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The surprising X-ray emission of Oe stars

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Abstract. Oe stars are thought to represent an extension of the Be phenomenon to higher temperatures. Dedicated XMM observations of HD 155806 revealed a surprising X-ray spectrum: soft character, absence of overluminosity, broad X-ray lines. These properties are fully compatible with the wind-shock model, which usually explains the X-rays from "normal", single O-type stars. In contrast, some other Oe/Be stars display a completely different behaviour at high energies.

Keywords. X-rays: stars, stars: early-type, stars: individual (HD 155806), stars: emission-line, Be

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1. Introduction

The Oe category was defined by Conti & Leep (1974) as O-stars displaying emission in Balmer lines without emission in the He II 4686 and N III 4634/41 lines. Their line profiles being reminiscent of those of Be stars, they are often seen as the continuity of the Be phenomenon at higher temperatures. While direct evidence of disk-like features has been found for Be stars, only indirect evidence can be put forward in the case of Oe stars, such as high projected rotational velocities (Negueruela *et al.* 2004) or long-term spectral variability similar to that of Be objects (e.g. Rauw *et al.* 2007). In this context, X-rays can be useful as they often provide crucial evidence for identifying peculiar wind features. Indeed, if the equatorial regions are optically-thick, some absorption effects should be seen, whereas a strong magnetic confinement would yield X-ray emission very different from that of "normal" O-stars (bright, hard vs faint, soft).

2. HD 155806

HD 155806 is the earliest Oe star (O7.5e), therefore potentially represents an extreme case among the Oe objects. As for Oe/Be stars, variations are detected for HD 155806 but the Hα emission never disappears completely. The star is thought to be single (Garmany *et al.* 1980) and may be magnetic (Hubrig *et al.* 2008, Petit *et al.* 2009).

We investigated its X-ray emission thanks to a sensitive XMM-Newton observation, which yields both medium-resolution spectra (EPIC-MOS and pn) and high-resolution data (RGS). This 35ks exposure was taken in mid-2008, and an archival UVES spectrum obtained close to that date shows strong Hα emission. The data analysis is described in length in Nazé *et al.* (2010). The main results are: the X-ray spectrum is very soft (average plasma temperature $\sim$0.2keV) and well fitted by two "cool" (<0.7keV) thermal components without the need of absorption in addition to ISM; no variations are detected on both short- and long-term ranges; there is no overluminosity ($L_X/L_{BOL} = -6.75$); the X-ray lines are symmetric, broad (with FWHM$\sim$2500 km s^{-1} and a strict lower limit of 1000 km s^{-1} for the 90% confidence interval of the worst fit), and with f/i ratios indicating line forming regions $< 10R_*$. All these properties are typical of O stars.

3. Do Oe stars have disks ?

The question of whether Oe stars have disks or not, we believe, is a wide open question. Using spectropolarimetric data, Vink *et al.* (2009) reported the non-detection of any wind asymmetries or disk-like features for a sample of peculiar O-stars (Oe, Of?p,...). However, before drawing such a conclusion, it is worth looking at these results a bit closer. Here, we summarize two main reasons why doubts could be cast (for a detailed rationale, see Nazé & Rauw 2010). First, no asymmetries/disk-like features are detected even for the well-known case of θ^1 Ori C (for which several evidences of a magnetically-confined wind have been found). A putative "inner disk hole" is put forward by the authors, but such a feature is neither detected in the data nor predicted by models (which otherwise reproduce well the observed stellar characteristics). This a posteriori guess of a "hole" should therefore be reconsidered to account for the star's known properties. Second, a similar absence of detection in Oe stars was found and attributed to the lack of disk-like features in the wind. This could at first seem to corroborate our high-energy results, but the authors then propose the presence of "an expanding shell which is spherically symmetric" to explain the double-peaked profiles, characteristics of Oe and Be stars. This scenario would result in strongly variable emission lines on rather short timescales: such changes are not observed, ruling out the shell scenario. The question of absence or presence of disk-like features in Oe stars thus remains open. Any new model should take into account the full properties of Oe stars, including their resemblance with Be objects.

4. X-rays from Oe/Be stars: comparison

For HD 155806, the X-ray emission is comparable to that of "normal" O-stars. There is no evidence for additional absorption or strong magnetic confinement. The physical phenomenon at the origin of the Oe characteristics (a disk-like feature?) thus seems to have no impact whatsoever in the X-ray range. This is very different from the case of θ^1 Ori C, where a magnetically-confined disk-like region clearly rules the X-ray emission.

Only one other Oe has been observed in the high-energy range: HD 119682 (O9.7e), whose high-energy properties were reported by Rakowski *et al.* (2006). Contrary to HD 155806, its X-ray emission is both hard (kT ~10keV) and bright ($L_X/L_{BOL} = -5.4$). It actually resembles that of some Be stars (the so-called "γ-Cas analogs"). At first, such emission was thought to be linked to the Be disk, but doubts have recently been expressed that the harder emission of γ-Cas itself is related to the Be phenomenon (Smith *et al.*, these proceedings). This seems to be supported by our observations, notably: not all Oe/Be stars show these peculiar characteristics.

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