EXTRASOLAR PLANET DETECTION WITH LIGHT CURVES: OGLE-TR-56B

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Reference: Carroll, Bradley W. & Ostlie, Dale A. (2007), *An Introduction to Modern Astrophysics*, 2nd Edition; Pearson Education - Chapter 7, Problem 7.18.

The TwoStars program can also be used to generate light curves in a binary system where one component is a star and the other is an exoplanet.

One example of this is the planet OGLE-TR-56b, which is a "hot Jupiter", in that it's a gas giant but with a surface temperature of around 1973 K. It was discovered in 2002 by observing a dip in the light received from its parent star, OGLE-TR-56, by a magnitude drop of only around 0.01. [OGLE stands for Optical Gravitational Lensing Experiment, and is a project based in Poland.]

Although the actual parameters of the planet are now believed to be quite different from those quoted in Carroll & Ostlie, we'll use their values in the TwoStars program to generate a light curve. They are $P=29$ hours, $a=0.023$ AU, $m_p=0.9M_J$, $T_p=1000$ K and $R_p=R_J$, where a subscript p indicates the planet and J indicates Jupiter. For the parent star, we are given that $R_s=\frac{0.023\text{ AU}}{4.5}$, and we can work out its mass using the same technique as before, by solving the formula:

$$\frac{m_s^3}{(m_p+m_s)^2}\sin^3 i=\frac{P}{2\pi G}v_{p,r}^3 \tag{1}$$

The radial velocity $v_{p,r}$ of the planet can be found by assuming the orbit is circular:

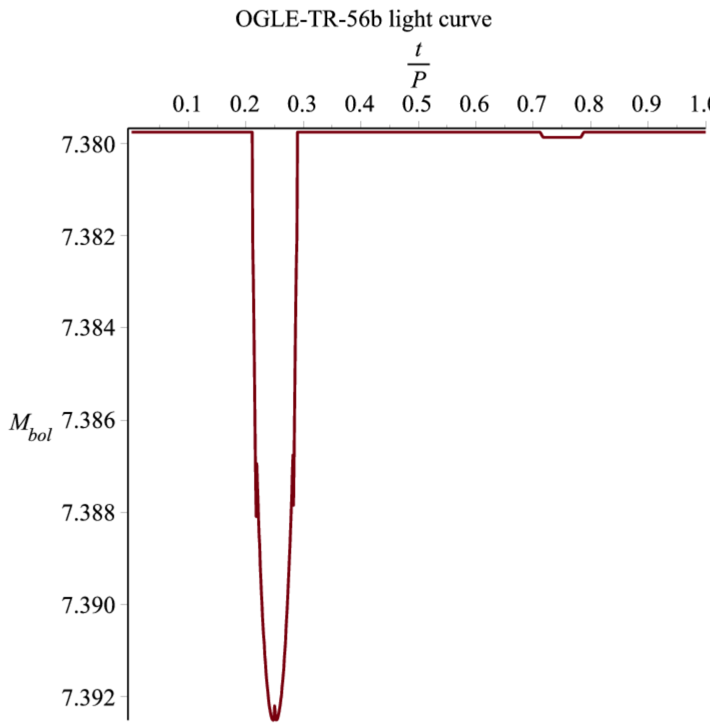
$$v_{p,r}=\frac{2\pi a}{P}=207\text{ km s}^{-1} \tag{2}$$

Taking $i=90^\circ$ and plugging in the numbers, and then solving for m_s (using Maple to get an exact value), we find

$$m_s=1.11M_S \tag{3}$$

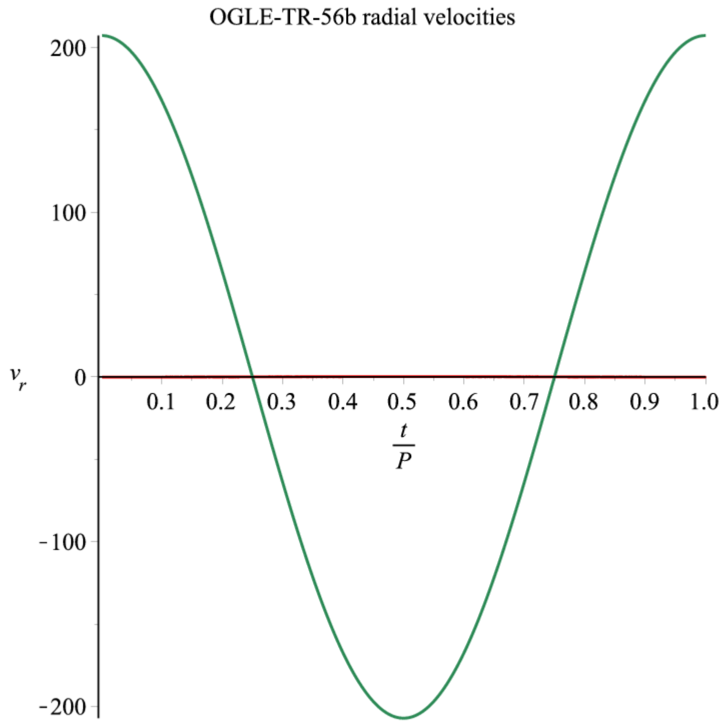
where M_S is the mass of the Sun. The temperature of the parent star is 3000 K. I used $\phi=90^\circ$ to position the light dips in the middle of the graph.

We now have all the data we need to run TwoStars. Carroll & Ostlie suggest using $i = 90°$ but this gives a spurious spike in magnitude at the centre of minimum. I'm not sure exactly what causes this, but it's probably something to do with the transformation to the plane of the sky coordinate system, which involves $\cos i$, thus giving a value near zero. In any case, if we use $i = 89°$ we get a more sensible light curve:

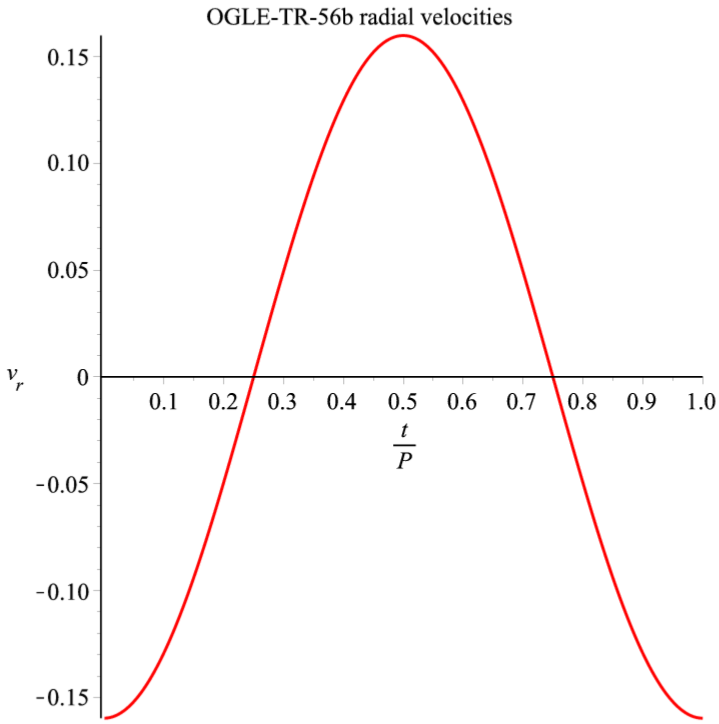


The drop in magnitude during a transit of the planet is around 0.012 magnitudes. We can also see a tiny drop between t/P values of 0.7 and 0.8 when the planet goes behind the star.

The radial velocity curves look like this:



The flat red line is the curve for the star, so we see that it's practically unaffected by the planet. Just to verify that it *does* actually change, here's a magnified view of the star on its own:



The maximum radial velocity of the star is only around 0.16 km/sec.