



# A Multiwavelength Study of Astrometrically-Variable Quasars: A New Population of Dual AGN?

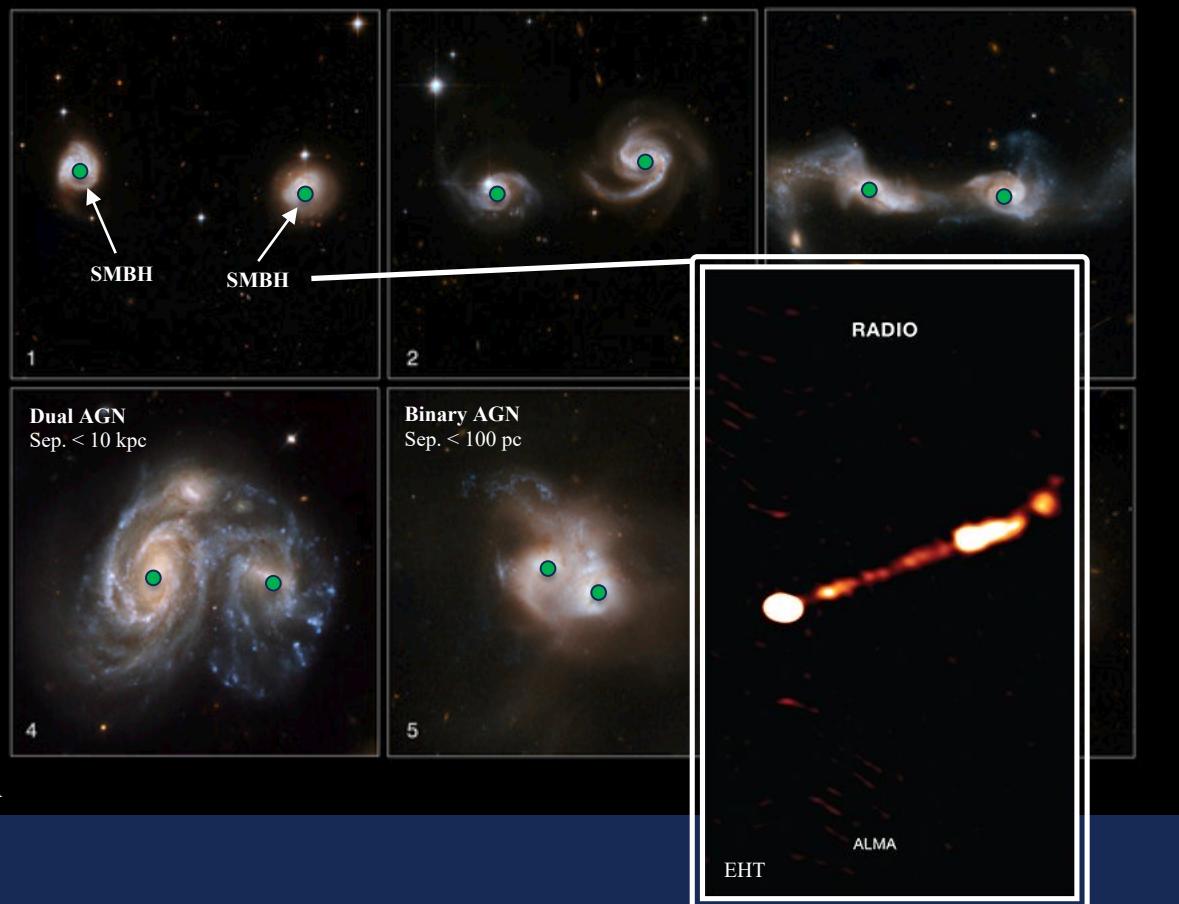
Emma Schwartzman

George Mason University  
US Naval Research Lab



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## Evolution of a Galaxy Merger

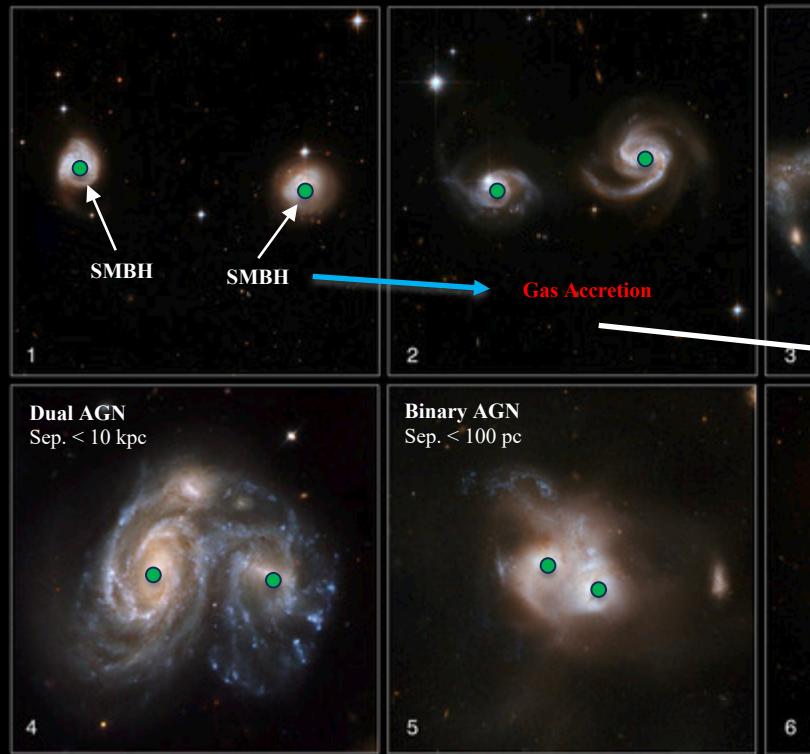


More massive galaxies are formed by the mergers of their smaller counterparts.

Galaxy mergers result in pairs of gravitationally-bound supermassive black holes.

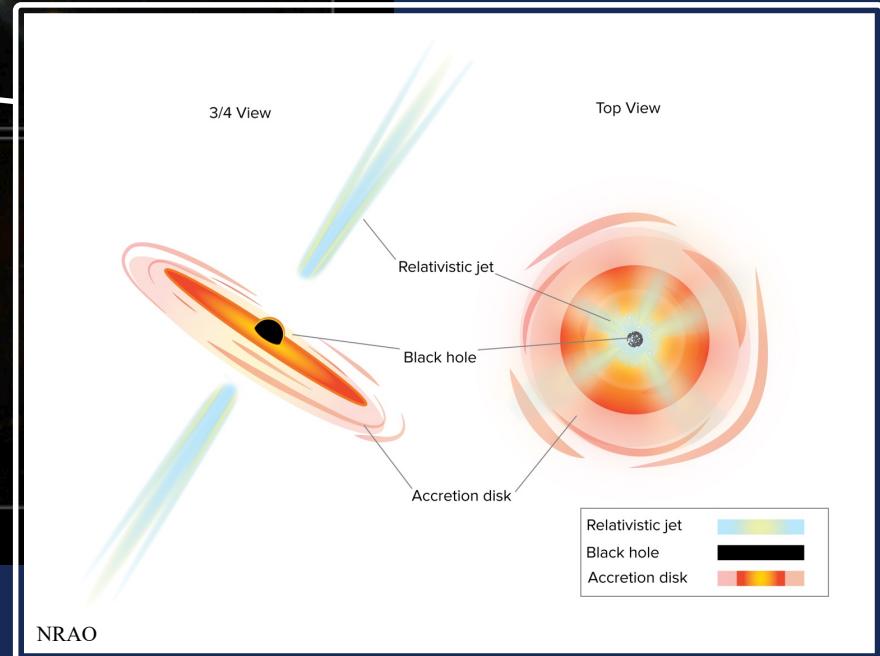
ESA

## Evolution of a Galaxy Merger

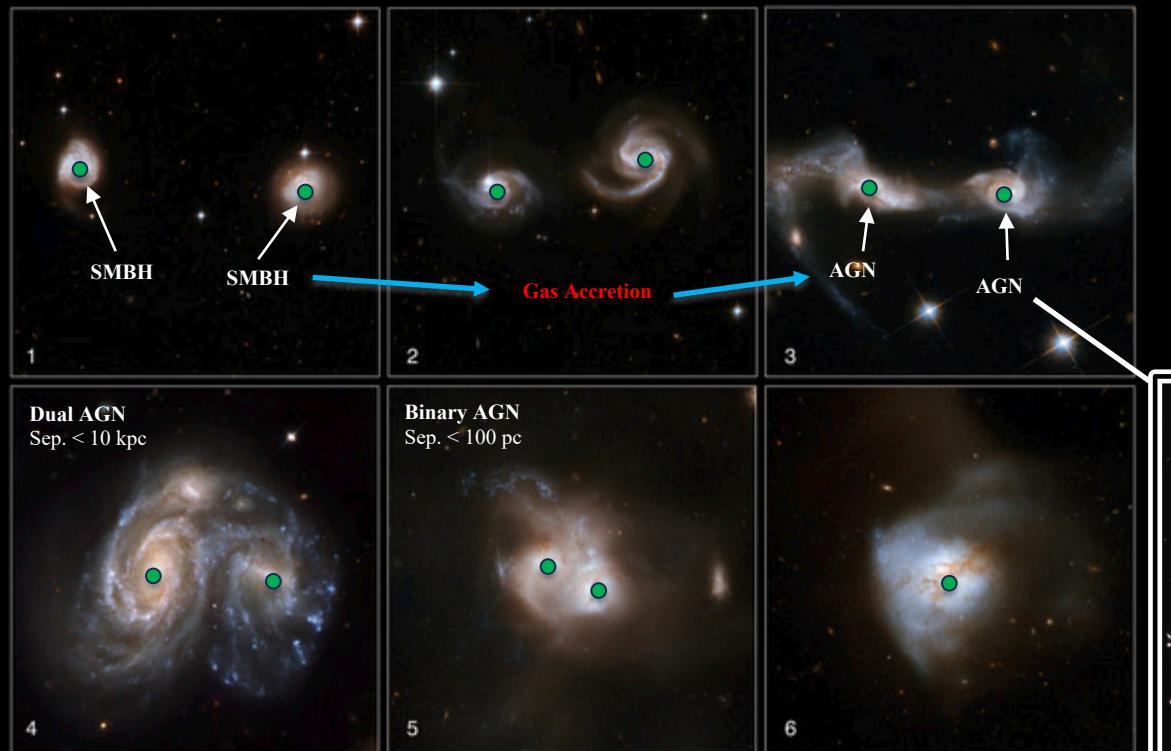


ESA

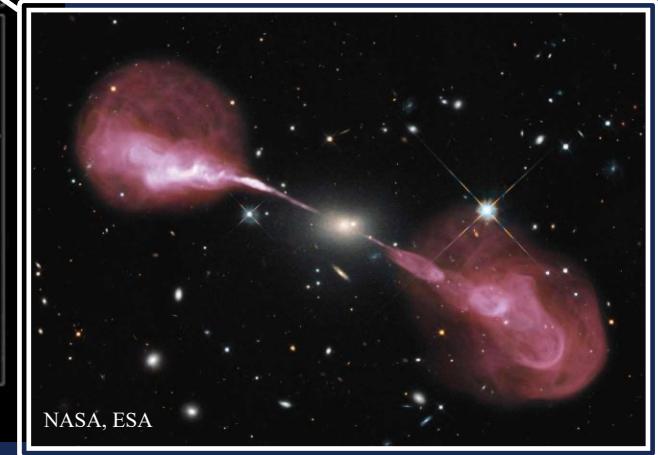
Merger driven torques  
drives gas accretion  
around SMBHs...



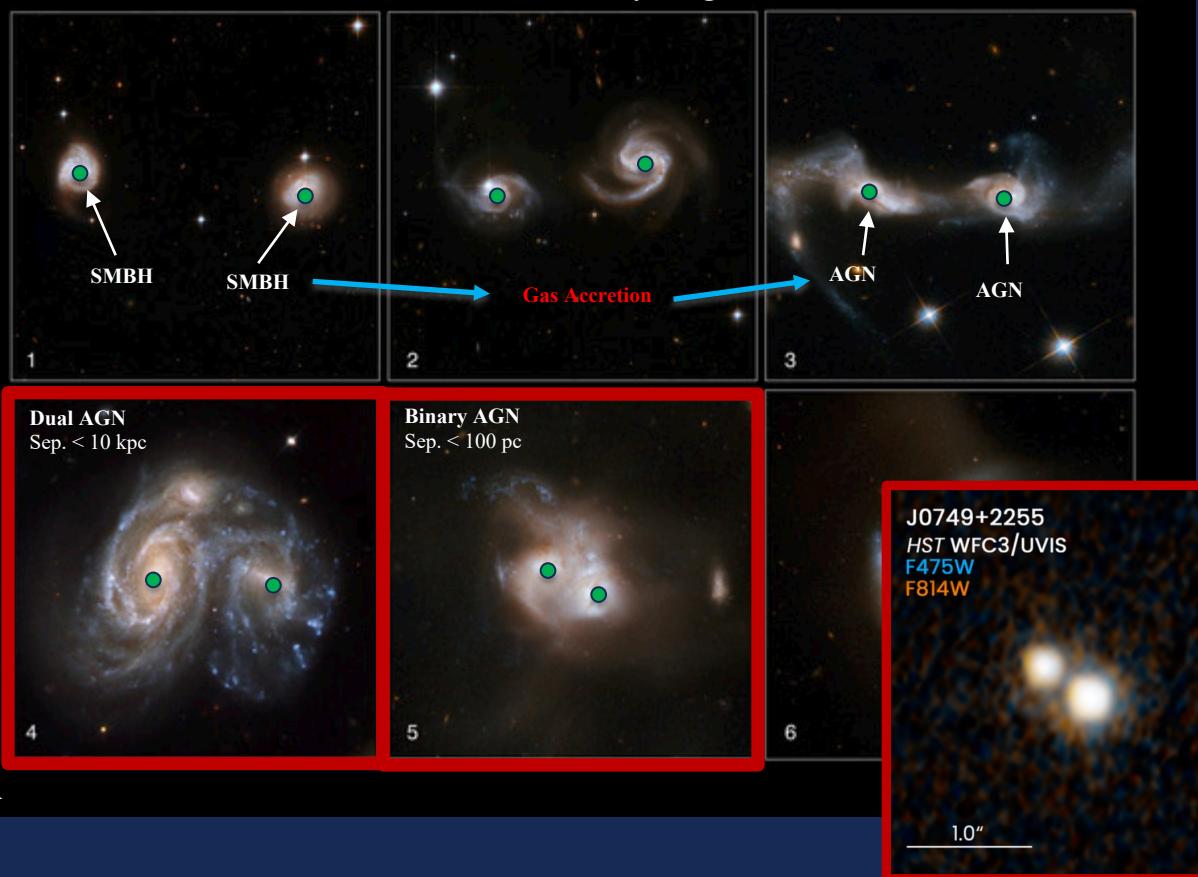
## Evolution of a Galaxy Merger



...which light up as  
active galactic nuclei.



## Evolution of a Galaxy Merger



Where are all the AGN pair systems?

Only 40-50 confirmed...

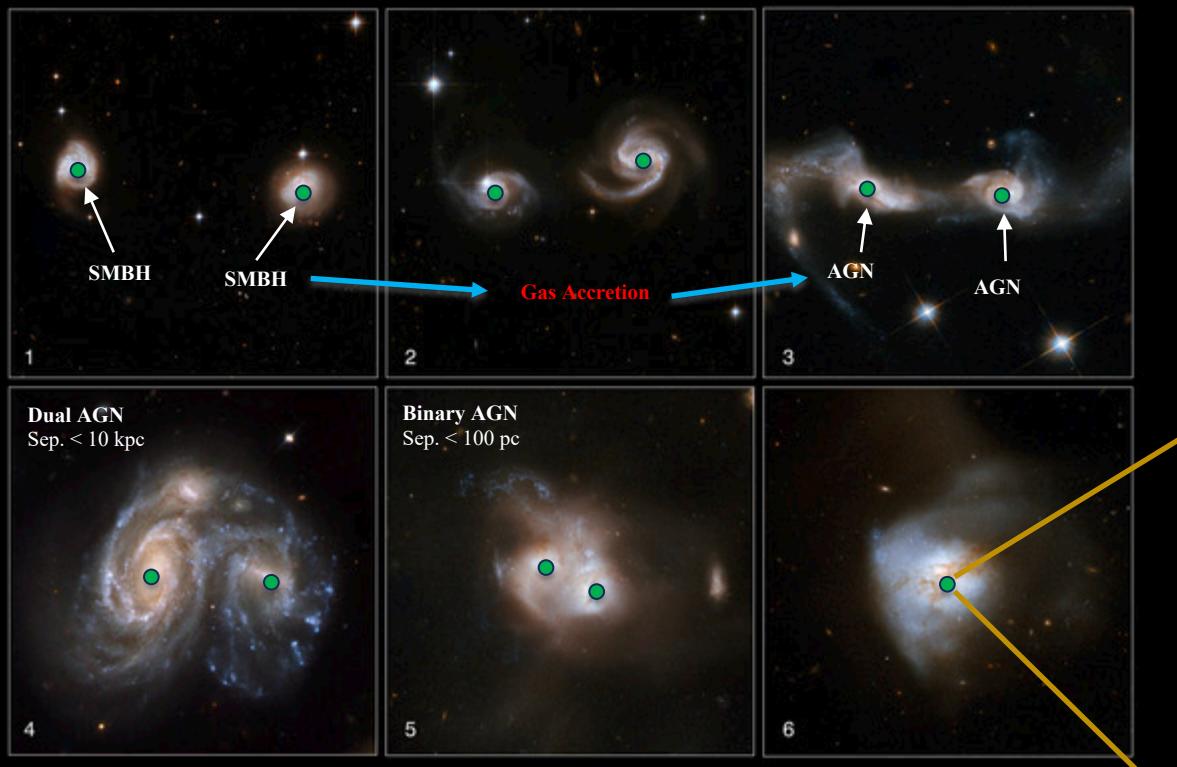
Is there a systematic method that can be used for their detection?

A new method pairs precise astrometric measurements with high-resolution radio surveys, such as VLASS.

Hwang et al. ApJ. 2020.

Emma Schwartzman

## Evolution of a Galaxy Merger



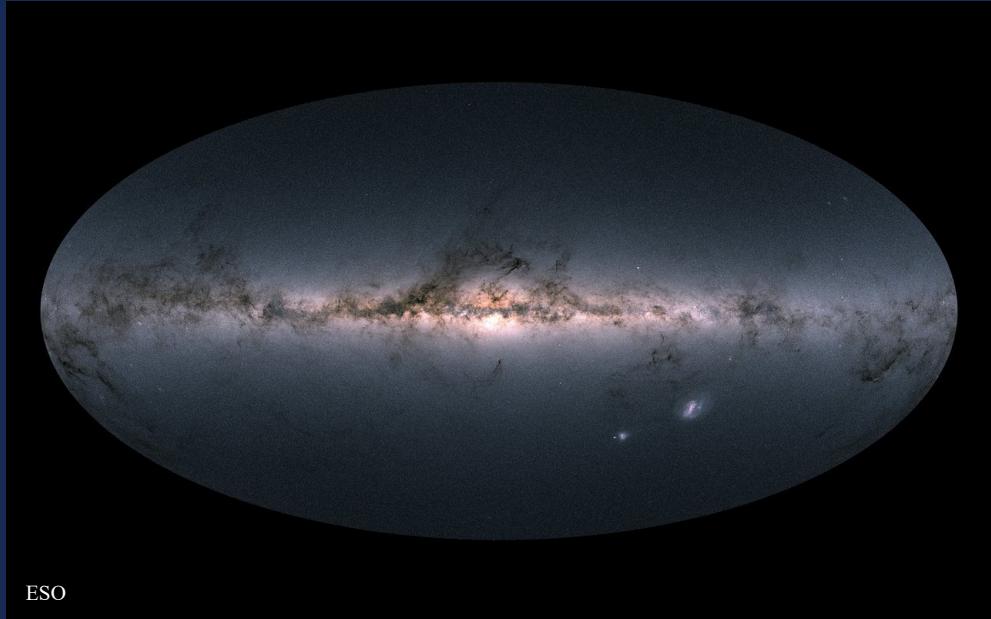
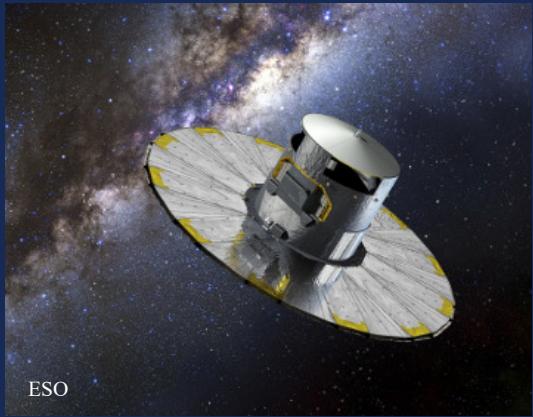
Evolution finishes with a more massive galaxy: the sum of the less massive ‘parts’

SMBHs inspiral, merge, emit gravitational waves, and ringdown, eventually forming a stable, single, more massive black hole

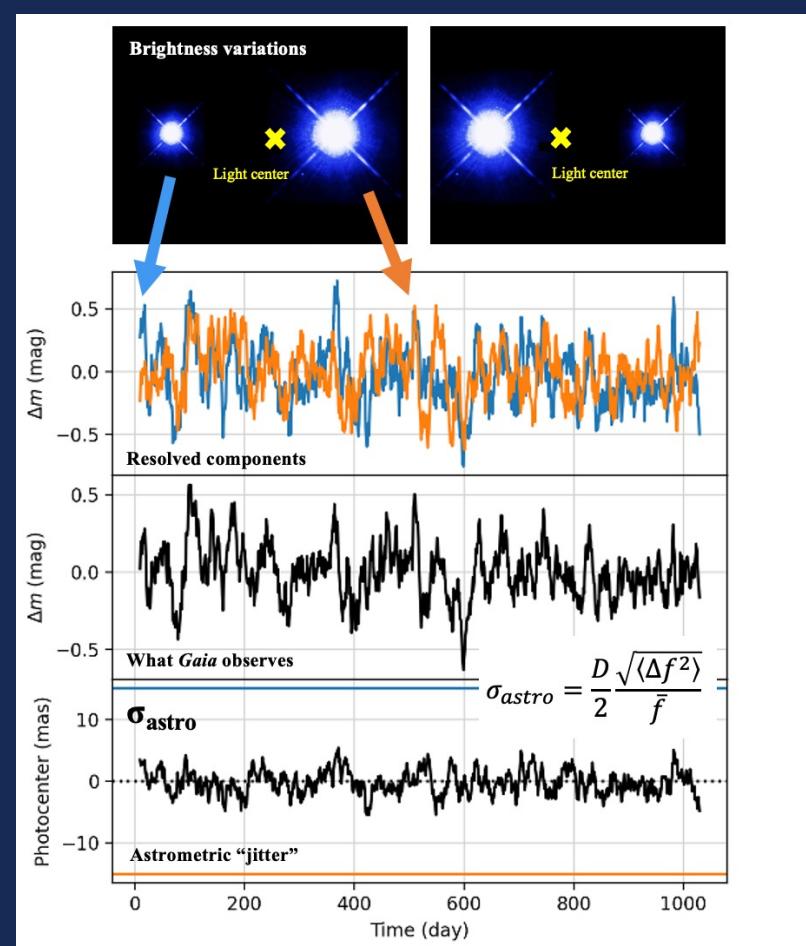


Bohn et al. CQG. 2014.

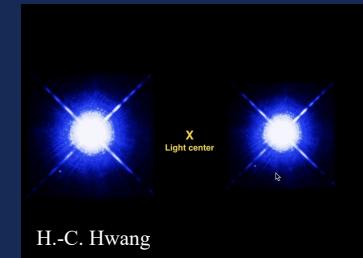
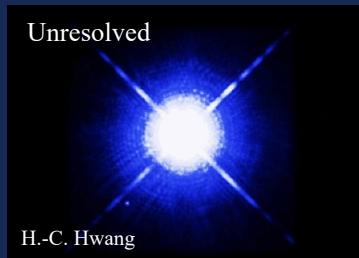
# Gaia



Sample of **astrometrically-variable quasars**:  
entirely new method for identifying AGN pair systems

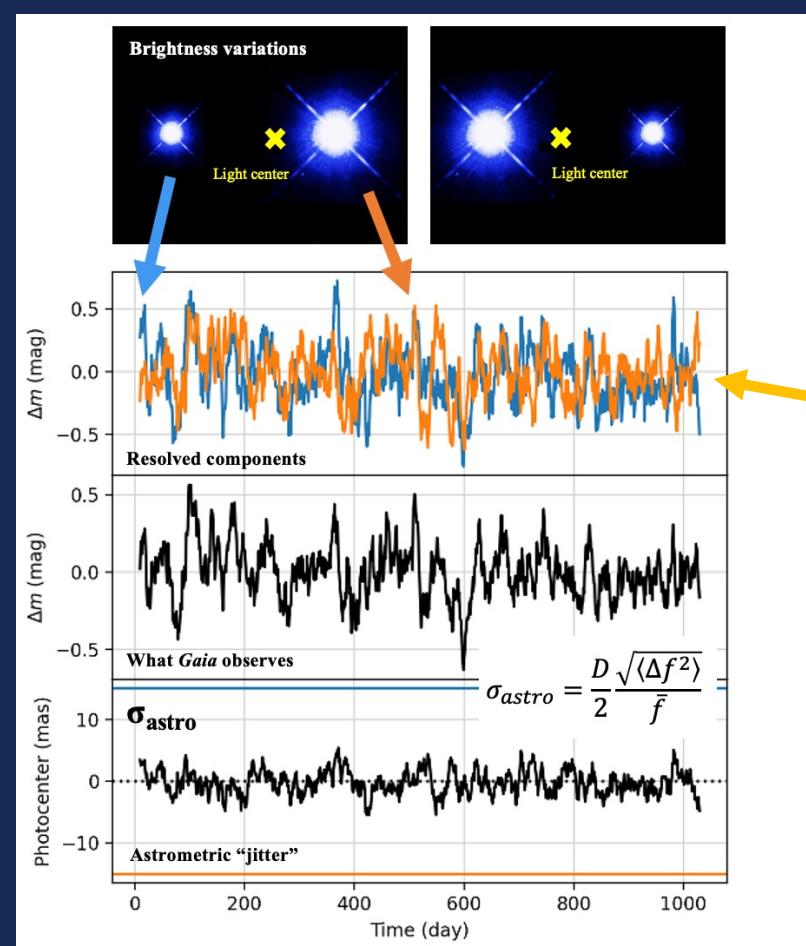


AGN pair, unresolvable with *Gaia*, light center appears to shift

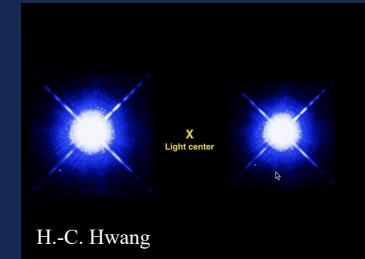
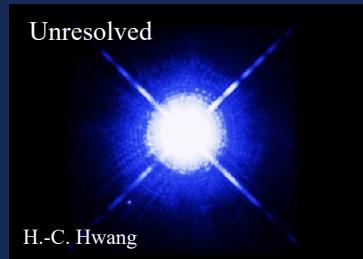


Variability + astrometry = varstrometry!

Hwang et al. 2019



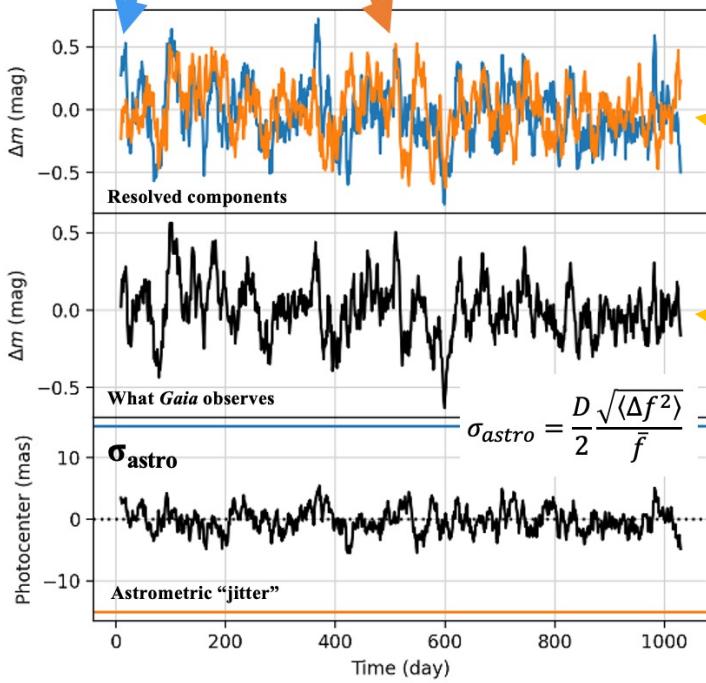
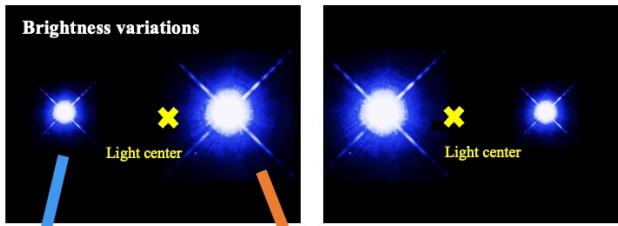
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If it was resolvable with *Gaia*, we might observe  
a lightcurve for both AGN

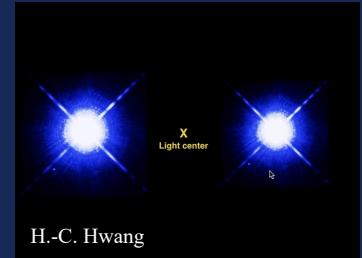
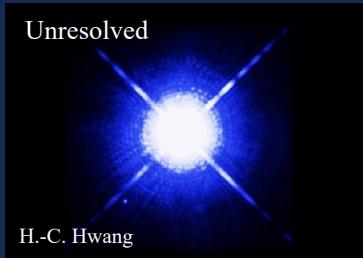
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Hwang et al. 2019



N. Secrest – private communication

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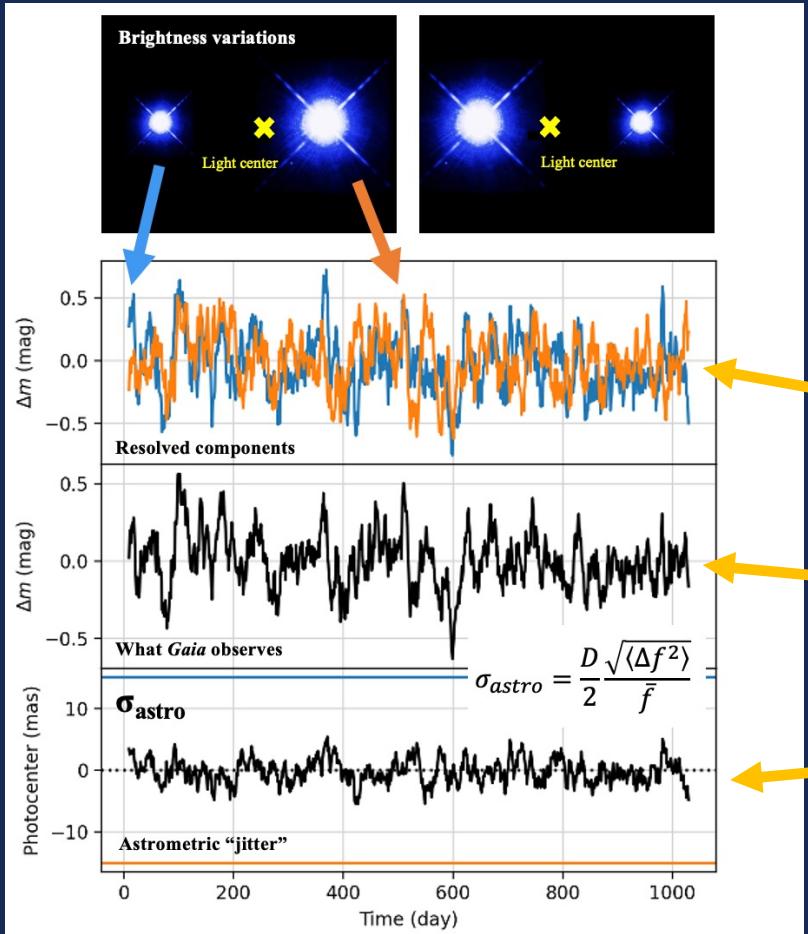


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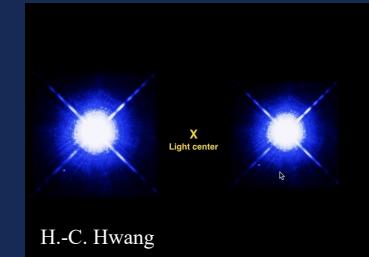
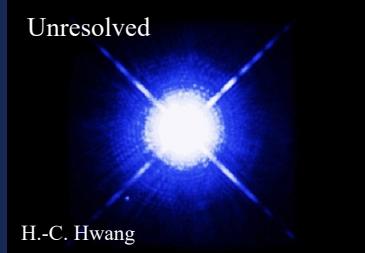
Instead, we see a joint-variability lightcurve,  
indistinguishable from a slightly variable single  
AGN

Variability + astrometry = varstrometry!

Hwang et al. 2019



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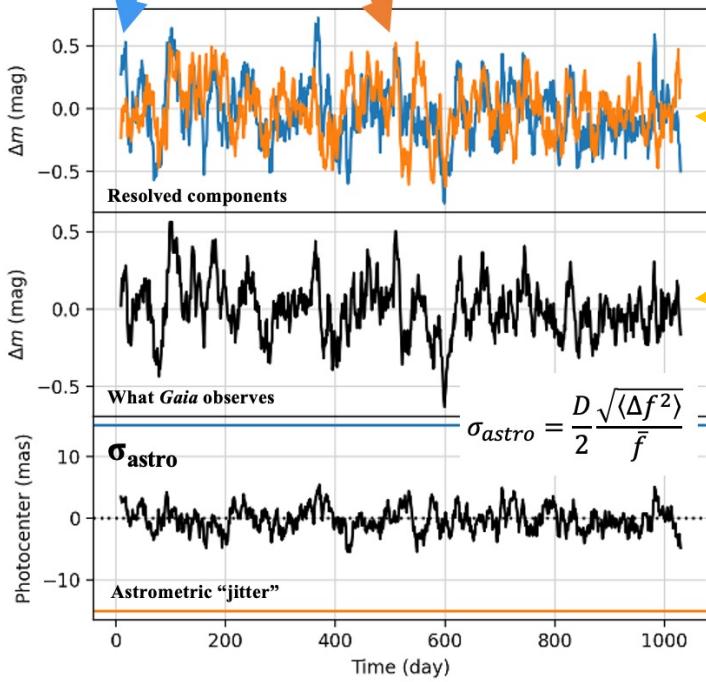
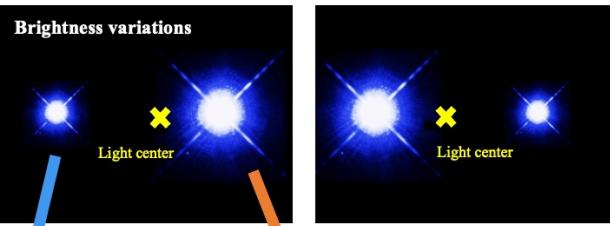
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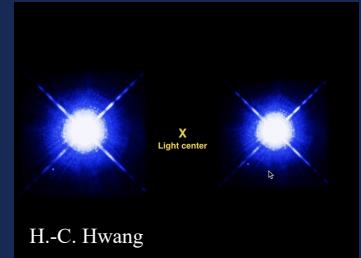
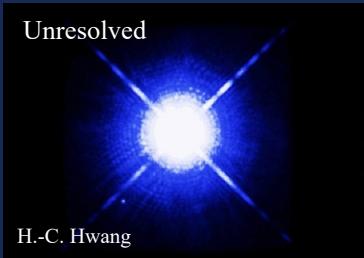
Shifting light center manifests in photometric  
data – excess “jitter”

Variability + astrometry = varstrometry!

Hwang et al. 2019



AGN pair, unresolvable with *Gaia*, light center appears to shift



If it was resolvable with *Gaia*, we might observe a lightcurve for both AGN

Instead, we see a joint-variability lightcurve, indistinguishable from a slightly variable single AGN

Shifting light center manifests in photometric data – excess “jitter”

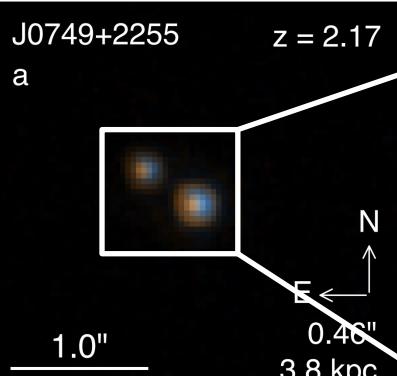
Lower limit on predicted separation, calculated from variability amplitude  $\sigma_{astro}$

Variability + astrometry = varstrometry!

Hwang et al. 2019

N. Secret - private communication

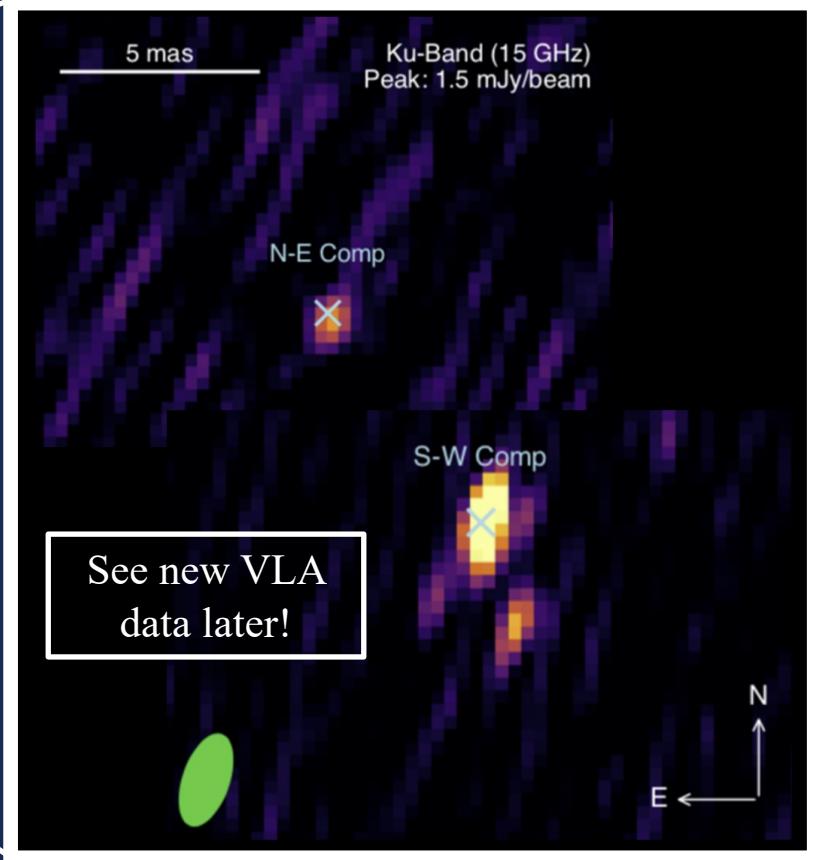
# Varstrometry



Chen et al. ApJ. 2021

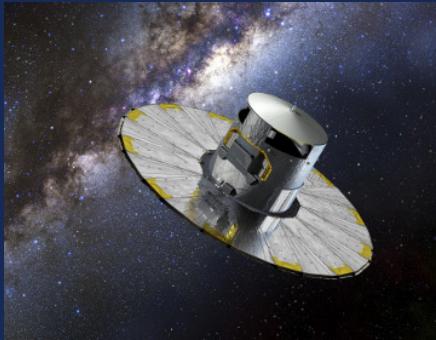
Varstrometry targets have been observed with HST – successful identification of AGN pair systems

Some further observed with VLBA



Adapted from Shen et al. *Nature*. 2021.

# Radio Varstrometry



ESO

+



NRAO

Our project:

Use VLA observations of astrometrically-variable quasars to place constraints on the drivers of astrometric variability.

**Can high resolution surveys like VLASS, combined with precise astrometry, discover a new population of AGN pair systems?**

Is the varstrometry method a possible systematic method for identifying AGN pair systems with radio observations?

# VLA Observations

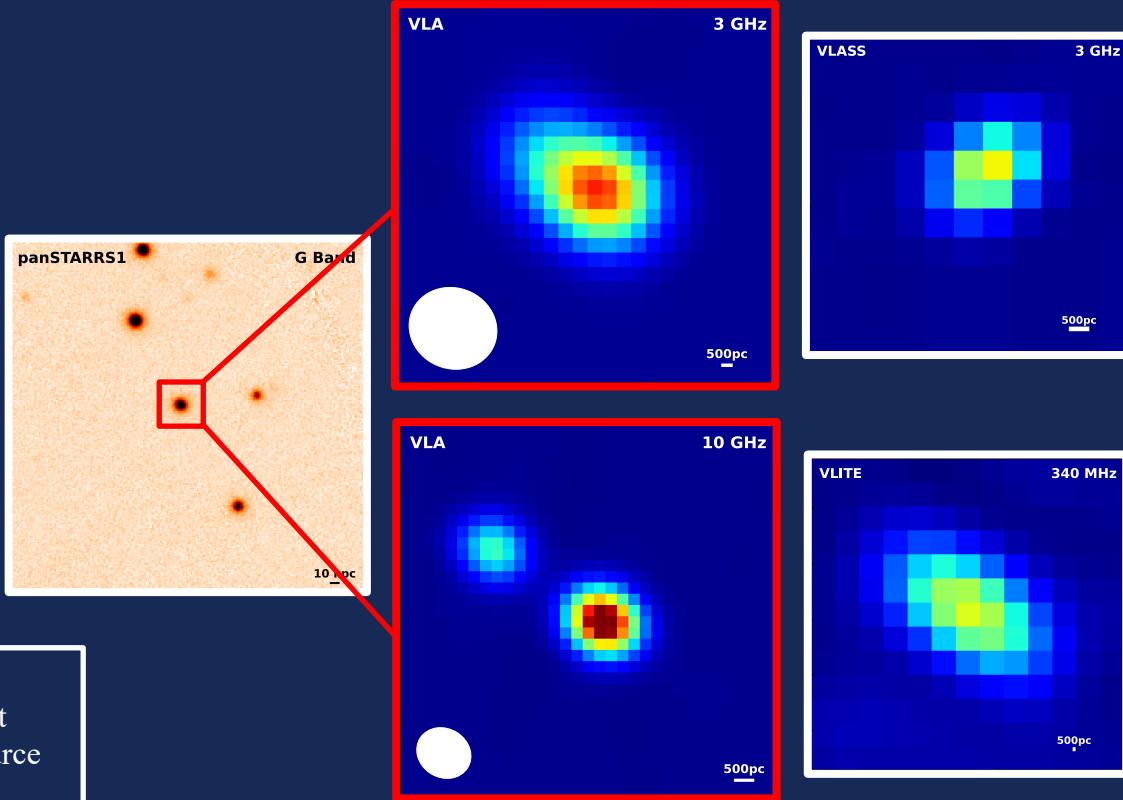
## Sample:

18 quasars (SDSS DRQ16), cross-matched  
with *Gaia* EDR3

- *astrometric\_excess\_noise\_sig* > 5
- $z > 0.5$
- *Gaia G* magnitude < 20
- radio survey catalog fluxes
  - VLASS, VLITE, etc.

## Observations:

VLA – A configuration  
S-band (2-4 GHz, 0.65", LAS 18")  
X-band (8-12 GHz, 0.2", LAS 5")



**Astrometric excess noise:** amount of statistical dispersion required such that *Gaia's* astrometric solution for the source leaves no unexplained variance.

Schwartzman et al. in prep

# Preliminary Results:

18  
targets

## Point-like

- Single AGNs
- Hidden small-scale structure?

## Extended/Jets

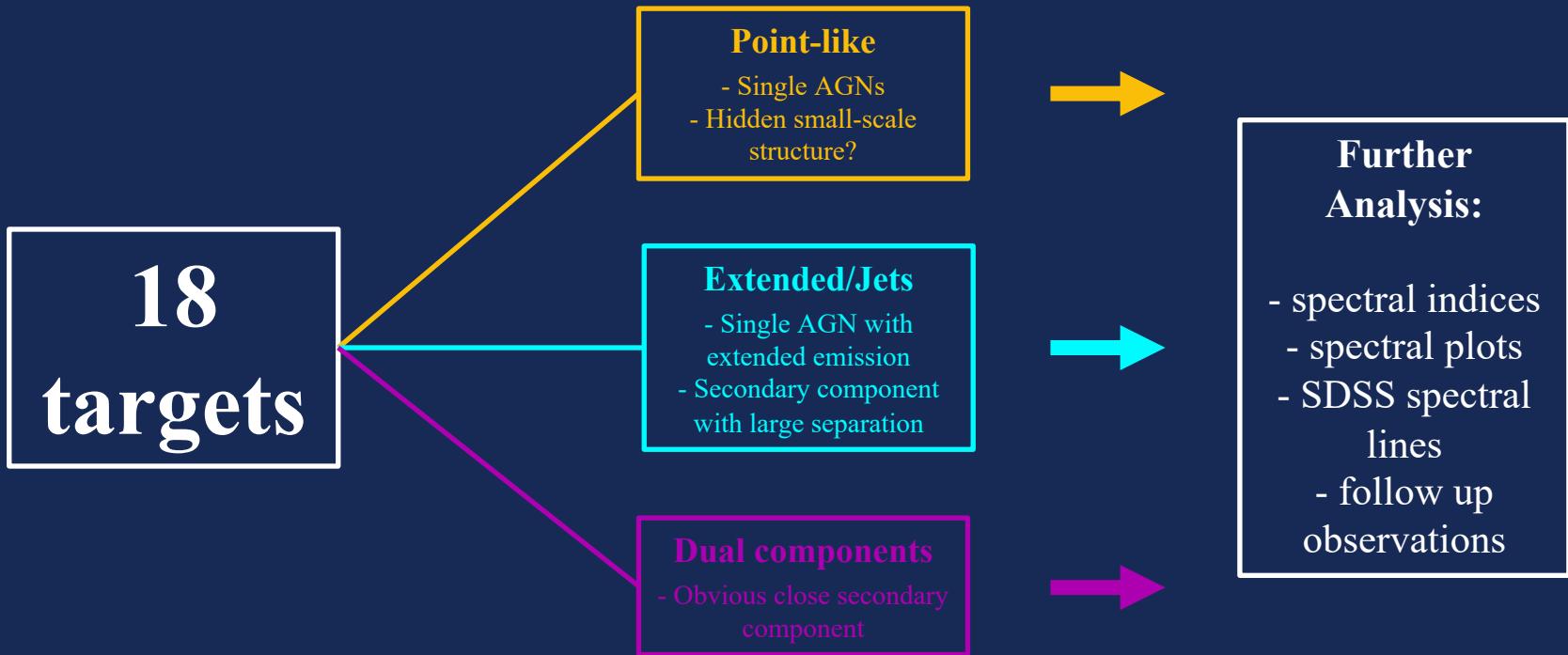
- Single AGN with extended emission
- Secondary component with large separation

## Dual components

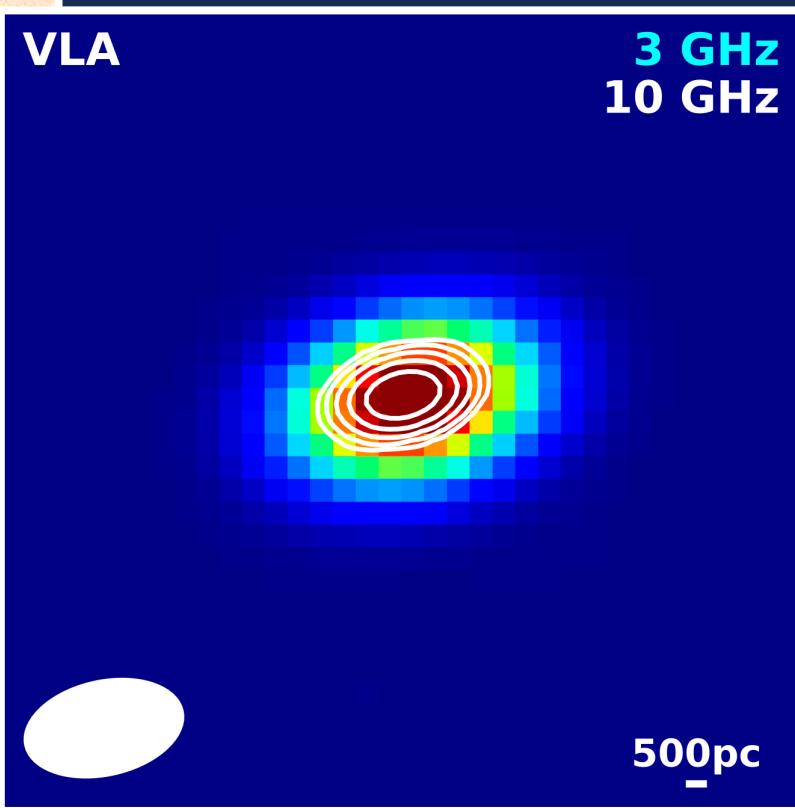
- Obvious close secondary component

# Preliminary Results:

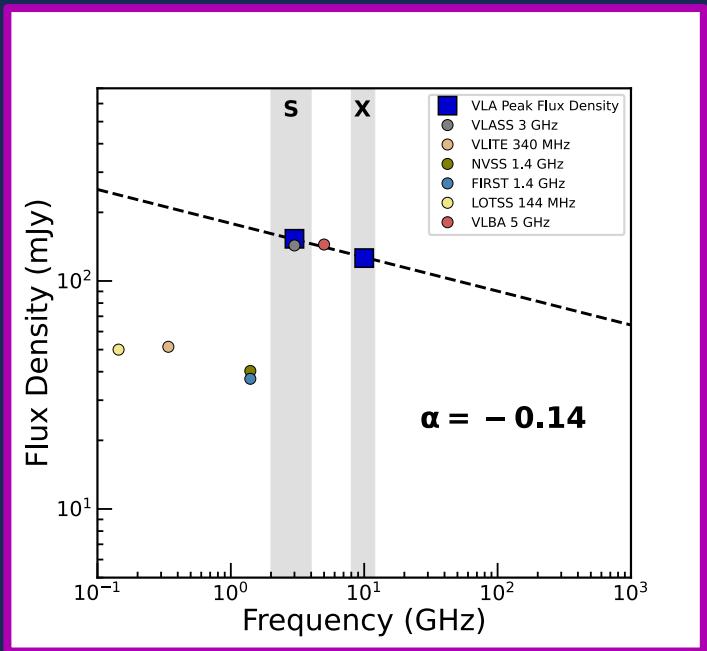
Morphology ≠  
Astrometric Driver!



# Point-like Candidate

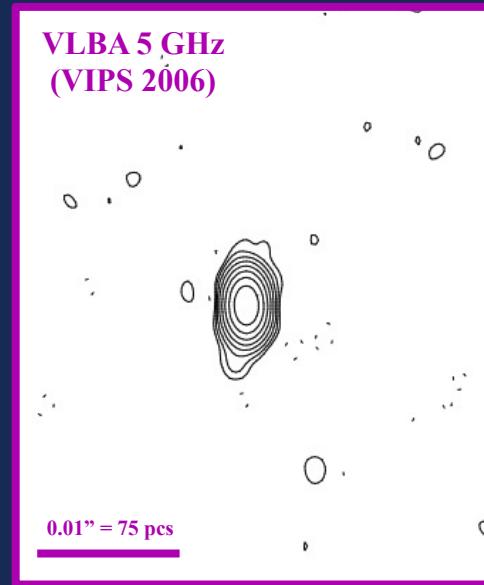
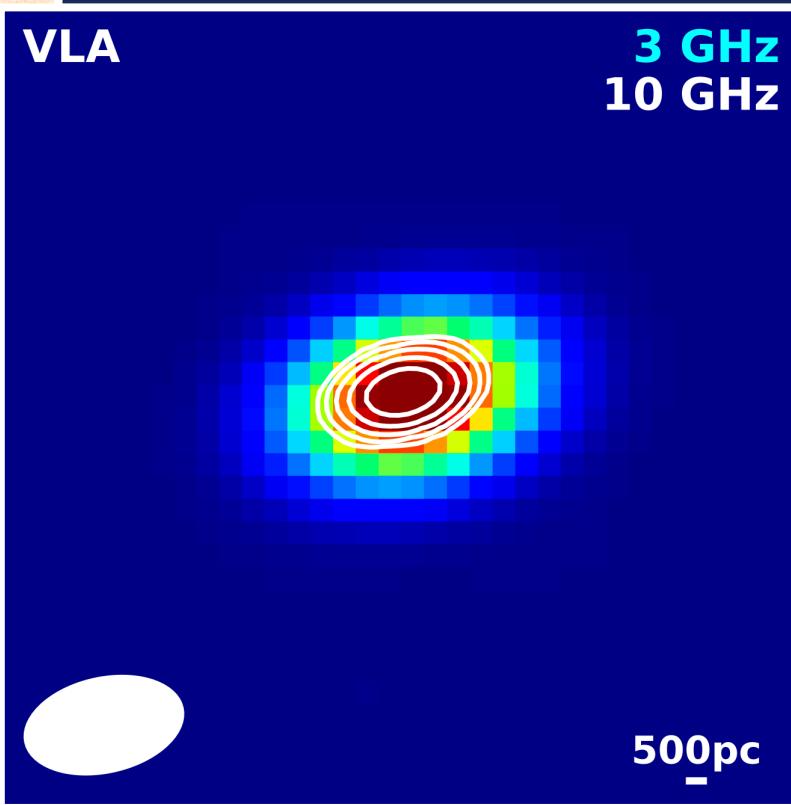


Schwartzman et al. in prep



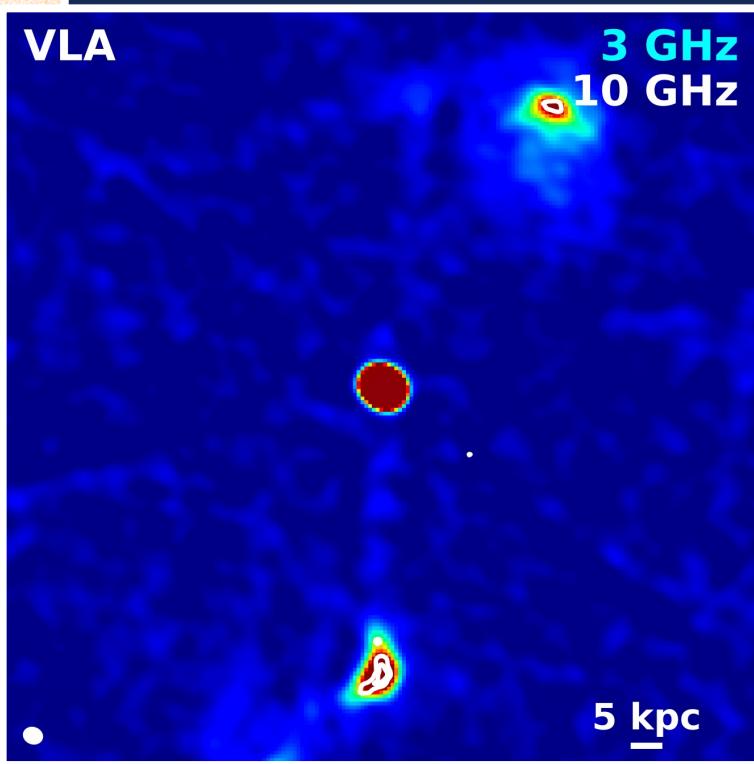
Point-like source at sub-arcsecond scales...

# Point-like Candidate

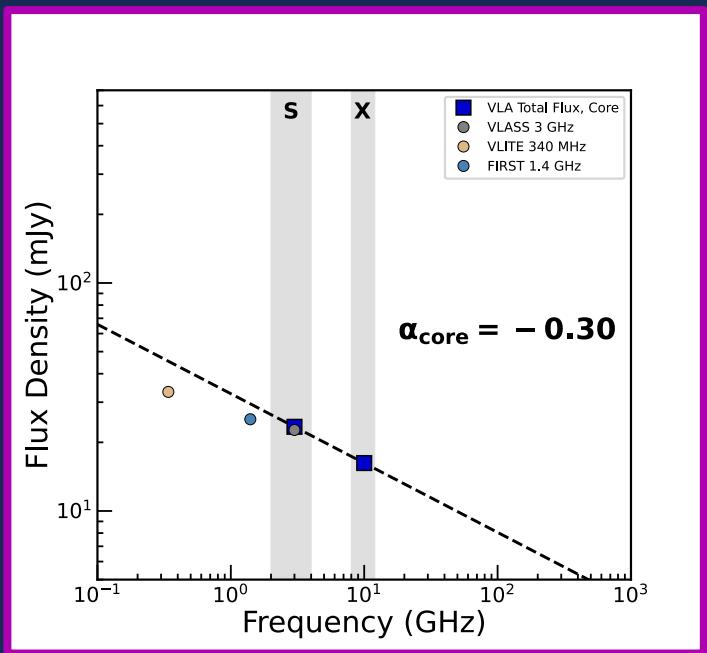


Point-like source at sub-arcsecond scales  
- Variability?  
- Smaller scales?

# Jetted Candidate

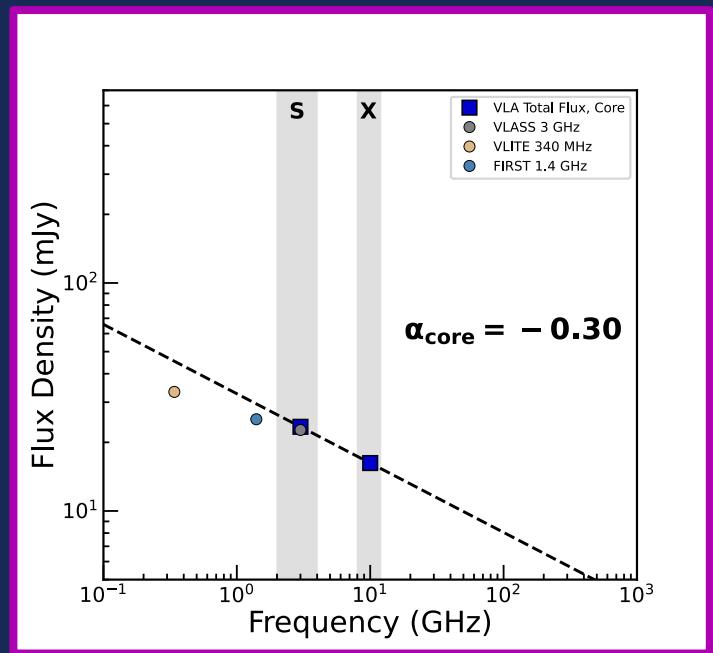
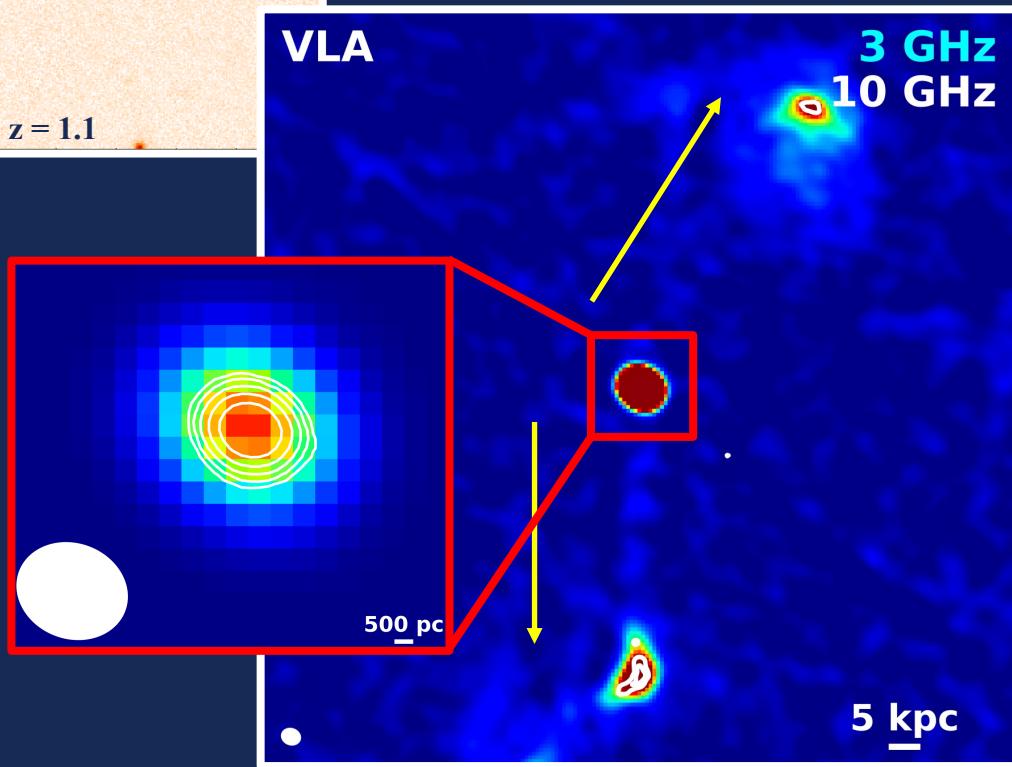


Schwartzman et al. in prep



Jets at arcsecond scales...

# Jetted Candidate



Jets at arcsecond scales...  
 - smaller scales?  
 - Jitter caused by jets or something else?

panSTARRS1

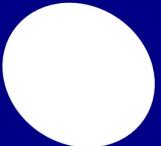
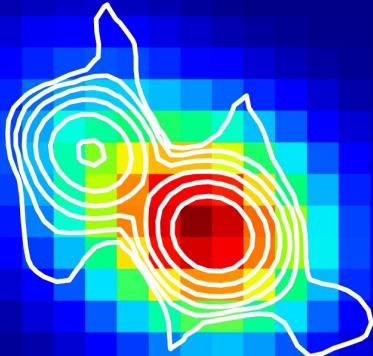
G Band

# J0749+2255

VLA

3 GHz  
10 GHz

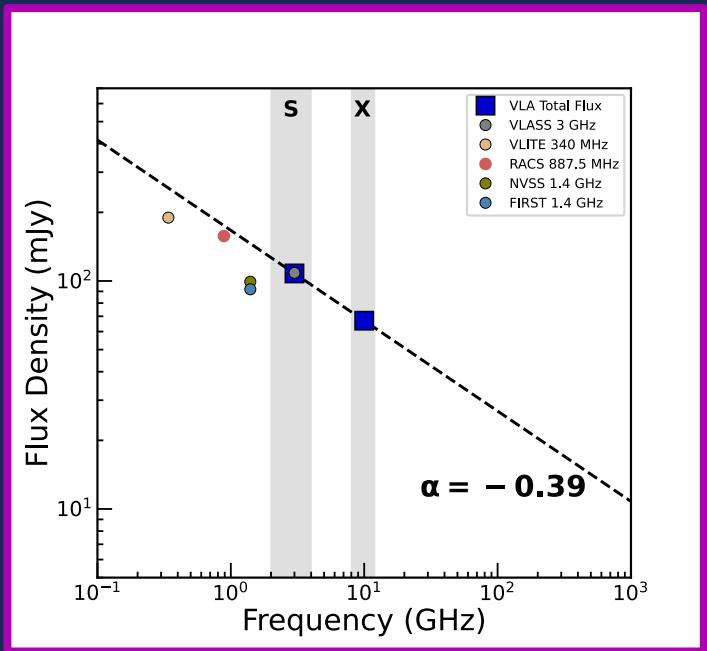
$z = 2.1$



Sep: 3.84 kpc

500pc

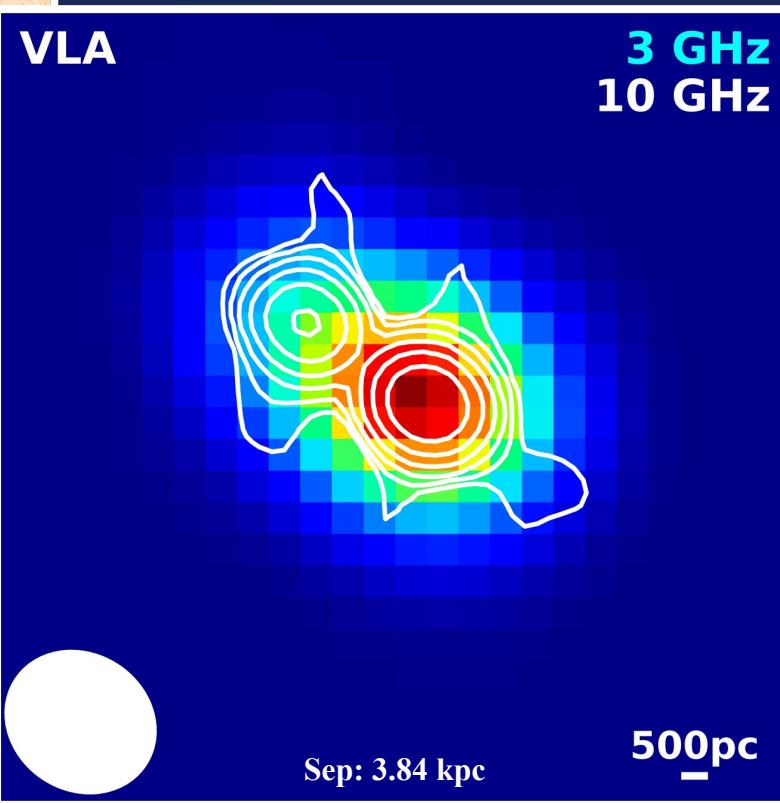
Schwartzman et al. in prep



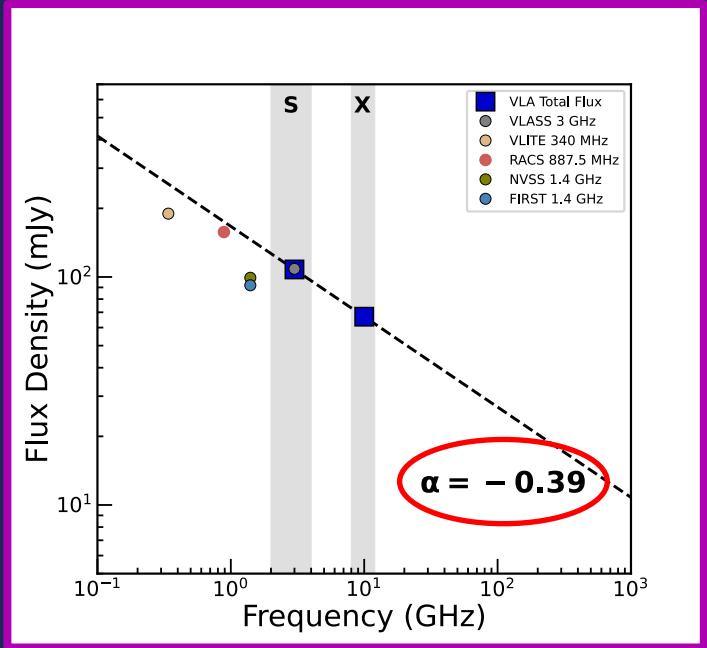
Dual-component source...

panSTARRS1 G Band

# J0749+2255



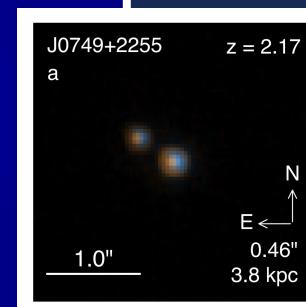
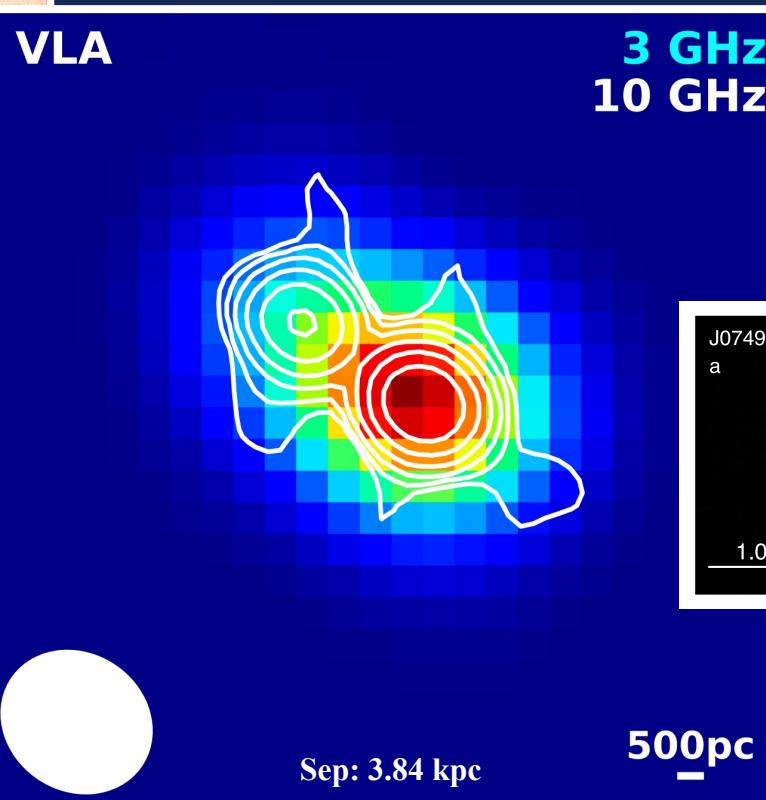
Schwartzman et al. in prep



**Dual-component source...**  
- Flat spectral index!

panSTARRS1 G Band

# J0749+2255



Dual-component source...

- Flat spectral index!
- HST observations – identical separations!

panSTARRS1

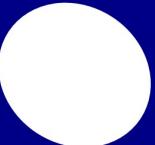
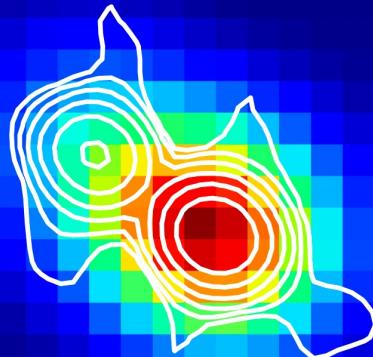
G Band

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VLA

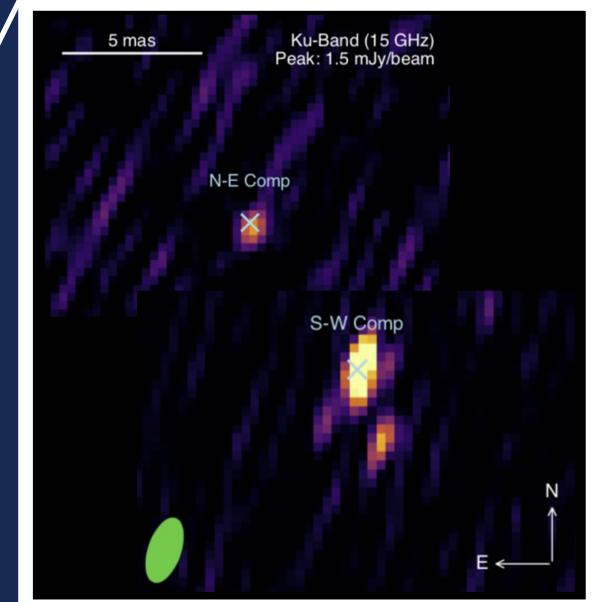
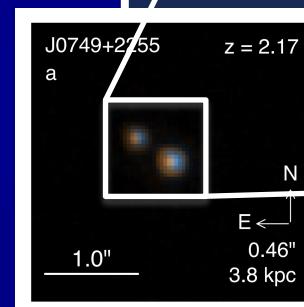
3 GHz  
10 GHz

$z = 2.1$



Sep: 3.84 kpc

500pc



Adapted from Shen et al. *Nature*, 2021.

Dual-component source...

- Flat spectral index!
- HST observations – identical separations!
- VLBA observations confirm result

Schwartzman et al. in prep

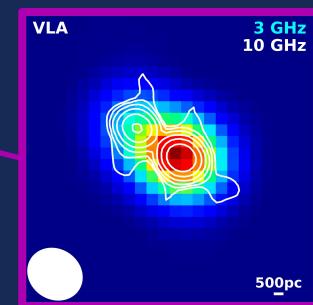
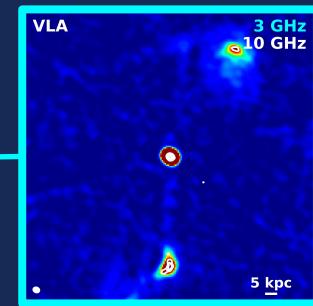
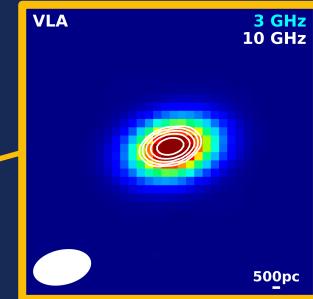
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targets

8 display  
point-like  
morphology

3 display  
jets/extended  
emission

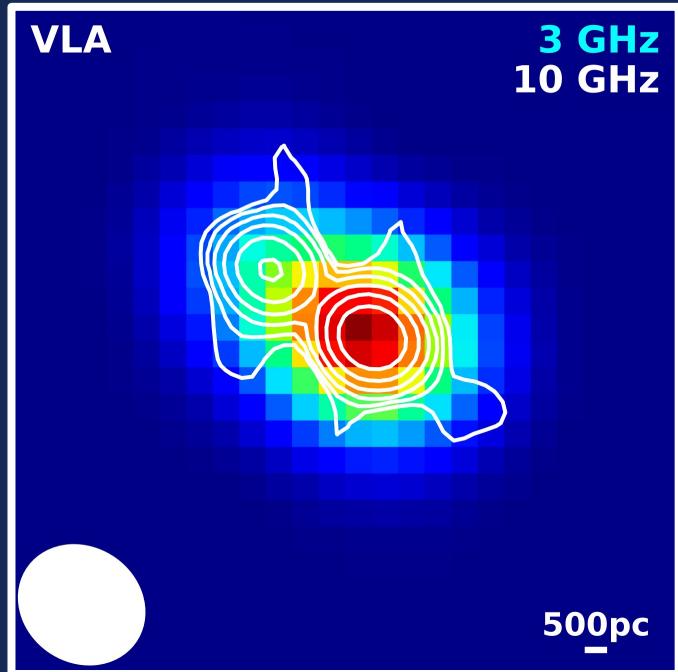
7 have dual-  
component  
signatures!



# Main Takeaways:

Varstrometry + multifrequency radio observations are a promising technique for systematic identification of AGN pair systems.

*Gaia* varstrometry + VLASS are an effective means of preselection of identifying new candidate AGN pair systems.



Questions?