INSIDE! NORTHERN LIGHTS GUIDE

HOW LIFE CAME FROM COMETS

All About Space

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THE HUNT FOR ALIEN MOONS

WHAT IF WE REPLACED OUR SUN?

WILL THE HIGGS DESTROY THE UNIVERSE?

- **How the 'God Particle' may cause the catastrophic collapse of space and time**
- Could a light-speed bubble wipe us out?
- **Stephen Hawking reveals the truth**

+

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Welcome to issue 61!

Did you know, life on Earth is thought to have originated from comets that crashed into our planet when it was younger? This issue, we meet the scientists and the missions with the proof that we came from the icy 'space snowballs' that whizz in and out of the solar neighbourhood. From the discovery of an amino acid (glycine) critical for the origin of life on the surface of Rosetta's comet, 67P/Churyumov-Gerasimenko, to infrared measurements and discovery of 'heavy water' on Comet Hartley 2 by the now-defunct Herschel Space Observatory, the Late Heavy Bombardment Period – some 4 to 3.8 billion years ago – likely brought a deluge of comets, which contributed oceans and basic lifeforms.

Elsewhere in the issue, we've investigated the 'rumours' that the Higgs boson, the recently-confirmed particle that gives the universe its mass, could have a hand in the destruction of the cosmos. Turn to page 16 to find out if we could have a light-speed vacuum bubble to worry about as the components that make up space and time spring apart.

If you're keen to observe the Northern Lights this year, then the next month or so is the perfect time to get to the northern latitudes of the planet to catch this stunning natural light show in action. Head over to page 70 for the best places in the world to see it, what to expect during a display, and how to create memories that last using your very own camera. Enjoy the issue!

Gemma Lavender
Editor

Contributors

Kulvinder Singh Chadha

The Higgs boson (or The God Particle) has caused quite a stir within the science community. Find out if it really has the potential to destroy the universe we live in over on page 16.

Colin Stuart

It has long been suspected life on our planet originated from comets. Colin reveals the evidence that suggests primitive lifeforms began from impacts on a young Earth.

Giles Sparrow

Who will win the race to land humans on Mars? Turn to page 40 for an update on where NASA, SpaceX and Blue Origin are on the 21st century's greatest competition for space supremacy.

Stuart Atkinson

Now is the perfect time to head to northern latitudes for aurora displays. Stuart provides a full guide on the best places to catch the Northern Lights and what you can expect to see during a show.

Comets could have played a role in delivering the ingredients necessary for life to the early Earth

"The average abundance of heavy water on comets is certainly higher than it is here on Earth"

Kathrin Altwegg, University of Bern [Page 26]

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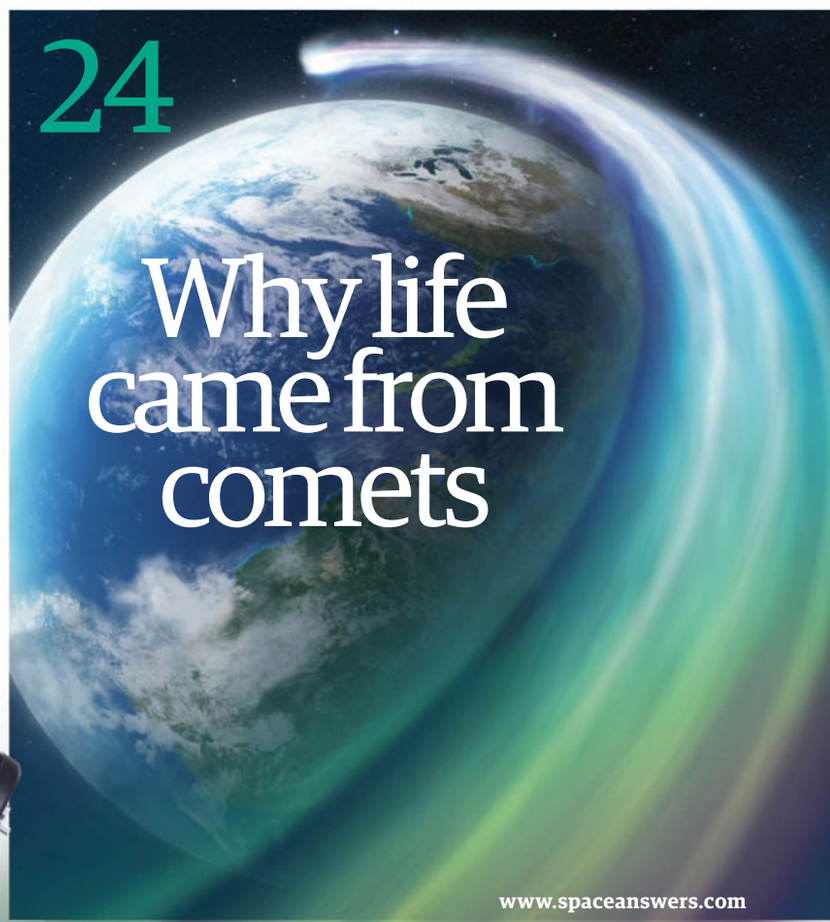
YOUR FIRST CONTACT WITH THE UNIVERSE

FEATURES



WORTH £409!

"I just feel privileged, even lucky, to be one of the 24 humans that have had the opportunity to fly on a lunar mission"

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Lunar Module Pilot for NASA's Apollo 13 mission

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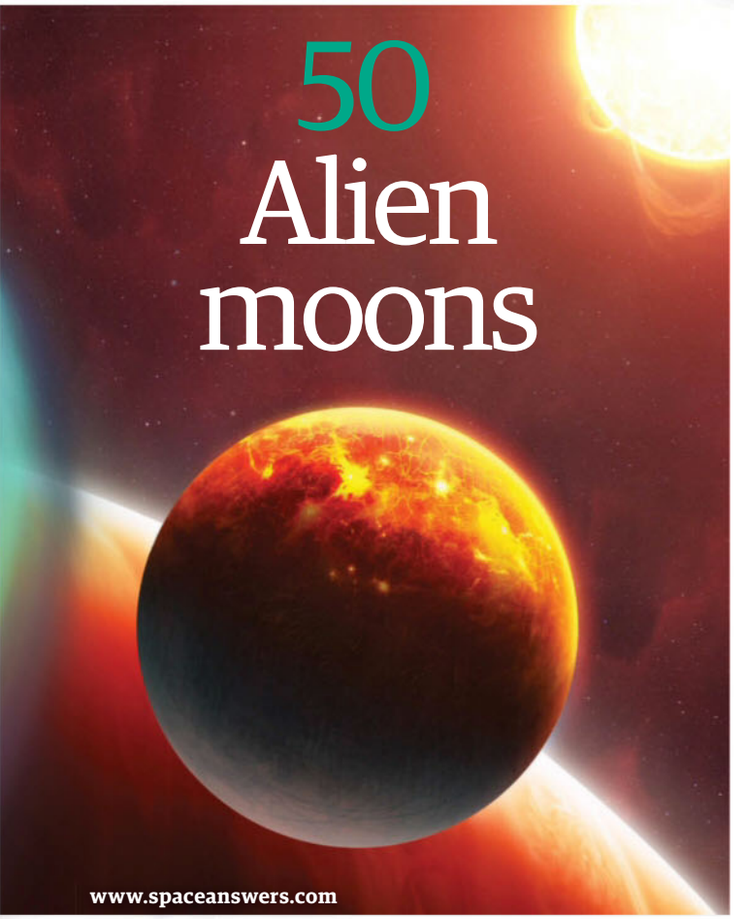

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STARGAZER
Your complete guide to the night sky

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A fisheye view of an exoplanet hunter and the Milky Way

Like a great dagger penetrating the night sky, the Milky Way hangs above the winding road that leads to La Silla Observatory, located on the outskirts of the Atacama Desert in Chile, in this fisheye projection, which was captured by astrophotographer Babak Tafreshi.

The centre of our galaxy is immediately obvious in this unique piece of astrophotography, and is home to supermassive black hole Sagittarius A*. Meanwhile, the European Southern Observatory's 3.6-metre (11.8-foot) telescope – which hosts the world's foremost exoplanet hunting instrument, the High Accuracy Radial velocity Planet Searcher (HARPS) – isn't just visible on the horizon; it's reflected in a roadside mirror.

© ESO, B. Tafreshi

ESA's Thomas Pesquet takes a space selfie

On Friday 13 January, ESA astronaut Thomas Pesquet went on his very first spacewalk with fellow astronaut Shane Kimbrough of NASA. The aim of the Extravehicular activity (EVA), which took five hours and 58 minutes in total, was to complete a battery upgrade to the International Space Station's power system. In this photograph, the spacewalker snaps a quick image of himself on one of many momentous occasions of his six-month mission, named Proxima. Pesquet comments: "The requisite space selfie! Nice reflection of Earth in the helmet. Unbelievable feeling to be your own space vehicle."

Cosmic 'winter' wonderland

While there are no seasons in space, this image of diffuse nebula NGC 6357 certainly gives the impression of a frosty winter landscape. You may be surprised to learn that this is far from the truth: this area of star formation is intensely hot, with young stars energising any cool gas with their radiation. Bubbles and cavities populate this nebula, which are the result of material being blown away from the surfaces of massive stars by radiation and supernova explosions. NGC 6357, which contains at least three clusters home to massive stellar objects, is located about 5,500 light years away.

© *X-ray:* NASA; CXC; PSU; L. Townsley et al. *Optical:* UKIRT. *Infrared:* NASA; JPL-Caltech

China's Tian Shan Mountains from space

Earth observation satellite Copernicus Sentinel-2A takes us over northwestern China, close to the border of Kazakhstan and Kyrgyzstan, in this false colour image of the Tian Shan Mountains. Sentinel-2A's imager is able to 'see' in different parts of the spectrum, which causes the snow to appear blue. The clouds are white and grasslands are orange. By observing our planet, we're able to see that the glaciers of Tian Shan have lost about a quarter of their ice mass since the 1960s – a key indicator of climate change, which poses threats to Chinese communities living downstream.

© ESA

Hubble spies a galactic mega laser

It may look calm and serene but this galaxy – known as IRAS 16399-0937 – has quite an exciting classification compared to others in the universe. That's because it hosts a megamaser, objects that are intensely bright and about 100 million times more luminous than the masers found in the Milky Way. Masers often cause entire galaxies to act as lasers that spew out microwave emissions rather than visible light. IRAS 16399-0937 is located over 370 million light years away from Earth. Its energetic nature has been downplayed by the Hubble Space Telescope, which instead painted it as a beautiful, unassuming galaxy that has been captured across various wavelengths. This particular image has given astronomers the opportunity to gaze upon the megamaser galaxy's double nucleus, which was formed from the merging of two cores.

ALMA gazes into a scorching soufflé

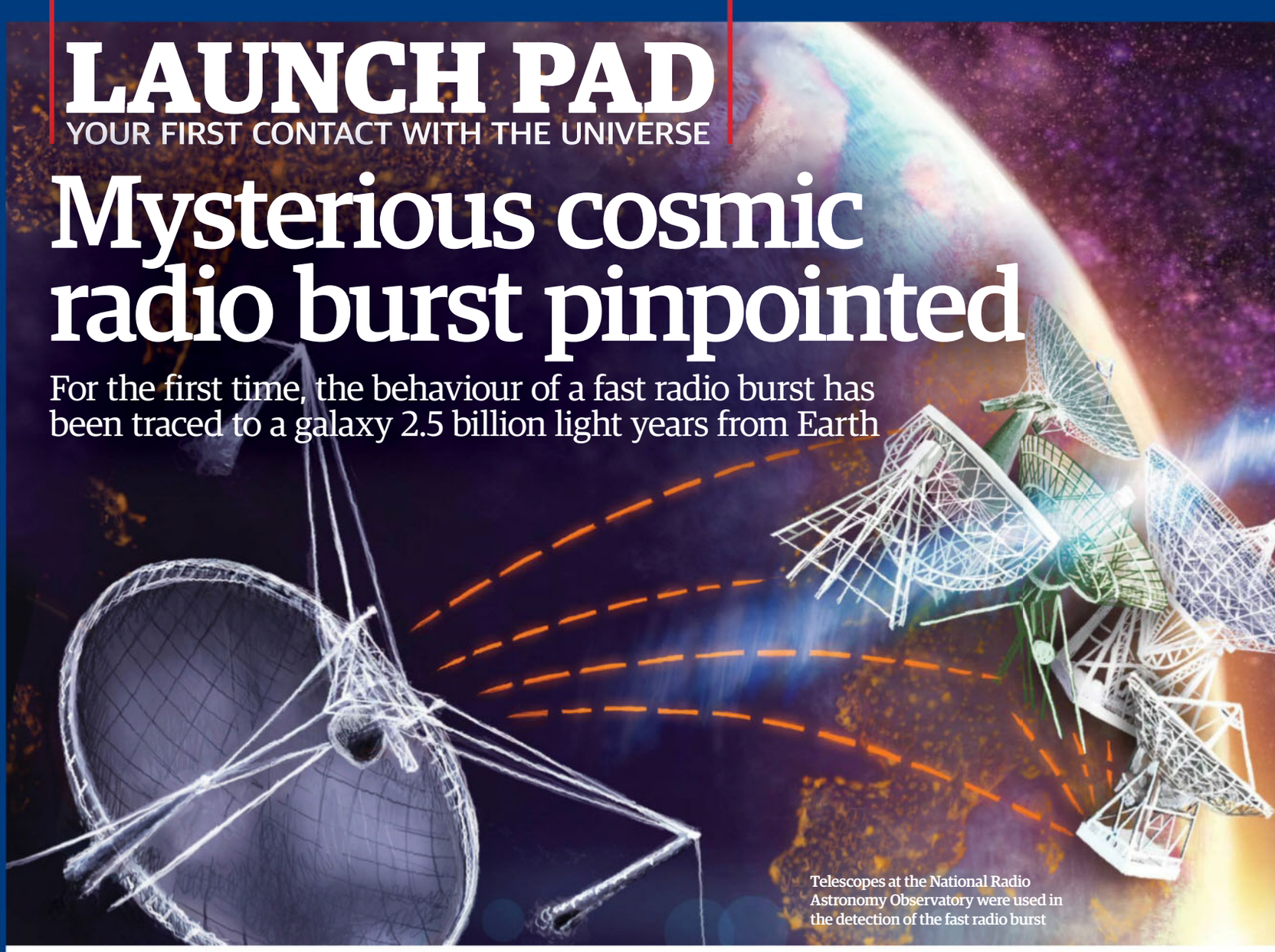
The state-of-the-art Atacama Large Millimeter/submillimeter Array (ALMA) has been shot in a very unusual situation as this photograph shows – the skies over the Chilean Andes are alive with a fiery, billowing cover of clouds at sunset. The ALMA observatory consists of a giant array of 66 antennas, used for peering into the universe to study molecular clouds – vast gatherings of gas and dust with temperatures of a few tens of degrees above absolute zero. ALMA has been built on the plateau at Chajnantor, which is 5,000 metres (16,404 feet) above sea level, making it an ideal place to take radio observations of the universe.

Japan ejects a small satellite

The Japan Aerospace Exploration Agency (JAXA) releases a small satellite from the International Space Station (ISS), known as the Space Tethered Autonomous Robotic Satellite (STARS-C). This satellite consists of two small satellites that separated at a safe distance from the ISS, yet were still connected by a 100-metre (328-foot) long tether made out of a Kevlar synthetic fibre. STARS-C's aim is to test a new technology while pointing toward Earth, where it will use a spring system and gravitational forces to separate even further, pushing one satellite closer to our planet. The spacecraft will also collect electrons from space's plasma environment in the hope of analysing the making of an electrical current.

Mysterious cosmic radio burst pinpointed

For the first time, the behaviour of a fast radio burst has been traced to a galaxy 2.5 billion light years from Earth



Telescopes at the National Radio Astronomy Observatory were used in the detection of the fast radio burst

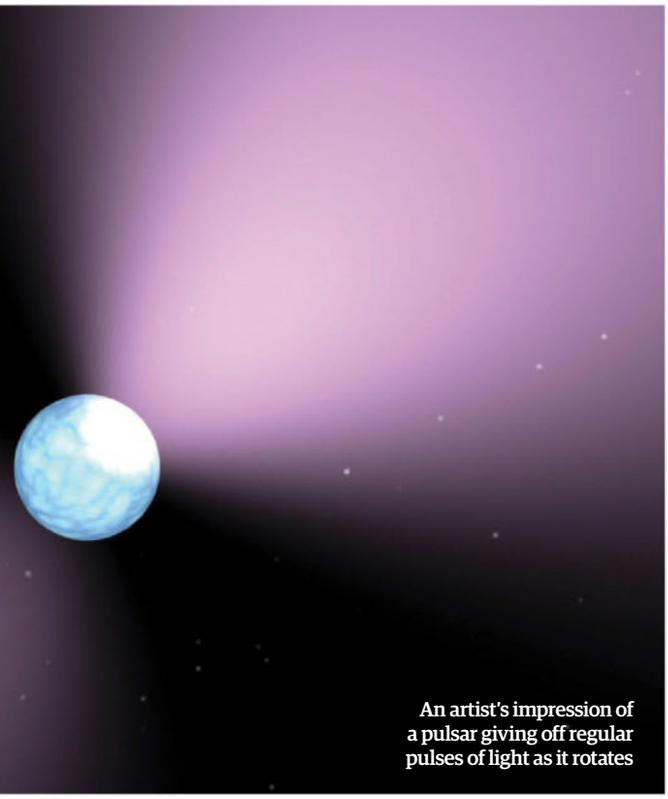
Part-time pulsars found to perform vanishing act

Astronomers spot neutron stars that temporarily turn off and vanish from view

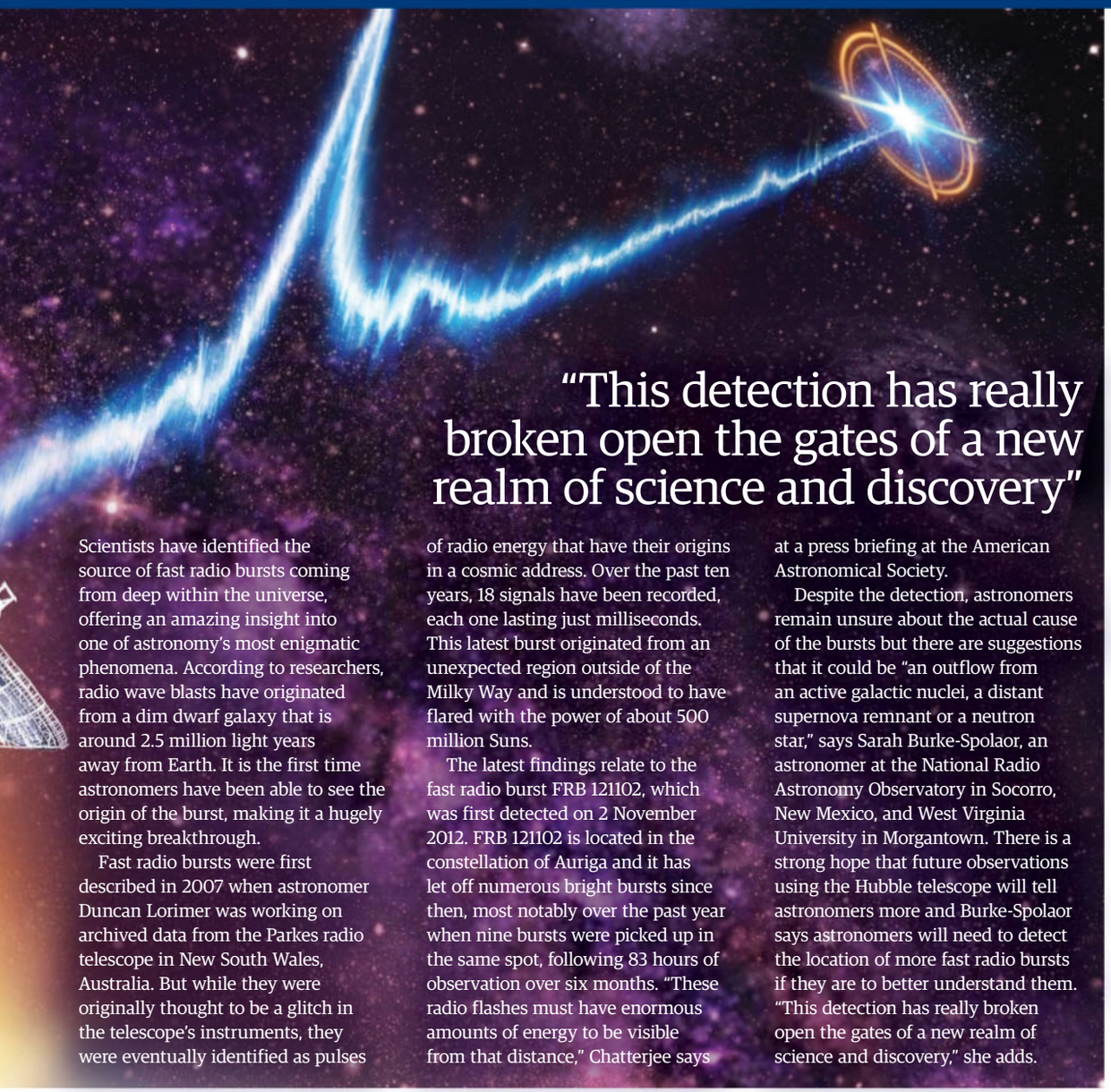
Two pulsars in the Milky Way have been seen to behave in a very odd manner: emitting radio waves for a while before suddenly becoming inactive until they are ready to fire again. Indeed, one of them has been seen to be in an active state only 30 per cent of the time with the other going as low as 0.8 per cent. Since most pulsars are continuously broadcasting, scientists are intrigued.

For a start, if such behaviour is typical of many other pulsars then it may well be that scientists are failing to see scores of them – their observations coming during the "off" phases. Second, there appears to be no real pattern. The pulsar, which emitted 0.8 per cent of the time at one stage, upped its game to 16 per cent at some other point and such irregularity has proven baffling for what are dubbed 'part-time pulsars'.

"When they're on, they're not particularly dim – you wouldn't know they have a dual personality," says Victoria Kaspi, an astronomer at McGill University in Montreal. The pulsars – which are extremely dense neutron stars that collapse in on themselves – were observed at the Arecibo Observatory in Puerto Rico and analysed at Manchester University's Jodrell Bank Observatory. "It implies that the known Milky Way radio pulsar population is far more incomplete than we thought," Kaspi adds.



An artist's impression of a pulsar giving off regular pulses of light as it rotates



"This detection has really broken open the gates of a new realm of science and discovery"

Scientists have identified the source of fast radio bursts coming from deep within the universe, offering an amazing insight into one of astronomy's most enigmatic phenomena. According to researchers, radio wave blasts have originated from a dim dwarf galaxy that is around 2.5 million light years away from Earth. It is the first time astronomers have been able to see the origin of the burst, making it a hugely exciting breakthrough.

Fast radio bursts were first described in 2007 when astronomer Duncan Lorimer was working on archived data from the Parkes radio telescope in New South Wales, Australia. But while they were originally thought to be a glitch in the telescope's instruments, they were eventually identified as pulses of radio energy that have their origins in a cosmic address. Over the past ten years, 18 signals have been recorded, each one lasting just milliseconds. This latest burst originated from an unexpected region outside of the Milky Way and is understood to have flared with the power of about 500 million Suns.

The latest findings relate to the fast radio burst FRB 121102, which was first detected on 2 November 2012. FRB 121102 is located in the constellation of Auriga and it has let off numerous bright bursts since then, most notably over the past year when nine bursts were picked up in the same spot, following 83 hours of observation over six months. "These radio flashes must have enormous amounts of energy to be visible from that distance," Chatterjee says at a press briefing at the American Astronomical Society.

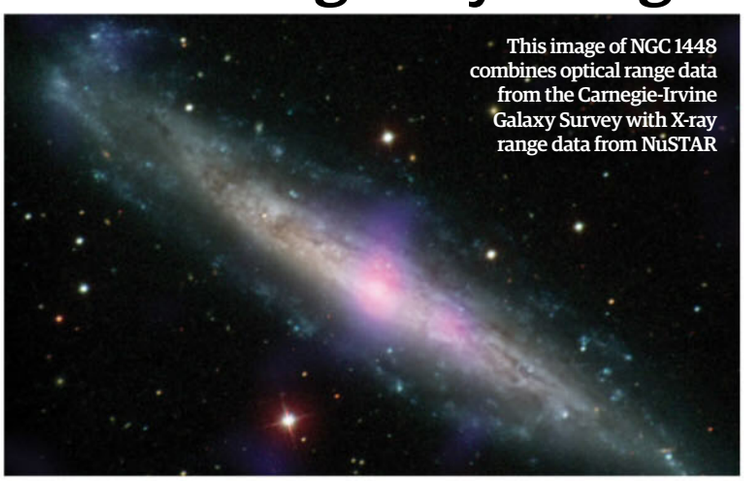
Despite the detection, astronomers remain unsure about the actual cause of the bursts but there are suggestions that it could be "an outflow from an active galactic nuclei, a distant supernova remnant or a neutron star," says Sarah Burke-Spolaor, an astronomer at the National Radio Astronomy Observatory in Socorro, New Mexico, and West Virginia University in Morgantown. There is a strong hope that future observations using the Hubble telescope will tell astronomers more and Burke-Spolaor says astronomers will need to detect the location of more fast radio bursts if they are to better understand them. "This detection has really broken open the gates of a new realm of science and discovery," she adds.

Black holes closer than originally thought

Exotic objects may be playing hide and seek in the cosmic background

Astronomers say supermassive black holes could be concealed behind thick layers of gas and dust, causing them to question just how many more may be "missing". Studies using NASA's space-based NuSTAR (Nuclear Spectroscopic Telescope Array), which is designed to see higher energy X-rays, discovered black holes at the centre of two "active" galaxies relatively close to the Milky Way. These would have been hidden from the view of most telescopes, paving the way for more discoveries.

The conclusion was made by researchers at Durham and Southampton universities who had been studying NGC 1448 and IC 3639, which are 38 million and 170 million light years away respectively. They were able to detect the X-ray emissions generated by the black holes when NuSTAR viewed them edge-on.



This image of NGC 1448 combines optical range data from the Carnegie-Irvine Galaxy Survey with X-ray range data from NuSTAR

Trying to see how bright the active galactic nuclei are when viewed head-on would have proven impossible because of a doughnut-shaped region of gas and dust obscuring the central regions. "They have remained hidden from us until now," says Ady Annuar, a Durham University graduate. "They're like monsters hiding under your bed."

Annuar presented the results at the American Astronomical Society meeting in Grapevine, Texas. It was also found that NGC 1448 has a large population of young stars under 5 million years old; researchers suggest the galaxy was producing new stars as the black hole was feeding on gas and dust.

Space News in Brief

Astronauts upgrade ISS power supply

NASA's Shane Kimbrough and Peggy Whitson carried out the first spacewalk of 2017 when they spent six-and-a-half hours outside the International Space Station on a mission to replace a set of fridge-sized batteries. Having completed the work within just four hours, they spent the remaining two-and-a-half hours outside of the ISS taking photographs and getting ahead with other tasks.

NASA explains why Moon dust levitates

Dust particles on the Moon are able to travel across the lunar surface via static electricity, it has recently been found. When the dust particles are exposed to ultraviolet radiation or electrically charged gas, it causes the particles to leap a few centimetres and this allows them to move around the surface of our lunar companion, even in the absence of water and wind.

Vast new galaxy catalogue built

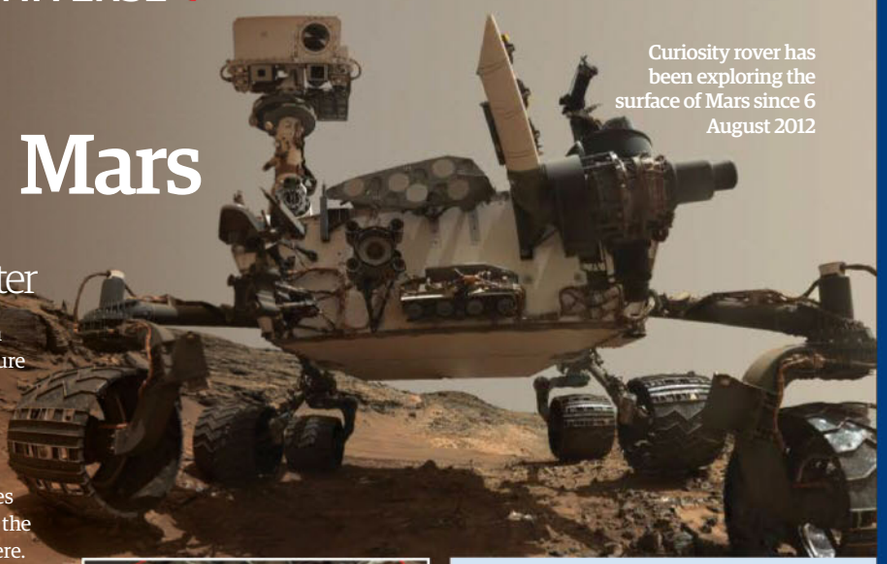
A new catalogue called NED-D, which is part of the NASA/IPAC Extragalactic Database, contains more than 166,000 distance estimates for more than 77,000 galaxies. Accessible to the public at **ned.ipac.caltech.edu**, the new catalogue also includes details of supernovae and gamma-ray bursts and it will aid astronomers in figuring out the speed of the universe's expansion.

Pluto's "snakeskin" terrain found on Earth

When NASA's New Horizons spacecraft flew by dwarf-planet Pluto in July 2015, it observed a snakeskin terrain of tall ridges. These, however, are now said to be similar to penitentes on Earth – that is, snow formations that are found at high altitude, pointing in the general direction of the Sun. The difference is that Pluto's are made of methane and nitrogen ices and not water ice.

Rover finds more evidence for life on Mars

Study of Gale Crater finds boron, a good indicator of a past abundance of groundwater



Curiosity rover has been exploring the surface of Mars since 6 August 2012

NASA's Curiosity rover has discovered boron on the surface of Mars for the very first time, delivering fresh evidence that life may have once existed on the Red Planet. During its study of the composition of rocks at Mars' Gale Crater, it has come across exposed mineral layers as it ascends Mount Sharp and takes samples every 25 metres (82 feet). These regular stops are allowing it to uncover younger layers of rock sediment and it's using its ChemCam instrument to analyse the elemental composition.

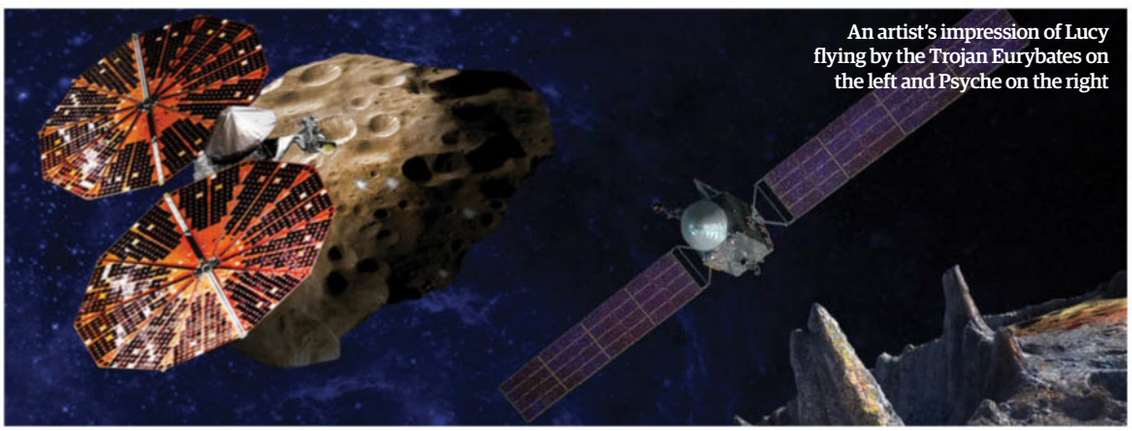
Finding boron is hugely significant because the element is typically found on Earth in arid areas that have a history of evaporated water. Scientists heading the mission say Gale Crater is the most likely location for signs of life and that the boron may have been deposited by flowing water. It was discovered in the calcium sulphate mineral veins on Mars. Currently, scientists are unsure if the boron on Mars is the same as that on our own planet. If it is, the fact that the ground water would be between zero and 60 degrees Celsius (32 and 140 degrees Fahrenheit) would vastly increase the possibility of life at some stage there.

"We are seeing chemical complexity indicating a long, interactive history with the water," says John Grotzinger of the California Institute of Technology. "The more complicated the chemistry is, the better it is for habitability. The boron, hematite and clay minerals underline the mobility of elements and electrons, and that's good for life." Even so, no forms of life have been found on Mars yet. The search will continue but it appears as if scientists are getting ever closer.

Boron is found in a calcium sulphate vein at Catabola on Mars – the orange bars show the element's abundance

New missions set to explore history of the Solar System

Psyche and Lucy will attempt to unlock the secrets of the planets



An artist's impression of Lucy flying by the Trojan Eurybates on the left and Psyche on the right

NASA is set to launch two missions aimed at uncovering new information about the birth of the Solar System. The Discovery missions Psyche and Lucy will be shedding fresh light on the 10-million-year period following the birth of the Sun, hoping to provide a better understanding of its history.

Lucy is due to launch in 2021 with the aim of visiting the target-rich area of Jupiter's Trojan asteroids. It will arrive at its first destination four years later and then explore six asteroids between 2027 and 2033. NASA says the asteroids are thought to be relics of a much earlier era and may have formed beyond Jupiter's current orbit.

Psyche will launch in 2023 and will look at how planets and other bodies are separated into layers early in their history. It will target asteroid 16 Psyche, which measures 210 kilometres (130 miles) in diameter and is three-times further away from the Sun than Earth. The asteroid's make-up is said to be similar to Earth's core and scientists want to know if it lost its outer layers due to collisions in the distant past. "These are true missions of discovery that integrate into NASA's strategy of investigating how the Solar System evolved," says NASA's planetary science director, Jim Green. "These additional pieces of the puzzle will help us understand how the Sun and its planets formed and changed."

Will we be able to stop a near-Earth object from colliding with our planet?

United States prepares for asteroid apocalypse

Emergency plans are drawn up by the White House in preparation for possible collisions

It may sound like something from Hollywood but fears of an asteroid collision are real. The US government has drawn up a plan as it seeks to locate 300,000 or more near-Earth objects (NEOs) – asteroids or comets that are close to Earth's orbit.

White House officials have released a *National Near-Earth Object Preparedness Strategy* that "seeks to improve our preparedness to address the hazard of NEO impacts by enhancing the integration of existing national and international assets and adding important capabilities that are currently lacking." It does add, however, that the risk of a "civilisation-ending" collision within the next 200 years is unlikely. But smaller collisions and disruptions are possible, as was seen in 2013 when the Chelyabinsk meteor caused injuries and damage in Russia. The document discusses seven strategic goals, such as enhancing NEO detection and tracking, developing methods to deflect and disrupt NEOs, and improved predictions.

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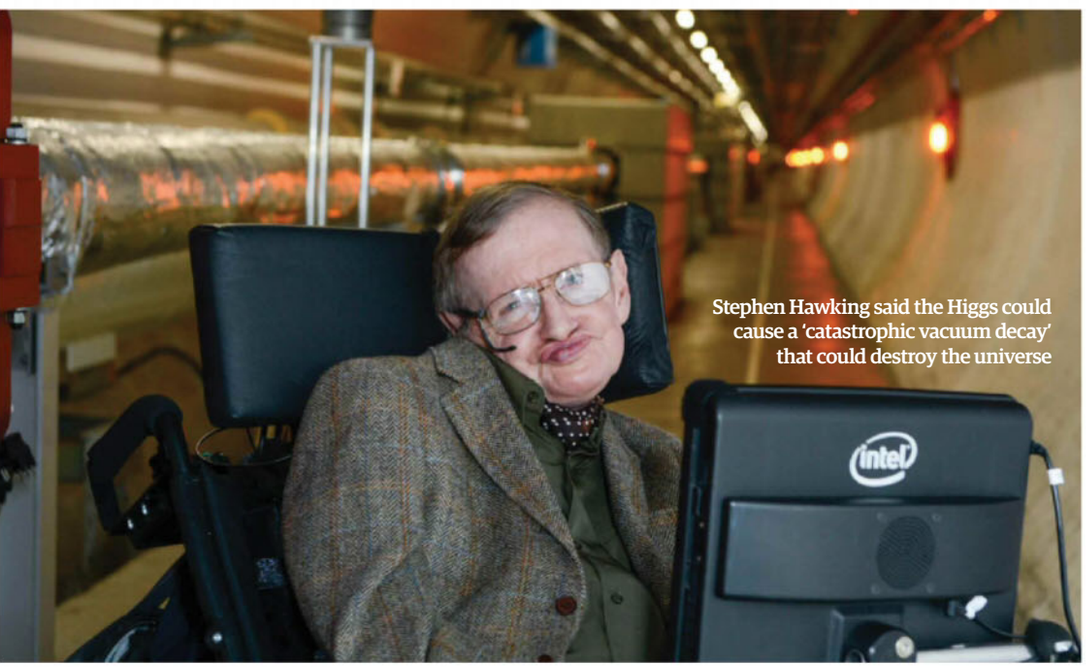
WILL THE HIGGS DESTROY THE UNIVERSE?

Could the God Particle cause space and time to collapse, as supposedly quoted by Stephen Hawking?

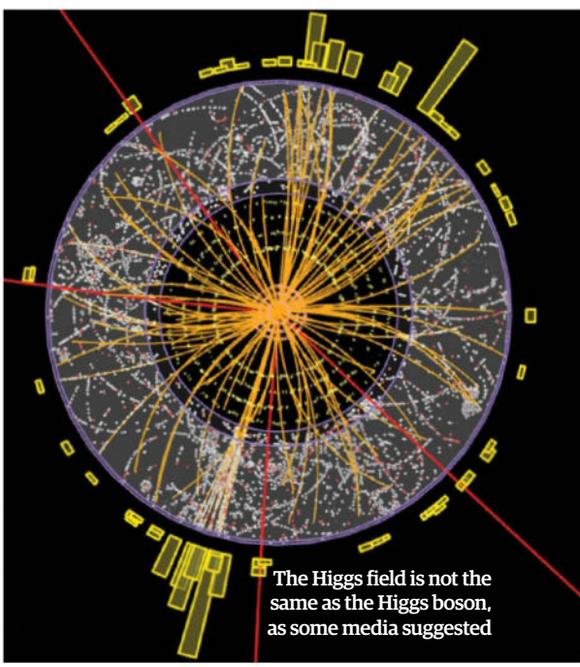
Written by Kulvinder Singh Chadha

Will the Higgs destroy us?

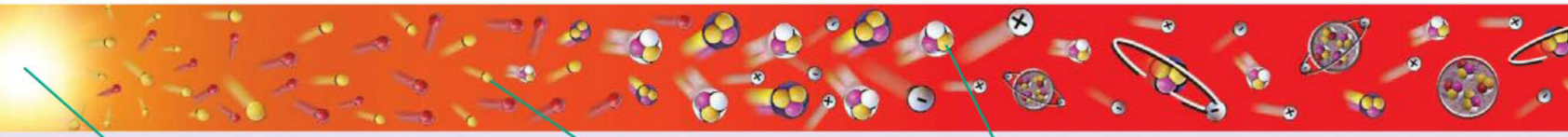
Professor Peter Higgs, whom the particle was named after, visits the CMS experiment in Switzerland



Stephen Hawking said the Higgs could cause a 'catastrophic vacuum decay' that could destroy the universe



The Higgs field is not the same as the Higgs boson, as some media suggested



Big Bang
0.00 seconds
Widely considered by scientists as the beginning of our universe. This point contains all of time and space, all of the universe's fundamental forces and is made of pure energy.

Inflation
10^{-38} seconds
A brief and rapid period of expansion of the universe begins, thought to be a consequence of the strong nuclear force becoming distinct.

Quarks and hadrons
10^{-10} seconds
The expanding universe cools enough for fundamental matter particles to form. These will combine into protons and neutrons as the universe nears it's first second of existence.

The universe could collapse into oblivion at any moment, the culprit being related to a recently discovered particle. The Higgs particle, known as the Higgs boson, was discovered in 2012 by the ATLAS and CMS detectors (A Toroidal LHC Apparatus and the Compact Muon Solenoid, respectively) of the Large Hadron Collider, also known as LHC. The Collider is a huge particle accelerator, 27 kilometres (16.7 miles) in circumference, located underground at the European Organisation for Nuclear Research (CERN) in Switzerland. The existence of the Higgs was first predicted by a group of scientists, including Peter Higgs, who won a Nobel Prize for the discovery alongside François Englert in 2013. They used the Standard Model to make their prediction, which scientists have been using as a guide to the discovery of new particles since the 1960s. The Higgs was included in those early days, but very few thought that it could ever be found.

The Higgs field gives matter particles (and also the Higgs boson) mass. However, scientists were somewhat torn on the discovery of the Higgs boson. Many were astounded and elated by it, while others were somewhat disappointed that the Standard Model didn't turn up something more unexpected and interesting. Well, it turns out that the Higgs may be exciting enough.

One of the most famous scientists in the world, Stephen Hawking, purportedly suggested that the Higgs particle would eventually destroy the universe and everything in it, although others previously made similar claims. But Hawking's supposed claim garnered wide publicity in 2014 in the mainstream media and largely went unquestioned. Except that this was a misquote and was based on a subtle but important scientific misunderstanding.

From the Starmus Festival in Tenerife, Hawking explains: "The Higgs potential has the worrisome feature that it might become metastable at energies above 100 [billion] gigaelectronvolts (GeV). This means that the universe could undergo catastrophic vacuum decay, with a bubble of the true vacuum expanding at the speed of light. This could happen at any time and we wouldn't see it coming." Although this sounds frightening, it is actually different from what media reported Hawking had exactly said back in 2014.

"Could our universe be on an unstable 'mound' with a danger of collapsing to a lower-energy ground state?"

Far into the future, star forming will cease, galaxies will die, and the Higgs may take over

Gigaelectronvolts (GeV) and megaelectronvolts (MeV) are how particle physicists quantify the masses of subatomic particles. For example, the proton would be around 1 GeV in mass and the Higgs boson is 126 GeV. Hawking was talking about the Higgs field – which permeates all of space – and not the Higgs particle, which is related but different. Imagine an electron and an electric field, two things that are clearly related, but different. Catastrophic vacuum decay means that the universe may not be in it's true 'ground' state and may be about to collapse at any time. So although Hawking didn't mention the Higgs particle, he did mention the Higgs field and vacuum decay. So what exactly is this phenomenon he spoke of?

Imagine that the vacuum of space isn't a true vacuum. The true vacuum would be the lowest-energy state, and a universe permeated by a Higgs field may not be in that state. As an analogy, imagine that the true vacuum is like the bottom of a depression, where it isn't possible to go any lower. Now imagine that our universe is on a mound within this depression, with a danger of collapsing. It may appear to us that we are in the lowest state but it wouldn't be the case. This is what the 'false vacuum' – which can seem like the true vacuum – means. Could our universe be on an unstable 'mound' with a danger of collapsing to a lower-energy ground state? And would the Higgs field be responsible for that? Some scientists share Hawking's views on this.

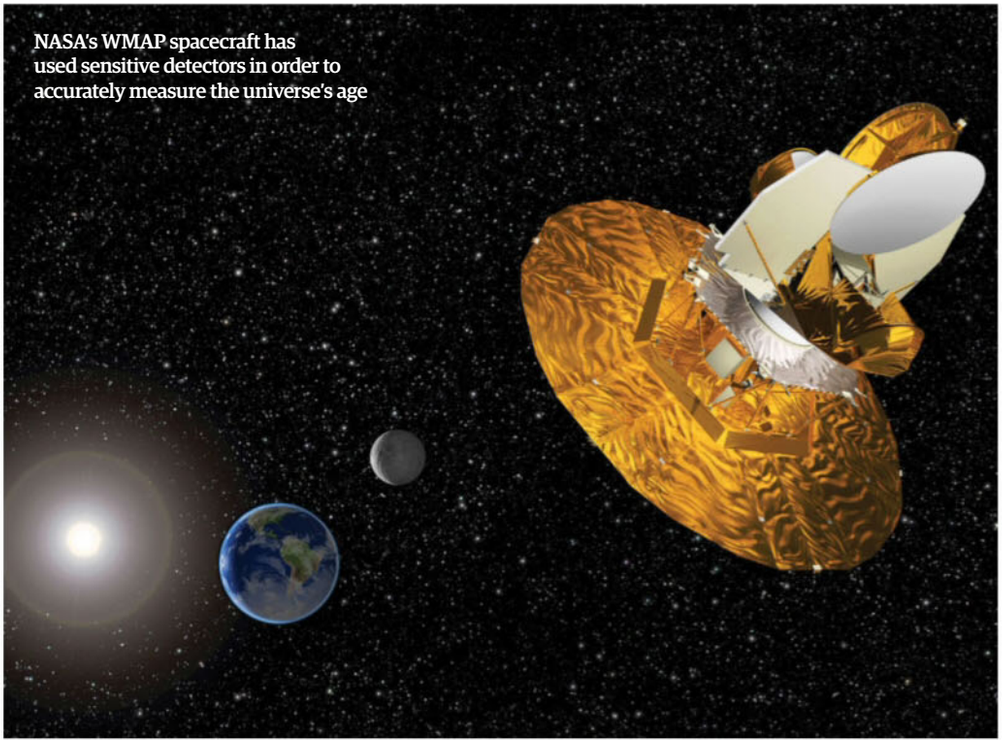
Dr Joseph Lykken of Fermilab, Illinois, said at the 2013 meeting for the American Association for the Advancement of Science: "There's a calculation you can do in the Standard Model once you know the mass of the Higgs. If you use all the physics we know and do this straightforward calculation, it's bad news." He explains how the calculation shows how quantum fluctuations could be created; this could tip the vacuum into a lower-energy state by creating bubbles. These bubbles travel at the speed of light and would cause the known universe collapse into a lower-energy state, effectively replacing it with another universe. As bizarre and scary as this sounds, Lykken reassures us that the chances of this happening are truly astronomical and depends on the particular cosmological epoch.

He says that if it does happen, most likely it'll take 10^{100} years anyway, "so you probably shouldn't sell your house and [should] continue to pay your taxes!" By that time, our Solar System and even our galaxy will be long gone, as all star-forming in the universe would stop and all of the stars would die out, leaving nothing but a dark void. So although there's nothing

First nuclei

180 seconds

As the expanding universe further cools the sea of protons and neutrons form atomic nuclei. Largely this is hydrogen and helium, with possibly some lithium.



NASA's WMAP spacecraft has used sensitive detectors in order to accurately measure the universe's age

The majority of physicists don't think that the Higgs is any threat to the universe

to worry about, the Higgs destroying the universe is still an extremely slim possibility. What's more, the universe could be complicit in this, but how?

When the universe began ~13.8 billion years ago (a figure that comes from NASA's Wilkinson Microwave Anisotropy Probe – WMAP), it expanded and grew ever larger at a decelerating rate. This expansion continues to this day. However, observations from the late 1990s showed that this expansion started to accelerate around 5 billion years ago. So some powerful, unknown force, which actually makes up 71.4 per cent of the energy density of the universe, is pushing space apart. The nature of this phenomenon is unknown to us but is called dark energy. This isn't really of any concern to us today, but imagine far into the future, the Higgs field starts to dominate an already-expanding universe and helps to destabilise it. Why should the Higgs behave like this at all?

With 126 GeV, the Higgs boson is a massive particle – much more so than the proton. For such a massive particle to exist, the Higgs field must possess a lot of energy. Einstein revealed in his paper on Special Relativity in 1905 that mass and energy are two sides of the same coin. This manifests itself in the famous equation: $E=mc^2$. The Standard Model claims that massive particles are 'metastable', which means they hover between stability and instability. According to Einstein's equation, related quantum fields would take a lot of energy to create particles of such mass. A change in the Higgs field could even change the mass of every particle in the universe (assuming they still existed in the future). "Then all the laws of physics change and everything is torn apart," says Dr Tim Barklow of the SLAC National Accelerator Laboratory in California, and a member of the ATLAS team at the LHC. So ultimately, should we be worried about the Higgs field after all?

Alexander Bednyakov of the Joint Institute of Nuclear Research, Russia, along with other scientists, carried out a detailed analysis in late 2015 using LHC data. They accounted for strong force interactions and other quantum corrections, revealing a painstaking body of work. They concluded that, as close as possible to the best theoretical fit, the universe is indeed in a metastable state. However, the values of the parameters they used are far closer to a region of absolute stability than what other previous studies suggested. It's important to remember that there are a few scenarios for the universe's eventual end; the Big Rip, the Big Freeze, the Big Crunch and the Heat Death of the universe. The Higgs is just another such theoretical scenario – and one that many physicists say is highly unlikely to ever happen.

First atoms

380,000 years

Free electrons combine with the hydrogen, helium and lithium nuclei to form atomic versions of the primordial elements. The dense 'fog' lifts as a result and the universe becomes transparent.

Dark ages

380,000 to 300 million years

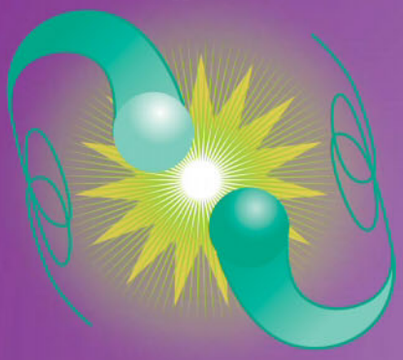
The universe remains dark for the next 299,620,000 years as primordial atomic hydrogen, helium and lithium atoms do nothing much.

What is the Higgs Boson?

This particle was discovered in 2013 and mediates mass via an energy field

Finding hints of the Higgs

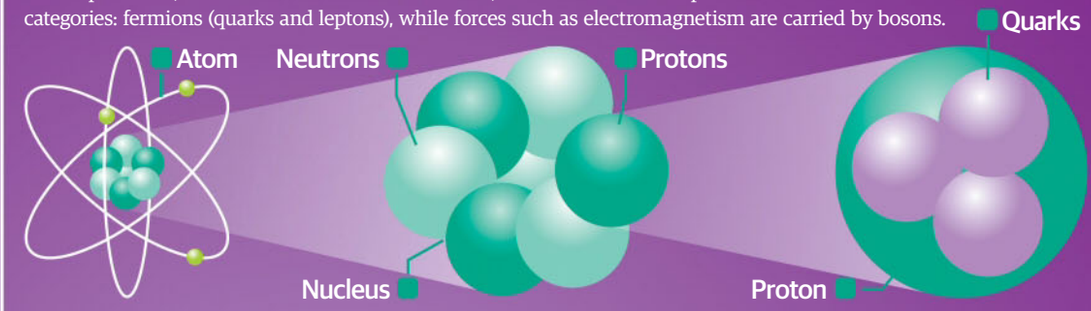
Was mass mediated by the Higgs boson? That's what the Large Hadron Collider tried to find out by using electromagnetic fields to whip beams of protons around and around to nearly the speed of light. When these protons collide, energy is released and new particles are made - which can provide evidence for the Higgs boson!



When particles collide, excess bosons or quarks may appear. How? They were formed from the Higgs boson!

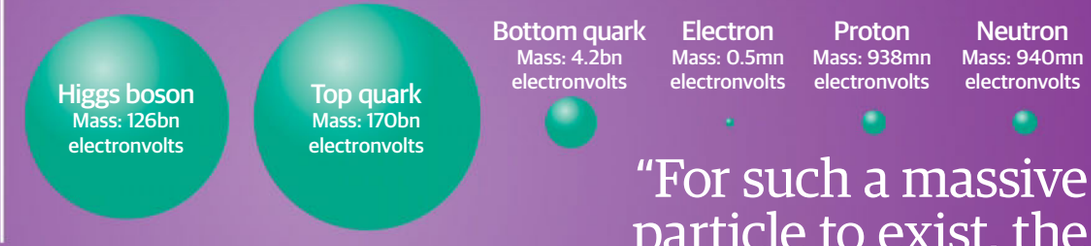
Mass and matter

Matter particles (such as those that constitute atoms) contain mass. These particles come in two categories: fermions (quarks and leptons), while forces such as electromagnetism are carried by bosons.



Higgs compared to other particles

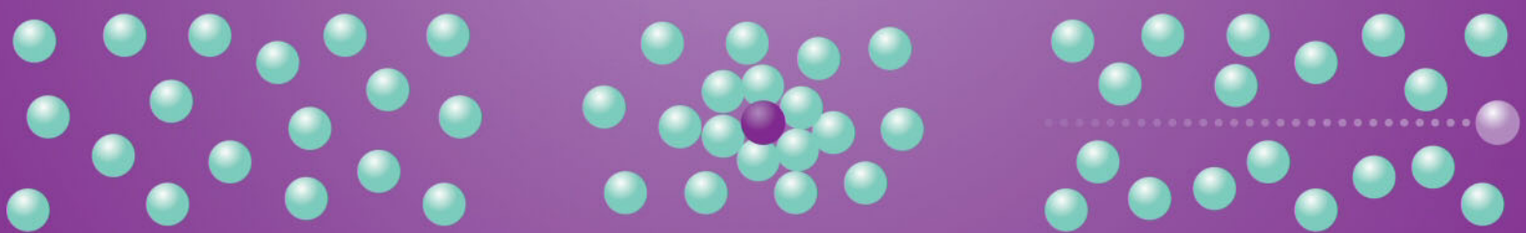
The mass of a particle is given in electronvolts, which is the energy an electron has when it's accelerated through one volt. The Higgs boson has a mass of about 125 billion electronvolts, while the photon has no mass at all.



"For such a massive particle to exist, the Higgs field must possess quite a lot of energy"

Higgs: why matter has mass

Particles may be more massive than one another because they feel the Higgs field differently. It's because of the Higgs boson that matter has mass.



Meeting the Higgs field

The Higgs field occurs everywhere and throughout the universe, and gives matter particles (as well as Higgs bosons) mass. We can imagine the Higgs field as a group of evenly separated balls for this scenario.

Enter ordinary matter

When a particle of ordinary matter moves through the Higgs field, the field becomes excited and forms Higgs bosons, which cluster around the particle and provide it with mass.

High-speed photons

Sometimes, particles move through space without interacting with the Higgs field. This means they don't gain any mass from Higgs bosons and remain massless. A photon is one such particle.

First stars

300 million years

Gravity eventually corrals the gaseous hydrogen and helium into galaxies and protostellar discs. These eventually collapse into the first stars, which start to shine.

Expansion accelerates

8.8 billion years

Since its inception the universe has been constantly expanding, but now this expansion starts accelerating. The phenomenon behind this isn't known but has been labelled 'dark energy'.

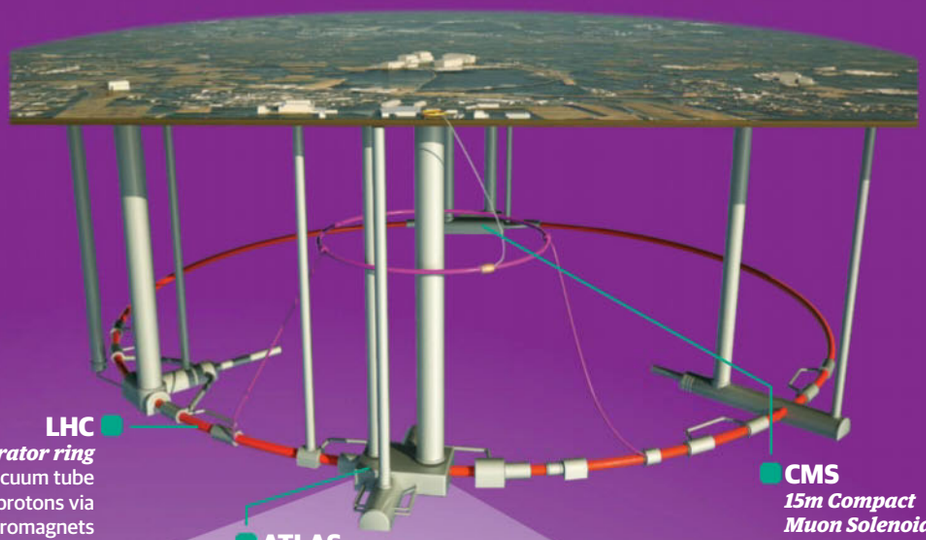
Present day

13.8 billion years

The present epoch of the universe, where several generations of stars have created complex elements in their cores, which have then scattered in supernovae explosions to create planets and life.

Understanding the Higgs and the universe's destruction

It took two detectors at the LHC to find the Higgs boson



LHC
27km accelerator ring
A large vacuum tube accelerates protons via powerful electromagnets to near-light speed.

ATLAS
7,000-ton collision detector
With solenoid magnets and radiation trackers, ATLAS can detect different particles from beam collisions.

CMS
15m Compact Muon Solenoid
Using different technologies, the CMS confirmed ATLAS' detection of the Higgs boson.

Muon detectors
Detecting the charged particles known as muons is an important task for ATLAS. The muon is similar to an electron, but 200-times more massive. Decay into muons is one of the 'signatures' of the Higgs boson.

Shielding

Forward calorimeters

Hadronic calorimeters
The Hadron Calorimeter (HCAL) measures the energy of hadrons – particles made of quarks and gluons (for example protons and neutrons)

Electromagnetic calorimeters
This calorimeter measures the energy of electrons and photons as they interact with matter.

Inner detector
The first part of ATLAS to see the decay products of particle collisions. The inner detector is very compact and highly sensitive.

Solenoid
The ATLAS detector at CERN is equipped with a superconducting magnet. Its solenoid, which is 2.4 metres in diameter and 5.3 metres long, rests at the heart of the experiment providing a field of 2 tesla.

Barrel toroid
ATLAS' Barrel toroid consists of eight coils, each made of two flat superconducting double pancakes in a racetrack.

© Adrian Mann

Expanding Sun
18.8 billion years
In 5 billion years the Sun will consume all of its hydrogen fuel and expand to become a red giant. In the process it will consume Mercury, Venus and the Earth.

Star formation ends
100 trillion years
All star formation ends about 100 trillion years after the Big Bang, and galaxies start to die out, leaving the universe cold and dark.

Higgs causes catastrophe
~100 trillion plus years
The Higgs field causes a 'catastrophic vacuum decay' of the universe, because the whole universe is inside a 'false vacuum' rather than the true one.

Galloway Forest Park

home to the UK's first Dark Sky Park

Dark sky at night, stargazer's delight

See the wonders of the universe at the UK's first dark sky park.

Home to some of the darkest skies in Europe, the **Galloway Forest Dark Sky Park** is the perfect winter destination for an exceptional view of our celestial neighbours.

With astronomer friendly accommodation, an amazing **research level observatory** and access to friendly **Dark Sky Rangers** the skies and opportunities are endless. To get your time with your very own Dark Sky Ranger go to: **www.gsabiosphere.org.uk** and click on the explore the biosphere tab.

With big skies, **beautiful settings,** quiet roads, miles and miles of walking and biking trails and fantastic access to wildlife; the **Galloway Forest Dark Sky Park** delights both night and day.

For more information visit our website or call us on 0300 067 6800

www.forestry.gov.uk/darkskygalloway

Why we came from COMETS

They race in and out of our Solar System and according to evidence, they could have brought life with them

Written by Colin Stuart

Why we came from comets

In the void between the planets, town-sized snowballs tumble quietly around the Solar System. These comets – relics from an age before large worlds circled the Sun – have been patrolling our local neighbourhood for 4.6 billion years. Hidden away in their icy layers are clues to what our Solar System was like all that time ago, along with teasers as to how our family of planets formed. But their real bounty could be knowledge of how one of the Solar System's stand-out features came to pass: life. Could these frozen foot soldiers marching around the Sun have played a role in delivering biology to its third planet? Scientists are starting to think so.

Let's be clear. The idea that life existed on comets first and was brought here as a complete, living entity – a notion called 'panspermia' – is one still very much marooned on the sidelines of mainstream science. Only a handful of researchers give it any credibility, and most look at it with outright derision. But a less extreme picture is gaining momentum: that comets played an indispensable role in peppering the early Earth with the ingredients necessary for life to later develop in our planet's warm and nurturing conditions.

Perhaps the single biggest factor in our planet's suitability for life is the presence of copious amounts of water. And thanks to our temperate position around the Sun – not close, nor too far away – that water can exist largely in liquid form. Yet, still fresh from the violent collisions that gave birth to it, the early Earth would have been too hot for any water molecules to escape evaporation.

"The impact that formed the Moon would have got rid of any ocean or atmosphere too," says Kathrin Altwegg from the University of Bern in Switzerland. The fact that we live on a wet planet today suggests that more water must have arrived on the surface some time later. And given that Earth is thought to have developed oceans within 500 million years and life is thought to have popped up within 800 million years, it must have come fairly quickly and in abundance.

So, naturally, astronomers turned their attention to the objects in space known to have a high water content: the comets. Often compared to "dirty snowballs", these small objects were formed far from the Sun when gravity gathered up grains of dust and ice into objects several kilometres across. Many of these comets crashed into the planets and their moons in the Solar System's youth.

By looking at the ones left today, scientists can judge whether their lost companions were the source of most of Earth's water. "Although

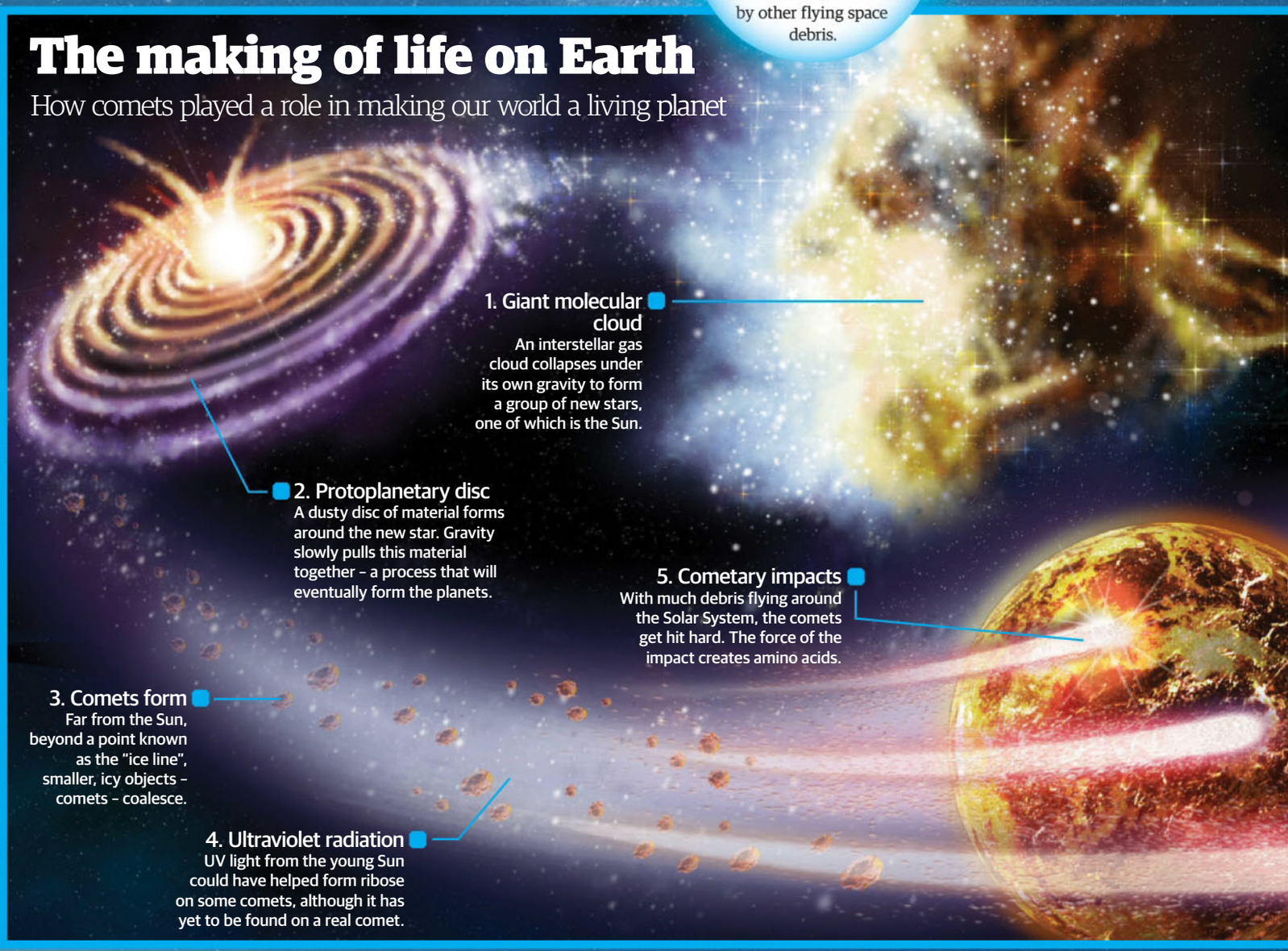
> "The fact that we live on a wet planet today suggests that more water must have arrived some time later"

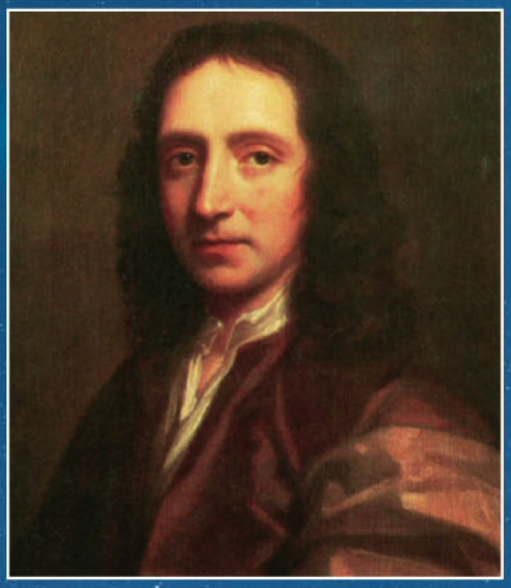
Comet impacts formed glycine

Laboratory experiments suggest amino acids, such as glycine, may form on comets as they are struck by other flying space debris.

The making of life on Earth

How comets played a role in making our world a living planet





In 1705, English astronomer, Edmund Halley correctly computed the orbit of Halley's Comet

This image of Comet Halley was taken in March 1986

Comet chemicals

Astronomers studying 'space snowballs' have found chemicals on them crucial for life on Earth

Water
The jury is still out on the exact role comets played in Earth's water supply.

Phosphorus
This element is crucial for forming DNA as well as cell membranes.

Ribose
Laboratory experiments on artificial comets have suggested that ribose could form on a comet.

Glycine
In living things, proteins are made out of amino acids. Glycine is the simplest amino acid.

Formaldehyde
Normally thought of as toxic, small amounts are key in the formation of DNA.

7. The spark of life
Somewhere deep in the ocean, probably around volcanic vents in the ocean floor, some unknown process turns these molecules into life.

6. The Earth is bombarded
Over time our planet is peppered with asteroid and comet impacts. The asteroids topped up our water and the comets delivered amino acids.

Comets contain amino acids

Complex molecules such as the amino acid glycine have been found on comets. Amino acids are chains of atoms that link together to form proteins: the workhorses of our cells.

Hunt for clues: missions to a comet

By getting up close and personal with comets, we've learned more about their role

Some comets have similar water

At least one comet has a similar proportion of heavy water as the Earth's oceans. If comets brought water, amino acids and ribose, they could form a recipe for life.

Herschel Space Telescope

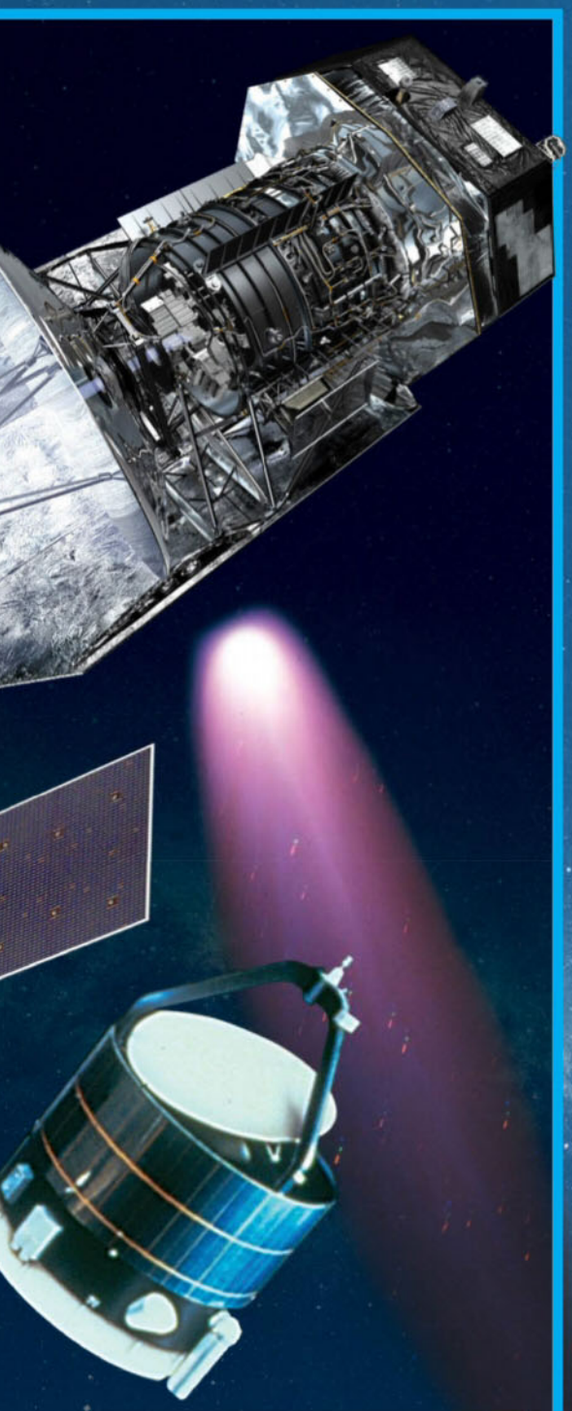
A telescope that saw in the infrared, Herschel was used to peer more closely at Comet Hartley 2. It found that there was a good match between the proportion of heavy water present on the comet and in the Earth's oceans. The comet is thought to have formed much further out in the Solar System than some of the other comets studied, and so may indicate that very long-period comets were the source of our water.

Stardust

This audacious NASA mission was sent to return a sample of Comet Wild 2 to the Earth. Launched in February 1999 and rendezvousing with its quarry in 2004, it successfully returned the sample home in 2006. Initial analysis found it contained the amino acid glycine, although some researchers had suggested the analysis might have contaminated the sample (even though the clean room used for the experiment was 100-times cleaner than a hospital operating room).

Rosetta and Philae

Perhaps the most famous comet mission of them all. In 2014, the European Space Agency successfully landed the washing-machine-sized Philae lander on Comet 67P. The orbiting Rosetta spacecraft found many examples of molecules never seen before on a comet, including the first undisputed discovery of glycine – the simplest amino acid. However, its findings also cemented the idea that the water content on comets is significantly different to that found on the Earth.



Giotto

This European Space Agency (ESA) mission was sent to study the famous Halley's Comet up close in 1986. The comet orbits the Sun roughly once every 76 years and so it was a once in a lifetime opportunity. One of the key findings was a higher proportion of so-called heavy water on Halley than is found in Earth's oceans. This suggests that comets like Halley were not the primary source of Earth's water as some astronomers had suggested.

you'd have needed 10 million comet impacts to provide enough water," explains Altwegg. And as far back as 1986, this idea hit another a snag.

Water comes in two main varieties – the ordinary water that we are used to on Earth and a rarer type called "heavy water". The difference is that in heavy water the two hydrogen atoms (water's composition is H_2O) each boast an extra particle called a neutron. Scientists can easily measure the ratio of ordinary water to heavy water in the Earth's oceans – there are 160 molecules of heavy water for every 1 million molecules of ordinary water. If comets did indeed bring that water here, the surviving ones that didn't bash into a planet or moon should also exhibit a similar ratio today.

So in 1986 the European Space Agency (ESA) sent the Giotto probe to sidle up to Halley's Comet during its once-in-a-lifetime jaunt through the inner Solar System. They found that heavy water is twice as abundant on the comet as it is on Earth. Telescopic analysis in 1999 of another famous comet – known as Comet Hale-Bopp – showed that it, too, has a significantly higher proportion of heavy water present than back here on Earth.

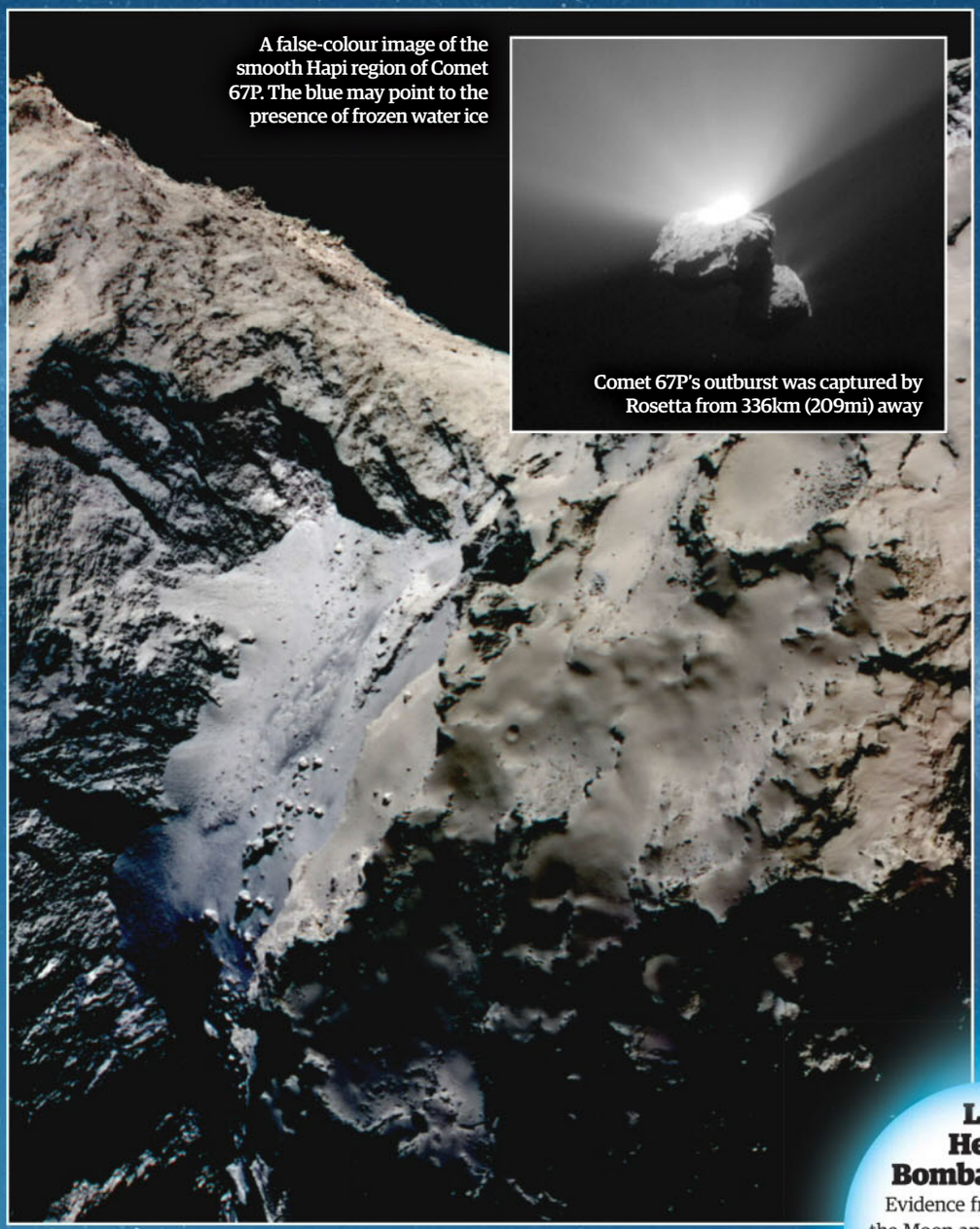
However, in 2011, astronomers used the Herschel Space Observatory to take a closer look at the Comet Hartley 2. There they found a good match between the heavy water content of the comet and the Earth. So the jury was still out.

Then came ESA's famous Rosetta probe, which carried the Philae lander on a decade-long trek to Comet 67P/Churyumov-Gerasimenko. On the 12 November 2014, the world watched as Philae made history by making humanity's first landing on a comet. Meanwhile, Rosetta studied the ancient, rubber-duck-shaped ice pile from orbit. Data from Rosetta's ROSINA instrument backed up the Halley and Hale-Bopp findings. "The proportion of heavy water on 67P is three-times higher than on Earth," says Kathrin Altwegg, the lead scientist for the ROSINA instrument.

So it seems unlikely, then, that comets are solely responsible for delivering water to our planet. "The average abundance of heavy water on comets is certainly higher than it is on Earth," comments Altwegg. That rules out comets as the dominant source of our water. However, there are two main alternative explanations. The first is that most of the water on Earth was brought here by asteroids. The second is that, over time, Earth itself replenished its surface water from deep inside the planet. "For me, this makes a lot more sense than comet or asteroid impacts because you would need a lot of them," explains Altwegg.

> "The average abundance of heavy water on comets is certainly higher than it is here on Earth" **Kathrin Altwegg, University of Bern**

The Herschel cryostat vacuum vessel being built at an ESTEC test centre in the Netherlands



A false-colour image of the smooth Hapi region of Comet 67P. The blue may point to the presence of frozen water ice

Comet 67P's outburst was captured by Rosetta from 336km (209mi) away

The Stardust capsule that crash-landed back on Earth with comet dust on board

Late Heavy Bombardment

Evidence from craters on the Moon and other celestial bodies indicates that the Earth was hit by a lot of impacts around 4 billion years ago.

While comets might not have brought us the majority of our life-giving water, other results from Rosetta suggest these ice mountains might have played a different, yet still vital role. Altwegg and her team scrutinised the comet's coma – the dusty cloud of material that cocoons 67P as it is warmed by the Sun. Tucked away inside they found glycine, the simplest version of molecules called amino acids, which are often referred to as the building blocks of life because on Earth they link together to form proteins, the workhorses of our cells. Glycine had previously been found in dust returned to the Earth from Comet Wild 2 by NASA's Stardust mission, but some researchers argued that the sample might have become contaminated during the analysis. The Rosetta finding was the first undisputed discovery of glycine on a comet.

The Rosetta team also found other chemicals important for life on 67P, including phosphorus and formaldehyde – both play a key role in the formation of DNA. Other molecules known to be important in building amino acids had already been found on Halley's Comet, Hartley 2 and Hale-Bopp, but Rosetta was a step up. "We more than doubled the number of molecule types found on comets from 28 to 60," says Altwegg. But how did these molecules end up there?

Zita Martins, an astrobiologist at Imperial College London, believes she might have the answer: they were forged when comets were struck by other space debris. Along with colleagues, including Mark Burchell at the University of Kent, she created mixtures of ices similar to those found on a comet and used a gas-powered gun to fire steel projectiles at them at seven kilometres (4.3 miles) per second in order to simulate the comet being hit. "It took us three years to get the ice mixtures right," says Burchell. "But after the impact the ices contained amino acids like glycine." They have called the effect "shock synthesis."

In a separate laboratory study, a team at the Institut de Chimie de Nice in France also mocked up artificial comets using different mixtures of ices. They cooled water, methanol and ammonia ices to -200 degrees Celsius (-328 degrees Fahrenheit), and then shone UV light onto the blend to simulate the glow of newborn stars. They then brought it up to room temperature to mock up the comet getting close to the Sun later in its life. They found several complex molecules had formed during the process – the most exciting of which was ribose, which helps form RNA (a simpler version of DNA). It must be stressed, however, that ribose is yet to be found on a real comet.

If amino acids and sugars are really created in this way in space, and many comets once rained down on our planet, the comets could have delivered them to the Earth. The exciting thing about that idea is that our planet wasn't the only place to get battered by comets in its infancy. The other planets, along with their bevy of moons, were also bombarded. So anywhere those molecules might have mixed with liquid water is an enthralling place to explore. That's

Comets contain sugars such as ribose

Laboratory experiments suggest ribose may form naturally on comets. Ribose is a crucial part of RNA (ribonucleic acid), which is highly similar to DNA (deoxyribonucleic acid).

The early Earth is thought to have been battered by a bevy of comets

"Anywhere these molecules [amino acids and sugars] might have mixed with liquid water is an enthralling place to explore"

particularly true for icy moons with liquid oceans orbiting Jupiter and Saturn.

"These moons have a big problem in that they orbit giant planets that might sweep up most of the impacts," says Duncan Forgan, an astrobiologist from the University of St Andrews, Scotland. "But all it takes is enough hits and enough might not need to be big numbers." That puts Jupiter's moon Europa and Enceladus around Saturn top of the destination wish list for future robotic exploration.

Although not all astrobiologists agree that comet impacts are a big deal when it comes to kick-starting life. Lewis Dartnell from the University of Westminster, UK, believes amino acids were probably here on Earth all along, even before the comets hit. "If that chemistry is going on in space then it was almost certainly already going on in the primordial seas of planets like Earth and Mars," he says. Glycine, for example, could have been present in the cloud of gas and dust that collapsed to form the Sun and the planets. That way glycine would have become incorporated into the Earth whether comets bombarded us or not. Radio astronomers have attempted to detect glycine in similar gas clouds elsewhere in our galaxy with mixed results. Some have claimed a discovery, but others have questioned their findings.

So the picture is still blurry. It just goes to show that the origin of life on Earth is a complex story with many twists and turns. Slowly but surely, however, we are starting to piece together the tale of how our planet came to host living things. And in doing so, we might also get a better idea of the chances of finding other life forms out there among the stars. Because if comets did indeed make a significant contribution to Earth's complex chemistry, there could be new planets out there being showered with comets right now, setting the wheels in motion for a brand new form of alien life to take hold.

An image of Comet Hale-Bopp with two distinct tails - the products of solar wind and flung grit

Restoring the rocket to the Moon

Astronaut Fred Haise and executive director of the Infinity Science Center, John Wilson, on bringing the Saturn V booster back to life here on Earth

Interviewed by Nick Howes

Can you tell us how restoring the Apollo 19 first stage [Saturn V booster] came about?

John: The idea of moving the booster goes as far back as 2005 in the aftermath of hurricane Katrina and the storm surge/flooding that impacted the NASA Michoud Assembly Facility in New Orleans, US, which is where it was being kept at the time. The booster sat in outdoor storage for more than 35 years, weathering hurricanes, salt air and blistering sunshine. I believe folks then began to see that this priceless artefact was at potential significant risk in its current location of rotting away to nothing. During that time, we were in the concept stages of designing Infinity [Science Center] and kicked around the idea of moving it here. However, we were very focused on raising the money to build Infinity and put this idea on hold. Since then, we did get Infinity built (our doors opened in April 2012) and have been building its fiscal stability. Although we are still a "toddler" in terms of a science centre type institution, we are growing up by adding exhibits and developing a presence in the area.

In January 2015 we went to the Mississippi State Legislature and asked for funding to do such a project as move the booster, as it carries both a historical significance and a huge tourism impact. We were awarded enough to accomplish Phase 1 of the project, which was to get it here. There are several more phases to go, including conservation, constructing a building to protect it, and developing the exhibition that will tell the story of building and testing such audacious hardware, as well as the roles played in that effort by Michoud Assembly Facility and Stennis Space Center (then Mississippi Test Facility).

We hope to secure more funding this summer to begin the conservation phase. In terms of timing, we moved it past June because the stars just seemed to be aligning. A combination of the secured funding and partnering with a stellar contractor to handle the move told us that the time was right. Now, the booster is here, and what was once a vision has become reality for us. We have much work to do yet, and we are very keen to get started.

> "At about 6.30am on 18 June the booster began its last journey on a water route it had traversed before, some 43 years earlier"

Fred Haise would have been the sixth person to walk on the lunar surface if the Apollo 13 landing had not been aborted

Was your vision for the restoration of the S-1C from Apollo 19 similar to Fred [Haise]?

John: I think we both want to see the last remaining piece of large-scale Apollo hardware preserved for future generations. Fred possesses a very unique perspective concerning this booster in that he has actually ridden on one. My job as a museum professional is to come up with a way to not only display the artefact, but also to translate and interpret its historical significance and how it still serves as a pathfinder technology for future heavy-lift missions.

Can you explain some of the logistical challenges you faced in moving such a huge piece of space hardware, and explain how some of this may have been similar or varied from the transportation of the S-1C in the Apollo era?

John: The logistical challenges were significant; let me put that one out there from the outset. First, because the booster had been stored in its horizontal transport configuration for more than 40 years, there was concern among many that its structural integrity had been compromised by corrosion and decay, as water had collected in many of the horizontal nooks and crannies. One of our volunteers at Infinity, Mr John Crouch, an Apollo era engineer, would gently remind us that this first stage was by far the strongest of the three and was designed to support in vertical configuration the second and third stages, as well as the Command and Lunar craft.

We moved on to worry about other things like the jacking up operation that enabled the placement of the SPMT (Semi Portable Modular Trailer) units. As you can imagine, that operation had to be performed very slowly accompanied by constant checks for torsional stressing, joint failures at the forward

transport "spider", and other indications that too much strain was being imparted into the booster. Once loaded onto the SPMT, it was now a matter to slowly move it to the dock at the Michoud Assembly Facility, a land transit of about 2.4 kilometres (1.5 miles). Once secured on the barge, a marine inspector surveyed the lashing and gave the thumbs up to begin the water transit phase. At about 6.30am on 18 June the booster began its last journey on a water route it had traversed before, some 43 years earlier, when it was brought over to the NASA Stennis Space Center, then the Mississippi Test Facility, for an all-up test of the booster and its five powerful F-1 engines.

The water route was approximately 64 kilometres (40 miles), and the booster, being towed by one tug and pushed by another, arrived at the NASA Stennis Space Center at approximately 6.30pm. At this point, only two other hurdles remained. The first was to off-load from the barge and transport by land on the smallest section of road yet; a very narrow one-lane gravel path with several very tight turns. The agility of the SPMTs and the skill of the crew made this part look easy – although it certainly was not. The last remaining bit was to pause for two days, allowing the crew to rest in preparation of the final leg, a 6.4-kilometre (four-mile) trek on one of the United States' busiest Interstate highways – I-10.

On the evening of 21 June, the crews assembled along with scores of transportation officials, law enforcement officers and utility crewmembers to begin the last part of the journey. The convoy was preceded by the utility crews who either lowered or raised electric power and fibre communication lines as required for the booster to transport. In several locations the tip of the Saturn V tail fins just cleared at approximately 14.3 metres (47 feet). The law enforcement officials first shut down all traffic on the westbound lane and the convoy proceeded down that lane for about 3.2 kilometres (two miles), conducted a ballet of turns, ending in preparation of transit in the opposite direction for the last 3.2 kilometres (two miles). At approximately 3.30am, the booster arrived at the Infinity parking lot, much to the great relief of many!

The state of Mississippi helped fund the initial move of the S-1C. Were there any petitions to the state governors or congress to help support it in full, as a national treasure?

John: We received tremendous support from state representatives and key corporate leaders to make this happen, but the process of raising the funds to move, conserve and protect the booster is a multi-faceted one and will continue over several years. We are exploring every avenue to make this project in total a reality. The state of Mississippi has been the first exemplary player with the appropriation of $1.2 million (£968,000). We're now turning our attention to corporate sponsors and crowd sourcing.

Fred, aside from being the state of your birth, can you tell us more about the role that Mississippi played in the Apollo programme?

Fred: For the purpose of rocket engine testing, the Mississippi Test Facility was created in the early 1960s. The large rocket engines planned by Dr

INTERVIEW BIO

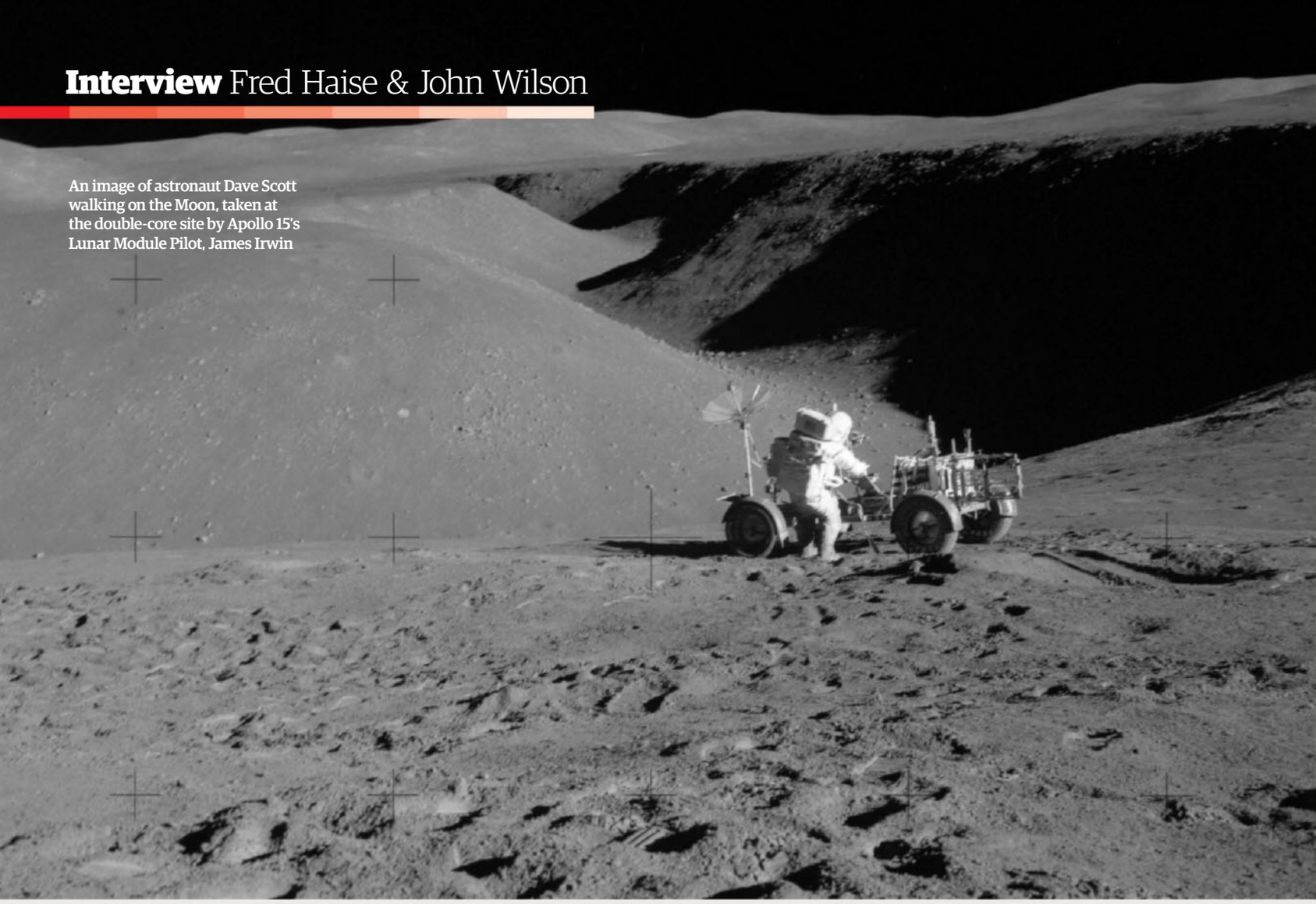
Fred Haise

One of 24 people to have flown to the Moon, Fred Haise is an American aeronautical engineer, former naval aviator, fighter pilot and former NASA astronaut. Haise would have been the sixth person to walk on the lunar surface but the Apollo 13 mission, of which he was the Lunar Module Pilot, was aborted before landing on the Moon, while what would have been his second lunar mission, Apollo 19, was cancelled entirely.

INTERVIEW BIO

John Wilson

John Wilson is the executive director of the Infinity Science Center, a museum in Mississippi, US, after serving at the Chief Technologist's Office at NASA's Stennis Space Center. Wilson held the role as NASA's representative during the design and construction of Infinity.



An image of astronaut Dave Scott walking on the Moon, taken at the double-core site by Apollo 15's Lunar Module Pilot, James Irwin

Wernher Von Braun would need a large area because of the noise created. The site itself was established on some 200,000 acres (80,937 hectares) but in addition, needed a larger buffer zone that extends several miles west into Louisiana and east toward the I-10 exit for Bay St Louis. Several small towns had to be vacated; this area was established by tests with a large acoustic horn mounted on a tower that resides at Infinity Science Center.

Every rocket engine that flew in the Apollo Programme was tested and certified flight ready for shipment to Kennedy Space Center. This included the five F-1 engines on the first stage, five S-2 engines on the second stage, and the single S-2 engine on the third stage. In fact, the first stage of the Saturn V, now resident at Infinity Science Centre, was shipped from the Michoud Assembly Facility to the now Stennis Space Center for certification firing, and then moved back to Michoud some 40 years ago.

Much has been said and written about the Apollo 13 mission, but in the context of the S-1C, how did the launch for you compare to the simulations, and was "staging" as much of a kick as the movie *Apollo 13* depicts?

Fred: Our simulation did not include any of the dynamics of the ride on the booster but primarily trained us to recognise system problems with the boosters that might require an abort or takeover of control. There never was a crew takeover of controlling the booster and I doubt the crew could manoeuvre the stack as efficiently as the automatic control through the Saturn Instrument Unit that resided in the third stage. At lift-off you could tell that you were moving but it was not a "big kick in the pants." The most unusual motion throughout first stage was caused by the gimbaling of the four outer F-1 engines. The motion was "herky-jerky" and the side-to-side seemed the to be the most unusual that I had experienced in aircraft. The couches we laid in were suspended with some clearance provided on each side, so they could stroke in event of a hard landing from failed parachutes, or even to support an abort resulting in a landing on land.

> "Our simulation did not include any of the dynamics of the ride on the booster but trained us to recognise system problems"

The highest G level was a bit over 4G; that was modest compared to our past career experience with combat manoeuvring in fighter aircraft. The biggest surprise to me was when the engines shut down ahead of staging. If I hadn't been strapped in, I would have been thrown into the instrument panel. I was ready for this "train wreck" from prior mission debriefings but it still was impressive to experience.

What are the plans in terms of how the S-1C will be displayed? Do you have ideas for how to let the public "feel" the power of the lift off in some way?

Fred: Our plans are to display the booster in its transport configuration, which includes the massive ground transport structure along with the aluminium "spider." Once the building is complete, we hope visitors experience what it was like standing on the deck of the barges NASA used to transport these mighty vehicles, either to be tested at the Stennis Space Center or to its launch destination at Cape Canaveral in Florida.

John: We do intend to display the booster in a way that visitors can get very close to it and we even have plans to open hatches and install cameras so that visitors can "fly" the camera inside the two fuel tanks that comprise the booster. And, of course, we plan to incorporate other artefacts in our collection or that we have on loan from NASA and the Smithsonian, such as the Apollo 4 capsule, Fred's A7L space suit, a lunar sample from Apollo 14 and much more.

Some 45 years on from Apollo 19, the mission you should have flown on, do you still look up at the Moon and think you should have walked on it?

Fred: I did think a lot about losing the chance to land and walk on the Moon on the Apollo 13 mission and, again, for some time after the cancellation of Apollo 18 & 19. However, my feelings have changed

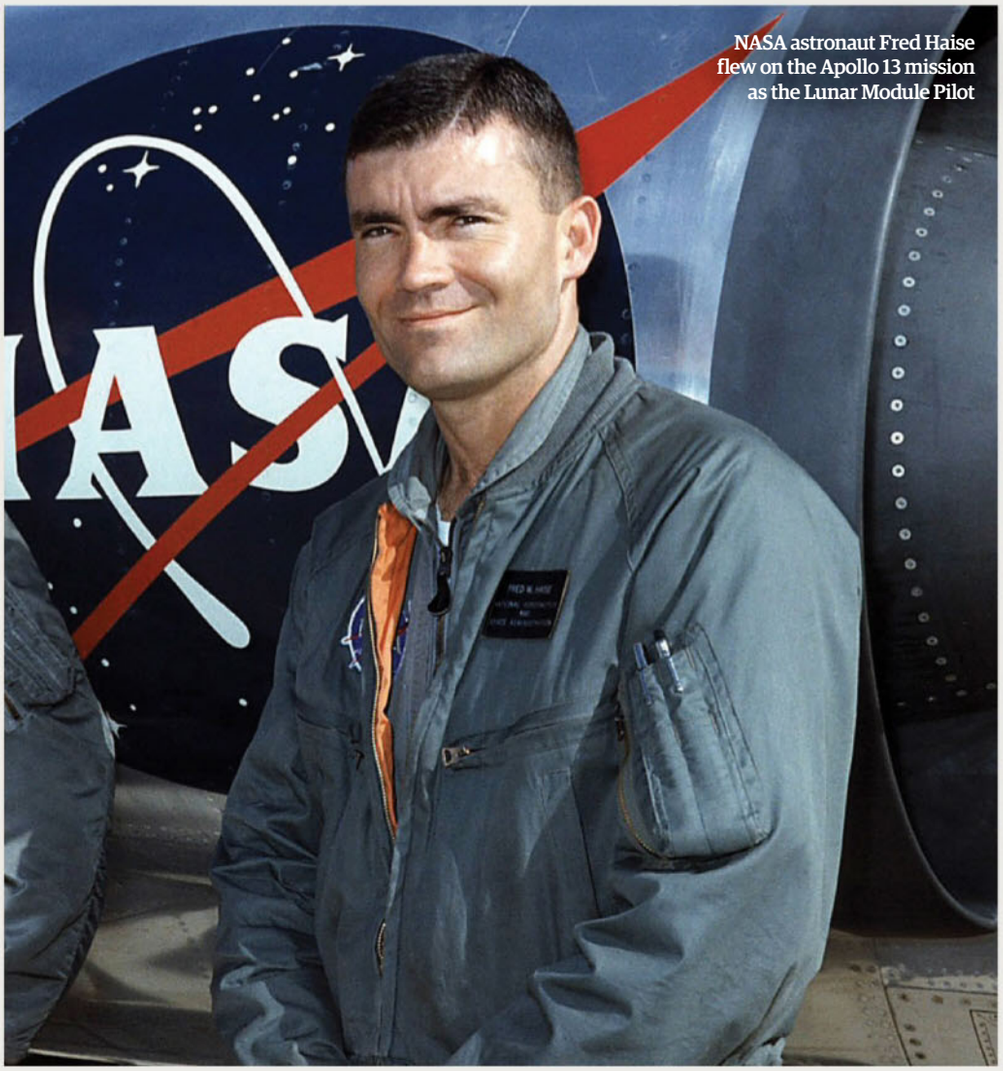
over the years. We have not gone back to the Moon since those days and today I just feel privileged, even lucky, to be one of the 24 humans that have had the opportunity to fly on a lunar mission.

Flight controllers have cited you as one of the very best of the pilots from the Apollo programme. What was it about the Space Shuttle programme that interested you?
Fred: I will accept the compliment with a grain of salt. Most of the astronauts through my pilot group chosen were very similar in their backgrounds and experience. All were military or former military, with comparable flight experience, and most were test pilots. I had heard that Deke Slayton's belief was that any of those chosen in that time could have flown any mission. The Space Shuttle interested me in several ways. It was an extension of the winged vehicles that I had witnessed in my NASA test pilot years with the X-15 programme. It also offered an opportunity to be a part of a major development of a new vehicle from day one. I participated in the source selection process, evaluating the proposals. I left the Astronaut Office to work under Aaron Cohen, orbiter project director, for four years; working more in a management role was great experience for my later career in the Aerospace World. I participated in contractor reviews, design reviews, engineering change board, engineering simulations, and a myriad of meetings dealing with the normal problems that are encountered in any new, complex vehicle creation. I considered then being assigned as the commander of one of the two crews to test the Space Shuttle Enterprise, the highlight of my career.

In terms of a lasting legacy to Apollo, does Infinity have any further plans once the restoration of this stage is complete, and can you tell our readers more about what they can see at the centre?
John: Fred would be reticent to concur with my plans but they include not only displaying and interpreting the booster, but also to tell the story of "Freddo", a true American hero in so many ways. His work ethic, forged in his childhood as a paperboy and demonstrated through countless hours in training as a pilot and later as an astronaut, serve as an example of what we need to rekindle in our youth today. He is a test pilot, astronaut, corporate executive, but he is also a devoted father and grandfather and one of the kindest men I have ever known. I want people to know that part about this wonderful individual.

Finally, how can our readers support this project?
John: There are three or four ways readers can support our efforts to conserve and restore the Apollo 19 booster and ultimately create a larger exhibit. Through our website, we have made available an Apollo 19 mission patch that is autographed by Fred Haise. For a donation of $150 (£120), you'll receive the autographed patch in a commemorative sleeve; the full-sized embroidered emblem is a replica similar to one Fred and his crew wore to the Moon. Supporters can also make a donation of any amount through our website. Fred is also very gracious with his time and accepts speaking engagements around the world, and he supports the Infinity Science Center by donating all of his speaking fees.

"I just feel privileged, even lucky, to be one of the 24 humans that have had the opportunity to fly on a lunar mission"



NASA astronaut Fred Haise flew on the Apollo 13 mission as the Lunar Module Pilot

The Saturn V S-1C-15 rocket stage arrives at Stennis Space Center, Mississippi, on 16 June 2016

The Mission Operations Control Room during the fourth television transmission from the Apollo 13 craft in 1970

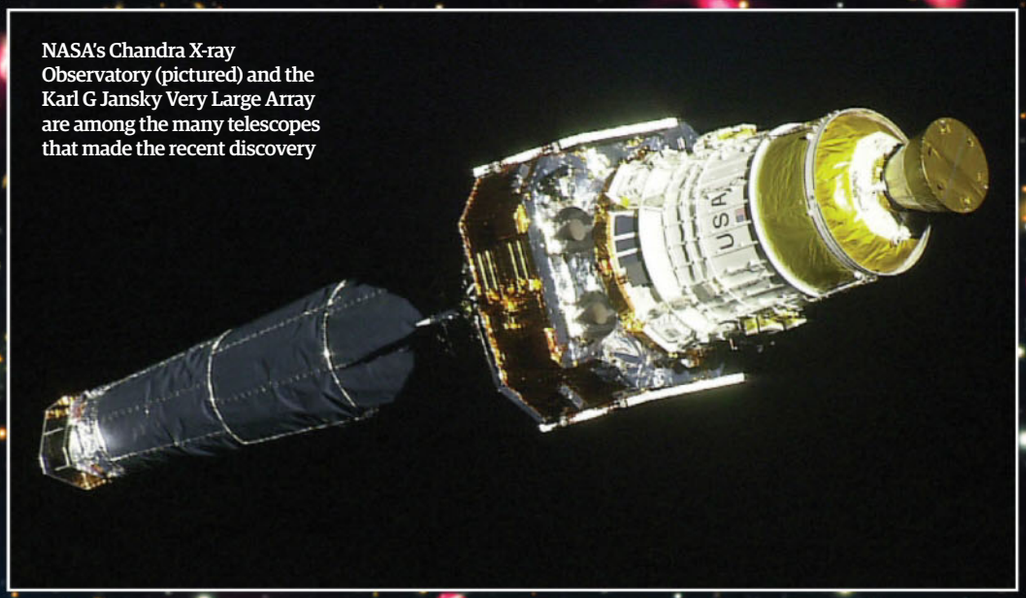
A cosmic double whammy

For the first time ever, astronomers have seen what happens when two of the most powerful phenomena in the universe combine

What happens when you combine the stupendous powers of a supermassive black hole with the collision of giant galaxy clusters? Astronomers using combined observations from NASA's Chandra X-ray Observatory, the Giant Metrewave Radio Telescope (GMRT) in India, the Karl G Jansky Very Large Array in New Mexico, among other telescopes, have discovered that you get a gigantic cosmic particle accelerator. This cosmic double whammy is the work of galaxy clusters Abell 3411 and Abell 3412, which have collided some 2 billion light years from Earth. Both of these clusters are massive, each weighing in at about a quadrillion – or a million billion – times the mass of our Sun.

The comet-shaped appearance, shown here in hot blue X-rays, is the result of hot gas from one cluster smashing into the hot gas of the other. Galaxies can be seen in the mash up between the two structures, while tell-tale signs of a spinning supermassive black hole at work are evident from the rotating, tightly-wound magnetic funnel. Electromagnetic fields have accelerated some of the inflowing gas away from the black hole in the form of a high-speed jet.

The discovery solves a long-standing mystery about the origin of swirls of radio emissions, which stretch for millions of light years



NASA's Chandra X-ray Observatory (pictured) and the Karl G Jansky Very Large Array are among the many telescopes that made the recent discovery

THE NEW SPACE RACE

Private companies and government agencies are racing ahead with ambitious plans to reach Mars – but who will get there first?

Written by Giles Sparrow

© Adrian Mann

THE PLAYERS

BLUE ORIGIN

Founded: 2000
Owned by: Jeff Bezos

The secretive Blue Origin aerospace company is developing pioneering reusable spacecraft that could play a key role in future Solar System exploration – but will it overtake its bigger rivals in the ongoing race to the Red Planet?

SPACEX

Founded: 2002
Owned by: Elon Musk

The fast-growing commercial space company has already made a big impact, and its Interplanetary Transport System (ITS) is a spacecraft like no other. But are the ambitious company's plans for a Mars landing in the next decade realistic?

NASA

Founded: 1958
Administrator: Charles Bolden

The US national space agency has a big budget on its side in the race for Mars, but delays to Orion and the SLS mean that it's still without a functional crewed spacecraft, and its necessarily cautious approach could take decades to put people on Mars.

MARS ONE

Founded: 2012
CEO: Bas Lansdorp

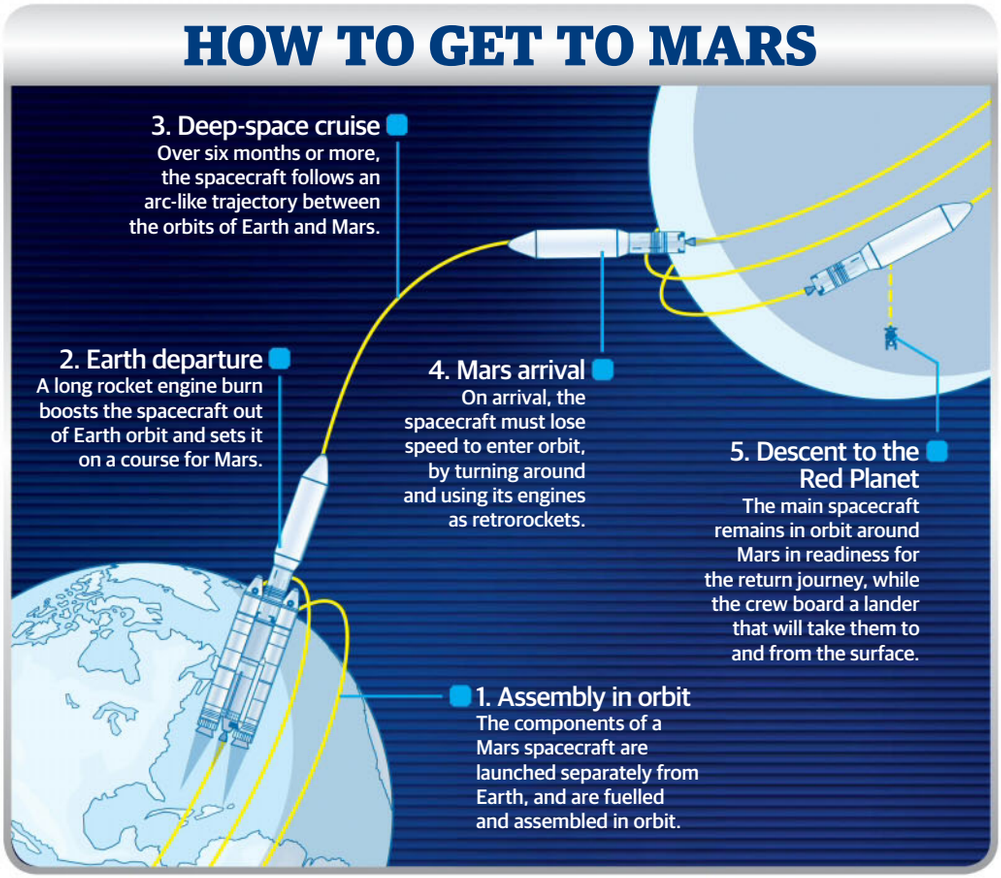
After processing applications from thousands of would-be Martian colonists, the cagey Mars One foundation faces a big challenge in striking deals for technology and hardware if it is to meet its ambitious launch targets.

Half a century ago, the dawn of the Space Age saw huge achievements, culminating in the Apollo Moon landings and humankind's first steps on the surface of another world. Now we're on the cusp of a bold new age where human explorers finally break free of Earth orbit, setting out on the much longer and more challenging journey to our next destination in space, the Red Planet. And just as those early leaps forward in space exploration were driven as much by fierce competition between political superpowers as they were by pure scientific curiosity, the new race to Mars is also inspired by a spirit of competition. This time, however, the players are not just rival national space agencies, but commercial enterprises and wealthy individuals with goals ranging from scientific curiosity and commercial exploitation, to nothing less than insuring the future of the entire human race.

In the aftermath of the Apollo missions, scientists and engineers confidently predicted that the colonisation of Mars was the next obvious step in our exploration of the Solar System – it seemed inconceivable that almost 50 years later, astronauts would not even have returned to the Moon, let alone ventured beyond Earth orbit. More than one US president gave NASA a mandate to prepare for Mars, but in reality the thawing of Cold War tensions made expensive space budgets an obvious target for cutbacks. Meanwhile, rapid advances in electronics and computing allowed the development of robotic space probes that could explore the Solar System on their own terms, with far less cost and risk than sending human crews.

> "There's a new space race underway, and the players have set their sights not just on easier travel to Earth orbit, but also on targets across the Solar System"

It took a traumatic event for things to change. The loss of the Space Shuttle Columbia during atmospheric re-entry in February 2003 led to the shelving of the entire shuttle programme as soon as work was complete on the construction of the International Space Station (ISS). In 2004, President George W Bush announced that NASA's mission would instead refocus on deep-space exploration beyond Earth orbit, with an ambitious new spacecraft and rocket system, the Constellation Programme, which would allow astronauts to establish a permanent settlement on the Moon and ultimately set out for Mars. And while NASA's new spacecraft were being designed and developed, the task of supplying the ISS would be turned over to new commercial spaceflight companies.



"It seemed inconceivable that almost 50 years later, astronauts would not have returned to the Moon, let alone ventured beyond Earth orbit"


Inside the huge fuel tank of NASA's Space Launch System, welders complete the final plug fusion welds

But rocket science is an infamously complex and expensive business, so perhaps it's little wonder that those ambitious plans didn't pan out quite as expected. In the face of delays and spiralling budgets, changes brought in by the Obama administration saw the twin launch vehicles of the Constellation Programme scrapped, and much of their technology incorporated into a new Space Launch System (SLS). NASA's new crewed spacecraft, known as Orion, has also gone through some significant changes, and is still not expected to make a crewed flight until 2023.

What no one could have anticipated, however, is that the commercialisation of space travel, unleashed by NASA's change of focus, would prove so successful that it now threatens to beat the government agencies at their own game. There's a new space race underway and the players have set their sights not just on easier travel to Earth orbit, but also on targets across the Solar System. Could it even be that private space companies will make the first crewed landing on Mars?

In order to assess where the various players currently stand, we need to appreciate the scale of the challenge they face. A crewed mission to Mars is a vastly more difficult proposition than a return to the Moon. Most obviously, there's the distance involved: while the Apollo astronauts took just a couple of days to cross the 400,000 kilometres (248,550 miles) to our satellite, Mars is 56 million kilometres (34.8 million miles) away, even at closest approach – a journey of several months at Apollo-like speeds. What's more, the distance between Earth and Mars is constantly changing as each planet follows its own orbit around the Sun. Astronauts reaching Mars could not simply return to Earth after a few weeks on the surface – instead, they will be stuck there for around two years, which is the time it takes for the two planets to return to a close alignment.

All this time spent beyond Earth's gravity, protective atmosphere and magnetic field would pose considerable health hazards, and with short-term supply runs from home impractical, the crew will need to take everything they need with them, or manufacture it on Mars. As a result, it's likely that supplies (perhaps even a fully-equipped Martian base) would need to be in place on the surface of the Red Planet before the astronauts even left Earth orbit.

And then there's the question of getting home again. A Mars mission might take the same approach as the Apollo programme, with the main spacecraft waiting in orbit while the crew used a smaller vehicle to travel to and from the surface. But with such a long journey in both directions, the mission would either need to take a huge amount of unused fuel all the way to Mars, or refuel in orbit – and once again, the risks involved might mean placing a fully-fuelled return vehicle in orbit before attempting a landing.

Fortunately, Mars is not the Moon – the environment may be hostile but as space probes have revealed its secrets, it has become clear that there is abundant ice in the Martian soil, which could be put to a variety of uses. A future settlement might be able to make not just water, but also oxygen and even rocket fuel for the return journey, in situ at Mars. The idea of manufacturing rocket fuel (specifically methane) at Mars, using an automated chemical plant sent from Earth, was first put forward in 1990 by

"When we have millions of people living and working in space, we want them to be able to go to lots of destinations. Mars would be one of them. The Moon would be another" **Rob Meyerson, president of Blue Origin**

engineers Robert Zubrin and David Baker as part of a cost-effective mission profile called Mars Direct, and as we'll see, it's already shaping the next generation of space technology even while a mission to Mars itself remains a distant dream.

NASA's own plans for an actual Mars mission remain tantalisingly (and perhaps wisely) undefined – for the moment, the agency is focusing on getting its new Orion spacecraft and SLS launch vehicle (both likely key elements of such a mission) into flight. Once Orion is up and running in the next decade, the agency foresees the next step as a series of "Proving Ground" missions in the space between Earth and the Moon. These would give the opportunity to attempt complex operations and test new technologies necessary for a Mars trip, while remaining within reach of Earth. Beyond that, perhaps in the 2030s, astronauts would begin "Earth-Independent" missions – perhaps an asteroid rendezvous and exploration, a trip to Martian orbit, or even the exploration of one of the planet's tiny Moons. Each of these would be considerably less risky than a full-blown landing, but still allow astronauts to test the limits of space endurance. At that rate, however, a full-blown landing might not happen before the middle of this century, and some people don't want to wait that long.

Until recently, private space companies have kept their plans for reaching Mars under wraps, but in the past few months we've started to get a better idea of what some of them have planned. Leading the field is SpaceX, the company founded by Elon Musk (an entrepreneur who made his fortune with PayPal and who is now equally well known for the pioneering Tesla electric cars).

In 2008, the SpaceX Falcon 1 became the first privately funded, liquid-fuelled rocket to reach orbit, and SpaceX has since carved out a substantial business in the highly competitive satellite launch industry. As well as delivering cargos to the ISS using the larger Falcon 9 rocket and an uncrewed spacecraft called Dragon, the company is developing a human-rated version of the Dragon, as well as perfecting the technology to return rocket stages to Earth with a vertical touchdown, for later reuse.

However, the full scope of SpaceX's ambition was only revealed in September 2016 when Musk

SUPPLIES

Transport
In order to explore the landing site, astronauts will need transport. This could range from small, agile buggies to a pressurised laboratory capable of spending weeks away from base.

Air
Using electricity from solar panels, water molecules can be split apart in a process called electrolysis, releasing oxygen for life support systems and hydrogen that could be recycled in a fuel plant.

Food
With food supplies from Earth limited, astronauts will grow as much of their own food as possible – at first in sealed hydroponic greenhouses, but perhaps later in the Martian soil itself.

Fuel
Using the Sabatier process, a fuel plant could combine a hydrogen 'feedstock' with carbon dioxide from the atmosphere to form methane and oxygen. Stored in liquefied form, these could provide rocket fuel for the journey home.

Shelter
Pressurised living quarters can maintain an Earth-like temperature and atmosphere, but burying them underground (in a cave or using a digger to cover the base in soil) would reduce temperature extremes and offer protection from radiation.

Water
As well as its icy polar caps, we now know that the Martian soil is rich in frozen water ice, just below the surface. Once melted using solar energy, water could have a variety of uses – but any used for drinking would need to be carefully filtered first.

addressed the 67th meeting of the International Astronautical Congress and unveiled its so-called Interplanetary Transport System (ITS). This mammoth project involves a fully-reusable two-stage launch vehicle – a lower-stage booster that would return to Earth after each flight and an upper stage with a large integrated spacecraft that would make interplanetary voyages, after taking on fuel from a tanker launched separately into Earth orbit.

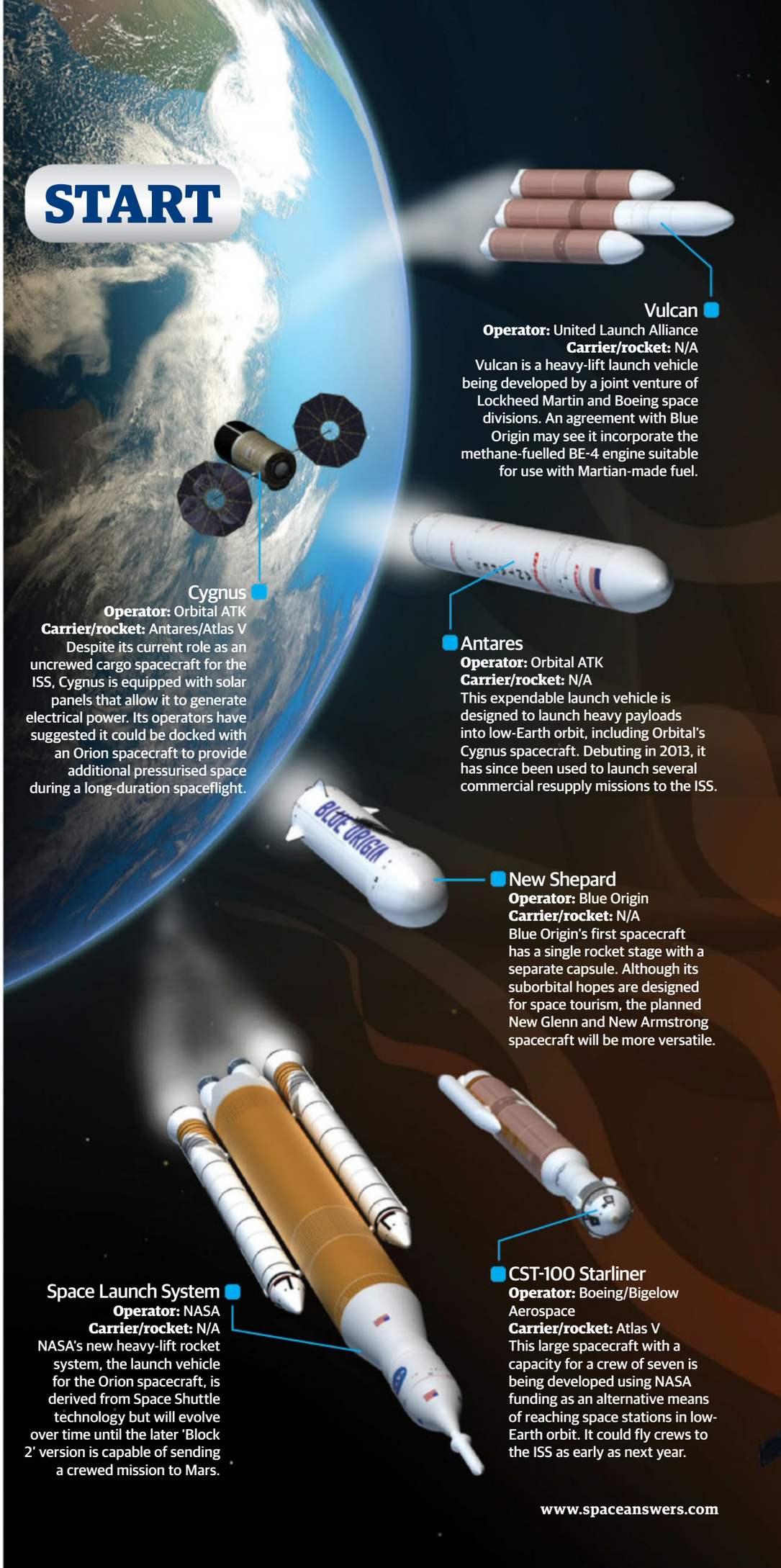
Previously called the Mars Colonial Transporter, the ITS has been renamed because, its designers claim, it has the potential to take astronauts far beyond Mars. Its Raptor rocket engines are designed to burn a mixture of liquid oxygen and methane (fuels that can be manufactured easily at Mars), and the finished vehicle will be taller than the Saturn V Moon rockets and capable of launching more than twice the payload to Earth orbit. "What I really want to try to achieve here is to make Mars seem possible – like it's something we can achieve in our lifetimes," says Musk. And his interest, he says, is not just driven by curiosity about the Red Planet, but by concern for the future of humanity.

"I really think there are two fundamental paths: one is that we stay on Earth forever and then there will be an inevitable extinction event," he says. "The alternative is to become a spacefaring civilisation and a multi-planetary species." SpaceX has an admirable track record of fast rocket development, but even optimists would have to wonder if it's being too optimistic with its plans for a first crewed flight to Mars in 2024. However, we may get a better idea in 2018, when the company plans to launch Red Dragon – an ambitious mission to land an uncrewed Dragon capsule on Mars using the company's as-yet-untested Falcon Heavy launch vehicle.

Taking a more measured approach is Blue Origin, another space venture founded by an internet entrepreneur (in this case, Amazon's Jeff Bezos). While SpaceX has aimed at the commercial launch market and NASA contracts, Blue Origin has remained rather more secretive, developing its own reusable technology and a reusable suborbital spacecraft called the New Shepard (after Alan Shepard, the first American in space). Crewed test flights are planned for later this year and the company is already moving on to more ambitious plans for an orbital spacecraft called the New Glenn, and a seldom-mentioned advanced vehicle called the New Armstrong.

Questioned about plans for the Armstrong in 2016, company president Rob Meyerson dropped some intriguing hints: "When we have millions of people living and working in space, we want them to be able to go to lots of destinations. Mars would be one of them. The Moon would be another. New Armstrong is really designed for that long-term vision." Blue Origin's vision and record so far suggest that they're thinking about the long term, developing spacecraft that may be used decades from now, rather than in a few years time. Another hint of an interest in Mars comes from the company's development of liquid oxygen/liquid methane rocket engines that could potentially be refuelled using Martian resources.

But something of a wildcard in all this excitement is Mars One, a venture set up by Dutch entrepreneur Bas Lansdorp. Founded in 2011, it received a lot of



CHALLENGES ON THE WAY

Hazards of low gravity
Long-duration spaceflight takes a toll on the human body, as muscles lose their strength and bone becomes less dense. Exercise during the journey would be a must to stay healthy.

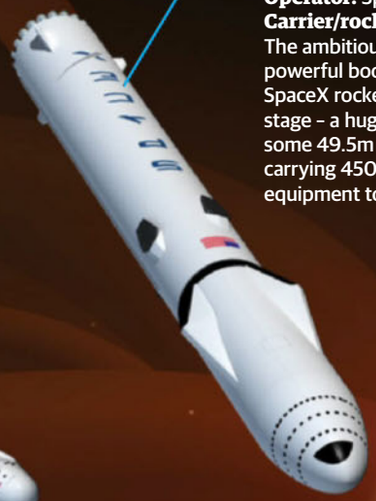
No turning back
Once a craft has left Earth orbit, the astronauts are on their own if anything goes wrong. Even if the mission aborted with a Mars slingshot, it would be unassisted for nearly a year.

Space radiation
Outside of Earth's magnetosphere, high-energy radiation can cause cell damage that accumulates over time. A craft may need heavy shielding to protect it, increasing the cost.

Entry to the atmosphere
Weakened by months in space, the crew will need protection from the pummelling of atmospheric entry. Putting a heavy craft onto the surface requires complex descent techniques.

Falcon Heavy
Operator: SpaceX
Carrier/rocket: N/A
Scheduled for its first launch this year, the Falcon Heavy adds two strap-on boosters to the standard Falcon-9 first-stage rocket, allowing it to lift heavier payloads to Earth orbit and send smaller ones, such as SpaceX's planned Red Dragon mission, towards Mars and other interplanetary targets.

Interplanetary Transport System
Operator: SpaceX
Carrier/rocket: ITS booster
The ambitious ITS system includes a powerful booster stage using successful SpaceX rockets and a unique upper stage – a huge Interplanetary Spacecraft some 49.5m (162ft) long, capable of carrying 450 tonnes of passengers and equipment to Mars and beyond.



Dragon & Red Dragon
Operator: SpaceX
Carrier/rocket: Falcon series
Initially an uncrewed cargo vehicle, SpaceX's Dragon capsule could soon carry astronauts to Earth orbit, while an adapted uncrewed capsule called Red Dragon is slated for a 2018 mission to Mars.

Orion crew module
Operator: NASA
Carrier/rocket: Space Launch System
The Orion Multi-Purpose Crew Vehicle (MPVC) is designed to carry four astronauts to destinations in interplanetary space. It will form the core of any NASA mission to Mars.

END

MARS DIRECT
Proposed by Robert Zubrin and David Baker in 1990, this sees an uncrewed Earth Return Vehicle launch to Mars before a crewed mission. After landing, it deploys a chemical plant for refuelling and generating other consumables. Some 26 months later a Mars Habitat Unit is launched. After six months in space, the crew of four explore the surface for 18 months.

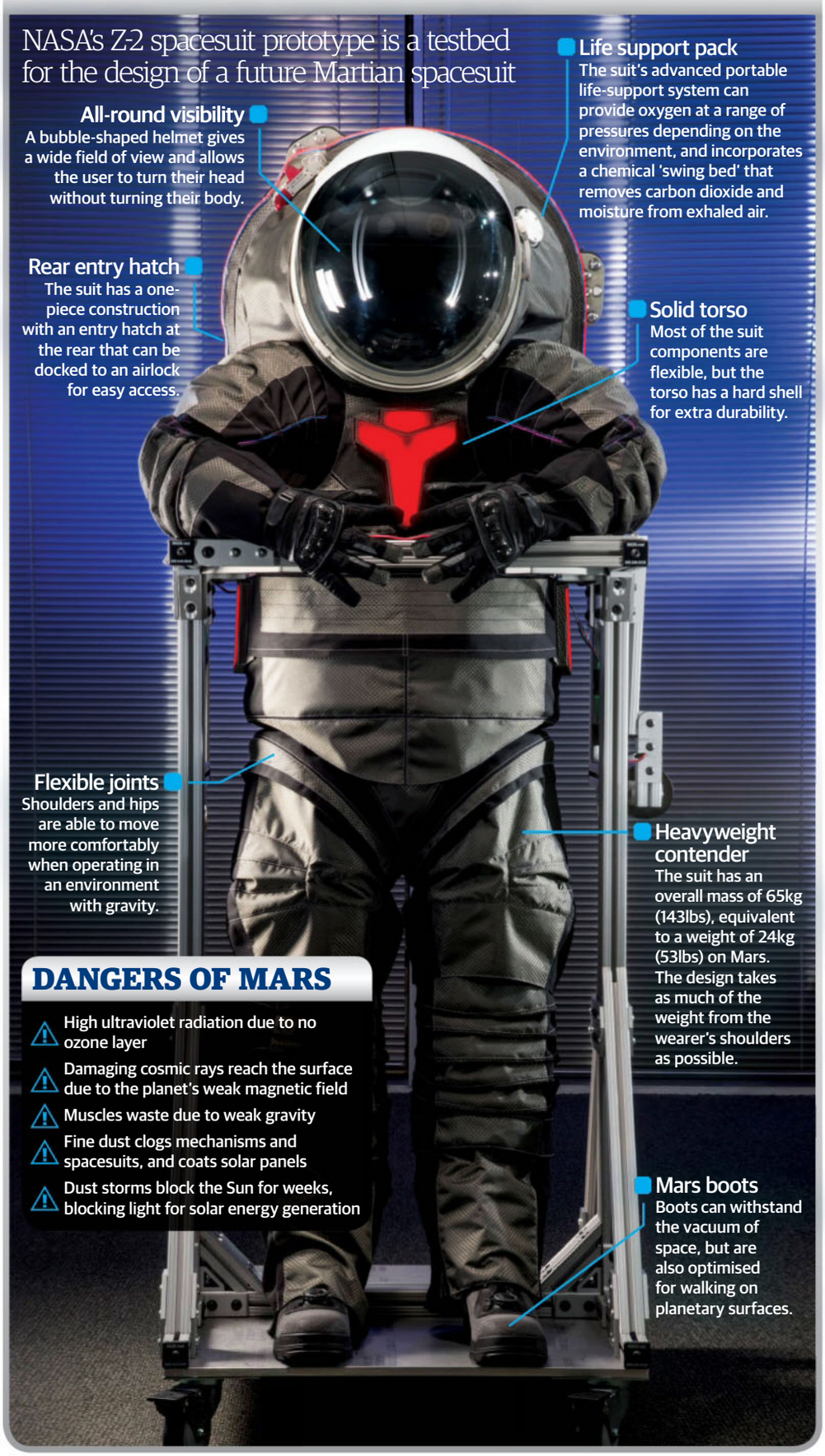
RED DRAGON
Planned for a spring 2018 launch, SpaceX's first Mars mission will send an uncrewed capsule to the Red Planet in order to test atmospheric entry and landing techniques, which may be used on later crewed missions by larger spacecraft. Follow-up missions could attempt a Mars sample return and test ascent from the planet's surface.

ITS
Details of SpaceX's crewed mission would involve the Interplanetary Spacecraft deploying a small crew and cargo including a propellant plant, vehicles and a basic habitat. The first crewed landing (targeted for 2024) could carry a crew of up to 12, and the craft's unique design would allow it to launch on a 'fast return' to Earth in the event of an emergency.

MARS ONE
Mars One's plans for a crewed landing on Mars involve paving the way with a series of uncrewed launches, including a test lander, communications satellite system and unpressurised rover vehicle. Six cargo missions in 2029 would deploy the key units for a Martian colony, while the first group of astronauts would arrive in 2032.

SPACESUIT FOR MARS

NASA's Z-2 spacesuit prototype is a testbed for the design of a future Martian spacesuit



All-round visibility
A bubble-shaped helmet gives a wide field of view and allows the user to turn their head without turning their body.

Life support pack
The suit's advanced portable life-support system can provide oxygen at a range of pressures depending on the environment, and incorporates a chemical 'swing bed' that removes carbon dioxide and moisture from exhaled air.

Rear entry hatch
The suit has a one-piece construction with an entry hatch at the rear that can be docked to an airlock for easy access.

Solid torso
Most of the suit components are flexible, but the torso has a hard shell for extra durability.

Flexible joints
Shoulders and hips are able to move more comfortably when operating in an environment with gravity.

Heavyweight contender
The suit has an overall mass of 65kg (143lbs), equivalent to a weight of 24kg (53lbs) on Mars. The design takes as much of the weight from the wearer's shoulders as possible.

Mars boots
Boots can withstand the vacuum of space, but are also optimised for walking on planetary surfaces.

DANGERS OF MARS

- High ultraviolet radiation due to no ozone layer
- Damaging cosmic rays reach the surface due to the planet's weak magnetic field
- Muscles waste due to weak gravity
- Fine dust clogs mechanisms and spacesuits, and coats solar panels
- Dust storms block the Sun for weeks, blocking light for solar energy generation

publicity for its talk of establishing a permanent Martian settlement by 2032, and even more for the sting in the tail – it plans to send its astronauts on a one-way trip, with no provision for their return. In other words, the first Martian colonists might very well end up dying on the Red Planet.

Mars One courted further interest with an open application process that attracted more than 200,000 people to its first round, and talk of funding the mission with stunts such as a reality television programme. As a foundation rather than an engineering company, Mars One will need to procure spacecraft and other technologies from elsewhere if the mission is to become a reality, and sceptical voices have criticised the plan from both an ethical standpoint and from a financial point of view – even without the costs of a return journey, the mission's proposed price tag of just $6 billion (£4.9 billion) seems tiny in comparison with the $100 billion (£81.6 billion) budget estimated by NASA in 2009 for a round-trip mission.

As Chris Welch, director of the Masters programmes at the Strasbourg-based International Space University, comments: "Even ignoring the potential mismatch between the project income and its costs and questions about its longer-term viability, the Mars One proposal does not demonstrate a sufficiently deep understanding of the problems to give real confidence that the project would be able to meet its very ambitious schedule."

Few, it seems, would put money on Mars One putting the first reality stars on the Red Planet, but billionaire technology pioneers are a different matter – especially when they have a growing track record in the growing space industry. So will SpaceX astonish the world by putting people on Mars in the next decade, or will we have to wait a little while longer to see NASA reach the Red Planet? Technical hitches and a long enough delay might even allow Blue Origin or the fast-growing Chinese space programme to catch up. At the moment, it's perhaps too soon to tell, and the long history of planned Mars missions shows that few things ever work out quite as planned.

One thing is for sure, though – the new Space Race is driving space technology forward at a rate not seen since the 1960s, and whether we're wannabe Martians or not, we may all reap the benefits.

"We either stay on Earth forever and then there will be an inevitable extinction event, or we become a spacefaring civilisation, a multi-planetary species"

Elon Musk, founder of SpaceX

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Suspended animation

A staple of science fiction, putting you to sleep during interstellar travel might be closer than we think

Space is big and this presents a problem for prospective interplanetary explorers, and screenwriters. With present technology even our upcoming missions to Mars will take a year or so but reaching the outer Solar System takes decades, and interstellar travel would take millennia. This is a very long time to have to spend in a small spacecraft, or write an engaging movie, so finding some way to put the passengers on hold so they don't have to perceive the duration of time, or suffer the ageing, has popped up in as many serious studies as movies.

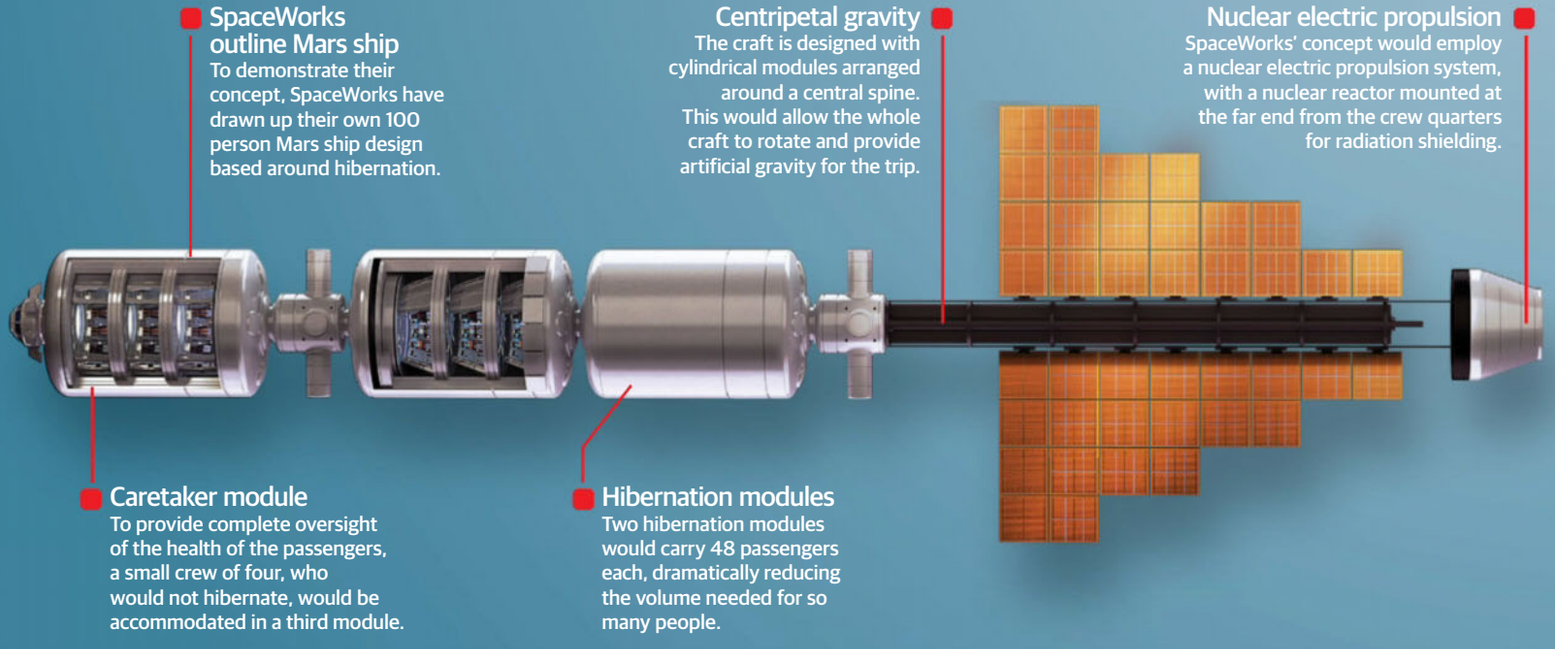
In *Interstellar* astronauts were covered in plastic and submerged in water; in *Alien* and *Avatar* sleeping pods helped pass a few years between the stars; in *Red Dwarf* Lister was conveniently freeze-framed behind a door for 3 million years while his cat evolved a civilisation; and in the latest movie *Passengers*, two sleeping inhabitants are woken up 90 years too early on their journey to a new planet when their ship malfunctions. But suspended animation, or at least some form of induced human hibernation, is on the verge of possibility.

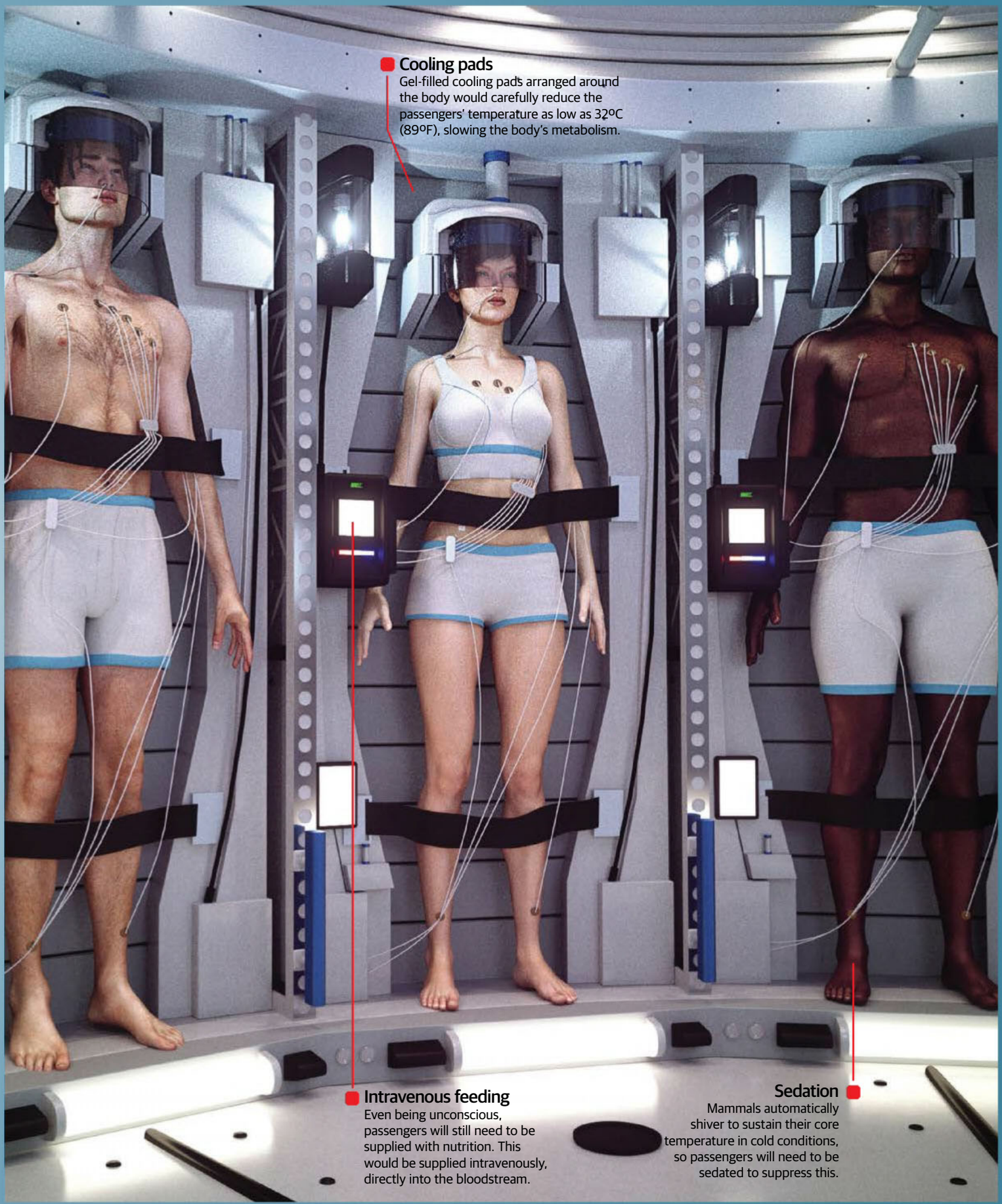
There are several documented cases of people surviving exposure to cold, sometimes combined with a lack of oxygen; in 1999 Anna Bagenholm was trapped under ice for 80 minutes. Her core temperature dropped to 13.7 degrees Celsius (56.6 degrees Fahrenheit) – the lowest recorded body temperature a human has survived after an accident. Her recovery was not simple but she has gone on to continue her career as a radiologist. Cases like Bagenholm's demonstrate that if the body's demand for oxygen is reduced as the metabolism is slowed, even humans can enter a kind of survivable stasis. Inspired by this, University of Washington researcher Mark Roth is studying how to bring about these states, though his focus is not on space voyages, but saving people from life threatening injuries.

Therapeutic hypothermia, or cooling the body, is already used in heart operations, but it is purely a matter of lowering body temperature under conventional anaesthetic; what Roth hopes to be able to do is perform the same trick of reducing the body's need for oxygen while slowing its functions. This could be very helpful in cases where people have lost a lot of blood, protecting the vital organs from oxygen starvation. Rather than outright refrigeration Roth has focused on hibernation induced by a gas; it has been found that small quantities of the otherwise unpleasant (poisonous, corrosive, explosive and bad smelling) hydrogen sulphide can induce hibernation in mice and rats. It is thought to displace oxygen within the body, reducing demand; humans do make a small amount of hydrogen sulphide and it has been suggested that it might be a factor in instances of unexpected cold or water survival.

But for those hoping to sleep away their trip to Mars, or indeed spaceship designers looking to package those pesky passengers more conveniently, NASA has funded a study into a possible hibernation concept suitable for at least Mars travel durations. This system, being developed by John Bradford of SpaceWorks Engineering, would cool Mars travellers to a more modest 32 degrees Celsius (89 degrees Fahrenheit); this would be achieved by cooling pads around the body. Sustenance would be provided intravenously during the months flying to Mars, sedation would stop shivering, and a small crew of non-hibernating caretakers would look after the system. Not having to accommodate and sustain active passengers would enable Mars spacecraft to be built on a much smaller scale, making missions cheaper and easier; though the research is at an early stage, it does appear to offer many advantages. Crews may yet be sleeping their way through space in the not too distant future.

> "If the body's demand for oxygen is reduced as the metabolism is slowed, even humans can enter a kind of survivable stasis"





The hunt for ALIEN MOONS

The life we find outside the Solar System might not be on a planet...

Written by Jonathan O'Callaghan

© Tobias Roetsch

As we continue to find more exoplanets, it's becoming abundantly clear that there is a huge variety; some may be habitable, others definitely not so. But perhaps the most overlooked part of exoplanet astronomy at the moment is what is orbiting these planets. Their moons, called exomoons, might prove to be even more fascinating, and more likely to be habitable, but we've barely scratched the surface.

In 2009, with the launch of the Kepler space telescope, the field of exoplanet astronomy was changed forever. Before, we knew of just a few dozen exoplanets; since then, thanks to Kepler, we now know of thousands. Finding exomoons is a lot more difficult, but is no less important, and in recent years it has become a key area of study for a number of scientists. One reason they are of particular interest is because of how abundant they might be.

"The most plausible evidence for the existence of exomoons for me is the sheer number of moons around the eight planets in the Solar System," René Heller, an astronomer from the Max Planck Institute for Solar System Research in Germany, tells **All About Space**. "So in my view it would be a very strange universe if none of the thousands of exoplanets that we know today would have a natural satellite." So far, though, we've never found one.

Despite a couple of false alarms, our first true exomoon discovery remains elusive. That's mostly due to how small they are, and how primitive our methods of hunting are. In our own Solar System, the biggest moon is Jupiter's Ganymede, which is only 40 per cent the size of Earth. Outside our Solar System, it's a struggle to even find planets of a similar size to Earth. At the moment, we only have indirect evidence for their existence. For example, a paper from astronomer Michael Hippke in 2015 suggested some might be hiding in the Kepler data, combined in the transits of planets crossing stars. Another paper in 2015 (Kenworthy and Mamajek) suggested that a ring system seen around a Sun-like star was sculpted by exomoons. That might all change in the future though.

The most exciting mission for exomoon hunters is ESA's upcoming PLATO (Planetary Transits and Oscillations of Stars) spacecraft. This telescope, larger in scope and ambition than Kepler, has a four year mission plan for its 32 telescopes. The larger collecting area could be enough to help us find exomoons, and astronomers are already highlighting some good candidates for it to observe when it is launched in 2025.

Until then, we can only speculate on what we might find. But it's safe to say that there will probably be plenty of surprises. With exoplanets, we started to find a huge number of strange worlds, such as gas giants orbiting incredibly close to their stars – hot Jupiters – and other ocean worlds that might be covered in water.

It's commonly said that our Sun is one of up to 400 billion stars in the Milky Way, itself one of up

"If there are moons in our Solar System that are potentially habitable, then who knows what else is out there in the universe"

Types of exomoon

How we can categorise the alien moons we expect to find

Snowball exomoon

A snowball exomoon is one where the entire moon is permanently frozen, and less than one tenth is habitable. These worlds are likely to have been born far from their star, or were perhaps moved there from a position nearer the star.

Habitable exomoon

Habitable exomoons are defined as those where at least a tenth of the surface could support liquid water. These will need to be in the star's habitable zone, as well as the right distance from the planet, but could be great bets for finding life.

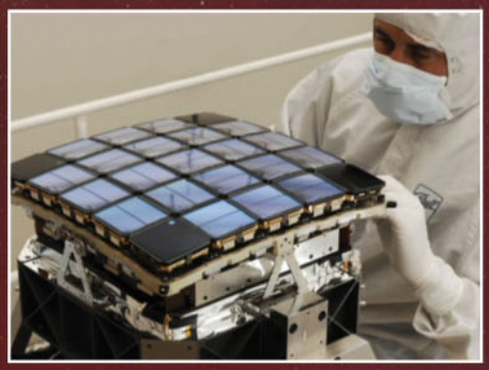
© Tobias Roetsch

Transient exomoon

A transient exomoon is said to be sort of habitable, but its habitability changes dramatically over time. The idea that a moon may shift in and out of habitability will need careful consideration when we look for and study exomoons.

Hot exomoon

Researchers Duncan Forgan and Vergil Yotov came up with a system for classifying exomoons in 2014. One class was a hot exomoon, defined as one with an average surface temperature of more than 100°C (210°F), with less than one tenth being habitable.

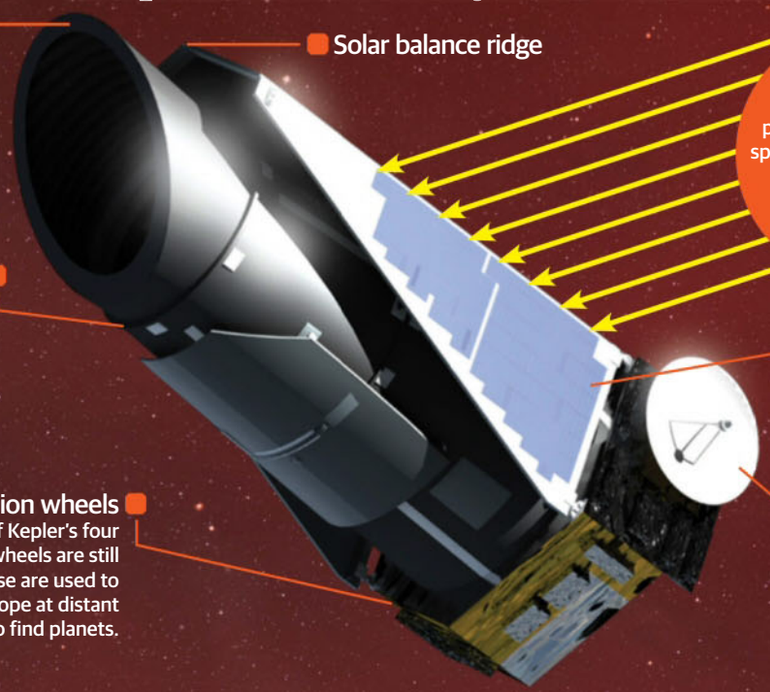


Kepler's focal plane consists of an array of 42 CCDs, creating an imaging capacity of 95 mega pixels

The Kepler spacecraft prepares to be shipped from Ball Aerospace to Florida

Hunting for exomoons

The Kepler telescope has helped us find exoplanets that may host exomoons



Sun shade
As its name suggests, the Sun shade blocks the Sun's rays from the photometer, so it can observe the universe without being obstructed.

Solar balance ridge

Photons in light emitted by the Sun exert pressure on the Kepler space telescope, allowing the spacecraft to be properly balanced against the pressure.

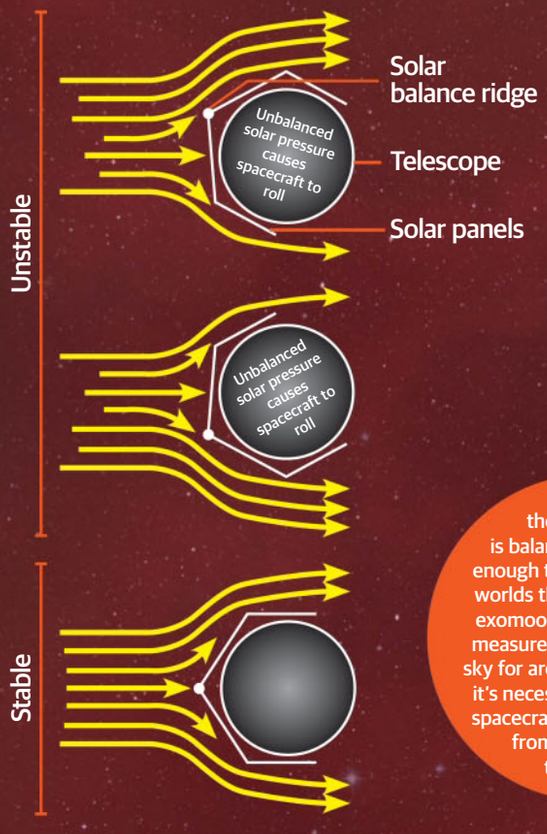
Photometer
The most important instrument on Kepler is the photometer, which looks at stars to notice dips in their light as planets pass in front – known as a transit.

Solar array
Kepler has to roll 90 degrees every three months to keep its solar panels pointed at the Sun and keep the telescope powered.

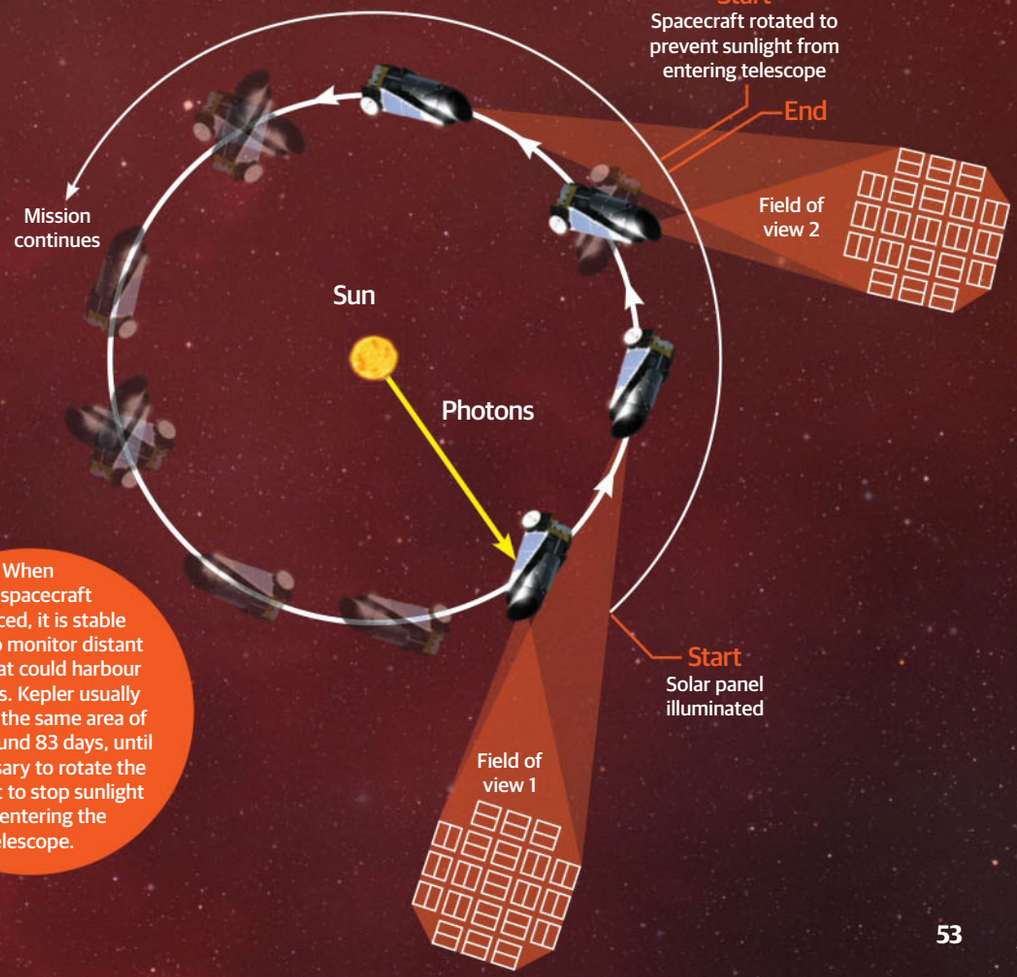
Reaction wheels
Only two of Kepler's four reaction wheels are still active. These are used to point the telescope at distant stars in order to find planets.

High gain antenna
This is used to communicate with Earth, receive commands, and send back data on any exoplanets that Kepler has found.

Top-down views of spacecraft



When the spacecraft is balanced, it is stable enough to monitor distant worlds that could harbour exomoons. Kepler usually measures the same area of sky for around 83 days, until it's necessary to rotate the spacecraft to stop sunlight from entering the telescope.



to 2 trillion galaxies. With each star thought to host at least one planet, there's a huge number out there. But in our Solar System alone, moons far outweigh planets. We have just eight major planets, but more than 140 moons. Several other bodies, including the dwarf planet Pluto and some asteroids, also seem to have their own moons. And what's more, exomoons might be a great place to search for life.

"One of the reasons exomoons are so interesting is that they could be habitable themselves," says David Kipping, an astronomer from Columbia University. "That's obviously an idea that sci-fi writers and movies have had fun with in the past."

Consider, for instance, red dwarf stars. These are stars of much lower light than our Sun, but much more common in the universe – three quarters of all stars are thought to be red dwarfs. For a planet to be in the habitable zone of one of these stars, where conditions are just right for liquid water to exist, they must be very close to the star. This means they are likely to be tidally locked due to the star's gravity, with the same side of the planet always facing the star. Immediately, this makes habitability complicated; on Earth, our planet's rotation is vital for the abundance of life.

But a moon orbiting one of these planets wouldn't be so restrained. As it swung around the planet, all of its sides would be able to bask in the glow of the star, possibly making it a much better location for life to exist. This is just one of the reasons exomoons

How to find an alien moon

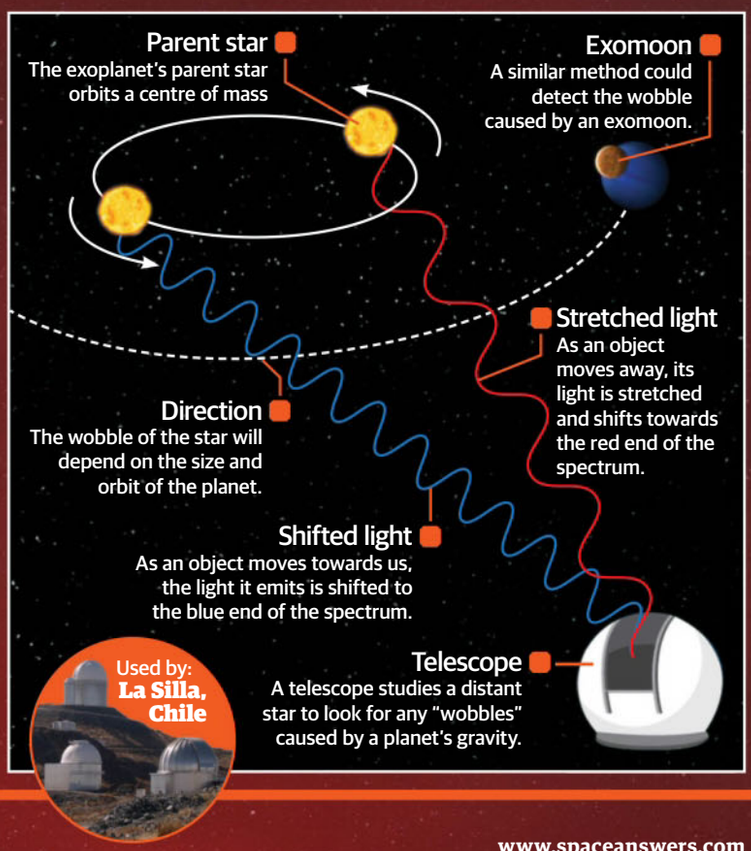
The different methods being used to hunt for exomoons

Transit timing effect

The transit timing method works by measuring a change in the regular transit of a planet. Essentially, as a planet swings around a star, if there are other objects in its vicinity then it can affect how often a transit is completed. This often indicates the presence of other planets in the system, but in theory the method could be used to hunt for large exomoons as well, revealing their tug on their parent planets. It's hard to distinguish between an exoplanet and an exomoon via this method, though, so it might be difficult to make a discovery with it.

Radial velocity method

When an exoplanet orbits a star, its gravity can cause a tug on the star, making its presence noticeable to us on Earth. The star's spectrum of light is shifted to the blue end of the spectrum if it's coming towards us, and the red end if it's going away from us. Using this method, some characteristics of the parent planet can be determined. Like the transit timing method, it's thought that the same principle could be applied to exomoons, noticing their effect on a planet. Again though, the effect is so small that it will be hard to find exomoons using this method.



"Exomoons might be the most abundant habitats in the universe"

René Heller, Max Planck Institute for Solar System Research

are so intriguing. "They might be the most abundant habitats in the universe," says Heller.

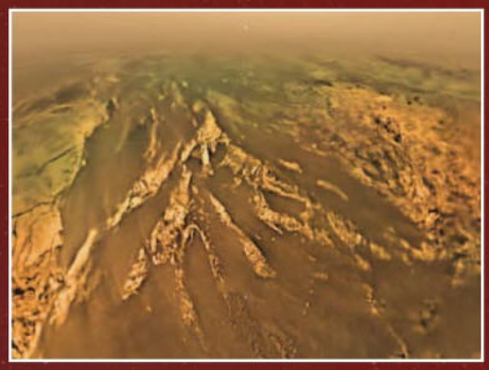
The only problem is, they're incredibly hard to find. Looking for planets is hard enough. Kepler has done it using something called the transit method, where the telescope is pointed at a set of stars for years. As planets swing in front of the star, they cause a tiny but noticeable dip in light – if, of course, we are looking at the same time. And seeing repeat transits allows us to discern if there is a planet there, and even determine its size and orbit.

Exomoons, though, do not produce such a noticeable effect. Being in orbit around the planet, they are relatively close from our point of view, making them almost impossible to independently resolve. In the future, it may be possible to see the combined transit of a moon and planet, and calculate the change in the transit due to the orbit of the moon. At the moment, we are unable to perform this technique to the required precision. Another, called the transit timing method, is similarly restricted. There are other methods for hunting planets, too. One is known as microlensing, and involves seeing a planet bend the light of a more distant object – like a galaxy – as it passes in front, sort of like a transit on a much bigger scale using gravity. Microlensing events by their nature are rare – they do not repeat, giving us just one chance to see a planet in orbit around a star. This makes it hard to find a planet, let alone a moon. In 2013, astronomers thought they had successfully used this method to find an exomoon, but it was later ruled out.

Perhaps another option in the future will be to directly image exomoons. We are already starting to do this with exoplanets, blocking out their stars' light to see them. It's possible that, with bigger and better telescopes, we might be able to see the combined light of a planet and moon. This will likely prove difficult, owing to the low resolutions involved – direct images of planets usually just look like small pixelated blobs – but it could be possible.

"If we're lucky, we might be able to see motion as a moon moves from left to right," says Kipping. "It will cause the centre of the light of that messy blob to sort of move around a bit. We could potentially try to find moons that way but it's very hard."

As for what sort of exomoons we can expect to find, well, that's very much speculation at the

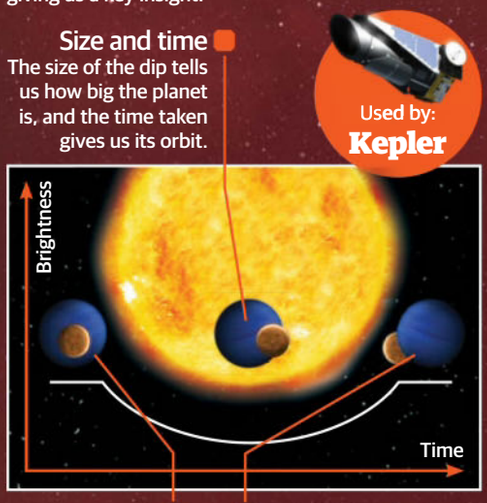


Saturn's moon Titan is the only moon we know to have a thick atmosphere

Pluto is only about twice the size of its moon Charon, leading some to label them a double-planet system

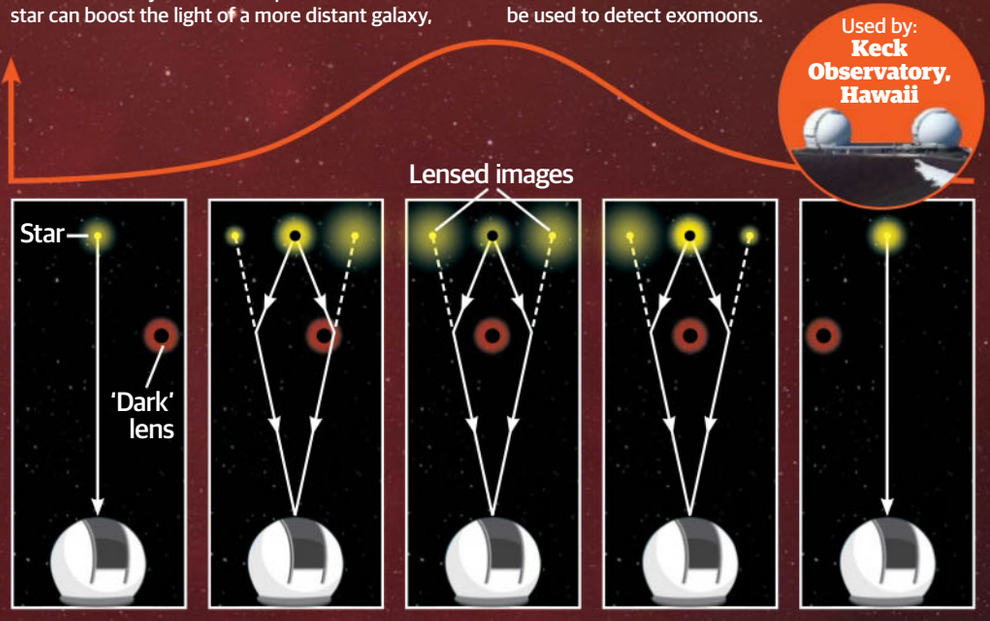
Transit method

Many exoplanets have been found using the transit method. As a planet periodically orbits its star, it causes a dip in the star's light – or flux – if it crosses our line of sight. Measuring this dip, we can then determine the orbital period, and even the size of the planet. The same method could also be used for exomoons, noticing the combined dip produced by both the moon and its planet. Indeed, as the moon will be moving around the planet, it may block a different amount of light depending on its position, giving us a key insight.



Microlensing

Microlensing events are one of those rare cosmic phenomena that remind you how awesome the universe is. Gravitational microlensing is basically the result of an object in the universe magnifying a much more distant object. For example, an intermediate star can boost the light of a more distant galaxy, although any given event will occur only once. If the intermediate star has a planet orbiting it, then the effect is altered, and the presence of the planet can be deduced. More recently, it has been suggested that this same method could be used to detect exomoons.

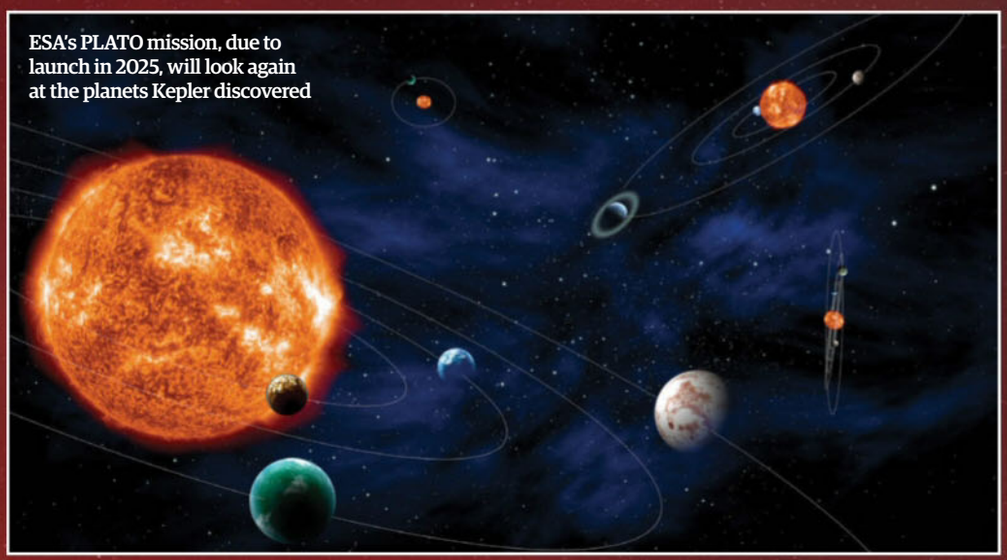


moment. Our single case study is our own Solar System, where the variety is good but not amazing. Most of the moons here are rocky and barren, and only one – Saturn's moon Titan – has a sizeable atmosphere. But we do have, of course, moons with vast amounts of water, notably Jupiter's Europa and Saturn's Enceladus. Already, these are looking like potentially habitable environments – the vast oceans are locked beneath the icy surface, free from radiation, and perhaps with a heat source caused by the moons' elliptical orbits around their parent planets. "Those are more exciting than Mars to me to look for life," says Kipping.

This makes exomoons an immediately attractive proposition. If there are some in our Solar System that are potentially habitable, then who knows what else is out there in the universe. "In our own Solar System, the moons of the giant planets (Enceladus, Europa, and even Titan) are seen as possible locations for life to exist," says astronomer Gregory Laughlin from Yale University. "By extension, we might expect that exomoons would provide a similarly fertile ground. This is separate from the question of actual detection, which will certainly be a difficult endeavour." There are major unknowns about them at the moment, though. For starters, we don't know what sizes they can be.

In our own Solar System, we are still finding tiny moons around planets even now, and we don't have much hope of finding similarly sized exomoons. But maybe they can be as big as Earth, or at least sizeable enough to be noticeable. Laughlin notes, though, that it does "seem clear" that really large exomoons similar in size to their parent planet are not common, as we surely would have seen some of these in the Kepler data.

Exomoons are fascinating in their own right and it's becoming clear that they may be a great place to look for life in the universe. Unfortunately, we don't have a huge number of tools at our disposal to find them at the moment, let alone study them in detail. But perhaps in the not too distant future, the first one will be discovered for certain, and a new age of exomoon astronomy can begin. And it's likely to be full of surprises. "It would be surprising if it wasn't surprising," says Kipping. "But what those surprises might be is anyone's guess." So for now, we must keep guessing.



ESA's PLATO mission, due to launch in 2025, will look again at the planets Kepler discovered

The gas giants, such as Saturn, possess many moons

QUICKFIRE

Discovered: the first alien moon?

Astronomer David Kipping from Columbia University thought he might have found the first concrete evidence for an exomoon around the planet Kepler-90g in 2013

Why did you think you'd found an exomoon?
The Kepler photometry seemed to show a decrease in flux compatible with the signal expected for an exomoon. It was close to Kepler-90g and indeed within the region of stability for a moon, and it had just the right depth and duration, too.

What made you doubt your finding?
The discovery of an exomoon would be a very major breakthrough, so we recognised that any claim had to be made with the highest levels of confidence. We looked at the individual pixels of the photometry and noticed that something weird went on at the time of the exomoon transit. We think the most likely explanation was a sudden pixel drop out [and not an exomoon], possibly caused by a cosmic ray hit that affected the electronics of the camera for a brief time, and coincidentally mimicked an exomoon-like signal.

Could there still be an exomoon there?
Sure, but we have no evidence to support such a hypothesis. So it would be mere speculation at this point. Exomoon signals can produce a wide range of morphologies and will by definition be very small signals. Human observers really want to claim, "I'm the first to discover an exomoon", so there's a high probability of [someone] claiming a bogus signal [in the future].

"To me, moons and exomoons are more exciting than Mars to look for life"
David Kipping, Columbia University

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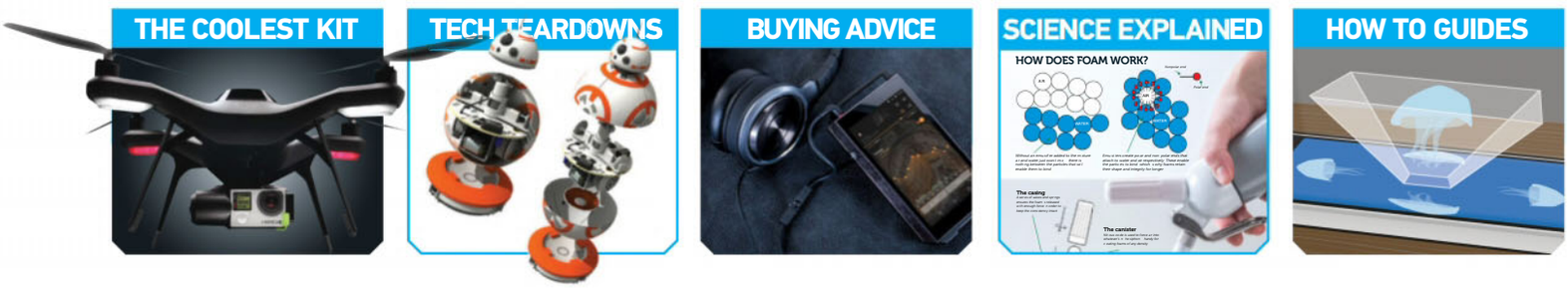

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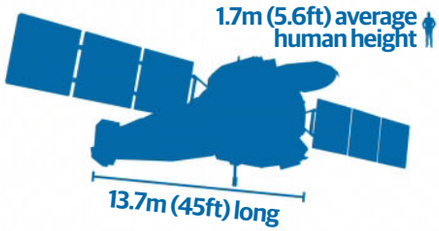
USER MANUAL

Chandra X-ray Observatory

High above the Earth floats one of humanity's Great Observatories, a NASA-built spacecraft that sifts through space in search of X-ray-laden mysteries

THE SPECS

Launch: 23 July 1999
Rocket: Space Shuttle Columbia (STS-93)
Target: High-Earth orbit
Operators: NASA
Components: Multiple components
Programme cost: $1.65bn (£1.3bn)
Finished construction: 1998
Number of orbits: 1,358



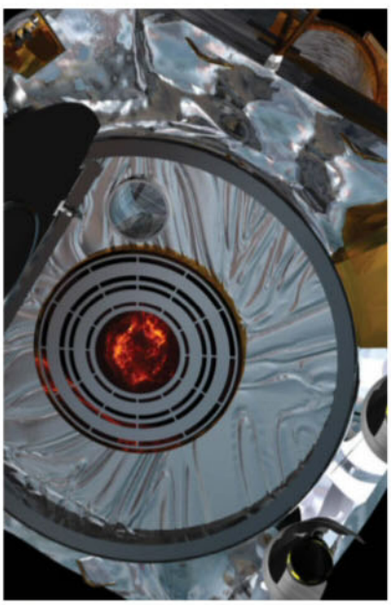
For over half a century, humankind has been launching satellites into the atmosphere of the Earth, peppering the heavens with unmanned craft that look down upon us and out into the stars, studying our planet and the wider universe in minute and incredible ways. Of all these thousands of craft, only four have been deemed Great Observatories, a title that defines the sheer breadth and depth of their capabilities. Hubble, the grand space telescope that's captured the universe beyond with incredible detail is one, and alongside it floats the Chandra X-ray Observatory, an equally powerful eye that gazes out into the great expanse.

Unlike Hubble, Chandra is a Flagship-class space observatory, one designed not to capture images of planets, stars and other celestial bodies in a traditional manner, but to capture data by measuring X-ray sources 100-times fainter than any previous X-ray telescope. It's an amazing feat of engineering that's operated in high elliptical orbit above the Earth for over 17 years and it's been at the forefront of some startling discoveries.

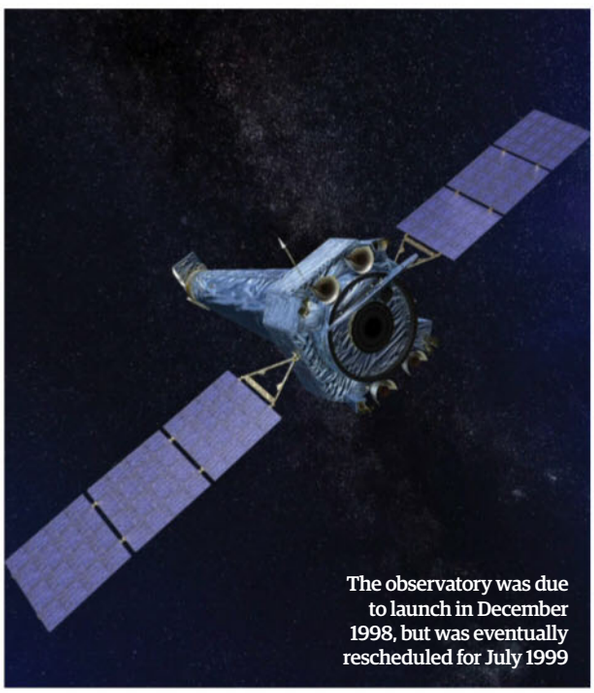
For instance, Chandra has revealed large quantities of cool gas spiralling into the centre of the Andromeda Galaxy; it has unearthed the existence of a new kind of black hole, one that bridges the gap between stellar-sized black holes and supermassive black holes; it has proven that all stars on the main sequence (a huge and distinct band of stars) emit X-rays of one form or another; and that X-ray emission lines (a continuous spectrum) are in fact tied to gamma-ray bursts.

So where did it all start and how did NASA come to settle on a powerful satellite tuned to forms of electromagnetic radiation? Like many programmes, Chandra first formed in the minds of NASA engineers and astronomers as far back as 1976, when the concept for an Advanced X-ray Astrophysics Facility (AXAF) was first proposed. The idea would continue to gestate as the world's first X-ray sensitive observatory was launched in the form of Einstein in 1978, with the plan to include multiple mirrors (as opposed to Einstein's single one) to see even further into the cosmos.

However, a more complex design and a grander vision soon led to increasing projected costs,



Chandra was known as Advanced X-ray Astrophysics Facility, but it was renamed following a competition before its launch

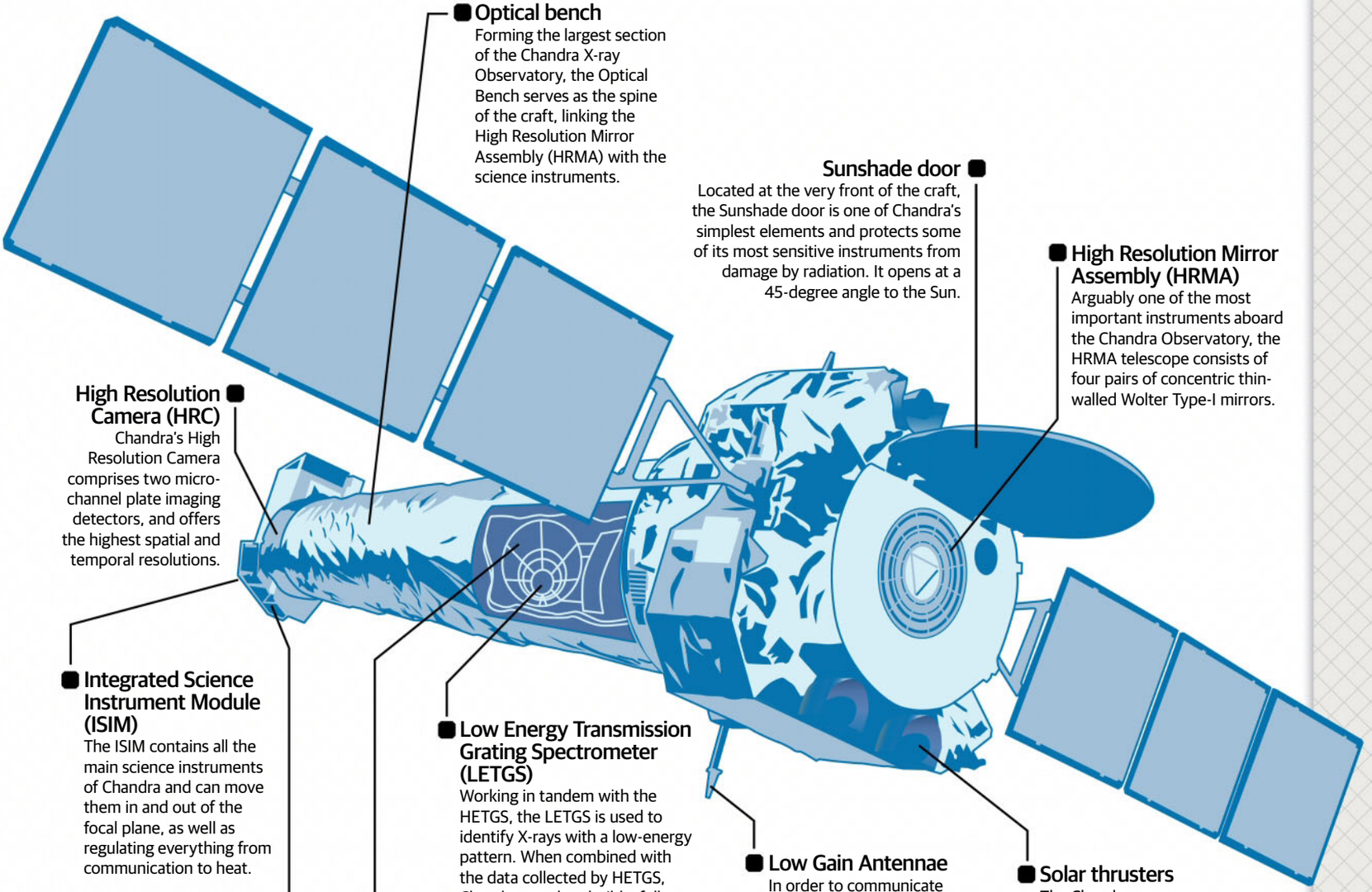


The observatory was due to launch in December 1998, but was eventually rescheduled for July 1999

Chandra's ultra-high sensitivity to X-rays has helped NASA study the wider cosmos with a new clarity, such as these images of Jupiter from 2000

Anatomy of Chandra X-ray Observatory

From its powerful solar array to the incredibly sensitive X-ray telescope, **All About Space** goes inside the workings of one of NASA's Great Observatories



Optical bench
Forming the largest section of the Chandra X-ray Observatory, the Optical Bench serves as the spine of the craft, linking the High Resolution Mirror Assembly (HRMA) with the science instruments.

Sunshade door
Located at the very front of the craft, the Sunshade door is one of Chandra's simplest elements and protects some of its most sensitive instruments from damage by radiation. It opens at a 45-degree angle to the Sun.

High Resolution Mirror Assembly (HRMA)
Arguably one of the most important instruments aboard the Chandra Observatory, the HRMA telescope consists of four pairs of concentric thin-walled Wolter Type-I mirrors.

High Resolution Camera (HRC)
Chandra's High Resolution Camera comprises two micro-channel plate imaging detectors, and offers the highest spatial and temporal resolutions.

Integrated Science Instrument Module (ISIM)
The ISIM contains all the main science instruments of Chandra and can move them in and out of the focal plane, as well as regulating everything from communication to heat.

Advanced CCD Imaging Spectrometer (ACIS)
Located next to the HRC, the Advanced CCD Imaging Spectrometer on board Chandra accurately measures the energy of single photons.

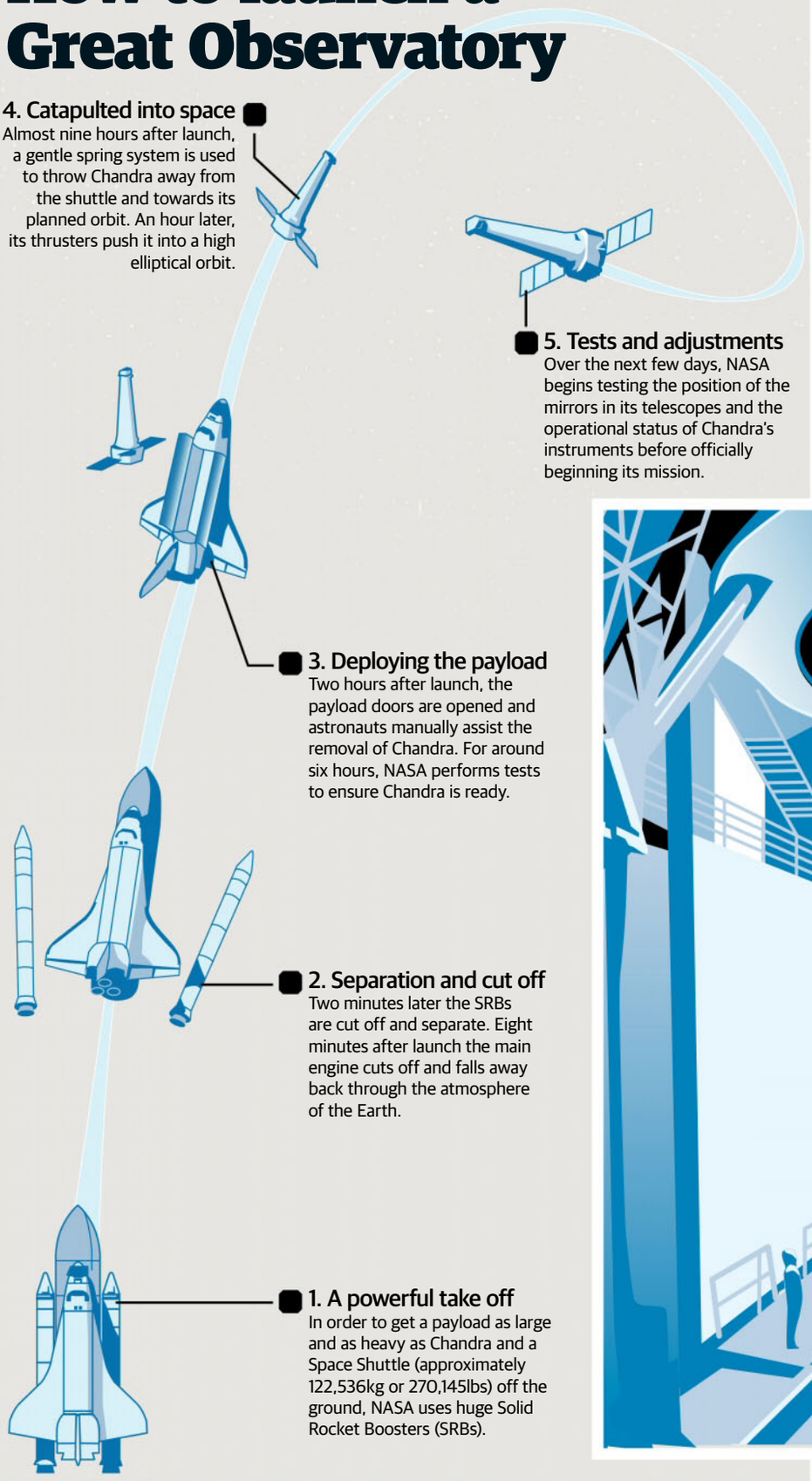
Low Energy Transmission Grating Spectrometer (LETGS)
Working in tandem with the HETGS, the LETGS is used to identify X-rays with a low-energy pattern. When combined with the data collected by HETGS, Chandra can then build a full X-ray picture of a given location.

High Energy Transmission Grating Spectrometer (HETGS)
Along with the ACIS, Chandra has two other main spectrometers to rely on – the first, known as HETGS, is used to locate diffracted X-rays, enabling a precise determination of their energies.

Low Gain Antennae
In order to communicate with NASA back on Earth, Chandra has two Low Gain Antennae for two-way communications with Chandra's Operations Control Center (OCC).

Solar thrusters
The Chandra comes fitted with two kinds of thrusters – one set for propulsion and another for momentum unloading (adjusting the course of the craft by applying levels of torque).

How to launch a Great Observatory



4. Catapulted into space
Almost nine hours after launch, a gentle spring system is used to throw Chandra away from the shuttle and towards its planned orbit. An hour later, its thrusters push it into a high elliptical orbit.

5. Tests and adjustments
Over the next few days, NASA begins testing the position of the mirrors in its telescopes and the operational status of Chandra's instruments before officially beginning its mission.

3. Deploying the payload
Two hours after launch, the payload doors are opened and astronauts manually assist the removal of Chandra. For around six hours, NASA performs tests to ensure Chandra is ready.

2. Separation and cut off
Two minutes later the SRBs are cut off and separate. Eight minutes after launch the main engine cuts off and falls away back through the atmosphere of the Earth.

1. A powerful take off
In order to get a payload as large and as heavy as Chandra and a Space Shuttle (approximately 122,536kg or 270,145lbs) off the ground, NASA uses huge Solid Rocket Boosters (SRBs).

and so Chandra disappeared into something of a development hell throughout the 1980s and into the 1990s. Eventually, the satellite's budget was brought in line, with the number of mirrors reduced from the original plan of 12 to a still considerable eight, and the array of six instruments dropped down to four. Changes were also made to its planned orbit path – by opting for an elliptical orbit the craft would no longer be eligible for future repairs by Space Shuttle but it would be positioned above the Earth's natural radiation belts (reducing the chance of radiation-based degradation).

While certain elements had been scaled back to ensure the craft could be built within budget and in time for the planned December 1998 launch, the satellite that would soon become Chandra was still set to be the most powerful X-ray-based craft ever built. With an eight-mirror setup, it was designed to build on the progress (and the failings) NASA encountered with the Einstein X-ray telescope in the 1970s. And with the launch of the Hubble Space Telescope in 1990, Chandra was quickly seen as the perfect counterpart to the powerful lens of NASA's

other impressive Flagship satellite. While the craft was still undergoing tests and improvements at TRW (now Northrop Grumman Aerospace Systems) in Redondo Beach, California, NASA launched a worldwide competition to rename the craft before its planned launch in 1998. Over 6,000 submissions were received from schools and colleges around the globe, but eventually the old title of AXAF was dropped in favour of the name Chandra. It was so named in honour of Nobel Prize-winning, Indian-American astrophysicist Subrahmanyan Chandrasekhar, whose work on stellar evolution changed the face of astronomy forever.

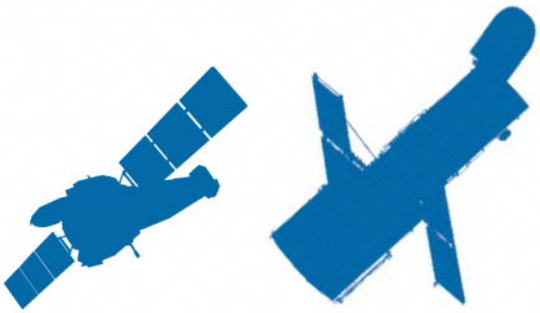
Unfortunately, the satellite's launch was pushed back from December 1998 to the following summer, and on 23 July 1999, Chandra was finally propelled away from Launch Complex 39 at Kennedy Space Center, Florida.

Carried out of our atmosphere aboard the Space Shuttle Columbia, the Chandra spacecraft was the heaviest payload ever ferried to space by the programme, but the craft still completed its journey into high-Earth orbit and began sending back data a month later.

For a craft designed to operate for a mere five years, Chandra continues to go above and beyond the initial vision of its creators. Now nearly two decades into its operational life, the craft has been at the forefront of studying the hottest spots in known space. NASA scientists agree Chandra has around 15 years of optimum performance under its radiation-proof chassis, meaning the powerful observatory is now working on borrowed time. However, with Hubble now well within its 26th year of studying the universe and with so much to discover, the future for the X-ray observatory may reach further than anyone ever expects.

Head to head
Chandra vs Hubble

When it comes to stats, Chandra is a monster compared to its fellow Great Observatories – it remains the largest satellite to be carried into space in history at 13.8m x 19.5m (45.3ft x 64ft). By comparison, Hubble clocks in at 13.2m x 4.2m (43.3ft x 13.8ft) – both of which are longer than a double decker bus. In terms of weight, Chandra is lighter than Hubble's 11,100kg (24,471lbs), with a launch mass of 4,790kg (10,560lbs). Still, neither is as heavy as a bus, which weighs 12,650kg (27,888lbs).



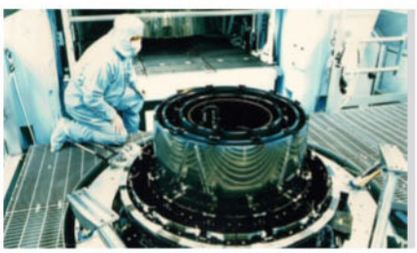
Chandra
4,790kg

Hubble
11,100kg

TOP TECH

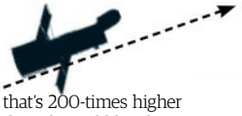
High Resolution Mirror Assembly:
A super telescope

The HRMA X-ray telescope is the most powerful ever built. It comprises eight cylindrical paraboloid and hyperboloid mirrors coated with iridium and gold, positioned almost parallel to incoming X-rays. HRMA enables Chandra to reach an unmatched resolution – between 80 and 95 per cent of the incoming X-rays are focused into a one-arcsecond circle. It can capture X-rays in the split second between their emission and the point they're sucked into black holes.

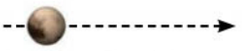


Vital statistics

45ft = 
The length of the Chandra satellite
that's even bigger than a double decker bus

134,527.6km =
The apogee of Chandra's orbit

that's 200-times higher than the Hubble telescope

1-2kW =
The charge required to power Chandra
the same energy needed to work a hairdryer 

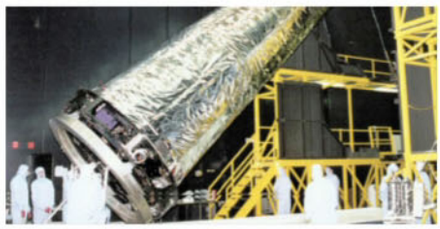
780mn =
The furthest distance, in light years, Chandra has gazed

for context, Pluto is less than one light year away

HOW TO...

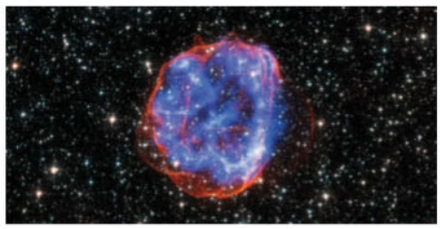
Take an X-ray image in space

1 Identify a 'hot' target
Chandra uses its three on-board spectrographs to locate celestial 'hot spots'. These long since completed events can be anything from exploded and dead stars to clusters of galaxies and the matter found around black holes.

2 X-rays are channelled into a barrel
X-rays don't behave like other spectral waves, so a traditional flat mirror would absorb them. So engineers have designed barrel-like mirrors that channel X-rays or 'graze' them towards a set of sensors at the end of the craft's design.



3 Data is sent to NASA
Once Chandra's sensors have collected the data, it is transmitted back to Earth via two antennae. Chandra usually conducts these communication bursts three times a day, sending information through NASA's Deep Space Network.



4 Images are constructed
Once the information is received through the Deep Space Network, it needs to be translated. Data is recorded not as images but as coordinates, which are recorded into a map. These images are given 'false colours' in order to categorise them.

Space ANSWERS

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SPACE EXPLORATION

How long would it take to travel to the known edge of the universe?

Jack Fraiser
The Voyager probes are already heading out of the Solar System, and if they were to keep on going to the edge of the observable universe, it would take an estimated 1,750 million million years! This is an incredibly long time - to put this in perspective, the Earth has only existed for around 4,500 million years. One thing this goes to highlight is just how large space is. Space is truly massive, and although we have been exploring it for the last 60 years, we have only just ventured out into the universe. Despite its enormous size, we still set our sights at pushing even further, the next goal for human exploration being to get to the Red Planet. **JB**

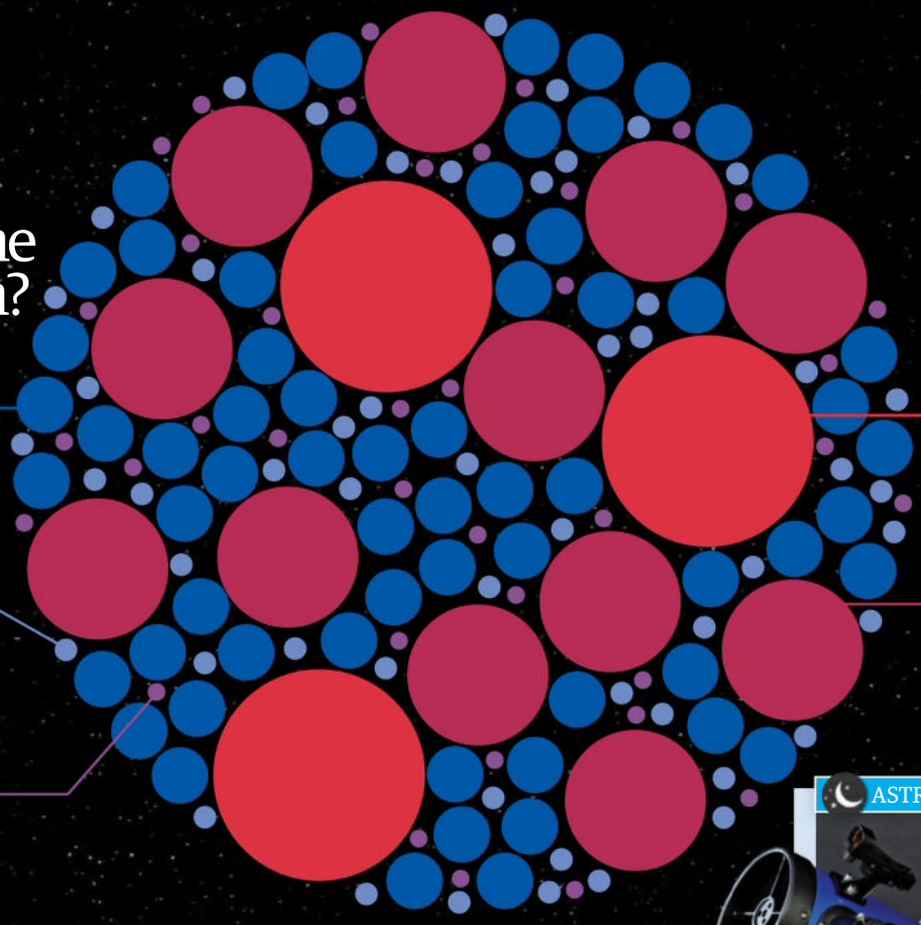
It would take an extremely long time to reach the edge of the observable universe

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

DEEP SPACE

What type of exoplanet is the most common?

Gerald Williams



Mini-Neptune planets
1,580
Icy gaseous planets with a diameter two to six times Earth's diameter

Super-Earth
1,313
Terrestrial planets 1.25 to two times the diameter of Earth

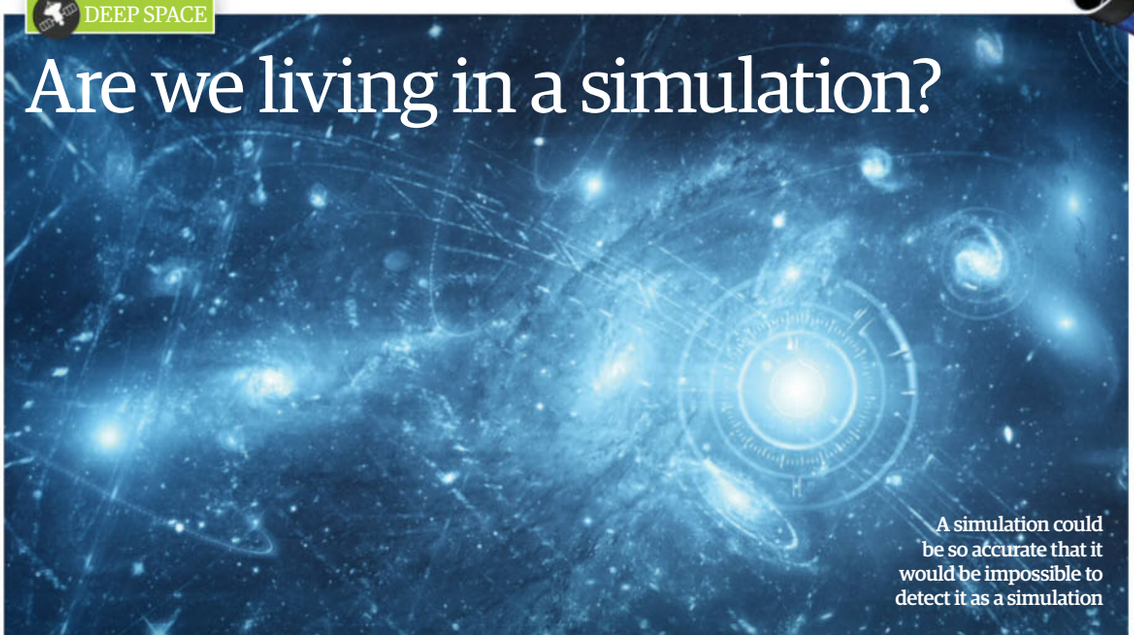
Rocky worlds
977
Rocky worlds less than 1.25 times Earth's diameter

Worlds larger than Jupiter
466
Gas giants 15 to 25 times Earth's diameter

Jupiter-diameter planets
288
Gas giants six to 15 times the diameter of Earth

DEEP SPACE

Are we living in a simulation?



A simulation could be so accurate that it would be impossible to detect it as a simulation

Len Hobart
This is a difficult question to give a definitive answer to. Many people have suggested that any highly intelligent civilisation with technology will build computers that get faster and more powerful, compiling ever more sophisticated and intricate simulations and improving in the ability to do so at a phenomenal rate. So could it be that most civilisations are part of a sophisticated simulation?

Well, technically, yes. Our own simulations are simply astonishing. We have accurately modelled the universe from 300,000 years after the Big Bang took place to the present day, tweaking the various interactions of dark matter, dark energy and galaxy formation to get a universe very similar to what we are able to observe today (but only on a large scale).

And if we were living in a simulation, it would be impossible to know. Any limitations of the computer system would be accounted for in the programming. So what would this mean for the nature of existence, of thought, of consciousness? That is a discussion for another question! **SA**

ASTRONOMY

The size of the telescope will depend on the type of observation you want to do

Are larger telescopes always the best?

Sharon Lane
A telescope's size is measured by its aperture, which refers to the diameter of its lens or mirror. Telescopes with bigger apertures are better in the sense that they collect more light and thus are more sensitive to faint, distant objects. But depending on how the telescope is being used, there are other things to consider. For amateur stargazing, portability and ease of setup might be more important. Consider whether you want to be able to load your telescope into your car for stargazing field trips before splashing out on that 10" aperture telescope.

Depending on focal length, some telescopes are better for small, close-up views of craters on the Moon and the details of planets. Others are best for wide-angle shots of galaxies and star clusters. If you're thinking of investing in a telescope, get to know your local astronomical society and draw on their wealth of knowledge. **TM**

ASTRONOMY

How can I track down the ISS?

Shaun Bankes

1 Check the timings

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

2 Check the weather

The weather and cloud cover is always a critical factor in a good observation of the ISS. A little cloud is okay but, of course, clear skies are much better!

3 Plan and prepare

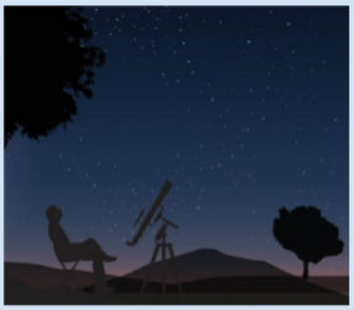
You'll find that observing the ISS is much more relaxed if you're well prepared. Dress appropriately and wrap up warm; it's surprising how cold you can get in just a few minutes.

4 Give yourself time

Go outside at least five minutes in advance of the expected appearance of the ISS in your sky. This will give you time to orientate yourself and enjoy the experience.

5 Know your direction

You need to know which direction to face in order to see the ISS rise over the western horizon. A compass can help here if you're not sure which way west is.



6 Be patient

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

DEEP SPACE

Will we ever know everything about the universe?

Darren Spencer

Probably not, but that's the wonderful thing about science – there's always more to know! There are some huge mysteries still to unravel before we can even begin to say we understand the universe.

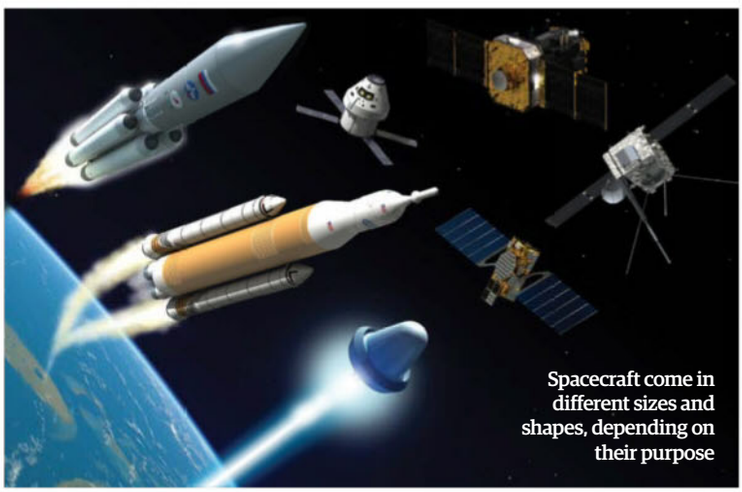
We don't understand what most of the universe is made of, and have given this mysterious substance the name 'dark matter'. We don't know what is causing the universe to accelerate its expansion outwards, and have called this force 'dark energy'. And we don't even fully understand gravity and how it works on very small scales.

Even if we solved all of these mysteries, we'll still always be limited by how much of the universe we are able to see. The universe is immense, seemingly infinite, but we can only see a small sphere of it known as the 'observable universe', which is limited by the speed of light and the age of the universe. The Holy Grail for many scientists would be a theory of everything, but we are a long, long way off that yet! **TM**

We still have much to learn about the universe and are limited by how much of it we can see

SPACE EXPLORATION

Do spacecraft have to be a particular shape for optimum performance?



Spacecraft come in different sizes and shapes, depending on their purpose

Fiona Williams

The shape that a spacecraft needs to be depends on what it will be doing, and where in space. If the spacecraft needs to travel through the atmosphere, like a rocket for example, it must be designed to minimise drag due to air resistance and so all rockets have a familiar shape. If it is going to be in orbit like a satellite, then drag is not a factor and it can be almost any shape (although the classic 'box' shape is most commonly used).

Some satellites, such as the GOCE satellite, orbit the Earth close enough that they experience slight atmospheric drag and so have to be a sleek design with aerodynamics in mind. In theory, if a spacecraft were to be constructed in space, and were not to encounter an atmosphere, it could take almost any shape. **SA**

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

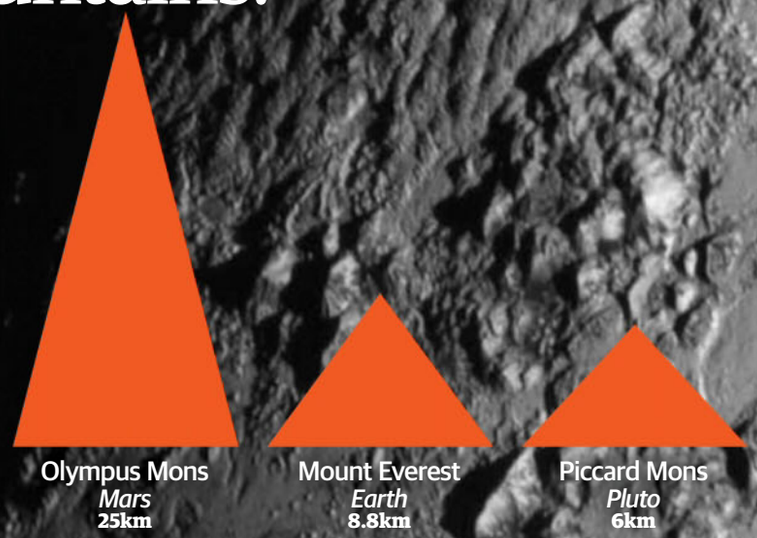
SOLAR SYSTEM

How big are Pluto's mountains?

Jamie Lewis

Thanks to New Horizons' flyby of Pluto in July 2015, we have new estimates of the tallest mountains on Pluto. Piccard Mons and Wright Mons rise six kilometres (3.7 miles) and four kilometres (2.5 miles) respectively above Pluto's surface and are thought to be ice volcanoes.

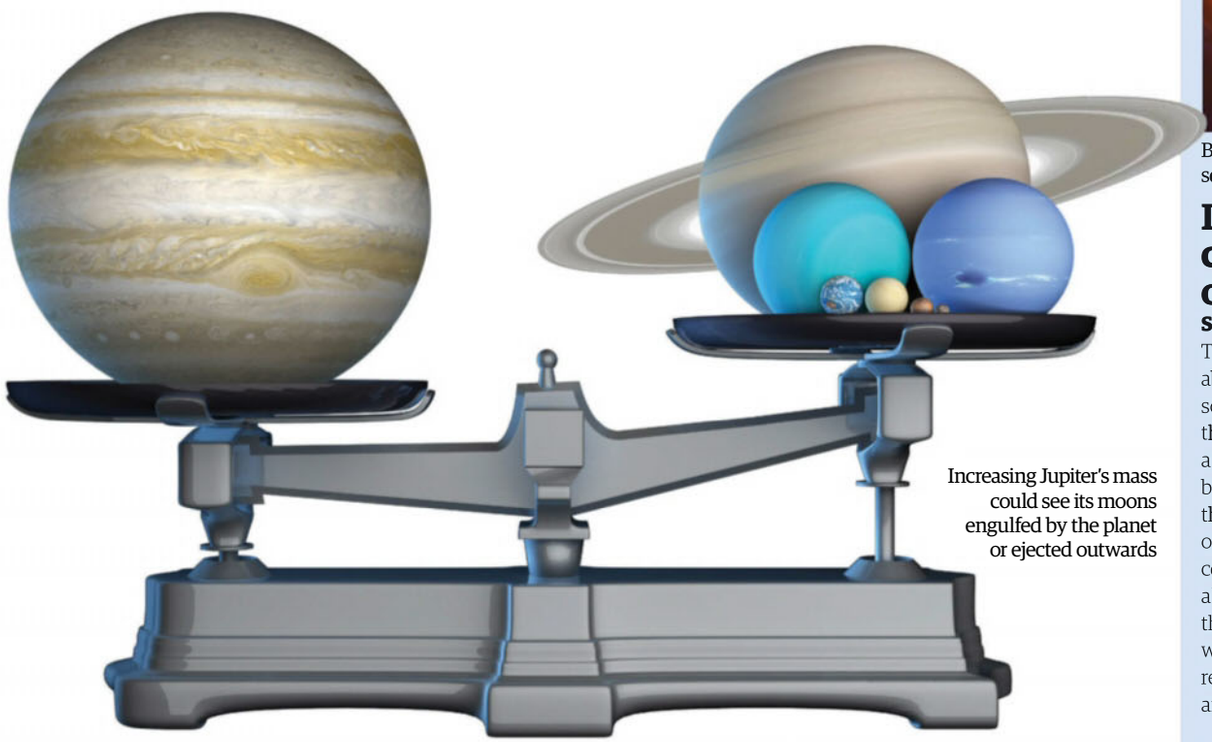
For comparison, Mount Everest on Earth rises 8.8 kilometres (5.5 miles), while Olympus Mons on Mars is 25 kilometres (15.5 miles) high. While they're not the tallest, Pluto's mountains do have something else to offer. Pluto's Norgay Mountains are among the newest in the Solar System, as they formed no more than 100 million years ago. **TM**



Pluto's Norgay Mountains are some of the newest in the Solar System

SOLAR SYSTEM

What would happen if we added more mass to Jupiter?



Increasing Jupiter's mass could see its moons engulfed by the planet or ejected outwards

Harriet Biggins

There are a few things that would happen if we increased the mass of Jupiter. First of all, as we increased the mass of the planet, its size would also probably increase. Alongside this, as the planet's mass increased, so would its gravitational force. This could have an influence on the Solar System. Initially, the increased gravity would have an effect on Jupiter's many moons; some would probably be pulled into Jupiter and this chaotic change could result in some being ejected into the Solar System, which could be quite dangerous.

If the mass of Jupiter was increased enough, there is a chance that it would begin to fuse hydrogen and start to shine like a star. However, the smallest known star is around 80 times the mass of Jupiter, so the mass would need to be increased substantially for this to happen. **JB**

DEEP SPACE

Black holes are created when material is squashed into a tiny space

Is it possible to create a black hole on Earth?

Steve Morris

Theoretically yes, practically no. While abundant in nature, black holes are something that can be created by the universe. To create a black hole a huge amount of material needs to be squashed into a tiny space, and this usually occurs during the death of massive stars. As the star rapidly collapses the core is squashed to almost impossibly small sizes. When this happens the core collapses into what we call a singularity, a tiny region of space containing a very large amount of mass.

Down here on Earth we are not quite at the stage where we can generate enough energy to construct a black hole. There was speculation that the Large Hadron Collider experiment in Switzerland could result in micro black holes being generated but no evidence exists that this has been the case so far. **JB**

ASTRONOMY

What if the Sun was replaced by other stars?

Take a look at how our sunsets and sunrises would appear if our nearest star was plucked out of the Solar System and replaced with another

Laurie Samways

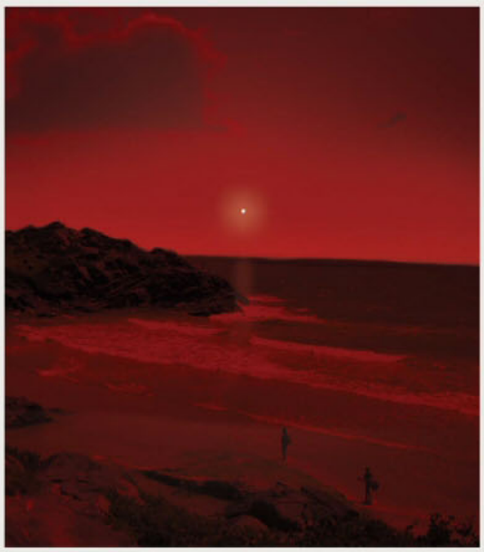
Although we tend to think of stars as one major category, there are large variations in their size. Our Sun is considered a yellow dwarf and is part of one of the largest groups of stars, but the smallest red dwarf is only nine per cent of our Sun's size, while the largest known star – UY Scuti, a red super giant – is more than 1,700 times the solar diameter.

Of course, the nature and formation of planets is heavily dependant on the nature of the star around which they form. The composition we see in the Solar System is a result of the physical characteristics of the elements available; dense rocky-iron terrestrial planets close to the Sun and diffuse gaseous and ice planets further out. As such, our Earth could not have evolved at the same distance from the centre of other stars, as there would either be insufficient heat or too much, but it is fascinating to consider how different our familiar sky would look if it were possible.

Starting at the lower end of stellar size with Barnard's Star, one of our closest neighbours and a red dwarf star around six light years away, this star would still appear circular but much smaller in apparent diameter. It would produce a level of illumination much like advanced sunset on Earth; dim red light even at midday and much less heat. Apparent diameter is how objects appear to us in the sky and is measured as the angle they take up on the perceived dome of the sky. It depends upon the real size of the object and how far away it is – this is how the Moon, which is one quarter the size of the Earth but is only 400,000 kilometres (248,550 miles) away, appears almost the same size as the Sun.

Getting bigger with Tau Ceti, a yellow dwarf around 70 per cent the size of the Sun, this star would look very similar to our Sun; while the binary star system Kepler 35, to the delight of *Star Wars* fans, would have two yellow dwarf stars slightly smaller than our Sun. The colour and individual size would be similar, but the planet would be nearly twice as bright and hot, making Earth more like Venus.

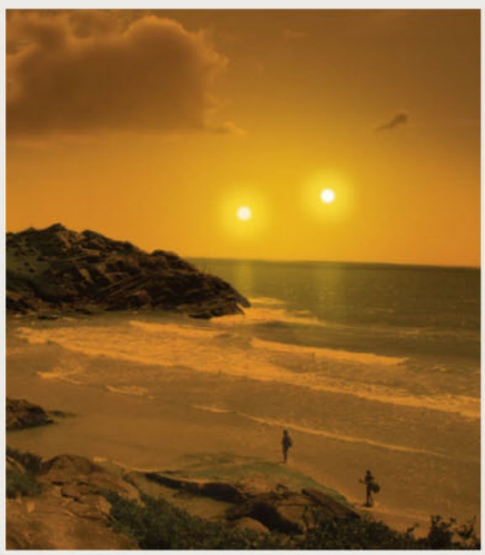
Last of all, if our Sun was swapped for Aldebaran, an orange giant star some 65 light years away, its globe would stretch a significant way along the horizon; Aldebaran is 44 times the radius and 518 times the luminosity of the Sun, and so our view and planetary conditions would be much like that experienced in our own Solar System by Mercury.



Barnard's Star
• 0.196 solar radius • 0.106 degrees angular diameter

Gliese 581
• 0.29 solar radius • 0.157 degrees angular diameter

Tau Ceti
• 0.79 solar radius • 0.428 degrees angular diameter



Kepler 35
• 1 solar radius • 0.535 degrees angular diameter
• 0.8 solar radius • 0.433 degrees angular diameter

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

The Sun
• 1 solar radius • 0.535 degrees angular diameter

Alpha Centauri A
• 1.2 solar radius • 0.65 degrees angular diameter

Procyon
• 2.1 solar radius • 1.119 degrees angular diameter

Pollux
• 8.8 solar radius • 4.763 degrees angular diameter

Arcturus
• 25.4 solar radius • 13.691 degrees angular diameter

Aldebaran
• 44 solar radius • 23.5 degrees angular diameter

STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

What's in the sky?

2 FEB
Conjunction between the Moon and Eris at a separation of 8°41' in Pisces and Cetus

3 FEB
The Moon and Ceres make a close approach, passing within 0°59' of each other in Pisces

15 FEB
The Moon and Jupiter make a close approach, passing within 2°33' of each other in Virgo

16 FEB
Conjunction between the Moon and Haumea at a separation of 25°13' in Virgo and Boötes

17 FEB
Venus shines in the evening sky at a brilliant magnitude of -5.5 in Pisces

20 FEB
The Moon and Saturn make a close approach, passing within 3°34' of each other in Sagittarius and Ophiuchus

22 FEB
Asteroid 9 Metis reaches opposition in Leo and glows at a magnitude of +8.7

22 FEB
Conjunction between the Moon and Pluto at a separation of 2°47' in Sagittarius

26 FEB
Conjunction between the Moon and Mercury at a separation of 2°29' in Aquarius

26 FEB
Mars and Uranus make a close approach, passing within 0°34' of each other in Pisces

28 FEB
Conjunction between Moon and Venus at a separation of 10°15' in Cetus and Pisces

In this issue...

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

11 FEB
Penumbral lunar eclipse

15 FEB
Conjunction between the Moon and Makemake at a separation of 27°35' Virgo and Coma Berenices

18 FEB
Asteroid 14 Irene reaches opposition in Leo and glows at a magnitude of +8.5

20 FEB
Asteroid 15 Eunomia reaches opposition in Sextans and glows at a magnitude of +8.9

26 FEB
Annular solar eclipse visible from Angola, Argentina, Chile, DR Congo and Zambia

1 MAR
Moon and Mars make a close approach, passing within 4°07' of each other in Pisces

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

Jargon buster

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

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.

How to observe the NORTHERN LIGHTS

How do you see one of the most beautiful sights in the sky, and where do you need to go?

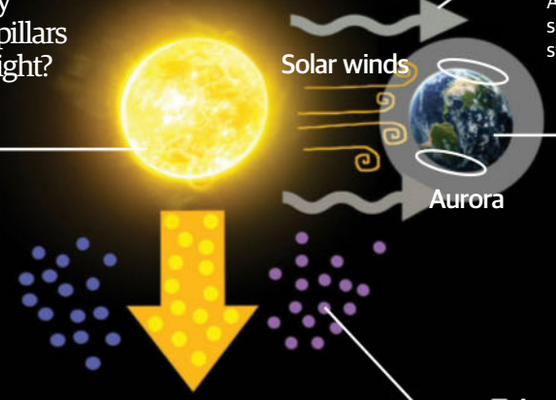
The Northern Lights. Even saying those words conjures up visions of beauty and mystery, doesn't it? More than a solar or lunar eclipse, a meteor shower or any other astronomical phenomena, the Northern Lights – or the Aurora Borealis to give them their proper scientific name – has a hold on our imagination that refuses to let go.

They call to us, like sirens. Non-astronomers who have never seen them long to with a passion, and dream of gazing up at them, arms outstretched. More seasoned observers who have seen too many aurorae to count over the years still smile at the mention of them and are always looking forward to the next display, and the one after that, because no two displays are ever alike and it's impossible to ever be bored or left unmoved by them.

They are shown in films every time the action moves to the far north, and although they are often depicted very unrealistically by Hollywood, they are always visions of absolute ethereal beauty. Here, we will tell you how to see them and the very best places to go to watch the "Merry Dancers" lighting up the sky.

How aurorae are made

What makes the night sky come alive with glowing pillars and swaying curtains of light?



Solar wind ejection
Activity on the Sun sends charged particles streaming out into space.

Magnetic field
The Earth's magnetic field funnels the particles of the solar wind towards our planet's poles.

Our changing star
The Sun is a variable star, reaching its peak of activity every 11 years. During this "solar maximum" we expect to see more aurorae than at other times. The next solar maximum is in 2024.

Atmospheric collisions
As the charged solar particles collide with atoms of oxygen and nitrogen gas in the Earth's atmosphere they produce light – known as the aurora.

A multitude of colours
The aurora glows different colours because the solar particles interact with different gases at different heights in Earth's atmosphere.

Red lights
Red aurorae are created when solar particles strike atoms and molecules of oxygen some 241 kilometres (150 miles) up in the atmosphere and higher.

Green lights
Green aurorae are the most common. They are created when solar particles strike atoms and molecules of oxygen up to 241 kilometres (150 miles) up in the atmosphere.

Northern and Southern Lights
The Northern Lights are also known as the Aurora Borealis. The Southern Hemisphere has its own lights too – the Aurora Australis, or Southern Lights. Fewer people see those displays than they do in the north because there is less inhabited land within the southern auroral oval.

Purple lights
Purple aurorae are caused by solar particles interacting with atoms and molecules of nitrogen gas in the atmosphere at heights above 97 kilometres (60 miles).

Blue lights
Blue aurorae occur very low in the atmosphere, at a height of 97 kilometres (60 miles) or lower. They are rare and are only seen during powerful displays.

Where and when can I see the Northern Lights?

If you want to see the aurora dancing, here's when you should look and where you should be

The key to seeing the Northern Lights is actually very simple – you just have to be in the right place at the right time. Unfortunately, the "right time" is totally out of our control; an aurora is triggered by activity on the Sun, and if Earth just happens to get in the way of a cloud of material blasted off the Sun, and a few things go the right way in the upper atmosphere and in Earth's magnetic field, an auroral display will be triggered that might be visible on the ground. We can narrow it down a little though: activity is increased around the equinoxes, so you have more chance of seeing the aurora between March and April and September and October.

Being in the right place at that time is the trick. Everyone knows that the further north you are the better your chances of seeing the aurora are, because auroral activity is concentrated around the poles. Consequently, an "aurora tourism" industry has sprung up over the past decade or so, with companies offering aurora-watching expeditions to places like Norway, Sweden and even Iceland. However, if those places are too expensive for your budget you can go on an "aurora flight"; a plane will head north to a latitude that is high enough to let you see any activity that is occurring, but which is usually hidden behind your northern horizon.

What about seeing the aurora from where you live, without any travel? Well, occasionally the Earth is hit by a solar "broadside" and then auroral activity can creep or even surge southwards, triggering an auroral display that is visible from much lower latitudes than usual. During a rare auroral "storm", the Northern Lights can be seen as far south as the Netherlands.

Remember that it's often a waiting game when it comes to aurora hunting. It's said that the best time to find the aurora is between the hours of 10pm and 3am during times of peak solar activity. However, there will be times where you'll be waiting out in the cold for hours, not seeing the aurora at all on your trip, along with varying degrees of activity.

Despite this, you should wrap up warm, check aurora forecasts, stay awake and be ready – it's very easy for a show to be over before it's really had a chance to begin.

> "It's often a waiting game when it comes to hunting for the Northern Lights"

Top places to catch the aurora

1 Norway

The Northern Lights are most visible between late autumn and early spring. The best areas are within the Arctic Circle in northern Norway or the Svalbard Islands, especially during the polar night. It's said there's no better place on Earth to see it!

2 Iceland

The Northern Lights can be seen from anywhere in Iceland but a great spot involves heading out to the plains of the Thingvellir National Park. The extended viewing season goes from Setember to mid-April, but the winter months are the darkest.

3 Sweden

The Northern Lights are best seen from Sweden during winter, with Abisko National Park, Jukkasjärvi, the Torne Valley and Porjus in Swedish Lapland favourite spotting locations. Even regions close to large towns in Swedish Lapland offer opportunities to see the aurora.

4 Finland

It's been estimated that you can see the Northern Lights 200 nights per year here – with the right conditions. Kakslauttanen, situated close to Urho Kekkonen National Park, is highly regarded as a very good place to spot aurorae. They are mostly visible from August to April.

5 Northern Canada

Northern Canada provides an excellent base for aurora seekers. Yellowknife in the Northwest Territories, also known as Aurora Village, is directly beneath the aurora oval and has plenty of clear weather, making it one of the best places in the world to see the aurora.

6 Russia

Being so close to the Arctic Circle, Russia is another ideal location to chase the aurora. The Kola Peninsula is a great location during December and January, where great stretches of wilderness are under pitch-black days and nights as the Sun disappears for around six weeks.

7 Alaska

A snowy wilderness in the far north of the US, Alaska is a great place to watch the Aurora Borealis – Fairbanks, Denali and even the less populated areas surrounding Anchorage can offer spectacular sights. The best months for viewing fall between September and April.

What can I expect to see?

Know when an auroral display is in action and how you can make the most of the view

NAKED EYE VIEW

CAMERA VIEW

In the olden days, following a solar flare, aurora-watchers just had to cross their fingers and hope that an aurora might be visible from where they lived. Today, things are very different. Dedicated websites feature daily "space weather" reports following solar activity and give early warnings of possible displays.

Special "aurora alert" apps downloaded onto your tablet or smartphone will tell you when auroral activity might be visible from your specific location, giving you invaluable "heads up" time that will help you decide whether you should stay where you are, or if you need to head somewhere with better weather prospects when the display is due to occur. Probably the most reliable way to follow auroral activity, and to be aware that an aurora might be visible from where you live, is to use social media. There are many Facebook communities and groups you can join, where aurora-watchers post alerts when activity is possible and share reports and photographs during displays and afterwards. You can also follow dedicated aurora alert accounts and enthusiastic aurora-watchers on Twitter.

But what will you actually see in the sky if you find yourself under an auroral display? Photographs of the aurora often show a sky literally ablaze with colour. Enormous flapping curtains of vivid crimson and ruby are shot through with stabbing pillars and searchlight beams of fluorescent marker pen green or blue, so bright they cast ink black shadows behind snow-dusted fir trees on the ground below. Unfortunately, astrophotography is proof that the camera can lie, and in the case of aurora photography, cameras often lie through their back teeth. Such dramatic photographs are commonly manipulated in image processing software, such as Photoshop, to enhance and exaggerate the colours of a display, making it seem much more vivid than it appeared to the naked eye.

So, while it's true that an auroral storm might fill the sky with violent reds and greens, most auroral displays only look grey white, with tinges of pink and green, to the naked eye.

Creating memories that last: imaging the Northern Lights

Effortlessly capture those vivid greens, purples and reds

Using the Moon

Any form of light pollution can wash out night sky astrophotography but in a snowy landscape, our natural satellite can play up terrestrial views that compliment the aurora.

Photographing the Northern Lights isn't as easy as lifting your camera to the sky during a display. As the aurora is usually a lot fainter than dramatic photographs published on websites and in magazines suggest, you need to be able to take long exposures and keep your camera very steady.

So, although a display might be bright enough for your smartphone or tablet's camera to capture it (and you should always try, just in case!), you'll need a good digital camera, such as a DSLR or a modern bridge camera. These will let you take the long exposures you need, and can also be mounted on a tripod to keep them steady and your images sharp.

For a faint auroral display – which are the most common kind – you'll need to set your camera to take exposures of several seconds, with the camera's ISO (what we used to call "film speed") set quite high, around 800 ISO or so, to gather as much of the aurora's faint glow as you can. During a brighter display you can reduce the exposure times and ISO settings. Because a good display can span the sky from west to east, and stretch almost overhead, you'll also need to have the camera fitted with the widest angle lens or widest field of view setting you have available; you'll want to capture as much of the sky as possible, and a standard 50mm lens would only capture a small part of it.

Make sure you use a remote shutter release or electronic timer to start and end your exposures; these will greatly reduce the shaking of the camera and give you sharper images. Finally, set your white balance to its "daylight" setting so you get the natural colours of the aurora.

Tips & tricks

- Decide if you want to shoot in RAW or JPEG – beginners may prefer JPEG for now.
- Set your camera's LCD brightness to low.
- Remove the filter from your lens – this will ensure that you don't have 'rings' in your images.
- Test a number of exposure times.
- Ensure you have a sturdy tripod and good ballhead.
- Keep a spare set of batteries and memory cards in your pocket. Cold weather drains batteries quickly and shooting in RAW uses memory fast.
- Get a lens hood to protect the camera from frost and condensation.

How to... capture a Northern Lights skyscape

Add trees or mountains to your images to compliment your shots of the aurora

1 Be prepared

You'll need a DSLR camera or a high-spec bridge camera, mounted on a tripod. It should be fitted with a wide-angle lens, or set to its widest field of view.

2 Set your camera's ISO to 800

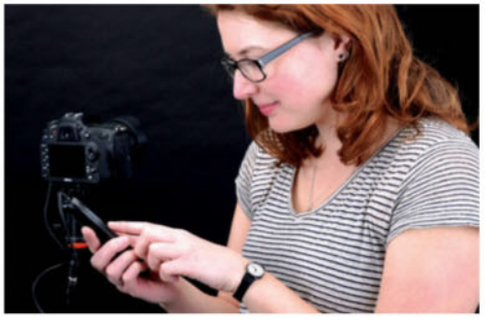
Set your camera to 'manual' mode so it can take long exposures of several seconds. Set the white balance to "daylight" and the ISO value to around 800.

3 Get into focus

To ensure your images are sharp, focus your camera on a bright star or a streetlight on the horizon. Keep checking your focus between images.

4 Frame your shots with scenery

Aim your camera towards the aurora, making sure there are foreground objects – such as trees, hills and mountains – in the frame to give your image visual impact and a sense of scale.



5 Take your first shot

Set your camera to take an exposure of five seconds, and then start the exposure with a remote shutter release to reduce any vibrations that might blur your image.

6 Experiment and have fun!

If your first photo looks too dark or too bright, or if the aurora's features are blurred, keep changing the exposure time until everything is sharp and clear.

STARGAZER

Planetarium

16 February 2017

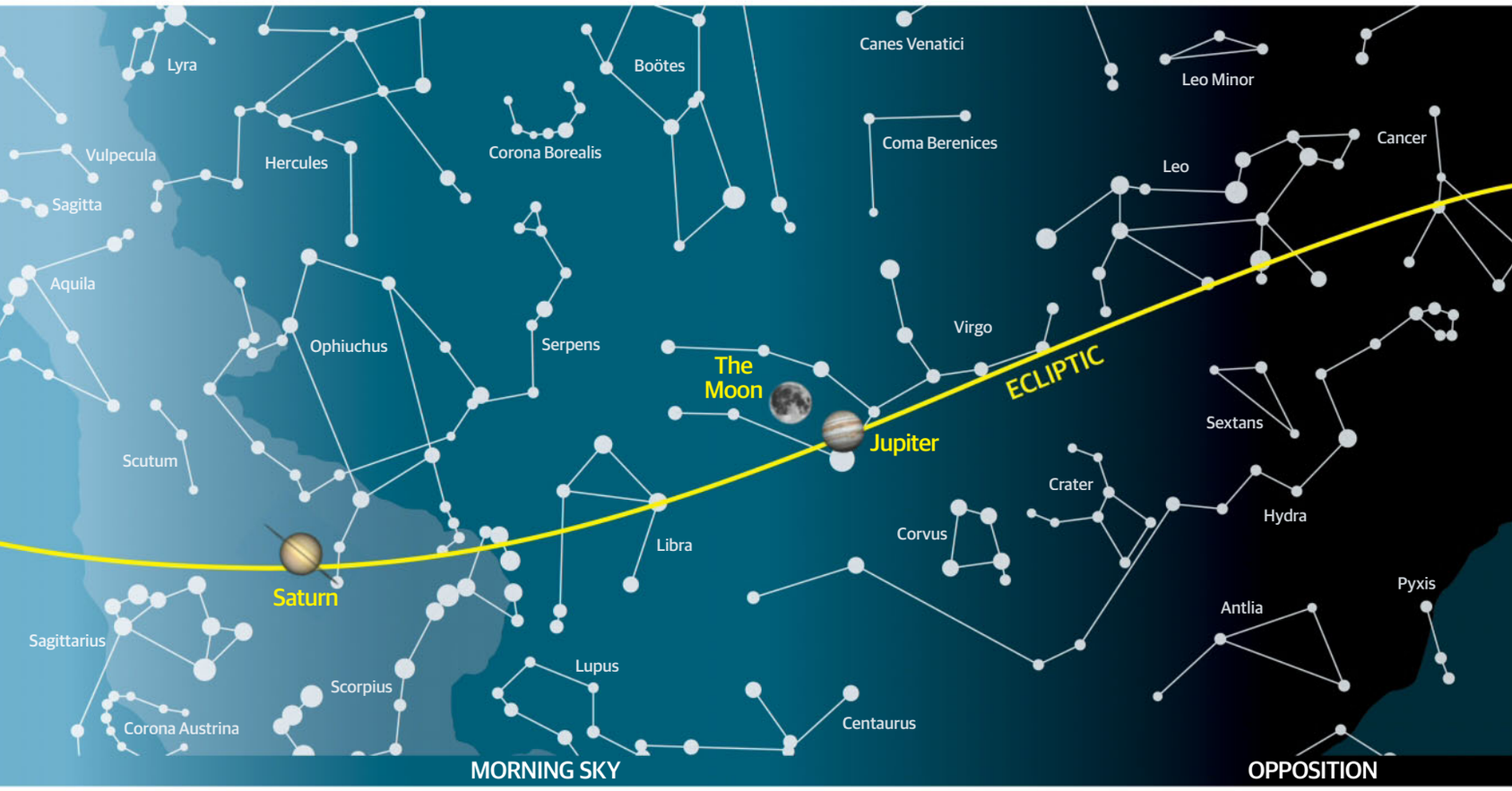
Moon phases

2 FEB 33.6% 10:10 23:34	**3 FEB** 45.1% 10:39 --:--	**4 FEB** FQ 56.9% 00:50 11:11	**5 FEB** 68.4% 02:04 11:48			
6 FEB 79.0% 03:16 12:32	**7 FEB** 87.8% 04:23 13:25	**8 FEB** 94.5% 05:22 14:25	**9 FEB** 98.6% 06:13 15:33	**10 FEB** 99.9% 06:55 16:44	**11 FEB** FM 100% 07:30 17:56	**12 FEB** 98.8% 07:59 19:07
13 FEB 95.2% 08:26 20:17	**14 FEB** 89.6% 08:50 21:24	**15 FEB** 82.5% 09:14 22:29	**16 FEB** 74.2% 09:38 23:33	**17 FEB** 65.2% 10:03 --:--	**18 FEB** LQ 55.6% 00:36 10:31	**19 FEB** 45.9% 01:36 11:03
20 FEB 36.3% 02:34 11:40	**21 FEB** 27.1% 03:29 12:23	**22 FEB** 18.6% 04:19 13:13	**23 FEB** 11.3% 05:04 14:11	**24 FEB** 5.4% 05:44 15:15	**25 FEB** 1.6% 06:19 16:23	**26 FEB** NM 0.0% 06:51 17:35
27 FEB 1.1% 07:19 18:50	**28 FEB** 4.8% 07:47 20:05	**1 MAR** 11.1% 08:14 21:22	**2 MAR** 19.7% 08:42 22:39			

% 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

	9 FEB	16 FEB	22 FEB	1 MAR
MERCURY	90%	90%	100%	100%
VENUS	30%	30%	20%	20%
MARS	90%	90%	90%	90%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

All rise and set times are given in GMT

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	02 Feb	19h 35m 30s	-22° 15' 38"	Sagittarius	-1.7	06:44	10:44
	09 Feb	20h 19m 01s	-21° 01' 11"	Capricornus	-1.6	06:51	15:09
	16 Feb	21h 04m 16s	-18° 42' 48"	Capricornus	-1.6	06:54	15:41
	22 Feb	21h 43m 57s	-15° 51' 46"	Capricornus	-1.7	06:53	16:14
	01 Mar	22h 31m 09s	-11° 30' 46"	Aquarius	-1.9	06:49	16:58
VENUS	02 Feb	23h 51m 12s	+01° 07' 48"	Pisces	-5.4	08:50	21:09
	09 Feb	00h 08m 59s	+04° 12' 33"	Pisces	-5.5	08:25	21:14
	16 Feb	00h 23m 11s	+06° 59' 56"	Pisces	-5.5	07:57	21:15
	22 Feb	00h 31m 45s	+09° 03' 07"	Pisces	-5.5	07:31	21:11
	01 Mar	00h 36m 31s	+10° 53' 17"	Pisces	-5.4	06:58	20:58
MARS	02 Feb	00h 12m 46s	+00° 59' 36"	Pisces	0.8	09:12	21:29
	09 Feb	00h 31m 43s	+03° 08' 51"	Pisces	0.8	08:53	21:32
	16 Feb	00h 50m 39s	+05° 15' 48"	Pisces	0.9	08:33	21:34
	22 Feb	01h 06m 54s	+07° 02' 09"	Pisces	0.9	08:17	21:36
	01 Mar	01h 25m 55s	+09° 02' 40"	Pisces	1.0	07:58	21:38
JUPITER	02 Feb	13h 26m 45s	-07° 35' 03"	Virgo	-2.2	23:07	10:02
	09 Feb	13h 26m 51s	-07° 33' 47"	Virgo	-2.2	22:40	09:34
	16 Feb	13h 26m 22s	-07° 29' 09"	Virgo	-2.3	22:11	09:07
	22 Feb	13h 25m 31s	-07° 22' 33"	Virgo	-2.3	21:46	08:43
	01 Mar	13h 24m 00s	-07° 11' 55"	Virgo	-2.3	21:16	08:15
SATURN	02 Feb	17h 36m 07s	-22° 02' 12"	Ophiuchus	1.2	04:43	12:47
	09 Feb	17h 38m 44s	-22° 03' 24"	Ophiuchus	1.2	04:18	12:22
	16 Feb	17h 41m 08s	-22° 04' 15"	Ophiuchus	1.2	03:53	11:57
	22 Feb	17h 42m 58s	-22° 04' 45"	Ophiuchus	1.1	03:31	11:35
	01 Mar	17h 44m 51s	-22° 05' 06"	Sagittarius	1.1	03:06	11:10

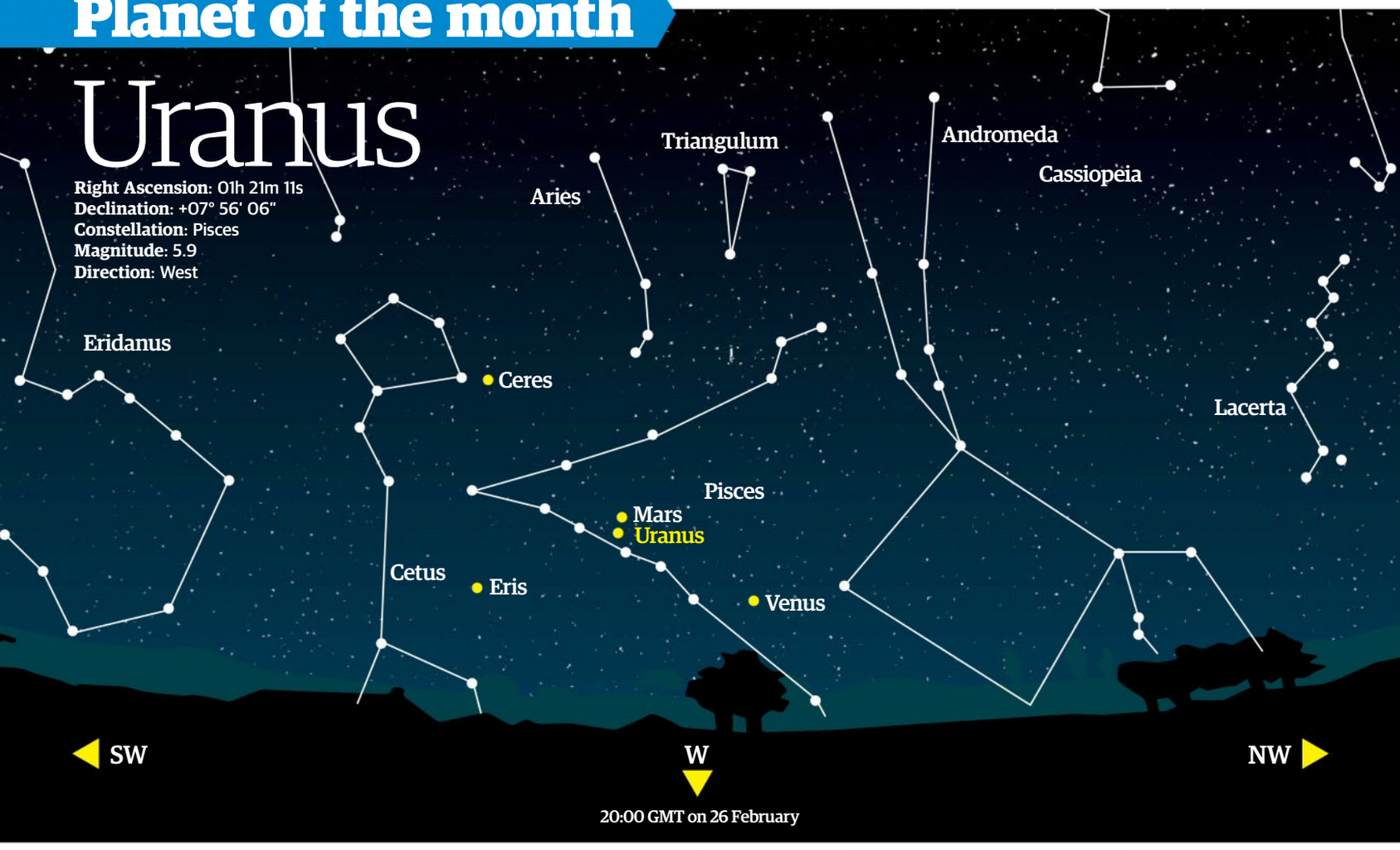
This month's planets

As we approach late winter, the worlds of our Solar System still remain a treat for astronomers during the long evenings and just before dawn

Planet of the month

Uranus

Right Ascension: 01h 21m 11s
Declination: +07° 56' 06"
Constellation: Pisces
Magnitude: 5.9
Direction: West



Many people think of Uranus as boring. After all, its rings are dark and thin, poor imitations of Saturn's glittering icy hoops; its cyan atmosphere is bland and featureless compared to Jupiter's, with its churning bands of caramel and toffee-coloured storms. And it's so far away that it takes 84 years to make one orbit of the Sun, which is 3 billion kilometres (1.8 billion miles) away.

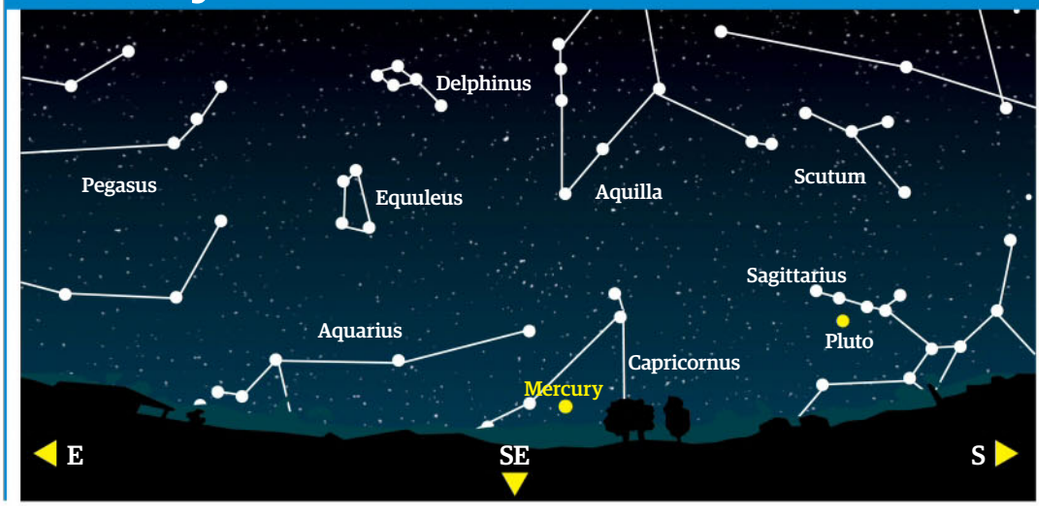
But Uranus is actually a fascinating world – an ice giant that could hold 63 Earths as it rolls around the Sun on its equator, more like a barrel than a spinning top. And when Voyager 2 flew past Uranus in 1986, just four days before Space Shuttle Challenger blew up, it found that Uranus' moons were fascinating worlds in their own right.

But how many of you have seen the planet Uranus? In theory, it shouldn't be too hard: with an apparent magnitude of just under six, the seventh planet from the Sun is, mathematically, bright enough to be seen with the naked eye. The problem is that there are thousands of stars in the sky of sixth magnitude too, so unless you know exactly where to look, it is impossible to pick Uranus out from the crowd; it doesn't jump out at you like Venus or Jupiter. So most sky-watchers stop hunting once they've found Saturn as they think finding faint Uranus is too hard – at least, not without either a really good star chart, or using something easier to find that's close by as a guide... Thankfully this month there is such a guide – Mars.

All through February, Mars will be shining in the constellation of Pisces with Uranus, and on 26 February, after slowly drawing together, the two planets will be just half a degree apart – so close they'll fit in the same binocular field of view or low-power telescope eyepiece. They'll also be very close for a couple of nights on either side of that date. Mars will be an obvious orange "star" to the naked eye and Uranus will be a much fainter, cyan-hued star to its left, which you'll need binoculars or a telescope to identify using the charts we've drawn for you. If you're still not sure you've found Uranus, use a different eyepiece to increase the magnification: if your candidate star is Uranus you will see a pale-green disc instead of a point of light.

When will we get a closer look at Uranus? Unfortunately, no space probes are due to visit anytime soon but one day this fascinating world will be studied in as much detail as Cassini is currently studying Saturn, or Rosetta studied Comet 67P. Until then, you can enjoy finding the enigmatic world from your own garden, using the Red Planet as a stepping stone.

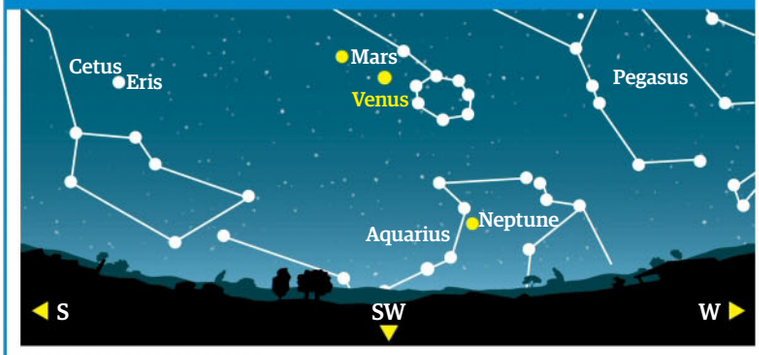
Mercury 07:30 GMT on 14 February



Right Ascension: 20h 51m 12s
Declination: -19° 29' 01"
Constellation: Capricornus
Magnitude: -1.6
Direction: Southeast

Because it orbits so close to the Sun in our Solar System, Mercury never appears to stray far from our star in the sky, so we only ever see it briefly before sunrise or after sunset - and even then it is hard to pick out from the bright sky without help from binoculars or a telescope. This is not a good month to see the planet Mercury. At the start of this month Mercury rises less than an hour before the Sun, so will only be visible to observers with a low and flat southeastern horizon, free of buildings and trees. But every day that passes this month sees Mercury a little closer to the Sun, and by the end of February the little planet will not be visible at all.

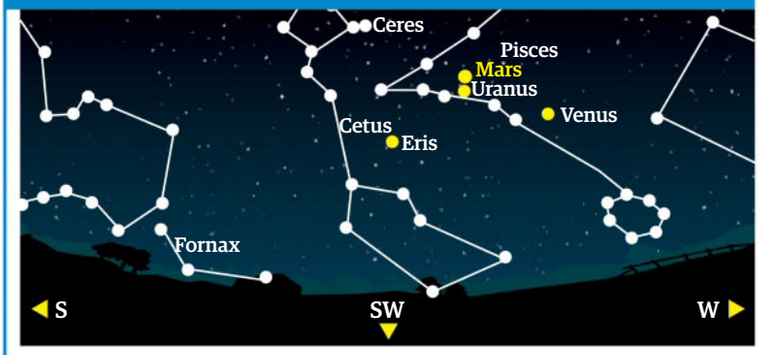
Venus 18:00 GMT on 5 February



Right Ascension: 23h 59m 13s
Declination: +02° 28' 38"
Constellation: Pisces
Magnitude: -5.4
Direction: Southwest

Venus continues to dominate the evening sky. At magnitude -5.4, it is as bright as it ever gets. An hour after sunset Venus will be blazing like a spark of burning magnesium, putting everything else in the sky to shame. Venus is close to Mars throughout the month, closest to it around 5 February when they are just 5.5 degrees apart.

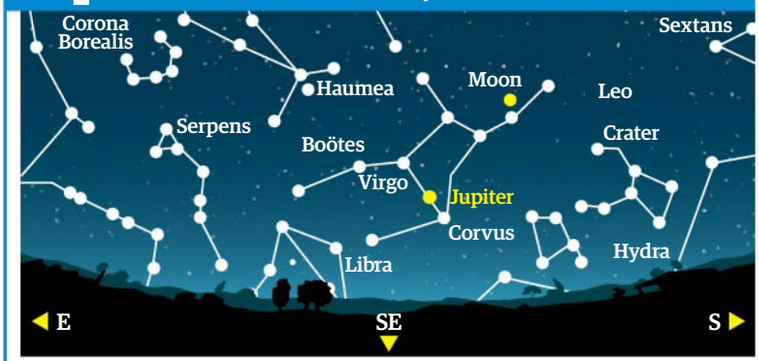
Mars 18:00 GMT on 26 February



Right Ascension: 01h 17m 45s
Declination: +08° 11' 32"
Constellation: Pisces
Magnitude: 1.0
Direction: Southwest

Mars spends this month staying close to Venus in the evening sky after sunset. Its orange hue will not be apparent to the naked eye until after dark, and even then, Mars is put to shame by nearby Venus' brilliance. At magnitude 1.0, Mars is fainter than many of the brightest stars you'll see in the sky at the moment.

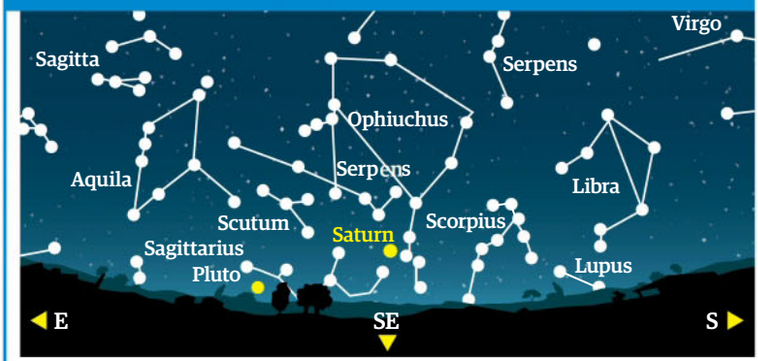
Jupiter 02:00 GMT on 14 February



Right Ascension: 13h 26m 34s
Declination: -07° 30' 49"
Constellation: Virgo
Magnitude: -2.3
Direction: Southeast

Jupiter is a very impressive object all through this month, shining at magnitude -2.3, brighter than anything else in the sky apart from the Moon and Venus. Jupiter can be found shining above Virgo's brightest star, Spica, the two looking like a beautiful "double star" as they rise and cross the sky together.

Saturn 06:00 on 16 February



Right Ascension: 17h 41m 08s
Declination: -22° 04' 15"
Constellation: Ophiuchus
Magnitude: 1.2
Direction: Southeast

Shining among the faint stars of Ophiuchus, Saturn rises at 5am in early February and spends the month slowly moving away from the Sun. A yellow-white colour to the naked eye, Saturn is a giant world, second only in size to Jupiter. Sadly its rings can only be seen through a telescope but they are wide open and thrilling to see.

Moon tour

Aristarchus crater

This is a good time to enjoy looking at the brightest major feature on the Moon...

© NASA; GSFC; Arizona State University

Top tip!

Don't be put off looking at the Moon when it's full, as it's a great time to see bright rays surrounding the youngest craters!

Many astronomers will tell you that full Moon is the absolute worst phase of the whole lunar month to look at our nearest celestial neighbour; after all, all you can see are the Moon's major light and dark areas – its flat seas and rugged highlands, respectively. That's a little unfair. While it's true that you can see a lot of stark and fascinating surface relief on the Moon when it is a crescent, or first or last quarter, at full Moon you can see things not obvious at any other time.

For example, at full Moon it's much easier to appreciate how the mare are connected to each other (forming the classic "Man in the Moon") and it's also easier to appreciate the huge difference in albedo (reflectivity, or brightness) between the rugged, mountainous highlands and the dark, flatter lowlands. But the best thing about full Moon is that it allows us to see how incredibly far the rays of bright debris spray away from the youngest impact craters on the Moon, such as Copernicus and Tycho. And full Moon is the very best time to look at the brightest feature on the whole Moon – Aristarchus.

A quick Google search for "Aristarchus" will turn up countless amateur sketches and images of the crater; as it has interesting near neighbours, including Herodotus crater and the Schroter's Valley, the crater is a favourite of lunar observers and photographers alike. It has also been photographed by lunar explorers, both robotic and human. It was snapped during several Apollo missions, most notably Apollo 15, and more recently NASA's Lunar Reconnaissance Orbiter sent back stunning images of the insides of the crater's shiny walls, boulder-strewn floor and bright central peak. It helps that it is a favourite target for lunar observers and photographers alike.

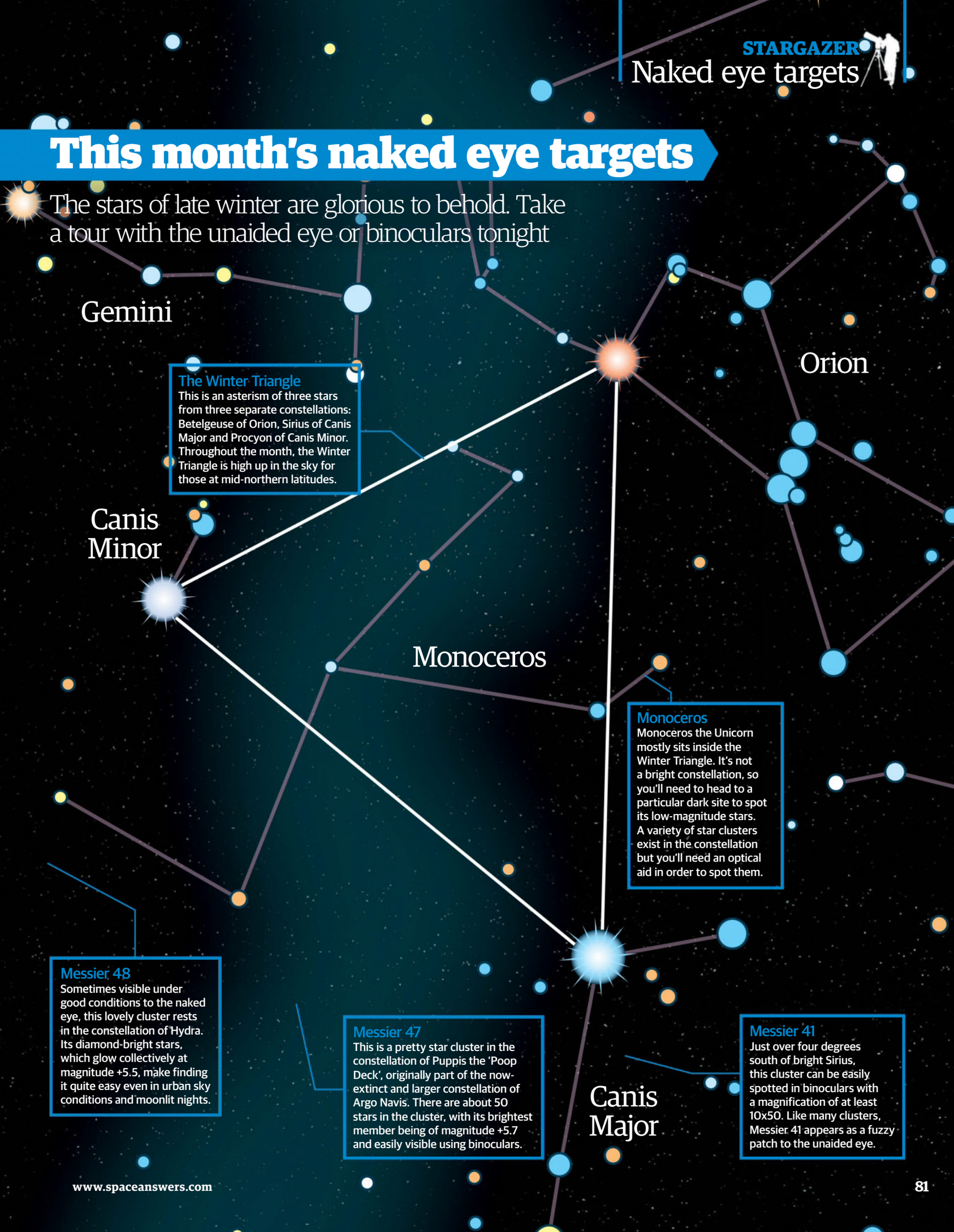
Aristarchus is in one of the regions observers claim to have seen "transient lunar phenomena", or TLP. This is the term Patrick Moore coined for short-lived lights, colours or changes in appearance of the Moon's surface. Some lunar experts think TLP might be brief releases of gas coming up from beneath the Moon's surface, but it is an area of some debate, to say the least...

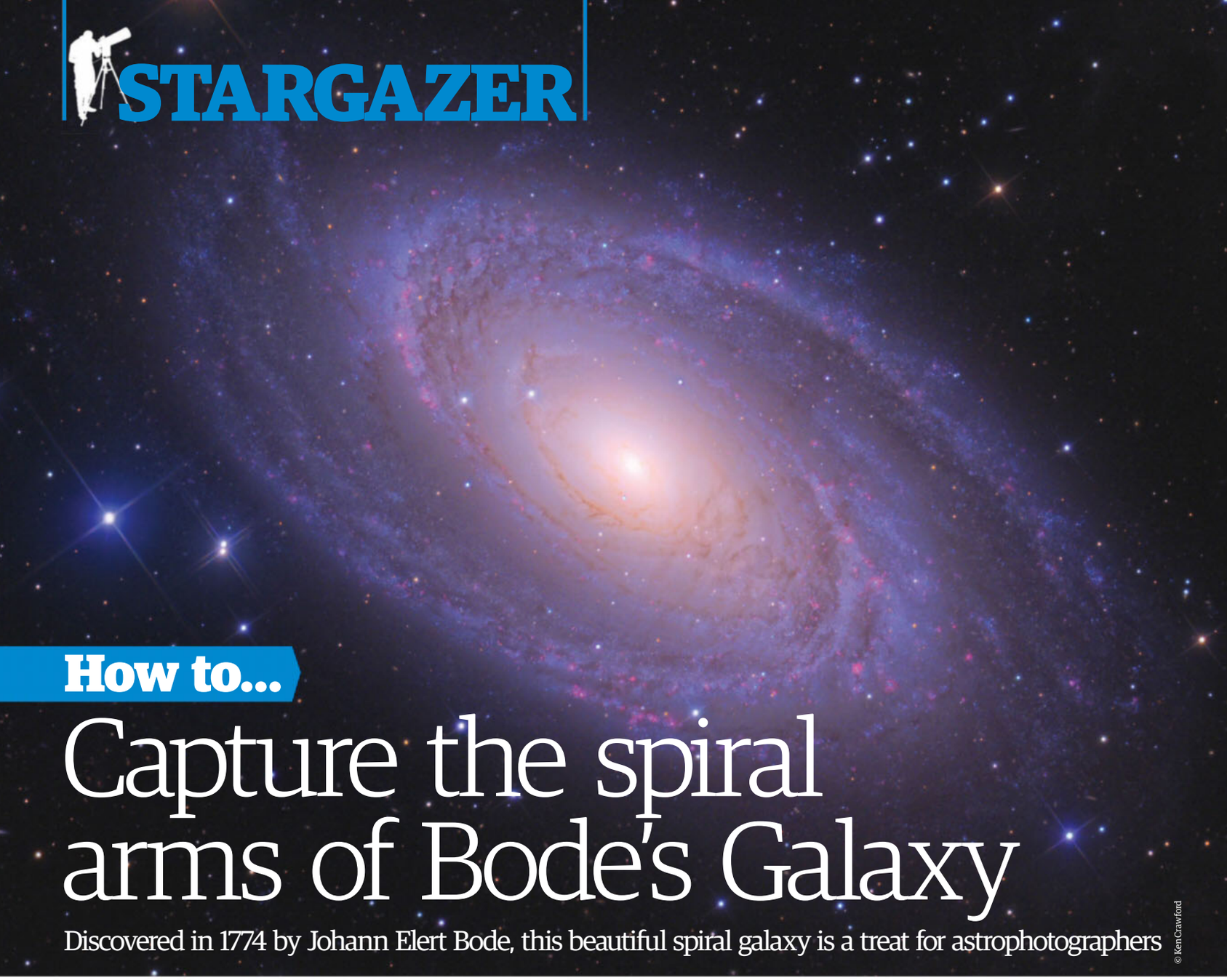
At the start of February Aristarchus can't be seen; the Moon is just a couple of days old and Aristarchus is still deep in lunar night. It's not until 8 February that the terminator finally sweeps over the crater and it emerges from the darkness. Then, up in the northwest quadrant of the disc at around the 10pm position, it will look like a small ding in a car windscreen through a small telescope. Three days later when the Moon is full, even just your naked eye will pick out Aristarchus as a very obvious bright spot. Binoculars will enhance its brightness considerably, turning the dot into a small tadpole or comma of striking silvery-white against the lunar disc, surrounded by a splash of fainter rays. Through a telescope at full Moon, Aristarchus is transformed into a fascinating splodge of white at the centre of an elaborate and beautiful web of silvery-white debris rays, as if someone has dropped a small pot of white paint on the Moon and it has burst open.

The crater remains visible as a white dab on the grey lunar surface until 21 February when the terminator sweeps towards it once again. At this time Aristarchus will look like a proper crater again, complete with terraced walls, flat floor and central peak. This will be the time to look at Aristarchus through the highest-powered eyepieces you have for your telescope, as you'll be able to see detail inside and around it that is not visible at any other time. Make the most of the view on this evening and into the next morning because a day later the terminator will have rolled over the crater, plunging it into darkness again until 9 March.

This month's naked eye targets

The stars of late winter are glorious to behold. Take a tour with the unaided eye or binoculars tonight





How to...

Capture the spiral arms of Bode's Galaxy

Discovered in 1774 by Johann Elert Bode, this beautiful spiral galaxy is a treat for astrophotographers

You'll need:

- ✔ A telescope
- ✔ Tracking mount
- ✔ DSLR camera
- ✔ Camera adaptor
- ✔ Remote shutter release

About 12 million light years from Earth lays one of the most beautiful galaxies in the entire night sky. Bode's Galaxy, also known as M81 or NGC 3031, can be found in the constellation of Ursa Major (The Great Bear) and it shares its region of sky with another galaxy of completely different shape, known as the Cigar Galaxy, catalogued as M82.

What makes Bode's Galaxy outstanding is its glorious spiral arms. It is almost face on to us, so we get a very good view of the entire galaxy, including the spiral arms. The galaxy itself is interesting, as it is thought to contain a supermassive black hole at its centre. It is, without doubt, a very photogenic object in the night sky, as it is of a good size and is quite bright for a galaxy. It is, therefore, a very popular object with amateur astronomers and astrophotographers. If you plan to image it in all it's glory for yourself, there are a few things you'll need.

First of all, you'll need a telescope; between 85mm and 100mm aperture for a refractor, or between 150mm and 200mm aperture for a reflector are good sizes. Of course, an even larger aperture will make imaging the galaxy and its spiral arms even easier. A tracking mount is also essential and an equatorial mount is preferable with a drive or a GoTo system. You'll also need a DSLR camera and an adaptor to fit it to your telescope.

A useful device to have here is a remote shutter release, as this helps to minimise vibrations when opening and closing the shutter on the camera. Depending on the focal length of your telescope, you may need to use a Barlow lens to increase the magnification and to fit the galaxy comfortably into the frame of the picture. Even though the galaxy is quite bright, you're still going to need to use long exposures to capture it well. You'll also need to be able to set your camera to manual settings to do this and adjust the ISO setting to get a good image.

It is a good idea to use a series of shorter-exposure shots and stack them together in software, rather than taking one long-exposure image. This helps to minimise the risk of something going wrong during the exposure and can also help to increase the contrast in the final image.

Take lots of exposures and check for good focus regularly, and adjust where necessary. Once you're happy with your shots you can process the images in Photoshop or similar software.

Tips & tricks

Choose your aperture carefully

Use a 85mm aperture refractor or a 150mm aperture reflector or larger for the best results.

Get a tracking mount

A tracking mount, preferably an equatorial mount, with a drive or a GoTo system is needed.

Use a removable DSLR lens

A DSLR camera with a removable lens will give you a good image and a remote shutter release will minimise vibrations.

Check your focus

Focus with the view screen on your camera if you have one, and check and adjust the focus regularly.

Be experimental

Take lots of exposures of the same length. These can be stacked in software to improve detail and contrast.

Imaging the deep sky

Achieve stunning results of this deep-sky wonder

Ensure you have sharp focus by using the magnify function on your camera's view screen. Then set the ISO value to 800 or 1000, as this allows good sensitivity of the imaging chip without too much unwanted noise. Take exposures between one and five minutes in length; the length depends on local conditions and how well set up your mount is. It is sometimes better to take five one-minute exposures rather than one five-minute exposure, but take lots of shots of the same duration though. Use software such as Deep Sky Stacker, which is free to download online, and/or Photoshop to process the images.

Send your photos to
space@spaceanswers.com

1 Prepare your camera

Attach your DSLR camera to your telescope using a T-Ring adaptor. You should make sure it is sturdy and attached securely.

2 Find Messier 81

Using a star chart or a GoTo system on a computerised telescope, track down Bode's Galaxy (otherwise known as Messier 81) in Ursa Major.

3 Turn on the telescope's drive

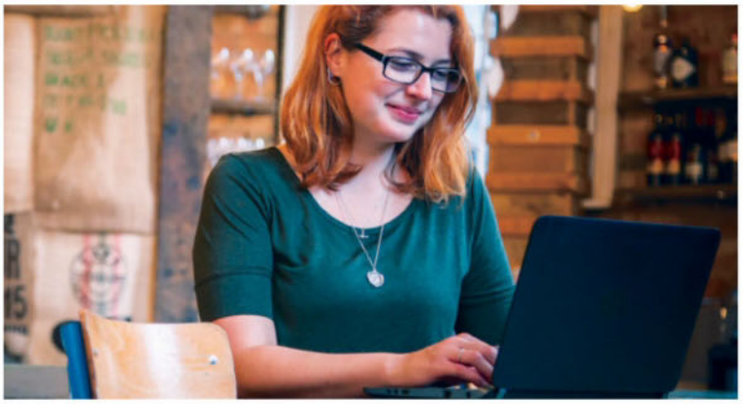
Make sure your telescope's motor drive is switched on and running smoothly before you start taking your exposures.

4 Adjust the camera settings

Set up the ISO value to 800 or 1000, adjust the exposure length - which should be between one and five minutes in length - and get a sharp focus.

5 Snap away!

Using a remote shutter release to reduce vibrations and create shake-free images, take several pictures of M81 with at least a one-minute exposure.



6 Use an image processing software

Process your shots using Deep Sky Stacker and/or Photoshop to pick out details of the spiral arms of M81.

Deep sky challenge

Star clusters of the Great Dog

Marked by the brightest star in the entire night sky, Sirius, get lost in Canis Major's many deep-sky wonders this evening

Only ever skimming the southern horizon during the winter from the Northern Hemisphere, the constellation of Canis Major is rich with beautiful star clusters and, of course, that extraordinarily bright star Sirius. The star clusters vary in size and brightness; some are easy to resolve in even the smallest backyard telescope, while others will require a much larger aperture.

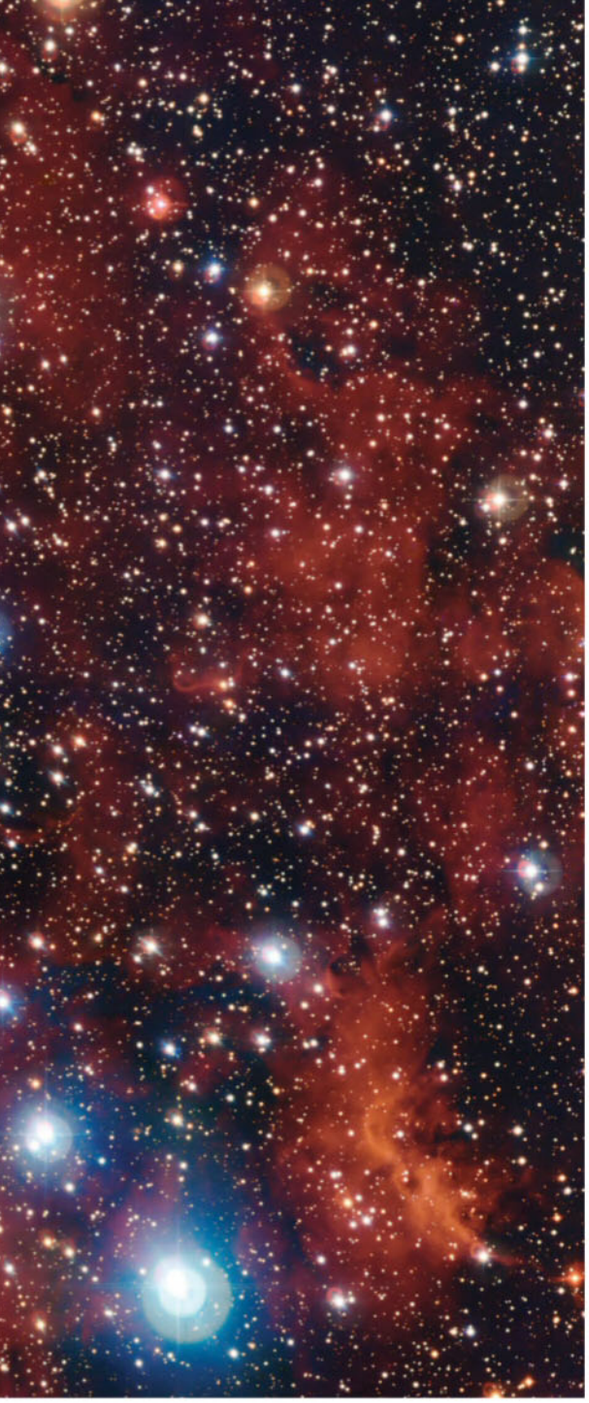
The largest and brightest of the clusters, M41, can be seen in binoculars but a telescope will resolve many of the stars in the group. There is also a faint nebula, a region of ionised hydrogen gas, labelled NGC 2359 and known as 'Thor's Helmet', which is visually challenging but shows up well in long-exposure astrophotographs. Sirius itself is a double star but it is hard to spot the companion due to the brightness of the main star. There is something for everyone in this lovely constellation though.

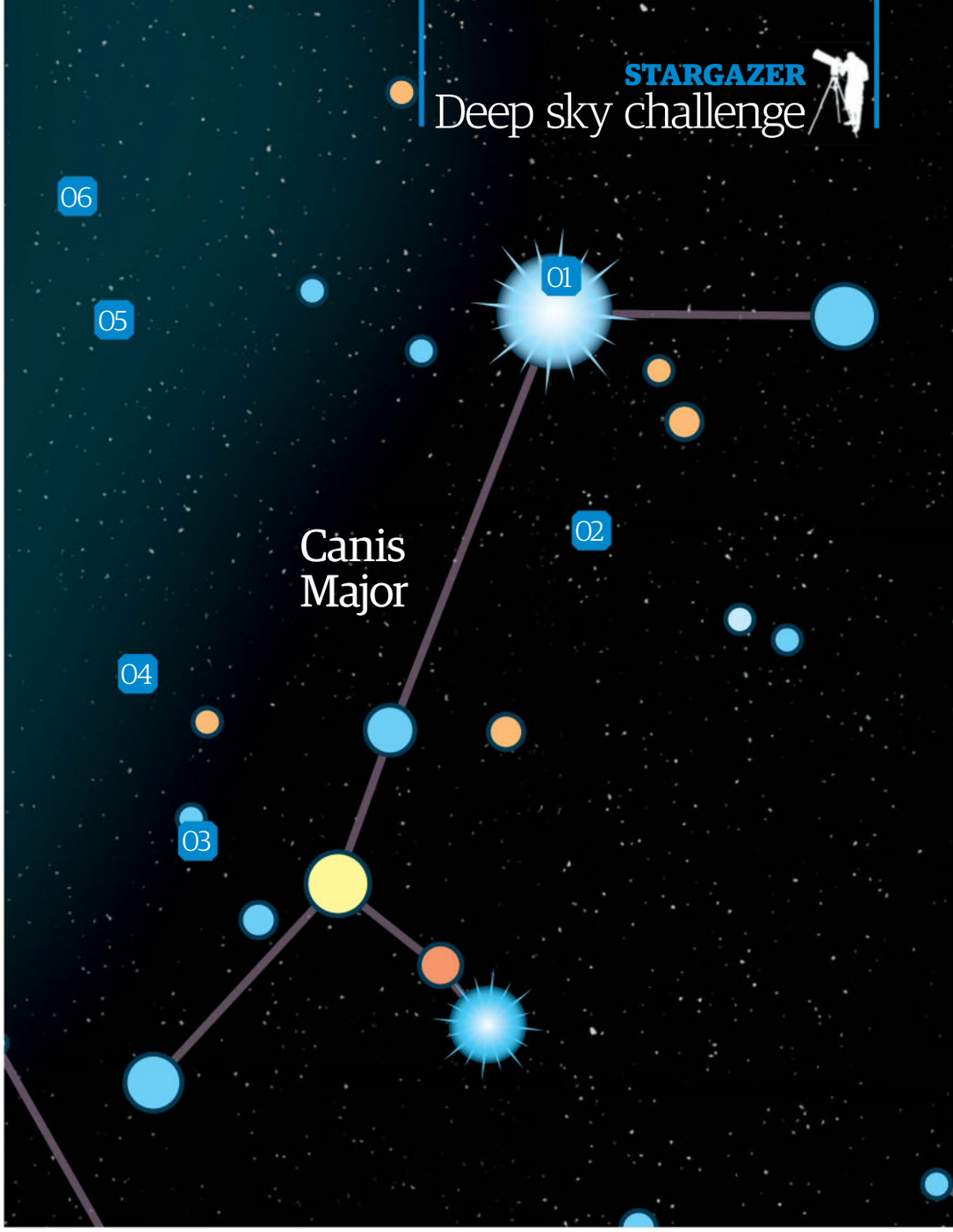

NGC 2367

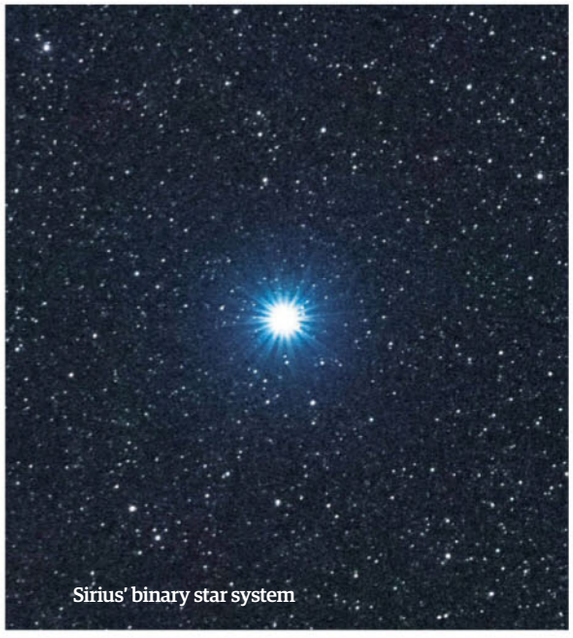

NGC 2362


Thor's Helmet (NGC 2359)

Deep sky challenge







Sirius' binary star system

1 Sirius' binary star system

The brightest star in the sky is a double star but you'll need a telescope with a large aperture and high magnification to split it. The main component, the white-blue Sirius A, is obvious with a magnitude of -1.42, while its smaller white dwarf companion is challenging to view at magnitude +8.42.

2 Messier 41

A small telescope and a low-power eyepiece are needed to pick out the member stars of this open cluster. This object is packed with 100 stars of different types, some of which are red giants and white dwarfs, and its 'wide-open' appearance makes it a favourite among amateur astronomers.

3 NGC 2362

A very attractive, yet not very well known, open cluster of stars surrounding the star Tau Canis Majoris, NGC 2362 is a visual delight through a telescope with even a small aperture. Given how sparse the cluster is, averted vision will give you a view that explodes much more readily with stars.

4 NGC 2367

A small cluster of young, hot blue stars, NGC 2367 is visible in a small telescope but is more impressive in larger apertures. Once you have trained your telescope on this bright object, the burst of intense white-blue light from its young, hot stars will be stunning to observe.

5 Caroline's Cluster (NGC 2360)

Named after its discoverer, Caroline Herschel, this +7.2 magnitude cluster is a beautiful sight through at least a pair of binoculars, as it occupies a rich section of our galaxy, the Milky Way. A telescope with a small aperture will allow you to pick this cluster out even in moderately light-polluted skies.

6 Thor's Helmet (NGC 2359)

A beautiful nebula surrounding a very hot 'Wolf Rayet' star, Thor's Helmet looks just like the helmet of the Norse god of thunder. Don't expect to see the detailing of this emission nebula through your telescope alone, as you'll need a UHC filter. When you locate it though, the views are rewarding.

© Kevin Baird

How to...

Observe a solar annular eclipse

This spectacular event will be visible on 26 February from South America and parts of West Africa. Here's how to make the most of it...

You'll need:

- ✔ Solar eclipse viewers
- ✔ DSLR camera
- ✔ Tripod

Solar eclipses, both total and annular, occur when the Moon lines up with the Sun for a few precious moments and the path of the shadow created by the Moon sweeps across the surface of the Earth. The Moon is about 400-times smaller than the Sun, but the Sun, by chance, is about 400-times further away from us, so they appear roughly the same size in our sky. The Moon's orbit around the Earth is also slightly elliptical rather than circular and so the distance it is from our planet can vary a little. This makes the Moon seem slightly larger at times in our sky when it's nearer, especially noticeable at the time of the full and new Moon. Conversely, it can seem a bit smaller when its orbit takes it further away from us. If this occurs at the time of new Moon, and it happens to be crossing the plane of Earth's orbit, then we'll see an annular eclipse.

What we see, in fact, is the silhouette of the Moon against the Sun, leaving a bright ring of light (the annulus) encircling the Moon, which has blotted out at least 90 per cent of the solar disc. On 26 February, such an eclipse will be visible. However, the path of the annular eclipse itself is quite narrow, crossing through Chile and Argentina, the South Atlantic and then on to the west coast of Africa through Angola and ending in the DR Congo. If you would like to see the annulus, then you'll need to be under this track. There are large parts of the world, though, that will see a partial solar eclipse, including much of South America, west and central Africa.

Because the eclipse is not total and the Moon will not completely cover the disc of the Sun, it is very important that suitable eye protection is worn at all times, otherwise serious damage to your eyes can occur. This is true of both the annular eclipse and the partial phases as well. You can use solar eclipse glasses, providing they have been obtained from a reputable source. Do not be tempted to use welder's glass or similar, as this just does not give adequate protection against the infrared and ultraviolet parts of the sunlight. If you plan to photograph the eclipse, make sure you have suitable filtering for your camera, as looking through the viewfinder can be dangerous and you could damage the sensitive imaging chip.

Tips & tricks

Never look at the Sun
The Sun can very easily cause blindness. It is vitally important that you exercise great care when viewing and imaging it!

Use eclipse viewers
Solar eclipse viewers or glasses must be in good condition, so check before use.

A solar filter is a must
You can photograph the eclipse but avoid looking through the camera and use a solar filter at all times.

Use a tripod
Use a sturdy tripod to help steady your shots, especially if you're using a telephoto lens.

Take short exposures
Exposures need to be short, just a few tenths of a second at most.

Getting good results

If you plan to photograph the eclipse, use these tips to get the best possible shots

If you plan to record your eclipse experience, make sure your camera is fitted with a solar filter. Baader Astro-solar Safety film is an excellent product – make sure it is securely fitted and can't be knocked off! Set up your camera manually if you're using a DSLR, as it will give you better control of the shots. Use short exposures and a low ISO of, say, 100. Shoot in RAW format and use a telephoto or zoom lens to add drama. Take a few wide-field images without a filter and away from the Sun, as this will provide context.

Send your photos to
space@spaceanswers.com

1 Check your solar filters for damage

Make sure that both your eclipse viewers and camera filters are in good condition. Any holes or scuffs could lead to serious eye damage.

2 Attach your camera to a tripod

Set up your camera on a sturdy tripod for sharp, vibration-free pictures. Make sure the surface is flat and the camera is securely attached.

3 Fix your solar filter

Attach the solar filter to the camera lens. You should make sure it is securely fitted and with no gaps in order to protect your eyesight.

4 Adjust your settings

Set up the camera manually with a low ISO value, short exposure length and in RAW. This will provide you with more control over the images.

5 Carefully start shooting

Point the camera towards the Sun, taking all necessary care to protect your eyesight, and then start taking pictures.

6 Provide context

Take a few shots of the surrounding landscape using a wide-angle lens without the solar filter, to provide context and get the feel of the event.

The Northern Hemisphere

Make the most of February skies as the gems associated with the cooler, darker evenings remain easy pickings

Astronomers with varying observing abilities are spoiled for choice this month, as Orion (The Hunter), Taurus (The Bull), Gemini (The Twins), Perseus (The Hero), Canis Major (The Great Dog) and Eridanus (The Celestial River) are strong during the clear, frosty evenings.

Next to the brighter planets, the Dog Star, Sirius – shining at magnitude -1.4 – is an unmissable sight for naked-eye observers. Meanwhile, red supergiant Betelgeuse on the shoulder of Orion is also an easy target for the unaided eye, glowing with a reddish hue.

Using 10x50 binoculars, sweep across the stellar members of the Pleiades (M45) and the Hyades star clusters. If you have a telescope with at least a small aperture, then head to the tip of Taurus' bottom horn to spot the stunning Crab Nebula (M1) under favourable sky conditions.

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

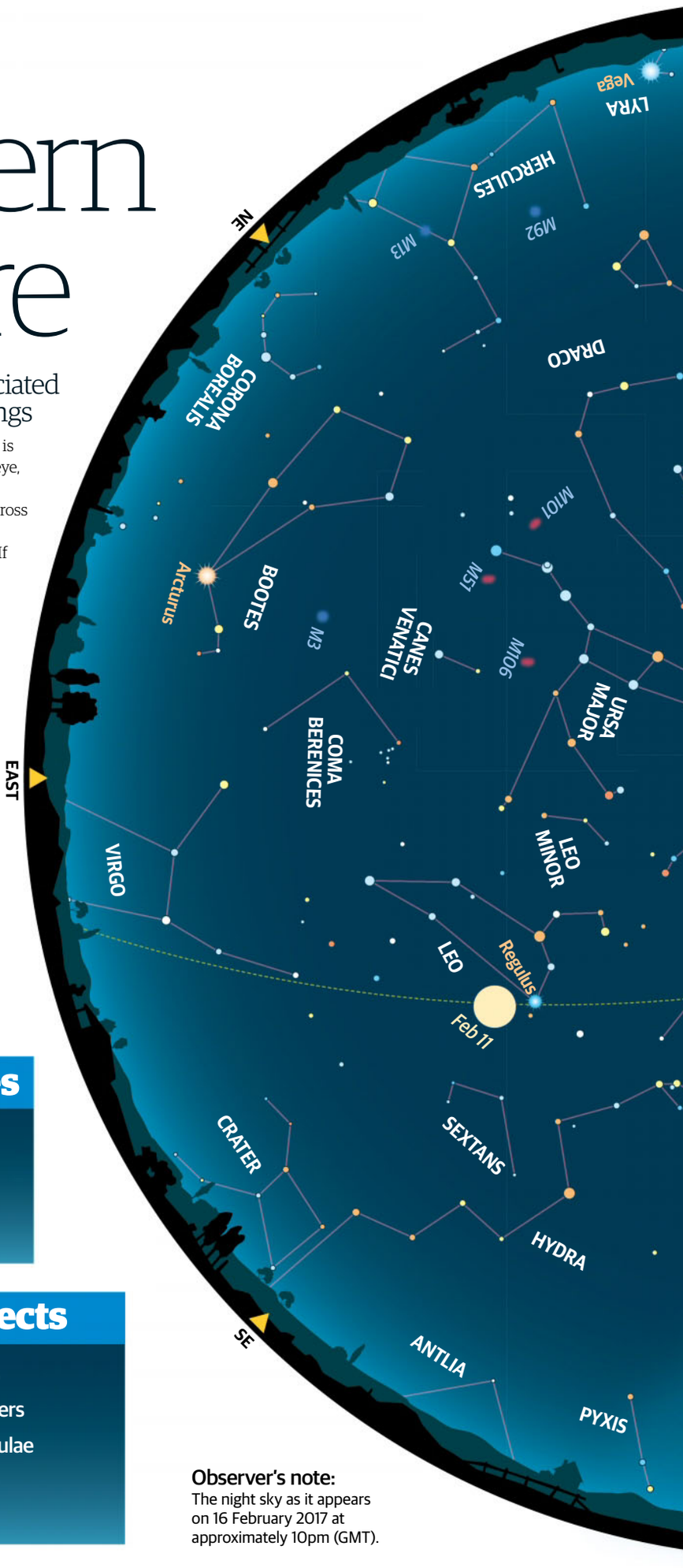
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

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

Deep-sky objects

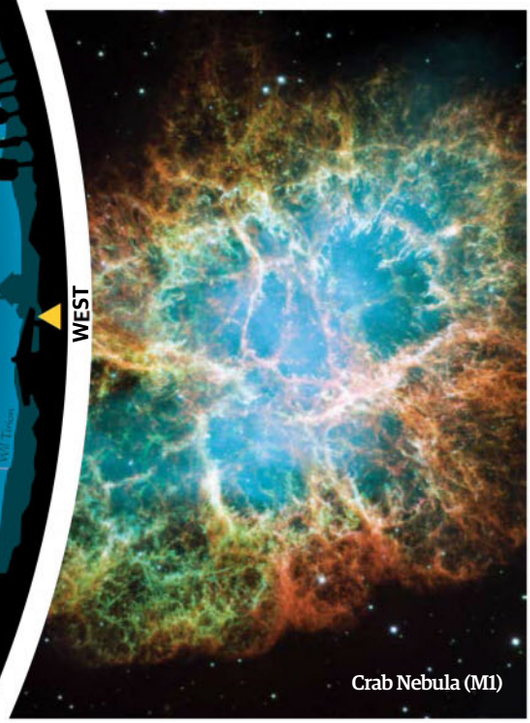
- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:
The night sky as it appears on 16 February 2017 at approximately 10pm (GMT).

The Northern Hemisphere


Messier 87


Crab Nebula (M1)


The Hyades (Melotte 25)

Me & My Telescope

Andromeda Galaxy (M31)

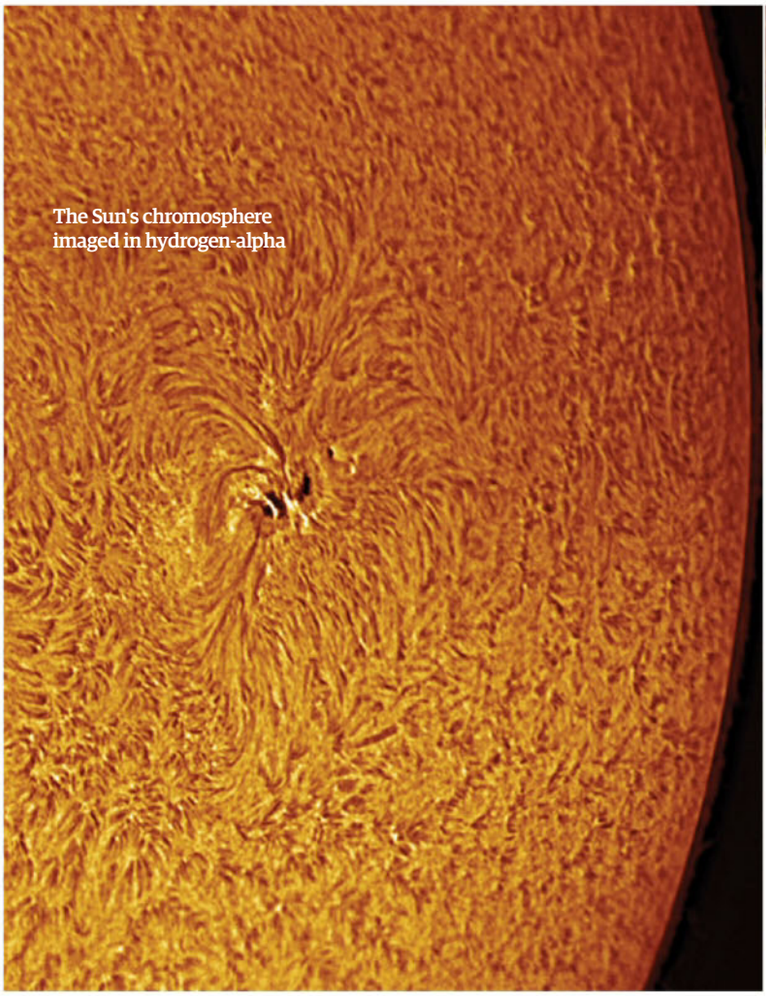
Send your astrophotography images to **photos@spaceanswers.com** for a chance to see them featured in **All About Space**

Jeff Johnson

Las Cruces, New Mexico
Telescope: Takahashi FS-60C refractor

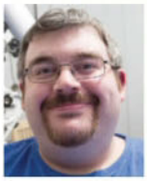
"I have a long love of astronomy and have observed the night sky for many years with binoculars and a telescope. I did my first "real" astrophotography in 1996, when I used a 35mm SLR (film) camera to take photos of Comet Hyakutake. I took a tripod out into the desert here in Las Cruces and just experimented with exposures. Later, I bought a 10-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."

Barnard 343



The Sun's chromosphere imaged in hydrogen-alpha

Mark Forbes



Stockport, UK
Telescope: Altair Astro StarWave 102 ED refractor
"Solar imaging is a recent area of interest to me, after seeing the spectacular images taken by astrophotographers using solar hydrogen-alpha filters. I was so keen to learn more about solar photography that I quite recently invested in a Daystar Quark hydrogen alpha filter for my telescope. Seeing so much detail on our own local star from my backyard is quite incredible."

Jaspal Chadha

London, UK
Telescope: Takahashi 130 refractor
"Last year was a great fun-packed astro year with poor weather and technical issues but, despite this, I got some decent hours of observing and imaging in! In particular, I captured Messier 81 – a galaxy in Ursa Major. I really pushed my filters knowing that light pollution would be a major killer. This object is one of the brightest galaxies in planet Earth's sky and is only about 12 million light years away from us. Towards the bottom of the image you can see Holmberg IX, a dwarf irregular satellite galaxy of M81, formed only 200 million years ago – I can count a dozen other faint galaxies!"

Messier 81

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

Celestron Astro Fi 130

Packed with the latest WiFi technology and new on the market, this reflector provides observing fun for the whole family

Telescope advice

Cost: £409 (approx. $498)
From: David Hinds Ltd
Type: Newtonian reflector
Aperture: 130mm (5.19")
Focal length: 650mm (25.59")

Best for...

- Beginner
- Medium budget
- Planetary viewing
- Lunar viewing
- Bright deep-sky objects
- Basic astrophotography
- Families

The Astro Fi series of telescopes are the new scopes on the market, suitable for beginners and families keen on touring the night sky. The new series features the latest WiFi technology, which enables you to control any Astro Fi with your smartphone or tablet using the free Celestron SkyPortal. The Astro Fi 130 employs a completely 'hands-free' experience without the need for a hand control – something that's sure to delight users and make navigation all the more fun. Some may miss the hand control that's often supplied with computerised telescopes, but we have to say that the Astro Fi doesn't suffer without it.

The Astro Fi 130 is made with children of 13 years of age or older in mind (although we recommend parental supervision) and we were pleased to discover that – once fully assembled – the instrument is 7.7 kilograms (17 pounds), providing a fair amount of portability. The overall build of the telescope is of fair price for an instrument of its type – the tube is of fair construction, while the aluminium tripod is sturdy and does the job, seeming to support the entire setup as a whole. This Newtonian reflector – similar to the other models in the series – is supplied with Kellner 10mm and 25mm eyepieces and a red dot finder. The eyepieces are enough to get a beginner started in astronomy, but with the Astro Fi 130 being a fast telescope, we recommend purchasing some mid-range Plössl eyepieces to ensure that the instrument is fully equipped for a variety of targets. The optical system employs a spherical main mirror instead of one with a parabolic shape, but when compared to similar scopes, we discovered that it didn't impede our observations.

The very clear, dark skies of January provided an excellent selection of night-sky targets to test the Astro Fi 130's mettle. Second planet from the Sun, Venus, shone at a brilliant magnitude of -5.1 and reached greatest elongation east, making it a stunning target alongside Mars, which was easy to spot with the reflector's 5.19-inch aperture at a subtler +0.5 magnitude.

> "The Astro Fi employs a completely 'hands-free' experience without the need for a hand control"

The overall build of the Astro Fi is fair and as expected for an instrument in the £400 price range

The Astro Fi is supplied with two Kellner eyepieces (10mm and 25mm). We recommend accessorising with Plössls due to the instrument's low focus

Marrying up our smartphone with the telescope's WiFi was, as expected, quite intuitive. The Celestron SkyAlign technology made aligning the telescope painless as we chose three bright stars to assist with the procedure. The beauty of the setup is that you don't need to know anything about the night sky to enjoy it, but it does also serve as a tool in learning your way around the heavens – we recommend that you take in as much information about the objects you're viewing as possible, especially if you or your family are keen on a serious stargazing hobby. If you're unsure what to observe on your first night, then the Celestron SkyPortal app recommends objects for you – a feature that will be of particular use to novice astronomers.

On evenings that are particularly cold, battery power can be drained quickly and 'motorised' telescopes can struggle. The Astro Fi 130 seemed to hold up well under frosty conditions, but we recommend purchasing a 12V rechargeable battery, especially since there's not really any other option: moving the telescope manually is quite painstaking and the Astro Fi seems unable to function without the app. Sadly, this renders the telescope useless should the WiFi facility cease to operate. The tube itself can be added to another mount, provided it uses a Vixen dovetail attachment, for those who like to switch between manual and computerised slewing of their instrument.

Views of the Moon were good through the Astro Fi but were not hugely crisp, but for a beginner's telescope this isn't too much of an issue. We observed our natural satellite in its waning gibbous phase, where the terminator gave splendid sights of a selection of craters and rilles, played up by the sunlight hitting the rugged lunar surface. Despite light pollution from the Moon, the Astro Fi seemed to fair well and we were still able to observe nearby Venus and Mars with ease. Views of the planets were as expected – small but slightly 'blurry' in the field of view. Slowly turning the focuser, we were able to bring a touch of clarity to our view; Mars' salmon pink disc in particular showed up well. The focuser isn't manufactured for fine-tuning, so this is something to keep in mind when getting the best views of your chosen target.

The adjustable aluminium tripod is sturdy and supported the mount and tube well. Prongs on the end of each leg are ideal for placing the scope on grass

The Astro Fi 130 uses the latest WiFi technology, which allows you to control the scope with your smartphone or tablet

Slewing the telescope manually is impossible, with the Astro Fi relying on the WiFi technology to explore the night sky

Once instructed, the Astro Fi took us to the constellation of Andromeda where we observed its galaxy Messier 31, known much more simply as the Andromeda Galaxy – a pleasant sight that just got better and better without the hassle of artificial and natural light pollution. For its low price, there is an excellent amount of technology packed into the Astro Fi, which allows you to keep up with the latest technology without breaking the bank.

A telescope that's suitable for the entire family, the Astro Fi 130 is a good telescope for those looking to get started in astronomy but don't know where to start.

WIN

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A brand new instrument on the market, this reflector uses WiFi technology to assist with stunning views of the night sky

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Packed with the latest technology, control the Celestron Astro Fi with ease using the free Celestron SkyPortal app for iPhone, iPad and Android devices, which takes away the frustration of locating challenging objects and allows you to get observing straight away. Fully equipped, this portable and versatile reflector comes with an accessory tray, a StarPointer finderscope, two Kellner eyepieces and a star diagonal, ensuring you have everything you need for your evening under the stars.

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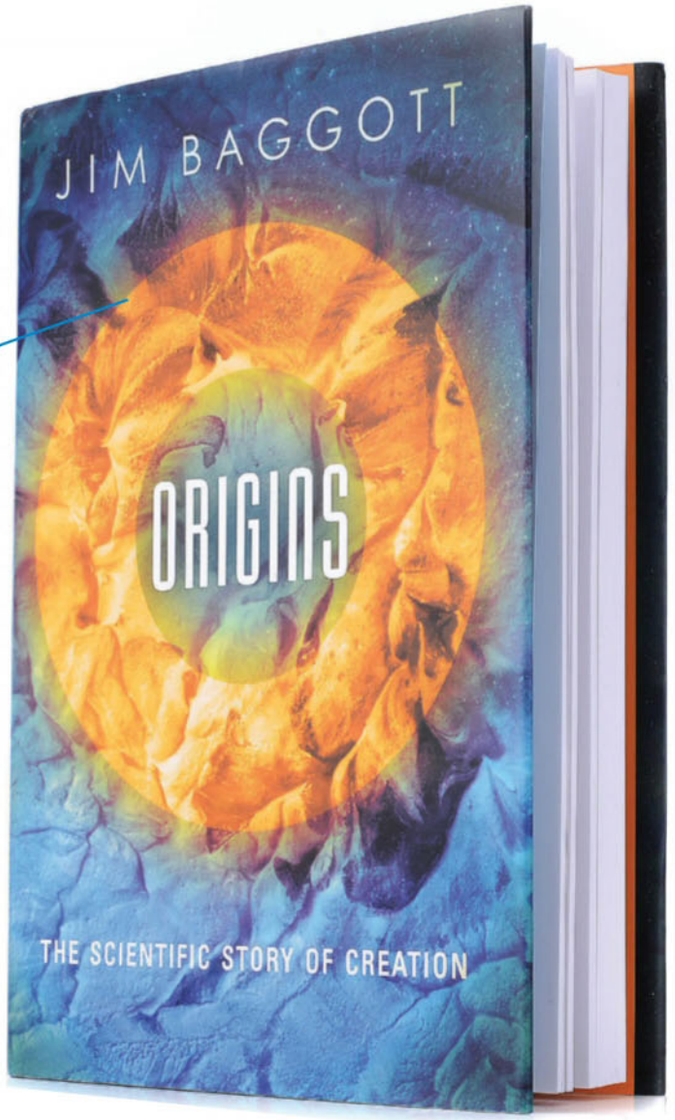


Book

Origins: The Scientific Story Of Creation

Cost: £25 ($34.95)

From: Oxford University Press

The Scientific Story Of Creation follows the evolution of the universe, from the Big Bang through to the present day. It's no secret that science can be challenging and often dry to read but author Jim Baggott takes the reader on a 13.8-billion-year journey in a well-written and extremely enjoyable way. Taking us through the formation of the first stars and galaxies and onto the birth of the Solar System, Baggott ensures that the current theories are incorporated into this weighty tome.

Aimed at those who perhaps have no prior knowledge of the chemistry, physics and biology that got us to where we are today, *Origins: The Scientific Story Of Creation* is a popular science book that's both well-written and thought-provoking. We have to applaud Baggott, however, on his brave attempt at a near-impossible task of making even the most complex science understandable, as he crams a great deal of information into a mere 400 pages. Having to cover an enormous amount of information means that this book can be an unsatisfactory read in places, skimping on details of important points in the birth of the Solar System, for example. However, if you feel you can fill in the gaps, then this book is certainly worth a look.

Torch

Hama UK LED flashlight

Cost: £7.99

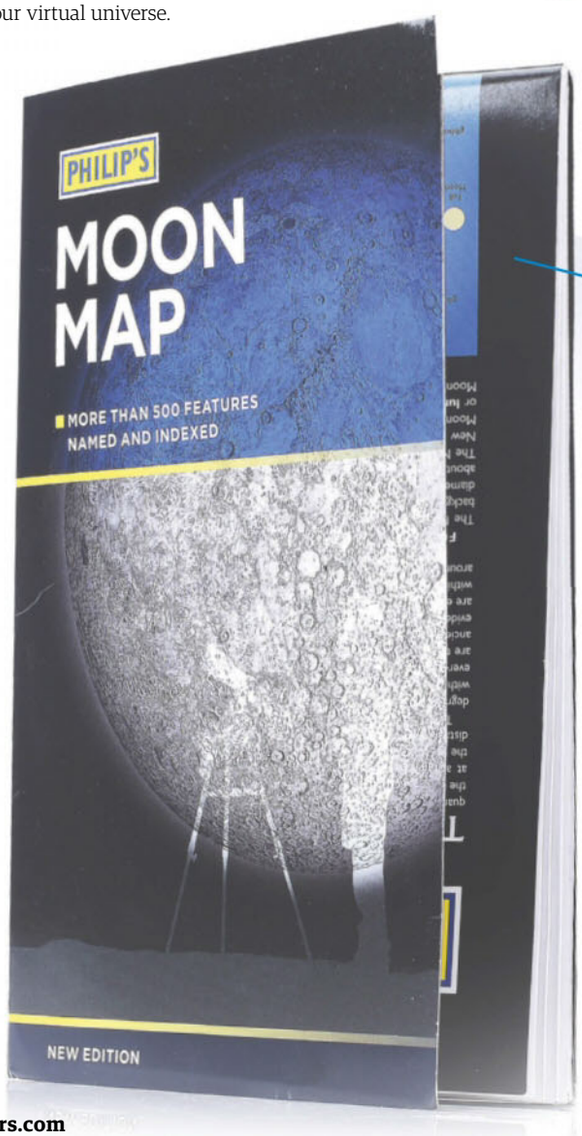
From: Hama UK Ltd

Granted, it doesn't look like a standard flashlight, but we think this is part of its appeal. Being round means that Hama UK Ltd – the manufacturer of this stargazing accessory – has been able to pack more LEDs into the unit over other flashlights on the market. We enjoyed the unique design, which allowed it to be slotted into pockets and fitted into the hand with ease. There are several settings on this torch, where both white and red LEDs can be used (simply by pressing the central button). The flashlight threw out an impressive amount of light for a small device and we were able to find our way around our dark sky site and use sky charts with ease, without ruining our dark-adapted vision. The batteries lasted for several observing sessions – especially if you keep the unit warm in your coat pocket when it's not in use. A red flashlight is a must for astronomers and we have to say that this essential piece of kit is one of the very best on the market. Make sure you get one!

Software
Celestia
Cost: Free
From: www.celestiaproject.net

Bringing the universe to your computer, Celestia offers a full three-dimensional representation of planets, stars and galaxies, and is based on the Hipparcos catalogue of more than 100,000 stars. What we enjoyed the most about this software is that you're not shackled to Earth – Celestia allows you to whizz off in any direction you feel like going, at any speed, whether it's a leisurely stroll or travelling at the speed of light. While the graphics are impressive for a free software, we noted that – due to computer memory limitations – Celestia didn't go out much further than 16,000 light years. As a result, we couldn't investigate the "entire universe" through our computer screens.

Celestia runs on a variety of operating systems including Windows, Linux and Macintosh and features a guided tour of the Solar System, an eclipse finder, updated exoplanet database and an International Space Station tracker. The specially made Celestia website features a user manual, showing you how to use the astronomy software – we recommend downloading this and taking the time to read it. Celestia isn't very user friendly but once you've cracked how to use it, it's perhaps one of the most powerful pieces of software you'll ever get to operate. If you find that you've explored what Celestia has to offer, there's the opportunity to download dozens of easy-to-install add-ons with more objects to explain your virtual universe.



Map
Philip's Moon Map
Cost: £6.99 (approx. $8.43)
From: Philip's Astronomy

If you're a keen lunar observer, then this beautifully illustrated *Philip's Moon Map* is one of the most detailed lunar guides on the market. Over 500 craters, mares, mountain ranges, peaks, valleys and rilles are labelled, ensuring that you can plan and identify features during your observations of the nearside of our natural satellite with ease. Priced at £6.99 ($8.43), *Philip's Moon Map* is reasonably priced – especially if you're keen to explore the lunar surface as closely as possible. It also includes details on its orbit around our planet and the Moon's phases. Using the map has its challenges – being so large, it catches even the slightest of breezes, making it difficult to use. We recommend pinning it down to a garden table using paperweights (or something similar), which will allow for hands-free use. Additionally, being made of paper, it's unable to withstand the elements sufficiently, which could lead to tearing and damage from moisture and general use. Under red light, the map can be read with ease – important for those wanting to maintain their night vision during observations. While being extremely detailed, there is no real contrast between the lunar seas and the higher areas of the lunar surface – as a result, the map doesn't seem to resemble what we see of the Moon with the naked eye at first glance. On occasions, we did struggle to find and identify even some of the most well known craters on the lunar surface. However, this is something that continual use of the map can solve.

HEROES OF SPACE

Valeri Polyakov

The cosmonaut who holds the record for the longest single space flight

Cosmonaut Valeri Polyakov spent a total of 678 days, 16 hours and 32 minutes in space

© Alamy

Cosmonaut Valeri Polyakov returned to Earth looking fresh. After being helped out of his capsule in Kazakhstan, he walked to a chair, sat down, lit a cigarette and took a sip of brandy. It was quite remarkable given he had lived in space for 437 days and 18 hours, especially since most of us feel quite groggy after a long car journey. But, as NASA astronaut Norman Thagard once said, Polyakov was different. Indeed, he looked "like he could wrestle a bear."

Polyakov's time in space is still talked about today. Launched aboard Soyuz TM-18 on 8 January 1994, he lived on the Mir space station and he arrived back on Soyuz TM-20 on 22 March 1995. The mission earned him a place in the record books for the longest single spaceflight in human history. Yet it wasn't even his first time in space. He had also spent 240 days, 22 hours and 32 minutes away from Earth between 1999 and 1989. "We can fly to Mars," his experience told him.

His walk from the capsule was his way of emphasising such a point: his belief that humans could travel to the Red Planet and walk on the surface after landing. During his time on Mir, his body had been tested to see if he could cope with a microgravity environment over a long period of time. It appeared that he could, although two hours of exercise each day is thought to have helped. Scientists also checked his mental health more than a couple of dozen times, and they found no sign of cognitive impairment.

That said though, there were two periods where his mood felt sombre. They came in his first three weeks in space and again two weeks after he had returned. Yet, crucially, for the rest of the time his mood and performance were stable and it was seen as an encouraging sign for future missions. Indeed, such examinations – combined with those carried out on Scott Kelly and Mikhail Kornienko during their recent year in space – continue to inform scientists working towards future missions to the Red Planet.

Certainly, he is proud of his achievements. Born on 27 April 1942 in Tula, USSR, he earned a place at the I M Sechenov First Moscow Medical Institute where he studied for a doctorate degree. He went on to specialise in astronautics medicine at the Institute of Medical and Biological Problems within the Ministry of Public Health in Moscow, and he later became strongly interested in space medicine. He became a cosmonaut when he was just short of his 30th birthday and he trained as a physician with the aim of providing medical assistance in orbit.

As such, he was a research-cosmonaut during his first flight and a doctor-cosmonaut on the second. During that latter trip, he travelled 300,765,500 kilometres (186,887,000 miles) and orbited Earth 7,075 times. Unsurprisingly, his work earned him many high honours including the Hero of the Soviet Union, Order of Lenin, Order of the Legion of Honour, and the Order of Parasat. He also had the honorary title Pilot-Cosmonaut of the USSR, which was presented to all cosmonauts who flew for the Soviet Space Agency.

While Polyakov retired as a cosmonaut in June 1995, his space-related work has continued. He looks after the medical aspects of long-duration space missions as the deputy director of the Ministry of Public Health in Moscow, and he has written many enlightening publications. But it will be for those 678 days, 16 hours and 32 minutes spent in space that he will be most remembered for. His record may have been broken in 1999 by cosmonaut Sergei Avdeyev but his legendary status never will.

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