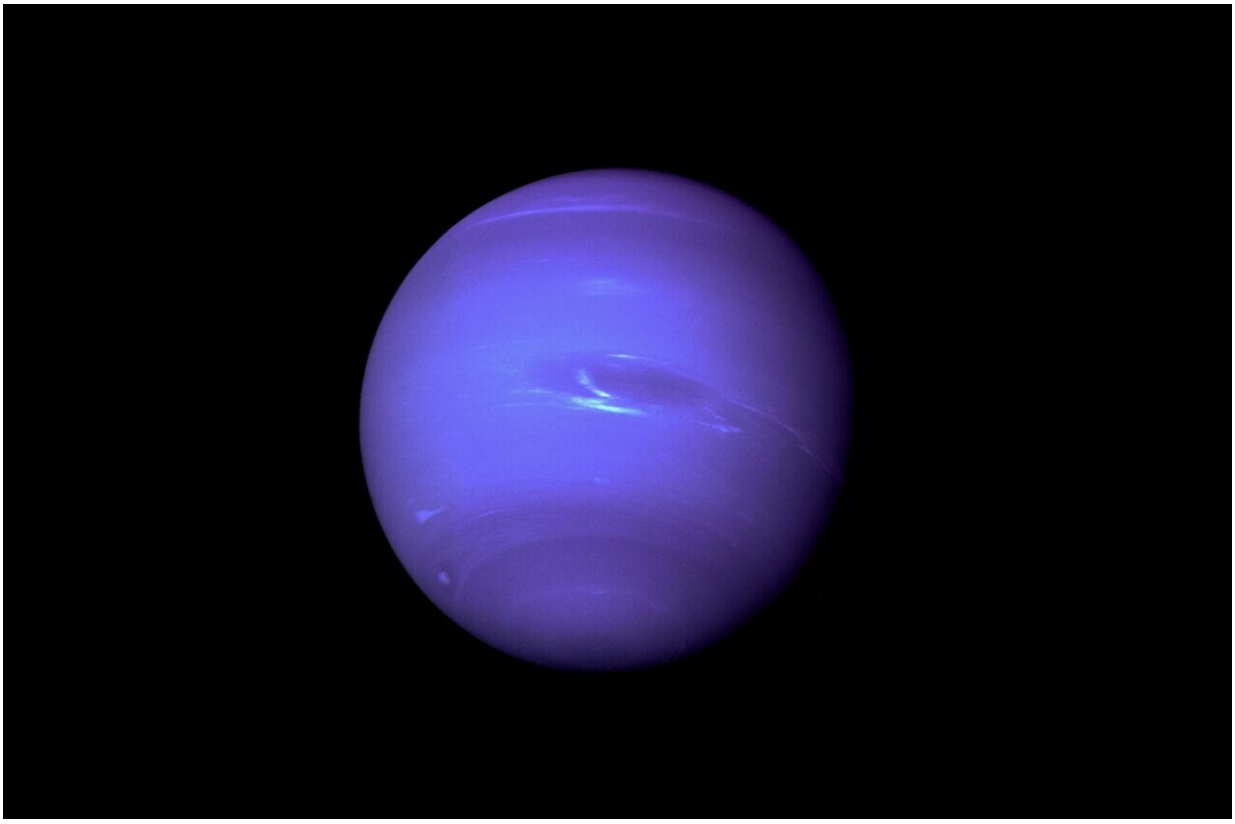
Astronomers reveal a new link between water and planet formation

February 29 2024



Credit: Unsplash/CC0 Public Domain

Researchers have found water vapor in the disk around a young star exactly where planets may be forming. Water is a key ingredient for life on Earth and is also thought to play a significant role in planet formation,

yet until now, astronomers have never been able to map how water is distributed in a stable, cool disk—the type of disk that offers the most favorable conditions for planets to form around stars.

For the first time, astronomers have weighed the amount of water vapor around a typical planet-forming star.

The new findings were made possible thanks to the Atacama Large Millimeter/submillimeter Array (ALMA)—a collection of telescopes in the Chilean Atacama Desert. The University of Manchester's Jodrell Bank Centre for Astrophysics hosts the UK ALMA Regional Centre Node (UK ARC).

Dr. Anita Richards, Senior Visiting Fellow at The University of Manchester and previously a member of the UK ARC, played a key role in the group verifying the operation of the "Band 5" receiver system, which was essential for ALMA to produce the detailed image of the water.

Dr. Richards said, "Directly measuring the amount of water vapor where planets are forming takes us a step closer to understanding how easy it could be to make worlds with oceans—how much water is attached to the agglomerating rocks, or is it mostly added later to an almost-fully-formed planet? This sort of observation needs the driest possible conditions and could only be made in such detail using the ALMA array in Chile."

The observations, published today in the journal *Nature Astronomy,* reveal at least three times as much water as in all of Earth's oceans in the inner disk of the young sun-like star HL Tauri, located 450 light-years away from Earth in the constellation Taurus.

Stefano Facchini, an astronomer at the University of Milan, Italy, who

led the study, said, "I had never imagined that we could capture an image of oceans of water vapor in the same region where a planet is likely forming."

Co-author Leonardo Testi, an astronomer at the University of Bologna, Italy, added, "It is truly remarkable that we can not only detect but also capture detailed images and spatially resolve water vapor at a distance of 450 light-years from us."

These observations with ALMA, which show details as small as a human hair at a kilometer distance, allow astronomers to determine the distribution of water in different regions of the disk.

A significant amount of water was found in the region where a known gap in the HL Tauri disk exists—a place where a planet could potentially be forming. Radial gaps are carved out in gas- and dust-rich disks by orbiting young planet-like bodies as they gather up material and grow. This suggests that this water vapor could affect the chemical composition of planets forming in those regions.

But, observing water with a ground-based telescope is no mean feat as the abundant water vapor in Earth's atmosphere degrades the astronomical signals.

ALMA, operated by European Southern Observatory (ESO), together with its international partners, sits at about 5,000 meters elevation and is built in a high and dry environment specifically to minimize this degradation, providing exceptional observing conditions. To date, ALMA is the only facility able to map the distribution of water in a cool planet-forming disk.

The dust grains that make up a disk are the seeds of planet formation, colliding and clumping into ever larger bodies orbiting the star.

Astronomers believe that where it is cold enough for water to freeze onto dust particles, things stick together more efficiently—an ideal spot for planet formation.

Members of the UK ARC are contributing to a major upgrade of ALMA, which with ESO's Extremely Large Telescope (ELT) also coming online within the decade, will provide even clearer views of planet formation and the role water plays in it. In particular, METIS, the Mid-infrared ELT Imager and Spectrograph, will give astronomers unrivaled views of the inner regions of planet-forming disks, where planets like Earth form.

More information: Resolved ALMA observations of water in the inner astronomical units of the HL Tau disk, *Nature Astronomy* (2024). DOI: 10.1038/s41550-024-02207-w

Provided by University of Manchester