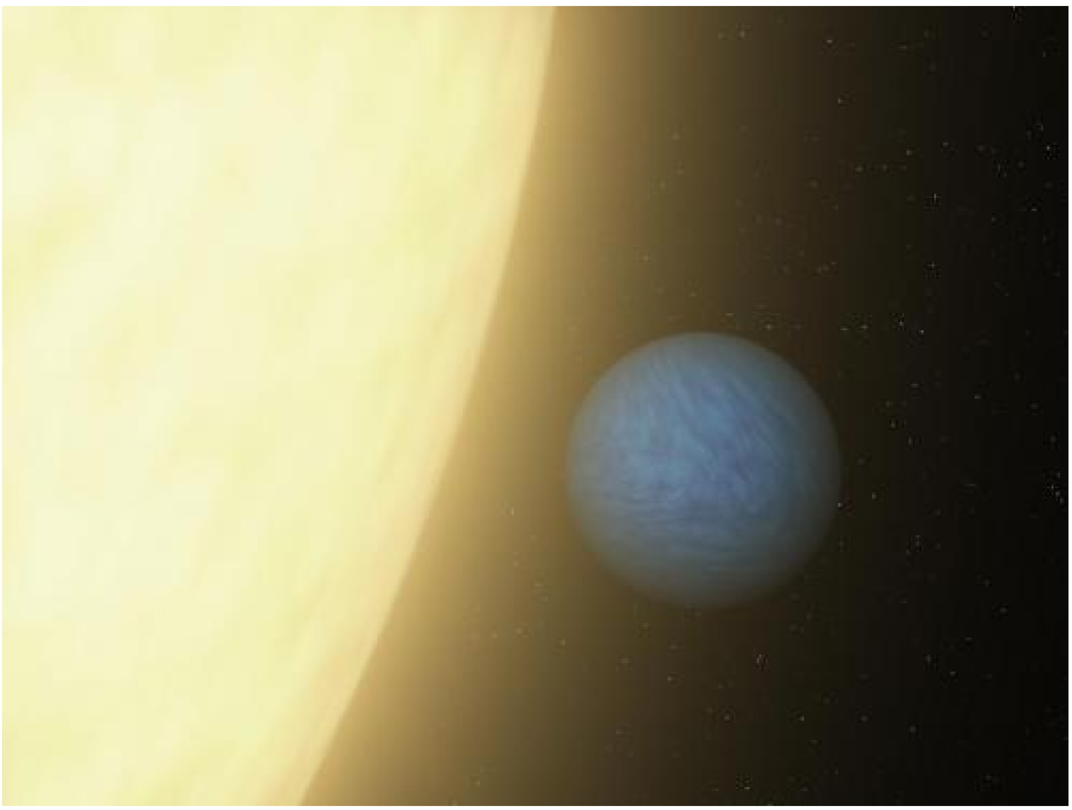
Hot super-Earths help track water-rich atmospheres

November 18 2014, by Nola Taylor Redd, Astrobio.net



This artist's concept of 55 Cancri e shows a heated world that orbits its star every 18 hours. By studying the atmospheres of hot rocky planets like this one, scientists can understand more about similar planets farther from their sun with the potential to host life. Credit: NASA/JPL-Caltech

As the discovery of planets beyond the Solar System becomes more common, scientists have begun the in-depth study of the atmospheres of these bodies.

In a new paper, a pair of astronomers investigated the detectability of water in the atmospheres of far-away planets and found that hot, bright super-Earths are more easily identifiable with today's instruments than cooler ones.

Super-Earths are rocky bodies up to 10 times as massive as Earth, but not quite in the gas giant range. The compositions of these planets can range from solid rock to water-worlds atop a rocky crust.

Focusing on the hot version of super-Earths, which maintain water in vapor form rather than as a liquid on the surface, can provide insights into how much water could exist on cooler super-Earths.

Some of the cooler super-Earths have the potential to be habitable but their atmospheres are much more challenging to observe.

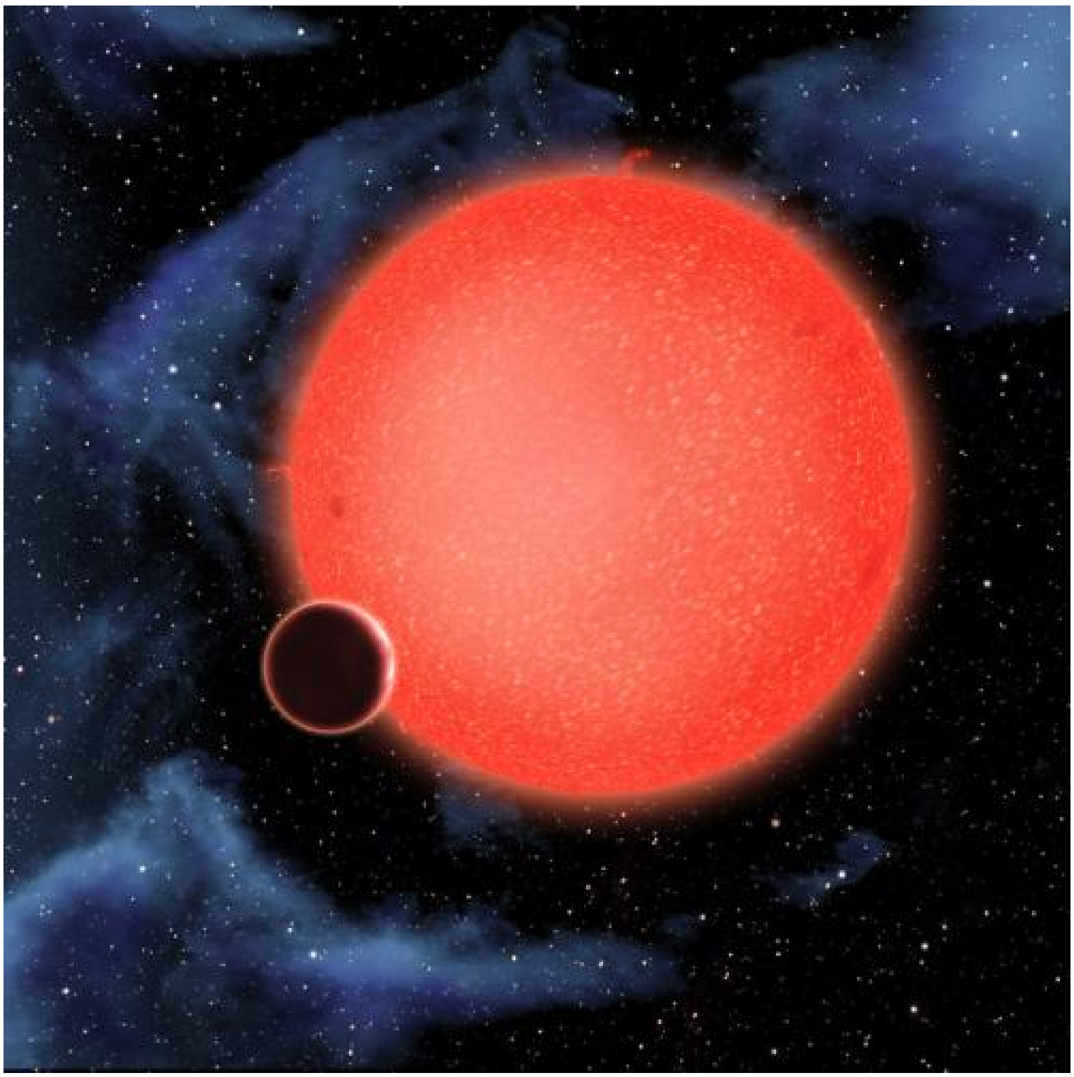
"We are interested in knowing how much water there is on super-Earths regardless of the phase—liquid or vapor," lead author Nikku Madhusudhan, of the University of Cambridge, told Astrobiology Magazine by email.

The research was published in a special exoplanet edition of the journal, The *International Journal of Astrobiology*.

Hotter planets, brighter futures

Madhusudhan and co-author Seth Redfield of Wesleyan University, in Connecticut, studied how qualities of an exoplanet that astronomers can observe, such as mass and radius, can help scientists narrow down what kind of atmosphere a planet could potentially have.

"Super-Earths are a mysterious class of planets because they seem to have a range of compositions, and also because we don't have any examples in the Solar System," planetary scientist Jacob Bean, of the University of Chicago, told Astrobiology Magazine.



Super-Earth GJ 1214b orbits a dim red dwarf star. Clouds in the planet's sky hinder the study of its atmosphere. Credit: NASA, ESA, and D. Aguilar (Harvard-Smithsonian Center for Astrophysics)

Bean, who was not involved in the research, probes the atmospheres of super-Earths.

The mass and radius of planets beyond the Solar System can be used to place some starting constraints on their atmospheres. If an observed planet has a larger radius than expected for a water-rich body, it would indicate that the planet has an atmosphere with a molecular composition lighter than water vapor, and might therefore be made up of elements such as hydrogen or helium, Madhusudhan said.

Atmospheres represent a challenge to scientists, who struggle to observe the translucent outer layers of a planet. The passing starlight changes as it interacts with molecules in the atmosphere. By studying this light, known as spectra, scientists can identify the atmospheric composition. However, changes in the spectra are small compared to the overall light from the star, and require precision to study.

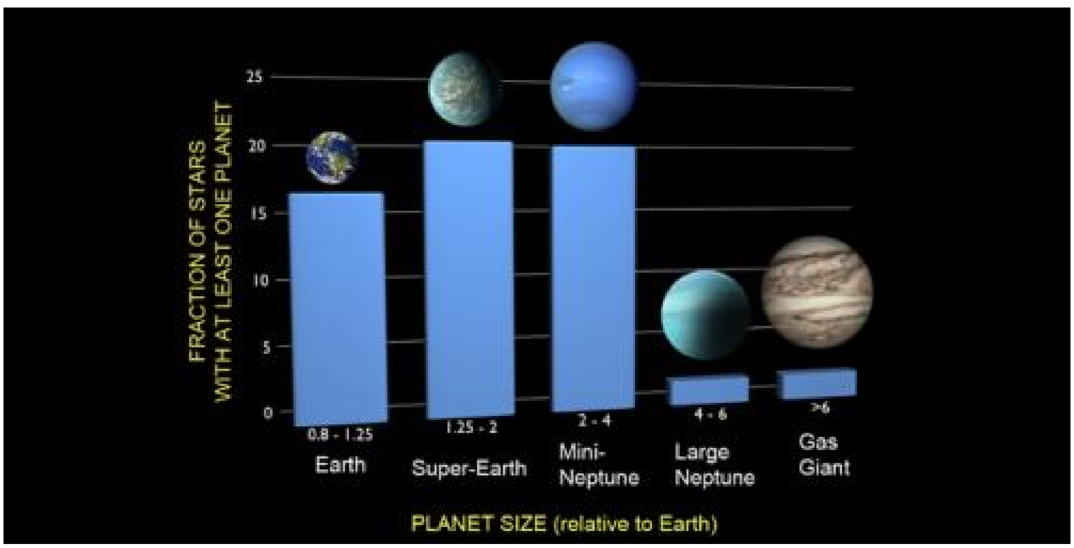
While the study of the atmospheres of larger gas giants, such as hot Jupiters, is in full swing, the smaller size of super-Earths makes their study more challenging. The smaller planets produce a smaller signal for scientists to study and identify.

The temperature of a planet, which primarily depends on how closely it orbits its star, also plays a role in our ability to detect its atmospheric composition. Scientists have a harder time detecting the atmosphere of a cooler planet than its warmer counterpart. Characterizing the atmosphere of a super-Earth orbiting a star in its habitable zone (the region where liquid water could exist on the surface) is outside the abilities of today's instruments. Future tools on upcoming telescopes, such as NASA's James Webb Space Telescope and the Thirty-Meter Telescope, which is expected to be the second-largest ground-based telescope when it sees first light around 2022, may be able to detect signatures in a few select cases, Madhusudhan said, but doing so will remain difficult.

As a result, the team focused on hot super-Earths with orbits on the order of days, particularly those traveling around hot, bright stars.

Only two hot super-Earths known today have good potential for atmospheric observations. 55 Cancri e boasts a temperature of over 3,100 degrees Fahrenheit (1,700 degrees Celsius) as it circles its star every 18 hours. Meanwhile, HD 97658 b travels around its star once every 9.5 days, reaching temperatures of about 1,100 degrees Fahrenheit (630 degrees C).

When it comes to detecting atmospheres, "clearly, 55 Cancri e is the ideal candidate at the moment," Madhusudhan said.



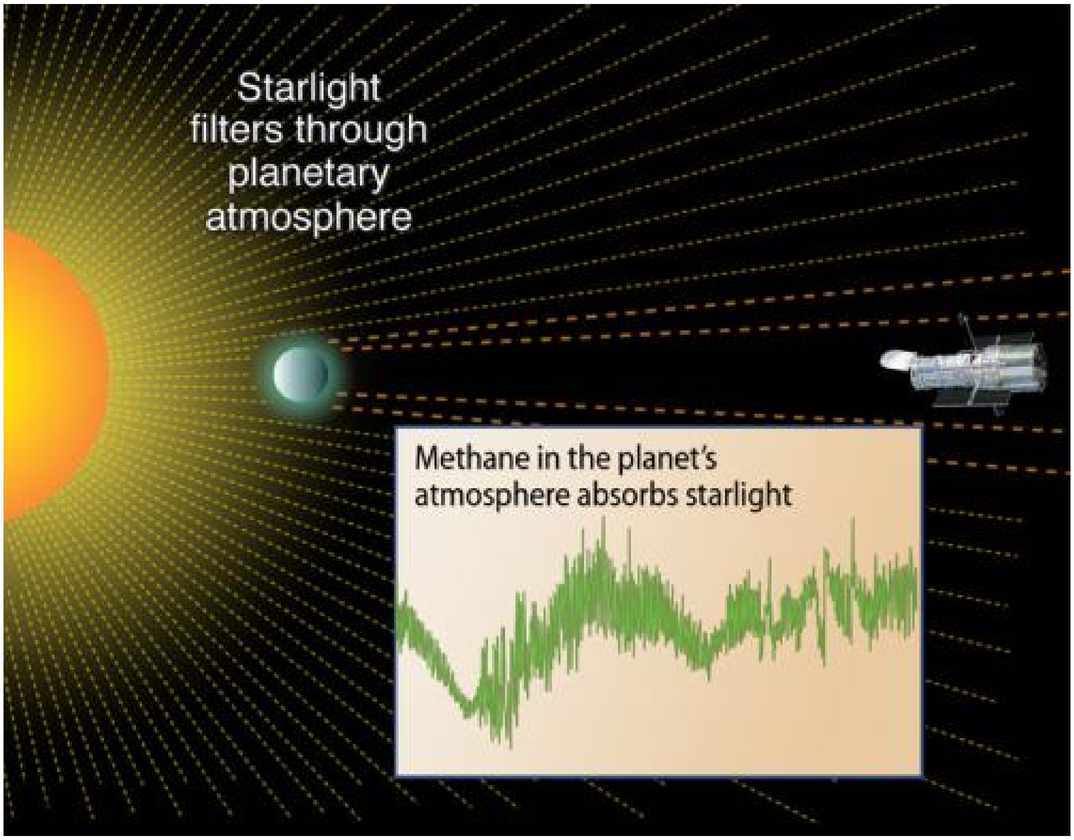
A 2013 analysis of Kepler data showed that a quarter of all stars in the Milky Way host a super-Earth. Credit: F. Fressin (CfA)

Many upcoming planet-finding surveys undertaken from space, such as TESS (Transiting Exoplanet Survey Satellite), CHEOPS (CHarcterising ExOPlanet Satellite), and PLATO (PLAnetary Transits and Oscillations of stars), as well as several ground-based surveys, are expected to find hundreds of such planets.

Cloudy skies

One reason close-orbiting super-Earths such as 55 Cancri e make better candidates to study is because their hot temperatures affect cloud formation. Although on Earth, clouds are made predominantly of water, at higher temperatures, clouds would form from heavier materials, such as iron and silicates. The cloud cover would settle lower to the ground, allowing more of the spectra of the atmosphere to pass through for scientists to identify.

Clouds lack the unique fingerprints that molecules present when scientists study their spectra, hindering the study of the atmosphere. For instance, GJ 1214b is a super-Earth orbiting a red dwarf star. Previous research suggested that this planet hosted a water-rich atmosphere, but Jacob Bean was part of a team that in 2013 detected clouds above the planet.



Scientists detect starlight as it passes through the atmosphere of a planet, revealing the atmospheric composition. Credit: NASA, ESA, and A. Feild(STScI)

Another benefit of studying near-orbiting super-Earths is that they pass frequently between their star and our sun, allowing astronomers to gather more data over the same time scale than can be done with their cooler counterparts.

Studying hot super-Earths can help scientists understand more about super-Earths that lie in the habitable zone, even though the atmospheres of the cooler planets continue to elude detection. Knowing how much water the hotter atmospheres contain can help constrain the amount of water on cooler planets, which should have formed from similar starting conditions that would have changed based on the planetary orbits.

"These calculations have helped sharpen our view of what information we can get from the spectra of super-Earths, and which individual objects are the best ones to focus our attention on," Bean said.

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