Wolf-Rayet Phenomena in Massive Stars and Starburst Galaxies
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The environments of Wolf-Rayet stars in M 31

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Abstract. We have conducted a systematic search for nebulae surrounding Wolf-Rayet stars in M 31, where 28 objects are found.

1. Introduction

We present the results of an ongoing study of the interaction of massive stars with the ISM in nearby galaxies, from single stars to associations (see Thilker *et al.* 1998). Together, these investigations provide a detailed view of the processes by which massive stars shape the surrounding ISM, from pc to kpc scales.

One aspect of our study is the search for Wolf-Rayet nebulae in M 31. Our results are based on existing and new Hα and [SII] imaging data of M 31 obtained at *Kitt Peak National Observatory*. M 31 is attractive for this type of study due to the fact that it is close — nebulae are resolvable down to $\sim$5 pc — and provides a uniform sample at a well known distance (690 kpc). Surveys for WR stars in M 31, while not complete, have resulted so far in a catalog of 47 WR stars (Massey & Johnson 1998). M 31 provides a high-metallicity environment compared to the Magellanic Clouds, the closest extragalactic objects that have been searched for WR nebulae (*e.g.*, Dopita *et al.* 1994), so a comparison of the properties of WR nebulae in these different environments may prove useful.

We compiled a catalogue of WR nebulae in M 31 by searching around all known WR stars. Here we briefly address the following questions. What fraction of WR stars are surrounded by nebulae? How frequent are multiple shells? Multiple shells, and their morphologies, can provide clues to mass ejection mechanisms. Is there evidence for the interaction of shells?

2. Results

Of the 47 WR stars known so far (the following spectral subtypes are from Massey & Johnson 1998), 15 are WN (32%) and 32 are WC types (68%). We find the number of WR without nebulae, or indeterminate cases, is 19 (40%); 5 of these are WN (33% of the WNs), 14 WC (44% of the WCs). The number of WR stars with single 'arclets', complete shells and multiple shells and/or arcs then is 28 (60%), of which 10 are WN (67% of the WNs) and 18 WC (56% of the WCs). The morphological breakdown is as follows. The number of WR stars with single arclets is 4 WN and 4 WC, single shells are 3 WN and 4 WC, and with multiple features 3 WN and 10 WC.

There are four good examples of interactions between shells (see Figure 1 for an example). Shells range in radius from 10 to 104 pc. Arclets have a median

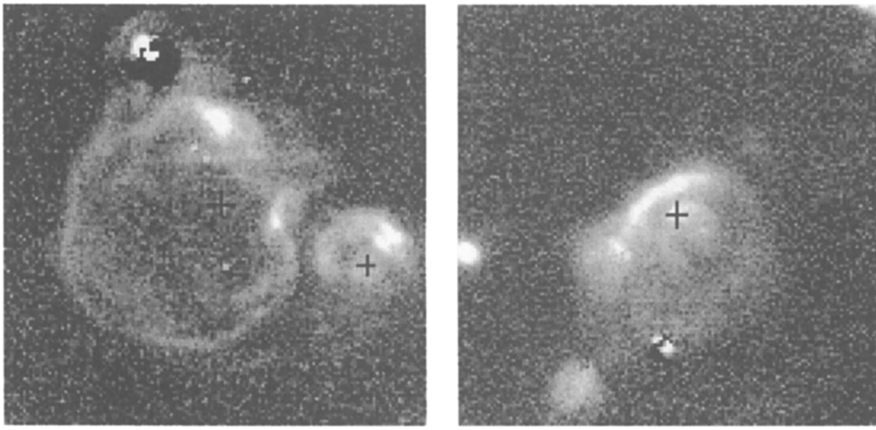

Figure 1. Hα+[N II] continuum subtracted images of WR nebulae. On the left are two shells, one surrounding MS 11 (the large shell) and MS 12 (the smaller, multiple shell), and appear to be interacting. On the right is the multiple H II shell associated with the WR star OB 138 WR1. The crosses indicate the locations of the WR stars. The images are 300×300 pc.

radius of 30 pc and single shells have median radius of 50 pc. Multiple shells have a median inner radius of 20 pc, and a median outer radius of 55 pc.

3. General Discussion

H II nebulae surrounding WR stars in M 31 have sizes similar to those reported by Drissen *et al.* (1991) in M 33. The Hα luminosity of the nebula surrounding WR star MS 6, a typical example, is 2×10^{36} erg s^{-1}, also consistent with the Hα luminosity of WR nebulae in M 33 (Drissen *et al.* 1991). Luminosities of the other nebulae are in the process of being determined.

We cannot say with certainty what fraction of the nebulae are ionized by a single WR star. Spectroscopy of stars within the projected boundary of the H II shell is needed in order to determine that the WR star is the most important ionizing source. However, in some cases (12 of 28), the most likely source of ionization is a single WR star, since they are centered on the nebula and are spatially separated from other hot stars. Follow-up spectroscopy will also allow us to quantify the kinematics and abundances.

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References

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