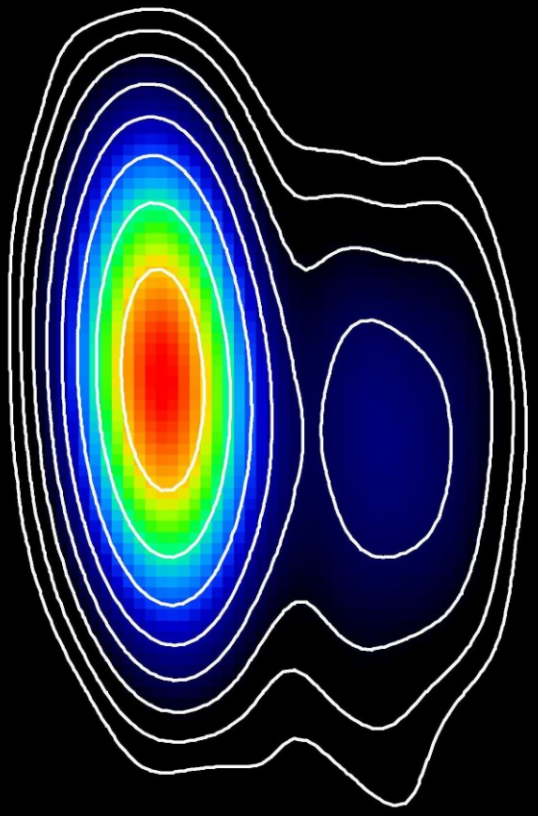
On the connection of apparent proper motion and the VLBI structure of compact radio sources



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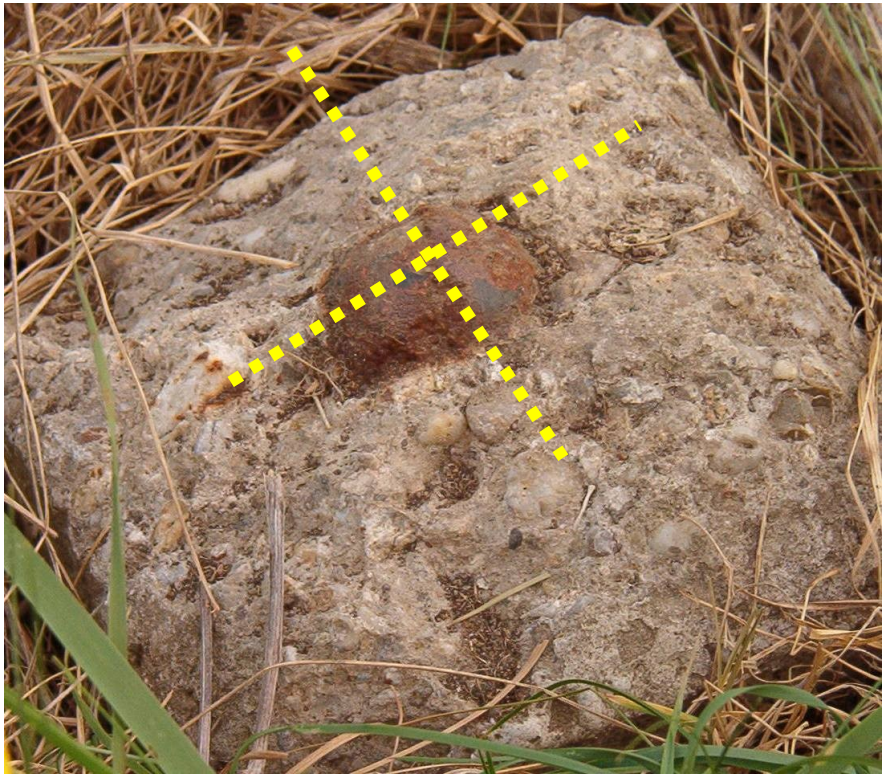
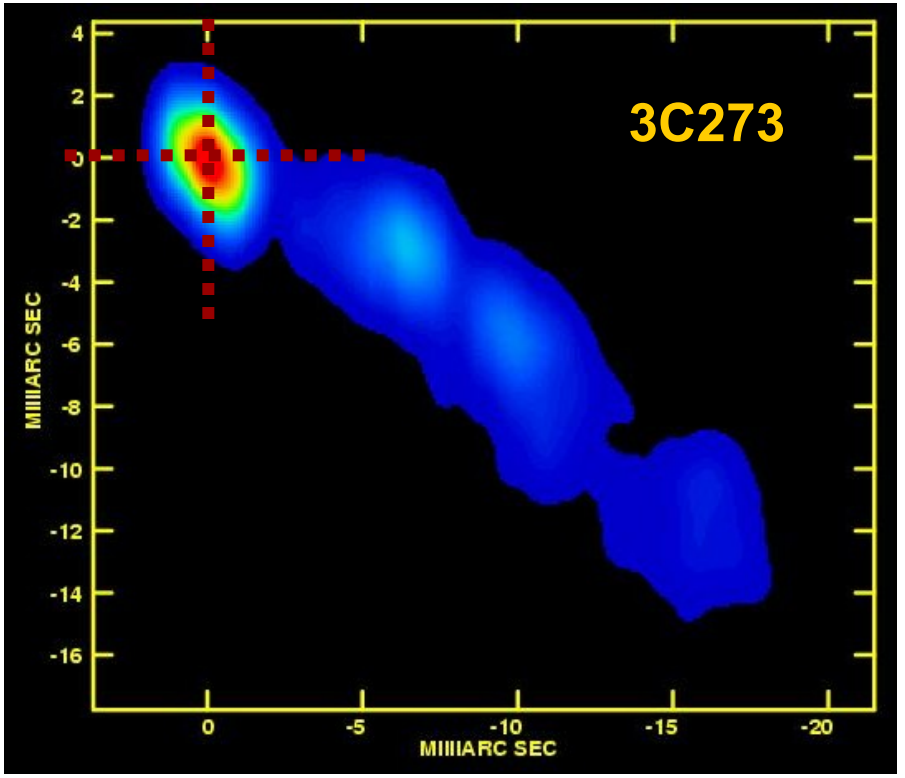
Overview

- Celestial reference points: not so stable after all
- Source astrometric quality vs. VLBI radio structure: is there a connection?
- Apparent proper motions from geodetic VLBI data
- A potential cause: source brightness distribution
- Analysis of the ”characteristic” directions in a sample of ~70 sources

Point marks on the Earth ... and in the sky





Source structure and astrometric quality

With good reason, we generally believe that the intrinsic radio source structure and the source position are connected.

In terms of the position, one can think of

❶ its uncertainty at a given epoch, or

❷ its changes over a longer interval of time

In this talk, we will deal with the latter, i.e. the apparent motions in the radio source positions

❶ Positional instability

Complex source brigtness distribution structure deteriorates the astrometric quality of the sources

e.g. *Charlot* (1990); *Fey & Charlot* (1996, 1997, 2000)

Compact sources seem a better choice for ICRF definition in terms of the extra unmodeled delay caused by the extended structure

However:

- ❖ very few sources are really very compact
- ❖ as structure evolves, the astrometric quality may vary over time

❷ Apparent proper motions

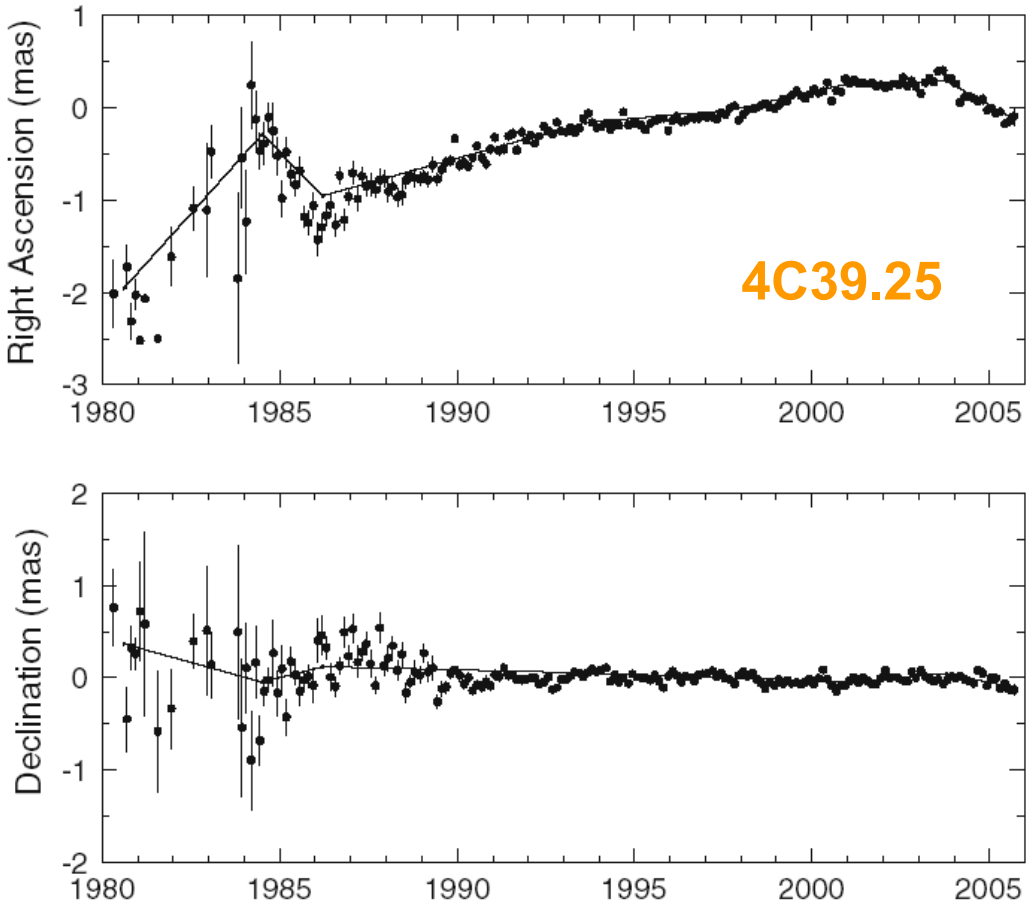
There is now well-established evidence that several sources that define the reference frame show apparent proper motions, up to ~100 μas/year (but typically an order of magnitude less)
e.g. *Feissel-Vernier* (2003); *MacMillan & Ma* (2007); *Titov* (2007)

Geodetic VLBI data accumulated over the past decades, with frequent observing of many of the sources

Different analysis strategies and software provide similar results

There are linear as well as non-linear systematic positional variations

Examples



45-day averages

MacMillan & Ma (2007), J Geod **81**, 443

Our study

❖ **Question:** is the long-term positional instability of a large sample of sources connected with the radio structures seen in the 8-GHz VLBI images?

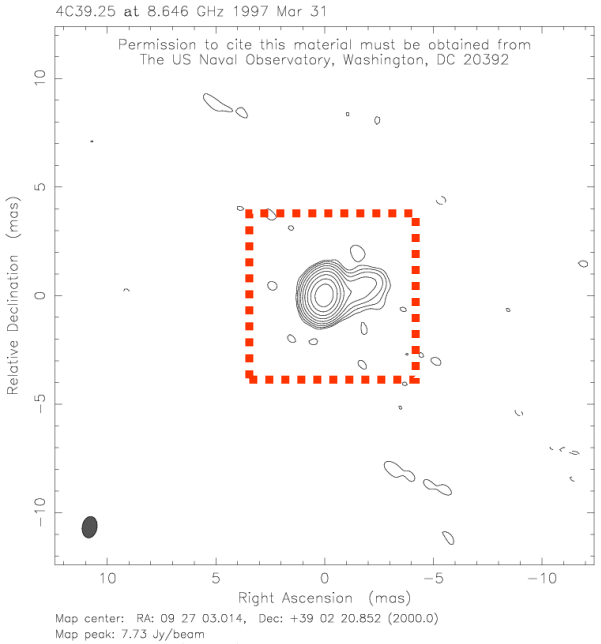
Detailed studies available so far only for some individual sources (e.g. 4C39.25, *Fey et al.* 1997)

❖ **Method:** statistically compare the typical *direction* of the proper motion with the characteristic jet direction

❖ **Proper motion** data from Titov; linear fit

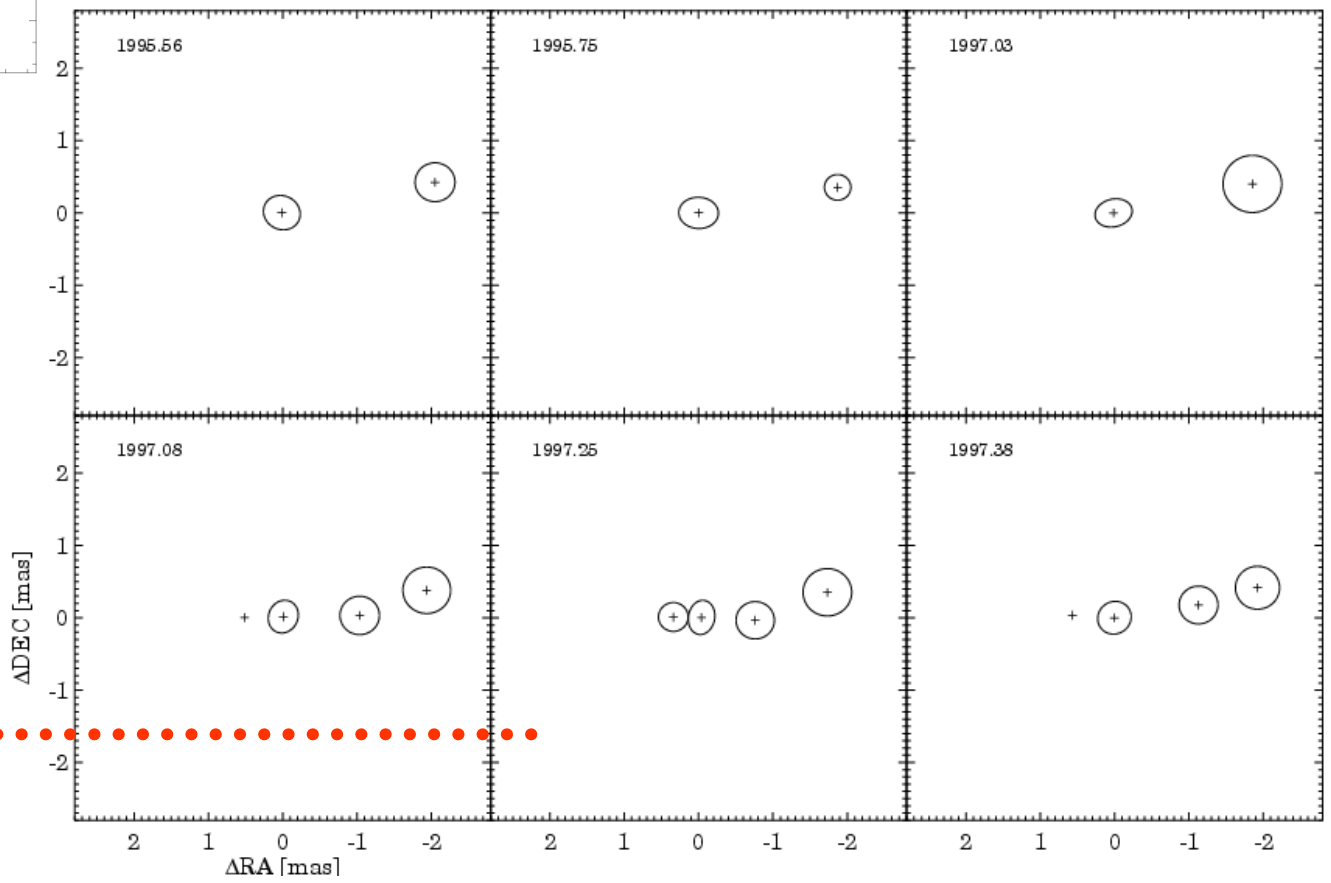
❖ **VLBI brightness distribution model** data from *Piner at al.* (2007), **AJ** 133, 2357

❖ Nearly 70 common sources that have sufficient data

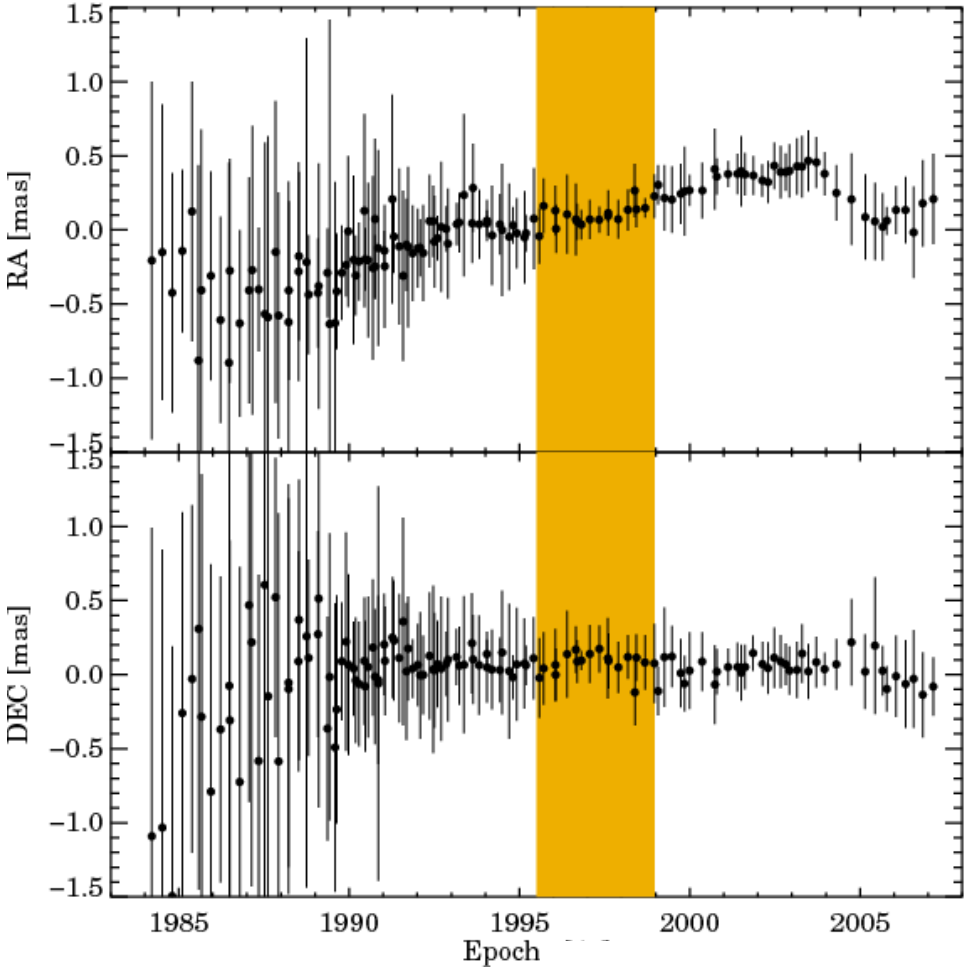


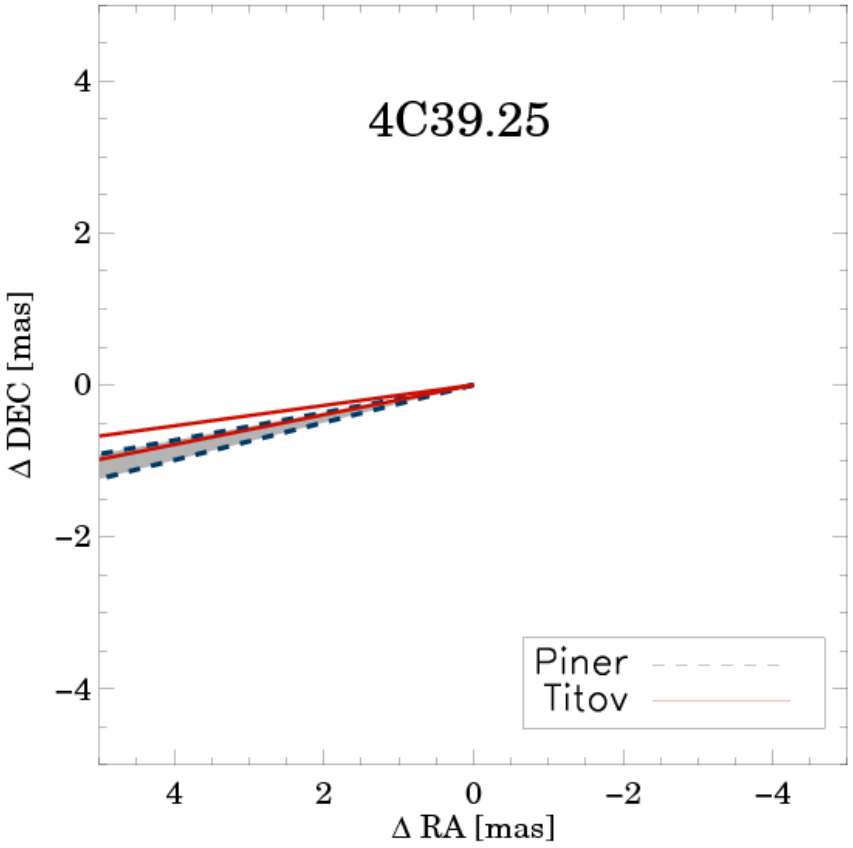
4C39.25

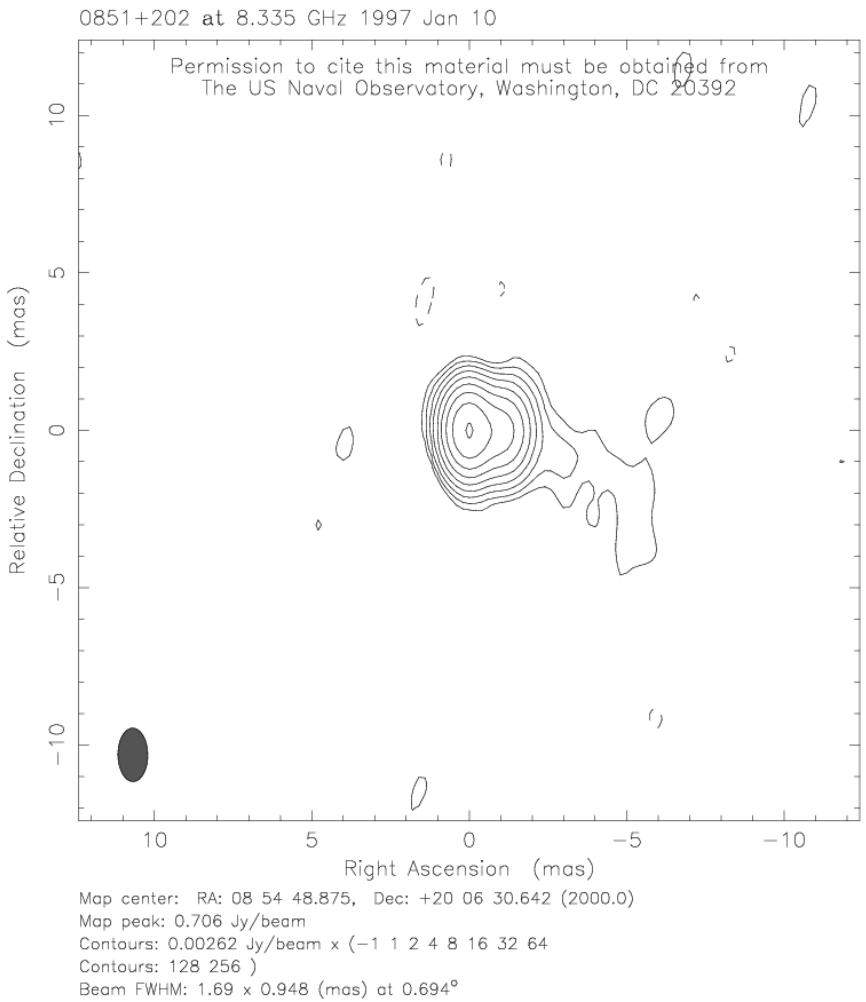
Model components from *Piner et al.* 2007

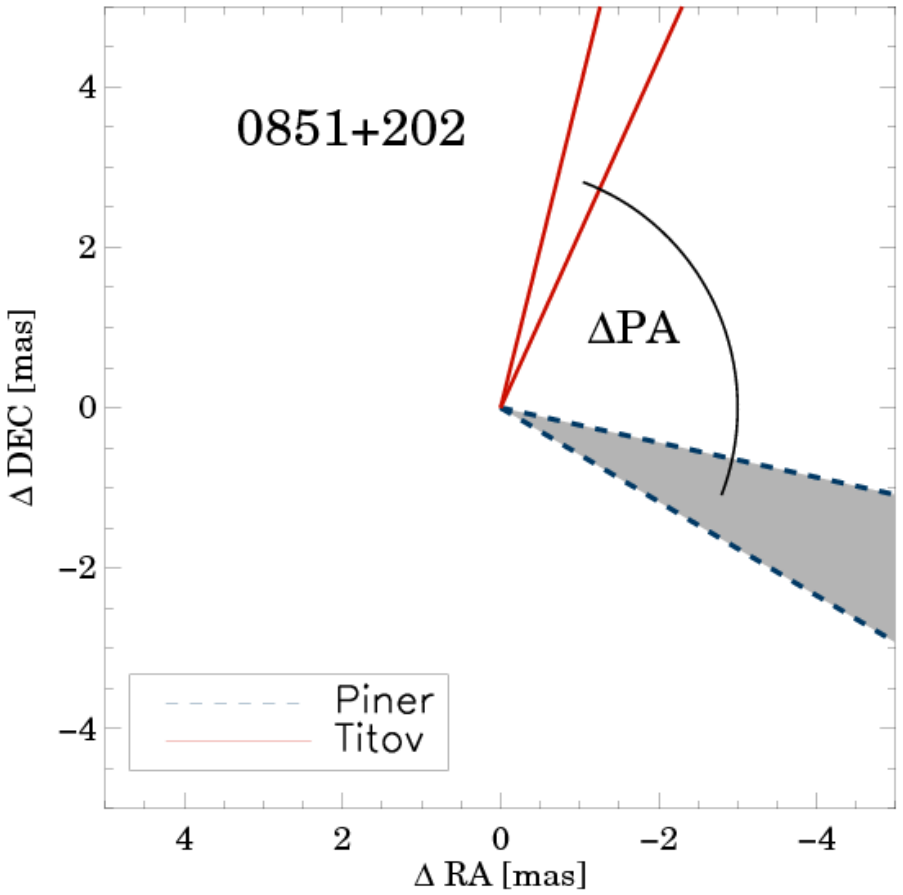


Time span of the VLBI imaging data analysed by *Piner et al.* 2007

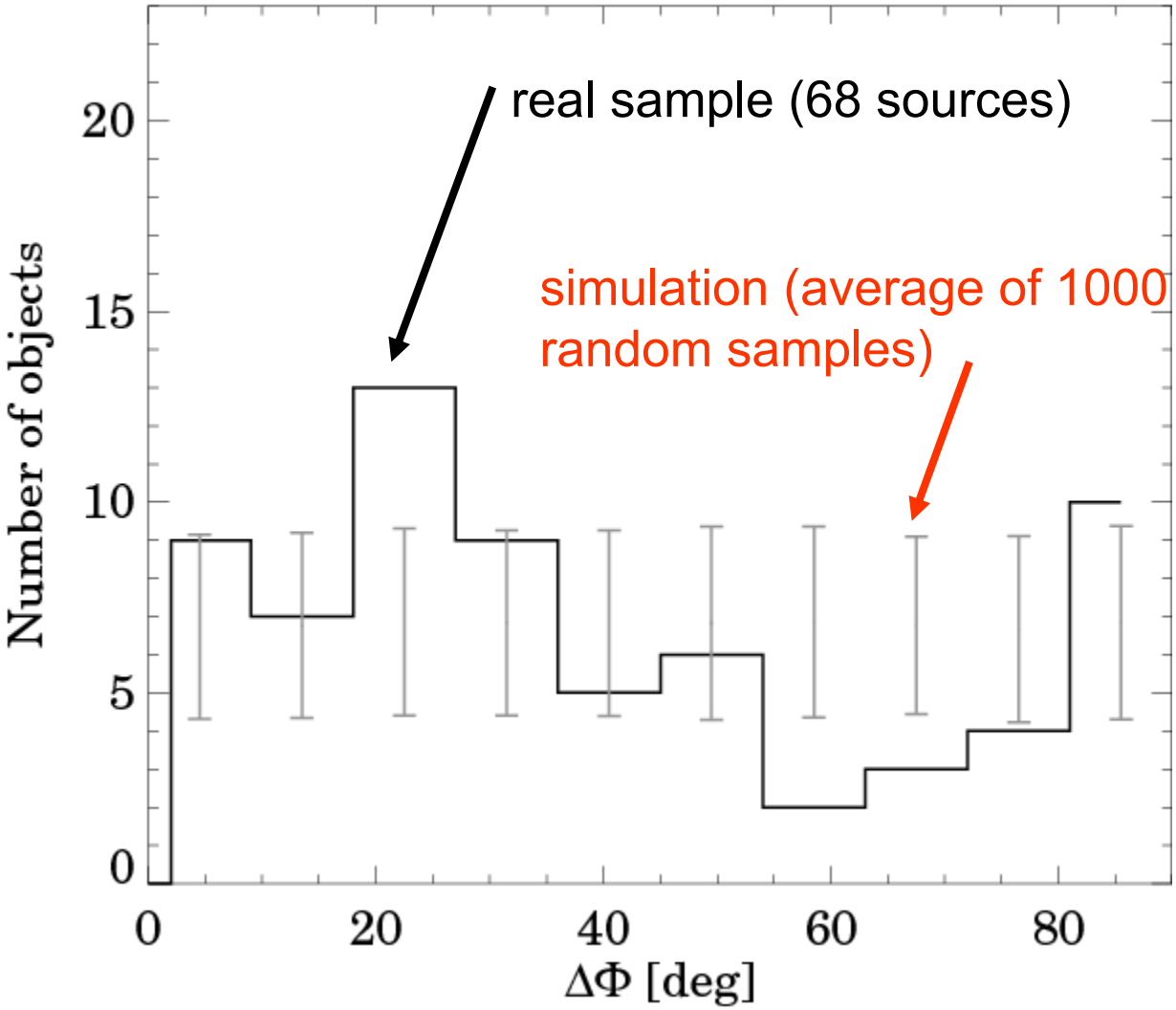




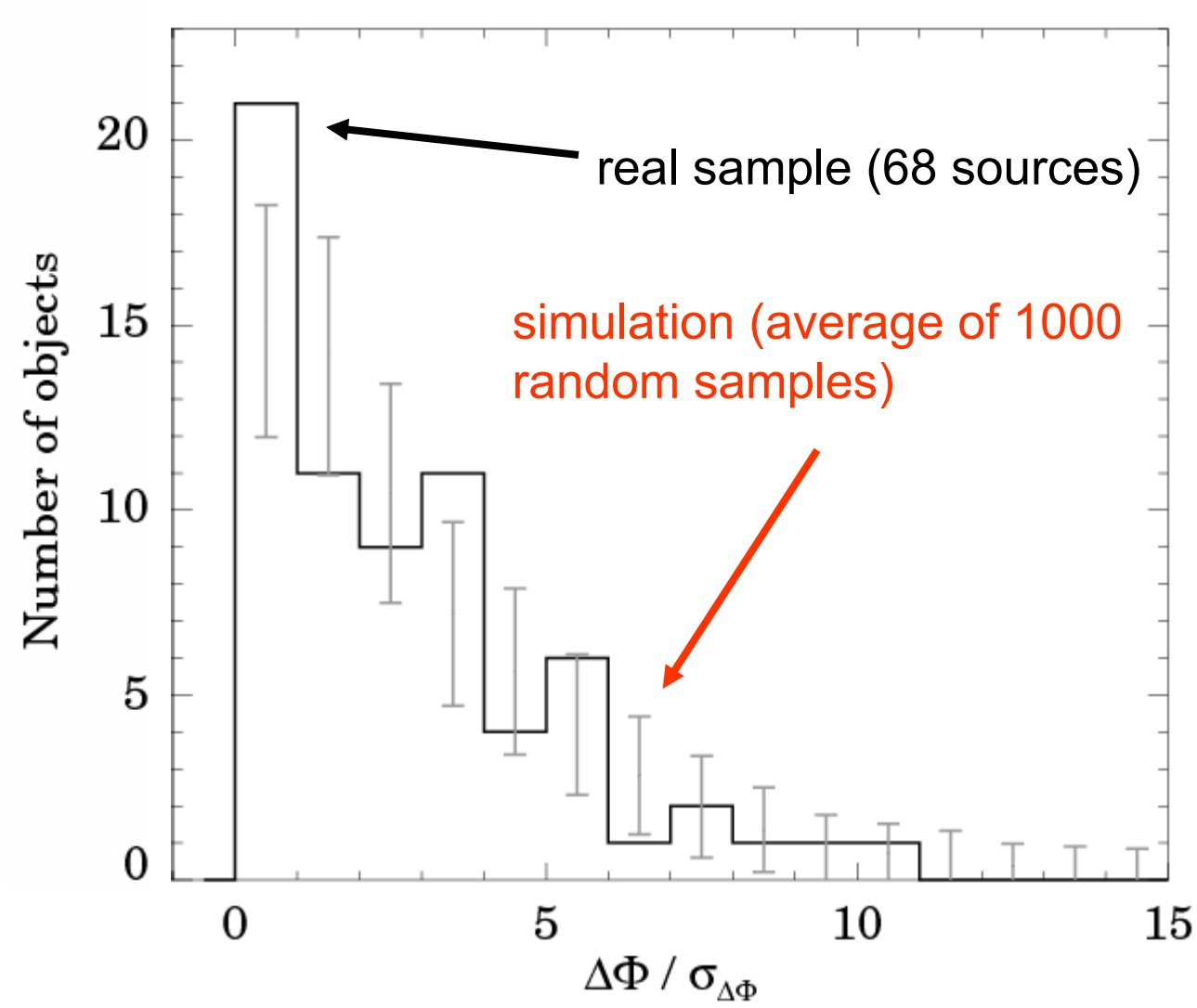

0851+202 at 8.335 GHz 1997 Jan 10
Permission to cite this material must be obtained from
The US Naval Observatory, Washington, DC 20392
Relative Declination (mas)
Right Ascension (mas)
10
5
0
−5
−10
Map center: RA: 08 54 48.875, Dec: +20 06 30.642 (2000.0)
Map peak: 0.706 Jy/beam
Contours: 0.00262 Jy/beam x (−1 1 2 4 8 16 32 64
Contours: 128 256)
Beam FWHM: 1.69 x 0.948 (mas) at 0.694°


0851+202
ΔPA
Piner
Titov
Δ DEC [mas]
Δ RA [mas]
4
2
0
−2
−4

Distribution of the directional differences



Directional differences over their uncertainties



Results (1)

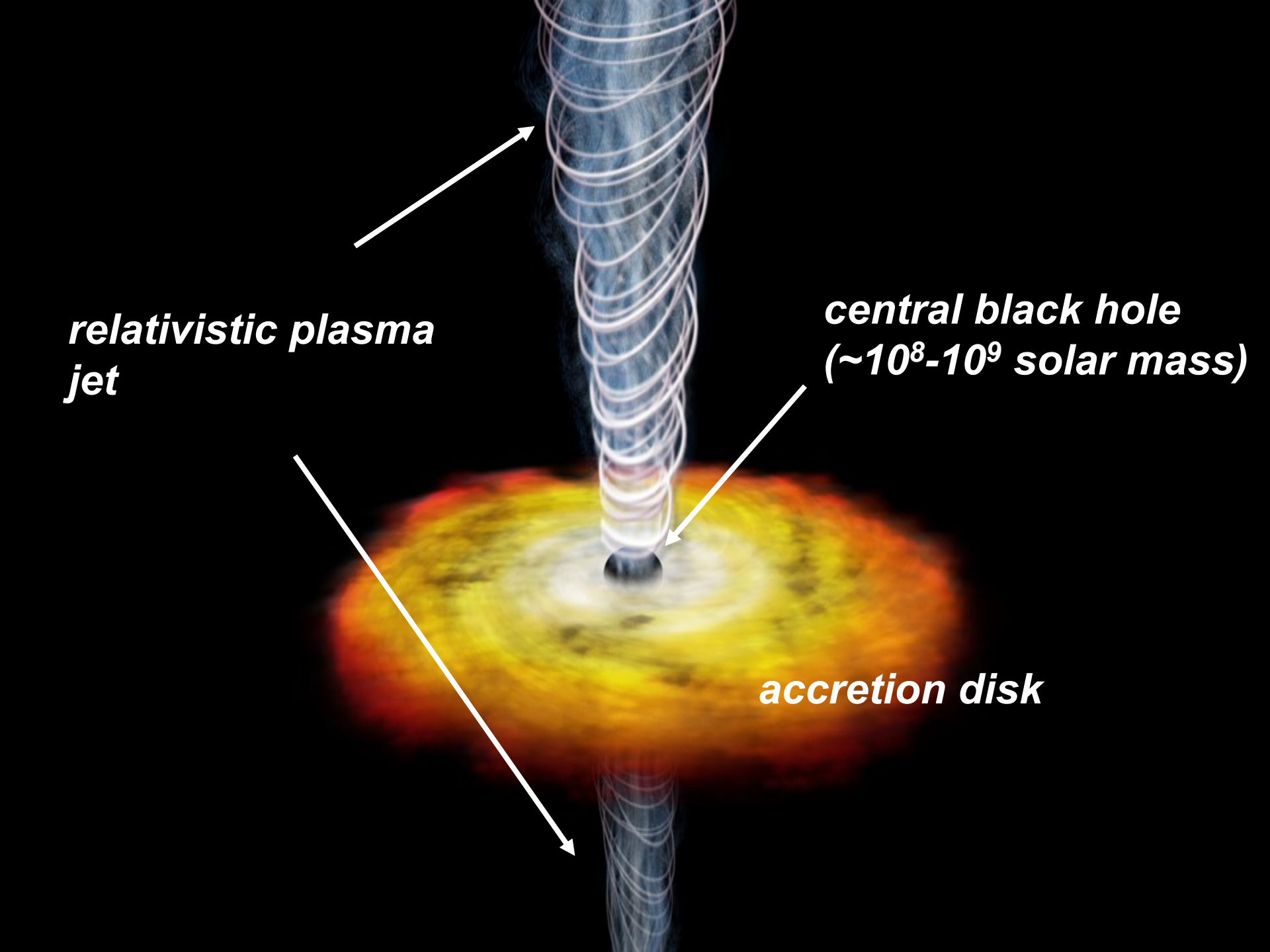
❖ Generally, the jet directions and the proper motion directions appear uncorrelated (although there might be a sub-sample with small $\Delta\Phi$)

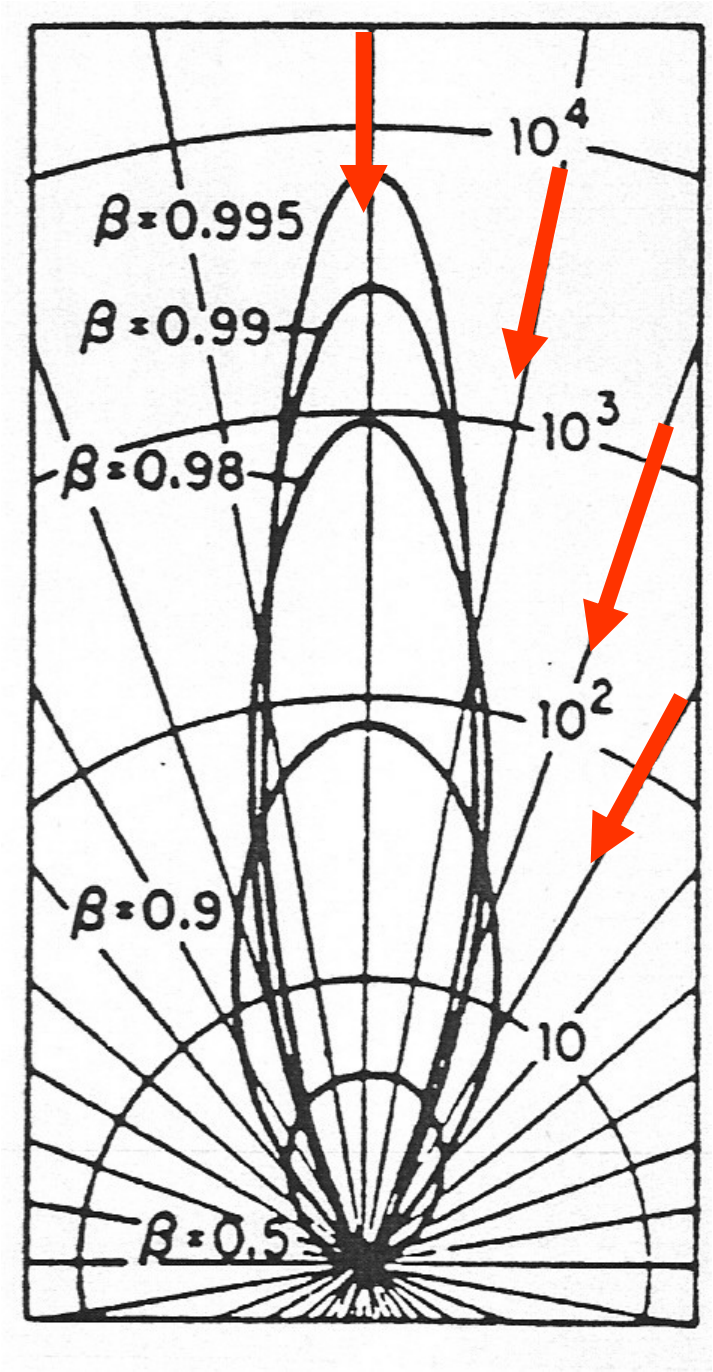
Is it surprising?

❖ We see the source structures at the ~1-10 mas angular scale in the VLBI images

❖ The measured apparent proper motions are at best in the ~0.01-0.1 mas/year range

❖ The characteristic jet direction is not necessarily the same within the unresolved VLBI ”core”


relativistic plasma jet
central black hole (~10^8-10^9 solar mass)
accretion disk

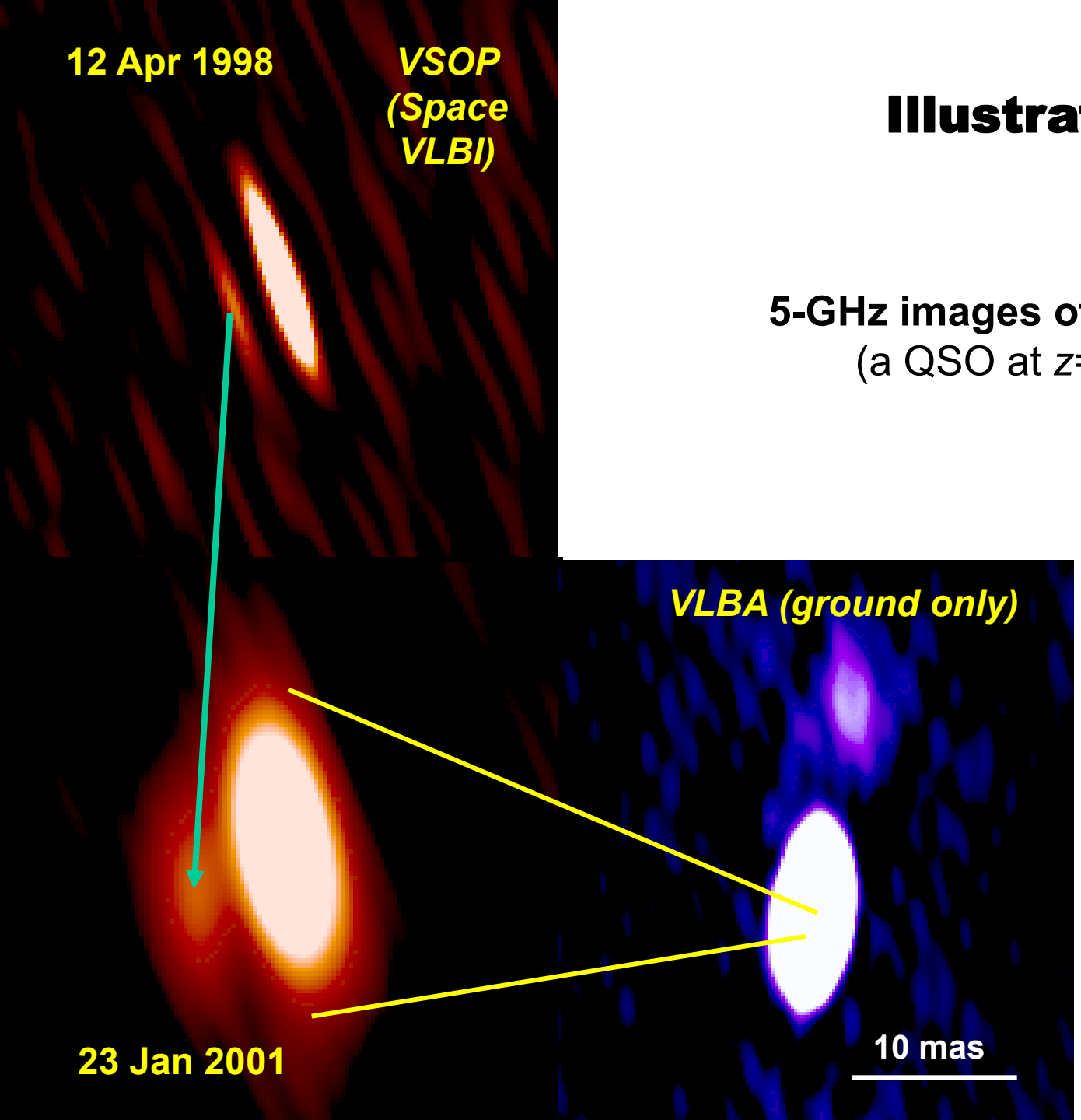


Doppler boosting: radiation is enhanced if viewed from a direction close to the line of sight

←

The radiated power as a function of viewing direction & speed ($\beta = v / c$)

Illustration



5-GHz images of 1351-018
(a QSO at *z*=3.71)

Frey et al. 2002

Results (2)

❖ Such jet misalignments are well known at larger angular scales (e.g. *Conway & Murphy* 1993; *Appl et al.* 1996)

❖ Jets are not necessarily linear structures. There could be a population of sources with e.g. curved (helical) inner jets, the appearance of which is strongly determined by viewing geometry and relativistic beaming

❖ Or: the observed position variations are *not (fully) related* to structure variations, but something else
→ the possible pattern in the proper motion vector field over the sky, *MacMillan 2005*
→ systematic cosmological effects? *Titov, previous talk*

❖ **Conclusion:** The reference source proper motion directions cannot be simply inferred from the mas-scale jet direction