Anyone out there?

by Bob Riddle

While there is ongoing debate about how many planets, dwarf planets, and moons exist within our solar system, even more interesting is the discovery of *exosystems*, or other stars with planets. These discoveries prompt new debates, such as what defines a solar system, how ours compares with others discovered so far, whether there are other Earthlike planets, and how we can discover exosystems. While there is no definitive or satisfying answer to the first two questions, these discoveries all point toward an overall question: Is there other life in the universe, or are we alone? Is anyone out there?

To investigate that last question, direct your students to the Kepler mission website (see Resources). This NASA mission's overall purpose is to discover other planets orbiting their respective stars using a space-based observatory, the *Kepler* telescope, which was launched into Earth's orbit in March 2009. The 95 cm telescope contains an extremely sensitive photometer and is aimed toward a region of the sky within the constellation Cygnus the Swan. The star-field area was chosen because it contains many stars and is also far enough away from the ecliptic that light from the Sun will not interfere with the photometer's sensitivity. A photometer works by capturing light energy using sensors that measure light intensity. This energy is then processed into digital data based on each sensor's measurement. *Kepler*'s photometer is so sensitive that, according to NASA, it can detect an Earth-sized planet, for which "the size of the effect…is similar to the dimming one might see if a flea were to crawl across a car's headlight viewed from several miles away" (2009).

Approximately 100,000 stars will be imaged regularly throughout the duration of the mission. As of this writing, the Kepler mission, now known as K2, will be scanning stars along the ecliptic for transits of planets (see Resources for the Kepler mission website). The K2 mission is a second use of the spacecraft after the mechanical breakdown of part of the telescope's steering and aiming mechanisms. For this second use of the *Kepler* telescope, engineers worked out an alternate method, using two steering wheels, to maintain the telescope's aim. This is called the telescope's *second light*, with *first light* referring to the first-time operation of a telescope, because the instrument is "seeing" light for the first time. Since the *Kepler* telescope is "seeing" light for the second time, the new mission has been nicknamed K2, or officially, *Kepler*'s Second Light (see Resources for an infographic that explains how K2 will be aimed).

The telescope's photometer is used to measure the brightness, or luminosity, of each of the 100,000 stars on a regular basis, looking for any change in the dimming of a star. The decrease in brightness is due to the passage of a planet across the disk of the star, or a *transit*, as we see the two from Earth. By graphing the star's decrease in brightness and its return to normal brightness over time, a light curve is created (Figure 1). In order for the transit to be detected from our perspective on Earth, the orbit of the planet must be edge-on as we "see" it. As of this writing (August 2014), *Kepler* had detected 4,234 objects that are considered possible planets and 978 objects that have been confirmed as planets. In addition to discovering exoplanets, the *Kepler* telescope has detected 2,165 eclipsing binary star systems (NASA 2014). An *eclipsing binary star system* is a pair of stars, both of which orbit around the *barycenter*, or the center of their combined masses. If the two objects are of different masses, the barycenter is not in the exact center of the two objects. The Earth-Moon barycenter, for example, is approximately 1,700 km (1,056 mi.) below the surface of the Earth. If viewed edge-on, as with exoplanets, there are two decreases in brightness within a regular repeating time as each star eclipses the other, which are detected and plotted into a light curve.

Two excellent free websites offer students opportunities for experimenting with light curves and the data collected. The lightcurve simulator (one of many astronomy-related animations available on the Astronomy Education website at the University of Nebraska–Lincoln; see Resources) could be used as a demonstration for an entire class. The simulator shows an eclipsing binary star system with a 3.65-day period, or the time it takes for the changes in brightness to repeat. Once started, the simulator displays an animation of the two stars in motion and a running graph of the changes in brightness. What students will see is an animation showing that there are two decreases in brightness as one star orbits another and the pair of stars is viewed edge-on. If you click on the plot-data button several times while the animation is running, the program will create a scatter plot of the changes in brightness that corresponds to the light curve.

A second and considerably more interactive simulator is found on the Agent Exoplanet website of the Las Cumbres Observatory Global Telescope Network (see Resources). Among other astronomical work, this observatory searches for exoplanets. After completing the tutorial, students work with actual images from the observatory and generate their own data to create a light curve. This simulation does require the creation of a log-in identity, including an e-mail address, so teachers should check school internet policies before using this website. This website also has a good collection of additional classroom materials.

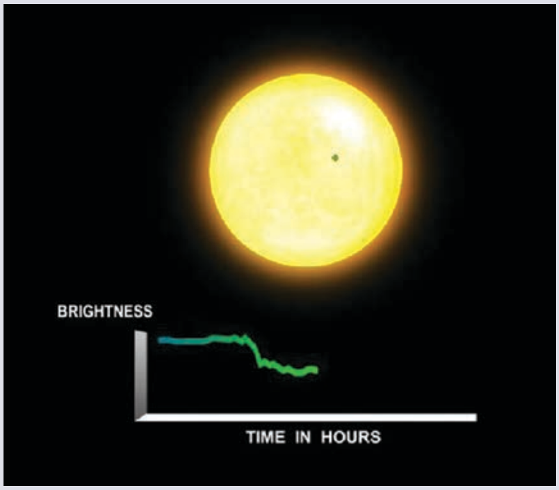
Solar hide-and-seek

Currently there are four methods used by astronomers to detect exoplanets. The *Kepler* telescope uses the *transit method*, where a dip in the star's brightness is detected. Using the transit method, which is best performed from space, a planet's size, orbital period, and distance from its star may be calculated.

The *astrometric method* and the *Doppler method* both rely on gravitational or tidal effects between the orbiting planet or planets and the star they orbit. These two methods work best with close stars that are orbited by massive planets, which cause slight changes in the star's position. Measurements made with these techniques are done using data from both ground-based and orbiting telescopes.

As a planet orbits a star, that star shifts its center of mass toward the orbiting planet or planets. This very slight motion in effect changes the star's coordinate position. If the star is close enough and the planet massive enough, the shift may be detected. A regular cycle to the shift indicates it is from an orbiting object, a planet or star massive enough to cause the detectable shift in position. If there is no detectable shift, then an orbiting partner object may not exist, or the partner object may be too small in mass or too distant to have any effect that we can measure using current technology. The astrometric method uses these data to calculate the planet's orbital period, distance from the star, and mass.

FIGURE 1 Transit and light-curve graph of change in brightness



NASA (WWW.NASA.GOV/MISSION_PAGES/KEPLER/MULTIMEDIA/IMAGES/KEPLER-TRANSIT-GRAPH.HTML)

The Doppler method uses measurements of the star's spectra and how much, if at all, the spectra are redshifted and blueshifted (see sidebar, page XX). The shifting toward the opposite sides of the electromagnetic spectrum is used to determine the direction of the star's motion relative to the Earth. Motion toward the Earth is shown by a blueshift, and motion away from the Earth is shown by a redshift. By measuring the amount of shift from red to blue, the orbital period and distance from the star may be calculated. However, the Doppler method is not as accurate for determining the planet's mass as the astrometric method.

The fourth detection method, *direct detection*, is only possible if we can directly measure the reflected starlight from the planet, calculate the infrared radiation given off by the planet itself, or use actual images of the planet. Due to the challenge of "seeing" a distant exoplanet, the direct detection method is somewhat limited, at least with current technology. Nonetheless, with spectral information, this method can be used to calculate atmospheric temperatures.

While it is obvious that the exosystems and exoplanets discovered so far are too distant to see with the unaided eye, let alone with even the largest of telescopes,

FIGURE 2 Location of Fomalhaut at 9:30 p.m. EST on November 15

it is possible most months to see some of the stars that we know harbor orbiting planets. "Where Are the Distant Worlds? Star Maps" is a 33-page PDF containing monthly all-sky star maps that show the location of some of the stars with exoplanets and additional information about some of the exoplanets (see Resources).

One of the easiest stars to locate this month, because of its relative brightness, is Fomalhaut, the alpha (or brightest) star in the constellation Pisces Austrinus, the Southern Fish. Figure 2 shows a view of the sky looking nearly directly south at about 9:30 p.m. EST during the middle of November. The brightest star you see above the southern horizon is Fomalhaut, which is sometimes known as the Lonely One because the sky around Fomalhaut appears empty of stars, as most of the stars around Fomalhaut are so dim they are not visible in city skies.

Fomalhaut is considered a young, hot white star, with an estimated age of a few hundred million years. Once thought to be part of a binary star system, a third companion star recently confirmed that it is in a triple-star system. It is an interesting stellar system where two stars, Fomalhaut A and B, orbit a barycenter, while a third star, Fomalhaut C, orbits the barycenter between it and the binary pair's barycenter [C + (A + B)]. While three stars make up this stellar system, to the unaided eye they appear as one star, and so this "one star" was named Fomalhaut based on that appearance. However, with the use of telescopes, the additional companion stars were seen and given their letter designations.

One focus of the system is centered on the white alpha star Fomalhaut A, with its two companions Fomalhaut B, an orange dwarf star, and Fomalhaut C, a red dwarf star. Fomalhaut A was the first of the very few stars for which astronomers have been successful in obtaining direct images of an orbiting exoplanet, Fomahault b (note a lowercase letter is used to indicate an exoplanet rather than a star).

Based on observations of the spectra from Fomalhaut b, some astronomers believe Fomalhaut b is not a star but possibly a loose collection of debris surrounded by a dust cloud that is reflecting starlight. Nonetheless, it is something with a spectral signature that orbits Fomalhaut A in a 2,000-year elliptical orbit that takes it into and out of the dust ring that encircles Fomalhaut A. It is possible that additional planets may be located within the dust ring, which extends out approximately 240 AU (35,903,488,966 km; 22,309,393,744 mi.) from Fomalhaut A. Fomalhaut C may also be surrounded by a dust ring, this one extending out 10 AU (1,495,978,707 km; 929,558,073 mi.). ■

November

1	Mercury at west elongation: 18.7°
2	End of daylight saving time
	Moon at perigee: 367,900 km (228,602 mi.)
4	Moon very close to Uranus
	Moon at descending node
6	Full Moon
8	Moon near Aldebaran
10	Mars near Pluto
14	Last quarter Moon
	Moon near Jupiter
	Jupiter at west quadrature

15 Moon at apogee: 404,300 km (251,220 mi.)
16 Neptune ends retrograde motion
17 Leonid meteor shower peak
18 Saturn in solar conjunction
19 Moon at ascending node
19 Moon near Spica
22 New Moon
Sun enters Sagittarius (astrological)
23 Sun enters Scorpius (astronomical)
26 Moon near Mars
27 Moon at perigee 369,800 km (229,783 mi.)
29 First quarter Moon
30 Sun enters Ophiuchus (astronomical)

Visible planets

Mercury will make its best appearance of the year this month. It will rise ahead of the Sun and be visible above the eastern horizon for the first two weeks of November.

Venus will not be visible again until next month, when it reappears in the evening skies east of the Sun.

Mars will still be visible but low over the southwest horizon at sunset.

Jupiter will rise several hours after sunset and be visible over the east-northeast horizon through the night.

Saturn will not be visible this month and will not reappear until later next month, when it will be in the morning skies west of the Sun.

References

National Aeronautics and Space Administration (NASA). 2009. *Kepler:* NASA's first mission capable of finding Earth-size planets. *www.jpl.nasa.gov/news/press_kits/Kepler-presskit-2-19-smfile.pdf.*

National Aeronautics and Space Administration (NASA). 2014. Kepler. *www.nasa.gov/mission_pages/kepler.*

NGSS Lead States. 2013. *Next Generation Science Standards: For states, by states.* Washington, DC: National Academies Press. *www.nextgenscience.org/next-generation-science-standards.*

Resources

Agent Exoplanet—*http://lcogt.net/education/agentexoplanet*

Daylight saving time—*http://geography.about.com/cs/daylightsavings/a/dst.htm*

Finding Earth-like planets—*www.pbs.org/wgbh/nova/space/finding-earth-planets.html*

Hunt for alien Earths—*www.pbs.org/wgbh/nova/space/hunt-alien-earths.html*

For students

1. Why is it difficult to directly detect exoplanets? (*Exoplanets are located at great distances, are very small in apparent size, and appear close to the much brighter star they orbit, which means they can get lost in the star's light.*)
2. What are red- and blueshift? (*Light, like sound, travels in wave form and has a specific frequency and wavelength. As waves approach a location, the wavelength decreases, causing the frequency to increase. For light, this is a shift toward the blue end of the electromagnetic spectrum. Conversely, as sound or light waves move away, the wavelength increases, creating a lower frequency. For light, this is a shift toward the red end of the electromagnetic spectrum. So as the light from an orbiting exoplanet reaches us, a spectroscope will reveal that the light has an increased frequency with shortened wavelengths, indicating that the planet is orbiting toward us. We know the planet is moving away from us because the spectra show a longer wavelength and lower frequency.*)
3. Why is the best location for detecting exoplanets in Earth orbit as opposed to telescopes on the ground? (*A telescope outside of the Earth's atmosphere is not hindered by the effects of the Earth's atmosphere or light pollution, as ground-based telescopes are. The atmosphere blocks many wavelengths, and its turbulent nature limits even further what may be seen.*)
4. Use one of the maps in "Where Are the Distant Worlds? Star Maps" to locate some of the stars with exoplanets (see Resources).

Addressing the *Next Generation Science Standards* (NGSS Lead States 2013)

Standard
MS-ESS1-2: Develop and use a model to describe the role of gravity in the motions within galaxies and the solar system.

Disciplinary core ideas
- ESS1.A: The universe and its stars
- ESS1.B: Earth and the solar system

Standard
MS-PS4-2: Develop and use a model to describe that waves are reflected, absorbed, or transmitted through various materials.

Disciplinary core idea
PS4.B: Electromagnetic radiation

Imagining alien life—*www.pbs.org/wgbh/nova/space/imagining-alien-life.html*
Kepler discoveries—*http://kepler.nasa.gov/Mission/discoveries*
Kepler mission—*http://kepler.nasa.gov*
Kepler's second light: How K2 will work—*www.nasa.gov/kepler/keplers-second-light-how-k2-will-work*
Leonids—*http://meteorshowersonline.com/leonids.html*
Light curves and what they can tell us—*http://imagine.gsfc.nasa.gov/docs/science/how_l1/light_curves.html*
Lightcurve simulator—*http://astro.unl.edu/classaction/animations/binaryvariablestars/lightcurve.html*
Where are the distant worlds? Star maps—*http://nightsky.jpl.nasa.gov/docs/SSDistWorldStarMap.pdf*

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