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Examining O and WR star winds with X-rays

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Abstract. The X-ray spectra of O stars show characteristic emission-line profiles. Their shape results from the attenuation of the X-ray emission by the inhomogenous wind material, and can be reproduced by adequate models. The wind absorption in Wolf-Rayet type stars is at least order of magnitude higher than in O-type stars. This high wind absorption was suggested to explain the lack of X-ray emission from WC-type stars. Winds of WN stars are less opaque for X-ray than winds of WC stars. Some putatively single WN stars are detected in X-rays, while others are not. It is presently unclear whether wind absorption alone can account for the different levels of X-ray emission observed in WR stars. – The profile of the N VII resonance line in the X-ray spectrum of ζ Puppis shows a self-absorption feature, indicating that the hot X-ray emitting plasma is optically thick.

1. X-rays from O and Wolf-Rayet type stars

High-resolution X-ray spectra of O stars were obtained by Chandra and XMM-Newton. These spectra and the emission line profiles are explained by taking account the clumped nature of O star winds (Oskinova et al. 2006). The clumping of O star winds is now widely accepted (e.g. Puls, these proceedings). No high-resolution spectrum of a single WR star is available yet.

The broad band (0.2-10 keV) X-ray observations of early type stars reveal interesting trends. The X-ray emission of O+O binaries do not differ significantly from O+WR binaries and the correlation $L_{\rm X} \approx 10^{-7}\,L_{\rm bol}$ holds in both cases. Some single WN type stars are relatively bright in X-rays, while no WN8 type star was ever detected. E.g. WR1 (WN4) has a luminosity of $L_{\rm X} = 2 \times 10^{32}\,{\rm erg\,s^{-1}}$, while an upper limit to the luminosity of WR40 (WN8) is $L_{\rm X} < 10^{30}\,{\rm erg\,s^{-1}}$ (see e.g. Oskinova 2005). No single WC star have been detected in X-rays either (Oskinova et al. 2003). We have employed the PoWR stellar atmosphere code (Hamann et al. 2004) to study the wind opacity in different types of hot stars. The radii in the wind where the radial optical depth is unity at X-ray wavelengths are shown in Fig. 1. As can be seen, the wind of WR40 is more transparent for X-rays than the wind of WR1, however the former star is at least two order of magnitude X-ray fainter than the latter. Other WN stars which are not detected in X-rays include WR16, WR124, WR148 (all WN8), and WR61, WR157 (both WN5). The lack of detectable X-ray emission and high spectral and photometric variability of WN8-type stars invokes questions about the nature of the wind driving in these stars.

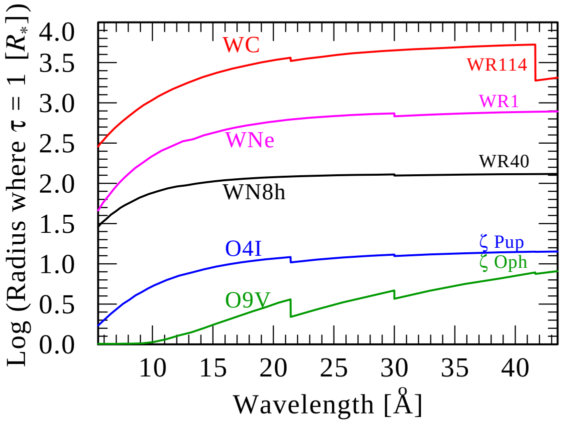

Figure 1. Radii in the wind where the radial optical depth is unity for different types of hot stars, calculated by PoWR models.

2. Self-absorption in the hot wind component in ζ Pup

The XMM-Newton observations of ζ Pup revealed a "ragged" structure of the N VII line profile with a "dip" at λ24.74Å. Our ζ Pup atmosphere models show that N VII is absent in the cool wind component, which therefore cannot be responsible for the observed absorption dip. However, such line profile is typical for optically thick lines in the winds of hot stars. Fig. 2 shows an optically thick He II line in the spectrum of WR 3, overplotted with the N VII line in ζ Pup spectrum. The similarity suggests that the dip in the N VII line is also due to self-absorption; a rough estimate yields that that there is enough N VII present in the hot plasma component of ζ Pup.

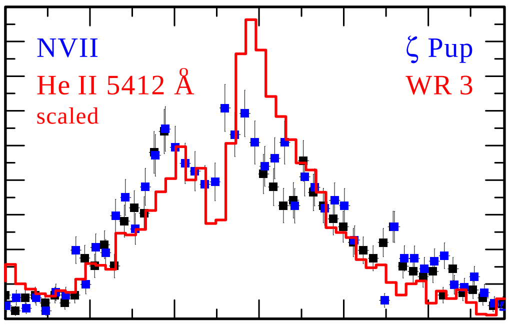

Figure 2. Comparison between the an optically thick He II line in WR 3 (histogram) and the N VII profile in the X-ray spectrum of ζ Pup (error bars)

References

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