Radio luminosity function at $z = 6$ and the future of 21cm absorption studies

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• **Introduction**: Why $z > 6$ radio galaxies?

• Finding radio galaxies at high redshifts

• Description of the analytical modelling of the radio luminosity function at $z = 6$

• **Results**: observable number density and number counts prediction and comparison

• Bonus: High-Z Extreme Spectrum Project (HiZESP)
Why \( z \geq 6 \) radio galaxies?

\( z \geq 6 \) RGs can help study the reionisation process!

A 21cm absorption feature in the continuum spectrum is a signature of neutrality and phase transition of the IGM.

What is the Reionization Era?
A Schematic Outline of the Cosmic History

- The Big Bang
  - The Universe filled with ionized gas
- The Universe becomes neutral and opaque
  - The Dark Ages start
- Galaxies and Quasars begin to form
  - The Reionization starts
- The Cosmic Renaissance
  - The Dark Ages end
- Reionization complete, the Universe becomes transparent again
- Galaxies evolve
- The Solar System forms
- Today, Astronomers figure it all out!
Laboratories for early structure formation and clustering

Deep HST ACS image of the high-redshift radio galaxy (HzRG) “Spiderweb”, at the centre of a protocluster at $z = 2.2$ (Miley et al. 2006)
Laboratories for early structure formation and clustering

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Such systems are instrumental in studying massive galaxy formation and AGN feedback
Radio sources at highest-z
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Highest-z radio galaxy known, $z = 5.19$ (van Breugel et al. 1998)
Radio sources at highest-$z$

K-band image with radio contours superimposed

$\alpha (365-1400) = -1.63$

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Two observing modes - LBA and HBA

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Before merrily pointing the telescope and hoping for the best, let us try and model what we might see at high redshifts...
Radio luminosity function at $z = 6$

Radio galaxies, like quasars, are powered by accretion on to the central supermassive black hole.

Black hole mass and accretion rate have an important effect on the jet power, and thus, the radio luminosity of an object.

Model (the thin accretion disk solution)!

$$Q_{jet} = 2 \times 10^{45} \left( \frac{M_{BH}}{10^9} \right)^{1.1} \left( \frac{\lambda}{0.01} \right)^{1.2} a^2$$

(Blandford & Znajek, 1977; Meier, 2002, Orsi et al. 2016)
Radio luminosity evolution: model prescriptions
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2. Synchrotron emission losses: dominate early in the life-time of a source when the lobe size is small and the magnetic field strength around the black hole is high.
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4. Inverse Compton losses due to interaction with the CMB. Once the sources is large enough, CMB photons (which are hotter at high-$z$) begin to play a role.
Turn the crank -> Results
Input: black hole masses and Eddington ratios at $z=6$, taken from the fantastic work of Willott et al. (2010)
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Number density prediction

Taking the luminosity function at a mean source age of 1.92 Myr…
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Number densities for objects with 5\sigma detection at a noise level of 0.1 mJy at 150 MHz.
Number density prediction

Taking the luminosity function at a mean source age of 1.92 Myr...

Number density compared with a simple power law evolution model.

The $z = 2$ radio luminosity function is evolved using a power-law consistent with optically selected quasar density evolution, which is better constrained at $z > 5$.

Evolutionary parameter $q = -0.47$

Number densities for objects with 5σ detection at a noise level of 0.1 mJy at 150 MHz
Number counts prediction and comparison

![Graph showing number counts prediction and comparison with different noise levels: 100 μJy, 30 μJy, 10 μJy, and an analytical model at 100 μJy. The graph plots N(z)/sq. deg. against Redshift (z).]
Number counts prediction and comparison

The LOFAR ‘Large Area’ survey is the best to detect a large number of HzRGs at $z > 6$!
Summary

• Radio galaxies, especially at high redshifts, are important laboratories to study the epoch of reionisation and massive galaxy and proto-cluster formation.
• We have constructed a model to predict the radio luminosity function at $z=6$ taking into account simple energy loss prescriptions.
• The model takes black hole mass function and Eddington ratio distribution as input and in principle, can be extended to every redshift.
• The model predictions match remarkably well with a power law density evolution consistent with optical quasars.

To do:
• Introduce orientation angles in the luminosity function calculation.
• Spectral aging?
HiZESP!

We have a large observational program in place!
The High-Z Extreme Spectrum Project

Initial analysis based on the TGSS ADR (Intema et al. 2016). Analysed the area co-inciding with the FIRST survey to look for potential HzRGs.

Found interesting candidates and follow-up high-res radio and K-band imaging proposals are in the pipeline!
Thanks and stay tuned!
Backup

Growth of lobe size:

\[ D = c_1 \left( \frac{Q_{\text{jet}}}{\rho a^\beta} \right)^{1/(5-\beta)} t^{3/(5-\beta)} \]

Synchrotron losses, max radio power:

\[ P_\nu = \frac{m_e c^2 f_n}{6\sqrt{A_\nu}} Q_{\text{jet}} \]