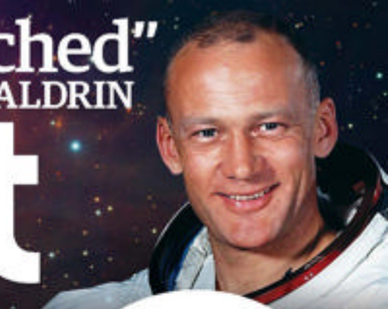
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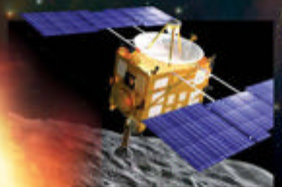
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Tired of Earth? Get into space!

All About Space is ten issues old, so a big thank you to everyone who has helped make this magazine a success so far, especially to the subscribers and regular buyers. If you're picking this magazine up for the first time we'd like to welcome you to the most accessible, exciting, innovative and entertaining space magazine available today. Every issue we try to compile a mix of informative articles, amazing illustrations and breathtaking photography that bring the universe around us to life in an engaging and entertaining way.

This month is no different and a quick flick through the pages will reveal some excellent content, including a fantastic piece on the deadliest weather in the Solar System. From radioactive solar winds that engulf the Earth to the 1,500mph winds on Neptune to giant megastorms on Saturn, this is a feature that will truly blow you away and it starts on page 16.

Other highlights this issue include a look at SpaceX, a privately owned company in the US founded by former PayPal entrepreneur Elon Musk in 2002. Over the last ten years the company has developed to a point where it now rivals many national space agencies in terms of technology and achievements, including winning a contract to supply the International Space Station via its Dragon spacecraft. We've taken an in-depth look at the story behind this success that can be found on page 32.

Finally, the size of space never fails to amaze and our feature on hypergiant stars perfectly illustrates our tiny stature in this vast emptiness. These gigantic balls of nuclear power grow to some 1,500 times bigger than our Sun and could fit our entire Solar System inside them, read more on page 54.

Sharing our passion for discovering the universe is something we love so we hope you enjoy reading the issue as much as we did creating it and return next month for more.



Dave Harfield
Editor in Chief

Crew roster

Jonathan O'Callaghan



■ A keen fan of space exploration and engineering, Jonny jumped at the chance to write our in-depth story on SpaceX

Shanna Freeman



■ Shanna's tour of the Solar System continued outward this issue with an in-depth look at the dwarf planet Pluto

Gemma Lavender



■ Gemma turned space weathergirl this issue, producing an excellent article on extreme weather in our Solar System

Giles Sparrow



■ Giles took on the gargantuan task of explaining hypergiant stars this issue and he certainly measured up to the task

Nigel Watson



■ Nigel takes us on a short trip to the future with FutureTech articles on ion drives and the ESA's Vinci spaceplane

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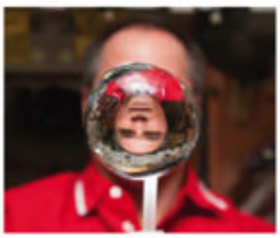
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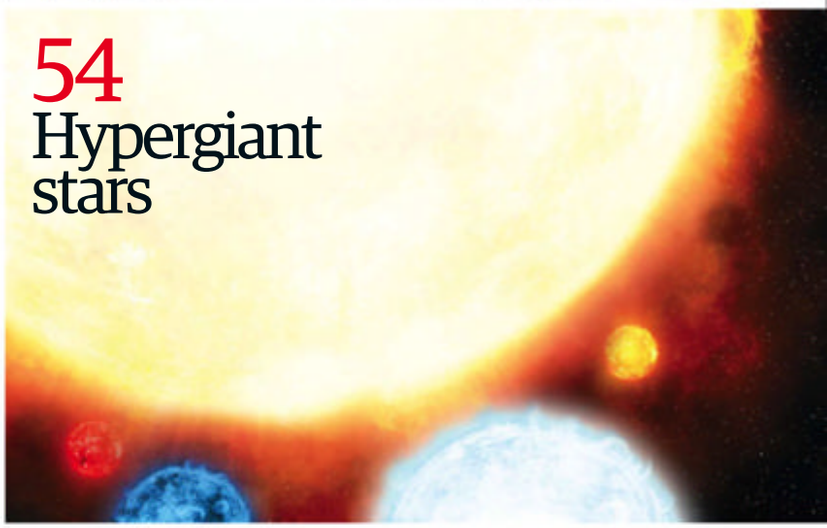
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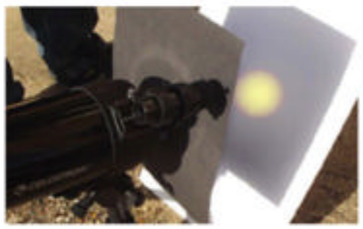
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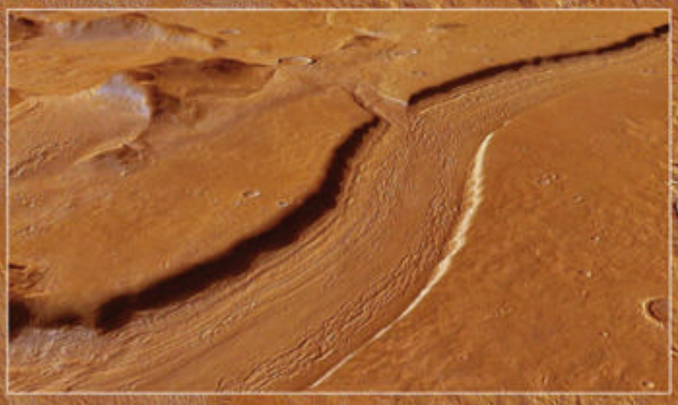
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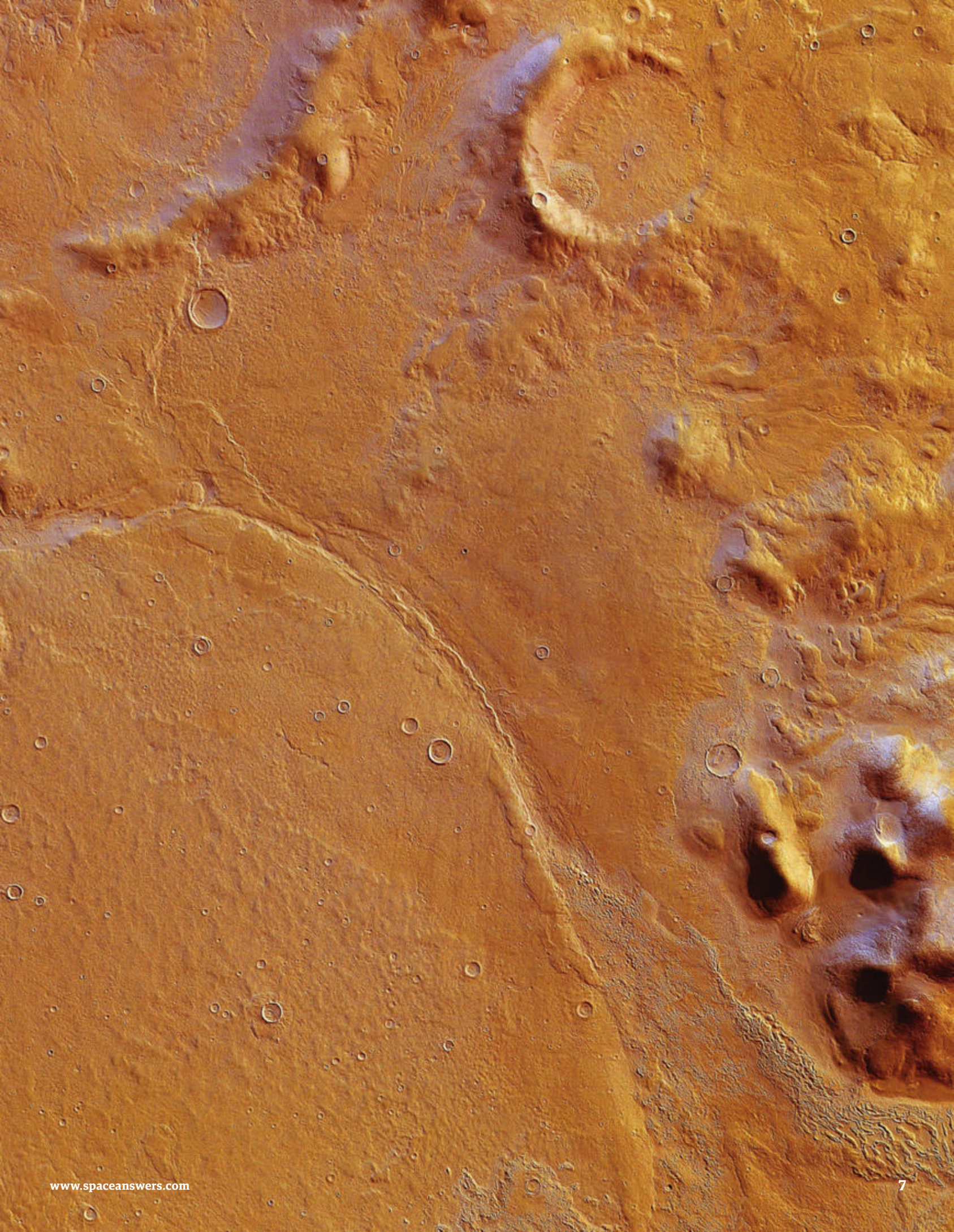
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Ancient river on the surface of Mars

The European Space Agency's Mars Express captured this fascinating image of the Reull Vallis region of Mars with its high-resolution stereo camera last year. Reull Vallis, the river-like structure in these images, is believed to have formed when running water flowed in the distant Martian past, cutting a steep-sided channel through the Promethei Terra Highlands before running on towards the floor of the vast Hellas basin.





Bubble vision

NASA astronaut Kevin Ford, Expedition 34 commander, watches a water bubble float freely between him and the camera, showing his image refracted, in the Unity node of the International Space Station (ISS).

Superbubble from a supernova

This composite image shows the superbubble DEM L50 (aka N186) located in the Large Magellanic Cloud about 160,000 light years from Earth. Superbubbles are found in regions where massive stars have formed in the last few million years. The massive stars produce intense radiation, expel matter at high speeds and race through their evolution to explode as supernovas. The winds and supernova shockwaves carve out huge cavities called superbubbles in the surrounding gas.

Atlas V blasts off

The umbilical tower drops back from a United Launch Alliance Atlas V 401 rocket as it lifts off from Cape Canaveral Air Force Station in Florida with NASA's Tracking and Data Relay Satellite-K or TDRS-K aboard.



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Interstellar seagull

This new image, captured by the Wide Field Imager on the MPG/ESO 2.2-metre telescope at ESO's La Silla Observatory in Chile, shows a section of a cloud of dust and glowing gas called the Seagull Nebula. The wispy red clouds form part of the 'wings' of the celestial bird and this picture reveals an intriguing mix of dark and glowing red clouds, weaving between bright stars.



An artist's impression of a habitable planet, complete with two moons, orbiting a red dwarf star in its habitable zone

Alien worlds are close to Earth

Harvard astronomers suggest that our search for Earth-like worlds might find them closer to home

Earth-like alien worlds could be as close as just 13 light years away, according to a team of astronomers at the Harvard-Smithsonian Center for Astrophysics (CfA). During their research the team found that six per cent of the most common stars in our galaxy – red dwarfs – have habitable planets similar in size to our own.

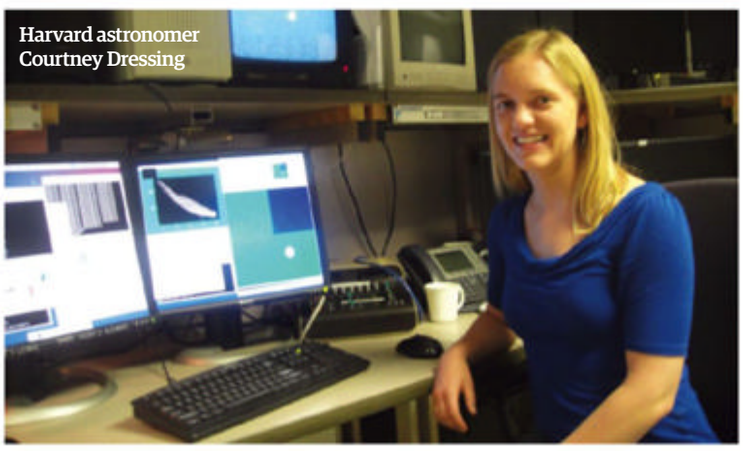
"Astronomers have learned that the universe tends to make many more small things than big things," says Harvard astronomer and lead author of the study Courtney Dressing, who believes that there's no need to search vast distances for an Earth-like planet. "Due to the physics of how molecular gas clouds collapse to form stars, there are roughly a dozen red dwarfs formed for each Sun-like star."

Despite being smaller, cooler and much fainter than our G-type Sun at an average one-third as large and one-thousandth as bright, red dwarfs are great places to search for habitable worlds. It is thought that these naked eye stars make up three out of every four stars found in the Milky Way with a total of at least 75 billion.

Since the star is smaller, an Earth-sized planet that crosses its host star's surface blocks out more light. Additionally, the habitable zone – the distance from a star where conditions are just right – will be much closer in to a red dwarf and so, the planet is most likely to transit from our point of view. Dressing used these two points to her advantage and, as a result, spied 95 planetary candidates implying that some 60 per cent of such stars host worlds smaller than Neptune.

"The actual temperature of a planet depends on the specific properties of the planet's atmosphere and the amount of light that the planet's surface reflects into space," says Dressing. "We can estimate a range of probable surface temperatures by considering several different assumptions about the composition of the planet's atmosphere and the reflectivity of the surface." Using this technique the team found that most of the candidates weren't quite the right size or temperature to be considered truly Earth-like. However, this just narrowed down the field, as co-author David Charbonneau, also of the CfA, states: "We now know the rate of occurrence of habitable planets around the common stars in our galaxy. That rate implies that it will be significantly easier to search for life beyond the Solar System than we thought."

> "It will be significantly easier to search for life beyond the Solar System" **David Charbonneau, CfA**



Harvard astronomer Courtney Dressing

Three of the planetary candidates – KOI 1422.02, which is 90 per cent the size of Earth in a 20-day orbit; KOI 2626.01, 1.4 times the size of Earth in a 38-day orbit; and KOI 854.01, 1.7 times the size of Earth in a 56-day orbit – which are tidally locked and hugging their red dwarf parents, were found to fit the bill of a warm and approximately Earth-sized planet, implying that six per cent of all of these stellar types should, in theory, have an Earthly world.

"We're still trying to figure out how life evolved on Earth and which factors are required for the formation and evolution of life," concludes Dressing. "I think its safe to say that life on Earth has demonstrated a remarkable ability to survive in seemingly inhospitable environments. Life on other planets might be quite different and I look forward to seeing the results of future surveys to look for biosignatures (signs of life) on exoplanets."



Antarctica's Super-TIGER is top cat

NASA's cosmic ray-hunting science balloon, the Super Trans-Iron Galactic Element Recorder (Super-TIGER), has smashed records for the longest flight by a balloon of its size and the longest flight of any heavy-lift scientific balloon during a flight over Antarctica, where it detected 50 million cosmic rays.

At a height of 38,000m (127,000ft), Super-TIGER was carried by the south polar winds for a lengthy 55 days, 1 hour and 34 minutes, breaking its own record of 46 days for the title of the longest flight by a balloon of its size. On board was a new instrument which, when bombarded by the high-energy rays that smash into Earth from within our galaxy, measured rare hefty elements such as iron among the radiation.

"From work we've done on the NASA Advanced Composition Explorer satellite and the TIGER experiment we believe that both the material and acceleration of galactic cosmic rays comes from groups of massive stars (up to 150 times the mass of our Sun) called OB associations," says principal investigator of the Super-TIGER mission, Bob Binns. "The galactic cosmic ray composition appears to be consistent with a mix of material ejected from these stars and normal interstellar medium material."

Super-TIGER earned its second title as the longest flight of any hefty scientific balloon by beating the record set by NASA's Super Pressure Balloon of 54 days, 1 hour and 29 minutes.

Energetic black hole spawns galaxy with four arms

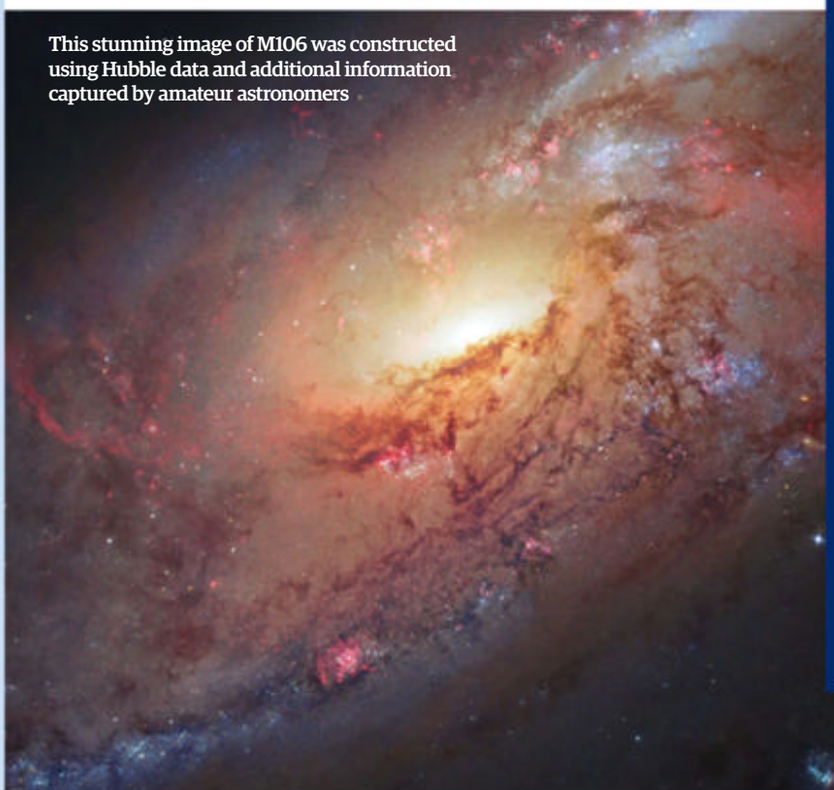
Astronomers create the most detailed portrait of the M106 galaxy

The combined efforts of the NASA/ESA Hubble Space Telescope and two amateur astronomers has not only produced the best view of neighbouring spiral galaxy Messier 106 to date, but the exquisite detail of this 20 million light-year-distant star factory could have helped to explain why it appears to have four arms.

One of the brightest galaxies that we know of, M106 has an impressively active supermassive black hole at its centre which devours material that falls into it, and this heavyweight object's insatiable appetite is thought to be responsible for the galaxy's extra arms – which are not your standard spiral arms, but wisps of hot gas. "The two strange arms are either indications of an interaction of the jets with the galactic disc or indications of material from the jets falling back to the disc which then interact," says Marita Krause from the Max-Planck Institute. "These 'anomalous arms' show no signs of star formation."

Armed with Hubble images of the mysterious galaxy, amateur astronomer Robert Gendler added his own observations of M106 as well as those of fellow astrophotographer Jay GaBany to assemble a mosaic of this brilliant galaxy. "I realised this would be a massive project – the image would be a mosaic of more than 30 panels and would incorporate both wideband and narrowband data sets," says Gendler, who was contacted by the Hubble Heritage Team for his assistance. "The anomalous arms emit light in the visual spectrum around 656nm (hydrogen-alpha) and I found a fair amount of hydrogen-alpha data for the arms in [this region]."

"M106 has an impressively active supermassive black hole at its centre"



This stunning image of M106 was constructed using Hubble data and additional information captured by amateur astronomers



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Meteor injures hundreds in central Russia

In the early hours of 15 February a meteor streaked across the sky in the Urals region of central Russia. The resultant shockwave blew out windows, damaged buildings and caused panic on the streets, as well as injuring hundreds of people.

Asteroids could be vapourised

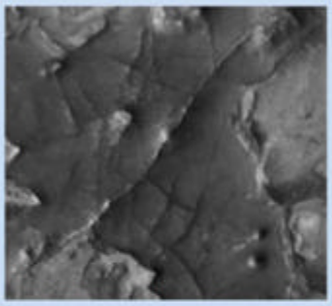
Scientists at the California Polytechnic State University have designed an energy orbital defence system to harness the power of the Sun, convert it into massive laser beams, and destroy incoming asteroids.

Rare explosion creates Milky Way's youngest black hole

Data from NASA's Chandra X-ray Observatory suggests that a highly distorted supernova remnant may contain the most recent black hole formed in the Milky Way galaxy.

Next NASA Mars mission begins testing

NASA's Mars Atmosphere and Volatile EvolutioN (MAVEN) spacecraft, which will study the Martian upper atmosphere, is assembled and is undergoing environmental testing ahead of a scheduled launch in November 2013.



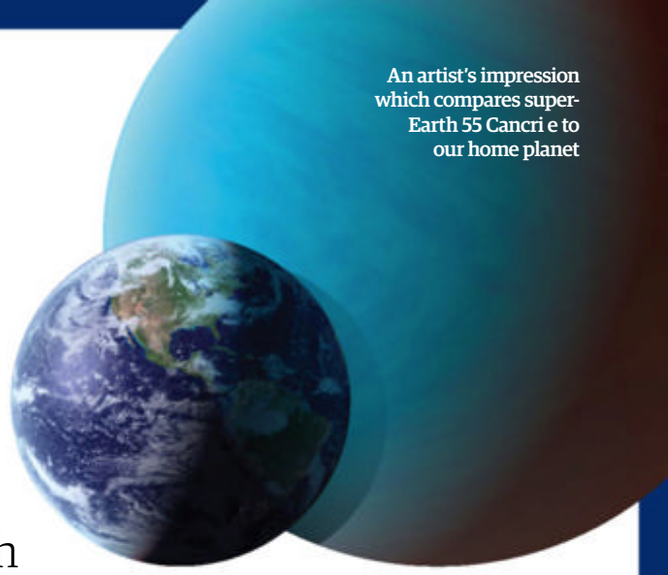
More evidence of water on Mars

Asteroid impacts on Mars created underground cracks in the ground that filled with water and might have been the perfect hiding place for Martian life, according to scientists at Brown University, USA.

Lee Saper and Jack Mustard studied 4,000 ridges in two cratered regions of Mars – Nili Fossae and Nilosyrtis. They surmise that the ridges formed when the cracks were filled with subsurface water carrying minerals that were then deposited within the underground cracks. The mineral deposits would have been harder than the surrounding rock, so after the water dried up wind erosion weathered the rock but left the deposits, which today form ridges on the ground. The ridges are orientated in radial fashion away from the impact craters, which suggests that they formed during the impact and are not a result of, for example, volcanic magma. In addition, the ground around the cracks is rich in iron-magnesium clay, which could only have formed in flowing, liquid water.

"The association with these hydrated materials suggests there was a water source available," says Saper. "That water would have flowed along the path of least resistance, which in this case would have been these fracture conduits."

While much of the previous exploration of Mars has focused on evidence for liquid water having once flowed on the surface, these findings are particularly exciting because they suggest a new environment in which to look for evidence of past life on Mars.



An artist's impression which compares super-Earth 55 Cancri e to our home planet

Super-Earths more similar to gas giants

Exoplanets more closely related to Neptune than Earth

The many super-Earths astronomers have found in our universe might be more closely related to gas giant Neptune than Earth, according to a study led by Helmut Lammer of the Space Research Institute (IWF) of the Austrian Academy of Sciences.

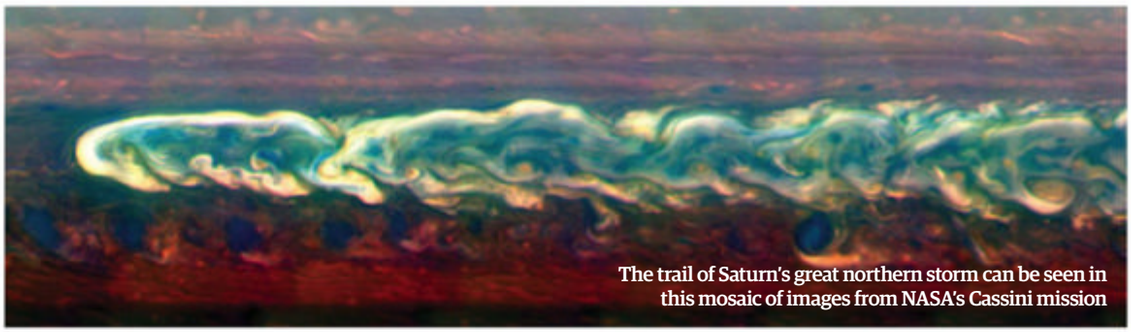
Significantly larger than our planet, super-Earths are envisioned to be made of a high level of rock but, according to Lammer, there is another feature at play – an atmospheric casing of hydrogen-rich gas. Looking at the impact of radiation on the upper atmospheres of the super-Earths orbiting the stars Kepler-11, Gliese 1214 and 55 Cancri, the researchers questioned whether these worlds could evolve into terrestrial bodies similar to those in our Solar System.

However, on close inspection of these distant worlds, Lammer suggests that not only is the exoplanet surrounded by a hydrogen-rich atmosphere, possibly built from the gas and dust from which the planets formed, but a solid core might be nestled at their centres. Additionally, his model suggests that the warmth of the ultraviolet light thrown out by host stars heats up the gaseous envelopes causing them to expand up to several times with gas escaping at an alarming rate. However, despite the atmosphere attempting to make a break for it, it still remains transfixed.

"Our results indicate that, although material in the atmosphere of these planets escapes at a high rate, unlike lower mass Earth-like planets, many of these super-Earths may not get rid of their nebula-captured hydrogen-rich atmosphere," says Lammer.

The study suggests that if super-Earths closer to their stars are unable to hold on to their atmospheres, then worlds of this type further out from their stars' habitable zones, where conditions are ideal for liquid water to exist, are more likely to hold on to their hydrogen-rich atmospheres but less likely to hold on to any life.

"The atmosphere attempts to make a break for it"



The trail of Saturn's great northern storm can be seen in this mosaic of images from NASA's Cassini mission

Great Saturn storm chases, and catches, its tail

A great Saturnian vortex has ended its life after consuming itself

NASA's Cassini spacecraft got a front row seat to a violent mixture of thunder-and-lightning raging through the northern atmosphere of Saturn as it churned and kicked up gas around the planet before meeting up with, and munching on its own tail, calming the rumbles of thunder and lightning bolts locked in its serpent like physique in the process.

"Even the giant storms on Jupiter don't consume themselves like this, which goes to show that nature can play many awe-inspiring variations on a theme and surprise us again and again," says Cassini imaging team member Andrew Ingersoll, who is based at the California Institute of Technology, of the storm that was first detected in late 2010.

Expanding up to 12,000 kilometres (7,500 miles), this storm, which behaved just like a terrestrial hurricane on our very own planet, is the largest vortex ever observed in Saturn's troposphere. "This storm on Saturn was a beast," says Cassini imaging team associate member and lead author of a paper in the journal *Icarus*, Kunio Sayanagi of Hampton University in Virginia. "The storm maintained its intensity for an unusually long time. The storm head itself thrashed for 201 days and its updraft erupted with an intensity that would have sucked out the entire volume of Earth's atmosphere in 150 days."

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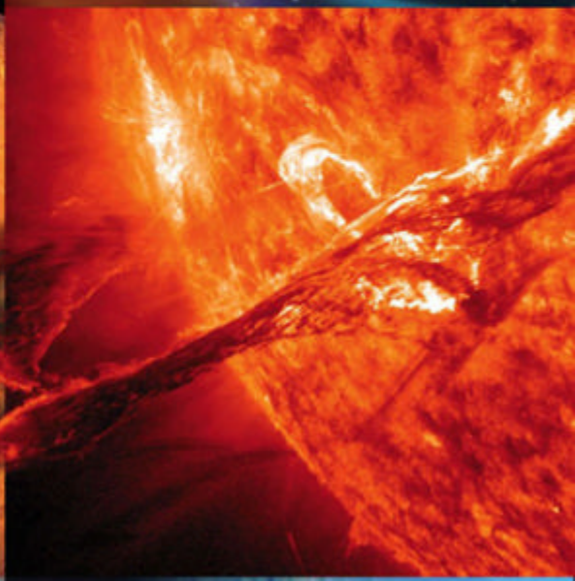
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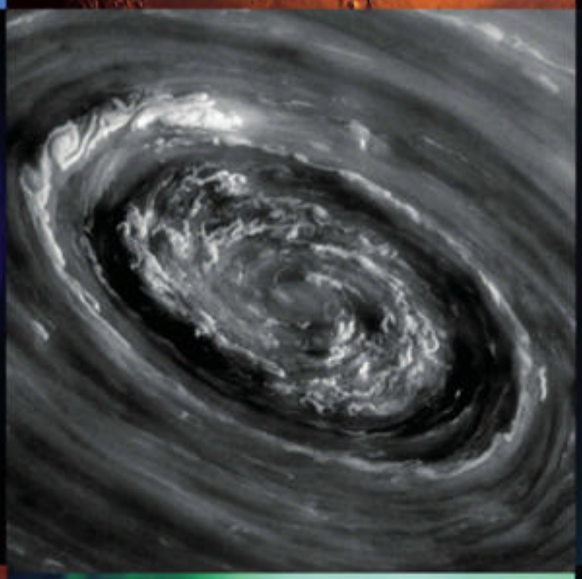
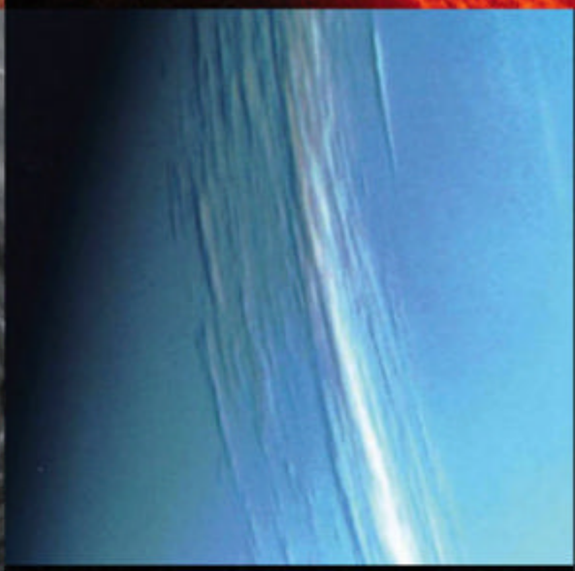
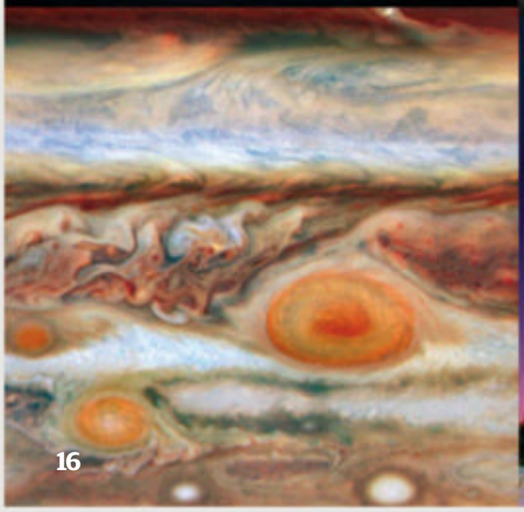
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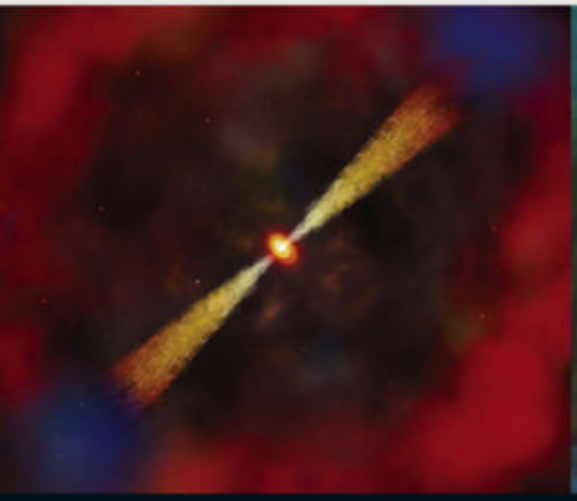


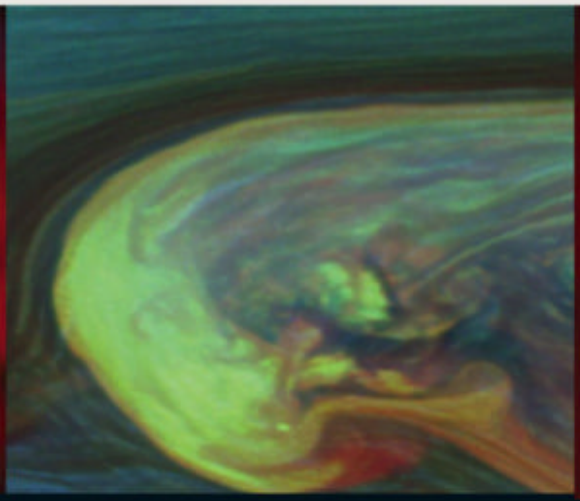








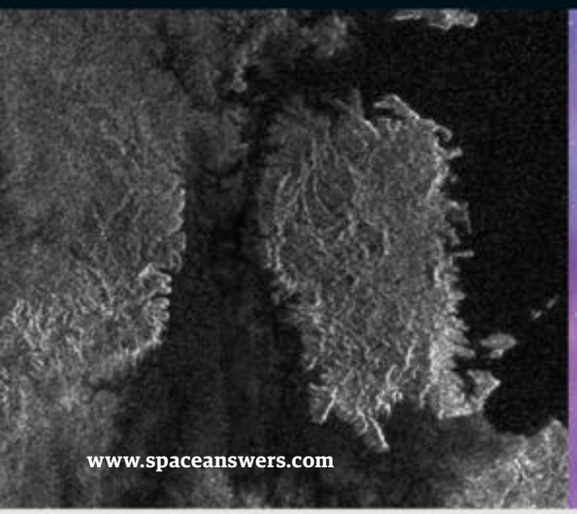


DEADLY WEATHER IN SPACE

MEGA STORMS

Written by Gemma Lavender

From solar flares that knock out satellites to 1,500mph hurricanes on the surface of alien worlds, **All About Space** explores some of the most extreme weather in the Solar System







Our angry, stormy Sun

We know our Sun as a brilliantly bright sphere that rises in the east and sets in the west each day. That's a simple way to describe it; what really goes on on its surface is far from the impression that it gives as it hangs, almost calmly, in the daytime sky.

While going anywhere near the Sun would be suicide with the searing heat and penetrating radiation combining to fry you alive in your spacesuit, technology has revealed this star to be an angry, bubbling cauldron of solar activity.

First up are solar flares - bursts of radiation from the sudden release of magnetic energy from active regions on the Sun's surface, the photosphere. These regions are centred on sunspots, which are tangled knots of magnetic fields. The flares release as much as a sixth of the total amount of energy that the Sun releases every second, with much of it in X-rays or ultraviolet light. The energy of a flare can drive a cloud of charged particles to escape the solar corona in a coronal mass ejection (CME). The CME becomes a giant cloud of plasma hurtling through space and, when CMEs are pointed towards Earth, they cause solar storms.

When a CME strikes the Earth's magnetosphere, it overloads the system and becomes a geomagnetic storm. Earth's magnetosphere is compressed to breaking point with charged particles flooding the magnetic field lines that loop down on to the magnetic poles of the planet. The particles excite atmospheric gases (mainly oxygen and nitrogen), causing them to glow in eerie shimmering curtains of light - the aurora borealis (northern lights) and the aurora australis (southern lights). Oxygen gas glows green, while nitrogen glows purplish-red - the two primary colours seen in auroras. Usually low-level solar wind activity means that the 'auroral arc' is kept, in the northern hemisphere, to the Arctic Circle but the power of a geomagnetic storm can see the auroral arc extend to more southerly latitudes, over Britain and Western Europe, as far south as Spain or even, on very rare occasions, Florida in the United States. The most severe solar storm on record was the Carrington event of 1859, when auroras lit up the skies as far south as the tropics and telegraph wires began to short, sparking electricity.

Those telegraph wires remind us that auroras are only the pretty side of a geomagnetic storm. Although they are not directly harmful to people on the ground, a storm instigated by a powerful CME can destroy our technology. Satellites can short-circuit, knocking out communications. Astronauts must take shelter from the radiation in a special, shielded room onboard the International Space Station. On the ground, power lines can become swamped by raw current from the CME plasma - in 1989, a solar storm caused a large, nine-hour blackout in Quebec in Canada. In our modern world, where we rely on electronic devices, the nightmare scenario is that a powerful enough solar storm could stop everything working, wiping computers, crashing the internet, knocking out global

Solar wind current

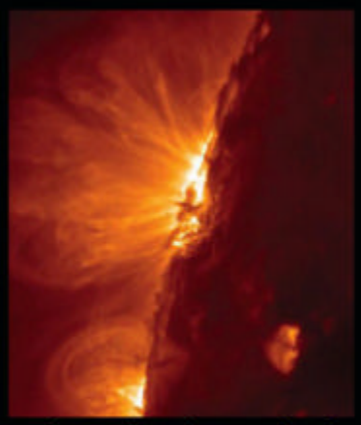
1. Surface of the Sun
The Sun's magnetic field is very complex on the solar surface, but as it rises into the corona it simplifies until it consists of two opposite polarities separated by the line of the heliospheric current sheet.

2. Corona
In the corona the solar wind begins to draw out the heliospheric current sheet into space, extending the Sun's atmosphere out into the rest of the Solar System.

3. Rotation
As the Sun rotates, it causes the heliospheric current sheet to become twisted.

4. Jupiter
It takes material in the heliospheric current sheet three weeks to reach Jupiter. The sheet eventually extends out into the Kuiper belt, where the Voyager spacecraft are exploring.





A solar prominence is an eruption of hydrogen gas from the Sun's surface

WHERE DOES THIS HAPPEN?



Solar winds that batter Earth

Magnetosphere
The Earth's magnetic envelope, generated by our planet's internal dynamo, protects Earth from the solar wind.

Magnetotail
The pressure of the solar wind sculpts Earth's magnetosphere, compressing it on the Sun-facing side and stretching it out into a tail shape on the opposite side.

Magnetopause
This is where the force of the solar wind balances with the strength of the magnetosphere and exists up to several hundred kilometres from Earth's surface.

Magnetic reconnection
When magnetic field lines break and reconnect in the magnetopause, it allows solar wind particles to sneak through.

The solar wind
The solar wind blows through holes in the Sun's outer atmosphere, known as the corona. The wind itself consists of energetic charged particles.

Auroras
Charged particles follow magnetic field lines down to the poles where they excite molecules in the atmosphere, causing them to glow as the northern and southern lights.

"A powerful enough solar storm could wipe computers, crash the internet and knock out global power systems"

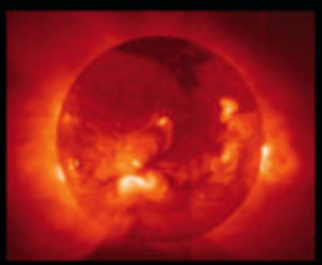
power systems and disrupting communications. It may take months to get everything back online, in which time the world has been sent into technological, social and economic chaos.

We're most vulnerable to solar storms at solar maximum, which is the point in the Sun's 11-year cycle of activity when our nearest star is at its most active. Solar flares happen all the time, and CMEs strike Earth frequently, but only rarely are they as powerful as the solar activity that plunged Quebec into darkness. However, scientists are currently unable to predict solar activity or when the next big CME will be.

All of this takes place in the Sun's heliosphere, which is the extent of its magnetic influence throughout the Solar System, where the solar wind still blows. The heliosphere goes out past the orbit of Pluto. The Voyager 1 spacecraft is currently 118 times further from the Sun than Earth is, and yet it has still to leave the heliosphere. CMEs disperse and lose power the deeper they get into the Solar System. However, solar activity can still have an effect, even on the edge of the heliosphere. Both Voyager 1 and 2 have experienced the heliosphere swelling and shrinking on gusts of the solar wind that inflate the Solar System's magnetic bubble.



The aurora borealis (northern lights) and aurora australis (southern lights) can be seen in the northern and southern hemispheres of our planet



The solar maximum

Roughly every 11 years, the Sun goes through a natural cycle marked by an increase or decrease in dark blemishes on the Sun's surface, or photosphere, known as sunspots. We refer to the multiplication of sunspots as the solar maximum and the smaller number the solar minimum.

During the solar maximum things get exciting; bright luminous regions also appear in the Sun's atmosphere, called the corona, and it is here where our Sun has an angry outburst; fiercely spitting charged particles and magnetic fields from its surface in a gigantic burst of a supersonic solar wind, called a coronal mass ejection.

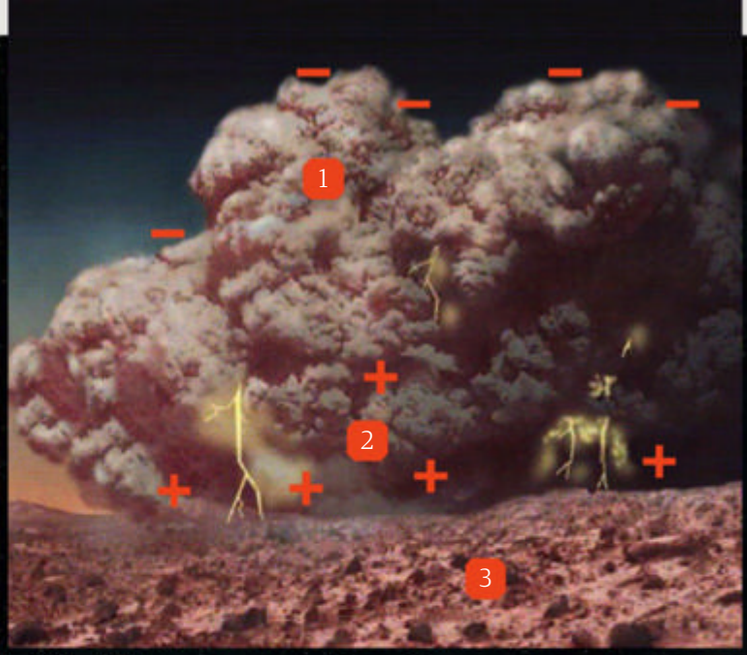


Dust storms that cover the planet

Now this is really bad weather – a dust storm that doesn't just cover an area, or even a hemisphere, but the entire planet. During summer in the Red Planet's southern hemisphere, when Mars is at its closest point to the Sun, solar heating can drive immense storms that blow up red dust and can obscure the surface for months. In 1971, when Mariner 9 arrived at Mars, it found the whole planet hidden under a veil of dust, with only the volcano Olympus Mons visible. More recently, the Mars Exploration Rovers Spirit and Opportunity would struggle to survive in dust storms as the Sun's light was blocked and their solar panels covered by a coating of dust.

On Earth, moisture arms swirling storms, but on Mars there is only dust. Normally most of the dust is on the ground, but some is found in the atmosphere, where it scatters sunlight and makes the sky appear pinky-red. When Mars is at its hottest – still cold enough to freeze water – the atmospheric dust can absorb the energy of the sunlight, which causes warm pockets of air to rapidly move towards colder, low-pressure regions, generating winds up to 45 metres per second (162 kilometres per hour or 100 miles per hour) that begin to pick up dust particles from the ground, adding to the atmospheric dust content and increasing heating, pushing the winds harder and faster until the atmosphere is filled by dust.

And then, just as quickly, the storm can die down. Perhaps by blocking the sunlight, the surface of Mars grows cooler, allowing some of the dust to begin sinking out of the atmosphere. Not all dust storms swallow the entire planet – some are more localised events. However, were you to be on the surface during a dust storm, other than the sky darkening and a fine coating of dust settling over you, the atmosphere is so thin that you'd barely notice the wind or the scouring dust.



Kicking up dust

1. Desert dust
The dust storms, that frequently rise from the cold deserts of Mars, sometimes rage across the entire Martian globe, which crackle and snap with electricity.

2. Electrifying dust
It is possible that dust particles could be electrified in Martian dust storms when they rub against each other as they are carried by the winds, transferring positive (+) and negative (-) electric charges similar to the way that static electricity can be built up from shuffling across a carpet.

3. Strong swirls
Electric fields generated by the swirling dust are thought to be strong enough to break apart carbon dioxide and water molecules in the Martian atmosphere recombining to make reactive chemicals like hydrogen peroxide, which you'll find in bleach or other cleaning agents, and ozone. Some of these reactive chemicals are likely to have accumulated in the Martian soil over time.

Snaking its way across Mars's surface, this dust devil is powered by solar heating just like the dust plumes found on Earth

How do dust storms form?

1. Heating up the atmosphere
The absence of clouds or water means that radiation cannot be reflected back into space and the thin atmosphere close to Mars's surface becomes hotter than the atmosphere above it.

Wind direction

2. Picking up the dust
As the atmosphere is heated dust is lifted into the air and, after absorbing more sunlight, the dust warms up the atmosphere further, propelling more dust into the air.

3. The storm begins
The change in temperature creates winds, swirling at great speeds of 96 to 193km/h (60 to 120mph), capable of dominating the entire planet.

4. Dusty dirt devils
As well as the gigantic dust storms, Mars's surface is also raked with frequent, and strong, dust devils.

WHERE DOES THIS HAPPEN?



Hurricanes bigger than Earth

Easily one of the most famous storms in the Solar System, Jupiter's Great Red Spot is so large that it is visible through many Earth-based telescopes.

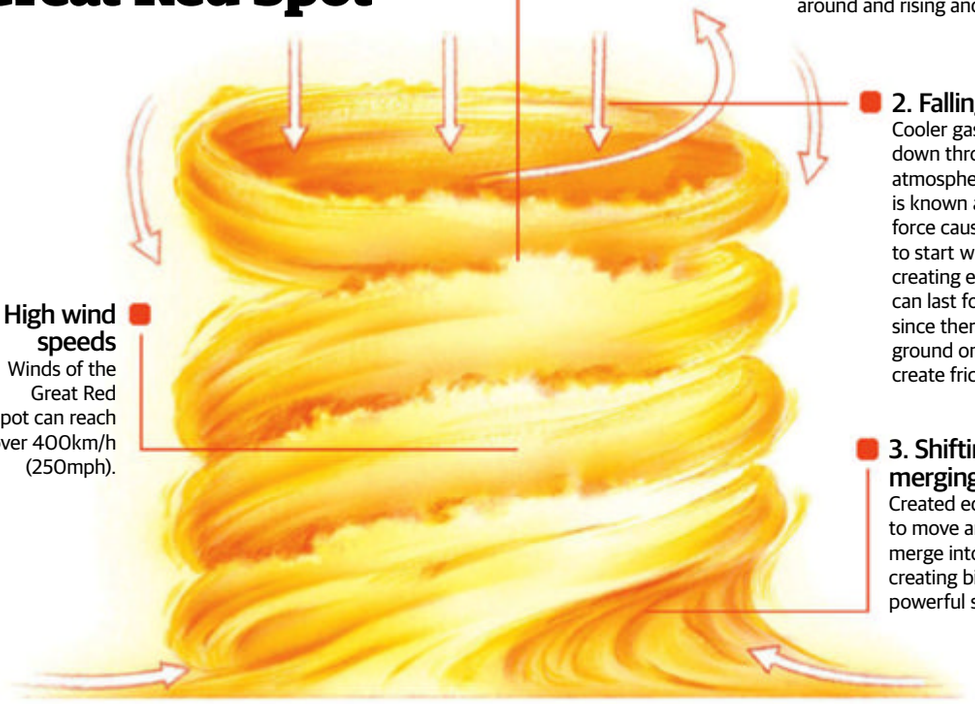
The Great Red Spot is thought to have been in existence for at least 340 years. The oval red eye rotates in an anticlockwise direction due to the crushing high pressure on the planet. Winds can reach over 400 kilometres per hour (250 miles per hour) around the spot, however, inside the storm they seem to be nearly nonexistent. And that's not all, this complicated weather system has an average temperature of about -162 degrees Celsius (-260 degrees Fahrenheit).

At around eight kilometres (five miles) above the surrounding clouds and held in place by an eastward jet stream to its south and a very strong westward jet flowing into its north, the Great Red Spot has travelled several times around Jupiter, but how did such a behemoth of a storm come to appear on the gas giant's surface?

The answer is not clear at this time despite the efforts of planetary scientists attempting to unravel the answers. However, what experts do theorise is that the storm is driven by an internal heat source, and it absorbs smaller storms that fall into its path, passing over them and swallowing them whole. Another thing that they also know is that the Great Red Spot hasn't always been its current diameter. In 2004, astronomers noticed that the great storm had around half the 40,000-kilometre (25,000-mile) diameter that it had around 100 years before. If the Great Red Spot continues to downsize at this rate, it could eventually morph from an oval shape into a more circular storm by 2040. You might think that this well-known feature won't be sticking around for long as it becomes smaller, but experts believe that the great age-old storm is here to stay since it is strongly powered by numerous other phenomena in the atmosphere around it.

Storms like these are not out of place on Jupiter, whose atmosphere is a zigzag pattern of 12 jet streams, with blemishes of warmer brown and cooler white ovals in the atmosphere owed to storms as young as a few hours or stretching into centuries.

The science of the Great Red Spot



1. A constant twirl
Hot gases in the gas giant's atmosphere are constantly swirling around and rising and falling.

2. Falling cool gas
Cooler gas falls down through the atmosphere, and what is known as a Coriolis force causes the area to start whirling, creating eddies that can last for a long time since there is no solid ground on Jupiter to create friction.

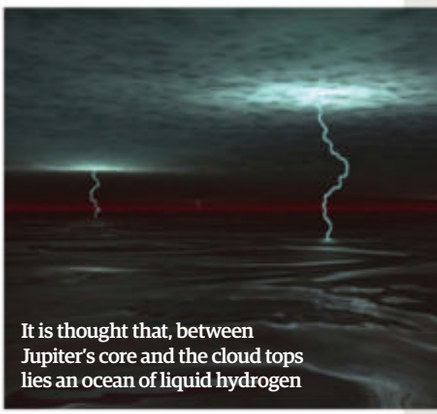
3. Shifting and merging eddies
Created eddies are able to move around and merge into one another, creating bigger and more powerful storms.

4. High wind speeds
Winds of the Great Red Spot can reach over 400km/h (250mph).



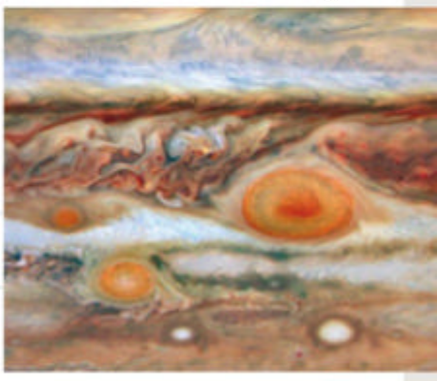


The white oval storm directly below Jupiter's Great Red Spot is about the diameter of Earth



It is thought that, between Jupiter's core and the cloud tops lies an ocean of liquid hydrogen

Interactions with other storms could give the Great Red Spot its monstrous energy



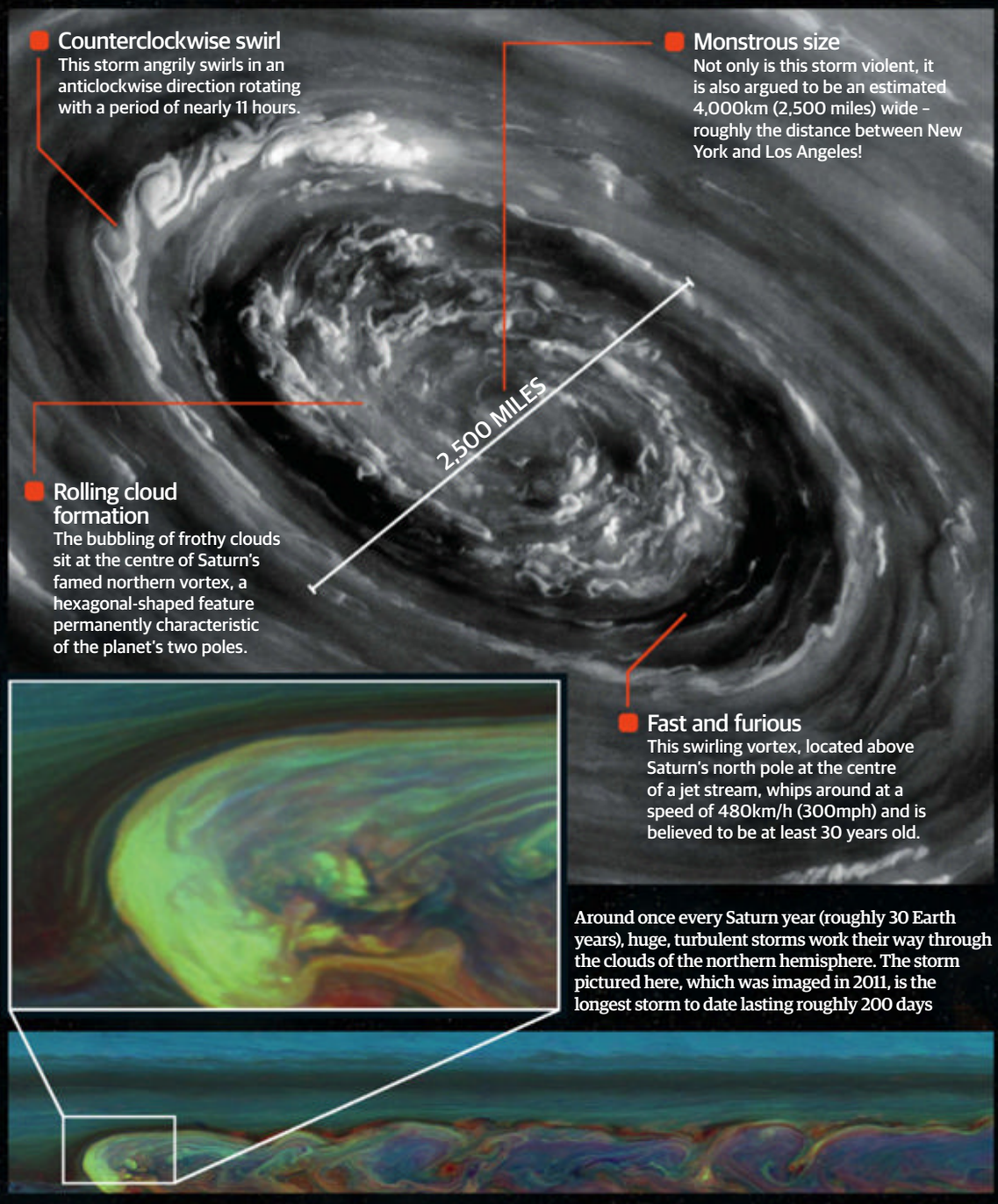
The violent polar vortex

On the outside, Saturn almost looks like a calm, bland world, but once in a while, huge storms flare up on the ringed planet. From the short-lived Great White Spot of 1990, to the more recent storm of 2010, which grew into an atmospheric belt covering around 4 billion square kilometres (1.5 billion square miles), Saturn has proven to be a turbulent world. And what's more, the storms on Saturn are the second fastest in the Solar System, after ice giant Neptune, peaking at an impressive 1,800 kilometres per hour (1,120 miles per hour) and blowing in an easterly direction.

Temperatures on Saturn are normally around -185 degrees Celsius (-300 degrees Fahrenheit), but near the giant swirling polar vortex – a persistent cyclone taking pride of place at the ringed planet's south pole – temperatures start to warm up, and while the climate doesn't reach high enough for a suntan, this -122 degrees Celsius (-188 degrees Fahrenheit) vortex is the warmest spot on Saturn, with a powerful jet stream smashing its way through this terrifyingly fierce feature.

Saturn's north pole also has a giant storm of its own surrounded by a persistent hexagonal cloud pattern. Spotted in 1980 and 1981 during the Voyager 1 and Voyager 2 flybys, Saturn's hexagon, complete with six clear and fairly straight sides, is estimated to have a diameter wider than two Earths. The entire structure rotates almost every 11 hours.

Sighted much more closely by NASA's Cassini spacecraft in 2009 as springtime fell on the ringed giant's northern hemisphere, experts believe that the storm could have been raging for at least 30 years, whipping around at over 480 kilometres per hour (300 miles per hour) in a counterclockwise direction and disturbing frothy white clouds in its wake.



Around once every Saturn year (roughly 30 Earth years), huge, turbulent storms work their way through the clouds of the northern hemisphere. The storm pictured here, which was imaged in 2011, is the longest storm to date lasting roughly 200 days

WHERE DOES THIS HAPPEN?

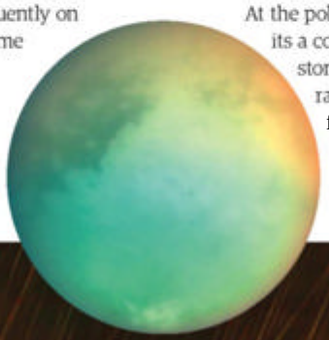


Deadly methane rain

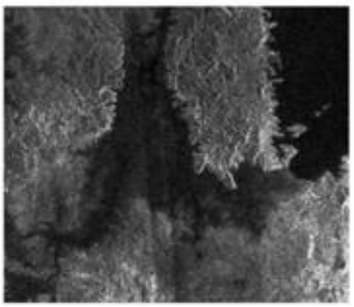
With a surface pressure almost one and a half times that of Earth's, Titan's atmosphere is slightly more massive than our planet's overall, taking on an almost chokingly opaque haze of orange layers that block out any light that tries to penetrate the Saturnian moon's thick cover.

Titan is the only other world, other than Earth, where liquid rains on a solid surface. However, rather than the water that we are used to falling from the skies above us, pooling into puddles and flowing as streams and rivers, this moon's rains fall as liquid methane – liquid hydrocarbons that add more fluid to the many lakes and oceans that already cover the surface. And it is thanks to the moon's complex methane cycle, similar to the natural processes found on Earth, that this is possible.

Rain falls quite frequently on Earth, however, the same can't be said for some regions on Titan. Springtime brings rain clouds and showers to Titan's desert with the moon only experiencing rainfall around once every 1,000 years on its arid equator. However, these rain showers certainly make up for the lack of activity by dumping tens of centimetres or even metres of methane rain on to the Titanian surface.



At the poles of the moon its a completely different story, however. Methane rain falls much more frequently, replenishing the lakes of organic liquid covering the Titanian land. ■



Titan's lakes and rivers of liquid hydrocarbon are thought to be fed by methane rains brought about by the moon's complex methane cycle

Titan's methane cycle

2. Ultraviolet
Methane molecules high in the atmosphere are smashed apart by ultraviolet light from the Sun, sparking a complex chain of organic chemistry. Hydrocarbons begin to drift back to the surface.

H_2

6. Escape
When ultraviolet light acts on methane molecules, it breaks it apart into component atoms and molecules, including hydrogen, which escapes into space.

N_2

CH_4

C_2H_6

5. Evaporation
As the seasons change the rains disappear and the lakes begin to dry, the hydrocarbons evaporate into the nitrogen-rich atmosphere and return methane back into the sky.

1. Methane
How Titan replenishes its methane is a mystery, but one likelihood is through cryovolcanoes, which spew out ice and methane gas.

3. Clouds
The hydrocarbons – including some methane and also the likes of ethane and propane – condense into clouds in the lower atmosphere and, in the right atmospheric conditions, can produce hydrocarbon rain.

$C_2H_6CH_4N_2$

4. Lakes
Liquid hydrocarbons precipitate out of the clouds and settle on to the frozen surface of Titan, forming lakes and rivers in the winter hemisphere.

"Permanent lakes of organic liquid cover the Titanian land"

Winds at twice the speed of sound

We've all got stuck out in or witnessed very strong winds here on Earth, from gusts that turn your umbrella inside out to tornadoes that rip up everything in their path. You might think these winds are a force to be reckoned with, but unless you've had a day floating around the gaseous atmosphere of ice giant Neptune you haven't seen anything yet!

You might think that Neptune's distance from the Sun, which creates temperatures as low as -218 degrees Celsius (-360 degrees Fahrenheit), would mean a world frozen solid by the subzero climate with not much going on in terms of weather. However, you would be incorrect. The winds that race through its hydrogen, helium and ammonia-laden atmosphere can reach maximum speeds of around 2,400 kilometres per hour (1,500 miles per hour), making this dark horse probably the most violently stormy world in the Solar System, and making our most powerful winds look like light breezes.

Neptune's fastest storms take the form of dark spots, such as the anticyclonic Great Dark Spot in the planet's southern hemisphere and the Small Dark Spot further south - thought to be vortex structures due to their stable features that can persist for several months - as well as the white cloud group, Scooter.

So what causes these winds? Neptune might be extremely frosty, but astronomers think that the freezing temperatures might be responsible; decreasing friction in the gas giant to the point where there's no stopping those super-fast winds once they get going.

Delving into its layers of gas, we find another possibility pointing to just how these active storms came about as the temperature starts to rise. As things get more snug closer to the centre, the internal energy could be just what is driving the most violent storms that we've ever witnessed. ●

"The most violently stormy world in the Solar System"



Long bright clouds on Neptune's surface are similar to cirrus clouds on Earth



The gas giant's atmosphere as imaged by the Voyager 2 spacecraft in 1989

Neptune's atmosphere

Clouds and storms
The cyclonic storms, which are thought to be holes in the upper cloud decks of Neptune, are thought to occur in the troposphere at low altitudes compared to the brighter white clouds.

A stormy surface
Storms reaching speeds up to 2,400km/h (1,500mph), are thought to continually rage on the surface of Neptune and make their presence known in the form of blemishes on the otherwise featureless surface.

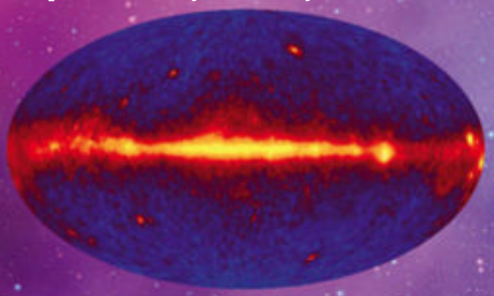
Small Dark Spot
This storm, also called The Wizard's Eye, was measured to be the second most violent storm on Neptune. Just like the Great Dark Spot, the Hubble Space Telescope found that this cyclone had disappeared in 1994.

Great Dark Spot
This anticyclonic storm, which was seen to be morphing into different shapes and sizes, was found to have disappeared by 1994 and was later replaced by a similar feature in the planet's northern hemisphere called the Northern Great Dark Spot.

WHERE DOES THIS HAPPEN?



An all sky gamma ray map taken by the Compton Gamma Ray Observatory (CGRO)



Deep space: Lethal gamma rays



While gamma-ray bursts (GRBs) are short-lived, they can pack a punch of energy hundreds of times brighter than your standard supernova

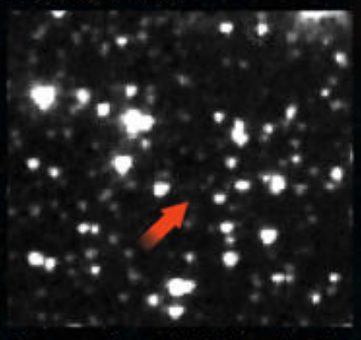
Releasing more energy in a mere ten seconds than the Sun will during its entire 10 billion-year lifetime, gamma-ray bursts reign supreme as the most deadly source of radiation known to man, pipping X-rays to the post.

Taking a trip just outside of the Earth's atmosphere, you'll find that gamma rays are everywhere, however, one of the greatest difficulties in detecting gamma-ray bursts is their incredibly short life span, lasting from just a fraction of a second to over 1,000 seconds. While they can't be seen by our visible light-sensitive eyes, space observatories such as NASA's Fermi Gamma-ray Space Telescope, which is currently performing observations from low Earth orbit, paints a picture of a gamma ray cosmos, proving just how exotic and fascinating our universe is.

But such a high level of radiation doesn't just come out of nowhere, there are many phenomena occurring deep in space, spilling out gamma rays from every pore of the hottest regions of the universe. These hot regions produced in the hearts of solar flares, the explosion of supernovas, neutron stars, black holes and active galaxies, provide these sources.

Back here on Earth we are protected from these bursts of gamma rays by our planet's atmosphere as, unless you're wearing a suit of lead, any interaction with this ionising radiation could prove disastrous as they penetrate through the human body destroying every cell in its path.

But what would happen to life on Earth if we happened to be in the firing line of some intense gamma ray spewing from phenomena such as the nearby explosion of supernovas, an off-the-scale burst from a solar flare destroying the ozone layer, or perhaps the collision between two nearby neutron stars? The answer is not a pleasant one as exposing life as fragile as ours to such a harsh environment would quickly change our currently perfectly balanced world into a deadly orb setting in motion a mass extinction, picking off and destroying life as we know it.

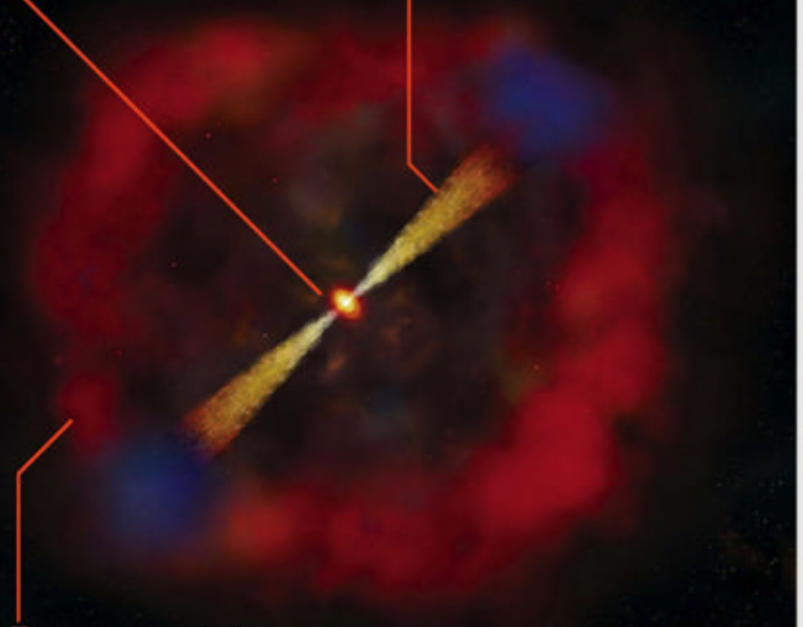


Gamma-ray bursts (GRBs) are gigantic blasts of light whose afterglows fade incredibly fast, lasting anywhere from just a few hours to a few days

Gamma ray formation

1. Rapidly rotating black hole
The spinning black hole, surrounded by a swirling disc of matter, is thought to be created by the collapse of a massive star's core.

2. High energy jets
Energetic particles from the rotating black hole shoot out in the form of high energy jets of excited particles.



3. Supernova shell
The collapse of the massive star's core causes an explosion that ejects the outer layers of the star at high speeds, producing a shell. The interaction of the jet with this supernova shell produces an X-ray afterglow which can last for days or even months.



Tarantula Nebula

This fantastic region of space is one of the brightest and most active areas in our cosmic neighbourhood

Around 160 thousand light years from Earth is a nebula that has astounded astronomers. The Tarantula Nebula, also known as 30 Doradus or NGC 2070, is a 600-light year wide nebula in our Local Group of galaxies, but it shines with such luminosity that it is one of the most active starburst regions in our relative vicinity.

First recognised as a nebula in 1751, the Tarantula Nebula is incredibly bright. According to the National Optical Astronomy Observatory in Arizona, USA, if it was at the same distance as the Orion Nebula (1,350 light years) it would be the size of 60 full Moons in the sky and its glow would cast shadows on the ground.

The reason for this luminosity is that the Tarantula Nebula is located in the region where gas and stars from the Large and Small Magellanic Clouds are colliding. This has ignited star formation in the Tarantula Nebula, in particular large stars that are more susceptible to supernovas, including the famous SN 1987A supernova from 1987 that was the first opportunity for modern astronomers to see such an explosion.

The majority of the energy in the Tarantula Nebula comes from a 35-light year wide compact super star cluster at its core called R136, which itself is barely 2 million years old. The stars of this inner cluster and the rest of the Tarantula Nebula will continue to unleash torrents of ultraviolet light and stellar winds long into the future, making this a sight to behold for generations to come.



5 AMAZING FACTS ABOUT

Titan



Humans could float in its sky

Titan's thick atmosphere, low gravity (less than our Moon) and reasonable surface pressure (1.45 times that of Earth's) mean that, by flapping a pair of wings strapped to your arms, you could fly in its skies with no more effort than walking.

We've landed on it, and we might again

The Saturn-orbiting spacecraft Cassini carried with it the Huygens probe, which landed on Titan (our only landing in the outer Solar System) on 14 January 2005. There are proposals being discussed for another landing, this time possibly using a boat.

It's bigger than Mercury

Titan is beaten in size only by the Sun, the seven planets other than Mercury, and Jupiter's Ganymede. It is over 5,000 kilometres (3,000 miles) wide, and is significantly more massive than all of Saturn's 61 other known moons combined.

It has a climate system like Earth

The liquids on Titan undergo a similar cycle to water here on Earth. Liquid methane evaporates from the surface, forming extremely thick clouds in the skies, before eventually raining down and replenishing the lakes and rivers on the ground.

It's the only other world with liquid

Aside from Earth, Titan is the only world we know of that has liquids on its surface. These are in the form of lakes and rivers composed of liquid hydrocarbons including Ontario Lacus, a lake about 240 kilometres (150 miles) long in Titan's southern hemisphere.

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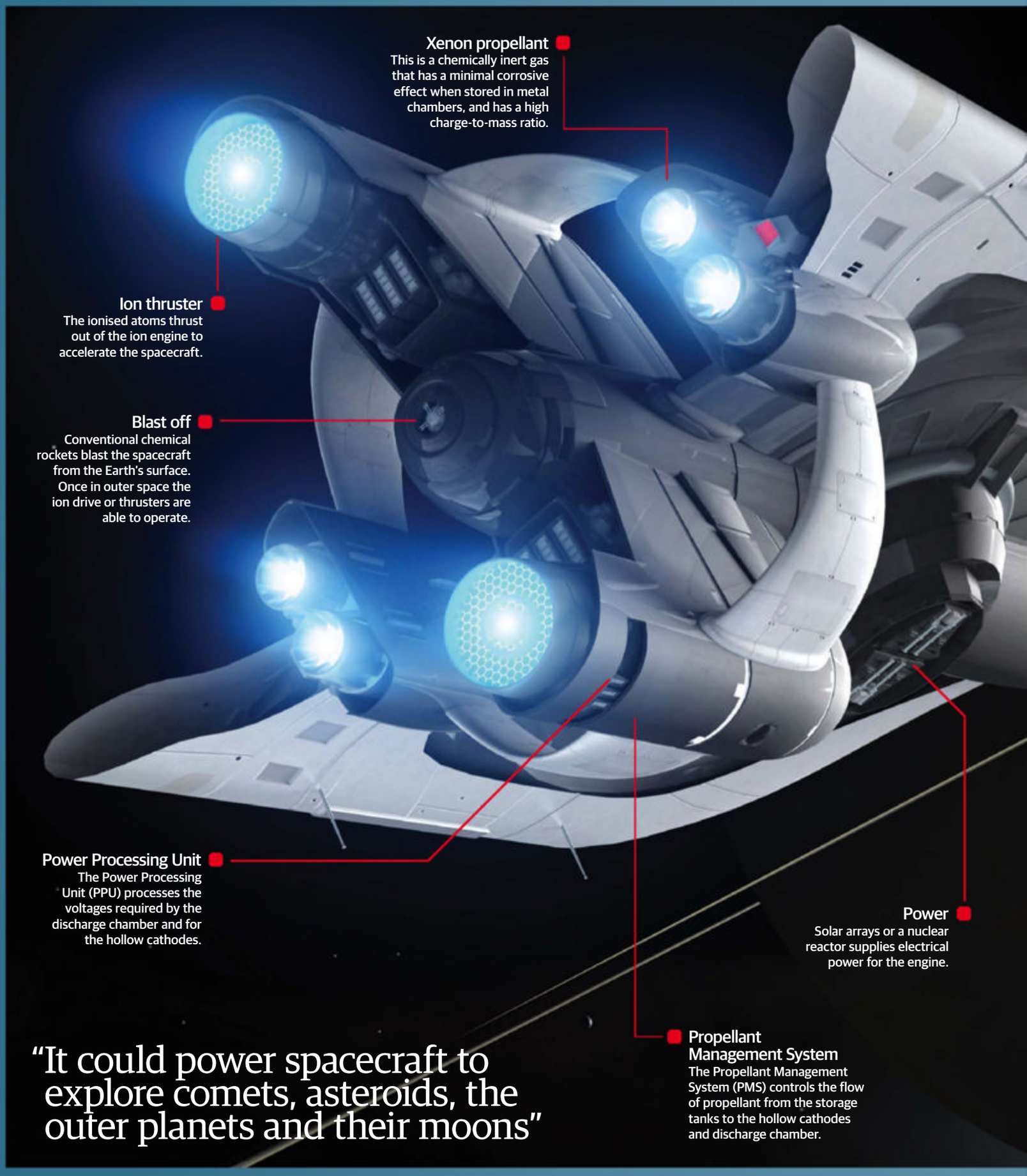
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Xenon propellant
This is a chemically inert gas that has a minimal corrosive effect when stored in metal chambers, and has a high charge-to-mass ratio.

Ion thruster
The ionised atoms thrust out of the ion engine to accelerate the spacecraft.

Blast off
Conventional chemical rockets blast the spacecraft from the Earth's surface. Once in outer space the ion drive or thrusters are able to operate.

Power Processing Unit
The Power Processing Unit (PPU) processes the voltages required by the discharge chamber and for the hollow cathodes.

Power
Solar arrays or a nuclear reactor supplies electrical power for the engine.

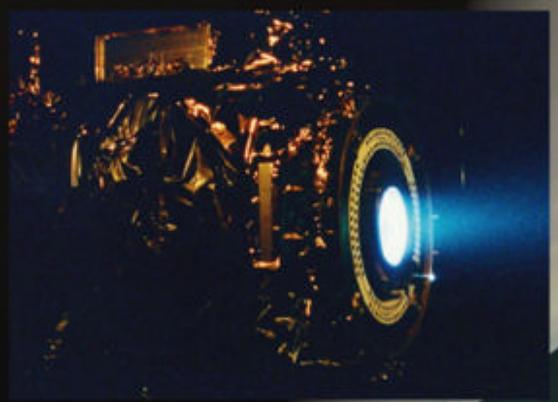
Propellant Management System
The Propellant Management System (PMS) controls the flow of propellant from the storage tanks to the hollow cathodes and discharge chamber.

"It could power spacecraft to explore comets, asteroids, the outer planets and their moons"

Ion drives

Ion drives are the most cost-effective propulsion systems currently available and can send deep space probes faster and further than any other type of rocket technology

Payload
The spacecraft can carry unmanned robot craft for exploring asteroids, comets and moons and planets in the Solar System.



This is the test firing of a Xenon ion engine at NASA's Jet Propulsion Laboratory, prior to the launch of Deep Space 1. The blue glow shows the ionised atoms leaving the engine

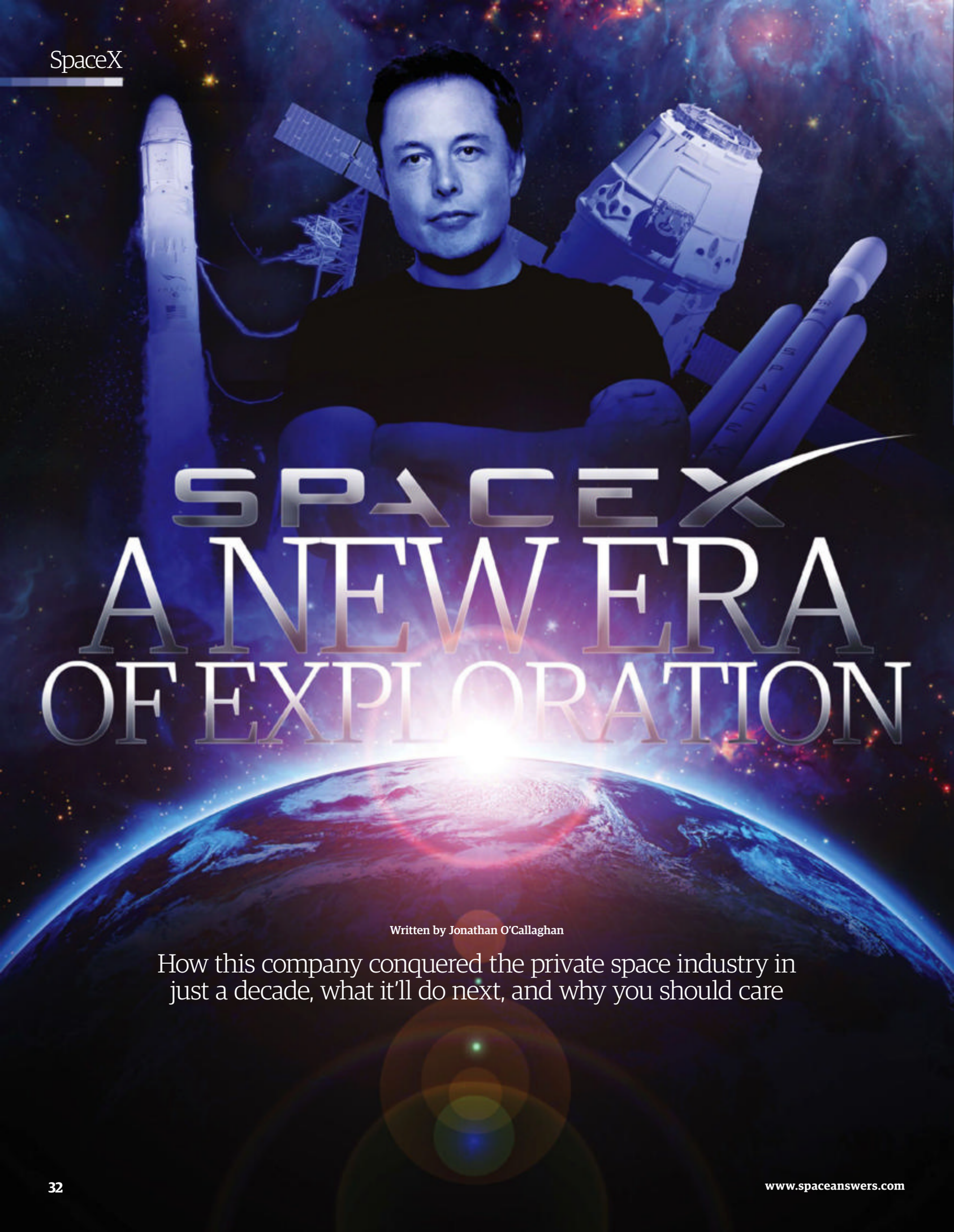
Unlike conventional chemical rockets that burn at a fast rate over a short period of time to generate huge thrust, ion drives run at a steady rate over a long period to generate a high velocity. The ions travel at 31.5 kilometres per second (19.6 miles per second) and produce 0.5 Newtons (0.1 pounds) of thrust. This force is equivalent to the weight of a few coins dropped into your hand, whereas chemical rockets can produce hundreds of thousands of Newtons of thrust. Despite the low amount of thrust, ions can accelerate a spacecraft to 90,000 metres per second (over 320,000 kilometres per hour or 200,000 miles per hour).

Currently, NASA favours xenon as a propellant gas for ion propulsion systems. One type of xenon-fuelled ion engine works by heating a hollow discharge cathode. This pushes a stream of electrons out of the cathode and towards the discharge chamber walls. The xenon propulsion gas is magnetised and forced into the chamber, and the flow of electrons that are stripped off the xenon atoms creates highly excited positive ions. An electric charge is then passed through a metal grid at the back of the chamber, which makes the positive xenon ions rush through the grid to accelerate the spacecraft.

The main drawback with the type of gridded electrostatic ion thruster described above is that the grid will eventually be degraded and destroyed. This isn't a major problem as NASA has successfully run its NASA Evolutionary Xenon Thruster (NEXT) for over 43,000 hours to simulate five years of continual operation. This is four times more than the time needed to accelerate a spacecraft to the asteroid belt and beyond, and shows that it could power spacecraft to explore comets, asteroids, the outer planets and their moons.

Besides the NEXT engine, NASA's Glenn Research Center, Cleveland, Ohio, has also produced the High Power Electric Propulsion (HiPEP) ion engine. This uses magnetic fields and microwaves to heat the atoms in the propellant, to create a plasma. The ions are then taken from the plasma to power the 'craft. Another revolutionary engine is the NASA-457M Hall thruster engine, which is ten times more powerful than any other ion thruster ever built.

Since ion drives reduce the need to carry large fuel loads into space and are durable, they are ideal thruster systems for keeping large geostationary communication satellites in position as well as for sending a new generation of unmanned spacecraft to the Solar System's outer planets.



SPACEX A NEW ERA OF EXPLORATION

Written by Jonathan O'Callaghan

How this company conquered the private space industry in just a decade, what it'll do next, and why you should care







1. Testing of the manned prototype of the Dragon spacecraft, which will be able to carry seven people.
2. Engineers work on a Dragon spacecraft in the SpaceX factory.
3. SpaceX's headquarters at 1 Rocket Road, California, USA.

SpaceX, formally known as Space Exploration Technologies, is currently the most exciting private space company in existence. Through its revolutionary Falcon family of rockets and the amazing Dragon spacecraft, it is doing things that no other private company has been able to match. And it is planning to do even more in the coming years that will cement its place as one of the world's most innovative companies, space-related or otherwise, that will change the way we access space forever.

In May 2012, the world watched in awe as SpaceX became the first private company to launch and dock a spacecraft, namely its Dragon capsule, with the International Space Station (ISS) and return it safely to Earth. It was a huge achievement not only for SpaceX but also for NASA. America's national space agency is currently investing huge sums of money in private space initiatives, and SpaceX is its shining example of how successful the gamble has been.

The most impressive thing about SpaceX, however, is that it has established itself as one of the world leaders in private space exploration in just ten years. Entrepreneur Elon Musk only founded the company in 2002. Its progress has been rapid ever since and, in some instances, largely unexpected. Nobody really thought that this fledgling company would be where it is today in a little over a decade. It has its own fleet of rockets and a cargo ship capable of launching to the ISS, and its next plans are equally as ambitious: it wants to build the world's first fully reusable rocket, and it wants to land humans on Mars. You only have to look at the name of SpaceX's Dragon vehicle to see just how underestimated the company was; CEO Elon Musk gave it this name as an homage to the 1963 song *Puff, The Magic Dragon* after critics had claimed it would never take flight.

In its early years of operation the company spent time acquiring staff and securing funding, including an estimated $100m USD (£64m) from Elon Musk himself. It hired a number of engineers to work on its numerous projects but it was not until 2006 that it built its first rocket, the Falcon 1, which became the first privately developed rocket to orbit Earth in September 2008. Two years later it had built the Falcon 1's successor, the Falcon 9, which was capable of taking a much higher payload into orbit. Its success is the cornerstone on which SpaceX has built its business, and it's allowing the company to set itself more lofty goals to achieve.

SpaceX made use of previous space exploration and aerospace facilities to ensure that it hit the ground running when it started designing and building rockets. Its headquarters, an old Boeing 747 hangar that has been refurbished into offices and a vehicle factory, is based in California at 1 Rocket Road, Hawthorne. Over in McGregor, Texas, SpaceX has a testing facility that used to belong to a company called Beal Aerospace, which has now ceased operations, and from here it tests out rockets and other spaceflight components.

While both of these facilities are used to manufacture and test flight components, the launches currently take place in two separate sites in California and Florida. The latter, the Vandenberg Air Force Base, is also where a number of other space companies launch rockets from, including the Atlas V and Delta IV. SpaceX is also considering building a

Decade of the Dragon

On 8 October 2012, SpaceX's Dragon capsule lifted off on its first scheduled cargo mission to the International Space Station. In fact, it was the first such mission to ever be performed by a private space company, and it means that SpaceX is currently the only commercial enterprise capable of resupplying the ISS. If some people doubted the company's ambitions before, they definitely don't now.

This wasn't the first flight of Dragon, though. This spacecraft has been a huge success story not only for SpaceX but also for NASA, who has invested a considerable sum of money in Dragon. In December 2010, Dragon became the first private spacecraft to launch into orbit and be successfully recovered, a huge milestone for SpaceX. Then, in May 2012, SpaceX again made headlines around the world when it performed a second Dragon flight, this time docking it with the ISS.

Dragon is currently the only spacecraft in operation that is able to both take supplies to the ISS and return cargo to Earth, with the latter including things like experiments and tools that need to be repaired. Other private spacecraft in operation, or soon to be, that take supplies to the ISS (like the ESA's Automated Transfer Vehicle or Orbital Sciences Cygnus spacecraft) burn up on re-entry, while Russia's Soyuz capsule is used only to ferry astronauts to and from the station, and not cargo. This makes SpaceX imperative to the continued success of the ISS.

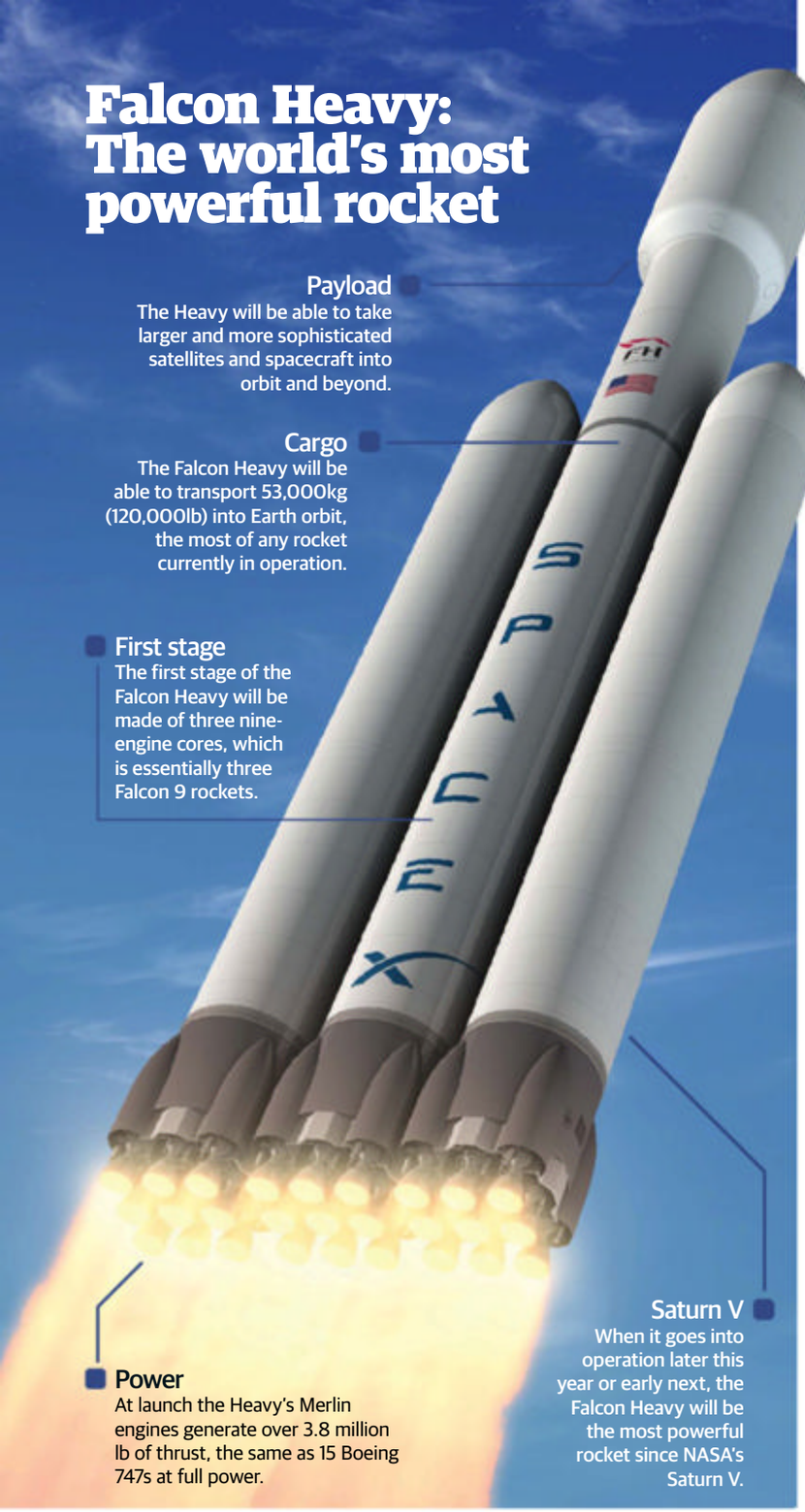
The next step will be to make Dragon human-rated. By 2015 it is hoped an upgraded Dragon spacecraft will be able to take astronauts into orbit, and possibly beyond.

The Dragon spacecraft is vital for the re-supply of the International Space Station





Falcon Heavy: The world's most powerful rocket



new commercial launchpad in the US, with southern Texas being mooted as a possible destination. With SpaceX's stock seemingly rising every month, many different states are keen to get the company on board.

SpaceX has not been without its problems, though. For one, the Dragon capsule was delayed quite considerably from a target launch date in 2011, and despite successful testing there were some problems that needed to be addressed, mostly revolving around safety and its ability to autonomously dock with the ISS. The Falcon fleet of rockets has also encountered minor issues, with an early launch attempt of the Falcon 1 ending in failure, but as the company grows in its experience it is ironing out the kinks and problems.

But SpaceX is a very transparent company that is not afraid to publish these tests, developments and plans. Elon Musk himself has made no secret of his intentions for the coming years, culminating in a manned trip to Mars, which has understandably been met with some caution in the space community. Can this company really live up to the hefty expectations that are being placed on it? Time will tell, but the early indications are exceedingly promising.

> "SpaceX wouldn't be where it is now without the continued assistance and support of NASA"

SpaceX wouldn't be where it is now, however, without the continued assistance of NASA. Prior to the decision to retire the Space Shuttle in July 2011 NASA had already begun programmes to fund private space companies for manned and unmanned missions. It has set private companies the task of building spacecraft that can take humans and cargo into orbit, such as to the ISS. While SpaceX has only built and flown its unmanned Dragon capsule, it is working hard on a crewed variant that could launch by 2015.

In fact, NASA has invested billions of dollars into such programmes. It's gambled a lot on the success of private space companies to take up the mantle of taking cargo and humans into Earth orbit, while NASA itself is focusing on taking humans into deep space with its Orion spacecraft, but thanks to SpaceX it's proving that the commercialisation of space was the correct decision to make at a time when budgets are being slashed and funding is hard to come by. Companies like SpaceX rely on NASA for its continued success, and it's thanks to these pioneering programmes that we see new companies like this thrive.

It's not just NASA, though, that is banking on the success of SpaceX. Many other bodies have been impressed by the meteoric rise of the company, and SpaceX has been keen to get involved. The United States Air Force has bought a number of contracts for flights from SpaceX, as has global satellite operator SES SA, while SpaceX has also been contracted to launch a number of Iridium satellites (used for global communications). Meanwhile, other



SpaceX staff members in mission control

PROFILE

CEO Elon Musk

Elon Musk was born on 28 June 1971 in South Africa. His father was an engineer and his mother an author and model, although Musk has said that his father was against technology and thought computers would never amount to anything. So, at the age of ten Musk bought his first computer and taught himself how to program, and when he turned 17 he left home to pursue his dreams.

He travelled to Canada where he studied at Queen's University until 1992. He then left Canada and took up business and physics at the University of Pennsylvania, Philadelphia. By the time he was on his way to Silicon Valley in California in his mid-twenties, he had two degrees in physics and one in business. It was at this point that he decided on three areas that he wanted to get into: the internet, clean energy and space.

In 1995, after spending just two days on a graduate programme in applied physics and materials science at Stanford University he founded the online publishing software company Zip2 with his brother, Kimbal. In 1999, they sold Zip2 for over $300m (£190m), and Musk went on to found X.com, an online payment company that would later become PayPal. In 2002, eBay acquired PayPal for $1.5bn (£970m) in stock.

With his first goal complete, Musk moved on to clean energy. He founded the company Tesla Motors in 2003. The company specialises in electric cars, with Musk's goal being to create affordable mass-market electric vehicles. In 2006, he unveiled the Tesla Roadster, an all-electric sports car. In June 2012, the Tesla Model S was launched, a full-sized electric four-door sedan, with the greatest range of any electric car on the market on a single charge.

Arguably Musk's greatest achievement, however, has been SpaceX. As early as 2001 Musk had plans for a 'Mars Oasis' project that would land an experimental greenhouse on Mars but, when he realised rocket technology needed to be advanced for such a goal to be achieved, he founded SpaceX in June 2002, pumping $100m (£64m) of his own money into the company. The ultimate goal of SpaceX is to reduce the cost of going to space and to take humans to new frontiers, specifically landing people on Mars in the next 10-20 years.

In a sense Musk has been fortunate that, around the time SpaceX was founded, NASA shifted its focus to the commercialisation of space exploration. SpaceX has received contracts from NASA totalling several billion dollars, and also millions of dollars in funding from elsewhere. After the Dragon capsule was docked with the ISS in May 2012, SpaceX was valued at $2.4bn (£1.5bn). Tying in with Musk's clean energy objective, one of SpaceX's goals is to build and operate a fully reusable rocket that can lift off and return to its launchpad fully intact, bringing the price of taking cargo to orbit down to $1,100 per kilogram ($500 per pound). Instrumental to SpaceX's success will be the continued involvement and vision of Musk himself.

In 2010, **Time** magazine listed Musk as one of the most important people who had affected the world. He's received numerous awards including the FAI Gold Space Medal and the National Space Society's Von Braun Trophy. In a Space Foundation survey in 2010 Musk was ranked as the tenth most popular space hero. He will continue to revolutionise the private space market, often in the face of criticism of his ambitions, for many years to come.

> "Sooner or later, we must expand life beyond this green and blue ball - or go extinct"



Musk invested around $100m of his early fortune in SpaceX


1


2



3

smaller private space companies are planning to use one of SpaceX's rockets for launches. These include Bigelow Aerospace, who will launch an inflatable module for the ISS in 2015, and Astrobotic Technology, a competitor in the Google Lunar X Prize that wants a Falcon 9 rocket to take its lunar rover to the Moon by October 2015.

While SpaceX is busy fulfilling contracts for other companies, one of its crowning achievements to date has been the Dragon capsule, a reusable spacecraft capable of taking cargo to and from the ISS. The vehicle entered production after SpaceX won a NASA Commercial Orbital Transportation Services (COTS) contract in August 2006, worth $278m (£180m). This money was intended as seed money to get the spacecraft up and running, and SpaceX duly obliged; in December 2010 the company successfully launched the Dragon spacecraft into orbit and returned it to Earth, the first private company ever to launch and return a spacecraft.

Now, SpaceX is contracted under NASA's Commercial Resupply Services (CRS) programme, an initiative for private space companies to resupply the ISS in the absence of the Space Shuttle. After a demonstration flight in May 2012 SpaceX completed the first of its 12 scheduled cargo flights in October 2012, with two more missions scheduled for 2013. The cost of the 12 missions for NASA is $1.6bn (£1bn), which is almost the same price as the estimated cost of a single Space Shuttle mission, significantly reducing the cost of taking cargo to orbit.

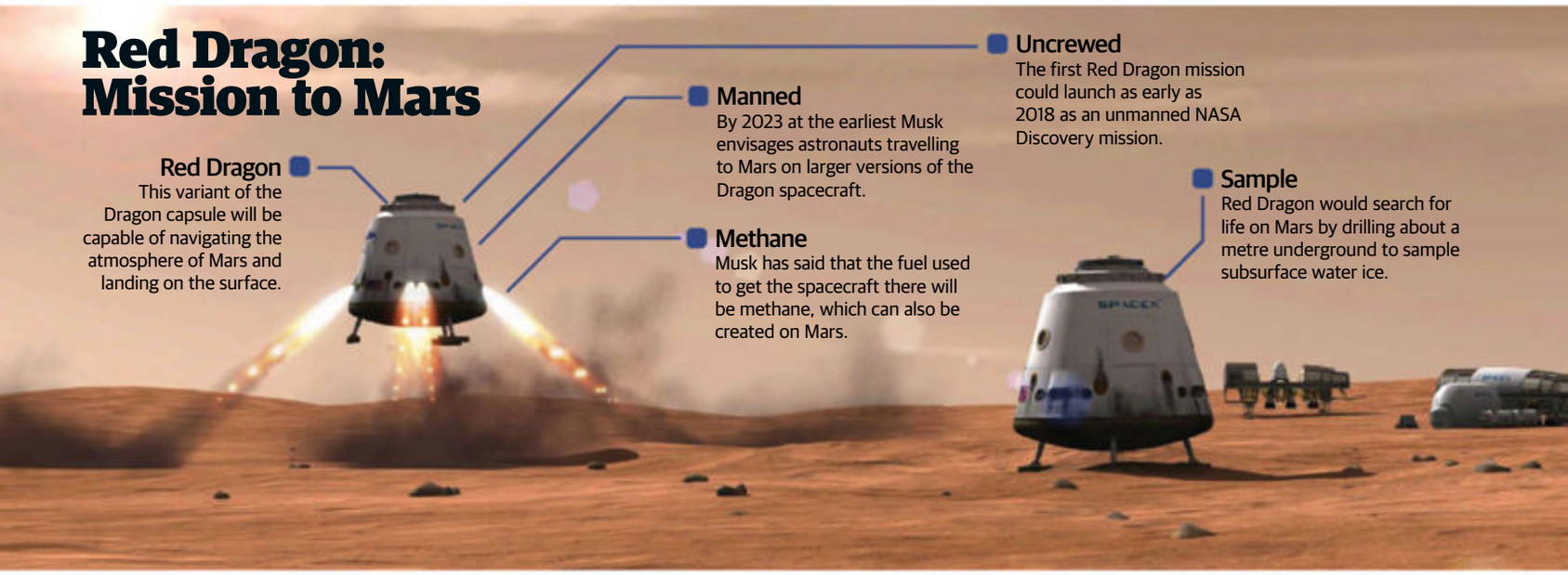
The ultimate plan for Dragon is to ferry astronauts into orbit and, eventually, deep space. This is again with help from NASA, this time under the Commercial Crew Development (CCDev) programme. Known as DragonRider, this crewed variant of Dragon will be able to support a crew of up to seven people, compared to just three for the Russian Soyuz spacecraft, the only current method available of getting people into space. DragonRider, which will also be capable of eventual missions to the Moon and Mars, is expected to launch by 2015 at the earliest.

Another of Musk's main goals for SpaceX ties in with another of his companies, Tesla Motors. This green company is building new fleets of electric cars that aim to reduce our dependence on oil, and therefore move us towards a greener and more sustainable future. Musk wants to apply the same level of thinking to rockets. According to Musk, taking a rocket trip at the moment and throwing away the rocket afterwards is akin to scrapping an aeroplane after every flight, and he wants to change that. SpaceX is currently working on revolutionary reusable rocket technology, which would allow each stage of a rocket to descend in a controlled manner back to Earth using rockets and land back on the original launchpad, ready to take off again in just a few hours. But unlike other companies with pie-in-the-sky ideas, SpaceX isn't just announcing its intention to do these things; it's actually doing them.

To test this reusable technology SpaceX is developing a modified Falcon rocket called Grasshopper. It's designed to lift partially off a launchpad, 'hopping' in a sense,

> "SpaceX has a desire to change the way we think about going to space"

Red Dragon: Mission to Mars







1. SpaceX employees watch Falcon 9 and Dragon launch in October 2012.
2. The spacecraft blasts of towards the ISS.
3. ISS crew members in the Dragon capsule after it docked with the station in May 2012.
4. Ready for liftoff on the Cape Canaveral launchpad.
5. A Merlin 1 rocket being tested in Texas.

and returning back to the ground. Grasshopper completed a successful 12-storey 'hop' in December 2012; the next step will be to rise up to thousands of metres in the air and return safely to Earth. Eventually, this concept will be used in future iterations of the Falcon family of rockets. This would be a huge breakthrough in rocket technology. Modern rockets generally launch with one or several expendable boosters that are discarded in the atmosphere, left either to burn up or fall into the sea. A reusable rocket would do exactly what it says on the tin: the whole thing would be able to land back on its initial launchpad fully intact. If such a technology came to fruition it would dramatically decrease the cost of going to space, one of SpaceX's primary goals.

Another of SpaceX's exciting proposals is a manned mission to Mars. A few years ago Musk outlined plans for SpaceX's Red Dragon mission, a series of spacecraft that would take humans and cargo to the Red Planet for the first time. Musk himself says that he wants to set foot on Mars, and he is adamant that it's a goal that will be achievable in most of our lifetimes. Paramount to the success of such a mission will be the Falcon Heavy rocket. This upgraded version of the Falcon 9 will be the most powerful rocket in existence until NASA finishes construction on its Space Launch System (SLS) rocket. It will be capable of taking 53,000 kilograms (120,000 pounds) into orbit, almost twice as much as the most powerful rocket currently in operation, the Delta IV Heavy. This increased cargo capacity will make a Mars mission possible.

While SpaceX is building the Falcon Heavy rocket, there are rumours that it is working on something even bigger that will be the most powerful rocket in the world. In late 2012, Elon Musk alluded to a new type of rocket engine that would be several times more powerful than the Merlin engines currently used on the Falcon 9 rockets. This as-of-yet unnamed engine would be capable of taking up to 200,000 kilograms (440,000 pounds) into low-Earth orbit, considerably more than NASA's SLS rocket, which will only be capable of taking 130,000 kilograms (290,000 pounds) to orbit. If this new SpaceX engine does materialise, it could make most other rockets obsolete and also be a vital component of a manned Mars mission.

It is the speed and efficiency of designing, building and flying rockets and spacecraft that has made SpaceX one of the biggest names in the modern space business. For decades space travel has been something that only national space agencies could afford, but we are truly entering an age of the commercialisation of space travel and Elon Musk is ensuring that SpaceX is at the forefront of this emerging market. It is not inconceivable to imagine that in ten years the majority of both manned and unmanned flights into Earth orbit will be carried out by private companies, while national agencies will do what many think they should be focusing on anyway; designing and building deep space vehicles that will take humans and new machines to distant destinations like Mars.

SpaceX is not the largest private space company, nor is it the longest running. Others, like Lockheed Martin and Orbital Sciences, have been designing spacecraft and launching rockets for much longer. But what SpaceX has that other companies don't is a radical vision of the future, a desire to not simply fall into line with previously accepted space technologies but to develop its own and change the way we think about going to space. In just ten years we could be sending rockets into orbit, retrieving them and then launching them again the same day thanks to SpaceX's new reusable rocket technology, while in 20 years we could see the first humans on Mars because of SpaceX. If you ever needed a reason to get excited about space exploration then SpaceX is it. It's doing things no one else thought possible, and it'll change the way we access space forever. ●



A Falcon 9 rocket in a hangar at Cape Canaveral in Florida prior to launch in October 2012



PROFILE
President Gwynne Shotwell

Gwynne Shotwell was born in 1963 in the suburbs of Chicago, Illinois. She was a straight-A student at school but had little interest in space, despite growing up during the Moon landings. However, her interest in the cosmos grew when she studied engineering at Northwestern University, and later a PhD in applied mathematics. Upon completion, she made her way into space aeronautics.

Prior to joining SpaceX Shotwell worked at the Aerospace Corporation where she focused on commercial space transportation. While there she completed an extensive study of NASA's future investment in space, and also served as a Chair of the American Institute of Aeronautics and Astronautics (AIAA) Space Systems Technical Committee.

She joined SpaceX in 2002 as vice president of business development, building the launch manifest of the Falcon rocket family to about 50 launches. She is now president of SpaceX, managing all customer and strategic relations.



8 Dec 2010



25 May 2012



8 Oct 2012



March 2013

SpaceX: Past, present and future

SpaceX is founded by Elon Musk.

June 2002

Buys 10% stake in UK-based Surrey Satellite Technology Ltd.

Jan 2005

SpaceX has 160 employees. By 2013, it will have over 1,800.

Nov 2005

The first Falcon 1 rocket launch ends in failure after 25 seconds.

24 Mar 2006

First successful launch of Falcon 1, with a dummy payload on board.

28 Sep 2008

First successful Falcon 9 launch, with prototype Dragon spacecraft.

4 June 2010

Maiden flight of Dragon capsule, first private spacecraft to return from orbit.

8 Dec 2010

Dragon becomes the first private spacecraft to dock with the ISS.

25 May 2012

Dragon launches on its first scheduled cargo mission to the ISS.

8 Oct 2012

Second Dragon cargo mission and last flight of Falcon 9 v1.0.

Mar 2013

First flight of upgraded Falcon 9 v1.1.

Apr 2013

Scheduled first geostationary launch of Falcon 9.

June 2013

Predicted first launch of Falcon Heavy rocket.

Nov 2013

Pad abort test of DragonRider, the crewed version of the Dragon capsule.

Dec 2013

In-flight abort test of DragonRider.

Apr 2014

First flight of DragonLab, a non-NASA and non-ISS uncrewed Dragon mission.

2014

First predicted crewed flight of DragonRider to orbit, with a flight to the ISS to follow.

June 2015

SpaceX will take Astrobotic Technology's Google Lunar X Prize rover to the Moon.

Oct 2015

Red Dragon, a low-cost unmanned Mars lander, is predicted to launch.

2018

Earliest date at which Elon Musk says SpaceX could land humans on Mars.

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Galactic tides



Tails
These two galaxies were nicknamed the Mice Galaxies due to their huge and pronounced galactic tails, which dramatically extend outwards and away from each other. The long tails were generated by tidal action, with the difference in gravitational attraction pulling on the near and far side of each.

Colours
The colours of both galaxies, but notably the upper NGC 4676A, are interesting, with the tails especially differentiating from other examples. Starting out blue and terminating in a yellow colour, the tails reverse the standard colour pattern for spiral galaxies – most likely caused by galactic tidal forces.

Coalesce
While not all orbiting pairs of galaxies converge, in the case of the Mice Galaxies this is predicted, with the pair predicted to continue to collide until they coalesce and form into one larger galaxy.

Spiral
The Mice Galaxies (NGC 4676) are two spiral galaxies in the constellation Coma Berencies, which is approximately 290 million light years from Earth. Both galaxies, which are members of the Coma cluster, are presently colliding and may have done so in the past.

"Galactic tides affect the shape and composition of stellar objects"

The power of Galactic tides

Galactic tides are capable of shearing entire galaxies in two and ejecting stars and debris into interstellar space

A galactic tide is a cosmic process in which an object of small mass is distorted gravitationally by one of larger mass, such as a satellite galaxy being influenced by a larger galaxy. This process occurs as gravitational attraction between two objects increases with a decrease in distance, with objects in close proximity to each other experiencing stronger attraction and greater probability of generating a galactic tide.

A good theoretical example of a galactic tide is two galaxies located close to each other, one with a large mass and the other with a smaller mass. Here, the stronger gravitational attraction of the large galaxy causes the outer layers of the smaller one to be siphoned and drawn off from its core, warping and elongating it from a rough disc shape to an uneven one. This shearing tidal force is experienced by the larger galaxy too, however, due to the smaller one's lesser mass and gravitational attraction – as described in Isaac Newton's law of universal gravitation – it does not experience the effect as strongly.

Interestingly, galactic tides do not necessarily result in galactic collisions, as tidal forces are dependent on the gradient of gravitational field as well as strength. For example, in the aforementioned example of two galaxies, the result of close proximity will not necessarily lead to a collision as the tidal forces involved will distort each galaxy along an axis both pointing towards and away from its opposite number. As the two galaxies orbit each other, which can be temporarily, these distorted stretched-out regions are sheared off the corresponding cores due to their differential rotation (different layers are rotating at different angular velocities) and ejected into intergalactic space. This ejection generates galactic tails, strongly curved expanses of stars and gas that extend out from the galaxy cores (a good example of this can be seen in the image of the Mice Galaxies on the opposite page).

Galactic tides not only affect the shape and composition of stellar objects but also other factors, too. In small-scale objects such as dwarf galaxies, tidal forces can alter their interior structure and motions, luminosity factor and – in galaxies – star formation rate. A good example of these effects can be seen in the case of dwarf galaxy M32, a satellite of the mighty Andromeda Galaxy. Here, not only has M32 had its spiral arms accreted by Andromeda in a tidal stripping process but also it has an anomalous mass-to-luminosity ratio as well as an abnormally high star formation rate in its core – the latter theorised to be generated by tidally induced motions in its remaining molecular clouds.

While galactic tides occur outside of a galaxy, tidal forces in general occur both outside and inside them, with the gravitationally weak boundaries of systems most prone (the region where the Sun's gravitational influence is overpowered; referred to as the tidal truncation radius). A good example of this can be visualised with our own Solar System, with the hypothetical Oort cloud that surrounds it being gravitationally distorted by the Milky Way's tidal forces. This distortion is postulated to be one of the primary generators of comets within our Solar System, with the galactic tide bending and distorting the orbits of bodies (such as comets) and drawing them towards the galactic centre. ■

Tides in space

Galactic tides are generated by galaxies due to their huge gravitational attraction and tidal forces. As such, satellites of major galaxies are the most common places to find evidence of the galactic tidal processes.

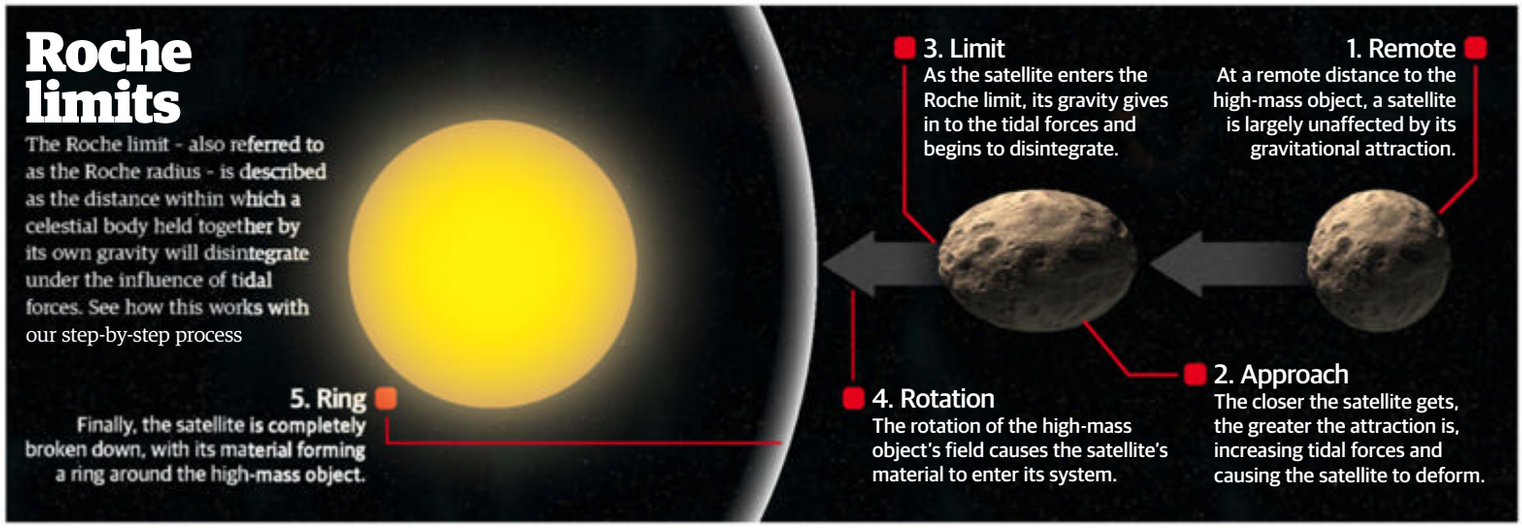
One of the best currently known interactions of this type can be found in the relationship between the dwarf elliptical galaxy M32 and Andromeda. Here, not only has the significantly smaller M32 had almost all of its outer layers (spiral arms) sheared away by the tidal forces of Andromeda but it is also having its core manipulated by them. This manipulation consists of tidally induced motions within its central molecular clouds, with the tidal forces kneading and compressing them on a large scale. This is inducing the creation of large quantities of new stars within the heart of the system and rapidly accelerating their full formation.

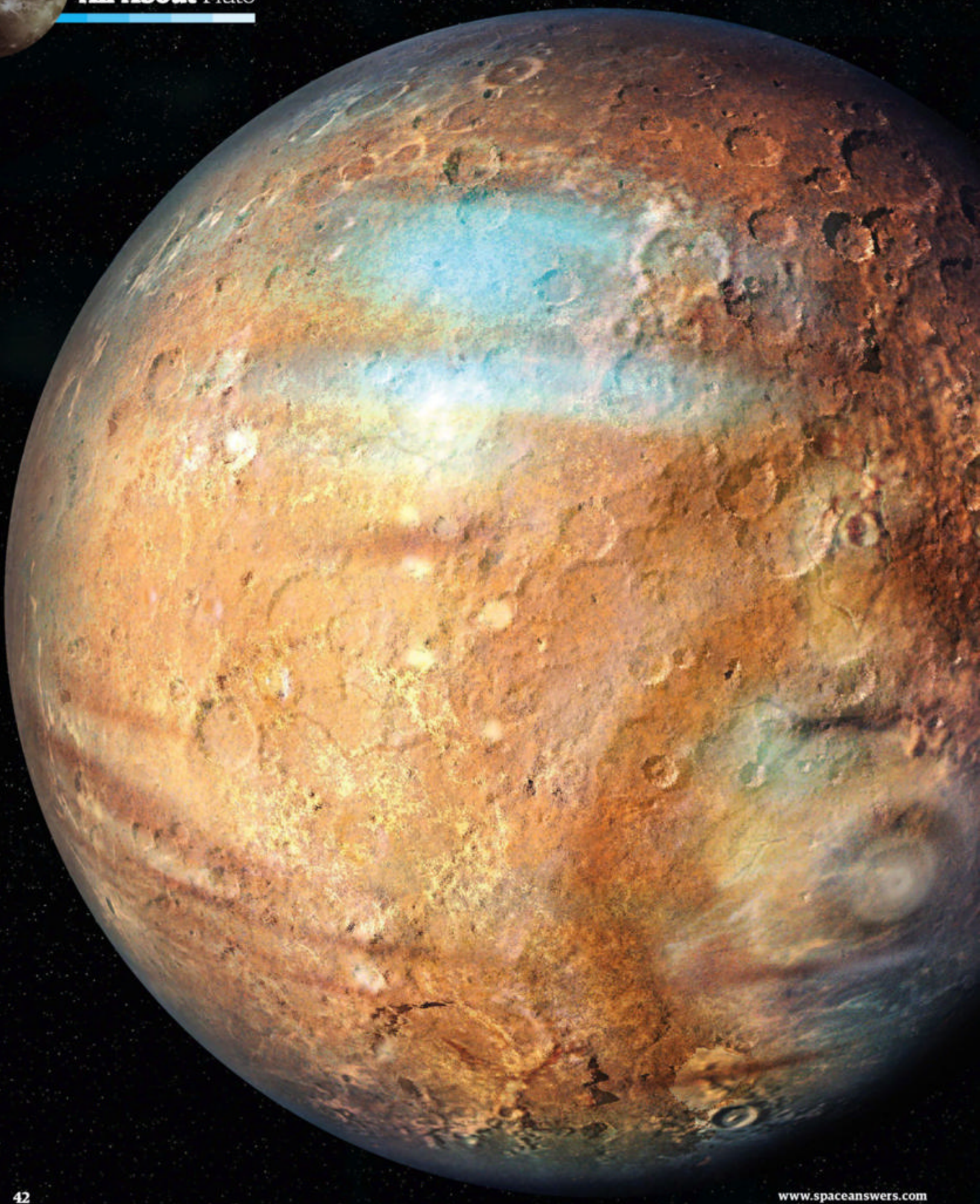


The Antennae galaxies are currently undergoing a galactic collision

Roche limits

The Roche limit – also referred to as the Roche radius – is described as the distance within which a celestial body held together by its own gravity will disintegrate under the influence of tidal forces. See how this works with our step-by-step process







All About... PLUTO

Written by Shanna Freeman

Once classified as the ninth planet in our Solar System, Pluto's demotion to a dwarf planet hasn't changed our fascination with the only planet never to have been visited by a spacecraft

All About Pluto

While some planets were discovered by accident, we actually sought out Pluto. In 1906, a wealthy astronomer named Percival Lowell, who founded an observatory in Flagstaff, Arizona, USA, began an extensive search for a planet beyond Neptune. He tasked the staff at the observatory with looking for what he called 'Planet X', a large planet causing perturbations in the outer planets' orbits. Pluto was photographed many times without astronomers knowing what it was, known as prediscoveries. Finally, a young astronomer named Clyde Tombaugh found the planet in 1930, after a year of examining photographs. Suggestions for a name came in from around the world, and an 11-year-old English girl named Venetia Burney suggested Pluto, receiving £5 (the equivalent of £234 or $376 today) as a reward. Although Pluto was too small to be Lowell's 'Planet X' – the so-called perturbations were explained later by more accurate measurements – it was still considered the ninth planet in our Solar System until 2006.

Pluto lies 5.87 billion kilometres (3.67 billion miles) from the Sun on average, but its highly elliptical orbit makes it come as close as 4.44 billion kilometres (2.76 billion miles) and as far away as 7.31 billion kilometres (4.54 billion miles). During its 248-year trip, sometimes it's closer to the Sun than Neptune. Pluto doesn't orbit in the ecliptic – the flat, circular plane of reference around the Sun – the way that the planets do. Instead, its orbit is inclined about 17 degrees. The dwarf planet's orbit is also chaotic and difficult to predict over time. While we can create models of planetary orbits millions of years from now, Pluto's small size makes it very sensitive to influences from other bodies in the Solar System.

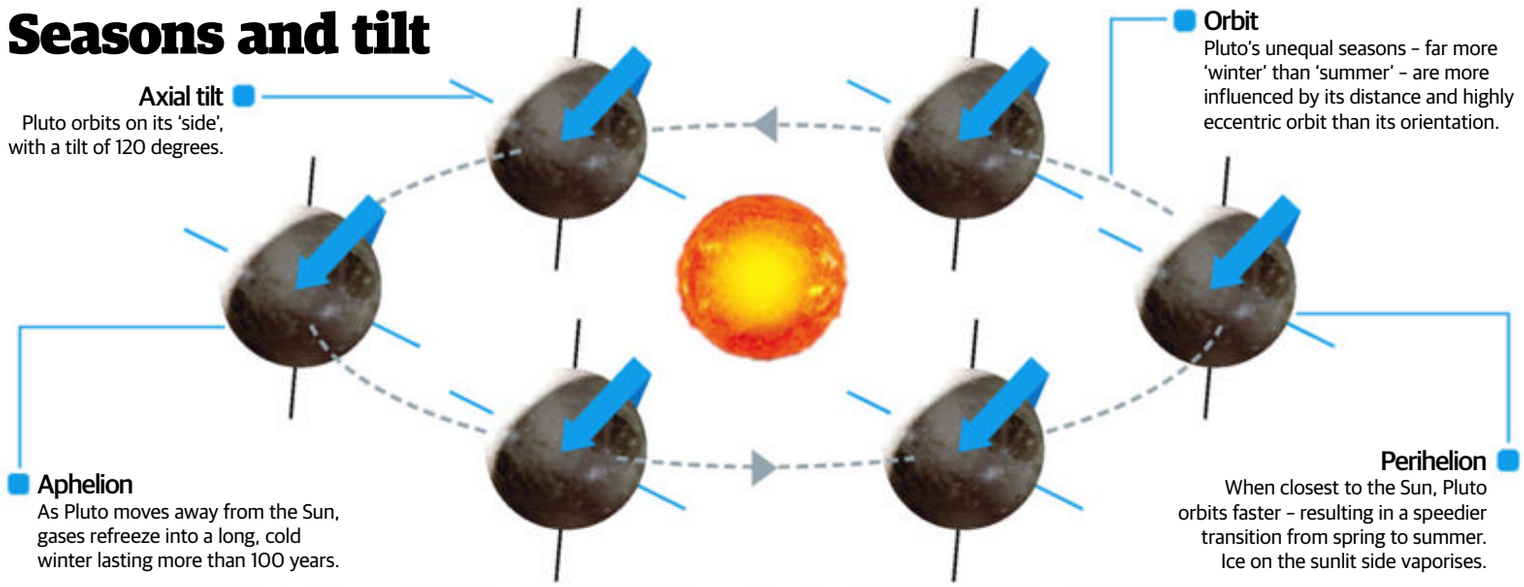
A day on Pluto lasts just over six Earth days and, much like Uranus, Pluto rotates while tipped on its 'side', with an axial tilt of 120 degrees. This results in extreme weather during its solstices; one-quarter of the surface is always in daylight and another quarter is in darkness. Pluto's distance from the Sun really has more to do with its seasons than the tilt, though. Summer lasts about 50 years, and occurs when Pluto is closest to the Sun. The usually frozen gases vaporise during this time. Otherwise, it's essentially a long, cold winter. Spring and fall are short transitions between the two.

Because Pluto is so tiny and far away, we simply don't know all that much about it – and much of what we do know is speculative. Our best images of Pluto have come from the Hubble Space Telescope, but if you're used to seeing clear images of planets, you may be taken aback by the mottled photographs of this rocky, icy dwarf planet. Pluto is smaller than the Earth's Moon with a diameter of around 2,300 kilometres (1,430 miles). Its mass is estimated to be around a sixth of the Moon's mass. Pluto also has its own satellites – five of them. The largest, Charon, is about half the diameter of Pluto.

So, if Pluto has all of these planet-like characteristics, why did the International Astronomical Union (IAU) change its classification? For one, we've learned a lot about the composition of the Solar System since its discovery. Pluto is located within a region called the Kuiper belt, just beyond the orbit of Neptune and extending about 7.5 billion kilometres (4.6 billion miles) from the Sun. Discovered in 1992, this massive area may contain as many as 100,000 objects left over from the formation of the Solar System. Pluto is probably the largest object in the belt, but there are others that rival it in size. It's also one of a group of Kuiper belt objects (KBOs) known as plutinos, which share similar characteristics that include being in a 2:3 orbital resonance with Neptune.

In 2006, the International Astronomical Union voted to redefine the meaning of the term 'planet'. A planet has to orbit the Sun, have enough gravity to be spherical and be the dominant object in its orbit. Pluto meets the first two requirements, but not the last because it's surrounded fairly closely by objects of a similar size. However, the reclassification of Pluto caused a lot of controversy among astronomers, with many disagreeing with the IAU's decision. And many non-astronomer types have a difficult time considering Pluto anything but a planet, even if purely for sentimental reasons. ●

Seasons and tilt



Pluto in relation to the Sun

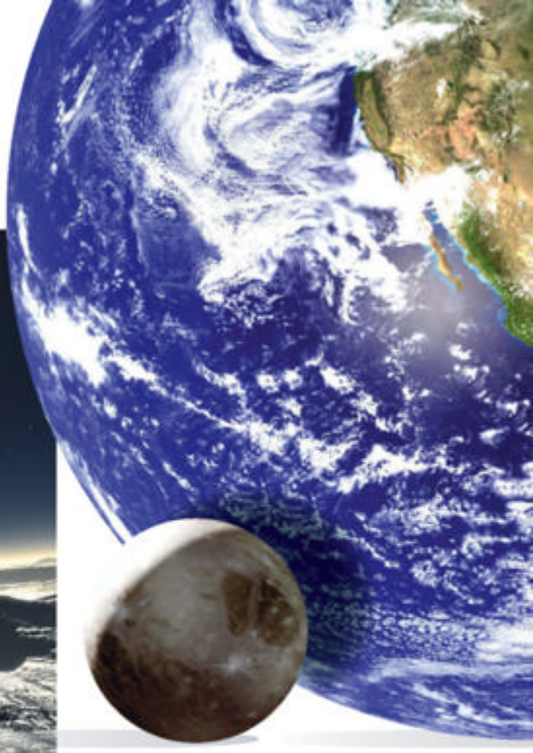
Pluto lies 5.87 billion km (3.67 billion miles) from the Sun and 4.28 billion km (2.66 billion miles) from Earth

All figures = million miles from Sun





This artist's rendering of Pluto shows a rocky, icy surface with pure methane gas on top. The Sun is just a pinpoint in the distance, while the moon Charon orbits nearby



At 2,300 kilometres (1,430 miles) in diameter, Pluto is about 18% of the Earth's diameter

A highly inclined and eccentric orbit

Pluto's orbit
Pluto's orbit is out of the orbital plane occupied by the eight planets – inclining 17 degrees above it.

Neptune's orbit
Pluto is locked into a 2:3 resonance with Neptune, meaning that for every two orbits it makes around the Sun, Neptune makes three.

Sun
Sometimes Pluto is closer to the Sun than Neptune, but their orbits do not actually intersect and there's little chance of a collision.

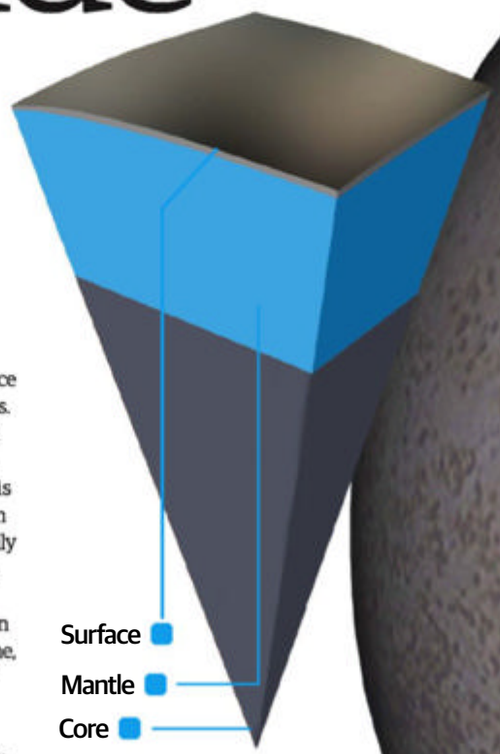
Pluto inside and out

Our best impressions of Pluto come from the Hubble Space Telescope

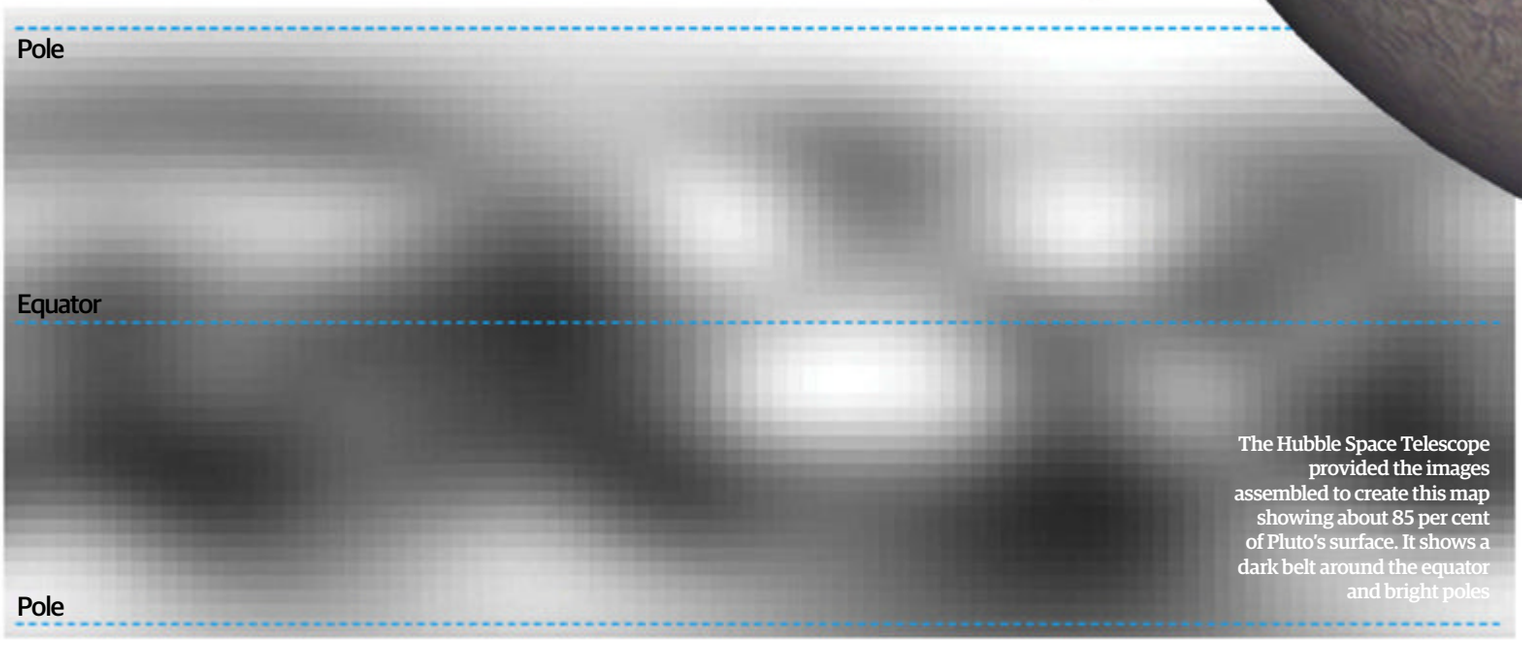
Since we've never visited Pluto, all of our knowledge about it comes from data recorded by ground-based telescopes or the Hubble Space Telescope (HST). Even the most powerful and largest telescopes on Earth show what looks more like a star than anything else. The HST, however, has given us maps showing changes in the brightness and colour of Pluto's surface, and we also have infrared data. This information has helped astronomers make rough estimates of the size of Pluto's polar regions, and to see that it has wide variations in colour and darkness. Pluto's colours include white, dark reddish orange and grey black. The differentiation and changes in colours over time can probably be attributed to seasonal changes. The pole most exposed to sunlight tends to brighten as the frozen gases on the surface melt. For example, the northern pole became brighter between 1994 and 2002, while Pluto overall became a darker red-orange colour from 2000 to 2002.

Astronomers have theorised that Pluto has a differentiated structure, with a rocky core, a mantle of water ice and a surface comprising frozen gases. There's the possibility that heating in the core has created a layer of liquid water under the mantle. The surface is mostly nitrogen, with traces of carbon monoxide and methane. Pluto is tidally locked with its moon Charon, which has affected the composition of its atmosphere. The side facing the moon has a higher concentration of methane, while the side opposite has a higher concentration of carbon monoxide.

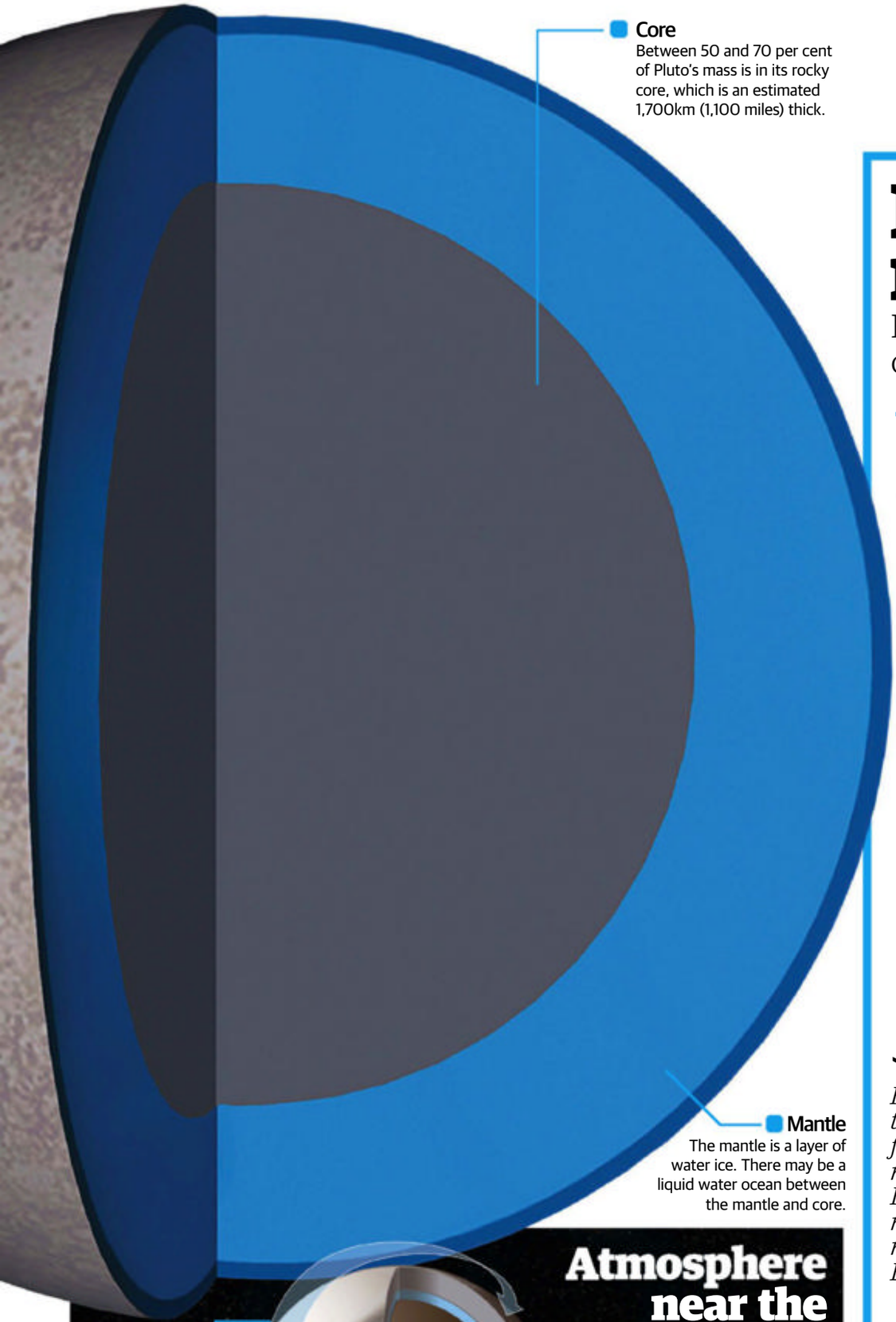
Pluto's atmosphere changes depending on where it's located along its orbit. When closest to the Sun, the sunlit side experiences sublimation – the gaseous ice turns into gases. This lowers the surface temperature, estimated to be about –230 degrees Celsius (-382 degrees Fahrenheit), an anti-greenhouse effect. When away from the Sun, the gases refreeze and fall to the surface. Temperatures above the surface are warmer thanks to a greenhouse effect caused by the methane. Pluto's atmospheric pressure ranges from 0.65 to 2.4 pascals. Evidence of Pluto's atmosphere was found by observing star occultation. Planets and other objects without atmospheres that pass in front of stars cause their light to go out immediately; if the planet has an atmosphere, the light slowly fades.



Surface
Pluto's surface is about 98 per cent nitrogen gas, with the rest as methane and carbon monoxide. It is usually frozen but sublimates in the summer.



The Hubble Space Telescope provided the images assembled to create this map showing about 85 per cent of Pluto's surface. It shows a dark belt around the equator and bright poles



Core
Between 50 and 70 per cent of Pluto's mass is in its rocky core, which is an estimated 1,700km (1,100 miles) thick.

Mantle
The mantle is a layer of water ice. There may be a liquid water ocean between the mantle and core.

Atmosphere near the Kuiper belt



Winds
It's estimated that there are winds up to 360km/h (225mph) sweeping clockwise around Pluto.

Sublimation
Frozen gases in the hemisphere facing the Sun become gaseous, cooling down the planet further.

Condensation
On the dark side of the dwarf planet, the gases condense and eventually refreeze.

Pluto in numbers

Fascinating figures about the once-ninth planet from the Sun

134340
Pluto's official name since being classified as a dwarf planet by the Minor Planet Center (MPC)

0.033
The surface area on Pluto is 0.033 times the surface area on Earth

5
How long it takes in hours for sunlight to reach Pluto. It takes eight minutes to reach the Earth

62.5
How many times greater Jupiter is in diameter compared to Pluto

3kg (6.7lb)
How much 45kg (100 pounds) would weigh on the surface of Pluto

39.482
How much greater Pluto's orbit size is compared to the Earth's orbit

Moons of Pluto

You don't have to be a planet to have satellites – Pluto has five of its own

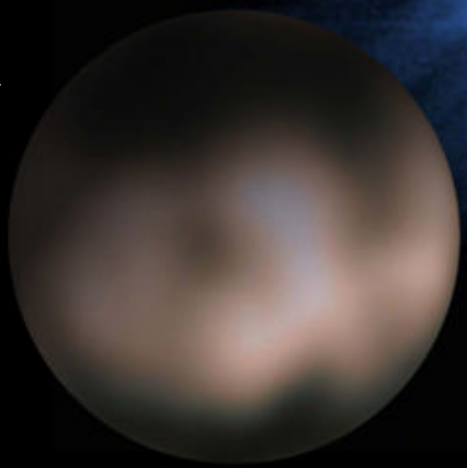
It may not be classified as a real planet any more, but Pluto still has a very planet-like feature – five satellites, or moons, of its own. The system may have been formed from an impact between Pluto and another body in the Kuiper belt. Unlike Pluto, each of the dwarf planet's satellites has a greyish, lunar appearance.

It took almost 50 years after the discovery of Pluto for astronomers to find its largest moon, Charon. Also known as (134340) Pluto I, the moon was discovered by James Christy at the United States Naval Observatory Flagstaff Station (NOFS) in 1978. Christy examined magnified images of Pluto and noticed a bulge in the rotation that indicated it must be accompanied by a satellite. Until the Hubble Space Telescope, we didn't have any images showing Charon as separate from Pluto. Advances in ground-based telescopes have allowed us to see the moon more clearly.

Charon is almost half the diameter of Pluto at about 1,200 kilometres (750 miles). Charon and Pluto are tidally locked – with the same sides of each body facing the other. The barycentre, or centre of mass, is outside either of them. On average, they are 19,570 kilometres (12,200 miles) apart and revolve around each other every 6.39 days. It has 11.65 per cent the mass of Pluto, and appears to have a surface of water ice. However, scientists are conflicted as to Charon's internal structure. Some believe that it is uniformly rocky, while others think that it is differentiated, with a rocky core and an icy mantle.

Nix, or (134340) Pluto II, and Hydra, or (134340) Pluto III, were discovered at the same time, in 2005, by the HST Pluto Companion Search Team. Both appear to be almost identical, and both are in near-resonance with Charon. Nix has an orbital period of 24.9 days and has been estimated to have a diameter between 46 and 137 kilometres (29 and 85 miles). Hydra has an orbital period of 38.2 days, with a diameter between 61 and 167 kilometres (42 and 104 miles). If the two moons are similar in brightness to Charon, they'll be on the smaller size; if they are dark like other bodies in the Kuiper belt, they may be larger.

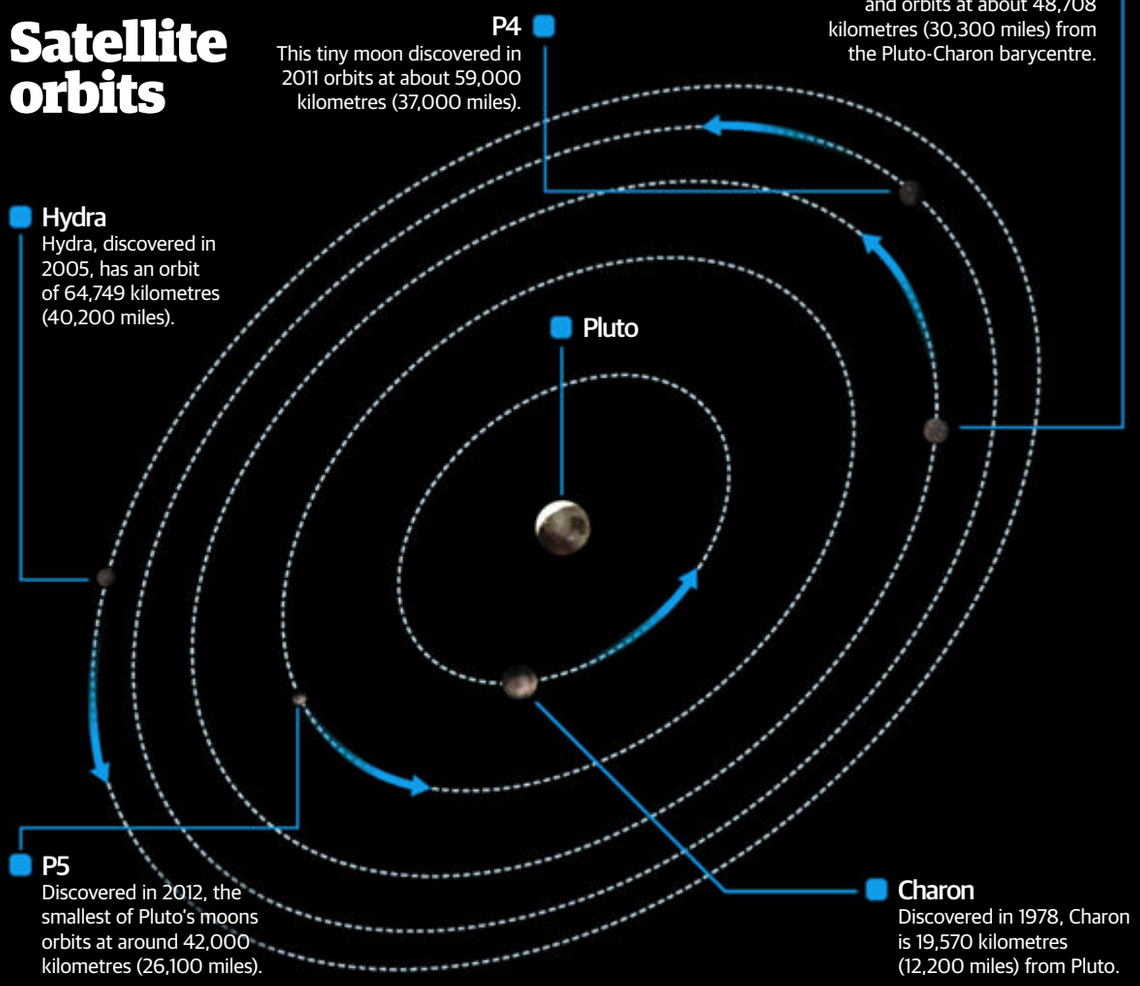
In 2011, the HST Pluto Companion Search Team discovered Pluto's fourth moon, designated P4 or S/2011 (134340) 1. The moon has an estimated diameter of 13 to 34 kilometres (8 to 21 miles) and an orbital period of 32.1 days. Its orbit lies between those of Hydra and Nix. In 2012, the team discovered the most recent moon – P5 or S/2012 (134340) 1. P5 is extremely tiny, at between 10 and 25 kilometres (6 and 16 miles) in diameter. It has an orbital period of 20.2 days and orbits 42,000 kilometres (26,100 miles) away. The orbit lies between those of Charon and Nix.



This rendering of Charon's Pluto-facing hemisphere was made from maps created by astronomer Marc W Buie

This Hubble Space Telescope image shows Pluto with its moons Charon, Nix, and Hydra

Satellite orbits



Exploration

Pluto is still mysterious because we haven't visited it yet – but that should change in 2015

The main obstacle to sending a spacecraft to Pluto has been its distance, hence why much of what we know about it has been gathered from Earth-based telescopes and the Hubble Space Telescope. Voyager 1 could have continued on its trajectory to fly by Pluto, but instead it conducted a flyby of Saturn's moon, Titan. NASA considered a space mission called the Pluto Kuiper Express to visit Pluto and its moons, but cancelled the mission in 2000 due to costs and delays.

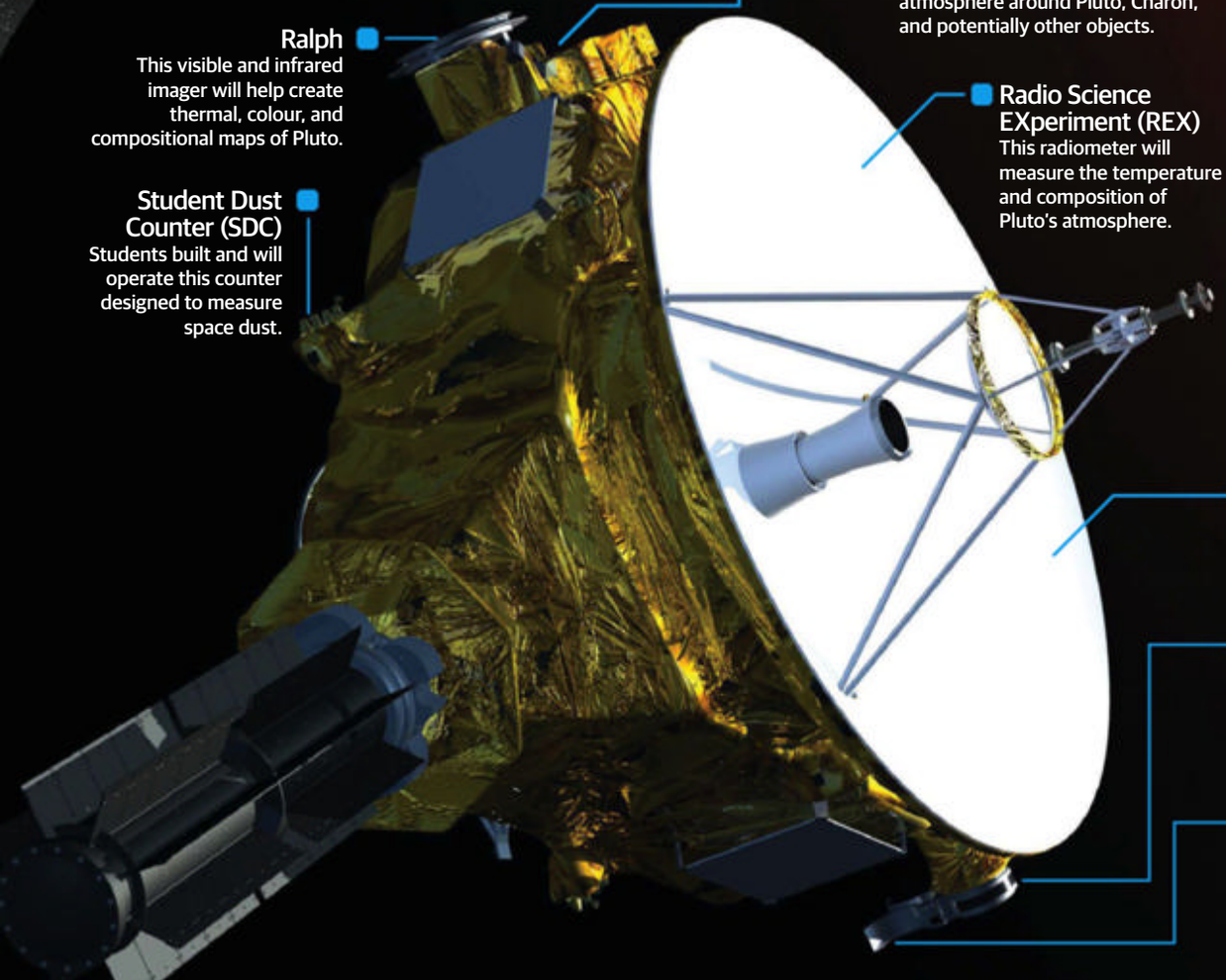
A new NASA mission launched successfully in 2006. The New Horizons spacecraft left Earth when Pluto was still classified as a planet, and many members of the team still consider it to be one. New Horizons launched at the highest-ever speed for a spacecraft at 58,536 kilometres per hour (36,373 miles per hour) and was pointed towards Jupiter to get a gravity assist on its way to Pluto. It reached Jupiter in 2007, and the gravity assist increased the probe's speed by about 14,000 kilometres per hour (8,950 miles per hour). While near Jupiter, New Horizons took some images of the planet and as of January 2013, the spacecraft had passed Uranus's orbit.

The probe began sending back images of Pluto in 2006. It should come within 10,000 kilometres (6,200 miles) in February 2015, and by May begin sending back images better than the HST has been able to provide. New Horizons will fly by Pluto and each of its moons, and then hopefully fly by one or more objects within the Kuiper belt. The controllers aren't sure yet exactly which Kuiper belt objects (KBOs) the probe will visit – they're still searching for ones with the right size and at the right distance for New Horizons to check out after it flies by the Plutonian moons.



NASA launched New Horizons on 19 January 2006 from Cape Canaveral, Florida. It reached the fastest launch velocity and left the Earth faster than any other spacecraft

New Horizons



Ralph
This visible and infrared imager will help create thermal, colour, and compositional maps of Pluto.

Student Dust Counter (SDC)
Students built and will operate this counter designed to measure space dust.

Alice
Alice will analyse and measure the atmosphere around Pluto, Charon, and potentially other objects.

Radio Science EXperiment (REX)
This radiometer will measure the temperature and composition of Pluto's atmosphere.

Long Range Reconnaissance Imager (LORRI)
This long-range camera will help to map Pluto's surface with high-definition data.

Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI)
This instrument measures the ions that escape from the Plutonian atmosphere.

Solar Wind Around Pluto (SWAP)
This system of spectrometers measures the amount of atmosphere escaping into space and observes solar wind.

Mission Profile

New Horizons

Mission dates: 2006-2026
Goals: In designing New Horizons, NASA chose instruments to help explore Pluto. It hopes to learn more about the dwarf planet's atmospheric composition and behaviour, and how solar wind interacts with the atmosphere. It's also hoped that we'll learn more about the surface features on Pluto.

The Vinci spaceplane

A European Space Agency spaceplane concept that meets the challenges of the new generation of reusable, low-cost, suborbital spacecraft

The testing of Virgin Galactic's SpaceShipTwo and many other similar projects in various states of development means that we are about to enter an era of commercial spaceflight.

This will bring about huge changes in the aerospace industry, which has prompted the European Space Agency (ESA) to look at how it should respond to this new environment. Being only able to help and fund commercial suborbital spaceplane projects in Europe, the ESA has proposed the construction of a generic European 'Cryogenic Sub-orbital Spacecraft'.

The ESA looked at three different reusable spaceplane concepts that could use the Vinci rocket engine that is currently being developed as an upper-stage rocket for the agency's Ariane launch vehicle. The first had a conventional tail assembly and wings, the second had a forward canard, wings and butterfly tail assembly, and the third had a canard and winglets.

The ESA report favoured the second vehicle concept, as the design allows it to carry payloads on its back that can be launched into low Earth orbit. It would have a total weight of 13,920 kilograms (30,625 pounds) at takeoff, and would operate from an airstrip like a conventional aircraft. Using a fuel load of 7,515 kilograms (16,534 pounds), it would blast the spacecraft to a maximum speed of about 4,200 kilometres per hour (2,600 miles per hour).

The Vinci engine, which is capable of being fired up to five times on each mission, would be able to take the two crew and six passengers to a height of 107.65 kilometres (66.8 miles), where several minutes of weightlessness could be experienced before the spacecraft glides back down to Earth.

This vision of a potential Vinci spaceplane would use the technology currently being developed by the European Space Agency, and it would also benefit from the agency's expertise in astronaut training and space medicine. The ESA is also able to help the flow and exchange of information between interested parties and to help meet the demands of European Aviation Safety Agency certification and other European legal requirements.

The Vinci spaceplane would certainly be able to send a variety of payloads into orbit at a lower cost per launch than conventional rockets, and could be equal to the commercial suborbital spaceplanes currently being developed in the United States. Whether any European companies are willing or able to take up the technological and economic challenges that need to be surmounted before the Vinci spaceplane can take flight, however, is something only time will tell.



On the outside it looks like an executive jet, but on the inside it carries a Vinci rocket engine and a crew/passenger compartment

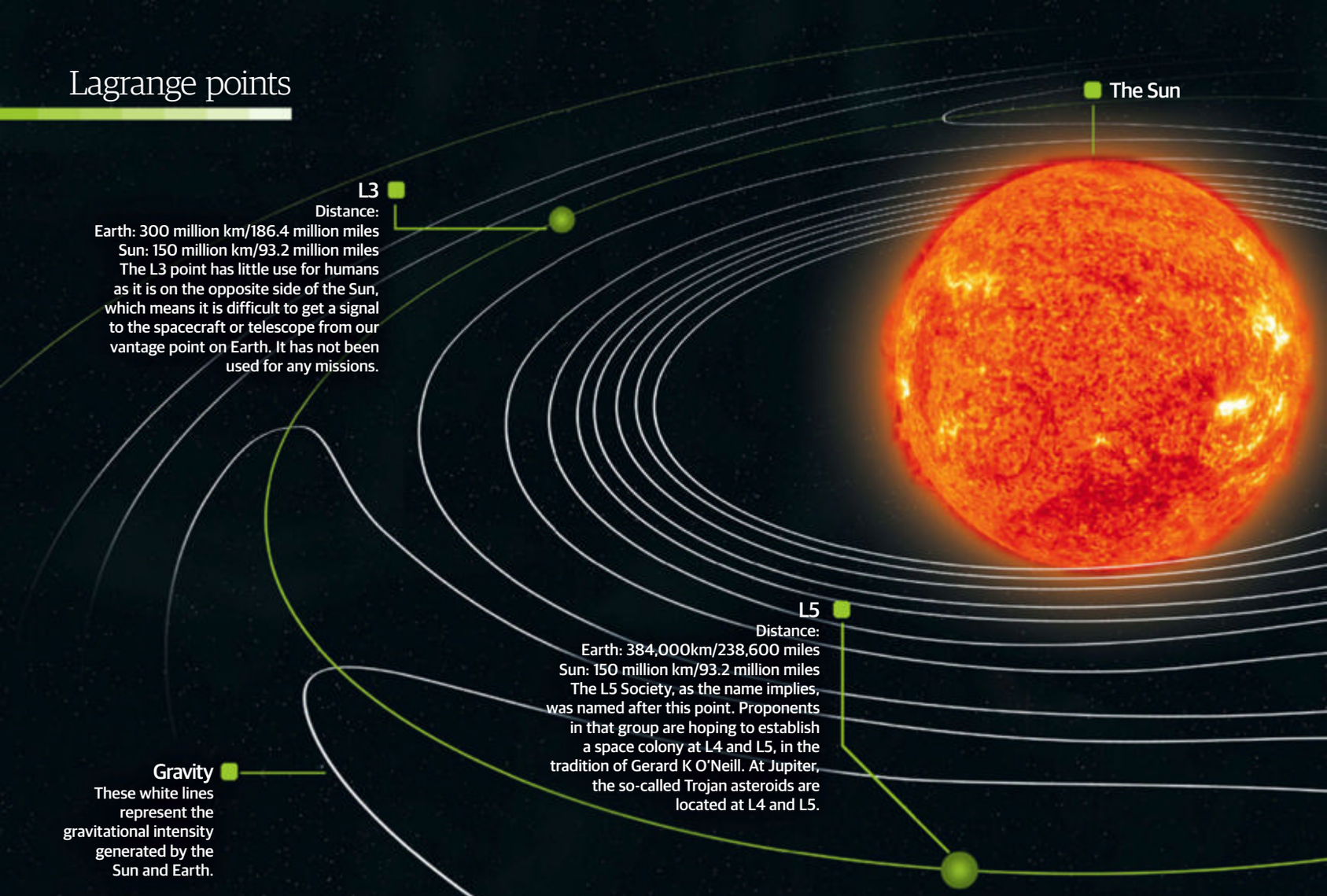


Fuselage
This consists of a Nomex honeycomb core sandwiched between carbon fibre reinforced plastic shells.

Undercarriage
The undercarriage would be sourced from an existing aircraft.

Canard
This small wing can be moved during flight to provide additional aerodynamic stability.

"The Vinci spaceplane could send a variety of payloads into orbit at a lower cost per launch than conventional rockets"



Lagrange points

Lagrange points are the spots where the gravity of two bodies – say, the Earth and the Moon – exactly balance each other out, a phenomenon that makes them very useful for research

NASA defines these areas as spots where a small body – such as a spacecraft – can stay in a consistent orbit between two very large masses, such as two planets or a planet and a large moon.

When standing above Earth and looking around, it's pretty straightforward to locate the five points. L1 is directly in front of Earth, between the Earth and the Sun. Extrapolating along the same line, L2 is behind Earth and L3 behind the Sun.

These three locations were first computed by Leonhard Euler around the 1770s, but as the name implies, the Lagrange points were actually named after French-Italian mathematician Joseph Lagrange.

A few years after Euler, Lagrange also found two other stable locations – known as L4 and L5 – at spots that are approximately 60 degrees from both the Earth and the Sun.

Space-faring nations have already sent several telescopes to Lagrange points near Earth, because they are far from interference from Earth's atmosphere and heat. Only L4 and L5 are stable locations, but with a little extra fuel a telescope can happily sit at any of the Lagrange points for years. Some of the more famous Lagrange residents include the Solar and Heliospheric Observatory (SOHO) – which keeps an eye on the Sun at L1 – and the James Webb Space Telescope, which will launch to L2 around 2018.

NASA has said that it has no real use for the L3 Lagrange point near Earth, although it has been the source of some psuedo-scientific speculation throughout recent years. "It remains hidden behind the Sun at all times," NASA wrote on its website, but added a tongue-in-cheek reference to what could be lurking there. "The idea of a hidden 'Planet-X' at the L3 point has been a popular topic in science fiction writing. The instability of Planet X's orbit (on a time scale of 150 years) didn't stop Hollywood from turning out classics like *The Man From Planet X*," the agency wrote.

While we most often think of the five Lagrange points located around the Earth, these points are possible between any celestial bodies that are massive enough. Jupiter, for example, has asteroids at its L4 and L5 points with the Sun. These are called Trojan asteroids.

German astronomer Max Wolf spotted the first of these asteroids in 1906. More than 100 years later, in 2012, NASA's Wide-field Infrared Survey Explorer revealed that these bodies are mostly burgundy in colour, and reflect little sunlight.

L4
Distance:
Earth: 384,000km/238,600 miles
Sun: 150 million km/93.2 million miles
L4 and L5 are most famous for being the sites of space colonies envisioned by American physicist Gerard K O'Neill, but so far there are no firm plans to start the colonisation. At Jupiter, the so-called Trojan asteroids are located at L4 and L5.

L1
Distance:
Earth: 1.5 million km/932,000 miles
Sun: 148.5 million km/92.3 million miles
L1 is between the Earth and the Sun, providing an ideal platform for telescopes focused on solar observations. The Solar and Heliospheric Observatory (SOHO) and International Sun-Earth Explorer 3 (ISEE-3) are among the missions who have spent time at the location.

L2
Distance:
Earth: 1.5 million km/932,000 miles
Sun: 151.5 million km/94.1 million miles
L2 is directly behind Earth, making it a relatively easy spot for spacecraft to access. Humans have already sent several space missions there as it is far from atmospheric interference from our planet, and it blocks the light of the Sun.

Spacecraft at Lagrange points

PAST PRESENT FUTURE

1. WMAP
Agency/nation: NASA
Dates: June 2001 - Oct 2010
Purpose: Studied Big Bang remnants

2. ISEE-3
Agency/nation: NASA/ESA
Dates: Aug 1978 - May 1997
Purpose: Studied Sun-Earth interaction

3. GRAIL
Agency/nation: NASA
Dates: Sept 2011 - Dec 2012
Purpose: Used L1 en route to the Moon

4. WIND
Agency/nation: NASA
Dates: Nov 1994 - Now
Purpose: Studying solar wind

5. SOHO
Agency/nation: NASA
Dates: Dec 1995 - Now
Purpose: Solar observations

6. ARTEMIS
Agency/nation: NASA
Dates: Feb 2007 - Now
Purpose: Lunar observations

7. Herschel
Agency/nation: ESA
Dates: May 2009 - Now
Purpose: Infrared observations

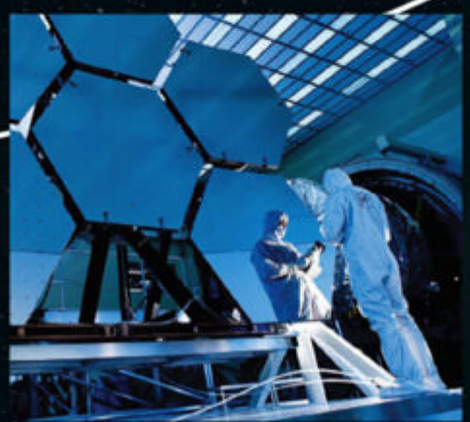
8. Gaia
Agency/nation: ESA
Dates: Sept 2013
Purpose: Catalogue stars

9. JWST
Agency/nation: NASA/ESA/CSA
Dates: 2018
Purpose: Infrared observations

10. Solar-C
Agency/nation: JAXA
Dates: 2018
Purpose: Solar observations



SOHO is a solar-observing telescope that is located at Lagrange point L1

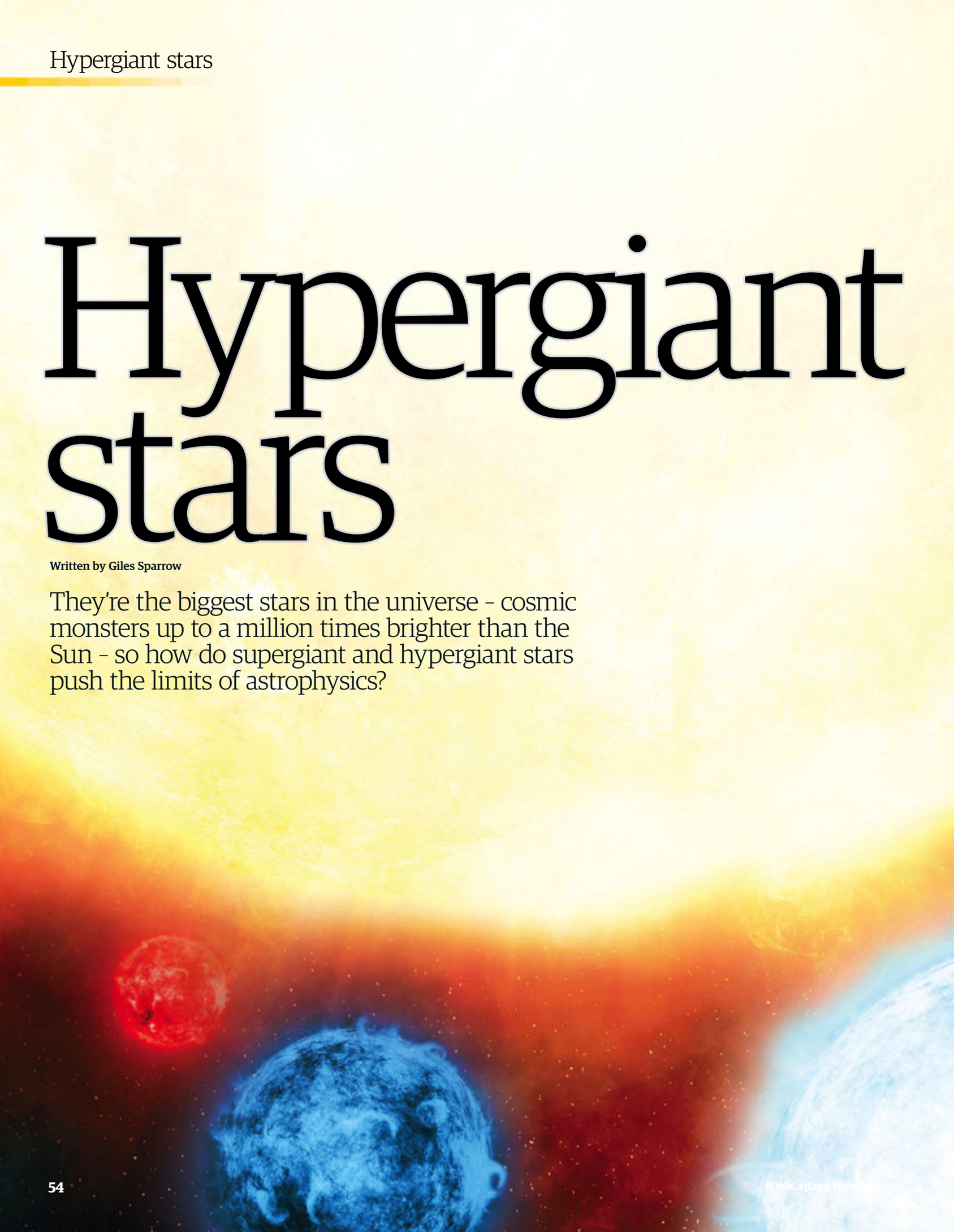


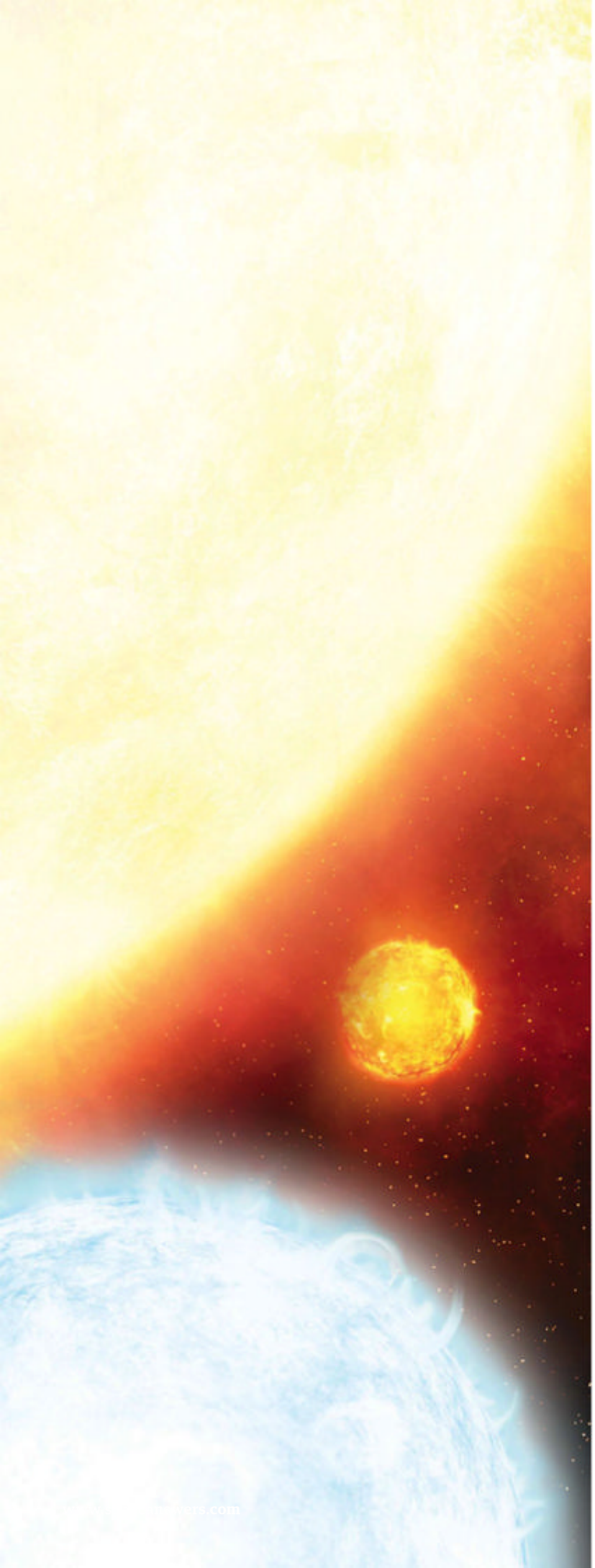
The James Webb Telescope will launch in 2018 and be located at L2

Hypergiant stars

Written by Giles Sparrow

They're the biggest stars in the universe – cosmic monsters up to a million times brighter than the Sun – so how do supergiant and hypergiant stars push the limits of astrophysics?





Look up at the sky on a dark night, and you'll see hundreds of stars. But only a few will really stand out – have you ever wondered why? For some, it's simply because they're quite close to Earth. For instance, Sirius is just 8.6 light years away – so, even though it's a fairly average star (though still 25 times more luminous than our Sun) it appears as the brightest star in our sky.

But other stars appear bright because they really are. The second brightest star in the sky, Canopus, is one such star – 310 light years from Earth and some 15,000 times more luminous than the Sun.

Stars in this class are usually known as supergiants – they have the mass of ten or more Suns, and evolve in a very different way from lower-mass 'Sun-like' stars, living fast, squandering their nuclear fuel and dying young in spectacular supernova explosions. The most massive stars of all, containing many tens or even hundreds of solar masses of material, are hypergiants, the most extreme stars known.

"In astronomy I think there's a natural tendency to be attracted to extremes," explains Professor Paul Crowther from Sheffield University. "Whether that's the most extreme by physical size, which are generally the cool red supergiants, or the most extreme by mass, which are the hottest and brightest blue hypergiants."

And Crowther should know – he's devoted much of his career to studying these stellar monsters, and in 2010 discovered the most extreme hypergiant so far, a stellar beacon 165,000 light years from Earth in the independent Large Magellanic Cloud galaxy, an incredible 9 million times more luminous and 265 times more massive than the Sun (see Interview).

Supergiants and hypergiants were first discovered through the theoretical tools of astronomy – in particular the Hertzsprung-Russell (H-R) diagram which allows astronomers to visualise the properties of stars en masse. However, the word 'giant' can be somewhat confusing, because in this case it combines concepts of mass and size. The largest stars by diameter can all be loosely defined as 'red giants' – an evolutionary phase that most stars pass through near the end of their lives, during which they swell to huge diameters (often larger than Earth's orbit around the Sun) and become far more luminous as they pump out more energy, but conversely turn red thanks to the coolness of their vast outer surfaces. The more massive a star is, the bigger it will grow as a red giant, and red supergiants with tens of solar masses (such as VY Canis Majoris, with a diameter larger than Jupiter's orbit around the Sun) are indeed the largest stars of all. However, really monstrous heavyweight stars never actually reach this stage, so while the larger a red giant is, the more massive it will be, the most massive stars of all aren't actually the largest.

The most massive stars are born at the heart of collapsing star-forming nebulas, where gas and dust are most readily available. Unlike the more sedate, Sun-like stars, which form around the edges and coalesce over many millions of years, these stellar heavyweights grow to their enormous proportions in just a hundred thousand years. The overall amount of raw material in the nebula (reflected in the size of the star cluster that emerges from it) also has a role to play.

"There seems to be a broad relationship between the total mass of a cluster, and the most massive star within it – so for instance the Orion Nebula has a mass of 1,000 Suns, and its most massive stars are about 30 times that of the Sun, while the NGC 3603 cluster has about 10,000 solar masses of material, and its most massive stars weigh around 100 solar masses. We don't know quite why this 'mass function' is the way it is in young star clusters, but it seems to be a universal rule," says Crowther

Competition between the massive central stars seems to act as a throttle to the formation process, ensuring that really massive stars are increasingly rare. "The next obvious question is whether if you had an even more massive cluster, would the mass of its biggest star keep going higher?" says Crowther. "And the answer seems to be no – we suspect there's a limit and it's linked to the star formation process. A star forms in a collapsing nebula full of competing stellar 'seeds', and it has a limited time to grab as much material as it can, or else its neighbours will. It's a bit like throwing a handful of sweets into a crowd of children – the ones nearest the centre will grab most of them really quickly, while those at the edges hardly get any. It's a competitive environment, and that probably puts an upper limit on how massive a star can get."

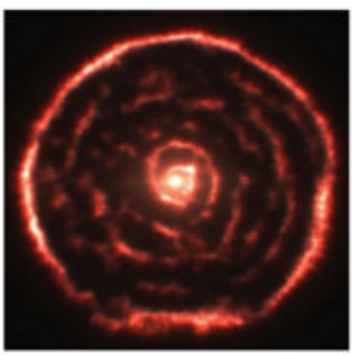
Another major difference between normal and monster stars lies in the nuclear reactions that keep them shining. In low-mass stars, these reactions are dominated by the 'proton-proton (p-p) chain', a process in which individual hydrogen nuclei

fuse together one reaction at a time, to eventually produce nuclei of helium, the next heaviest element. The p-p chain releases small amounts of energy at every step, but proceeds relatively slowly allowing Sun-like stars to keep shining for billions of years.

In more massive stars, however, another process called the CNO cycle becomes important. This fusion chain also converts hydrogen nuclei into helium, but it uses carbon nuclei as a sort of 'catalyst', allowing the reactions to happen at a much faster rate. The CNO cycle becomes increasingly dominant at higher temperatures and densities, and causes heavyweight stars to shine many thousands of times more brightly than their less massive neighbours. But the price for this brilliance is a drastically shortened life span – even though their cores contain much more nuclear fuel than those of Sun-like stars, massive stars exhaust themselves in just a few million years and begin to swell into supergiants or hypergiants.

This short life span means that supergiants are almost always found at the heart of newborn star clusters – these clusters disintegrate over millions of years, eventually scattering their longer-lived stars over a broad region of space, but supergiants simply don't live long enough to make it out of their stellar nurseries.

"These stars are incredibly rare – they only form in a few places and have very short lifetimes, so even if you find a star cluster that's just 5 million years old, its most massive stars will already have died," says Crowther. "There's only a handful of really young, massive clusters close enough to Earth for us to look for these guys and they're losing mass at a terrific rate, so the mass we measure depends on just how old the stars happen to be. The places where you usually find these really massive clusters tend to have enhanced star



This image shows a spiral structure in the material around the R Sculptoris star

The size of stars

Our Sun
Type: Yellow dwarf
Solar Radii: 1

Arcturus
Type: Orange giant
Solar Radii: 25.7

Sirius A
Type: White main sequence
Solar Radii: 1.711

Pollux
Type: Orange giant
Solar Radii: 8.8

Antares
Type: Red supergiant
Solar Radii: 883

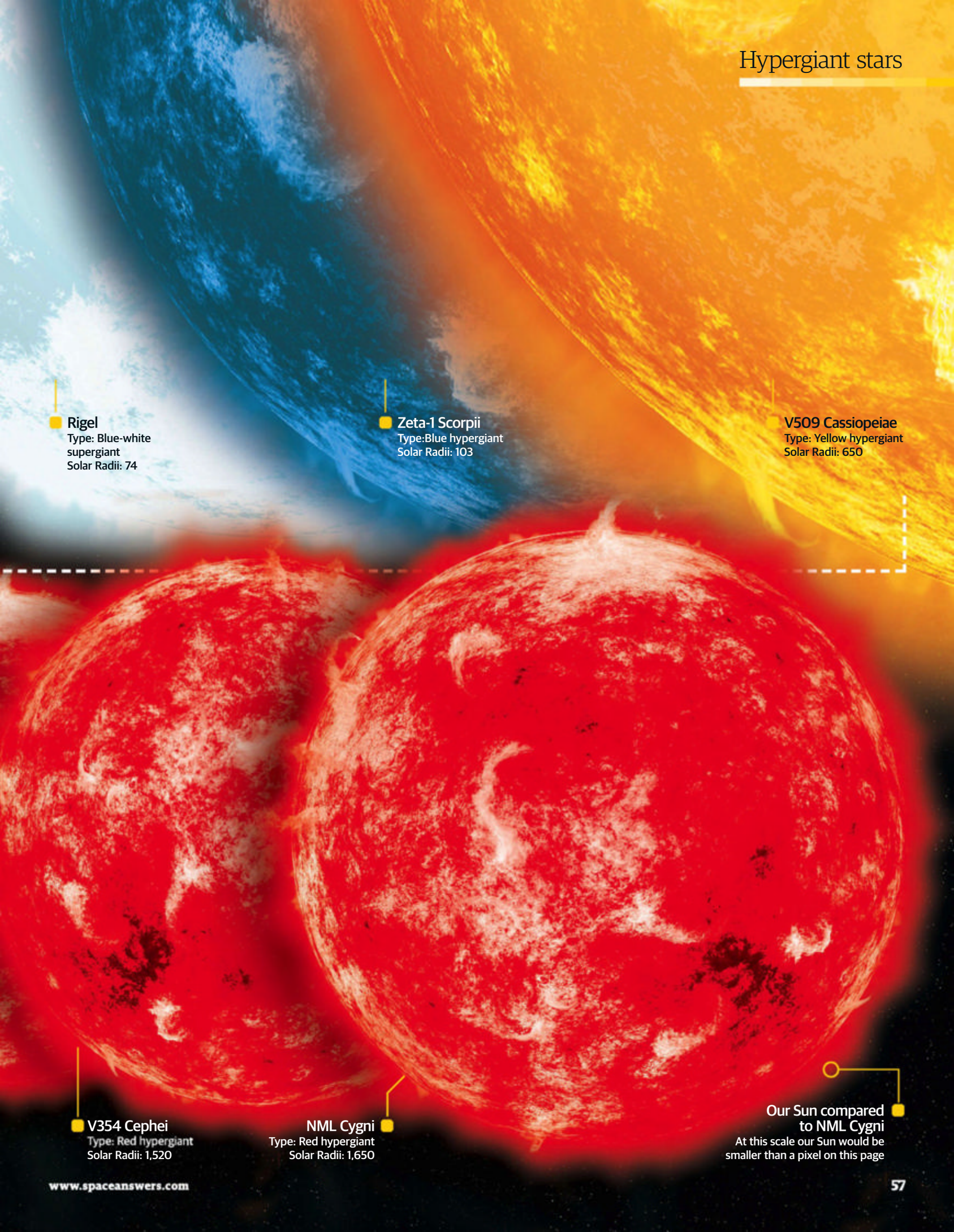
Betelgeuse
Type: Red Supergiant
Solar Radii: 1,075

V509 Cassiopeiae

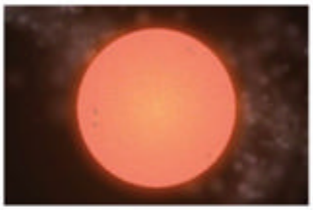
VV Cephei
Type: Red supergiant
Solar Radii: 1,050

VY Canis Majoris
Type: Red hypergiant
Solar Radii: 1,420

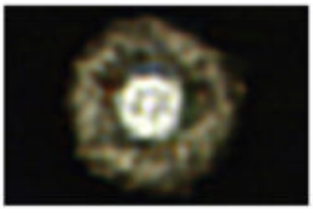
"Supergiants simply don't live long enough to make it out of their stellar nurseries"


Rigel
Type: Blue-white supergiant
Solar Radii: 74
Zeta-1 Scorpii
Type:Blue hypergiant
Solar Radii: 103
V509 Cassiopeiae
Type: Yellow hypergiant
Solar Radii: 650
V354 Cephei
Type: Red hypergiant
Solar Radii: 1,520
NML Cygni
Type: Red hypergiant
Solar Radii: 1,650
Our Sun compared to NML Cygni
At this scale our Sun would be smaller than a pixel on this page

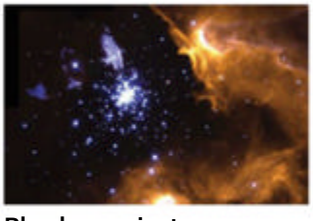
Types of giant stars



Red supergiant
The biggest red giants are the largest stars in the universe, swollen to diameters of a billion kilometres or more by changes in their cores as they near the end of their lives. As they swell in size and brighten to hundreds of thousands of times solar luminosity, their surfaces cool to a distinctive red colour. But many scientists say these stars are supergiants rather than true hypergiants.



Yellow supergiant
Yellow supergiants seem to be a rare intermediate stage, though again they get their name from their size and brightness rather than their mass. They seem to be red supergiants that have shed large amounts of their outer gas as they head towards a supernova explosion. In this photo of the 'Fried Egg Nebula', rings of ejected material can be seen surrounding the central star.



Blue hypergiant
Blue hypergiants are the real heavyweights of the universe – tens or even hundreds of times more massive than the Sun, and millions of times more luminous. Their powerful gravity limits their size, so their surfaces are intensely hot. The young star cluster NGC 3603, shown here, contains one binary system whose stars contain a staggering 90 and 120 solar masses of material.

formation rates, usually due to galactic collisions or interactions."

So what do supergiants and hypergiants look like? The truth is that they're surprisingly varied – while the H-R diagram might suggest that they'd all have extremely hot surfaces and appear blue in colour, in reality they range across the spectrum of colours. Supergiants show the most variety, and it seems that their colours simply reflect the precise balance between the inward pull of gravity and the outward pressure generated by its radiation at a particular phase in their lives. This balancing act, known as 'hydrostatic equilibrium' governs a star's overall diameter and therefore its surface area: even highly luminous stars can display Sun-like yellow, or even cooler red surfaces if they are large enough for the heating effect of their escaping radiation to be thinly spread.

Most stars retain more or less the same mass throughout their lives, and therefore maintain the same gravity, so their equilibrium is mostly affected by changes to their luminosity as the nuclear reactions in their cores change and evolve – from this, we can work out that blue supergiants are still close to the 'main sequence' of stellar evolution, while yellow ones have begun to swell in size as they reach

> "The borderland between supergiants and hypergiants is filled with unusual stars"

the end of their lives. Red supergiants are even further along their life cycle, and are the largest stars of all.

But for really massive hypergiant stars, there's a different story. These stars never make it across to the red side of the H-R diagram – instead their brilliant radiation generates such huge pressure that it blows their outer layers away into space, exposing the interior and ensuring that such stars remain hot, maintaining blue or white-hot surfaces throughout their lives. This strong outflow of hydrogen-rich material gives itself away in a hypergiant's spectrum and is one of the key means of distinguishing them from really bright supergiants.

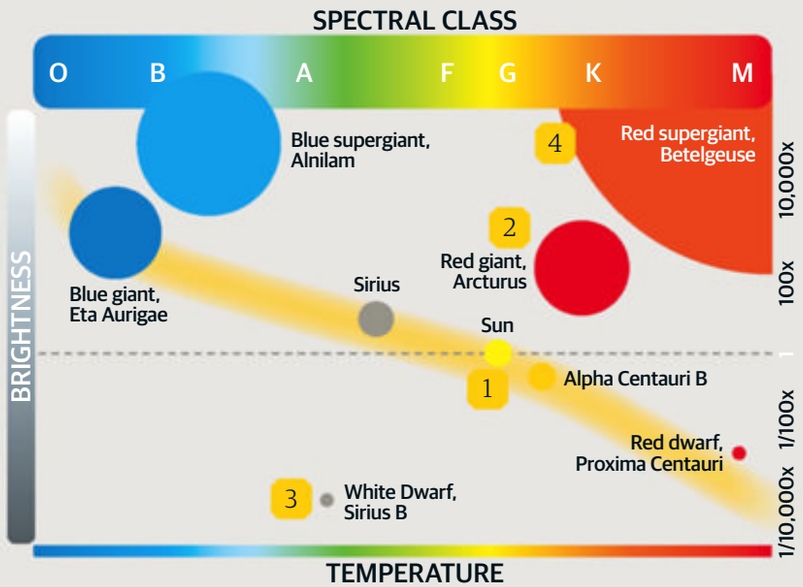
The borderland between supergiants and hypergiants is filled with a strange variety of unusual stars, and no two astronomers really agree on the precise dividing lines between them. For example, luminous blue variables are extremely bright stars that show long, slow changes in brightness with occasional outbursts, and include both supergiant and hypergiant stars. Most of the rare so-called 'yellow hypergiants', despite their name, actually seem to be red supergiants that are shedding their outer layers and heating up. And, as we've seen, astronomers also differ about whether red hypergiants even exist! Depending on their features displayed in their light, other categories of supergiant or hypergiant bear exotic names such as Wolf-Rayet stars and Ofpe stars.

However, until recently, the only certain means of weighing really massive stars, and identifying supergiants and hypergiants, was to pick them out in binary systems. Here, the orbital motions of the two stars can be used to calculate their masses. Fortunately, a recent breakthrough in modelling the behaviour of really high-mass stars promises to remove some of these limitations (see Interview).

Supergiant and hypergiant stars live fast and die young, but what fate awaits them at the end of their lives? Once a star has exhausted the hydrogen fuel in its core, it has reached the end of its main sequence lifetime

Star classification

One of the most useful tools for classifying stars is the Hertzsprung-Russell (H-R) diagram. It plots stars according to their surface temperature and colour or 'spectral type' (on the horizontal axis) and their luminosity (on the vertical axis). When a large number of randomly selected stars are plotted, a pattern soon emerges: most stars are arranged along a diagonal ribbon known as the 'main sequence', that runs between the faint, cool and red and the bright, hot and blue. Luminous cool stars and faint hot ones ('red giants' and 'white dwarfs') occupy regions to either side of the main sequence and are comparatively rare.



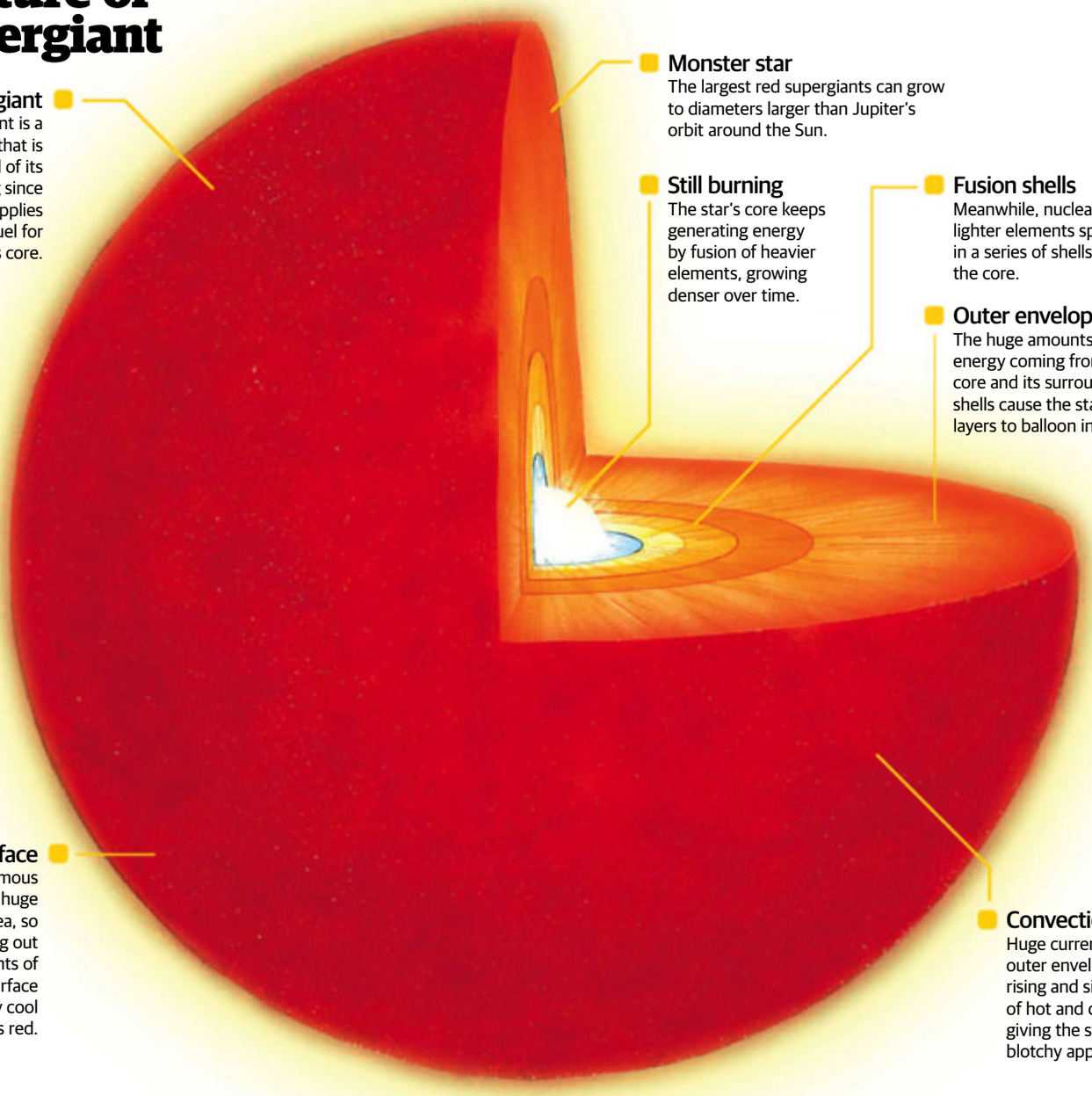
1. Main sequence
This is the region where stars spend the majority of their lives – a star's position on the main sequence is largely determined by its mass.

2. Red giants
Most stars pass through this phase near the end of their lives, brightening and developing an atmosphere with a cool surface.

3. White dwarfs
These hot stars are faint because of their tiny size – they are the burnt-out, slowly cooling cores of stars like our own Sun.

4. Supergiants
These high-mass stars are brilliantly luminous and display a variety of colours as they move back and forth across the H-R diagram.

Structure of a supergiant



Red supergiant
A red supergiant is a high-mass star that is nearing the end of its life and has long since exhausted the supplies of hydrogen fuel for fusion in its core.

Monster star
The largest red supergiants can grow to diameters larger than Jupiter's orbit around the Sun.

Still burning
The star's core keeps generating energy by fusion of heavier elements, growing denser over time.

Fusion shells
Meanwhile, nuclear fusion of lighter elements spreads out in a series of shells around the core.

Outer envelope
The huge amounts of energy coming from the core and its surrounding shells cause the star's upper layers to balloon in size.

Cool surface
The star's enormous size gives it a huge surface area, so despite pumping out huge amounts of energy, the surface remains relatively cool and appears red.

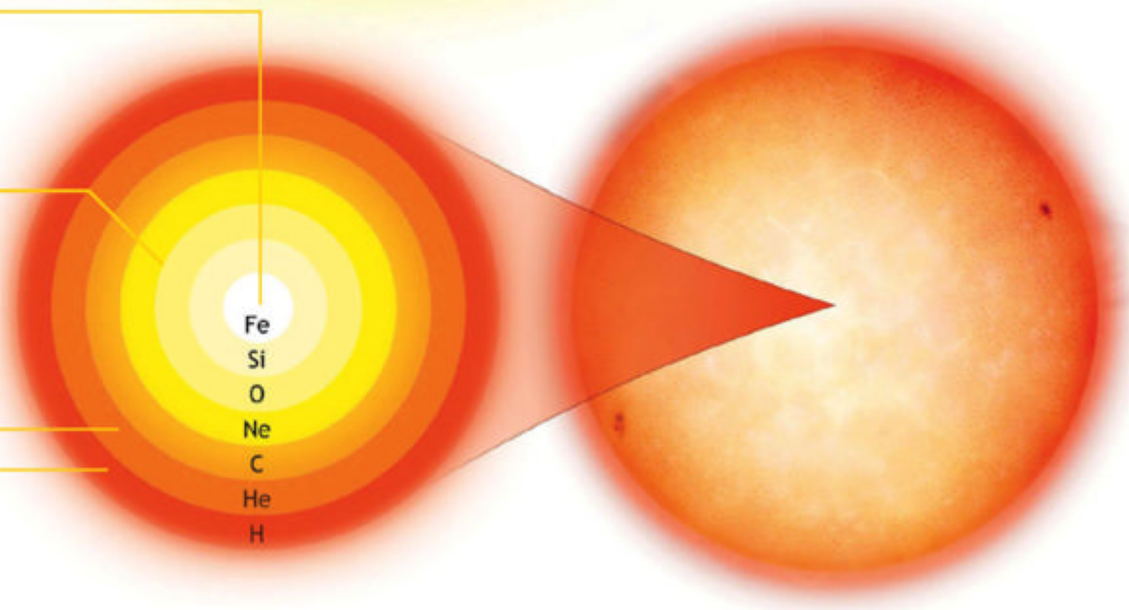
Convection cells
Huge currents within the outer envelope create rising and sinking masses of hot and cool gas, often giving the star's surface a blotchy appearance.

Iron core
Just before the star dies, a core of solid iron begins to build up. Unlike the lighter elements, iron fusion absorbs, rather than releases energy, triggering the core's collapse and a supernova explosion.

Heavier shells
Closer to the core, heavy elements continue to fuse into still heavier ones, allowing the supergiant to keep shining.

Helium fusion
A second shell of helium fusion follows the hydrogen shell out into the star, creating heavy elements such as carbon and oxygen.

Hydrogen fusion shell
Changes in the star's density and temperature allow hydrogen fusion to continue in an expanding shell around the core after hydrogen in the very centre has been exhausted.



and can only continue to shine by burning hydrogen from the shell surrounding the core, and heavier elements in the core itself. These processes cause the dying star to brighten and swell, shifting it towards 'red supergiant' territory, while its core develops a complex layered structure of increasingly heavy elements. Each new phase of fusion produces less energy than the previous one, and is exhausted more quickly, but the radiation that continues to pour from the core still helps to support it against its own enormous gravity.

That all changes when the star attempts to fuse iron – the first element whose fusion absorbs energy. Abruptly, the star's power supply falters and dies, and the huge weight of its outer layers comes crashing down. In what is known as a 'core-collapse supernova', the iron-rich core is compressed to a tiny size, while a tremendous shockwave rebounds through the remainder of the star, heating and compressing it until the whole star ignites in a blaze of nuclear fusion that may last for months and outshine a billion stars. As the supernova fades and the debris clears, the compressed remains of the core may be revealed as a super-dense neutron star, or even a black hole.

But, for the most massive stars of all, there may be a third option. "Theorists tell us that if a star dies with roughly 200 solar masses of material remaining, it could just blow up – it wouldn't be the usual core-collapse event, but a 'pair-instability supernova', which would blow itself to bits before it could form a super-dense core. These things would be amazingly bright and there have been a few observations of events that might be this kind of 'superluminous supernova'."

So, while they may be rare, these monster stars are certainly making their presence felt – and interest is only likely to increase in the next few years. Astronomers believe that supergiants and hypergiants would have been far more widespread in the early universe, when the lack of heavy elements would have given them a more compact structure with a hotter surface. Thanks to the expansion of the universe, the ultraviolet radiation that poured from the surface of these superhot stars should now be stretched or 'Doppler-shifted' to infrared wavelengths. Here it should be visible to NASA's James Webb Space Telescope when it launches in 2018 to give us our first view of the earliest stellar generations. ■

Hypergiants in our galaxy



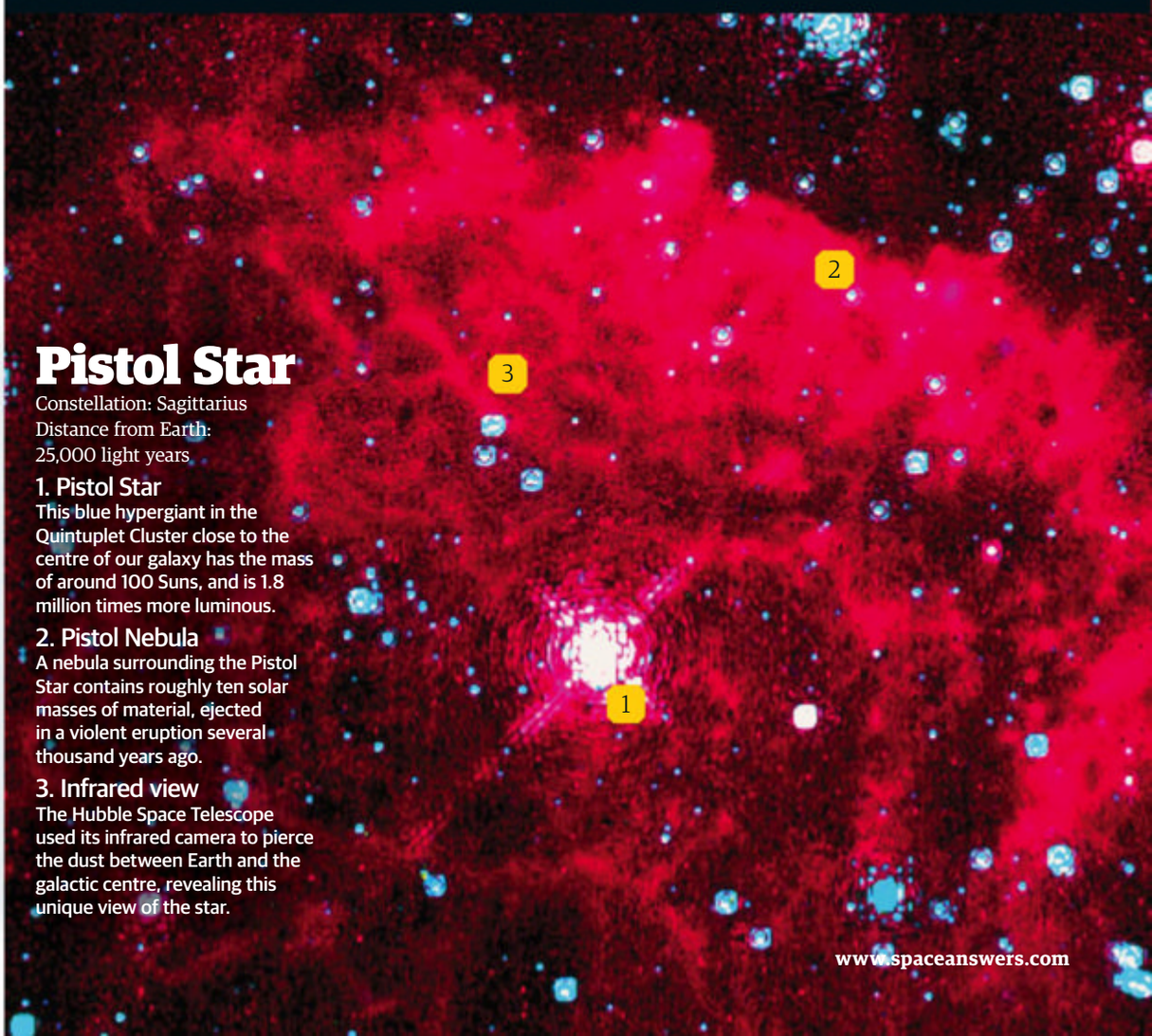
Eta Carinae

Constellation: Carina
Distance from Earth:
7,500-8,000 light years

1. Massive binary
The hypergiant Eta Carinae in the southern constellation of Carina is a binary system in which one star has at least 120 times the mass of the Sun, and is 5 million times more luminous.

2. Violent outbursts
Eta Carinae is prone to sudden eruptions that cause it to brighten unpredictably as it hurtles towards an eventual death as a supernova.

3. Homunculus Nebula
The star is still surrounded by this famous double-lobed nebula, ejected during its last major eruption around 1843.



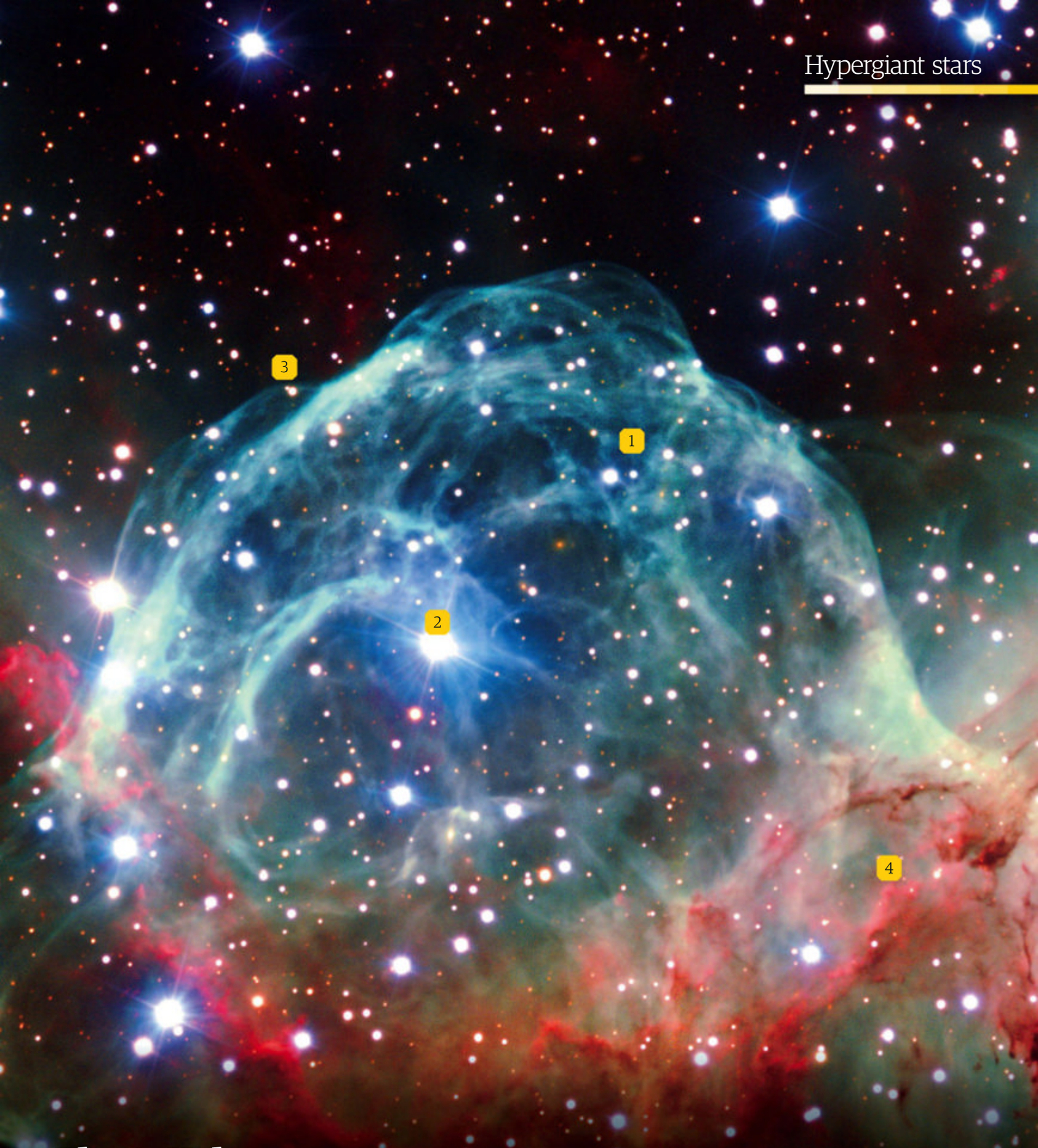
Pistol Star

Constellation: Sagittarius
Distance from Earth:
25,000 light years

1. Pistol Star
This blue hypergiant in the Quintuplet Cluster close to the centre of our galaxy has the mass of around 100 Suns, and is 1.8 million times more luminous.

2. Pistol Nebula
A nebula surrounding the Pistol Star contains roughly ten solar masses of material, ejected in a violent eruption several thousand years ago.

3. Infrared view
The Hubble Space Telescope used its infrared camera to pierce the dust between Earth and the galactic centre, revealing this unique view of the star.



Thor's Helmet

Constellation: Canis Major Distance from Earth: 15,000 light years

1. Thor's Helmet
This distinctive nebula, which is catalogued as NGC 2359, lies 15,000 light years from Earth in the constellation of Canis Major.

2. Wolf-Rayet star
The central star is a blue supergiant with a powerful stellar wind blowing material away off its surface – an object known as a Wolf-Rayet star.

3. Gas shell
As wind from the star collides with the nearby interstellar medium, it is heated and excited to release energy through light, creating a glowing gas bubble.

4. Swept wings
Collisions with interstellar material as the star travels through space create the nebula's distinctive helmet-like wings.



R136a1 was discovered in the massive, young star cluster R136, which resides in the 30 Doradus Nebula, a turbulent star-birth region in the Large Magellanic Cloud galaxy



Searching for monster stars

In 2010, Professor Paul Crowther and his team discovered the most massive known single star, R136a1

Can we start by asking what first drew your attention to the R136 star cluster?
Well, it's probably the prime target for anyone looking for the most massive stars – it's the most obvious place to look really because it's the most massive young star cluster in our part of the universe. It's about the same size as the famous Orion Nebula, but while that's got a couple of thousand stars, R136 probably contains 100,000 stars or more, if you could see them all. It's been known about for a long time, but the exciting thing is that now, with Hubble and large ground-based telescopes, we can resolve separate stars and look at them individually.

As I understand it, there's a really tight knot of stars at the cluster's centre, called R136a?
Yes – and originally there were claims that R136a was a single supermassive star thousands of times more massive than the Sun. But about 25 years ago astronomers confirmed that it was actually a cluster and now, thanks to technological advances, we can finally analyse the individual stars within it. When our team looked at it with the European Southern Observatory's Very Large Telescope in Chile, we were actually looking for binary stars, hoping we could use them to measure the masses of stars directly. We didn't find any binaries, but we did find that the individual stars in the cluster, and the brightest one in particular, are far more exceptional than anyone had thought.

So a binary system would have let you measure the mass of its stars directly – but how do you work out the mass of a giant single star like R136a1?
The first thing you do is work out the star's luminosity, but that's a problem in itself. If you're looking at a yellow star with the same surface temperature as the Sun, then it's fairly straightforward – you're seeing most of the radiation in the optical and can work out the total energy output quite easily. Red stars such as cool supergiants emit only a tiny fraction of their energy as visible light, but you can still measure them in the infrared, where most of the energy is coming out. The challenge with hot stars like R136a1 is that the energy's coming out in the ultraviolet, at wavelengths that get soaked up by the interstellar medium on their way to Earth. We can't measure the star's peak energy directly, so we have to infer it in other ways, through other features of its light.

But even once you've got an idea of the star's temperature and its overall luminosity, you still have to go an extra leg to get a mass. Fortunately on the main sequence there's a clean relationship – the more luminous a star, the more massive it is. So for R136a1, where we came up with a luminosity not far off 10 million times that of the Sun, we asked our colleagues to work out evolutionary models for what the expected mass would be. That's how we arrived at the figure of 265 solar masses, and the star probably started its life even bigger.

And is there any way to check that theoretical result?
Well, the problem is that you're relying on one method to get a temperature, used to resolve separate stars another to get a mass, and so on. For me as a sceptical scientist, that's all a bit dubious – the figures are an interesting possibility, but not really backed up by enough evidence to prove it.

So what we did was go looking for another example of a similar star to prove the technique. Ideally we were looking for a star in a close eclipsing binary system [where the two stars regularly pass in front of each other as seen from Earth], which would let us work out the mass independently. We eventually found just such an object in a cluster called NGC 3603, about 25,000 light years from Earth. That's now the most massive star system to be confirmed through the laws of orbital motion – it's got two stars in an orbit of about four days, with masses of 120 and 90 Suns. Once we'd got those robust numbers for that system, we used them to test our temperature and luminosity-based method, and we got basically the right answer. So that was a sanity check – if it works for that object, there's no reason why the method, and the final result, shouldn't be correct for R136a1.

"R136a1 probably started its life even bigger than its current 265 solar masses"

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Helix Nebula

A dying star unleashes its last breath captured by this fantastic image

Found around 650 light years away in the constellation of Aquarius, the Helix Nebula (also known as NGC 7293) is a stunning example of a planetary nebula. Don't be fooled by the name, though; planetary nebulas are actually the remains of stars that were once similar to our Sun.

When stars like these run out of hydrogen and helium fuel for their fusion reaction, just as the Sun radiates light and heat into the Solar System, the outer layers of the star are thrown off and all that is left is an extremely hot and dense core known as a white dwarf. These stars are about the size of Earth but have almost the same mass as the original star. Intense ultraviolet radiation from the white dwarf heats up the expelled gas, shining brightly in infrared wavelengths. The odd shape of the Helix Nebula, with two sides of the structure apparently flattened, is due to the gas colliding with the interstellar medium.

If the original star had any planets, comets or otherwise, these would also have been thrown about by the resultant expansion of the star's layers, similar to what will happen to our Solar System when our Sun runs out of fuel in around 5 billion years. The inner planets would have been destroyed, while the outer gas planets and icy bodies may have collided and added to the cosmic dust storm.

The Helix Nebula, which is believed to be about 11,000 years old and 2.5 light years across, also contains something called 'cometary knots', which are areas of nebulosity (relatively concentrated dust and gas) in the main ring. They are described as cometary because they radiate tails away from the centre of the nebula, however, their size is anything but cometary; each knot is thought to be about the size of our Solar System, excluding their tails. More than 20,000 of these knots are estimated to be in the Helix Nebula.



The story of Hayabusa

Written by Jonathan O'Callaghan

How this spacecraft overcame all the odds to return the first asteroid samples to Earth and inspire a nation to invest in space

In the early-2000s, Japan was one of the largest economies in the world not to have a dedicated space agency, lagging behind even its fierce rival China. Despite a variety of missions in the 20th Century, the space industry in Japan was something that was yet to receive much public interest.

Unlike Russia and the United States, Japan's space programme had until 2003 been limited to a variety of demonstrations and experiments in space that did little to enthuse any real interest in the country's under-funded cosmic exploits.

But when Japan announced in 2002 that it would attempt to become the first nation to return a sample from the surface of an asteroid, the public was instantly hooked. Here was something they could be genuinely excited about, something that would put Japan firmly on the radar in the space industry.

The revolutionary spacecraft for this mission would be called Hayabusa (originally MUSES-C), and aside from landing on an asteroid it would perform key tests on ion drives that would be a necessity for any nation hoping to launch a future deep space mission using ion engines. In fact, this was the primary objective of Hayabusa; the sample return from an asteroid was merely a useful way to test out the technology, but it became much more than that throughout the course of the mission.

From the initial target launch date to the return home seven years later, however, this would be a mission dogged by problems. But where other nations might see failure, the Japanese instead saw Hayabusa as the inspiring team effort the nation's space programme needed to ensnare the public in a cosmic grip like never before. Just as Apollo 13 sparked national pride in the USA, so too would Hayabusa prove to be Japan's pivotal moment in its long overlooked space industry.

Hayabusa (which translates as 'peregrine falcon') was scheduled to launch in July 2002 to either of the asteroids 4660 Nereus or (10302) 1989 ML, but the failure of a Japanese rocket pushed the launch back to May 2003 and the target was changed to the asteroid 25143 Itokawa. Five months after the launch in October 2003, Japan's three separate space agencies merged into a single one: the Japanese Aerospace Exploration Agency (JAXA). The country now had a dedicated space agency. All it needed next was a successful mission.

On 9 May 2003, Hayabusa lifted off from what is now known as the Uchinoura Space Center in Japan. Four xenon ion engines would take the spacecraft on a two-and-a-half year journey to the vicinity of Itokawa in June 2005. Hayabusa would remain in a heliocentric orbit (one around the Sun), similar to Itokawa's, in order to approach the asteroid relatively slowly. But just several months after launching, disaster struck.

The Sun, with unfortunate timing, unleashed a huge solar flare that bathed Hayabusa in solar radiation, crippling the cells on its solar panels. Engineers at JAXA frantically sought a solution to the early setback, and they eventually found a way to operate the ion engines on limited power. Hayabusa's rendezvous with Itokawa would have to be delayed from June to September in 2005 as the spacecraft could only limp towards its target.

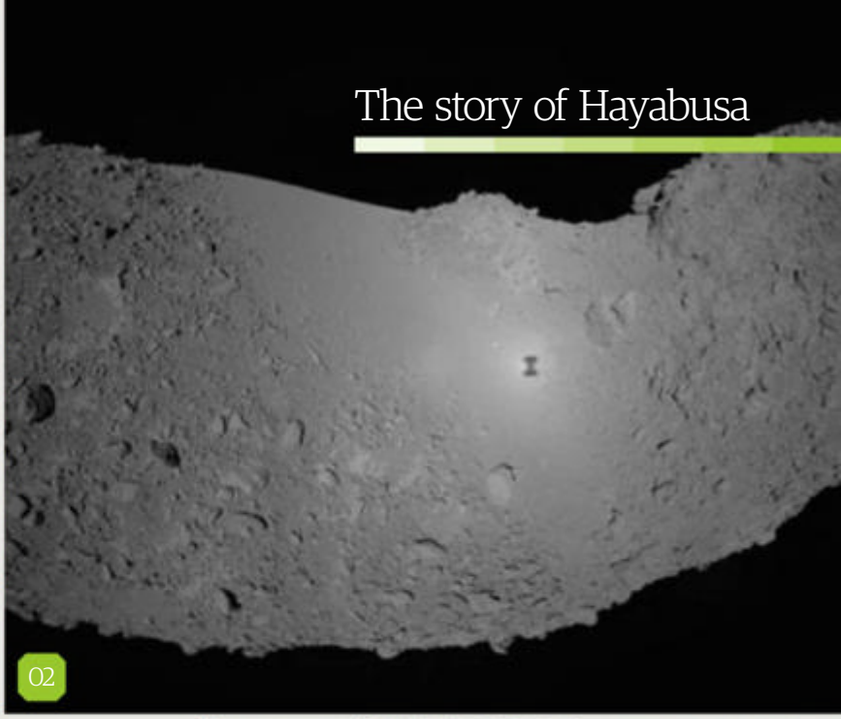
By the time Hayabusa was settled in position near Itokawa in late 2005, maintaining a distance of 20 kilometres (12.4 miles) from the asteroid, it was looking worse for wear. Not only were its ion engines subdued, but it had also lost functionality in two of its three reaction wheels that allowed the spacecraft to rotate in the X and Y-axis. Through a clever workaround, engineers were able to use the one remaining reaction wheel and two chemical thrusters to maintain attitude control (orientation).

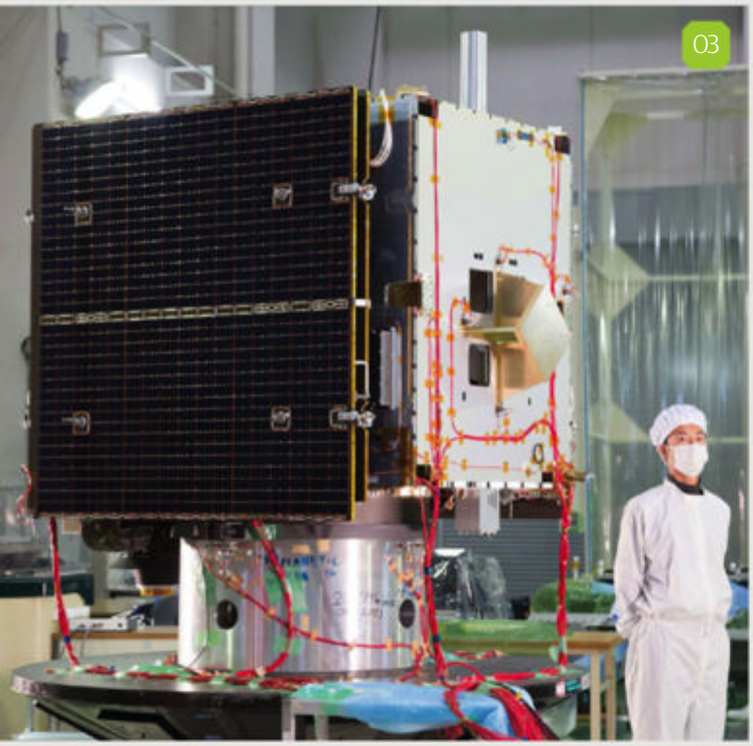
Now, thankfully, the true science of the mission could begin. Hayabusa began surveying Itokawa, mapping the surface and analysing the characteristics of the asteroid. Itokawa is an S-type ellipsoid asteroid that is roughly 630 metres (2,070 feet) long and 250 metres (820 feet) wide. It has a fragmented appearance that suggests it may have formed when two smaller asteroids stuck together, but a lack of impact craters on its surface, which itself is rough and covered in boulders, suggests that several smaller asteroids rather than just two may have coalesced into a 'rubble pile'. Itokawa's elliptical 556-day orbit around the Sun takes it from outside the orbital plane of Mars to within Earth's.

On 4 November 2005, Hayabusa moved closer to Itokawa and attempted a rehearsal touchdown, but an anomalous signal at an altitude of 700 metres (2,300 feet) sent it scampering back to safety. A second practice landing was attempted on 12 November, but this would prove even more disastrous. Hayabusa carried with it a small lander called Minerva,

The story of Hayabusa


01


02


03

1. Capsule
The sample capsule was successfully retrieved from the Woomera Prohibited Area in south Australia in June 2010.

2. Shadow
Hayabusa's shadow can be seen here on the asteroid Itokawa in an image taken by the spacecraft.

3. Assembly
Hayabusa was assembled in a clean room before it launched on its way to Itokawa.

4. Dust
Hayabusa specialists get ready to open the sample container and examine its contents.

5. Sample
The capsule had to be carefully retrieved so that the sample inside was not contaminated.

6. Study
Two scientists at the German Aerospace Center study asteroid dust collected by Hayabusa, one of several samples sent out for study.


04


05


06

weighing just over half a kilogram and measuring ten centimetres (3.9 inches) in height and 12 centimetres (4.7 inches) in width. The tiny solar-powered vehicle was designed to take advantage of Itokawa's low gravity and 'hop' across the surface, relaying images to Hayabusa.

However, Hayabusa's distance from Earth meant that it could take upwards of 40 minutes to communicate with the spacecraft, meaning that a lot of its tasks were carried out autonomously. It was creeping towards the asteroid at just three centimetres (1.18 inches) per second, and an order was given to release Minerva when Hayabusa was just 55 metres (180 feet) above the surface of Itokawa, close enough for the asteroid to grab hold of the tiny space hopper. When the signal was sent, however, Hayabusa had already reached the 55-metre mark and had begun its ascent from the asteroid back to its 'parking' distance. When the signal arrived, Hayabusa released Minerva at much too high an altitude. Unable to move itself closer to the asteroid and therefore be grabbed by its gravity, Minerva drifted off into space, never to be heard from again.

It was yet another setback for the now seemingly ill-fated Hayabusa, which had encountered problem after problem, but JAXA pushed ahead. A week later they attempted to land for real. On 19 November, Hayabusa began its descent towards Itokawa at 12 centimetres (4.7 inches) per second, releasing a target marker (containing 880,000 autographs) at an altitude of 40 metres (130 feet) to track its descent to the surface. Hayabusa inched towards the surface until, 17 metres (56 feet) up, the unthinkable happened: contact was lost.

It's not clear what happened next. It's thought that it 'bounced' twice off the surface before actually landing on the asteroid. This was something it wasn't quite supposed to do; instead, it should have fired two bullets into the ground while hovering above Itokawa, which would have kicked dust up into its sample collector, but these failed to deploy. After half an hour Hayabusa left the surface, and in doing so inadvertently carried out the only controlled landing and ascent from any other Solar System body, except the Moon, to date.

On 25 November, it reached the surface again, but it's not clear if the bullets worked here either. However, just by hovering and touching the surface engineers were convinced that dust from the asteroid would have been kicked up into the sample collector, and they made the decision to return home. They would not know until the sample capsule was retrieved on Earth whether Hayabusa had been successful or not in collecting a sample, but it was a risk they would have to take.

Things went from bad to worse on 9 December. A thruster leak altered the direction that Hayabusa's antenna was pointing, and JAXA lost all communications with the spacecraft. After a month having to face the possibility that their pioneering spacecraft might be lost in space, contact was made again in late January 2006. It would be a year until the journey home began.

That fuel leak had caused another problem, though. The chemical thrusters, which had been used to orientate the spacecraft, were now no longer useable. Hayabusa needed to be able to move in three axes to make it home. The one remaining reaction wheel controlled the yaw, while the ion engines could be slightly tilted to alter the pitch, but the spacecraft was unable to roll. Ingeniously, JAXA engineers discovered they could utilise the Sun's photon pressure on the solar panels. It was a tiny force, but it was enough to roll the spacecraft.

With just two of its four ion engines operational, Hayabusa soldiered home on a journey that lasted over three years, starting in February 2007. With the engines' functionality continually fluctuating, Hayabusa finally made it back to Earth in June 2010 and, on 13 June, it re-entered our atmosphere. The main spacecraft burned up as planned, while the sample capsule separated and parachuted safely to Earth in south Australia.

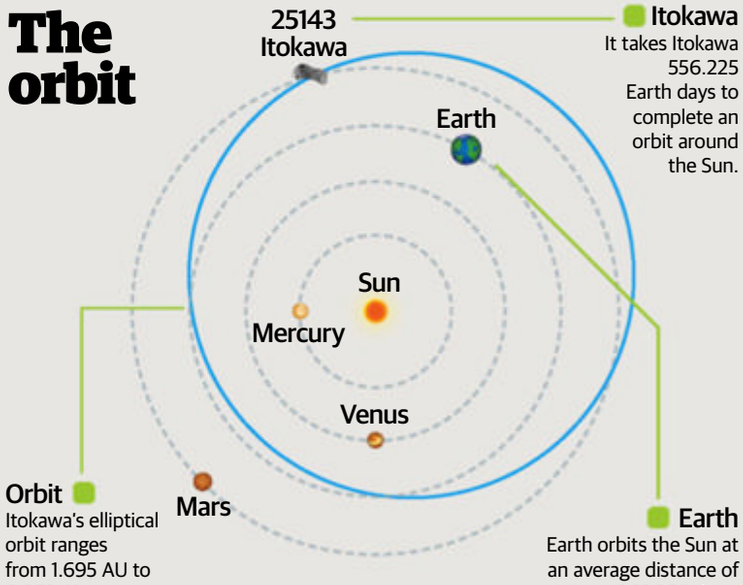
The sample it carried weighed less than a gram, with barely 100 particles each smaller than 0.001 millimetres present, but it wasn't known if they originated from Itokawa or not. Then, on 16 November 2010, the news JAXA had been hoping to hear for almost a decade arrived: the particles were from the surface of Itokawa. Japan had become the first nation to return a sample from the surface of an asteroid, thanks to a little spacecraft and a dedicated team. Now, work is underway on a successor, tentatively named Hayabusa 2, which will have advanced capabilities and return more samples from an asteroid that is yet to be chosen. Despite the ultimate success of Hayabusa, JAXA could be forgiven for hoping that Hayabusa 2 goes a little more smoothly. ■



Yoshiyuki Hasegawa, associate executive director of JAXA, briefs media ahead of the re-entry of Hayabusa in 2010

"Hayabusa 'bounced' twice off the surface before coming to rest on the asteroid"

The orbit



Mission timeline



Hayabusa's shadow seen on Itokawa

1. Launch
Hayabusa launched on its mission towards Itokawa on 9 May 2003.





2. Approach
The spacecraft arrived at Itokawa in September 2005, but lost the use of two of its three reaction wheels.



3. Landing
In mid-November 2005, Hayabusa lost the Minerva mini-lander and failed a landing attempt.



Second landing attempt

4. On the surface
In late-November Hayabusa successfully touched down on the asteroid and collected a sample.



5. Re-entry
After limping home, Hayabusa re-entered the Earth's atmosphere on 13 June 2010.

Mission Profile
Hayabusa

Launch: 9 May 2003
Agency: JAXA
Mass: 510kg
Cost: $100m
Mission duration: 7 years, 1 month, 4 days
Re-entry: 13 June 2010

Second landing attempt

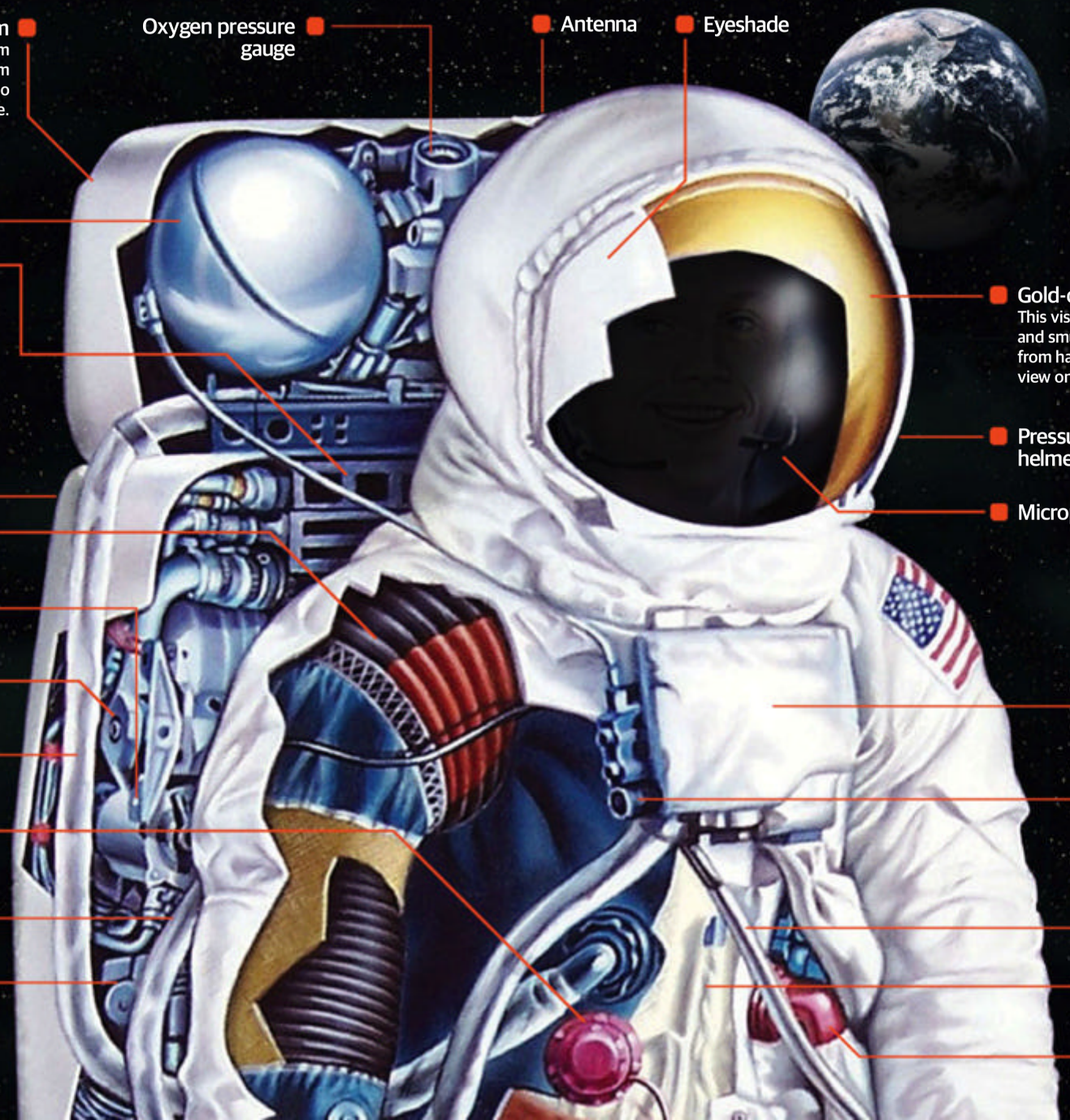


Bounce
Hayabusa accidentally landed on Itokawa.

Sample
Its brief encounter allowed it to get a sample.

Inside the Apollo spacesuit

Take a look inside the suit that Neil Armstrong wore on the Moon



Emergency oxygen system
In the case of the primary system failing, this emergency system would immediately supply oxygen to maintain the suit's pressure.

Oxygen pressure gauge

Antenna

Eyeshade

Emergency oxygen container

Communications radio

Backpack with oxygen and cooling systems
Combined, the Apollo spacesuit and backpack weighed around 82kg (180lb) on Earth but only 14kg (30lb) on the Moon.

Bellows for flexible joint

Oxygen dehumidifier

Oxygen circulating fan

Emergency oxygen tube

Emergency valve pressure and ventilation

Oxygen tube

Coolant water pump

Gold-coated Sun visor
This visor prevented fogging and smudges, as well as the Sun, from hampering an astronaut's view on the lunar surface.

Pressure-tight helmet

Microphone

Backpack remote control unit
The Portable Life Support System (PLSS), which purified the air and circulated water in the suit, was controlled with the Remote Control Unit (RCU).

Emergency oxygen supply switch

Electrical cable

Liquid-coolant tube

Oxygen tube

Pressure gauge

Urine collection assembly

Self-sealing patch for emergency medication
If required, astronauts could administer a hypodermic injection to themselves without compromising the suit's pressure using this patch.

Protective glove

Pocket for rock samples

Utility pocket

Liquid cooled underwear
A water-cooled nylon undergarment ensured the Apollo astronauts remained at a moderate temperature while they were operating on the lunar surface.

Lunar overshoe with tractor-tread soles

Fibreglass outer layer

Rubber pressure-tight layer

Eugene Cernan's back-up spacesuit on the left, with the current Shuttle Space Suit Assembly (SSA) in the centre and the 1997 I-Suit on the right



"The Apollo suits were groundbreaking, allowing greater flexibility than ever before, while also being lightweight"

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Sophie Allan



National Space Academy Education Officer

■ Sophie studied Astrophysics at university. She has a special interest in astrobiology and planetary science.

Megan Whewell



Education Team Presenter

■ Megan has a first-class Master's degree in Astrophysics and Science Communication and specialises in the topic of star formation.

Josh Barker



Education Team Presenter

■ Having achieved a Master's in Physics and Astrophysics, Josh continues to pursue his interests in space at the National Space Centre.

Gemma Lavender



Science journalist

■ Gemma holds a degree in Astrophysics and has worked as a science journalist for three years. She was recently elected as a fellow of the Royal Astronomical Society.

Jonathan O'Callaghan



Senior Staff Writer

■ Jonathan read Physics and Astrophysics before becoming a writer on our sister publication How It Works, where he specialised in space science and exploration.



The radiation levels on Mars would be fatal to astronauts without the right protection

SPACE EXPLORATION

How could we protect ourselves from radiation on Mars?

Richard Fawcett

At an average distance of 228 million km (142 million miles) from the Sun, Mars is about 1.5 times as far away as the Earth. This means that the Red Planet receives around half as much light from the Sun than our planet. The Mars Odyssey spacecraft, which carried the Mars Radiation Environment Experiment (MARIE) to measure the levels of radiation for future human spaceflight to Mars, found that radiation levels in orbit around Mars are some 2.5 times higher than measured at the International Space Station (ISS). Scientists believe that levels on the surface of Mars might be significantly lower and vary at different locations dependent on altitude. However, while the radiation might be lower, it is still hazardous to us.

Mars does not have much of an atmosphere, which means that the ultraviolet light from the Sun is not absorbed and passes through whatever atmosphere there is and reaches the ground, while some of it will be scattered out of the atmosphere by the gases in the Martian skies. While there are global dust storms that rage across the surface of Mars absorbing all of the sunlight and preventing it from reaching the ground, astronauts should not rely on this for full protection since the atmosphere is clear a majority of the time. Nor should they rely on the little bit of dust that is in the atmosphere all of the time and the occasional clouds and hazes that block some of the Sun's light.

Stepping on to Mars, you would need to wear something that would shield you from these fatal rays and this can be the same material that would be needed for a spacesuit that would assist in your survival in the incredibly thin atmosphere. Another alternative would be to either tunnel underground or take shelter in the lava tunnels carved out by volcanic activity in Mars's past. **GL**

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

DEEP SPACE

Will Comet ISON light up the sky in late 2013?

Kirsty Brown

Comet ISON was discovered by astronomers Vitali Nevski and Artyom Novichonok from images they obtained last year using a 400mm (16in) Santel reflector. At the time, the comet was found to be glowing at a very dim 19 magnitudes.

Just how brightly Comet ISON will shine this year is up for debate. However, the general consensus is that ISON will hopefully be the brightest comet anyone alive has ever seen. Current predictions suggest that it will come within 1.8 million km (1.1 million miles) of the Sun at the end of November 2013. It is here that ISON could reach, or even exceed, the brightness of the full Moon, meaning that it will be visible to the naked eye.

However, it is possible that we will not be able to see the comet at its brightest point because its closeness to the Sun could mean that it is washed out by our daytime star's glare.

Heading north almost immediately after it reaches its closest approach to the Sun, ISON will start to dim. However, it could still be as bright as Venus and will have a spectacular tail. Observers in the northern hemisphere should get a great view in the runup to Christmas. Astronomers predict that it will get no closer to Earth than about 60 million km (37 million miles) on 26 December 2013.

While Comet ISON has been dubbed the 'Comet of the Century', astronomers point out that comets are notoriously unpredictable and while most evidence points to a spectacular show, ISON could just fizzle out or even break up! **GL**

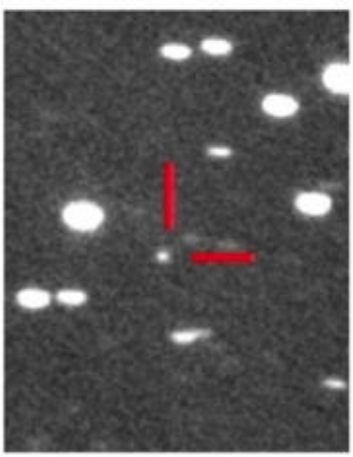
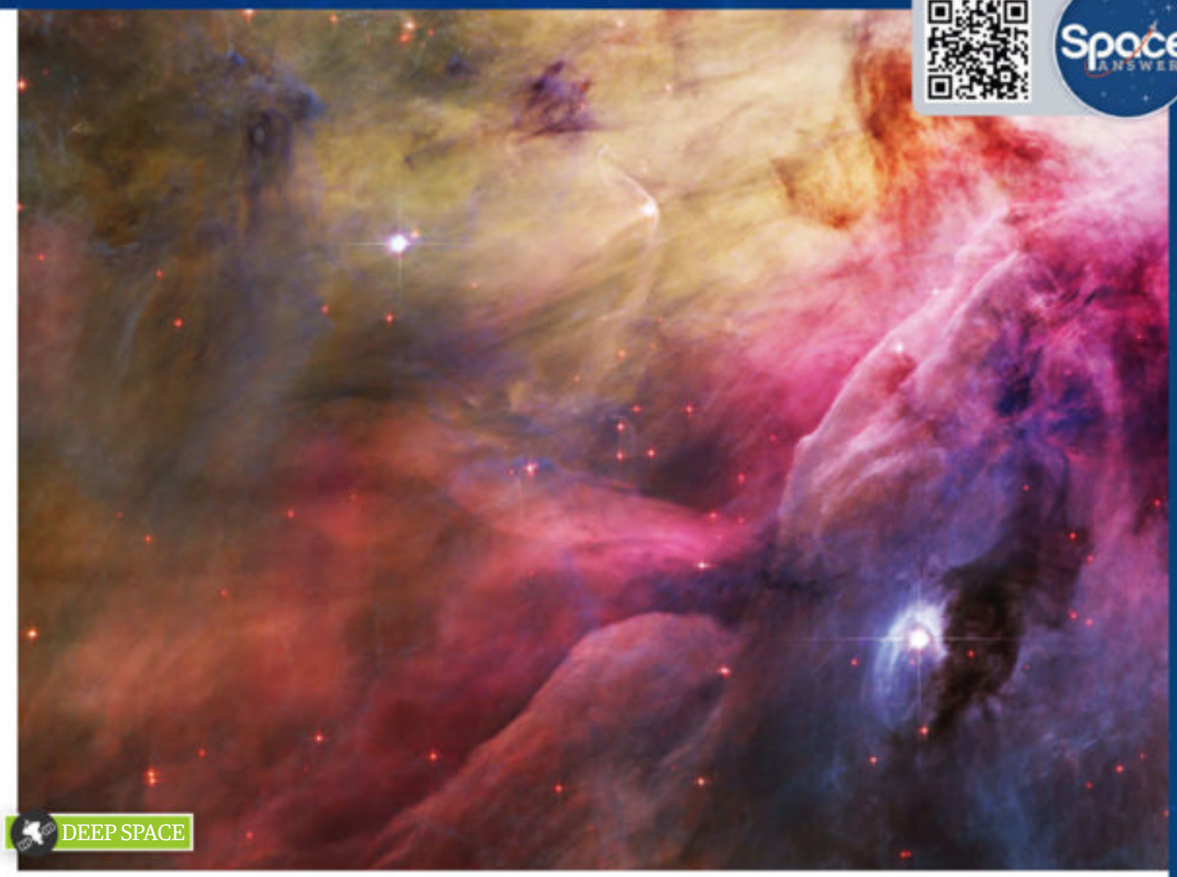


Image of comet ISON as seen on 22 September 2012 by the Remanzacco Observatory



DEEP SPACE

Are there any planets that exist inside nebulas?

Tom Boulevard

In a sense, yes, because nebulas are huge clouds of dust and gas, from which stars (and planets) can form, but there aren't any planets in nebulas to begin with, only the materials to form them. As part of a nebula collapses, the centre of that collapsing sphere may become hot enough to start nuclear fusion and become a star. A disc of remaining dust and gas is likely to be left swirling around the star, and it is from here that planets may form. Some pieces of dust will be larger than others and therefore have greater gravitational pull. Smaller pieces of dust get pulled towards the larger piece, making it larger still. This can continue until the 'large' object has collected enough material to be called a planet. So the material to make the planet has been in the nebula since before it collapsed, but only collected together at a later point. **MW**

SPACE EXPLORATION

Where would a compass point to in space?

Joshua Perkins

Compasses work using magnetic fields. Here on Earth, a compass would point towards magnetic north. A compass will align itself with the strongest magnetic field in the region. This is why if you get a magnet and hold it close to a compass, it will change the direction it is pointing.

As you leave the Earth and move into space the magnetic field will get weaker. Even though the field is weaker, the compass can still align with it meaning that a compass on the International Space Station would still be a reliable guide to the location of the North Pole.

If you choose to go further away, things would get a little more interesting. If you move far enough away from Earth you will reach a point where the Sun's magnetic field will be stronger than the Earth's. At this point, your compass would swap allegiance, and would begin pointing towards the Sun's magnetic north pole.

Of course, if you were to send a compass right out into intergalactic space, the space between galaxies, then your compass would probably not work at all. A stronger compass will detect fainter magnetic fields, but get far away enough from a magnetic source and your compass would not point anywhere. **JB**



SOLAR SYSTEM

Why do gas planets not have gas moons?

Steve Hampton

The main reason we don't get gas moons is that they are simply not big enough. Gas is very volatile, it has a high degree of movement, and this makes it easy for gas to escape. This happens on all the bodies in the Solar System that have gas in the atmosphere. Although the rate at which they lose gas tends to be very small. This high movement rate means that objects have to reach a certain size before they are able to hold on to an atmosphere. Most moons don't reach this minimum size limit.

As the moons are small their gravitational influence usually cannot rival that of their parent planets. This means that the planet usually strips any gas away from the moons around it.

A gas moon, in the style of a gas planet could not exist. The closest you could possibly get would be a binary planet system, where roughly similar size gas planets orbited each other. As of yet, we haven't found anything like this, but as the search continues, maybe we will. **JB**





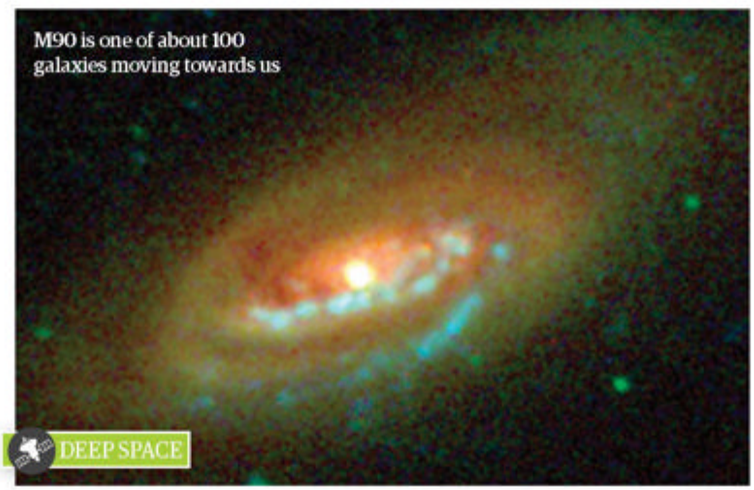
A larger Sun would live a much shorter life than our current star

SOLAR SYSTEM

If the Sun was ten times bigger, would the planets also be bigger?

Jack Walker

If the Sun was made of ten times more material, the first thing to change would be the type of light it emits. The environment around a massive star is very different to an average-sized star. For example, there would be a much stronger solar wind (a stream of charged particles flowing from the star outwards in all directions), which could disrupt planet formation. Massive stars also live much shorter lives than average stars, they run out of hydrogen fuel after millions of years rather than billions, and this would limit the time any planet had over which to form. This could cause any planets around massive stars to be small compared to those in our Solar System, if they had time to form at all. **MW**



M90 is one of about 100 galaxies moving towards us

DEEP SPACE

Apart from Andromeda, are any other galaxies moving towards us?

Claire Armstrong

Most of the galaxies in the universe are moving away from us and, as a result, the light that they emit is shifted to the red end of the spectrum due to an increase in wavelength as the universe expands. When a galaxy moves towards us, for example in the case of the Andromeda Galaxy (M31), the wavelength of the light emitted is shortened thanks to the Doppler effect (the same effect that causes the siren of an ambulance to rise and fall in pitch as it drives by), shifting the light to the blue end of the spectrum. The galaxy is then said to be blueshifted.

Andromeda is not the only galaxy moving towards us. With the help of galaxy surveys, astronomers have found that about 100 galaxies are heading our way. Compared to the numbers of galaxies that we know of (hundreds of billions), blueshifted galaxies are seemingly quite rare. Those that are moving towards us are either part of our Local Group, which means that we are gravitationally connected to each other, or they are found in the Virgo Cluster which everything in our Local Group is moving towards. The galaxies M90, M86 and M98 are all in the Virgo Cluster and all show blueshifts. **GL**

ASTRONOMY

What do letters of stellar classification stand for?

Christopher Attwood

Astronomers have always searched for ways to separate stars into different groups. These letters of spectral classification started off as an alphabetical ordering of the types of stars (eg A, B, C, D etc), but have become reordered and minimised as more is discovered about the stars they represent. The full order of classification is O, B, A, F, G, K, M – more easily remembered by using the mnemonic 'Oh Be A Fine Girl/Guy, Kiss Me'. This also orders adult (main sequence) stars from hot to cool; the hottest (and largest) main sequence stars are O and B type, while the coolest (and smallest) stars are M dwarfs. Astronomers can infer the temperature of a star by looking at the type of light it emits. Very hot stars (O and B stars) look blue to our eyes, and as stars get cooler they become more white, then yellow, then orange, then red (M dwarfs). Our Sun is a G type star on this classification; pretty average by all accounts. **MW**

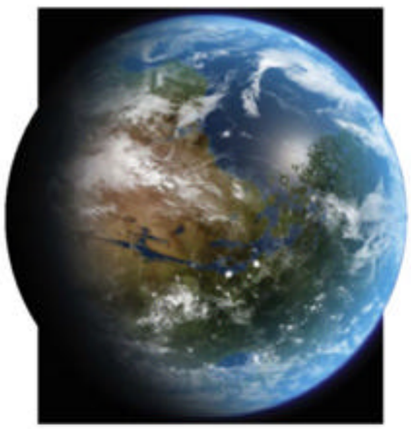
SOLAR SYSTEM

Did Mars used to have lakes and rivers?

Tom Farmery

It is very likely that there were lakes, rivers and even oceans on Mars in the past. The great channels and flood plains that are carved out on the surface of Mars and have been spotted by missions such as NASA's Mars Global Surveyor spacecraft suggest that some 3.5 billion years ago, the terrestrial planet experienced the largest known floods in the Solar System, where the water possibly pooled into these lakes and shallow oceans. Of course, its surface has also been changed by volcanism, impacts from other bodies, movements of its crust and atmospheric effects such as dust storms.

Just where this ancient water came from, how long it lasted and where it went is continuing to be investigated by missions such as the Mars Science Laboratory. With an average temperature at the equator that can dip as low as -50°C (-58°F) and even colder at the Martian poles where it can reach -153°C (-243°F), today water on Mars is frozen. **GL**





SPACE EXPLORATION

Do astronauts have their spacesuits and helmets personally made for them?

Melanie Hall

While the Apollo spacesuits were tailor-made for each astronaut, most modern day spacesuits are a little more 'off the shelf'. Modern spacesuits are made from interchangeable parts in different sizes that can be 'slotted together' through a series of seals to form a full spacesuit. When an astronaut needs a new suit they are measured, and the correct-sized parts (torso, legs, arms etc) are assembled. The helmets are also standard issue since they do not fit closely to the head of the astronaut.

However, there are some things that you can not generalise, and since astronauts conducting a space walk will often have a number of complex tasks to perform, it is vital that they have good dexterity and freedom of movement in their hands. As a result, the gloves of a spacesuit are custom-made for each astronaut.

As for how many times it can be worn, it is a matter of total usage time during space walks. Each suit is rated for a certain number of hours of exposure to vacuum, solar radiation and micrometeoroids. The modular nature of modern spacesuits also means that each part can be replaced as and when it is needed, making the whole process more economical. Once a suit or part of a suit has served its time, it will be used in astronaut training – so this expensive piece of fashion does not go to waste! **SA**

SOLAR SYSTEM

Why are planets closer to the Sun more dense?

Will Pittenger

The planets in our Solar System formed from the solar nebula – the disc of gas left over from the formation of our Sun. Over time, this material began to collide and stick together, forming large clumps that could collide with other large clumps and gradually gather more matter. All of the planets in our Solar System began to form this way, but close to the Sun the temperature was too high for volatiles (gases like water and methane) to condense, so only the materials with a higher melting point (and higher density) were able to form at this point. The gas giants, on the other hand, formed far enough away from the Sun that the temperature was cool enough for these volatile gases to condense, and form these huge, less dense planets. **SA**

Quick-fire questions

@spaceanswers

How do we assign geographic poles to planets?

The geographic poles of a planet or any of its satellites are assigned based on its rotational axis – the axis about which its spins.

What is at the core of a gas giant?

It is thought that, in Jupiter's case, its core is a mixture of iron-nickel alloy, rock and other substances heated to a temperature of 20,000°C (36,000°F), while rock and ice are believed to be at the centres of Saturn, Uranus and Neptune.

Do galaxies have magnetic fields?

Yes, they do. It is thought that these magnetic fields control the rate of star formation as well as the dynamics of interstellar gas.

What's been our biggest space probe?

With a mass of 3,625kg (8,000lb) and three gigantic solar panels measuring 2.7m x 8.9m (9ft x 29ft) each, NASA's mission to Jupiter, Juno, which was launched in 2011, is the largest.

What extrasolar system has the most planets?

To date, Sun-like star HD 10180 has at least seven confirmed exoplanets orbiting it. Astronomers believe that there could be more – possibly nine – making it potentially larger than our Solar System!

Does every star have a planet?

According to recent research, every star in our galaxy could very well host at least one planet.

Why was Neil Armstrong the first on the Moon?

Since he was the spacecraft commander of Apollo 11, Armstrong gained the privilege of being the first man to not just land the spacecraft on the Moon but also to be the first to set foot on to its surface.

Quick-fire questions

@spaceanswers

How many different nationalities have been to space?
Citizens of around 38 countries have been into space.

Why don't Mercury and Venus have moons?
It is thought because they are too close to the Sun that the chances of these two planets forming moons during the creation of the Solar System, let alone keeping hold of any, were very narrow due to instabilities and tidal gravitational forces.

What's at the edge of the Milky Way?
The Milky Way is surrounded by a halo of old stars and a layer of dark matter. Anything past that is intergalactic space.

Why are galaxies flat and not circular?
Not all galaxies are flat. Some galaxies, such as ellipticals, are actually quite round.

Could we drink subsurface water from Mars?
While it is referred to as 'water ice', water on Mars is probably so salty and acidic that it would be essentially poisonous unless it had been filtered.

How long does it take for light to reach us from the sun?
Light takes about 8 minutes and 19 seconds to travel the distance from the Sun to the Earth.

What's the difference between an asteroid and a comet?
A comet has a tail that is created as the Sun heats substances on the comet to beyond their boiling point.

What does NASA mean?
It stands for National Aeronautics and Space Administration.

"A reflector telescope, uses mirrors to bounce incoming light through to a eyepiece lens"



ASTRONOMY

What's the best type of telescope for an amateur?

Katie Sims

When choosing your first telescope, the most important quality to look out for is the aperture diameter rather than the magnification. You should avoid any telescopes that are small but claim that they have some great magnification power, of 400x or even 500x, at all costs. To see faint objects your telescope needs to be able to collect as much light as possible and so the wider the aperture (the wider the diameter of the telescope tube), the fainter the object that you can see. The minimum aperture that you will require will be around 100mm for a refracting telescope and somewhere around 100-150mm for a reflecting telescope like a Dobsonian. Just what type of telescope that you wish to purchase depends on what you wish to observe. A refractor telescope, which uses an objective lens to concentrate light into the eyepiece at the viewing end, gives better images of the planets and Moon. A reflector telescope, on the other hand, which uses mirrors to bounce incoming light through to a eyepiece lens, will be great at picking out dimmer objects such as galaxies or nebulas. You should expect to pay between £200 and £500 for a good beginners' telescope.

For more advice check out our feature on getting started in astronomy in issue 7 of **All About Space**, where you can get some great tips on choosing your equipment (where we have picked out our top three beginner telescopes, eyepieces and binoculars), your first night of observing, naked eye astronomy and learning your way around the night sky. **GL**



SPACE EXPLORATION

What future missions will explore the outer Solar System?

Beth Foster

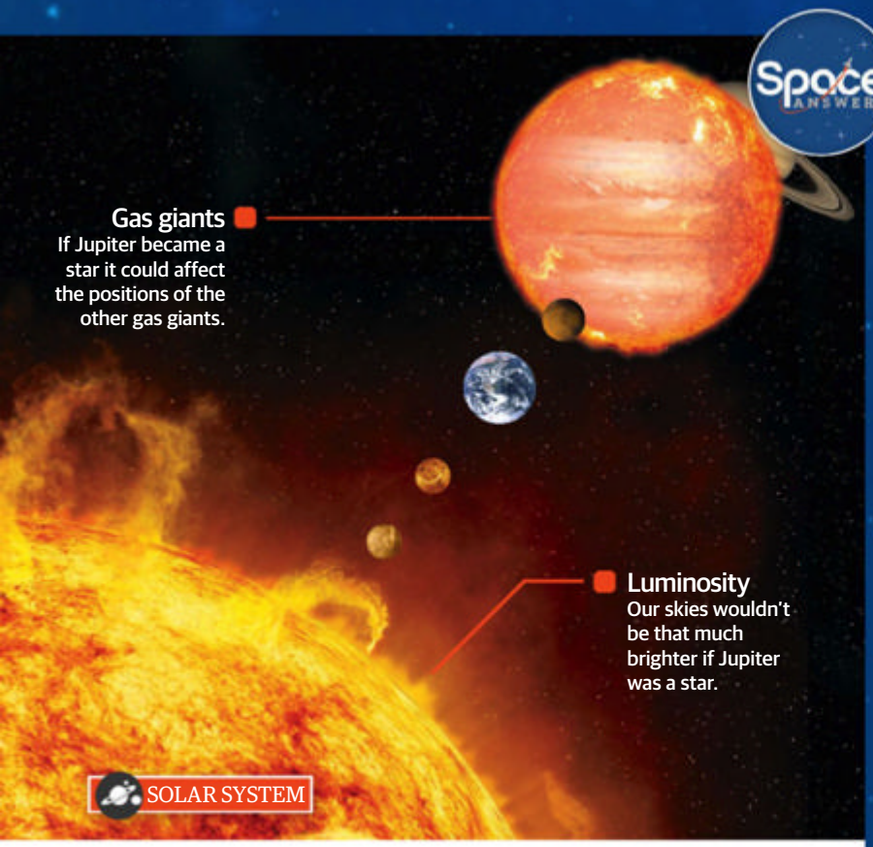
The European Space Agency's Jupiter Icy Moon Explorer (JUICE) is set to take off on a mission to Jupiter and its system some time around 2022. It will launch on an Ariane 5 carrier rocket and is expected to arrive at Jupiter in 2030. The spacecraft will be focused on studying three of Jupiter's moons – Ganymede, Callisto and Europa. These distant worlds are all believed to harbour bodies of liquid water beneath their surfaces and are currently thought to host potentially habitable environments.

It is planned that JUICE will enter into orbit around Ganymede in 2033 with proposed instruments such as cameras, spectrometers and radar to study the moon.

Other missions, which have been launched but have not yet reached their destination, are also set to explore the outer Solar System. NASA's Jupiter-bound spacecraft Juno will arrive at the gas giant in 2016 where it hopes to search for clues about how Jupiter formed, investigate whether the planet has a rocky core, study the atmosphere, its mass distribution as well as the planet's winds.

Travelling even further into the outer reaches of the Solar System, NASA's New Horizons mission is currently making its way to dwarf planet Pluto with a planned arrival during July 2015. New Horizons will be the first spacecraft to study the demoted planet and its five moons – Charon, Hydra, Nix, S/2011 P1 and S/2012 P1. **GL**

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



If Jupiter became a star, what would happen to the Solar System?

Rob Zwetsloot

It is often said that Jupiter is a failed star – it is regularly mentioned that with a little extra material Jupiter may have started fusing and shining like a star. So what would happen if this occurred? The smallest star we know of is OGLE-TR-122b. This star is around 20% bigger than Jupiter but has around 96 times more mass. So what would happen if we replaced Jupiter with OGLE-TR-122b? Well, the first thing to consider would be how much brighter our skies might get. The answer to that is, not much. OGLE-TR-122b has a luminosity that is equivalent to 0.005% that of the Sun's. This isn't going to light up the sky much more than Jupiter already does.

The brightness isn't necessarily the major issue, though. The current theory surrounding the formation of the Solar System features Jupiter quite heavily. It is believed that Uranus and Neptune couldn't form at the distance from the Sun they are at. To explain their current location it is required that these planets migrate. This migration was heavily reliant on the relative masses and positions of all four of the gas giants. If we replaced Jupiter with OGLE-TR-122b this change in mass would have a major effect on this migration process. This could result in the gas giant planets being in different positions, or even one of them being kicked out of the Solar System completely. **JB**

DEEP SPACE

What is a gravity well?

Will Gibbs

We know that gravity is the force that pulls all matter together and the more matter, or the denser the matter, the more gravity. Objects like planets, their moons and stars have a huge amount of matter which means that the force of gravity pulls together much more strongly than smaller objects, say, like the magazine or computer you're reading from right now. Additionally, the more massive something is, the more of a gravitational pull it will exert. A gravitational well is the pull of gravity that an object exerts. The more mass that a body has, or the denser the mass, the deeper the gravitational well. **GL**

Next Issue

THE MOST POWERFUL FORCE IN THE UNIVERSE

From black holes to gamma rays to hypernovas... what's the mightiest force in the cosmos?



THE HISTORY OF SPACESUITS

Pictures from their invention to the modern day



ALL ABOUT DWARF PLANETS

The mysterious planetoids of the Kuiper belt explained



MANNED LUNAR BASES

Will humanity ever live permanently on the Moon?

MARTIAN AIRCRAFT
10 MYSTERIES OF THE KNOWN UNIVERSE
THE APOLLO LANDER
BINARY STARS
LIGHT POLLUTION
REFRACTOR TELESCOPES

In orbit **4 April 2013**

STARGAZER

GUIDES AND ADVICE TO GET STARTED IN AMATEUR ASTRONOMY

In this issue...

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Get the safest and best views of our star

84 **What's in the sky?**
We take a look at the finest sights of early spring

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Enjoy our Solar System's most fascinating satellites

88 **Me & my telescope**
Readers show off their telescopes and favourite images

93 **Astronomy kit reviews**
We take a look at the latest and greatest equipment

How to view THE SUN

By looking at the Sun, our nearest star, you can see amazing processes going on all the time, but remember, you need to be very, very careful...

Safety first!

The Sun is incredibly bright and can easily damage a human eye if you look directly at it and will certainly destroy eyesight if concentrated through binoculars, telescope or even a camera lens even for an instant. Only use proper solar filters to view the Sun and then only in strict accordance with the manufacturer's instructions.

It's sometimes hard to remember that when you see all those tiny twinkling points of light up in the night sky, that each one of them is a raging nuclear inferno. To appreciate this for yourself, you only need look at the Sun. Of course it's so powerful, you need to take great care as it is very easy to blind yourself. If you are in the slightest bit doubtful about what you are doing, then don't do it. But if you are careful and follow the guidelines given here, you will find that observing the Sun is both fun and an endless source of fascination.

The Sun is constantly changing and darker areas called 'sunspots' move across its disc over the course of a few days. They come and go in a cycle of roughly 11 years. Very occasionally you might see a brighter region on the disc. These are known as 'faculae' and are associated with flares where the Sun blows out very hot material into space.

The safest way to see the surface of the Sun or the 'photosphere', to give it its correct name, is to project the disc using a small telescope and two cardboard squares. The first square fitted around the telescope tube casts a shadow on the second so you can see the projected disc of the Sun clearly. You point the scope at the Sun by watching the shadow cast by the 'scope; when the shadow is smallest is when the telescope should be pointing in the right direction. Never attempt to look through the telescope! Focus the telescope in the usual way to get a sharp image of any sunspots. The best time to view the Sun is early to mid-morning or late afternoon. The heat of midday can spoil the view, making the atmosphere turbulent and causing images to wobble.

You can get special solar filters to use with your telescope, but only buy these from reputable dealers. These fit over the front aperture of your telescope and are made from either specially coated glass or from a special metallised film called 'astro-solar film'.

> "You can get special solar filters to use with your telescope, but only ever buy these from reputable dealers"

This looks a little like aluminium foil, but is designed to block out dangerous radiation such as ultraviolet. Always check such filters before each and every use. Hold them up to a light bulb and check for any scuffs or pinholes which could let sunlight through. If these are present, discard the filter. If you find your telescope supplied with a small filter which is supposed to fit on to the eyepiece, do not use it! These are very dangerous as they can shatter in the heat thereby exposing your eye to the full force of the Sun's energy.

There is a new type of filter available now called a 'hydrogen-alpha filter' often coming fitted into special telescopes designed for solar viewing. These are amazing instruments which will show you otherwise impossible to see features. With such a telescope or filter you can see 'prominences', huge fountains of material standing out from the surface of the Sun and also 'filaments', which look like dark lines etched on the disc. These are in fact prominences seen from above. The disc of the Sun looks mottled through this type of filter as well. Here you are looking at 'cells' of material thousands of miles across, bubbling up from the lower layers of our star.

All in all, the Sun is an amazing, dynamic object and well worth your time as long as you're careful. After all, it's astronomy in the warm! ■

Setting up your telescope to view the Sun



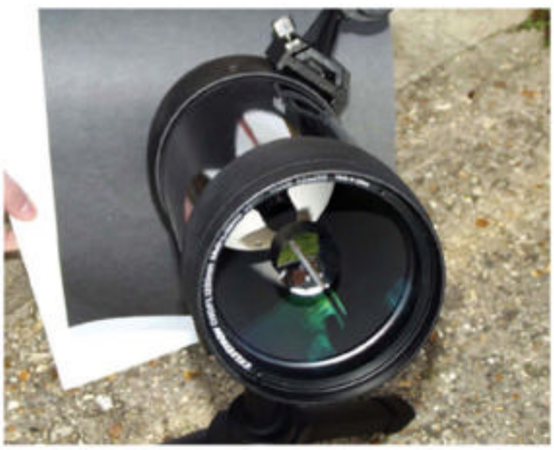
1 Get prepared

First of all you will need to get a sheet of white card or poster board on to which we are going to project the Sun's image.



2 Cast a shadow

You will also need another piece of card around the telescope tube to cast a shadow so you can see the projected image.



3 Beware of overheating

The best telescope to use to view the Sun is a small inexpensive refractor. However, beware of heat building up in the telescope tube.



4 Low-power eyepiece

Use a low power eyepiece to get the best results. Again, check regularly to make sure that it is not getting too hot.



5 Focus your telescope

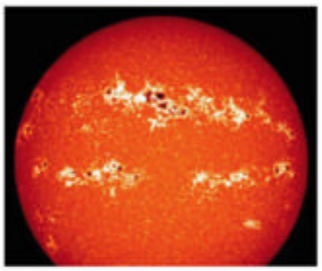
You will need to focus the telescope so that you get a sharp, clear image of sunspots and other features on the Sun's surface.



6 Enjoy the results

The telescope will reflect light from the Sun on to your sheet of white card or poster board, giving you a fascinating and safe view of our star.

Jargon Buster



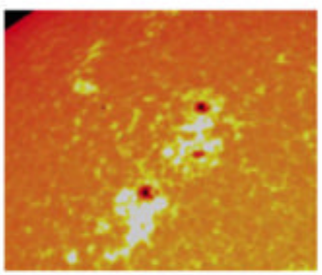
Solar filters

There are several types of solar filter you can buy for use with telescopes, binoculars and camera lenses. Telescope manufacturers will often make metal-coated glass filters to fit over the front of their instruments. These start from around £50 to several hundred!

A cheaper and very effective way of obtaining a good solar filter is to use a material called 'astro-solar safety film'. This comes in A4 sheets and looks a little like kitchen foil and is made from a metallised polymer. An A4 sheet costs around £20.

For a more professional finish, you can buy filters using this material in metal rings made to fit the aperture of your telescope. These start at around £40.

Dedicated solar telescopes using Hydrogen-Alpha filters start at around £500.



Sunspots

These are regions of complex magnetism on the Sun. You can see them as dark blotches with a dark centre and lighter outer either by projecting the image through a telescope or by using a 'white light' filter as described in this article. The reason sunspots are darker than the rest of the disc of the Sun is because they are cooler. They travel across the disc of the Sun as it rotates and grow and shrink as the magnetic fields change.

What's in the sky?

The cold, dark night skies of February are starting to show us the first hints of spring...

The Whirlpool Galaxy (M51)

Viewable time: All through the hours of darkness

Otherwise known as the Whirlpool Galaxy, M51 is possibly one of the most famous galaxies after the Andromeda and Milky Way galaxies. The reason for this is the beautiful photograph taken by the Hubble Space Telescope. As you can see in the picture, the larger galaxy is pulling material from the smaller in an act of celestial vandalism.



The Beehive Cluster (M44)

Viewable time: After sunset through to the early hours

This lovely cluster, which looks like a swarm of bees around a hive, was recorded by ancient Chinese astronomers. It is full of red giant and white dwarf stars and is around 550 light years away. It also goes by the name of Praesepe, the Latin word for 'manger'. It is also known by its catalogue number of Messier 44.



Northern hemisphere

The Sombrero Galaxy (M104)

Viewable time: Mid-evening until the early hours

The picture of the galaxy shows why it picked up the name of the 'Sombrero' as it does look quite like a Mexican hat. There are lots of features that make this an interesting galaxy, including its bright nucleus and large central bulge and more specifically the dark dust lane running around the edge of this beautiful object.

Galaxies M65, M66 and NGC 3628

Viewable time: Almost the whole night

These three galaxies, although separate, are all in the same field of view of a low power telescope and have become known as the Leo Triplet. They are all spiral galaxies but each is tilted at a different angle. M65 and M66 are at oblique angles so we can see the spiral structure, whereas NGC 3628 is edge on to us.





Omega Centauri

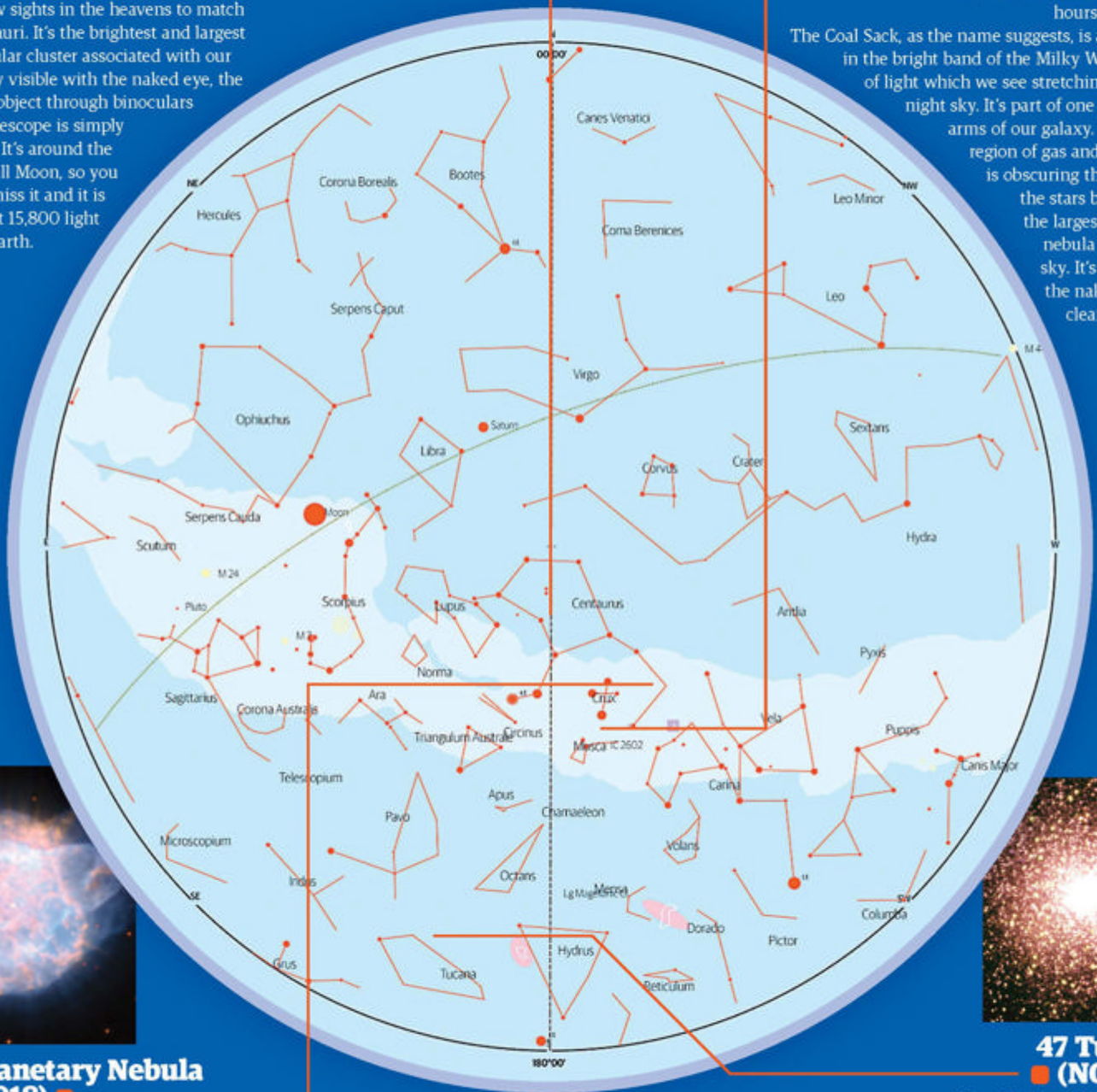
Viewable time: All through the night

There are few sights in the heavens to match Omega Centauri. It's the brightest and largest known globular cluster associated with our galaxy. Easily visible with the naked eye, the view of this object through binoculars or a small telescope is simply magnificent. It's around the size of the full Moon, so you can't really miss it and it is located about 15,800 light years from Earth.

The Coal Sack

Viewable time: All through the hours of darkness

The Coal Sack, as the name suggests, is a dark patch in the bright band of the Milky Way, the river of light which we see stretching across the night sky. It's part of one of the spiral arms of our galaxy. It is a dense region of gas and dust which is obscuring the light from the stars behind it. It's the largest such 'dark' nebula in the night sky. It's visible with the naked eye on a clear dark night.



Blue Planetary Nebula (NGC 3918)

Viewable time: Through most of the hours of darkness

Found in the constellation of Centaurus, the Blue Planetary Nebula, which is also known as The Southerner, is easily visible in a small telescope and, as the name suggests, has a bluish tinge making it look a little like Neptune. Interestingly, the faint central star at the heart of the nebula is invisible to visual observers.

Southern hemisphere

47 Tucanae (NGC 104)

Viewable time: All through the hours of darkness

47 Tucanae is the second brightest globular cluster after Omega Centauri. It can be seen with the naked eye and appears roughly the size of the full Moon. It is a magnificent sight in binoculars or a small telescope. Globular clusters are enigmatic objects, as they contain some of the oldest stars in the known universe.

Viewing the Galilean moons

Named after their discoverer Galileo Galilei, the four moons which orbit around Jupiter are easily seen in binoculars and small telescopes

The moons of Jupiter are some of the most fascinating things to observe in the night sky. The reason being is that they change their position from night to night and are relatively easy to see; a pair of 7x50 or 10x50 binoculars will show them well.

First recorded in 1610 by the Italian astronomer Galileo, the moons of Jupiter have proved to be an endless source of fascination for amateur and professional astronomers ever since. Jupiter, we now know, has dozens of moons orbiting around it, but the four largest are the only ones visible using ground-based amateur telescopes.

Among the most interesting things to observe with respect to these moons are the ways they move almost on an hourly basis. They can change their position from two moons each side of the planet to all being in a row on just one side as well as various other combinations. Even more interesting are the occultations and transits. An occultation is where the moons pass behind the planet, so for a short time being obscured to us here on Earth, whereas when they pass in front of the disc of Jupiter, it is known as a transit.



Callisto
The third largest moon in the Solar System, Callisto is slightly smaller than Mercury. It's 'tidally locked' to Jupiter, and therefore it always presents the same face to the planet. It's made up from rock and ice and may even contain liquid water.

Ganymede
Not only is Ganymede a moon of Jupiter, it is also the largest moon in the Solar System and is slightly larger than the planet Mercury! It also has the largest mass of any planetary satellite, being a little over twice the mass of our own Moon.

Io
Io is the innermost of the four moons. It's being continually kneaded by Jupiter's gravitational pull and so has a molten core. It's the most geologically active object in the Solar System and has active volcanoes producing plumes of sulphur.

Europa
The smallest moon of Jupiter, Europa has a very tenuous oxygen atmosphere and it's thought that it may have an ocean of water under its surface ice. It is also thought that this ocean may possibly harbour extraterrestrial life.

Jupiter
The giant planet Jupiter was one of the first objects Galileo viewed through his new telescope. When he saw the four moons travelling around Jupiter he realised the Earth could not be at the centre of the Solar System.

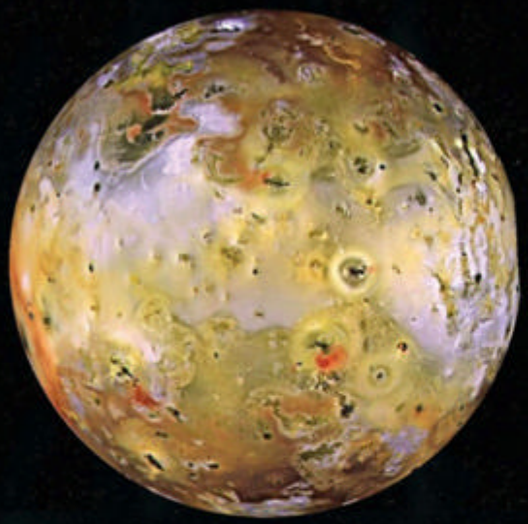
Which telescope?

You can spot the four moons in modest binoculars, 7x50 or 10x50 being the best for this, and you'll even be able to watch them weave around the planet night by night. If you have a small telescope where you can increase the magnification depending on which eyepiece you use, you'll see the planet much more clearly and the moons will be more obvious.

Among the most interesting events to observe in the Solar System are the transits, occultations and shadow transits, where you can watch the shadow cast by a moon move across the surface of Jupiter's disc. This can be accompanied by the transit of the moon itself before, during or after the passing of the shadow. In order to see this well, you'll need at least a three-inch aperture (75mm) refractor telescope or a six-inch (150mm) reflector. A reasonable magnification of around 120x or even more is also required, as is a good quality eyepiece. Here, the Plössl design of eyepiece is good as it provides a nice wide and flat field of view with minimal distortions. Bear in mind that the quality of the atmosphere counts here too, so you may have to reduce the power if the air is particularly unstable causing a 'wobbly' image.

Longer focal length telescopes are better for planetary viewing, so this is where refracting telescopes also have an advantage, but again reflectors can also give you splendid views of the giant planet and its moons.





Io

Diameter: 3,642km (2,263 miles)

Io is an amazing little world. Orbiting Jupiter every 1.8 days, it has over 400 active volcanoes which were only discovered during a flyby of Jupiter by the Voyager probes. Like the other three main moons, it was discovered by Galileo in 1610. Sometimes described as looking a little like a pizza, its surface is covered in sulphur and sulphur dioxide. Unlike most other moons in the Solar System it is composed of silicate rock surrounding a molten iron core, the heat being produced by the gravitational squeezing effect of Jupiter. Because of its fairly close proximity to the planet there are strong interactions between Io and Jupiter's magnetic and radiation belts, resulting in the moon being bathed in huge amounts of radiation every day.



Callisto

Diameter: 4,800km (2,985 miles)

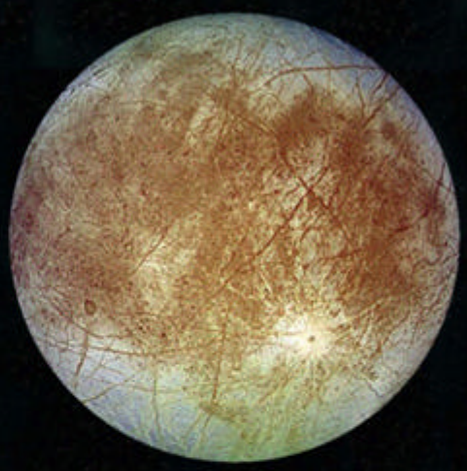
The fourth Galilean moon out from Jupiter is Callisto. Because of its greater distance from the giant planet than the other three moons, it doesn't experience the tidal flexing the others do. However, there is still the possibility of subsurface liquid water, although this has yet to be confirmed. It is the second largest moon of Jupiter and the third largest in the entire Solar System. It is made up from approximately equal amounts of rock and ice and we know that the surface is covered mostly in water ice, carbon dioxide and silicates with some organic compounds, although this isn't the same as having life. It is heavily cratered on the side facing away from Jupiter as can be seen in the picture. It is thought that it would make a suitable base for future human exploration of the Jovian system.



Ganymede

Diameter: 5,268mm (3,273 miles)

Orbiting Jupiter roughly every seven days, Ganymede is also the largest moon in the Solar System. It is the third main moon out from Jupiter and due to its distance from the planet it is tied into a 1:2:4 ratio 'orbital resonance' with two other satellites of Jupiter – Io and Europa. It has a molten iron core and because of this has a magnetosphere. It also has a very thin atmosphere consisting mostly of oxygen. It's heavily cratered due to asteroid impacts over its 4 billion year history, but mostly only on its darker regions, suggesting that the lighter areas are or have been renewed probably due to the action of plate tectonics reshaping the surface, this in turn being due to tidal heating caused by Jupiter's immense gravitational pull.



Europa

Diameter: 3,100km (1,900 miles)

The smallest of the four moons, Europa is also the most interesting. Its icy surface seems to be scored with dark lines, but little cratering is evident, suggesting that there may be an ocean of liquid water under the surface, which could be warm enough to sustain life. Europa has a near circular orbit and goes around the planet in just over three and a half days. It is tidally locked to Jupiter, so always shows the same face to the giant planet. The dark streaks in the surface ice are possibly caused by the ice cracking and re-freezing, although the surface of Europa is one of the smoothest in the Solar System. Due to its potential habitability, Europa is now the focus of ideas for missions to explore its ocean in the search for life.

Me & My Telescope

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

Sarah Lewis, Manchester, UK

Telescope: NA



"I had always been into astronomy but didn't explore it much until recently when I heard about the ISS passing over. I was amazed that we could see something orbiting us as I never thought the space station was big enough to see. I started taking long-exposure images of it that displayed its path as it floated over. I love observing the ISS because even after two years, it still fascinates me. I also like discovering new things through my binoculars such as the moons of Jupiter. I'm still learning how to image more of the night sky but it is very interesting and I hope to become better in time."







Mark Weaver, Lancashire, UK



Telescope: Sky-Watcher 250PX

"I saw your request on Twitter (@spaceanswers) for photos, and this is one my 16-year-old son George took of the Orion Nebula. It was taken with a Canon EOS D600 on a Sky-Watcher 250PX on a HEQ pro mount. When we are lucky enough to get a clear night, we like to go out to search for deep sky objects, although we never turn down an opportunity to gaze at the rings of Saturn or craters on the Moon."

Alex Rancovas, UK



Telescope: National Geographic 50mm telescope

"I'm using a National Geographic 50mm refractor telescope. Since I got the telescope, I've enjoyed looking at the Moon a lot and Jupiter. I was so surprised when I saw Jupiter, it was a miracle. I also took a photo through my telescope of the Moon and it looked beautiful. I could see the craters easily."

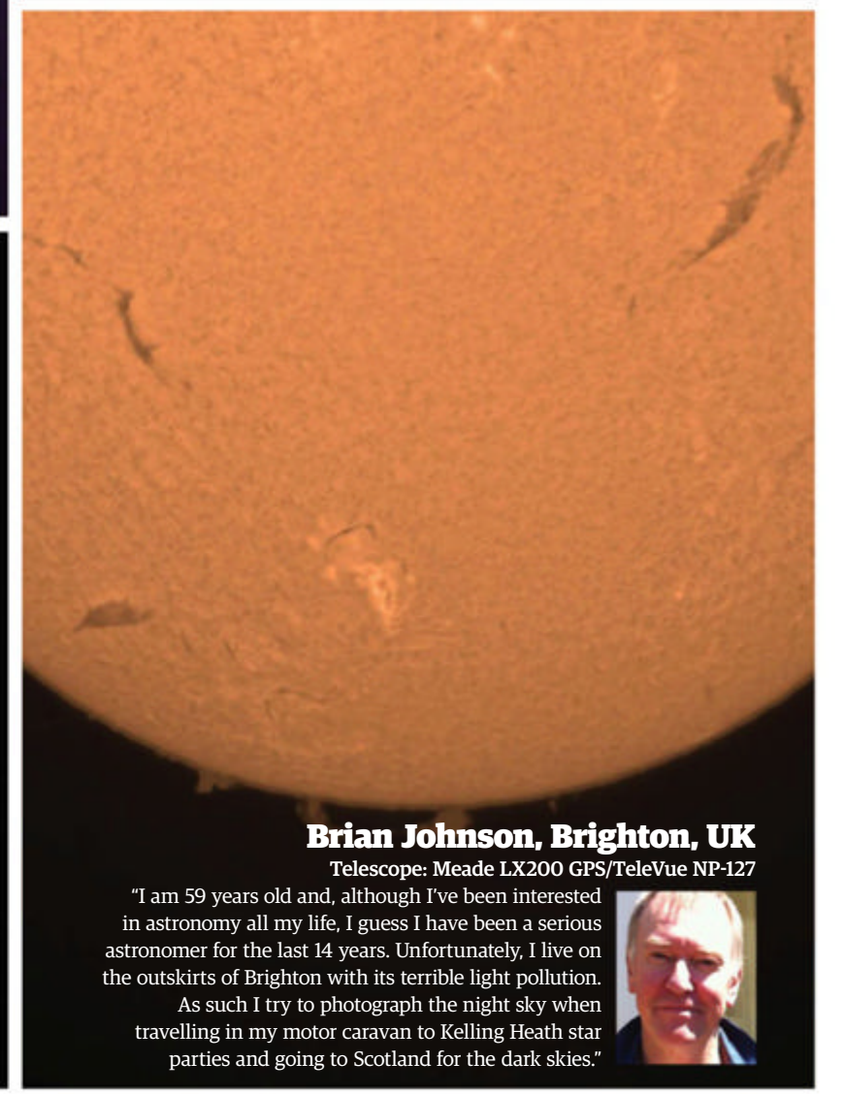


Mark Viney, Kent, UK



Telescope: Celestron CPC 1100

"This is my first attempt at a photograph, using a Pentax Optio compact camera focused down the eyepiece of a Celestron CPC 1100. I have been getting into astronomy for the last year but only got my telescope about six months ago. I have only just started trying my hand at astrophotography."



Brian Johnson, Brighton, UK

Telescope: Meade LX200 GPS/TeleVue NP-127

"I am 59 years old and, although I've been interested in astronomy all my life, I guess I have been a serious astronomer for the last 14 years. Unfortunately, I live on the outskirts of Brighton with its terrible light pollution. As such I try to photograph the night sky when travelling in my motor caravan to Kelling Heath star parties and going to Scotland for the dark skies."

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

Me & My Telescope

First time astronomers

We let two novice stargazers loose on our telescopes to see how they got on

Celestron NexStar 4SE



Tested by: Steven Litton
Cost: £479/$499
From: www.celestron.uk.com

"The Celestron NexStar 4SE telescope is well packaged and quick and easy to assemble. It looks very modern and professional with its orange barrel and chrome tripod. The tripod is solid, sturdy and easy to adjust in height with the quick release screws. The instructions are clear and I had the telescope set up in less than 30 minutes. It needs eight AA batteries for the main motor and a CR2032 battery for the laser pointer. You will also need a screwdriver to fit the pointer to the dovetail bracket on the side of the telescope and to get into the battery compartment.

"The pointer is simple to use with a single power dial, although it is easy to forget to switch it off because you can't see the red dot shining outside of the sight. The hand controller is a good size with a big backlit screen, and before starting you need to set up the basics like the time, date and your location. Once these are set you can move on to using some of the built-in features. The first thing to do is to up the motor speed to the top setting (9) so you can start moving the telescope around. You can lower the motor speed for more accurate positioning when you are lined up to stars or planets with the pointer. The focusing wheel is easily accessible while looking through the eyepiece.

"Once you have the hang of lining up the stars you can start to use the star align features. This feature is really useful, as it can take you to the position of a variety of stars and constellations. The accuracy of this feature is directly relative to the accuracy of your original positioning. We found it really useful to cross-reference what we were seeing with the Google Sky map app (free).

"For those looking to capture the sights there is a camera attachment that allows you to programme up to nine locations to position to and photograph them via the shutter release port on the camera. You will need the additional eyepiece adapters as they are not included.

"Overall the telescope was very good. I managed to view Jupiter as well as many different stars and constellations. My only small complaints would be that it is very noisy and not very portable so you may find yourself annoying neighbours. It also uses a very old-fashioned computer interface cable so you will more than likely need an adapter to make it work. Not an expensive fix but annoying if you want it working out of the box." ■

"To help capture the sights there is a camera attachment that allows you to programme up to nine locations"



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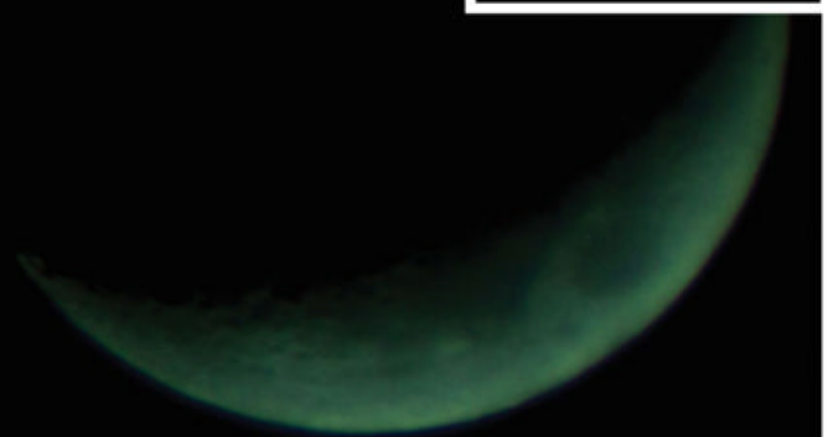


The NexStar 5SE performed above expectations, even in poor conditions





Practice makes perfect when it comes to astrophotography



Celestron 5SE



Tested by: James Sheppard
Cost: £679/$699
From: www.celestron.uk.com

"Coming from the unique position of a complete amateur, I found the Celestron NexStar 5SE, at first, to be quite daunting to look at, but once out of the box and set up it was a different story.

"First of all, the construction and setup were smooth and non-complicated with easy-to-follow instructions. The body build is lightweight, yet stable. After screwing it all together and having the batteries in place we were ready to go. I have to state that I was using this 'scope on a slightly overcast night, possibly not the best start, however, the results were better than expected.

"With the standard optics included with the kit, I was surprised to have such clarity and range. In fact it was able to give me a clear view of Jupiter and its surrounding moons, so clear in fact that I could make out the faint markings of the planet, as well as a clear view into the nebula in Orion's belt. Obviously it wasn't as massively close and colourful a view as I would have liked, but I was intrigued and this got me dialling in the coordinates for other objects and planets.

"This was the death knell for my first venture into proper stargazing, however. As I was in the middle of planning a route for the Big Dipper, a huge waft of dappled clouds moved in to block my view, so, I repositioned the 'scope and decided to go back to viewing Jupiter. I sat back and just watched it, originally I was manually tracking and refocusing the unit, but on further inspection I realised I was able to set the 'scope to track the planet, allowing me to watch it more clearly and for longer.

"My favourite points about the NexStar 5SE, aside from its light weight and user-friendliness, were the simple things: the light-up display and buttons on the handset, which were a blessing in the pitch black, but also the focus pull, as it was large enough to use with gloves on and responsive enough that the fact I was wearing gloves didn't impede my use of it at all.

"All in all, this telescope is a brilliant first step in astronomy. The only downsides are the lack of a USB attachment for a laptop, although these are available separately, and that I'm going to have to invest in some better optics for closer focusing, but for all-round, out-of-the-box goodness? This one was a hit for me."

> "It was able to give me a clear view of Jupiter and its surrounding moons"



The 5SE is compact and user-friendly

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Telescope advice

This month we get hands-on with Celestron's NexStar 130 reflector telescope

Finderscope
The StarPointer finderscope will help you align the telescope and find celestial objects to observe.

Aperture
The telescope does a great job of gathering light with its 130mm aperture.

Auxiliary port
You can plug additional accessories into the telescope's auxiliary port.

Database
Over 4,000 night sky objects are available for you to observe at the touch of a button.

Set up
Putting the telescope together is quick and easy, so you'll be observing in no time at all.



View the planets with ease with the Celestron NexStar 130



There are over 4,000 night sky objects built in to the telescope's database

Celestron NexStar 130 SLT

Cost: £399/$430
From: www.hama.co.uk
Type: Reflector
Aperture: 130mm
Focal Length: 650mm
Magnification: 307x

This fully computerised reflector telescope from Celestron is the perfect way to view the stars. The 130mm aperture does an excellent job of gathering light and will afford you some fantastic views of the planets and also deep sky objects.

It's a quick and easy telescope to set up that doesn't require any additional tools, while a handy accessory tray is provided to store your various accessories on. The telescope itself is sleek and stylish, with a lovely light black finish.

The telescope's database has over 4,000 celestial objects built in, so at the touch of a button you'll be able to traverse the night sky and find various objects of interest. Helping you find your way is Celestron's excellent SkyAlign technology, which makes setup a breeze.

The NexStar 130 SLT is light and portable but it doesn't skimp on quality, with some great optics and a sturdy tripod to boot. You'll easily observe Saturn, Mars and more with this telescope.

Our only qualm was that the NexStar 130 doesn't remember the date and time, so you'll have to input this manually each time you use it, which is a minor annoyance. Otherwise this is a great 'scope to purchase for amateur or experienced astronomers alike.

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Astronomy kit reviews

Must-have products for budding and experienced astronomers alike



1 Book: The Cosmic Gallery

Cost: £20/$30

From: www.quercusbooks.co.uk

This fantastic book, penned by **All About Space** contributor Giles Sparrow, is a stunning look at some amazing cosmic photographs. From startlingly clear images of Saturn to distant nebula and sunspots, Giles takes us on a fantastic photo-led tour of the universe. Each photo is accompanied by some key information, as well as an informative description telling you what exactly you're looking at. Written in a tone that is easily understandable, you'll get a kick out of this book whether you're a casual astronomer or a hardened space nut. We especially loved some of the surface imagery from worlds in the Solar System, shown in crisp high resolution with particular features clearly visible. It's the perfect book to whet your cosmic appetite.

2 Scope: Sky-Watcher Heritage 114-P Virtuoso

Cost: £184/$285

From: www.365astronomy.com

This excellent miniature telescope is the perfect companion for astronomers of all levels. Inside are some powerful optics, including a nifty parabolic mirror, that will grant you some superb views of the night sky. You'll be able to view the Moon, planets and deep sky objects with ease. This mini 'scope is also computerised, so to find celestial bodies you can use the handset, with over 40,000 objects ready for observation. The mount itself is stable and simple, so you'll get clear views and there's no complicated setup required. If you're looking to do photography as well, the mount also offers preset positions and time-lapse functionality. We would highly recommend this telescope to anyone looking to get into astronomy.

3 Binoculars: Opticron Vista EX 10x50

Cost: £59/$90

From: www.amazon.co.uk

This entry-level pair of binoculars is perfect for anyone who wants to get started in astronomy but doesn't want to buy an expensive telescope. With a welcomingly low price, we'd definitely suggest picking up a pair of these binoculars. They're light and compact, perfect for some quick astronomy and easily transported around, and the views you'll get through them are surprisingly good considering their size. They have a porro prism design, and a sleek black rubber armouring makes them comfortable and easy to hold. The focusing wheel is easily accessible in the centre so you can hone in on your celestial object. With a tripod adaptor underneath as well, you'll not be left wanting if you do pick up a pair of these.

4 Battery: Deben Rechargeable 12V battery pack

Cost: £50/$77

From: www.sherwoods-photo.com

If you're planning to take your telescope out and about to do some observing, a source of power can be an issue. While many computerised telescopes now can use batteries, these are normally eaten up in a matter of hours. For that reason it's a good idea to pick up a power pack, either as your main source of power or as a backup, and this particular product is a great choice. The Deben Rechargeable 12V battery pack can power a telescope for days, and it also comes with a handy carrying case (and strap) so you can easily transport it with your telescope. A fused connection and a 12V telescope connection cable, as well as an AC mains charging unit, ensure you'll never be left power hungry again.

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▪ The Universe through a Large Telescope

Images (left to right)
Gamma Ray Burst (artists impression)
The Liverpool Telescope in La Palma
A Liverpool Telescope image of M16

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Buzz Aldrin

The second man on the Moon, Aldrin played a key role in the success of the Apollo lunar missions

Edwin Eugene 'Buzz' Aldrin Junior was born on 20 January 1930 in Montclair, New Jersey, USA. In 1946, after graduating from high school, he turned down a scholarship from the Massachusetts Institute of Technology to join the US Military Academy. Aldrin's nickname 'Buzz' came from his sister mispronouncing 'brother' as 'buzzer'; Aldrin legally changed his first name to Buzz in 1988.

Buzz graduated from West Point, New York with a bachelor of science degree in mechanical engineering in 1951 (and a doctor of science degree in astronautics in 1963). He received pilot training in the US Air Force in 1951 and flew 66 combat missions in the Korean War. In October 1963, after his initial application was rejected, he was selected by NASA among the third group of astronauts for the Mercury, Gemini and Apollo missions.

Just three years later, in November 1966, he orbited Earth 59 times in four days aboard Gemini 12, the last flight of the Gemini programme. The mission would prove hugely important for one reason in particular, namely the perfection of extravehicular activities (EVAs), or spacewalks. Until Gemini 12, spacewalks had been tiresome affairs, with astronauts often caked in sweat and exhausted from the exertion of operating in space. It was Aldrin's research that suggested they train underwater on Earth, and also have footholds and handles on the exterior of the spacecraft, that would allow NASA to perfect the art of the spacewalk and ultimately proceed with the Apollo lunar missions.

His PhD in astronautics, along with his flight experience, made him an ideal candidate for the Apollo 11 crew and, on 20 July 1969, Buzz became the second man to walk on the Moon after the late Neil Armstrong. It was actually Buzz who spoke the first words from the lunar surface, though, with him exclaiming "Contact light!" when the Lunar Module touched down. They spent several hours on the Moon, imaging the surface and collecting samples of lunar soil. When it was time to depart, Buzz accidentally broke a circuit breaker that would arm the main engine on the Lunar Module for lift-off. Buzz improvised and used a felt-tip pen to activate the switch, and they rendezvoused back with Michael Collins in lunar orbit for their return.

Interestingly, all previous EVAs had involved the commander remaining in the spacecraft while his partner ventured outside, which would have made Buzz the first man on the Moon. However, Apollo marked the first time the commander of a spacecraft, namely Neil Armstrong, performed an EVA before his subordinate because in the confined space of the Lunar Module Armstrong was seated closer to the hatch than Buzz.

Buzz resigned from active duty in March 1972 after 21 years of service, taking up a managerial role in the US Air Force. Since then he has made a variety of public appearances and published several books about his mission and space exploration in general, becoming an advocate for the continued expansion of space and missions to Mars. He remains highly regarded as one of the pioneers of space exploration, and will forever be revered for his fateful steps on the lunar surface. ■

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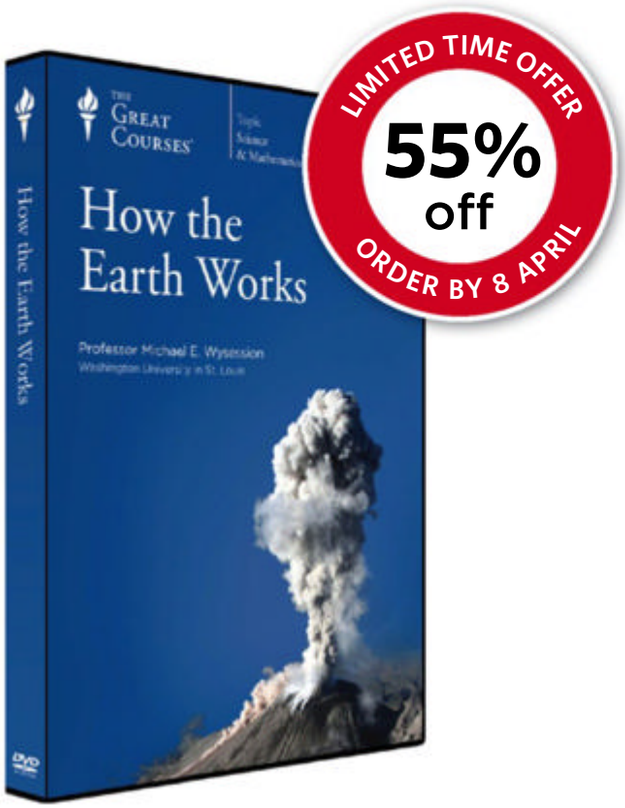
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