



$L\alpha$ blobs: signposts of clustering in the early universe

Povilas Palunas
(Carnegie Observatories/ Magellan)

James Colbert (Spitzer SC)
Paul Francis (MSSSO)
Claudia Scarlatta (Spitzer SC)
Harry Teplitz (Spitzer SC)
Gerry Williger (U Louisville)
Bruce Woodgate (NASA/GSFC)



Lyman α Blobs

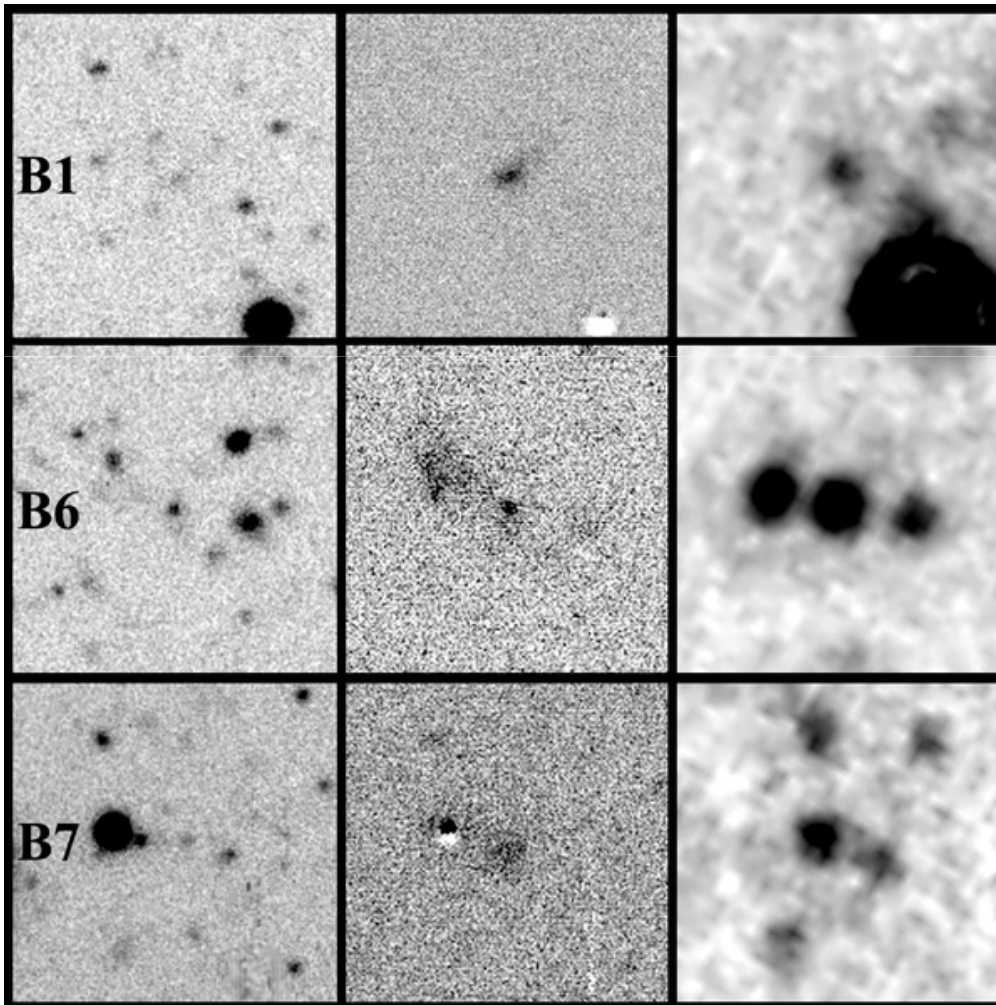
- Ly α blobs represent a new class of high redshift object characterized by:
 - high emission line flux ($>10^{-15}$ erg cm $^{-2}$ sec $^{-1}$, $>10^{43}$ erg sec $^{-1}$)
 - high emission line equivalent width ($\gg 100\text{\AA}$ observed frame)
 - large angular extent ($> 10''$, 90 proper kpc)
 - Radio quiet ($<100\mu\text{J}$)
 - Associated with
 - Submillimeter sources (Chapman+2001, Geach+05, Beleen+08)
 - AGN (Bunker+03, Weidinger+05, Geach+05,06)
 - ULIRGS (Colbert+06...)
 - LBG (Matsuda+04, Scarlatta+09)
 - Nothing (Nilsson+06)
 - high velocity internal motions (>1000 km sec $^{-1}$)
 - Associated with structures at high redshift with 5–10x overdensities.



Association with Clusters

- First discoveries targeted over-densities
 - Francis+96, Palunas+04
 - Near a cluster of damped Ly α absorbers $z\sim 2.38$
 - Keel+99
 - Near a radio galaxy $z\sim 2.39$
 - Steidel+00, Matsuda+04
 - Near an overdensity of Ly break galaxies $z\sim 3.09$
- First unbiased LAE surveys now emerging:
 - Gronwall+07 $z\sim 3.1$, Guaita+09 $z\sim 2.1$ MUSYC
 - Yang+08
 - Show strong clustering (See poster)
 - Matsuda+04 +unpublished
 - Preferentially observed in high density regions/ themselves clustered
 - Smith+

LAB Detections



- NB images 5 hours with Mosaic Camera on the Blanco 4m
- Spitzer MIPS 24 μ m
- B7 detected at 850 μ m with APEX /LABoCa



What Powers LABs

- Inflow/Shocks — Cooling Flow
 - Initial Galaxy Formation, “primeval galaxies”.
- Outflow/Shocks — Starburst Superwind
 - Next Stage of Galaxy Formation, metal enrichment of the ICM
- UV Illumination—AGN
 - Must be highly obscured
- Which it is remains a mystery.



B1 in detail

- Multiple optical–IR components observed with HST/Spitzer

- Chandra (20ks)

$$f_{0.5-7\text{keV}} < 10^{-15} \text{ erg cm}^{-2}\text{s}^{-1}$$

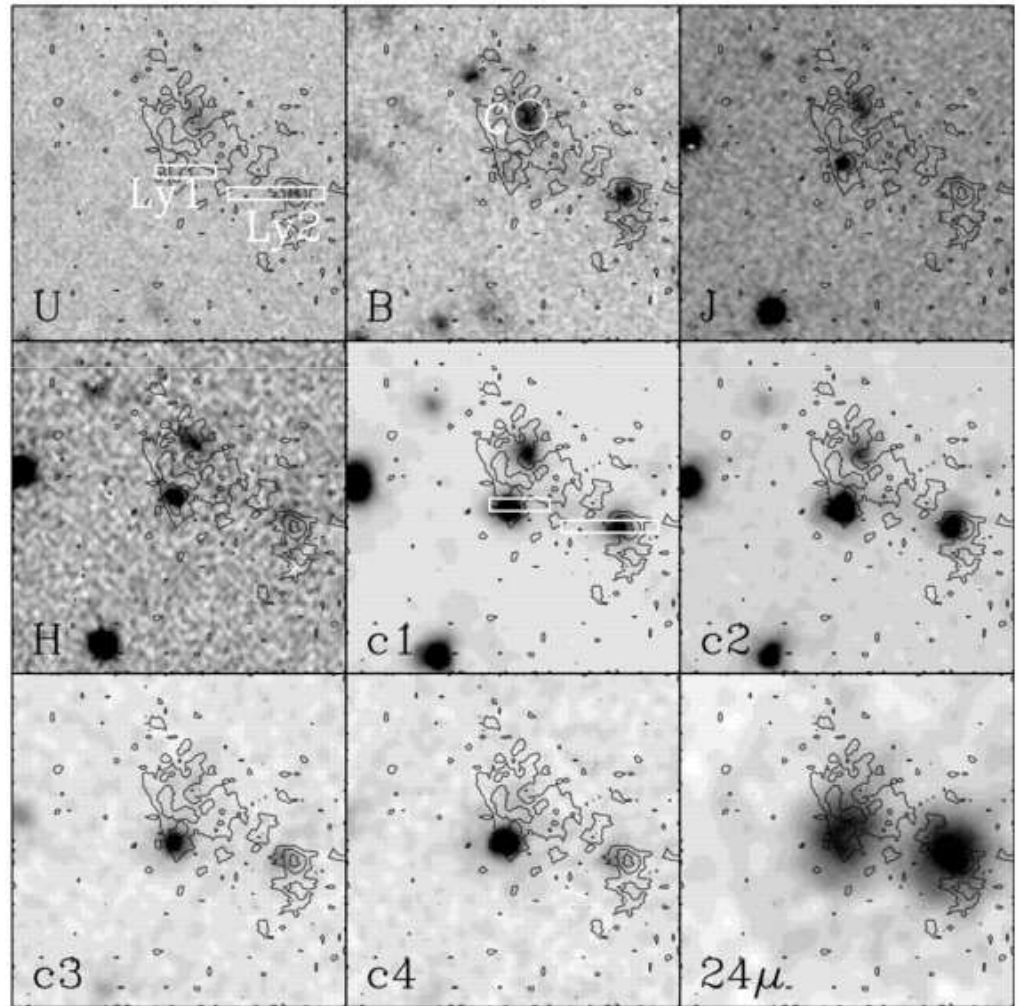
- APEX /LABoCa

- $f_{850\mu\text{m}} < 2.3\text{mJ}$

20"
160kpc

- B1a & B1b very red indicating evolved stellar populations

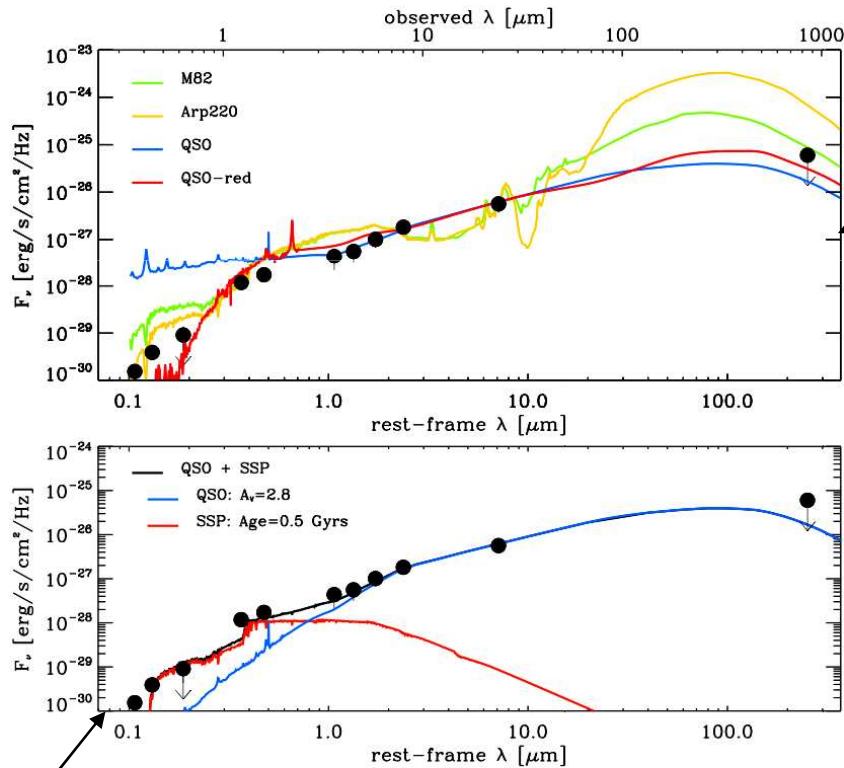
- B1c foreground $z \sim 0.82$



Scarlata+09

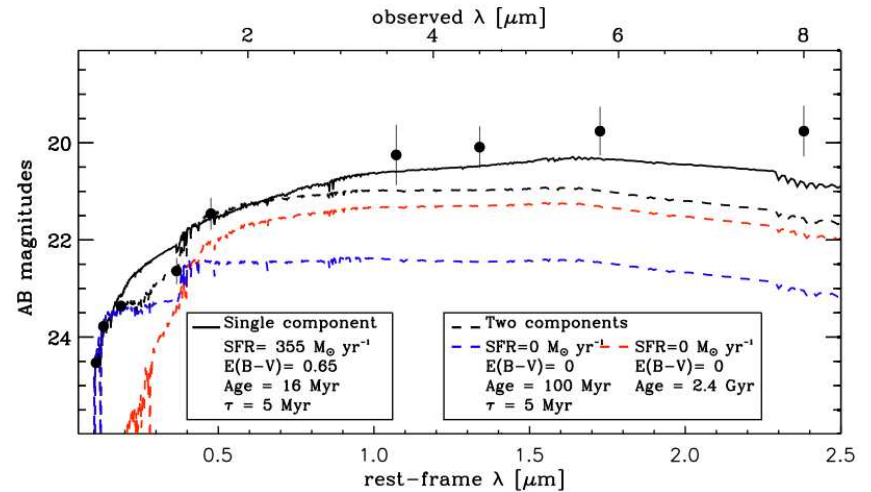
B1 SED fitting

B1a

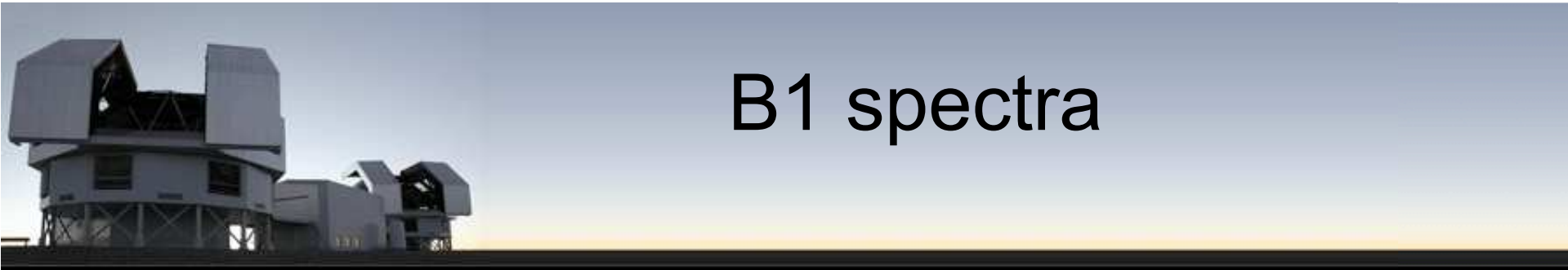


Assorted active & star forming sources: None fit well.
PAHs contribute at 10% to mid-IR

B1b- A star forming galaxy
Bright mid-IR dominated by PAHs



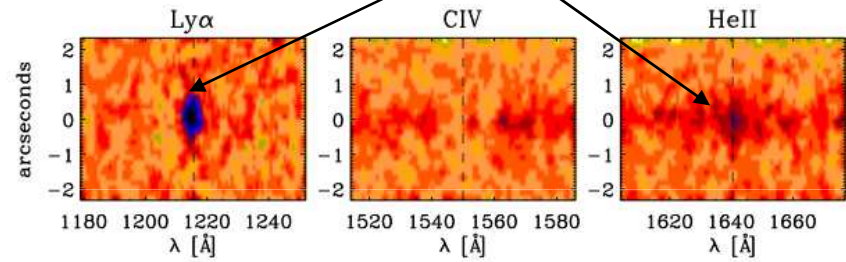
QSO ($A_v=2.8$) + 0.5Gyr stellar pop



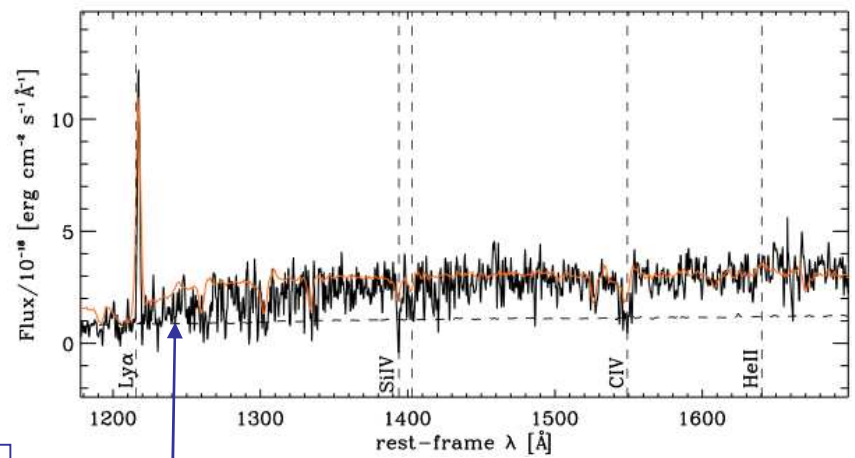
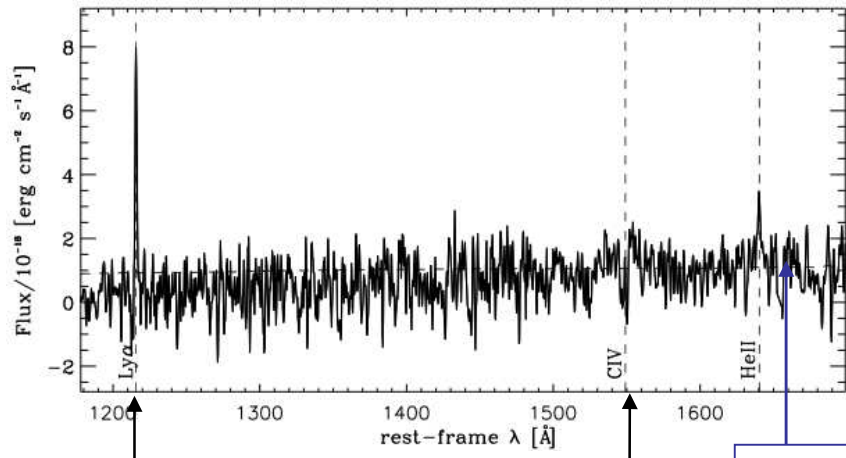
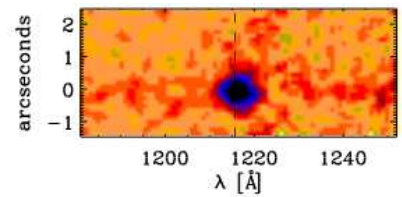
B1 spectra

Not extended along slit
so extent of HeII unknown

B1a



B1b- a Lyman break galaxy



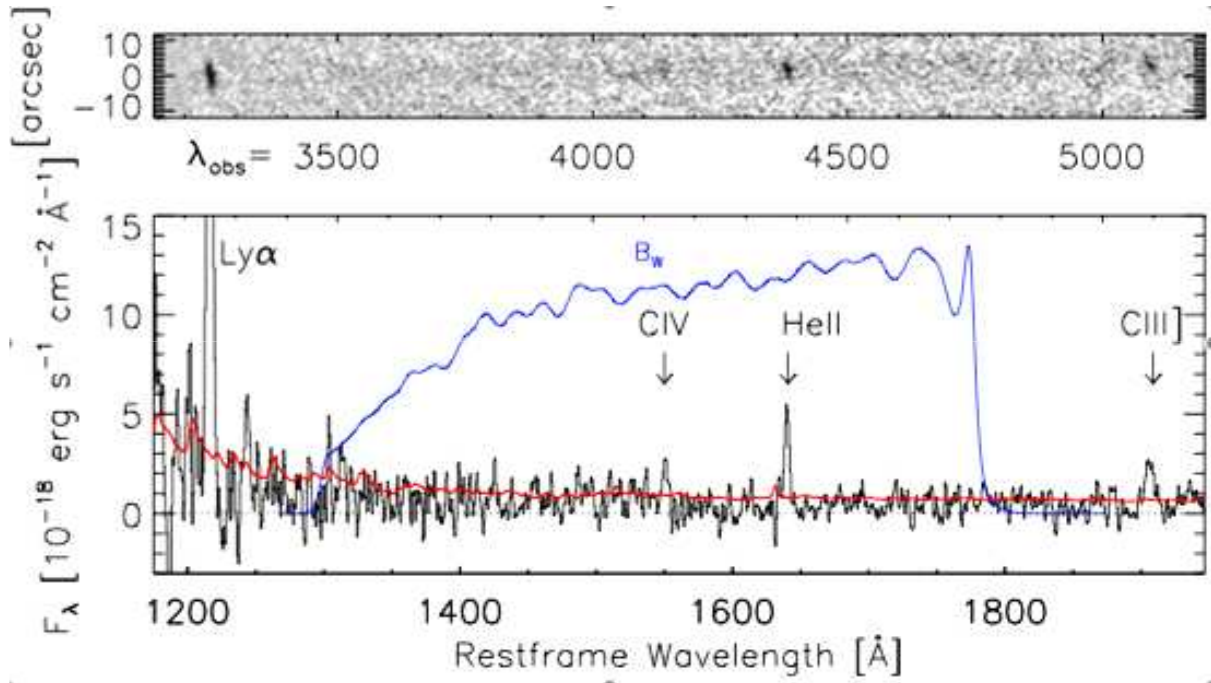
Narrow line

No CIV

1σ error



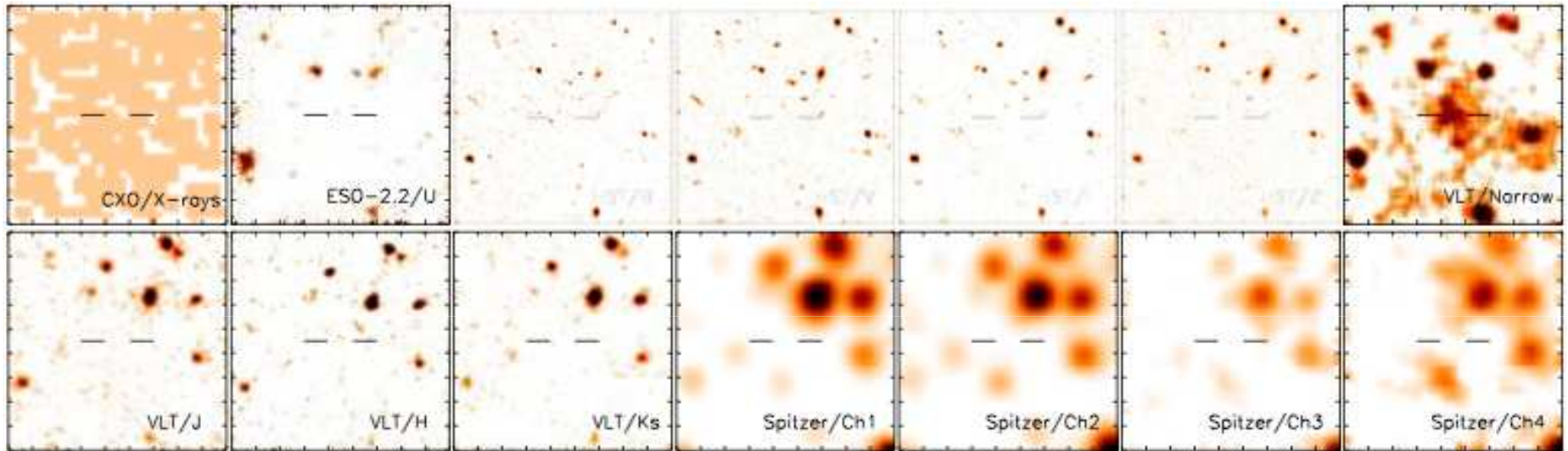
LAB zoo



- Selected based on extended flux detection in a broad band filter!
- $z \sim 1.7$

Prescott+09

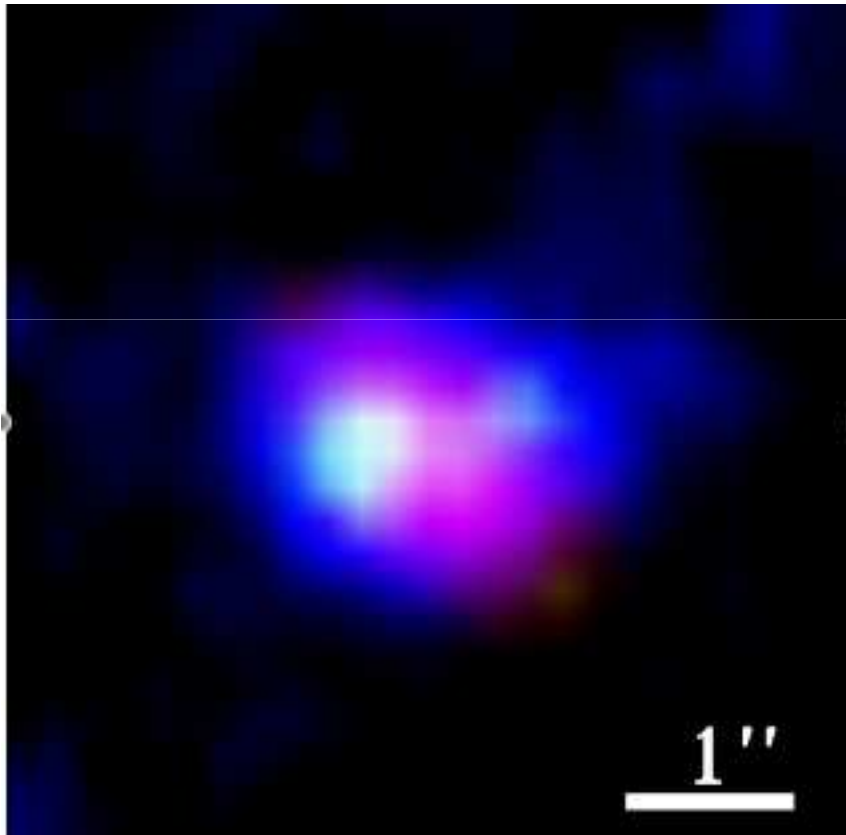
LAB zoo



- Nilsson+08 GOODS South $z \sim 3.16$
- No continuum counterparts!
- 24 LAE candidates 6.6' field

Nilsson+06

LAB zoo

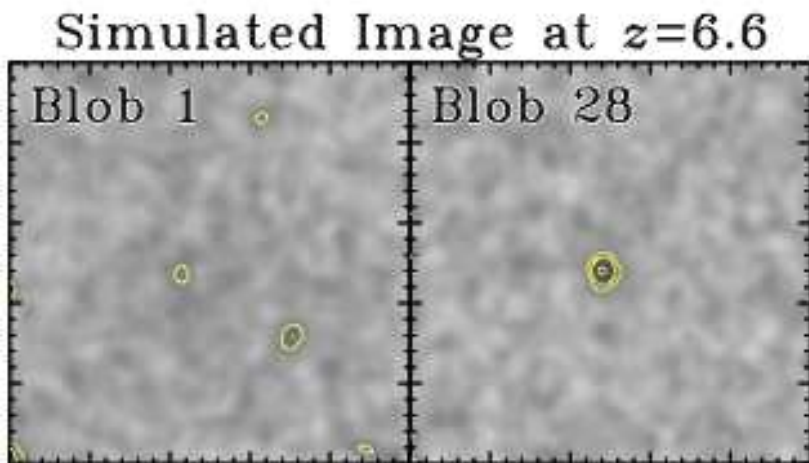
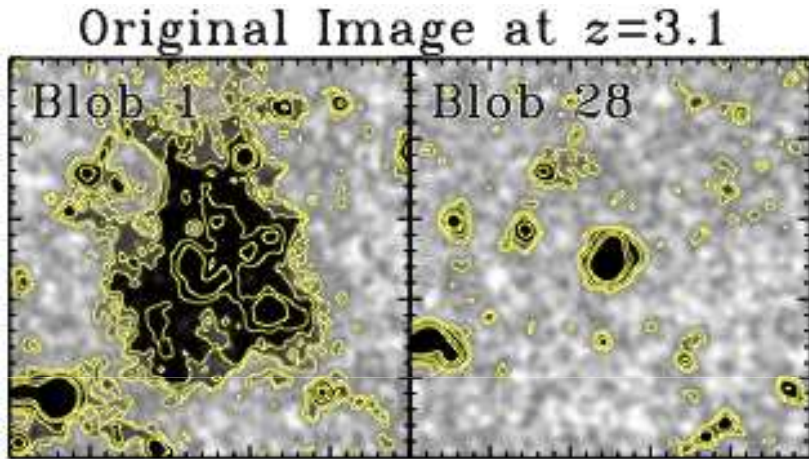


Ouichi+09

- Himiko $z \sim 6.6$
 - (SXD X survey)
- $f = 8 \times 10^{-17} \text{ erg cm}^{-2} \text{ sec}^{-1}$
- $L = 4 \times 10^{43} \text{ erg sec}^{-1}$
- Line Width = 250 km sec^{-1}
- Size $\sim 17 \text{ kpc}$

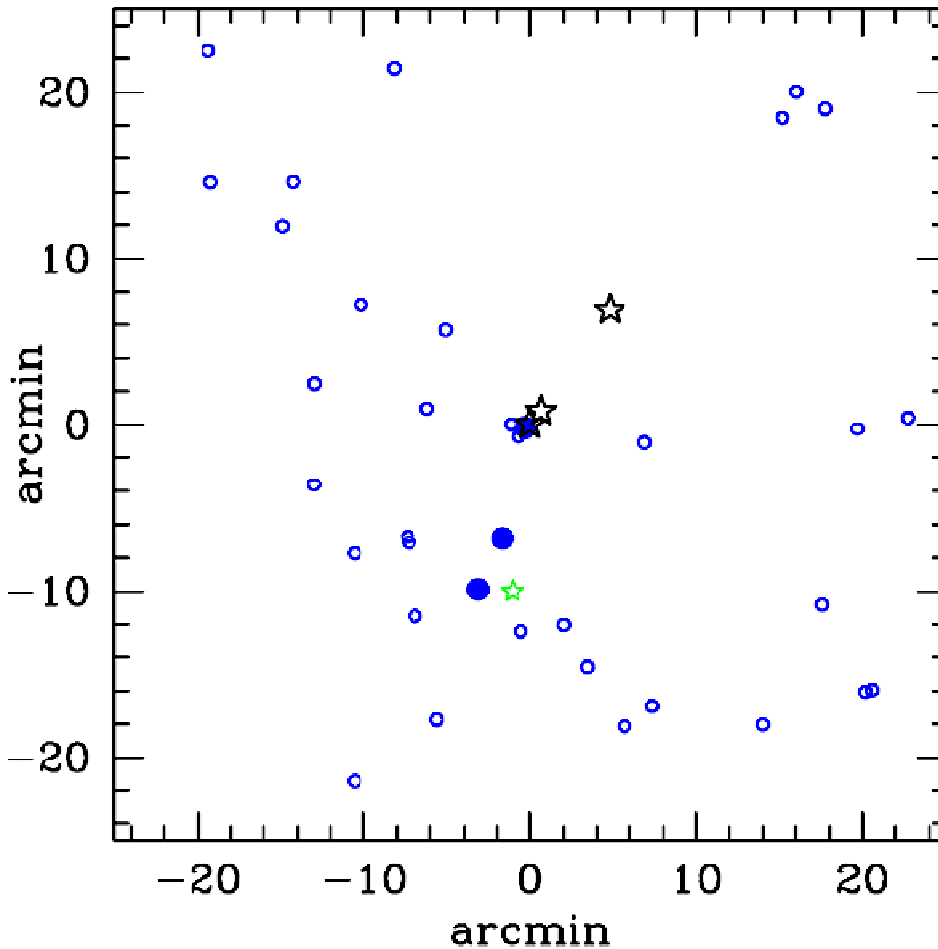
- 207 additional LAE candidates 1deg field

LAB zoo

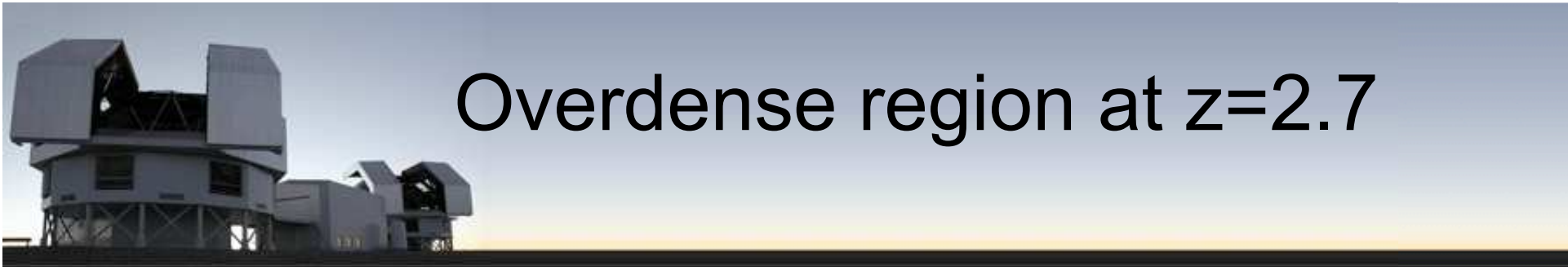


- Simulation of Steidel Blob at $z=6.6$
- The surface brightness dimming causes it to disappear.

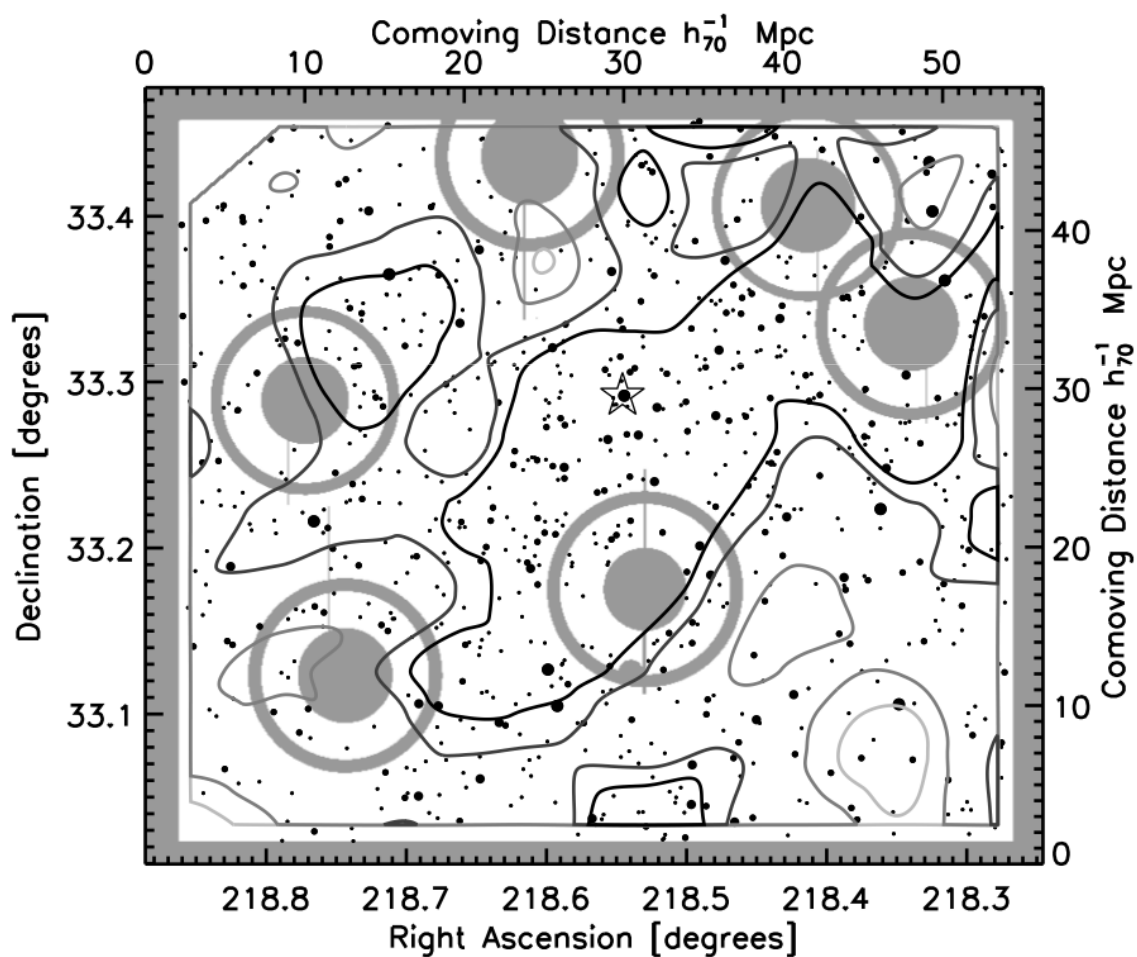
A filament of Galaxies at $z=2.38$



- Blobs associated with a large filament of galaxies.

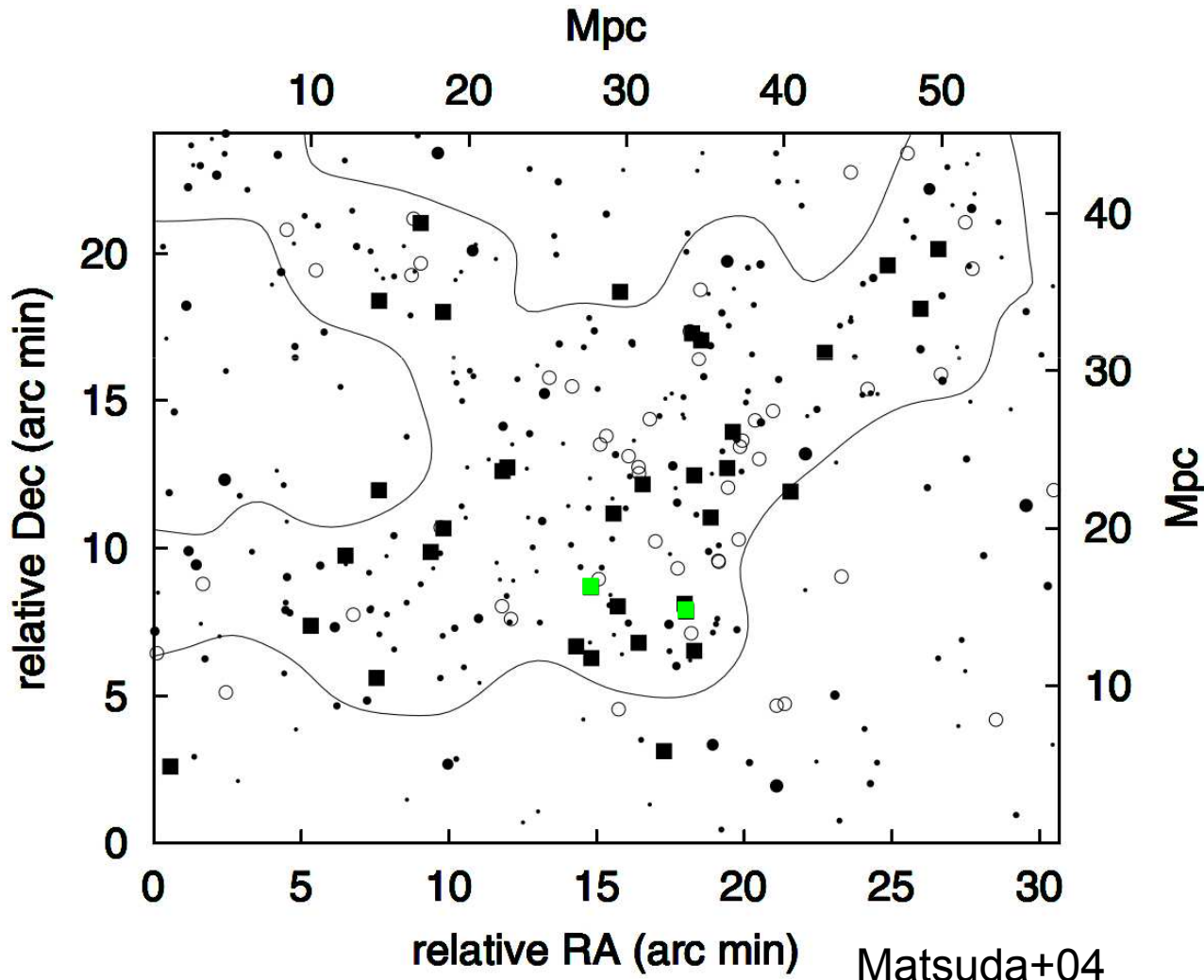


Overdense region at $z=2.7$



- LAB selected via Spitzer detection.
- Ly α follow-up shows overdensity of LAEs

A filament of galaxies at $z \sim 3.1$



SSA22 LABs

– follow up over
much larger field
not yet published.

See also poster
by Kousai



Where they aren't

- No Blobs detected in dense clusters
CL1054-0321 & CL0023+0423 at $z \sim 0.8$ Keel+09
 - Galex slitless spectroscopy limits of $(0.5-3) \times 10^{-43}$.
- Some 0.5-1 deg LAE surveys (covering a few hundred Mpc^3) have not detected blobs (or strong overdensities)
 - MUSYC (Gronwall+07, Gawiser+07) $z \sim 3.1$



Ly α Blobs : Clustering

- Extremely rare yet most often found in overdensities in targeted and now blank field
- LABs are often composed of multiple components
- LABs themselves are clustered



Conclusions

- Ly α Blobs are extremely bright objects that appear to trace the densest known regions in the early universe.
- A relatively shallow LAB survey could be used to select high redshift protoclusters
- Redshift $z \sim 2-2.5$ is an ideal place to search
 - $(1+z)^4$ is not as daunting
 - Protoclusters are more evolved
 - Well positioned for infrared follow-up