An XMM-Newton Search for X-ray Emission from Wolf-Rayet Stars in the Magellanic Clouds

University of Leicester

J. A. Carter[1], M.A. Guerrero[2] & Y-H. Chu[3]

Wolf –Rayet (WR) stars have fast stellar winds with high mass loss rates. The energetic WR wind can interact with the winds of massive companions, the ambient stellar medium and the stellar wind itself, resulting in hot gas than can emit in X-rays. The Magellanic Clouds (MCs) contain approximately 150 known WR stars. We report an on-going search for X-ray emission from the MCs WR stars using archival XMM-Newton observations. We have found X-ray emission from 5 LMC WR stars and 3 SMC stars, all of which occur in binary systems.

The study of X-ray emission from Galactic WR stars is hampered by their uncertain distances and by the heavy absorption in the Galactic plane. The MC WR stars, however, are at known distances and have small foreground extinction. Therefore the MCs are an ideal location to study X-ray properties of WRs stars and the interaction of their winds with companion stars or the ambient medium.

WRs and X-rays

WRs may produce X-rays in the following ways:

- Shocks in the wind are produced by stochastic or radiatively-induced instabilities. The post-shock gas reaches X-ray emitting temperatures
- In a binary system (WR+OB), the WR wind collides with the companion's fast wind and generates shock-heated plasma. The X-ray luminosity may vary with the orbital phase of the binary system.
- The fast WR wind may blow a bubble in the ambient medium. The shock-heated stellar wind interior of the bubble can emit in X-rays. X-ray emission is expected to peak at the emission wall.

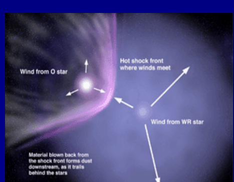


Image: courtesy of D. Baril, Université de Montréal

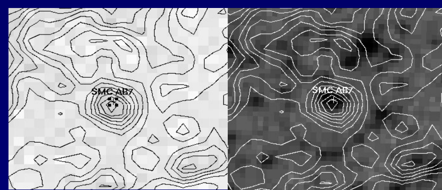
Most X-ray emitting WR stars are expected to occur in binary systems.

Investigations with Chandra and ROSAT data

Studies using archival data from the Chandra and ROSAT laboratories have revealed X-ray emission associated with 25 MCs with X-ray luminosities in the range 2×10^{32} to 2×10^{35} ergs s^{-1} (Guerrero & Chu in prep.). A number of WR stars did not have available Chandra observations, thus ROSAT observations were searched for X-ray emission from these stars. However, ROSAT's sensitivity and resolution proved to be inadequate for this task.

Investigations with XMM-Newton

The XMM-Newton Science Archive (XSA) database was searched for observations of the MCs, and those with acceptable angular separations between the observation pointing and the position of the WR star were extracted (WR star identification from Breysacher et al. 1999; Massey et al. 2003). In total, 31 observations were used for the analysis, including 46 WR stars.

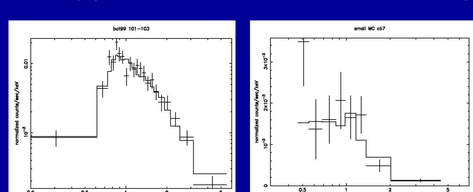


(left) X-ray and (right) optical images of the WR star AB 7 (AV 336a) in the SMC overplotted with X-ray contours

To increase the signal to noise ratio, multiple observations of the same field were stacked, providing the EPIC instrument filter and imaging mode were compatible.
Using the SIMBAD database, optical counterparts were considered. Example images, created from the X-ray event files (between .35 keV and 7.0 keV) for the detected WR stars and overlaid with X-ray contours, are shown above for the SMC WR star AB 7. The optical counterpart of the star is also shown, taken from the ESO Digitized Sky Survey and is overlaid with the X-ray contours.
A summary of the WR stars found with X-ray emission is given in the table. Several of these are unresolvable in position by XMM-Newton, and the X-ray emission cannot be attributed to a single WR star. The group of WR stars in the LMC BAT99 101-103 is the multiple system R140, containing at least three WR stars, one a binary (Breysacher et al. 1999). The group around the LMC BAT99 116 includes 18 WR stars, seven of which exhibited X-ray emission according to the Chandra data. Hardness ratios are given in the table (2.0-7.0kev/0.35-7.0keV).

Galaxy	Name	Count Rate(s^{-1})	Counts	H-R
SMC	AB5	3.2×10^{-3}	136 ± 18	0.34
SMC	AB6	1.3×10^{-3}	60 ± 11	0.09
SMC	AB7	2.8×10^{-3}	133 ± 14	0.16
LMC	BAT99 77-78, 80	5.1×10^{-4}	47 ± 11	0.25
LMC	BAT99 79	2.2×10^{-4}	20 ± 7	0.46
LMC	BAT99 99 -100	9.3×10^{-3}	332 ± 19	0.27
LMC	BAT99 101-103	1.2×10^{-2}	419 ± 22	0.17
LMC	BAT99 116 group	3.5×10^{-2}	1233 ± 36	0.35

We are in the process of fitting the spectra of the found X-ray emitting WRs with a single temperature thin plasma emission model, and with a photoelectric absorption component. The SMC WR star AB 7 was, for example, found to have a flux of 2.7×10^{-14} ergs cm^{-2} s^{-1}, corresponding to a luminosity of 8.0×10^{33} ergs s^{-1}. In the case of the group BAT99 101-103, a two MEKAL model was required, most probably due to components from two of the three stars within the group. These two examples are shown below.
It appears that in all cases of X-ray emission from WR stars that the star occurs in a binary system. This would suggest that the primary process of X-ray production for WR stars is from colliding winds.



Spectra fitted for SMC AB7 and bat99 101-103

References
Guerrero M.A. & Chu Y-H., in prep.
Breysacher J., Azzopardi M. & Testor G., 1999, AAS, 137, 117
Massey P., Olsen K. A. G., & Parker J. W. 2003, PASP, 115, 1265

[1]email: jac48@star.le.ac.uk [2]Instituto de Astrofisica de Andalucia [3]University of Illinois