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THE UNSTABLE O6.5f?p STAR HD 148937 AND ITS INTERSTELLAR ENVIRONMENT

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The massive, early-type star HD 148937 (spectral type O6.5?p) is surrounded by a unique set of nebulosities. A spherically symmetric Strömgren sphere (Radius ≃ 25 pc), an ellipsoidal filamentary nebulosity (semimajor axis ≃ 5 pc) interpreted as a stellar-wind-blown shell, and a bipolar nebular complex (semimajor axis ≃ 1 pc) with HD 148937 located in the apparent center of symmetry. Here we report on observations of these nebulosities (narrow-band CCD imaging, IDS spectrophotometry, high resolution ($\Delta V \simeq 7$ km sec^{-1}) spectroscopy) in an attempt to establish a consistent model of HD 148937 and its nebulosities.

The two bipolar nebulosities (known as NGC 6164/5 show striking resemblance. They are of similar extent and distance from HD 148937 implying a simultaneous origin due to an explosive event in HD 148937. A comparison of H_α- and H_β-images and IDS fluxes gives a rather homogeneous dust distribution all over the bipolar nebula with an extinction in agreement with E(B-V) of HD 148937. We conclude that the apparent morphology of NGC 6164/5 is not simulated by variable extinction but rather reflects the actual distribution of (excited) gas. Moreover, it is safe to assume that the distribution of H_α emission is identical with the total amount of gas in the inner nebulosities (i. e. NGC 6164/5 is density-bounded). The output of Lyman quanta of HD 148937 (log $N_L \simeq$ 49.15 sec^{-1}) even suffices to keep ionized the stellar-wind-blown shell and the Strömgren sphere. The ratio [O III]/H_β drastically decreases with increasing distance from HD 148937. This behavior is paralleled by a corresponding increase of [N II]/H_α indicating the transition from the high-ionization zone to the low-ionization zone. We stress the similarity to the structure of ejecta from novae (see Gallagher and Anderson 1976).

In establishing a geometrical model for the bipolar nebula we are led by its striking resemblance to ejecta from novae or symbiotic stars (e. g. Solf 1983). The high rotational velocity of HD 148937 ($v \cdot \sin i = 200$ km sec^{-1}, Conti and Ebbets 1977) strongly implies axial symmetry for the system and thus giving rise to the ejection of matter preferentially along the two axes of symmetry. The detailed kinematic structure is derived from our highly-resolved line profiles. We find a double-cone structure nearly perpendicular to the line of sight with a kinematic age of 10^3 - 10^4 yr. The ejection of the nebulosities may be due to instabilities in this star close to the Of-WR transition phase. The high rotational velocity may play a crucial role in these instabilities.

The influence of rotation on the stellar wind of HD 148937 and the resulting non-isotropic mass flow could also account for the oval--shaped structure of the wind-blown shell. We underline that the spectral appearance of this shell is typical of wind-blown shells from e. g. WR-stars and clearly excludes an origin as due to a SN explosion.

The age of the bubble as determined from the luminosity of the wind is a few times 10^5 yr.

Since NGC 6164/5 is clearly ejected by the star and expands into space with virtually no contamination by ISM (the density in the stellar-wind cavity is $\sim 10^{-2}$ cm^{-3}) it provides the unique possibility of studying the chemical abundances of an evolved Of star. Our physical analysis gives an electron density of $1 \cdot 10^4$ cm^{-3} for NGC 6164 and $7 \cdot 10^3$ cm^{-3} for NGC 6165, respectively. The electron temperature is 6700 K. In these respects the nebulosities closely resemble normal H II regions. We find no evidence for shock excitation in the lines. The abundance analysis is treated in the usual way following Peimbert and Costero (1969). We find an overabundance of nitrogen relative to hydrogen by a factor of 6 relative to the sun for NGC 6164/5. On the other hand, the outer border of the Strömgren sphere (NGC 6188) shows abundances typical of normal H II regions. An overabundance of N by a factor of 6 is in good agreement with theoretical evolutionary modelling of stellar abundances by Maeder (1983). This provides strong support for the evolutionary state of Of stars as being intermediate between O- and WR-stars.

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