Compact radio quasars at $z>4.5$ observed with the EVN

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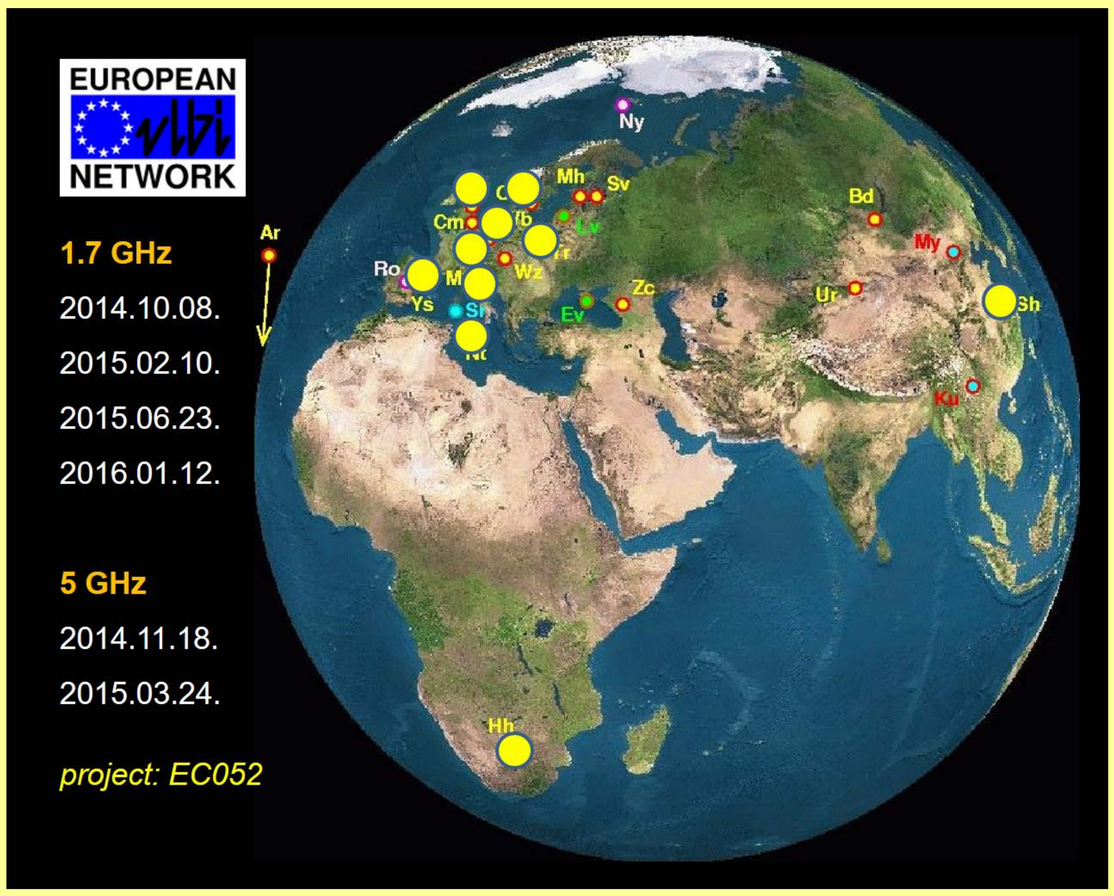
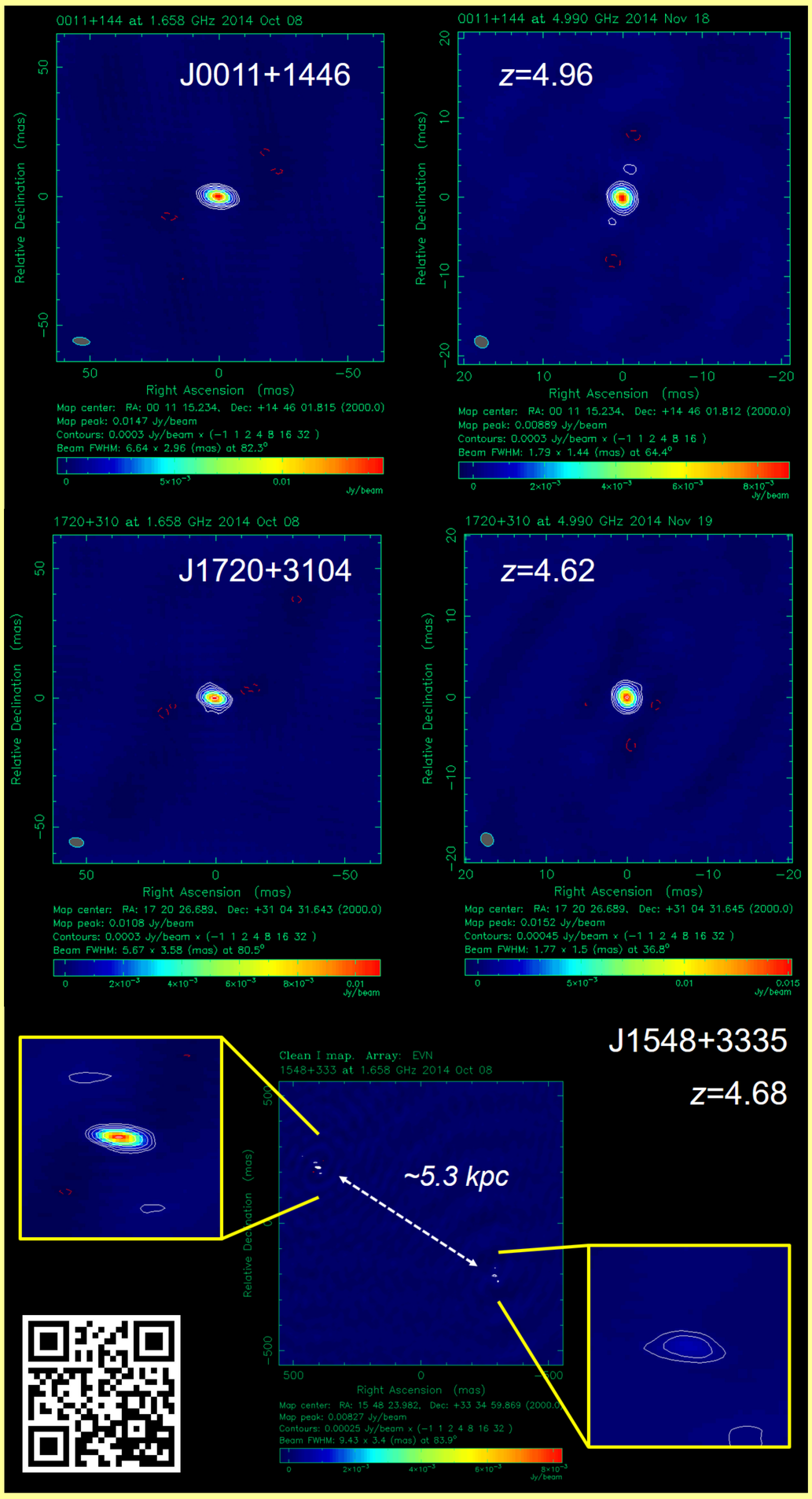
Why are radio quasars at extremely high redshifts interesting?

- At redshifts above $z>4.5$, the Universe was **younger than ~10%** of its present age
- Active galactic nuclei (AGN) powered by supermassive black holes are seen at least until $z\sim7$
- High-redshift quasars are associated with the **youngest supermassive black holes** in the Universe
- Some of them are **radio-loud** and thus can be studied with VLBI at the highest possible resolution; radio provides an unobscured view of the nucleus
- They can be used to test the predictions of **cosmological models** (angular size-redshift and apparent proper motion-redshift relation)
- They can be used to set constraints on **black hole growth** in the early Universe and better understand **galaxy evolution**
- Recently we increased the number of VLBI-imaged AGN at $z>4.5$ by 50%, from 20 to 30, using **e-EVN measurements**





More details and further references:
Coppejans R. et al. 2016, *MNRAS*, in press (arXiv:1609.00575)

Sample selection

- Optical quasars with known **spectroscopic redshift** $z\geq4.5$ (mostly from SDSS)
- **Radio emission**, compact on arcsec scales (1.4-GHz flux density $S > 5$ mJy from the VLA FIRST survey)
- Not yet observed with **VLBI**

$\Longrightarrow$ 10 new targets identified with $4.5 \leq z \leq 5$

Still very few similar objects are known

Results in a nutshell

- **All 10 targets are detected** with the EVN (9 at both frequencies, 1 at 5 GHz only)
- The images mostly show **featureless objects**, but the measured properties indicate a **mix of resolved and compact sources** on mas scales *(two examples are shown in the images)*
- The most intriguing one of the targets (J1548+3335) has a wide-separation **double structure** seen at 1.7 GHz *(see the image)* the brighter component that coincides with the optical quasar position is also detected at 5 GHz

The sample of z>4.5 radio sources observed with VLBI to date…

- …consists of 30 objects and is **incomplete and heterogeneous**
- The highest redshift is z=6.21 (J1429+5447)
- The radio emission in one source (J1205-0742) originates form star formation; the others are AGN
- Based on **spectral index**, **brightness temperature** and (limited) **variability** information, roughly equal numbers of the rest are either **flat-spectrum radio quasars** or **steep-spectrum sources** (including two wide extended ones)
- Objects in the steep-spectrum category are most likely young sources with spectra peaking at GHz or ~100 MHz frequencies

Coming next:

- Larger well-defined high-redshift radio quasar samples
- Better understanding of the selection effects
- Tackle the question of apparent overabundance of highly-beamed sources (i.e. blazars) at very high redshifts