1. Figure Fig. 1.1 plots the apparent orbits of the primary and secondary star in a visual binary system.

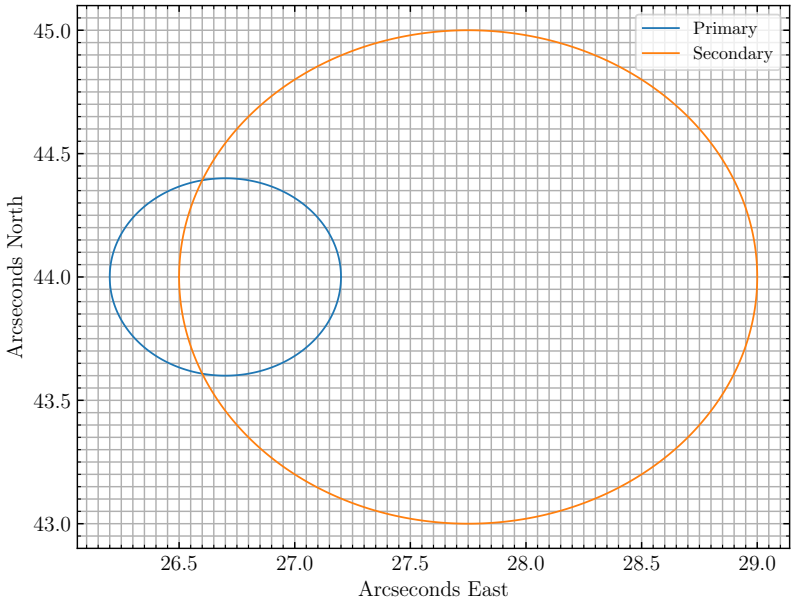

Figure 1.1: Apparent orbits of the primary and secondary stars in the visual binary system of Q1.

(a) On a copy of the figure, for each apparent orbit, mark the center of the ellipse and measure the angular semi-major axis (α_1 and α_2, respectively) and semi-minor axis (β_1 and β_2), in arcseconds.

(b) What is the mass ratio M_2/M_1 of the system?

(c) Evaluate the eccentricity e of the apparent orbits (you should get the same value for primary and secondary).

(d) On your copy of the figure, for each apparent orbit, use your knowledge of the semi-major axis (α_1 and α_2, respectively) and e to mark the two foci of the ellipse.

(e) What piece of evidence suggests that we are viewing the system face-on?

(f) If the parallax of the system is $0.05''$, what is the distance d to the system, in parsecs?

(g) For each orbit, what is the linear semi-major axis (a_1 and a_2, respectively), in AU?

(h) What is the overall semi-major axis a of the system?

(i) If the period of the orbit is 55 yr, what is the combined mass $M_1 + M_2$ of the system?

(j) What are the individual masses, M_1 and M_2, of the stars?

12 points

2. Observations of an spectroscopic/eclipsing binary system, having a period of 5 d, show sinusoidal radial velocity curves for each star. The primary has a velocity semi-amplitude of 120 km s^{-1}, and the secondary 200 km s^{-1}.

   Based on these observations, determine the following quantities (if you lack the data to evaluate a given quantity, answer 'insufficient data'):

   (a) the mass ratio M_2/M_1

   (b) the mass sum $M_1 + M_2$

   (c) the inclination i

   (d) the eccentricity e

   Be sure to justify your answers. **6 points**

3. Submit three *MESA-Web* calculations, for masses 5 $M_\odot$, 1 $M_\odot$ and 0.2 $M_\odot$. In each case, set the following parameters on the *MESA-Web* submission page:

   - *Mass* (in the *Initial Properties* group) to the stellar mass in $M_\odot$.
   - *Convective Premixing* (in the *Convection* group) to 'Enabled'.
   - *Quantity* (in the *Custom Stopping Condition* group) to 'central hydrogen mass fraction lower limit'.
   - *Value* (in the *Custom Stopping Condition* group) to 0.35.

   (leave other parameters at their defaults). This set of parameters will ensure that the calculation stops about half-way through the main sequence phase, when the central hydrogen abundance has dropped to half its initial value. **7 points**

   Then, use data from the final (highest-numbered) profile file of each *MESA-Web* run to plot the hydrogen mass fraction X (on the vertical axis) versus fractional mass m/M (on the horizontal axis). All three stars should appear on the same plot. With reference to the discussion on the second page of *Handout 14*, explain the differences you see in the three curves in the plot.

   Implementation notes: assuming you have read profile data into the variable `prof_data`, you can access the X values as `prof_data['h1']`, m values as `prof_data['mass']` and M value as `prof_data['star_mass']`.