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Testing the Wind-shock Paradigm for B-Type Star X-Ray Production with θ Car

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Abstract. We present Chandra X-ray grating spectroscopy of the B0.2V star, θ Carina. θ Car is in a critical transition region between the latest O-type and earliest B-type stars, where some stars are observed to have UV-determined wind densities much lower than theoretically expected (e.g., Marcolino *et al.* 2009). In general, X-ray emission in this low-density wind regime should be less prominent than for O-stars (e.g., Martins *et al.* 2005), but observations suggest a higher than expected X-ray emission filling factor (Lucy 2012; Huenemoerder *et al.* 2012); if a larger fraction of the wind is shock-heated, it could explain the weak UV wind signature seen in weak wind stars, but this might severely challenge predictions of radiatively-driven wind theory.

We measured the line widths of several He-, H-like and Fe ions and the f/i ratio of He-like ions in the X-ray spectrum, which improves upon the results from Nazé *et al.* (2008) (*XMM-Newton* RGS) with additional measurements (*Chandra* HETG) of MgXI and SiXIII by further constraining the X-ray emission location. The f/i ratio is modified by the proximity to the UV-emitting stellar photosphere, and is therefore a diagnostic of the radial location of the X-ray emitting plasma. The measured widths of X-ray lines are narrow, <300 km s^{-1} and the f/i ratios place the X-rays relatively close to the surface, both implying θ Car is a weak wind star. The measured widths are also consistent with other later-type stars in the weak wind regime, β Cru (Cohen *et al.* 2008), for example, and are smaller on average than earlier weak wind stars such as μ Col (Huenemoerder *et al.* 2012). This could point to a spectral type divide, where one hypothesis, low density, works for early-B type stars and the other hypothesis, a larger fraction of shock-heated gas, explains weak winds in late-O type stars. Archival IUE data still needs to be analyzed to determine the mass loss rate and hydrodynamical simulations will be compared with observations to determine which hypothesis works for θ Car.

Keywords. line: profiles, techniques: spectroscopic, stars: winds, outflows, X-rays: stars

References

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