A new route to high-redshifts?

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Coppejans at al. (2015)

Title:

Megahertz peaked-spectrum sources in the Boötes field I - a route towards finding high-redshift AGN?

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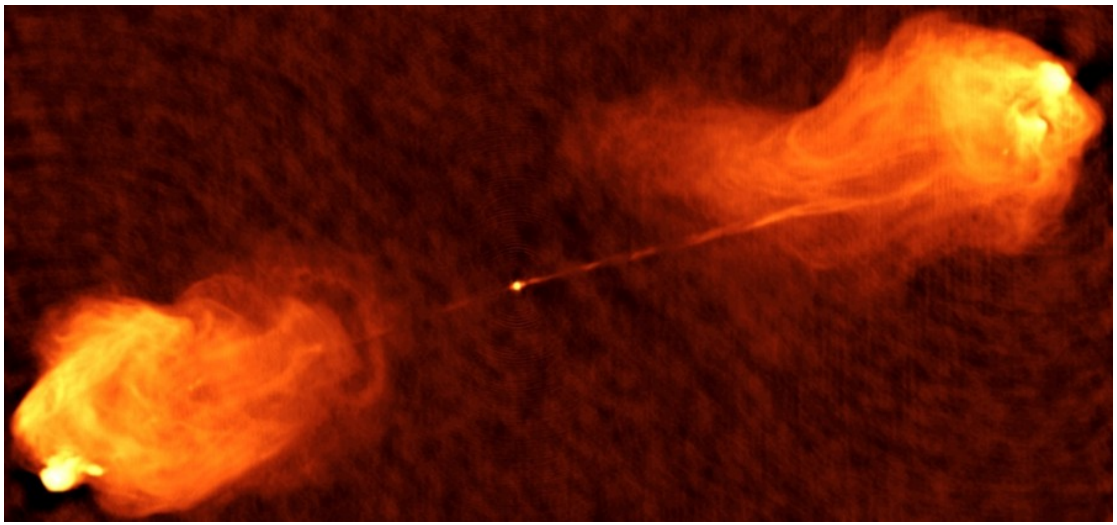
Aim

- Supermassive black holes are believed to lie at the center of nearly every galaxy, shaping and influencing their host and the inter-galactic medium via feedback from their relativistic jets.
- To understand galaxy evolution, we need to understand how active galactic nuclei (AGN) evolve.
- Finding high-redshift AGN is currently a great observational challenge.
- AGN have been identified in optical surveys out to $z = 7.1$ (Mortlock et al. 2011) but Ly-alpha absorption makes detecting them beyond $z \gtrsim 6.5$ very difficult.

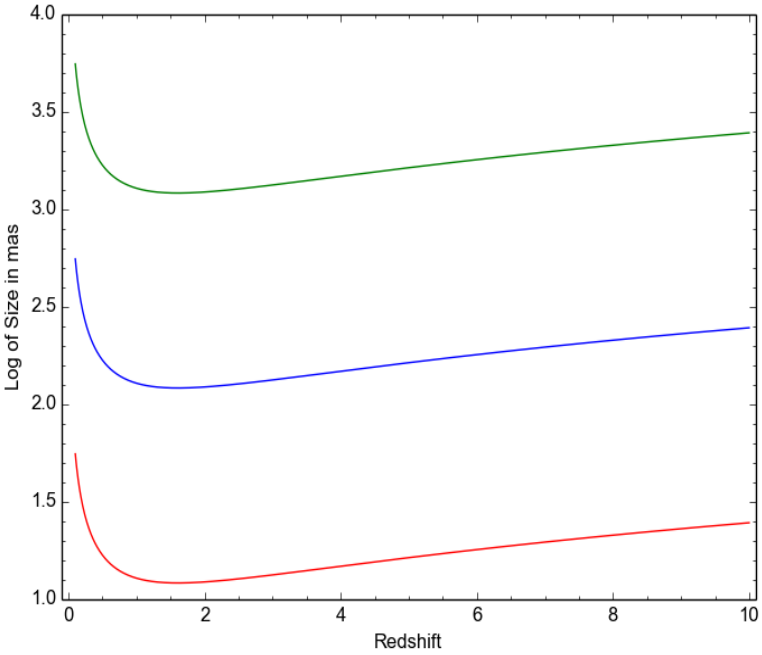


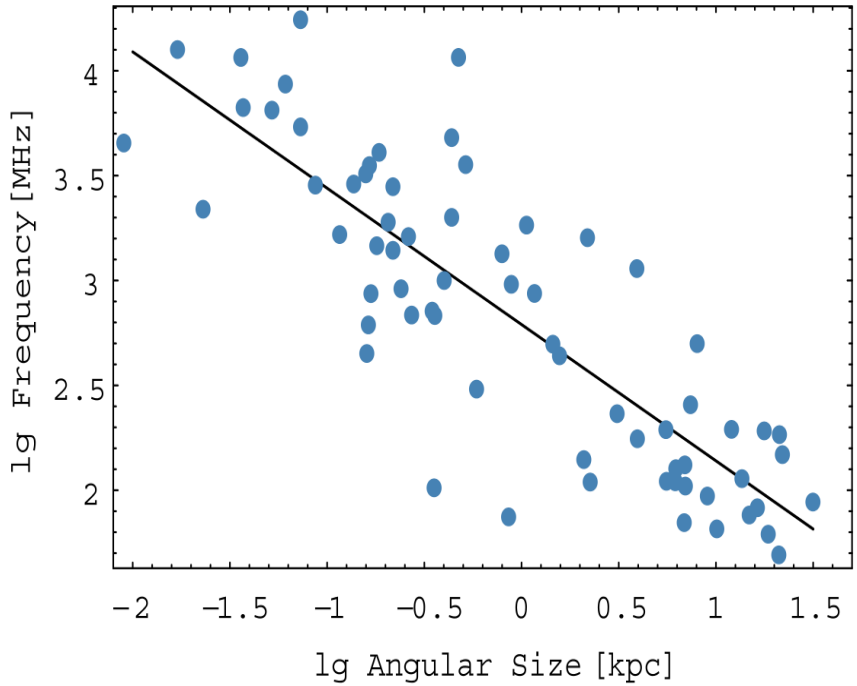
5 GHz VLA image of the FR-II radio galaxy Cygnus A. Cygnus A has a size of ~ 140 kpc and is predicted to have a 1 GHz flux density of 13 mJy at z=8, well within the capabilities of modern radio telescopes. Image courtesy of NRAO/AUI.

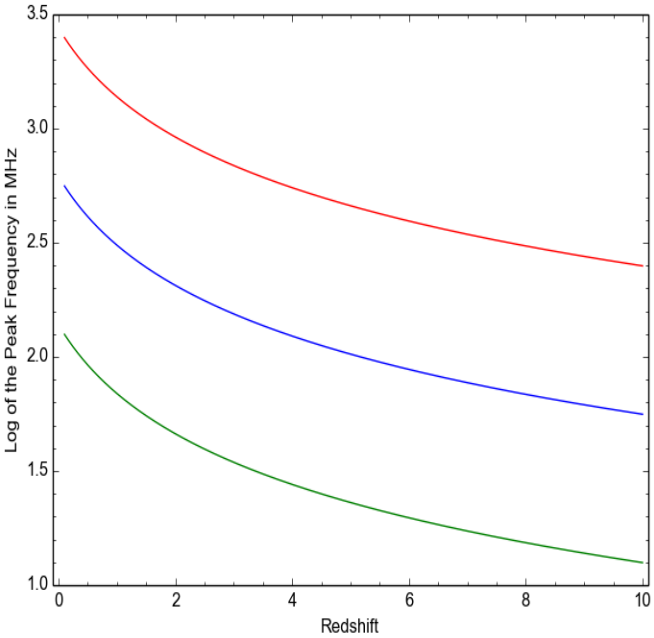
The USS Technique

- Observed correlation between redshift and spectral index (eg. De Breuck et al. 2000).
- This method has proven successful in finding sources out to $z \sim 4$ (eg. Jarvis et al. 2001; Cruz et al. 2006; De Breuck et al. 2006).
- The physical reason for why ultra-steep-spectrum (USS) sources should be at higher redshifts than non-USS sources remains unclear (Miley & De Breuck 2008).
- Observations of the COSMOS field with the VLA found no clear evidence that sources at higher redshift have steeper spectral indices (Smolcic et al. 2014).
- Ker et al. (2012) found that the fraction of $z > 2$ sources is not significantly higher in the sub-sample of USS sources compared to the full sample.

Searching for High-Redshift AGN

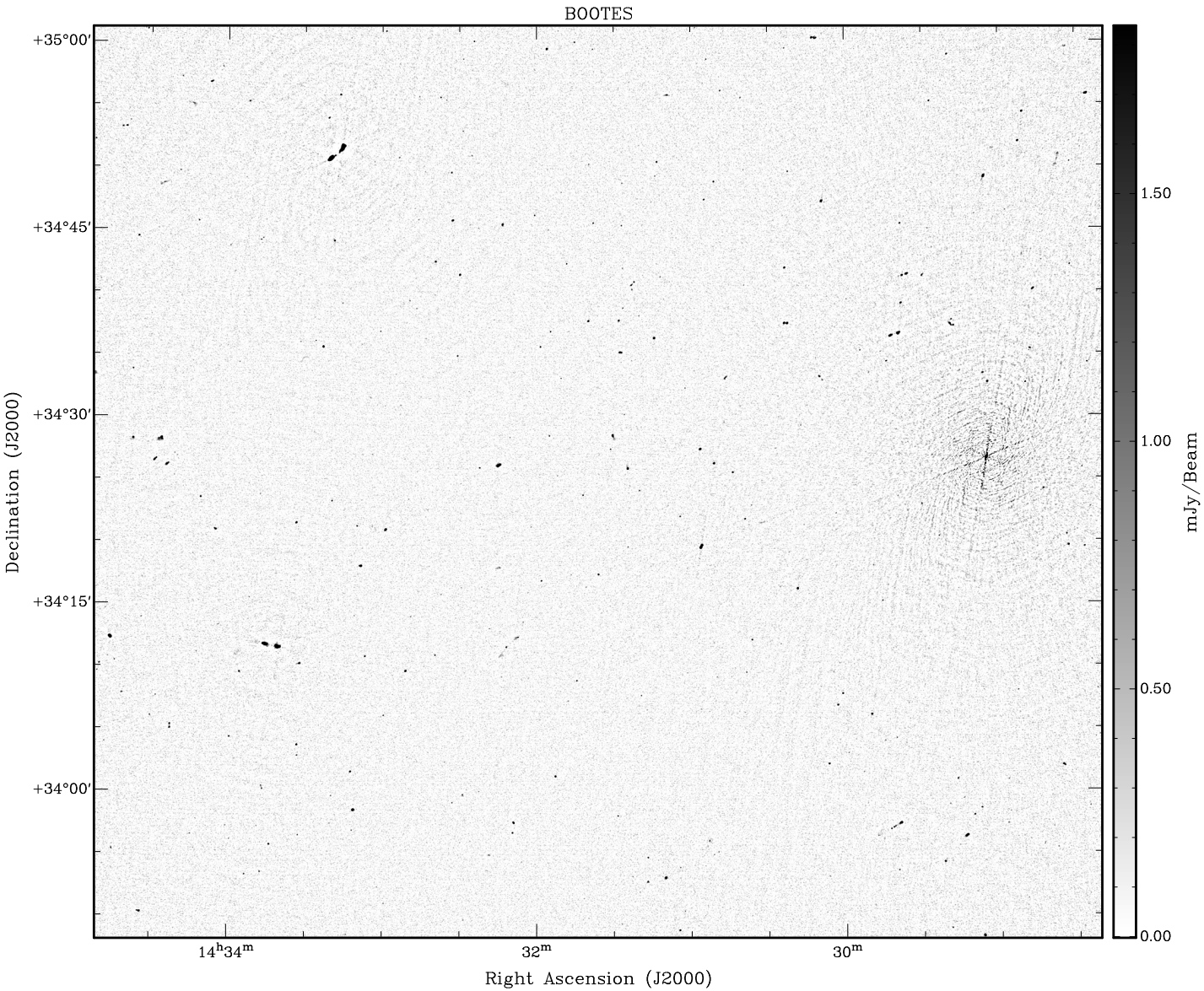






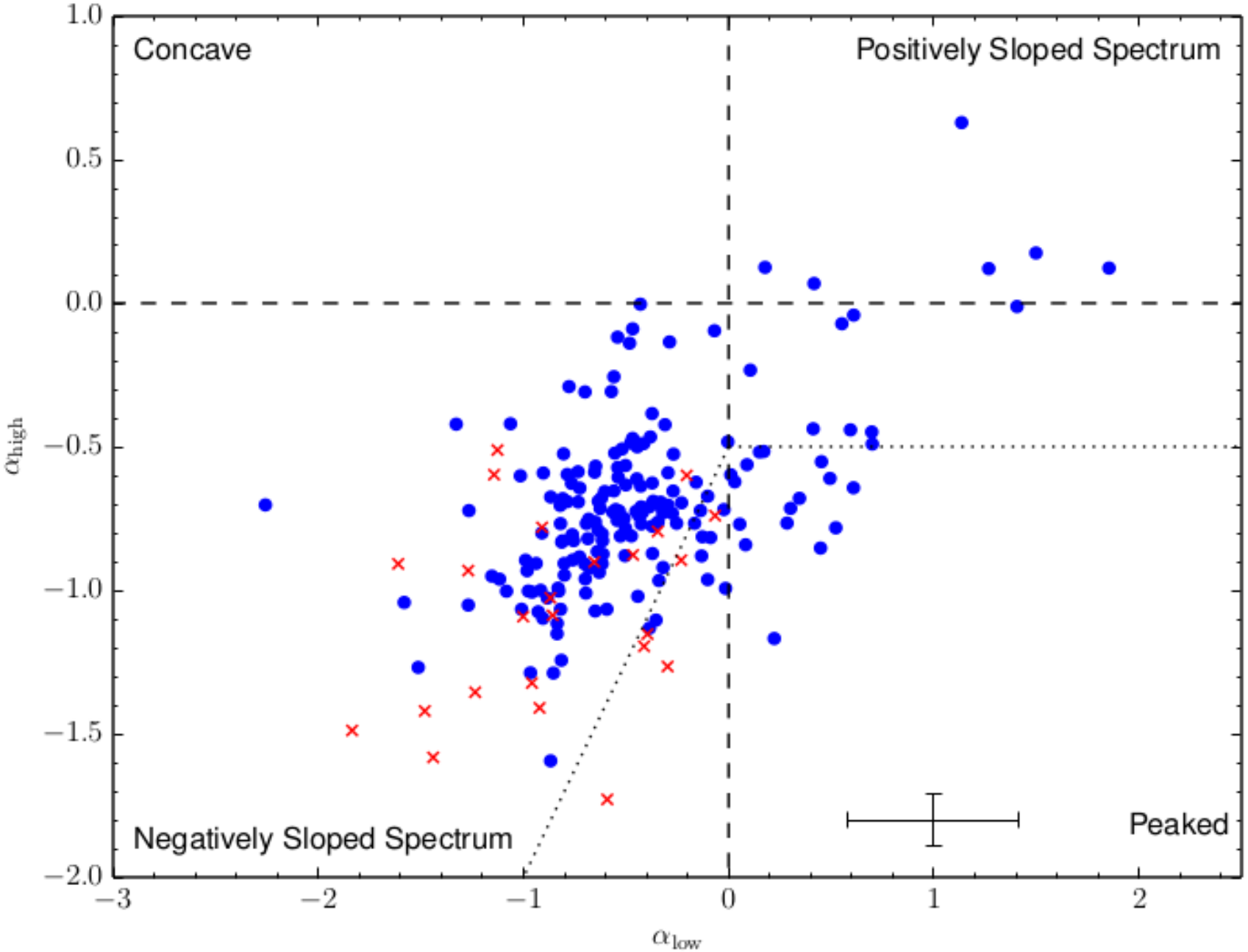
- Top left and bottom: Angular size and peak frequency plotted as a function of redshift for a 0.1 kpc (red), 1 kpc (blue) and 10 kpc (green) source. Top right: The turnover-frequency linear-size relation for GPS and CSS sources, image from Falcke et al. (2004).
- A 100 pc GPS source with peak frequency of 2.7 GHz is expected to appear as a 25 mas source with peak frequency of 245 MHz at $z = 10$.

The Image



- Telescope: VLA P-band
- Total integration time: 20 hours
- Central frequency: 325 MHz
- Central noise: 0.2 mJy/beam
- Resolution: 5.6×5.1 arcsec
- Image size: 4.1°
- Number of sources: 1370

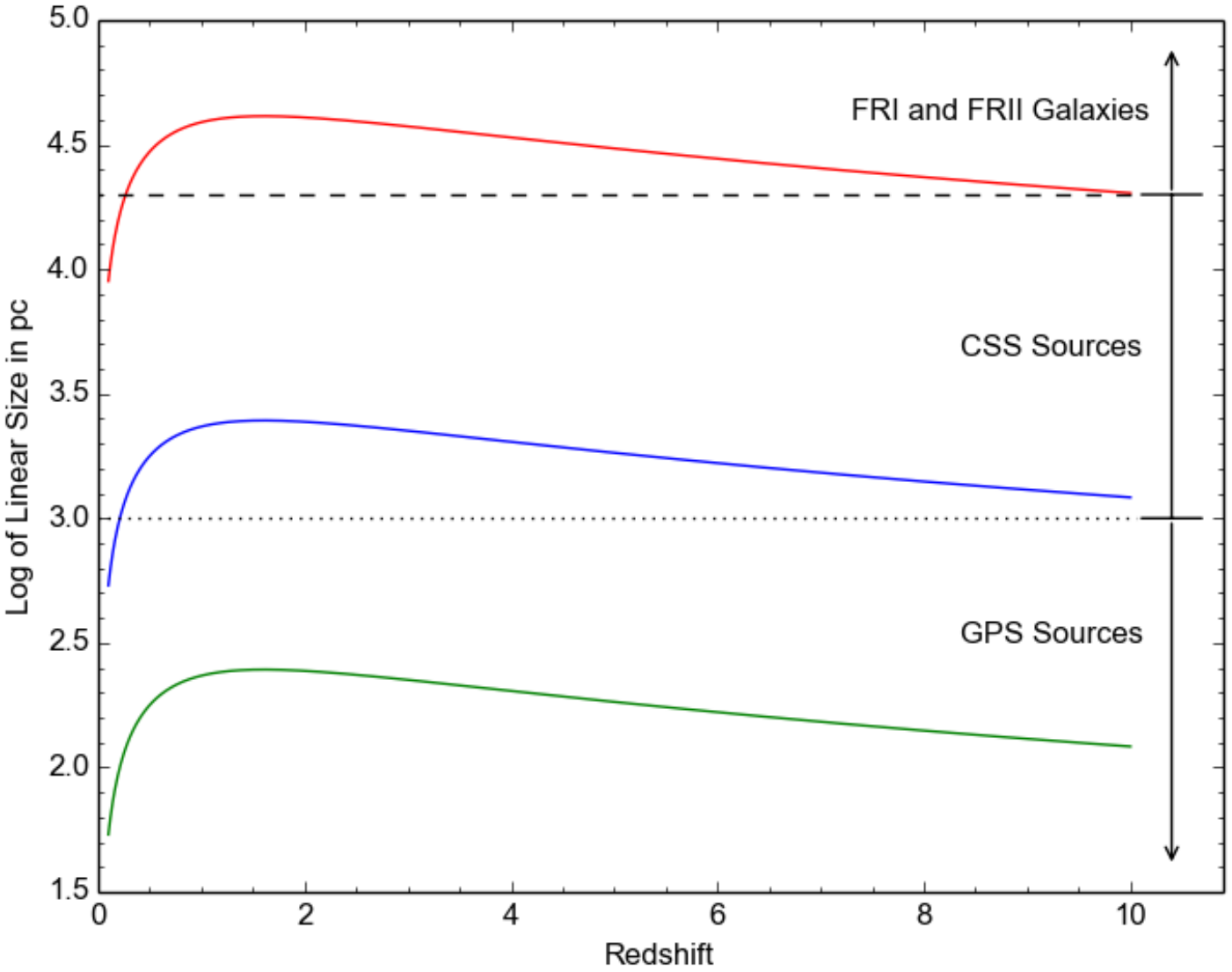
Finding the MPS Sources



Results: Coppejans at al. (2015)

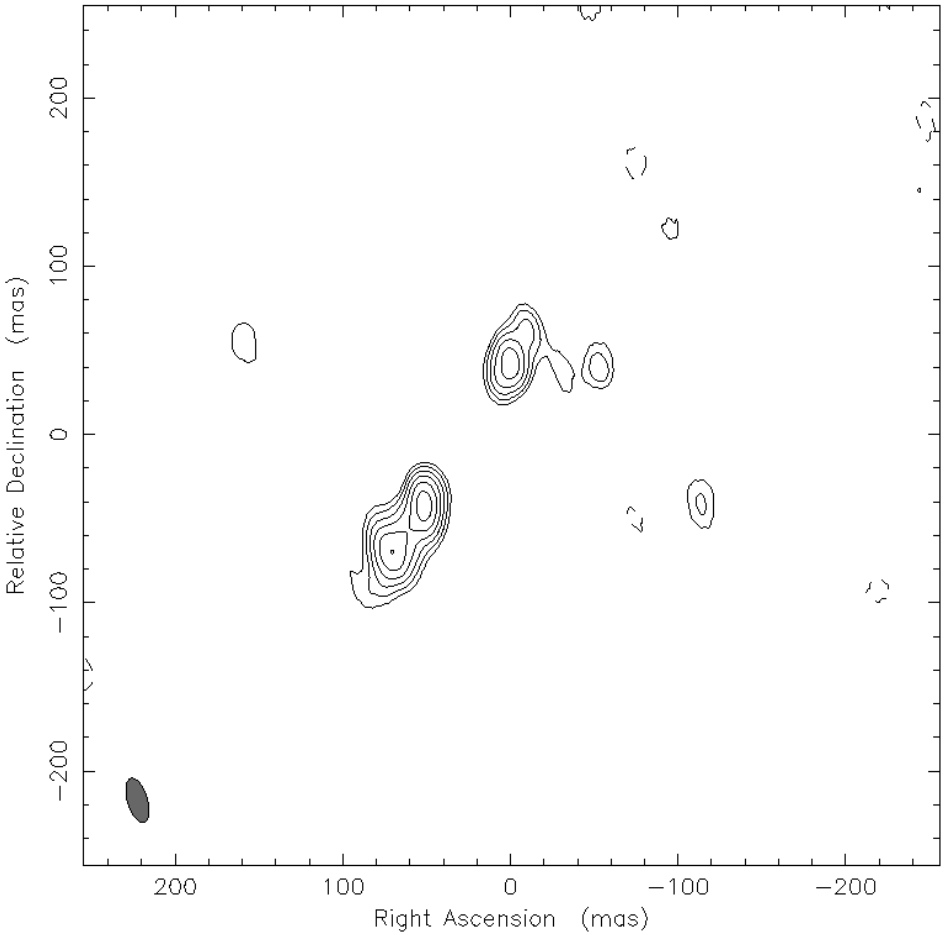
- Of the 33 megahertz peaked-spectrum (MPS) sources, we were able to determine redshifts for 24.
- The redshift values range between 0.1 and 3.2 with a median of 1.0.
- Five of the sources are at $z > 2$.
- Of the nine sources without redshifts, five lie outside the multiwavelength coverage while the remaining four were to faint to be matched and are likely at $z > 2$.
- We expect the high-redshift sources to be compact on scales of tens of milliarcseconds while we could only select sources that are compact on a scale of ~ 5 arcsec.
- We expect that the 11 sources at $z < 1$ are nearby CSS sources.
- Using the same spectral index cut in two different frequency ranges does not select the same group of sources.

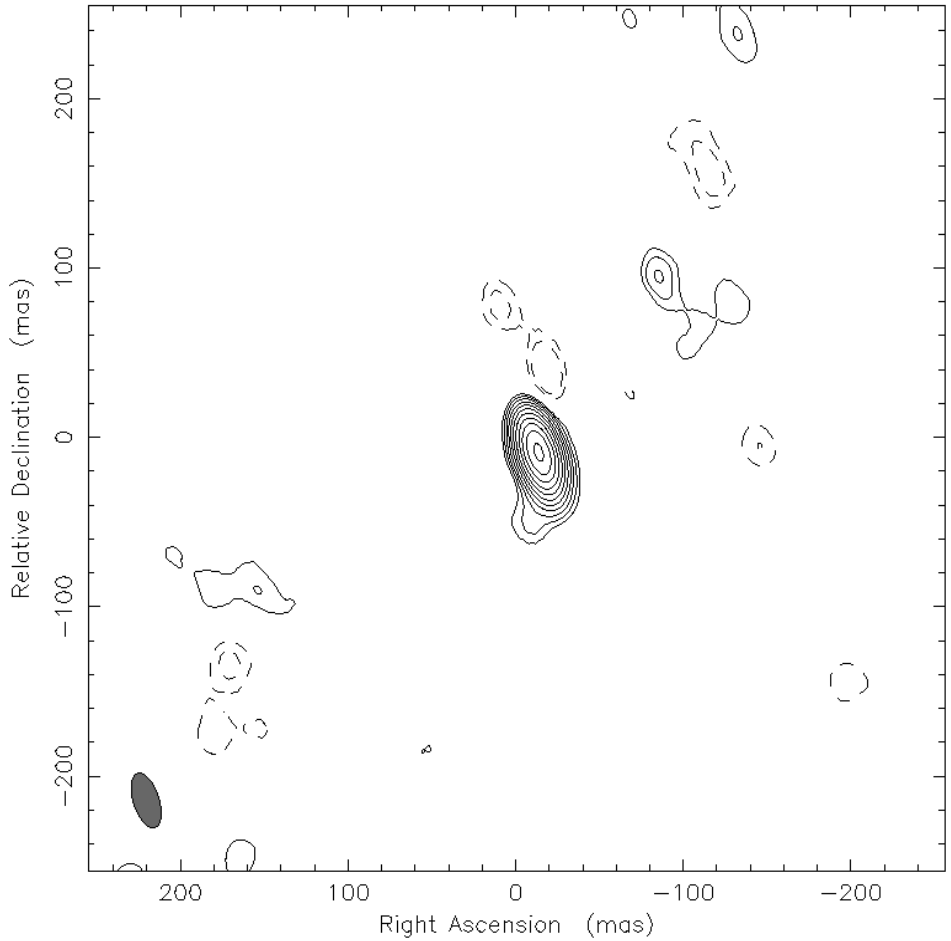
The Next Step



- Red: 5”; FIRST @ 1400 MHz
- Blue: 0.3”; LOFAR @ 153 MHz
- Green: 0.03”; EVN @ 1600 MHz

VLBI follow up





- Eleven sources have so far been observed with the European VLBI Network (EVN) at 1.6 GHz and a proposal have been accepted to observe eight more using LOFAR's long baselines at 153 MHz.

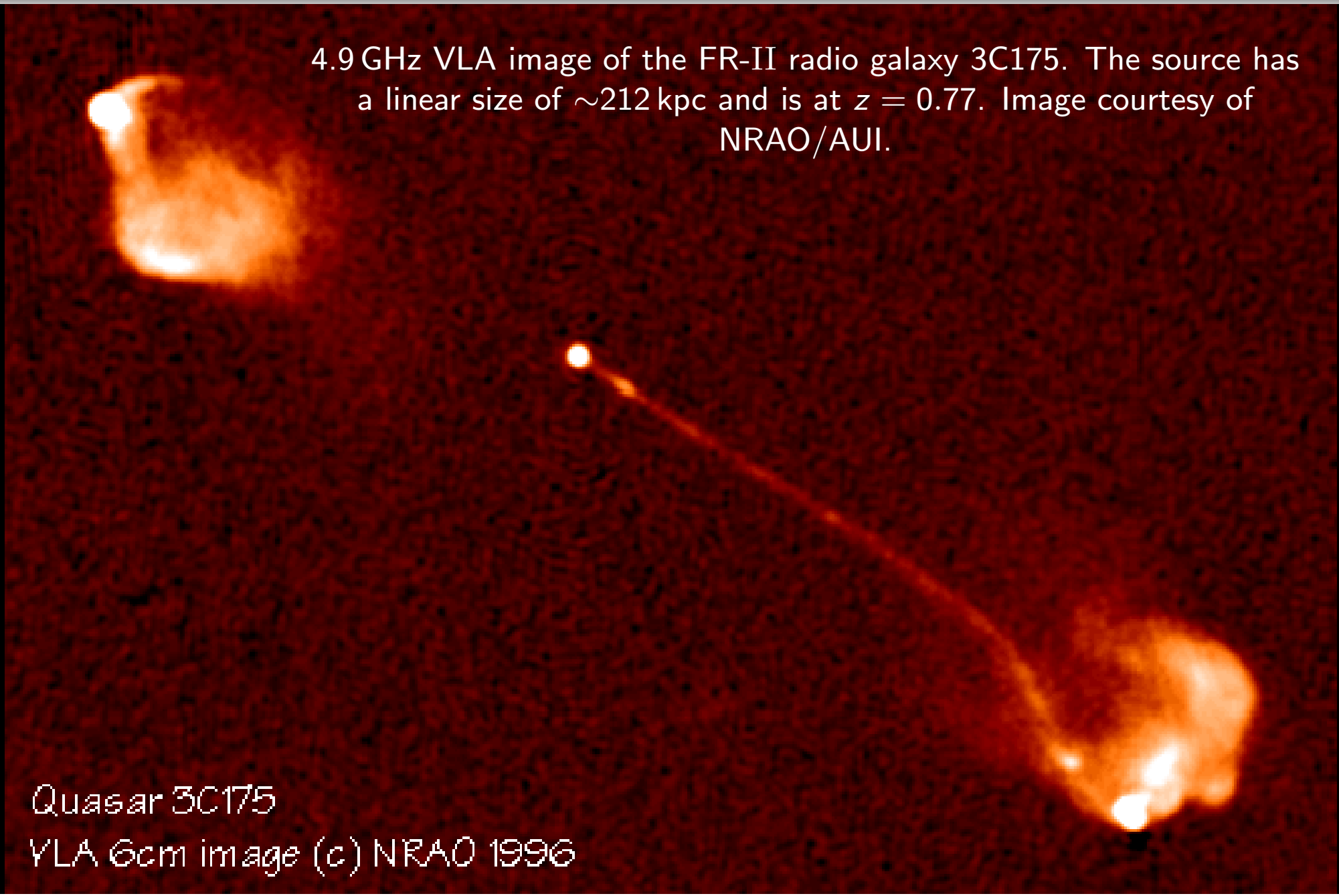
Initial EVN Results

- Of the 11 sources observed with the EVN, two were not detected (rms noise 0.01mJy/beam and 0.02mJy/beam respectively).
- The two sources that were not detected could be variable or extended.
- The 1.4 GHz flux density of the sources varies between 16.3 and 3.1 mJy.
- The photometric redshifts of the eight sources with known redshifts vary between 0.8 and 2.8 with one of the sources being to faint to be matched and likely being at $z > 2$.
- Six of the sources are unresolved at a resolution of 14 mas, two have a dubble structure and one has a triple structure.
- The angular size of the sources vary between 135 mas and < 12 mas while the linear size varies between 1100 pc and < 90 pc.
- Eight of the sources have brightness temperatures greater than 10^6 K while the final (triple) sources has a brightness temperatures greater than 2.5×10^5 K.
- The seven sources that we can place on the turnover-frequency linear-size relation derived by Orienti & Dallacasa (2014) broadly follow it.

Conclusion and Future Work

- There is encouraging evidence that the MPS method can be used to search for high-redshift sources (Coppejans at el, 2015).
- To confirm the MPS method as a way to find high-redshift AGN using radio selection we need to build up a statistically significant sample of MPS sources with known redshifts and angular sizes.
- Confirm the photometric redshifts with spectroscopy (specifically for the sources without photometric redshifts).
- The greatest challenge to finding MPS sources are that there are very few high resolution ($<$10 arcsec), high sensitivity ($<$0.5 mJy/beam) surveys at low frequencies ($<$1 GHz).
- LOFAR is ideal for searching for MPS sources.
- By building up a large enough sample of MPS sources, we hope to test whether the turnover-frequency linear-size relation holds at high redshifts.

Thank You



4.9 GHz VLA image of the FR-II radio galaxy 3C175. The source has a linear size of $\sim$212 kpc and is at $z = 0.77$. Image courtesy of NRAO/AUI.