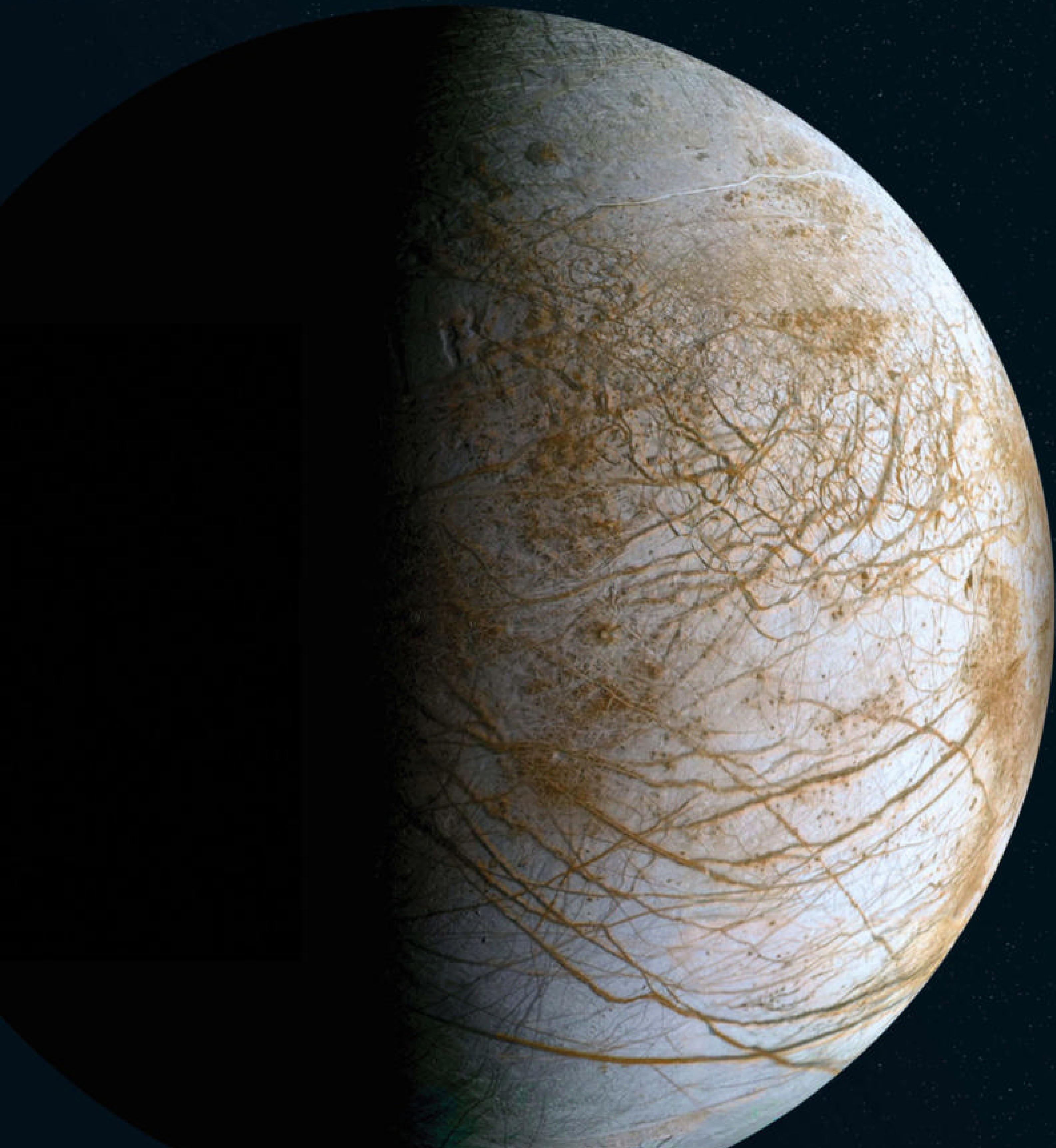


All About... EUROPA

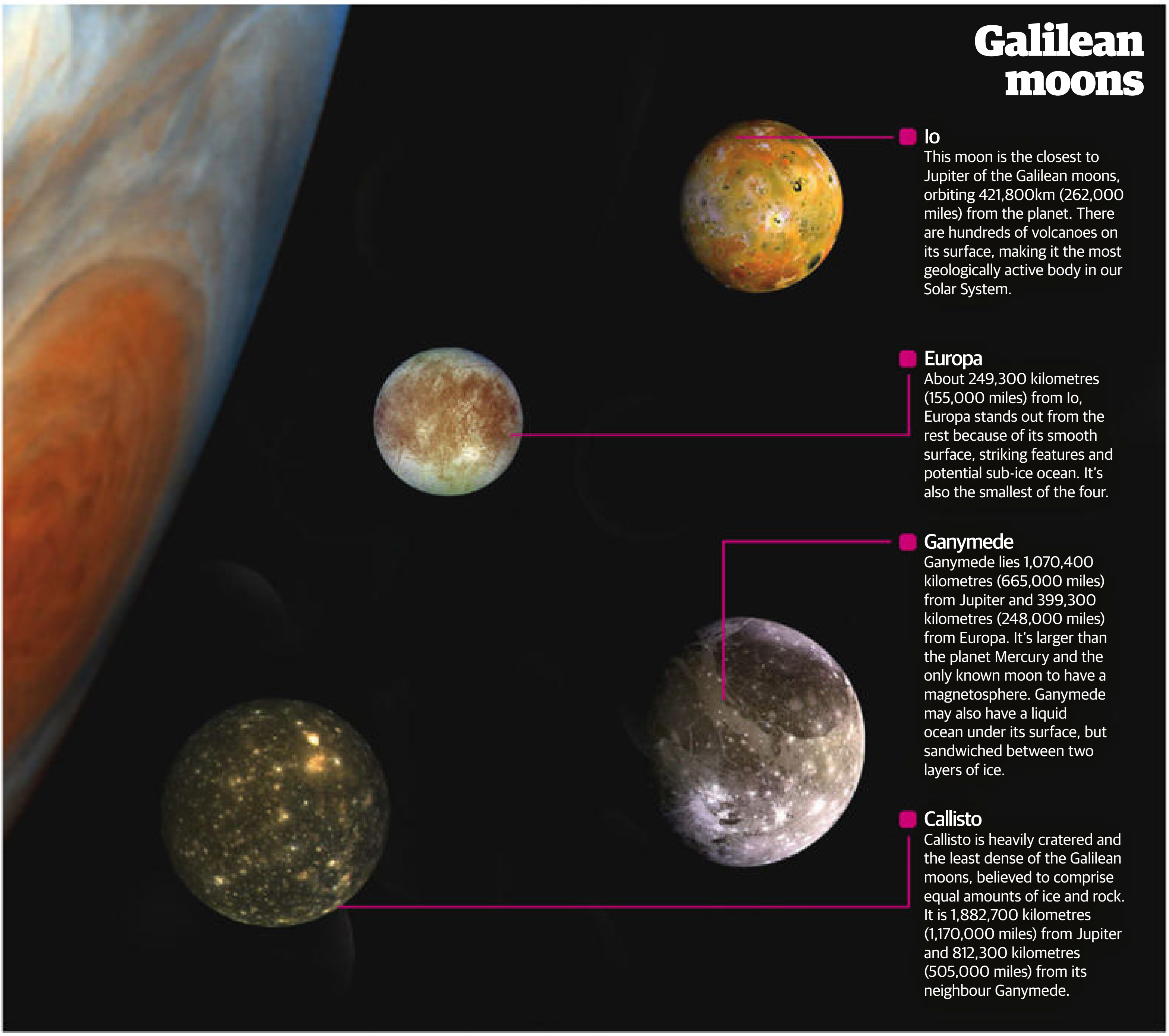
Written by Shanna Freeman

This striking Jovian moon seems like a wasteland of ice, but may be capable of supporting life beneath its frozen exterior

Jupiter has more confirmed moons than any other planet in the Solar System, with 67 natural satellites. However, just four moons make up more than 99 per cent of the total mass. These are the Galilean moons, so-named after their discoverer, Galileo Galilei. The smallest of these four, Europa, is Jupiter's sixth-closest moon. It's just a bit smaller than our Earth's Moon, with a diameter of 3,122 kilometres (1,940 miles). Europa's volume is 0.015 that of Earth's, and its mass is 0.008 of Earth's. It may not be large, but it looms large in astronomical circles for more than a few reasons. Visually, the moon captures attention for its smooth, marbled appearance – mostly bluish white, with reddish orange streaks and splotches – due to tidal flexing, a phenomenon caused by gravitational forces from the bodies around it. Tidal flexing is also the potential cause for a liquid water ocean beneath the young and active surface.

The moon has an orbital radius of 670,900 kilometres (417,000 miles) and takes about 3.5 Earth days to make its circuit around Jupiter as well as rotate on its axis. Its orbit is mainly circular, with an eccentricity of 0.0094 (compared to our Moon's 0.0549). Europa is tidally locked to Jupiter, with the same side facing the gas giant at all times. There is a sub-Jupiter point on the surface of the moon, so that if you were standing on it, it would appear that the planet is hanging directly above you. However, some researchers believe that the relationship between Jupiter and Europa isn't a full tidal lock. There's evidence that Europa rotates faster than its orbit, or at least it used to – the icy crust of the moon may rotate faster than its interior. It also has an iron core, a rocky mantle and a liquid ocean under the crust. There's evidence of a weak magnetic field that can vary wildly as the moon passes through Jupiter's strong magnetic field.

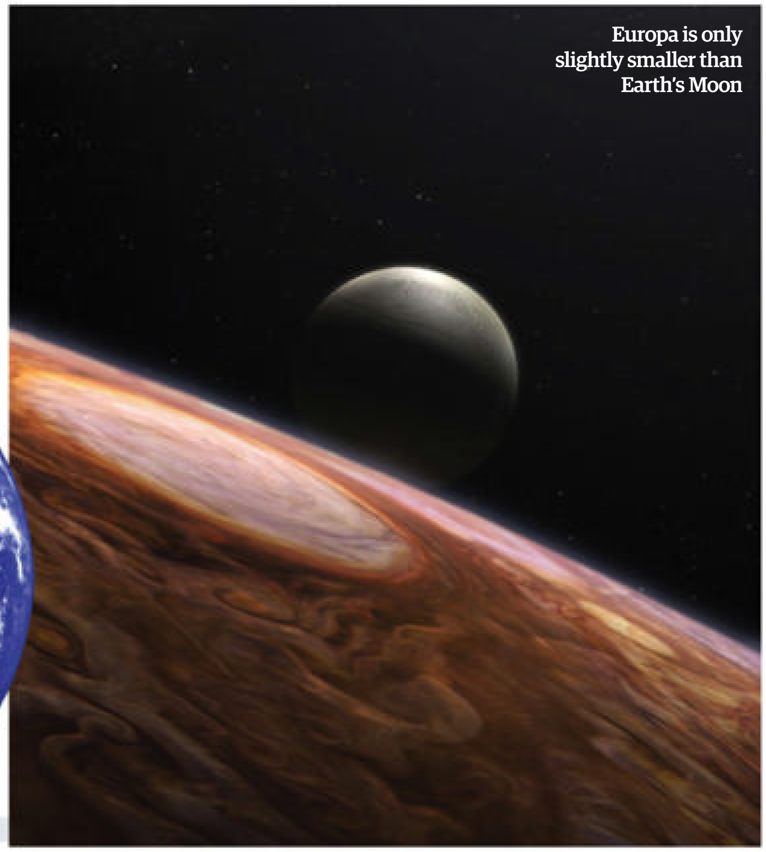
> "Europa's subsurface ocean has intrigued researchers due to its potential to harbour extraterrestrial life"



This ocean has intrigued researchers due to its potential to harbour extraterrestrial life, and yet we didn't really know much about the moon at all until the Galileo spacecraft arrived in the mid-Nineties. There's also some thought that humans could colonise the moon, although at first it doesn't seem likely. Europa doesn't seem to be very hospitable – it's very far from the Sun, so temperatures don't reach higher than -160 degrees Celsius (-260 degrees Fahrenheit) at the equator and -220 degrees Celsius (-370 degrees Fahrenheit) at the poles. It also has a thin atmosphere of mostly oxygen, and radiation levels high enough to kill a person in a day. But perhaps we could use the ocean for drinking water and extract its oxygen for breathing – both issues that serve as roadblocks to colonising other planets and moons. There's even been speculation about building a base underneath the crust to use the ice as a radiation shield. Before seriously entertaining the idea of extraterrestrial life or living on the moon, we have to return to it – but that's not scheduled to happen for another decade or so.

Size and mass

Although Europa is a shade under a quarter of the size of Earth, Earth is over 100 times more massive.

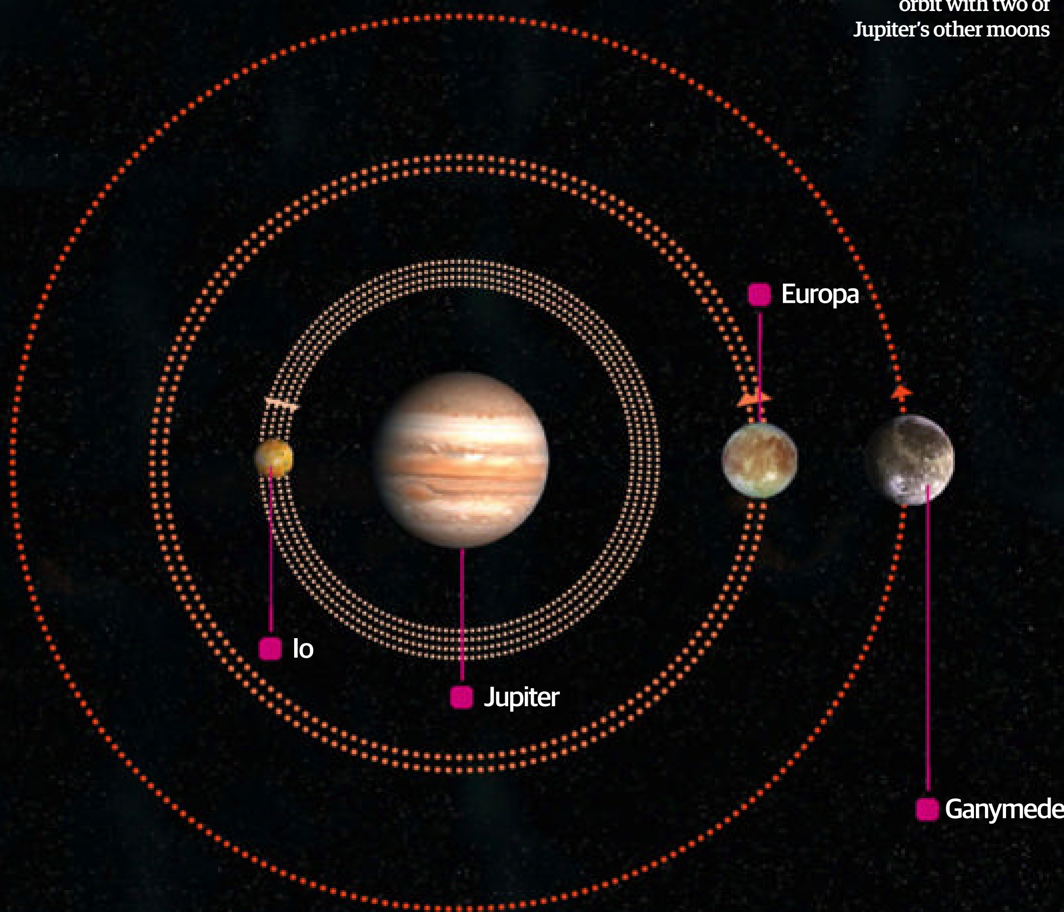


Europa is only slightly smaller than Earth's Moon

Orbital resonance

Europa is in an orbital (Laplace) resonance with both Ganymede and Io. This means that these three moons are exerting a regular gravitational influence on each other because their orbits are related to each other by a small integer (non-fractional) number. These three moons are in what's known as a Laplace resonance, because they have a simple integer ratio between them. In order, Ganymede, Europa and Io are in a 1:2:4 ratio. For every orbit of Ganymede, Europa orbits twice and Io orbits four times. The gravitational pull from this resonance distorts each moon's orbit into an ellipse, while the pull from Jupiter tries to make the orbits circular. This flexing action causes tidal heating in each moon.

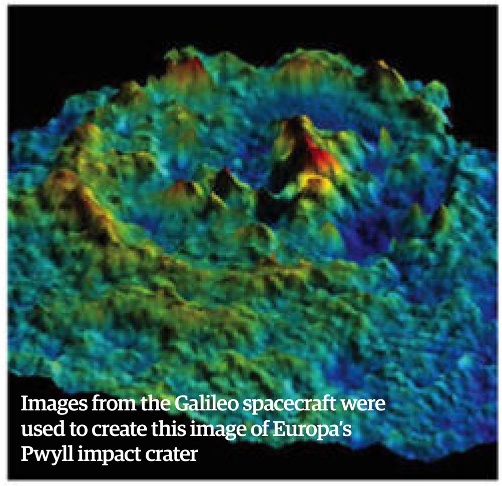
Io and Europa (top), Jupiter's moons of fire and ice



Europa is in a resonant orbit with two of Jupiter's other moons

Europa inside and out

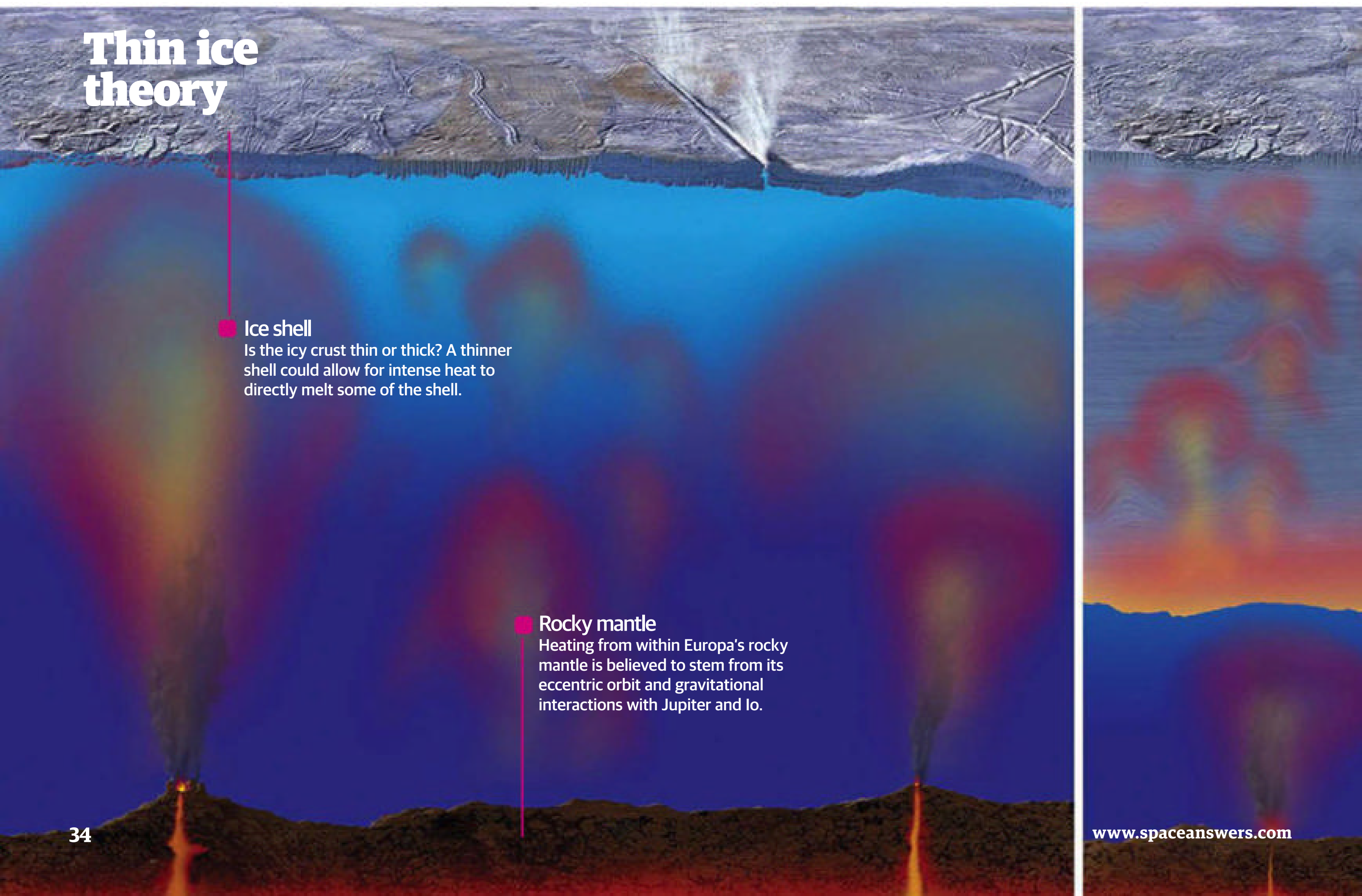
Although Europa is an icy moon, evidence suggests that its composition is much like the rocky planets – an iron core surrounded by a silicate rock mantle

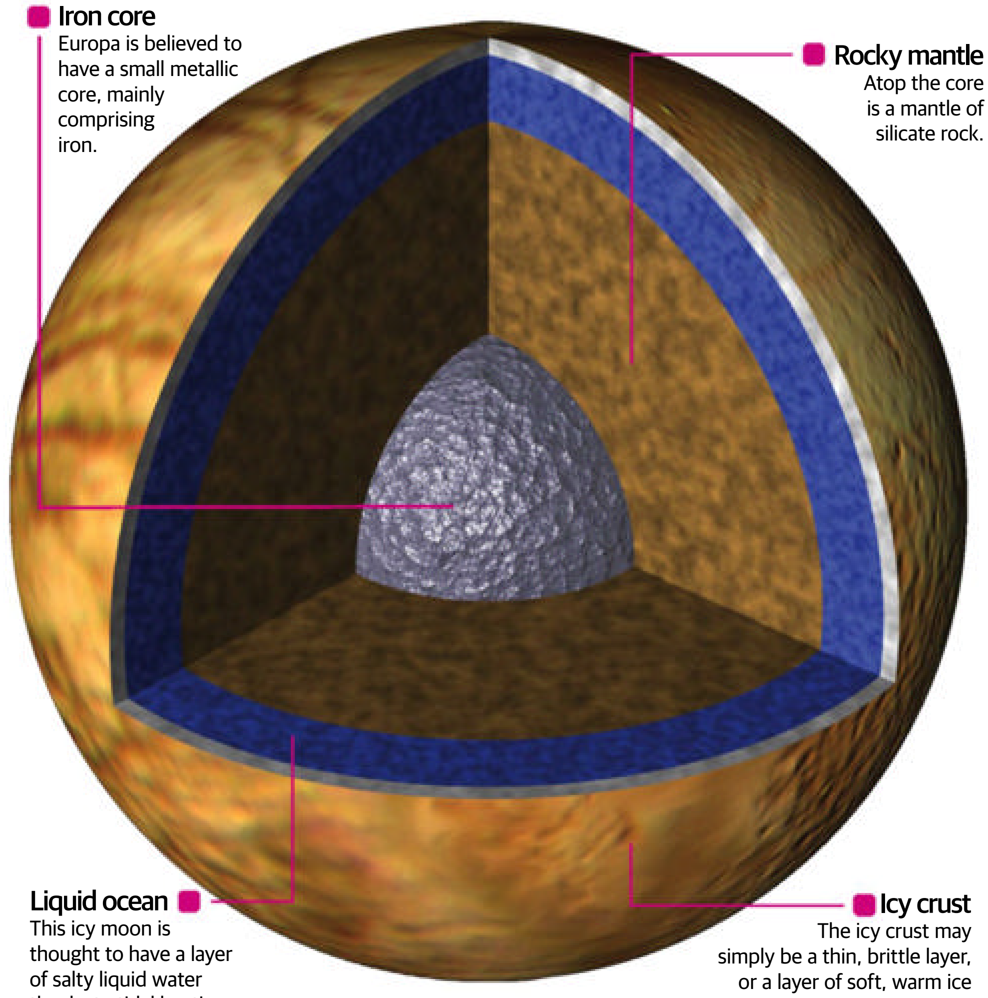

Images from the Galileo spacecraft were used to create this image of Europa's Pwyll impact crater

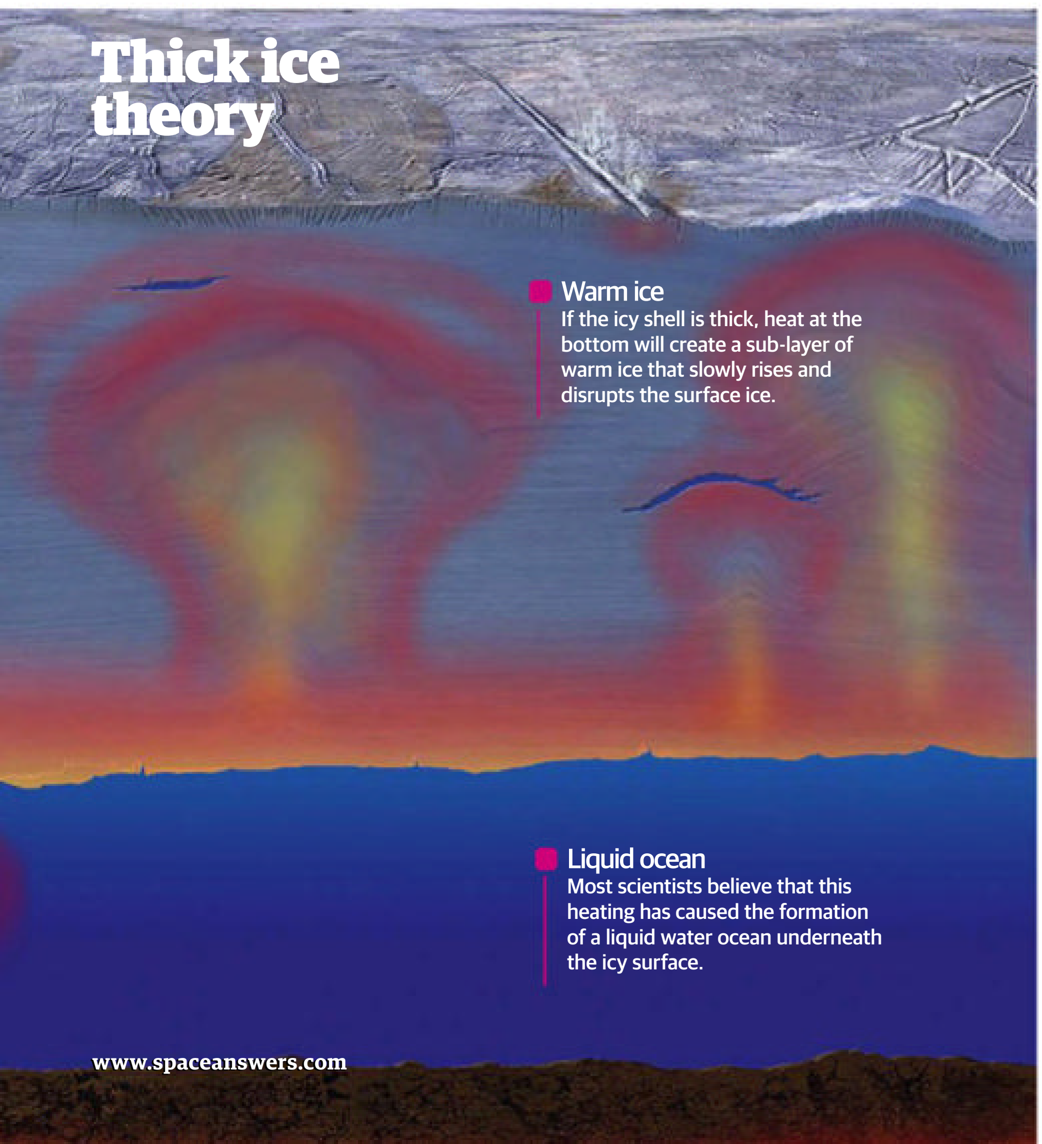
The first evidence of a liquid ocean came from the Galileo spacecraft, which revealed that the moon has an induced magnetic field. In order for this to happen, there has to be a conductive layer under the surface and a salt water ocean is the most likely explanation. Although this part has been commonly accepted, there are two different possibilities for the ice layer: the thin ice model and the thick ice model.

In the thin ice model, the crust would be just a few kilometres thick and float atop the liquid ocean layer. Heat from the mantle would rise through the water and crack the crust, causing some of the striking surface formations such as the jumbled chaos terrain. More researchers agree with the thick ice model, in which the crust is somewhere between 10 and 30 kilometres (6 to 19 miles) thick. Rising heat creates a softer, warmer layer of ice underneath. These can function as glaciers, floating around and causing fractures in the hard surface. The remaining craters on Europa give some indication that the ice is thick instead of thin. They are flat on the bottom and appear to contain flat, fresh ice, which would be less likely to happen if the ocean was directly reacting with the crust.

> "The remaining craters on Europa give some indication that the ice is thick instead of thin"







Europa by numbers

Europa is a moon of extremes.

780,000,000km
(485,000,000 miles)
The distance from Europa to the Sun

0.64
The light reflectivity of Europa, compared to our Moon's 0.12

6kg
What you would weigh on Europa if you weighed 45kg (100lb) on Earth

540 rem
(roentgen equivalent in man) per day
The level of radiation on Europa (500 rem is fatal)

90°
Researchers believe Europa's poles have shifted by this much due to ice buildup (called polar wander)

15
Europa is the 15th largest body in the Solar System

250 metres
(800 feet)
The estimated height of an icy mountain found in the Conamara Chaos region

12,000 years
The amount of time it's believed to take for Europa's crust to completely revolve relative to its interior

On the surface

With its thick ice and frosty brine-spouting cryovolcanoes, the smooth surface of Europa is a strange place to observe

Europa has an unusual-looking surface. It's incredibly smooth for the most part – one of the smoothest objects in existence in the Solar System. That doesn't mean that the moon is a featureless ball of ice, however. The icy surface is also cracked in places, and criss-crossed with numerous reddish-orange lines and splotches. There are also ridges, domes and possibly even cryovolcanoes. The exact mechanism for the formation of these features is unknown, and there are a number of contradictory theories. The prevailing theory is that they're likely due to intense tectonic activity within, caused by tidal heating. Opposing gravitational influences from Jupiter and other Jovian moons work to keep the moon's interior on the move. This generates heat, warming ice below the surface and causing the colder crust on top to crack and shift. This tidal flexing may also spawn cryovolcanoes – the icy equivalent of Earth's volcanoes that spew ice and gases into Europa's atmosphere.

The dark lines, or lineae, arcing across Europa were likely produced by a series of eruptions of warm ice and are coloured dark because of contaminants such as magnesium sulphate in the ice. The spots, or lenticulae, may be the result of melted water that pushed up through the surface, then froze. There are also jumbled chunks of ice, known as chaos regions, scattered around. Some researchers believe that these are areas where the subsurface ocean has melted through the crust, but a newer hypothesis has emerged. There may be pockets of liquid water – separate from the ocean – encased just under the icy crust. These could be the source of the chaos regions, not the ocean. Regardless, all of this shifting seems to have got rid of all but the largest impact craters.

Europa has a very thin, tenuous atmosphere, mostly comprising oxygen, that exists at a much lower pressure than Earth's atmosphere. This atmosphere doesn't come from biological processes on the moon itself; instead, it's a result of ultraviolet radiation from the Sun and charged particles from Jupiter's magnetosphere hitting Europa's surface. The radiation splits water into separate oxygen and hydrogen molecules, which are drawn to the surface of the moon. The hydrogen molecules are lighter and quickly escape Europa's atmosphere, joining with other gases to form a neutral cloud around the moon. The denser oxygen stays in the atmosphere and may even reach the subsurface ocean.

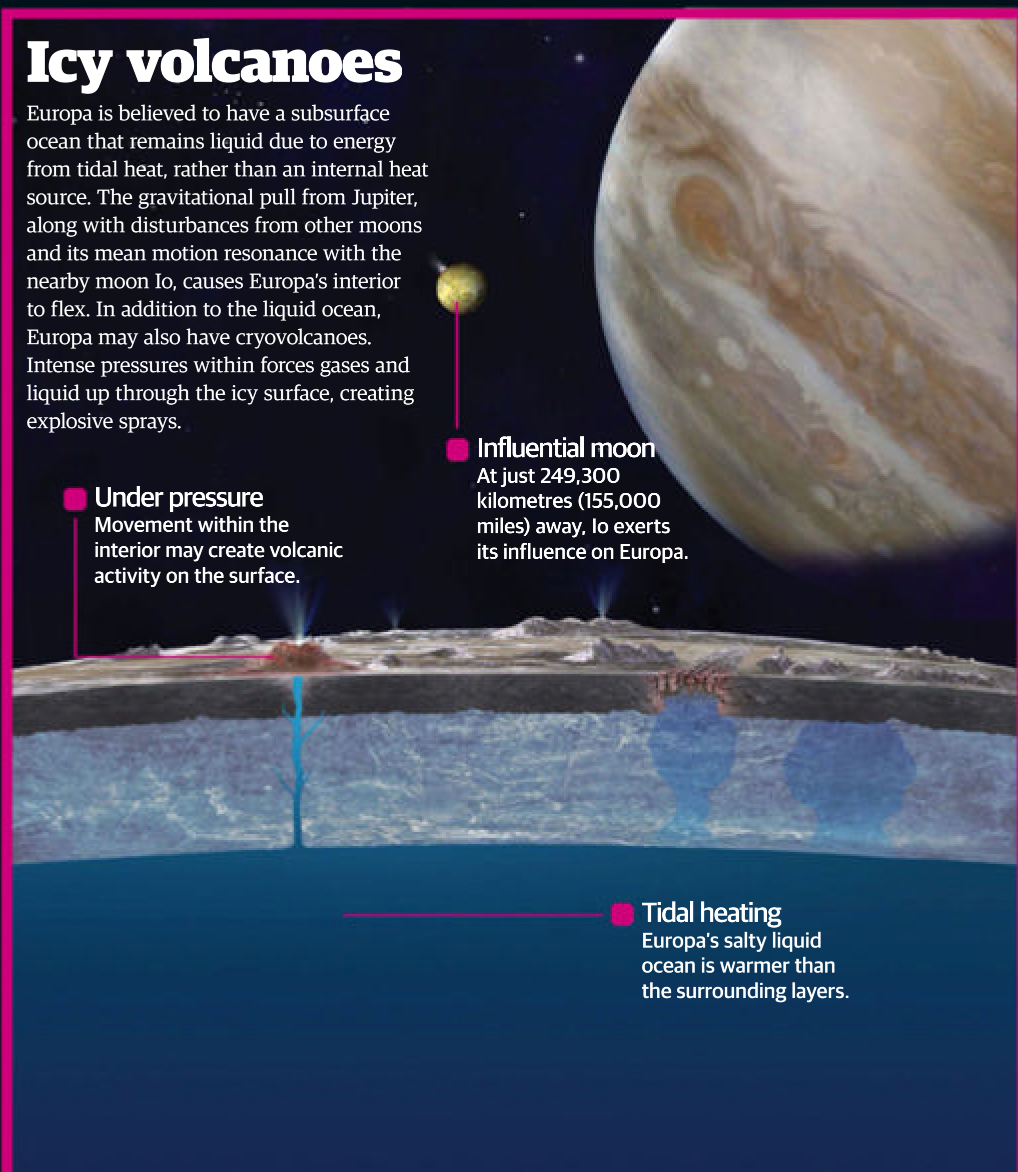
At the equator, temperatures on Europa average approximately -160 degrees Celsius (-260 degrees Fahrenheit) and -220 degrees Celsius (-370 degrees Fahrenheit) at the poles. That hasn't kept us from speculating about the habitability of the moon, or the possibility of life existing there right now. The subsurface ocean has been compared to the deep ocean on Earth, where microbial life exists near hydrothermal vents. There is no evidence yet, but a NASA researcher wrote in March 2013 that there is likely an abundance of hydrogen peroxide on the surface. When hydrogen peroxide is mixed with liquid water, it decays into oxygen. This would make the oxygen concentration high enough to theoretically support life.

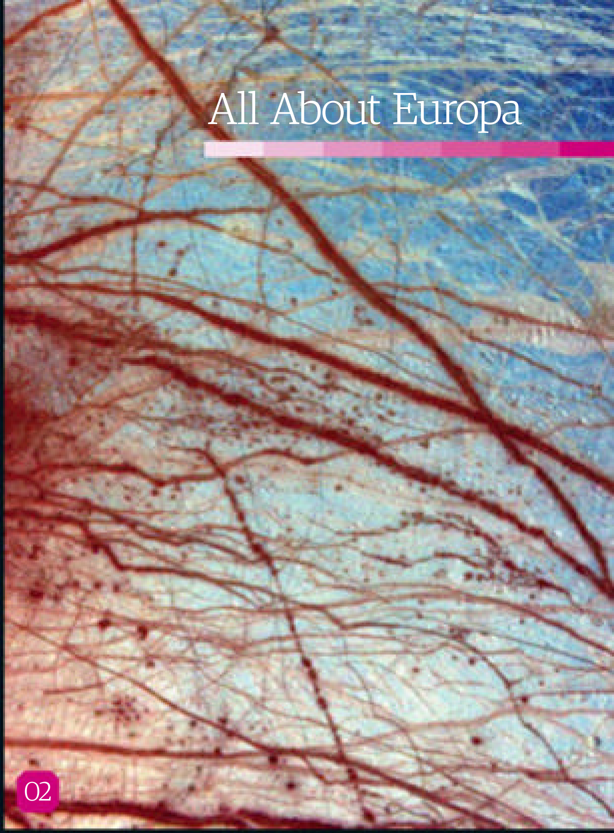
> "The subsurface ocean has been compared to the deep ocean on Earth"

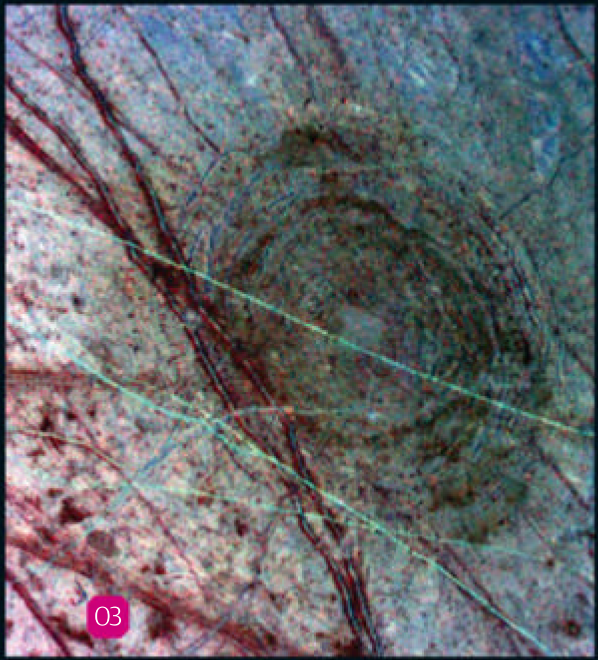
The icy cliffs seen in this image are over 100m tall

Icy volcanoes

Europa is believed to have a subsurface ocean that remains liquid due to energy from tidal heat, rather than an internal heat source. The gravitational pull from Jupiter, along with disturbances from other moons and its mean motion resonance with the nearby moon Io, causes Europa's interior to flex. In addition to the liquid ocean, Europa may also have cryovolcanoes. Intense pressures within forces gases and liquid up through the icy surface, creating explosive sprays.







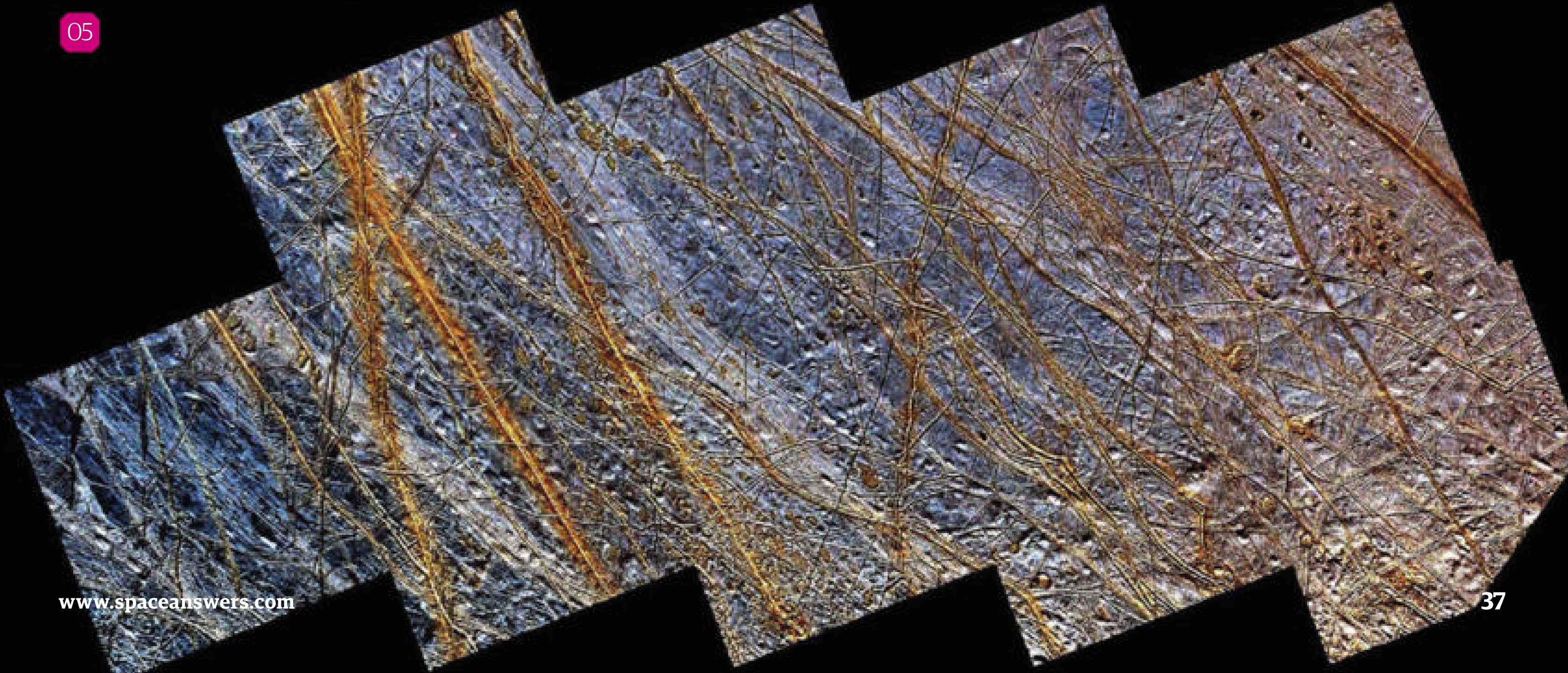
1. Lenticulae
These spots are lenticulae, Latin for 'freckles'. They suggest churning underneath the surface as colder ice sinks and warmer ice rises, with the reddish colour giving a clue as to the ocean's composition.

2. Minos Linea
This shot of the Minos Linea region of Europa is a composite from images taken by Galileo. The brown and red splotches and lines indicate the presence of contaminants within the ice.

3. Tyre
Galileo captured this ringed scar measuring about 140 kilometres (87 miles) wide on Europa's surface, the product of an impact from a comet or asteroid.

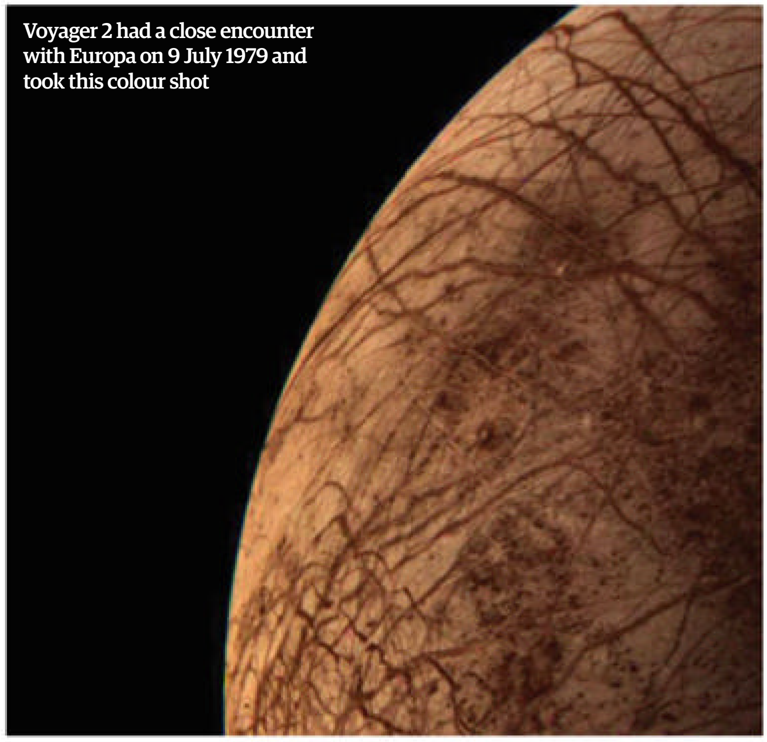
4. Conamara Chaos
This close, high-resolution image shows the details of Europa's icy crustal plates, which have broken apart and moved across the surface. This suggests soft ice or water underneath the hard icy layer.

5. Europa's surface features
This mosaic created from images taken by Galileo shows the smooth icy plains, dark spots and brown linear ridges that cover the moon's surface.



Exploring Europa

The Galileo spacecraft gave us so much information about Europa that we're planning to return soon



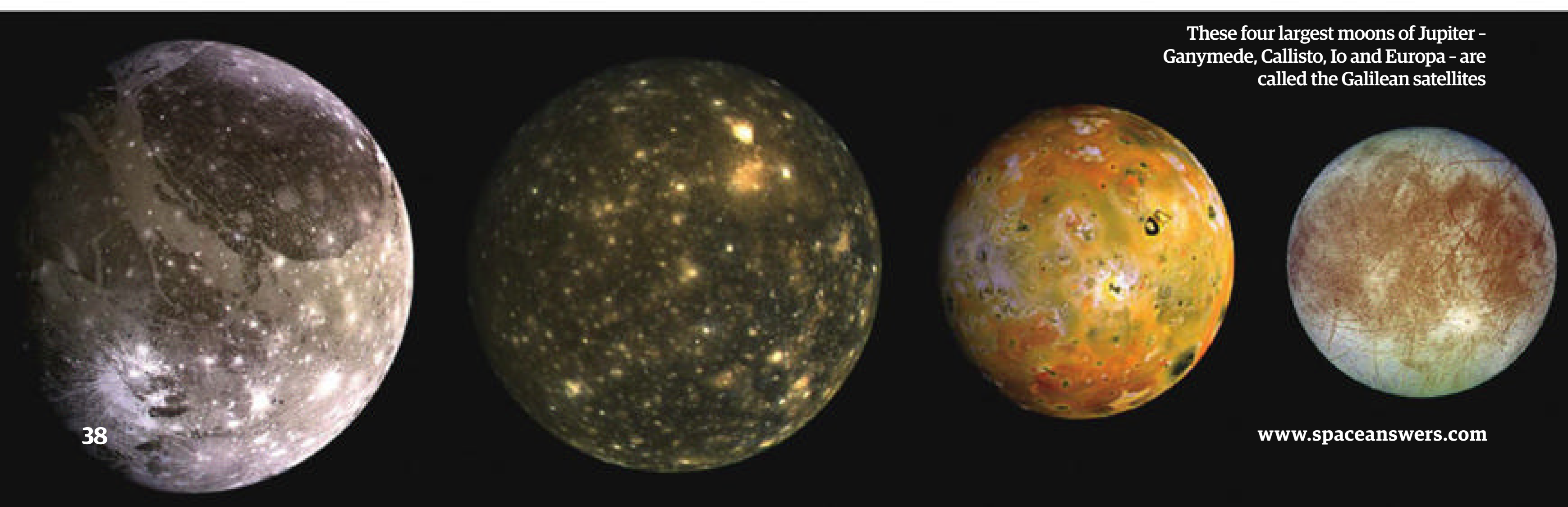
Voyager 2 had a close encounter with Europa on 9 July 1979 and took this colour shot

Although Galileo was the first spacecraft to closely observe Europa, it wasn't the first look we've had of the moon. Pioneer 10 captured images, albeit fuzzy ones, from about 321,000 kilometres (200,000 miles) away in 1973. These showed some of Europa's albedo features, but that's about it. The two Voyager probes gave us better images of the moon in the late-Seventies, showing enough detail to make some believe that there was a liquid ocean under its icy surface. Astronomers on Earth had been observing Europa since its discovery, and the Hubble Space Telescope provided some crucial details about its atmosphere in 1995. That same year, the Galileo spacecraft entered Jupiter's orbit. After finishing its main mission in 1997, it went on an extended mission called Galileo Europa and made numerous flybys, coming within 587 kilometres (365 miles) of the moon. It gave us the most detailed images of Europa's surface to date, as well as revealing its atmospheric composition, magnetic field and further potential for a subsurface ocean. Galileo finished in 2003 with the Millennium Mission, during which it collected further data on Ganymede and Io. In 2007, New Horizons imaged Europa on its way to Pluto.

Europa's ocean and its potential for life have made it a target for future space exploration. There have been several proposed missions that haven't made it past the early stages. NASA commissioned a study in 2012 to explore lower cost options for missions to Europa. The European Space Agency has a planned three-year mission titled JUICE (Jupiter Icy Moon Explorer) to check out Jupiter as well as Callisto, Ganymede and Europa. JUICE is currently scheduled for launch in 2022.

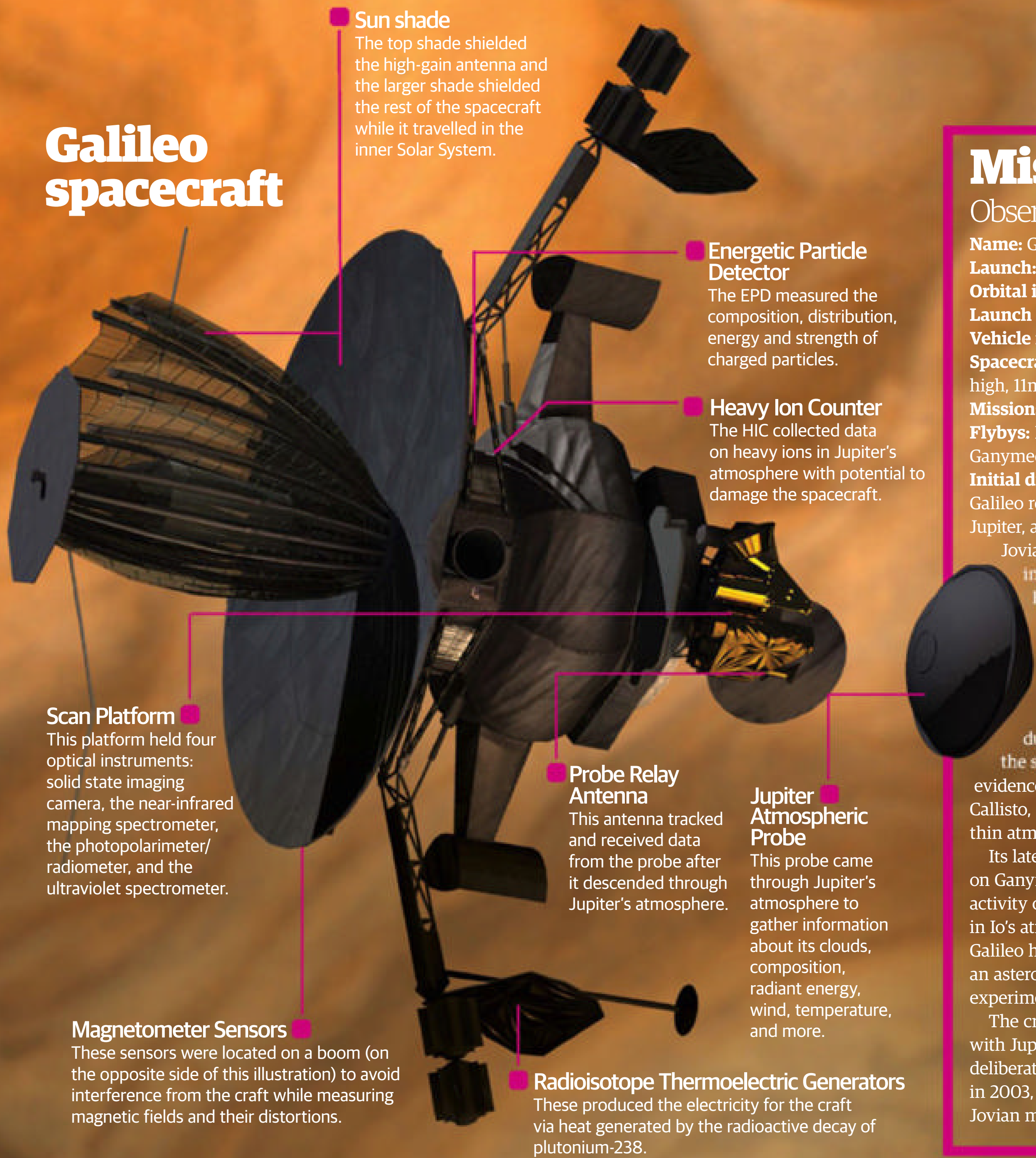
"The European Space Agency has a planned three-year mission titled JUICE to check out Jupiter as well as Callisto, Ganymede and Europa"

NASA's New Horizons spacecraft took this image of Europa above Jupiter on 28 February 2007



These four largest moons of Jupiter – Ganymede, Callisto, Io and Europa – are called the Galilean satellites

Galileo spacecraft



Mission Profile

Observing Europa

Name: Galileo
Launch: 18 October 1989
Orbital insertion: 8 December 1995
Launch vehicle: Space Shuttle Atlantis
Vehicle mass (orbiter): 2,380kg (5,200lb)
Spacecraft dimensions (orbiter): 5.2m (17ft) high, 11m (32ft) wide
Missions: Galileo orbiter, Galileo probe
Flybys: Earth, Venus, asteroid belt, Io, Europa, Ganymede
Initial discoveries:

Galileo remains the only spacecraft to orbit Jupiter, and its probe was the first to enter the Jovian atmosphere. It gave us numerous insights into Jupiter and its moons. Highlights from the mission included mapping the structure and extent of the Jovian magnetosphere, observing ammonia clouds in Jupiter's atmosphere and discovering that Jupiter's ring system is formed by dust created when asteroids smash into the small inner moons. Galileo also found evidence of liquid oceans under the surfaces of Callisto, Europa and Ganymede, while finding thin atmospheric layers on the same moons.

Its later discoveries include a magnetic field on Ganymede, plus evidence of strong volcanic activity on Io and interactions between plasma in Io's atmosphere and Jupiter's atmosphere. Galileo had the first spacecraft encounter with an asteroid (951 Gaspra) and performed the first experiments in astrobiological remote sensing.

The craft was damaged by its long contact with Jupiter's intense radiation and was deliberately crashed into Jupiter's atmosphere in 2003, to avoid potentially contaminating the Jovian moons with bacteria from the planet.

Galileo's technology

Galileo had a unique design, with a spun side and a de-spun side. This meant that one section rotated at three rotations per minute, which kept the spacecraft stable. The instruments mounted on this section gathered data from many different directions as it spun. The spun section also carried the power supply, electronics and computer systems. The de-spun side held instruments like the imaging systems and the probe that descended through Jupiter's atmosphere. The spacecraft also had two different sun shades, which were necessary to protect the instruments from the intense radiation from the Sun.