National Research Foundation of Korea

Is PKS 1540−077 a Compact Symmetric Object or a SMBH Pair?

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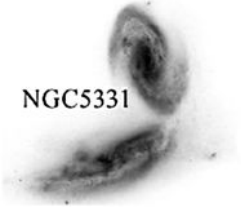
2025.10.29

Towards high-performance mm-VLBI science operations with multi-band receivers
Area della Ricerca CNR, 29 Oct 2025

Dual/Binary SMBHs can form during a major merger

Galaxy Merger



Dynamical friction drives massive objects to central positions

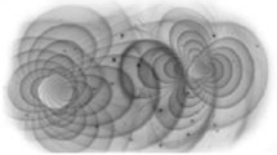
Stellar Core Merger

Dynamical friction less efficient as SMBHs form a binary.

Binary Formation

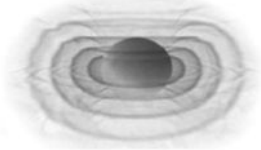
Stellar and gas interactions may dominate binary inspiral?

Continuous GWs



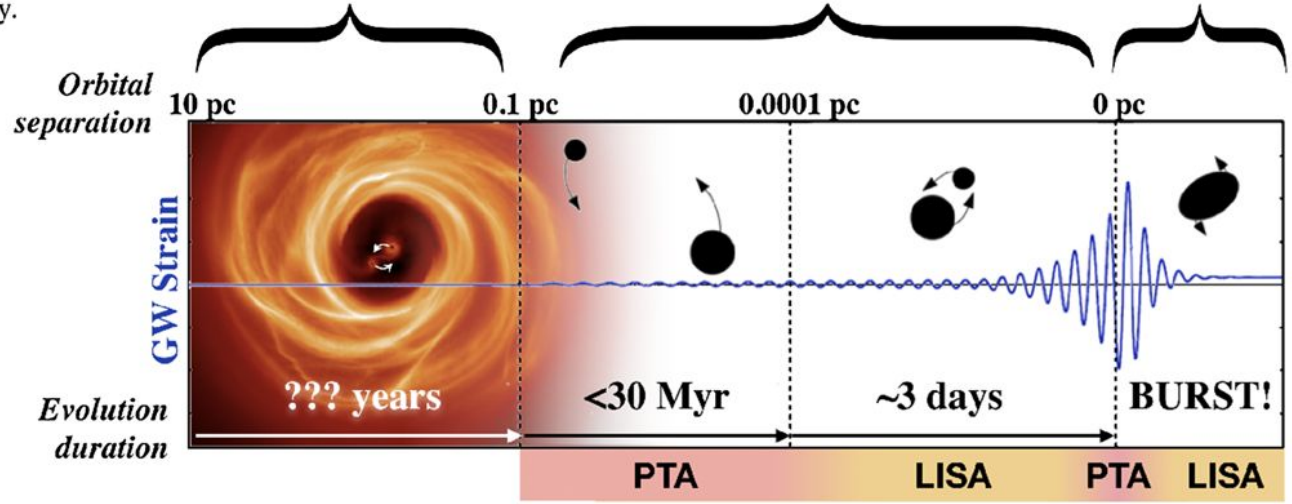
Gravitational radiation provides efficient inspiral. Circumbinary disk may track shrinking orbit.

Coalescence, Memory & Recoil



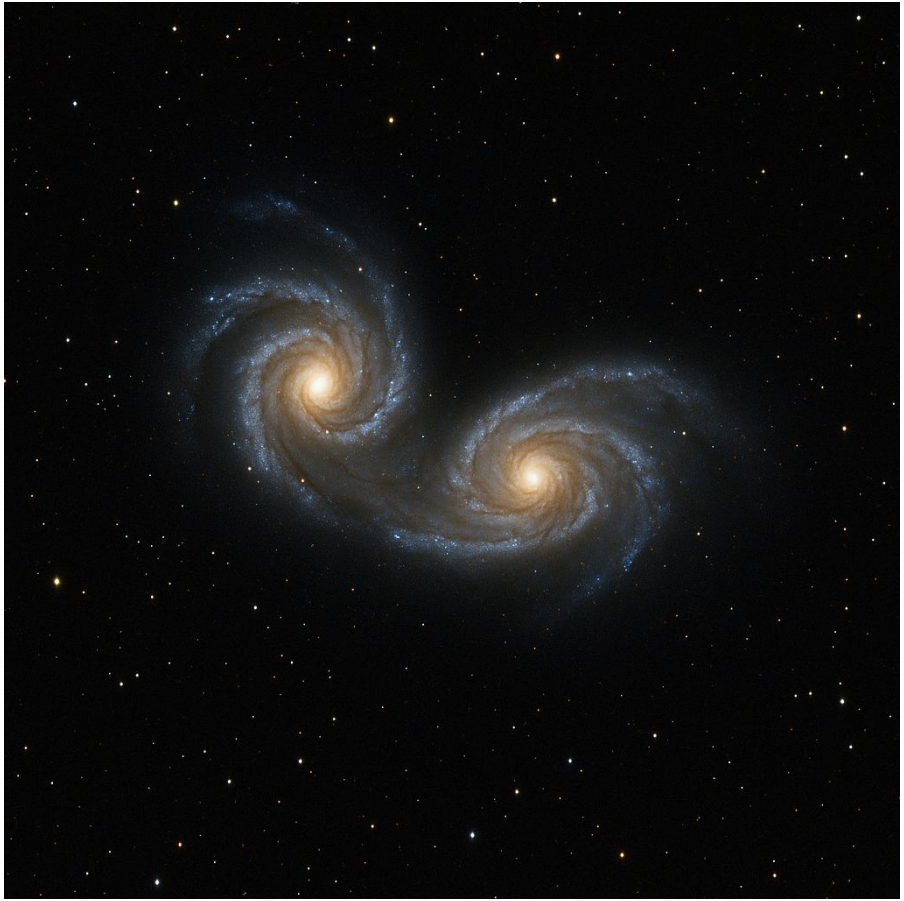
Post-coalescence system may experience gravitational recoil.

The Lifecycle of Binary Supermassive Black Holes



Sarah B. et al 2019

Mergers play an important role in dual SMBHs

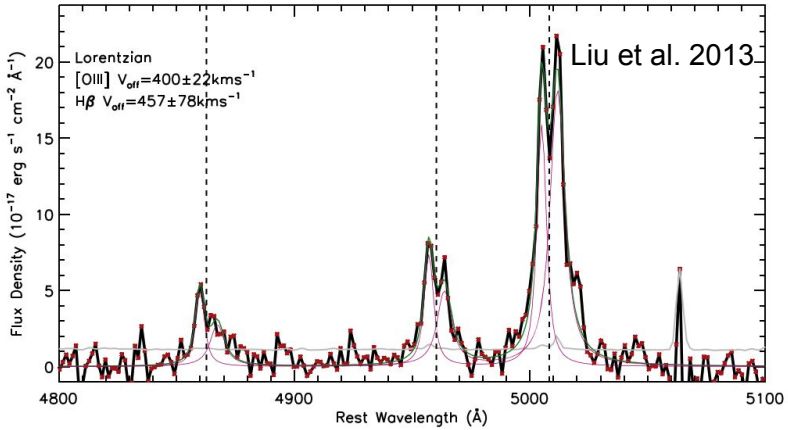


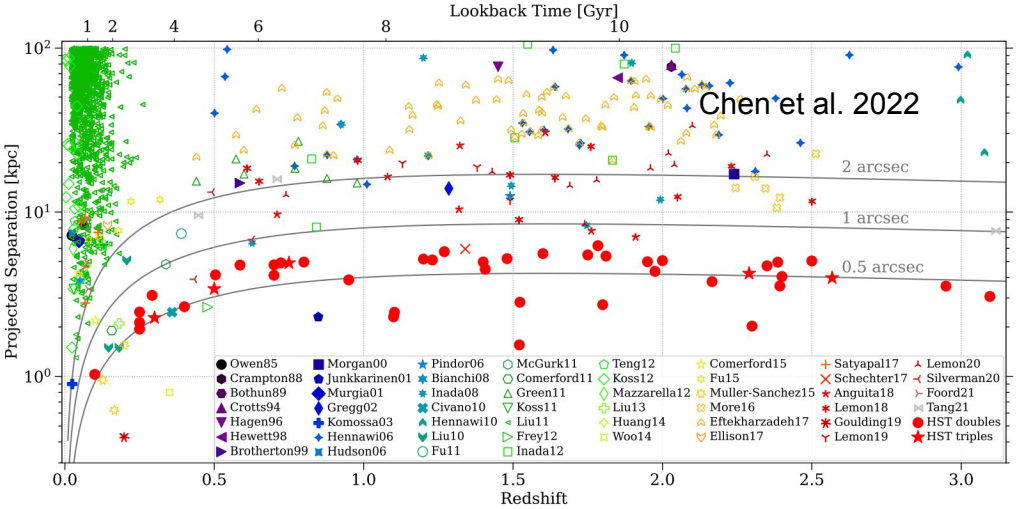
A dual SMBH system forms after the host galaxies merge, and the two SMBHs are expected to merge through dynamical processes over cosmic time.

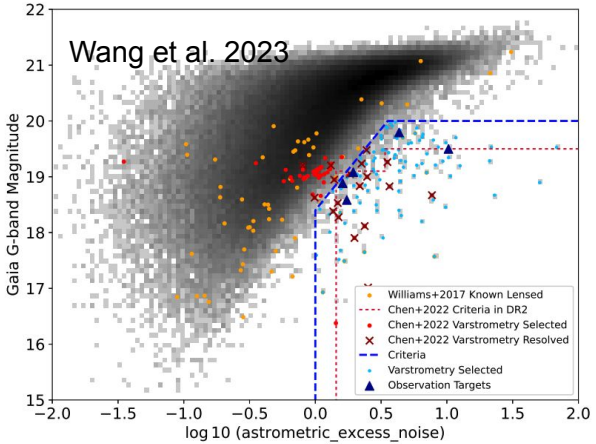
Dual SMBH:

- SMBH pair at a few - hundreds pc
- not yet gravitationally bound
- losing energy and decreasing separation via dynamical friction

Searching for the dual/binary SMBH candidates







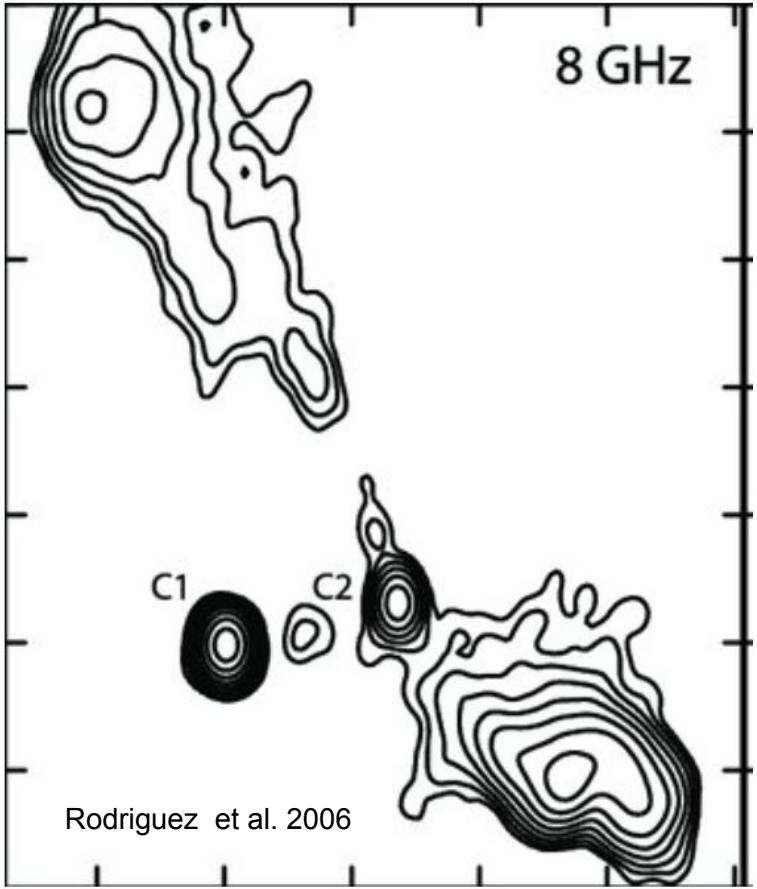
Double peaked emission lines

HST imaging

Varstrometry

…

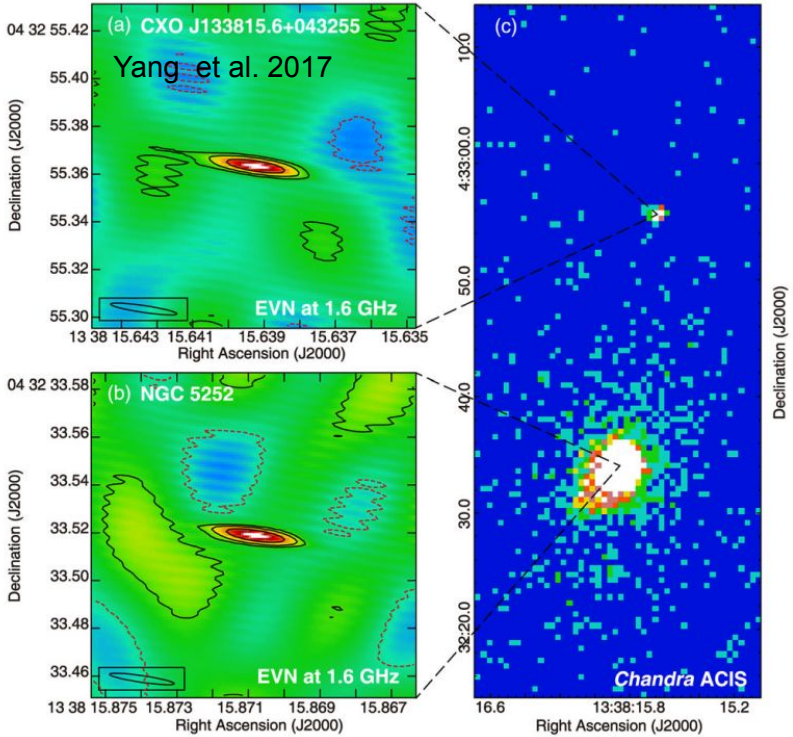
VLBI is the best way to confirm closely dual SMBHs

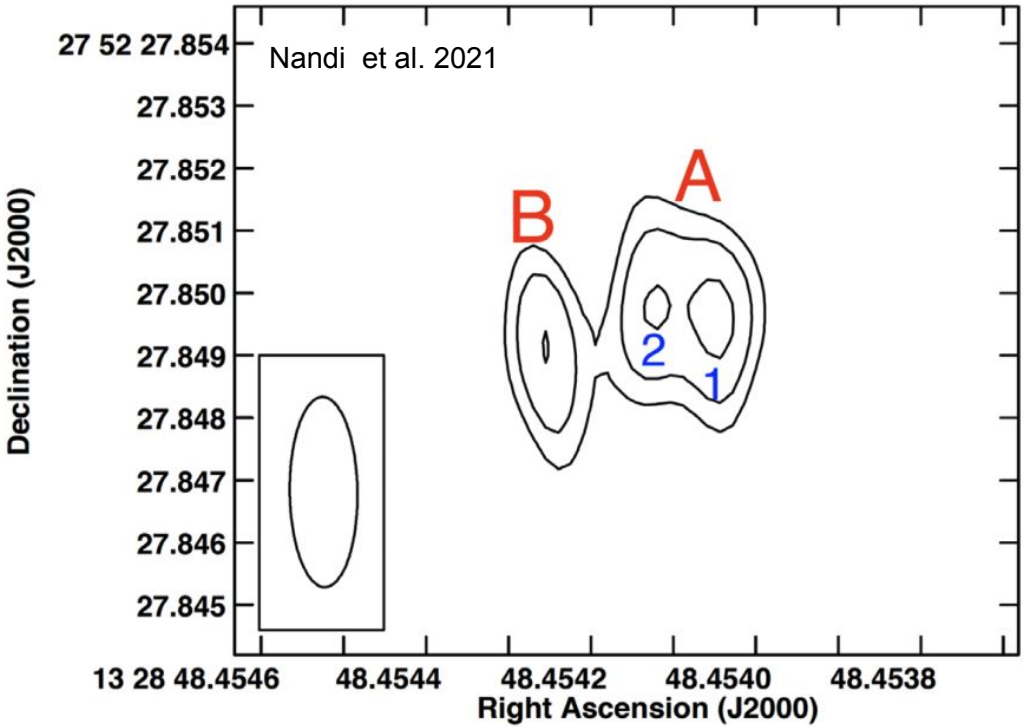


The typical mas-scale angular resolution achievable with VLBI networks allows directly resolve as small as ~1 pc in the local Universe and ~ 10 pc at any redshift.

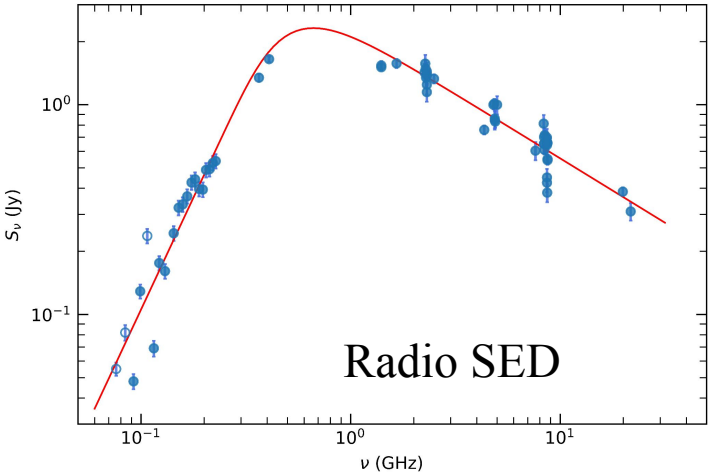
0402+379 at 8 GHz. Components C1 and C2 correspond to the two radio nuclei at projected separation of 7.3 pc

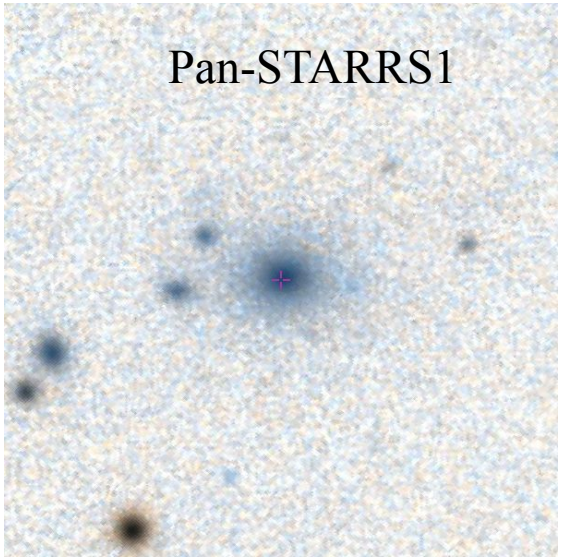
Only a handful of dual SMBHs are observed with VLBI

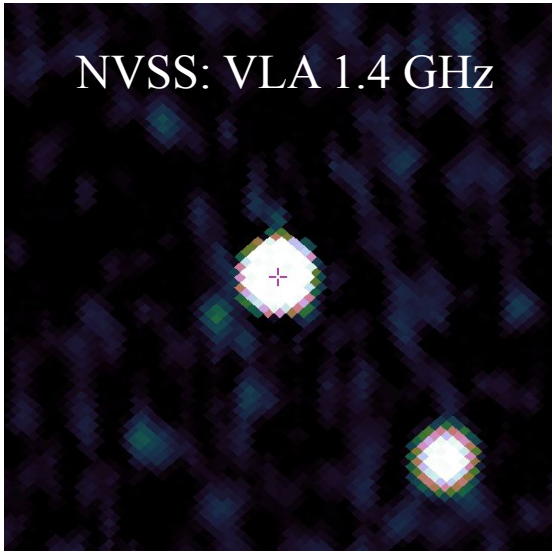




Why we selected GPS J1543-0757？





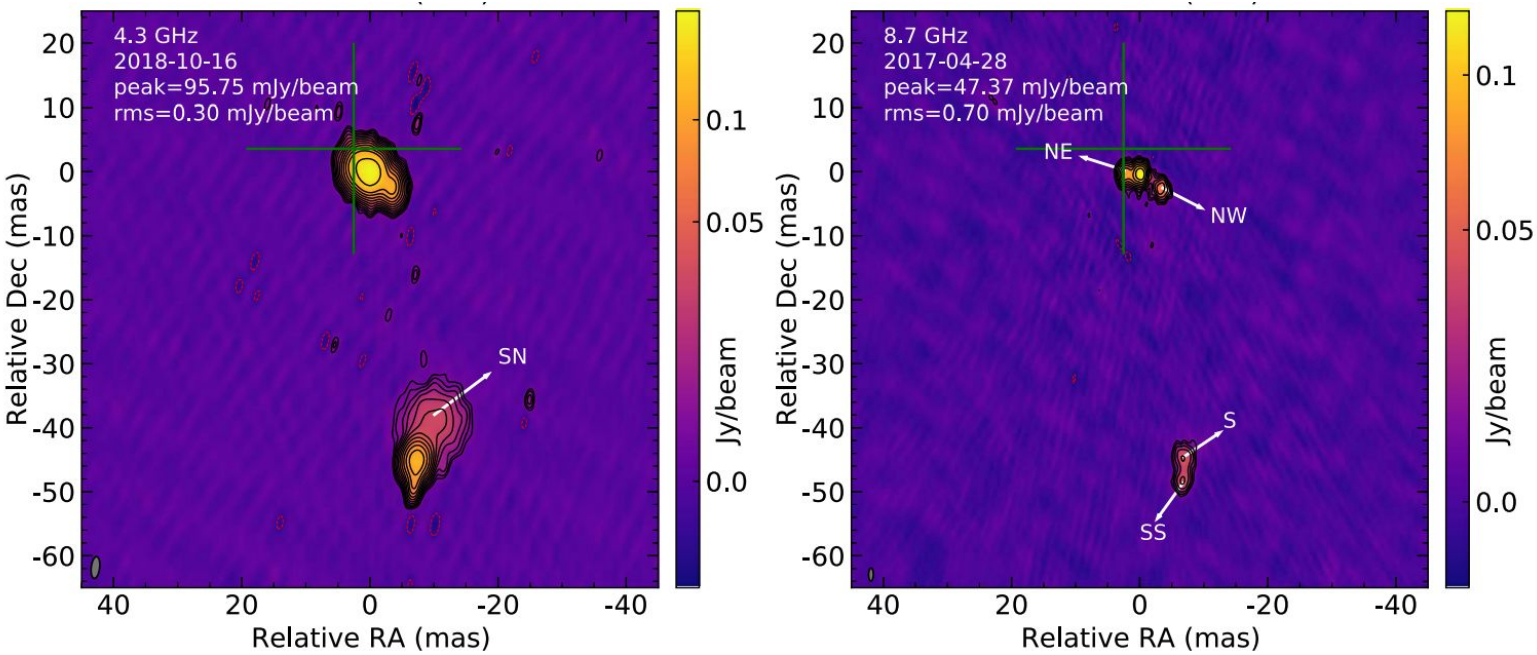


z = 0.172

Gaia and Pan-STARRS1 detected; G band: 21.575375

Excess noise: 60.874 mas

GPS J1543-0757: radio images



compact symmetric object (CSO) ?

gravitational lensing (~ 46 mas) ?

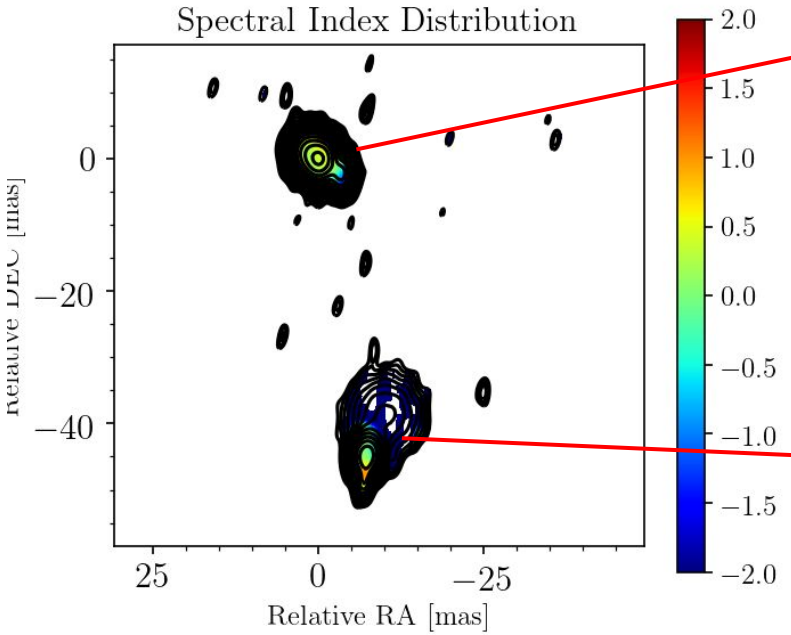
A new dual SMBH system (~ 130 pc) ?

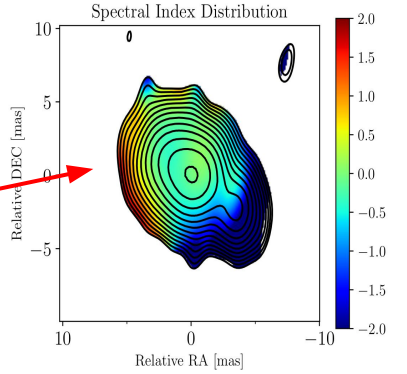
GPS J1543-0757: no CSO!

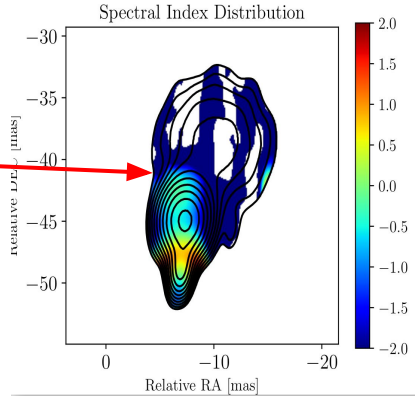
For the north component
N: $\alpha = -0.24 \pm 0.15$

For the south component
S: $\alpha = -0.16 \pm 0.20$

Both components show compact radio core and two-sided jet structure.





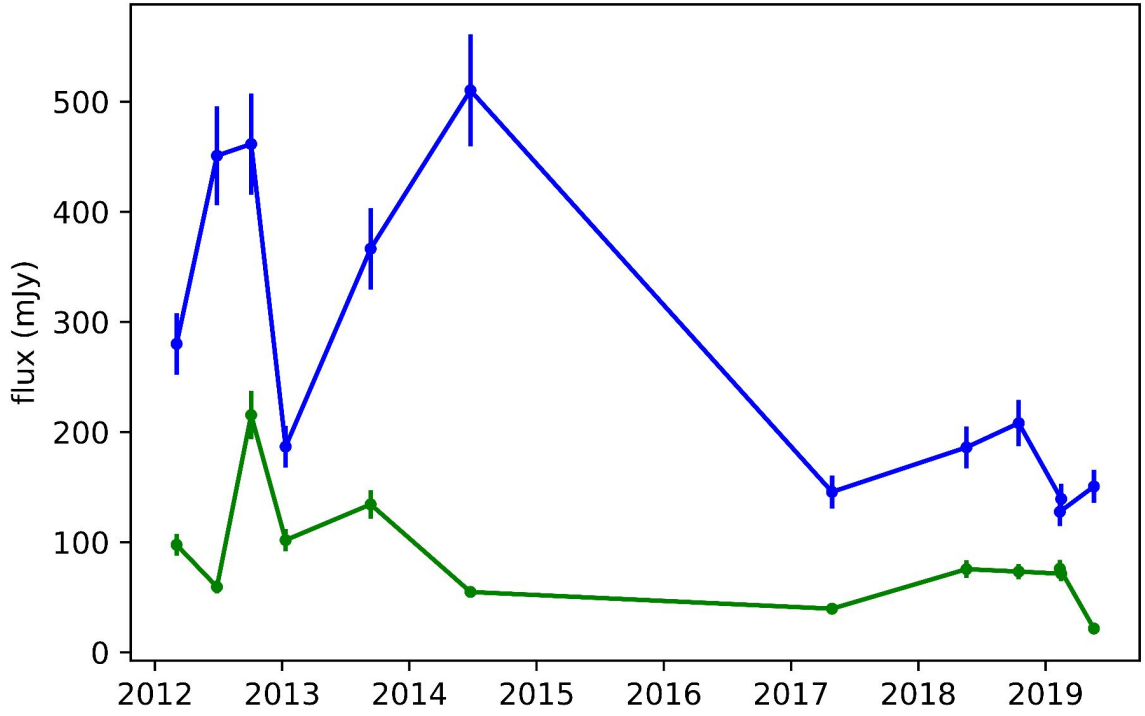


GPS J1543-0757: maybe not gravitational lensing source

Typical several min - several days for time delay

There was no cross-correlation between components N and S in the light curve data.

E-KVN (4 stations) dense observations will be helpful to test this possibility.



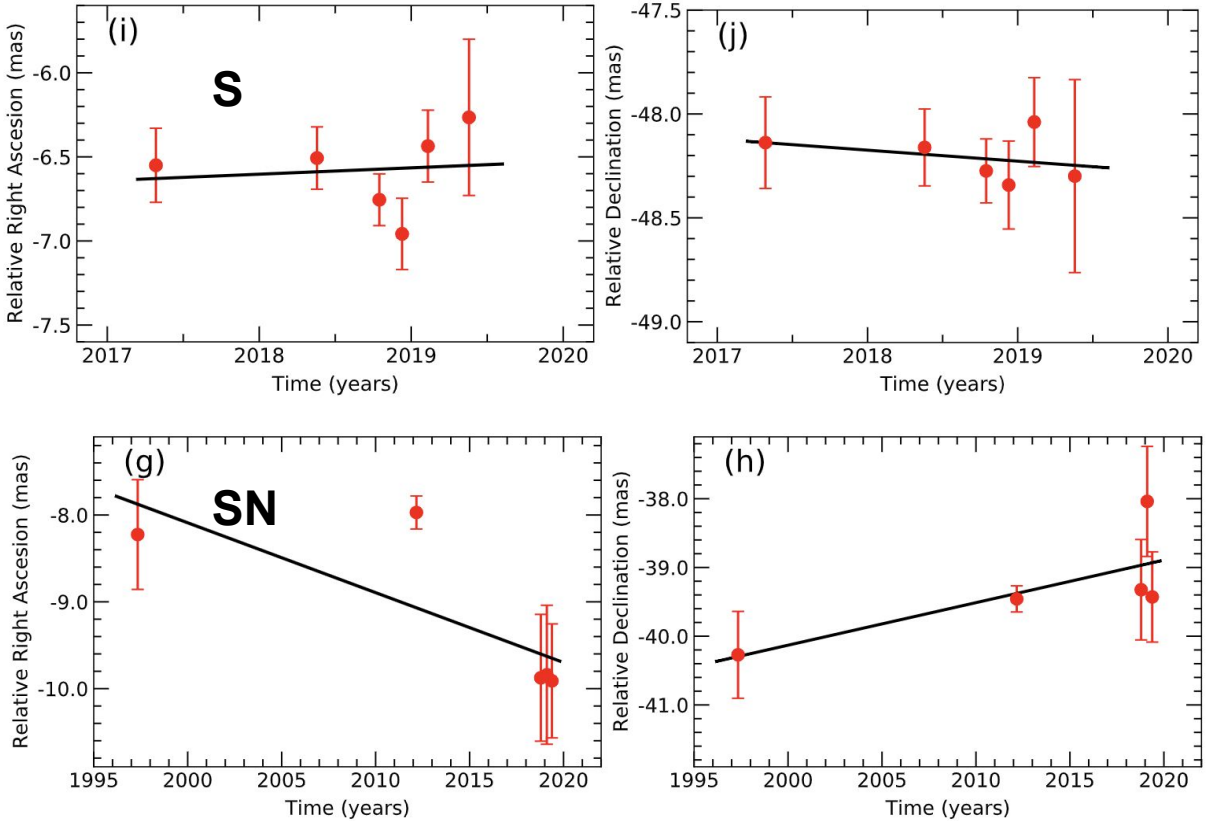
GPS J1543-0757: a new dual SMBH system?

No significant proper motion between N and S

< 0.010±0.006 mas/yr (0.09c)

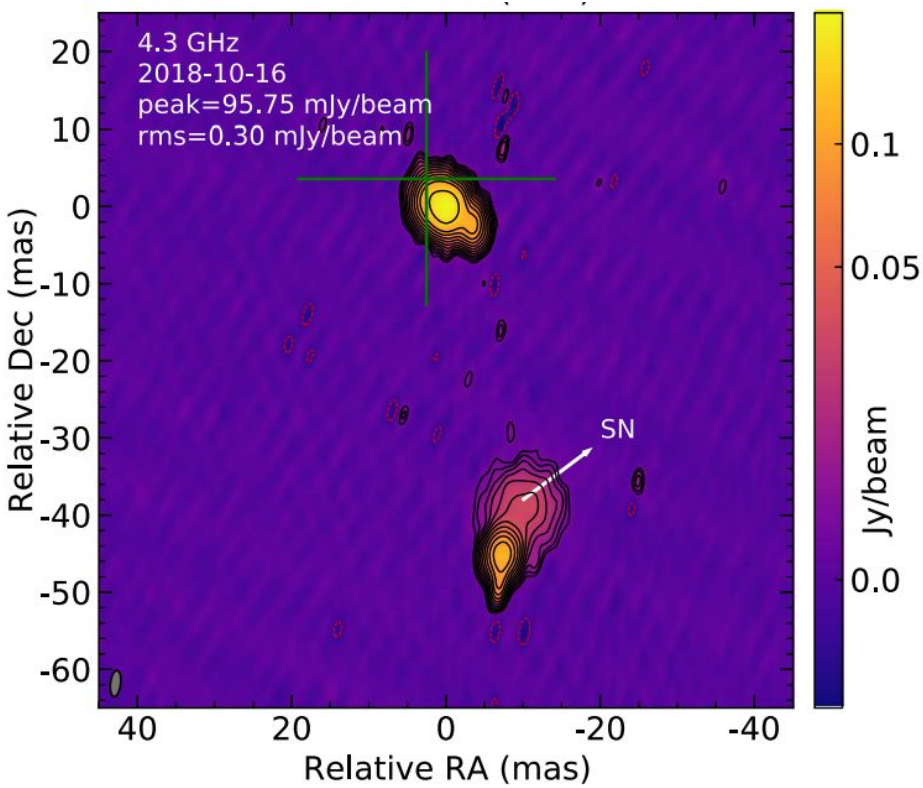
moderate relativistic speeds for the 4 jet components

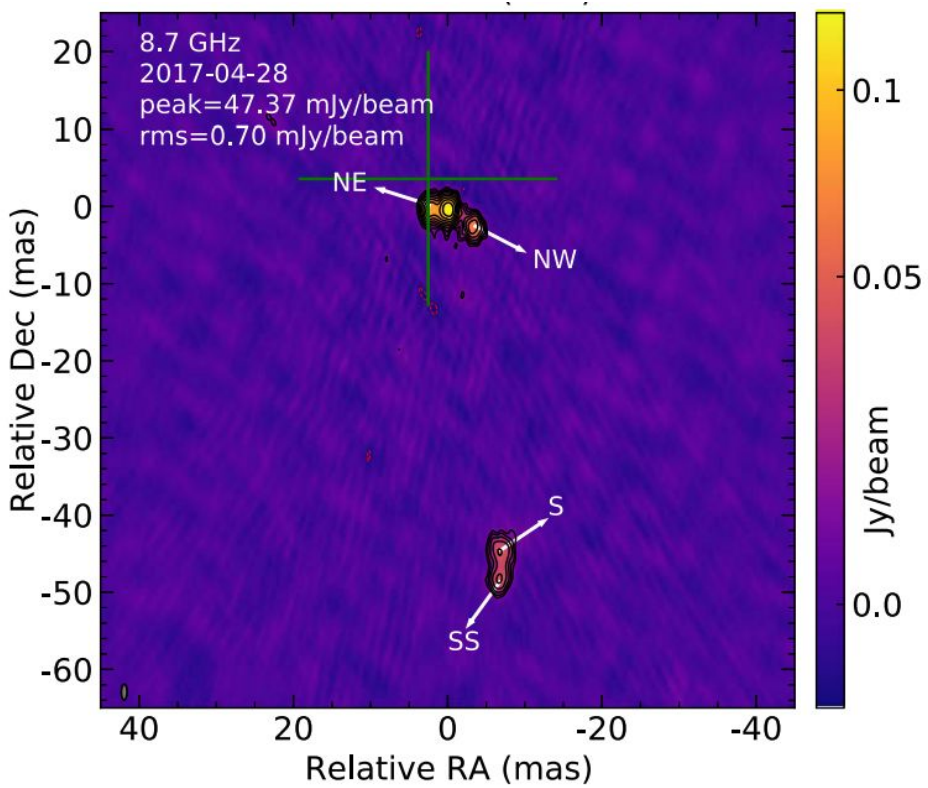
Ranging 0.161c to 0.954c



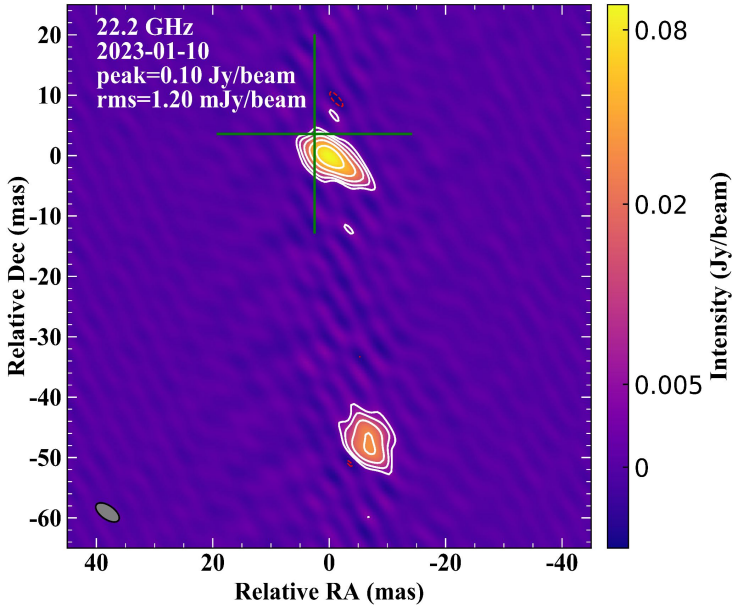
Cheng & Sohn, 2024, ApJ, 974, 155C

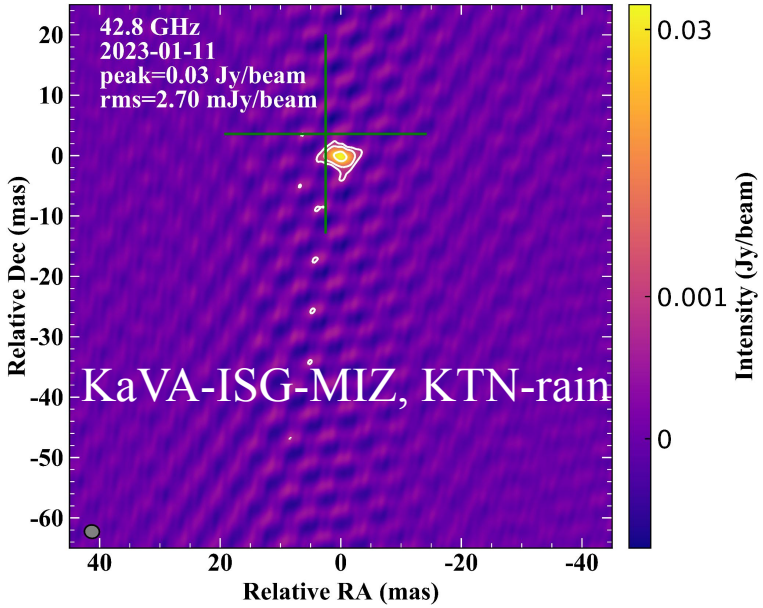
GPS J1543-0757: a new dual SMBH system?





GPS J1543-0757: New K and Q bands EAVN results





The northern component exhibits a slightly steep (-0.5) spectrum, while the southern component was not detected at 43 GHz (rms = 2.7 mJy) and is inferred to have a flat spectrum based on its 43 GHz upper limit.

Cheng & Sohn, 2025, in prep.

New EAVN observations this year

The observations were conducted on 20th and 21st Feb!

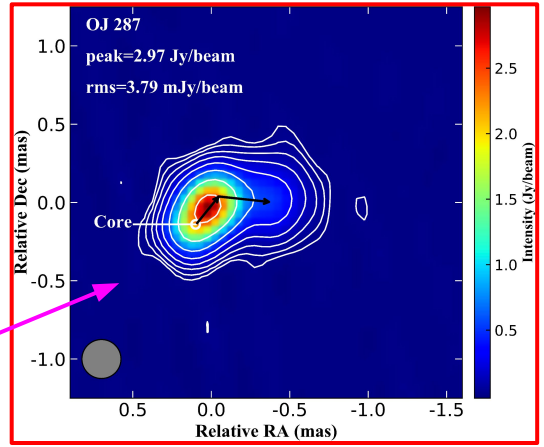
Unfortunately, the K-band observation was affected by poor weather conditions at KUS, data leading to the failure of all VERA stations (Failed to start automatically). In addition, Tianma had to cancel its participation due to a last-minute commitment to a space observation mission. As a result, the K-band data cannot be used.

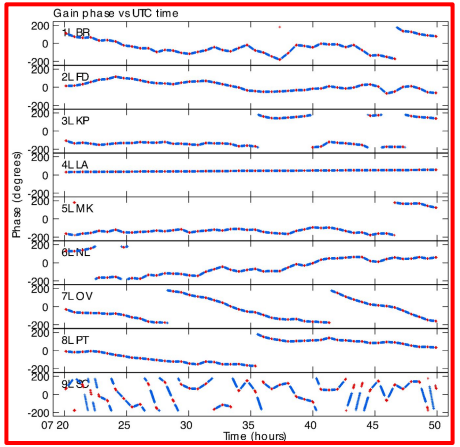
We sincerely appreciate the EAVN observing team for their coordination efforts. A recovery observation at K band is scheduled for November 21.

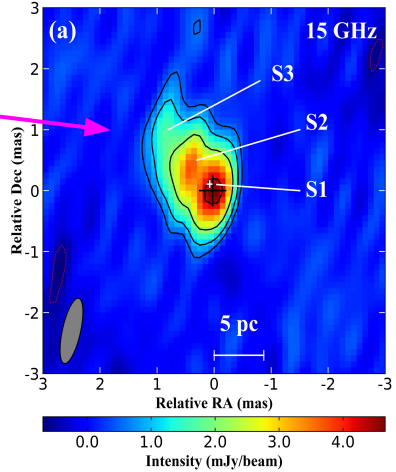
FPT can be better choose for not only simultaneous observations but also increasing the detection at Q band, maybe even W band!

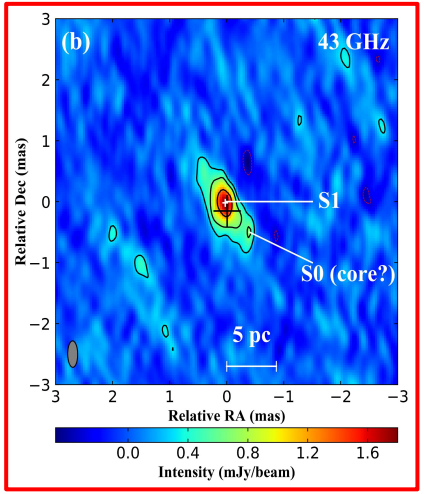
Discovery of a compact, stable, and 7-arcmin-apart reference source for Binary SMBH candidate OJ287

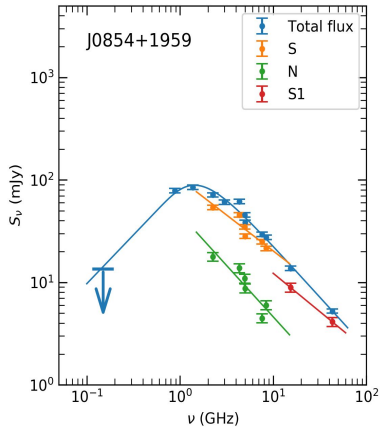
Collaborators: Jun Yang, Guang-Yao Zhao, Bong Won Sohn, Taehyun Jung











Cheng et al. 2023, ApJL

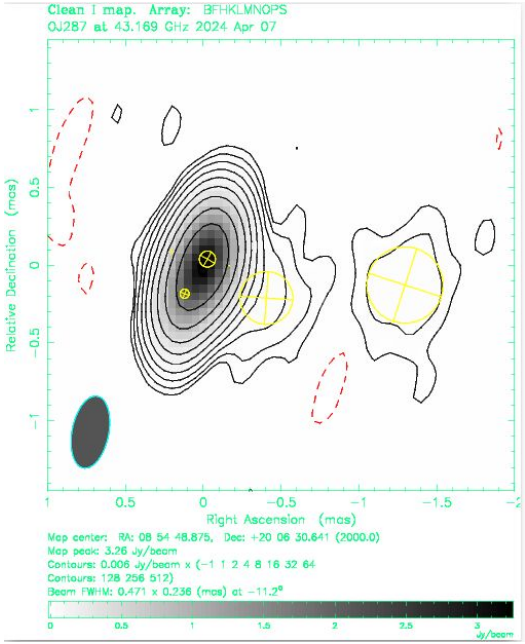
Monitoring its innermost wobbling jet

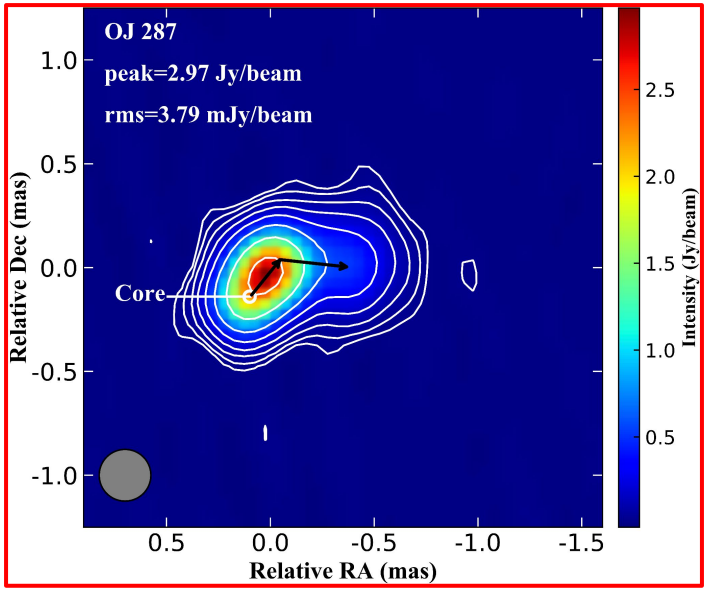
12 epochs are observed and correlated.

We have a 1.5 year period data.

Stay tuned …

A core shift proposal was submitted in August





Cheng X., Yang J., et al. 2026, in prep.

Thank you!