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OPTICAL EMISSION FROM THE SNRs G126.2+1.6, G206.9+2.3 AND CTB 13

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RESUMEN

Se obtuvieron fotografías con filtros de interferencia angostos y centrados en Hα, [S II] y [O III] de los remanentes de supernova G126.2+1.6.y G206.9+2.3, cuya emisión óptica se descubrió recientemente, y también del remanente CTB 13 el cual había sido asociado a filamentos visibles en las Cartas de Palomar.

Los primeros dos remanentes presentan altos cocientes de las líneas: [S II]/Hα y [O III]/Hα. La fotografía de CTB 13 correspondiente al [O III] presenta una nebulosidad que coincide con los filamentos de las Cartas de Palomar. Se da también una discusión sobre cada uno de los remanentes.

ABSTRACT

I have obtained narrow-band interference filter photographs in the light of Hα, [S II] and [O III] of the SNRs G126.2+1.6 and G206.9+2.3 whose optical emission has been recently discovered, as well as that of the SNR CTB 13 which has been identified with some filaments on the PSS prints.

The first two SNRs show high [S II]/Hα and [O III]/Hα line-ratios. The photograph of CTB 13 obtained in [O III] shows a spur coincident with the filaments visible on the PSS. A discussion of these individual SRNs is also given.

Key words: INTERSTELLAR MATTER – SUPERNOVAE REMNANTS

I. INTRODUCTION

The optical counterparts to the SNRs G126.2+1.6 and G 206.9+2.3 have been found in the past two years. G126.2+1.6 appears as a faint filament in the [O III] photograph of Parker *et al.* (1979). Blair *et al.* (1980) performed [O III] imagery on part of the structure and spectrophotometric work on the brightest filament of this SNR and found that it shows an unusually high [O III]/Hα line-ratio. The optical identification of the SNR G206.9+2.3 has been given by van den Bergh (1978) based on inspection of a glass copy of the red plate of the PSS. He found faint filaments at the position of the radio non-thermal source. Davies and Meaburn (1978) have photographed this region with a Hα + [N II], 100 Å wide, interference filter, finding a complex filamentary structure. The radio SNR CTB 13, appears to have some optical emission evidenced by an inspection of the blue and red prints of the PSS. The faint filaments are located 0°75 to the south of the position of the radio source as discussed by Wilson (1963).

In this work I have obtained narrow-band interference filter photographs of these regions in the light of Hα, [S II] and [O III] in order to obtain a better knowledge of their structure with application to future work and to verify (in the case of G206.9+2.3 and CTB 13) that the optical emission found at the position of the radio sources is indeed associated with the SNR and is not due to foreground nebulosity.

II. THE OBSERVATIONS

The imagery of these SNRs has been performed by means of a focal reducer (Snyder F/2 objective) coupled with a single-stage image tube at the Cassegrain focus of the 83 cm telescope of the observatory at San Pedro Mártir of the University of Mexico. Three interference filters have been employed: Hα ($\lambda_0 = 6563$ Å, $\Delta\lambda = 10$ Å), [S II] ($\lambda_0 = 6719$ Å, $\Delta\lambda = 16$ Å) and [O III] ($\lambda_0 = 5018$ Å, $\Delta\lambda = 9.7$Å). The fiber optics output of the image tube was recorded on 103a-G films. The scale of these photographs is about 2 arcmin mm^{-1} their angular field is 30 arcmin. Table 1 reports the main characteristics of these photographs. Separate calibrations of the plates were also performed to enable a better analysis of the spatial variations of the line-ratios throughout each of these nebulae.

III. THE INDIVIDUAL SNRs

a) G126.2 + 1.6

The radio isophotes of Reich *et al.* (1979) show a circle, separated from the adjacent SNR G127.1+0.5 of 68 arcmin in angular diameter. In the photographs of

TABLE 1

CHARACTERISTICS OF THE FILTER-PHOTOGRAPHS

Plate Number	Filter	Exposure time (min)	Object
SN 133	Hα	90	G126.2+1.2
SN 136	[O III]	90	G126.2+1.2
SN 138	[S II]	90	G126.2+1.2
SN 156	Hα	75	G206.9+2.3
SN 157	[O III]	63	G206.9+2.3
SN 145	[S II]	75	G206.9+2.3
SN 148	[O III]	90	CTB 13

Parker *et al.* (1979), this SNR is located at the edge of the field and only the [O III] emission is visible, with some difficulty, due to the scale of those plates. The [S II] emission is at the limit of their detectability. The [O III] photograph of Blair *et al.* (1980), shows more clearly, the filamentary arc of about 12 arcmin of angular dimensions. This arc covers only a sector of the circle defined by the radio isophotes and corresponds to a radio feature of maximum surface brightness. Blair's spectroscopic work shows that this arc exhibits emission typical of SNRs but with a very high [O III]/Hα line-ratio. Figure 1 (Plate) shows the Hα, [O III] and [S II] emission of this SNR obtained with the system mentioned in § 2. As seen in this figure, the [O III] emission extends further to the north and forms another circular filament with a curvature different from the filament photographed by Blair *et al.* (1980). There is also some diffuse emission at the south exhibiting a high [O III]/Hα ratio. The [O III]/Hα line-ratio seems to vary within the optical features, while the [S II]/Hα line-ratio appears to be rather uniform. The [S II] emmission is relatively high and consequently in agreement with Blair's (λ6717/Hα) reddened line-ratio of 0.61. If the X-ray pulsar located at the southern edge of the SNR is really associated to it, G126.2+1.6 would be very similar to the Vela SNR and possibly to HB3 as well. More accurate distance determinations of both the pulsar and the SNR are needed in order to establish a possible association. The physical conditions derived from the spectroscopic work and a summary of the radio observations on this SNR have been already discussed by Blair *et al.* (1980).

b) G206.9 + 2.3

This SNR located at the eastern edge of the Monoceros Ring has a radio spectral index of about – 0.5 as reported by Haslam and Salter (1971). The work of Day *et al.* (1972) has shown that this non-thermal radio source was a different source from that of the Monoceros SNR. Van den Bergh (1978), by inspection of a red plate of the PSS found at the northeastern edge of the radio source a very faint filamentary nebula of 57 arcmin in angular diameter. Further imagery performed by Davies and Meaburn (1978) with the SRC Schmidt camera, in the light of Hα + [NII], gave the whole structure of this nebula appearing to have the same angular dimensions (of about 57′ × 29′) as the radio source but with the major axis of the optical nebula in a direction appreciably different from the major axis of the radio source. The identifications of this optical nebula with the radio SNR were performed only on the basis of the position of this nebula relative to the radio source. Figure 2 (Plate) shows the Hα, [O III] and [S II] images of this nebula obtained for this work. By inspection of these photographs one can deduce that the emission is characteristic of a SNR. Then, on the basis of these high [S II]/Hα and [O III]/Hα line-ratios, the optical nebula appears to be associated with the radio SNR. The [O III]/Hα line-ratio appears to vary along the filaments.

c) CTB 13

This source from the catalogue of Wilson (1963) has been classified by this author as a possible SNR on the basis of the existence of optical filaments at about 0°.75 south of the center of the radio source observed on both O and E plates of the PSS. This source also appears in the catalogue on Ilovaisky and Lequeux (1972), Downes (1971) and Milne (1970). The latter reports angular dimensions of 300 × 120 sq. arcmin for this object and a radio spectral index of – 0.5, characteristic of a SNR. The distance and linear diameter estimates of this SNR vary depending on the Σ–D relation employed in the computations. Consequently, the computed value of the distance lies in the range 600 pc to 1.1 kpc corresponding to a diameter for the SNR in the range 30 to 66 pc. The reality of this radio source is however a subject of controversy. In fact, Haslam and Salter (1971) claim that this radio structure should be considered as a section of the low latitude disk component of the galactic continuum background rather than a large, discrete source. I tried to obtain Hα, [O III] and [S II] photographs of this region. The results were positive only for the [O III] photograph thanks to the exceptional observing conditions. However, the observed spur, Figure 3 (Plate), which is about 10 arcmin from the filaments shown in the red print of the PSS, Figure 4 (Plate), is at the very limit of detectability of the instrument and further work must be done. If this detection of [O III] emission is real, then, one could consider CTB 13 as a SNR with an optical counterpart and with high [O III] emission as in the other two cases already discussed. However, this last statement must be taken with caution until better observations confirm it.

TABLE 2

ESTIMATES OF THE DISTANCES TO THE DISCUSSED SNRs

Object	Angular diameter (arc min)	Distance (kpc) Optical lower limit $E_0/n_0 = 10^{50}$	$E_0/n_0 = 10^{51}$	Radio obs.	References[a]
G126.2+1.6	68	1.24	4.1	4.5	RKS
G206.9+2.3	43	3.0	6.5	4-8.3	DM
CTB 13	210	0.62	1.33	0.6-1.1	IL,D,M

a. RKS, Reich *et al.* (1979); DM, Davies and Meaburn (1978); IL, Ilovaisky and Lequeux (1972); D, Downes (1971); M, Milne (1970).

IV. DISCUSSION

The [S II] and [O III] photographs obtained on G206.9+2.3 show that the Hα + [N II] emission already identified as the optical counterpart of the radio source is indeed associated with it. It is desirable to have further photographs covering the entire nebulosity found in the Hα + [N II] by Davies and Meaburn (1978). As some other SNRs (i.e., G65.2+5.7, and CTA 1) the three SNRs discussed here appear to have a high [O III]/Hα line-ratio. The case of CTB 13 must be confirmed by further observations with a telescope of larger aperture. High values of the [O III]/Hα line-ratio turn out to be quite common although shock models are incapable of predicting them. This could be due to a departure from a steady flow shock giving rise to a relatively weak Balmer line emission. Thermal instabilities in the flow behind a radiatively cooling shock, recently shocked clouds entering the recombination phase or SNRs during the shell formation phase could explain this departure as suggested by Raymond *et al.* (1980). Whatever the origin of this high line-ratio, it is very useful to take [O III] photographs of radio SNRs in order to investigate their optical counterparts.

The high [O III]/Hα line-ratio implies shock velocities greater than 60 km s^{-1} according to existing theoretical shock models (Raymond 1979; Shull and Mc Kee 1979). It is therefore likely that the filaments appearing in the photographs have these values for the shock velocities. As discussed by Fesen *et al.* (1981), one can relate these velocities to the initial energy of the SN explosion, E_0, the pre-shock density, n_0, and the angular diameter in order to estimate the distance to the SNR by assuming that the pressure in these filaments is representative of the pressure in the SNR. Table 2 gives lower estimates to the distance to the SNRs by taking a shock velocity, $V_s = 60$ km s^{-1}, and two values for E_0/n_0 namely, 10^{50} and 10^{51} erg cm^3, typical of SN explosions. The table also gives the distances derived from radio observations. As seen in this table, the agreement between the distances obtained in this way and the distances derived from the Σ–D relations is quite satisfactory. Improvements in such distance determinations can be achieved by Fabry-Pérot interferometry and spectroscopy, which could give a better knowledge on n_0 and V_s, or by UV observations.

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