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Is there anybody out there? Looking for new worlds

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Extra-solar planets from wobbles, winks and blips

Planet Earth is home to a huge variety of living organisms, yet people have always been fascinated by the idea that life might exist elsewhere in the Universe, and this theme has been widely explored in science fiction books and films.

We cannot rule out the possibility of life existing elsewhere in the Solar System, but in the last decade the odds for life existing elsewhere in the Galaxy have been raised by the discovery of planets orbiting other stars. Speculation about the existence of these extra-solar planets began centuries ago, but they remained undetected simply because revealing them is so difficult. Stars are much brighter than the planets that orbit them, so all detections to date rely on one of three indirect techniques.

Finding the nearby planets? Measuring the 'wobble' from gravity's pull

As an extra-solar planet and its host star orbit their common centre of mass, both will move. Imagine a sumo wrestler and a hamster balanced on a see-saw: the heavy star, like the sumo wrestler, moves only slightly in response to the gravity of the much less massive planet, while the planet speeds around a large orbit, similar to the hamster.

Figure 1: The eight transit-hunting cameras of SuperWASP-N.

Astronomers detect this subtle motion as a 'Doppler wobble': the colour (or wavelength) of characteristic features in the spectrum shifts very slightly towards the red as the star moves away from us and very slightly towards the blue as the star approaches us. This phenomenon is the optical version of the Doppler effect – more commonly experienced as the change in pitch heard from the siren of passing police cars.

Figure 2: Artist's impression of the 5 Earth mass planet OGLE-2005-BLG-390Lb. © ESO – permission granted.

Using current technology, the star's velocity can be measured with an accuracy of one metre per second, which is below walking speed!

Using the Doppler-wobble technique, the first planet orbiting a star other than the Sun was found in 1995, and has enabled discovery of most of the nearly 300 extra-solar planets known today. Doppler-wobble measurements tell us the length of the planet's year and the shape of its orbit, but because the orientation of the orbit is usually unknown, these only provide a lower limit to the mass of the planet.

Finding the special planets? Looking for the 'wink' as planets block light

Sometimes we see Venus or Mercury pass between us and the Sun, blocking some of the Sun's light. A fraction of the planetary systems around other stars happen to be aligned so that the extra-solar planets pass between

us and the host star, similarly blocking some of the stars light from our view. Such planetary 'transits' occur periodically. By regularly monitoring millions of stars, astronomers can identify those that 'wink' at us. In this way, so far, over 40 transiting extra-solar planets have been discovered.

Transiting planets are special, because for them we know the orientation of the orbit exactly. So we can measure their mass exactly, and work out how far they are from their host star. We can also measure their size, as bigger planets block more starlight. Consequently we know their density, thus learning what these unseen planets are made of. We can also measure their temperatures, and get an indication of the composition of their atmospheres.

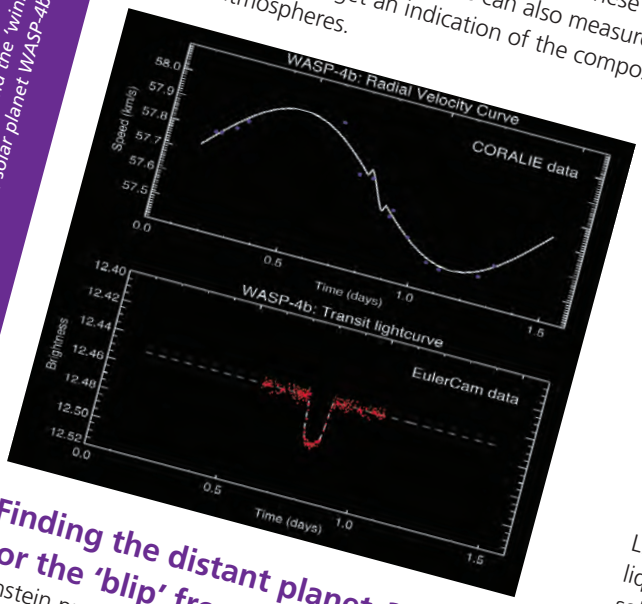

Figure 3: The 'wobble' and the 'wink' from the extra-solar planet WASP-4b.

Finding the distant planets? Waiting for the 'blip' from gravity's bend

Einstein predicted that mass curves space, which then bends light passing through it. 'Gravitational microlensing' exploits the transient brightening of a distant star caused by the gravitational bending of its light when another star drifts in front of it. The motions of stars within our Galaxy are such that these chance alignments last for about a month. If the foreground star has planets orbiting it, these further modify the curvature of space slightly, which can lead to a small 'blip' (lasting between hours and days) in the observed light curve.

In contrast to the other methods, microlensing observations can provide a census of planets orbiting distant stars within the Milky Way, rather than being restricted to the Solar neighbourhood. It is also sensitive to planets that are far from their host star: these planets take many earth-years to complete a single orbit, and consequently are not yet being detected by other means. Microlensing allows astronomers to find a new world in just one night, but we will never encounter a sign of it again.

Planet hunting in the UK

There is major UK involvement in all three successful techniques: a Doppler-wobble search is based at the Anglo-Australian Telescope; SuperWASP is carrying out the world's largest ground-based transit programme using self-owned and -operated telescopes on the Canary Islands and in South Africa; and RoboNet-II is exploiting a network of the largest telescopes that are currently used for a microlensing planet search. RoboNet-II also makes use of further UK technology in the form of the ARTEMiS (Automated Robotic Terrestrial Exoplanet Microlensing Search) expert system for target selection, and the eSTAR (e-Science Telescopes for Astronomical Research) system for scheduling observations by means of intelligent agents.

Towards Earth's twin

Life forms like those on Earth cannot develop without liquid water on a planet's surface: water provides a solvent for bio-chemical processes. Its presence therefore defines a 'habitable zone' around every star. Nearly all of the known extra-solar planets are gas giants (like Jupiter or Saturn), but a few 'Super-Earths' are known too. These planets, between 5 and 10 times more massive than Earth, may harbour a rocky or icy surface under a thin atmosphere. Although several gas giants have been found in habitable zones, so far, all of the Super Earths are either too close to their host star, and therefore too hot, or too far away, and therefore too cold for the existence of life as we know it. However, the discovery of a true Earth-twin appears to be only a question of time. Young people alive now will probably live to know whether our Earth's habitat is unique. They may even learn for certain – 'Is there anybody out there?'

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Further information

Exoplanet UK website (Exhibitor's page) http://exoplanet.org.uk/
Anglo-Australian planet search http://www.phys.unsw.edu.au/~cgt/planet/
SuperWASP transit detection programme http://www.superwasp.org
RoboNet network http://www.astro.livjm.ac.uk/RoboNet/
Microlensing outreach portal and live light curves by ARTEMiS http://www.artemis-uk.org
International Exoplanet database http://www.exoplanet.eu

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