AGN activity and the LSS

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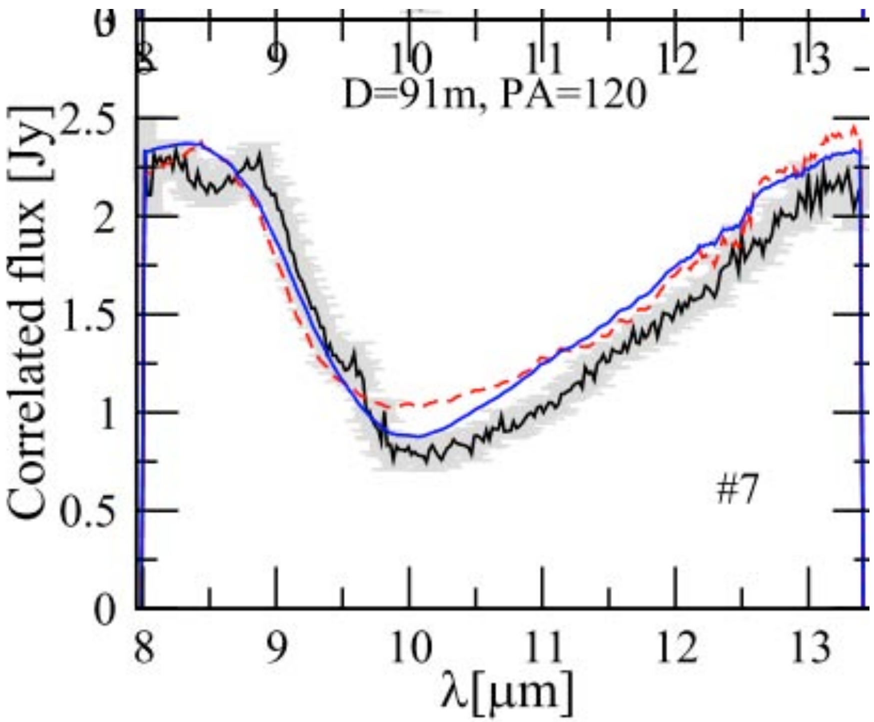
- Big Question: Coupled formation and evolution of
  - Black holes / AGN
  - Galaxies
  - Large Scale Structure
- Some recent key results
  - AGN Feedback deposits large amounts of energy influencing the evolution of clusters and galaxies
  - Hierarchical clustering lead to most massive BH in the most massive galaxies which are in the most massive clusters
    - z>2 powerful radio galaxies are located in protoclusters

    (Overzier, Venemans, Kurk, Miley, de Breuk, van Breugel, Maschietto, van Breugel, Pentericci, Carilli, HR et al.)
  - Tori exist, but not in all AGN
    - Raban, Jaffe, Meiserheimer, Tristam, HR
  - Radio loudness is a strong function of galaxy mass



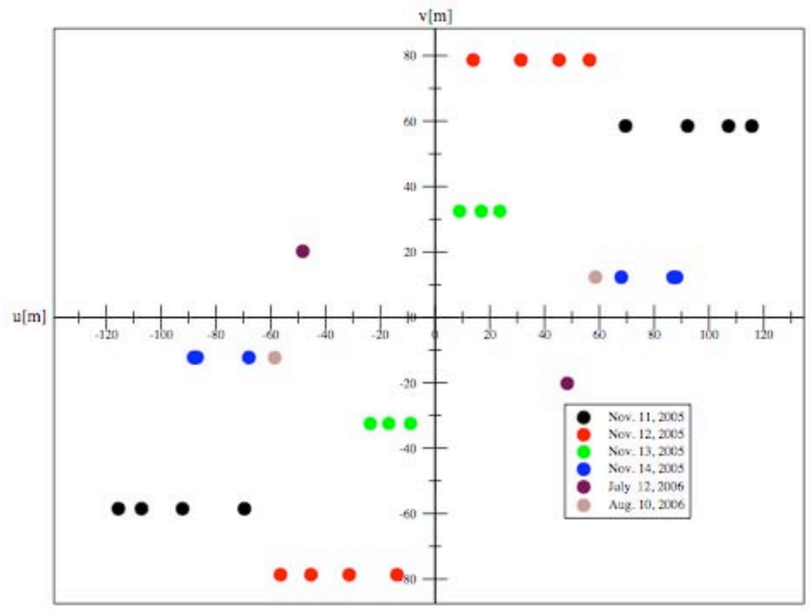


Figure 1. UV coverage for NGC1068, color coded according to date. Due to the ~0.0 declination of NGC1068, the UV tracks are parallel to the u-axis. u-v coords. [u,v] are complex conjugates of uv coords. [-u,-v], and both are plotted since they are indistinguishable.

Image of the torus of NGC 1068

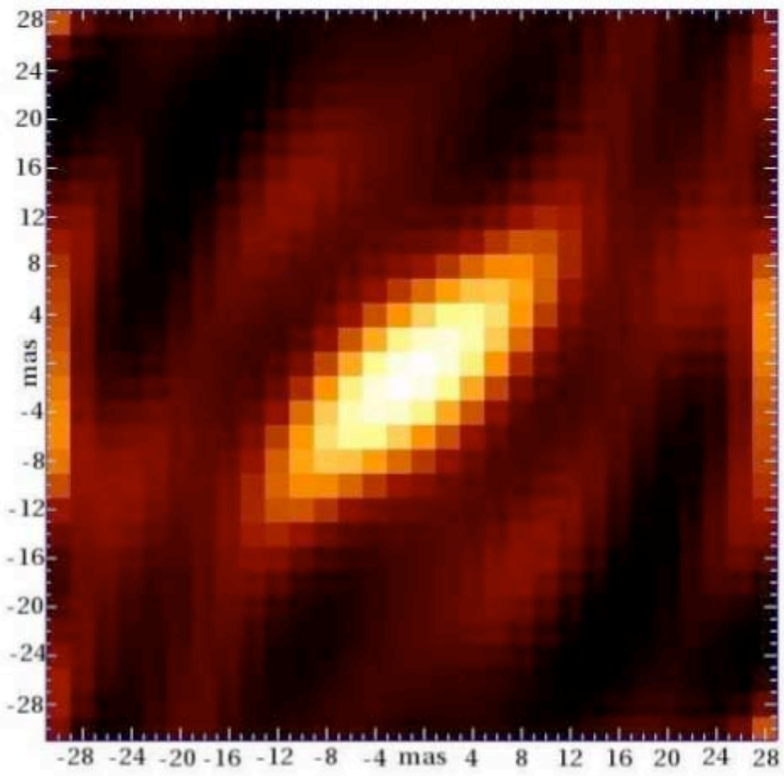


Figure 7. Maximum entropy reconstruction at 8μm . Image size is 30 × 30 pixels, with 1pix=2mas. color scale is linear. the extended blobs are artifacts caused by the low UV coverage. Gaussian fitting to this image measures it to be 7.7 / 21 mas in FWHM with PA=46°, very close values to the grey body model results, and in agreement with the results of the one Gaussian fitting at 8μm .

Two components:

- **Hot 800K, 1.4x0.5 pc "funnel"**
- **Cool 300K 3x4 pc torus**

Raban, Jaffe, HR, Meisenheimer, Tristam in prep.

9 other AGN show 'similar Structure, except the radio Galaxy CenA that does not seem to have a torus

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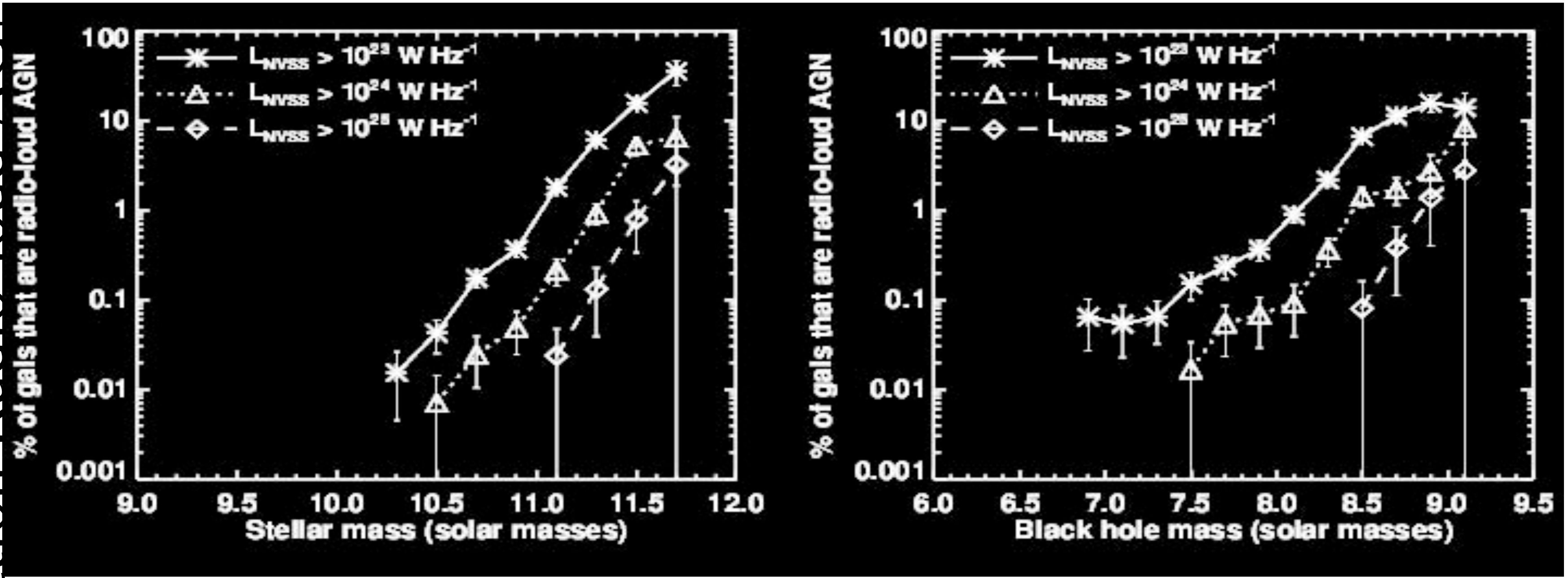
fraction Radio-loud AGN



$f_{radio\text{-}loud} \sim M_*^{2.5}$ $f_{radio\text{-}loud} \sim M_{BH}^{1.6}$

Best et al 2005:

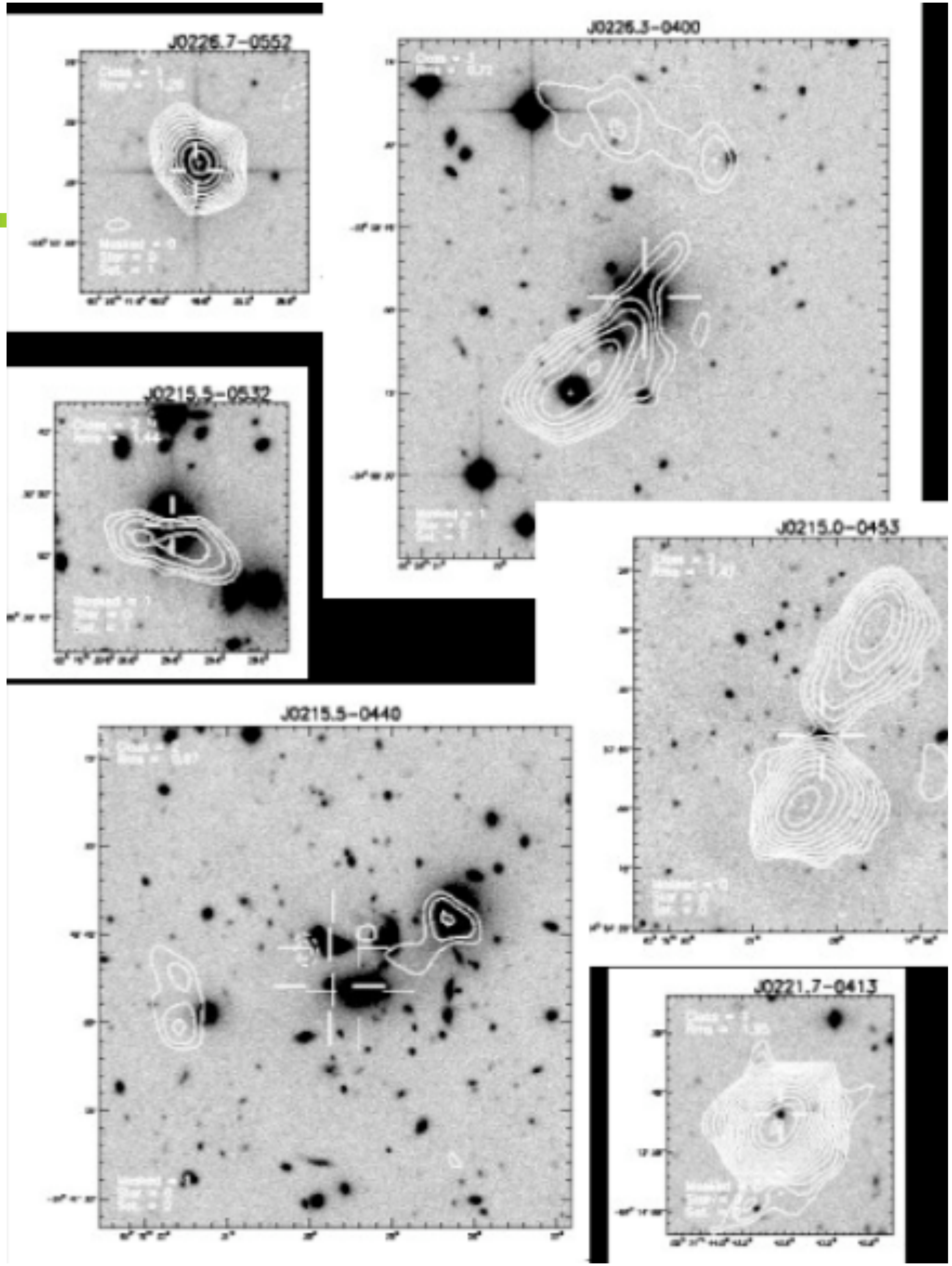
For massive galaxies, the rate of activity and energy output sufficient to heat their hot halos

Key questions

- How does the radio loud fraction evolve?
- How does the radio loud fraction depend on the environment?
- How does AGN activity depend on accretion mode ?
  - Cold accretion / quasar mode / “torus mode”
    - Activity due to a merging event
  - Hot accretion / radio mode
    - Activity due to hot gas cooling
- Topic of Cyril Tasse’s thesis
  - Best, Cohen, Le Borgne, Pierre, HR, et al.

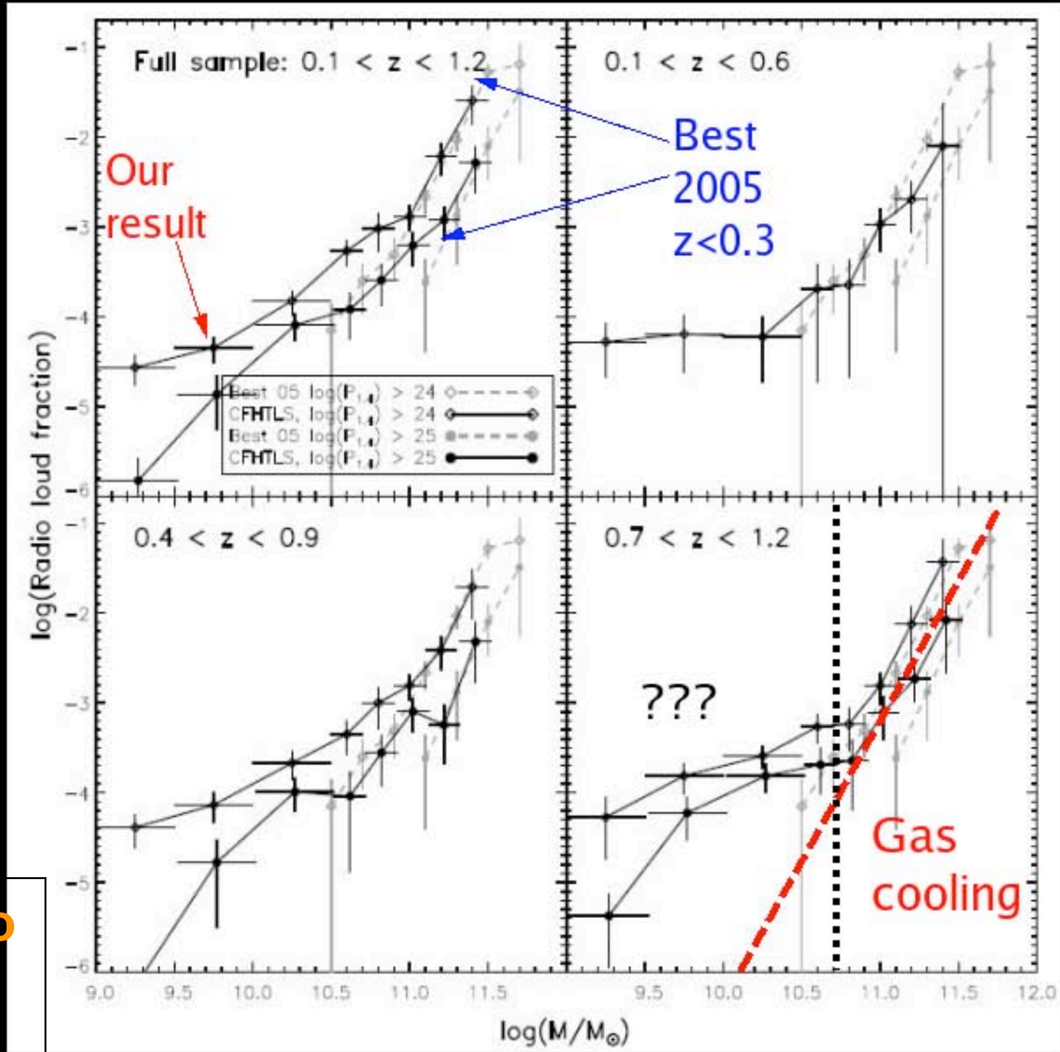
XMM-LSS survey

- 10 sqr degree of XMM data
- Spitzer Swire survey
- CFHTLS (u,g,r,i,z) survey with 3 million galaxies
- GMRT and VLA surveys 74, 230, 325 and 610 MHz
- Complete catalogue with for each object:
  - Phot-z, galaxy mass, AGN loudness, density of its environment

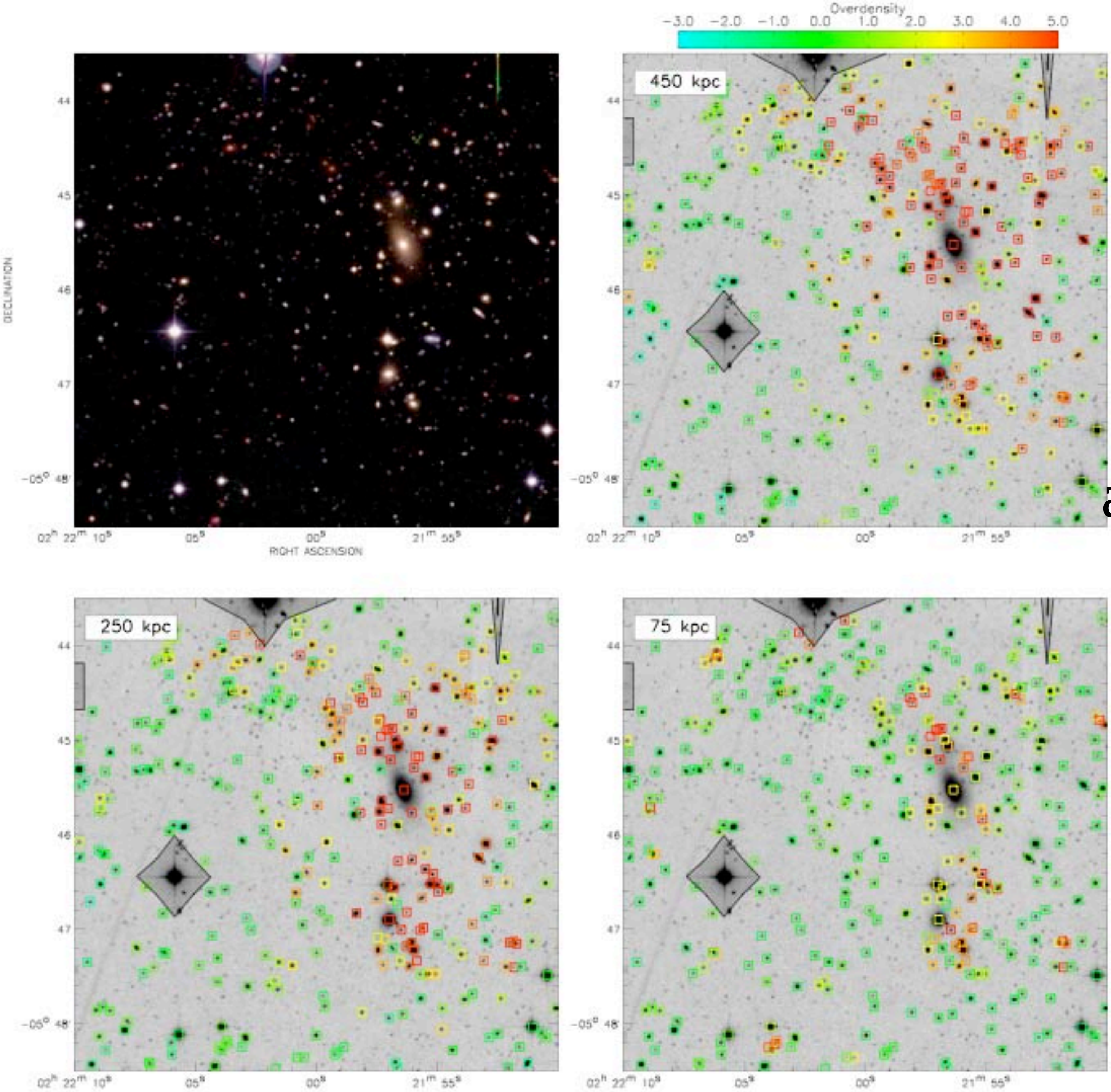


Fraction-mass relation

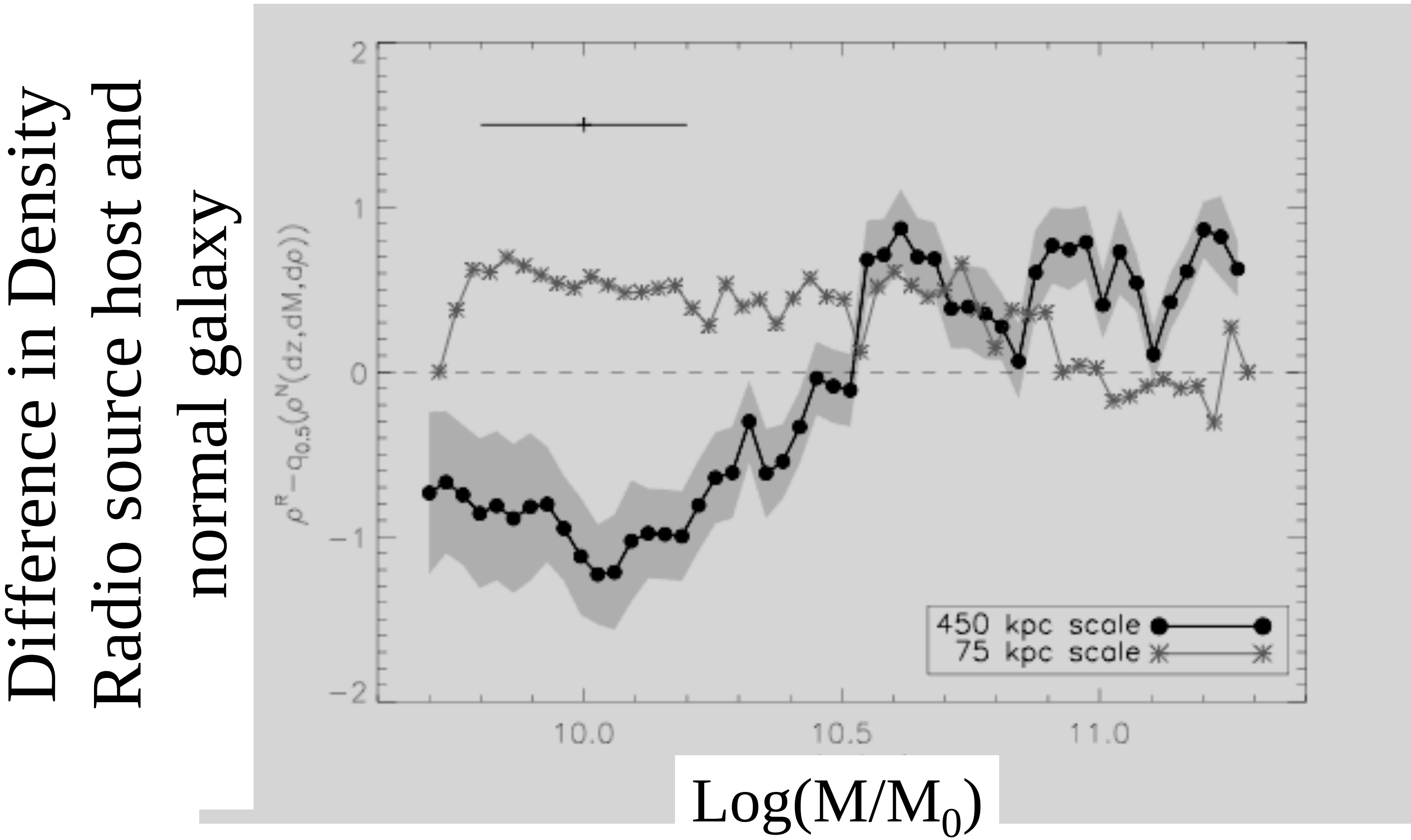
- Following Best 2005, we derive the fraction of galaxies that are radio loud: $f=\Phi_{rad}/\Phi_{opt}$
- Agreement with the SDSS measurement at low redshift and in similar mass range
- A break appears 10^10.5 10^10.8 Msol



Upturn of the radio LF due to less massive galaxies become more active

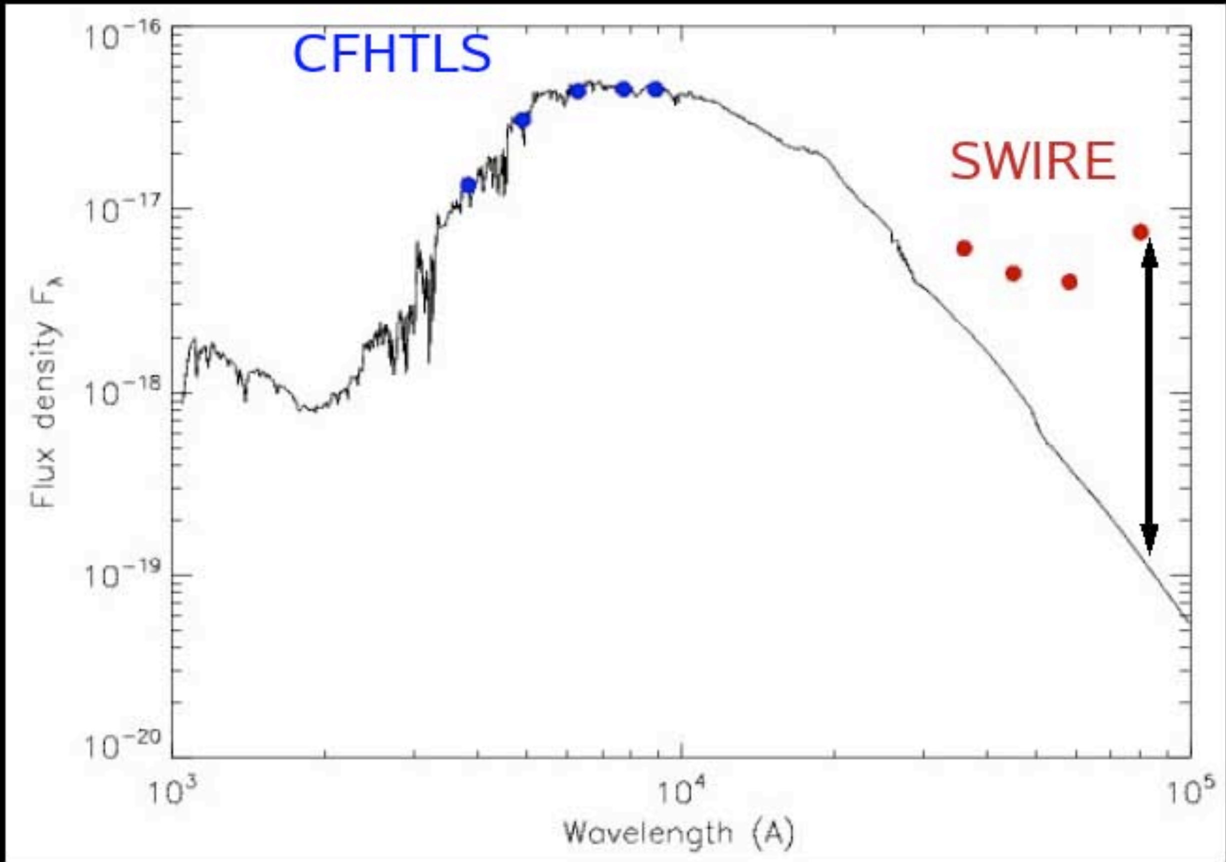


Overdensity
as
a function of
scale



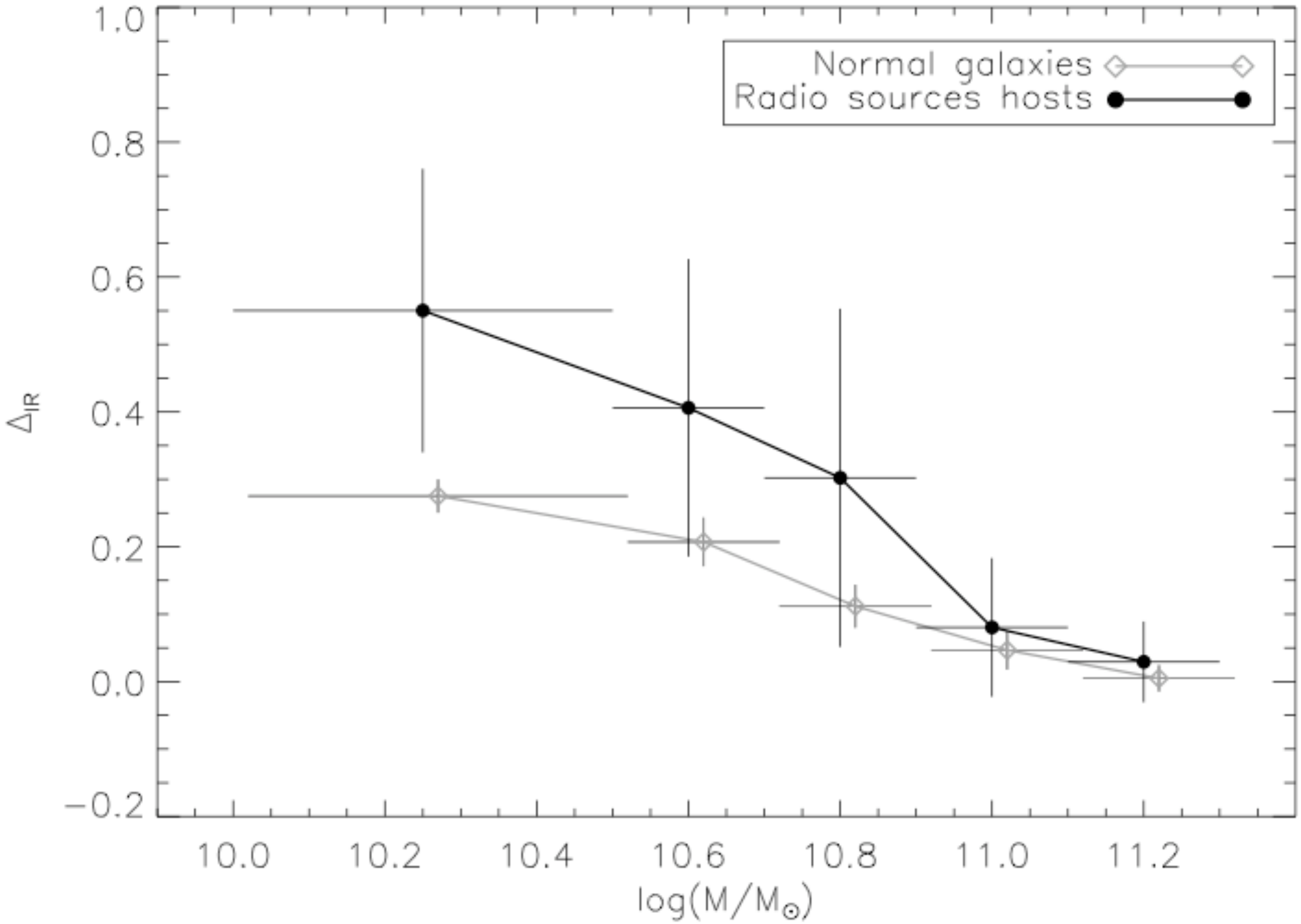
- **Higher galaxy mass radio galaxies in clusters**
- **Lower galaxy mass radio galaxies are in the field**
  - **Cold accretion - due to merging more dominant at higher z ?**
  - **The reason for the upturn in the radio LF?**

Infrared properties



- **ZPEG does not take into account dust emission in the infrared**
- **Infrared excess in the observer frame:**

$$\Delta_{IR} = \log(F_\nu(\lambda_{IRAC})/F_\nu^{ZPEG}(\lambda_{IRAC}))$$



Normalized IR excess for radio loud galaxies
Only excess/torus emission for the lower mass galaxies

Summary Radio sel. AGN

- **Galaxies with M>10^(10.6-11) Msol:**
  - The fraction-mass relation agrees with the z<0.3 radio sources (Best 2005)
  - They prefer large scale overdensities
  - These sources do not show infrared excess

Hot Gas?

?

Radio mode?

- **Galaxies with M<10^(10.6-11) Msol:**
  - Their fraction-mass relation is flatter
  - These sources show a hot infrared excess
  - These sources were more present in the past
  - They prefer large scale underdensities

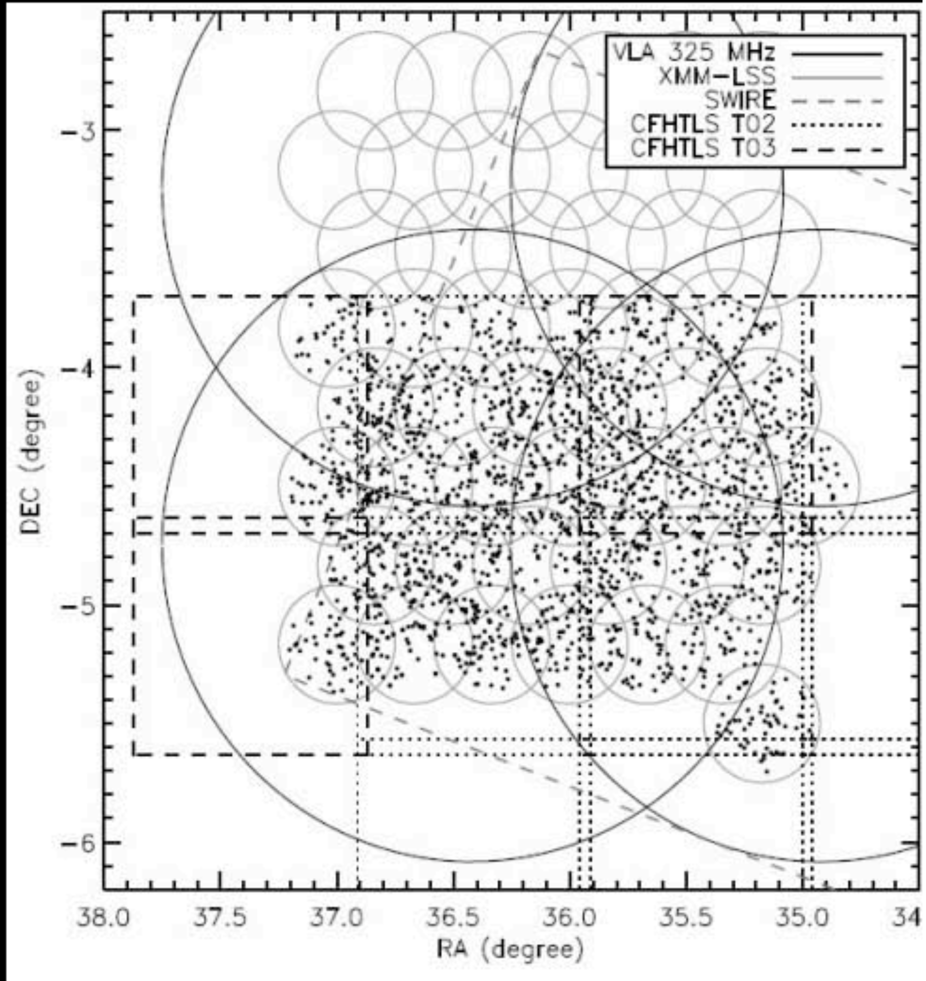
Quasar mode?

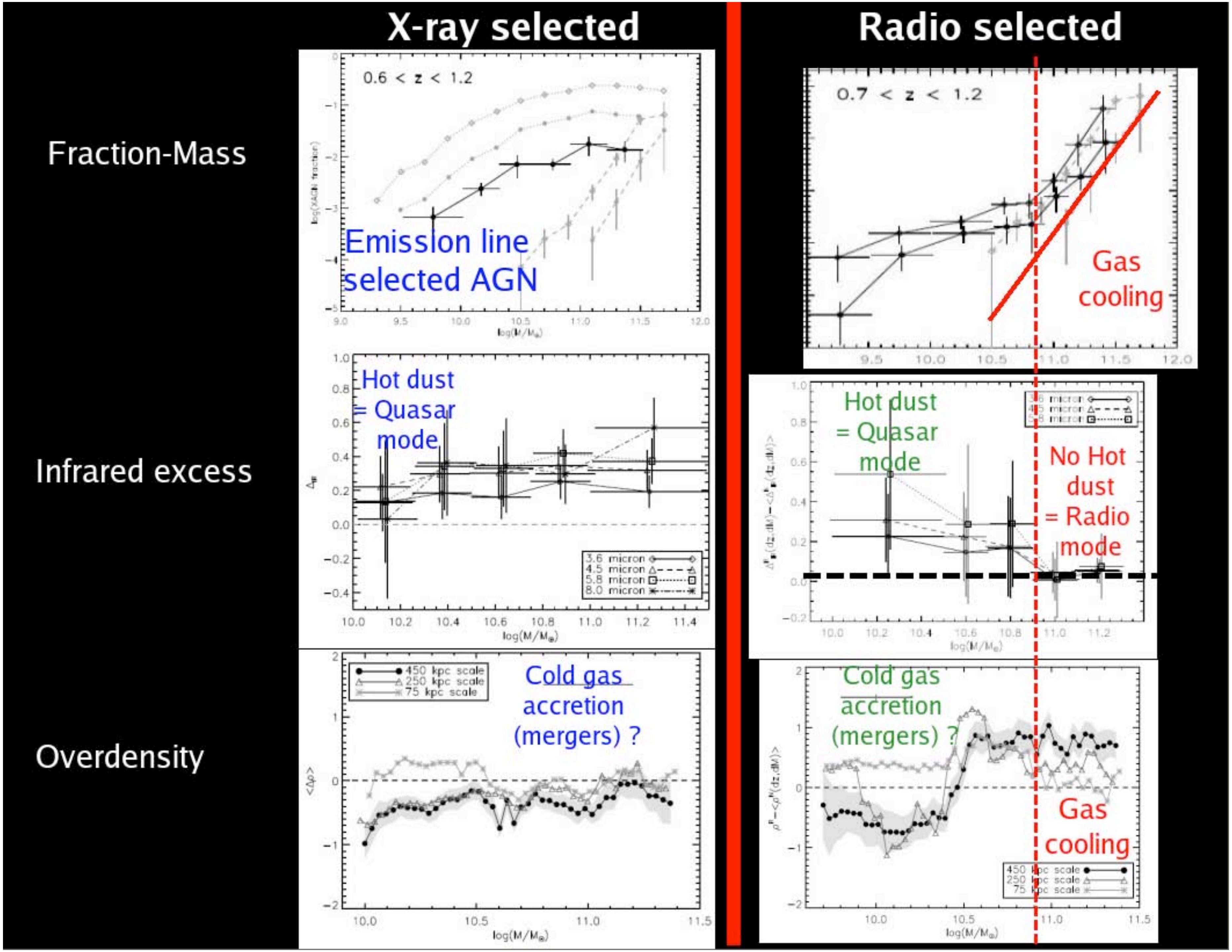
?

Cool gas, Mergers?

X-ray selected AGN

- Sample of ~1000 point-like X-ray sources (~4 sq deg)
- ~80% have optical identification
- We select the type-2 AGN
- Using the soft X-ray flux, we estimate the hydrogen column density and derive intrinsic luminosities
- ZPEG (z, M)
- 0.1<z<1.2, 18<i<24
  → ~200 X-ray sources hosts

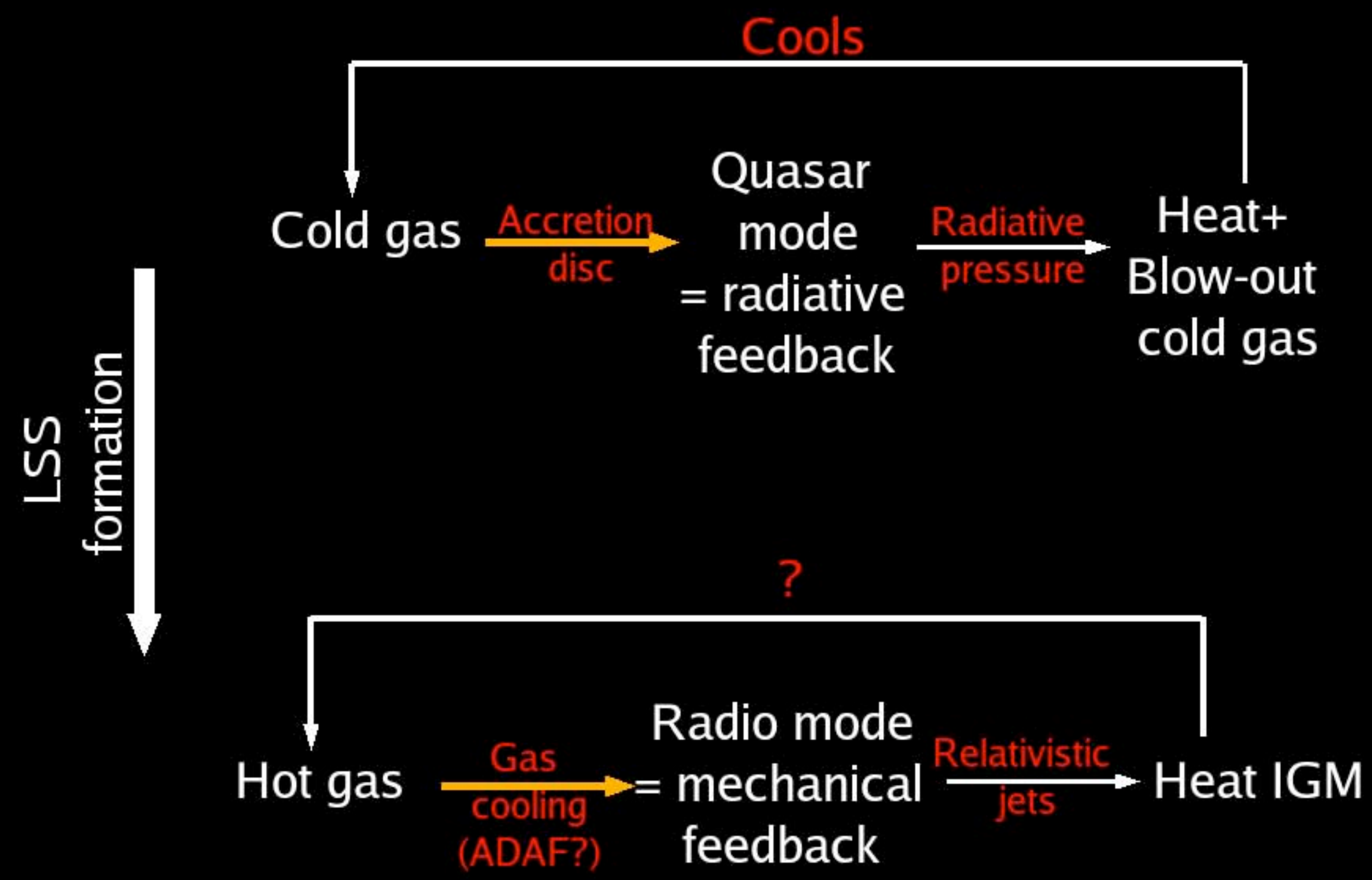



X-ray selected
Radio selected
Fraction-Mass
Infrared excess
Overdensity
0.6 < z < 1.2
Emission line selected AGN
0.7 < z < 1.2
Gas cooling
Hot dust = Quasar mode
3.6 micron
4.5 micron
5.8 micron
8.0 micron
Hot dust = Quasar mode
No Hot dust = Radio mode
Cold gas accretion (mergers) ?
450 kpc scale
250 kpc scale
75 kpc scale
Cold gas accretion (mergers) ?
Gas cooling
log(M/M⊙)

Summary X-ray sel. AGN

- Xray selected AGN is a homogeneous population:
    - Their fraction-mass relation agrees with emission line selected AGN
    - They show a hot infrared excess → Quasar mode?
    - They lie in underdense environment → Cool gas, Mergers?

Summary: Triggering processes and evolution?



Next steps

Key questions

- How does the radio loud fraction evolve?
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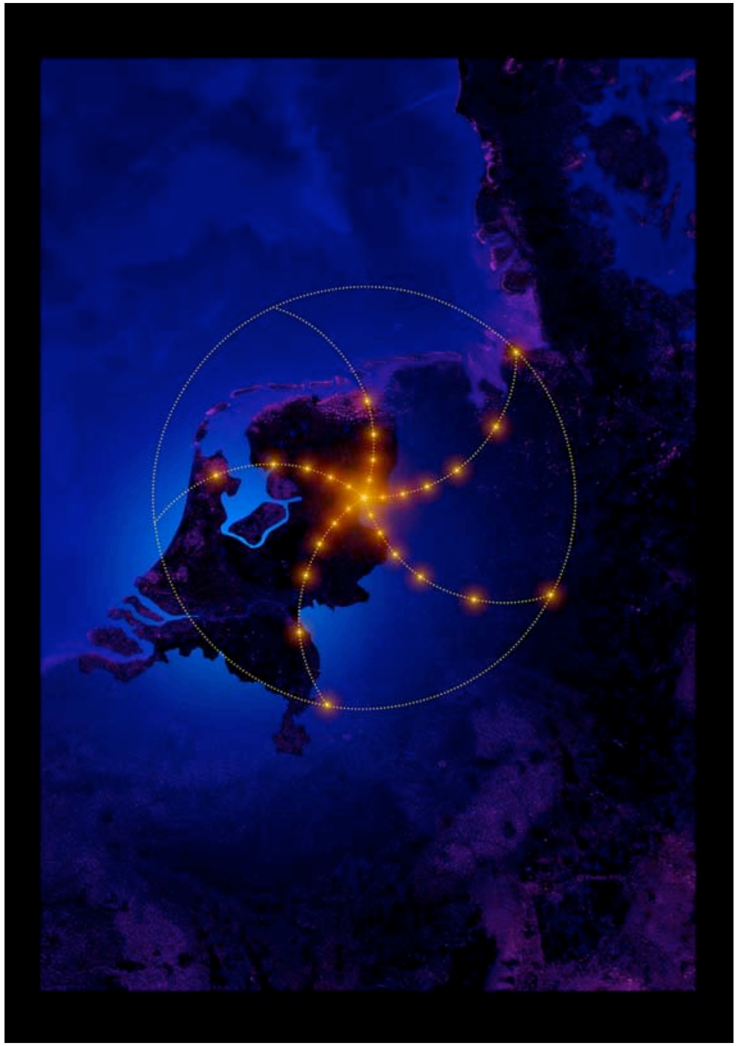
- How does AGN activity depend on accretion mode ?

Next goal

Trace these up to z~1.5

LOFAR opens up the last ``unexplored'' wavelength region

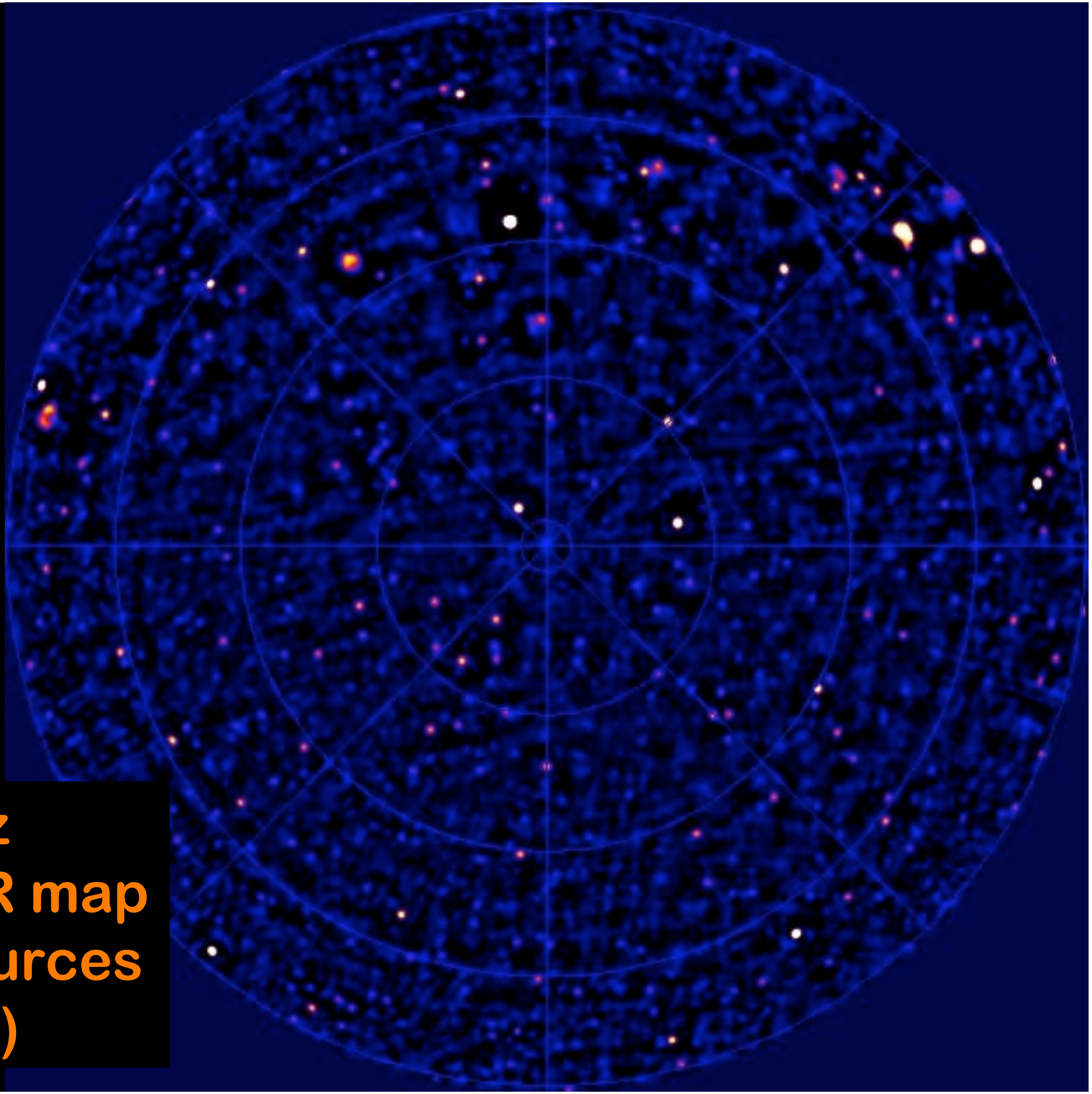
- Unique frequency range
  - $\nu \sim 10 - 240$ MHz
- Unprecedented sensitivity
- Enormous field of views
  - Multi-beaming: up to 24 beams
- Phase I: Fully funded (!)
  - ~50 stations with baselines of up to 100 km
  - Angular resolution:
  - 4 arcsec at 200 MHz
- Phase II
  - Baselines up to 1000 km
  - Angular resolution:
  - <1 arcsec at 200 MHz
- Science
  - Reionisation, cosmic rays, transient radio sources
  - z>6 radio galaxies, clusters and distant starbursts




Low Band Antennas:
30-80 MHz

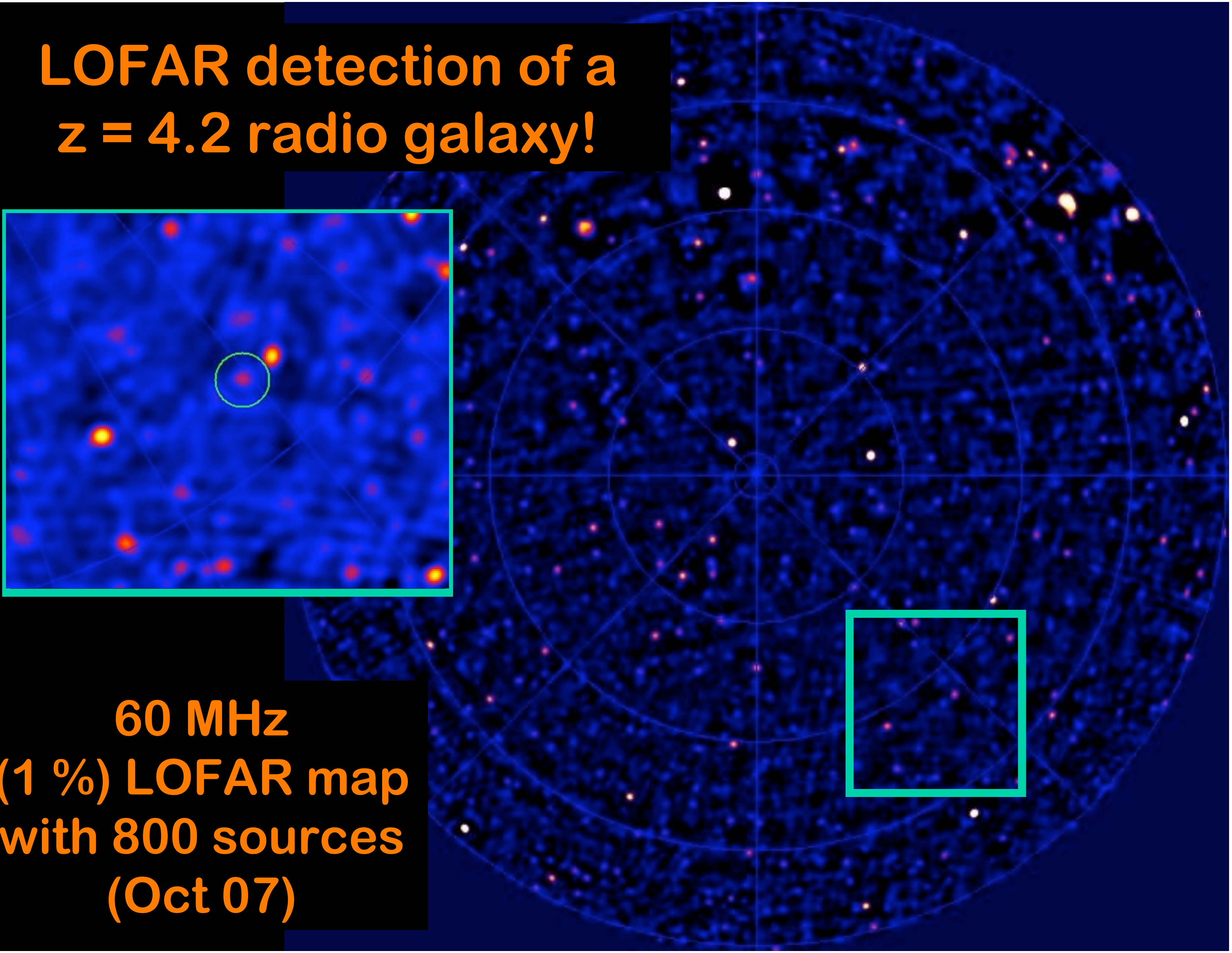

(the not enclosed) High Band Antennas:
115-240MHz


Phased arrays: beams are formed
electronically and not mechanically



60 MHz
(1 %) LOFAR map
with 800 sources
(Oct 07)

LOFAR detection of a z = 4.2 radio galaxy!



60 MHz
(1 %) LOFAR map
with 800 sources
(Oct 07)

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Next goal: trace these up to z~1.5

- Significant sample of z>1 clusters
- A X-ray AGN sample with same range in luminosity as at z~0.4
- Need for excellent optical and IR data

-> 50 deg^2 with 40 ksec