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VLBI Astrometry of the Ultra-Compact Nucleus of M81

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Abstract. M81 has been shown to have a compact flat-spectrum core with a possible steep-spectrum jet. We report on position determinations of the brightness peak of the nucleus relative to the position of the early supernova 1993J with uncertainties as low as 0.08 mas. At early epochs, the supernova was largely pointlike at any frequency and therefore an ideal phase reference. We describe how VLBI astrometry at several frequencies could be used to support a model with a core and a one-sided jet for the nucleus of M81.

M81 is a nearby grand-design spiral galaxy which hosts an extremely compact nucleus with a size is only 0.18 x 0.07 mas (FWHM, 700AU x 300AU) at 22 GHz (Bietenholz et al. 1996; see also Bartel et al. 1982, Kellermann et al. 1976). The nucleus is slightly asymmetric with its brightness falling off along its major axis toward the north-east, providing evidence for a core-jet nature. The size varies with observing frequency, with the length of the major axis increasing to 1 mas at 3 GHz. Such frequency dependence is expected if the nucleus consists of a flat-spectrum core and a barely resolved steep-spectrum jet. Further evidence for the existence of a one-sided steep-spectrum jet could come from VLBI astrometry. For a pure, elliptical core model as sketched in Figure 1, the center of brightness is not expected to show any particular frequency dependence. However, for a core with a one-sided steep-spectrum jet, one would expect that the center of brightness shifts with decreasing frequencies away from the core in the direction of the jet.

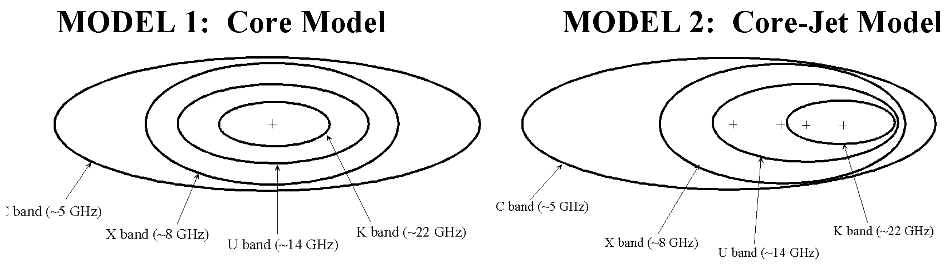

Figure 1. Possible models for the structure of the ultra-compact nucleus of M81.

We observed the nucleus of M81 as a phase reference for our multi-frequency, multi-epoch VLBI observations of SN 1993J (Bartel et al. 1994; Rupen et al. 1994; Rupen et al., these Proceedings, p. 355). The data of the first sessions in 1993 were partly correlated at Haystack and later, together with the data of all subsequent sessions, fully correlated at Socorro.

From the 8.4 GHz data correlated completely at Socorro, we determined via phase-referencing with AIPS the position of the phase center (essentially the brightness peak) of the nucleus of M81 relative to the early SN 1993J. The latter source was largely pointlike (< 0.2 mas) at that time at any frequency and therefore an ideal phase reference. In addition, from the data obtained on 16 May and 26 June 1993 and correlated at Haystack, we determined the position with our least-squares-fitting astrometry package ASPY. These latter position determinations are plotted in Figure 2 relative to the AIPS position as the origin of the diagram. Uncertainties are standard errors with the weighted rms of the residual phase delays approximately equal to unity for each of the baselines and with uncertainties due to the atmosphere added in quadrature to the statistical contributions. Our most accurate position determination was obtained from the May 1993 data with an uncertainty less than 0.08 mas in agreement within 0.1 mas with the AIPS position. Preliminary position determinations at 14.9 GHz indicate slightly lower values in relative RA and Dec. consistent with a core-jet model for the nucleus of M81. It remains to be seen whether this trend can be confirmed.

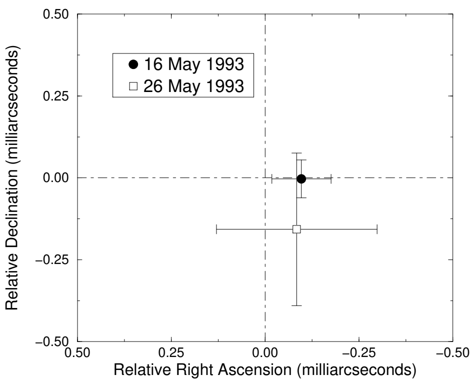

Figure 2. Positions of the brightness peak of the nucleus in M81 at 8.4 GHz relative to the compact early SN 1993J, determined with ASPY. The origin of the diagram is the equivalent position for May 1993 determined with AIPS.

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References

Bartel, N., et al. 1982. *ApJ*, **262**, 556–563.

Bartel, N., et al. 1994. *Nature*, **368**, 610–613.

Bartel, N., Bietenholz, M. F. & Rupen, M. P. 1995. *Proc. Natl. Acad. Sci. USA*, **92**, 11374–11376.

Bietenholz, M. F., et al. 1996. *ApJ*, **457**, 604–609.

Kellermann, K. I., et al. 1976. *ApJ*, **210**, L121–122.

Rupen, M. P., et al. 1994. in *Compact Extragalactic Radio Sources*, eds. J. A. Zensus & K. I. Kellermann (Green Bank: NRAO), 103–108