APPARENT MOTION OF A BINARY STAR: COMPUTER MODEL

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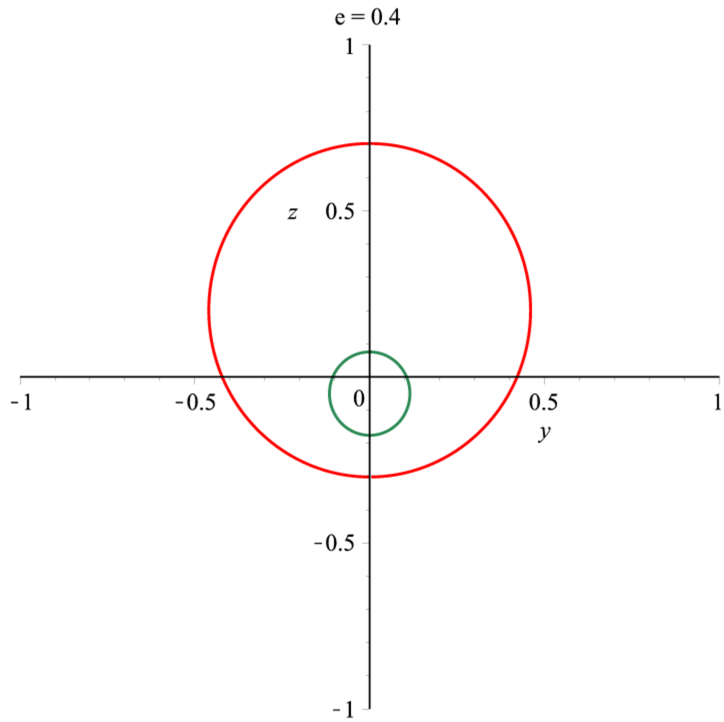
Reference: Carroll, Bradley W. & Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, 2nd Edition; Pearson Education - Chapter 7, Problem 7.16.

The *TwoStars* program included in Carroll & Ostlie's Appendix K also produces the positions of the two components of a binary star system as seen by an observer on Earth, that is, as projected onto the plane of the sky, taken to be the $y'z'$ plane. The output of the program gives these positions in metres, measured from the stars' positions at $t = 0$. To convert this to seconds of arc, we need to know the distance d (in parsecs) to the system. We then get these positions in seconds of arc from

$$[y,z] = \frac{180\times 3600}{\pi}\frac{[y',z']}{(3.08567758\times 10^{16}\text{ m pc}^{-1})\,d} \tag{1}$$

I've produced a Maple version of this program that generates these positions in seconds of arc, and produces plots of the motion of the system relative to the origin, which corresponds to the position of the centre of mass at $t = 0$. The Maple file is available here (with the usual caution that the code is a direct translation of the C++ original, and is therefore rather ugly!).

We'll use the same binary system as in the previous post, with the additional information that this system is 3.2 parsecs from Earth. The parameters are $M_1 = 0.5M_S$, $R_1 = 1.8R_S$, $T_1 = 8190$ K, $M_2 = 2.0M_S$, $R_2 = 0.63R_S$, $T_2 = 3840$ K, $P = 1.8$ yr, $\phi = 0$, and $i = 30°$. First, we'll check the program in the case where the eccentricity is $e = 0.4$, the inclination is $i = 0$ (so we're viewing the system face on) and the centre of mass velocity is zero. In that case, the apparent paths of the stars looks like this:

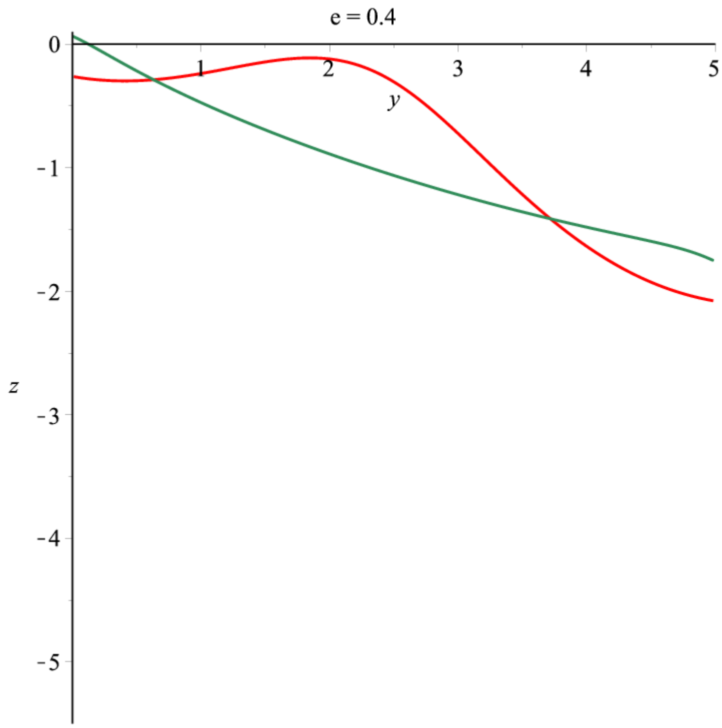


This looks OK, since the two paths are ellipses with their focus at the origin.

Now suppose we make the inclination $i = 30^{\circ}$ and give the centre of mass a velocity of

$$\mathbf{v}_{cm} = [30, 42, -15.3] \text{ km s}^{-1} \tag{2}$$

Over one period, the motion looks like this (the axes of the plot are chosen so that the scale is the same in both directions, giving an actual view of the paths):



This is actually quite a large apparent motion (it corresponds to a proper motion of the centre of mass of around $3.5'' \text{ yr}^{-1}$, which is comparable to that of α Cen, the closest star to our solar system. This is due to the proximity of this fictional system to Earth and to its large velocity through space.

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