1984A&A...133L...4R

Astron. Astrophys. 133, L4–L7 (1984)

ASTRONOMY AND ASTROPHYSICS

Letter to the Editor

Two new filled-center supernova remnants: G24.7+0.6 and G27.8+0.6

W. Reich[1], **E. Fürst**[1], **and Y. Sofue**[1,2,*]

[1] Max-Planck-Institut für Radioastronomie, Auf dem Hügel 69, D-5300 Bonn 1, Federal Republic of Germany
[2] Nobeyama Radio Observatory, Tokyo Astronomical Observatory, Univ. Tokyo, Minamisaku, Nagano 384-13, Japan

Received January 19, accepted February 2, 1984

Abstract. Two new plerionic supernova remnants (SNR) were discovered through radio continuum observations at 2.695, 4.75 and 10.2 GHz. Both objects show filled-center morphology, consisting of an extended component over 30' and a peaked central component of extent 10' - 20'. The objects are linearly polarized, which indicates their nonthermal origin. The radio spectrum of G24.7+0.6 is as flat as $\alpha \sim -0.17$ over 0.4 to 10 GHz ($S \propto \nu^{\alpha}$). The spectral index of G27.8+0.6 is about -0.3 below 5 GHz and turns steeper ($\alpha \sim -1$) above 5 GHz. The distance, size and age are estimated as 4.4 kpc, 40 x 20 pc and 12000 years for G24.7+0.6, and 2 kpc, 30 x 20 pc and 35000 - 55000 years for G27.8+0.6. The two objects provide a promising clue to investigate the late-stage evolution of filled-center SNRs.

Key words: plerion supernova remnants — SNR evolution

1. Introduction

The existence of a new class of galactic supernova remnants (SNRs) — filled-center (plerionic or Crab-like) SNRs — has been established by Weiler and Panagia (1980) and Weiler (1983). Since the current studies of SNRs have been mainly devoted to those with shell structures, studies of filled-center SNRs are still limited to a small sample of objects.

We have noticed two extended radio sources of this type in our 2.695 and 10.2 GHz galactic plane surveys, which are being carried out at the MPIfR and NRO (Reich et al., in preparation; Sofue et al., 1983a,b). The two sources, which we call hereafter G24.7+0.6 and G27.8+0.6, have a morphology similar to the known filled-center SNRs. To investigate their nature in more detail we mapped the two objects at 4.75 GHz in continuum including linear polarization.

2. Observations and Results

The sources, located at $(\ell,b) = (24\overset{\circ}{.}7, +0\overset{\circ}{.}6)$ and $(27\overset{\circ}{.}8, +0\overset{\circ}{.}6)$ both extending more than $0\overset{\circ}{.}5$, were mapped at 2.695, 4.75 and 10.2 GHz. The observational data are listed in Table 1. The 2.695 and 4.75 GHz observations were made using the Effelsberg 100-m telescope. The 10.2 GHz observations were made at NRO using the 45-m telescope.

Send offprint requests to: W. Reich
* A. von Humboldt Fellow, June–Sept. 1983, on leave from NRO

The observational results are displayed in the form of contour maps in Figures 1 through 6 limited to the source areas.

The estimation of the flux densities of the two sources requires a careful inspection of the background emission. Both objects are located in regions showing a smooth gradient of the diffuse galactic radiation (Altenhoff et al., 1970; Haynes et al., 1978; Reich et al., in preparation). Flux density values have been obtained by a method of "ring"-integration starting at the center of the sources with the restriction to areas covering the objects properly. This method provides a reasonable estimate of the smooth contribution of the background. The errors of the flux density values quoted in Table 2 are mainly due to a background scatter.

(i) G24.7+0.6

This is catalogued by Milne (1979) as a SNR. Figs. 1 - 3 show that the object has no shell but has a filled-center morphology. The object is elongated and the major axis is roughly parallel to the galactic plane. It consists of a broad, extended component of 30' x 15' and a centrally peaked component of 15' x 10'. The central part is polarized at about 5% at 4.75 GHz, which indicates its nonthermal origin. No significant polarization was detected at 2.7 GHz, probably due to large depolarization through the galactic plane.

The strong point source at $(\ell,b) = (24\overset{\circ}{.}5, 0\overset{\circ}{.}5)$ is a compact HII region (Wink et al., 1982) at a distance of 10 kpc. Integrated flux densities within the area 30' x 15' centered on $(\ell,b) = (27°40', 0°35')$, excluding the compact HII region, are 19 Jy at 2.695 GHz, 17 Jy at 4.75 GHz and 15 Jy at 10.2 GHz. Figure 7 shows the spectrum of total flux densities, where additional data points are taken from the literature. A best fit spectral index of $\alpha \sim -0.17$ is derived from these flux densities ($S \propto \nu^{\alpha}$). The observed parameters are summarized in Table 2. No optical counterpart is seen on the Palomar prints and on the emission line survey of the Milky Way by Parker et al. (1979) due to the heavy obscuration near the galactic plane. No X-ray source is found on the UHURU catalogue (Forman et al., 1978), no γ-ray source is listed in the COS-B catalogue (Bignami and Hermsen, 1983).

The above radio characteristics satisfy the identifying properties of a filled-center SNR as given by Weiler (1983). We conclude that this object is a Class P (plerionic) filled-center SNR.

Application of a $S\theta^2$-d relation derived for filled-center SNRs by Weiler and Panagia (1980) leads to a

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1984A&A...133L...4R

Table 1: Observational parameters

Frequency [GHz]	2.7	4.75	10.2
Telescope	Effelsberg 100 m	Effelsberg 100 m	Nobeyama 45 m
HPBW [']	4.3	2.4	2.7 for G24.7+0.6 4.3 (convolved) for G27.8+0.6
Receiver	3 channel cooled FET correlation receiver	3 channel cooled Paramp/FET correlation receiver	He cooled paramp + Dicke switching with cold load
Bandwidth [MHz]	80	500	500
T_{sys} [K]	60	65	100
Observed quantities	total intensity + linear polarization	total intensity + linear polarization	total intensity
Instrumental polarization [%]	< 1	< 1	
Date of observations	April, July 1983	Aug. 1983	Dec. 1982, June 1983
Calibration sources	3C 286	3C 286	see Sofue et al. (1983b)
Flux density [Jy]	10.4	7.5	
Polarization [%]	9.9 at 33°	11.5 at 33°	

Table 2: Observed and derived parameters for G24.7+0.6 and G27.8+0.6

Object	G24.7+0.6	G27.8+0.6
Position RA/DEC (1950)	$18^h31^m.5$ / -7°07'	$18^h37^m.1$ / -4°28'
ℓ/b	24°40' / 0°35'	27°40' / 0°35'
Size of extended (core) component	30' x 15' (15' x 10')	50' x 30' (10' x 20')
Integrated flux density		
$S_{10.2\ GHz}$	15 ± 3 Jy	8.5 ± 2 Jy
$S_{4.75\ GHz}$	17 ± 4 Jy	18 ± 2 Jy
$S_{2.695\ GHz}$	19 ± 3 Jy	23 ± 2 Jy
$S_{1\ GHz}$ (estimated)	20 Jy	30 Jy
Linear polarization degree of central part:		
$P_{5\ GHz}$	∿ 5%	∿ 5 - 20%
$P_{2.7\ GHz}$	< 2%	∿ 5%
Spectral index α ($S \propto \nu^{\alpha}$)	-0.17 ± 0.3	-0.3 ± 0.1 at < 5 GHz -1 ± 0.5 at > 5 GHz
Critical frequency ν_c	—	5 ∿ 10 GHz
Distance	4.4 kpc	1.9 ∿ 2.3 kpc
Linear size	40 x 20 pc	34 x 20 ∿ 28 x 17 pc
Age	12000 years	55000 ∿ 35000 years
Average expand. velocity	3000 km s^{-1}	600 ∿ 800 km s^{-1}

distance of d = 4.4 kpc, where S (1 GHz) = 20 Jy was estimated from the spectrum in Figure 7. The linear extent of the object is then about 40 x 20 pc. The Sd^2-t relation gives a rough estimate of the age of about 12000 years, which is comparable to that of the Vela X Nebula. The derived parameters are summarized in Table 2.

(ii) G27.8+0.6

This extended source is catalogued neither as a SNR nor as HII region. The source is isolated from the strong galactic background at higher frequencies and is particularly prominent on the 2.695 GHz survey map. The source is again composed of a very extended component of extent about 50' x 30' elongated parallel to the galactic plane and a central component of 10' x 20'. Although the brightness is about a half, the morphological structure is similar to G24.7+0.6. The central part is strongly polarized between 5 to 20 percent at 5 GHz and about 5 percent at 2.695 GHz, indicating that the source is of nonthermal origin.

A weak point source at (ℓ,b) = (27°45', 0°45') is identified with a planetary nebula, M2-45, of SF (suspected and faint) class (Milne, 1978), which has a flux density of 140 mJy at 5 GHz. The optical position of the planetary nebula is (RA,Dec) = ($18^h36^m43^s.5$, -4°22'52") and the distance is between 2.5 and 6.7 kpc (Maciel, 1981). The quoted flux densities at 5 and 14.7 GHz are 130 and 146 mJy, respectively. It is interesting to note that the source is located just at the geometrical center of the extended component.

Integrated flux densities of G27.8+0.6 after removing the planetary nebula are 23, 18 and 8.5 Jy at 2.695, 4.75 and 10.2 GHz, respectively. Figure 7 shows the spectrum of the source, where at 408 MHz an upper flux limit was estimated from the 408 MHz all-sky survey (Haslam et al., 1982) after correcting for the steep gradient of galactic emission seen on the original maps. The spectrum indicates a bend toward higher frequencies. The spectral index below $\nu_c \approx$ 5 - 10 GHz is $\alpha \cong -0.3$ and $\cong -1$ beyond.

All these radio properties are well indicative of a filled-center SNR. No optical emission and UHURU X-ray or COS-B γ-ray source is associated.

If we believe in this bend the evolutionary model for filled-center SNRs by Weiler and Panagia (1980) can be used to derive the age. We get an age of 35000 years for ν_c = 10 GHz and 55000 years for ν_c = 5 GHz. According to the model the age and flux density at 1 GHz is related to the distance. If we adopt a flux density of $S_{1\ GHz}$ = 30 Jy (Figure 7), we obtain a distance of 2.3 kpc for ν_c = 10 GHz and 1.9 kpc for ν_c = 5 GHz. This distance is consistent with the value of d ≅ 2 kpc derived by applying the $S\theta^2$-d relation of Weiler and Panagia. The linear size is then 34 x 20 pc (ν_c = 10 GHz) to 28 x 17 pc (ν_c = 5 GHz). We note that the smaller distance (∿ 2 kpc) of G27.8+0.6 compared to G24.7+0.6 (4.4 kpc) is consistent with the fact that G27.8+0.6 is less depolarized, showing stronger polarization than G24.7+0.6.

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1984A&A...133L...4R

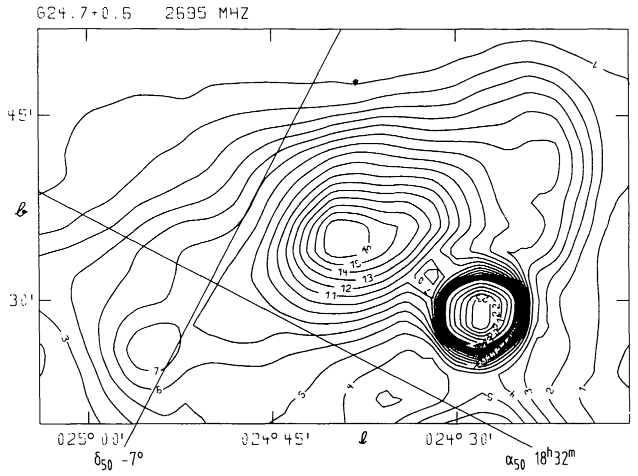

Fig. 1: A 2.695 GHz total intensity map of G24.7+0.6 in galactic coordinates. The contour unit is 300 mK T_B (1 K T_B above 5.4 K = contour 18). The HPBW is 4!3.

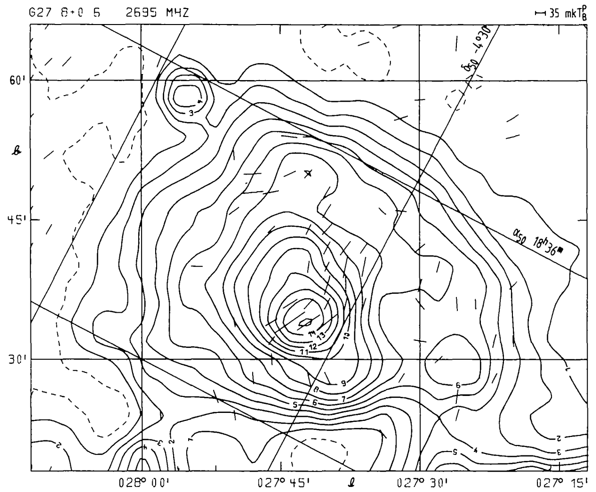

Fig. 4: A 2.695 GHz total intensity map of G27.8+0.6. The contour unit is 200 mK T_B. The HPBW is 4!3. E vectors whose lengths are proportional to polarized intensity are shown above 35 mK T_B^p.

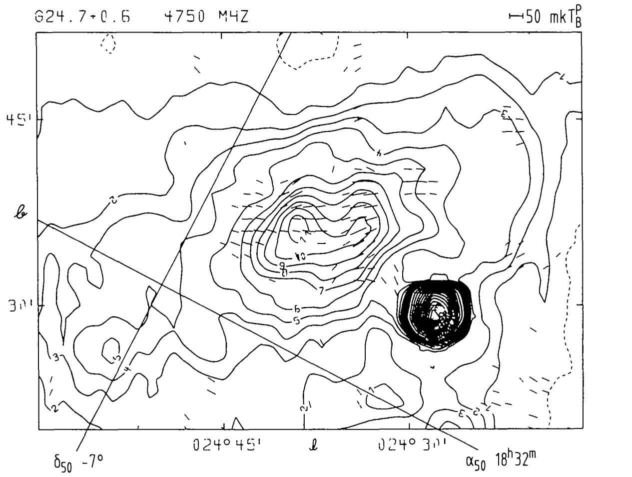

Fig. 2: A 4.75 GHz total intensity map of G24.7+0.6. The contour unit is 150 mK T_B (0.6 K T_B above 1.8 K = contour 12). The HPBW is 2!4. Superposed lines are E vectors of linear polarization, whose lengths are proportional to polarized intensity shown above 25 mK T_B^p.

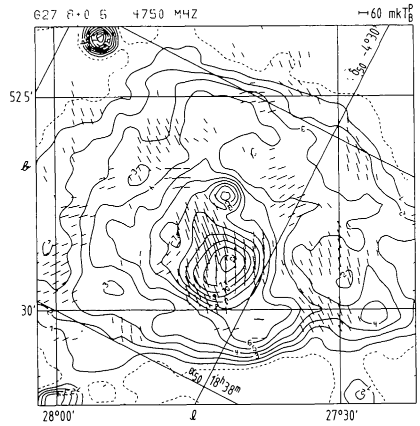

Fig. 5: A 4.75 GHz total intensity map of G27.8+0.6. The contour unit is 75 mK T_B. The HPBW is 2!4. E vectors whose lengths are proportional to polarized intensity are shown above 30 mK T_B^p.

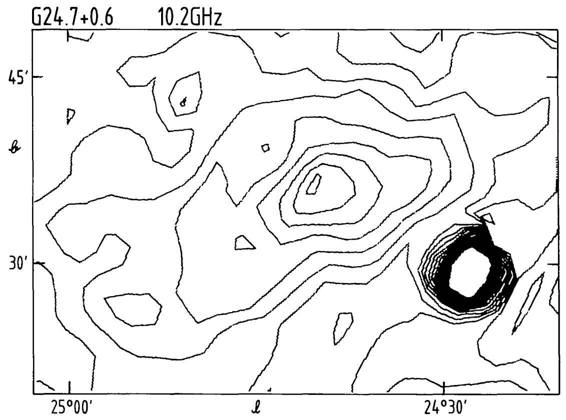

Fig. 3: A 10.2 GHz total intensity map of G24.7+0.6. The contour unit is 50 mK T_B. The HPBW is 2!7.

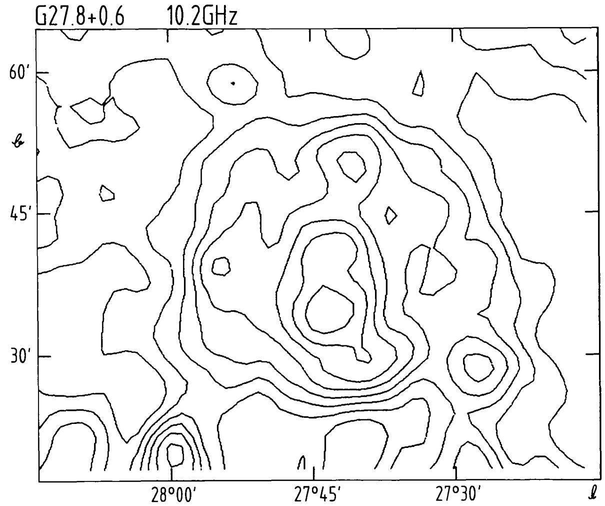

Fig. 6: A 10.2 GHz total intensity map of G27.8+0.6. The contour unit is 10 mK T_B. The map has been convolved to a HPBW of 4!3.

© European Southern Observatory • Provided by the NASA Astrophysics Data System

1984A&A...133L...4R

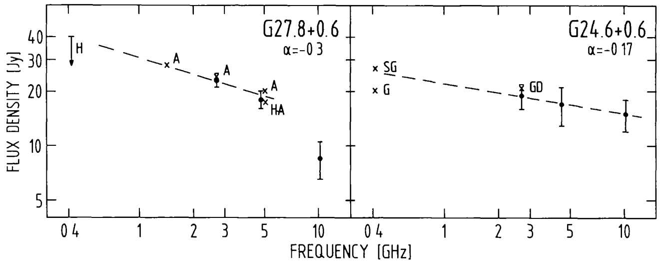

Fig. 7: Radio spectrum of G27.8+0.6 (left). Filled dots represent the present observations. The upper limit of 40 Jy (H) at 408 MHz was derived from an analysis of the all-sky survey (Haslam et al., 1982). A represents data from Altenhoff et al. (1970), HA was obtained by integration of the data of Haynes et al. (1978).
Radio spectrum of G24.7+0.6 (right). Additional data points are taken from the literature: SG (Shaver and Goss, 1970), G (Green, 1974), GD (Goss and Day, 1970).

3. Discussion

From the present observations we conclude that the two objects of peculiar morphology, G24.7+0.6 and G27.8+0.6, are new filled-center SNRs. As is the case for the majority of filled centers, the two objects have no clear boundaries, which makes the estimation of the dimensions, distances and ages somewhat ambiguous. Although the derived quantities are still not accurate, the two objects may provide promising clues to investigate the late stage of evolution of Crab-like SNRs.

The centrally peaked sources in both objects are suggestive of some energetic sources at the centers. X-ray observations are highly desirable for further studies. It is to be noted that the central region of G24.7+0.6 is not resolved in our observations and seems to be associated with a plateau- or jet-like extension toward the west. High angular resolution observations are also desirable.

Acknowledgement

The authors are indebted to the NRO staff for making the 10.2 GHz data available before publication. One of the authors (Y.S.) thanks the A. von Humboldt-Stiftung for the fellowship. He also thanks Prof. R. Wielebinski for the kind hospitality during the stay at MPIfR.

References

Altenhoff, W.J., Downes, D., Goad, L., Maxwell, A., Rinehart, R.: 1970, Astron. Astrophys. Suppl. 1, 519
Bignami, G.F., Hermsen, W.: 1983, Ann. Rev. Astron. Astrophys. 21, 67
Forman, W., Jones, C., Cominsky, L., Julien, P., Murray, S., Peters, G., Tananbaum, H., Giacconi, R.: 1978, Astrophys. J. Suppl. 38, 357
Goss, W.M., Day, G.A.: 1970, Australian J. Phys. Suppl. 13, 3
Green, A.J.: 1974, Astron. Astrophys. Suppl. 18, 267
Haslam, C.G.T., Salter, C.J., Stoffel, H., Wilson, W.E.: 1982, Astron. Astrophys. Suppl. 47, 1
Haynes, R.F., Caswell, J.L., Simons, L.W.J.: 1978, Australian J. Phys. Suppl. 45, 1
Maciel, W.G.: 1981, Astron. Astrophys. Suppl. 44, 123
Milne, D.K.: 1978, Astron. Astrophys. Suppl. 36, 227
Milne, D.K.: 1979, Australian J. Phys. 32, 83
Parker, R.A.R., Gull, T.R., Kirshner, R.P.: 1979, in "An Emission-line Survey of the Milky Way", NASA SP-434, US Government Printing Office, Washington, D.C.
Shaver, P.A., Goss, W.M.: 1970, Australian J. Phys. Suppl. 14, 77
Sofue, Y., Hirabayashi, H., Akabane, K., Inoue, M., Handa, K., Nakai, N.: 1983a, in "The Milky Way Galaxy", IAU Symp. 106, ed.: H. van Woerden, Reidel Publ. Co., Dordrecht, in press
Sofue, Y., Hirabayashi, H., Akabane, K., Inoue, M., Handa, K., Nakai, N.: 1983b, to appear in Publ. Astron. Soc. Japan
Weiler, K.W.: 1983, The Observatory, 1054th edition
Weiler, K.W., Panagia, N.: 1980, Astron. Astrophys. 90, 269
Wink, J.E., Altenhoff, W.J., Mezger, P.G.: 1982, Astron. Astrophys. 108, 227

© European Southern Observatory • Provided by the NASA Astrophysics Data System