THE FIRST GALAXIES: A VIEW FROM HST AND SPITZER

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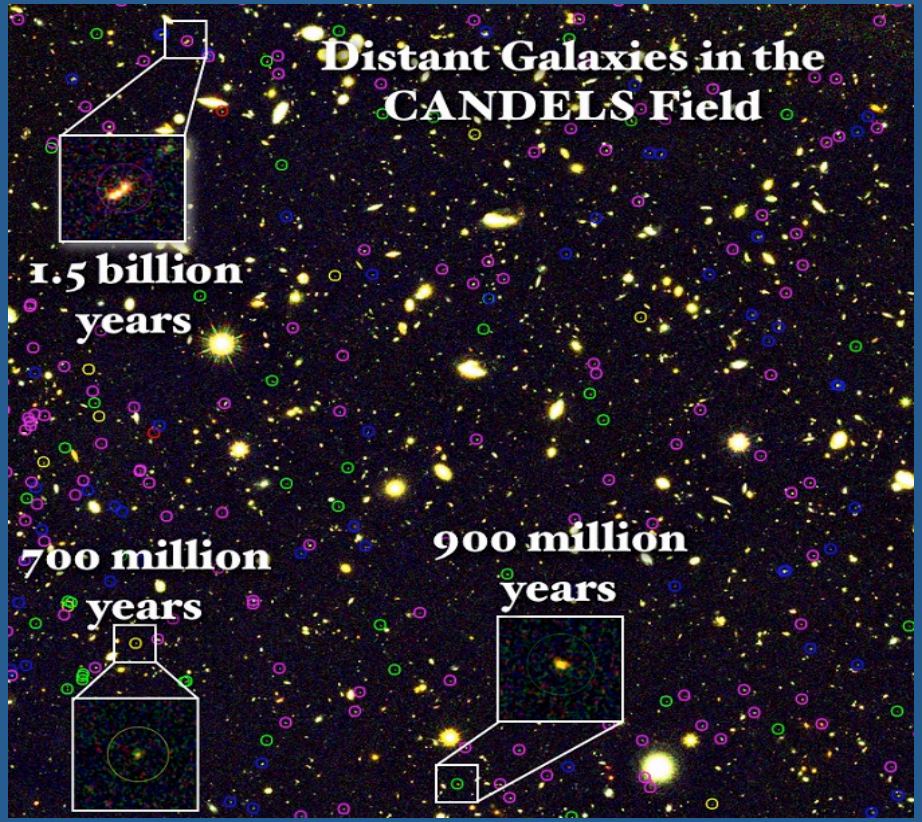
The HST CANDELS Survey



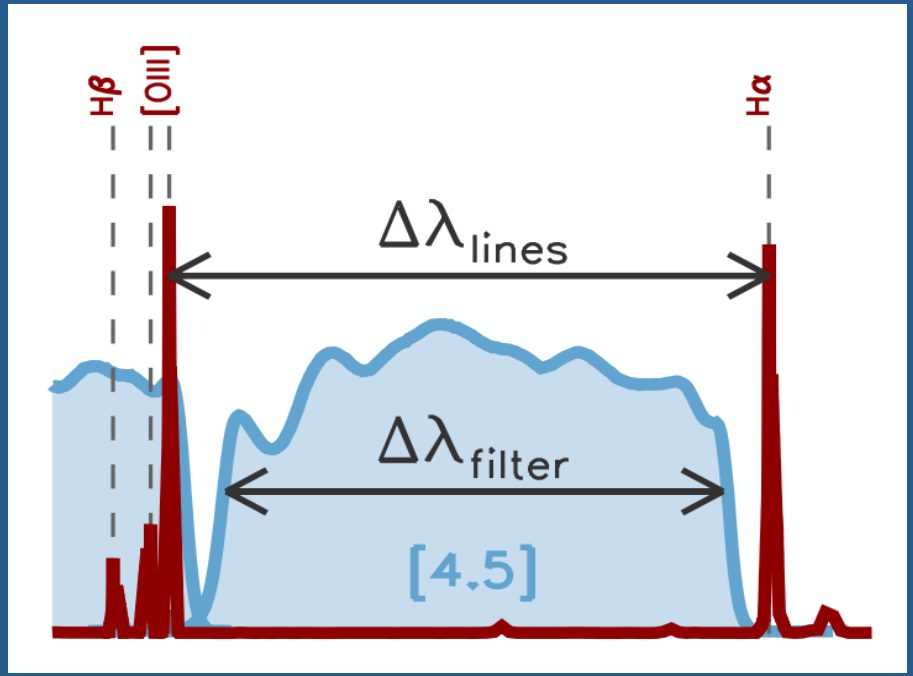
- Near-infrared survey with HST, covering ~900 arcmin^2 - largest survey undertaken by Hubble
- Started in 2010 and completed in 2013 (~902 orbits)
- Separated into 5 fields: EGS, COSMOS, UDS, GOODS-NORTH, GOODS-SOUTH
- Deep imaging of more than 250,000 galaxies with the WFC3 and ACS camera on HST
- Problem: lacks Y-band data needed to select Lyman-break galaxies at z~7-9..

Emission Line Contamination

- Studies (eg., Stark et al., 2013; Labbé et al., 2013; Smit et al., 2013) have suggested the presence of strong nebular emission lines in LBGs, contaminating photometric filters.

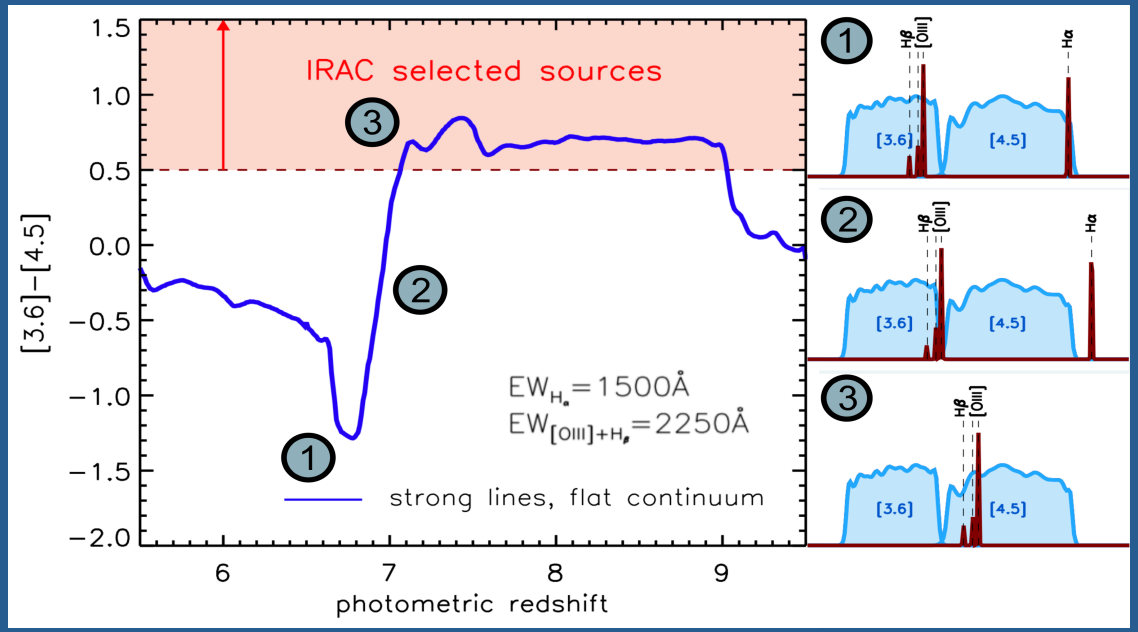
- Examples are Hα (6563 Å) and [OIII] (5007 Å).

- The lines boost the fluxes in the contaminated filters, rendering photometry sometimes unreliable.



Smit et al. (2014)

Spitzer/IRAC Color Selection



Roberts-Borsani et al. (2015)

Can use IRAC [3.6]-[4.5] colors to segregate z>7 galaxies!

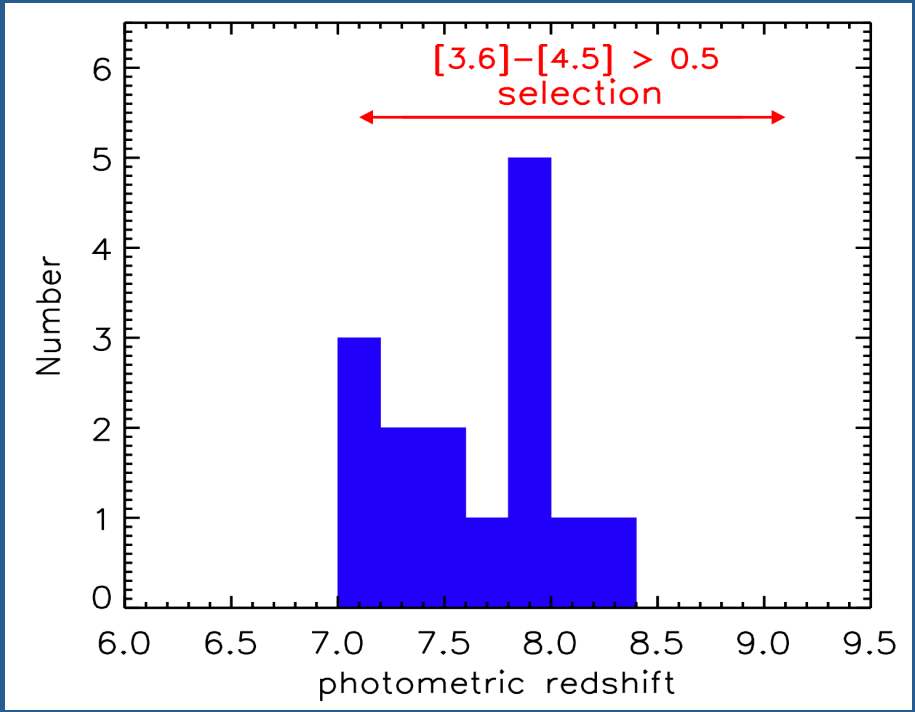
1) Hα is leaving the [4.5] band, [OIII]+Hβ are in the [3.6] band: very blue
2) Hα has left the [4.5] band, [OIII]+Hβ are transiting bands: neutral color
3) Only [OIII]+Hβ contaminate the [4.5] band: very red

Our Aims

Using HST, Spitzer and ground-based photometry from Bouwens+2015 and Skelton +2014 catalogs, we:

- Search for the brightest (H_{160} < 25.5) galaxies in the full CANDELS survey
- Require Spitzer/IRAC [3.6]-[4.5] > 0.5
- Require <1.5σ detection in V_{606} filter and 2.5σ non-detection blueward of Lyman-break to remove any low-redshift candidates
- Use EAZY (Yale) to estimate redshifts and fit SEDs to found candidates

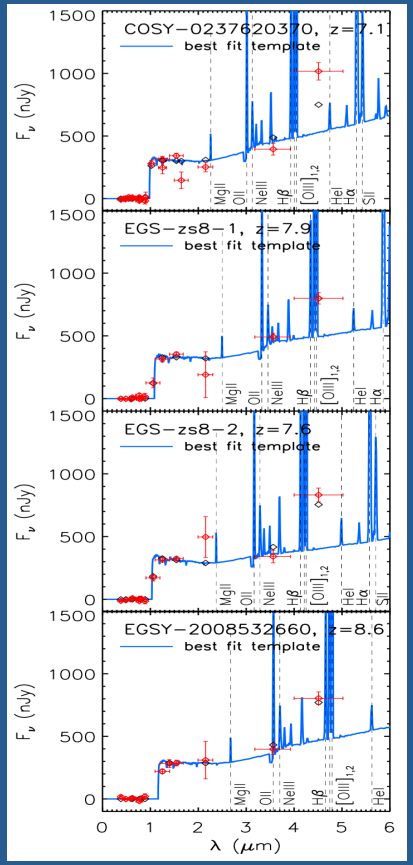
Prior Validation



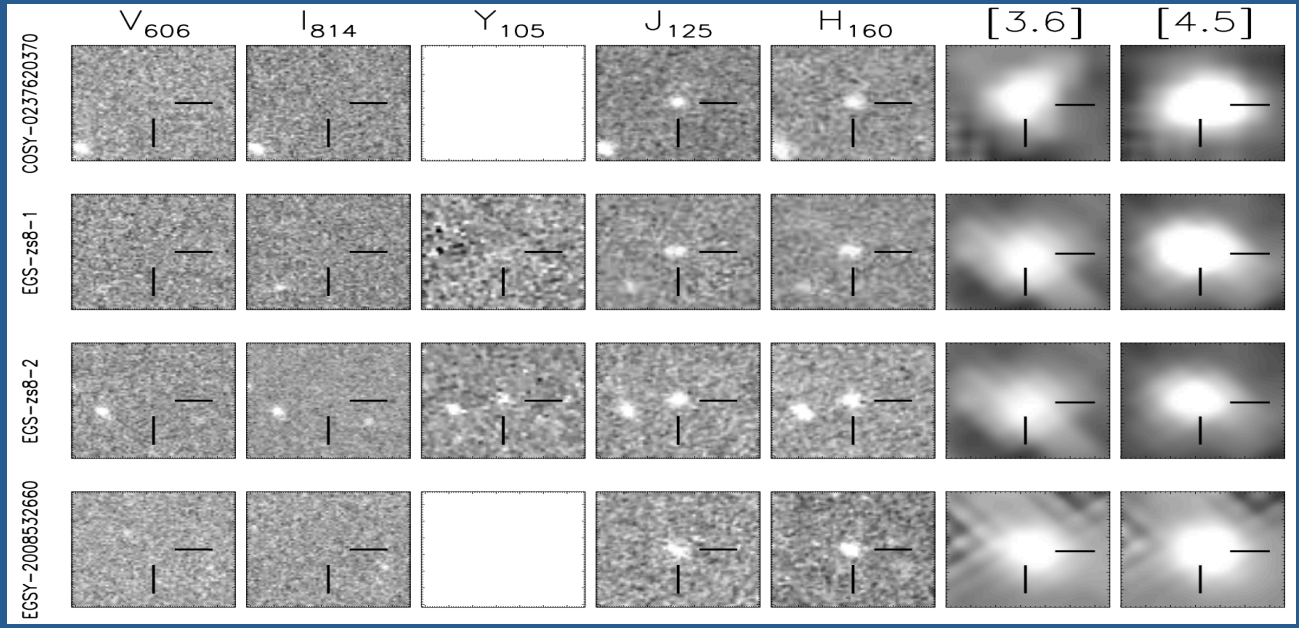
Roberts-Borsani et al. (2015)

- Searched over UDS, COSMOS, GOODS-N, GOODS-S, ERS, where Y-band is available.
- 15 candidates found at z~7-8.3.
- All 15 candidates have [3.6]-[4.5]>0.5 and are at z>7.
- Photometric redshifts estimated with EAZY (including Y-band).
- No IRAC data is used in EAZY's fitting for these objects, to ensure the two redshift measurements are entirely independent.

Results?



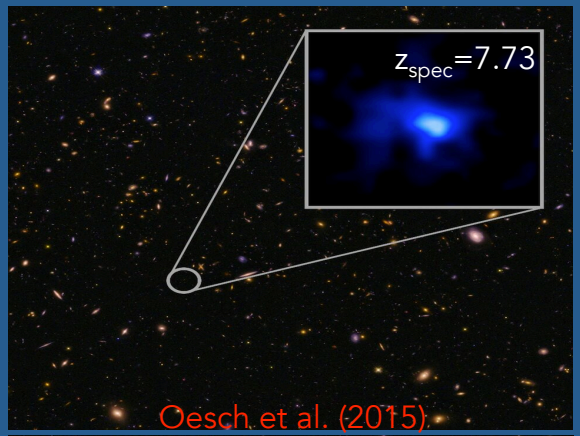
- 4 candidates at z>7 with red Spitzer/IRAC colors
- Brightest-known (H_{160}) galaxies at z>7.5 (to date)

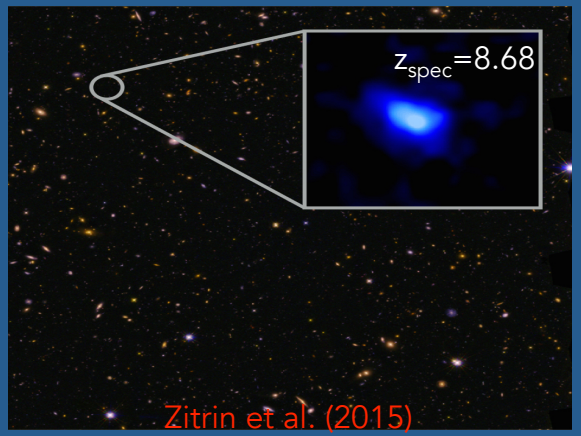


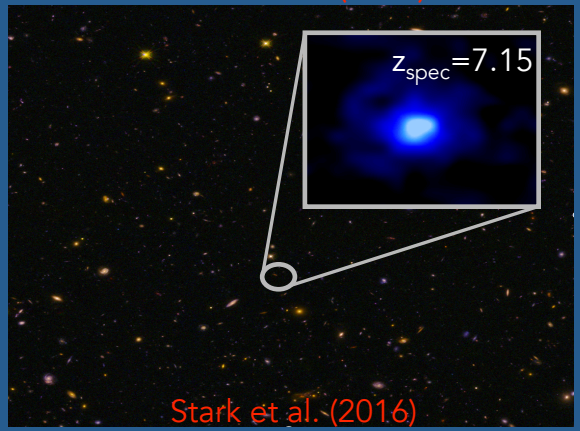
Roberts-Borsani et al. (2015)

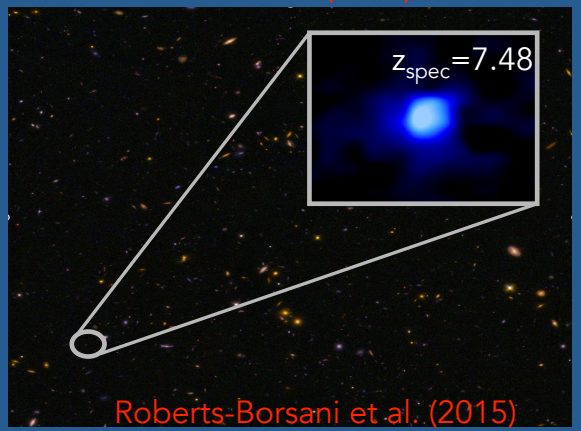
Spectroscopic Confirmations!

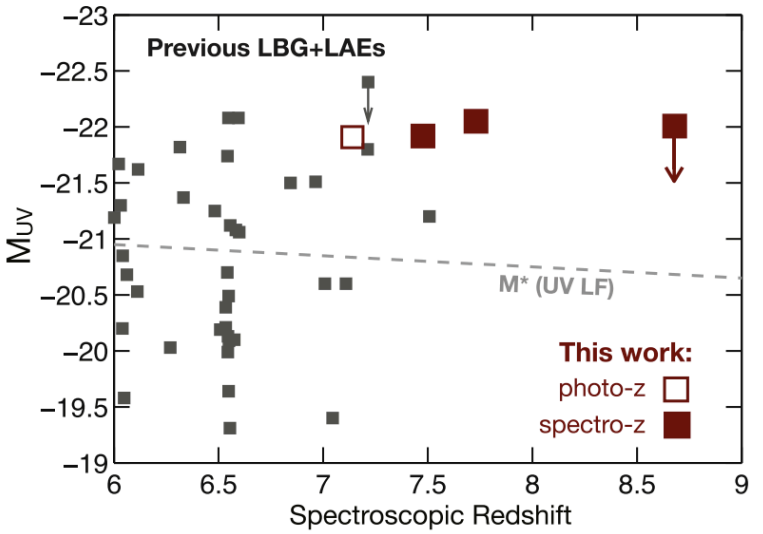
All candidates spectroscopically confirmed (Lyα) with Keck/MOSFIRE.
Spectroscopic redshifts in excellent agreement with our photometric redshifts!

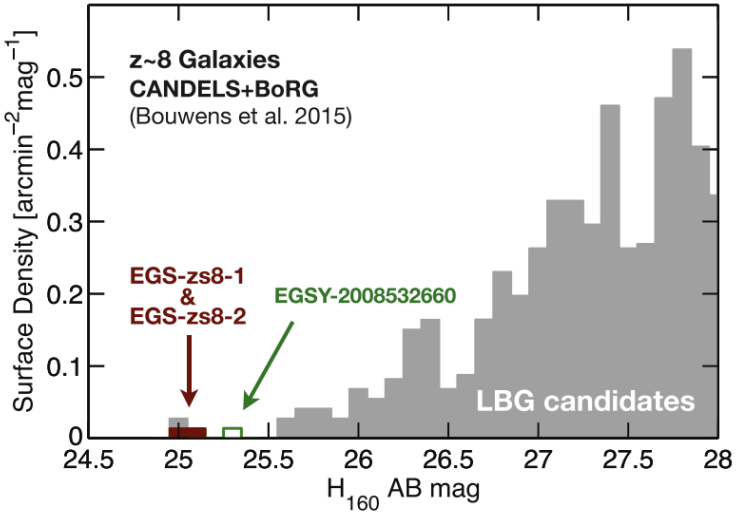








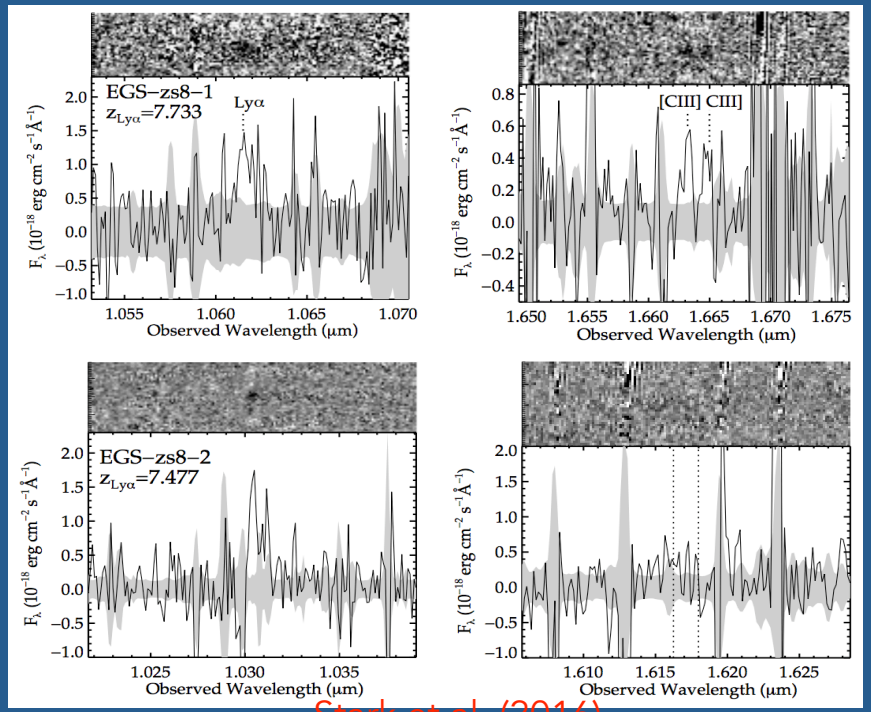

Previous LBG+LAEs
M* (UV LF)
This work:
photo-z
spectro-z
M_{UV}
Spectroscopic Redshift


z~8 Galaxies
CANDELS+BoRG
(Bouwens et al. 2015)
EGS-zs8-1
&
EGS-zs8-2
EGSY-2008532660
LBG candidates
Surface Density [arcmin^{-2}mag^{-1}]
H_{160} AB mag

Why do we see them?

- 100% success in Lyα detections at such high z is puzzling. Universe is likely still dominated by surrounding hydrogen.

- Stark+2016 find CIII] emission in 1/2 observed galaxies of the RB15 sample.



Stark et al. (2016)

Photoionization models suggest high [OIII]+Hβ EW pick out galaxies with low metallicity and a hard ionizing spectrum resulting from very massive and young stellar populations.

SUMMARY

- We used a Spitzer/IRAC [3.6]-[4.5] color criterion to select the brightest galaxies at z>7 over the full CANDELS survey.
- 4 unusually bright objects were found at z>7: 3 in EGS, 1 in COSMOS.
- All galaxies were spectroscopically confirmed and are in excellent agreement with the derived photometric redshifts from EAZY.
- [OIII]+Hβ preselects low metallicity systems with a hard ionizing spectrum from massive, young stellar populations.
- Although a small sample, the confirmation of these galaxies at z~8 challenges our understanding of reionization until now.


That's all Folks!