Boletim da Sociedade Astronômica Brasileira, **35**, no. 1, 197-198

Confirming the magnetic nature of the white dwarf in CRTS J160346+193540

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Abstract. CRTS CSS160906 J160346+193540 (J1603+19) is a cataclysmic variable (CV), classified as a polar. The system has an orbital period (P_{orb}) of 81.96 min, near the minimum observed value in CVs. In the long term, J1603+19 alternates between high- and low-brightness states, which differ by 2 - 3 magnitudes in optical bands. Recent studies indicate that the system has a mid-infrared flux above the expected from the secondary star. This emission modulates with the orbital period with an amplitude of around 1 mag, which is interpreted as cyclotron emission from a magnetic accretion structure. We used data from the Transiting Exoplanet Survey Satellite (TESS) to confirm and refine P_{orb}. We also detected circular polarization modulated with this period in the R_C and I_C bands. The amplitude is higher in infrared band.

Resumo. CRTS CSS160906 J160346+193540 (J1603+19) é uma variável cataclísmica (CV), classificada como uma polar. O sistema tem um período orbital (P_{orb}) de 81.96 min, perto do valor mínimo observado em CVs. No longo prazo, J1603+19 alterna entre estados de alto e baixo brilho que difere de 2 a 3 magnitudes nas bandas ópticas. Estudos recentes indicam que o sistema tem um excesso de fluxo no infravermelho médio em relação ao que seria esperado para uma estrela secundária. Essa emissão é modulada com o período orbital com uma amplitude de cerca de 1 mag, que é interpretada como emissão ciclotron originada de uma estrutura de acreção magnética. Nós utilizamos dados do *Transiting Exoplanet Survey Satellite* (TESS) para confirmar e refinar P_{orb}. Nós também detectamos polarização circular modulada com este período nas bandas R_C e I_C. A amplitude é maior no infravermelho.

Keywords. (Stars:) novae, cataclysmic variables – Magnetic fields – Stars: rotation – Techniques: photometric – Techniques: polarimetric

1. Introduction

Cataclysmic variables (CV) are semidetached binary stellar systems, in which the primary star is a white dwarf (WD) and the secondary star is a low-mass red dwarf. In these systems, the secondary star is also known as a donor star, as it is overflowing its Roche lobe and donating matter to the WD. This matter is accreted through an accretion disk around the WD or through a magnetic accretion column, depending on the magnetic field of the WD. A magnetic CV of the polar type has a WD magnetic field strong enough to synchronize the WD rotation with the orbital period and to prevent the formation of an accretion disk.

J1603+19 is a CV, recently classified as polar (Oliveira et al. 2020; Liu et al. 2023). The system has a P_{orb} of 0.05691863(25) days (≈ 81.96 min, Liu et al. 2023), close to the minimum observed value in CVs. The authors collected photometric and spectroscopic data. Near-infrared spectra show possible cyclotron features indicating that the white dwarf has a magnetic field of about 5 MG, a very low value for a polar. The spectra show emission lines with two components; one can be associated with the magnetic accretion column and the other from the Roche overflow point.

This contribution is organized as follows. In Sec. 2, we present the optical photometry and polarimetry of J1603+19 in the V, R_C and I_C bands. The TESS observation is presented in Sec. 3. In Sec. 4, we analyze P_{orb} with TESS and OPD data. Section 5 describes the polarimetric results. Our conclusions are summarized in Sec. 6.

Table 1. Summary of the observations of J1603+19.

Date Obs.	Bands	Exp. Time (s)	N. of exps.
2020 Mar 24	V	90	138
2020 Mar 25	R_C	85	159
2020 Mar 26	I_C	40	301

2. Ground-based observations

Photometric and polarimetric data were obtained at the Observatório do Pico dos Dias (OPD), using the 1.6 m Perkin-Elmer telescope coupled with the IAGPOL polarimeter equipped with a quarter-wave retarded plate and a Savart Prism (Magalhaes et al. 1996; Rodrigues et al. 1998). The observations were made using an iXon EMCCD in the V, R_C and I_C bands. The dual-beam polarimetric technique divides the source light into two beams of orthogonal polarizations. This technique naturally removes the sky polarization from the estimated Stokes parameters. The observations were performed on three different nights, March 24, 25, and 26, 2020. The summary of the observations is shown in Tab. 1.

Data reduction was performed using the ASTROnomical POlarimetry and Photometry Pipeline (ASTROPOP) (Neves

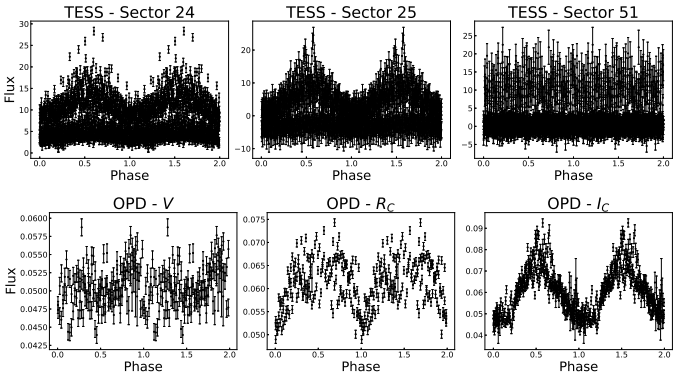

Figure 1. Phase diagrams of J1603+19 for TESS sectors 24, 25 and 51 (top) and OPD bands V, R_C and I_C (bottom).

Campagnolo 2019), which is an open-source package written in Python. ASTROPOP can perform image pre-processing, source detection, photometric and polarimetric reduction, and astrometric and photometric calibration. The differential photometry was obtained by adding the ordinary and extraordinary fluxes of J1603+19 and dividing it by the total flux of a reference star, assumed to be non-variable. We used ASTROPOP's cross-matching functions with the GaiaDR3 (Gaia Collaboration et al. 2016, 2023) catalog to calibrate reference star magnitudes of the reference star. The aperture photometry of each beam is used to perform the polarimetric reduction in J1603+19, obtaining time series of circular (V) and linear (P) polarization.

3. TESS observation

TESS observed J1603+19 with a cadence of 30 minutes in sectors 24 (2020-04-16 to 2020-05-12) and 25 (2020-05-14 to 2020-06-08), and with a cadence of 10 minutes in sector 51 (2022-04-23 to 2022-05-18). Light curves were created from full frame images (FFI) using the Python packages *TESSCut* (Brasseur et al. 2019) and *Lightkurve* (Lightkurve Collaboration et al. 2018). Considering the chance of source confusion inside the large TESS pixel scale of 21arcsec, we checked the confidence of the target to be the source of the measured variability with the package *tess_localize* (Higgins & Bell 2023). The relative likelihood returned was greater than 99%.

4. Photometry Results

In Fig. 1, we present the TESS and OPD light curves. The OPD data were observed in the high state, as in sectors 24 and 25 of the TESS. Sector 51 was observed in the low state. Furthermore, analysis of other objects of the same sector (51) suggests that there are instrumental problems. We use TESS data from sectors 24 and 25 to analyze P_{orb} and the epoch ($T0$). Sector 51 does not show any modulation. We applied the Lomb-Scargle (LS, Lomb 1976; Scargle 1982) method to determine the dominant period in the light curves. To estimate the uncertainty of the determination, we performed a hundred simulations scrambling the fluxes and injecting a sinusoid with period and amplitude coming from LS, adding random phases in each case.

In the OPD data, we can detect the modulation in the bands R_C and I_C, but not in the V band. Then we use the technique of the observed minus calculated (O-C) diagram with the TESS sectors 24 and 25 and the OPD bands R_C and I_C for a more refined determination of P_{orb}. The result obtained was: P_{orb} = 0.05692021(86) days and $T0$ = 58962.15051(41)days.

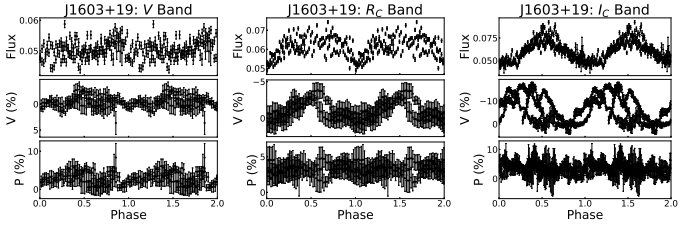

Figure 2. Phase diagram of OPD data. From left to right: V, R_C and I_C bands. From top to bottom: differential photometry, circular and linear polarization.

5. Optical polarimetry

Fig. 2 shows the ground-based multiband photometry and polarimetry of J1603+19. The object has no clear periodical variability in flux or polarization in the V band, but both the flux and the circular polarization have an increasing amplitude to redder wavelengths. In particular, the circular polarization has an amplitude of 4% in the R_C and 15% in the I_C bands. The circular polarization does not present a change of sign, which indicates that we probably see only one accretion region on the WD surface.

6. Conclusions

We present a preliminary analysis of optical polarimetry and TESS data of J1603+19. Our main findings are as follows.

- the TESS data show a periodical signal consistent with the previous finding in the literature and no hint of asynchronism is shown;
- the TESS data show the system in two different states;
- the circular polarization detected in R_C and I_C bands confirms the presence of cyclotron emission and, consequently, magnetic accretion onto a magnetic white dwarf.

All the above properties confirm that J1603 + 19 is a polar system, but with a less intense magnetic field compared to the currently known systems.

Acknowledgements. We thank CNPq (310930/2021-9) and FINEP (0/1016/0076/00) for the grant in the process, INPE for the opportunity and supervision, and OPD-LNA for the observations. CVR thanks CNPq (310930/2021-9) and partial support from Brazilian Space Agency (AEB). E.M. thanks FAPEMIG (APQ-02493-22) and CNPq (309829/2022-4.), W.S. thanks CNPq (300343/2022-1)

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