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

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LOFAR Science Meeting

5 April 2016

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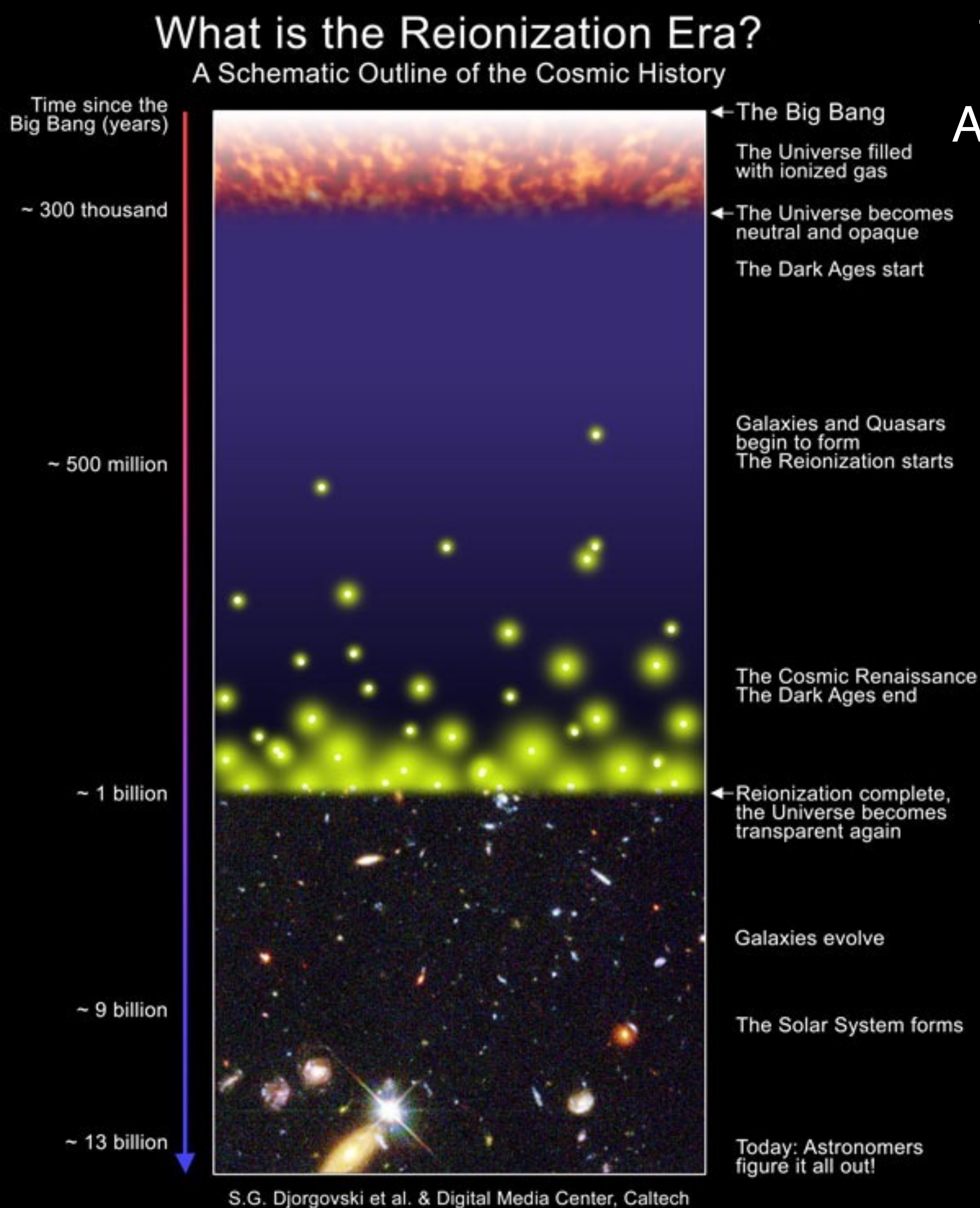
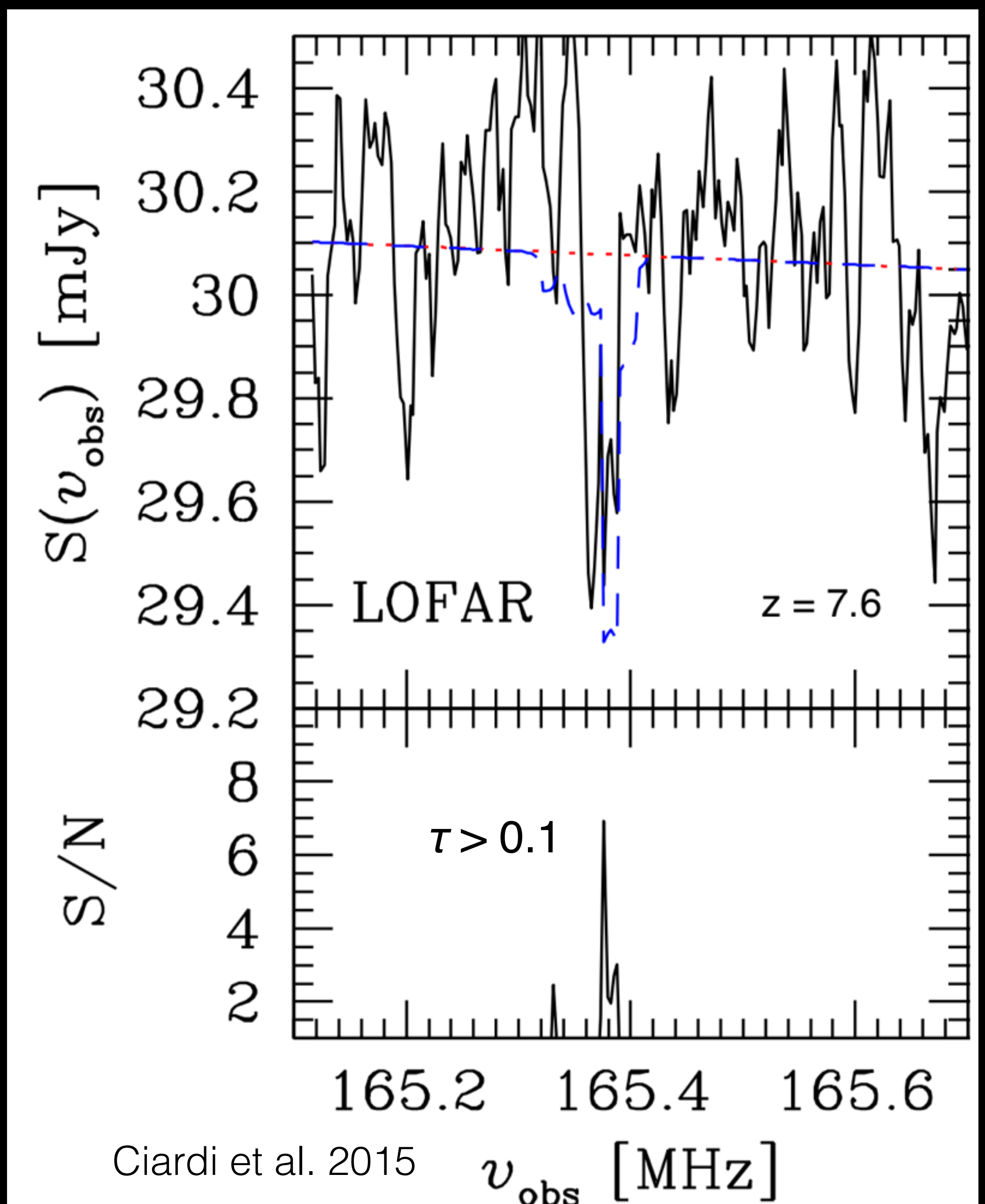
- Finding radio galaxies at high redshifts
- Description of the analytical modelling of the radio luminosity function at $z = 6$
- **Results**: observable number density and number counts prediction and comparison
- Bonus: High-Z Extreme Spectrum Project (HiZESP)

Why $z \geq 6$ radio galaxies?



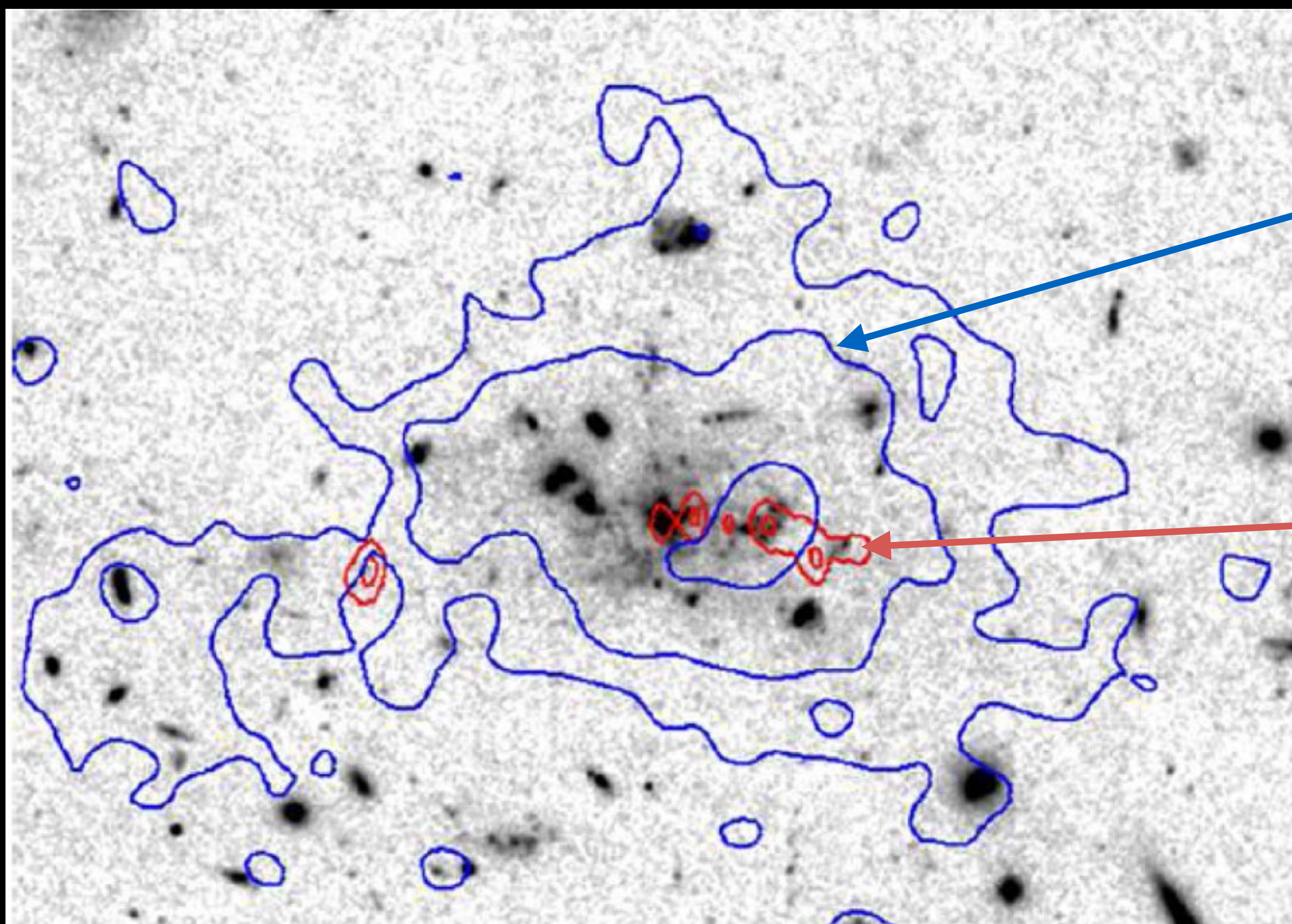
$z \geq 6$ RGs can help study the reionisation process!

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



Ciardi et al. 2015

Laboratories for early structure formation and clustering



Ly-α contours

VLA 8 GHz radio contours

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)

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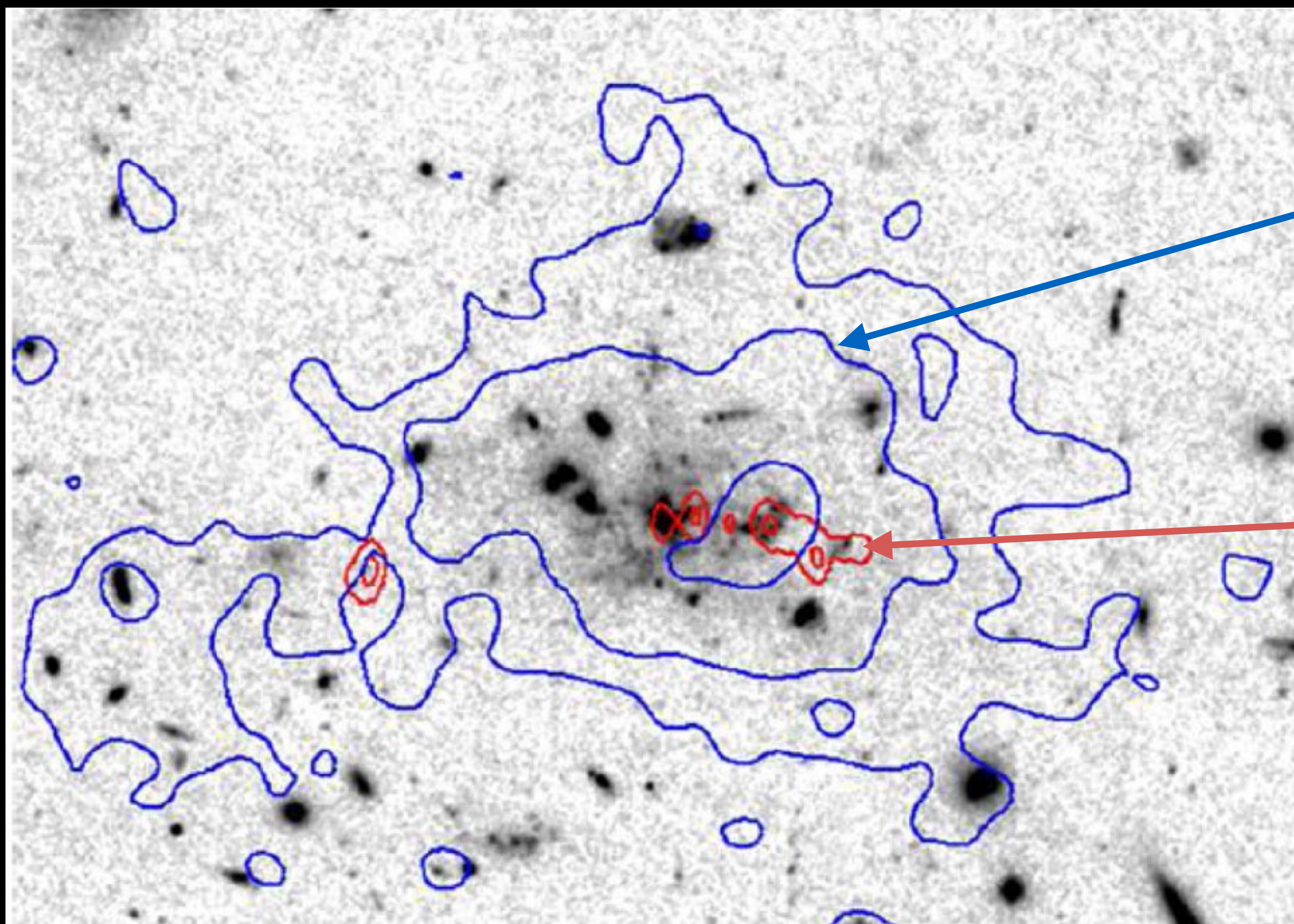

Deep HST ACS image of the high-redshift radio galaxy (HzRG) “Spiderweb”, at the centre of a protocluster at z = 2.2 (Miley et al. 2006)

Such systems are instrumental in studying massive galaxy formation and AGN feedback

Radio sources at highest-z

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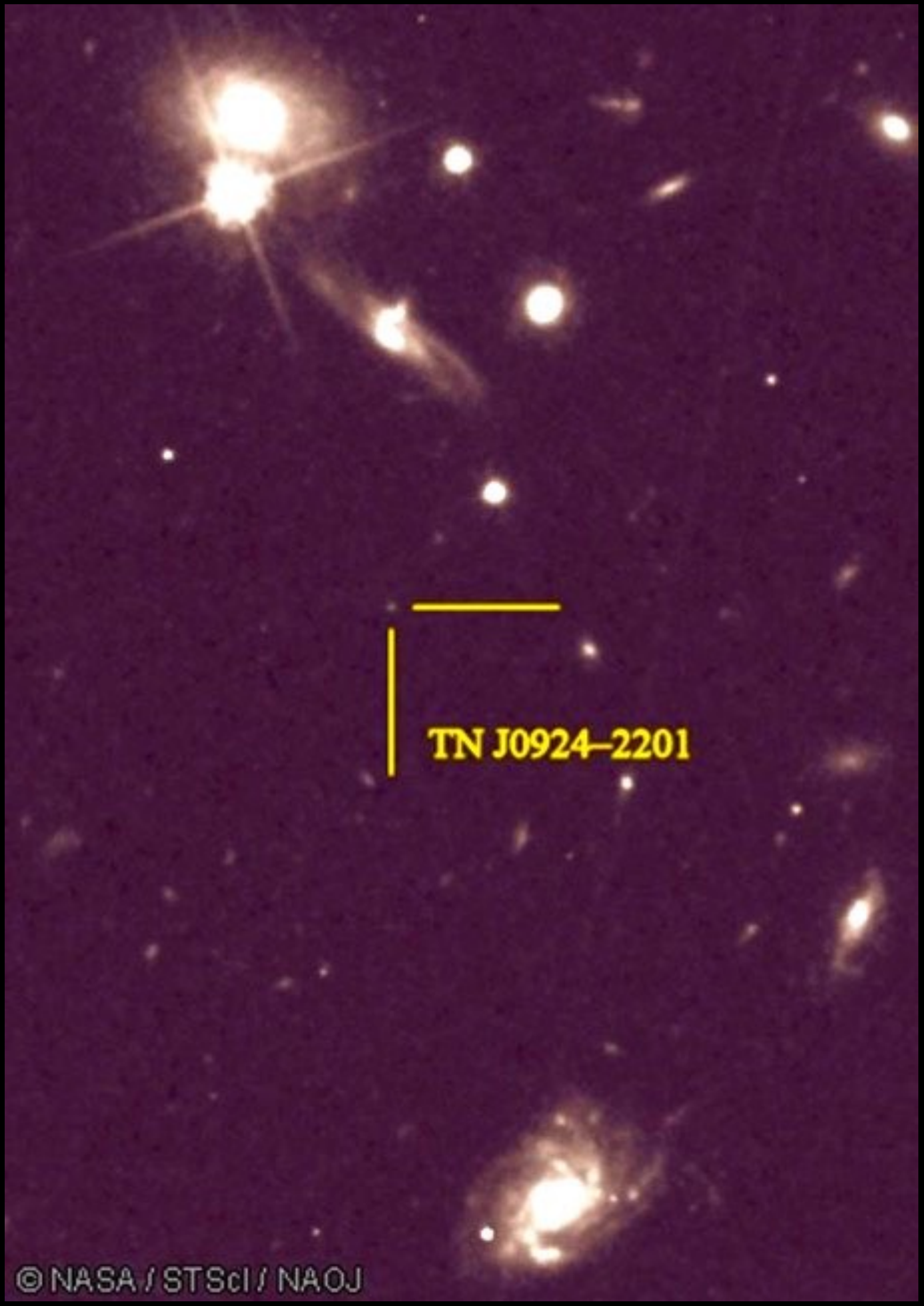

Highest-z radio galaxy known, z = 5.19 (van Breugel et al. 1998)

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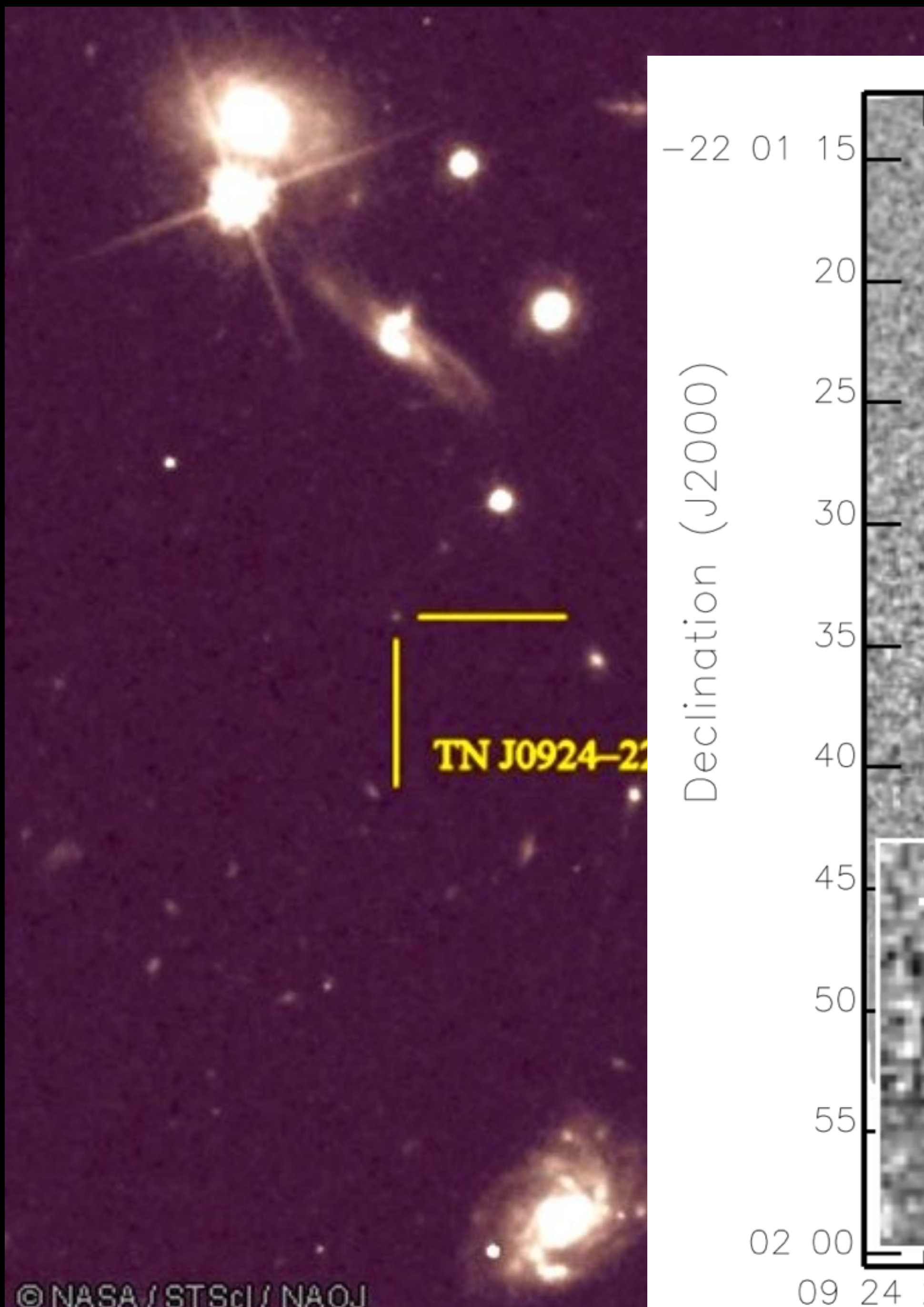

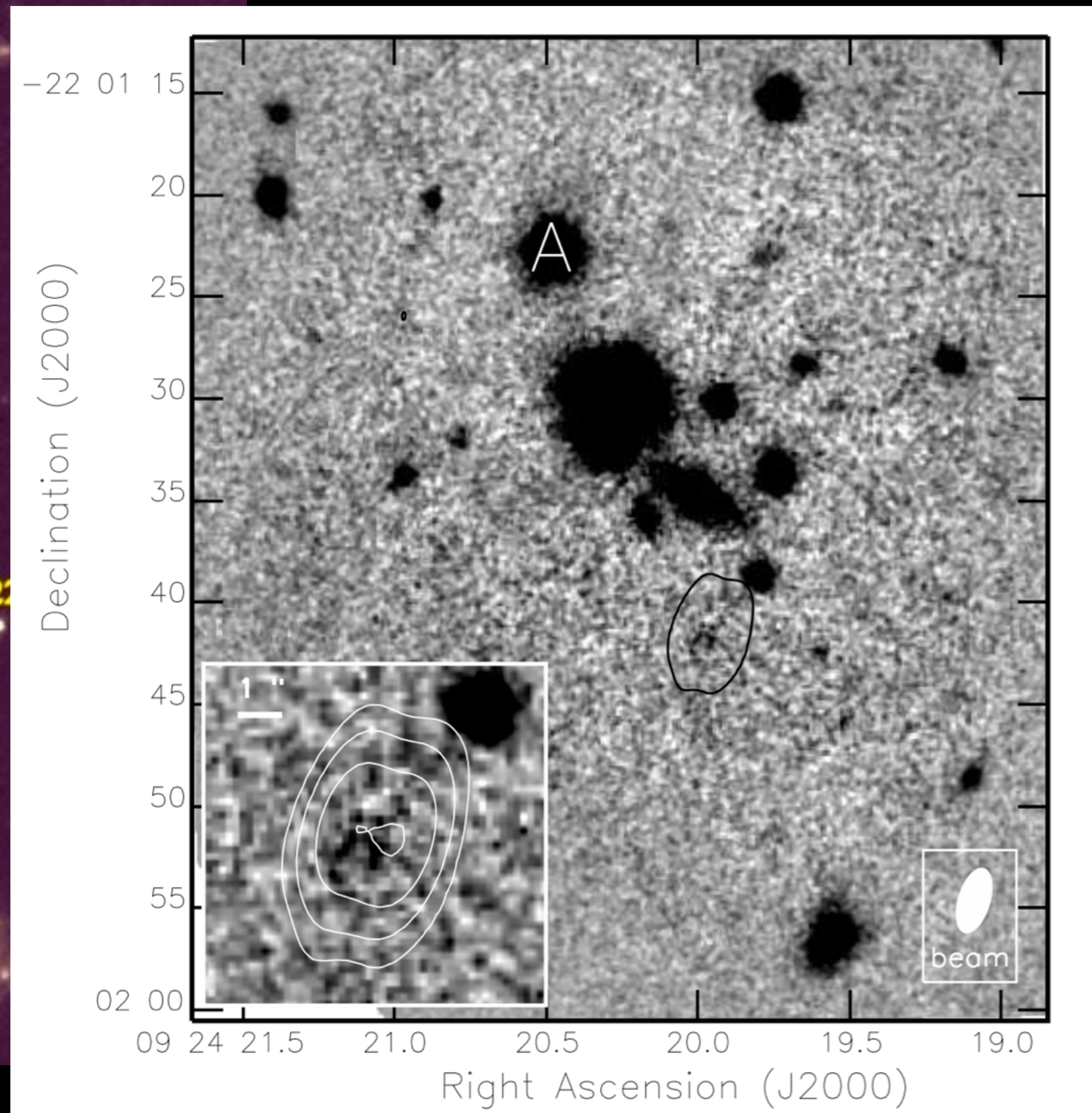

K-band image with radio contours superimposed

α (365-1400) = -1.63

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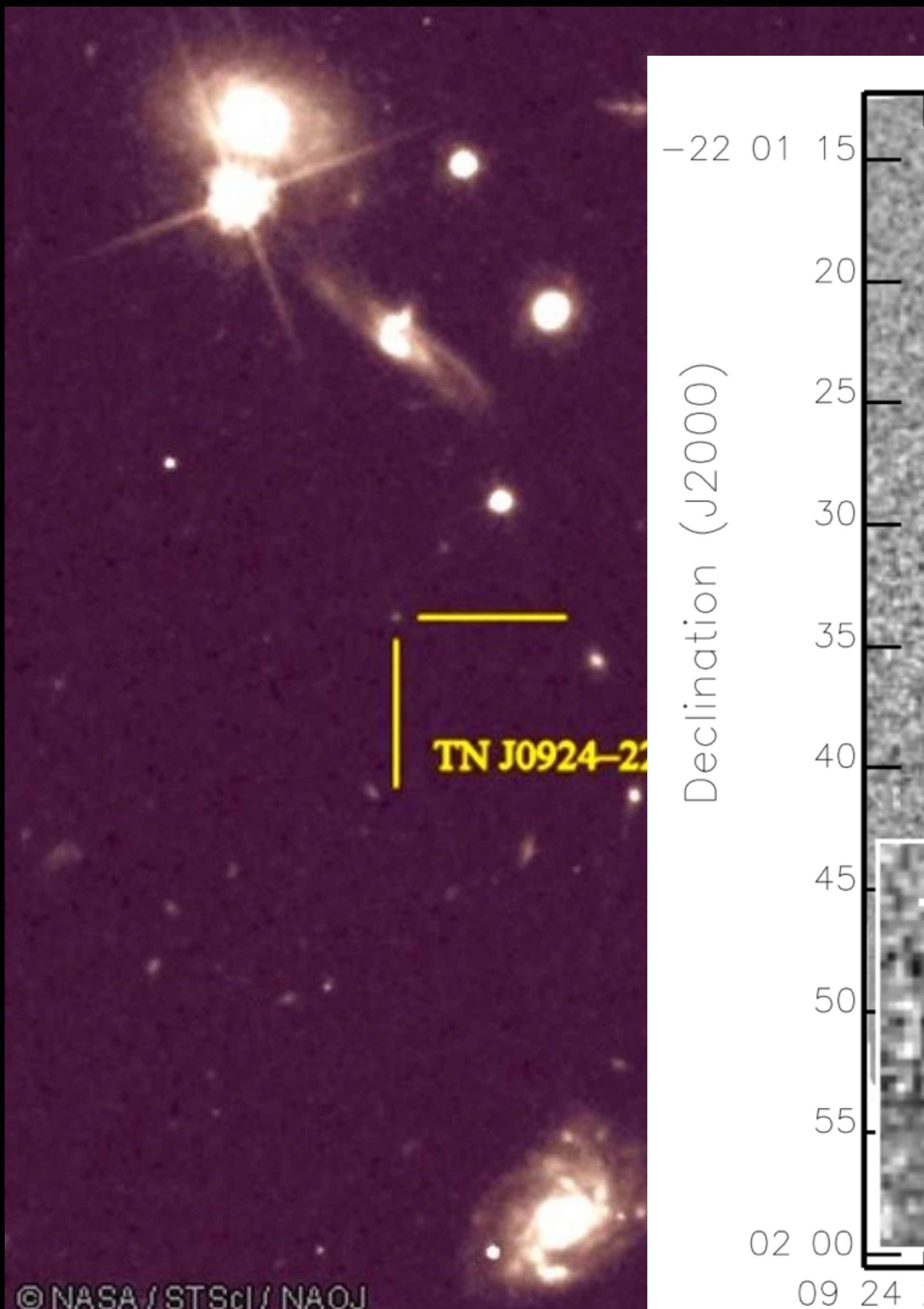

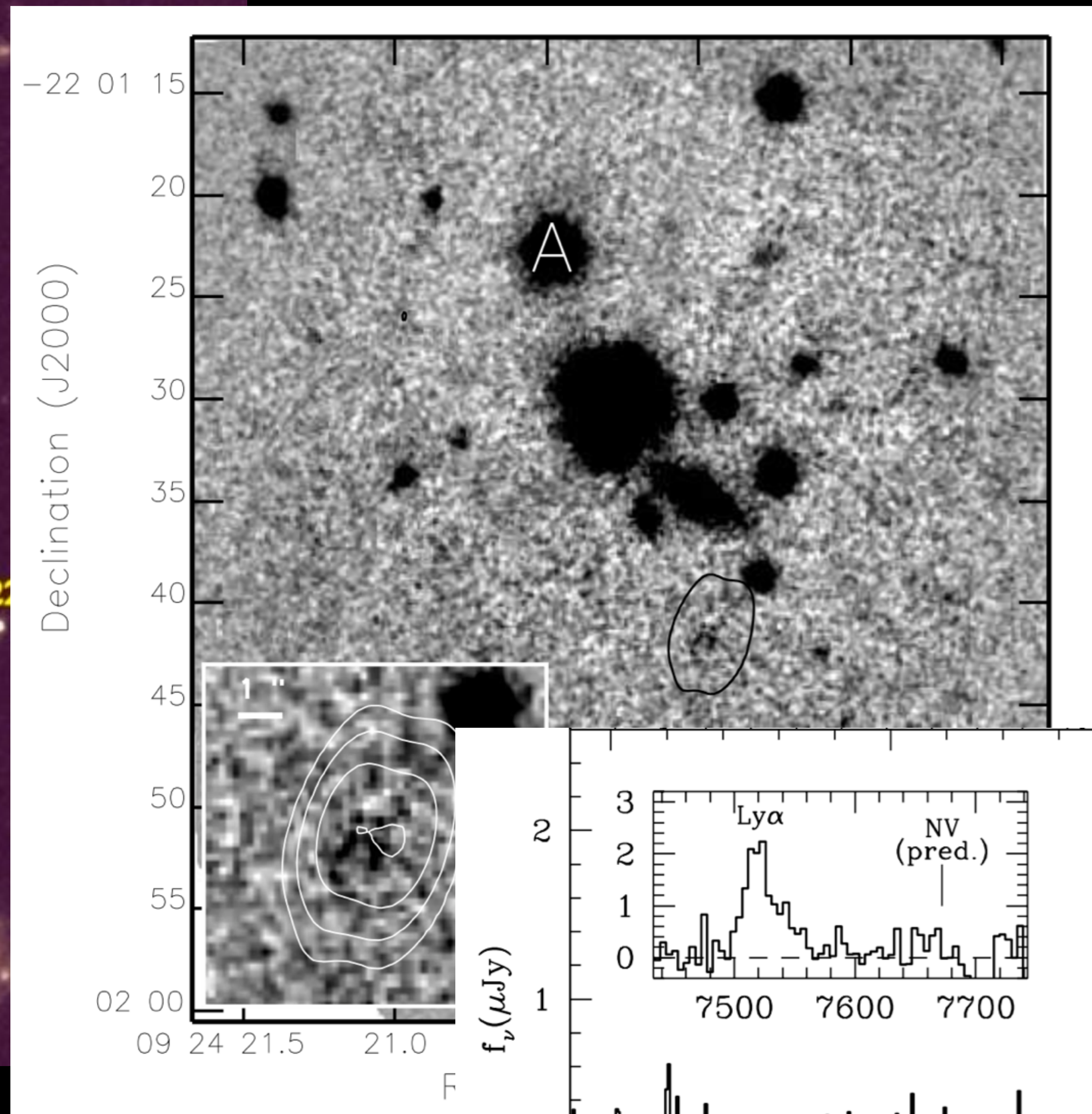

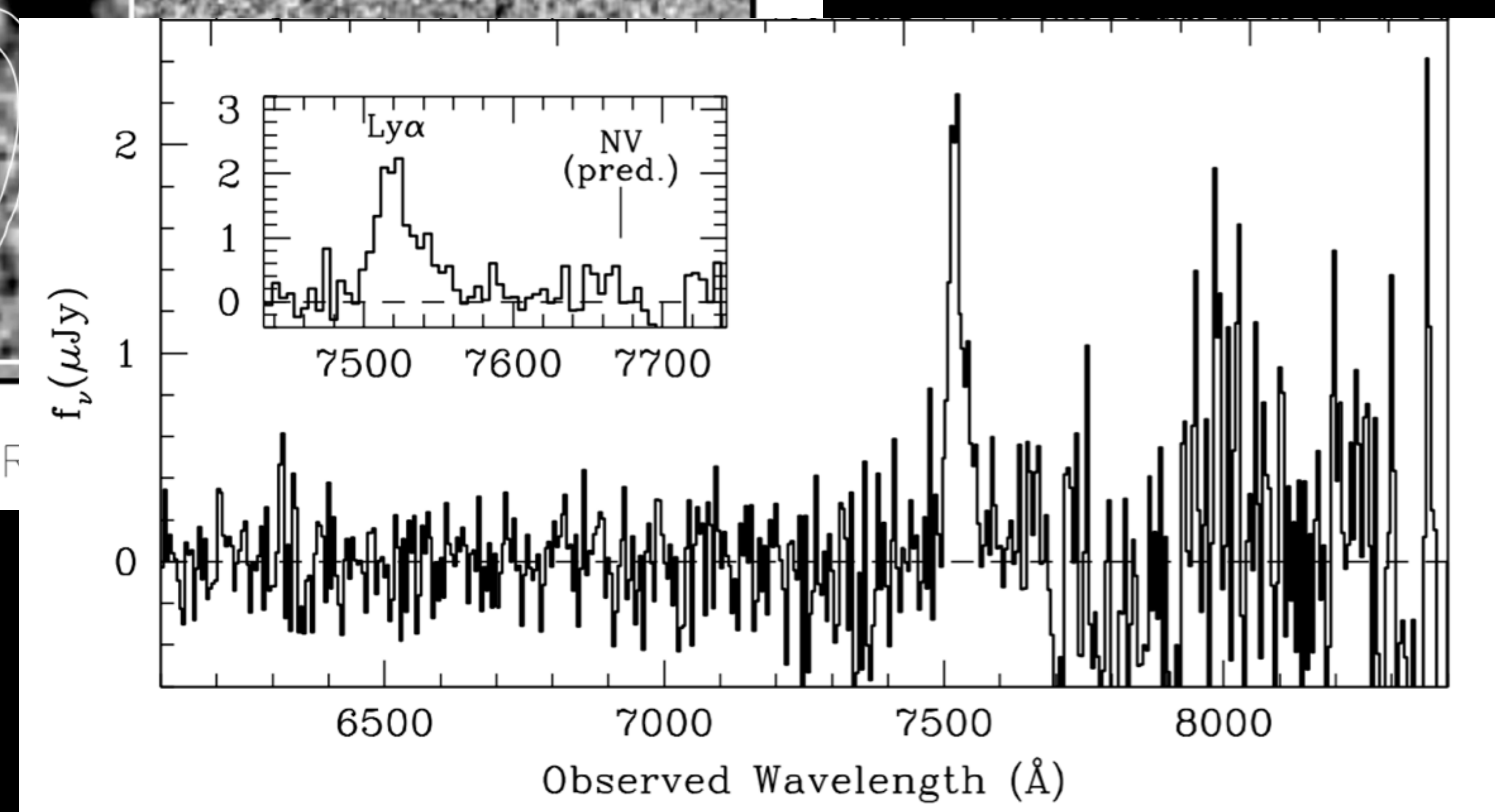

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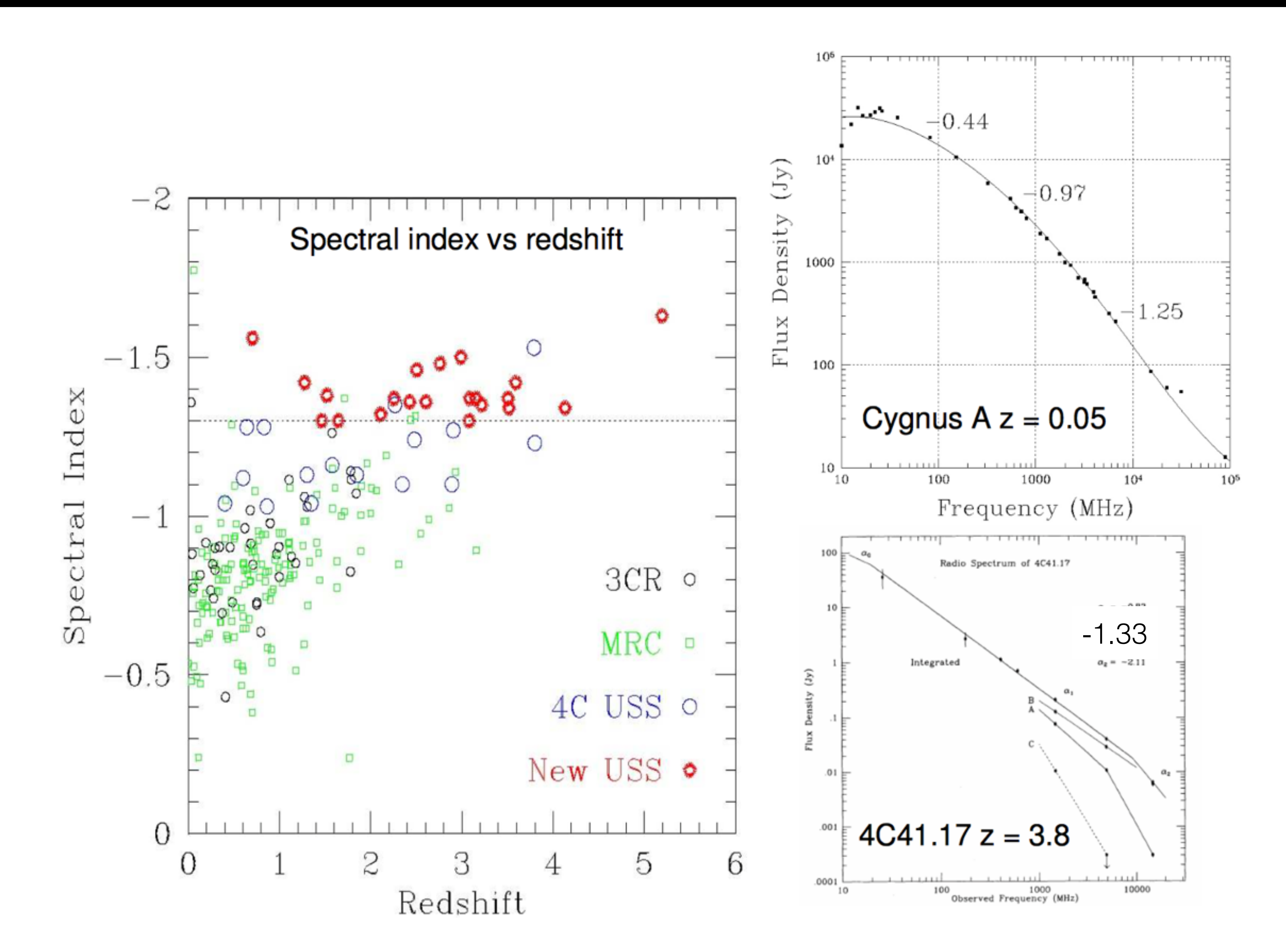

Observed steepening of spectral index with redshift suggests high-z radio sources are brighter at low frequencies (Miley & De Breuck review

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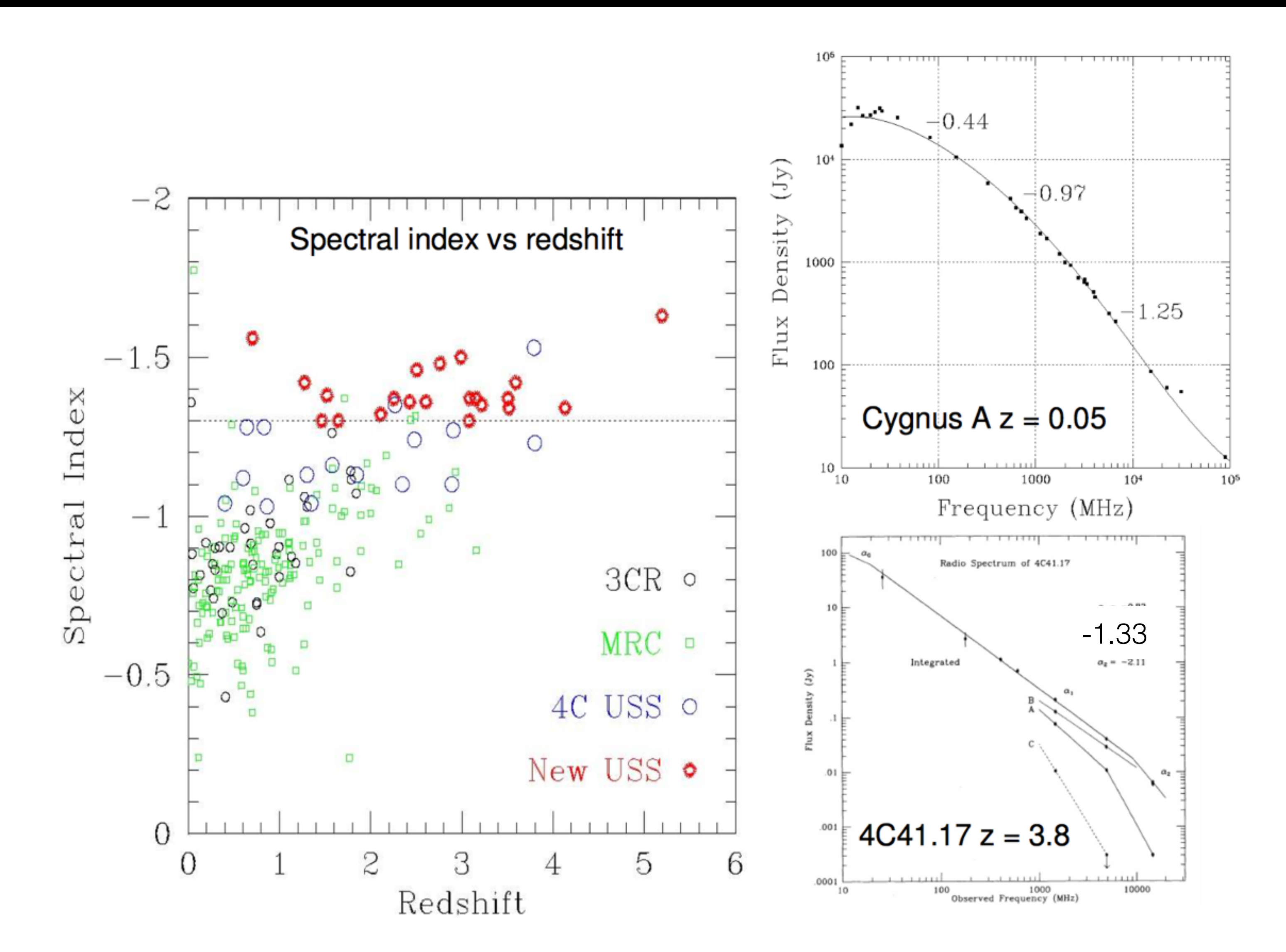

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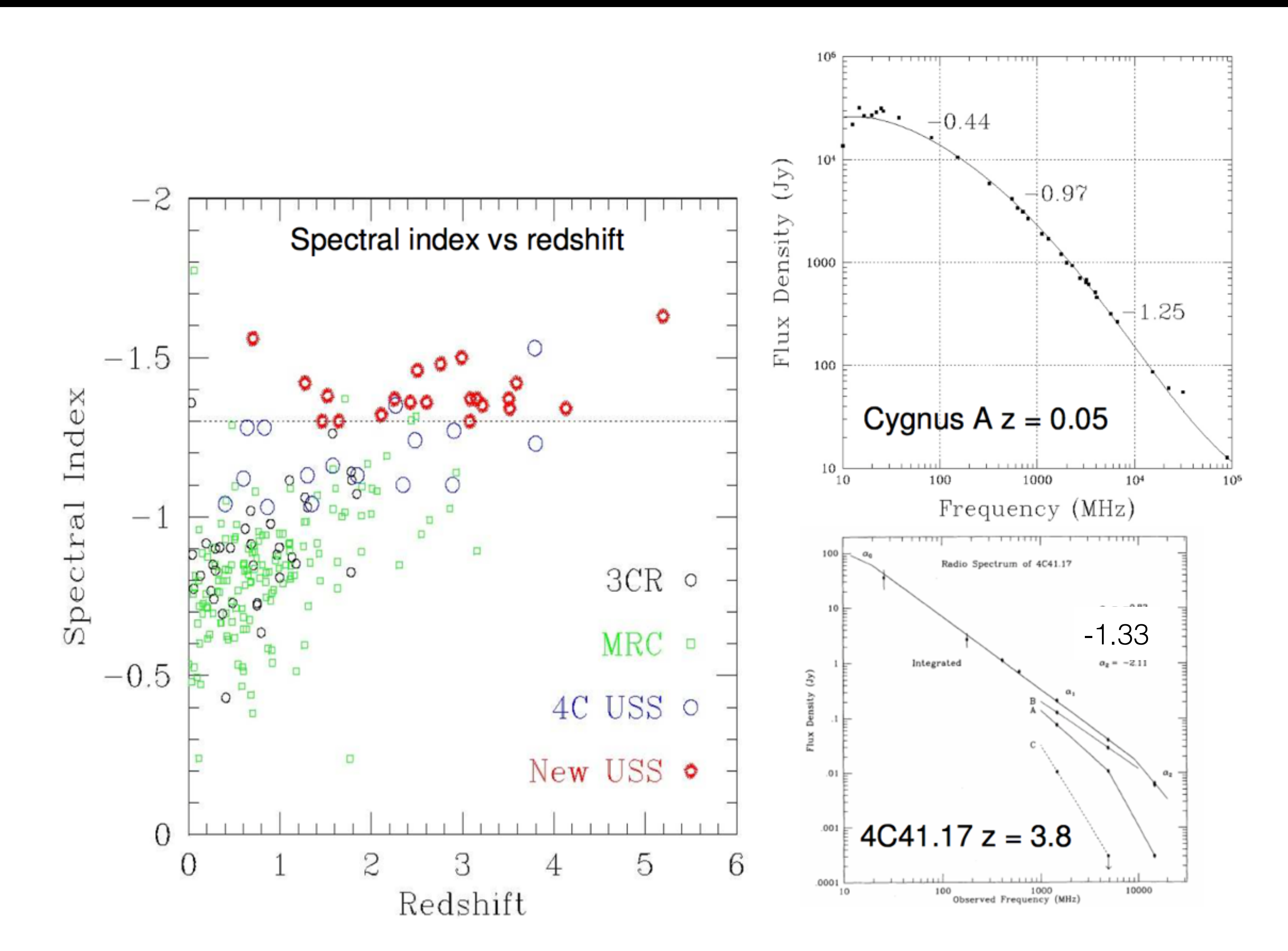
LOFAR all-sky surveys will offer unparalleled sensitivities at low frequencies

Two observing modes - LBA and HBA

Low radio frequency surveys for HzRG searches



LOFAR all-sky surveys will offer unparalleled sensitivities at low frequencies

Two observing modes - LBA and HBA

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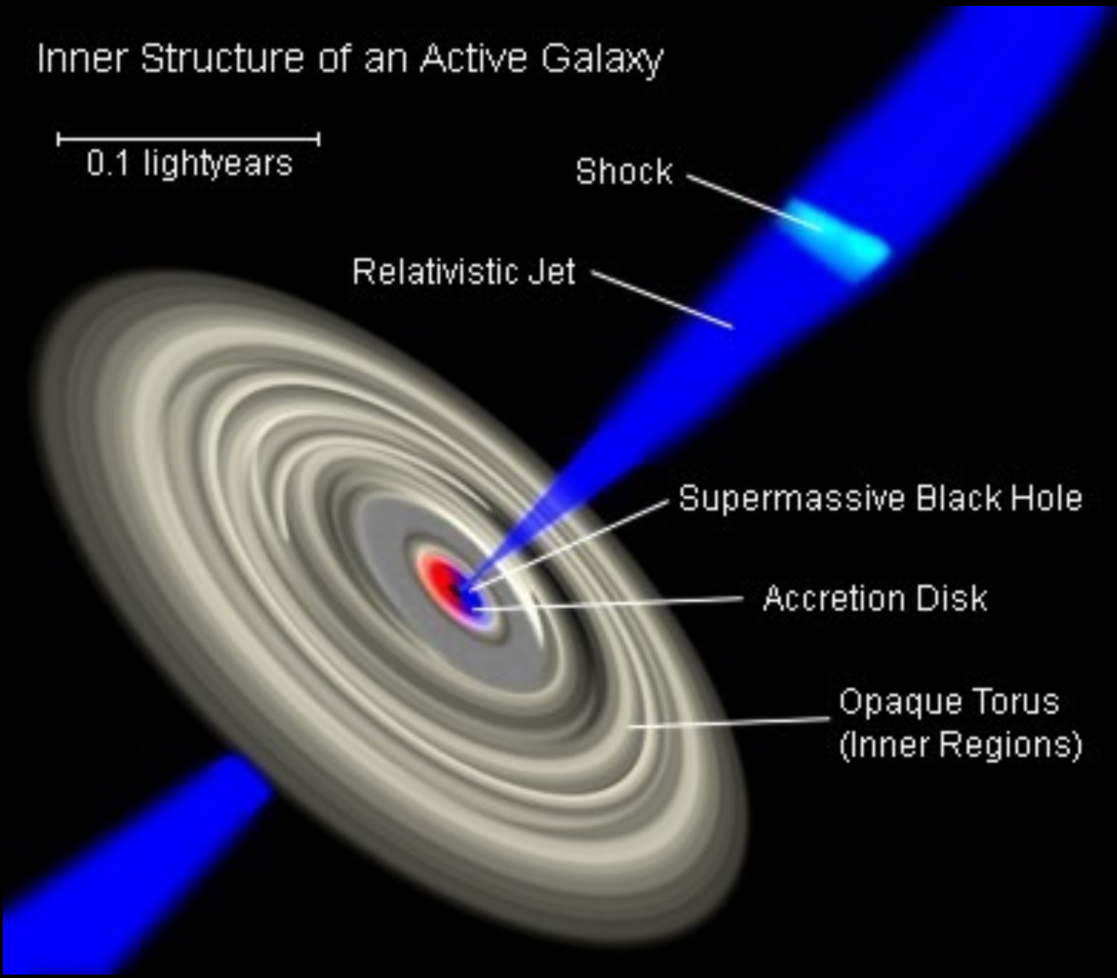
The Swedes love the HBA antenna!

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

Based on Kaiser & Best (2008)

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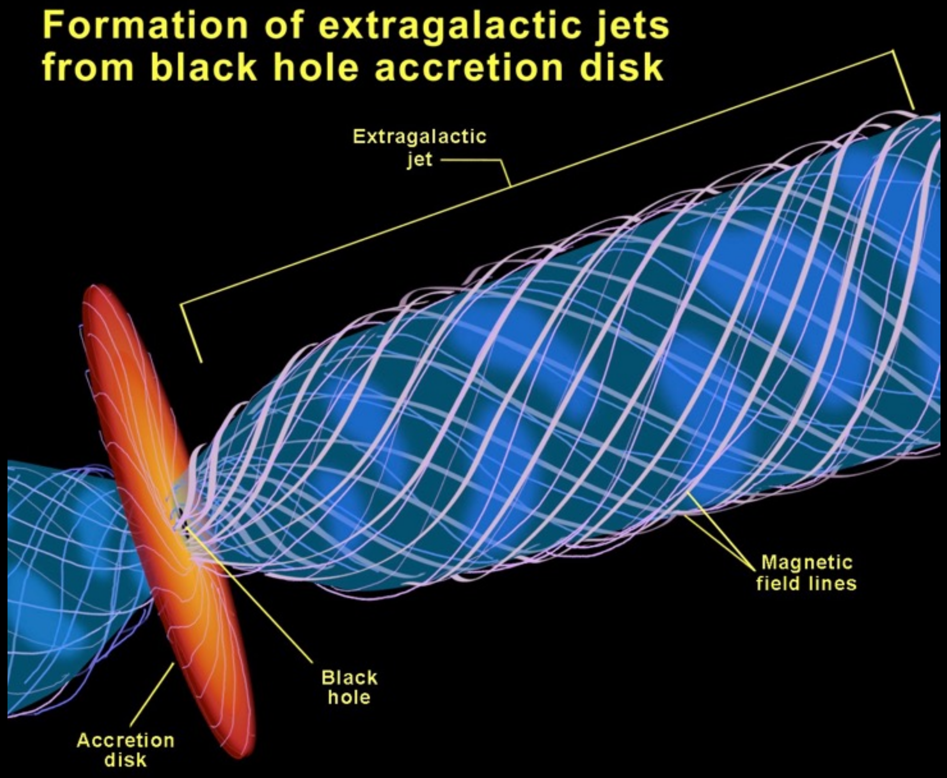

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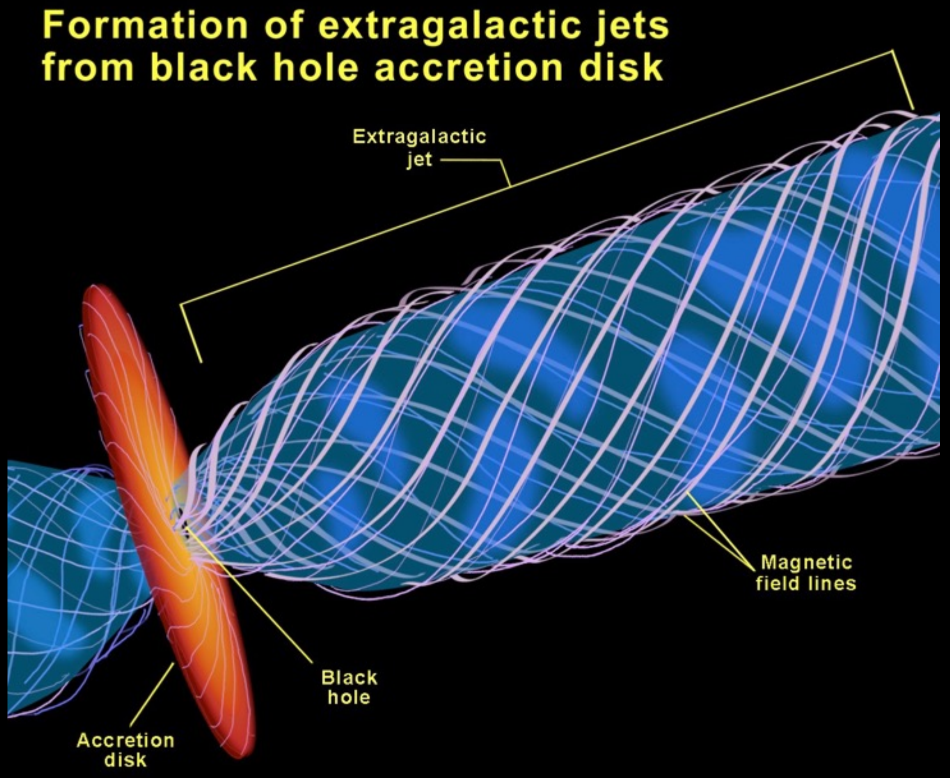

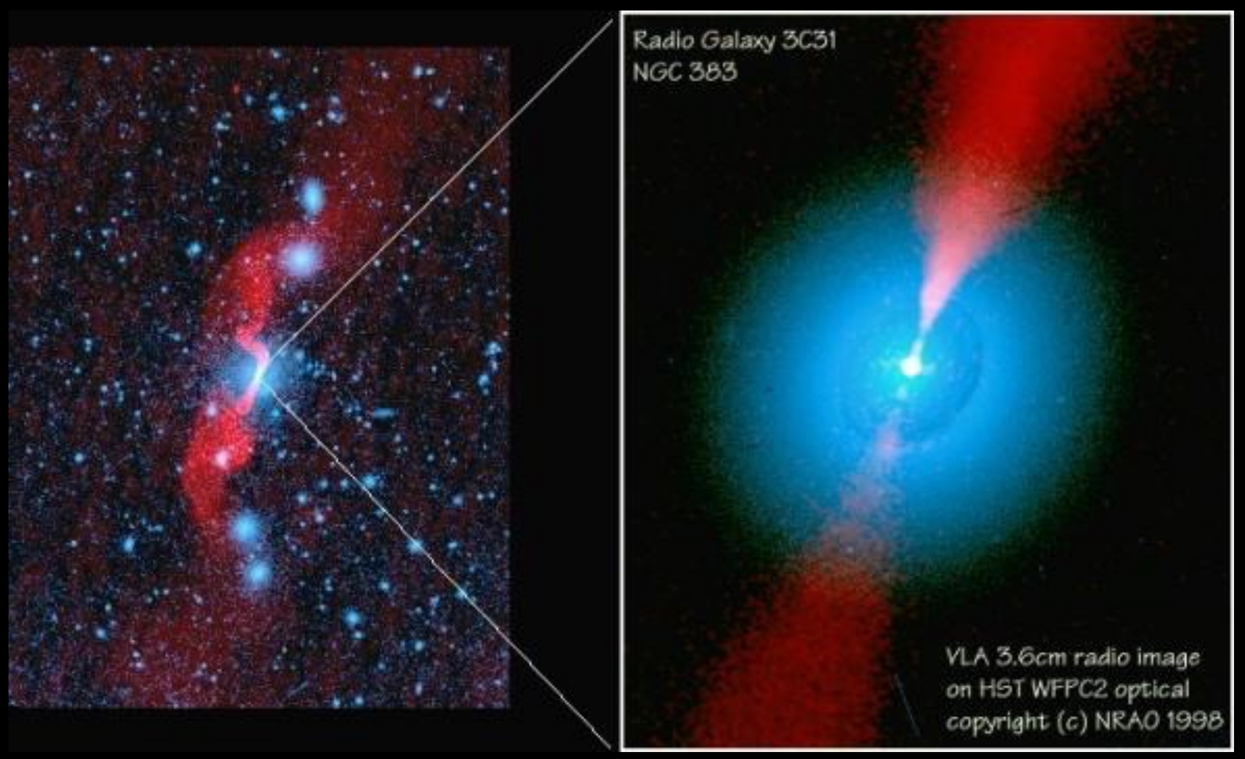

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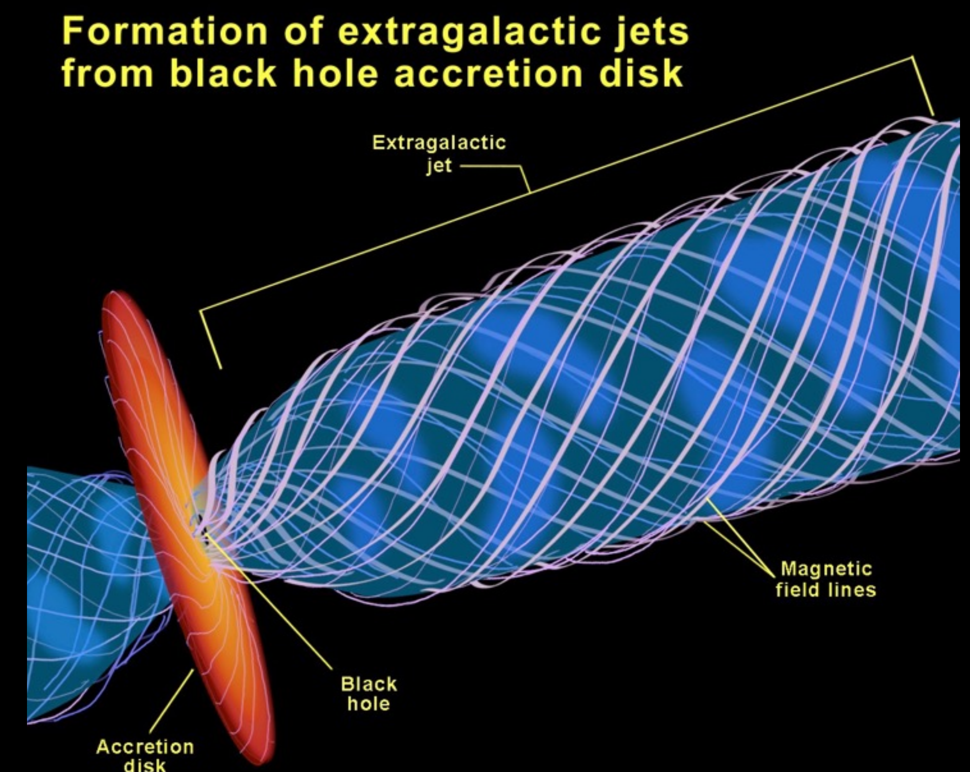

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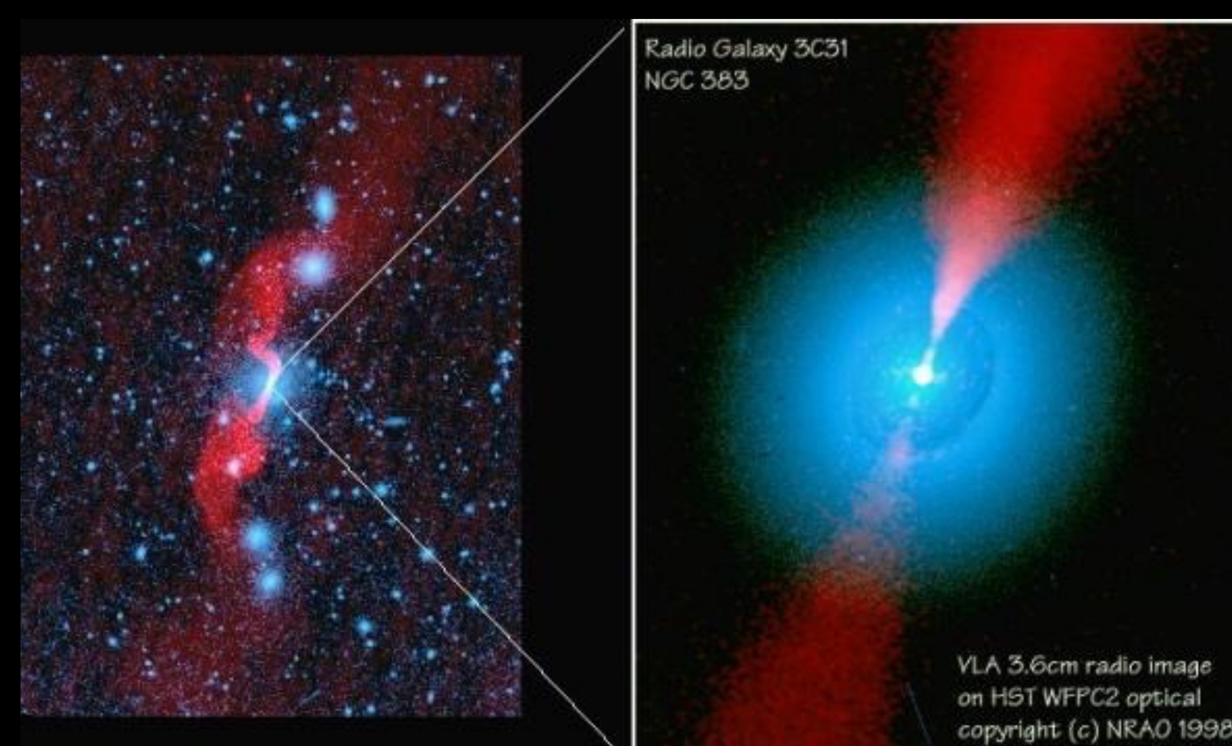

4. Inverse Compton losses due to interaction with the CMB. Once the sources is large enough, CMB photons (which are hotter at high-z) begin to play a role.

Turn the crank -> Results

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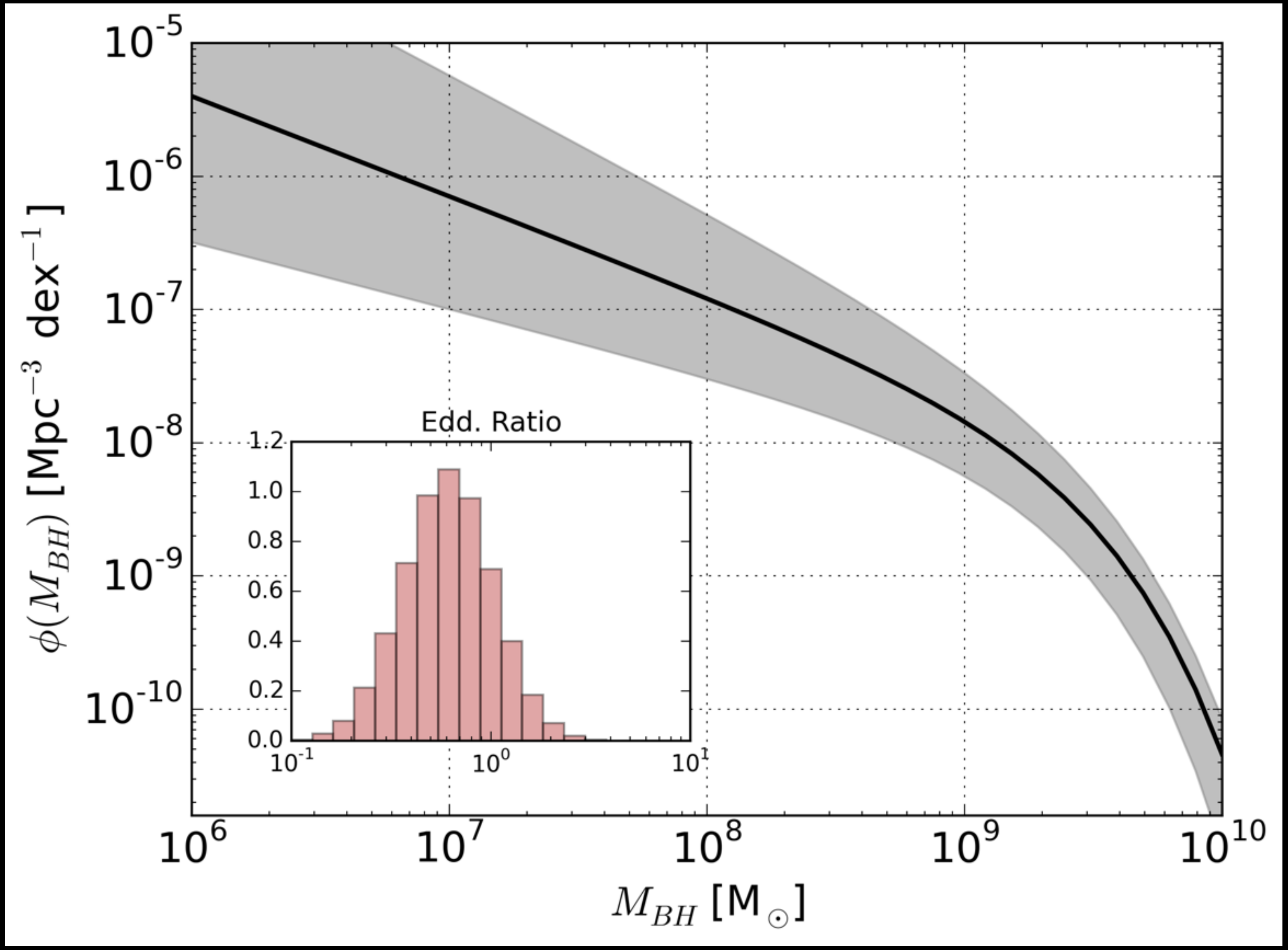
Input: black hole masses and Eddington ratios at z=6, taken from the fantastic work of Willott et al. (2010)



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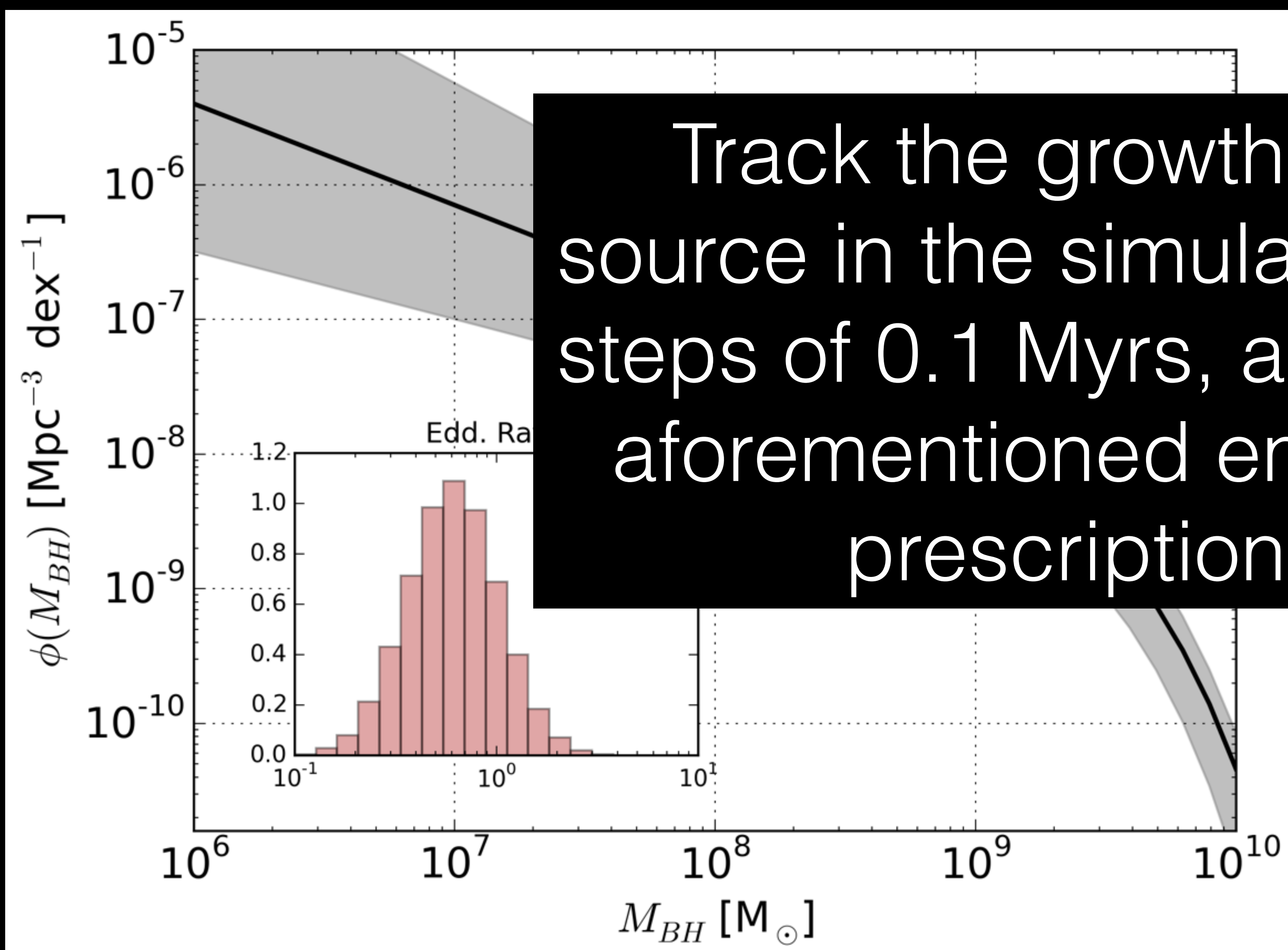

Track the growth of each source in the simulation in time steps of 0.1 Myrs, applying the aforementioned energy loss prescriptions…

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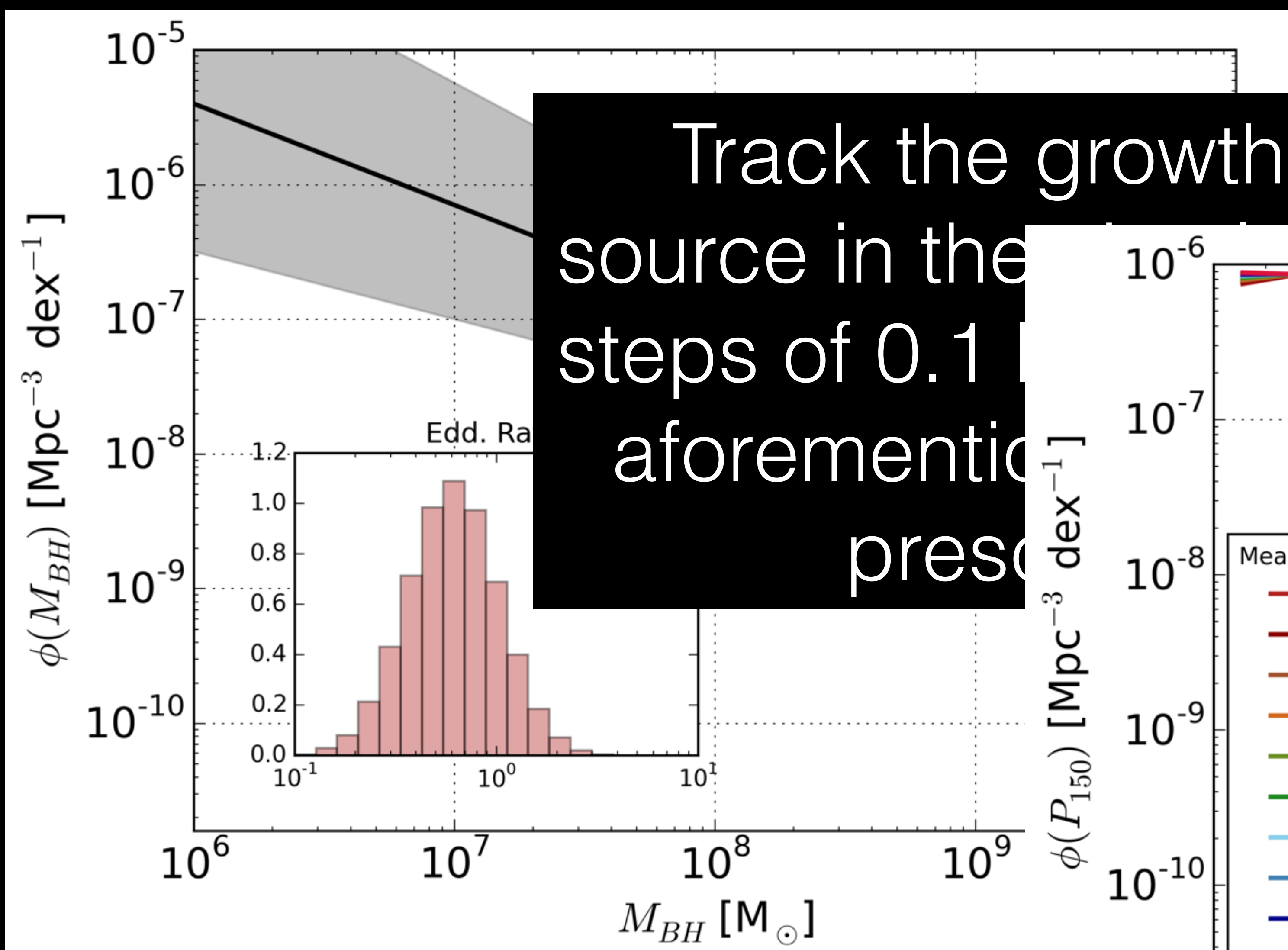

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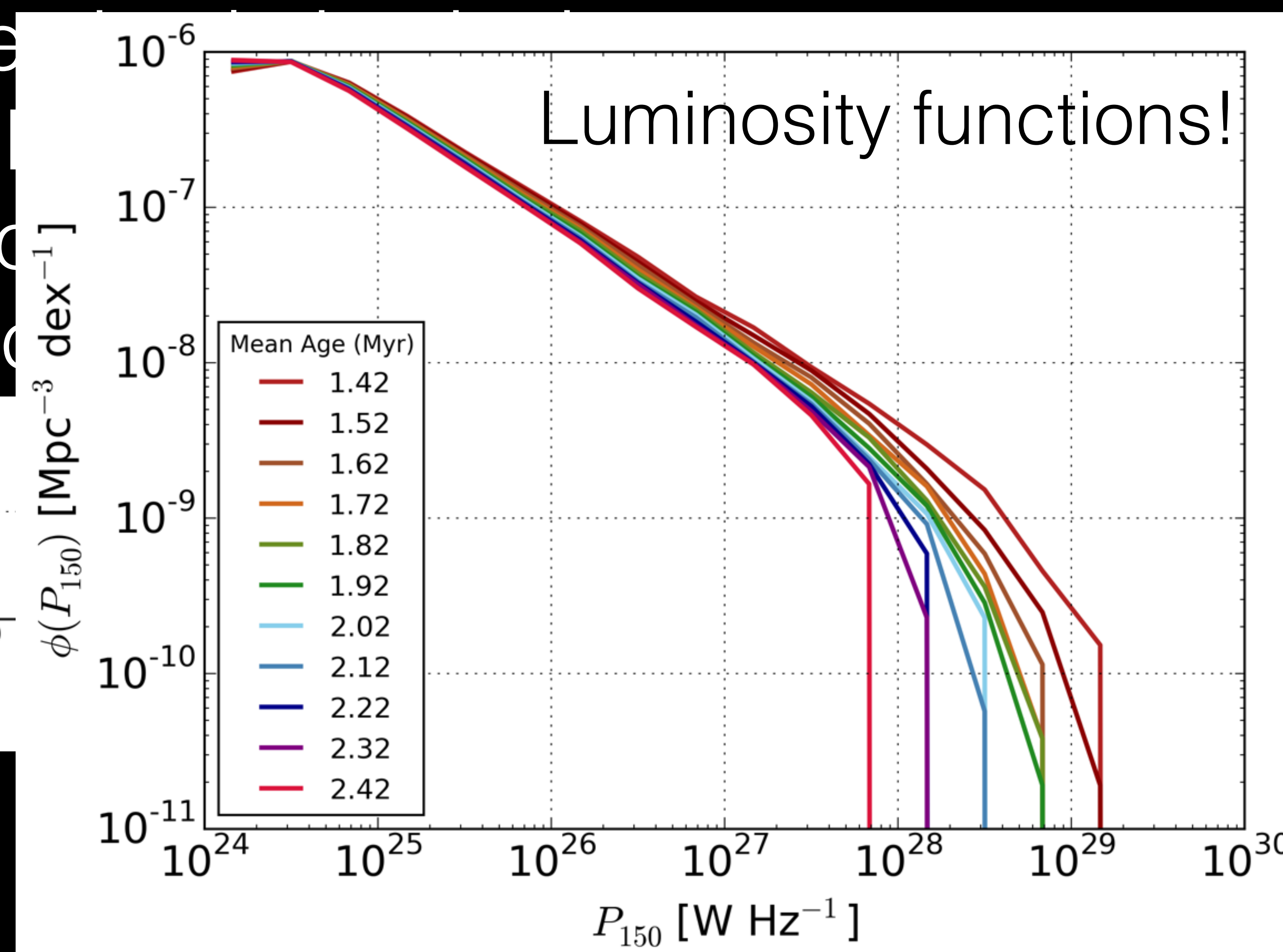

Number density prediction

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

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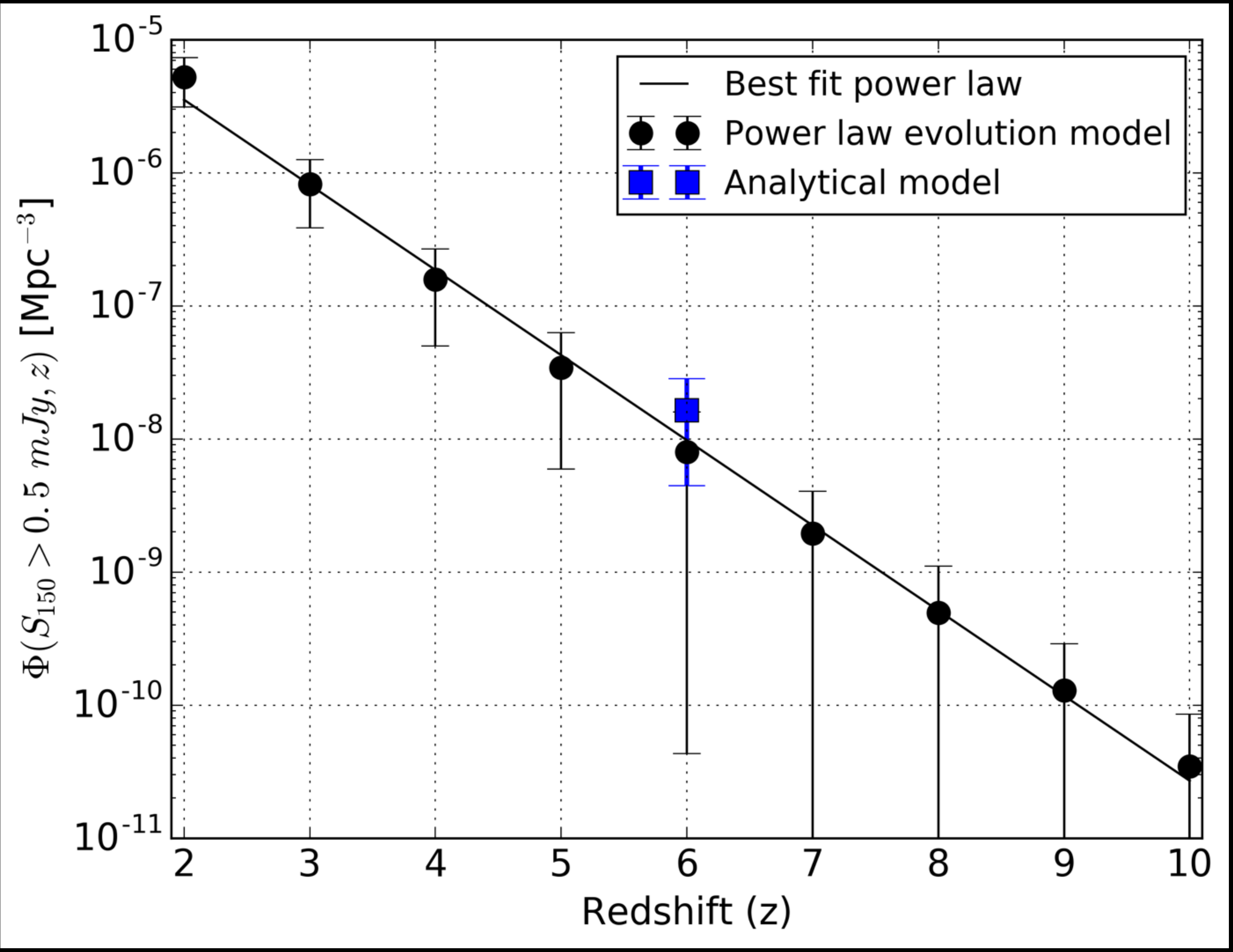

Number densities for objects with 5σ detection at a noise level of 0.1 mJy at 150 MHz

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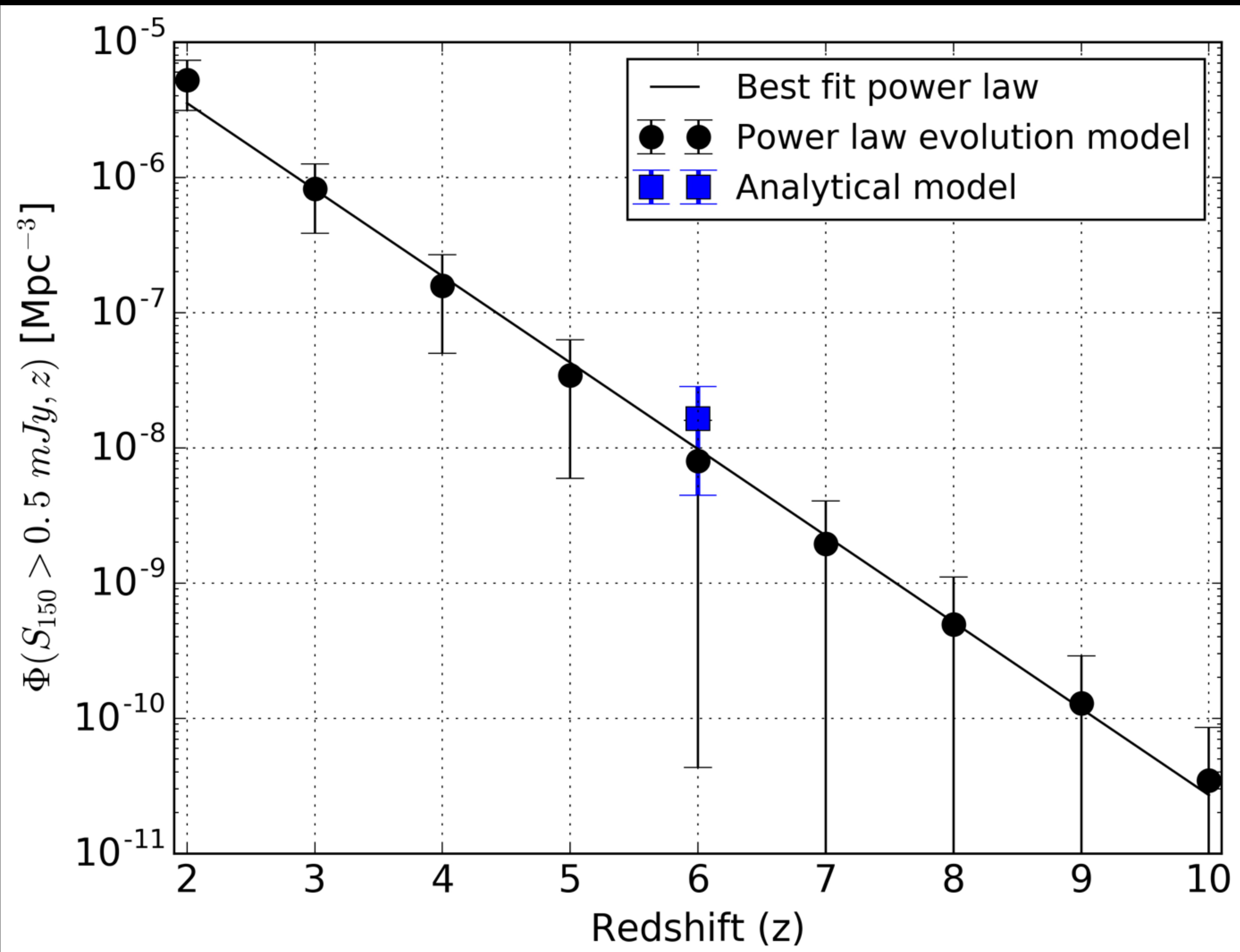


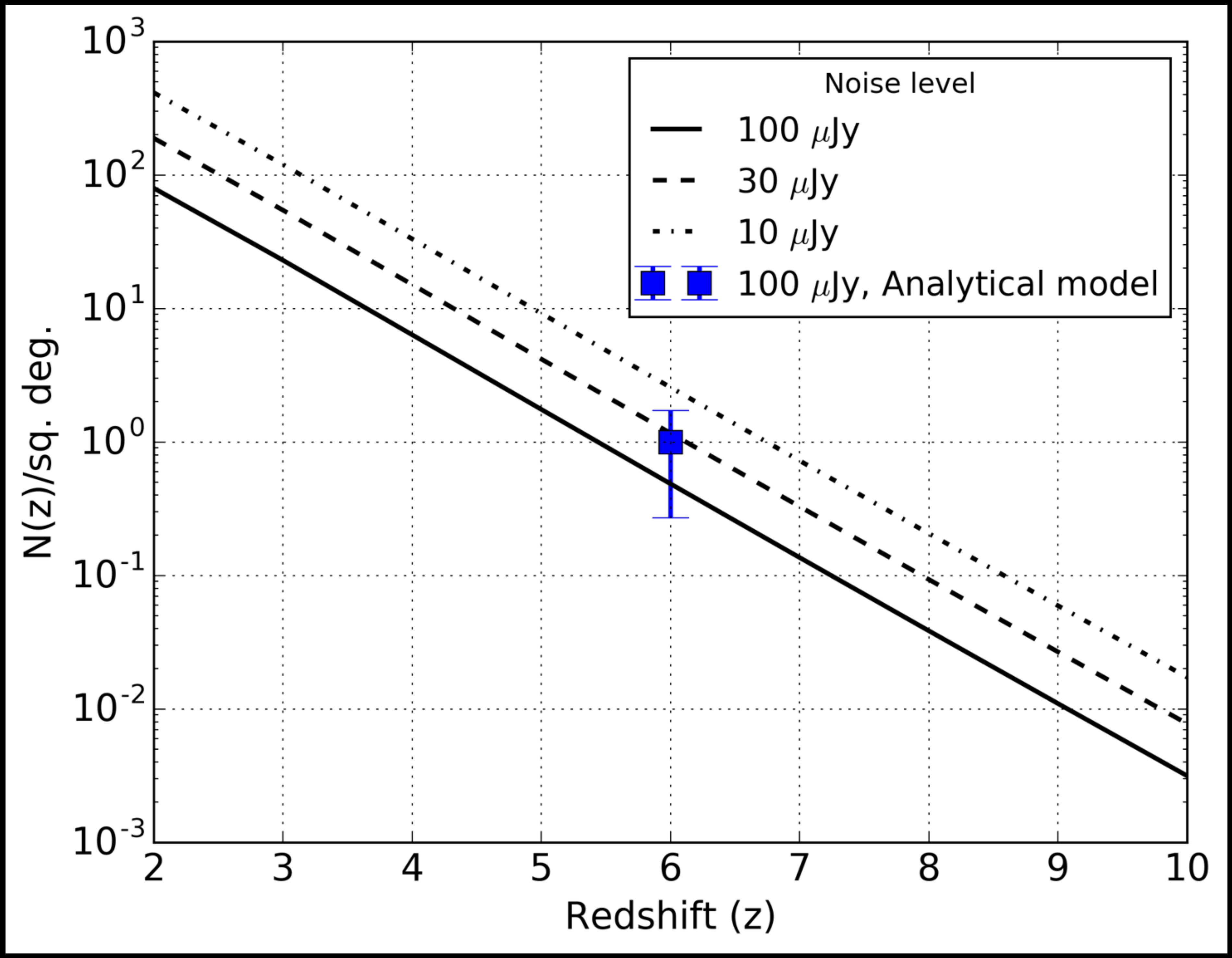
Number densities for objects with 5σ detection at a noise level of 0.1 mJy at 150 MHz

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 counts prediction and comparison



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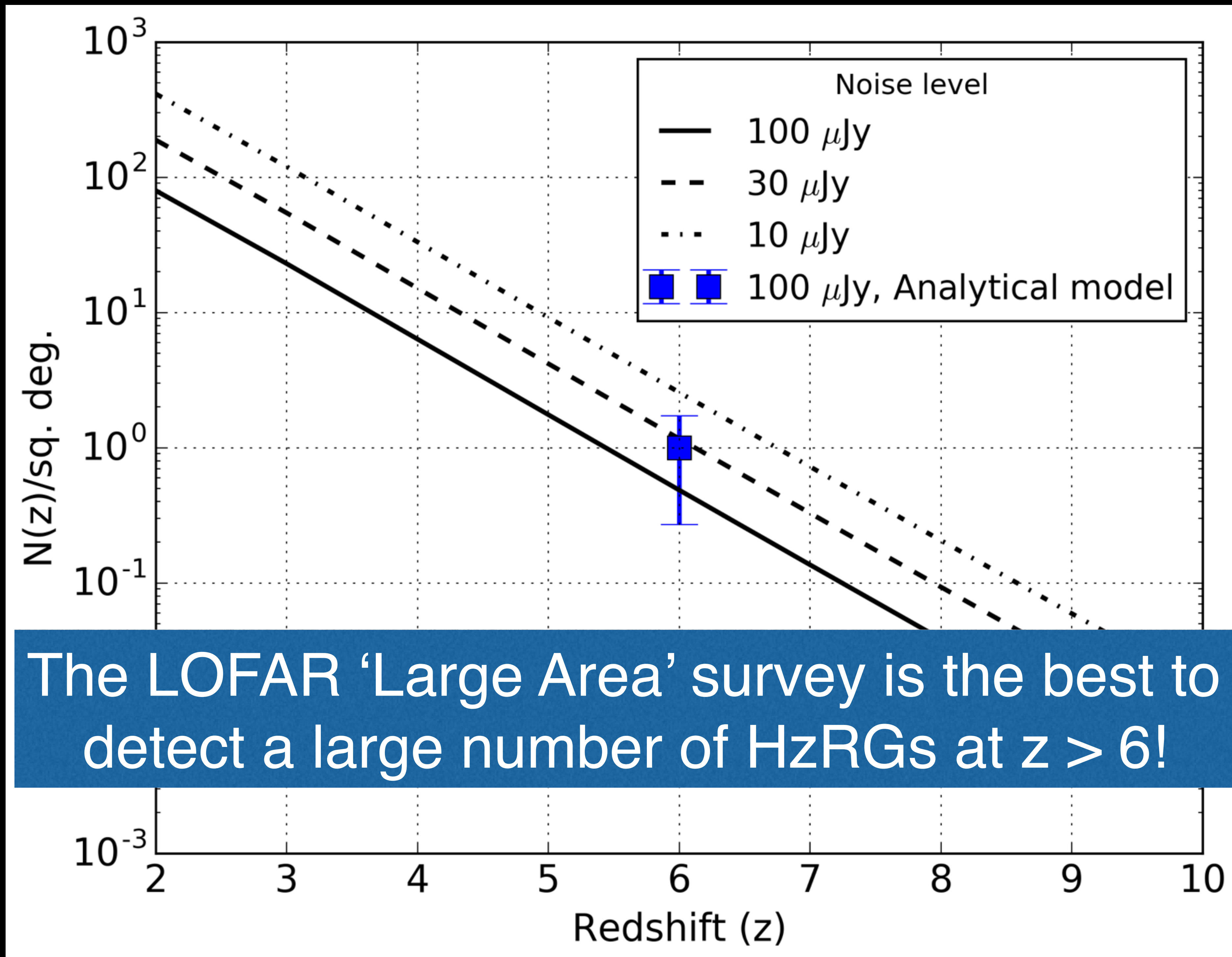


The LOFAR ‘Large Area’ survey is the best to detect a large number of HzRGs at $z > 6$!

Summary

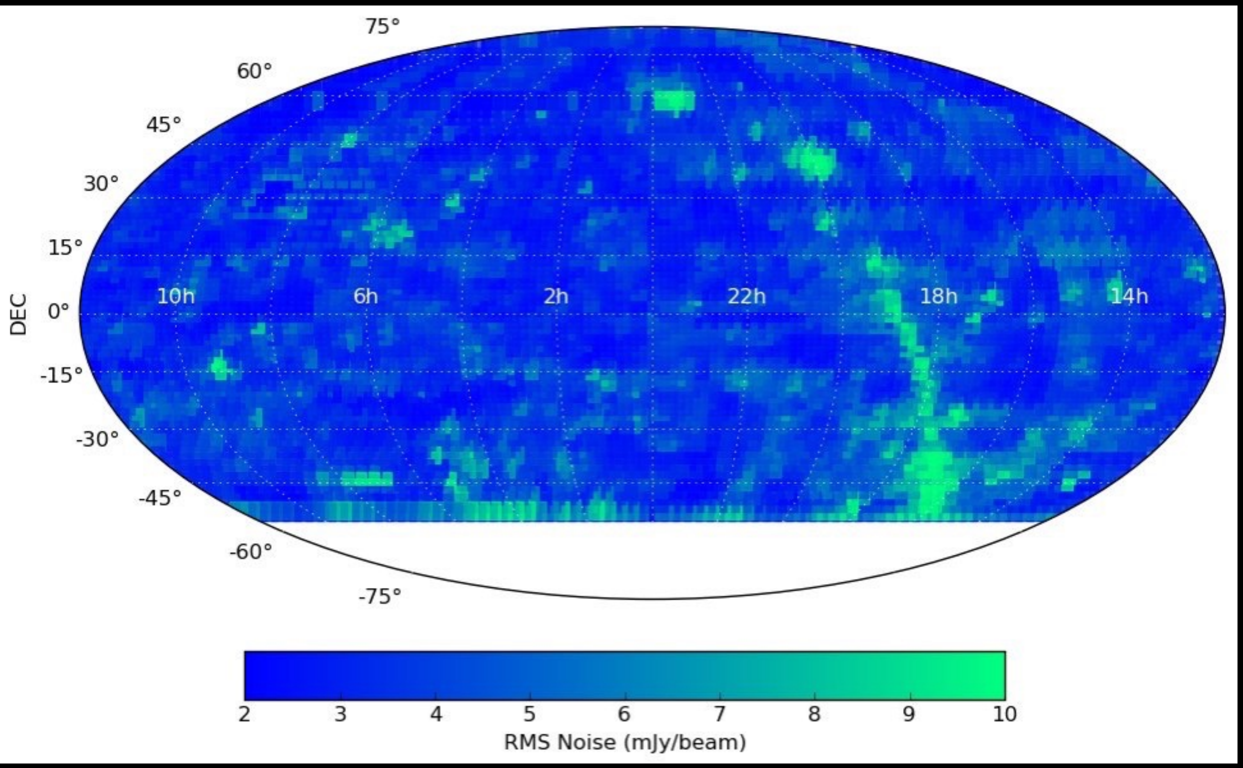
- Radio galaxies, especially at high redshifts, are important laboratories to study the epoch of reionisation and massive galaxy and proto-cluster formation.
- We have constructed a model to predict the radio luminosity function at z=6 taking into account simple energy loss prescriptions.
- The model 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: $D = c_1 \left(\frac{Q_{jet}}{\rho a^{\beta}} \right)^{1/(5-\beta)} t^{3/(5-\beta)}$

Synchrotron losses, max radio power: $P_{\nu} = \frac{m_e c^2 f_n}{6\sqrt{A}\nu} Q_{jet}$