Wolf-Rayet Phenomena in Massive Stars and Starburst Galaxies
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An X-ray survey of Wolf-Rayet galaxies

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Abstract. We report on an ongoing survey of the X-ray properties of Wolf-Rayet galaxies. The current sample now has 14 detections, as well as a number of upper-limits. WR galaxies have soft thermal X-ray spectra with properties consistent with an origin from superbubbles in a young starburst.

Discussion

We are conducting an ongoing survey of the X-ray properties of Wolf-Rayet galaxies, a class of objects believed to be very young starbursts, with the most recent burst being only $\sim$3–6 Myr. More comprehensive results from the survey are presented in Stevens & Strickland (1998a, 1998b). The basis for our sample is the original catalogue of Conti (1991), but we have also included additional WR galaxies discovered subsequently.

Out of a sample of $\sim$80 WR galaxies looked at, a total of 24 have been observed with the *ROSAT*-PSPC and of these 14 have been detected. We note that additional WR galaxies have been detected with the *ROSAT*-HRI (NGC 6764, NGC 3125, NGC 4214).

The galaxies detected by *ROSAT* include I Zw 18, NGC 1569, NGC 3353, NGC 4449, NGC 5253 and NGC 5408. The majority are dwarf starbursts, though some exceptions include NGC 1365, a barred spiral galaxy possibly with an active nucleus, and more "normal" starbursts such as NGC 7714.

The X-ray properties of WR galaxies can be summarised thus: they are typical unresolved in the *ROSAT*-PSPC, and are X-ray overluminous for their L_B (compared to a sample of nearby spirals and starbursts) and have soft thermal X-ray spectra with $kT \simeq 0.4$–1.0 keV. There are some oddities: NGC 5408 is particularly X-ray overluminous, while I Zw 18 has a harder X-ray spectrum ($kT \simeq 2$ keV). There is a good correlation between L_X and L_B for the WR galaxy sample as a whole, with $L_X \propto L_B^{0.8}$. However, when just the dwarf galaxies are considered there is less evidence of correlation. A correlation also exists between the ratios L_X/L_B and $L_{\rm FIR}/L_B$, indicating an increase in specific X-ray luminosity with star-forming activity. As discussed in Stevens & Strickland (1998a) these properties are consistent with a young starburst model, where the X-ray emission comes primarily from superbubbles.

One puzzle is that the X-ray determined metallicities for the WR galaxies are low (typically $\leq 0.1\,Z_\odot$). We might expect the hot phase of the ISM in

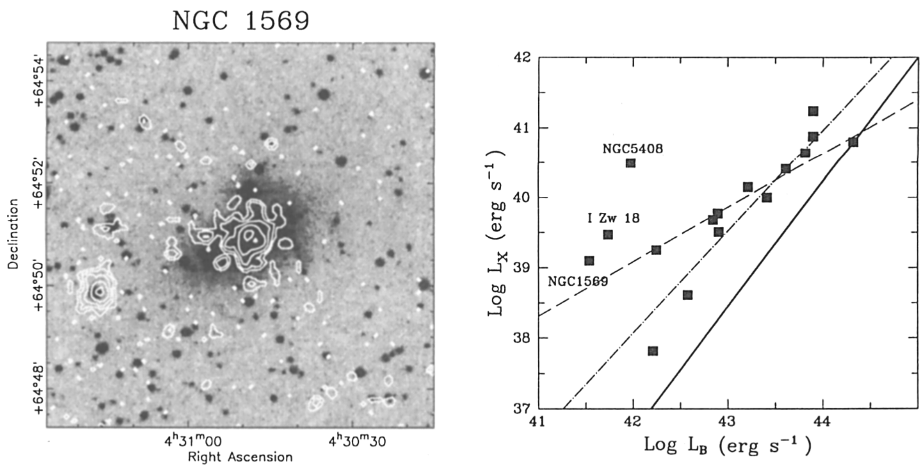

Figure 1. *Left:* An X-ray/optical overlay of the WR galaxy NGC 1569. Shown are the X-ray contours, superimposed on a Digitised Sky Survey image. *Right:* The L_X:L_B relationship for WR galaxies. The filled squares are WR galaxies from this survey. The solid line is the L_X:L_B trend for nearby spiral galaxies (Read *et al.* 1997), the dashed line is the derived trend including all WR galaxy detections, and the dot-dashed line is the correlation excluding the four very over-luminous dwarf WR galaxies.

WR galaxies to have a substantially higher abundance due to the enhanced abundance material from stellar winds and SN (Kobulnicky & Skillman 1998). We suspect that the low determined X-ray abundances are an artifact of the low spectral resolution of *ROSAT* and assuming too simple a spectral model for what is likely to a complex multi-temperature gas. Higher spectral resolution observations with *AXAF* and *XMM* will clarify this.

In addition to constraining metallicities, future work will investigate the fate of star-bursting dwarf galaxies — is the starburst strong enough to remove much of the ISM from the galaxy. Again the X-ray data provides the best view of the hot material from the starburst that may eventually blow-out to form a superwind.

References

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