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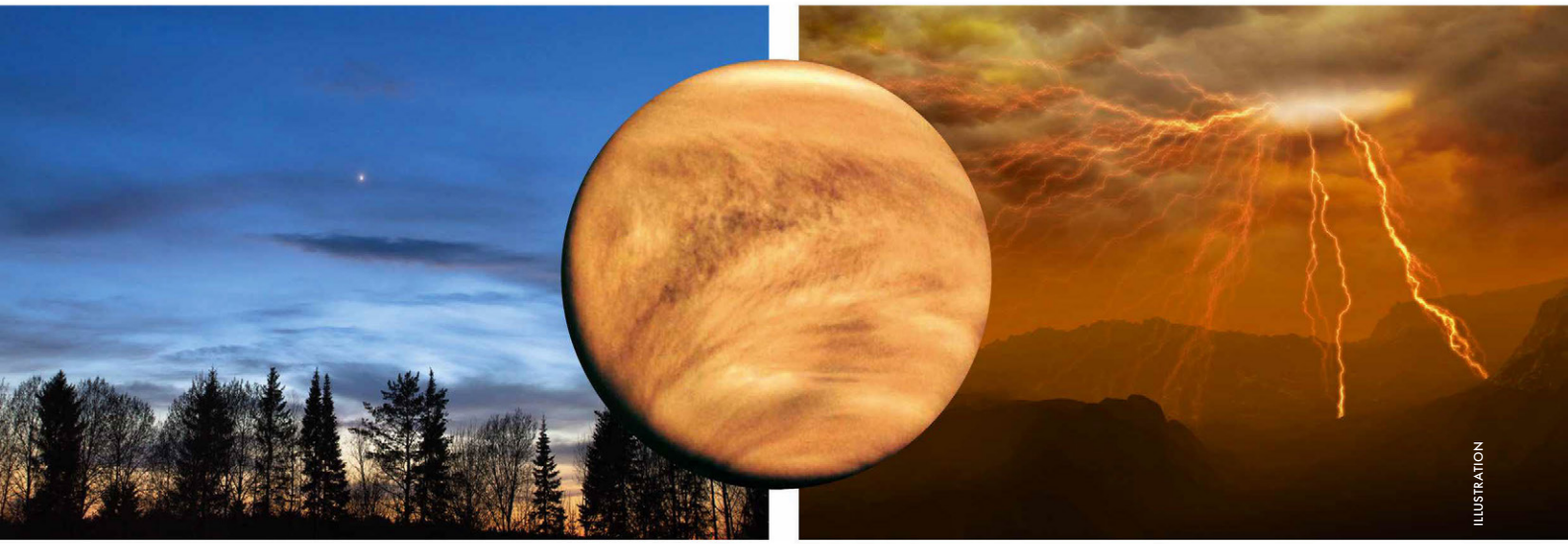
EXPLAINER

Venus's hostile atmosphere

Katrin Raynor takes a look at a planet where the skies boil and the clouds rain acid



Christiaan Huygens, a Dutch astronomer, first hypothesised the existence of Venus's atmosphere in 1698 when he observed the planet through his telescope. Despite viewing its waxing and waning phases, he could not see any features on its surface and guessed that a thick atmosphere must be obscuring his view. Years later in 1761, Russian Mikhail V Lomonosov detected the refraction of solar rays while observing the transit of Venus across the Sun – and thus discovered the atmosphere of Venus.

In 1962, Venus became the first planet to be visited by spacecraft, when NASA's Mariner 2 flew within 34,854km of the planet. Since then, nearly 40 missions have visited Venus and this month marks the 45th anniversary of NASA's Pioneer Venus mission and the Soviet Venera 11 and 12, all of which collected data about the planet's hostile atmosphere.

Venus is the second planet from the Sun and our nearest planetary neighbour. It has a rocky body similar in nature to Mercury, Earth and Mars. Named after the goddess of love and beauty, and described as Earth's twin, Venus is only 638.4km smaller in diameter than Earth and has a similar mass.

Despite being further from the Sun than Mercury, Venus is the hottest planet in the Solar System. Surface temperatures reach a scorching average of 475°C, a stark contrast to Earth's average of 15°C. It's theorised that four billion years ago, Venus's atmosphere was like Earth's, but today the planet has a dense atmosphere composed of 96 per cent carbon dioxide, 3 per cent nitrogen and the remaining percentage made up of trace elements, including sulphur dioxide. It's believed that early volcanism released carbon dioxide into the atmosphere on both Earth and Venus. But while our planet's plate tectonics helped to recycle this back into the rock, Venus was unable to do so. The carbon dioxide simply built up in the atmosphere.

▲ A beautiful, bright fixture of our skies at sunrise or sunset, Venus has a similar composition to Earth. But our 'twin' is a toxic-cloud-cloaked world ravaged by a runaway greenhouse effect, crushing pressures and lead-meltingly hot temperatures

This locked the planet into a runaway greenhouse effect, where the carbon dioxide in the atmosphere

▲ Venera 9 and 10 sent back the first-ever images of the surface on 22 and 25 October 1975, transmitting for 53 and 65 minutes before contact was lost

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ILLUSTRATION

The possibility that phosphine, a signature for life, could be in Venus's atmosphere has been highly contentious

Signs of life over Venus?

Though the atmosphere looks unsurvivable, there could be microbes living in the clouds

Three years ago, Venus hit the headlines when the presence of phosphine gas, a possible life signature, was discovered in the planet's atmosphere. Phosphine, comprising hydrogen and phosphorus, can be found on Earth as the product of natural processes such as volcanic activity, but is also created by anaerobic bacteria living in marshlands and bogs. Could Venus's atmosphere, filled with boiling clouds of sulphuric acid, be home to a similar, yet alien, microbe?

Using the James Clerk Maxwell Telescope (JCMT) in Hawaii in 2017, a team of astronomers led by Professor Jane Greaves of Cardiff University discovered a tantalising hint of the gas in the skies over Venus. Confirmation was later obtained from observations by the Atacama Large Millimeter Array observatory in Chile in 2019.

Controversy soon surrounded the announcement though, with scientists disputing whether the gas had been discovered at all. Groups of scientists posted statements questioning the data, suggesting an absorption line of sulphur dioxide had been mistaken for the presence of phosphine and the data was flawed and analysed incorrectly.

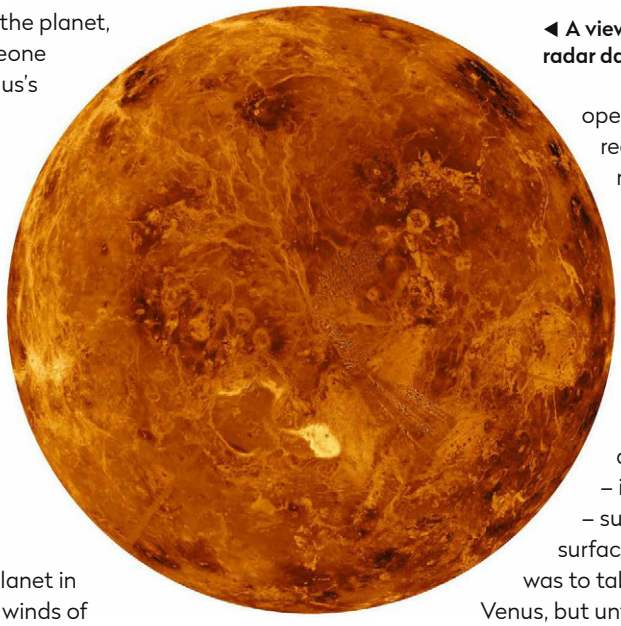
Then, earlier this year, further observations from the JCMT and data from the Stratospheric Observatory for Infrared Astronomy (SOFIA), along with different methods of analysis, again showed signs of phosphine in the planet's upper clouds, backing the initial discovery.

blocks thermal radiation from exiting the planet, resulting in high temperatures. If someone were unlucky enough to stand on Venus's surface, they would experience a pressure over 90 times Earth's – the equivalent of being 3,000 metres below the ocean.

Earth's toxic twin

Venus's atmosphere also makes it the third-brightest object visible with the naked eye. Dense clouds composed of sulphuric acid cover the planet, preventing sunlight penetrating through to the surface. These clouds reflect up to 84 per cent of the incoming rays from the Sun, causing it to outshine most night-sky objects. The clouds race around the planet in days, blown by powerful atmospheric winds of around 300km/h, releasing droplets of sulphuric acid that evaporate before reaching the planet's surface.

The information we have about Venus's atmosphere today is credited to the many missions sent to the planet. After several fly-bys throughout the 1960s and 1970s following Mariner 2, NASA mounted the Pioneer Venus project to enter the planet's atmosphere. In December 1978, Pioneer Venus entered orbit around the planet before deploying the Pioneer Venus Multiprobe (also known as Pioneer Venus 2), containing four smaller probes, into the atmosphere. The orbiter continued to operate until 1992. Crucial data recorded during this mission revealed the absence of a magnetic field, extremely high wind speeds and three cloud layers above the surface.



◀ A view of the northern hemisphere from radar data from NASA's Magellan, 1996

A few weeks later, the French–Soviet Venera 11 and 12 missions arrived. From 1961 to 1983, the Soviets sent 13 spacecraft into the planet's atmosphere, eight of which – including Venera 11 and 12 – survived to transmit from the surface. The main aim of these missions was to take colour photos of the surface of Venus, but unfortunately the camera lens caps failed to open once on the surface. Still, crucial atmospheric data was captured, including evidence of thunder and lightning, and low levels of carbon monoxide at low altitudes.

In recent decades, most spacecraft have only snapped a quick view of Venus as they sped by on their way elsewhere, though a handful – including NASA's Magellan and ESA's Venus Express – stayed for a longer look.

Interest is beginning to grow again, and now three new missions are currently being planned, a potential renaissance for this most hostile of worlds.

Katrin Raynor is an astronomy writer and a fellow of the Royal Astronomical Society