Astro 118 – Physics of Planetary Systems
Problem Set #4, Winter 2014
Due in class on Friday, February 21, 2014

This homework set uses the online version of the Systemic Console. Univ. of Texas astronomer and former UC Santa Cruz astronomy grad student Stefano Meschiari created the Console. Its main purpose is to obtain orbital fits to radial velocity data sets. The fits correspond to models of planetary systems, using real RV data. The goal of the fitting procedure is to find a planetary model that does the best possible job of fitting the data. The Console has all of the features that professional astronomers use to find planets, and indeed, planets such as Gliese 581c were found by users of the Systemic Console before professionals announced them. You should know up front that this will take some patience, and if you wait until the last day, you will not finish. If you have trouble with the exercises, and have *truly exhausted your patience,* ask me for help.

1. **Getting Going.** Go to the following address: http://www.stefanom.org/systemic-live/ with your Internet browser and click on "Open Systemic". The page that opens is the Systemic Console, where you will be carrying out the assignment. You can click on the question mark icons to open help pop-ups that explain the function of each panel.
Note: if Systemic warns you that your browser might be too slow, please access the website using the Google Chrome browser (http://www.google.com/chrome) or update your browser.

2. **51 Pegged. (a)** In 1995, two Swiss astronomers shocked the world by announcing that they had discovered a bizarre planet orbiting the Sun-like star 51 Pegasi. Follow along the tutorial at http://www.stefanom.org/51-pegged to fit your first planetary model. What is the final period and mass of the planet you found? **(b)** To understand better where radial velocity data come from, read Tutorial #1 at http://oklo.org/ (this tutorial was made with an older version of Systemic, but you should still be able to find your bearings). More tutorials are available at www.oklo.org, near the top of the page. oklo.org is also an exoplanets blog from UCSC professor Greg Laughlin and there is a lot of great stuff there. **(c)** Then, pull up the "HD4208_B06K.sys" data set in Systemic and try to find the planet around the star HD 4208; you can follow the same procedure you used to fit 51 Peg. What is the final period and mass of the planet you found?

3. **Ups And.** Follow the tutorial at http://oklo.org/systemic-console-tutorial-2-upsilon-andromedae/. This tutorial was made for an older version of Systemic, but the tools mentioned are all available on the new version. Select "upsand.sys" from Systemic, add the first planet at about 4 days, and then read the power spectrum (periodogram) to find the residuals peaks in the data. Those peaks are indicative of additional planets. Try to find your best fit for the Upsilon Andromedae system. Print out the RV curve and the picture of the orbit (use the icon on the top right corner for the former, and the "Download" button for the latter). Please make sure that your χ^2 (Chi^2, chi-square) value is as close to unity as possible. Write down the χ^2, RMS, and Jitter from the "Statistics" panel on the right-hand side.

4. **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 chi-square. **(b)** Print out the RV curve and the picture of the orbit (as above). Write down the χ^2, RMS, and Jitter from the window on the right-hand side. **(c)** Select the "Dynamics" panel and integrate your fit for 1000 years using the stability checker. Is the system stable? **(d)** Increase the mass of the middle planet to one Jupiter mass (this makes the chi-square go way up). Is this modified version of the system stable? **(e)** Compare your model planetary system to the published model: http://exoplanet.eu/star.php?st=HD+69830.

A scientific publication that describes the implementation of the console is available at: http://adsabs.harvard.edu/abs/2009PASP..121.1016M