The most distant radio quasars at the highest resolution

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The outline of the talk

- Quasars already formed as early as <1 Gyr after the Big Bang
- How many of the *z*~6 quasars are radio emitters?
- High-resolution radio interferometric imaging with the EVN:

  compact structures down to ~10 pc scales
- Are they similar to each other? Are they ”young”?
- The first blazars – or not?

A brief introduction

Quasars at z~6 became known quite recently (in the last decade or so)

First discoveries in the
Sloan Digital Sky Survey (SDSS)

Fan et al. (2001, 2003, 2004, 2006)

To date, there are ~40-50 quasars
known at z~6

e.g. Willott et al. (2007, 2010)

Most of the observed properties (e.g. metallicity, emission line strength, BH mass) are very **similar** to those of quasars at low redshifts

But: hot-dust-free quasars (2 out if 21) found
– they may represent the **first generation**

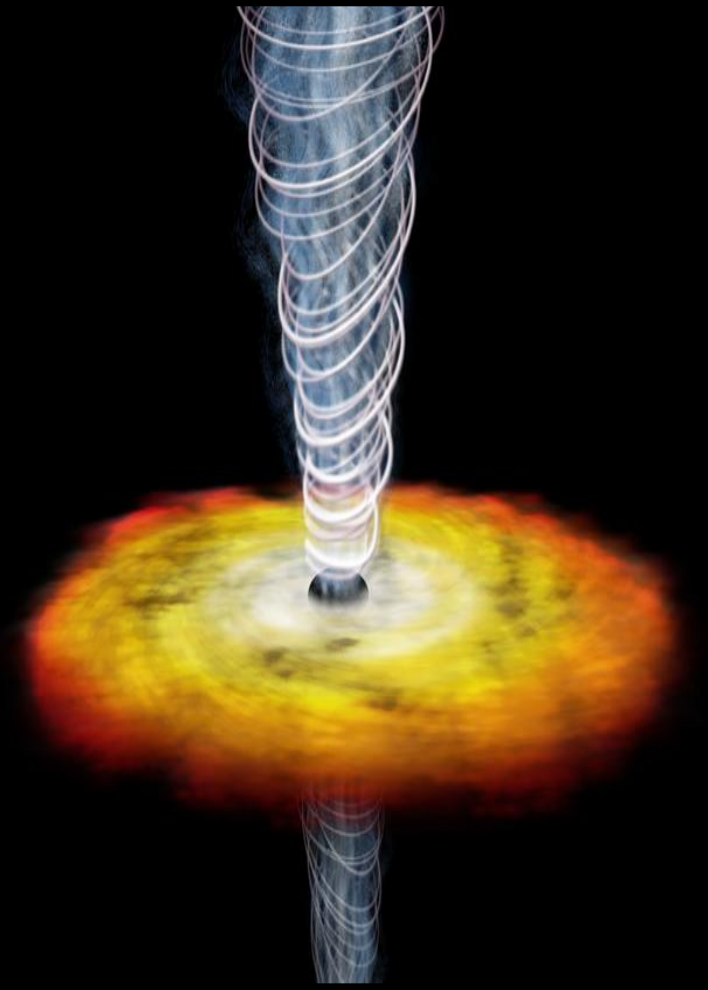
Jiang et al. (2010)

Apparently not all of the earliest quasars we see are completely evolved objects (lack of the dusty structures around the accretion disk)

Radio quasars at *z*~6

Among the *z*~6 quasars, only three are ”strong” continuum **radio sources**
For comparison, ~8% of all SDSS quasars have FIRST radio counterparts

Ivezić et al. (2002)



If the radio emission is **compact**, it should come from an AGN:
synchrotron jet in the vicinity of the central SMBH

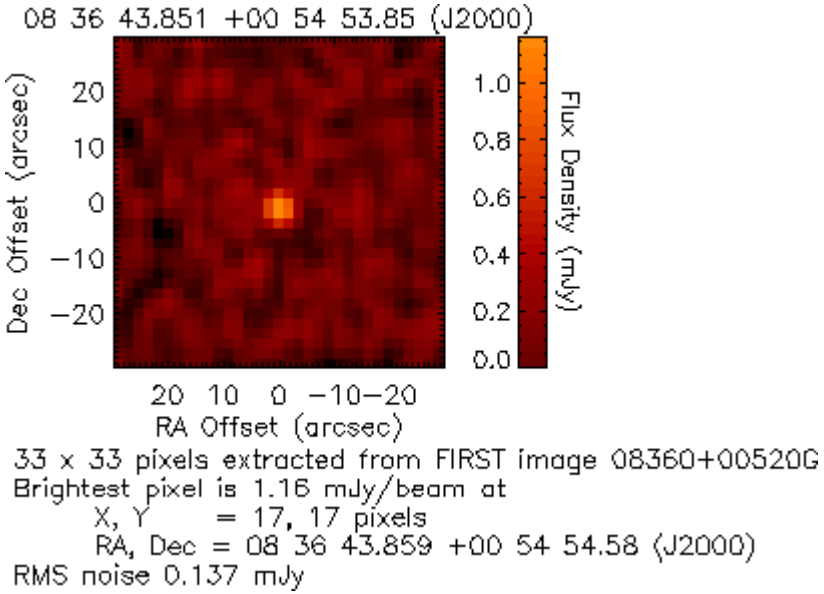
This can be tested with **Very Long Baseline Interferometry** (VLBI) imaging

J0836+0054

***z*=5.77**

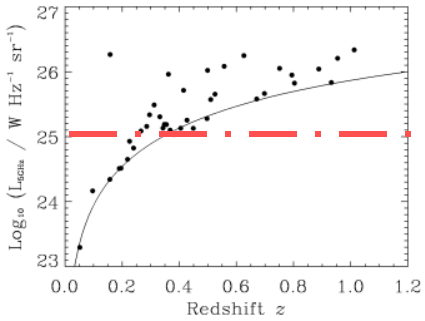
Fan et al. (2001)

FIRST (VLA, 1.4 GHz) radio image



Weak (~1 mJy) radio sources
→ VLBI imaging is challenging

SDSS J0836+0054: luminosity



$L_5 = 10^{25}$ W Hz^{-1} sr^{-1}

z=5.774

example: Parkes Half-Jansky Flat-Spectrum Sample

Jarvis & McLure (2002)

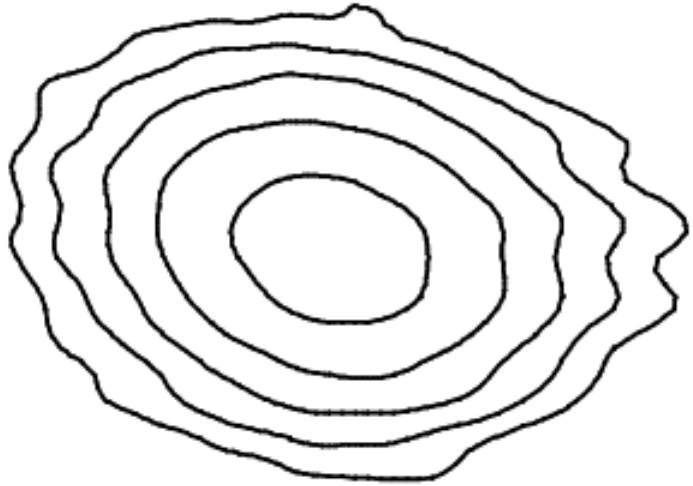
1.6 GHz

peak: 770 μJy/beam

20 mas

5 GHz

peak: 333 μJy/beam



10 mas

1 mas angular size corresponds to ~6 pc linear size at around this z

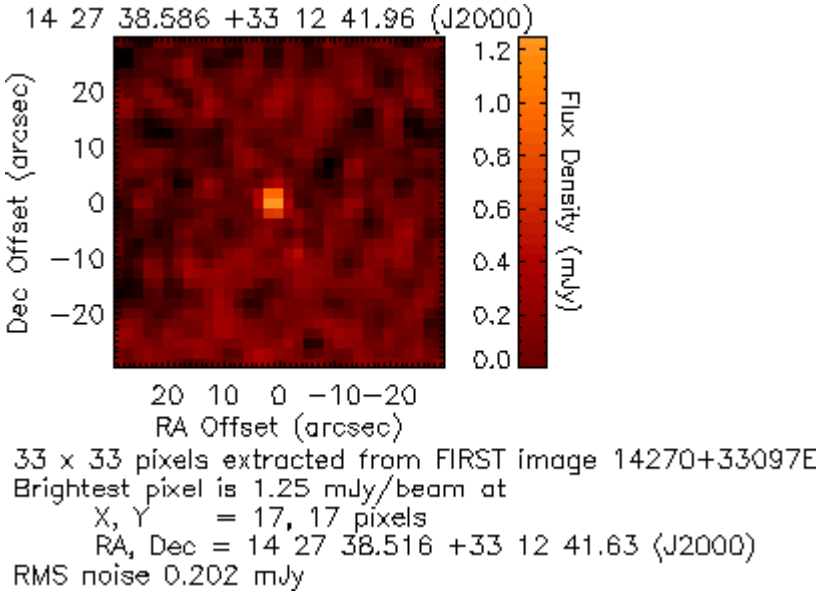
- **compact** but somewhat resolved structure
- radio emission is confined to the central **few tens of parsecs**
- steep radio spectrum (α = -0.8) , no indication of strong relativistic beaming

Frey et al. (2003, 2005)

J1427+3312

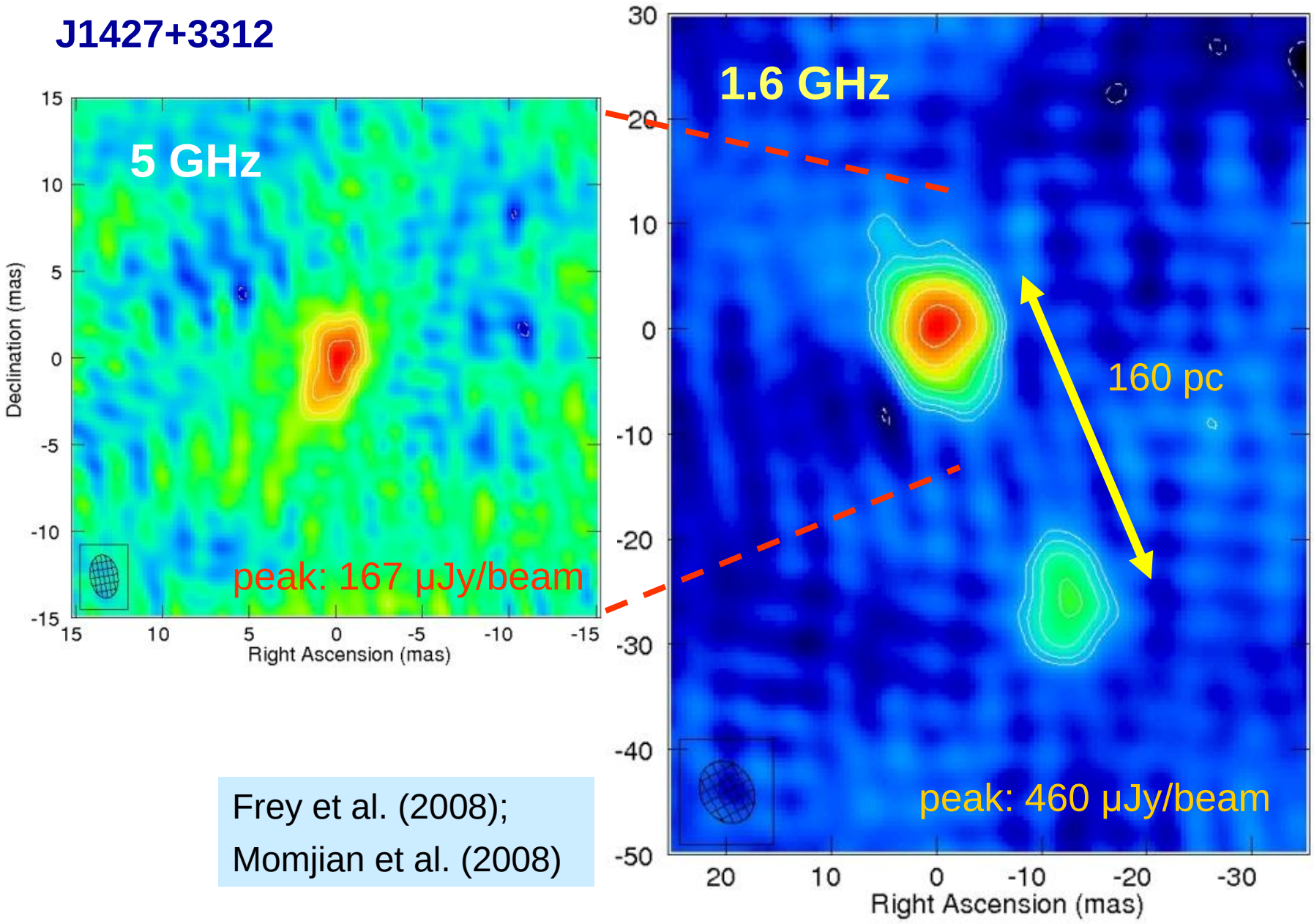
z=6.12

McGreer et al. (2006); Stern et al. (2007)



33 x 33 pixels extracted from FIRST image 14270+33097E
Brightest pixel is 1.25 mJy/beam at
X, Y = 17, 17 pixels
RA, Dec = 14 27 38.516 +33 12 41.63 (J2000)
RMS noise 0.202 mJy

J1427+3312



Frey et al. (2008);
Momjian et al. (2008)

J1427+3312:

- **double structure** seen at the lower frequency
- again, compact but resolved (~10^6-10^7 K brightness temperatures)
- comparison with lower-resolution VLA & WRST data:

no significant ”missing” flux density, the total radio emission is also detected with VLBI

- again, steep radio spectrum ($\alpha = -0.6$)

The source is remarkably similar to the **Compact Symmetric Objects** (CSOs), known typically at $z<1$

Those are really **young** (up to ~10^4 yr) ”baby” radio AGNs

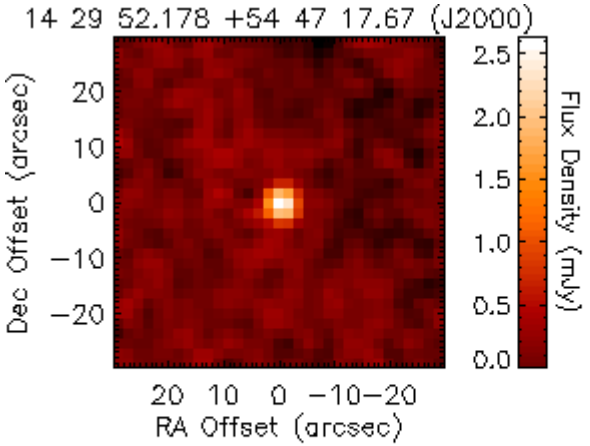
Their (kinematic) age is derived from the separation speed

Is our $z>6$ quasar a newborn radio AGN? – could be verified with VLBI monitoring over the time scale of a decade

J1429+5447

***z*=6.21**

Willott et al. (2010)



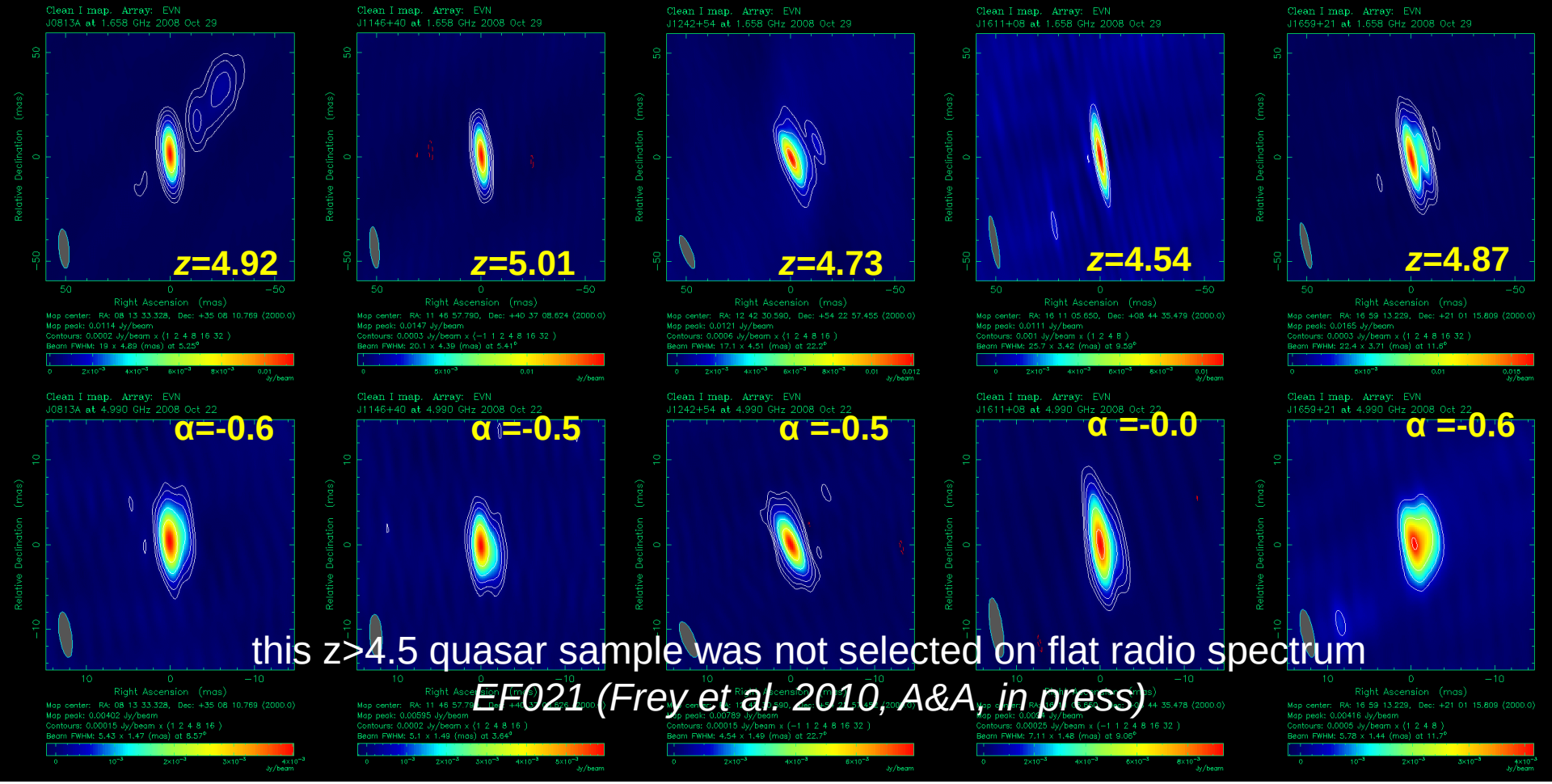
33 x 33 pixels extracted from FIRST image 14300+55098G
Brightest pixel is 2.64 mJy/beam at
X, Y = 17, 17 pixels
RA, Dec = 14 29 52.232 +54 47 17.84 (J2000)
RMS noise 0.167 mJy

Preliminary images made from recent EVN data (EF022)
1.6 GHz (2010 Jun 8), **5 GHz** (2010 May 27)

J1429+5447:

❖ strikingly **similar** compact double structure & steep spectrum for both known *z*>6 radio quasars

Is it the ”rule”, or these are just accidental exceptions?



this z>4.5 quasar sample was not selected on flat radio spectrum

EF021 (Frey et al. 2010, A&A, in press)

❖ Apparently at *z*>4.5, the blazar-type sources (with flat spectrum and high Doppler-boosted brightness temperatures) are the *minority*

❖ Do we see mainly young **GPS sources** at early cosmological epochs?

❖ Their turnover frequencies should be ~500 MHz (in the observer's frame)

Falcke et al. (2004)

Conclusions & future directions

❖ Among the known *z*~6 quasars, <10% is radio-emitting

❖ The three imaged with high angular resolution show compact but resolved radio structures at ~10-100 pc linear scales

❖ Their radio spectra are steep

❖ Two of them (at *z*>6) are doubles, and remind us to the CSOs (very young radio AGNs at low redshifts)

❖ The highest-resdhift radio quasars are still very rare

❖ There must be a lot more, just waiting for discovery…

❖ Existing at around the end of the era of reionization, these radio sources could also serve as ”radio beacons” for sensitive HI absorption studies towards their lines of sight