The Diverse Sizes of Diffuse Lya Emission around High-z Star-Forming Galaxies

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• Very extended Lya emission around continuum-selected LBGs at high redshift (exponential scale length 20-25 kpc)

• “Accounting for diffuse Lya halos, all LBGs would be LABs if surveys were sensitive to 10 times lower Lya surface brightness thresholds; similarly, essentially all LBGs would qualify as LAEs.” (Steidel+ 2011).
Are All Star-Forming Galaxies LAEs?

Hayes+ (2013)
Lyα Reference Sample
(14 galaxies, z=0.028-0.18)
Jens’s talk Monday

Red: Hα
Green: UV continuum
Blue: Lyα

Steidel et al. 2011 (91 galaxies z=2.8–3.1)

- Most local analogs of high-z galaxies show extended Lyα emission but smaller by a factor of 5-10
What powers extended Lya?

- Scattered light in the CGM
- Cold streams
- Satellite galaxies
- AGN fluorescence
- Shock heating by super winds

Probably not important for normal SF galaxies

Momose+ (2016)
Large Spectroscopic Surveys of LAEs

The NOAO Deep Wide-Field Survey
  Jannuzi & Dey 1999

PCF LAE Survey
  Lee at al. 2014, 2015
  Dey, Lee et al. 2016

LAB LAE Survey
  Prescott+ 2008, Hong+ 2014
LAEs at $z=3.78$

PCF sample

165 LAEs (100 confirmed)
21 non-LAE LBGs
$z=3.769-3.803$

Lee+ (2014), Dey, Lee+ (2016)
LAEs at $z=2.66$

LAB sample

1336 LAEs
429 LAEs confirmed at $z=2.556-2.755$

Prescott+ (2008), Hong+ (2014)
Galaxy Distribution at $z=3.78$

Two LAE overdensities: likely evolve into $(1-2) \times 10^{15} M_{\text{sun}}$ and $(3-7) \times 10^{14} M_{\text{sun}}$ by $z=0$  

Lee+ (2014), Dey, Lee+ (2016)
Galaxy Distribution at \( z=2.66 \)

A \(~120\) kpc \( \text{Ly} \alpha \) nebula, LABd05, lies at the center of redshift spike: another forming cluster (Dey+ 2005, Prescott+ 2008, Xue, Lee+ 2017)

\[ z=2.55 \Rightarrow 2.76 \]
Stacking: Measuring Diffuse Light around Galaxies

Systematics that mimic diffuse emission

- unmatched point spread functions
- mismatch in astrometry
- imperfect sky subtraction
Diffuse Lyα Emission around Galaxies

$z=3.78$

$z=2.66$

Diffuse Lyα Emission around Galaxies

$z=3.78$

$z=2.66$

Diffuse Lyα Emission around Galaxies

- Radially averaged 1d SB profile
- Measured exponential scale lengths: 5-6 kpc for both samples
- in agreement with the Momose+ (2016) sample (similarly selected as ours)
- not in agreement with the Steidel+ (2011) measures at 20-25 kpc
Physical Origin of Diffuse Lya Emission

- both measurements generally consistent with a model in which Lya photons from central galaxy scatter out in outflowing medium
- gravitational cooling radiation may play a minor role at large galactocentric distances


What Drives Lya Halo Sizes?

- LAHs are not universally large
- No correlation with LAE overdensity and EW
- A possible weak correlation with Lya luminosity
- Strongest correlation is found with UV luminosity (scales with SFR)

Steidel+ (2011)
Wisotzki+ (2015)
Matsuda+ (2012)
Momose+ (2016)

$z \sim 3.78$
$z \sim 2.66$
Potential Systematics

- **PSF wings**: typically present in ground-based obs)

- **Halo fraction**: the fraction of Lya flux coming from the galaxy and from the diffuse `halo’ component

- Measuring scale length directly from observed profile may be biased

Xue, Lee+ (2017)
Potential Systematics

• Your **sky background** is not the same as your neighbors

• 400 LAHs with 10 kpc simulated with or without nearby sources, then stacked

• Your true local background is lower near your galaxies because any source too close to a bright (typically unrelated) source is removed.

Xue, Lee+, to be submitted (2017)
• A large sample of UV-luminous but “normal” star-forming galaxy sample in the COSMOS field

• 309 zCOSMOS deep galaxies with well-determined rest-UV redshifts, HST sizes
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The sizes of UV-ultraluminous Galaxies

- A large sample of UV-luminous but "normal" star-forming galaxy sample in the COSMOS field
- 309 zCOSMOS deep galaxies with well-determined rest-UV redshifts, HST sizes
- most UV-luminous galaxies have larger halos ~ 14 kpc (still not as large as the Steidel halos!)
- Lya EW probably not the main driver of halo size

Xue, Lee+, to be submitted (2017)
Are All Star-Forming Galaxies LAEs?

Steidel et al. 2011 (z=2.8–3.1)

• Even accounting for the extended Lya emission, UV-luminous galaxies with no Lya coming out from the center have a much lower Lya escape fraction than the LAEs at a few percent.

• Perhaps something special about luminous protocluster LBGs (satellite contribution? gravitational cooling? AGN fluorescence?)

Xue, Lee+, to be submitted (2017)
Wide-Field Lya emission survey @ Purdue

- WIYN (Wisconsin-Indiana-Yale-NOAO telescope) will image multiple HST fields using the One Degree Imager
- multiple narrow-band filters to target redshifted Lya emission at different cosmic epochs, collecting Lya photons emitted by galaxies in a wide range of morphologies, large-scale environment, star formation rates, etc.
- total of \( \sim (1-2) \times 10^6 \) Mpc\(^3\) volume; an order of magnitude improvement
- a search for giant Lya nebulae: physical connection to be explored
Multiple spectroscopic samples used to study how Lya halo sizes vary with other galaxy properties; UV luminosity appears to be the primary driver of LAH sizes.

No Lya halo as large as 20-25 kpc found around any sample *including* galaxies as luminous as (2-3)L*, except AGN.

Multiple systematics that can bias the scale length measurements.

Surface brightness profile of our LAEs appears to be consistent with Lya from central star formation scattering out, with a little contribution from satellites or cooling radiation.

Concerted efforts in all fronts — robust bias-free measurements, model predictions that can simultaneously satisfy multiple constraints (f_{esc}, profile, outflows, etc.) — required to make further progress!