ΠΑΝΕΠΙΣΤΗΜΙΟ ΠΑΤΡΩΝ
UNIVERSITY OF PATRAS

G P09

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

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• 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 the investigation of period variations in eclipsing binaries is the analysis of eclipse time variations (ETVs) via O−C.

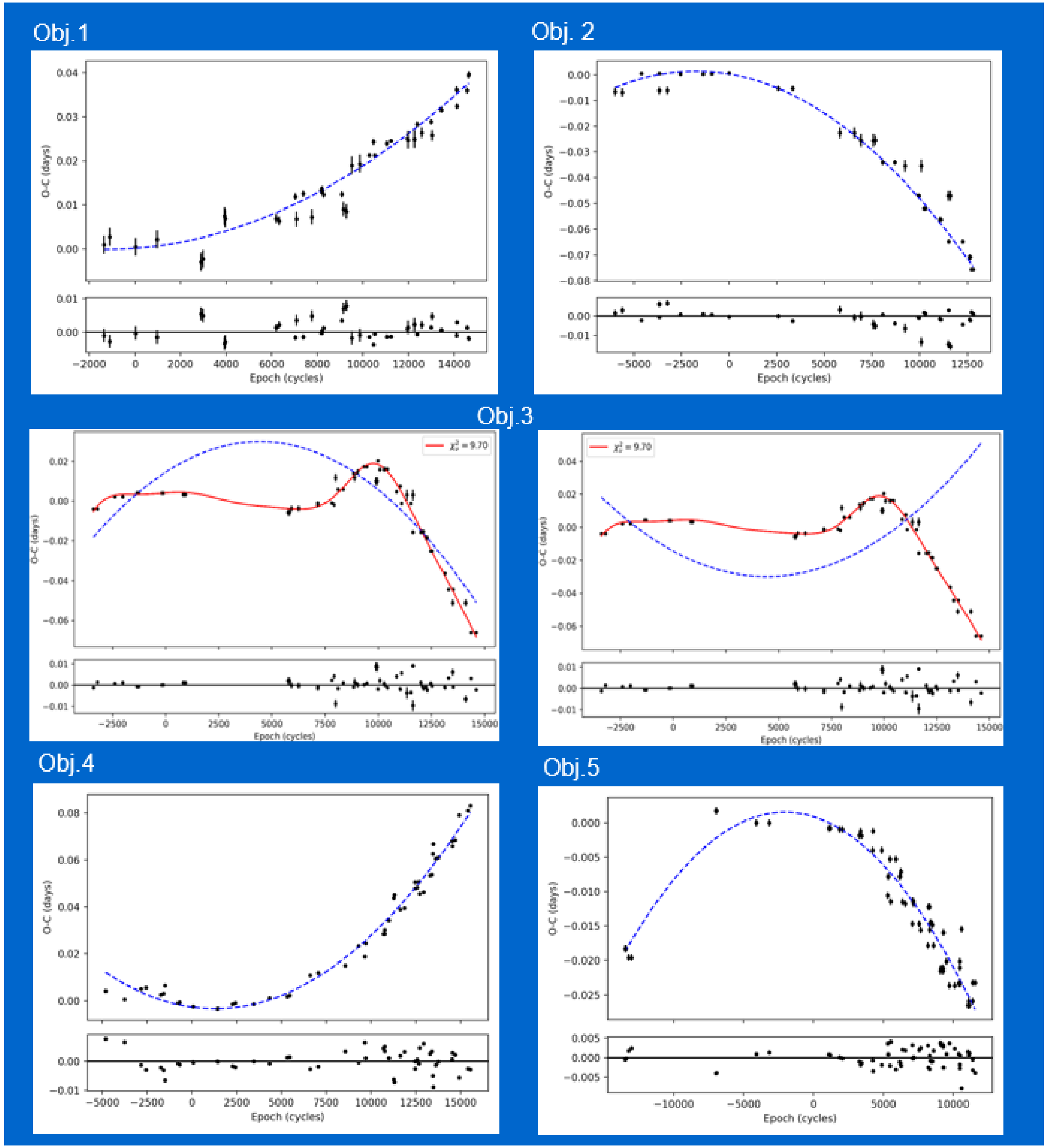
• Here we present the first results of our project to analyze the orbital period variations of the first 5 out of 30 newly discovered LMRs from the Catalina Sky Survey (Christopoulou et al. 2022)

Obj	ID	HJD_0 (245 0000+)	Period (d)	V CSS (max) (mag)	ToM	Years
1	CSS J075848.2 + 125656	4922.69449	0.34998	14.08	40	2005-2023
2	CSS J093010.1 −021624	5240.80316	0.3214746	15.56	42	2005-2023
3	CSS J110526.4 + 285617	4977.70007	0.3491059	14.93	60	2006-2023
4	CSS J155637.0 + 060949	4477.0245	0.3605211	15.81	51	2003-2023
5	CSS J233821.8 + 200518	6167.79999	0.3545902	13.23	67	1999-2023

• We constructed O-C diagrams with archival data from ATLAS, CRTS, ASSAS-SN, LINEAR, NSVS and ZTF covering a time span of 15-25 yrs.

• We used PHOEBE (Prša and Zwitter, 2005) to fit the light curve of each survey with the model and linear ephemeris of Christopoulou et al. 2022 using the parameters shown in Table 2.

ID	q	$i(deg)$	$T_1(K)$	$T_2(K)$	$\alpha(R_\odot)$	Ω_{12}
CSS J075848.2+125656	0.080(15)	81.0(2.6)	6111(25)	5951(41)	2.3481	1.870(3)
CSS J093010.1−021624	0.110(20)	78.0(2.3)	5720(223)	5894(232)	2.1559	1.921(3)
CSS J110526.4+285617	0.110(15)	85.8(2.4)	5273(209)	5435(216)	2.2757	1.923(3)
CSS J155637.0+060949	0.120(25)	75.9(1.6)	6309(167)	6516(178)	2.3913	1.944(9)
CSS J233821.8+200518	0.220(15)	86.3(2.6)	5987(175)	6006(176)	2.4482	2.236(9)



The following equation is applied to fit the O-C curves

$$O{-}C = \Delta(T_o) + \Delta P \ x\ E + 0.5\ (dP/dE)\ x\ E_2\ + \tau$$

Obj	dP/dt ($\times 10^{-7}\frac{\text{days}}{\text{year}}$)	dM/dt ($\times 10^{-7}\frac{M_\odot}{\text{year}}$)	$P/\dot{P}$ (kyr)	t_{th} ($\times 10^7$) yr	t ($\times 10^7$)yr
1	3.10	3.02	1130	2.49	0.44
2	–8.14	-5.96	395	2.00	0.20
3	±16.38	±2.29	213	1.38, 2.74	0.55, 0.06
4	8.37	5.91	431	0.37	0.02
5	-3.20	-8.05	440	1.34	0.16

Third body investigation.

From the cyclic oscillation of the object's 3 O-C we derived the parameters of the assumed third body (Irwin 1952) as: P_3=12.85 yrs, A=0.025 days, ω_3=0.75 rad, e_3=0.56 and mass function $f(M_3)$=0.70$M_\odot$.

Applegate investigation

We calculated the required energy to drive the Applegate mechanism ΔE/E. As shown in Table 3, the $\Delta E/E$ is calculated to be 0.229 using the thin-shell model, depending on solar-like magnetic cycles in primary star. Thus, the LTTE can be attributed to the magnetic cycle of the primary.

Obj.3	Two-zone model Voelschow et al. (2016)	Constant density model Voelschow et al. (2016)	Thin-shell model Tian et al. (2009)
Active M_1	ΔE/E=4.080	ΔE/E=115.7	ΔE/E=0.229
Active M_2	ΔE/E=78.47	ΔE/E=108.68	ΔE/E=1.791

Conclusions

- The results of the dP/dt and dM/dt rate are in agreement with other investigations of LMRs (Liu et al. 2024).
- We compare the time scale of $P/\dot{P}$ (kyrs) as shown on Table 3 and found that object 3 has the **most rapid decreasing period rate.**
- To investigate whether the change in period is only due to mass transfer, we compare the timescale of the materials transfer rate $t = M/(dM/dt)$ with its thermal time (Kelvin-Helmholtz time) t_{th}. For all the objects, $t_{th} > t$ so the primary or secondary star can maintain thermal equilibrium or stable mass transfer, without ruling out the contribution of angular momentum loss (AML).
- Our preliminary analysis of the five new LMRs shows that the O-C curves of obj 1, 4 is an upward parabola which means that the period is slowly increasing and of obj 2, 5 is a 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 obj 3 is more complex and indicates the possible existence of a third body or the action of a magnetically active primary (Applegate mechanism).

- **Therefore, future monitoring of all the systems is required.**

Thank you for your attention!