Discovery of the most Earth-like planet to date

By Don Barrett
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On July 23, astronomers with the NASA Kepler mission announced the discovery of Kepler-452b, the most nearly Earth-like planet yet found around a Sun-like star.

This marks for the first time the identification of an object which generally fits all three principal “Earth-similar” criteria that can be currently measured at the remote distances of other stars: the planet is not too different in size, having a diameter 60 percent larger than Earth; it orbits a star very similar to our own Sun; and its orbit places it within the “habitable zone,” where it is possible for liquid water to exist and thus Earth-like life to evolve.

The announcement included the release of data on an additional 500 planet candidates outside of our own solar system, bringing the number of known planet candidates now to 4696, the great majority of them discovered by the Kepler spacecraft. Over 1000 planets are now confirmed from this candidate pool.

It has been not even 20 years since Michel Mayor and Didier Queloz published the very first detection of an extra-solar planet orbiting an ordinary star, on October 6, 1995. Decades earlier, other stars were found to share, like the Sun, the necessary chemical elements from which rocky planets are formed. In 1984, the first debris disk around a young star was found, confirming the independent proposals of Kant and Laplace of over two centuries ago on the origins of planetary systems. However, the specifics of these systems were largely a matter of speculation until new techniques permitted indirect discovery of specific “exo”-planets beyond our Solar System.

Two methods are generally used: the first examined the light from the parent star itself for shifts in the characteristic colors of light absorbed by chemical elements in its surface layers. These shifts are produced by changes in the velocity of the star: as the planet and star orbit one another, both are pulled by the other’s gravity in mutual motion, though the star’s motion is far less, because of the planet’s far smaller mass. The best techniques today can detect changes in the velocity of a star of only 2 meters per second (about 5 miles per hour), the speed of a fast walk or slow run.

The other method, used by Kepler, is to monitor the brightness of a star continuously over long periods of time for a small dip in brightness, indicating the blocking of some of the starlight by a “transiting” planet. This technique was pioneered with ground-based telescopes, but the inability to monitor 24 hours per day and the twinkling of a star’s brightness produced on Earth by its atmosphere greatly limited this technique compared to the space-based Kepler.

Both methods most easily find large planets close to their stars. The transit method furthermore misses entirely planets that lie in orbits whose motion does not carry them in front of their parent star, from our view. The bias can be understood, however, and has allowed a view of the overall population of planets to emerge.

These techniques have been continuously refined in the search for smaller planets orbiting their stars more distantly—both to better understand the distribution of planets of all types, and specifically to find systems possessing parallels to Earth.

Kepler-452b orbits a star of almost exactly the same temperature as the Sun, but which is about 1.5 billion years older. Sun-like stars slowly increase in brightness over their 10 billion-year life; the output of this star is about 20 percent greater than that of the Sun. The orbit of the planet is about 5 percent larger than the Earth’s, producing 10 percent less brightness were it orbiting the Sun. Taken together, the planet receives about 10 percent more light and warmth from its star than does

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the Earth. The largest discrepancy is with the planet's size, some 60 percent larger than Earth. The size is known from the amount of light blocked by the planet when transiting its star, but reveals nothing about the composition, atmosphere, or conditions on the planet. Assuming Earth-like composition, the planet would weigh over four times Earth's mass, and the gravity on its surface would be about twice as strong as Earth's.

During Kepler's six-year life, the last three years of which have been in an extended mission degraded by the failure of Kepler's ability to accurately point, this planet has produced five transits with its orbital period of 385 days. The third and subsequent transits confirm detection and refine the parameters for its size and orbit.

This system is remote compared to most other planetary detections, at a distance of 1,400 light years. The distance dims the appearance of the star to a level some 1,000 times fainter than the eye can see without a telescope. Such a star can easily be imaged with a telescope. Ideally, one would next measure the mass of the planet by detecting its pull on its parent star through the shift in its characteristic light absorptions. From its mass and size, an additional comparison to Earth's density would be possible.

Unfortunately, only a small number of such precise planetary-shift spectrographs capable of this observation have been built. They generally are located at and used at smaller telescopes (some at risk of closure), which can dedicate large amounts of time to the necessary observations. These are not capable of measuring the mass of the faint parent of Kepler-452b, nor are larger telescopes with the necessary instrumentation currently funded.

There is no replacement currently funded for the substantially crippled Kepler spacecraft. A different mission, TESS, is funded to launch in 2017—it will examine the bright stars scattered about the entire sky continuously, conducting a more in-depth survey of planets around a much smaller sample of stars. At a cost cap of $200 million, TESS received less than one-third the $640 million budget of Kepler.

Thanks to tireless international scientific work over the last two decades, the technology now exists for the next and greatest challenge ahead, that of isolating the light of a planet itself, free from the billions of times greater glare of its parent star. The spectrum of a planet's light contains within it fingerprints to its composition, including the presence of oxygen and perhaps even the signatures to biological life itself. Even in the 1980s, scientists at the Jet Propulsion Laboratory were developing mission concepts for a "Terrestrial Planet Finder" (TPF) mission. Twenty years later, in 2006, a U.S. House of Representatives subcommittee voted to fund TPF, but 2007 spending limits have postponed the mission indefinitely.

By 2011, just as Kepler began producing a cavalcade of planetary candidates, among them closer and closer analogs to our Earth, NASA could only describe the Terrestrial Planet Finder mission as "cancelled."

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