Lyα-Emitting Galaxies at z=3.1: L* Progenitors Experiencing Rapid Star Formation

Gawiser et al., 2007

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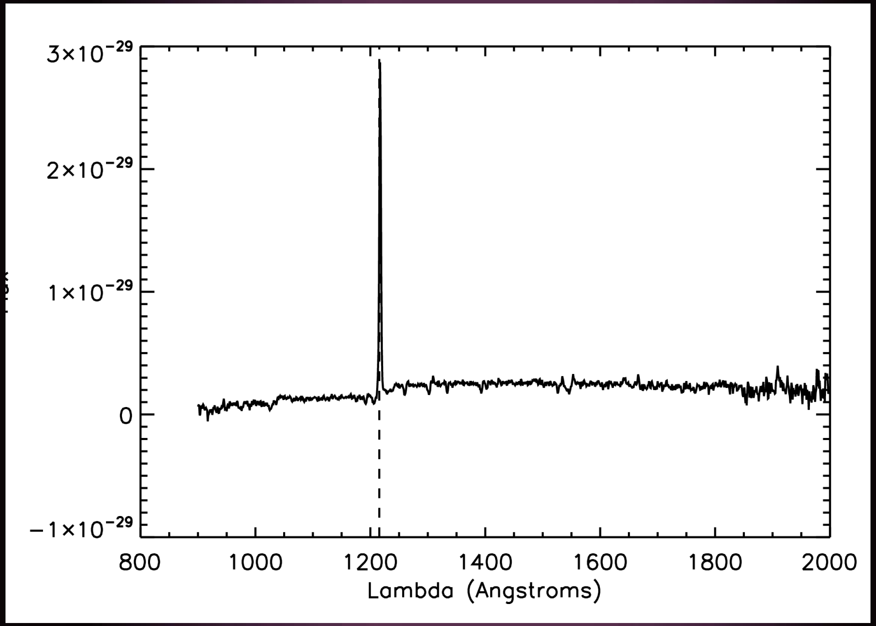
PHYS 689: Galaxy Formation

Lyman-α Emitters (LAEs)

- Lyα line is easily *quenched;* in LAE it has large equivalent width and typically asymmetric
- Detectable Lyα implies systemic burst of star formation (lack of dust)
- Less massive than other high-*z* populations, i.e. LBG's, SMG's; shows moderate clustering
- Plausible ancestors *L** galaxies like Milky Way, not found in massive clusters?



LAE spectrum, *Shapley template*

LAE Emitter, *C. Gronwell*

Outline

- Imaging and spectroscopic observations of Lyman Alpha Emitters
- Results from clustering analysis and spectral energy distribution (SED) modeling
- Implications for the formation process of typical present-day galaxies

Observations

- 162 strong Lyα-emitting galaxies, discovered in MUSYC survey of Extended Chandra Deep Field-South; analyzed by deep narrowband imaging

- Of the entire sample, only 2 appear to house AGN with X-ray counterpart and extended narrow emission lines (C*handra*); a 3rd object has X-ray

- Removed from survey; estimate from these numbers that only 1.2%$\pm$0.9% of LAE contain AGN at this redshift; expect remaining population's emission from extensive amounts of star formation

Clustering Analysis

- Angular correlation function calculated using Landy-Szalay estimator from histograms of pairs of points at separation θ

- Try to determine an age for the LAE based on the mass of the halos they inhabit

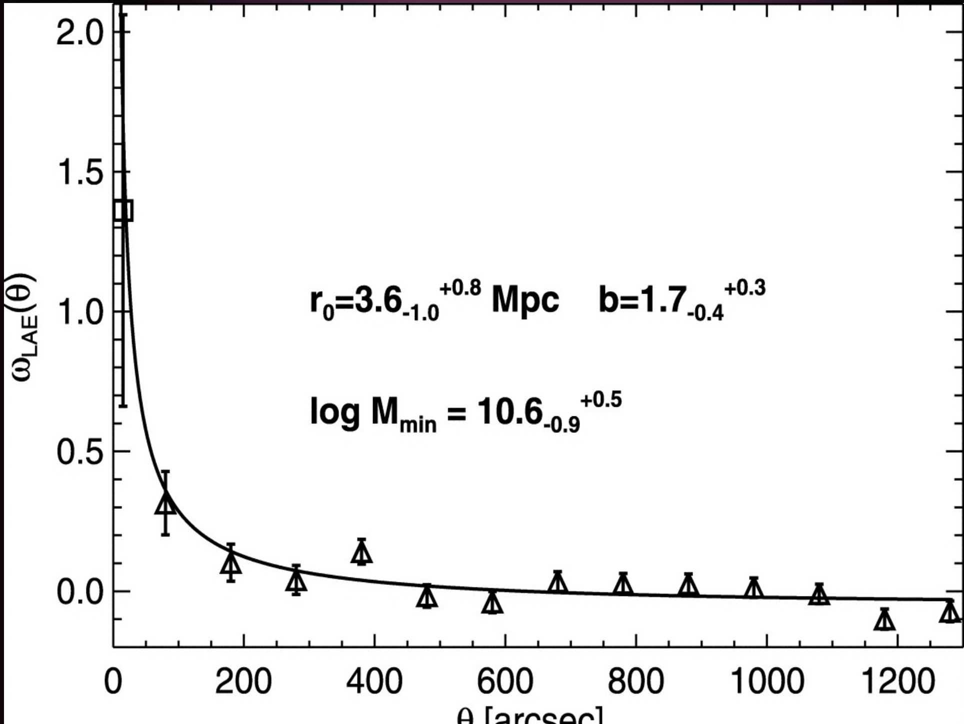


Figure 1, from *Gawiser et al. (2007)*

Deprojection of $w(\theta)$

- Determine the expected redshift distribution $N_{exp}(z)$, implemented a Monte Carlo simulation:
  - Scattered a large number of LAEs over redshift $3<z<3.2$, randomly assigned spectral Lyα profiles drawn from the distribution of LAE sample
- Used result of $N_{exp}(z)$ to estimate $\xi(r)=(r/r_0)^{\gamma}$ from $w(\theta)$

$$w_{12}(\theta)=\iint dz_1 dz_2\, p(z_1)p(z_2)\xi(r,\theta,z_1,z_2)$$

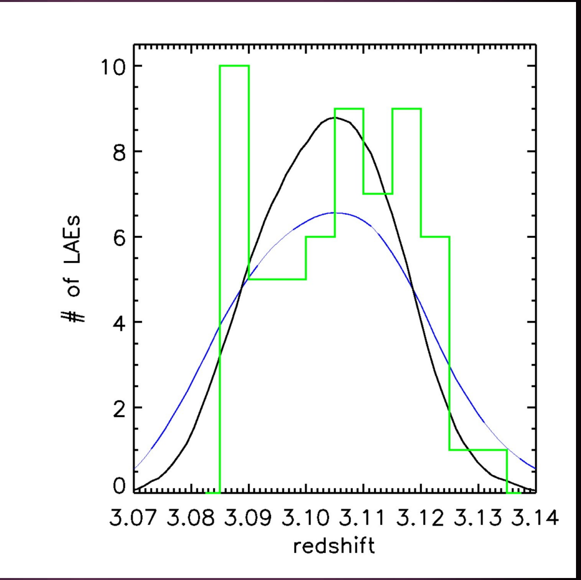


Figure 3, from *Gawiser et al. (2007)*

Sheth-Tormen DM estimate

- Estimates for dark matter halo distribution made with an Extended *Extended* Press Schechter formalism, *Sheth-Tormen*

- Bias factor b between calculations of
  $\xi_{LAE}=b^2\xi_{DM}$
  - The corresponding median halo mass for correlation length $r_0=3.6h^{-1}$ Mpc:
    $\log_{10}M_{med}=10.9^{+0.5}_{-0.9}$ M_{solar}

Clustering Findings

- For a typical correlation function given as a power law,
 $N(r)=n_g(1+\xi(r))$, ξ is a basic power law

 $\xi(r)=(r/r_0)^\gamma$
- Clustering length found $r_0=3.6^{+0.8}_{-1.0}\,h^{-1}$ Mpc
- Stronger clustering than dark matter: bias factor $b=1.7^{+0.3}_{-0.4}$
- Number density of DM halos gives mean halo occupation $5^{+10}_{-4.5}$%
- Excess of LAE counts appears in the bin $3.085\leq z<3.090$d

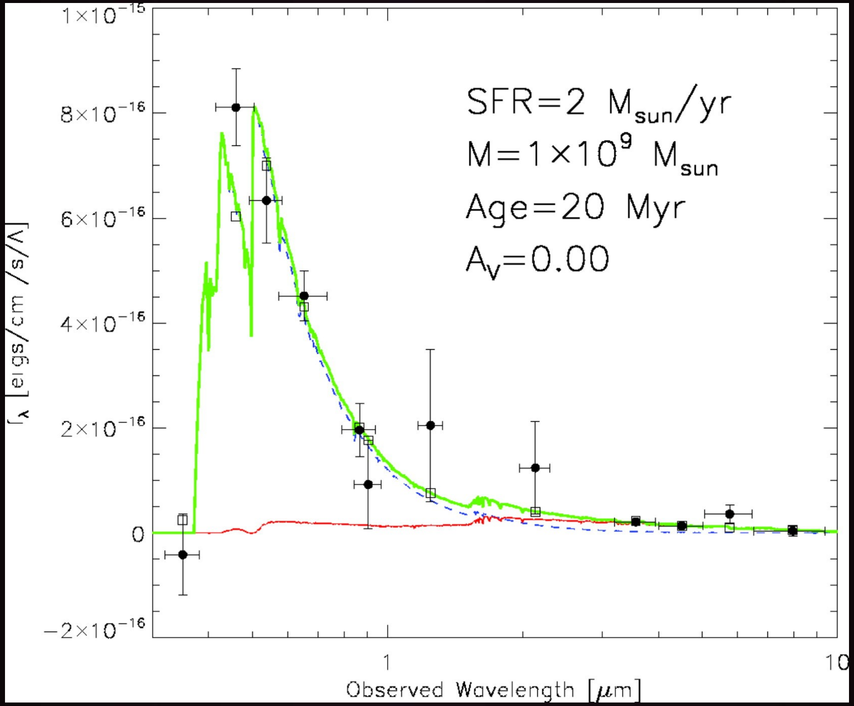
SED Modeling

- Only 3 of the 162 LAEs have enough stellar mass to be directly detected and spectra individually measured by IRAC *(Spitzer*)*;* these probably sample high-mass end

- Lai et al. (2007) performed SED fitting on more distant (z=5.7) LAEs and concluded they were not undergoing first burst of star formation, were as old as 700 Myr and had significant stellar mass

- For more typical, less massive LAEs, stacked images from 52 weak samples and averaged fluxes assembled to approximate a spectrum

Stellar inhabitants



- Modeled star formation history using *two-burst* scenario:
- Older stars that already existed when halos merged, all formed at once
- Younger stars which started forming more recently with exponentially decreasing frequency

Two-Population Fitting

- Best fit model corresponds to total stellar mass $1.0^{+0.6}_{-0.4} \times 10^9 M_{solar}$
- SFR: $2 \pm M_{solar} yr^{-1}$
- Dust extinction: $A_v = 0.0^{+0.1}_{-0.0}$
- Age of young starbursting population 20^{+30}_{-10} Myr with very long *e*-folding time ~750 Myr

Age constraints

- Not many constraints on either the old or young populations
- Old population best fit: 2 Gyr (age of universe at z=3.1)
- Young population: estimates range from 60-350 Myr
- Single-component (starburst-only)fit can also be made to agree with data
- Future refinements: additional flux bins?

Comparison of methods

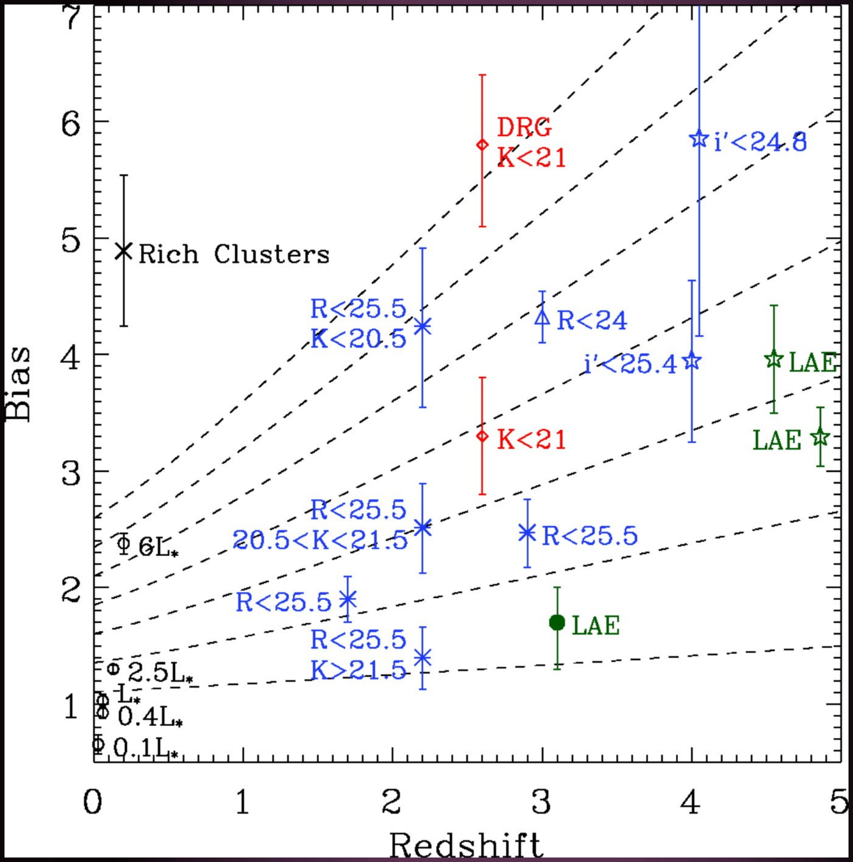
- Comparison of correlation length of LAE and DM estimates halo median mass $\log_{10} M_{med} = 10.9^{+0.5}_{-0.9}\ M_{solar}$

- SED fitting to flux profile estimates starburst population age 60-350 Myr

- Additional cross check with Milli-Millennium simulation finds for halos of mass$>10^{10.6} M_{solar}$ a median age 600 Myr

Evolution of bias

- Predicting future evolution of the relative bias in order to arrive at *L** type
- Estimate bias is smaller at present day than in past—closer ratio of galaxies to halos
- LAE point falls within evolutionary track between 1*L** and 2.5*L**



Conclusions

- Observed properties of LAEs at $z=3.1$ make them the most promising candidates for ancestors of present-day L^* galaxies like the Milky Way

- Analysis suggests LAEs are in early phases of a burst of star formation

- Cannot yet conclude if all present-day L^* experienced a LAE stage at $z=3.1$