Are We Alone?

Is there other life out there? It's a question humans have been asking for a long time. In search of an answer, astronomers are making careful observations of exoplanets. Astronomers have developed many ways to make incredible discoveries about exoplanets. One kind of tool they use is a telescope with a spectrometer inside. Using spectrometers, astronomers are able to split the light from stars and other objects by wavelength.

Sometimes, astronomers find that the apparent dip in brightness for an exoplanet's light curve changes depending on which wavelength they are looking at. For example, if light from a star is split into red and blue wavelengths by the spectrometer, the brightness of the red wavelengths may dip more than the brightness of blue wavelengths. That difference would suggest that a planet passing in front of the star is bigger when looking at red light than it is when observing it with blue light. But that doesn't make sense! A planet only has one size! How come it can seem larger or smaller depending on the wavelength of light you observe, and could we know which is "right"?

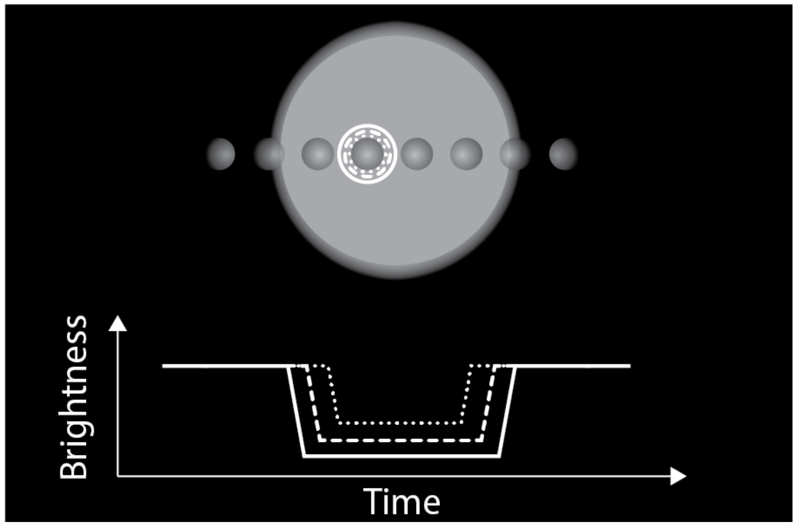

Figure 1. Representation of Light Curve Using Transmission Spectroscopy. Light curve data collected at three wavelengths, represented by different types of lines (solid, dashed, and dotted). The different types of lines in the plot each represent different wavelengths that are each absorbed by a different element or molecule found in the atmosphere of the exoplanet. Several factors will contribute to each element's or molecule's influence on the shape of the light curve, such as how strongly it absorbs light, its velocity, and how it's distributed throughout the planet's atmosphere. But most often, the element's or molecule's abundance is the critical factor.

The reason for this apparent size difference is a phenomenon known as *atmospheric absorption*. As the light of a star passes through the atmosphere of a planet, each different type of molecule in the upper atmosphere of the planet absorbs very specific wavelengths. Let's consider an example to understand how that can affect spectroscopy. Say there are two planets, a small planet, Planet S, and a big planet, Planet B. Planet S has an atmosphere rich in elements and molecules that absorb violet wavelengths. As light passes through its atmosphere, a lot of violet light is absorbed, causing a big dip in brightness on the light curve. Planet B's atmosphere has very few of these elements and molecules. As light passes through its atmosphere, relatively little violet light is absorbed, but because the planet is so big, a large brightness dip is still observed. Therefore, if you were to look at the violet light curves for both planets they might look the same, even though the planets are different sizes. It would be like if both the large and small planets produce the solid-line light curve as shown in **Figure 1.** Same light curve, different reasons: Planet S has a small atmosphere but a lot of violet-light absorption, and Planet B has a big atmosphere with little violet-light absorption.

So, let's go back to the planet that seems bigger when observed with red light than with blue light. It's not that the planet itself gets somehow bigger, it's that its atmosphere has more red light-absorbing components than average, so it absorbs as much red light as a larger planet does. That means that the inferred size of an exoplanet when viewed at different wavelengths correlates to the abundance of elements and molecules in the upper atmosphere of the planet that absorb at that wavelength. So if a planet appears medium-sized at most wavelengths but jumbo at orange wavelengths, an astronomer can infer that the planet is likely medium-sized with an atmosphere rich in molecules and elements that absorb orange light.

Astronomers compare the different observed dips in brightness at different wavelengths with a computer model of absorption to determine the types and abundances of different molecules in the planet's atmosphere. Why do this? Well, curiosity! I mean, how cool is it that they can even *do* this!? But also, if the atmosphere's composition is similar to Earth's, then this could suggest that there is life on the planet! For example, the oxygen and methane abundances on Earth are hard to explain without the presence of living organisms that use oxygen to breathe and release methane. If we were to observe abundances of oxygen and methane similar to those on Earth, astrobiologists may conclude that life is likely to exist on that planet. Unfortunately, astronomers have so far been unable to obtain the observational precision required to observe the molecules of interest for life, but expect to reach this milestone with the new generation of telescopes being built.

Reference

S. Seager, D. Sasselov, 2000. "Theoretical Transmission Spectra During Extrasolar Giant Planet Transits." *The Astrophysical Journal.* 537: 916–921

BiteScientist Profiles

Chima McGruder is an astronomy graduate student at Harvard University. His research is focused on using ground based telescopes to study exoplanet atmospheres with transmission spectroscopy. He is currently a part of the ACCESS (Arizona-Cfa-Catolica Exoplanet Spectroscopy Survey) research group, which is focused on producing a complete and uniform spectroscopic survey of exoplanets ranging in radius, distance from the host star, and mass.

Bonnie Tate is a physics and chemistry teacher at Apponequet Regional High School in Lakeville, MA. She has been teaching science in Massachusetts and Connecticut for fifteen years. She majored in Science at Western Connecticut State University and has a doctorate in Biochemistry from the University of Connecticut. Her first career was as a science researcher in the field of cancer.