A new possible association between a Pulsar and a Galactic Supernova Remnant

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Summary

We present evidence for a physical association between the PSR 1922+20 and the galactic radiosource G 55.0+2.3. Recent observations at 408 MHz and 1415 MHz support the hypothesis that G 55.0+2.3 is a Galactic Supernova Remnant.

Key Words: pulsars - Supernova remnants

1. Introduction

A close relationship between pulsars (PSR) and supernova remnants (SNR) is commonly accepted, but the found number of direct associations is indeed very small, in spite of the fact that the number of both detected pulsars and known SNR's is more than a hundred. Only the Crab association is certain; the Vela association is very probable, and the less than ten remaining associations are all questionable (see, for example, Schönhardt, 1974; Weiler et al., 1974; Goss et al., 1977; Manchester and Taylor, 1977; Smith, 1977).

The absence of a one-to-one correspondence between pulsars and SNR's is generally explained by the much longer lifetime of pulsars in respect to that of SNR's (which explains the lack of SNR's around known pulsars) and by the sensitivity limits of pulsar searches and beaming effect of pulsars (which explains the lack of pulsars inside known SNR's).

Along these lines, we believe it interesting to report on a new association namely that between the PSR 1922+20 (Hulse and Taylor, 1975) and the possible SNR G 55.0+2.3 (Fanti et al., 1979b).

2. The data

The pulsar's main parameters, derived from Taylor and Manchester (1975) and Manchester and Taylor (1977) are:

R.A. $19^h22^m30^s\pm20^s$	DM = 215 ± 20 cm^{-3} pc
Dec. $20°30'\pm5'$	d = 8400 pc
P = $0.237\,790\pm0.000001$ sec^{-1}	S_{400} = 4 mJy
W_s = 20 msec	

The surrounding area has been observed in the past by several authors at frequencies ranging from 178 MHz and 5000 MHz (Pilkington and Scott, 1965; Shimmins and Day, 1968; Felli and Churchwell, 1972; Fanti et al., 1974; Kazès et al., 1975).

Two radio components, separated by 11' in declination and 1' in right ascension, are present in the higher frequency observations, but the poor resolution at the lowest frequencies had previously prevented an accurate determination of their radio spectra.

Recently this region has been observed with high resolution at 1415 MHz (with the Westerbork Synthesis Radio Telescope, Fanti et al., 1979a) and at 408 MHZ (with the Bologna Cross, Fanti et al., 1979b) as part of a systematic search for galactic radiosources selected from the BG survey of the galactic plane (Fanti et al., 1974).

The northern component, for which 5 GHz Westerbork synthesis observations are also available (Felli et al., 1978) has a flat thermal spectrum and is clearly associated with the HII region S83. Data pertaining to this source are discussed in more detail in a forthcoming paper (Felli, 1979).

In fig. 1 the 1415 MHz map of the southern component (G 55.0+2.3) is displayed. The relative 408 and 1415 MHz data are given in table 1. The source has a slightly elongated structure which may be considered as the brightest part of a shell; such incomplete shells are not uncommon in SNR's. Any possible weak disk structure or missing parts of the shell (that could possibly be lost in the interferometric observations) are expected to contribute to less than 20% of the total flux density, as proved by the good agreement between the present results and the single dish measurements made at the same frequency (Shimmins and Day, 1968).

The spectrum shown in fig. 2 can be fitted with a straight line with a spectral index $\alpha = -0.65\pm0.05$ (where $S_\nu \propto \nu^\alpha$) which is well within the range of possible values for SNR's (Clark and Caswell, 1976).

Note that this is also the source 12W32 of the field studied by Goss et al. (1977). The 610 MHz flux density quoted there, $S_{610} = 0.550\pm0.065$ Jy, does not agree with the other values shown in fig. 2. However, Goss et al. (1977) assumed the source to be point-like. To account for the diameter measured at 21 cm., the flux has to be increased by a factor of about 3 (Goss, private communication). The corrected flux density now agrees quite well with the derived spectrum.

Linear polarization at 1415 MHz is below 5σ of the noise everywhere in the source, which corresponds to less than 3% in the source peak and less than 20% in the weaker plateau. This is not inconsistent with the hypothesis of an SNR since SNR's are in general very weakly polarized at 1415 MHz.

In the Palomar Sky Survey Prints the region around G 55.0+2.3 appears obscured by dust and no nebular or filamentary structure is visible.

No X-ray source is present in the IV UHURU catalogue in the direction of G 55.0+2.3 (Forman et al., 1978) stronger than 4.8 x 10^{-11} erg/cm sec^{-1} in the range

2 ÷ 10 KeV.

3. Discussion

In the SNR hypothesis the distance of G 55.0+2.3 can be derived by using the surface brightness - linear diameter (Σ - D) relation for galactic SNR's. Determining the source diameter is not simple in our case, but it seems reasonable to assume as an angular size that of the ring which fits the arc-shaped structure, i.e. 4'-6'. Following Sabbadin (1977) we have chosen the Σ- D relation of Ilovaisky and Lequeux (1972). The surface brightness at 1000 MHz is $(4.4 < \Sigma_{1000} < 10)\ 10^{-21}$ W m^{-2} $Hz^{-1} sr^{-1}$, which corresponds to a linear diameter of 25-30 pc and a distance of 17-21 Kpc.

The PSR distance quoted in section 2 assumes the commonly accepted value of 0.03 cm^{-3} for the electron density, corrected for the distance of the object from the galactic plane. However, the 21 cm line absorption measures in front of pulsars by Gomèz-Gonzalez and Guèlin,(1974) suggest that in this region of the Galaxy the average electron density might be lower by a factor of as large as two. This implies that 8.4 Kpc must be considered as a lower limit for the PSR distance. Therefore, it is possible that the two objects are at the same distance.

The main argument supporting the association between the PSR 1922+20 and the SNR G 55.0+2.3 is the very good agreement between the projected positions of the radiosource and that of the pulsar. It is therefore important to evaluate the number of expected chance coincidences. This PSR belongs to a region of the Galaxy which has been fully surveyed for pulsars with the Arecibo radiotelescope (Hulse and Taylor, 1975) down to a flux density of 1.5 mJy. The average pulsar's found density is about 0.3 per square degree. In the same region Fanti et al. (1979a) observed six fields each centered on a galactic radiosource.

To compute the number of expected random coincidences, we have associated the central radiosource in each field with an area equal to the quoted error box for pulsars (i.e. $\frac{\pi}{4}$ x 10' x 10') if the radiosource diameter θ is less than 10', or with an area equal to $\frac{\pi}{4}\theta^2$ if θ is greater than or equal to 10'. In this way the total area in which we may expect to find pulsars by chance is about 1000 $arcmin^2$. Taking into account the quoted pulsar's density, we estimate that one should have to examine an area 12 times larger in order to find one pulsar coinciding with an extended radiosource. Therefore, we conclude that the proposed association is likely to be real.

Finally it is interesting to compare this association to that of the PSR 0833-45 and the Vela SNR, the brightest part of which has an incomplete shell structure like G 55.0+2.3 (see, e.g. Milne, 1968). If we move the Vela to a distance of 15 Kpc, we obtain the following parameters:

S_{408} (SNR) = 2 Jy
S_{400} (PSR) = 2.8 mJy
θ (SNR) = 6 arcmin

These values are very close to those found for the PSR 1922+20 and G 55.0+2.3.

Detection of linear polarization at high frequencies to confirm the supernova remnant interpretation for the continuum radiosource, plus the narrowing down of the uncertainty in the position of the PSR 1922+20 and derivation of $\dot{P}$ (and hence the age) in order to confirm the suggested association would be clearly of extreme interest at this point.

Table 1. SNR parameters

Obs. Freq.	R.A.	Dec.	Flux (Jy)
408 MHz	$19^h22^m27^s.4 \pm 0^s.5$	20°29'13"±12"	2.0±0.1
1415 MHz	$19^h22^m26^s.6^\dagger \pm 0^s.2$	20°29'24"†±8"	0.88±0.04

†Peak position

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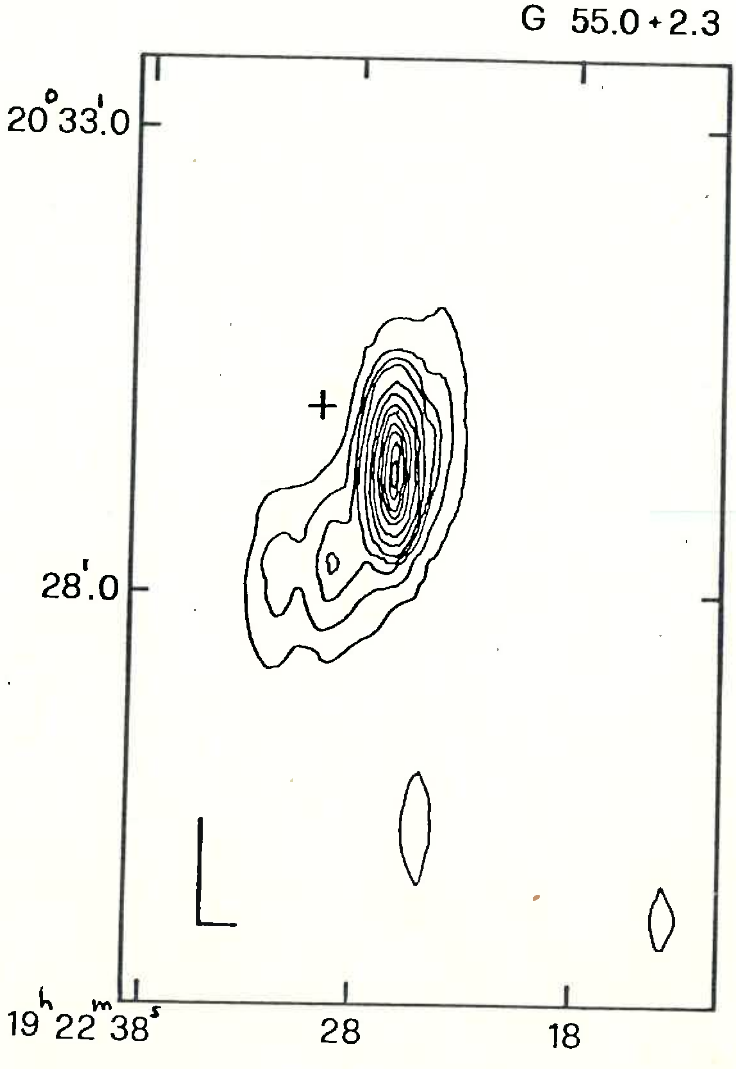
Figure Captions

Figure 1 - 1415 MHz map of SNR G 55.0+2.3. Contours are at 12, 36, 60, 84 and in steps of 48 mJy per beam area up to 485 mJy. The half power beam width is given in the lower left corner. The cross marks the PSR position.

Figure 2 - Radio spectrum of SNR G 55.0+2.3. References are: 4C, Pilkington and Scott (1965); B, Fanti et al. (1979b); WSRT, Fanti et al. (1979a); PKS, Shimmins and Day (1967).


G 55.0+2.3
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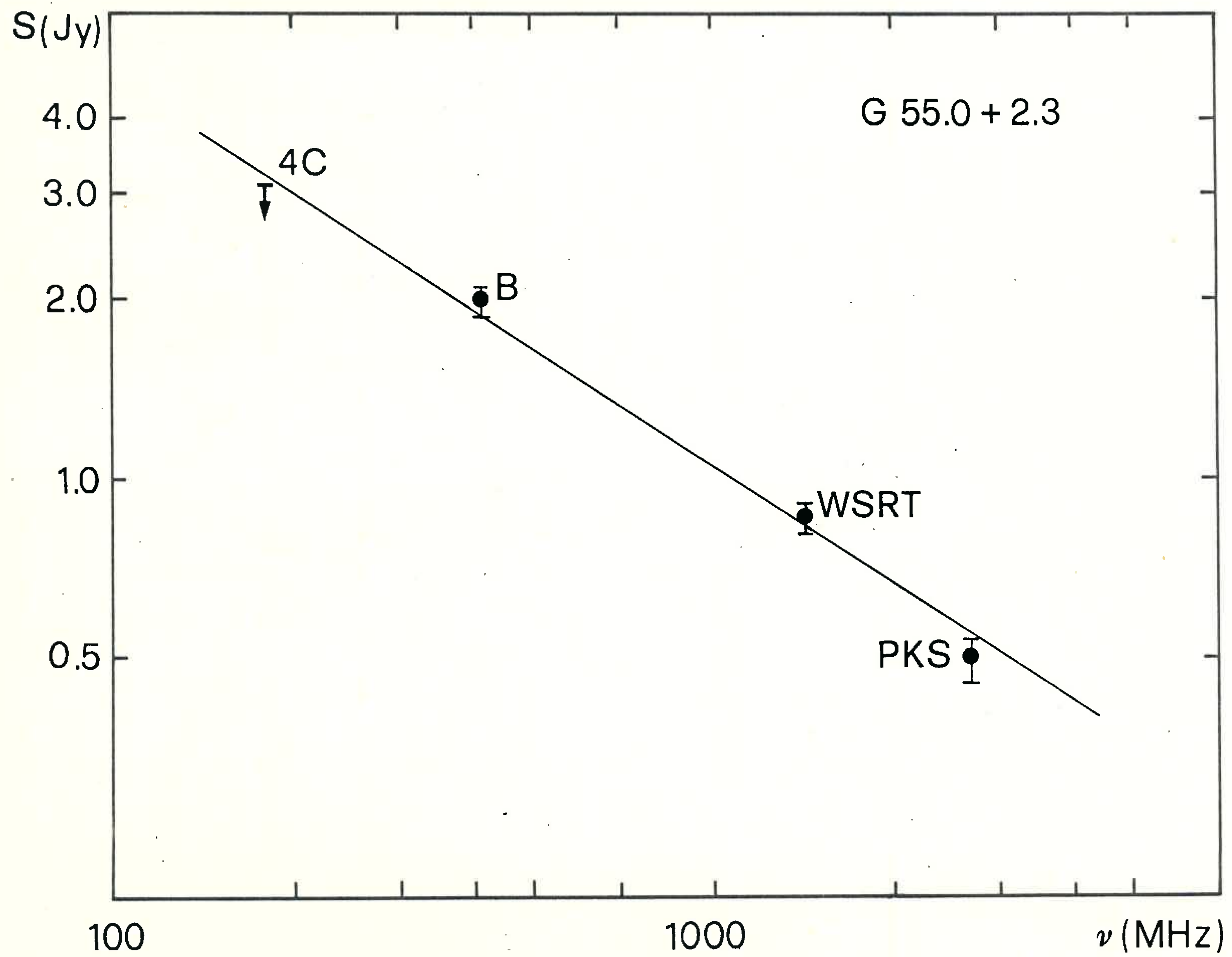
28'.0
19h22m38s
28
18


S(Jy)
4.0
3.0
2.0
1.0
0.5
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ν (MHz)
G 55.0 + 2.3
4C
B
WSRT
PKS