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Optical Spectral Evolution of the Gamma-Ray Binary PSR J2032+4127/MT91 213 Toward Its 2017 Periastron Passage

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The gamma-ray binary PSR J2032+4127/MT91 213 (hereafter J2032) harbours a radio and gamma-ray pulsar (Abdo et al. 2009; Camilo et al. 2009), which orbits around its B0Ve companion (Lyne et al. 2015) at ~1.33 kpc, every 45–50 yr. Ho et al. (2017) reported on a significant increase of the X-ray emission one year before the pulsar approached its periastron passage on 2017 November. This X-ray enhancement was explained by the interaction between the stellar and the pulsar winds (Ho et al. 2017; Li et al. 2017). By the time of periastron passage, the source showed a deep X-ray decrease for ~26 days that was followed by a post-periastron rebrightening (Figure 1, middle panel; Li et al. 2018). Similar behavior has also been observed in the gamma-ray binary PSR B1259-63 (hereafter B1259, Chernyakova et al. 2015). In addition, a continued increase in TeV gamma-ray emission of J2032 was detected during this period (Mirzoyan & Mukherjee 2017).

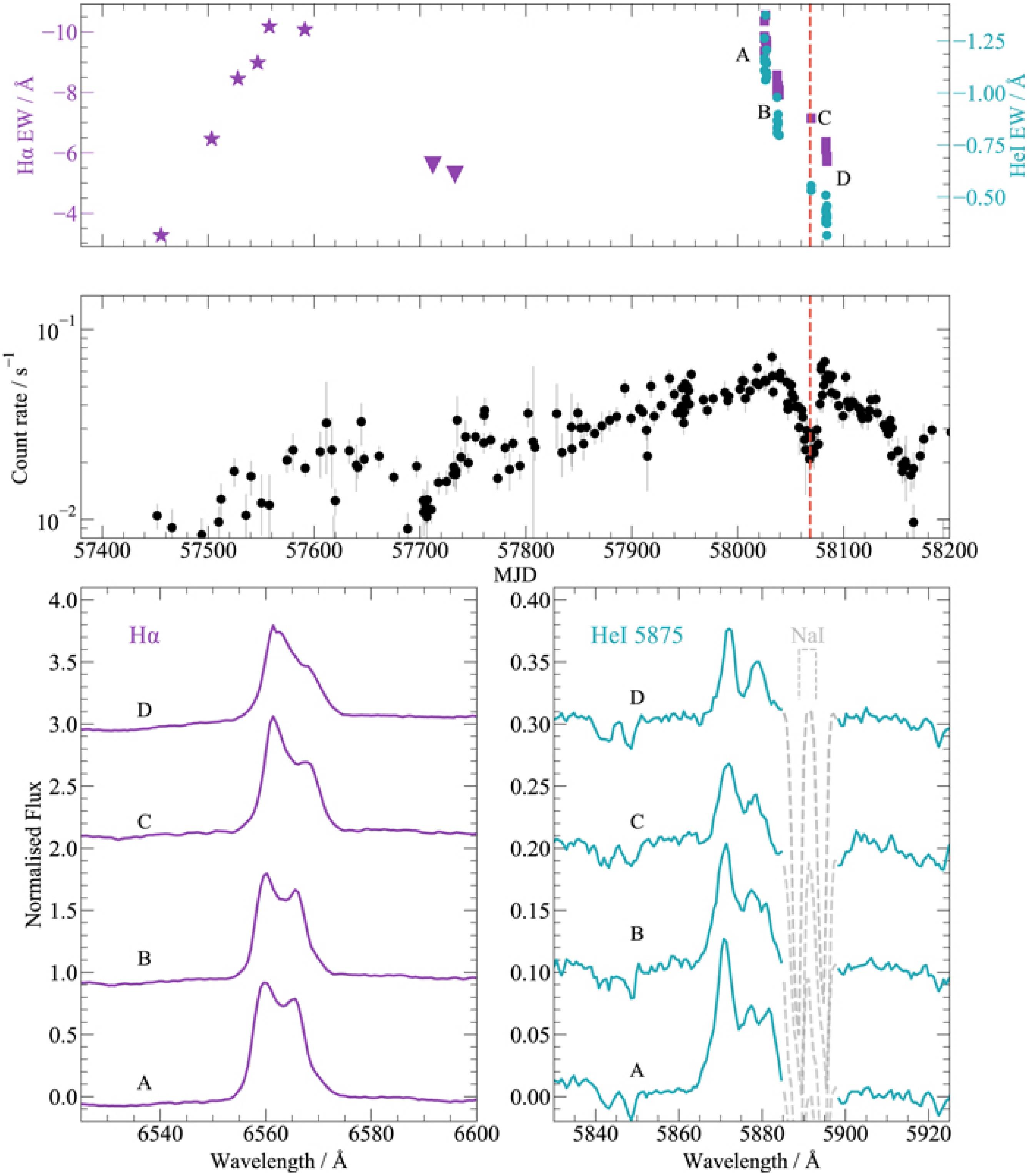

Figure 1. Top: Hα (purple squares) and He I 5875 Å (blue circles) EWs evolution during our campaign. Stars and triangles show the Hα EWs reported by Ho et al. (2017) and Li et al. (2017), respectively. Middle: *Swift*/XRT light-curve. Bottom left: Hα line-profile evolution. Labels show the different campaign stages indicated in the top panel. Bottom right: He I 5875 Å line-profile evolution with previous labels (Na I D doublet is plotted in gray). Vertical red lines indicate periastron passage.

The aim of our campaign was to study the J2032 optical behavior toward periastron. We used the 2.1 m telescope at Observatorio Astronómico Nacional, Sierra San Pedro Mártir (OAN-SPM, Mexico), with the Boller & Chivens spectograph (resolution of $R \sim 1200$) in the 5400–6600 Å range. Our monitoring spanned from 2017 September to November, and consisted of four epochs with a length of three nights each run. The cadence corresponded to one run every month, except in November where two epochs were obtained to get better coverage of the periastron and post-periastron activity. Standard spectroscopic data reduction was performed using IRAF[3] tasks and flux calibration was carried out using the BD+28 4211 standard star (Oke 1990).

Here we report on the results of our J0232 monitoring. Our campaign epochs ("A" to "D" in Figure 1) showed an evolution in the Hα and He I 5875 Å emission-line profiles. The double-peak Hα profile became a single-peak line in the blue part of the line with a broader wing in the red part after the periastron (Figure 1, bottom left panel). While the full width half maximum (FWHM) of the blue part of the Hα line slightly varied from ~200 to ~225 km s^{-1}, the FWHM of the red part decreased from ~300 to ~225 km s^{-1} in 3 months. In the case of He I 5875, the line's profile not only changed from three-peak to double-peak like, but also the normalized flux declined with the proximity of the periastron passage (Figure 1, bottom right panel). All these changes contributed to the evolution in the equivalent widths (EWs) of both Hα and He I 5875 (Figure 1, top panel). The Hα EWs decreased from ~10 to ~6 Å (consistent with the EW evolution reported by Kolka et al. 2017) while He I 5875 Å EWs from ~1.35 to ~0.3 Å. We calculated the change of the circumstellar decretion-disk size using Equation (1) in Ho et al. (2017), which relates the decretion disk and stellar radii (R_{OB}) to the Hα EW. The decretion disk shrank from ~90 to ~60 R_{OB} during our monitoring.

The detection of the Hα and He emission lines confirm the presence of a decretion disk around the companion star during our monitoring. The line-profile variations and EW values indicate that global changes were occurring in the disk. In particular, the decrease in EWs indicates a disk-size reduction while the neutron star was approaching its periastron. However, we cannot conclude that the shrinking of the disk was exclusively driven by the neutron-star influence as other factors (e.g., stellar activity or an asymmetric disk structure) may also play important roles in the system's evolution (Reig 2011). Additionally, the optical behavior of J2032 during periastron is completely opposite to that of B1259 (Chernyakova et al. 2015), despite their similar

X-ray behavior.

Observations obtained at OAN-SPM and using the Neil Gehrels *Swift* observatory. J.E. is indebted to DGAPA (UNAM) for financial support, PAPIIT project IN114917.

Footnotes

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