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G. 179.0 + 2.7, an unusual galactic radio source?

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Summary. Radio continuum observations of a new nonthermal large diameter source in the galactic anticentre direction are reported. It consists of a nearly circular shell-like structure with a diameter of $\approx 70'$ and radial magnetic field, possibly a supernova remnant. At the centre a polarized, nonthermal triple source is seen. It might be extragalactic, but an association with the extended emission cannot be ruled out.

Key words: radio emission – supernova remnants – radio galaxies

1. Introduction

In the course of galactic continuum surveys with the Effelsberg 100-m telescope at 1.42 and 2.695 GHz an extended, circular object has been detected near the galactic anticentre direction at the position $l = 179\overset{\circ}{.}0$, $b = 2\overset{\circ}{.}7$. Near the centre of this object a strong point source and an arclike structure have been noticed. This morphology has given reason to observe the source in more detail. There are a few galactic nonthermal objects consisting of extended radio emission associated with small-scale structures, W 50/SS 430 and possibly G 357.7 − 0.1 and G 5.3 − 1.0 (Helfand and Becker, 1985) or G 18.95 − 1.1 (Fürst et al., 1985). The study of such objects may provide useful information on compact binary systems and the formation of radio jets.

2. Observation and results

Maps at 1.425, 2.695, and 4.75 GHz have been obtained with the Effelsberg 100-m telescope. Some observational parameters are given in Table 1. Standard reduction methods for continuum mapping with the 100-m telescope have been applied. The results are displayed in Figs. 1–4. The integrated spectrum of G 179.0 + 2.7 and spectra of compact structures near its centre are shown in Fig. 5. In Table 2 flux densities of some small diameter sources within the field are listed. The spectral index of the extended emission is $\alpha = 0.3 \pm 0.15$ ($S_\nu \sim \nu^{-\alpha}$) after subtracting the radio source at $l = 178\overset{\circ}{.}83$, $b = 2\overset{\circ}{.}65$ (4C 31.21). The uncertainty in α is mainly caused by the estimation of the relative zerolevels. Another procedure to determine the spectral index independent of a temperature offset is the wellknown method of temperature T_{ν_1} versus T_{ν_2} plots (TT-plots). A flux density spectral index of $\alpha = 0.4 \pm 0.2$ has been obtained by this method for all possible frequency combinations. Part of the error may be due to intrinsic variation of α. A spectral index of $\alpha = 0.35$ may be taken as representative.

At 2.695 and 4.75 GHz also the linear polarization has been observed. The signal-to-noise ratio in the polarized intensity is relatively low. Polarization vectors are shown above 10% polarization percentage at 2.695 GHz (Fig. 2) and greater than 1.5 × r.m.s. polarization intensity at 4.75 GHz (Fig. 4). For the central bar-like feature and 4C 31.21 a polarization of ≈15% and ≈4.2% respectively has been found at both frequencies. After subtracting

Table 1. Observational parameters

Frequency (MHz)	1425	2695	4750
Angular resolution (′)	9.4	4.3	2.4
System temperature (K)	45	60	65
Bandwidth (MHz)	40	80	500
Date of observation	Jan. 1984 March 1985	May 1985	May 1985
Coverages	2	4	4
T_B/S	1.95	2.56	2.71
r.m.s. noise (mK T_B)			
Total power	25	12	5
Polarized intensity	–	5	3
Main calibrator	3C286	3C286	3C286
Flux density (Jy)	14.4	10.4	7.5
Percentage polarization	–	9.9	11.5
Polarization angle (°)	–	33	33

Table 2. Peak flux densities of unresolved small diameter sources

Position [a]		1.425 GHz	2.695 GHz	4.750 GHz
l (° ′ ″)	b (° ′ ″)	(mJy)		
178 50 04	02 38 51	1020 ± 100	640 ± 60	380 ± 30
179 02 13	02 26 25	–	128 ± 10	85 ± 8
179 28 06	02 38 02	210 ± 20	66 ± 10	39 ± 4
179 37 08	03 13 28	260 ± 50	140 ± 10	80 ± 10

[a] Positions are from 4.75 GHz observations, typical errors are ∼10″

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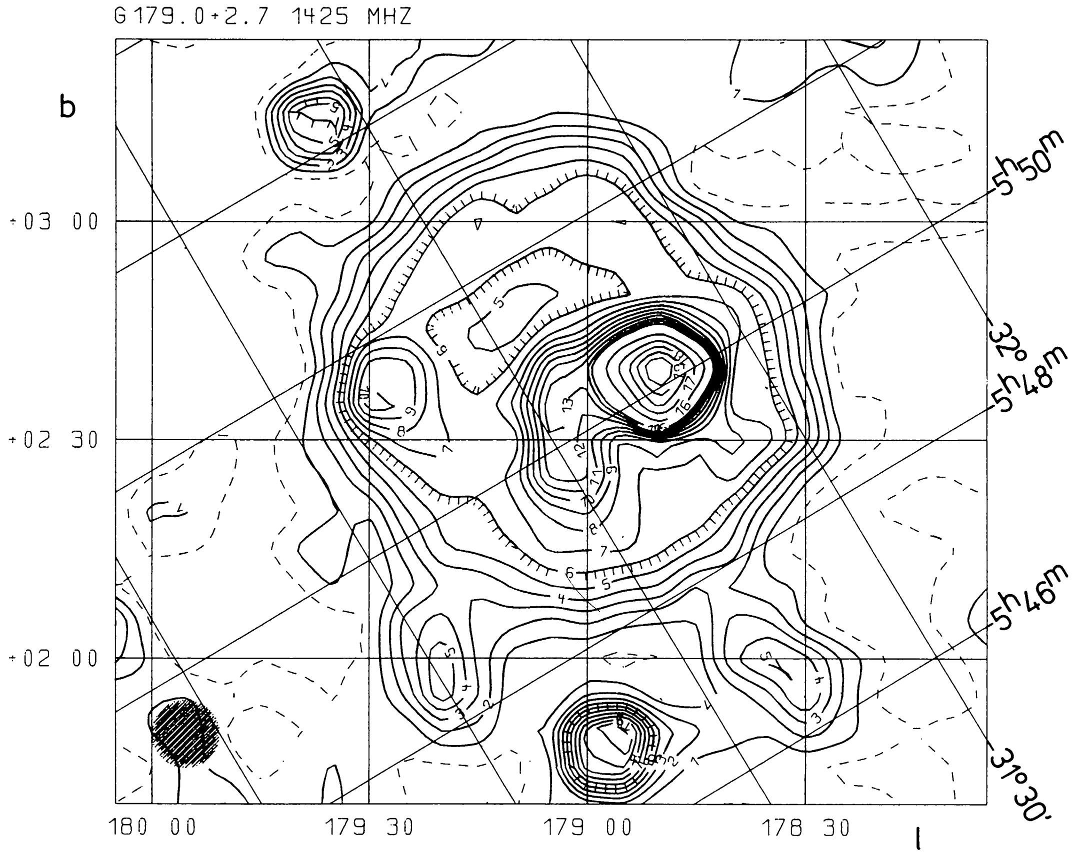

Fig. 1. Total intensity of G 179.0+2.7 at 1425 MHz. Contours run from zero (dashed) in steps of 50 mK T_B to 700 mK T_B (contour label 15) and further in steps of 250 mK T_B. The angular resolution of 9.'4 is indicated as a dashed circle

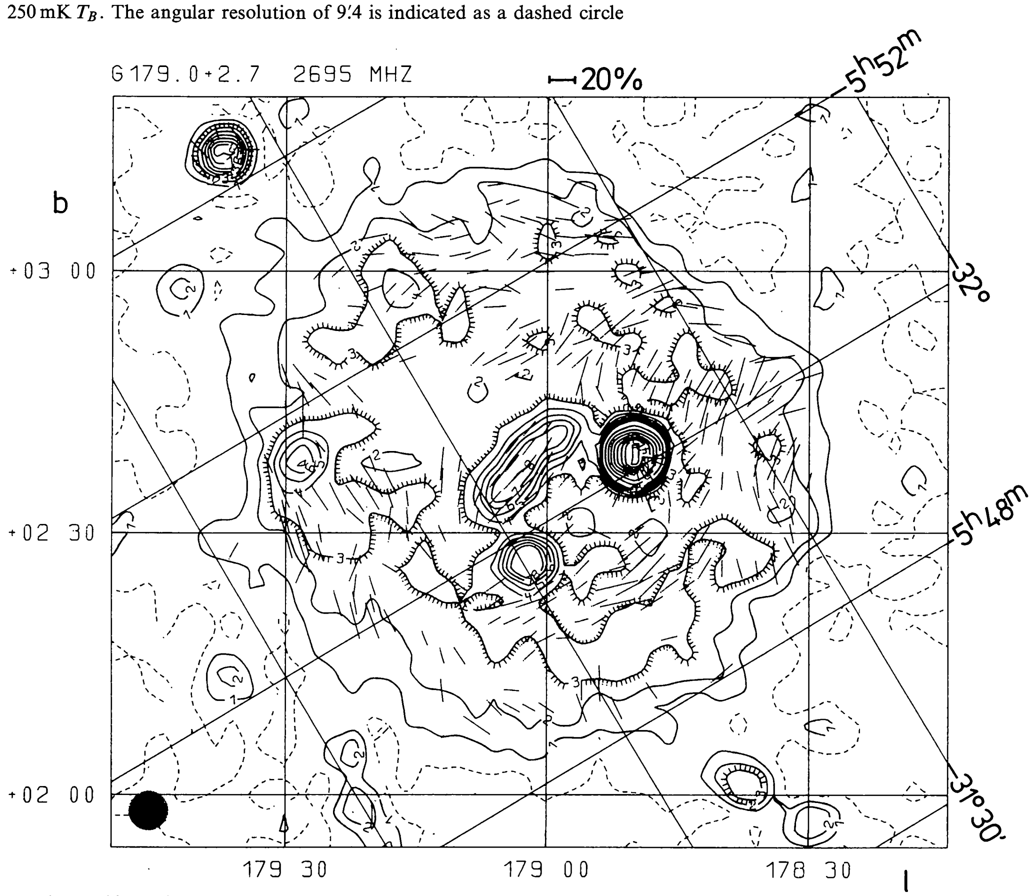

Fig. 2. Total intensity and percentage polarization of G 179.0+2.7 at 2695 MHz. Contours run from zero (dashed) in steps of 35 mK T_B to 280 mK T_B (contour label 8) and further in steps of 140 mK T_B. Polarization *E*-vectors are superposed showing the percentage polarization starting at 10%. The angular resolution of 4.'3 is indicated as a dashed circle

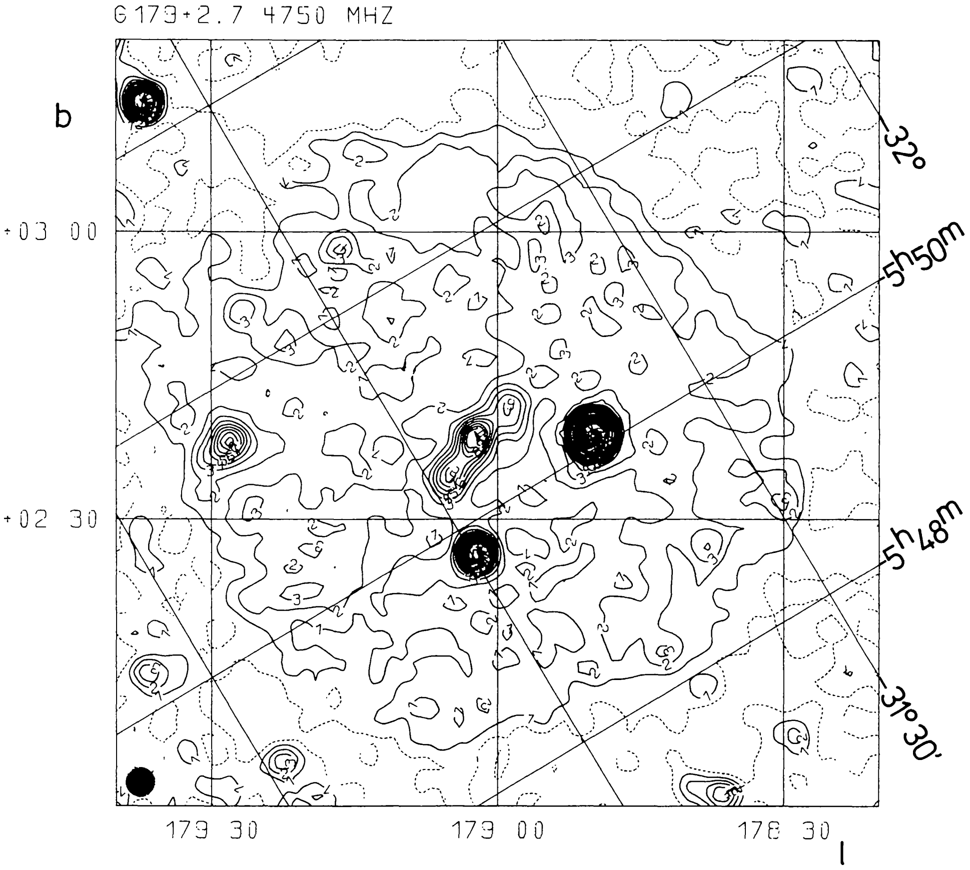

Fig. 3. Total intensity of G 179.0 + 2.7 4.75 GHz. Contours run from zero (dashed) in steps of 10 mK T_B to 150 mK T_B (contour label 15) and further in steps of 50 mK T_B. The data are slightly convolved to 3′ angular resolution as indicated by a dashed circle

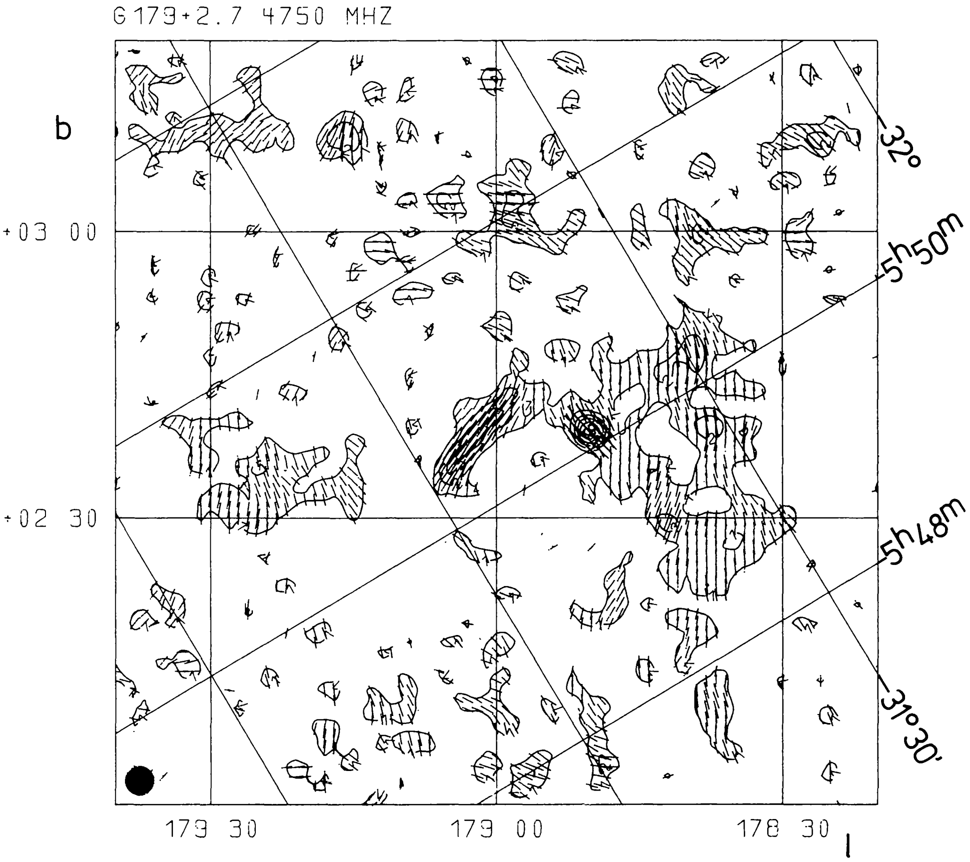

Fig. 4. Polarized intensity of G 179.0 + 2.7 at 4.75 GHz. Contours run from 4.5 mK T_B^p in steps of 4.5 mK T_B^p. Polarization *E*-vectors are shown in addition

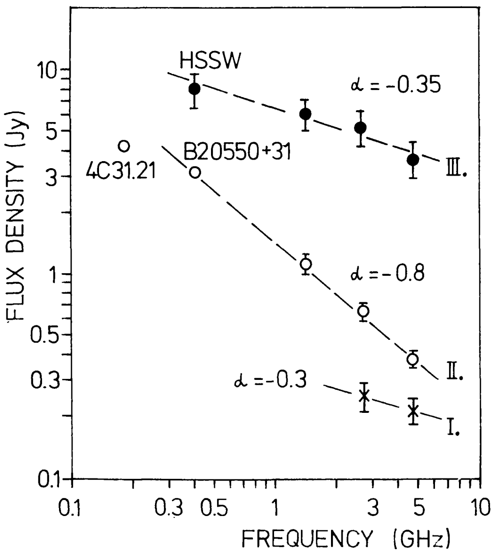

Fig. 5. Flux density spectra of the bar-like structure in the centre of G 179.0 +2.7 (*I*), the radio source 4C 31.21 (II) and of the integrated emission of G 179.0 +2.7 (III) after subtraction of (II). Flux density values have been taken from Haslam et al. (1982, HSSW), Roub (1970, B 20550+31), and Pilkington and Scott (1965, 4C31.21). All other values have been derived from the present observations

these two structures the integrated polarization of the extended emission has been estimated to 8±2% at 2.695 GHz and 9±2% at 4.75 GHz.

The distribution of *E*-vectors in Figs. 2 and 4 is very similar except a few areas in the western part. The minimum rotation measure RM is relatively low, the ambiguity being 376 rad m^{-2} between the two frequencies. The bar-like structure and 4C31.21 show RM ≈ −15 rad m^{-2} and ≈ +10 rad m^{-2} respectively. The diffuse emission shows RM between −80 rad m^{-2} and +80 rad m^{-2}. The corresponding intrinsic angle of the projected magnetic field is plotted in Fig. 6 for minimum rotation measure and polarized intensity >2 × r.m.s. noise at both frequencies. There is a strong indication of a radial magnetic field for the shell-source. The polarization *E*-vector of the bar-like structure is $\phi = 150° \pm 10°$ and that of 4C31.21 $\phi = 40° \pm 10°$. There are two arguments supporting the minimum rotation solution. Firstly, the nearest extragalactic sources do not show rotation measure up to 376 rad m^{-2}. Secondly, the almost negligible depolarization contradicts a large Faraday rotation. If the slab model by Burn (1966) can be applied for the extended emission a polarization of less than 3% at 2.695 GHz would be expected for RM = RM (min) + 376 rad m^{-2}. Therefore, the observations of the extended emission may be summarized as follows: nonthermal emission with spectral index $\alpha = 0.35$, linearly polarized with 8% and radial projected magnetic field.

An interesting feature in the contour maps is the bar-like structure with its centre almost exactly at the centre of the extended emission. It consists of at least three sources. At the highest available angular resolution (4.75 GHz) the sources are separated

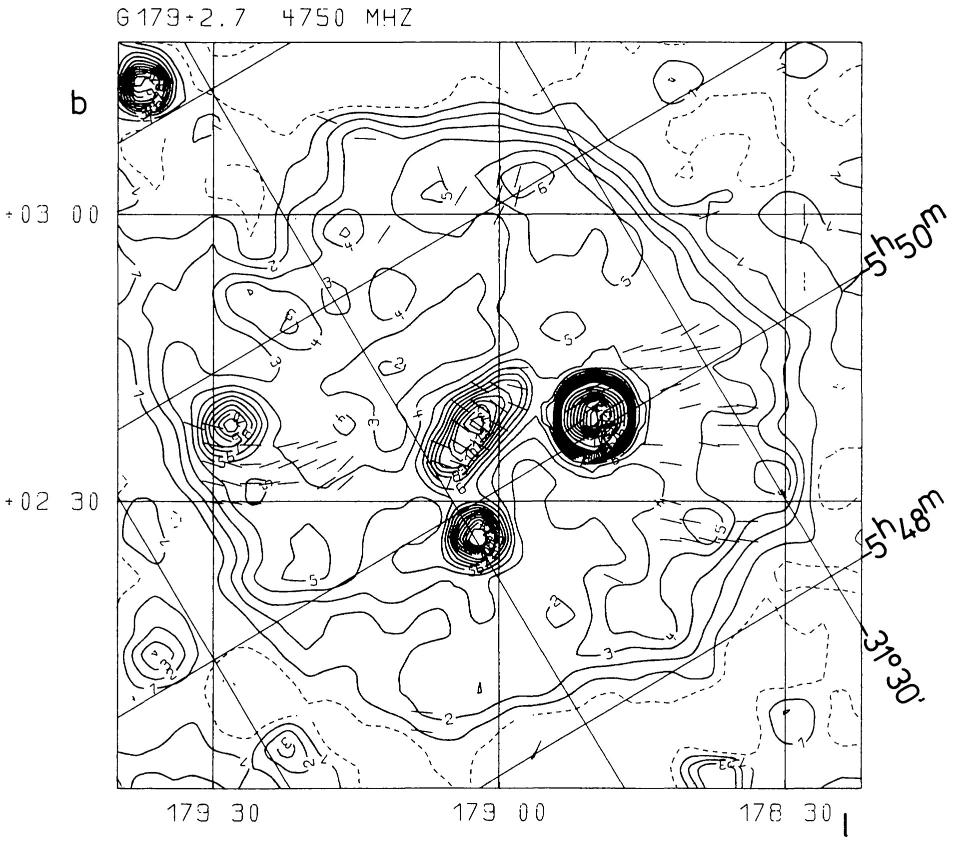

Fig. 6. Total intensity of G 179.0+2.7 at 4.75 GHz convolved to 4.'3 angular resolution (as Fig. 2). Contours run from zero (dashed) in steps of 5 mK T_B to 75 mK T_B (contour label 15) and further in steps of 25 mK T_B. The projected magnetic field distribution is represented by bars (see text)

but remain unresolved. At 4.75 GHz the peak flux density of the central source ($l = 179°02'29''$, $b = 2°38'18''$) is ≈ 47 mJy. The apparent distance to the northern source (≈ 24 mJy, $l = 178°58'59''$, $b = 2°41'27''$) is 4'.1 and that to the southern source (≈ 29 mJy, $l = 179°05'05''$, $b = 2°34'24''$) is 5'.2. The orientation of the whole structure is within the errors identical with the intrinsic electric polarization angle. A spectral index cannot be given for the individual sources. However, the whole feature has been separated from the background. The spectral index between 2.695 and 4.75 GHz is $\alpha = 0.3$, where it steepens from $\alpha = 0.2$ at the central source to $\alpha = 0.6$ towards the outer sources. While the absolute value of the spectral index depends on the chosen baselevels, the spectral index variation is unaffected. If convolving the 4.75 GHz to the 2.695 GHz resolution the central source is still more pronounced (compare Fig. 2 with Fig. 6). One should notice the highly uniform polarization vector distribution across the bar-like structure. This suggests that the three small diameter sources belong physically to one object and that a relatively large fraction of the magnetic field is well-ordered and perpendicular to the axis of the object.

3. Discussion

3.1. The extended emission

After subtracting the small diameter sources and the central bar-like structure G 179.0 + 2.7 reveals a thick shell structure. This morphology and the nonthermal, polarized emission classifies the object as a shell-type supernova remnant. The surface brightness is very low $\Sigma_{1\,\mathrm{GHz}} \cong 2\ 10^{-22}\ \mathrm{W\,m^{-2}\,Hz^{-1}\,ster^{-1}}$. According to the Σ-D relation by Milne (1979) the size is ≈ 70 pc corresponding to a distance $d \approx 3.5$ kpc with a large uncertainty. Such a low surface brightness is used to be taken as a hint for a large age, possibly some $10^4 - 10^5$ yr. This conclusion is unexpected in view of the radial projected magnetic field, which is typical for young objects and is reported only for some historical SNR's: CAS A, Tycho and SN 1006 (Dickel and Milne, 1976). It is also noticeable that other old SNR's in the neighbourhood of G 179.0 + 2.7 (S147, IC443) do show optical filaments, while for the new object no filaments could be detected on the Palomar prints and in the spectroscopic atlas by Parker et al. (1979). It should be emphasized that S147 is only 3° apart. Of course, if the distance is large, extinction may be high enough to explain the lack of optical emission of G 179.0 + 2.7.

If G 179.0 + 2.7 is assumed to be young (≈ 1000 yr), the size should not be larger than ≈ 10 pc corresponding to a distance of ≈ 500 pc. In this case the radio luminosity would be a factor 10 lower than that of SN 1006, which is known to have an unusually low luminosity. We are left with the fact that in either case, young or old, G 179.0 + 2.7 is an unusual nonthermal source.

Two additional remarks should be given here. There is a Korean record of a "new" star AD 1356 (Clark and Stephenson, 1977) at a position $l = 180°$, $b = 0°$. The report does not show typical characteristics of a supernova, it could have been a nova. The energy release during a nova event is of order 10^{45} erg. Assuming that this amount of energy has gone into relativistic electrons and the observed radio emission of G 179.0 + 2.7 originates from the AD 1356 event, a magnetic field of $> 10\ \mu$G at a distance < 100 pc has to be assumed. Since only a small fraction of the total energy is expected to go into accelerated electrons, this association seems unlikely.

In the infrared extension of the Palomar survey a small diffuse object ($\approx 1'$ across) has been noticed $\approx 4'.5$ north of 4C31.21. The nature of this object and its relation to G 179.0 + 2.7 is unclear.

From these considerations we conclude that the age of G 179.0 + 2.7 is unknown.

3.2. The central bar-like structure

The morphology of the central triple source suggests a classification as an extragalactic object. Polarization percentage and projected magnetic field direction are not unusual. If for instance a two sided radio jet dominates the observed polarization, a magnetic field perpendicular to the jet direction is expected (Bridle and Perley, 1984). Also the detected spectral index variation from the centre towards the outer edges is similar for extragalactic objects. We could not find an optical counterpart of the central source from the Palomar prints. The location of the central source at the centre of the extended emission could be by chance [a similar case may be, for instance, the central source of G 127.1 + 0.5, van Gorkom et al. (1982)], but has given reason to speculate on a possible association. Morphologically, the whole object could be similar to W 50/SS 433. There is a striking similarity of the bar-like structure with the galactic source Sco X-1, which is also a triple radio source with similar spectral indices (Geldzahler et al., 1981). However, no pulsar has been found in the area of G 179.0 + 2.7 (Manchester and Taylor, 1981). Also no X-ray source (HEAO I, Wood et al., 1984), (*UHURU*, Forman et al., 1978) or enhanced soft X-ray emission (McCammon et al., 1983) is associated. The available observations do not allow a reliable conclusion. Deep observations with higher angular resolution in the radio-, optical- and X-ray domains are requested to reveal the origin of the barlike structure and its relation to the extended emission of G 179.0 + 2.7.

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