Extended Lyα Nebulae at z=2.3: Tracers for High-Redshift Protocluster?

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Abstract
Radio-quiet Lyα nebulae (aka “blobs”), extended sources at z = 2-5 with typical sizes of ~100 kpc, are among the most mysterious of astronomical objects. While the nature of these blobs has been hotly debated, they are likely the sites of massive galaxy formation. To understand their abundances and environments, we carried out two complimentary narrowband imaging surveys targeting blobs at z=2.3: one shallow but ultra-wide survey (with Steward 30k-2.3m) and the other deeper survey but with smaller sky coverage (with NOAO 4m telescopes). After searching over ~5 deg\textsuperscript{2} on the sky, we found a pair of radio-quiet blobs that are separated only by 70” (550 kpc) on the sky and have almost identical redshifts (<350 kpc), suggesting that they are strongly clustered. Furthermore, from the deeper survey searching four 30’x30’ fields (CDFS, CDFS, two COSMOS subfields), we discovered ~six largest/brightest blobs (area > 16 ˚) only in one survey field (CDFS). This strong field-to-field variation indicates that these extended Lyα nebulae occupy high density regions and perhaps they are the precursors of brightest cluster galaxies. Spatial distribution of compact Lyα emitters in CDFS confirms the presence of large-scale belt-like structure, possibly a proto-cluster, with 10x40 comoving Mpc in size.

1. What Are Lyα Blobs (Lyα Nebulae)?
Lyα blobs have been discovered by narrowband imaging surveys and are extended over ~10\textsuperscript{4} (100 kpc) with Lyα luminosity of 10\textsuperscript{44} erg/s. While blobs may represent an important phase of massive galaxy formation, their energy sources (e.g., AGN, superwind, cold accretion), kinematics of their surrounding gas (infall vs. outflow), and what they will turn into at the present-day universe are poorly understood. Nonetheless, our study (this poster) will show that blobs are strongly clustered populations at z=2.3, therefore, likely tracers for protoclusters at the high redshifts.

2. Blind Surveys for Lyα Blobs
- **Identify Lyα blobs in blank fields at key redshift (z=2.3)** to constrain number density/environment/clustering

3. Close Pair of Blobs from Wide-Field Survey
- **Total sky coverage = 4.82\textsuperscript{2}**
- **Line-of-sight depth: Δz ~ 0.04 = 50 cMpc**
- **Survey volume = 2.1 \times 10\textsuperscript{7} Mpc\textsuperscript{3}**
- **Wide-FOV narrowband survey to date:**
  - **After searching over ~5 \textsuperscript{2} on the sky, we discover a pair of radio-quiet blobs that are separated only by 70” on the sky and have almost identical redshifts, suggesting that Lyα blobs are strongly clustered.**

4. Strong Field-to-Field Variation of Blobs

5. Dark Matter Halo Mass of Lyα Blobs
With the number density and the clustering of blobs in hand, we can now constrain the mass of dark matter halos where blobs reside, therefore how blobs will evolve into the present-day universe.

The abundance (1.2 \times 10\textsuperscript{7} Mpc\textsuperscript{3}) and 100% duty cycle requires DM halos with $M_{\text{halo}} \geq 10^{13} M_{\odot}$ at $z=2.3$ ($\sim 1 \times 10^{14} M_{\odot}$ at $z=0$), which exhibits the strong cosmic variance ($\sigma_{v}=100\%$; see left).

Probability of finding 6 or more blobs in one field but none from other three fields is Probl10(6, 0, 0, 0) = 0.5 – 1.5%: plausible!

6. Lyα Blob: Tracer for High-z Protocluster?
- **Extremely Rare:** n = 3 – 12 \times 10\textsuperscript{-6} Mpc\textsuperscript{-3}, consistent with cluster number density
- **Strongly Clustered:** close pair of blobs, strong field-to-field variation
- **Occupying Massive Halos:** $M_{\text{halo}} \geq 10^{13} M_{\odot}$ at $z=2.3$
- **Lyα blobs are precursors of brightest cluster galaxies in proto-clusters**

7. So... Did We Find a Proto-cluster in CDFS?
- **Small dots (ø): Compact Lyα emitters**
- **Large dots (ø): Lyα blobs**
- **Large-scale structure over ~50 cMpc**
- **Blobs reside in the over-dense region**
- **Effective technique to find proto-clusters at high-z if wide-FOV tunable filters are employed**