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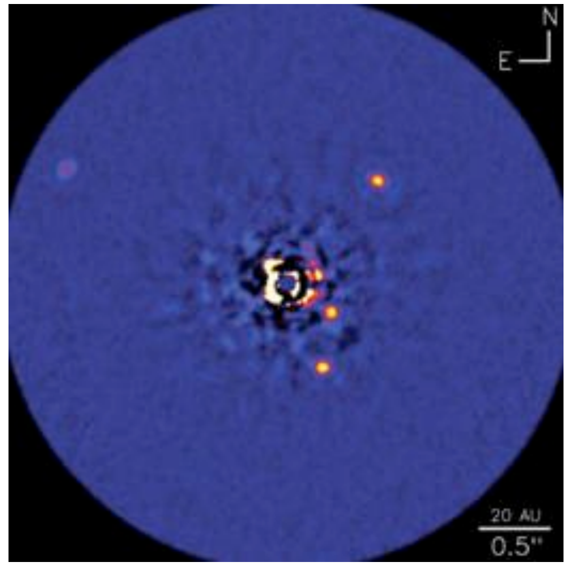
News

Exoplanets cast doubt on astronomical theories

Planets in other solar systems are set to change ideas on how worlds form

Katharine Sanderson

Astronomers who study how planets form are scratching their heads after two studies have shown that all is not as theory would predict in the world of other-worldly worlds.



Four gas giants, each more massive than Jupiter, circle in the star system HR 8799, shown in this image from the Keck II telescope.

NRC-HIA, C. Marois & Keck Observatory

The papers, both published online in *Nature* today, concern planets outside our own Solar System. The existence of one confounds current ideas on planet formation, whereas measurements of the other's atmosphere throw into doubt theories about atmospheric composition and its relationship to a planet's interior.

How planets are born

The first challenge has been posed by Christian Marois, an astronomer from the Herzberg Institute of Astrophysics in Victoria, Canada, and his colleagues, who used the Keck II telescope on Mauna Kea in Hawaii to spot a fourth planet in the star system HR 8799, some 39 parsecs (129 light years) away from Earth[1].

The planet, HR 8799e, is a gas giant rather like Jupiter, but about 10 times as massive — similar to the other three planets in the system, which Marois discovered in 2008. It sits fairly close to its star, at 14.5 astronomical units (AU; one AU is the average distance between Earth and our Sun. Saturn is some 9.5 AU from our Sun, and Uranus is at a distance of some 19.6 AU). The other planets in the HR 8799 system are 24, 38 and 68 AU from their star, respectively.

HR 8799e's relative closeness to its star makes it difficult to explain how both it and its gas-giant companions formed. "There's something weird going on," says Marois.

Current theories suggest two ways in which a gaseous, dusty ring around a young star can form into gas-giant planets. In one — the 'accretion' model — small clumps of dust build up over millions of years to form a planet's solid core, which then pulls gases towards it. The other model, 'fragmentation', suggests that small clumps of a gaseous disk form directly into planets over 10,000 years.

Neither model on its own explains all four of the planets around HR 8799. The accretion model can't account for the three outer gas giants. At their distances from the star, the rocky planetary core would have taken so long to form that the gaseous disk would have dissipated before the core could attract the gas.

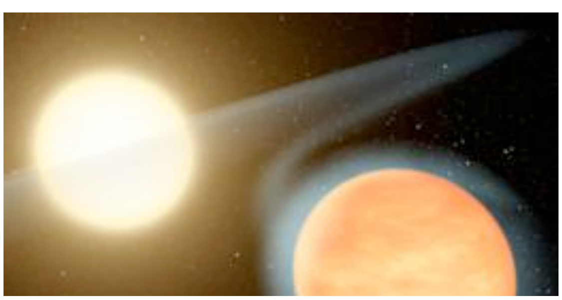
On the other hand, according to theory the fragmentation process suits the outer planets, but not the inner one. Laird Close, an astronomer at the University of Arizona in Tucson, explains in an accompanying comment piece to Marois' paper that this is because at 14.5 AU the gaseous disk would have been too hot and have rotated too quickly for a clump to form[3].

Marois thinks that only one — not both — of the formation mechanisms can be responsible for the system, because the planets have similar masses and seem to be locked in orbital resonance, meaning that the times that they take to orbit the star are related in ratios, much like the frequency of musical notes on a piano keyboard. He suggests that the planets probably migrated to their current positions after being formed.

But Melvyn Davies from Lund Observatory, Sweden, who works on theories of planet formation, prefers the idea that the planets remain where they were formed, perhaps directly from a gaseous disk by the fragmentation process. Until more is understood about planet formation, the system will remain a conundrum.

Carbon question

Planetary theorists also have a second problem on their hands, thanks to work by Nikku Madhusudhan, an astrophysicist at Princeton University in New Jersey[2]. He and his colleagues have taken a close look at another exoplanet: WASP 12b, a gas giant 267 parsecs from Earth, which was discovered in 2009. By combining new and existing measurements, Madhusudhan has discovered that there is more carbon than oxygen in the planet's atmosphere, something never seen before. Most models of planets assume that they are similar to the terrestrial planets in our own Solar System, with about half as much carbon as oxygen in the atmosphere.



Madhusudhan says that WASP 12b's atmosphere implies that the planet's solid centre is not rich in silicates (minerals composed mainly of silicon and oxygen) like that of Earth, but instead is rich in carbon. Mountains of diamond or graphite could exist there, Madhusudhan suggests, and any life forms might thrive on carbon-rich

An artist's impression of the extremely hot exoplanet WASP 12b and its host star.

NASA/JPL-Caltech/R. Hurt (SSC)

methane rather than water or oxygen.

But it is difficult to draw comparisons between WASP 12b and planets that we know, because of a lack of data on carbon/oxygen ratios for gas giants in our own Solar System. "The only analogue [for WASP 12b] is Jupiter. And for Jupiter at this time we don't have the answer," says Sushil Atreya, a planetary scientist at the University of Michigan in Ann Arbor.

Jupiter's carbon/oxygen ratio cannot be established by spectroscopic observations because most of its oxygen is trapped in water, which has condensed out of the atmosphere because Jupiter is so cold. But efforts are underway to correct this lack: Atreya is a co-investigator in NASA's Juno mission, which will launch in 2011 and arrive at Jupiter in 2016 to map water and measure the abundance of oxygen. If Jupiter turns out to be carbon-rich like WASP 12b, it could mean that the small bodies from which some planets form in our own and other solar systems should be thought of as more like carbon-rich tar than like ice, says Madhusudhan.

The results of both Marois's and Madhusudhan's studies are set to throw up many more anomalies for planet hunters — and they cover only a few of the hundreds of exoplanets that have been discovered and are ready for analysis. "We still have many questions, but so far very few answers. Our community has a lot of work to do," says Marois.

References

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