# Direct confirmation of the VLBI–Gaia offsets nature



### **Alexander Plavin** (Lebedev Physical Institute, Moscow) **Yuri Kovalev, Leonid Petrov, Eileen Meyer, Alexander Pushkarev**

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# 2 billion objects: Gaia DR3, June 2022

### Astrometry: radio and optical 20 thousand AGNs: Radio Fundamental Catalog, 2022 Visible light Mostly 2-8 GHz





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## Astrometry: radio and optical

#### **20k** AGNS: Radio Fundamental Catalog, 2022



### In common: 12k AGNs with 0.5 mas typical position accuracy Generally good positional agreement... Mignard+16, Charlot+20 ... but about 10% VLBI-Gaia offsets not explained by measurement errors

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#### 2 billion objects: Gaia DR3, June 2022

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## VLBI – Gaia offsets

#### **Expectations**

- Jet: a distinguished axis
- VLBI points close to the origin, can be shifted downstream: self-absorption, bright emission in the jet
- Known optical jets are too weak to noticeably affect Gaia (Mimica+2009)



5 mas





## VLBI – Gaia offsets

#### Reality



jet



Effect is real and grows with accuracy improvementsGaia DR1, RFC 2016Gaia DR3, RFC 2022



## VLBI – Gaia offsets

#### Reality



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## VLBI – Gaia offsets

#### Reality



- VLBI points close to the origin or slightly downstream
  - Radio position shifted in 1/4 of offsets

jet





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jet

## VLBI – Gaia offsets

#### Reality



- VLBI points close to the origin or slightly downstream Radio position shifted in 1/4 of offsets
- Known optical iets are too noticeably affect Gaia The majority of significant offsets are caused by optical jets?









- VLBI–Gaia offsets reach 10s of mas, optical emission even more extended?
- We see lots of evidence for bright optical jets: optical spectra, polarization, proper motion, agreement with the unification scheme...





## Chasing optical jets

- VLBI–Gaia offsets reach 10s of mas, optical emission even more extended?
- We see lots of evidence for bright optical jets: optical spectra, polarization, proper motion... Plavin+19, Petrov+19, Kovalev+20
- ... but indirect
- Try to see the longest jets with the Hubble?





## Chasing optical jets with the HST



- 150 AGNs with the largest VLBI–Gaia offsets along the jet direction
- Select 75 based on their known properties and observing conditions
- 29 observed by the HST in 2021-2022

### Preliminary imaging results available

## Optical jets – captured!

## Sub-second jets clearly seen in quicklook images:

## Long jets in AGNs selected by VLBI–Gaia offsets: most direct confirmation of the offsets nature

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HST



## Jets and VLBI astrometry

• Several AGNs remain point-like on subsecond scales: (in optical)

- VLBI and Gaia positions coincide with bright components in radio maps
- "Gaia" component is the actual jet origin? VLBI happened to catch a brighter feature downstream?

Deeper multifrequency VLBI studies required Alexander Plavin – VLBI/Gaia offsets 9

Discussed in e.g. Xu+21





## Ongoing programs

- VLBI studies of AGNs with large VLBI–Gaia offsets EKO46 at EVN: 1 to 22 GHz, analysis in progress
- Deep & high-res VLA observations to compare kpc structure with the Hubble: since March 2022
- HST image improvements, archival studies

• Gaia continues observing, new DRs will include variability details: important for modeling the disk-jet system

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## Summary

### Synergy between VLBI and optical telescopes provides unique opportunities to studying AGN disk-jet systems

- Majority of VLBI–Gaia offsets caused by optical jet emission: direct confirmation obtained with the HST
- VLBI astrometry: helps selecting AGNs with bright extended optical jets, remains more robust for jetted sources
- VLBI is still the only way to resolve pc-scale structures crucial for proper understanding of more extended emission
- Jet emission may have a strong effect on VLBI positions as well, detailed studies will help untangling these effects





## Backup slides





## Flares and Gaia astrometry

### Optical centroid should move back and forth during flares:

### 35 AGNs with significant motion (Gaia DR2)





## Not only jets: dust extinction



Dust lanes are apparent is some AGNs: probably they also cause VLBI–Gaia offsets No jet visible?

### Remember: we probe the very tail, extreme cases are expected

## See Skipper+18

#### 2d histogram: offset direction vs its length

