The Innermost Regions of Relativistic Jets and Their Magnetic Fields

Theory, simulations, and observations of AGN jets from radio to gamma-rays

Granada (Spain), June 10th-14th, 2013

Topics Covered:

- Jet formation
- Black hole, accretion disk, jet connection
- Multi-spectral-range emission
- Magnetic fields and polarization
- Jet dynamics and stability
- Unification models, microphysics, particle acceleration
- Relativistic stellar jets

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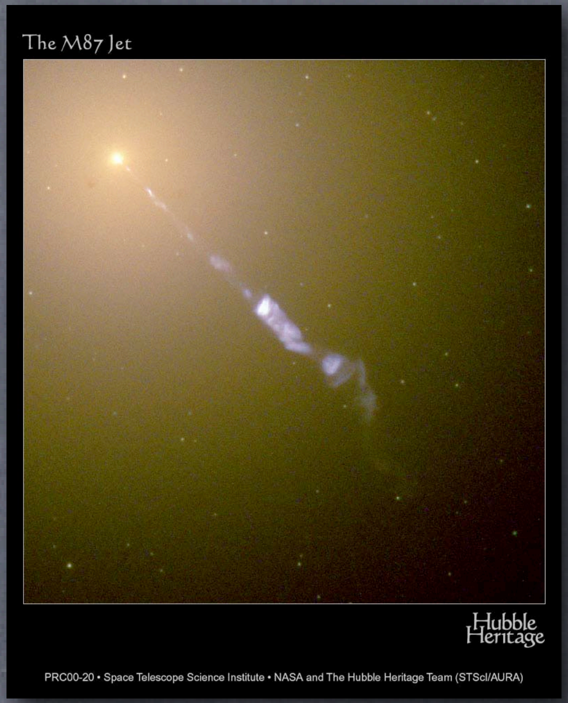
This conference would correspond to the “extended” version of previous “Relativistic Jet Physics” workshops in 1998, 1999, and 2005.

For some rather unknown reason better known as the “Tapas” workshops.

First or second (?) “Tapas” Workshop

Third “Tapas” Workshop

The early days



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It took, however, more than half a century until Martin Rees realized in 1971 that the mysterious “ray” in fact corresponds to a permanent channel, or jet, along which mass, energy and electromagnetic field are conveyed at relativistic speeds.

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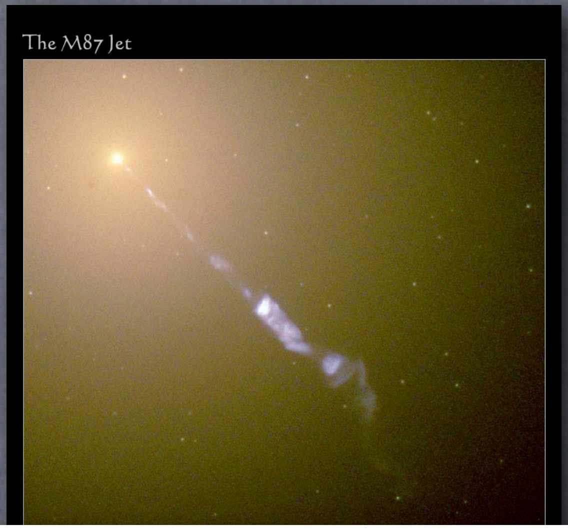

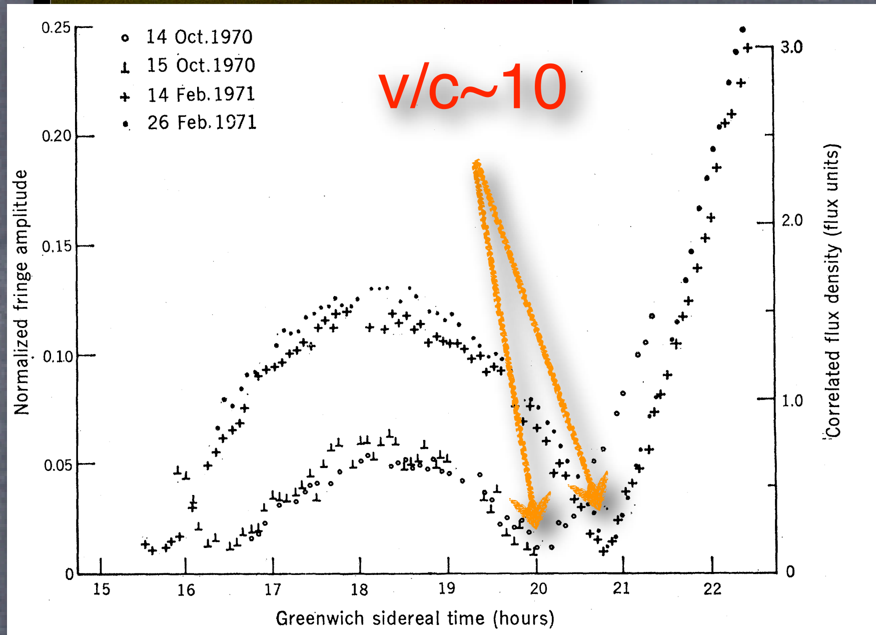

Fig. 1. Fringe-amplitude data from observations of 3C 279 with the Goldstone-Haystack interferometer. Each point is based on 110 seconds of integration.

Whitney et al. (1971)

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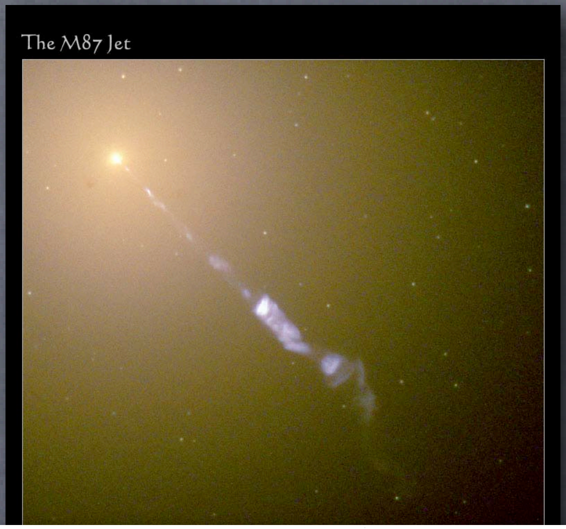
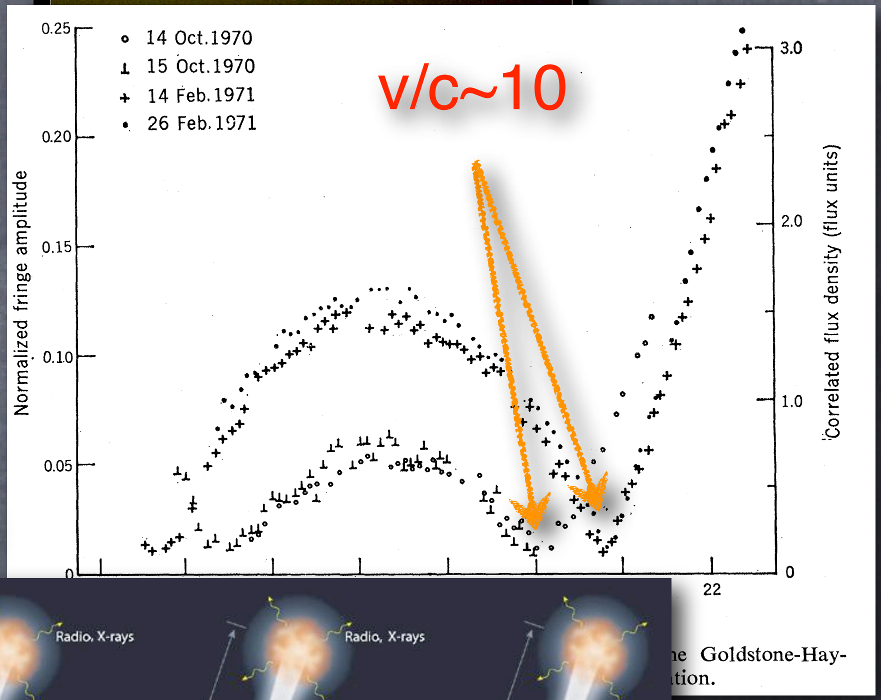


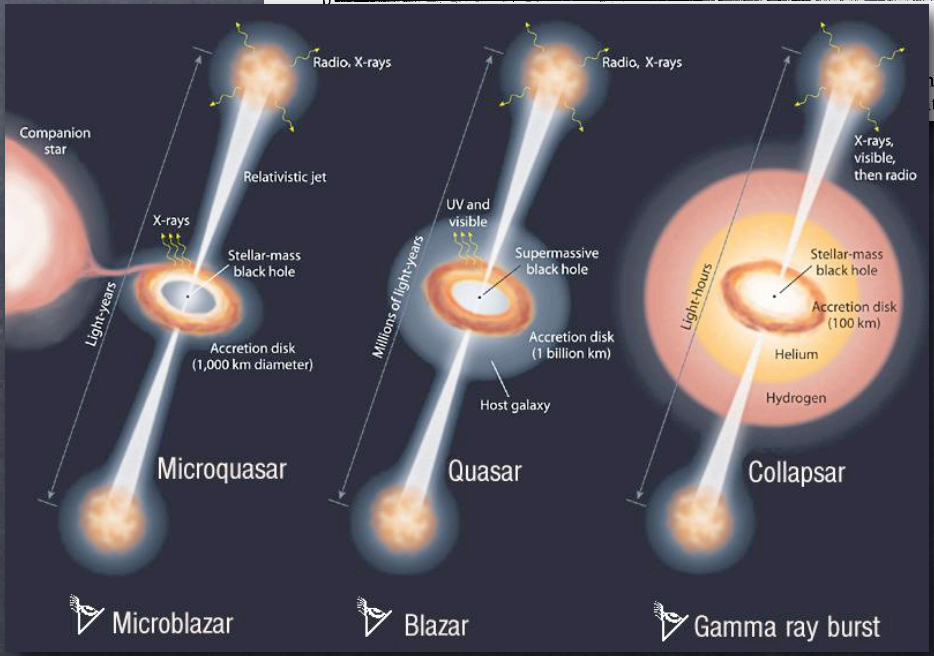


(1971)

Jets everywhere!

Relativistic jets are usually associate with AGN, but jets are seen in other multiple astrophysical systems:

- Microquasars (Mirabel et al., Nature, 2001)
- GRBs (Sari et al., ApJ, 1999)
- Tidal disruption flares (Burrows et al., Nature, 2011)
- Pulsars (Velusamy, Nature, 1984)
- Supernova (Paragi et al., Nature, 2010)
- Dwarf Nova (Körding et al., Science, 2008)
- AGB stars (Sahai et al., Nature, 2003)
- Star formation (Carrasco-Gónzalez, et al., Science, 2010)
- Planetary nebulae (Soker & Livio, ApJ, 1994)
- Sun (Cirtain et al., Science, 2007)
- Even in planets! (Sánchez-Lavega et al., Nature, 2008)



Mirabel & Rodriguez (2002)

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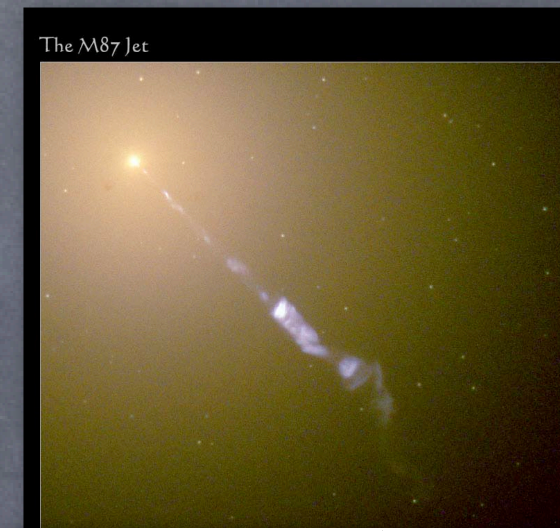

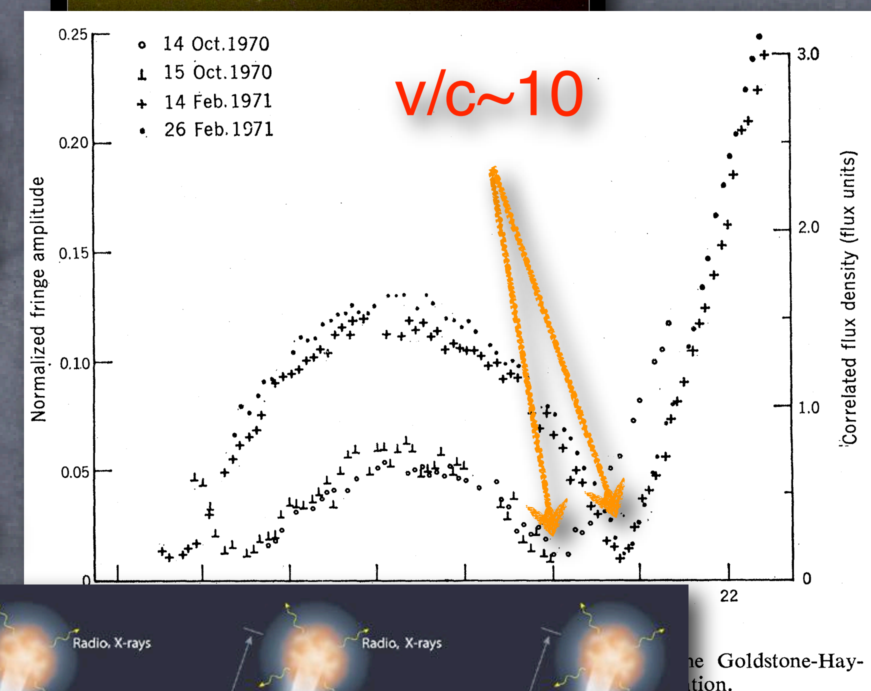

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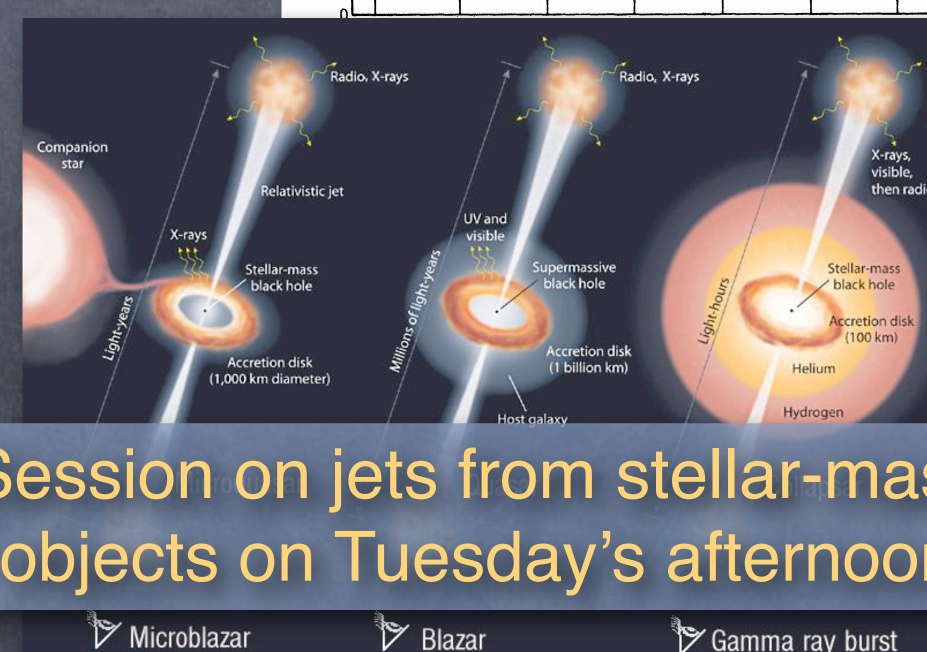


Session on jets from stellar-mass objects on Tuesday’s afternoon

Mirabel & Rodriguez (2002)

Polarization

First polarimetric VLBI observations were performed in the early 70’s by the Brandeis group (Wardle 1971), followed by direct imaging of the polarization in the jet components, and detailed studies of the polarization differences among the different AGN populations (e.g., Gabuzda et al. 1989).

We are lucky to have in our meeting two review talks by the “father” (John Wardle) and the “mother” (Denise Gabuzda) of polarimetric VLBI !!

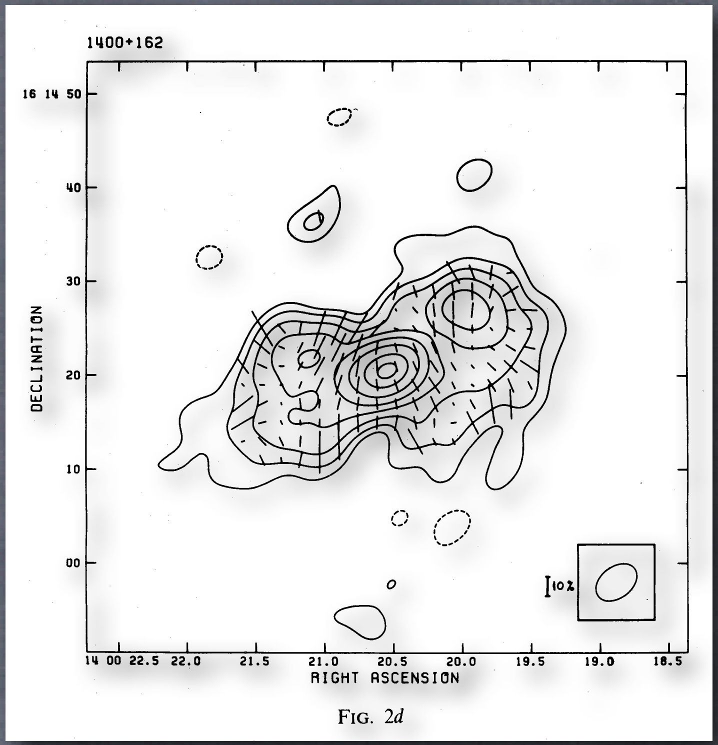


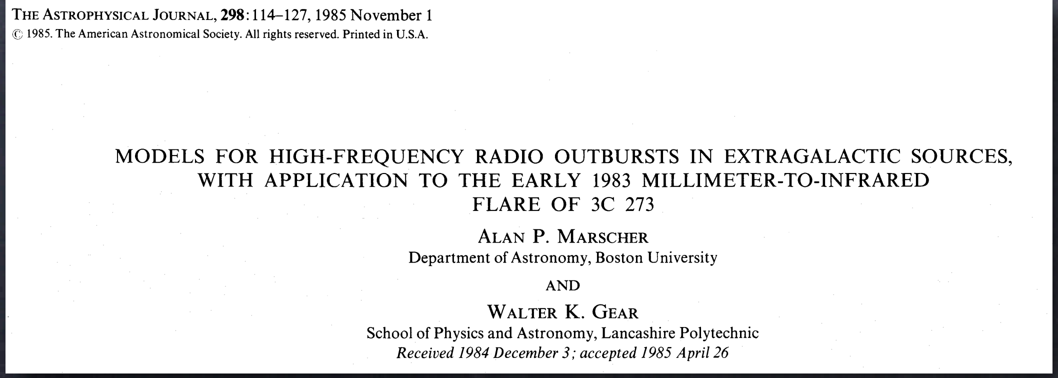
FIG. 2d

Wardle et al. (1984)

The shock-in-jet model

In 1985, two seminal papers, Marscher & Gear (1985) and Hughes, Aller & Aller (1985), established the “shock-in-jet” model, which explains the “knots” observed moving at superluminal speeds as produced by shocks in a relativistic jet.

The observed higher polarization in the components is then explained as produced by the shock compression of the magnetic field.



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MODELS FOR HIGH-FREQUENCY RADIO OUTBURSTS IN EXTRAGALACTIC SOURCES, WITH APPLICATION TO THE EARLY 1983 MILLIMETER-TO-INFRARED FLARE OF 3C 273

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AND

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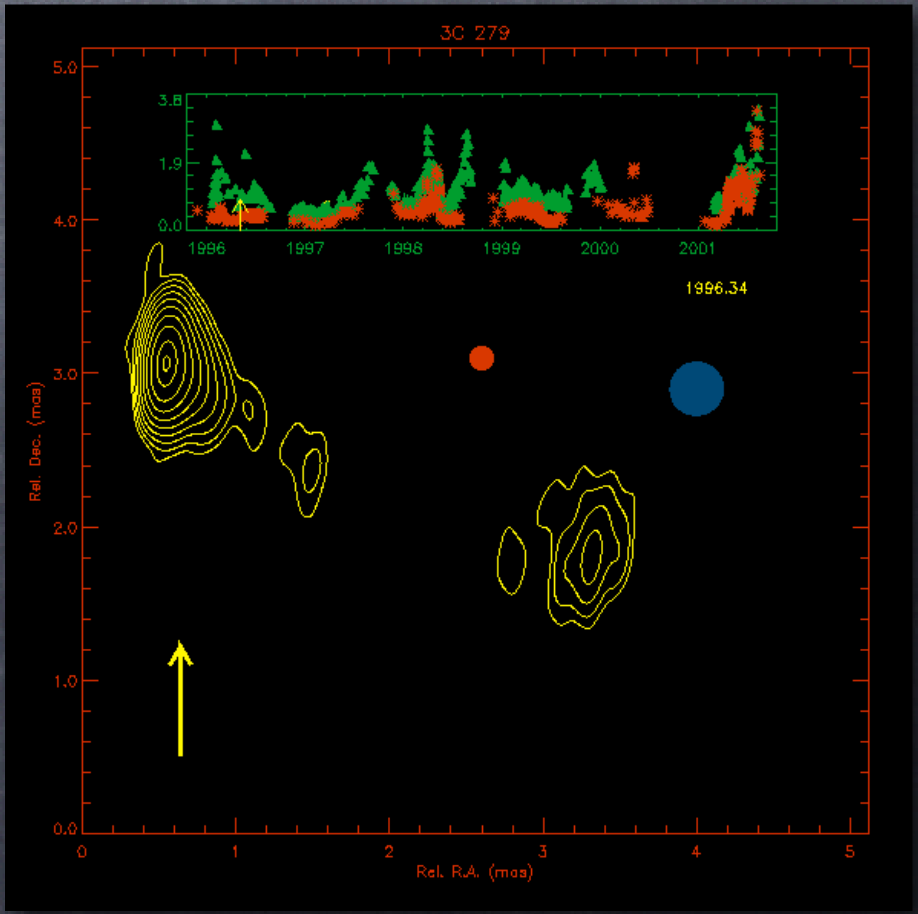
School of Physics and Astronomy, Lancashire Polytechnic

Received 1984 December 3; accepted 1985 April 26

Marscher & Gear (1985)



3C279 movie by the Boston group

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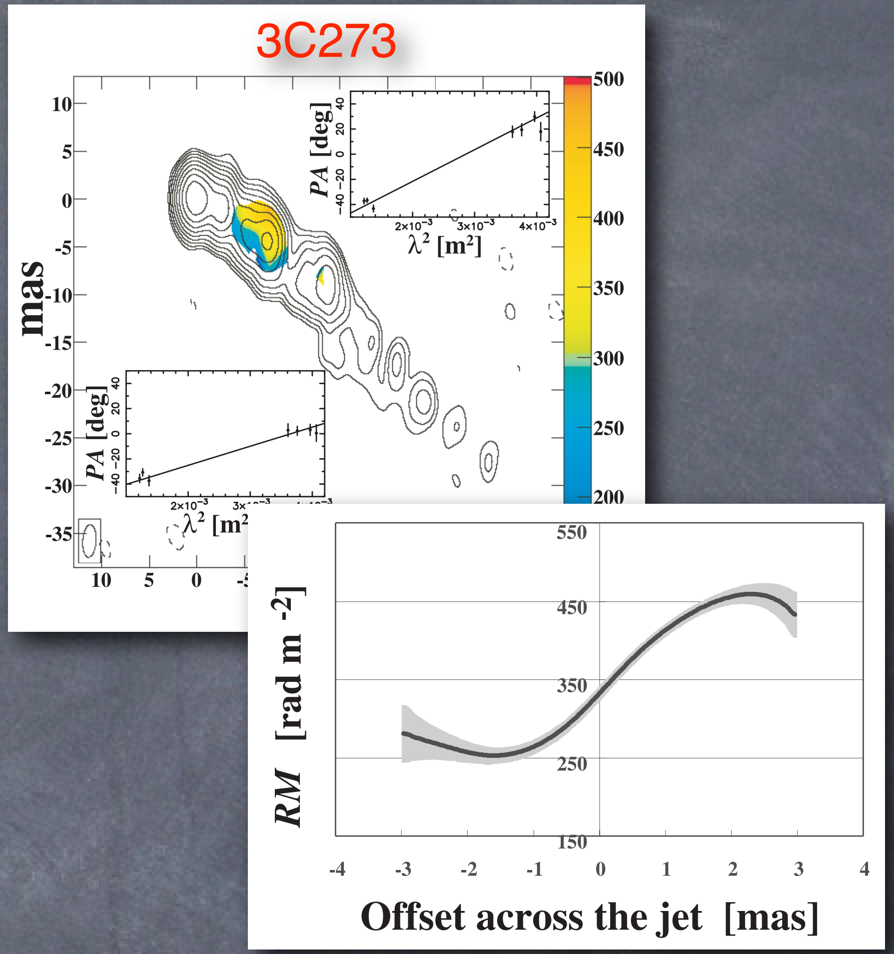
Helical magnetic fields?

Robert Laing in 1981 first suggested that is possible to detect the presence of helical magnetic fields by looking for a stratification in Faraday rotation (as well as total and polarized intensity) across the jet width.

First observational indication was obtained by Asada et al. (2002), in observations of 3C273, followed by others (e.g., Gabuzda 2004; Gómez et al. 2008).

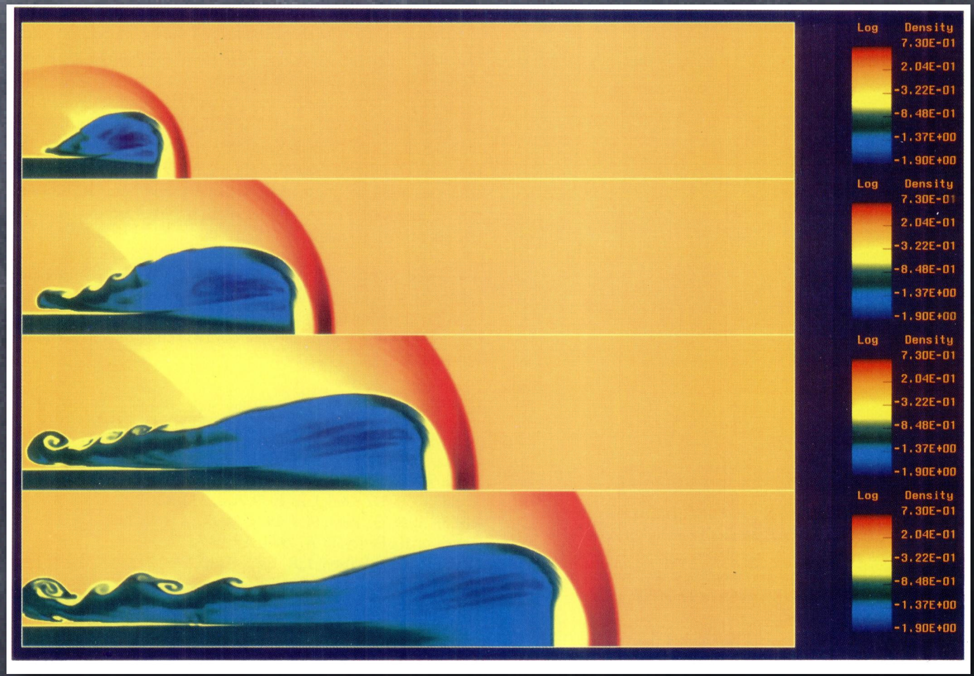


Asada et al. (2002)

Magnetic fields and jet physics to be discussed on Thursday and Friday

Numerical simulations

Newtonian simulations performed by Norman in the 80's were followed by the first *relativistic* HD simulations by the Univ. of Valencia's group (Martí et al. 1994), Michigan and Leeds Univ.



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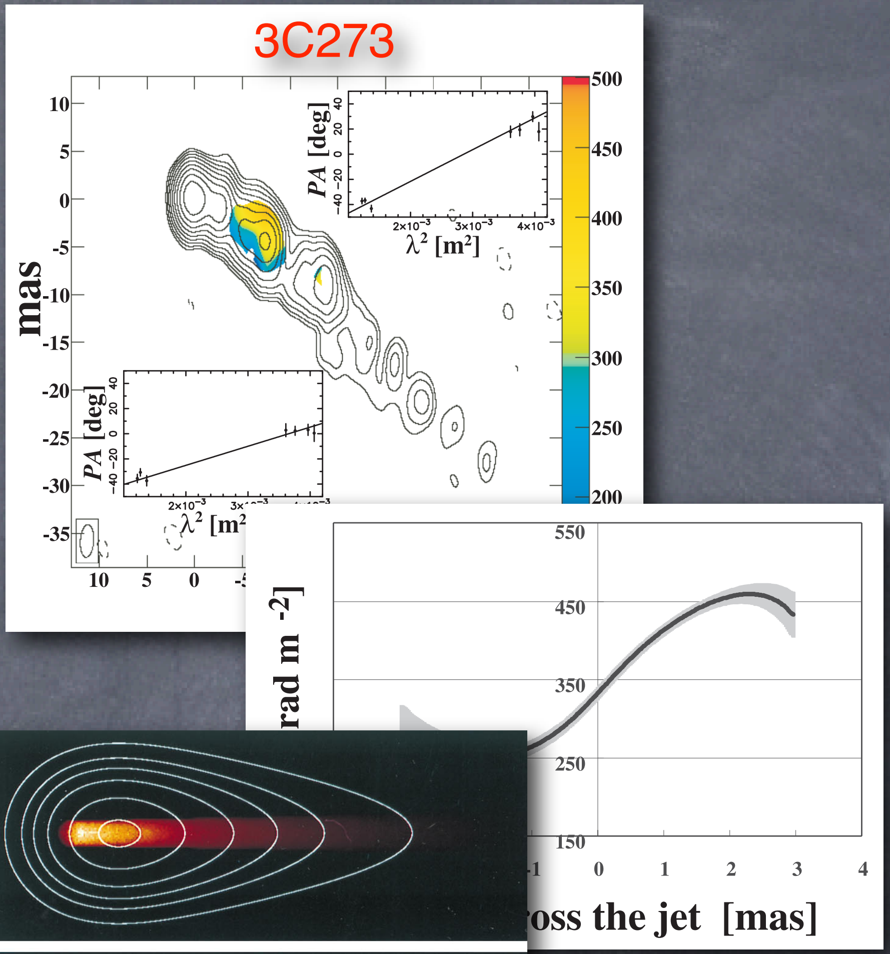

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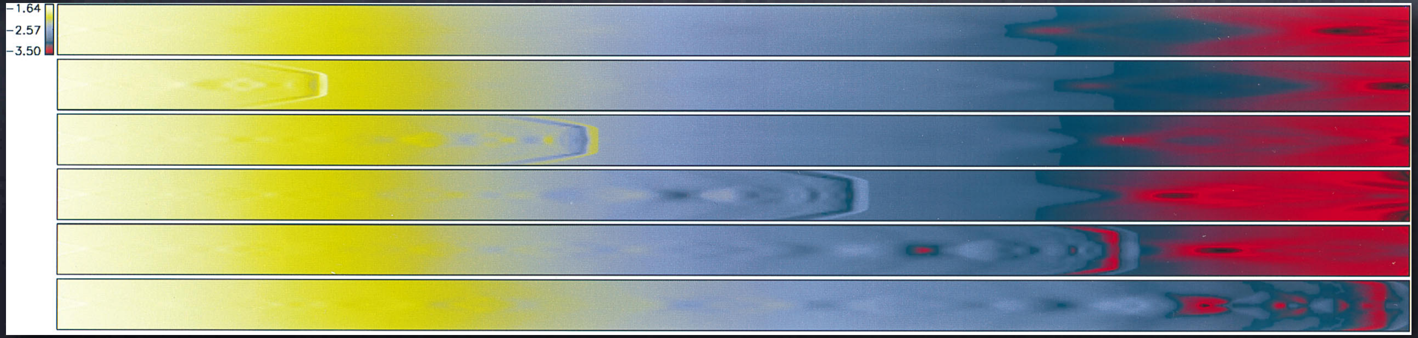
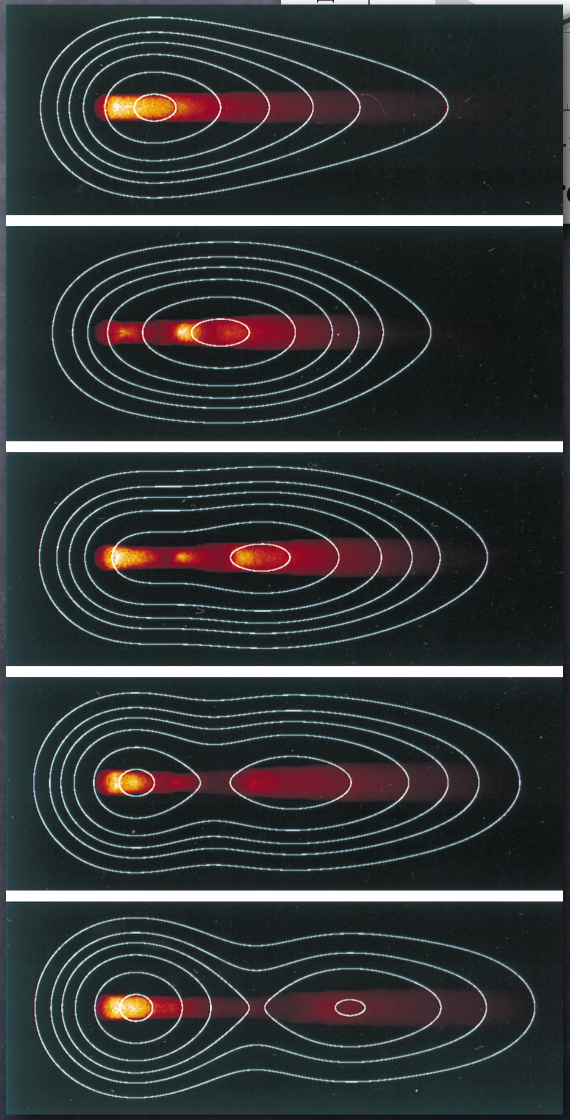
Computation of the emission from the RHD models provided the first synthetic maps to be directly compared with VLBI observations (Gómez et al. 1995; Komissarov & Falle 1997; Mioduszewski et al. 1997).



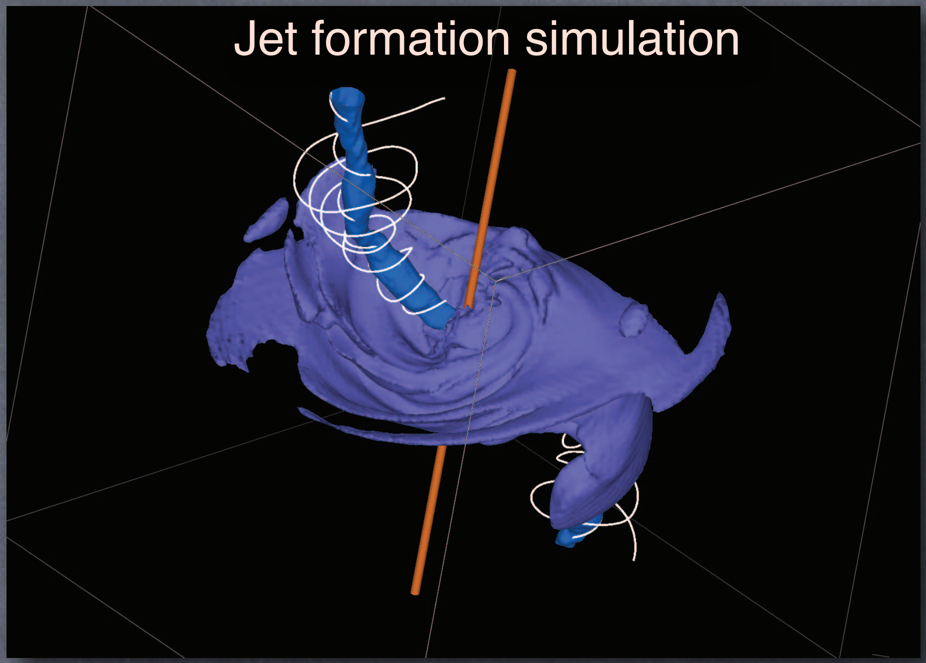


Gómez et al. (1997)

General Relativity Resistive Magneto Hydrodynamical Simulations

In the last decade we have witnessed an impressive development on numerical simulations. GRMHD simulations are now capable of simulating jet formation (e.g., McKinney et al. 2013).

Look for upcoming simulations coupling resistive GRMHD, microphysics, electron energy transport and emission at high energies, to provide a comprehensive self-consistent "super" simulation of relativistic jets.



McKinney, Tchekhovskoy & Blandford (20013)

(G)RMHD simulations on Monday.
MWL simulations on Wednesday

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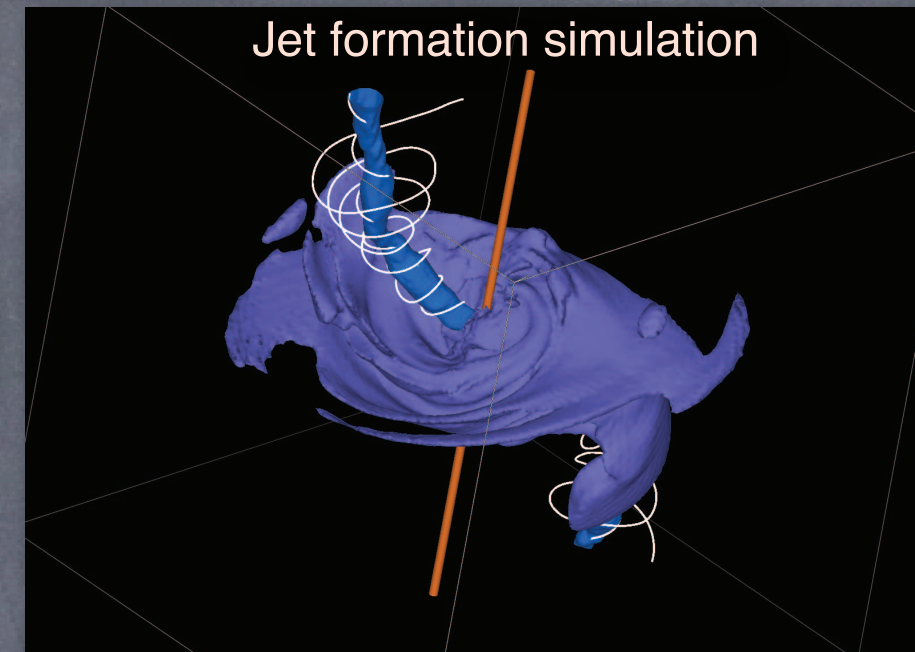


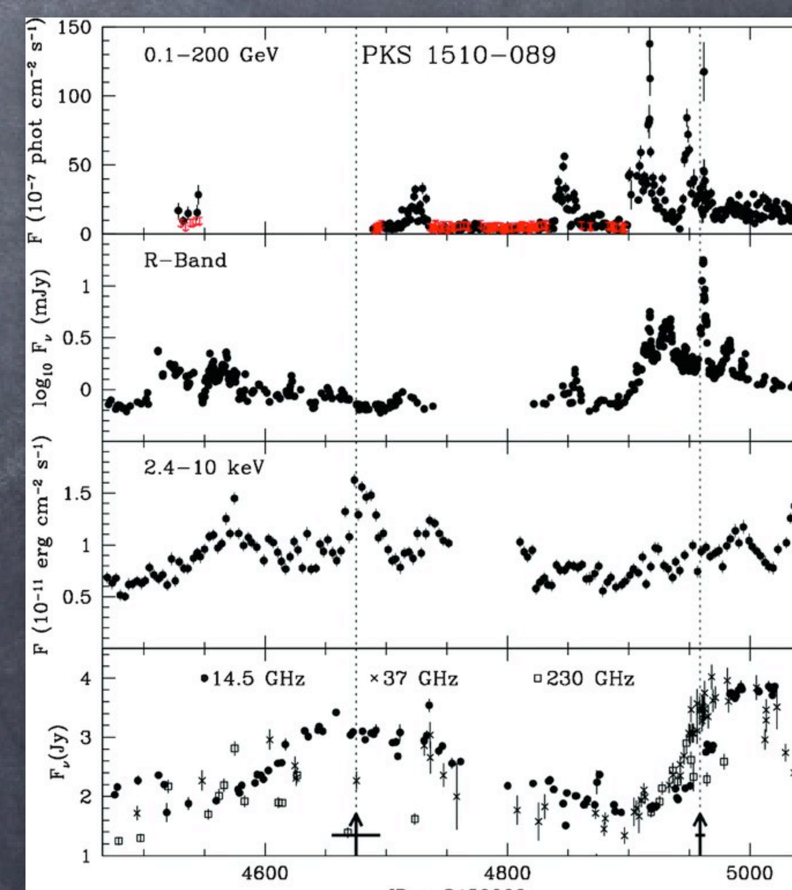
McKinney, Tchekhovskoy & Blandford (20013)

The radio-gamma connection

Locating the sites and establishing the mechanisms for the high energy emission in blazars has become one of the most active fields.

MWL monitoring programs including Fermi, Cherenkov telescopes, X-ray, optical, mm and radio-wavelengths, combined with VLBI monitoring (Boston group, MOJAVE, TANAMI), are allowing to address these questions for the fist time.

Are gamma-rays produced within the BLR (e.g., Tavecchio et al. 2010) or parsecs away (e.g., Marscher et al. 2010)?



Marscher et al. (2010)

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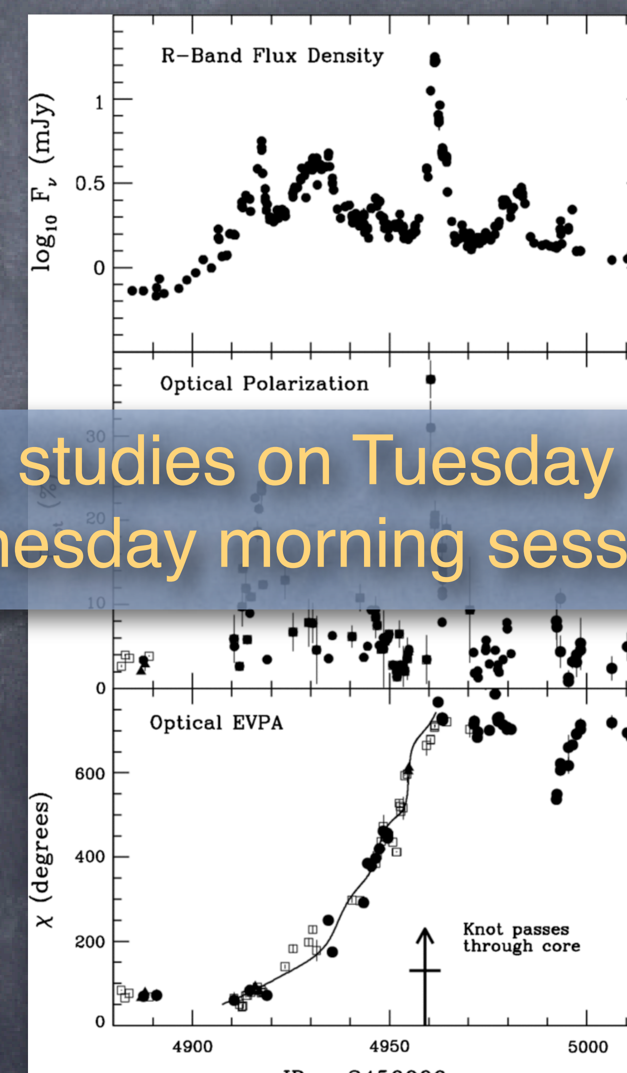
MWL observations are also providing information about the ACZ, suggesting the existence of helical fields and the possibility that the radio core is a recollimation shock, leading to gamma-ray flares when new components pass by (Marscher et al. 2010).



MWL studies on Tuesday and Wednesday morning sessions

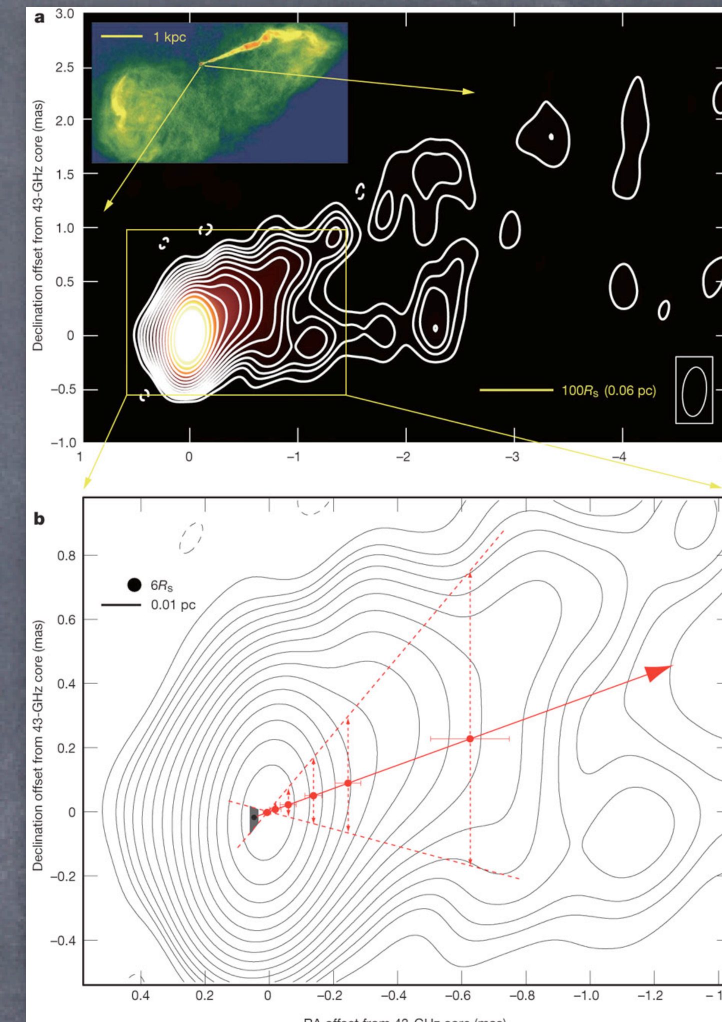
Marscher et al. (2010)

Imaging (and simulating) the innermost jet regions

Imaging the acceleration and collimation zone, determining the distance between the central black hole and radio core, and ultimately imaging the black hole silhouette remain one of the main challenges.

Great progress through numerical simulations (e.g., Dexter et al. 2012), multi-frequency phase-reference observations (e.g., Hada et al. 2011), and mm-VLBI observations (e.g., Doeleman et al. 2012).

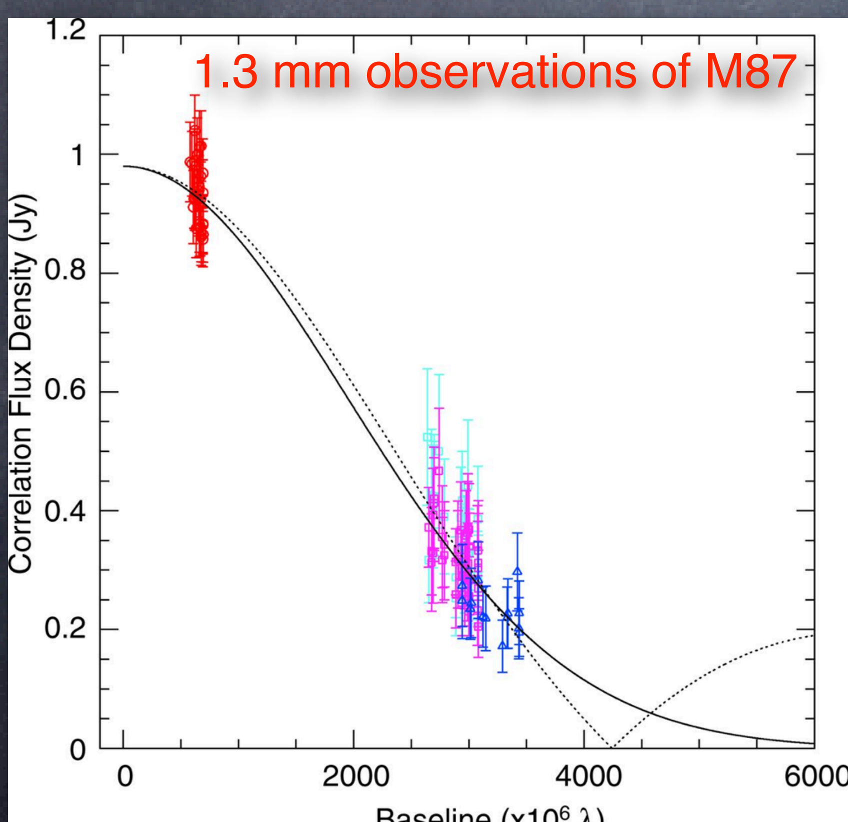
The inclusion of ALMA in mm-VLBI and RadioAstron holds great expectations for future imaging of the innermost jet regions.



Hada et al. (2011)

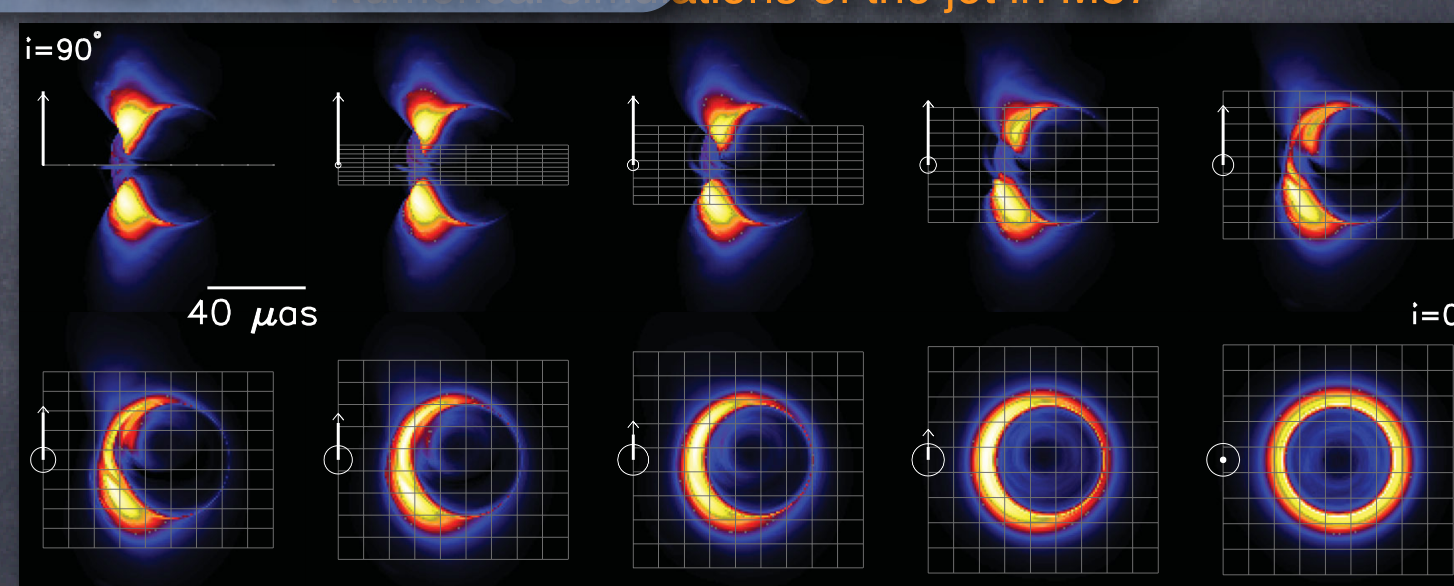
Jet formation on Monday.
RadioAstron on Friday.

Summary talk by
Alan Marscher



Doeleman et al. (2012)

Numerical simulations of the jet in M87



Dexter, McKinney & Agol (2012)

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