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AN ANGULAR SIZE FOR THE COMPACT RADIO SOURCE AT THE GALACTIC CENTER

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ABSTRACT

Simultaneous very long baseline ($10^8\ \lambda$) and intermediate-baseline ($4 \times 10^6\ \lambda$) interferometer observations at $\lambda = 3.7$ cm in 1976.2 show that the galactic-center compact radio source has a linear size of ~140 AU. The observations also set an upper limit of ~0.1 Jy to the emission from any core of size less than ~10 AU at that epoch. The total flux density of the compact source was slightly higher than the value reported previously.

Subject headings: galaxies: Milky Way — galaxies: nuclei — radio sources: general

I. INTRODUCTION

The radio source at the galactic center, Sgr A, has a rather complex structure (Downes 1974), with a core which is probably composed of a thermal component, Sgr A West, and a nonthermal component, Sgr A East (Ekers *et al.* 1975). Nearly coincident with the peak of Sgr A West is a compact radio source which is presumably nonthermal (Balick and Brown 1974; Lo *et al.* 1975). This compact source is similar to but of lower luminosity than the extragalactic compact radio sources; it is thus important to determine the structure and spectrum in order to define the physical nature of the galactic nucleus. However, to avoid confusion by the surrounding thermal emission with spatial structure of 2″ or less (Balick and Sanders 1974), the use of sensitive interferometers with maximum fringe spacing of less than 0″.5 is necessary. Because of the likelihood of time-variation effects, simultaneous observations with interferometers covering a range of baseline lengths are necessary for an unambiguous determination of the source structure.

We report detailed 3.7 cm VLBI observations that indicate that the galactic-center compact radio source has a linear size of ~140 AU and a total flux density of 0.9 Jy in 1976.2.

II. OBSERVATIONS

The observations were made on 1976 March 6 with the Goldstone 64 m Mars telescope, the Owens Valley Radio Observatory (OVRO) 40 m telescope, and the Haystack 36.5 m telescope. The system temperatures toward Sgr A were, respectively, ~70, ~160, and ~90 K. Standard Mk II VLBI recording terminals and maser frequency standards were used at all sites.

The galactic center was observed essentially from rise to set, while NRAO 530 was observed for ~10 minutes roughly once an hour for calibration. The pointing corrections determined for NRAO 530 were also applied to the galactic-center source. The projected baseline of the OVRO–Mars interferometer subtended by Sgr A during the observation is shown in Figure 1.

III. RESULTS AND CALIBRATION

The corrected flux density of the galactic-center compact source on the OVRO–Mars interferometer decreased with increasing projected baseline length. The data are consistent with a Gaussian brightness distribution, with a half-power diameter of 0″.014 ± 0″.002 and a peak flux density of 0.9 ± 0.06 Jy. The data as well as the Gaussian model are shown in Figure 2. Because of the limited coverage of the (u, v)-plane (Fig. 1), the model parameters should be taken to indicate angular size only along a position angle of 135°.

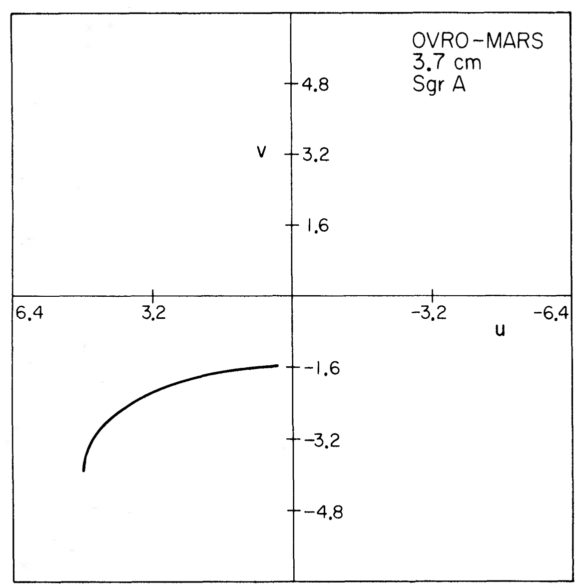

FIG. 1.—The locus of the projected baseline of the OVRO–Mars interferometer during the observation of the galactic-center compact radio source.

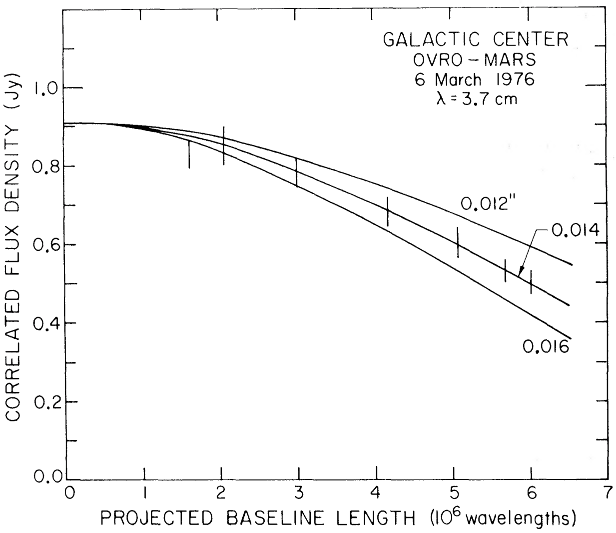

FIG. 2.—The curves are circular Gaussian models with half-power diameters (in arcsec) as indicated. Each point is the average of five to seven 4 minute coherent integrations, and the error bar corresponds to 1 σ for the 4 minute integration.

Calibration and error estimation follow the procedure of Cohen *et al.* (1975). The flux-density scale was calibrated by using a value of 5.3 Jy for the flux density of NRAO 530 at 3.7 cm. This value was obtained from measurements taken at the 64 m Mars telescope during the observations, and it agrees with the 3.7 cm measurements made at the NRAO three-element interferometer at the same epoch (P. C. Crane, private communication). The assumption that NRAO 530 is unresolved on the OVRO–Mars interferometer is well supported by the constant visibility (Fig. 3).

The decrease in the correlated flux density of the galactic-center compact source is not due to a decrease in antenna gain or to atmospheric effects at low elevation, because such effects have been corrected for. Any residual effects due to imperfect corrections would similarly affect the correlated flux density at small baseline length, measured also at low elevation while Sgr A was rising.

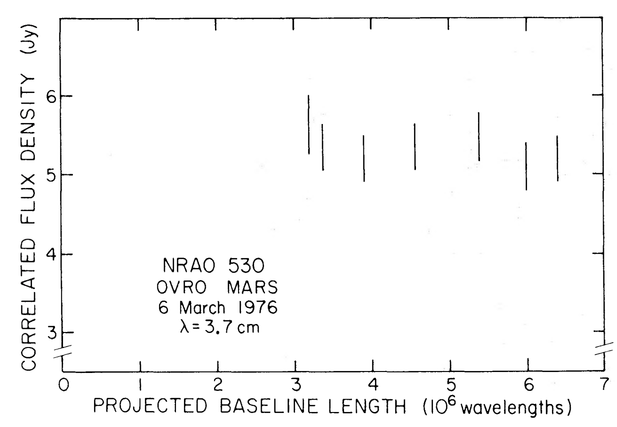

FIG. 3.—Visibility curve for NRAO 530

On the Haystack-Mars interferometer, which has a fringe spacing of $\sim$0".002, we did not detect any convincing signal above 0.1 Jy (3 σ).

IV. DISCUSSION

Kellermann *et al.* (1977) reported the detection of $\sim$0.1 Jy from the galactic-center compact source on an interferometer with a baseline length of $\sim 10^8\ \lambda$ at 3.7 cm. They presented a core-halo model, with diameters of 0".001 and 0".017 and flux densities of 0.2 and 0.6 Jy for the core and the halo, respectively. Our OVRO–Mars interferometer data alone cannot differentiate between our model and the Kellermann *et al.* model. Their model would predict a flux density of 0.13 Jy on the Haystack-Mars interferometer in 1976.2, marginally above our detection limit. In particular, they quoted a measured flux density of 0.16 Jy in 1974.8 on the Haystack-Mars baseline. Our failure to detect the core in 1976.2 might be due to time variations in the core, either in intensity or in size.

In addition, the flux density of the galactic-center compact source in 1976.2 appears to be slightly higher than the previously reported value (Balick and Brown 1974). This is consistent with data from the NRAO 35 km interferometer, which indicate intensity variations of about 25% in the compact component (Lo and Brown 1977). Thus measurements of the galactic-center compact source made at different epochs should be intercompared with caution.

Davies, Walsh, and Booth (1976) reported that the observed diameter of the galactic-center compact source varies with the square of the observing wavelength, and they suggested that interstellar scattering affects the apparent sizes. Such an effect may explain the negative results obtained by K. Y. Lo, R. C. Walker, K. J. Johnston, and B. F. Burke in 1974, at 6 cm (unpublished). However, the effects of a non-uniform synchrotron source with internal absorption (de Bruyn 1976; Condon and Dressel 1973) could also provide the explanation (Lo, Brown, and Johnston 1977).

The evidence Davies *et al.* presented included diameters at 18 and 31 cm measured by themselves and diameters at 3.7 and 11 cm derived from previously published measurements. In particular, from the short-baseline flux density of 0.8 $\pm$ 0.1 Jy measured by Balick and Brown (1974) and the flux density of 0.6 $\pm$ 0.1 Jy measured at $\sim 4 \times 10^6$ by Lo *et al.* (1975), they derived a 3.7 cm diameter of 0".014 $\pm$ 0".004. The published values of the flux density allow a range for the source diameter θ of 0".0 $\leq \theta \leq$ 0".02, with a mean of 0".014. The nature of their quoted error (0".004) is unclear. Furthermore, in view of the definite possibility of variability in the galactic-center compact source, the remarkable agreement between our measured diameter and the value quoted by Davies *et al.* is likely to be fortuitous.

While the source structure is far from being well determined observationally, it appears that the compact source in the galactic center is at most $\sim$140 AU in size, has a ~ 10 AU core that may be varying with time, a brightness temperature greater than $\sim 10^8$ K, and a radio luminosity greater than $\sim 10^{33}$ ergs s^{-1}. In any case, the internal source must supply energy at a rate appreciably higher than the observed radio luminosity from an extremely small volume of space at the galactic center. If the source itself is a pulsar, as Davies *et al.* suggested, the observed radio luminosity and the radio source spectrum (though as yet inadequately determined) would make this pulsar unique (cf. Sieber, Reinecke, and Wielebinski 1975). The small size of the source (less than 10^{15} cm) naturally has led to comparisons with the Schwarzschild radius of a massive object (Kellermann *et al.* 1977; Oort 1977), and Shlovskii (1975) has considered the possibility of a massive black hole constituting the core of the Galaxy.

Formulation of a physical model of the galactic center itself will have to await better and more complete observations of the compact radio source. High-resolution observations at many wavelengths are necessary. Such observations are in progress or are being planned.

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