Intensity Mapping for Extended Lya Emission around z~2-7 LAEs

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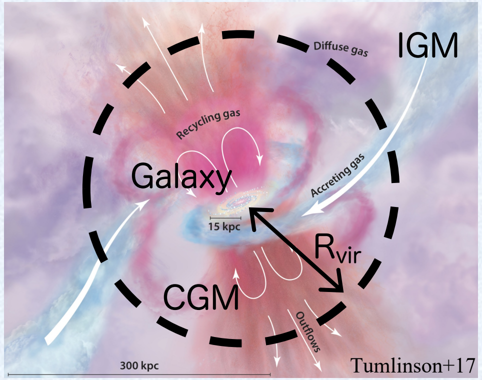
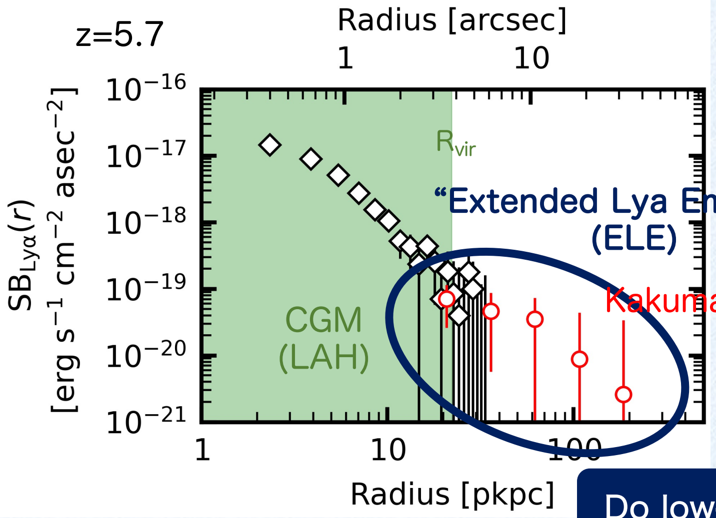
Galaxy-IGM Workshop 2021

Why Lya Halos?



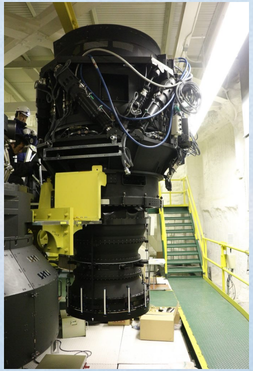
- Gas surrounding galaxy = Circumgalactic medium (CGM)
  - CGM fuel star formation in galaxy
  - Hydrogen gas in CGM can be traced by Lya → "Lya halo" (LAH)
  - Surface brightness (SB) radial profiles around Lya emitters (LAEs)?



Do low-z (z<5) LAEs host such ELE?

Observation & Sample

- Data: narrow-band (NB) images from Subaru/HSC intensive surveys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HSC-SSP NB816 (λ=8177Å), NB921 (λ=9215Å) → z=5.7 & 6.6 LAEs

Subaru Strategic Program (Aihara+19)

CHORUS NB387 (λ=3863Å), NB527 (λ=5260Å) → z=2.2 & 3.3 LAEs

Cosmic Hydrogen Reionization Unveiled with Subaru (Inoue+20)

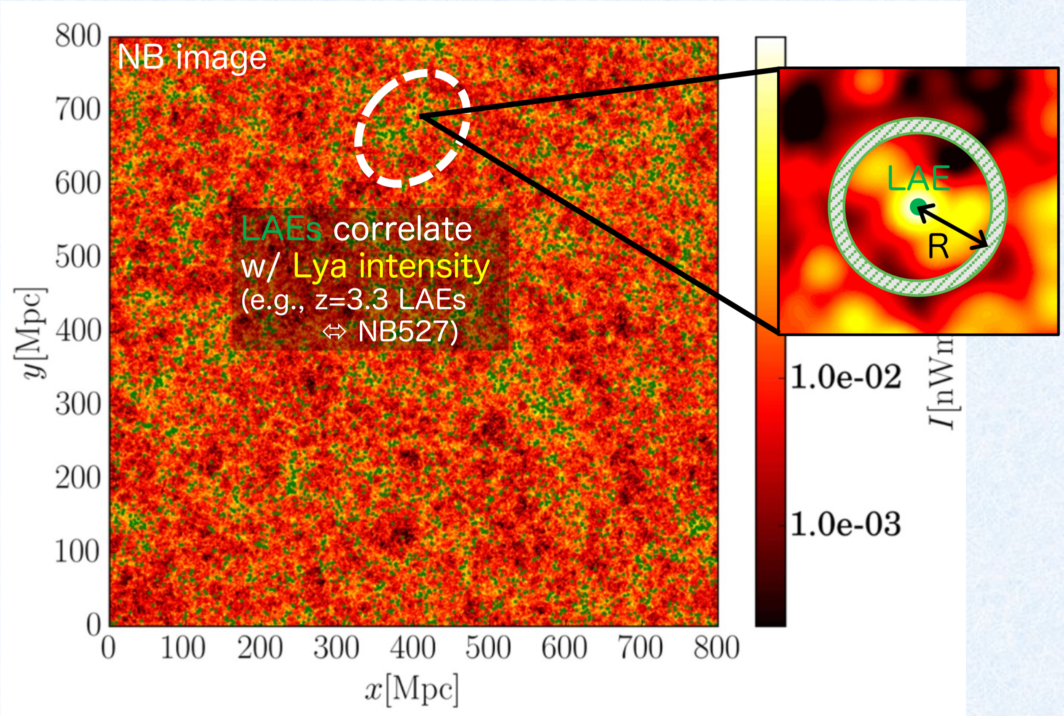
  - UltraDeep (UD) layer images (5σ ~ 26 mag) → advantageous to detect very diffuse emission
  - COSMOS+SXDS fields (~4 deg^2) → large LAE sample

- Sample: from Ono+21 (as a part of SILVERRUSH Systematic Identification of LAEs for Visible Exploration and Reionization Research Using Subaru HSC)

  - Selected from S18A images
  - N=369 (z=2.2), 793 (z=3.3), 603 (z=5.7), 80 (z=6.6)
    → Total 1,845 LAEs

Added >1,000 LAEs at z=2.2&3.3 to Kakuma+21

Method: Intensity Mapping

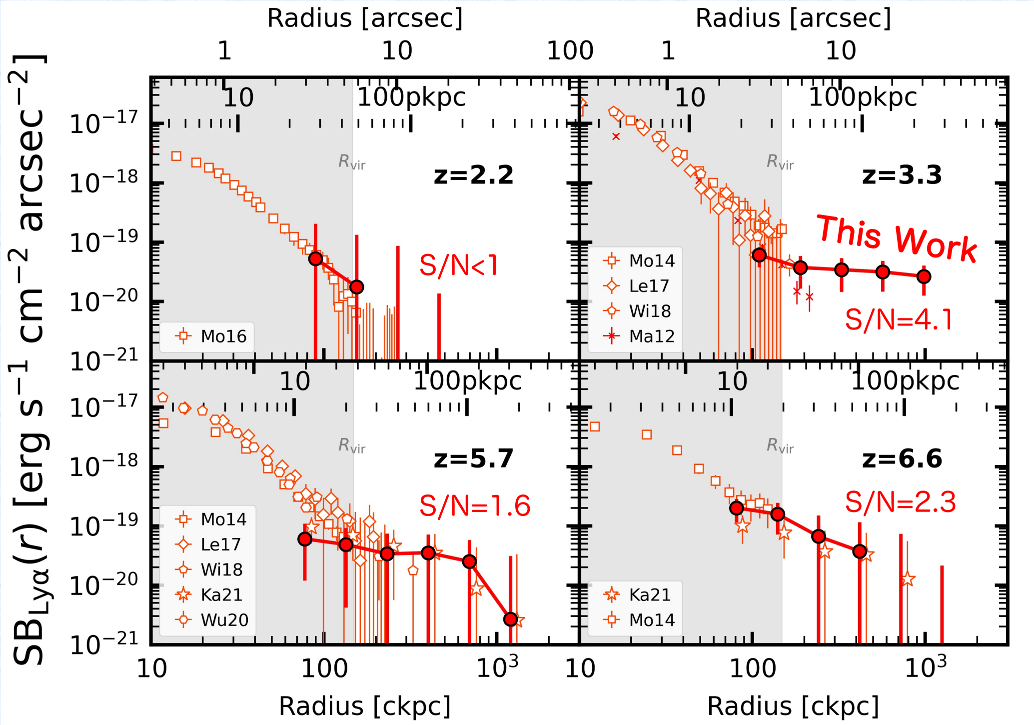


Comaschi&Ferrara16, Li+16, Kovetz+17

$$\mathrm{SB}(r) = \sum_i \mu_{r,i} \Big/ \sum_i i$$

$\mu_{r,i}$: pixel values in ◯

Result: SB Radial Profiles



※ SB are normalized such that luminosities in r < 1" become similar
Our SB are averaged over COSMOS & SXDS fields at z=5.7 & 6.6

- No clear detection at z=2.2
- Newly detected (S/N=4.1) at z=3.3
- Potential detection (S/N~2) at z=5.7 & 6.6

- Our SB agree w/ previous results at ~R_{vir} when compared under similar luminosity

Ma12: Matsuda+12 (stacking)
Mo14: Momose+14 (stacking)
Mo16: Momose+16 (stacking)
Le17: Leclercq+17 (individual detection)
Wi18: Wisotzki+18 (stacking)
Wu20: Wu+20 (stacking)
Ka21: Kakuma+21 (intensity mapping)

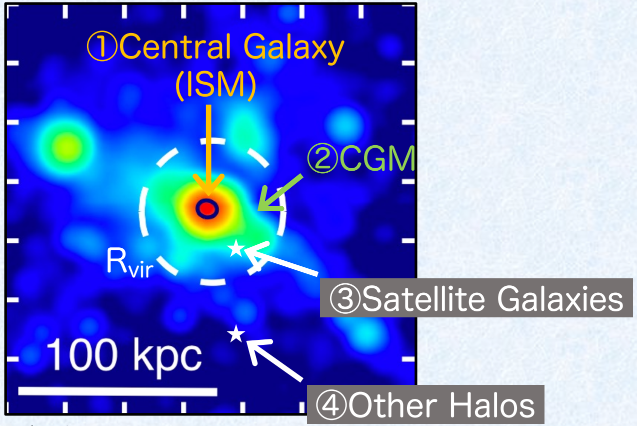
What Power Lya Emission?

- Possible physical *processes* (*how* Lya photons are produced):

= Fluorescent =	= Scattering =	= Cold flow =
Recombination of HI gas in the CGM by ionizing photons from central galaxies	Resonant scattering of Lyα photons from central galaxies by HI gas in the CGM	Shock heating by the cold gas from the IGM (~10^4 K) can radiate Lyα
Likely Matsuda+12 Leclercq+17, 20 Kusakabe+19 Unlikely	Matsuda+12 MR+16 Wisotzki+16 Xue+17 Leclercq+17, 20 Claeyssens+19 Kusakabe+19 Wu+20	Matsuda+12 Leclercq+17 MR+16 Xue+17 Kusakabe+19 Leclercq+20

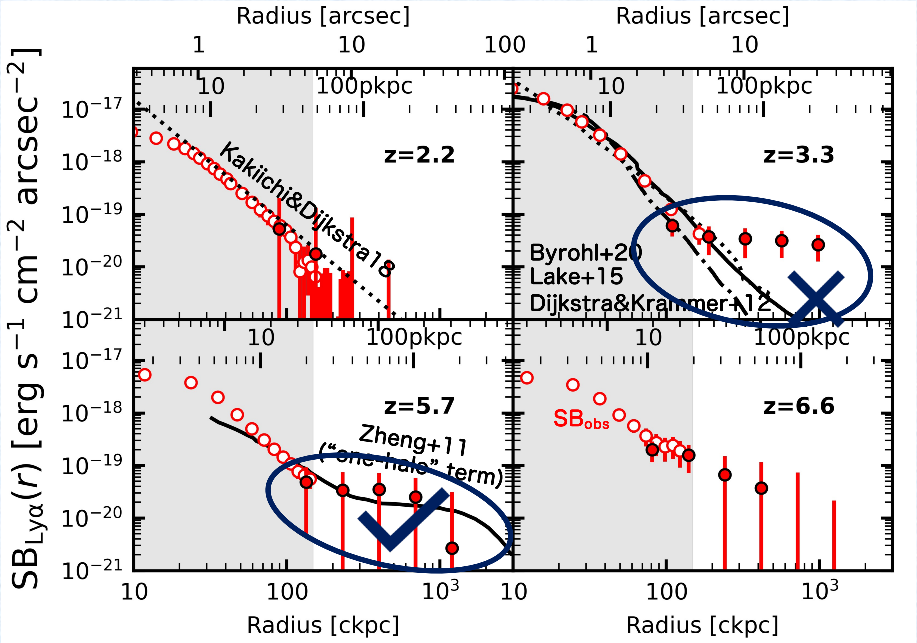
©Momose-san's review talk from IGM-Galaxy Workshop 2020
See also Umehata-san's review talk in this morning

→ Alternatively, we discuss based on Lya emission *origins* (*where* Lya photons are produced)



Lake+15

What Power Lya Emission? (1): Central Galaxy



※ SB are normalized such that luminosities in r < 1" become similar

- Star formation in central galaxy
  → Lya photons via recombination
  → transfer outward while being scattered

Results

- Zheng+11 reproduces SB_{obs} (z=5.7)
- All model predictions lie below SB_{obs} (z=3.3)

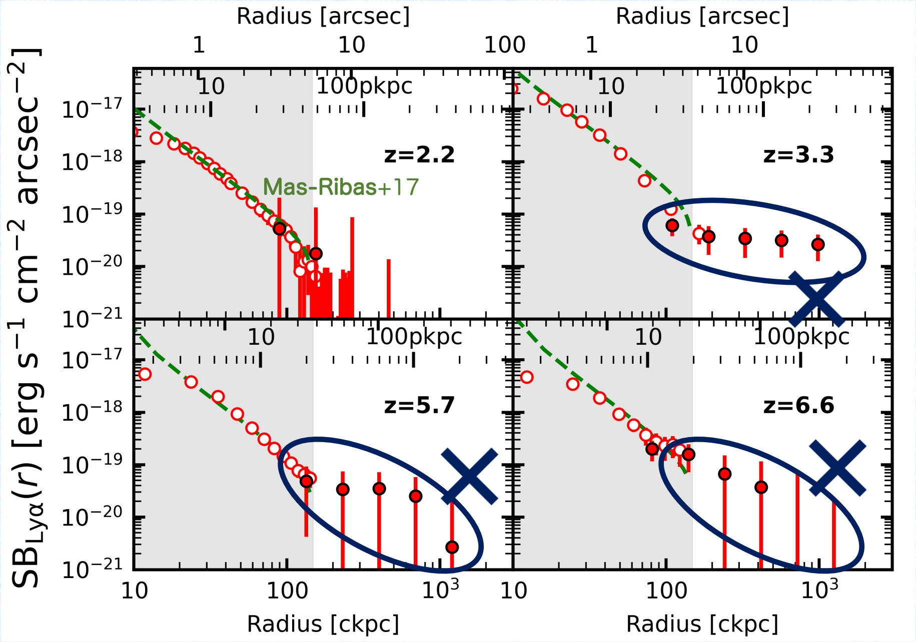
Intepretations

- Contribution decreases toward low-z?
- Discrepancy among models?

Scattered Lya from central galaxy is *candidate* of ELE powering source

c.f.
- IGM scattering → plateau-like SB profile (Jeeson-Danieli+12)
- Lya line profile asymmetry (Chen+21)
- Halo luminosity vs mass relation (Kusakabe+19)

What Power Lya Emission? (2): CGM



※ SB are normalized such that luminosities in r < 1" become similar

- Star formation in central galaxy
  → ionizing photons
  → *fluorescent* emission in CGM

Results

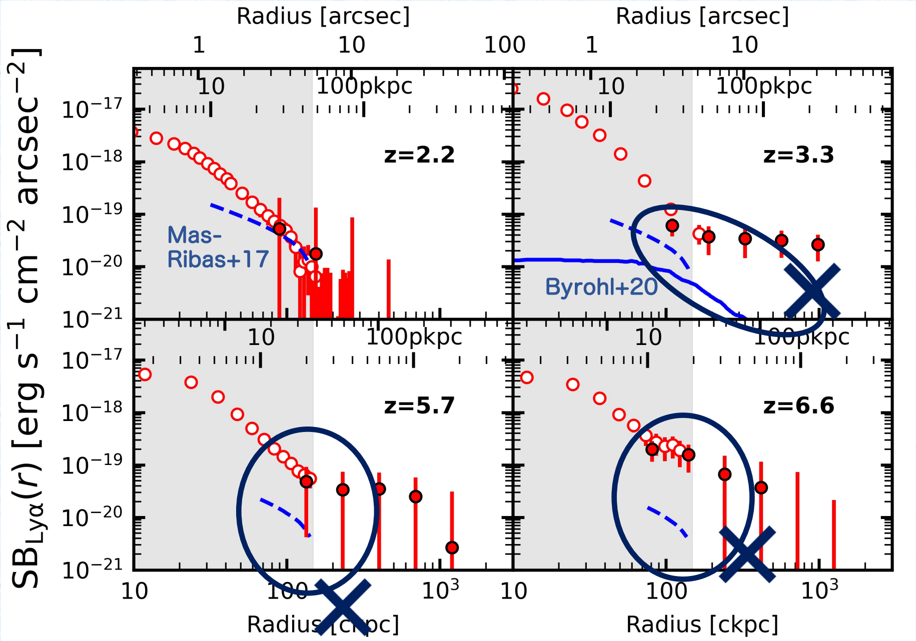
- Predicted SB drop at R_{vir}
  → CGM contribution alone cannot reproduce SB_{obs}

Intepretations

CGM fluorescence *unlikely* to power ELE

c.f. Cooling radiation contribution is not dominant
(Rosdahl&Blaizot+12, Byrohl+20)

What Power Lya Emission? (3): Satellite Galaxies



※ SB are normalized such that luminosities in r < 1” become similar

- Star formation in satellite galaxies
  → Lya photons via recombination

Results

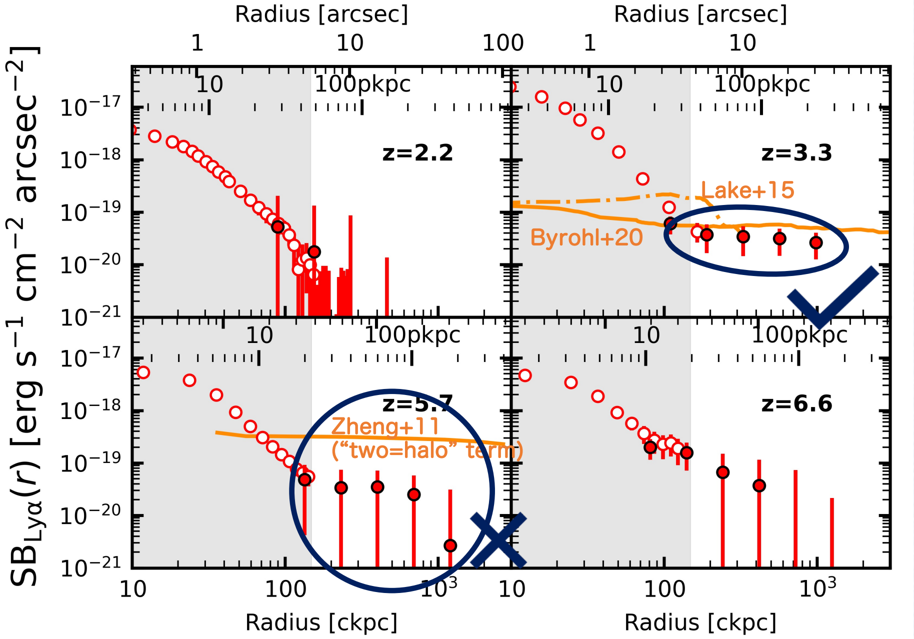
- Predicted SB ≪ SB_{obs} (except at z=2.2)

Intepretations

Satellite galaxies *only marginally* contribute to ELE

c.f. SB(Lya) is more extended than SB(UV)
(e.g., Momose+14, +16, Wu+20)

What Power Lya Emission? (4): Other Halos



※ SB are normalized such that luminosities in r < 1" become similar

- Lya emission from other halos

Results

- Model predictions agree w/ SB_{obs} (z=3.3)
- Zheng+11 overpredicts SB_{obs} (z=5.7)

Intepretations

- Masking bright sources → $SB_{obs} < SB_{model}$ (Kakuma+21)
  → Then why $SB_{model} = SB_{obs}$ at z=3.3?

Other halos *may contribute* to ELE

c.f. MXDF (Bacon+21):
population of faint galaxies can reproduce ELE

Summary

- Intensity mapping to 1,845 LAEs (z=2.2-6.6) + Subaru/HSC NB images (HSC-SSP & CHORUS)
- Very diffuse "extended Lya emission" (ELE) beyond R_{vir} identified around z=3.3-6.6 LAEs
- ELE can be reproduced by …
  - Scattered Lya photons produced in central galaxy
  - Contribution from other halos

- This is first systematic investigation of ELE across z~2-7
- Systematic comparison w/ models is necessary to tackle physical origins

Origins differ among LAEs, populations (LAE/LBG/QSO), radial scales ($<R_{vir}$ or $>R_{vir}$), redshifts, etc. Thus systematic comparison is crucial.