# Substellar and stellar companions in eclipsing binaries

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**Abstract.** We present an extensive analysis of O-C diagrams constructed by previously published times of minima and updated by photometric observations carried out at Mythodea Observatory (Astrophysics Laboratory, Department of Physics, University of Patras). A two-companion model is attributed to the over-contact (W UMa type) binary system TZ Boo according to a Light-Time Effect (LITE), while in the case of the post-common envelope binary NSVS 14256825 a Jovian type circumbinary companion is the most plausible explanation of the apparent period variation.

**Key words:** binaries: eclipsing – binaries (including multiple): close – planetary systems

## 1. Introduction

The apparent cyclical period variation of an eclipsing binary can provide an indirect evidence of a circumbinary companion as a result of gravitational attraction (Light-Time Effect, LITE; Irwin, 1952) or might instead be due to stellar magnetic activity (Applegate, 1992).

## 2. O-C diagram analysis

We implement a series of optimization techniques which consist of a first solution determination using Nelder-Mead Downhill Simplex and Levenberg-Marquardt algorithms, while the globality of solution (lowest $\chi^2$) is sought by a Heuristic Scanning scheme which implements the two aforementioned methods with a parameter kicking or by a Genetic Algorithm (PIKAIA; Charbonneau, 1995).

As a last step of scanning the topology of $\chi^2$ parameter space and in order to acquire more realistic parameter value errors we implement a Metropolis-Hastings MCMC algorithm.

**Table 1.** Orbital parameters of tertiary companions for TZ Boo and NSVS 14256825 according to M-H MCMC.

| Parameter | TZ Boo | NSVS 14256825 |
|---|---|---|
| $e_3$ | $0.81 \pm 0.02$ | $0.03 \pm 0.02$ |
| $A$ (days) | $0.025 \pm 0.001$ | $0.0005 \pm 0.0010$ |
| $\omega_3$ (rad) | $5.92 \pm 0.01$ | $2.92 \pm 0.01$ |
| $qmt = {}^{dP}/_{2dE}$ (days cycle$^{-1}$) | $-0.12 \pm 0.01 \times 10^{-10}$ | ... |
| $P_3$ (years) | $35.81 \pm 0.11$ | $10.38 \pm 0.12$ |
| $T_3$ (HJD) | $2448510.51 \pm 0.01$ | $2456358.95 \pm 0.01$ |
| $P_{bin}$ (days) | $0.29715974 \pm 2.6 \times 10^{-8}$ | $0.11037416 \pm 2.1 \times 10^{-8}$ |
| $T_0$ (HJD) | $2452500.16 \pm 0.01$ | $245274.21 \pm 0.01$ |
| $M_3$ (coplanar) | $0.84\,M_\odot$ | $16\,M_{Jup}$ |
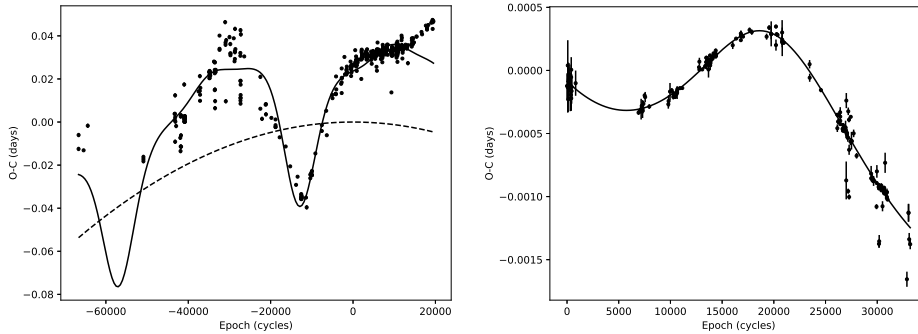


**Figure 1.** O-C diagrams with best fitting curve for tertiary components of TZ Boo and NSVS 14256825.

In case of TZ Boo the O-C residuals reveal a secondary companion, however, magnetic activity cannot be ruled out as a possible contribution since the energy threshold of Applegate mechanism is relatively small $\Delta E/E_{sec} = 0.12$ (Applegate, 1992) and $\Delta E/E_{sec} = 0.1$ (Tian et al., 2009).

# References

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