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.

WR 146 — observing the OB-type companion

Sean M. Dougherty

University of Calgary/Dominion Radio Astrophysical Observatory NRC, P.O. Box 248, Penticton, B.C. V2A 6K3, Canada

Peredur M. Williams

Royal Observatory, Blackford Hill, Edinburgh, Scotland EH9 3HJ, UK

Abstract. Using both *MERLIN* and the *VLA*, we have succeeded in detecting the radio emission from three components in WR 146: the WR star, the wind-wind collision region, and for the first time, the stellar companion to the WR star. This allows the unique possibility of determining the mass loss rate ratio of the two winds, an important observable that is independent of distance.

1. Introduction

Previous *MERLIN* observations at 5 GHz of WR 146 show two components, N_5 and S_5, separated by $\sim$120 mas (Dougherty *et al.* 1996). S_5 is thermal and is identified as the free-free emitting envelope around the WR star, whereas N_5 is non-thermal. An optical spectrum reveals an OB-type companion, leading to the suggestion that the non-thermal emission arises from relativistic electrons in the region where the wind of the WR star and the OB-type companion interact (*e.g.*, Eichler & Usov 1993). Using the *HST*, Niemela *et al.* (1998) identified a visual companion to the WR star $\sim$170 mas from WR 146, somewhat further from WR 146 than the non-thermal emission region, confirming the wind-wind collision as the origin of the non-thermal emission.

2. New observations

New observations were obtained with the high resolution A-configuration of the *VLA* at 22 GHz. These observations reveal two components, N_{22} and S_{22}, very similar in appearance to the *MERLIN* 5-GHz data. The flux of S_{22} is 7.0 ± 1.3 mJy, consistent with that expected from the free-free emitting stellar wind from the WR star with a spectral index of $+0.74 \pm 0.2$. We conclude that S_{22} and S_5 are both the stellar wind of the WR star. The separation of the 22-GHz components is 162 ± 8 at a position angle of 22°, consistent with the relative separation (168 ± 31 mas) and position angle ($21 \pm 4°$) of optical components WR 146A and B observed by the *HST* (Niemela *et al.* 1998). From a simple proper motion study of N_5 and S_5 observed by *MERLIN* at two earlier epochs we conclude that N_5 and N_{22} are not the same feature. This leads us to suggest that the two components detected in the 22-GHz observations are the two stellar components imaged by the *HST*.

The relative position of the three components gives the momentum ratio of the two winds, η, and the flux ratio of the emission from both stellar winds gives

https://doi.org/10.1017/S0074180900205664 Published online by Cambridge University Press

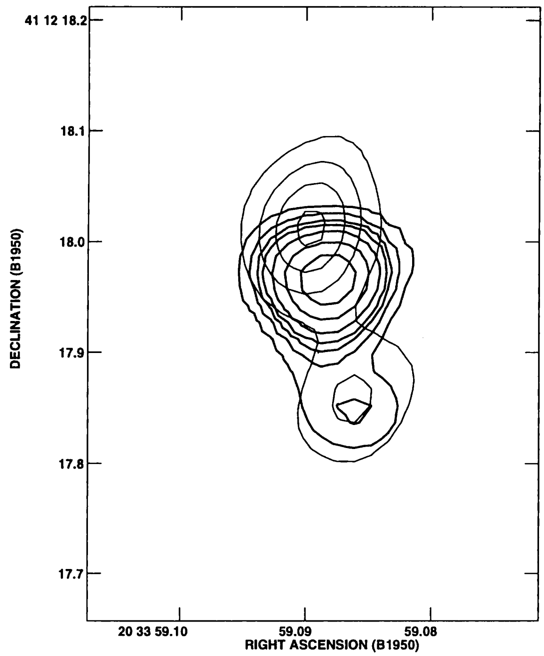

Figure 1. Overlay of the *VLA* 22-GHz image (thin contours) with a *MERLIN* 5-GHz image obtained in 1992 (thick contours), assuming S_{22} and S_5 are coincident. Clearly, the northern component at 22 GHz is displaced to the north of the non-thermal region observed at 5 GHz.

the density ratio of the two winds, ξ. Note that both η and ξ are independent of distance and inclination, though ξ is dependent on the wind composition, particularly the mean atomic weight μ. Taking reasonable values of μ, we find that $\eta = 0.11 \pm 0.03$ and $\xi = 0.47 \pm 0.25$. From these values, the ratio of mass loss rates of the two stars ~ 0.25, a value *independent of distance.* This is about an order of magnitude larger than expected for an O star wind relative to that of a WR star. For the derived ratio to be smaller, ξ has to decrease, which implies that we have to attribute some of the flux of N_{22} to the wind collision region. For example, if we assume that the terminal velocities of the winds are the same ($\xi = \eta$), then the wind flux from the O star companion would be $\sim$2–3 mJy, implying that 7–8 mJy of the flux observed in N_{22} comes from the wind collision zone. If this is the case, the coincidence of the peak of the 22-GHz emission with the location of the companion, as observed by the *HST*, presents a different puzzle.

References

Dougherty, S.M., Williams, P.M., van der Hucht, K.A., Bode, M.F., Davis, R.J. 1996, MNRAS 280, 963

Eichler, D., Usov, V.V. 1993, ApJ 402, 271

Neimela, V.S., Shara, M.M., Wallace, D.J., Zurek, D.R., Moffat, A.F.J. 1998, AJ 115, 2047

https://doi.org/10.1017/S0074180900205664 Published online by Cambridge University Press