# Спектральные свойства струй активных ядер галактик на парсековых масштабах

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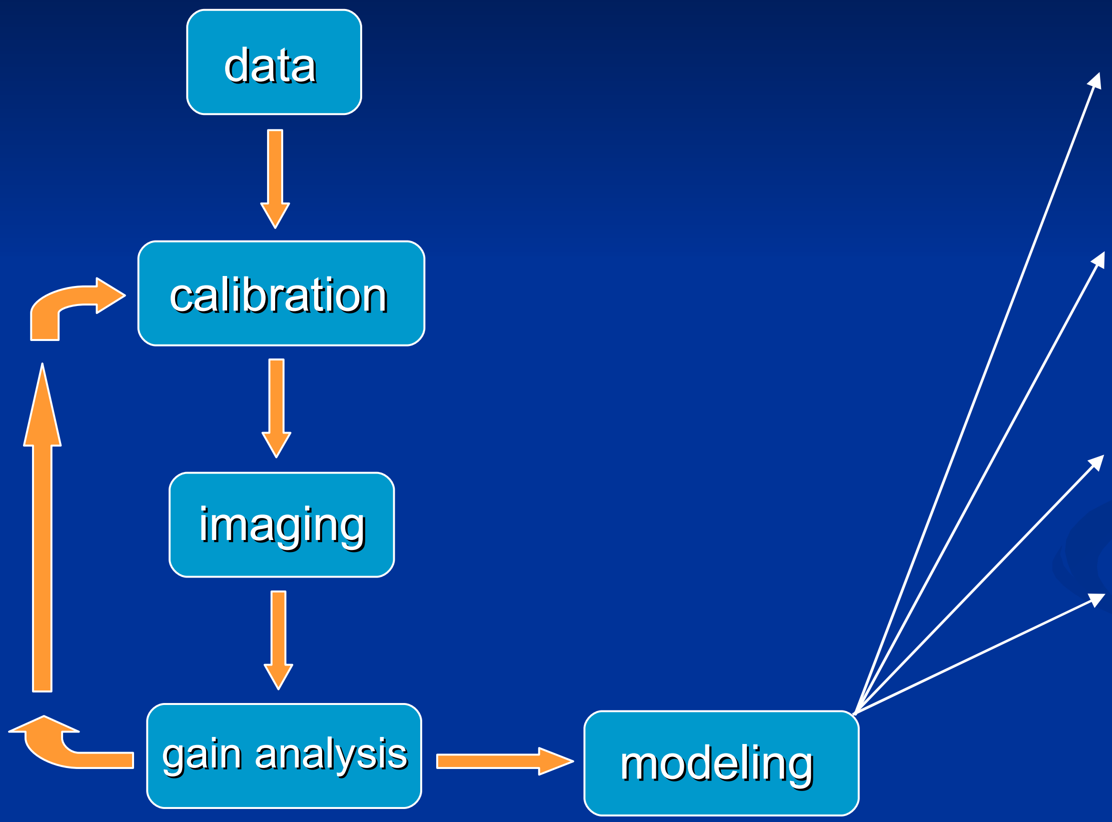
Актуальные проблемы внегалактической астрономии, Пущино 2008

# Outline

- Data reduction strategy
- Overall statistics
- Brightness temperature evolution
- Testing shock model at adiabatic stage
- Examples
- Conclusion & Future

# data reduction & analysis



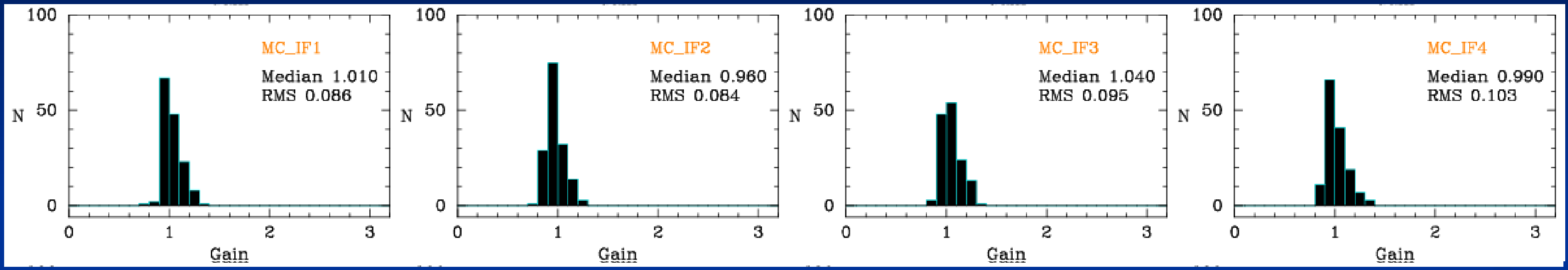

Brightness temperatures

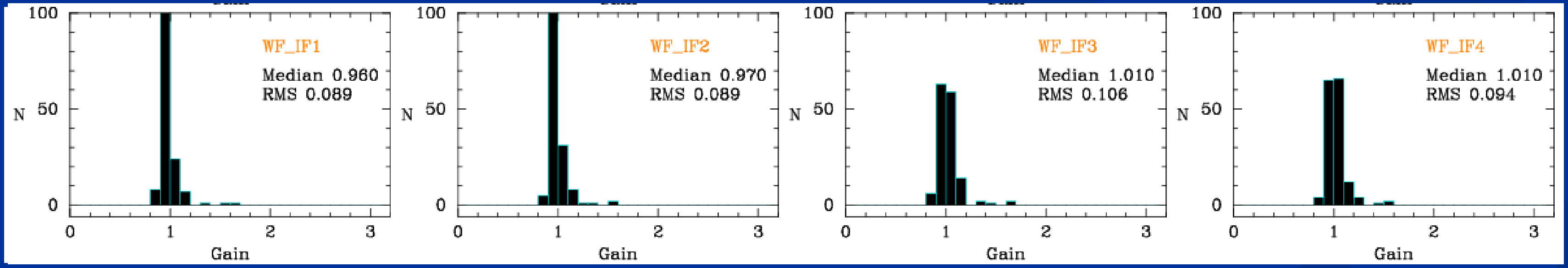
Spectral properties

Kinematics (for the first 5 years see G. Piner et al. 2007)

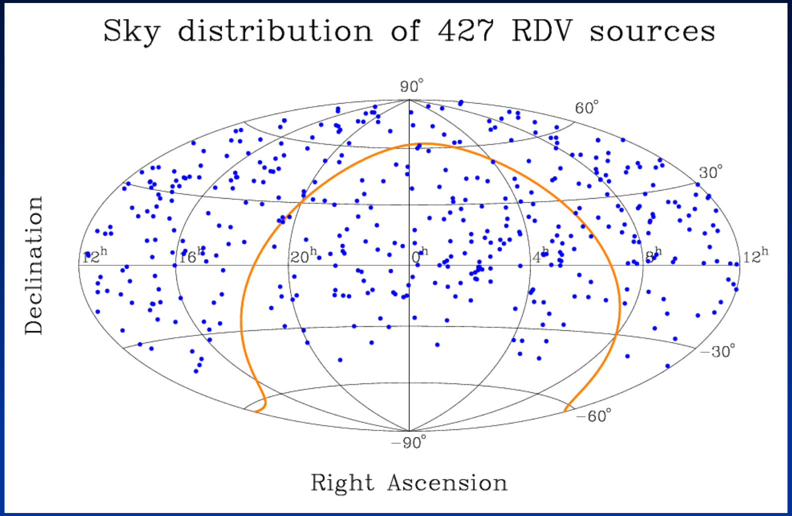
Core shifts (see poster Y.Y. Kovalev et al.)

# gain correction



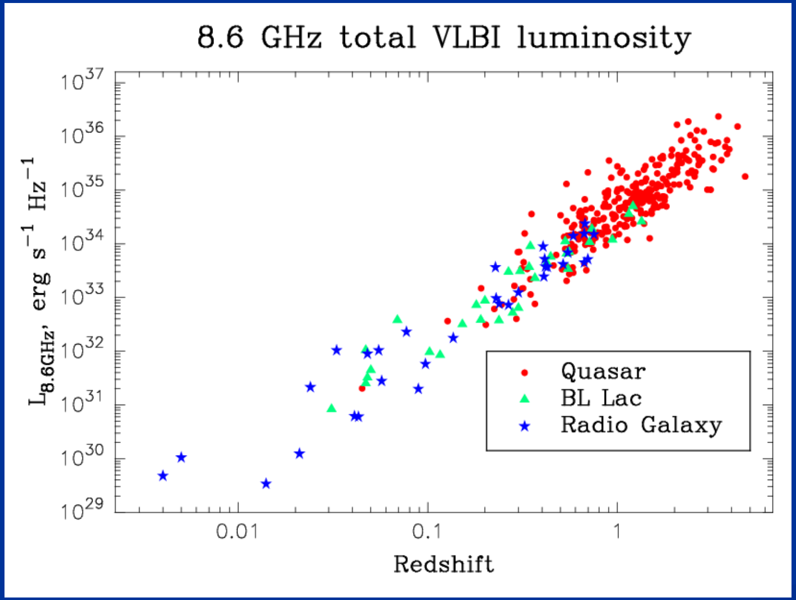



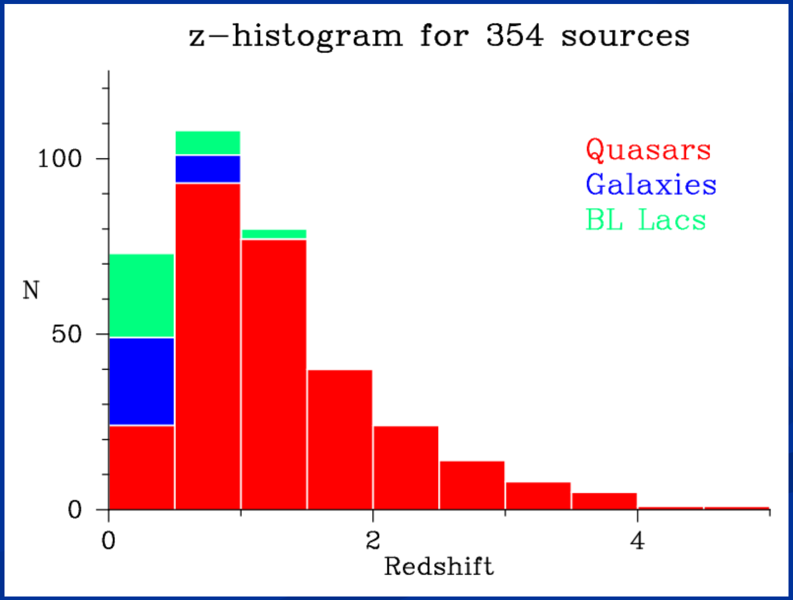
# sources observed




294 (69%) – Quasars
51 (12%) – BL Lacs
35 (8%) – Radio Galaxies
48 (11%) – unidentified sources

354 (83%) sources have measured redshifts (from Veron-Cetty&Veron, 2006)



# spectral properties

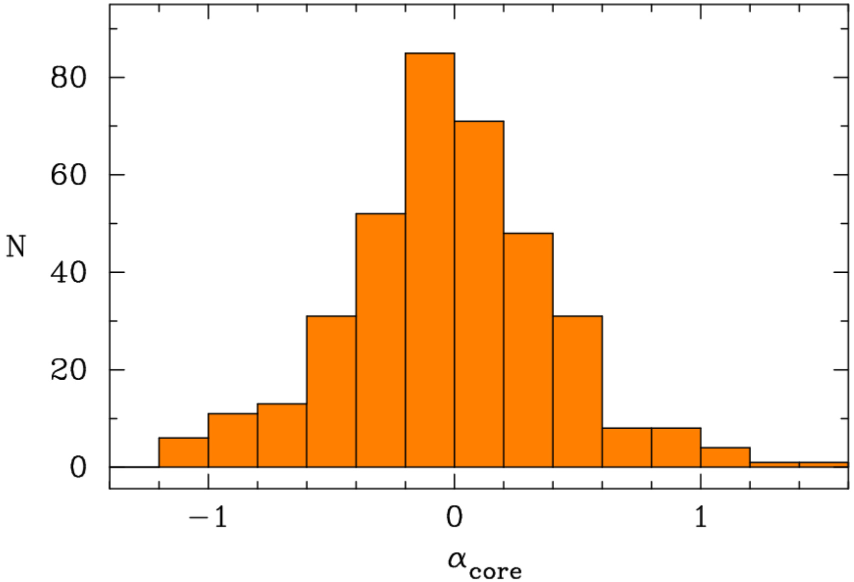
Median value of core spectral index

$$\alpha_{2-8\mathrm{GHz}} = -0.03$$

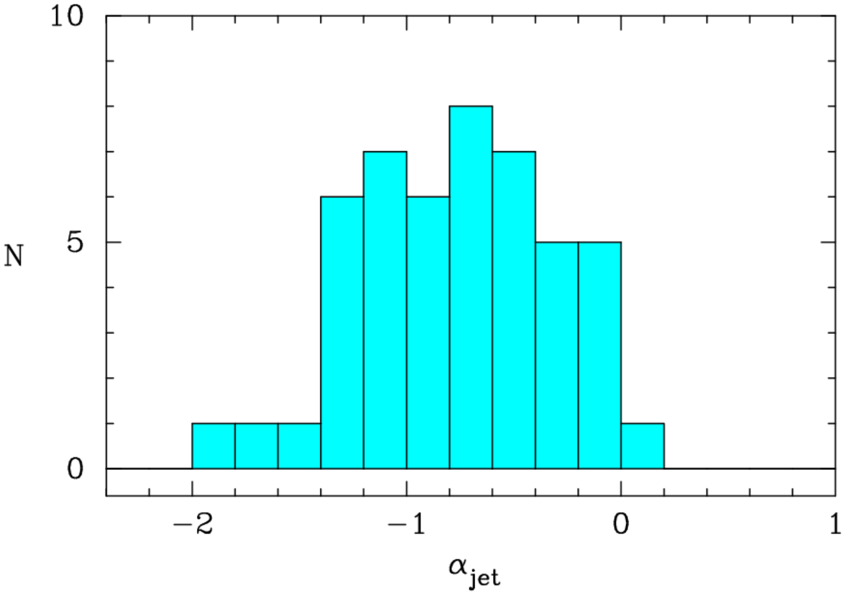
Median value of jet spectral index

$$\alpha_{2-8\mathrm{GHz}} = -0.75$$

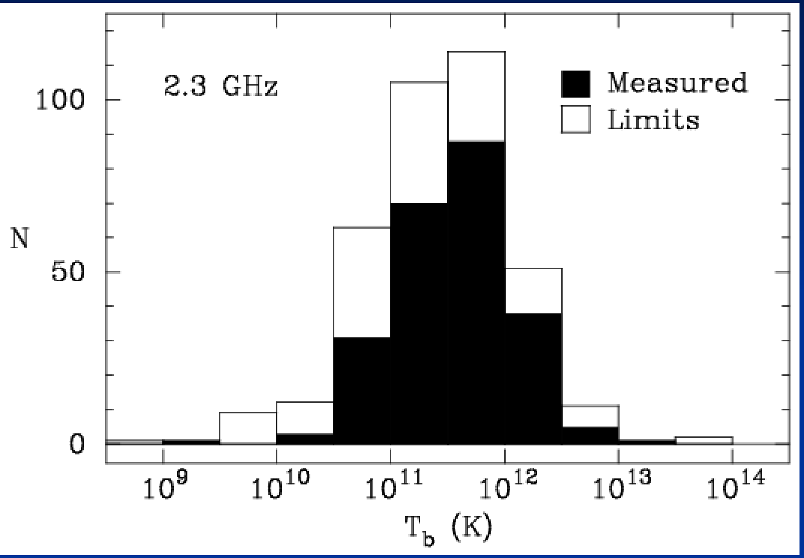
## core components

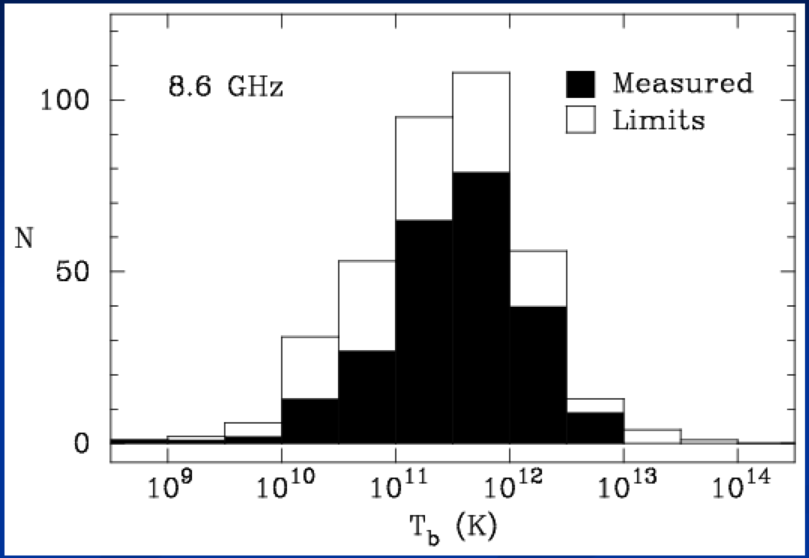



## jet components



# core brightness temperatures




$$T_b = \frac{2\ln 2}{\pi k}\frac{S\lambda^2(1+z)}{\theta_{\rm maj}\theta_{\rm min}},$$

*k* – Boltzmann constant

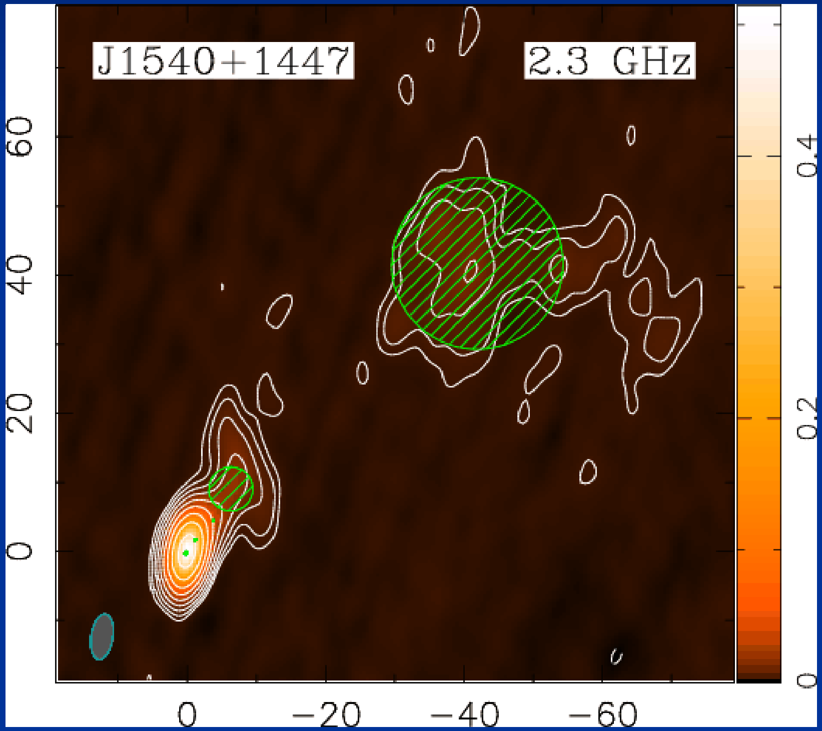
*S* – core flux density

*θ* – angular size of the core

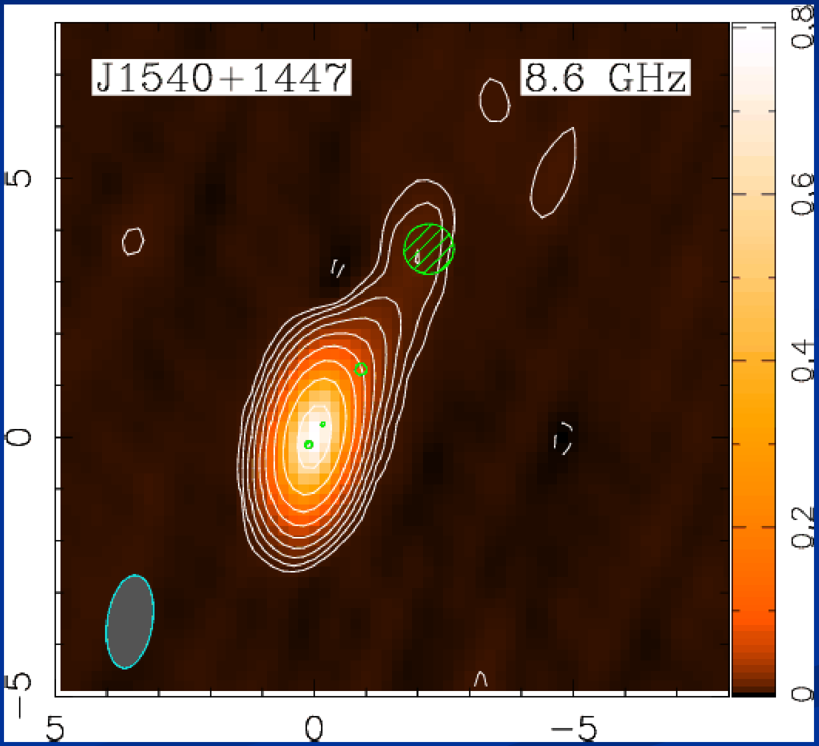
$$\text{median } T_{b\_2GHz} = 2.7\cdot 10^{11}\ \text{K}$$

$$\text{median } T_{b\_8GHz} = 2.7\cdot 10^{11}\ \text{K}$$

# maps + models



J1540+1447
2.3 GHz
60
40
20
0
0
−20
−40
−60
0.4
0.2
0

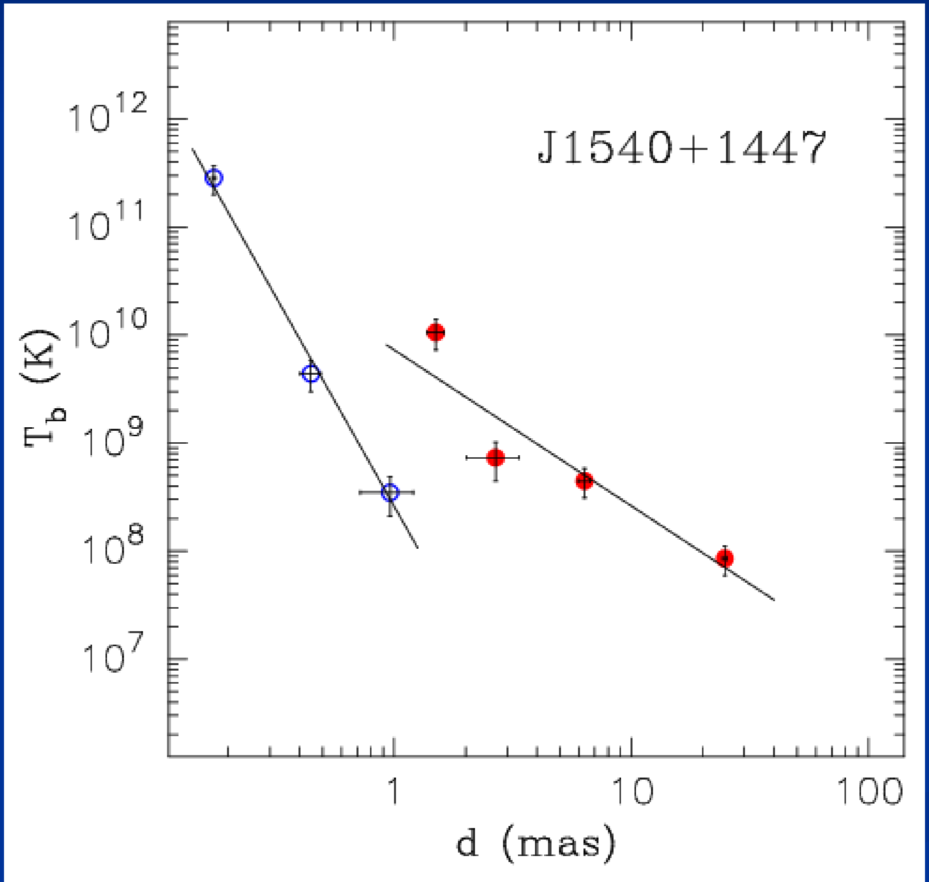



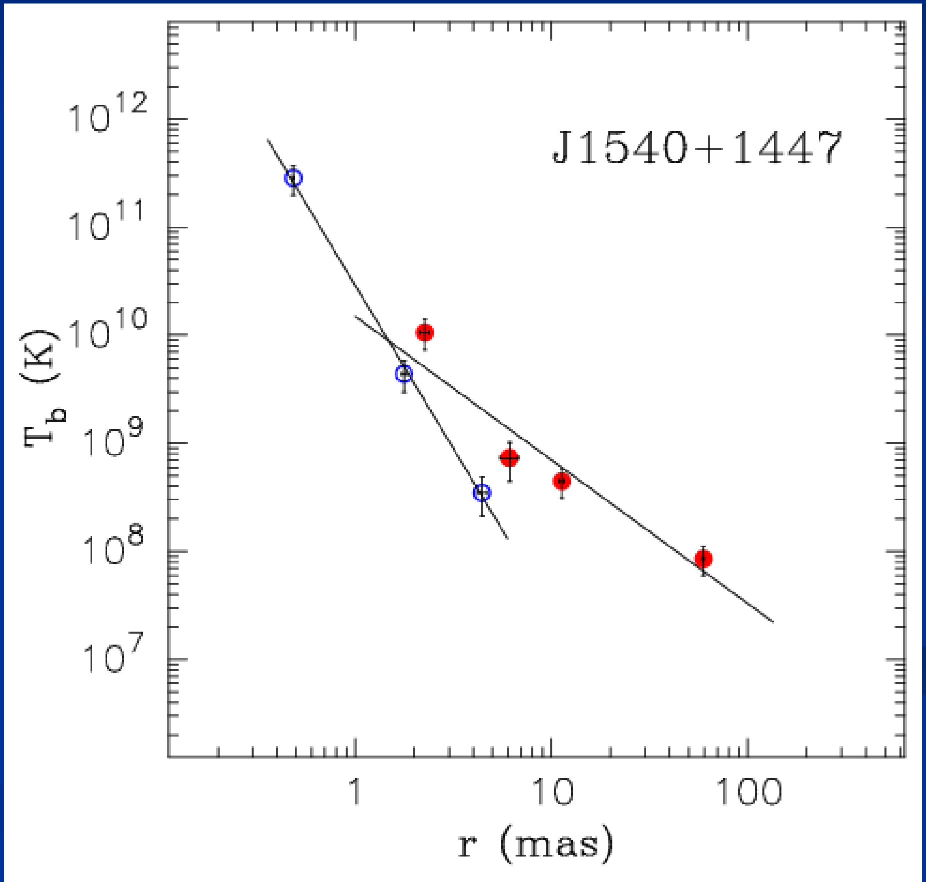
J1540+1447
8.6 GHz
5
0
−5
5
0
−5
0.8
0.6
0.4
0.2
0

# brightenss temperature evolution

$$T_b \sim d^{-\xi}$$

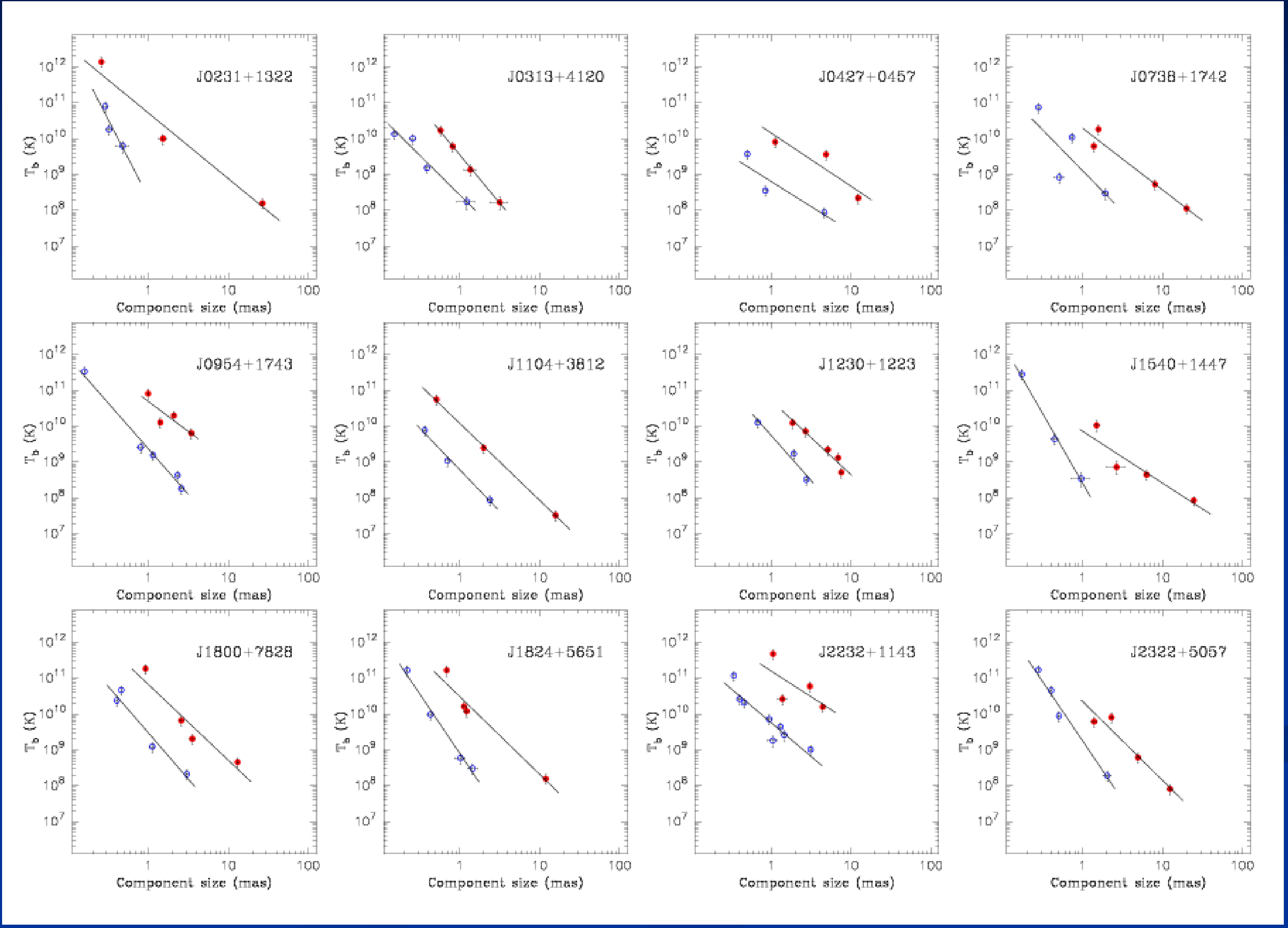
$$T_b \sim r^{-k}$$



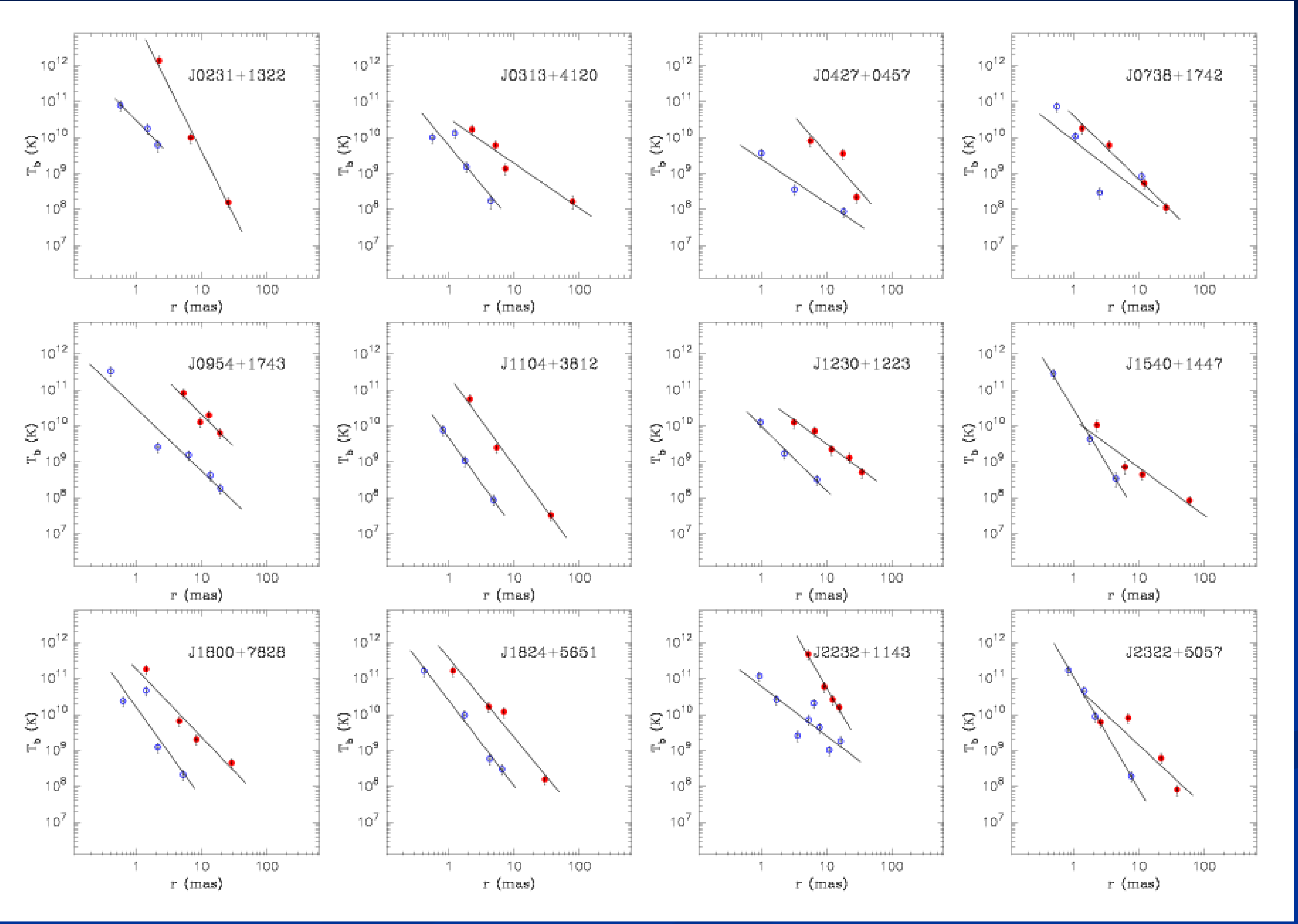
# brightness temperature evolution

$T_b \sim d^{-\xi}$



# brightness temperature evolution

$T_b \sim r^{-k}$



# brightness temperature evolution

$$B \sim r^{-b}$$

$$T_b \sim r^{-k}$$

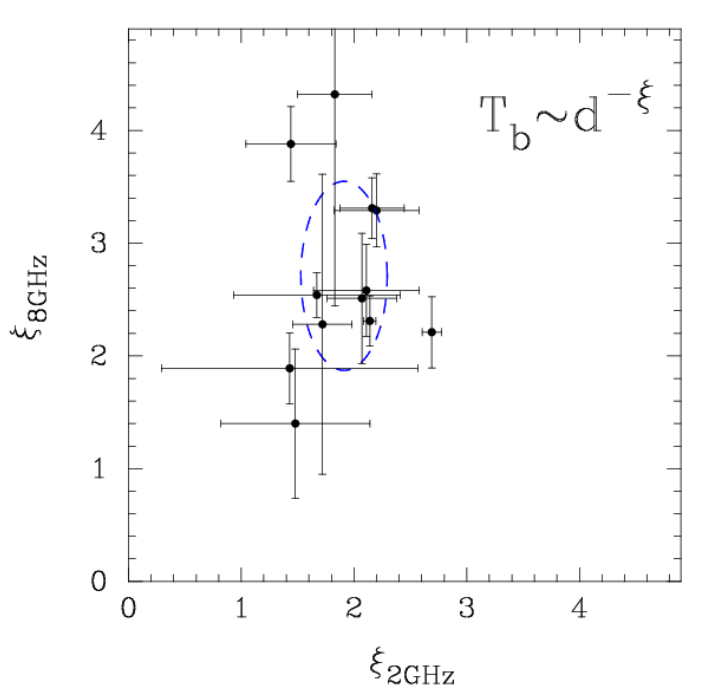
$$n_e \sim r^{-n}$$

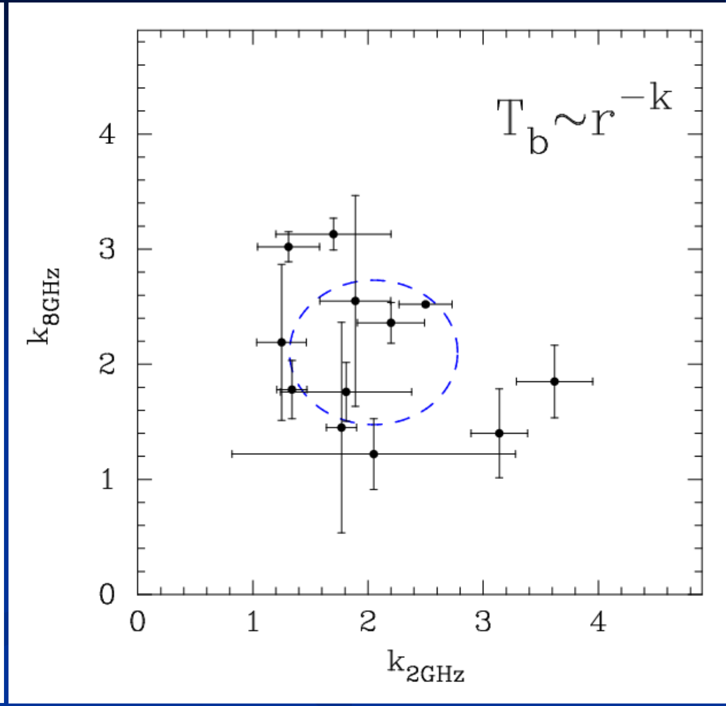
$$d \sim r^{l}$$

$$S \sim \nu^{\alpha}$$

$$b = \frac{k + l - n}{1 - \alpha}$$

(Kadler 2001)




$\bar{\xi}_{8GHz} = 2.7 \quad \bar{\xi}_{2GHz} = 1.9$

$\bar{k}_{8GHz} = \bar{k}_{2GHz} = 2$

Assuming

- $l = 1$ conical jet
- $n = 1.5$

$k = 2$
$\alpha = -0.75$

$$B_{jet} \sim r^{-0.9}$$

# shock model at adiabatic stage

$$N(E)\,dE \sim E^{-s}\,dE$$

$$B \sim d^{-a}$$

(Marscher 1990)

$d$ – transverse jet size

$a$ – B-field orientation

$a = 1 \quad ==> \quad \mathrm{B} \perp \mathrm{jet}$

$a = 2 \quad ==> \quad \mathrm{B} \parallel \mathrm{jet}$

---

$$T_{b\,\mathrm{jet}} = T_{b\,\mathrm{core}} \left(\frac{d_{\,\mathrm{jet}}}{d_{\,\mathrm{core}}}\right)^{-\xi}$$

(Lobanov et al. 2000)

$$\xi = \frac{2(2s+1)+3a(s+1)}{6} = $$

$$= \left[\begin{matrix} s = 1-2\alpha \\ S \sim \nu^{\alpha} \end{matrix}\right] = 1 + a - \alpha(a + 4/3)$$

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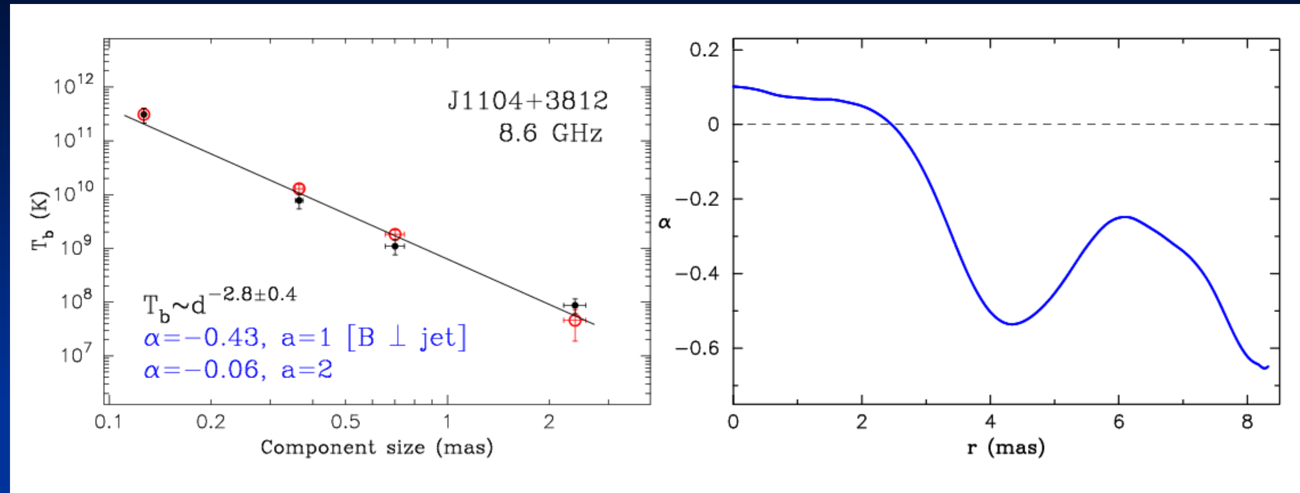
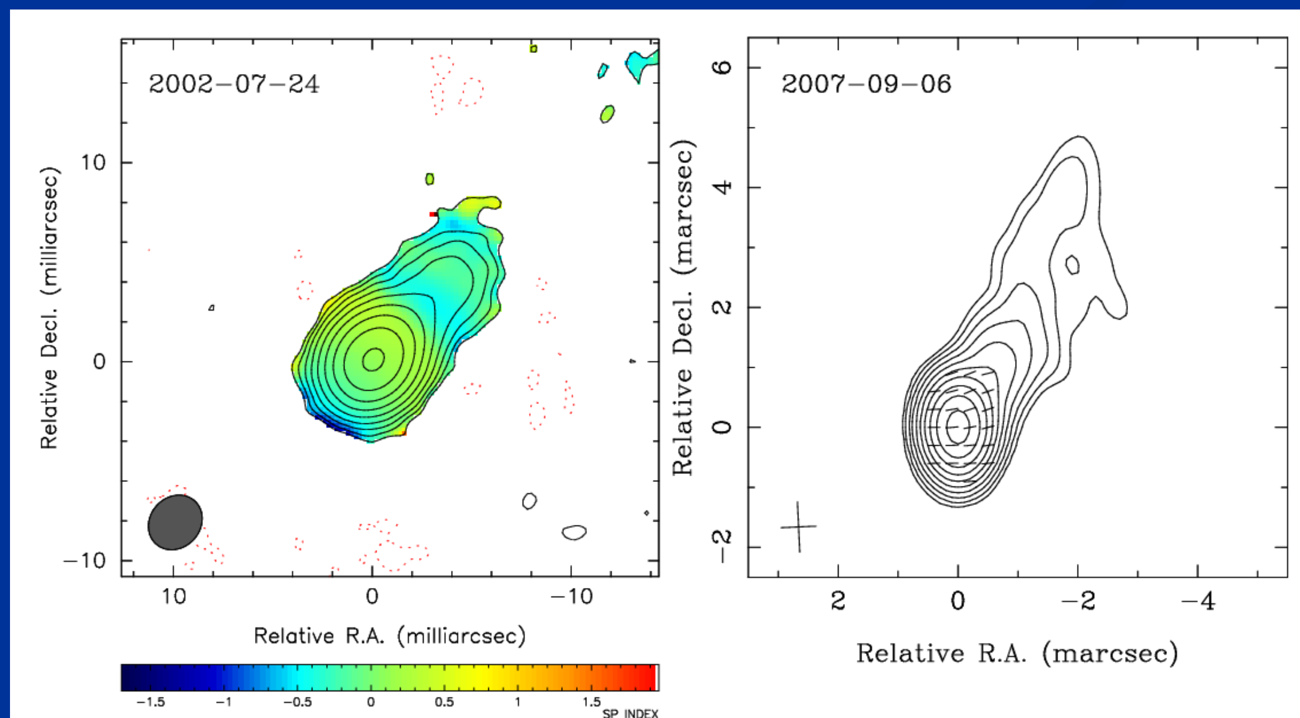
- Determining power index $\xi$ from data and setting $a = 1$ and then $a = 2$ one can obtain $\alpha_{model}$ and compare it with $\alpha_{obs}$
- Additional test is comaping magnetic field orientation predicted by model and detected by polarimetric observations

# J1104+3812 BL Lac

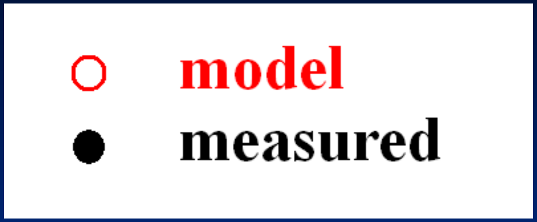
○ **model**
● **measured**

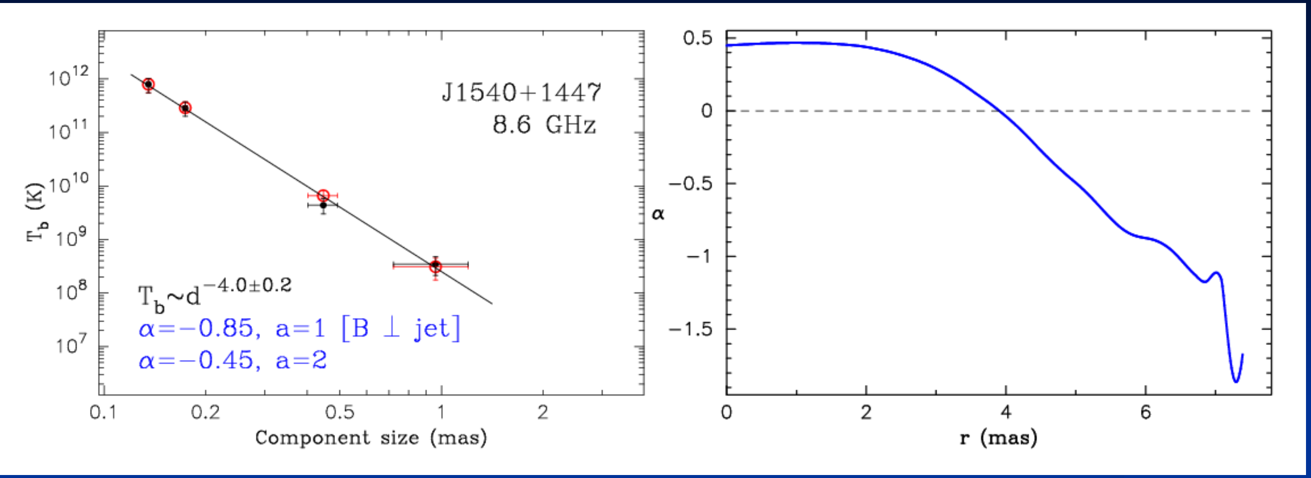


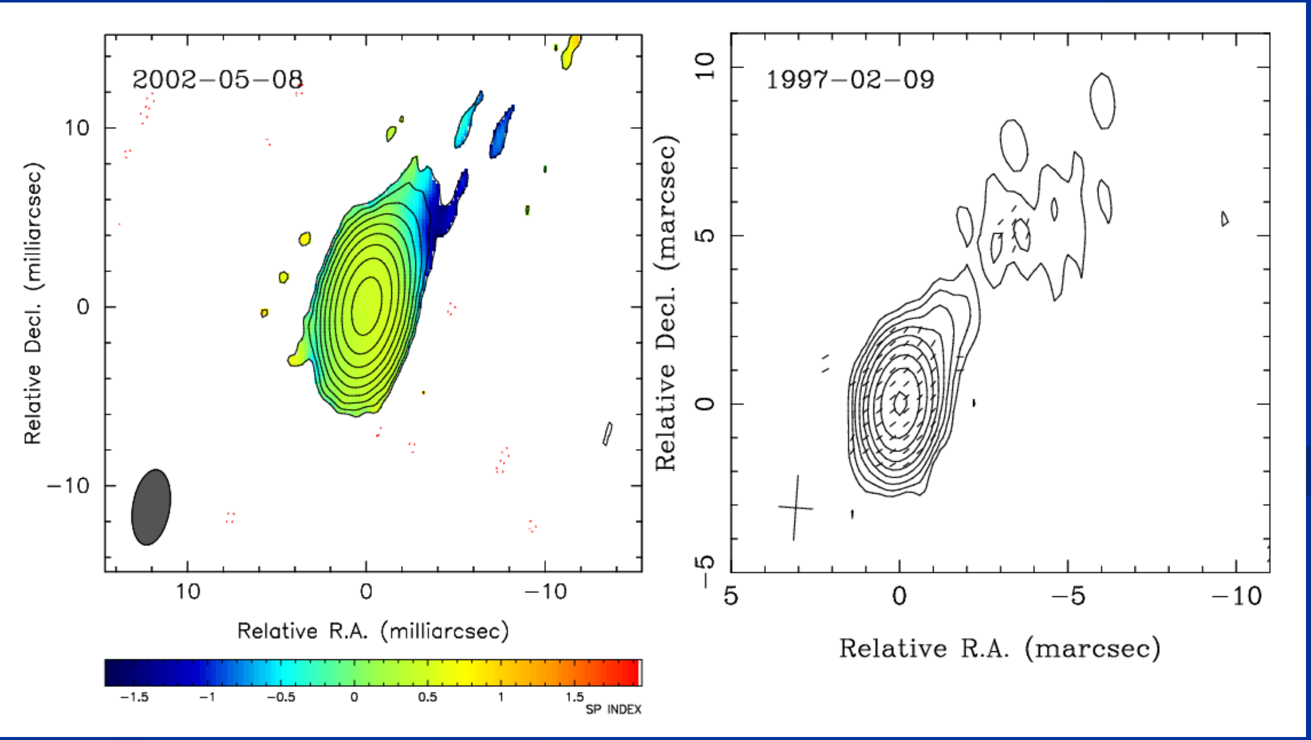

P-map from 15GHz MOJAVE observations (Lister and Homan, 2005, AJ, 130, 1389)



# J1540+1447 BL Lac



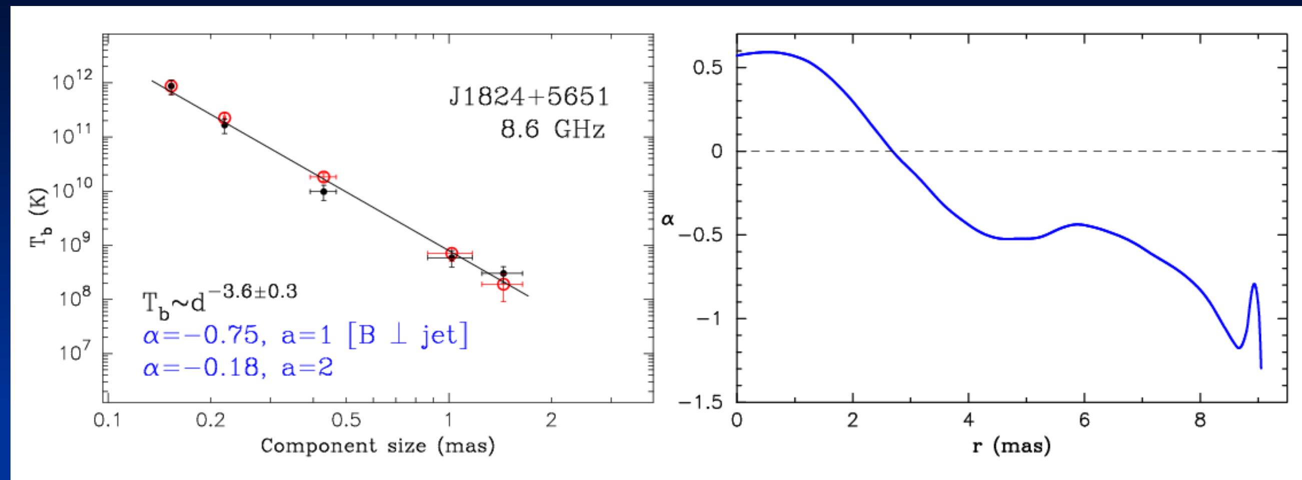



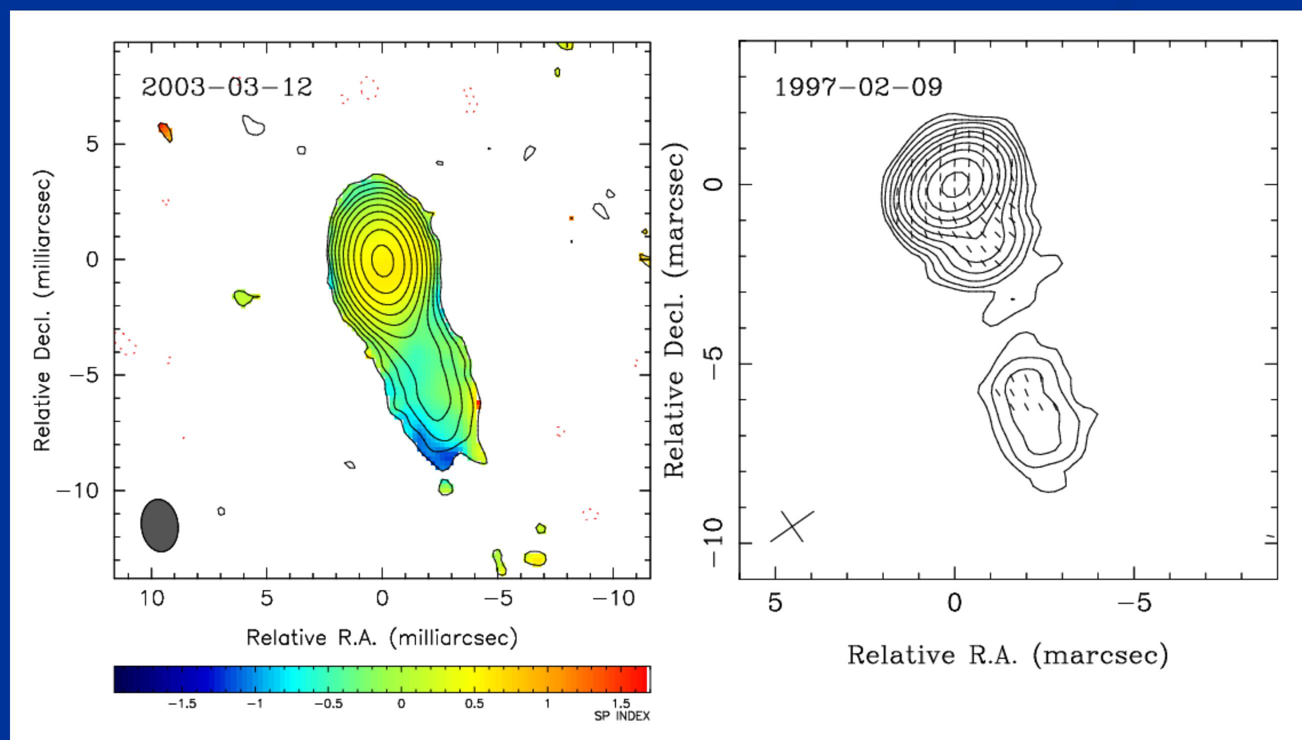




P-map from 8GHz VLBA observations of Kühr & Schmidt BL Lac sample (Pushkarev et al., 2008, in prep.)

# J1824+5651 BL Lac

○ model
● measured

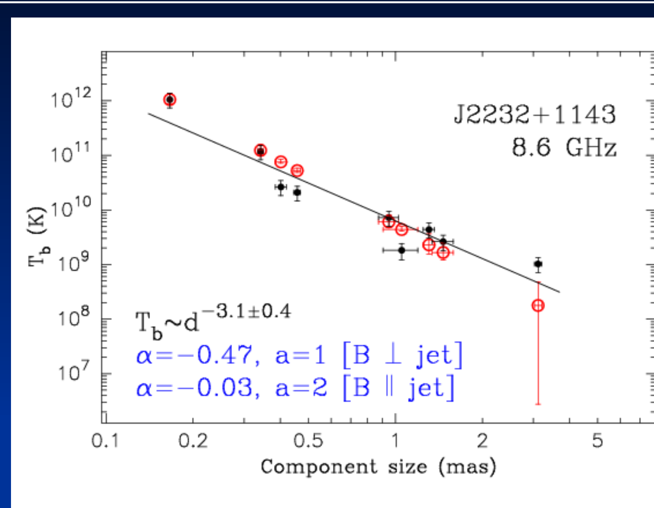


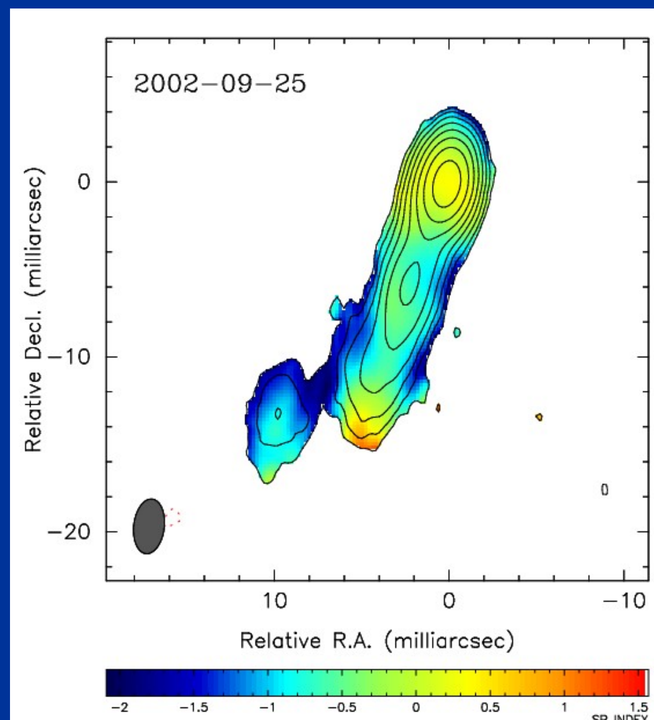



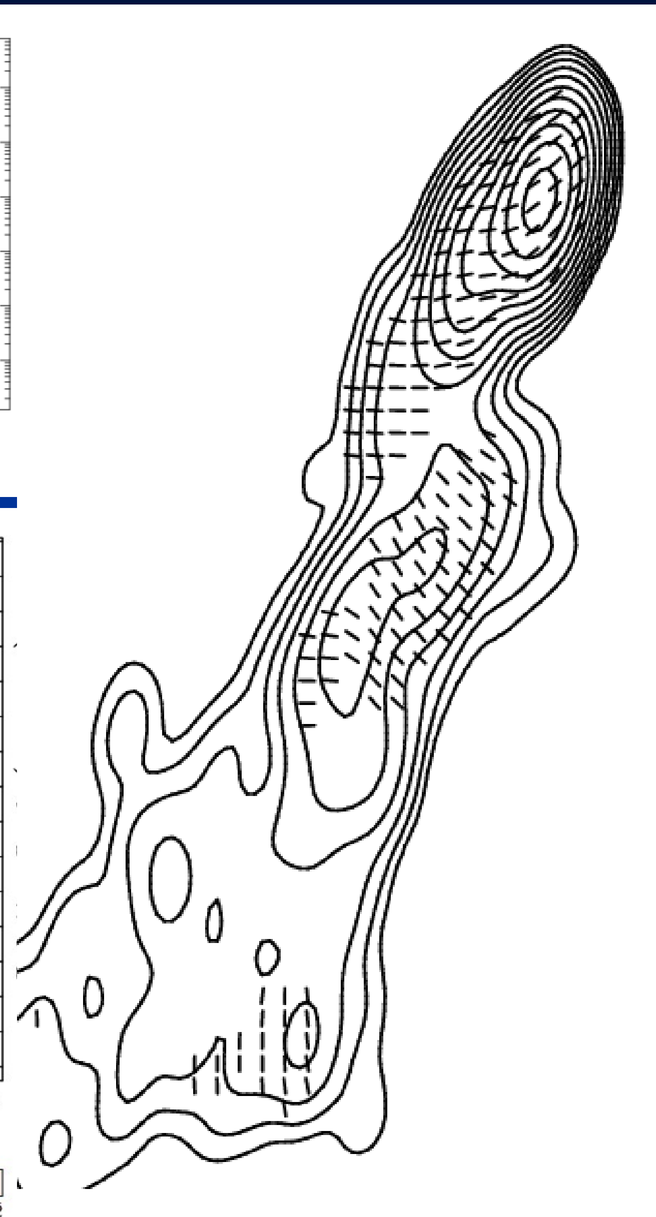

P-map from 8GHz VLBA observations of Kühr & Schmidt BL Lac sample (Pushkarev et al., 2008, in prep.)

# J2232+1143 Quasar

○ model
● measured



P-map from 15GHz MOJAVE observations (Lister and Homan, 2005, AJ, 130, 1389)

# Conclusion & Future

- The measured (determined) brightness temperatures and sizes of bright jet features in three BL Lacs and a quasar  are found to be consistent with emission from relativistic shocks dominated by adiabatic losses of energy
- We will analyze multi-frequency MOJAVE-2 data (8.1, 8.4, 12.1, 15.4 GHz) that allow to determine individual spectral index for each cross-identified jet component

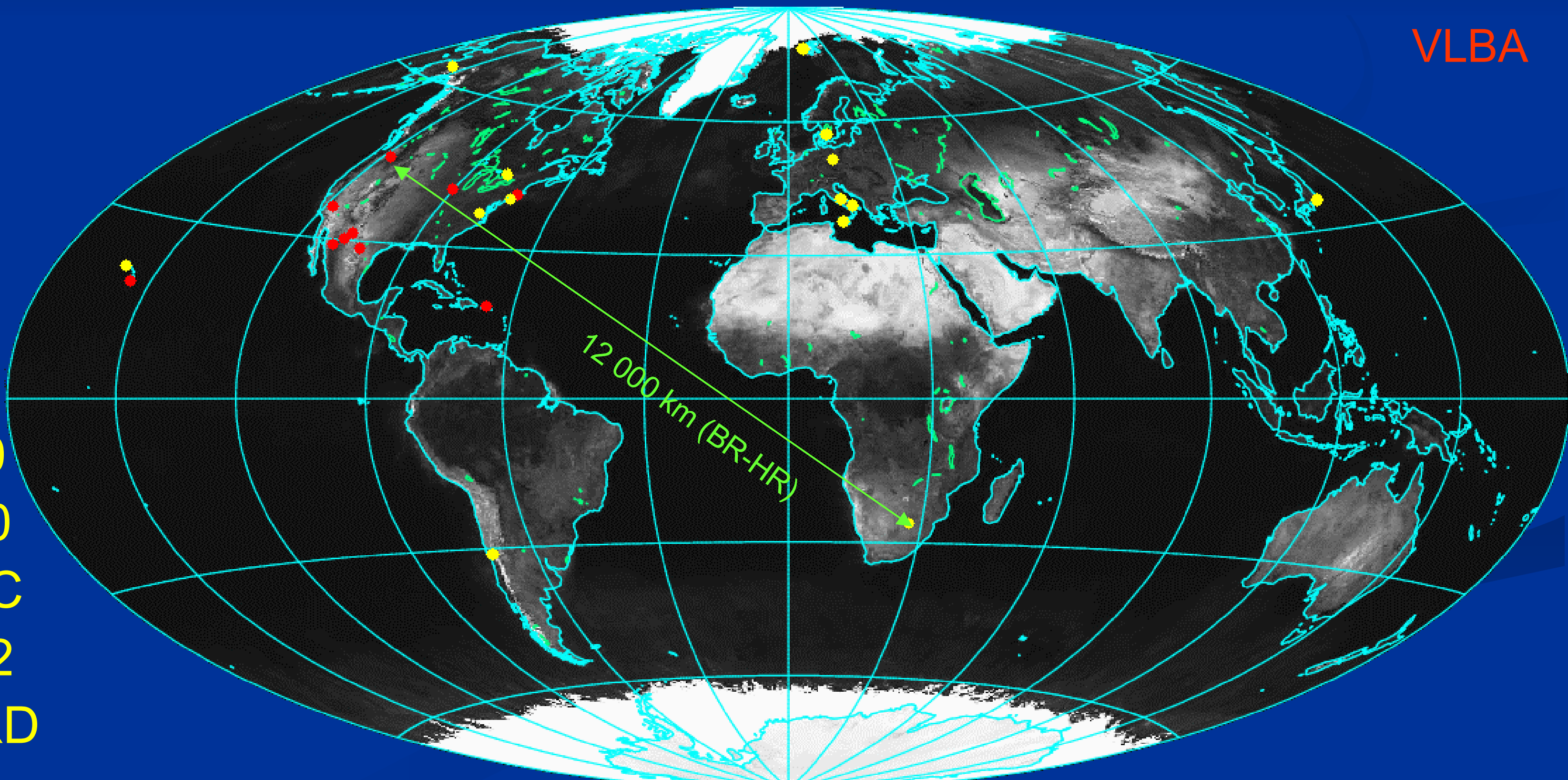
# Observations

- Started in 1997
- Not finished. Ongoing project
- Goals: Astrometry, Geodesy, Astrophysics
- Instrument: VLBA + up to 9 additional stations
- Frequency: S/X (8 and 2 GHz or 3.6/13 cm)
- Polarization: RCP
- Bandwidth: 32 MHz (4 IFs, 16 channels in each one)
- Time sampling: bi-monthly
- Session duration: 24 hr
- Correlator: VLBA
- Sample: pool of ~500 Northern Hemisphere International Celestial Reference Frame sources. 80-90 scheduled sources per session. 40-50 remain the same from experiment to experiment → core of the sample. Not flux limited sample! 75% - quasars, 16% - BL Lacs, 6% - radio galaxies, 3% - unidenfied objects

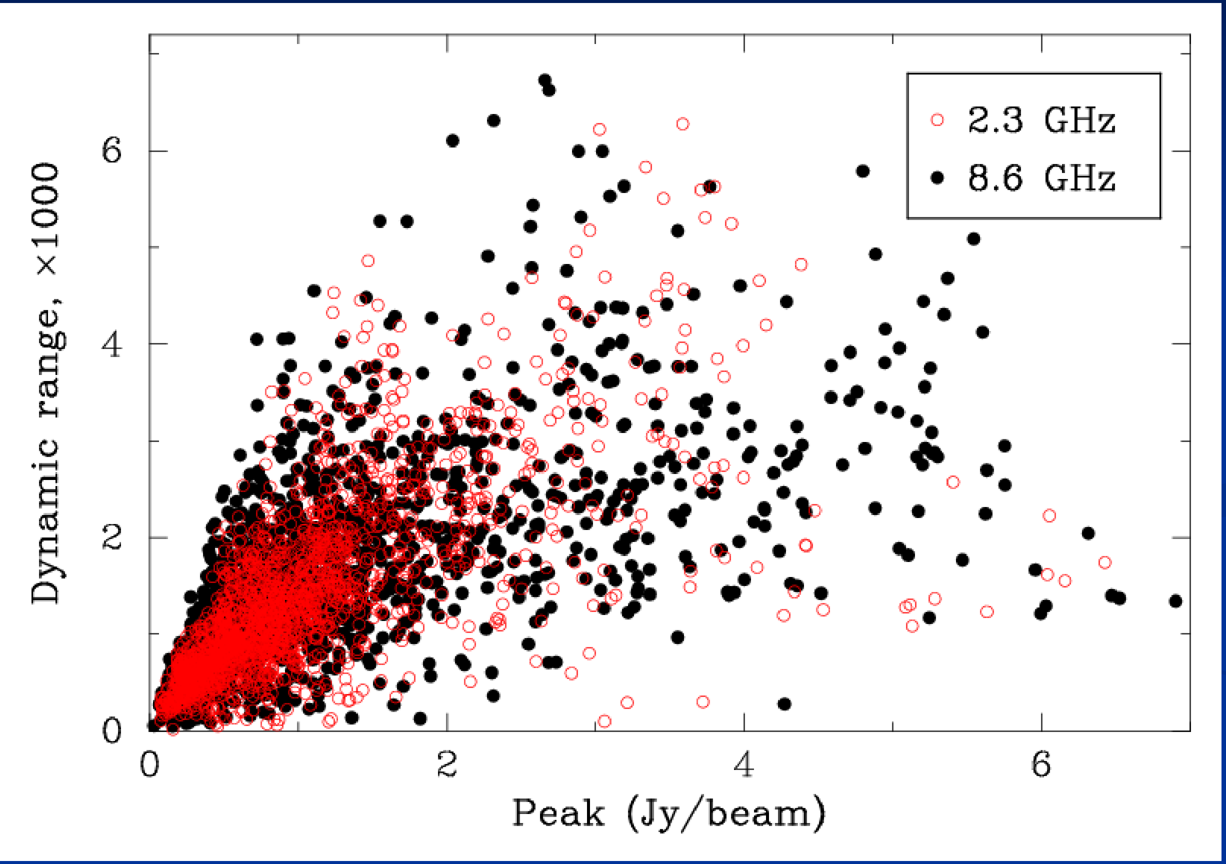
# **Instrument:** VLBA+ (Global VLBI)

14 additional stations (with up to 9 in each session) extend the maximum baseline up to 12 000 km (BR-HR) which is close to the limit for earth-based VLBI observations

ALGOPARK
GILCREEK
HARTRAO
KOKEE
MATERA
MEDICINA
NOTO
NRAO20
NYALES20
ONSALA60
TIGOCONC
TSUCUB32
WESTFORD
WETTZELL



# map statistics




S-band average:

rms = 0.682 mJy/beam

dynamic range = 1100

bottom level = 0.41%

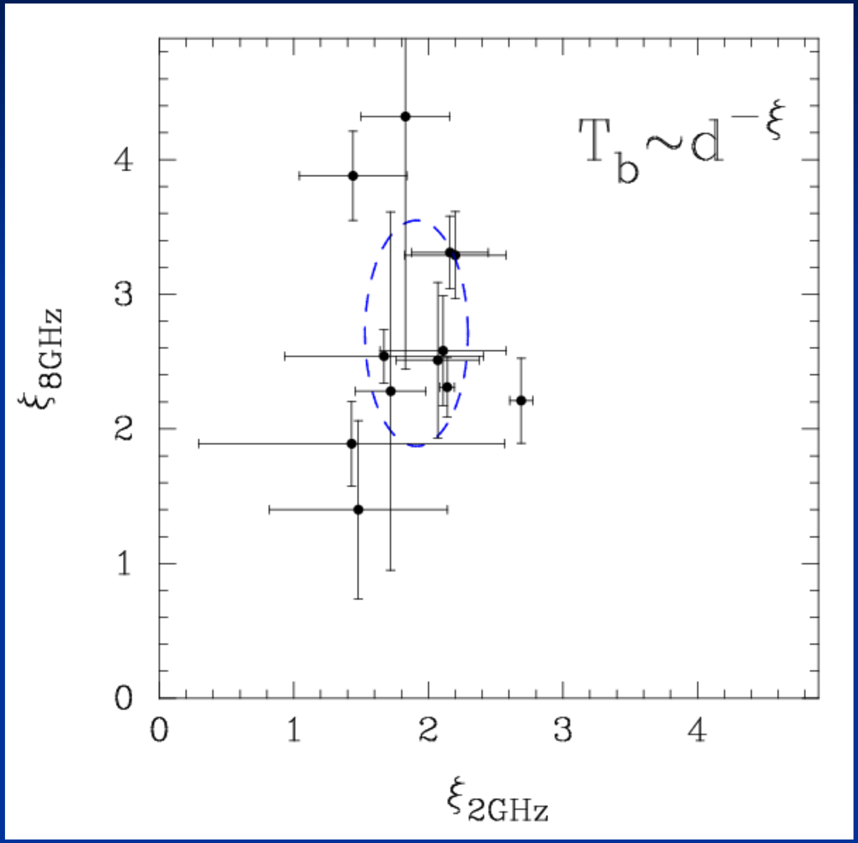
X-band average:

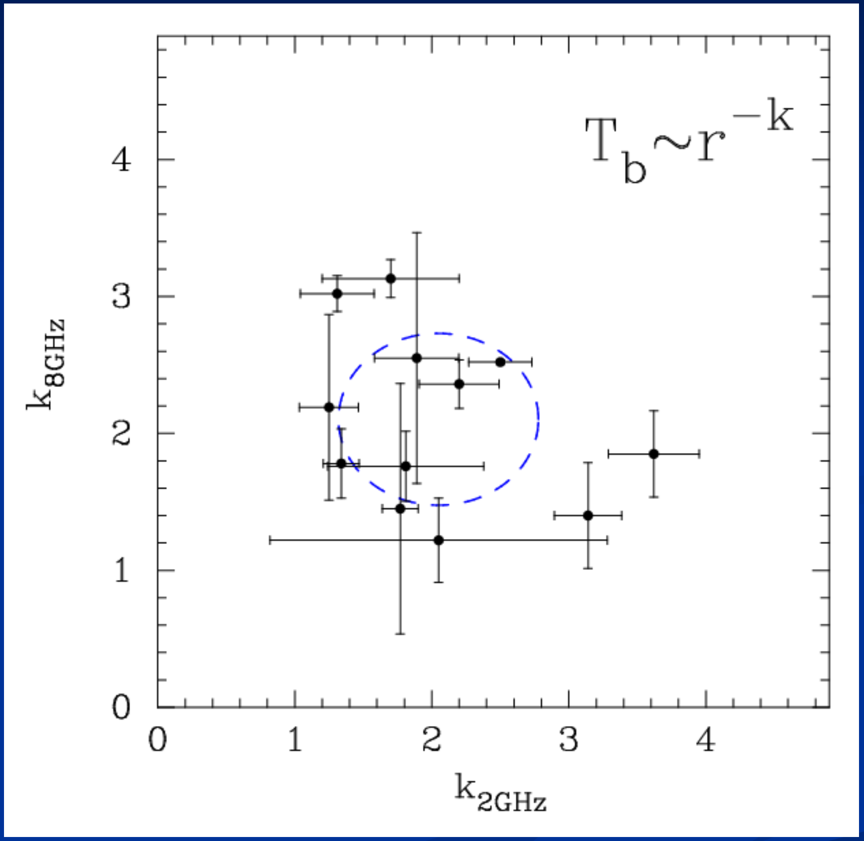
rms = 0.663 mJy/beam

dynamic range = 1200

bottom level = 0.40%

# Brightness temperature evolution

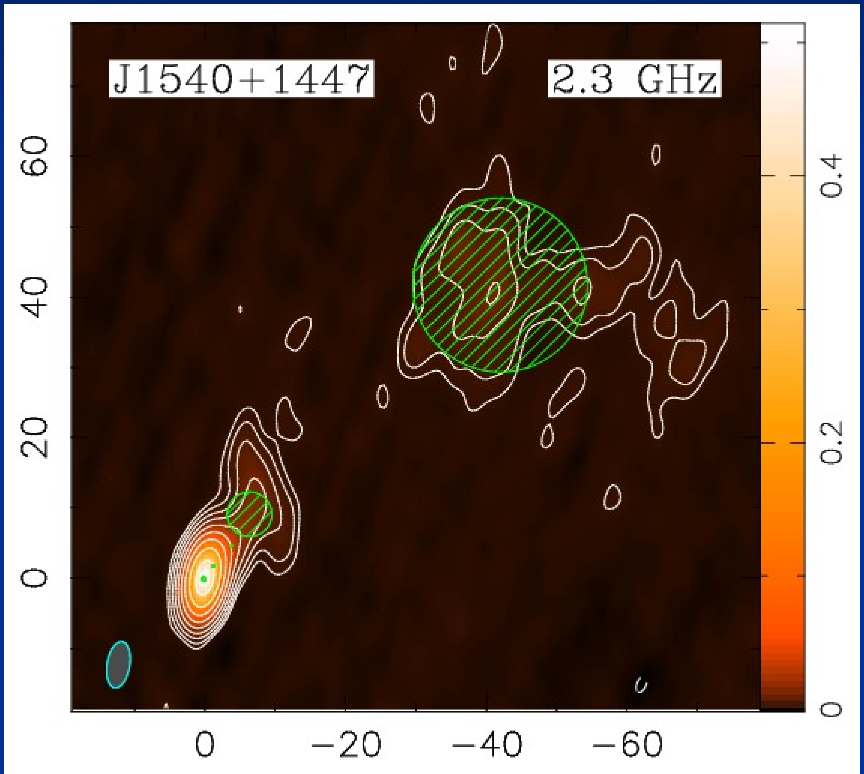


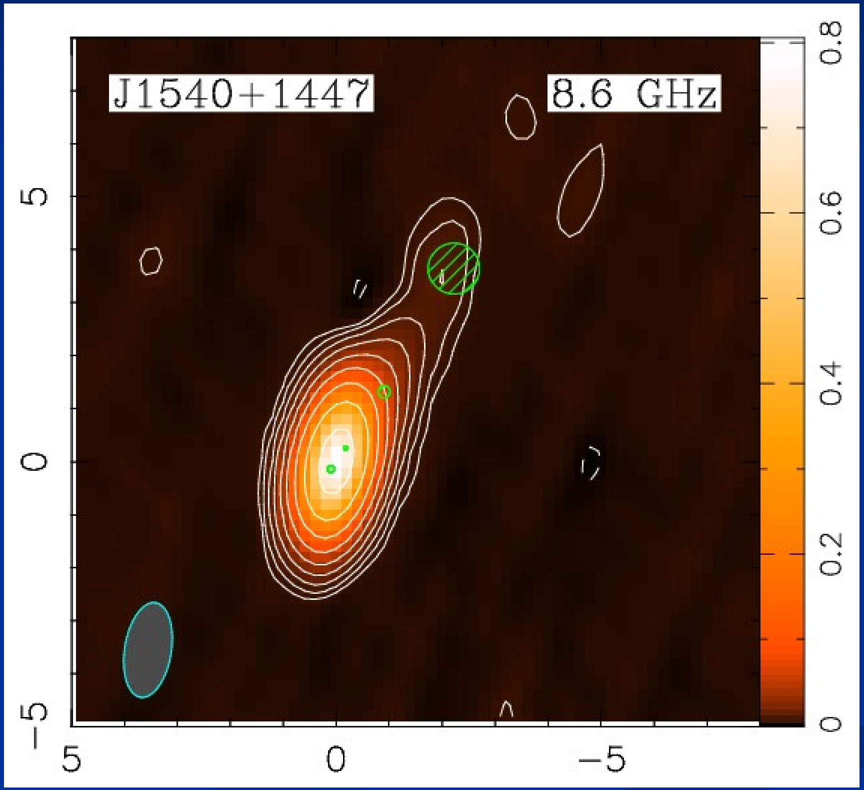




$$\bar{\xi}_{8\mathrm{GHz}} = 2.7 \quad \bar{\xi}_{2\mathrm{GHz}} = 1.9$$

$$\bar{k}_{8\mathrm{GHz}} = \bar{k}_{2\mathrm{GHz}} = 2$$

# maps + models


J1540+1447
2.3 GHz
60
40
20
0
0
−20
−40
−60
0.4
0.2
0


J1540+1447
8.6 GHz
5
0
−5
5
0
−5
0.8
0.6
0.4
0.2
0

# Future

- Jet kinematics (apparent velocity and acceleration)
- Spectral properties evolution of the core and jet components (with time for the same knots and with distance from the VLBI core for different components)
- Reduction VLBA observations at six frequencies to measure and study the frequency dependent VLBI core shifts in a sample of 20 radio bright AGN. This will be the first systematic study of the core shift effect and its application to AGN physics and astrometry