An X-ray Survey of Wolf-Rayet Stars in the Magellanic Clouds


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X-RAY EMISSION FROM WOLF-RAYET STARS

Wolf-Rayet (WR) stars exhibit extremely powerful stellar winds. Three types of X-ray sources have been attributed to their stellar winds:

1. Shocking Winds: Shocks within the WR wind.
2. Colliding Winds: Interaction with the stellar wind of an OB companion.
3. Wind-Switc Bubbles: Interaction with the circumstellar medium.

Therefore, X-ray observations of WR stars probe the opacity of their stellar winds, the orbital configuration of a WR+OB binary system, and the stellar radiation energy injection into the circumstellar medium.

X-ray studies of Galactic WR stars are difficult because their X-ray emission is heavily absorbed in the Galactic plane, accuracy in their $L_x$ is affected by the uncertainty in distances, and the unknown existence of binary companions confuses the assessment of origin of X-ray emission.

X-ray studies of the Magellanic Clouds (MCs) are interesting because their foreground and internal extinctions are low, the X-ray luminosities can be derived accurately as distances are well known, and their low metalilities probe abundance effects on the stellar winds.

THE X-RAY SURVEY OF WR STARS IN THE MCs

The ROSAT, Chandra, and XMM-Newton archives have been used to search for X-ray emission from WR stars in the MCs. The data set is composed of:

- All ROSAT PSPC and HRI pointed observations in the ROSAT Archive with X-ray emission from WR stars in the MCs.
- All Chandra ACIS observations of all WR stars in the LMC and SMC.
- All XMM-Newton EPIC/pn and EPIC/MOS observations of 67 WR stars in the LMC and 8 in the SMC available by 2008 March.

The survey includes observations for 126 WR stars in the LMC and 11 in the SMC, i.e., 90 percent of the 134 WR stars in the LMC (Brey et al. 1999) and 12 WR stars in the SMC (Massey et al. 2003).

The high number of the observations and the use of data from different archives has allowed us to critically assess some X-ray detections. For instance, the X-ray source near LMC-WR 10 (Brey 9) is found to be associated with the OB association LH 9 in N11, while the bright source near LMC-WR 10 (Brey 9) and 69 (TSWR 4) is clearly offset from these stars.

The X-ray detections presented in this survey are highly reliable.

RESULTS

X-ray emission from WR stars in the MCs is more frequently associated with binary stars than single stars. However, single WR stars show detectable X-ray emission, and only 15% of single WN stars are detected in X-rays.

There is also a correlation between X-ray emission and spectral types of the WR stars. In the MCs, X-ray emission is preferentially shown by stars of spectral types W9/W8 and WC6, i.e., WR stars with large terminal velocities. WR stars of spectral types WN3-5, W7-9, and WC4 have lower detection rates, while none of the 7 WN-2 and WN-11 are detected.

The $L_x$ distribution shows a broad peak at $3 \times 10^{35}$ erg s$^{-1}$ and a tail extending towards higher $L_x$. The peak in the $L_x$ distribution is present for both single and binary WR stars, and that its origin is uncertain. The high-$L_x$ tail seems to be associated with binary systems.

The $L_x/\dot{M}$ distribution shows two peaks, at $10^{35}$ and $10^{36}$ erg s$^{-1}$. The lower $L_x/\dot{M}$ peak corresponds to single WR stars, while the higher $L_x/\dot{M}$ distribution of binary WR stars exhibit both peaks.

While some of the binary WR stars in the MCs emit up to 100 times more X-rays than their single counterparts, some other binary WR stars have very similar X-ray levels as single WR stars.

In many respects, the X-ray properties of WR stars in the MCs are similar to those of their Galactic counterparts:

1. No single WC star is detected in X-rays.
2. Single early type WN-5 stars are preferentially detected.
3. Binary WR stars show higher $L_x$ and $\dot{M}$.

However, Galactic WR stars have lower $L_x$ and $\dot{M}$ than their WR stars counterparts. The higher $L_x$ of WR stars in the MCs is attributed to the lower opacity of their stellar winds (because the lower metallicity of the MCs).

The highest X-ray luminosity WR stars in the MCs ($L_x > 10^{35}$ ergs s$^{-1}$) may be unassociated with high-mass X-ray binaries (HMXB), in which the companion of the WR star is a neutron star or a black hole.