High angular resolution at high redshift: the task for uGMRT

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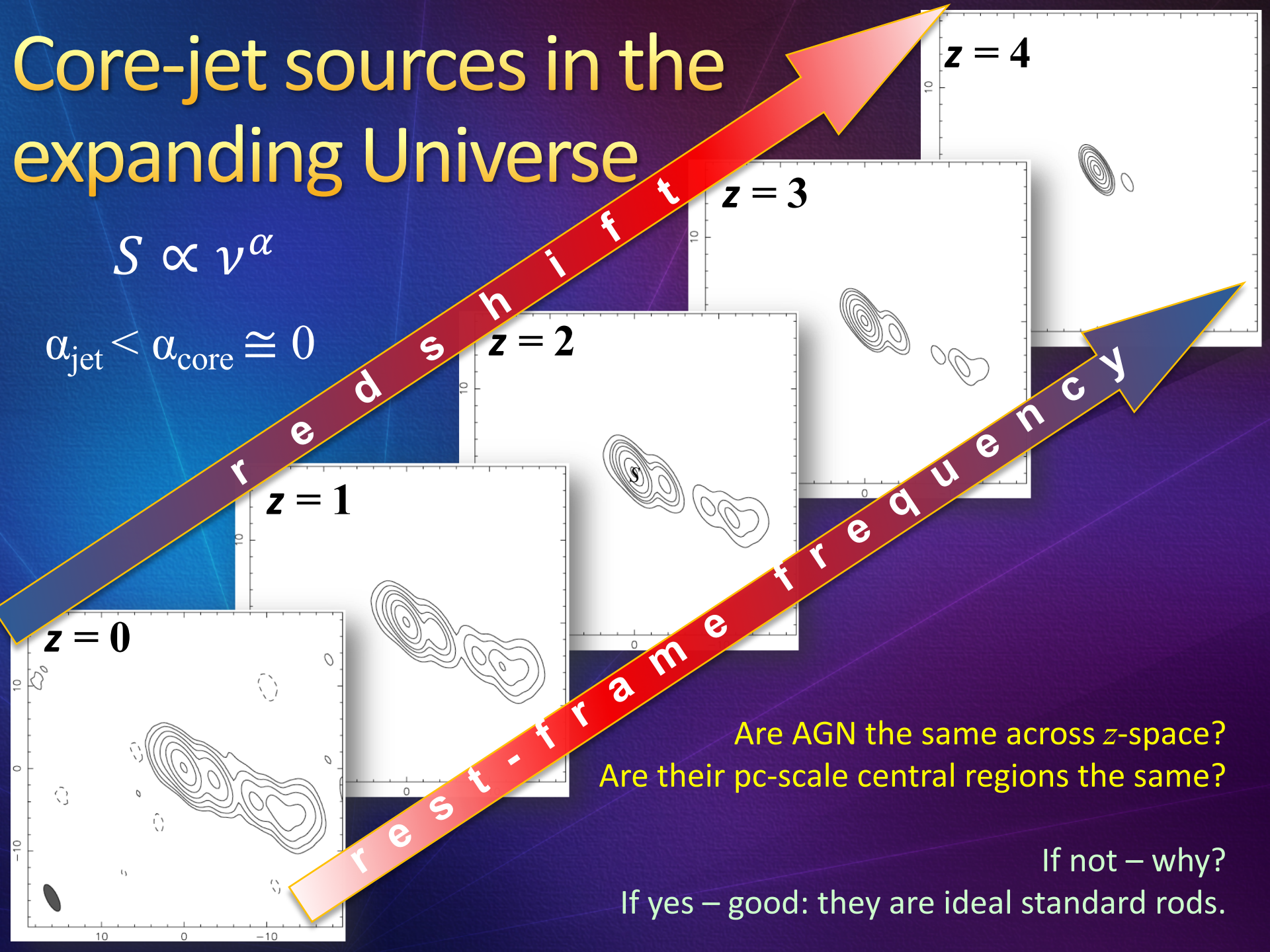
Core-jet sources in the expanding Universe

$$S \propto \nu^{\alpha}$$

$$\alpha_{\rm jet} < \alpha_{\rm core} \cong 0$$



Are AGN the same across z-space?
Are their pc-scale central regions the same?

If not – why?
If yes – good: they are ideal standard rods.

High-z AGN value:

resource for comparative studies

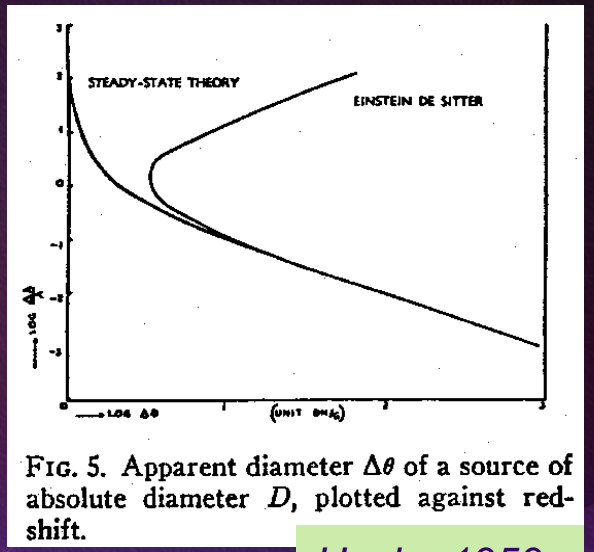
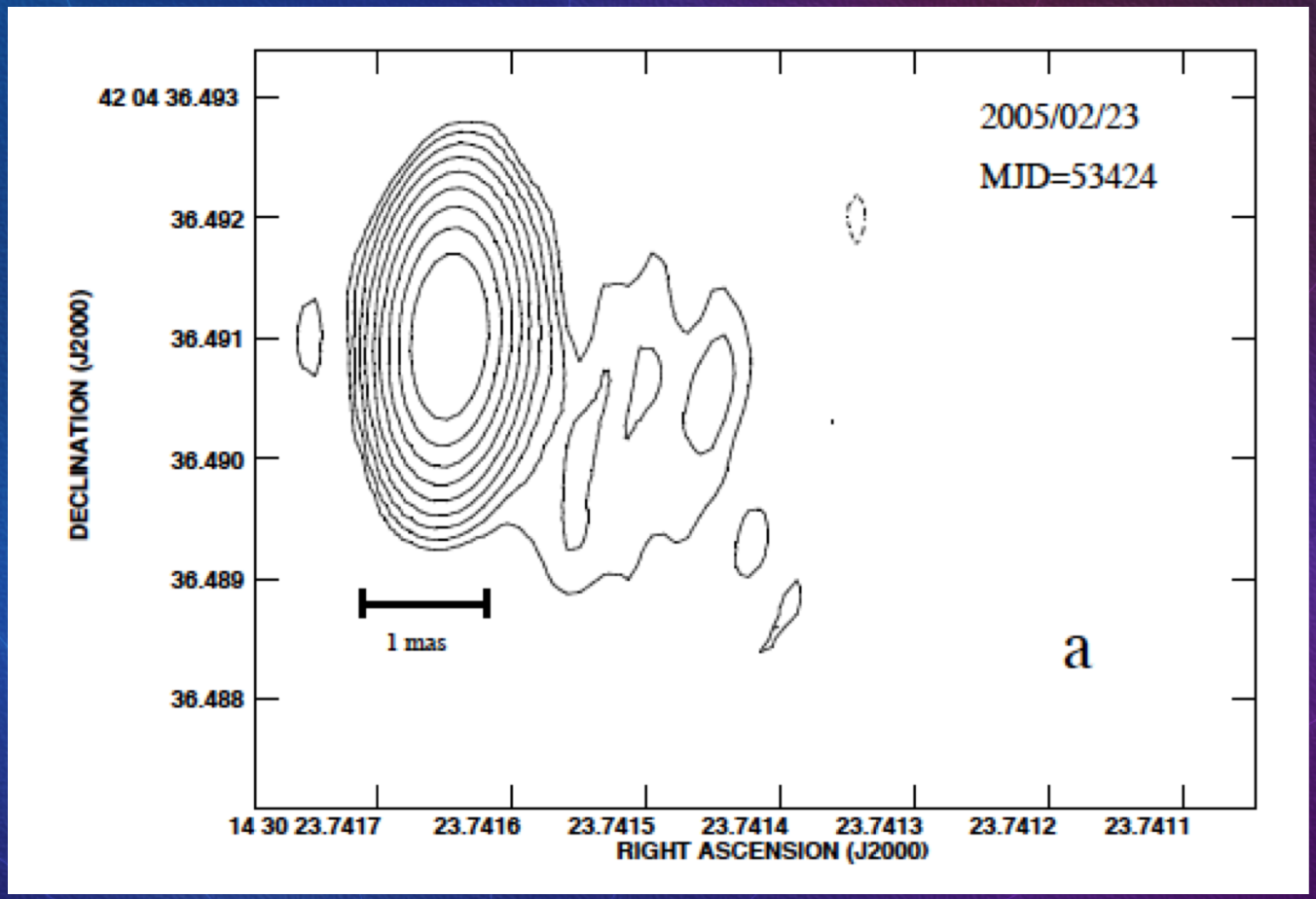


FIG. 5. Apparent diameter $\Delta\theta$ of a source of absolute diameter D, plotted against redshift.

Hoyle, 1959

- Match in linear resolution
  - $z > 3.5$ vs $z < 0.8$ – cosmology at work
- Match in rest-frame frequency & liner resolution
  - $(1+z)$ factor for z~4
  - GVLBI (w uGMRT) 0.3 GHz ⟷ EVN_{W_E}, CVN, LBA @ 1.5 GHz
  - GVLBI (w uGMRT) at UHF ⟷ EVN_{W_E}, CVN, LBA @ 5 GHz
- Match in angular resolution for the same source:
  - VLBI @ 1.5 GHz and $B{=}0.5D_{\mathrm{Earth}}$ ⟷ EVN_{W_E}, CVN, LBA @ 8 GHz
  - VLBI @ 0.3 GHz and $B{=}0.5\mathrm{x}D_{\mathrm{Earth}}$ ⟷ eMERLIN (MeerKAT+) @ 5 GHz
- "z-matching" and "baseline-matching"for uGMRT-VLBI?

J1430+4204, z = 4.72



VLBA 15 GHz
Rest frame 86 GHz

2 epochs

$\Gamma \approx 5 \div 10$

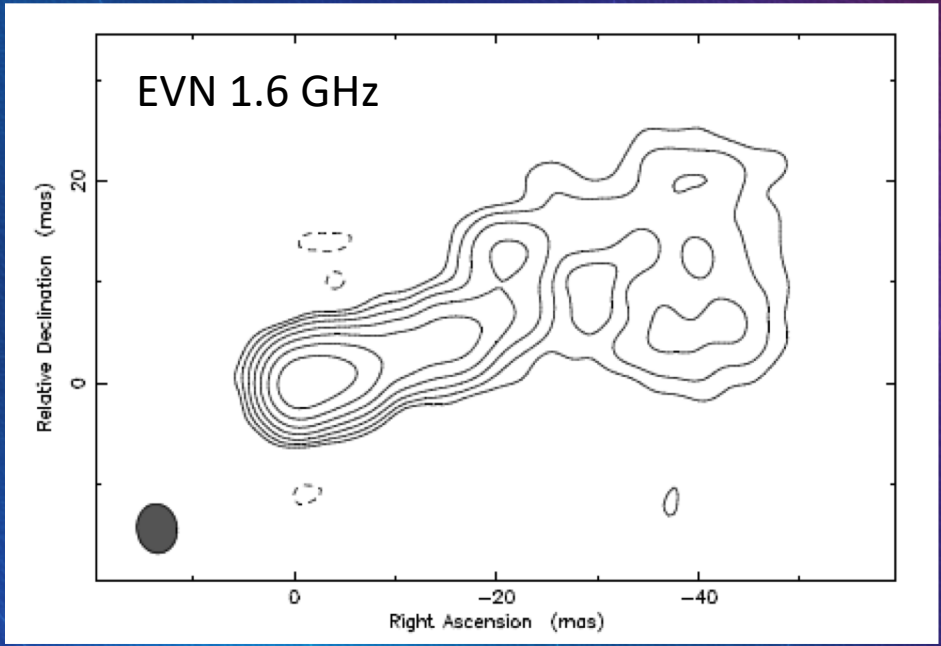
Notes: – *high-frequency jets do exist!*
– *but are they common?*

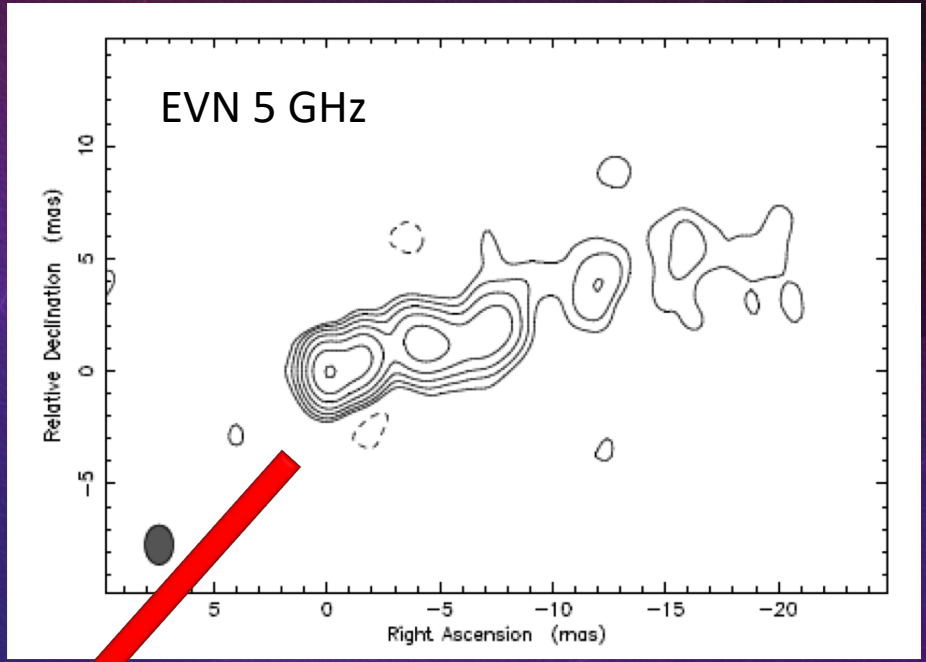
Need for 10–mas resolution low-frequency imaging

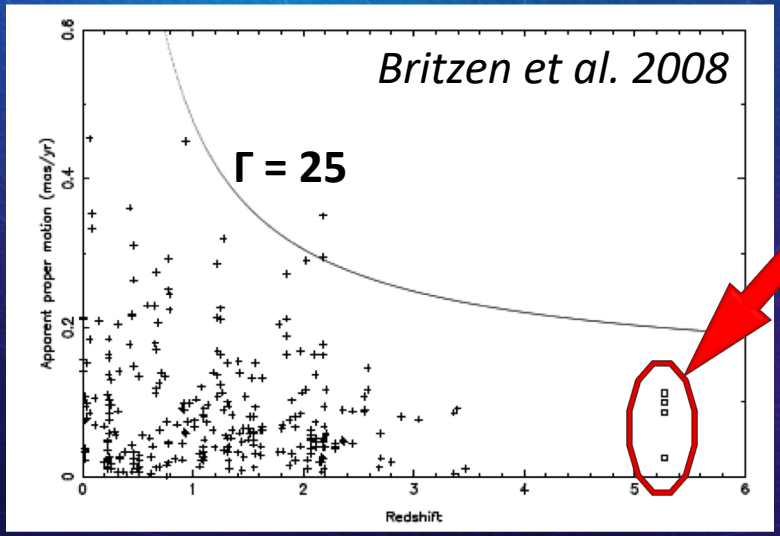
Veres et al. 2010

J1026+2542, z=5.266

Frey et al. 2013, 2015







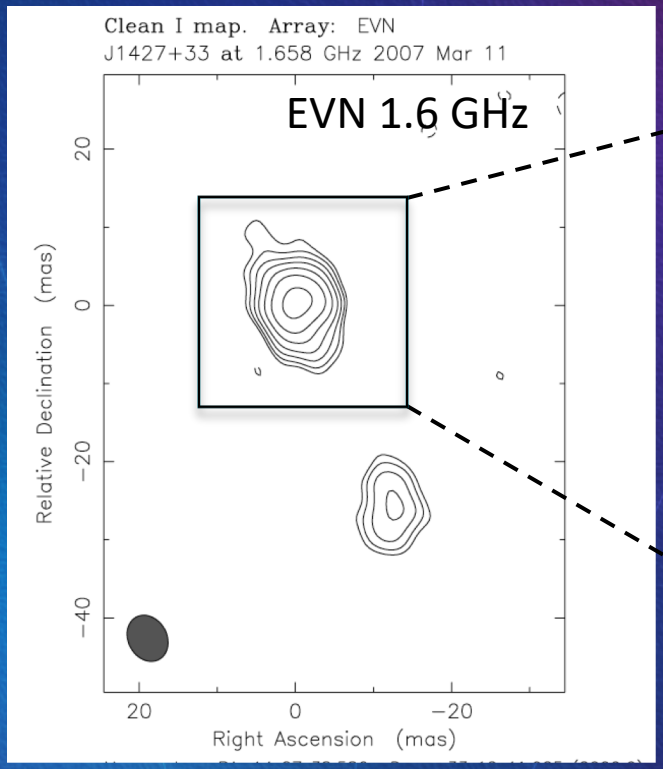
μ = 0.03±0.11 mas/yr
In combination with 7-yr earlier 5 GHz image by Helmboldt et al. (2007)

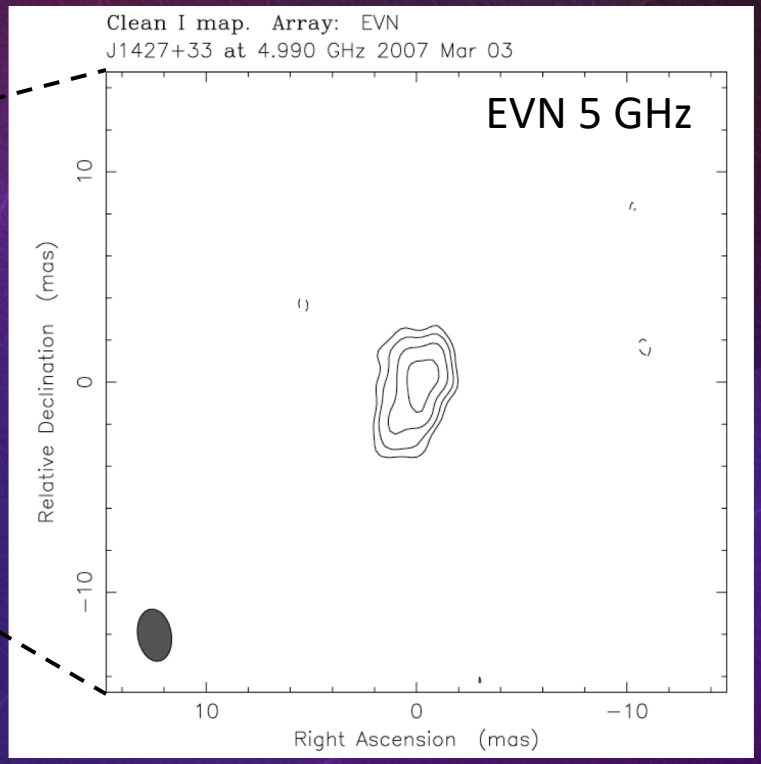
Notes:

- the gap in redshift coverage !
- time dilation (1+z) needs quiate a bit patience…

J1427+3312, z=6.12

Frey et al. 2008



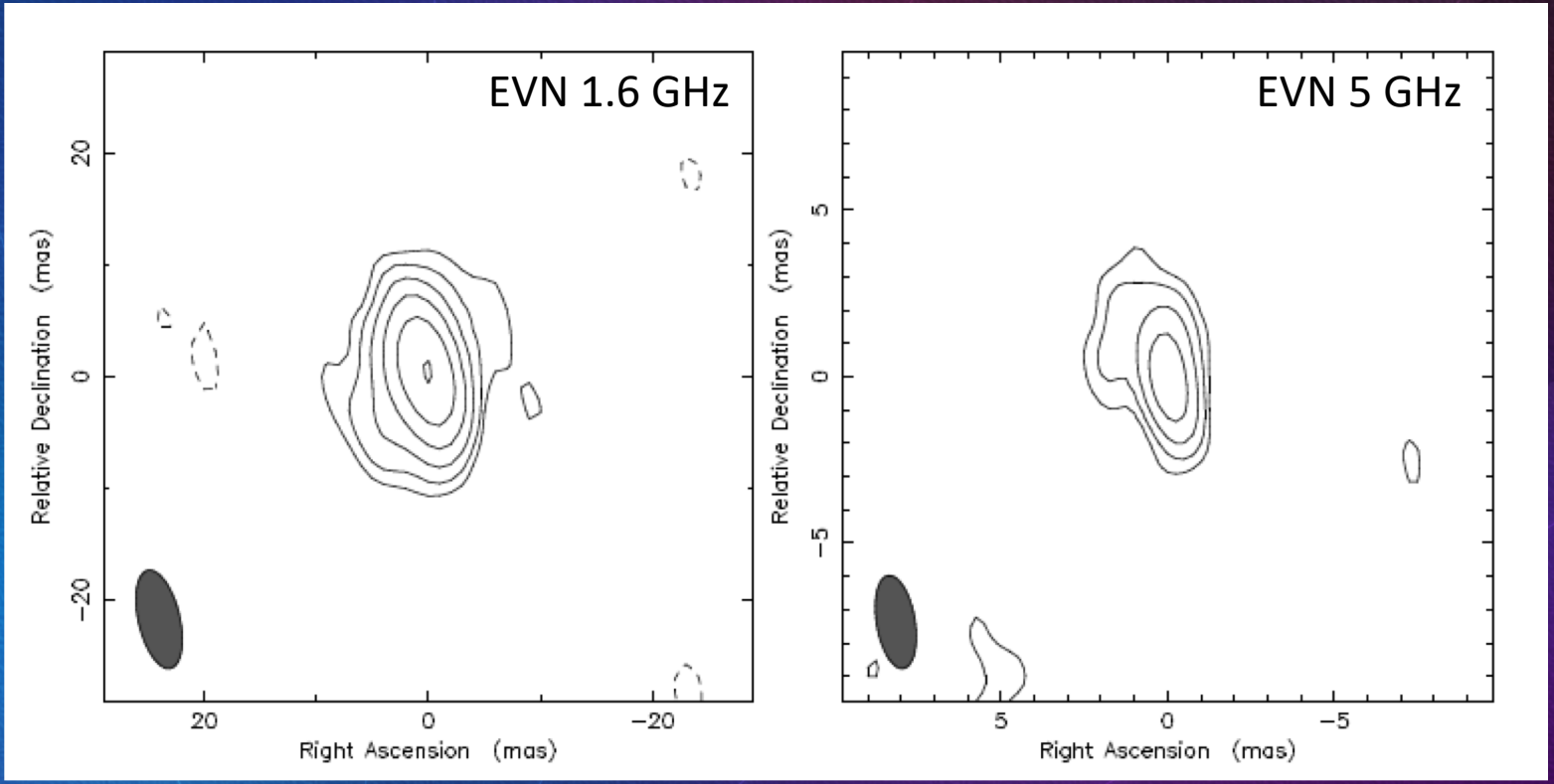


Archetypal CSO object (young?) – a record holder in "*z*-category"
Prevalence of CSO/CSS sources at high redshifts predicted long ago (*Savage and Peterson, 1983)*

- *Statistics is too small – does this prevalence hold?*
- ***Lower frequency 10–mas resolution image at UHF and lower bands badly needed!***

J1429+5447, z=6.21

Frey et al. 2011

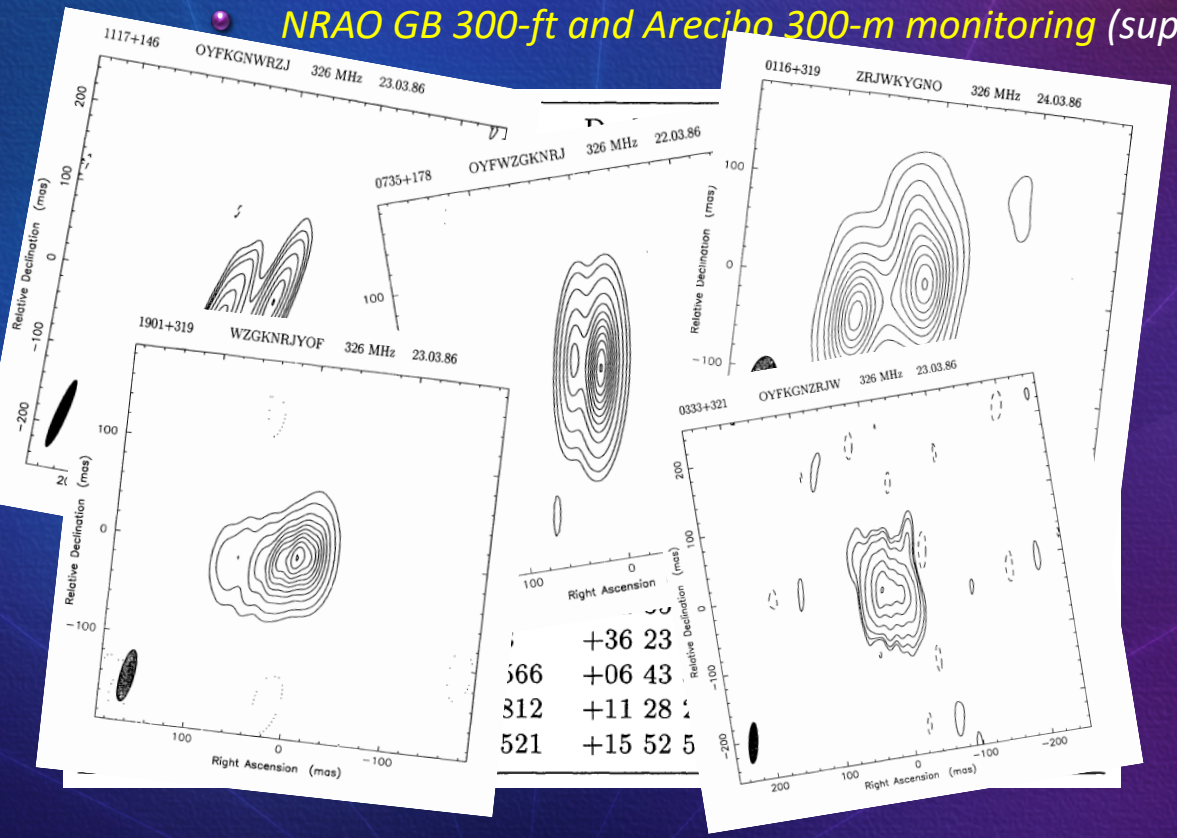


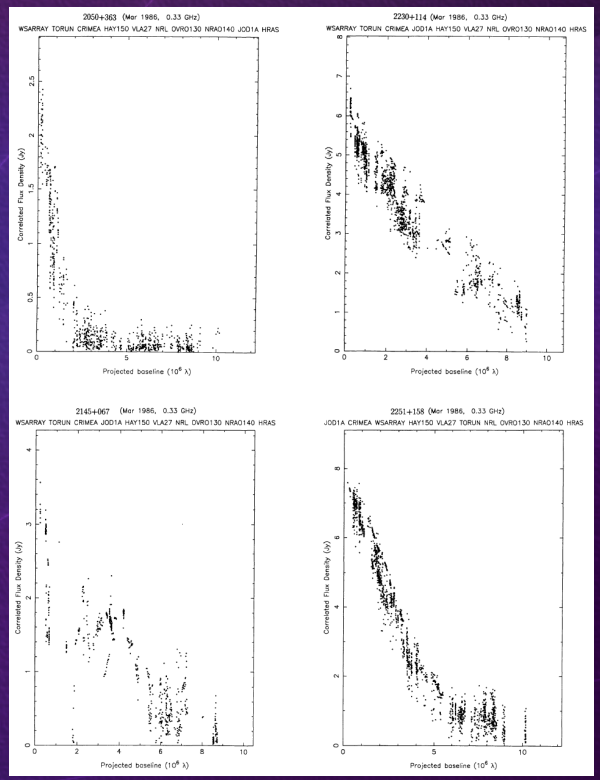
Mildly resolved, $T_{\rm B} \cong 10^8$ K - well below the equipartition limit of $10^{10.5}$ K

Looks "normal" at ~10% of the present age of the Universe…

AGN at *cas* resolution at sub-GHz

- Message from MkII era: *Altschuler et al. 1995, A&A Suppl. S 114, 197*
  - *(Total) FD-limited sample*
- 16 variable extragalactic sources, global VLBI at 327 GHz, based on
  - *NRAO GB 300-ft and Arecibo 300-m monitoring (supersticious listners: please, leave the room)*





Dominance of steep-spectrum jets over flat-spctrum cores

Structures well resolved at B $\gtrsim$ 6 Mλ

Wide-field phase-ref VLBI at 92 cm

Lenc et al. 2006, PoS(8thEVN)079

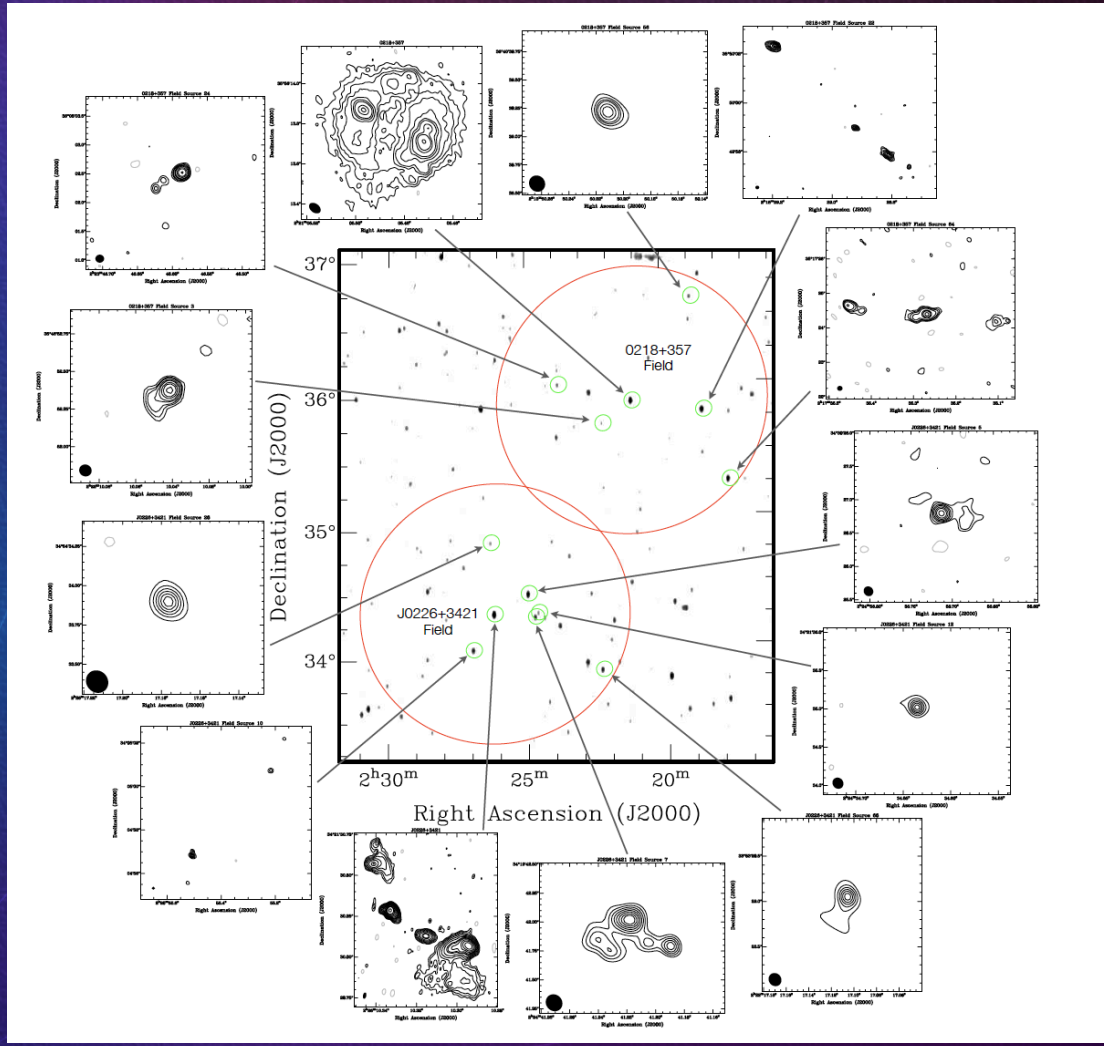
- VLBA, Jb, WSRT
- ΔB = 4 MHz
- Image noise ~ 1 mJy/beam

- Opportunity for wide-field piggy-back VLBI at 90 cm

- AGN vs. star-burst galaxies across redshift space

- High synergy with future SKA (and current LOFAR) surveys

- See further details in *Lenc et al. 2008, ApJ 673, 78*



Take aways

- Imaging VLBI at metre wavelengths and global baselines
  - Perfectly feasible
  - Rich in applications, especially for studies of steep spectrum sources (e.g., jets)
  - Uniquely suitable for studies of z-evolution of AGN
    - *population studies (N–S diagrams)*

- VLBI with uGMRT – science-rich niche opportunity for AGN studies
  - Supersensitive arrays SKA_Mid – uGMRT – FAST – ASKAP ?
    SKA_Low – uGMRT– LOFAR – FAST ?
  - Opening up of lage enough new parameter space – expect unexpected!
  - Wide-field VLBI imaging at m–wavelengths (*see Lenc et al. 2006, 2008*)
    - incl. piggy-back on ”trageted” observations
    - matching high-frequency surveys
    - the role of refractive sub-structure to be analysed (see RadioAstron pulsar results)