EVIDENCE FOR NON-ISOTROPIC MASS LOSS FROM CENTRAL STARS OF SOME EMISSION NEBULAE

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1. INTRODUCTION

In our general program of research on the velocity field of emission nebulae, using the photographic Fabry-Pérot technique, we have included: NGC 6164-5, an H II region with striking symmetry, NGC 2359 a "ring nebula" and M1-67. The exciting stars in all three are centrally located and are of spectral types O6f (showing P Cygni profiles), WN 5 and WN 8 respectively.

The detailed analysis of the velocity distribution of these three regions affords evidence that these have originated from gas ejected by the central star; that ejection has occurred not isotropically but rather from localized regions, spots, on a rotating star. These spots tend to be situated on opposite hemispheres on the star, approximately at the extremities of a diameter which is oblique to the rotation axis. It is suggested that the present mass loss from the central stars observed by their spectra may also be occurring from localized regions. We shall discuss briefly the three regions.

2. NGC 6164-5

Both the velocity distribution and the morphology of this H II region show a striking bi-symmetry around the exciting O6f star (HD 148937). A confrontation of the velocity field with optical features has led to a model, described earlier (Pişmiş 1974). In Figure 1, we give a sketch of the main features, blobs, of emitting matter. Average radial velocities with respect to the sun are indicated for each feature. A plausible interpretation is that the ejection from the central star which is at present of type O6f, and presumably single, has occurred in puffs.

3. NGC 2359

This nebula has a "double ring" structure surrounding the exciting star.

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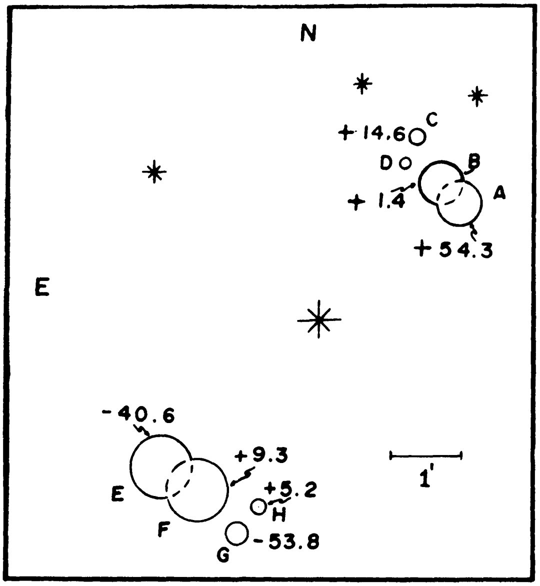

A sketch of the main features and the average radial velocities relative to sun are shown for each feature in Figure 2. The overall radial velocity of the nebula is 71 km s^{-1}. It is clear that the inner ring is approaching the observer relative to the central star while the outer ring is receding indicating that the rings denoted by f_1 and f_2, were formed by ejection from the central star, HD 56925. The detailed velocity field and a model proposed to explain it are given in a recent paper (Pişmiş <u>et al</u>. 1977).

Figure 1. Sketch of the main features, blobs, of NGC 6164-5. Numbers indicate the average velocities of points within the features.

4. M1-67

This object is so far considered to be a planetary nebula and is the only one to have a central WR star of the nitrogen sequence (WN 8). The structure of this nebula, dominated by blobs, shows again bi-symmetry. This object, which may well be an H II region rather than a planetary, is rather small for our equipment to give as detailed a velocity field as in the former two H II regions. But clearly, the outer filaments are moving away from the central star while the regions closer to the star show expansion (Pişmiş and Recillas-Cruz, 1977). Thus, here again, we have a nebula formed probably by mass ejected from the central star.

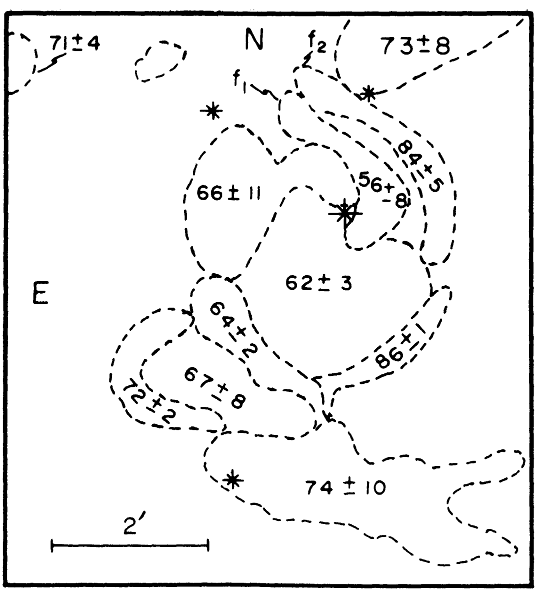

Figure 2. A sketch of the main feature of NGC 2359 and the average heliocentric velocities within each feature.

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5. A MODEL FOR THE MASS EJECTION

The following model which we propose may explain the velocity field and the main structural properties of NGC 2359 and NGC 6164-5. Ejection of matter started t years ago ($t= 1\text{-}2\times10^5$ for NGC 2359 and $4\text{-}5\times10^3$ for NGC 6164-5) from active regions, spots, located nearly at the extremities of a diameter on a fast rotating star. This direction of the ejecting regions is oblique to the axis of rotation. In the case of NGC 2359 the axis of rotation is close to the line of sight whereas that of NGC 6164-5 is close to the plane of the sky.

6. CONCLUSION

If the proposed model of non-spherical ejection is correct one should expect other nebulae ejected from the parent star to be observed at varying projection angles. Objects formed in this manner in general would show bi-symmetry and sometimes ring structure. It would be interesting to determine the velocity field of H II regions with axial symmetry to check the validity of our model.

The parent stars of NGC 2359, of NGC 6164-5 and of M1-67 are all losing mass at present. It is reasonable to expect that if the gas ejected from these stars in the past has been non-isotropic the present mass loss may also be taking place in a similar fashion, that is from localized regions on the star.

In the light of this suggestion we may ask whether the line profiles of the Wolf Rayet and Of stars would not be consistent with a non-isotropic ejection of matter at the present time. It may be worthwhile to construct synthetic line profiles for rotating stars with active spots and compare them with observed profiles. Perhaps the variations of the spectral line profiles in some WR star may find an explanation by this mechanism of mass ejection.

REFERENCES

Pişmiş, P.:1974, Rev. Mexicana Astron. Astrof., 1, 45.
Pişmiş, P., Recillas-Cruz, E., Hasse, I.: 1977, Rev. Mexicana Astron. Astrof., 2, 209.
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DISCUSSION FOLLOWING PISMIS

<u>Seggewiss</u>: The H II-region M1-67 is listed as planetary nebula in the catalogue of Perek and Kohoutek. What are your reasons that M1-67 is not a planetary nebula but a population I object? My second question refers to the high velocity (200 km s^{-1}) of the nebula and the central star as well.

Pismis: According to the "classical" criteria for a planetary M1-67 will not qualify as a planetary since (1) its excitation degree is too low, (2) the object has a peculiar morphology and too large dimensions for a planetary, the internal motions show too high a dispersion and though it is a high velocity object, the velocity is too high, even for a planetary, its galactic orbit is hyperbolic. We probably have here a real runaway object!

Hutchings: Can you estimate the size and age of the nebula around HD 148937?

Pismis: In my paper on NGC 6164-5 I have given an estimate of the size of the nebula as 3 pc and an age of $4-5 \times 10^3$ yrs. These are however very rough estimates since the distance of the nebula, and star, is only approximate.

Niemela: Are there studies of any of the central stars to determine if they are binaries? If they are binaries the mass loss could be through the two external equilibrium points.

Pismis: According to Conti the central star of NGC 6164-5 is single. The central star of NGC 2359 is also believed to be single but I don't think we can be certain about this; more observations are needed. The same can be said about the central star of M1-67.

Conti: HD 148937, the central star of NGC 6164-5, has been the subject of an extensive spectroscopic study by myself, Garmany, and Hutchings [Ap. J. 215, 561 (1977)]. There is no evidence of velocity variation that could be attributed to a binary nature.

Bolton: A graduate student of mine at Toronto, Steven N. Shore, has succeeded in modeling the helium-rich spectrum variables on the upper main sequence, the model is based on the oblique rotator geometry like that used in Ap star models. A consequence of the model is that the wind streams out preferentially at the magnetic poles. A similar model could account for the phenomena you have observed.

Pismis: It is difficult to imagine that active spots on a star located, as we suggest, nearly diametrically opposite on the star may be due to anything but magnetic phenomena. In fact in my paper on NGC 6164-5 I have suggested that the agent funneling the ejecta is likely to be a magnetic dipole along the direction of ejection, that is along a diameter oblique to the rotation axis of the star.

Hummer: Two other possibilities for asymmetric ejection have been suggested by those persons dealing with planetary nebula (1) Harwit showed there was a correlation of the dipolar structure in planetary nebulae with direction of galactic disc. This suggests the IS medium may control the morphology, (2) bipolar shapes could be due to gravity darkening in the rotating central stars. Then the polar regions could tend to get blown away preferentially when the planetary forms, giving a donut structure.