Candidate sub-kpc dual SMBHs revealed with variability-induced jitters of quasars

Hao-Chen Wang

Department of Astronomy, University of Science and Technology of China

Supervisor: Jun-Xian Wang (USTC)

With M.-F. Gu (SHAO) and M. Liao (NAOC)

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中国科学技术大学
University of Science and Technology of China

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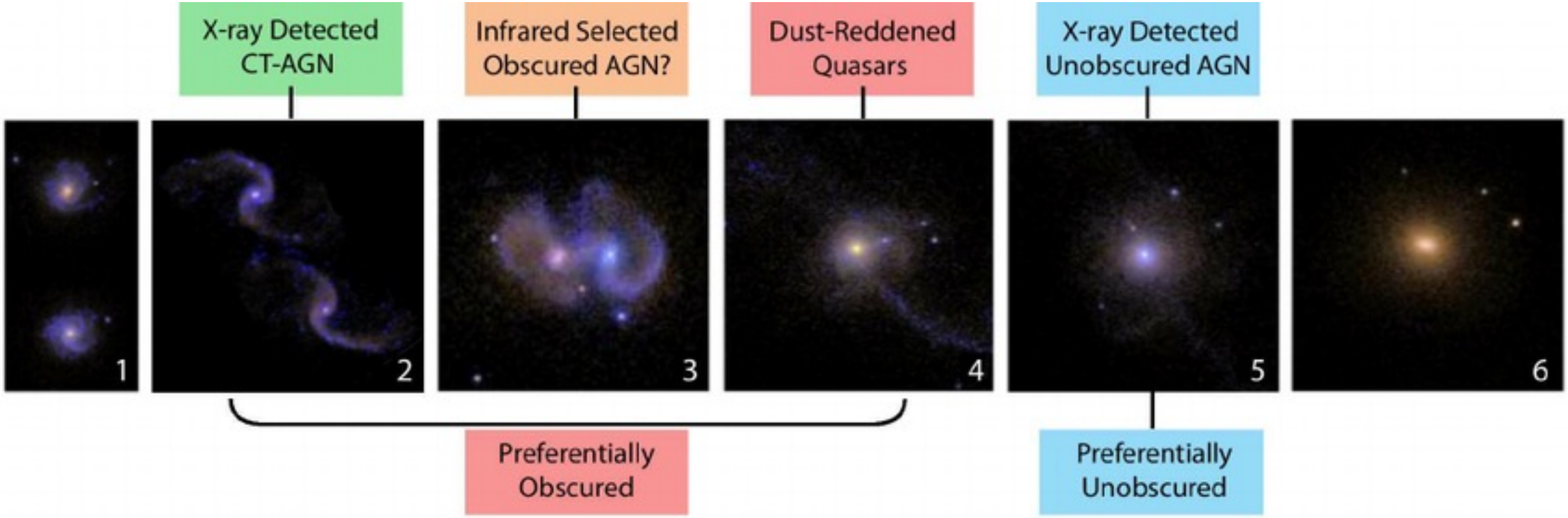
Background: why finding dual SMBHs?

- Dual and off-nucleus AGNs: active and unobscured dual SMBHs in galaxy mergers
- Dual SMBHs with **small angular separations & large redshifts** are rare.



Kocevski+2015

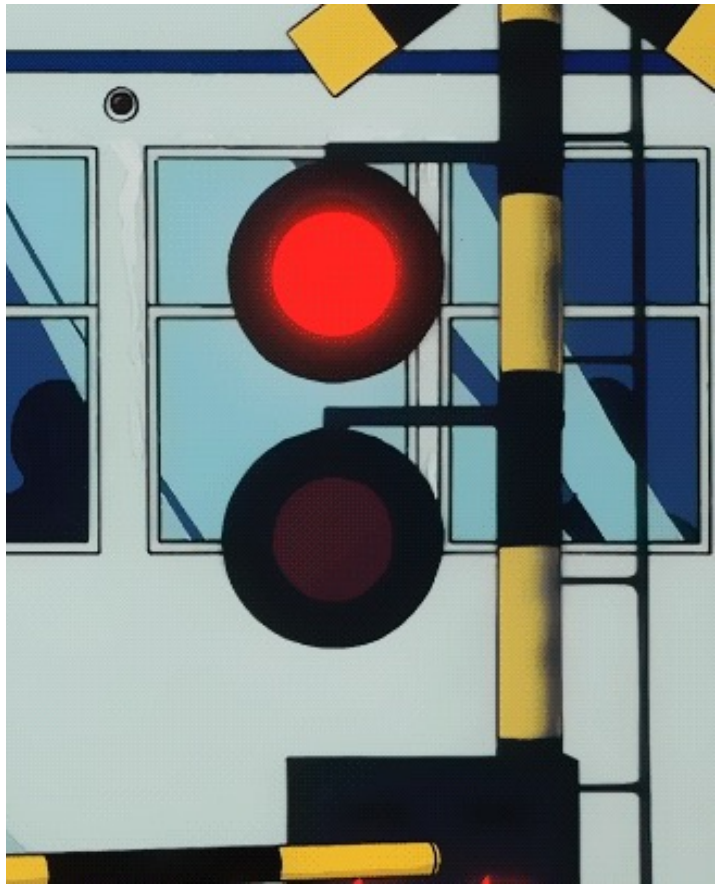
Varstrometry: variability induced astrometric jitters

- Target: Gaia unresolved dual and off-nucleus quasars

- The **position of photocenter** changes with the unsynchronized **stochastic flux variation** of each quasar, creating **astrometric jitters**.

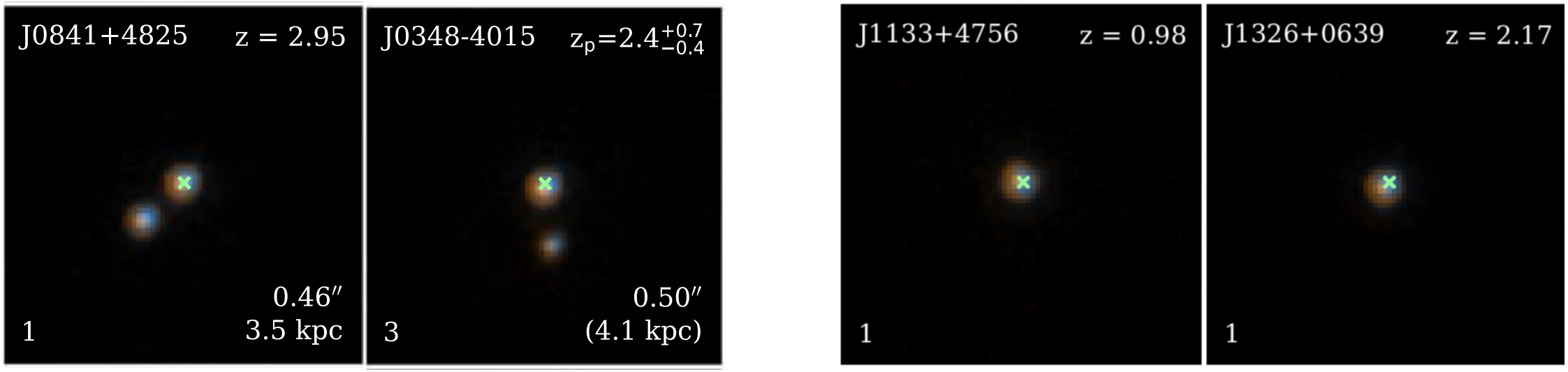
  → extra noise when fitting observational positions with normal astrometric model

  → large ***astrometric_excess_noise*** in Gaia data release



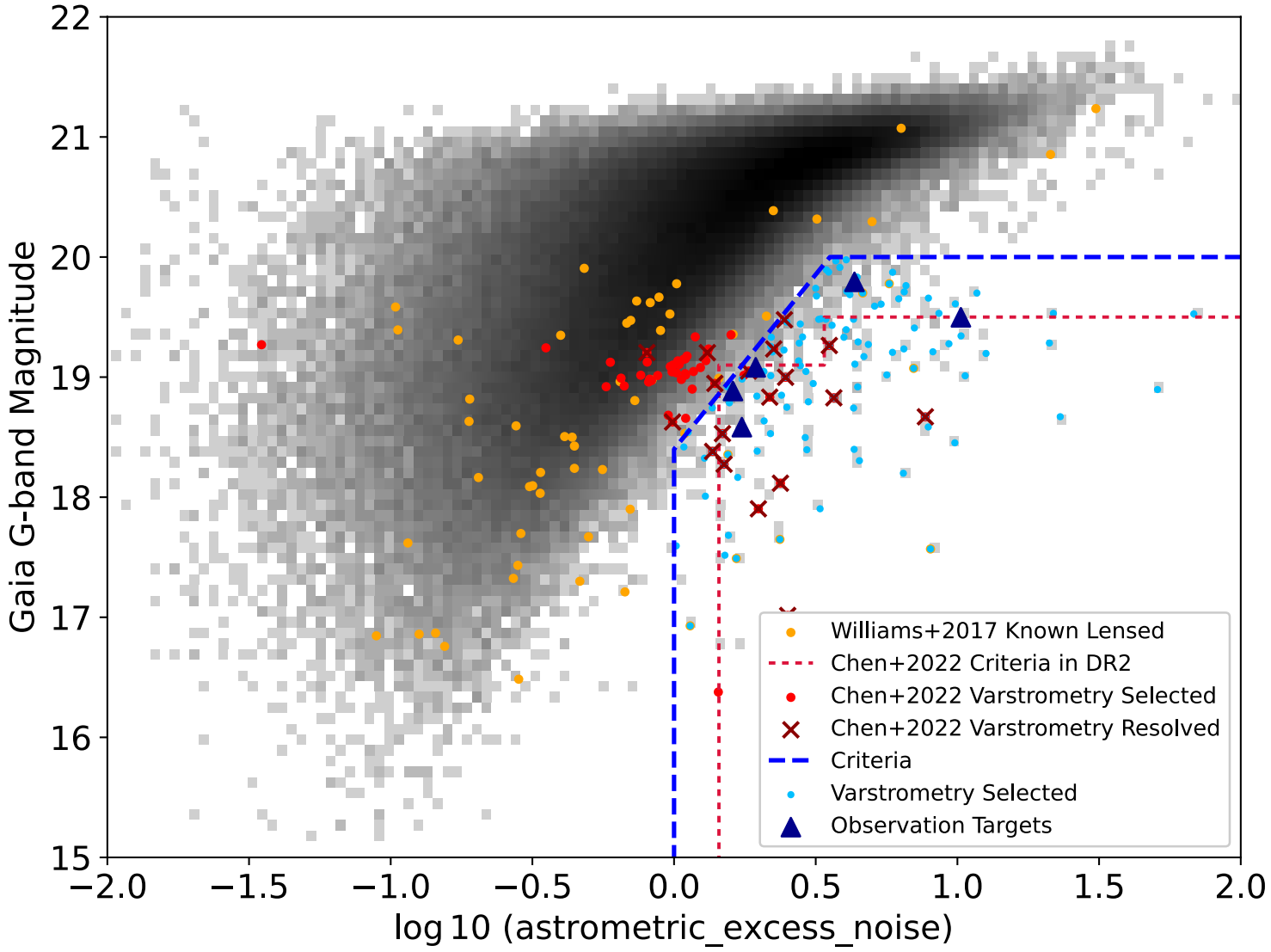
Varstrometry: variability induced astrometric jitters

- Varstrometry was firstly introduced in Hwang+2020.
- Chen+2022 took HST snap images of 56 varstrometry selected quasars, with 17 resolved into two or multiple sub-arcsecond cores.
- **Radio observations with higher resolution**? (also see Schwartzman’ s poster)



Chen+2022

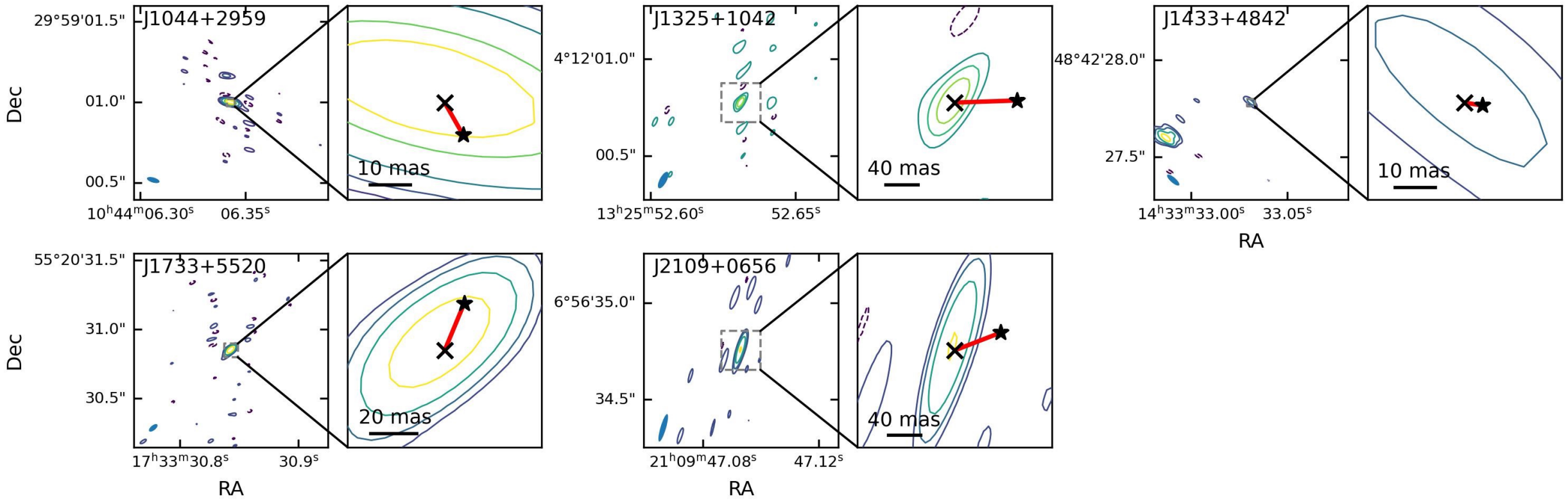
Targets selection



- Gaia EDR3 x SDSS DR16Q in 3 arcsec
- **Extended magnitude-dependent criteria of *astrometric_excess_noise***
- Redshift > 0.5 to avoid extended host galaxy
- FIRST flux > 5 mJy
- AEN_sig > 10
- **5 new candidates** were selected

Radio observations

- We propose e-MERLIN observations on 5 sources in C-band, 6 hours each.
- Detect **one compact radio core** close to the optical position for each target.
- **Gaia-radio offsets** are measured.

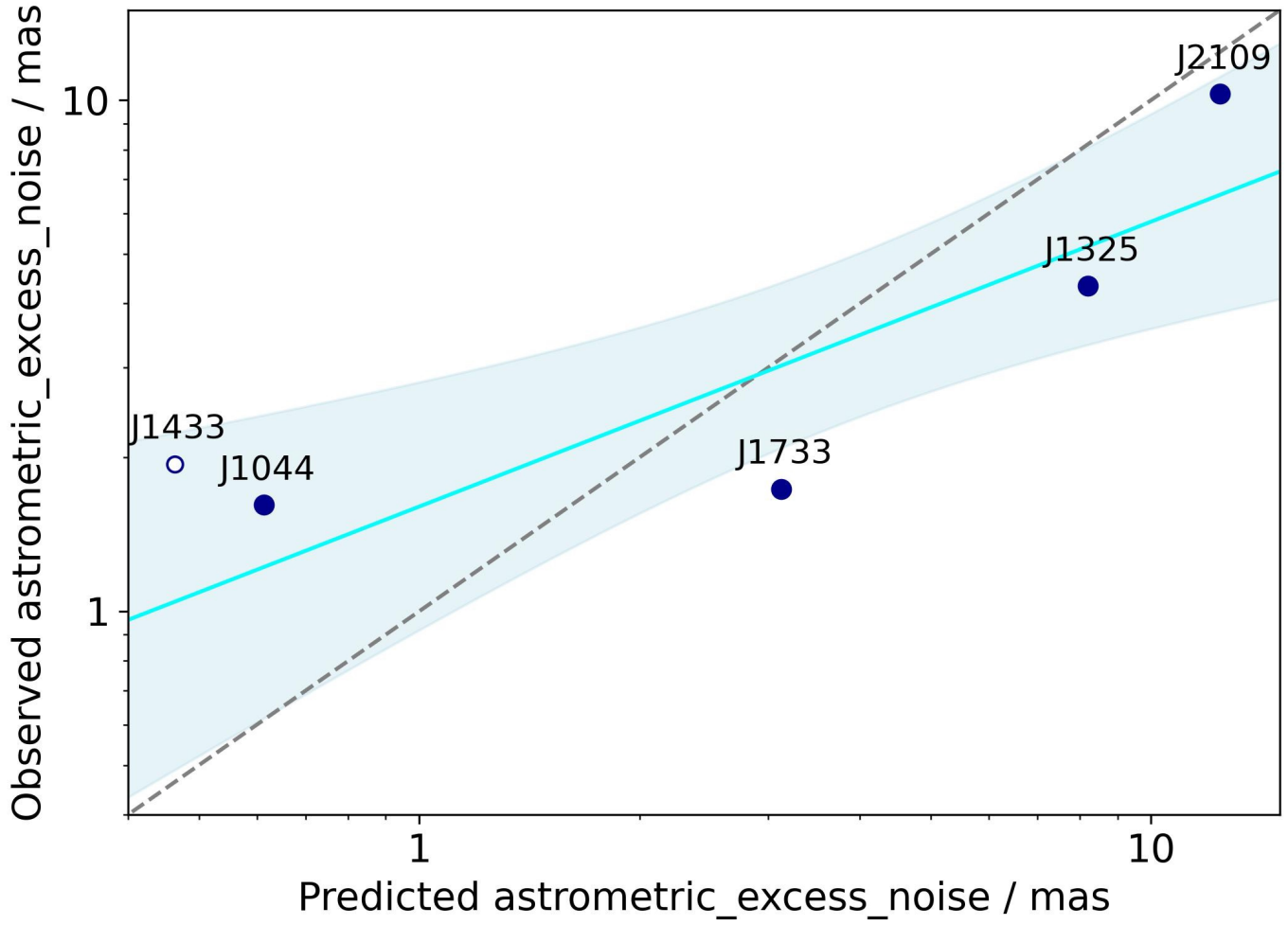


Gaia-radio offsets & significances

- **Gaia-radio offset: separation between the radio-loud quasar and the photocenter**
- Observed Gaia-radio offsets: 3.8 mas for J1433, **9 – 60 mas** for the rest four targets
- e-MERLIN positional errors: < 5 mas, Gaia positional errors: < 1 mas

- The significance of Gaia-radio offsets is calculated with **normalized separations** (Mignard+2016)
- **Significant offsets are witnessed** in all sources except J1433.

Discussion: AEN as a good indicator?



- Gaia-radio offsets + variability info for each quasar

  → predicted *astrometric_excess_noise*

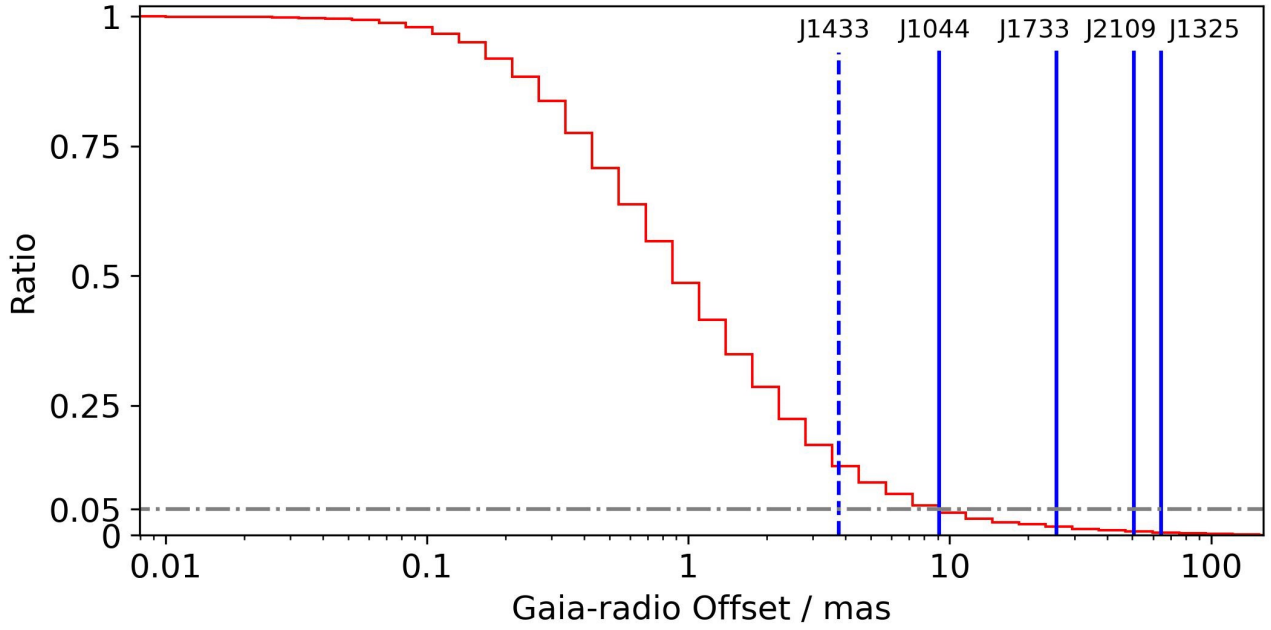
- Assume off-nucleus quasars

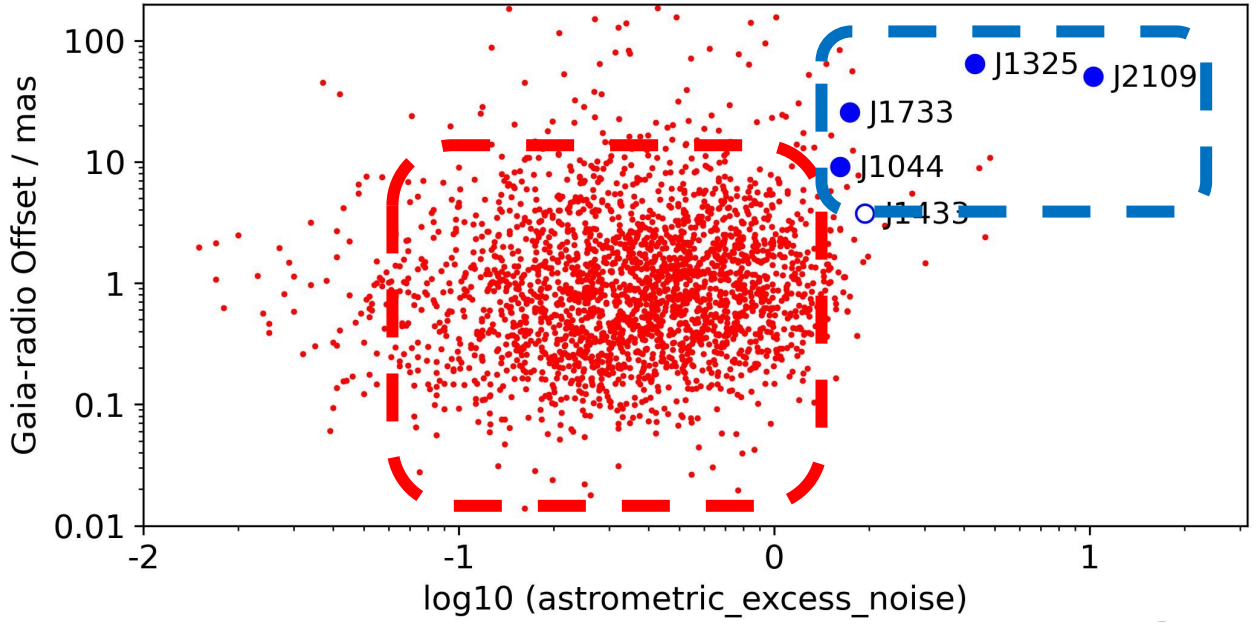
- **Good agreement between observed and predicted *astrometric_excess_noise***

- Similar results in Hwang+2020 for Gaia unresolved binary stars

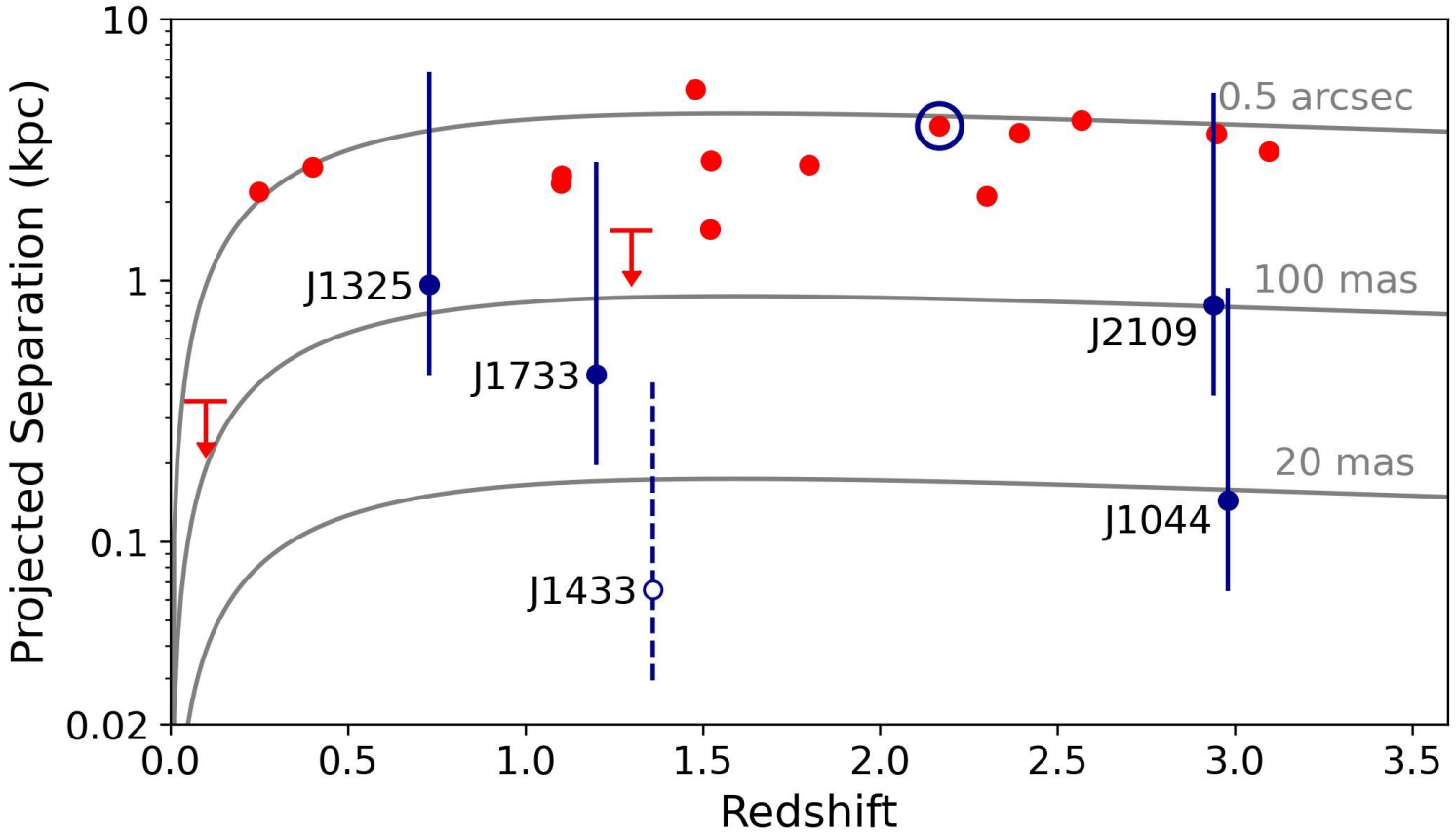
Discussion: unreal Gaia-radio offsets?

- Gaia-radio offsets are **rarely > 10 mas** for most quasars
- For quasars with offsets larger than normal: Optical jets (e.g. Plavin+2018)?
  - Our sample have weaker radio flux, higher *astrometric_excess_noise* and larger Gaia-radio offsets.
  - **Offsets barely change with increasing *astrometric_excess_noise***.





Discussion: projected separations



- Gaia-radio offset + optical flux ratio → projected separation
- Assume the optical flux ratio is between 1:10 and 10:1
- **Possible sub-kpc projected separations**

Discussion: outlooks

- Quasar + star? Low possibility if separations are small. (But J2109, see Schwartzman’ s poster)
- Lensed quasars? Resolved spectral observations are needed.

- Ongoing EVN observations on 5 targets for better measurements of the offsets.
- The enlargement of our sample is expected.

- More observations? future data release of Gaia, Euclid/CSST and SKA

Summary

- We find 5 new candidate dual SMBHs with variability-induced jitters of quasars measured by Gaia (namely varstrometry).
- Radio observations with high resolution are conducted, and 4 of 5 candidates show significant Gaia-radio offsets.
- The *astrometric_excess_noise* works as a good indicator for astrometric jitters.
- The offsets can be best explained by the existence of dual and off-nucleus quasars.
- Depending on the optical flux ratio, our dual SMBH candidates may have separations less than 1 kpc.
- More observations are undergoing.

THANKS FOR YOUR ATTENTION!

Contact: hcw062@mail.ustc.edu.cn