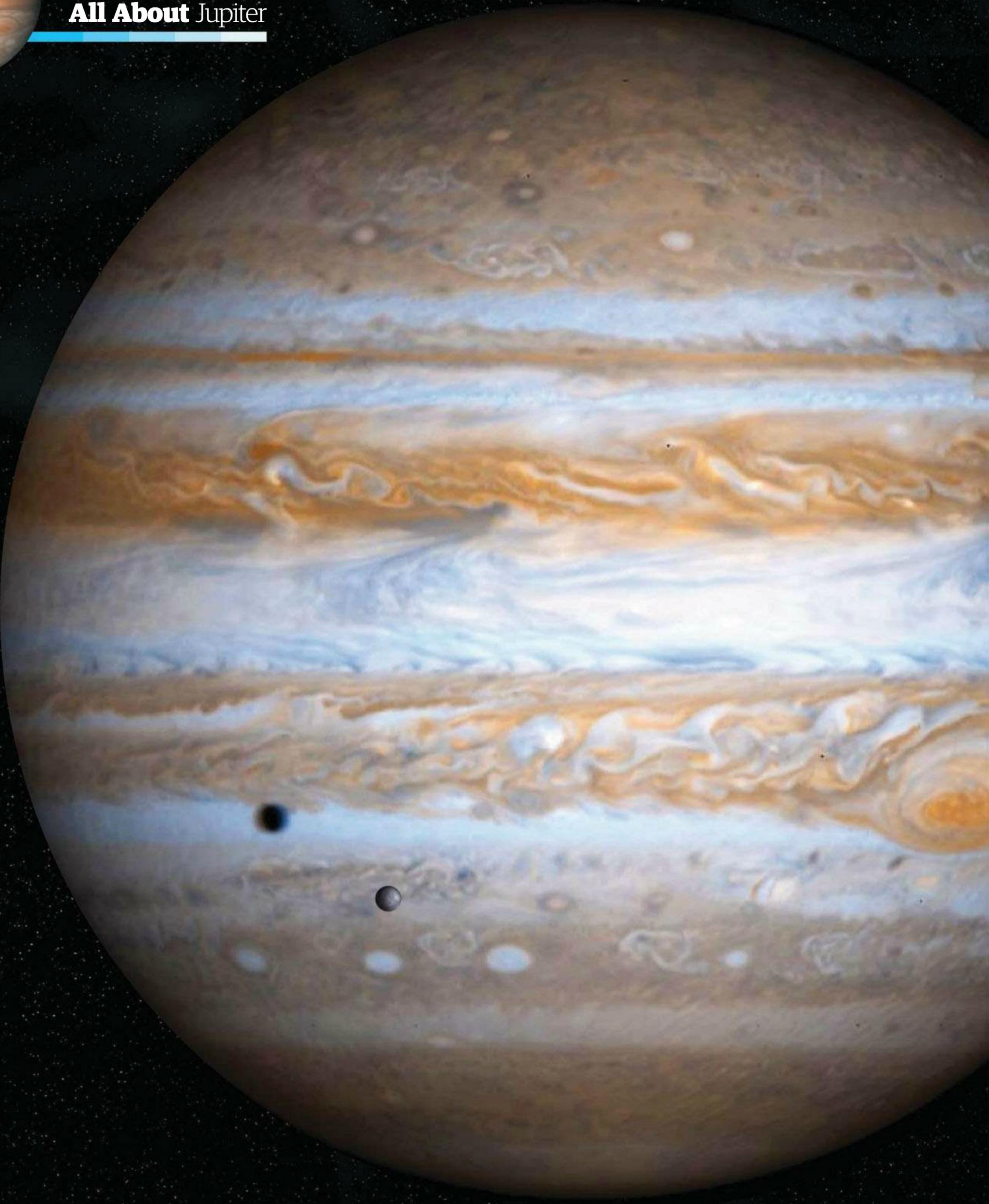


All About... JUPITER

Written by Shanna Freeman

Volatile and violent in nature and named after the Roman king of gods, the largest world in our Solar System has twice the mass of all other planets combined. Discover more about the gas giant that is king of the planets

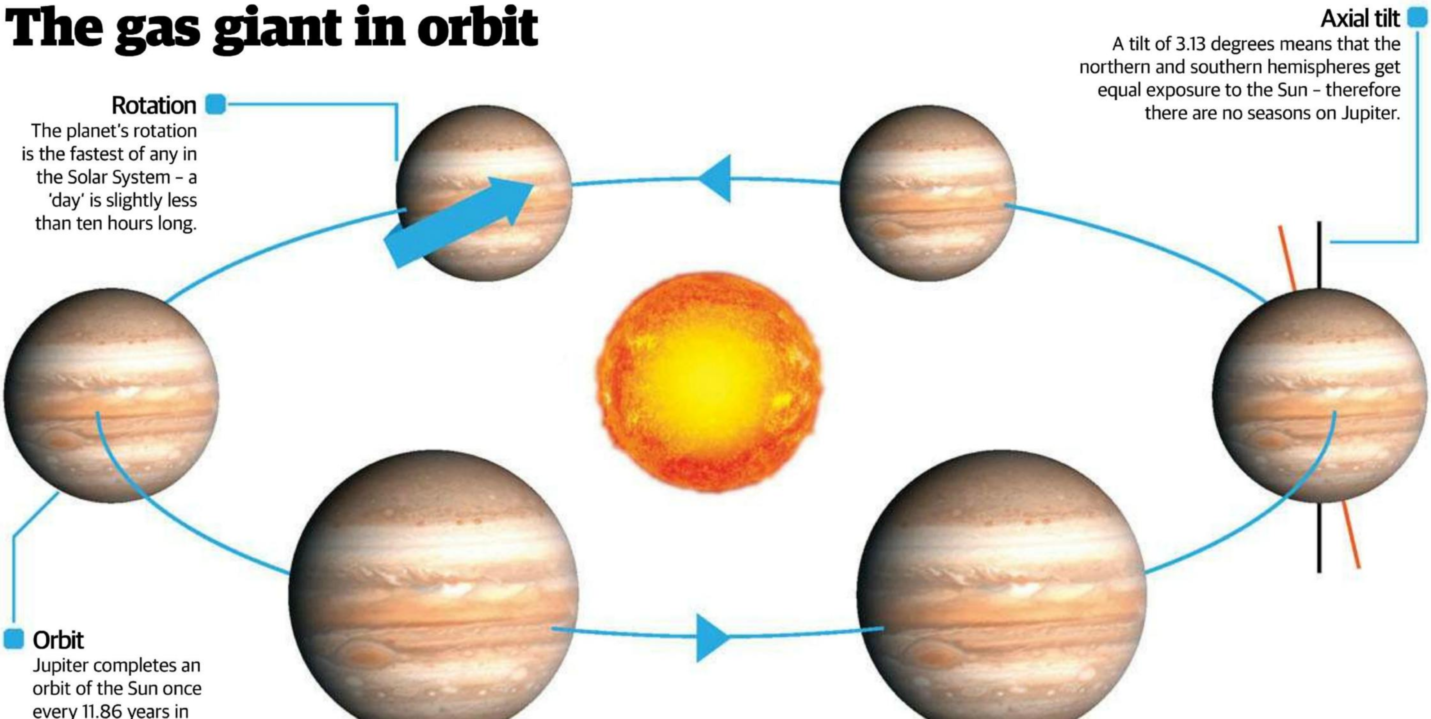
If you had to choose just one word to describe Jupiter, it would have to be 'big'. It has a diameter of 142,984 kilometres (88,800 miles) at its equator, about 11 times that of Earth's diameter. As the largest planet, with a huge magnetic field and 64 moons and natural satellites, Jupiter could almost be a miniature solar system. Sometimes it's even been referred to as a 'failed star' because it's made of the same gases as the Sun – although it doesn't have anywhere near the mass or temperature to actually be a star. Jupiter would need a mass about 80 times that of its current one, and that's never going to happen. But 'star' is how the ancients thought of it, at least until Galileo noticed that the planet had four prominent moons – Callisto, Europa, Ganymede and Io – that moved around it. It was the first time movement in the Solar System not centred on Earth was discovered, which helped cement Copernicus's theory of a heliocentric – or sun-centred – astronomical model.

Jupiter is the innermost of the four gas giants, along with Saturn, Uranus and Neptune – planets that mainly comprise gas and are also more than ten times that of Earth's mass. The gases get denser as you get closer to the planet's core. Since Jupiter is the largest – the next-largest is Saturn with a diameter of 120,536 kilometres (75,000 miles) – it's not surprising that these gas giants are also called the Jovian planets. Jupiter's mass is 317.8 times that of Earth's and 0.001 times that of the Sun's; sometimes planets outside the Solar System are defined in terms of Jupiter's mass because it's so large. What's amazing is that Jupiter was actually larger when it was first formed – it's been shrinking about two centimetres (0.8 inches) per year due to its heating and cooling process. Jupiter's so massive that its barycentre – or centre of mass with the Sun – lies outside the Sun at 1.068 solar radii above its surface. Although Jupiter is large in diameter and mass, it's not very dense thanks to its gaseousness. Jupiter has a density of 1.33 grams per cubic centimetre, which is about 25 per cent that of Earth's density.

Jupiter is 779 million kilometres (484 million miles) from the Sun on average, completing an orbit once every 11.86 years. This is two-fifths the orbit of Saturn, putting the planets in an orbital resonance of 5:2. It has a very small axial tilt of just 3.13 degrees, so there are no seasons on the planet. It has the fastest rotation of all the planets, taking a quick spin on its axis once every ten hours or so. This gives the planet a bulge around its equator and the shape of an oblate spheroid – it has a larger diameter around its centre than its poles. Because Jupiter is a gas

> "With a huge magnetic field and 64 moons it could almost be a miniature solar system"

The gas giant in orbit



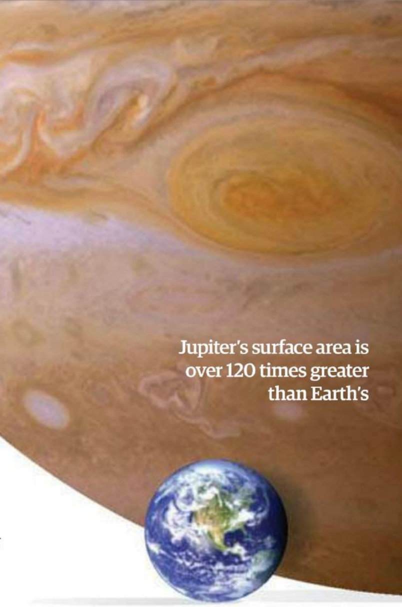
The planets in relation to the Sun

All figures = million miles from Sun

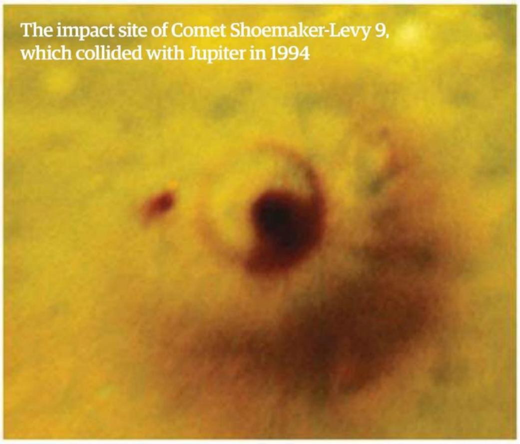
Jupiter lies 779 million km (484 million miles) from the Sun on average, and 629 million km (391 million miles) from Earth

planet, not all of the planet orbits at the same speed. It basically has three different systems – the atmosphere at the poles rotates about five minutes faster than the equatorial atmosphere, which is a little bit slower than the rotation of the magnetosphere (it clocks in at just under ten hours, the official rotation period).

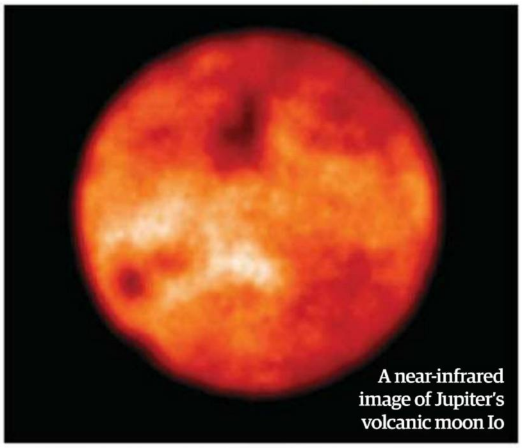
Jupiter is about more than just its size, of course. It has a very striking and unusual appearance, with moving bands of red, orange, white and brown. The planet is the fourth-brightest object in our night sky. If you do some long-term observation of Jupiter, you might notice that at some point it appears to move backwards, or in retrograde, with respect to the stars. That's because the Earth overtakes Jupiter during its orbit once every 398.9 days. You'll also see that Jupiter never appears completely illuminated – its phase angle, the angle of the light reflected from the Sun, is never greater than 11.5 degrees. To see the entire planet, we had to visit it. ●



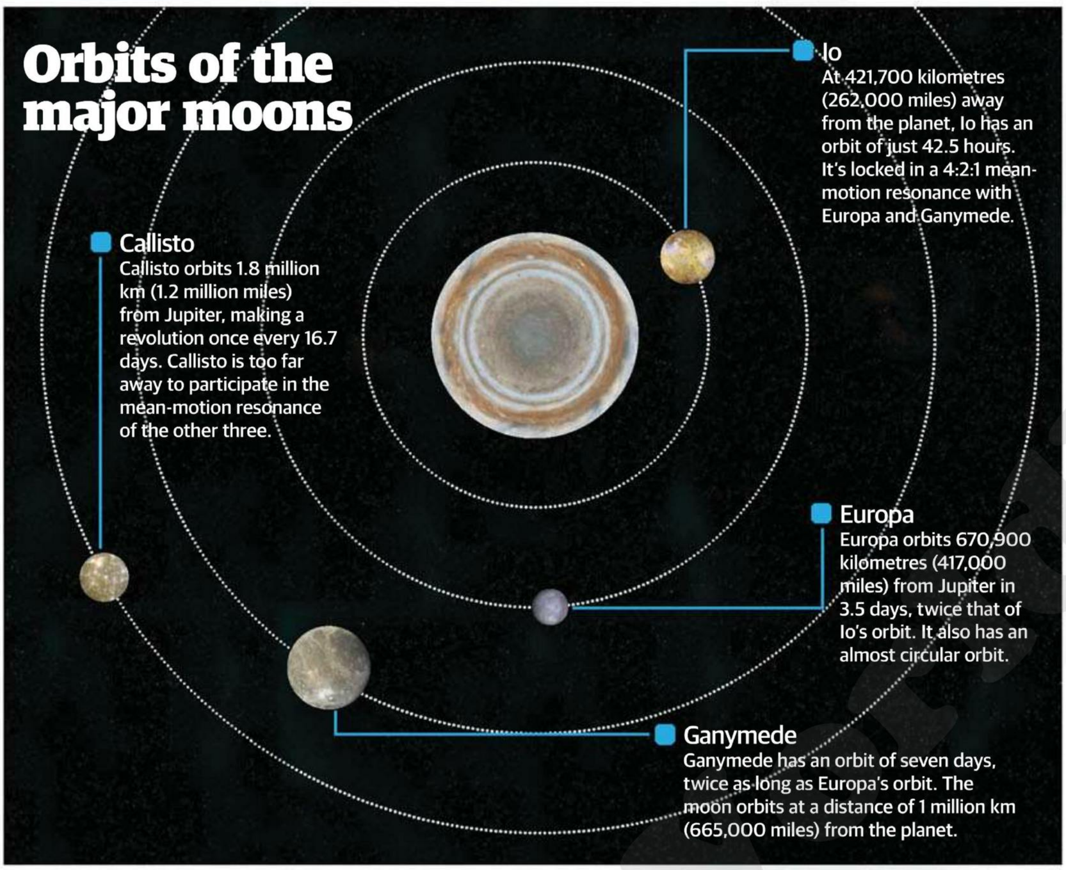
Jupiter's surface area is over 120 times greater than Earth's



The impact site of Comet Shoemaker-Levy 9, which collided with Jupiter in 1994



A near-infrared image of Jupiter's volcanic moon Io



The Galilean moons

Io

Io is the innermost of the Galilean moons, and also the fourth-largest moon in the Solar System at 3,642 kilometres (2,200 miles) in diameter. Unlike most moons, Io is mainly silicate rock and has a molten core. That's probably why it has more than 400 active volcanoes, making it the most volcanically active body – moon or planet.

Europa

The second-closest Galilean moon to Jupiter, Europa is also the smallest of the four moons. It's slightly smaller than our own Moon with a diameter of around 3,100 kilometres (1,940 miles). It has a smooth surface of ice and probably has a layer of liquid water underneath, leading to theories that life may be able to exist on this moon.

Ganymede

Ganymede is the largest moon in the Solar System – at 5,268 kilometres (3,300 miles), it's actually larger than the planet Mercury, although it has half the mass. This moon is also the only known moon with a magnetosphere, probably due to a liquid iron core. This moon also comprises both ice and silicate rock, and it's believed that there may be a saltwater ocean below the surface.

Callisto

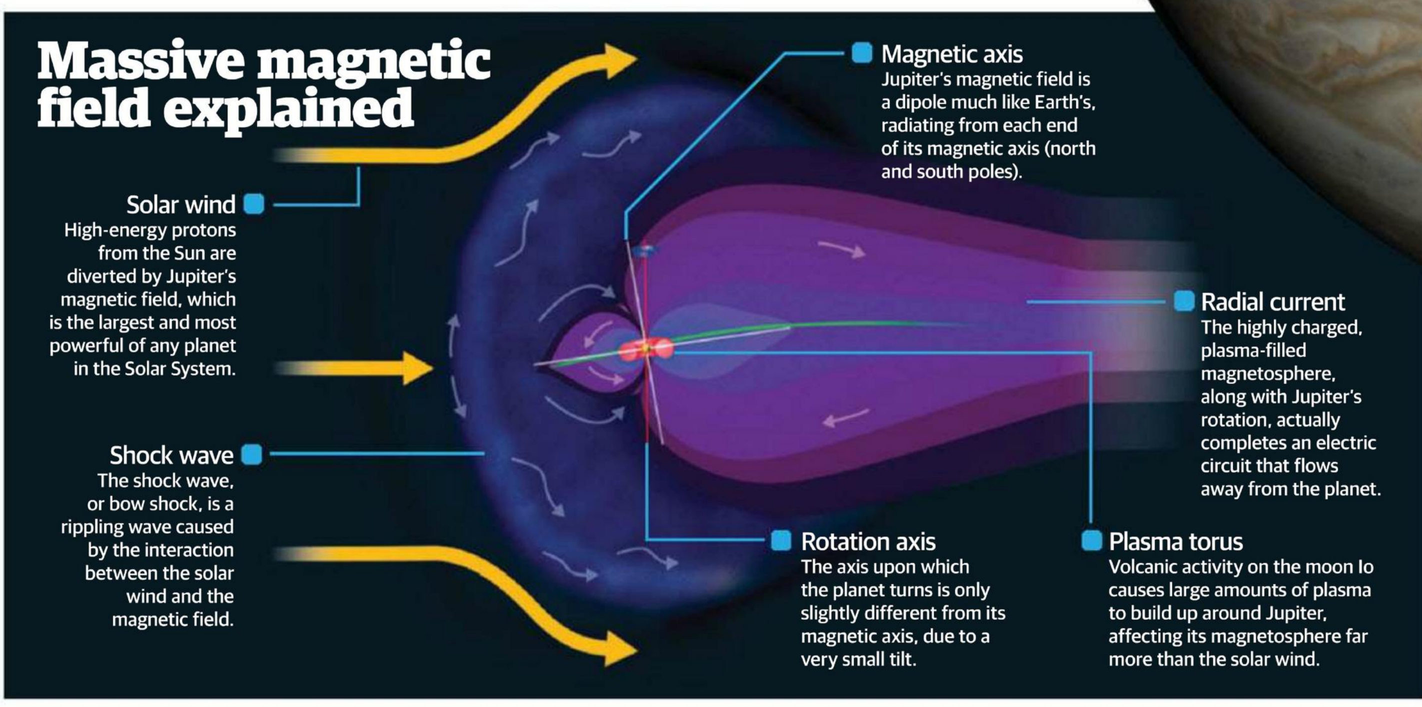
Being the outermost Galilean moon, Callisto is furthest from Jupiter and its strong radiation and therefore might be a good base for exploring the planet. The moon is composed equally of water-ice and rock, and there's also the possibility that it may be able to support life. It has a heavily cratered surface as well as a thin atmosphere, which is most likely composed of oxygen and carbon dioxide.

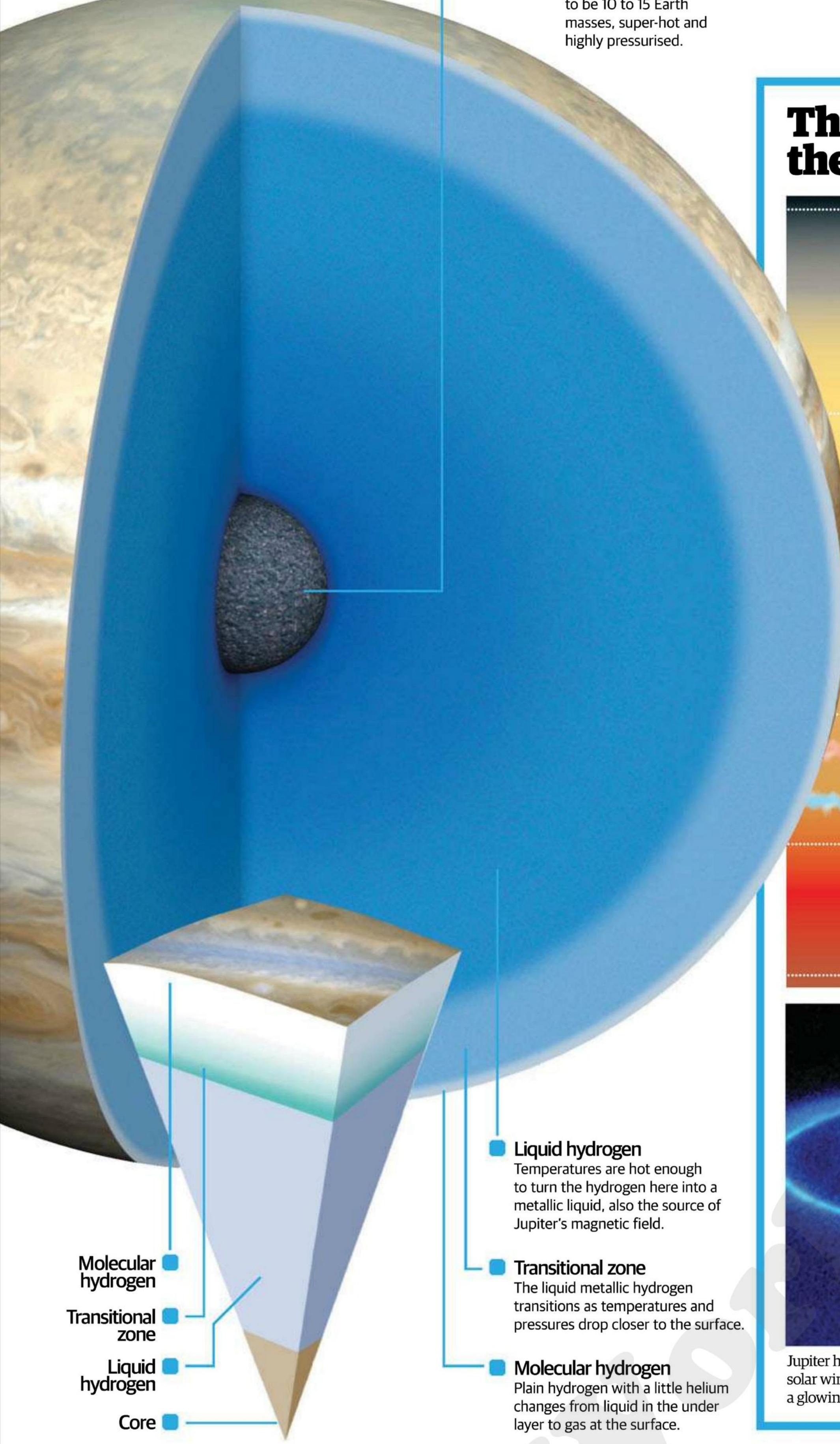
Jupiter inside and out

A rocky core surrounded by liquid metallic hydrogen, Jupiter gets more interesting the closer you get to its centre

Since Jupiter is a gaseous planet, it's mostly about atmosphere. The gases just get denser, hotter and under greater pressures as you go further towards the centre. Jupiter is about 90 per cent hydrogen and ten per cent helium – volume-wise. But if you measure the composition of the planet by mass, there's 75 per cent hydrogen and 24 per cent helium. There are also traces of ammonia, methane, carbon, hydrogen sulphide and other elements and compounds. We don't know that much about the interior because no probe has penetrated the cloud cover below 150 kilometres (93 miles). But we do think that Jupiter isn't entirely gaseous; we believe it has a rocky core containing silicates and other elements, with a mass that is 10 to 15 times that of Earth's mass. The concept of a rocky core is based on gravitational measurements taken by probes, but this model is very uncertain until we get more data from NASA's Juno mission (set to enter Jupiter's orbit in 2016). Current projections for the interior show a layer of liquid metallic hydrogen along with helium surrounding the core, with a layer of molecular hydrogen outside. There is no actual boundary between the liquid and gaseous layers, however.

Temperatures on Jupiter vary widely. In the cloud layer, they are very cold at -145 degrees Celsius (-234 degrees Fahrenheit). As you move further towards the core, as the hydrogen becomes liquid, the temperature reaches 9,700 degrees Celsius (17,500 degrees Fahrenheit), and the core may be as hot as 30,000 degrees Celsius (54,000 degrees Fahrenheit). The planet is thought to have been much hotter and also much bigger – as much as twice its current diameter – when it first formed. Jupiter generates almost as much heat on its own as it receives from the Sun, via a process called the Kelvin-Helmholtz mechanism. The surface cools, which also results in a loss of pressure. The whole planet shrinks, which compresses the core and causes it to heat up. The pressure at the core may be up to 4,000 GPa (gigapascals). By comparison the Earth's core is at a pressure of 360 GPa. The pressure inside Jupiter is so intense that some scientists believe that the core may actually be gradually liquefying.





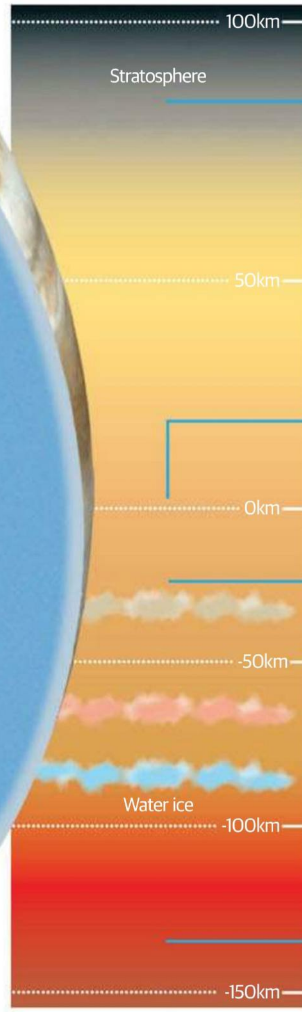
Core
This rocky core is believed to be 10 to 15 Earth masses, super-hot and highly pressurised.

Liquid hydrogen
Temperatures are hot enough to turn the hydrogen here into a metallic liquid, also the source of Jupiter's magnetic field.

Transitional zone
The liquid metallic hydrogen transitions as temperatures and pressures drop closer to the surface.

Molecular hydrogen
Plain hydrogen with a little helium changes from liquid in the under layer to gas at the surface.

The structure of the atmosphere

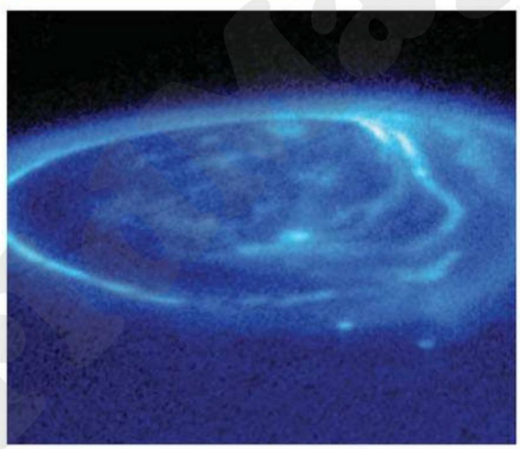


Stratosphere
The stratosphere is still mostly hydrogen, with methane, ethane, acetylene and other light hydrocarbons.

Haze layer
Above the cloud layer there's a layer of hydrazine haze, made by interactions between ultraviolet radiation from the Sun and methane in the stratosphere.

Troposphere
The upper clouds are the lightest, of ammonia, and get denser as they change to ammonium hydrosulphide, then to water.

Gas layer
The 'surface' of the planet is defined by pressure and temperature – both begin to drop as the gases dissipate.



Jupiter has auroras just like Earth – charged particles from the solar wind interact with the planet's magnetic field, resulting in a glowing display

In the clouds

It might not have a surface, but the clouds of Jupiter are a fascinating phenomena

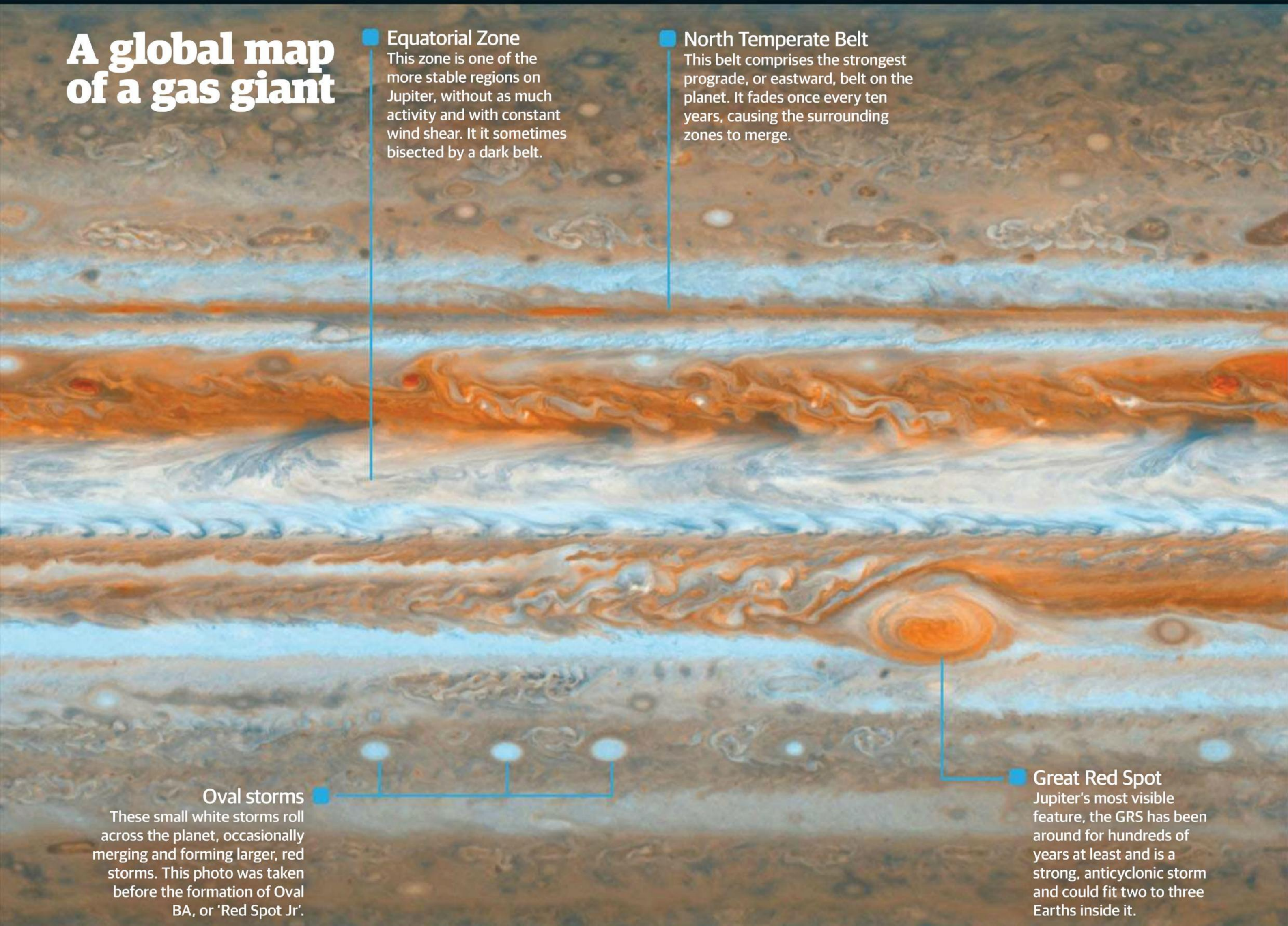
The colours visible in photos of Jupiter are a result of the different layers of clouds in the planet's atmosphere. The cloud layers aren't static, either - they move and flow in complex patterns. The approximately dozen lines are called bands, and there are two different kinds: the lighter-coloured areas are known as zones, while the dark-coloured ones are called belts.

Zones comprise dense, ammonia ice clouds in higher areas and are colder, while the dark belts contain thinner, lower, warmer clouds. Their red and orange colours come from sulphur and phosphorous, while carbon may create some of the lighter grey colours.

The equator is circled by a zone, known as the Equatorial Zone (EZ), that stretches from seven degrees north and seven degrees south of the equatorial line. There are dark Equatorial Belts (EB) extending from the EZ at 18 degrees north and south on either side. Tropical zones are on either side of each EB. The zones and belts then alternate until reaching each of the poles, where they become more difficult to distinguish. None of them have perfect boundaries. Many of the belts and zones have names, each with distinctive features and movements. While most have remained fairly constant for as long as we've been observing and recording them, there are both temporary and permanent changes in things like features, appearance and wind speed. Sometimes the Equatorial Zone is bisected by a dark band, and irregular dark areas known as 'hot spots' can come and go.

Each belt is surrounded by wind jets, called zonal atmospheric flows. The transitional areas from the belts to the zones (headed towards the equator) are marked by westward, or retrograde jets. Eastward, or prograde jets, mark the transitions from zones to belts heading away from the equator. These are more powerful than the retrograde jets, and can reach speeds of up to 100 metres per second or 328 feet per second (360

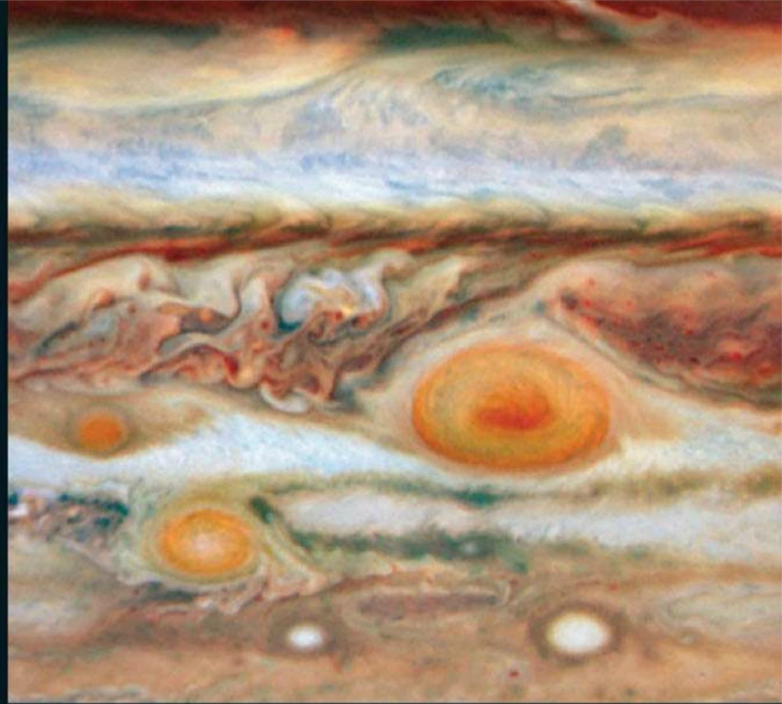
A global map of a gas giant



kilometres per hour or 224 miles per hour). In the belts, the wind shear is cyclonic – the air flows in the same direction as Jupiter's rotation. Zone wind shear, however, is anticyclonic. The exception to these rules is the Equatorial Zone – it has a prograde jet with very little movement right along the equator.

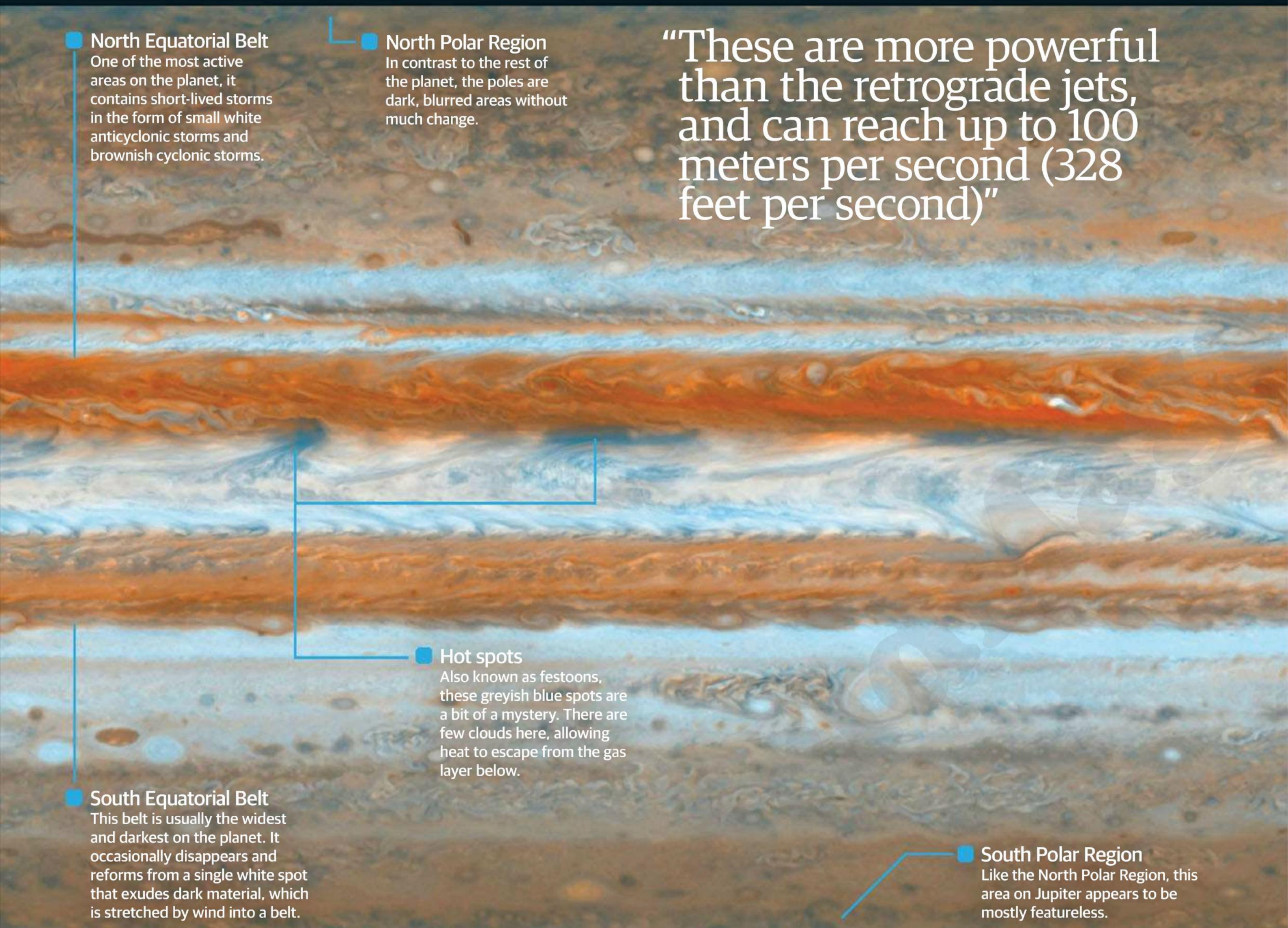
We do not yet know exactly how deep the jets go, but we do know that they exist as far down as the Galileo probe was able to measure, about 150 kilometres (93 miles) below the top of the clouds. We're also not sure what causes this band structure on Jupiter, but one theory is that the belts are areas of downwelling (higher density material sinking beneath lower density material), while the zones are areas of upwelling. The ice clouds rich in ammonia cool and expand, causing the dense light-coloured clouds in the zones. In the belts, the same clouds warm and eventually evaporate. This allows the darker, mineral-laden clouds below to show through.

While Jupiter doesn't have seasons because of its small axial tilt, it does have weather patterns. The evaporation and condensation process of water creates dense clouds. These are strong storms, including powerful lightning strikes, mainly in the belts. Most storms on Jupiter tend to be very short, but there are a few major storms that have been raging for a long time. The biggest and most well-known of these is the Great Red Spot, which has been around for a minimum of between 180 and 300 years, and there's also the Oval BA storm (which is sometimes referred to as 'Red Spot Jr').



The Great Red Spot and Oval BA got some company in 2008 when small white oval storms merged and formed a new red spot (on the far left). Its appearance may mean that Jupiter is undergoing climate change and warming near its equator

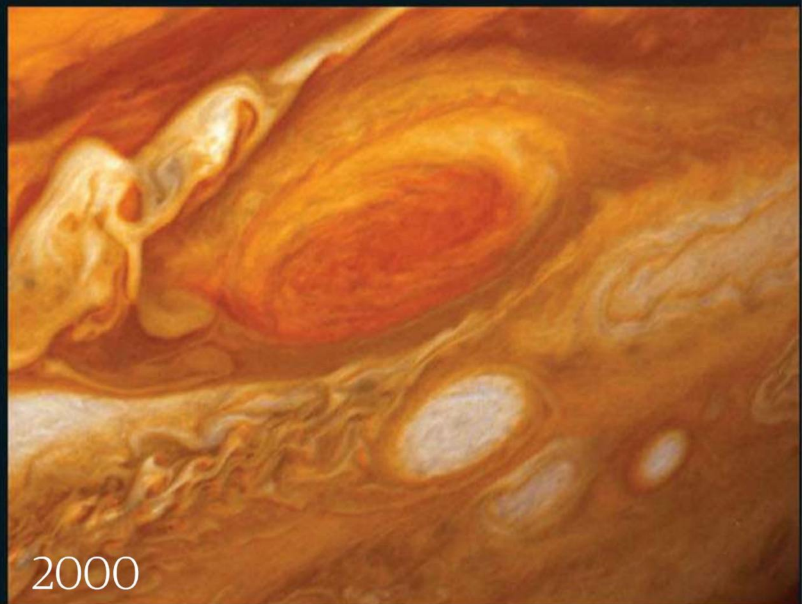
"These are more powerful than the retrograde jets, and can reach up to 100 meters per second (328 feet per second)"



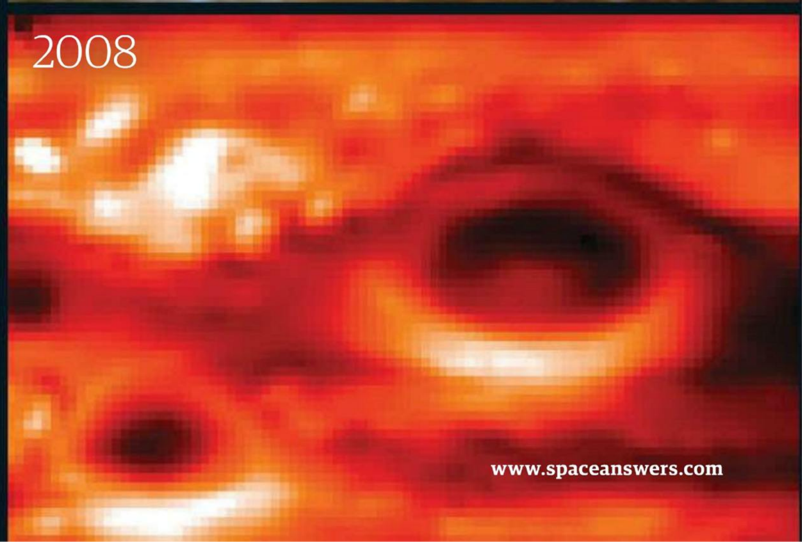

1979


1996


1999


2000


2006


2008

The changing Great Red Spot

A storm with the circumference of Earth that's raged for centuries

Sometimes our storms seem like they're never going to end, but imagine a storm that's been going for hundreds of years. The Great Red Spot is a dark red, anticyclonic storm with high pressure.

It is currently between 12,000 and 14,000 kilometres (7,500 to 8,700 miles) wide north to south and 24,000 to 40,000 kilometres (15,000 to 25,000 miles) east to west. Some data suggests that it was originally much bigger, but its shrinkage doesn't mean that it's disappearing.

The clouds that make up the GRS are higher – at least eight kilometres (five miles) – and therefore colder than the surrounding clouds. Its darkest, reddest area in the centre is significantly warmer than the rest, and actually has a mild clockwise rotation. The colours of the GRS vary wildly – sometimes they're strong, dark reds and oranges, other times, it gets so pale that it disappears, leaving a sort of niche behind in the South Equatorial Belt until it reappears. The colour is linked to that of the SEB – when the GRS is darker, the SEB tends to be lighter, and vice versa. Why has the Great Red Spot lasted so long? We can't be sure, but one theory is that it's continually powered by the intense heat from the planet, there's no landmasses or other formations to disrupt it. It has also absorbed smaller storms in the past.

1979
Taken by Voyager 1, this image of the GRS shows details of the storm's cloud patterns. The wavy pattern on the left is due to variable wave motion. The white spot visible has a diameter roughly equivalent to Earth's.

1996
Another white storm in this image trails along with the GRS, which is at a more elongated and salmon-coloured stage. Note that the equatorial belt in which it resides is about the same colour.

1999
The storm and its belt are still about the same colour, but the GRS appears to be getting darker and the belt, lighter. This image also shows two of the three white spots that would eventually become the Oval BA.

2000
This Hubble image shows a darker and more compact GRS. It also features the Oval BA, or 'Red Spot Jr.' A similar merger centuries ago may have created the original GRS.

2006
This image taken by Hubble shows a darker and more compact GRS. It also reveals the Oval BA.

2008
Obtained by the VLT, this image was taken in an infrared wavelength which is sensitive to Jupiter's atmospheric temperatures in the 300 to 600 millibar pressure range.

A hidden ring system

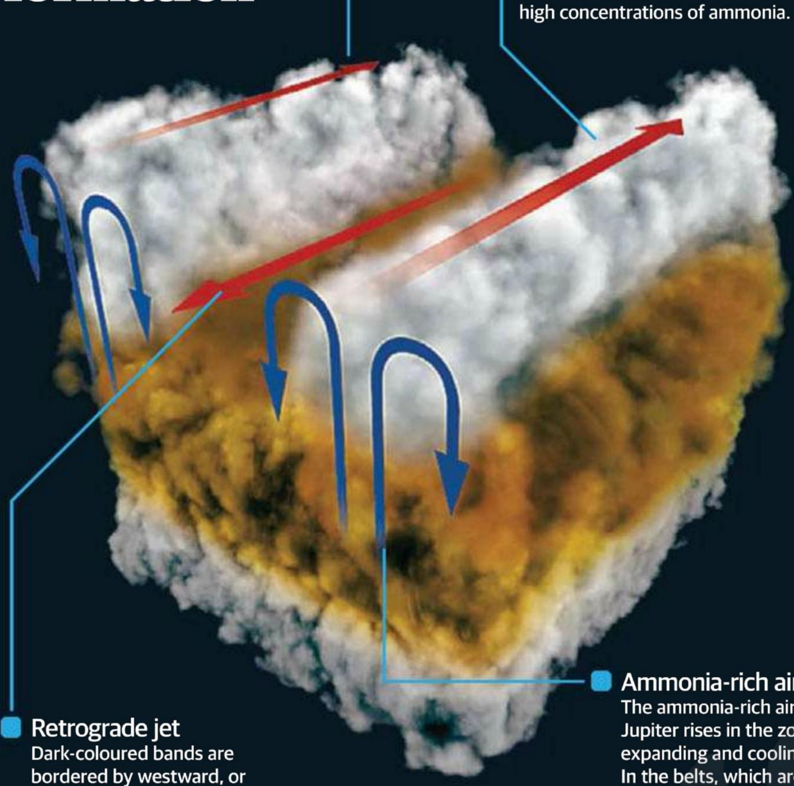
When it comes to rings in our Solar System, Uranus and Saturn get all the attention. But it turns out that Jupiter has a ring system of its own. It was first discovered by the Voyager 1 probe in 1979, while Galileo revealed more about the rings in the Nineties.

The Jovian ring system consists mainly of dust and has four main components. The two outer rings are wide, faint and named after the moons that connect them. The Thebe gossamer ring is 97,000km (60,300 miles) wide and has a radius of 129,000km (80,200 miles) to 226,000km (140,400 miles), while the next ring is the Amalthea gossamer, with a width of 53,000km (32,900 miles) and a radius of 129,000km (80,200 miles) to 182,000km (113,000 miles).

The main ring is the thinnest, but also the brightest. It has a radius of 122,500km (76,100 miles) to 129,000km (80,200 miles) and is just 6,500km (4,000 miles) wide.

The inner ring is a halo at 30,500km (18,600 miles) wide and with a radius of 92,000km (57,200 miles) to 122,500 km (76,100 miles). While the other rings look reddish, the halo ring appears blue and is the thickest ring. The other rings are made up of particles coming off the tiny moons located within them, while the halo ring is likely formed from particles sucked towards the planet from the main ring.

Cloud formation



Jupiter by numbers

Fantastic figures and surprising statistics about the gas giant

1,321

This is how many Earths could fit inside Jupiter

2.4 times

How much more you would weigh on Jupiter if you could stand on it, due to its stronger gravity

64

Of Jupiter's 64 natural satellites, most of them measure less than five kilometres (3.1 miles)

1st

The Galilean moons of Jupiter were the first objects in the Solar System discovered by telescope

318 times

The mass of Jupiter is 318 times greater than the mass of Earth and 2.5 times that of all the other planets in our Solar System combined

50km

The thickness of the clouds and storms on the planet

Exploring a gas giant

Sending back pictures from the outer Solar System

Although we've been observing the gas giant since the time of the ancient Babylonians, we only really began to learn about the planet's wonders when NASA sent the Pioneer 10 space probe to take a closer look in 1973.

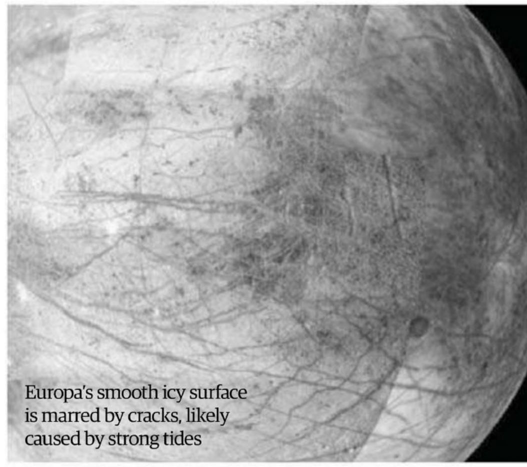
The probe became the first spacecraft to traverse the asteroid belt and upon getting close to Jupiter, it began sending back the most detailed images of the planet that we had ever seen. They were being shown in real time back on Earth, and it was so impressive that NASA would later win an Emmy for its presentation. Pioneer 10 also sent back images of the Galilean moons Europa and Ganymede, although they were blurry and not as detailed due to the distance. The closest Pioneer 10 got to the planet was 132,252 kilometres (82,000 miles), at which time it took detailed, close-up images of the Great Red Spot. Communication between Earth and Pioneer 10 was eventually lost in 2003 with the probe at a distance of 12 billion kilometres (7.5 billion miles) from Earth. Pioneer 11, launched a little over a year after Pioneer 10, came even closer to the planet at 42,828 kilometres (26,600 miles) and took a number of even more detailed images.

Voyagers 1 and 2, which launched in 1977, made some important discoveries and brought us even better images (see the 'Flight of the Voyager' boxout). However, the most significant Jovian mission to date has been NASA's Galileo – the first and only spacecraft to orbit the planet. Launched in 1989, Galileo not only vastly expanded our knowledge of Jupiter and its moons from orbit, but it also sent a probe down through the atmosphere. The probe revealed more details about the planet's complex cloud system, and also the huge scale of its thunderstorms. Galileo showed that the volcanoes on Io are more active than those on Earth. Ganymede was found to have a magnetic field, and both Europa and Callisto are now believed to have oceans underneath their surfaces as a result of data from Galileo. The mission lasted until 2003 when Galileo was destroyed in a controlled impact with Jupiter.

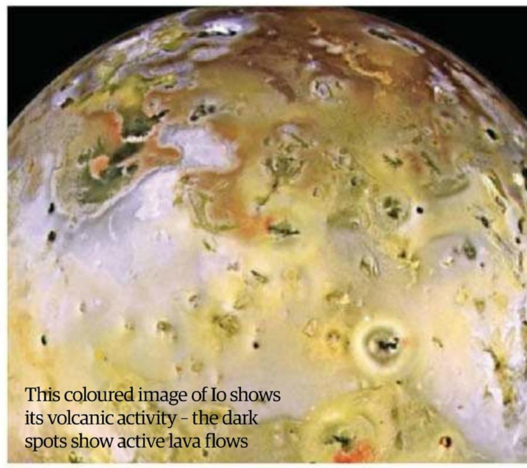
In 2000, the Cassini-Huygens probe, on its way to Saturn, took the time to capture more than 25,000 images of Jupiter, including the most detailed colour image ever taken. Cassini also made some important discoveries about cloud circulation in the planet's belts and zones. The New Horizons probe, on its way to Pluto, made a stop in 2007 and sent back more images and info. NASA's current mission is the probe Juno. Launched in 2011, it is scheduled to enter Jupiter's orbit in 2016.

"Galileo not only vastly expanded our knowledge of Jupiter and its moons from orbit, it also sent a probe down through the atmosphere"

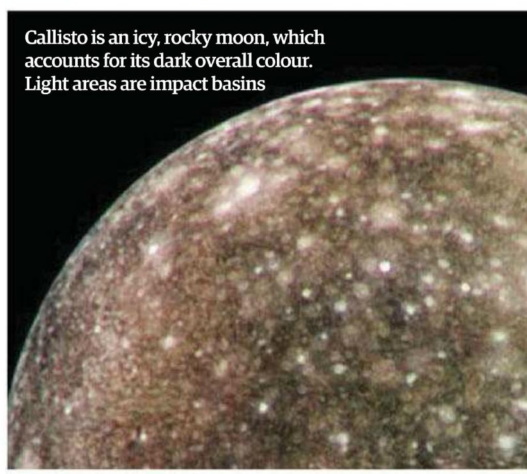
The darker areas on Ganymede are heavily cratered, while the lighter ones show more recent impacts



Europa's smooth icy surface is marred by cracks, likely caused by strong tides



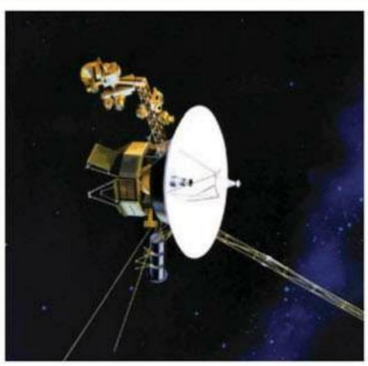
This coloured image of Io shows its volcanic activity – the dark spots show active lava flows



Callisto is an icy, rocky moon, which accounts for its dark overall colour. Light areas are impact basins

Flight of the Voyager

Comprising two different probes, Voyager 1 and Voyager 2, NASA's Voyager programme was launched in 1977. The launches were timed to take advantage of a favourable alignment between the planets that only happens once every 177 years, allowing a single probe to visit Jupiter as well as Saturn, Uranus and Neptune. Voyager 2 was launched first, on 20 August 1977. It came within 570,000km (350,000 miles) of Jupiter on 9 July 1979 and set about making some important discoveries, such as volcanic activity on Io, the ring system and some new moons. Voyager 1 began sending back photos in 1979. These images revealed details of Jupiter's radiation belts, its rings and the Great Red Spot.



Galileo – the first to orbit Jupiter

Mission Profile

Galileo

Mission dates: Launched October 1989; deorbited 21 September 2003

Goals: Study the planet Jupiter and its moons. Measure the atmospheric composition and its magnetosphere for two years.

Findings: Imaged Galilean moons, supporting theories for liquid oceans under the surface of Europa, Ganymede and Callisto. Galileo discovered that Jupiter's faint ring system consists of dust from impacts on the four small inner moons.