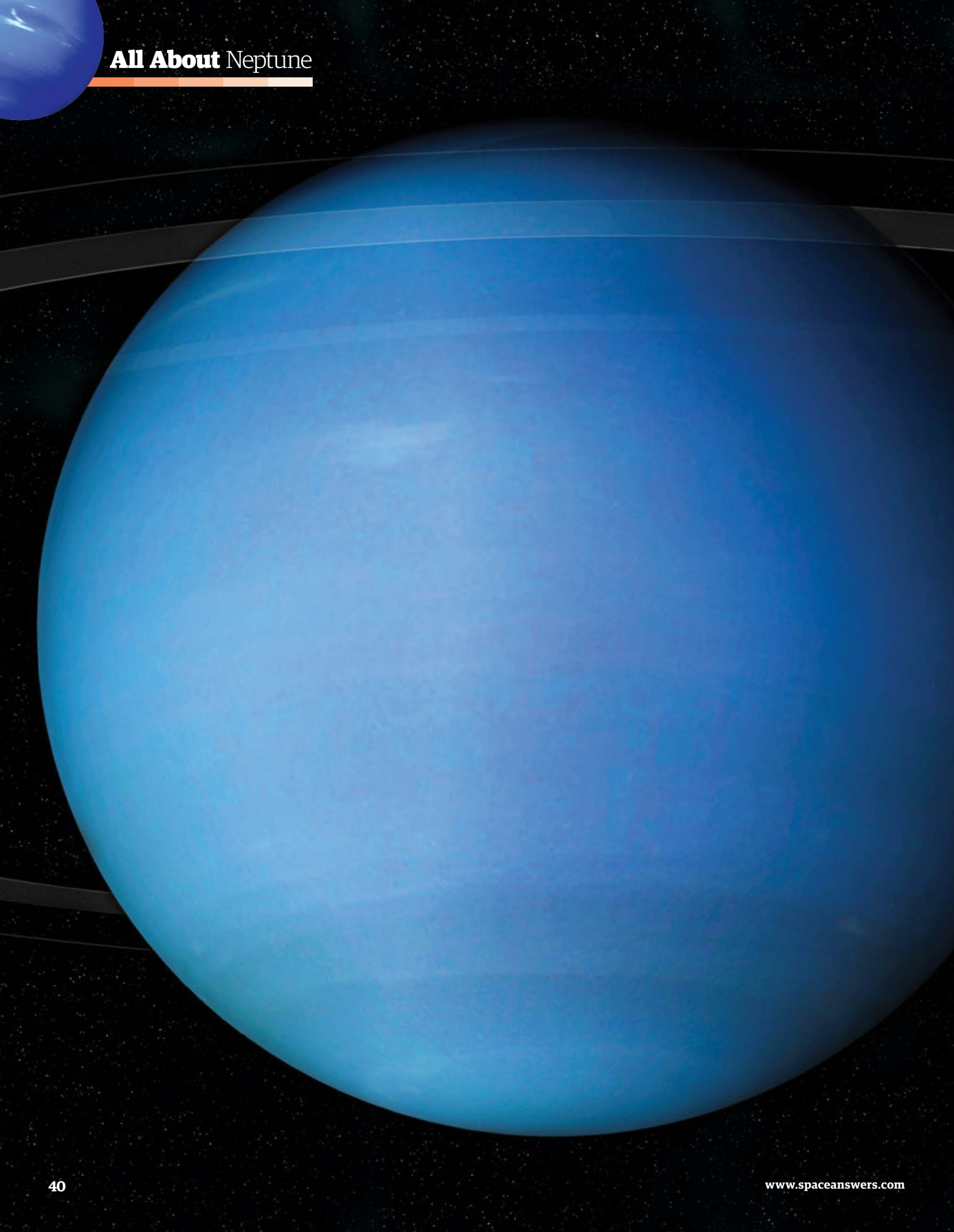
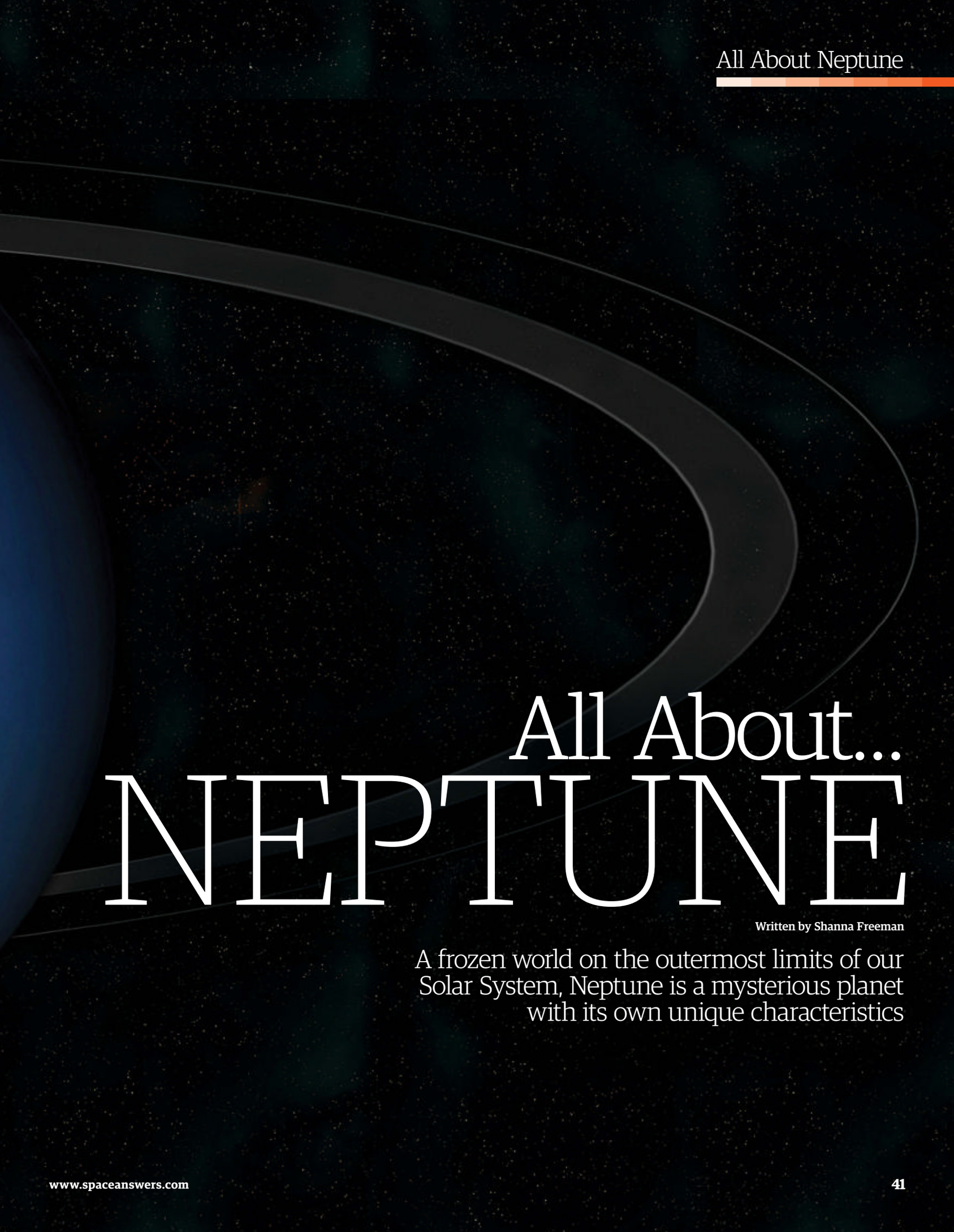




All About... NEPTUNE

Written by Shanna Freeman

A frozen world on the outermost limits of our Solar System, Neptune is a mysterious planet with its own unique characteristics

This image of the planet Neptune, seen as a small blue disc in the centre, was taken from the Earth in 1998 using a camera fitted to a telescope

Each planet is unique, and Neptune's claim to fame is being the first planet to be discovered not by observation, but by prediction. French astronomer Alexis Bouvard spent a lot of time closely observing the orbit of Uranus, and detected a gravitational perturbation that he deduced could only be explained by the existence of another planet. From his observations, other astronomers calculated the location of Neptune. To be fair, Galileo actually spotted Neptune more than 200 years before, but since he thought it was a star, he didn't get the credit.

There's still some debate over who did deserve the credit – French astronomer Urbain Le Verrier or British astronomer John Couch Adams – and some sources include a third astronomer, Johann Galle of Germany. At any rate, Galle was the first to look at Neptune and understand what he was seeing, using calculations from Le Verrier, on 23 September 1846. He discovered Neptune's largest moon, Triton, shortly afterwards. Given the distance – 4.3 billion kilometres (2.7 billion miles) from Earth – Neptune is not visible to the naked eye. But if you use strong binoculars or a telescope, you'll see the planet as a small blue disc. Until powerful modern telescopes on the ground and the invention of the Hubble Space Telescope, it was difficult to really study Neptune.

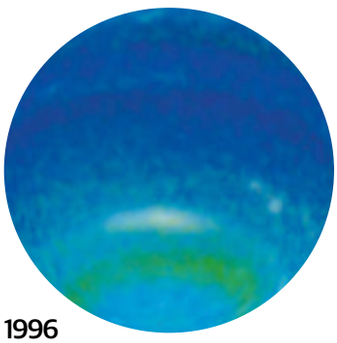
Neptune is the third-largest planet by mass, and 17 times the mass of Earth. It's also the fourth-largest planet by diameter. As the eighth planet from the Sun, Neptune was the furthest known planet until Pluto was discovered in 1930. Although it's back to being the outermost planet since Pluto's demotion, Neptune was still occasionally the outermost planet prior to that because Pluto's eccentric orbit caused it to cross inside Neptune's orbit on occasion. It's one of the four gas giants, and is also called Uranus's 'twin'. Because they're very similar in composition, both planets are often known as ice giants to distinguish them from Jupiter and Saturn. They're mostly made up of hydrogen and helium, with ices of water, methane, and ammonia, surrounding an icy rock core. While the methane content results in Uranus having a blue-green colour, Neptune is a brighter blue. We're not sure what in the atmosphere intensifies the colour. Neptune also has an extremely cold atmosphere like Uranus, topping out at about -218 degrees Celsius (-360 degrees Fahrenheit) in the upper levels.

Although Neptune doesn't have the extreme horizontal tilt of Uranus, its magnetosphere is strongly tilted away from its rotational axis, at 47 degrees. Neptune also has a ring system and more than a dozen known moons. But that's where the similarities mostly end between the two planets. Uranus has a relatively dull atmosphere, for example, but there's lots happening weather-wise on Neptune. When Voyager 2 flew by in 1989 (the only spacecraft to visit Neptune), it observed lots of interesting weather. This includes some of the fastest winds in the Solar System, at around 2,000 kilometres per hour (1,240 miles per hour).

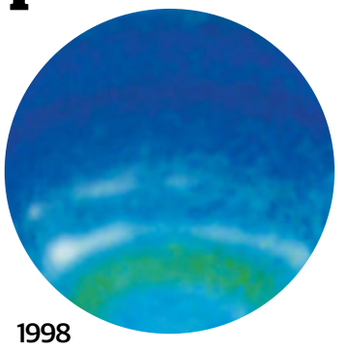
Neptune's tilt is much like Earth's at 28.32 degrees, so it has regular seasons, which happen to last about 40 years, because at 4.50 billion kilometres (2.8 billion miles) from the Sun, it has an orbit of 164.79 years. That means that in 2011, it completed its first orbit since it was discovered. Neptune's gravitational pull also has an impact on the Kuiper belt, a large ring of tiny, icy objects – including the dwarf planet, Pluto. Neptune's gravity has destabilised areas of the belt, and it has also created a resonance between the planet and at least 200 of the objects. ●

> "Neptune has some of the fastest winds in the Solar System, at around 2,000km/h"

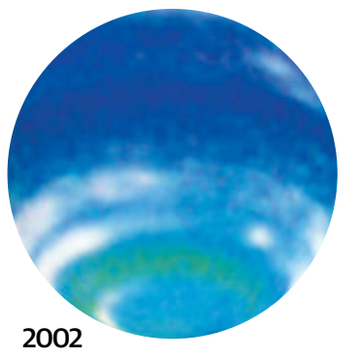
Seasons on Neptune



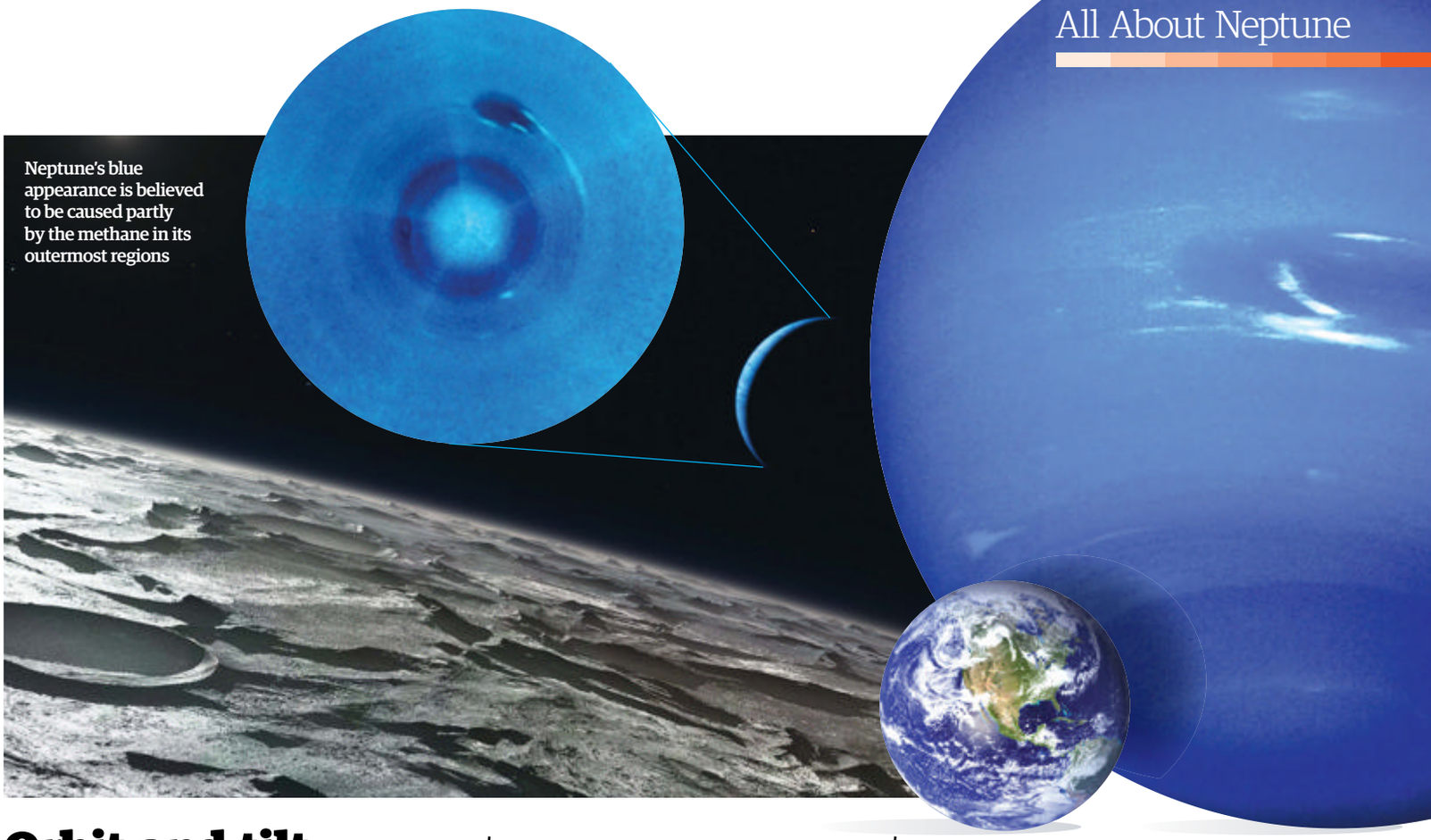
1996
Neptune has four seasons in each hemisphere, just like Earth, but each one lasts about 40 years.



1998
The cloud bands in the southern hemisphere brighten as spring begins on Neptune.



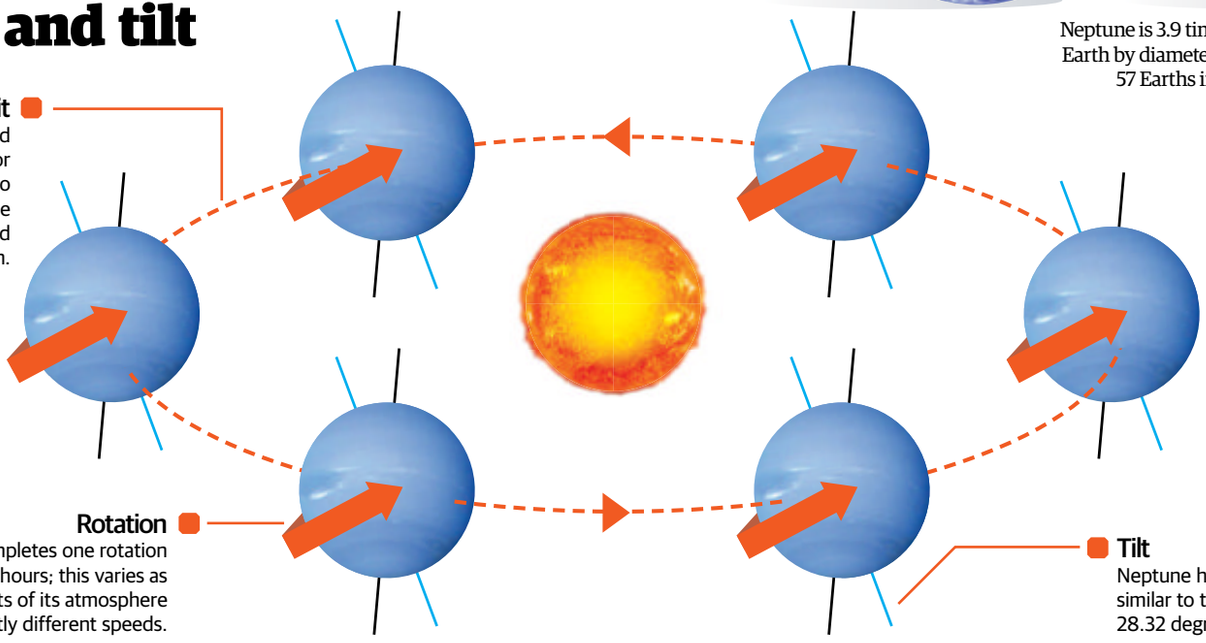
2002
There are about 20 more years of lightening clouds before the seasons change.



Neptune's blue appearance is believed to be caused partly by the methane in its outermost regions

Neptune is 3.9 times bigger than the Earth by diameter, and you could fit 57 Earths inside one Neptune

Orbit and tilt



Orbit
It takes around 164 years for Neptune to complete one orbit around the Sun.

Rotation
The planet completes one rotation in about 16 hours; this varies as different aspects of its atmosphere rotate at slightly different speeds.

Tilt
Neptune has an axial tilt very similar to that of Earth's at 28.32 degrees.

The planets in relation to the Sun

All figures = million miles from Sun

Neptune lies 4.50 billion km (2.8 billion miles) from the Sun and 4.3 billion km (2.7 billion miles) from Earth

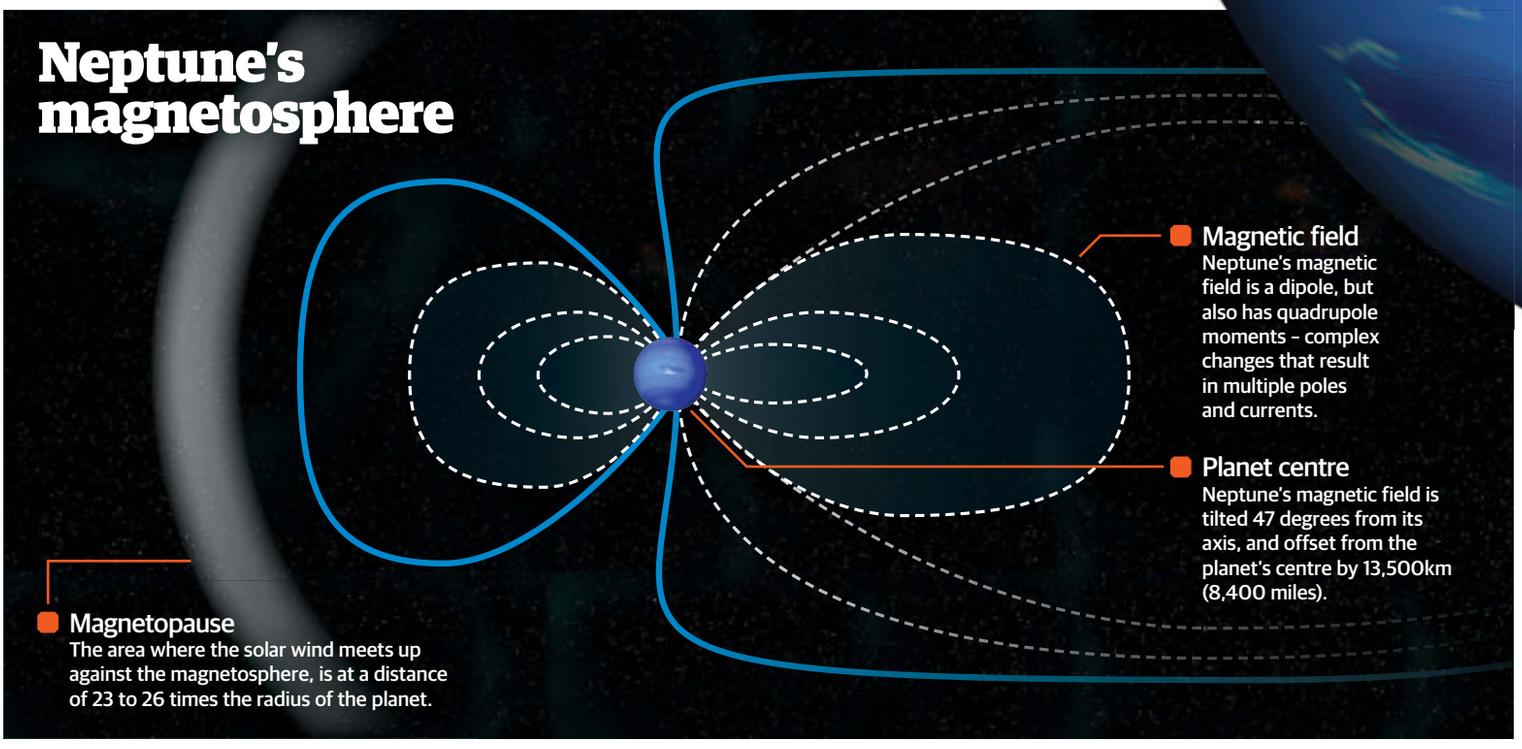
Neptune inside and out

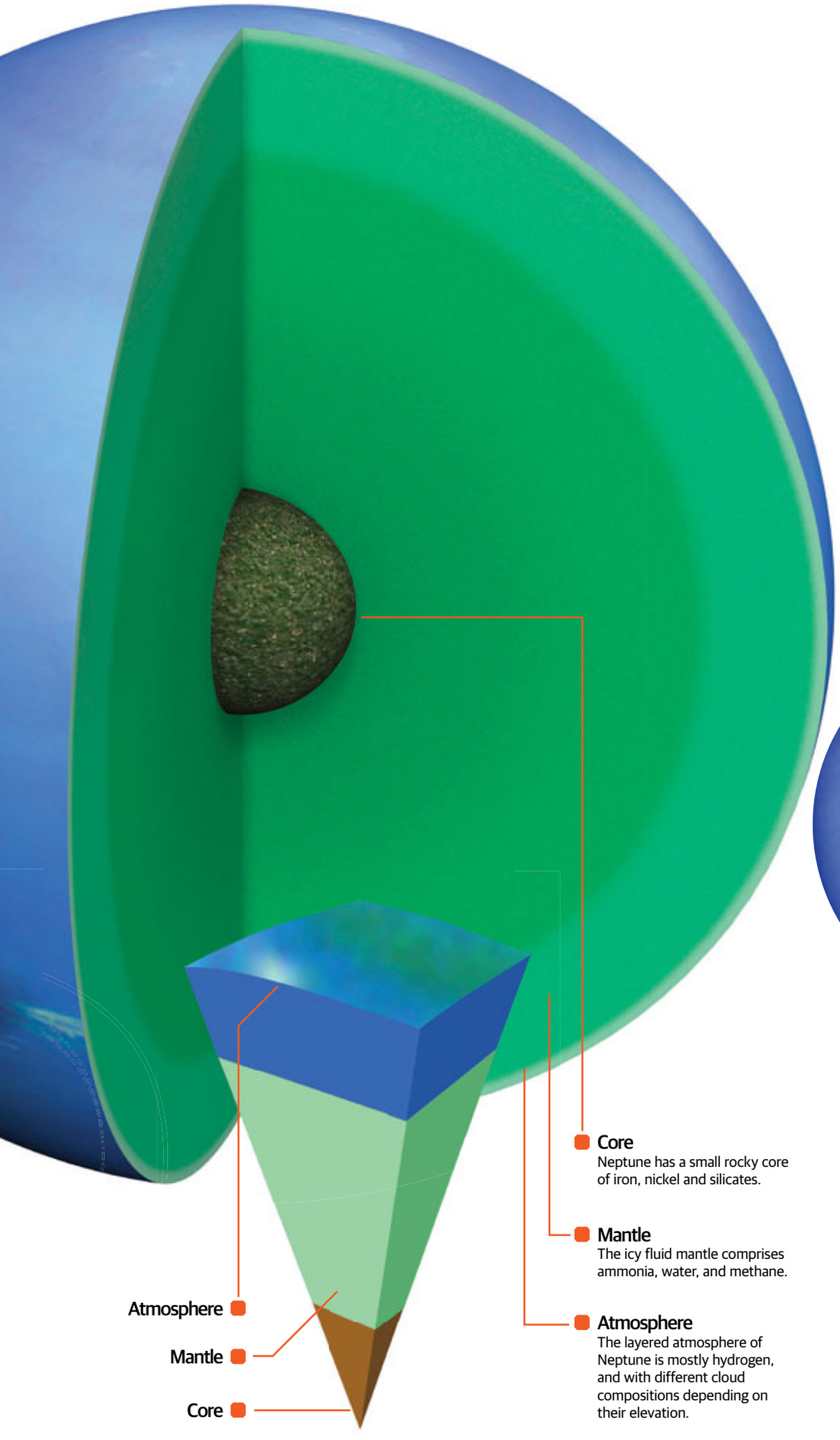
Neptune is a lot like Uranus, but brighter blue, warmer and with more active weather

Like Uranus, Neptune is a gas giant but not solely comprising gases. Its core contains silicate rock, iron and nickel and is a little larger than planet Earth. Neptune's core is also under great pressure (twice as much pressure as the Earth's core) and about 5,100 degrees Celsius (9,200 degrees Fahrenheit). The mantle surrounding the core is icy, but that's a relative term when it comes to planet temperatures because it's actually a hot, dense liquid. Made of methane, ammonia, and water, the mantle is electrically conductive and its temperature ranges between 1,700 degrees Celsius (3,100 degrees Fahrenheit) and 4,700 degrees Celsius (8,500 degrees Fahrenheit). The mantle may also consist of additional layers, including a layer of ionised water (with electrically charged hydrogen and oxygen) and a deeper layer of superionised water.

Neptune's atmosphere surrounding the mantle is about 80 per cent hydrogen, 19 per cent helium, and the rest traces of ammonia, water and methane. The methane, which absorbs red light in the spectrum, gives Neptune its colour. Since the atmospheric composition is supposed to be very similar to that of Uranus's, there must be something else in the atmosphere that makes Neptune a bright blue versus Uranus's bluish-green. It has two main divisions – the troposphere and the stratosphere. The troposphere probably has several different types of cloud bands, depending on where they're located. The lowest levels are clouds of hydrogen sulphide and ammonia. Then there are water ice clouds as the temperature drops, at a pressure of 50 bars. A cloud layer of water, hydrogen sulphide, ammonia and ammonium sulphide floats above five bars of pressure. Between one and five bars, in the uppermost layer of the troposphere, the clouds are ammonia and hydrogen sulphide. Bands of these clouds wrap around the planet, casting shadows on opaque clouds below them.

Neptune is warmer overall than Uranus. Its stratosphere has traces of carbon monoxide, and the thermosphere is unusually warm at 480 degrees Celsius (900 degrees Fahrenheit) given Neptune's distance from the Sun. The planet radiates more than twice the energy of Uranus and receives only 40 per cent of the sunlight of its twin, yet has about the same surface temperature. We aren't sure why, but these differences in heat may be why Neptune has weather like storms and high winds, while Uranus does not.





Core
Neptune has a small rocky core of iron, nickel and silicates.

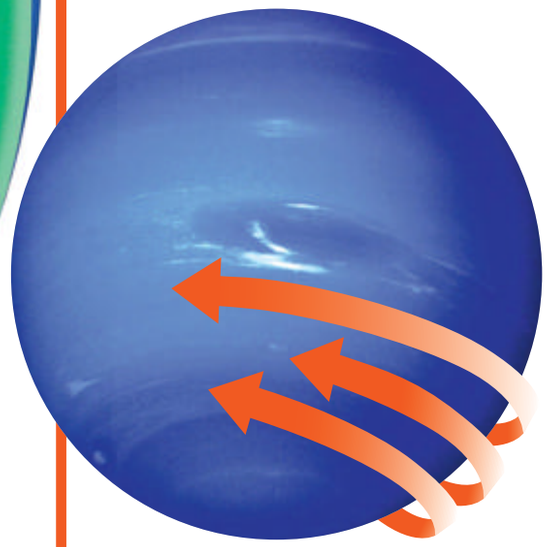
Mantle
The icy fluid mantle comprises ammonia, water, and methane.

Atmosphere
The layered atmosphere of Neptune is mostly hydrogen, and with different cloud compositions depending on their elevation.

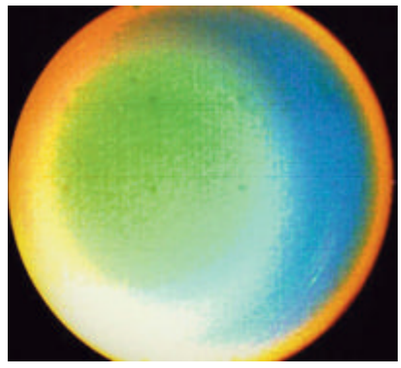
Supersonic winds and storms

Neptune's massive winds and storms set it apart from Uranus. Most of the winds blow in retrograde rotation (opposite the planet's rotation), but the general pattern is prograde rotation (in the direction of the planet) in the higher latitudes and retrograde rotation in the lower latitudes. The winds reach almost 2,000 kilometres per hour (1,240 miles per hour) - nearly supersonic speeds.

On Voyager 2's flyby in 1989, it observed a massive anti-cyclonic storm that was 13,000 by 6,600 kilometres (8,700 by 4,100 miles) in size. The storm was dubbed the Great Dark Spot. It wasn't present when the Hubble Space Telescope viewed the planet five years later, but another storm was found and given the name. Neptune also has other large storms named the Scooter and the Small Dark Spot.



Neptune has storms, including hurricane-force winds that constantly blow around the planet



Special processing of this Neptune image taken by Voyager 2 shows the variations in temperature in its atmosphere

Moons and rings

Neptune has two very different groups of moons – inner moons with regular, circular orbits, and outer moons with irregular, eccentric orbits

Neptune has 13 known moons. Triton is by far the largest moon, comprising more than 99 per cent of the total mass in orbit around the planet. It has a diameter of 2,705 kilometres (1,700 miles) and is the only spheroid moon. Triton was probably a dwarf planet in the Kuiper belt before being captured by Neptune's orbit. Astronomers believe it was captured instead of forming as a satellite because it has a retrograde orbit – it circles Neptune opposite of the planet's rotation. Triton has an irregular orbit, and is the second known moon (along with Saturn's moon Titan) to have an atmosphere. The atmosphere mostly comprises nitrogen, with some trace amounts of carbon monoxide and methane. It is also one of the coldest objects in the Solar System. The moon is very dense, and is probably two-thirds rock and one-third ice.

Triton is one of the seven outermost moons, which have irregular orbits. The next moon to be discovered, Nereid, was discovered in 1949. It is the third-largest moon. Unlike Triton, it has a prograde orbit. Nereid's orbit is also extremely eccentric – it gets as close as 1.4 million kilometres (850,000 miles) to Neptune, but is 9.6 million kilometres (5.9 million miles) at its furthest point. The cause of its eccentricity is unknown, but it may have been perturbed by Triton, or have been a Kuiper belt object like Triton that was captured. We don't know exactly what Nereid looks like or what shape it takes. Two of the other irregular moons, Sao and Laomedeia, have prograde orbits. Both were discovered in 2002. Halimede, Psamathe and Neso all have retrograde orbits. Halimede and Neso were discovered in 2002, and Psamathe a year later. Neso and Psamathe both orbit very far away from Neptune; Psamathe orbits at 48 million kilometres (30 million miles) away. Both of these moons may have come from a larger moon.

The six inner moons have regular, prograde orbits: Naiad, Thalassa, Despina, Galatea, Larissa and Proteus. Little is known about the four innermost moons, except that they are small and irregularly shaped. All of these likely formed from debris leftover when Triton was pulled into orbit. Naiad is the innermost moon and was discovered in 1989 by Voyager 2. It orbits just 23,500 kilometres (14,600 miles) above Neptune. Thalassa was discovered around the same time. These two innermost moons orbit between two rings, Galle and Le Verrier. Despina, the third-closest moon, lies inside the Le Verrier ring, and the next moon, Galatea, may serve as a shepherd moon, holding the Adams ring in place.

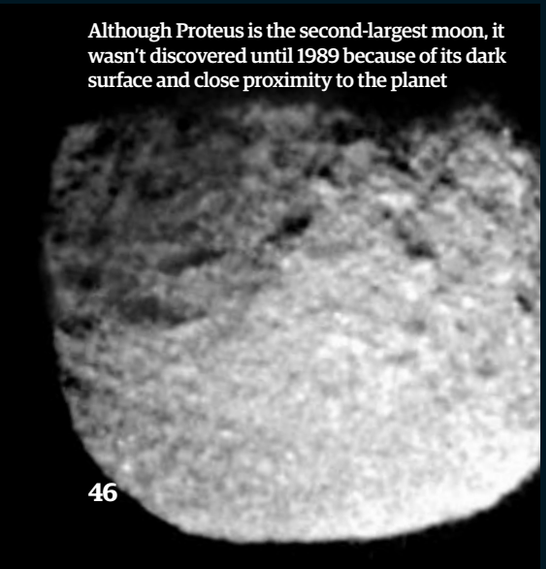
Larissa, the fourth-largest moon, was discovered in 1981. It is known to be about 200 kilometres (124 miles) in diameter and with an elongated shape. It's also heavily cratered. Proteus, the outermost of these moons, is also the second-largest moon in orbit around Neptune. Voyager 2 also discovered it, and we learned then that it is at least 400 metres (248.5 miles) in diameter. Proteus is also heavily cratered.

Neptune's ring system was first spotted in 1984 in Chile, by a group of international astronomers. Astronomers prior to this had suspected rings when observing dips in the brightness of stars viewed between the observer and the planet. The existence of the rings was proven by images taken by Voyager 2, and we have since viewed the brightest rings using the Hubble Space Telescope as well as Earth-based telescopes. There are five distinct rings, named in order of their distance from Neptune: Galle, Le Verrier, Lassell, Arago and Adams. Galle is a very faint ring, named after the first astronomer to view the planet. The next ring, Le Verrier, is extremely narrow at just 113 kilometres (70 miles) wide. Le Verrier may be confined by the moon Despina, which orbits just inside it.

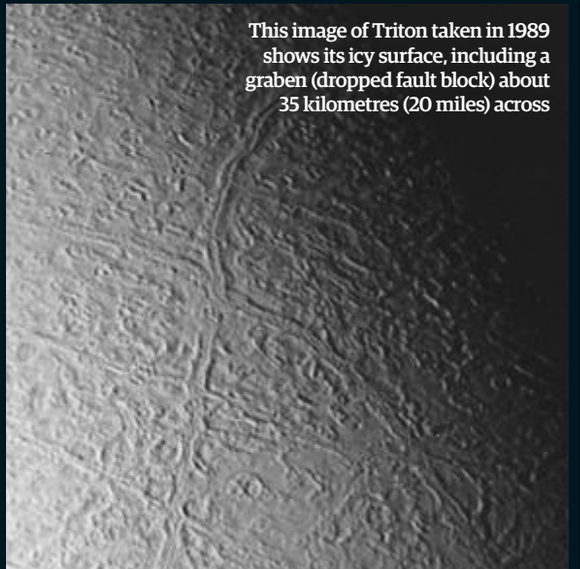
Neptune's widest ring, Lassell, is also called the plateau. It's a thin sheet of dust stretching from Le Verrier to the next ring, Arago. Some don't consider Arago to be a ring at all; it looks like a bright rim around the edge of Lassell, but is less than 100 kilometres (62 miles) wide.

We know the most about the outermost ring, Adams. It is a narrow ring slightly slanted. The moon Galatea shepherds the Adams ring and creates 'wiggles', or perturbations, at 42 different places in the ring. Adams has an unusual feature: five bright spots called arcs located along the ring, where the particles of dust are clustered together. They're named Fraternité, Égalité 1, Égalité 2, Liberté and Courage. Courage is the faintest, while Fraternité is the brightest. Ground-based telescopes first detected them, and Voyager 2 confirmed their existence. They have dimmed slightly since their discovery and some of the arcs seem to have moved slightly, but overall they are stable. We just aren't sure why the dust particles have clustered together in those areas. There could be as-yet-undetected moons or moonlets, or the arcs could be caused by an unusual resonance with the moon Galatea.

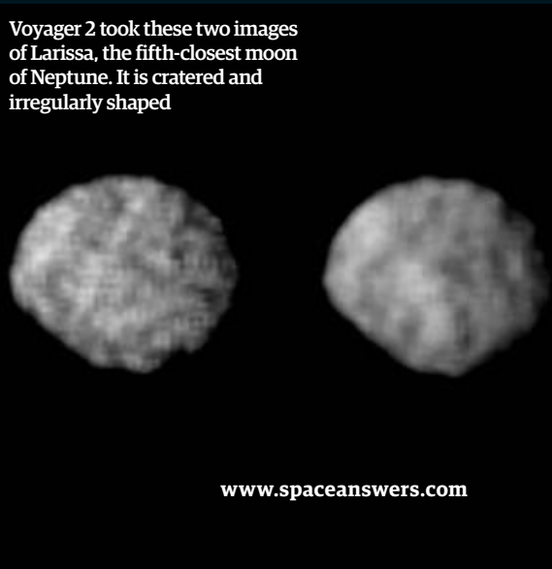
> "Triton comprises more than 99 per cent of the total mass in orbit around the planet"



Although Proteus is the second-largest moon, it wasn't discovered until 1989 because of its dark surface and close proximity to the planet



This image of Triton taken in 1989 shows its icy surface, including a graben (dropped fault block) about 35 kilometres (20 miles) across



Voyager 2 took these two images of Larissa, the fifth-closest moon of Neptune. It is cratered and irregularly shaped

Triton, Neptune's most amazing moon

2. Cantaloupe terrain
This greenish-blue terrain is called cantaloupe because of its appearance. It is likely fresh nitrogen ice, but the reason for its appearance is a mystery.

3. Strange spots
These dark maculae are likely deposits of nitrogen dust from geyser explosions.

1. South pole
The south polar region of Triton has a cap of nitrogen and methane ice. The latter reacted with sunlight to turn the cap pink.

The rings of Neptune

1. Galle
Galle is 2,000km (1,240 miles) wide and orbits Neptune at a distance of 41,000 to 43,000km (25,500 to 26,700 miles).

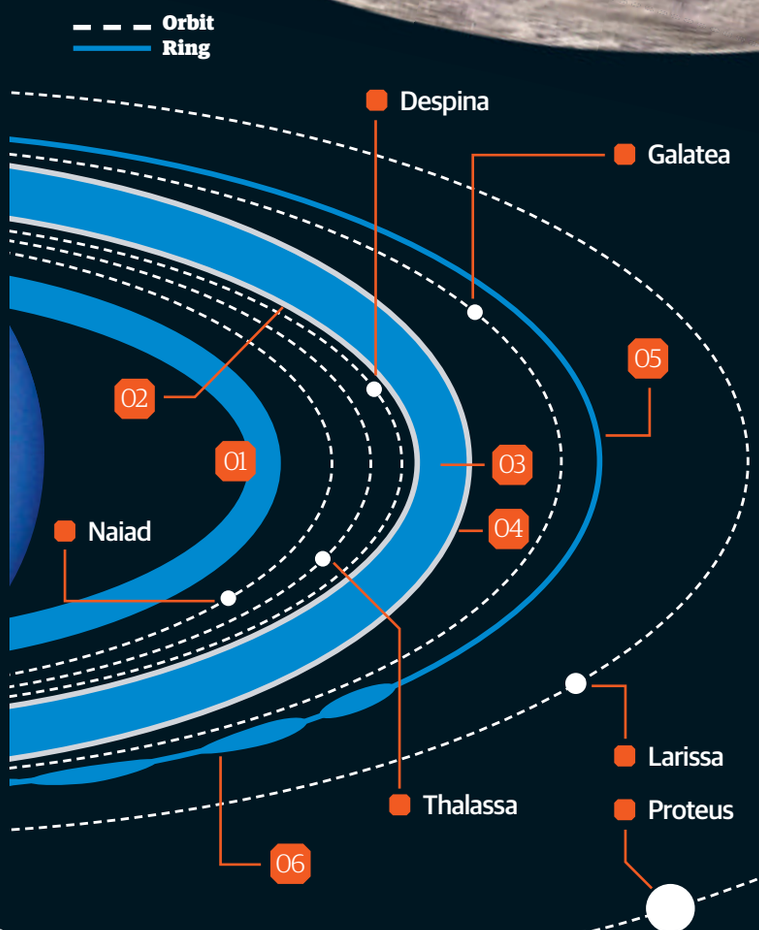
2. Le Verrier
Le Verrier is 113km (70 miles) wide and orbits 53,200km (33,000 miles) away.

3. Lassell
Lassell is more like a broad dust sheet than a ring, with its orbit around Neptune between 53,200 and 57,200km (33,000 and 35,500 miles).

4. Arago
Arago orbits Neptune at 57,200km (35,500 miles) and is less than 100km (62 miles) wide.

5. Adams
Adams is 35km (22 miles) wide and orbits around Neptune at 62,900km (39,000 miles).

6. Arcs
These arcs are the particles of dust clustered together in the Adams ring, named Fraternité, Égalité 1, Égalité 2, Liberté and Courage.



Neptune in numbers

Fascinating figures about the eighth planet from the Sun

500,000

A 1999 study at the University of California simulated the atmospheric pressure of Neptune and estimated it to be 100,000 to 500,000 times that of the Earth's

17%

Neptune's gravity is only 17% stronger than Earth's gravity – the closest of any planet in the Solar System

248 years

Neptune will be closer in its orbit to Pluto than to the Sun for 248 years, as Pluto's eccentric orbit takes it inside Neptune's

1/900

Neptune receives 1/900th of the energy from the Sun that the Earth receives

2

Triton is locked in synchronous rotation with Neptune, so one side always faces it. But because of its unusual orbit, both poles still get time in the Sun

100 yrs

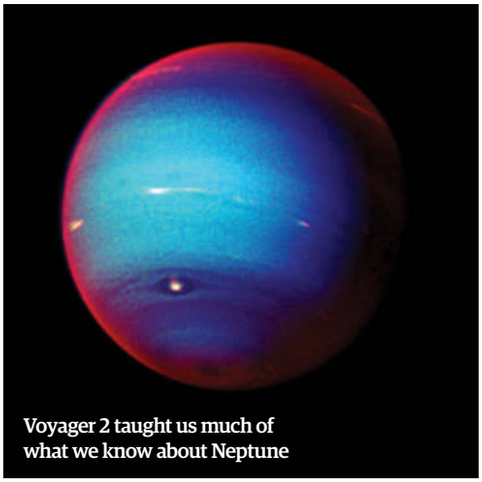
Neptune's moons are named after Greek and Roman water deities, since the planet is named after the god of the sea. None of the moons were named immediately after discovery – in Triton's case, it took over 100 years

Exploring Neptune

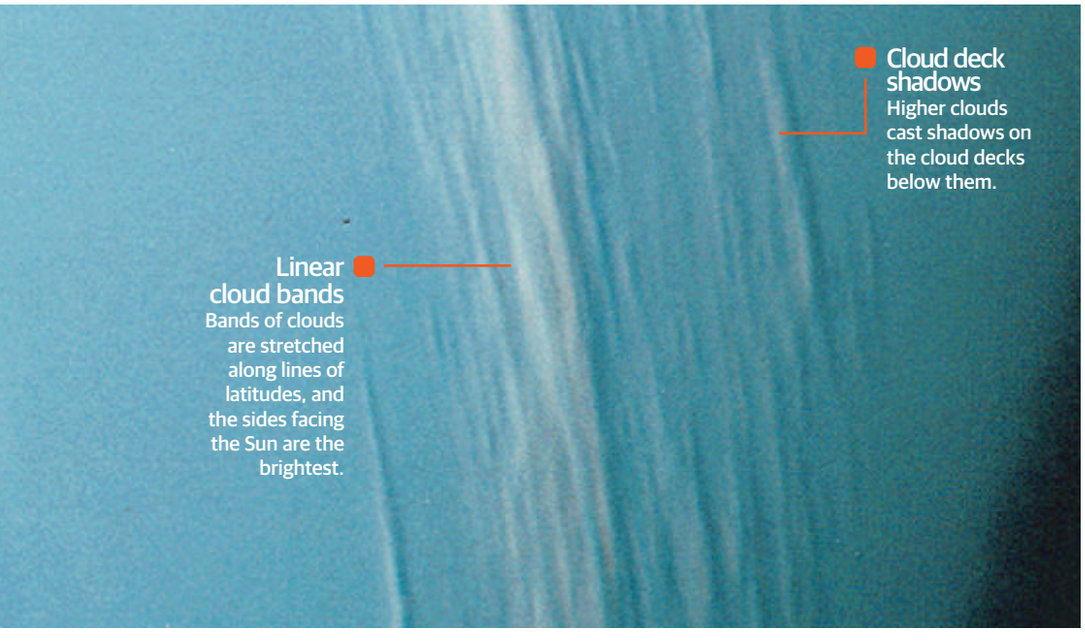
Voyager 2 revealed much of what we know about Neptune, but we've continued to make discoveries

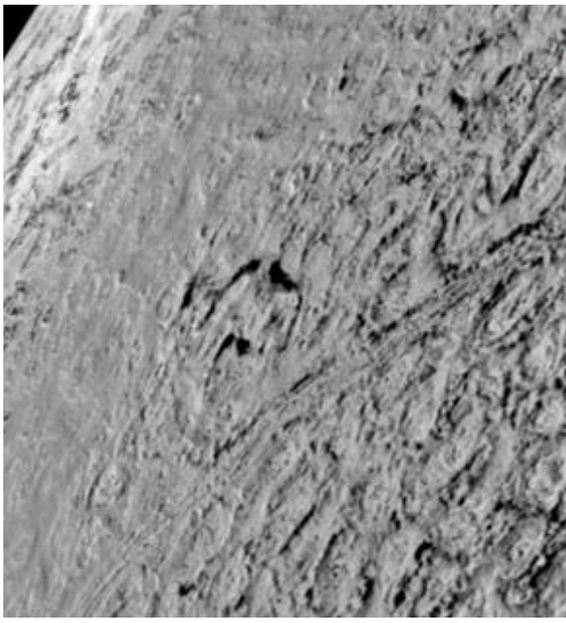
Neptune has only been visited once, but it was a fruitful trip. Voyager 2 did a flyby of the planet on 25 August 1989 and provided us with a lot of images and data. The probe came within around 5,000 kilometres (3,000 miles) of Neptune's north pole. It studied the planet's magnetosphere and atmosphere, revealing the active weather systems, cloud layers, high winds and large storms known as spots. It learned that Neptune has auroras, and that its days are 16 hours and seven minutes long. During the trip, Voyager 2 also made some important discoveries. It discovered four of Neptune's rings, the ring arcs in the Adams ring and five of Neptune's moons. The probe sent back the first images of three of them: Triton, Proteus and Nereid. Its encounter with Neptune was Voyager's last stop on its journey, so NASA flight controllers programmed the probe to come very close to Triton to gather information, regardless of the trajectory it took afterward. It came within 40,000 kilometres (25,000 miles) of Triton and revealed that the moon has a thin atmosphere, polar caps and active geysers.

Although we learned the bulk of what we know about Neptune from Voyager 2, astronomers have continued to study the planet using the Hubble Space Telescope as well as land-based telescopes at observatories such as the Keck Observatory in Hawaii. Neptune's rings and Adams' arcs were both photographed for the first time this way in 1998. Five additional moons were discovered using land-based telescopes in 2002 and 2003. So, although there are currently no missions planned to visit the planet in the near future, astronomers continue to study Neptune to learn more. ●

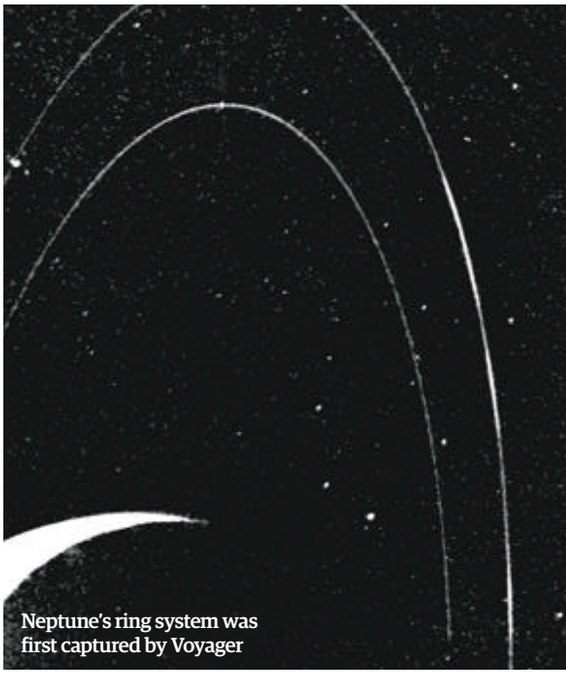


Voyager 2 taught us much of what we know about Neptune

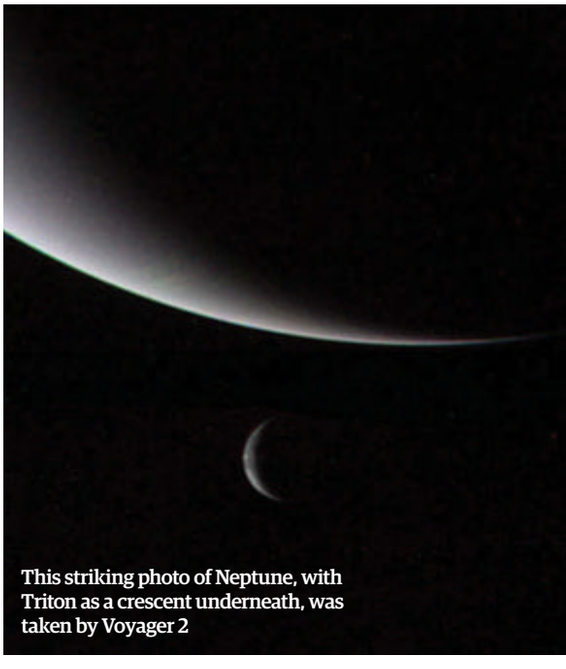




This image of Triton shows the moon's grooved surface, which was probably caused by melting on its icy surface

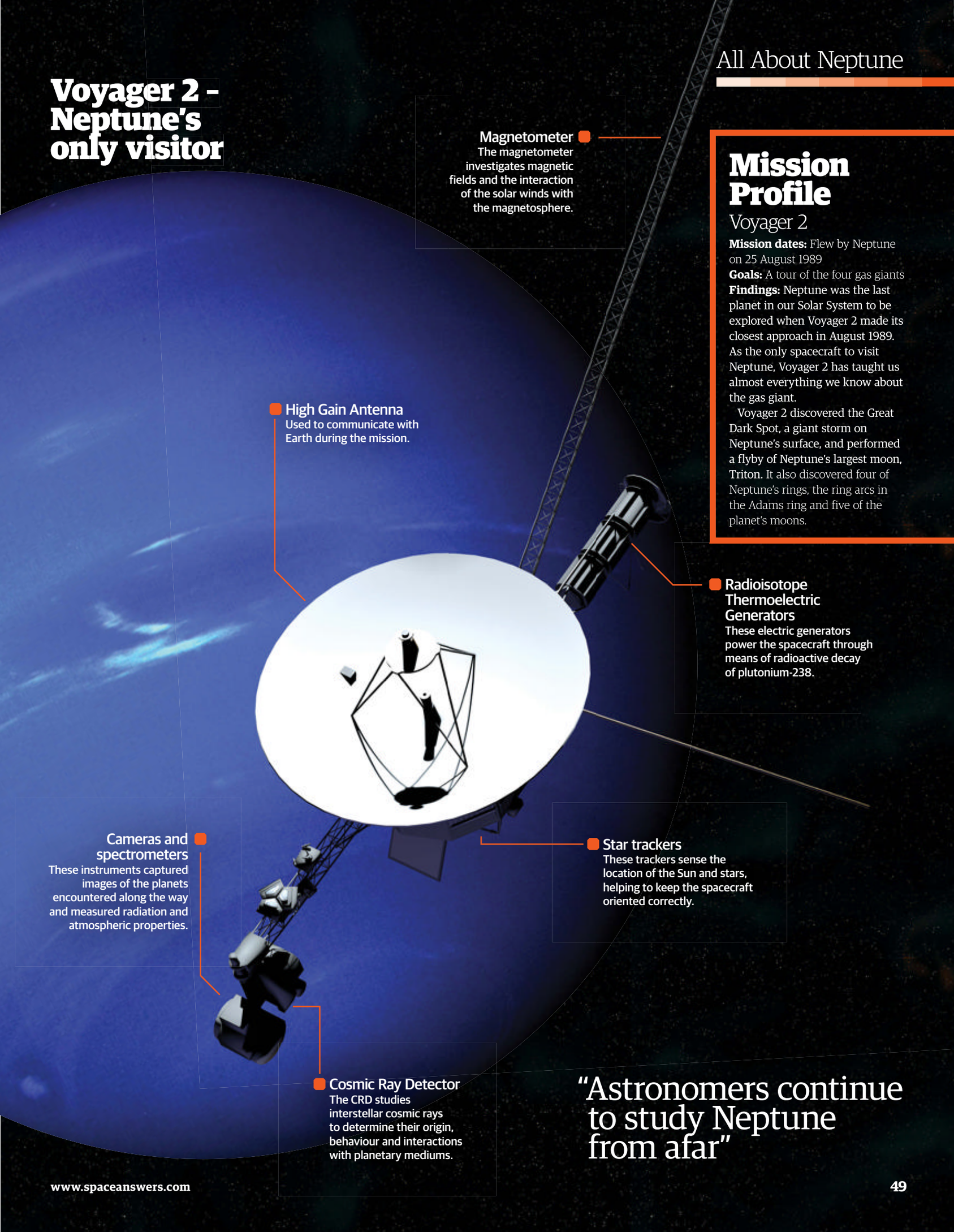


Neptune's ring system was first captured by Voyager



This striking photo of Neptune, with Triton as a crescent underneath, was taken by Voyager 2

Voyager 2 – Neptune's only visitor



Magnetometer
The magnetometer investigates magnetic fields and the interaction of the solar winds with the magnetosphere.

High Gain Antenna
Used to communicate with Earth during the mission.

Radioisotope Thermoelectric Generators
These electric generators power the spacecraft through means of radioactive decay of plutonium-238.

Star trackers
These trackers sense the location of the Sun and stars, helping to keep the spacecraft oriented correctly.

Cameras and spectrometers
These instruments captured images of the planets encountered along the way and measured radiation and atmospheric properties.

Cosmic Ray Detector
The CRD studies interstellar cosmic rays to determine their origin, behaviour and interactions with planetary mediums.

Mission Profile

Voyager 2

Mission dates: Flew by Neptune on 25 August 1989
Goals: A tour of the four gas giants
Findings: Neptune was the last planet in our Solar System to be explored when Voyager 2 made its closest approach in August 1989. As the only spacecraft to visit Neptune, Voyager 2 has taught us almost everything we know about the gas giant.

Voyager 2 discovered the Great Dark Spot, a giant storm on Neptune's surface, and performed a flyby of Neptune's largest moon, Triton. It also discovered four of Neptune's rings, the ring arcs in the Adams ring and five of the planet's moons.

"Astronomers continue to study Neptune from afar"