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Physical Properties of Lyα Emitting Galaxies from 2<z<3

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Collaborators:

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Our LAE Surveys

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We have concentrated on observing relatively low-redshift LAEs, with $2 < z < 3$.

- Make use of existing [O II] and [O III] filters
- Obtain large, statistically complete LAE samples with minimal contamination which can be compared to higher redshift samples.
- Lyα efficiently selects low-luminosity galaxies at high redshift. Need to understand LAEs in order to have a full census of the high-redshift galaxy population.
- LAEs at these redshifts progenitors of L* galaxies today.
- Compare LAEs to $z \sim 2$-3 continuum selected galaxies.
- Study the peak of star-formation rate in the universe – cosmic noon!
- Informs HETDEX experimental design and complements HETDEX dataset.

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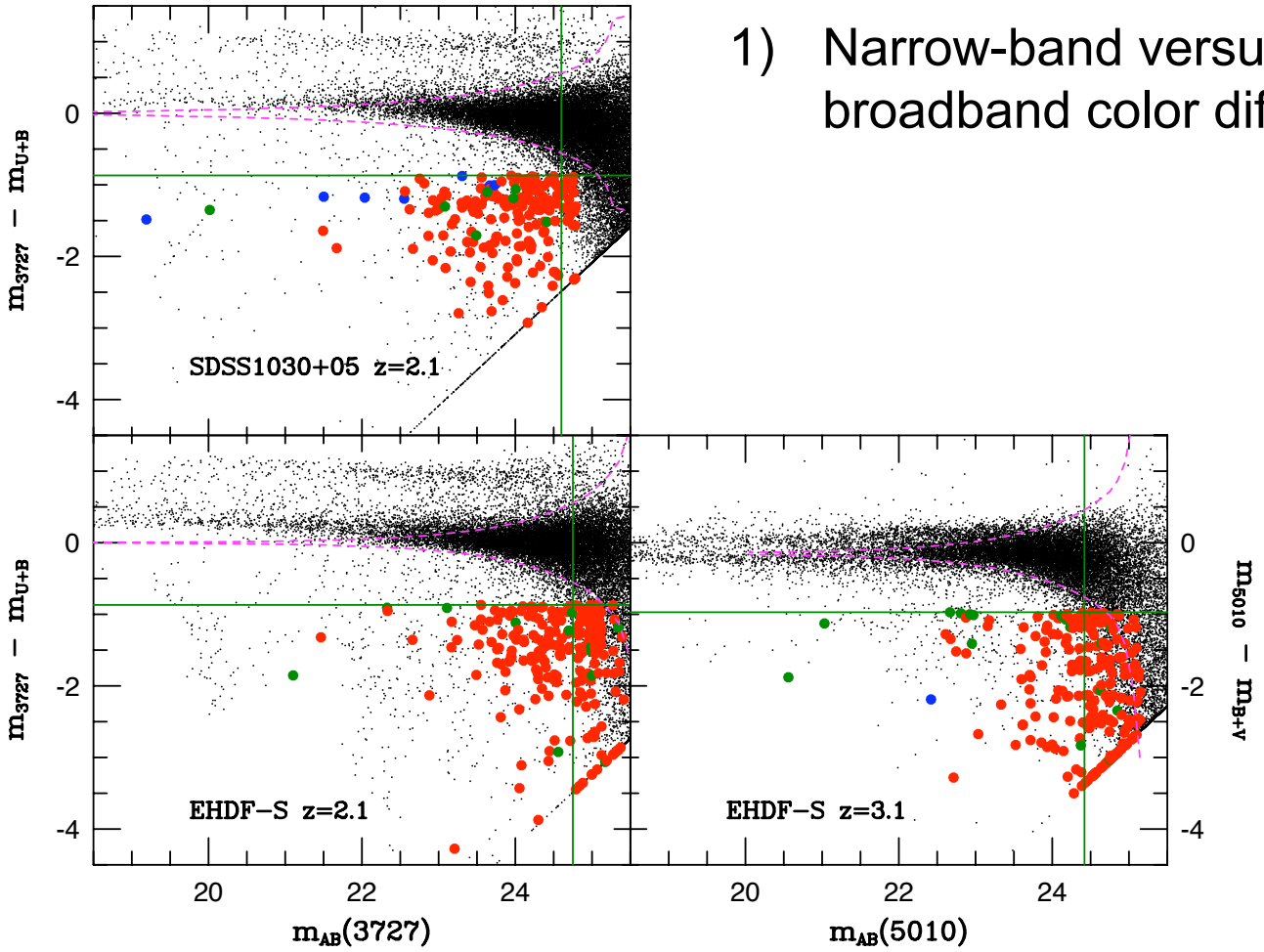
Narrow-band Observations

- Published results from narrow-band [O III] λ4990,5010 and [O II] λ3727 imaging of the Extended Chandra Deep Field South using Mosaic camera on the CTIO 4-m telescope
  - 32′ x 32′ region, 0.28 square degrees
  - z = 3.08 - 3.15 and z=2.05 – 2.09
  - Broadband derived from U, B, V images from MUSYC
  - λ4990 results published in Gronwall+ 2007, Gawiser+ 2007
  - λ5010 results published in Ciardullo+ 2012
  - λ3727 results published in Guaita+ 2010
- Narrow-band imaging in hand for 3 additional MUSYC fields (EHDF-S, SDSS 1030, CW 1255) at both redshifts
  - Extended Hubble Deep Field South analysis complete at both redshifts; SDSS 1030 complete at z=2.1 ← Gronwall+ 2013
  - CW 1255 z=2.1 & 3.1 + SDSS 1030 z=3.1 data being reduced now

Identifying the LAEs

LAEs were found using two completely different and complementary techniques:

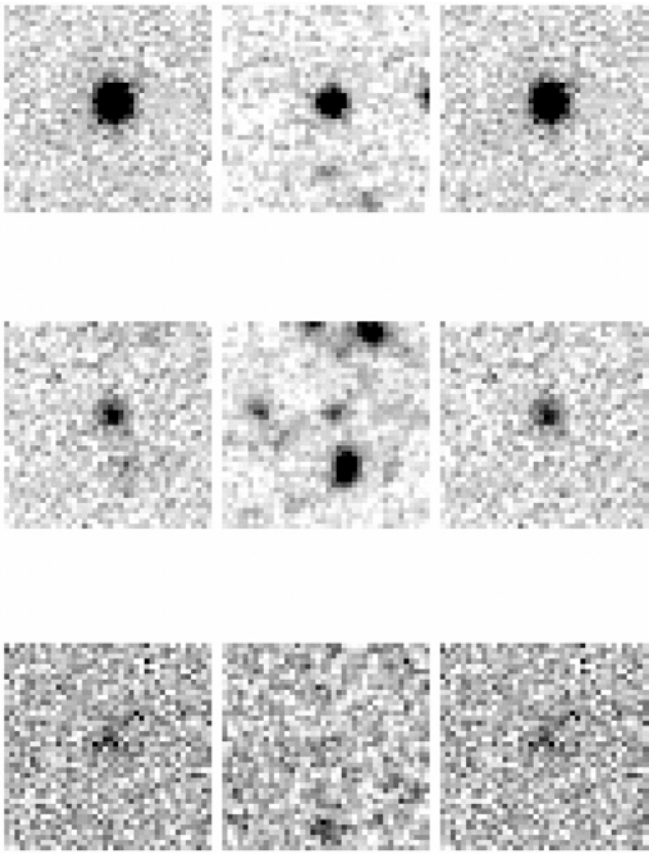
1) Narrow-band versus broadband color difference



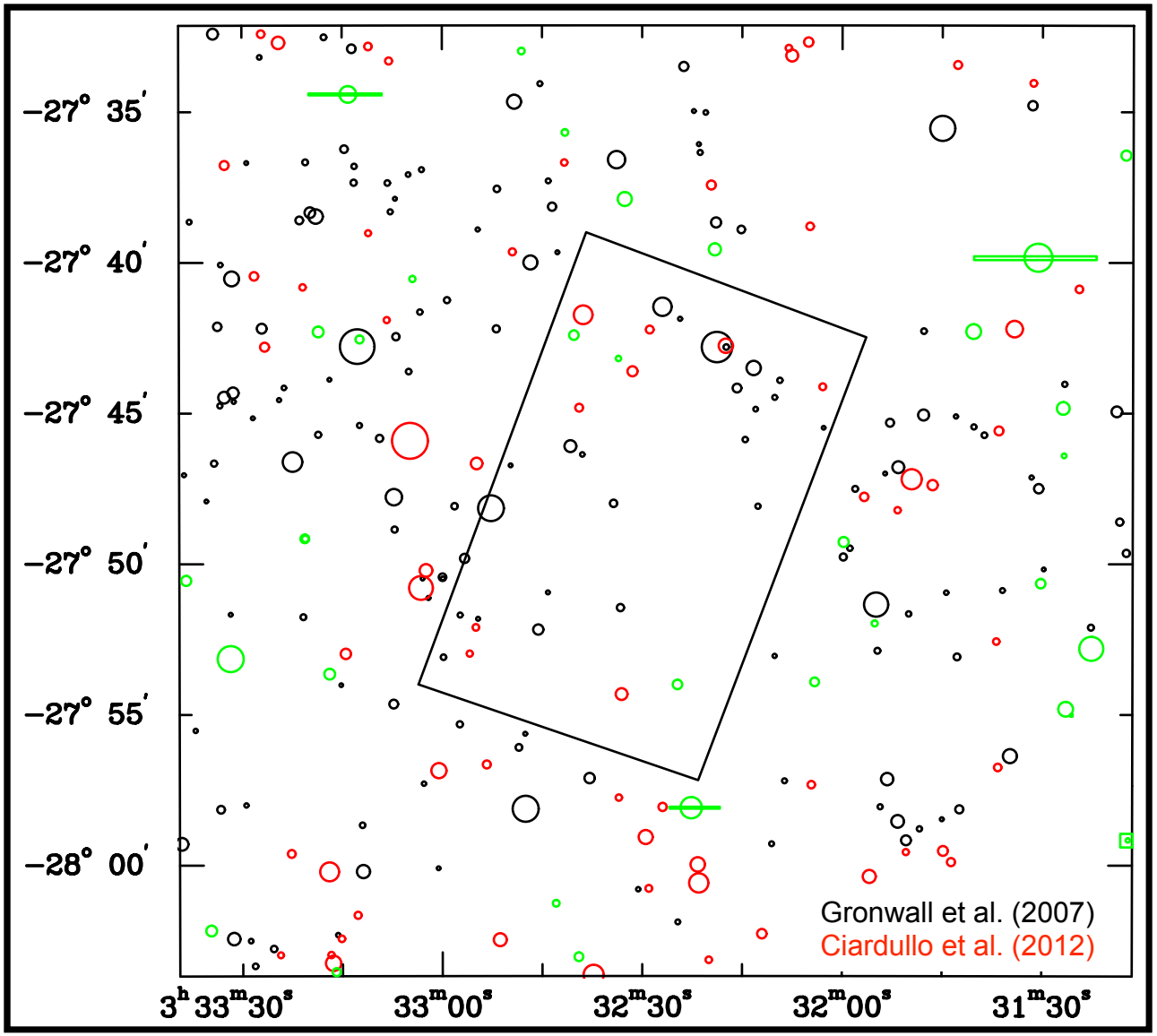
Identifying the LAEs

LAEs were found using two completely different and complementary techniques:

1) Narrow-band versus broadband color difference
2) Narrow-band minus broadband difference frame

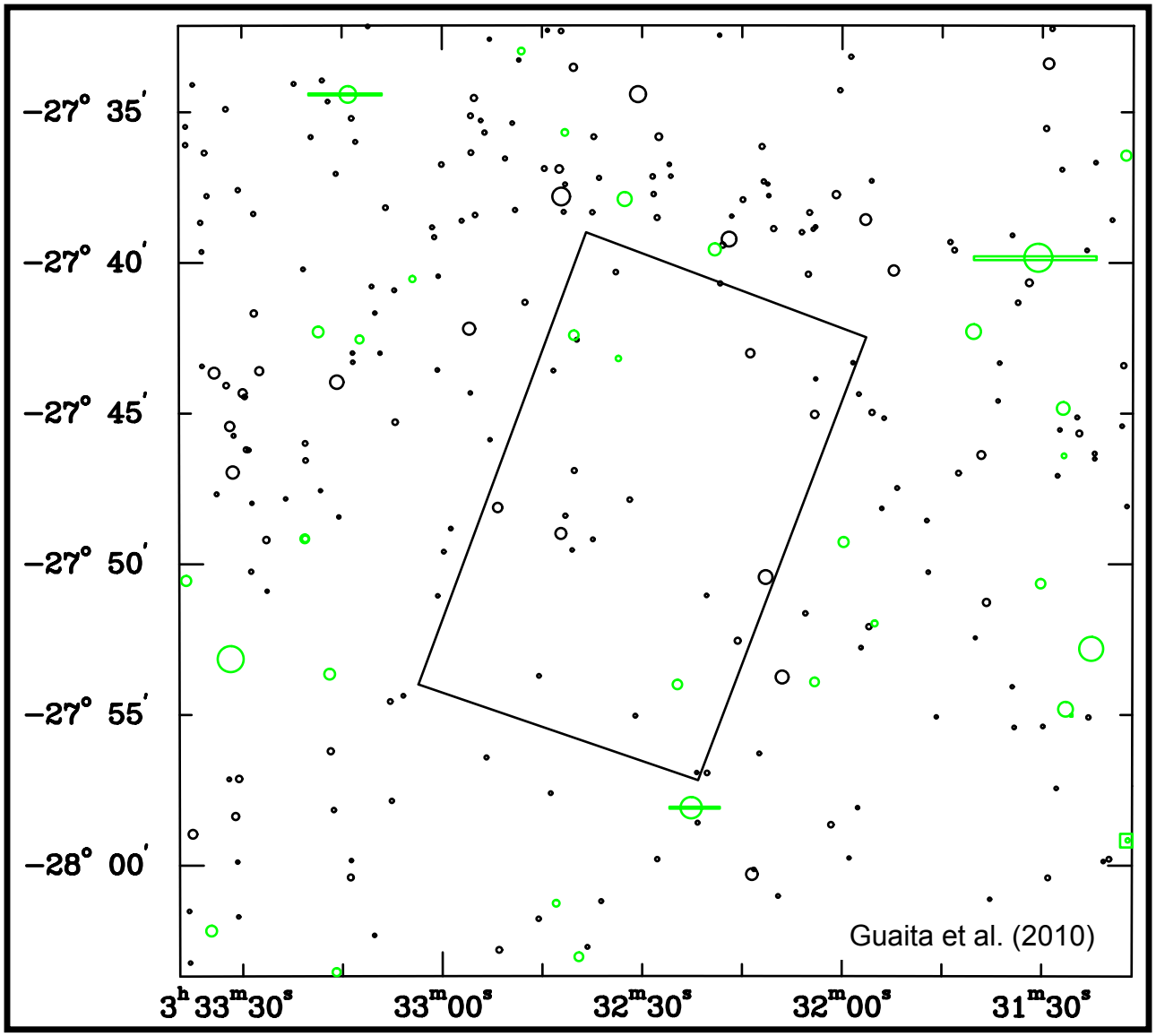


ECDF-S z ~ 3.1 LAEs



- Circle sizes are proportional to luminosity
- *z* ~ 3.1 LAEs avoid the deep HST GOODS field.
- Most of the brightest objects are AGN or other contaminants

ECDF-S z ~ 2.1 LAEs



- *z* ~ 2.1 LAEs also avoid the deep HST GOODS field.

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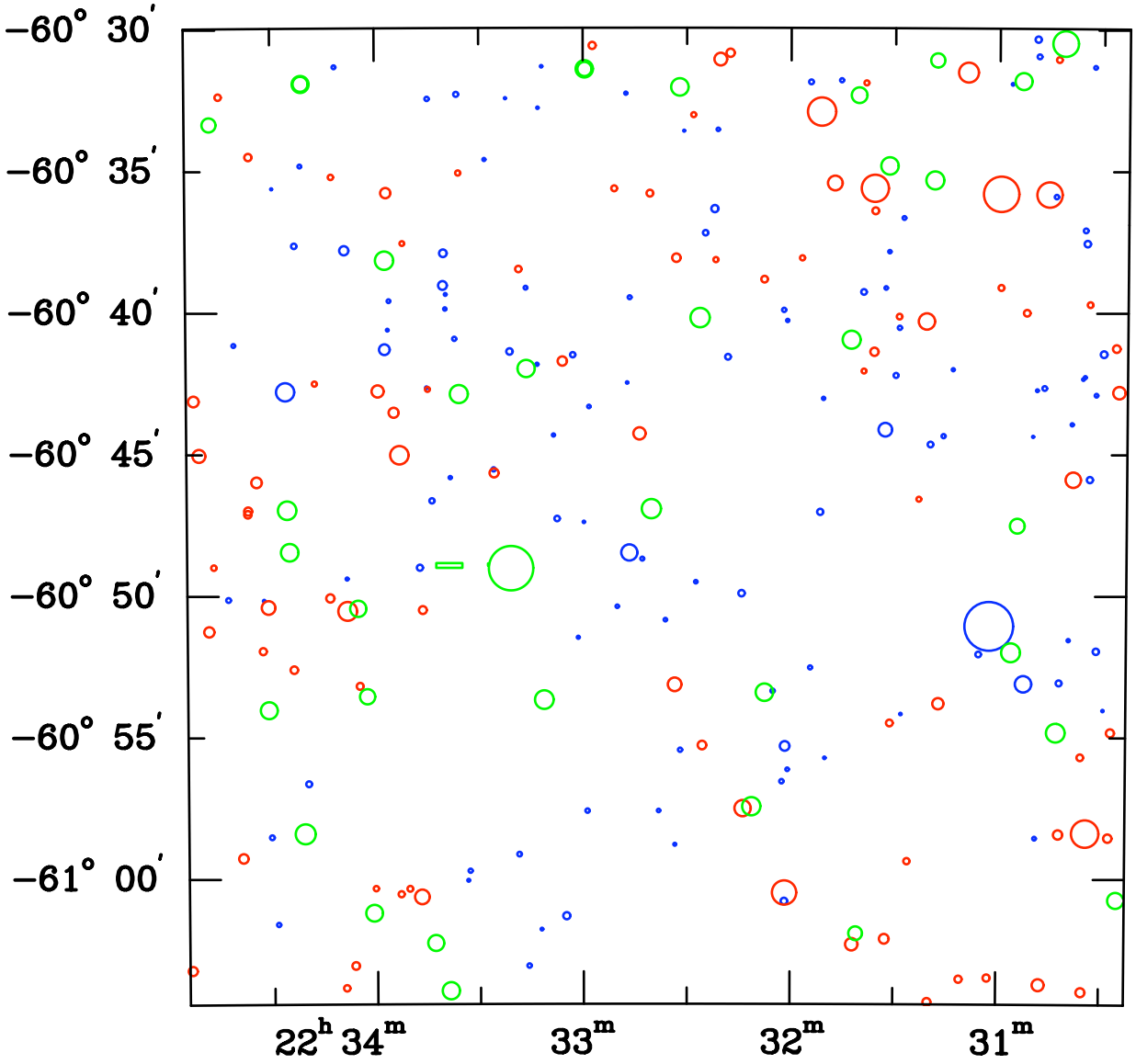
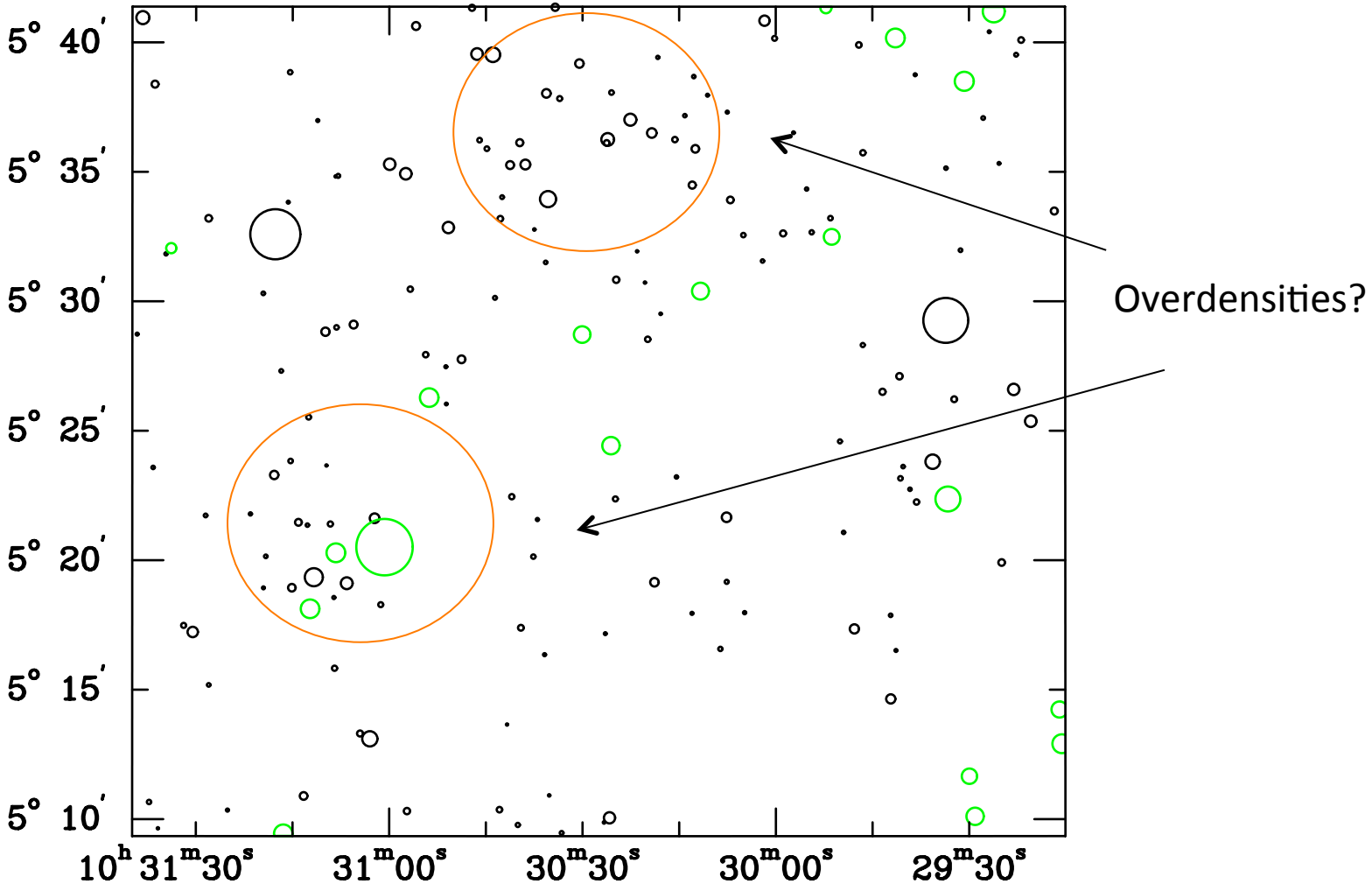
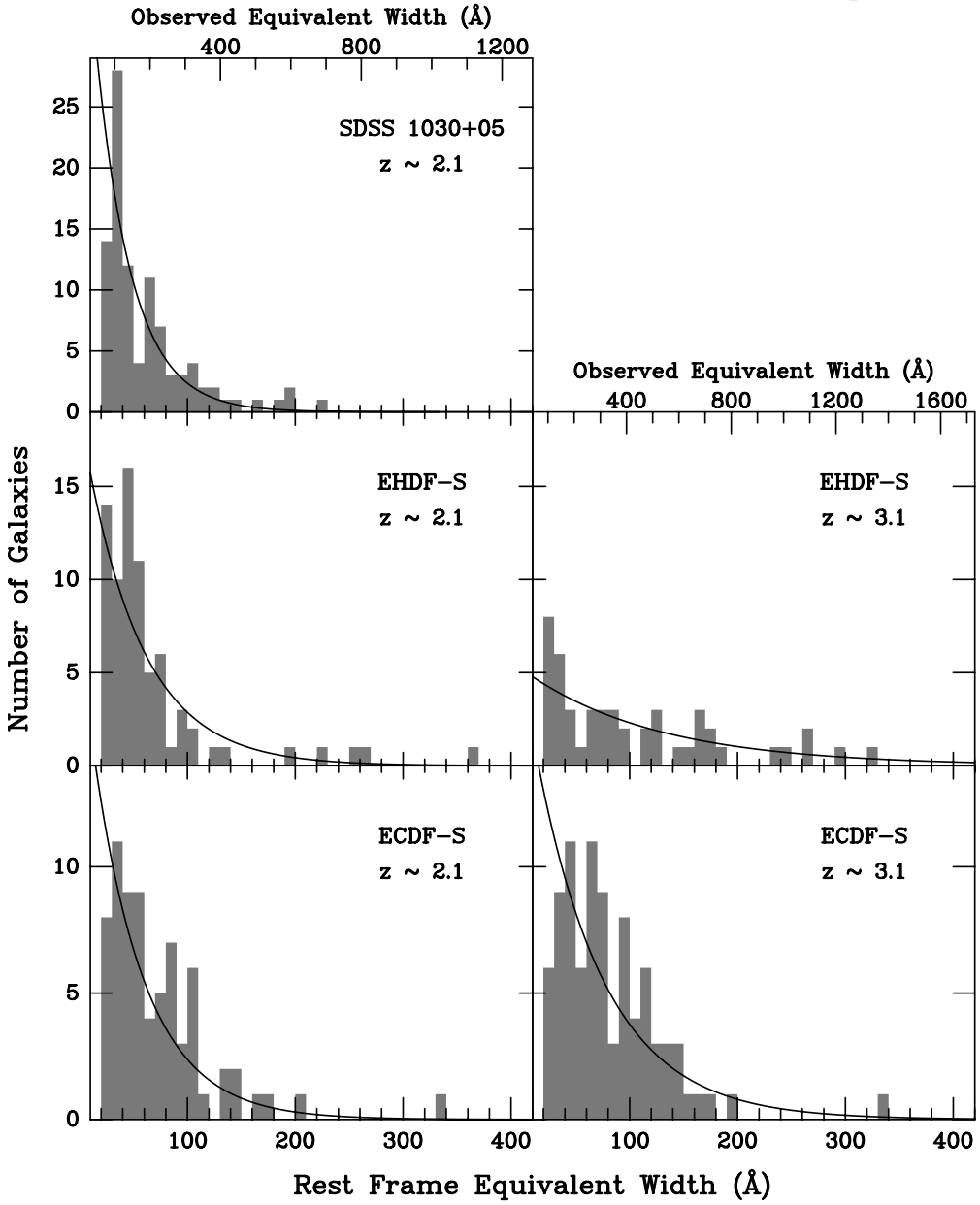
EHDF-S LAEs at z=2.1 & 3.1



SDSS 1030 LAEs at z=2.1



Rest Frame Equivalent Widths



- Only slight variation seen between fields.
- The LAE EW distribution appears exponential (for EW > 20 Å) with a scale length of 100 Å at z = 3.1, and 50 Å at z = 2.1.
- Few, if any LAEs have rest-frame EW > 240 Å. There is no evidence for top-heavy IMFs.

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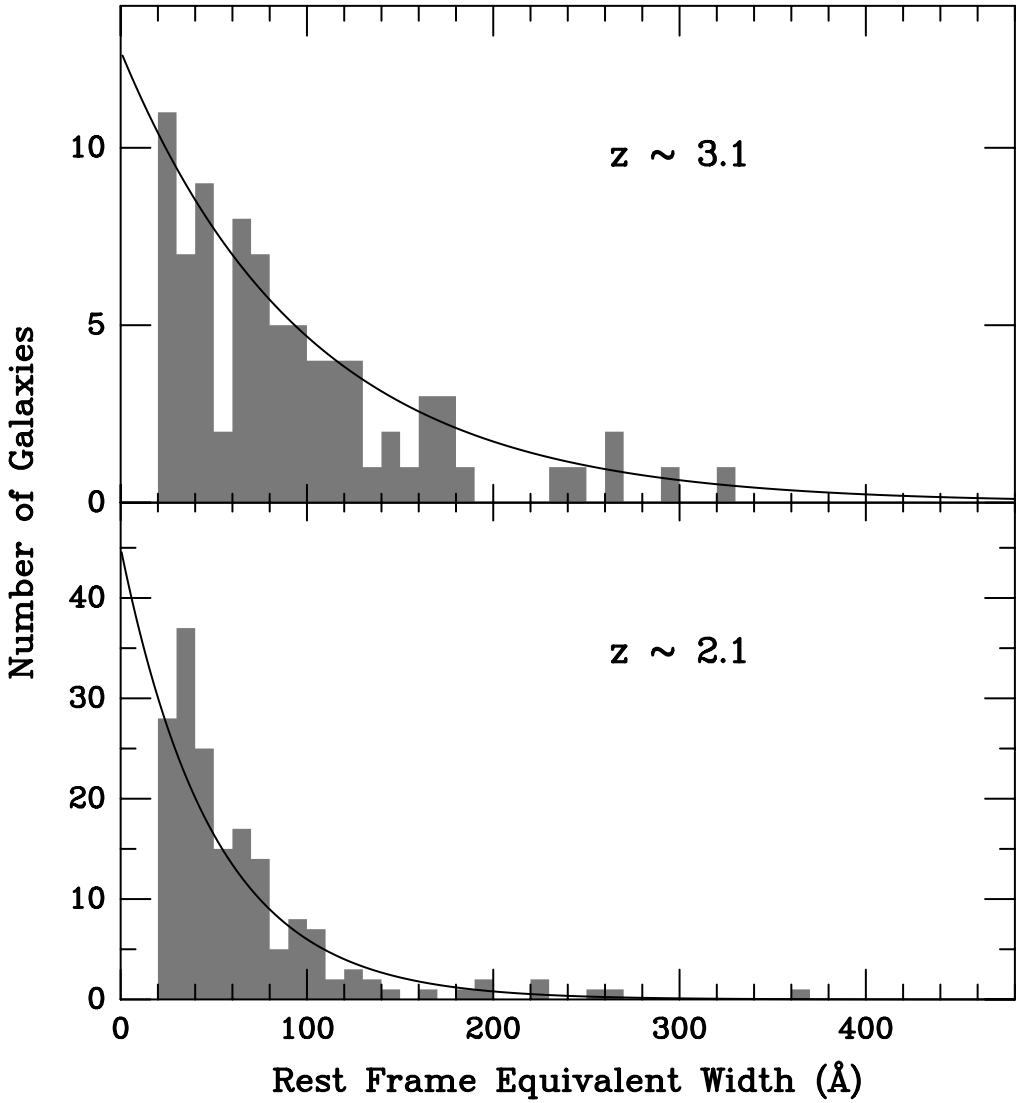

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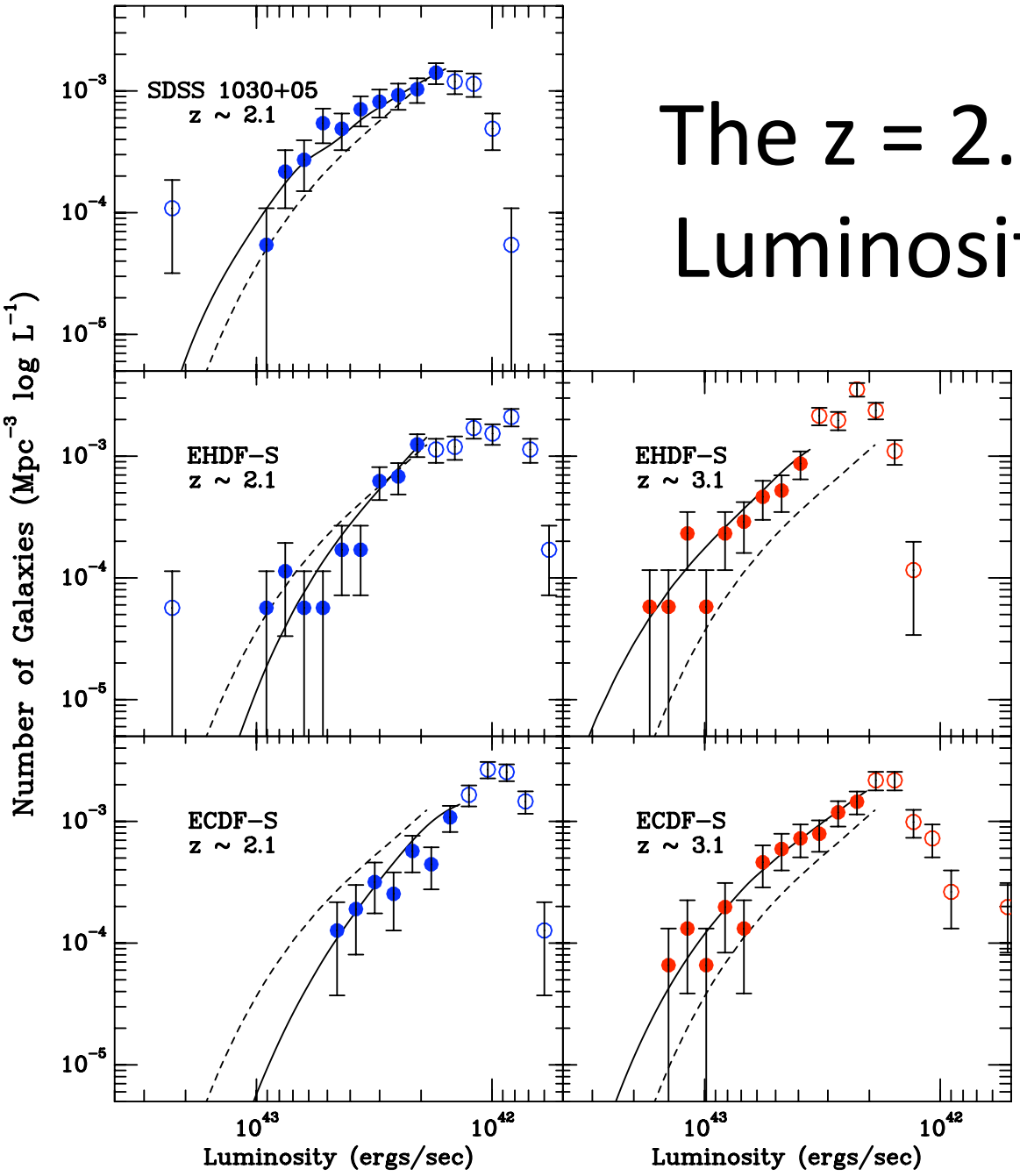
The z = 2.1 & 3.1 LAE Luminosity Function



α is fixed to -1.65.

Dashed line is summed LF @ z=2.1.

Variations seen between fields and between z=3.1 & 2.1.

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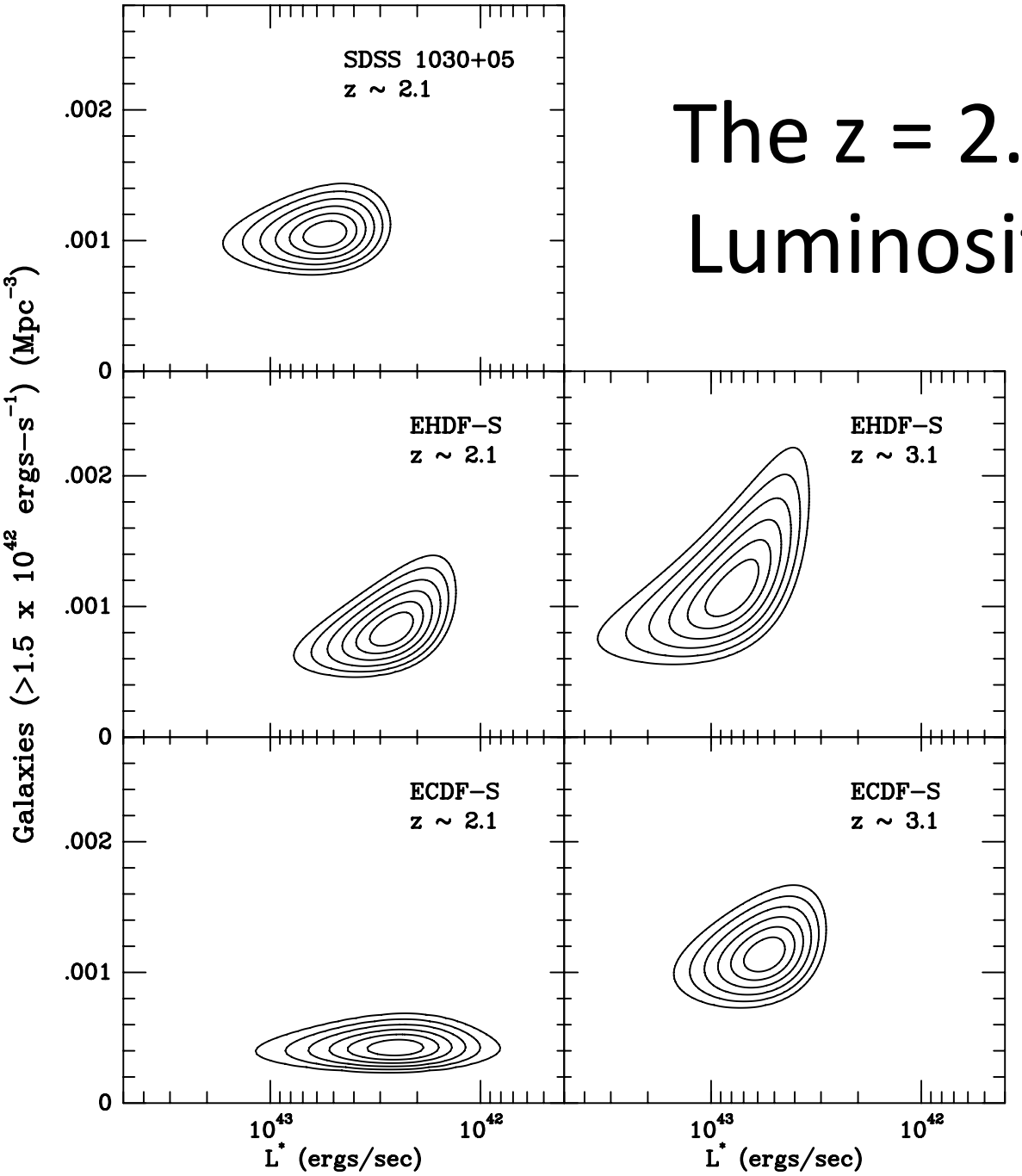
The z = 2.1 & 3.1 LAE Luminosity Function



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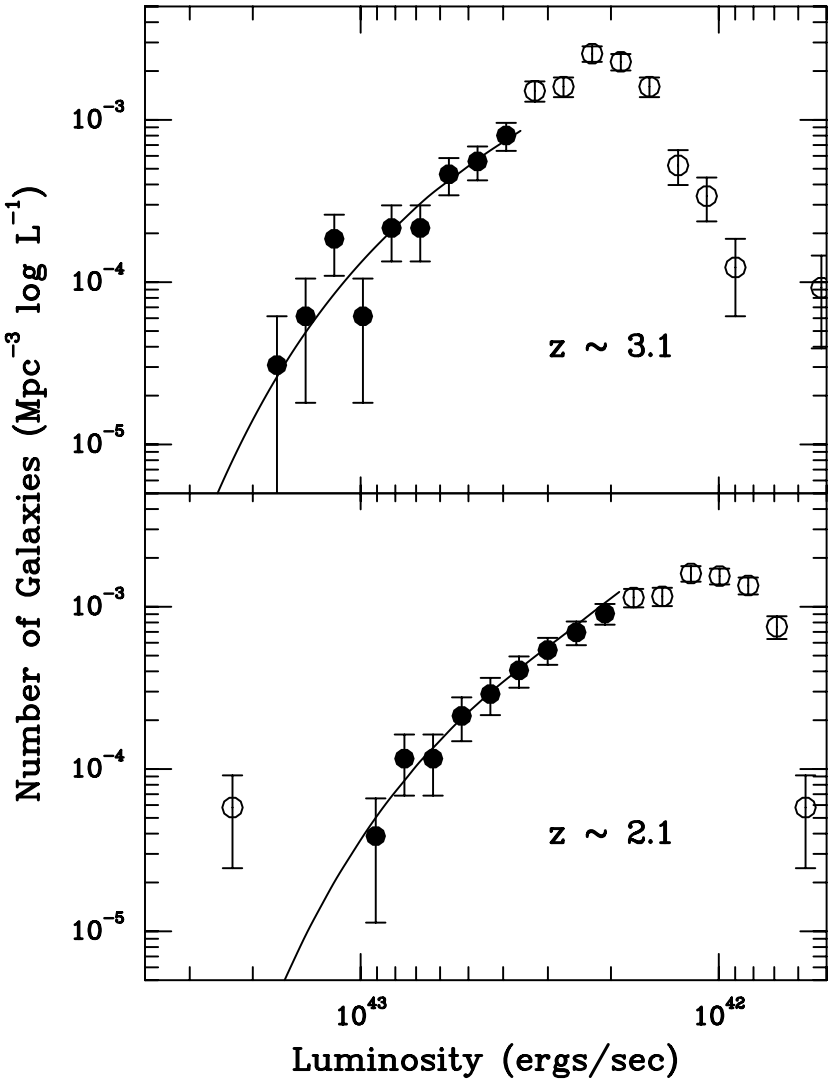
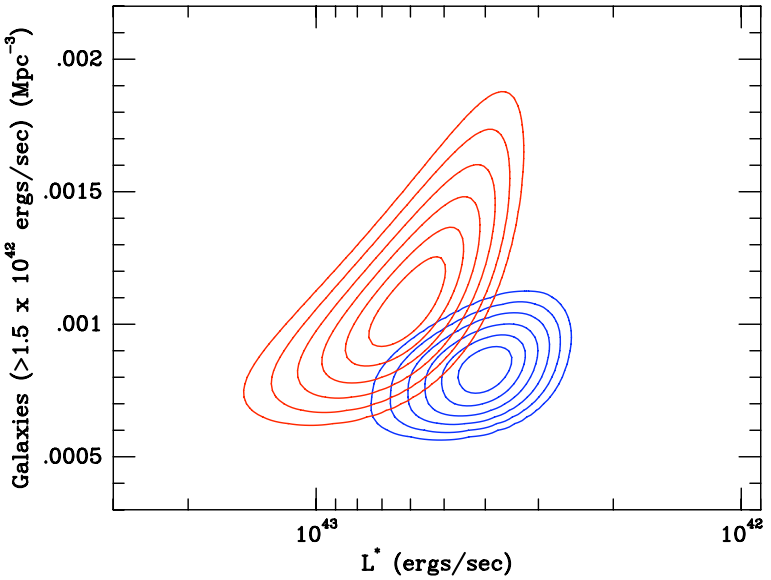
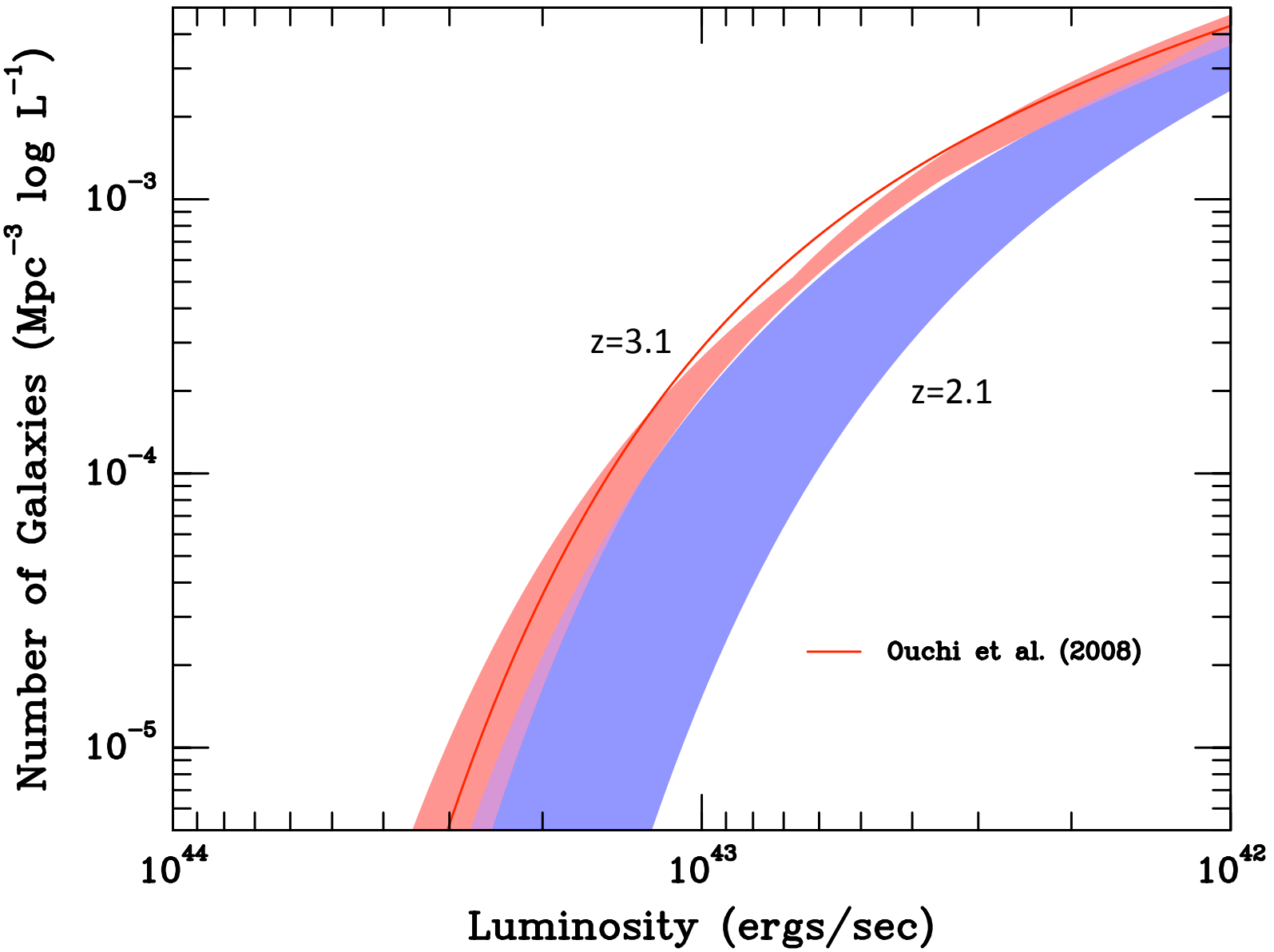


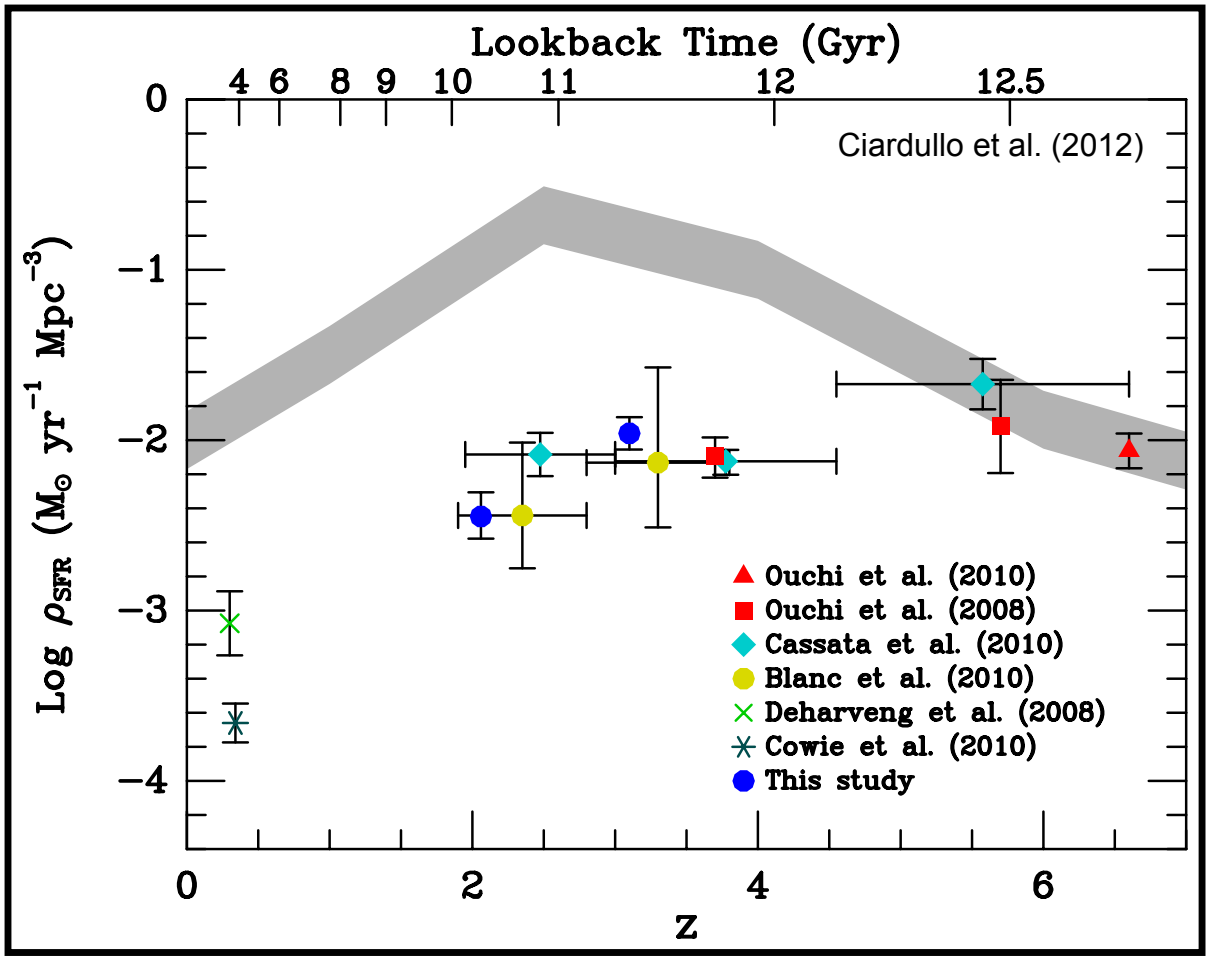


L* fades by 0.3 dex and there is a 25% decrease in number density of LAEs from z=3.1 to 2.1.

The z = 2.1 & 3.1 LAE Luminosity Function



LAEs and Global Star Formation



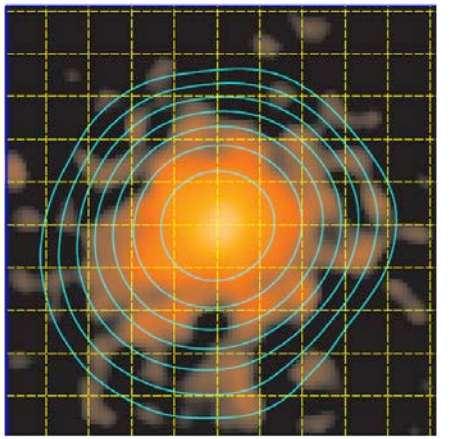
The LAE evolution tracks that of star-formation in the universe. At z ~ 6, most star-forming galaxies had Lyα in emission. But by z ~ 3, only ~ 0.1 of star-formation takes place in LAEs.

Cosmic Variance in LAEs

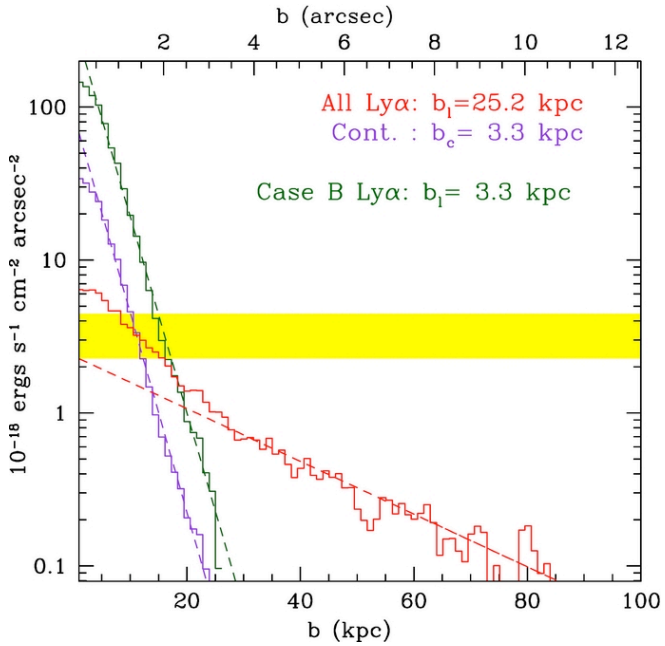
- Currently have a samples of 221 z=2.1 and 232 z=3.1 LAEs in several fields above our 90% completeness limit with more on the way.
- Minor variations in field to field EW distributions, but strong evolution in typical equivalent width scale length from 100 Å at z = 3.1 to 50 Å at z = 2.1.
- See fluctuations of ~30% in number density of LAEs in 0.3 square degree fields as expected from Poisson errors + cosmic variance (Trenti & Stiavelli 2008) and similar to that seen by other groups.
- There is little observed evolution in the LAE luminosity functions from z ~ 6 to z ~ 3 (Ouchi et al. 2008), but clear evolution from z ~ 3 to 2.

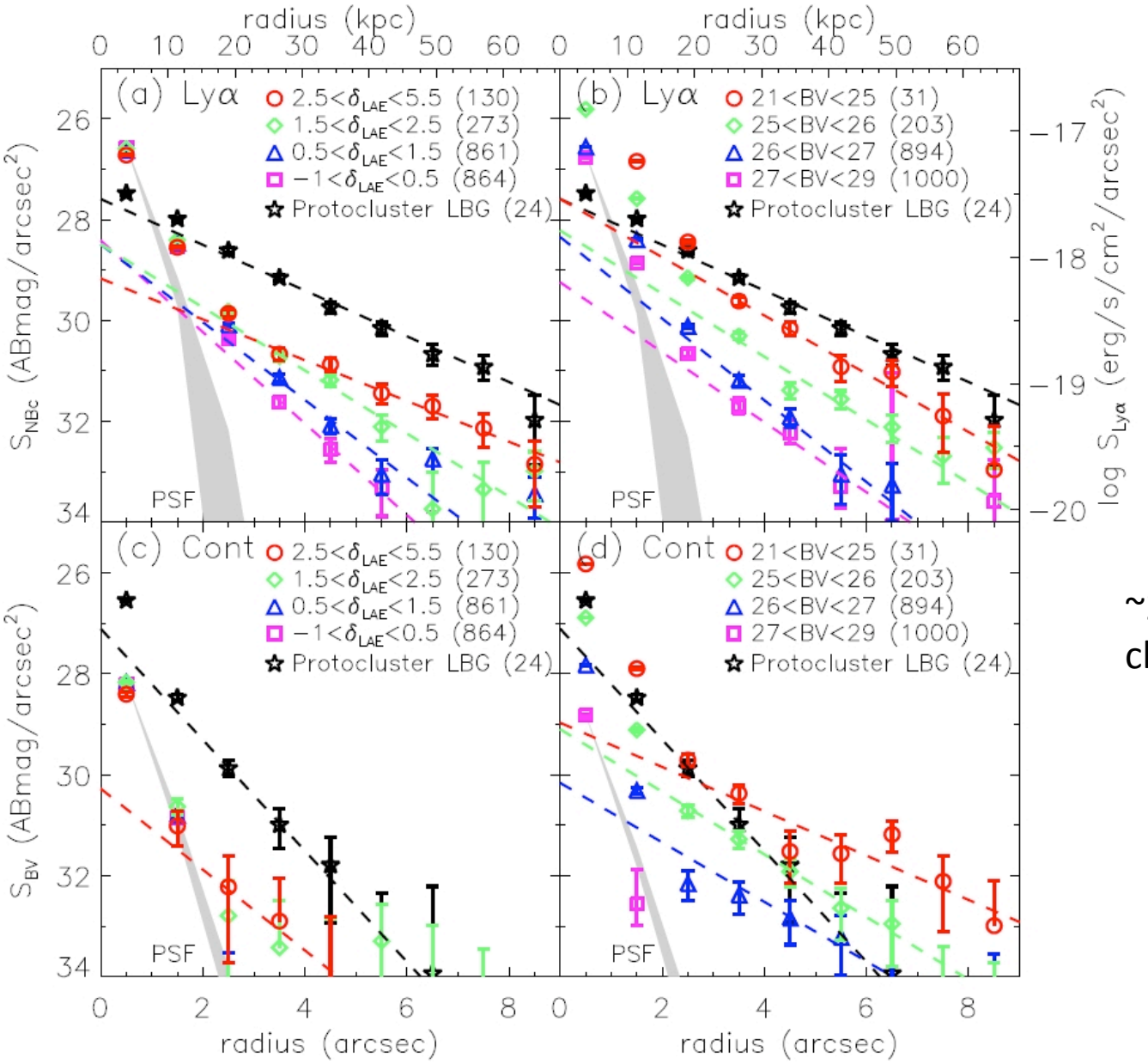
Diffuse Extended Lyα Halos

- Steidel et al (2011) stacked sample of 92 LBGs from 2.3 < z < 3.1.
- Total narrow-band exposure time of 43.9 hours
- Found Lyα emitting halos extending ~80 kpc (10")
- Are halos generic feature of high-z star forming galaxies?



20"





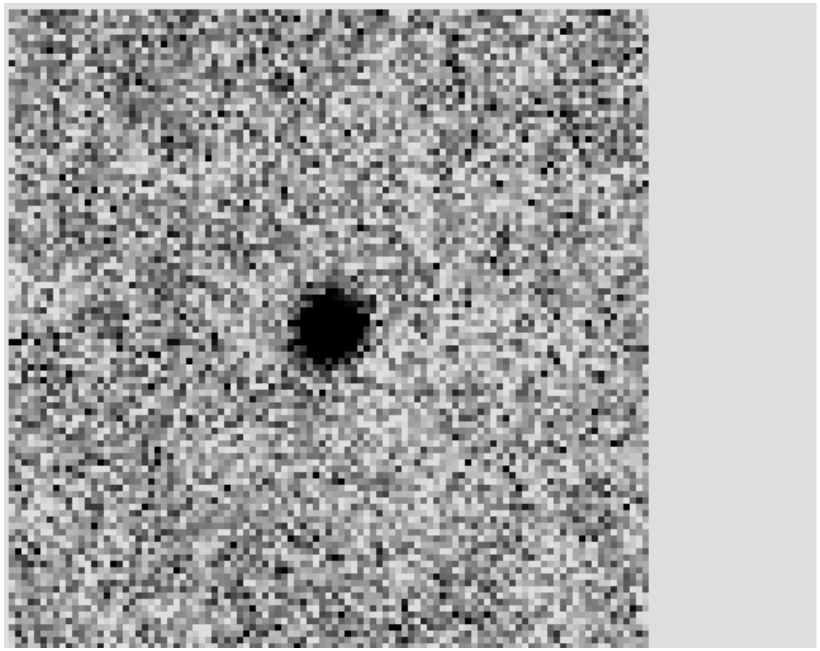
Matsuda+ 2012

Halos most pronounced in high density environments. Slight dependence on UV luminosity.

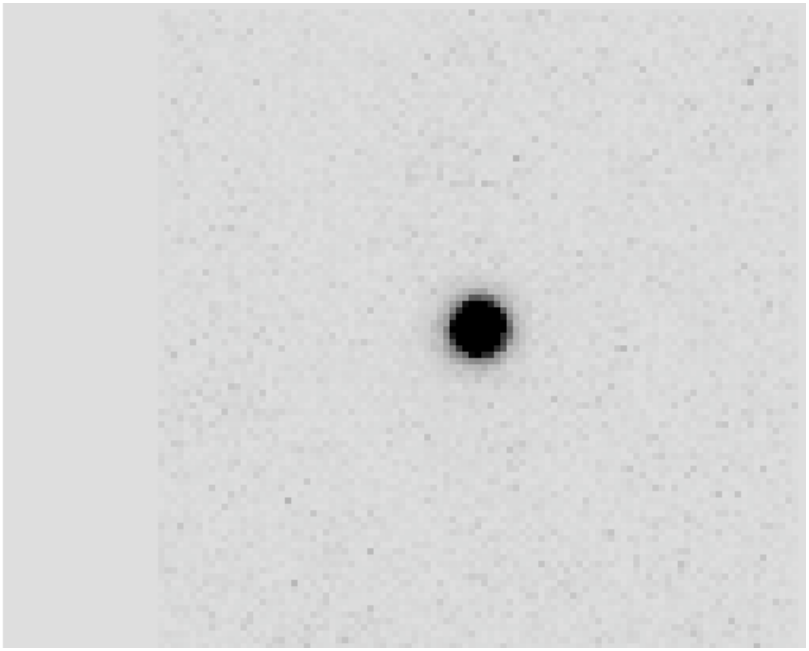
~2000 LAEs + 24 proto-cluster LBGs

Lyα Halos

•Feldmeier, Hagen et al. (2013, ApJ, in press, arXiv:1301.0462) stacked our samples of narrow-band selected LAEs at z=2.1 & 3.1 in the ECDF-S.
•Careful modeling of PSF and flat-field effects.

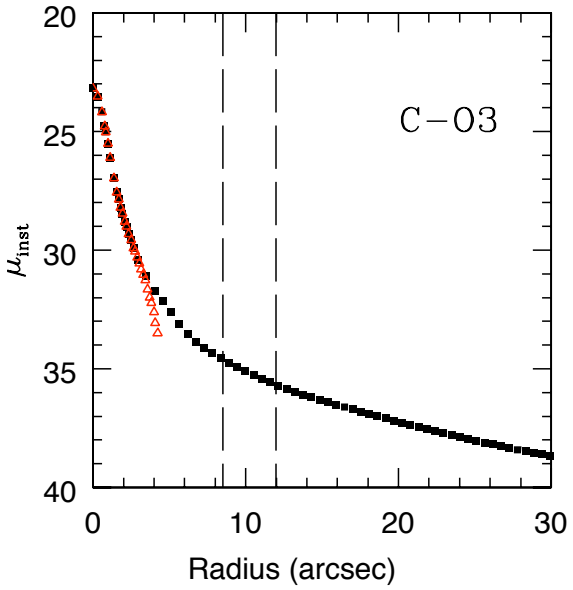


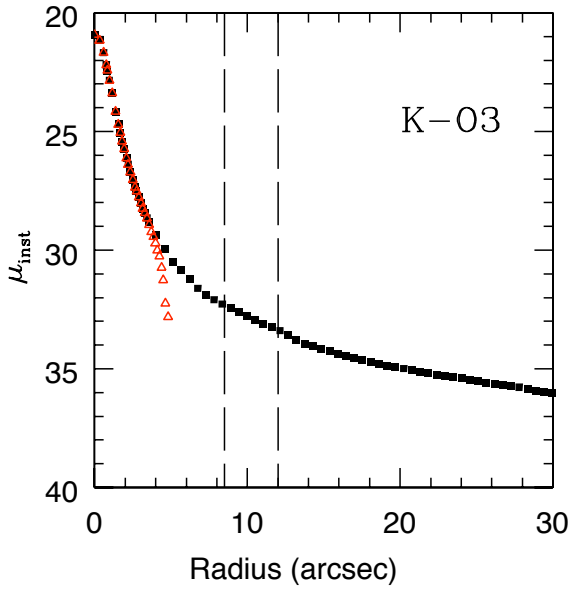
Stack of 146 z=3.1 LAEs



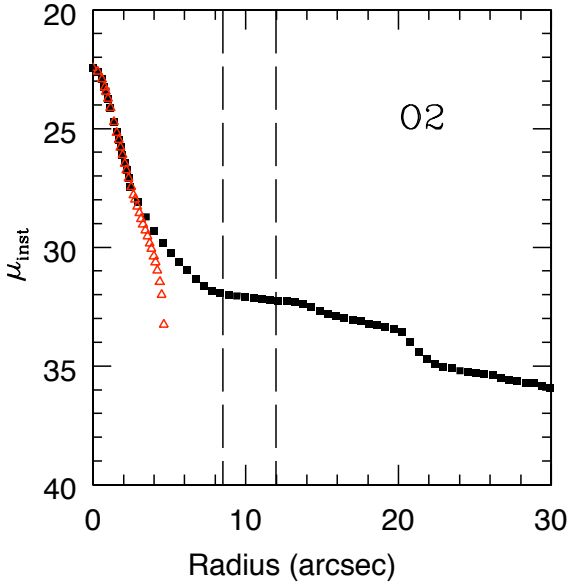
Stack of 55 stars

Extended PSFs





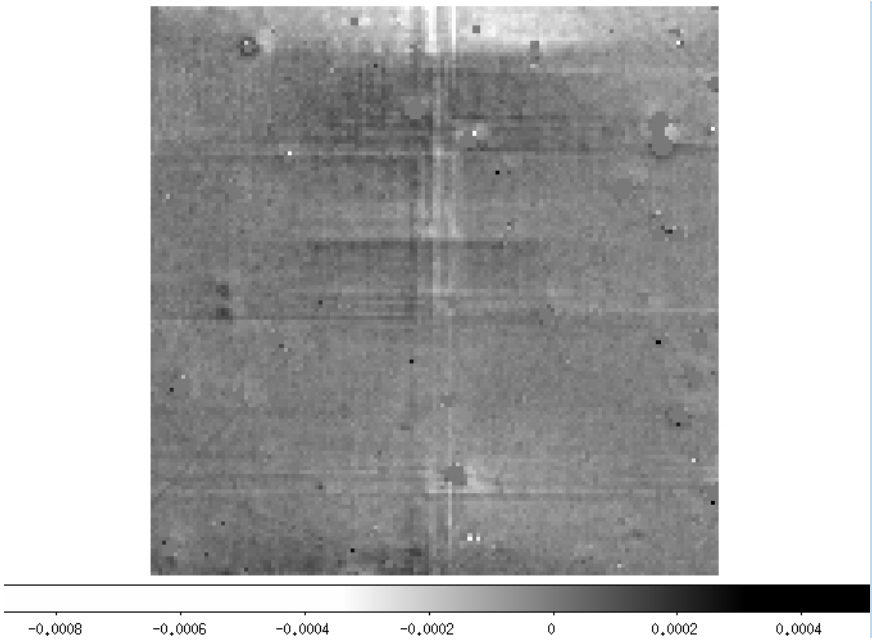
z=3.1



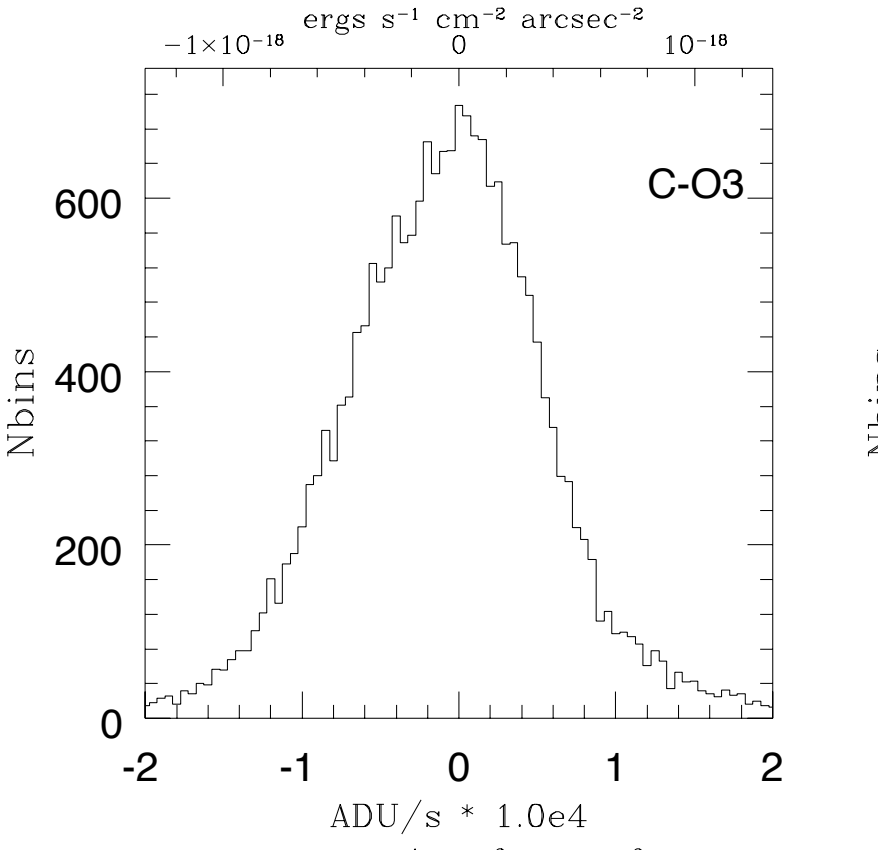
Red = small scale PSF
Black = large scale PSF

z=2.1

Large Scale Flat Fielding Errors

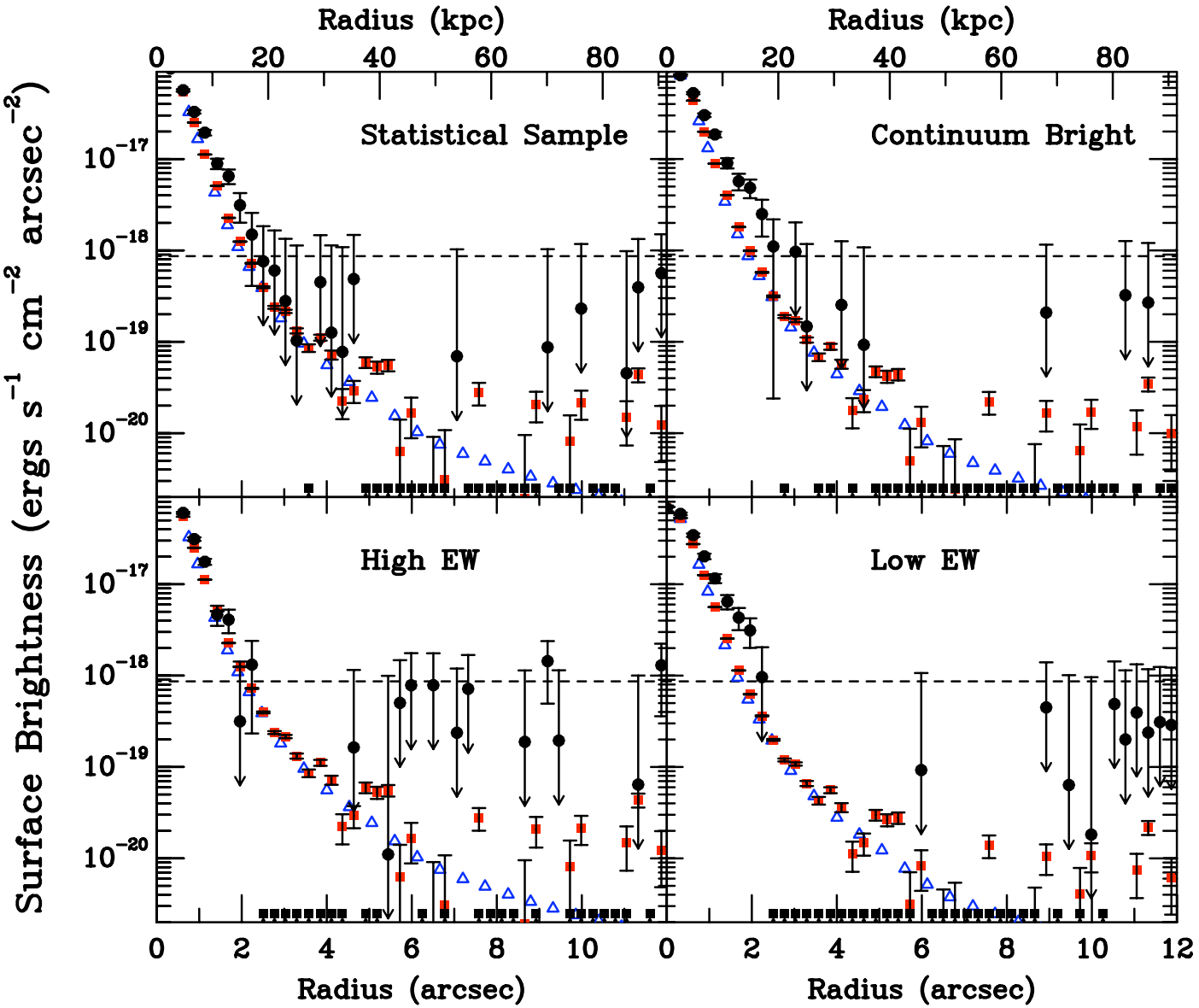


Superbinned image after all objects masked out.



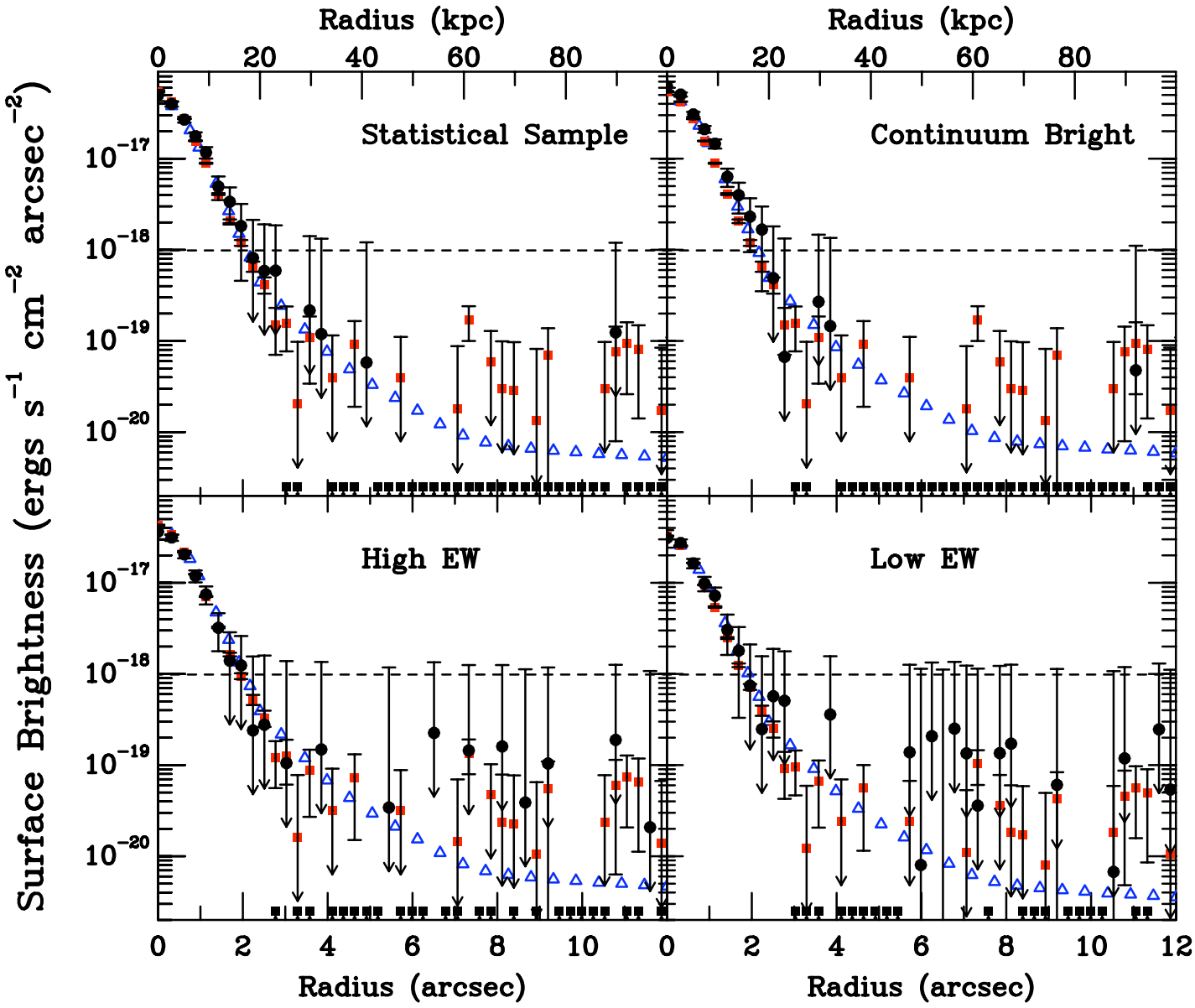
Histogram of sky values for each of our block-averaged images. large-scale flat-fielding error as the full-width at half-maximum of distribution.

Stack at z=3.1



Black = stacked LAEs
Blue = large-scale PSF
Red = stack of stellar sources
Dashed line = SB limit with our systematic uncertainties!

Stack at z=2.1


Radius (kpc)
Radius (kpc)
Statistical Sample
Continuum Bright
High EW
Low EW
Surface Brightness (ergs s^{-1} cm^{-2} arcsec^{-2})
Radius (arcsec)
Radius (arcsec)

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Lyα Halos

- Marginally detect halos for low-EW or high continuum magnitude subsamples of LAEs at z~3.1 at small radii (3-8 kpc.)
- No detection at z~2.1 down to our detection limits.
- Monte Carlo simulations imply we would have easily detected Lyα halos similar to those seen by Steidel+ for LBGs in our NB data.
- Need to take into account systematic flat-field effects and large-scale PSF when searching for diffuse Lyα halos!

Future Plans

- Stacking analysis for Lyα halos in all four fields.
- Clustering measurements.
- Resolved optical spectroscopy using VLT/FORS and SALT/RSS to measure line profiles.
- Near-IR spectroscopy using Magellan/MMIRS, Keck/MOSFIRE, and Gemini/Flamingos-2: measure rest-frame optical emission-lines and measure metallicity, extinction, etc.
- Rest-frame optical morphology using WFC3.
- 800,000 LAEs with HETDEX!