RADIO CONTINUUM OBSERVATIONS OF SUPERNOVA REMNANTS AT 22 GHz

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Abstract: We describe in this work the results of high frequency radio continuum observations of 96 supernova remnants (SNRs) obtained at the Itapetinga Observatory at 22 GHz. We have detected 15 SNRs. Most of the strongest SNRs detected were previously classified in terms of their spectral and morphological properties as filled-center type (Crab-like). Some of the others have doubtful classifications.

Introduction: Our knowledge of SNRs is based primarily on radio observations. Their non-thermal spectra made them objects of intense investigation at low frequencies. There is, however, a lack of high frequency observations. To obtain information on their spectral indices at high frequencies we have made radio continuum observations at 22 GHz. This is the highest frequency survey of SNRs done up to the present time.

Observations: The SNRs were observed during November 1985 at 22 GHz using the 13.7 m radome-enclosed Itapetinga radio telescope. The transmission of the radome was 0.77 and the beamwidth 4.2 arcmin. The main beam efficiency was 63%. The receiver was a K-band mixer with a 1 GHz d.s.b. providing a system temperature of about 1000K. We operated the receiver in the total power mode. We used a rectangular horn sensitive to the horizontal E vector, i.e. we detected only one polarization component; the total intensity was obtained by assuming that the linear polarization of the sources was negligible. The use of a room-temperature load as a calibrator provided a value for the source temperature free from the effects of atmospheric attenuation (Ulich and Hass, 1976; Abraham et al., 1984). Virgo A was the absolute calibration source, with a flux density of 21.5 Jy at 22 GHz (Janssen et al., 1974).

The observations consisted of scans through each source in right ascension and declination. Each scan lasted 20 seconds; each observation consisted of the average of 30 scans (10 minute integration), preceded by a calibration. A baseline was fitted to the points at the beginning and at the end of the scan to eliminate the sky temperature. The amplitude of the scan was chosen according to the sources; 1° for compact sources and 2° for the extended ones. The minimum detectable surface brightness was about 3×10^{-21} Wm^{-2} Hz^{-1} sr^{-1}.

We observed all the SNRs from the catalogue by Green (1984) with declination $\delta<12°$, and angular sizes less than 2°.

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Results: Table I is the list of the 15 SNRs detected at 22 GHz with the Itapetinga radio telescope.

TABLE I

Galactic source number	Size (')	S_{22} (Jy)	Σ_{22} (W m^{-2} Hz^{-1} Sr^{-1})	Peak flux 22GHz (Jy)	Peak flux 5GHz (Jy)	Map* reference	$\alpha_{408,5}$	$\alpha_{5,22}$
G 0.0+0.0	3.0	11.5	0.19 E-18	55.0	116.0	4	-	-0.5
G11.2-0.3	4.2	3.9	0.33 E-19	2.5	5.9	1	-0.56	-0.58
G21.5-0.9	1.2	5.1	0.53 E-18	5.9	5.9	3	0.00	0.00
G31.9+0.0	4.8	4.2	0.27 E-19	1.3	3.5	3	-0.71	-0.67
G41.1-0.3	3.6	4.2	0.32 E-19	1.5	3.3	2	-0.49	-0.53
G43.3-0.2	4.2	8.0	0.68 E-19	7.8	11.2	1	-0.47	-0.24
G290.1-0.8	12.6	12.4	0.12 E-19	1.5	2.5	3	-0.55	-0.35
G291.1-0.1	10.0	5.5	0.82 E-20	2.2	3.8	1	-0.35	-0.37
G292.0+1.8	5.4	4.2	0.21 E-19	5.2	6.0	1	-0.41	-0.10
G298.5-0.3	3.7	1.8	0.19 E-19	1.0	1.6	1	-0.36	-0.32
G328.4+0.2	4.0	7.7	0.72 E-19	5.9	8.8	1	-0.24	-0.27
G337.0-0.1	7.6	4.0	0.10 E-19	2.6	5.5	1	-0.47	-0.50
G338.5+0.1	12.4	9.9	0.96 E-20	3.0	5.4	1	-0.33	-0.40
G349.7+0.2	1.7	4.4	0.23 E-18	4.6	8.6	2	-0.49	-0.42
G357.7-0.1	5.2	9.8	0.54 E-19	4.6	5.8	2	-0.43	-0.16

* 1 Goss and Shaver (1970)
2 Caswell, Clark and Crawford (1975)
3 Haynes, Caswell and Simons (1979)
4 Whiteoak,J.B. and Gardner,F.F. (1973)

Column 1 gives the galactic identification number for each SNR; column 2, the angular size (Θ) obtained from the catalogue of Clark and Caswell (1976); column 3, the integrated flux density S(22) extrapolated to 22 GHz from data at 0.408 GHz and 5 GHz (Clark and Caswell, 1976); column 4, the corresponding surface brightness at 22 GHz, calculated from the relation:

$$\Sigma(22) = 1.505 \times 10^{-19} \frac{S(22)}{\Theta^2} \ \mathrm{W\ m^{-2}\ Hz^{-1}\ Sr^{-1}}$$

Column 5 is the peak flux density equivalent to a point source at 22 GHz; column 6, the peak flux density at 5 GHz obtained from the

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references listed in column 7; column 8, the spectral index between 0.408 GHz and 5 GHz derived by Clark and Caswell (1976) and column 9 gives the spectral index calculated from the flux densities at 5 GHz and 22 GHz; both observations have the same angular resolution.

The SNRs G4.5 + 6.8, G34.7-0.4, G39.2 - 0.3, G348.5 + 0.1 & G348.7 + 0.3 were not detected at 22 GHz although they had an expected surface brightness higher than the minimum detectable value. For some of them the expected flux density was up to ten times higher than the upper limit obtained. These supernova remnants must present a break in the spectra somewhere between 5 GHz and 22 GHz.

Discussion: Three sources, G357.7 - 0.1, G292.0 + 1.8 and G43.3 - 0.2 show a spectral index derived from the 5 GHz data ($\alpha_{5,22}$) which is flatter than the index obtained from 0.408 GHz and 5 GHz ($\alpha_{408,5}$). This flattening may be due to a change in the spectral index across the supernova, since $\alpha_{5,22}$ was calculated at the center of the remnant (integrated over a 4' beam) and the $\alpha_{408,5}$ index was calculated from the integrated flux of the remnant. G43.3 - 0.2 is recognized as a composite type of SNR. The radio morphology is shell type while in X-ray it shows centrally peaked emission without limb-brightening. This region was mapped at 22 GHz (Sabalisck et al., 1987) and it is partially resolved with the 4.2' beam. The strong molecular cloud (G43.2 - 0.0) may be contributing to the emission. G357.7 - 0.1 and G292.0 + 1.8 are classified as filled-center SNRs, however X-ray observations of G292.0 + 1.8 do not show the normal morphology of a centrally localized source. The other SNR, G357.7 - 0.1 shows a peculiar morphology and was even classified as a new class of non-thermal object by Becker and Helfand (1985).

The sources G328.4 + 0.2, G349.7 + 0.2 and G21.5 - 0.9 are filled center SNRs. There is no reported detection of X-rays for G328.4 + 0.2. The SNR G349.7 + 0.2 has a spectral index consistent with the typical value of a shell-type SNR, but it does not have the ring-like appearance which is characteristic of an SNR with a prominent cavity in the central region.

The SNRs G11.2 - 0.3, G31.9 + 0.0 and G290.1 - 0.8 are weak sources at 22 GHz. They are classified as shell-type SNRs and their spectral indices are consistent with objects of this type. The source G290.1 - 0.8 shows a flattening in the spectral index $\alpha_{5,22}$.

There are no identifications of the sources G41.1 - 0.3, G298.5 - 0.3, G337.0 - 0.1 and G338.5 + 0.1 as either filled center or shell type. They are weak sources at 22 GHz. The SNR G337.0 - 0.1 and G338.5 + 0.1 are in the vicinity of strong HII regions and the determination of the peak flux is difficult because of the uncertainty in the determination of the base line.

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