# VLA OBSERVATIONS OF SGR A

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Summary:

The radio source Sgr A has been mapped with the Very Large Array (VLA) at 6 and 20 cm with an angular resolution of 5" × 8" arc. In agreement with the earlier "WORST" map, the non-thermal source Sgr A East shows a shell structure, while the thermal source Sgr A West shows a spiral-like morphology. We suggest that Sgr A East is a supernova remnant (SNR) near the galactic centre. Its surface brightness is the third largest in our galaxy after Cas A and the Crab Nebula. The diameter is 9 pc and the source fits the surface-brightness diameter relationship of Clark and Caswell (1976) if a distance of 10 kpc is assumed.

## I. INTRODUCTION

Since the discovery of Sgr A in the early 1950's, the nature of this source has been puzzling. The identification with the centre of the galaxy now seems certain, based on the associations established by IR observations. Detailed, high resolution observations of the radio structure have been difficult from the northern hemisphere because of the declination of −29°. The multiple nature of the radio source became evident in the early 1970's (e.g. Downes and Martin, 1972; Ekers and Lynden-Bell, 1972). The eastern part of Sgr A (Sgr A East) has a non-thermal spectrum (Dulk and Slee, 1974), while Sgr A West is predominantly a thermal source which is associated with the IR sources and the radio recombination lines (e.g. Bregman and Schwarz, 1982). The compact VLBI radio source discovered by Balick and Brown (1974) is located within Sgr A West. It has usually been assumed that this source is the galactic nucleus.

Jones (1974), Gopal-Krishna and Swarup (1976) and Ekers, Goss, Schwarz, Downes and Rogstad (1975) have all discussed the possibility that Sgr A East is a SNR. Given the relative low luminosity of Sgr A

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East, it was recognized that this source was not related to the active sources in the nuclei of galaxies. As an example, Sgr A East would have a 6 cm flux density of only about 1 mJy at a distance of 3 Mpc. In addition, the measured brightness of Sgr A East is similiar to galactic SNR.

Until the present, the best available map of the ~ 5' arc near Sgr A was the "WORST" (Westerbork, Owens Valley Radio Synthesis Telescope) map at 6 cm published by Ekers et al.(1975). The synthesized beam was 6 × 34" (α × δ). There was some evidence for shell structure in Sgr A East. Gopal-Krishna and Swarup (1976) have suggested the existence of steeper spectrum portions of Sgr A East which form part of a SNR shell.

In order to elucidate the structure of the possible SNR, the VLA was used in 1981-1982 to map the Sgr A region at 2, 6 and 20 cm. The 6 and 20 cm observations used scaled arrays (C and B, respectively) so the angular resolutions are nearly identical at the two wavelengths. The details of these observations are presented by Ekers, van Gorkom, Schwarz and Goss (1983); in particular the thermal, spiral component of Sgr A West is discussed. In this paper, we will discuss the parameters of Sgr A East based on the 6 and 20 cm observations. The H76α observations (14.7 GHz) with the VLA are discussed by Van Gorkom, Schwarz and Bregman (in preparation).

## II. RESULTS

In the figure we show the 20 cm map with a resolution of 5" × 8" (α × δ); the galactic plane is indicated. By comparing the 6 and 20 cm maps the spectral index distribution can be derived and this is shown as grey scale shading. The total flux densities of Sgr A East in the 6 and 20 cm maps are 31 and 77 Jy, respectively. The expected values are 90 and 170 Jy (Dulk and Slee, 1974). This difference is due to the fact that our observations are insensitive to angular scales $\gtrsim$ 3'arc; thus the larger scale structure underlying the Sgr A complex is not included in the spectral index estimate. This can cause an offset in the value of the spectral index, especially at the lower brightness levels. This could explain the differences between our value of -0.76 for the average spectral index across Sgr A East and the value of -0.47 deduced from lower resolution observations (Dulk and Slee, 1974). Gopal-Krishna and Swarup (1976) have, however, suggested that the peaks in Sgr A East have a spectral index of -0.7, in better agreement with our data.

The shell structure in the non-thermal source Sgr A East is now obvious for the first time. The projected distance of the centroid of Sgr A East from Sgr A West is ~ 50"arc. The major and minor axes are 3.6 and 2.8 arc with an orientation parallel to the galactic plane. These correspond to 10.5 and 8 pc if the distance is 10 kpc. At this distance, Sgr A East is in reasonable agreement with the Σ-D (surface brightness - diameter relationship) for SNR proposal by Clark and Caswell (1976) and by Milne (1979). As an example the Clark and Caswell relation would imply a distance of ~ 7 kpc. If the Σ-D relation proposed by Mills (this conference) is used, a much smaller distance is derived. Based on these considerations, we conclude that Sgr A East is a bright galactic SNR. This SNR is the third brightest SNR in our galaxy after Cas A and the Crab.

## III DISCUSSION

The relative locations of Sgr A West and Sgr A East with respect to the strong 40 km $s^{-1}$ molecular cloud is a well-known problem (see Güsten and Downes, 1980). From the figure it is clear that the non-thermal shell of Sgr A East extends to the position of Sgr A West. This structure has important consequences for the interpretation of the 40 km $s^{-1}$ absorption. Interpretations which place this cloud between Sgr A East and West are unlikely. Although the apparent optical depth in the direction of Sgr A West would decrease, there would still be some absorption occurring in the continuum radiation from the portion of the superposed shell structure. Our observations make it clear that the 40 km $s^{-1}$ cloud must have a boundary which causes the large increase in optical depth from Sgr A West to East. Thus, the structure of this absorption line provides no information on the relative locations along the line of sight.

One of the major questions concerning Sgr A East is its location. As discussed in the previous paragraph, there is now no compelling evidence to suggest that the SNR is several hundred pc behind Sgr A West (Güsten and Downes, 1980). Three obvious possibilities remain for the relative location of the SNR and Sgr A West (the galactic centre):

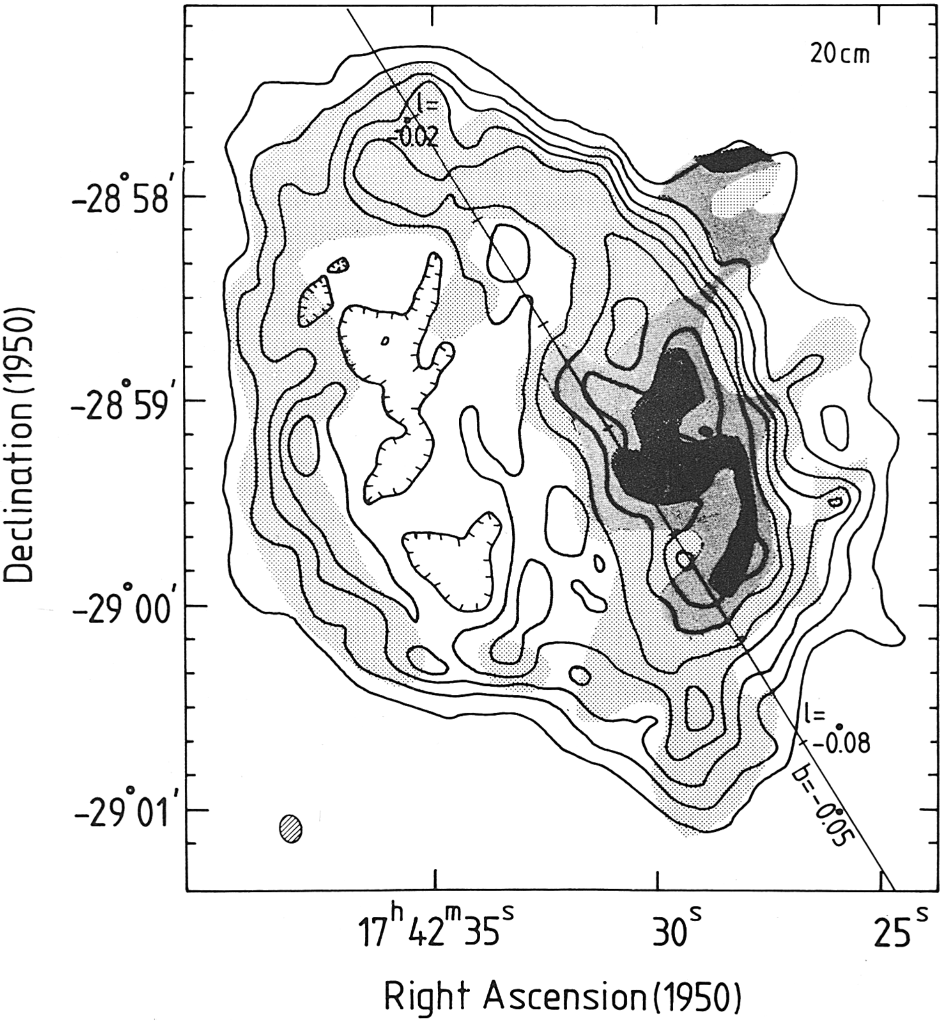
(1) a chance coincidence along the line of sight,

(2) a physical association of the two, and

(3) a location for the SNR within 200-300 pc of the centre inside the nuclear bulge.

The coincidence on the sky of such an unusual SNR is a strong qualitative argument against possibility (1). The choice between (2) and (3) is difficult without further knowledge. The present observations make it clear that the western side of the shell of Sgr A East is coincident with the Sgr A West source and that the southern thermal spiral arm merges smoothly into the shell. Is this evidence for a physical interaction or is it just projection along the line of sight? If a physical interaction with the galactic centre is occurring, the Sgr A West diffuse non-thermal source (see Ekers et al., 1983) can be considered as an enhancement in the SNR shell.

If the Sgr A East SNR is at the galactic centre, then the probability of a SNR in a small volume of the galactic disk becomes a relevant consideration. If the varions $\Sigma$-t or $\Sigma$-D relations are used (e.g. Caswell and Lerche, 1979; Srinivasan, private communication; Mills, this conference), the derived ages are in the range 140 to 440 years. These ages are only meaningful if the energy in the explosion and the surrounding density in the interstellar medium near Sgr A East are comparable with the conditions for the "average" galactic SNR. The implications of these young ages are discussed by S. van den Bergh in the remarks.




20 cm map of Sgr A as observed with the VLA. The half-power beam width of 5" × 8" is indicated, as well as a line parallel to the galactic plane. The contours are 40, 80, 120, 200, 280, 340, ... mJy/beam. The spectral index between 6 and 20 cm is shown by shading. (1) is $\alpha < -1$, (2) $-1 < \alpha < -0.5$, (3) $-0.5 < \alpha < 0.0$, and (4) $0.0 < \alpha$.

An alternative possibility is that Sgr A East has gone off in a very high density medium (molecular cloud?) in the galactic centre region. In this case, the age can be much larger (see Ekers et al., 1983) since the higher density medium confines the SNR for a longer time.

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DISCUSSION

VAN DEN BERGH: Your conclusion that Sgr A East might be only a few hundred years old is a very exciting one! This object is situated within a region that contains only about $10^{-4}$ of the total mass of the galaxy. This corresponds to a SNR rate near the galactic nucleus that is $\sim 10^3$ times the galactic average. In this connection one is reminded of the fact that the only supernova ever seen in M31 occured in a region near the nucleus of the galaxy which only contains ~ 1% of the light of M31. These results suggest the possibility that the nuclear regions of galaxies are particularly supernova prone. Because the central regions of most galaxies are heavily exposed on Schmidt survey plates our sample of more distant supernovae may be heavily biased against the discovery of such a population of "nuclear supernovae".