Overall properties of hot, massive stars in the X-ray domain

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Abstract. Despite the absence of large surveys, the recent X-ray observatories provide X-ray data for hundreds of massive stars (294 OB stars detected in the 2XMM catalog, 129 OB stars detected in the Chandra Carina Complex Project). Analyzing medium-resolution spectra led to new results on the relationship between the X-ray luminosity and the bolometric luminosity, as well as on the typical properties (plasma temperature, variability) of these objects.

Keywords. X-rays: stars, stars: early-type

1. Introduction

The X-ray emission of hot stars was serendipitously discovered in 1978-9 (Harnden *et al.* 1979, Ku *et al.* 1979, Seward *et al.* 1979). A link between the X-ray and the visible/bolometric luminosities was readily suggested (Harnden *et al.* 1979, Pallavicini *et al.* 1981). With time, this relation was investigated theoretically as well as observationally.

Theoretical considerations show that Lx "naturally" scales with $\dot{M}/v_\infty$ and therefore with the bolometric luminosity IF there is "a delicate balance between X-ray emission and absorption" AND "a special form for the radial distribution of wind shocks" (Owocki & Cohen 1999). In fact, the X-ray filling factor should vary with radial distance from the star as r^{-s} (with s=0.25–0.4, but recent fitting of X-ray lines rather yields s=0, Cohen *et al.* 2006).

In-depth observational studies of that $L_X - L_{BOL}$ relation were also performed, with two different approaches. On the one hand, Berghöfer *et al.* (1997) correlated the Rosat All-Sky Survey (RASS) with the Yale bright star catalog (i.e. an heterogeneous population of massive stars, mixing field and cluster objects). Fixing the interstellar absorption, they used the RASS count rates and hardness ratios to derive absorption-corrected X-ray luminosities. They confirmed that $L_X = 10^{-7} \times L_{BOL}$ down to 10^{38} erg s^{-1} ($\sim$B1–1.5), though a large scatter (0.4 dex) existed around the relation. On the other hand, XMM-Newton and Chandra took sensitive observations of several clusters (i.e. homogeneous populations). In some cases (e.g. NGC6231 Sana *et al.* 2006, Carina OB1 Antokhin *et al.* 2008), a detailed analysis of the X-ray spectra, taking into account the interstellar absorption (fixed) but also the potentially additional wind absorption, could be done. It provided precise X-ray ! luminosities while, in parallel, precise bolometric luminosities were derived from dedicated monitorings. From these studies, the scatter around the $L_X - L_{BOL}$ relation appears reduced (0.1–0.2 dex). The difference in scatter could have two causes: (1) the improvement in the knowledge of the physical parameters in the recent studies (stellar multiplicity, spectral types and improved photometry from monitorings, detailed X-ray spectral characteristics) or (2) the difference in data analysis (single/several instrument and reduction software, same/different BC and gas-to-dust ratio) and stellar populations (homogeneous vs heterogeneous populations).

2. Hot stars in the 2XMM

The 2XMM survey is not an all-sky survey but a compilation of all archival XMM-Newton datasets (Watson *et al.* 2009). Nevertheless, it permits to combine the characteristics of both approaches, i.e. a detailed fitting and a homogeneous treatment of a large (but heterogeneous) sample of stars. Cross-correlating the Reed catalog (Reed 2003, which takes into account the recent monitorings), 294 OB stars were detected, half of these being bright enough for lightcurve/spectral analyses. The results are (Nazé 2009): X-ray variability appears rare on short timescales but rather common on long timescales; the distribution of the detected O-stars is similar to the overall catalog distribution but there is a lack of detections for late and giant B-stars; the spectral fitting revealed the need for both an additional absorption and a second, hot thermal component (often at ∼2keV, which is unexpected!) in O-stars; O+OB binaries display X-ray luminosities quite similar to those of sin! gle objects. Finally, the L_X/L_{BOL} ratio shows a scatter similar to that found in the RASS: cluster-to-cluster differences therefore probably exist.

3. Hot stars in the CCCP

The Chandra Carina Complex Project led to the detection of 129 OB stars, half of them having more than 50 recorded counts (i.e. being fit for at least a rough spectral analysis). Spectral fitting was then performed as for the 2XMM sample, on a large but homogeneous sample of stars. The results (Nazé *et al.* 2010, submitted) confirm the 2XMM findings, i.e. there is a need for additional absorption and 2nd hard thermal component in O-stars and, apart from HD 93403, X-ray bright wind-wind collisions are rare in most O+OB binaries. In addition, there is a smooth transition in the X-ray properties from the late O- to the earliest B-stars; the scatter around the $L_X - L_{BOL}$ relation is small, as for NGC6231; and there is a shallow increasing trend (to be confirmed!) of medium-to-soft flux ratio with larger L_X/L_{BOL} ratio or L_{BOL}. Open questions remain, however, e.g. most sources are soft and not luminous and the few overluminous and hard ones are CWB or MCW candidate! s - but what are the other outliers?

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