RADIO OBSERVATIONS OF THE SUPERNOVA REMNANT CTB109 (G109.2-1.0)

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The supernova remnant G109.2-1.0 was discovered at λ49cm by Hughes, Harten and van den Bergh (1981) during a survey of part of the Galactic plane. The northern part of it had been detected previously as the non-thermal radio source CTB109 by Wilson and Bolton (1960), and by Raghava Roa et al (1965), but the extended low brightness of the source and its close proximity to the very strong source Cas A, from which it is separated by ~5′, excluded it from any further detailed study. It was discovered independently at X-ray wavelengths by Gregory and Fahlman (1980). Recently, the original WSRT radio observations have been found to be in error as a result of applying the CLEAN procedure to an extended source, and since the object appears to contain an X-ray pulsar (Fahlman and Gregory, 1981), it was decided to carry out a more detailed and extensive mapping of the remnant using different antenna arrays and frequencies. This paper describes the results obtained at λ49cm and λ21cm using the Westerbork Synthesis Radio Telescope (WSRT), at λ21cm using the aperture synthesis array at the Dominion Radio Astrophysical Observatory (DRAO) and at λ4.6cm using the 46m telescope of the Algonquin Radio Observatory (ARO). Thus, data has been obtained from three completely independent telescopes, using completely independent data reduction systems. Of importance is the fact that not only have wavelengths been chosen such that the larger dimensions of the array give a reasonable angular resolution of <1′, but also that the smallest spacing enables the larger angular dimensions of the remnant to be observed. This paper presents some of the results and a brief interpretation.

Figure 1 shows the revised map of the SNR, convolved to a beamwidth of 100", using the WSRT at λ49cm. The map shows a half-shell of emissions with a number of radio condensations. There is very clear indication of a "hole" in the emission, offset from the centre of the remnant. Also indicated are the positions of two compact sources, and the position of the X-ray pulsar (Fahlman and Gregory 1981). It is clear that the pulsar is not coincident with one of the compact sources, or with the peak of the nearby region of extended emission. The overall

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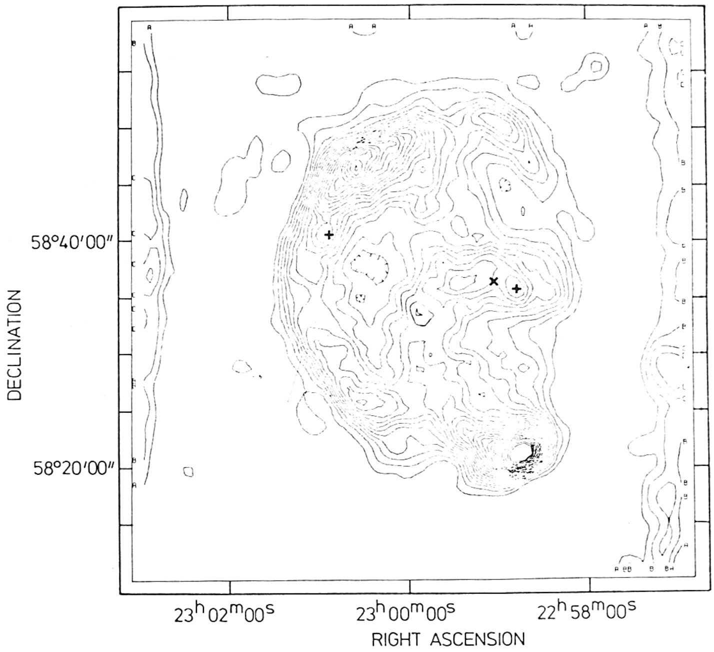

Figure 1. WSRT λ49cm map of CTB109, convolved to a resolution of 100". Marked by a + are the positions of two compact sources; X marks the position of the X-ray pulsar.

dimensions of the SNR are ~36′ and ~26′ in the N-S and E-W directions, respectively.

In an attempt to detect possible radio emission from the pulsar, observations were made with the WSRT at λ21cm. In this case, the minimum antenna spacing of 36m (171λ) did not receive the wide angle components associated with the SNR, but enabled the detection of sources as small as 20" with a flux density limit of 0.5 mJy. It was quite clear that though there were about 13 compact sources observed, corresponding to the number of extra-galactic sources expected, no radio source at this level was detected within 2′ of the position of the pulsar. Thus, we see no radio evidence for any obvious small diameter remnant from the supernova explosion.

In Figure 2 we show a comparison of the WSRT λ49cm map with resolution in the E-W direction of 56" and the DRAO map at λ21cm with resolution of 60". The minimum spacings are 36m (73λ) and 17.14m (82λ) respectively. Contours are drawn in units of 1, 3, 5, 7....... in each case, the unit values being 5 mJy for the WSRT map and 4 mJy for the DRAO map. As can be seen, the remarkable similarity between the two maps indicates no detectable variation in the spectral index of the radiation across the map, and when account is taken of the difference in

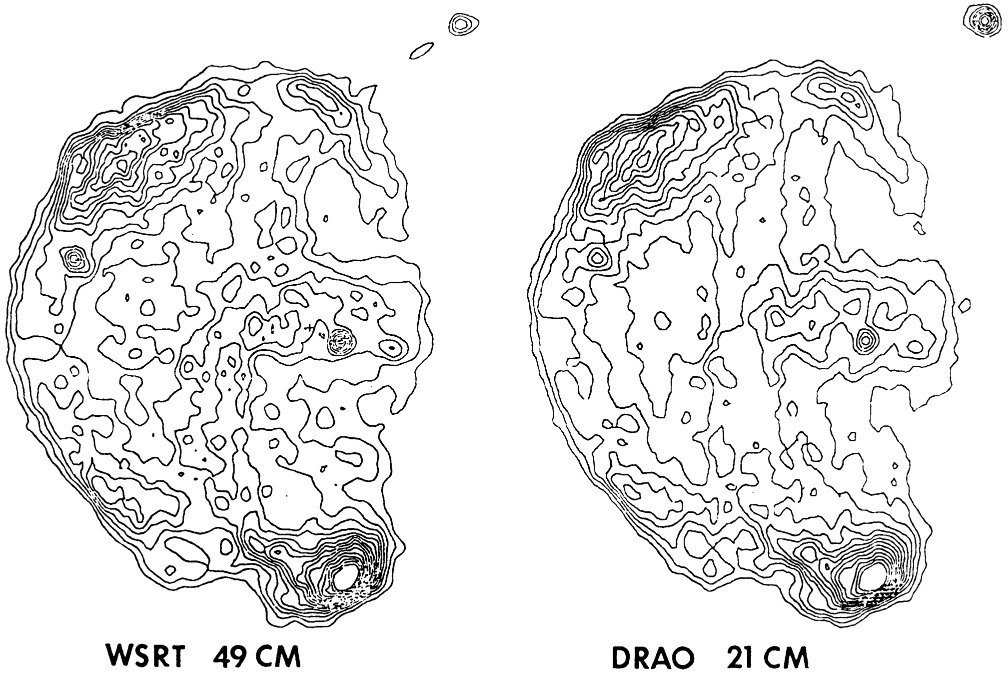

Figure 2. WSRT λ49cm map of CTB109, resolution of 56", and DRAO λ21cm map, resolution 60". Contour units in each case are 1,3,5,7,..... The unit for the WSRT map is 5 mJy and that for the DRAO map is 4 mJy.

angular resolution, leads to a uniform spectral index over the maps of $\alpha = 0.45$ where $S \propto \nu^{-\alpha}$. Such a value for α is typical for well established SNR's, and shows no evidence for any component of radiation that could be associated with the pulsar.

Finally, the DRAO λ21cm map was convolved to the beamwidth of 4.8′, equal to the resolution of the ARO map at λ4.6cm. A comparison showed that at this resolution, again no change in spectral index was apparent over the source. The total flux of 13 Jy at λ21cm and 6.6 Jy at λ4.6cm gives a value of $\alpha = 0.45$ between these two wavelengths, similar to the value obtained above between λ21cm and λ49cm.

From the above data we have derived a number of properties of the SNR. Our previous distance of 4.3 - 5.2 kpc, obtained using the Σ-D relationship, has been revised to 5 - 6 kpc in the light of the new flux densities. Since the Perseus arm bifurcates in this direction with one part being at an estimated distance of 5 kpc, we would place the remnant in or close to this outer arm. However, the uncertainties involved in the use of the Σ-D method, as discussed at this Symposium, do not allow a more accurate distance to be derived. Noting that the optical filaments as seen by Hughes, Harten and van den Bergh (1981) have not moved by more than 1" in the 27 years since the PSS plates were taken, we obtain the maximum transverse speed of these filaments as

<900 km/sec, though it is not clear how this speed is related to the expansion speed of the SNR.

With regards to the band of X-ray emission in an approximately E-W direction across the centre of the radio SNR, it is clear that this does not have a counterpart in the radio emission and in fact passes through a radio "hole". In addition, there is no apparent change in the radio spectrum that we can associate with it. The angular extension of the apparent jet is ~16′ or 23 pc, so that if it is the result of electrons being emitted from the pulsar at the speed of light, it would take them about 100 years to travel its length. This puts rather stringent limits on the mechanism for producing the jet; for instance, it is difficult to build models of synchrotron emission at X-ray wavelengths when the electron decay time is <100 years. More likely, the X-ray emission is due to bremsstrahlung from a hot plasma situated behind the expanding shock front. Models are at present being developed and will be published at a later date.

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DISCUSSION

BLAIR: Bob Kirshner and I obtained spectra of one of the outer optical filaments in this object. Because of the faintness of the filament, the quality of the spectrum is not high, but it does indicate a large amount of reddening and an otherwise normal SNR spectrum (i.e. strong [SII] and [NII] in comparison to Hα).

WEILER: I think that you have shown very strong evidence for removing CTB 109 as a possible member of the Class-C combination SNR's. I don't believe any doubt remains.