Liang et al. 2025, ApJ, 986, 60

The Cosmic Himalayas:

The Highest QSO Density Peak at Cosmic Noon Bridging AGNs, Galaxies, and IGM

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In collaborations with:

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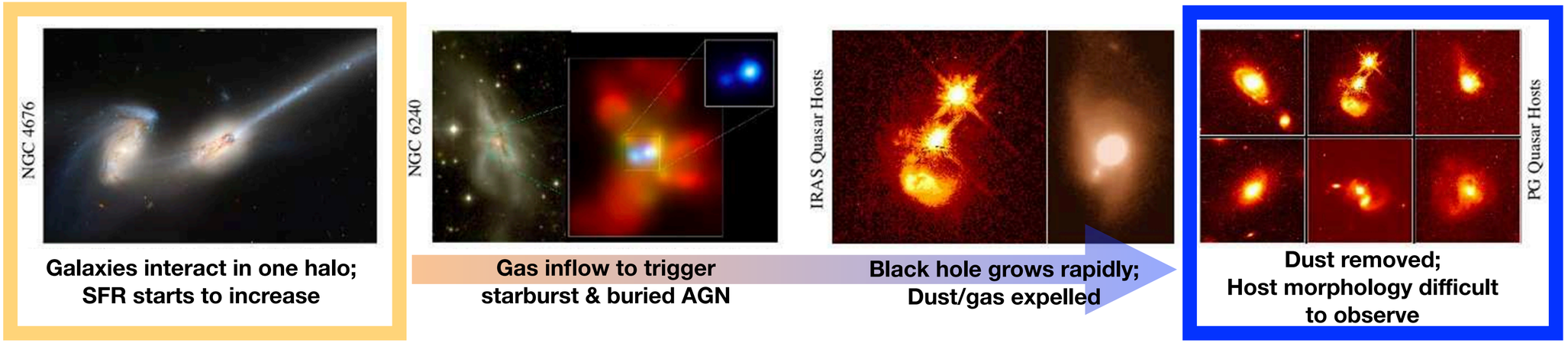
Background: Galaxy Evolution and AGN

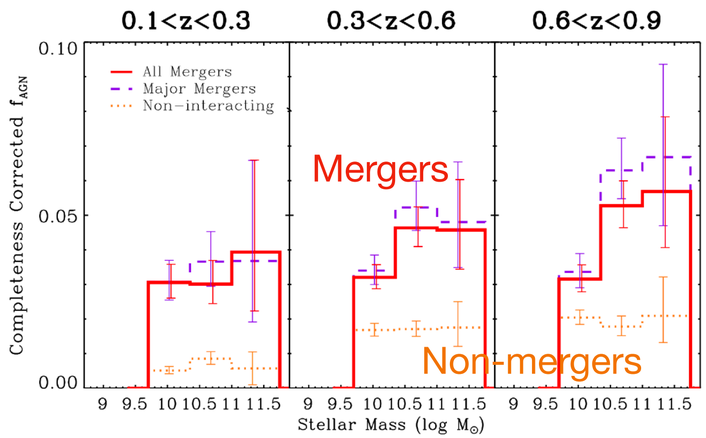
✦ Galaxy Evolution with QSO/AGN in Theory

(Hopkins+2008)



✦ AGNs Triggered by Mergers?

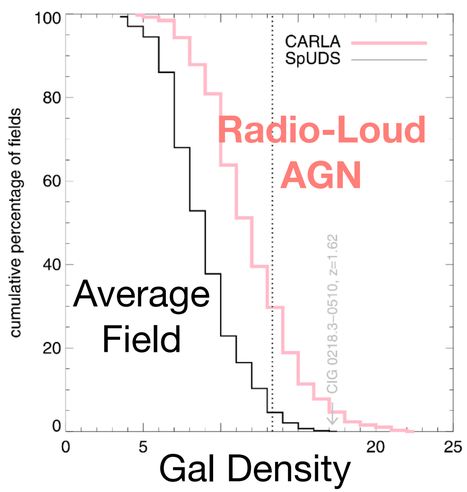
Type-2 IR-AGN Fraction



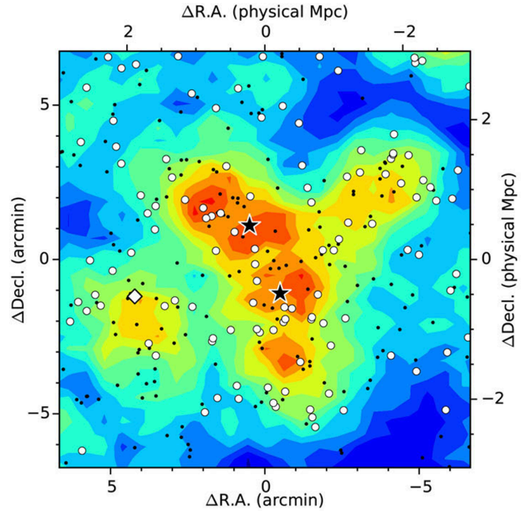
Evidence is found at z<~1 (e.g., Goulding+2019)

BUT: How about higher-z? Type-1 QSO?

✦ QSOs Trace Protoclusters?



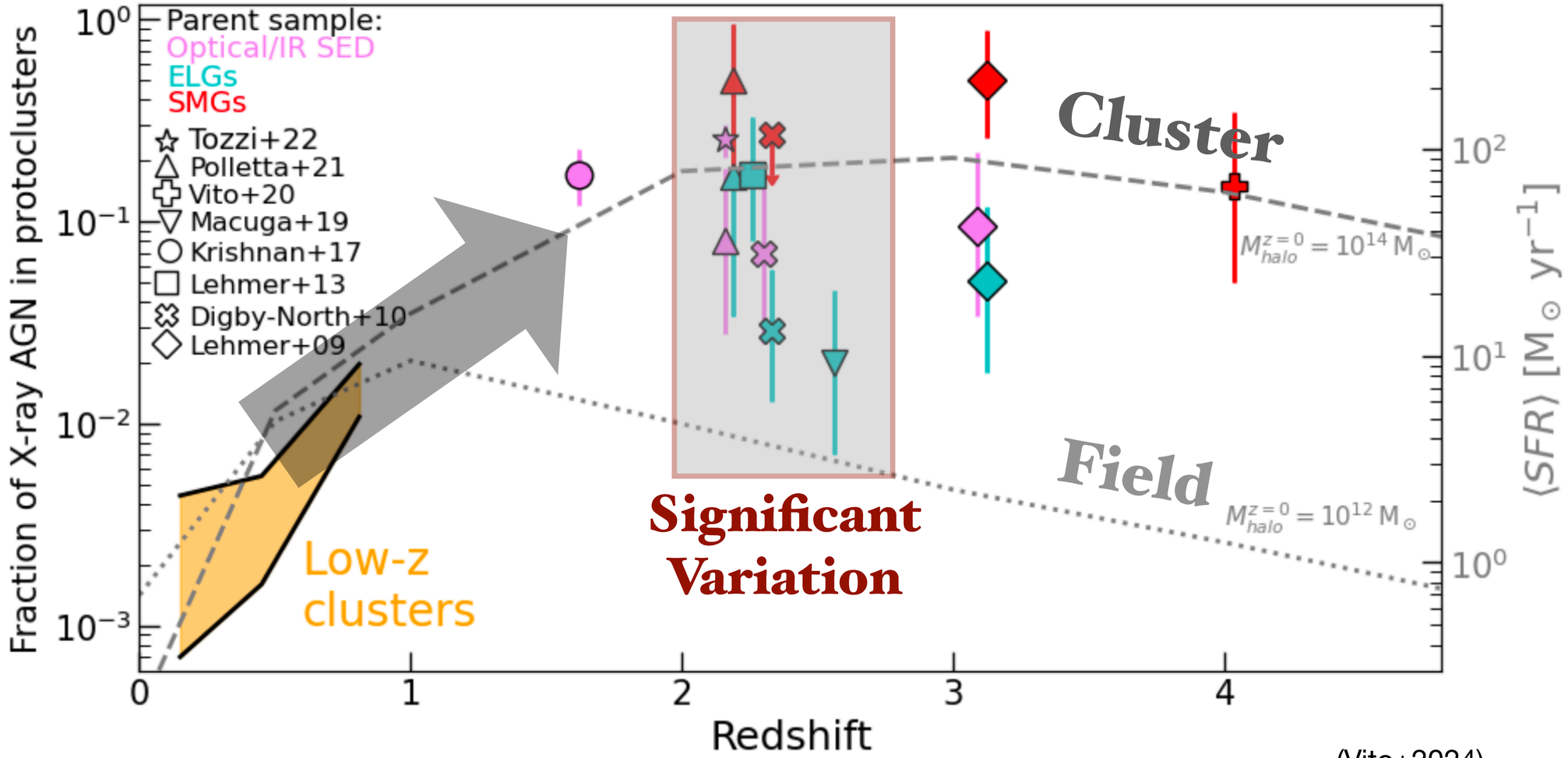
(RLA; Wylezalek+2013)



(QSO pairs@z=4; Onoue+2018)

Background: AGNs in Overdensities

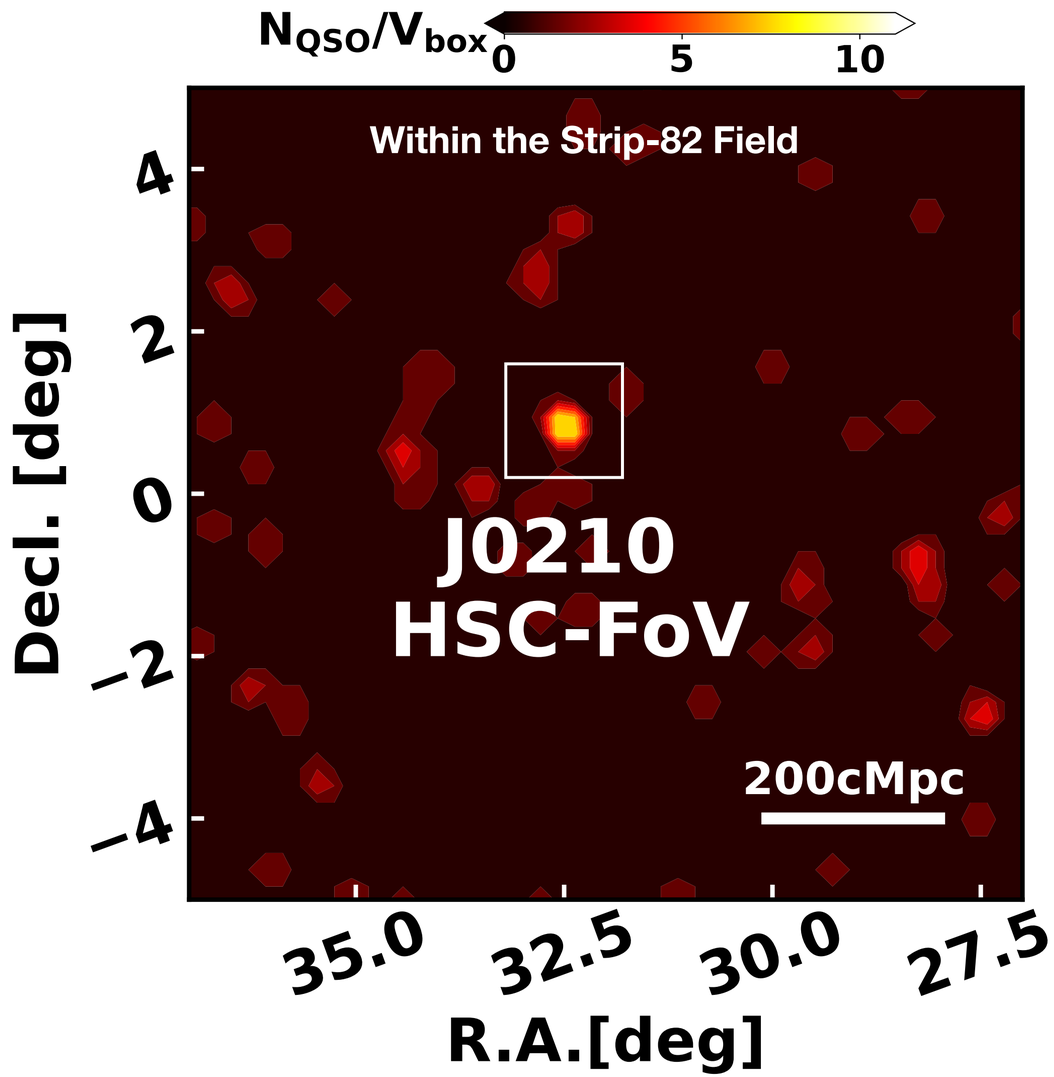
✦ **AGN Fraction in (proto-)clusters:** increasing towards high-z and peak at z~2?

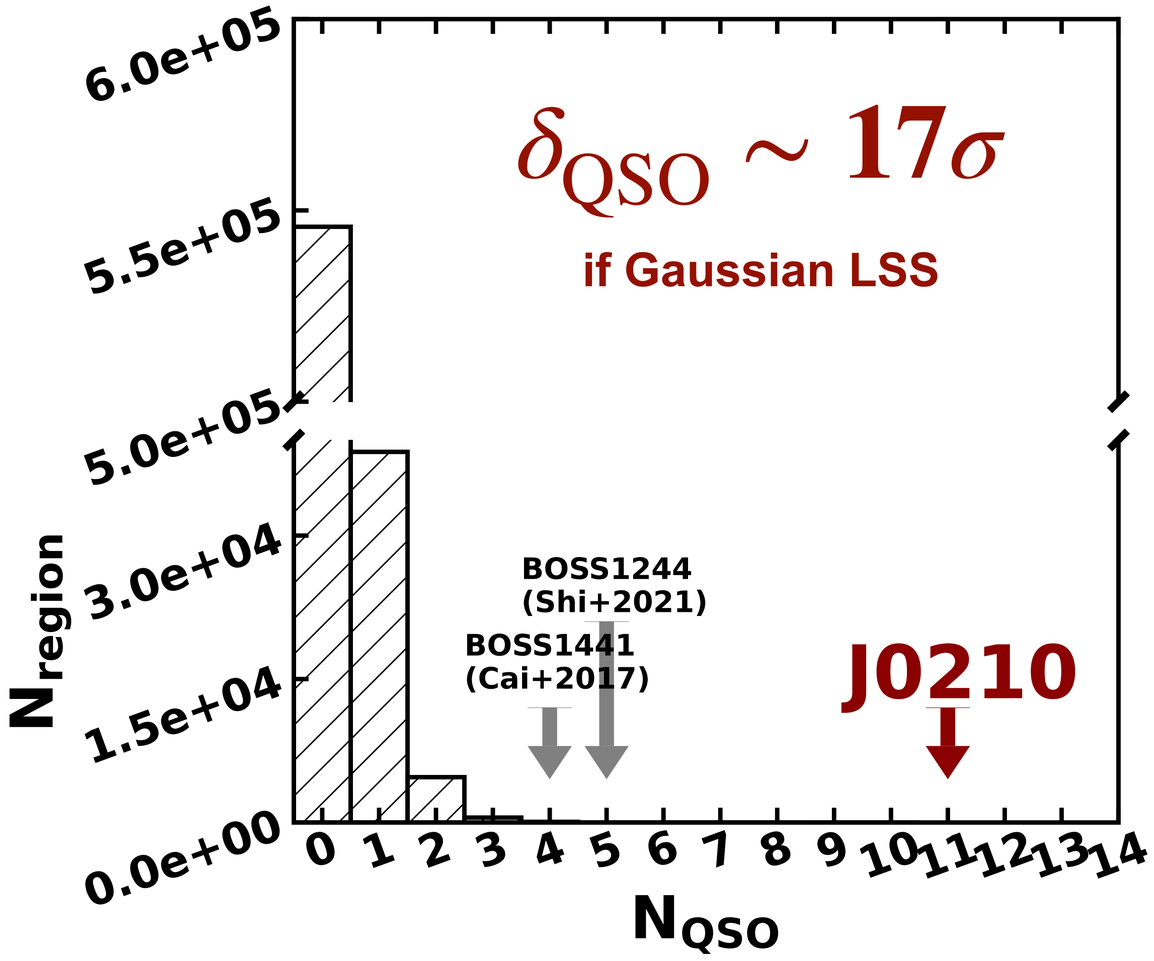


(Vito+2024)

3. An Extreme QSO Overdensity

✦ **The Most Clustered SDSS/eBOSS QSOs@z=2.2 Over 10,000 deg^2**





An Extreme QSO Overdensity

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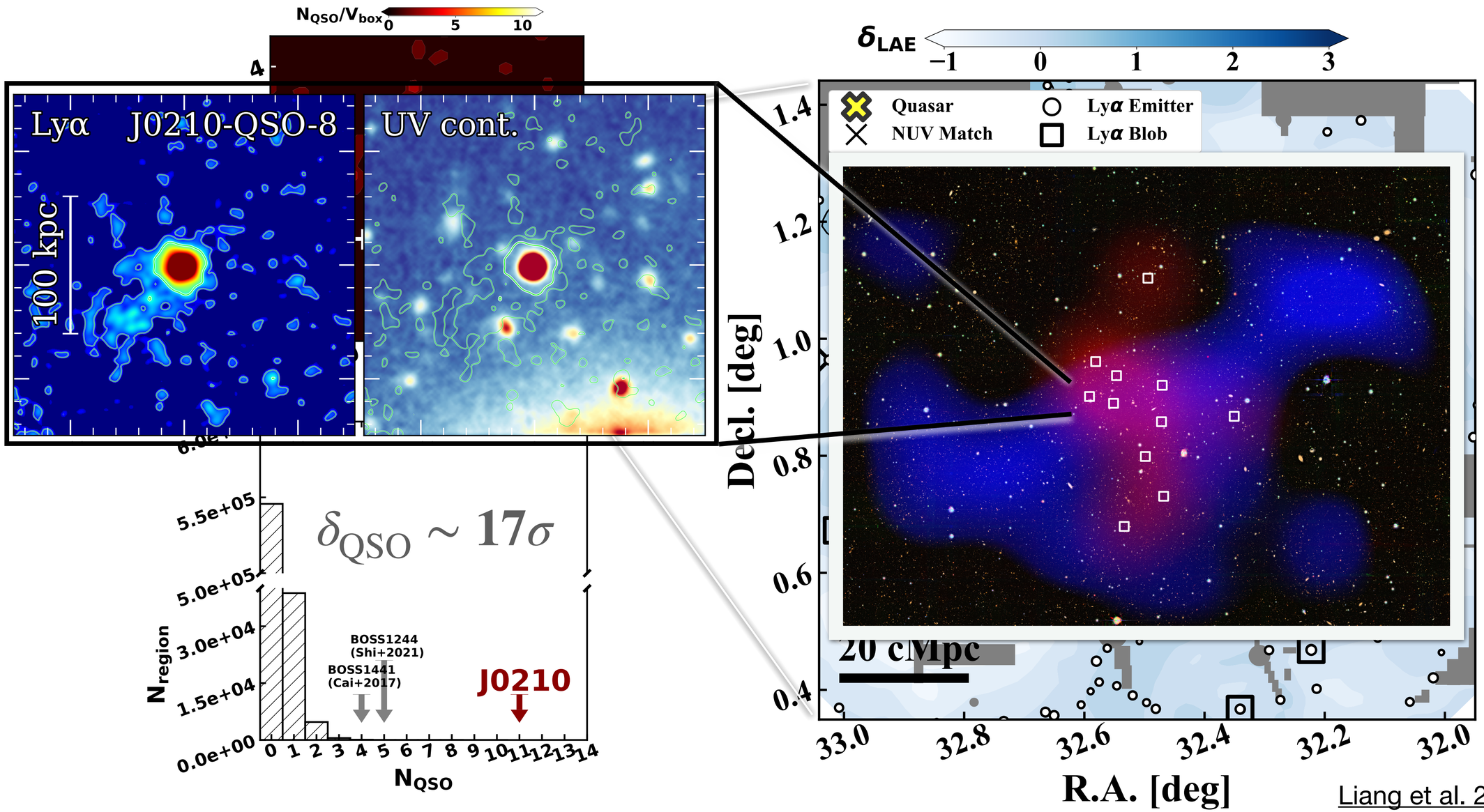

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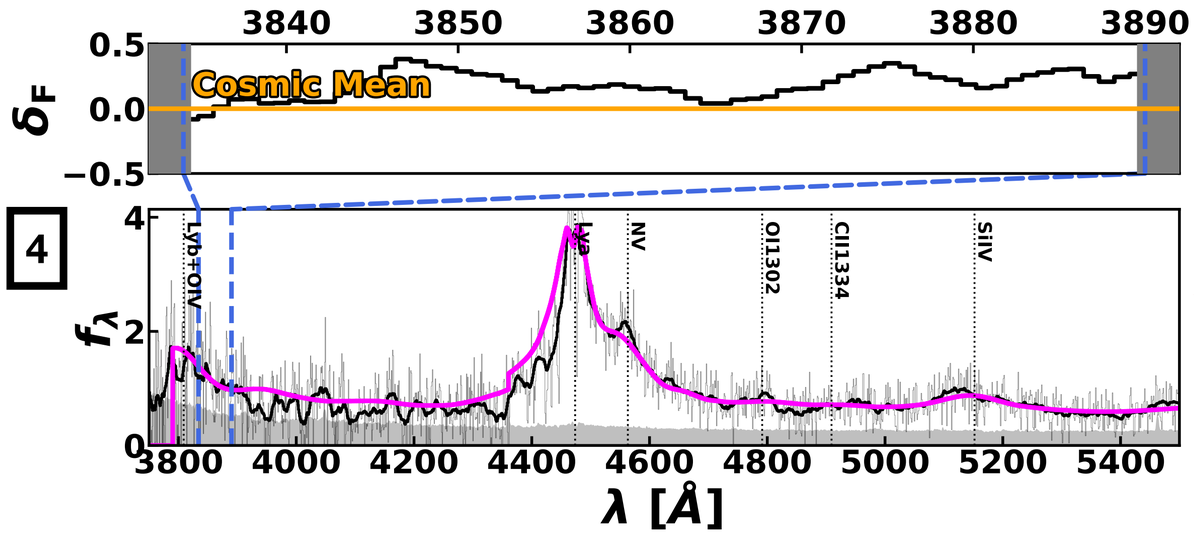
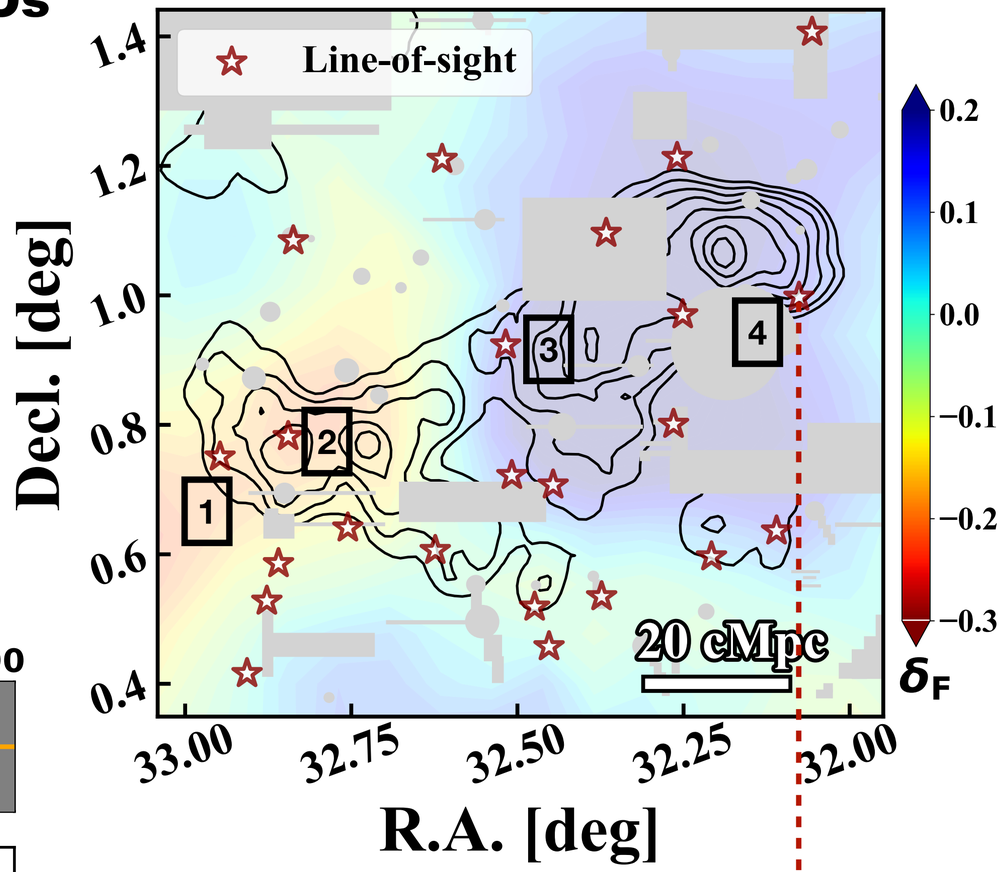
IGM Tomography Methodology

✦ 3D HI Tomography from SDSS/eBOSS QSOs

- **Calculate δ_{F} for each lines-of-sight**
  - Intrinsic continuum by MF-PCA.
  - Transmission at each pixel
  - Lyα transmission contrast δ_F compared to cosmic mean.

$$\delta_F = F_{\mathrm{Ly}\alpha} / \langle F(z) \rangle_{\mathrm{cos}} - 1$$

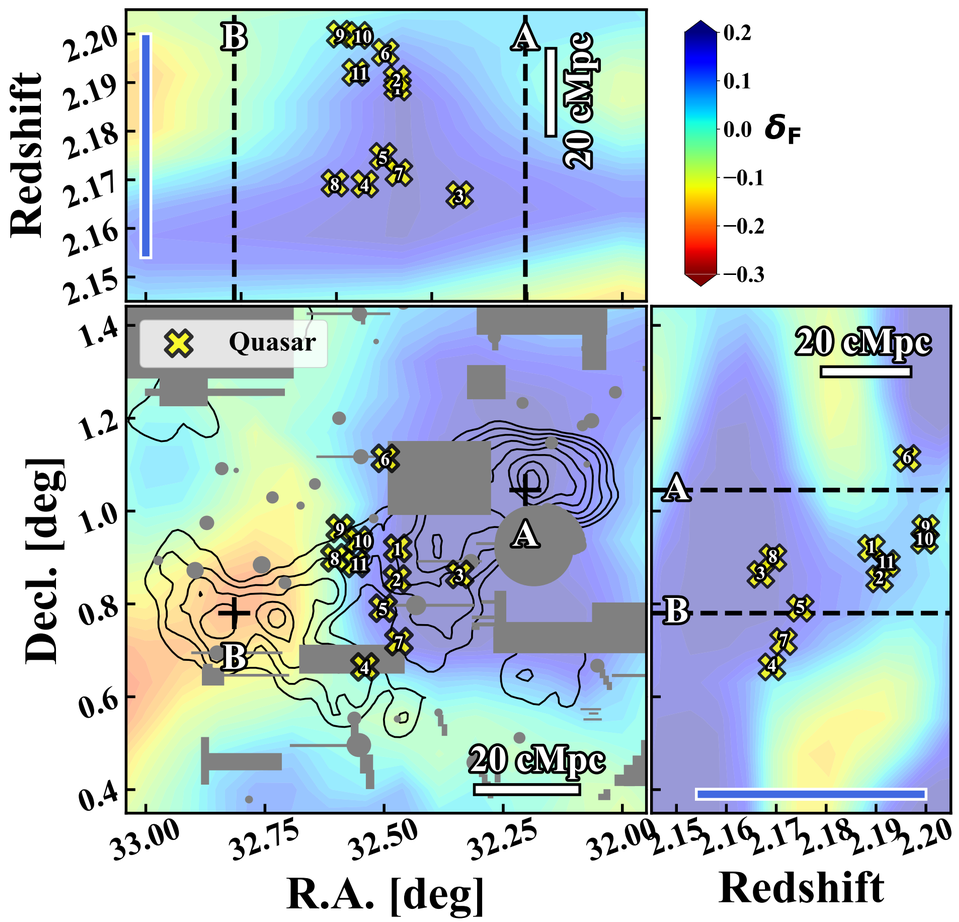


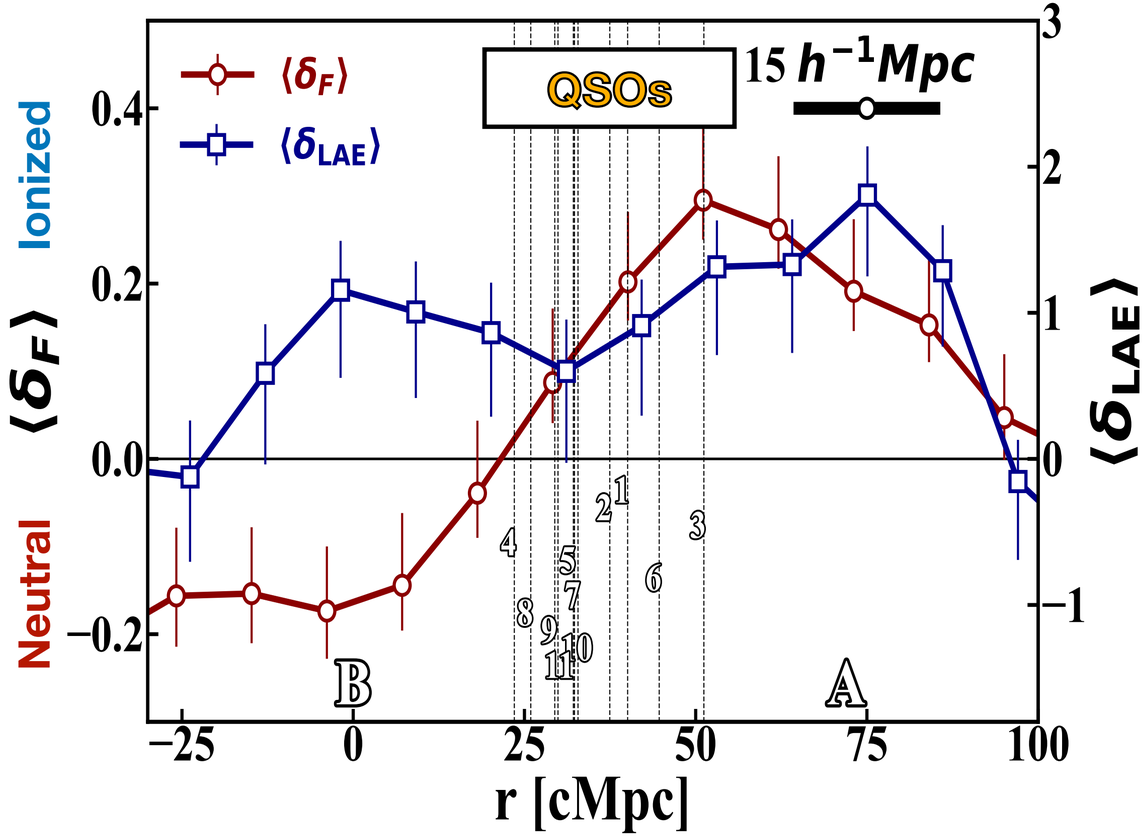


IGM Tomography Result

✦ 3D HI Tomography from SDSS/eBOSS QSOs: Collapsed Map

- Distinct ionizing stages between the two LAE nodes.
- QSOs centered at the transitioning regions.





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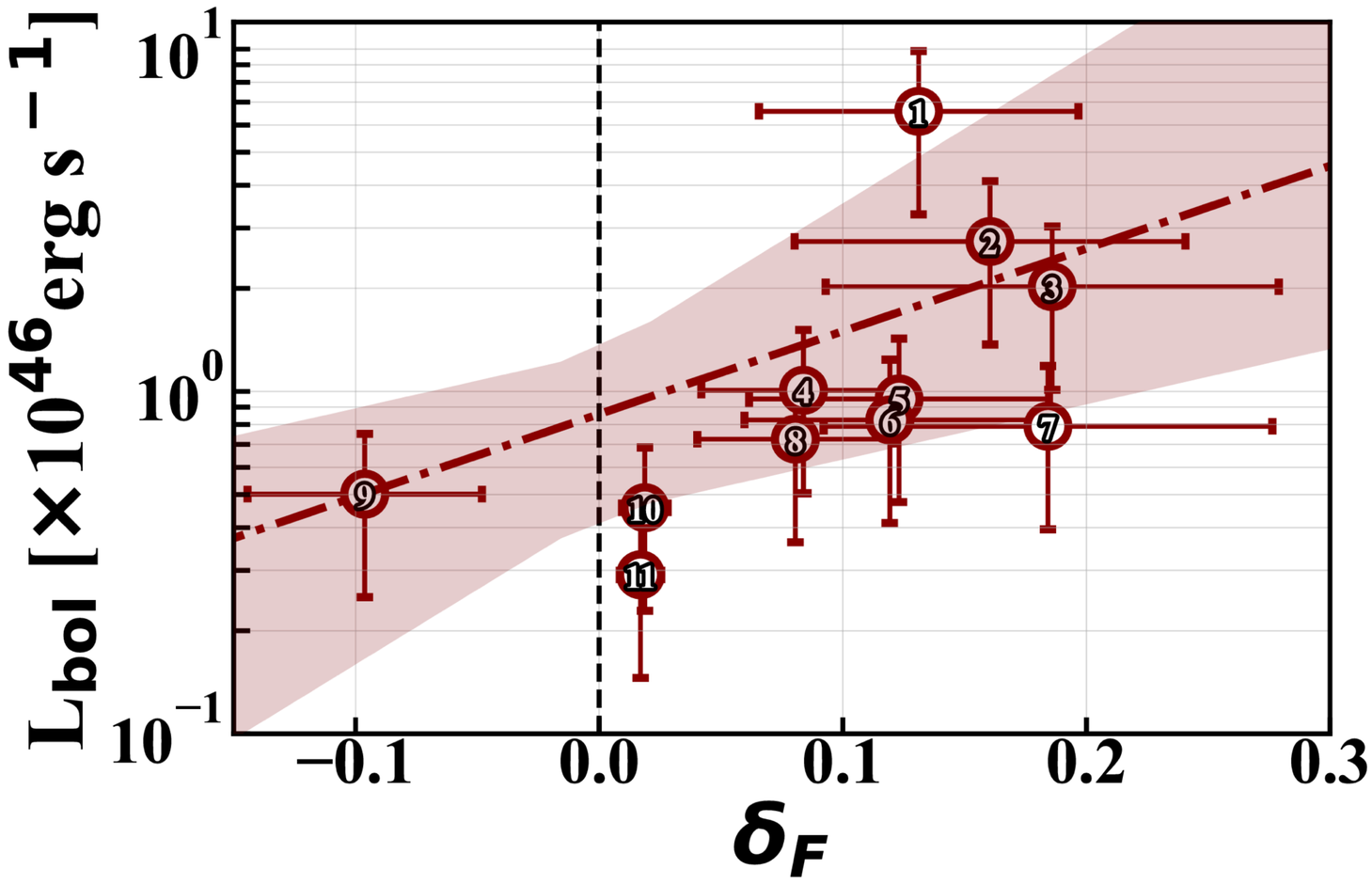
Cosmic Himalayas: IGM Tomography Result

✦ Possible Ionizing Sources in the Ionizing Boundary

- **Contributions from luminous quasars**
  - A significant correlation between the local HI transparency and $L_{\mathrm{bol,QSO}}$



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Cosmic Himalayas: IGM Tomography Result

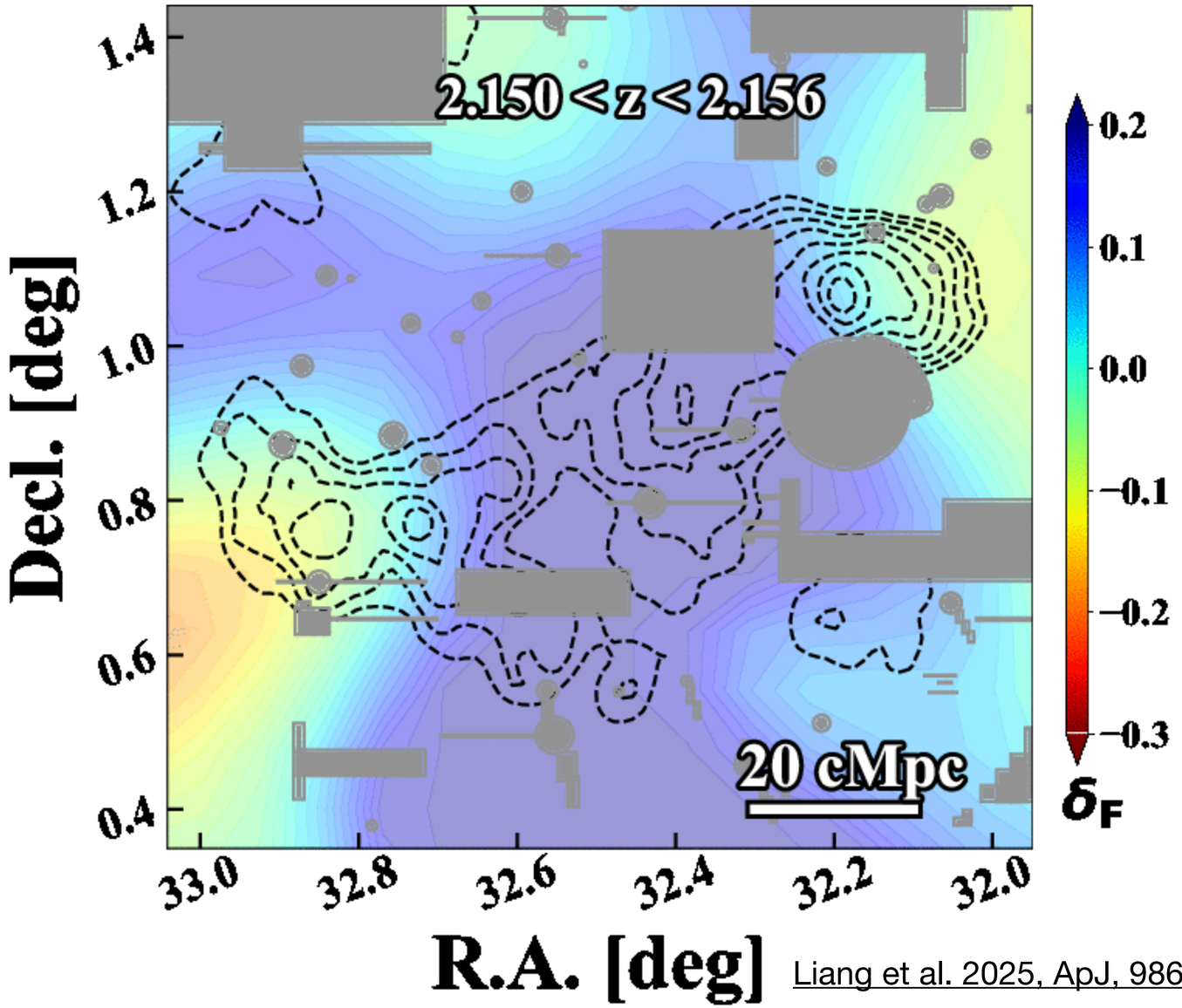
✦ 3D HI Tomography from SDSS/eBOSS QSOs: Slicing Map

- Photoionization contributed in the QSO proximity zone:

$$\Gamma_{\mathrm{HI,\ i}}^{\mathrm{QSO}} = 8.8 \times 10^{-7} \xi \left(\frac{r_i}{10\ \mathrm{kpc}} \right)^{-2}$$

- Photoionization radius that QSO > UVB

$$\Gamma_{\mathrm{HI,\ i}}^{\mathrm{QSO}} > \Gamma_{\mathrm{HI}}^{\mathrm{UVB}} \sim 10^{-12}\ \mathrm{s}^{-1}$$



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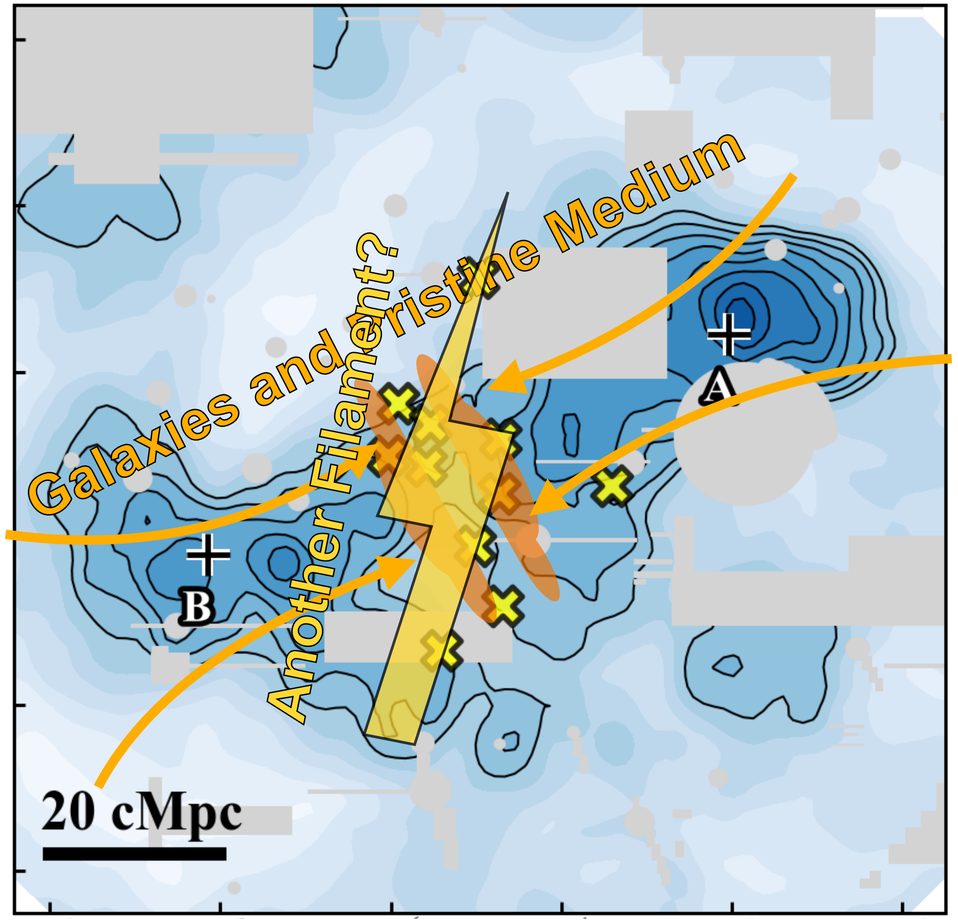
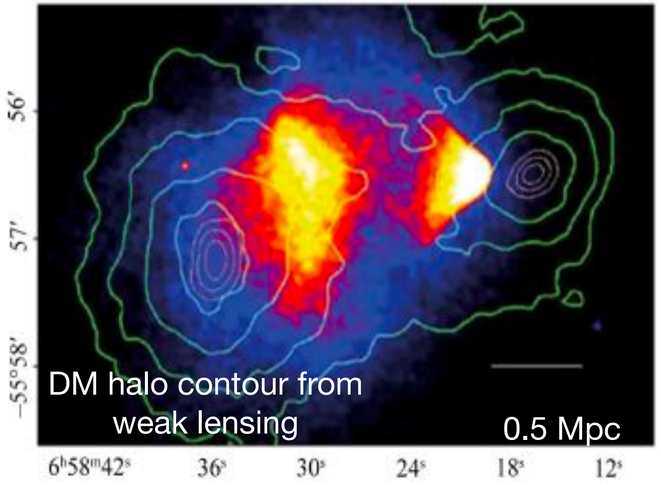
Cosmic Himalayas: How are the QSOs triggered?

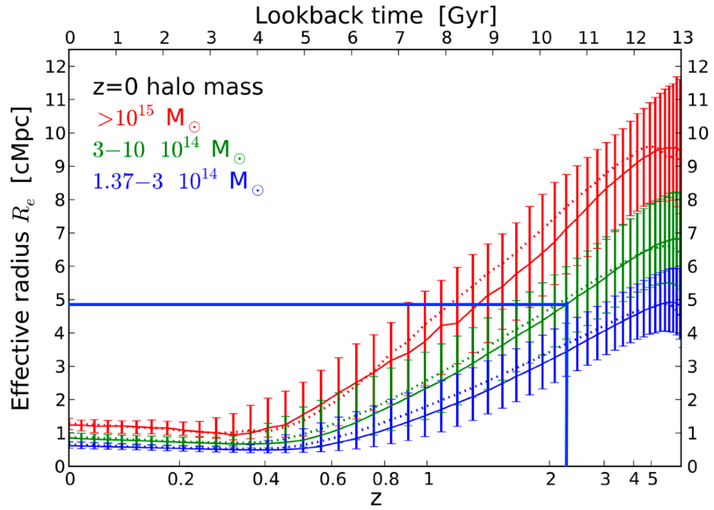
✦ Possible Interpretations of the Quasar Overdensity

- An extreme protocluster w/ rich dust or heated gas, suppressing LAEs?
- A progenitor of cluster merger or intersection of filaments at z=2.2?





Clowe+2004

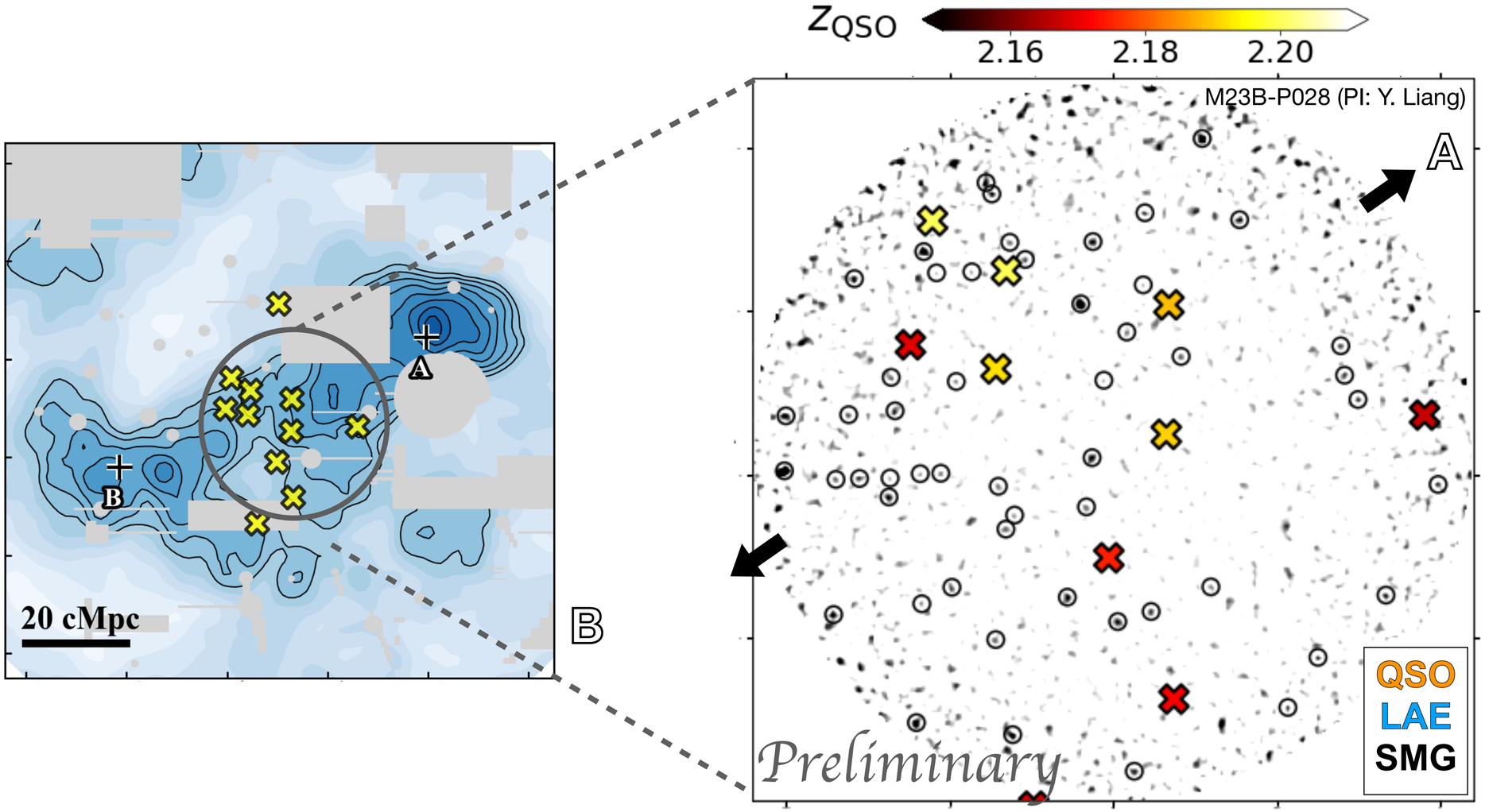


Chiang+2013

Cosmic Himalayas: How are the QSOs triggered?

✦ Possible Interpretations of the Quasar Overdensity

- The Dusty Population Revealed by JCMT/SCUBA-2 850um down to **3 mJy**



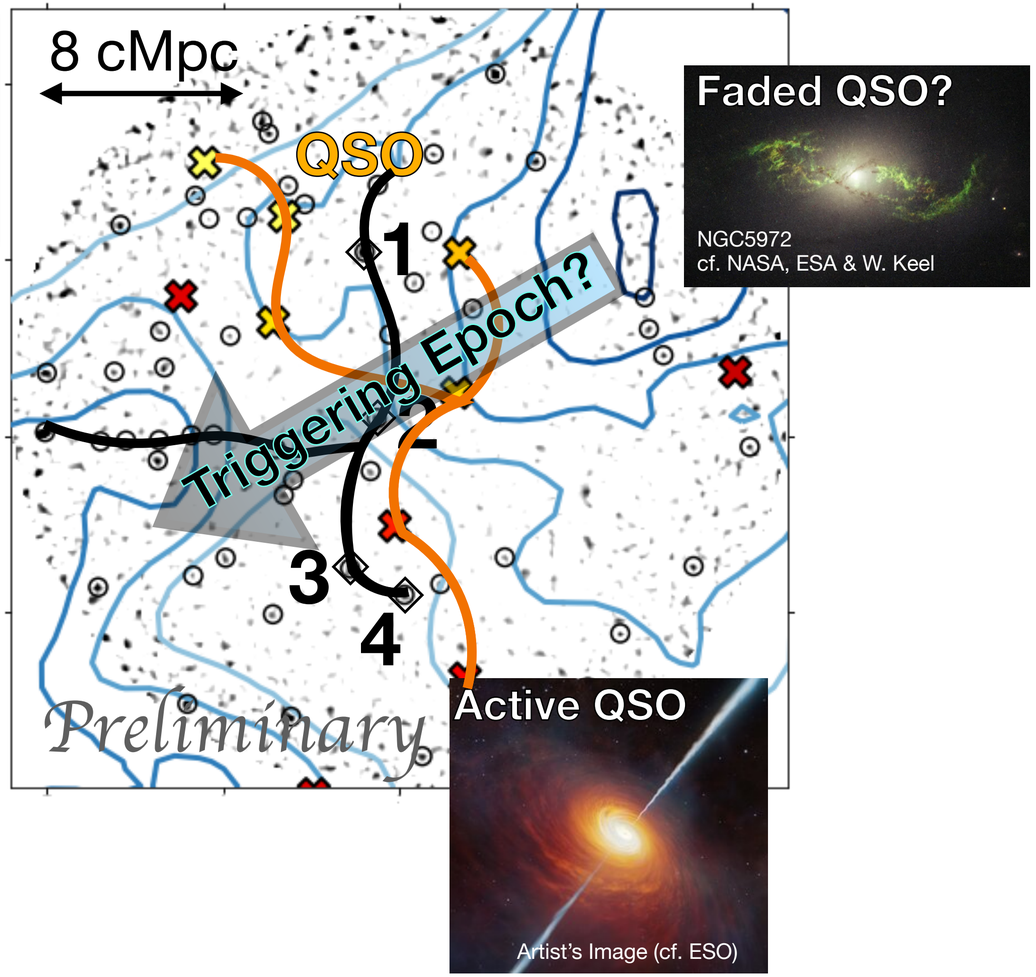
Cosmic Himalayas: How are the QSOs triggered?

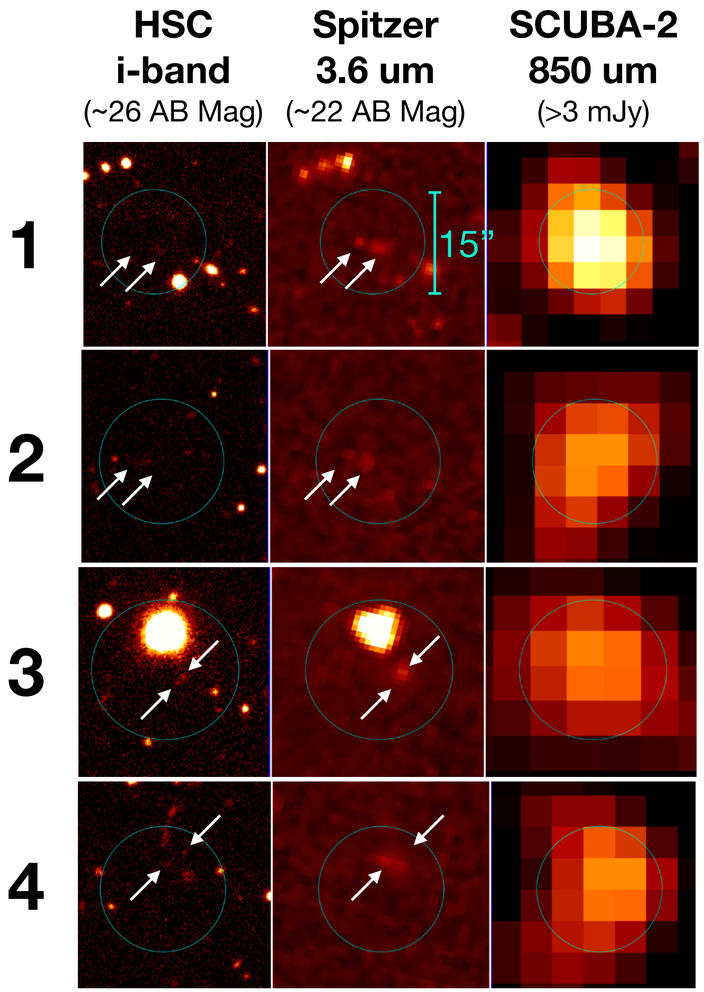
✦ Galaxy evolution along a filament where dust play a crucial role

- JCMT/SCUBA-2 850um maps also indicate a transitioning nature?

Three Accepted ALMA Cycle 12 Proposals:

1. QSO Host CO+CI+Dust
2. SCUBA-2 SMG CO line
3. Blind search w/ mosaic





Future Perspective with Subaru/PFS

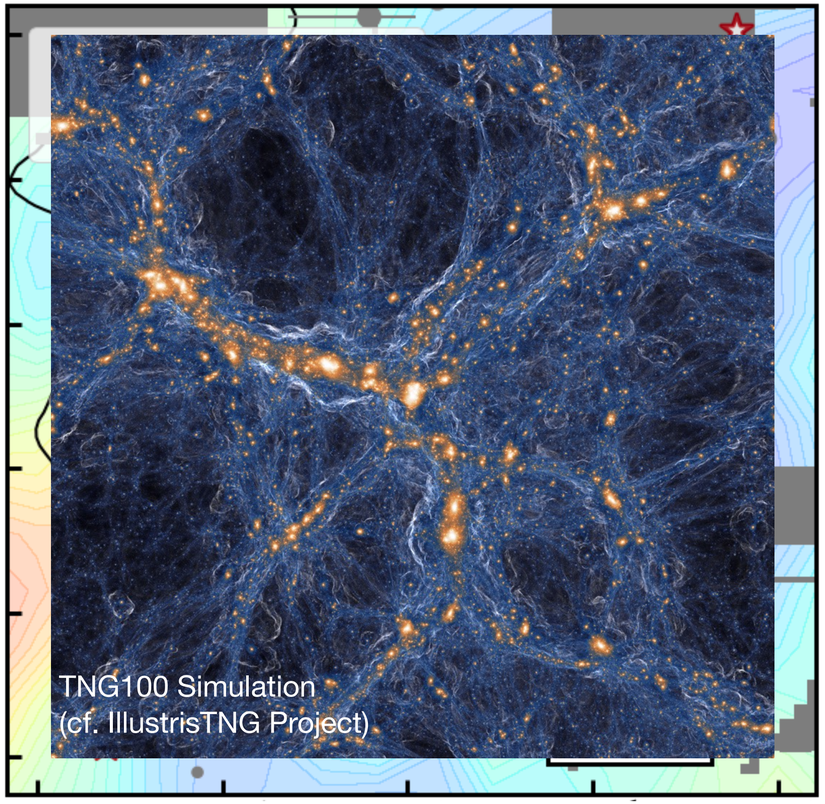
✦ **PFS observation: evolution along a filament of diverse galaxies and fined IGM structures**

- **Spec-z & galactic properties of photometric galaxies:**
  - LAEs (#450) + LBG/BX Gal. + HAEs/BzK + SMGs + X-ray/Radio sources…
    (+u image) (+NB, K image) (+JCMT) (+Chandra/MeerKAT)
- **LOS sampling from background QSOs to LBGs:** $N_{\rm LoS}$ = 23 → O(1000)
  - $d_\perp \sim 20$ cMpc → $d_\perp \sim$ 4-2 cMpc @ 6-12 hrs (ref. SSP GE survey; Greene+2022)

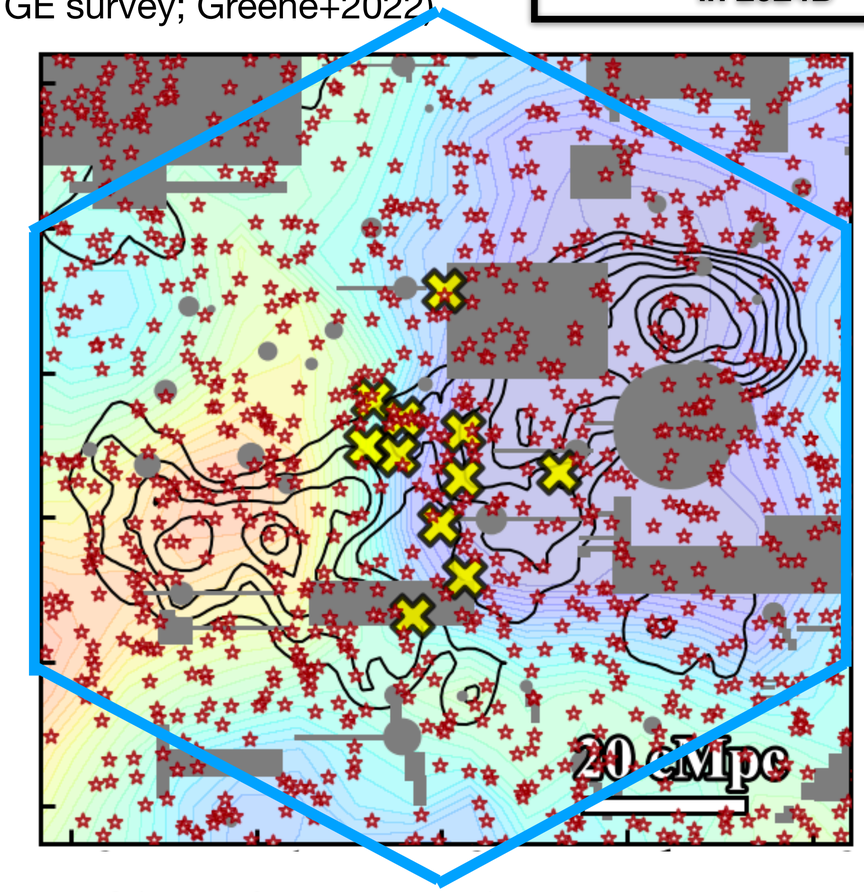
u+K Imaging finished in 2024B +2025B:

1. CFHT MegaPrime (u)
2. Subaru MOIRCS (K, NB)
3. Blanco-4m NEWFIRM (K, NB)

MeerKAT L-band finished in 2024B



With PFS



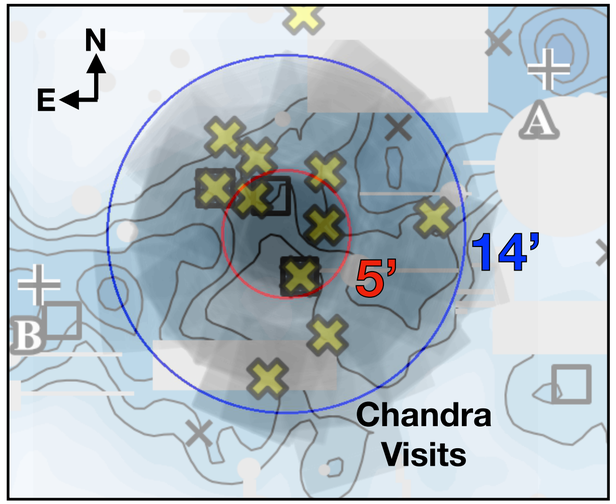
Future Perspective with X-ray Observation

✦ **Chandra X-ray observation: SMBH growth and QSO triggering associated with the ongoing accretion disk**

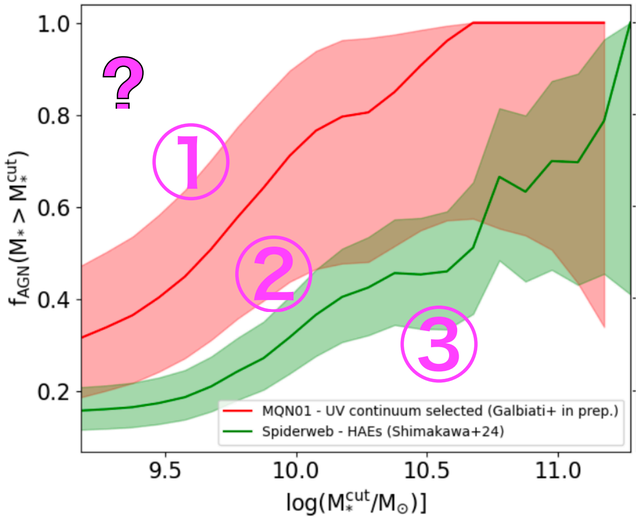
Host Properties

N_H, λacc, XLF

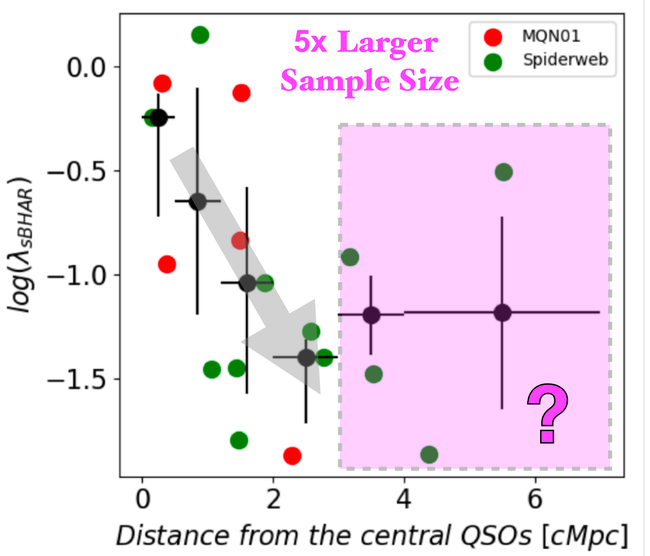
340 ks to $L_{2\text{-}10keV} = 10^{43.7}$ erg/s



AGN Fraction vs. Stellar Mass Limit



AGN Accretion vs. Distance to QSOs



(Travascio+2024)

- **Chandra Cycle 27 Approved Targets**

https://cxc.cfa.harvard.edu/target_lists/cycle27/cycle27_approved_peer_targets_by_radec.html

01:44:04.1	-15:56:14.9	tau Ceti	HRC-S	NONE	60.00		27200138	Mélis	University of California, San Diego (UCSD)
01:46:35.7	49:14:43.1	ZTF 0146	ACIS-S	NONE	50.00		27300224	Cunningham	Harvard University
01:48:37.6	06:00:20.0	SDSS J014837.63+0600	ACIS-I	NONE	750.00		27700099	Eilers	Massachusetts Institute of Technology (MIT)
01:57:50.0	62:12:26.7	PSR B0154+61	ACIS-S	NONE	60.00	Alt	27500298	Ng	McGill University
02:08:48.0	01:00:00.0	BOSS0210E	ACIS-I	NONE	170.00		27700042	Lepore	INAF/OA - Arcetri
02:10:00.0	00:50:24.0	CH_Chandra01	ACIS-I	NONE	340.00		27700187	Liang	National Astronomy Observatory of Japan (NAOJ)
02:10:56.4	58:45:17.7	PSR J0210+5845	ACIS-S	NONE	60.00	Alt	27500298	Ng	McGill University
02:11:00.0	00:46:48.0	BOSS0210W	ACIS-I	NONE	170.00		27700042	Lepore	INAF/OA - Arcetri
02:42:41.3	-00:00:31.9	SN 2018ivc	ACIS-S	NONE	40.00		27500336	Chandra	NRAO/Charlottesville
03:14:26.1	-01:08:46.6	J0314-0108	ACIS-S	NONE	30.00		27620318	Oskinova	Universitaet Potsdam
03:33:16.7	-26:53:46.3	SpARCS 0333	ACIS-S	NONE	280.00		27800080	Noble	Arizona State University (ASU)
03:41:41.4	52:57:28.3	1LHAASO J0343+5154u	ACIS-I	NONE	50.00		27910143	Mori	Columbia University
03:43:05.9	52:47:48.4	1LHAASO J0343+5154u	ACIS-I	NONE	50.00		27910143	Mori	Columbia University
03:44:02.9	-06:53:00.6	QSO J0344-0653	ACIS-S	NONE	60.00		27700175	Ighina	Smithsonian Astrophysical Observatory (SAO)

Summary

The Cosmic Himalayas:

An unprecedented quasar overdensity (δ_{QSO} **~17σ** if Gaussian LSS) at z = 2.2, serving as a unique laboratory to study galaxy and black hole co-evolution at Cosmic Noon.

- ✦QSOs located at ionization transition zones, jointly shaping IGM environments.
- ✦QSO luminosity correlated with HI transparency, highlighting **quasar-driven ionization processes on tens of Mpc scales**.
- ✦Spatially offset populations of LAEs, QSOs, and dusty SMGs, indicating diverse galaxy **evolutionary stages and feedback mechanisms**.

Subaru/PFS is of high necessity:

- ✦The combination of **Wide FOV** & **Highly Multiplex Fibers** & **Large Telescope** is crucial to simultaneously take the spectroscopic data for diverse **foreground** galaxies and **background** LBGs in the ~100-Mpc scale structures.

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