PI information

Name: Joaquín Maximiliano Meza Lagos
Email: joaquin.mezal@usm.cl
Affiliation: Universidad Técnica Federico Santa María
Status: Undergraduate Student

CO-Is information:

Odette Toloza, odette.toloza@usm.cl, Universidad Técnica Federico Santa María

Proposal information:

Title: *"Discovery of a new intermediate polar CV J194827-131733: Searching for High-low state variations"*

Abstract: We report the discovery of a new intermediate polar cataclysmic variable system, J194827-131733, identified through Xshooter observations in September 2023, which has experienced a low-state phase in the past identified by a decrease of 3 magnitudes is its optical magnitude. The underlying mechanisms driving these variations remain poorly understood, with implications tied to the accretion disc and accretion rate dynamics. To Understand the mechanisms, we propose an intensive monitoring campaign utilizing SPECULOOS, involving 30-minute observations every 10 days in i'r' and g' filters (nine hours in total including overheads). The strategic frequency of observations will allow us to systematically capture and study the periodic variations. Of particular significance is the advantage of detecting the system in a low state, providing a unique opportunity to study the magnetic white dwarf which is currently hidden by the disc. This approach is crucial given the scarcity of well-characterized intermediate polar systems, where only a fraction includes knowledge of the white dwarf properties. With fewer than 40 known intermediate polar systems and limited insights into the white dwarf characteristics, our investigation holds the promise of contributing valuable data to the broader understanding of cataclysmic variable stars.

Instrument: SPECULOOS

Time requested: 9 hours of SPECULOOS data to observe J194827-131733, allocating 30 minutes of observations every ≃10 days.

Preferred dates: The target visibility is from mid-may to end of the semester.

SCIENTIFIC AIM AND RATIONALE

Astrophysical context: Interactions between binary systems lead to some of the most extraordinary and captivating events in the universe. These range from formidable thermonuclear supernova explosions to potent generators of gravitational wave radiation (Branch & Tammam 1992, ARA&A, 30, 359). Additionally, the inflow of gas onto these compact entities establishes conducive settings for investigating accretion processes, with significant implications for more intricate sources such as active galactic nuclei. Despite the persistent endeavours of theorists, prevailing formation and evolutionary models encounter challenges in elucidating the underlying physical mechanisms steering these interactive systems and comprehensively characterising their observed properties across the entire population. An ideal laboratory to study many of the above processes are the systems known as *cataclysmic variables* (CVs). CVs consist of a low mass main sequence star and a white dwarf typically that experience accretion of the material from main sequence donor star, commonly forming an accretion disk. CVs can go through different luminosity changes, that could be caused by the accretion disk instabilities (Hameury & Lasota, 2017, 602, 102).

Certain CVs feature a magnetic white dwarf (see Ferrario et al. 2015, 191, 111 and references therein), and these systems are categorised based on the strength of the magnetic field. The intensity of the magnetic field has a profound impact on the morphology of the accretion disk within these systems. This influence arises from the fact that charged particles follow the magnetic field lines of the white dwarf, resulting in accretion occurring predominantly at the magnetic poles. The strength of the magnetic field further contributes to the degree of disruption experienced by the accretion disk; stronger magnetic fields (strength above $\sim$10 MG) tend to cause more pronounced disturbances (hereafter, the polar systems), while intermediate cases exhibit varying degrees of disruption (hereafter, the intermediate polars).

Some CVs with magnetic fields display significant brightness variations of approximately ~ 3 magnitudes over extended time-scales (i.e. on time-scales of many epochs of P_{orb}; e.g. Kalomeni, 2012, MNRAS, 422, 1601). The period of heightened luminosity is conventionally denoted as the "high-state", contrasting with the phase characterized by reduced luminosity, named the "low-state". Only very few observed systems with an intermediate strong magnetic field exhibit both high and low states. Exemplary cases are the systems J1832.4-162, which the first eclipsing stream-fed intermediate polar (Beuermann et al. 2022, 657, 101) or alternatively the candidate system J0746.3-1608 (Bernardini et al 2019, MNRAS, 484, 101). In addition, the high/low state activity is different from that of CVs which have discs, such difference can be caused by such a strong magnetic field of the white dwarf that it affects the donor component (Wu & Kiss 2008, A&A, 481, 433)

The origin of the high/low state phenomenon remains unclear. An explanation suggested by Livio & Pringle (1994, ApJ, 427, 956) is that the donor star obstructs the L1 Lagrangian point, where mass transfer occurs. In order to understand this process is crucial to characterised the stellar components in these systems. The headcount of intermediate polars stands at $\simeq 40$ systems[1] however, the white dwarf masses in these systems is known for only a handful of them, and the majority of them are determined from X-ray observations which is highly model dependant (e.g. Cropper et al, 1998, MNRAS, 293, 222, Ramsay 2000, MNRAS, 314, 403)

One advantageous aspect of the system being in a low state is the discernible presence of the white dwarf and donor star fluxes in spectroscopy, allowing measurements the mass and radii of the stars.

J194827-131733: A new eclipsing intermediate polar:

As part of a large program of cataclysmic variables, we discover a new intermediate polar, which we obtain spectroscopy displaying helium II emission feature which is a characteristic feature in magnetic

[1] https://asd.gsfc.nasa.gov/Koji.Mukai/iphome/catalog/alpha.html

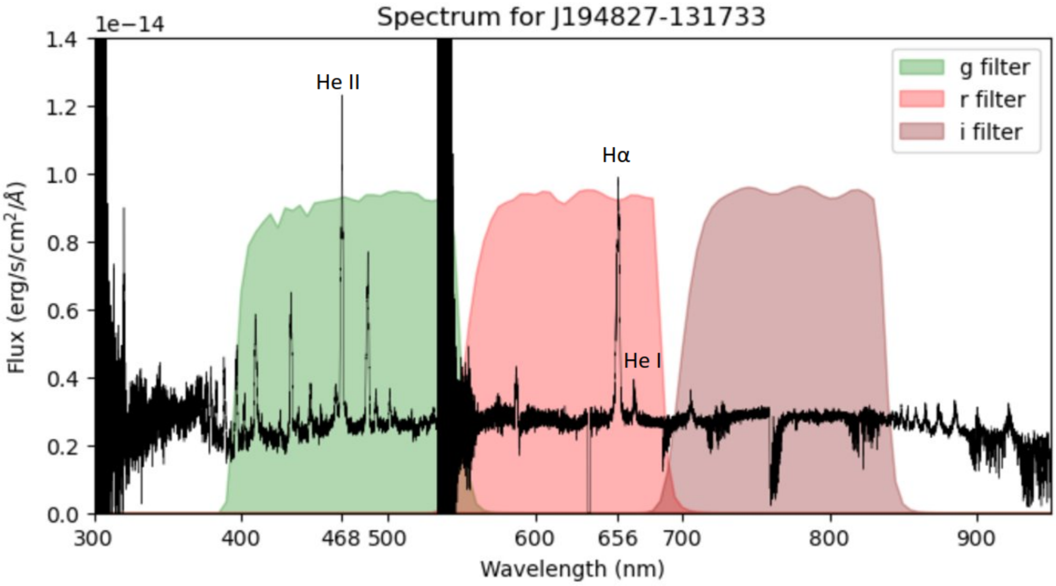

Figure 1: X-shooter spectrum taken in September 2023 which clearly displays that the systems is an intermediate polar, i.e. emission lines of hydrogen and helium. The spectrum is dominated by the flux coming by the bright spot formed by the shock of the material hitting the edge of the accretion disc. Overplotted are the g', r', and i' filters of SPECULOOS.

CVs (see Figure 1). The spectrum is dominated by the bright spot formed by the impact of the material from the donor to the outer region of the accretion disc. This system fell in the footprint of *TESS* in sector 52 collecting one month of high-cadence photometry (see Figure 2). The *TESS* lightcurve displays clearly eclipses of the bright spot every $\simeq$5.2 hours (thus the system inclination is likely less than 70). Aditionally, *Gaia* flagged this system as variable and hence recorded long-term photometry (see Figure 3). The lightcurve displays a drop in brightness of about 3 magnitude in 2015. This magnitude faintness is the average value (e.g. the polar prototype, AM Her Kafka et al, 2005, 130, 2852) observed when systems enter to low state (it is worth to mention that the photometric variability due to the eclipses is about one magnitude). Given the eclipsing nature of the system, we can measure the masses and radii if the stars with high precision (e.g. Hardy et al. 2017, MNRAS, 465, 4968).

Here, we request 9 hours of SPECULOOS data to observe J194827-131733, allocating 30 minutes of observations every $\simeq$10 days. This project aims to scrutinize the system extensively, with the goal of testing the low/high state explanation based on obstruction of the mass transfer flow (

To delve into the heart of this enigma, we propose an intensive monitoring campaign utilizing SPECULOOS, involving 30-minute observations every 10 days in i'r' and z' filters. The strategic frequency of observations will allow us to systematically capture and study the periodic variations in luminosity. Of particular significance is the advantage of detecting the system in a low state, providing a unique opportunity for spectroscopy to discern the white dwarf. This approach is crucial given the scarcity of well-characterized intermediate polar systems, where only a fraction includes knowledge of the white dwarf properties.

With fewer than 40 known intermediate polar systems and limited insights into the white dwarf characteristics, our investigation holds the promise of contributing valuable data to the broader understanding of cataclysmic variable stars. Unraveling the mysteries of J194827-131733 will not only enhance our understanding of this specific system but also shed light on the broader population of intermediate polar cataclysmic variables.& Pringle (1994, ApJ, 427, 956)), potentially marking a pivotal moment in our understanding.

Work plan with SPECULOOS data:

The *Gaia* long term lightcurve has confirmed that our target undergoes phases of low-state. In the event of detecting the low state of J194827-131733, we will apply for a Director's Discretionary Time (DDT) program to acquire photometry and optical spectroscopy. In addition, the monitoring can serve to identify a disc outburst which is rare in intermediate polar and potentially to study the interplay that the magnetic field of the white dwarf has on the disc. during the outbursts

Aside of detecting the entrance to the low-state of our target, the SPECULOOS photometry will provide immediately the magnitude difference when the out target enters into low state. The photometry will be reduced with the python code PROSE. The photometry of this project will be provided to the The American Association of Variable Stars Observers (AVVSO[2]) which is the largest database of variable systems under monotoring, such that the data can serve as laegacy for future studies.

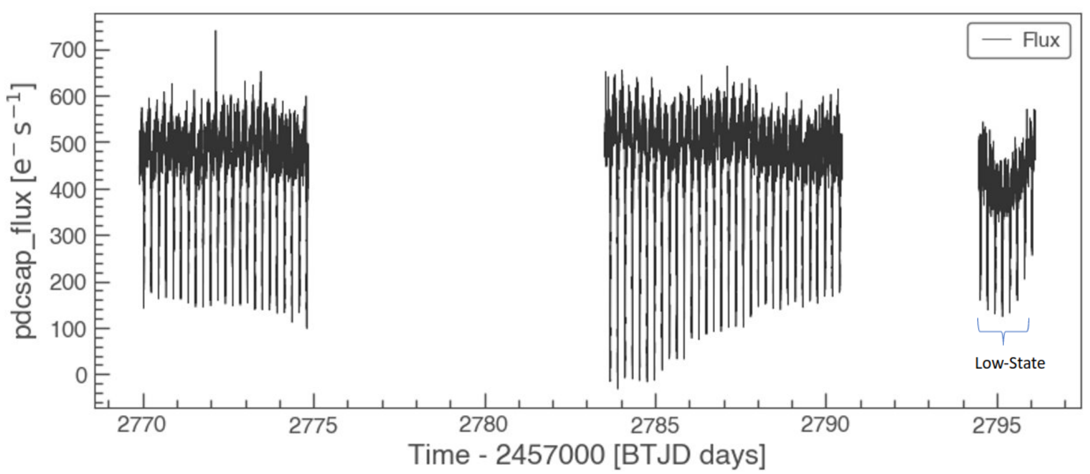

Figure 2: High cadence *TESS* lightcurve (sector 54 starting from 2022-07-09 to 2022-08-04) (the PDCSAP light curves are already corrected by crowding). The light curve shows clearly eclipses of the bright spot which occur every $\simeq$5.2 h providing the orbital period of the system. The brigthness change produces by the eclipses is only 1 magnitude.

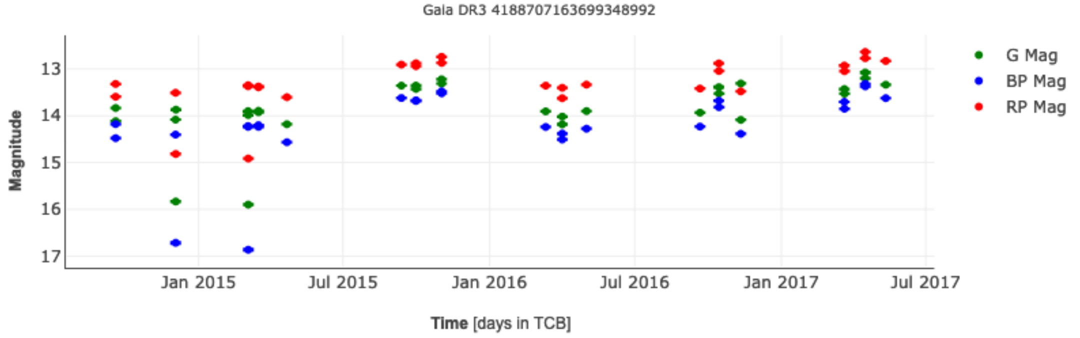

Figure 3: *Gaia* lightcurve of our target, which displays a drop of 3 magnitudes in 2015 likely due to a phase of low-state of the system.

[2] https://www.aavso.org/

TECHNICAL DESCRIPTION

The target's visibility extends from mid-May to the end of the semester, aligning with the schedule for the 2024A semester.

Observing Strategy: To maximise the detection during the low state, we plan to observe for half an hour in each of the 3-day blocks allocated to Chilean time (which occur approximately every 10 days on average according to the calendar provided in the bases). Within this half an hour, our goal is to capture four photometric points for each of the g, r, i filters, covering emission features of Balmer lines, He I, He II (see Figure 1). These four data points are necessary to assess the data's variance and identify significant variability.

Given the brightness of our target (G$\simeq$ 13.99 mag; see Table 1), we utilise the SPOCK script to calculate exposure times, for which we incorporate our X-shooter spectrum into the SPOCK spectra library. Setting exposure times of SPOCK to $g' = 180$ s, $r' = 130$ s, and $i' = 115$ s will provide approximately 14830, 14600, and 15000 ADUs, respectively. Since the readout plus overhead is very short (only 10 seconds), we will not request binning. Standard calibrations will be applied. Finally, lunar phase constraints are not applicable given the brightness of our target.

In summary, we request 9 hours (half an hour in every 3-day block allocated to Chilean time) out of the 45 FAST-TRACK CNTAC nights available for SPECULOOS photometry, distributed throughout the semester.

Table 1: Targets

target name	RA (deg)	DEC (deg)	G (mag)
J194827-131733	297.1155978970	-13.2927237201	13.99

CURRENT STATUS OF THE PROJECT

This is a discovery project was possible to joint efforts of a large project which aims to understand to evolution of cataclysmic variables. Currently we are aiming to build larger volume-limited samples (P 1) that are being observed within the compact white dwarf binary subsurvey in the ongoing spectroscopic survey SDSS-V, which is already producing important results (e.g. (P 2), (P 3)). Also many candidates to CVs will be observed in the upcoming *white dwarf binary survey* within 4MOST (P 4). Therefore, our objective is to conduct a targeted investigation of the target into its magnetic behaviour. The inclusion of this new system is crucial, given the limited existing sample, as it imparts significant constraints to theoretical models.

Relevant publications

[P1] K. Inight, B. T. Gänsicke, E. Breedt, T. R. Marsh, A. F. Pala, and R. Raddi "Towards a volumetric census of close white dwarf binaries - I. Reference samples", MNRAS, vol. 504, June 2021.

[P2] K. Inight, B. T. Gänsicke, A. Schwope, S. F. Anderson, C. Badenes, E. Breedt, V. Chandra, B. D. R. Davies, N. P. Gentile Fusillo, M. J. Green, J. J. Hermes, I. A. Huamani, H. Hwang, K. Knauff, J. Kurpas, K. S. Long, V. Malanushenko, S. Morrison, I. J. Quiroz C., G. N. A. Ramos, A. Roman-Lopes, M. R. Schreiber, A. Standke, L. Stütz, J. R. Thorstensen, O. Toloza, G. Tovmassian, and N. L. Zakamska "Cataclysmic Variables from Sloan Digital Sky Survey - V. The search for period bouncers continues", MNRAS, vol. 525, Nov. 2023.

[P3] V. Chandra, H.-C. Hwang, N. L. Zakamska, B. T. Gänsicke, J. J. Hermes, A. Schwope, C. Badenes, G. Tovmassian, E. B. Bauer, D. Maoz, M. R. Schreiber, O. F. Toloza, K. P. Inight, H.-W. Rix, and W. R. Brown "A 99 minute Double-lined White Dwarf Binary from SDSS-V", ApJ, vol. 921, Nov. 2021.

[P4] O. Toloza, A. Rebassa-Mansergas, R. Raddi, N. Reindl, B. Gaensicke, N. G. Fusillo, S. Scaringi, D. Belloni, E. Breedt, M. Camisassa, T. Cunningham, D. de Martino, A. Ederoclite, S. Geier, M. Green, K. Inight, T. Kupfer, J. Maldonado, T. Marsh, A. F. Pala, S. Parsons, I. Pelisoli, J. Ren, P. Rodriguez-Gil, S. Sahu, L. Schmidtobreick, M. Schreiber, A. Schwope, D. Steeghs, P. Szkody, S. Toonen, P. E. Tremblay, and M. Zorotovic "The White Dwarf Binary Survey (WDB)", The Messenger, vol. 190, Mar. 2023.

STUDENT THESIS

This data will be part of the first research project of a PhD thesis. The viva of the thesis is planned to the end of the program which is on Dec 2028.

The importance of the monitoring is to detect a low state which can have timescales of years, and therefore a long term monitoring guarantees a detection of a low state using only 9 hours throughout months. Thus additional spectroscopic observations using a DDT program can be made during the low state to characterise the white dwarf that currently is outshined by the bright spot. It is worth mentioning that the success of the thesis does not depend solely on the data; however, acquiring it will significantly enhance the impact of the project investigated during the thesis.