Massive Galaxies at High z

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FLARE meeting
Marseille
15 March 2016

Outline

- *Massive galaxies at high z*

  State-of-the-art and open questions

- *The role of FLARE in the study of massive galaxy assembly at high z*

  The importance of FLARE's unique capabilities

  Complementarity to JWST & Euclid

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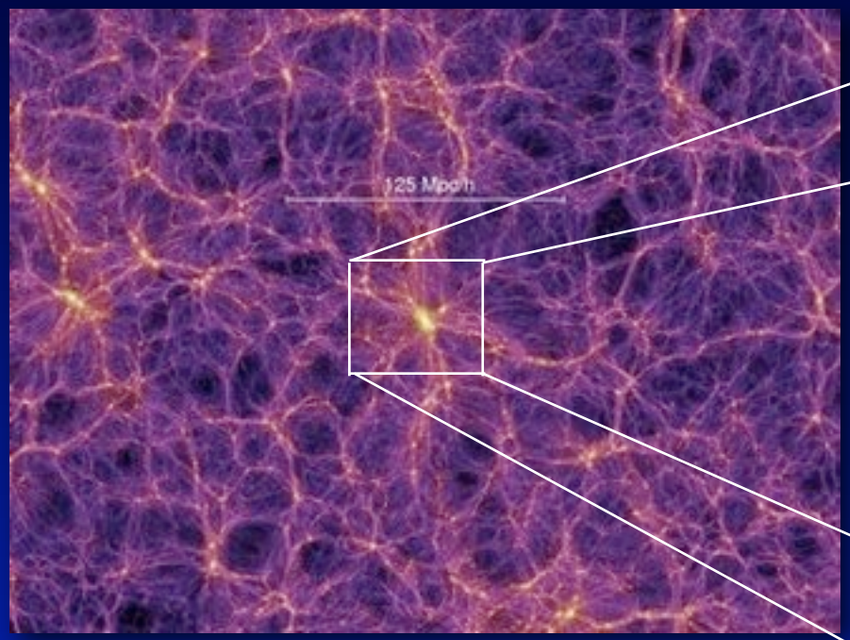
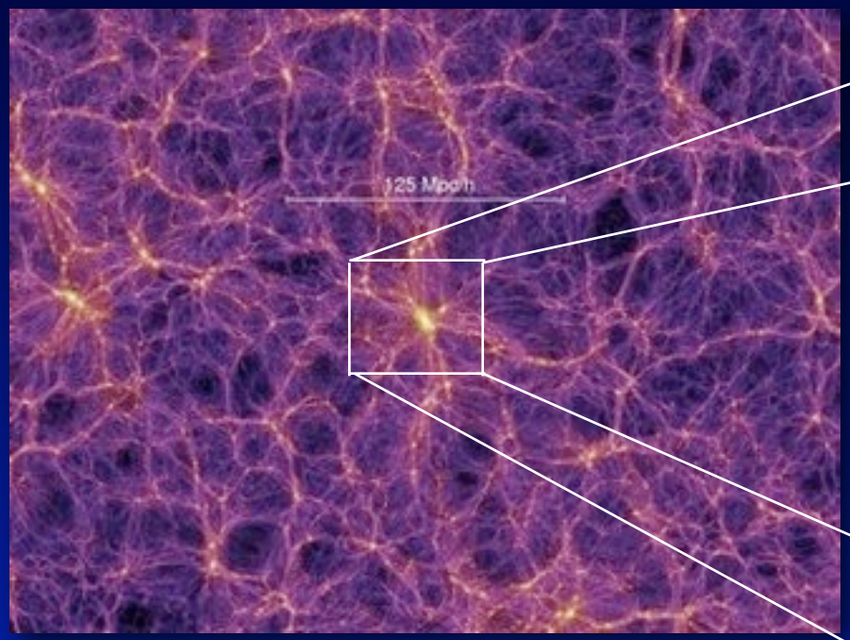
The overall picture



Millenium Run - z=0

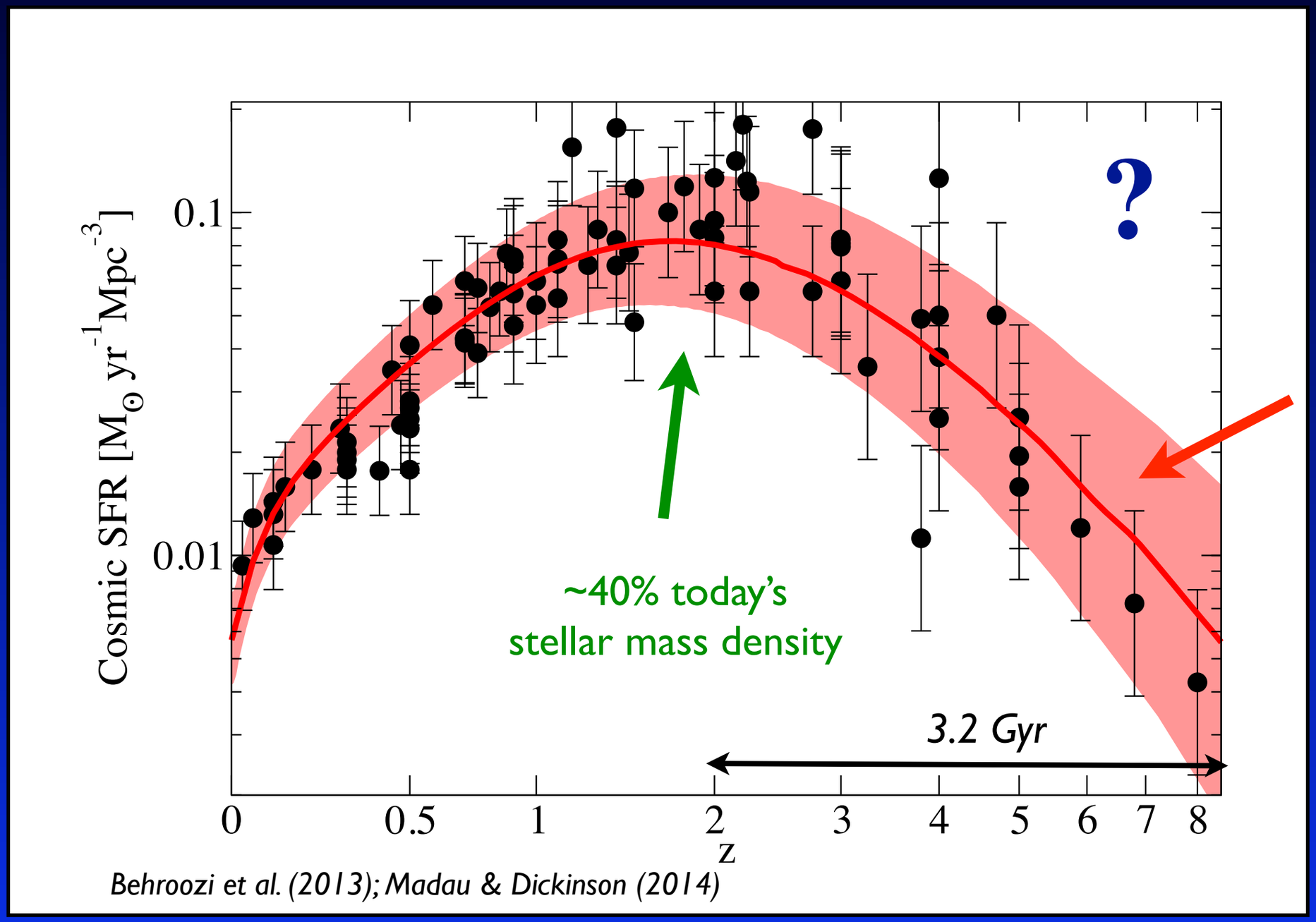
The overall picture



Millenium Run - z=0

- *When and how have massive galaxies formed?*
- *How efficient was (massive) galaxy assembly at different z?*
- *When did galaxies become massive galaxies for the first time?*

Stellar mass assembled by z~3

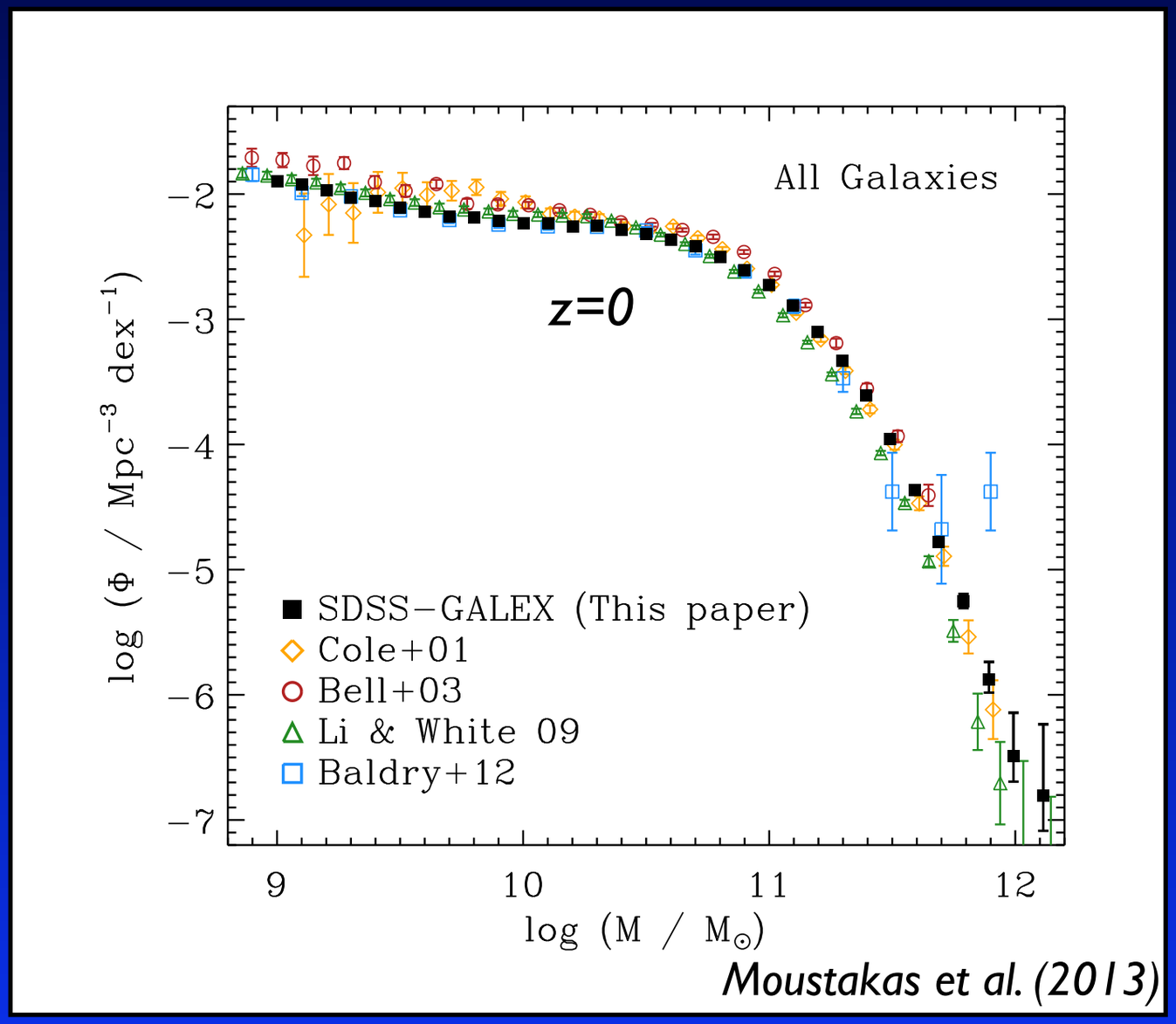


Behroozi et al. (2013); Madau & Dickinson (2014)

very efficient period of galaxy stellar mass assembly

The GSMF as cosmological probe of galaxy assembly

The GSMF is a powerful statistical tool to study
the evolution of stellar mass assembly



Moustakas et al. (2013)

Many physical processes folded in:

- ✓ star formation
- ✓ gas consumption
- ✓ feedback processes
- ✓ environment

See e.g. Peng et al. (2010)

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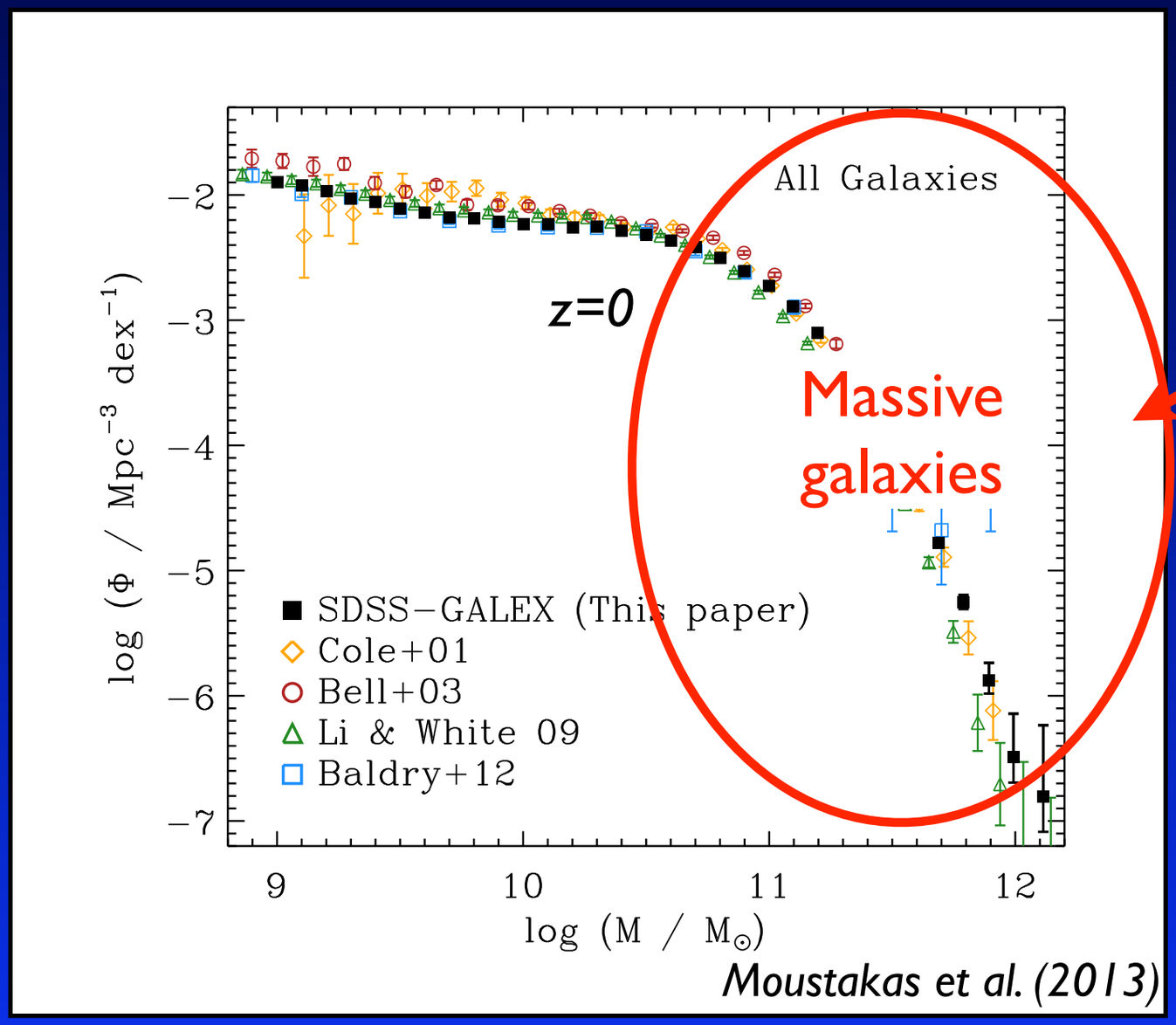


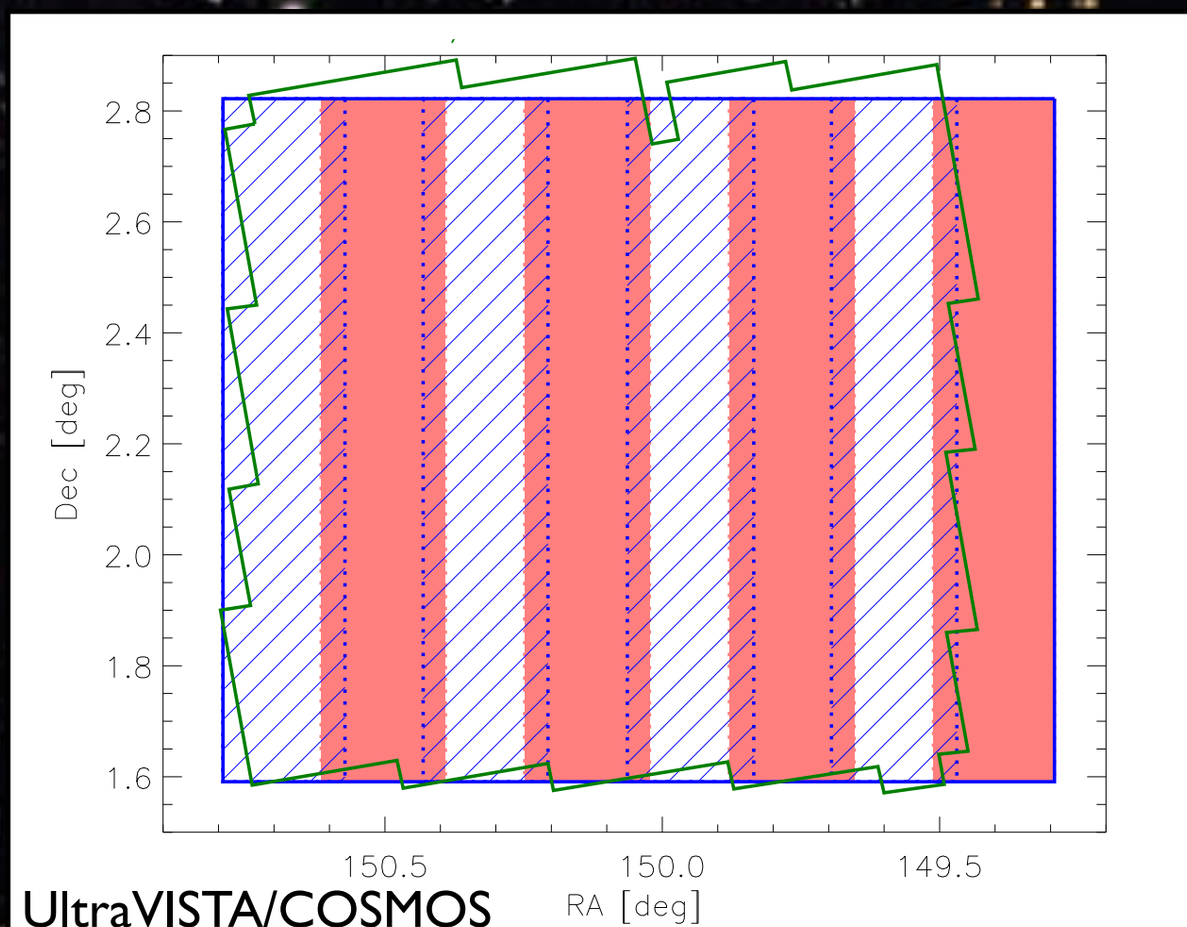
Moustakas et al. (2013)

Trace back in time...

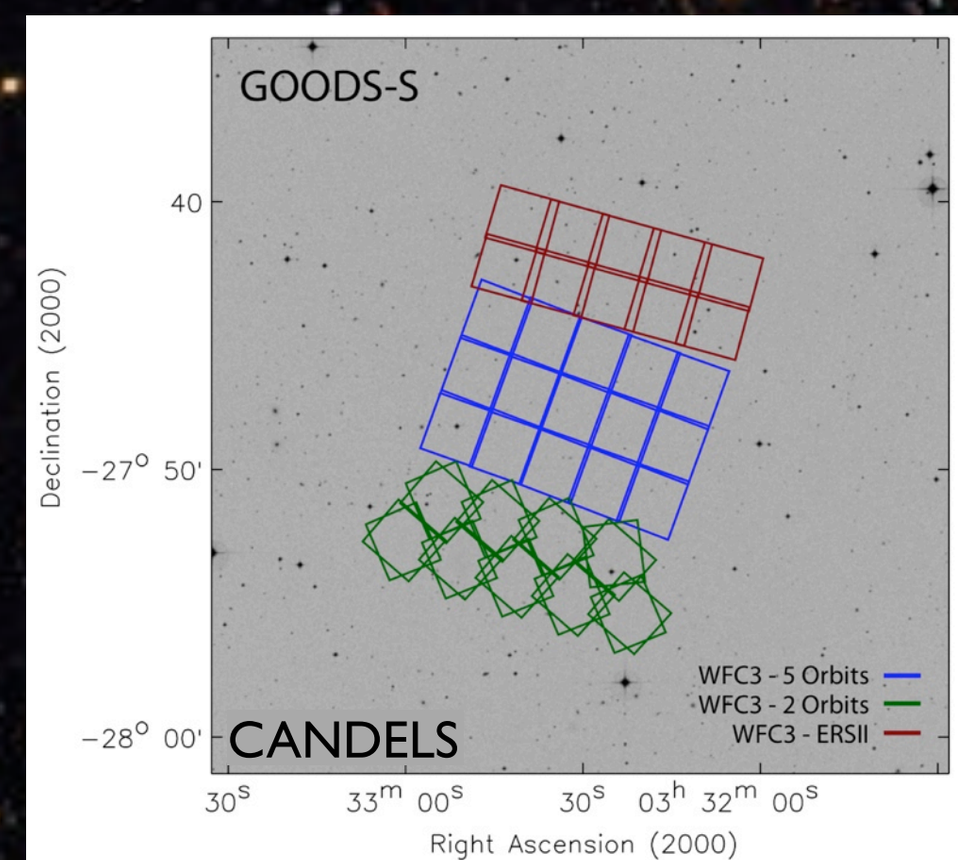
Deep blank galaxy surveys: a tool to probe the high z Universe

Select galaxies on near- / mid-IR images to trace old stellar populations

best proxy for stellar mass selection

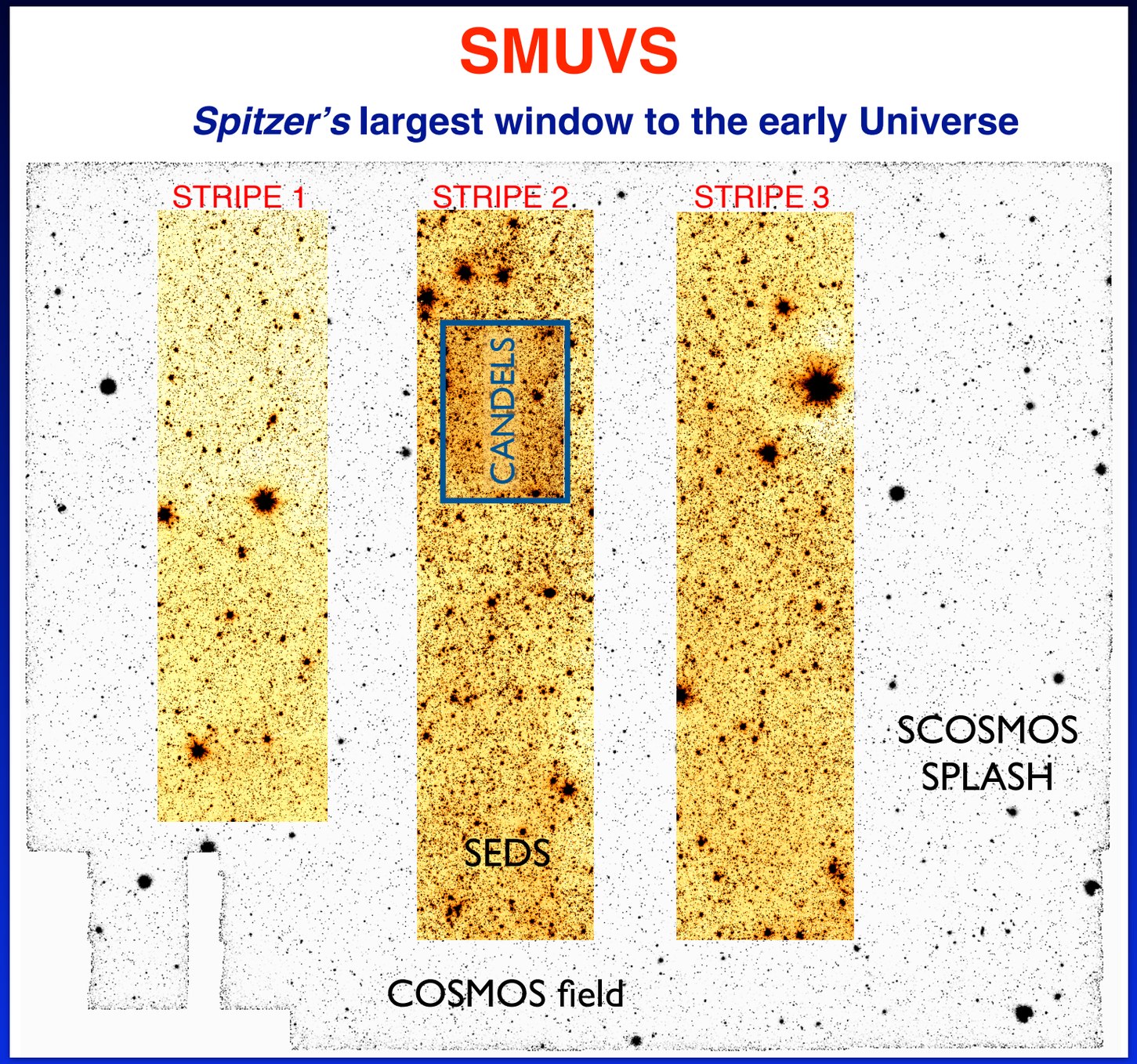


Ks~24.0; 25.1 (3σ;AB)

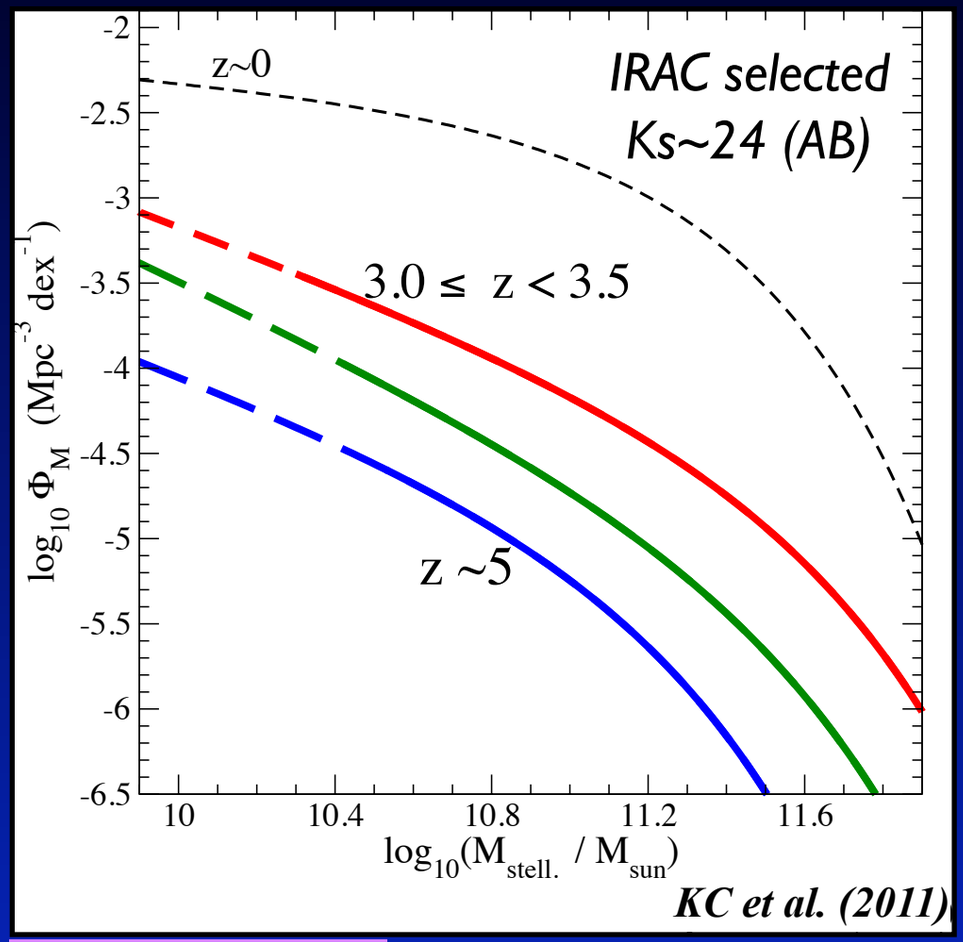


F160W~27 (3σ;AB)

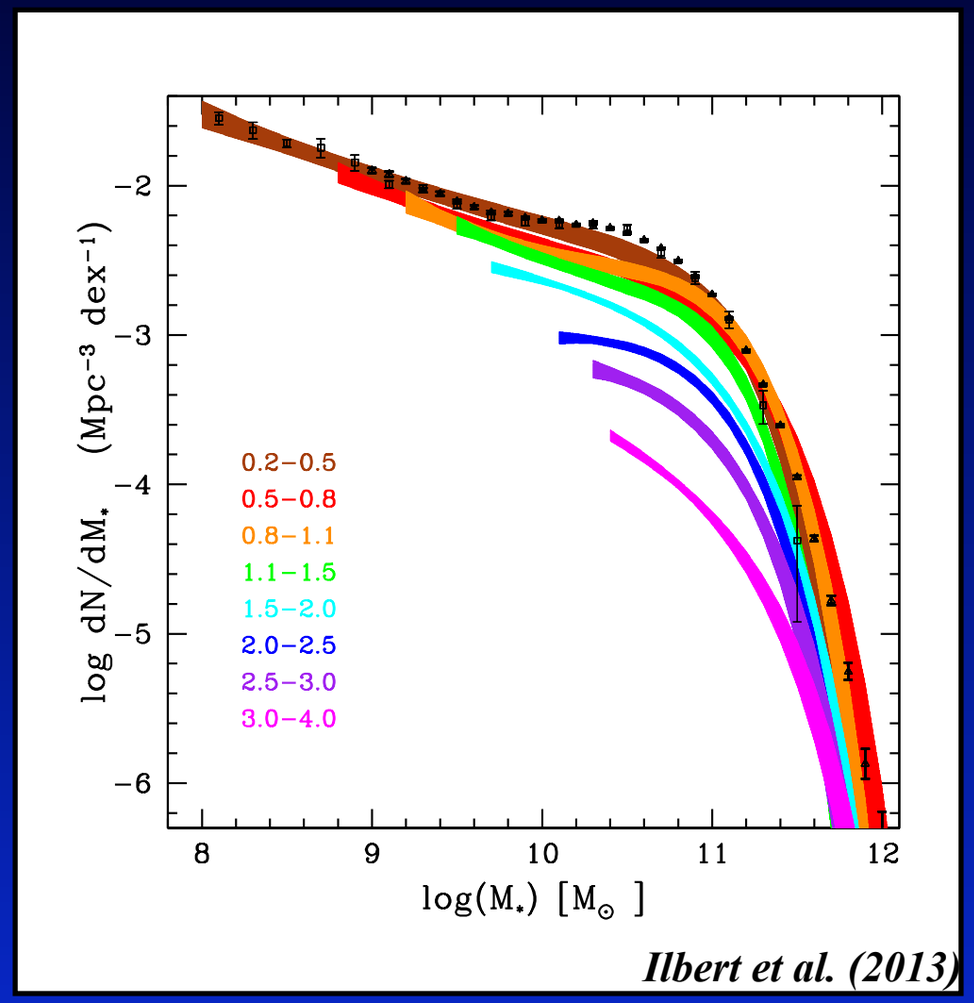
Spitzer matching surveys at 3.6 and 4.5 microns



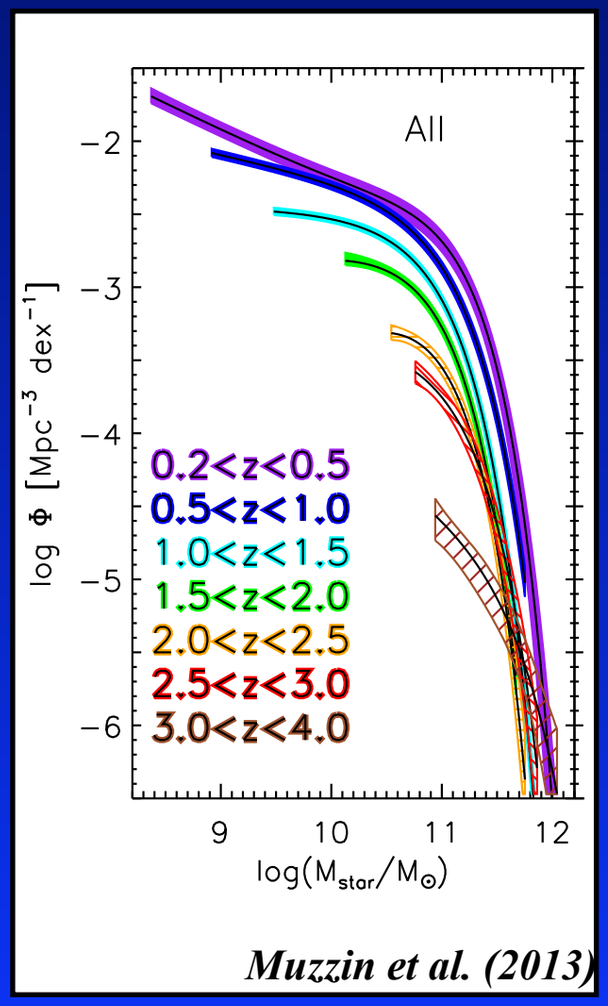
The GSMF up to z=4-5 from large-area surveys



UKIDSS / UDS
0.6 sq. deg

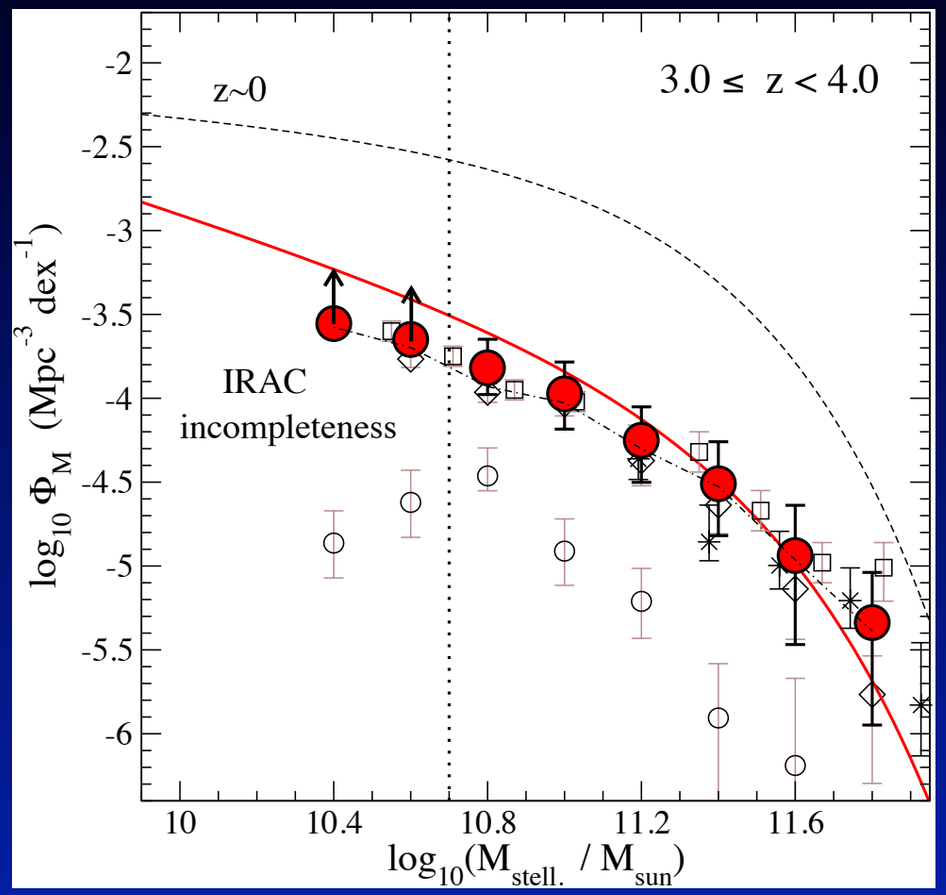


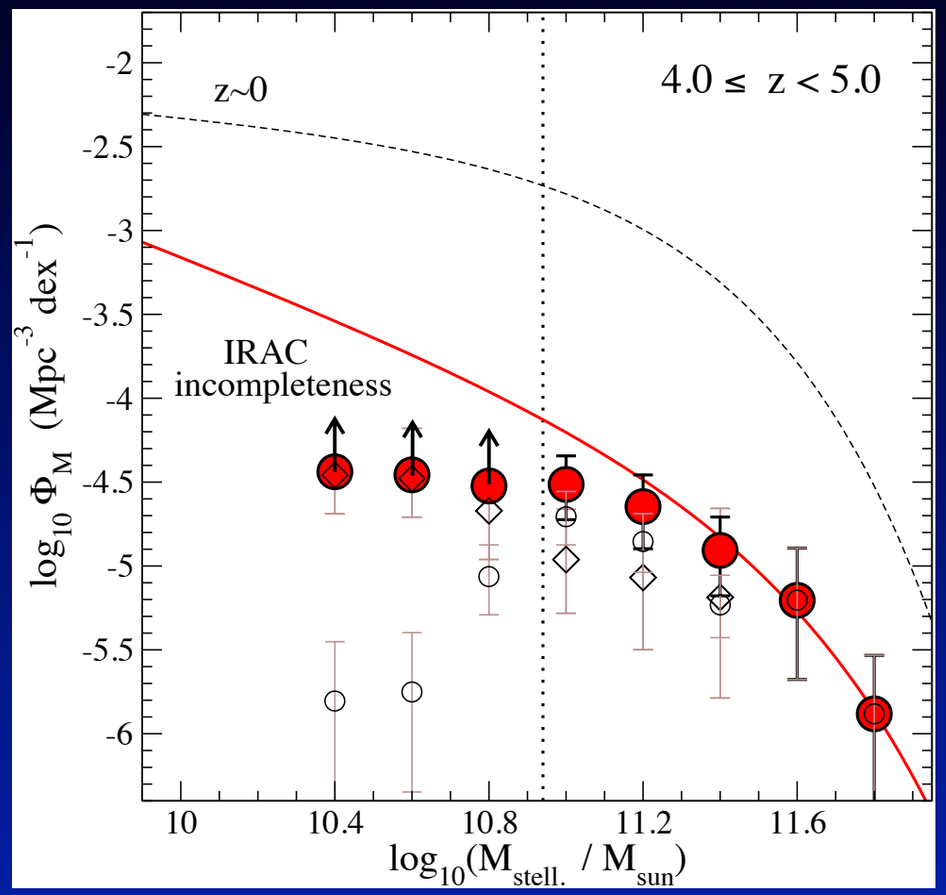
COSMOS
UltraVISTA
1.5 sq. deg
Ks~24 (AB)



GSMF high-mass end well constrained to z~4
(incomplete at higher z)

The updated GSMF at 3<z<5

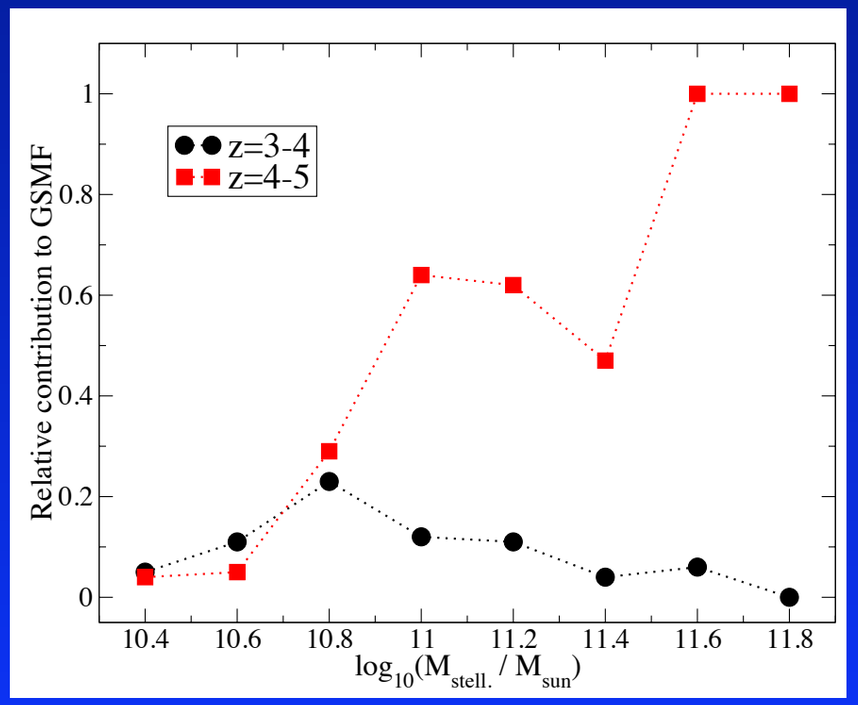




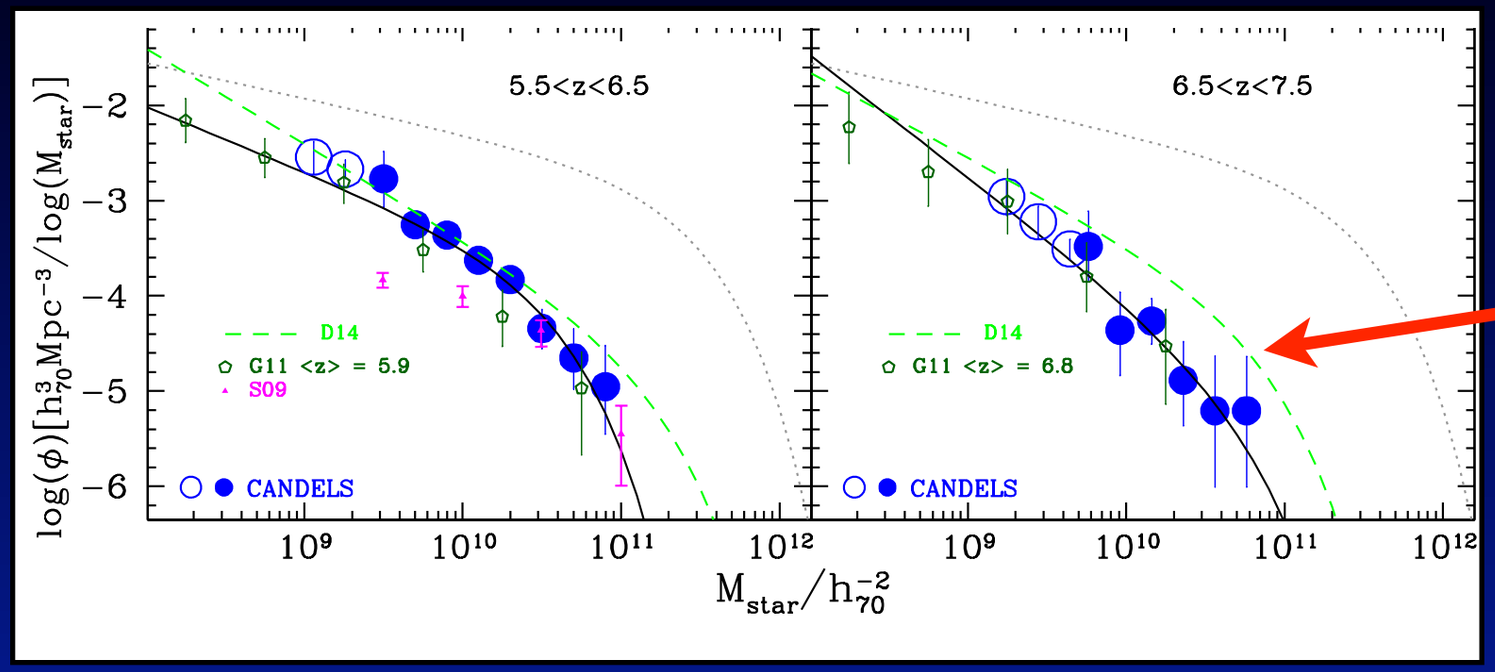
KC et al. (2015)

[4.5]<23, Ks>24 galaxies have an important contribution to the high-mass end at 4<z<5

Wide-area, ultra-deep near-IR surveys are necessary for complete census of massive galaxies at z>4



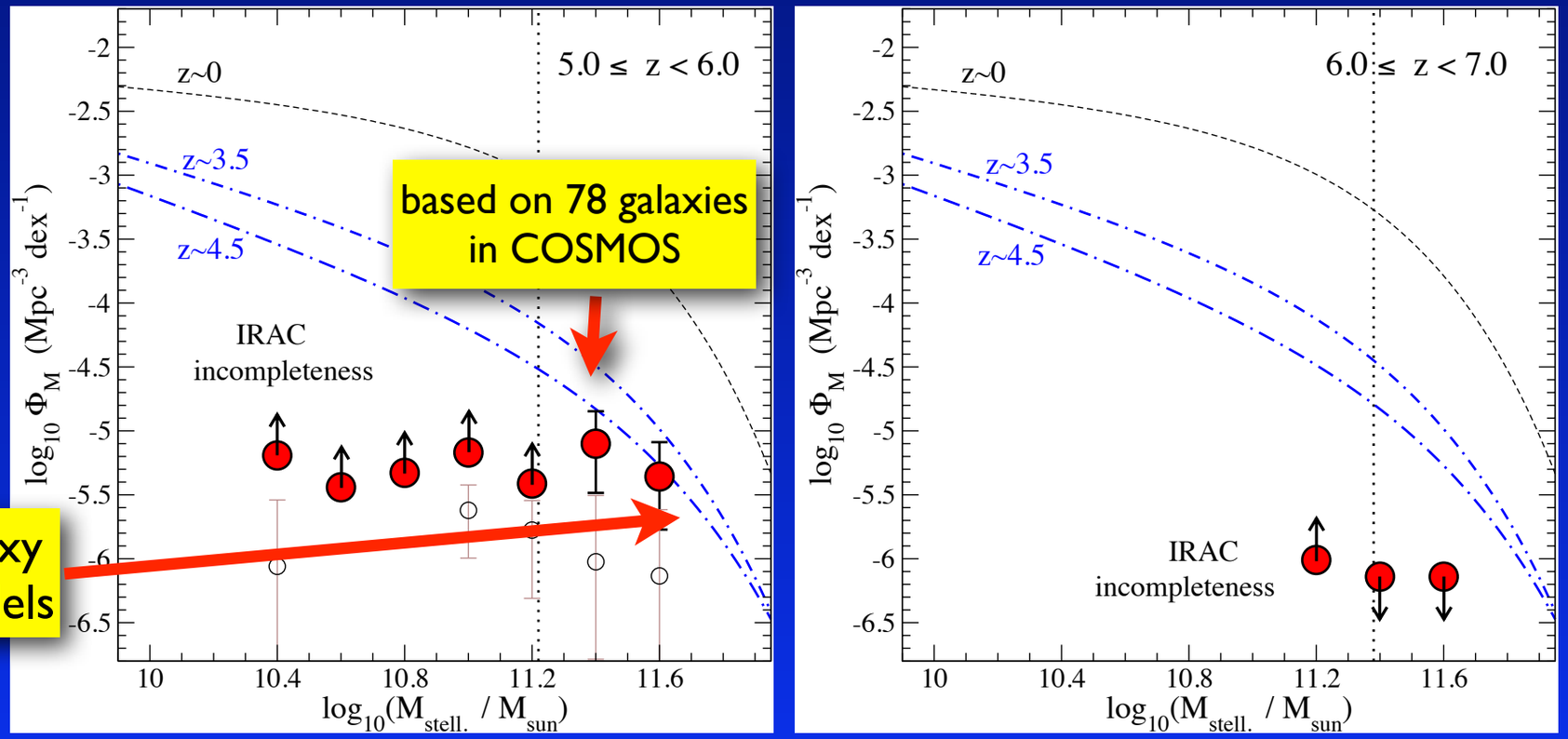
The GSMF at z~6-7



discrepancies among CANDELS results

Grazian et al. (2015)

FLARE needed to solve these puzzles!



based on 78 galaxies in COSMOS

tension w/galaxy formation models

No candidates with $M>2x10^{11}$ Msun at z>~6

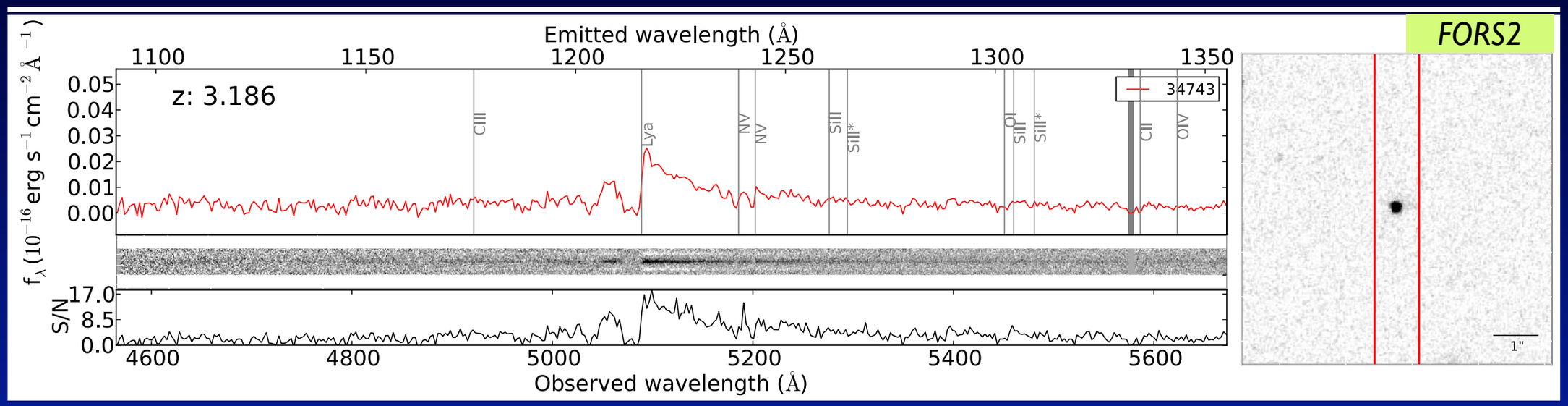
Needs to survey larger areas!

KC et al. (2015)

Number density of >2x10^{11} Msun galaxies drops by (at least) a dex at z>6

Outstanding Problem

Limited spectroscopic confirmation for massive galaxies at z>3



Karman, KC et al. (2014) -- see also VUDS survey

biased to optically bright galaxies

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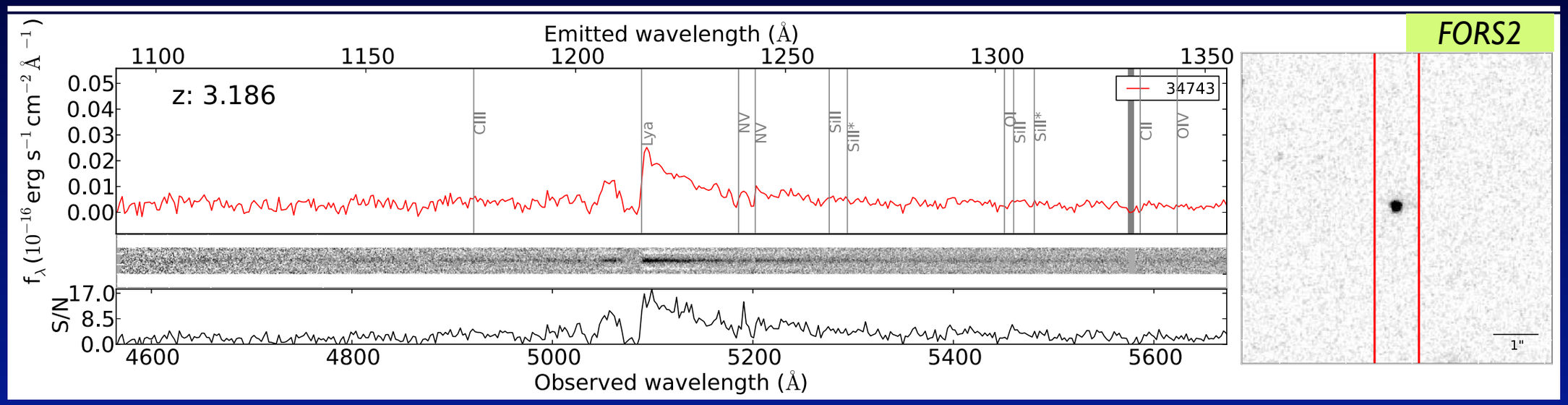

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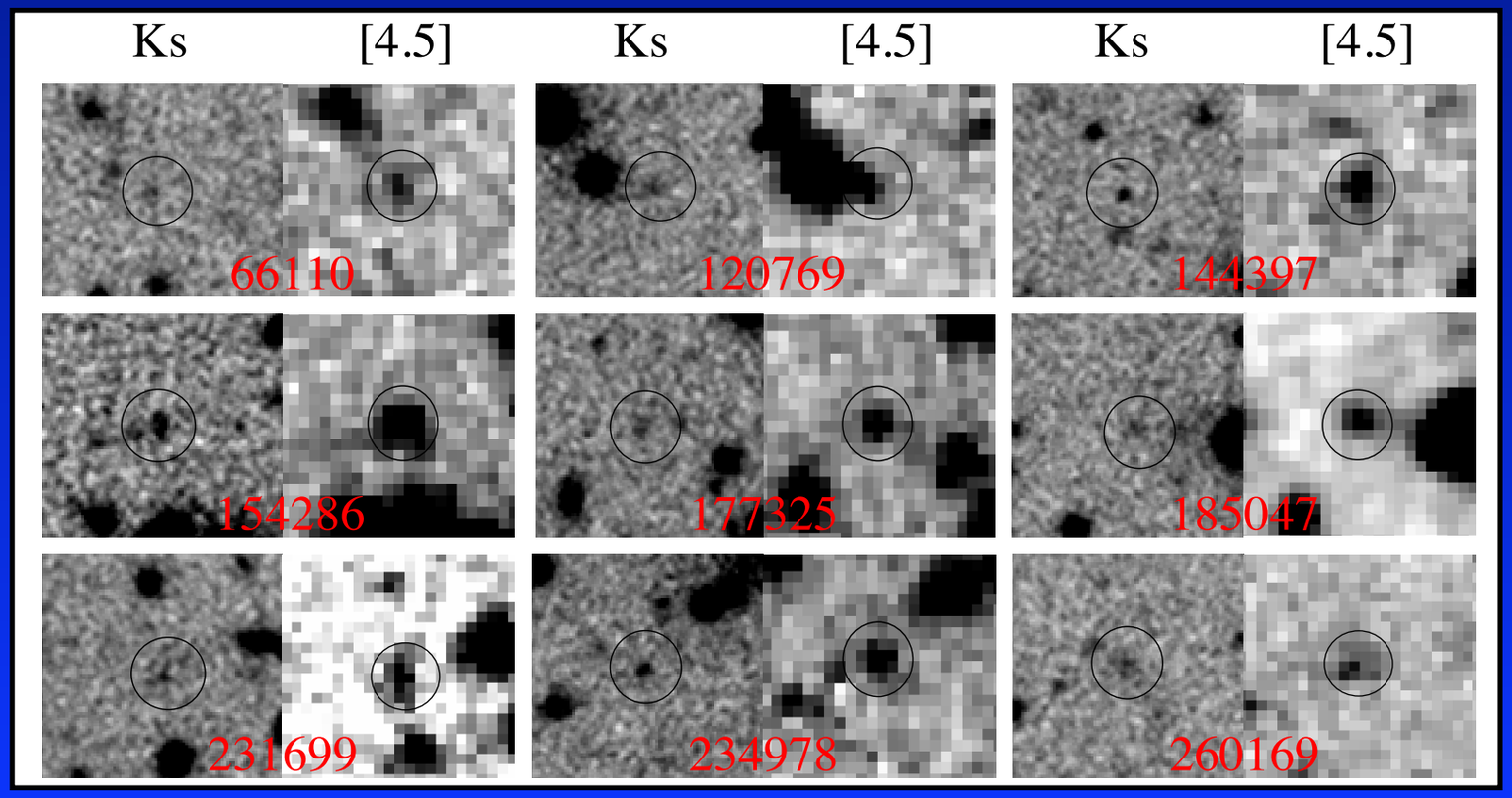

too faint for current spectrographs!

KC et al. (2015)

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FLARE imaging - expected statistics

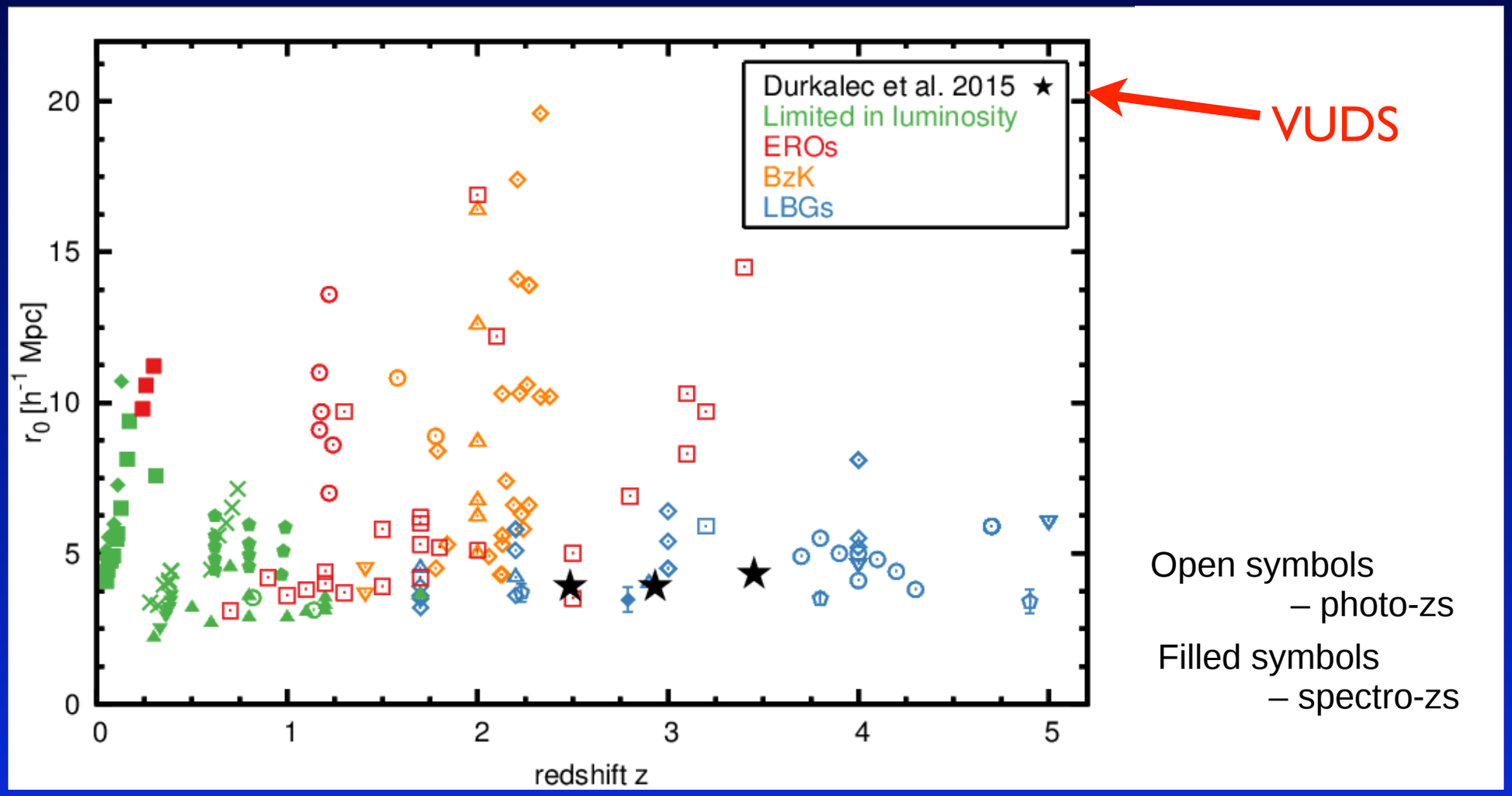
Redshift	Total Nsrc [1] 28 mag 100 sq.deg.	Nsrc [2] $M>10^{10}$ Msun 100 sq.deg.
3.5<z<4.5	6×10^{6}	250,000
4.5<z<5.5	3.5×10^{6}	150,000
5.5<z<6.5	1.8×10^{6}	28,000
6.5<z<7.5	1.5×10^{6}	5,000
7.5<z<8.5	500,000	?
z>9	20,000	?

1 - extrapolated from existing LF, based on *HST* near-IR selections

2 - obtained by integrating GSMF

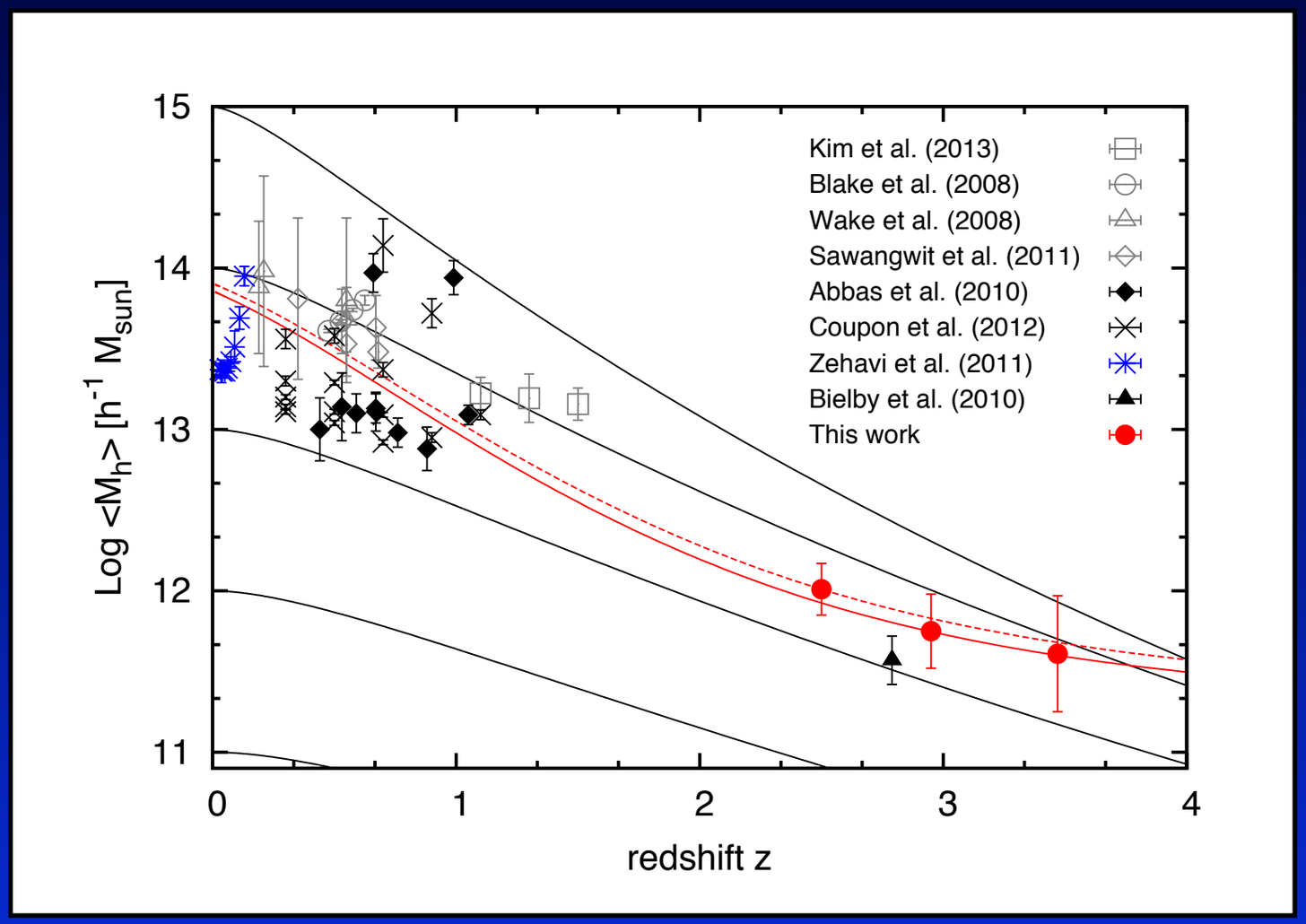
Galaxy clustering analysis at high z

Poor constraints on galaxy clustering at z>2

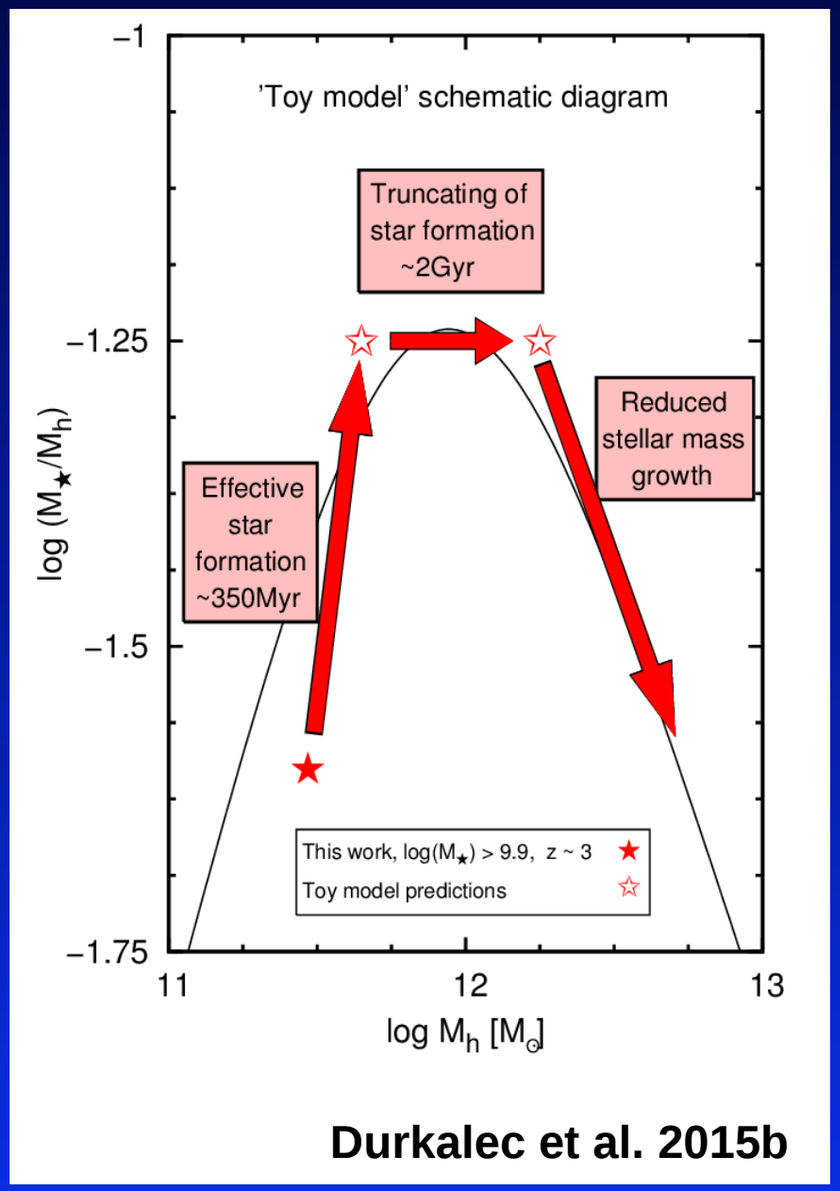


selection biases - difficult to connect galaxy populations at different z

Connecting galaxies to DM haloes



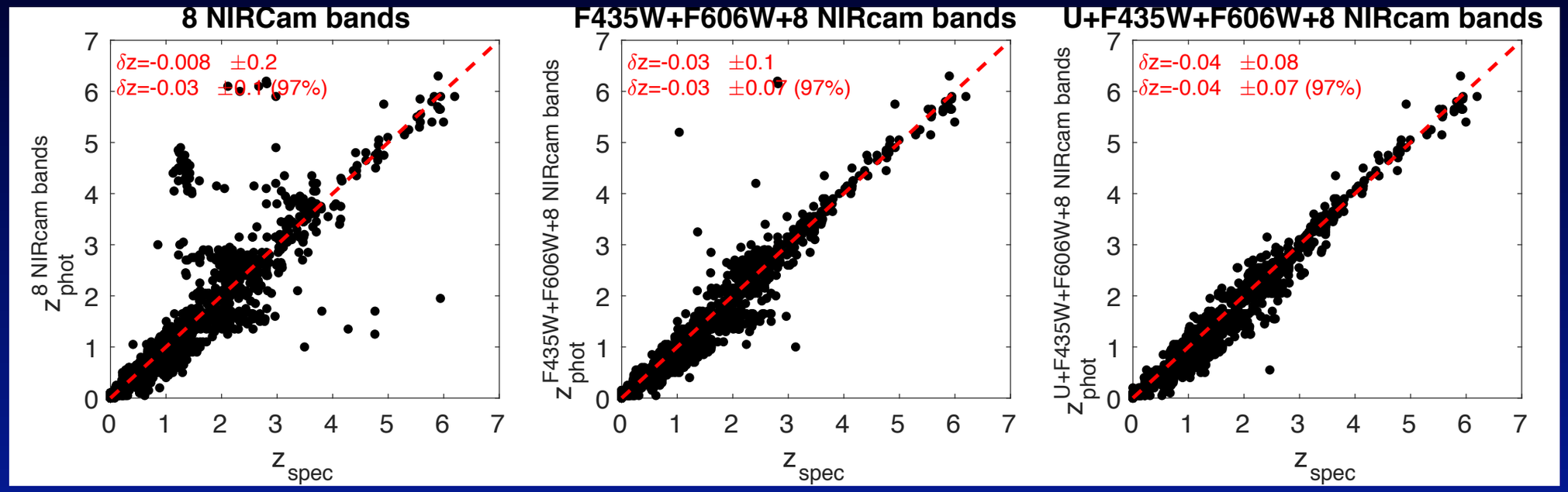
Durkalec et al. (2015a)



Durkalec et al. 2015b

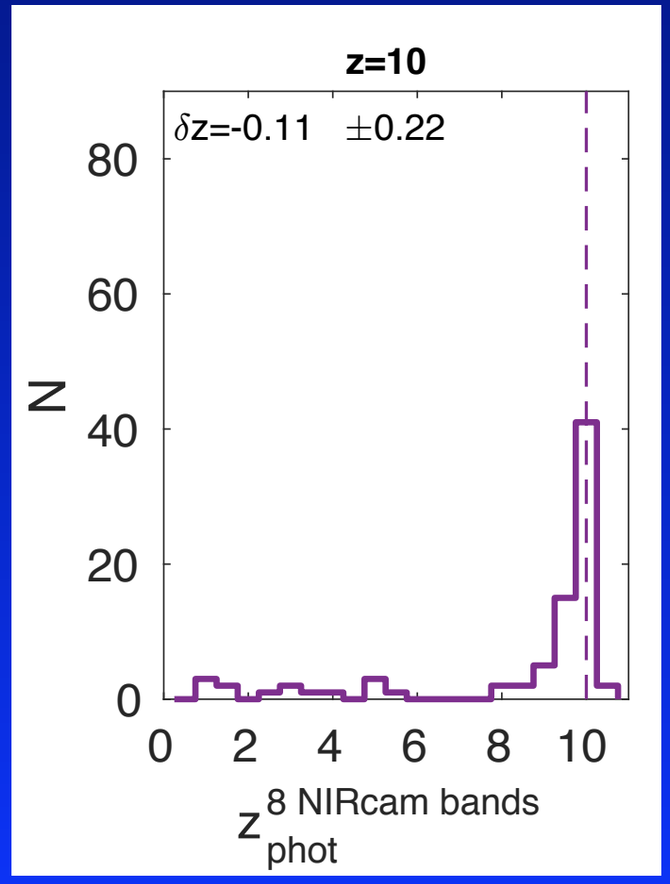
Euclid will provide statistics, but stellar masses at z>3 require observations at λ >1 μm

Caveat for FLARE imaging: limited bands for zphot



zphot tests for *JWST*

Bisigello, KC et al., in prep.



Optical ancillary data necessary for FLARE fields

Euclid depth will not be enough to match FLARE imaging

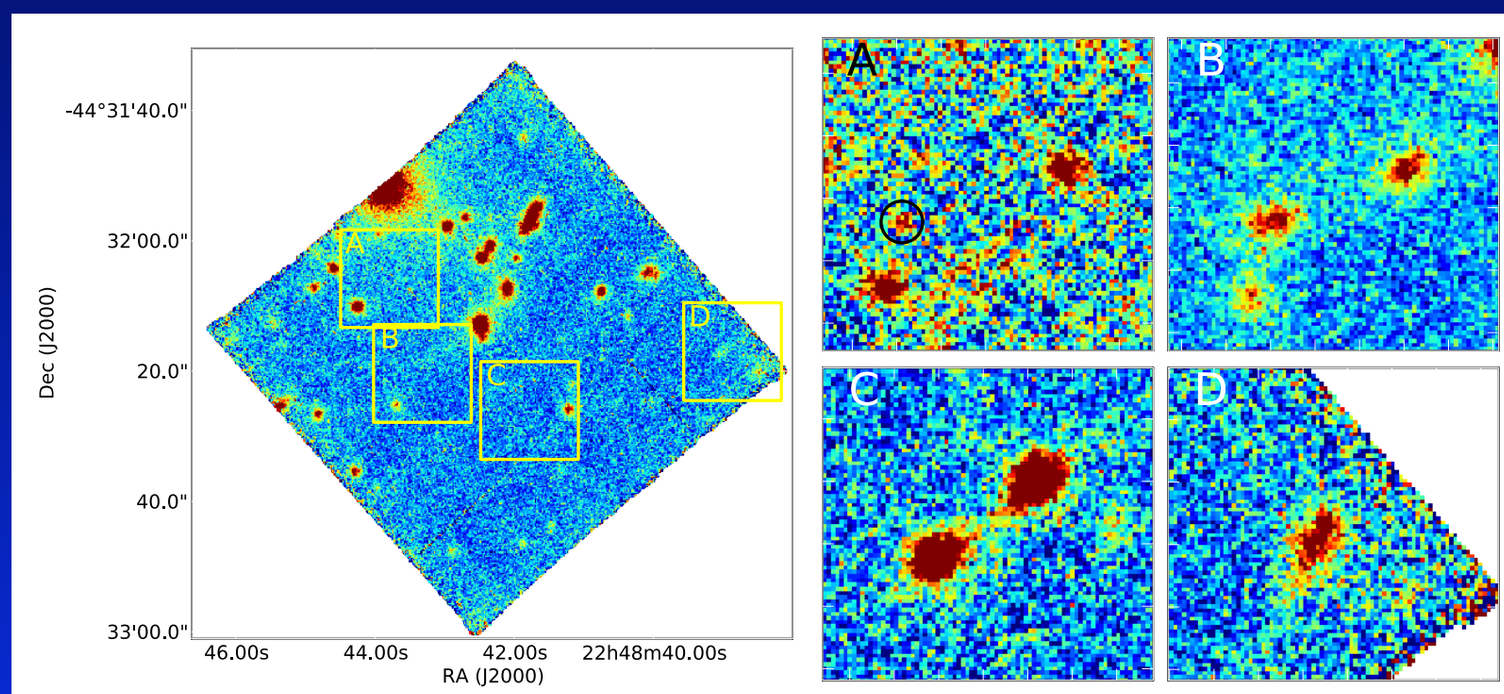
FLARE spectroscopy

1 sq. arcmin IFU like VLT/MUSE
powerful for different science cases

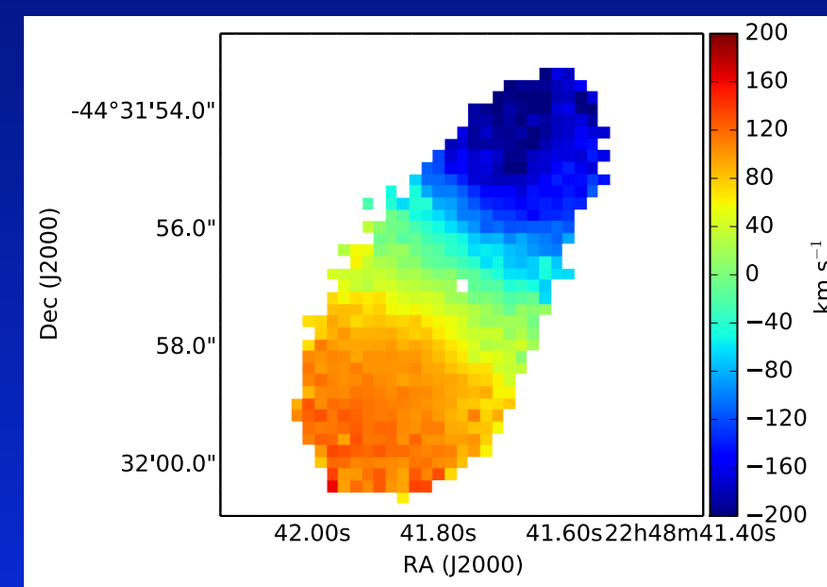
Massive galaxies

✓complete census of galaxy dynamics for M>10^{11} Msun galaxies up to z~3-4 over ~1 sq.deg.

dynamics of stars (continuum) + gas (Paα; Hα)



MUSE data



Karman, KC et al. (2015)

JWST can do this on individual objects - FLARE will bring large stats

FLARE spectroscopy

1 sq. arcmin IFU like VLT/MUSE
powerful for different science cases

<u>Massive galaxies</u>

✓ zspec for strongest line emitters up to z~16

Hα to z~6.6; OIII to z~9; Hβ to z~9.3, CIII to z~16

evolution of sSFR with redshift - *efficiency of stellar mass assembly in different haloes at different z.*

✓ BPT diagram and gas metallicities at 1<z<6.5

✓ (Further) AGN line diagnostics

NeV at 1.9<z<13 (only limited by sensitivity)

JWST can do this on individual objects - FLARE will bring large stats

FLARE spectroscopy - what *JWST* cannot (easily) do

Massive galaxies

✓ massive galaxy close environment up to very high z

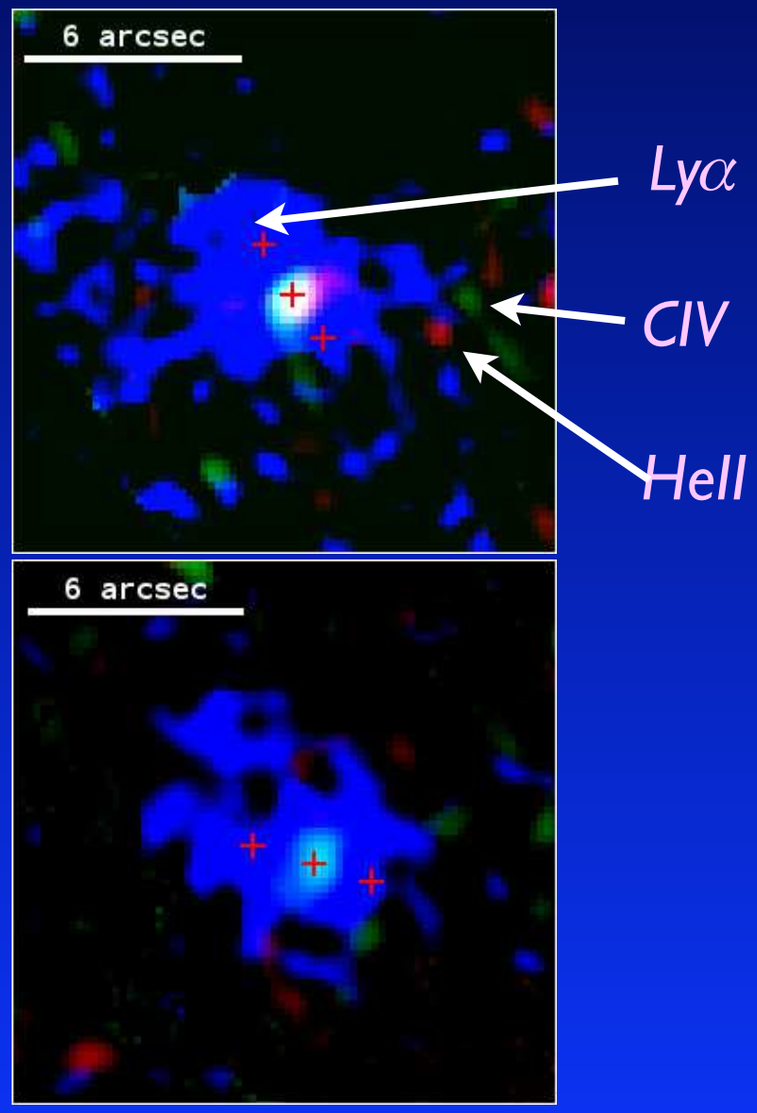
discover/confirm protoclusters

map all galaxies within massive galaxy DM haloes

✓ spec maps of bright extended structures

Is there any bright Lyα blob at z>7?

(plausible relation to massive galaxy formation?)



Caminha et al. (2015)

Summary

❖ FLARE imaging will achieve an unprecedented level of statistics to study massive galaxies up to very high z

<u>key question:</u> are there very massive (>2x10^{11} Msun) galaxies at z>6?

❖ FLARE will allow for cosmological studies of galaxy clustering versus stellar mass to very high z

'precision' cosmology only limited by zphot quality (systematics)

❖ Need of optical ancillary data for zphot - FLARE imaging is unlikely to be self-sufficient!

❖ FLARE (MUSE-like) spectroscopy will enable study of close environment of massive galaxies and serendipitous search for extended line emission plausibly associated with massive protoclusters at high z

'unique' FLARE science - unlikely to be done with JWST

Thanks!