High-mass X-ray Binaries: Illuminating the Passage from Massive Binaries to Merging Compact Objects
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Studying the H-alpha line of the B[e] supergiant binary GG Carinae using high-cadence optical spectroscopy

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Abstract. We present a case study of GG Carinae (GG Car), a Galactic B[e] supergiant binary having significant eccentricity (0.28), based on Global Jet Watch spectroscopy data which has been collecting high-time-sampled optical spectra since early 2015. GG Car has so far not been observed in the X-ray band, however it is of similar phenomenology to known X-ray binaries and may therefore be an obscured X-ray source. We have discovered that the absorption component of the H-alpha line displays a ∼462-478-day period in both equivalent width and wavelength centroid indicating cycles in the dynamics of the circumstellar environment, such as precession of the circumbinary or circumprimary disk. Circumbinary disk precession is an as-of-yet under-explored origin of super-orbital variations in the X-ray flux of X-ray binaries, since the rate of precession is generally much longer than the orbital period of the inner binary.

Keywords. stars: binaries - stars: emission-line, Be - stars: supergiants - stars: individual: GG Car

1. Introduction

GG Car is a Galactic eclipsing binary comprising a B[e] supergiant (sgB[e]) in the post main sequence phase of its evolution and a secondary of an unknown type. GG Car has been known for a few decades to display both spectroscopic and photometric variability with a period of ∼31 days (Hernandez *et al.* 1981; Gosset *et al.* 1984; Brandi *et al.* 1987). Lamers *et al.* (1998) classified GG Car as an sgB[e] based on its effective temperature and luminosity, and its exhibiting the B[e] characteristics. The orbital solution was revised by Marchiano *et al.* (2012) to a period of 31.033 days, eccentricity of 0.28, and mass ratio of 2.2. Kraus *et al.* (2013) discovered GG Car's circumbinary disk from CO emission, and Maravelias *et al.* (2018) found that the forbidden emission must originate from circumbinary regions. Doolin & Blundell (2011) found that the orbits of test particles in circumbinary orbits are expected to precess in inclination and longitude of ascending node, with the rate determined by the binary eccentricity and mass ratio. Martin & Lubow (2018) confirmed this behaviour applies to gaseous circumbinary disks.

2. Results

GG Car's H-alpha line can be adequately fit throughout all epochs using a model comprising five gaussians. The time-dependence of the centroid and the equivalent width of the absorption component was studied with Fourier analysis utilizing the CLEAN algorithm to extract the spectrum from unevenly sampled data (Roberts *et al.* 1987). Figure 1, left, displays the variation of the centroid of the absorption component and

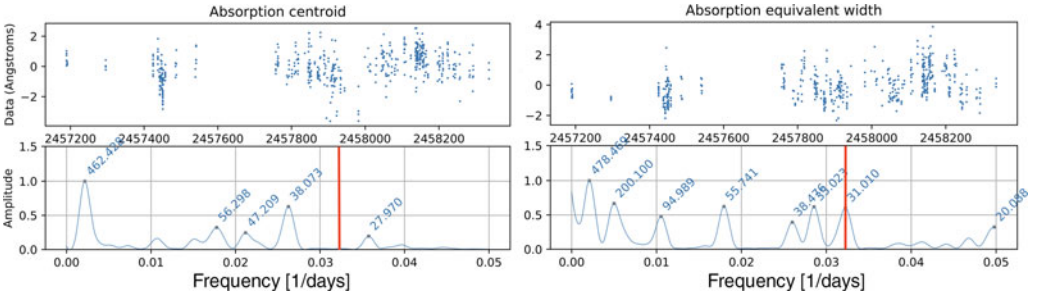

Figure 1. The variation of the centroid of the absorption component of the H-alpha line in GG Carinae (top figure, the data is mean subtracted) and the corresponding Fourier power spectrum (normalised to the strongest peak). Significant peaks have been labeled with their corresponding periods in days. A thin red line denotes a 31.033 day period.

its corresponding Fourier spectrum, while right displays the same but for the equivalent width of the absorption component.

The Fourier spectrum of the centroid has its strongest peak around 462 days, a period which has not been noted before for GG Car, and it does not have any variation with the ∼31 day period of the inner binary. The Fourier spectrum of the equivalent width has its strongest peak at 478 days, which is consistent with the 462-day peak in the centroid power spectrum. The two long periodicities possibly indicate super-periodic variations in GG Car's circumstellar environment. The equivalent width of the absorption component, but not the centroid, has a dependency on the ∼31 day period of the inner binary.

3. Discussion

A ∼470-day candidate period is apparent for the centroid position and strength of the absorption component of the H-alpha line, indicating that there are varying amounts of absorbing atomic Hydrogen along the line of sight with this period. This long-term variation may be indicative of precession of the circumbinary disk as the orbits changes their inclination and longitude of ascending node, or due to changing conditions in the stellar wind of the sgB[e] primary. A similar study will be carried out on the Helium lines in GG Car, which also display strong P-Cygni profiles to disentangle the scenarios. This work explores the possibility that periodic precession of a circumbinary disk may obscure the inner binary with a super-periodic timescale. Circumbinary precession could therefore explain some of the super-periodic variations seen in many X-ray binary sources.

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