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INTERNAL MOTIONS IN H II REGIONS. X. ARE THERE OPTICAL H II REGIONS ASSOCIATED WITH THE ORIGEM LOOP?

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RESUMEN

Se examina la proposición de que las nebulosas de emisión S254, S255, S257, S261 y S269 están físicamente relacionadas con el viejo remanente de supernova, la llamada "Origem Loop". Velocidades radiales ópticas determinadas con el método Fabry-Pérot están dadas en las regiones S261 y S269 mientras que las de S254, S255 y S257 están publicadas anteriormente. Se ha hecho una discusión de las distancias cinemáticas de las regiones H II así como de las fotométricas de sus estrellas ionizantes. Basándose en estas distancias se concluye que de estas cinco regiones H II solamente S261 puede pertenecer al Origem Loop.

ABSTRACT

The proposition that the emission nebulae S254, S255, S257, S261 and S269 are physically related to the old SNR –The Origem Loop– is examined. Optical radial velocities obtained by the Fabry Pérot method are given over the regions S261 and S269 while those of S254, 255 and 257 are published earlier. The kinematic distances of the H II regions as well as the photometric distances of their ionizing stars are discussed. On the basis of these distances it is concluded that of these five H II regions only S261 may belong to the Origem Loop.

Key words: **H II REGIONS – RADIAL VELOCITIES – SNR**

I. INTRODUCTION

A ring-like structure in the 178 MHz continuum map of Caswell (1969), and centered on $l = 194.7$ and $b = 0^{\circ}.4$ was singled out by Berkhuijsen as an old supernova remnant (1974). It was designated as the Origem Loop since it is located at the border of Orion and Gemini. The area was mapped at various other wavelengths, results of which gave support to Berkhuijsen's suggestion; at 820 MHz (Berkhuijsen 1972) at 38 MHz (Williams *et al.* 1966) at 408 MHz (Haslam *et al.* 1970) at 2700 MHz (Day *et al.* 1972).

The difficulty to discover old supernova remnants stems from the extent and therefore the faintness of these structures as noted by Berkhuijsen, hence the importance of the Origem Loop.

From its radio properties the distance of the shell is estimated to be 1 kpc. Further, Berkhuijsen carried out a search in the literature to find out whether other sources such as H I, H II, dust, OH, IR, pulsars or X rays are associated with the Loop and stated that the association of some of these sources, existing in the area, with the SNR is inconclusive except for the optical H II regions Sharpless S261, S269 and the triple nebula S254, 257, 255, all of which are located on the Loop. From a selection of the published distances of these nebulae Berkhuijsen concludes that they probably belong to the Loop and are the outcome in some way of the SN phenomenon; "either star formation has taken place inside the shell, or has been triggered by the passage of the shock through the clumpy interstellar medium".

In our general program on the Internal Motions in H II Regions, extending over the years, the objects considered by Berkhuijsen are also to be found. Our study of the triple object S254, 257 and 255 has appeared earlier (Pişmiş and Hasse 1976) while the radial velocities of the other two H II regions, S261 and 269 will be given below for the first time.

We have therefore deemed it useful to present a discussion of our kinematic data of these H II regions as well as of their photometric distances in relation to the problem of the Origem Loop.

We argue in this paper against the association of all of these regions to the Origem Loop. In particular we show that S269 and the triple H II regions S254, 257 and 255 are much more distant than the Loop and are definitely not associated with it. Only S261, located on the periphery, has a distance comparable to that of the shell and may be part of the Loop.

Our velocities are obtained from photographic Fabry-Pérot interferometry using a focal reducer mounted at the Cassegrain focus of the 1-meter reflector at

Tonantzintla Observatory. The étalon has a free spectral range of 283 km s^{-1} at Hα which is isolated by a 10 Å half-width interference filter. The interferograms of the triple nebula and S261 are recorded on Kodak Special 098-01 plates, unless specified otherwise. The plate scale is around 3 arcmin per millimeter.

II. S254, S257, S255. THE TRIPLE NEBULA

These are small H II regions aligned at almost equal declination and close together in the sky, the largest dimension of this triple object not exceeding 20 arcmin.

In our previous paper (Pismis and Hasse 1976) we have shown that these nebulae are at a common distance from us, a circumstance suggesting strongly that they were formed out of the same interstellar cloud. Our data consisted of FP radial velocities as well as photometry of the central stars. Arguments were also brought forth to conclude that the nebulae were formed sequentially: S254 being the oldest and S255 the youngest.

The relevant result to the present discussion is the value we have found for the common distance of these three regions both kinematically and spectroscopically.

There is, however, a discrepancy between our velocities and those previously given by Georgelin and Georgelin (1970) who also used the FP technique; their velocities of the triple nebula are smaller than ours (as of 1976) by about 8 km s^{-1} - Their average of the 3 nebulae is around 6 km s^{-1} (LSR) whereas ours was around 14 km s^{-1}. Radial velocities obtained from molecular lines are also smaller than ours. In our FP work we have not encountered thus far a systematic effect; our average velocities have agreed reasonably well with determinations by other authors. We therefore believe that our velocities are the correct ones.

For an independent check on our data, 21 velocity points were determined on a recently obtained interferogram (FI 749, March 1981) using the same equipment as described above but through a one-stage Varo image intensifier, giving a linear scale of 1.5 arcmin mm^{-1}. The mean LSR velocity is now 12.9 slightly smaller than our earlier average. Although the discrepancy between our new velocities and those of the Georgelins persists, our values based on a larger number of interferograms and points as the Georgelin data are expected to be more reliable, particularly because convolution effects, if they exist at all, will be cancelled out. Supporting the larger value of the velocities is the radial velocity of the ionizing star of S254, HD 253247, 16.2 km s^{-1} obtained by Crampton and Fisher (1974).

Also an agreement with our data is provided by the profile of the 21 cm H I line of S255 which occurs at an LSR velocity of 12 km s^{-1} as obtained by Kazès *et al.* (1977). These authors believe the feature to be real as it is present both at 6 kHz and 60 kHz profiles.

There remains the discrepancy between the molecular line velocities and our optical velocities. If the difference is physically significant it should be rewarding to look into the cause of it.

We adopt the mean radial velocity of the triple nebula as $V_{LSR} = 12.9$ km s^{-1} which is the average over the four interferograms giving double weight to the velocities from the recent interferogram. With this value and using the Schmidt curve for galactic rotation we obtain a kinematic distance of 2.36 kpc. It is interesting to point out a peculiarity in the radial velocity data of S255 obtained from the recent interferogram, FI 749; there is a marked tendency for the radial velocity of the central region to be more negative by about 5 km s^{-1} with respect to the peripheral regions. This suggests that the nebula S255 is expanding at a velocity of at least 5 km s^{-1}.

The photometric distances of the central stars were previously determined as 2.5 kpc (Pişmiş and Hasse 1976). Such a value is also arrived at, independently, by Moffat *et al.* (1979).

III. S261 ($\alpha = 6^h06.1$ $\delta = +15°49'$; 1950)

This nebula has the appearance of a supernova remnant with small well defined arc-like details, particularly on the SW side surrounding the star HD 41997, O7 (Georgelin and Georgelin 1970). The shell is more elongated and fainter towards the north east. No radio continuum radiation has been found coincident with it, although Downes (1971) has identified a non-thermal source about 1° to the north of it. S261 should be regarded as an H II region with only one ionizing source.

The observational data on S261 are given in Table 1 together with the average velocities from each interferogram; the latter cover only the brightest southwestern part of S261. A sample interferogram appears as Figure (Plate) 1. The linear scale on the original plate is 3.1 arcmin per millimeter.

TABLE 1

OBSERVATIONAL DATA FOR S261

Plate	V	n	V_{LSR}	Date
F 173	22.41	50	8.51	7/8 March, 1975
F 176	18.91	79	5.01	1/2 April, 1975
F 180	17.86	32	3.96	5/6 April, 1975

The velocity field is rather smooth; no appreciable internal motions were detected. The average radial velocity over all three interferograms has yielded 19.8 ± 5.1 km s^{-1} ($V_{LSR} = 5.9$) from which a kinematic distance based on Schmidt's curve is 0.9 kpc. Our radial velocity of S261 is in agreement with that of Georgelin *et al.* (1973). The photometric distance of the central star (HD 41997) is 1.63 kpc (Georgelin and Georgelin 1970).

IV. S269 ($\alpha = 6^h11.7$, $\delta = + 13°50'$; 1950)

This is a small compact H II region which on blue PSS prints has a distinctly bi-polar structure. It is also classified as a cometary nebula by Parsamian (1965). The reflection component of this object is proved to exist from a spectroscopic study by Méndez and Parsamian (1974).

We have obtained radial velocities from 4 interferograms covering the nebula. The object is rather small for our plate scale (1.5 arcmin per millimeter) and the interferograms somewhat overexposed such that although radial velocity variations over the face of the nebula do seem to exist we have not performed a deconvolution to obtain reliable relative velocities. However, an interferogram recently obtained with short exposure through a 1-stage Varo image intensifier suggests that there are expanding motions in the nebula. A list of the observational material is given in Table 2.

TABLE 2

OBSERVATIONAL DATA FOR S269

Plate	V	n	V_{LSR}	Date
FI 233	29.82	36	15.42	5/6 March, 1976
FI 317	23.26	7	8.86	11/12 January, 1977
FI 425	28.978	19	14.578	5/6 March, 1978
FI 603	24.22	11	9.82	26/27 February, 1979

The mean radial velocity of S269 from all significant measured points is 28.1 km s^{-1} ($V_{LSR} = 13.7$ km s^{-1}) which yields a kinematic distance of 1.86 kpc. This is about 1.8 times the distance suggested for the Origem Loop (Berkhuijsen 1974). We note that our V_{LSR} of S269 is in excellent agreement with that of Georgelin *et al.* (1973).

V. A DISCUSSION OF THE DISTANCES

The assignment to the Origem Loop of the H II regions treated above is based on a unique criterion: the distance of the nebulae. The kinematic distance of these emission regions have yielded values according to different authors in the range 1 kpc to 3.5 kpc. The photometric distance range is 1 to 3.8 kpc. The diameter of the SNR is 116±52 pc at a distance of *1.1* kpc (Berkhuijsen 1974). On the basis of the latter values, the largest difference in the distance of two objects near the center of the Loop (belonging to the shell) should not be larger than, say, 200 pc. For regions on the periphery of the Loop the difference in distance should be much less if not for random effects or errors. The distances of S254, 257, 255 and 269 both photometric and kinematic are much larger than the confines of the Origem Loop.

In Table 3 we list the V_{LSR} velocities representative of the H II regions discussed above together with determinations of their distances by different authors. All the data are optical; Column 1 is the designation of the H II region. Columns 2 and 3, independent determinations of the V_{LSR}. Columns 4, 5, 6, kinematic distances from the group of Georgelin; 7, kinematic distance from our velocities (of Column 3) based on the Schmidt rotation curve; 8, kinematic distance based on the curve from CO velocities given by Blitz (1979) for the anticenter region; 9 and 10, photometric distauces from different authors. Further details are given as footnotes to the table.

The LSR velocities obtained by a number of authors from atomic H in the radio region and from molecules are listed in Table 4. For the sake of ease in the comparison with the optical data we include in the table our FP velocities from the Hα line averaged over all interferograms.

The distance of the H II regions S254, 257, 255 which Berkhuijsen uses to support the proposed association of these nebulae with the SNR are the smallest out of several sets of kinematic distances available at the time, and which are listed in Table 3. We also note that kinematic distance at the galactic longitude of these objects (192°) may not be too reliable as it may vary rapidly with a few km s^{-1} of difference in the V_{LSR}.

We believe our radial velocities for S254, 257 and 255 to be more reliable than previous ones. The kinematic distances using the Schmidt rotation curve are correspondingly 2.44 kpc, 2.39 kpc and 2.14 kpc. We therefore adopt the weighted mean of the distances, 2.36 kpc, as the distance of this triple nebula.

The photometric distances of the central stars of H II regions are as a rule larger than the kinematic ones in this, third, quadrant of the galaxy (Georgelin and Georgelin 1970) as clearly seen from Table 3.

Berkhuijsen brings the photometric distance down to agree with the kinematic one by adopting R = 5.8 instead of the usually accepted value, R = 3, arguing that such a high value of the ratio of extinction to reddening is obtained by Johnson for the region in question (Berkhuijsen 1974).

A systematic difference between the photometric and kinematic distances is known to be present in other regions of the Galaxy but not always in the same sense. In the second quadrant it is the photometric distance that is smaller than the kinematic one, a tendency opposite to that found around Gemini (the third quadrant). To explain this discrepancy in the same fashion, by varying R, would require a value for R smaller than 3.

As an illustration we take the double cluster in Perseus; its "photometric" distance from the color-magnitude diagram is 2360 pc (Johnson and Svolopoulos 1961) and its $E(B - V) = 0.56$ magnitudes (Johnson 1957). The kinematic distance is 3.0 kpc with a V_{LSR} = –41 km s^{-1} (Johnson and Svolopoulos 1961) and using the Schmidt rotation law. To bring the photometric

TABLE 3

OPTICAL VELOCITIES AND DISTANCES OF THE H II REGIONS

	LSR Radial Velocities (km s^{-1})		Distances (kpc) Kinematic					Distances (kpc) Photometric	
Region (1)	V (2)	V_{G^2} (3)	r_{G^2} (4)	r_{G^2R} (5)	r_G (6)	r (7)	r_B (8)	r_p (9)	r_M (10)
S254	13.3 ± 4.5	6.6 ± 6.0	1.79	1.12 ± 0.92	2.05	2.44	3.46	2.5 }	
S257	13.2 ± 4.1	7.8 ± 3.6	2.04	1.34 ± 0.95	3.57	2.39	3.36	2.7 }	2.5
S255	12.2 ± 3.8	5.3 ± 5.1	1.53	0.88 ± 0.89	1.69	2.14	2.95	2.5 }	
S261	5.9 ± 5.12	6.0 ± 5.7	1.50	0.90 ± 0.80	1.70	.82	.82		1.63
S269	13.7 ± 5.78	13.6 ± 3.5	2.5	1.88 ± 0.80	3.22	1.86	2.38		3.8

V. This paper.
V_{G^2}. Georgelin and Georgelin (1970).
r_{G^2}. Georgelin and Georgelin (1970).
r_{G^2R}. Georgelin, Georgelin and Roux (1973) using the same velocities as in r_{G^2} but with "improved treatment".
r_G. Georgelin 1975, adopting a rotation curve different for the N and S hemispheres.
r. This paper with the Schmidt curve.
r_B. This paper, with the Blitz curve.
r_p. Photometric distance of central stars of S254, 257 and 255 from Pişmiş and Hasse (1976).
r_M. Photometric distance by Moffat *et al.* (1979); distance of S261 from Georgelin and Georgelin (1970).

TABLE 4

LSR VELOCITIES FROM RADIO REGION (km s^{-1})

Region	H109α	H137β	HI	CO	CS	OH	Hα
S 255	6.0	3.9	12	7.8	8.3	6	12.9
S 269	10.9	...	...	17.5	...	+14,+17	13.7

Remarks: H109α, H137β HI and CO velocities are from Kazès *et al.* (1977).

CS, from Morris *et al.* 1974.
OH, from Turner 1971.
Hα, from this paper.

distance into agreement with the kinematic one would lead to a value of R around 2.0. There are no indications so far for such a small value for R neither in the Perseus region nor anywhere else.

We therefore state that most probably it is the kinematic distance which is unrealiable not only because the Schmidt curve underlying the determination is not adequate for the anti-center region (and random motions may also not be negligible) but because the rotation curve in the Galaxy, as in many other spirals, aside from showing flat maxima, (1) is wavy, and (2) is a function of direction. These last two points are discussed in a recent review paper by Pişmiş (1981). Note also that the kinematic distances based on the Blitz curve (1977) are largest among all other kinematic distances.

VI. CONCLUSION

We have recalled a previous investigation where we have shown that the triple nebula composed of S254, 257 and 255 is at a distance of 2.5 kpc. The inclusion of recently obtained velocities affects this kinematic distance only slightly bringing it down to 2.36 kpc. Within the expected uncertainties there is agreement between our kinematic and photometric distances of S254, 257 and 255 as seen from Table 3. The photometric distance of the triple nebula given by Moffat *et al.* (1978) is also 2.5 kpc.

New data given in this paper consist of (a) the systemic velocity and kinematic distance of S261, these are 19.8 km s^{-1} and 0.82 kpc respectively; (b) the systemic velocity and kinematic distance of S269; these are 28.1 km s^{-1} and 1.86 kpc respectively. Based on kinematic arguments brought forth in section V we expect that 1.86 kpc is smaller than the real value. However, even the adoption of this minimum distance would suffice to eliminate S269 from association to the Origem Loop.

We may conclude by saying that of the H II regions discussed here only S261 is close in distance to the

Origem Loop to be considered physically associated with it.

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