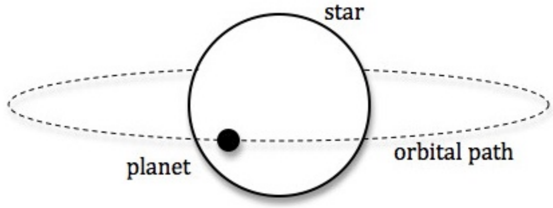
Detecting and characterising exoplanets

Astronomers have used several different techniques for discovering planets orbiting other stars – called extrasolar planets or exoplanets. Although in rare cases you can take a photograph of the tiny dot of the planet itself (like you might with Mercury or Neptune in our own solar system), most planets have been detected indirectly – by the effect they have on the light shining from their host star. The two most successful techniques are called the *transit method* and the *radial velocity method*.

Transit method

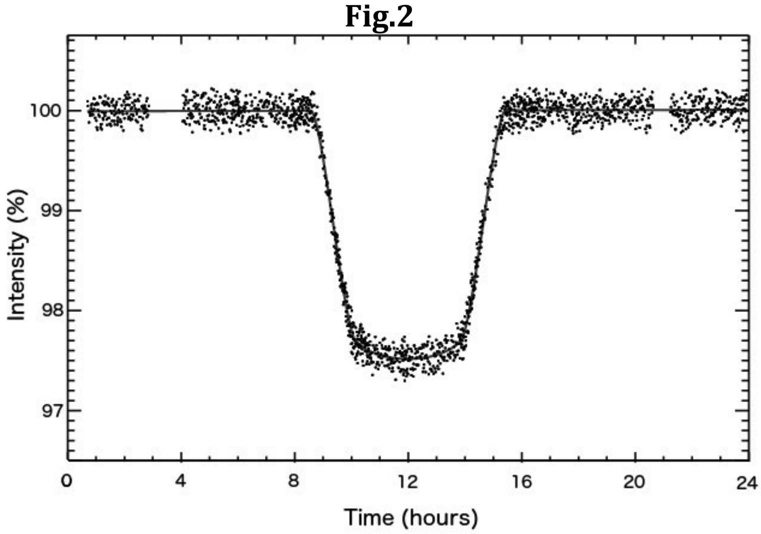
If the orientation of the other solar system just so happens to line up with our line-of-sight from Earth (as would be expected of a percentage of planetary systems by chance), the orbiting planets will pass across the disk of its star. This is exactly what happens with Mercury and Venus within our own solar system.

Fig.1



Our telescopes aren't able to actually see an image like Fig.1, but they can measure the drop in brightness of the star as the planet passes in front of it and blocks some of the starlight. So if you plot the measured brightness of a star over time, and see periodic dips in this 'lightcurve', you can infer the presence of an unseen exoplanet.

Fig.2



1. How long did this exoplanet transit event last?

2. The 'depth' of a transit event is how much the starlight intensity dims by. What is the depth of the transit in the lightcurve shown in Fig.2?

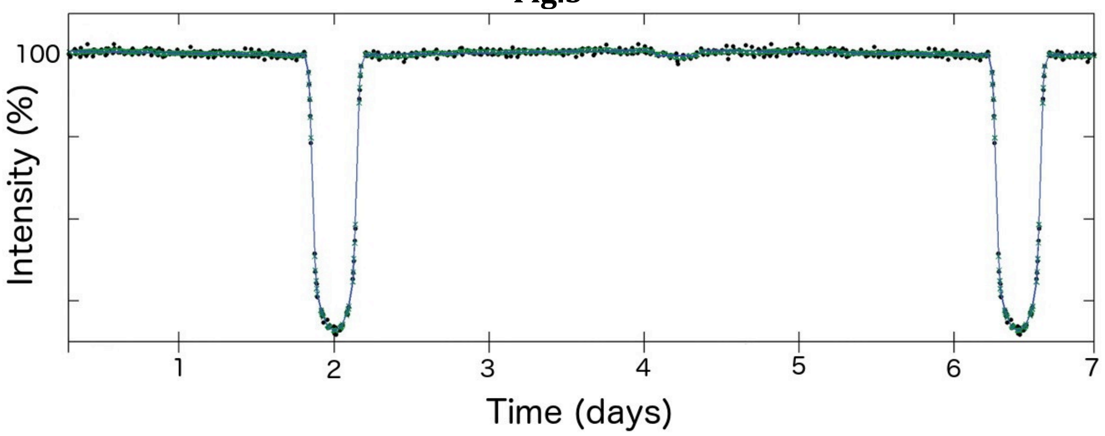
3. The depth of a transit tells astronomers some very important information about the exoplanet. Look back at Fig.1, depicting the transit. What determines how much the starlight dims by?

4. The radius of the star being observed in Fig.2 is 5×10^8 m. Think carefully about how this relates to the answer for Q3, and calculate the radius of the transiting planet.

5. The radius of Jupiter is 7.0×10^7 m. Compare the size of this exoplanet to that of Jupiter.

If you watch the star for long enough, the same planet will transit across again and then again.

Fig.3



6. What information do you learn about the planet in its solar system by looking at the time interval between transits in Fig.3?

7. If you find an exoplanet that doesn't transit with perfect regularity like you might expect, but instead sometimes the transit occurs slightly earlier than expected and sometimes slightly later, what might cause this variation in the planet's motion?

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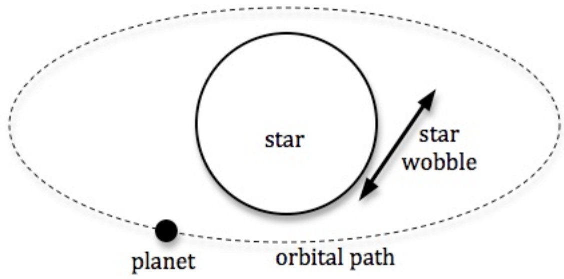
Radial velocity method

The gravity of the star keeps the planet moving in an orbit around it, but the planet's gravity also pulls on the star so that it wobbles around its centre ever so slightly. This means that as the planet orbits, the star is sometimes being tugged towards our telescope and at other times, when the planet is around the other side, the star is pulled away from our telescope.

Fig.4



8. This motion towards and away from our telescope changes the wavelength of the starlight we see. What is the name for the effect whereby the apparent wavelength of a wave is shifted by motion?

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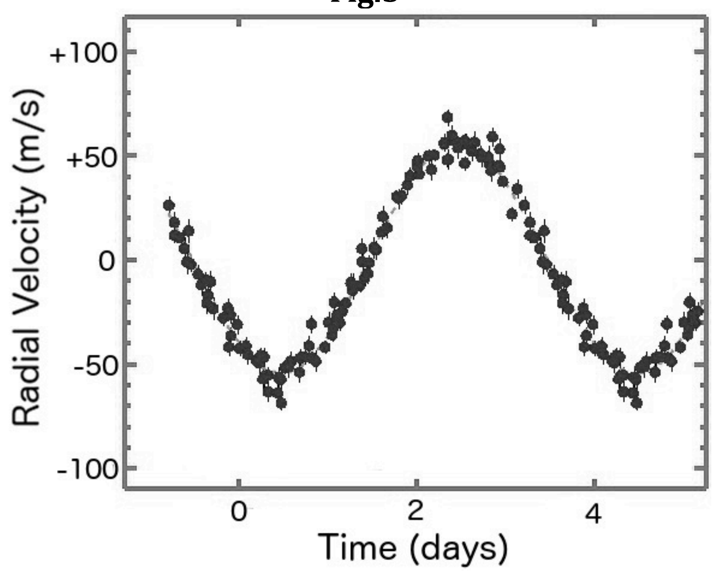
Astronomers can very precisely measure the change in the wavelength of light from a star and from this calculate its velocity towards or away from the Earth – the 'radial velocity' of the star. If the planet has a circular orbit, the radial velocity of the star will follow a sine curve.

Fig.5



This sine wave of the radial velocity of the star contains two important pieces of information about the star. Look at Fig.4 and think about the physics of the situation.

9.a) What does the amplitude of the sine wave in Fig.5 reveal?

9.b) What does the period of the sine wave in Fig.5 reveal?

Sometimes astronomers are lucky, and the same planet can be picked-up by both the transit method and the radial velocity method. This means that they can collect two pieces of information about the exoplanet, and combining the two learn something very important about it. The transit method allows you to calculate the radius of the planet and the radial velocity allows you to calculate its mass.

10. What can you calculate about the planet from these two pieces of information?

If you want to find out more about exoplanets and how we discover them, try:

http://exoplanets.org
http://kepler.nasa.gov/Mission/