

Course 12.425. Problem Set 2. Due 2 Oct. 2007.

1. The Stellar Magnitude System.

- a. Derive the stellar magnitude formula given below, using the fact that five magnitudes is a factor of 100.

$$m_b - m_a = -2.5 \log_{10} \frac{F_b}{F_a}. \quad (1)$$

- b. If the planet-star flux ratio is 10^{-3} , what is the difference in magnitude?

2. Planet-Star Center of Mass.

The HD 209458 star and planet system have the following properties: $M_* = 1.01M_\odot$, $M_p = 0.69M_J$, $P = 3.525$ days, $a = 0.045$ AU, and $e = 0$.

- a. Find a_1 , the star's distance to the planet-star common center of mass. How does this compare to the radius of the star HD 209458A ($1.12R_\odot$)?
- b. What is a_2 , the planet's distance to the planet-star common center of mass? How does this compare to the semi-major axis a ?

Problems 3 through 6: Radial Velocity Fits to Real Data Sets.

The section lead by TA on Tuesday September 25 will introduce radial velocity fits to data sets as relevant to this problem set. We will be using computers to try some fits. If you have a laptop, please bring the laptop to section on Tuesday September 25. If you do not have a laptop, you can share with a friend,

The rest of this homework set involves orbital fits to radial velocity data sets. The fits correspond to model planetary systems. The goal of the fitting procedure is to find a planetary model that does the best possible job of fitting the data. We will use the Systemic console to obtain the orbital fits. The console has all of the features that professional astronomers use to find planets, and indeed, planets such as Gliese 581 c have been found by users of the Systemic console before they were announced by professionals. It is possible that you can discover a previously unknown planet by doing the best possible job on problem 6.

For each planet you fit, be sure to print out either 1) a screen shot of your best fit, including the χ^2 value or 2) the data plot including your fit, and a list of χ^2 , period, mass, mean anomaly, eccentricity, and longitude of perihelion. See the attached sample printout. If a residual periodogram is needed in a given problem, please print and submit that periodogram as well.

Please make sure to upload your fits for problems 3, 4b, 5a,b and 6 to the Systemic backend. Also, be sure to save all of your work on your desktop.

3. Getting Going.

- a. Download the console from http://oklo.org/?page_id=86 and install it on your computer. The directions are given on the download page.
- b. Register as a new user on the Systemic backend at <http://www.oklo.org/php/login.php>. The first nine characters of your username should be mit12.425. The last characters should be _initials.
- c. Follow the first two tutorials using the console. They are available at www.oklo.org.
- d. Following the instructions on the backend, upload the fit for Upsilon Andromedae that you will make using tutorial 2. Please make sure that your χ^2 value is as close to unity as possible.

4. 51-Pegged.

In 1995, two Swiss astronomers shocked the world by announcing that they had discovered a bizarre planet orbiting the Sun-like star 51 Pegasi. It is interesting to find this planet in the radial velocity data sets, which are available on the console under 51Peg_B06L.

- a. Using the periodogram to get started, find the best 1-planet fit to the data set. What period and mass does the planet have?
- b. Using the periodogram of the residuals, find a 2-planet fit to the data. You must submit this fit following the instructions on the backend, as you did for the previous problem. Do not submit your results for part (a)! What is the value of the F-test statistic for your 2-planet fit in comparison to your 1-planet fit? Does this indicate a strong chance that you have discovered a new planet?

- c. Explain how one could go about confirming whether this second planet is really present in the system.
 - d. The data set 51peg-cc contains only the data obtained by the California-Carnegie planet search team. Are both planets present in this dataset? Give a reasonable hypothesis for what might be going on here.
5. **Trois Neptunes.** HD 69830 is a multiple-planet system with three low-mass planets.
- a. Using the console, find a three-planet fit to the data set that has the lowest possible χ^2 .
 - b. Upload your fit to the Systemic backend.
 - c. Integrate your fit for 1000 years using the stability checker. (This may take minutes to hours to run, depending on your stepsize and which integrator you choose). Is the system stable?
 - d. Increase the mass of the middle planet to one Jupiter mass (this makes the χ^2 go way up.) Is this modified version of the system stable?
6. **Bonus Problems: Your Chance to Help Find New Exoplanets.**
- a. HD 74156_HET07 is a new 3-planet system just announced. Find the best 3-planet fit to this system.
 - b. GJ876 is a 3-planet system. There is evidence for an additional, potentially habitable planet in this system. Find the best 4-planet fit and provide the F-test probability for the stability of this 4th planet.