A Massive Star Odyssey, from Main Sequence to Supernova
Proceedings IAU Symposium No. 212, © *2003 IAU*
K.A. van der Hucht, A. Herrero & C. Esteban, eds.

The dominant X-ray wind in massive star binaries

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Abstract. We investigate which shocked wind is responsible for the majority of the X-ray emission in colliding wind binaries, an issue where there is some confusion in the literature, and which we show is more complicated than has been assumed. We find that where both winds rapidly cool (typically close binaries), the ratio of the wind speeds is often more important than the momentum ratio, because it controls the energy flux ratio, and the *faster* wind is generally the dominant emitter. When both winds are largely adiabatic (typically long-period binaries), the slower and denser wind will cool faster and the *stronger* wind generally dominates the X-ray luminosity.

1. Introduction

The violent wind-wind collision in massive star binaries creates a region of high temperature shock-heated plasma, which can contribute to the total system emission at radio, infrared, optical, ultraviolet and X-ray wavelengths (*e.g.*, Williams *et al.* 1990). As the X-ray emission depends on the physical conditions within the wind collision zone (WCZ) and on the distribution and properties of the unshocked attenuating wind material, such observations can provide information on the system parameters (*e.g.*, Stevens *et al.* 1996; Zhekov & Skinner 2000; Pittard & Corcoran 2002).

To interpret these it is useful to know which wind dominates the X-ray emission. Simple expressions for the X-ray luminosity from each of the shocked winds have been presented in an elegant paper (Usov 1992), and are often used in the literature. However, we have recently discovered inconsistencies between results from these expressions and those determined from numerical models, leading to some confusion on the issue of the dominant X-ray emitting wind. We summarize here the results of a recent analysis (Pittard & Stevens 2002) which addresses this point.

2. Results

Let us define L_1 as the X-ray luminosity from the shocked wind with the greater momentum flux (*i.e.*, the 'stronger' wind), and L_2 the equivalent from the shocked weaker wind. There are analytical estimates in the literature of the

https://doi.org/10.1017/S0074180900212114 Published online by Cambridge University Press

ratio of L_1/L_2 for two limiting cases: the radiative limit, where the cooling timescale for the hot gas from both winds is assumed small in comparison to the timescale for flow of this gas out of the system; and the adiabatic limit, where the opposite is true.

In the radiative limit, the entire kinetic energy thermalized by the shocks is immediately radiated (normally with the majority at X-ray energies), and the WCZ is thin. If we consider the region of the WCZ which lies directly between the stars, we deduce that the relative kinetic energy fluxes are proportional to the ratio of the wind speeds, so emission from this volume is dominated by gas from the star with the faster wind. Since the bulk of the emission likely arises close to the stars, the faster wind therefore also dominates the *total* emission. We further find that the value of L_1/L_2 depends to a much lesser extent on the wind momentum ratio, $\eta = (\dot{M}_2 v_{\infty 2})/(\dot{M}_1 v_{\infty 1})$.

A highly radiative WCZ generally exists only in very close binaries, so in reality it is probable that neither wind will have room to reach terminal speed. As the stronger wind will have more room to accelerate, we would normally expect it to be faster, and to dominate the emission. However, if there is substantial radiative braking (Owocki & Gayley 1997), this will cause the strong wind to be significantly slower and may shift the dominant energy generation back to the weaker wind.

In the adiabatic limit, we confirm earlier findings (*e.g.*, Myasnikov & Zhekov 1993) that the stronger wind is typically the dominant X-ray emitter, often by an order of magnitude relative to the weaker wind. The dominant driver of L_1/L_2 is the ratio of the cooling parameters, χ_1/χ_2 (see Stevens, Blondin & Pollock 1992 for the definition of χ), so that the stronger wind is in general more radiative. If we force $\chi_1/\chi_2 \approx 1$, we find that both winds contribute roughly equally to the X-ray emission irrespective of the value of η. In contrast, the equations in Usov (1992) yield $L_1 \approx L_2$ irrespective of the assumed wind parameters.

For systems in-between these limits, we anticipate that the dominant luminosity should generally switch from the faster wind (radiative limit) to the slower wind (adiabatic limit). Where one shocked wind is substantially closer to the radiative limit than that of the other, the X-ray emission will naturally be dominated by the former.

Acknowledgments. We would like to thank Ken Gayley, whose comments led to this work and who as referee helped to clarify some of the points.

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