Highest-precision measurement of water in planet outside the solar system

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A team of astronomers using NASA's Hubble Space Telescope have gone looking for water vapour in the atmospheres of three planets orbiting stars similar to the Sun – and have come up nearly dry.

The three planets, HD 189733b, HD 209458b, and WASP-12b, are between 60 and 900 light-years away, and are all gas giants known as 'hot Jupiters.' These worlds are so hot, with temperatures between 900 to 2200 degrees Celsius, that they are ideal candidates for detecting water vapour in their atmospheres.

However, the three planets have only one-tenth to one-thousandth the amount of water predicted by standard planet formation theories. The best water measurement, for the planet HD 209458b, was between 4 and 24 parts per million. The results raise new questions about how exoplanets form and highlight the challenges in searching for water on Earth-like exoplanets in the future. The findings are published today (24 July) in the journal *Astrophysical Journal Letters*.

"Our water measurement in one of the planets, HD 209458b, is the highest-precision measurement of any chemical compound in a planet outside the solar system, and we can now say with much greater certainty than ever before that we've found water in an exoplanet," said Dr Nikku Madhusudhan of the Institute of Astronomy at the University of Cambridge, who led the research. "However, the low water abundance we are finding is quite astonishing."

Dr Madhusudhan and his collaborators used near-infrared spectra of the planetary atmospheres observed with the Hubble Space Telescope as the planets were passing in front of their parent stars as viewed from Earth. Absorption features from water vapour in the planetary atmosphere are superimposed on the small amount of starlight that passes through the planetary atmosphere before reaching the telescope. The planetary spectrum is obtained by determining the variation in the stellar spectrum caused due to the planetary atmosphere and is then used to estimate the amount of water vapour in the planetary atmosphere using sophisticated computer models and statistical techniques.

Madhusudhan said that the findings present a major challenge to exoplanet theory. "It basically opens a whole can of worms in planet formation. We expected these planets to have lots of water in their atmospheres. We have to revisit planet formation and migration models of giant planets, especially hot Jupiters, to investigate how they're formed."

The currently accepted theory on how giant planets in our solar system formed is known as core accretion, in which a planet is formed around the young star in a protoplanetary disc made primarily of hydrogen, helium, and particles of ices and dust composed of other chemical elements. The dust particles stick to each other, eventually forming larger and larger grains. The gravitational forces of the disc draw in these grains and larger planetesimals until a solid core forms. This core then leads to runaway accretion of both planetesimals and gas to eventually form a giant planet.

This theory predicts that the proportions of the different elements in the planet are enhanced relative to those in their star, especially oxygen, which is supposed to be the most enhanced. Once a giant planet forms, its atmospheric oxygen is expected to be largely in the form of water. Therefore, the very low levels of water vapour found by this research raise a number of questions about the chemical ingredients that lead to planet formation.

"There are so many things we still don't understand about exoplanets – this opens up a new chapter in understanding how planets and solar systems form," said Dr Drake Deming of the University of Maryland, who led one of the precursor studies and is a co-author in the present study. "These findings highlight the need for high-precision spectroscopy – additional observations from the Hubble Space Telescope and the next-generation telescopes currently in development will make this task easier."

The new discovery also highlights some major challenges in the search for the exoplanet 'holy grail' – an exoplanet with a climate similar to Earth, a key characteristic of which is the presence of liquid water.

"These very hot planets with large atmospheres orbit some of our nearest stars, making them the best possible candidates for measuring water levels, and yet the levels we found were much lower than expected," said Dr Madhusudhan. "These results show just how challenging it could be to detect water on Earth-like exoplanets in our search for potential life elsewhere." Instruments on future telescopes searching for biosignatures may need to be designed with a higher sensitivity to account for the possibility of planets being significantly drier than predicted.

The researchers also considered the possibility that clouds may be responsible for obscuring parts of the atmospheres, thereby leading to the low observed water levels. However, such an explanation requires heavy cloud particles to be suspended too high in the atmosphere to be physically plausible for all the planets in the study.

More information: The paper, "H2O abundances in the atmospheres of three hot Jupiters" is published in the journal *Astrophysical Journal*

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