# VLBI OBSERVATIONS OF THE COMPACT COMPONENTS IN M82

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The nearby IrrII galaxy M82 (3C 231, NGC3034) is known to have a complex, very elongated radio brightness distribution in the central region of the galaxy (e.g., Kronberg and Wilkinson 1975). Because of the galaxy's proximity (distance $\sim$ 3.3 Mpc; Tammann and Sandage 1968), the brightness distribution can be investigated in considerable detail. Recently Unger *et al.* (1984) and Kronberg, Biermann, and Schwab (1985; see also Kronberg 1986) distinguished about 20 compact components in the central region, most of them unresolved with an upper limit on their angular sizes of $\sim$ 150 mas corresponding to an upper limit on their linear sizes of $\sim$ 2 pc. About half of the components were observed at more than one frequency and at several epochs and were found typically to have steep spectra ($\alpha_{15}^{5} < -0.4$, $S_\nu \propto \nu^\alpha$) between 5 and 15 GHz and (Kronberg and Sramek 1985) slowly decreasing flux densities.

The nature of the compact sources is not yet known. It has been suggested that they are:

i) supernovae, or
ii) supernova remnants, or
iii) an active galactic nucleus and jet condensations.

On 9 May 1983 we made Mark III VLBI observations at 2.3 and 8.4 GHz simultaneously with an array of eight telescopes with baseline lengths ranging from $\sim$ 200 km to $\sim$ 8000 km. From the 2.3-GHz observations, we found that most of the compact sources are at least partly resolved even with the two-element interferometer with the shortest baseline. Using a circular Gaussian model, we estimated for each source the full-width-at-half-maximum (FWHM) of its brightness from the VLBI data at 2.3 GHz and from the total flux density at 2.3 GHz, as extrapolated from Kronberg *et al.*'s (1985) dual-frequency observations, and interpolated between Kronberg and Sramek's (1985) multi-epoch observations. The sources' sizes are given in Table 1.

Of the 15 sources investigated, six are partly resolved. Seven additional sources are probably also partly resolved since the conditions required on $\alpha$ and $\dot{S}$, the time derivative of $S$, for this conclusion to be valid are consistent with the properties of many other compact sources in M82. For the remaining two to be at least partly resolved would require that they have rather steep spectra. These last two sources might therefore be unresolved and have linear sizes smaller than 0.3 pc.

The strongest of the 15 compact sources, $41.9 + 58$, was investigated in more detail.



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**Table 1**
**The (FWHM) Angular Sizes $\theta$ and Linear Sizes $D$[1] of the Compact Sources in M82[2]**

| Source[3] | $\theta$ (mas) | $D$ (pc)[4] | Condition on $\alpha$ ($S_\nu \propto \nu^\alpha$) and $\dot{S}$ | |
|---|---|---|---|---|
| $39.1+573$ | $\gtrsim 90$ | $\gtrsim 1.4$ | | |
| $40.7+550$ | $\gtrsim 60$ | $\gtrsim 1.0$ | | |
| $41.9+58$ | $20 \pm 10$ | $0.3 \pm 0.2$ | | |
| $43.3+591$ | $40 \pm 10$ | $0.6 \pm 0.2$ | | |
| $44.0+595$ | $80 \pm 10$ | $1.3 \pm 0.2$ | | |
| $44.3+592$ | $\gtrsim 20$ | $\gtrsim 0.3$ | if $\alpha \lesssim -1.3$ | and if |
| $44.9+611$ | $\gtrsim 20$ | $\gtrsim 0.3$ | if $\alpha \lesssim -1.1$ | $\dot{S} \gtrsim -10\%\ \mathrm{yr}^{-1}$ |
| $45.2+612$ | $60 \pm 10$ | $1.0 \pm 0.2$ | | |
| $45.3+651$ | $\gtrsim 20$ | $\gtrsim 0.3$ | if $\alpha \lesssim -0.6$ | |
| $45.4+673$ | $\gtrsim 60$ | $\gtrsim 1.0$ | if $\alpha \lesssim -0.6$ | |
| $45.7+652$ | $\gtrsim 60$ | $\gtrsim 1.0$ | if $\alpha \lesssim -0.6$ | and if |
| $45.9+638$ | $\gtrsim 20$ | $\gtrsim 0.3$ | if $\alpha \lesssim -1.1$ | $\dot{S} \gtrsim -10\ \%\ \mathrm{yr}^{-1}$ |
| $46.2+676$ | $\gtrsim 50$ | $\gtrsim 0.8$ | if $\alpha \lesssim -0.6$ | |
| $46.5+638$ | $\gtrsim 70$ | $\gtrsim 1.1$ | if $\alpha \lesssim -0.6$ | |
| $46.7+670$ | $\gtrsim 50$ | $\gtrsim 0.8$ | if $\alpha \lesssim -0.6$ | |

[1] A circular Gaussian brightness distribution model is assumed. If instead an optically thin shell model or an optically thin uniform sphere model is assumed, the angular and linear sizes in the table have to be multiplied by $\sim 1.4$ or $\sim 1.8$, respectively, in order to obtain the models' full-widths at zero intensity.

[2] Seven of the 15 sources (entries 3 to 8 and 12) were detected with the interferometer with the shortest baseline. For the other sources upper limits on the correlated flux density were obtained. The uncertainties of $\theta$ and D are derived from the root-sum-squares of a statistical standard deviation ($1\ \sigma$) of the flux densities and the contribution from 15% antenna gain calibration errors. The lower limits on $\theta$ are based on the inferred total flux density (see text) and the correlated flux density or an upper limit on it of $\gtrsim 1$ mJy ($3\ \sigma$) depending on the source's angular separation from the strongest source 41.9+58.

[3] The source names are adopted from Kronberg *et al.* (1985).

[4] The distance to M82 is assumed to be 3.3 Mpc.

Results of previous VLBI observations of $41.9+58$ were reported by Geldzahler *et al.* (1977), Shaffer and Marscher (1979), Jones, Sramek, and Terzian (1981), and Wilkinson and de Bruyn (1984). Although half of our 28 two-element interferometers were not sensitive enough to detect $41.9+58$, we obtained enough data to determine the brightness distribution of the source; a preliminary map is shown in Fig. 1. We can distinguish two dominant, elongated components oriented at an angle of $\sim 20°$ and having maximum dimensions of 10 to 30 mas. In addition, we found, from the data obtained with the interferometers with the longest baselines, indications of the existence of one or two components of only $\lesssim 3$ mas in size and only a few millijanskies flux density.

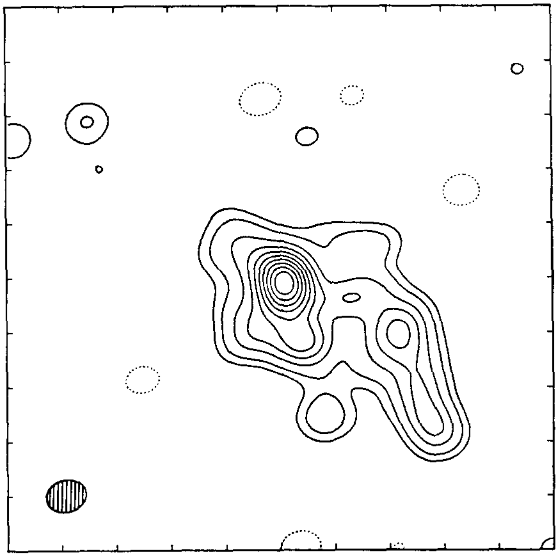

Figure 1. A preliminary hybrid map of 41.9 + 58 in M82. Tick marks are separated by 6.4 mas. The contours are at 90, 80, 70, 60, 50, 40, 30, 20, 10, 5, −5% of the peak flux density per beam area. The FWHM of the Gaussian restoring beam is shown as the striped ellipse in the lower left corner. North is up, east to the left.

## CONCLUSION

Most of the 15 investigated compact sources in M82 have linear sizes in excess of 0.3 pc and are therefore too large to be young supernovae. The strongest of the compact sources, 41.9 + 58, has a complex brightness distribution that is not reminiscent of a typical supernova remnant. More light on its physical nature, and by inference the nature of M82's other sources, could be shed by investigating the source's kinematics through multi-epoch VLBI observations of M82.

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