Earth-sized planet in a star’s habitable zone confirmed

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An Earth-sized exoplanet orbiting within the habitable zone of another star, dubbed Kepler-186f, has been confirmed. Initial observations from NASA’s Kepler spacecraft were verified by the ground-based W.M. Keck and Gemini observatories, showing for the first time that other planets exist that are both the size of Earth and orbiting their parent star at a distance where the surface temperature would permit water to exist in a liquid state (its “habitable zone”).

This discovery is a significant step in the discovery of a truly Earth-like world. The primary mission of the Kepler spacecraft, launched in 2009, has been to observe 150,000 nearby stars, detecting planets by watching for extremely faint changes in each star’s brightness, caused by planets transiting in front of those stars. While most of these exoplanets are far from having the potential for Earth-like climate, there has been a steady progression of results indicating planets that individually have the basic prerequisites for liquid water on an Earth-size planet: the systems Kepler-62 and Kepler-69 were among the first discovered to have planets in habitable zones, Kepler-20f is an exoplanet with almost the exact same radius as Earth, and ? Centauri Bb has a similar mass to Earth.

As of February 2014, Kepler and supporting observations had found 961 confirmed exoplanets in 76 star systems, with another 2,903 unconfirmed candidates.

Kepler-186f orbits a main-sequence red dwarf star about 500 light years away that has surface temperature of about 4,000 degrees Kelvin and half the mass of the Sun. Red dwarfs have proven useful in searching for Earth-like worlds, as they are less luminous than the Sun, meaning that their habitable zones are located closer in. This in turn means that the orbital periods of planets are smaller, making detection easier. The low amount of light coming from the star also means that any subsequent attempts to directly observe the planet will be easier.

The search for exoplanets by the Kepler spacecraft is the product of a centuries-long process of using transits in astronomy. In 1667, the Italian astronomer Geminiano Montanari noted that the star Algol changed its brightness. It was not until 1783 that British astronomer John Goodricke noted that these changes in brightness were always the same and occurred with clockwork regularity. He proposed that the phenomenon was caused by an orbiting pair of mutually eclipsing stars. This was verified with evidence presented by Edward Pickering in 1881 and observations by Hermann Carl Vogel in 1889. This technique is still used today to discover and characterize a class of binary stars known as Algol variables.

The second method to find exoplanets is known as the radial velocity method. As a result of the work done by Isaac Newton in the mid-1600s, William Herschel in 1800, and Joseph Fraunhofer in 1817, it is known that all starlight is a composite of a spectrum of colors. Further research done by Christian Doppler in 1842 demonstrated that the frequency of waves changes as the source of those waves either comes closer or moves farther away from the observer. This concept was then applied to light (electromagnetic waves) coming from stars.

At first, the technique was applied to Mizar, which had a spectrum that exhibited a red shift and a blue shift, indicating that the star was at some point approaching the Earth and at others receding from it as it traveled through the Milky Way. Subsequent studies showed that the system was in fact two stars orbiting around each other, causing the red and blue shifts observed.

The same thing happens as a planet orbits a star. As a planet orbits a star, it exerts a small shift in the motion of the star, which would otherwise be uniform. This results in subtle changes in the color of the light the star emits: redder at the times the star is receding from the Earth, bluer when the star is approaching. Importantly, this change is directly tied to the masses of the objects involved. If the mass of the star can be determined (using its luminosity and temperature), the mass of the planet can then be determined.

Already, the mass of Kepler-186f has been constrained to lie between one third the mass of Earth and 3.75 times Earth mass, using knowledge of its parent star and planetary evolution models. Detailed radial velocity studies such as the one done for ? Centauri Bb could provide further limits on Kepler-186f’s mass.

As more data from the Kepler mission is analyzed, more results along these lines are expected. A recent study concluded that there are *billions* of Earth-sized planets within a star’s habitable zone in the Milky Way galaxy, of which only a handful have been sampled. Given that there is growing evidence for Earth-like worlds even with the little that has been discovered, it is almost certain that such worlds exist and will soon be discovered.