Massive Stars Near and Far
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Deciphering hard disks

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Abstract. Some Be stars were found to emit very bright and extremely hard thermal X-rays. This so-called γ Cas-star category is rapidly growing, showing that the phenomenon is far from being uncommon and its consequences on Be population feedback should be examined. The origin of this X-ray peculiarity is however much debated. In this contribution, we review the most recent observational clues and derive constraints on the cause of the phenomenon: properties of these stars (multiplicity status, photometric variability), X-ray reaction to disk changes, impact of stripped-star companions on the X-ray emission,...

Keywords. stars: emission-line, Be; stars: early-type; X-rays: stars

1. Introduction

In the 19th century, emission lines were detected in the spectrum of γ Cas, the star at the heart of the Cassiopeia constellation, leading to the definition of the Be category. A century later, the star was however found to be atypical in the X-ray range (for a review, see Smith et al. 2016). In the last two decades, two dozen other Be stars were found to display similar high-energy properties (e.g. Nazé & Motch 2018). Their X-ray emission is bright ($\log(L_X) \sim 31.6 - 33.2$, $\log(L_X/L_{BOL})$ of –6.2 to –4) and hard ($kT > 5$ keV). It also presents short-term "flares" and a fluorescent FeKα line is also detected in the X-ray spectrum near the usual iron complex at 6.7 keV. The origin of such an emission remains debated, with different scenarios proposing to link the emission to a companion (accretion onto a compact object, collision of companion's wind with the Be disk) or to magnetic star-disk interactions.

2. Photometric variability

The variability of most γ Cas stars was studied using SMEI, BRITE, and TESS high-precision photometry (Nazé et al. 2020a,b). The periodograms display red noise, frequency groups, isolated NRP frequencies (including dominant ones and signals at high frequencies). Changes in the frequency content are also detected during/near outbursts. All these characteristics are also found, with a similar incidence, in other Be stars.

3. Are they alone?

While Be stars are now often considered as binary interaction products, only two γ Cas stars were previously known to be binaries (γ Cas and π Aqr). Thanks to a monitoring done with high-resolution spectrographs (UVES, Carmenes, HEROS - Nazé et al. 2022a),

6 new orbital solutions were found (even revealing one quadruple system!) and five other stars showed velocity shifts reminiscent of binary motion although more data are needed to establish an orbital solution. Other objects are too faint or their spectrum too variable to perform a velocity study. For the detected binaries, the small velocity amplitudes and long periods are similar to other Be spectroscopic binary systems.

4. What happens if the disk changes?

A long-term monitoring of the Hα line in several γ Cas stars was undertaken, and X-ray observations were triggered when the disk changed substantially (Rauw et al. 2019 and submitted, Nazé et al. 2019, 2022b). For HD 45314, the hottest γ Cas object, the hard X-rays nearly fully disappeared when the Hα emission was very reduced. In contrast, π Aqr always displayed γ Cas characteristics, even when its disk was extremely small. Its X-ray emission does vary somewhat in brightness and hardness but these changes are not correlated with orbital phase or *EW* values. In addition, γ Cas has shown a recent strong increase in Hα emission but it didn't lead to much change in the hard X-rays or in V-magnitude. Finally, despite very weak Hα emissions, V767 Cen and HD 119682 always remained γ Cas analogs. Their X-ray properties were unchanged as their disk varied, with a general trend towards smaller Hα emission superimposed on short-term surges in emission.

5. Impact of stripped-star companions in the X-ray range

We have performed the first X-ray survey of all known Be+stripped systems (Nazé et al., submitted). Most systems remain undetected in the X-ray range, with very low X-ray luminosity limits. Amongst the detections, only two systems display γ Cas characteristics while other systems show faint and soft X-ray emissions. The γ Cas incidence appears similar to that of general Be samples. Furthermore, no link was found between X-ray luminosity and orbital period or companion properties, in contrast with expectations from the wind-disk collision scenario.

6. Conclusion

No specific signature of the γ Cas phenomenon was found outside the X-ray range. Many γ Cas stars actually are binaries, but no link is found between the X-ray emission and the orbital phase. Moreover, the γ Cas character of the X-ray spectrum remains even if the Hα emission is very small. No obvious correlation is found between X-ray flux and Hα strength or with orbital phase, but changes are detected in X-rays when both broad-band magnitude and Hα strength vary. All this suggests that the external parts of the disk are of limited importance in the γ Cas phenomenon, thereby favoring the star-disk interaction scenario.

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