Populations of High Energy Sources in Galaxies
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Colliding Wind Binary X-ray Sources

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Abstract. Very massive stars ($\gtrsim$20 $M_\odot$) are rare but important components of galaxies. Products of core nucleosynthesis from these stars are distributed into the circumstellar environment via wind-driven mass loss. Explosive nucleosynthesis after core collapse further enriches the galactic medium. Clusters of such stars can produce galactic chimneys which can pierce the galactic disk and chemically enrich intergalactic space. Such processes are vitally important to the chemical evolution of the early Universe, when the stellar mass function was much more weighted to massive stars.

Very massive stars are difficult to study, since they are formed in distant clusters which yield problems of sensitivity and source crowding. A relatively new tool for studying these systems is via high spatial, spectral and temporal resolution observations in the X-ray band. In this note we describe some recent progress in studying mechanisms by which very massive stars produce X-ray emission.

Keywords. X-ray emission, binary stars, winds.

1. Introduction

The advent of modern X-ray optics and detectors has revolutionized our astrophysical understanding of high energy processes in galaxies. While X-ray luminosity functions in normal galaxies are dominated by the end-products of stellar evolution (black holes, neutron stars and supernova remnants) the study of the fainter stellar X-ray source populations has increased our knowledge of the evolution of these sources, and how they contribute to the evolution of the galactic and intergalactic medium. A particularly rare but important population of such relatively faint sources are the "colliding wind" X-ray binaries. In these objects, which are composed of a pair of massive stars (O stars, Wolf-Rayet stars, or some combination) undergoing strong mass loss, X-ray emission primarily arises in the "bow-shock" where the winds from the stars collide. The emission from these systems provides an extremely useful probe of the nature of the shock, and by inference the nature of the mass-loss process, itself important since mass loss drives the subsequent evolution of the star and determines the final outcome for it (a neutron star or black hole, a supernova or a hypernova).

Problems in observing X-ray emission from such "colliding-wind" binaries (CWBs) arise due to limitations in spatial resolution (many such systems occur in crowded cluster cores), in spectral resolution (the emission tends to be thermal and thus X-ray line properties provide important information about the flow) and in monitoring (the X-ray emission is variable due to changes in emission measure &/or intervening absorption). The availability of the high resolution and high sensitivity detectors on the *Chandra* and *XMM-Newton* X-ray observatories, along with the scheduling flexibility of the *Rossi X-ray Timing Explorer* (*RXTE*) has allowed detailed examination of some of the bright CWBs.

2. A Brief Review of Current Observations

Observations of massive clusters with *Chandra* and *XMM-Newton* have shown that many of the bright stars in the core either show X-ray excesses &/or X-ray variability. Examples include studies of NGC 3603 by Moffat *et al.* (2002), the Galactic Center clusters (Law & Yusaf-Zadeh 2004) and NGC 6231 (Sana *et al.* 2004). These observations reveal emission at a level of $\gtrsim 10^{34}$ ergs s^{-1} in NGC 3603, far exceeding the canonical relation $L_x/L_{bol} \approx 10^{-7}$ by at least an order of magnitude. The identification of long-period binaries via their X-ray excesses can have important implications on understanding the formation of extremely massive stars (e.g., Bonnell & Bate 2002).

High resolution X-ray spectroscopy has been obtained by *Chandra* of the "canonical" CWB, WR 140, at two phases around its X-ray minimum (Pollock *et al.* 2005). High-resolution spectroscopy by *Chandra* of η Car was obtained at 5 phases around its X-ray minimum (Corcoran *et al.* 2006, in prep.). These X-ray observations show broad, blueshifted X-ray emission line profiles at least at some orbital phases, while the grating spectra of η Car reveals clear changes in line width and line centroid vs. orbital phase. These effects are probably dominated by the changing viewing geometry of the shock cone as it follows the weaker-wind star in its orbit. There are also indications that at least some of the hot plasma is out of collisional ionization equilibrium. If so this has important implications for models of the shock emission.

Detailed monitoring of the X-ray emission from η Car (Corcoran 2005) and (recently) WR 140 (Pollock *et al.*, 2006, in prep.) has been obtained, showing in detail the shape of the X-ray "eclipse" in both systems. The durations of the minima are different, in that the minimum in η Car lasts about 3 months, whereas the minimum in WR 140 lasts only a few days. This indicates differences in viewing geometry between the two systems, differences in the stability of the colliding wind shock, or some combination.

References

Bonnell, I. A. & Bate, M. R., MNRAS, 336, 659
Corcoran, M. F. 2005, AJ, 129, 2018
Law, C., & Yusef-Zadeh, F. 2004, ApJ, 611, 858
Moffat, A. F. J., *et al.* 2002, ApJ, 573, 191
Pollock, A. M. T., *et al.* 2005, ApJ, 629, 482
Sana, H., *et al.* 2004, MNRAS, 350, 809