1.3 mm VLBI study of M87

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August 6, 2009
M87

• Largest galaxy in the Virgo cluster.
• Located about 16 Mpc away.
• Active galactic nucleus (AGN) powered by a supermassive black hole ($6.5 \times 10^9$ 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

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

- Jet Formation
- 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


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

- [http://www.cv.nrao.edu/course/astr534/Interferometers2.html](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.
Acknowledgements

- Mentor: Shep Doeleman
- Vincent Fish, Chris Beaudoin, Mike Titus
- Phil Erickson, KT Paul, Madeleine Needles
- Haystack Observatory
- Rivier College
- My fellow REUs