1.3 mm VLBI study of M87

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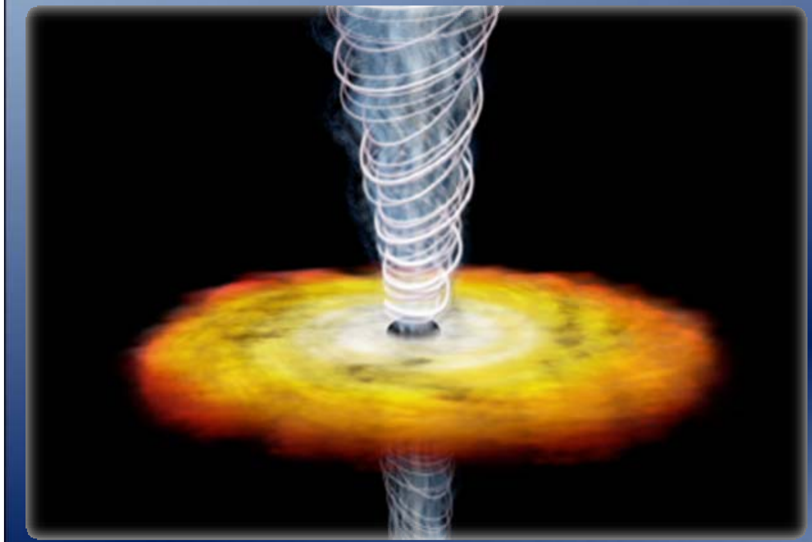
MIT
HAYSTACK
OBSERVATORY

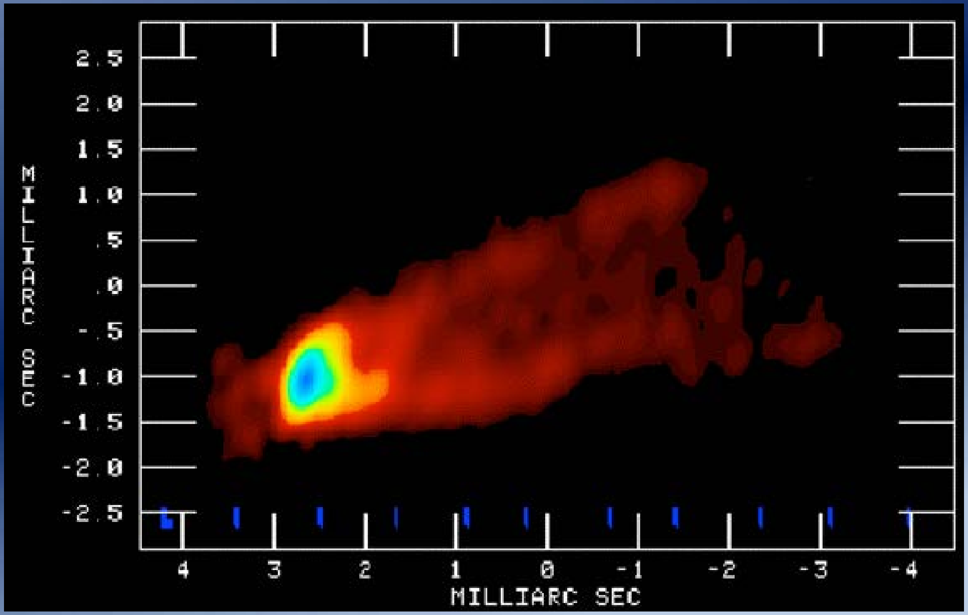
M87

- Largest galaxy in the Virgo cluster.
- Located about 16 Mpc away.
- Active galactic nucleus (AGN) powered by a supermassive black hole (6.5*10^9 solar masses)
- An AGN is a compact region at the center of a galaxy that emits large amounts of energy.
- Second largest black hole in apparent size behind Sagittarius A*.

Very-high-energy Emission and Jet Formation

- Emission of gamma-rays reaches tens of TeV (10^{12} eV).
- Emission varies on a timescale of just 2 days.
- The mechanisms that drive the emission and jet are unknown.
- The location and size of the emitting region and jet base are also undetermined.

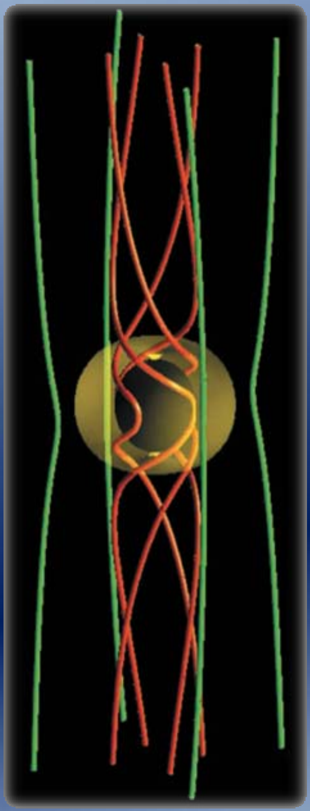




Models

- <u>VHE emission</u>
- Synchrotron radiation
- Inverse Compton scattering
- Synchrotron self-Compton scattering
- Cosmic ray interactions
- Knots caused by shocks propagating through the jet.
- Dark matter annihilation

- <u>Jet Formation</u>
- Twisting magnetic field
- Gas pressure
- Extraction of black hole rotational energy
- “Spine-sheath” model



- The size scales associated with these models range from a few Schwarzschild radii to hundreds of Schwarzschild radii.

VLBI

- Very Long Baseline Interferometry
- Multiple telescopes separated by hundreds or thousands of kilometers used to replicate a giant telescope.
- Allows for much greater angular resolution than what any individual telescope can achieve.
- High resolution was needed due to small angular size of M87.

Stations

- James Clerk Maxwell Telescope (JCMT): Mauna Kea, Hawaii.

- http://www.cv.nrao.edu/course/astr534/RadioTelescopes.html

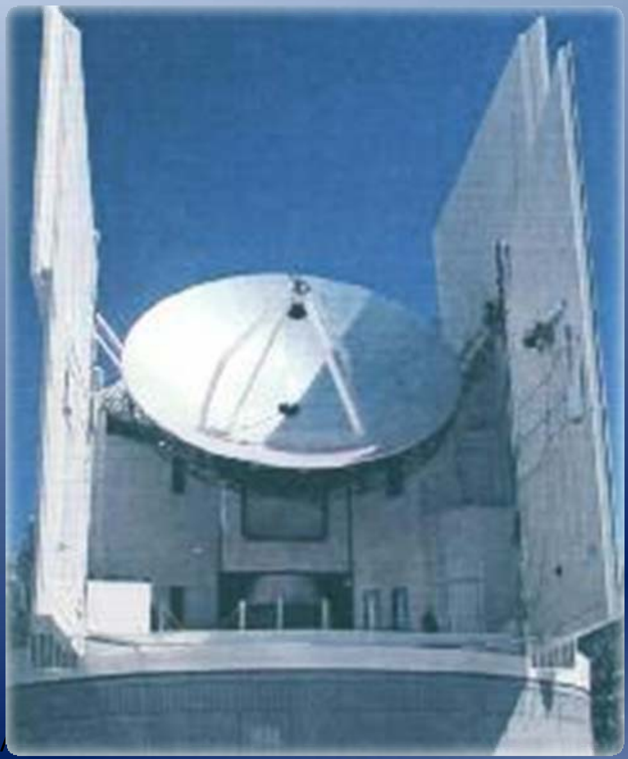
Stations

- Combined Array for Research in Millimeter-wave Astronomy (CARMA): California.

- http://www.cv.nrao.edu/course/astr534/Interferometers2.html

Stations

- Submillimeter Telescope Observatory (SMTO): Arizona.



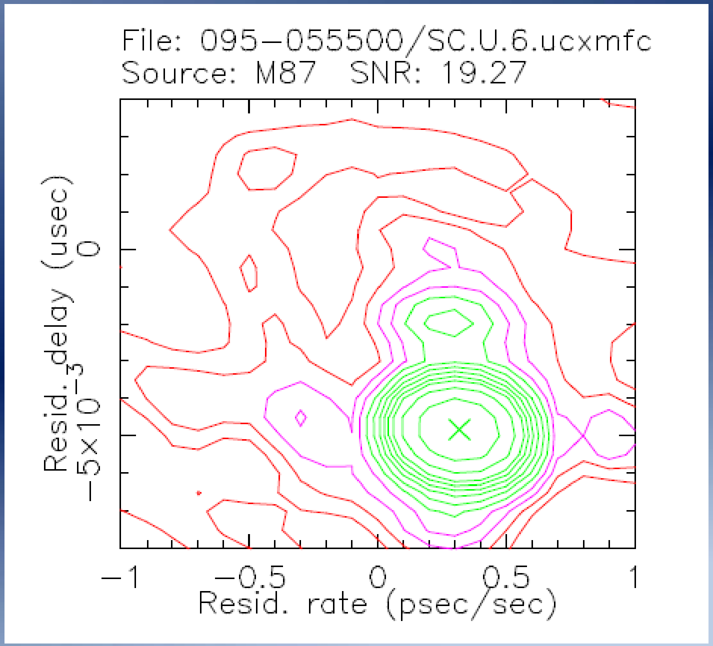
- http://www.mpifr-bonn.mpg.de/div/

Goal

- Achieve highest ever resolution observation of M87.
- Frequency: 230 GHz (1.3 mm)
- The resolution is comparable to that of the innermost stable circular orbit, a widely accepted inner boundary of the accretion disk.
- Get an estimate of the size of the radio emitting region.
- Determine which models of the emission and jet formation are in agreement with our size limit.

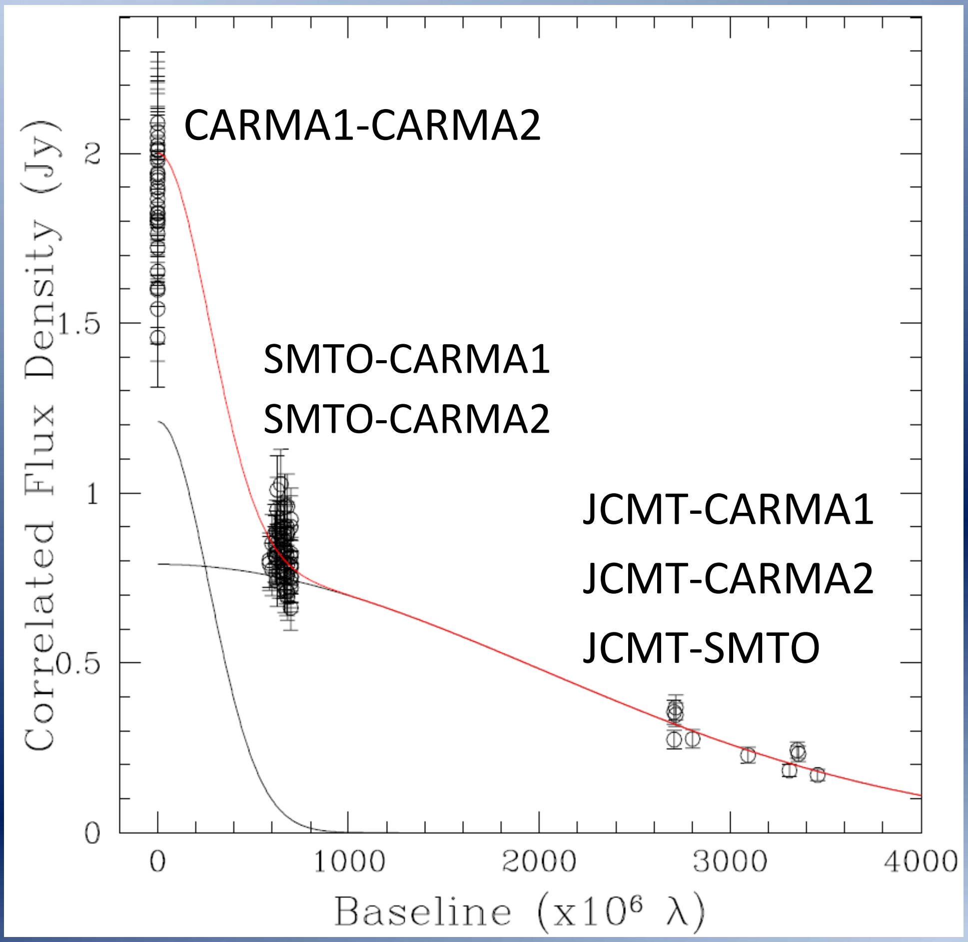
Data Reduction

- Detections were searched for in grid of single-band delay, multi-band delay, and delay rate.
- Detections with signal-to-noise ratio above 4.0 and appropriate location in the grid were deemed “good”.
- The good detections were calibrated.
- Due to inconsistency in the data collection at the separate stations, each set of data had to be treated specially.



Results

- Correlated flux density vs baseline length.
- Points are fitted by sum of two Gaussians.
- A wide Gaussian in u,v space corresponds to a thin Gaussian on the sky.
- The two components have sizes of about 38 and over 200 microarcseconds.



Conclusions

- The size derived from the Gaussian fit corresponds to about 4.5 Schwarzschild radii for the size of the radio emitting region. (Former limit was 30).
- Certain models of electron and hadronic synchrotron radiation and inverse Compton scattering have appropriate size scales.
- Cosmic ray interactions and dark matter annihilation predict far too large of an emitting region.

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