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The first orbital period investigation of low mass ratio systems from Catalina Sky Survey

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Abstract. We present the first results of our project to analyze the orbital period variations of 5 newly discovered low-mass ratio (LMR) eclipsing binaries from the Catalina survey. We collected data from CRTS, LINEAR, SUPER-WASP, ASSASN, ZTF, and ATLAS, covering a time of 10 − 15 years, and determined the mid-eclipse times by fitting our CSS light curve model and varying the conjunction times. Analyzing the ETVs the highest rate of period variation was found in the order of 10^{-6} days/year and only in one case, we derive an additional light-time effect and a period of a possible third body of 12.8 yr.

Key words: contact binaries- eclipsing binaries - period variation

1. Introduction

In the era of large surveys contact binaries remain one of the most interesting research fields of astrophysics as they provide unique insights into the study of binary evolution, including mass and energy transfer in the common envelope. The low mass ratio (LMR) contact binaries present particular interest as they can lead to mergers and appear as peculiar stars such as blue stragglers and fast-rotating FK Com stars (Rasio, 1995; Wadhwa et al., 2021). A well-known technique for investigating period variations in eclipsing binaries is the analysis of eclipse time variations (ETVs) via O-C. Here we present the first results of our project to analyze the orbital period variations of the newly discovered LMRs (Christopoulou et al., 2022) from the Catalina Sky Survey (CSS; Drake et al., 2014): Obj 1($q = 0.080 \pm 0.015$), Obj 2 ($q = 0.110 \pm 0020$), Obj 3 ($q = 0.110 \pm 0015$), Obj 4 ($q = 0.120 \pm 0025$), and Obj 5 ($q = 0.220 \pm 0015$).

1.1. O-C diagram analysis

We constructed O-C diagrams with archival data from ATLAS, CRTS, ASSAS-SN, LINEAR, NSVS, and ZTF covering a period of 15-25 years. We used the ephemeris (HJD_0, P_{bin}) and the CSS light curve model from (Christopoulou et al., 2022) to determine the mid-eclipse times by fitting the phased light curve from every survey. We used PHOEBE-0.31 (Prsa & Zwitter, 2005) to fit the light curve model using the parameters of Christopoulou et al. (2022). Limb-darkening coefficients were interpolated from van Hamme (1993) tables for the

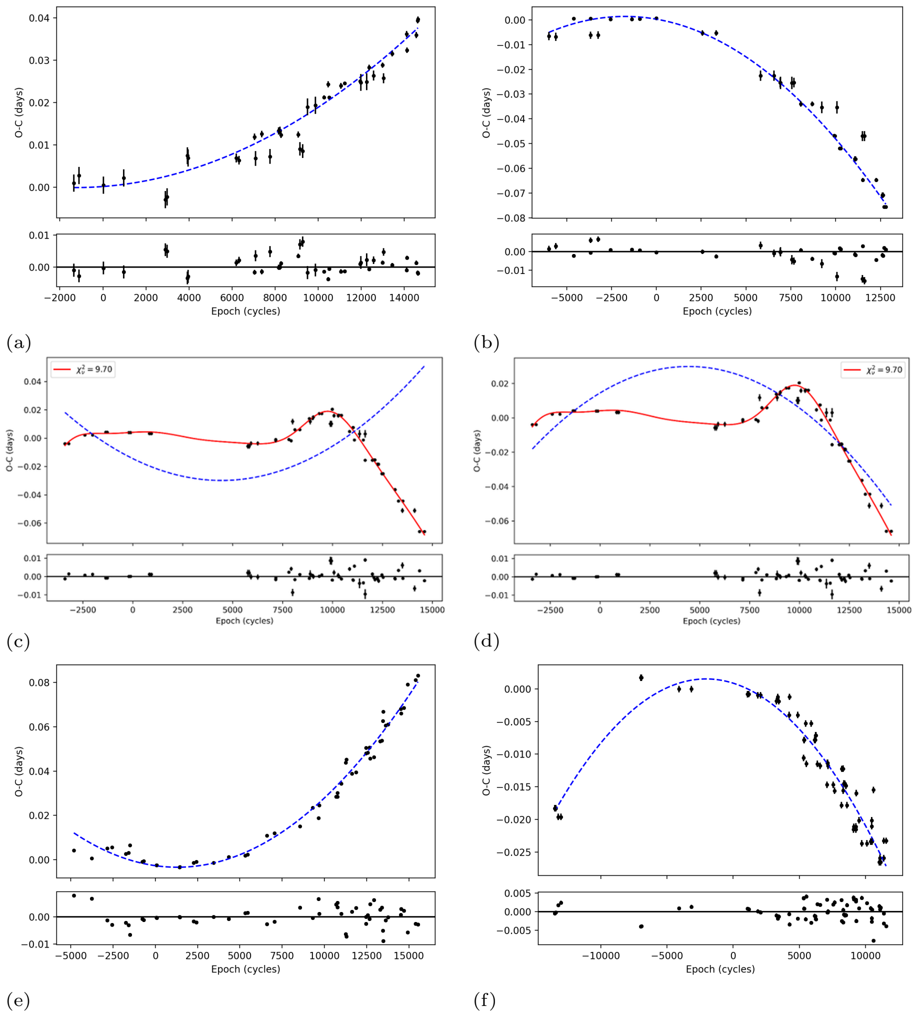

Figure 1. The O-C versus epoch of the five LMRs: (a) Obj 1, (b) Obj 2, (c) and (d) Obj 3, (e) Obj 4 and (f) Obj 5. Upper panel: the dashed line represents the quadratic curve and the solid line the cyclic curve. Lower panel: the residuals.

given temperatures while gravity-darkening coefficients g and surface albedos A were accordingly assumed for convective ($g = 0.32$, $A = 0.5$) envelopes as all objects have $T < 7200$ K. The (O-C) curves are plotted in Fig.1 together with the residuals in the lower panel. The following equation is applied to fit the O-C curves

$$O - C = \Delta HJD_0 + \Delta P + (dP/dE) \times E^2 + \tau. \tag{1}$$

where ΔHJD_0 is the modification value of the initial epoch, ΔP the correction of the orbital period, dP/dE the rate of orbital period variation in the long term, and τ is related to more complex periodic variations such as the third body light time orbital effect (LTTE) or periodic magnetic activity.

2. Preliminary results and conclusions

Our preliminary analysis of five new LMRs shows that the general trend of objects 1 and 4 O-C curves is an upward parabola, which means that the period is slowly increasing. For objects 2 and 5, it is downward, which means that the period is decreasing. An alternative description is that the parabolic line may be a segment of a cyclic variation. The O-C curve of object 3 is a more complex one and reveals the possible existence of a third body or the action of a magnetically active primary (Applegate mechanism), therefore, future monitoring of the system is required. The results of dP/dt and dM/dt rates are in agreement with other investigations of low mass ratio systems (Liu et al., 2023).

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