

Radio Deep fields & Star-formation at high redshift

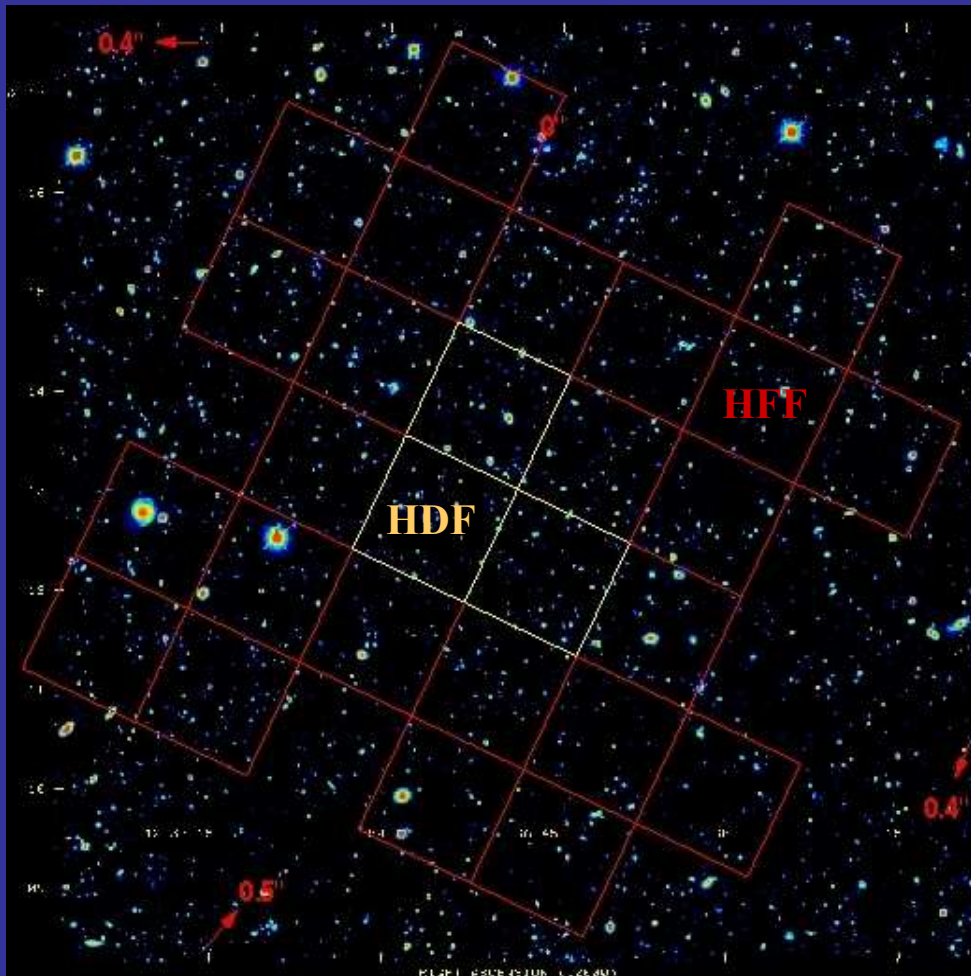
Rob Beswick

Tom Muxlow, Hannah Thrall, Anita Richards et al

4nd April 2006

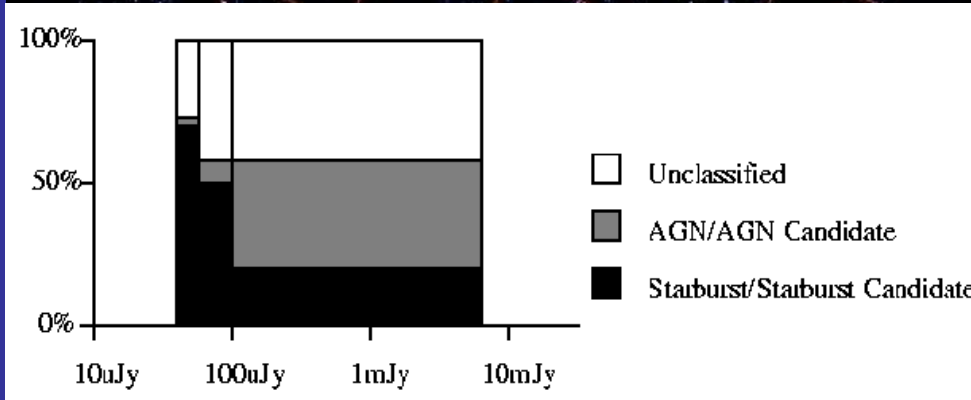


MERLIN & VLA observations of the HDF-N



- **From Muxlow et al 2005:**
- **A field 10 arcminute square centred on the HDF and imaged by MERLIN+VLA contains 92 radio sources with flux densities $>40\mu\text{Jy}$**
- **Radio sources have angular sizes in the range $0.2''$ – $3''$ & 85% associated with galaxies brighter than 25th mag**
- **Below $\sim 60\mu\text{Jy}$ sources are dominated by starburst systems.**

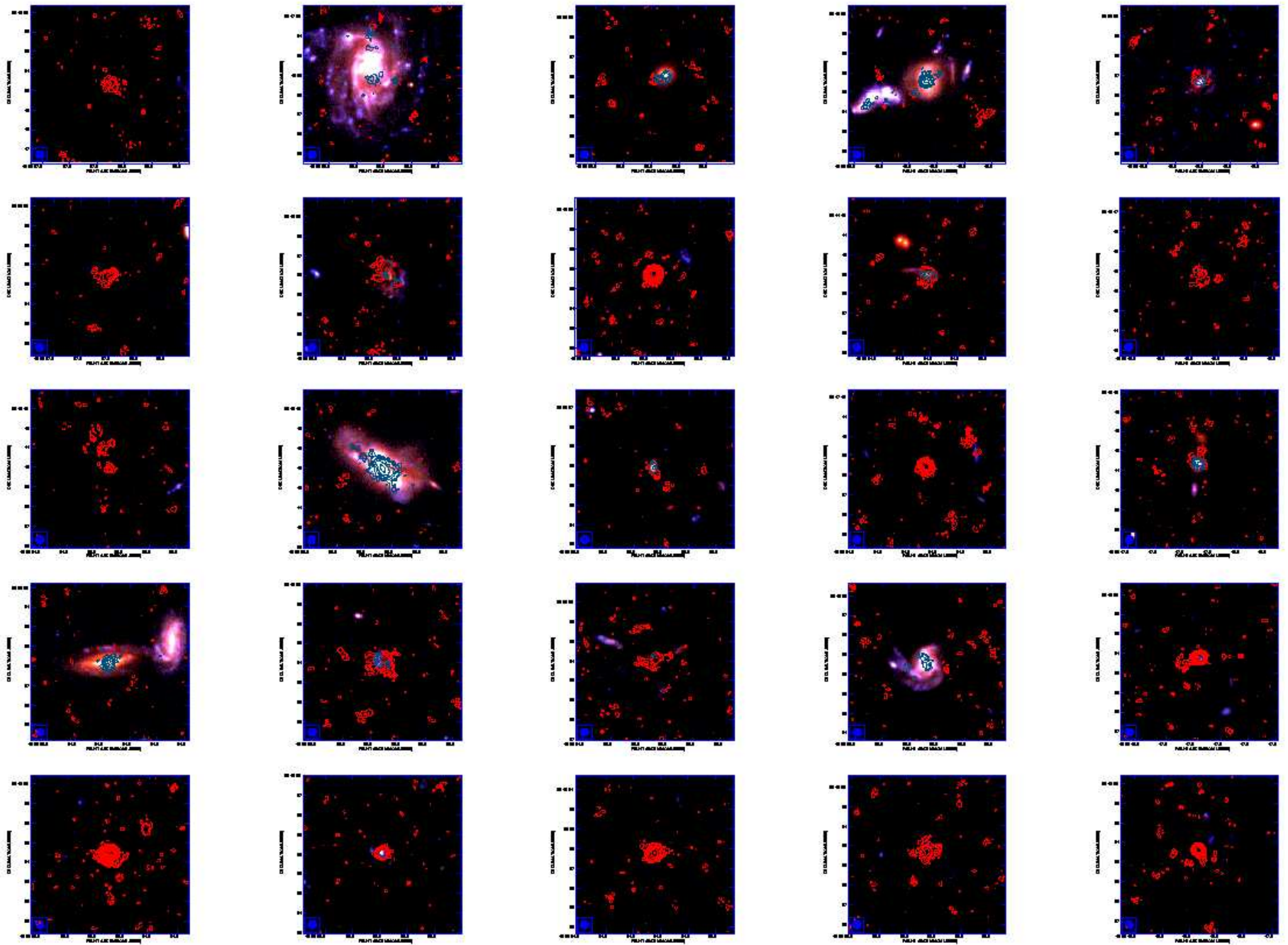
MERLIN & VLA observations of the HDF-N



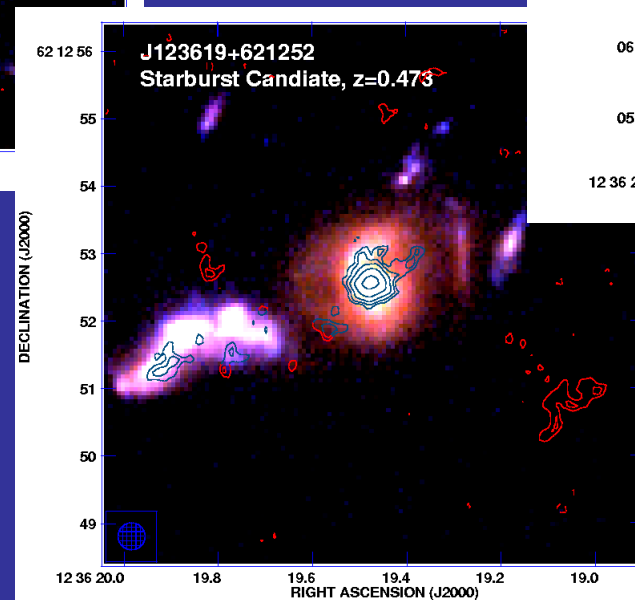
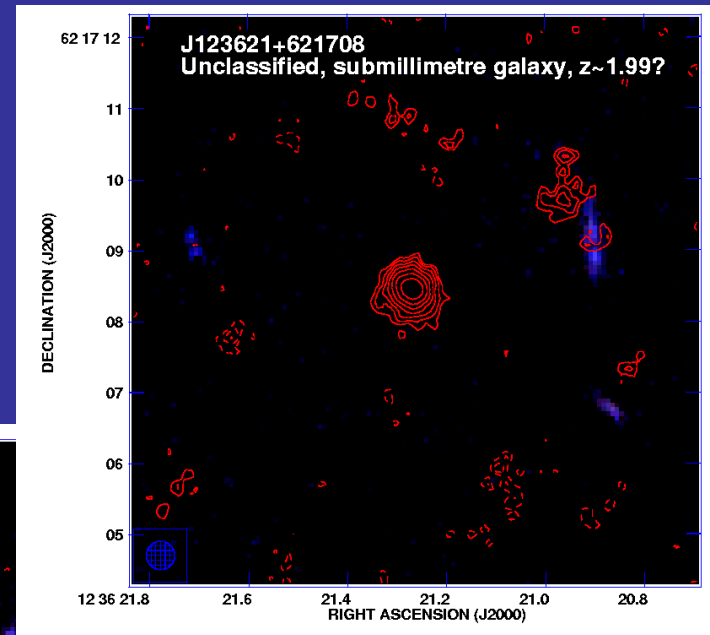
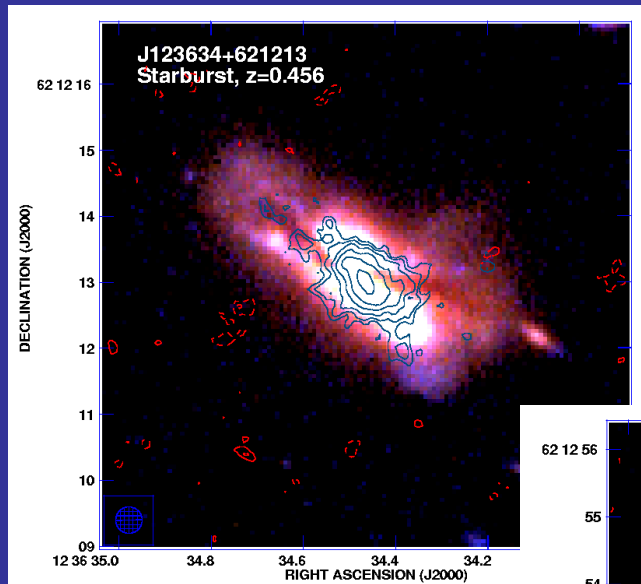
- Starburst systems with measured redshifts lie in the range $z=0.3$ to 1.3 [ρ]
- Optically faint systems (EROs) are dominated by starburst systems at significantly higher redshifts

MERLIN + VLA data

- 18 days of MERLIN & 32hrs of VLA A-configuration observations:-
- Covers 8.5 arcmin² centred on the HDF-N (limited by the Lovell primary beam)
- Angular resolution $\sim 0.2-0.5$ arcsec
- Image rms $\sim 3.3\mu\text{Jybm}^{-1}$
- ONE OF THE MOST SENSITIVE RADIO MAPS SO FAR MADE (at least until e-MERLIN!)



Bright(ish) radio sources



4th April 2006

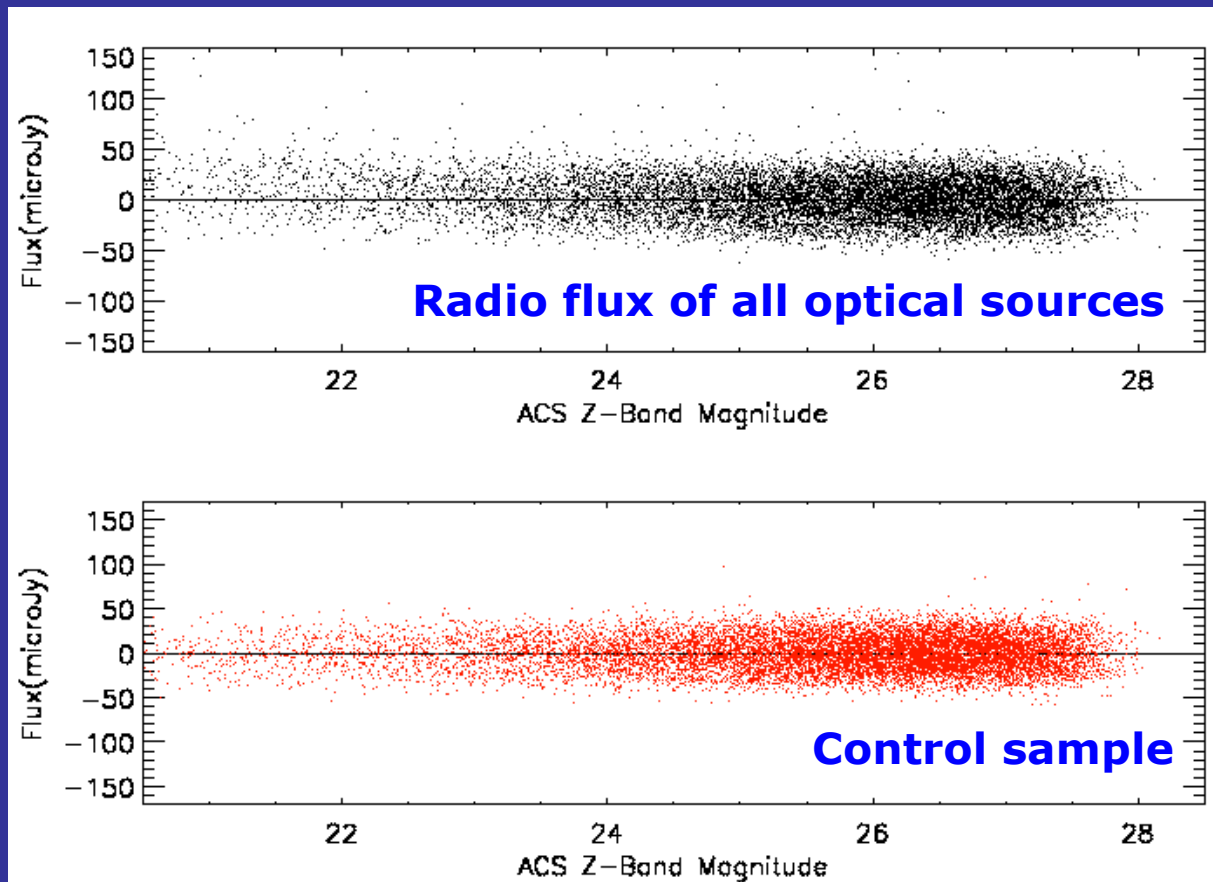
Radio Instruments

GOODS NORTH: New ACS & Spitzer data

- The historical HDF-N is coincident with the GOODS north field.
- → deeper wider field HST ACS images & catalogues in (B, V, I, z bands)
- → deep Spitzer MIPS & IRAC images & catalogues
- PLUS all the previously existing X-ray & optical data (redshifts – photometric & spectroscopic etc ...)
- These new ancillary data imply we can now extend the statistical analysis, beyond Muxlow et al 2005, of the existing MERLIN + VLA high resolution 1.4GHz observations.

GOODS – ACS data

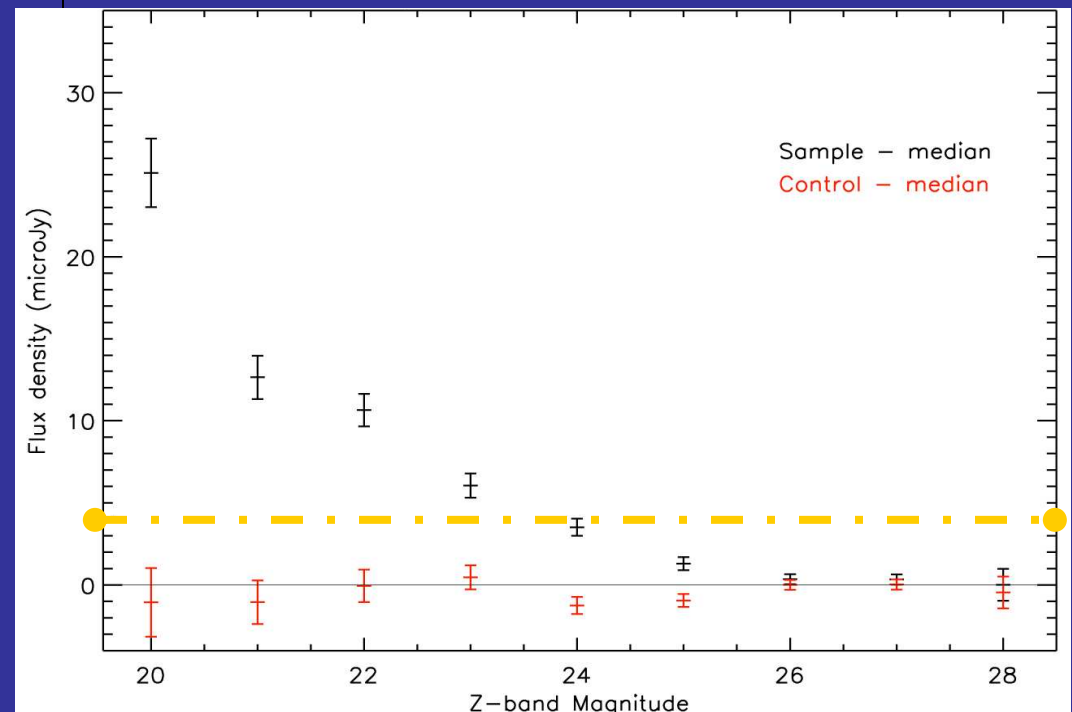
- **~13030** galaxies above mag 28.3 mag in z-band (just in 8.5 arcmin² field)
- ACS images aligned with MERLIN radio image to <0.05 arcsec rms.



Radio census of ACS sources

- Radio flux within 0.75arcsec of all z-band optical galaxies.

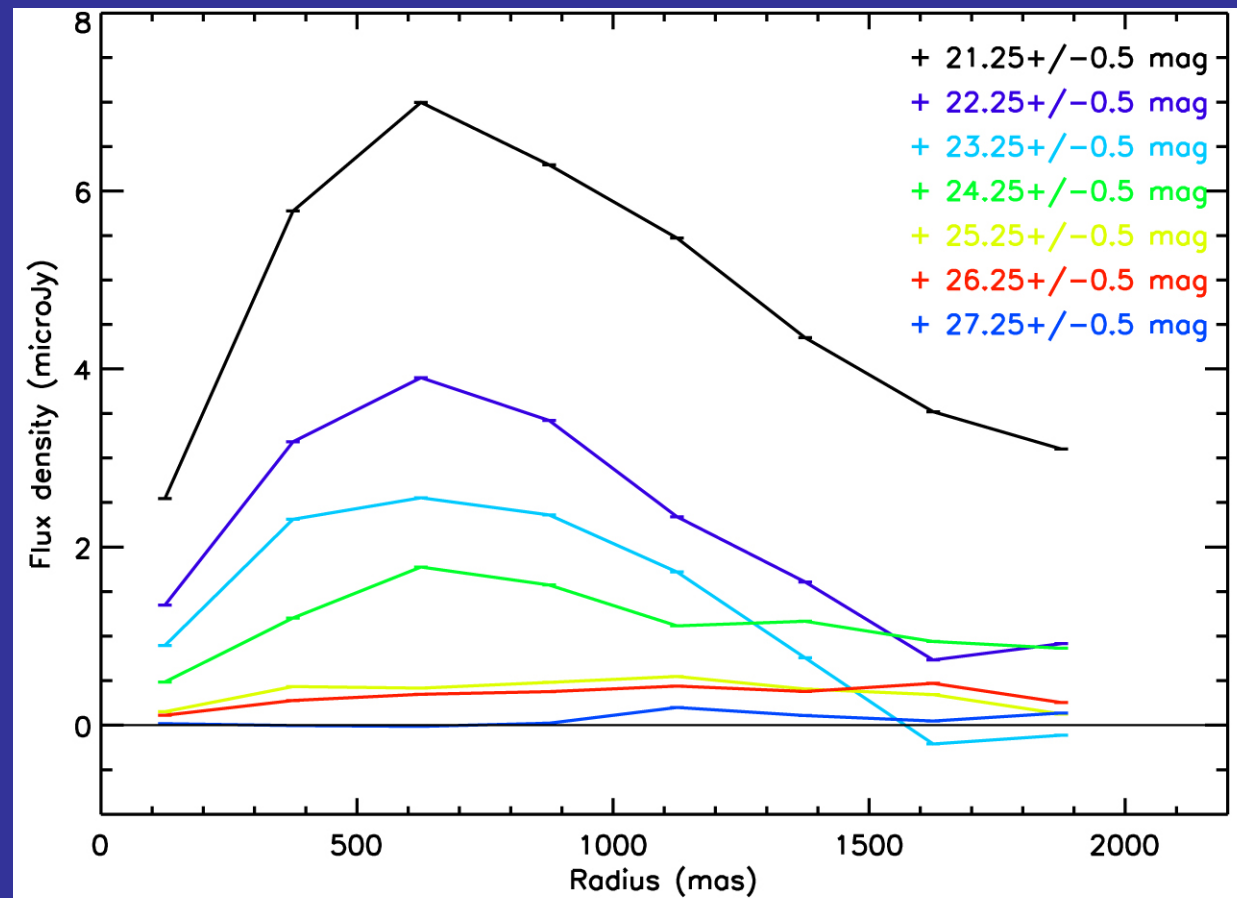
(Note excluding all bright radio sources ($>20\mu\text{Jy}$ pixel))



Median values are not statistically different from means implying that of the ~ 2700 galaxies brighter than $Z=24\text{mag}$, around 1400 will have radio flux densities of $\sim 4\mu\text{Jy}$ or greater ($\sim 8\sigma$ for a deep e-MERLIN/EVLA image)

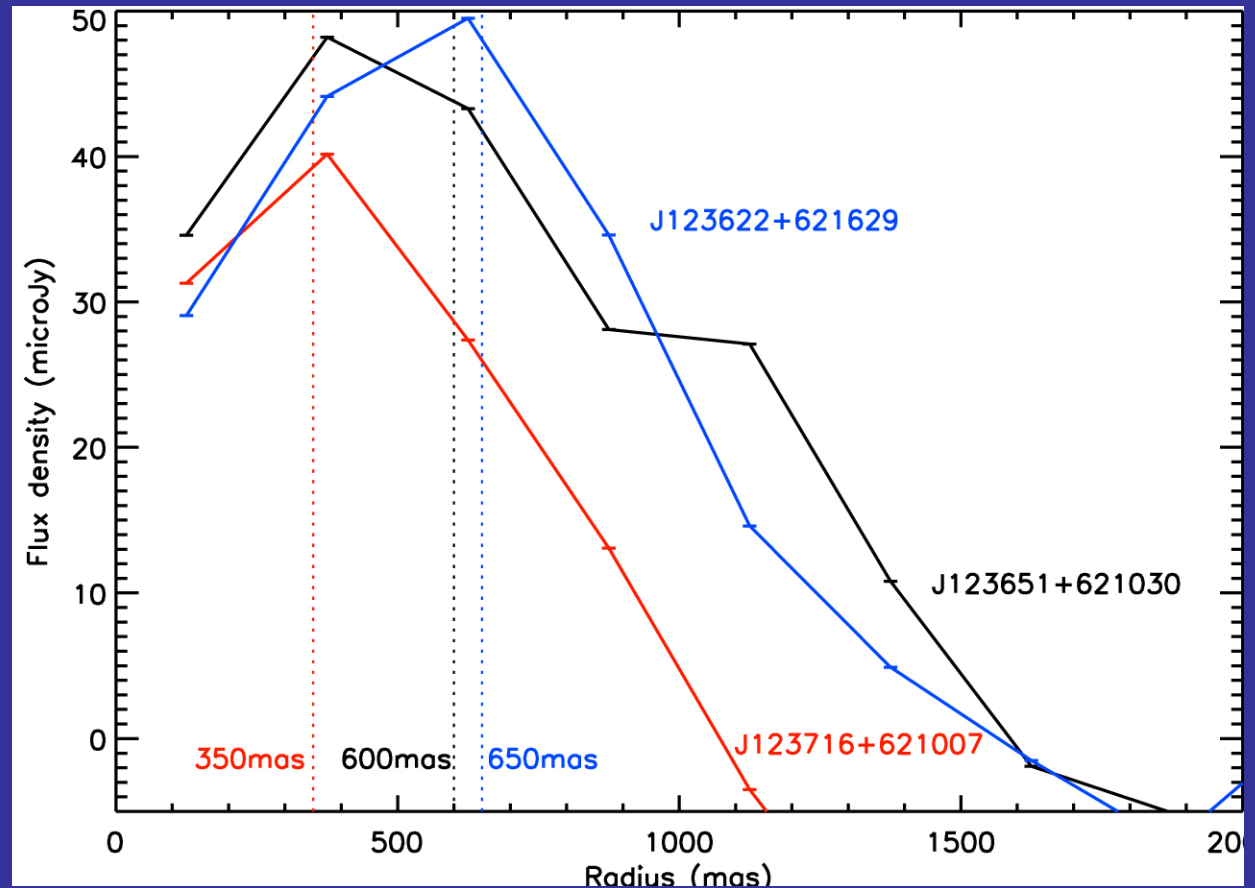
Radio source sizes: *very weak (sub-20 μ Jy) radio sources*

Average radio source sizes in each magnitude bin can be derived from flux densities found in annuli over radii of 0.25-2 arcsec



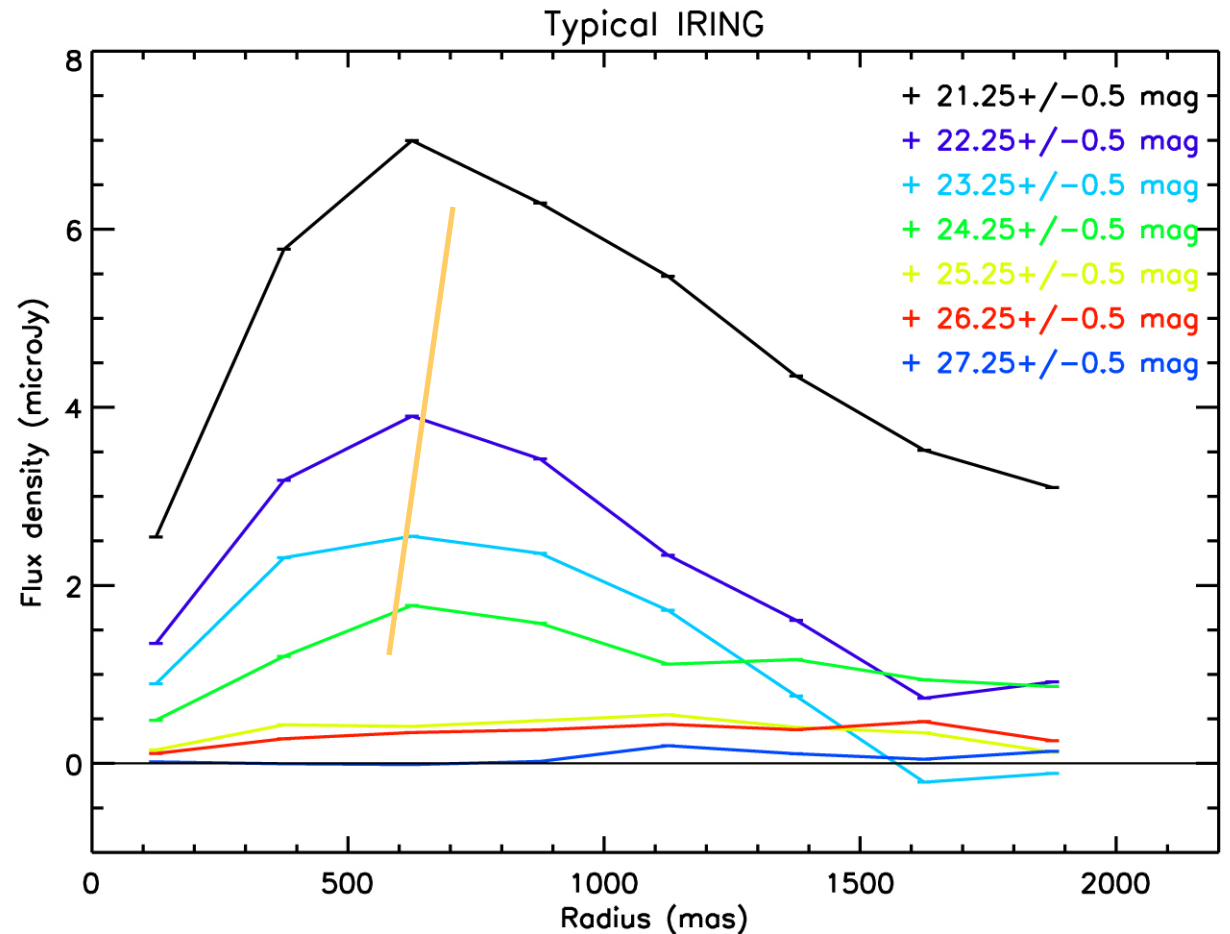
Radio source sizes: *very weak (sub-20 μ Jy) radio sources*

Source angular sizes can be calibrated by comparison with individual sources brighter than 40 μ Jy

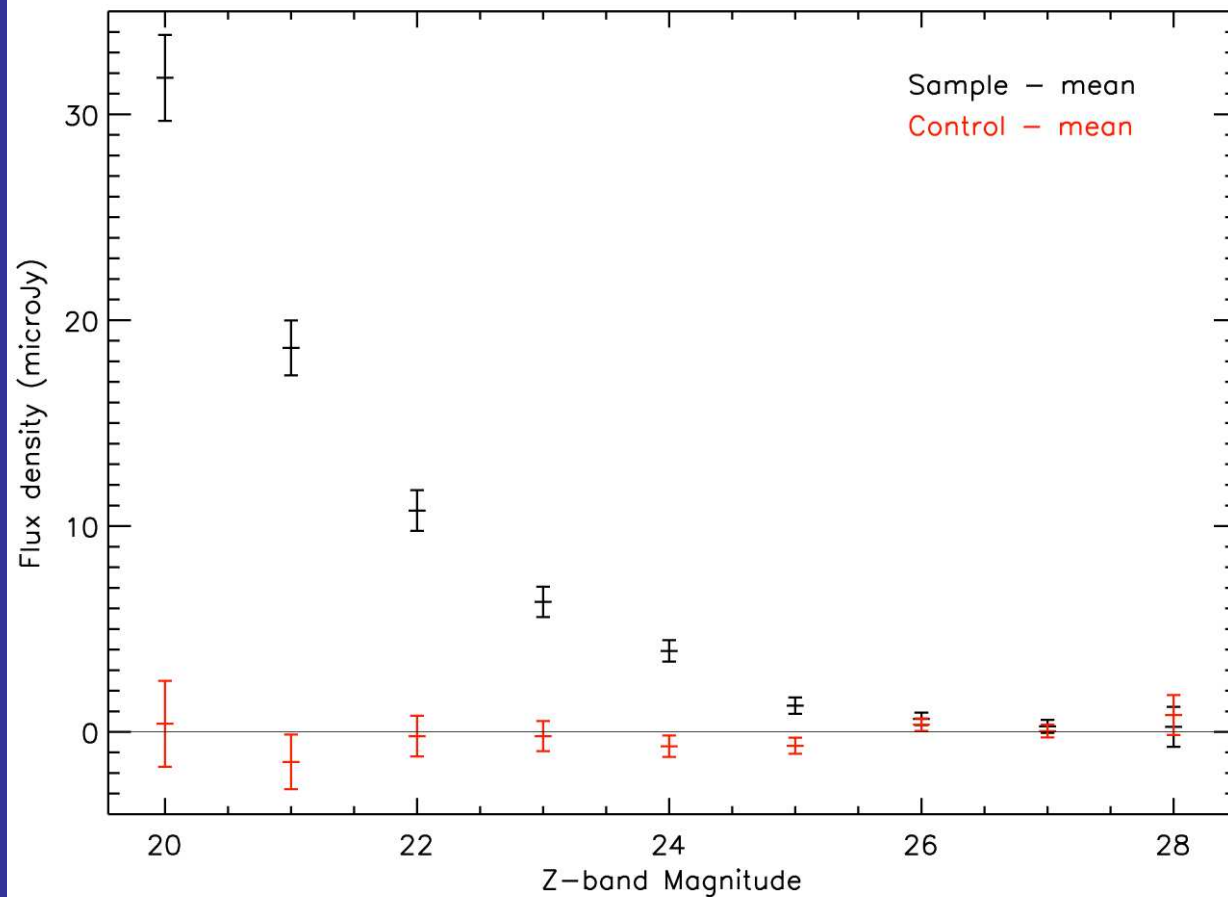


Radio source sizes: *very weak (sub-20 μ Jy) radio sources*

**Average
source sizes
range from
 $r \sim 0.75$ arcsec
(21.25^{mag}
[$\sim 12 \mu$ Jy]) to
 $r \sim 0.6$ arcsec
(23.25^{mag}
[$\sim 6 \mu$ Jy]) --
ideally suited
to e-MERLIN**

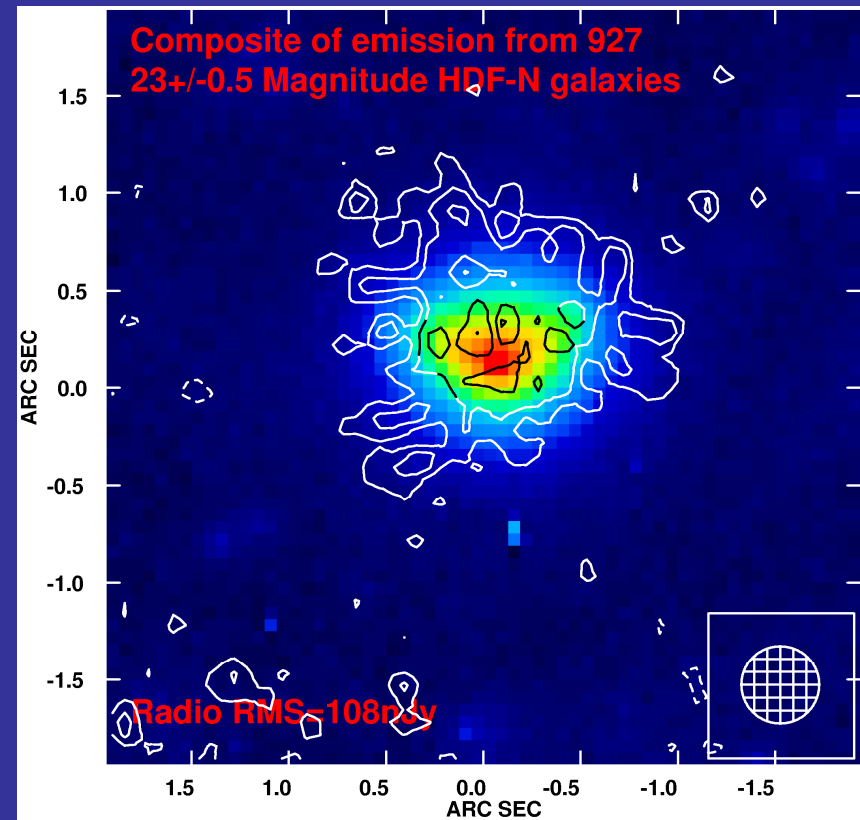
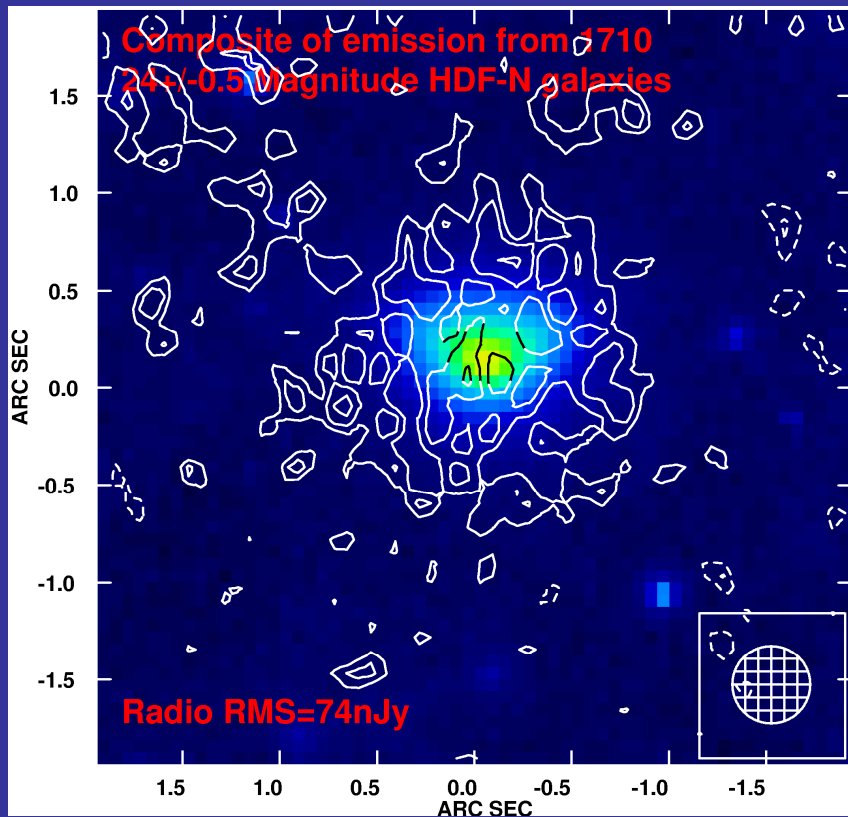


Average images of starbursts in the HDF-N



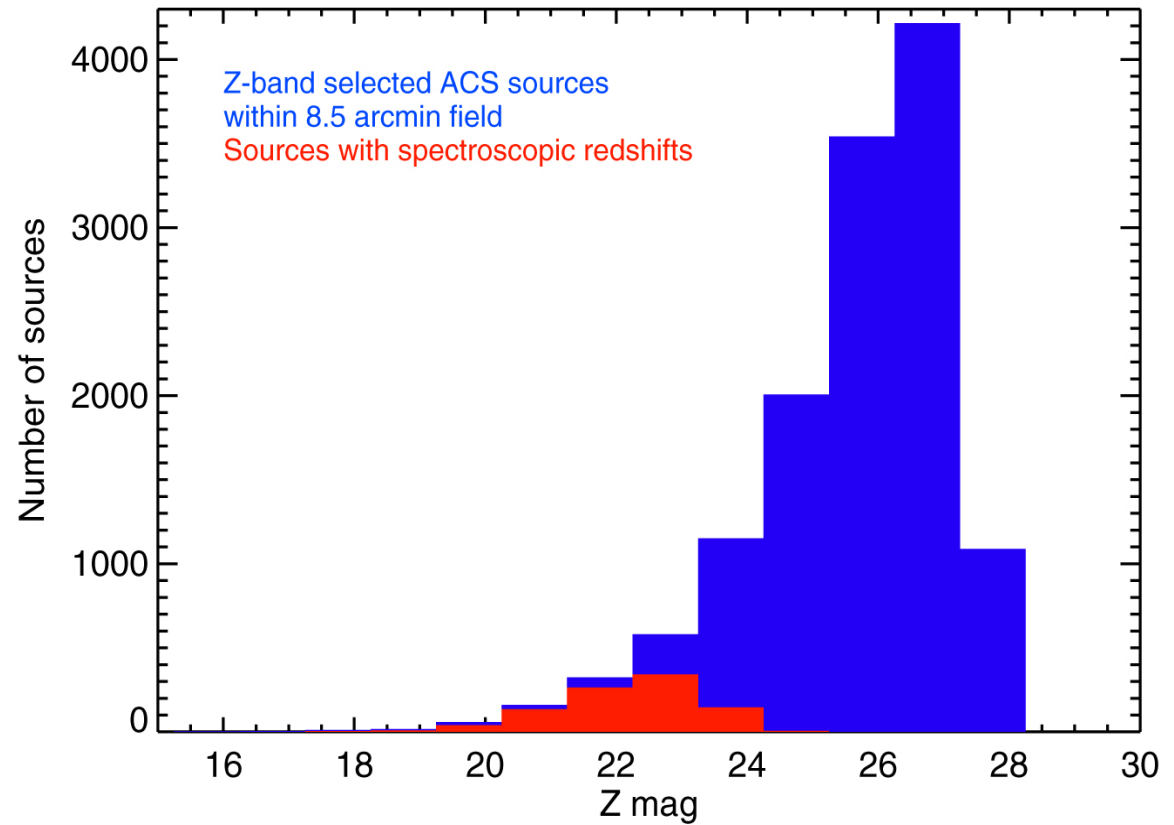
Radio flux density contained within an annulus of radius 0.75 arcseconds centred on the position of each of 13000 catalogued galaxies in the region of overlap between the ACS and MERLIN/VLA image binned by Z-band magnitude. Control sample incorporates a random 7 arcsecond offset.

Average images of starbursts in the HDF-N



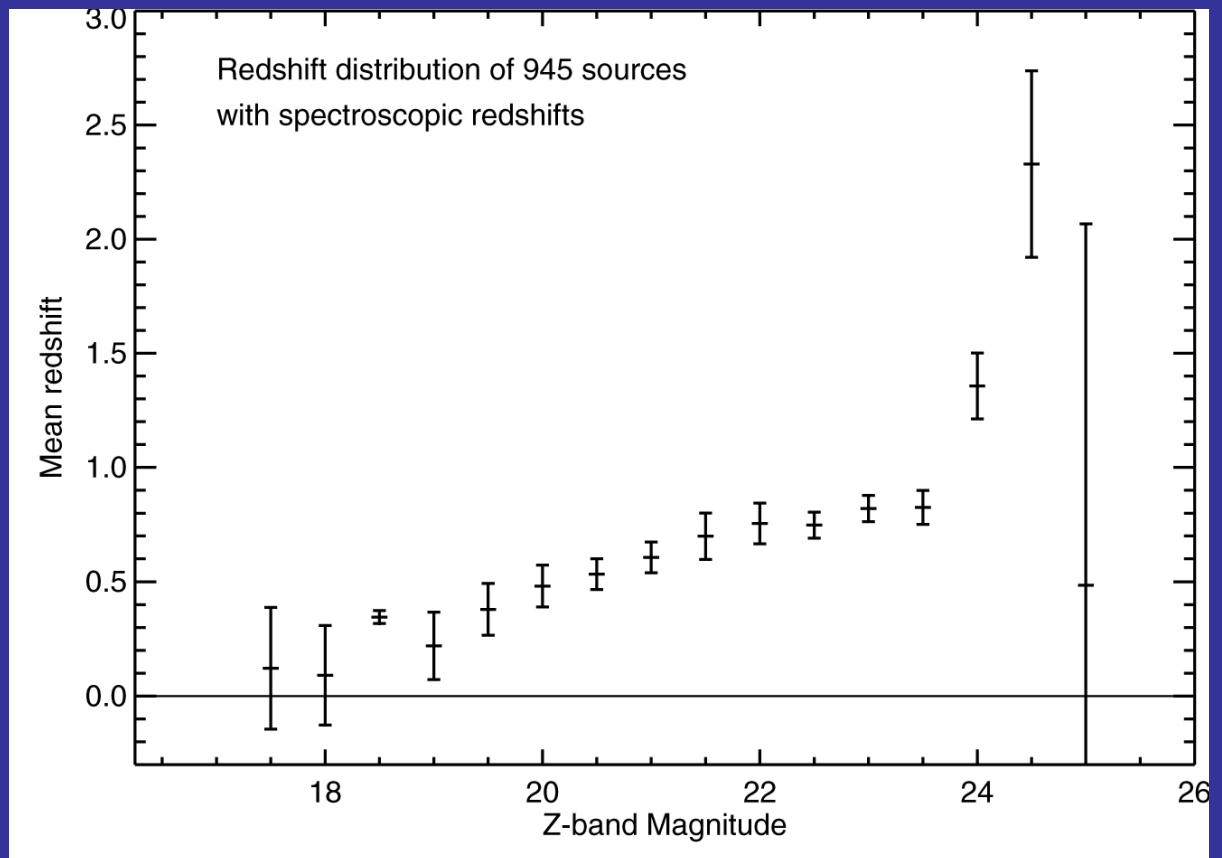
Luminosities

**Only ~1000 of
the 13000
galaxies have
published
spectroscopic
redshifts
available (Keck)**



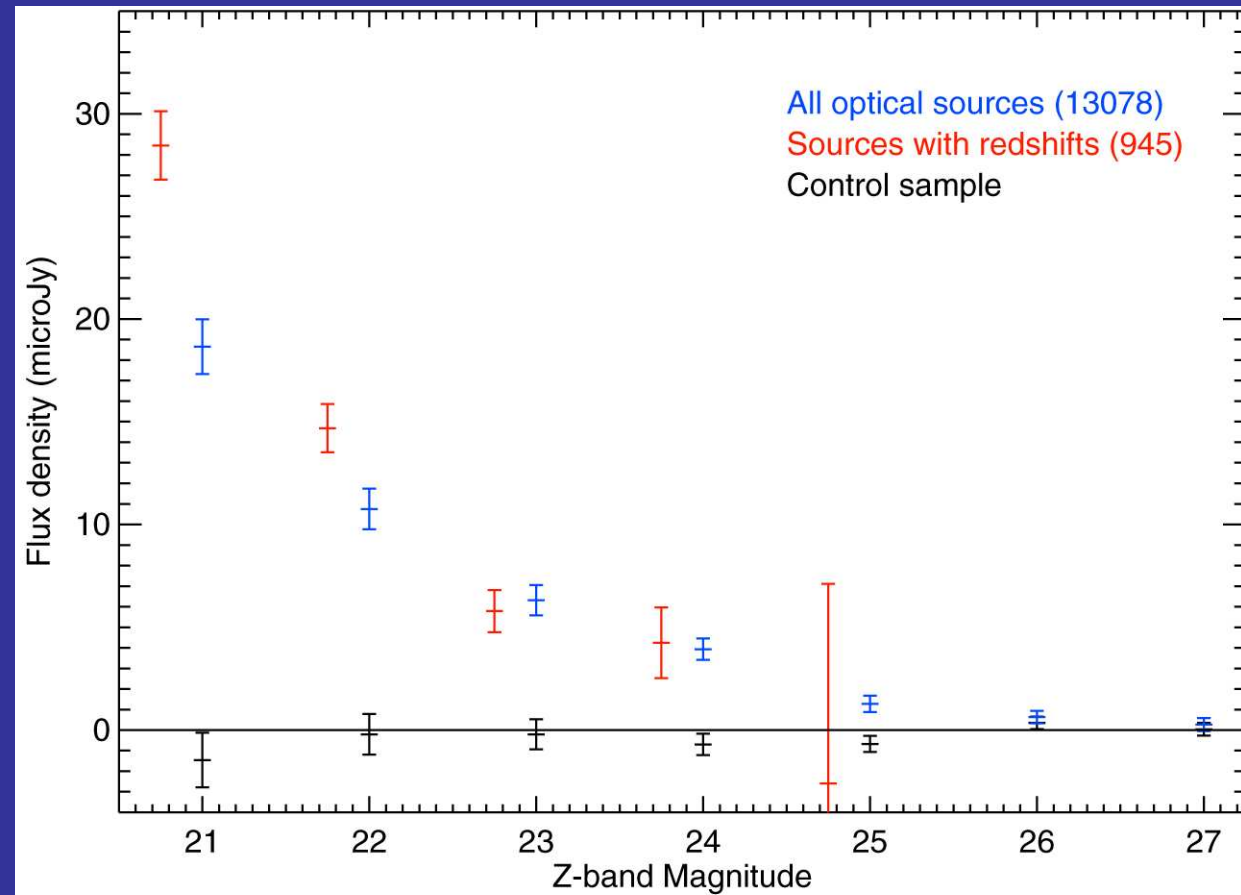
Luminosities

Measured redshifts binned by magnitude. With average redshifts and radio flux densities in each magnitude bin (down to 24th magnitude) we may now derive luminosities



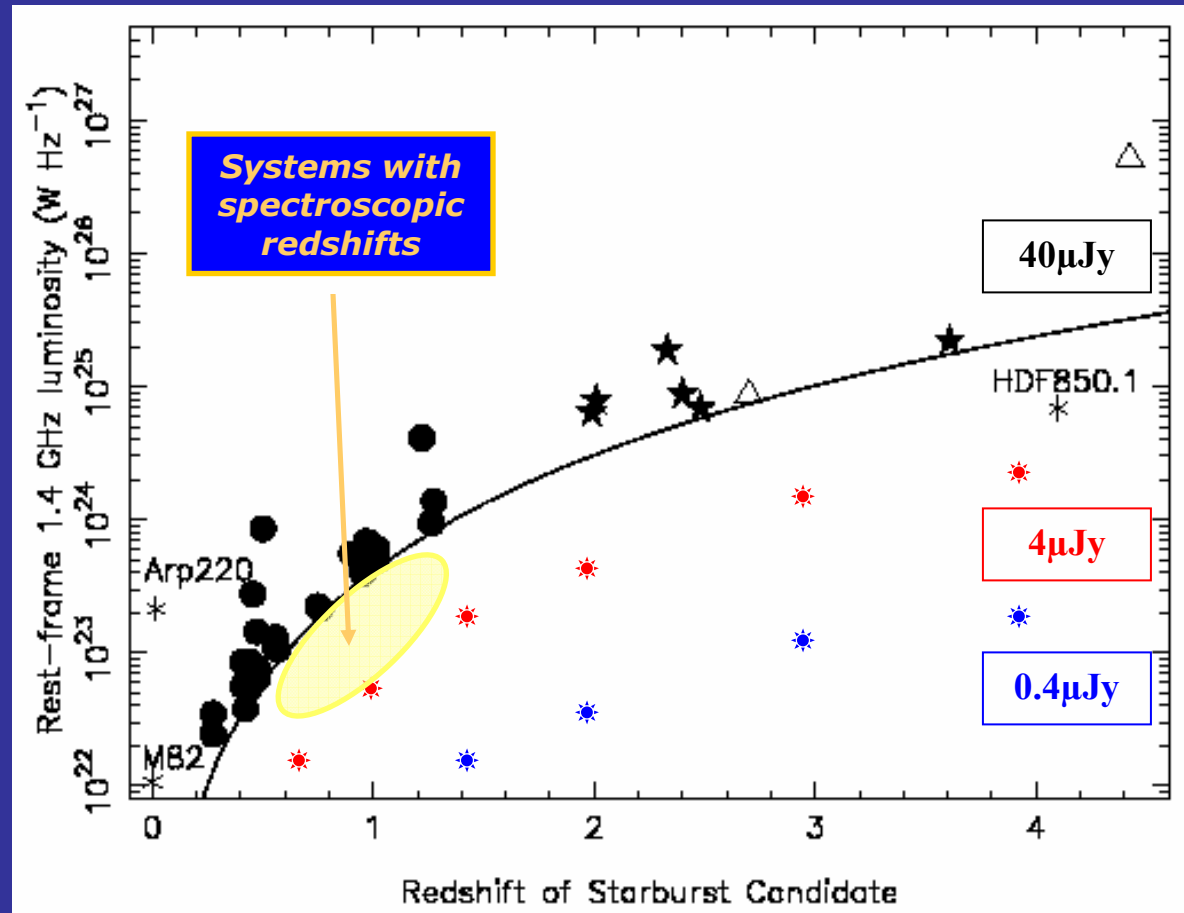
Luminosities

The radio properties of the galaxies with measured redshifts appear to mirror those of the full sample



Luminosities

**e-MERLIN
should image
>1000 starburst
systems to
~4 μ Jy with
perhaps 150-
200 at high
redshift in a
single field.
Many thousands
of systems with
radio flux
densities <1 μ Jy
will be studied
statistically**



Conclusions & ongoing work

- One of the deepest & longest MERLIN observations to date has revealed:
 - A plethora of radio sources with flux < few tens of μJy . *The majority of which are star-forming galaxies.*
 - At 1.4GHz the deepest current MERLIN observations can statistically detect 1000s of optically faint sources.
 - MERLIN angular resolution is ideal. Resolving these sources to sizes $\sim 750 \rightarrow 600\text{mas}$ (mag 21 \rightarrow 23 mag).

What will e-MERLIN do?

- **e-MERLIN at 1.4 GHz will be the instrument of choice to image in detail the regions of extended radio emission in these very weak starburst galaxies.**
- **e-MERLIN at 5 GHz will be the instrument of choice to detect any embedded radio-quiet AGN which may be present.**
- **e-MERLIN at 1.4GHz should image >1000 sources to $\sim 4\mu\text{Jy}$ with perhaps 150-200 at very high redshift (per pointing). Statistical studies on many thousands of sources $< 1\mu\text{Jy}$ will investigate the population that SKA will image.**