



Rudiments of Light Curve Analysis - Part II

An excellent way to get a "feeling" for what kind of parameters will create what kinds of light curves is to explore the **Catalog and Atlas of Eclipsing Binaries** at <http://caleb.eastern.edu>. You can list the hundreds of on-line binaries by binary type and look at the light curves and perhaps find one that is similar to your own. Many of the systems listed in this database are also included in the Zip library accompanying *Binary Maker 3*. Additional systems can be downloaded directly from the site.

Once you have determined the basic type of binary from the shape of the light curve, there are several straightforward techniques that can be used to hone in on a possible solution.

If the light curve appears to be an [overcontact](#) system (*i.e.*, relatively short period (less than 1 day), light variation throughout the light curve and similar depth eclipses) then put the program into [fillout mode](#). If color indices exist then an approximate [effective temperature](#) can be set for both stars, *i.e.*, initially set both stars to the same temperature. If the period is less than 0.4 days, then the system will likely be a W-type overcontact system where the larger star is the cooler star. This requires a mass ratio input that is [greater than unity](#). Obviously use a spectroscopic mass ratio if that is available. If the system displays a total eclipse then the mass ratio can be determined through trial and error modeling of different mass ratios until the eclipses are properly fitted. If the system is partially eclipsing then a series of solutions with different mass ratios will have to be attempted, and the best fit parameters will be the best estimate of the actual ones.

Once a mass ratio has been input, a good starting point for both [fillouts](#) is 0.15, the average value found for overcontact systems (Robertson and Eggleton 1977). Start with an [orbital inclination](#) of 85 degrees unless the system exhibits total eclipses. If it does then begin with 90 degrees. If the estimated temperatures are less than 7200 K, then treat the stars as convective and let the [gravity brightening](#) coefficients be 0.32. If the stars are believed to be higher in temperature than 7200 K (mostly radiative stars), then set the gravity brightening coefficients be 1.00. Linear [limb darkening](#) coefficients can be determined from Van Hamme's (1993) tables which are available [here](#) as well as in the Appendix of the User Manual. The [reflection coefficients](#) will be 0.5 for convective stars and 1.0 for radiative stars. If there is extraneous light in the data then that will have to be compensated for by entering a value for [Third Light](#). Be certain that the [effective wavelength](#) entered corresponds to the effective wavelength of the filter through which the data were observed.

Assuming that the light curve has been read into the [Light Curve Plot](#) and that you have generated a theoretical (synthetic) model, compare the theory to the observations. If the theoretical eclipses are both too deep, then decrease the inclination until the depths are more comparable to the observations. If one eclipse seems the correct depth but the other is not, then the temperature of one of the stars must be changed (usually the smaller star is changed). Light curve analysis does not give the absolute temperatures of stars but rather the temperature difference between the two stars. Therefore changing the temperature of just one of the stars is sufficient. If the eclipse that doesn't fit is too low then the star being eclipsed is too high in temperature. If the theoretical eclipse isn't low enough, then that star is too cool. Note that adjusting the temperature of one star will affect the relative depths of both eclipses. When both eclipses are too low or too high from the observations **by the same amount**, then simply adjust the inclination at that point to make both the eclipses fit.

Once a solution for a particular wavelength has been achieved, save it and then load in another bandpass dataset and change the **wavelength and limb darkening coefficients** to match that wavelength (also **third light** if it is nonzero). If your first model is a good one, then the other wavelength independent parameters should fit the other dataset as well. If it does not, then adjustments will have to be made in the model (temperatures, sizes, mass ratio, etc.) until a coherent model satisfactorily fits all of the light curves with only the wavelength-

dependent parameters (wavelength, limb darkening and third light) being different for each filter.

If the light curves vary in brightness throughout the cycle but the eclipse depths are quite different, then you probably have a contact or near contact system. You can again use fillout mode, setting one star's fillout to zero (0.0) and the other to a slightly less than zero value, say -0.10. Experiment with different mass ratios and different temperatures until a satisfactory fit is obtained.

If the light curve appears to be an Algol system (semi-detached with the less massive star being more evolved than the more massive star), then you should probably set the program to [Radii input mode](#). The cooler star will be at its Roche limit so set its radius to -1 (the flag that forces the star to exactly fill its inner lagrangian surface). Estimate the mass ratio and radius of the primary star and experiment until your synthetic light curve matches your observed one.

For detached systems, again use Radii input mode and experiment with different sizes, temperatures and inclinations until you achieve success in matching your data.

Asynchronous Systems

Because of tidal friction between the two stars in the binary, their rotation periods usually are identical to their revolution periods. This condition is called *synchronous* rotation, and the best known example of this situation occurs between the Earth and Moon with the same face of the Moon always facing Earth because of this synchronism. The majority of observed binary systems appear to have come into synchronous rotation, and this condition is parameterized by the rotation parameters [F₁ and F₂](#). When they are both equal to unity, this means that the stars are in synchronous rotation, *i.e.*, that their revolution and rotation angular velocities are equal. Asynchronous rotation can be modeled in *Binary Maker 3* by setting these rotation parameters to values other than 1.00, usually values greater than 1.00, signifying that the stars are rotating faster than synchronously. It will be rare to run into binaries with asynchronous rotation, but there are several examples of such systems included in the Zip library, *e.g.*, RZ Cas, LZ Cen, SW Cyg, RW Mon, and RZ Sct.

Eccentric Systems

Eccentric orbit binaries are more complicated than circular orbit systems because there are two more parameters that need to be specified, namely the **eccentricity (e)** and the **longitude of periastron (ω)**. The eccentricity parameterizes the shape of the orbit (how much it differs from a circle) and the longitude of periastron is the angle in degrees (measured the direction of revolution) from the ascending node to the periastron point. This parameter, along with the eccentricity, will determine where the secondary eclipse will occur in the light curve. It will usually not be exactly halfway in phase (*i.e.*, at 0.50P) as it always is with circular orbit binaries. For eccentric systems it will depend on both the eccentricity and the longitude of periastron. And to make matters more complicated, the longitude of periastron changes with time (precesses) and therefore will be different at different epochs. Let us look at an eccentric system to get a feel for what an eccentric orbit light curve looks like and how it would change in appearance as its longitude of periastron changes. There are many examples of eccentric systems included in the Zip library. We will look at V1647 Sgr and the observations and analysis of Clausen et al. (1977) and Andersen & Gimenez (1985). The diagram below shows the *b* light curve of V1647 Sgr and next to each light curve is the orbital position of the stars at the phase of secondary eclipse for the longitude of periastron noted for each curve.