Exoplanet Detection Lab: Part 1

Goals: Learn about modern technologies for detecting planets around other stars and think carefully about the inherent biases towards detecting certain types of planets via each method.

Introduction

The field of Extrasolar planet detection went from being the stuff of science fiction to a reality quite suddenly in 1995, and since then has become one of the dominant research areas in modern astronomy. Like most things in the universe, the first examples of exoplanets that were detected were likely quite unusual objects and were detected first because of the ease of detecting them. Many fields of modern science are similar, in the sense that each method of detecting or measuring a physical quantity is generally biased towards detecting objects with certain properties that make its detection easier via that method. No single planet detection method, for example, can detect all types of exoplanets.

It is important to recognize these so-called "selection effects" in data and to think about them when evaluating how universally applicable the results of a certain study are. For example, when the general public is polled via telephone surveys, the most likely respondents are those with strong opinions for or against the topic being discussed. If people with moderate opinions on the subject are unlikely to want to take the time to answer the survey questions, the results of the survey are no longer representative of the population as a whole. This is true of much of the data that you are confronted with in everyday life, and a sign of a truly scientific study is that it makes efforts to mitigate, recognize or quantify the effects of biased sampling on results.

This is one of the current challenges in modern exoplanet research. The questions that we'd really like to know, including

- -How common are exoplanets?
- -How common are earth-like exoplanets?
- -How typical is our own solar system?
- -What percentage of planets are born in the "Habitable Zone" of their host stars, where liquid water can exist on their surface?

are difficult to answer, and maybe even impossible to answer with one detection method alone. As you go through this lab, you should think carefully about the biases inherent in each detection method and how they might ultimately compliment each other.

Part 1: Learn About Three of the Exoplanet Detection Methods

First, Remind yourself what the following terms mean (and define below)

Semimajor Axis

Eccentricity

Doppler Effect (for light!)

Method 1: Radial Velocity

Based on what you learned in class, describe how planets are detected via the radial velocity method. It may help to draw a picture.

Go to the following website to learn more about the RV Method.
http://astro.unl.edu/naap/esp/animations/radialVelocitySimulator.html

With the simulator, try altering each of the following properties of the star-planet system, one at a time. Watch what each does to the Radial Velocity curve at the upper right. In particular, watch the y-axis of the graph (which will tell you the amplitude, or strength, of the signal) and the shape of the curve. Describe the observable effect of changing each of the following parameters on the curve (do shape, amplitude or both change? in what way?) below.

Planet Properties:

(a) Planet Mass

(b) Planet Semimajor Axis

(c) Planet Eccentricity

Star Properties:

(a) Mass

Large amplitude radial velocity signals are the primary thing that makes an exoplanet detectable via this method. Based on what you've discovered above, what kinds of planets are astronomers most likely to find through the radial velocity method? Answer by circling a choice for each of the options below.

Astronomers are most likely to find (low/high) mass planets in (close/far) orbits around (low/high) mass stars.

Method 2: Transits

Go to the following website to learn more about the Transit method of planet detection: http://astro.unl.edu/naap/esp/animations/transitSimulator.html

Vary each of the following parameters and watch its effect on the light curve in the upper right. This time watch the depth and length of the transit and describe how they vary when you change the parameters.

Planet Properties:

(a) Planet Mass

(b) Planet Radius

(c) Planet Semimajor Axis

(d) Planet Eccentricity

Star Properties

(a) Star Mass

The longer and deeper a transit is, the easier it is to detect. What does the information you gathered above tell you about what types of exoplanets are most easily detected via the transit method? Write a statement similar to the one you circled at the end of your radial velocity investigation.

Now try changing the inclination of the system (under "System Orientation and Phase"). What happens as you move the slider from right to left? Can you make the planet transit disappear? If so, over what range of inclinations is it visible and over what range is it invisible?

What does this tell you about the geometry of transiting exoplanetary systems and the likelihood of our detecting planets via this method? What types of systems can we see transits in and which can't we?

Method 3: Direct Imaging

This is the newest of the three main exoplanet detection methods The famous direct images of each of the exoplanets detected via the direct imaging method are linked below. Read the descriptions and fill in the information below. In some cases, you might need to click on the links in the first page to find the information you need.

2M1207: http://apod.nasa.gov/apod/ap050510.html
HR 8799: http://apod.nasa.gov/apod/ap081117.html AND
http://keckobservatory.org/news/keck_observatory_pictures_show_fourth_planet_in_giant_solar_system/
Fomalhaut b: http://apod.nasa.gov/apod/ap081114.html
Beta Pictoris: http://apod.nasa.gov/apod/ap100703.html

Planet Name	Mass and type of Star (in Solar Masses)	Mass of Planet (in Jupiter Masses)	Planet-Star Distance (in AU)	Year of Discovery
2M 1207				
HR8799b				
HR8799c				
HR8799d				
HR8799e				
Fomalhaut b				
Beta Pictoris b				