Evolution of AGN jets from multi-epoch core-shift studies

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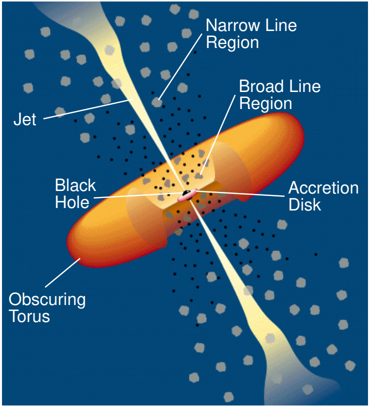
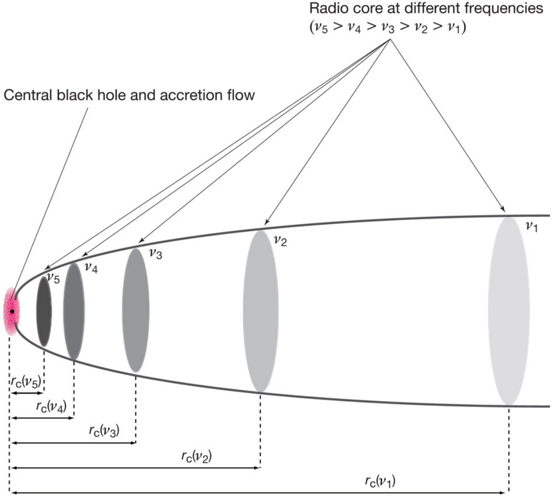
October 10, 2018
EVN Symposium

This presentation has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 730562 [RadioNet].

Core shift in AGN jets

Due to synchrotron self-absorption
(e.g. Blandford & Konigl,1979)
apparent jet origin (*core*) location r_c depends on ν





Why study core-shift variability

AGN physics

- What is the nature of radio flares and how they propagate?
- Independent estimates of jet parameters close to its origin.

Astrometry

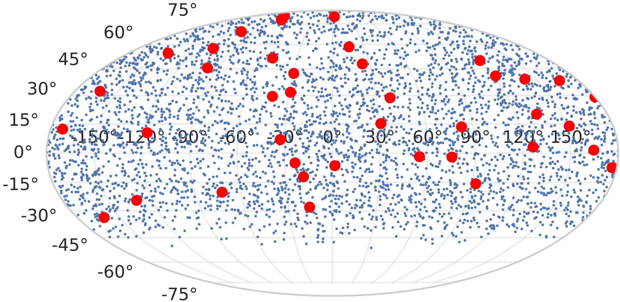
- Is AGN position jitter expected?
- Can group delay measurements be affected? Not when $r_c \sim 1/\nu$.
- Effect on VLBI/Gaia alignment? Talk by Petrov+ today.

Observational data

- Simultaneous 2 and 8 GHz VLBA+, 1994-2016
- 40 AGNs with jets & observed at > 10 epochs

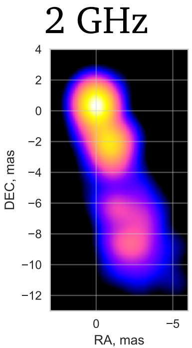
Blue — all 4143 AGNs
Red — 40 studied here

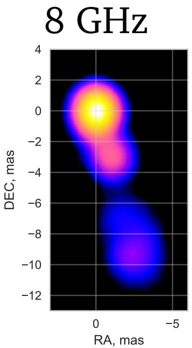
Redshifts
up to $z = 2.37$,
median $z = 0.74$



Core-shift measurement

1. Acquire two-frequency calibrated images:



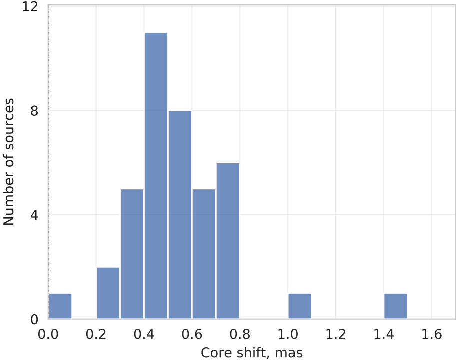


2. Align them: no absolute position.
3. Estimate core position on each image.

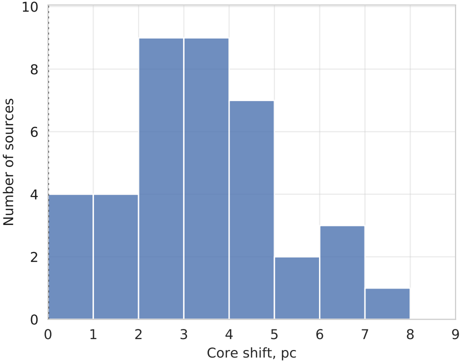
We developed an automated method.

Median magnitudes of 8-2 GHz core shift

40 quasars, 1691 individual observations



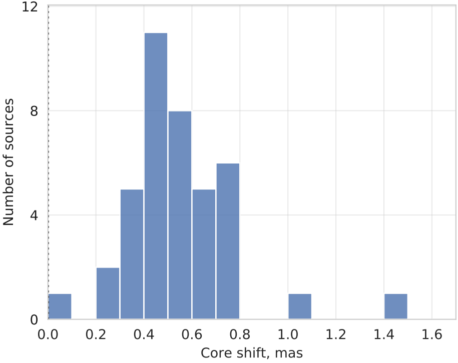
Median 0.55 mas

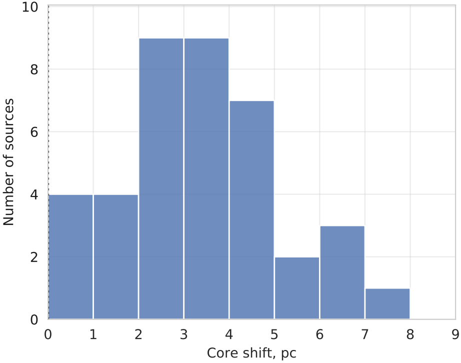


Median 3.2 pc

Median magnitudes of 8-2 GHz core shift

40 quasars, 1691 individual observations





Median 0.55 mas

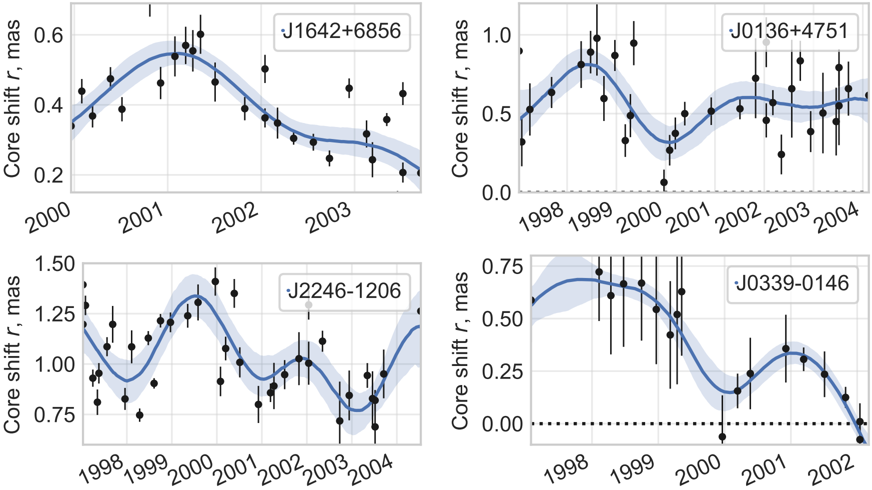
$\Rightarrow r_c(8\text{ GHz}) = 0.2$ mas

Median 3.2 pc

$\Rightarrow r_c(8\text{ GHz}) = 1$ pc

assuming $r_c(\nu) \sim 1/\nu$

Detected 8-2 GHz core-shift variability

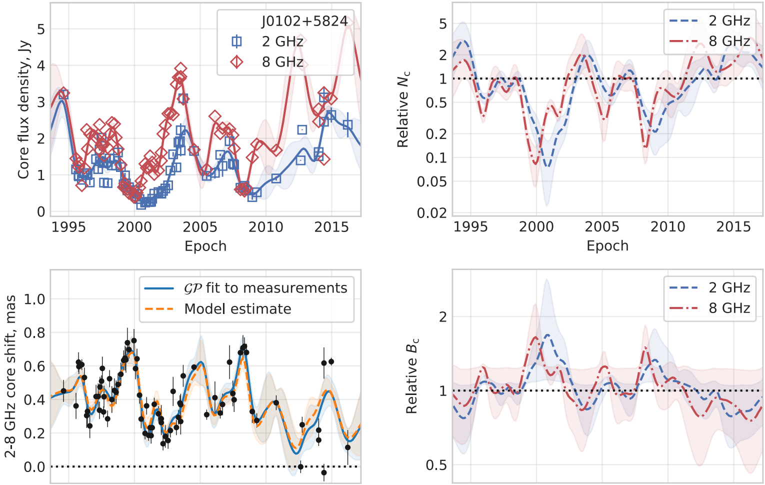


Median max – min difference 0.35 mas, maximum around 0.8 mas

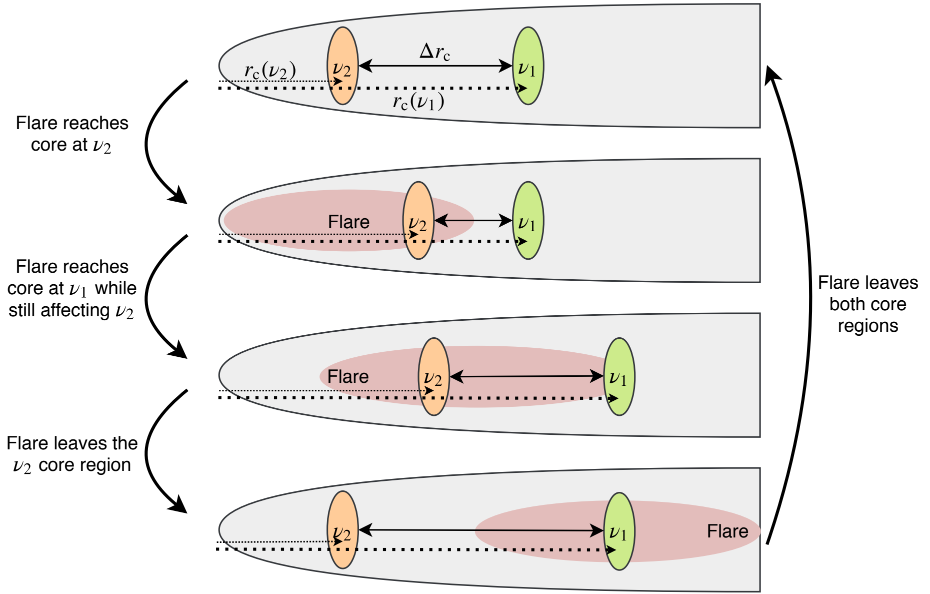
Significant variability for 33 of 40 AGNs!

Assume: flux & position change due to the same parameter variations.

Find that $r_c \sim S_c^{0.3}$ $\Rightarrow N_c \sim S_c^{1.5}$ and $B_c \sim S_c^{-0.33}$



Flare propagation



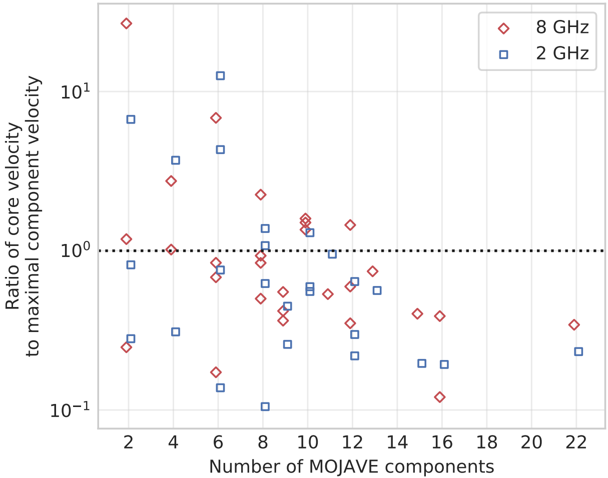
Implications

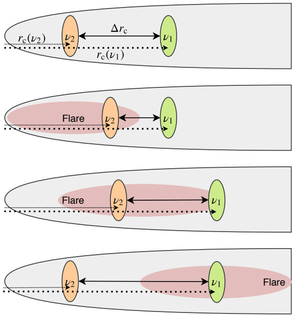
Core position varies by ~ 0.5 mas $\Rightarrow$
flare region extent is at least this long

Flares at ν_1 and ν_2 happen with a delay $\Rightarrow$
cores $r_c(\nu_1)$ and $r_c(\nu_2)$ move separately $\Rightarrow$
any fixed dependency like $r_\mathrm{c} \sim 1/\nu$ cannot hold.

- Apparent core is not only shifted from the jet base, but the shift varies in time;
- Need to take variability of Δr_c into account when inferring physical parameters.

Apparent velocity: comparison with MOJAVE





MOJAVE measurements from Lister+13, 16.

Core velocity: lower bound on the jet flow speed.

Summary

- We measured 8-2 GHz core shift for the largest sample of AGN observations; typical values are ~ 0.5 mas;
- Variability detected for the majority of AGNs: up to 0.8 mas, typically ~ 0.3 mas;
- Cores at different frequencies move separately from each other: no fixed frequency dependence.
- Flare regions are extended along the jet, ≥ 2 pc.
- Independent method to probe flow speed: apparent core velocity as a lower bound.