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A search for Ejecta nebulae around Wolf-Rayet Stars in the SHS Hα survey

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Abstract: Using the Southern Hα Survey (SHS), we have visually inspected every catalogued WR star in the Milky Way and the Magellanic Clouds for the presence of nebulosity suggesting an origin as stellar ejecta with the Southern Hα Survey (SHS) . Our survey revealed one new nebula around the star HD 62910 (WR 8) along with some correlations regarding binarity and WR nebulae progenitors.

1 Introduction

Since the suggestion that some Wolf-Rayet stars could be creating nebulae via mass loss (Johnson & Hogg 1965), efforts to detect more examples have been ongoing. The first attempt to morphologically categorise nebulae presumed to have been created by the influence of WR stars was performed by Chu (1981), who devised three broad categories for possible nebulae: W, R & E.

Our interest lies with the E type nebulae, which were defined to be those which were likely to contain processed ejecta from the progenitor star. These were suggested by Chu to have been formed by a violent mass loss episode recently in the star's history, which may not have been isotropic or homogeneous. The nebulosity can therefore be very clumped and irregular. Chu (1991) modified the scheme to refine the definition of E type nebulae, splitting the category into Stellar Ejecta nebulae and Bubble/Ejecta (W/E) nebulae: the former covering pure E type nebulae as defined above, the latter introduced to cover the case of ejecta shells having merged with the swept up shell.

Recent publicly available Hα surveys (like the SHS Parker et al. 2005) allow re-inspection of the environs of all known WR stars with a view to identifying new E type nebulosities which can provide constraints on the nucleosynthetic effects of WR stars. In contrast to this approach, several new WR nebulae and WR stars have been found recently by searching for rings in IR data, e.g. Mizuno et al. (2010), Wachter et al. (2010), Gvaramadze et al. (2010).

2 Morphology of Confirmed Ejecta Nebulae

For the two nebulae which Chu (1981) regarded as E type (M 1-67 and RCW 58) the nebulosities were found to be enriched relative to the ISM in nitrogen and helium but depleted in oxygen (Kwitter 1984,

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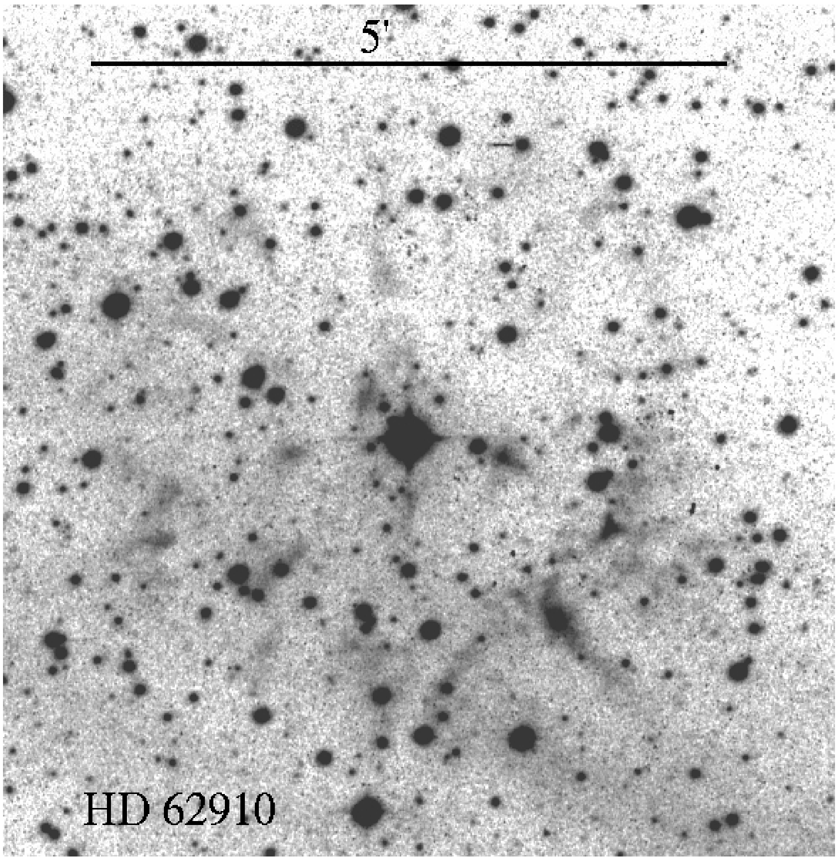

Figure 1: The SHS Hα image of the field around HD 62910 (WR 8, WCE+) shows newly revealed nebulosity. North is up, east is to the left.

Esteban et al. 1991). The anonymous nebula surrounding WR 16 was also shown to be comprised of material with a very similar abundance pattern to those of M1-67 and RCW 58 (Marston et al. 1999). The detection of processed material in these nebulae was a major success for the categorisation scheme, as this showed that it is possible to infer likely patterns in the chemical composition of a WR nebula by studying its morphology.

However, material displaying the same patterns of enrichment was also detected in NGC 6888 - a nebula Chu had initially classified as W type (Esteban & Vilchez 1992, Moore et al. 2000). This showed clearly that the lines between the inital Chu classes can be blurred: NGC 6888 appears to be a mixture of different kinds of nebulosity. The edge looks like a wind-blown shell, whilst there is evidence of flocculent nebulosity in the central regions, suggesting ejected material. NGC 6888 was later re-classified as a W/E nebulae by Chu (1991).

These spectroscopic results lead to the conclusion that the morphological criteria for ejecta nebulae presented by Chu (1981) may be too stringent, a problem addressed by the introduction of the Bubble/Ejecta (W/E) class (Chu 1991). Wind-blown bubbles can also contain ejecta in their filamentary nebulosities (e.g. NGC 6888). This suggests the following, revised criteria: ejecta nebula candidates must have either a highly flocculent structure, as in Chu's scheme or, alternatively, possess flocculent structure within their wind-blown shells, similar to that shown by NGC 2359, NGC 6888 & NGC 3199.

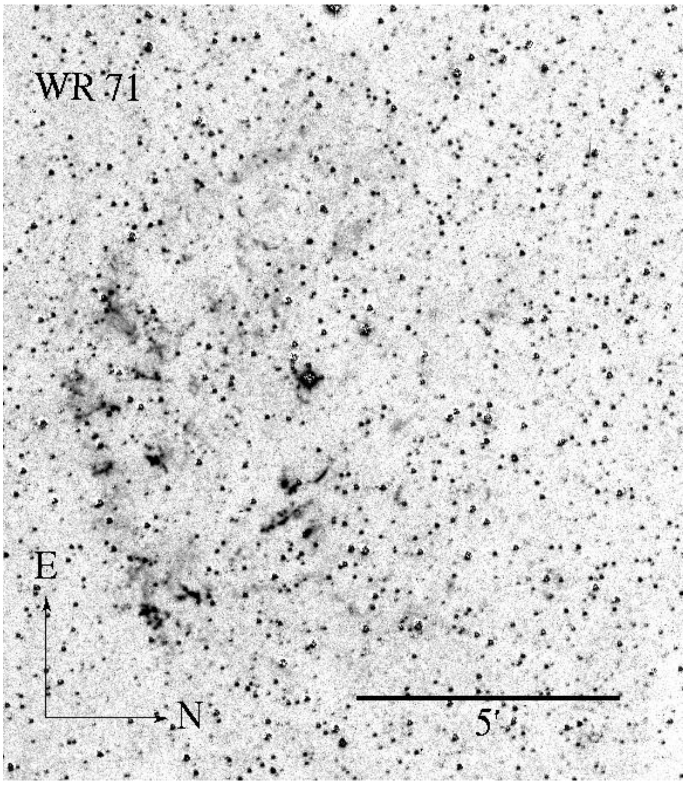

Figure 2: SHS image of the field around WR 71 (WN6) (Hα-red subtraction). The tenuous flocculent nebulosity to the south strongly suggests stellar ejecta, as noted by Marston et al. (1994).

3 Results

In the SHS imagery of the region around WR 8 (Figure 1) one can clearly discern nebulosity that appears to be associated with the star. It is aligned along radial "spokes" with an especially prominent example to the south-west. These spokes define a circular structure approximately 5 arcminutes in diameter, internal to which there are several prominent clumps of nebulosity.

The spectral type of the host star is listed by van der Hucht (2001) as WN7/WC4. Its spectrum places WR 8 neatly between those of WN and WC stars (Crowther et al. 1995). This was initially interpreted as a sign of binarity - a system comprising both WC and WN stars - however Crowther et al. (1995) showed that the wind properties were the same for both the N and C components - implying a single star origin.

The SHS image, shown in Figure 2, confirms the tenuous nebula around WR 71 first noted by Marston et al. (1994) and later classified as an E type nebula by Marston (1997). It appears similar to RCW 58 and anon (WR 8), in that it has highly clumped nebulosity to the south, although much fainter than either of the above. The SHS subtracted (Hα-R) image (Figure 2) also shows some arcs to the west while improving on the detail of the flocculent structure to the south. The progenitor is a runaway star and as such is significantly out of the plane (z = 1190 pc) suggesting that this object may have unique kinematics due to the low ISM density at this z distance.

Along with the detection of a new nebula around WR 8 and confirmation of an E type nebula around WR 71, several nebulae in the LMC were identified as WR ejecta nebula candidates.

Table 1: WR Nebulae with Binary Central Stars

	Isolated WR	Binary WR	All WR
Milky Way^a			
Ejecta Nebulae	13	0	13
All WR Stars	142	85	227
Ratio	0.09	0.00	0.06
LMC^b			
Candidate Ejecta Nebulae	4	0	4
All WR Stars	102	32	134
Ratio	0.04	0.00	0.03

a: Not including WR stars discovered by Wachter et al. (2010) as they were discovered by examining progenitor stars of detected IR ring nebulae.

b: Counting all O3If*/WN6-A stars as isolated WN type.

4 Discussion

From our sample of ejecta nebulae a curious fact emerges: none of the nineteen WR Ejecta nebula central stars listed here are binaries. In Table 1 we summarise the binary fractions for the WR populations in the MW and LMC along with the fraction that we have identified as ejecta nebulae for each case. The binarity classifications of van der Hucht (2001) and Breysacher et al. (1999) were adopted for the Galactic and LMC populations respectively. It is striking that the fraction of binary WR stars having ejecta nebulae is so low.

If the fraction of WR stars with ejecta nebulae were the same for binaries as single WR stars we would expect $\sim 7-8\%$ of WR binary stars to possess ejecta nebulae, which translates to around 6 expected in the MW compared to none observed. In the LMC we might expect $\sim$ 4 LMC binary WR stars to possess ejecta nebulae.

It has long been speculated that there are two methods of creating WR stars, mass transfer between binary partners and mass loss of an isolated star (e.g. Smith & Payne-Gaposhkin 1968). A possible reason for the relative absence of ejecta nebulae around binary WR stars is that mass transfer onto a companion inhibits the mechanism that produces an ejecta nebulae around single WR stars.

The nebulosity surrounding WR 71 (see Figure 2) is possibly an exception to the previous discussion. The progenitor star is of spectral type WN6+? (van der Hucht 2001). Isserstedt et al. (1983) suggested that WR 71 has a binary partner that is a low-mass evolved stellar remnant - either a neutron star or a black hole - and that the supernova which created the collapsed object likely occured when the system was in the disk of the MW. However this finding has been disputed, and WR 71 is now normally thought to be an isolated star (Hamann et al. 2006), its runaway status probably coming about not through binary interactions, but rather dynamical cluster interactions leading to ejection (as it is very unlikely that a WR star could form in the low density environment 1000 pc above the galactic plane).

The nebulosity appears to be physically much larger than counterparts in the plane (although this is heavily dependent on the distance adopted) while retaining the appearance of a pure E type nebula. This may be caused by the size of the ISM cavity created by stellar winds being larger than those created by counterparts in the plane due to lower local ISM density beyond the galactic plane.

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Discussion

E. Pellegrini: Why not use the MCELS Survey for the LMC?
D. Stock: I had not previously been aware of MCELS. However it does sound like an invaluable ressource for this kind of work.

S. Wachter:

1. Have you looked at the Spitzer observations for your LMC shells? Do you see any 24 μm emission?
2. What was your input WR list? Just the van der Hucht catalog or also the more recent newly discovered WRs by Shara, or Mauerhan, or Hadfield?

D. Stock:

1. I have not yet examined the Spitzer $24\mu m$ images, although that is a good idea.
2. I used the van der Hucht (2001) catalog along with its 2006 annex. In the Magellanic Clouds I used the Breysacher, Azzopardi & Testor Catalog of 1999.
   As far as I know most new WR discoveries are in clusters or bubbles and hence would be discounted anyway.

N. Smith: Regarding the WNh stars at the center of these nebulae, I suppose this is expected in either the post-RSG or post-LBV stage because new-born WN stars may still need to get rid of a small amount of H. Also, quiescent LBVs are sometimes seen with spectral types of Ofpe/WN9 or WN11 (with H), so there is a connection there as well.

S. Wachter: A comment on the idea that shell #16 from my sample shows streamers and special structure: There are a couple of similar looking shells like this in my sample and my interpretation from looking at the multiwavelength data is that these might just be in a denser environment, they have much more diffuse edges than most of the other shells.

A.J. van Marle: A comment on the remark by N. Smith: “Streamers” in WR nebulae may result from partial photo-ionization by the central star. If purely hydrodynamic, they can give very good indications of wind properties.