VLBI observations of AGNs

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OUTLINE

Single sources: Mkn 501
1144+35

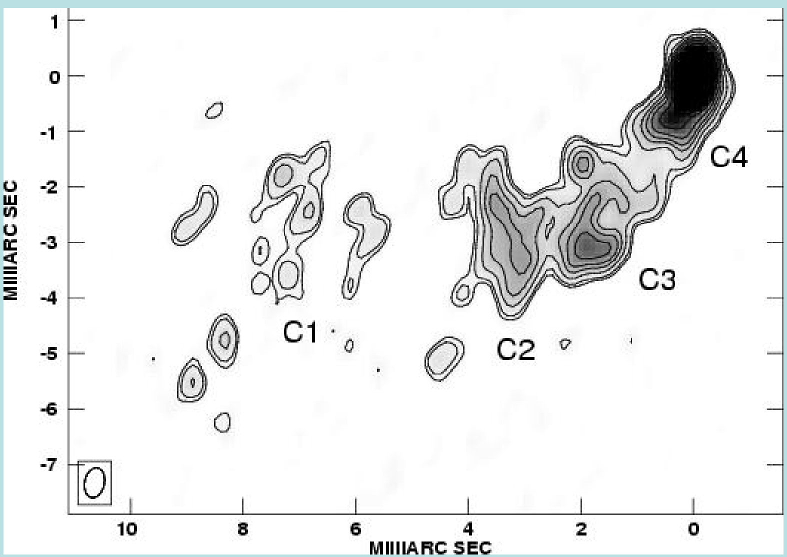
Sample: nearby BL-Lacs
nearby radio sources
more....

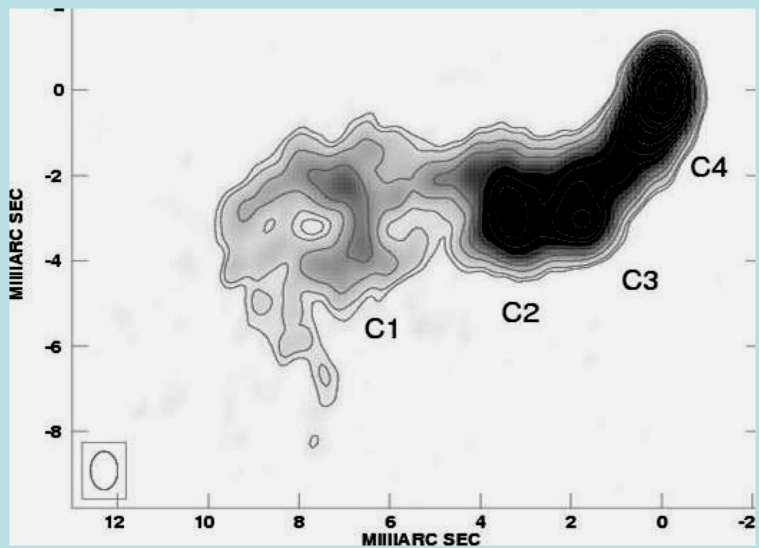
Instruments: single dish – Medicina and Noto
interferometry: VLA – EVN – VLBA ....

Markarian 501

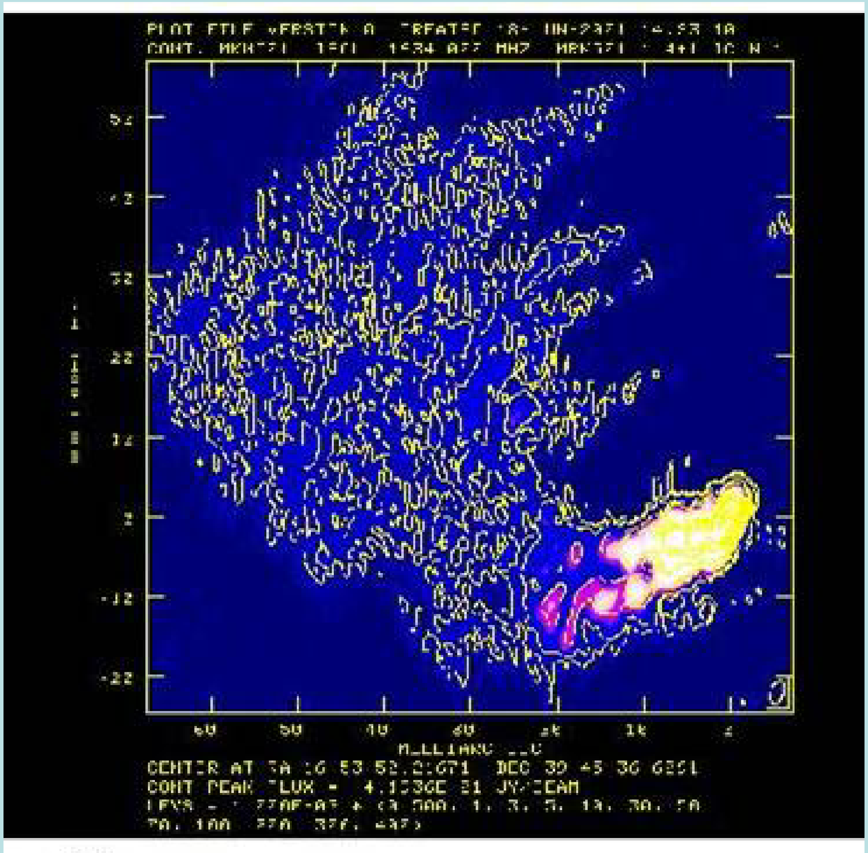
This low redshift (0.034) BL_Lac object is well known for its emission at high frequency. We studied its radio properties on the pc scale using data at 14 different epochs and at mas resolution (high frequency VLBI and space VLBI) – Giroletti et al. 2004 ApJ

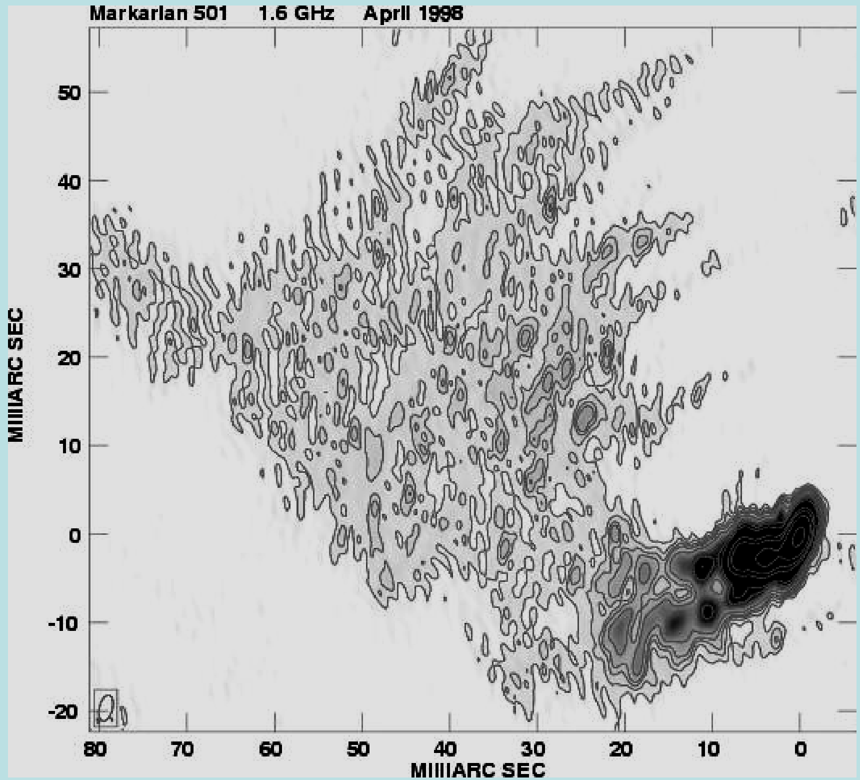
Despite of the large number of different high quality images no proper motion has been found.





The jet shows a complex and continuous morphology with many sharp bends before undergoing a last turn in the PA of the kpc scale structure. The jet is clearly limb brightened at < 1 mas from the core (< 4 pc – deprojected).





Radio results seem in disagreement with constraints derived from the high frequency (gamma-ray) emission.
To reconcile radio and high frequency results we need:

Jet Velocity Structure - Parallel Magnetic Field

R_{core} pc	θ °	Γ_{spine}	δ_{spine}	Γ_{layer}	δ_{layer}	Notes
0.0001 – <0.03	4	15	15	?	?	γ-ray region
0.03 – 0.15	10	15	4	10	5	Radio core
0.15 – 7	15	15	2	3	5	First jet region
7 – 20	15-20	15	2-1	3	4-3	Before of large bending
20-30	25	10-3	1-2	2	2.5	After the large bending
50	25	1.25	1.8	1.1	1.5	Final VLBI jet region

Notes: R_{core} = projected distance from the core

Table 6b

Jet Velocity Structure - Perpendicular Magnetic Field

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20-30	15	10	2.5	3	4	After the large bending
50	15	10	2.5	3	4	Final VLBI jet region

Notes: R_{core} = projected distance from the core

Physical parameters

Magnetic field core region (0.03 to 0.15 pc) = 0.03 gauss
(self-absorption)

Jet region = 0.015 – 0.010 gauss (equipartition)

Relativistic jet up to 300 pc
Symmetric non relativistic structure on the kpc scale

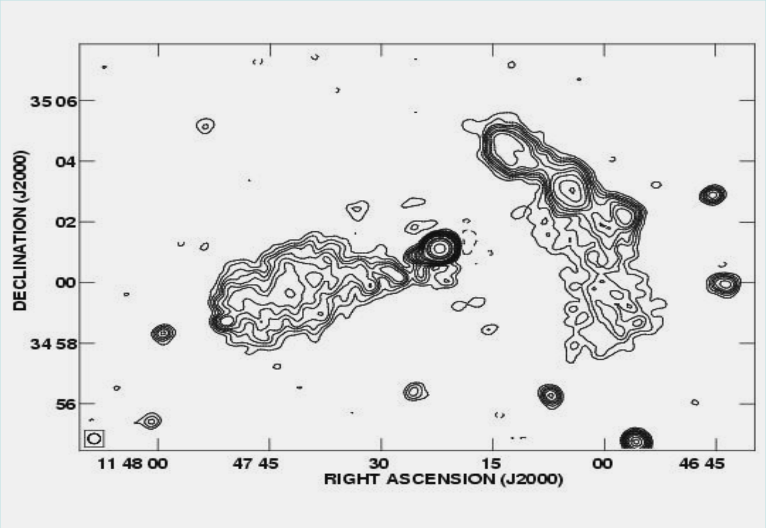
To observe the intermediate region we need the extended VLA (or SKA).

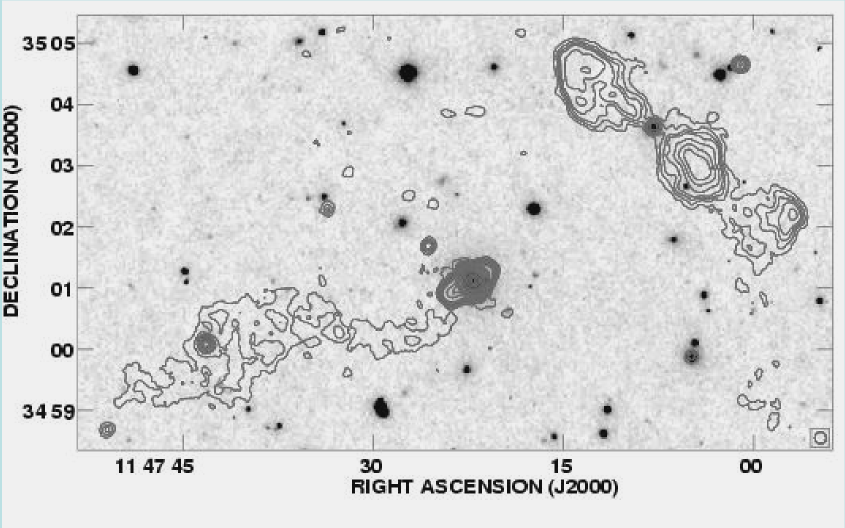
New observations

December 2004 at 18 cm with the High Sensitive Array: VLBA+Y27 +GBT+Bonn
Requested with the global array at 86 GHz (mm VLBI)
linear resolution < 0.03 pc

1144+35

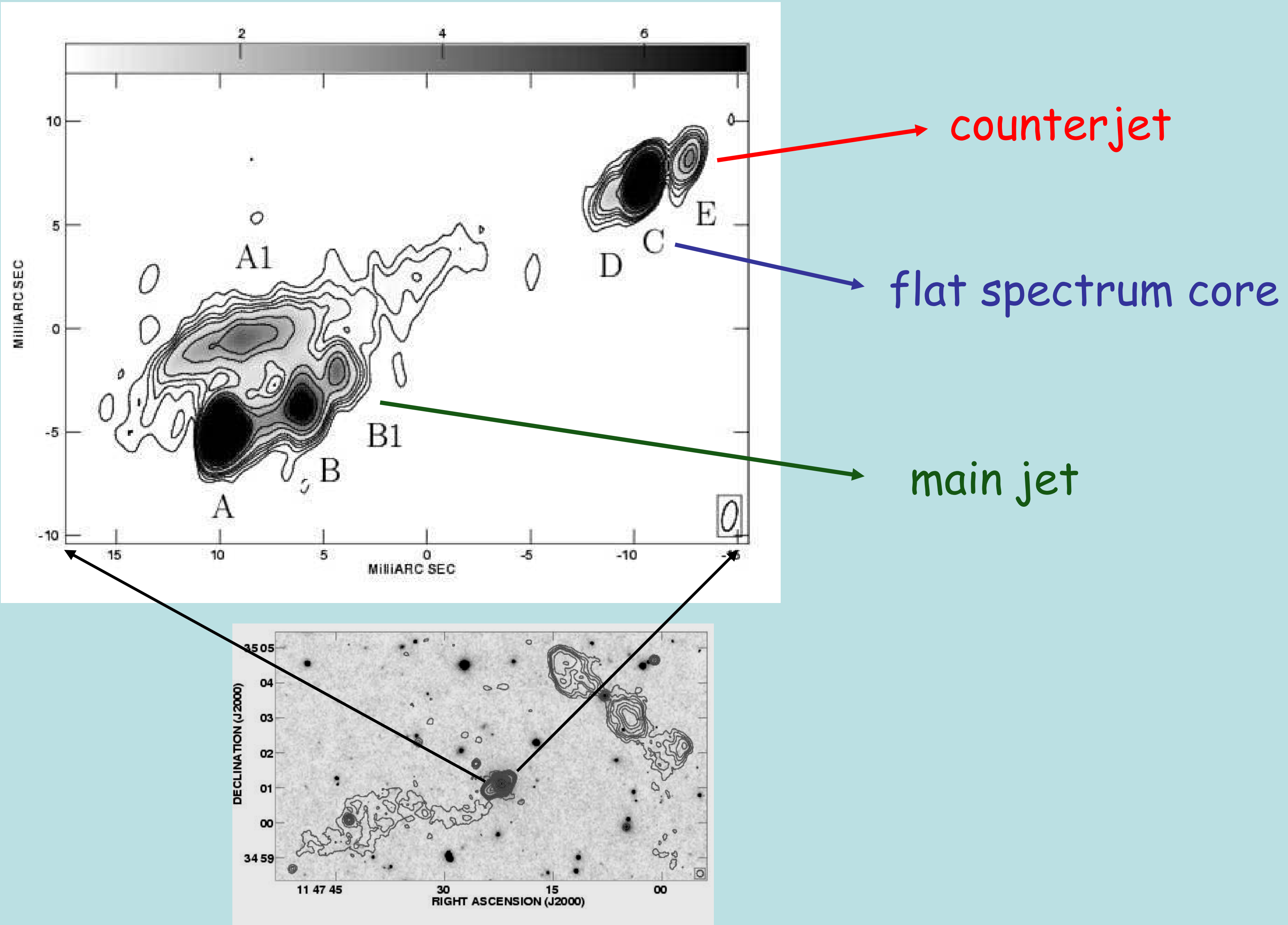
1144+35 is a giant radio galaxy: projected linear size 1.0 Mpc h_{65}^{-1}





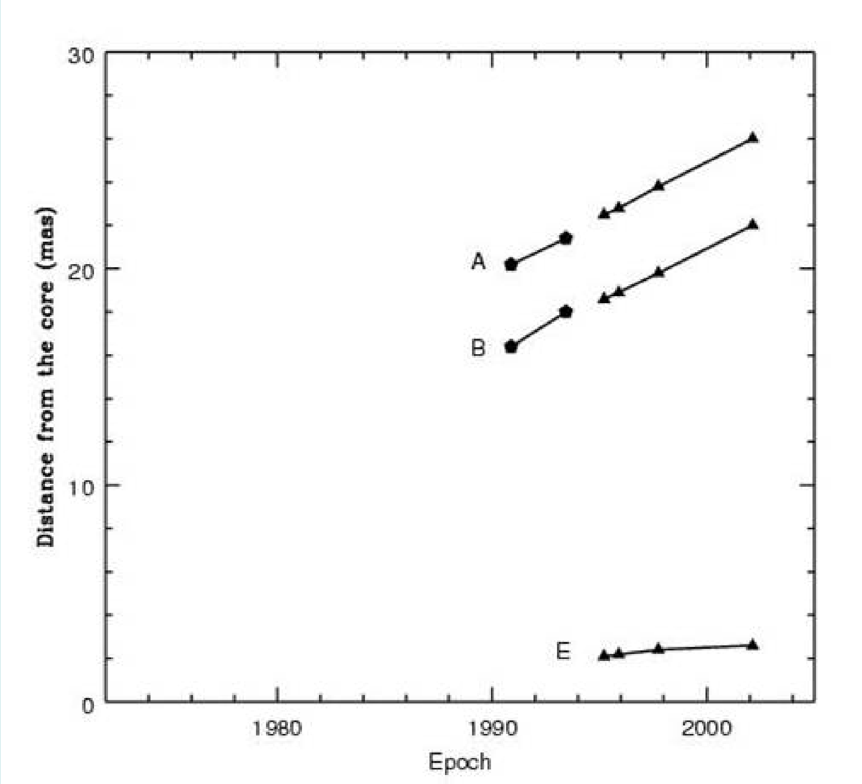
The arcsecond core is the dominant feature

On the parsec scale it shows a core, a strong extended jet and a short cj



Superluminal motion

Well defined components – 11 epochs from 1991 to 2002



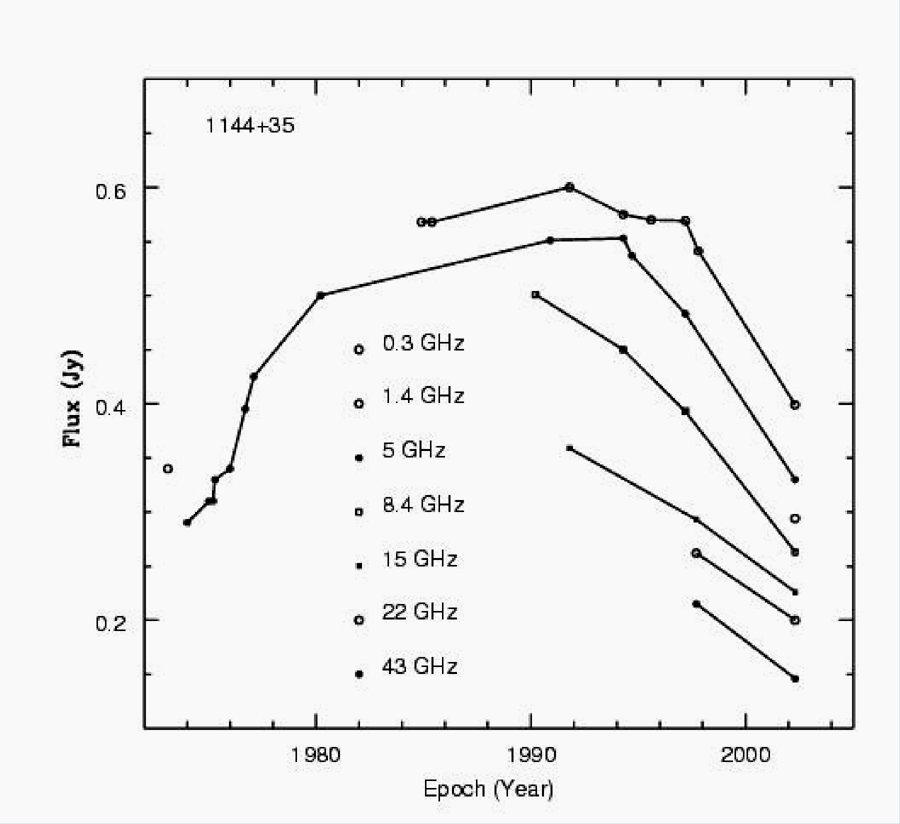
Only high quality data:

jet: 5 and 8.4 GHz data
cj 8.4 GHz only

Jet: β_{app} = 2.7 constant
All components constant velocity

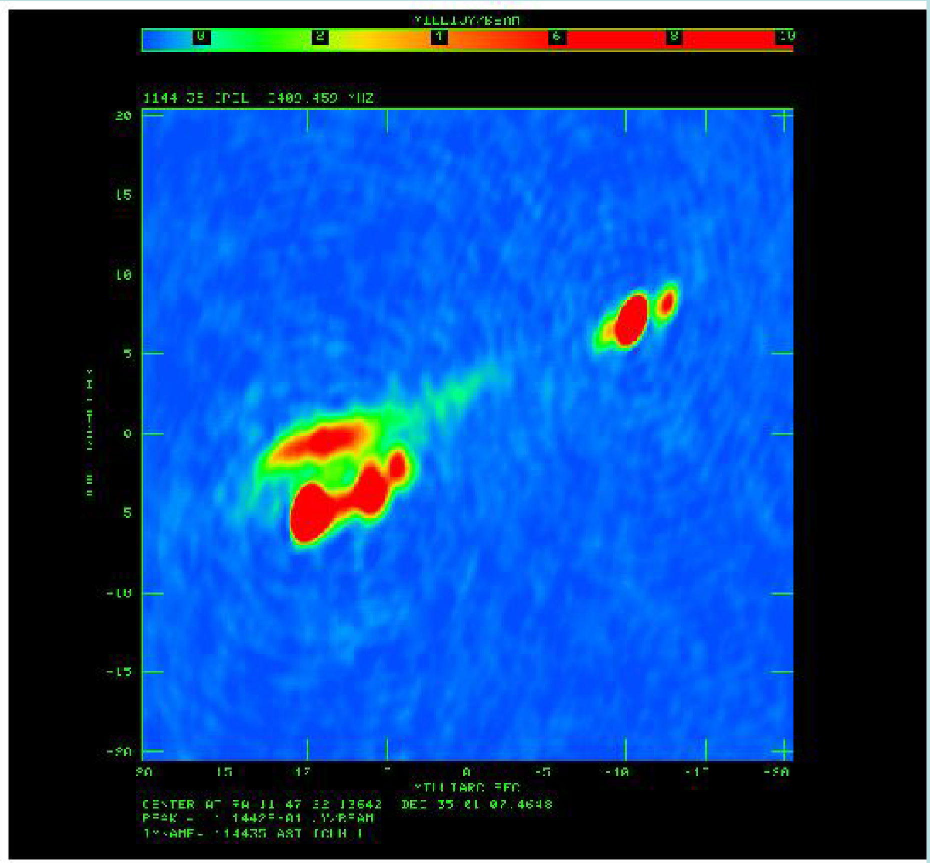
cj side β_{app} = 0.3

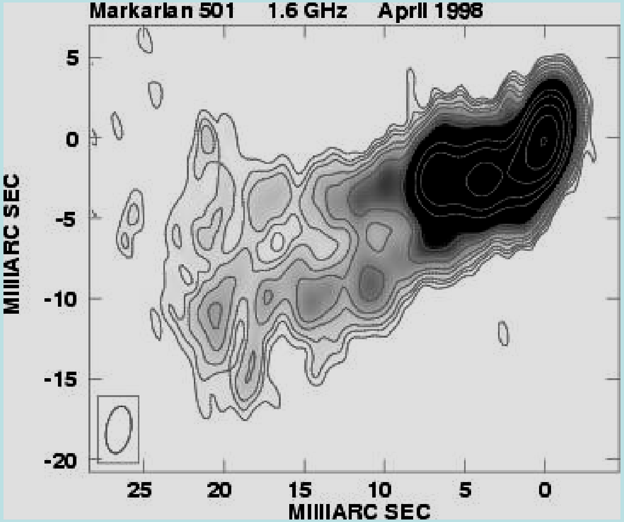
The arcsecond core flux density has long been known to be variable. It shows a strong increase from 1974 to 1980, a smoother decrease up to 1990-92 and a fast flux density decrease up to now (March 2002).



Velocity Structures

An evident limb brightened jet morphology on the parsec scale is present in some FR I sources:
1144+35, Mkn 501, 3C 264, M87, 0331+39……





According to Ghisellini et al. Astro-ph/0406093, there will be a strong radiative interplay and feedback between the layer and the spine and this will enhance the inverse Compton emission of both components.

This suggest that radio galaxies could be

bright γ-ray emitters.

Ghisellini et al. suggest a list with more than a dozen of FR I galaxies which could be detected by GLAST

Nearby BL Lacs: the radio view

Marcello Giroletti
Dip. di Astronomia, Univ. di Bologna
Istituto di Radioastronomia

and
G. Giovannini, G.B. Taylor, R. Falomo

The Sample

From

- Falomo et al. 2000, ApJ 542, 731 (HST observations of BL Lacs)
- 30 objects with $z<0.2$ (out of the 110 sample)
  - all fully resolved
  - “normal” elliptical host galaxies
  - Central Compact Cores
  - 3 optical jets: 0521-36, 3C 371, 2201+044

We started a project to obtain

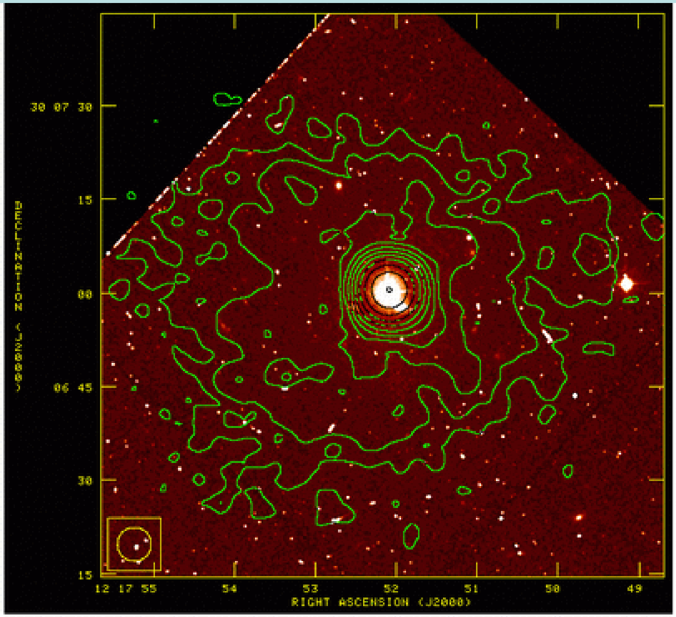
- VLA, VLBA, EVN, MERLIN observations
- Up to now: 54 hrs of new radio data between <0.001” and 10” resolution

Giroletti, Giovannini, Taylor & Falomo 2004, ApJ 613, 752

Main results from VLA & VLBA observations

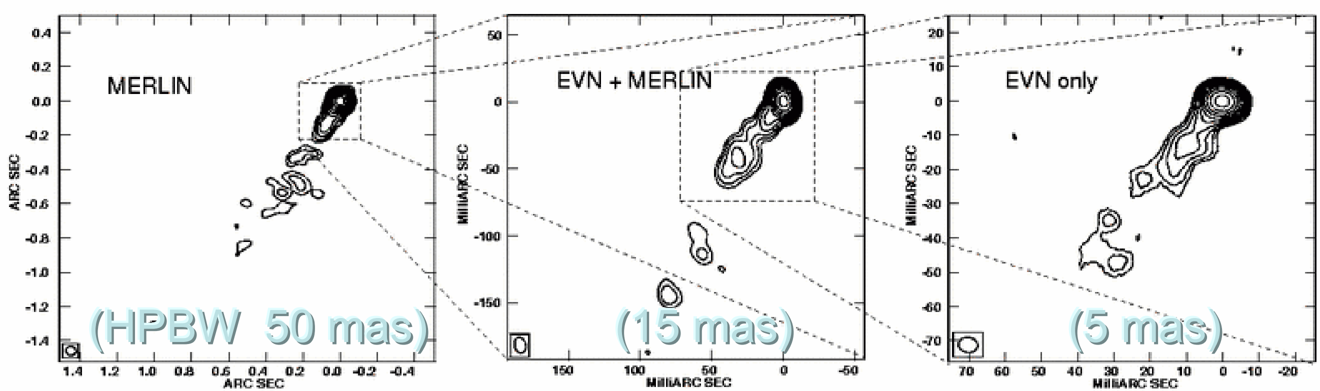
- Significant structures exist on sup-kpc scale: jets, halos (=lobes?), secondary compact components (=hot spots?)
- Core dominance <R> = 3.2 ($R=S_{core}/S_{ext}$): nearby BL Lacs are core dominated objects, though less than those in other samples (e.g. 1 Jy)
- If BL Lacs follow same P_c/P_t as other radio loud AGNs, than LBLs may have faster jets than HBLs/TeV sources
- Doppler factors: $1 < \delta < 10$ (and $\langle\theta\rangle = 18° \pm 5°$)
- Debeamed luminosity fully consistent with FR I radio galaxies

Pretty pictures (I): 1215+303

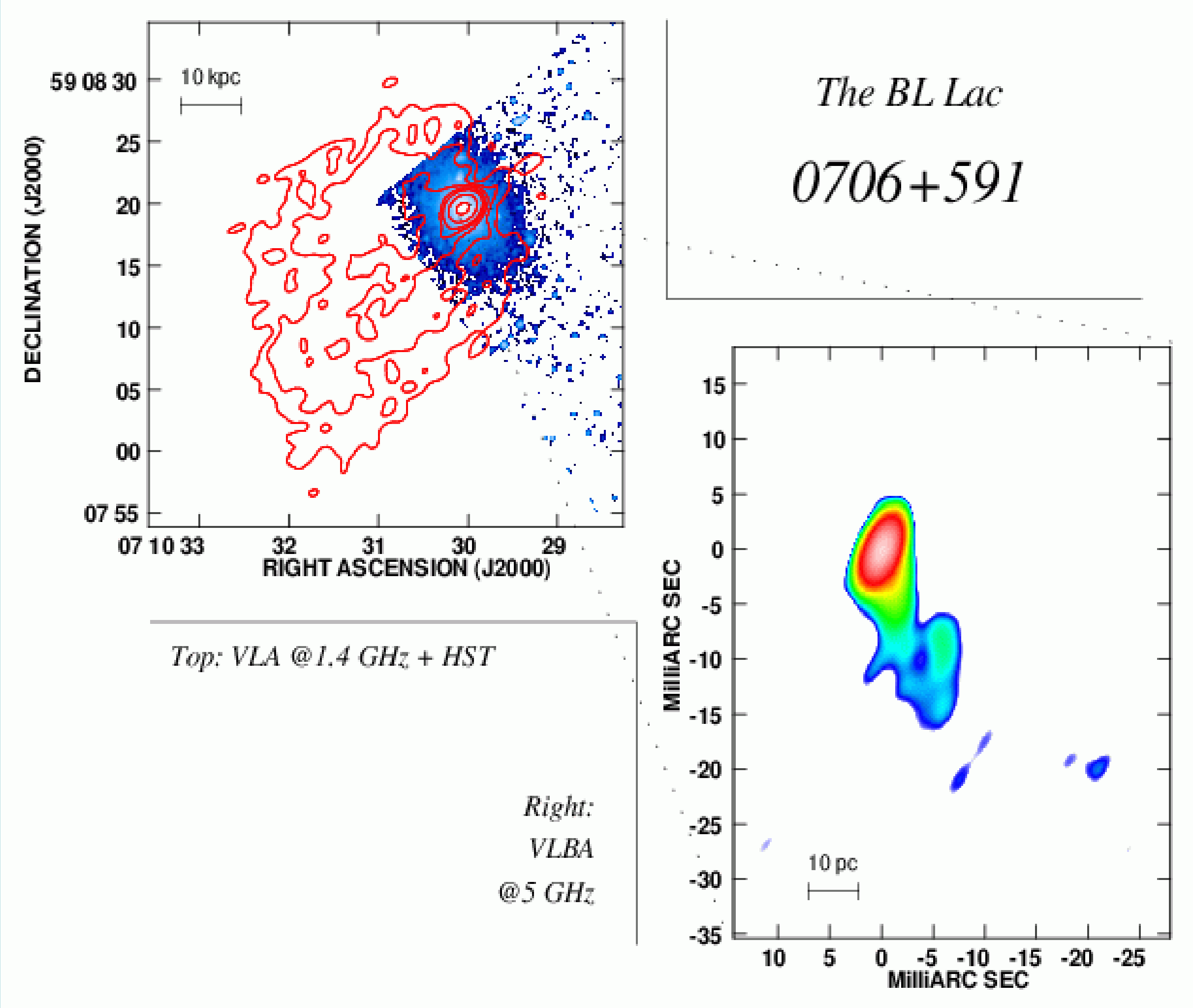


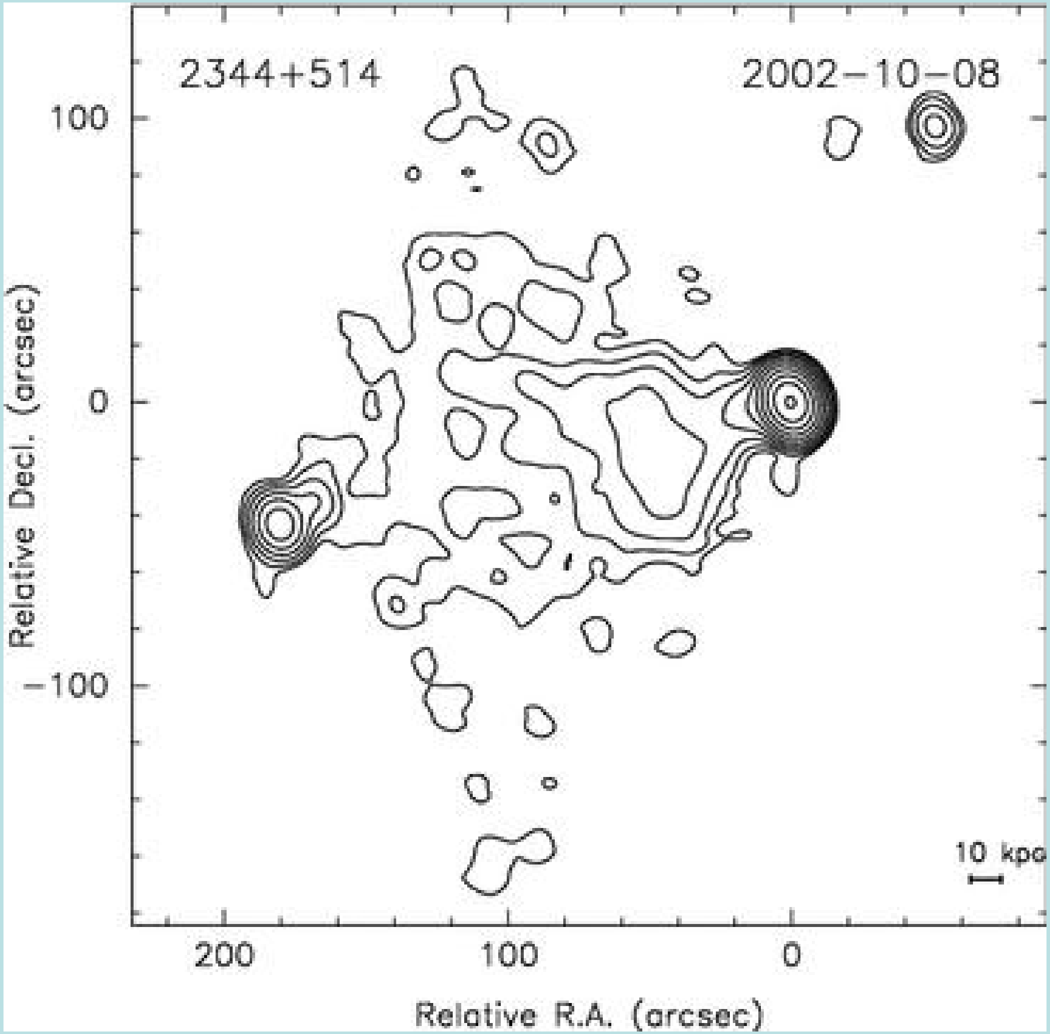
Left: radio contours from the FIRST survey, overlayed to the Hubble Space Telescope image of 1215+303.

Below (left to right): MERLIN, combined EVN+MERLIN, and EVN only images of 1215+303.



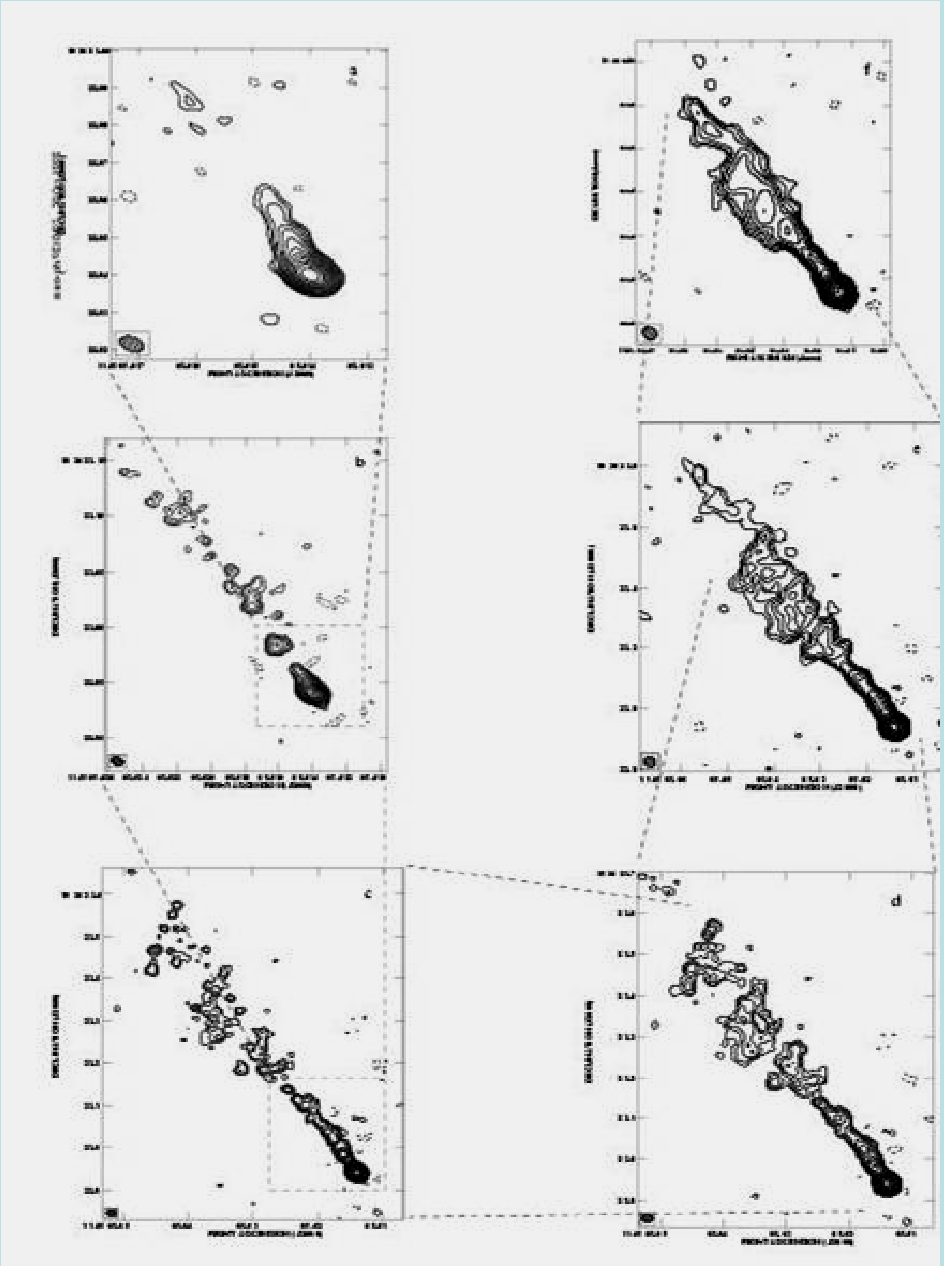
Pretty pictures (II): 0706+591




2344+514
2002-10-08
100
0
-100
200
100
0
Relative Decl. (arcsec)
Relative R.A. (arcsec)
10 kpc

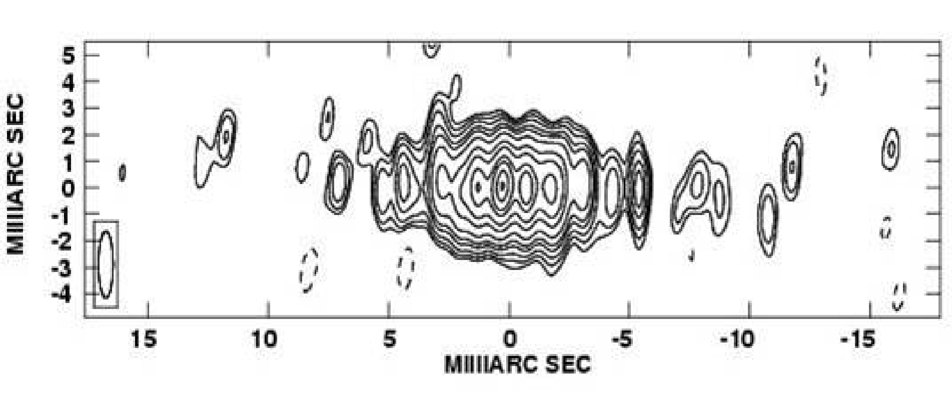
The Bologna Complete Sample

- All the radio galaxies from the B2 and 3Cr with a redshift lower than 0.1
- 95 radio sources
- Observed with VLBI 53 sources (Giovannini et al. 2005)
- Requested 24 now
- To be observed 18 -- near future

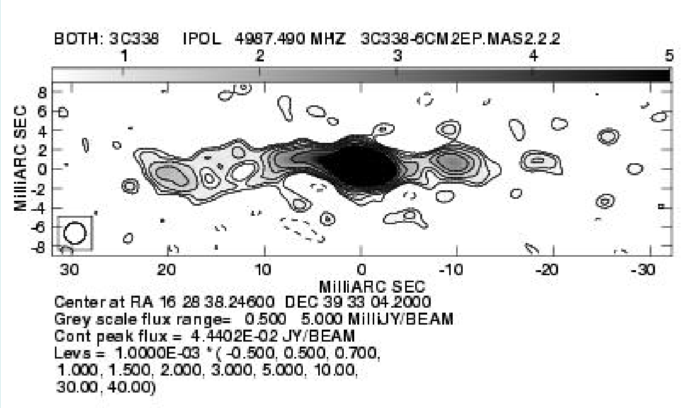


Radio jet of the FR I radio galaxy 3C264 at different angular resolutions

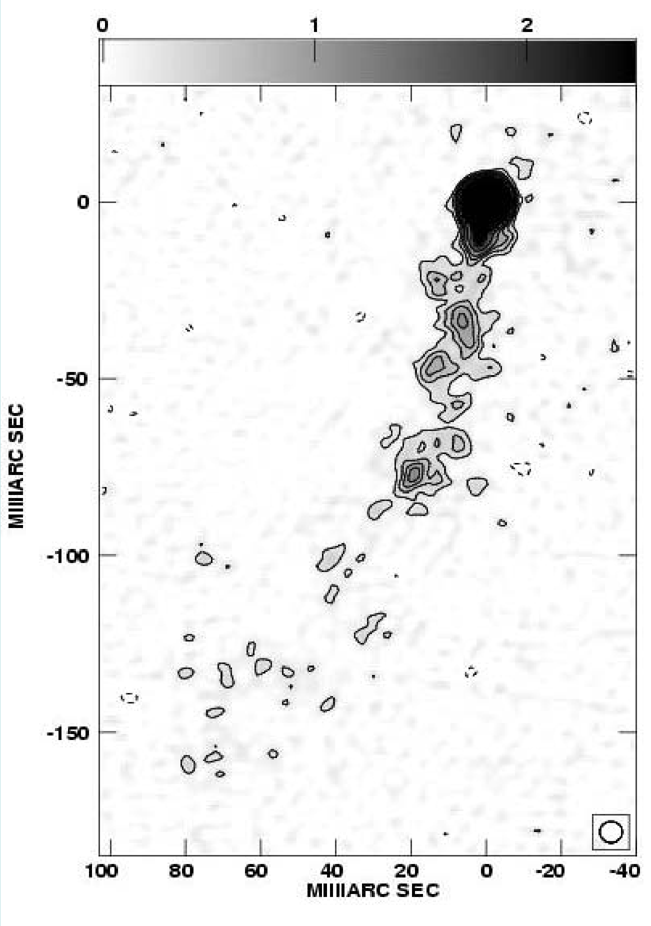
(Lara et al. 1999)



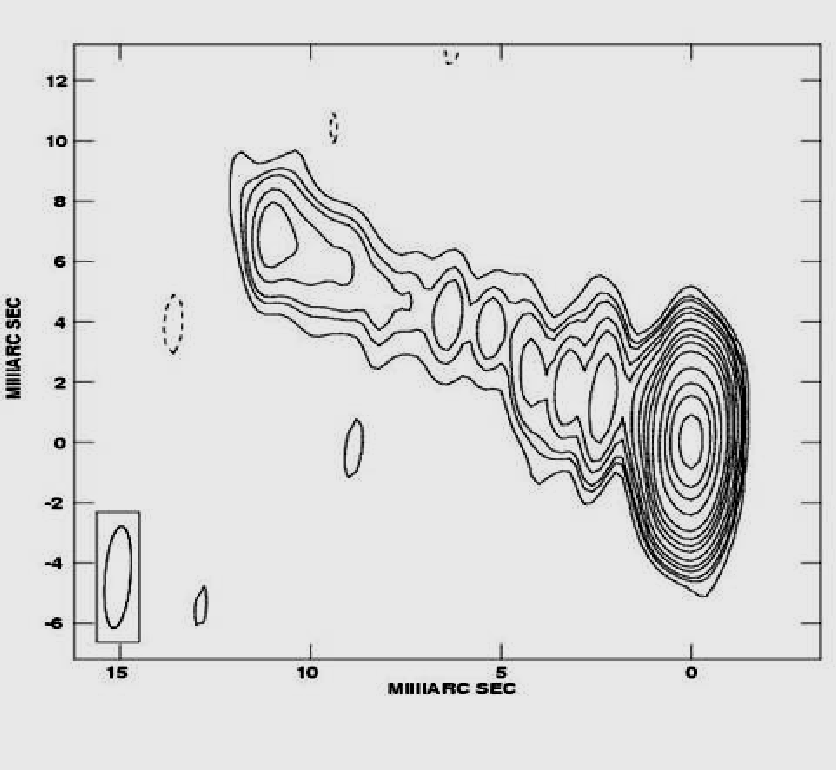
3C 452 a NL FR II radio galaxy

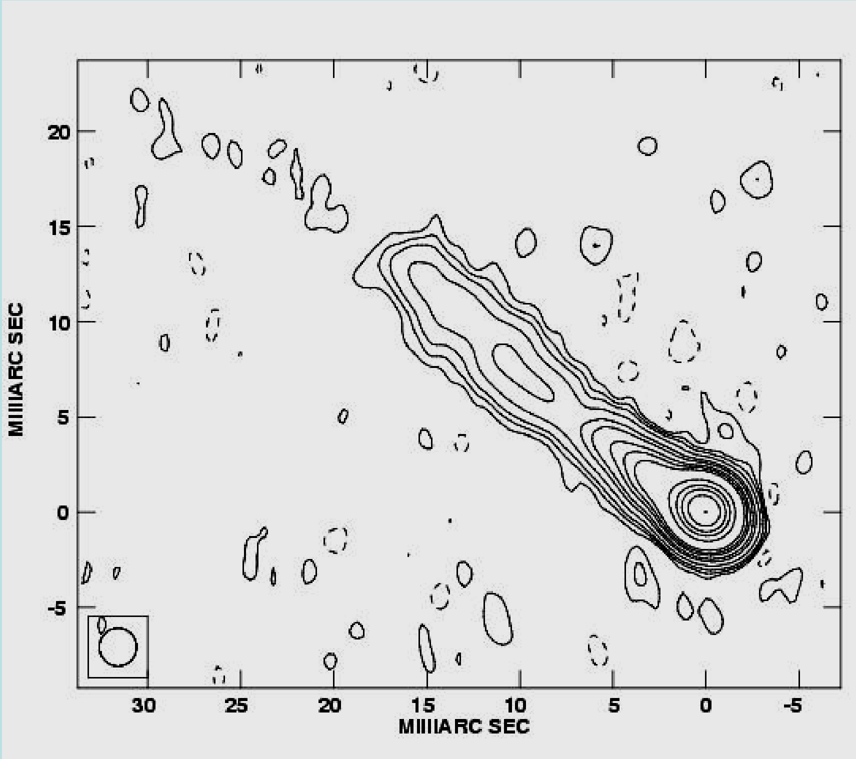


3C 338 a FR I radio galaxy



0331+39 a low power compact radio galaxy





3C 382 a BL FR II radio galaxy

3C 66B a FR I radio galaxy

CONCLUSIONS

- The parsec scale jet velocity is highly relativistic (Γ = 3 to 10).
- The jet morphology is the same in high and low power sources
- The jet decelerates dramatically from the pc to the kpc scale in FR I radio sources and more slowly in FR II sources.

- A two velocity regime is necessary to explain some observational properties in low power sources and possibly in a few high power sources. The different Doppler factor can explain the limb-brightened structure visible in high resolution images.

- It is not yet clear if the jet velocity structure is an intrinsic jet property or it is due to the jet interaction with the ISM. In any case at some distance from the core the jets slow down because of interaction with the ISM

More sources:

Gamma ray sources observed multi-epoch multifrequency with VLBI: 0954+658, PKS1510-089, 1749-096

15 EGRET sources VLBI + VLA (0202+149, 1604+159, 2356+196.....

Multi epochs of ON231, OQ530

....

CSS – GPS – CSO sources (young sources)

ISTITUTO DI RADIOASTRONOMIA

CALL FOR PROPOSALS

Download Form

Submit Proposal

Medicina Schedule

Noto Schedule

The Istituto di Radioastronomia offers observation time at the two 32-m radio telescopes at Medicina and Noto.

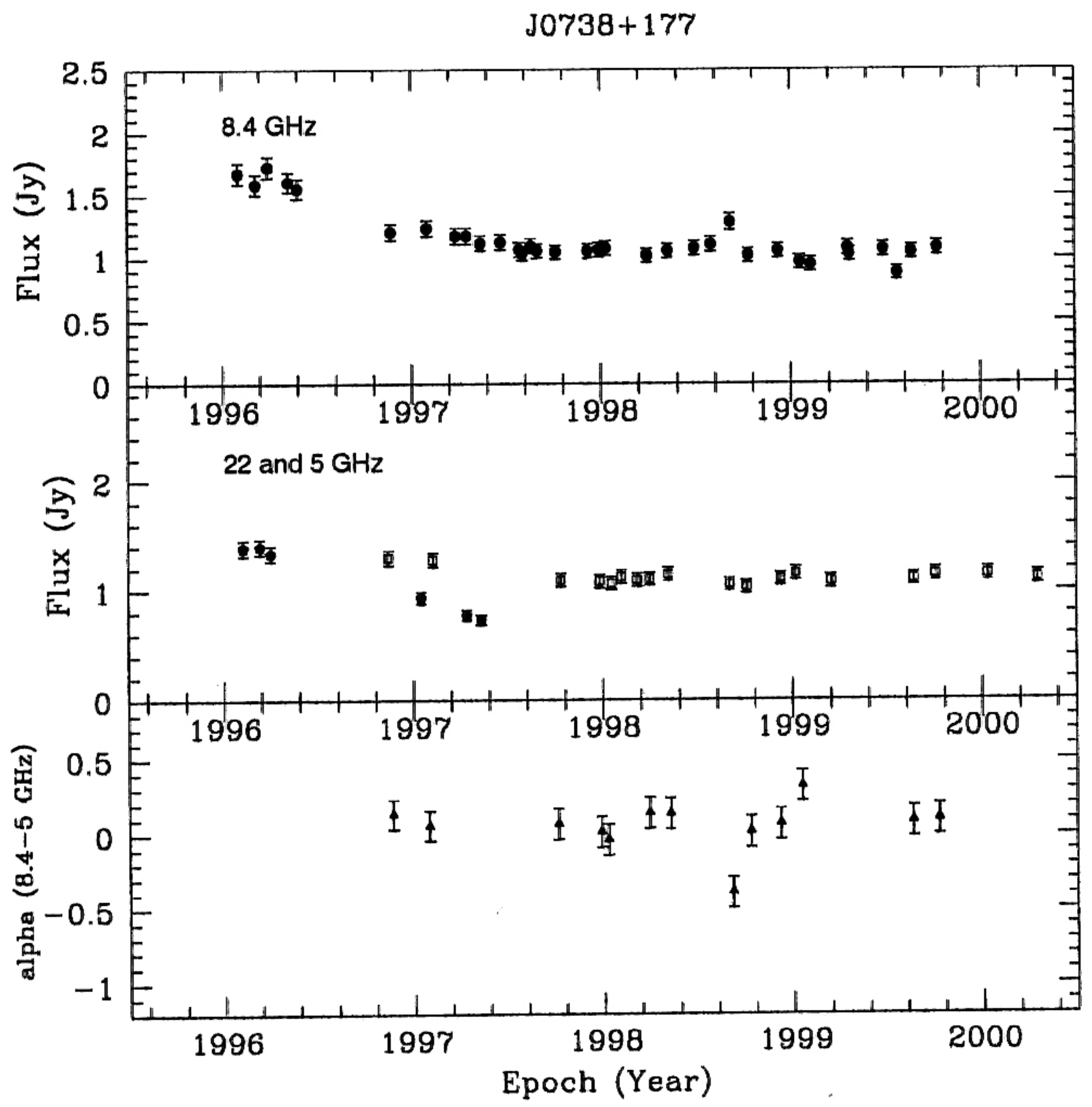
The Medicina telescope is furnished with a suite of receivers between 1.4 and 22 GHz which can be connected to various backends. In addition to a state-of-the-art digital backend, a polarimeter system with 400 MHz bandwidth can be attached to any available frontend. Spectroscopic observations can either be done with ARCOS, a 4096-channel autocorrelator with a maximum instantaneous bandwidth of 160 MHz and a maximum resolution of 40 Hz (8.4 m/s at 1.4 GHz) or a spectral analyser with an input bandwidth between 0.5 and 20 MHz, a temporal resolution of one spectrum/msec and a frequency resolution between 512 and 131,072 channels. Pulsar observations can be performed with a 2 x 64 x 1 MHz filter bank (left and right-hand polarisation). Receiver frequencies can be switched within a few seconds.

The telescope at Noto possesses an active surface which increases the telescope efficiency in particular at high frequencies. More information about the active surface and first results of test measurements can be found here . A receiver system at 86 GHz will become available within the next months. Possible backends are the digital backend and the ARCOS autocorrelator.

In addition to all standard radioastronomical frequencies both telescopes allow observations of methanol lines in the 6.6-GHz (with Noto also in the 12-GHz band). Coordination of these two telescopes for two-antenna VLBI or simultaneous single-dish observations is possible. VLBI observers should however provide tapes and correlator time. Visiting astronomers can also install their own backends.

Proposals for observing time in the period 1st April 2005 to 31th October 2005, should include the IRA cover form. The package for proposal preparation can be downloaded from URL in the frame to the left. They should be sent by 1st March 2005 to the Istituto di Radioastronomia following the instructions on the given URL.

Venturi et al. 2001
AA 379, 755



The sensitivity of Medicina or Noto radio telescopes

is of the order of 40 mJy in 1 h

A reasonable project to measure AGN flux density at the same time of AGILE observations can be done for sources with a flux density > 200 – 300 mJy

Angular resolution is from 1.4 to 6.4 arcmin (22 – 5 GHz)

===

Other observations possible with

VLA	ToO
MERLIN	
EVN	
VLBA	ToO

Refereed proposals – Archive data available (free after 1 yr)

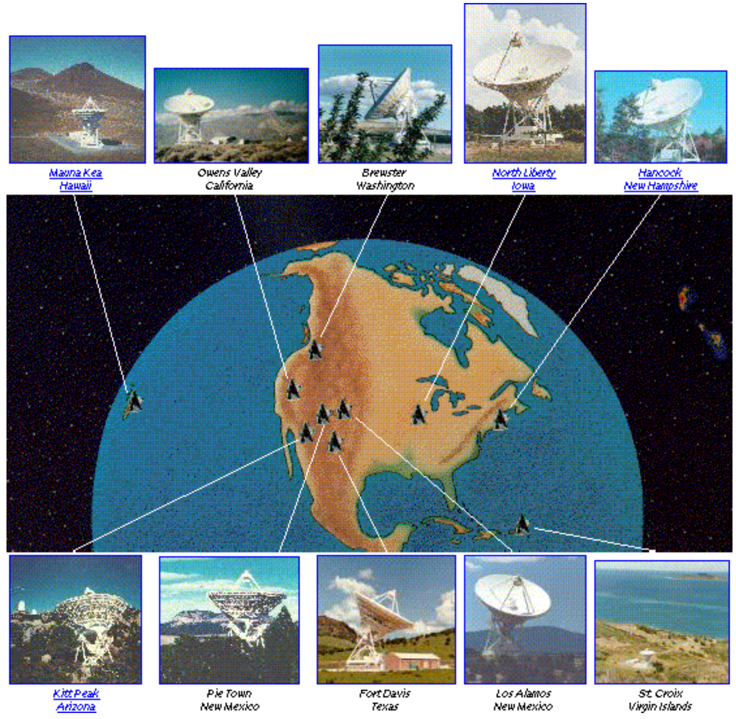
HIGH RESOLUTION RADIO IMAGING:

VERY LONG BASELINE INTERFEROMETRY (VLBI)

- Telescopes across a continent are combined toform a global, virtual radio telescope

- The <u>resolution is</u> that of a telescope the size of the earth

- It provides the highest resolution achievable in astronomy



VLBA

Outline:

List of sources to be observed with AGILE should be included in sources list or samples that we are observing in radio band (archive and literature data too)

Proposals should be submitted when AGILE launch will be
Near in time (3-6 months in advance)

From observational data:

1) The jet structure (limb-brightened)
2) j/cj ratio
3) core dominance and

studying the functional dependence of the jet intensity on the jet velocity and radius assuming an adiabatically expaning jet we derived the following results:

-- an angle $\theta \geq 15^{o}$ with respect to the line of sight is necessary to reproduce the jet morphology
-- θ has to be in the range 10^{o} – 27^{o} from the core dominance and the j/cj ratio
-- assuming an adiabatic model we need a radio jet starting with a high velocity: $\beta = 0.998$

Since we know the j and cj proper motion according to Mirabel et al. 1994 we can derive the jet orientation:

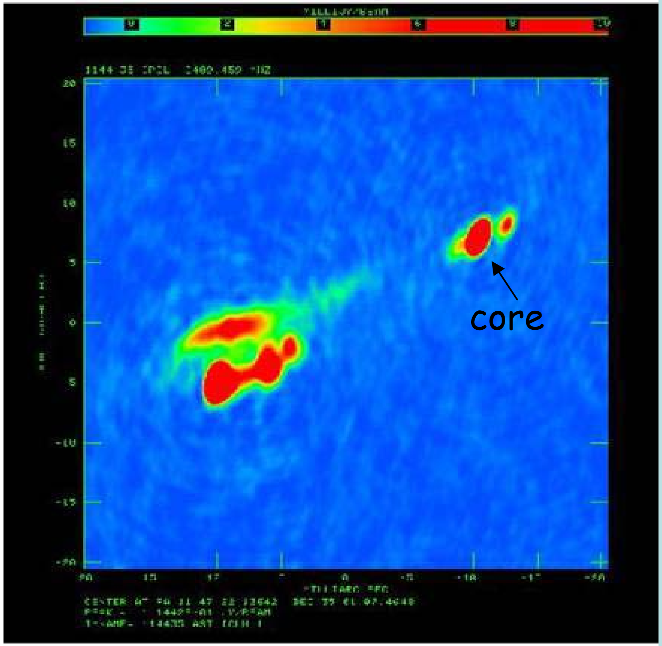
$$D = 0.5c\tan\theta(\mu_a - \mu_r)(\mu_a\mu_r)^{-1}$$

Assuming H_0 = 65, the source distance D is 295 Mpc and

$\theta = 25^o$

Therefore $\beta = 0.88$ is the pattern velocity of the shear layer. The Doppler factor is 2.4 – the structure is boosted.

From the j-cj brightness ratio and from the j-cj arm ratio we derive a jet bulk velocity $\beta > 0.8$ in agreement with the measured pattern velocity.



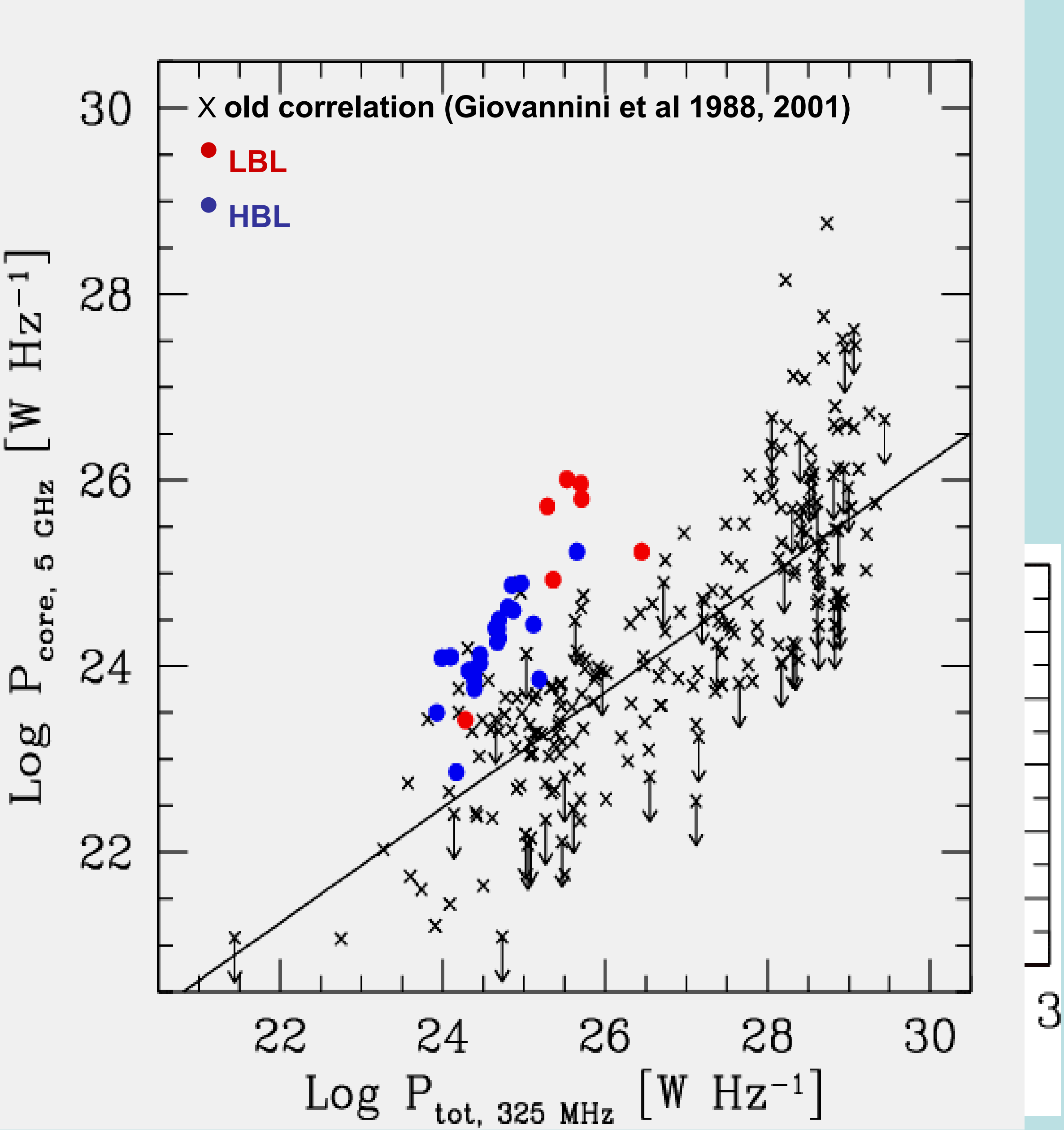
Shear-layer $\delta = 2.4$ - boosted

If the inner spine is moving with e.g. $\Gamma = 15$ the corresponding Doppler factor is 0.7 – deboosted.

A fast spine and a lower velocity shear layer can explain the limb brightened structure.

With $\Gamma = 15$ we expect a jet opening angle of 4^{o}. The measured intrinsic opening angle is 4.2^{o}

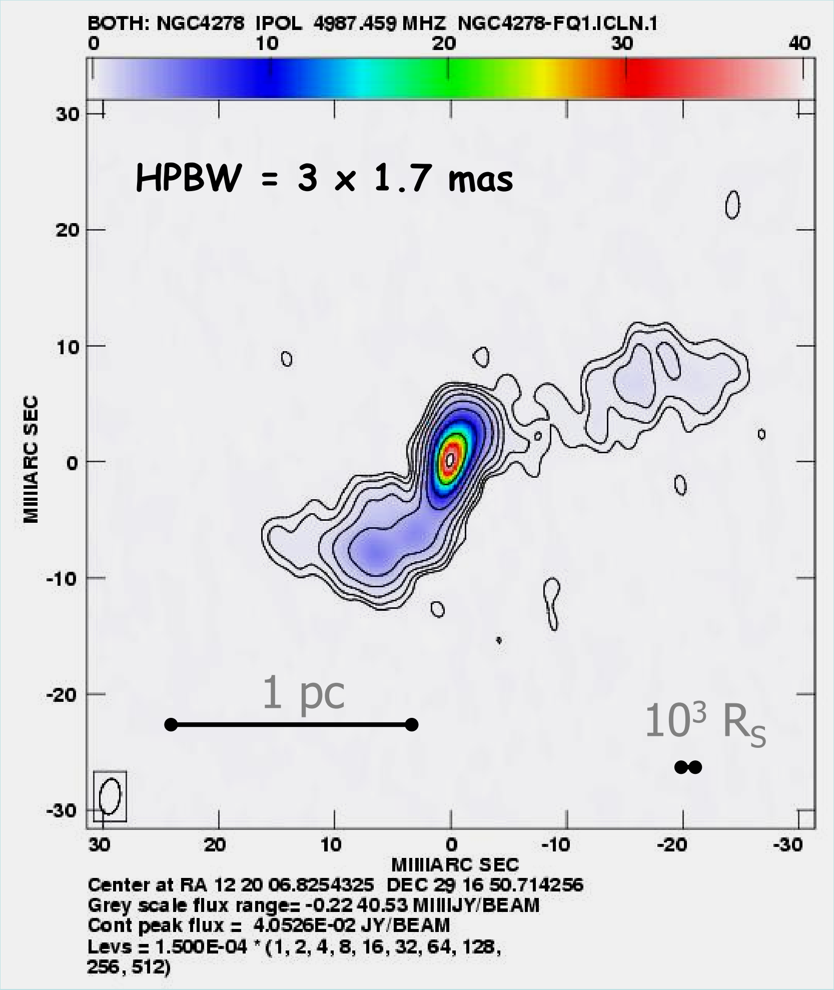
If the external region started with the same velocity of the inner spine, its velocity decreased from 0.998 to 0.88c in less than 100 pc. This suggest a velocity structure already present at the jet beginning.

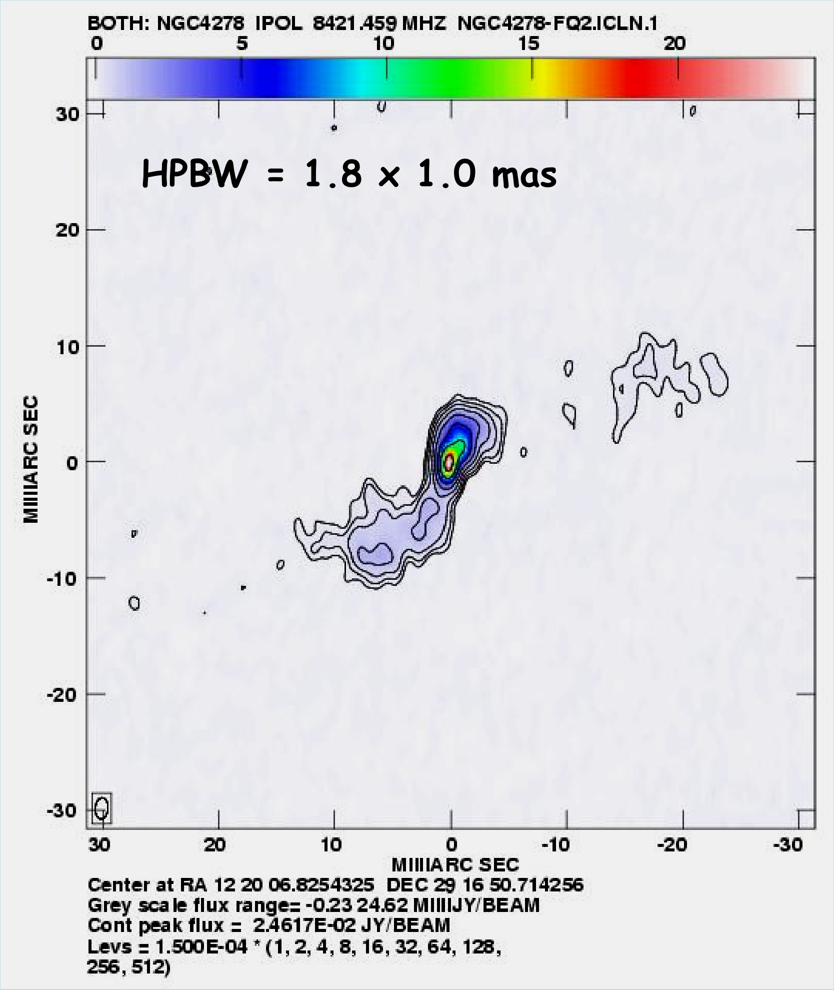

X old correlation (Giovannini et al 1988, 2001)
LBL
HBL
Log $P_{core,\ 5\ GHz}$ [W Hz^{-1}]
Log $P_{tot,\ 325\ MHz}$ [W Hz^{-1}]
22
24
26
28
30
22
24
26
28
30

NGC 4278

- Nearby large dusty elliptical
- Direct distance measure = 14.9 Mpc (Jensen et al. 2003) ➔ 1mas = 0.071 pc
- $S_{1.4\ GHz}$=300 mJy, $P=10^{21.6}$ W Hz^{-1}: LLAGN
- Ionized nuclear gas typical of a LINER (Goudfrooj et al. 1994)
- HST observations reveal a central point source and a large distribution of dust N-NW of the core (Carollo et al 1997)

NGC 4278, images





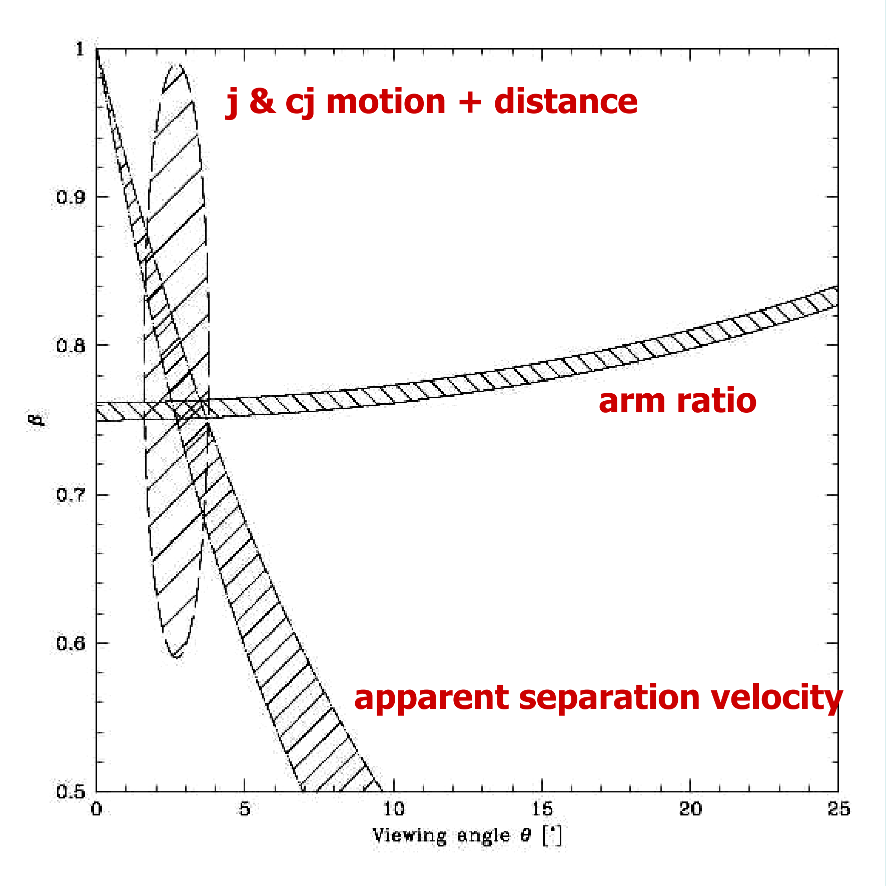
5 GHz

8.4 GHz

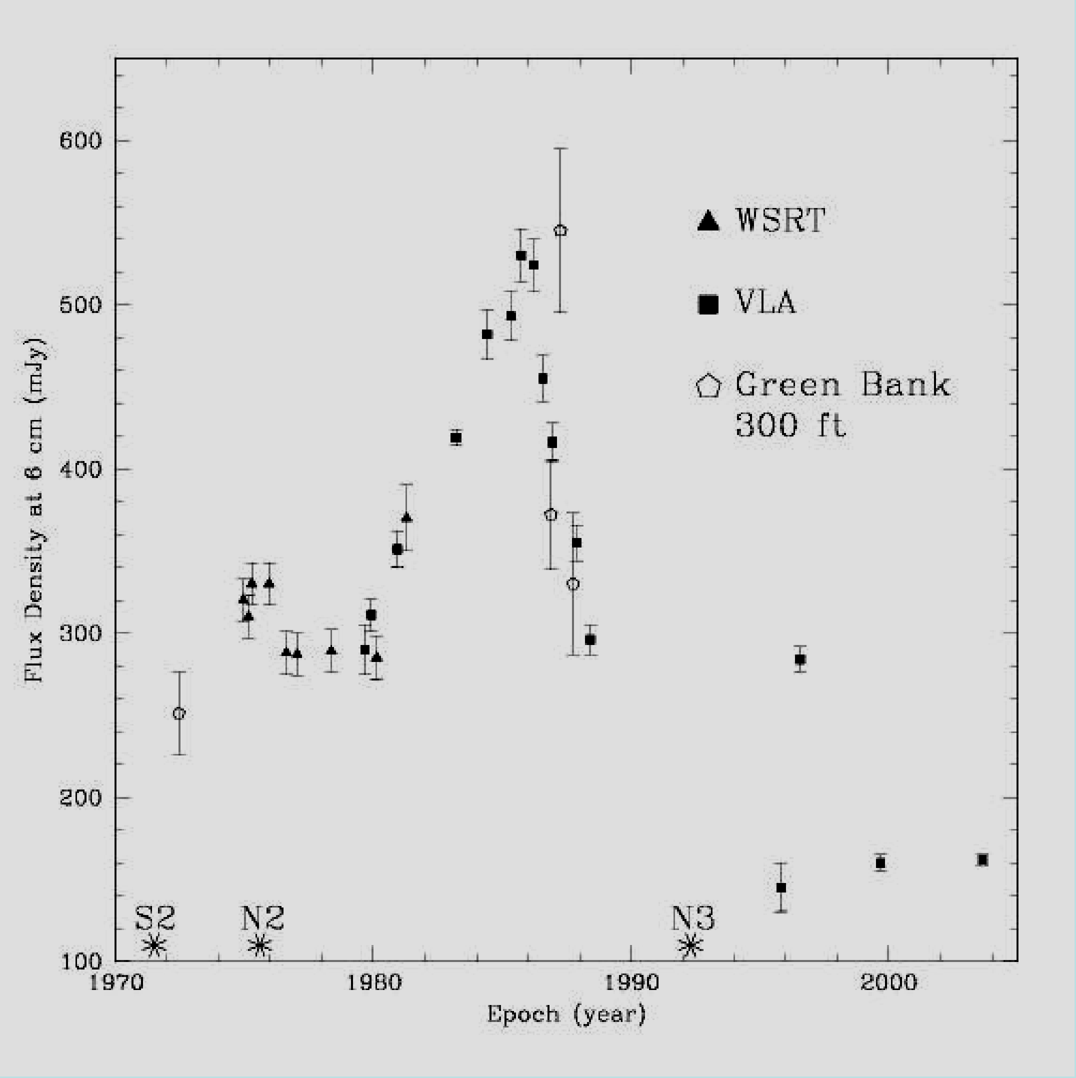
1 mas = 0.07 pc

NGC 4278, jet properties

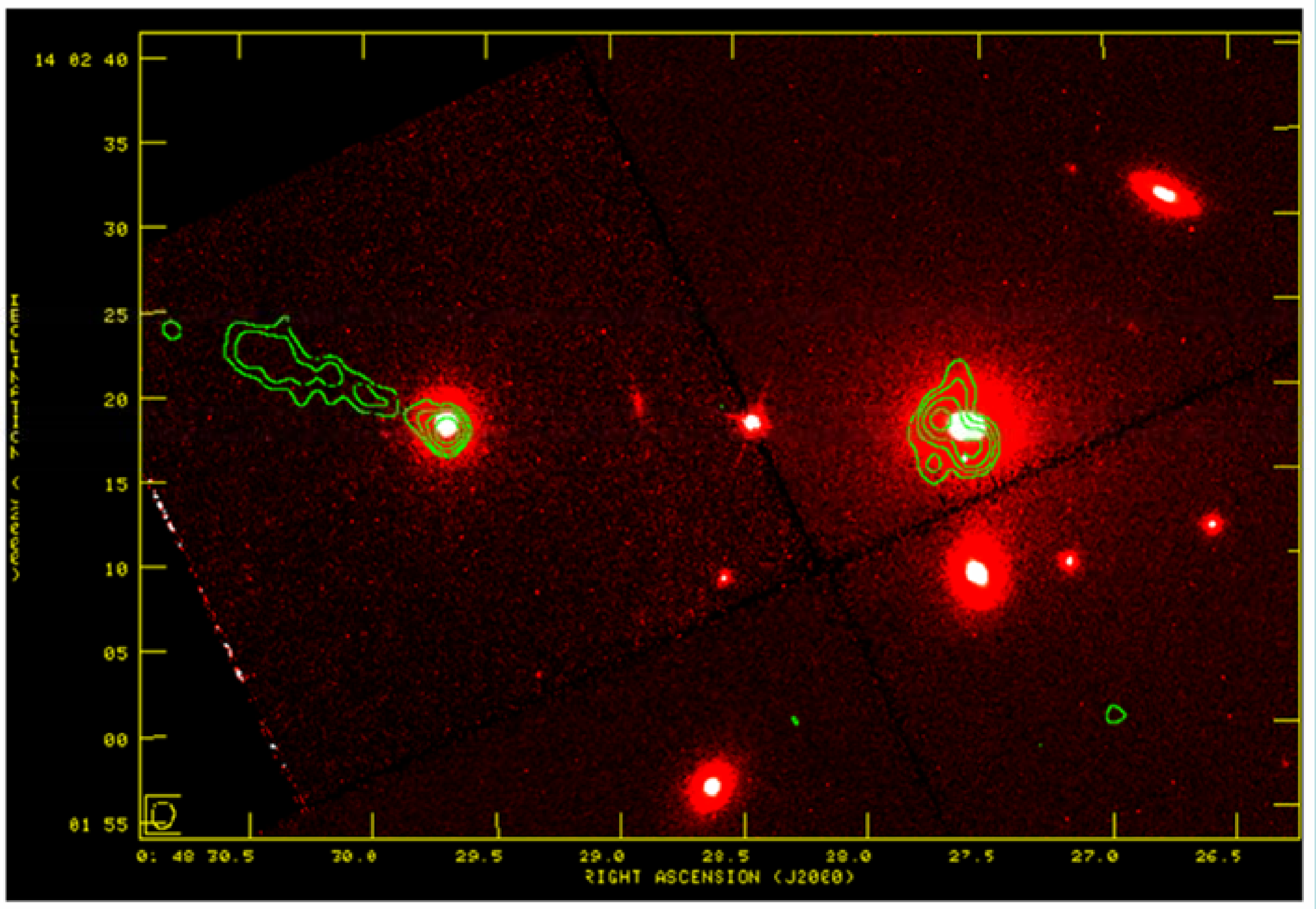
- $0.65 < \beta < 0.85$
- $1.3 < \Gamma < 1.9$
- $2° < \theta < 4°$
- $2 < \delta < 3.5$
- $P_{int} < 10^{21}$ W Hz^{-1}



Light curve for NGC 4278 at 5 GHz

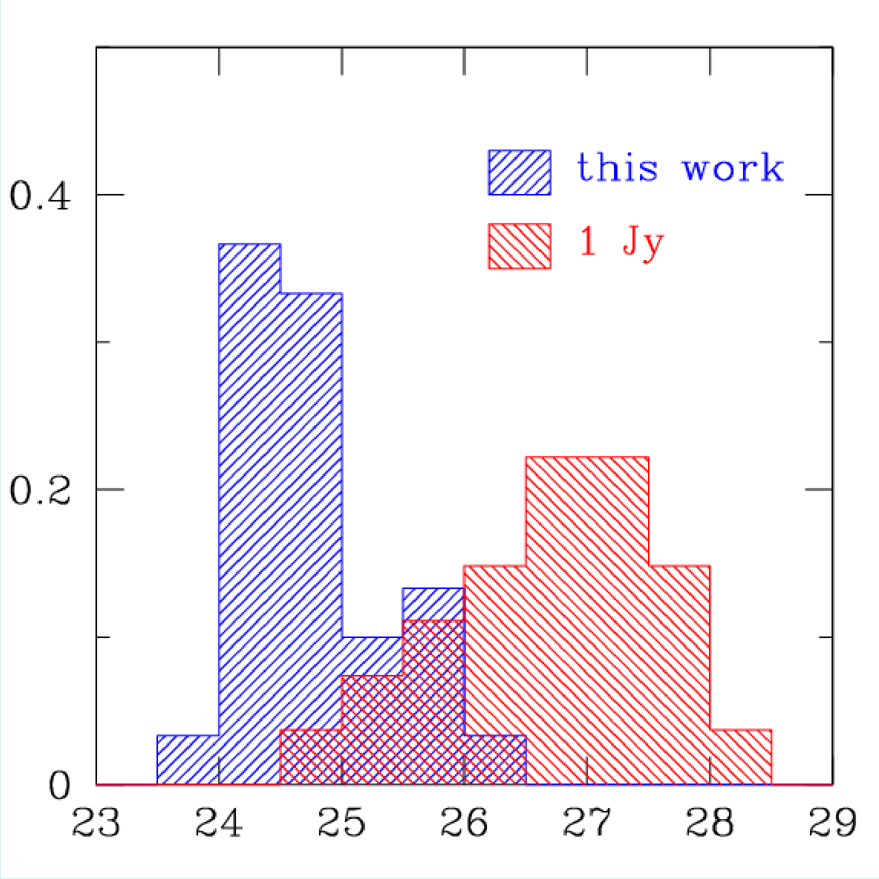


Pretty pictures (III): 0145+138



A comparison to the 1 Jy sample

- <Log $P_{1.4\ GHz}$> = 26.8 +/- 0.9
- <Log $P_{1.4\ GHz}$> = 24.8 +/- 0.6
- few objects already known in radio (less than 50% have VLBI or VLA)



[Log $P_{tot,\ 1.4\ GHz}$]