

ASSIGNMENT No. 3

DUE: Thursday, Feb. 26

READING: Read pp. 99-101 of Maoz on interacting binaries

1. Extrasolar planet parameters

You have obtained a time-series set of radial-velocity observations of a solar-type star (you may assume the mass = $1 M_{\odot}$), and find a sinusoidal variation in v_{obs} with a period of 197 days, and amplitude $v_{max} = 2.2 \text{ m s}^{-1}$. You interpret these variations as reflex motion caused by a planet in a circular orbit around the star. With sensitive photometric observations from HST, you conclude that there is a periodic eclipse of the star with the same period as that of the planet; you interpret this as a transit of the planet between you and the star. From this information, you add a new extrasolar planet to your list. What are the mass of the new planet (in units of the mass of the Earth and the mass of Jupiter), and its distance from its parent star (in AU)? If you had not observed the eclipsing behavior, how would your conclusions have changed?

2. Two-plus-one-body orbits

In this problem, you will investigate three-body orbits using one of the “Astronomy Workshop” web tools mentioned in class. If you don’t have access to a computer elsewhere, you may use one in the Astronomy Lab (CSS rm. 1220). First, go to the page <http://janus.astro.umd.edu/orbits/3bdy/B2D.html> There, you will see different options for the orbit of the binary stars (the two “massive” bodies, which we’ve called M_1 and M_2) and the orbit of the planet (which we’ve called m).

Choose for the first set of options (“**Orbit of the Binary Stars**” on the web page) $M_1 = 1M_{\odot}$, $M_2 = 0.05M_{\odot}$, the distance between the binary 1 AU, and the eccentricity of the binary 0.

For the second set of options (“**Orbit of the Planet**”), choose orbital elements of the planet relative to “star 2” (you can play with other options later if you want, for fun) eccentricity 0, and pericenter at 0 degrees (again, you can play with these later to see what changes).

Keeping all of the above choices the same, first run five different cases with the planet’s semimajor axis equal to 0.08, 0.09, 0.10, 0.11, and 0.12 binary separation distances. Choose integration time of 10 binary periods at the top of the page, and true anomaly of 0 degrees for the planet parameters.

Then do another set of runs with the planet’s semimajor axis equal to 0.13 binary

separation distances, and true anomaly of 0, 40, and 80 degrees for integration time of 10 binary periods. To understand what is happening in some of these cases, run again for shorter and longer integration times.

Then do two runs with with the planet’s semimajor axis equal to 0.13 binary separation distances and true anomaly of 179 and 180 degrees for integration time of 5 binary periods, looking at your results both in the inertial and rotating coordinate systems (see below), and using color “to indicate the time evolution of the 3rd body orbit.”

For all of the runs, after you press “submit run,” you will be transferred to the “graphics driver” page so you can look at your result. Use the “custom plot” option first (although you can play with this to see other options). You can keep most of the values set at the defaults, but try both the “inertial” and “rotating” options for the coordinate system, and use color to “differentiate between the three bodies” at first if you find the other option confusing. The option of using color “to indicate the time evolution of the 3rd body orbit” just means that the “planet” orbit is plotted with red at the beginning changing to green at the end, as indicated in the key.

Describe/sketch the results you found for all of the different runs, relating what you’ve found to the ideas we’ve discussed in class. (Instead of a hand sketch, if preferred you may use the “plot” function, screen capture, etc., to save images of the orbits.) In particular, relate your findings to what we found for the radius of the secondary’s “Roche lobe”,

$$\frac{R_{Roche}}{a} = \left(\frac{M_2}{3M_1} \right)^{1/3}$$

(what is the value of this for the system you’re looking at?), and to the ideas we’ve discussed about chaos in three-body systems. (Note that in the Roche formula above, a is the semimajor axis, which is equal to the binary separation distance.)