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INTERNAL MOTIONS IN H II REGIONS. VII. THE EMISSION NEBULAE COMPLEX S 147, 148 AND 149

E. Recillas-Cruz and P. Pişmiş

Instituto de Astronomía
Universidad Nacional Autónoma de México
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RESUMEN

Se presentan velocidades radiales determinadas a partir de interferogramas Fabry-Pérot del complejo de regiones H II formado por las pequeñas nebulosas S 147, 148 y 149.

Se aprecian movimientos internos considerables; la velocidad común del complejo es -62 km s^{-1}, estimándose una distancia cinemática de 4.3 kpc. S 148 está probablemente expandiéndose a una velocidad de 8 km s^{-1}. La estrella central de S 148 muestra un enrojecimiento de 0.4 magnitudes debido al contenido de polvo de esta nebulosa.

Estos resultados indican que posiblemente S 148 sea un objeto joven, más joven aún que S 147 y S 149. El complejo nebular puede ser entonces uno más de los casos en los que condensaciones dentro de una misma nube interestelar se encuentran en diferentes etapas evolutivas.

ABSTRACT

Radial velocities determined from Fabry-Pérot interferograms of the H II region complex composed of the small nebulae S 147, 148 and 149 are discussed. Large internal motions are exhibited in S 148 and S 149; the common velocity of the complex is -62 km s^{-1} from which the estimated kinematic distance is 4.3 kpc. S 148 is probably expanding at a rate of 8 km s^{-1}. The central star of S 148 shows a reddening of 0.4 magnitudes caused by the high dust content of this nebula. These results indicate that S 148 is probably a young object younger than S 147 and S 149. The nebular complex may therefore be another case where condensations within the same interstellar cloud are at different evolutionary stages.

Key words: **H II REGIONS — INTERFEROMETRY — RADIAL VELOCITIES.**

I. INTRODUCTION

The emission nebulae S 147, 148 and 149 were discovered by Sharpless in his first survey of H II regions using Palomar 48-inch Schmidt plates (Sharpless 1953). The estimated diameters are, in arc minutes, 2, 2 and 1 respectively and the brightness estimates are, in relative scale, 1, 3 and 2. (Sharpless 1959). Figure 1 (Plate 6) shows an enlargement of an image tube direct plate taken through a 10 Å halfwidth filter at Hα. There is a faint Hα extension between S 147 and S 148 not noted or mentioned earlier. On the 1400 MHz map of the area by Felli and Churchwell (1972), S 148 and S 149 lie within the same flux density contour while S 147 lies in the next fainter contour, although the three nebulae are not detected individually. Bergeat *et al.* (1975) have reported the discovery of a very bright infrared point source in the northern edge of S 149. This object is distinctly seen on Figure 1. We have carried out Fabry-Pérot interferometry of the region particularly of S 148 and S 149. In this paper, we present in particular, the radial velocity field we have obtained and some consequences thereof.

II. THE OBSERVATIONAL MATERIAL

The present work is based on 4 interferograms taken with a focal reducer attached to the Cassegrain focus of the 83 cm reflector of the Observatorio Astronómico at San Pedro Mártir, B. C. The Fabry-Pérot étalon used in this study (constructed by ICOS) has an inter-order separation of 190 km s^{-1} and a finesse of about 8.

An interference filter of 10 Å halfwidth isolates the Hα-line radiation. A one-stage Varo image tube and 103aG films are used throughout. The linear scale on the film is 1.5 arcmin per millimeter. The interferogram of a hydrogen lamp taken after the field exposure is used for wavelength calibration. The interferograms are measured using the Mann comparator of the NASA Johnson Space Center and the reductions carried out following the scheme given by Courtès (1960).

III. THE VELOCITIES

In Table 1 we list the observational material. The first column is the identification of the interferogram. The second and third, the 1975 equatorial coordinates of the plate center. The fourth, the mean radial velocity from all significant points measured on an interferogram and the standard deviations, the fifth the number of points measured. In our discussion we have attempted, by visual comparison of the interferograms and the direct image of the nebulae, to discard all velocity points which would be affected by convolution of the interference rings with the image of the nebula. However there may still exist some effects of convolution in our velocities. We should also mention that the H II regions discussed here are rather small for our plate scale so that few points could be measured on each interferogram. An enlarged sample interferogram, FI 360, is reproduced in Figure 2 (Plate 6). In any case we can safely state that large internal motions exist in S 148 and to some extent also in S 149.

A first step towards a comparison of the different interferograms was to obtain a mean velocity from all points measured on an interferogram. The average velocities on the different interferograms show a sizable range: from −52 km s^{-1} to −70 km s^{-1} while the average over all points of the four interferograms is −62 km s^{-1}. This large range may be the combined manifestation of the different effects mentioned in the foregoing paragraph. For these same reasons we shall not give a detailed discussion of the overall average velocity field from the interferograms.

Next, we divided S 148 and 149 into sub-regions identified by letters, following the contours suggested largely by the direct Hα image given in Figure 1 (Plate 6). The sketch of the sub-regions appears in Figure 3. Table 2 gives the mean velocity of each sub-region with the standard deviations where the inner part of S 148 proper marked A is singled out by dashed lines. An excess negative velocity of 4 km s^{-1} is shown with respect to the surrounding region. Although the evidence is weak it is tempting to interpret this relative velocity of approach as due to the expansion of S 148; if so the radial expansion velocity would be around 8 km s^{-1}, twice the observed line of sight component. The differences between S 148 (sub-regions A and B) and S 149 (sub-region D) do not seem to be significant. We adopt a common radial velocity of −62 km s^{-1}, the average over all measured points (63 points) to represent the motion of the complex of the three nebulae. This velocity after correction for the standard solar motion gives V_{LSR} = −51 km s^{-1}. Based on the Schmidt rotation

TABLE 1

OBSERVATIONAL MATERIAL

Plate Number	Coordinates of Plate Center (1975) α	δ	Mean Radial Velocity* (km s^{-1})	Number of points
FI 360	22^h55^m	+58°26′	−62.5 ± 4.8	21
FI 362	22 55	+58 26	−52.4 ± 5.5	19
FI 363	22 55	+58 20	−70.3 ± 13.8	12
FI 522	22 55	+58 26	−63.4 ± 15.0	11

* with standard deviations.

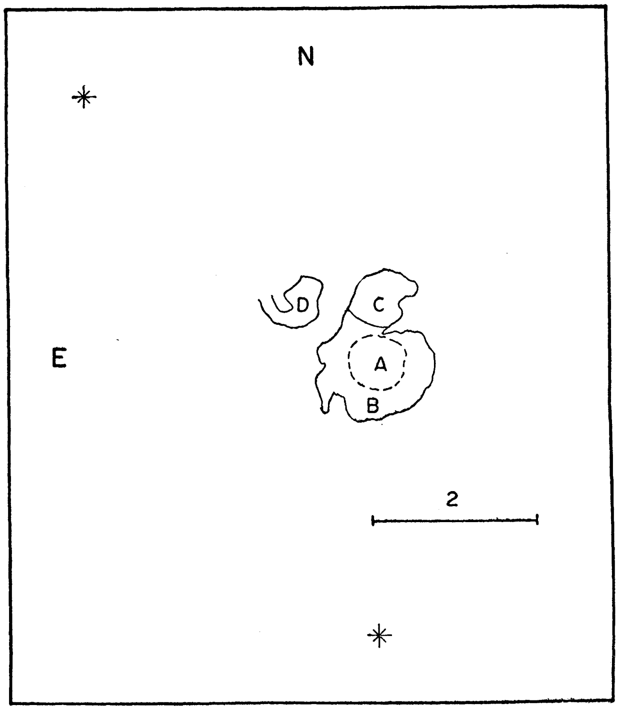

FIG. 3. A sketch of the sub-regions into which the H II regions S 148 and 149 are divided.

law the common kinematic distance of the complex is 4.3 kpc. This is an uncertain value and probably an underestimate for there is at present evidence to believe that the rotation curve of the Galaxy deviates from the Schmidt curve in that its maximum is rather flat. Clearly with a flat maximum, radial velocities cannot provide a sensitive measure for distances determined by such a rotation curve.

IV. THE EXCITING STARS

Crampton *et al.* (1978) have identified the exciting stars of S 148 and S 149 and tentatively that of S 147. Table 2 summarizes the relevant data of the three regions and their exciting stars. We call attention to the colors of the exciting stars; it strikes to attention that the B-V color index of the central star of S 148, 0.94 magnitudes, is much too large compared with that of S 149 which is 0.54 magnitudes. The intrinsic *B-V* colors of these stars are quite similar, namely −0.31 and −0.30 magnitudes respectively. (See Cruz-González *et al.* 1974) With these values the reddening amounts to 1.25 magnitude for the exciting star of S 148 and 0.84 magnitude for that of S 149. The linear diameter of S 148 is around 2.6 pc for a distance of 4.3 kpc (kinematic) or 3.3 pc if we use the photometric distance of the central star. Thus the observed internal extinction of S 148 is occurring within a depth not exceeding 3.3 pc. The common distance from us of these two regions and their proximity to one another makes it quite unlikely that the difference in the reddening, 0.41 magnitude, will be interstellar. We therefore conclude that this difference is intrinsic to S 148, caused by the high density of dust in this nebula. A maximum reddening of 0.84 magnitudes, equal to the reddening undergone by the central star of S 149 and hence an extinction of 2.52 magnitudes (for R = 3) could well be attributed to interstellar extinction for a distance of 4.3 kpc which we obtain from our kinematical data; the corresponding extinction per kiloparsec could be about 0.6 magnitudes quite an acceptable value. This indicates that there is little or no excess extinction within S 149; the dust content is quite comparable to that of the average interstellar medium in the galactic plane.

We have made estimates of the distances of S 148 and S 149 from the known spectra and colors of the central stars. From the absolute magnitudes and intrinsic color calibrations of FitzGerald (1970) we obtain a distance of 5.5 kpc for the central star of S 148 and 5.4 kpc for the central star of S 149. These distances, although larger than the kinematic distances

TABLE 2

PHYSICAL PARAMETERS OF CENTRAL STARS (FROM CRAMPTON *ET AL.* (1978)) AND THE MEAN NEBULAR VELOCITIES

Region	Star	*V*	*B-V*	Sp. Type	Mean Velocities
S 147	Anon	12.89	0.85	(A4V)	-61 ± 5 km s^{-1}
S 148	Anon	12.55	0.94	O8V	-62 ± 15 km s^{-1}
S 149	Anon	12.47	0.54	B0V	-64 ± 10 km s^{-1}

are comparable and provide evidence for the physical relationship of the two nebulae.

The star associated with S 147 given in the list of Crampton *et al.* (1978) is evidently not the star exciting S 147, if indeed the spectral type is as listed in Table 2.

V. DISCUSSION AND CONCLUSIONS

The kinematic as well as the photometric data together with the fact that at least S 148 and 149 are contained in the same flux contour at 1400 MHz (Felli and Churchwell 1972) indicate that S 147, 148 and 149 are spatially sufficiently close as to be considered members of a nebular complex. The three nebulae must therefore have originated from the same interstellar cloud. In particular the more reliable data on S 148 and 149 may warrant further discussion. The higher dust content of S 148 is indication, according to current ideas, that it is a young region younger than S 149 (and far younger than S 147). Here we probably have one more case, resembling the nebular complex S 254, 257 and 255 (Pişmiş and Hasse 1976) where the H II regions formed out of the same cloud are at different evolutionary stages; they are not formed coevally but rather at successive epochs. It should be interesting to search for IR or molecular sources in the region of these emission nebulae.

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Note added to the proof:

The infrared point source in the direction of S 149 mentioned in the text is shown by R. W. Russell (1978, *Astr. and Ap.*, **67**, 273) to be of spectral type M1 and luminosity class Ib-II and not a highly reddened O star as stated by Bergeat *et al.* (1975).

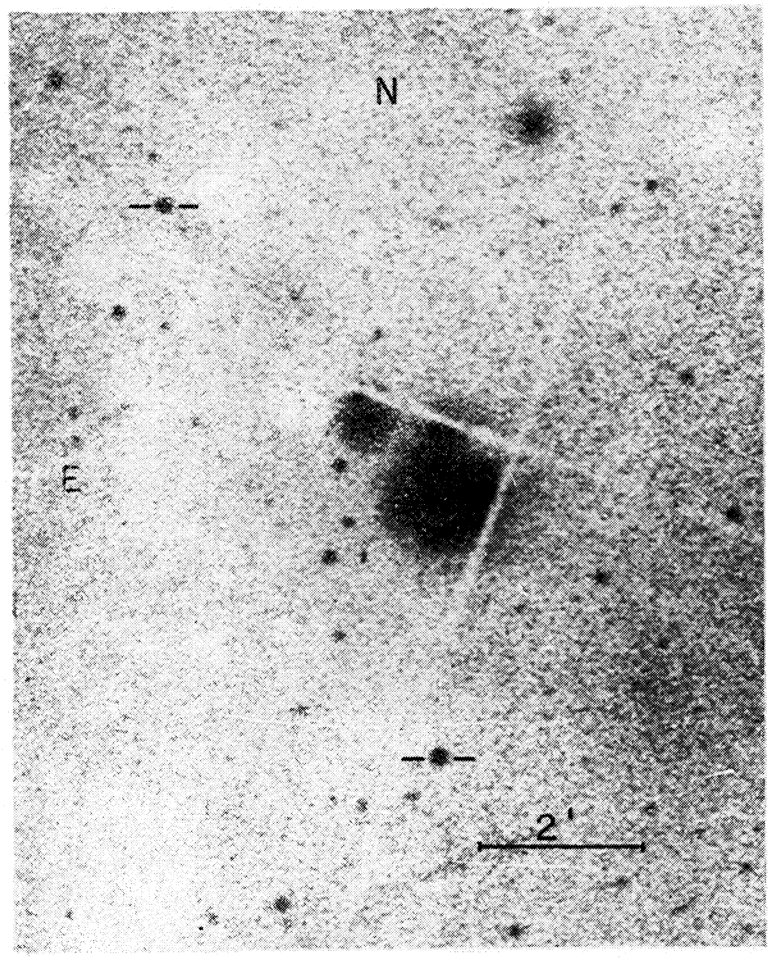

FIG. 1. Enlargement of an image tube Hα photograph of the H II region complex S 147, 148 and 149 taken with a focal reducer mounted at the Cassegrain focus of the 83 cm reflector of the observatory at San Pedro Mártir, B. C. The scale on the original film is 1.5 arc min per millimeter.

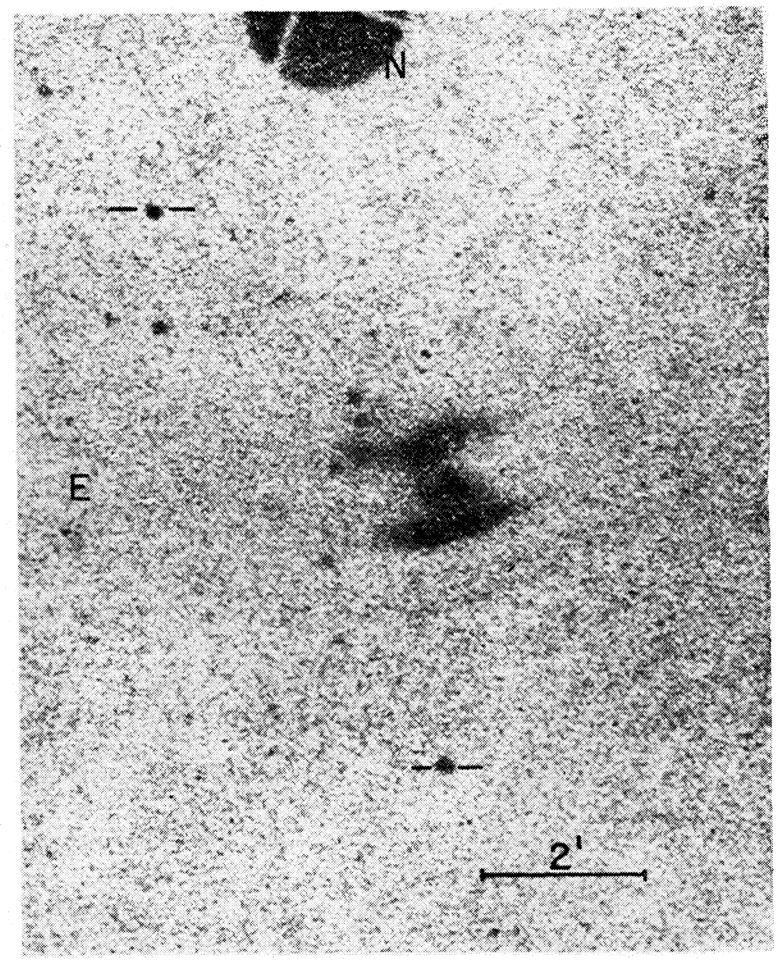

FIG. 2. An image tube interferogram at the H II regions discussed in the text taken through a 10 Å interference filter and a Fabry-Pérot étalon giving an interorder separation of 190 km s^{-1}.

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