THE ASTROPHYSICAL JOURNAL, 202:L63–L65, 1975 December 1

VLBI OBSERVATIONS OF THE COMPACT RADIO SOURCE IN THE CENTER OF THE GALAXY

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Received 1975 August 27

ABSTRACT

A compact radio source at the galactic center has been detected at 3.7 cm on a very long baseline interferometer composed of the Goldstone 64-m and the Owens Valley 40-m telescopes (separation 242 km). The source has an angular size, θ_s, on the order of or less than 0".02, corresponding to a linear size $\lesssim$200 AU or 10^{-3} pc, at the distance of the galactic center (10 kpc). The measured flux density is 0.6 ± 0.1 Jy. The brightness temperature of the source is 3×10^7 K if $\theta_s \approx 0''.02$. Comparison with previous high-resolution observations of the galactic center suggests time variation in the flux density. The nature of the compact radio source is discussed.

Subject headings: galactic nuclei — Galaxy, The — interferometry — radio sources

We report the detection of a compact radio source in the direction of the galactic center during VLBI observations at 3.7 cm on 1975 May 19 between the Owens Valley Radio Observatory 40-m telescope and the Goldstone 64-m telescope.

The recording of the signals and the subsequent cross-correlation were made with the standard Mk II VLBI system with a bandwidth of 2 MHz (Clark 1973). The sensitivity of the interferometer to correlated flux density was ~0.1 Jy (5 σ) for 15^m integration.

The galactic center was observed for ~45^m near transit during which time the length of the projected baseline changed from 3.6 to 4.4×10^6 wavelengths. A plot of the fringe amplitude of the compact source in the galactic center as a function of trial fringe rate is shown in figure 1. The flux density scale was calibrated using the 10 sources shown in Table 1, assuming that they are all unresolved on this baseline. The fringe amplitude of the galactic center source was constant at 0.6 ± 0.1 Jy during the observation. The angular size derived from the projected baseline is on the order of 0".02; however, the constant fringe amplitude suggests that this may be an upper limit to the size. The position of the source agrees, within about ±1", with that of the compact unresolved source detected by Balick and Brown (1974) in 1974 March. We presume that these are detections of the same object. Our results show that it has a brightness temperature $T_b \gtrsim 3 \times 10^7$ K, and a luminosity of about 10^{33} ergs s^{-1}, assuming a flux density of 0.6 Jy over a bandwidth of 10^{10} Hz. This source presumably is nonthermal, because of the high brightness temperature.

The source may be variable in flux density. It was not detected in VLBI observations in 1974 June at 6 cm above a limit of 0.15 Jy using the NRAO 43-m and NRL 26-m telescopes as an interferometer (Lo *et al.* 1974), although other extragalactic radio sources were detected during the same experiment (Walker *et al.* 1975). The projected baseline for the 6-cm Sgr A observations was ~4×10^6 wavelengths. However, Balick and Brown (1974) measured flux densities of ~0.6 Jy at 11 cm and ~0.8 Jy at 3.7 cm. Thus, unless the galactic center source has a very unusual spectrum between 11 and 3.7 cm, the negative 6-cm results strongly suggest time variability in the source.

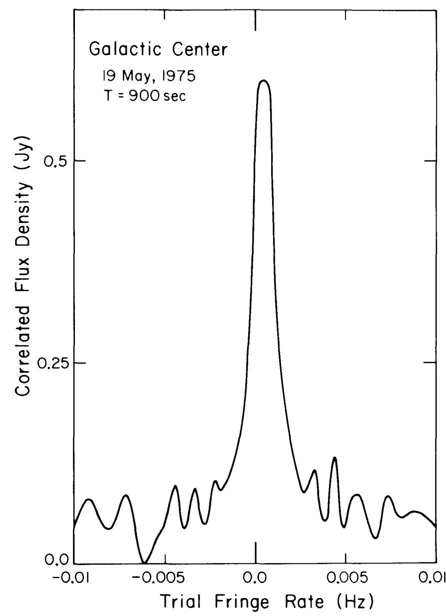

FIG. 1.—The fringe amplitude of the compact source in the galactic center is plotted as a function of trial fringe rate, for a coherent integration of 15^m.

The characteristics of the galactic center source that are revealed by the various high resolution observations are (i) it is nonthermal, (ii) it probably is time variable in flux density, (iii) it has a linear size on the order of 10^{-3} pc or smaller, and (iv) it has a radio luminosity on the order of 10^{33} ergs s^{-1}.

Aperture synthesis observations of the galactic center region with angular resolution of 10"–30" (Downes 1974; Ekers *et al.* 1975) indicate the presence of two

TABLE 1

FLUX DENSITIES OF THE CALIBRATOR SOURCES AT 3.7 CENTIMETERS

Source	Flux Density* (Jy)
3C 84	59.0
NRAO 150	10.8
3C 120	12.6
OJ 287	3.9
1127-14	5.0
3C 273	49.2
OQ 208	2.9
OR 103	2.4
1555+00	2.2
3C 345	7.3

* Measurements were made at Goldstone on 1975 May 19. Typical errors are ± 5%.

components in the Sgr A radio source. The compact galactic center source falls very nearly on the peak of the brightness distribution of Sgr A West (G0.06–0.05). Since Sgr A West has the characteristics of a thermal source (Ekers *et al.* 1975) and the compact source is nonthermal, they may be generated by different physical mechanisms associated with the same object.

The infrared core in the galactic center has recently been mapped at a 2."5 resolution by Becklin and Neugebauer (1975) at 2.2 μ. The compact galactic center source is nearly centered on an extended component which, according to Becklin and Neugebauer, could be the position of the highest stellar density in the Galaxy.

It is interesting to compare the compact radio source in the galactic center to those in nuclei of radio galaxies (Kellermann 1971; Kellermann *et al.* 1975). We list in Table 2 some parameters of the compact sources found in M87, Cen A, Cyg A, and the galactic center. D is the distance to the source, θ and d are the angular and linear sizes, and L is the radio luminosity. The galactic center source is at least 10^7 times less luminous and 10 times smaller in linear size than the extragalactic sources.

Whether objects similar to the galactic center source are common in the nuclei of other normal spiral galaxies cannot now be answered. Present observations of radio sources in nuclei of spirals (e.g., Ekers 1974) indicate that many spirals have a radio source similar to the Sgr A source (Downes and Martin 1971; Downes 1974; Jones 1974) in their centers. But the compact galactic center source would have a flux density of $\lesssim 10^{-4}$ Jy at a distance of 1 Mpc and would be impossible to detect with the sensitivity of present-day radio telescopes. However, the large range in size and luminosity between this source and the more common nuclear sources (Table 2) suggests that objects of intermediate strength also exist. This conjecture could be tested by making high-sensitivity VLBI observations of the nuclei of nearby spirals.

Past explosive activity in the center of our Galaxy is suggested by the observed expanding motions of hydrogen and molecular clouds within a radius of 3 kpc from the center (e.g., Oort 1974). It is possible that the galactic center source is causally related to these observed motions.

The nature of the compact radio source in the galactic center can be better determined only with more comprehensive observations. By virtue of its proximity it can be studied in great detail—linear resolutions of $\lesssim 10^{-4}$ pc ($\lesssim$0."001) are possible. Further observations are planned, and it is hoped that the results may allow us to discriminate, for our own Galaxy at least, between various models of galactic nuclei (e.g., Spitzer 1971; Morrison and Cavaliere 1971; Lynden-Bell 1971). It may also help in the understanding of the origin and evolution of extragalactic radio sources.

We thank Drs. P. Goldreich, A. C. S. Readhead, and P. Wilkinson for informative discussions. Research at Owens Valley Radio Observatory is supported by the National Science Foundation grant GP30400-X and by the Office of Naval Research, contract N00014-67-A-0094-0019.

TABLE 2

PARAMETERS OF COMPACT NUCLEAR RADIO SOURCES

Source	D*(kpc)	θ(″)	d(pc)	L(ergs s^{-1})	Reference
Galactic center	10	$\lesssim$0.02	$\lesssim 10^{-3}$	$\sim 10^{33}$	
Cen A (NGC 5128)	4000	$\lesssim$0.0005†	$\lesssim 10^{-2}$	$\gtrsim 10^{40}$	1
M87	21800	$\lesssim$0.001	$\lesssim 10^{-1}$	$\sim 10^{40}$	2
Cyg A	306000	$\lesssim$0.002	$\sim$ 2	$\sim 10^{45}$	3

* Assuming $H_0 = 55$ km s^{-1} Mpc^{-1}.

† Inferred from the turnover frequency in the radio spectrum.

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