Scattered light could reveal alien atmospheres

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Extrasolar planet Upsilon Andromedae d lies in the habitable zone and if sufficiently large moons of Upsilon Andromedae d exist, they may be able to support liquid water, as the image shows. On the horizon of this hypothetical moon can be seen Upsilon Andromedae d, possibly a class II planet (Sudarsky classification): since it is too warm to form ammonia clouds this ones are made up of water vapor, white in colour instead of the caracteristic yellow-reddish clouds of Jupiter and Saturn. Credit: Lucianomendez

The light scattered off distant worlds could help reveal details about their atmospheres that no other method could uncover, scientists find.

Nearly all the information astronomers have of the atmospheres of alien planets or exoplanets comes from worlds whose orbits happen to be precisely aligned from our vantage point. Once per orbit, these exoplanets go in front of (transit) their host stars from our point of view, and the light from these stars passes through the atmospheres of these planets on its way to Earth. The molecules in these alien atmospheres absorb some of this starlight, resulting in patterns known as spectra that allow scientists to identify what they are.

However, "we know of many other planets that do not transit their host stars, and we therefore know almost nothing about those atmospheres," said astronomer Sloane Wiktorowicz at University of California, Santa Cruz. Indeed, "less than 10 percent of the known exoplanets have had their atmospheres detected. This is because planets are at least a thousand times fainter than their host stars."

Instead of looking at starlight that has passed through alien atmospheres on its way to Earth, Wiktorowicz and his colleagues aim to look for light that has scattered off alien atmospheres. This strategy should work equally well for exoplanets in both transiting and non-transiting orbits, "which will open up many previously unstudied planets for exploration," he explained.

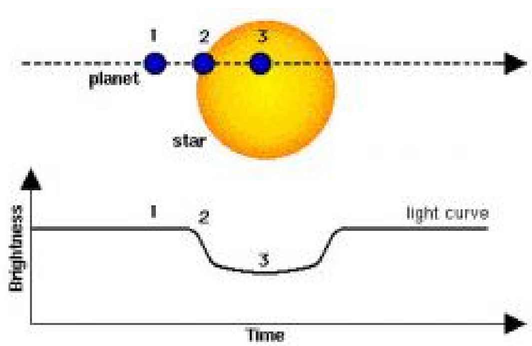
Tripping the Light Fantastic

To understand how this strategy works, one can think of all light waves as electric fields rippling either up and down, left and right, or at any angle in between, a property known as polarization. When starlight gets scattered off a planet's atmosphere, its polarization changes in a way that makes it distinct from both the direct light from a star and the light bouncing off the surface of a planet. Analyzing this polarization, a technique known as polarimetry, could yield details not only concerning the existence of an alien atmosphere, but also its composition and how it might be structured into different layers.

"Polarimetry provides extra information over photometry — measuring planet brightness at different colors — because there is extra information encoded in the polarization of scattered light," said astrophysicist Sara Seager at the Massachusetts Institute of Technology, who was the first to propose polarimetry studies for exoplanets. "This extra information can tell us whether or not clouds or hazes are present, and something about the properties of the clouds or hazes. It's information that is difficult to get any other way."

The canonical example are the clouds of Venus, Seager explained. "Very early in planetary atmosphere studies, people thought Venus could potentially have water clouds," she said. Although photometry measurements of Venus could not uniquely identify the droplets in these clouds, polarimetry studies from ground-based measurements reported in the early 1970s discovered the Venusian clouds were sulfuric acid droplets, findings confirmed via spacecraft sent to the the planet.

With polarimetry, "we can tell if clouds are present on exoplanets and potentially what clouds are made of," Seager said.



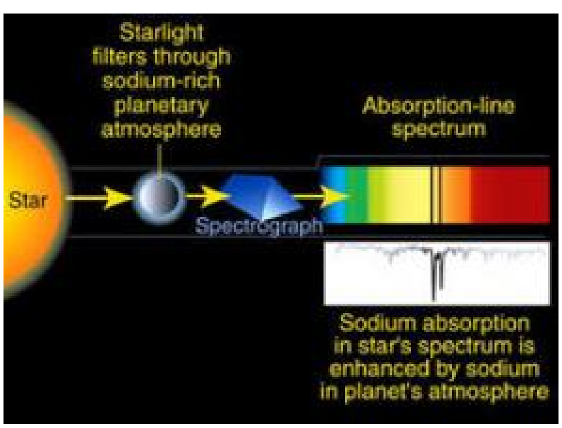
As a planet passes in front of its parent star, the brightness of the star decreases. Credit: Hans Deeg

"It's a completely new way to look at extrasolar planets, a completely novel technique for getting information," said astronomer Greg Laughlin at the University of California, Santa Cruz, who did not take part in this research. "It's very hard to get any information about what extrasolar planets are like — we can detect they exist, but anything that can tell you about their physical properties other than that is extraordinarily valuable. Also, it doesn't require a billion-dollar build-up — we can do it with existing resources. I think Sloane's on the ground floor of something that's going to be a big deal."

A major advantage of this strategy "is that we may be able to study the composition of exoplanet atmospheres with comparatively small, ground-based telescopes," Wiktorowicz explained. This is crucial for future exoplanet research, given the difficulty in funding space-based observatories such as the James Webb Space Telescope.

One disadvantage of this method is that the farther the planet orbits from its star, the fainter it will be. This means only the closest-in planets can be studied with this technique, which means it won't be of much help finding new exoplanets — existing planet-hunting strategies are already quite good at discovering worlds that are near their stars, Wiktorowicz said. Still, he noted this method is not meant to find new planets — "rather, it's meant to study planets we already know about."

POLISH2 See the Light



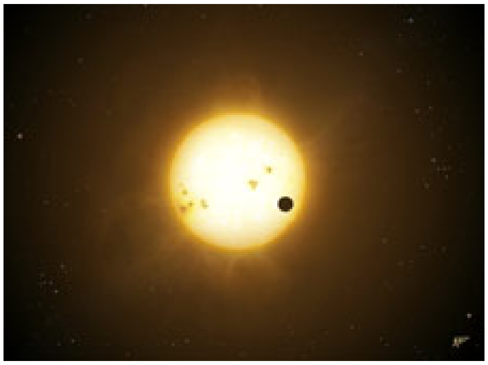
Bright yellow lines in the absorption-line spectrum are produced by the sodium content in the planet's atmosphere. Credit: SpaceRef.com

To see how starlight is polarized, Wiktorowicz and his colleagues developed a polarimeter based on bars of glass that vibrate tens of thousands of times per second. These "photoelastic modulators" will each very subtly alter a select polarization of light while leaving others unchanged. The latest version of his instrument, POLISH2, has two of these vibrating glass bars, which allows it to simultaneously detect all the key polarizations of light.

The search for exoplanet atmospheres using polarimetry has taken place for nearly two years with POLISH2, which is attached to the Lick Observatory's 3-meter telescope.

"It's amazing to think that we might be able to see light scattered from the surface of a planet tens of light years away," Wiktorowicz said.

Although POLISH2 should already be precise enough to detect exoplanets, "the issue is whether my system, and the stars themselves, are stable enough to allow such detections," Wiktorowicz said. Many factors might affect what the instrument observes on a nightly basis. "Any changes to the telescope or the atmosphere or anything else might cause a change in measurements — the amount of dust that settles on a telescope mirror from one night to the next can actually affect what you see," he explained.



Artist's impression of a 'hot Jupiter' during transit. Credit: Mark A. Garlick

To overcome this challenge, the researchers have to account for all the minute disturbances the polarimeter may experience nightly — to set the scale to zero, essentially. They do this by looking at nearby stars. The light from these stars tends to have almost no polarization, and thus helps calibrate every other measurement the instrument makes. In contrast, light from more distant stars has encountered more interstellar dust grains, which can reflect away some polarizations of light but not others, making the light from them that does reach Earth polarized.

Such calibration observations are very time-consuming — "about a third of every night is spent on them," Wiktorowicz said.

To increase his chances of finding planets, "I'm currently working on improving my data-processing software, because squeezing out every last drop of information from 500 gigabytes of data per night can be difficult," Wiktorowicz said. "Once this is done, I will re-analyze my old data, while gathering new data as well, and hopefully detect some planets."

This strategy involves monitoring exoplanet systems at different times in that world's orbit. "I'm spending most of my effort on two stars known to have one planet each," Wiktorowicz said. "But I have recently added three more stars, and the list will increase with time." In the end, "I hope to be able to study a few tens of exoplanets," he added.

Bringing polarimetry to a 10-meter telescope would enable analysis of still more exoplanets. "A larger telescope should allow smaller, Neptune-sized planets to be detected, which are thought to be much different from larger, Jupiter-sized planets," Wiktorowicz said. There has even been interest in bringing instruments similar to POLISH2 to the 30-meter telescopes that groups in Europe the United States and elsewhere are contemplating building. "Of course, we have to prove that it works on the smaller telescopes first," he added.

Seager , who did not participate on this work, noted, "research with exoplanets is pushed forward only when people like Sloane are brave enough and bold enough to push a technology most people don't think is viable."

Wiktorowicz and his colleagues detailed their findings Jan. 11 at the annual meeting of the American Astronomical Society in Austin, Texas.

Provided by Astrobio.net

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