Astr 423, Spring 2019

Homework 3: Binary systems

1 An eclipsing binary in the LMC

Data taken from Pietrzynski et al. 2009, ApJ, 697, 862. We will assume that the orbits are circular, which is OK, because the eccentricity is small. We also assume that the orbital inclination is 90 degrees, which again is close to the truth.

1.1 Orbital size, sum of stellar masses

The orbital period is 214.37 days. The semiamplitudes K are 32.65 and 33.67 km/s. Calculate the orbital size $(a_1 + a_2)$. Use this result to calculate the sum of the stellar masses.

1.2 Mass ratio and individual masses

Calculate the mass ratio from the ratio of the semiamplitudes, and calculate the individual masses.

1.3 Angular sizes and distance to the LMC

The values of the apparent magnitude K (do not confuse with the semiamplitude K) are 14.895 and 15.446 for the two binary components. The values of the colors V-K are 1.843 and 1.749. The equation for the Barnes-Evans relation is

$$K + 5\log\phi = 2.76 + 0.252(V - K)$$

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Calculate the angular sizes. The analysis of the light curve has provided the physical radii of the two stars, 26.06 and 19.76 solar radii. Calculate the distances to both stars.

2 Elliptical orbits

Assume the following parameters for an elliptical orbit: orbital eccentricity 0.7, and radial velocity semiamplitude K = 50 km/s. Define a set of values for the true anomaly (from 0 to 355 degrees, incrementing by 5 degrees). A similar set of values can be used for the longitude of the periastron, ω, but with a larger increment of 20 degrees.

Write a computer program that will calculate and plot the radial velocity curve as a function of orbital phase for any given value of ω. Build the family of radial velocity curves for all the values of ω in the set you have defined. Try to make small plots, so that several curves can be shown in one page.

3 Period search using radial velocity data

File rv2346.dat is a set of 48 measurements of the heliocentric radial velocity of the central star of the planetary nebula NGC 2346. The first column gives the heliocentric Julian date (the number 2400000 has been subtracted). The second column gives the heliocentric radial velocities in km/s.

3.1 Method of Lafler and Kinman

Write a computer program that will read all the data and calculate the parameter Θ defined by Lafler and Kinman (1965, ApJS, 11, 216) for a given set of periods (you have to define an initial period, a final period, and an increment). For every period to be tested, you have to calculate the orbital phases and sort them.

Start by making a broad search for periods between 3 and 40 days, with a large increment. Find the few best values of Θ and plot the radial velocity curves. Which period looks more plausible?

Now reduce the period range around the selected period and reduce the increment. Run your program again to improve the period determination.

Report your final P determination and plot the final radial velocity curve. Measure the semiamplitude of the radial velocity curve. What is the binary system's radial velocity? Verify in the SIMBAD database if this agrees with the radial velocity of the planetary nebula.

3.2 Lomb-Scargle method

Find a Python implementation of the Lomb-Scargle method and build the periodogram. See if you can confirm the period determined in the previous subsection.