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Kepler Mission: A First Step Toward Finding Other Earths

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What's the Basic Question?

Whenever the question comes up "Are there intelligent beings out there beyond our solar system?" people's imaginations fire up. But, currently, we have skimpy to non-existent information about extraterrestrial life. The search is on, but, so far, ET has not been found. NASA's Kepler Mission is underway to detect Earth-size extrasolar planets that could support life. To date, most of the extrasolar planets discovered are giant planets, the size of Jupiter and bigger. Kepler is poised to find small planets, 30 to 600 times less massive than Jupiter. The Kepler mission is designed to answer the question, "Are Earth-size planets in the habitable zone of stars common or rare in our galaxy?"

back to top

How?

NASA's Kepler Mission uses the transit method to search for planets. This method relies on the simple fact that when the Kepler spacecraft observes a star as a planet passes in front it, a tiny fraction of the starlight will be blocked—the star dims a minuscule amount. The word *transit* means "going" and in astronomy it means one heavenly object going in front of a larger heavenly object, like one of Jupiter's moons going in front of (transiting) Jupiter, or a planet is going in front of (transiting) a star. If we detect one transit, it could be a planet. But, the dip in light could be caused by other phenomena: the random changes of a variable star or starspots (sunspots on other stars). When there are

Credit: NASA *Kepler Mission*/Wendy Stenzel

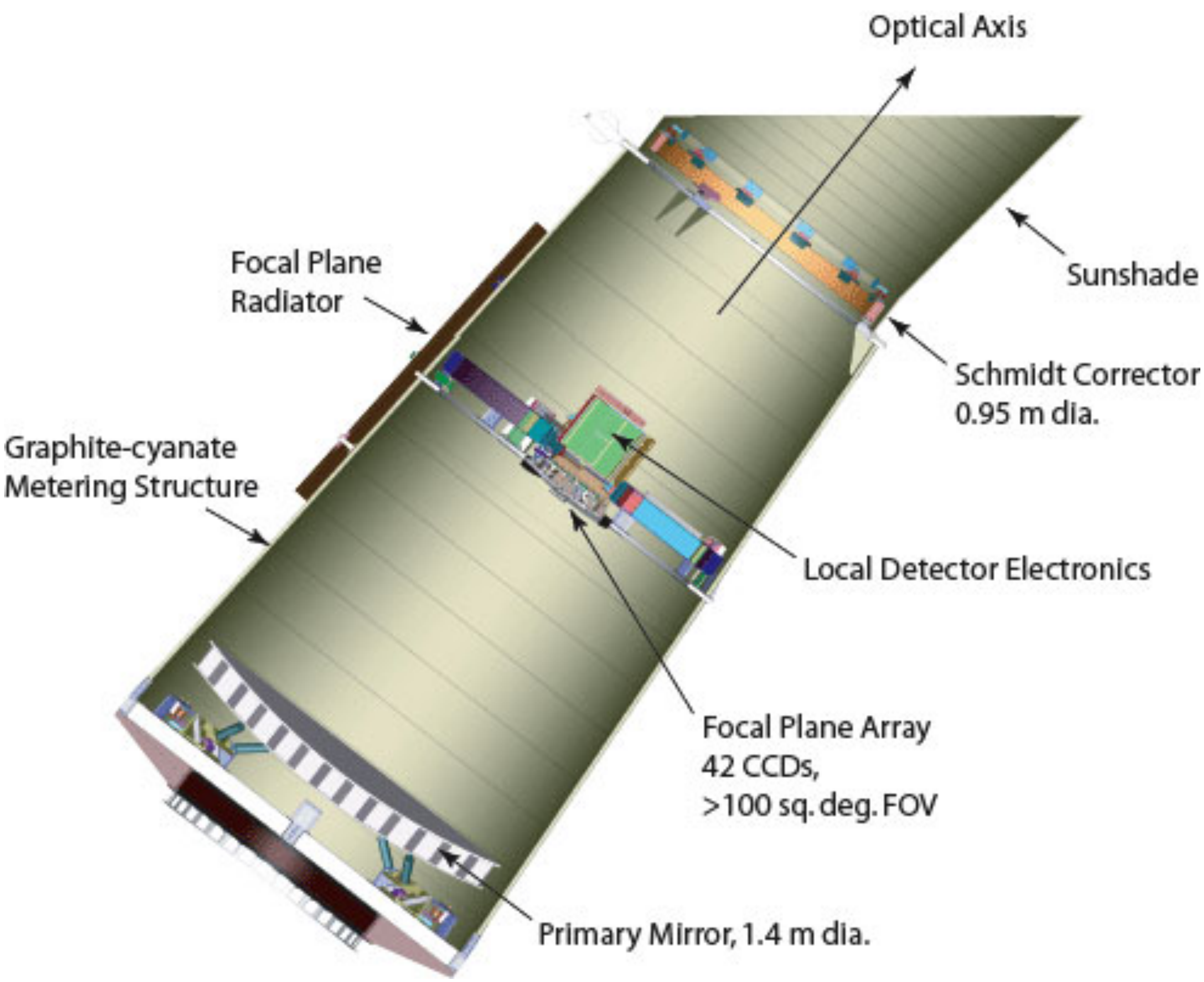
repeated transits at regular times, we may have discovered a planet.
Other "false positives" must be ruled out, such as changes in brightness caused by a binary star that appears nearly in our line of sight with the target star. Earth-based observatories do follow-up work to study the target stars and eliminate phenomena that masquerade as transits.

Once a planet is discovered, we can determine the planet's size from the drop in brightness—the "transit depth." The orbital period of the planet is simply the time between successive transits. We use Johannes Kepler's 3rd Law of Planetary Motion to calculate the average distance of the planet from its star from the orbital period. Knowing the planet's distance from the star, we can estimate the planet's surface temperature. Kepler seeks planets in the "habitable zone" of stars, the distance where liquid water can exist on the surface of the planet.

back to top

What?

The Kepler spacecraft is a 0.95 meter reflecting telescope—a Schmidt telescope with a wide field of view. At the focus of the telescope is the largest astronomical camera ever launched. The camera has 42 CCDs (charge-coupled devices) totaling 95 megapixels. Altogether, the array covers nearly a square foot in area. Compare this with cell phone or digital camera CCDs which are typically 1 to 10 megapixels, and physically much smaller. The Kepler instrument is an extremely sensitive light meter also known as a *photometer*, designed to precisely detect changes in brightness. The field of view is a bit over 10 degrees on a side (or 100 square degrees, an area of sky the size of your hand at arm's length). Most telescopes have a field of view as a small pebble or even grain of sand held at arm's length. Kepler's wide field of view allows scientists to observe more than 150,000 stars simultaneously in the search for transits.



Credit: NASA *Kepler Mission*

To find an Earth-size planet, the photometer must be able to detect a drop in brightness of only 1/100 of a percent. This is akin to sensing the drop in brightness of a car's headlight when a fruitfly moves in front of it. The photometer must be space-based to obtain this precision.

Artist's depiction of a very hot giant planet that could be something like the first planets Kepler discovered. Credit: NASA *Kepler Mission*/Dana Berry

back to top

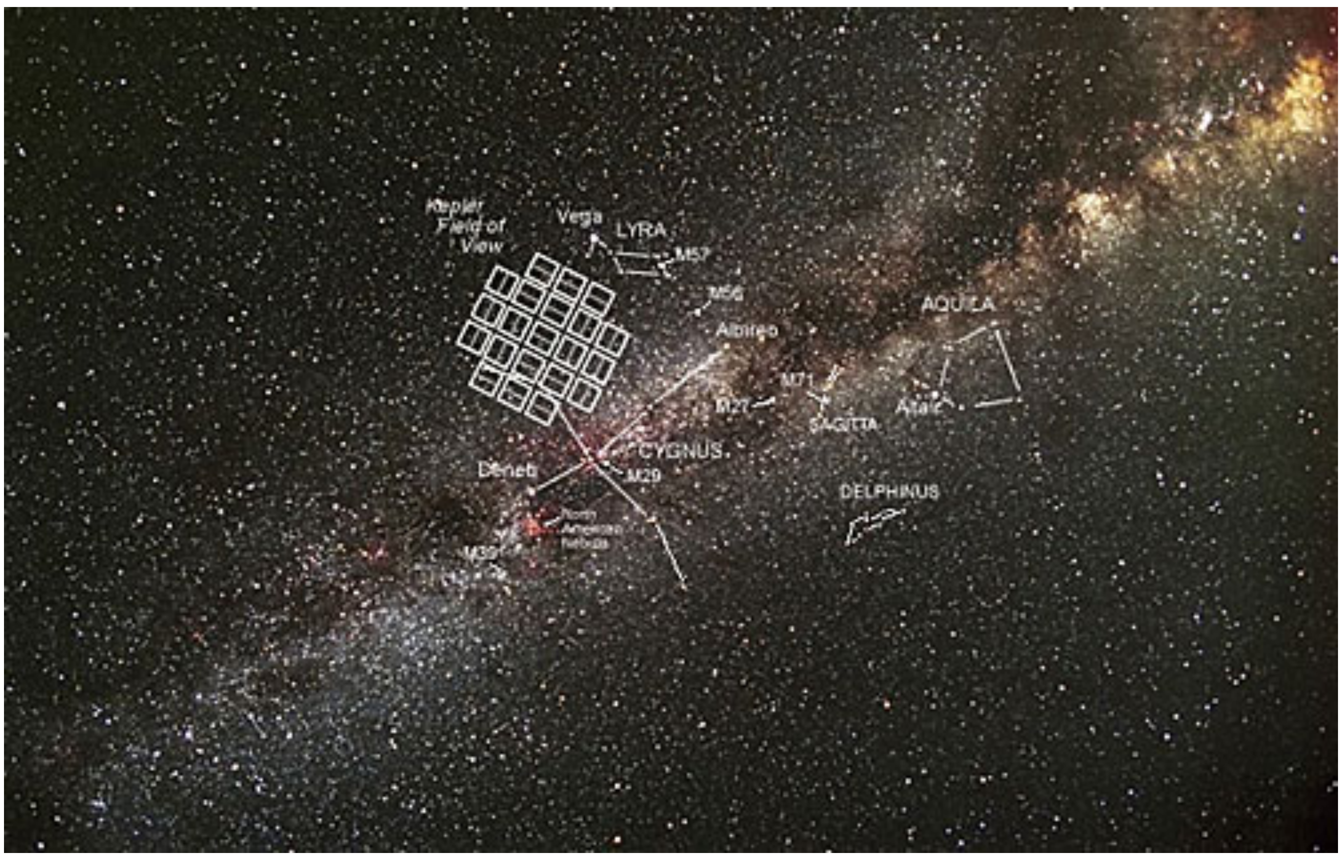
When?

Kepler launched in March 2009, and, with data from the first month of observation, five giant planets were discovered. They are hot Jupiters, with temperatures over 1500 K (over 1100°C or 2200°F), that orbit their host stars in just a few days. To find habitable planets (surface temperature of liquid water), Kepler seeks transits of planets that have periods comparable to Earth's period, one year. This means that it takes at least a year to see two transits, which allows scientists to predict future transits. To confirm a discovery, scientists require that Kepler detects at least 3 or 4 transits with the same period and transit depth. Thus, the Kepler mission is scheduled for more than 3 years to achieve its science goal.

back to top

Where?

The choice of where to point Kepler was governed by the requirement that the field-of-view is always clear of the Sun and the Moon. Kepler points away from the ecliptic—the line in the sky where the Sun, Moon, and solar system planets traverse. Additionally, scientists chose to look at an arm of the Milky Way galaxy that has stars similar in age and composition to our Sun, and at about the same distance from the center of the galaxy. They settled upon region in the constellations Cygnus and Lyra, north of the visible band of the Milky Way.



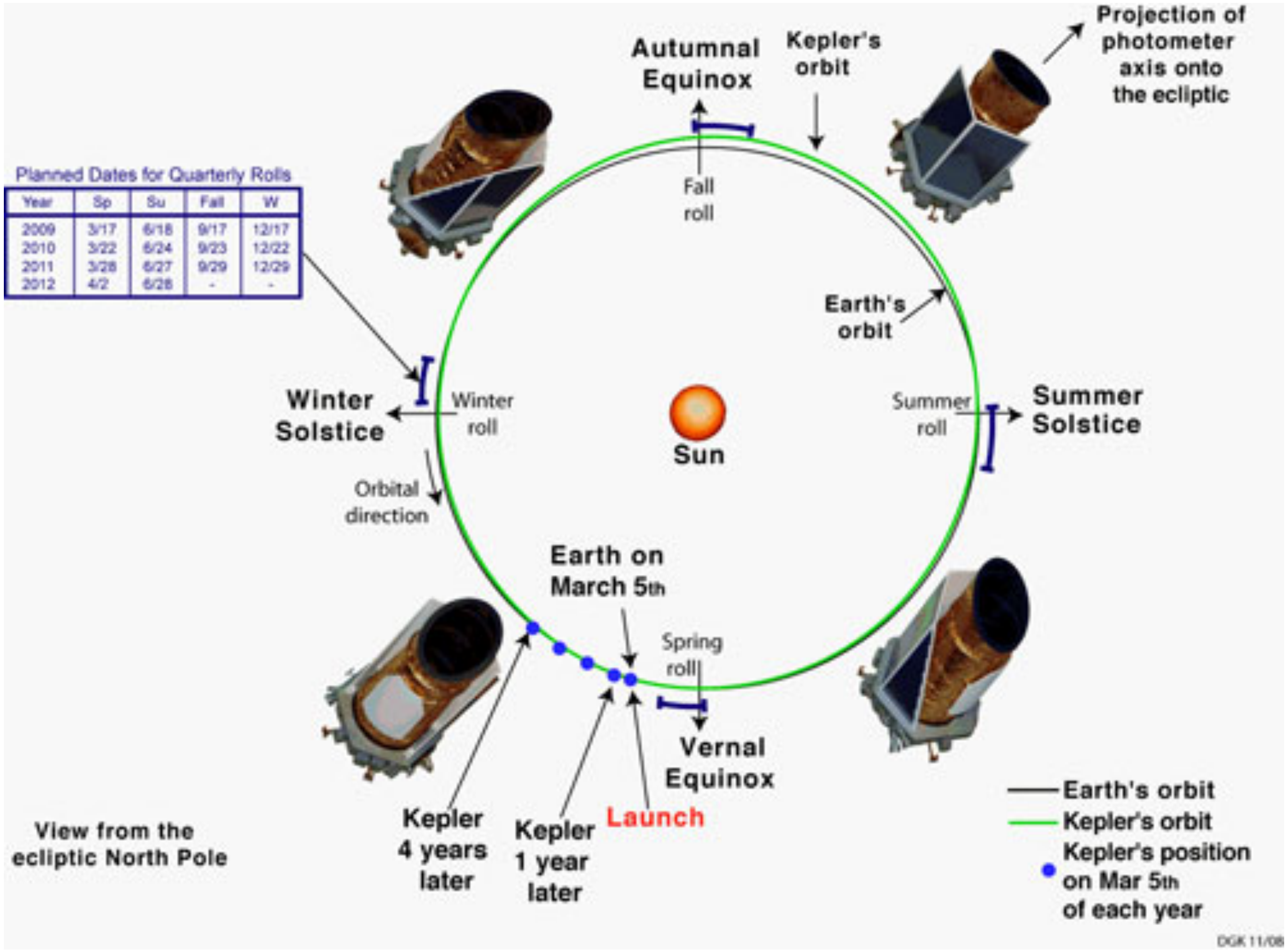
Credit: NASA *Kepler Mission*

The Kepler spacecraft travels in an *Earth-trailing heliocentric orbit* with a period of 372.5 days (slightly longer than an Earth-year). *Heliocentric* means Sun-centered; *geocentric* means Earth-centered. In its longer-period, Earth-trailing orbit, the spacecraft slowly drifts away from Earth.

[back to top](#)

What Next?

By the time the separation between Earth and the Kepler spacecraft approaches 50 million miles (75 million km, 0.5 AU), the Kepler scientists should have collected sufficient data to answer the question “Are Earth-size planets in the habitable zone of stars common or rare in our galaxy?” We’ll know whether or not small, habitable planets exist elsewhere in our galaxy.



Credit: NASA *Kepler Mission*

If Kepler finds other Earths, future space missions will seek evidence of substances in the planets� atmospheres that indicate life. And SETI searches will listen for signals in the EM spectrum from all the Kepler planets, seeking evidence of ET�s technology. Kepler is a key step toward finding life beyond our solar system. As Bill Borucki, the Principal Investigator for the Kepler mission says, �We won�t find ET, but we might find ET�s home!�

[back to top](#)

What do I do in the Classroom?

For information on the Kepler, please visit the website http://kepler.nasa.gov/

Classroom activities are in the education section: http://kepler.nasa.gov/education

They include:

Grades K-3: [Kepler Coloring Sheet](#)

Grades 2-adult: LEGO� [Orrery](#)

Grades 4�adult: [Kepler Star Wheels](#)

Grades 3-8: Morning Star and Evening Star

Grades 6-8: Detecting Planet Transits, Human Orrery, Observing the Jupiter System

*Grades 7-10: Transit Tracks, Orbits of Jupiter�s Moons

Grades 9�12: Tracking Jupiter�s Moons, Exoplanet Transits

College: Transit Problem

Online Interactive: Exoplanet Transit Hunt

*An abbreviated version of �Transit Tracks� appears with this article. A longer, PDF version may be downloaded from the Kepler website.

Transit Tracks (abbreviated; Grades 7�10)

Materials

- Optional: light bulb and bead on a string (about 50cm long) for transit demonstration.
- �Transit Light Curves� and worksheet on last 2 pages.

A. What is a transit?

1. Demonstrate a transit by swinging the bead on a string in a circle around the light bulb, with the bulb at the center of the plane of the orbit. Tell the class that the light bulb represents a star and the bead a planet.

2. Ask if anyone can see the bead go directly in front of the star. If the bulb is high enough, none of the students will be able to see the bead go directly in front of the star.

3. Ask students to move to where they can see the bead go directly in front of the star--it�s OK to stand or crouch.

4. Confirm that is what we mean by a transit--an event where one body goes in front of another, like a planet goes in front of a star.

B. How does a planet�s size and orbit affect the transit?

Ask the students �How do planets differ from each other?� They should identify: size, color, period, distance from the star.

Ask them, �Is there any relationship between how long it takes the planet to orbit its star (called its period) and how far it is from the star? By holding the string so that it makes a shorter swing, demonstrate that closer the bead is to the light, the shorter its period.

C. Interpreting Transit Graphs

1. What�s a light curve? Have students imagine they have a light sensor to measure the brightness of the star (light bulb). Move a large opaque object (e.g. a book or cardboard) in front of the star so that its light is completely blocked for all the students. Ask, �If we plotted a graph of brightness vs time�with brightness measured by our light sensor�and this [book] transited the star for 3 seconds, what would the graph look like?� Have volunteers come up and draw their ideas on the board and discuss with the class. We would expect the graph to look like the one shown in Fig. 1: a drop in brightness to 100% blocked.

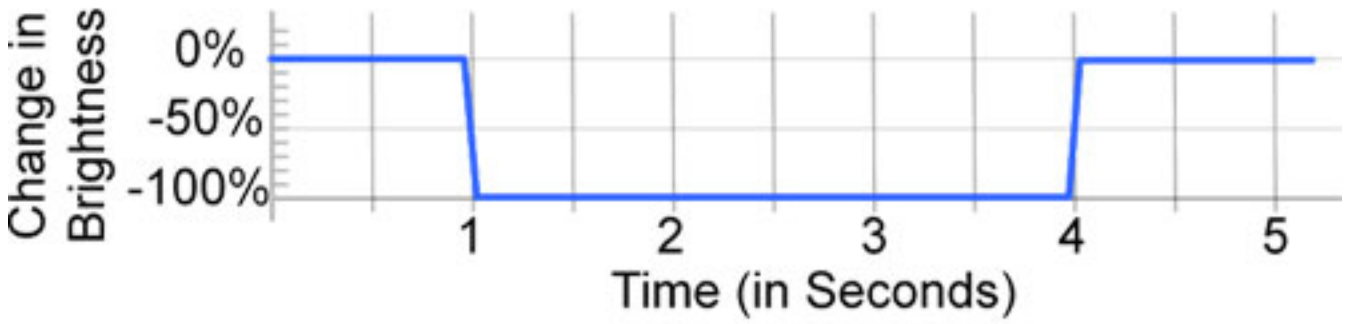


Figure 1. Light curve of book.

2. What does a transiting planet light curve look like? Ask the students, �What would a graph of sensor data look like for the orbiting planet, if we plotted brightness vs time?� Have volunteers draw their ideas on the board, and discuss with class. If their comments do not encompass the idea that the dips in brightness would be very narrow and that their depth would depend on the size of the beads/planets, ask them questions about how wide and deep the dips should be. We would expect the graph to look like the one shown in Fig. 2: horizontal line with dips in brightness to X% blocked.

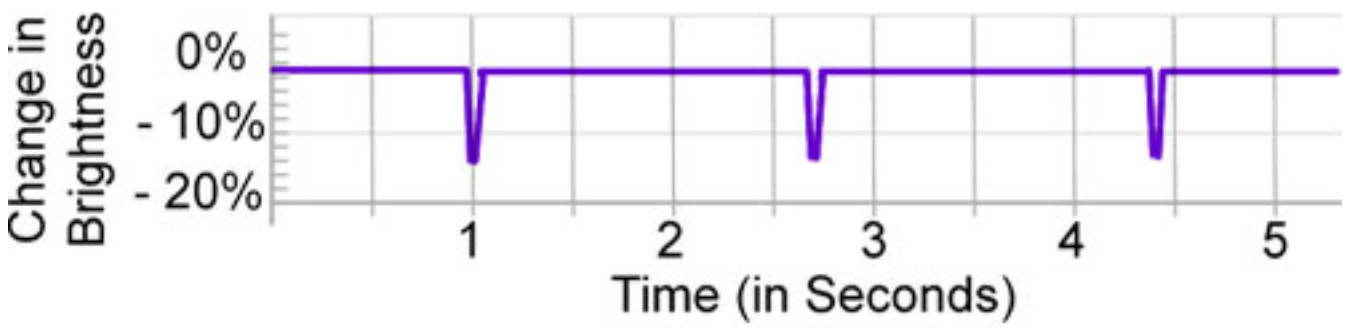


Figure 2. Light curve of bead.

3. What can light curves tell us? Explain that with transit data, it�s possible to calculate a planet�s diameter and distance from its star. Ask, �Why do you think those two properties, planet diameter and distance from star, might be important?�

4. How do we analyze light curves? Hand out a set of 5 sample graphs of Transit Light Curves to each group of 2-5 students and have them interpret the graphs. Pose these questions: How big is the planet compared with the star? Assuming the star is Sun-like, and that Earth would make at 0.01% drop in brightness of the Sun if it transited, how big is the planet compared with Earth? What is/are the period(s) of the planet(s)? (In Earth years.) How far is the planet from its star? (Use graph of Kepler�s 3rd Law) Lead a whole class discussion about the graphs, ultimately aiming at answering the questions.

[For additional ideas for this activity, see version on the Kepler website]

Download supplemental PDFs:

Transit Light Curves
Kepler's Third Law Graphs
Analyzing Light Curves worksheet

back to top

The Search for Planets Around Other Stars

Click here to go to the resource guide.

back to top