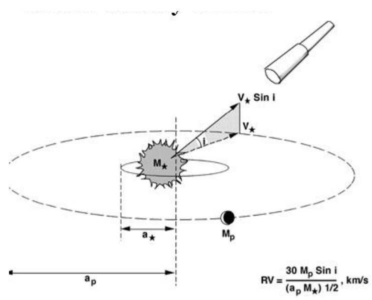
<u>Climate Change and Extraterrestrial Atmospheres Assessed Question.</u>

Describe techniques that are currently being used to detect extrasolar planets and methods that could be used in the next decade or two to try and determine the atmospheric composition of these planets.

Looking for extrasolar planets is a difficult task, since the planets themselves are not bright, ie they don't emit their own light as stars do, therefore the only way they can be seen is by the light it reflects from the star that it is orbiting. Also, the planets are relatively tiny next to the huge size of the stars, and the brightness of the stars means that extrasolar planets cannot be seen with a conventional telescope. The main solution to this is to look at the effect the planets have on the stars they orbit, due to their gravitational force. Although the planet is small in comparison to the star, it will still exert a gravitational "pull" on the star. As the planet orbits the star, it will pull at it from different sides. If the star is watched for a very long time, the net effect of this gravitational pull is a slight wobble in the stars position. The amplitude of the "wobble" depends on the orbital distance of the planet (a_p) and the mass of the two bodies (m_* and m_p), as shown in the equation below:

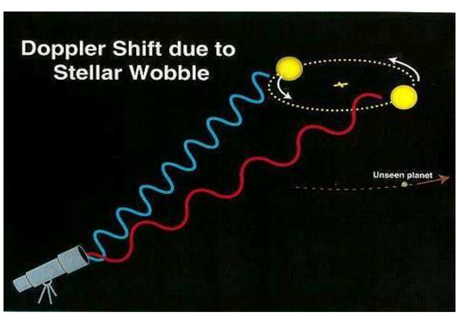


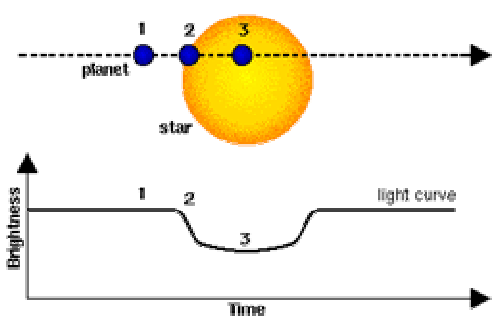
$$\text{Radial Velocity} = \frac{30 m_p \sin i}{0.5 a_p m_*}$$

There are two basic methods of seeing this gravitational effect:

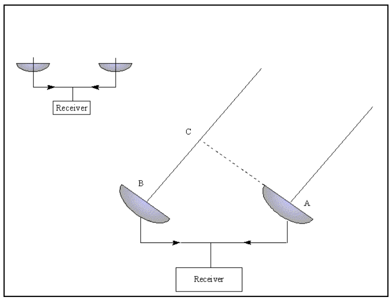
- Astrometric
- Radial velocity detection

Astrometric detection: as a planet orbits a star, it exerts a gravitational pull on the star. If a periodic change in position is seen, this can indicate an orbiting body, and analysis of these measurements can give information on the nature of this body.



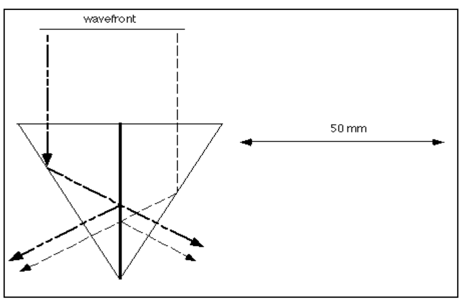


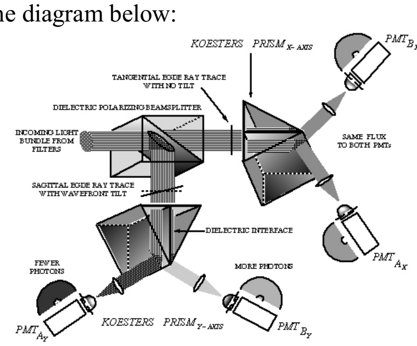
Radial Velocity Detection: as the planet "tugs" at its star, the change in the stars position will cause a Doppler shift in the light from the star. As the star is pulled away slightly, the observed wavelength is longer and will appear more red. As the star is pulled towards the earth, the wavelengths will appear shorter, making the light bluer. The effect is, however, very small. The effect of Jupiter on our sun is a 12m/s velocity change. The stare method also uses the radial velocity principle to detect extrasolar planets. STARE's method of detection relies on the edge-on alignment of the extrasolar system. If a planetary system is oriented so that Earth lies near the plane of the planet's orbit, then once per orbit the planet passes between its star and the Earth, causing a transit. This orientation is more likely for planets orbiting close to their parent star. During a transit, the planet blocks some of the light from the star, causing the star to appear dimmer (see figure left). For Jupiter-sized planets transiting Sun-sized stars, the expected dimming of the star's light will be about 1%, and the duration of the transit should be a few hours. To look for such a transit, the STARE telescope takes timed exposures of the same field-of-view all night for as many nights as the field is favourably positioned (usually around 3 months). When observations are complete for a particular field, the multitude of data are run through software which, after correcting for many sources of distortion and noise, produces light curves (see left) for thousands of stars in the field. Other software is run to analyze the processed data for variable stars and transit candidates. It takes two or more transits (or cycles in a variable star) to discern the period of the orbit (or the variability). The STARE method therefore favours giant planets orbiting sun-like stars in close orbits. The results of successful radial-velocity planetary searches have shown that planetary systems of this type could be quite common.



Direct detection: A lot of research at the moment is focusing on methods that will actually allow these planets to be seen, which will allow detection of smaller planets, and therefore planetary systems more like our own. This will use space borne interferometers, which consists of two or more separate telescopes which combine their signals almost as if they were coming from separate portions of a telescope as big as the two telescopes are apart. The resolution of an interferometer approaches that of a telescope of diameter equal to the largest separation between its individual elements (telescopes). However, not as many photons are collected by the interferometer (eg a fine guidance sensor) as would be by a giant single telescope of that size.

Fine guidance sensors are the only readily available white light interferometers in space. The interfering element is called a Koesters prism (see left), of which each fine guidance sensor has two, one for the x axis and one for the y axis, as shown in the diagram below:





The dual-axis Koester's prism configuration for FGS 3, with wavefront tilt in the y-axis

The laser interferometer gravitational wave observatory in Livingston USA is an example of an interferometer. It searches for gravitational waves created in supernova collapses of stellar cores (which form neutron stars and black holes), collisions and coalescences of neutron stars or black holes, rotations of neutron stars with deformed crusts and the remnants of gravitational radiation created by the birth of the universe.

Spectroscopic Analysis of Planetary atmospheres: this is a difficult technique because light reflected from the planet must be analysed without the light from its parent star. Only direct methods of planet detection are suitable for obtaining these observations. In the future, large systems employing coronagraphs (observe solar atmospheres, and allow calculation of temperature, density and velocity of solar clouds, which can therefore be removed from the relevant information), apodization (mathematical technique which reduces the spurious ringing around sharp edges known as Gibbs Ringing), and supersmooth mirrors with diameters ≥10m may allow full characterization of the temperature, pressure, atmospheric composition, etc., of extrasolar planets. These large-aperture instruments may be monolithic but will most likely be composed of multiple phased elements. Therefore, additional technologies involved in stabilization of the point spread function of a multiple-element telescope will be needed.

Another alternative is an optical aperture synthesis interferometer, which may be sufficient to achieve sub arc second resolution sufficient to isolate the planet from the star. Stellar light can be suppressed by apodization and precise positioning of the star in a null of the interferometer.