TIMING VARIATIONS ON BINARIES WITH CoRoT

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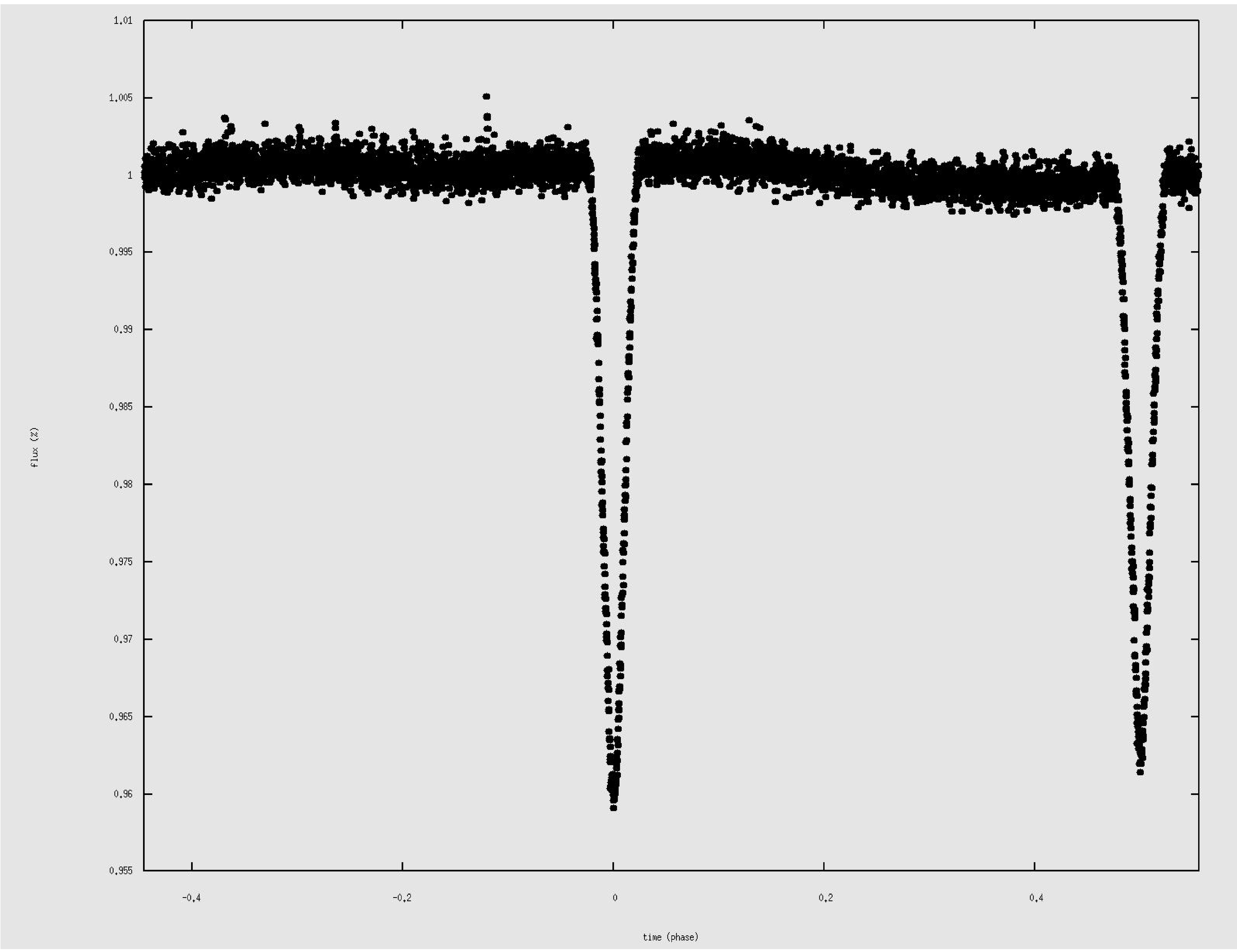
Context: CoRoT's exoplanet channel provides continuous light curves for up to 12000 target stars during 150 days. Those light curves are analyzed in the search for planetary transits, but many of eclipsing binary stars (EBs) are also found. In some cases, EBs show changes in the period of their eclipses (timing variations: TVs).

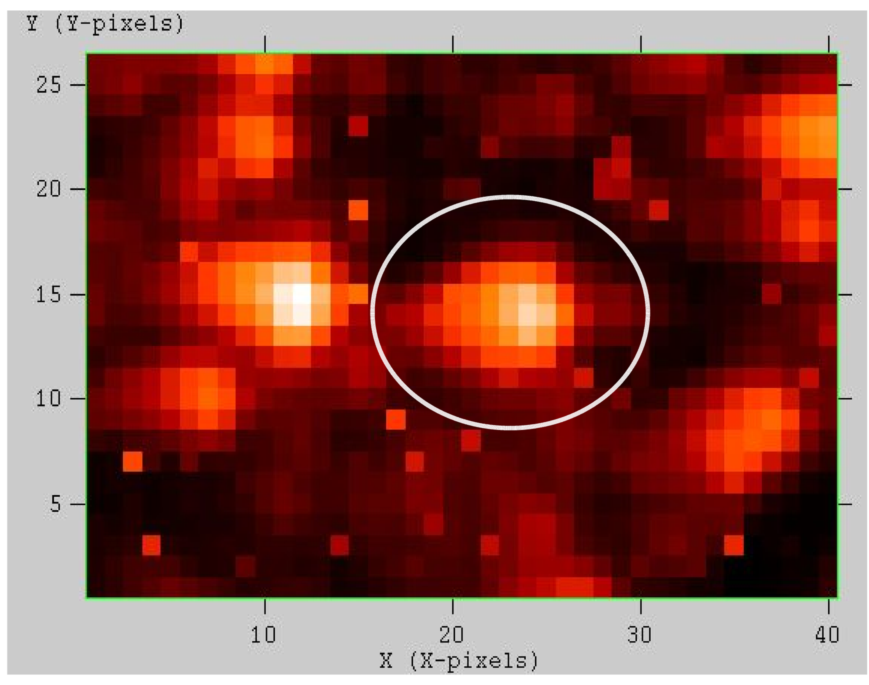
Aims: TVs of eclipses and transits are a useful tool to provide an insight into the physical structure of the system. In this work, we study the capability of CoRoT to measure TVs of EBs and we explore its limits.

Methods: We analyze the eclipses of an EB star to obtain the precise time of the arrival of the signal. We analyze the observed minus calculated (O-C) times of the eclipses in the search for TVs and we characterize them.

Results: We present a study of the object CoRoT-ID 101290947: a m_V=14.7 eclipsing binary of the LRc01 field with a period of 2.04880+/-0.00001 days and eclipse depths of 5%; which shows TVs compatible with the presence of a third body of minimal mass 2.6 solar masses in an orbit with a period of 110 days.



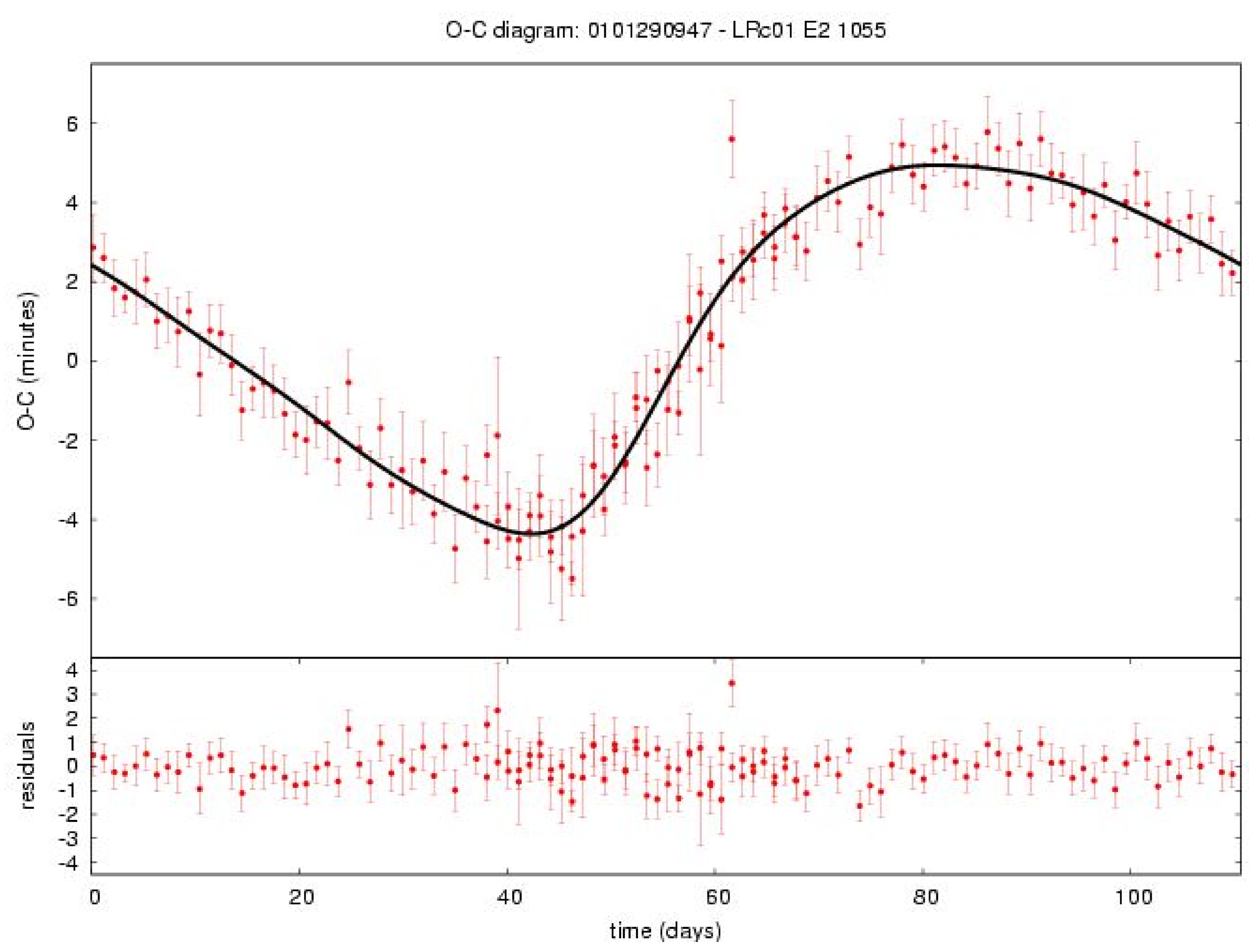
0101290947 is a m_V=14.7 (m_J=12.2) eclipsing binary in the LRc01 CoRoT field with a period of 2.04880 days. The depth of the primary eclipse is 4.1% in white light. However, in the mask of the target we find several faint (m_J>16) contaminants. After subtraction of their contribution, the measured depths of the eclipses are 4.8% in red, 2.0% in green and 1.4% in blue for the primary (4.4%; 1.9%; 1.2% for the secondary), which is compatible with the presence of yet another unresolved blue contaminant.



0	0	1.67	3.99	7.76	11.86	13.2	10.79	4.47	1.35
1.5	4.23	11.36	25.16	49.02	72.94	76.84	51.39	13.97	4.7
8.64	19.46	***57.21***	69.4	126.03	226.86	328.26	196.28	41.76	11.25
16.39	30.2	50.22	77.96	129.74	243.98	***436.01***	316.97	91.07	19.42
12.19	21	36.36	56.56	86.23	***153.36***	274.08	171.46	37.88	8.58
5.32	9.32	16.21	25.88	48.14	51.32	62	43.2	12.82	3.8
0	3	5.17	8.12	14.45	22.52	15.54	14.18	10.62	***22.33***
0	0	2.3	3.57	5.35	6.18	6.23	7.89	9.17	4.66

CoRoT photometry of bright targets is divided in three channels: red, green and blue. In the mask of our target there are several stars: the brighter one is responsible of 93% of the flux.

LEFT: folded light curve of the binary. **CENTER:** image of the CoRoT PSF of the target star. **RIGHT:** flux received by each pixel in the mask of the target. The colors correspond to the three photometric channels. In bold we have marked the position of the binary and the three main contaminants.

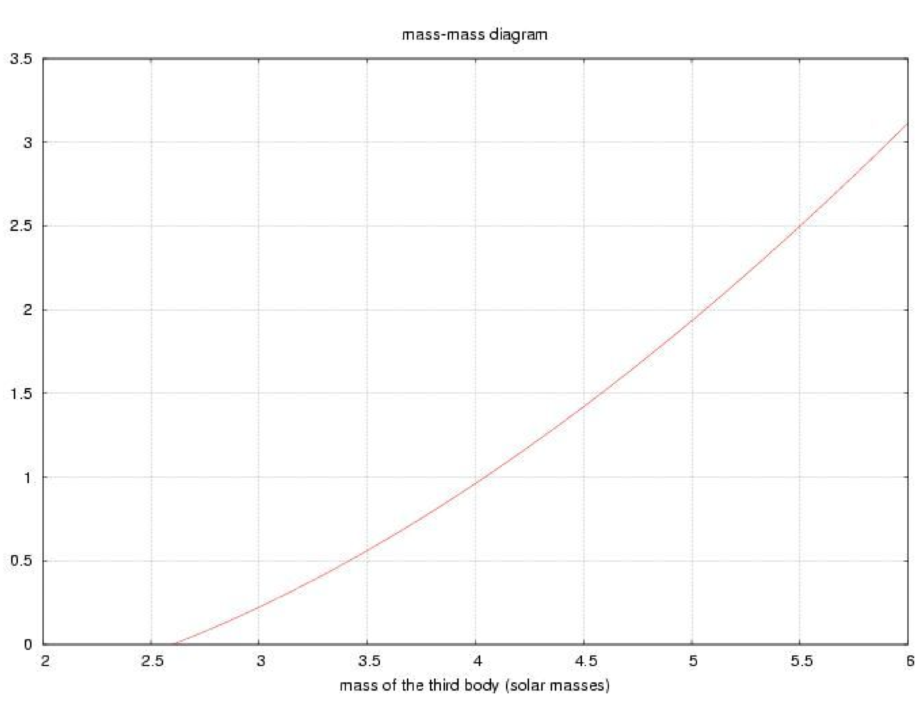


In many cases EBs show changes in the period of their eclipses and sometimes these changes are caused by the presence of a third body in the system. As the EB orbits the center of mass of the three body system, its distance to the observer changes and one can measure the timing variations of the eclipses. This is the so-called light-time effect “LITE” (Irwin 1952, Irwin 1959), which was used by Römer (1676) to measure the value of the speed of light observing the eclipses of the Galilean moons of Jupiter.

There are several possible explanations for TVs in eclipsing systems: we have already mentioned LITE, but pulsations of the components; precession of the orbits (apsidal motion); magnetic activity (works by Hall 1989; Applegate 1992; Lanza et al. 1998); mass loss or transfer between the components are other possible sources of TVs.

In our target we find TVs compatible with the presence of a third body in the system; the period of the TVs is 110 days and the amplitude is 5 minutes, which corresponds to a semi-major axis of 0.62 au and a minimal mass of 2.6 solar masses. The eccentricity is 0.5.

LEFT: O-C diagram of the binary folded to the period of 110 days with the orbital fit of the LITE and the residuals.



Mass-mass diagram of 101290947 with the ratio between the mass of the binary and the mass of the third body.

The mass-mass diagram on the left gives an idea of the potential limits of missions like CoRoT and Kepler to detect circumbinary objects by the method of TVs. The minimum detectable mass of a circumbinary object of mass m_3 depends on the amplitude of the perturbation A, the mass of the binary m_B and the orbital period P_3 (and the inclination). This is the well known mass function (see for example Borkovits & Hegedüs 1996):

$$f(m_3) = \frac{(m_3 \sin i)^3}{(m_B + m_3)^2} = \frac{4\pi^2}{G} \frac{(A\,c)^3}{P_3^2}$$

For **CoRoT:** if the amplitude of the perturbation is **10s** and its period is **70 days**, the minimum mass of the third body is 0.23 Jupiter masses (if m_B=0); however, if binary's mass is 1 solar mass then $\mathbf{m_3>60\ M_J}$.

For **Kepler:** if the amplitude of the perturbation is **10s** and its period is **150 days**, the minimum mass of the third body is 0.1 Jupiter masses (if m_B=0); however, if binary's mass is 1 solar mass then $\mathbf{m_3>47\ M_J}$.

Both missions can only detect circumbinary objects of planetary mass around binaries with masses smaller than 0.1 solar masses (stars later than M8).

CONCLUSIONS: Often eclipsing binaries show TVs which can be characterized with long term ground observations. But CoRoT, and future missions like Kepler, can explore regions of the parameter space of TV discoveries which are hardly accessible from ground (low amplitude, small period). LITE is favored by the presence of massive objects; with the current design of these missions it is difficult to arrive to the region of the parameter space where circumbinary planets can be found. But we have shown that it is possible to find TVs of stellar mass bodies and characterize them.

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