X-rays and TESS observations of symbiotic binary stars

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Resumen / Las estrellas simbióticas son binarias que interactúan fuertemente compuestas por una enana blanca que acumula masa desde su compañera gigante roja. Estudiamos cinco estrellas simbióticas: BD Cam, V1261 Ori, NQ Gem, CD-27 8661, CD-36 8436 usando observaciones de los satélites Swift/XRT y XMM-Newton en rayos X y de TESS en el óptico. Los espectros de rayos X se ajustaron con modelos de plasma térmico ópticamente delgado absorbido, con temperatura única o múltiple. Los espectros son todos compatibles con el que surge de la región más interna del disco de acreción; la capa límite. Las observaciones TESS de estos cinco sistemas muestran que la presencia de parpadeo estaría relacionada con la existencia de un disco de acreción. Estas cinco simbióticas pertenecen al tipo impulsado por acreción, un hallazgo respaldado por su baja luminosidad de rayos X, así como por sus curvas de luz parpadeantes.

Abstract / Symbiotic stars are strongly interacting binaries composed of a white dwarf accreting from its red giant companion. We studied five symbiotics stars: BD Cam, V1261 Ori, NQ Gem, CD -27 8661, CD -36 8436 using observations from the Swift/XRT and XMM-Newton satellites in X-rays and from TESS in the optical. The X-ray spectra were fit with absorbed optically thin thermal plasma models, with either single- or multi-temperature. The spectra are all compatible with that arising from the most internal region of the accretion disk; the boundary layer. The TESS observations of these five systems show the presence of flickering, would be related with the existence of an accretion disk. These five symbiotics thus belong to the accretion-powered type, a finding supported by their low X-ray luminosity as well as flickered light curves.

Keywords / binaries: symbiotic — white dwarfs — X-rays: binaries

1. Introduction

Symbiotic stars are long-period binaries consisting of a late-type giant and a compact object, a white dwarf (WD) in most cases, surrounded by an ionized nebula (e.g., Mürset et al. 1997). Based on their X-rays energy range characteristics, symbiotic stars are divided into: (*i*) α-type, supersoft emission with energies of less than 0.4 keV; (*ii*) β-type, soft emission with energies of less than 2.4 keV; (*iii*) γ-type, neutron symbiotics stars with hard X-ray emission (E > 2.4 keV); and (*iv*) δ-type, WD symbiotic stars with hard X-ray emission (E > 2.4 keV); (*v*) β/δ-type, WD symbiotics with two X-ray thermal components, soft and hard emissions (Mürset et al., 1997; Luna et al., 2013). X-ray emission from symbiotic stars comes from nuclear burning, colliding winds, accretion, or combination between them (Mukai 2017).

The stochastic broad-band variability on time scales of minutes to hours (also referred to as flickering) is rarely observed in the optical band. The lack of detection of flickering suggests that optical radiation from the red giant and the wind nebula overwhelms radiation from the disk (Sokoloski et al., 2001). About 12 symbiotic stars presents clear signs of flickering on time scales of ∼10 minutes with amplitude > 0.1 magnitude - RS Oph, T CrB, MWC 560, Z And, V2116 Oph, CH Cyg, RT Cru, *o* Cet, V407 Cyg, V648 Car, EF Aql, and ZZ CMi (Zamanov et al., 2022). The presence of flickering and its amplitude can be understood as an indicator of the presence of the accretion disk (Bruch, 1992). The study of symbiotic stars is of special significance as it can be used to study the possibility that these objects as progenitors of Supernovae Type Ia (Kenyon et al., 1993). Also, these systems provide an unique astrophysical laboratory to study the stellar evolution, the mass transfer accretion processes, the stellar winds jets, the dust formation, and the thermonuclear outbursts (e.g., Mürset et al. 1997; Mukai 2017).

2. Observations and data reduction

We present observations of the symbiotics BD Cam, V1261 Ori, NQ Gem, CD-27 8661, CD -36 8436 obtained with *XMM*-Newton, *Swift*, and *TESS*. *XMM*-Newton observed three symbiotic stars of our sample: V1261 Ori, NQ Gem, and CD-27 8661

Poster contribution

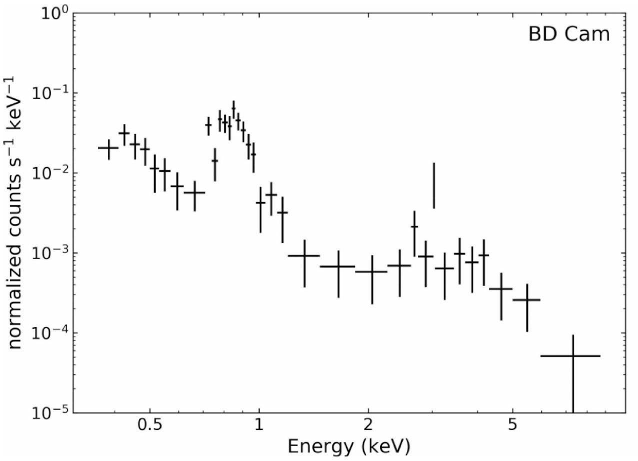

Figure 1: Example of optical loading from *Swift/XRT-PC* mode spectra of BD Cam prepared by the online *Swift/XRT* data products generator.

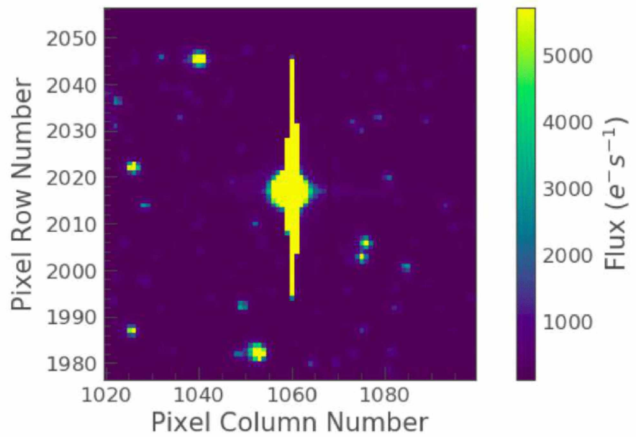

Figure 2: BD Cam image observed by *TESS* in Sector 19.

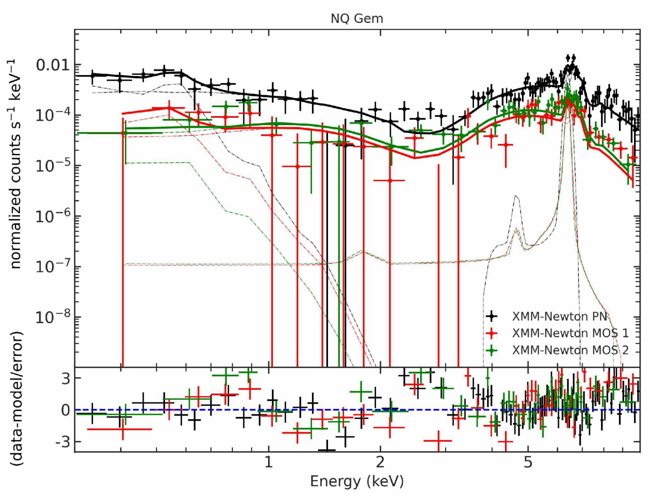

Figure 3: *XMM*-Newton spectrum of NQ Gem. The solid lines show the best-fit model.

with the European Photon Imaging Camera (EPIC) PN/MOS 1/MOS 2 cameras. Usually in the 0.3-10 keV energy range. The EPIC cameras were operated in full frame mode with the thick filter, except for CD-27 8661 which was observed with the medium filter during both. The *Swift* X-ray Telescope (XRT) observed all sources of sample. However, not all data were used since some of these observations are effected by optical loading. The optical loading is a consequence of the presence of optical photons that are detected on-board as X-ray photons, producing spurious events in the CCD. This effect is severe for optical bright sources and does not depend on the exposure time of the observation, but on the readout time of the CCD. Therefore *Swift/XRT-WT* mode, whose readout time is ∼1500 times shorter than *Swift/XRT-PC* mode, has less probability being affected by optical loading.

Figure 1 shows BD Cam spectrum observed by *Swift* in XRT-PC mode during three pointings in 2012 April 13, 16, and 17. This object has intense brightness in optical wavelength (V = 5.11 mag, J = 1.31 mag) and its X-ray spectrum is significantly distorted by optical loading precluding any meaningful analysis. The impact of the optical loading in BD Cam spectrum is detected with the presence of Fe XVI, Fe XX, O VII, O VIII emission lines, which significantly appears at low energies (0.7 – 0.9 keV). Typically, optical loading photons will dominate below ∼0.4 keV and will be dramatically reduced it above 2 keV (Hare et al., 2021). However, the X-ray photons at higher energies are not likely real, because they still will suffer a grade migration inducing overall gain shift and loss of flux, which means that optical loading will affect the entire spectrum. Therefore, we are not using any spectra with optical loading in this work. One simple tests which can be done in order to identify optical loading in X-ray data consist of extracted a image from the event file and verify the existence of an hole in the center of the source due to rejection in the center of the PSF, in other words, the count-rates are underestimates.

The Transiting Exoplanet Survey Satellite (TESS) covers a broad bandpass (600 – 1000 nm) which represents both R and I bands and near-infrared light (Ricker et al., 2015). We downloaded and extracted the light curves using the TESS Full Frame Images (FFIs) with 30 min cadence through TESSCut tool (Brasseur et al., 2019) from Python package *lightkurve* (Lightkurve Collaboration et al., 2018). BD Cam was observed during 2019 November 27 to December 24 in Sector 19. Although SAP and PDCSAP TESS light curve are given by MAST*, these data are saturated and not be used here (see Figure 2).

3. Results

We used the *PyXspec*, a *Python* interface to the *XSPEC* version 12.12.0 spectral-fitting software for all X-ray spectral analyses. The X-ray emission from our targets were modeled by an absorbed and an optically thin thermal emission from either a single- or multi-temperature plasma. The spectrum of NQ Gem is shown in Figure 3

*See `https://mast.stsci.edu/portal/Mashup/Clients/Mast/Portal.html`

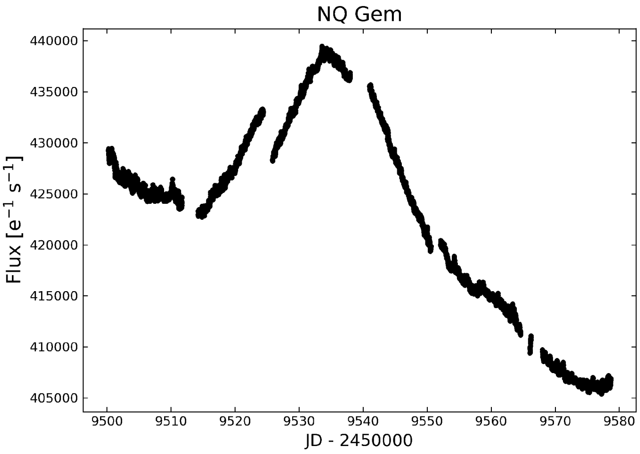

Figure 4: NQ Gem observed by *TESS* in Sectors 45, 46, 47.

(Lima et al. 2023, in preparation). The X-ray spectra of our targets are consistent with β and δ-type symbiotic stars, which the X-ray emission arises from accretion-powered symbiotic stars, in the boundary layer between the white dwarf and accretion disc.

We are searching for variability in *TESS* data of our targets. The preliminary results indicate the presence of flickering on timescales of minutes. Figure 4 shows the light curve of NQ Gem observed during 2021 October 12 to November 05 in Sector 44, 2021 November 07 to December 02 in Sector 45, and 2021 December 02 to 30 in Sector 46. Flickering variability is a phenomenon typical for the cataclysmic variables (Bruch, 1992). In symbiotic stars, it is commonly detected in ultraviolet band (Sokoloski et al., 2001; Luna et al., 2013), but it is the first time that it is reported in optical data from *TESS*. We expect that all the accretion powered symbiotics should display flickering when the accretion disc is active. For example, the recurrent nova RS Oph has flickering in high state and disappears in the low state, when the accretion disc was interrupted by the nova outburst (Zamanov et al., 2022).

4. Conclusion

We present our study of five symbiotics stars: BD Cam, V1261 Ori, NQ Gem, CD -27 8661, and CD -36 8436 using observations from the Swift/XRT and XMM-Newton satellites in X-rays and from TESS in optical. Accretion-powered symbiotic binaries are detected in the X-rays with luminosities in the range of 10^{30-32} ergs s^{-1}. A very wide range of temperatures and densities, probably dominated by the innermost region of the accretion disk, the boundary layer, where the accretion flow releases half its energy before settling onto the white dwarf surface. In our continuous effort to identify accretion-powered symbiotics, we used *XMM*-Newton and *Swift* data in order to search for X-ray emission that would enable us to measure its accretion rate. Additionally, we extracted optical light curves from the *TESS* archive in order to search for short-term aperiodic variability, i.e. flickering, that would point to the presence of an accretion disk.

Acknowledgements: This study was supported by grant PICT 2017-0901 from Consejo Nacional de Investigaciones Científicas y Técnicas (CONICET).

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