



# JUPITER'S water mystery

NASA's Juno mission has provided its first science results on the amount of water in Jupiter's atmosphere. Published recently in the journal *Nature Astronomy*, the Juno results estimate that water makes up about 0.25% of the molecules in Jupiter's atmosphere at the equator – almost three times that of the Sun.

These are the first findings on the planet's abundance of water since the agency's 1995 Galileo mission suggested Jupiter might be extremely dry compared to the Sun (the comparison is based not on liquid water but on its components, oxygen and hydrogen, present in the Sun).

An accurate estimate of the total amount of water in Jupiter's atmosphere has been on the wish lists of planetary scientists for decades. It represents a critical missing piece to the puzzle of our solar system's formation, given that Jupiter was likely the first planet to form, and it contains most of the gas and dust that wasn't incorporated into the Sun.

The leading theories about its formation rest on the amount of water the planet soaked up. Water abundance also has important implications for Jupiter's meteorology and internal structure. Although Voyager and other spacecraft observing Jupiter had detected lightning – a phenomenon fuelled by moisture – an accurate estimate of the amount of water deep within Jupiter's atmosphere remained elusive.

Before the Galileo probe stopped transmitting in December 1995, it radioed out spectrometer measurements of the amount of water in Jupiter's atmosphere down to a depth of about 120 km, where the atmospheric pressure reached about 22 bar. The scientists working on the data were dismayed to find 10 times less water than expected.

Even more surprising, the amount of water the Galileo probe measured appeared to be still increasing at the greatest depth measured, far below where theories suggest the atmosphere should be well mixed. In a well-mixed atmosphere, the water content is constant across the region and more likely to represent a global average – in other words, it's more likely to be representative of water planet-wide. When combined with an infrared map

NASA's Juno spacecraft captured this image of Jupiter's southern equatorial region in September 2017. The image is oriented so Jupiter's poles (not visible) run left-to-right of frame.

obtained at the same time by a ground-based telescope, the results suggested the probe mission may have just been unlucky, sampling an unusually dry and warm meteorological spot on Jupiter.

"Just when we think we have things figured out, Jupiter reminds us how much we still have to learn," said Scott Bolton, Juno principal investigator at the Southwest Research Institute in San Antonio, Texas. "Juno's surprise discovery that the atmosphere was not well mixed, even well below the cloud tops, is a puzzle that we are still trying to figure out. No one would have guessed that water might be so variable across the planet."

## Measuring water from above

A rotating, solar-powered spacecraft, Juno was launched in 2011 with a mission to obtain water abundance readings across large regions of the immense planet. Its microwave radiometer – a new kind of instrument for deep space planetary exploration – observes Jupiter from above using six antennas that measure atmospheric temperature at multiple depths simultaneously. The measured temperatures are used to constrain the amount of water and ammonia in the deep atmosphere, as both molecules absorb microwave radiation.

The Juno science team used data collected during the spacecraft's first eight science flybys of Jupiter to generate the findings. They initially concentrated on the equatorial region because the atmosphere there appears more well mixed, even at depth, than in other regions. From its orbital perch, the radiometer was able to collect data from 150 km into Jupiter's atmosphere, surpassing the record set by the Galileo probe.

"We found the water in the equator to be greater than what the Galileo probe measured," said Cheng Li, a Juno scientist at the University of California, Berkeley. "Because the equatorial region is very unique at Jupiter, we need to compare these results with how much water is in other regions."

## Northward bound

Juno's 53-day orbit then moved northward, as intended, bringing more of Jupiter's northern hemisphere into sharper focus with each flyby. The science team is eager to see how atmospheric water content varies by latitude and region, as well as what the cyclone-rich poles can tell them about the planet's global water abundance.

Juno's 25<sup>th</sup> science flyby of Jupiter occurred on April 10, 2020.

"Every science flyby is an event of discovery," said Bolton. "With Jupiter there is always something new. Juno has taught us an important lesson: we need to get up close and personal to a planet to test our theories."

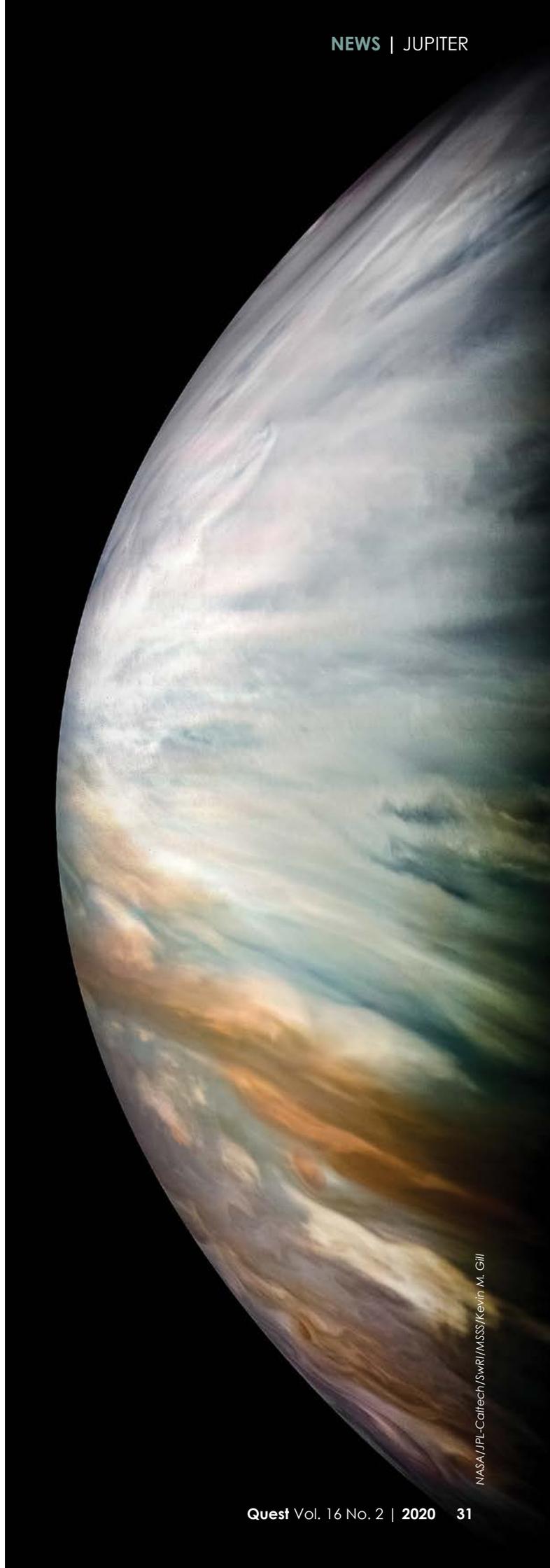
- The public can follow the mission on Facebook and Twitter at 'NASAJuno'.

*Issued by NASA and Southwest Research Institute. NASA's Jet Propulsion Laboratory in Pasadena, California, manages the Juno mission for the principal investigator, Scott Bolton, of the Southwest Research Institute. Juno is part of NASA's New Frontiers Programme, which is managed at NASA's Marshall Space Flight Centre in Huntsville, Alabama, for NASA's Science Mission Directorate. The Italian Space Agency contributed the Jovian Infrared Auroral Mapper and the Ka-Band translator system. Lockheed Martin Space in Denver built and operates the spacecraft.*

### Jupiter: 10 facts

1. Jupiter is the largest planet in the solar system, being approximately 143 000 km wide at its equator.
2. It is more than twice as massive as all the other planets combined. More than 1300 Earths would fit inside Jupiter!
3. Jupiter is the fifth planet from the Sun, with about 775 000 km of space between them.
4. Its average distance from the sun is 5.2 astronomical units, or AU. This is a little more than five times the distance from Earth to the Sun (1 AU).
5. Jupiter rotates once every 10 hours (a Jovian day), but takes about 12 Earth years to complete one orbit of the Sun (a Jovian year).
6. When viewed from Earth, Jupiter is usually the second brightest planet in the night sky, after Venus.
7. Jupiter is called a gas giant planet. Its atmosphere is made up mostly of hydrogen gas and helium gas, like the Sun. Its stripes and swirls are cold, windy clouds of ammonia and water.
8. Jupiter's Great Red Spot is a giant storm – bigger than Earth – that has raged for hundreds of years.
9. Jupiter has more than 75 moons. The largest are Ganymede, Callisto, Io and Europa. These four moons are called the Galilean satellites because they were discovered by Italian astronomer Galileo Galilei in the year 1610.
10. The planet is named after Jupiter, the king of the Roman gods in mythology.

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