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INTERNAL MOTIONS IN H II REGIONS. VIII. THE NEBULAR COMPLEX S152-S153

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RESUMEN

Se han determinado velocidades radiales en 170 puntos del complejo nebular S152 y S153, por medio de interferometría Fabry-Pérot. Se ha demostrado que las nebulosas están a la misma distancia de nosotros, basándose tanto en las estimaciones de distancias cinemáticas como en las fotométricas. Se encuentra que la distancia cinemática es más grande que la distancia de las estrellas excitadoras. Hay evidencia de que S152 es una región más joven que S153. Este complejo se parece a otros complejos estudiados previamente (S254, S257, S255 y S147, S148, S149) en el sentido de que regiones H II originadas de la misma nube se encuentran en etapas evolutivas diferentes.

ABSTRACT

Radial velocities at 170 points in the nebular complex S152 and S153 are determined by Fabry-Pérot interferometry. It is shown that the nebulae are at the same distance from us based on kinematic as well as photometrical estimates. The kinematic distance of the complex is found to be larger than the distance of the exciting stars. Evidence is given for the younger age of S152 compared to S153. This complex resembles two other previously studied complexes (S254, S257, S255 and S147, S148, S149) in that, H II regions originating out of the same cloud are found to be at different evolutionary stages.

Key words: **H II REGIONS – INTERFEROMETRY – NON-COEVALITY – RADIAL VELOCITY.**

I. INTRODUCTION

The two small emission nebulae S152 and S153 with diameters of 2 and 5 arcmin respectively, and touching one another in projection, appear to form a physically related pair. Figure 1 is an image tube photograph of the region through a 10Å interference filter centered at Hα. In Felli and Churchwell's map at 1 400 MHz radiation, and with 10 arcmin resolution the two nebulae are enclosed within the same flux density contour, (Felli and Churchwell 1972). With better resolution, Kazès *et al.* (1977) have obtained brightness temperature contours at λ11 cm in the region of this complex; S152, the smaller and the more compact of the two nebulae, lies at the center of the closed contours, while S153 is close to the outer low temperature contours. Evidently the source of the 11 cm radiation lies in S152 proper.

Radial velocities from the Hα line are obtained by Georgelin and Georgelin (1970) for S152 and S153. The radial velocity of S152 from the H 109α line has been obtained by Kazès *et al.* (1977). The existence of a CO cloud 12 arcmin in diameter centered at the position of S152 is reported by Dickinson *et al.* (1974). Lo *et al.* (1970), have detected an H_2O source which, although outside the H II region, lies at the edge of the associated CO cloud.

In this paper we present Fabry-Pérot radial velocities of the H II region complex, discuss our results together with previously known data and relate them to the morphology of the region in Hα.

II. THE OBSERVATIONS

Five interferograms constitute the basis of our data. These interferograms are obtained by using a focal reducer attached to the 83 cm reflector of the Observatorio Astronómico Nacional at San Pedro Mártir, B.C.N. The étalon has an inter-order separation of 283 km s^{-1} and a finesse of around 10. An interference filter of 10 Å halfwidth and maximum transmission at λ6 563 Å isolates the Hα line. The inteferograms as well as the direct images are recorded on 103aG films through a one-stage Varo image intensifier. A list of the interferograms appears in Table 1 where the first column is

TABLE 1

LIST OF INTERFEROGRAMS

Interferogram	Coordinates 1977 α	δ	Region	Mean radial velocity	n
379	$22^h\ 57^m0$	+ 58°28′	152/153	−62.6 ± 7.7	(30)
380	22 57.2	+ 58 28	153	−64.5 ± 3.8	(30)
381	22 57.2	+ 58 28	152/153	−65.1 ± 6.5	(32)
384	22 57.1	+ 58 28	152/153	−65.9 ± 6.4	(26)
385	22 57.0	+ 58 28	152/153	−61.7 ± 4.4	(52)

the identification of the interferogram; the second and third, the coordinates of the plate center, the fourth, the specification of the region recorded and the last column the average radial velocity, the standard deviation and the number of significant points measured on each interferogram.

The average radial velocity of all measured points is −63.6 km s^{-1}, over a total of 170 points.

The detailed velocity field separately for each interferogram will not be given in this report. They are, however, available upon request. Combining the five interferograms, averages over small regions containing up to 8 points are plotted in Figure 2. In that figure we also give a sketch of the different sub-regions into which we have divided the complex, on the basis of the direct Hα image, reproduced in Figure 1 (Plate 1). Sub-regions *A* to *F* are within S153 while *H* and *I* are within S152 (see Figure 2).

From our data the average radial velocity of S153 is −64.7 km s^{-1} ± 4.9 (st. dev.). The average velocity of S152 will be discussed later. S153 although rather smooth, still exhibits some structure suggesting that perhaps one is observing the projection of a helical form around the exciting star. Such a structure is most likely produced by matter ejected from the parent star, but the velocity field is not sufficiently detailed and reliable to give a definite answer to this query. In Figure 3 we give the mean radial velocities of the sub-regions. S152 is overexposed on Figure 1 (exposure 15 min). A short exposure (2.5 min) taken with the same filter and image tube combination as in Figure 1 appears as Figure 4, which shows rather clearly that S152 consists of a series of compact H II condensations.

Although our spatial resolution is rather low (scale 1.5 arcmin mm^{-1}) three very bright condensations, apparently at the vertices of an equilateral triangle, are

TABLE 2

OVERALL RADIAL VELOCITIES OF S152 AND S153

Source	Hα (1)	Hα (2)	H109α (3)	CO (4)	H_2O (5)	HI (3)
S152						
3 condensations	−65.2					
Overall	−59.0	−55.0	−61.1	−61.7	−62.4	−69.7
Curling feature	−51.7					
S153	−64.7	−66.0				

Velocities are heliocentric and in km s^{-1}.
(1) This paper.
(2) Crampton *et al.* (1978).
(3) 109α and HI are from Kazès *et al.* (1977).
(4) CO velocities are from Blair *et al.* (1975).
(5) H_2O velocity from Lo *et al.* (1970).

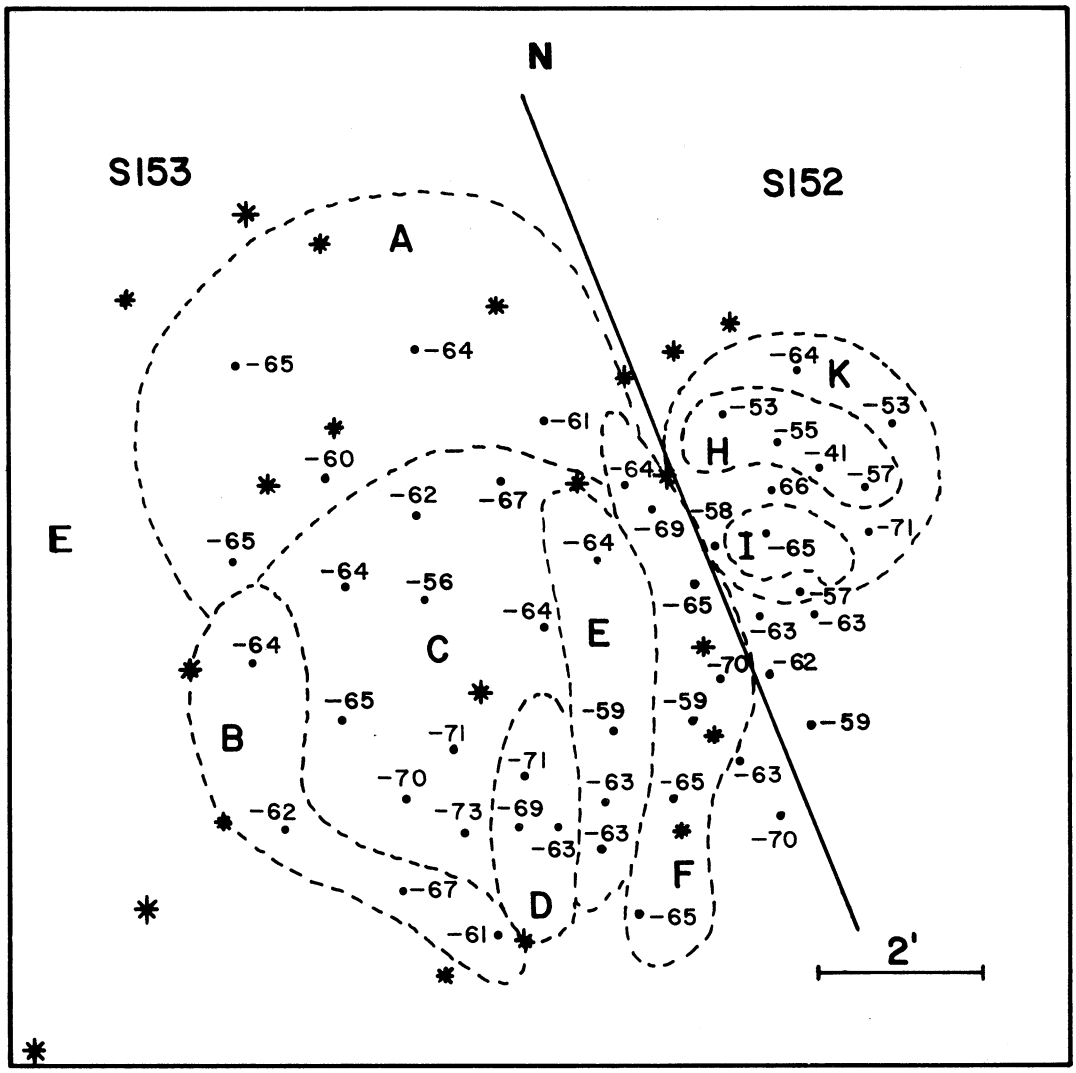

Fig. 2. Map of region with sub-regions into which the complex is divided and radial velocities averaged over 2 – 8 neighboring points.

clearly present at the southern portion of S152. The next prominent feature is a string of four fainter condensations starting from the three intense blobs and curling around. Our material does not permit determination of the radial velocity of the individual condensations, however, our data indicate that the average velocity of the three blobs (sub-region *I*), –65.2 km s^{-1} is nearly the same as the overall velocity of S153, while the four fainter blobs with a mean radial velocity of –51.7± 6.9 km s^{-1} are redshifted with respect to the bright condensations (sub-region *H*) by 13.5 km s^{-1}. Such a velocity structure suggests the following picture: that S153 and S152 proper, of comparable distance from us, are probably related to one another physically and that the string of blobs is an offshoot from the main body of S152.

According to this picture our velocity of the complex is –65 km s^{-1}, which is the average over the three intense blobs of S152 and the total of S153. If their velocities are the same the kinematic distances of the two nebulae should also be the same. It should be rewarding to look into the detailed velocity field of the blobs that constitute S152.

There exist velocity determinations in the radio wavelengths for S152 only. These are listed in Table 2 together with Hα velocities.

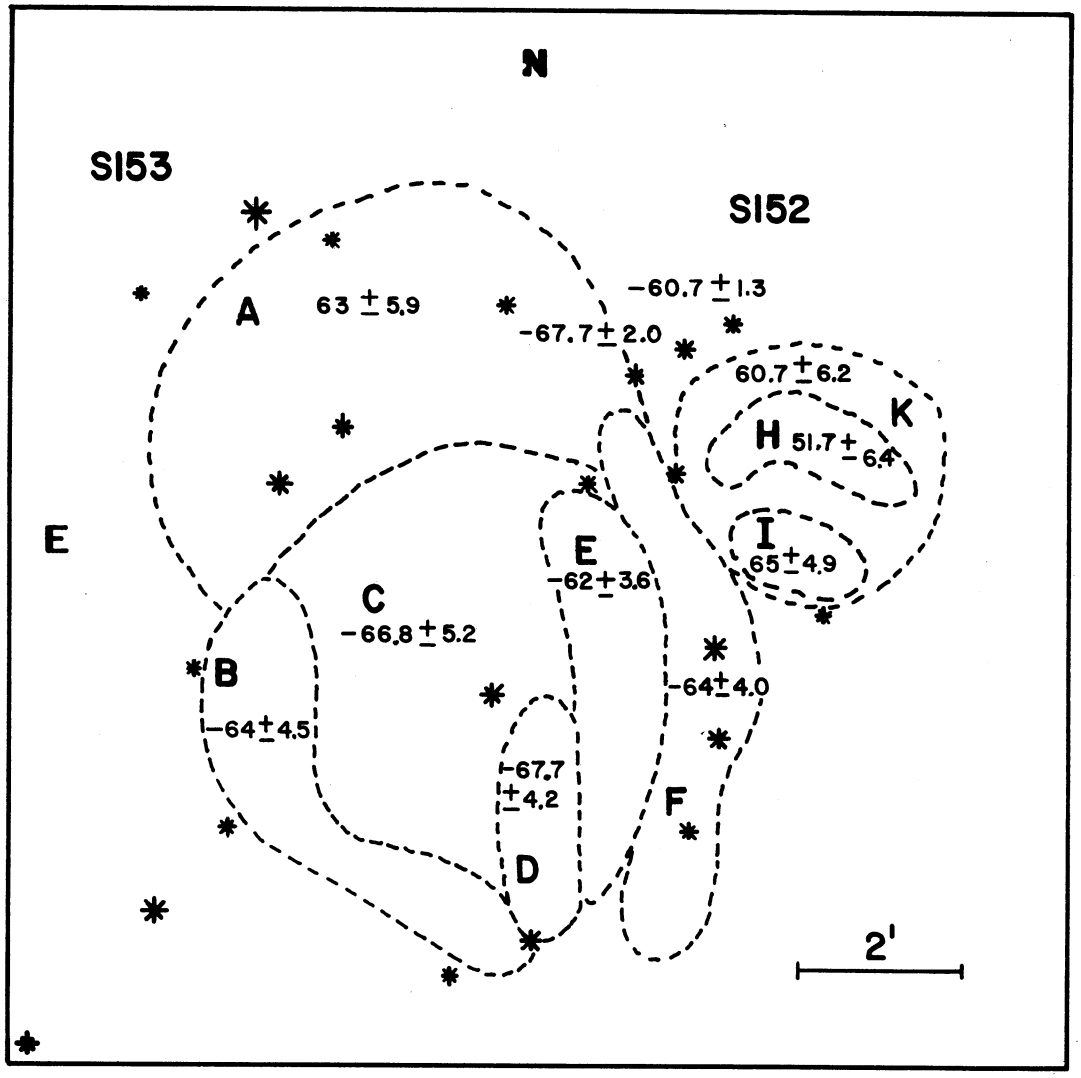

Fig. 3. Same map as in Figure 2 with average velocities in the sub-regions with standard deviations.

The radial velocity for S153 by Crampton *et al.* (1978) is in agreement with ours, however, for S152 they find a much smaller negative value. This difference could arise if their interference rings fell mostly on the region of the receding string of blobs giving thus higher weight to the smaller negative velocities.

Our adopted radial velocity for the complex, −65 km s^{-1}, lies between the H I velocity, −69 km s^{-1}, and 109α, CO, H_2O velocities which are quite comparable to one another ($\approx$ −62 km s^{-1}). We believe that the differences of the velocities, obtained from different wavelengths, are not significant since they are smaller than the standard deviations of, say, our Hα velocities. The unweighted average of all Hα velocities (taking into account only the 3 compact condensations) is −64.1; this is in good agreement with our overall velocity, −65.0 km s^{-1}. Accordingly the LSR velocity is −54.3 which gives a kinematic distance of 4.58 kpc (for $\ell = 108°$) based on the Schmidt rotation curve. Incidentally, with this distance the diameters of S152 and S153 will be of the order of 2.7 and 6.8 parsecs respectively.

III. THE EXCITING STARS

The photometry for the exciting stars of S152 and S153 is tabulated in Table 3. Using the parameters given

TABLE 3

PHYSICAL PARAMETERS OF THE EXCITING STARS

Region	Star	Coordinates (1900)	V	$B-V$	$U-B$	Spectral type	M_{V*}	Source
S152	Anon	$22^h54.4^m$ $+58°15'$	12.14	0.94	...	09V	−4.4	Cramtpon *et al.* (1978)
S153	CGO 649	22 54.6 +58 15	11.30	0.46	−0.52	09.5V	−4.0	Georgelin *et al.*(1973)
			11.27	0.47	−0.48	BOV	−3.7	Mayer and Macak (1973)

* Absolute magnitude calibration is from Crampton and Georgelin (1975).

in this table and adopting the intrinsic colors as −0.31, −0.30, −0.30 for spectral types O9V, O9.5V and B0V respectively (Cruz-González *et al.* 1974) and with R = 3, we obtain the distance for S152, 3.6 kpc. With the same assumptions the distance of S153 is 3.7 kpc which is the mean of two independent determinations based on the two sets of parameters of the exciting star given in Table 3. It is clear that the photometric distances of the two exciting stars, and hence of the nebulae, S152 and S153, are in excellent agreement. Thus we have here a second line of evidence that S152 and S153 are physically related.

IV. KINEMATIC VS. PHOTOMETRIC DISTANCES

We call attention to the fact that although the two nebulae are at the same distance from us their common distance is found to be 3.6 – 3.7 kpc photometrically and 4.6 kpc kinematically. Larger kinematic distances compared with the photometric ones are common to almost all H II regions in the second galactic quadrant –essentially in the Perseus Arm. It appears that the kinematics of the second quadrant cannot possibly be represented by pure rotation. Some interpretations of the discrepancy are as follows: Roberts (1972) argues that the gas may possess a velocity additional to the circular one, due to a shock front; Georgelin (1975) suggests that the discrepancy can be accounted for if the gas is located at the near side of the spiral arm.

These interpretations do not seem to be valid, since the discrepancy persists for kinematic distances based on stellar radial velocities as well. As an example we mention the case of the double cluster in Perseus. With the known velocities of the star and some additional velocity data (Pişmiş, unpublished) one obtains a kinematic distance for the double cluster of 3.5 kpc whereas from the color-magnitude diagram the distance is not more than 2.5 kpc. As yet the kinematic behavior of the Perseus arm is a mystery.

V. DUST WITHIN S152

The observed color indices of the exciting stars of S152 and S153 listed in Table 3 and the intrinsic colors, mentioned earlier, yield color excesses of 1.25 mag. and 0.76 mag. (or 0.77 from Mayer and Macak) respectively. Thus the exciting star of S152 suffers a reddening in excess of the star in S153 by 0.49 magnitudes. For R = 3, this would correspond to an excess in extinction of the order of 1.47 magnitudes for S152. Given the proximity of the two nebulae it is highly improbable that the excess in reddening and extinction is interstellar. If the star is located at the far end of S152 the rate of extinction will be 0.5 mag. per parsec as a minimum, adopting a diameter of 2.7 for this nebula. Incidentally, the exciting star is within the blob nearest S153. We can safely state that the extinction is intranebular, and that the density of dust in S152 with respect to S153 is very high. These considerations suggest that S152 is younger than S153. Other lines of evidence supporting this suggestion are: the existence in S152 of molecules such as CO and H_2O and the strong radio continuum observed at several frequencies. Thus we here have another case where two H II regions formed out of the same interstellar cloud are at different evolutionary stages. We have encountered similar phenomena in our previous investigations and have shown that sequential star formation has occurred in the complex S254, S257 and S255 (Pişmiş, and Hasse

1976) and in the complex S147, S148 and S149 (Recillas-Cruz and Pişmiş 1979). The presence of the very compact blobs in S152 in contrast to S153, smooth and extended, also points to the younger age of S152; the former is old enough to have dispersed the excess dust.

VI. SUMMARY AND CONCLUSIONS

We have presented the Hα radial velocities of the H II region complex S152 and S153. The average radial velocity of S153 is found to be similar to the main body of S152 supporting the suggestion that the two nebulae form a physical pair. Distances based on the photometry and spectral types have confirmed the common distance of these nebulae. The kinematic distance is larger than the photometric one by about 40%, in agreement with such discrepancy found in general in the Perseus Arm. The cause of this discrepancy appears to lie in the kinematics of the Galaxy.

The complex studied here is one of those where the condensations formed probably out of the same interstellar cloud are at different evolutionary stages. Further study of these H II regions with higher resolution to obtain a detailed velocity field, the emission measure and Balmer decrement determinations would shed more light on the problems discussed above. What is it that causes one portion of the cloud to evolve faster than the other or that its gestation period is different from that of other portions of the same cloud remains unknown.

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