Spectroscopic study of the sgB[e]-high mass X-ray binary CI Cam

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Resumen / En este trabajo presentamos espectros ópticos e infrarrojos de la estrella binaria de rayos X CI Cam, compuesta por una estrella B[e] y un objeto compacto. Se observa varibilidad en la línea Hα y en las líneas de He I y Fe II, que podría estar relacionada con el movimiento orbital y con una tercera componente del sistema.

Abstract / We present optical and near infrared spectra of the X-ray binary CI Cam. This system is formed by a compact object and a B[e] star. We report line profile variability in Hα, He I and Fe II lines, that could be related with the orbital movement and the presence of a third component.

Keywords / X-rays: binaries — stars: early-type — circumstellar matter

1. Introduction

CI Cameleopardalis is an eccentric binary system consisting of a B[e] star and a compact object, probably a white dwarf (e.g., Ishida, Morio & Ueda, 2004). The system has been identified as the optical counterpart of X-ray transient XTE J0421+560. Barsukova et al. (2006) obtained an orbital period of 19.41 d and an eccentricity of 0.62. First Gaia data release gave a parallax to CI Cam $p = 0.71 \pm 0.24$ mas (Gaia Collaboration et al., 2016). Considering the observed magnitude $m_V = 11.77$ and taking into account an extinction E(B-V)=0.85 (Robinson, Ivans & Welsh, 2002) we obtained an absolute magnitude $M_V = -1.69$ $(+0.63 - 0.90)$, which is in agreement with the spectral type B4 III–V[e] suggested by Barsukova et al. (2006).

2. CI Cam activity

CI Cam was the first galactic B[e] supergiant star detected during an X-ray outburst in 1998, revealing its binary nature. Few days after the outburst, the UBVRI photometry started to decline and the IR spectra displayed H, He and Fe emission lines, as well as warm CO molecular emission bands in the $2.3 - 3.5$ μm region (Clark et al., 1999, 2000). The molecular emission was proposed to arise due to collisional excitation from regions shielded from the stellar radiation, which requires high densities. Interferometric observations suggested that CI Cam developed an equatorial disk wind with a dust-free, high-temperature zone close to the star viewed almost pole-on (e.g. Thureau et al., 2009). Over a period of 7 yr the star kept stable and slightly brighter than in its pre-outburst state. Many years after the prominent outburst, Gemini/GNIRS and LBT-Luci I K-band spectra revealed the absence of Pfund lines and CO molecular bands (Liermann et al., 2014) suggesting the loss/dilution of a high-density circumstellar material and the return of CI Cam to a quiescent transition phase.
Motivated by reports of a new potential outburst in 2016 (Wijngaarden et al., 2016), we spectroscopically monitored this star during several months. In spite of the fact that there was no real outburst, our observations provided valuable material for a deep study of CI Cam in its quiescent phase.

3. Optical observations

Follow-up optical spectroscopic observations from October 2016 to March 2017 were performed at the 1.5-m telescope of the Tartu Observatory, Estonia, using a single slit spectrograph attached to the Cassegrain focus. Spectra in the wavelength range $6\,315 - 6\,720$ Å with spectral resolution R $\simeq$ 10 000 were obtained using a grating with 1800 lines mm^{-1}. Spectra with resolution R $\simeq$ 4 500 covering spectral interval from 6 230 Å to 6 970 Å were obtained with a 1 200 lines mm^{-1} grating.

All data were reduced and corrected for heliocentric velocity using standard IRAF* tasks. Systemic velocity -51 km s^{-1} (Aret et al., 2016) was applied to all spectra.

An echelle spectrum with resolution R $\simeq$ 11 000, taken on November 20 2017, was obtained from BeSS database (observed by Olivier Thizy and reduced using ISIS** V5.8.0).

*IRAF was distributed by the National Optical Astronomy Observatories, which are operated by the Association of Universities for Research in Astronomy, Inc., under cooperative agreement with the National Science Foundation.
**http://www.astrosurf.com/buil/isis-software.html

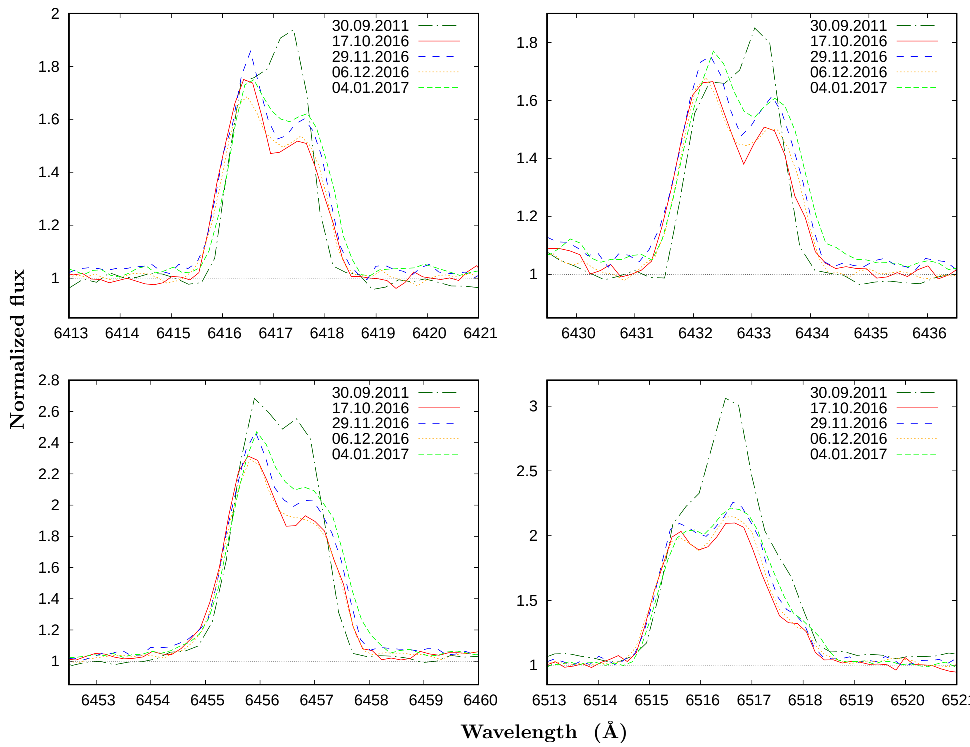

Figure 1: CI Cam Fe II emission line profiles for different epochs. Fe II 6 416 Å (top left) and 6 432 Å (top right), Fe II 6 456 Å (bottom left) and 6 516 Å (bottom right).

We searched for evidences of an outburst in Hα, He I and Fe II emission lines. In Figs.1 and 2 we show line profiles with spectral resolution R $\simeq$ 10 000 at different epochs. Spectra taken within one night revealed no variability beyond noise level and were combined for better signal-to-noise ratio. From the figures we can observe that between the end of 2016 and the beginning of 2017 CI Cam displayed no signs of outburst, the observed variability remained at the same level.

For comparison, we also show spectral line profiles from an earlier observation, which was obtained at Perek 2-m telescope at Ondřejov Observatory on September 30, 2011 using a Coude spectrograph with resolution R $\simeq$ 12 000 (Šlechta & Škoda, 2002).

4. Near infrared observations

The infrared spectroscopic data consists of JHK-band observations taken on November 5 and 14 and December 15, 2016 with GEMINI/GNIRS (Gemini Near Infrared Spectrograph). The spectra were obtained using the XD mode with the 0.15/pix short camera, the 111 mm^{-1} grating and a 0.3 arcsec wide slit, that gives a spectral resolution of R $\simeq$ 6 000. The grating was centered at two different wavelengths 2.13 μm and 2.32 μm, allowing to cover a spectral range of 9 400 to 24 000 Å. Similarly to what is observed in the optical range, IR features do not vary in a significant way during November and December 2016, ruling out the occurrence of an outburst. In Fig.3 we show parts of the near infrared spectra indicating the main identified features. The JHK spectra displays emission in hydrogen Paschen and Brackett series lines, and He I and Fe II lines, similar to the ones observed in the spectrum shortly after the 1998 outburst (Clark et al., 1999). However, CO molecular emission, and He II, Na I, and Pfund series emission lines, that were detected by Clark et al. (1999), are not present in our spectra.

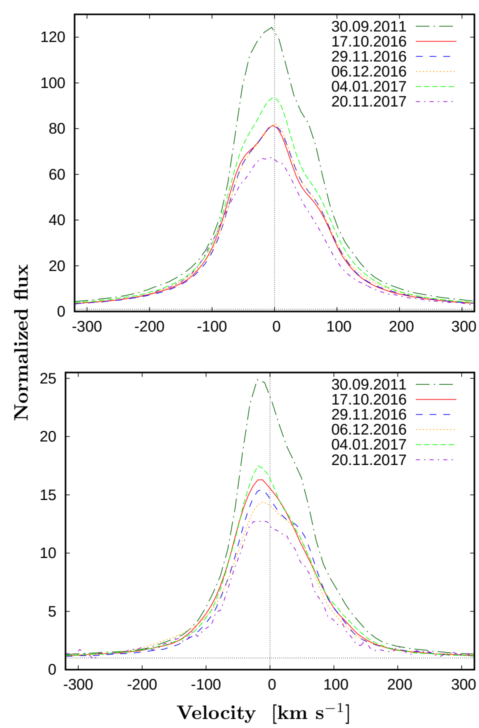

Figure 2: Hα (top) and He I 6 678 Å (bottom) lines in velocity scale.

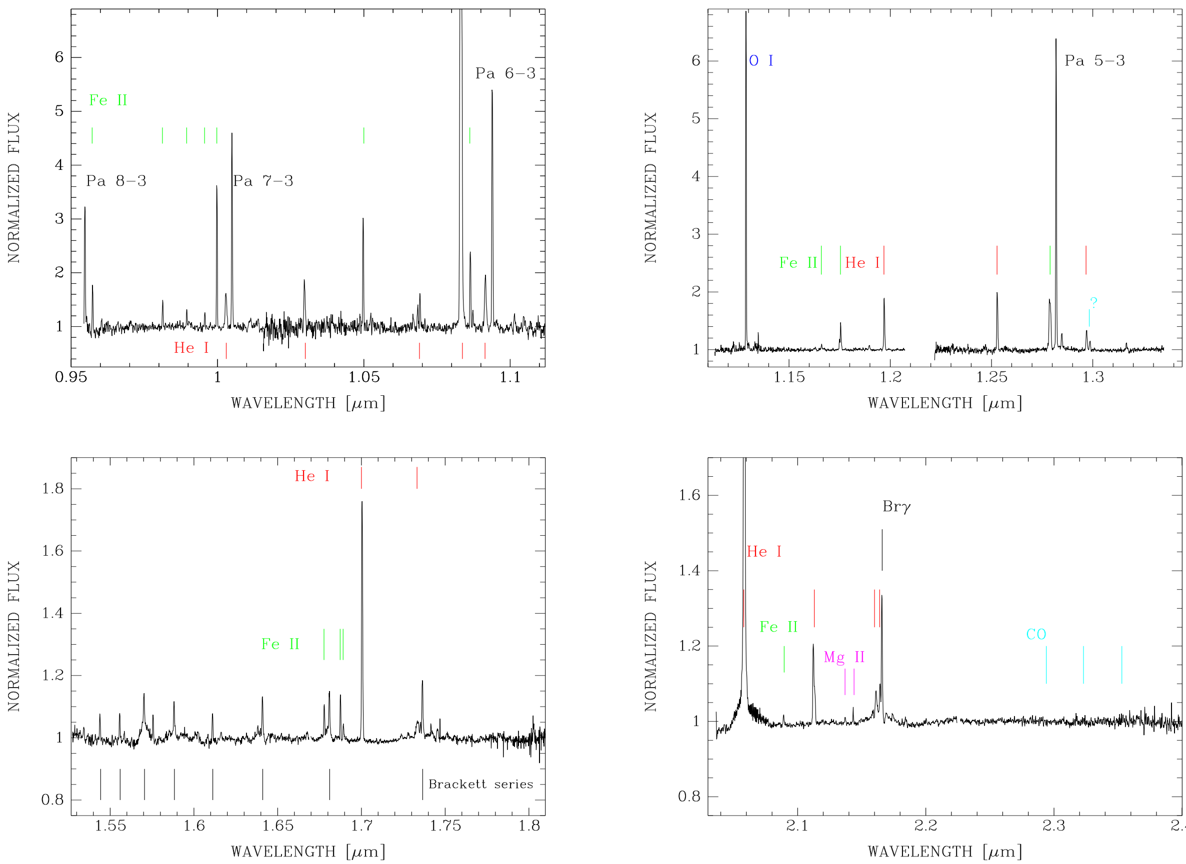

Figure 3: GEMINI/GNIRS medium resolution near-infrared spectra of CI Cam taken in 2016

5. Comments and future work

CI Cam is a unique star that has shown spectroscopic and photometric variability in different timescales. Barsukova et al. (2006) reported variability in brightness and in the radial velocities of He I and Fe II lines. The orbital motion of the binary B[e] star plus compact object is undoubtedly one of the causes of this variability, but not the only one. Barsukova et al. (2006) reported orbital period of 19.4 d, however Bartlett et al. (2019) found no evidence of such a period from X-ray observations. Based on photometric observations, Goranskij et al. (2017) suggested pulsations of the B-type star during CI Cam quiescence phase. Moreover, Goranskij & Barsukova (2009) proposed the presence of a third companion in the system. According to our new optical and infrared observations, although the outburst is not observed, all lines displayed short term variability that deserves to be studied in detail and discussed in the context of different hypothesis (pulsations, binary motion or the presence of a third component). Consequently, CI Cam is a star in permanent active state that deserves to be more deeply studied.

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