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THE RADIAL VELOCITY FIELD OF THE OPTICAL FILAMENTS WITHIN THE BOUNDARIES OF CTB 80 [1]

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RESUMEN

Se obtuvieron tres interferogramas de Fabry-Pérot y una fotografía directa, en la longitud de onda de Hα, de los filamentos localizados al suroeste del núcleo de la fuente CTB 80. Las velocidades radiales obtenidas para estos filamentos indican una asociación física entre éstos y la fuente central.

ABSTRACT

One direct photograph and three Fabry-Pérot interferograms, in the light of Hα, of the filaments located at the SW of the core of the source CTB 80 were obtained. The radial velocities of these filaments point to a physical association between these and the central source.

Key words: INTERFEROMETRY – INTERSTELLAR-MATTER – NEBULAE-SUPERNOVA

I. INTRODUCTION

The radio source CTB 80 has a complex nature which makes its identification as a supernova remnant (SNR) somewhat uncertain. At radio wavelengths it has a central core about 50 arcsec of angular diameter, with a centrally peaked surface brightness distribution, strong linear polarization and flat spectral index ($\alpha = 0.0$). This core is embedded in a plateau of 10 arcmin in diameter. Some exterior features of low surface brightness resembling jets extend nearly at the same angular distance of about 33 arcmin of the central source towards the east, north and SW forming a global three-lobed structure. This three-lobed structure is embedded in an irregular envelope of low surface brightness with a radius of about one degree. The spectral index steepens smoothly from the central region to the outer lobes up to $\alpha = -0.8$ (Velusamy and Kundu 1974; Velusamy, Kundu, and Becker 1976; Strom, Angerhofer, and Velusamy 1980; Angerhofer *et al.* 1981, and Dickel *et al.* 1981.

Its X-ray emission is centrally peaked and reveals the existence of a point source embedded in a diffuse component extending at least 8 arcmin to the east with a morphology more jet-like than shell-like. In addition, there is another jet-like structure of very low surface brightness running from the central point source to about 16 arcmin to the south. While not completely established, it is believed that the X-ray spectrum of the diffuse component is non-thermal (Becker, Helfand, and Szymkowiak 1982; Wang and Seward 1984).

At visual wavelengths, the core is seen as a network of filaments which in [O III] (λ5007 A) reveal a shell structure; in Hα, [N II] (λ6548,6584 A), and [S II] (λ6717,6731 A) the filaments appear to form an irregular ring elongated in the E-W direction. These filaments could be photoionized by radiation of the central point source (Angerhofer, Wilson, and Mould 1980, hereafter AWM; Blair *et al.* 1984). Deep Hα + [N II] and [S II] photographs (van den Bergh 1980) reveal the existence of other filaments far away from the core. Some of these (the SW filaments or filament 1 according to van den Bergh) are located within the boundaries of the radio emission, and it is known that they are shock excited. Other set of optical filaments is located outside the boundaries of the radio emission (the NE filaments of filament 2 after van den Bergh). It is presumed that they are also shock excited because of their high [S II]/Hα ratio. These is no direct evidence that these two filamentary sets are associated with CTB 80 other than the fact that a shock is necessary to excite them and that CTB 80 may provide in a natural way the source of excitation.

The best estimate of the distance to this source is given in AWM. These authors used different methods to estimate a distance of 3±1 kpc to CTB 80.

This work presents arguments strengthening the physical relationship between the central and external components of CTB 80 by comparing the kinematical properties of the optical SW filaments with those associated with the central core. It is shown that the systemic velocities are similar, consequently there is no chance superposition but a casual relationship between them.

II. OBSERVATIONS

We have observed the optical filaments located SW (hereafter SW filaments) of the central core of CTB 80. The observations were of two types: a monochromatic

1. Based on observations collected at the Observatorio Astronómico Nacional of San Pedro Mártir, B.C., México.

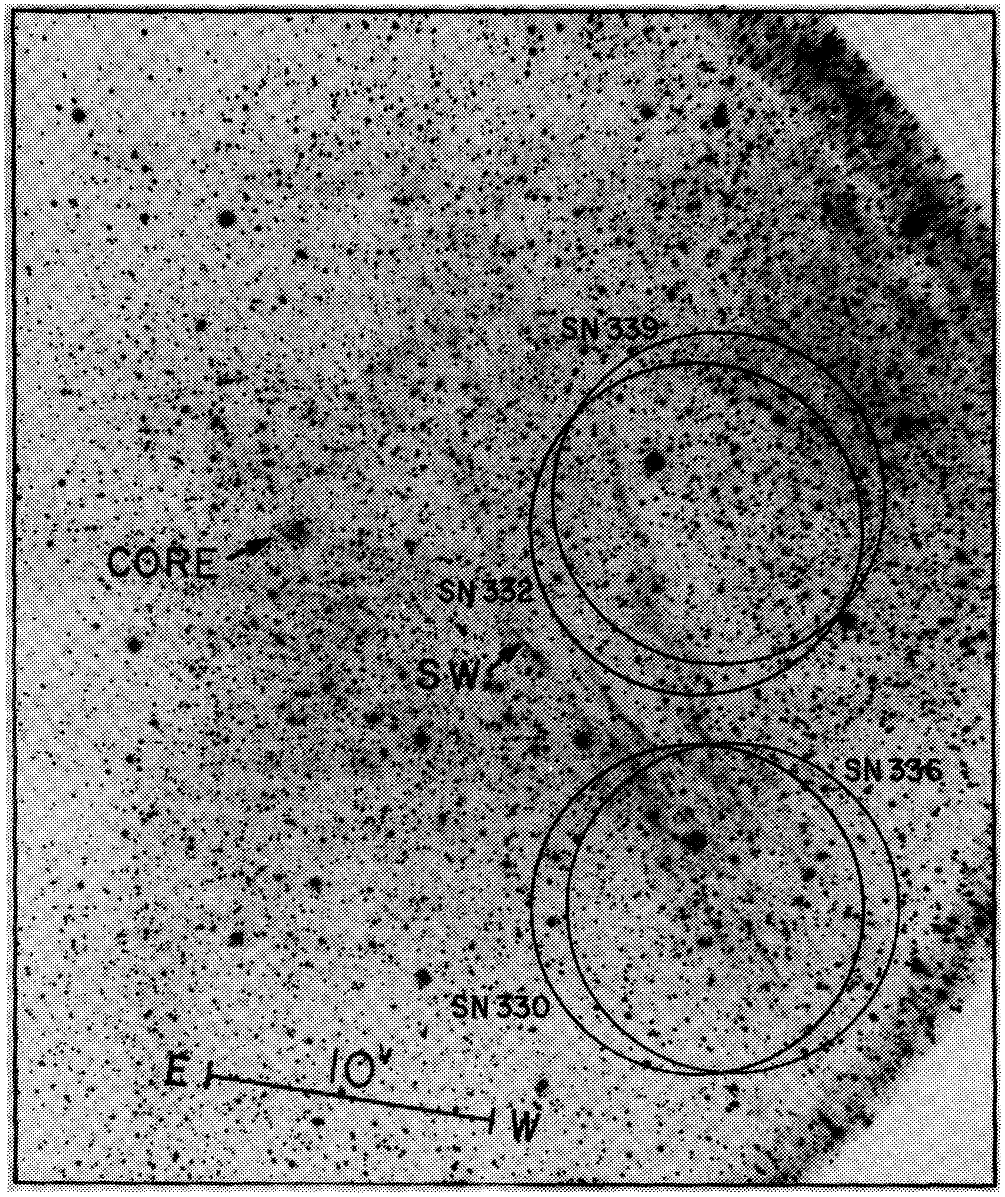

Fig. 1. The fields covered by the Hα photograph and the FP interferograms (see Table 1 for the information on the plate's numeration) marked on a reproduction of the photograph taken by Blair *et al.* (1984).

filter photograph in the light of Hα and three Hα Fabry-Pérot (FP) interferograms. Table 1 gives information about the plate characteristics of the direct photograph and interferograms. Figure 1 shows the locations of the fields covered by the Hα photograph and interferograms marked in a reproduction of a photograph published by Blair *et al.* (1984). The fields covered by our observations correspond to two regions of the SW filaments: Region I (the northern one) and Region II (the southern one).

All our data were obtained using the 2.1-m Cassegrain focus telescope of the Observatorio Astronómico Nacional at San Pedro Mártir, B.C. with the same equipment as described earlier (Rosado 1983, 1986). The scale and angular field of the photographs were about 49 arcsec mm^{-1} and 11 arcmin respectively.

The étalon used to obtain the FP interferograms has a free spectral range of 285 km s^{-1}, a resolving power of 10600 and a mean linear dispersion of about 20 A mm^{-1}. Figure 2 shows one of the interferograms of the SW filaments taken with this equipment. The radii of the interference rings were measured at the Marseille Observatory. The measurements and data reductions were obtained in the standard way (Courtès 1960). Further description of the measurements and data reductions can be found in Rosado *et al.* (1982). Unfortunately some of the rings are contaminated by lines of the night-sky near the Hα line; these are the geocoronal Hα and the OH lines at λ6568.6, 6553.7 and 6577.0 A respectively. Since these lines appear clearly separated from the nebular rings, they could be identified and eliminated.

The accuracy in the measurements of the velocity points, assuming ideal conditions, i.e., fringes of high quality (definition, uniformity, intensity) is of about 2 km s^{-1}. Lower quality fringes could have velocity dispersions as high as 10 km s^{-1} in the average (Courtès 1973).

III. RESULTS

Figure 3 shows the Hα photograph of Region II (southern part of the SW filaments). This photograph shows more details of the filamentary structure than the photographs published earlier. The filaments are embedded in a diffuse component. The higher lumi-

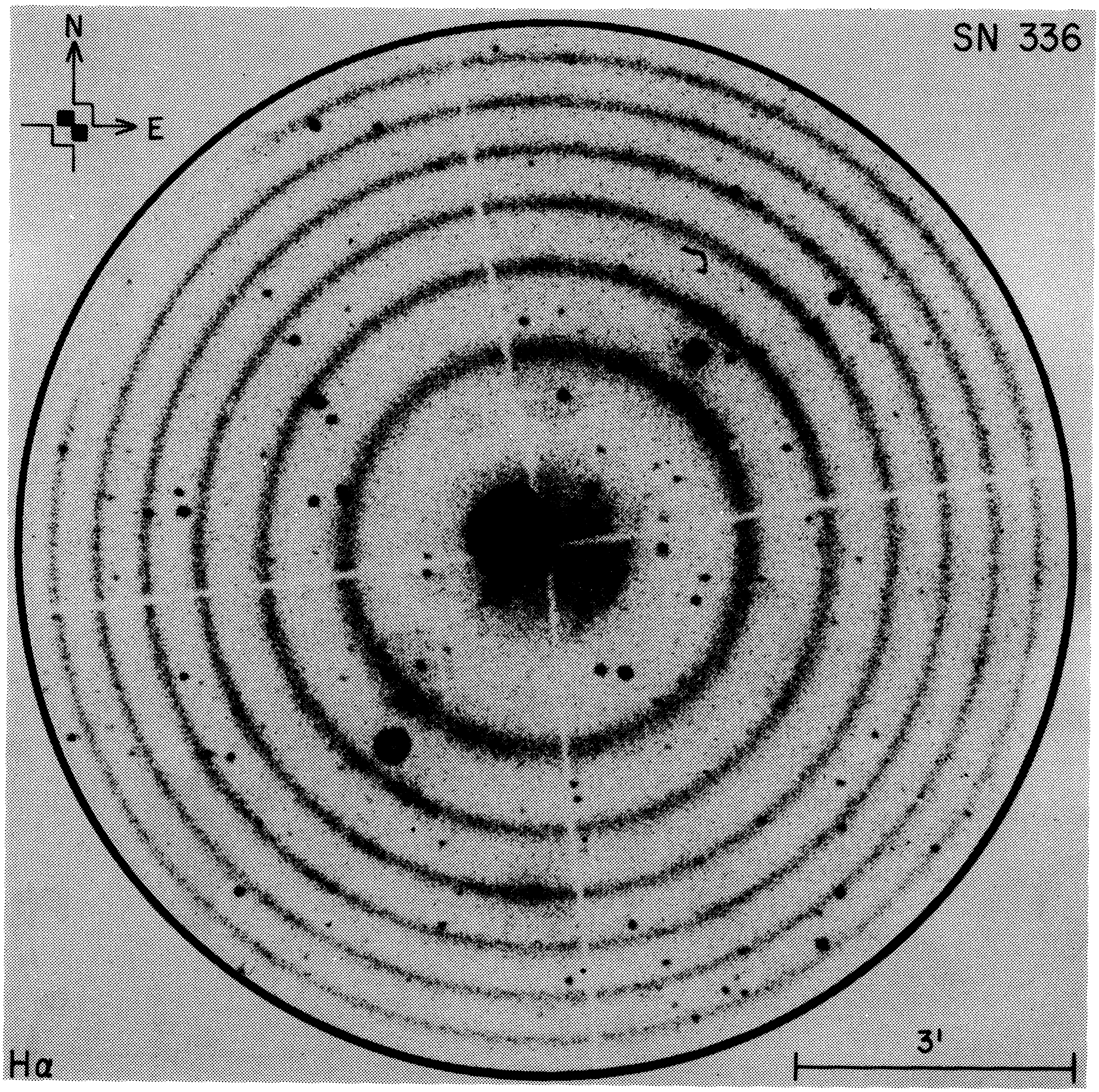

Fig. 2. Hα interferograms of a region of the SW filaments (Region II), presumably associated with the radio source CTB 80 (see Table 1 for details on the plate's characteristics).

nosity of the filaments could be the effect of the limb-brightening of curved sheets seen in projection.

The FP interferograms obtained for Regions I and II of the SW filaments give a total of 180 radial velocity points. Figures 4 and 5 show the radial velocity fields of Regions I and II respectively.

Only at three locations did the FP rings show splittings; the points where the splittings are present have lower S/N than the other nebular points. These splittings are associated with the diffuse gas and not with the sharp filaments. This is in agreement with the idea of considering the filamentary region as the projection of curved sheets where the sharp filaments observed correspond to the edges of these sheets seen along the line of sight. The maximum difference in radial velocities of these splittings amounts to about 60 km s^{-1}. If these splittings are interpreted as portions of an expanding shell seen in projection, then the

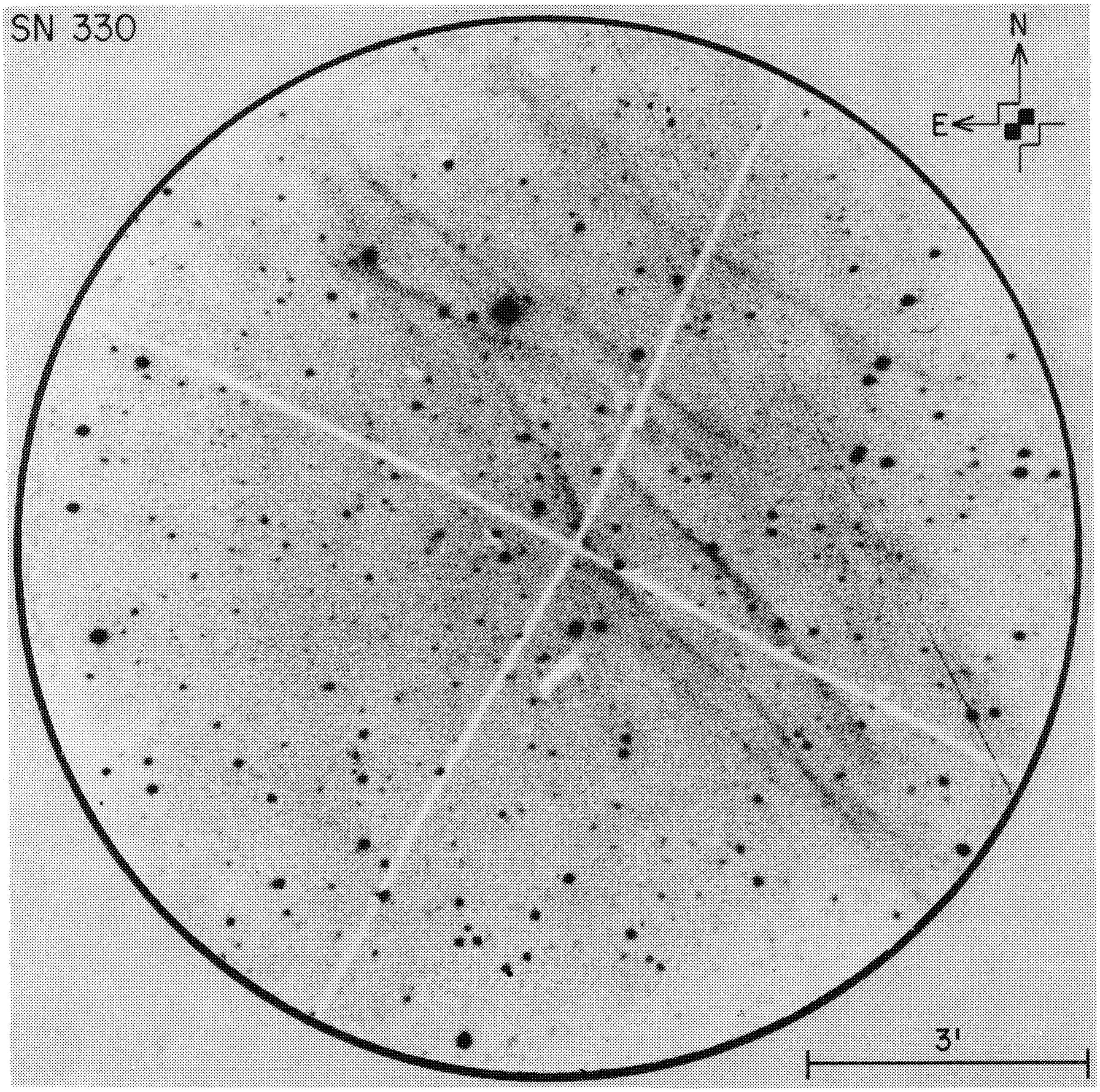

Fig. 3. Hα photograph of a region of the SW filaments (Region II), presumably associated with the radio source CTB 80 (see Table 1 for details on the plate's characteristics).

TABLE 1

CHARACTERISTICS OF THE OBTAINED PLATES

Plate Number	Date	Type	Exposure Time (min)	Location[a]
SN 330	13-6-85	Direct Hα	60	Region II
SN 336	15-6-85	FP interf.	75	Region II
SN 332	14-6-85	FP interf.	75	Region I
SN 339	17-6-85	FP interf.	90	Region I

a. The location of the fields covered by these plates is shown in Figure 1. They correspond to two regions designated as Region I (the northern one) and Region II (the southern one). See Section III of the text.

expansion velocity of this shell would be of 30 km s^{-1} multiplied by an unknown geometrical factor. However, in view of the complicated structure of the radio source with which the filaments seem to be associated, it may be too daring to state that a simple spherical expansion is at work. On the other hand, the low S/N ratio of these splittings suggests us to be cautious about their interpretation.

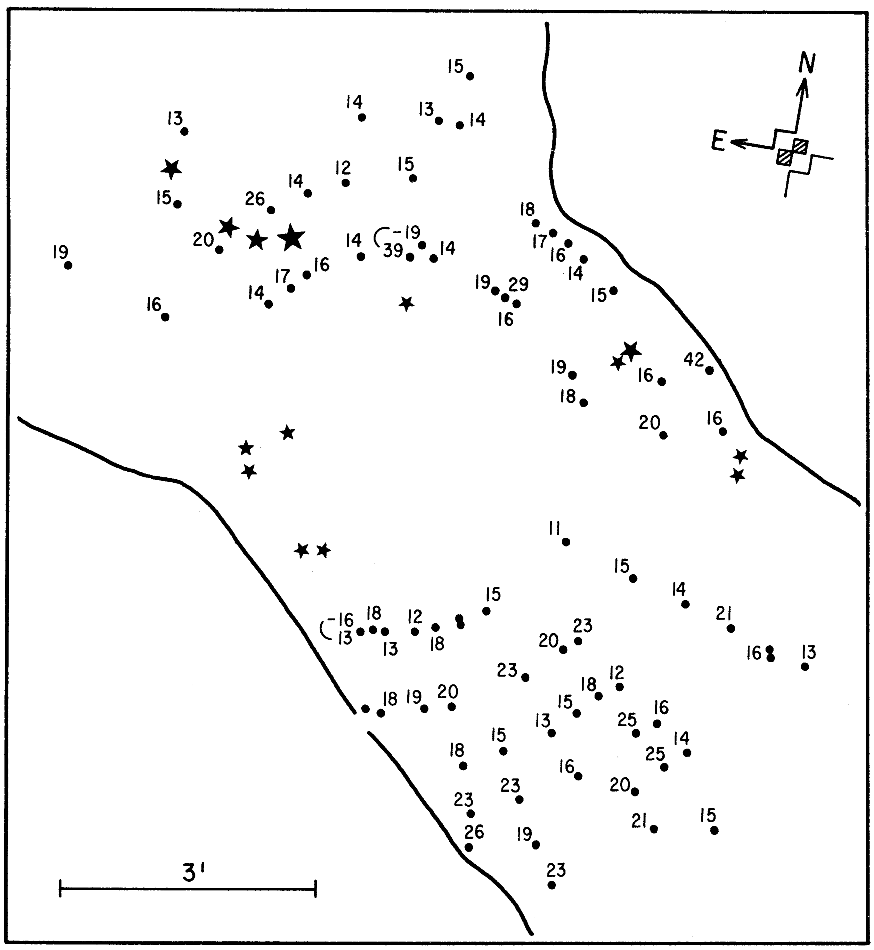

Fig. 4. The radial velocity field obtained (referred to the LSR) for Region I (at the north) of the SW filaments.

The radial velocity fields displayed in Figures 4 and 5 allow an estimate of systemic velocity of the SW filaments by taking the mean value of the radial velocities obtained from the interferograms. Referred to the LSR this quantity amounts to 17±8 km s^{-1}.

IV. DISCUSSION

It is important to compare the results given above with the observations reported in AWM of the optical shell structure associated with the central radio core. The radial velocities of these authors were obtained from a photographic spectrum of lower dispersion (52 A mm^{-1}) than that of our interferograms. Figure 7 of AWM is a plot of the radial velocity as a function of the position across the central source. From this, several facts can be noted:

The radial velocity pattern of the western region is compatible with a spherical expansion of a shell of gas with an overall translational motion of about 10 km s^{-1} (which can be regarded as the value of the systemic velocity) and an expansion velocity of about 40 km s^{-1}.

This latter point is consistent with the existence of a central splitting with velocity peaks at +35 and −35 km s^{-1}.

The radial velocity pattern of the eastern portion is not consistent with a simple expansional motion. Thus, one cannot take the radial velocity at the eastern edge of the shell as indicative of the systemic velocity.

In comparing the above results on the nuclear shell

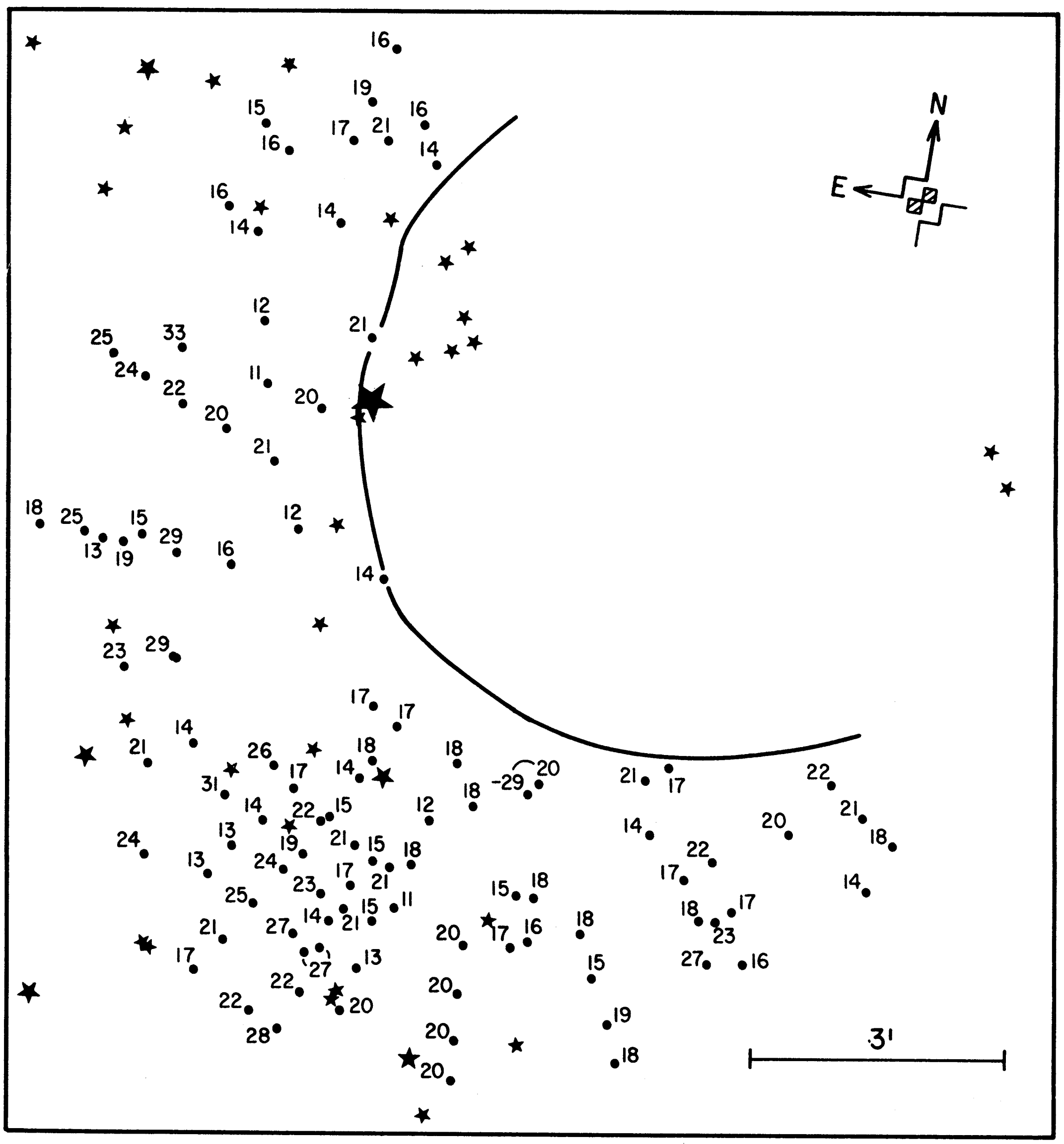

Fig. 5. The radial velocity field obtained (referred to the LSR) for Region II (at the south) of the SW filaments.

with the results given here for the SW filaments, one obtains a kinematical argument favoring the association of these filaments with CTB 80. Indeed, the SW filaments and the nuclear shell have the same systemic velocity (within the uncertainties of our FP velocities and the uncertainties of the velocities of AWM: up to 10 km s^{-1}) indicating that they are probably at a comparable distance. This rules out the hypothesis of a chance superposition of the core with the larger radio and optical structure and reinforces the estimate of the kinematical distance of this object already made in AWM.

Assuming that the velocity of matter ejected by the supernova explosion is constant and taking into account the probable ages of CTB 80: 579 yr if this SNR is the remnant of the explosion of the SN 1408 (Wang and Seward 1984) or about 10^4 yr as deduced from its X-ray emission and the present curvature of the jet-like structure (Blair *et al.* 1984; Dickel *et al.* 1981) one can estimate a lower limit of this velocity from the position of the SW filaments which, as we have demonstrated, are associated with this SNR. At a distance of about 3 kpc, the location of the SW filaments (at most 20 arcmin from the central core) implies ejecta velocities of about 30000 or 1600 km s^{-1} if the age of CTB 80 is 579 or 10^4 yr, respectively. Taking into account a possible deceleration, these values of the ejecta velocity are in rough agreement with the values of the ejecta velocities in typical SNs. The value of the ejection velocity would have to be as high as c/3 for the NE filaments to be also associated with this SNR. In such a case, the existence of relativistic flows, perhaps directed, is implied. At the moment, there is no evidence of high velocity material in the core of CTB 80 to support the idea of relativistic jets nor evidence that the NE filaments are associated with CTB 80. It would be interesting to make a similar analysis of the kinematical properties of the NE filaments in order to check the association of the NE filaments with this SNR.

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