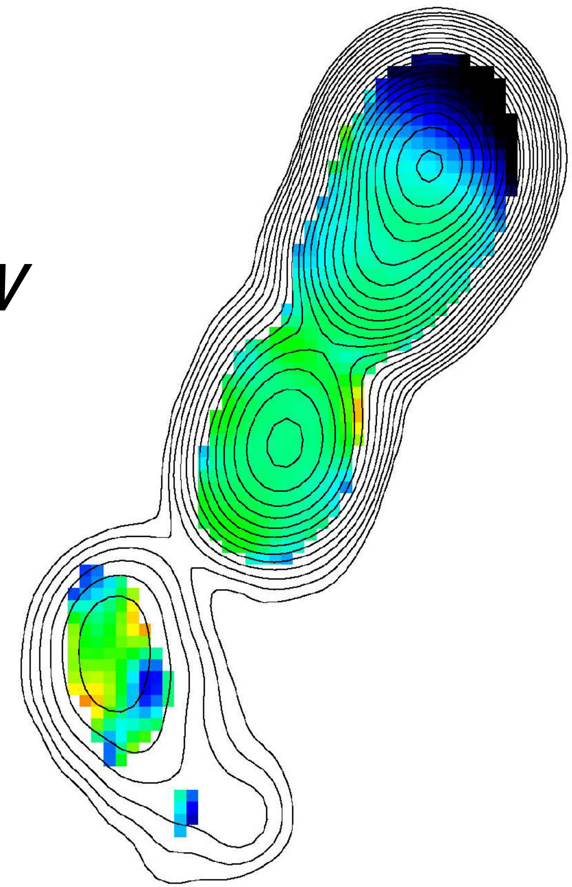
Opacity in parsec-scale jets of Active Galactic Nuclei

Yuri Kovalev

MPIfR, Bonn
ASC Lebedev, Moscow

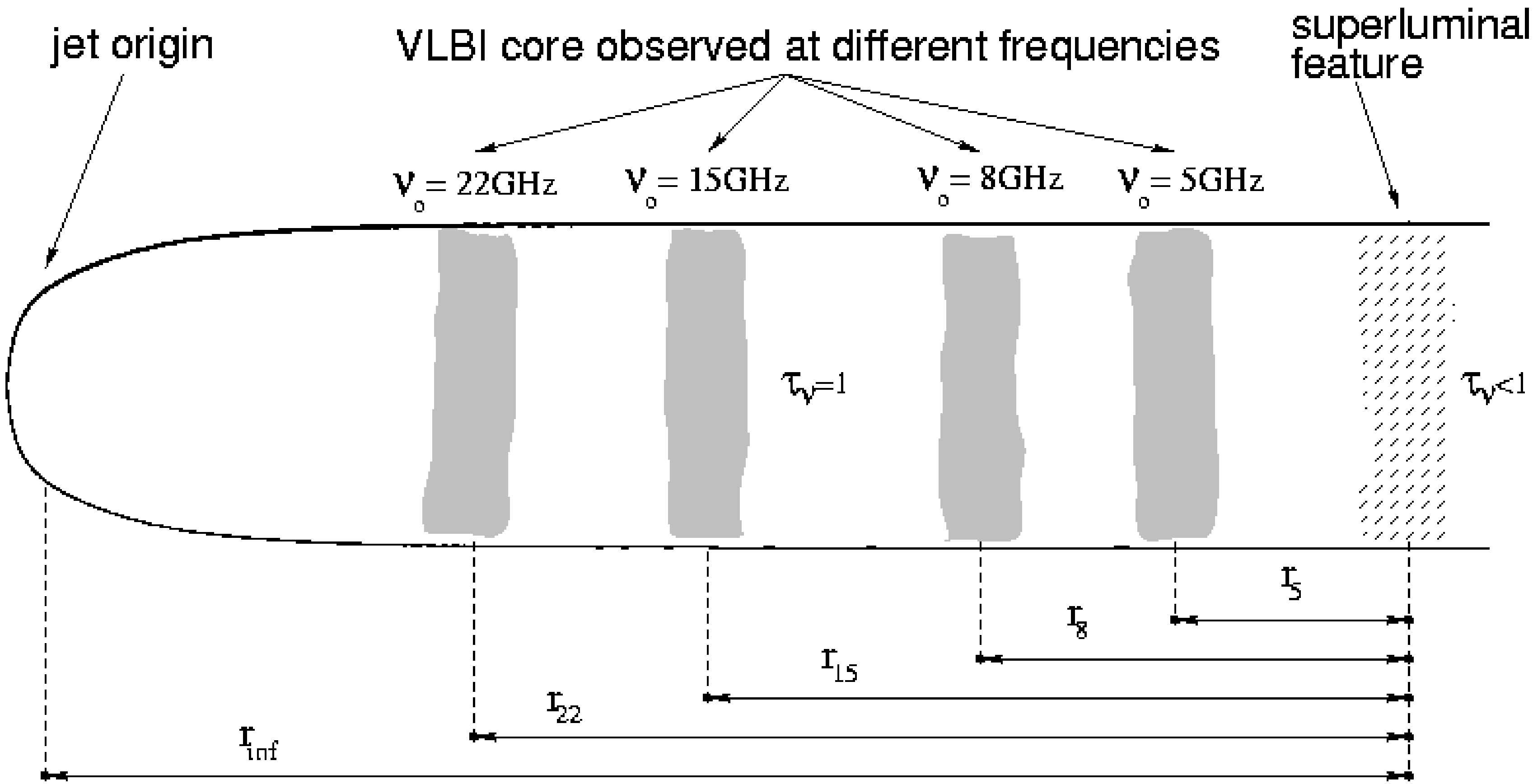
In collaboration with:
Andrei Lobanov,
Alexander Pushkarev
Kirill Sokolovsky,
Anton Zensus
(MPIfR, Bonn)



Outline

- Properties of the nuclear opacity in compact relativistic jets of active galactic nuclei.
  Why is this important?
- Measuring the positional shift of the core ("core shift") due to the nuclear opacity
- Results of the first systematic study of the core shift and its applications to astrophysics and astrometry
- Further selected results and plans

Frequency dependent position shift of the VLBI core



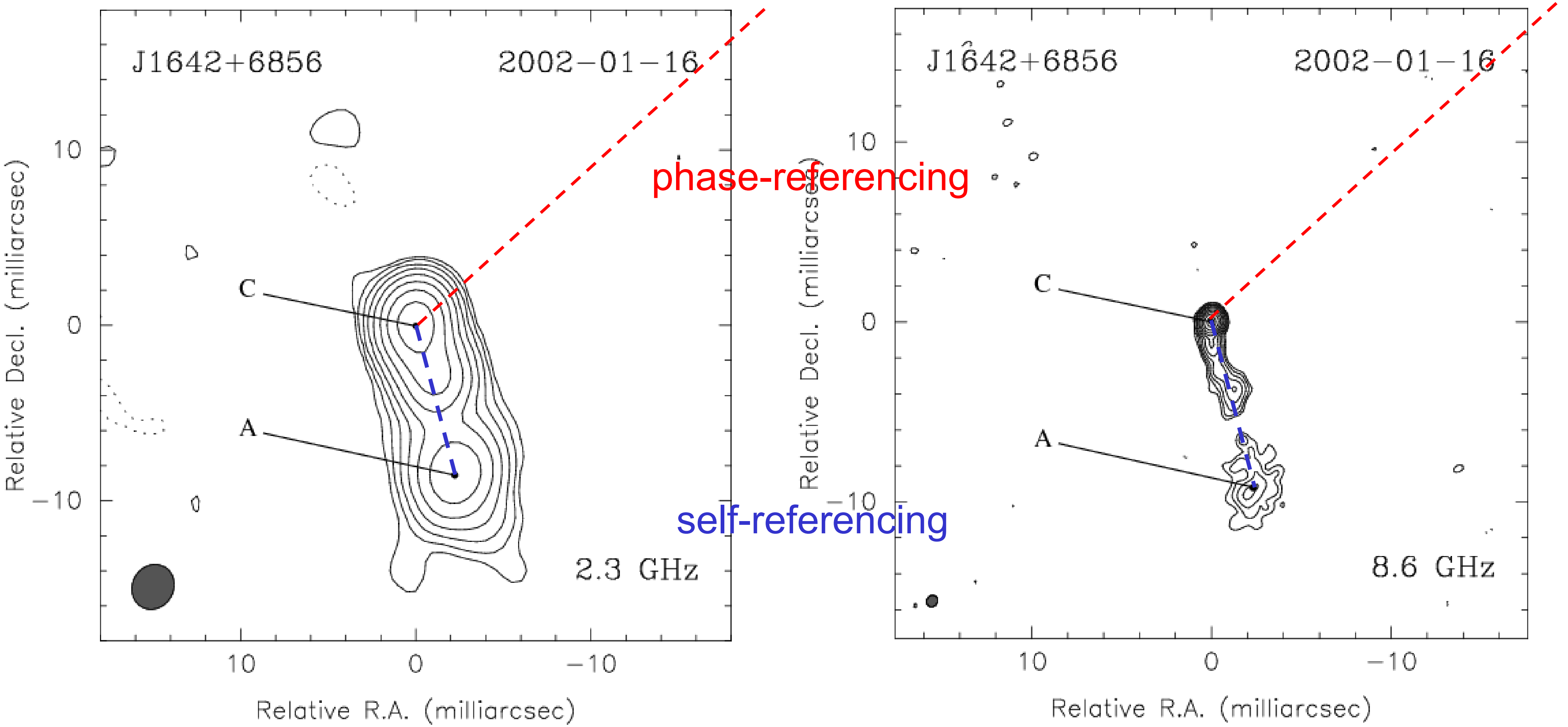
Lobanov 1998

The condition τ_ν=1 determines the variable location *r* of the core at different frequencies. Core location: $r \sim \nu^{-1/k_r}$.

k_r=1 ⟹ synchrotron self-absorption,

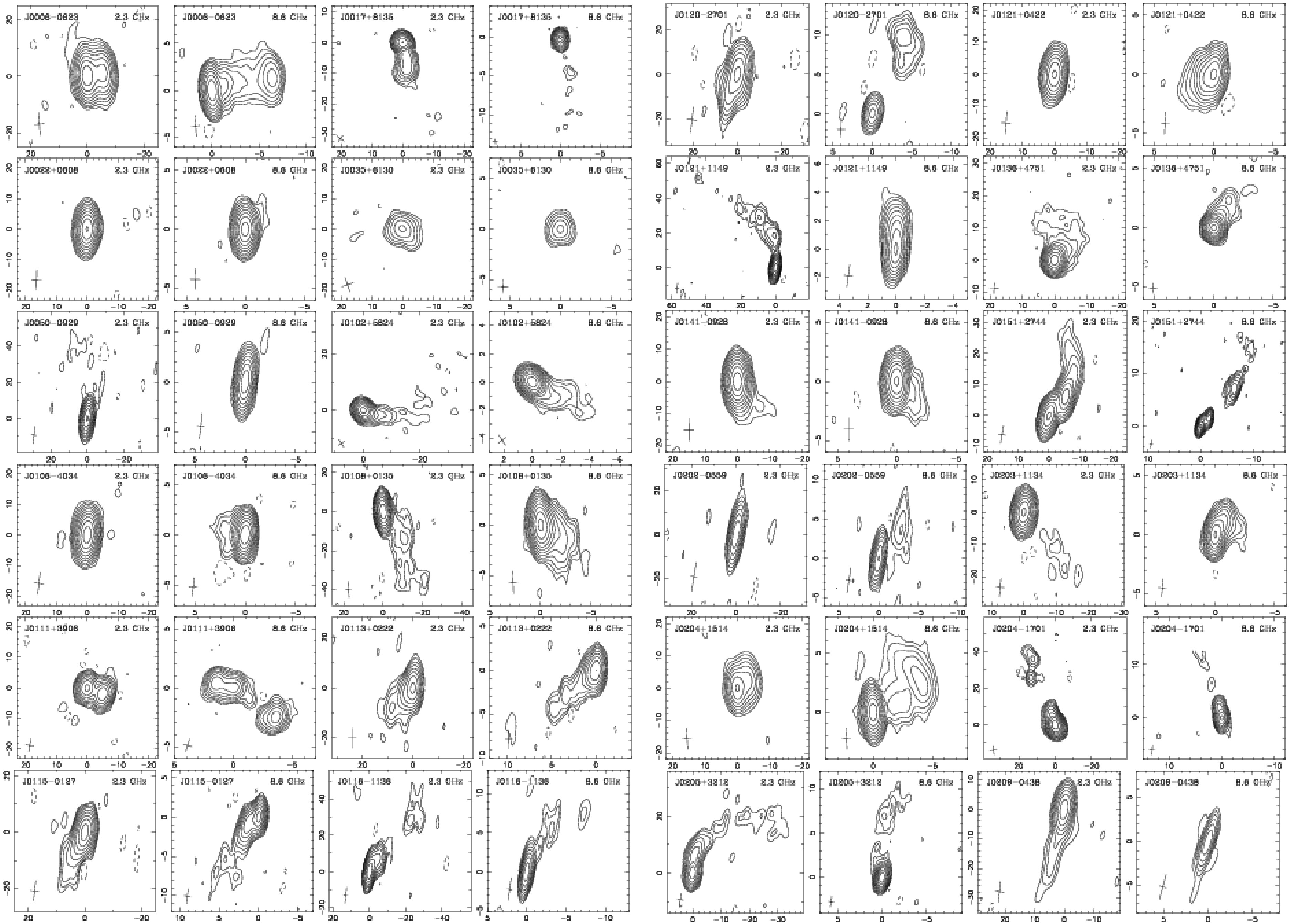
k_r>1 ⟹ synchrotron self-absorption+external absorption (i.e., free-free in BLR).

Methods to measure the core shift



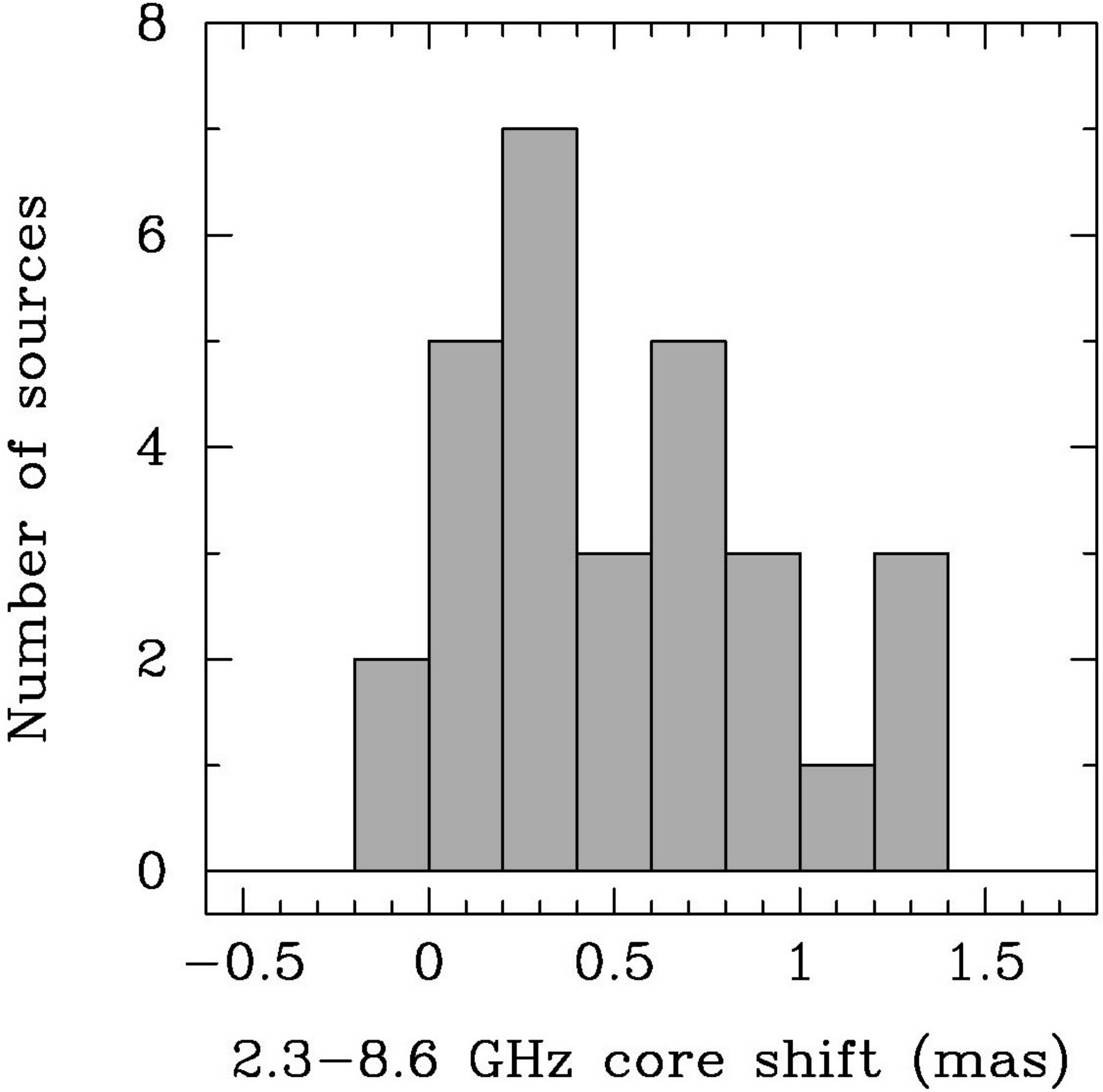
and 2D cross-correlation

RDV data are used for the first systematic study of the core-shift effect: 2 & 8 GHz global VLBI



See poster by Pushkarev

Result of the first systematic study: 29 objects out of about 250 imaged in 2002-2003

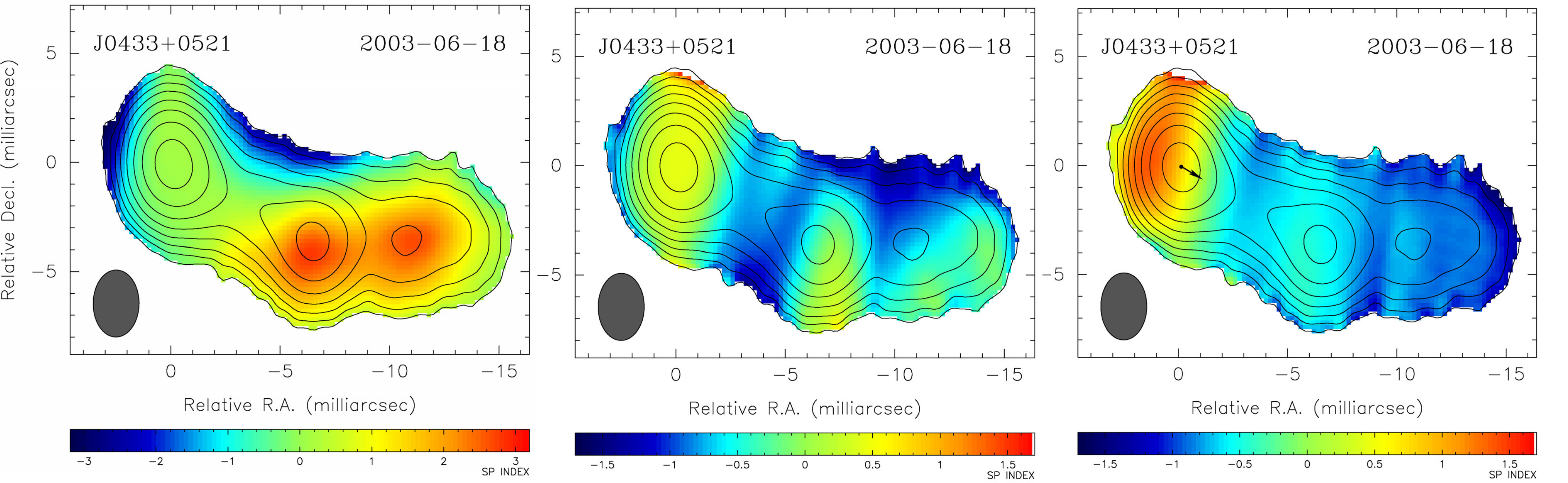


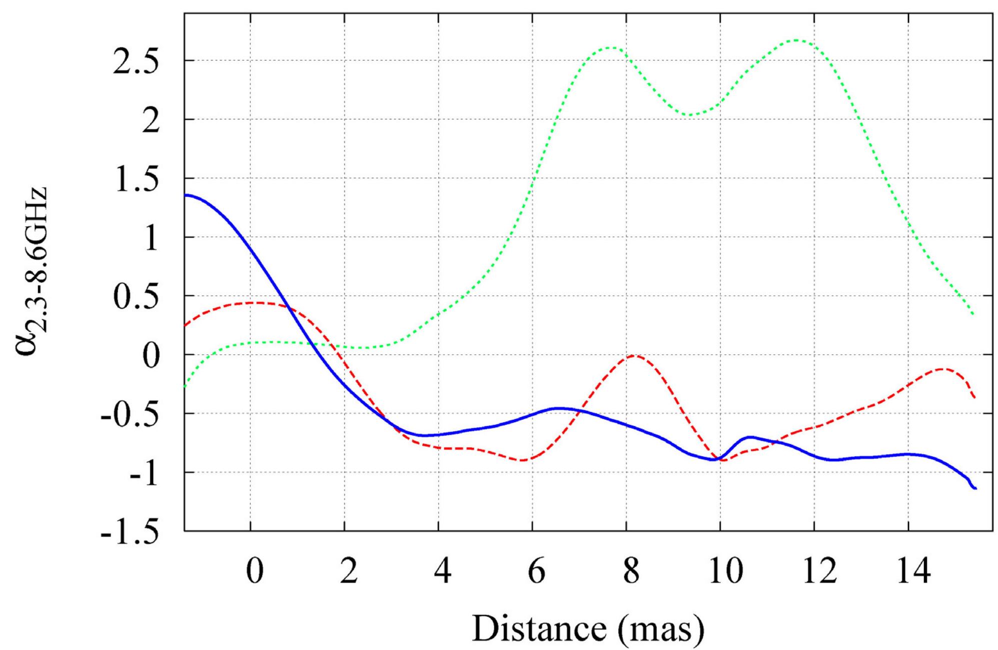
Median value:
0.44 mas

Theoretical predication for a complete sample:
average value of the core shift between 2 and 8 GHz:
~0.3 mas

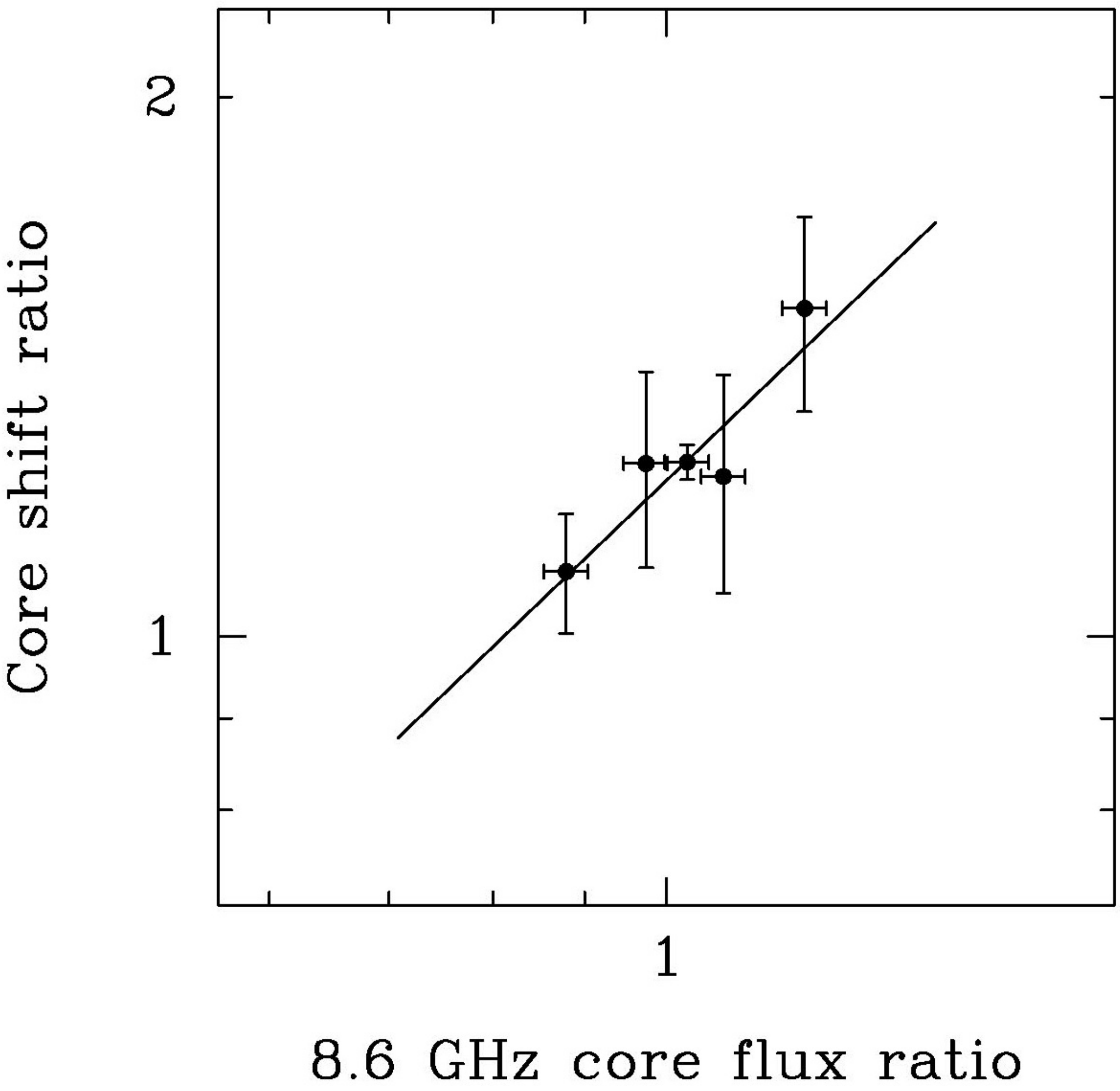
Kovalev et al. (2008)

What happens if we do not take the core-shift into account (astrophysical analysis)?





Core shift variability due to nuclear flares



Slope: 0.96±0.18

Theoretically predicted slope for flares produced by particle density variations: **2/3**

Astrometry applications and the core shift

radio-optical reference frame alignment

There is potentially an issue.

We have *theoretically* estimated an average shift between the radio (8 GHz) and optical (6000 Å) positions to be around 0.1-0.2 mas for a complete sample of radio selected active galactic nuclei.

The estimated shift exceeds the positional accuracy of GAIA and SIM. It implies that the core shift effect should be carefully investigated, and corrected for, in order to align accurately the radio and optical positions.

Further studies

1. Use 4-frequency MOJAVE VLBA observations in 2006 (8.1, 8.4, 12, & 15 GHz) to estimate core-shift values or their upper limits for a complete sample of ~200 bright extragalactic radio sources.

2. A dedicated experiment in 2007-2008: deep 1.4-15 GHz VLBA observations of 20 selected targets plus one special case at 5-43GHz. Estimate relativistic jet geometry and intrinsic parameters.

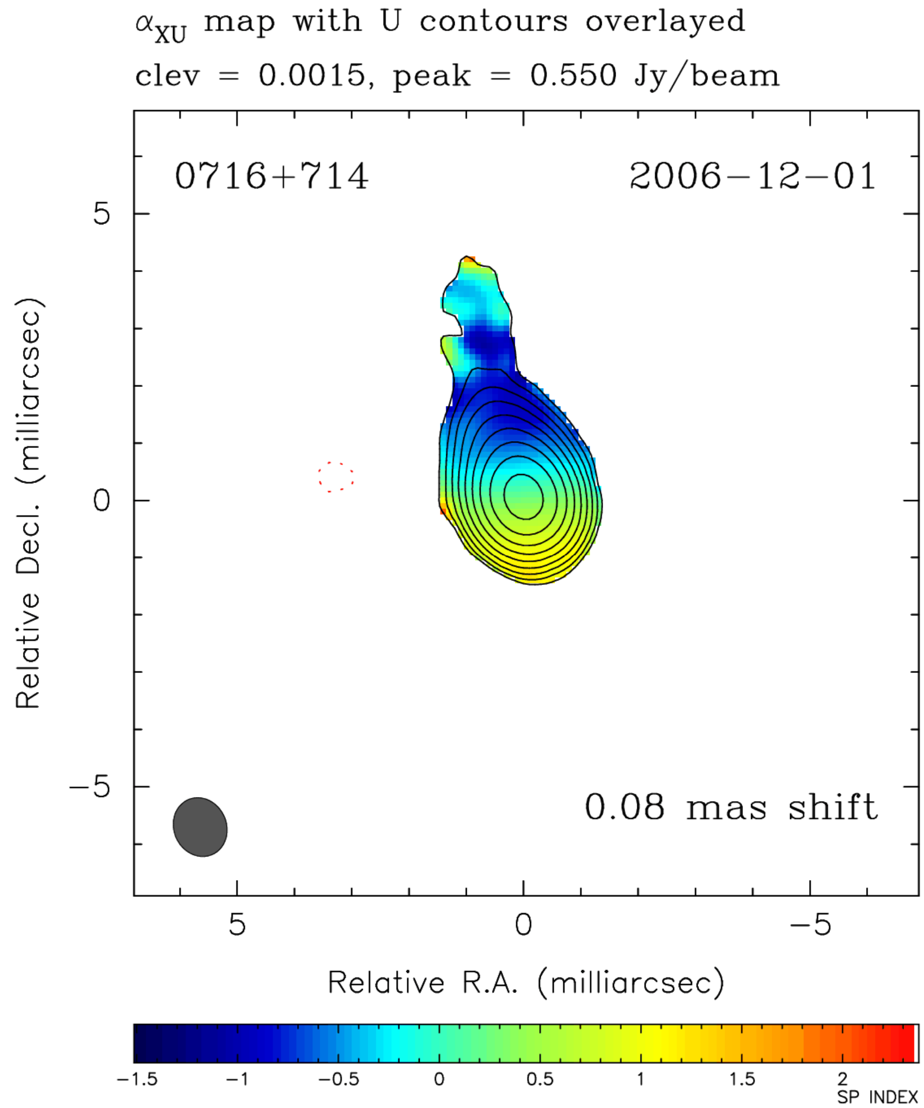
3. Twenty γ-ray bright AGN @ VLBA (5-43 GHz) in 2008-2009.

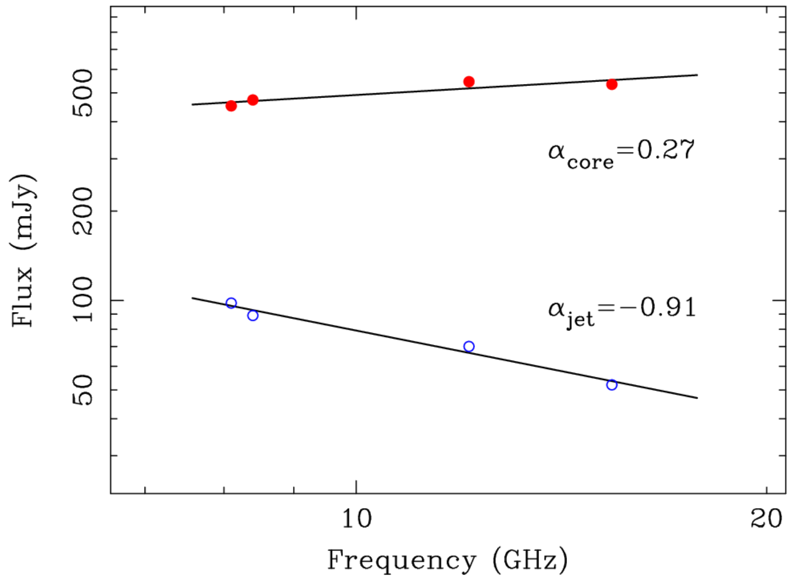
4. Dedicated EVN+QUASAR phase-referencing experiment on the most compact geodetic VLBI targets (1.4-8.4 GHz) in 2008.

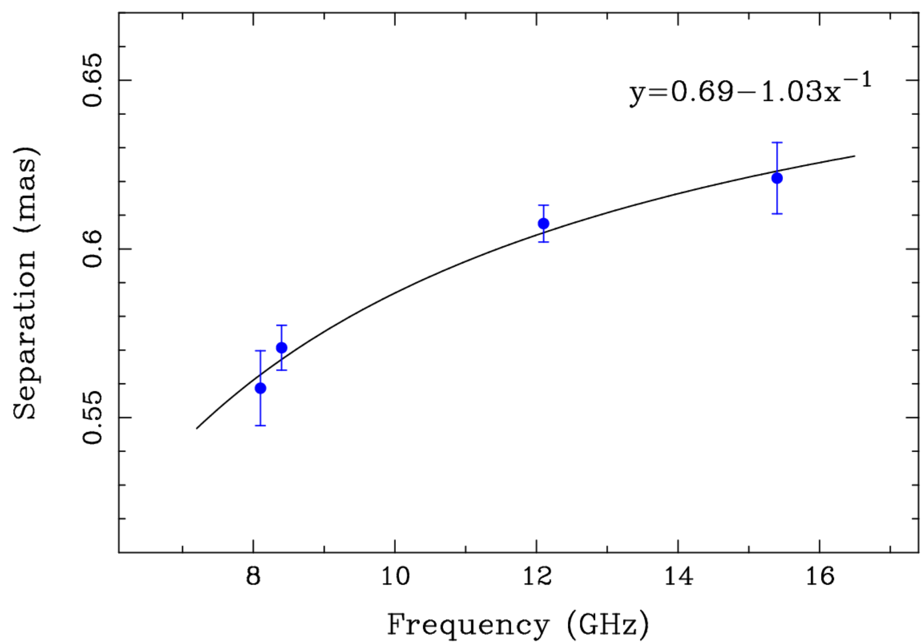
5. Continue to measure core-shifts in RDV 2/8 GHz data. Investigate variability data and dominating mechanism of the flares.

Further study of a large complete sample
Four-frequency MOJAVE-2 project

Year 2006, VLBA, frequencies: 8.1, 8.4, 12, & 15 GHz.
About 200 brightest AGN jets.
Example: **0716+714**

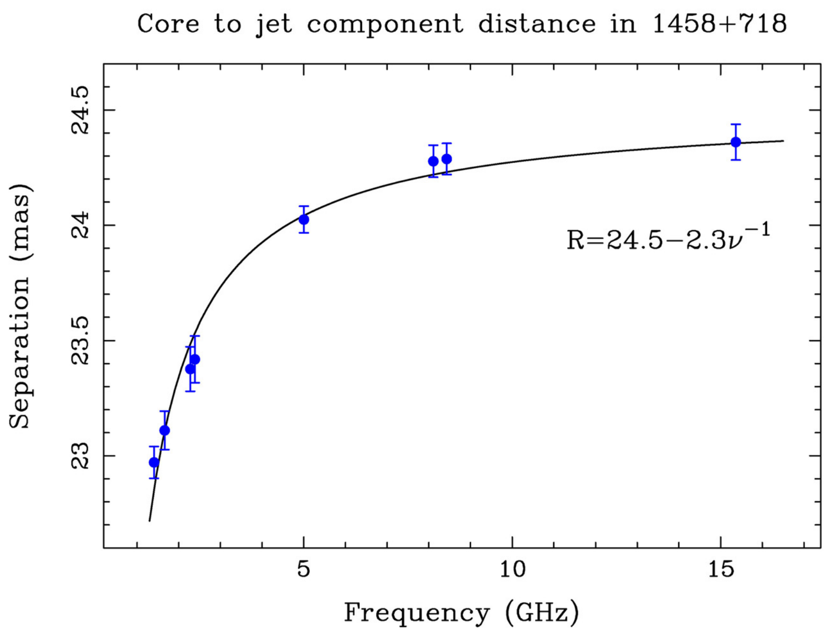


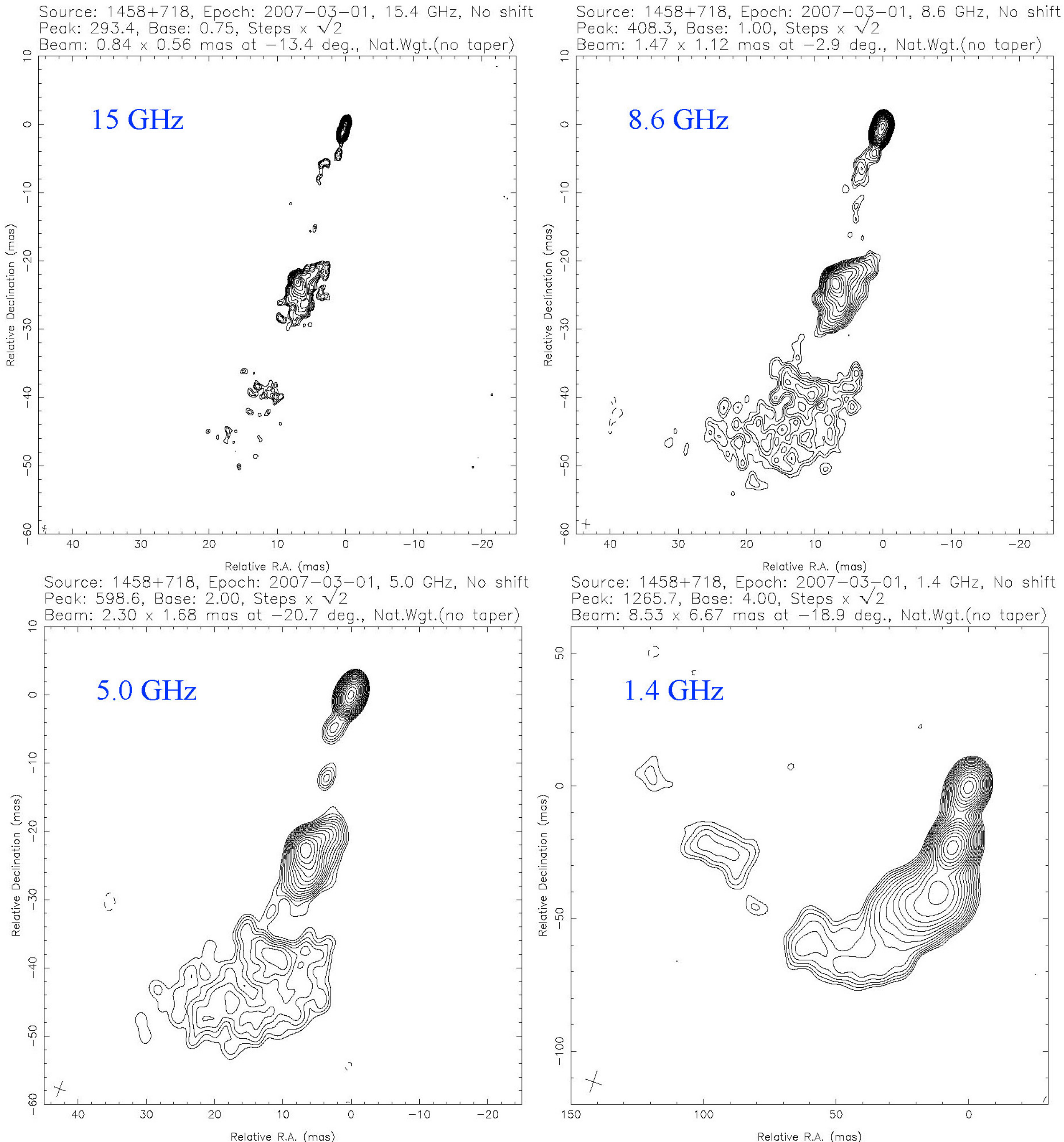




3C309.1 (z=0.9, β=7c)

1.4-15 GHz first results (March 2007)

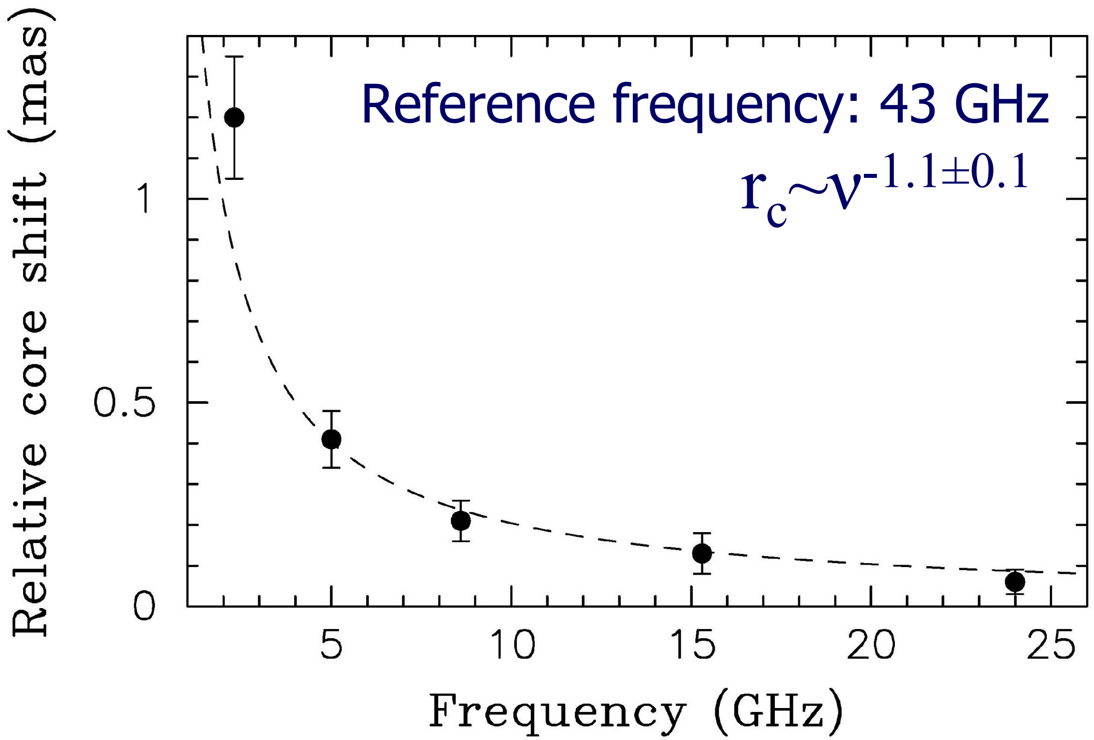


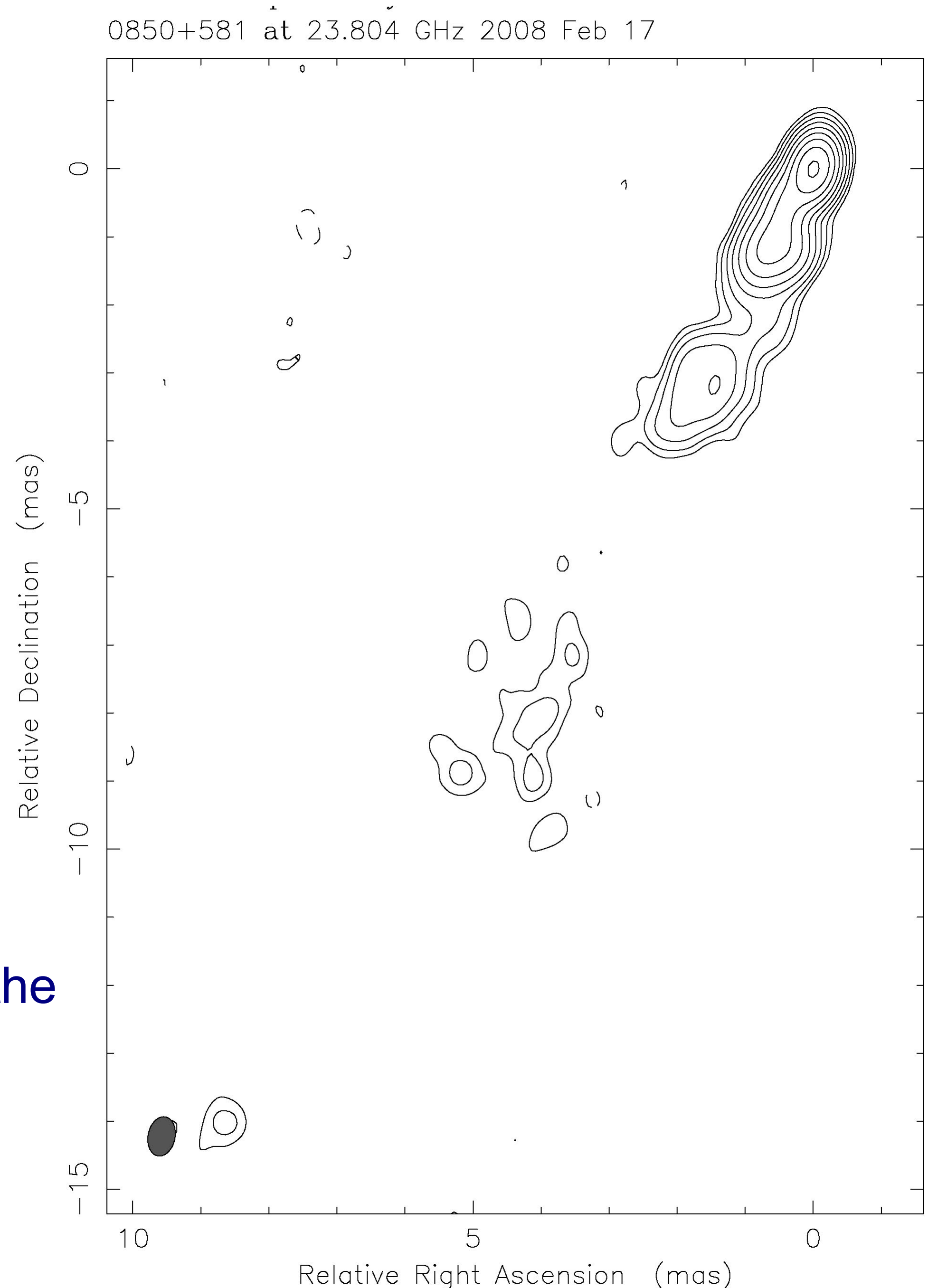


- Distance from the 15 GHz core to the black hole: 5±2 pc.
- Magnetic field at a distance of 1 parsec from the nucleus: B=2.3±0.5 G, B_{eq}=1.7±0.8 G.
- Magnetic field in the 15 GHz core: B=0.1±0.2 G.

Quasar 0850+581 (z=1.3, β=9c)

5-43 GHz first results (February 2008)





- Distance from the observed core to the black hole: from 17 pc to 5 pc (corresponds to 5-24 GHz).
- Magnetic field at a distance of 1 parsec from the nucleus:
  B=3.1±0.2 (N_e [cm^{-3}]/1000) G, B_{eq}=2.9±0.7 G.
- Magnetic field in the observed 24 GHz core:
  B=0.2±0.4 G.

Summary

- The nuclear opacity in relativistic jets affects observed positions of compact radio sources.
- The effect should be taken into account in astrophysicsal applications. Provides an efficient tool to study physics and geometry of the compact jet nuclei.
- Average positional shift in a complete sample can reach ≥0.1 mas between the radio and optical bands, exceeding the positional accuracy of GAIA and SIM. A dedicated campaign to study the core shift in a Reference Sample would improve substantially the fidelity and accuracy of the reference frame alignment.


Thank you