UC SANTA CRUZ

LICK OBSERVATORY

Galaxy Build-up in the First Billion Years II: UV LF Evolution and Mass Growth

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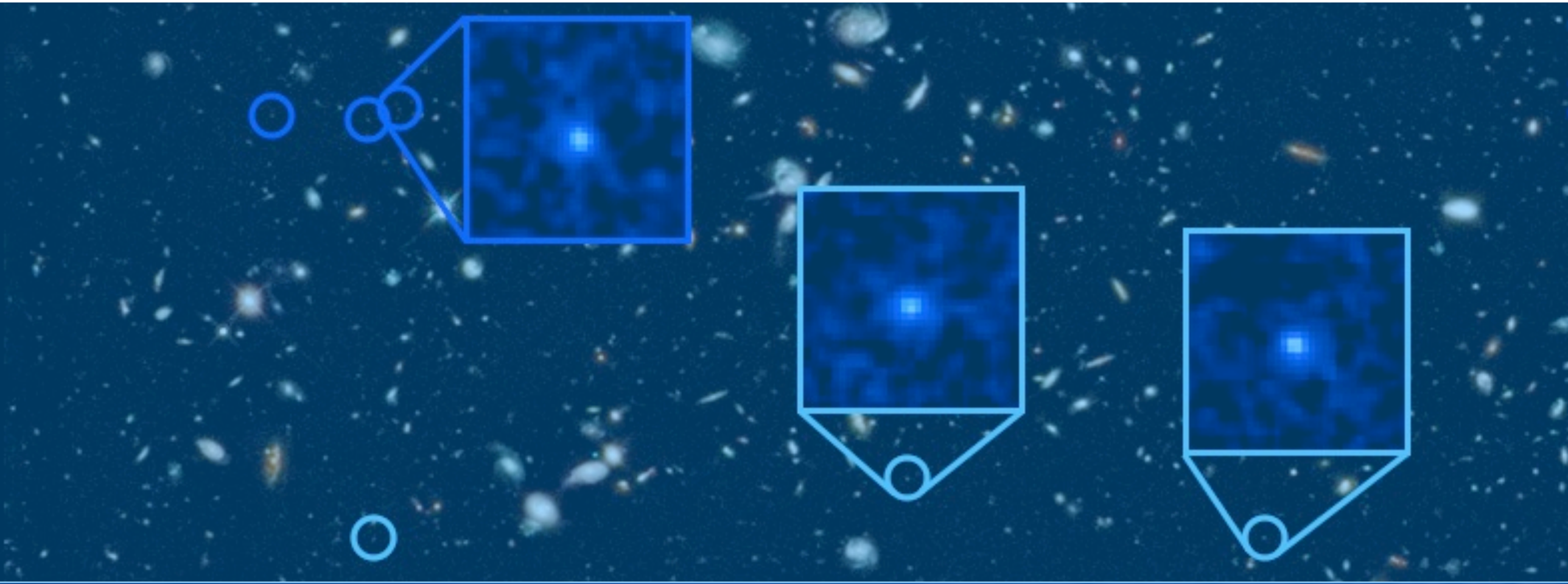
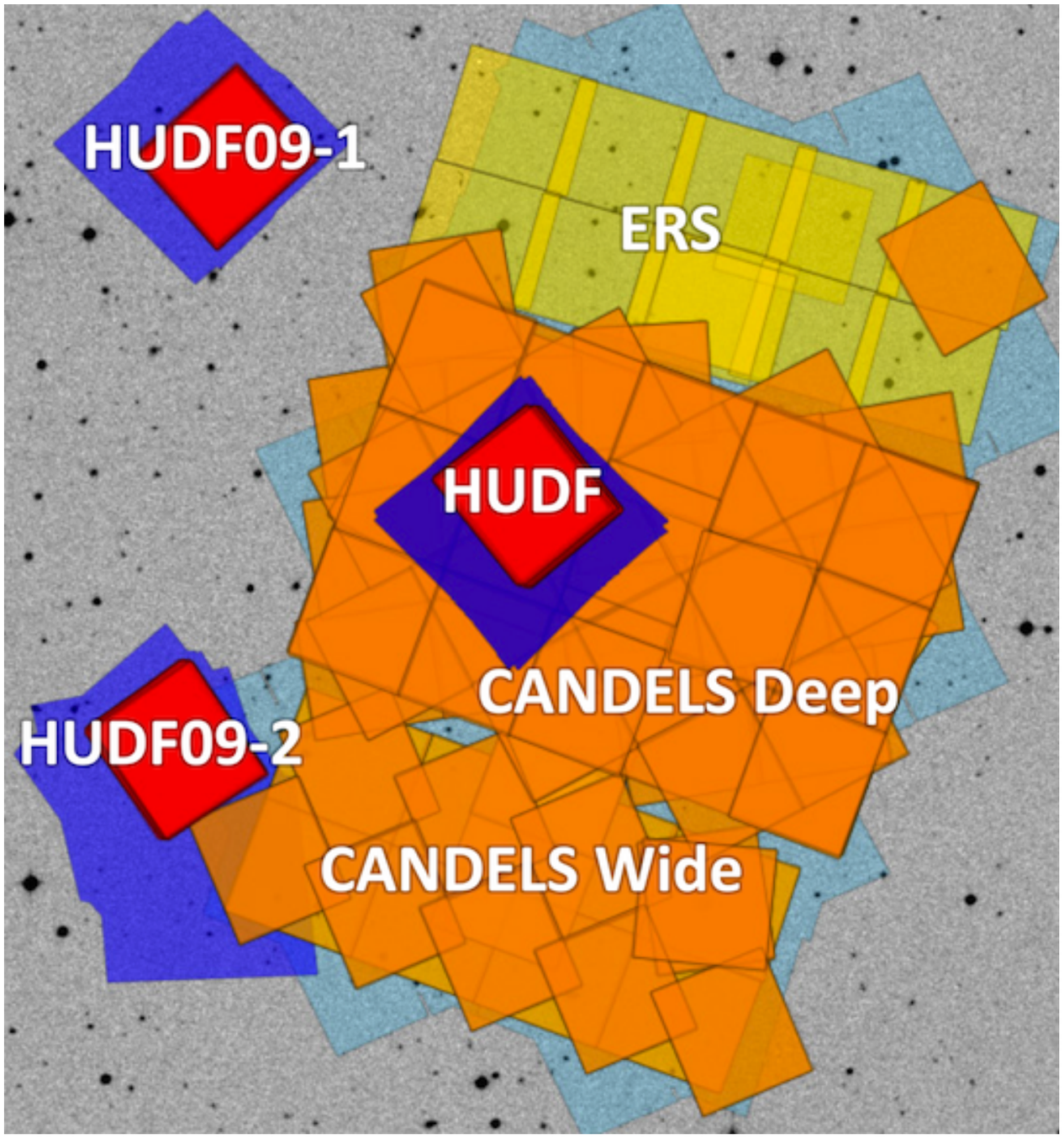
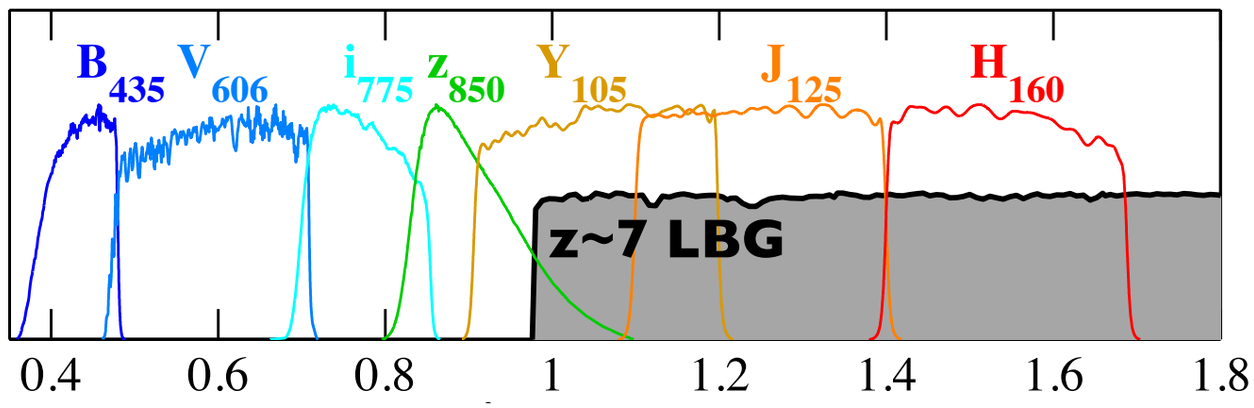


The Dataset: Deepest optical + NIR



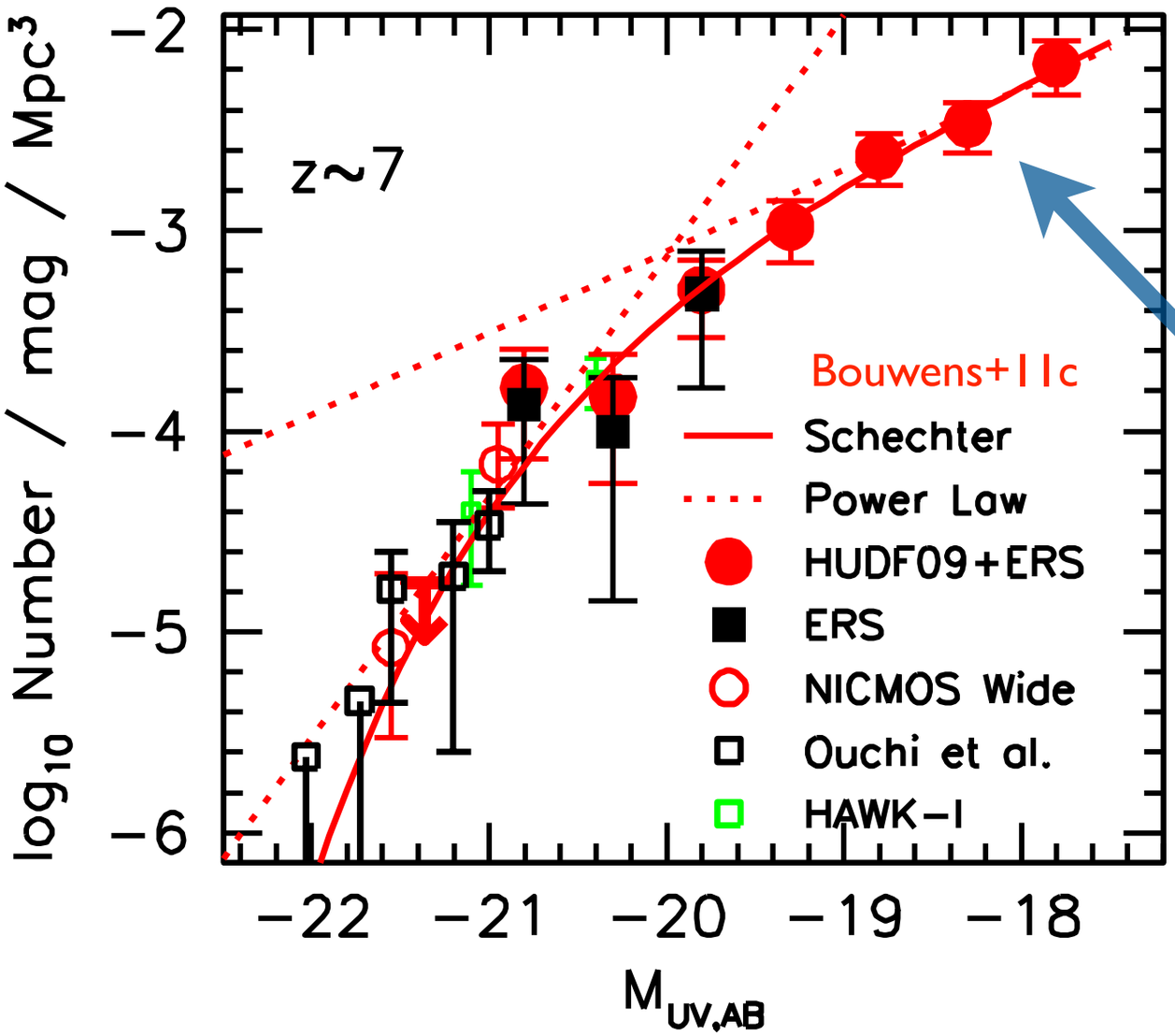
- CDFS is covered by perfect dataset for z>6 galaxy search
- Large amount of public optical (ACS) and NIR (WFC3) data
  - *HUDF09*
  - ERS
  - CANDELS (Deep & Wide)
- Total of 160 arcmin^2
- Reach to 26.9 - 29.4 AB mag



Galaxy Build-up Based on the UV Luminosity Function

WFC3/IR probes rest-frame UV,
after dust-correction this is proportional to SFR

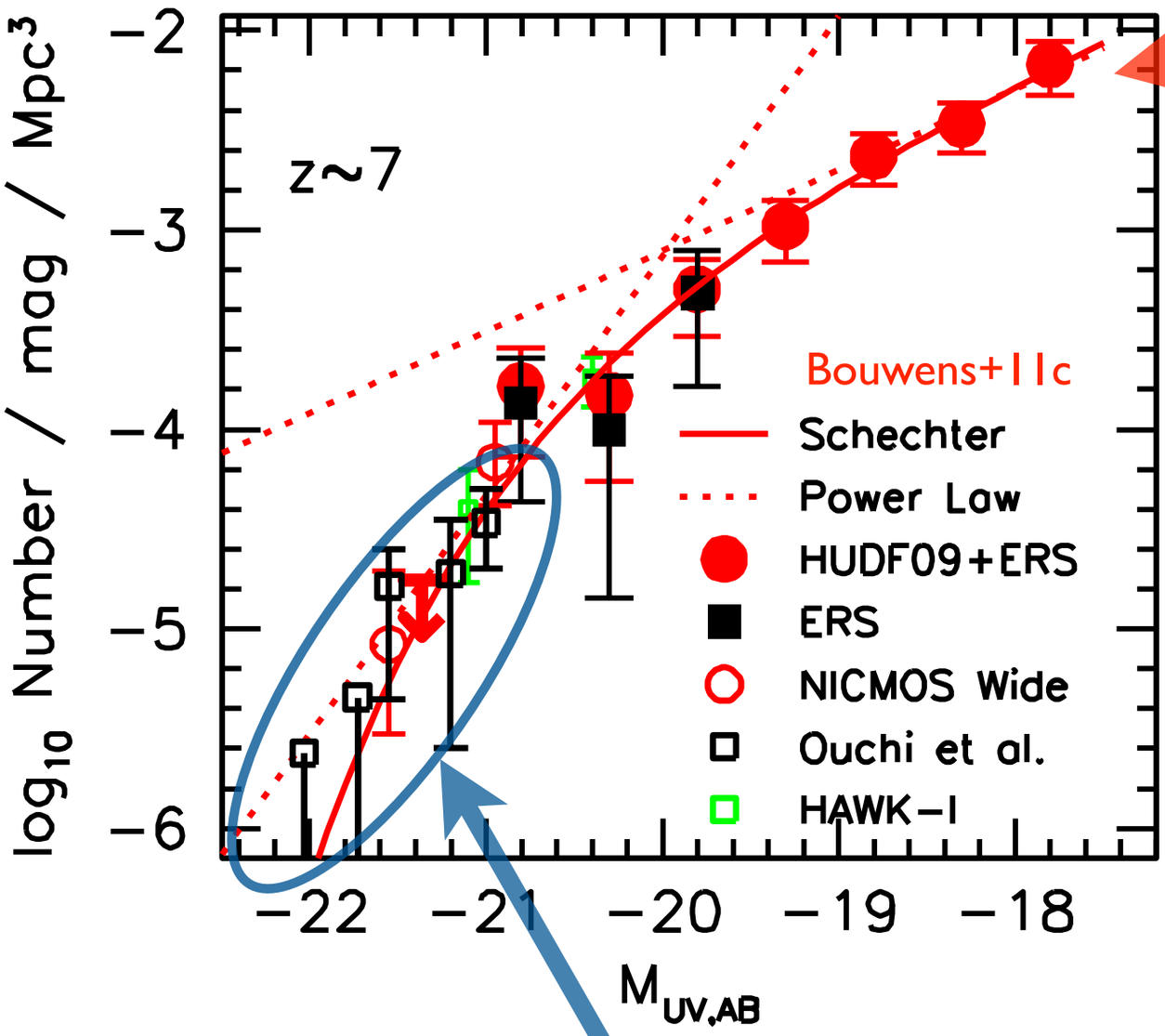
z~7 LF from HST and from Ground



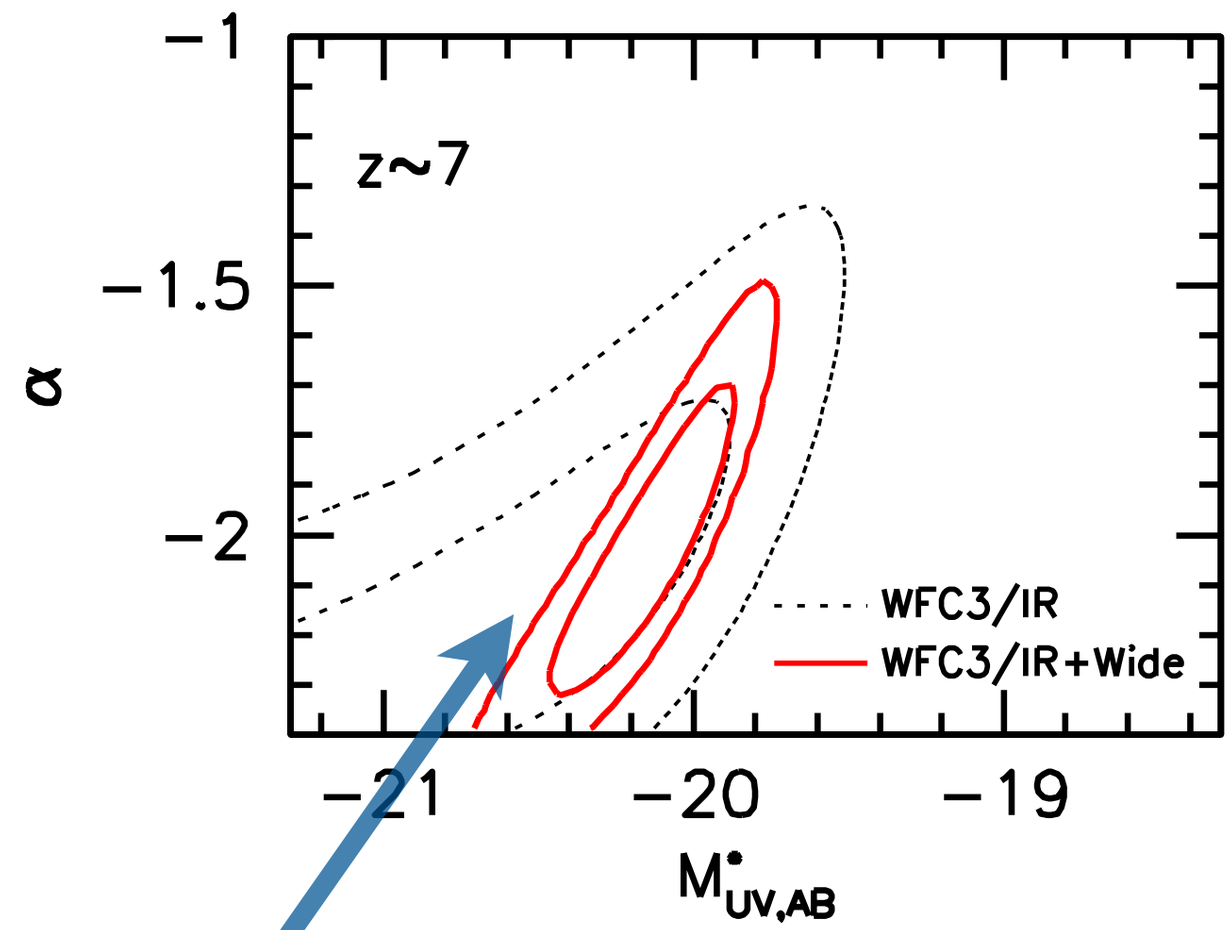
HST (HUDF09+ERS): well-sampled faint end

Extremely steep slope: **α ~ -2**

z~7 LF from HST and from Ground



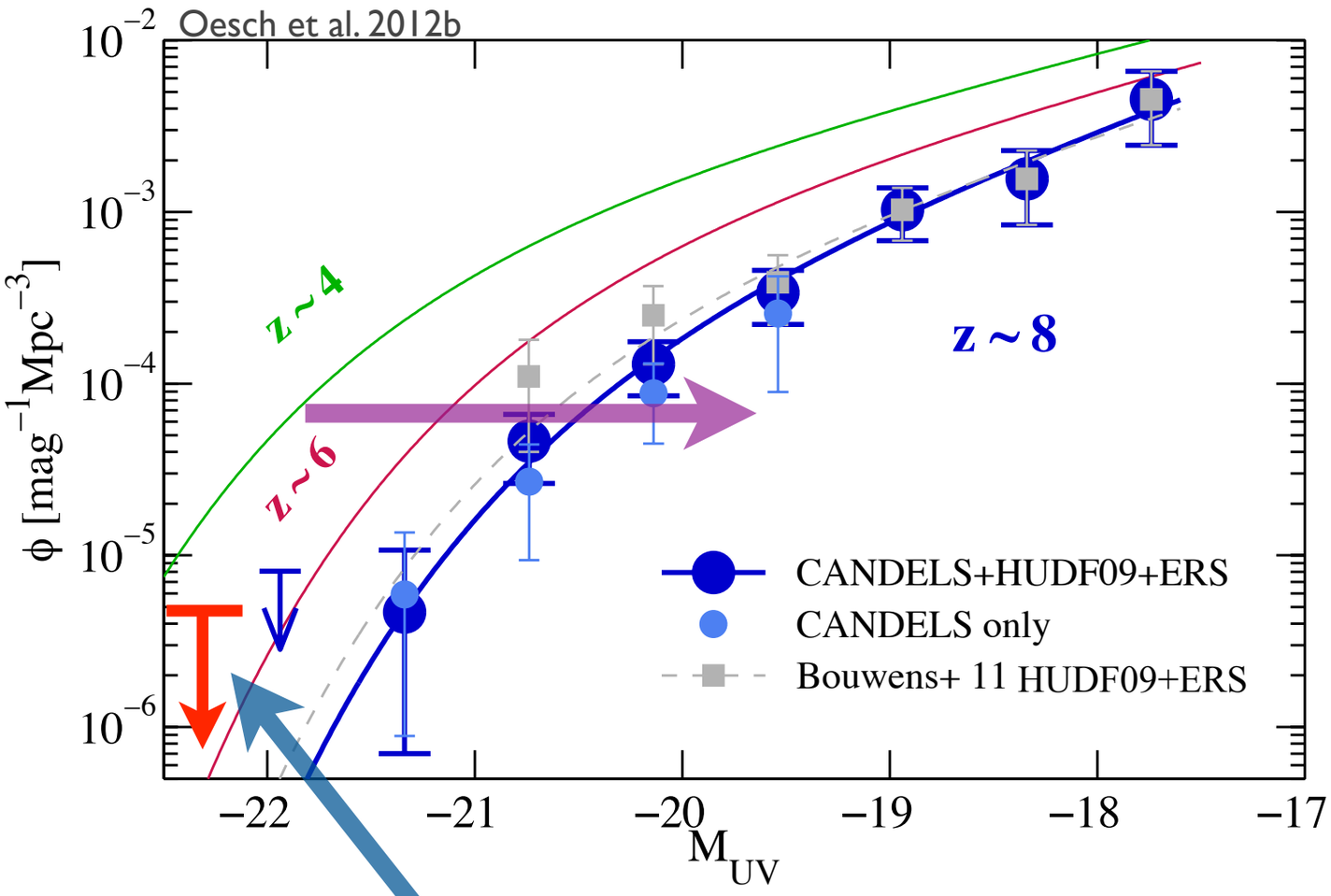
HUDF09+ERS only

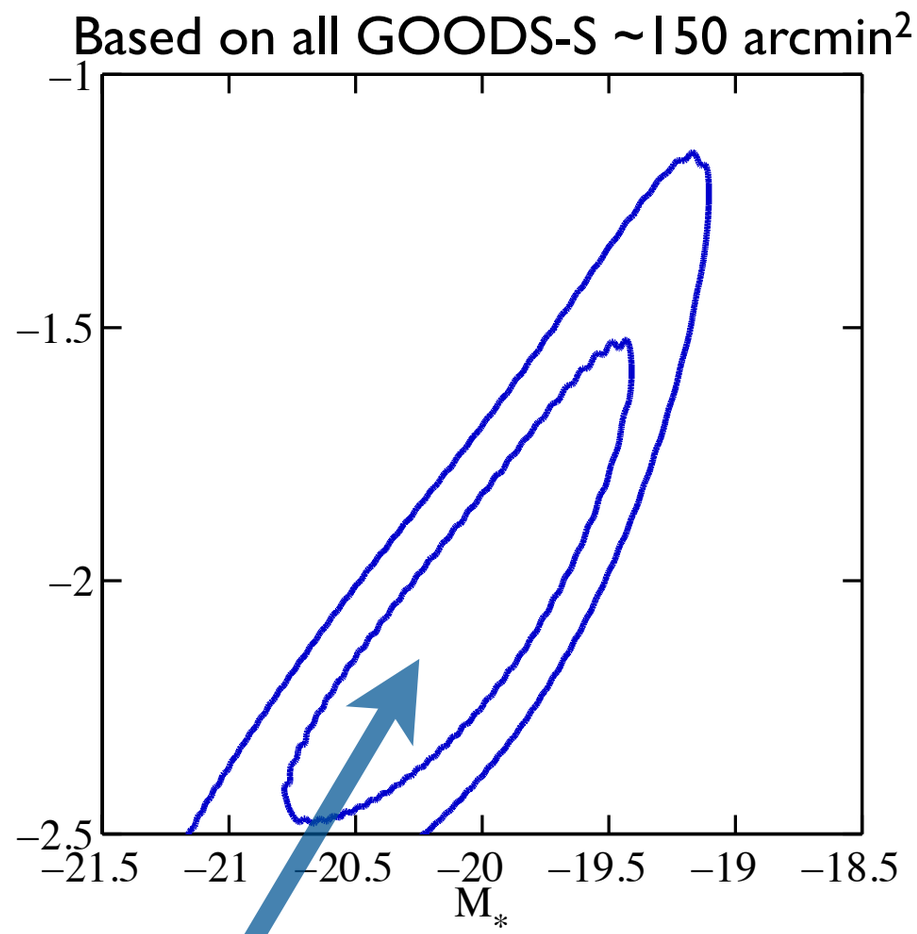


Ground-based data extremely useful for bright end constraints

See also: e.g. Oesch+10, Bunker+10, Finkelstein+10, Yan+10, Wilkins+10/11, McLure+10

z~8 LF: from HST only





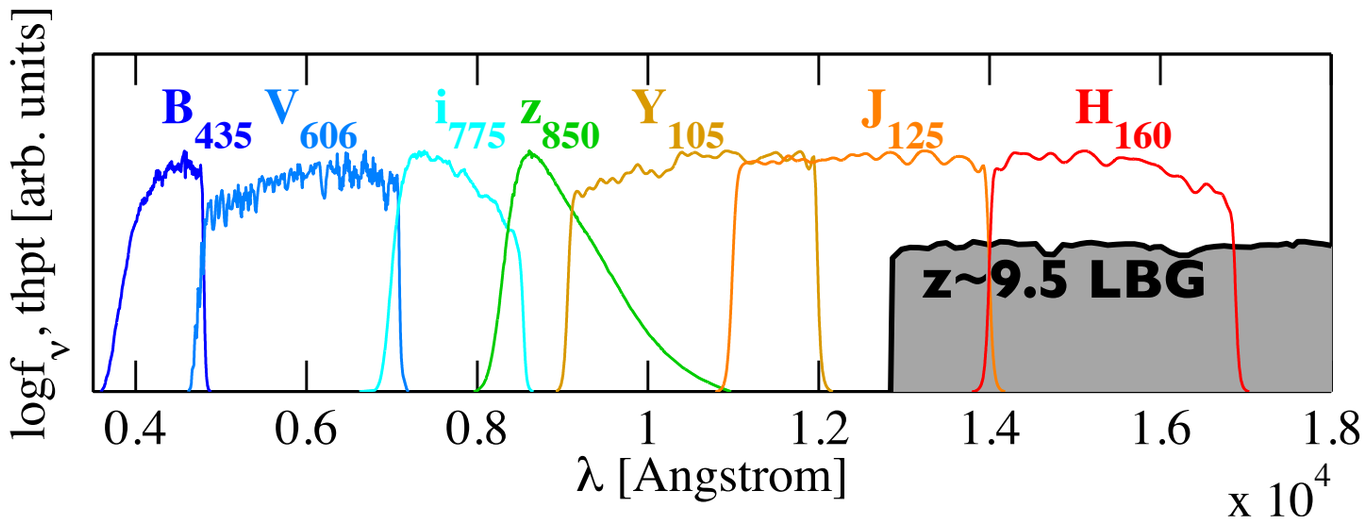
At z~8: Ground-based data only achieved upper limits at very bright M_{UV}

Correspondingly, errorbars are still quite large

Combination with pure parallel data (e.g. BORG), CANDELS GOODS-N, CLASH, and Ellis-HUDF will help reduce this in near future.

See also: Bouwens+10, Bunker+10, Finkelstein+10, Yan+10, McLure+10/11, Lorenzoni+11

HST Can Push the Frontier to z~10

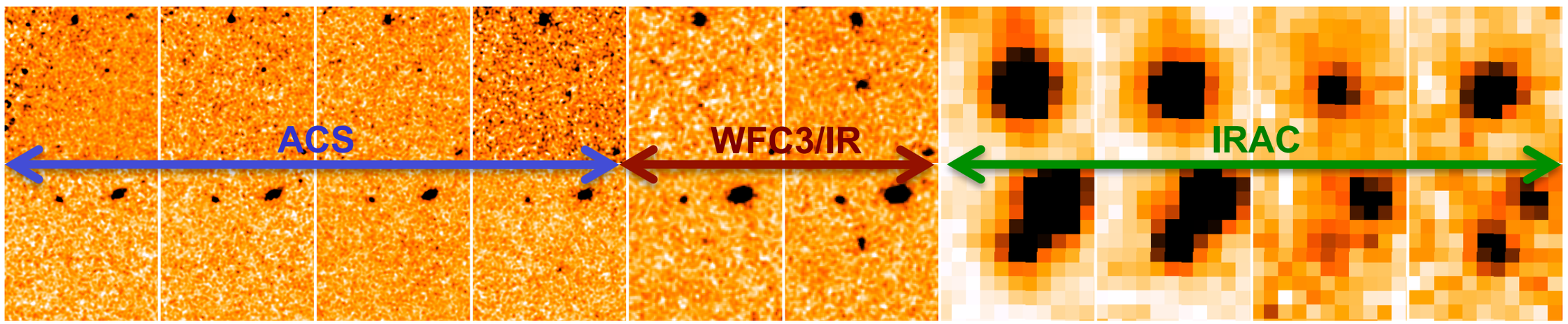


Can select z>9.5 galaxies based on their red J-H colors

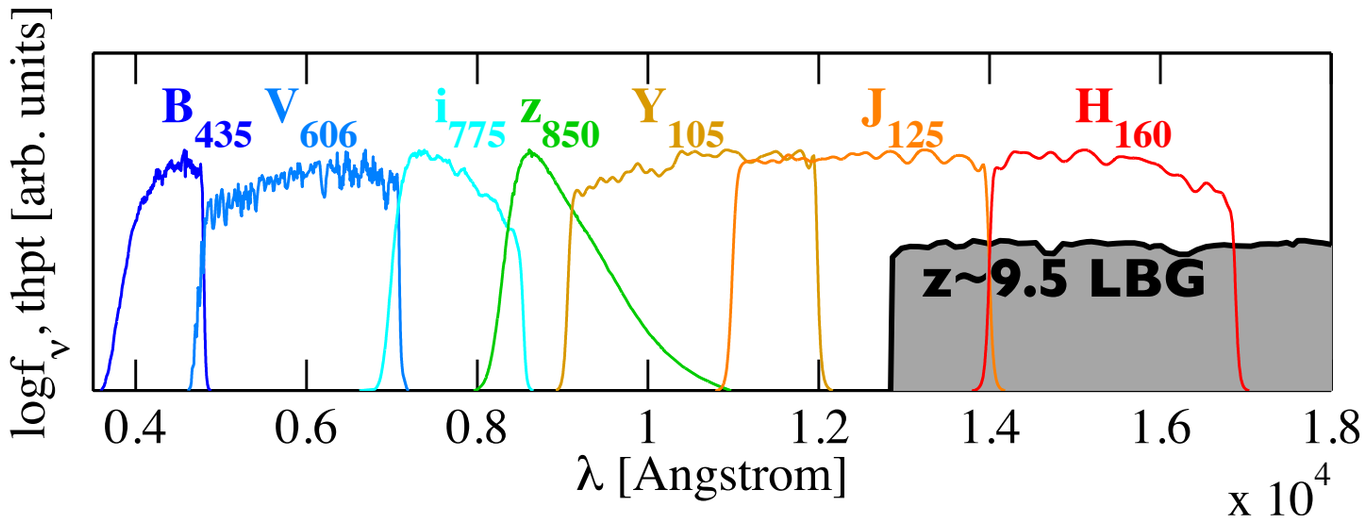
Have to reject lower redshift interlopers (z~2 dusty/quiescent galaxies)

➔ Spitzer IRAC!

The data revealed 17 sources which satisfy HST selection criteria.
16 are contaminants and look like this:



HST Can Push the Frontier to z~10



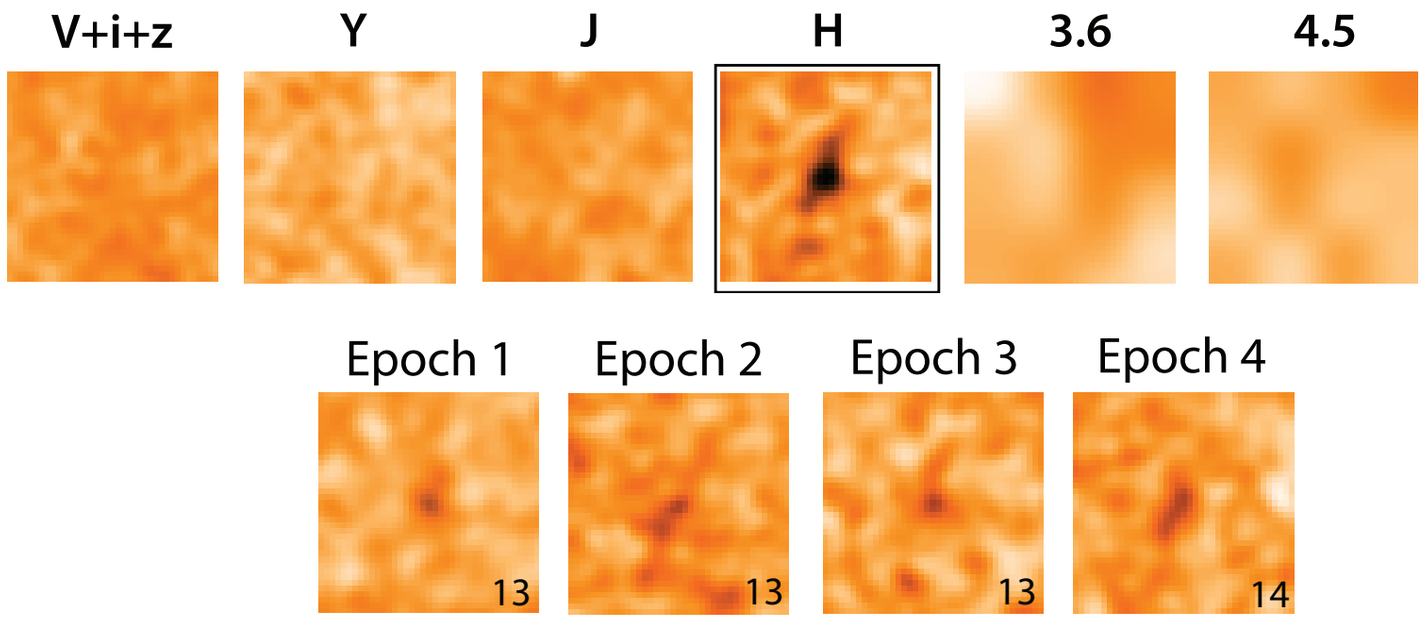
Can select z>9.5 galaxies based on their red J-H colors

Have to reject lower redshift interlopers (z~2 dusty/quiescent galaxies)

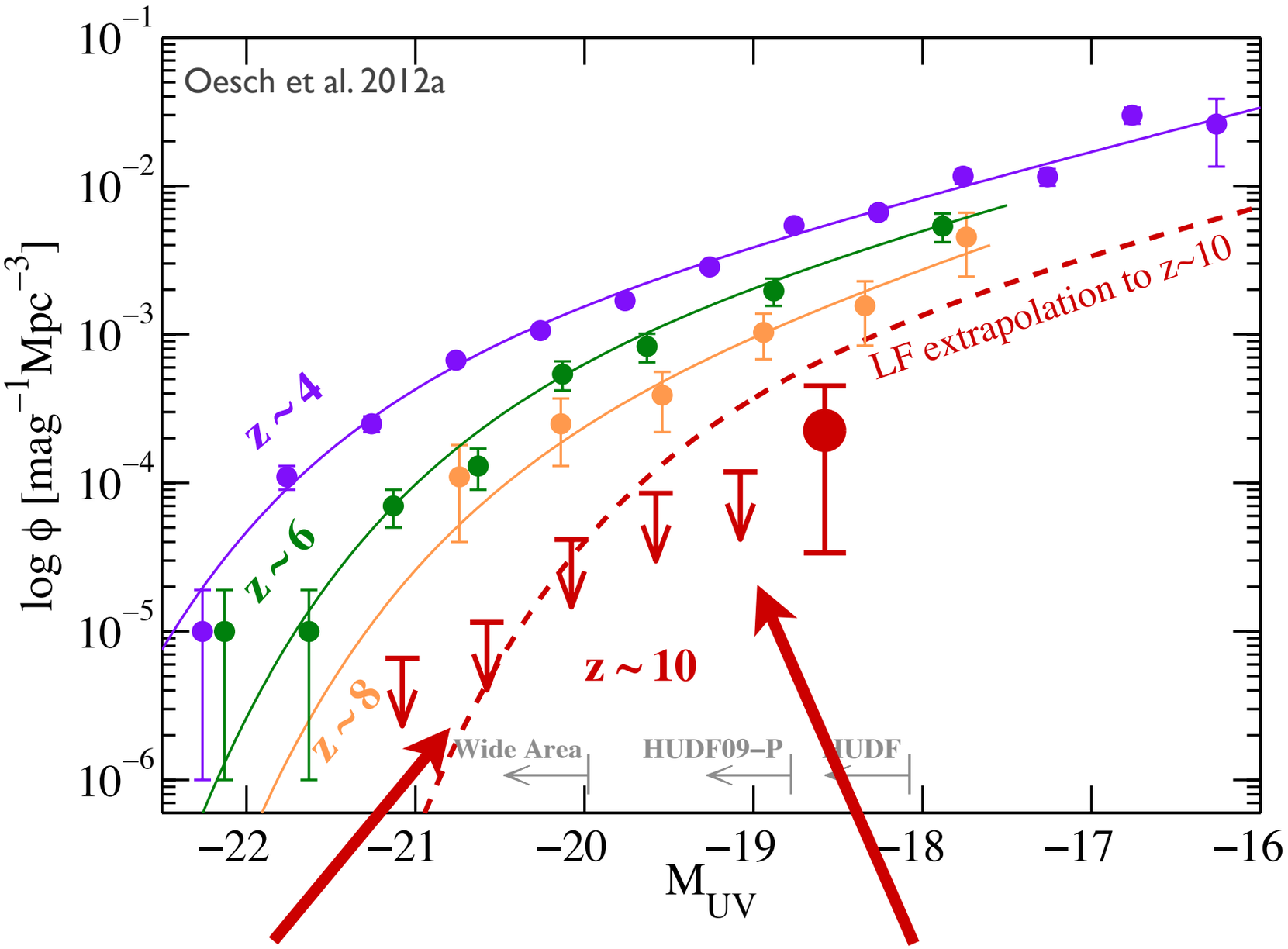
➔ Spitzer IRAC!

Systematic search over all CDFS data reveals **only one** z~10 candidate in HUDF:

- Very faint: H_{AB}=28.8±0.2
- Small chance of being spurious:
  - It is detected at ~6σ
  - It is visible at >2.5σ in 4 independent splits of the data
- Only small chance of being low-z source (<~10%): z_{phot} = 10.4



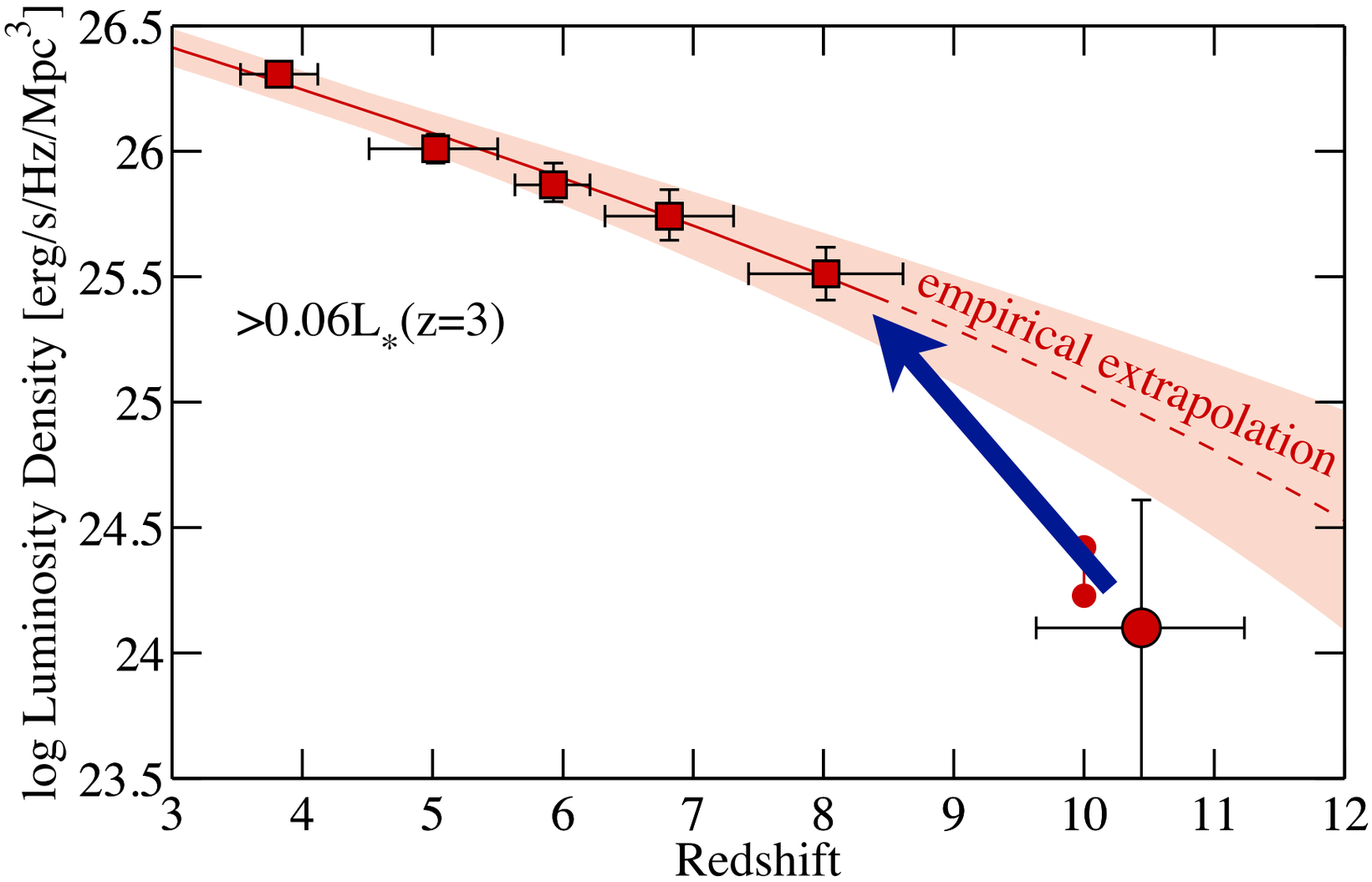
Constraints on z~10 LF



Three Wide Fields (CANDELS+ERS):
limits are below z~8 LF

Three HUDF09 Fields:
z~10 limits are below extrapolation

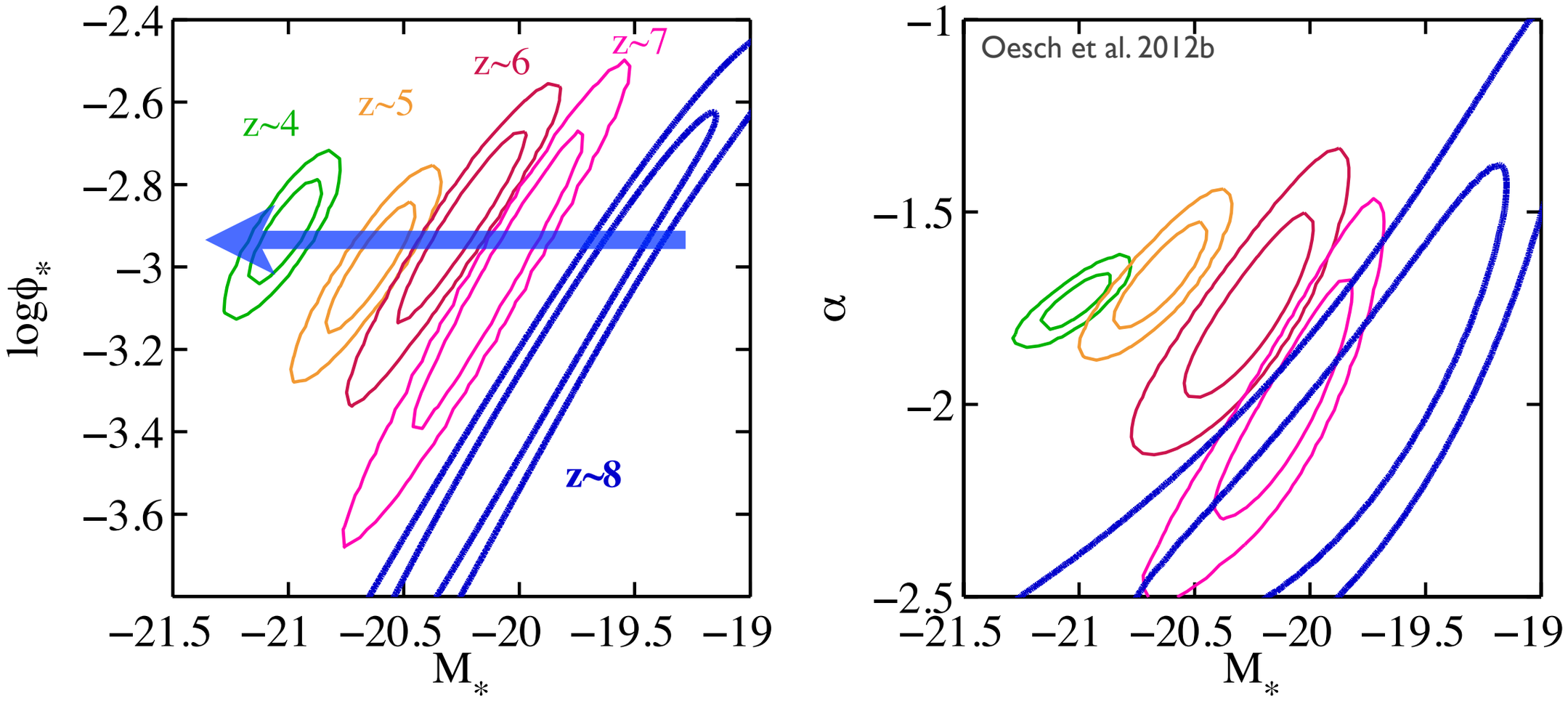
Accelerated Evolution of the UV Luminosity



Rapid build-up of UV luminosity in galaxies within only 170 Myr followed by smooth build-up from z~8 to z~4

Build-up of UV LF from z~8 to z~4

UV luminosity increases uniformly to lower redshift



Main Evolution: only in M* (0.33 mag per unit z)

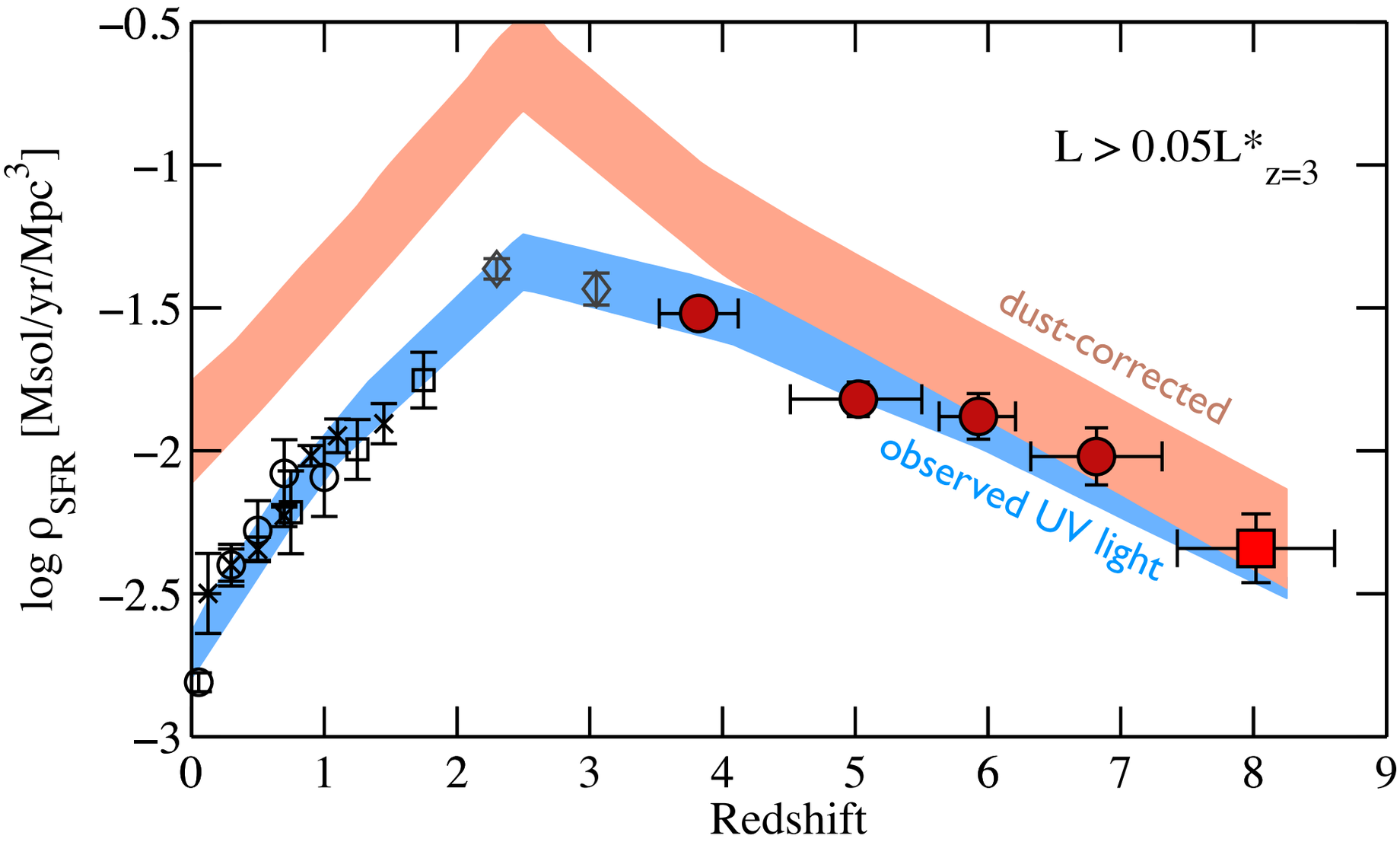
Very steep faint-end slope: -1.7 at z<7, with possible trend to steeper slopes at higher z

➡ **Note:** For galaxies to become brighter in UV, their SFRs must increase!

Cosmic SFR Density

Combination of ACS and WFC3/IR observations allows us to measure UV continuum slopes of galaxies at z~4-7, which is needed for dust-corrected SFRs.

→ cosmic SFR density

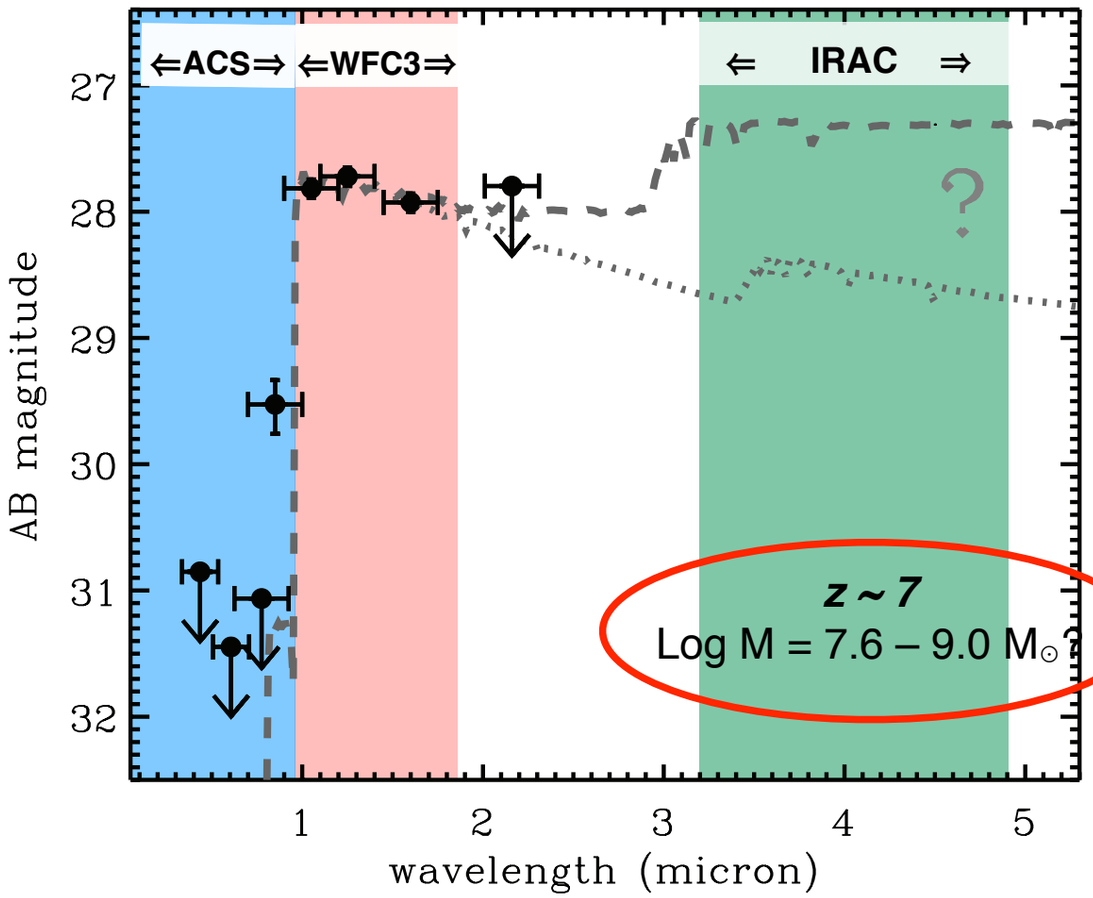


Above our completeness limit: **factor ~10x** growth of SFR density from z~8 to z~4

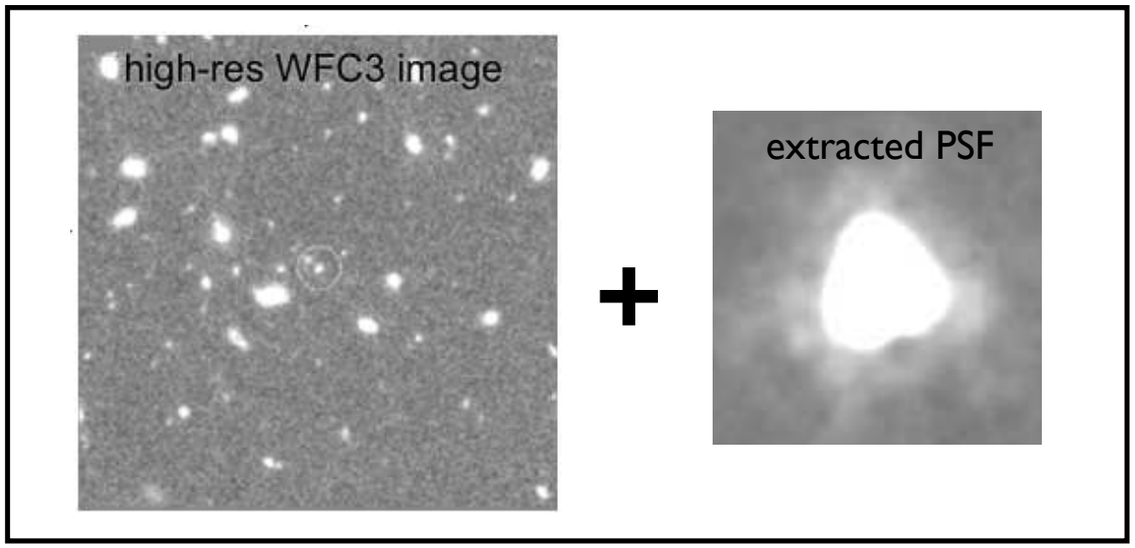
Galaxy Build-up Based on the Mass Function

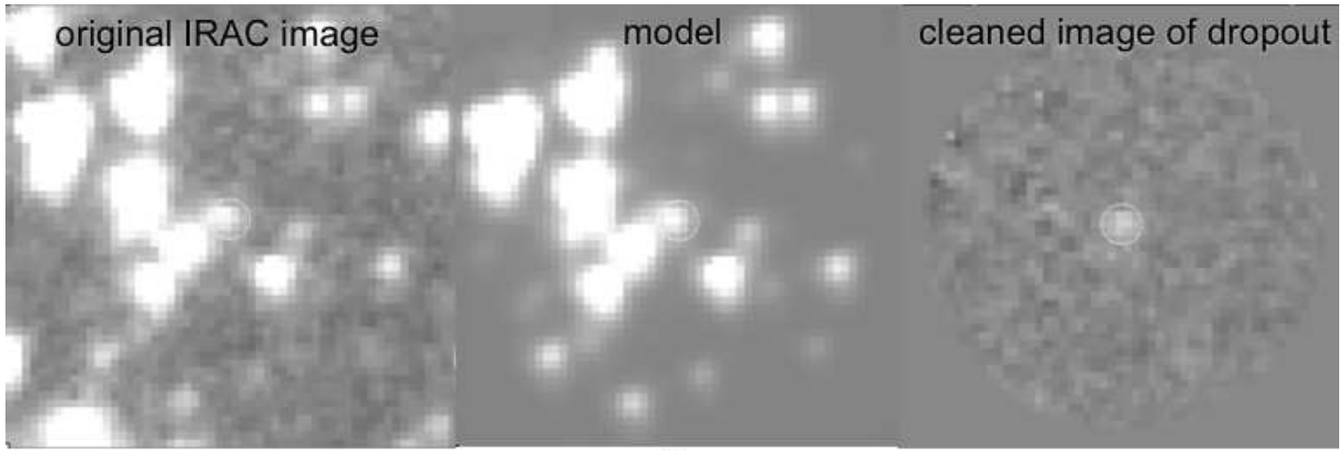
Spitzer IRAC probes rest-frame optical

Rest-Frame Optical SEDs of z>4 Galaxies



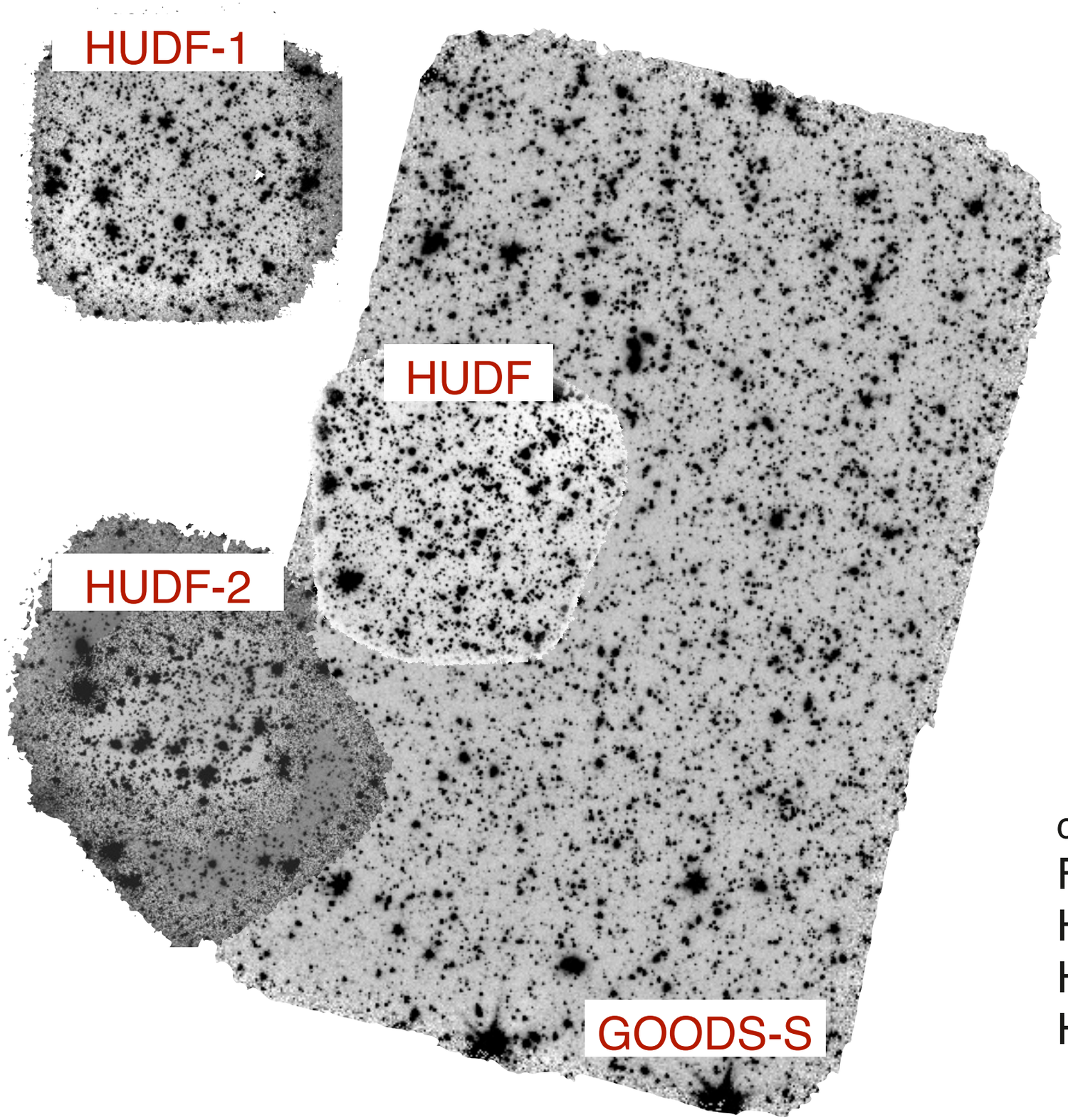
IRAC is crucial for rest-frame optical SEDs and constrains on stellar masses/ages at z>4





Need to model neighboring sources in a crowded field to extract accurate photometry

IRAC Data over CDFS: The IUDF10 Survey



coverage (hours):

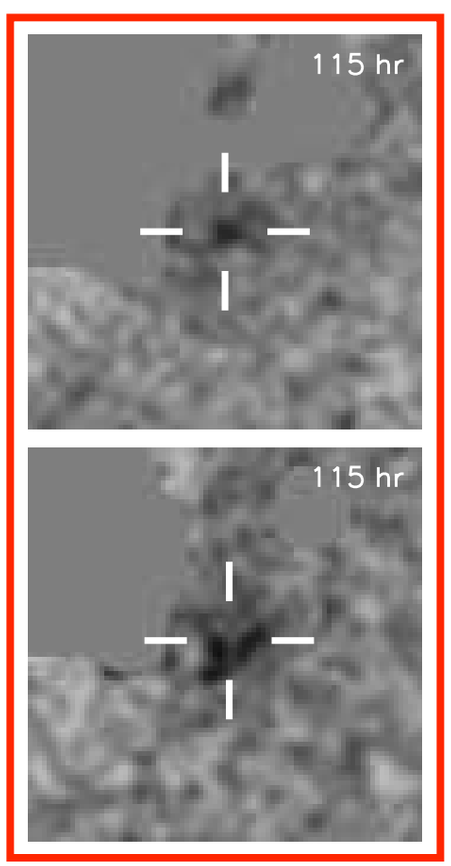
FIELD	[3.6]	[4.5]
HUDF	126	126
HUDF-1	52	52
HUDF-2	125	92

Mass Estimates out to z~8 are possible

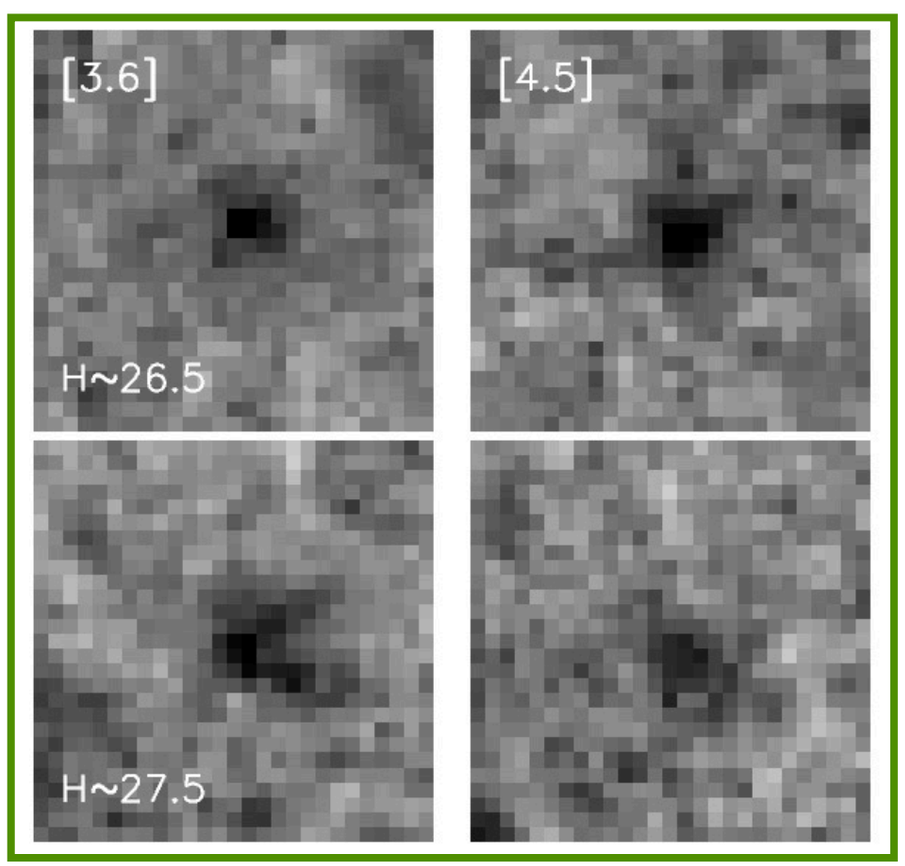
The IUDF10 led to the first robust (>5σ) detections of three z~8 candidates (~25% are detected at >2.5σ).

Median stacked images of 55 Y-dropouts in IUDF10 yield z~8 SED at >L*.

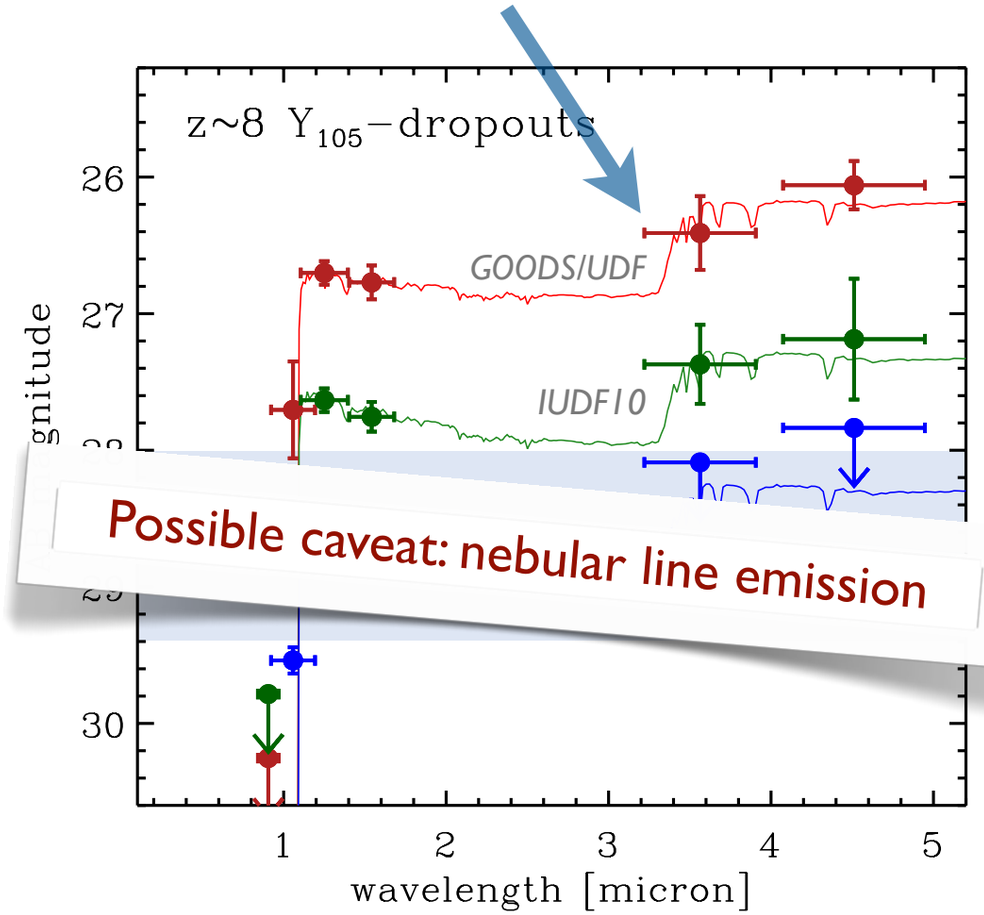
few robust individual detections



clear detections in stacks

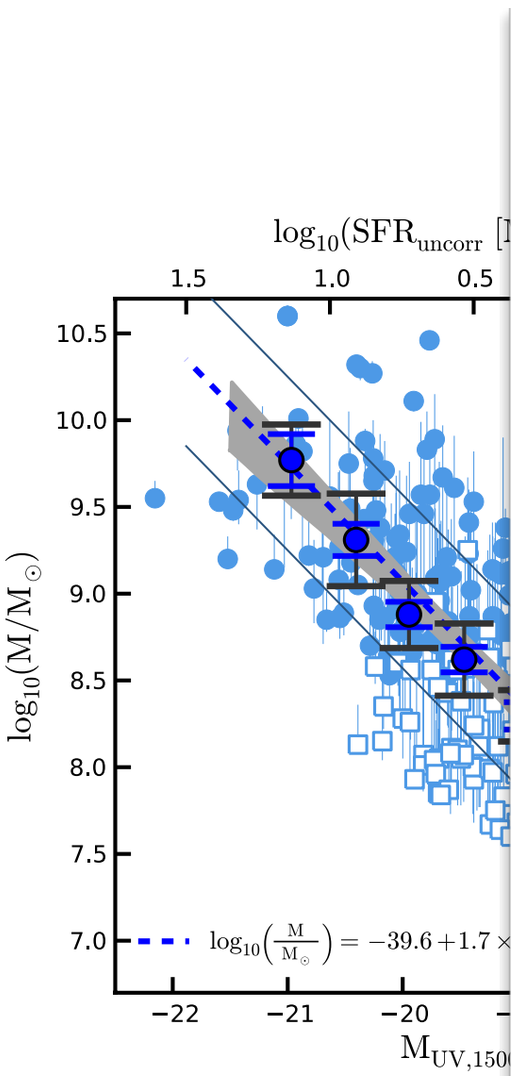


spectral break: indicates ages>~300 Myr, i.e. onset of SF at z>~12

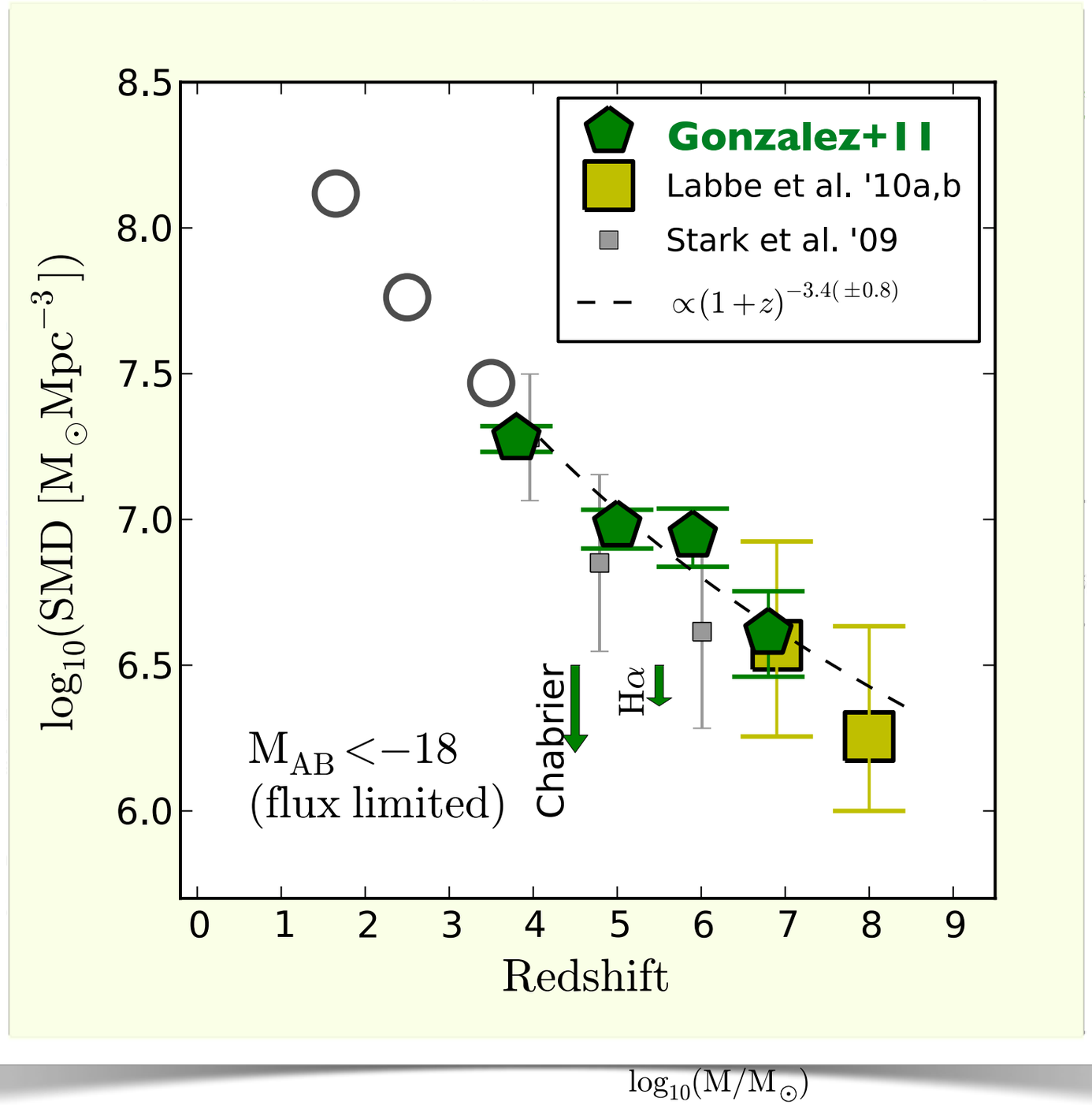


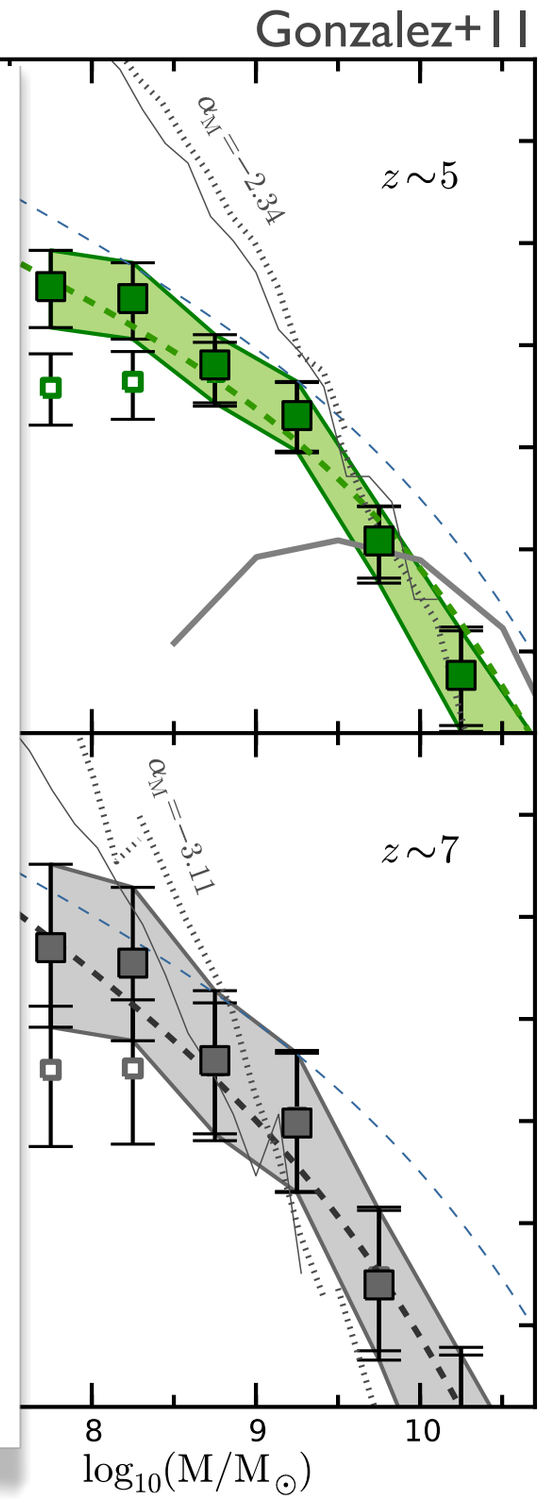
Labbé et al. (to be submitted)

Evolution of the Mass Function

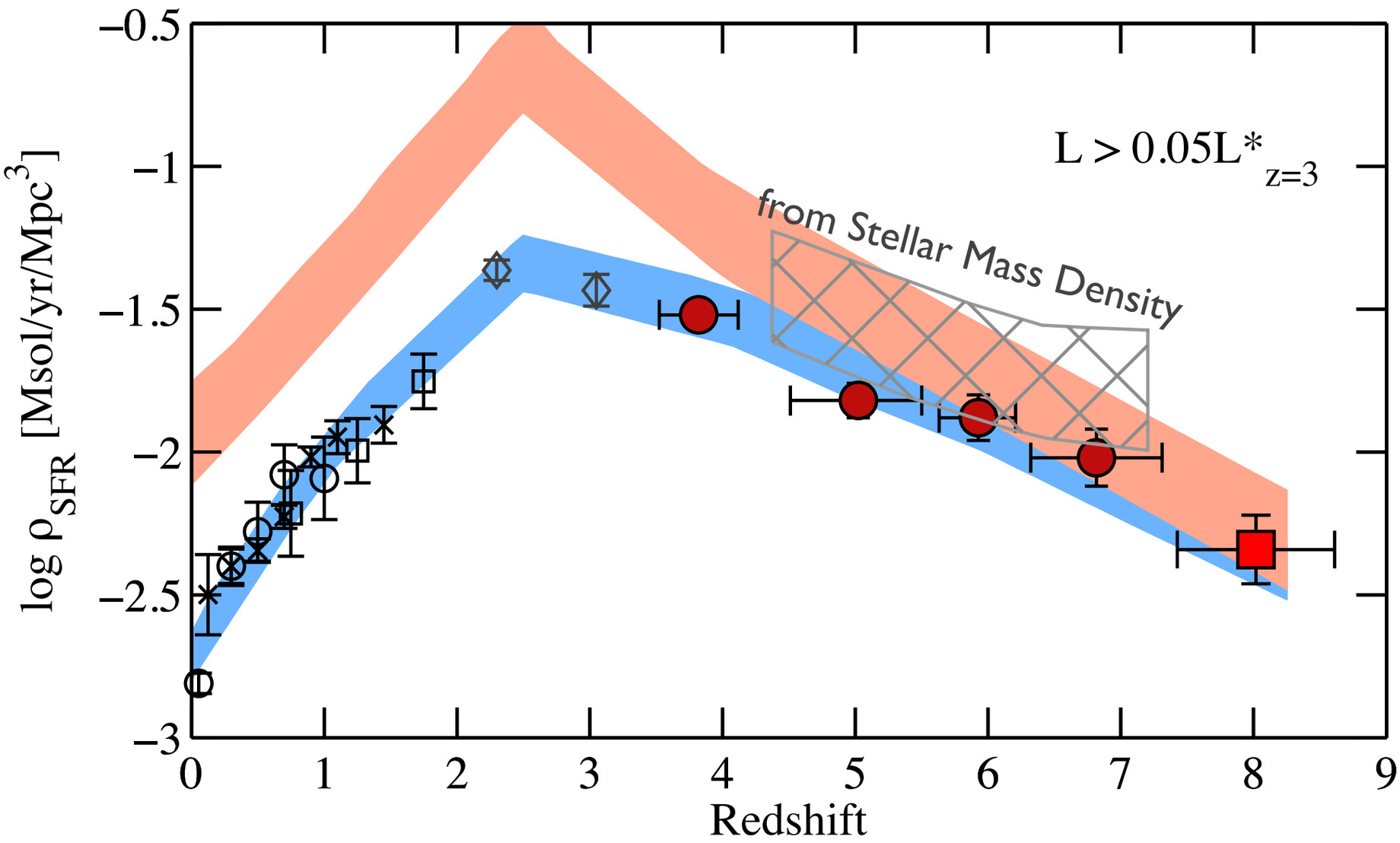


UV luminosity c
relatively well with





Growth between SFR and Mass is consistent



Summary

- WFC3/IR has opened up the window to very efficient studies of z>6.5 galaxies: by now, we have identified >100 galaxy candidates at these redshifts; one at z~10!
- We have extended the analysis at z~8 to the full WFC3/IR data over the CDFS, but uncertainties on the z~8 LF are still very large
- The UV LF appears to evolve smoothly from z~8 to z~4, mainly changing in M* only corresponding to a growth in UV luminosity by a factor ~4
- The increase in the UV luminosities is connected to a factor ~10x increase in the SFRs of galaxies from z~8 to z~4
- Spitzer IRAC was able to robustly detect individual z~8 candidate, and to measure median SEDs as a function of luminosity at >L*
- The stellar masses are tightly correlated with the UV luminosities, which can be used to obtain first estimates of stellar mass function out to z~7
- Stellar mass density builds up consistently with SFR density, both increasing by ~10x from z~8 to z~4