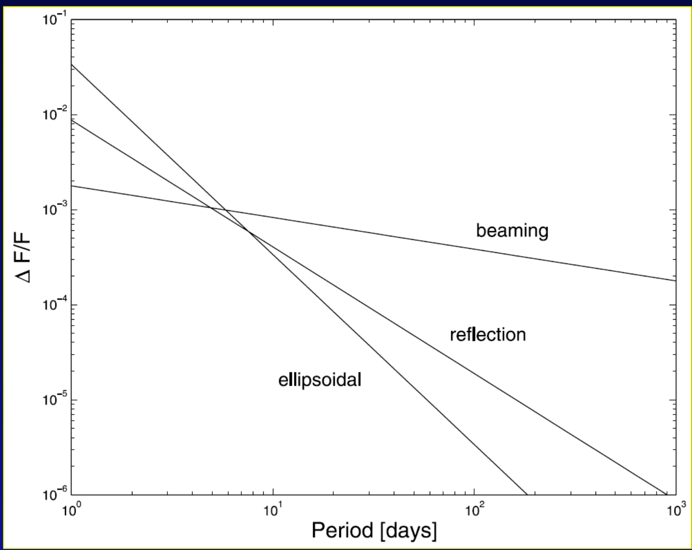
New binary systems: beaming binaries

J. C. Morales[1], J. Weingrill[2], T. Mazeh[3], I. Ribas[1,4]

[1] Institut d'Estudis Espacials de Catalunya (Barcelona, Spain), [2] Space Research Institute, Austrian Academy of Sciences (Graz, Austria),
[3] School of Physics and Astronomy, Tel Aviv University (Tel Aviv, Israel) , [4] Institut de Ciències de l'Espai (CSIC, Bellaterra, Spain)

Abstract: Exoplanet missions such as COROT and Kepler are providing precise photometric follow-up data of new kinds of variable stars undetected till now. Beaming binaries are among these objects. On these binary systems, the orbital motion of their components is fast enough to produce a detectable modulation on the received flux due to relativistic effects (Zucker et al. 2007). The great advantage of these systems is that it is possible to reconstruct the radial velocity curve of the system from this photometric modulation and thus, orbital parameters such as the mass ratio and the semi-major axis can be estimated from photometry without the necessity of spectroscopic follow-up. In this poster, we briefly introduce the analysis of this kind of binary systems and in particular, the eclipsing cases.



Comparison of the beaming, ellipsoidal and reflection effects for a F0-K0 binary star with different orbital periods. Figure from Zucker et al. (2009).

Beaming effect on binary stars

According to Zucker et al. (2007), in a star with a radial velocity v_R (velocity in the direction of the line of sight) the flux variation due to the relativistic effects is given by:

$$F = F_0\left(1+(3-\alpha)\frac{v_R}{c}\right)$$

where F_0 is the emitted stellar flux and α is the average spectral index at the bandpass of observation. Thus, the observed flux of a star increases when it is moving towards the observer and decreases when moving in the opposite direction. This modulation, in phase with the orbital motion, is proportional to the velocity of the star.

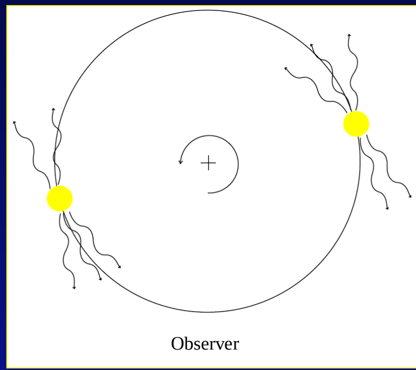


Figure illustrating the variation of the flux of one of the components of a binary system due to the beaming effect.

Ellipsoidal and reflection effects on binaries produce comparable modulations on the flux, however, they are much more dependent on the period of the binary, becoming the beaming effect dominant for periods over ~10 days.

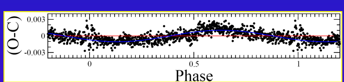
The potential of beaming eclipsing binaries

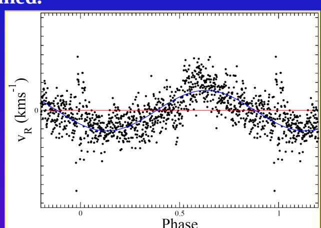
The beaming effect has been recently observed in eclipsing binaries observed by Kepler (van Kerkwijk et al., 2010) and in exoplanets observed by COROT (Mazeh & Faigler, 2010). In the case of eclipsing binaries, the detection of this effect is especially interesting because it can provide information about the mass ratio and the semi-major axis of the system, and therefore it complements the sample of parameters known from the light curves to derive the masses and radii of the components.

Figures to the right of these panel show two examples of beaming eclipsing binaries detected by COROT with preliminary fits to the eclipsing light curves (including ellipsoidal and reflection effects). These fits provide the first set of parameters to derive the fundamental properties:

From light curves: P, i, $T_{eff,2}/T_{eff,1}$, r_1, r_2

The modulation observed in the computed residuals is mainly due to the beaming effect, which, according to the equation above, is proportional to the radial velocity of the brightest component through the spectral index α, so the primary semi-major axis and the mass function of the system can be determined.



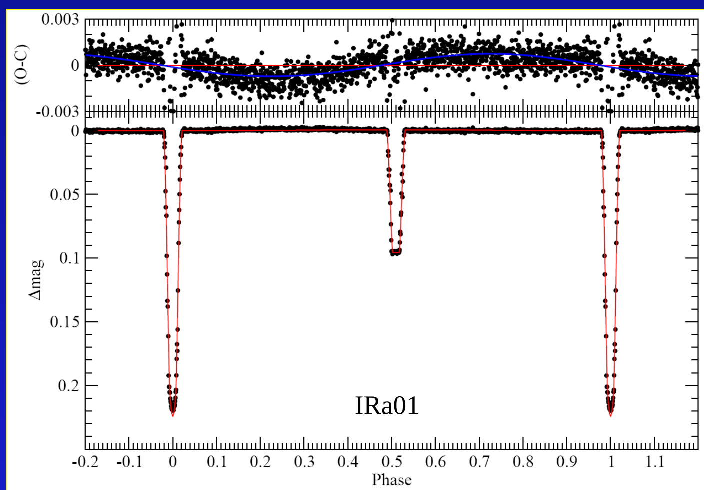


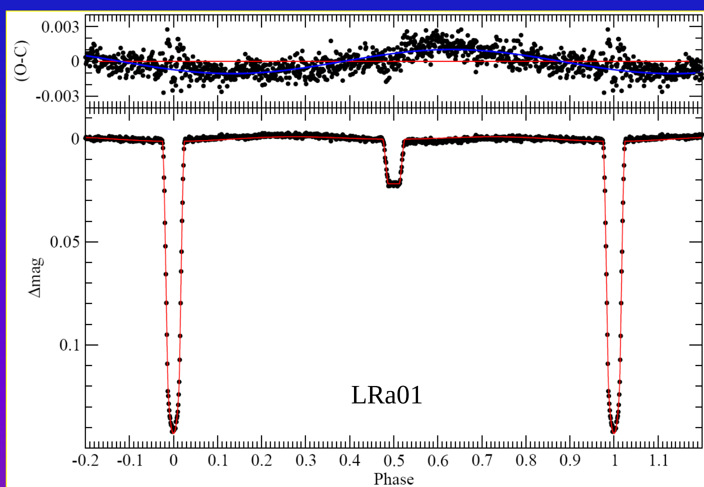
From O-C: K_1, $a_1\sin i$, $f(m)$

Photometric observations in different band filters could provide sufficient constraints to disentangle the primary and secondary beaming effects. This allows to estimate the radial velocity curves of both stars, thus the radial velocity set of parameters.

From multi-band O-C: K_1, K_2, $a\sin i$, M_2/M_1

Therefore the full set of parameters to derive the absolute masses and radii of the components can be determined without spectroscopic follow-up as needed in the case of usual eclipsing binaries.





Example of two eclipsing beaming binaries in the COROT IRa01 (top) and LRa01 (bottom) fields, with a preliminary fit to their eclipsing light curves. The residuals (top panels on both figures) show the beaming effect as a modulation with the same period as the orbit. The amplitude of the beaming effect for these systems is ~0.74 mmag for IRa01 and ~1.0 mmag for LRa01.

Bibliography

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