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A catalog of exoplanets around post-common envelope eclipsing binaries: CuPS-ETV

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Abstract. A significant part of circumbinary planet discoveries to date have been identified in post-common envelope binaries (PCEBs) using the Eclipse Timing Variations technique (ETV). The detectability of these additional bodies is largely thanks to the total masses, relative radii, and close proximity of the companions of these binary systems, which make ETV-based discoveries possible. Additionally, processes from earlier stages of binary star evolution may impact third-body formation around these systems. The CuPS-ETV catalog compiles the physical and observational properties of these systems and their companions from multiple sources in the literature. Organized for structured queries and visualizations, this catalog is a comprehensive and accessible resource designed to support population analyzes of PCEBs, exploring their complex dynamics and evolutionary patterns.

Key words: circumbinary planets, post-common envelope binaries, catalog, exoplanets

1. Introduction

We are developing the first catalog specific to PCEB systems with additional bodies discovered with the ETV technique, aiming to provide insights into the population and distribution of their physical parameters.

Post Common Envelope Binary systems (PCEB's) are binary star systems where at least one component has completed its main-sequence evolution. Additional objects have been proposed around such systems in the substellar mass regime, and most of these binary systems with evolved components consist of a hot sub-dwarf of spectral type O or B (sdOB), or a white dwarf (WD) primary and a cool M-dwarf companion. These systems have short orbital periods, often on the order of hours, and their total masses are relatively small.

The progenitors of binary systems with evolved components are binary systems consisting of two main-sequence stars. During their evolution, the more massive primary component fills its Roche lobe and transfers mass to the companion. The companion, receiving this transferred material, may not be able to fully accrete the mass from the primary. As a result, the material that cannot be accreted by the companion surrounds the system, leading to a phase known as the "common envelope" (Paczynski, 1976). During the common envelope phase, the components of the binary lose angular momentum to the envelope and spiral-in to form a close binary. The material in the envelope spreads via angular momentum transfer (common envelope ejection). This process results in a binary system that has undergone a common envelope evolution, forming what is known as a Post-Common Envelope Binary (PCEB) system (Heber, 2016).

Binary systems that have undergone common envelope evolution are ideal to look for additional objects in the substellar mass regime with the eclipse timing method due to their small total masses and short orbital periods. Precise measurements of minimum eclipse times are possible thanks to the V-shaped minima profiles, and the Light Time Effect (LiTE) due to low-mass additional bodies is easily revealed with the help of small total mass of the binary (Baştürk et al., 2023). Magnetic activity in the low-mass companion star may cause ETVs, and determining whether variations are due to magnetic activity or LiTE involves calculating the required energy using the companion's physical parameters (Völschow et al., 2016).

Apsidal motion in eccentric binaries causes large ETV cycles, but strong tidal forces during the evolution of these compact systems typically lead to nearly circular orbits. Radial velocity studies support this, indicating circular orbits (Vučković et al., 2007), making apsidal motion an unlikely cause of ETVs in PCEBs. Other mechanisms, such as tidal interactions or gravitational wave effects, can result in loss or gain of angular momentum, which affects orbital periods in a secular fashion.

Substellar objects around such systems suggested based on the observed ETVs attract attention. Therefore, their long-term follow-up is required to reveal their nature, which can be best acheived through a custom catalog. For the development of such a catalog, we have conducted an extensive review of existing studies focused on PCEBs and additional bodies suggested around them based on the ETVs they display. We have systematically collected and organized data from various sources, ensuring that the information is comprehensive and readily usable for researchers.

We collect parameters related to binaries and their companions, organizing them into a user-friendly structure for future research. The catalog will be open-access and query-friendly, aiming to provide researchers with an organized resource for analyzing the population and distribution of parameters related to PCEBs and their potential companions.

2. Catalog structure

The catalog is structured into four main layers:

1. **System layer:** Includes the orbital parameters of binary systems, such as orbital period, semi-major axis, and mass ratio.

2. **Star layer:** Contains the physical properties of the primary and secondary stars, including effective temperatures, masses, and radii.

3. **Planet layer:** Describes the proposed planets, providing details such as periods, masses, orbital distances, and eccentricities.

4. **Reference layer:** Links all layers using reference numbers and corresponding literature sources.

Users can merge these layers through reference numbers to track the origin of each dataset. Bar charts, such as the one in Fig. 1, provide visual representations of data sources.

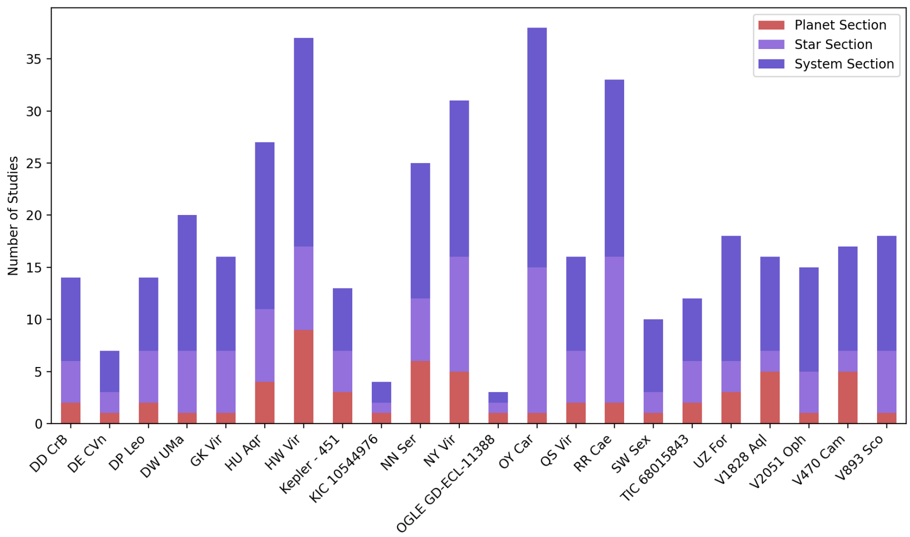

Figure 1. Number of studies referenced per dataset.

Table 1 provides a detailed overview of the four main layers in the catalog structure. The "method" in subscript is to denote which method is used to obtain the aforementioned parameter, e.g. q-search for the mass ratio (q).

Most of the primary stars in our catalog are either white dwarfs (WD) or *O* or *B*-type hot sub-dwarfs (sdOB). Both groups have cooler, low-mass secondaries. These findings may provide clues about their evolutionary paths and formation mechanisms of planetary mass objects around PCEBs (Zorotovic & Schreiber, 2013).

Table 1. The physical parameters included in the layers of the catalog with updated units.

System layer	**Star layer**	**Planet layer**	**Reference layer**
System Name	Star Name	Planet Name	System Name
Alternate Name	$T_{\rm eff}$ (K)	$P_{\rm orb}$ (days)	First Author/Year
T_0 (BJD-TDB)	$T_{\rm eff,method}$	$M_{\rm min}$ ($\rm M_{Jup}$)	Ref. Number
$P_{\rm orb}$ (days)	$\log g$	a (AU)	NASA/ADS Link
a ($\rm R_\odot$)	$\log g_{\rm method}$	ω (deg)	
$a_{\rm method}$	M ($\rm M_\odot$)	$T_{\rm per}$ (JD)	
q	$M_{\rm method}$	M (deg)	
$q_{\rm method}$	R ($\rm R_\odot$)	Ref. Number	
i (deg)	$R_{\rm method}$		
$i_{\rm method}$	Ref. Number		
d (pc)			
Ref. Number			

An example of graphical representations of the information in the catalog can be a mass versus orbital period plot, which demonstrates the distribution of planetary discoveries across various techniques (Fig. 2). Another key plot, the Hertzsprung-Russell diagram, illustrates the temperature and radius distributions of the primary and secondary stars, based on the luminosities derived from standard relations (Fig. 3).

3. Results

Our catalog identifies 37 planets proposed around PCEBs. Notably, twenty-two substellar objects within planetary or brown dwarf mass limits (M<80 $\rm M_{jup}$) have been suggested around systems where the primary star is a hot sub-dwarf

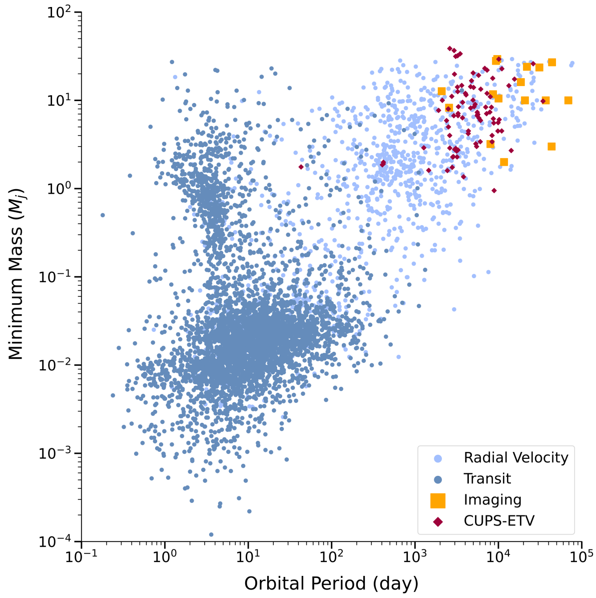

Figure 2. Distribution of planetary discoveries across techniques.

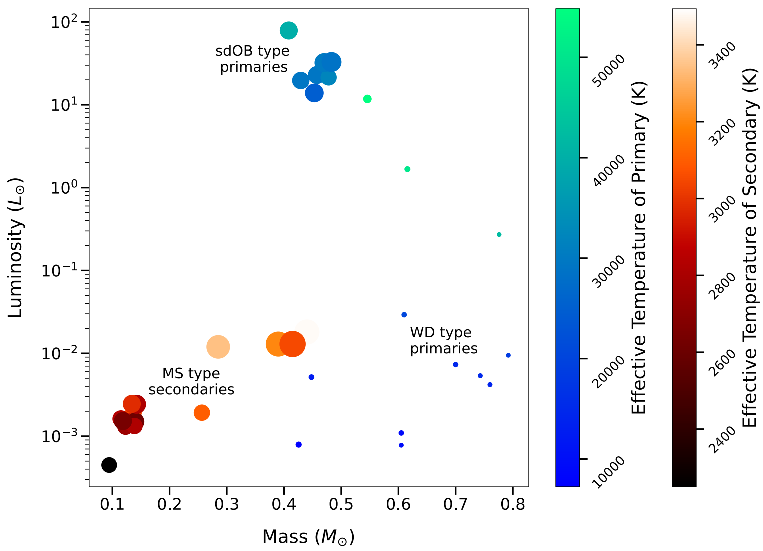

Figure 3. Mass-temperature-luminosity distribution of primary and secondary stars.

on the extreme horizontal branch of the Hertzsprung-Russell diagram or a white dwarf, while the companion star is a low-mass main-sequence star.

Our catalog provides a tool for the analysis of the population characteristics of these unique systems. The results highlight distinct groupings among the host stars and suggest diverse evolutionary scenarios for third-body formation in these environments.

4. Acknowledgements

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