Young Close Eclipsing Binaries in the Orion Star Forming Complex

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Abstract

Based on the analysis of TESS light curves, we detected and characterized 17 Young Close Eclipsing Binaries (YCEB) in the Orion Star Forming Complex. The light curves (LC) with their preliminary rotational analysis were obtained ~~from~~ using the TESSExtractor tool. The binary models were computed using STARRY (Luger et al 2019). In general, these systems have separations smaller than 0.1 AU, very small eccentricity, and orbital periods close to or equal to the rotational period of the primary. The orbital parameters obtained for our YCEB sample support the scenario in which tidal interaction circularized the orbits and synchronized the rotational and orbital periods of the systems in a few Myr. The binary Brun 691 is fascinating among the analyzed systems because it exhibits a detectable decrease in the transit depth in only ~two years. Our binary models indicate that a radius reduction of ~90% of the original companion's size could cause this decrease, suggesting an extreme photoevaporation scenario for the companion.

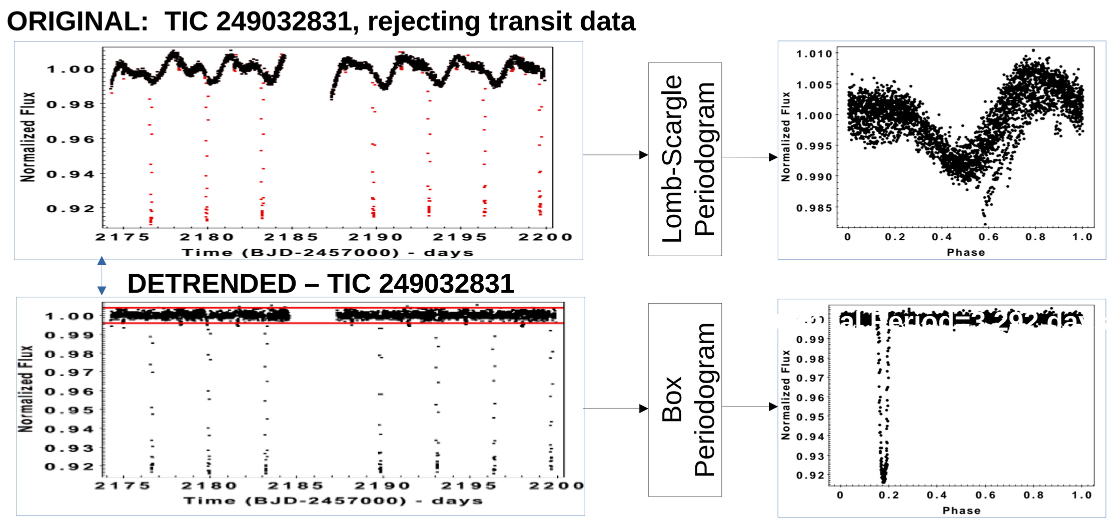
Methodology

Sample. Based on the analysis of GAIA-DR3 data, more than 6000 stars were included in several kinematic structures belonging to the OSFC (Kounkel et al., 2018; Sanchez S. et al., 2024). Also, 2500 T Tauri stars were spectroscopically confirmed based on the analysis of the Li I and Hα lines (Briceno et al., 2019; Hernandez et al., 2014, 2023). We visually inspected the TESS LCs obtained in cycles 1 (cadence of 30 minutes) and 3 (cadence of 10 minutes) in these samples, selecting 17 YCEBs with at least three primary transits in the TESS observational window (~27 days) corresponding to binary systems with orbital periods smaller than nine days.

Fig. 1

https://www.tessextractor.app/

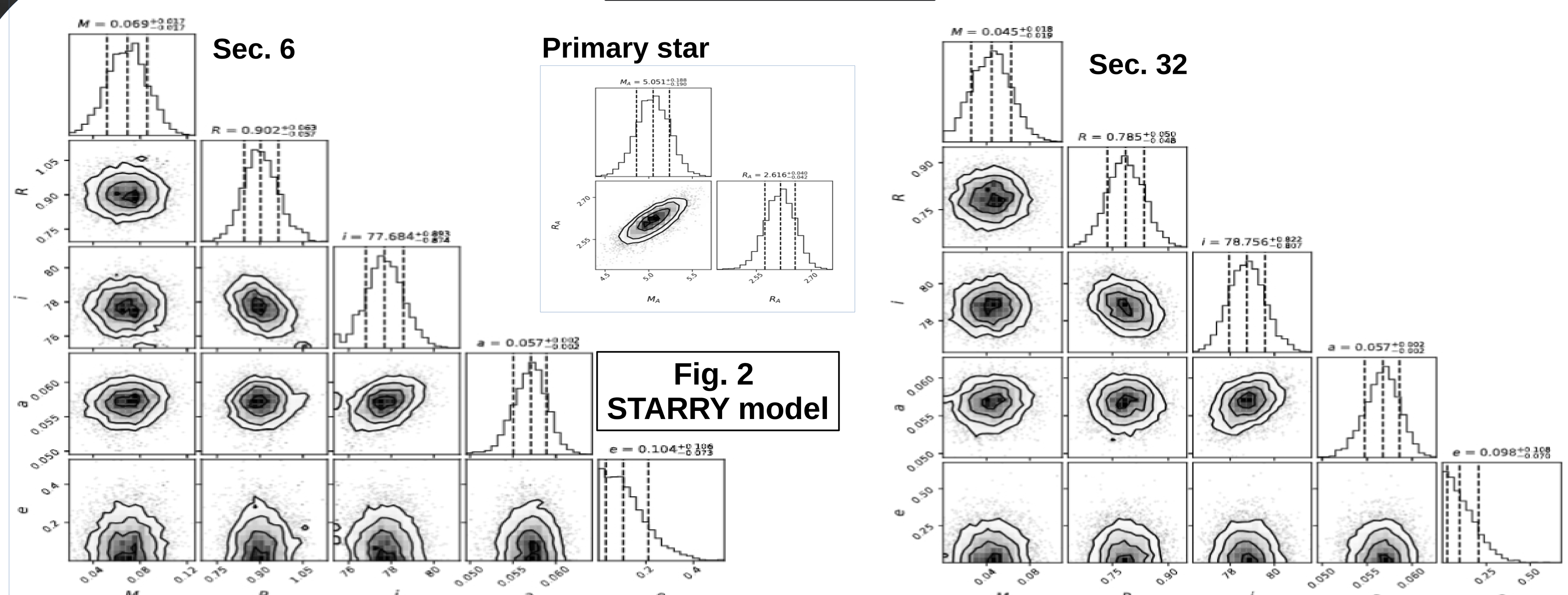
ORIGINAL: TIC 249032831, rejecting transit data



Initial analysis (Fig. 1). We obtained the LCs corrected by systematic effects from the web application tool TESSextractor (Serna et al., 2024). The LCs were detrended using the LightKurve tool, and the transit data points (TDP) were flagged. The rotational period (Prot) was obtained using the Lomb Scargle Periodogram on the LC without the TDP. The orbital period (Porb) was obtained using the box least squares periodogram on the detrended LCs. The initial size ratio of the components was estimated from the transit depth (R2/R1).

The Starry tool includes a Bayesian approximation that returns the best parameter solution for modelling LCs. It assumes prior distributions for the binary system properties (e.g., Porb, R2/R1, eccentricity, inclination). We also include stellar properties priors (Luminosity, Temperature, radius) estimated from the MassAge tool (Hernandez et al., 2023).

Results



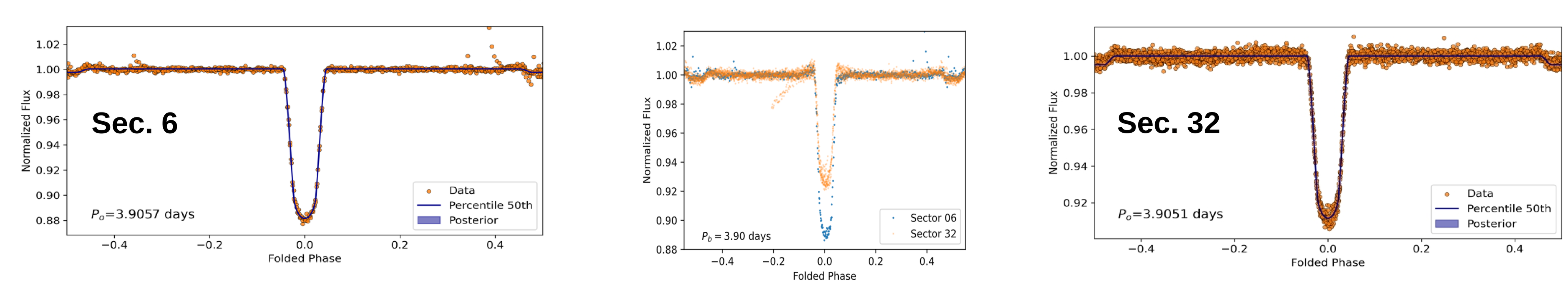
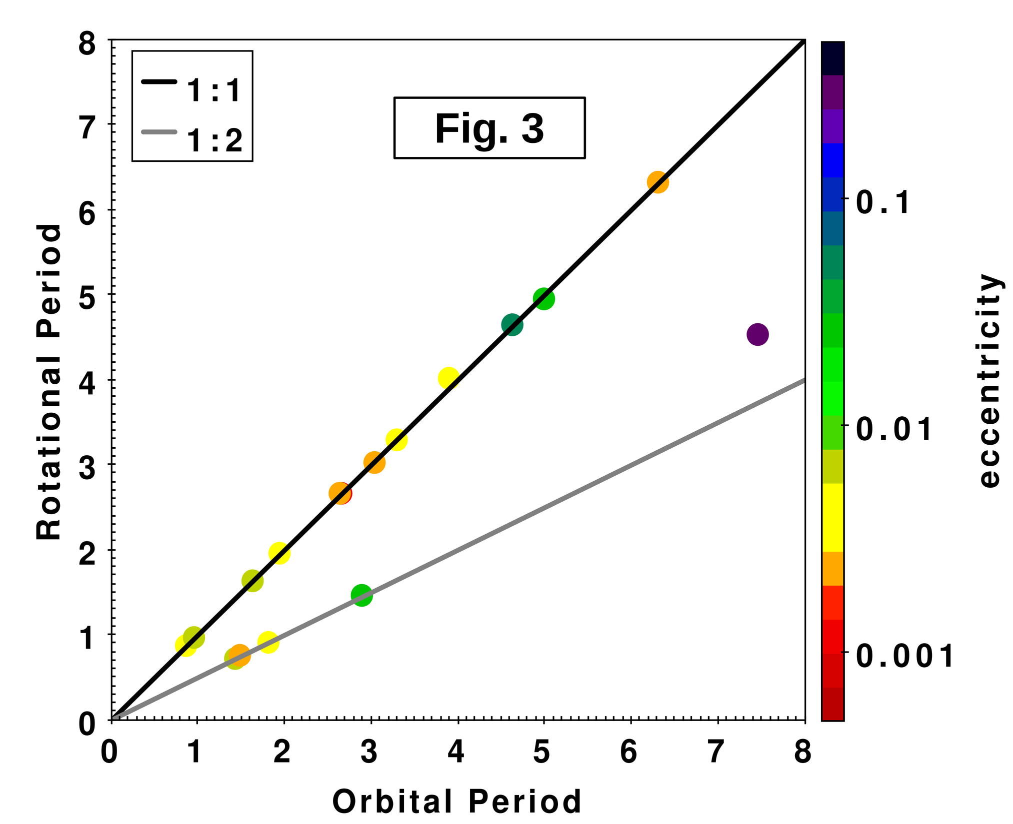


Fig. 2: The best model solution for TESS LCs of Brun 691 using STARRY. This binary system includes a T Taury Star and a Brown Dwarf (Morales et al., 2012). The TESS observations include sectors 6 (~ December 2018) and 32 (~December 2020). The models suggest a decrease in the size of the stellar companion from 0.9 Rsun in sector 6 to 0.79 Rsun in sector 32. We obtained the best binary model for the 17 YCEBs. Brun 691 is the only binary system with a detectable reduction in the transit depth.

Fig. 3: The relation between orbital and rotational periods for the YCEBs. The error bars are smaller than the symbol size. Except for TIC 276662451, which has the largest eccentricity in our sample (e=0.27), orbits of the YCEBs are synchronized with the rotation, with spin-orbit resonances of 1:1 or 1:2. This suggests that tidal interaction in a few Myrs circularized the orbits and synchronized the rotational and orbital periods of these systems.



YCEBs

Table 1. Sample of Young Close Eclipsing Binaries

NAME	TIC	Orbital Period (days)	Rotational Period (days)	e	i °	Spectral type	TESS Sectors
HD 36695	50897998	1.485	0.743	0.002	65	B1	6, 32
HD 36954	427378979	4.624	4.631	0.049	83	B4	6, 32
HD244407	138829403	2.902	1.451	0.023	83	A2	6, 32
HD287808	264483228	1.950	1.945	0.005	82	A3	6, 32
V536 Ori	264459857	6.317	6.310	0.002	87	A6	6, 32
05412424-0149348	11412481	1.438	0.719	0.007	84	F6	6
05154248-0137111	249032831	3.289	3.283	0.004	88	~G3	5, 32
Brun691	427393298	3.906	4.015	0.007	87	K1	6, 32
V1642Ori	264741359	3.038	3.02	0.002	86	K2	6, 32
05371161-0232087	276662451	7.46	4.53	0.265	87	K3	6, 32
V1174Ori	427353034	2.635	2.65	0.002	85	M0	6, 32
CVSO 416	249074181	1.630	1.637	0.006	84	M0	5, 32
CVSO1932	72829000	2.655	2.655	0.001	83	M1	6
05335754-0052455	427347964	4.99	4.95	0.028	83	M1	6, 32
V564 Ori	388918012	0.958	0.958	0.006	79	M3	6
05454167-0004024	72921630	1.817	0.910	0.005	82	M3	6
CVSO 1975	176775425	0.859	0.858	0.005	84	M4	6, 33

Concluding Remarks

- The LC analysis and modelling of YCEBs studied in this work support the scenario in which the orbital circularization and the synchronization between rotational and orbital motion in close binaries occurs during the pre-main sequence (PMS) phase (e.g., Melo et al. 2001; Zahn & Bouchet, 1989).
- Additional analyses of radial velocity curves are required to provide a robust characterization of young binary systems. This will enable us to obtain a mass-ratio calibration independent of PMS evolutionary models (e.g., David et al. 2016).
- We observe a significant decrease in the transit depth of Brun 691 by analyzing two LCs. Our models suggest a companion size decrease of 88% of the original size in only two years. A strong flare (with a total energy of 3x10^{35} erg) in the LC of sector 6 could cause an extreme erosion of the stellar companion (e.g., Atri & Mogan 2021). Additional studies are required to infer the real nature of the transit decrease of Brun 691. For example, we are analyzing high-resolution spectroscopic observation obtained with the Planet Finding Spectrograph at Las Campanas Observatory to ~~support~~ confirm or reject the extreme erosion scenario.

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