News from the edge of the Universe – recent results from EVN studies of z~6 quasars

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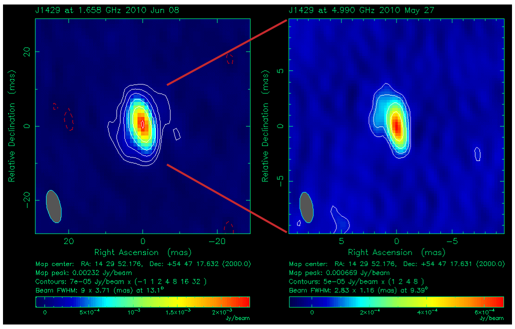
There are more than 60 quasars known at redshifts z>5.7 to date. The most distant one has been identified at z=7.085 (*Mortlock et al.* 2011). However, only 3 of them are detected in the radio above 1 mJy flux density at 1.4 GHz: **J0836+0054** (z=5.77, *Fan et al.* 2001), **J1427+3312** (z=6.12, *McGreer et al.* 2006), and **J1429+5447** (z=6.21, *Willott et al.* 2010). A fourth distant radio source, **J2228+0110** (z=5.95, *Zeimann et al.* 2011) has 0.3 mJy total flux density. Assuming a cosmological model with H_0=70 km s^{-1} Mpc^{-1}, Ω_m=0.3 and Ω_Λ =0.7, the redshift z=6 corresponds to 0.9 Gyr after the Big Bang (<7% of the present age of the Universe).



VLBI images of J1429+5447 (z=6.21)

Observations of quasars at the highest redshifts can constrain models of the birth and early cosmological evolution of active galactic nuclei (AGNs) and the growth of their central supermassive (up to ~10^9 $M_\odot$) black holes. These radio-emitting high-redshift objects are particularly valuable, because the ultimate evidence for AGN jets can be found in the radio by the highest-resolution **Very Long Baseline Interferometry** (VLBI) observations. Synchrotron radio emission of the jets originates from the close vicinity of the spinning supermassive black hole. The radio-emitting plasma is fueled from an accretion disk and is accelerated and collimated by the magnetic field. All the four powerful (but, due to their distance, fairly weak) z~6 radio quasars have already been successfully detected and imaged with the European VLBI Network (EVN) at one or two different observing frequencies, 1.6 GHz and 5 GHz (*Frey et al.* 2003, 2005, 2008, 2011; *Gurvits et al.*, in prep.).

What did we learn from this small sample?

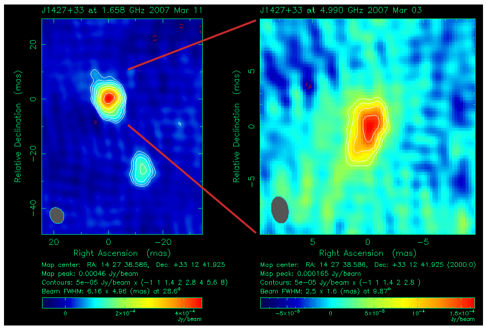
❖ The entire radio emission is confined to a **small (central) region** in all these radio quasars; the VLBI data prove the AGN origin of the emission.

❖ The sources are compact but slightly **resolved** at ~10 mas scales. The brightness temperatures do not exceed ~10^9 K.

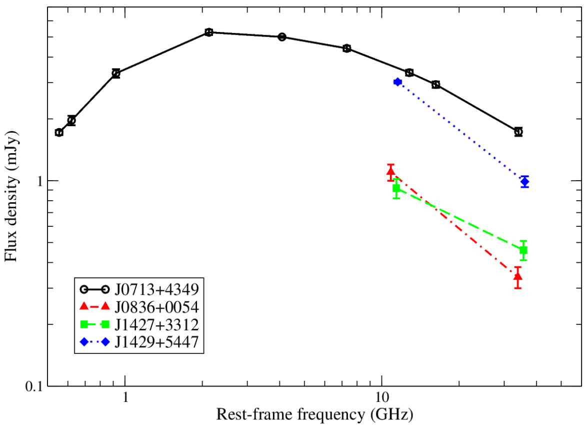
❖ **Steep radio spectrum**, with spectral index α=–0.6 … –1.0

(S~ν^α, where S is the flux density, and ν the frequency).

One of the objects (J1427+3312) shows a prominent **double structure**, with two components separated by 28 mas in the 1.6-GHz image, corresponding to a projected linear distance of ~160 pc.



VLBI images of J1427+3312 (z=6.12)



Two-point radio spectra of three VLBI-imaged z~6 quasars (filled symbols). For comparison, spectral data points taken from the NASA/IPAC Extragalactic Database (NED) for J0713+4349 (z=0.52) are also plotted. This was the first CSO whose expansion speed could be measured with VLBI (Owsianik & Conway 1998). The frequencies are shifted to the rest frame of each source. The flux densities of J0713+4349 are scaled down to match the luminosity distance of the high-redshift quasars.

The three z~6 radio quasars for which we have dual-frequency data remind us to the well-known *Gigahertz Peaked Spectrum* (GPS) sources (e.g. *O'Dea* 1998). GPS sources are believed to be *young* (i.e. in the early stage of their evolution), or perhaps *frustrated* (i.e. confined by the dense interstellar medium). Given the early cosmological epoch at z~6, both scenarios seem plausible. The high-redshift steep-spectrum objects may represent **GPS sources at early cosmological epochs**. The first generation of supermassive black holes could have had powerful jets that developed hot spots well inside their forming host galaxy, on linear scales of 0.1−10 kpc (*Falcke et al.* 2004). The double structure and the separation of the components of J1427+3312 are similar to those of the young (<10^4 yr) *Compact Symmetric Objects* (CSO), a sub-class of GPS sources found typically in radio galaxies at much lower redshifts.

According to the preliminary results of the **most recent** 1.6-GHz EVN experiment (EG057), the image of the weakest z~6 radio quasar, J2228+0110, shows a somewhat resolved compact source with ~200 μJy/beam peak brightness.

References

» Falcke H. et al. 2004, *NewAR* **48**, 1157
» Fan X. et al. 2001, *AJ* **122**, 2833
» Frey S. et al. 2003, *MNRAS* **343**, L20
» Frey S. et al. 2005, *A&A* **436**, L13
» Frey S. et al. 2008, *A&A* **484**, L39
» Frey S. et al. 2011, *A&A* **531**, L5
» McGreer I.D. et al. 2006, *ApJ* **652**, 157
» Mortlock D.J. et al. 2011, *Nat* **474**, 616
» O'Dea C.P. 1998, *PASP* **110**, 493
» Owsianik I. & Conway J.E. 1998, *A&A* **337**, 69
» Willott C.J. 2010, *AJ* **139**, 906
» Zeimann G.R. et al. 2011, *ApJ* **736**, 57