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Exoplanet Detection Methods and Characterization

Draft Introduction

The discovery of the first extrasolar planet by (Mayor M & Queloz D., 1995) introduced a developing field into astrophysical research that is now one of the most exciting and fast moving fields in modern astrophysics. More than 20 years on, the Extrasolar Planets Encyclopaedia records in excess of 1000 extrasolar planets that have been discovered using a variety of detection methods utilising both ground and satellite based telescopes in a multitude of collaborative missions **[examples]**. These vary from simply discovering new exoplanets to actively searching for Earth analogs that could, under the right circumstances, harbor life.

Extrasolar planet detection methods are divided into two classes: direct and indirect detections. A direct detection uses data that explicitly shows the presence of an extrasolar planet. An indirect detection uses effects that an extrasolar planet has on it's parent star to infer the planet's existence. To date there are 5 well established detection methods. These are discussed below.

Direct Imaging

Direct imaging detections utilise the thermal emission of an extrasolar planet to detect the planet as a source of infrared radiation in an image taken in the infrared band of the spectrum.

Direct imaging has several disadvantages. One such limitation is that exoplanets lying close to a large, luminous star will effectively be disguised owing to the large luminosity difference between the two objects.

Microlensing

Microlensing detections use the principal of gravitational microlensing to infer the presence of an exoplanet. Specifically, the light from a distant star undergoes magnification when passing through the gravitational field of a host star closer to the observer. The gravitational field of the exoplanet, if present, will create observable effects **[what effects?]** in the detected image allowing the inference of the exoplanetary companion to be made.

Radial Velocity

The existence of an exoplanetary companion orbiting a host star alters the system's centre of mass causing both the exoplanet and host star to orbit about it. As a direct result of this the radial velocity of the star changes over time, peaking at a maximum when the star is moving directly toward, or away from, the observer. Conversely the radial velocity of the star is at a minimum when the star moves normal to the observer's line of sight. **[Insert image to demonstrate]**

This variation is detected by observing the Doppler shift of the star's spectral lines. Whilst the star is moving towards the observer an increase in frequency of the spectral lines is observed. When it is moving away from the observer a decrease in frequency of the spectral lines is observed. No change is observed when the star is moving normal to the observer's line of sight.

Bold text indicates further research/elaboration required.

This detection method is heavily biased towards large exoplanets orbiting less massive stars **[insert some numbers to quantify 'large' and 'less massive']**, owing to the larger perturbation induced in the host star's orbit, which in turn increases the probability of detection. The inference that a star's orbit indicates an exoplanet presence could be misleading however as another object could be causing the orbital perturbation **[elaborate on potential sources of error here]**.

Transiting
When a dim object, such as an exoplanet, passes in front of a very luminous object, such as a star, a dip in the total luminosity of the system is observed owing to the exoplanet blocking a portion of the star's flux from the observer. By plotting the total flux received as a function of time the presence of an exoplanet can be suggested if a dip in the total flux received is observed.

This method is limited in its applicability to extrasolar systems however. For example, bias exists towards exoplanets with large radii as they block more of the star's flux incident upon the observer. Another limitation is the inherent constraint that exoplanets with orbital inclinations of 90 degrees cannot be detected as they do not pass in front of their host star relative to the observer.

(M Deleuil, AS Bonomo, S Ferraz-Mello, A Erikson, F Bouchy et. al, 2012) estimated that as many as 35% of detections using the transiting method on the Kepler mission were false positives. This highlights a significant flaw in this method, as any fully or partially opaque object, when passing in front of a star, will have the effect of reducing the total flux received by the observer.

Timing
Timing detections themselves can be split into several sub categories.