THE YOUNG Of STAR HD148937 AND ITS ASSOCIATED INTERSTELLAR BUBBLE - H II REGION

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ABSTRACT

HD148937 and nebulosities surrounding the star are found to be closely inter-related. IUE spectroscopy of HD148937 shows the star to be a young Of star with low mass loss. Properties of the surrounding interstellar bubble and the H II region support the implied youth of HD148937.

DESCRIPTION OF NEBULOSITIES

The peculiar Of star HD148937 with its symmetrical S-shaped nebulae, NGC 6164 and 6165 plus the two gaseous shell structures enshrouding this star make it one of the most intriguing objects in the sky.

As photographs reveal, the outermost shell is very thin, dusty, and very nearly circular. This shell extends 44' to the northeast and 64' to the west of HD148937. The mottled appearance and the increase of dust to the east may indicate that the eastern rim of this shell is interacting with the nebula NGC 6188.

Enclosed within this thin shell is what appears to be an H II region. Narrow bandpass photography shows diffuse emission in Hα and [O III] λ5007 emanating from this interior region. The inner periphery of this H II region is marked by a thin filamentary arcuate structure traced out by well defined [O III] emission. This inner filamentary shell or 'halo' has a major axis of 20' and a minor axis of 15' (aligned with the major and minor axes of the inner nebulosities NGC 6164-5). The filamentary nature of this halo is identical to that seen in shock interfaces in supernova remnants. Inside this halo appears to be a real hole in the diffuse emission. The detectable emission in this region is limited to the well defined blobs defining NGC 6164-5.

The inner nebular complex NGC 6164-5 shows remarkable symmetry and has been considered a planetary nebula. However, Westerlund (1960) rejected this hypothesis based upon the luminosity of HD148937. The notable investigation of Pismis (1974), concluded that the symmetry of these blobs of gas were indeed strong evidence that they were ejected by the central star.

THE CENTRAL STAR: HD148937

The central star HD148937 has been identified as an extreme Of star classified as either O6f (Westerlund 1960) or O7f (Hutchings 1976). Westerlund by assuming membership in the ARA OB1 association derived

M_V = -6.2 corresponding to a distance of 1400 pc. However, Hutchings, based upon the Hα equivalent width, derived a more luminous $M_V = -7.2 \pm 0.4$.

Recently, from studies of IUE high-dispersion spectra, Hutchings and Rudloff (1980) find high mass-loss rates for extreme Of stars. Yet, the two extreme Of stars HD108 and HD148937 were exceptions and did not fit into this scheme. The UV resonance profiles of C IV and Si IV in these stars were unsaturated indicating mass-loss rates of $2 \times 10^{-7} M_\odot\ yr^{-1}$, a rate two orders of magnitude below what is expected from extreme Of stars. The reason for these low mass-loss rates remain unexplained. A clue may be found in that Hutchings and Rudloff refer to a private communication by Walborn who noted that these stars are quite different in their spectral morphology from other Of stars; an aspect also described by Westerlund (1960) in the case of HD148937.

The narrow bandpass photographs show very strong diffuse [O III] indicating a rather hot O star exciting NGC6188, the nebula immediately to the east of HD148937. Two O stars HD150135 (O6.4V) and HD150136 (O5III) fall on the sky where the most intense emission is observed.

In Table 1, the pertinent information for these stars is given. By adopting M_V = -5.0 for a typical O6.5V star (Panagia 1973) and assuming interaction of the large circular shell and NGC6188, we deduce a distance of 1200 for both HD150135 and HD148937. This in turn implies a M_V = -5.7 for HD148937. This is a luminosity much less than found by Hutchings (1976) and slightly lower than adopted by Westerlund (1960). Clearly the H II region around HD148937 is in the foreground to NGC6188 and likely interacting with it. As such, M_V = -5.7 represents an approximate upper limit to the luminosity of HD148937.

Examination of an IUE high-dispersion spectrum of HD148937 loaned to us by Peter Conti revealed that it closely mimicked UV spectra of O stars like the subdwarf HD48798 and the MK spectral standard 15 Mon (O7 V). One might add that by accepting that HD148937 is near the main sequence that the low mass-loss rate found for this star in the UV is no longer discrepant since mass-loss rates of main-sequence stars are much lower.

PHYSICAL CONDITIONS AND AGES OF NEBULOSITIES

In order to estimate the physical conditions in the outer nebula we adopt the approach of Lasker (1967, 1966) in describing H II regions. For this discussion the interstellar medium interior to the filamentary 'halo' can be ignored. Using the data from Panagia (1973) and taking radii of the H II region corresponding to the range of possible luminosities and distances of HD148937 (i.e. ZAMS to a star of M_V = -5.7) we can derive the parameters describing the physical conditions of the expanding H II region surrounding HD148937.

As a H II region expands into the interstellar medium at some point a compressed neutral shell forms just ahead of the ionization front. This best describes what we see in the outer nebula surrounding HD148937. In this case, the thin dust shell delineates the compressed neutral gas.

With the relative thickness of this dust shell ($1-ri/_{rs}$), and the physical dimensions in hand we can use the models and approximations of Lasker (1960, 1966) to estimate the physical conditions and age of this H II region. The results are given in Table 2 for values for a star with $M_V = -4.7$ (a star near the ZAMS) and for a star with $M_V = -5.7$. These results indicate that the H II region is quite young with an age on the order of 3×10^5 to 6×10^5 yrs.

If we consider that the inner shell or filamentary halo is due to an interstellar bubble, the snowplow approximation gives for the radius of the bubble (Weaver, McCray, and Castor 1977)

$$R = 27\ n_6^{-1/5}\ L_{36}^{1/5}\ t_6^{3/5}\ \text{pc.}$$

This was determined by scaling the mass-loss rate found by Hutchings and Rudloff to the lower luminosities found relevant here. Taking the angular dimensions of the inner halo structure, we find the range of deduced ages varying from 2.4×10^5 to 5×10^5 years for the less and more luminous cases at 790 and 1200pc respectively. These results compare favorably with the ages determined for the H II region for these same two cases.

CONCLUSION

The ages implied from the interstellar bubbles and the H II region imply a young age and are in relatively good agreement. In addition, the UV spectrum is very similar to other high gravity O stars. The evidence strongly favors the interpretation that HD148937 is an unevolved O star. The inner S-shaped nebulosity (NGC 6164-5) may in fact be due to instabilities which have occurred in a very young O star. The remarkable symmetry of this nebulosity has lead Pismis (1974) to suggest that this material was ejected from the polar regions of the central star.

The strong similarities of this nebulosity to planetary nebulae plus the fact that HD148937 is quite bright ($M_V = 6.71$) suggest that similar objects may be masquerading as planetary nebulae.

Table 1

HD148937 and the Exciting Stars of NGC 6188

star(HD#)	Sp. Type	V	A_V
148937	06-07V	6.71	1.98
150135	06.5V	6.89	1.47
150136+	05III	5.62	1.44

\+ possible binary

Table 2

Physical Conditions of the H II Region

	CASE A	CASE B
distance	790 pc	1200 pc
ionization radius	12 pc	18.5 pc
interior number densities	10 cm^{-3}	13.4 cm^{-3}
shell density	37-70 cm^{-3}	50-95 cm^{-3}
ambient number density	17-18 cm^{-3}	22.5-24
$1-(r_i/r_s)$	.05-.09	.05-.09
t_{char}	3.5×10^5 yr.	5×10^5 yr.
S_o	8-8.5 pc	12.5-13 pc

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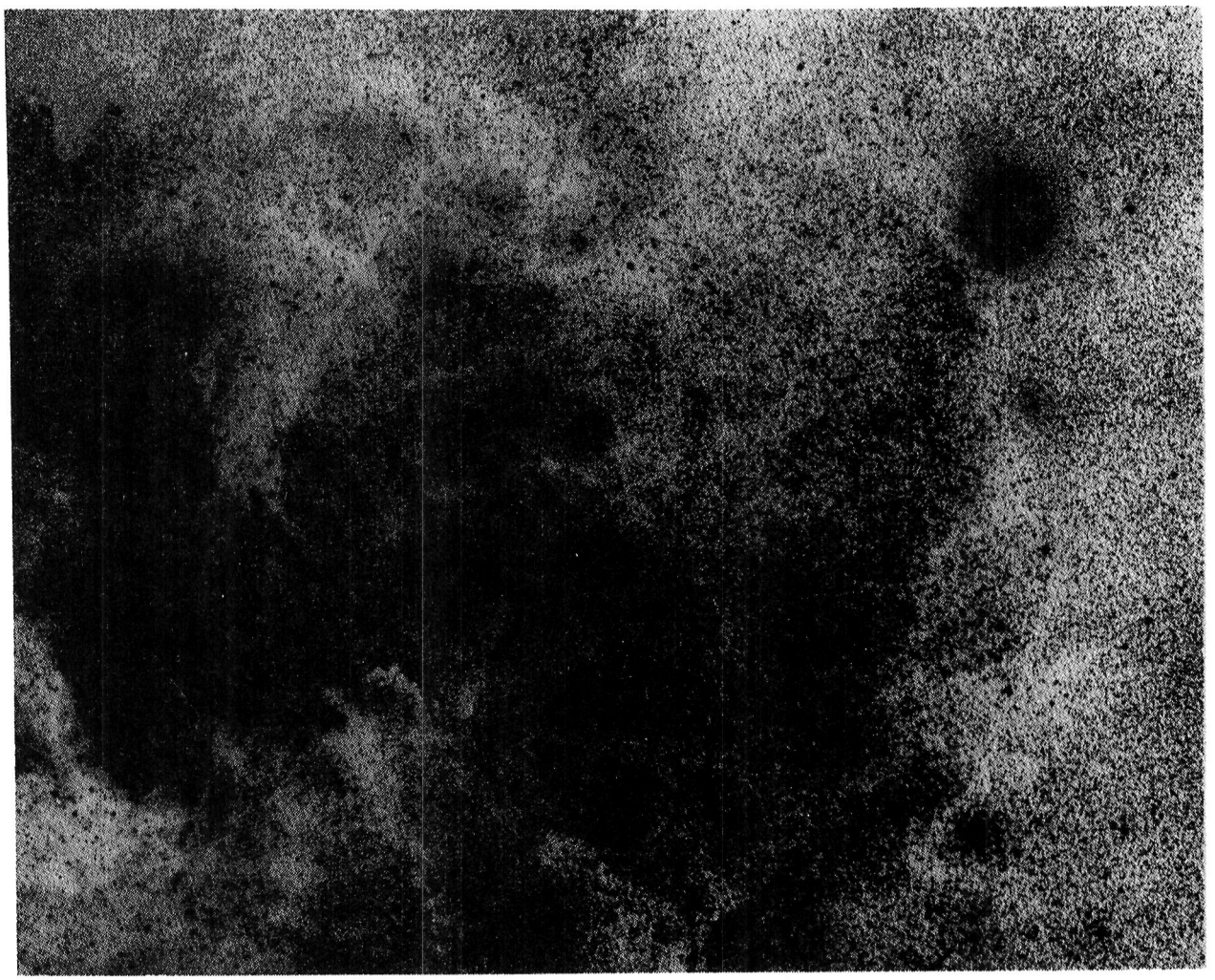

Figure 1 - The nebulosities surrounding HD148937 as imaged by the SRC Schmidt telescope using IIIaJ emulsion and GG395 filter. Innermost is the S-shaped nebulosity, NGC6154-5, centered upon HD148937. Faintly discernible is the hollow cavity immediately surrounding the star. The cavity is sharply bounded by filamentary structure initially detected as [O III] filaments. The H II region, extending two degrees, is faintly detected here but well-defined in Hα imagery. The H II region is bounded by a thin, dusty shell surrounding the entire structure. NGC 6188 is seen to the east.