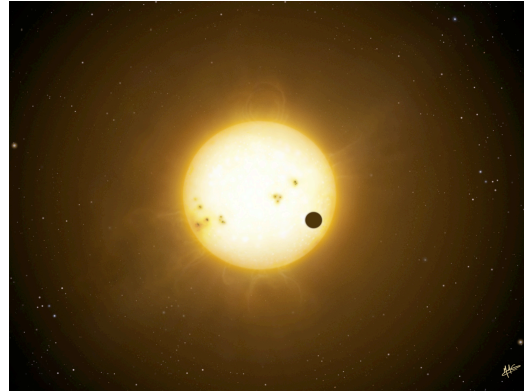


Extrasolar Planets

Introduction

The study of planets outside our own solar system is a relatively new scientific field; the first detections of extrasolar planets were announced in the mid 1990s and since that time, the number of detections has grown into the thousands.



One of the reasons that we've only recently become aware of other planets is that they are very difficult to detect. They emit only a tiny bit of light (most of it is reflected light) and are washed out by the comparatively brilliant light of their host stars. However, using spectral observations, it is possible to detect the planets gravitational “tug” on the star. This causes the star's spectral lines to oscillate back and forth in wavelength as a doppler shift. More recently, it has become possible to detect planets as they transit in front of their host stars. This causes a dimming of the stars light in a predictable way that reflects the properties of the planet and its orbit.

Each of these methods have their pros and cons and the success of each is ultimately determined by the noise level of the detection. The lower the observational error (or noise) the more likely a planet is to be detected. Also, with lower noise, smaller or more distant planets can be detected. In this lab, we explore both the doppler shift and the transit detection methods and the role of noise in extrasolar planet detection.

Our goals for this lab include:

- Learn how planets are detected using radial velocities
- Learn how different orbital properties affect radial velocities and planetary detection
- Learn how planets are detected using the transit method
- Learn how observational error (noise) affects planet detection.

Part 1: Radial Velocities

Open up the exoplanet radial velocity simulator located at:

<http://astro.unl.edu/naap/esp/animations/radialVelocitySimulator.html>

Look over the simulation and note that there are several distinct panels:

- a **3D Visualization** panel in the upper left where you can see the star and the planet (magnified considerably). Note that the orange arrow labeled **earth view** shows the perspective from which we view the system.
- The **Visualization Controls** panel allows one to check **show multiple views**. This option expands the 3D Visualization panel so that it shows the system from three additional perspectives:
- a **Radial Velocity Curve** panel in the upper right where you can see the graph of radial velocity versus phase for the system. The graph has **show theoretical curve** in default mode. A readout lists the **system period** and a cursor allows one to measure radial velocity and thus the **curve amplitude** (the maximum value of radial velocity) on the graph. The scale of the y-axis renormalizes as needed and the phase of perihelion (closest approach to the star) is assigned a phase of zero. Note that the vertical red bar indicates the phase of the system presently displayed in the 3D Visualization panel. This bar can be dragged and the system will update appropriately.

There are three panels which control system properties.

- The **Star Properties** panel allows one to control the mass of the star. Note that the star is constrained to be on the main sequence – so the mass selection also determines the radius and temperature of the star.
- The **Planet Properties** panel allows one to select the mass of the planet and the semi-major axis and eccentricity of the orbit.
- The **System Orientation** panel controls the two perspective angles.

(simulation description continues on next page)

Inclination is the angle between the Earth's line of sight and the plane of the orbit. Thus, an inclination of 0° corresponds to looking directly down on the plane of the orbit and an inclination of 90° is viewing the orbit on edge.

Longitude is the angle between the line of sight and the long axis of an elliptical orbit. Thus, when eccentricity is zero, longitude will not be relevant.

There are also panels for **Animation Controls** (start/stop, speed, and phase) and **Presets** (preconfigured values of the system variables).

Vary the settings as instructed and answer questions 1-13 in your packet.

Part 2: Radial Velocities and Noise

This simulator has the capability to include noisy radial velocity measurements. What we call 'noise' in this simulator combines noise due to imperfections in the detector as well as natural variations and ambiguities in the signal. This is a source of observational error. A star is a seething hot ball of gas and not a perfect light source, so there will always be some variation in the signal, even if measurements are made very carefully. The level of this noise fundamentally limits the ability to detect faint signals.

In this section of the lab, you will explore the effect of different noise levels on planet detections.

Vary the settings as instructed and answer questions 14-16 in your packet.

Part 3: Planetary Transits

Open the exoplanet transit simulator:

<http://astro.unl.edu/naap/esp/animations/transitSimulator.html>

The panel in the upper right now shows the variations in the total amount of light received from the star. The visualization panel in the upper left shows what the star's disc would look like from earth if we had a sufficiently powerful telescope. The relative sizes of the star and planet are to scale. Experiment with the controls until you are comfortable with their functionality.

Vary the settings as instructed and answer questions 17-19 in your packet.

Part 4: Planetary Transits and Noise

In this section you will explore the effects of observational error on detecting planets using the transit method.

Vary the settings as instructed and answer questions 20-22 in your packet.