Name:____________________________ Section:___________________

Earth 110 – Exploration of the Solar System

Assignment 5: Exoplanets Due in class Tuesday, March 1, 2016

Up until the mid 1990's, we did not know if planets existed around other stars. Advancements in technology have led to the detection of almost 2,000 known exoplanets in two short decades. But why should we care about planets outside our solar system? Most are too far away to ever visit (unless we develop light-speed capabilities or wormhole technology), so any kind of settlement or resource development is pretty much out of the question. The abundance and type of exoplanets, however, are beyond anything we could have expected.

The presence of planets outside our solar system tests the nebular theory – a theory that was developed with just one data point (our solar system). The abundance of other planetary systems, including some of the incredible uniqueness of these systems, has already forced modifications to the nebular theory. Why is this important? By comparing exoplanets with planets in our solar system, we can better understand solar system and planet formation and evolution, *including our Earth*. The presence of exoplanets also suggests that maybe we aren't unique, maybe there are other worlds out there like Earth with life – maybe even technologically advanced life – that we can someday detect or even communicate with. We are living in the exoplanet revolution!

This assignment references Chapter 13 in the textbook. The recent discovery of exoplanets has really forced scientists to reassess how solar systems form and evolve. There are so many worlds that are incredibly different than any planet we have in our solar system – ranging from Hot Jupiters to mini-Neptunes to Super-Earths to water worlds, not to mention average densities ranging from styrofoam to iron. Figure 13.16 provides an excellent introduction to some of the "weirder" planets that have been discovered, as well as possible planet composition. There is so much out there that we haven't even detected yet!

Exoplanet Detection

Exoplanets are detected in two ways: *indirectly* and *directly*. Indirect methods observe motions of stars to detect either gravitational effects or changes in star brightness due to orbiting planets. Direct methods observe visible light reflected by the planet or infrared light radiated by the planet, or obtain spectra of the planet. At present, indirect methods are more commonly used because direct methods require really high-resolution data that is difficult to obtain.

Explain the Astrometric method of indirect detection. How is this method different than the Doppler method?

Explain the Transit method. How does the total brightness of a system change over a planet's period?

What are the limitations of the indirect methods listed above? What is the required planetary system orientation relative to Earth? Explain.

Exoplanet Properties

The Astrometric, Doppler, and Transit methods all tell us the orbital period of a planet, which means we can also determine its orbital distance from the star through Newton's version of Kepler's third law. Why do we have to use Newton's version and not just $p^2 = a^3$?

How can we tell planet eccentricity using the Doppler method?

How do the Astrometric and Doppler methods measure planet mass? Why is it that the Doppler method can only measure *minimum* planet mass?

How is the Transit method used to determine planet radius?

Explain how exoplanet atmospheric composition and temperature can be measured. What method(s) is best for this?

We are going to use NASA's Eyes again (eyes.nasa.gov), only this time to look at exoplanets. Open NASA's Eyes and click "Start" for Eyes on Exoplanets.

Click on the icon with the exclamation mark and choose "Weirdest Planets". Choose one from the list of eight (at bottom of screen) and describe why it's so weird. Make sure to note which planet you chose.

Now click the Home button. Choose any star that has at least one planet. Which system is it? How far away is it? How long would it take to travel there if traveling by jet? Is the planet in the star's habitable zone? What *is* a habitable zone? How does the layout of this system compare with our solar system?

Read the article at http://tinyurl.com/ldzrrok. Explain how these incredible rings were detected.

Read the article at http://tinyurl.com/leocr9b. Describe the orbit of Kepler-432b with relation to Mercury's. What does this mean for surface temperature and seasons? What other reason makes this planet uninhabitable?

Read the article at http://tinyurl.com/n4mzco3. What are Hot Jupiters? How can their orbital distance and inclination be explained?

Read the article at http://phl.upr.edu/press-releases/gliese832. Explain why a Super-Earth like Gliese-832 c would have a denser atmosphere and might be too hot for life.

Read the article at http://tinyurl.com/pjr4nge. What other requirements would make these planets habitable *other* than being in the habitable zone?

Read the article at https://www.cfa.harvard.edu/news/2013-11. Explain the differences we think there are between Kepler-62e and Kepler-62f. Why this difference?

Read the article at http://tinyurl.com/k75zjsl. How could a mini-Neptune become habitable?

Based on exoplanet discoveries, what types of modifications need to be made to the nebular theory (list at least two)? Do you think that our solar system is a rare type, or that we just haven't yet detected other solar systems like ours?