Searching for high-z LAEs and LBGs in the SHARDS survey

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Introduction

One sentence summary: Characterize the high-z galaxy population and study its implication in the reionization epoch.

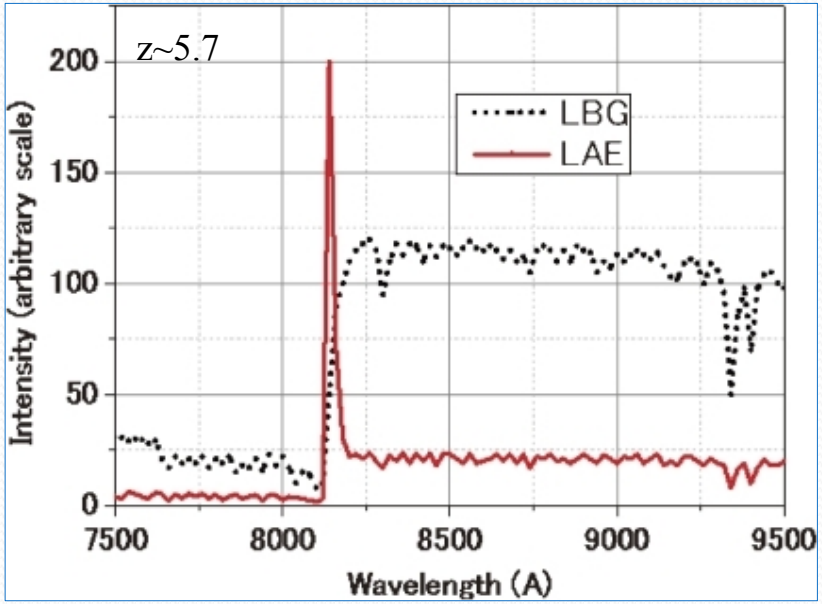
- **Reionization** epoch still not completely understood. Approximately between **z~15-5.5** (Fan+2006, Robertson+2010).

- Looking for **Lyman alpha emitters (LAEs)** and **Ly break galaxies (LBGs)**.

  - Traditionally, LAEs have been detected using narrow band filters while broad band filters are used to detect LBGs.

  - Many previous studies but very few good spectroscopy yet.

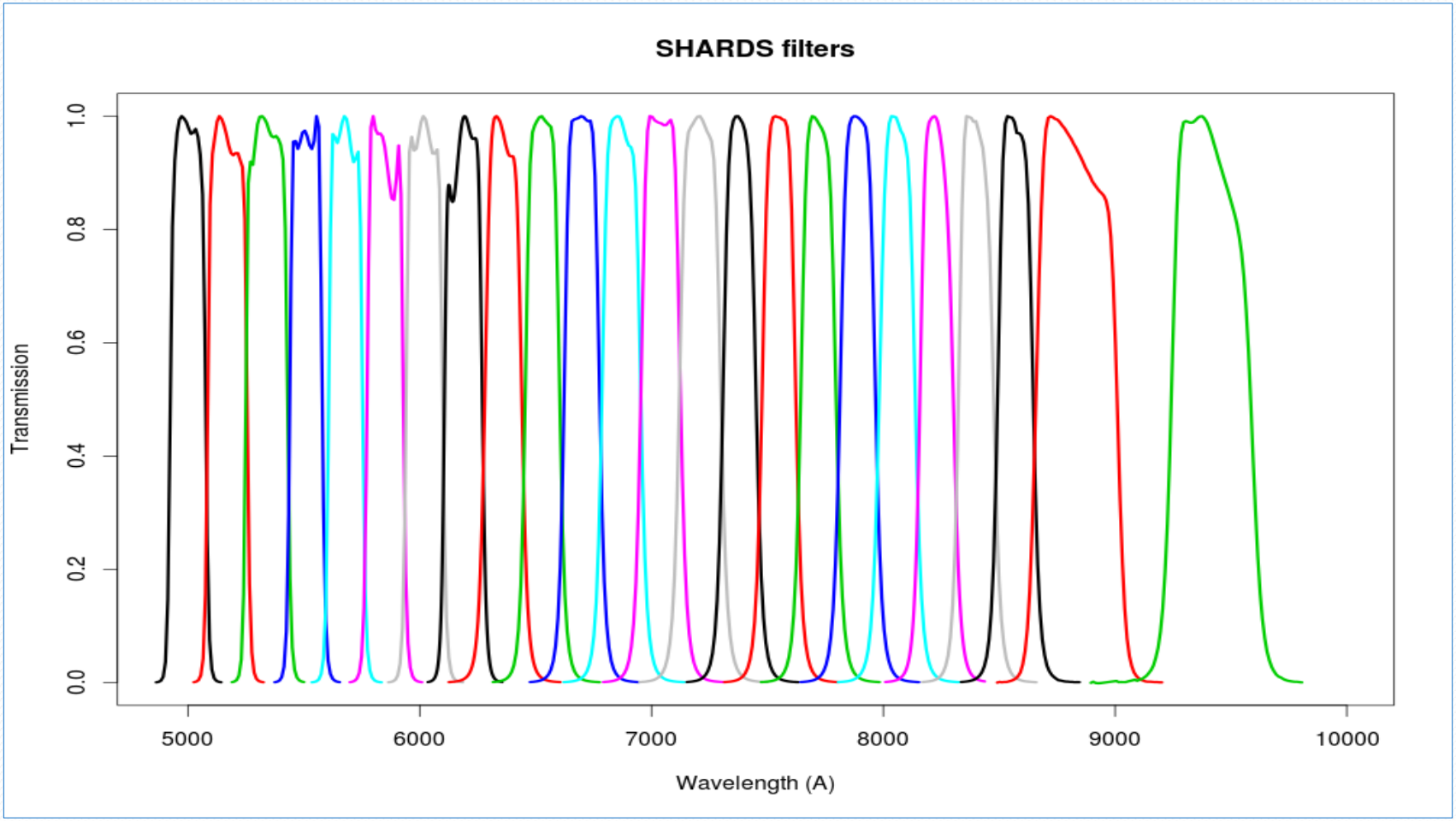
(Steidel+2003, Shapley+2003, Giavalisco+2004, Malhotra+2004, Fan+2006, Ouchi+2010, Bouwens+2015, Cassata+2015, Sobral+2017…)



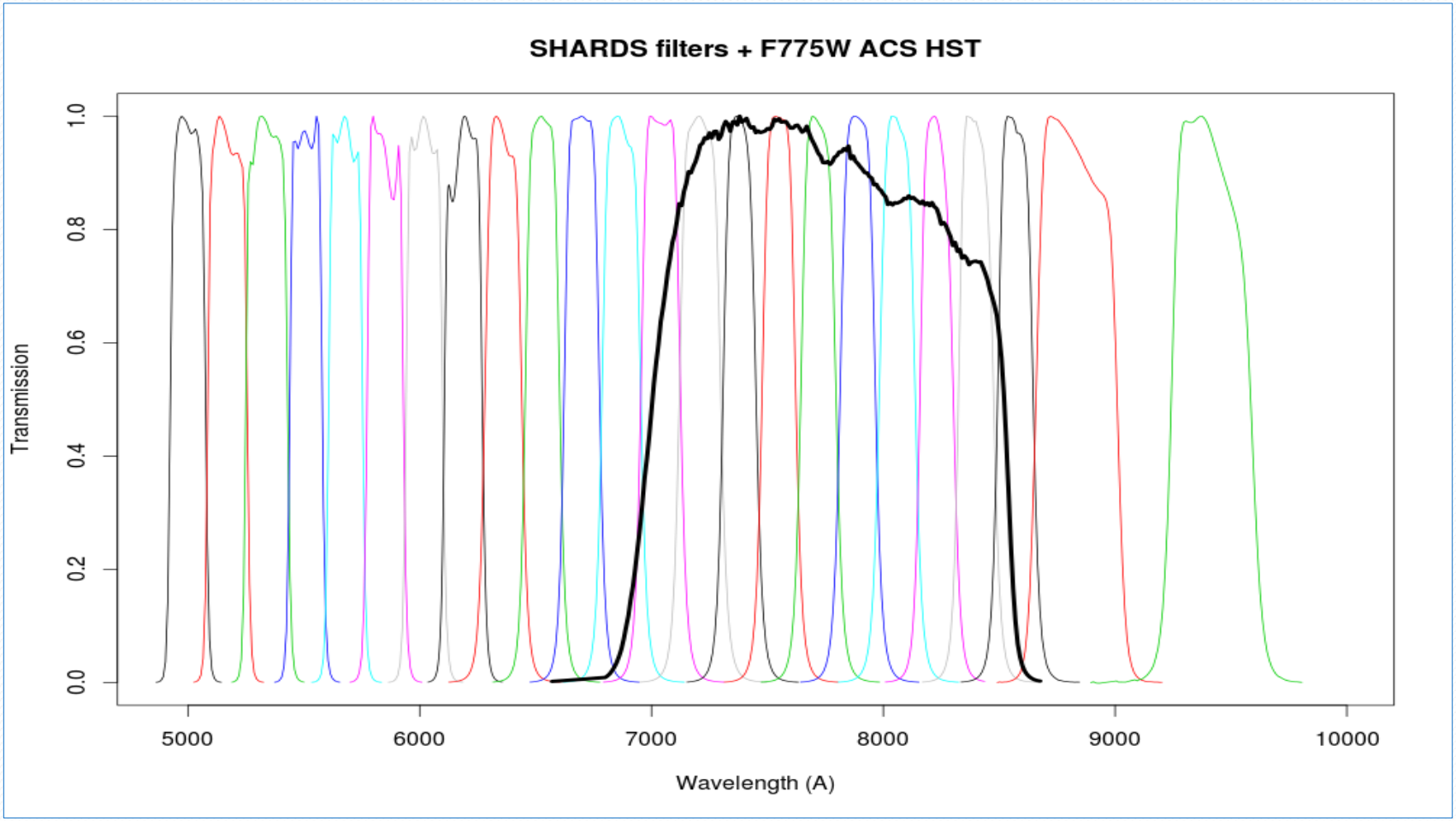
Working data

- Survey for High-z Absorption Red and Dead Sources (**SHARDS**) survey.
  - ESO/GTC large program (200h) that surveyed ~130 arcmin^2 in the **GOODS-N field** (P.I. Pablo Pérez González, UCM).
  - 25 GTC/OSIRIS medium band filters (~17 nm FWHM) in the range 500-950 nm.
  - Seeing~**0.9 arcsec**; 3σ magnitude~**26.5-27.0 AB**.
  - We can sample **3.3<z<6.8**.
  - Filter narrowness allows us to better detect Lyα line or drop-out sources. We can detect both LAEs and LBGs at the same time.
- **Rainbow database** (UCM partnered with UCSC) helps us to obtain ancillary data from other surveys (Subaru, WIRCam, WFC3, ACS, IRAC and GALEX).

Working data



Working data

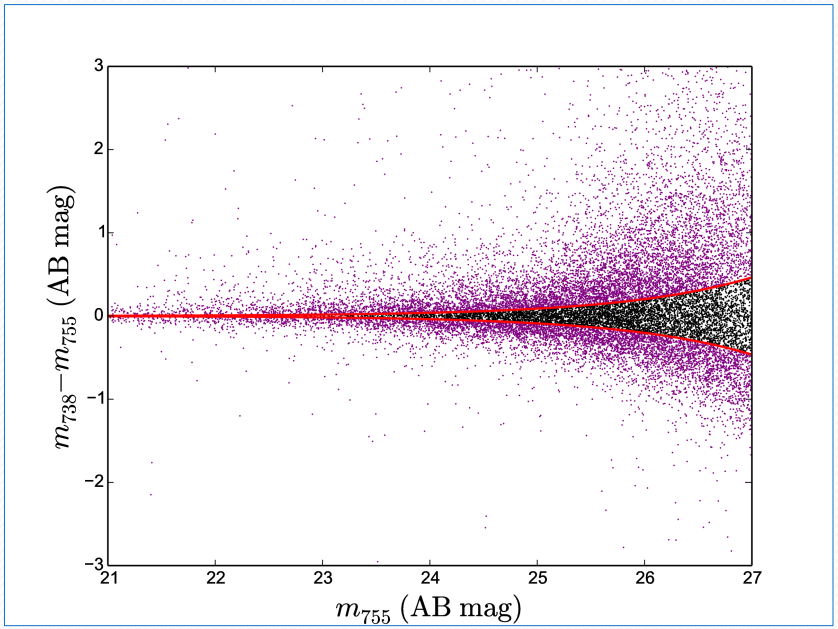


Sample selection

- Used previous available **EAZY photo-z fitting with SHARDS data** (Barro, in prep.)

- Study of the dependence of the magnitude with its error.

- Color-Magnitude diagrams to know the minimum emission change we can reliably consider at each magnitude.

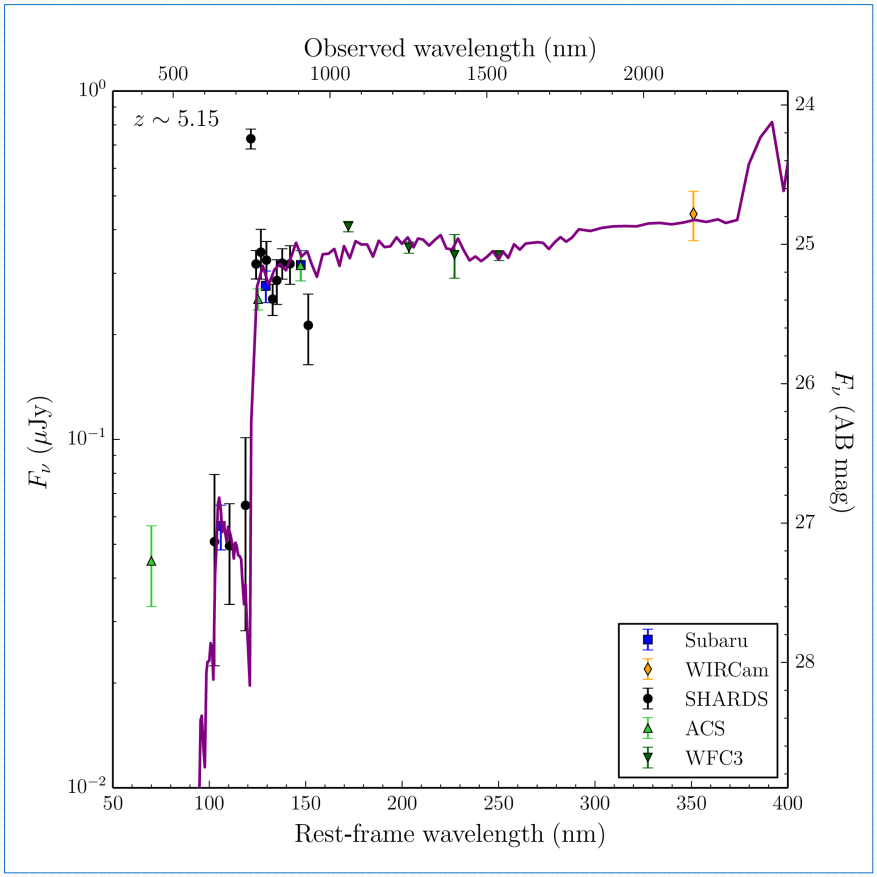


- Trimming our effective search field to avoid borders effects.

- With that information, we defined our own **selection criteria**:

$$\delta \leq \langle m_{j<i} \rangle - m_i \wedge \Delta m_i < \langle m_{j<i} \rangle - m_i,$$

Sample selection



- Development of another code to isolate objects emitting only in a few filters.

- **SEDs creation using Rainbow data**.

- **Visual check and first interlopers rejection**.

- Whole process iterated several times changing the δ value.

Interlopers rejection

- Main interlopers in this kind of study:
  + **Lower z galaxies**. Wrongly identifying Balmer jump as the Lyman break.
  + **Cool M, L, T stars** with high slopes can simulate an emission drop.

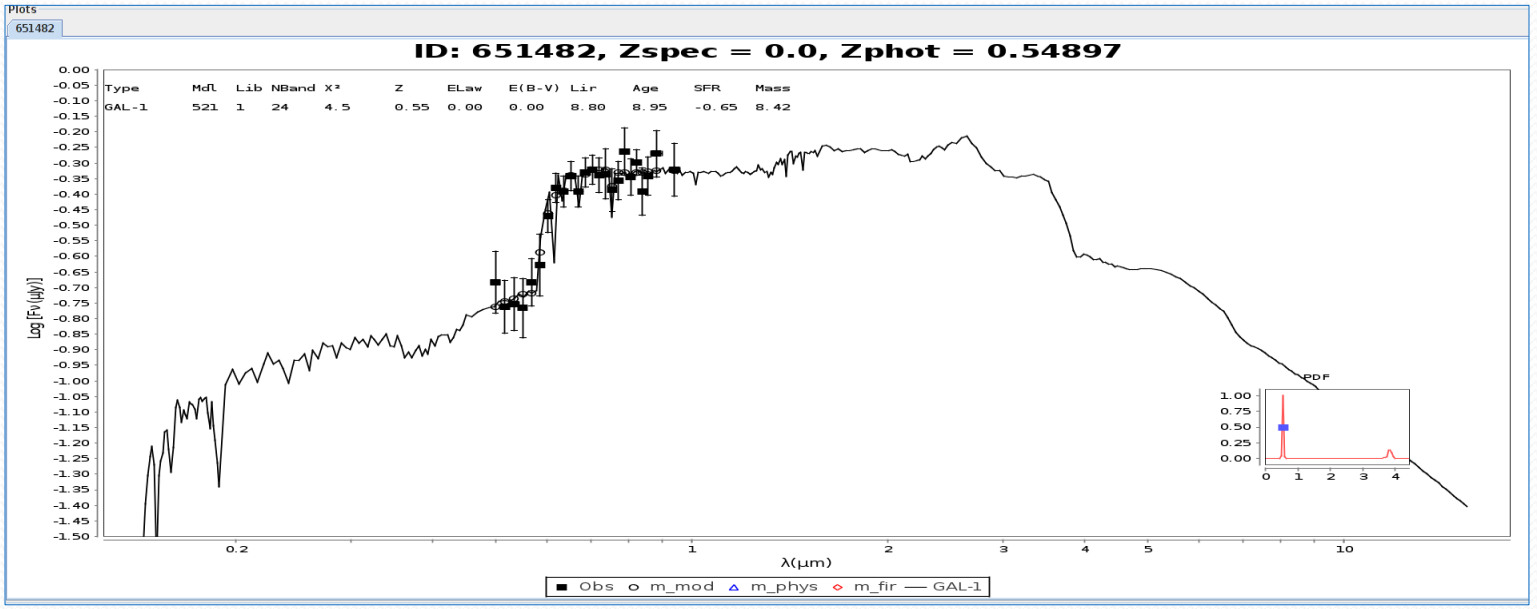
- Fitted theoretical spectra using the code *Le Phare* (Arnouts+1999; Ilbert+2006).
  + Galaxy models from Coleman+1980; Kinney+1996; Bruzual & Charlot 2003 and others.
  + Stellar models from Bohlin+1995, Kinney+1996, Chabrier+2000, with special care in cold M, L, T stars from Burgasser+2004.

Interlopers rejection

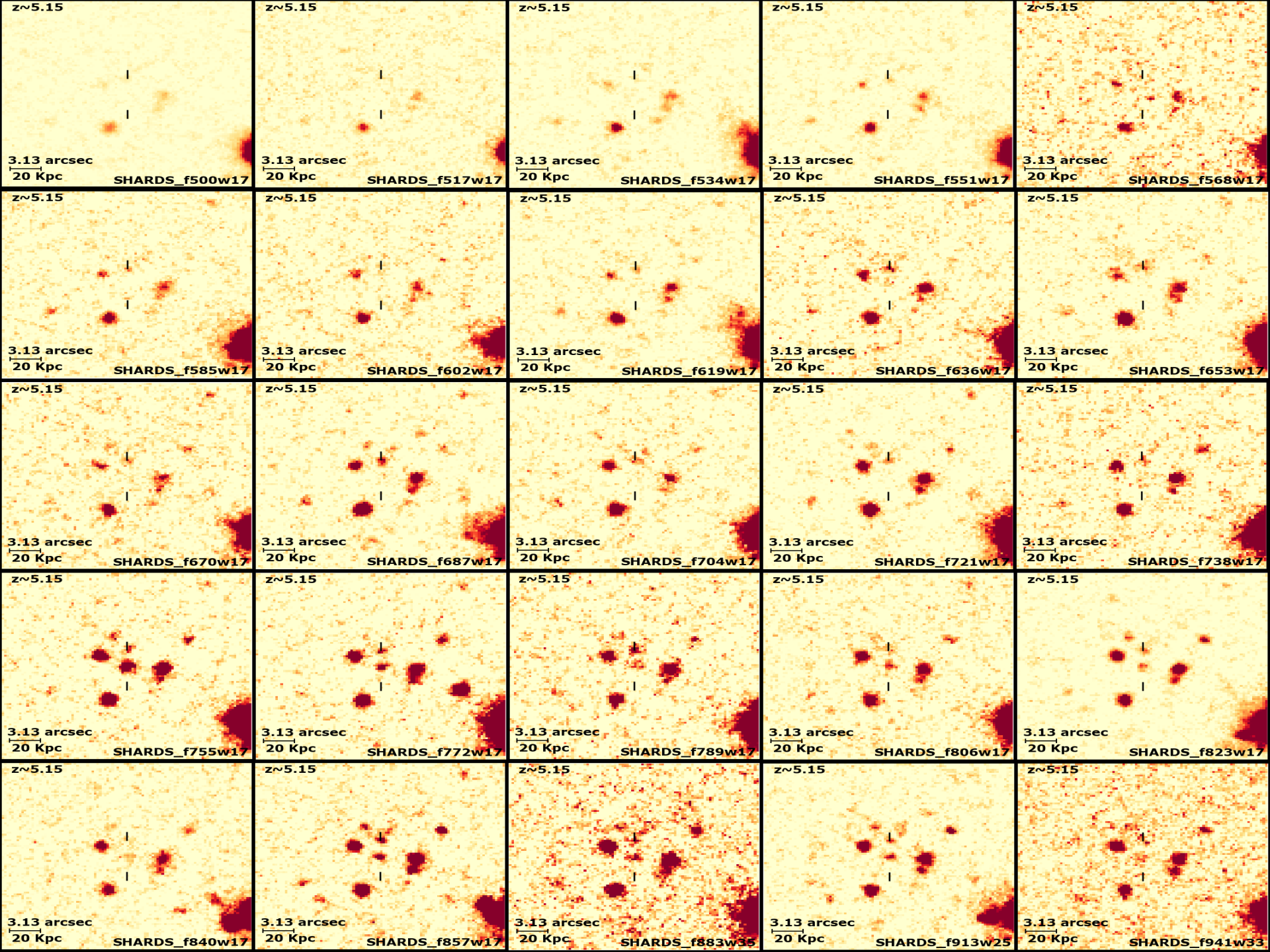
- Only **12 out of 644** well fitted candidates **were lower z interlopers**.

- None of the candidates was a star. Multi narrow/medium-band advantage.

- Not good χ^2 for all candidates. We still estimate **around ~2% of interlopers** in our final sample.



Final sample: 1558 high-z sources, separated in 1030 no emission LBGs, 404 LAEs/LBGs and 124 pure LAEs.

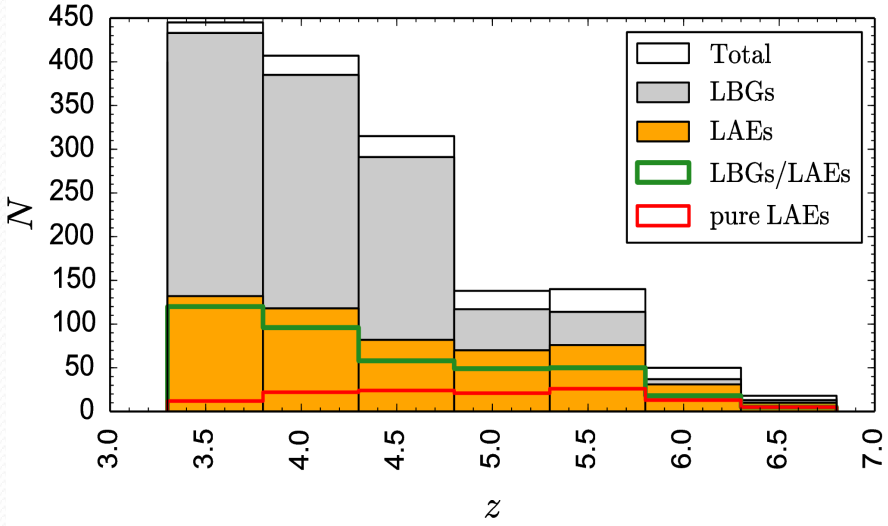

z~5.15
3.13 arcsec
20 Kpc
SHARDS_f500w17
SHARDS_f517w17
SHARDS_f534w17
SHARDS_f551w17
SHARDS_f568w17
SHARDS_f585w17
SHARDS_f602w17
SHARDS_f619w17
SHARDS_f636w17
SHARDS_f653w17
SHARDS_f670w17
SHARDS_f687w17
SHARDS_f704w17
SHARDS_f721w17
SHARDS_f738w17
SHARDS_f755w17
SHARDS_f772w17
SHARDS_f789w17
SHARDS_f806w17
SHARDS_f823w17
SHARDS_f840w17
SHARDS_f857w17
SHARDS_f883w35
SHARDS_f913w25
SHARDS_f941w33

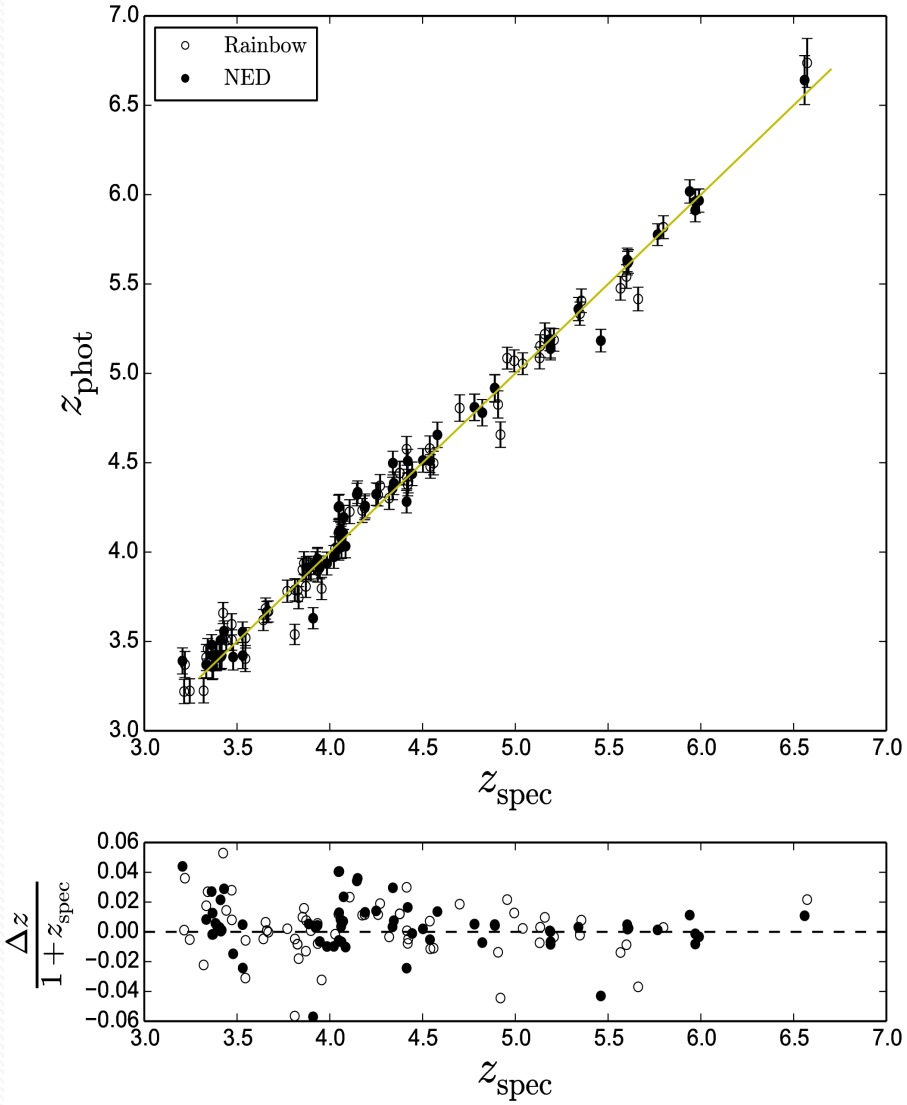
Redshift distribution

- Redshift calculated through the **observed Ly break** wavelength.

- Typical error of ±0.07.

- **Really good comparison with the spectroscopic z** available in Rainbow and NED.



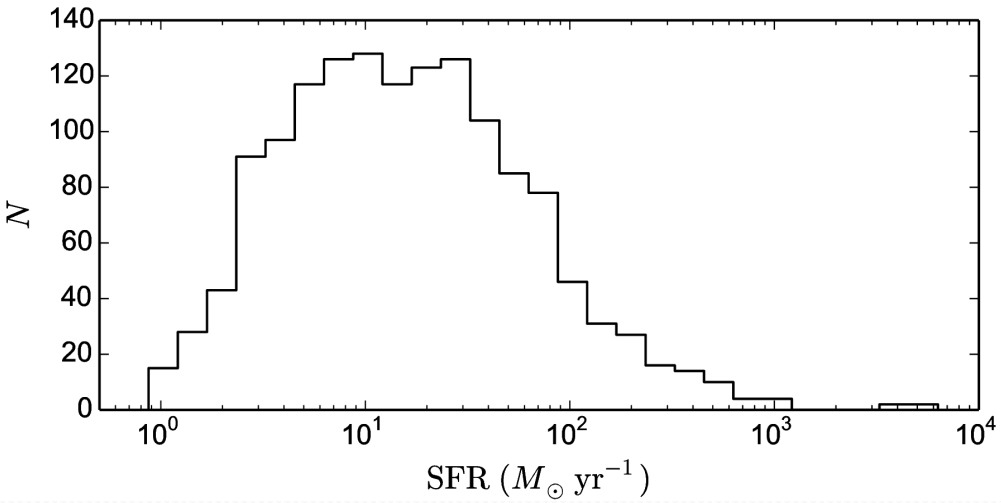


SFRs

- Calculated through L(Lyα) (Kennicutt+1998) and L_{1500} (Madau+1998).

- Dust correction through UV slope (Calzetti+2000).

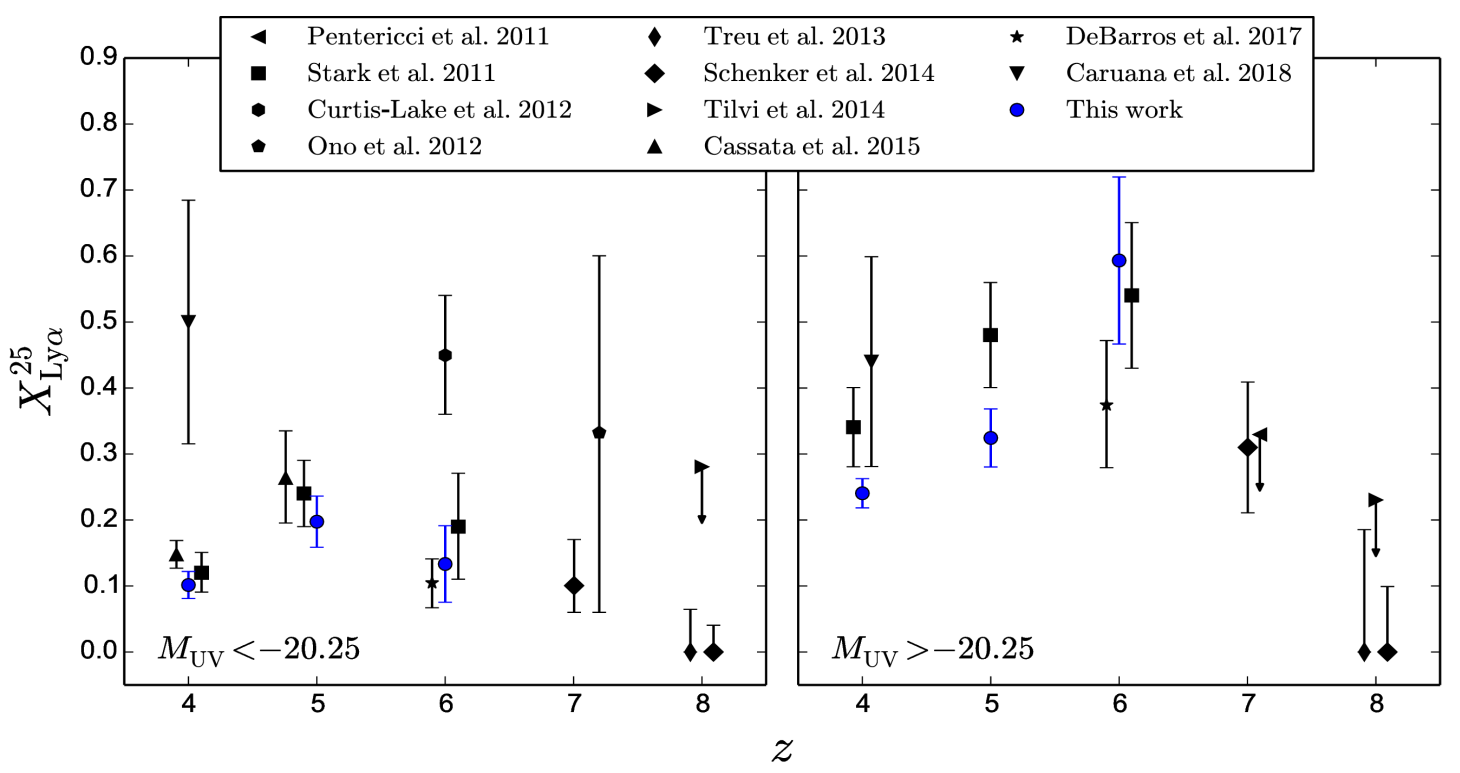
- Mean β values: -1.85±0.49, -1.98±0.57, -2.19±0.66
  z=4, z=5 z=6
  Consistent with previous studies (*e.g.*, Dunlop+2012).



- Mean SFR ~ 58 M_{sun} yr^{-1}

EWs

- Decreasing fraction of objects with rest-frame Lyα EW>25 Å beyond z~6. Probably related with intergalactic HI abundance in that epoch of the Universe.



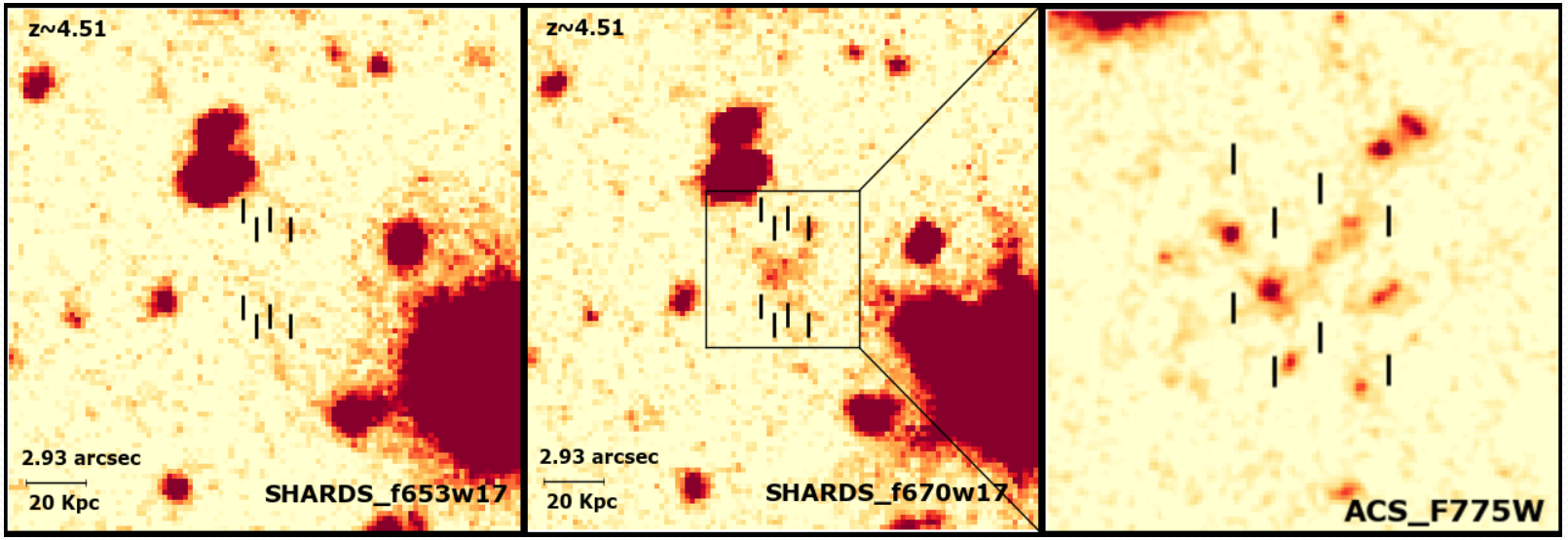
Grouping

- Looking for possible **neighbors**: Close in the images and close in z.

- Find 202 candidates (~13% of the sample) forming **92 compact groups**: 79 pairs, 10 trios, 2 quartets and a sextet.

- Most of them separated by distances below 30 ckpc.

- **No special relation with z nor SFR**.



Grouping

- **GOODS-N z=5.198 overdensity**.

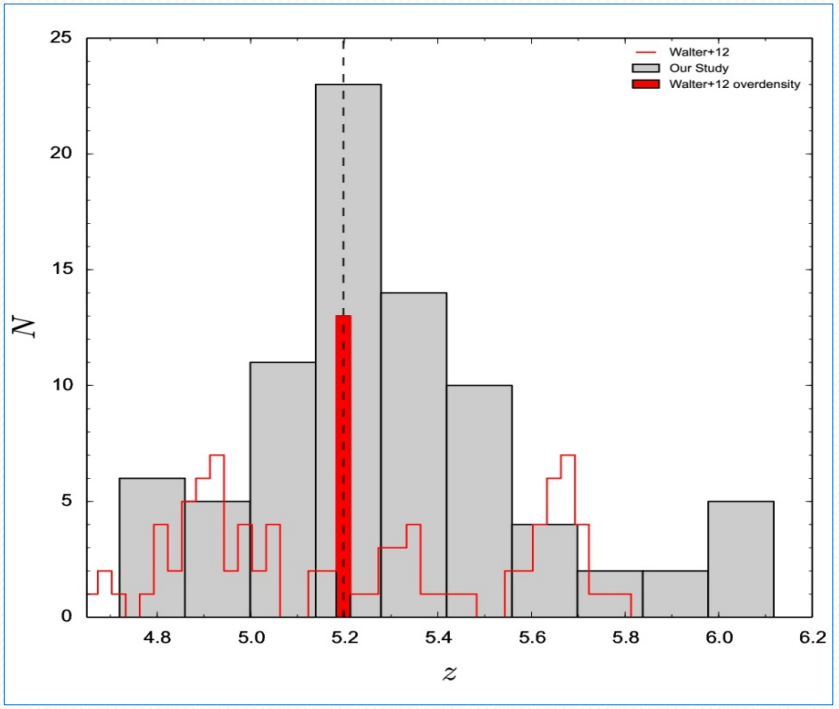
- Walter+2012 already reported 13 objects at that z with Δz=0.015.

- **We found 44 additional candidates** that can belong to that overdensity **within our z error** (±0.07).

- Granted Q1 MOS with OSIRIS/GTC to confirm.

- If confirmed, this proto-cluster would be **one of the richest beyond z=5**.

- Could it be an ionization bubble of ~3 Mpc radius?



Comparison with previous studies

- Compared the selection with last big high-z survey made with HST broad band filters in Bouwens+2015.

- B15 detect 3455 LBGs within our z range in GOODS-N.

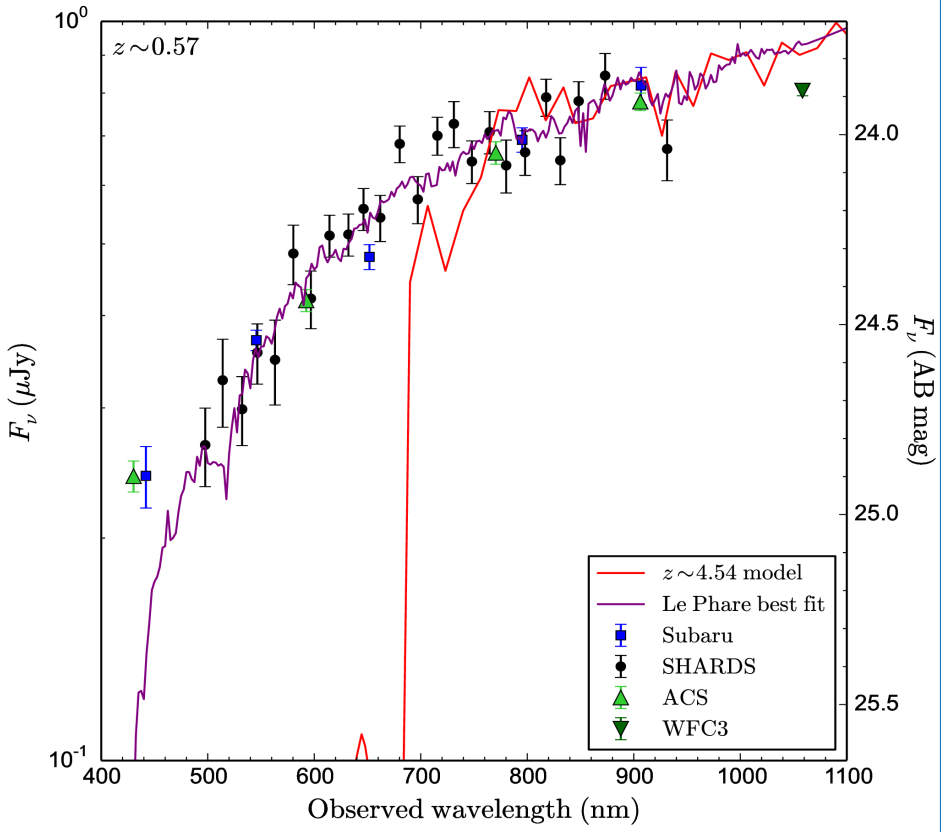
- We miss candidates because of three main reasons:

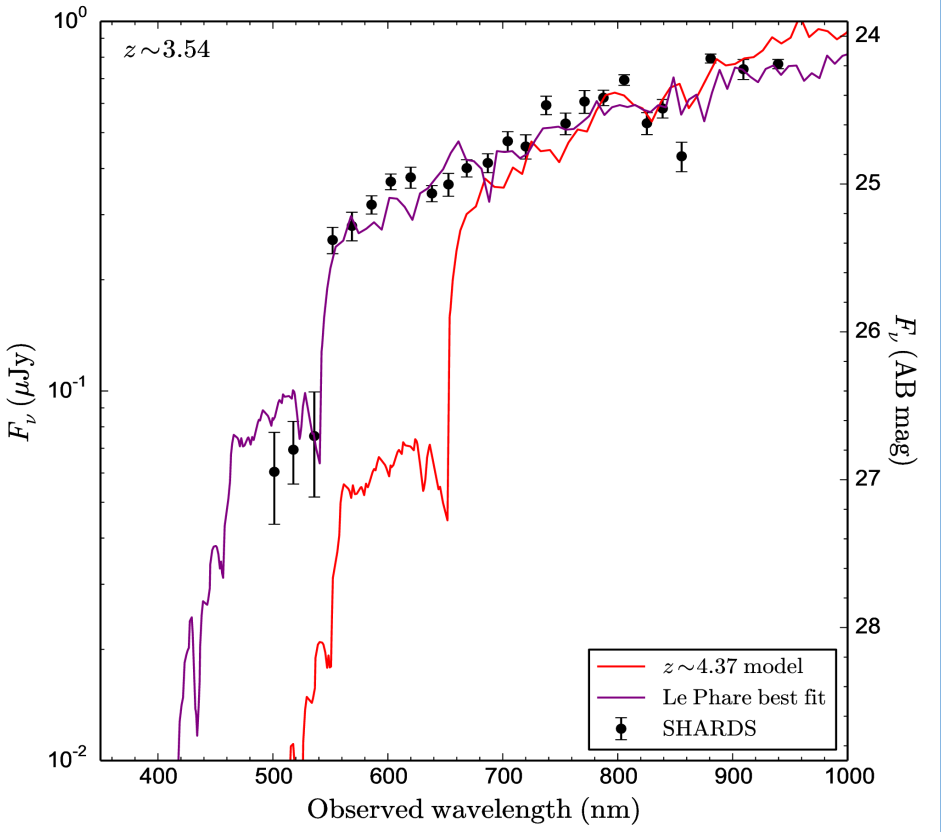
  + A bit **smaller field** of search.

  + **Magnitude limit.** ACS and WFC are deeper than SHARDS. 90% **completeness** of our sample **at m_{1500}~25.87 AB**.

  + **Spatial resolution** of a ground-based survey. Some objects SEDs can be **contaminated by neighbor** emission.

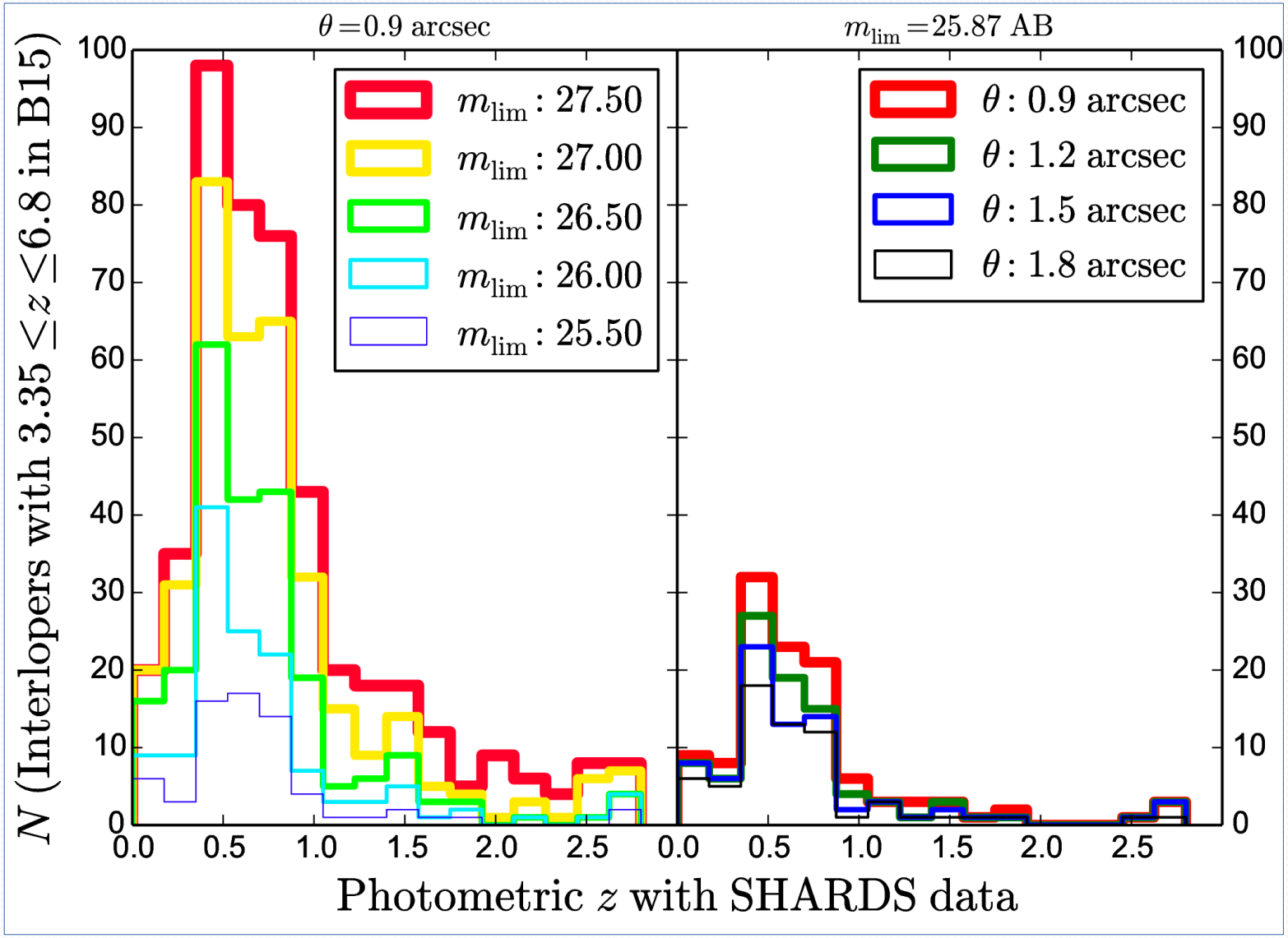
- Considering all these effects we **should still detect 575** LBGs from B15 sample, out of which **we only detect 460.** What's happening with the other 115?





- **Around 20% low-z interlopers using broad band selection criteria** up to our completeness magnitude, quite above the previously estimated ~2-6% (Vulcani+2017). Presumably even more at fainter magnitudes.

- In addition, **~15% of the sample in common differ** from both ours and Barro's (in prep.) photo-zs **in more than Δz=0.3.**


θ = 0.9 arcsec
m_lim = 25.87 AB
m_lim : 27.50
m_lim : 27.00
m_lim : 26.50
m_lim : 26.00
m_lim : 25.50
θ : 0.9 arcsec
θ : 1.2 arcsec
θ : 1.5 arcsec
θ : 1.8 arcsec
N (Interlopers with 3.35 ≤ z ≤ 6.8 in B15)
Photometric z with SHARDS data
0.0
0.5
1.0
1.5
2.0
2.5
0
10
20
30
40
50
60
70
80
90
100

LFs

- **Good** characterization of the **exponential term** of the Schechter function.

- **Not enough** faint objects to sample the **potential term** of the Schechter function.

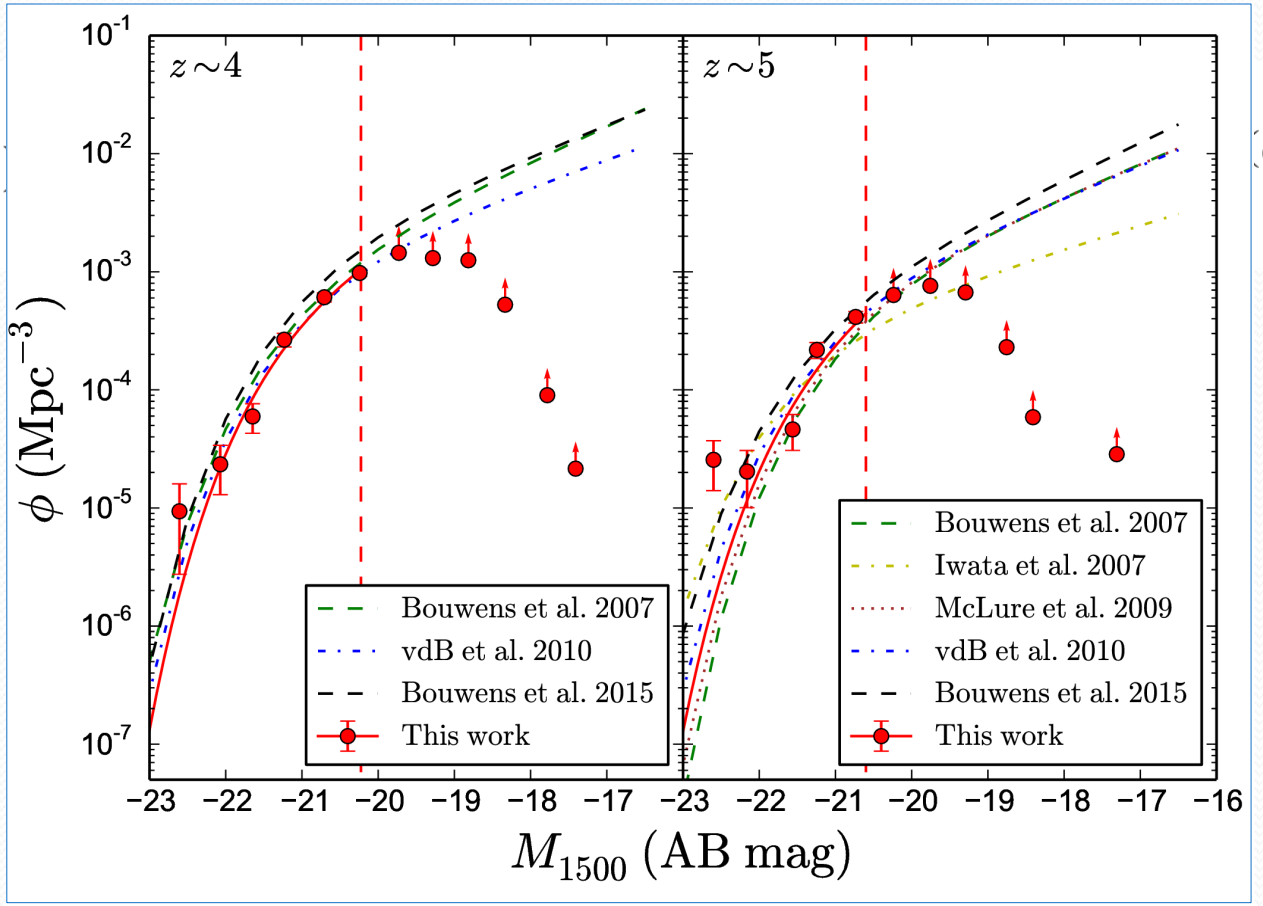
$$\phi(M) = \phi^* \frac{\ln(10)}{2.5} \times \exp[-10^{0.4(M^*-M)}] \times 10^{0.4(M^*-M)(\alpha+1)}.$$

z	M^*_{1500}	ϕ^* $(10^{-3}$ Mpc$^{-3})$	α [1]
4	-20.75±0.13	1.55±0.31	-1.64
5	-20.85±0.26	0.90±0.34	-1.64
6	-20.74±0.58	0.54±0.61	-1.79

LFs

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- **Not enough** faint objects to sample the **potential term** of the Schechter function.



An atractive idea

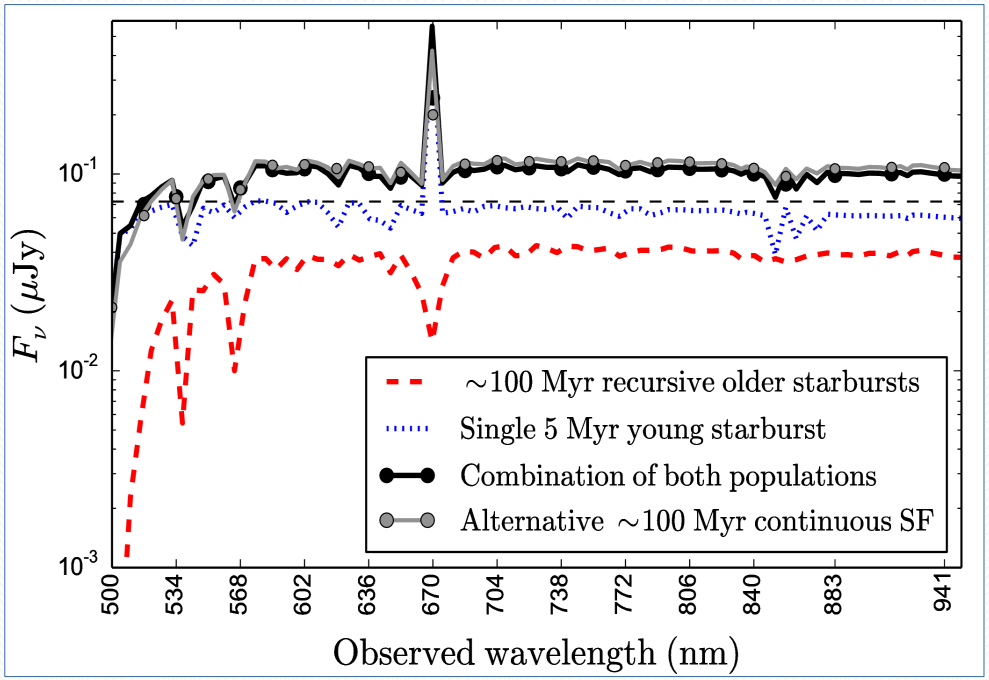
- Are **LBGs a more evolved stage of pure LAEs**?

- Results from single stellar population simulations with Starburst99 (Leitherer+1999, 2014):

  + **Lyα line quickly decays (~10-15 Myr)** → pure LAEs have to be young starbursts.

  + If no UV continuum detected in SHARDS, i.e. pure LAE → $M_{burst}<2x10^{8}\ M_{sun}$.

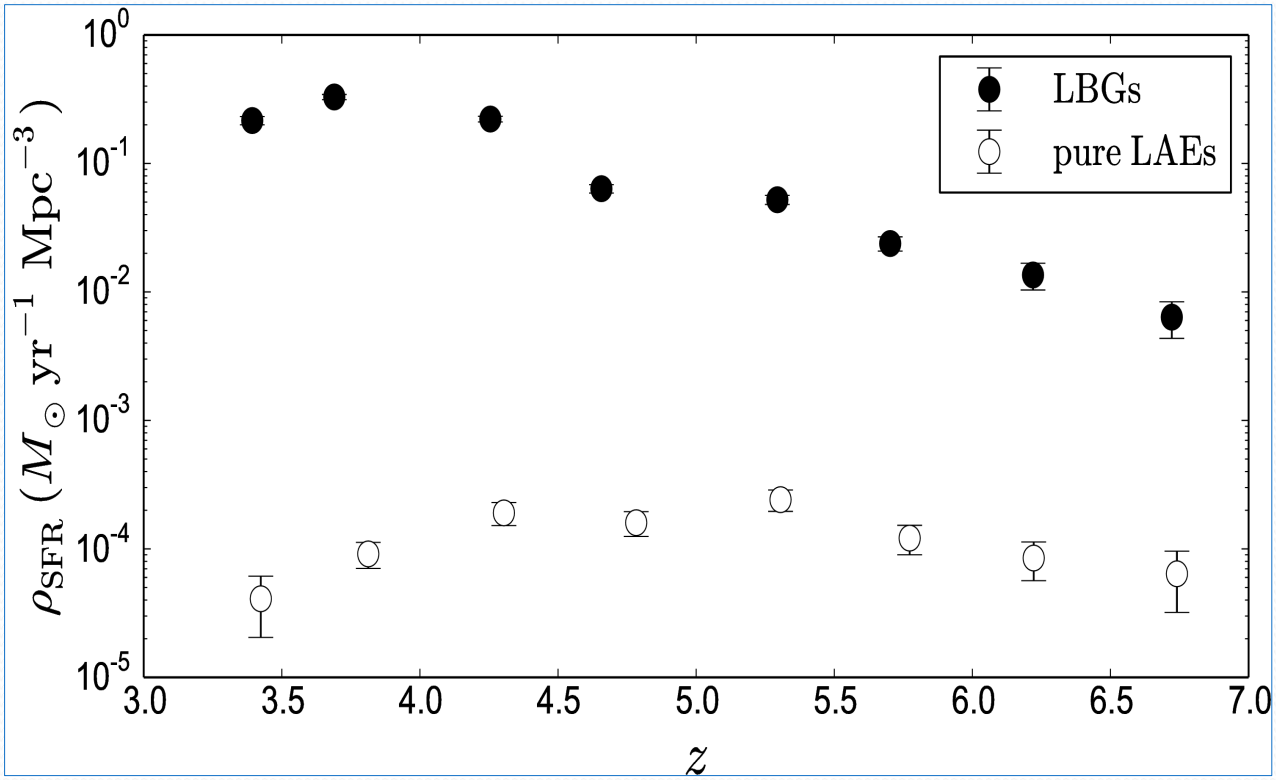
  + It is possible to reproduce a LAE/LBG combining an **old massive population** of the order of ~100 Myr **with a single young starburst** or just a **continuous SF** process along **~100 Myr**.



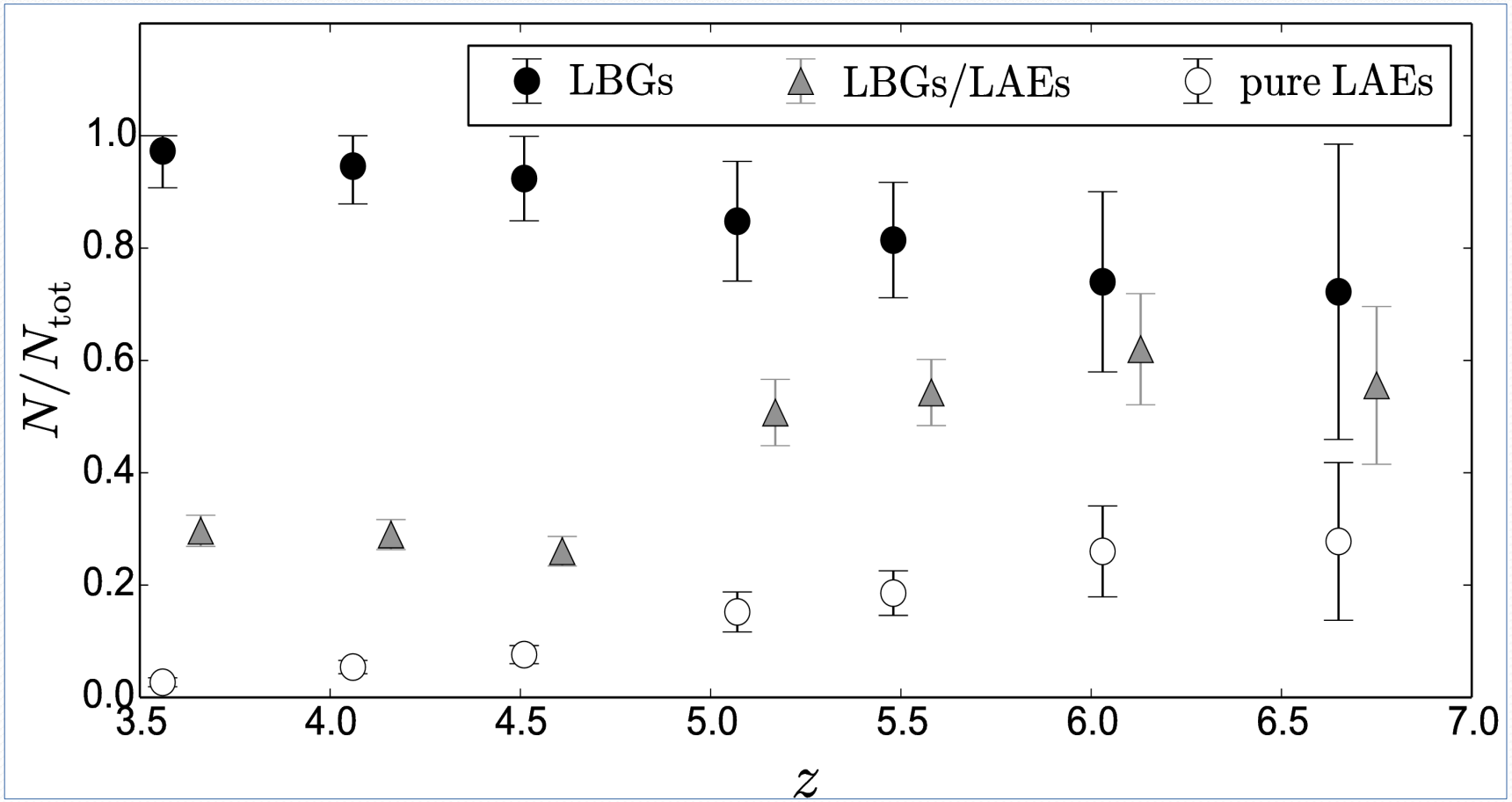
- Would **expect to see ~10 times more LBGs than pure LAEs**, which matches what we observe.

N(LBGs)/N(pure LAEs) = 11.6

- This hypothetical evolution scenario also makes sense with our z, SFR and EW distributions. But is it physically reasonable?



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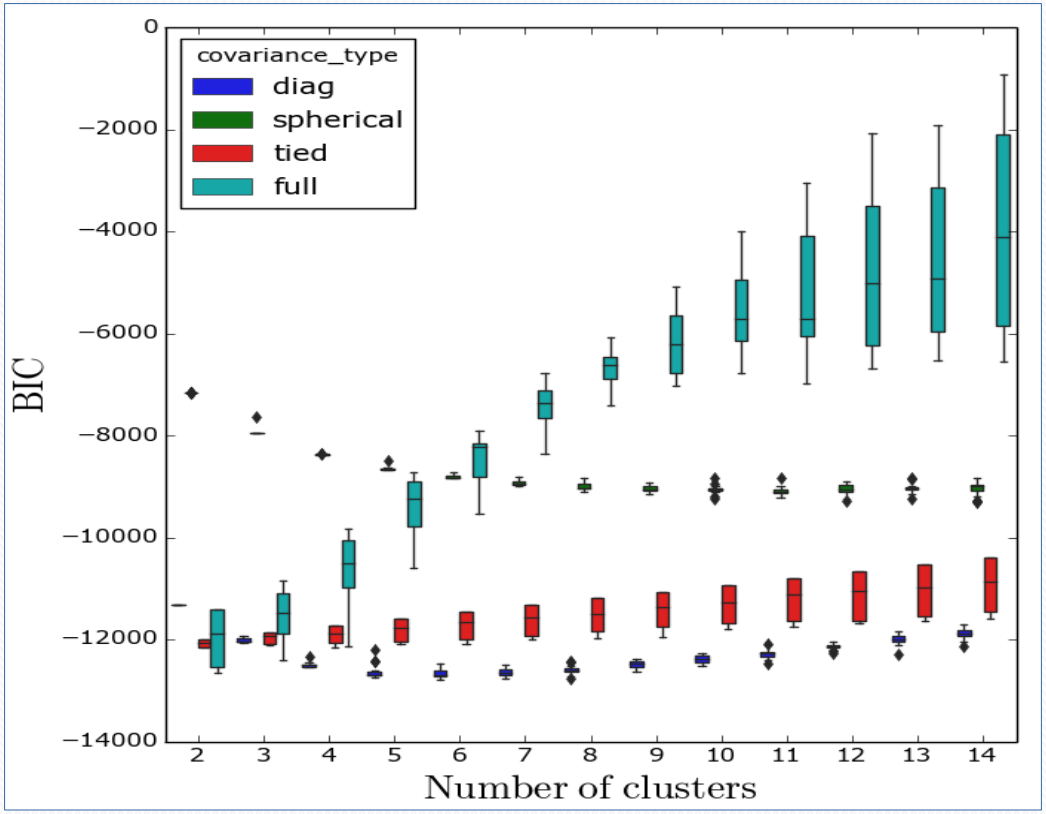
Machine learning with our SEDs

- **Gaussian mixture** clusters search.

- Division in three z groups. z~4, 5, 6.

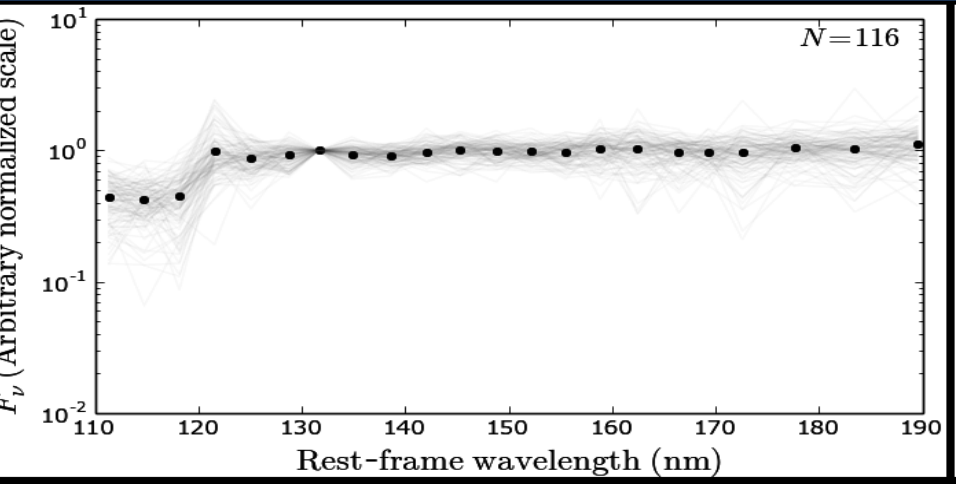
- Interpolation to set the SEDs to the exact same rest-frame wavelengths.

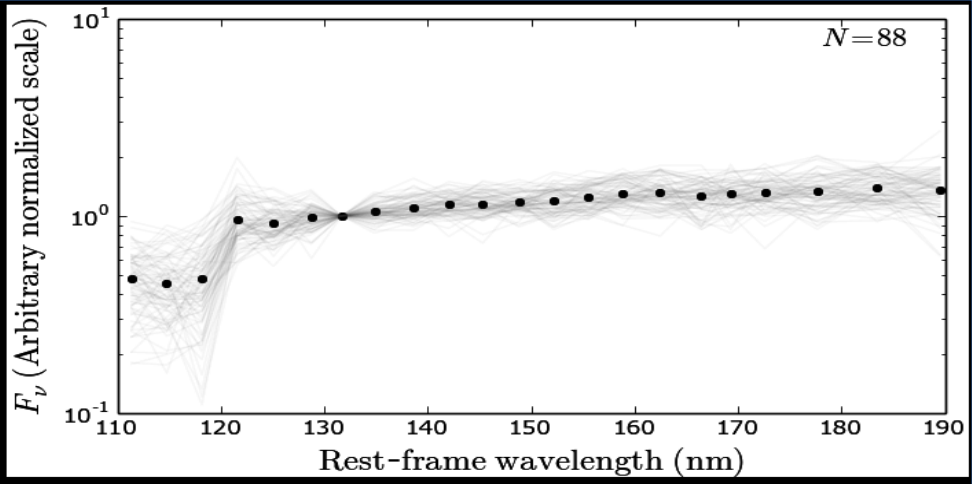
- Normalization to the UV continuum.

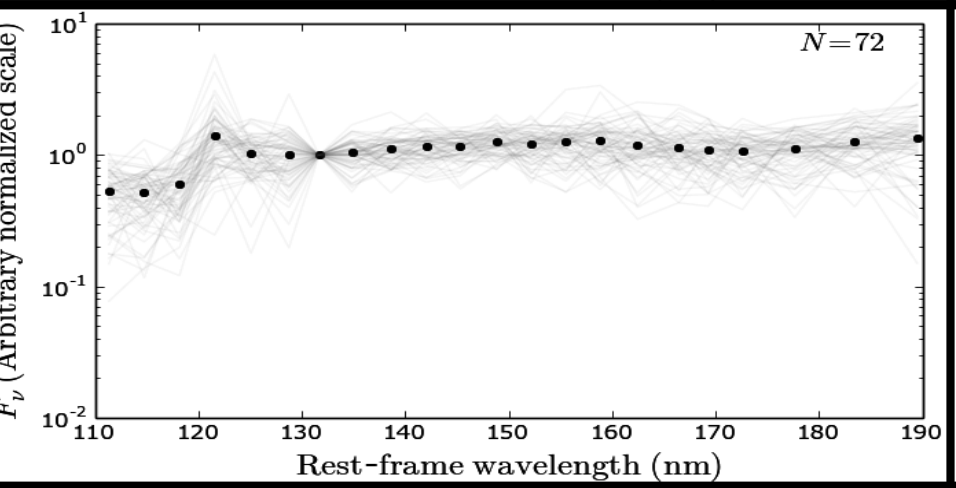


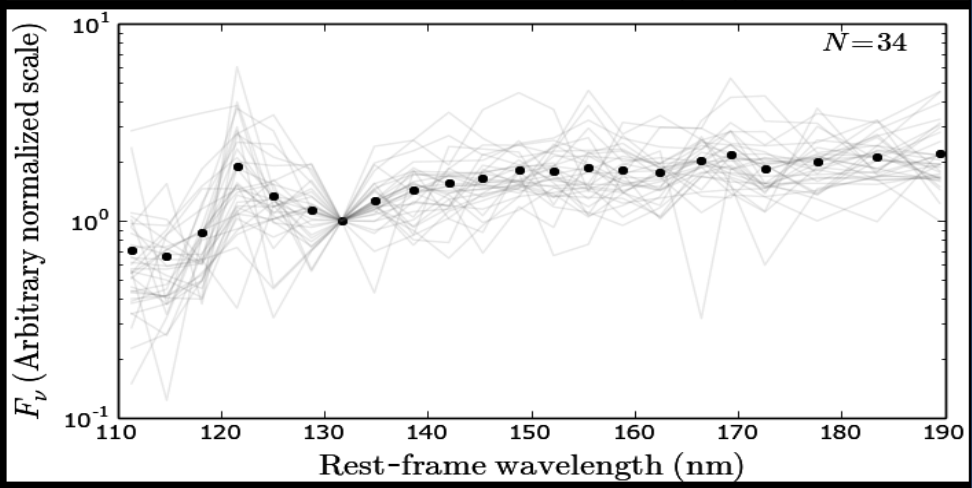
- Running the models for a large number of clusters.

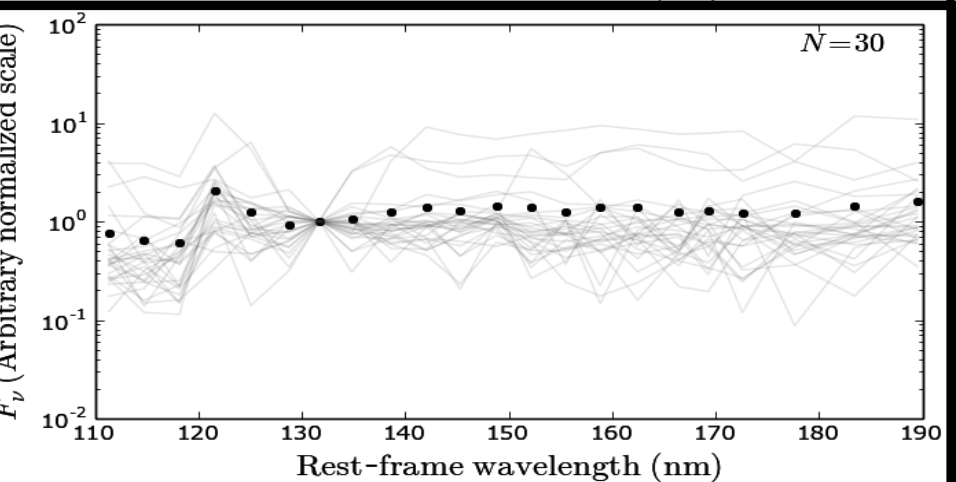
- Looking for the models with the **lowest BIC** and the **highest silhouette**.


N=116
F_ν (Arbitrary normalized scale)
Rest-frame wavelength (nm)


N=88
F_ν (Arbitrary normalized scale)
Rest-frame wavelength (nm)


N=72
F_ν (Arbitrary normalized scale)
Rest-frame wavelength (nm)


N=34
F_ν (Arbitrary normalized scale)
Rest-frame wavelength (nm)


N=30
F_ν (Arbitrary normalized scale)
Rest-frame wavelength (nm)


WORK IN
PROGRESS

Thanks!