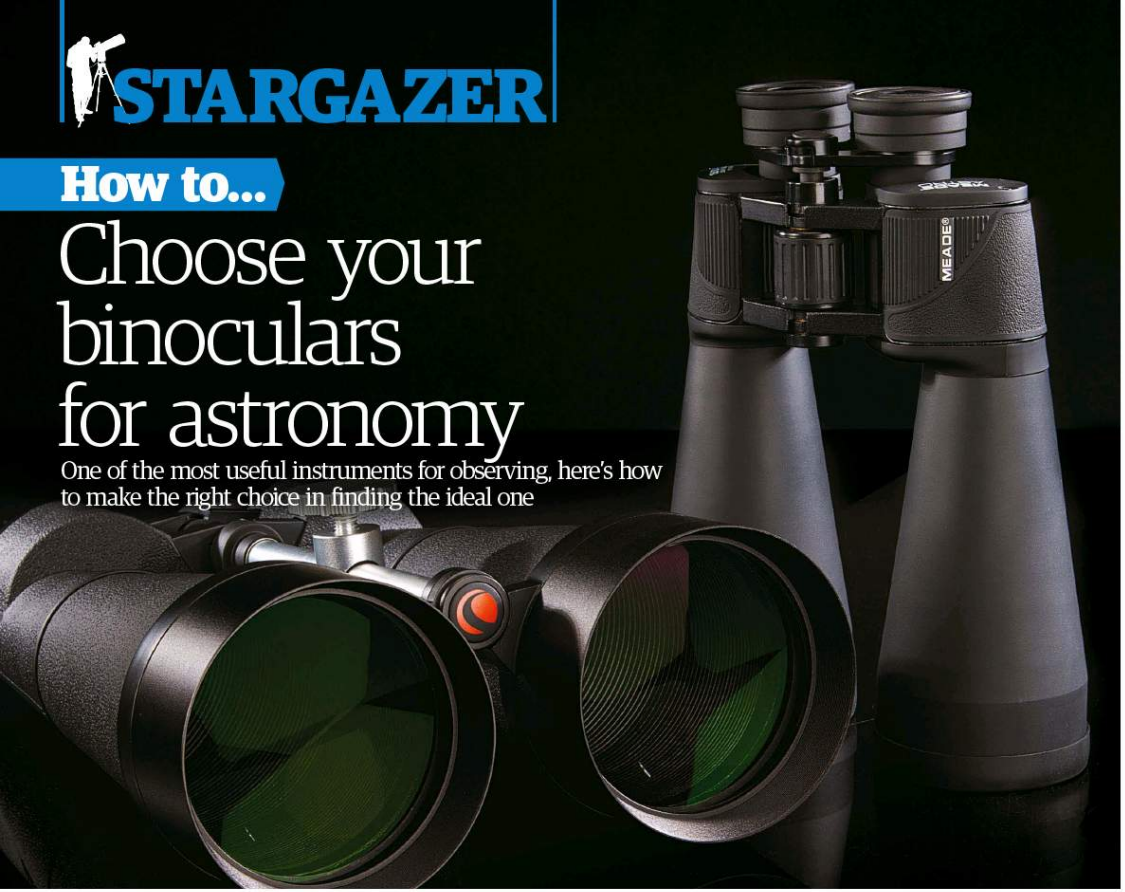


Running Man Nebula (NGC 1977)

How to...

Choose your binoculars for astronomy

One of the most useful instruments for observing, here's how to make the right choice in finding the ideal one



You'll need:

- ✔ Be aware of your budget
- ✔ Know what you're interested in viewing
- ✔ This guide!

Binoculars make great 'grab-and-go' instruments for the astronomer. Depending on the size and type, they can show you many craters on the Moon, the moons of Jupiter and the grandeur of the Milky Way. In fact, there are many deep-sky objects that look better through binoculars than through some telescopes!

When choosing binoculars for astronomy, the important parameter is the aperture - or the diameter of the front lens. For comfortable hand-holding you don't want them too big, so a good size is 50mm or thereabouts. Magnification is less important, but should be somewhere between 7x and 10x. These, combined, give the number you frequently see inscribed on binoculars, for example 10x50 is 10x magnification and 50mm aperture. The ratio between magnification and aperture provides the field of view, or how much area of sky you can actually see through them. With 10x50 instruments, it is usually around 5 degrees.

The magnification also affects the amount of light entering the pupil of your eye through something known as the 'exit pupil'. This can be seen as a circle of light at the eye lens if you hold the binoculars at arm's length in the daylight. Ideally, you want this exit pupil to match the diameter of the pupil of your own eye once it has become dark adapted. In older adults, this doesn't get much larger than about 5mm, although it can be as much as 7mm in youngsters. As you can see, 10x50s giving an exit pupil of 5mm are ideal. That is not to say that you shouldn't use 7x50 or any other similar specification though.

Optical coatings are important for good light transmission as well, so it's best go for binoculars which state that they are fully multi-coated. When you are looking at faint objects, as most things in the night sky are, you want as much of the light to reach your eyes as possible. If you wear spectacles, you will also need something called 'long-eye relief', which means that you won't have to remove your glasses in order to use them for your night-sky tours.

> "There are many deep-sky objects that look better through binoculars"

Tips & tricks

Consider the aperture
When choosing binoculars for astronomy, go for instruments, which are in the region of 7x50 or 10x50.

If you can, go for Porro prisms
All binoculars use prisms. 'Porro prism' binoculars are preferable to 'Roof prism' binoculars, but are not essential.

Avoid a fixed focus
Most binoculars use a centre wheel for focusing, along with an independent right-eye adjustment. This is better than fixed focus.

Choose multi-coated lenses
Go for fully multi-coated lenses, as this will give you better light transmission and less internal reflections.

Check the exit pupils in daylight
During the day, hold the binoculars at arm's length and you should see a perfect circle of light at the eye lens.

Ensuring you're ready to begin observing

Now you have got the right binoculars, are they set up properly?

Each side of the binocular needs to be aligned with the other, known as collimation, because if they are not, you will end up with a headache! Make sure that when you look through them with both eyes, you see just one perfectly circular field of view. If you feel that one eye is straining, or worse, you can see two images of the same object, either do not buy them, or take them to an expert for re-collimating.

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

1 Pay close attention to the specification
In order to work out how 'powerful' your binoculars are, look out for a magnification marker. These numbers are usually found on the barrels.

2 Multi-coated optics will provide better views
Multi-coated reflect more stray light, allowing 'good light' through the barrels for better observations of your night-sky targets.

3 Seek out the right prisms
Check to see if they are binoculars with 'Porro prisms', which are preferable due to their higher quality image, or 'Roof prisms'.

4 Make focuser adjustments
Check that the focus wheel in the centre is smooth in operation, and that there is a separate right eye adjustment to ensure comfortable viewing.

5 Check for good eye relief
If you wear glasses, see if you can see the full field of view without removing your spectacles. If you don't need to, you have good eye relief.

6 Ensure that you're fully collimated
Finally, check that you can see a single circular field with both eyes, and that there are no double images. Duplication means poor-quality optics!

The Northern Hemisphere

The December constellations swing into view, offering an impressive array of targets to enjoy in darker skies

If you're a fan of splitting double stars with your telescope, then head over to the constellation of Aries (the Ram), which makes its appearance this month, bounded by the star patterns of Taurus (the Bull), Pisces (the Fishes) and Cetus (the Whale). In particular, binary star systems Lambda Arietis, Epsilon Arietis and Mesarthim are splendid targets to resolve for astronomers with medium- to large-sized telescopes. Meanwhile, orange giants Hamal (the Head of the Ram) and Botein (Little Belly) can be picked out using nothing more than the naked eye.

Orion (the Hunter) is also prominent this month, featuring red supergiant Betelgeuse, De Mairan's Nebula (M43) and the Orion Nebula (M42).

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

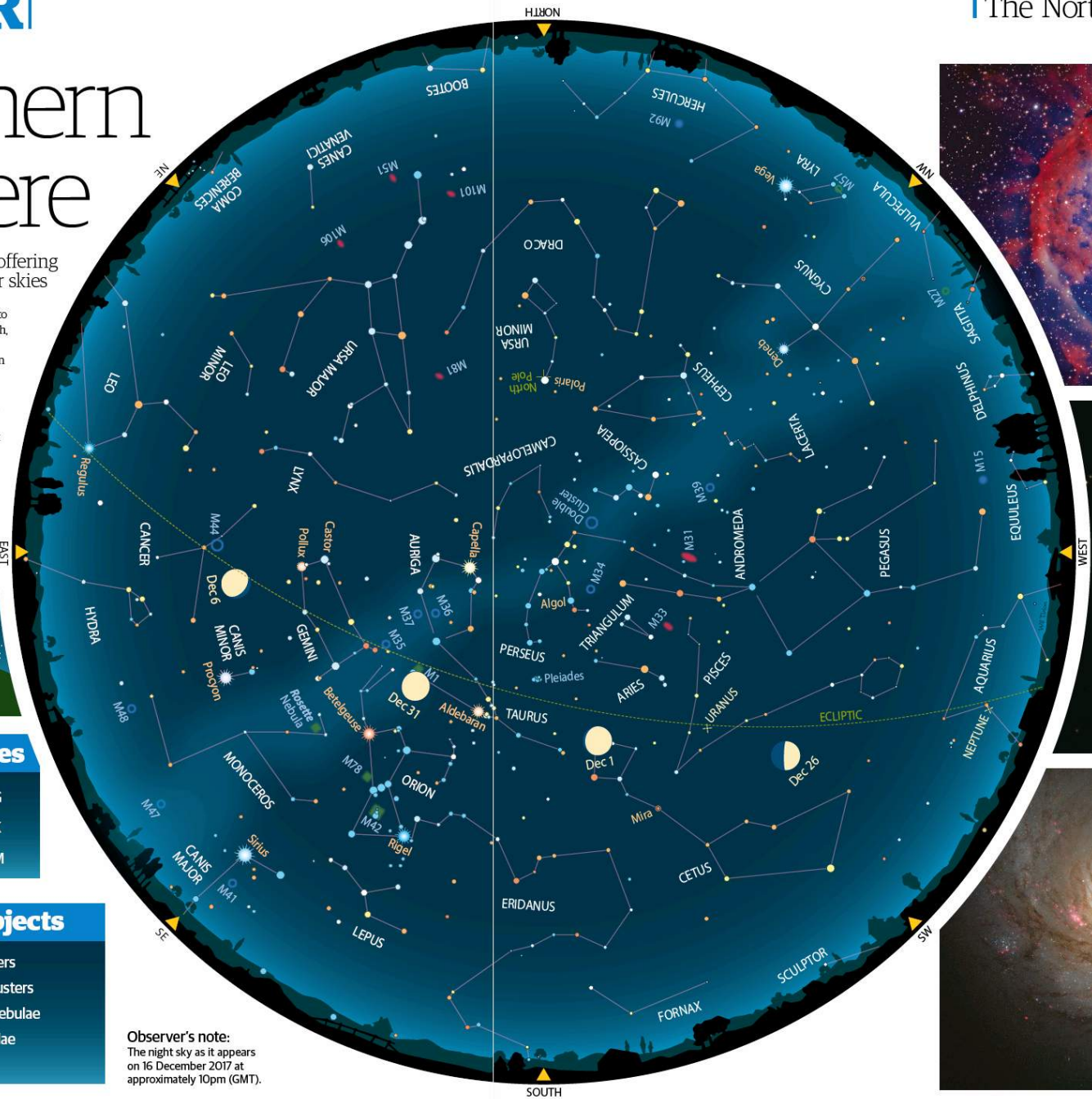
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

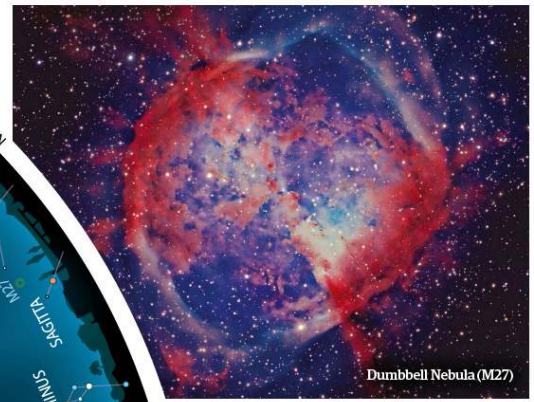
- O-B
- A
- F
- G
- K
- M

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 December 2017 at approximately 10pm (GMT).


Dumbbell Nebula (M27)


Zeta Lyrae


Messier 77

Astroshots *of the month*

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

Jeff Johnson

Las Cruces, New Mexico
Telescope: Takahashi TOA-130F

"I have a long love of astronomy and have observed the night sky for many years with binoculars and a telescope, from the age of ten. I first got involved in 'real' astrophotography in 1996, when I used a 35mm SLR (film) camera to take photos of Comet Hyakutake. I took a tripod out into the desert in Las Cruces and just experimented with exposures. Later, I bought a ten-inch Dobsonian for viewing, and within a week I was taking pictures through the eyepiece for fun. Within a few more weeks, I knew I wanted to get serious with astroimaging."

At the centre of the Eagle Nebula (Messier 16)

Caph (Beta Cassiopeiae) in constellation Cassiopeia

Jaspal Chadha

London, UK
Telescope: Takahashi 130

"I usually just focus on the star Caph (Beta Cassiopeiae) at the beginning of an imaging run, but I thought to actually image this giant star, which is the second brightest in the constellation Cassiopeia. This month, I also captured NGC 869 and NGC 884, a pair of open star clusters in Perseus, which can be picked out using a decent pair of binoculars. I decided to spend time on this double cluster as it fascinates me how two collections of stars appear to be close in a field of view, yet are actually light years apart!"

Double Cluster (NGC 869 and NGC 884) in Perseus

Rob Johnson

Liverpool, United Kingdom
Telescope: 14" Newtonian Reflector

"I have been interested in astronomy since I was seven years old, inspired by the first spaceflights and of course the Apollo program. Later on I became interested in photography, so it was natural to take up astrophotography. I enjoy imaging many different kinds of objects, from stunning deep-sky objects to 'nearby' Solar System bodies and I also dabble with spectroscopy. My favourite objects are galaxies and galaxy clusters, it's incredible to think of the number of planets there must be in one image, possibly harbouring life. Imaging from my light-polluted location has its challenges, but with the help of CCD cameras some great results can be achieved."

The pockmarked face of the Moon, with prominent lunar mare

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

NexStar Evolution 8 HD with StarSense

An impressive set up for observing and imaging, this Schmidt-Cassegrain will satisfy your astronomical needs

Telescope advice

Cost: £2600 ($3407.00)
From: David Hinds Ltd
Type: Schmidt-Cassegrain
Aperture: 8"
Focal length: 80"

Best for...

- Intermediate
- High budget
- Planetary viewing
- Lunar viewing
- Deep-sky objects
- Astrophotography

Celestron telescopes continue to evolve and improve, and they have done an amazing job of merging their highly-regarded Schmidt-Cassegrain telescopes with a computerised, single-fork mount for an easier and more enjoyable experience. Granted, it has quite a hefty price tag, however, it has everything an intermediate astronomer needs to navigate the celestial landscape and gaze upon some tantalising views, whilst also providing a very good platform for serious astrophotography.

Included in the package is a robust, stainless steel tripod, which supports the set up with ease. The single-fork arm mount is the pride of the package, as it can mechanically navigate the night sky with the touch of a button via two perpendicular movements (alt-azimuth mount) and powered by its long-lasting, rechargeable lithium-ion battery. In our opinion, the internal battery is an underappreciated aspect - it saves having to spend extra on a battery pack and an international AC adapter is also provided, so you can recharge it ready for your observing sessions.

Also built into the mount is its own Wi-Fi network that allows the user to connect, and control, the telescope via the Celestron SkyPortal app (available on both iPhone and Android). By making use of the most modern technologies available, navigating from planet to star to nebula can be done at your fingertips.

The icing on the cake is the 8-inch Schmidt-Cassegrain telescope, with improved EdgeHD optics for crisper, clearer sight of targets you wise to observe. There are also several important extras included in this package, most notably the latest StarSense technology, which features an attachable camera and hand control intended to deliver a painless AutoAlign process. There is also a StarPointer Pro finderscope, which employs a red dot technology with a surrounding ring that aids with pinpointing your desired object in the field of view with minimum fuss. The NexStar Evolution also comes with a 1.25-inch star diagonal and two 1.25-inch 12.5mm and 40mm Plössl eyepieces, allowing magnifications of 51x and 163x respectively.

This package includes two Plössl eyepieces, 12.5mm and 40mm

Before we headed out for a night of observing, the first thing we noted was the telescope's weight, which totals 18.5 kilograms (40.6 pounds). The set up will be tricky to transport for many, so it is important to take that into account before planning any stargazing trips beyond your very own backyard.

Upon arrival at our designated site for the night, the assembly of the telescope proved to be fairly straightforward - something that's welcomed by every astronomer. In less than 30 minutes, the telescope was up, running and ready for alignment. We decided to utilise the StarSense AutoAlign camera, as it was a clear night at our location in a dark-sky reserve. This was a new experience to us, but it was straightforward and didn't take longer than your average alignment. Be warned though, the technology will only work at its best under reasonably clear skies free of light pollution and with an array of stars at your disposal. Anything less and a message will pop up on the hand control that says 'Too Few Stars'.

Once we were set up and aligned, we couldn't wait to test the NextStar Evolution's mettle. Our smartphone connected to the telescope with ease, and, with the interactive interface also doubling as a planetarium app, choosing our targets was easier than ever. The first object on the observation checklist was the biggest, brightest and most obvious object visible to the naked eye - the Moon.

The finderscope is of incredibly high quality

"It has the capability of giving you a complete tour of the night sky"

Our lunar companion was a waxing gibbous at the time, with 85.9 per cent luminosity, and with the 40mm eyepiece attached, the Moon was delightful to look at. It was a crisp, bright and visually stimulating sight that fit perfectly within the field of view. Switching to the 12.5mm Plössl allowed us to take a closer look at the rugged lunar terrain. From the dark patches of the lunar mares, to the distinguishable craters of Tycho and Copernicus and the lunar terminator, the optics presented a crisp view with high clarity and resolution.

Moving away from the Moon, we explored some deep-sky treasures. Heading over to our winter favourite, Orion (the Hunter), we took the time to gaze upon stellar opposites, Rigel and Betelgeuse. The redness of the latter was easily recognisable, and the optical system seemed to have no major issues with chromatic or spherical aberration. Slewing to the opposite corner of Orion, we picked out the bluish-white hue of Rigel. Again, there was no interference or issues with the resolution of this brilliant, 0.12-magnitude supergiant.

Continuing our tour of the constellation, we tested the optical system on the more-diffuse Orion Nebula, also dubbed M42, which required reverting back to the 40mm eyepiece. Even with the star forming region's large size, the Plössl could accommodate the majority of the nebula. The central concentration of light was a magnificent sight and, when combined with the surrounding dust trails stopping the visible light in its path to Earth, there was an appreciated disparity.

As this mount is motorised, and is capable of tracking a celestial object as it moves across the sky, it's a must-try for some serious astrophotography. It is specified that the telescope can accommodate most cameras, especially larger format CCD and DSLR cameras. However, if you want to improve on this hobby, you should purchase the 'Wedge' for the NexStar Evolution, which enables long-exposure photography at a cost of £350.00 (approximately $463).

Overall, we're extremely impressed: this scope is easy to set up and, by taking advantage of all the latest technology and mechanical prowess, is capable of providing a complete night-sky tour. While it's an expensive piece of equipment, it's a sturdy, reliable and rechargeable instrument that comes with a 24-month warranty that's well worth the price!

The total weight of the telescope is 18.5kg (40.6 lbs)

The single-fork mount is motorised with built-in Wi-Fi and an internal battery

The StarSense AutoAlign promotes an uncomplicated alignment process

WIN!

CELESTRON SKYMASTER 25 X 100 BINOCULARS

Get the finest views a pair of binoculars has to offer with our latest prize

WORTH £379!

'Tis the season to win a pair of binoculars, and what a great pair to win! The Celestron SkyMaster 25x100 are the largest pair of binoculars in the SkyMaster series, and are capable of unlocking an incredible medley of astronomical and terrestrial sights.

Fitted with BAK-4 prisms and multi-coated optics, the optical system offers an incredibly crisp, magnified and high-quality view of a planets, nebulae, galaxies and star clusters with maximum image brightness even in low-light and long-range scenarios.

The Celestron SkyMaster binoculars may be a bit too heavy to hold for some – especially for long periods – but not to worry; a rigid tripod adapter is also included, allowing you to observe in comfort while still being able to navigate the night sky.

CELESTRON
DavidHinds

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

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Congratulations to Mark Viney, who is the winner of the Celestron Inspire 80AZ

In the shops

The latest books, apps, software, tech and accessories for space and astronomy fans alike

1 Book The Cambridge Photographic Atlas of Galaxies

Cost: £44.99 (approx $60.00) **From:** Cambridge University Press

Galaxies are everywhere across the universe, appearing in an impressive range of sizes and shapes, that illustrate the uniform to the quirkiest of galactic structures. It is the individuality from one structure to the next that drives us to fill in the gaps of our knowledge of galaxy formation and evolution and despite the ongoing puzzle, *The Cambridge Photographic Atlas of Galaxies* provides a wealth of information. This atlas explains all of the features of a galaxy in the finest detail, including their classification and a catalogue of viewable targets you can observe at night.

Authors, Michael König, who holds a doctorate in astrophysics, and experienced astrophotographer Stefan Binnewies have combined their knowledge to showcase what is within an amateur astronomer's grasp, while explaining current astrophysical research of any one target - a refreshing approach, that gives the reader a bigger picture when turning their eyes, binoculars or telescopes to the night sky.

2 App Pocket Universe

Cost: £2.99 ($3.93) **For:** iOS

There are many astronomy apps on the market; planetariums, Space Station trackers, lunar calendars and interactive orrerys. Pocket Universe does more than one thing, making it a highly varied and educational program to have at your fingertips. The in-built planetarium aspect does a fantastic job of helping users to navigate their way around the night sky thanks to a vast database.

This app calls up the latest weather forecast and planetary positions throughout the night for observation planning. There are several quizzes and games to get stuck into (we recommend trying out 'Falcon Lander'), along with orrerys that allow you to scour the Solar System with ease.

Unfortunately, it's only available on iOS, but if you are the owner of an Apple product, there will be an update coming out soon that includes an exciting new augmented reality (AR) feature. Excitingly, this will bring the orrery into your room and will also be infused into the planetarium software, providing further visual assistance with guides between 'real' celestial viewings.

3 Movie The Farthest

Cost: DVD: £11.99 / Blu-ray: £17.99 **From:** Screenbound Pictures

The Farthest is a fine testament to one of the greatest space exploration missions NASA has ever launched. In 1977, the two Voyager spacecraft blasted off into space in an attempt to explore beyond our very own solar neighbourhood. Since then, the twin spacecraft have whizzed past the orbit of Pluto, with Voyager 1 officially entering interstellar space.

This film, which is available on DVD and Blu-Ray, has achieved a marvellous job of recapping the NASA missions, with highlights explained by the mission's key scientists, eye-catching graphics and animations as well as nostalgic videos and images of Voyager's greatest successes. Some of the spacecraft's most influential scientists, including Frank Drake, Carolyn Porco and John Casani, discuss Voyager's highs, lows and what we've learned from the mission so far. Another important question that is addressed during the 120-minute runtime is: what if we aren't alone in the universe? A superb film, that's directed by Emer Reynolds, *The Farthest* is definitely worth a watch.

4 Binoculars Celestron SkyMaster 25x100

Cost: £379.00 ($498.76) **From:** David Hinds Ltd

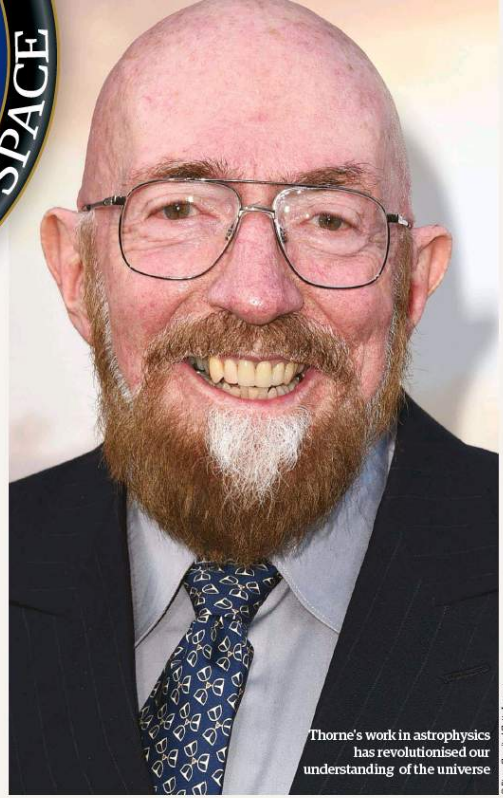
The Celestron SkyMaster 25x100 binoculars have the largest aperture in the SkyMaster series. This grants extremely powerful light-gathering power that's ideal for astronomical viewing. The SkyMaster 25x100 are also useful for terrestrial viewings, but we feel that you shouldn't miss out on observing the wonders of the night sky, especially given the clarity and contrast these binoculars achieve. BAK-4 Porro prisms are built into the optical system, while the lenses are multi-coated, resulting in a crisp magnification of 25-times the human eye's capabilities.

The binoculars showed the Moon in impressive detail, and brought some of the brighter deep-sky objects into elegant focus. Based on our experiences, the optical system is able to handle planetary observations, but when it comes to the dimmer, more diffuse targets, it cannot collect as many photons as a smaller pair of binoculars - a consequence of its large magnification. The binoculars are quite hefty, so your arms will ache during long periods of time, but come with an integrated rigid tripod adapter.

"*The Farthest* is a fine testament to one of the finest space exploration missions ever launched"

Kip Thorne

He may have retired, but the physicist has recently become a Nobel laureate in physics



Thorne's work in astrophysics has revolutionised our understanding of the universe

© Steve Granitz / Getty Images

It seems like news of gravitational waves is never out of the headlines, especially with the recent discovery of a neutron star collision causing the gravitational wave detection GW170817. These discoveries never would have been possible without the work of Kip Thorne, and that's exactly why he, along with Barry Barish and Rainer Weiss, won the 2017 Nobel Prize for Physics for their "decisive contributions to the LIGO [Laser Interferometer Gravitational-Wave Observatory] detector and the observation of gravitational waves".

Born in Logan, Utah, United States on the 1 June 1940, Thorne excelled rapidly through his education, picking up respected degrees, including his PhD, from a combination of the California Institute of Technology (Caltech) in Pasadena, California, and Princeton University in New Jersey. This education led him to have a long and illustrative career, and although he retired in 2009, he still remains Emeritus Feynman Professor of Theoretical Physics at Caltech.

His work in the fields of theoretical physics, gravitational physics and astrophysics have revolutionised astronomy and astrophysics. With the bulk of his career being at Caltech, Thorne is considered to be one of the world's leading experts when it comes to Einstein's General Theory of Relativity. This was emphasised by the fact he won the 'Albert Einstein Medal' in 2009, as this award commemorates any scientific work related to Albert Einstein.

After his retirement in 2009, Thorne decided to get involved in the glamour of Hollywood in the form of being a scientific consultant and executive producer for the 2014 box-office film *Interstellar*. The blockbuster proved to be a massive hit, with a worldwide gross of over $675 million (over £500 million), and this was largely down to the film's concept of sci-fi meets reality. For this, Thorne worked closely with the director, Christopher Nolan, to ensure the film had an authentic scientific feel to it, particularly when it came to the science behind black holes and wormholes. In fact, in an interview with *TIME*, Thorne explained that he had to spend a significant amount of time persuading Nolan that nothing can travel faster than the speed of light. Additionally, Thorne also wrote the book *The Science of Interstellar*, which dissects the physics behind the futuristic film in impressive and fascinating detail.

Thorne's latest headlines come from his phenomenal work with LIGO and their recent discoveries of gravitational waves from several black hole mergers. This evidence is essential for proving that Einstein's one-hundred-year-old General Theory of Relativity is correct, hence leading to Thorne being one of the three 2017 Nobel laureates in physics. Thorne has also continued to outline the importance of this field in astronomy - in particular the future work to be done by the European Space Agency (ESA)'s Laser Interferometer Space Antenna (LISA), which is scheduled for launch in 2034.

It is because of all this work, that the theoretical physics has become a popular figure in astrophysics, refining and improving on our understanding of our complex and fascinating universe.

"Thorne's latest headlines come from his phenomenal work with LIGO"

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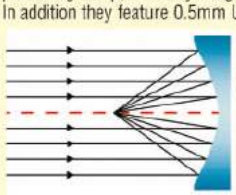

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