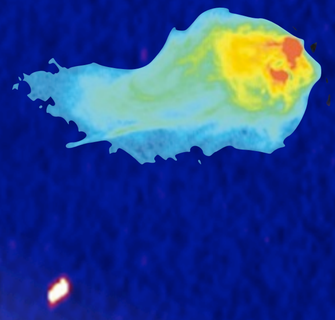
Towards the discovery of the *first* radio galaxies



José Afonso
Center for Astronomy and Astrophysics, Faculty of Sciences of the University of Lisbon
XXIII Encontro Nacional de Astronomia e Astrofísica · July 18-19, 2013

PTDC/FIS/100170/2008

Where are the first radio galaxies?

Where are the first radio galaxies?

- The earliest AGN activity in the Universe.

- Powerful tracer of AGN physics at very high redshifts.

- If (when!) found will allow for HI absorption studies in the EoR.

- Possibly already *well* within current day capabilities.

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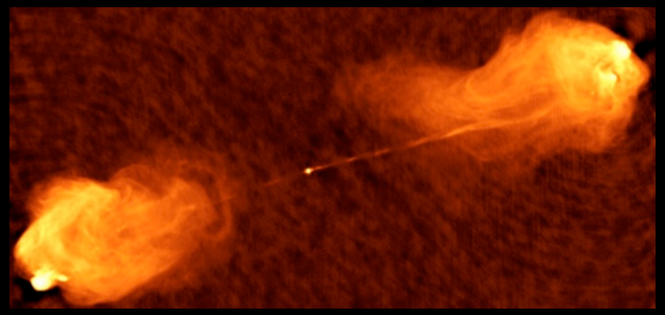
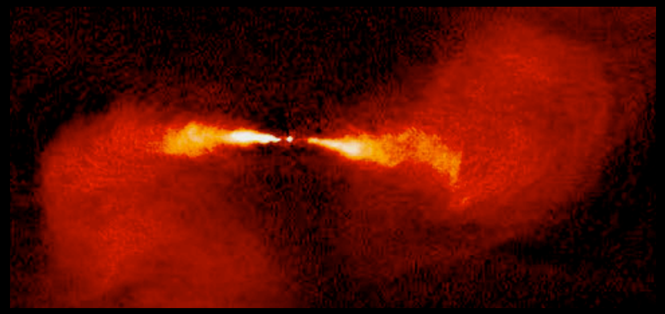
Radio Galaxies = Active Galactic Nuclei

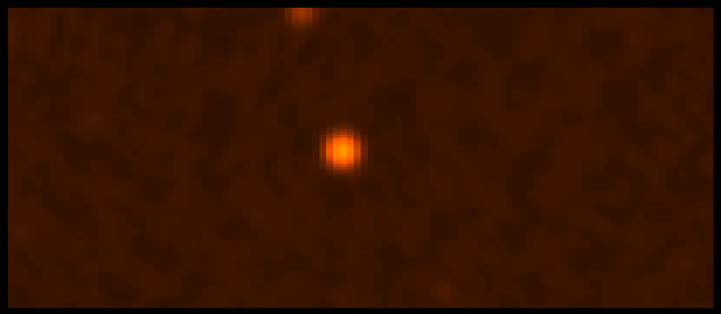
More powerful...

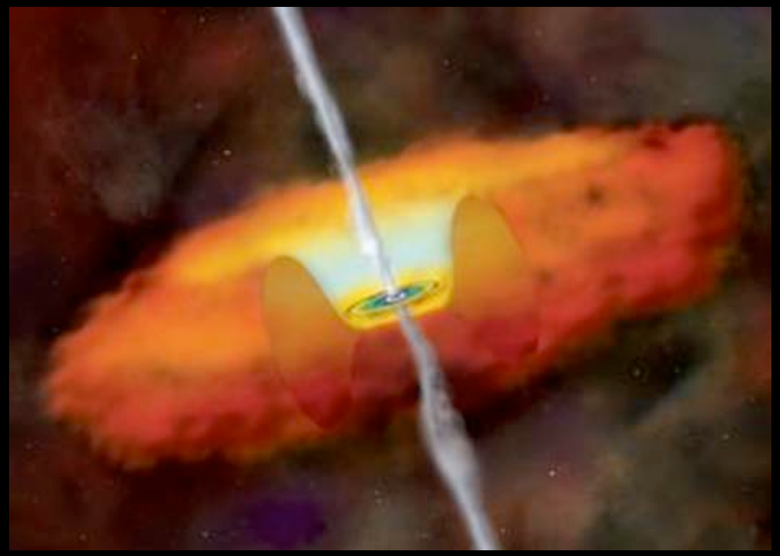


...less powerful...



...or “radio-quiet”.





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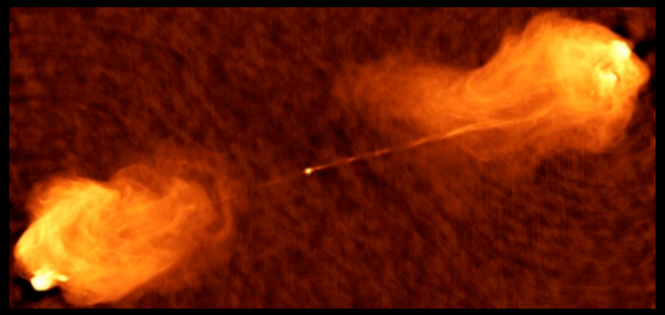
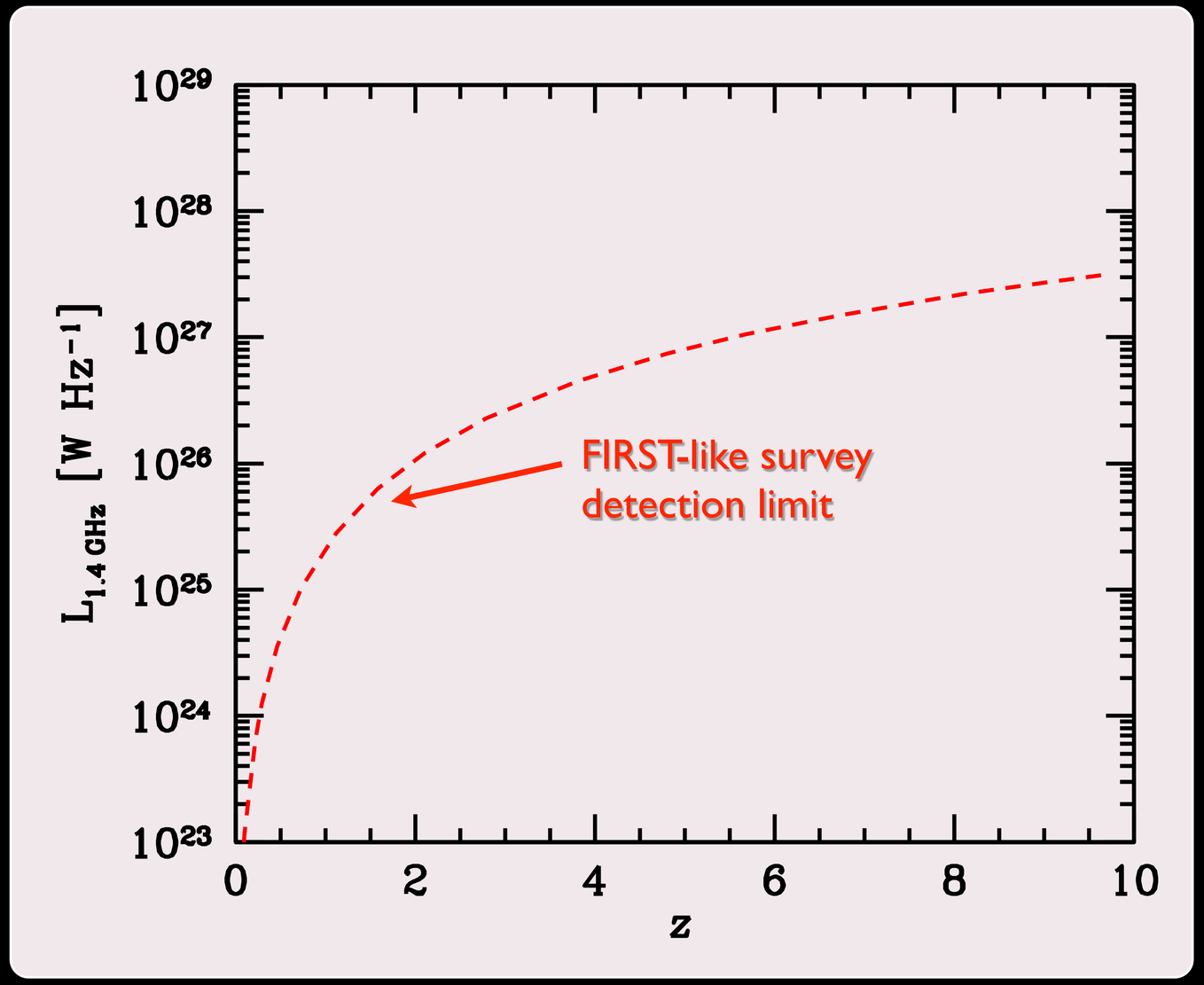


1) Among the most luminous galaxies at any redshift
2) Associated with the most massive systems
3) Progenitors of brightest cluster ellipticals
4) Track proto-cluster environments
5) Dusty and Starbursting
6) May show large gas reservoirs (Ly-α halos)

Tracers of galaxy buildup AND structure formation (z>2)

The (radio) road to the highest redshifts

The (radio) road to the highest redshifts



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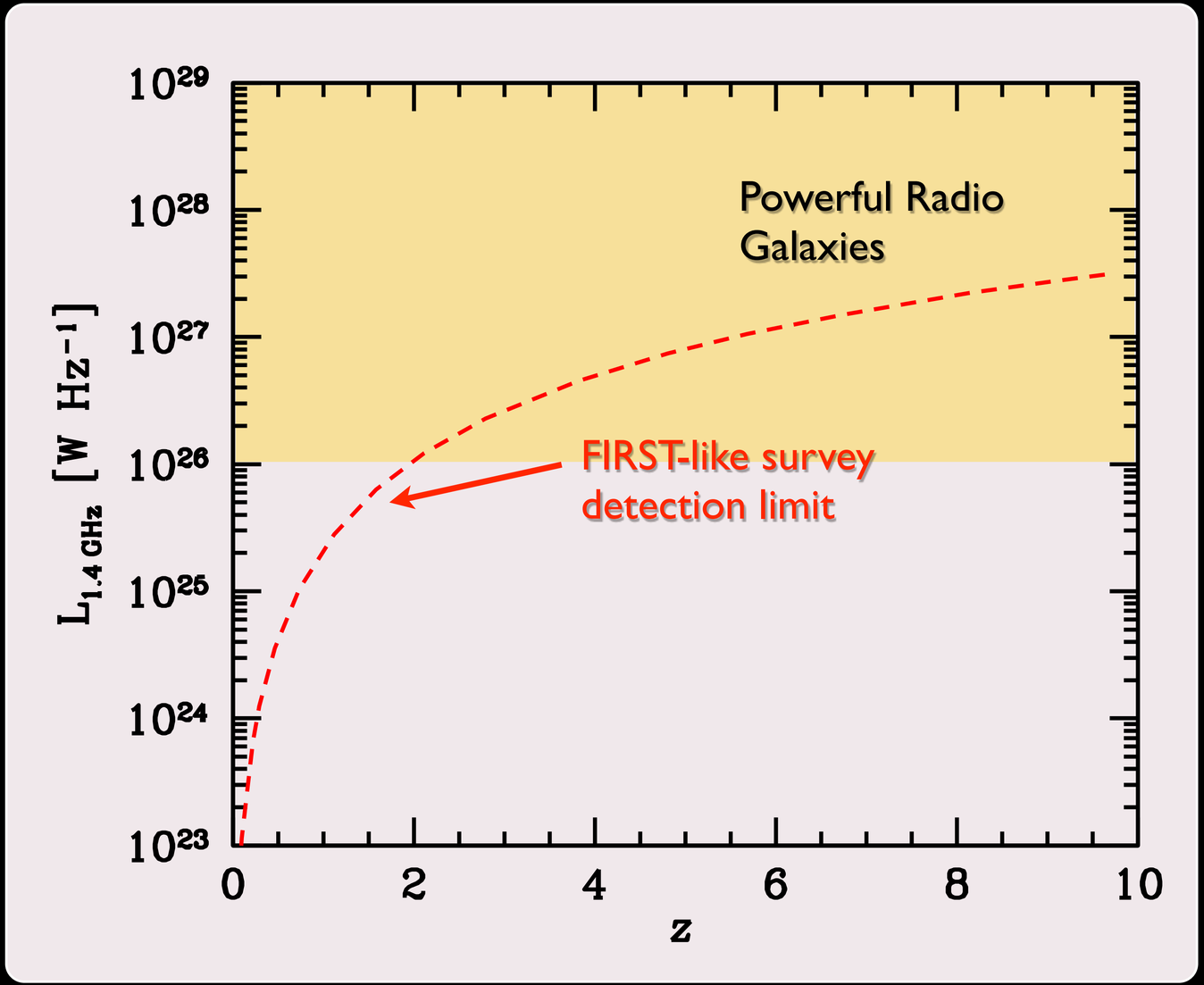

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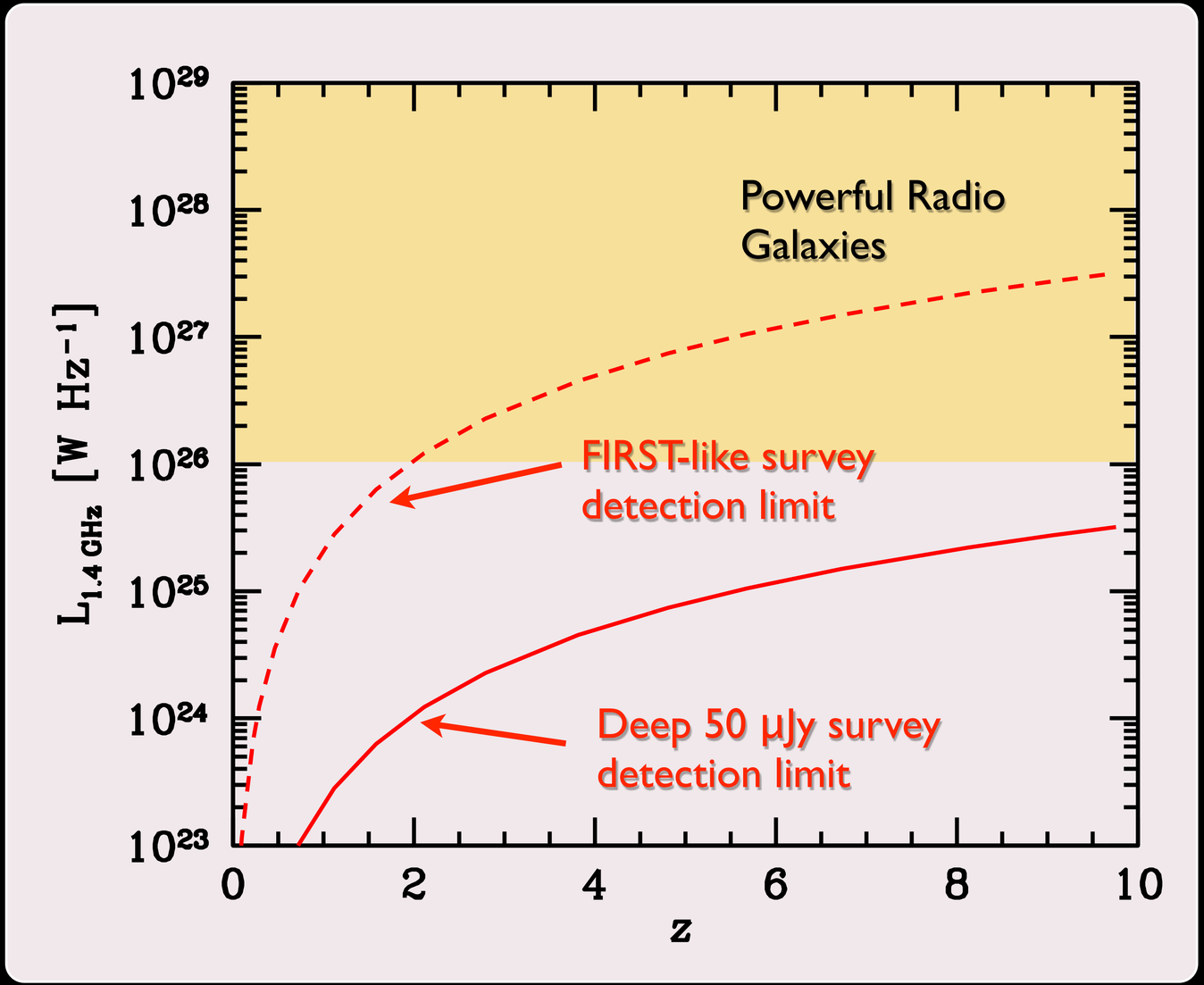

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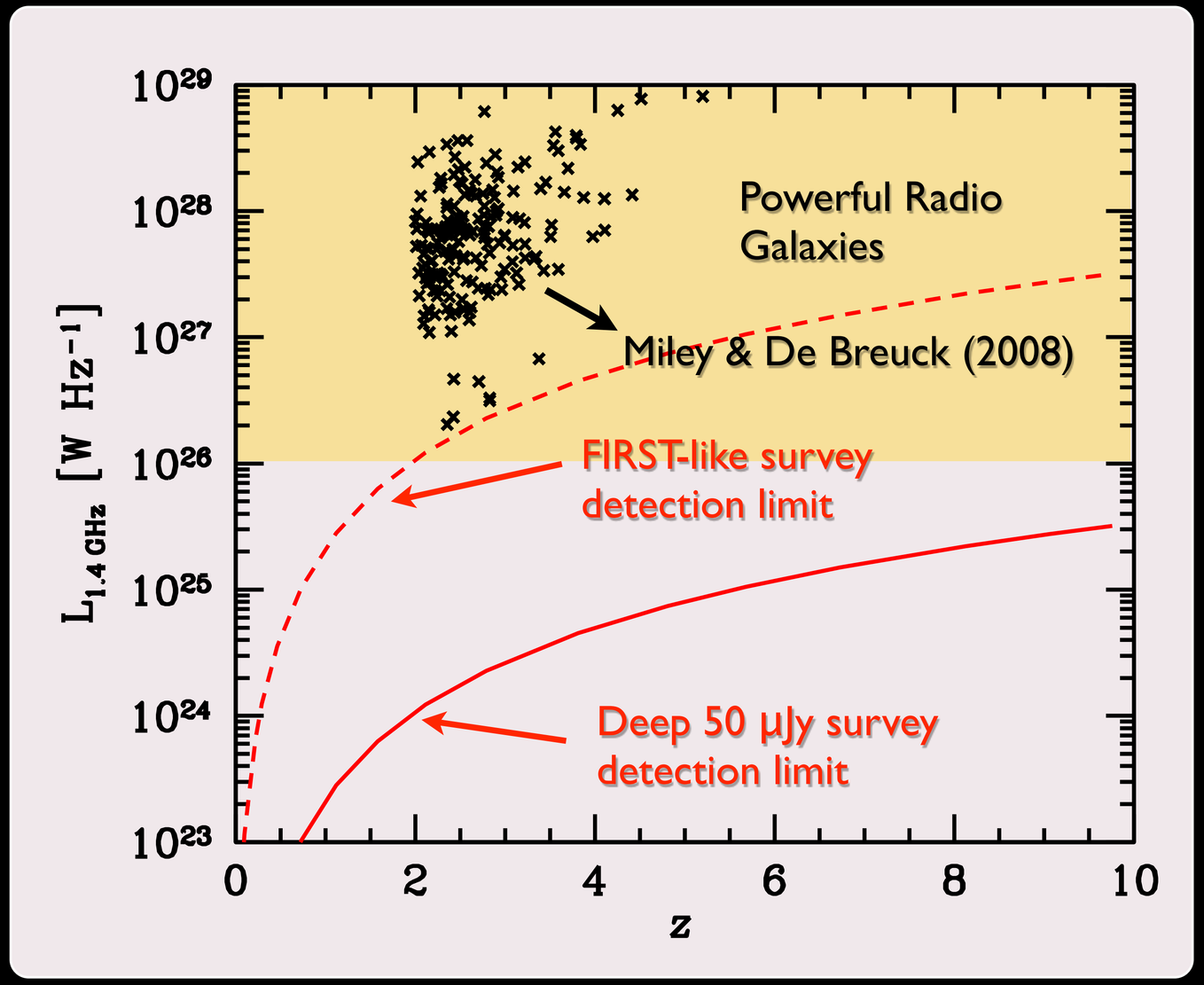

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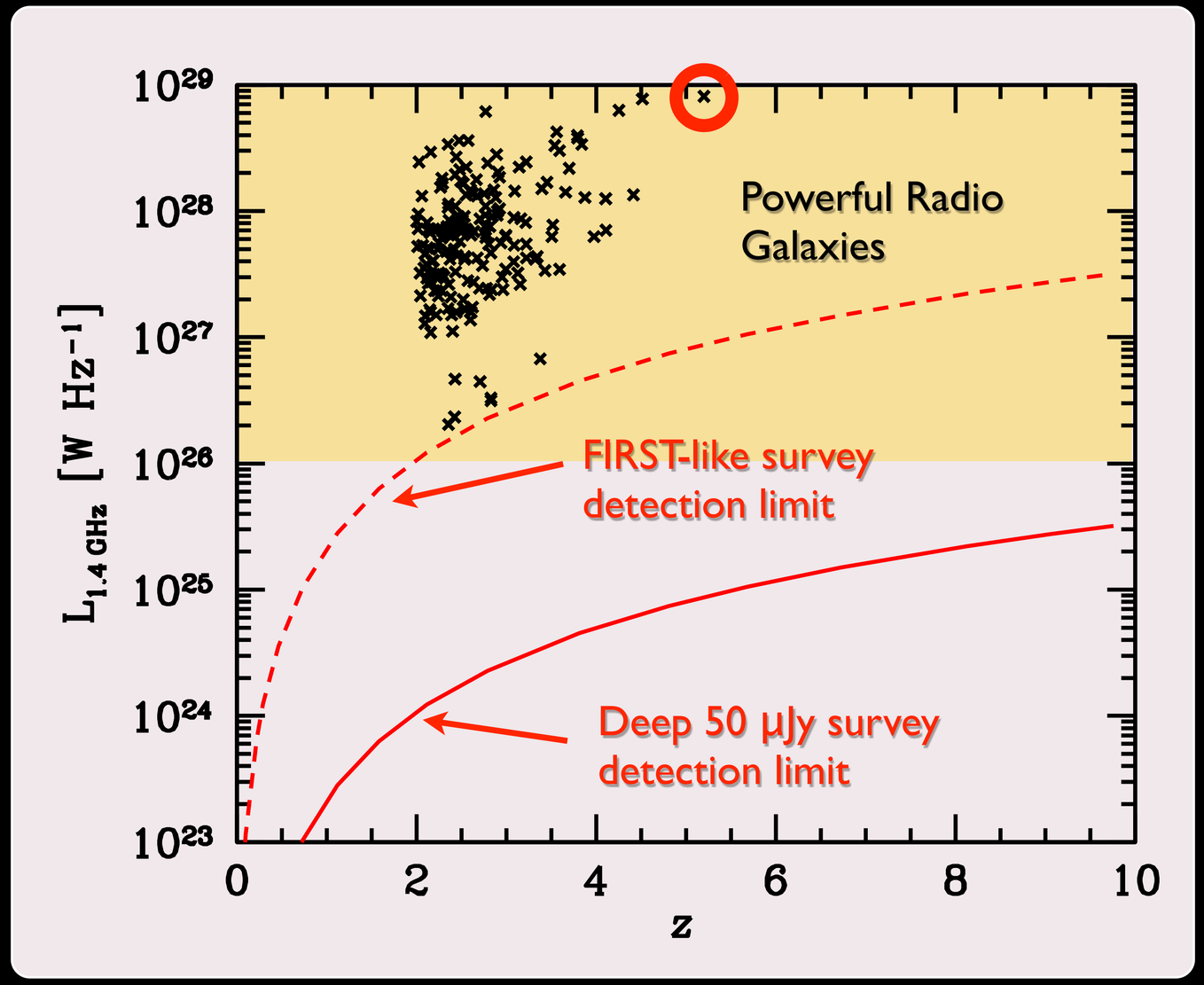
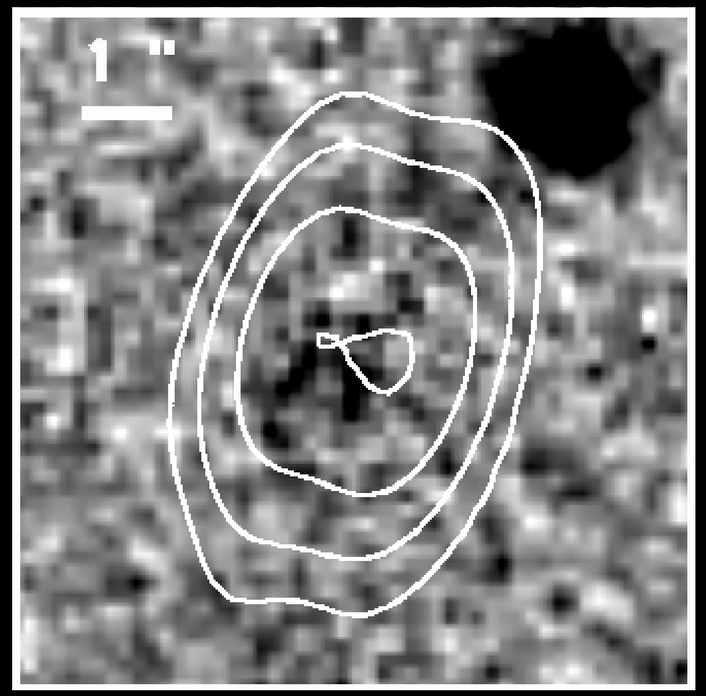
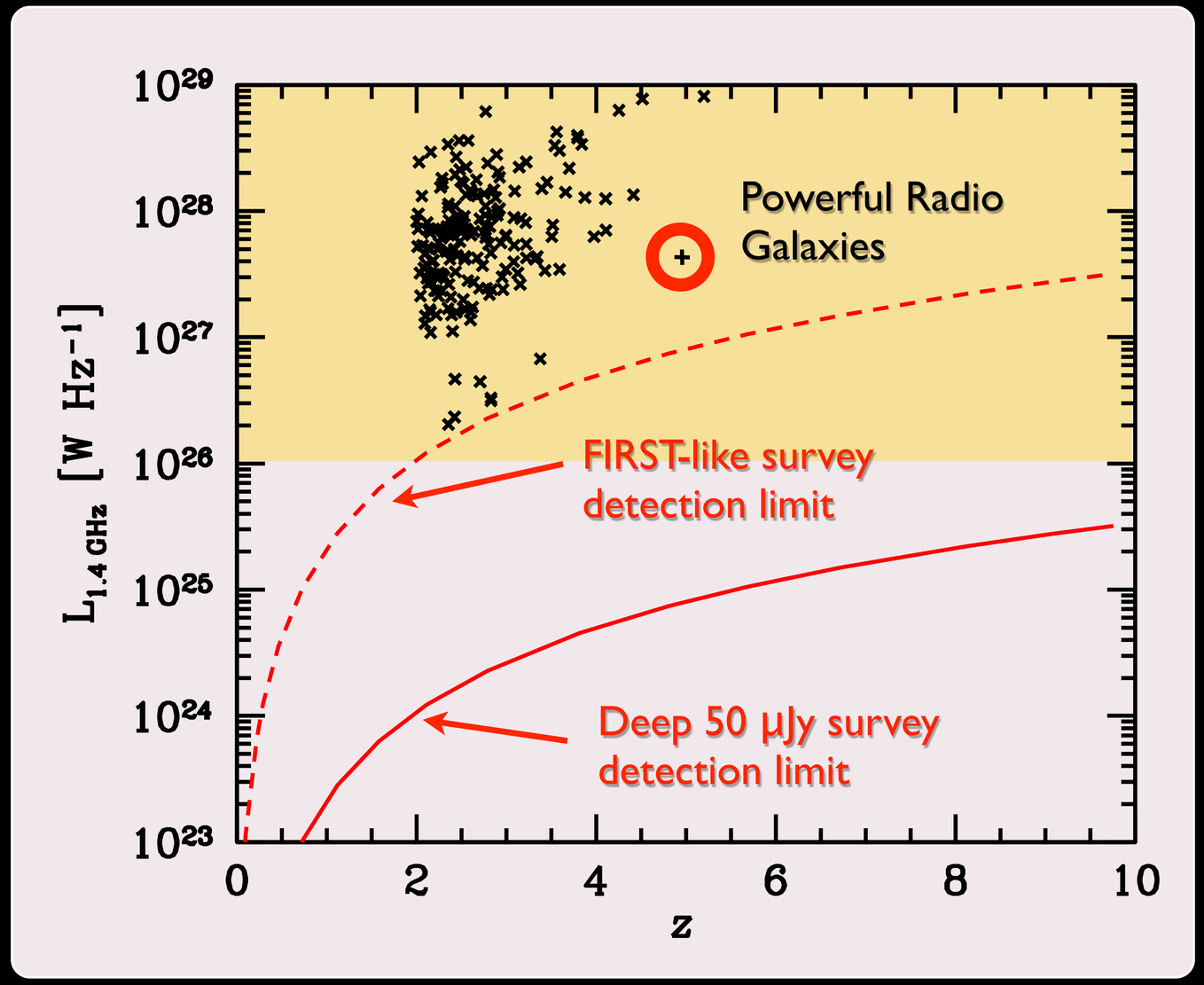


TN J0924-2201 @ z=5.2
(van Breugel+, 99)

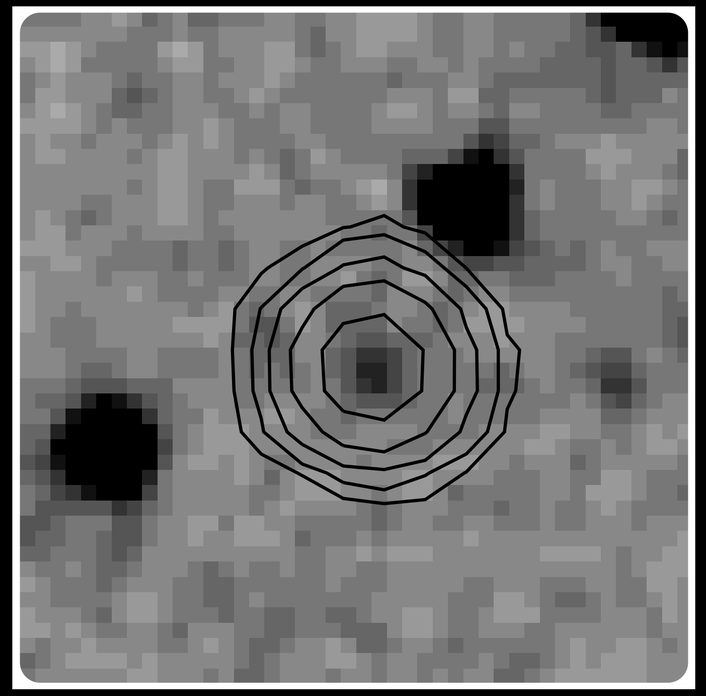


$S_{1.4GHz}$=73 mJy

The (radio) road to the highest redshifts

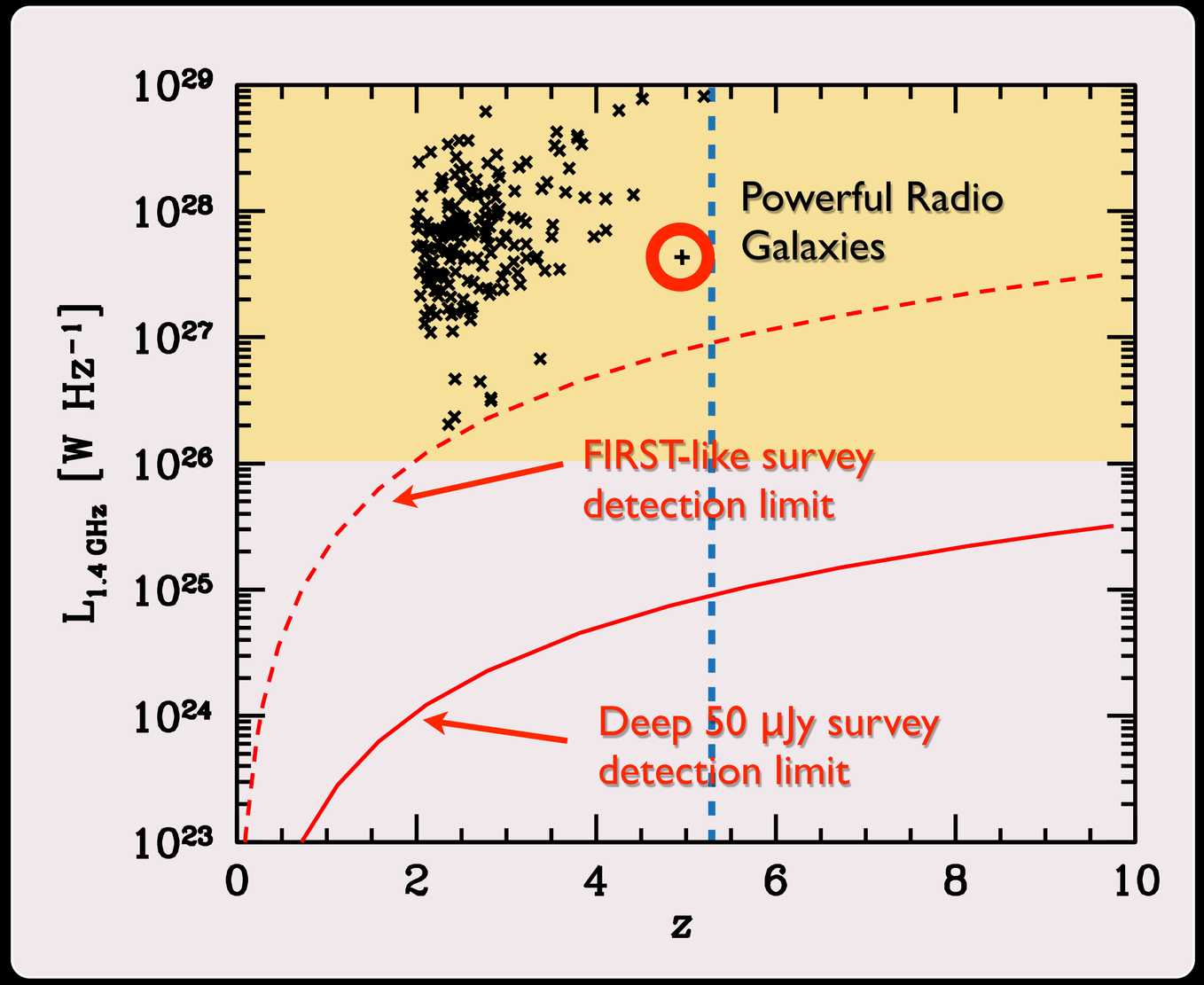


J163912.11 + 405236.5 @ z=4.9
(Jarvis+, 09)

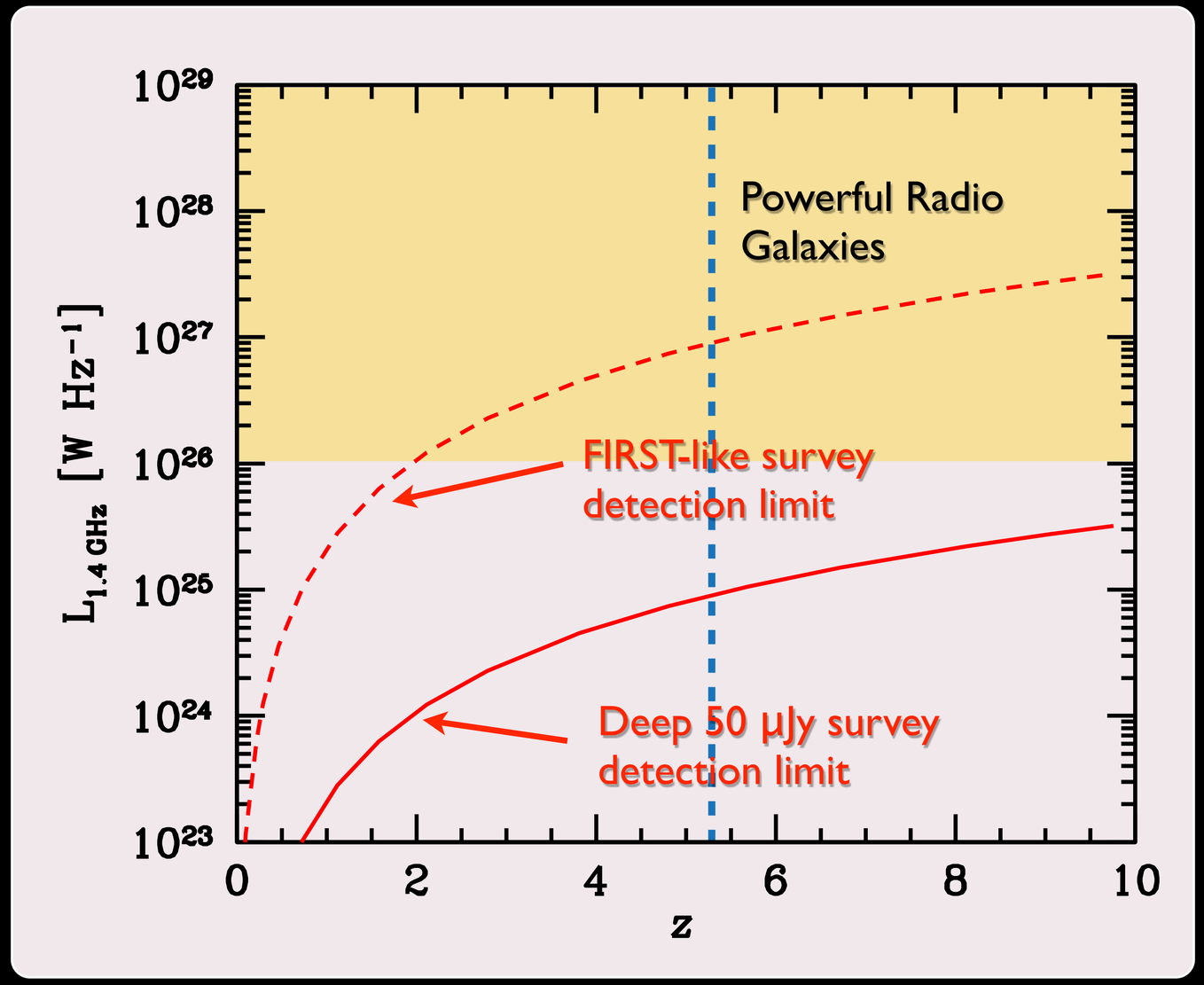


$S_{1.4GHz}$=22 mJy

The (radio) road to the highest redshifts



Do they even exist?



Observations of high-z AGN:
- Highest z QSO from UKIDSS (z=7.09, Mortlock+, 11)
- Over 30 QSOs known at 6<z<7 (Fan, 2012)

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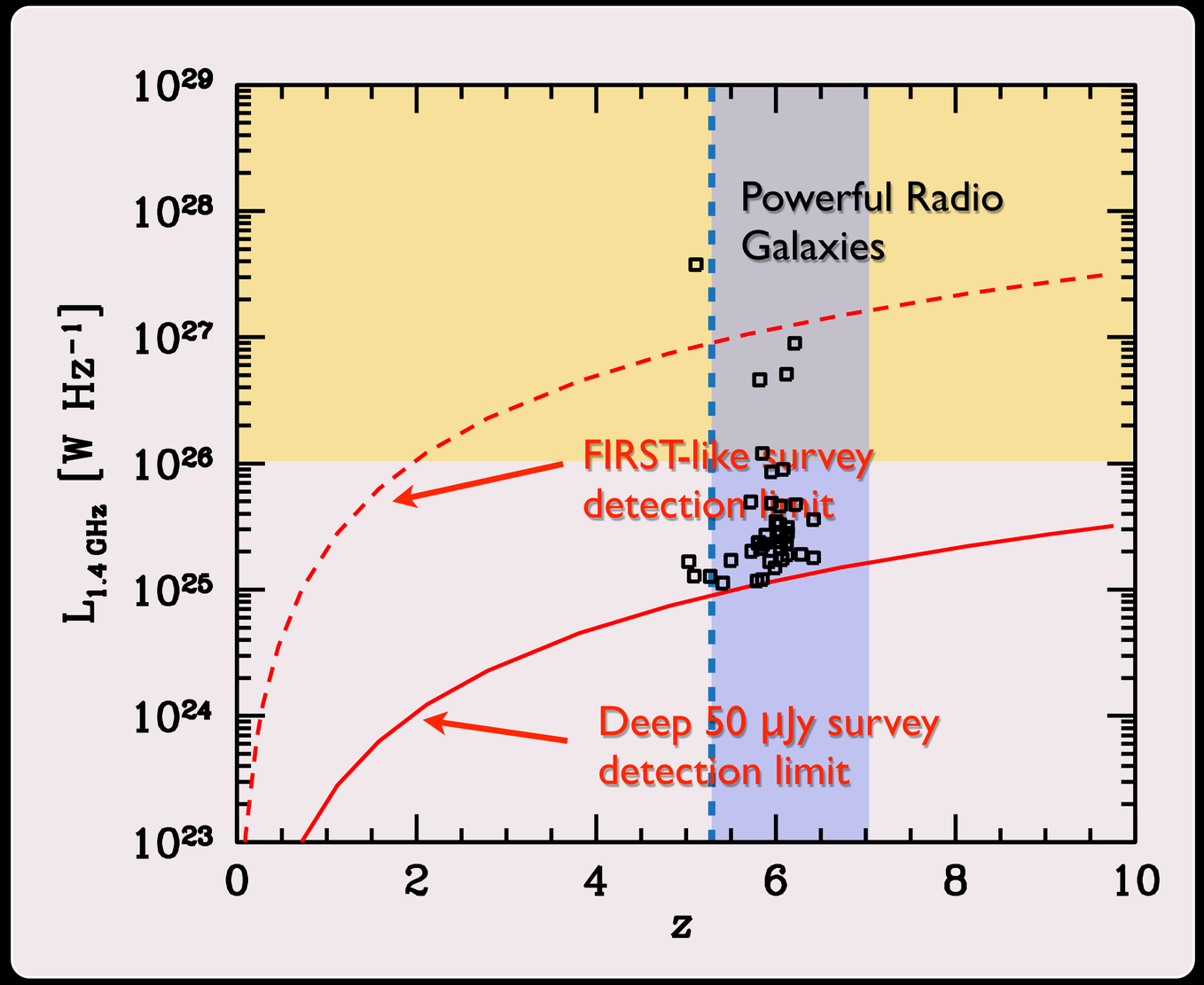

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$\Rightarrow 10^8$-10^9 $M_\odot$ SMBHs

Powerful AGN *do exist* at z~7: OK

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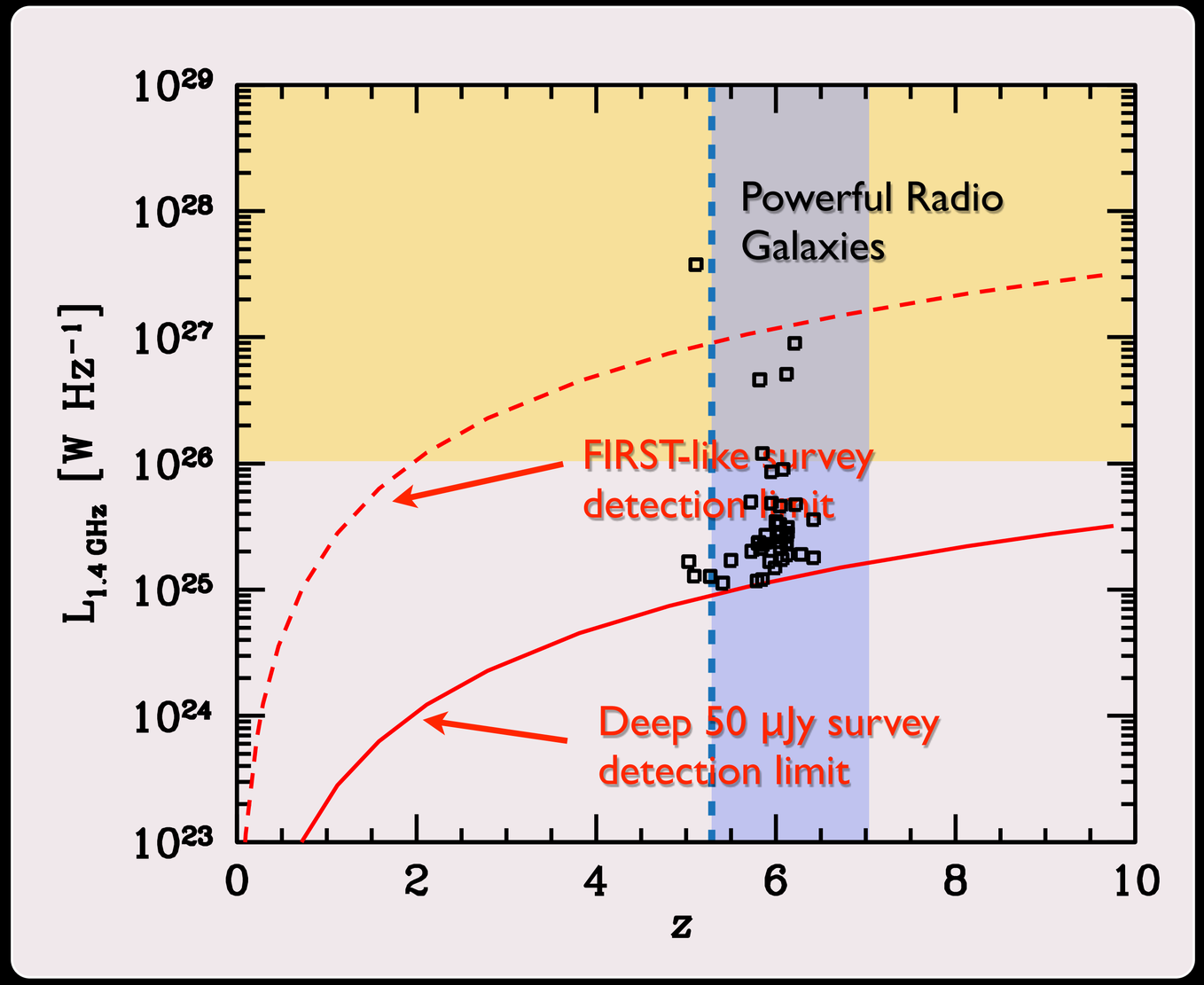

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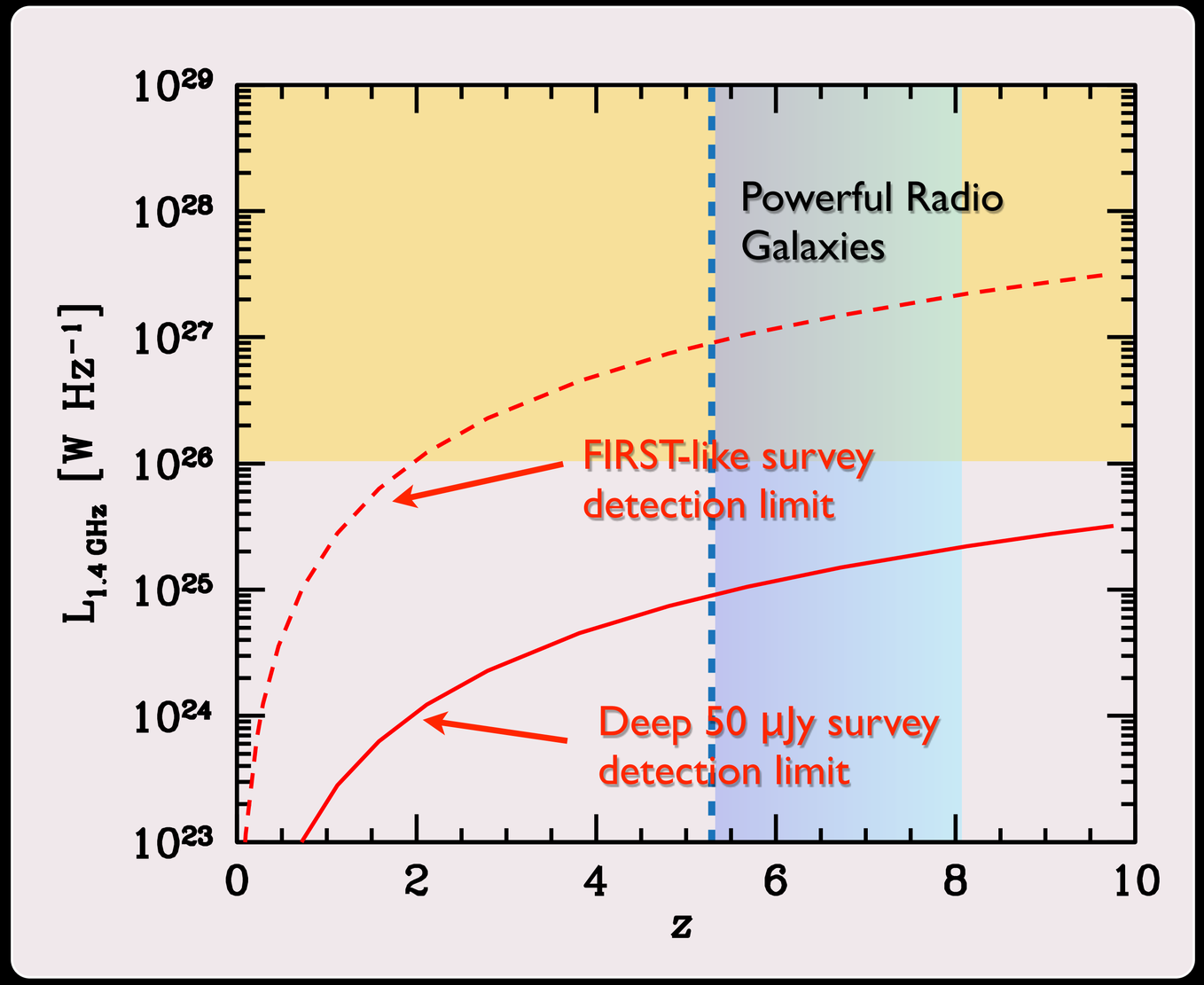
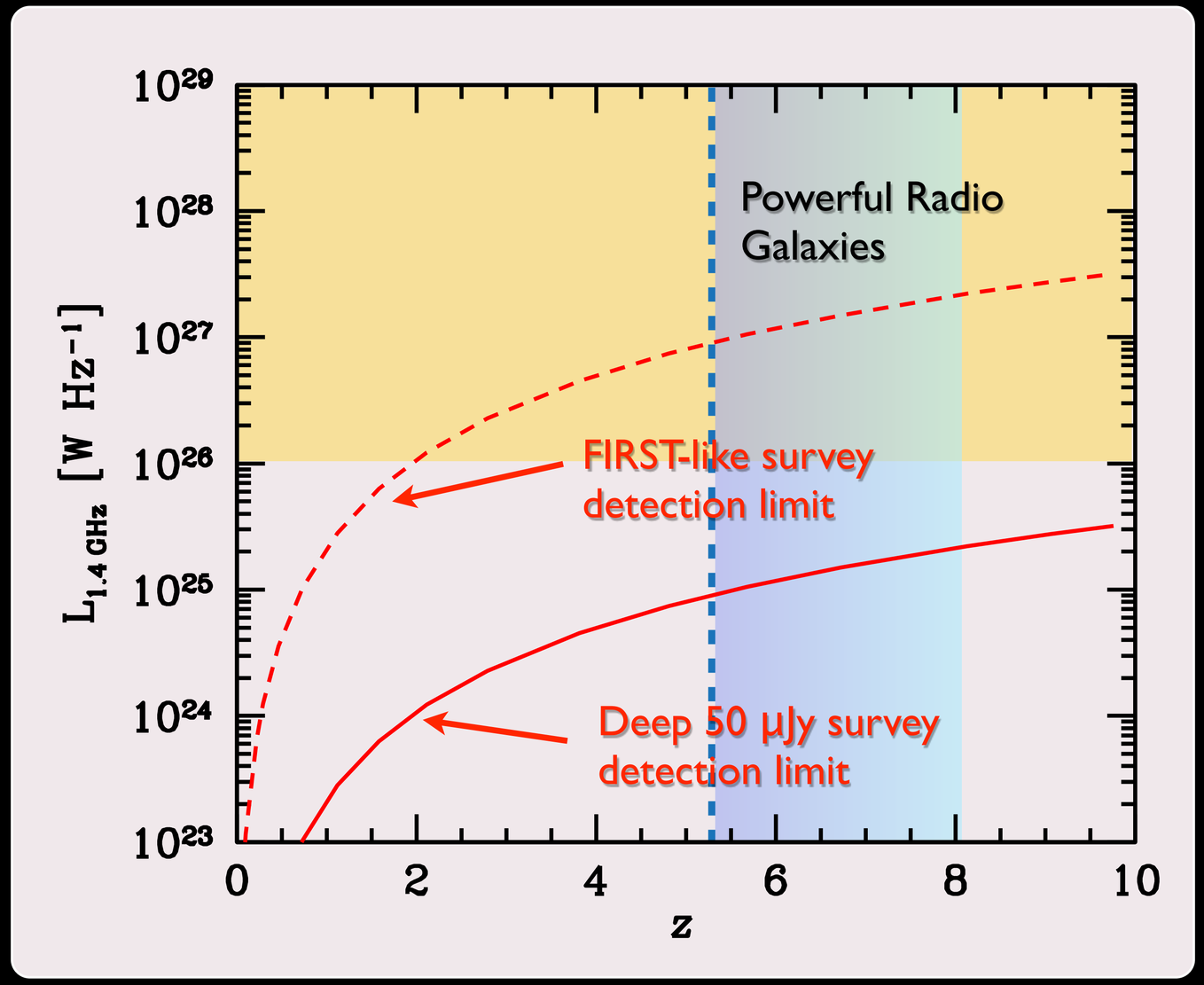


Powerful AGN *do exist* at z~7: OK

Large pop of SMBHs at z~8 possible, depending on initial seeds (Haiman+, Volonteri+, Johnson+...):
- massive pop III collapse
- DCBH
- runaway collapse in dense stellar clusters at z~10-20

Theory: OK

Do they even exist?



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Theory: OK

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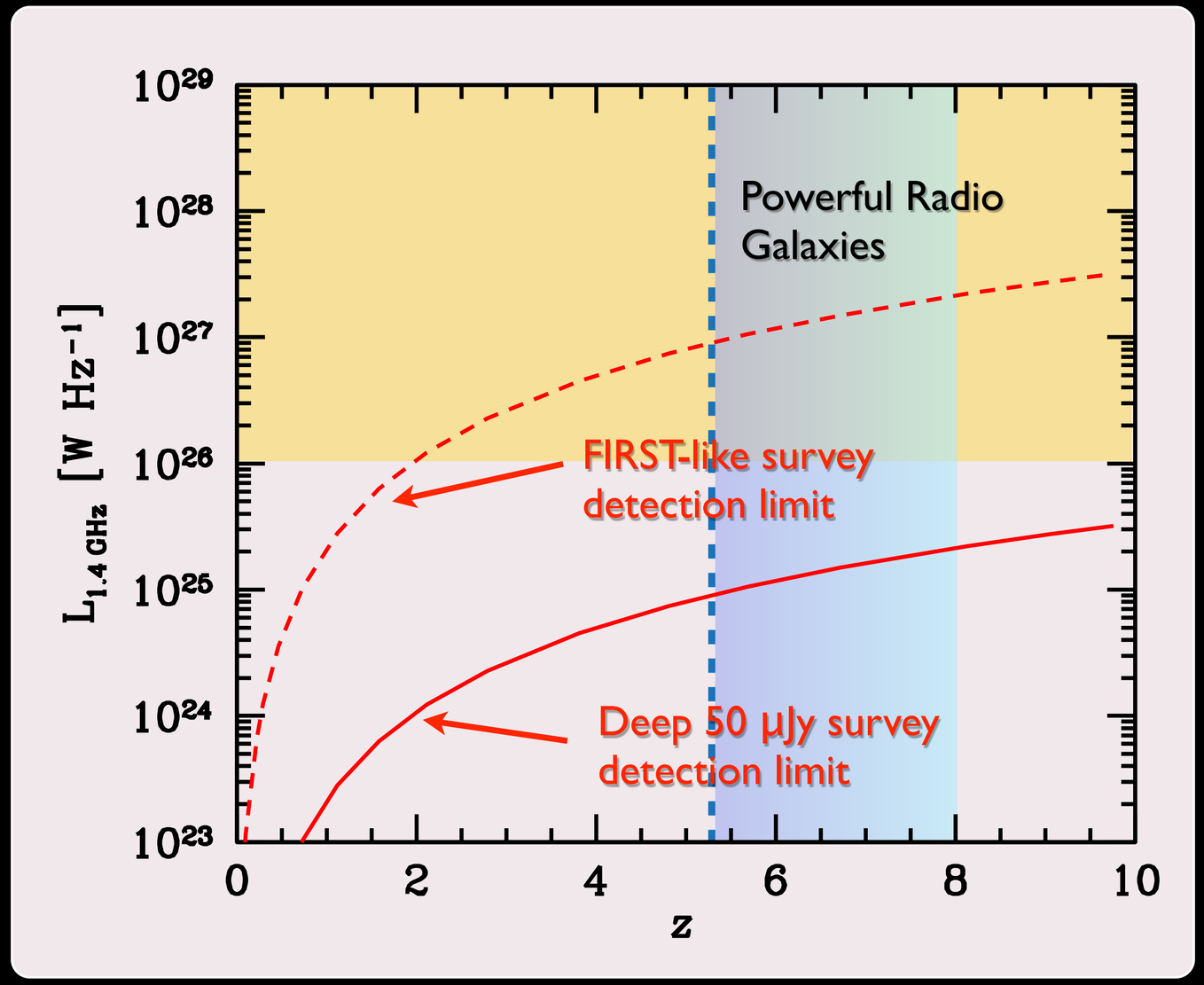


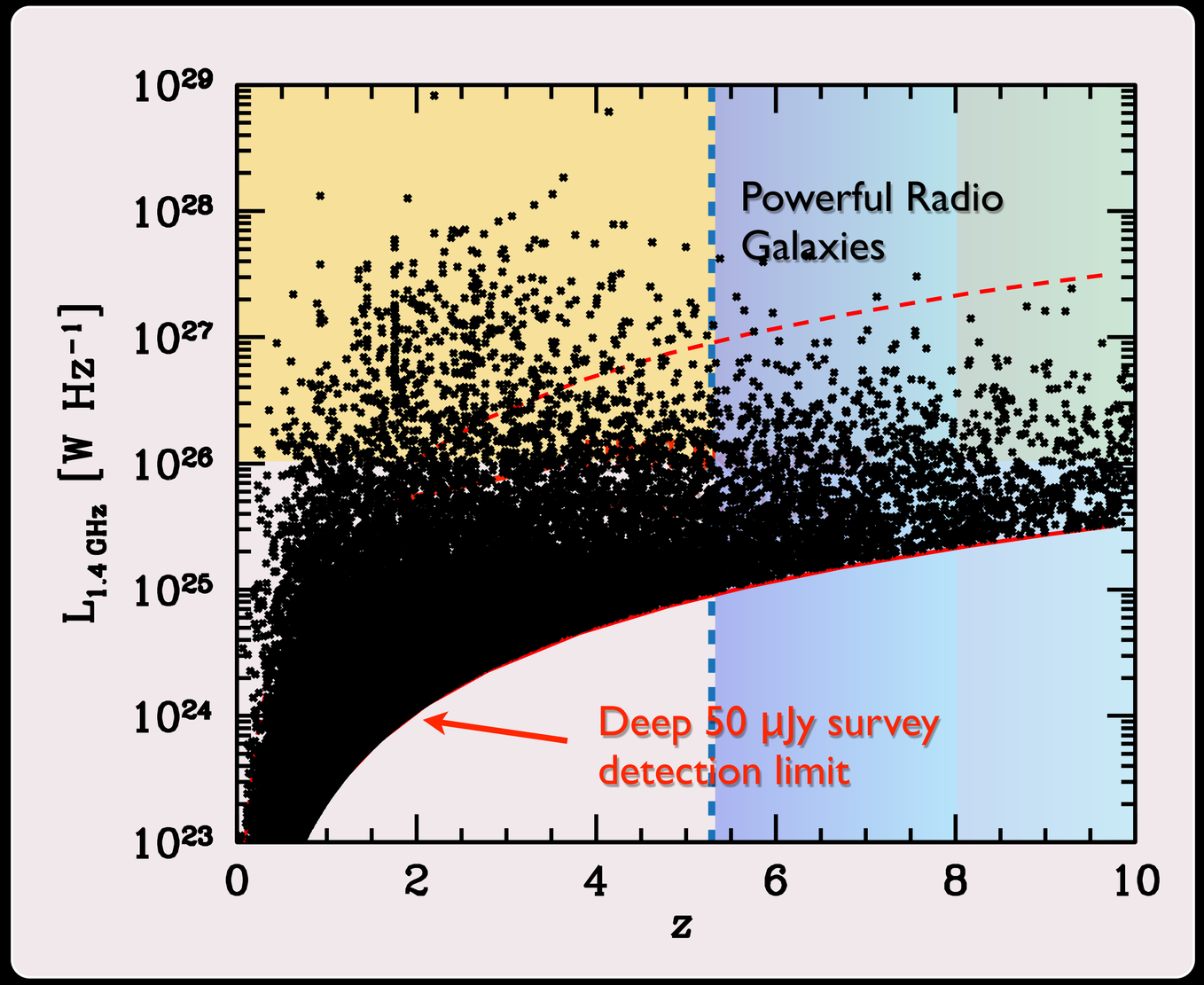
Powerful AGN *do exist* at z~7: OK

Theory: OK

Extrapolate from observations?

SKA Simulated Skies:
- 10 sq deg
- $S_{1.4GHz} > 50$ μJy

Do they even exist?



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Radio population evolution: OK

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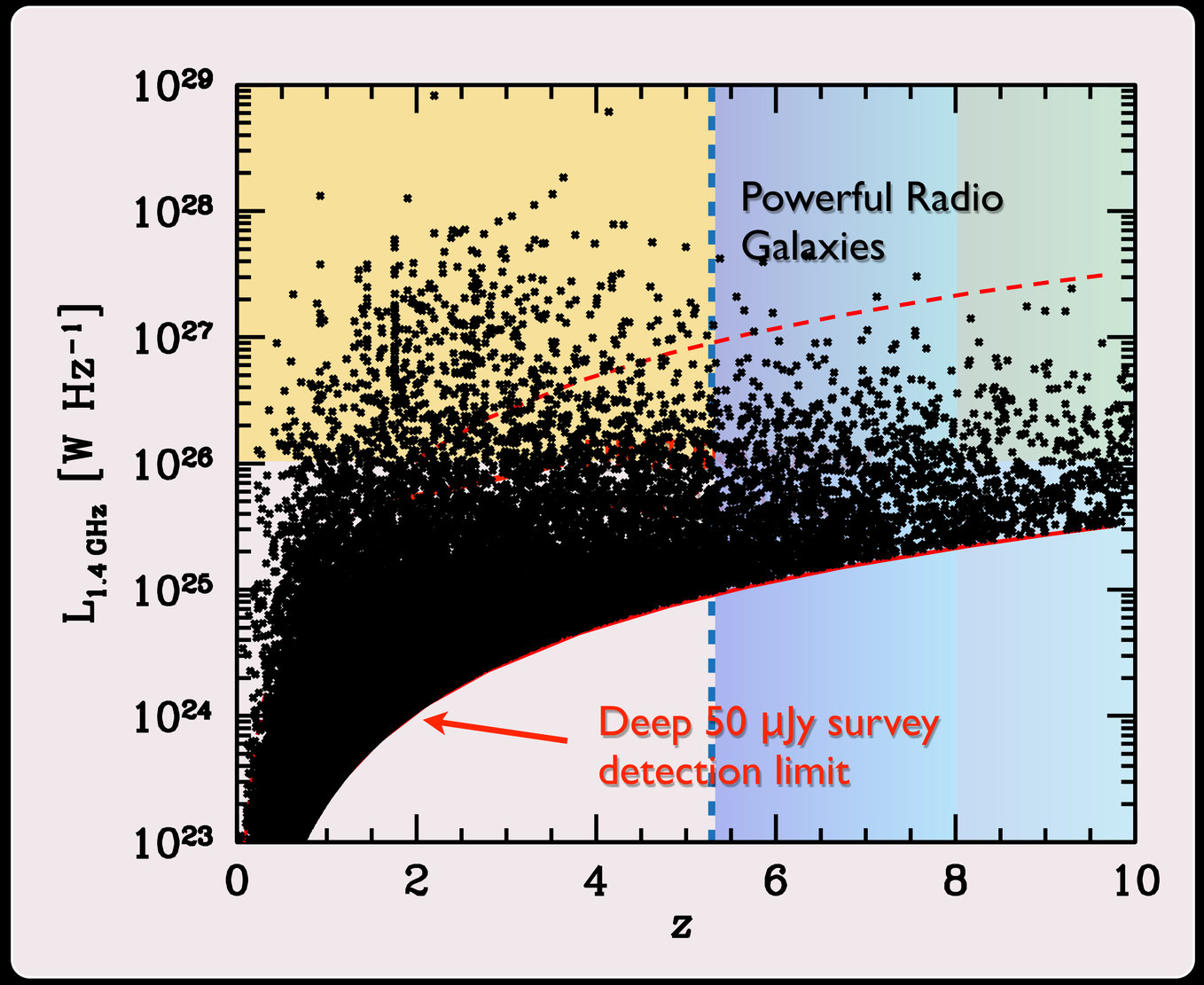
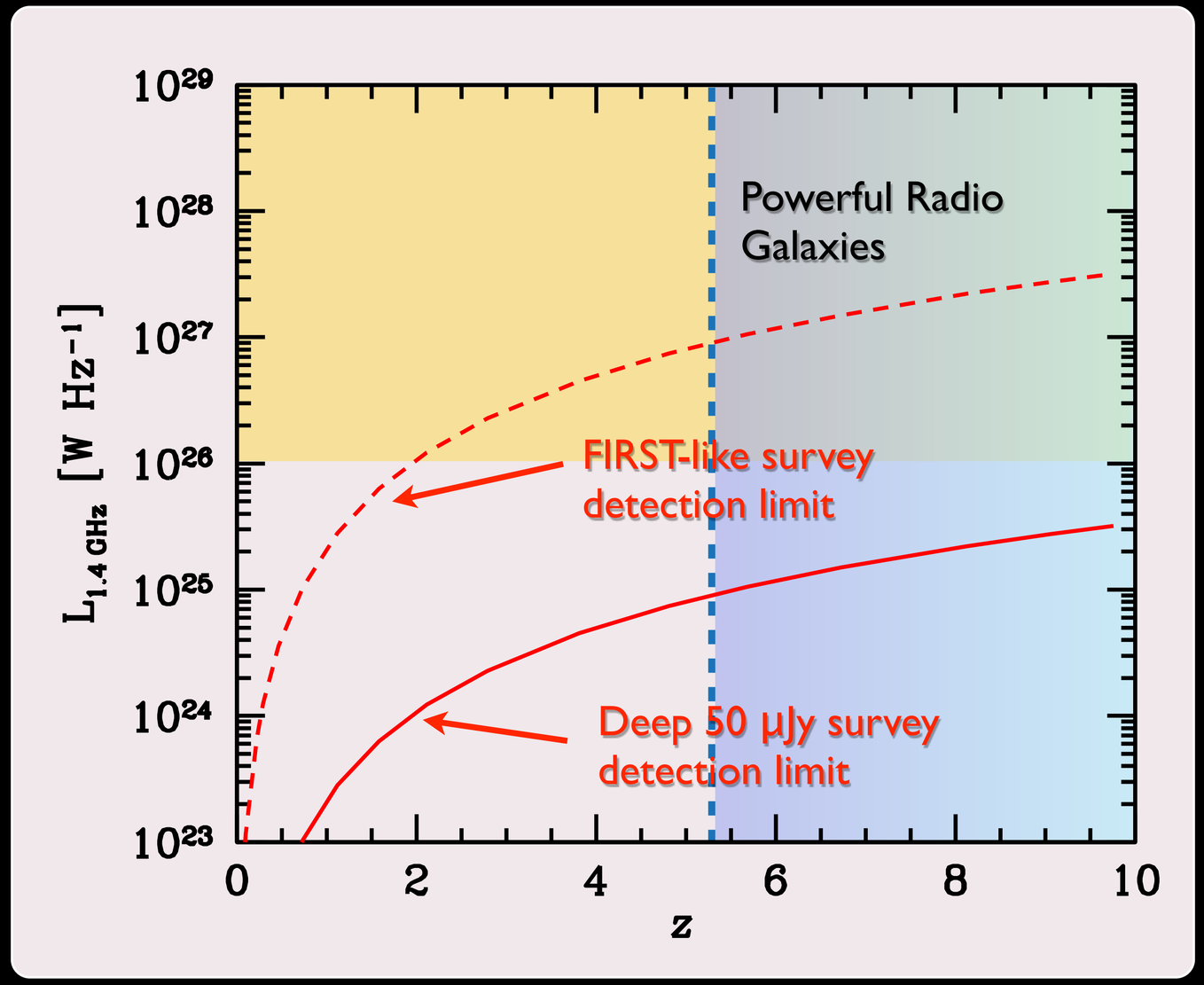


Powerful AGN *do exist* at z~7: OK

Theory: OK

Radio population evolution: OK

Can they be observed?



Powerful AGN *do exist* at z~7: OK

Theory: OK

Radio population evolution: OK

Increased electron losses to CMB - probably not problematic (enough energy available; denser environments;...)

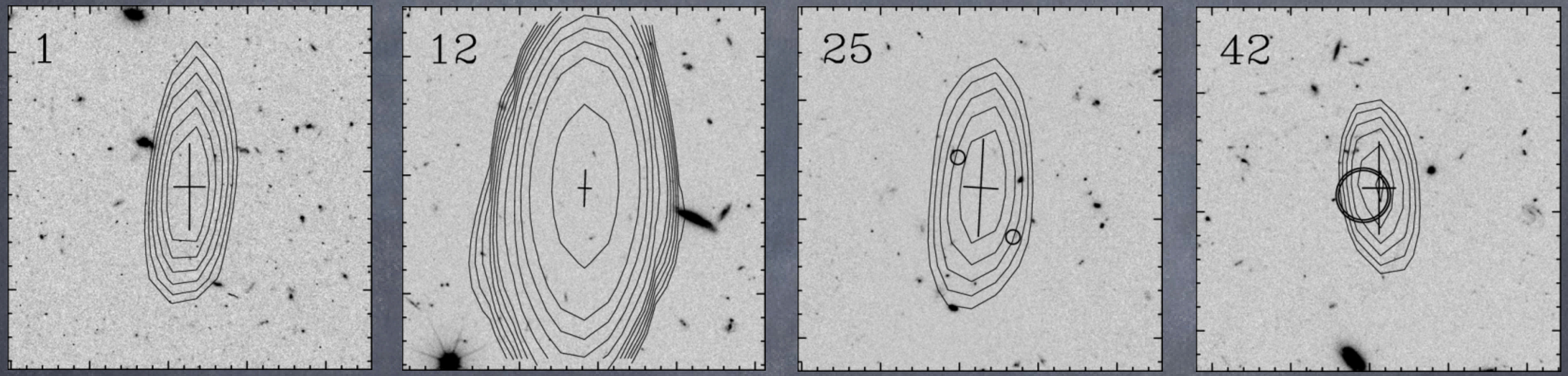
CMB losses: probably OK

Where are the first radio galaxies?

They (must) have been observed already!

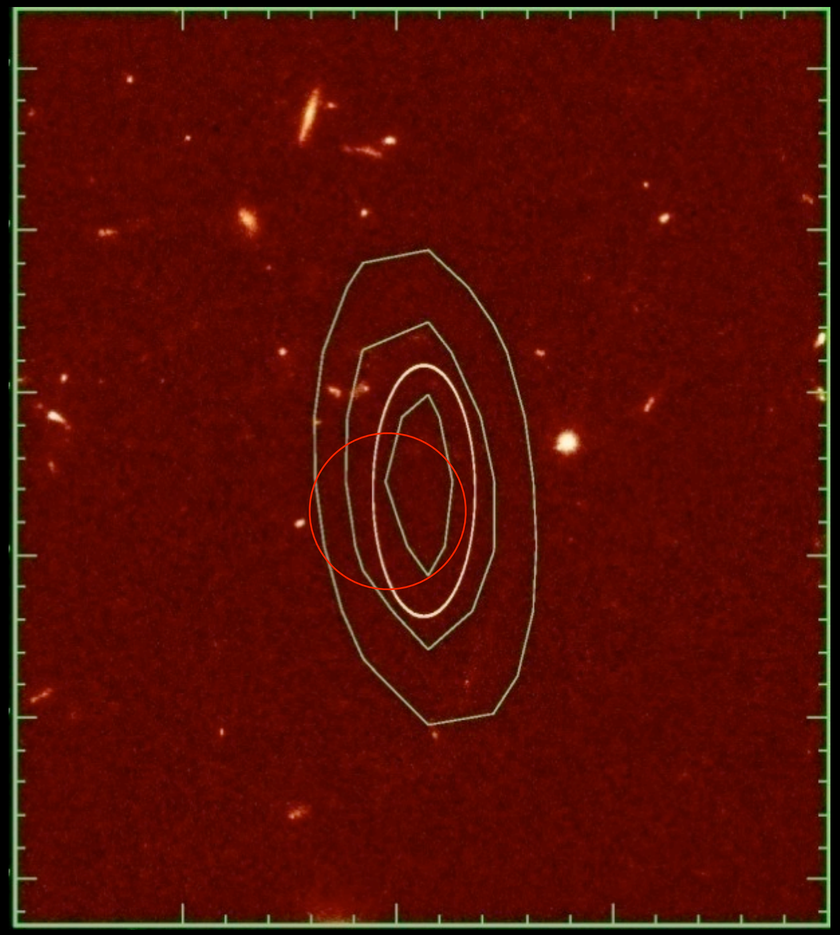
The currently "unknown" radio panorama

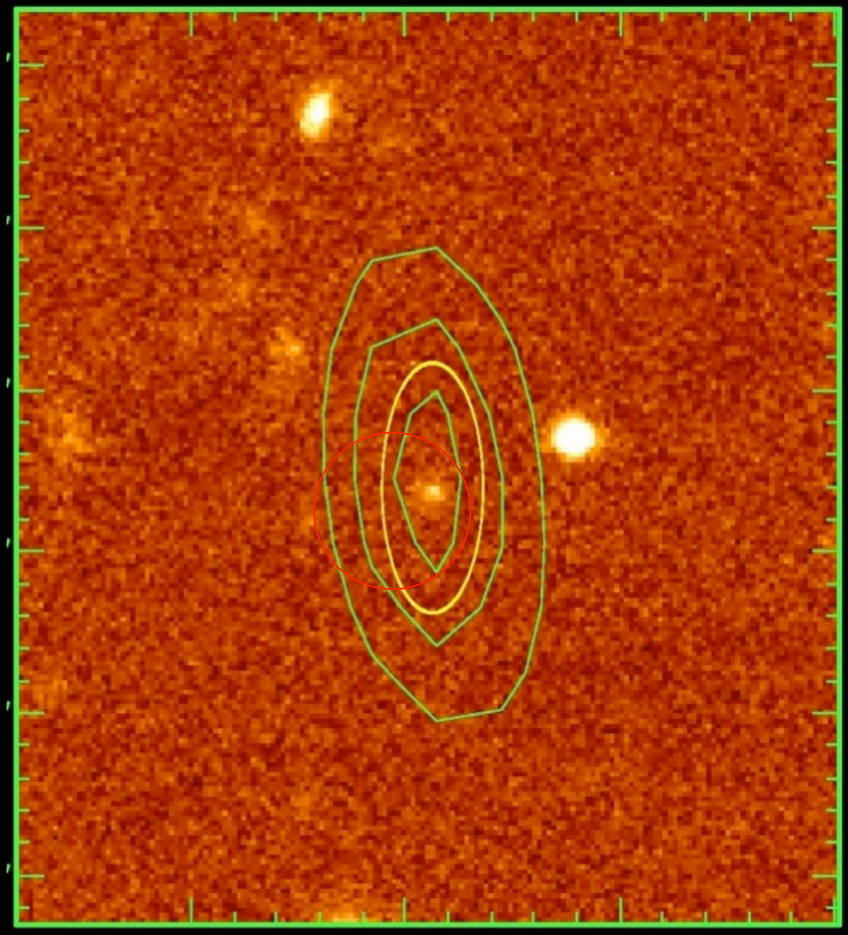
- RGs (including USS) undetected in the optical to very deep levels



(e.g., CDFS, Lockman Hole: Afonso et al 2006; 2011)

An extreme ERO AGN



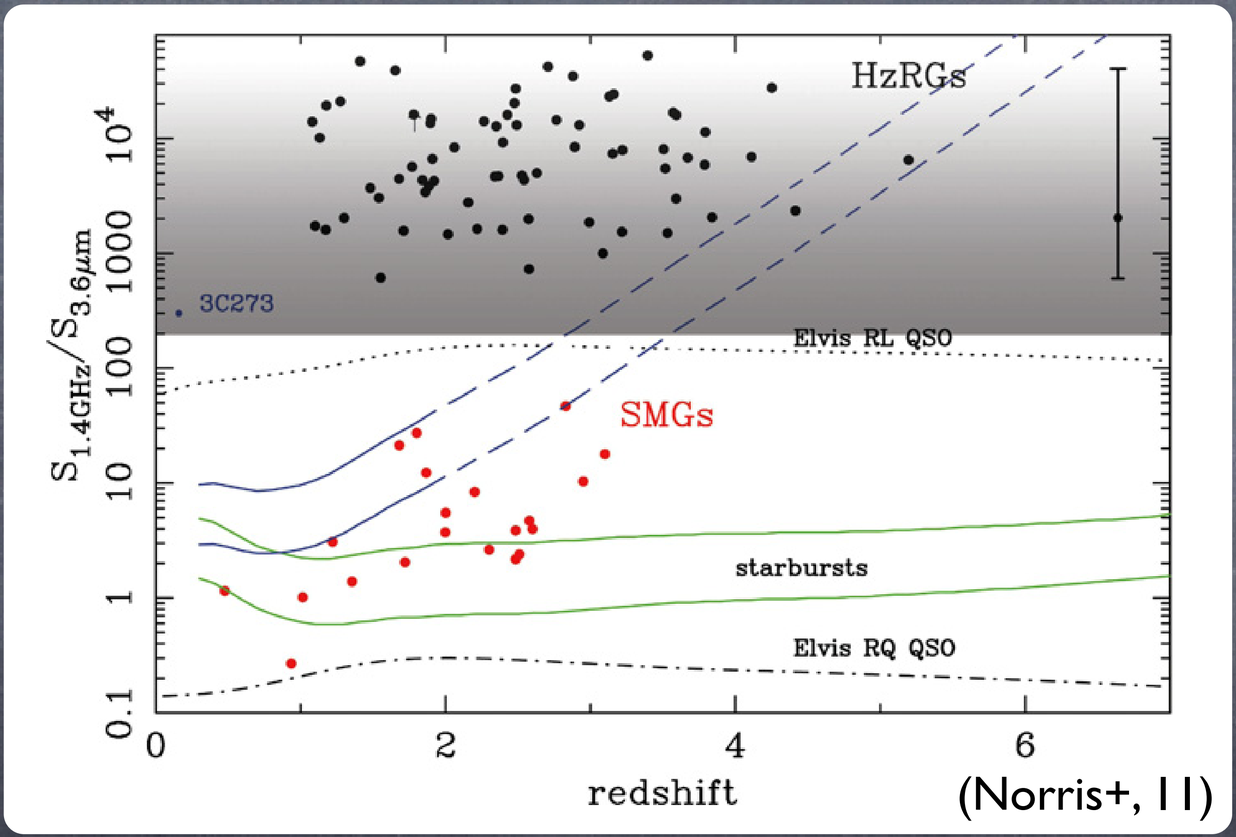


VLT: J_{AB}, K_{AB}= 27.2, 23.1

z-K>4.5, J-K=4.1

The currently "unknown" radio panorama

- RGs (including USS) undetected in the optical to very deep levels
- Infrared Faint Radio Sources (high radio/IRAC flux ratios)



(Norris+, 11)

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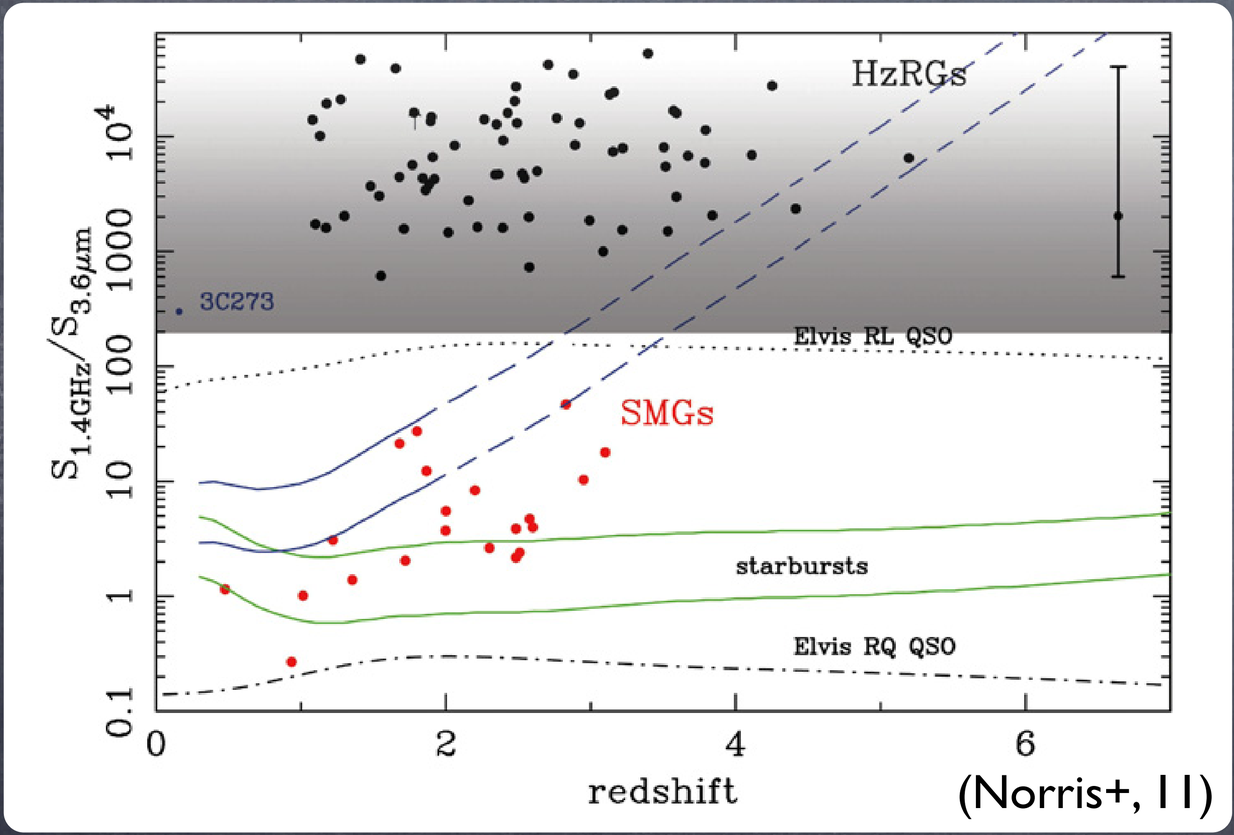
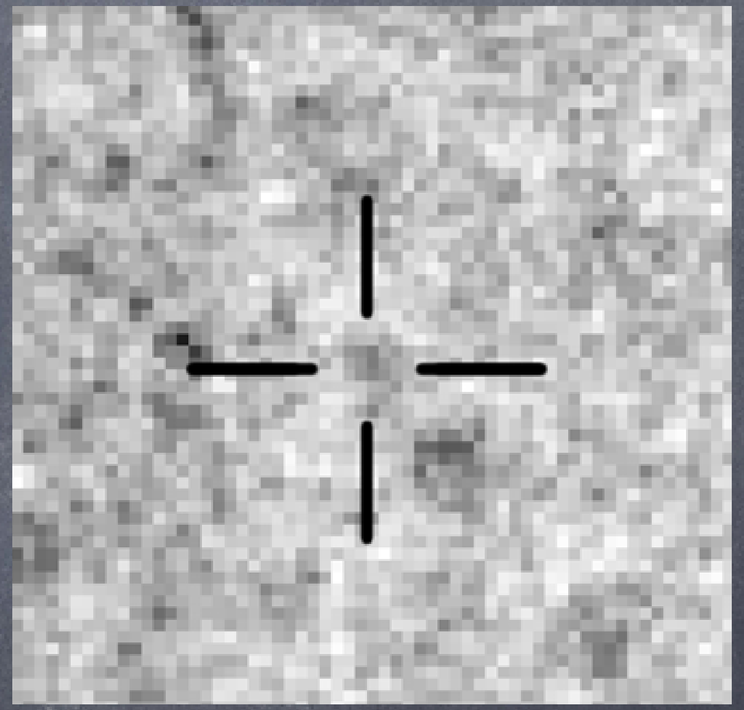


(Norris+, 11)



IRAC stack of 39 sources
$S_{1.4GHz}$~0.1-20 mJy

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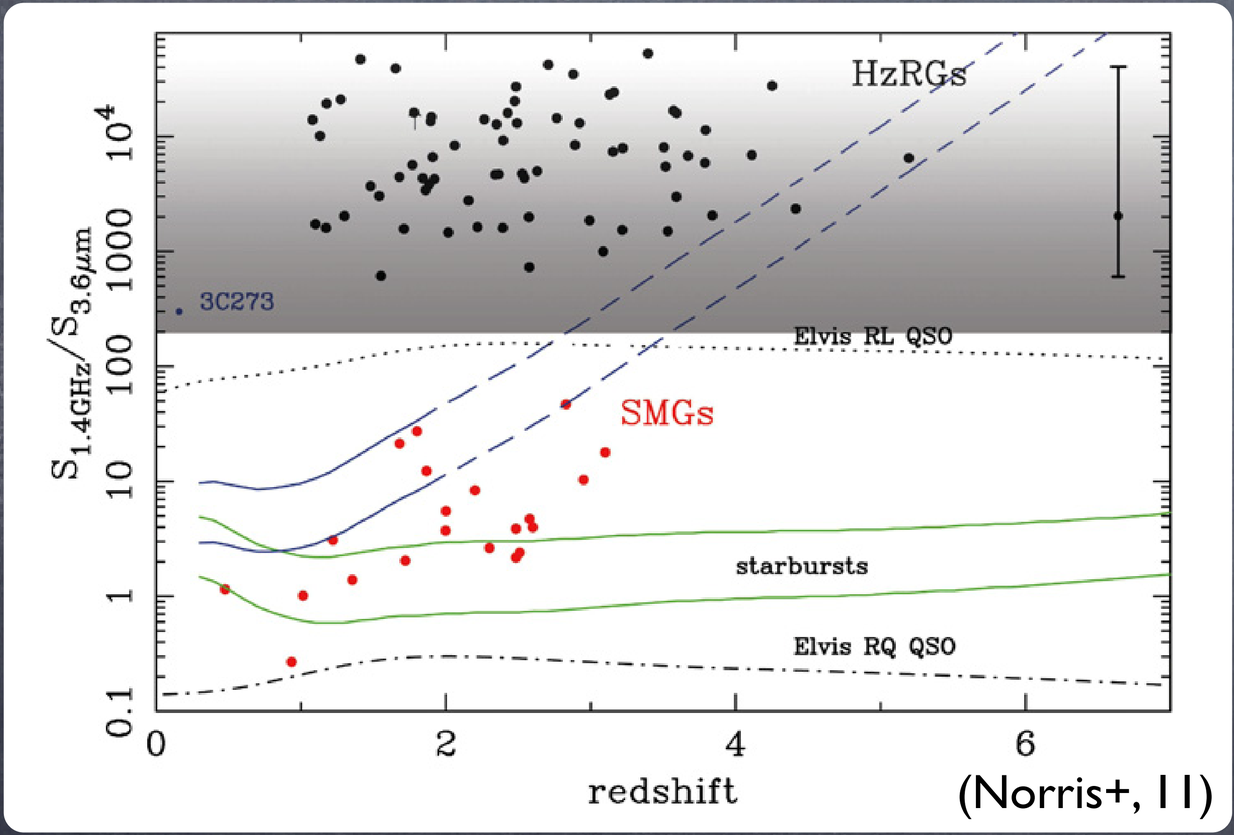

(Norris+, 11)

- Possibly, "the most efficient method for selecting high-z radio sources" (Ker+, 2012)

The currently "unknown" radio panorama

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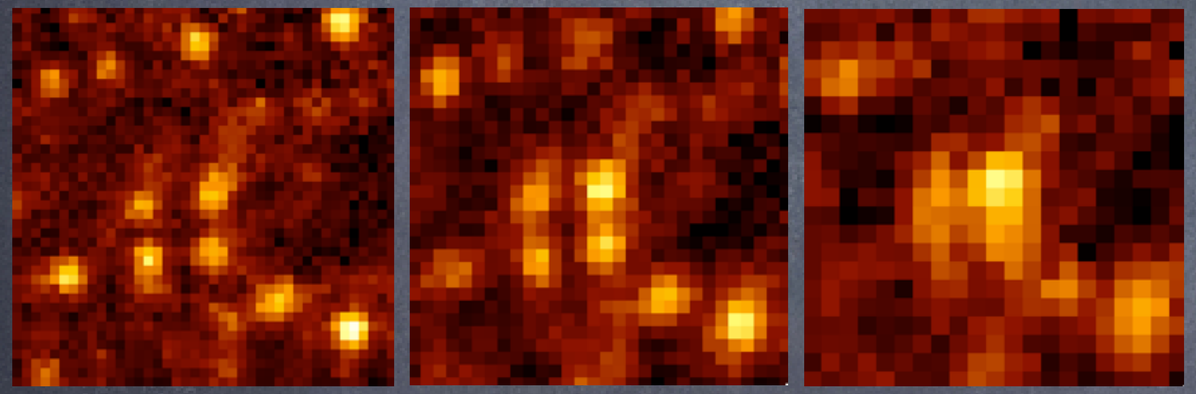
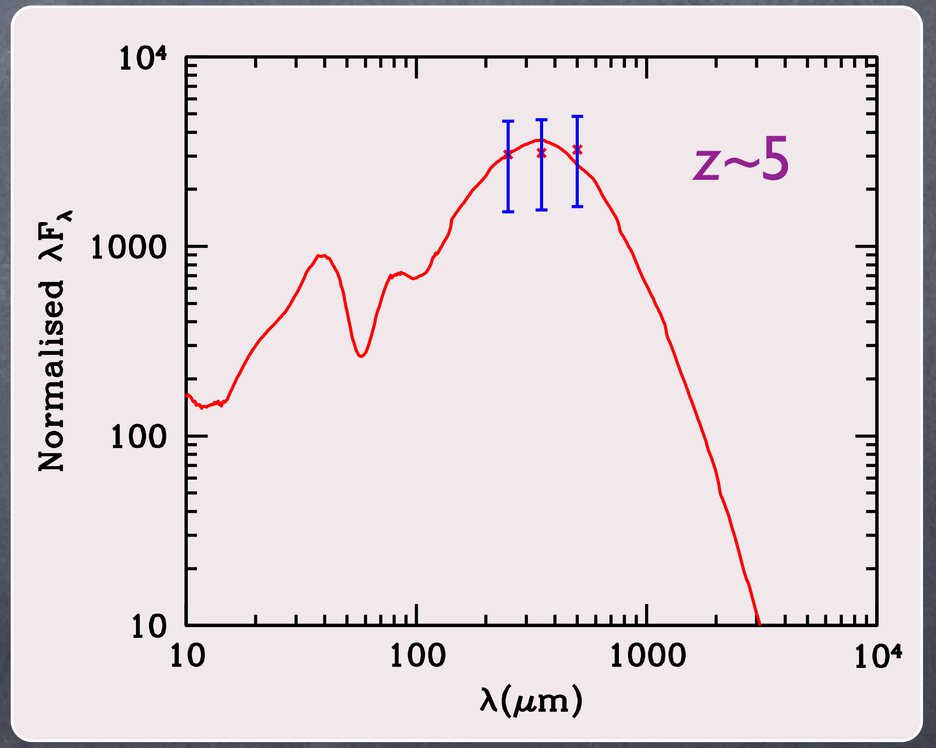
Some are detected with Herschel, with interestingly raising SED slopes in the FIR:



250 μm 350 μm 500 μm



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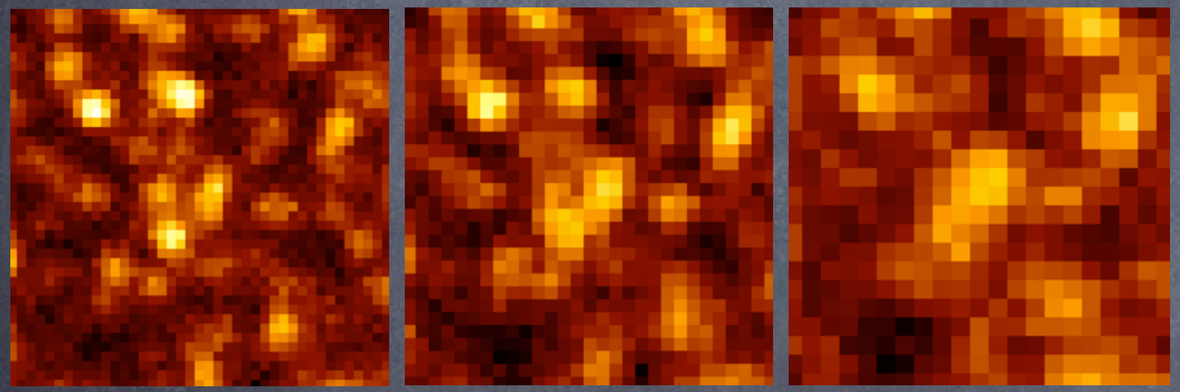

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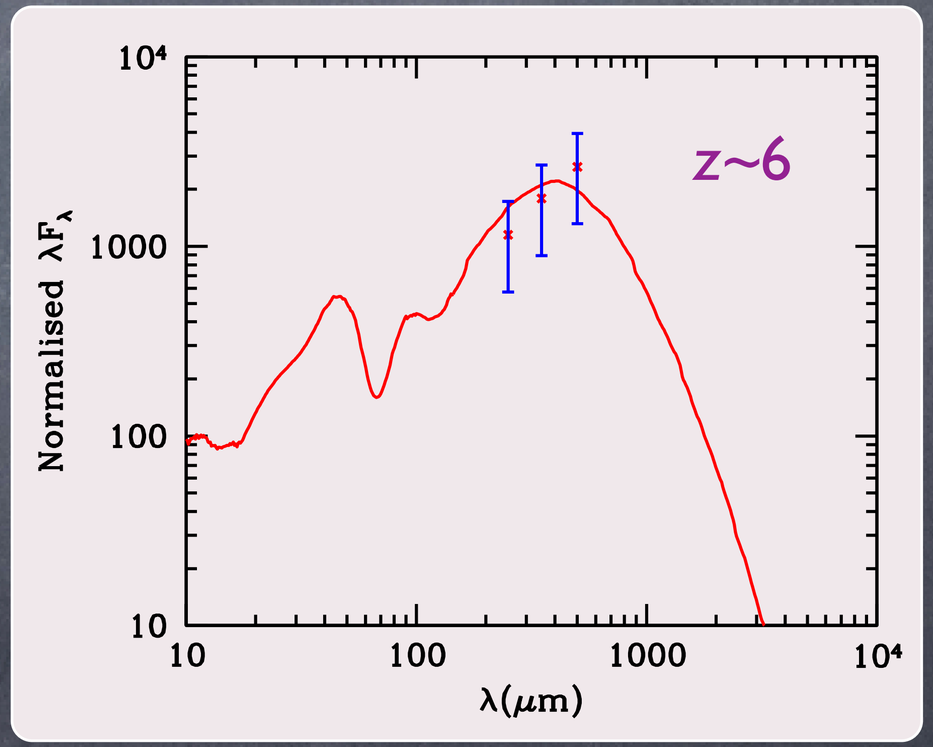

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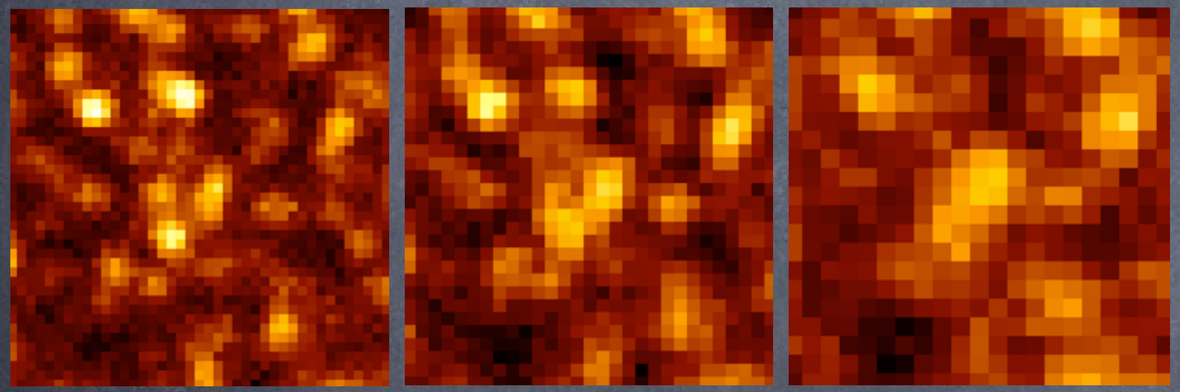

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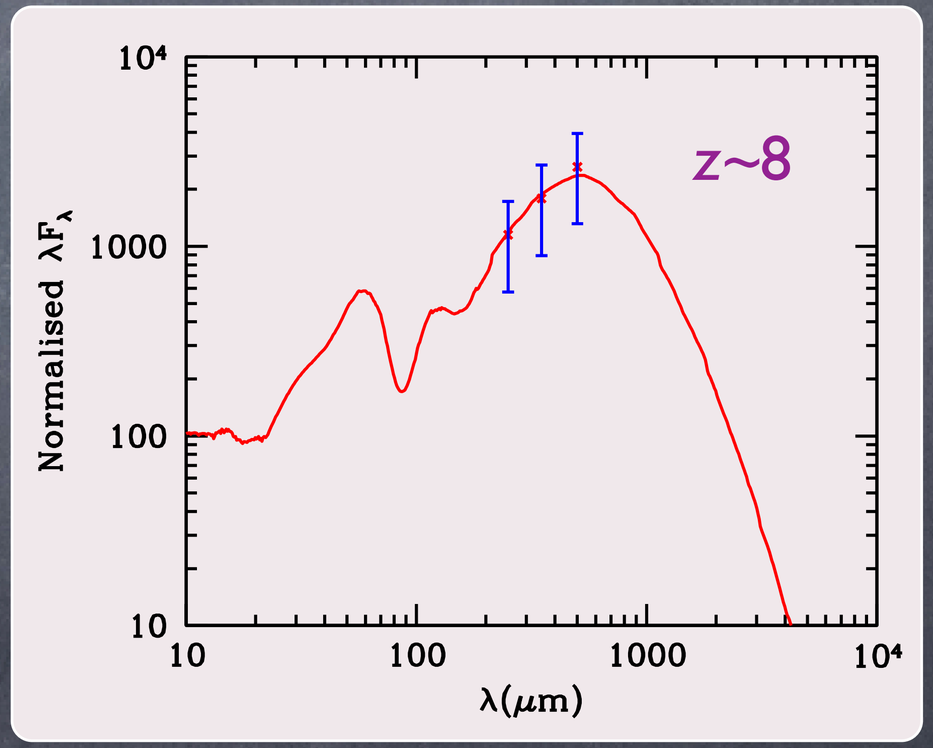

Ideally (and only) suited for ALMA...

Upcoming ventures in Deep Radio Probes of the Universe

By 2018, millions of sources from EMU and WODAN (and LOFAR...), over the entire sky!

Evolutionary Map of the Universe (ASKAP); Norris+, 11

Westerbork Observations of the Deep APERTIF Northern-Sky; Rottgering+, 11

=> FULL SKY @ 1.4GHz, ~15" resolution, 10-20 μJy rms

Cross-match to IR surveys + {ALMA, JWST, EELT}
will reveal the (radio) z~6-10 Universe.

In epitome...

Where are the first radio galaxies?

» Radio Surveys have probably already revealed tens of z>6 AGNs (to z~??).

» Essential to match next generation of radio surveys with deep multiwavelength (IR) follow-up.

» Confirmation only(?) possible with ALMA, JWST, EELT.

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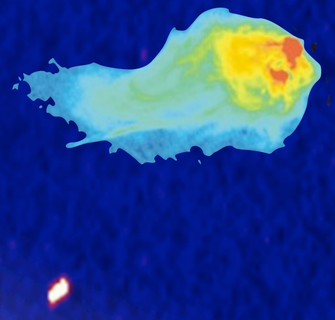
Towards the discovery of the *first* radio galaxies



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