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No Detectable Supernova Remnant near the Pulsar PSR 1930 + 22

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Abstract. No supernova remnant has been found near the third youngest pulsar PSR 1930+22 down to a –limiting brightness temperature of 1·4 K at 610 MHz. This is 6–8 times less than expected of a typical remnant whose age is that of the pulsar (3·6 0× 10^4 years).

Key words: pulsar — supernova remnant

1. Introduction

It is normally assumed that pulsars are formed in supernova explosions. However, so far supernova remnants have only been found associated with the two youngest pulsars PSR 0531+21 and PSR 0833—45. Their spin down ages are 10^3 and 1·1 × 10^4 years, respectively. Any remnants associated with older pulsars (age ≈ 10^6 yr) will probably be too weak to be detected because of their limited lifetime (≈ 10^5 years) and because the proper motion of the pulsars may carry them far from their birth place in 10^6 years.

An exception might be PSR 1930+22 (period 144 ms) which is the third youngest pulsar known at present and at whose age (p/2p=3·6 × 10^4 years) a typical supernova remnant should be detectable.

2. Observations

We have thus observed a field (FWHB=82′) centered on the pulsar position (equinox 1950·0, R.A. 19^h 30^m 12^s·5 ± 0^s·3, dec 22° 15′ 19″ ± 4″, Gullahorn and Rankin 1978). The Westerbork synthesis telescope was used at a frequency of 610 MHz. A full 12^h synthesis was made using the 4+10 antenna array *i.e.* 40 interferometers. The resulting synthesized beam dimensions are (R.A. × dec) 52·5″ × 155·5″. The

*Present address: I. R.A.M., B.P. 391, F 38017 Grenoble, France shortest spacing was 36 m (73 wavelengths) so that the maximum fringe spacing was 47′ are. Thus extended features much greater than 30′ in diameter are significantly resolved out. A 1° diameter source would not be detectable. The first grating ring was at 47′ (R.A.) × 124′ (dec).

3. Results

Previous low resolution radio frequency surveys have detected structure in the neighbourhood of PSR 1930+22. Wendker (1968) reported a non-thermal source (number 26 in his list) and the map of Terzian (1965) shows extended structure to the north (G 57·6+1·6 and G 57·6+1·9) and south of the pulsar.

The present observations show that this emission can be accounted for by a grouping of point sources (number 9, 11 and 12 of Table 1) and one extended triple source (S=l·6 Jy) at R.A. (1950) 19^h 32^m $55^S \pm 2^S$, dec (1950) 21° 50′ ±0′·5 which may be a head-tail source. When all these sources have been subtracted (see Table 1) no detec-

Table 1. Point sources found in the field of PSR 1930+22 at 610 MHz.

W.S.R.T. No.		R.A. (1950.0)				dec (1950.0)				S (mJy)
38	W1	19^h	26^m	$48^s{\cdot}8$	$\pm\, 0^s{\cdot}4$	22°	38′	23″	± 15″	67 ± 28
	W2	19	27	41.9	± 0·4	21	56	42	± 20	36 ± 10
	W3	19	27	53·7	± 0·2	22	52	07	± 5	180 ± 20
	W4	19	28	04·9	± 0·4	22	17	17	± 15	25 ± 4
	W5	19	28	11·3	± 0·1	22	39	05	± 5	112 ± 10
	W6	19	28	25·3	± 0·3	22	45	22	± 20	35 ± 6
	W7	19	28	58·3	± 0·2	22	54	54	± 6	115 ± 20
	W8	19	28	58·7	± 0·2	21	58	28	± 5	57 ± 10
	W9	19	29	06·7	± 0·1	22	25	42	± 2	252 ± 15
	W10	19	29	07·3	± 0·5	21	36	43	± 20	39 ± 6
	W11	19	29	08·1	± 0·1	22	12	56	± 2	150 ± 10
	W12	19	29	16.5	± 0·1	22	37	07	± 2	430 ± 20
	W13	19	29	40·2	± 0·3	22	27	19	± 15	43 ± 6
	W14	19	30	09·1	± 0·2	21	48	04	± 10	40 ± 7
	W15	19	30	19·1	± 0·4	22	12	28	± 15	18 ± 5
	W16	19	30	26·8	± 0·2	22	37	54	± 6	62 ± 7
	W17	19	30	30·7	± 0·3	21	51	16	± 20	33 ± 6
	W18	19	30	58·3	± 0·1	22	42	36	± 5	100 ± 8
	W19	19	31	11·5	± 0·2	22	34	25	± 6	64 ± 6
	W20	19	31	21·7	± 0·1	21	31	09	± 2	330 ± 50
	W21	19	31	29·1	± 0·2	22	19	57	± 8	39 ± 6
	W22	19	31	32·2	± 0·2	22	29	12	± 13	31 ± 7
	W23	19	31	38·4	± 0·2	22	42	59	± 10	44 ± 10
	W24	19	31	41·0	± 0·6	22	20	19	± 25	27 ± 10
	W25	19	31	53·0	± 0·5	21	50	52	± 20	38 ± 10
	W26	19	32	06·2	± 0·2	21	54	37	± 7	74 ± 8
	W27	19	32	13·4	± 0·3	21	40	34	± 12	49 ± 15
	W28	19	32	23·7	± 0·3	21	27	01	± 12	85 ± 25
	W29	19	32	29·9	± 0·2	22	36	32	± 8	65 ± 10
	W30	19	33	03·7	± 0·2	22	42	18	± 8	87 ± 13
	W31	19	33	36·1	± 0·3	22	57	02	± 12	130 ± 35
	W32	19	33	55·1	± 0·2	21	42	20	± 9	170 ± 25
	W33	19	34	21·1	± 0·2	22	39	40	± 8	240 ± 30

table extended source $\leqslant 1^{o}$ in diameter remains. The limiting brightness temperature corresponds to an R.M.S. of σ=1·4 K (2·8 mJy per beam). This limit is determined by ionospheric phase errors. Furthermore, no detectable point source coincides with the pulsar. So we must conclude that the flux of the integrated pulses was below the detection threshold at the time of observation. The expected 610 MHz average flux density is 7·2 mJy $\approx$ 2·6 σ. This implies either a steep spectrum or that the mean flux density is time variable and was low by a factor 2–3 during our observations. The nearest point source (No. 15) is 3′·2 from the pulsar position. None of the sources in Table 1 is a 4C source.

4. Discussion

No extended source—either shell or filled ' Plerion ' type has been detected down to the limit set by the rms noise of 2·8 mJy per beam or 1·4 K brightness temperature.

It only remains to estimate the expected remnant brightness. The most complete semi-empirical theory of shell type remnant evolution is that of Caswell and Lerche (1979). This takes into account the effect of the changing interstellar medium as a function of z, the distance from the galactic plane. As principal input we use the remnant age assumed to be 3·6 × 10^4 years from the rate of slow down of the pulsar. To enable a z correction to be made we assume a distance of 8·1 kpc—from the pulsar dispersion measure (Taylor and Manchester 1975). From this follows z=210 pc. The equation (8) of Caswell and Lerche (1979) then yields a shell diameter of 77 pc which corresponds to an angular diameter of 33′. The predicted average surface brightness, from equation (9) is then 12 K at 400 MHz. If a spectral index (flux density) of —0·5 is assumed this corresponds to 4·1 K at 610 MHz. For a typical shell source the peak brightness will be higher than the average by about 2·0 *i.e.* 8·2 K. So this calculation would predict a shell detection with a peak signal to rms noise ratio of about six.

This estimate is uncertain due to the intrinsic scatter of the age-brightness relation and to uncertainties in the z distance correction. These uncertainties might easily amount to a factor three.

The evolution of the filled remnants is less well understood but recently Weiler and Panagia (1980) have given analagous formulae to those for shell remnants. They are based on observations of the Crab Nebula, 3C58 and Vela X which they argue is also a filled remnant. They assume adiabatic expansion up to an age $\gtrsim 3 \times 10^4$ yr, and that all such sources have had a similar energy input and expansion velocity. Their formulae (45) and (47) yield a 1 GHz flux density of 2·4 Jy and an angular diameter of 18′. If we assume a spectral index (flux density) of —0·25 this corresponds to an average brightness temperature of 11 K at 610 MHz. This is also well above our rms limit (*i.e.* eight times) for the peak brightness temperature. However, this may be an overestimate for several reasons. The calculation neglects any influence of the height of the remnant above the galactic plane and also assumes that the observations were made below the cut-off frequency in the spectrum. However, equations (42) and (43) of Weiler and Panagia (1980) predict a critical frequency of 16 GHz, which is well above our observing frequency of 0·61 GHz. Finally the basic assumption that PSR 1930+22 had an energy and an expansion velocity similar to those of the Crab Nebula, 3C58 and Vela X may be unjustified.

The failure to detect any remnant associated with PSR 1930+22, either shell or filled type, is unexpected. Although this may be just the result of an incorrect estimate of the expected remnant brightness there are several possible alternative explanations. According to the suggestion of Radhakrishnan and Srinivasan (1980) no shell remnant is to be expected around a pulsar; however, the lack of any filled remnant is unexpected since according to their theory all young pulsars should make filled remnants. This may indicate that the theory of Weiler and Panagia (1980) over-estimates the lifetime of older remnants at high latitudes—for example their assumption of adiabatic expansion may be in error. Furthermore, their intrinsic properties (energy, expansion velocity) may show a large scatter. For these reasons it may be of interest to search again with higher sensitivity.

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