AGN Samples, Fermi and VLBI

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Blazars: an extreme class of Active Galactic Nuclei

FSRQs (high luminosity radio galaxies)

BLLacs (low luminosity radio galaxies)

Characteristics: high luminosity

rapid variability

high optical polarisation

Emission: a broad continuum of non-thermal origin, extending from the radio wavelengths through gamma rays

Radio band: flat ($\alpha < 0.5$) radio spectra

core-dominated objects

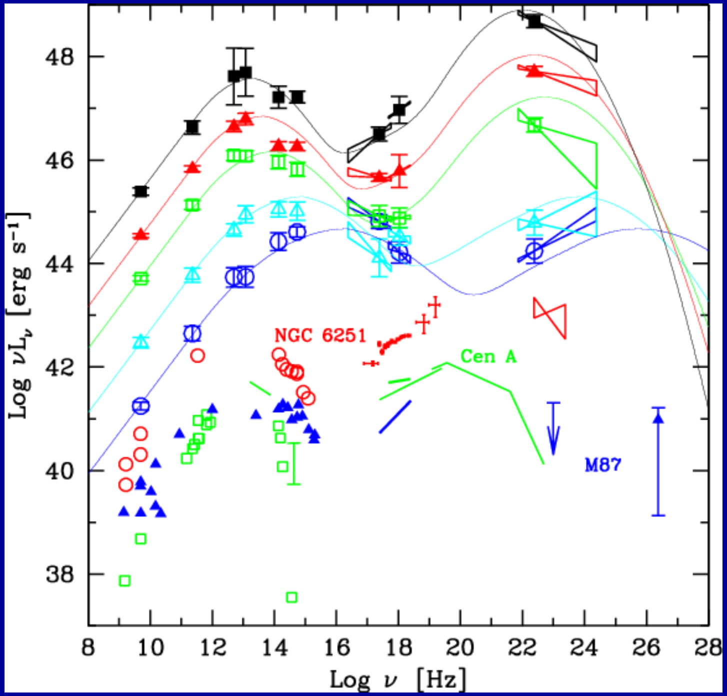
apparent superluminal speeds

Gamma band: vast majority of sources in the EGRET catalogue

Any connection between radio and γ-ray emission ?

Radio emission:

synchrotron radiation from relativistic electrons

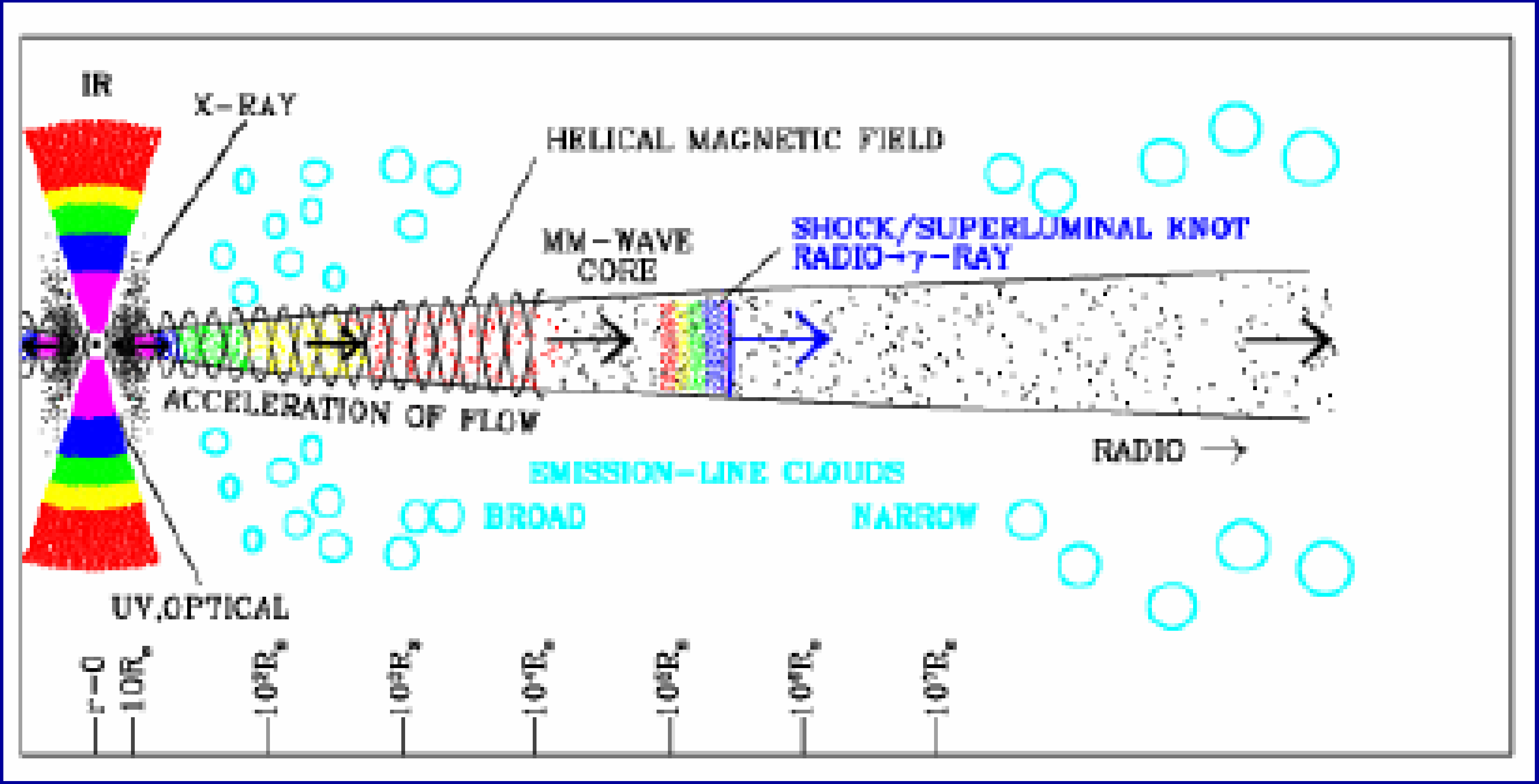


γ-ray emission:

low energy photons plus relativistic beaming → up-scattering of the photons (Inverse Compton)

Blazar sequence:

connection between radio luminosity and peak frequency and relative intensities of the Spectral Energy Distribution (SED)
(Fossati et al. 1998)



Curtesy A. Marscher

Fermi / Large Area Telescope (LAT) :

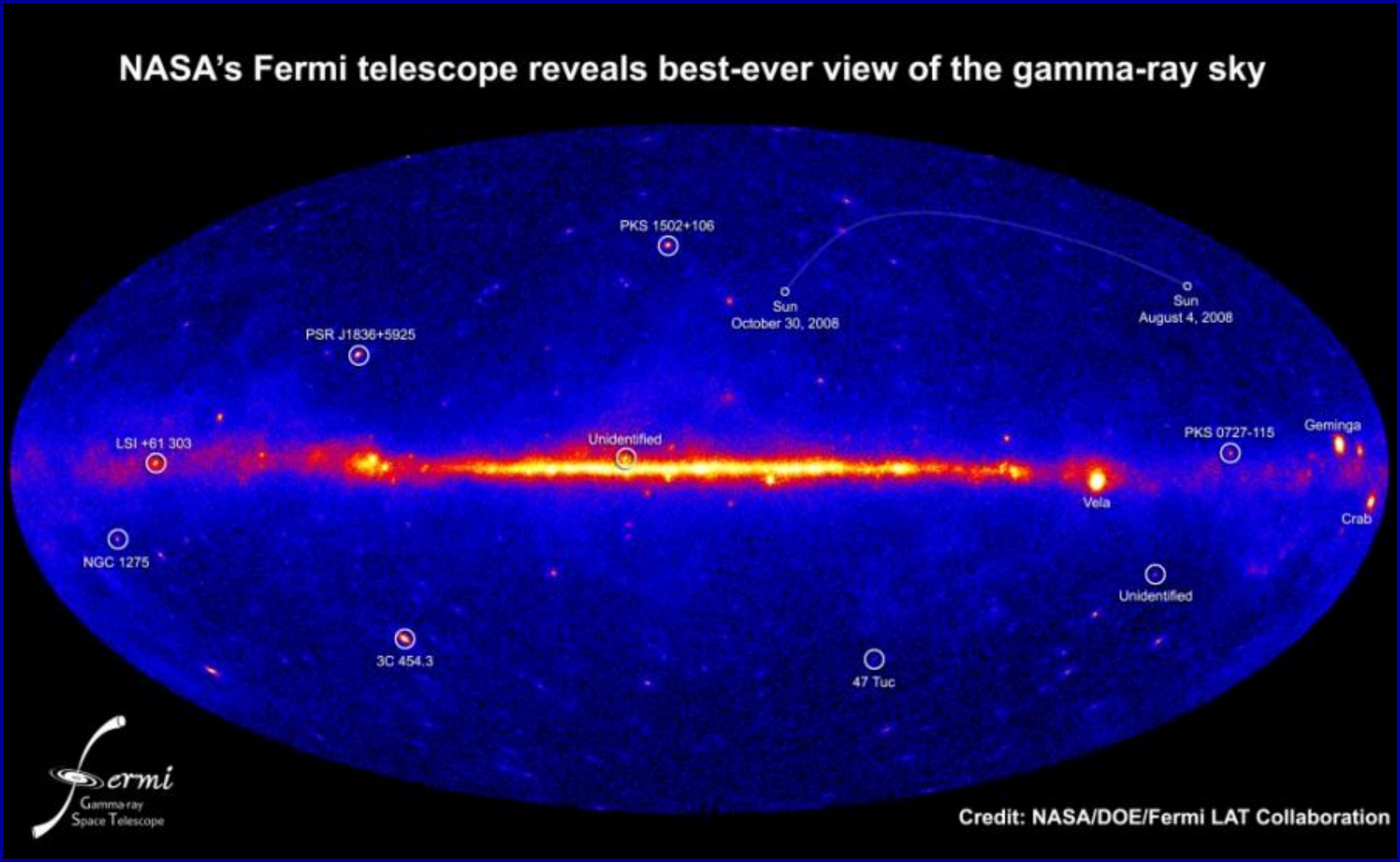
Launch: 11 June 2008

Sky covered in 3 hours:
- Monitoring
- variability studies (time scale: months - few ours)

Large energy range: 100MeV – 100 GeV
10 – 100 GeV (previously little explored)

First Source Catalogue (1FGL, Abdo et al. 2010): 1451 sources

663 associations of a given source:
281 Flat Spectrum Radio Quasars
291 BL Lacs
30 other AGNs (starburst galaxies, radiogalaxies NLR and BLR)
61 unknown type (lacks or insufficient optical spectrum)


NASA's Fermi telescope reveals best-ever view of the gamma-ray sky
PKS 1502+106
Sun
October 30, 2008
Sun
August 4, 2008
PSR J1836+5925
LSI +61 303
Unidentified
PKS 0727-115
Geminga
Vela
Crab
NGC 1275
Unidentified
3C 454.3
47 Tuc
Fermi
Gamma-ray
Space Telescope
Credit: NASA/DOE/Fermi LAT Collaboration

Single-Dish Monitoring Programmes

programme	freq. (GHz)	sampling	size	
OVRO	15	2-3 weeks	> 1000	
Effelsberg	2.6 – 43	monthly	≈ 60	F-GAMMA
IRAM	86 – 270	monthly	≈ 60	F-GAMMA
APEX	345	monthly	≈ 60	F-GAMMA
UMRAO	4.8, 8, 14.5	15 days	35	
Metsähovi	37	monthly	≈ 100	
RATAN-600	1 – 22	2-4 weeks	600	

VLBI monitoring programmes

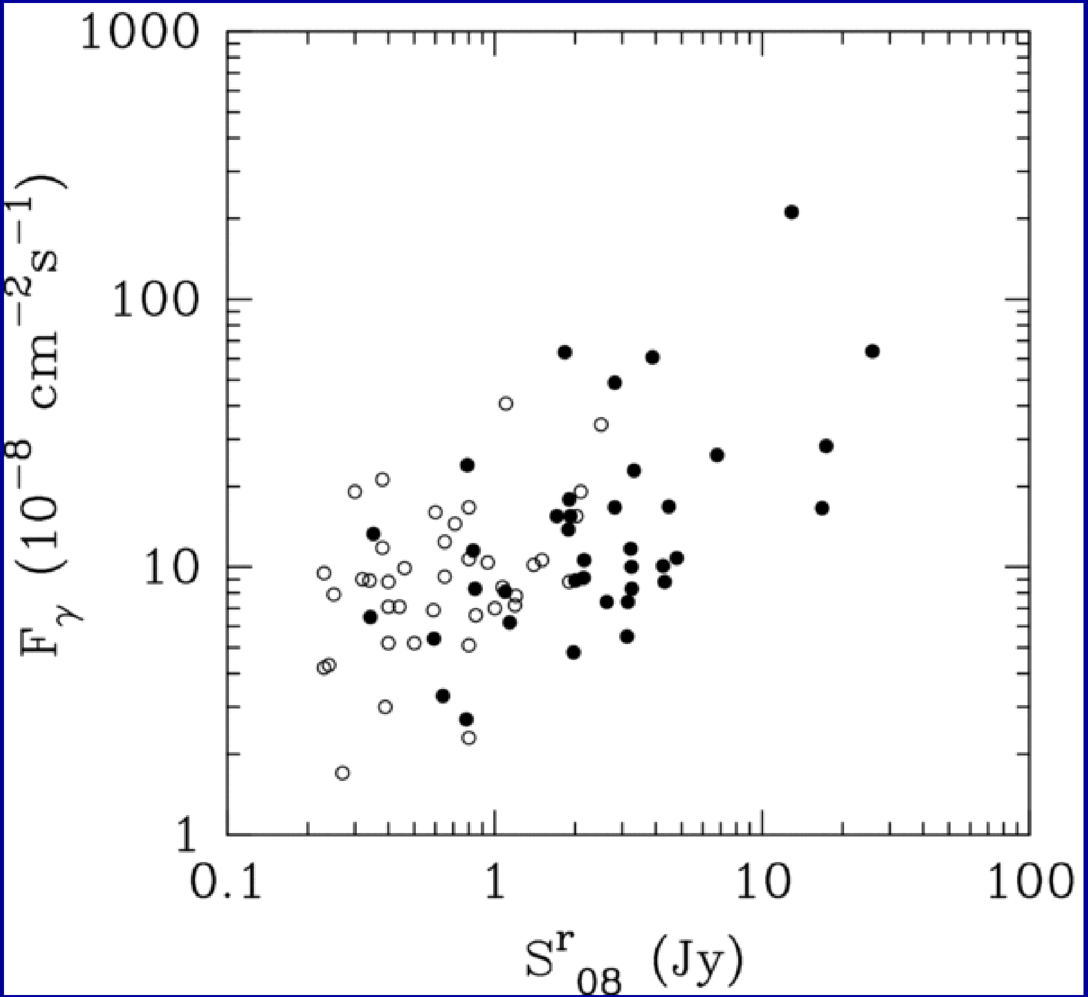
VLBA Monitoring at 43 GHz of EGRET blazars (Jorstad et al. 2001)

MOJAVE (Lister et al. 2009)
Monitoring **O**f **J**ets in **A**ctive galactic nuclei with **V**LBA **E**xperiments
VLBA observations at 2 cm of 300 sources

- ~50 Fermi LAT-detected gamma-ray AGN
- Flux > 200 mJy
- Obs. every 3 weeks

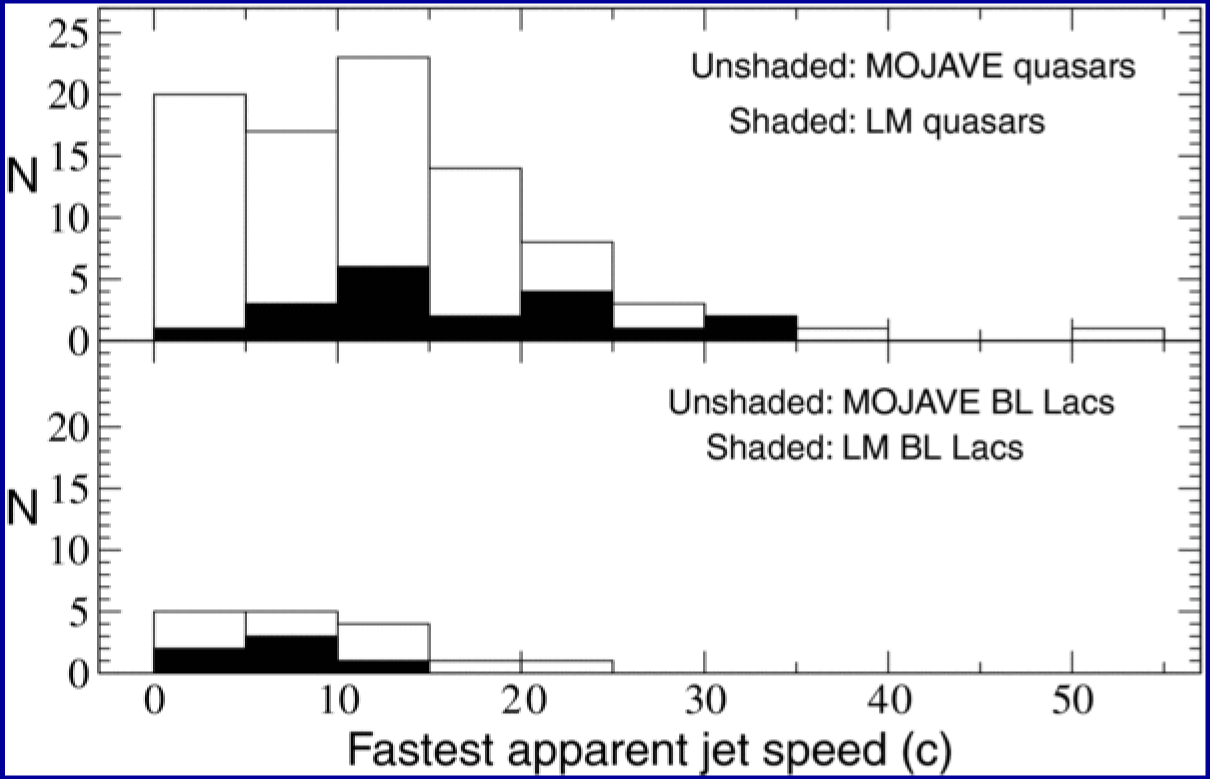
VISP (Helmboldt et al. 2007)
VLBA Imaging and Polarimetry Survey
a combined 5 GHz and 15 GHz survey of ~1100 AGN
with full polarization and high dynamic range

TANAMI (Ojha et al. 2010)
Tracking AGN with AU-SA Milliarcsecond Interferometry
80 sources with Dec < -30 deg at 8.4GHz and 22GHz



Direct relation between the γ-ray and parsec-scale synchrotron radiation

Figure 1. Kovalev et al. 2009
Average *Fermi* LAT 100 MeV-1 GeV photon flux (Abdo et al. 2009b) vs. quasi-simultaneous 15 GHz flux density. The filled circles represent total VLBI flux density while open ones—single-dish flux density.



Significant difference in the speed distributions of LAT-detected and non-detected MOJAVE quasars

The statistics for BL Lacs objects are more sparse

Figure 2 – Lister et al. 2009
Top panel: maximum jet speed distributions for all MOJAVE quasars.
The γ-ray detected (LM) quasars in each bin are shaded.
Lower panel: same plot for BL Lac objects.

Deep X-ray Radio Blazars Survey

(Perlman et al. 1998; Landt et al. 2001)

Cross-correlation ROSAT sources

WGCAT catalogue – White, Giommi, Angelini 1995

and radio sources with flat radio spectra

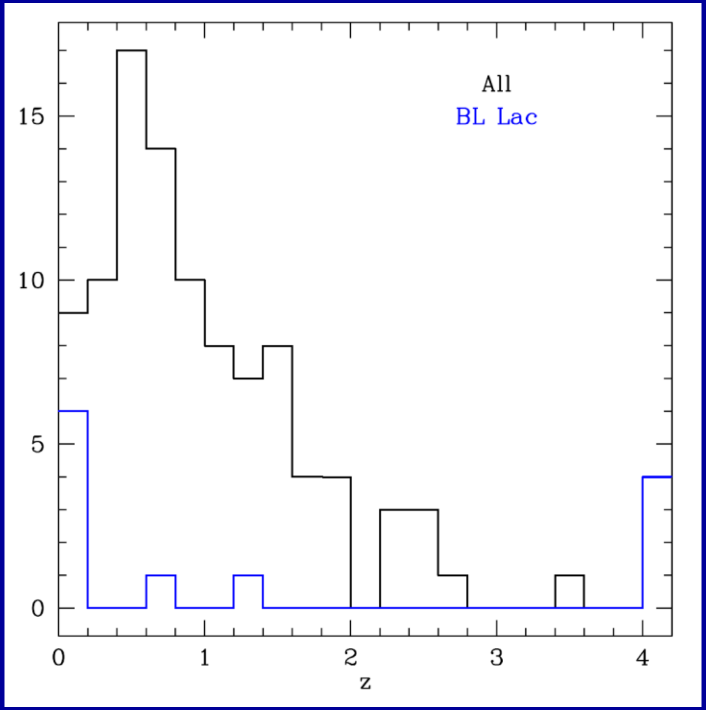
GB6	Gregory et al. 1996
NORTH20CM	White and Becker 1992
PNM	Griffith and Wright, 1993

- flux density down to ~ 50 mJy at 5 GHz
- power down to ~ 10^{24} W Hz^{-1}
- nearly complete optical identification
- includes both FSRQs and BL Lac sources

298 objects: 234 quasars, 181 FSRQs, 53 SSRQs
36 BL Lacs
28 narrow-line radio galaxies

"Faint blazars sample"

redshift distribution



87 " DXRBS " sources selected

Selection criteria: Dec > – 10 deg

Blazars are γ-ray emitter candidates

EGRET	→	130
Fermi Gamma-Ray Space Telescope	→	20,000

Investigation:

> Effelsberg observations (down to Dec – 20 deg)

> European VLBI Network observations

Source extraction from NVSS and FIRST catalogues

Effelsberg
100-m telescope
observations

Frequencies: 2.64 GHz 4.85 GHz 8.35 GHz 10.45 GHz
Observing mode: standard cross-scans (4 or 8)

Results on Spectral Indeces

14% inverted spectrum

6% spectral index steeper than 0.7 (S prop to $\nu^{-\alpha}$)

80% complex spectral index
flattening at higher frequencies - FSRQs

Flux density variability Effelsberg *vs* GB6 at 5 GHz

(S > 18 mJy – σ ≈ 5 mJy)

~ 50 % of sources exhibit flux density variability > 20 %

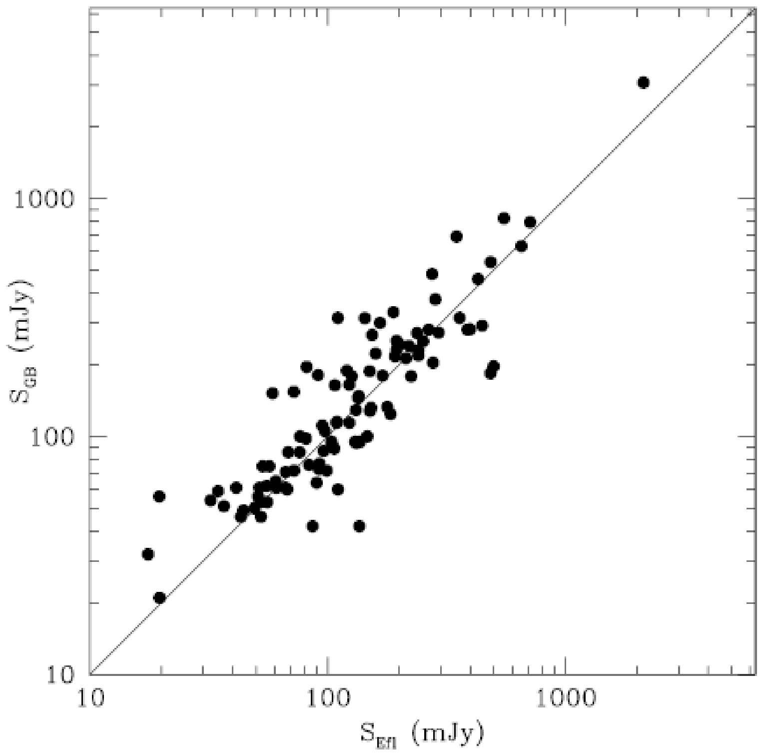


Fig. 1. Effelsberg flux densities *vs* GB6 flux densities at 5 GHz. The straight line means a ratio of 1. The size of a dot represents a flux density error of 10%.

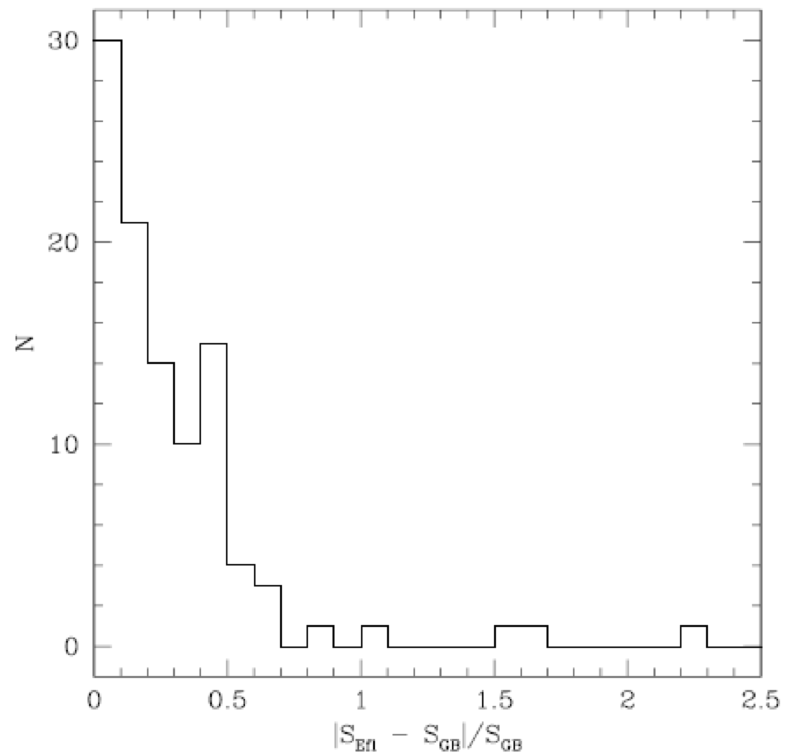


Fig. 2. Cumulative histogram of the ratio between the Effelsberg flux density minus the GB6 flux density module and the GB6 flux density.

EVN observations

Frequency	5 GHz
Stations	11
Recording	512 Mbits, 2 bit sampling (~ 2.5 TBytes/station)
Strategy	5 scans, 6 minutes long each per source
Observations	Session 3, 2009 → 18 sources, EM077A Session 2, 2010 → 40 sources, EM077B, C
Correlation	MPIfR DiFX software correlator 1 sec integration time → field of view ~ 11”

Main aims of the project

- first mas resolution observations of a sample of faint blazars
- direct comparison between γ-ray detected and non-detected sources in the same flux limited sample
- observations done while *Fermi* is making its survey
- ratio of the correlated to the total flux density
- core and jet brightness temperature evaluation
- ratio of the core to the extended flux density → jet inclination

EM077A - Preliminary results

Data analysis: AIPS and Difmap

- All the 18 sources observed are detected
- 12 exhibit a core-jet structure
- 6 are point-like (resolution higher than 5 mas)
- S_{VLBI} much smaller S_{EF} ; $S_{VLBI} / S_{EF} < 0.55 \quad 0.51>$

  (indication of extended emission)
- $Tb_{median} = 3.0 \times 10^{10}$ k

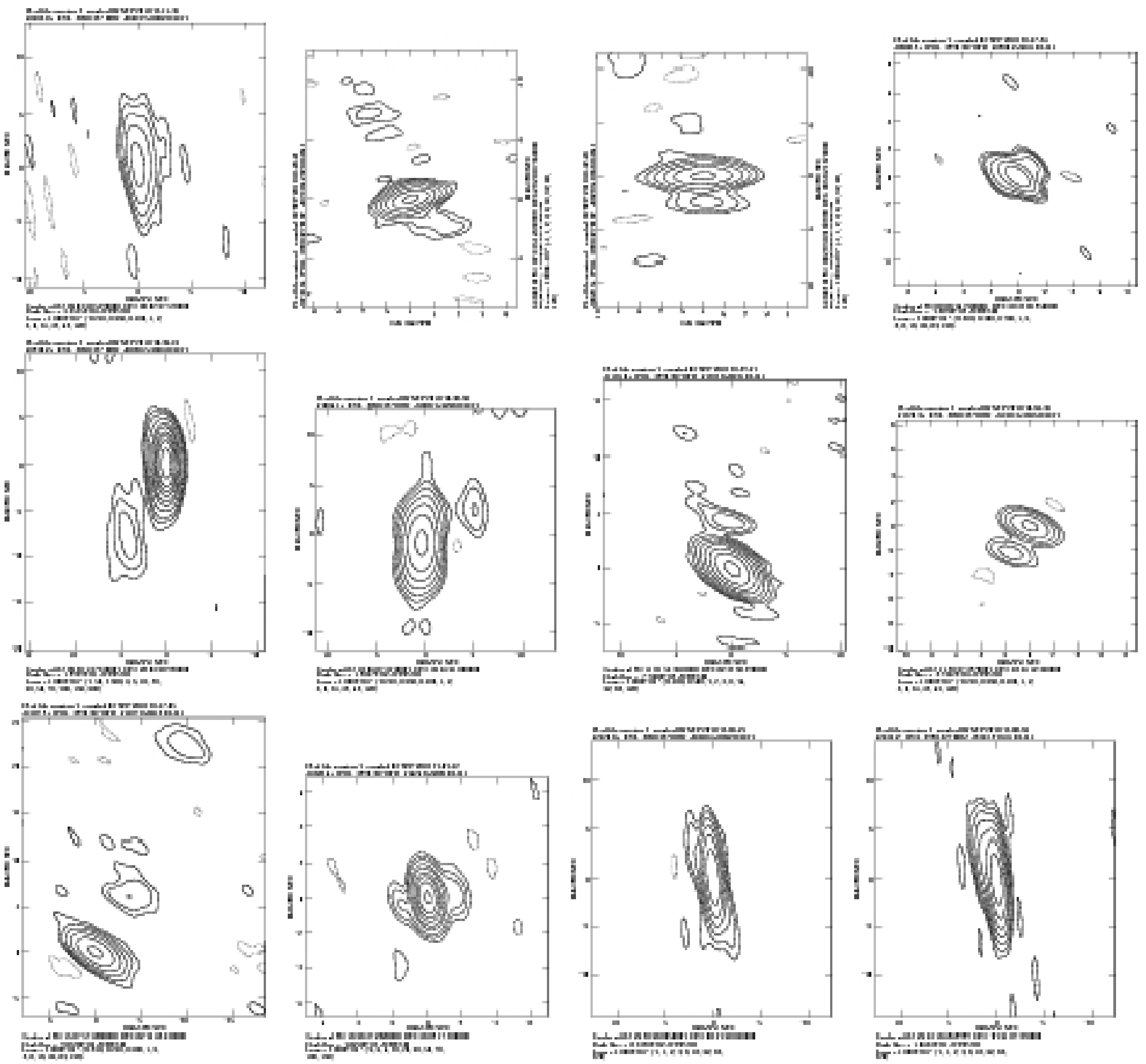
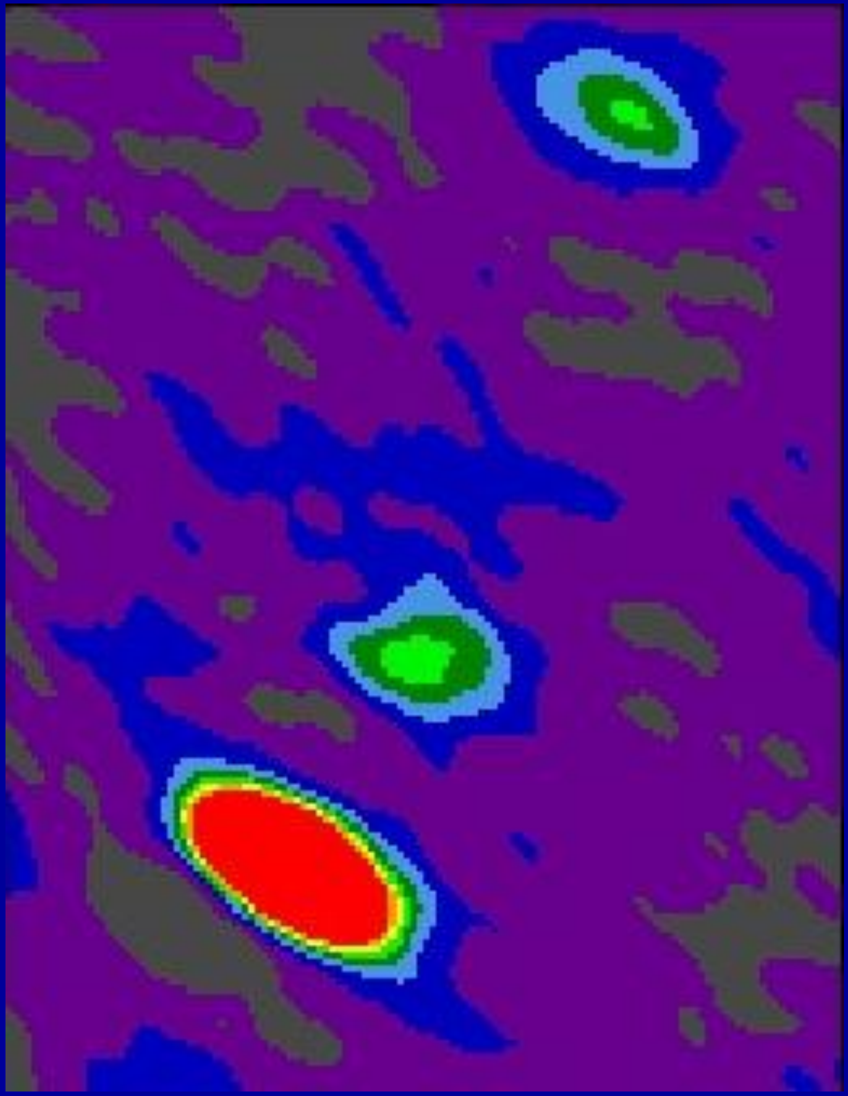
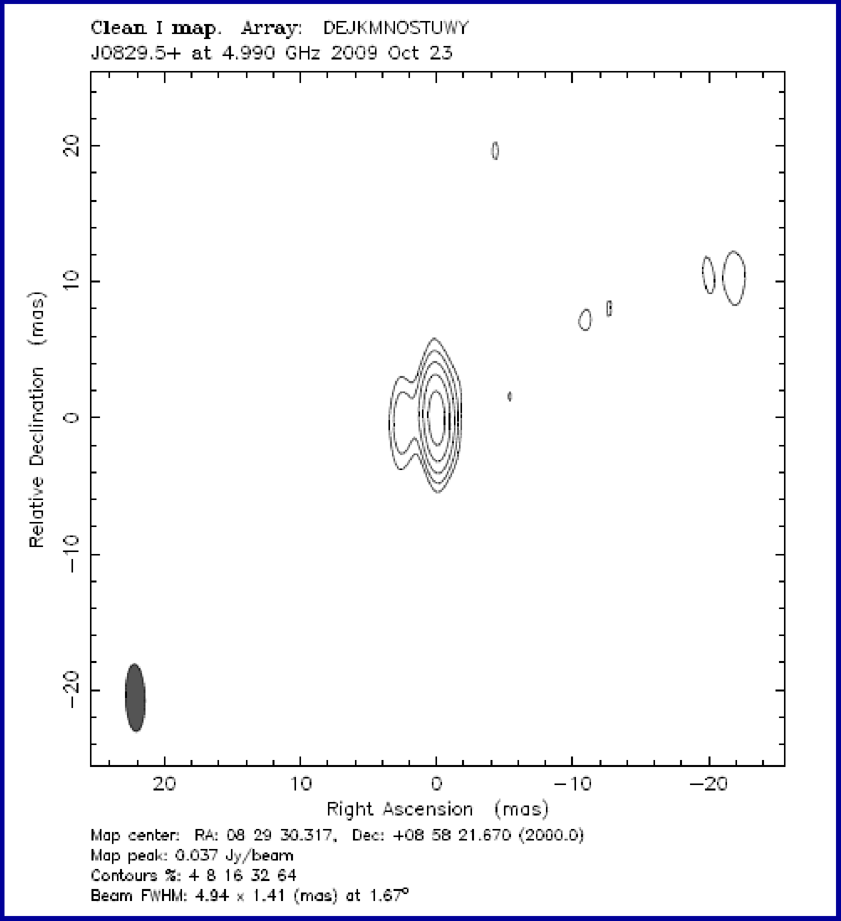


Figure 1: EVN images at 5GHz of the detected DXRBS core-jet sources in project EM077A





J1507.9+6214 Beam = 4 x 2 at 60 ; rms=0.12 mJy/b

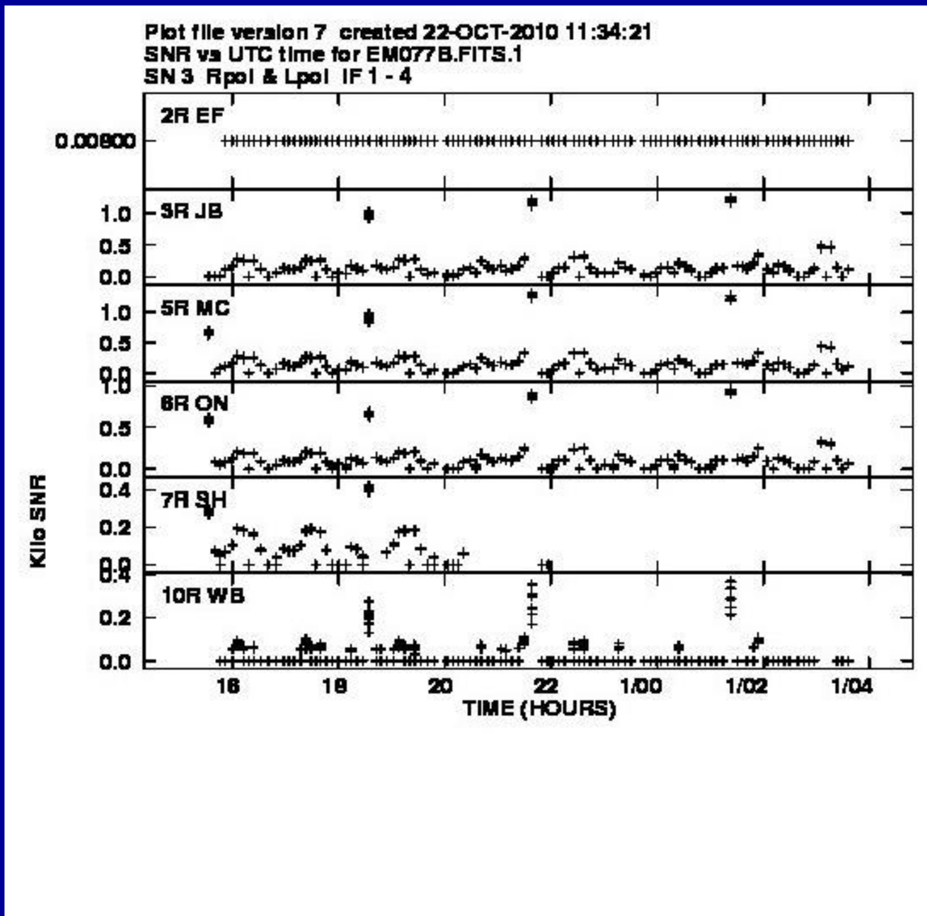
J0829.5+0858 Beam = 5 x 1.5 at 2 ; rms=0.35 mJy/b

EM077B and C data analysis

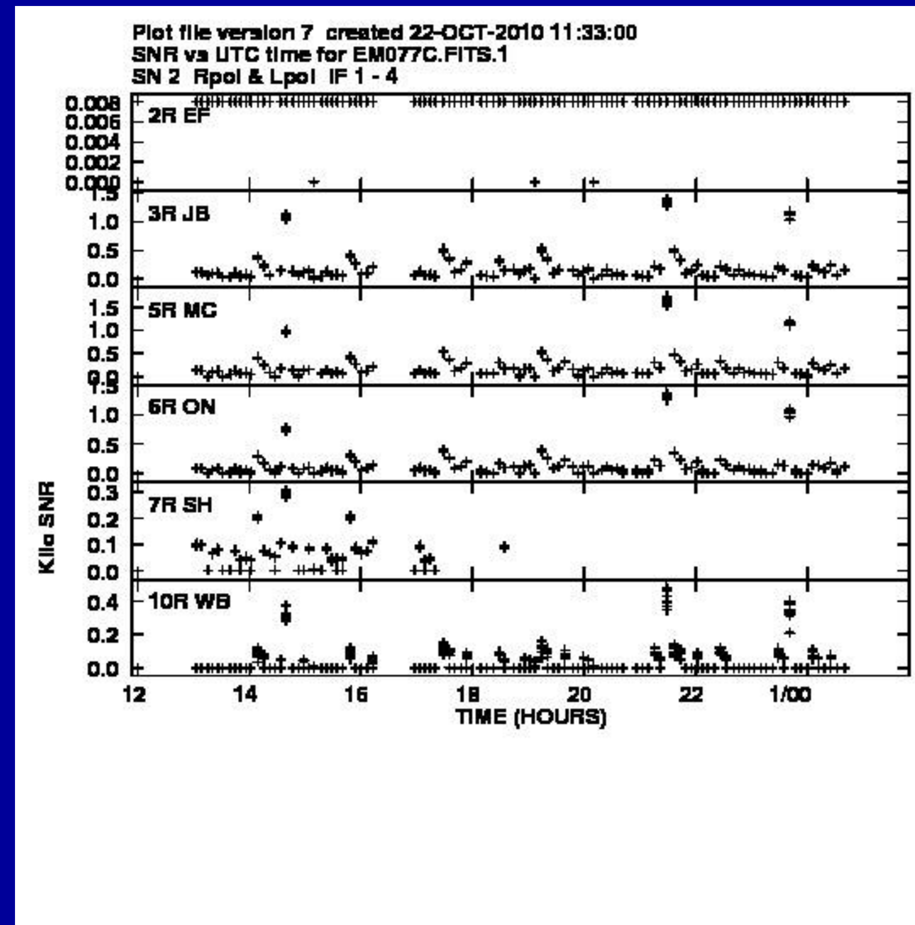
12 + 12 hours of observations
40 sources observed

not available:	Yebes and Noto
no fringes:	Knocking, Torun, and Urunqui,
limitations:	Cambridge (only 1 IF) Shanghai (short time on-source in common) Westerbork
good data:	Effelsberg, Jodrell Bank, Medicina, Onsala

EM077B



EM077C



~ 90 % of sources detected

Fermi and the "Faint blazars sample"

8 out of 87 sources detected by *Fermi*

(first year list, Abdo et al. 2010)

2 are among the 18 sources imaged with the EVN

WGAJ0847.2 + 1133

WGAJ0937.1 + 5008

WGAJ0937.1+5008   (z = 0.275)

- \> point-like structure
- \> S_{VLBI} / S_{EF} = 2.3
- \> Inverted spectral index
- \> 60 – 70 % variability

Deserving follow-up monitoring observations to check for
flux density variability
structural changes.

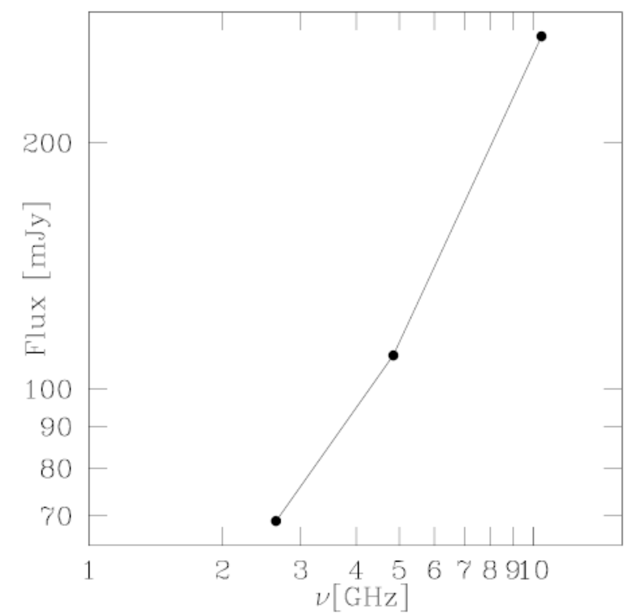


Figure 1: Radio spectrum of the DXRBS quasar J0937+5008 obtained from simultaneous observations carried out with the 100-m Effelsberg antenna at 2.64 GHz, 4.85 GHz and 10.45 GHz in July 2009.

Future programme

- EVN observations of the 29 sources left
- Start a similar project in the Southern Hemisphere
  LBA observations at 8.4GHz
- Follow-up monitoring programme in VLBI
- Comparison of the results with those on bright AGN
  (in particular with the MOJAVE monitoring programme)

Thanks for your attention