Towards a complete census of star formation in massive galaxies at z>3

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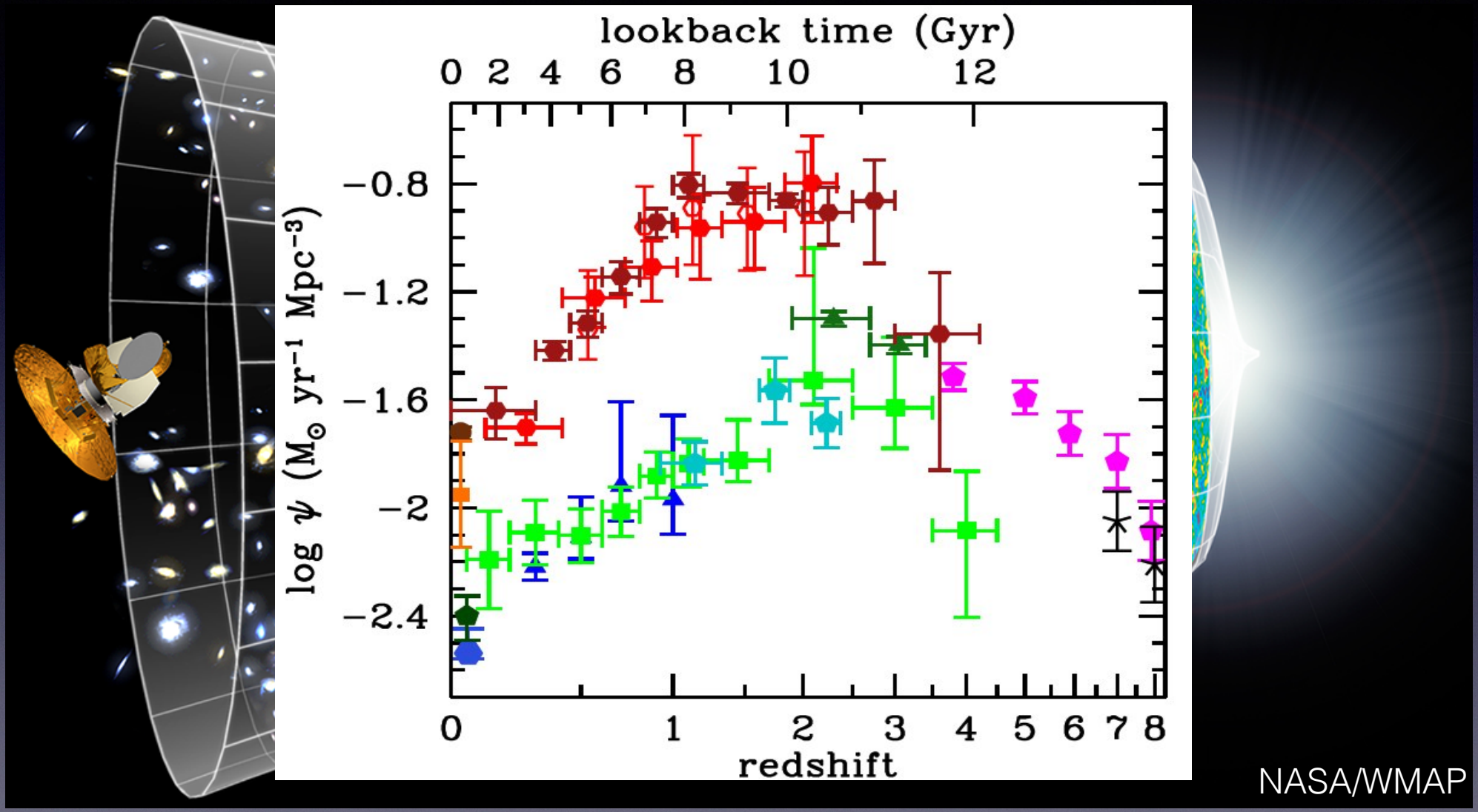
Outline

- Motivation & Introduction : Why do we want to search for massive (dusty) galaxies at $z > 3$?
- Sample selection: Do they exist, and how to identify them ?
- What are their physical properties?
- Conclusions

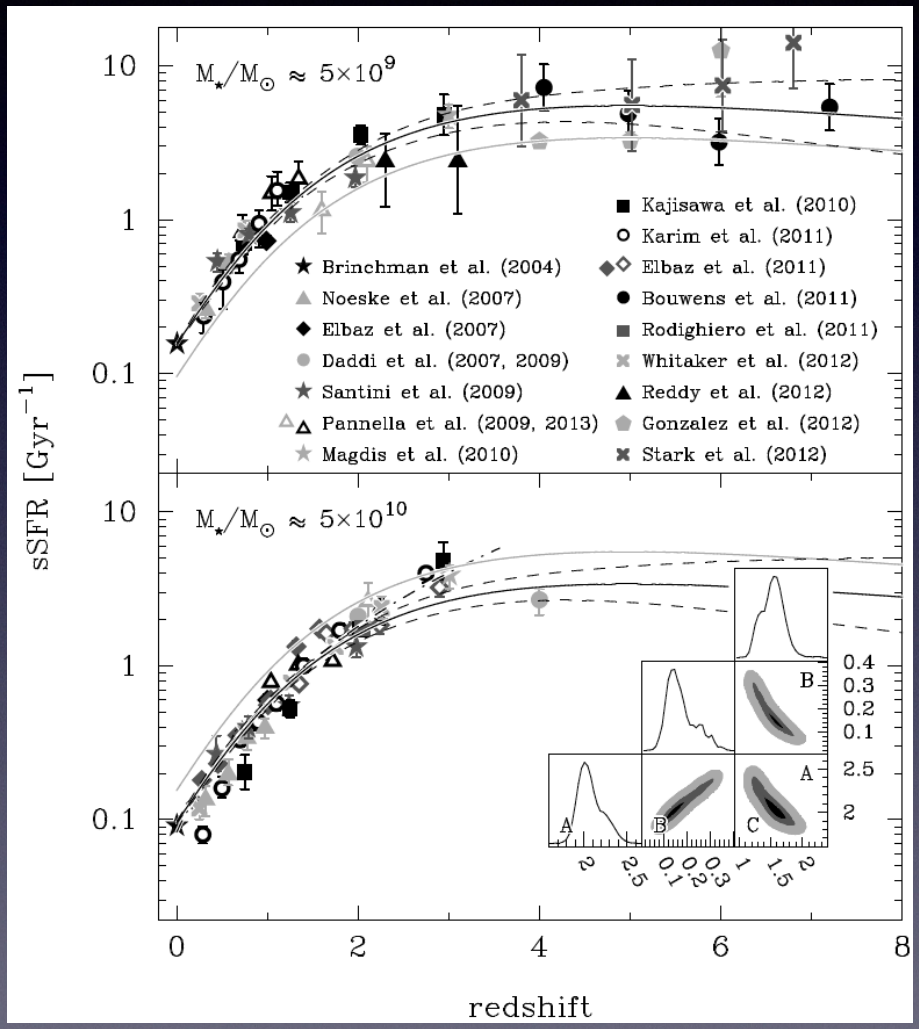
The cosmic star formation history



Madau & Dickinson 2014

The cosmic star formation rate density determination at $z > 3$ is mostly based on solely UV-selected samples

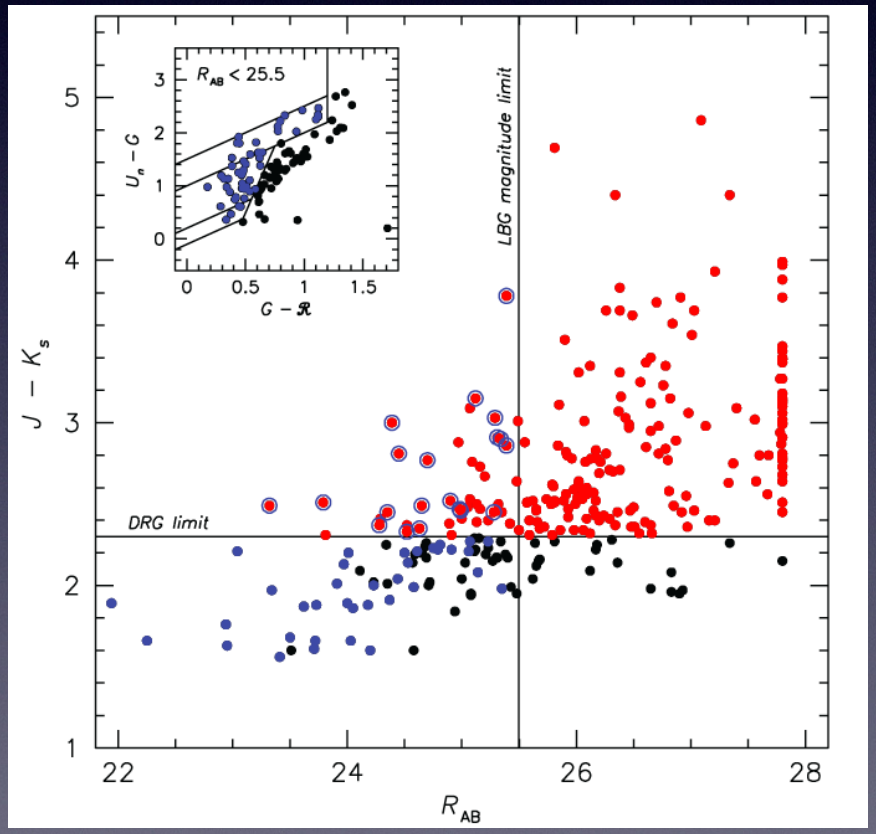
The global specific star formation rate



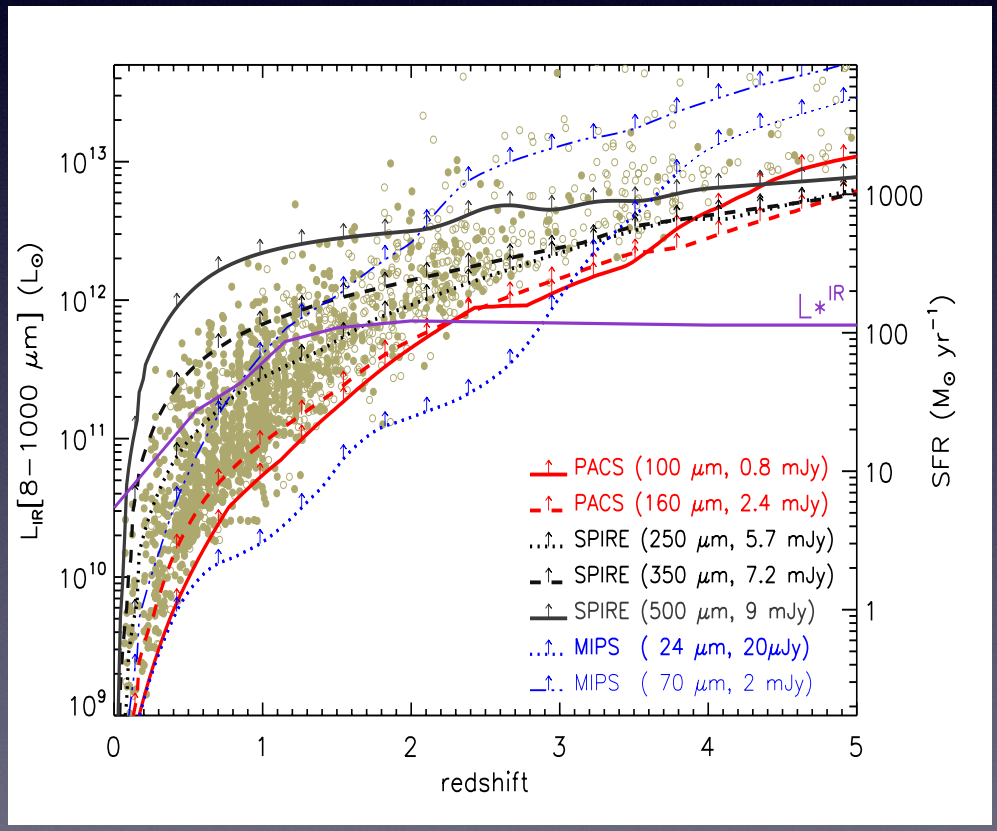
SSFR of massive galaxies at z > 3 remain largely unexplored.

argent et al. 2014, but see more recent work by Pannella+2014, Schreiber +2014 and Salmon+2014

- UV-selection may miss most massive dusty/old galaxies at z > 3
- Current infrared/submillimeter surveys are not deep enough to probe obscured star formation in typical (M*) galaxies at z > 3.



van dokkum+2006

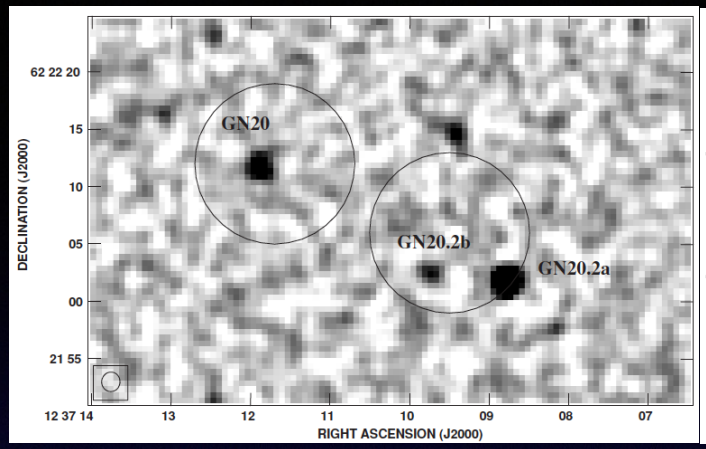


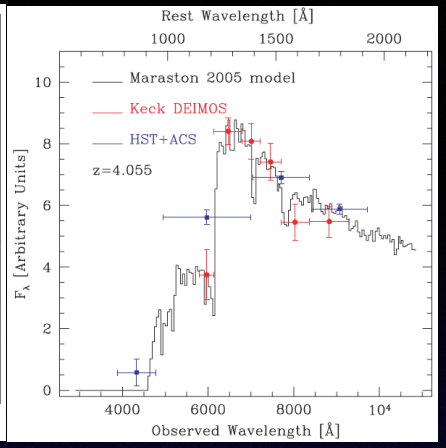
Elbaz+2011

Do they exist ?

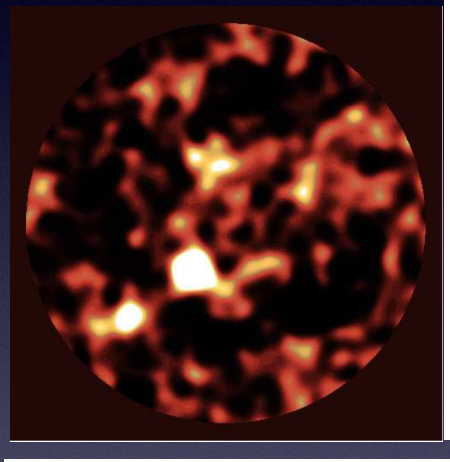
- The existence of a significant population of quiescent galaxies at z ~ 2 (age ~ 1 Gyr, n ~ 10^{-4}Mpc^{-3}) requires the existence of a significant population of massive star-forming galaxies at z~3-5;

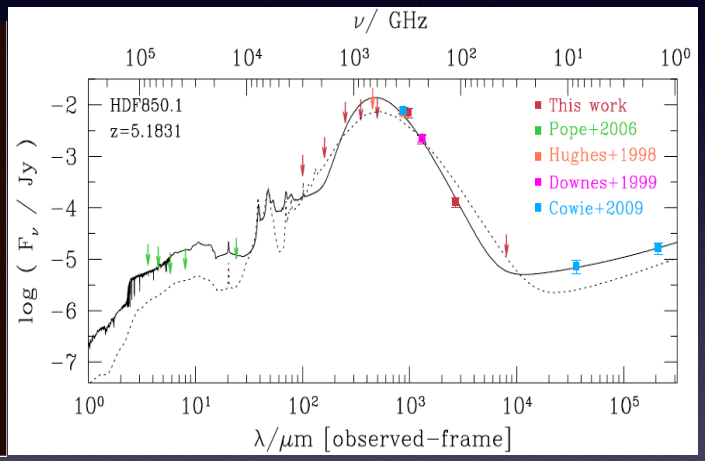
- high-z Submillimeter/far-infrared bright galaxies/AGNs e.g., SMGs(Chapman+2003;Dunlop+2004;Younger +2007;Daddi+2009;Riechers+2010;Vieira+2013), red SPIRE sources ($S_{250} < S_{350} < S_{500}$,Cox+2011,Casey +2012,Riechers+2013), and FIR luminous radio galaxies and FIR luminous quasar hosts (e.g.,Wang+2013;Carilli +2013;Wagg+2014)



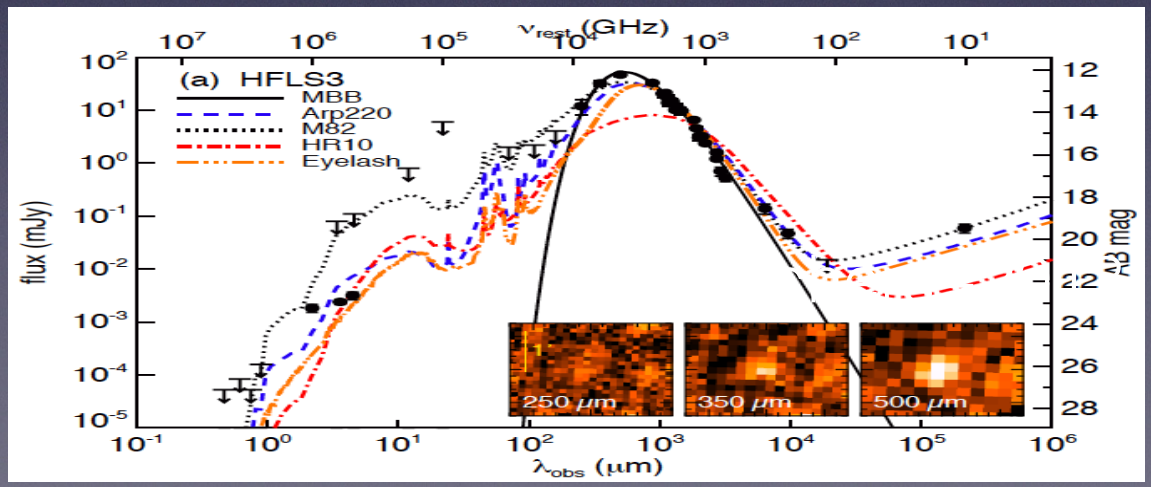


GN20,z=4.05
Daddi et al. 2009

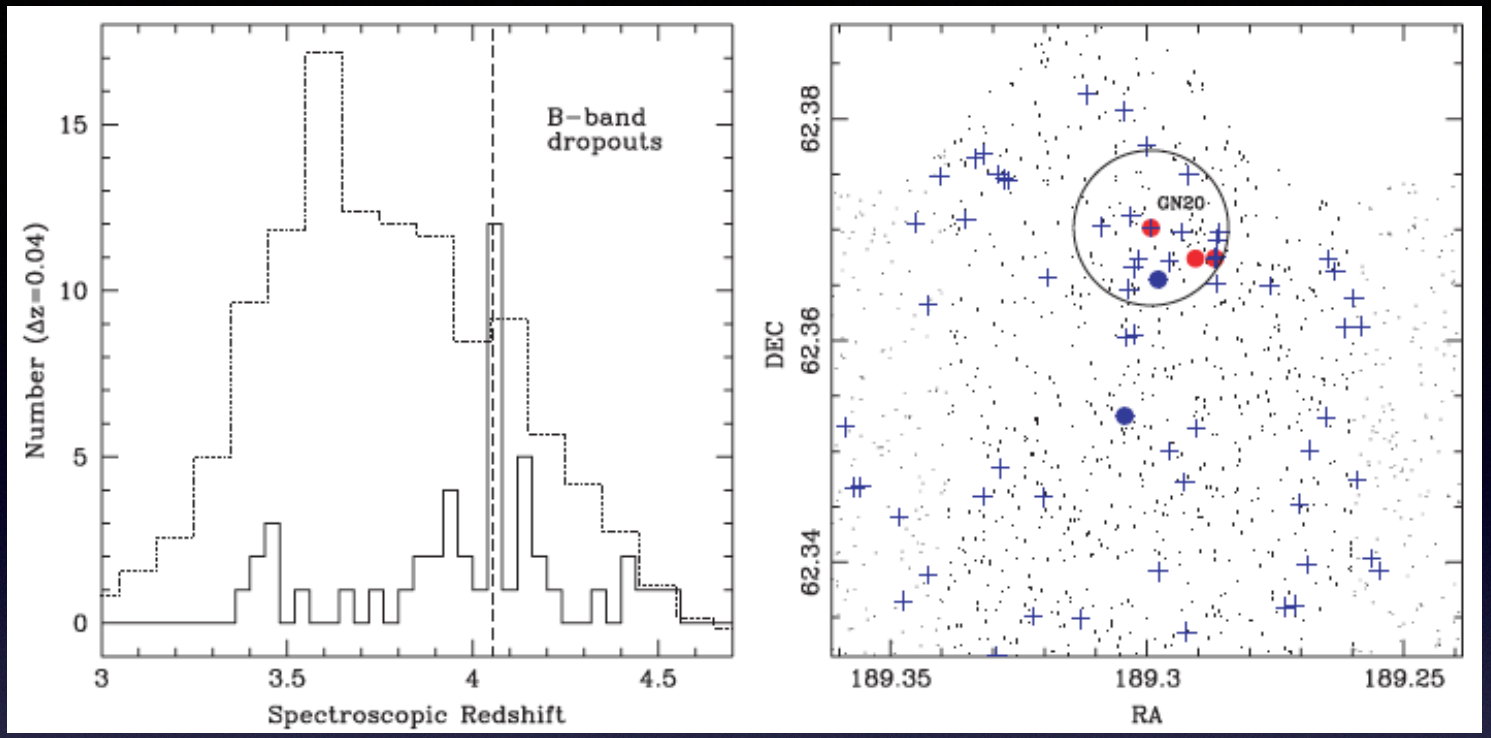




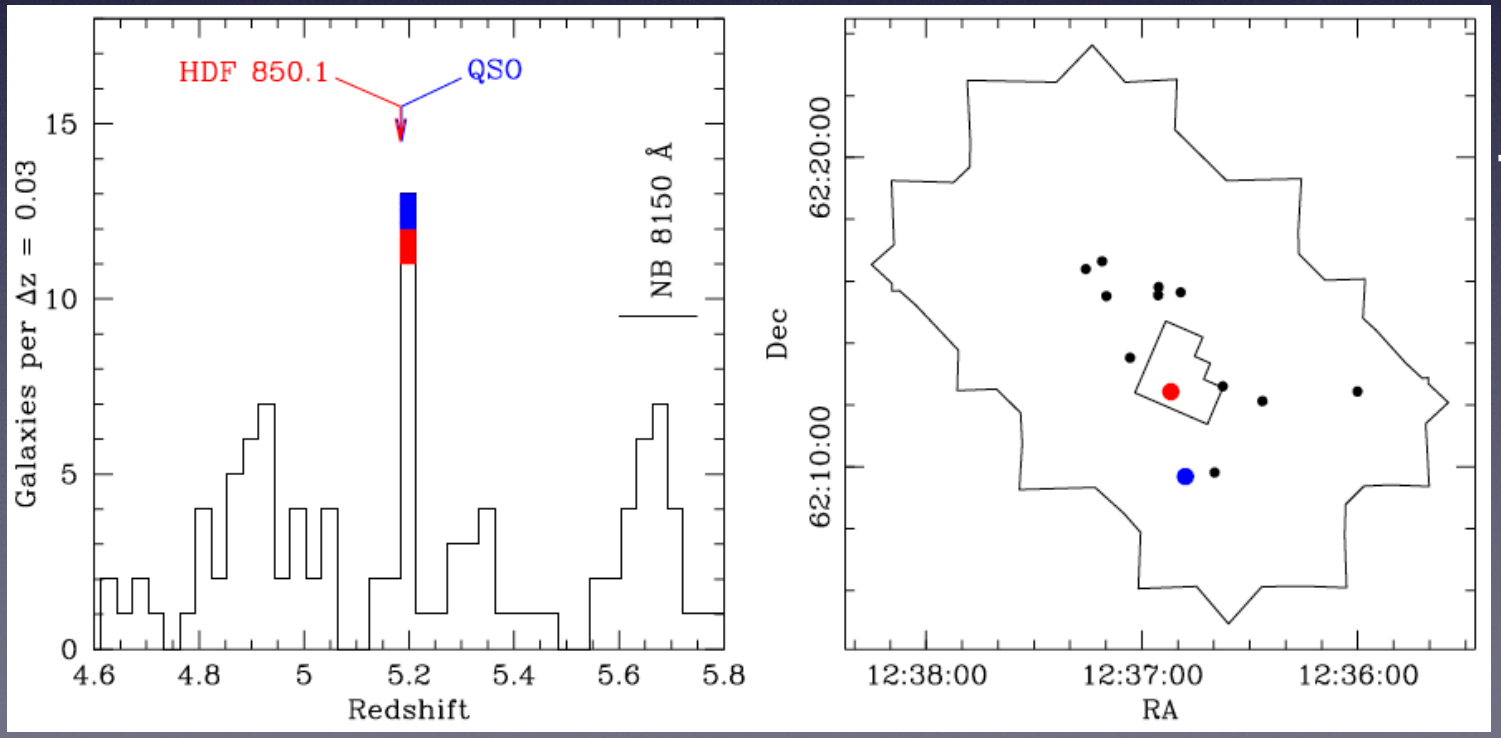
HDF850.1, z=5.18
Hughes et al. 1998
Walter et al. 2012



HFLS3, z=6.34
Riechers et al. 2013



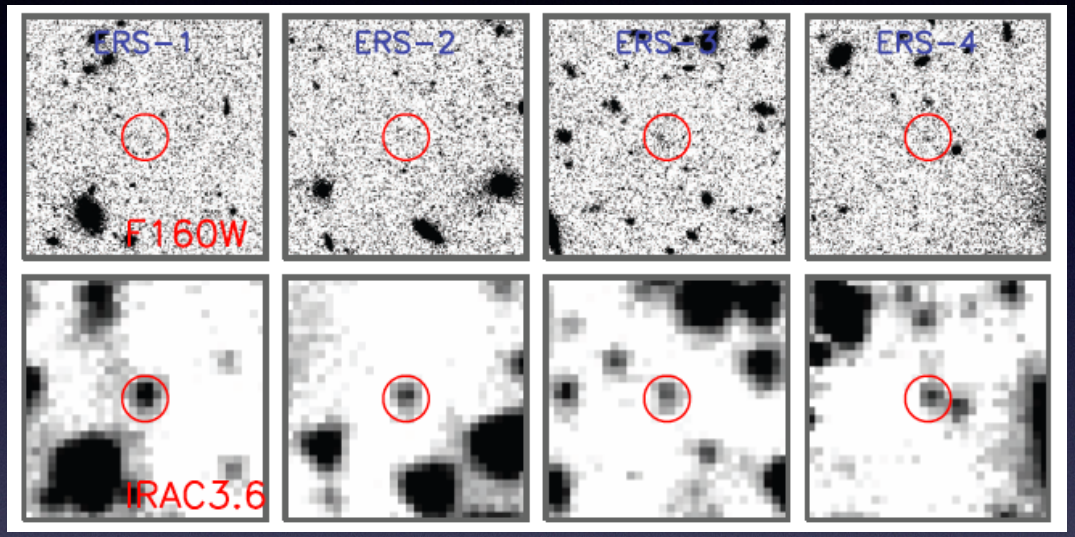
Daddi+2009

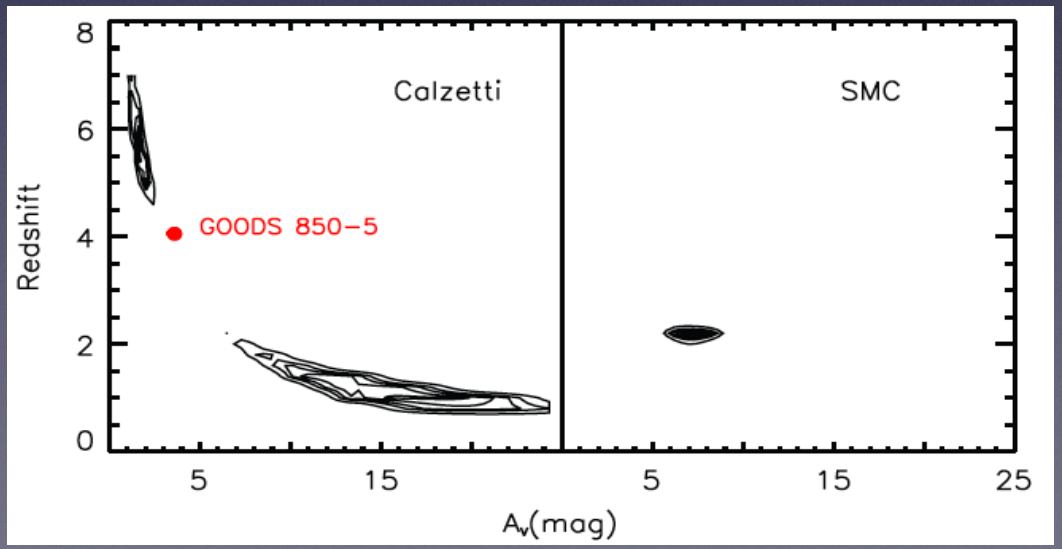


170 arcmin^2

Riechers+2013

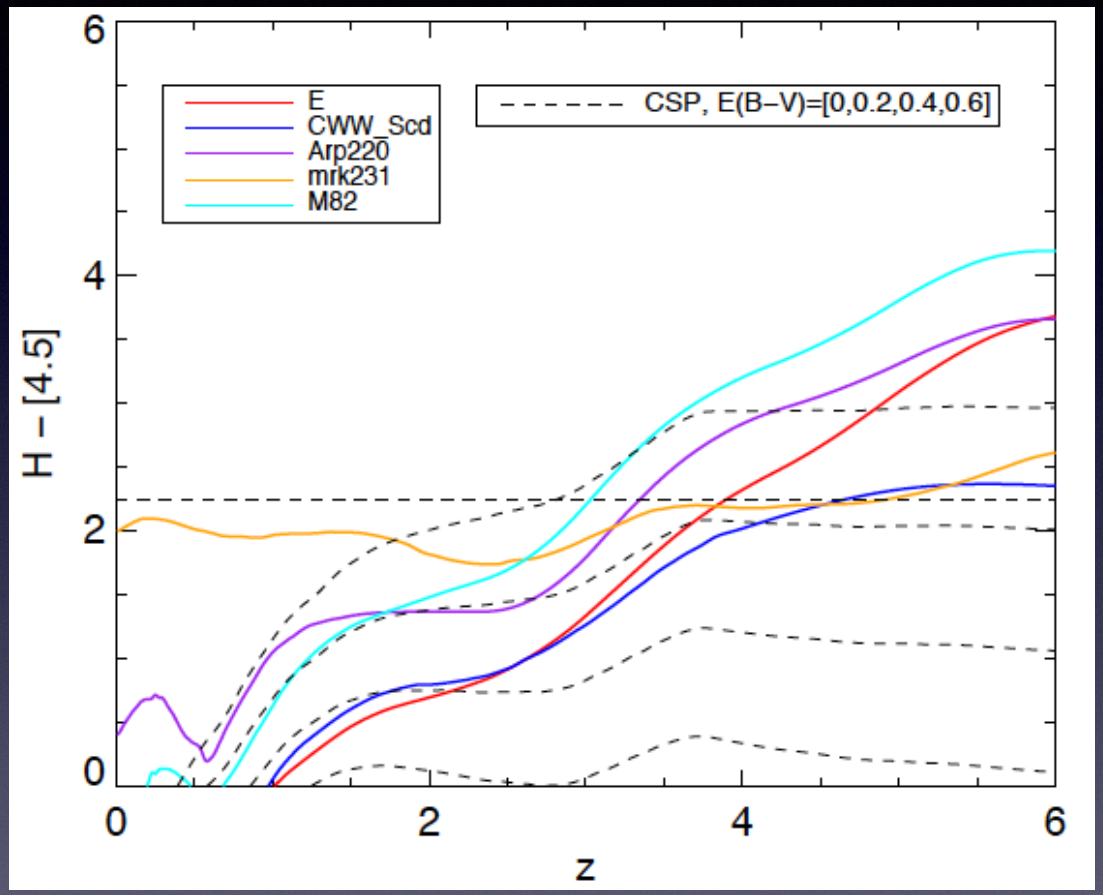
H-dropouts

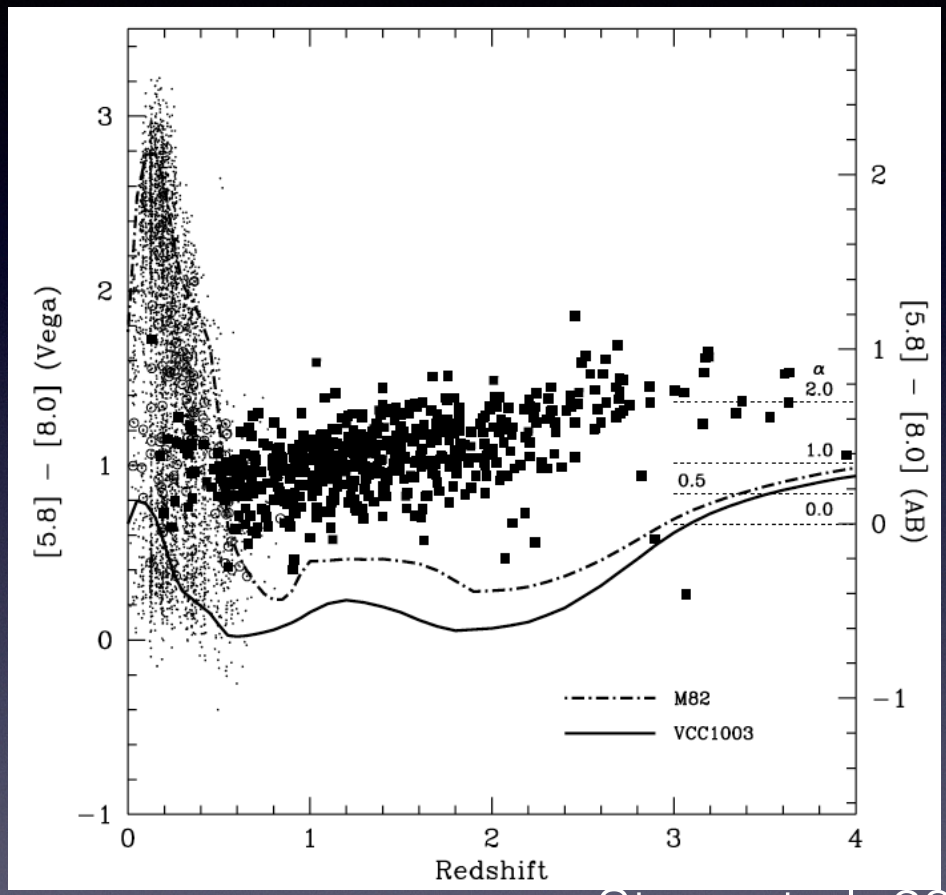




Huang+2011
also, see Caputi+2012

How to identify them





Stern et al. 2005

H and IRAC selected Extremely Red Ojbects:
H-[4.5] > 2.25 and [5.8] - [8.0] >0,
a combination of 4000A break and 1.6um break as redshift indicators

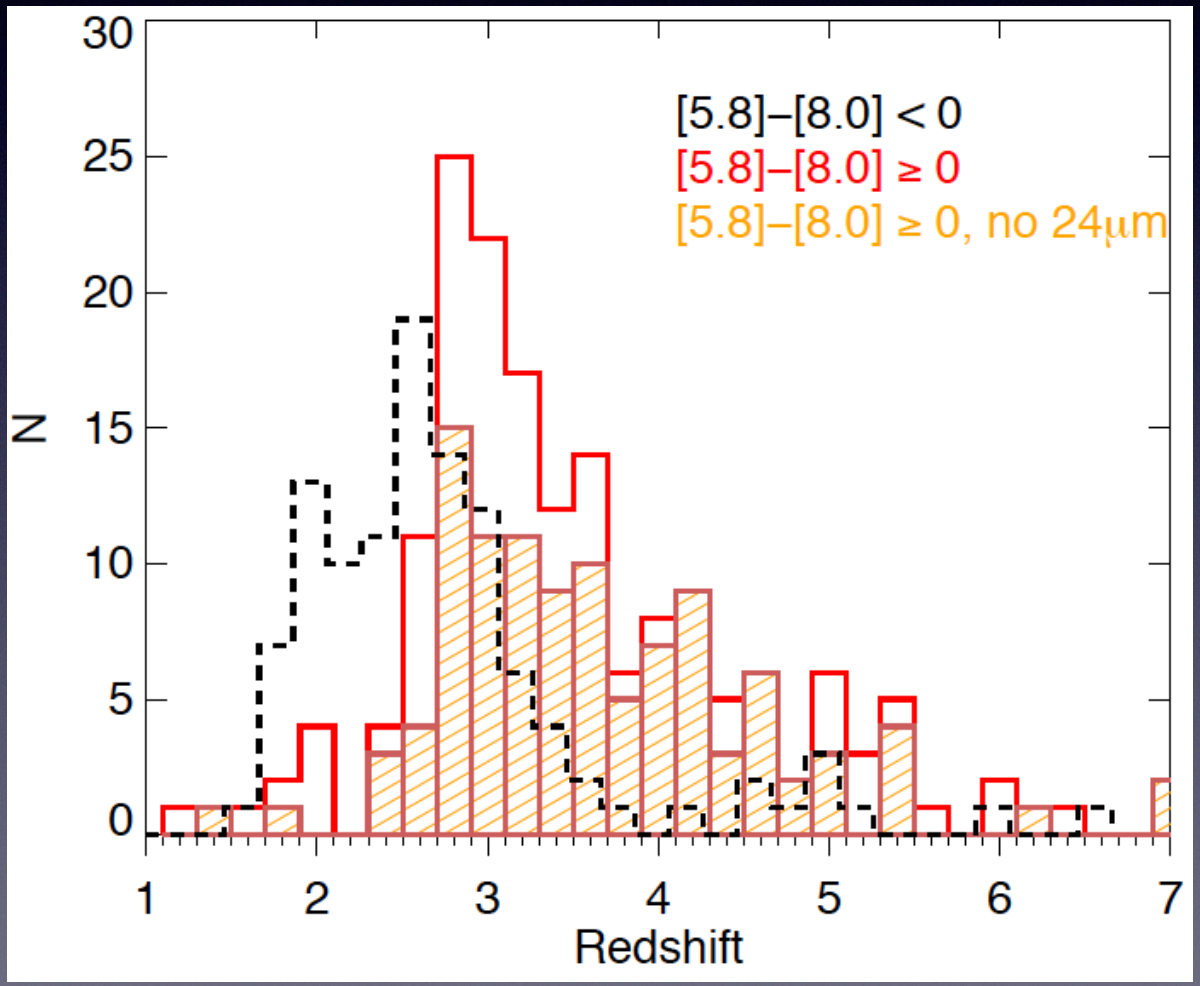
Wang et al. 2004, to be submitted

Sample selection

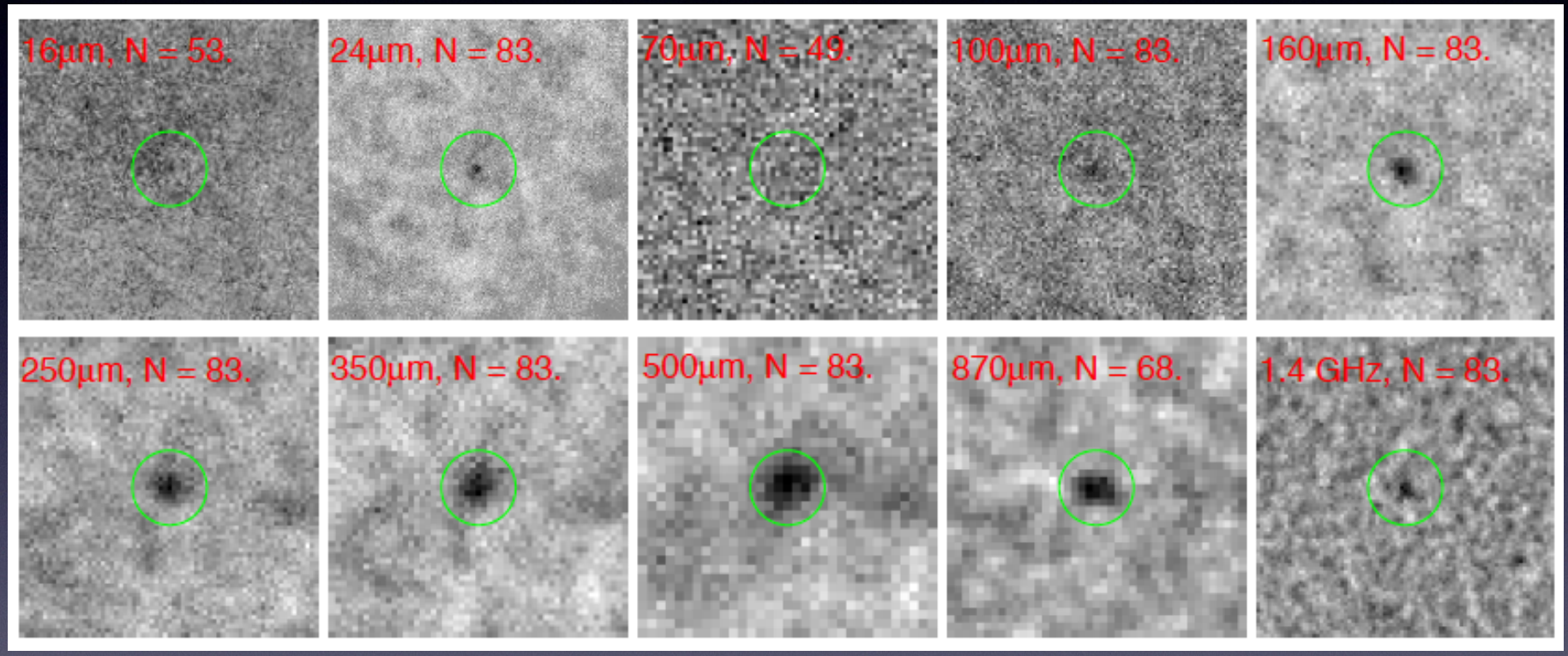
- A combined CANDELS/3dHST F160W-selected and SEDs 4.5um selected catalogue in GOODS-North and GOODS-South, complete to [4.5] < 24 and H -[4.5] >2.25.

- The HIEROs have a number density 0.5 arcmin^{-2} down to [4.5] < 24mag, 10% of which are H-dropouts.

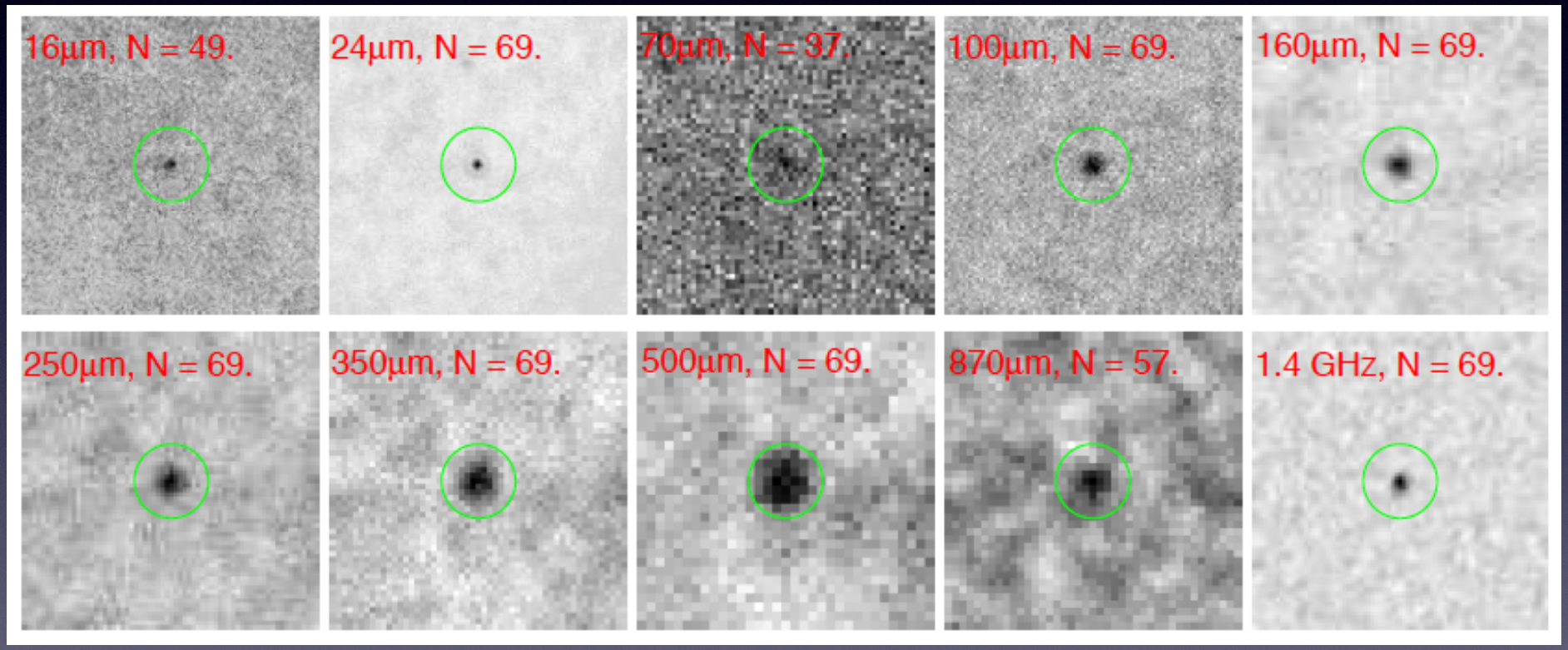
redshift



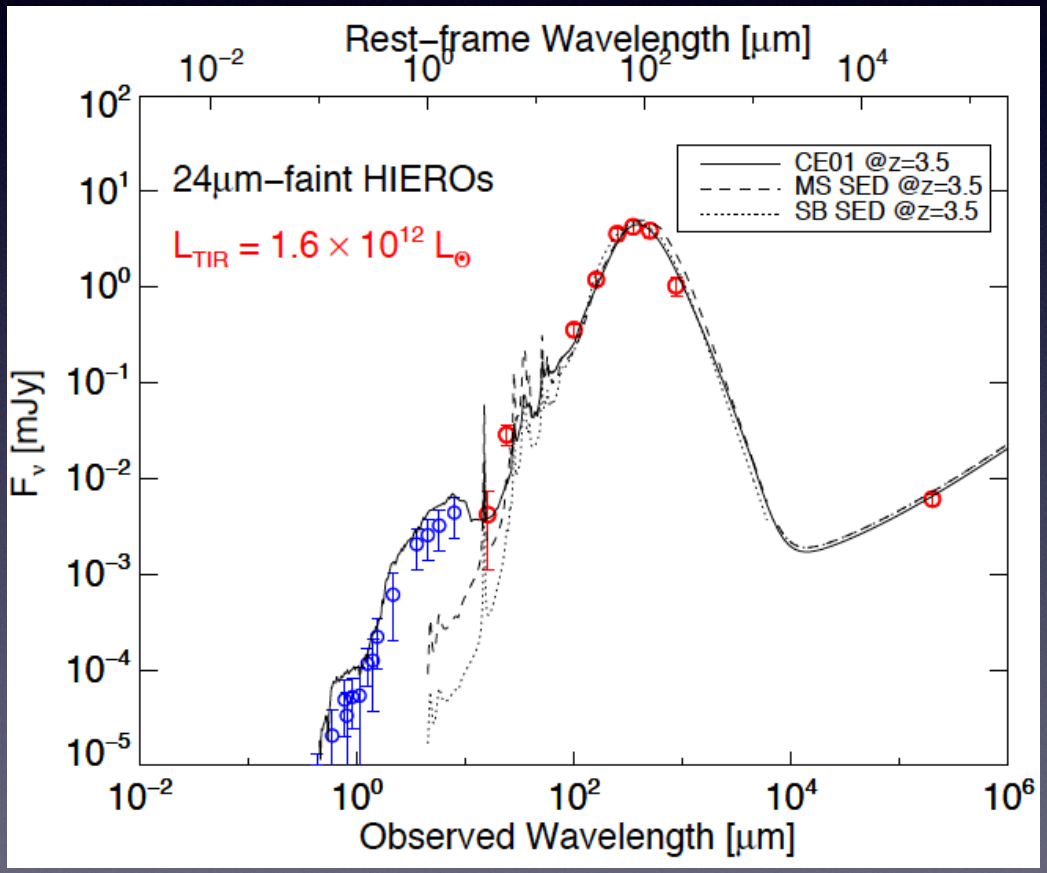
Stacking

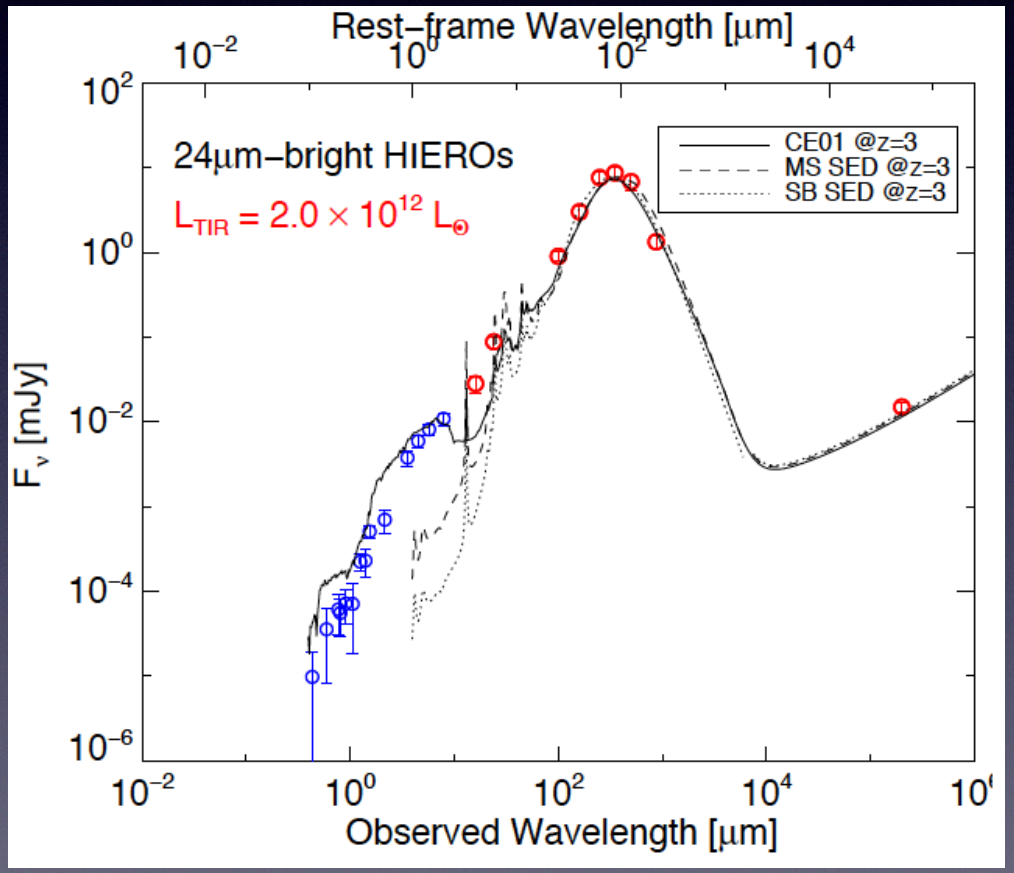


24um-faint (< 30uJy) HIEROs,

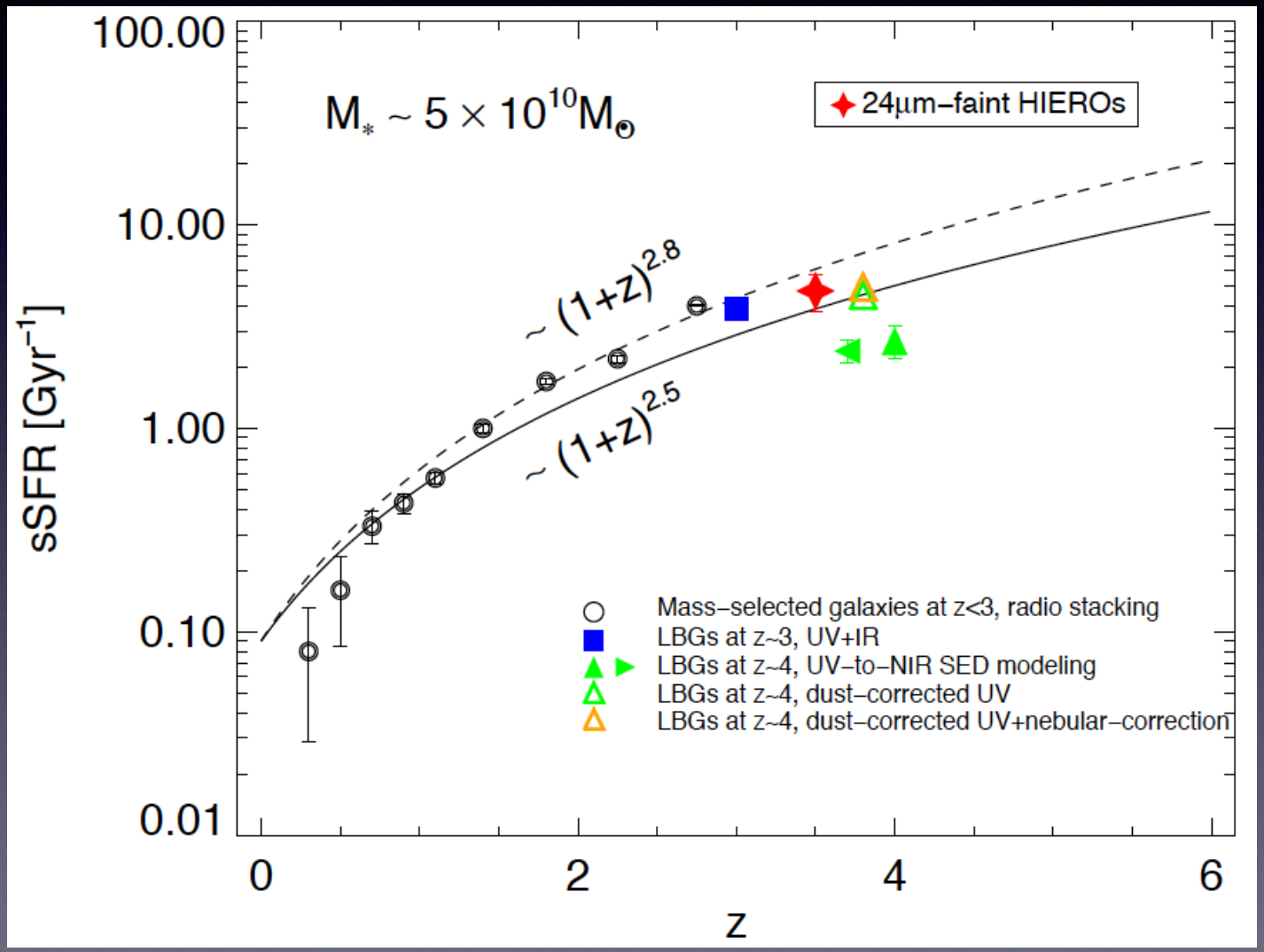


24um-bright (> 30uJy) HIEROs


Rest–frame Wavelength [μm]
24μm–faint HIEROs
$L_{TIR} = 1.6 \times 10^{12}\ L_\odot$
CE01 @z=3.5
MS SED @z=3.5
SB SED @z=3.5
F_ν [mJy]
Observed Wavelength [μm]


Rest–frame Wavelength [μm]
24μm–bright HIEROs
$L_{TIR} = 2.0 \times 10^{12}\ L_\odot$
CE01 @z=3
MS SED @z=3
SB SED @z=3
F_ν [mJy]
Observed Wavelength [μm]

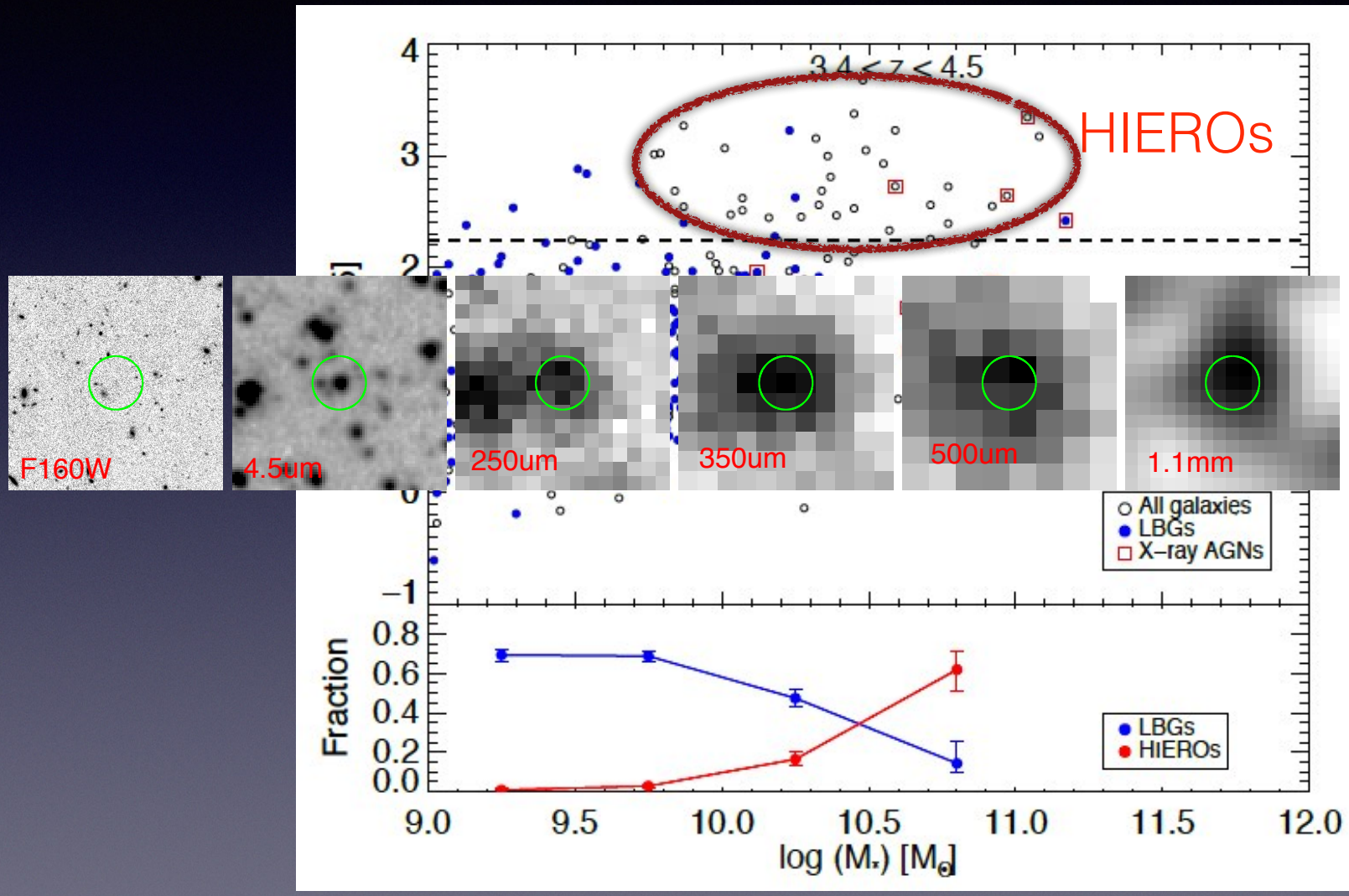
Specific SFR of HIEROs

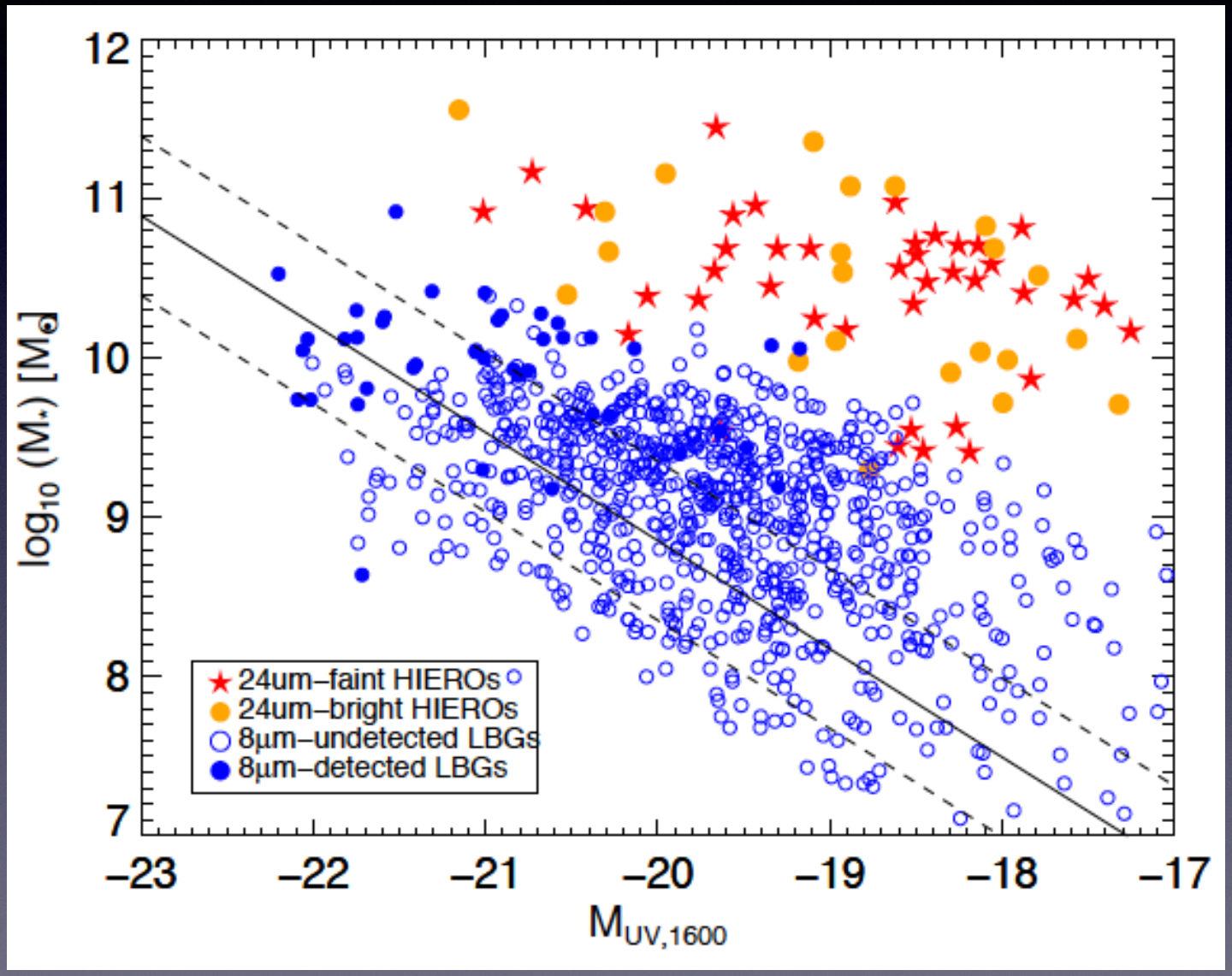


4.6 Gyr^{-1}

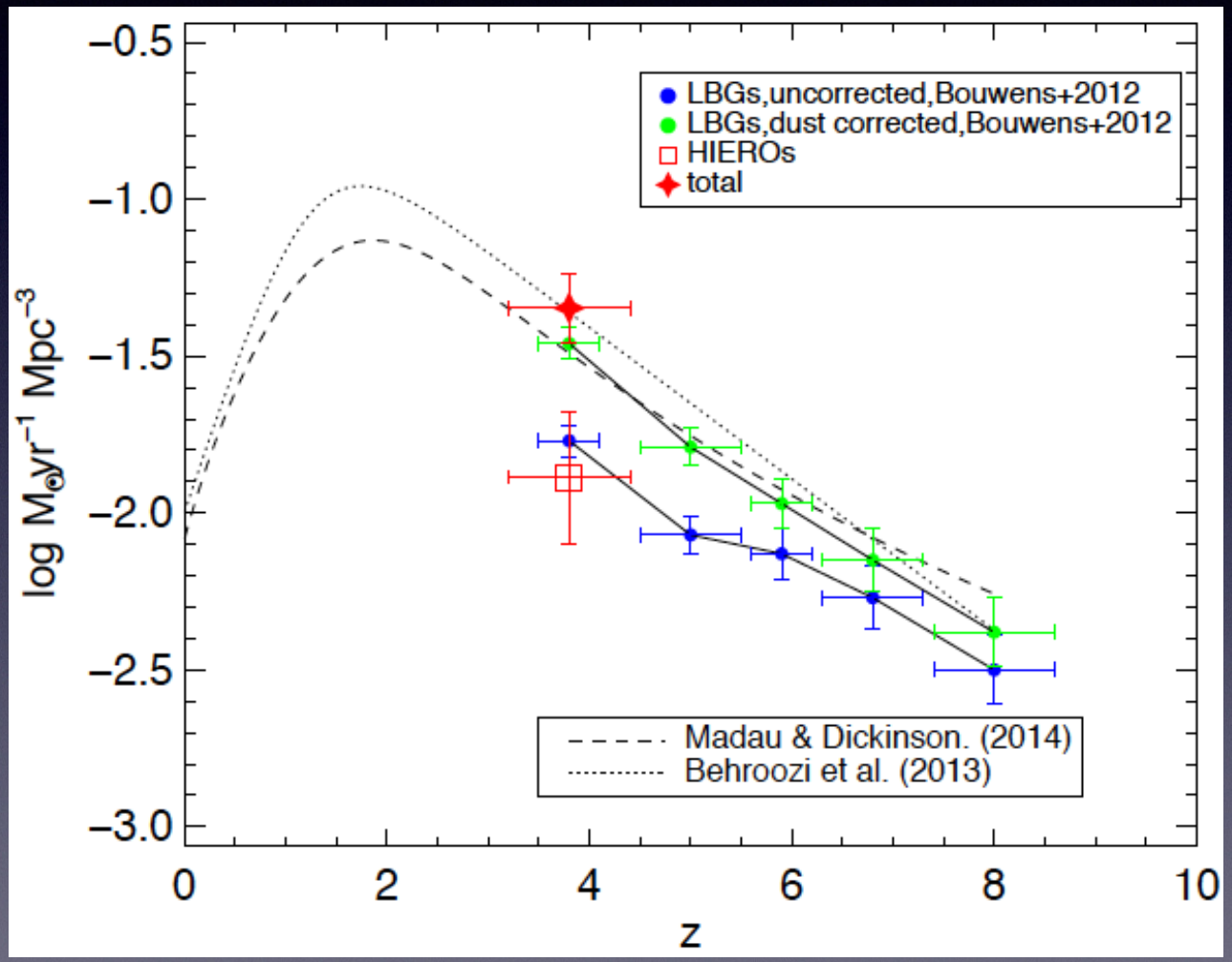
Sargent+13,Karim+11,Lee+12,Bouwens+12,Stark+13

The completeness of HIERO selection of massive galaxies

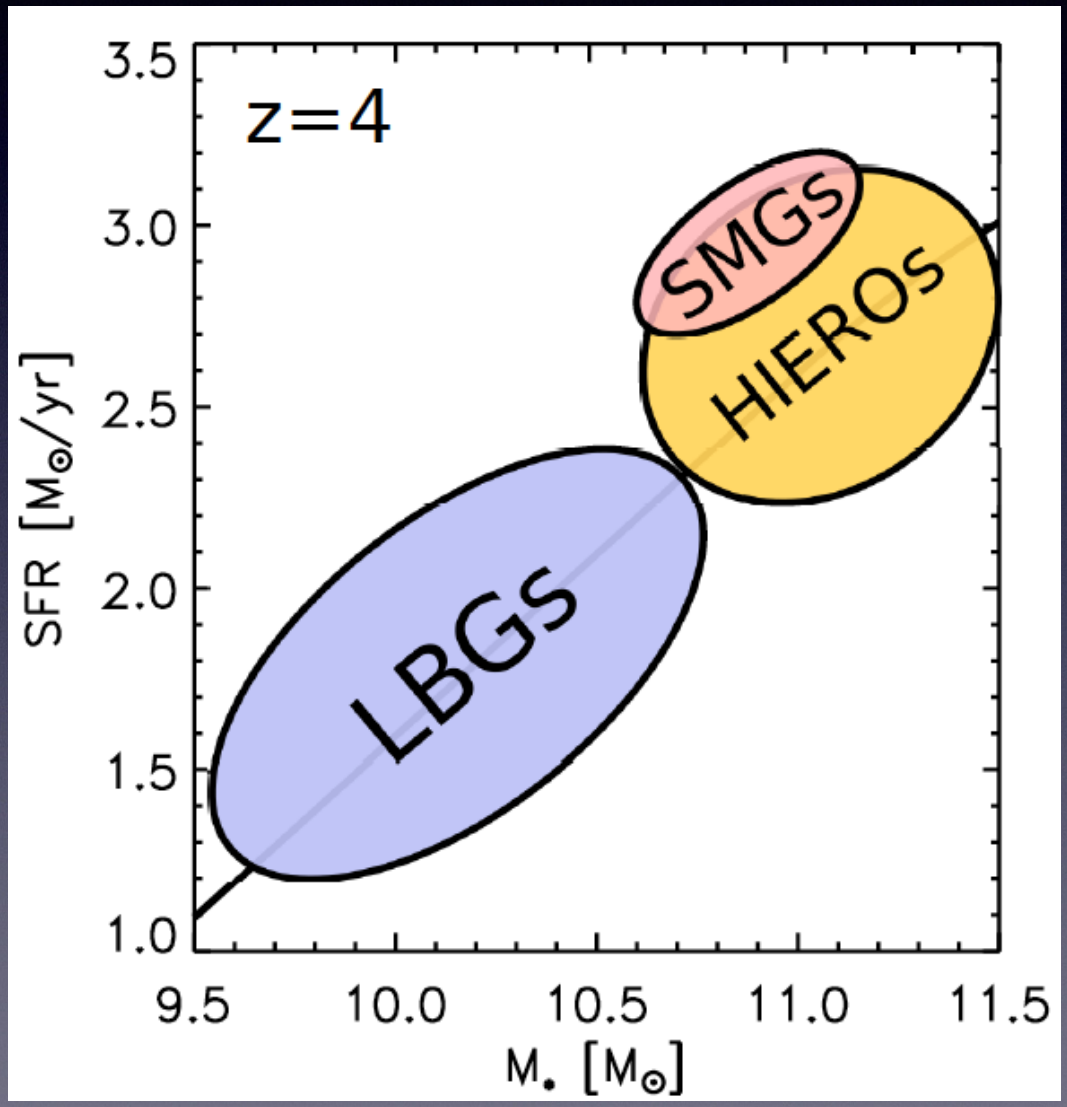



12
11
10
9
8
7
log10 (M*) [M⊙]
−23
−22
−21
−20
−19
−18
−17
MUV,1600
24um−faint HIEROs
24um−bright HIEROs
8μm−undetected LBGs
8μm−detected LBGs

Contribution to the cosmic star formatin density



0.013M yr^{-1} Mpc^{-3}


z=4
SMGs
HIEROs
LBGs
SFR [M⊙/yr]
M* [M⊙]
3.5
3.0
2.5
2.0
1.5
1.0
9.5
10.0
10.5
11.0
11.5

Conclusion

- We propose a two-color selection method (HIEROs, H-[2.5] > 2.25 and [5.8] - [8.0] > 0) to identify massive (dusty) galaxies at z > 3.
- The HIEROs have a number density 0.5 arcmin^{-2} down to [4.5] < 24mag, 10% of which are H-dropouts.
- Most of them are at z~3-5, with M_* ~$10^{10.5}$ $M_\odot$ and SFR ~ 150 $M_\odot yr^{-1}$
- They have SSFR~4.6 Gyr^{-1}, which is a factor of 2-3 higher than galaxies with similar stellar masses at z~2. The value is comparable to the most massive LBGs (B-dropouts) at z~4.
- They contribute ~0.013M yr^{-1} Mpc^{-3} to the SFRD at z~3.5
- The H-dropouts likely contribute 30-50% of galaxies with M_* >$10^{10.5}$ $M_\odot$ at z > 4