Contrib. Astron. Obs. Skalnaté Pleso **49**, 390 – 392, (2019)

Eclipse timing variation of candidate long-period triple systems

A. Kurtenkov[1] and V.A. Popov[2,3]

[1] *Institute of Astronomy and NAO, Bulgarian Academy of Sciences, 72 Tsarigradsko Shose Blvd., 1784 Sofia, Bulgaria*
(E-mail: al.kurtenkov@gmail.com)

[2] *Department of Physics, Shumen University, 115 Universitetska Str., 9712 Shumen, Bulgaria*

[3] *IRIDA Observatory, Rozhen NAO, Bulgaria*

Received: November 1, 2018; Accepted: February 11, 2019

Abstract. The continuous photometric monitoring within the original Kepler mission allowed for the identification of a number of eclipsing binaries that display considerable eclipse timing variations (ETV). In their work on candidate triple systems in the Kepler field Conroy et al. (2014) drew a selection of 31 systems with ETV curves, whose shapes within the 1400-day monitoring period are seemingly parabolic. There are several possible explanations, including mass transfer, the Applegate effect, and a third component with a period considerably longer than 1400 days. We tried to determine the cause of the parabolic ETV curves by timing minima of 8 systems from this selection in 2017 and 2018, thus checking whether the ETV curves preserve their parabolic shapes or show signs of periodicity a further 1500 days after the original Kepler data. Results from the 30 cm IRIDA-South and the 50/70 cm Schmidt telescopes at the Rozhen observatory (Bulgaria) are presented.

Key words: eclipsing binaries – celestial mechanics

1. Introduction

Eclipse timing variation (ETV) of eclipsing binaries can be caused by a number of factors. Some of these physically change the orbital period of the binary (e.g. mass transfer or the Applegate effect), while others only shift the minima times by influencing the geometry of the system (e.g. a light travel time effect caused by a tertiary component or apsidal motion).

With its high photometric precision and a long time base, the Kepler mission (Borucki et al., 2010) gives an unprecedented opportunity to study ETV of eclipsing binaries. Conroy et al. (2014) investigated ETVs of over 1000 binaries while searching for third-body signals. Within this work they also selected 31 systems with seemingly parabolic ETV curves. The authors suggest mass transfer as a probable factor for these systems, because a constant change of the period over time would result in a parabolic ETV curve. However, long-period

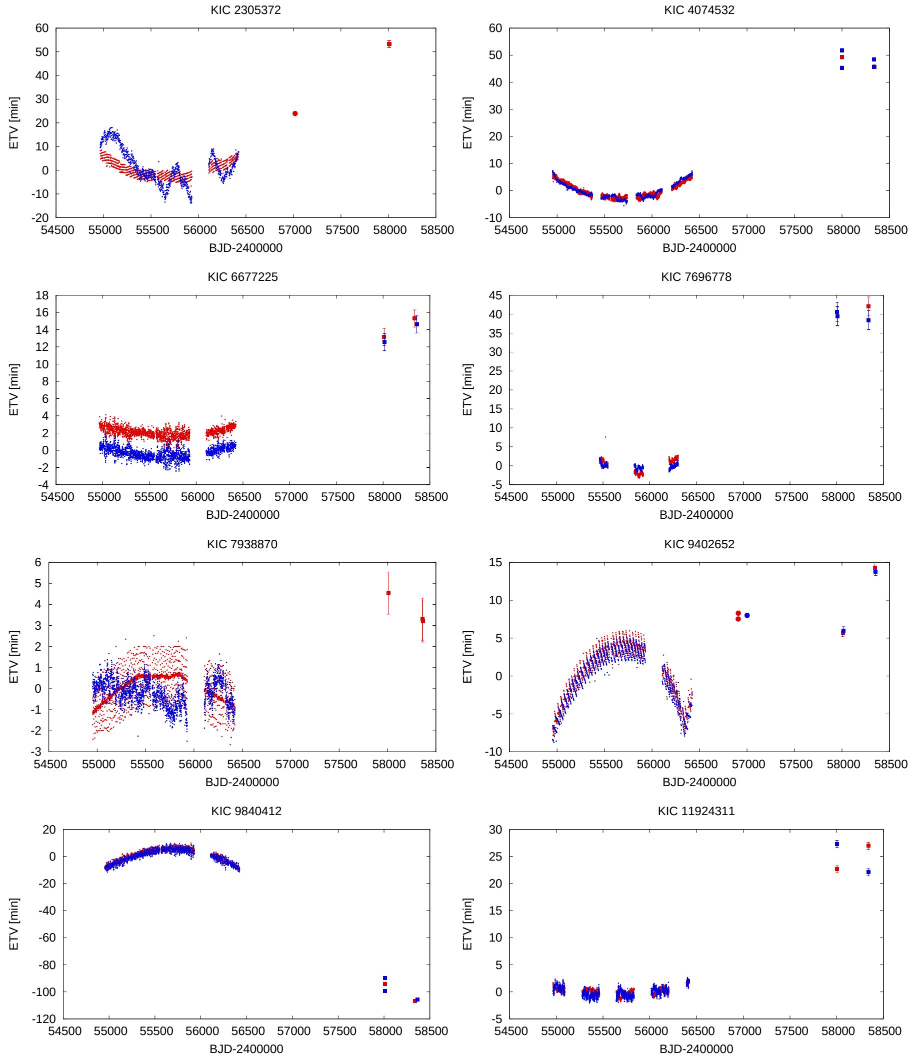

Figure 1. The obtained ETV values *(large squares)* plotted alongside the Kepler ETV data *(small circles)*. ETV values calculated from minima times obtained by Zasche et al. (2015) are included for KIC 2305372 and KIC 9402652 *(large circles)*. Primary and secondary minima are indicated in red and blue, respectively.

tertiary components would cause periodic ETV curves, parts of which may appear to have a parabolic shape. These tertiary components would have to orbit the binaries at periods much larger than the 1400-day base of the original Kepler mission. We selected 8 of these 31 systems and timed their minima in 2017 and 2018 in order to determine the actual reason for the ETV.

2. Observations and results

Time series observations of the selected eclipsing binaries were obtained in the Johnson V-band, covering a phase interval of $\sim$0.1 near each minimum. We used the 30 cm IRIDA-South telescope at Rozhen NAO in Bulgaria (f/5 with a focal reducer), equipped with an ATIK 4000M CCD camera (2048$\times$2048 pixels, yielding a $35.5' \times 35.5'$ FOV) and the 50/70 cm Schmidt telescope at Rozhen NAO, equipped with a FLI PL 16803 CCD camera (4096$\times$4096 px, yielding a $74' \times 74'$ FOV). Time resolution was a priority, therefore lower exposure times were preferable. The lightcurves around the minima were then fitted with 2^{nd} and 4^{th} degree polynomials to obtain the minima times. The calculated ETV values were plotted on the ETV curves (Fig.1) after applying the barycentric JD correction. The obtained minima times are to be presented in a separate paper.

In at least 6 of the 8 systems the ETV values 6 years after the Kepler mission do not lie on the extrapolated parabola. Instead, the sign of the second derivative of the ETV curve changes over the whole baseline, which indicates periodicity in the ETV signal. The test shows that in most cases the apparently parabolic ETV curve actually is a fragment of a periodic curve, probably due to the light-travel-time effect, caused by a long-period third component. Systems KIC 2305372 and KIC 9402652 were previously investigated by Zasche et al. (2015) and our results are in accordance with theirs.

Acknowledgements. This work was supported by grant DFNP-17-13 of the Young Scientists Support Program of the Bulgarian Academy of Sciences. Partial support under Bulgarian NSF contract DN 18/13 is acknowledged. Based on data obtained at the IRIDA Observatory, Bulgaria.

References

Borucki, W. J., Koch, D., Basri, G., et al., Kepler Planet-Detection Mission: Introduction and First Results. 2010, *Science*, **327**, 977, DOI: 10.1126/science.1185402

Conroy, K. E., Prša, A., Stassun, K. G., et al., Kepler Eclipsing Binary Stars. IV. Precise Eclipse Times for Close Binaries and Identification of Candidate Three-body Systems. 2014, *Astron. J.*, **147**, 45, DOI: 10.1088/0004-6256/147/2/45

Zasche, P., Wolf, M., Kučáková, H., et al., Ten Kepler Eclipsing Binaries Containing the Third Components. 2015, *Astron. J.*, **149**, 197, DOI: 10.1088/0004-6256/149/6/197