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A COMPACT RADIO SOURCE IN THE NUCLEUS OF M82

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ABSTRACT

The brightest compact radio source in the nucleus of M82 has a linear diameter of about 0.02 parsecs (25 light-days). On the basis of this small size and energy considerations, it seems that this source is probably not a supernova remnant, but that it is similar in nature to the compact radio sources found in the nuclei of spiral and elliptical galaxies, Seyfert galaxies, radio galaxies, and in quasi-stellar objects.

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

The radio structure of the I0 galaxy M82 (NGC 3034, 3C 231) consists of extended emission as well as many compact components near the nucleus, lying along or near position angle 65° (cf. Kronberg and Wilkinson 1975), which is close to the optical position angle of 62° (Burbidge, Burbidge, and Rubin 1964).

Hargrave (1974) has found a flux density of 3.1 Jy in the extended emission of M82 at 6 cm. The strongest compact nuclear source, 41.9+58 (Kronberg and Wilkinson 1975), or Source A of Hargrave (1974), has a nonthermal spectrum with a low-frequency turnover near 1 GHz. Kronberg and Wilkinson (1975) have speculated that this turnover may be due to foreground H II absorption. If, however, the nuclear source is similar to that of compact sources in the nuclei of other radio galaxies, then the turnover is more probably due to synchrotron self-absorption.

In order to clarify the nature of the strong nuclear component of M82, we observed it in 1974 May and November at 7850 MHz with a long-baseline interferometer consisting of the Haystack Observatory 37 m antenna near Westford, Massachusetts, the NRAO 43 m antenna at Green Bank, West Virginia, and the NASA 64 m antenna near Goldstone, California. The data were recorded and analyzed using the NRAO Mk II recording systems as described by Clark (1973). All the local oscillators were stabilized by hydrogen masers. The rms noise in a single 15 minute period was about 25 mJy on the short NRAO–Haystack baseline, and 10 mJy on the longer transcontinental baselines. The lengths of the projected baselines ranged from 18 to 98 million wavelengths.

In Figure 1, the measured fringe amplitude is plotted against the length of the projected baseline. The filled circles represent data obtained in 1974 May, the open circles represent data taken in 1974 November, and the cross is the data point of Kronberg and Wilkinson (1975). The limited data are adequately fitted with a simple circular Gaussian model which has an angular diameter of 0".0015. Assuming that M82 is a member of the M81 group (Tammann and Sandage 1968), and thus at a distance of 3.25 Mpc, the corresponding linear diameter is 0.02 pc (∼25 light-days).

The radio spectrum of the nuclear source shows a low-frequency turnover near 1 GHz with a maximum flux density of about 0.7 Jy (Hargrave 1974; Kronberg and Wilkinson 1975). The observed brightness temperature at 8 GHz is $\sim 10^{10}$ K, so the source is clearly nonthermal. If the size is independent of wavelength, the peak T_B is $\sim 10^{12}$ K at 1 GHz. The total radio luminosity between 1 and 100 GHz is about 10^{38} ergs s^{-1}. The angular size, the peak flux density, and the cutoff

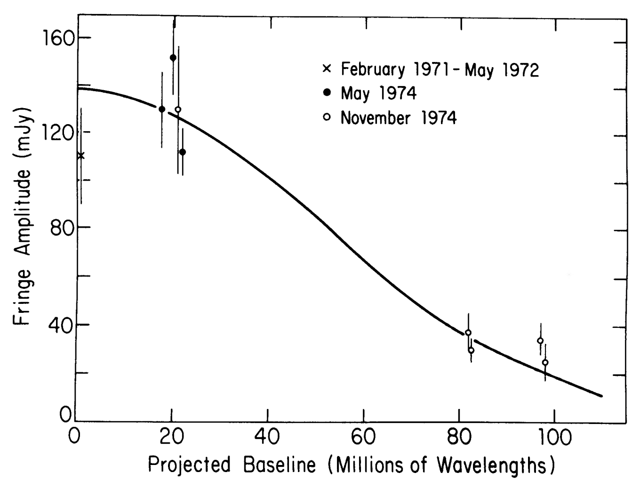

FIG. 1.—Fringe amplitude of M82 as a function of projected baseline. The data are as follows: ×, Kronberg and Wilkinson (1975); ●, this paper 1974 May data; ○, this paper 1974 November data.

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frequency are all well determined, and we find the magnetic field strength $B \approx 2 \times 10^{-4\pm1}$ gauss, the energy in relativistic electrons $E_e \approx 2 \times 10^{54\pm2}$ ergs, and the energy in the magnetic field $E_m \approx 6 \times 10^{41\pm2}$ assuming a self-absorbed synchrotron source (e.g., Kellermann 1974). As in other compact radio sources, the energy contained in the form of relativistic particles greatly exceeds that in the magnetic field.

It has been suggested that the compact radio sources in M82 are supernovae (Hargrave 1974) or multiple supernova events (Kronberg and Wilkinson 1975). Our estimate of the total energy content of $\sim 10^{54}$ ergs is consistent with an energetic supernova, but there are compelling arguments against the supernova hypothesis: (a) the total radio luminosity of the source is about 250 times that of the strong supernova remnant Cas A, and the energy in particles is about 10^5 greater than Cas A (Rosenberg 1970); (b) Hargrave (1974) has argued that for reasonable expansion velocities, the size of the nuclear source should lie between 0.4 and 4 pc if it is the result of a supernova. The small size we find of 0.02 pc seems to exclude the possibility of a supernova event; (c) in placing the nuclear source on the surface brightness–linear diameter diagram for supernova remnants (Ilovaisky and Lequeux 1972), probably not valid for young, optically thick remnants, the observed surface brightness of $\sim 2 \times 10^{16}$ Jy sr^{-1} is about a factor of 100 less than expected for a size of 0.02 pc.

The compact radio source in the nucleus of M82 is the first such object found in an irregular galaxy. Superficially, it is similar to the compact radio sources found in normal spiral and elliptical galaxies, Seyfert galaxies, radio galaxies, and quasi-stellar sources; the particle energy is much greater than the magnetic field energy, the magnetic field strength is $\sim 10^{-4}$ gauss, and the brightness temperature is comparable to that of the more luminous nuclei of radio galaxies and quasi-stellar radio sources. The luminosity and size of the M82 nucleus are within the broad range found for other radio nuclei. The compact radio sources in the nuclei of radio galaxies such as NGC 1275 (3C 84) are about 10^4 times more luminous and have linear sizes about 10 times larger than that in M82. The M82 radio nucleus is comparable in luminosity and size to the compact source in the nucleus of the normal spiral galaxy M81 (Kellermann *et al.* 1976), whereas the radio source at the center of our Galaxy is weaker by a factor of $\sim 10^5$ and smaller by a factor of $\sim 10^3$ (Kellermann *et al.* 1977).

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