The ongoing quest to find other worlds

Distant Systems

KRZYSZTOF ZIOŁKOWSKI
Space Research Center, Warsaw
Polish Academy of Sciences
kazet@cbk.waw.pl

For nearly two decades now, astronomers have been detecting the existence of planetary systems orbiting stars other than the Sun

Although most extrasolar planets are not observable with current technology, we can still detect them indirectly in various ways: such as by noticing a star's wobbling around its common center of mass with the planet, or by momentary dips in a star's brightness caused when a planet passes in front of its disk. So far (as of March 2009), 350 planets orbiting nearly 300 different stars have already been discovered in such ways.

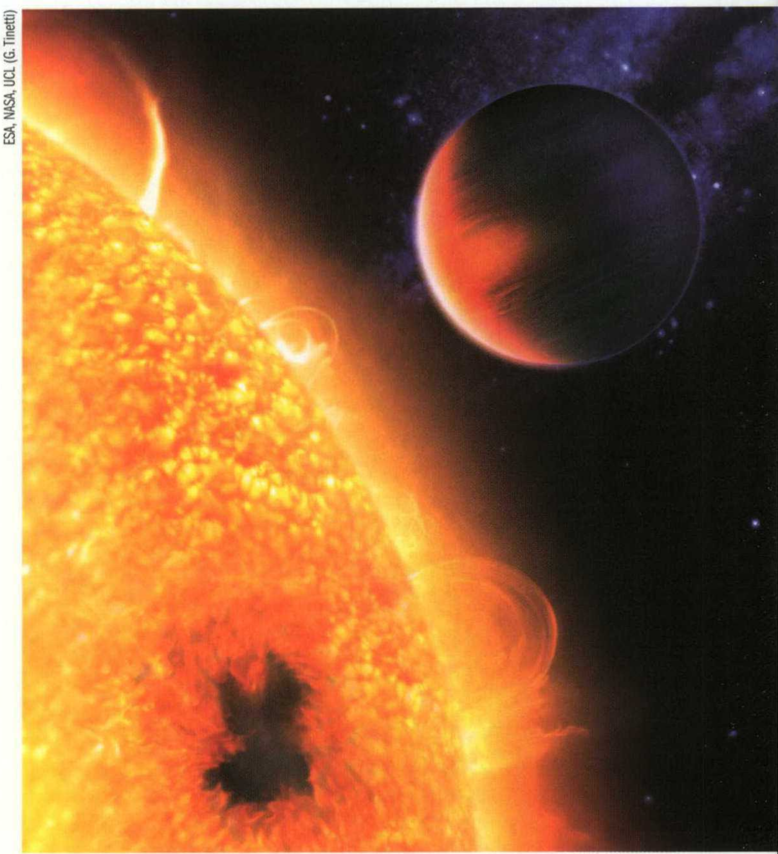
First discoveries

The first confirmed extrasolar planetary system was discovered by the Polish astronomer Aleksander Wolszczan in early 1992. The planetary system of the pulsar PSR 1257+12 consists of three objects with masses 0.02, 4.1, and 3.8 times the mass of the Earth, moving along nearly circular orbits at distances of 0.19, 0.36, and 0.46 AU (the Earth's distance from the Sun) and with revolution periods of 25, 67, and 98 days, respectively. In 2005, Wolszczan and Maciej Konacki reported the probable existence of a fourth object within the same system, this one with a mass of just 0.0003 of the Earth's, orbiting the pulsar significantly farther away than the other planets (at around 2.6 AU) and taking around 3.5 years per revolution. The suggestion has arisen that this is not a planet *per se* but rather something like a comet or dwarf planet (to use terminology analogous to what is now used for the bodies in our Solar System). It remains an open question, however, how such planets originated and how they might have formed around a neutron star.

The first planet circling a star similar to the Sun was discovered in 1995. Regular, repetitious shifts in a star's spectrum, caused by what is known as the Doppler effect, may result when it moves slightly towards and away from the observer as it circles around a common center of mass it shares with a planet. The observed changes in this star's spectrum indeed turned out to be best explained by the presence of a planet with around 0.5 the mass of Jupiter, circling it every 4.2 days at a distance of 0.05 AU. This method of scrutinizing the radial velocities of stars is currently the most fruitful technique in the search for new planetary systems, having yielded nearly 80% of all extrasolar planets discovered so far. Given the limits of modern observational technology, however, this method can only detect large planets with masses on the order of that of Jupiter, circling relatively close to their stars. In a vast majority of extrasolar planetary systems, only one planet has so far been discovered. The most complex planetary system identified to date is that of the star 55 Cnc, with five known planets.

Transit method

A second way of seeking extrasolar planets is called the transit method, which involves detecting planets as they cross in front of (or "transit") a star. When a planet partially obstructs a terrestrial observer's view of a star's


ESA, NASA, UCL (G. Tinetti)

The first extrasolar planetary atmosphere to be studied, encircling the planet HD 189733b, is known to contain methane and hydrogen

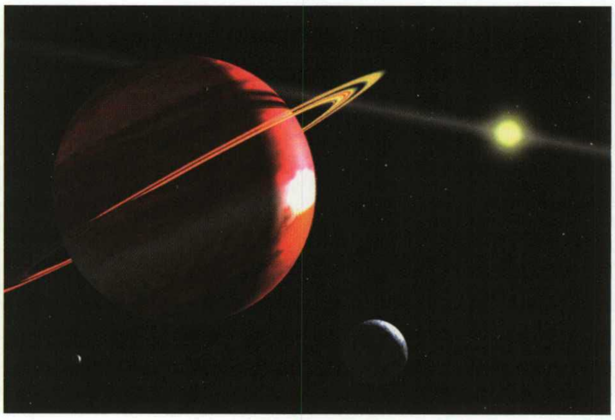
disk, a slight dimming is observable in its brightness. If cyclical repetitions of such dips are observed, they may attest to the presence of a planet. Very careful analysis of changes in a star's lightcurve can even reveal the size of its transiting planet. The first discoveries using the transit method were made by Polish astronomers from the Warsaw University Astronomical Observatory as part of the OGLE project led by Andrzej Udalski. This program, chiefly concerned with implementing of the idea put forward by the late Bohdan Paczyński (1940-2007) to utilize gravitational microlensing to look for so-called dark matter in the Universe, has unexpectedly turned up spectacular successes in discovering planetary systems. In 2002 OGLE found a planet the size of Jupiter circling a weak and distant star (some 5000 light years away), at an orbital distance of 0.02 AU. By the end of 2008, eight planetary systems had been discovered by the OGLE program using the transit method, and these are not its only achievements in this field.

Earth – lens – star

In 2004, an extrasolar planet was discovered using a completely different method, using gravitational microlensing itself - the fact that rays of light become bent by gravitational fields. Just as an optical lens can make an observed object brighter, a gravitational lens can cause an observed star to increase in brightness. If we manage to observe a configuration when a star A is situated along the line of sight between the Earth (the observer) and a star B, star A may act as a gravitational lens. Because all of these objects are moving, the geometry of the "Earth - lens - star" system changes over time, altering the brightness of the observed star: its brightness increases as the lens comes closer to the line of sight between the Earth and the observed star, then returns to its initial value as the lens moves away from that line. Careful analysis of the lightcurve of the observed star obtained while observing the gravitational microlensing event (which may last up to several months) may turn up evidence of possible planets circling the lens-star.

The gravitational microlensing method turns out to be sensitive enough to detect planets of masses comparable to the Earth's. Unfortunately, the likelihood of noticing three such bodies entering into just the right spatial configuration is very low, at around once per year per million observed stars. Nevertheless, mass observations of stars under the OGLE program have already managed to discover 5 planetary systems in this way.

The gravitational microlensing method was responsible for the discovery of one particularly interesting planetary system, consisting of two massive planets similar to Jupiter and Saturn, circling a star similar to the Sun located around 4500 light years away from us, shining with a magnitude of just 17. The discovered planets have masses of 0.71 and 0.27 the mass of Jupiter, and orbit their star at distances of 2.3 and 4.6 AU with periods of 5 and 14 years, respectively. The paper announcing this discovery in 2008 lists as many as 69 authors (including 9 Polish astronomers) from 32 research centers around the world.



NASA, ESA, G. Bacon (STScI)

The closest known extrasolar planet circles the star Epsilon Eridani, 10.5 light years away

Extrasolar planetary systems are also being sought by the COROT mission. One of the tasks of its telescope, with a mirror 13 cm in diameter and a field of vision 2.8 × 2.8°, is to track changes in the brightness of nearly 12,000 stars. It discovered its first extrasolar planet using the transit method in May 2007, finding a further 6 by the end of March 2009. A particularly exciting object was discovered this February: the smallest planet found so far, which seems to be only 1.7 times larger than the Earth.

The quest has also recently been joined by the US space telescope Kepler, slated to spend at least three years monitoring around 100,000 stars in a selected area of the Milky Way at the edge of the Cygnus and Lyra constellations. The Kepler probe was launched on 6 March 2009, not into an Earth orbit but rather into an Earth-trailing heliocentric orbit, circling the Sun every 371 days. The telescope's mirror has a diameter of 1.4 m, and its radiation detector is a CCD matrix consisting of 42 elements, each of them with 2000 × 1024 pixels (the largest CCD detector ever launched into space). The mission's sole task is to look for extrasolar planetary systems using the transit method. Great hopes are riding on the Kepler mission, as it is expected to find the first known planets of masses and sizes similar to the Earth. ■

Further reading:

Szymański M. (2007). 15 lat projektu OGLE [15 Years of the OGLE Project]. *Urania - Postępy Astronomii*, volume LXXVIII, no. 1 (727).

The Extrasolar Planets Encyclopaedia, http://exoplanet.eu