

A Search for Compact Sources in Supernova Remnants

J. H. van Gorkom *National Radio Astronomy Observatory, PO Box 0,
Socorro, New Mexico 87801, USA*

R. D. Ekers *National Radio Astronomy Observatory, PO Box 0,
Socorro, New Mexico 87801, USA*

K. Johnston *Code 7134, Naval Research Laboratory, Washington DC 20375, USA*

V. Radhakrishnan *Raman Research Institute, Bangalore 560080*

C. J. Salter *National Radio Astronomy Observatory, Tucson,
Arizona 85721-0655, USA*

1. Introduction

Ryle *et al.* (1978) have suggested that there is a class of radio sources associated with supernova remnants, which are possibly the stellar remains of the outburst. Although many of the sources originally suggested by Ryle *et al.* are now known to be extragalactic, the class remains interesting since at least one of its members, SS 433, is definitely associated with the remnant W 50.

In addition, if an active pulsar within a shell type remnant is not detected because of statistical factors, one might still expect to see radio emission from a centrally condensed nebula produced by the pulsar, provided that the initial conditions of the pulsar are right (Srinivasan, Bhattacharya & Dwarkanath 1984). With the above considerations in mind we have performed a search for compact sources in supernova remnants. The search is biased toward the class of objects proposed by Ryle *et al.*: the observing wavelength was 6 cm, thus favouring flat spectrum objects, the search was insensitive to structures larger than 15 arcsec (Section 2)

In Section 2 we describe the sample, the observations and the data reduction. In Section 3 we discuss the results and give some comments on individual sources.

2. The sample, observations and data reduction

The sample consists of, 25 shell type remnants with diameter < 10 arcmin, 3 shell type remnants with diameter ≥ 10 arcmin, and 11 filled remnants (all the known objects in class P and C).

The observations were made with the Very Large Array (Napier & Thompson 1983) in May 1981 during reconfiguration from the 30 km array to the 10 km array. The search was done at 6 cm to optimize sensitivity and minimize confusion problems. As flux calibrator, 3C 286 was used assuming a flux density of 7.4 Jy at 4863 MHz. The total bandwidth was 6.25 MHz making the effective field of view as large as possible. Each source was observed for 10 minutes.

Spacings less than 1 km were not included in the maps. The resulting synthesized HPBW is about 2 arcsec, structures larger than 15 arcsec remain invisible. Initially, maps were made of 6.4 arcmin in size. If there was an indication of the presence of a source outside this field a map was made of 13 arcmin. The FWHM of the primary beam at 6 cm is 10 arcmin. In Table 1 we list the observed remnants and the rms noise in the maps. The noise varies from map to map because of the effect of the flux from the supernova remnants themselves. In Table 2 we list the detected compact sources.

Table 1. List of observed SNR.

Source	Right Ascension			Declination			rms noise (mJy)
	h	m	s	°	'	"	
G 5.3-01	17	58	25.7	-24	49	20.0	0.8
G 5.3 X	17	58	03.9	-25	04	32.0	0.6
G 11.2-0.4	18	08	15.0	-19	22	00.0	2.3
G 11.4-0.1	18	07	54.0	-19	04	30.0	0.7
G 12.0-0.1	18	09	18.3	-18	38	25.0	1.5
G 15.9+0.2	18	15	50.0	-15	02	00.0	0.5
G 18.8+0.3	18	20	56.0	-12	25	00.0	0.6
G 21.5-0.9	18	30	47.0	-10	36	13.6	1.5
G 23.6+0.3	18	30	23.3	- 8	14	39.0	0.6
G 27.3+0.0	18	38	22.0	- 5	06	00.0	0.7
G 29.7-0.2	18	43	46.7	- 3	02	21.0	1.5
G 31.9+0.0	18	46	49.2	- 0	59	36.0	1.0
G 32.8-0.1	18	48	52.0	- 0	05	00.0	0.6
G 33.7+0.0	18	49	60.0	0	31	30.0	0.5
G 34.7-0.4	18	53	36.0	1	19	00.0	0.5
G 35.6-0.4	18	55	27.0	2	04	60.0	0.9
G 39.2-0.3	19	01	38.0	5	22	30.0	0.6
G 41.1-0.3	19	04	50.6	7	00	00.0	1.0
G 43.3-0.2	19	08	38.0	9	01	54.0	2.0
G 49.2-0.5	19	20	45.0	14	11	00.0	3.0
CL4	20	48	47.4	31	16	10.9	1.0
G 74.9+1.2	20	14	14.0	37	03	16.0	3.4
G 93.3+6.9	20	51	27.0	55	09	28.4	0.5
G 93.6-0.2	21	27	13.1	50	23	37.0	1.1
G 130.7+3.1	02	55	30.0	64	34	60.0	0.6
G 184.6-5.8	05	31	30.0	21	59	00.0	2.0
G 340.4+0.4	16	42	56.0	-44	34	20.0	2.0
G 340.6+0.3	16	44	03.0	-44	30	20.0	2.5
G 341.9-0.3	16	51	18.0	-43	54	20.0	0.6
G 342.1+0.0	16	15	11.0	-43	20	18.0	0.5
G 344.7-0.1	17	18	60.0	-41	37	18.0	0.5
G 346.6-0.2	17	06	42.0	-40	06	20.0	1.5
G 348.5+0.1	17	10	50.0	-38	07	30.0	1.1
G 348.5 W	17	10	24.0	-38	07	30.0	0.7
G 348.7+0.3	17	11	12.0	-38	30	00.0	0.7
G 349.7+0.2	17	14	36.8	-37	23	09.0	1.9
G 350.1-0.3	17	17	42.0	-37	23	00.0	0.8
G 351.2+0.1	17	19	06.0	-36	10	00.0	0.6
G 352.7-0.1	17	24	20.0	-35	04	15.0	0.8
G 357.7-0.1	17	37	04.0	-30	56	45.0	1.6

Table 2. List of detected compact sources.

Source	Right Ascension (1950)			Declination			Flux (mJy)*
	h	m	s	°	'	"	
G 11.4-0.1	18	07	47.5	-19	06	00.5	6.3 (1)
G 12.0-0.1	18	08	57	-18	37	06	157 (25)
CL4	20	48	47.4	31	16	11.2	628 (10)
G 74.9+1.2	20	13	37.0	37	01	44.5	1300 (100)
G 93.6-0.2	21	27	13.7	50	24	04.1	33 (2)
(CTB 104A)							
G 349.6+0.2	17	14	47.0	-37	25	15.1	21 (3)

* The flux densities have been corrected for the effects of the primary beam; the number in brackets is the estimated error.

3. Discussion

3.1 Significance of Detections

In order to test the hypothesis that there is an excess number of point sources in these supernova fields we must first define a sample which is not biased with respect to finding these point sources. A suitable subsample includes the 25 known shell sources less than 10 arcmin in extent and the 11 filled remnants. Both these samples are complete and selected without bias with respect to any point sources in the field. For a comparison sample we have used a large survey of planetary nebula candidates (S. R. Pottasch & R. C. Bignell, private communication). Since this survey is also done with the VLA at the same frequency we can compare the detection rate as a function of peak flux without correction for the effect of the primary beam. In both surveys the effect of bandwidth smearing is small and will be ignored. The observations of Pottasch & Bignell cover 249 fields in the galactic plane and have higher sensitivity than our observations. The detected planetary nebulae have been removed in order to obtain counts for the background sources in the galactic plane. Table 3 is a cumulative distribution showing the comparison of the sources detected in this supernova search with that expected from the Pottasch & Bignell fields. It can be seen that there is a small excess of sources in the supernova fields in the highest flux densities and a deficiency at the lowest flux densities. The deficiency in the supernova fields at low flux densities is highly significant, but this is almost certainly caused by the differing resolution of the supernova search programme, and the Pottasch & Bignell survey which includes sources which are

Table 3. Distribution of detections.

S* (mJy)	Total no. in 36 fields		Excess
	SNR	Expected	
> 200	1	0	1
> 63	2	0.6	1.4
> 33	3	1.9	1.1
> 16	4	3.9	0.1
> 5.5	5	10	-5

* peak flux; no primary beam correction.

extended. More precise analysis of this point must await better statistics on the angular size distribution of background sources at this flux level. The small excess of sources in the higher flux density bins could correspond to a real detection of one or two objects associated with the remnants. However a Kolmogorov–Smirnov test gives a 30 per cent probability for having this difference occur by chance. Consequently we must conclude that we have no statistically convincing evidence for an association of point sources with either the small shell or the filled supernova remnants.

3.2 Notes on Individual Sources

Of the compact sources found in this search only the sources in G 11.4 – 0.1 and in CTB 104A have a position that falls within the supernova remnant. The distance toward both sources is unknown however and thus an association is uncertain.

CL4 is known to be extragalactic (Margon, Downes & Gunn 1981). The sources near G 12.0 – 0.1, G 74.9 + 1.2 and G 349.9 + 0.2 are all displaced from the supernova remnants by several arcmin and are therefore probably not associated with the remnants.

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References

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