*Wolf-Rayet Phenomena in Massive Stars and Starburst Galaxies*
*Proceedings IAU Symposium No. 193,* ©*1999 IAU*
*K.A. van der Hucht, G. Koenigsberger & P.R.J. Eenens, eds.*

# Molecular gas associated with Wolf-Rayet ring nebulae

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**Abstract.** We present the first $^{12}$CO 1→0 emission-line maps of the vicinities of two Wolf-Rayet stars (WR 16 and WR 75) and their associated ring nebulae. We illustrate that sizeable amounts of molecular gas appear associated with these ring nebulae and therefore that the mass of gas in ring nebulae is significantly higher than inferred from observations of the ionized gas component alone. We discuss the possible stellar and interstellar origins of these molecular materials and the implications for the evolution of massive stars up to the WR phase.

## 1. Introduction

Little is known about the neutral gas associated with ring nebulae around WR stars. Schneps *et al.* (1981) and Gruendl & Chu (1998) have observed the strong interaction between the fast stellar wind of WR 7 and a nearby molecular cloud. H I maps have been made of the large-scale environments of galactic WR stars by various authors (see Arnal, these Proceedings) and atomic hydrogen appears associated with the ring nebula S 308 (Arnal & Cappa 1996). In this poster we present initial studies of the molecular gas content of the two WR ring nebulae around the stars WR 16 and WR 75.

## 2. Observations

Observations were made with the Swedish-*ESO*-Submillimeter Telescope (*SEST*) using a 100 GHz receiver tuned to the $^{12}$CO 1→0 emission line. A high resolution receiver produced a resolution of 0.22 km s$^{-1}$ per channel. Maps were made of a region approximately $16' \times 8'$ around WR 16 at beamwidth intervals ($45''$), providing a slight under-sampling. A similar sized region covering the northern half of the nebula RCW 104 around the star WR 75 was also mapped. These regions covered the optically observed ring nebulae and the regions immediately surrounding them (Marston 1995).

## 3. Discussion

Significant molecular emission was noted around both stars, suggesting a molecular mass of 4–40 $M_{\odot}$ in the nebula around WR 16 (depending on excitation temperature and abundances) and a slightly smaller amount associated with RCW 104, the nebula around WR 75. Emission-line filaments have been observed both interior to and exterior to the cocoon of molecular gas around WR 16. Optical spectra suggest this material is enhanced in its nitrogen content, indicating the molecular material has been formed in ejecta from an earlier phase in the evolution of the central WR star.

The CO emission associated with the ring nebula RCW 104 around WR 75 has two velocity components that were also noted in the optical observations of Goudis *et al.* (1988). High velocity CO components appear superimposed on the nebula and appear coincident with the optical emission components, which were observed to be moving approximately 50 $\mathrm{km\,s^{-1}}$ relative to systemic as well as at the systemic velocity of RCW 104. The faster component was observed to be composed of knots of nitrogen-rich material. The coincidence with the high velocity CO emission suggests these knots are CNO rich and are therefore likely to have come from an earlier evolved stage of the star WR 75, possibly a LBV eruption. However, abundances in the nebula suggest a red supergiant origin (Esteban *et al.* 1992). It appears likely that two ejection events may have created RCW 104, a slow red supergiant wind, followed by a LBV eruption. Just such an evolution has been proposed in the models of Stothers & Chin (1996).

**Acknowledgments.** The work in this presentation was funded in part by a grant from NASA administered by the AAS and NASA ADP grants NAG5-2999 and NAG5-6854.

## References

Arnal, E.M., Cappa, C.E. 1996, MNRAS 279, 788

Esteban, C.E., Vílchez, J.M., Smith, L.J., Clegg, R.E.S. 1992, A&A 259, 629

Goudis, C., Meaburn, J., Meaburn, J. 1988, A&A 191, 341

Gruendl, R., Chu, Y.-H. 1998, BAAS, 30, 830

Marston, A.P. 1995, AJ 109, 1839

Schneps, M., Haschick, A.D., Wright, E.L., Barret, A.H. 1981, ApJ 243, 184

Stothers, R.B., Chin, C.-W., 1996, ApJ 468, 842