JET STUDIES IN LATIN AMERICA

Zulema Abraham
University od São Paulo
Brazil

Outline

- Jets in Quasars
- Micro quasars
- Radio – Optical - High Energy relation
- Future

Quasars in Brazil in the 70s

- Studies started in Brazil in the 70s and in Argentina in the 80s
- Observations in Brazil were made with the 12 m radome enclosed Itapetinga radiotelescope
- Frequencies: 22 GHz and later 43 GHz (1.3 cm and 7mm)
- Objective: detect radioemission from peculiar galaxies, determine the spectra of quasars, study variability
- Of course, nobody knew about the existence of jets in these radiosources

What was it known at that time?

- Quasars had large redshifts (discovered in the 60s)
- Question: redshift was cosmological? If so, the bolometric luminosity would be very large.
- In 1964 Sholomitskii reported variability at 32 cm in the source CTA 102, with a timescale of about 100 days.
- By that time Ginzburg and Syrovatskii had already developed the theory of synchrotron emission and inverse self Compton to explain the spectra of quasars
- The calculated brightness temperature of CTA 102 exceeded 10^{12} K, not allowed by the "Compton Catastrophe"

Quasars are at cosmological distances?

- The detection of a source with $T_B > 10^{12}$ K incentivated the belivers of non-cosmological origin for the redshift.
- Rees in 1966 presented a model of relativistically expanding source that could explain the observations.
- This controversy estimulated the observations of variability, and several works were published, led by Pierre Kaufmann between 1974 and 1979.
- In particular, variability was reported in Centaurus A by his group, but contested by Fogarty & Schuch (1975)
- Controversy showed the need to improve calibration, pointing and sky subtraction in the observations.

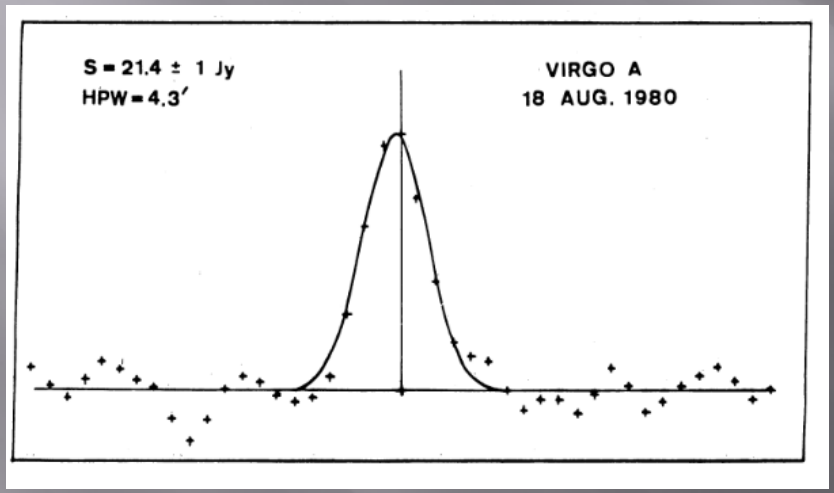
Improvements at Itapetinga in the 80s

- I joined the group in 1978 and was given the task to improve the observing modes.

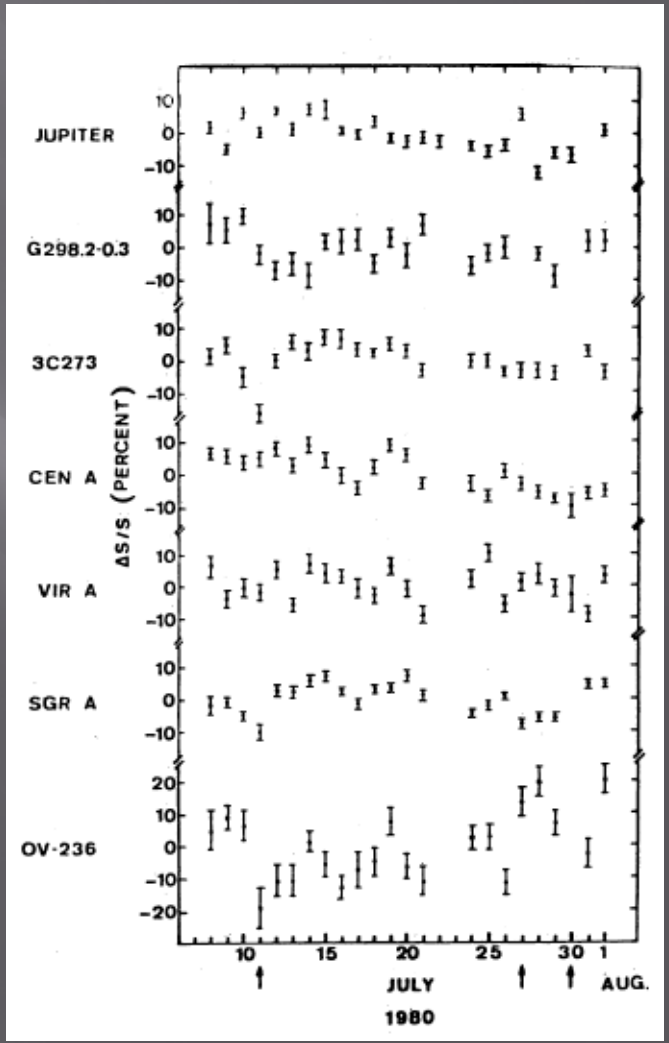
- ON-OFF duration was decrease from 1 min to 20 sec
- Scan technique was developed (on the fly)
- Pointing models were developed
- Atmospheric opacity was eliminated by calibration with a room temperature load and a noise source.

Search for daily variability

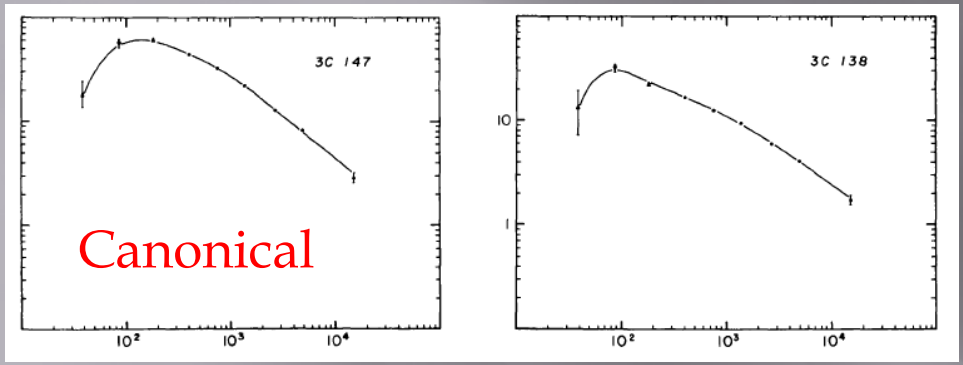
Abraham, Kaufmann & Botti (1982)



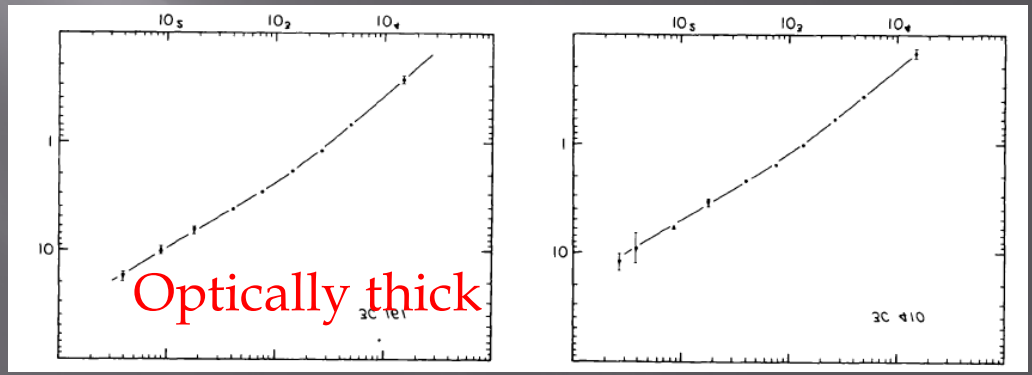
Calibrator

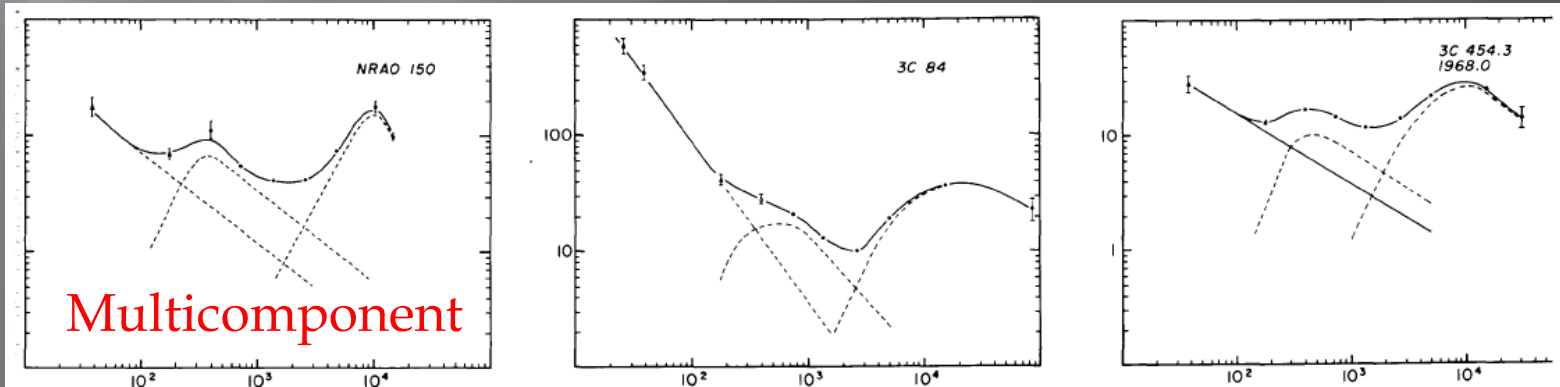


The spectra of Quasars



Kellermann & Pauliny-Toth (1969)



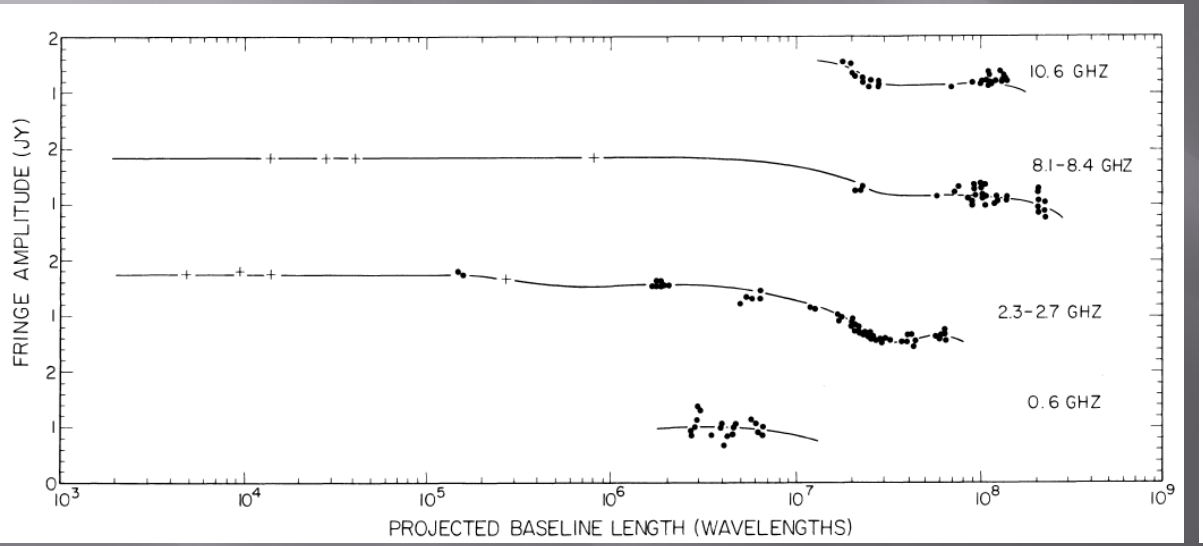


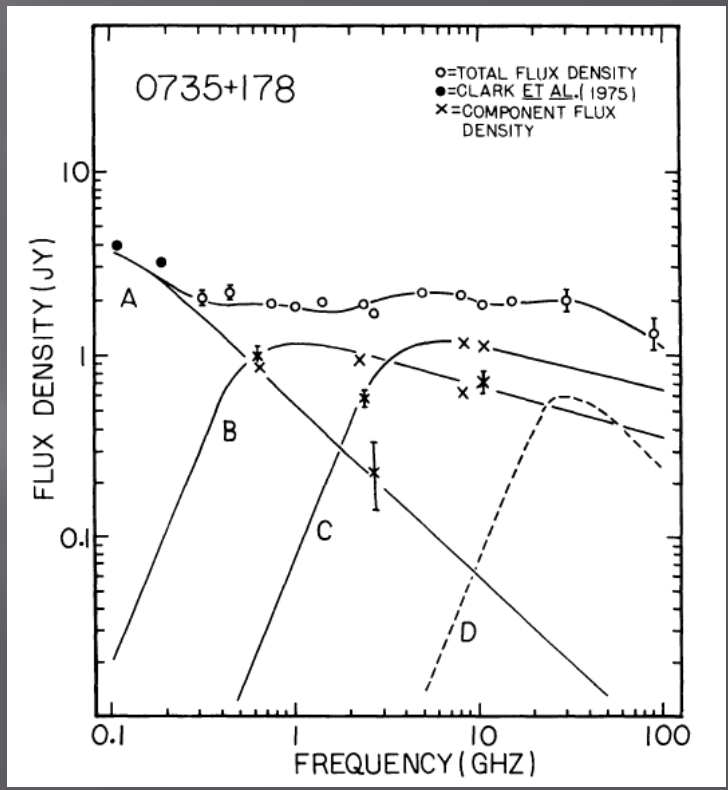
The Cosmic Conspiracy

- Many quasars presented a flat spectrum, difficult to explain with a random combinations of canonical sources.
- It was called the Cosmic Conspiracy by Marscher (1980)
- VLBI observations showed that the source 0735+178, which has a very flat spectrum has several components
- However, the VLBI observations did not provide images, but were the results of very simplified models.
- Again, this motivated further studies at Itapetinga

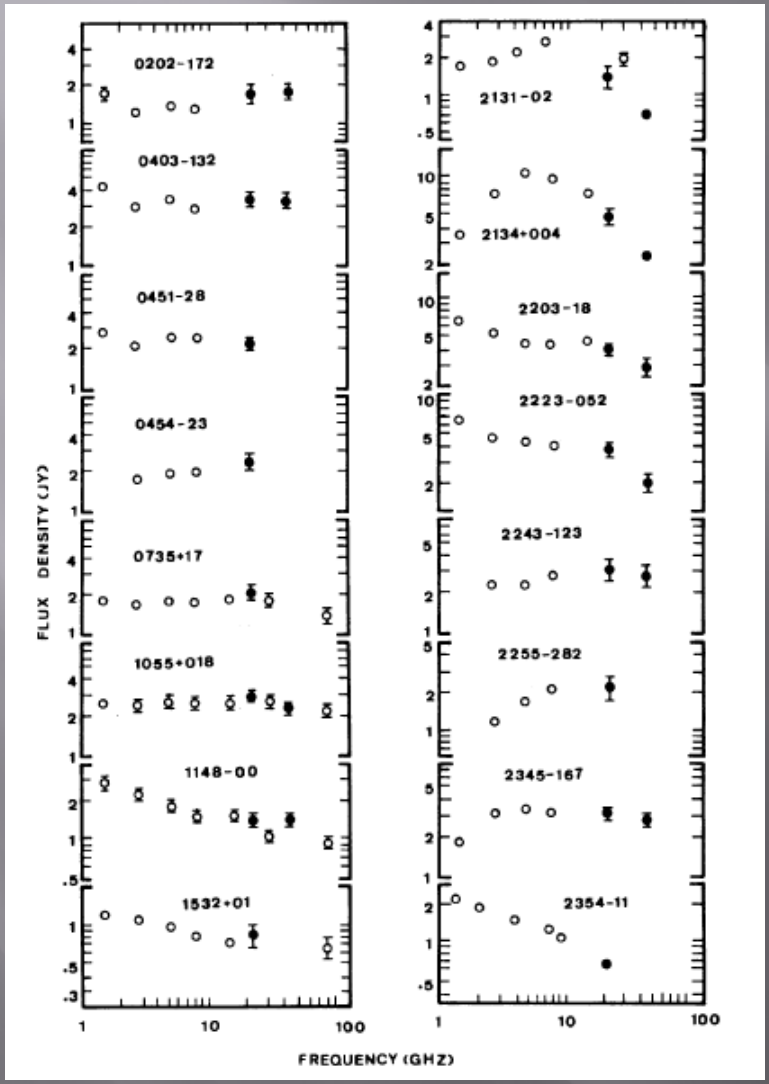
Superposition of components

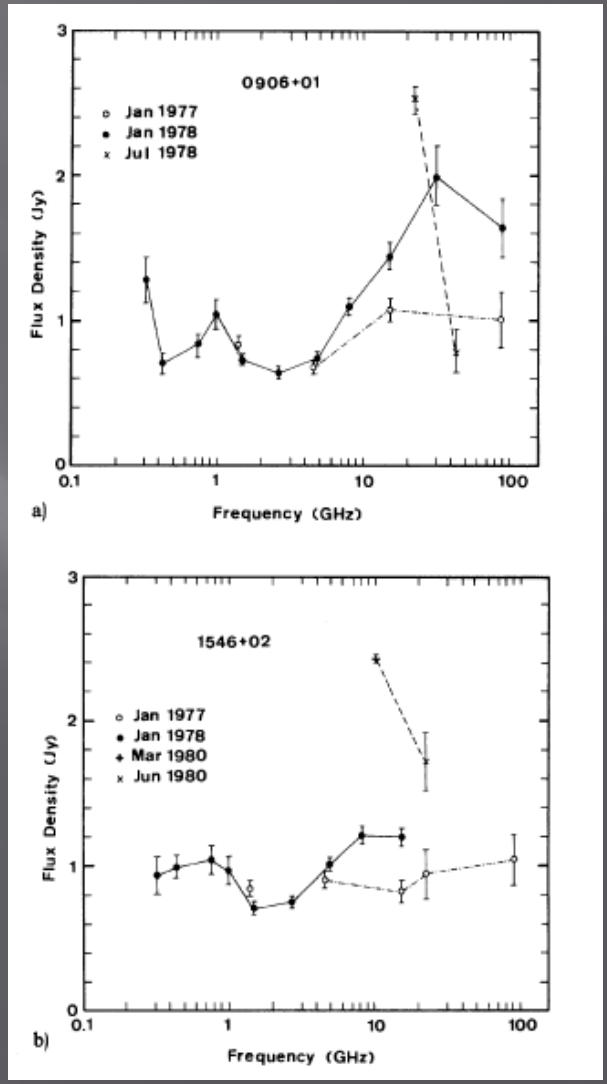
Cotton et al. (1989)





Abraham, de Medeiros & Kaufmann (1984)

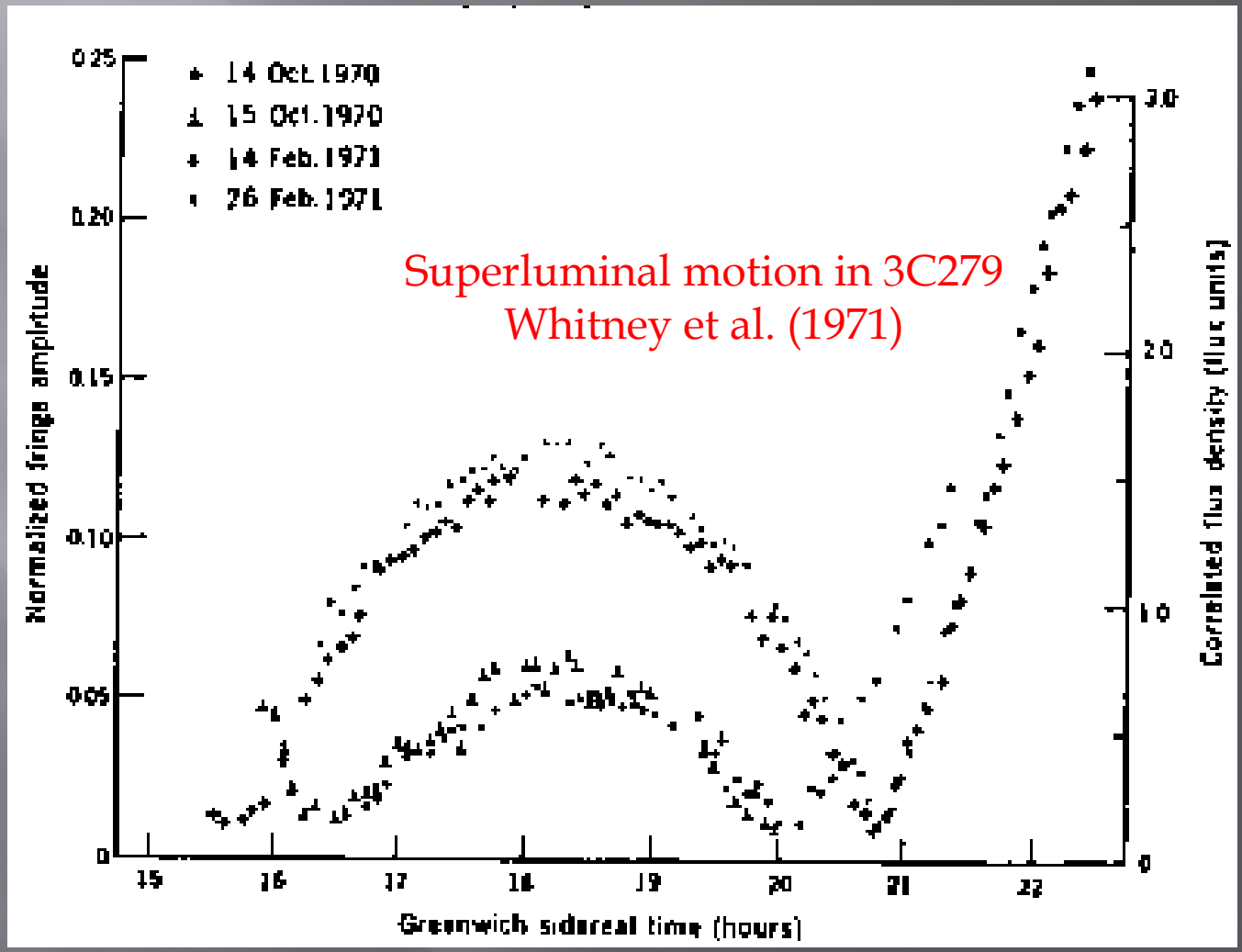




First Observations in Argentina in the 80s

- They started in the early 80s, at 1420 MHz, with one of the 30 m antennas of the Instituto Argentino de Radioastronomia, IAR
- Observations of BL Lac objects were made in 1982-1983 to search for variability (Colomb et al. 1985).
- A more detailed study was conducted between 1983 and 1985, with weekly observations (Giacani et al. 1985)

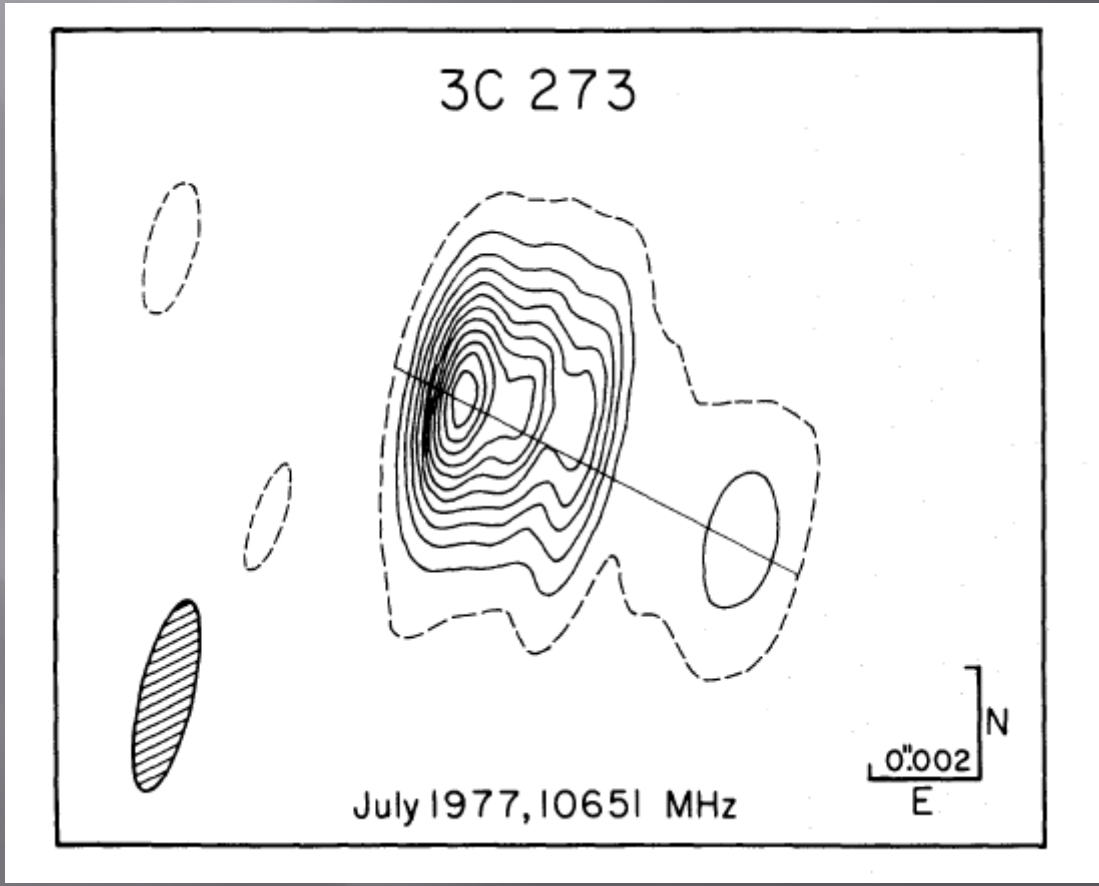
First VLBI observations



Superluminal motion in 3C279
Whitney et al. (1971)

Hybrid mapping

Readhead et al. (1979)



Shocks in Jet Models

- In 1979 Blandford & Konigel introduced the model of shocks in a supersonic jet to explain the newly discovered jets.
- In 1985 Marscher & Gear extended this model to explain a IR-to-radio flare observed in 3C273 in 1983.
- The model predicted delays between the maxima at different frequencies
- It was used by Botti & Abraham to analyze the light curves at 22 and 43 GHz obtained at Itapetinga with light curves at other frequencies obtained from the literature.

VLBI at Itapetinga in the 80s

- Used the MARK II system, rubidium frequency standard, frequency of 10.7 GHz with a receiver provided by CALTECH.
- Radiotelescopes from USA and Europe were used
- A special sub reflector had to be installed.
- Two sources were observed 3C273 and 3C279 (Biretta et al. 1985, Cohen et al. 1987)
- Diffmap mas not invented yet, workstations were used and displays were not available.
- Observations ended when the system changed to MARK III , with a very expensive recording system.

Biretta et al. (1985)

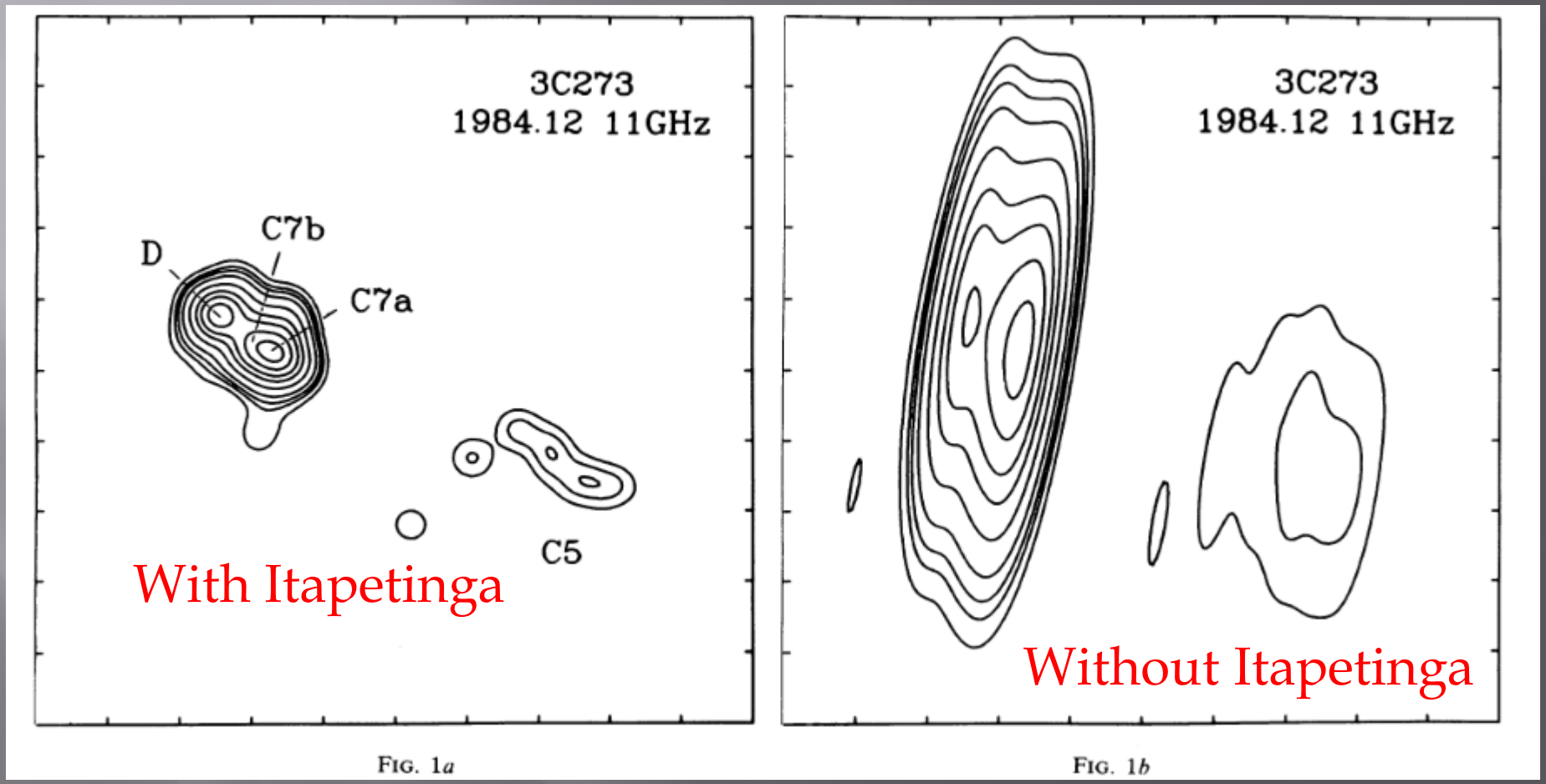
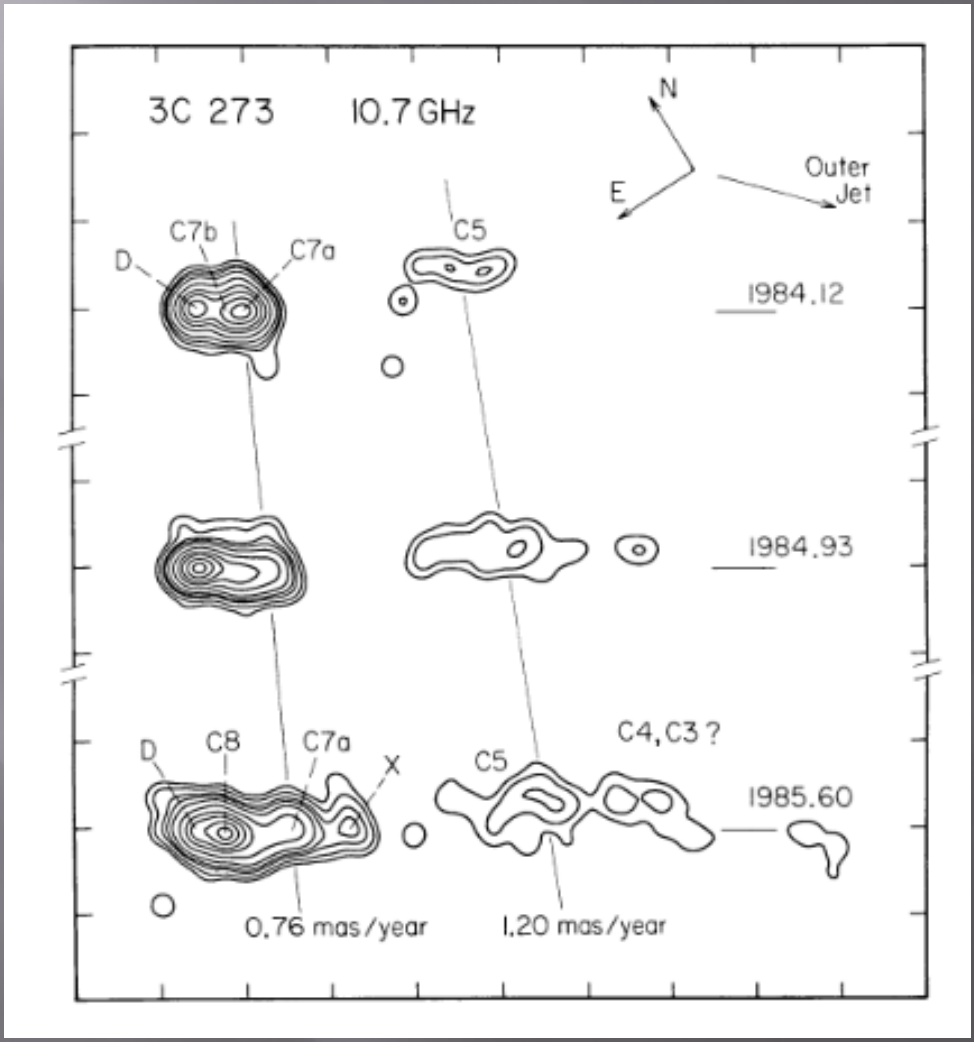


FIG. 1*a*

FIG. 1*b*

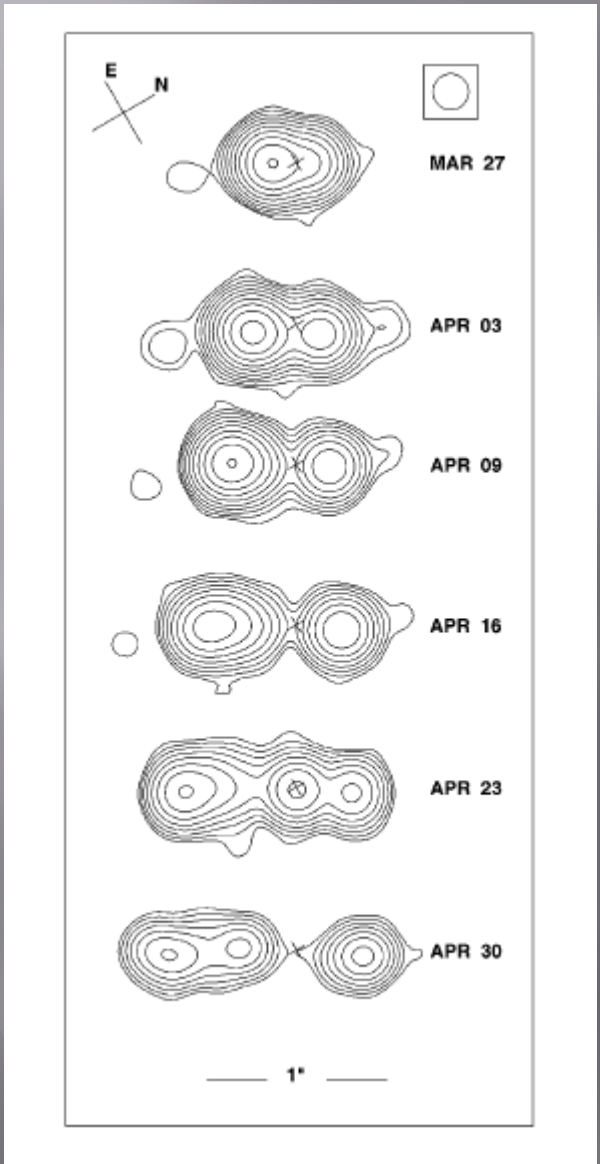
Cohen et al. (1987)

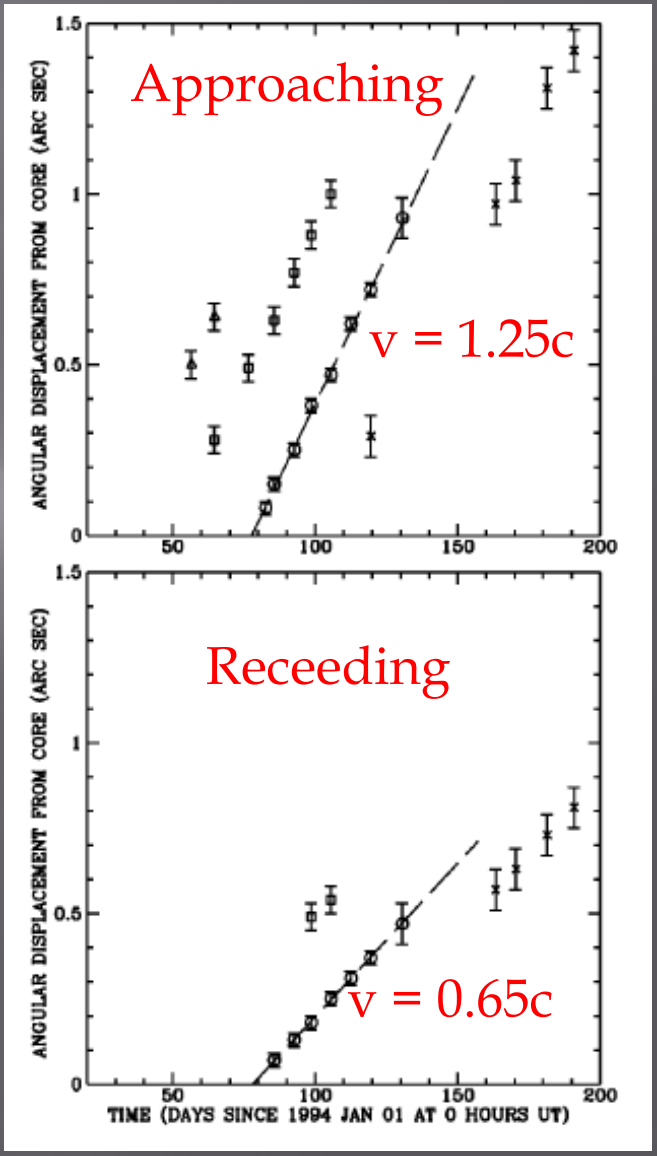


Microquasars (Argentina and Mexico in the 90s)

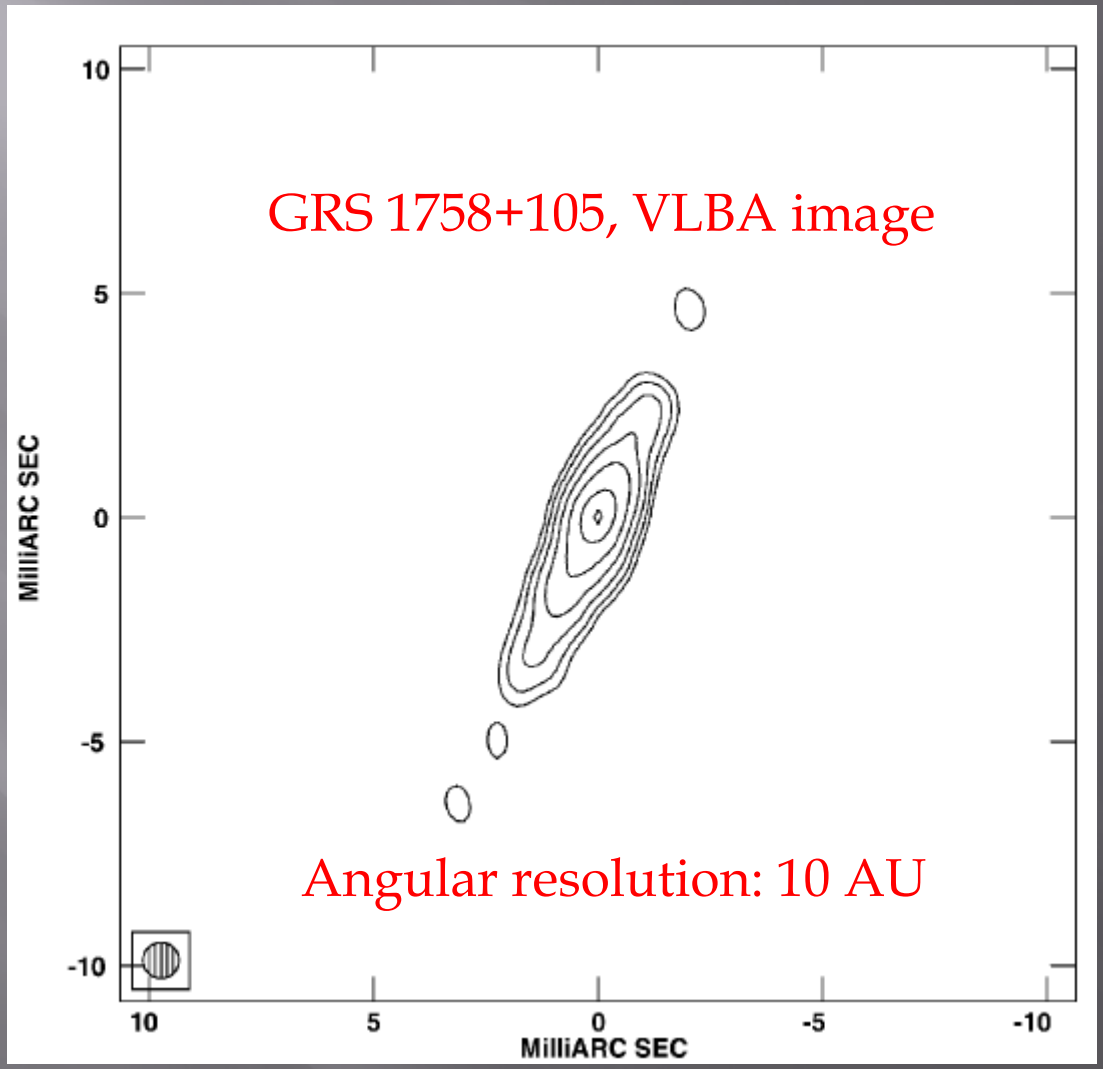
- Relativistic jets were already known in compact objects, like SS433, but not with superluminal velocities.
- In 1992 Mirabel & Rodriguez reported the radio image of a galactic X-ray source, and called it a microquasar.
- In 1994, they discovered the first galactic superluminal source GRS 1915+105
- This was the last necessary proof that the quasars were extragalactic sources.
- Notice that proof of the existence of a black hole in the centers of quasars was only obtained in 1995, with the H_2O masers in NGC 2548.

GRS 1915+105, Mirabel & Rodriguez (1994, 1999)



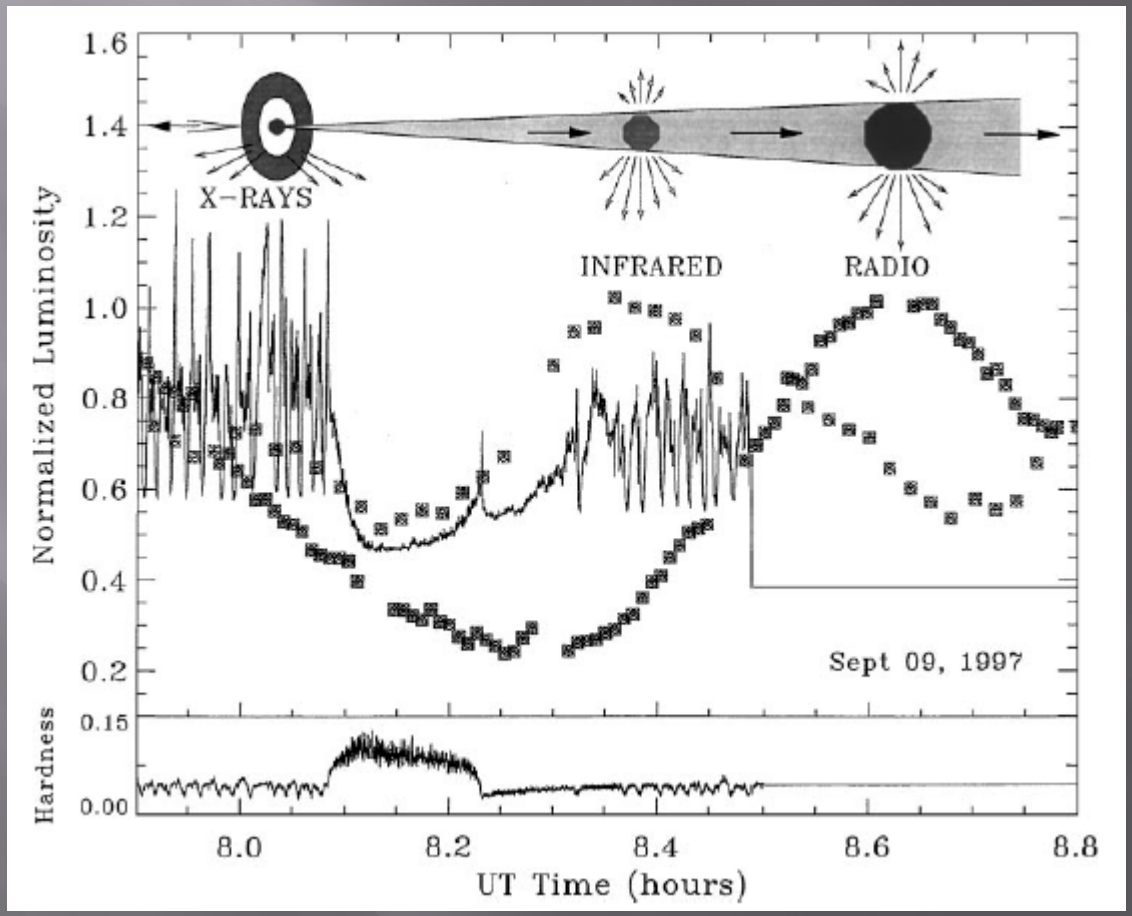


Dhawan et al. (1999)



Relation between X-rays, IR and radio

Mirabel et al. (1988)



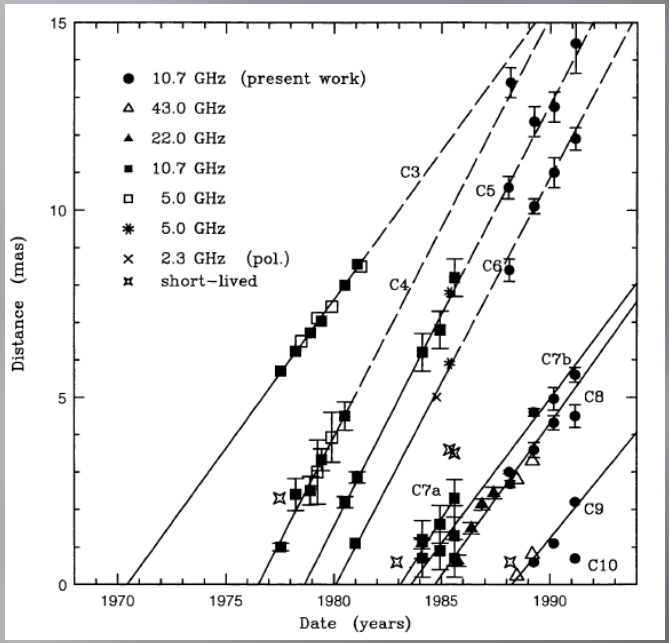
Radio to γ-rays in Argentina in the 90s

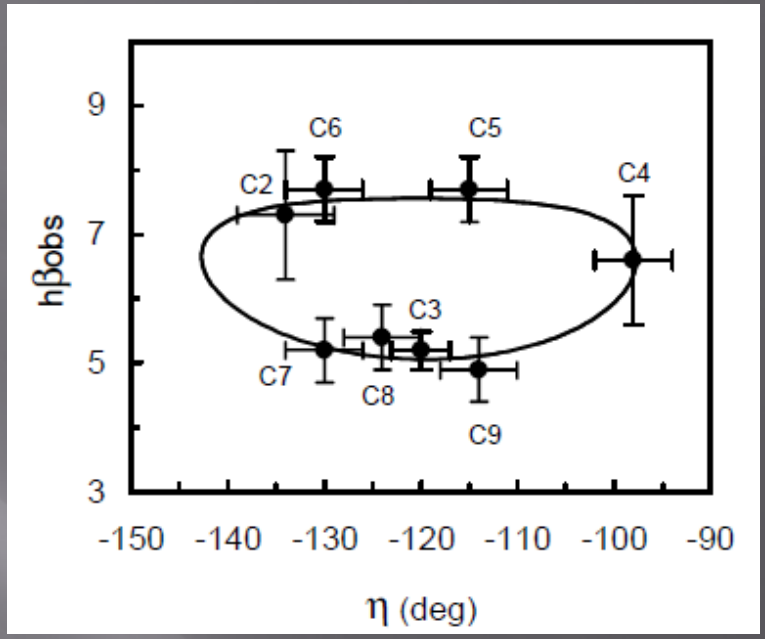
- In the 90s, a new very productive group was born in Argentina, (afterwards called GARRA), which started with radio observations at 1420 MHz and later migrated to high energies.
- The main purpose of the radio observations was to detect short term variability, including intraday, which resulted in several papers published by the group starting in 1993.
- Rapid variability and polarization, probably related to jet components, were studied at optical bands.
- Finally the attention was focused in high energies.

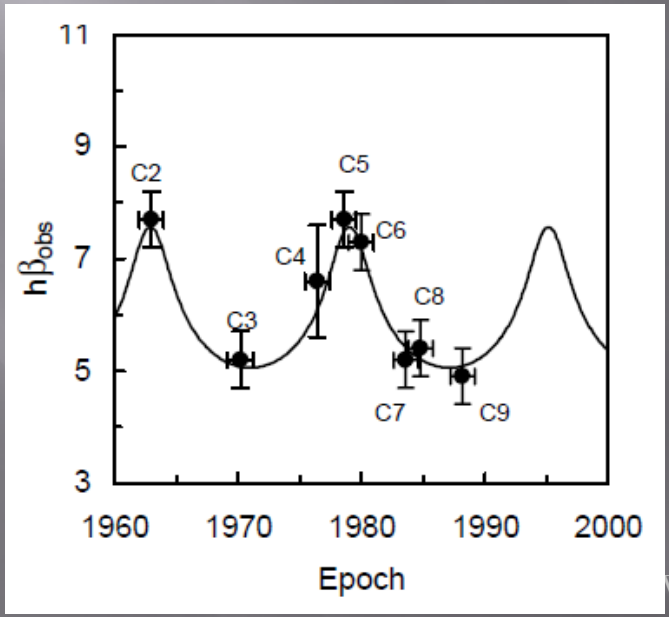
Jets in Brazil in the 90s

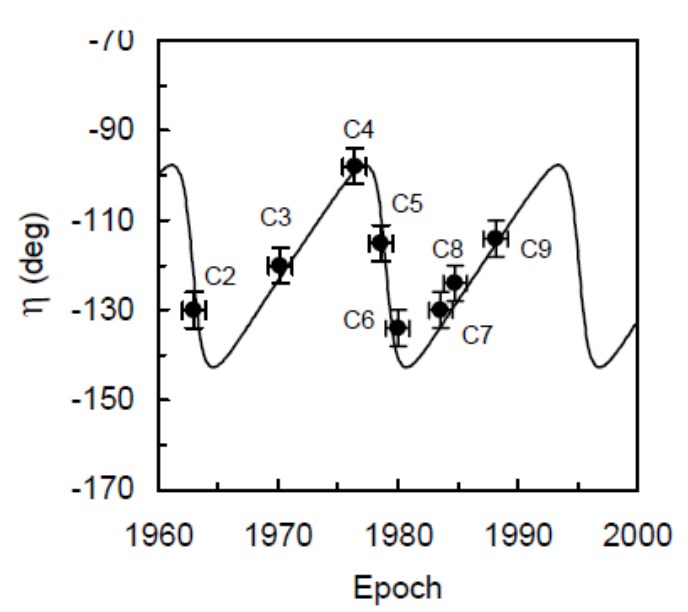
- The work was mostly dedicated to the imaging of some quasars from data obtained from VLBI observations (Carrara et a. 1993, Abraham et al. 1997).
- It was possible to trace the movement of the components, which seemed to be ballistic but with different velocities (Abraham et al 1996).
- It was already known that the components had different position angles in the plane of the sky
- We concluded that the jet could be precessing, maybe as part of a binary system (Carrara et al. 1993, Abraham et al. 1997, Abraham & Romero 1999, Abraham et al. 2000, Romero et al. 2001)

Abraham & Romero (1999)



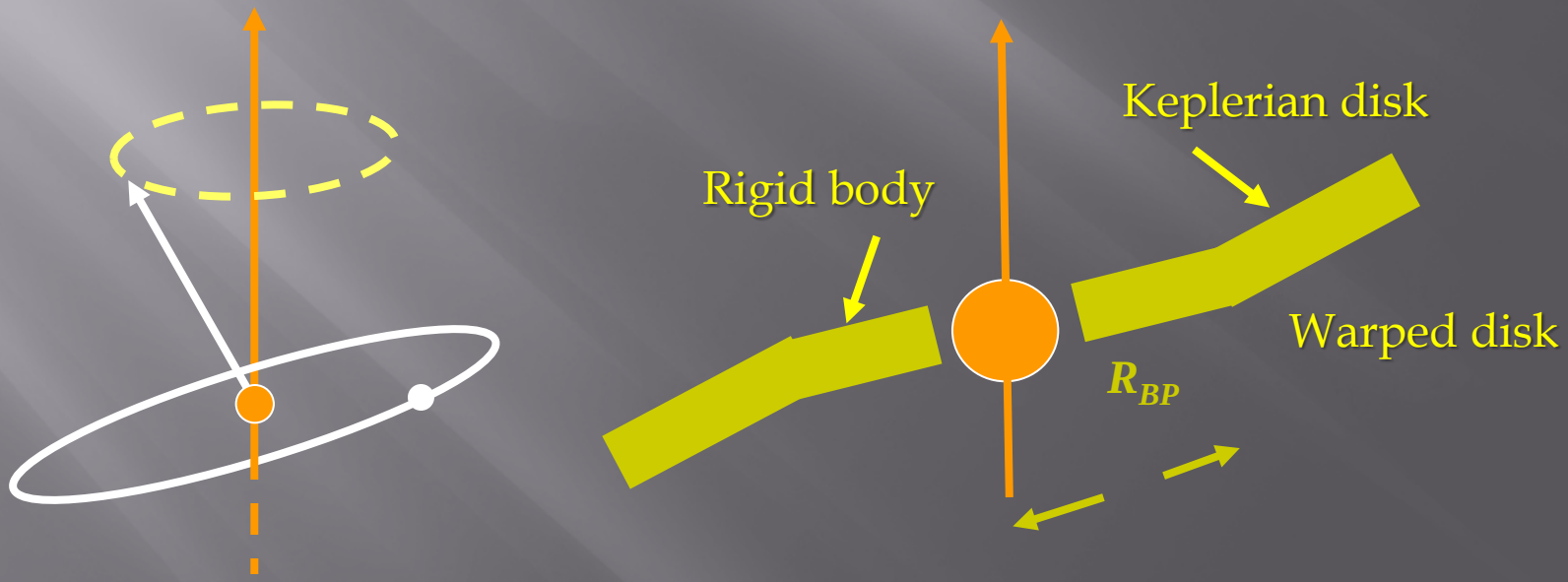






21th Century: Kerr Black Holes and Precession

- Modeling of jet precession in Brazil was extended to other sources and a new mechanism other than binary black hole systems was proposed: the Bardeen-Petterson effect (Caproni et al. 2004)

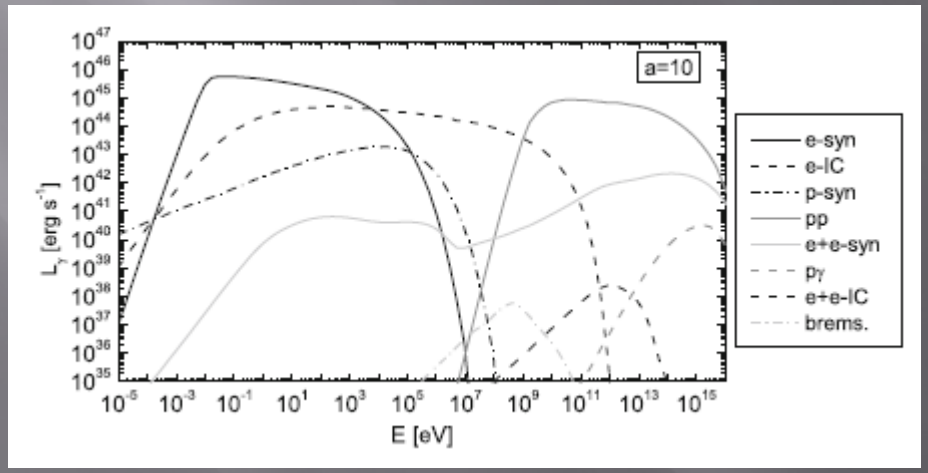


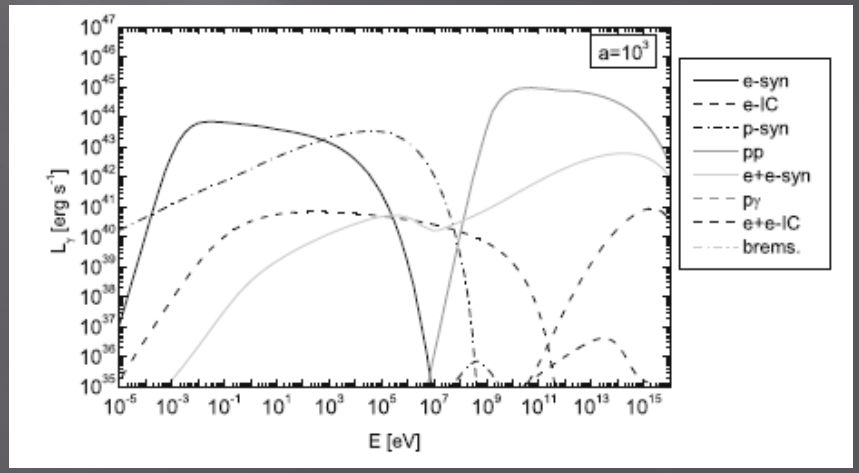
21th Century: Modeling of Jet Superluminal Components

- The ballistic motion of the superluminal components was questioned in some quasars, and accelerated motion were proposed instead.
- This interpretation depended strongly of the identification of the components across the different epochs
- Besides, the separation of a jet in Gaussian components can be questioned.
- To solve this problem we developed the Cross Entropy Method to adjust the components, using random values for their parameters, until the best solution was obtained
- This technique was used to define the components in the jets of several objects (Caproni et al. 2009-)

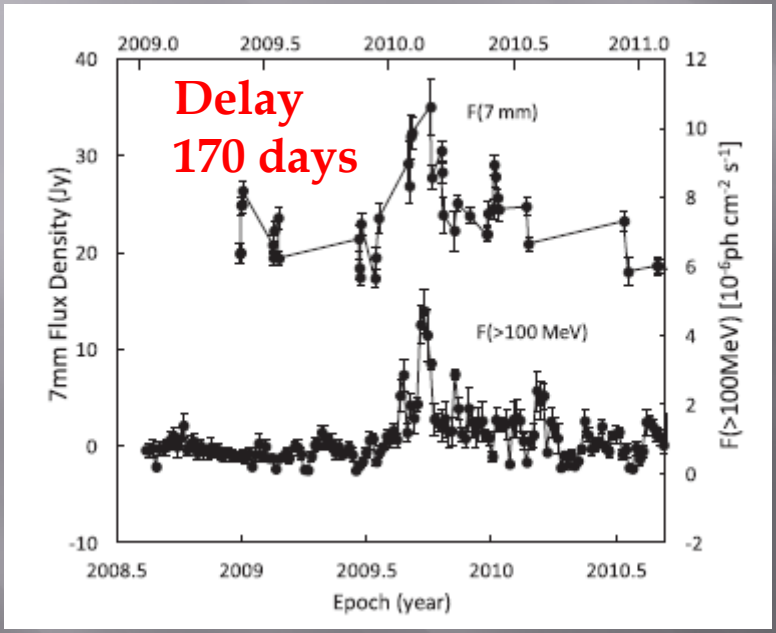
21th Century: Models of High Energy emission

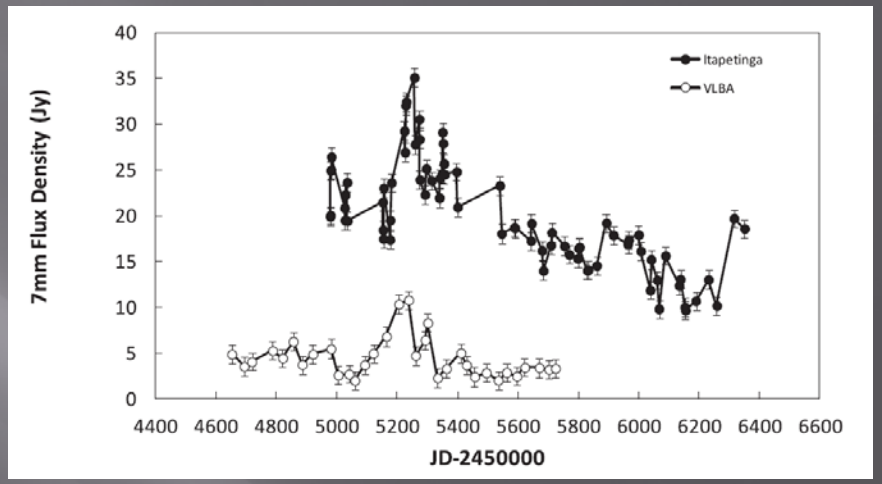
- In Argentina, the group led by Gustavo Romero studied microquasars and their relation to the observed high energy sources
- In particular, emphasis was given to the hadronic models, with interactions between jet and cold protons, also applied to Blazar spectra (Romero & Reynoso, 2011)

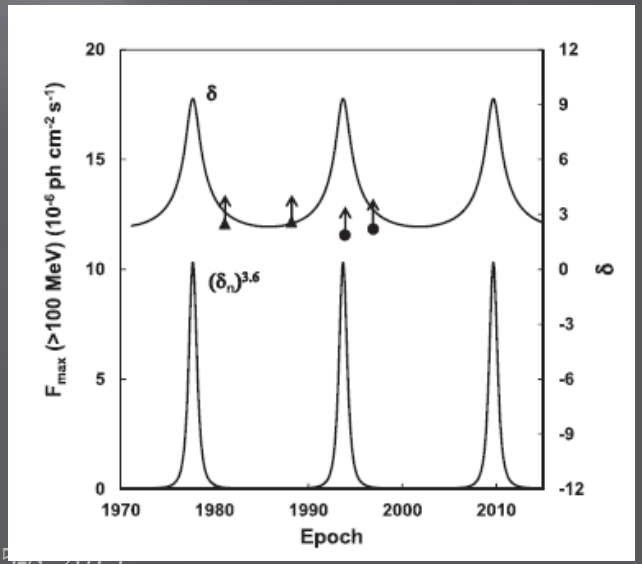




21th Century: The radio γ-rays connection







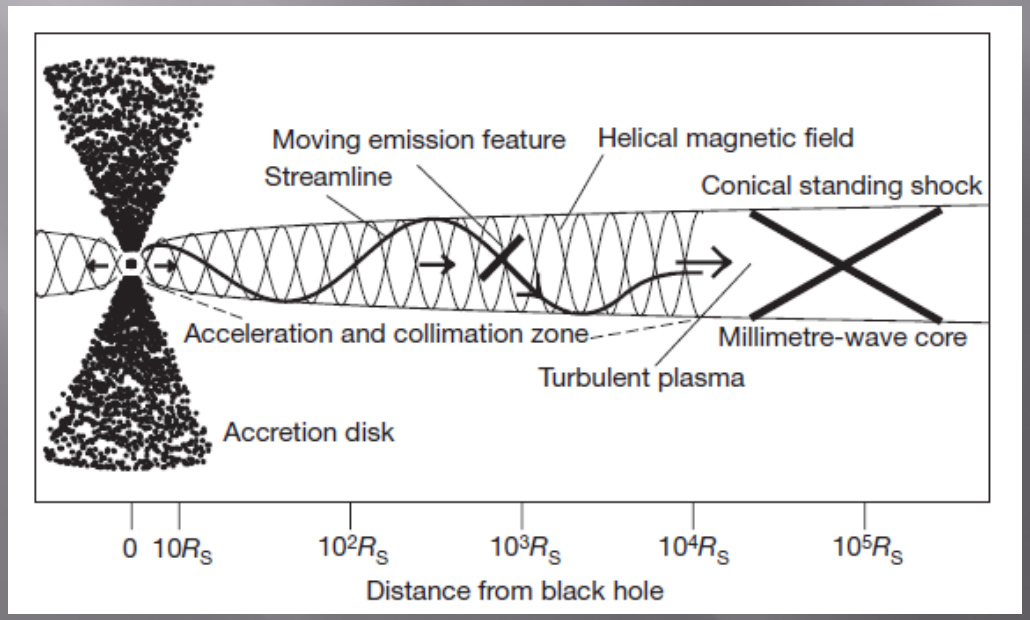
Beaklini & Abraham (2014)

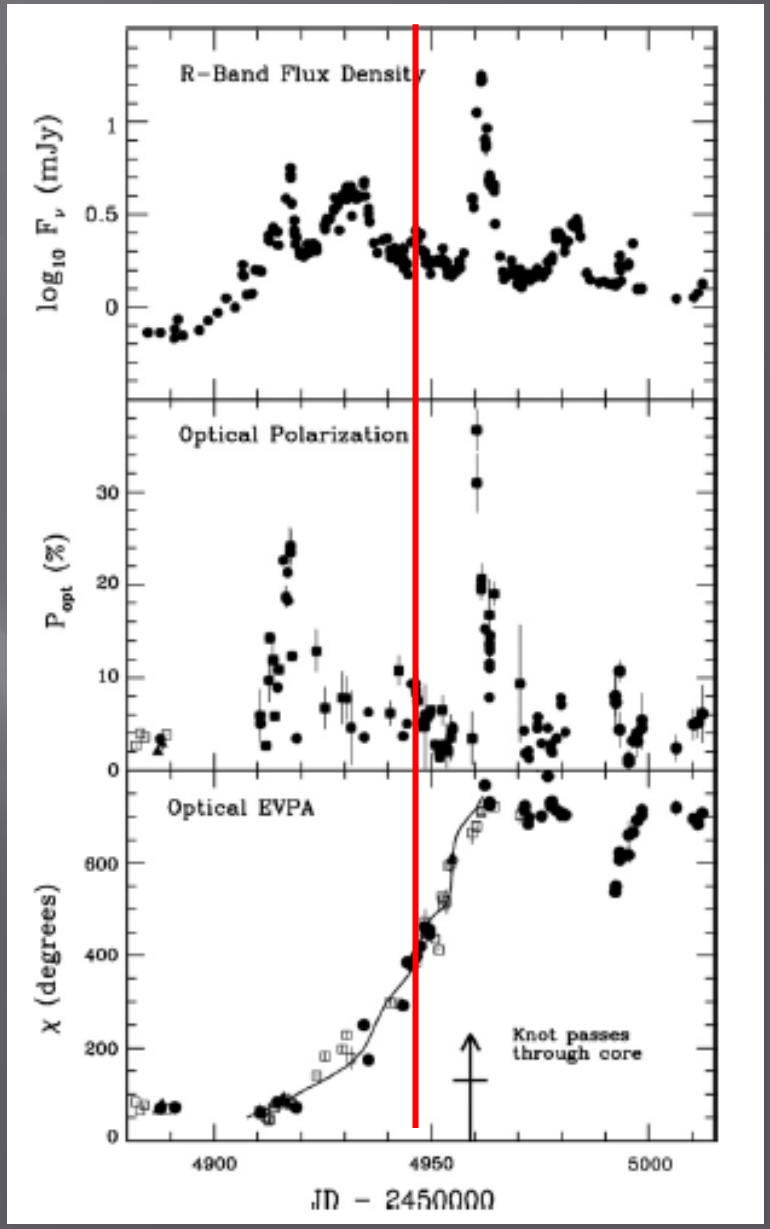
21th Century: Optical Polarization

- Polarization of AGNs in the optical bands was studies in Argentina and Brazil (Andruchow et al. 2003, 2005, 2008, 2011)
- In Brazil me measured polarization at optical bands, simultaneous with 7 mm continuum and compared them with γ-rays from Fermi/LAT (Beaklini, Dominici & Abraham, 2015)
- The most important result was the detection in PKS 1510-089 of an abrupt change in PA (>100°) together with a decrease in PD, simultaneous with a γ-ray flare, between April 20-22, 2009.
- We explained that as the superposition of two sources: the jet and a newly formed shock component.
- This contradicts the model of Marscher et al. (2010)

Marscher et al. (2008, 2010)

PKS 1510-089





The future: LLAMA radiotelescope

- Radio observations of quasars and microquasars will be extended to submillimeter wavelengths with the installation of a submillimeter radiotelescope (similar to ALMA and APEX) in Salta, at an altitude of 4800 m, at a distance of 180 km from ALMA.
- It is an Argentinian-Brazilian project (financed in equal parts by the two countries) and counts with collaboration from Chile, Sweden and the Netherlands.
- It will have receivers in six of the ALMA bands, from 43 GHz to 700 GHz, and will be equipped to do VLBI observations
- As single dish, it will be able to obtain quasi simultaneous spectra of AGNs, improving significantly our knowledge about these objects

The future: the EHT

- A new VLBI array is being formed, The Event Horizon Telescope (EHT), dedicated to detect the shadow of the black hole at the center of our Galaxy and of M87
- LLAMA will be part of this array, a project was submitted in answer to a call between FAPESP and NWO, which will allow us to developed the software necessary to run the experiment

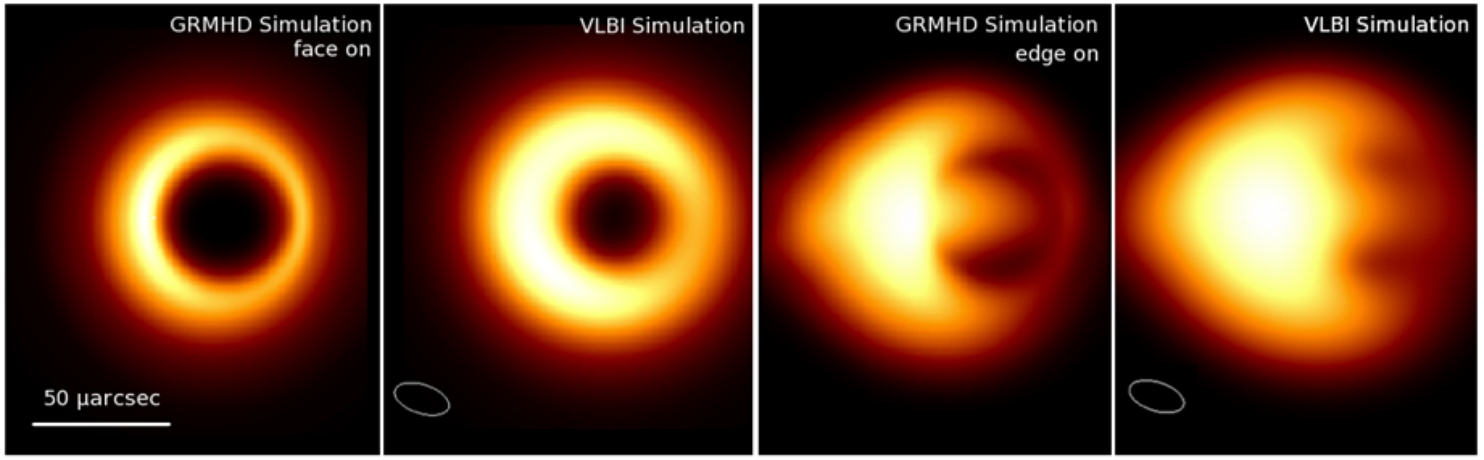


Figure 1: *Simulation of the emission of an accretion flow around the BH in the Galactic Center. This is compared to a reconstructed image from simulated VLBI (Falcke et al. 2011, Mościbrodzka et al. 2009) for face-on and edge-on orientations.*

Thank you