Searching for supermassive binary signatures in large-scale radio jets

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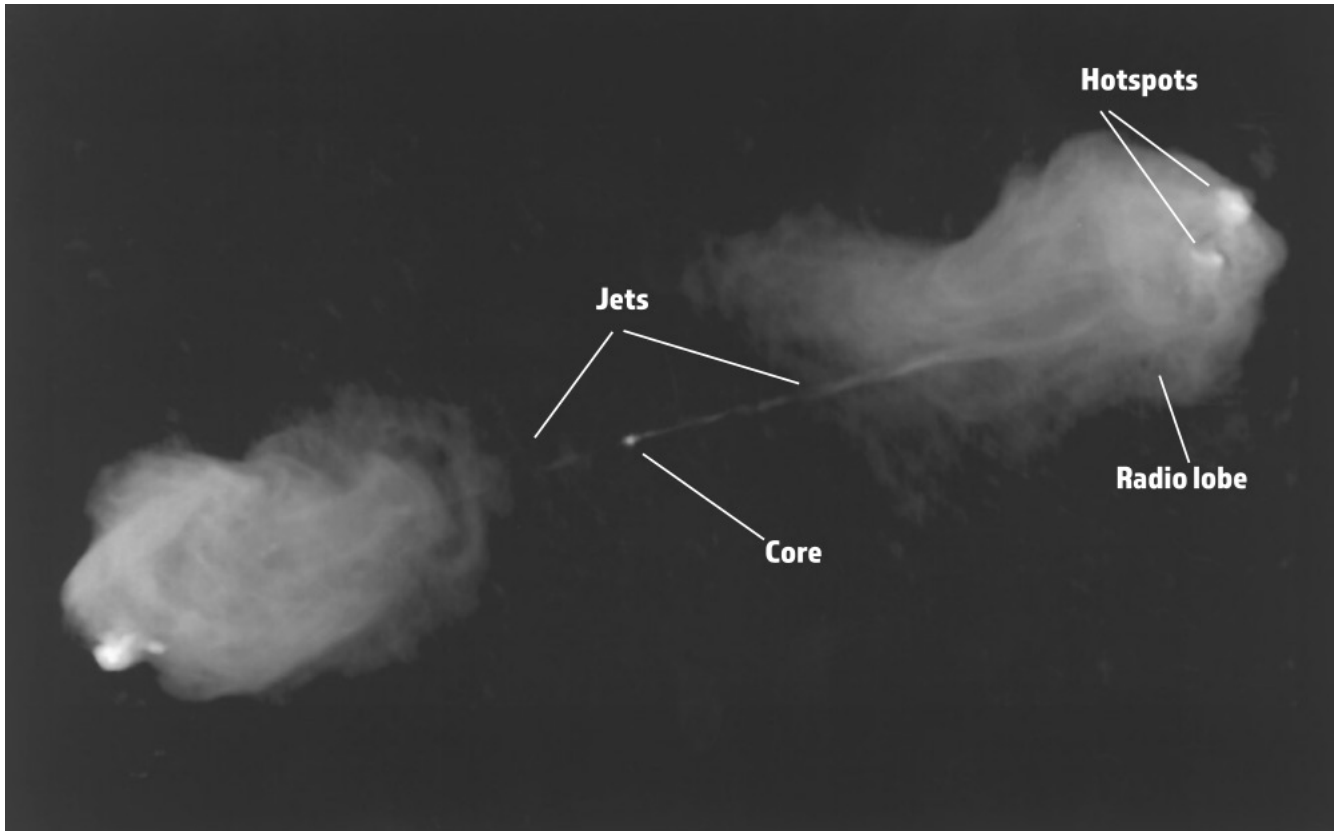
Structure of a large-scale jet

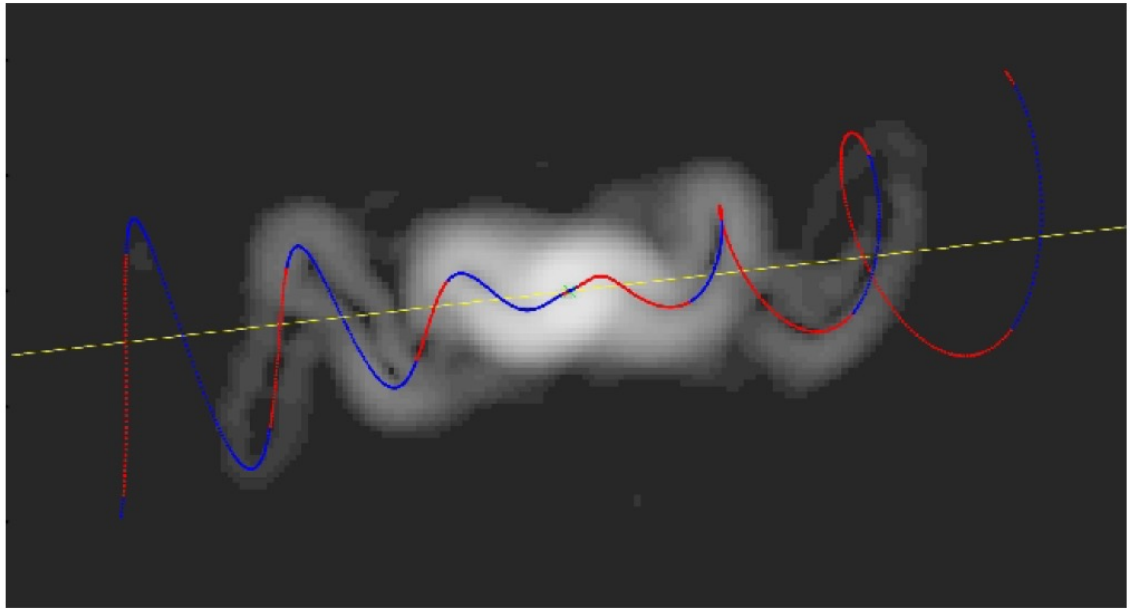
- Can extend many hundreds of kiloparsecs away from host galaxy
- Powered by ’central engine’ of supermassive black hole
- Complex structure can reveal host galaxy properties and local environment and even merger history

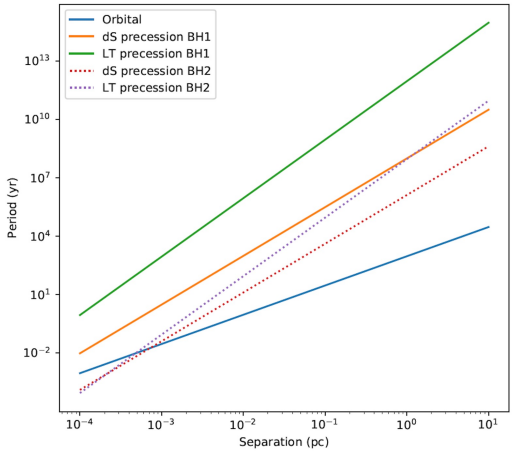


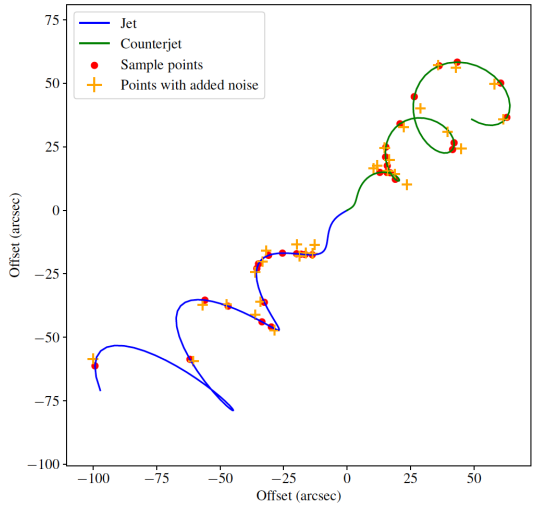
Cygnus A, adapted from Carilli & Barthel (1996)

The case for jet precession

- Well-studied jet precession in stellar-mass objects e.g. SS 433
- Expected consequence of galaxy mergers when conditions are right for binary stalling
- Periodic wobbles in jet path long associated with precession
- Precession **does not** have to come from binary sources – can be caused by e.g. accretion disks







Binary constraints from jet path

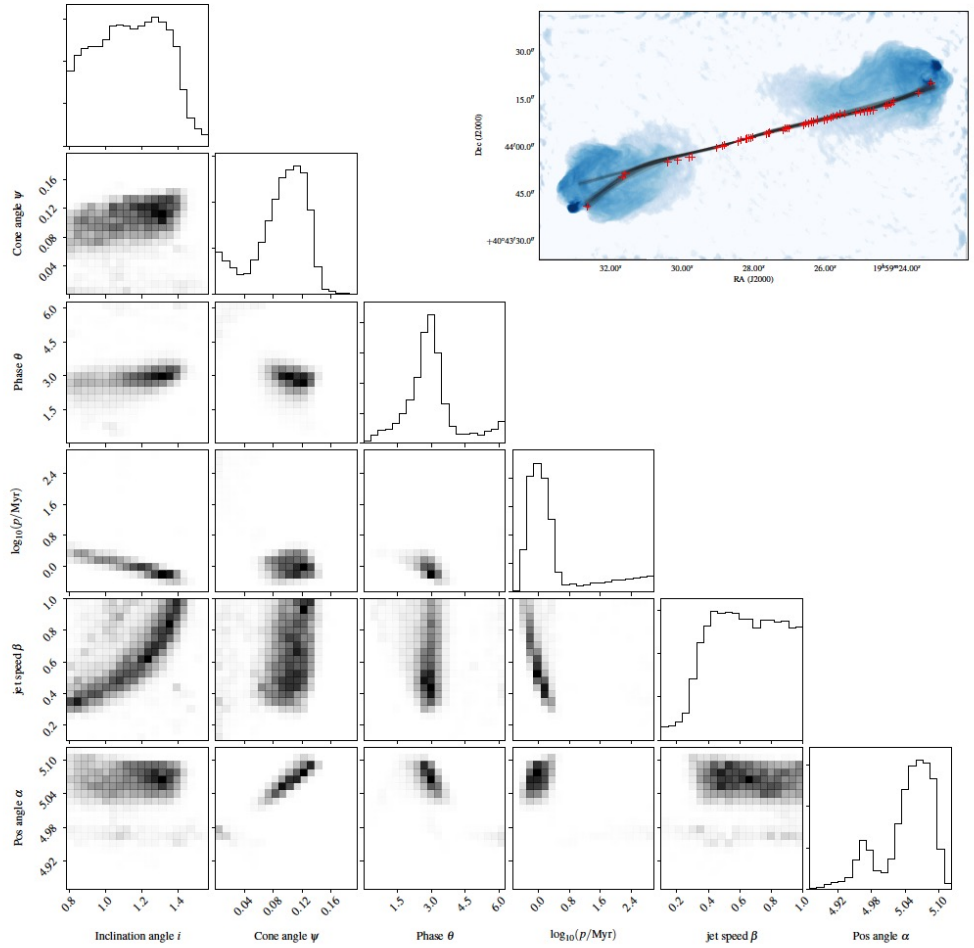


FIGURE 2.6: Main: 'Corner plot' of one-dimensional and two-dimensional marginalized posterior probability distributions for the model parameters given the observed jet path of Cygnus A, including all identified jet points up to terminal hotspot. Inset: jet paths based on parameters drawn at random from the posterior overplotted on the radio image of Cygnus A.

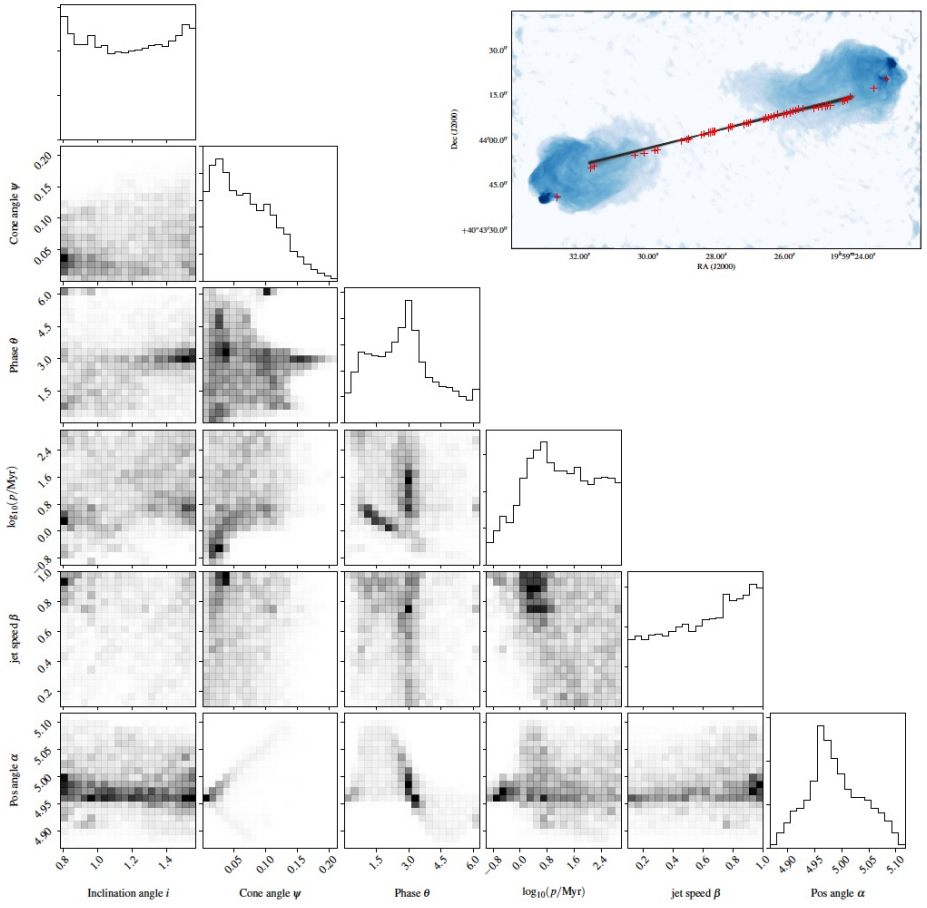
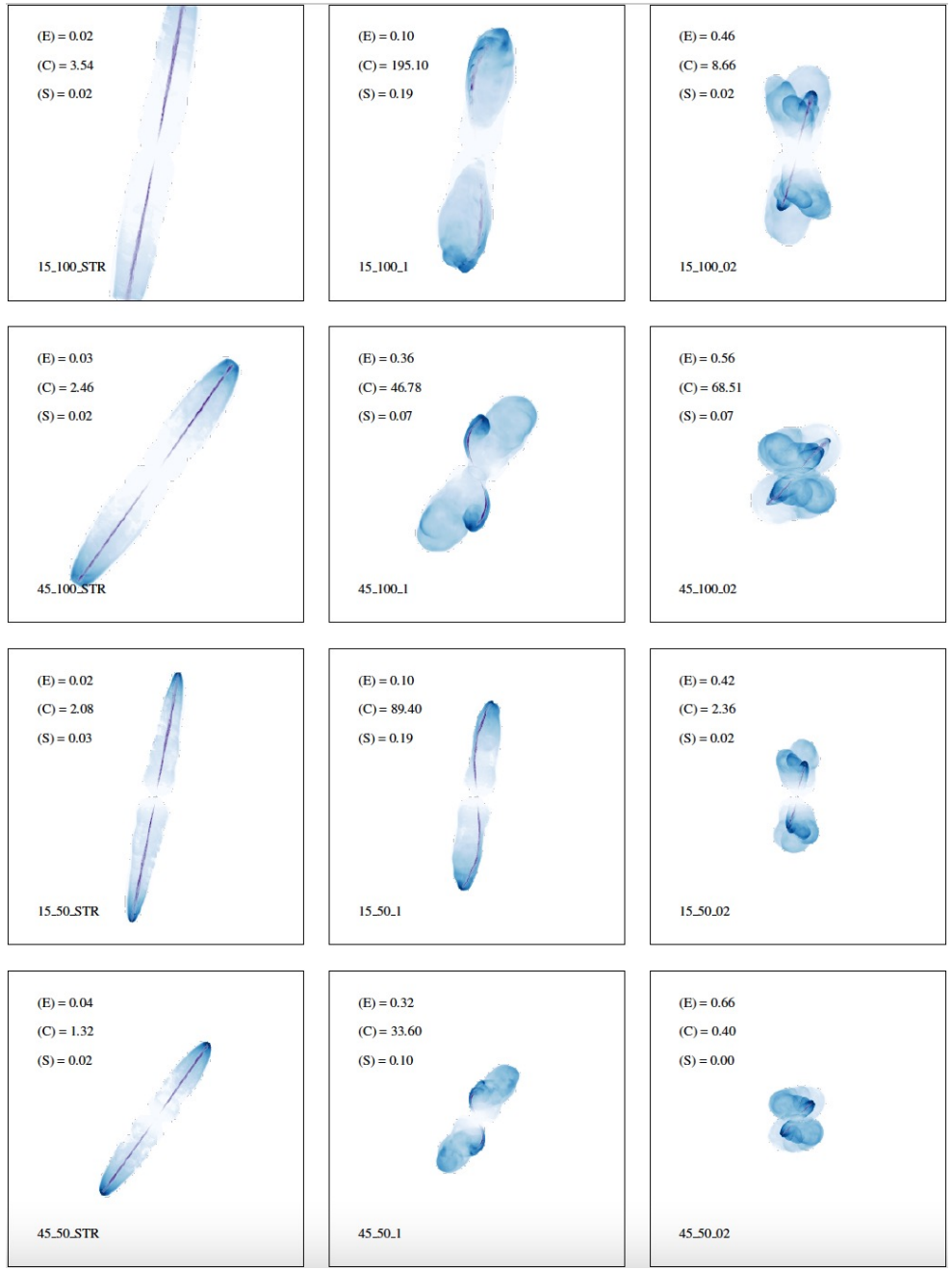


FIGURE 2.7: Main: 'Corner plot' of one-dimensional and two-dimensional marginalized posterior probability distributions for the model parameters given the observed jet path of Cygnus A, limited to straight portions of jet. Inset: jet paths based on parameters drawn at random from the posterior overplotted on the radio image of Cygnus A. The jet points used for this fitting are indicated by the extent of the overplotted jet paths.

Precession morphology

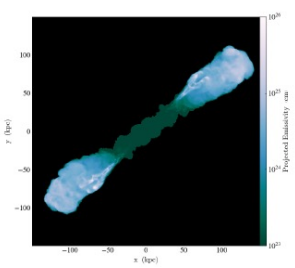
- Precession signatures
  - Jet at edge of lobe
  - S-shaped symmetry
  - Misaligned / multiple hotspots
  - Jet curvature

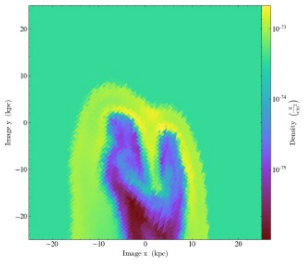
- Simulations showed that presence of signatures meant jet was almost certainly precessing; false positives were rare

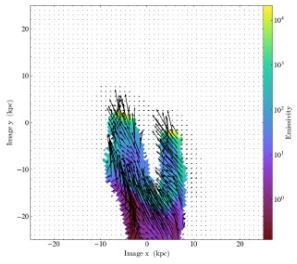


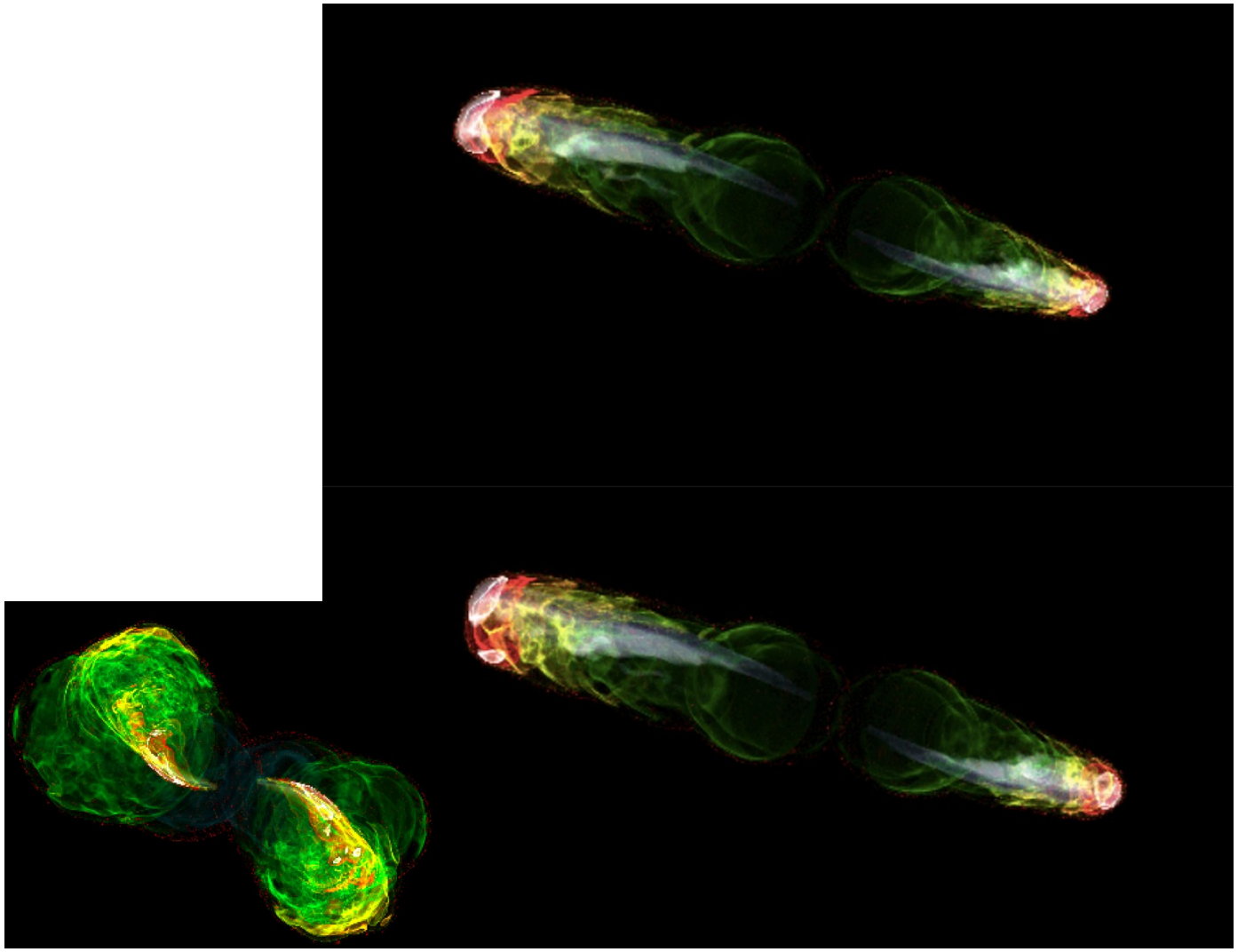
Novel signatures and constraints

- Precession may result in novel mechanisms for hotspot generation
  - Hotspot splitting
  - Multiple jet paths
  - Hotspot complexes
- What will this mean for constraining jet paths?



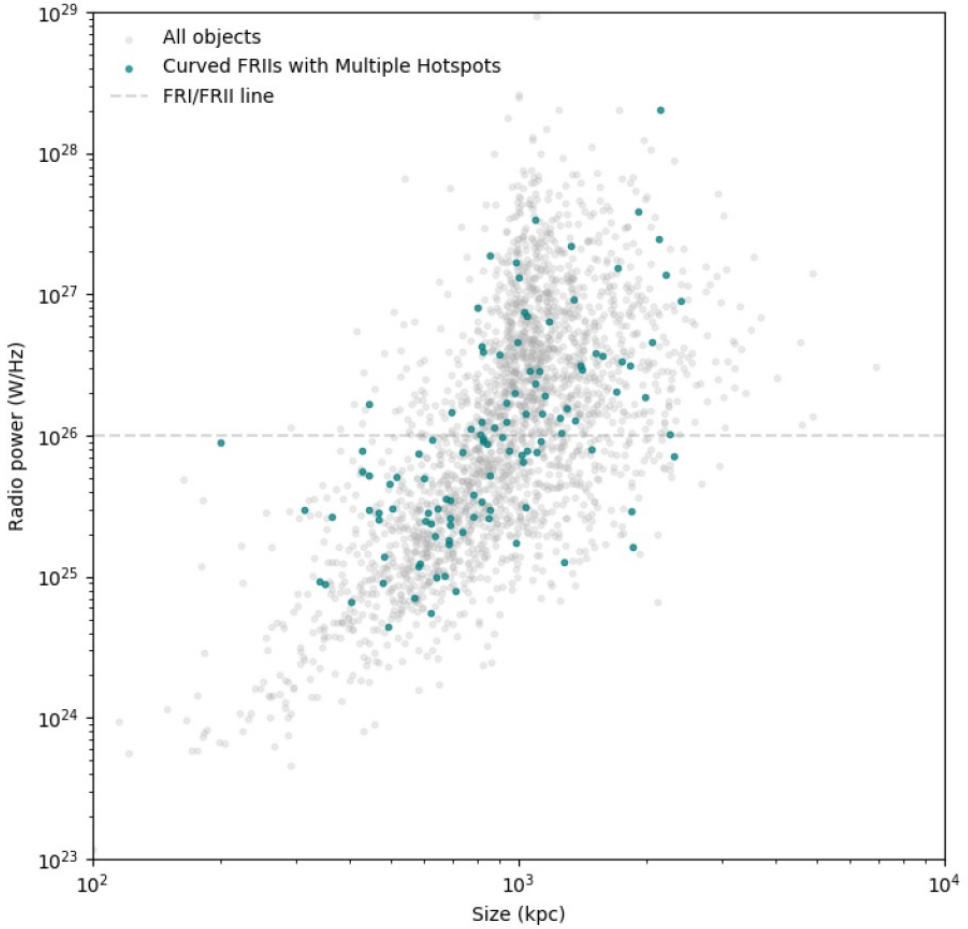






Jet precession and sky surveys

- LOFAR Two-metre Sky Survey (LoTSS)
- Supported by Lofar Galaxy Zoo citizen science project
- Over 4 million radio sources in the Northern Sky
- Largest 100,000 sources gone through visual inspection
- Thousands of precession candidates identified
- Not ‘special’



Next steps and closing thoughts

-- Exploring LoTSS and VLA data to look for morphological trends
-- Fitting jet model on a larger scale
-- Connect with gravitational wave strain modelling
-- Numerical simulations to help understand environmental impact

Morphology is subjective but we now have a sample of many thousands of binary candidates!