Revista Mexicana de Astronomía y Astrofísica, Volumen 4, Agosto 1979

INTERNAL MOTIONS IN H II REGIONS. VI. S 140 AND THE ASSOCIATED CO CLOUD

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Received 1978 December 7

RESUMEN

Se discuten las velocidades radiales obtenidas en 283 puntos mediante interferometría Fabry-Pérot en la línea Hα de la región S 140 y de la nube obscura de CO contigua.

Las velocidades de la nube obscura y la región en emisión son comparables, obteniéndose una velocidad promedio de -22 km s^{-1}. El borde brillante presenta un corrimiento al rojo de 2 km s^{-1} con respecto al resto. La fotometría *UBV* revela un nuevo cúmulo estelar en el cual el miembro más brillante es la fuente de excitación de S 140. Se sugiere que la emisión Hα de la región obscura es la de S 140 dispersada por el polvo de la nube obscura.

ABSTRACT

Radial velocities of 283 points obtained by Fabry-Pérot interferometry of Hα on S 140 and the contiguous dark CO cloud are discussed. The velocities of the dark and emission regions are comparable and yield -22 km s^{-1} as an average. The bright rim is redshifted with respect to its surroundings by 2 km s^{-1}. *UBV* photometry discloses a new star cluster of which the brightest member is the source of excitation of S 140. It is suggested that the Hα emission of the dark region is that of S 140 scattered by the dust of the dark cloud.

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

I. INTRODUCTION

Sharpless 140 is a small H II region with an overall diameter not exceeding 30 arcmin, and is characterized by an intense ionization front, an interface, bordering the dark molecular cloud Lynds 1204 (see Figure, 1 Plate 5). Maps in a variety of molecular lines of this cloud show a strong density peak near the H II rim. Embedded in the extended CO dark cloud is a small near-infrared source, presumably the site of an early type star, surrounded by a dense CO envelope. The energetics of the region are studied in detail by Blair *et al.* (1978). Observation of carbon recombination lines suggests the dark cloud to be of unusually low temperature and of inhomogeneous density (Knapp *et al.* 1976).

Within our general program on the internal motions in H II regions we included S 140 in order to make a detailed study of the velocity structure of this object and the ionization front in particular. The results obtained will be presented in what follows.

II. THE OBSERVATIONS

Several image tube interferograms were obtained with a focal reducer mounted at the Cassegrain focus of the 83 cm reflector of the Observatorio Astronómico at San Pedro Mártir, B. C. The Fabry-Pérot étalon used has an inter-order separation of 190 km s^{-1} and a finesse of around 8. A 10 Å halfwidth interference filter is employed to isolate the Hα line. 103aG films are used throughout. The linear scale on the plates is 1.5 arcmin per millimeter. Wavelength calibration is done by means of a hydrogen lamp interferogram taken after the field exposure. The interferograms were measured for radial velocity using the Mann comparator of the NASA Johnson Space Center. The reductions were carried out following the method given by Courtès (1960).

A direct Hα photograph of S 140 is shown in Figure 1 (Plate 5) and a sample interferogram in Figure 2 (Plate 5).

III. THE VELOCITY FIELD

Four interferograms constitute the basis for the present study. In Table 1 we give data relating to the interferograms, mean velocities and their standard deviations obtained from all points measured on each interferogram. The average velocities over all points from the different interferograms are in excellent agreement.

Although on Palomar Sky Survey red plates emission stops rather abruptly at the bright rim of S 140, our direct image tube photograph (Figure 1, Plate 5) in Hα displays an appreciable radiation in the region of the dark cloud. Our interferograms have also recorded Hα rings in the dark region of sufficient intensity as to allow reliable velocity measurements. The overall velocity field of the dark and bright regions does not show any systematic trend.

The existence of a bright rim had suggested to us that the dust cloud, a presumably young region would be expanding into the H II region, S 140. We were expecting therefore that we would be observing essentially the nearer side of the expanding dark cloud, the far side being unobservable due to the high extinction by dust in the cloud. As a result a net velocity of approach of the dark region with respect to S 140 would ensue. However, our observations show that the velocity field is quite regular and that no difference is present between the mean velocities of the dark region and S 140 proper. If we omit an outlying region where the velocities are not too reliable, the remaining 283 velocities indicate a smooth velocity field. We consider it unnecessary to present in detail all 283 points; rather we have divided the observed region into sub-regions. A quick look showed velocities on either side along the ionized rim to be slightly redshifted with respect to the outer regions. We therefore separated two strips along the ionized front; they are marked by *B* and *C* while *A* and *D* represent the regions further out. These regions are shown in Figure 3, where mean velocities with standard deviation and the number of velocity points in each section are also indicated. The mean velocities in *B* and *C*, -19.9 ± 4.3 and -19.9 ± 3.6 km s^{-1} respectively, are slightly more positive than the velocities of *A* and *D*, -23 ± 9.0 and -22 ± 5.1 respectively. Thus a mean redshift of about 2-3 km s^{-1} is shown along the bright rim with respect to the larger region on either side of it. In other words the dark and bright regions are approaching the observer with respect to the region of the bright rim at a velocity of the order of 2 km s^{-1}.

The difference, though systematic, is rather small to attach serious physical significance to it. All we can say with certainty is that the overall region —dark cloud and S 140 alike— shows a homogeneous velocity structure and that there is practically no relative motion between the dark cloud and the larger emission region. The kinematic distance corresponding to

TABLE 1

THE OBSERVATIONAL MATERIAL

Interferogram	Coordinates of Center (1975) α	δ	Average Velocity	No. of measured points	Exposure time	Date of Observation
FI 353	$22^h18^m59^s$	$+63°$ 03′	-20.8 ± 7*	39	20^m	Aug. 12, 1977
FI 358	22 18 21	+63 06	-20.2 ± 6*	69	20	Aug. 13, 1977
FI 359	22 19 00	+62 04	-20.9 ± 5*	139	20	Aug. 13, 1977
FI 459	22 18 23	+63 01	-20.4 ± 4*	90	40	Jul. 4, 1978

* Standard deviation

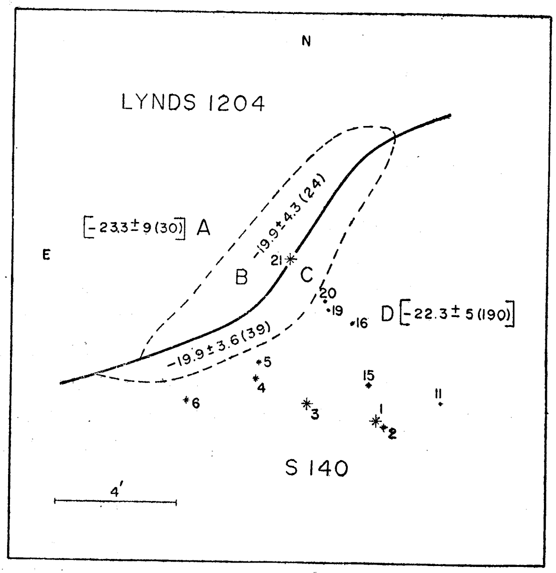

FIG. 3. The scheme of the sub-regions into which we have divided the overall region of S 140 and its contiguous molecular cloud. The average velocities of *A, B, C* and *D* are given in the figure together with the standard deviations and the number of velocity points within each sub-region. The stars in the cluster are marked by their numbers.

−22.0 km s^{-1} the overall radial velocity of S 140 and adopting the Schmidt model for the galaxy yields 900 pc for the distance of this H II region. Crampton and Fisher derive a photometric distance of 910 pc on the basis of their photometry of HD 211880 the exciting star of S 140.

Molecular line velocities of the dark cloud Lynds 1204 are slightly more positive than our Hα velocities. Blair *et al.* (1978) find a peak emission CO velocity of −20.1 (V_{LSR} = −8.0) over most of the dark cloud; they state moreover that "there seems to be little evidence for systematic velocity shifts across the cloud". Velocities from H_2CO absorption lines at 6 cm and 2 cm are given as −19.3 and −19.8 respectively, essentially in agreement with the CO emission velocities. The overall molecular line velocities thus agree better with our Hα velocities along the ionization front of S 140 (19.9 km s^{-1}).

IV. THE EMBEDDED STARS; A NEW STAR CLUSTER

On direct photographs (Figure 1, Plate 5) a clustering of stars is noticeable within S 140. A preliminary photoelectric UBV photometry of some stars in the group was carried out with the 83 cm reflector of the Observatorio Astronómico at San Pedro Mártir. The photometric data for the stars identified in Figure 3 are listed in Table 2. In the resulting color-magnitude diagram shown in Figure 4 for the 12 stars, a main sequence is clearly defined. The U-B versus B-V diagram is also well defined (Figure 5) and is compatible with a reddening of 0.6 magnitude. There is thus strong indication that the grouping is physical and that it may qualify for an open cluster. We plan to carry out a detailed photometric and spectroscopic

TABLE 2

PHOTOMETRY OF STARS WITHIN S 140

No. in the map (Fig. 3)	Name	*V*	*B-V*	*U-B*	Sp. Type	No. of Observations
1	BD + 62 2061	7.75	0.32	−0.60	B0.5 V[1]	6
2	BD + 62 2060	7.83	0.33	−0.59	B2 V[1]	6
3	BD + 62 2064	7.86	0.30	−0.55	A0[2]	3
4	...	8.04	0.35	−0.54	...	2
5	...	8.07	0.33	−0.55	...	2
6	...	8.05	0.32	−0.38	...	1
11	...	8.01	0.33	−0.55	...	3
15	...	8.02	0.33	−0.56	...	2
16	...	8.08	0.33	−0.56	...	1
19	...	8.09	0.35	−0.47	...	1
20	...	8.27	0.34	−0.48	...	1
21	BD + 62 2065	7.93	0.34	−0.51	...	1

1) This paper
2) Henry Draper Catalogue.

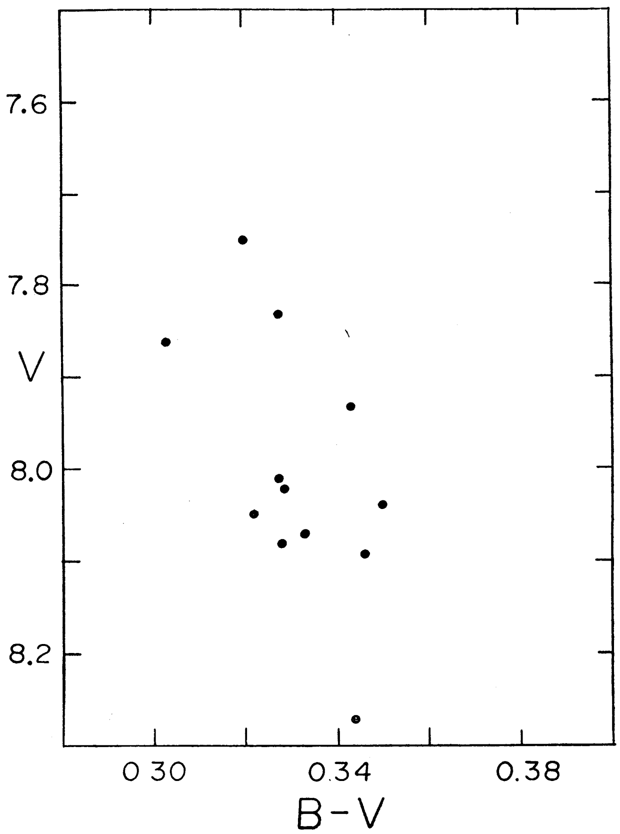

FIG. 4. A color-magnitude diagram of 12 stars embedded in S 140. The stars are identified in Figure 3.

study of the cluster during the next observing season. Meanwhile from an estimated apparent diameter of 6 arcmin and a distance of 900 parsecs we obtain a linear diameter of 1.5 parsec, quite an acceptable size for an open cluster. So far we have found no mention of a cluster in this region in the literature.

The exciting star of S 140, the brightest of the region, is BD 62°2061 (HD 211880) while the next brightest is BD 62°2060. Spectra of these stars were obtained with a Boller and Chivens spectrograph attached to the 1-meter reflector at Tonantzintla Observatory. The spectra were recorded through a Vidicon television tube. The estimated spectral types are B0.5 V and B2 V respectively for the two stars. Previous estimates of the spectral types are B0 V and B2 V and their radial velocities −22.2 and −22.9 km s^{-1} respectively (Crampton and Fisher 1974). These velocities are in excellent agreement with our overall Hα velocity of −22 km s^{-1} for S 140. An earlier determination by Georgelin and Georgelin (1970) of the interferometric velocity of the Hα line is −22.1 km s^{-1}.

V. DISCUSSION AND CONCLUSIONS

We have searched for a possible instrumental effect i. e., reflection –due to the Fabry-Pérot étalon– that might produce spurious interference rings on the side of the dark nebula. It appears that no such spurious instrumental effect is likely to exist. Moreover the direct Hα photograph where no instrumental effect of the kind is expected (Figure 2) has also appreciable intensity recorded on the side of the dark nebula. Probably the Hα velocities do not represent the velocity of the dark cloud for it may well be that the Hα observed there does not arise from excitation of the region itself but rather it is the scattered light by the dust cloud of the Hα emission of S 140 particularly that of the bright rim. To our knowledge this is the

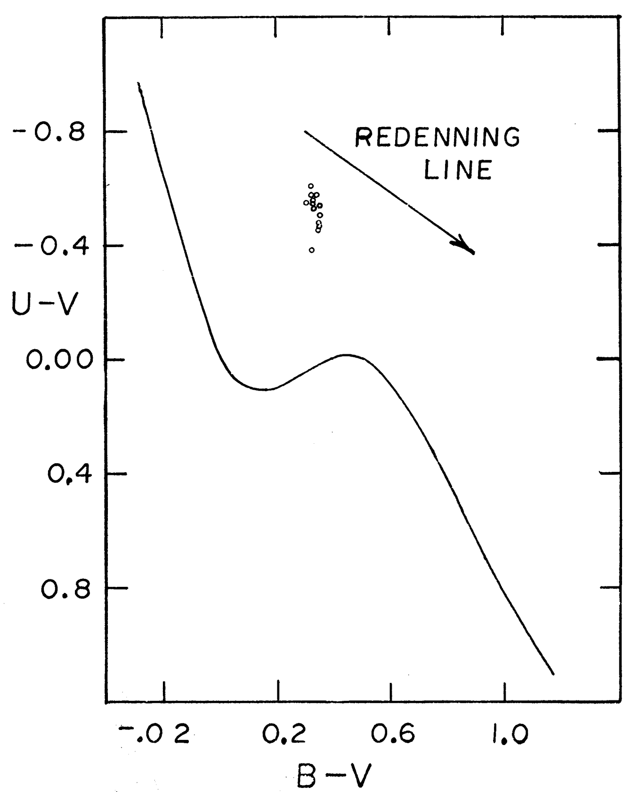

FIG. 5. A (U–B) versus (B–V) diagram of the 12 stars marked in Figure 3.

first instance where the existence of scattered Hα line radiation by dust particles is pointed out. If our suggestion is valid the equality of the average motion of the dark and bright parts can thus find an explanation.

We are indebted to Dr. C. Firmani for the spectra obtained with the Vidicon tube and to A. Quintero for assistance at the telescope. One of us (P.P.) acknowledges the facilities offered at the Earth Resources Division of the NASA Johnson Space Center where the measurements of the interferograms were carried out.

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PLATE 5

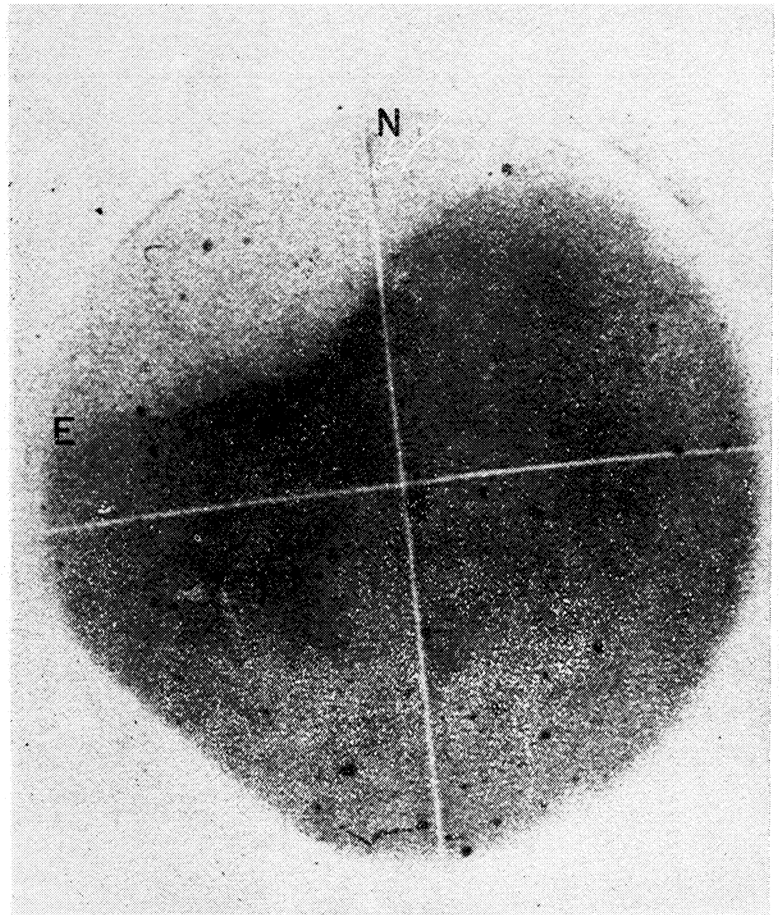

FIG. 1. An image tube Hα photograph of the H II region S 140 taken with a focal reducer attached to the 83 cm reflector of the Observatory at San Pedro Mártir, B. C. The scale on the original (103aG) film is 1.5 arcmin per millimeter.

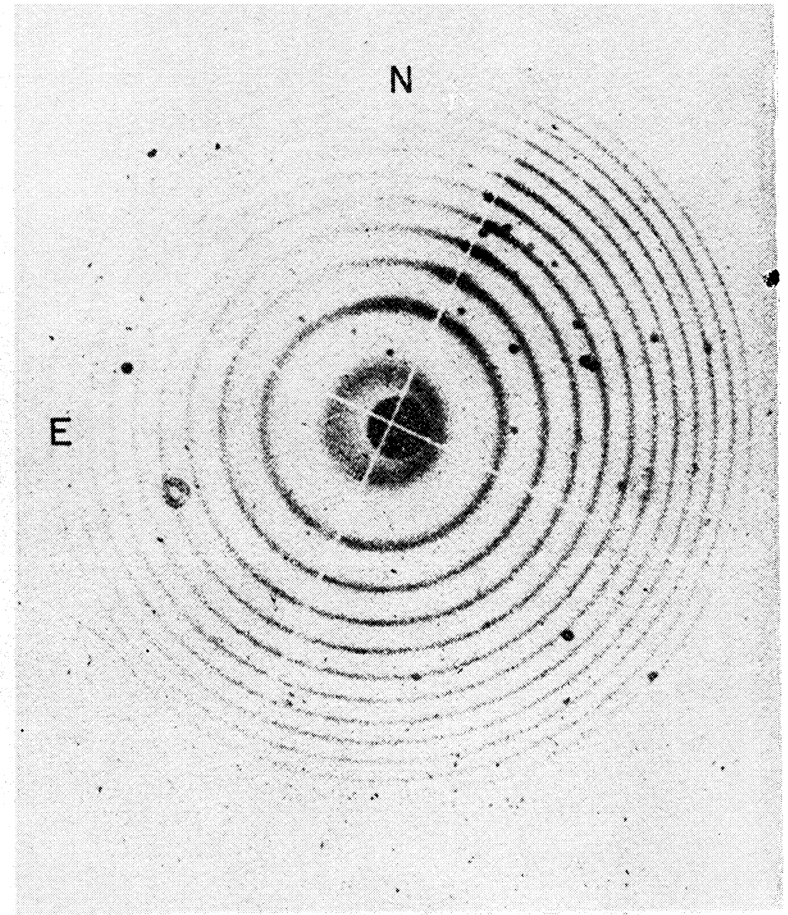

FIG. 2. An image tube Hα interferogram of S 140 using an étalon with an inter-order separation of 190 km s^{-1}.

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