A NEW SEARCH FOR NEBULAE SURROUNDING WOLF-RAYET STARS

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INTRODUCTION

We have used the plate data from An Emission Line Survey of the Milky Way by Parker, Gull and Kirschner(1979) to make a new search for ring nebulae around Wolf-Rayet stars. The Survey consists of narrow-band interference filter direct imagery centered on the emission lines of Hα + [N II] at λ6570, [O III] at λ5007, and [S II] at λ6730. We have discovered at least five new ring nebulae. Of the fifteen ring nebulae we were able to detect on the Survey, including our new discoveries, eleven were brighter in the [O III] bandpass than in the Hα + [N II] bandpass, and were filamentary in [O III]. All of the nebulosities we were able to detect were rated on the basis of three criteria:

1) Sharp, filamentary structure present in any or all bandpasses.
2) Wolf-Rayet star centered in projected nebulosity, or, if off-center, the segment of the ring nearest the star proportionally brighter than the rest of the ring.
3) Absence of any O stars within the nebulosity, or O star in off-centered position not adjacent to the brightest or sharpest portion of the ring.

Thirty additional shell-like structures have been identified as "possible" or "probable" ring nebulae associated with Wolf-Rayet stars on the basis of how well these three criteria were satisfied.

DESCRIPTION OF SELECTED NEBULAE

The [O III] plate of Θ Mus (Figure 1), reveals an arcuate structure approximately 33 arc minutes south of the Wolf-Rayet star. The feature has a scalloped appearance with three distinct, connected lobes and a total length of 67 arc minutes. On the Hα plate, a sharp, "J"-shaped filament is visible in approximately the same place as the [O III] shell, but not coincident with it. The Hα feature is smooth and thicker than the [O III] feature. No emission structure is visible either in [S II] or Hβ.

C. W. H. de Loore and A. J. Willis (eds.), Wolf-Rayet Stars: Observations, Physics, Evolution, 463–468.

HD 187282 is a WN4 star located 24 arc minutes west of a diffuse emission region 60x49 arc minutes in size (Figure 2). The exciting discovery here is on the [O III] plate, which reveals a sharp, hollow shell structure in the form of a parabolic segment with the vertex pointing east, and 20 arc minutes in diameter. No hint of this sharp shell is seen on any of the other plates of this field. The Wolf-Rayet star is 10 arc minutes south, south-west of the vertex of this [O III] shell structure.

HD 191765 (Figure 3) lies in the Cygnus region. On the Hα plate, this object is found in a field of bubble-like structures. It appears to lie 8.8 arc minutes east of a diffuse and hollow arc of emission. However, the number of interrelated filaments in this region precludes the detection of a complete shell. On the [O III] plate the filamentary structure seen in Hα is only faintly, diffusely and incompletely defined. There is a very bright, sharp, hollow arc of emission eleven arc minutes west of HD 191765. This arc is not coincident with the arc seen in Hα.

The ring structure around HD 211564 (Figure 4) is composed of two distinct shells, an outer one of diameter 36 arc minutes and an inner structure 17 arc minutes in diameter. On the [O III] plate, this double ring structure is quite pronounced. The inner shell, as it appears on the original [O III] plates, is very sharp and complete, and the Wolf-Rayet star is displaced 3.7 arc minutes north-east of the center. The outer shell is diffuse.

CONCLUSION

The _Emission Line Survey of the Milky Way_ represents a reasonably consistent set of plate data in which the intensity ratio of [O III]/Hα +[N II] varies by no more than a factor of 2, and is probably much better than that. We found that ring nebulae and shell structures associated with early WN stars tend to be brighter in [O III] than in Hα + [N II], while nebulae associated with late WN stars tend to be brighter in Hα + [N II] than in [O III]. Our sample of shell nebulae associated with WC stars is quite small; however they tend to be faint in [O III] regardless of their brightness in Hα + [N II].

REFERENCE

Parker, R.A.R., Gull, T.R., and Kirschner, R.A., _An Emission Line Survey of the Milky Way_, 1979, NASA Sp. 434.

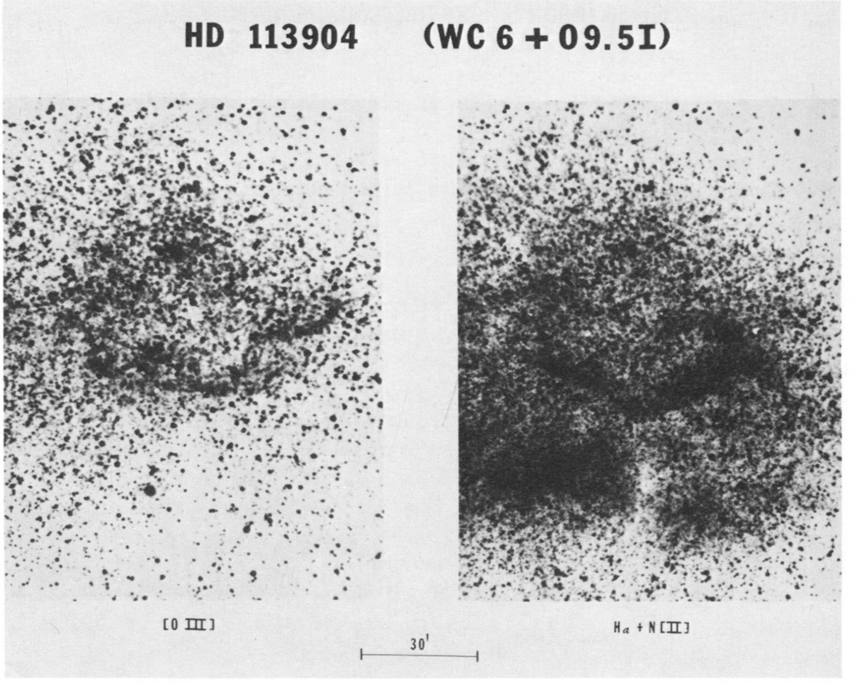

Figure 1

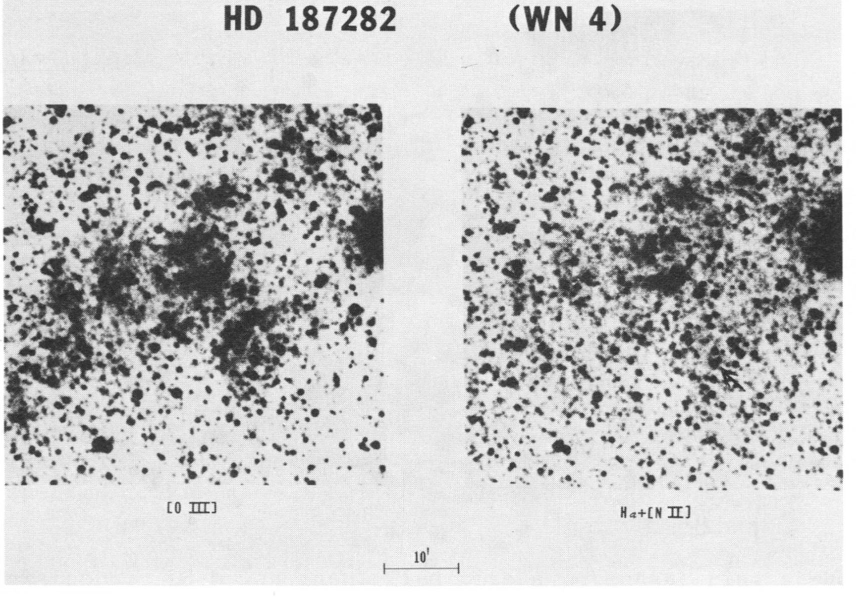

Figure 2

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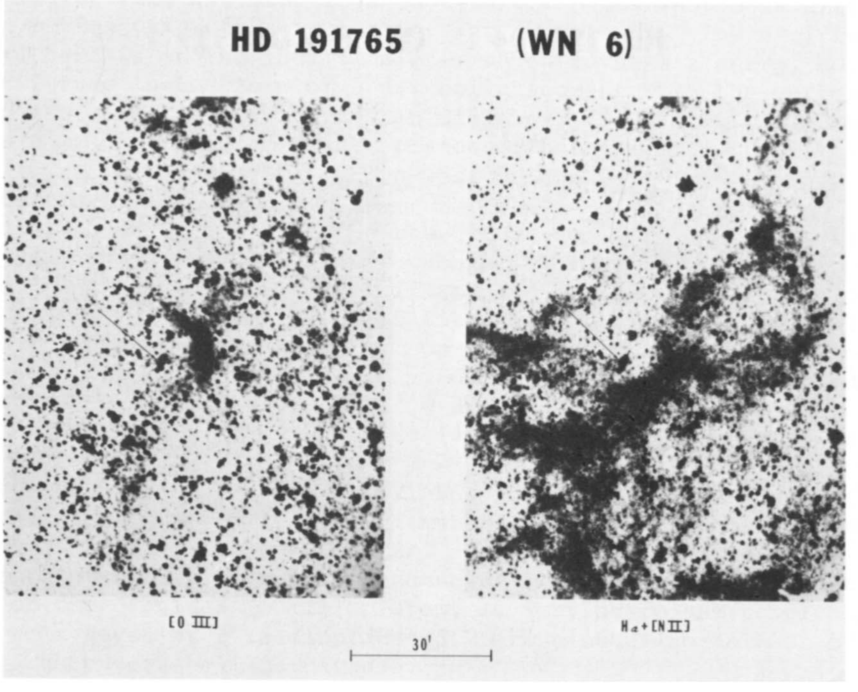

Figure 3

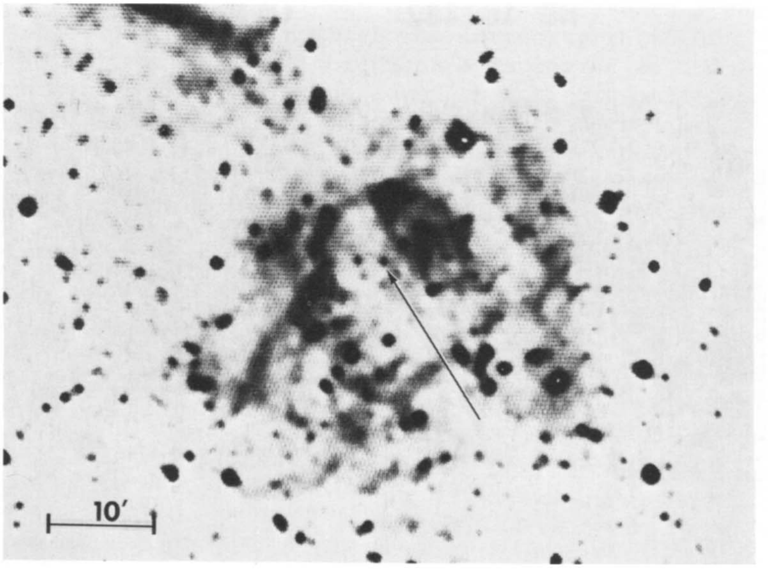

Figure 4. HD 211564 in [O III] bandpass

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DISCUSSION FOLLOWING HECKATHORN et al.

Williams: Did you find anything around HD 193793?

Heckathorn: Yes, a double ring structure was detected around this object.

Shara: How wide (FWHM) were the filters used? To what limiting magnitude (mag/arcsec^2) did the survey reach?

Heckathorn: The Hα+(N II) filter was 75 Å wide, and the (O III) filter was 28 Å wide. I'm not sure of the limiting magnitude of the survey.

Hiltner: To answer the question in part in regard to the exposure times it may be adequate to know as I recall that the plates were sky limited, aided by a 2 stage image intensifier.

Nussbaumer: Was the purpose of your observations limited to find nebulae ans their shapes, or did you also try to deduce physical properties of these nebulae?

Heckathorn: I only identified the nebulae.

Stenholm: Did you look for nebulosity around all WR stars known?

Heckthorn: All but 3 of the Wolf-Rayet stars in van der Hucht's catalogue were included in the Emission Line Survey. However the resolution is low: about 30 arc seconds, so I could have missed some small structures.

Stenholm: I'm asking because we have spectrograms of two faint WR stars, namely LS 5 (= WR34) and LS 6 (= WR36) which show the forbidden lines 372.7 nm (OII) and 495.9 and 500.7 nm (OIII). The stars are of spectral class WN 4.5 and WN 4 respectively.

Heckathorn: LS 6 was identified with a potential ring structure in our survey.

Niemela: a) Did you search ring nebulae around O stars also?
b) Is there any difference between the nebulae surrounding the O stars and the WR stars?

Heckathorn: a) Yes, the same type of search has been done for all O stars in the galactic plane. There are over 200 identified shell structures among the O stars.
b) Yes. Nebulosities around O stars tend to be fainter in the (OIII) plate materials than in the Hα+(NII) material. They are also diffuse structures rather than accurate, as a class.

Conti: Do you think it is possible that all WR stars have such nebulae and that the ones you have discussed are just those where the interstellar conditions are "best"?

Heckathorn: No, I don't think all Wolf-Rayet stars will prove to have ring nebulae. The presence of a ring nebula is more a statement about the conditions in the local interstellar medium than a statement about the properties of the Wolf-Rayet star. For example, if the Wolf-Rayet star is situated in a very low density gas, a ring nebula could not form.

Lortet: There are strong selection effects for the detection of bubble nebulae. For instance, they can be missed is the WR star is a low ultraviolet luminosity object and no nearby O stars illuminate the swept up material. Also we can miss a number of nebulae of the class named "ejecta" by Chu, which are low mass faint nebulae: they can be detected only when the ejecting star has gone far enough from interstellar matter clouds.