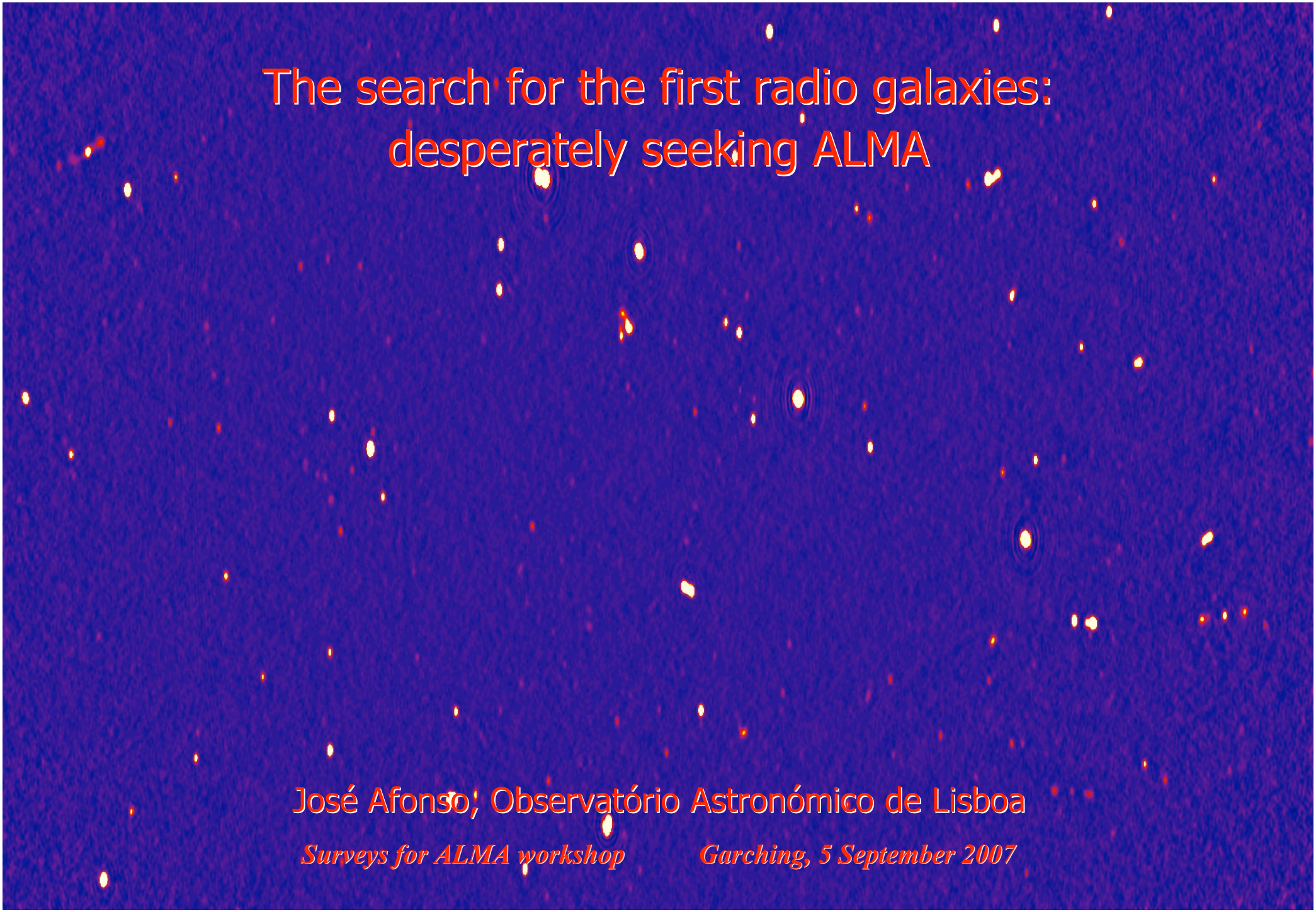


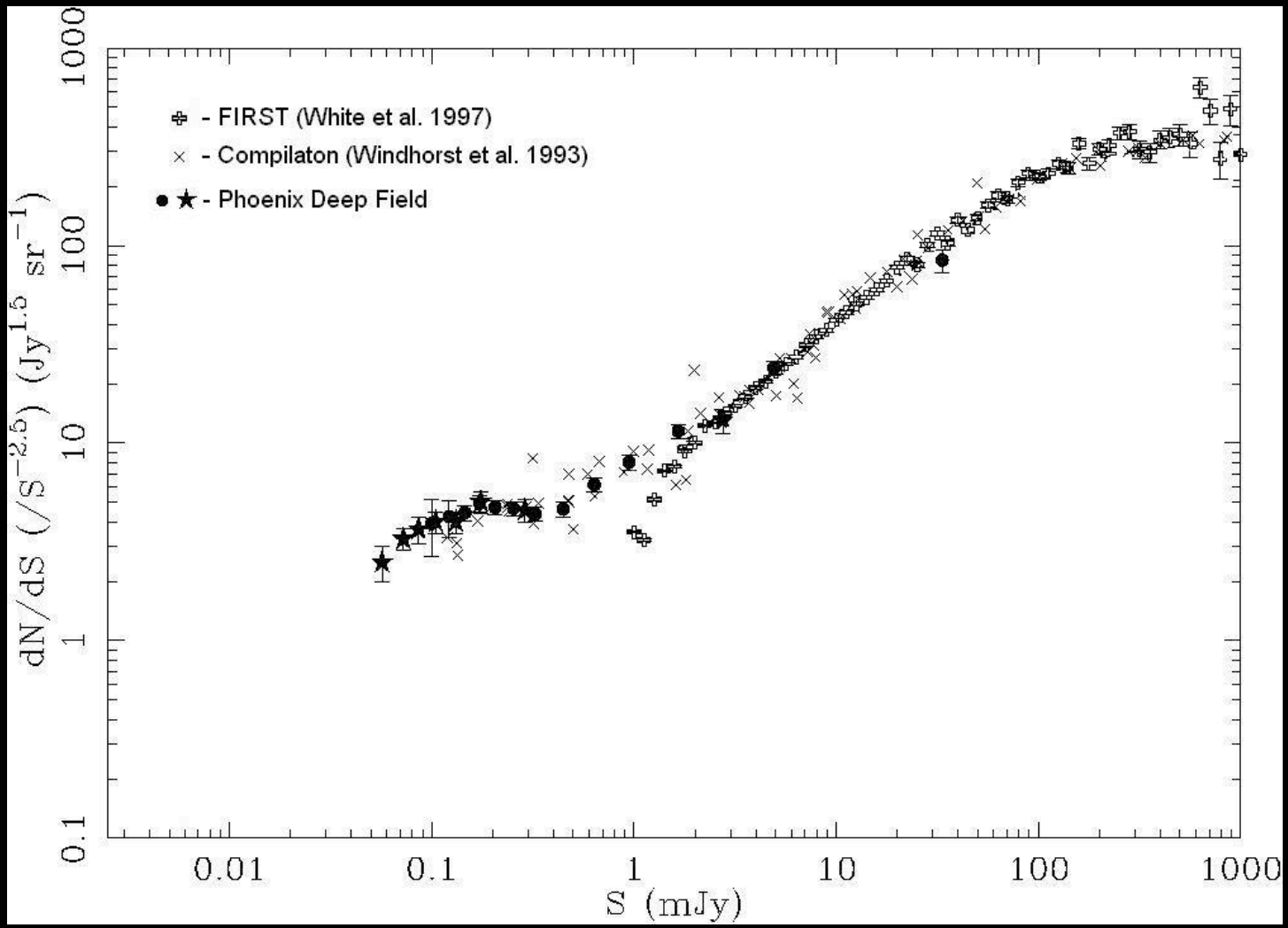
The search for the first radio galaxies: desperately seeking ALMA

José Afonso, Observatório Astronómico de Lisboa

Surveys for ALMA workshop *Garching, 5 September 2007*

Background: The radio galaxy population

- Radio source counts - well established from μJy to Jy level



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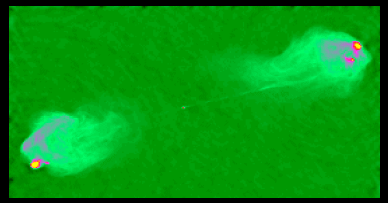

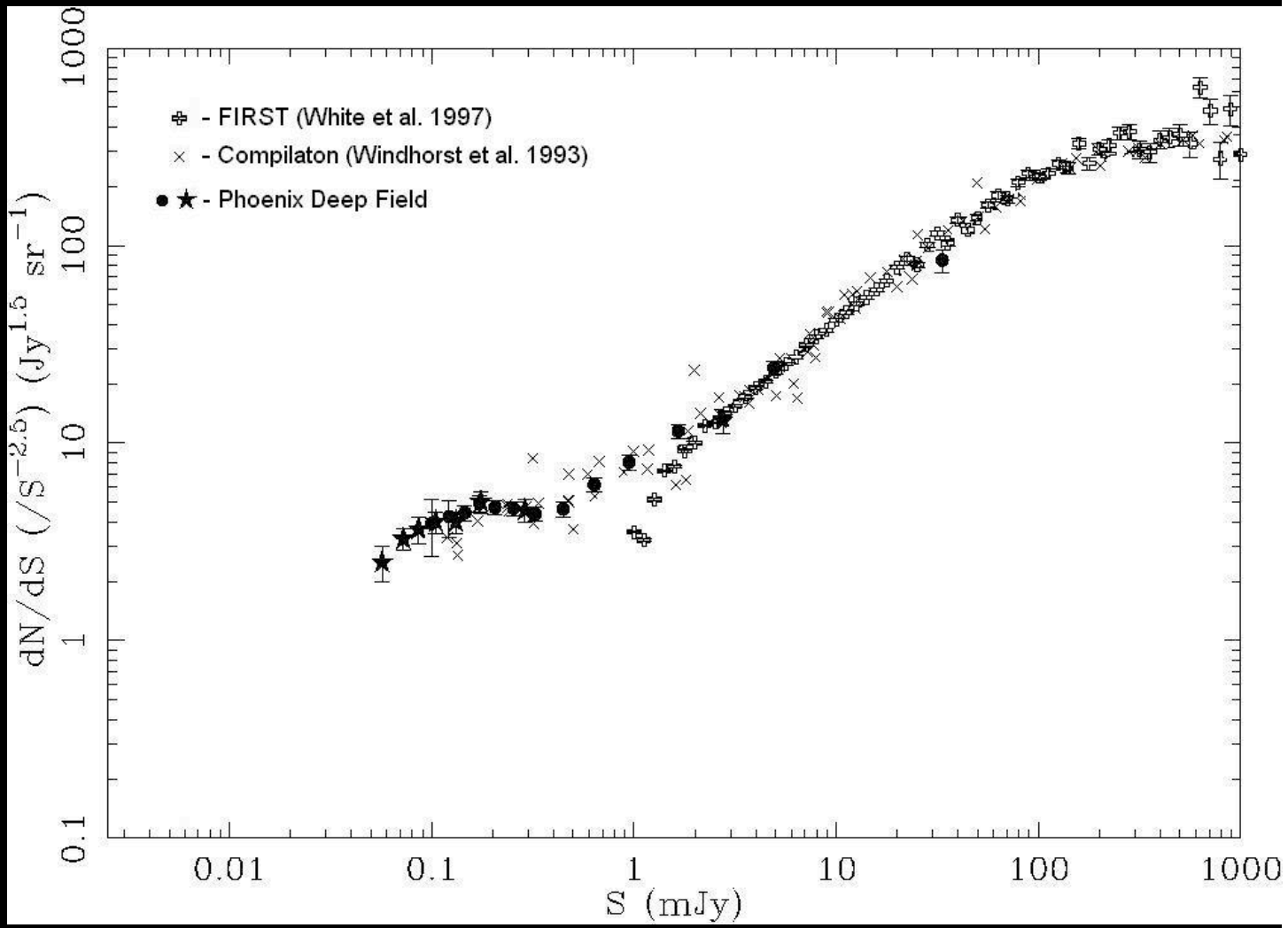

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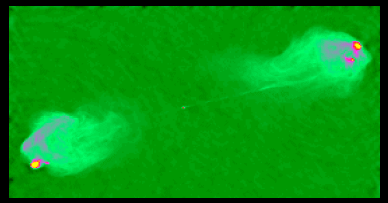

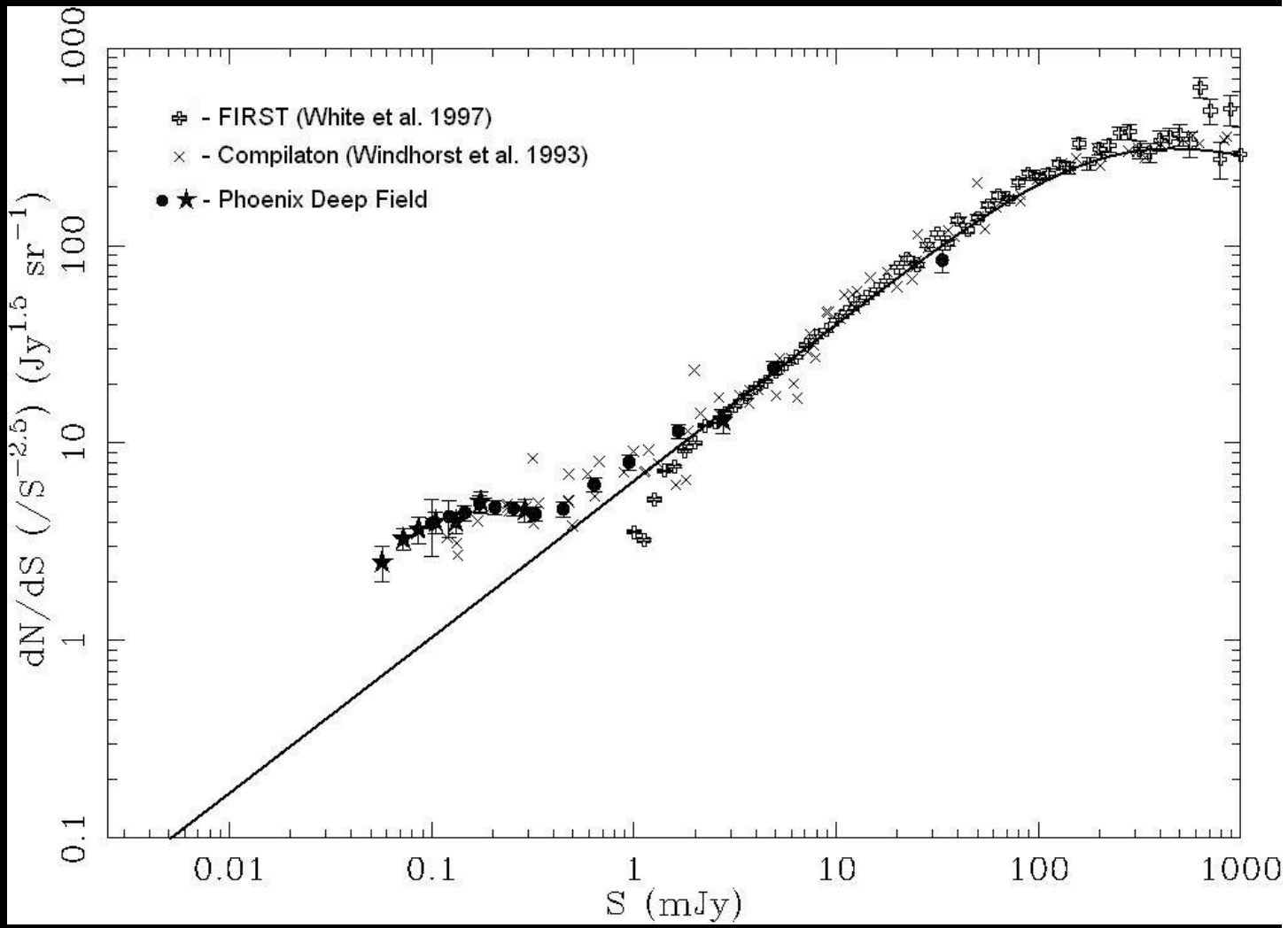

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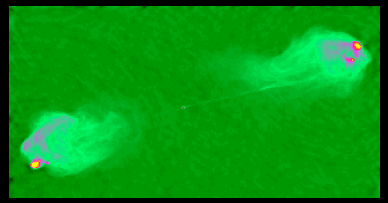


- sub-mJy population explained by star-forming galaxies (IRAS 60 μm) with…

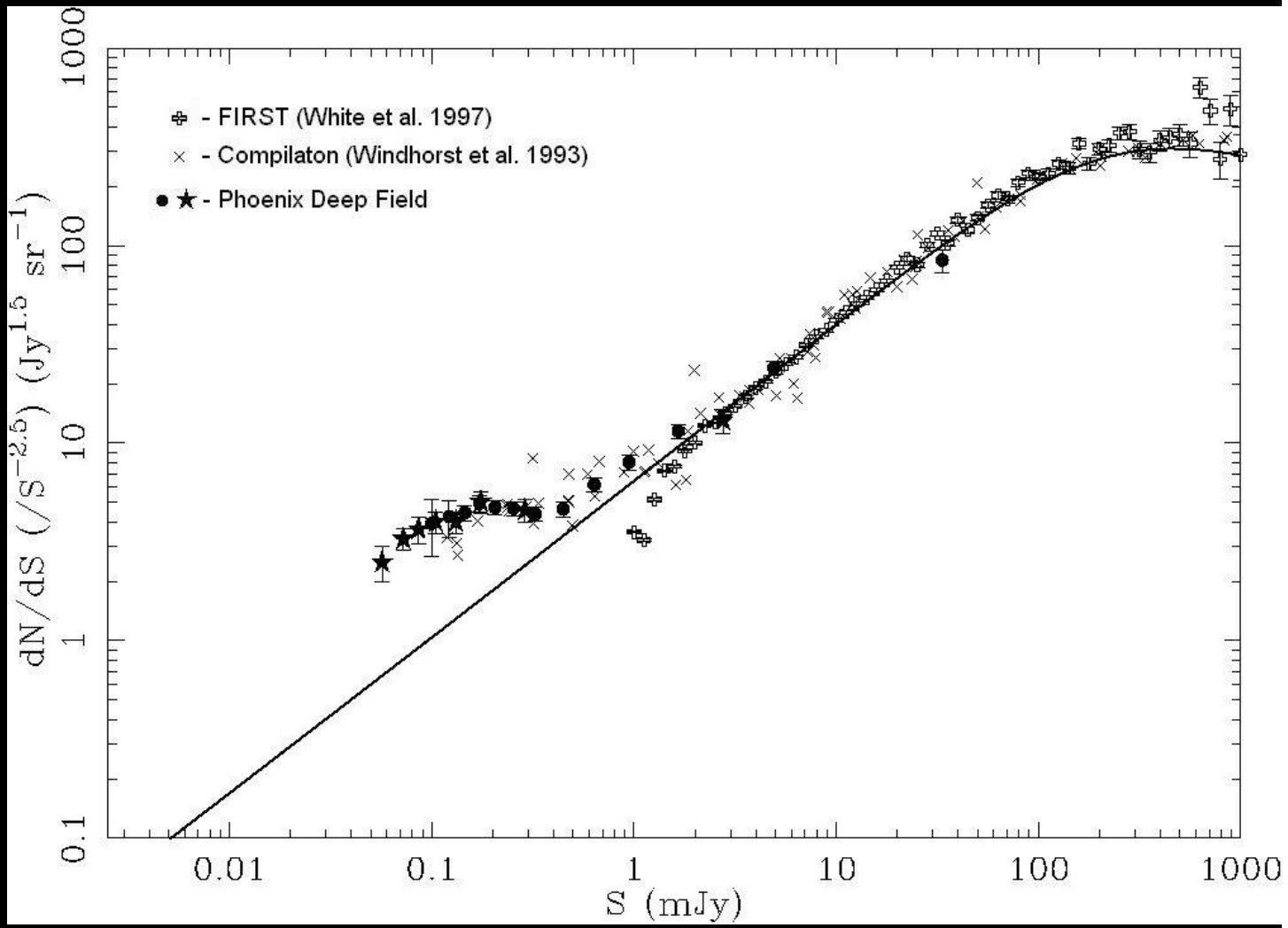
  no evolution

  density evolution

  $\Phi(z)= \Phi(0).(1+z)^P$

  luminosity evolution

  $L(z)=L(0).(1+z)^Q$



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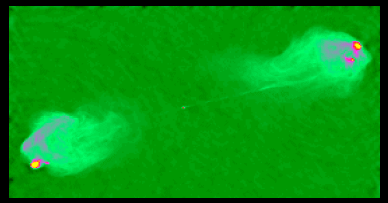

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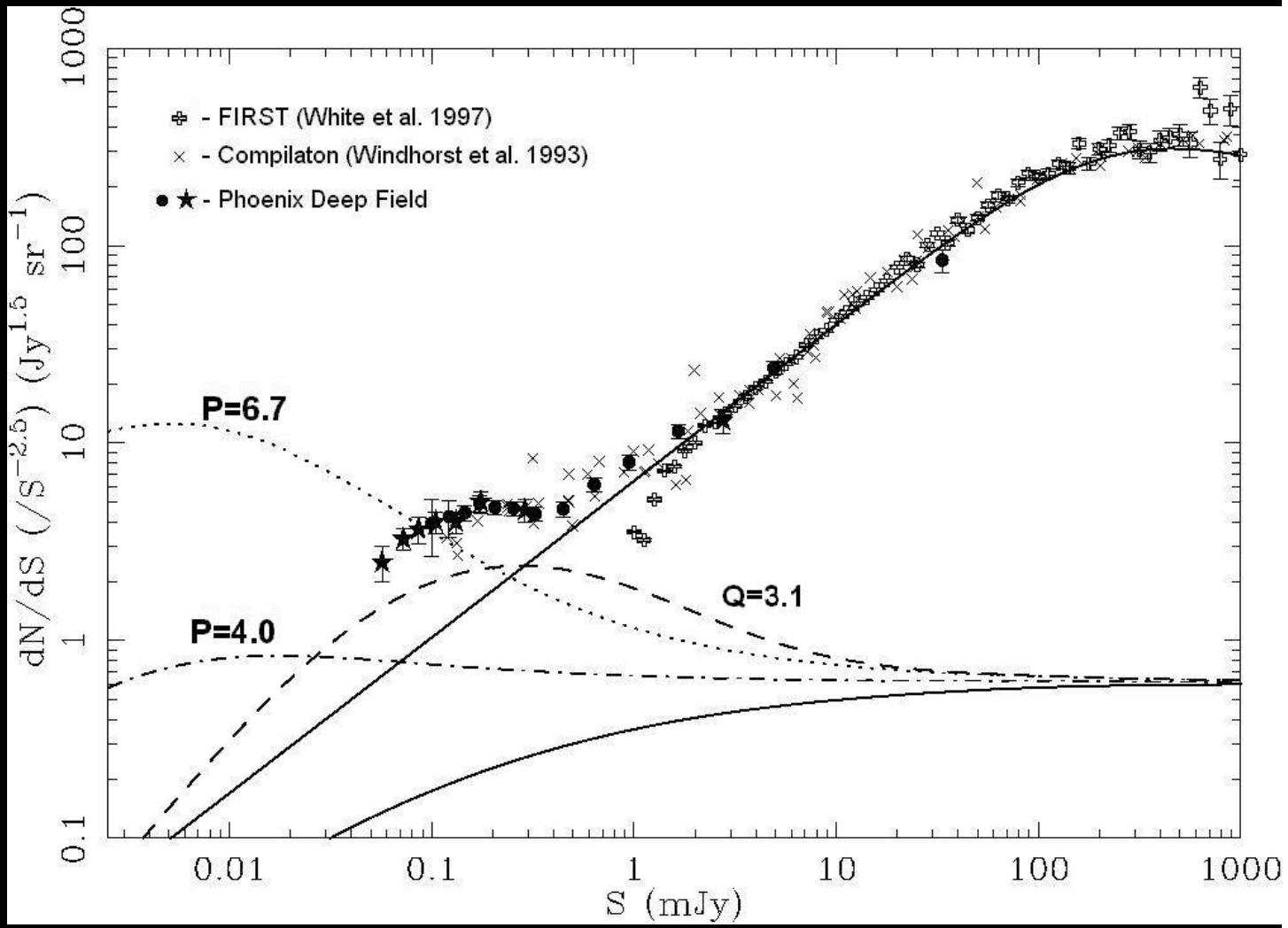

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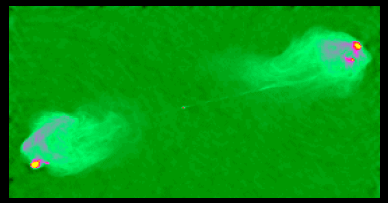

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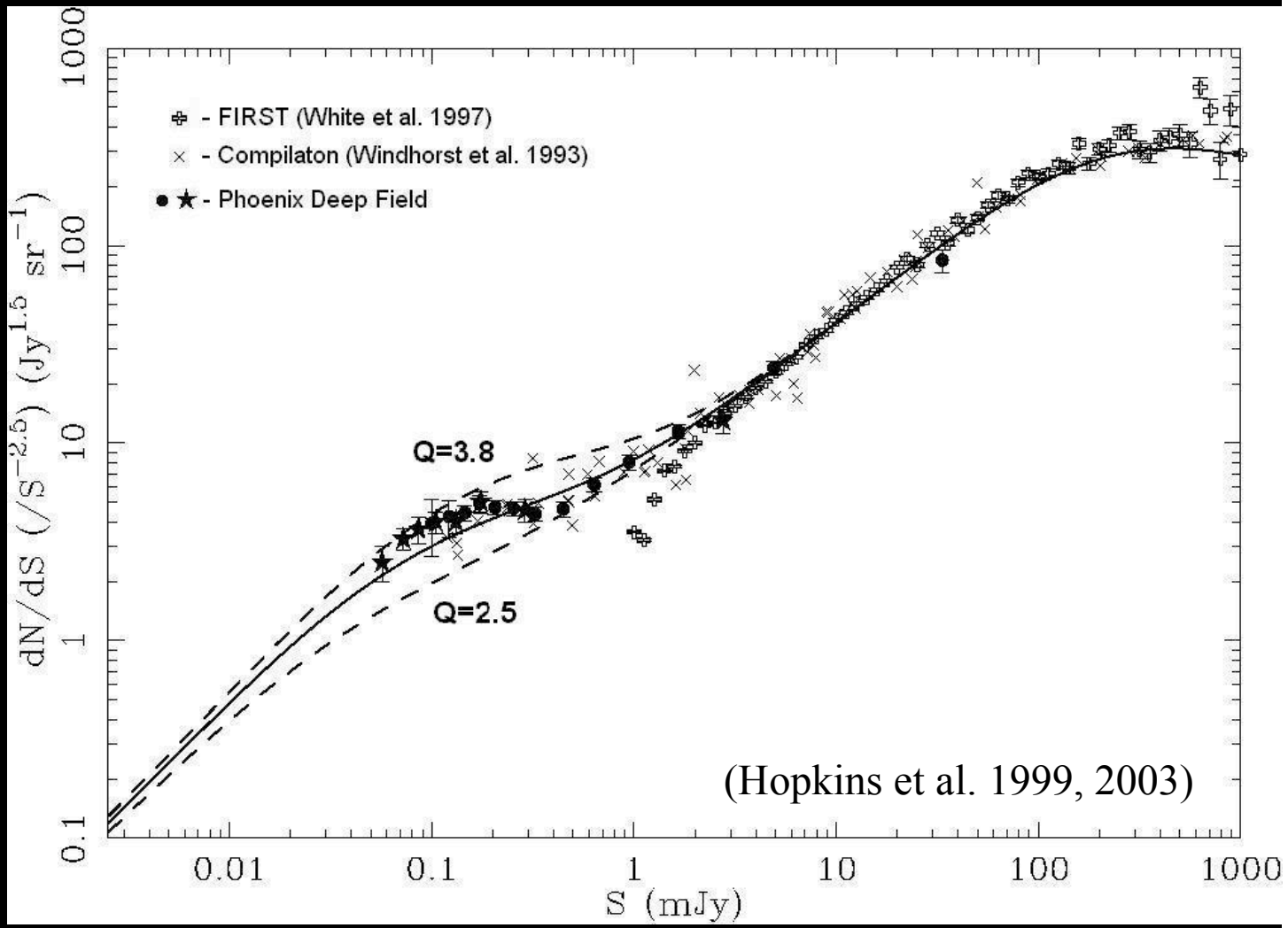

(Hopkins et al. 1999, 2003)

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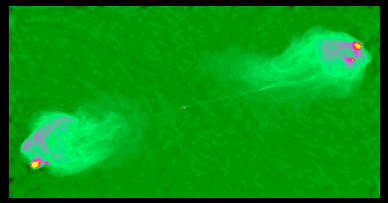

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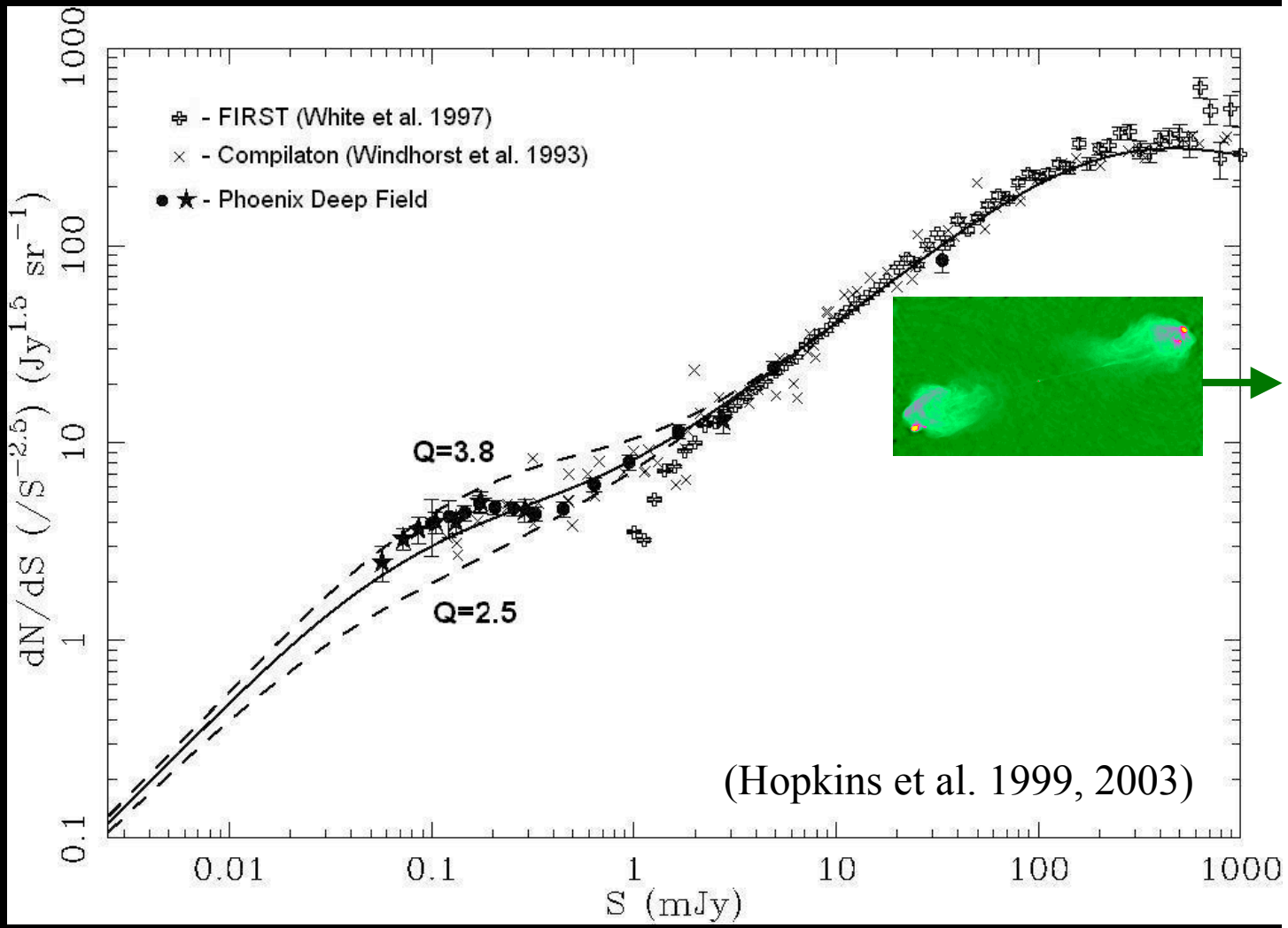

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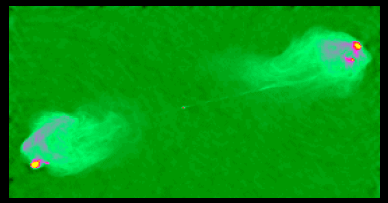

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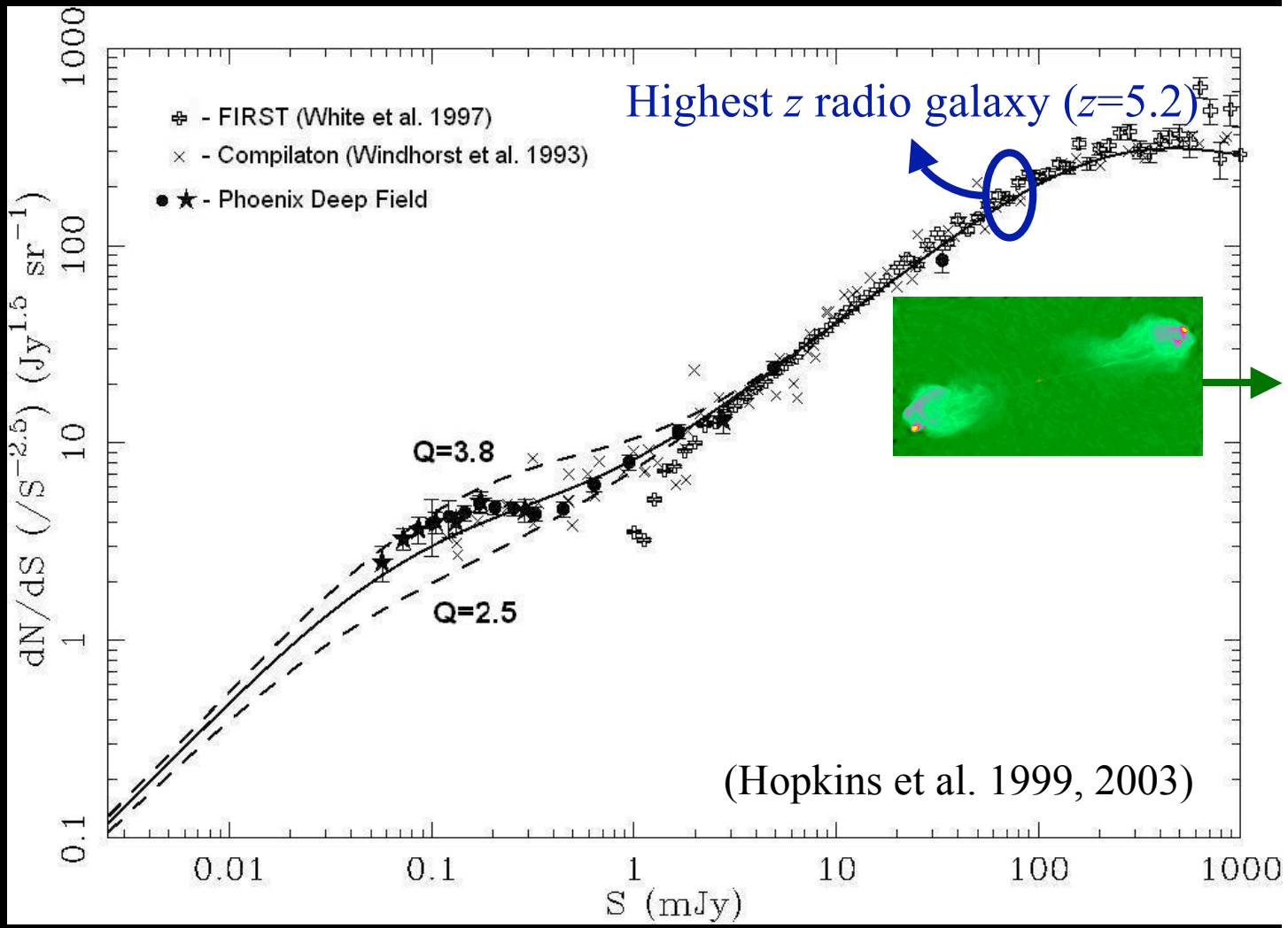

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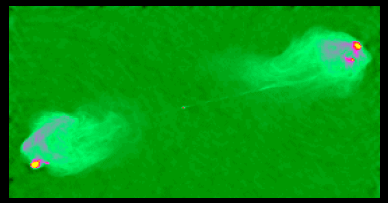

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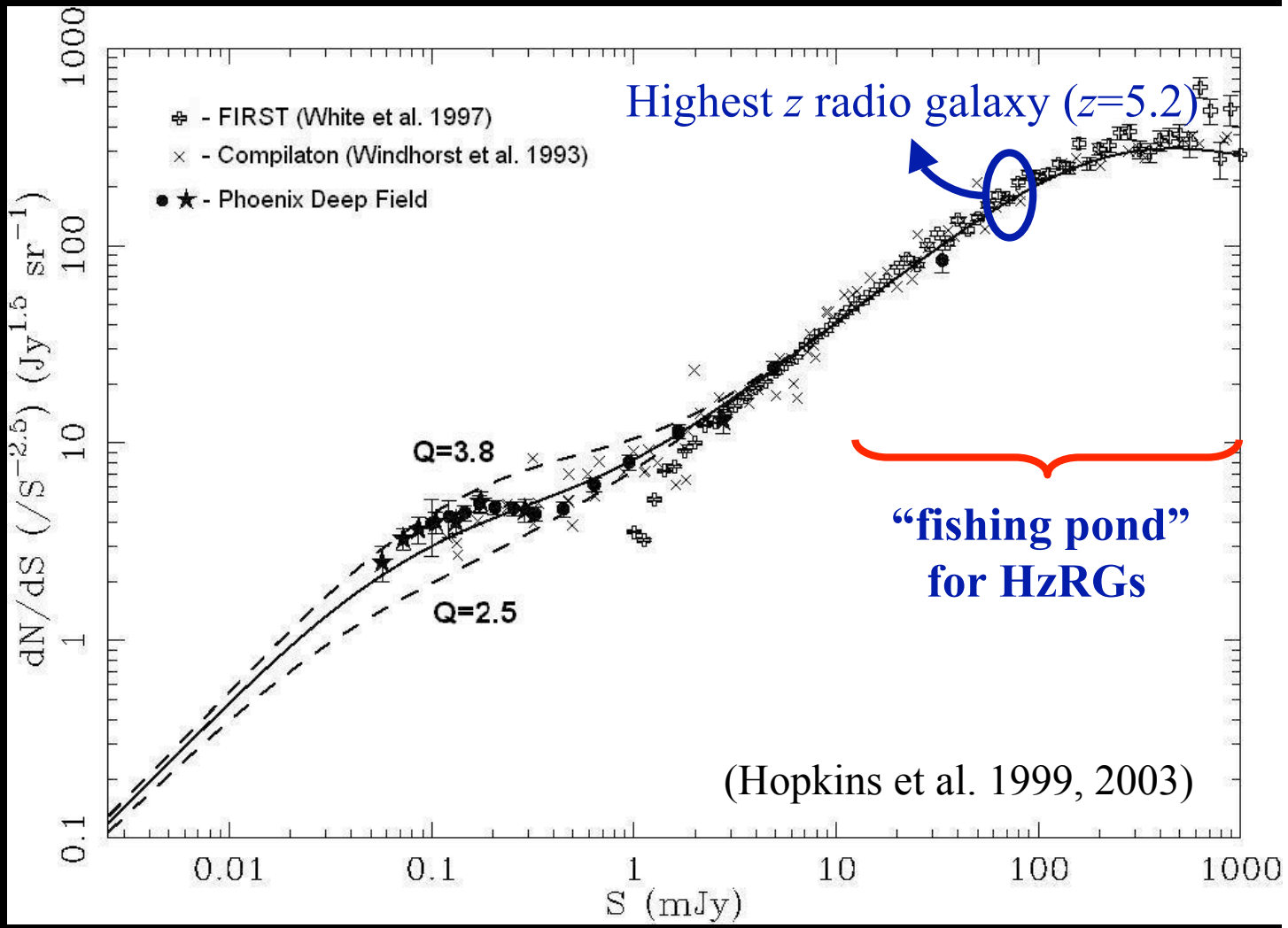
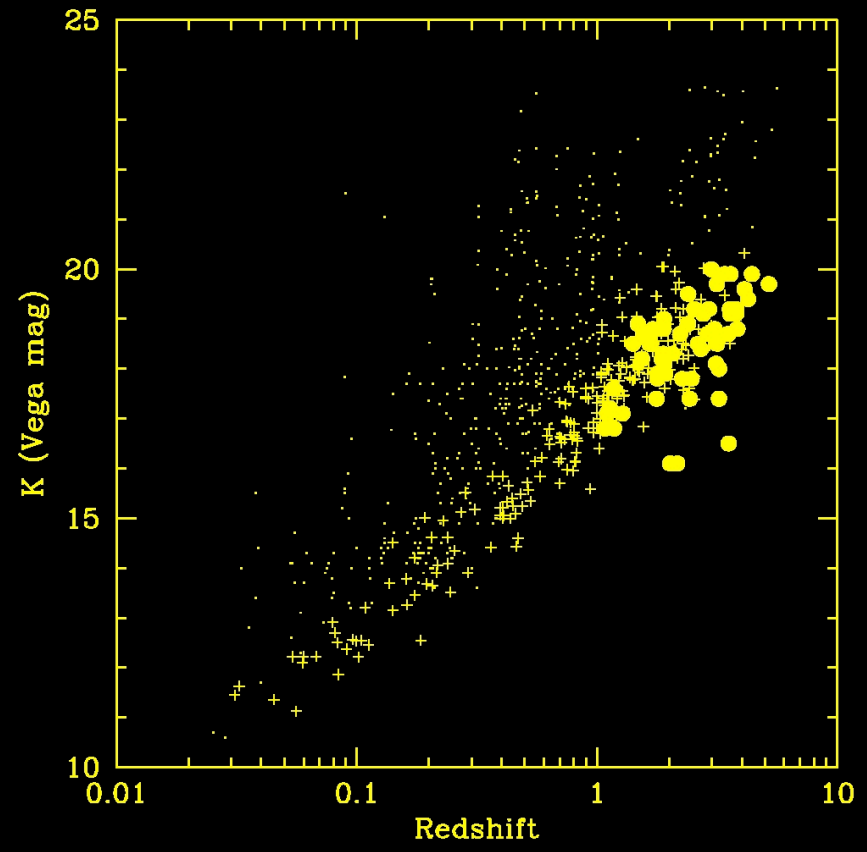


High-z Radio Galaxies (HzRGs)

- Among the most luminous galaxies at any redshift
- Associated with the most massive systems



(Seymour et al. 2007)

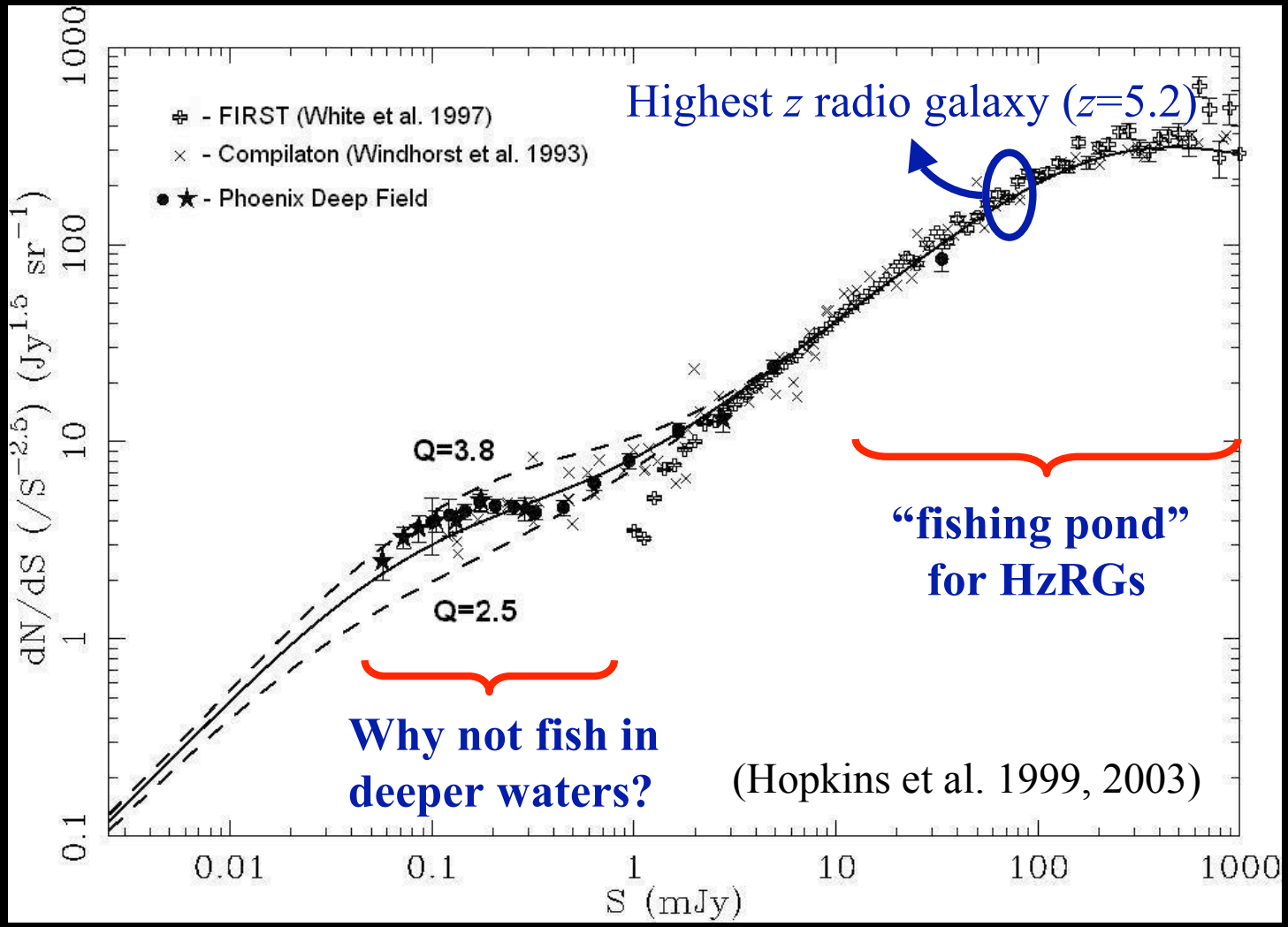
High-z Radio Galaxies (HzRGs)

- Among the most luminous galaxies at any redshift
- Associated with the most massive systems
- Progenitors of brightest cluster ellipticals
- Track proto-cluster environments (z = 2-5, e.g. Venemans et al 2007)
- May show large amounts of dust, and sub-mm detections imply violent SF (~1000 M_{sun} yr^{-1}, Reuland et al 03, 04)
- May show large gas reservoirs (Ly-α halos)

All this at z ~ 2-5…

High-z Radio Galaxies (HzRGs)

Challenge: how to find the most distant / earliest "monsters" in the Universe?

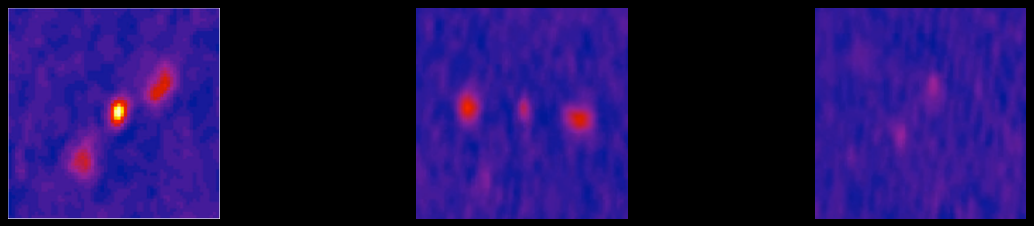


High-z Radio Galaxies (HzRGs)

Challenge: how to find the most distant / earliest “monsters” in the Universe?

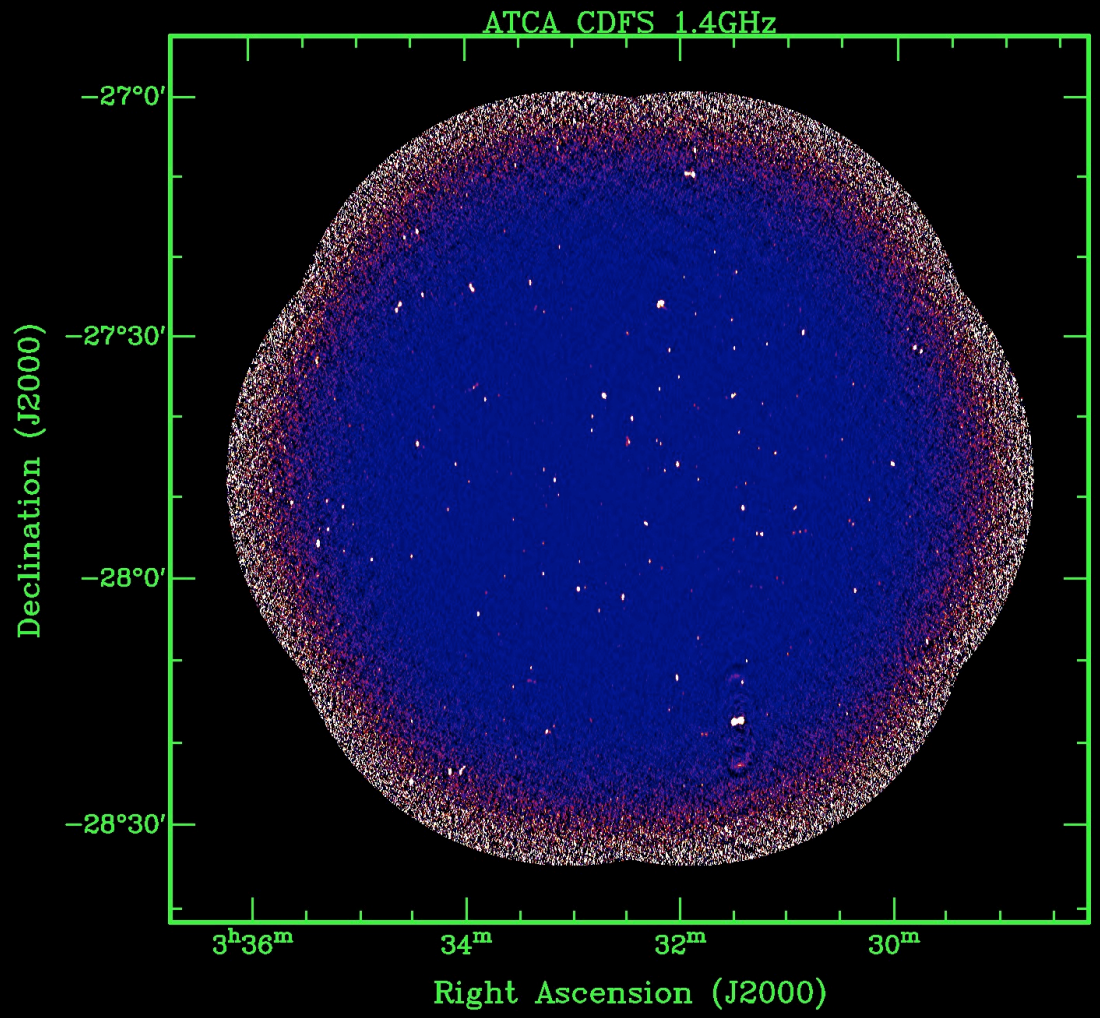
- If these sources exist at $z \sim 10$:

they may have been already detected in microJansky radio surveys…



However, their identification may well be impossible with today's capabilities.

ATCA 1.4GHz observations of the CDFS



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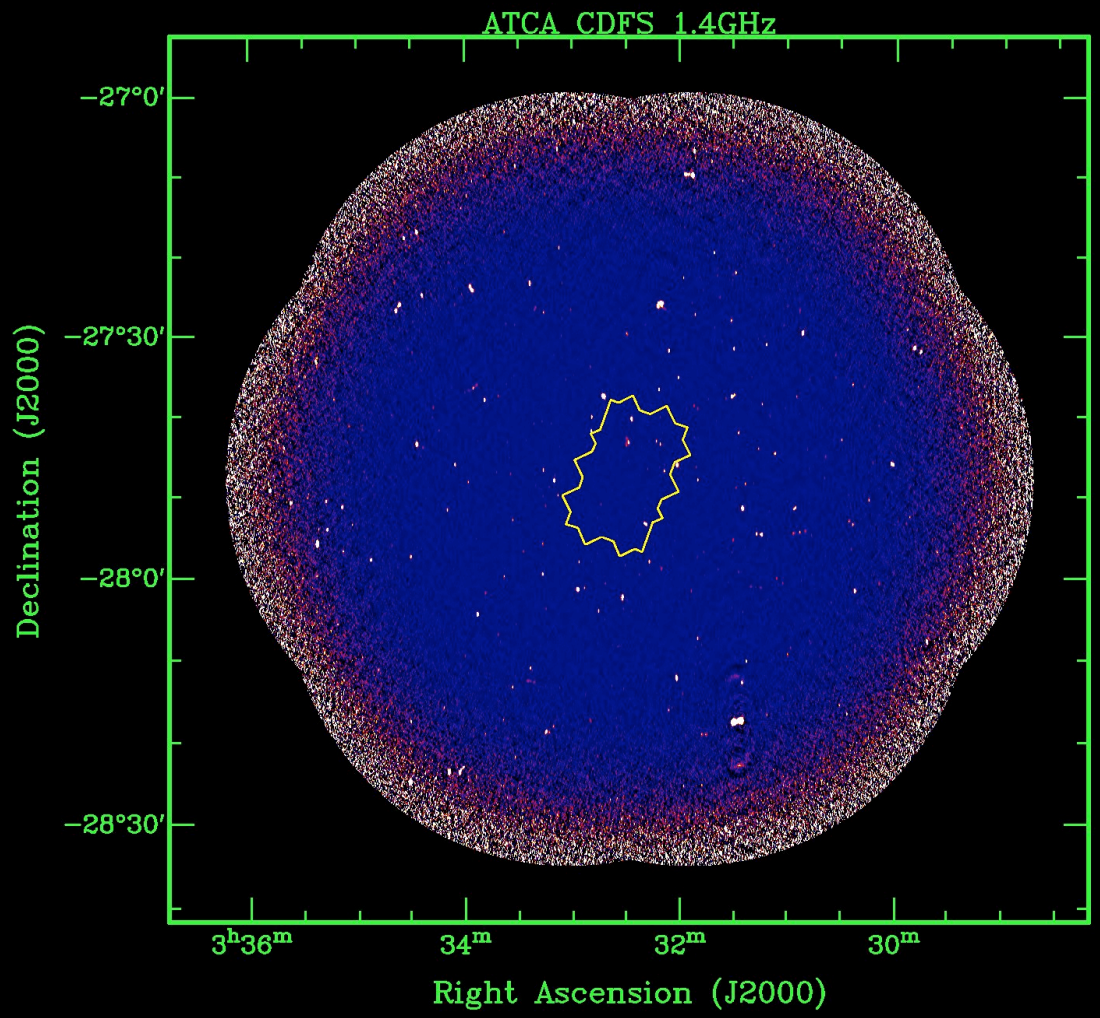

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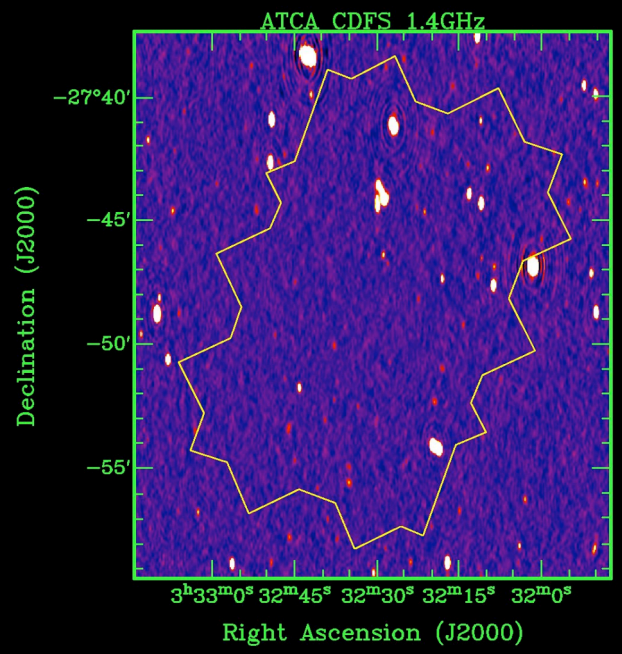


- GOODS/ACS region:

  14-17 μJy rms level;

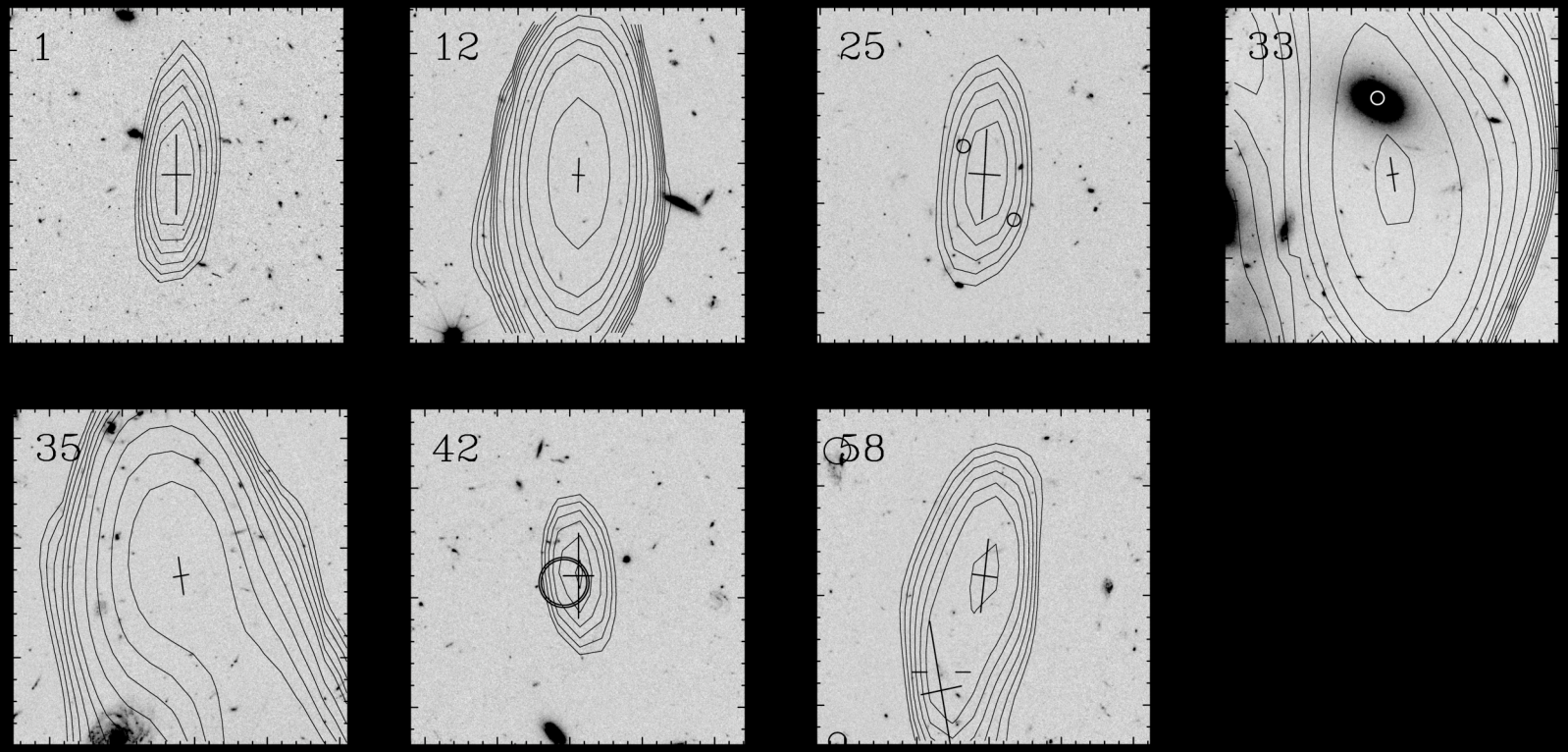
  64 sources with
  63 μJy ≤ $S_{1.4\,GHz}$ ≤ 20 mJy

- 57 sources have optical counterparts
- 34 sources have X-ray counterparts
- 31 spectroscopic redshifts ($0.04 \leq z \leq 3.06$);
  20 further with a photometric redshift

(Afonso et al, 06)

ATCA 1.4GHz observations of the CDFS

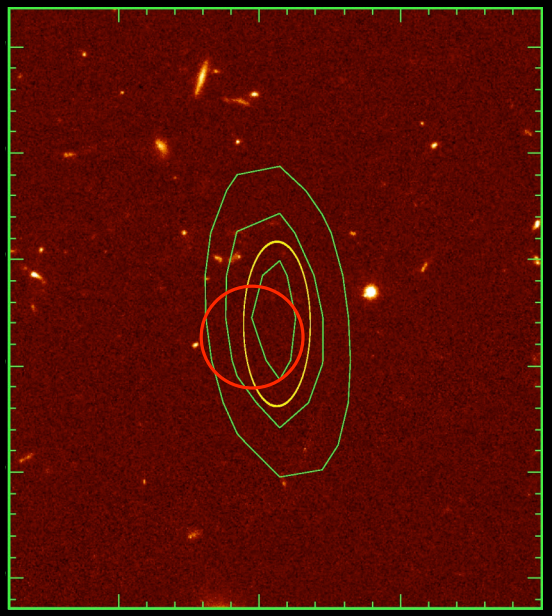
- Optically unidentified faint radio sources in GOODS/CDFS

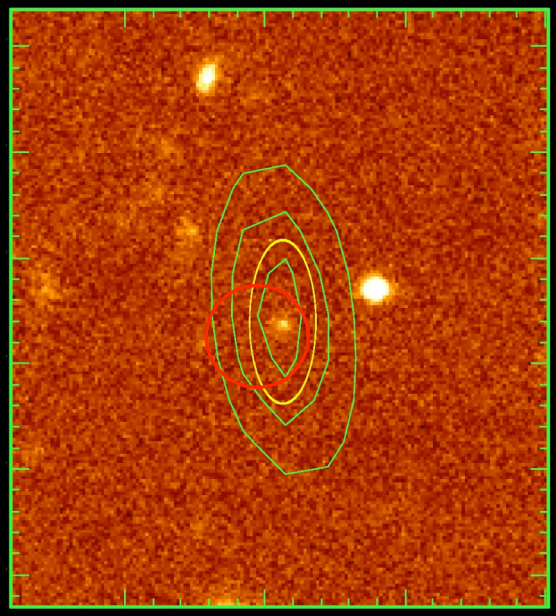


72 μJy ≤ $S_{1.4\,GHz}$ ≤ 4 mJy, z_{AB}>27.5 mag

ATCA 1.4GHz observations of the CDFS

1 shows up in the near-infrared:





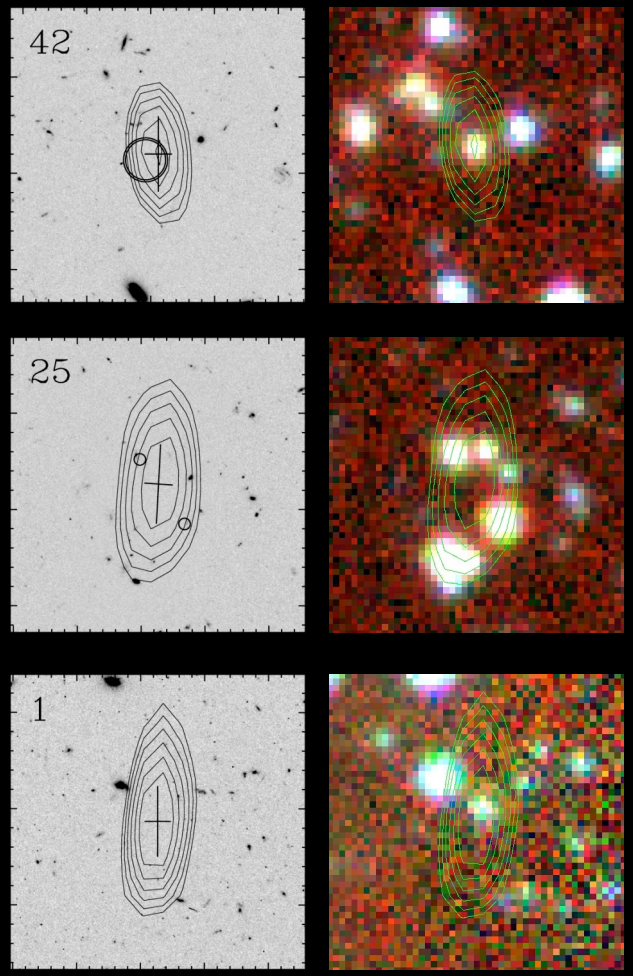
VLT/ISAAC, *Ks*-band

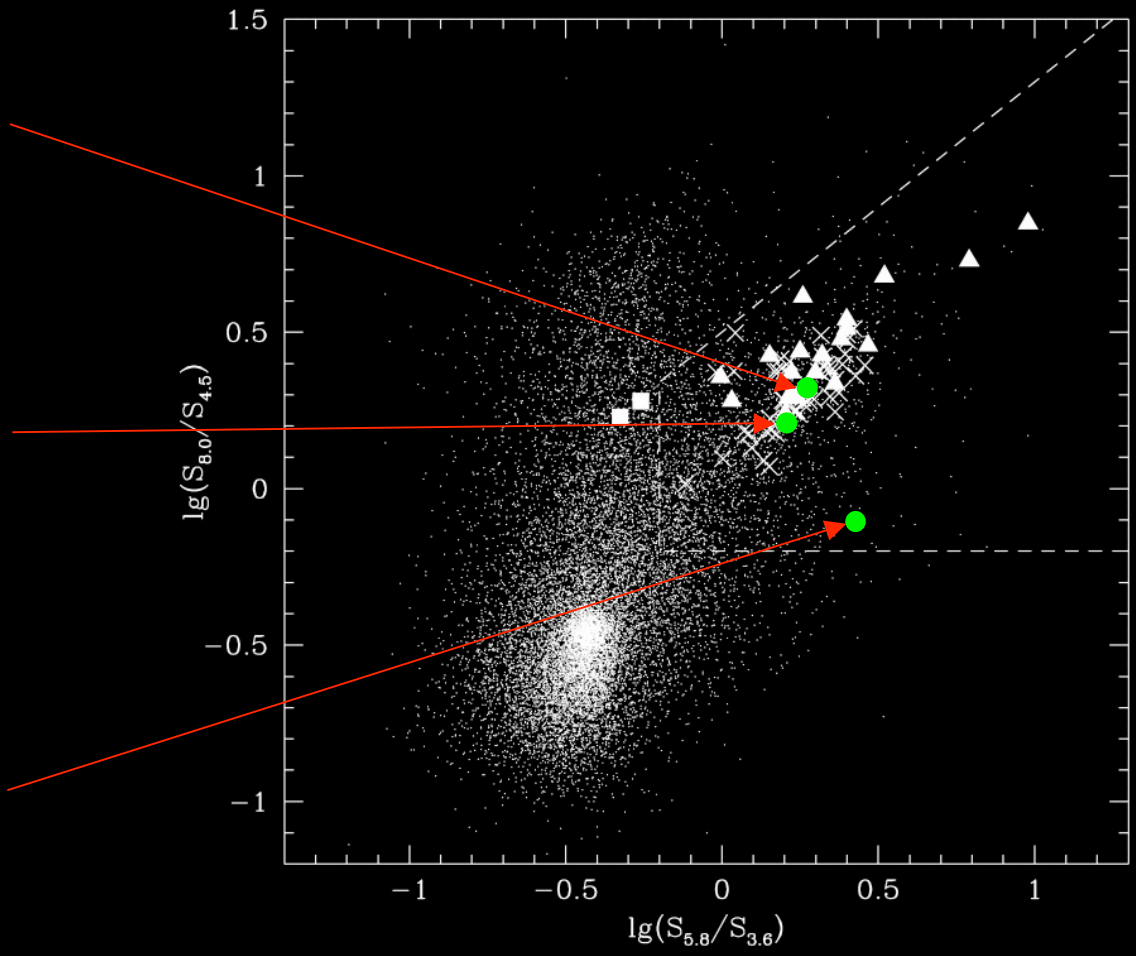
K_{AB}=23.1
J_{AB} =27.2
=>
z_{AB}-K_{AB}/4.5
J_{AB}-K_{AB}=4.1

...a very extreme ERO/DRG AGN

ATCA 1.4GHz observations of the CDFS

and two more in the mid-infrared:

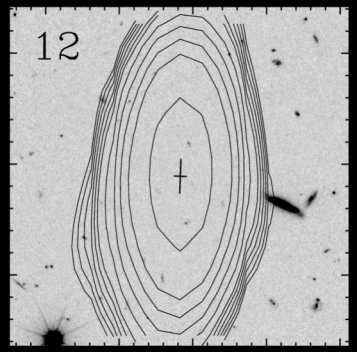


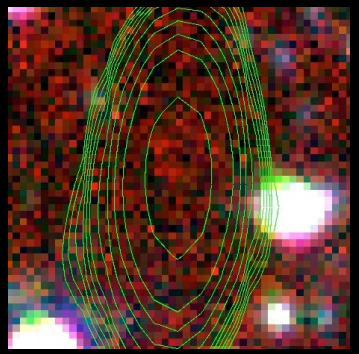


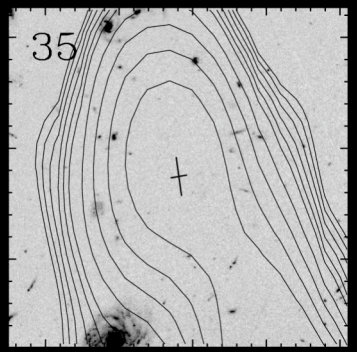
(Lacy et al 04)

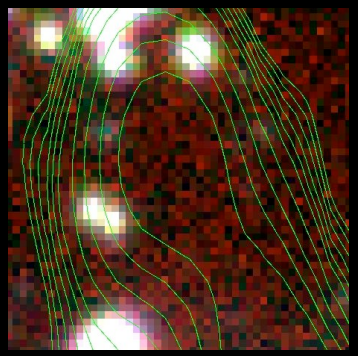
ATCA 1.4GHz observations of the CDFS

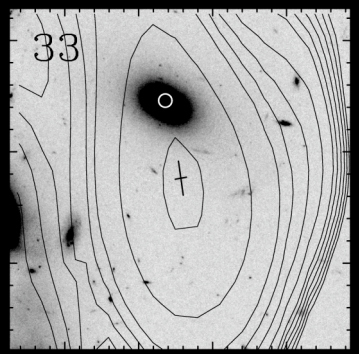
No identification for 4 sources:

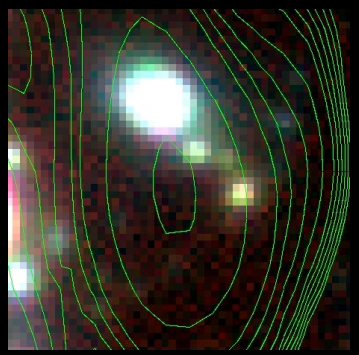


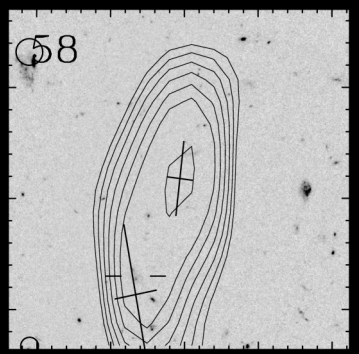


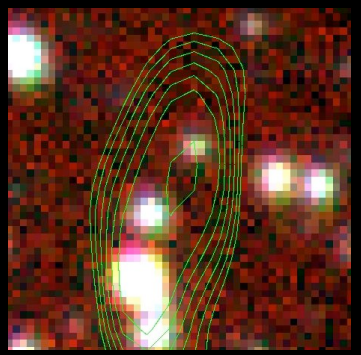






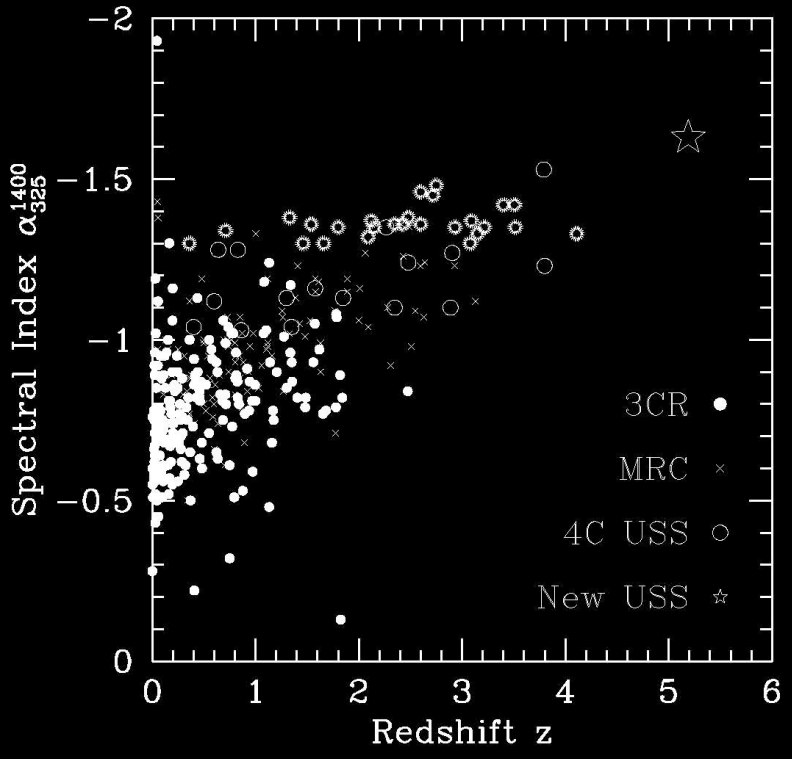


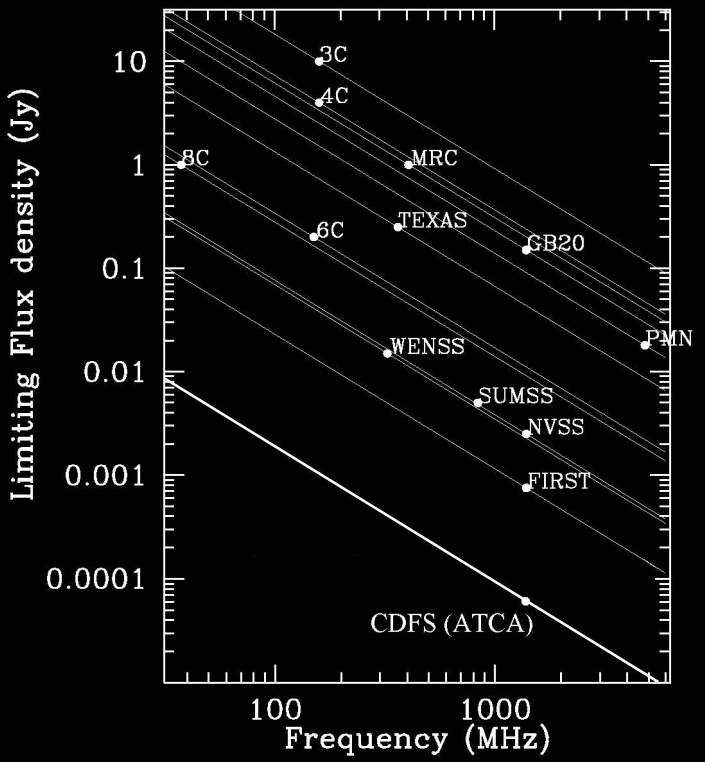




fishing expedition not bad so far, but can't say much more on these…

Change bait, keep fishing...





Steep radio spectral index is efficient in selecting high-z galaxies (De Breuck et al 2000) .

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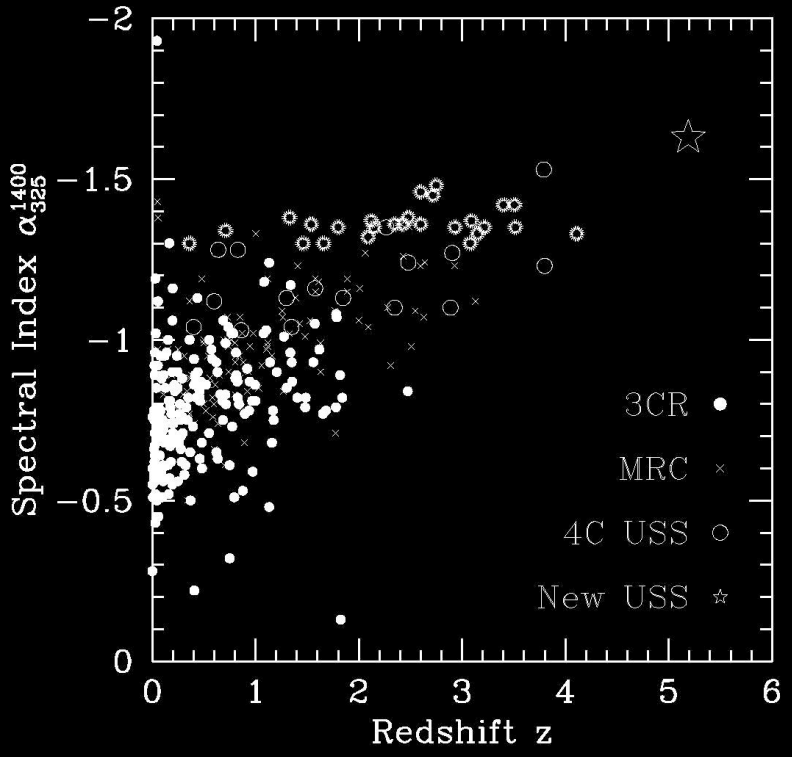
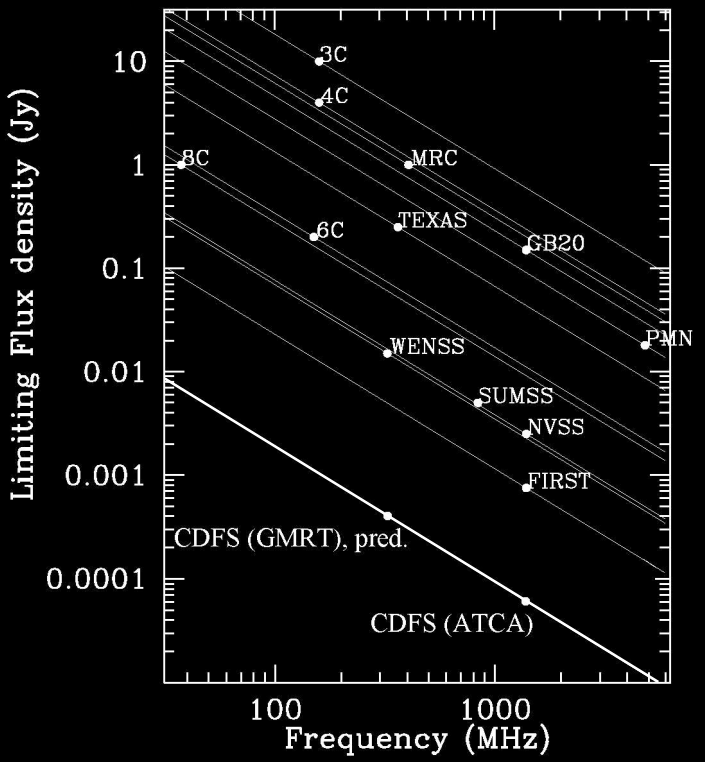




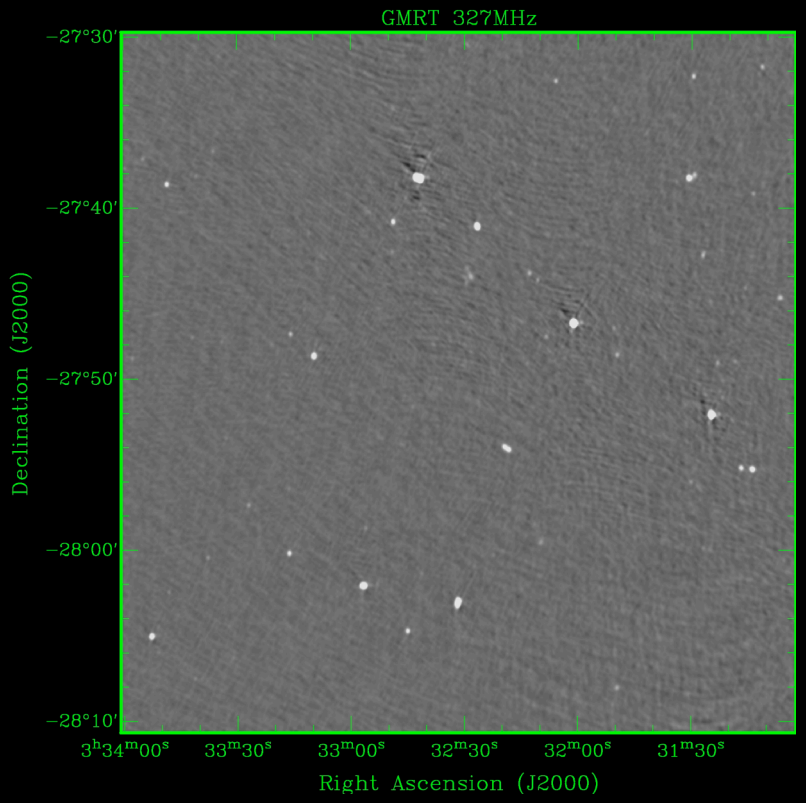
Steep radio spectral index is efficient in selecting high-z galaxies (De Breuck et al 2000) .

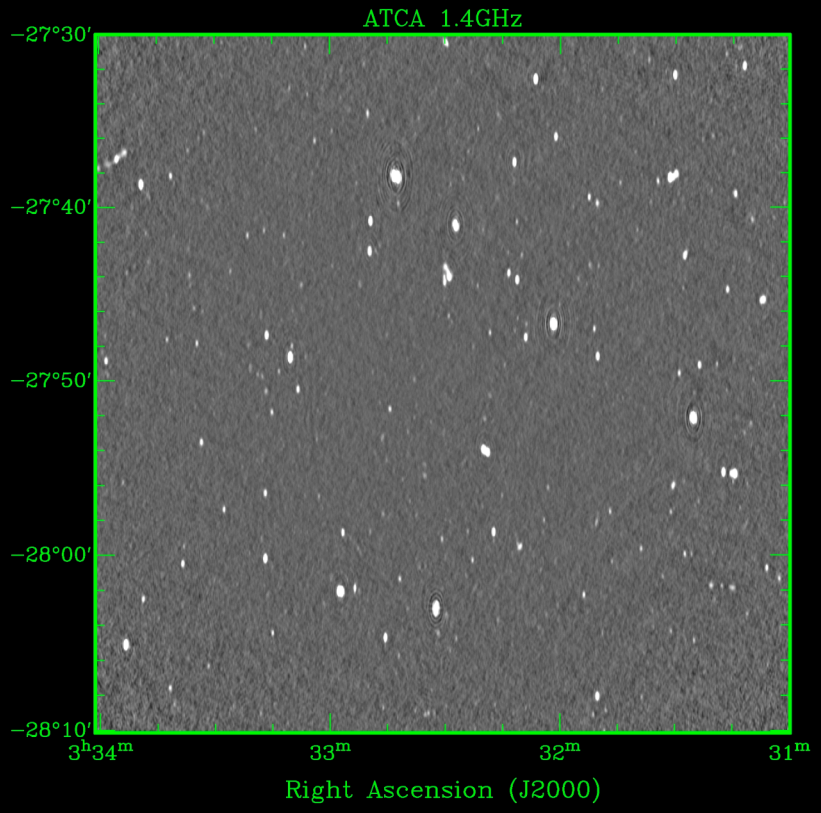
Aim to sample fluxes *at least* 40 times fainter than previously done for USS searches.

USS sources in CDFS

A deep GMRT 327 MHz survey of the Chandra Deep Field South

- Pilot observations: 22h (single 16 MHz sideband)





- rms: 0.20-0.30 mJy

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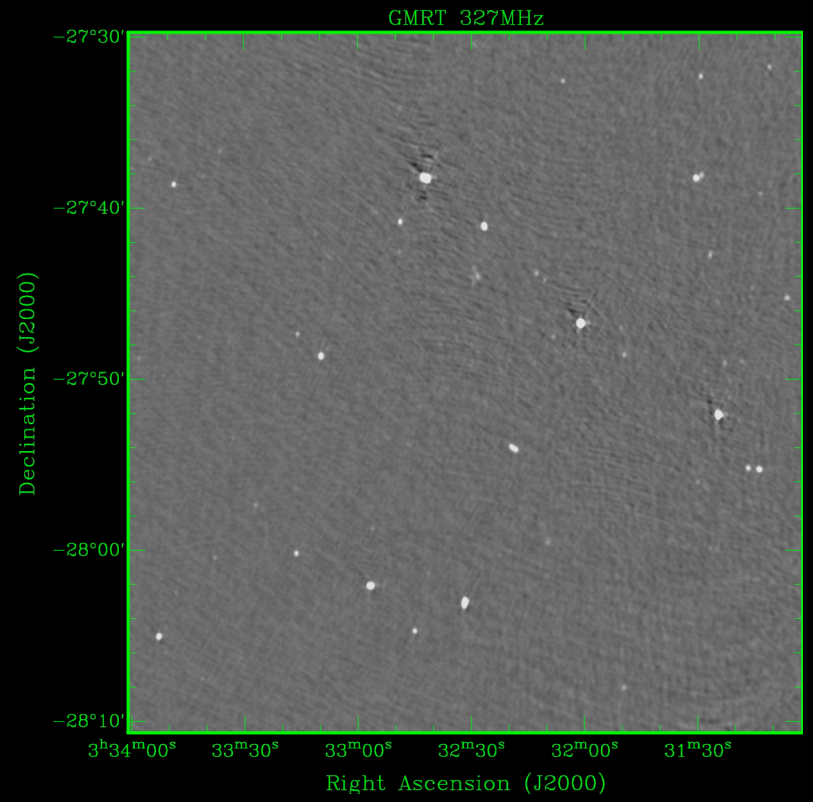

- rms: 0.20-0.30 mJy

8 USS sources found:

- 4 sources have $-1.7<\alpha<-1.4$
- 4 sources have $\alpha<-1.4$ (no 1.4 GHz detection)

Much higher surface density than at mJy+ levels

No overlap with optically unidentified sources in ACS field.

USS sources in CDFS

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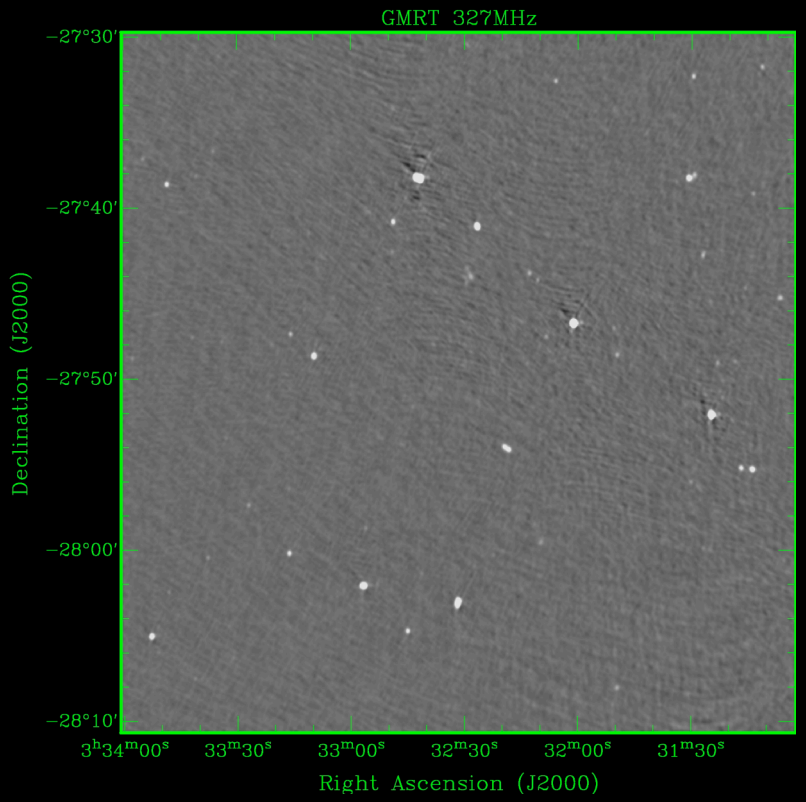

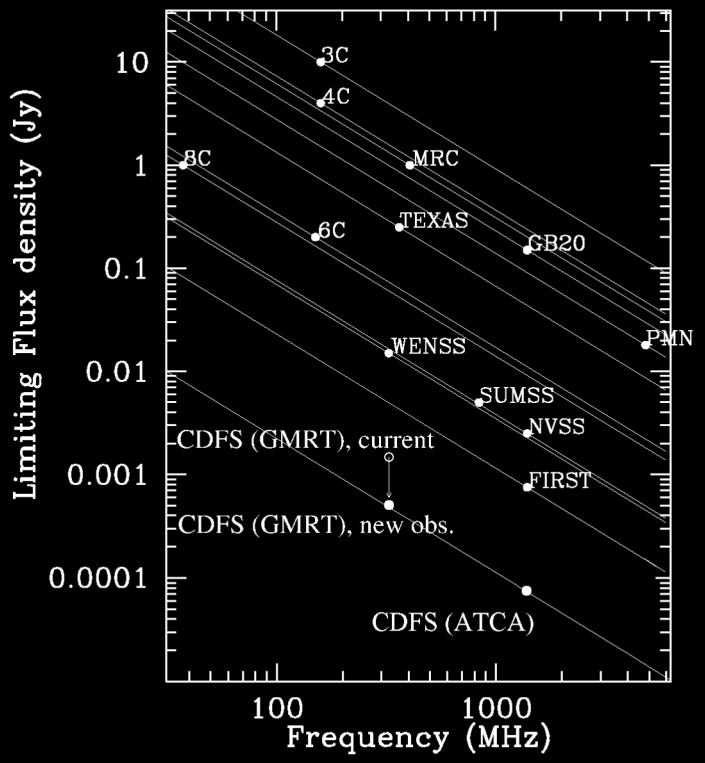

- rms: 0.20-0.30 mJy

50h, two sidebands – data being reduced…

(see also Bondi et al, Seymour et al)

Conclusions:

- The search for HzRGs has now been extended to the radio microJansky regime.
- With very deep multiwavelength coverage, unidentified radio sources are potentially very HzRGs (worst case scenario, "uninteresting" extremely obscured sources).
- An abundant microJansky USS source population exists (potentially including the *first* radio galaxies?).

Fishing expedition caught quite a few something, don't really know what…

Desperately need ALMA to loose the annoying "potentially" above…

The search for the first radio galaxies desperately seeking ALMA

José Afonso, Observatório Astronómico de Lisboa

Surveys for ALMA workshop *Garching, 5 September 2007*

The search for the first radio galaxies desperately seeking ALMA

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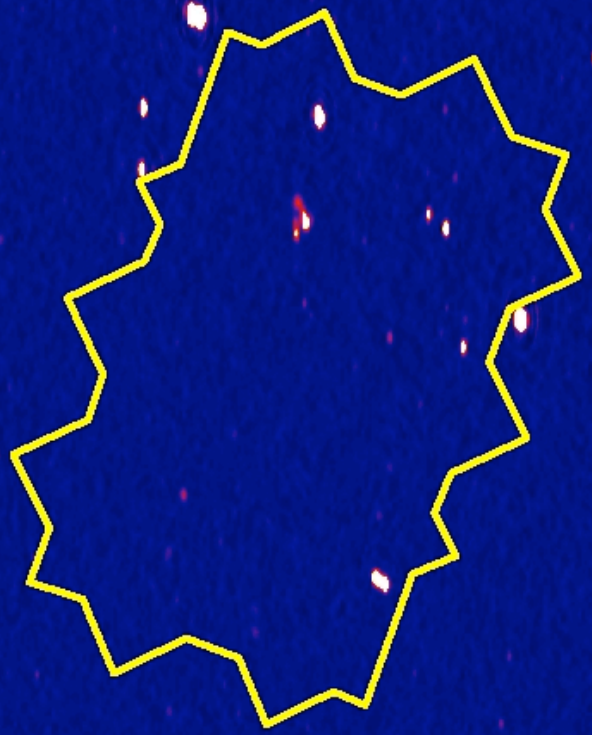
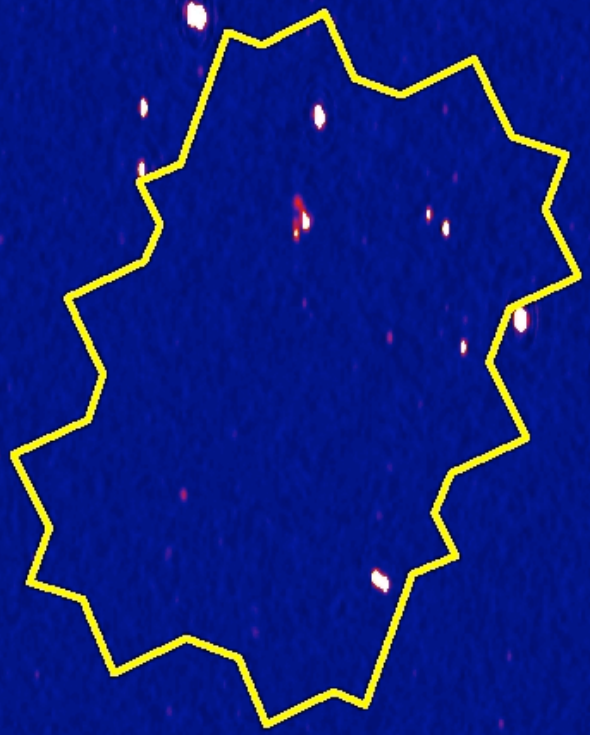


José Afonso, Astronomical Observatory of Lisbon

Surveys for ALMA workshop *Garching, 5 September 2007*

Deep ATCA and GMRT observations of the Chandra Deep Field South

Bahram Mobasher (STScI)
Anton Koekemoer (STScI)
Ray Norris (ATNF)
Lawrence Cram (ANU)

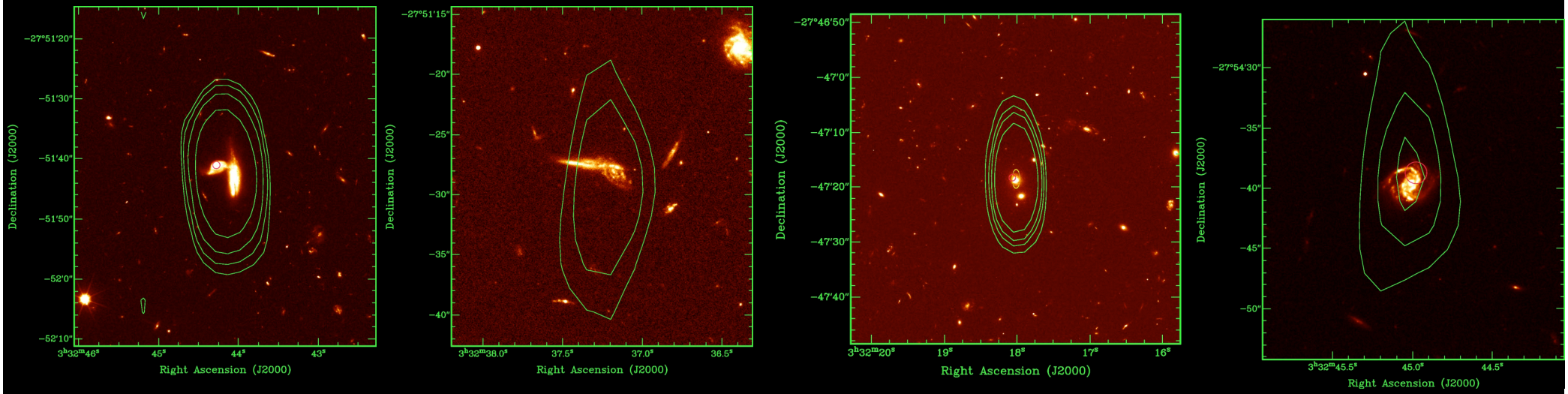


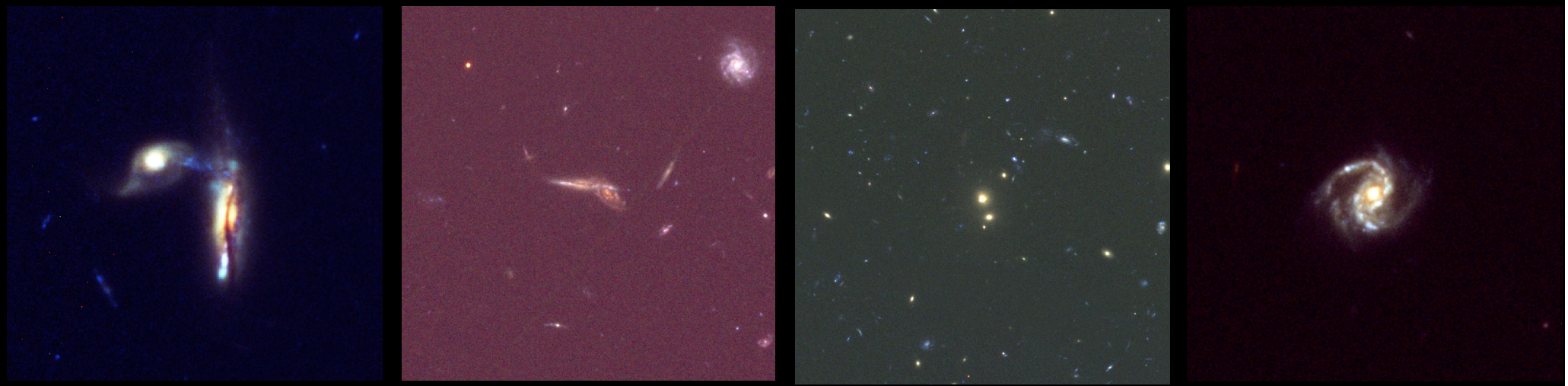
Hugo Messias (aka The Messiah)
Nissim Kanekar (NRAO)
Jayaram Chengalur (NCRA)
Duncan Farrah (Cornell)

José Afonso, Astronomical Observatory of Lisbon

At the Edge of the Universe – latest results from the deepest astronomical surveys *Sintra, 12 October 2006*

Faint radio sources in GOODS/CDFS





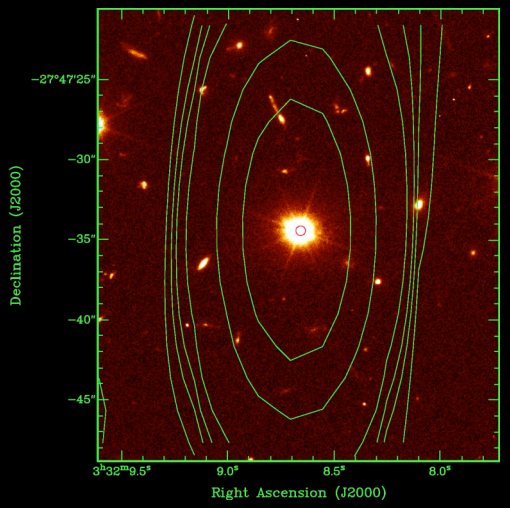
$z = 0.279$, starforming

$z = 0.53$, starforming

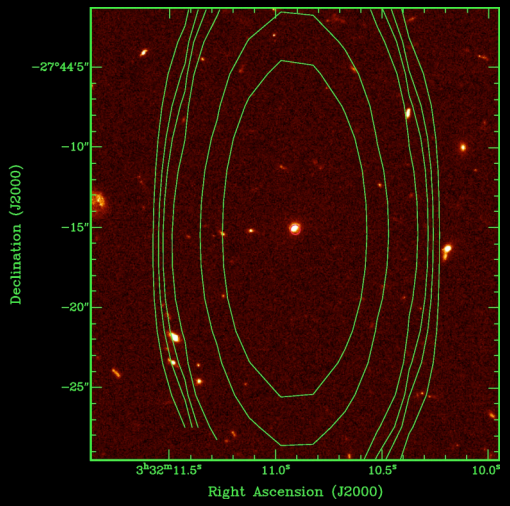
$z = 0.734$, starforming

$z = 0.458$, unclass.

Faint radio sources in GOODS/CDFS



z = 0.543, QSO-1



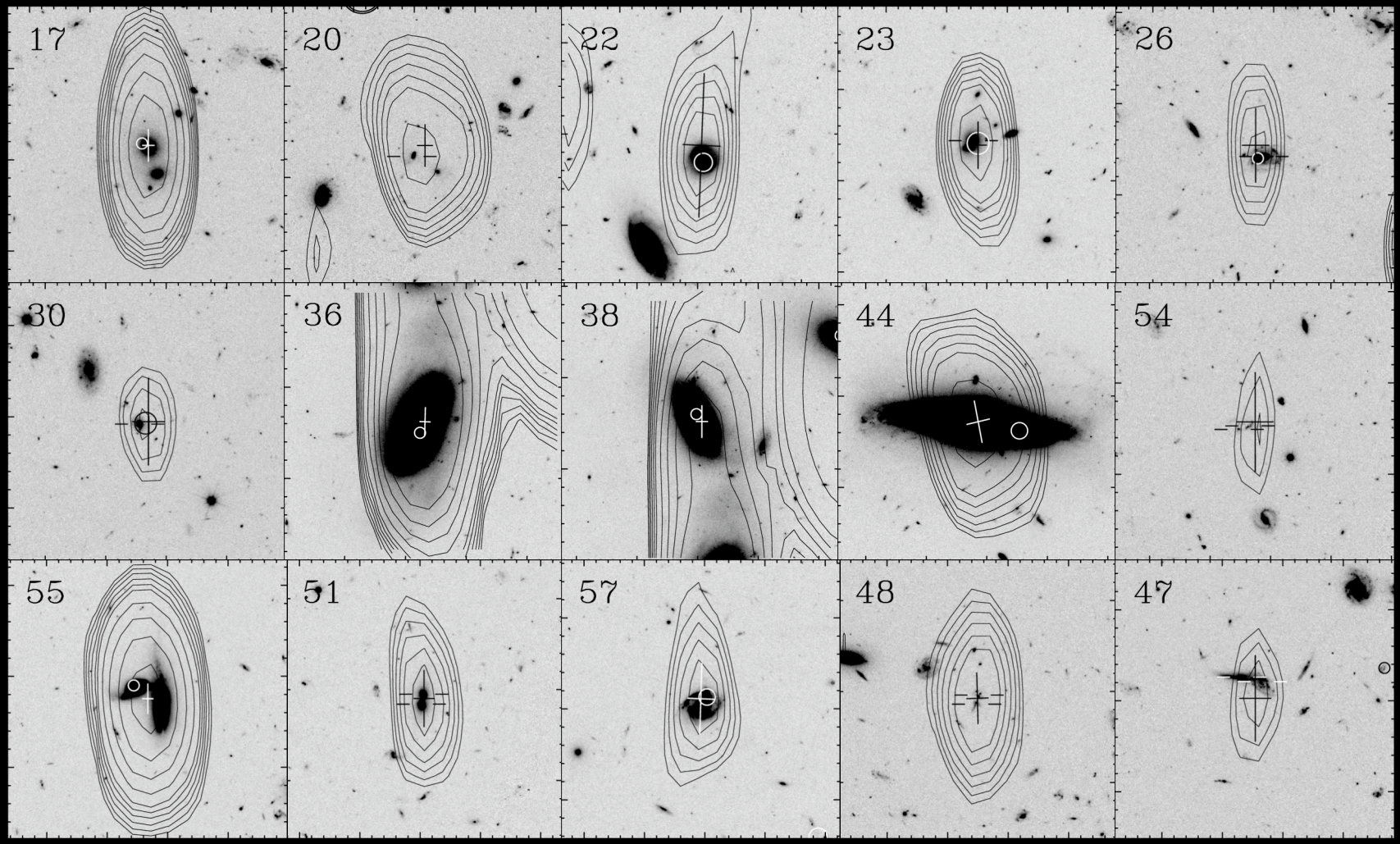
z = 1.615, QSO-1

- Structures observed at z~0.73 and z~1.10
- Based on X-ray properties, 19 sources (out of 23 with an X-ray classification) are AGN

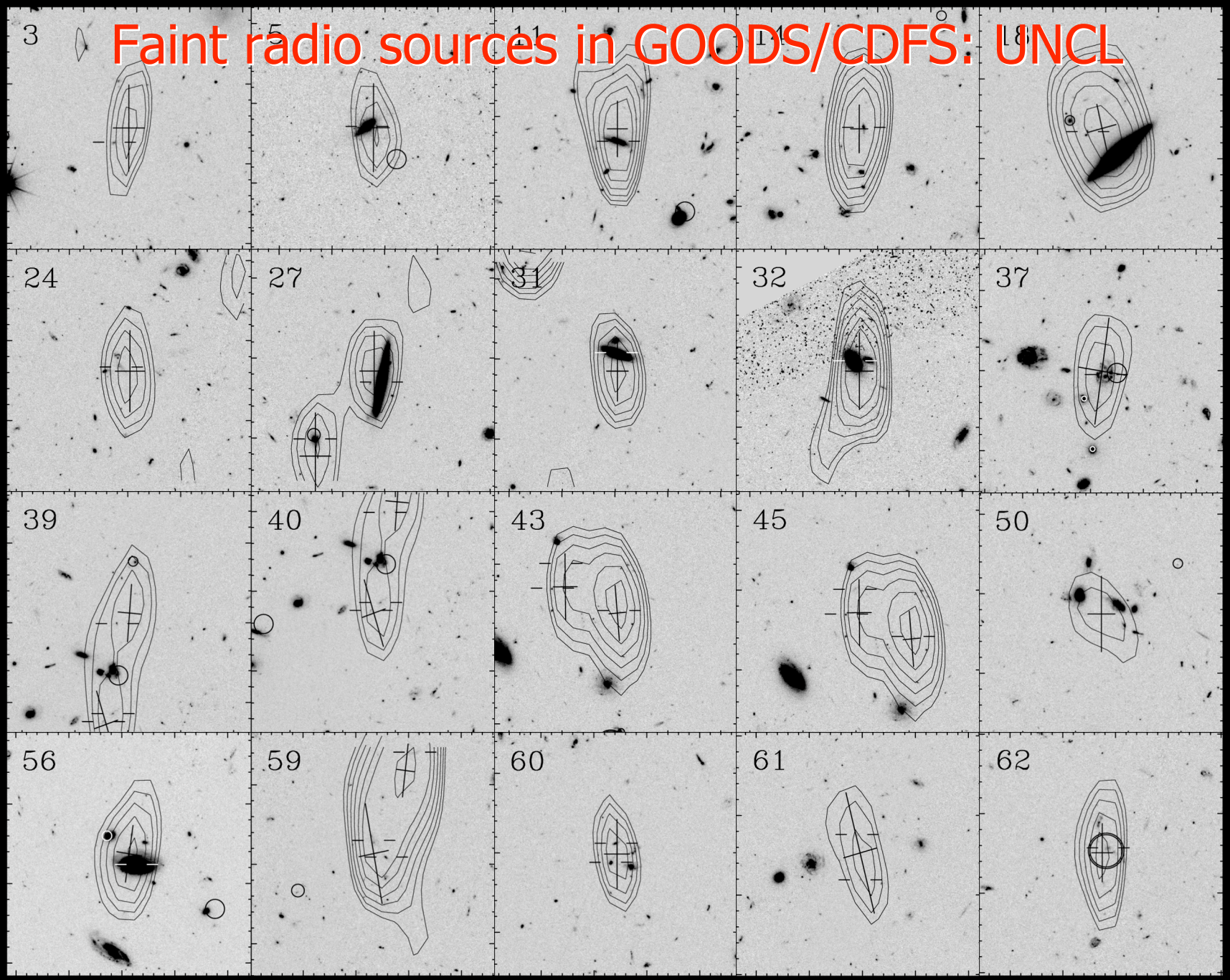
>27% of sub-mJy sources are AGN

(Richards et al. 99: 20% from radio spectral index and optical morphology)

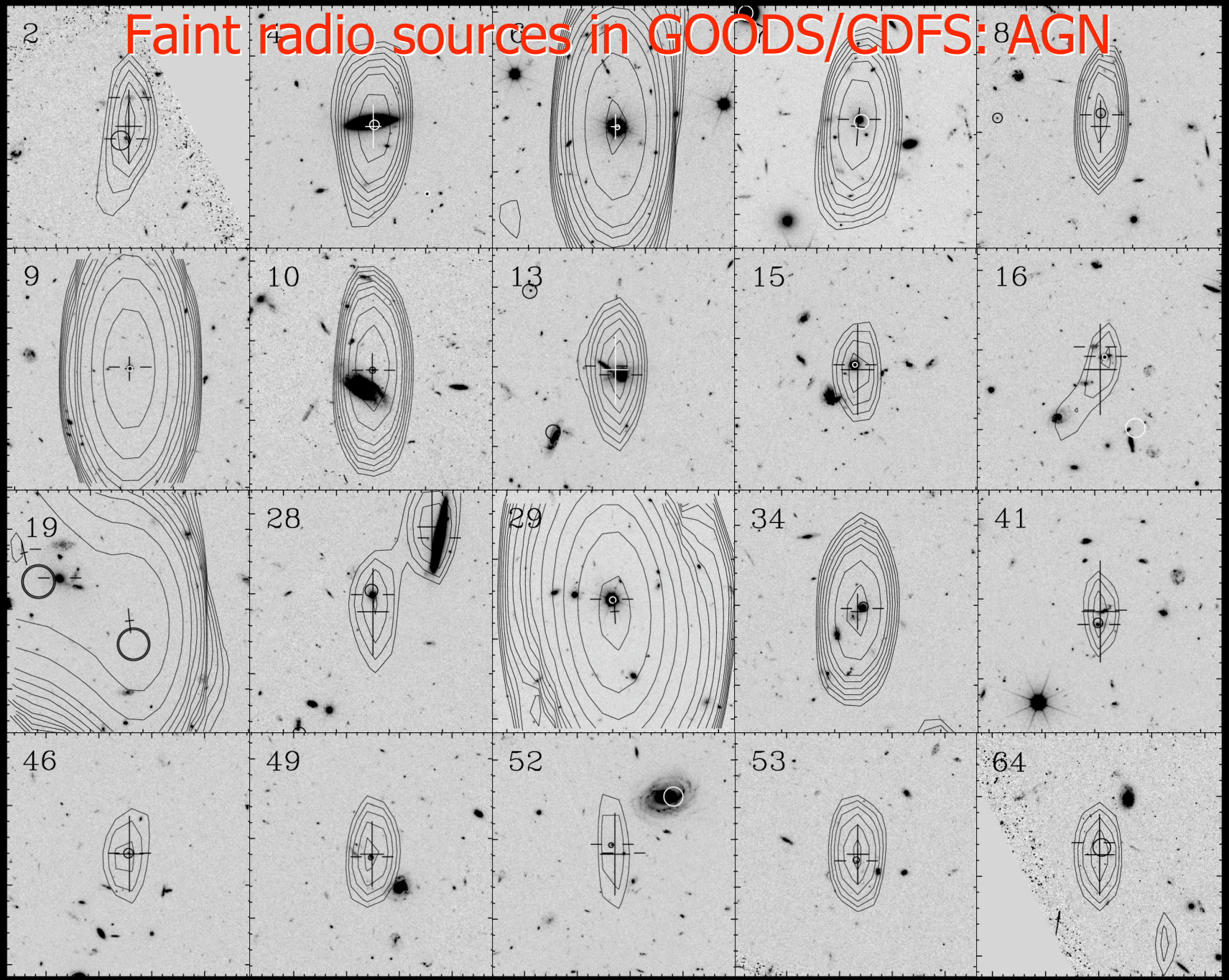
Faint radio sources in GOODS/CDFS: SF



Faint radio sources in GOODS/CDFS: UNCL

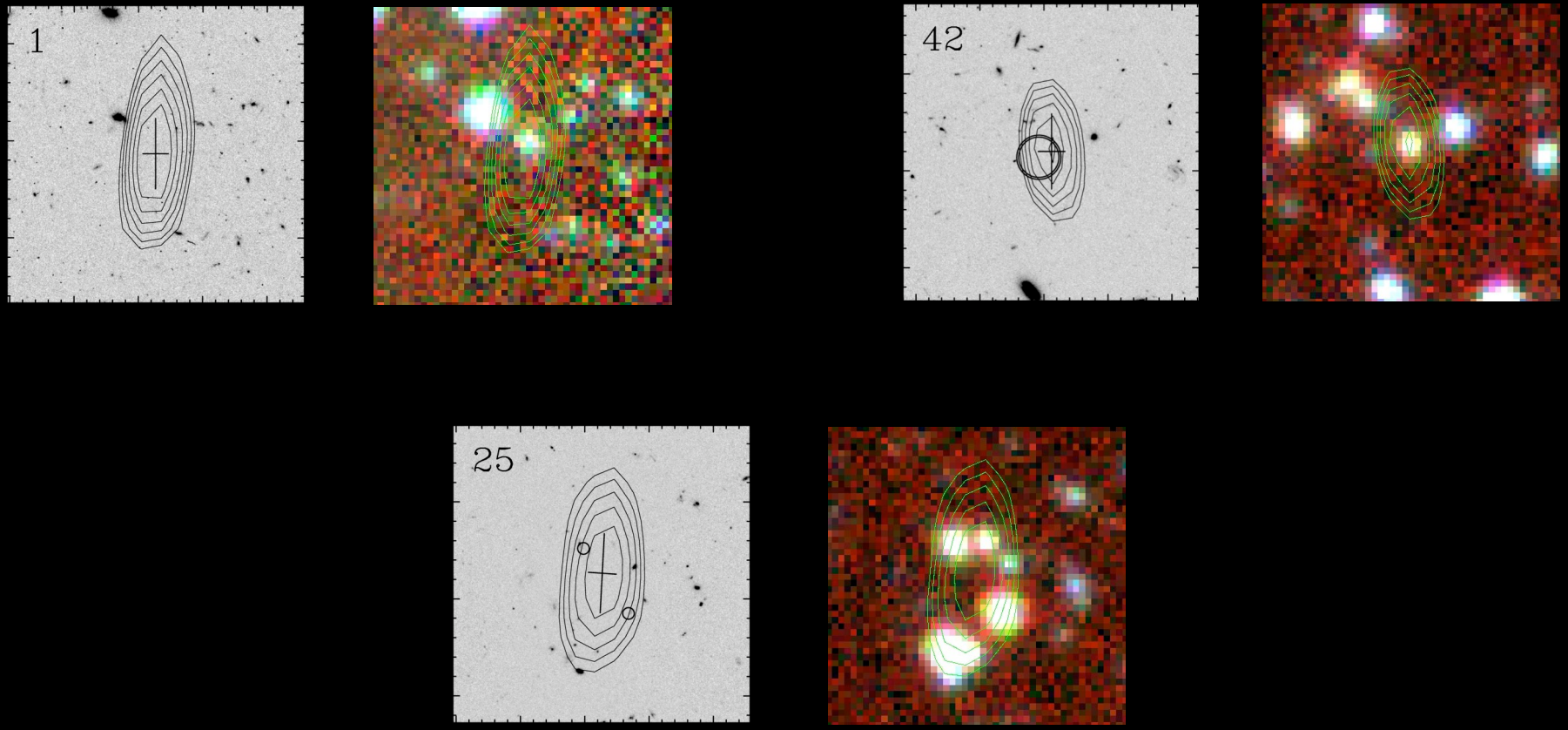


Faint radio sources in GOODS/CDFS: AGN



Faint radio sources in GOODS/CDFS: unidentified

Look in the mid-infrared (Spitzer):



- 4 undetected; 3 revealed