VLBA Observations of the Structure and Motions of the Inner Parsec of the M87 Jet

R. C. Walker (NRAO), P. E. Hardee (U. Alabama), F. Davies (MPIA), W. Junor (LANL), C. Ly (Steward Obs.)

There should be an iPad showing the M87 movie in this space. If not, see the movies at http://www.aoc.nrao.edu/~cwalker/M87

Movie of 11 images from 2007 at 3 week intervals.

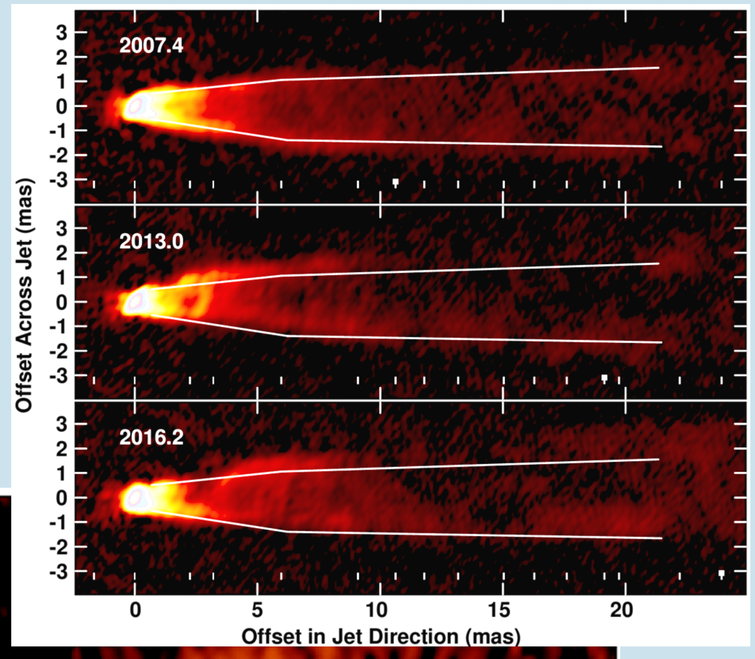
INTRODUCTION

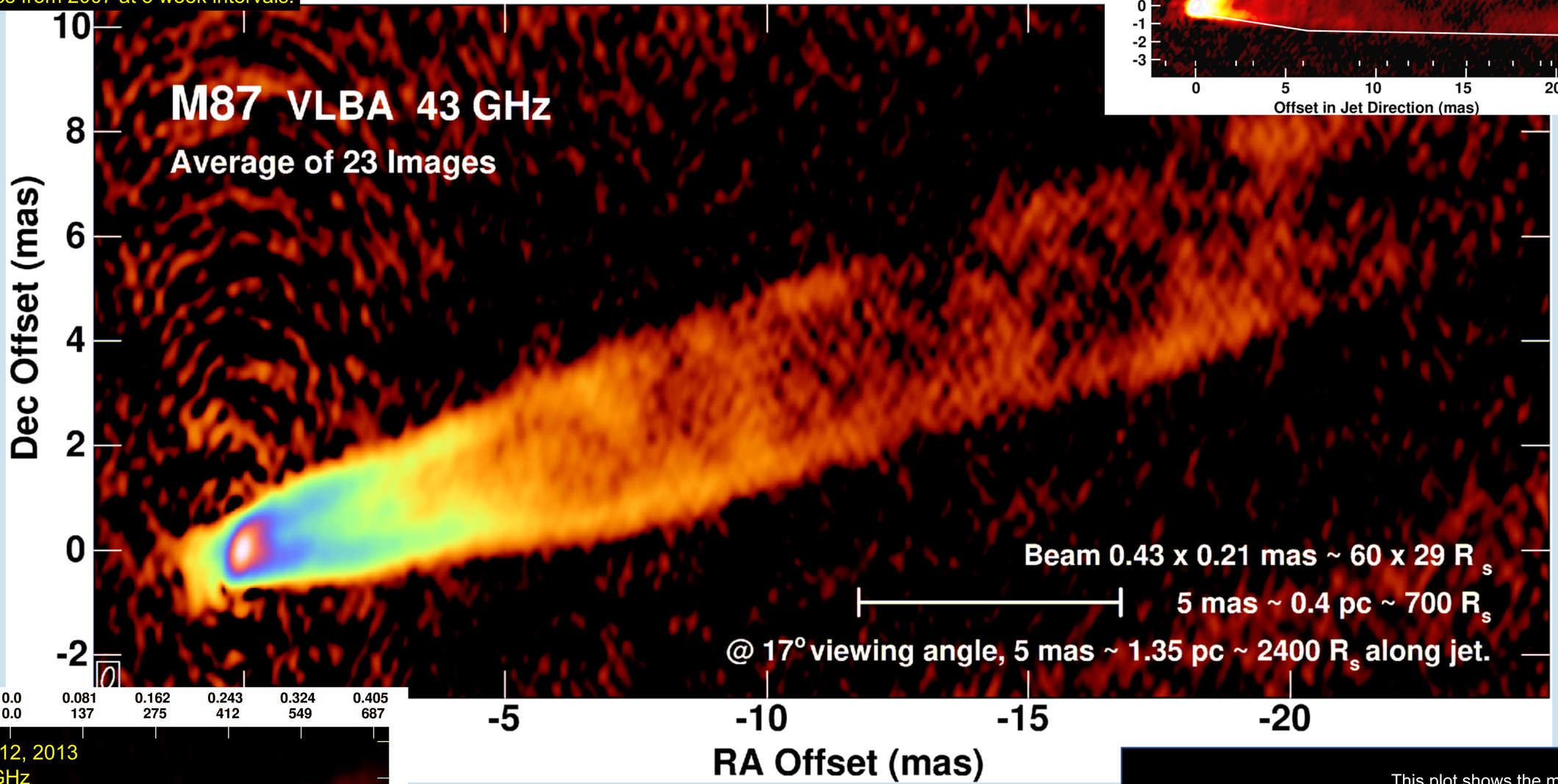
Walker et al. (2018, Ap.J. 855, 128: arXiv:1802.06166) reported results from Very Long Baseline Array (VLBA) observations of M87 at 43 GHz which include intensive monitoring in 2007 and 2008 plus 17 years of roughly annual observations, for a total of 50 individual observations. The results from that study are reviewed on this poster.

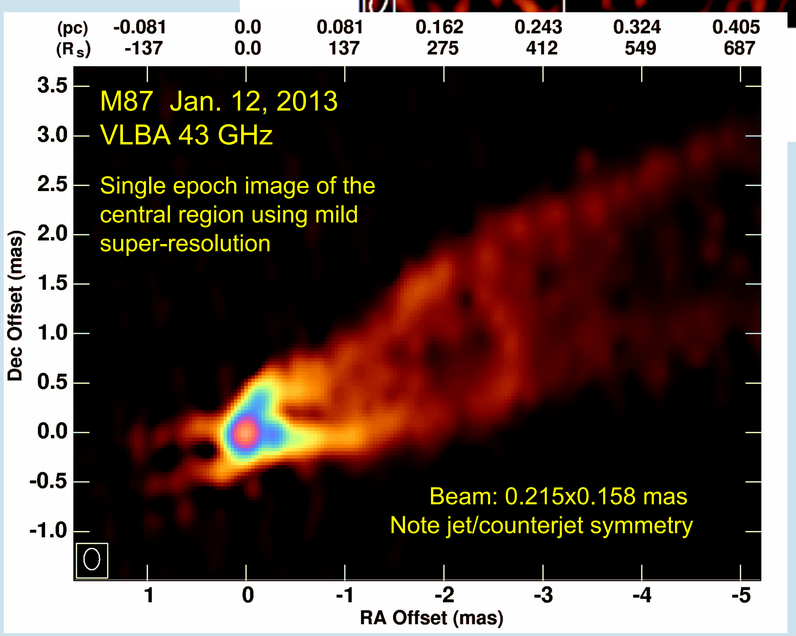
The central radio source in M87 provides the best opportunity to study jet formation because the gravitational radius of the black hole subtends a large angular size and it has a bright jet that is well resolved by VLBI observations. The 43 GHz VLBA observations have a resolution of about 0.21 x 0.43 milli-arcseconds (mas) which is about 29 by 60 Schwarzchild radii (R_s) for D = 16.7 Mpc and M_{bh} = 6.1 X 10^9 $M_\odot$*.

* Note the black hole mass is controversial with some studies giving about half the mass assumed.

Three of 17 annual images showing side-to-side motion. The white lines are fixed along the 2007 jet ridges to help see the changes.







Find more information and movies at http://www.aoc.nrao.edu/~cwalker/M87 . Movies include 2007 (11 frames at 3 week intervals), 2008 (12 frames at 1 week intervals, 1999-1016 (17 annual frames). Some frames are averages.

RESULTS SUMMARY

Our high-dynamic-range images clearly show the wide opening angle structure of the jet and show the counterjet.

The jet and counterjet are nearly symmetric in the inner 1.5 milli-arcseconds (0.12 pc in projection) with both being edge brightened.

Both jet and counterjet show deviations from parabolic shape in the form of an initial rapid expansion in width and subsequent contraction followed by further rapid expansion and, beyond the visible counterjet, subsequent collimation.

Proper motions and counterjet/jet intensity ratios both indicate acceleration from apparent speeds of less than about 0.5c to greater than about 2c in the inner 2 mas (0.16 pc or 240 R_s in projection) and suggest a helical flow.

The jet displays a sideways shift with an approximately 8 to 10 year quasi-periodicity. The shift propagates outwards non-ballistically and significantly more slowly than the flow speed revealed by the fastest moving components.

Polarization data show a systematic structure with magnetic field vectors that suggest a toroidal field close to the core.

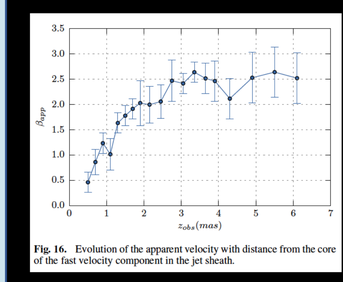


Fig. 16. Evolution of the apparent velocity with distance from the core of the fast velocity component in the jet sheath.

This plot shows the measured speeds of the fast components as found by Mertens et al. (2015, A&A 574, A67) who used a wavelet based method to analyze our 2007 data. Results from component motions in Walker et al. (2018) are similar. Acceleration over about 2 mas to an apparent speed (projected) of over 2c is seen. Slowly-moving features are also seen, which, along with the edge brightening, suggest a stratified structure.

NGVLA

The NGVLA, with the long baseline antenna option, will significantly enhance studies of the inner M87 jet. The observing frequency can be double that used here which will double the resolution, reaching scales only about one order of magnitude larger than the black hole itself. There will be significantly more baselines so the image fidelity will be much higher and the larger scale structures will be far better defined thanks to the many short baselines.

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