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THE SMALL RADIO SOURCE AT THE GALACTIC CENTER

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ABSTRACT

Very long baseline interferometer observations show that the compact radio source at the Galactic Center has dimensions ~200 AU and that about 25% of the emission comes from a region only 10 AU across. There is no evidence for any expansion or contraction of this compact source, with a velocity $\gtrsim$ a few tens of kilometers per second.

Subject headings: interferometry — galaxies: nuclei — radio sources: general

The radio source at the galactic center has two major components: a thermal one known as Sgr A West, and a nonthermal one, Sgr A East (e.g., Ekers *et al.* 1975). High-resolution radio observations made at 8 GHz have shown the presence of a compact radio source with dimensions less than 0″.1 located near the peak of Sgr A West (Balick and Brown 1974). Very long baseline interferometer (VLBI) observations made with a spacing of about 4 million wavelengths showed this component to be smaller than 0″.02 (Lo *et al.* 1975). Source No. 16 in the 2.2 μm map of Becklin and Neugebauer (1975) and the centroid of the longer wavelength infrared emission (Rieke and Low 1973) are coincident with this compact radio source. Becklin and Neugebauer have suggested that this could be the position of the highest stellar density in the galaxy.

We have made VLBI observations at 7.8 GHz with antenna spacings between 15 and 105 million wavelengths which indicate that the compact radio source is 0″.01 to 0″.02 in extent and has a core $\lesssim$ 0″.001 which contains about 25% of the total flux density. These high-resolution observations were made in 1974 May and November using the Haystack 37 m antenna near Westford, Massachusetts, the NRAO 43 m antenna in Green Bank, West Virginia, and the NASA 64 m antenna at Goldstone, California. The overall system noise temperatures when pointed at the Galactic Center were 100, 110, and 70 K, respectively. The local oscillators at all stations were stabilized by hydrogen maser frequency standards which permitted coherent integration times of about 15 minutes. The rms noise in a single 1 minute period was about 100 mJy on the short NRAO–Haystack baseline and 40 mJy on the transcontinental baselines.

The present observations, as well as those of Balick and Brown (1974) and Lo *et al.* (1975), were all made at frequencies near 8 GHz, and they may be combined to describe the structure of the compact source. The data refer to the structure along position angle ~70°. In Figure 1 we have plotted the fringe amplitudes measured by Lo *et al.* and by ourselves as a function of total baseline length. A reasonably good fit to the data is obtained with two circular Gaussian components, a 0.6 Jy halo component which is 0″.017 (170 AU) in extent plus a core of 0.2 Jy which is only slightly resolved on the longer baselines, and is only ~0″.001 (10 AU) across. Sizes quoted are full-width at half-maximum.

More extensive observations will be required to determine the structure more precisely, but the data do establish that most of the flux density comes from a halo 0″.01 to 0″.02 in extent, while ~25% comes from a core $\lesssim$ 0″.001. The scatter in the data may be due to

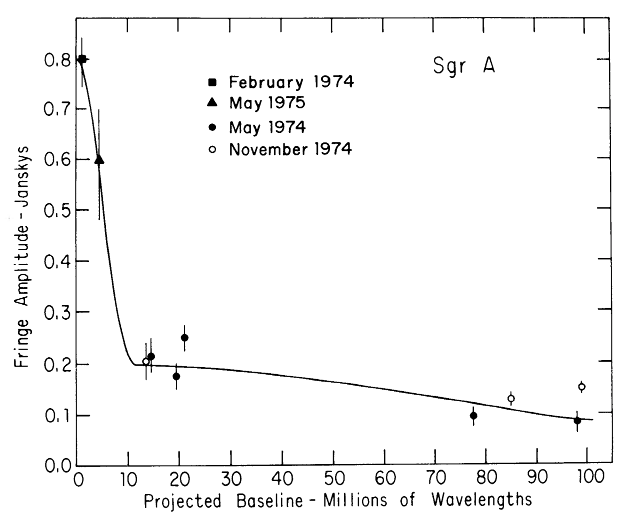

FIG. 1.—Fringe amplitude of Sgr A as a function of projected baseline. The data are as follows: *filled square*, Balick and Brown (1974); *filled triangle*, Lo *et al.* (1975); *filled* and *open circles*, this paper. The solid line represents the model described in the text.

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error in the antenna pointing and atmospheric extinction, or to local oscillator instabilities, but may also reflect more complex structure than the simple model which we have used, or small changes in flux density or structure. The observations do not indicate any change in the apparent size of the smaller component greater than a few AU over a 6 month period, corresponding to a maximum possible velocity of expansion (or contraction) of a few tens of kilometers per second.

At 5 GHz, Lo *et al.* (1974) have failed to find interference fringes above a level of 0.15 Jy on a baseline of $4 \times 10^6\ \lambda$, in apparent disagreement with the 8 GHz observations made with comparable resolution (Lo *et al.* 1975). Davies, Walsh, and Booth (1976) have suggested that the discrepancy may be due to the greater effect of interstellar scattering at the longer wavelengths, rather than the result of time variations, as suggested by Lo *et al.* (1975).

If the measured total size of 0".017 at 7.8 GHz is actually a scattering size, then the expected size at 5 GHz is 0".041. Assuming a flux density of 0.6 Jy at 5 GHz (Ekers *et al.* 1975), the corresponding fringe amplitude at $4 \times 10^6\ \lambda$ would be only 0.06 Jy or under the limit of Lo *et al.* (1974). However, it is not clear if a scattering interpretation is consistent with the large fringe amplitude which we observe at 7.8 GHz with baselines ~100 million wavelengths. Backer (private communication) has suggested that the observed fringe visibility may reflect a more complex scattering than the usual Gaussian law resulting from a random distribution of scattering cells.

If, in fact, interstellar scattering has affected the apparent size we measure at 7.8 GHz, then the true dimensions could be very much less than 0".001 (10 AU) and VLBI observations at shorter wavelengths will be required to determine the true extent of the source. The negative results of Lo *et al.* (1974) at 5 GHz and the large apparent size measured at 0.96 and 1.66 GHz of 1".5 ± 0".3 and 0".3 ± 0".1, respectively (Davies, Walsh, and Booth 1976), appear consistent with the scattering interpretation and could be confirmed by more extensive observations at several shorter wavelengths.

The radio luminosity of the compact Galactic center source is $\sim 10^{33}$ ergs s^{-1} or about 4 to 13 orders of magnitude less than the radio nuclei found in other spirals and elliptical galaxies or in radio galaxies and quasars. The nature of the galactic center source is, however, unclear. The measured brightness temperatures of the larger and smaller components are $\sim 5 \times 10^7$ and 5×10^9 K, respectively, so a thermal origin is unlikely. Its location at the probable position of the highest stellar density in the Galaxy suggests that it might be a supernova, pulsar, or other type of galactic star. Alternately, it may be considered as the smaller, low-luminosity end of a sequence running through spiral and elliptical galaxies, radio galaxies, and quasars. However, the volume emissivity of the 0".001 source in Sgr A is about 100 times greater than the mean emissivity of 3C 273, which itself is greater than most other galaxies and quasars.

The possible existence of a black hole at the center of the Galaxy has been suggested to explain the various phenomena observed at the Galactic Center (e.g., Lynden-Bell 1969), and the detection of a radio source with milli-arcsec dimensions has been suggested as a possible test of the presence of such an object (Lynden-Bell and Rees 1971). The observed size of the radio source corresponds to the Schwarzschild radius of a black hole of $\sim 10^8\ M_\odot$, which is close to the upper limit of a condensed massive object at the galactic center determined from dynamic arguments (Sanders and Wrixon 1973).

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