Scientists reveal the secret of the formation of a strange 'gas world' suspended in the universe

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A new study using data from the world's most expensive space telescope, the James Webb Space Telescope (JWST), has helped scientists better understand how the distant planet WASP-121b formed. Led by astronomers Thomas Evans-Soma and Cyril Gapp, the team focused on detecting key molecules in the planet's atmosphere to decipher the planet's history and movements through space.

WASP-121b is an extremely hot gas giant, locked in a super-tight orbit around its star – so close that it completes a rotation every 30.5 hours. One side of the planet is always facing the star, reaching temperatures above 3000°C, while the other side is in permanent darkness at around 1500°C.

Using JWST's Near Infrared Spectrometer (NIRSpec), the team detected water vapor (H?O), carbon monoxide (CO), silicon monoxide (SiO), and methane (CH?). The signals were strong: water at 5.5–13.5? significance, CO at 10.8–12.8?, SiO at 5.7–6.2?, and methane on the dark side at 3.1–5.1?.

Interestingly, both refractory elements (materials that typically remain solid at high temperatures, such as silicon, iron, magnesium) and volatiles (such as water, methane) were detected. Normally, it is difficult to detect them at the same time because the signals are at different wavelengths. *"The surface temperature is high enough that refractory materials, which are solid compounds that can withstand high temperatures, exist as gases in the planet's atmosphere," Evans-Soma explains.*

Comparing the detected elements to the composition of its host star, the team found that the planet contains more carbon, oxygen, and silicon than expected. These values exceed those of its host star (a supergiant), suggesting that the planet formed by collecting both gas-rich 'pebbles' and rocky planetesimals. With so many compounds existing in gaseous form, astronomers view WASP-121b as a natural laboratory for exploring planetary atmospheric properties.

The planet probably formed in a colder region of the primordial gas-dust disk—far enough away for water to freeze but warm enough for methane to turn into gas. This environment is similar to the region between Jupiter and Uranus in our Solar System. It then migrated closer to its star.

Another surprising finding is methane on the dark side. Current models suggest that methane cannot exist in abundance here because air from the hot day side would mix with the dark side and destroy the methane. This fact challenges known exoplanetary dynamics models – they may need to be tweaked to reproduce the strong vertical gas mixing we found on the dark side of WASP-121b'.

Methane is probably pushed up from deeper layers of the atmosphere by strong vertical winds. These deeper layers are rich in methane due to their lower temperatures and high carbon/oxygen ratios.

The team collected data throughout the planet's orbit and even as it passed in front of its host star. During these transits, some of the starlight passes through the planet's thin outer atmosphere, helping to determine its chemical composition. *"The spectra confirmed the presence of silicon monoxide, carbon monoxide, and water from the emission data," Gapp explains. "However, we did not find methane in the day-night transition region."*

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