Astronomers conduct first remote reconnaissance of another solar system

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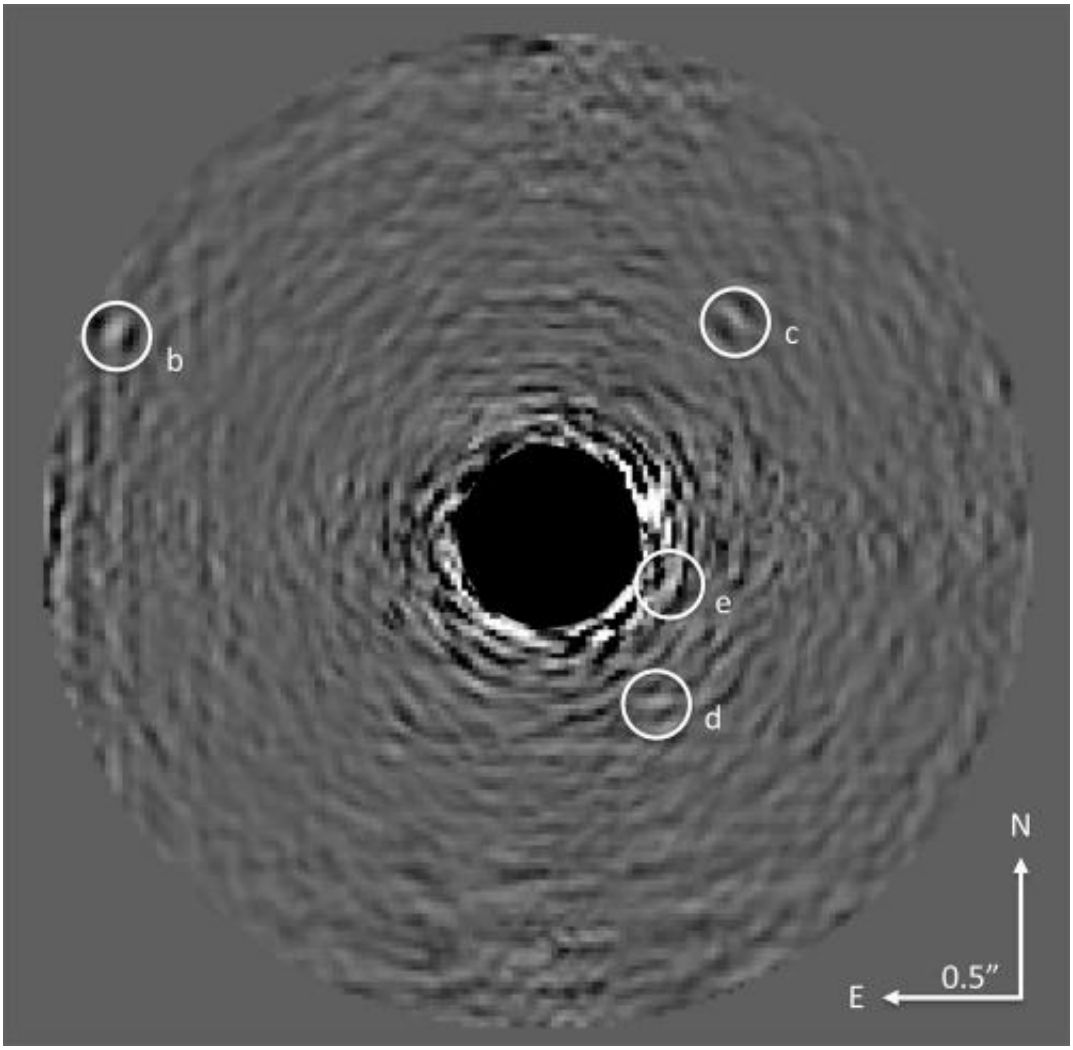


This image of the HR 8799 planets was taken with starlight optically suppressed and data processing conducted to remove residual starlight. The star is at the center of the blackened circle in the image. The four spots indicated with the letters b through e are the planets. This is a composite image using 30 wavelengths of light and was obtained over a period of 1.25 hours on June 14

and 15, 2012. Credit: Project 1640

Researchers have conducted a remote reconnaissance of a distant solar system with a new telescope imaging system that sifts through the blinding light of stars. Using a suite of high-tech instrumentation and software called Project 1640, the scientists collected the first chemical fingerprints, or spectra, of this system's four red exoplanets, which orbit a star 128 light years away from Earth. A detailed description of the planets—showing how drastically different they are from the known worlds in the universe—was accepted Friday for publication in *The Astrophysical Journal*.

"An image is worth a thousand words, but a spectrum is worth a million," said lead author Ben R. Oppenheimer, associate curator and chair of the Astrophysics Department at the American Museum of Natural History.

Oppenheimer is the principal investigator for Project 1640, which uses the Hale telescope at the Palomar Observatory in California. The project involves researchers from the California Institute of Technology, NASA's Jet Propulsion Laboratory, Cambridge University, New York University, and the Space Telescope Science Institute, in addition to Oppenheimer's team at the Museum.

The planets surrounding the star of this study, HR 8799, have been imaged in the past. But except for a partial measurement of the outermost planet in the system, the star's bright light overwhelmed previous attempts to study the planets with spectroscopy, a technique that splits the light from an object into its component colors—as a prism spreads sunlight into a rainbow. Because every chemical, such as carbon dioxide, methane, or water, has a unique light signature in the spectrum,

this technique is able to reveal the chemical composition of a planet's atmosphere.

"In the 19th century it was thought impossible to know the composition of stars, but the invention of astronomical spectroscopy has revealed detailed information about nearby stars and distant galaxies," said Charles Beichman, executive director of the NASA Exoplanet Science Institute at the California Institute of Technology. "Now, with Project 1640, we are beginning to turn this tool to the investigation of neighboring exoplanets to learn about the composition, temperature, and other characteristics of their atmospheres."

With this system, the researchers are the first to determine the spectra of all four planets surrounding HR 8799. "It's fantastic to nab the spectra of four planets in a single observation," said co-author Gautam Vasisht, an astronomer at the Jet Propulsion Laboratory.

This photo shows the Project 1640 instrument in the telescope dome of the 200-inch Hale Telescope at Palomar Observatory, prior to being installed for observations. Credit: Palomar Observatory/S. Kardel

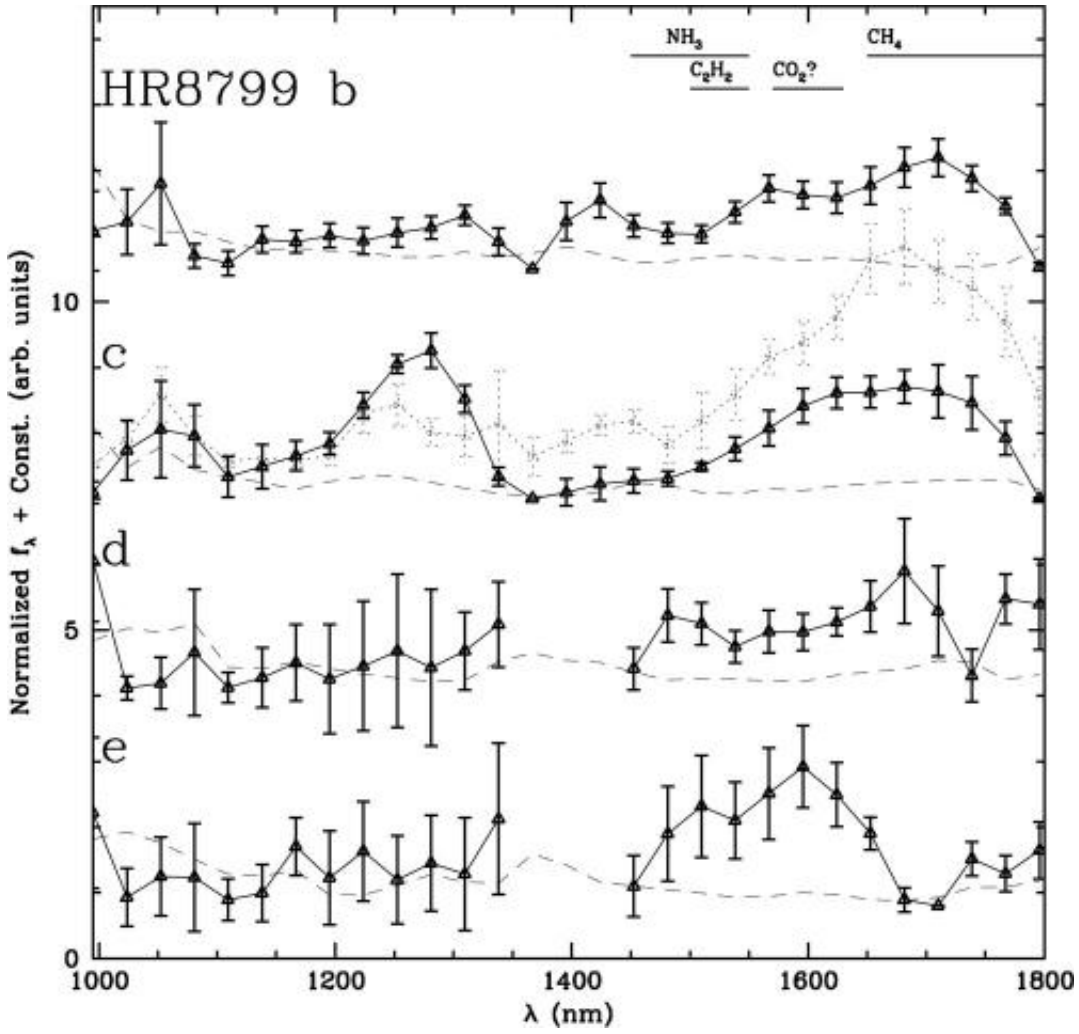
The results are "quite strange," Oppenheimer said. "These warm, red planets are unlike any other known object in our universe. All four planets have different spectra, and all four are peculiar. The theorists have a lot of work to do now."

One of the most striking abnormalities is an apparent chemical imbalance. Basic chemistry predicts that ammonia and methane should naturally coexist in varying quantities unless they are in extremely cold or hot environments. Yet the spectra of the HR 8799 planets, all of which have "lukewarm" temperatures of about 1000 Kelvin (1340

degrees Fahrenheit), either have methane or ammonia, with little or no signs of their chemical partners. Other chemicals such as acetylene, previously undiscovered on any exoplanet, and carbon dioxide may be present as well.

The planets also are "redder," meaning that they emit longer wavelengths of light, than celestial objects with similar temperatures. This could be explained by significant but patchy cloud cover on the planets, the authors say.

With 1.6 times the mass and five times the brightness, HR 8799 itself is very different from our Sun. The brightness of the star can vary by as much as 8 percent over a period of two days and produces about 1,000 times more ultraviolet light than the Sun. All of these factors could impact the spectral fingerprints of the planets, possibly inducing complex weather and sooty hazes that could be revealed by periodic changes in the spectra. More data is needed to further explore this solar system's unusual characteristics.



This graph shows the spectra of all four planets orbiting HR 8799. The plot shows how bright each object is (y-axis) versus the wavelength of light or color measured. Dips and peaks in these plots are due to the presence or absence of certain molecules (indicated at the top of the plot). Credit: Project 1640

"The spectra of these four worlds clearly show that they are far too toxic and hot to sustain life as we know it," said co-author Ian Parry, a senior lecturer at the Institute of Astronomy, Cambridge University. "But the really exciting thing is that one day, the techniques we've developed will give us our first secure evidence of the existence of life on a planet outside our solar system."

In addition to revealing unique planets, the research debuts a new capability to observe and rapidly characterize exoplanetary systems in a routine manner, something that has eluded astronomers until now because the light that stars emit is tens of millions to billions of times brighter than the light given off by planets. This makes directly imaging and analyzing exoplanets extremely difficult: as Oppenheimer says, "It's like taking a single picture of the Empire State Building from an airplane that reveals the height of the building as well as taking a picture of a bump on the sidewalk next to it that is as high as a couple of bacteria."

Project 1640 helps scientists clear this hurdle by sharpening and darkening a star's light. This technical advance involves the coordinated operation of four major instruments: the world's most advanced adaptive optics system, which can make millions of tiny adjustments to the device's two 6-inch mirrors every second; a coronagraph that optically dims the star but not other celestial objects in the field of view; an imaging spectrograph that records 30 images in a rainbow of colors simultaneously; and a specialized wave front sensor that distinguishes between residual starlight that sneaks through the coronagraph and the light from planets, allowing scientists to filter out background starlight more effectively.

Altogether, the project has produced images of celestial objects 1 million to 10 million times fainter than the star at the center of the image, with only an hour of observations. It is also capable of measuring orbital motion of objects.

"Astronomers are now able to monitor cloudy skies on extrasolar planets, and for the first time, they have made such observations for four planets at once," said Maria Womack, program director for the Division of Astronomical Sciences at the National Science Foundation. "This new ability enables astronomers to now make comparisons as they track the atmospheres, and maybe even weather patterns, on the planets."

Researchers are already collecting more data on this system to look for changes in the planets over time, as well as surveying other young stars. During its three-year survey at Palomar, which started in June 2012, Project 1640 aims to survey 200 stars within about 150 light years of our solar system.

"The variation in the spectra of the four planets is really intriguing," said Didier Saumon, an astronomer at Los Alamos National Laboratory who was not involved in this study. "Perhaps this shouldn't be too surprising, given that the four gaseous planets of the solar system are all different. The hundreds of known exoplanets have forced us to broaden our thinking, and this new data keeps pushing that envelope."

More information: www.amnh.org/content/download/ … /808131/file/Project%201640%20solar%20system%20imaging.pdf

Provided by American Museum of Natural History