New space telescope to search for earth-sized planets

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On March 6, the US National Aeronautics and Space Administration (NASA) successfully launched the Kepler mission. Operated out of the Laboratory for Atmospheric and Space Physics in Boulder, Colorado, it is the first mission, space-based or otherwise, designed to look for extrasolar planets en masse.

Looking for periodic drops in the brightness of the 100,000 stars it will be observing, Kepler's instruments are sensitive enough to detect the decrease in star brightness caused by a planet as small as Earth.

While humanity has long pondered the existence of planets outside of our solar system, the first discovery of an extrasolar planet around a living star, 51 Pegasi b, came only in 1995.

Over the past 14 years, 342 extrasolar planets have been discovered. Most of these have been gas or ice giants, the size of Jupiter or bigger, and with short orbital periods. All these planets are significantly larger than Earth.

The nature of the planets discovered so far is due to the methods by which they have been detected. Because the light emitted or reflected from a planet is very faint, it is extremely difficult to detect the planets directly. Instead, a variety of indirect methods have been employed. Most of the planets have been found using the radial velocity method, as well as the astrometric, pulsar timing, photometric or transit, and gravitational lensing techniques.

The radial velocity method works by measuring small changes in the frequencies of light emitted by the star due to relative motion with the Earth (Doppler effect). The motion is caused by the orbit of nearby large, invisible massive objects. The existence of planets can therefore be inferred from the behavior of the star.

During the search for extrasolar planets, only one find, Gliese 581 c, has been deemed a planet potentially suitable for Earth-like life. The difficulty in finding Earth-like planets is due in part to the small perturbations caused by low mass objects, as well as the difficulty in finding planets in a star's ‘Goldilocks zone,' in which the surface temperature is potentially what it is on Earth.

The astrometric method is a somewhat crude version of the radial velocity method. Instead of measuring the Doppler shift of a star, the actual path of the star is observed. If a large mass is nearby, the center of mass of the system will not be the center of the star. Both the star and the other mass will orbit the center of mass, and this can be detected. However, if the planet is small, the center of mass is very close to the star's center, and the star will seem to behave as if it has no planets.

The photometric or transit method—the method to be employed on a large scale by Kepler—is extremely difficult to use. It watches for periodic drops in a star's light output, potentially corresponding to a planet passing in front of it. The reason for the difficulty of this method is that a planet must pass in front of the star with respect to our vantage point, a rare occurrence given the vastness of space.

Gravitational lensing is a slight variation of the transit method, where a planet is passing directly in front of a star with respect to Earth. Instead of dimming, the star's light is actually focused towards Earth by the gravitation effect of the planet, and we see an increase in brightness of the star.

To determine whether a slight dimming in the light output of a star is due to the transit of a planet, repeated observations must be made. Each drop in apparent magnitude must be the exact drop in intensity as the last transit, and last precisely as long as the previous drop (within error bounds). The constraints provide for a reliable way of determining if what was detected is an actual planet, or whether it was a group of sunspots, random debris large enough to cause a drop in a star's brightness, or other phenomena capable of causing a star to drop in brightness.

For scientists to confirm a planet with the transit method, four transits of the same intensity drop, duration, and period must be detected. As such, it would take four years to discover Earth, and 48 years to discover Jupiter.

Kepler itself is a technological advance far beyond any current observation equipment, including the Hubble Space Telescope. It will be looking at 33,000 times the amount of space looked at by Hubble, while simultaneously taking a snapshot every six seconds.

Looking at the Cygnus-Lyra region, it has the ability to detect a drop in light of 20 parts per million. An Earth-sized planet only makes a drop of 84 parts per million. As James Fanson, Kepler's project manager at NASA's Jet Propulsion Laboratory in Pasadena, California, said, "If Kepler were to look down at a small town on Earth at night from space, it would be able to detect the dimming of a porch light as somebody passed in front."

The Cygnus-Lyra region in particular is being studied for its relative proximity and high abundance of Sun-like stars. At first, Kepler will be looking at 150,000 stars, but this will slowly be whittled down to 100,000 after scientists single out G-type stars, those like the Sun; A- and F-type stars, which are slightly larger; and K- and M-type stars, which are smaller than the Sun.

When using the transit method, an extrasolar planet must pass between its parent star and Earth. The chance of this happening is approximately 0.5 percent. This is the reason for Kepler observing so many stars at once. With these odds, it is expected that Kepler will find several hundred Earth-sized planets in its expected mission lifetime.

Kepler is armed with a .95-meter photometer (95 megapixel array), or light meter. Covering 105 square degrees of the night sky, a size comparable to the area of your hand at arm's length, it will stare at this same field of 100,000 stars in Cygnus-Lyra for the predicted three-and-a-half to six-year life expectancy of the mission.

Currently, Kepler is traveling to its final destination, a spot that trails Earth and orbits the Sun. This is to avoid the light reflected off Earth, as well as any gravitational deviations that would require adjustment. It will be out of commission for 60 days while calibrations of its systems take place. After that period, observations of the Cygnus-Lyra region will begin.

Kepler's sole task is to search the Cygnus-Lyra region for potential Earth-like planets. It is up to the European Space Agency's Darwin mission to directly image these extrasolar planets.

Darwin uses three separate, free-flying telescopes acting as an astronomical interferometer. The basic concept is that the three telescopes will act as one large telescope, attempting to directly image Earth-sized planets in the infrared spectrum (where a star outshines a planet by a factor of one million, not a factor of one billion in the visible range). The configuration of the telescopes' position in space would also cause the light of the star to undergo destructive interference, making the nearby planets even easier to detect.

Over the course of a 10-hour observation spread over several months, a more detailed study of the planet's atmosphere would commence. Darwin would take an infrared spectrum of the atmosphere, and the analysis of the spectrum would give the chemistry of the atmosphere. From this, the potential viability for life on the planet could be determined.

Darwin is currently slated for a 2015 or 2016 launch.

Another mission—NASA's Space Interferometry Mission, also known as SIM PlanetQuest—will use the same science behind the Darwin mission to find extrasolar planets and determine their atmospheric chemistry as well as life viability.

When the mission was conceived in 1998, the launch date was planned for 2005. By 2000, however, the launch date had been pushed back to 2008. In 2007 and 2008, budget cuts to NASA pushed back the launch date to 2015 or 2016 at the earliest.

In addition to searching for terrestrial-like planets, SIM will search for Neptune- and Jupiter-sized planets to aid scientists studying models of solar system creation; analyze the upper and lower limits of star masses; use optical interferometry to map the galaxy; and measure nearby galactic motion in the study of the elusive dark matter.