James Webb Space Telescope to inspect atmospheres of gas giant exoplanets

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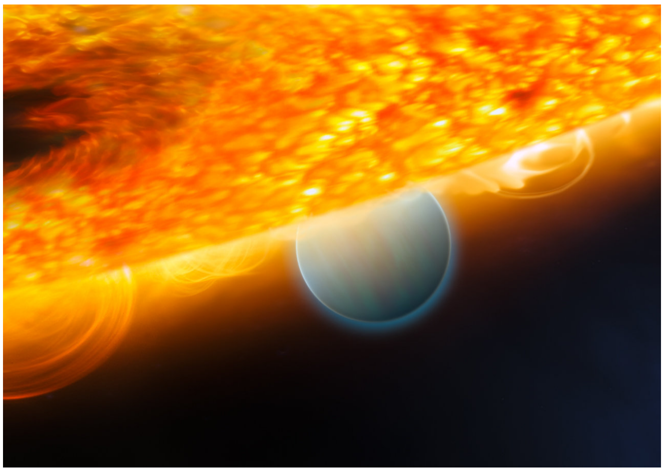

Artist's impression of the Jupiter-size extrasolar planet, HD 189733b, being eclipsed by its parent star. Astronomers using the Hubble Space Telescope have measured carbon dioxide and carbon monoxide in the planet's atmosphere. The planet is a "hot Jupiter," which is so close to its star that it completes an orbit in only 2.2 days. The planet is too hot for life as we know it. But under the right conditions, on a more Earth-like world, carbon dioxide can indicate the presence of extraterrestrial life. This observation demonstrates that chemical biotracers can be detected by space telescope observations. Credit: ESA, NASA, M. Kornmesser (ESA/Hubble), and STScI

In April 2018, NASA launched the Transiting Exoplanet Survey Satellite (TESS). Its main goal is to locate Earth-sized planets and larger "super-Earths" orbiting nearby stars for further study. One of the most powerful tools that will examine the atmospheres of some planets that TESS discovers will be NASA's James Webb Space Telescope. Since observing small exoplanets with thin atmospheres like Earth will be challenging for Webb, astronomers will target easier, gas giant exoplanets first.

Some of Webb's first observations of gas giant exoplanets will be conducted through the Director's Discretionary Early Release Science program. The transiting exoplanet project team at Webb's science operations center is planning to conduct three different types of observations that will provide both new scientific knowledge and a better understanding of the performance of Webb's science instruments.

"We have two main goals. The first is to get transiting exoplanet datasets from Webb to the astronomical community as soon as possible. The second is to do some great science so that astronomers and the public can see how powerful this observatory is," said Jacob Bean of the University of Chicago, a co-principal investigator on the transiting exoplanet project.

"Our team's goal is to provide critical knowledge and insights to the astronomical community that will help to catalyze exoplanet research and make the best use of Webb in the limited time we have available," added Natalie Batalha of NASA Ames Research Center, the project's principal investigator.

Transit—An atmospheric spectrum

When a planet crosses in front of, or transits, its host star, the star's light is filtered through the planet's atmosphere. Molecules within the atmosphere absorb certain wavelengths, or colors, of light. By splitting the star's light into a rainbow spectrum, astronomers can detect those sections of missing light and determine what molecules are in the planet's atmosphere.

For these observations, the project team selected WASP-79b, a Jupiter-sized planet located about 780 light-years from Earth. The team expects to detect and measure the abundances of water, carbon monoxide, and carbon dioxide in WASP-79b. Webb also might detect new molecules not yet seen in exoplanet atmospheres.

Phase curve—A weather map

Planets that orbit very close to their stars tend to become tidally locked. One side of the planet permanently faces the star while the other side faces away, just as one side of the Moon always faces the Earth. When the planet is in front of the star, we see its cooler backside. But as it orbits the star, more and more of the hot day-side comes into view. By observing an entire orbit, astronomers can observe those variations (called a phase curve) and use the data to map the planet's temperature, clouds, and chemistry as a function of longitude.

The team will observe a phase curve of the "hot Jupiter" known as WASP-43b, which orbits its star in less than 20 hours. By looking at different wavelengths of light, they can sample the atmosphere to different depths and obtain a more complete picture of its structure. "We have already seen dramatic and unexpected variations for this planet with Hubble and Spitzer. With Webb we will reveal these variations in significantly greater detail to understand the physical processes that are responsible," said Bean.

Eclipse—A planet's glow

The greatest challenge when observing an exoplanet is that the star's light is much brighter, swamping the faint light of the planet. To get around this problem, one method is to observe a transiting planet when it disappears behind the star, not when it crosses in front of the star. By comparing the two measurements, one taken when both star and planet are visible, and the other when only the star is in view, astronomers can calculate how much light is coming from the planet alone.

This technique works best for very hot planets that glow brightly in infrared light. The team plans to study WASP-18b, a planet that is baked to a temperature of almost 4,800 degrees Fahrenheit (2,900 K). Among other questions, they hope to determine whether the planet's stratosphere exists due to the presence of titanium oxide, vanadium oxide, or some other molecule.

Habitable planets

Ultimately, astronomers want to use Webb to study potentially habitable planets. In particular, Webb will target planets orbiting red dwarf stars since those stars are smaller and dimmer, making it easier to tease out the signal from an orbiting planet. Red dwarfs are also the most common stars in our galaxy.

"TESS should locate more than a dozen planets orbiting in the habitable zones of red dwarfs, a few of which might actually be habitable. We want to learn whether those planets have atmospheres and Webb will be the one to tell us," said Kevin Stevenson of the Space Telescope Science Institute, a co-principal investigator on the project. "The results will go a long way towards answering the question of whether conditions favorable to life are common in our galaxy."

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