NEBULAE ASSOCIATED WITH Of STARS: S60, S108, and Of #23

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RESUMEN. Se obtuvieron fotografías e interferogramas F-P en Hα de tres nebulosas supuestamente asociadas a estrellas Of con el objeto de confirmar la asociación con las estrellas y obtener las velocidades de expansión de las nebulosas. Los resultados preliminares que se muestran, indican que dos de estas nebulosas son burbujas formadas por los vientos de las estrellas.

ABSTRACT. We obtained Hα photographs and Fabry-Pérot interferograms of three nebulae presumably associated with Of stars in order to check such association and to obtain the nebular expansion velocities. Preliminary results indicate that two of these nebulae are wind-blown bubbles.

Key words: NEBULAE-H II REGIONS — STARS-Of TYPE

I. Introduction:

    In an attempt to study the characteristics of the nebulae associated with Of stars, Lozinskaya (1982) has searched for Of stars in the direction of HII regions. She found 41 such cases but she was unable to establish a real association between the nebulae and the Of stars, except for a small number of cases. She also gave a classification of nebulae around Of stars in the same way as Chu (1981) has done for nebulae around WR stars.
    In this work we select three such nebulosities: Of#23, SG154 (S60) and SG196 (S108) (where the SG refers to the catalogue of HII regions of Shajn and Gaze (1954) and Of#23 is the name given by us for the Hα emission reported by Lozinskaya (1982) in the direction of the star HD313864). In this way one could check whether these nebulae are really associated with the Of stars present and, if so, to determine their nature (wind-blown bubbles, simple HII regions, etc.). Table 1 gives the data of these nebulae and of their presumably associated stars.

TABLE 1. DATA OF THE OBSERVED NEBULAE

#	NEBULA	STAR	SP. TYPE	m_v	α(1950)	δ(1950)	ASOC.
1	EM Hα,Of#23	HD 313364	O f	10.70	18 02 24	-23 01	
2	S 60,SG 154	HD 172175	O6 f	9.44	18 36 24	- 7 54	SCT OB2
3	S 108,SG 196	HD 193514	O7 I bf	7.40	20 17 18	+39 07	CYG OB1

    In what follows we give our preliminary results (Hα photographs and Fabry-Pérot (F-P) interferograms). The Hα photographs and the systemic velocities, obtained from the radial velocity field of the nebulosities, allow us to establish the morphology of the nebulosity at the location of the Of star and the kinematic distance of the nebula (to be compared with the stellar distance) respectively. These data allow us to decide if the nebula is really associated

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with the Of star. The radial velocity field allows us also to obtain the expansion velocity of the nebulae in the case of wind-blown bubbles. The expansion velocity, together with an estimate of the electron density, could give insight into the evolutionary stage of the nebula by evaluating the parameters ε and π defined as (Chu 1981 ;Rosado 1986a):

$$\epsilon = Ms \ Vs^2/2 \ Lw \ t \qquad\qquad \pi = Ms \ Vs/Mw \ Vw \ t$$

where Ms is the mass of the wind-blown bubble obtained from the electron density as in Rosado (1985 and 1986a), Vs is the expansion velocity of the bubble, t, the kinematical age and Lw, Mw and Vw are the luminosity of the wind, mass-loss rate and the wind velocity respectively.

II. Observations:

The observations of these nebulosities were of two types: Hα photographs and F-P interferometry. Both of these were performed at the 2.1m Cassegrain focus telescope of the Observatorio Astronómico Nacional at San Pedro Mártir, Baja California. Details of the equipment and the reduction of data are given in Rosado (1983 and 1986b).

III. Preliminary Results:

Figures 1 shows the Hα photographs obtained for the three nebulae. In two of the photographs (SG196 anad SG154) we noted a limb-brightening effect which is in agreement with the idea that the Of star has given origin to the nebula. In the case of Of#23 we cannot say much because the field of the photograph is smaller than the overall extent of this nebulosity. It is necessary to obtain more photographs in order to know the diameter of this region and to see if a limb-brightening effect is at all present.

The F-P interferograms of these regions enable us to obtain the kinematic distance of SG 196 and Of#23 and the expansion velocities of the nebulae SG154 and Of#23. Figure 2 shows some of the profiles obtained from digitizing the photographic density of the F-P rings by means of a PDS. Table 2 gives the systemic and the expansion velocities obtained. It gives also the kinematic distances estimated from the systemic velocities as well as the photometric distances of the stars.

TABLE 2. SYSTEMIC AND EXPANSION VELOCITIES OBTAINED FOR THE NEBULAE

nebulae	:	Vs (km/s)	:	Vexp (km/s)	:	Kinematic D. (pc)	:	Photometric D. (pc)	:
SG 196	:	6.01	:	---	:	1250	:	1310 *	:
Of #23	:	6.13	:	>20	:	1250	:	---	:
SG 154	:	---	:	≥16	:	---	:	---	:

* from Cruz-González et al. (1974); exciting star HD193514

SG196 seems to be at the same distance as the Of star HD193514 implying that this nebula is indeed associated with the star. However, the F-P rings do not show any violent motion. This could mean that SG196 is simply illuminated by the Of star.

We did not find any estimate of the photometric distance of HD313864 and consequently we could not establish if the nebula Of#23 (the kinematic distance of which is 1.25 kpc) is at the same distance. On the other hand this nebula shows some violent motions (revealed through splittings of its F-P rings, see Fig. 2). We estimate an expansion velocity of about 20 km/s. Since there are no data reported about the electron density of this region, we cannot estimate
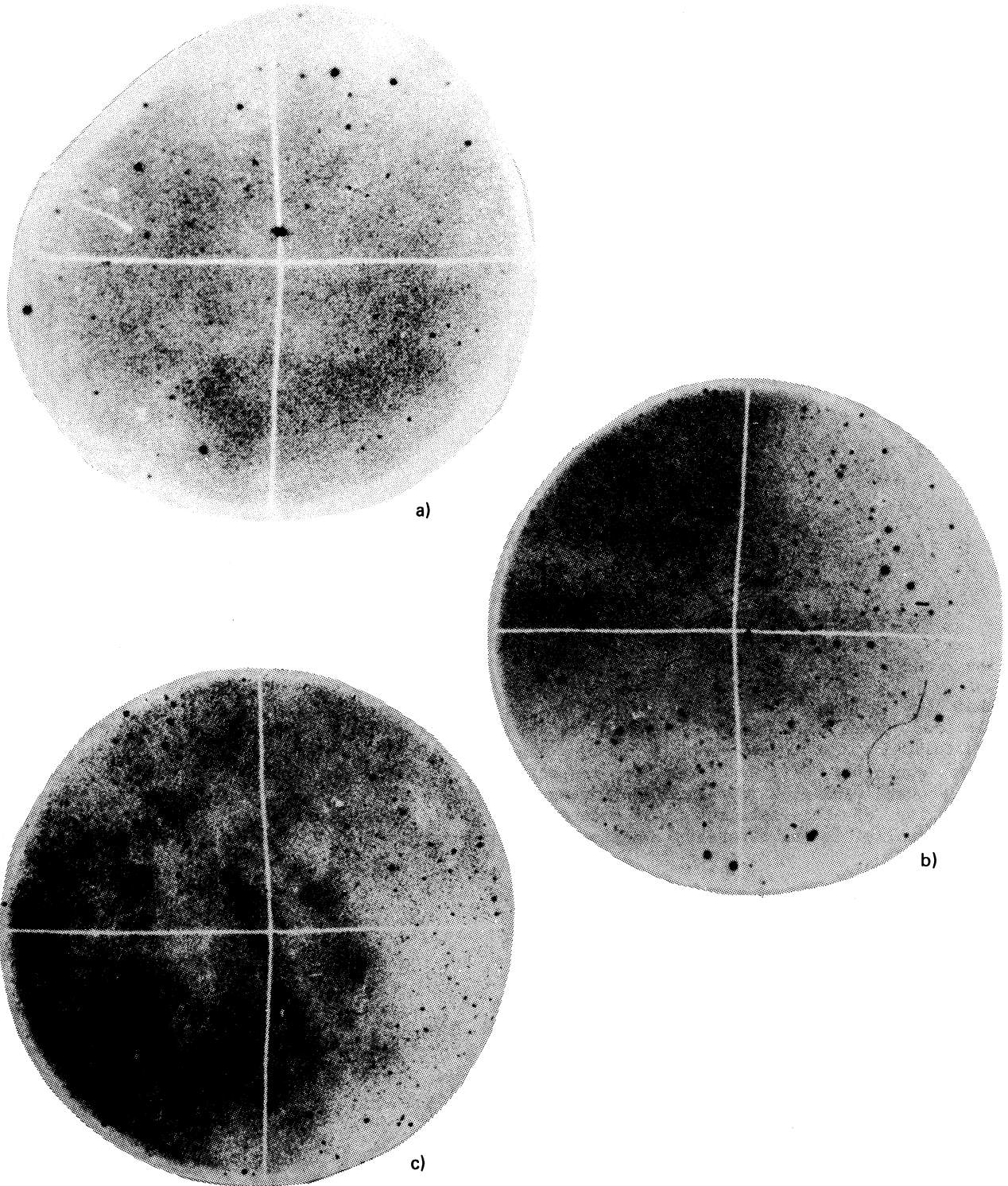
Fig. 1. Hα photographs of the nebulae: a) SG 196; b) Of #23; c) SG 154.
In all cases the north is at top, east at right. The angular diameters
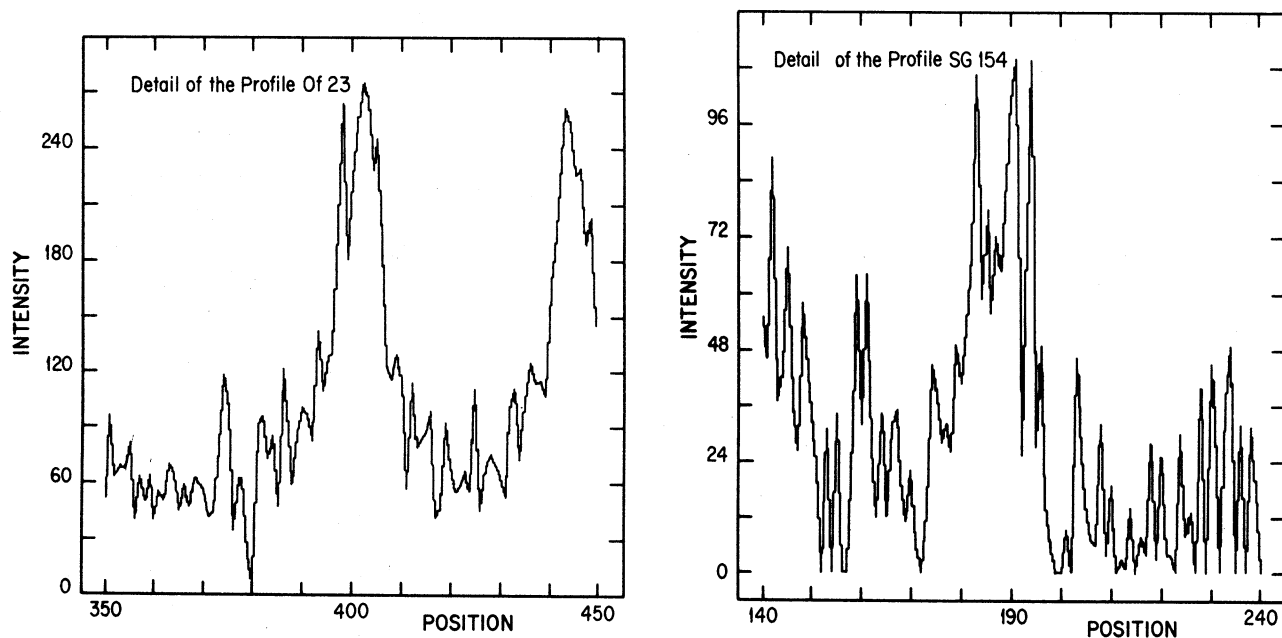of the pictures are for a) and b) φ = 12' and for c) φ = 30'.

Fig. 2. Details of the F-P interferograms of: a) SG 154; b) Of #23. The horizontal axis shows the position across the nebula, the vertical one the intensity in arbitrary units.

the ε and π parameters defined above.

SG154 seems to be a complex nebulosity. From its radial velocity field it appears that the nebula could be expanding with a velocity of about 16 km/s. With an estimated rms electron density of $1.13 \mathrm{cm}^3$ (obtained from the Hα surface-brightness of Shajn and Gaze (1954) and following the method given in Rosado 1986a), we obtain that the ε and π parameters defined above would be: 5.51×10^3 and 0.66 respectively, in agreement with evolutionary models where the shocked wind slab is radiating (for ex.: Steigman et al. 1975). However, given the complexity of this nebula, it is necessary to obtain more interferograms in order to see if there really is an expansion motion and in order to obtain the kinematic distance of the nebula.

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