

Subaru Users Meeting 2026 @NAOJ, June 18th



Diverse Mpc-scale environments of low-luminosity quasars at $z \sim 6$

Junya Arita (UTokyo, D3)

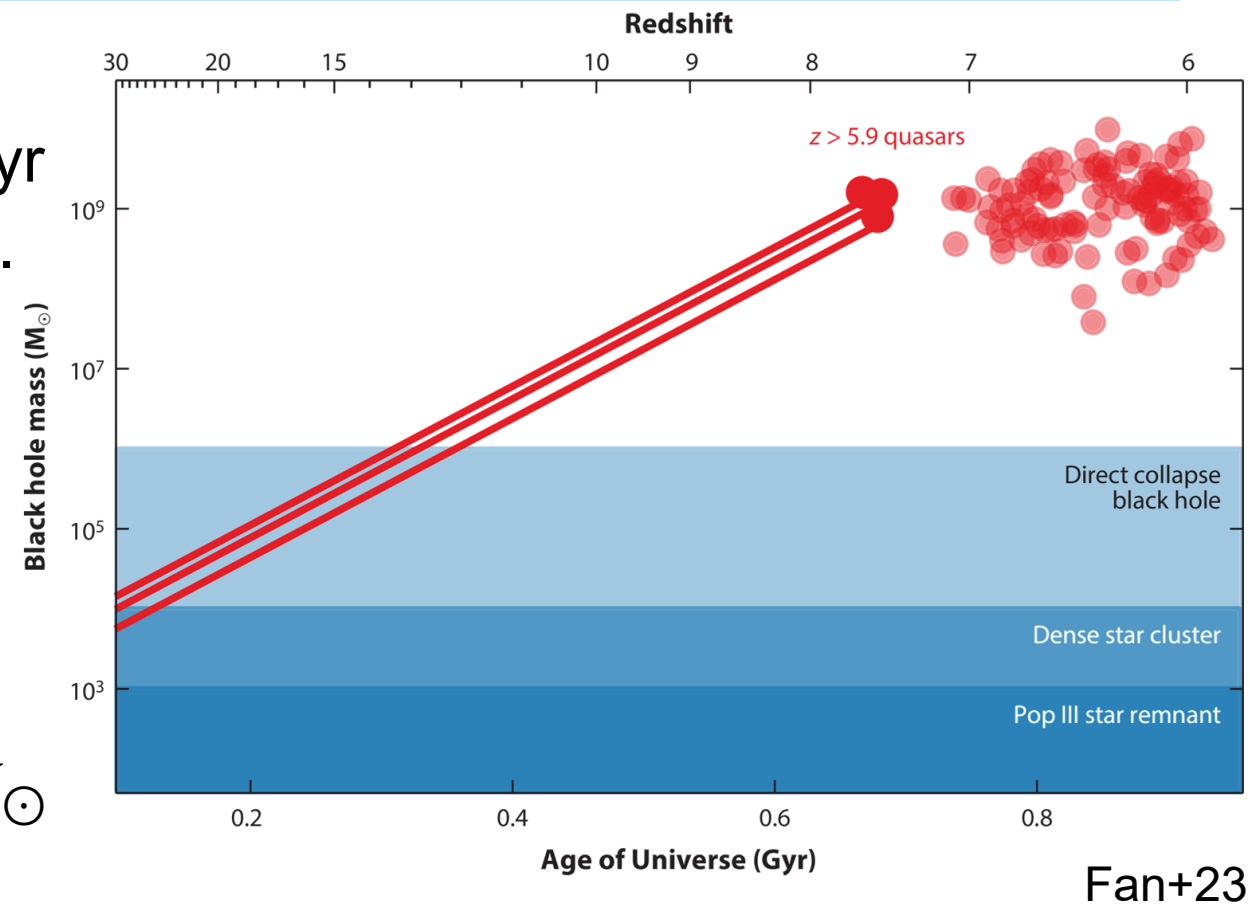


Nobunari Kashikawa (UTokyo), Yoshiki Matsuoka (Ehime U.), Masafusa Onoue (Waseda U.), Michael A Strauss (Princeton U.), Kentaro Koretomo, Yoshihiro Takeda, Ryo Emori (UTokyo), Wanqiu He (NAOJ), Hiroki Hoshi (UTokyo), Masatoshi Imanishi (NAOJ), Rikako Ishimoto (UTokyo), Kei Ito (DAWN), Kazushi Iwasawa (ICCUB), Satoshi Kikuta, Yongming Liang (UTokyo), Camryn L Phillips (Princeton U.), Shunta Shimizu, John D Silverman (UTokyo), Yoshiki Toba (Ritsumeikan U.), Takehiro Yoshioka (UTokyo)



Introduction

- Supermassive black holes (SMBHs) with $M_{\text{BH}} \sim 10^9 M_{\odot}$ emerge within 1 Gyr after the Big Bang (e.g., Banados+18).
- SMBHs should grow quickly in the early Universe.
- Quasars should reside in **massive dark matter halos** (Volonteri+06).
- Recent studies confirm $M_{\text{halo}} > 10^{12} M_{\odot}$ by clustering analysis of quasars (Arita+23; Eilers+24, Huang+26).



These biased regions must be traced by **galaxy overdensity** (Overzier+09).

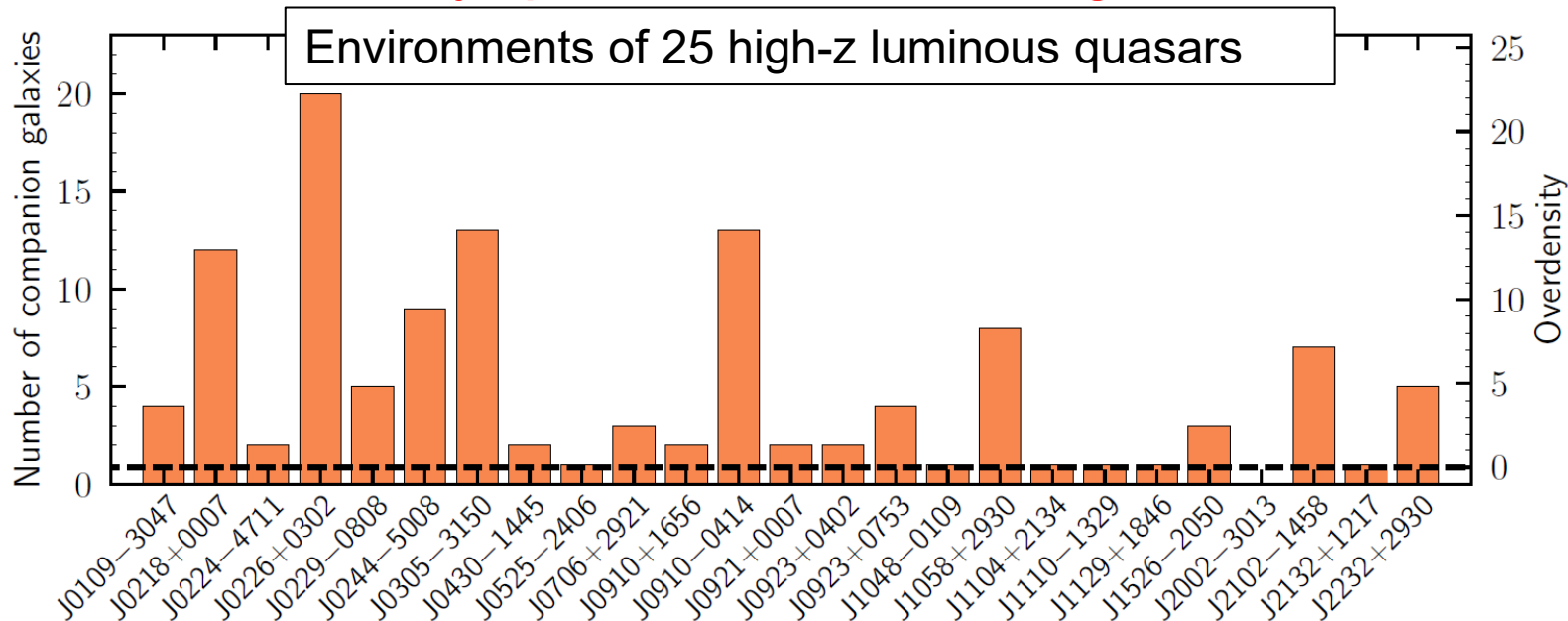
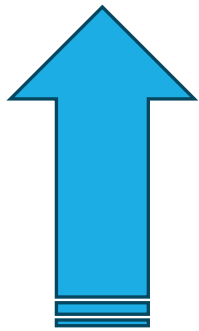
Previous Quasar Environmental Studies

□ Quasar environments

- Large variety (Mazzucchelli+17: no overdensity; Wang+23: protocluster)
- Biased to bright quasars ($M_{1450} < -25$) → photoevaporation effect (e.g., Lambert+24)
- Small field of view (FoV $\sim 3\text{-}5$ arcmin) relative to the overdensity scale (~ 10 arcmin)

➔ Observing **lower-luminosity quasar** fields with **large FoV** is needed.

Overdense

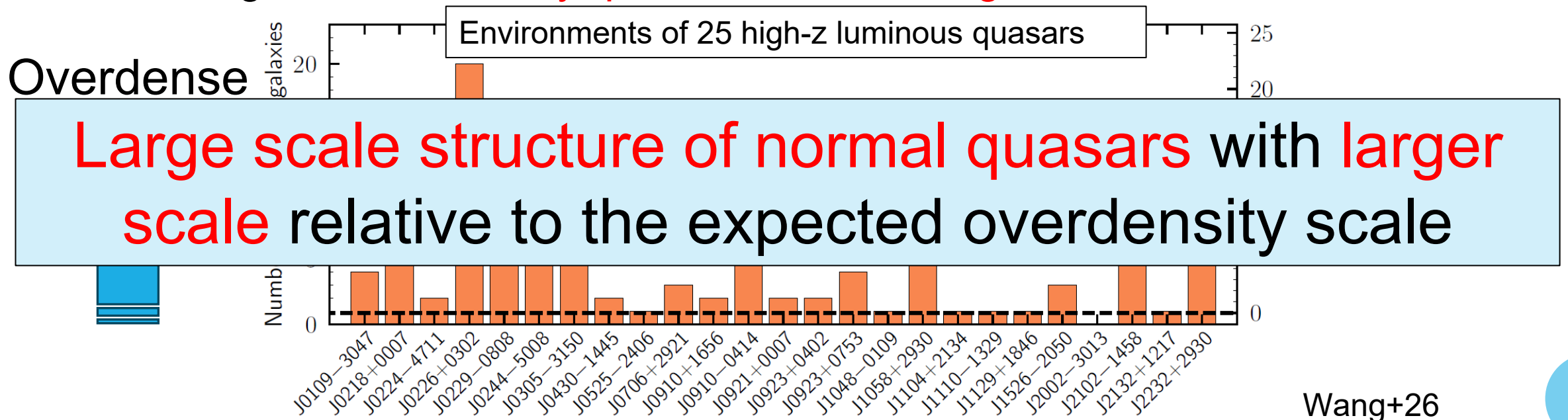


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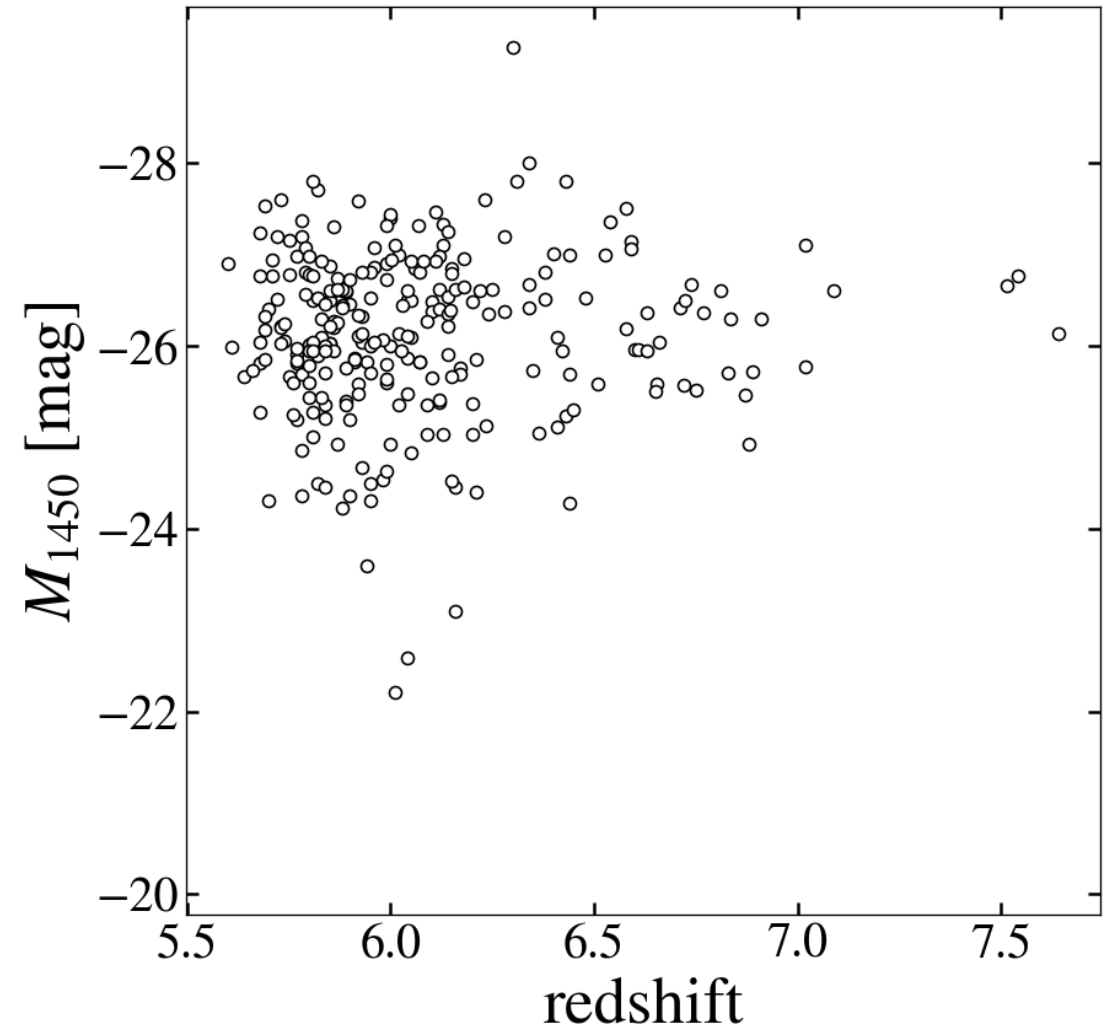
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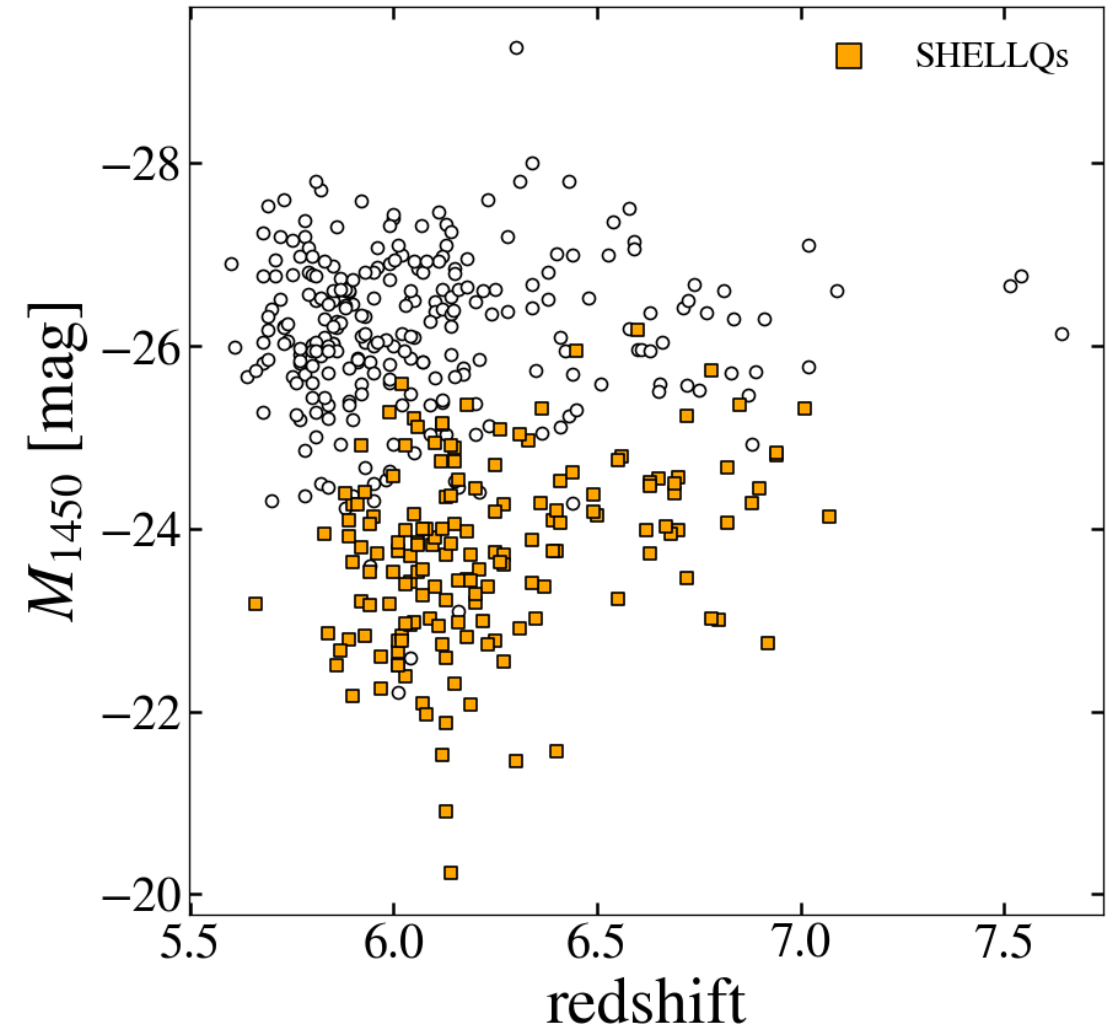
Target selection

- **SHELLQs**: High-z low-luminosity quasar survey with HSC-SSP.
- 12 SHELLQs quasars have been observed by NIRSspec and NIRCcam.
- Targeting **4 quasars** out of the 12 SHELLQs quasars, with host galaxies detected and systemic redshift.
- New narrowband (**NB872**) can detect LAEs at $z = 6.174 \pm 0.028$, which maximize the sample size.



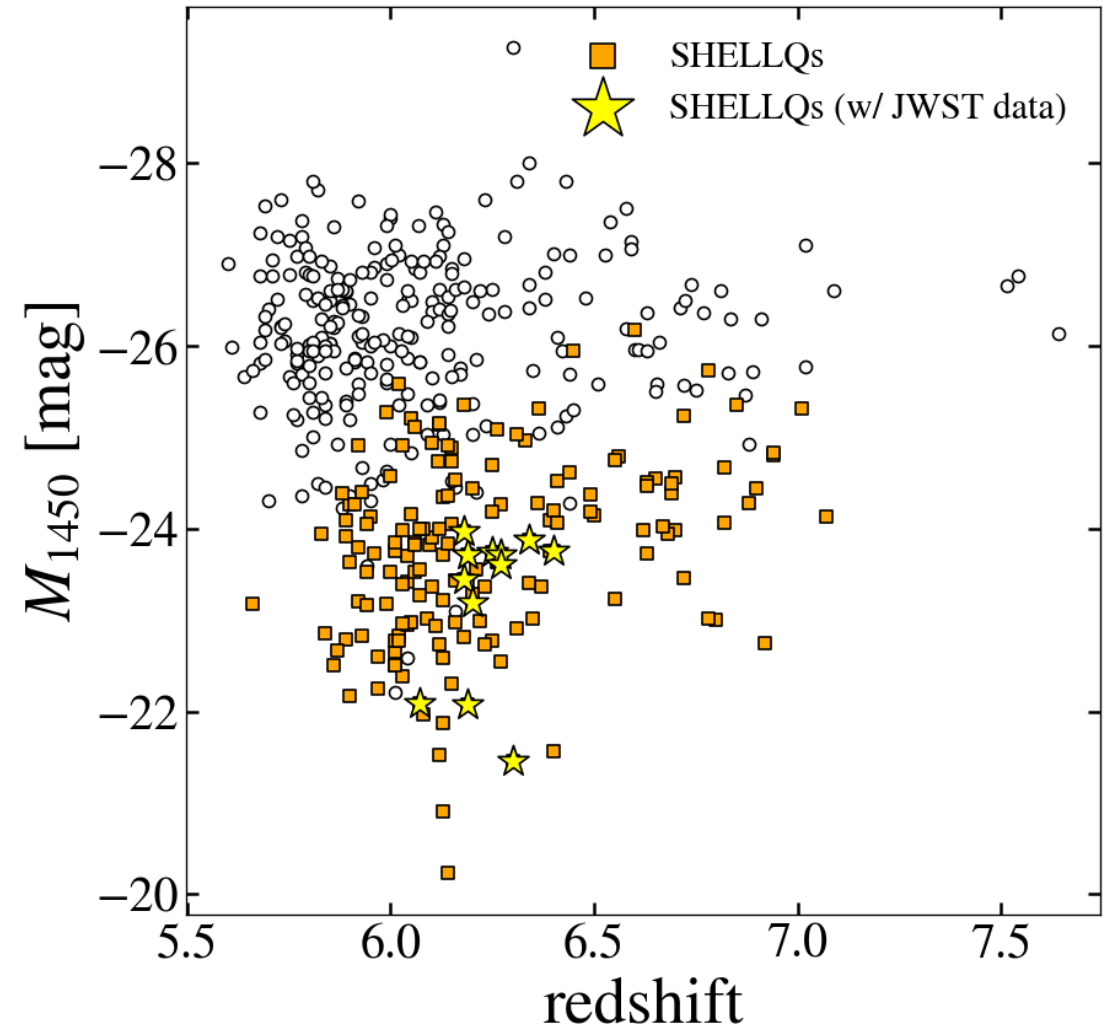
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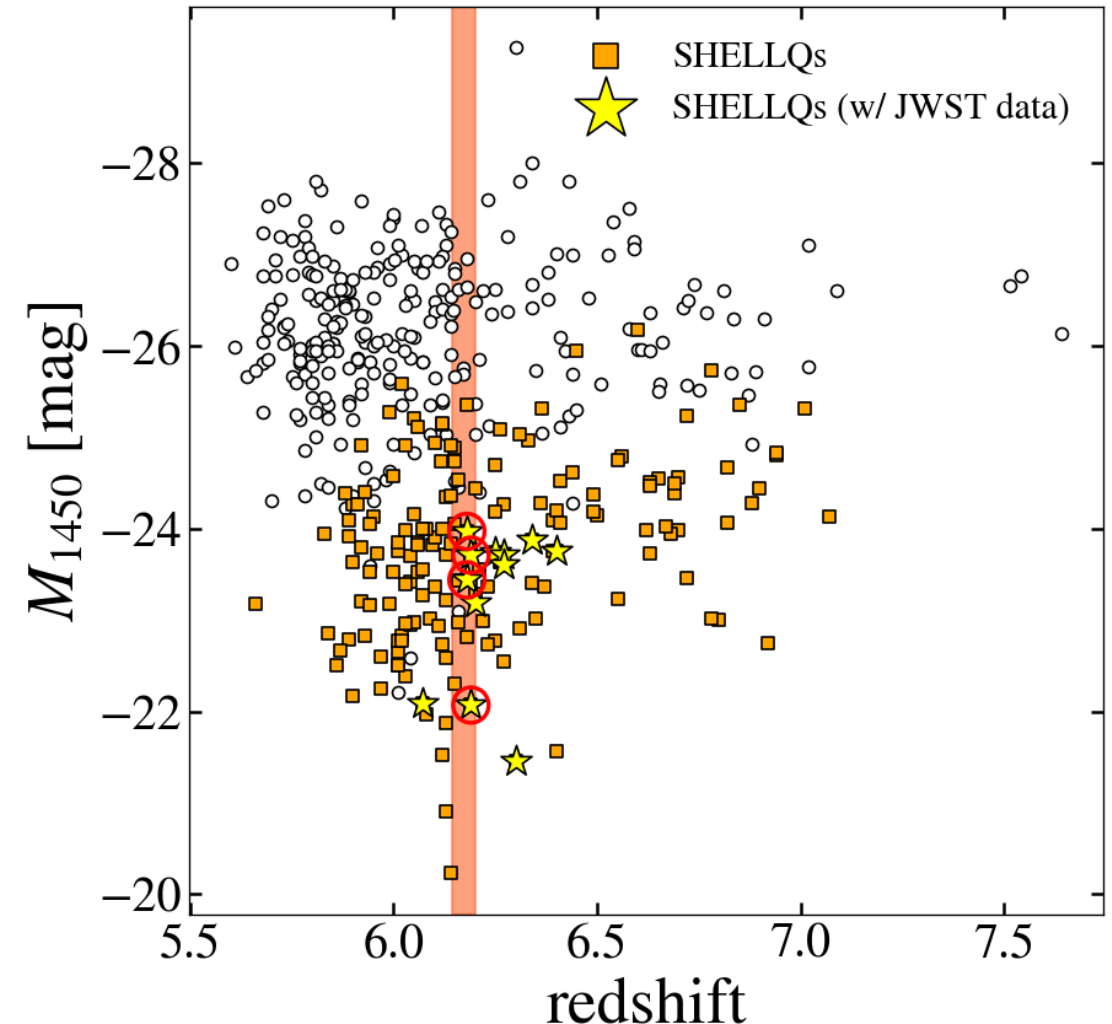
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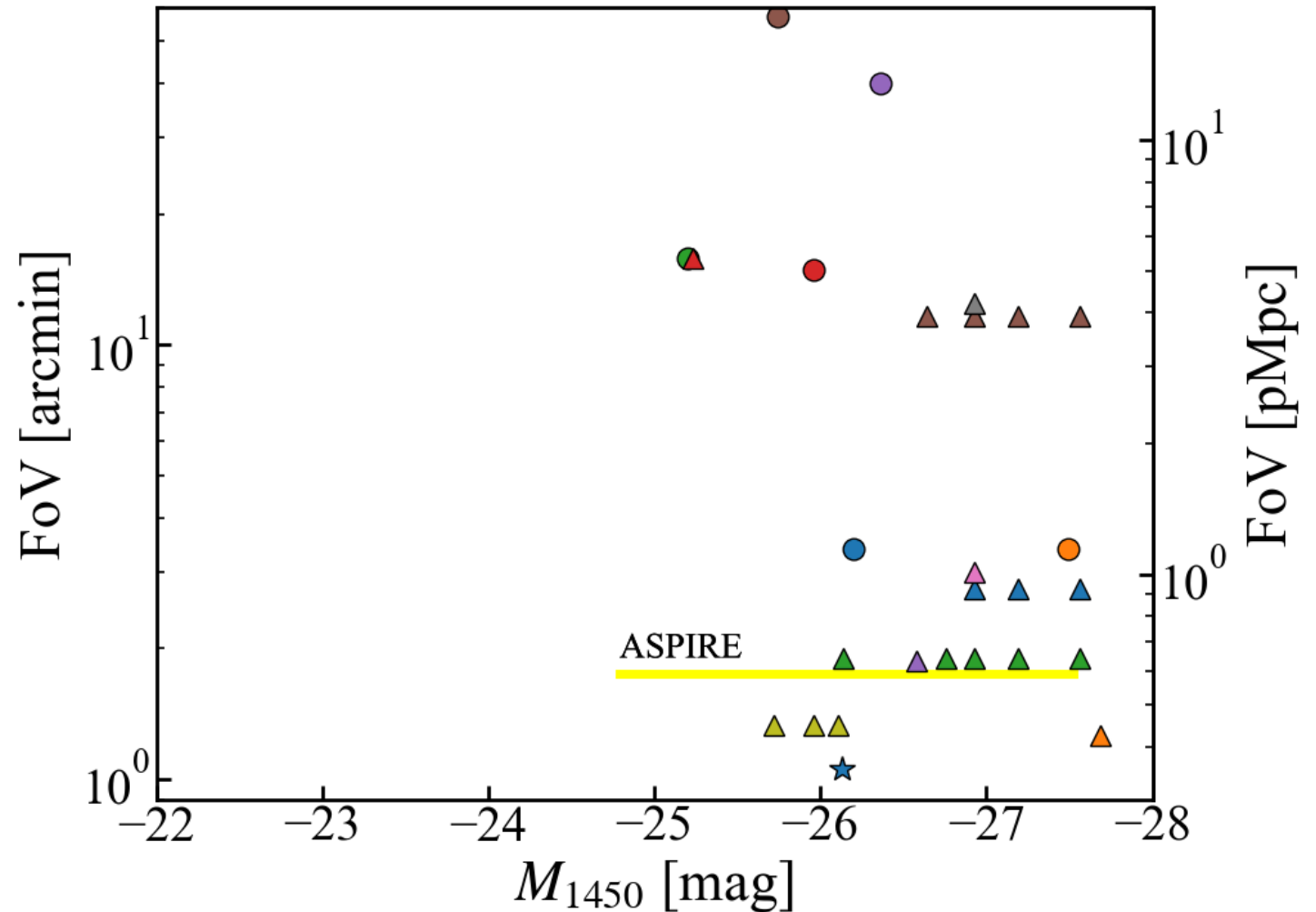
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Environments of low-luminosity quasars

Field	M_{1450}	z
J0844-0132	-23.97	6.183
J0918+0139	-23.71	6.179
J1425-0015	-23.44	6.178
J1512+4422	-22.07	6.180

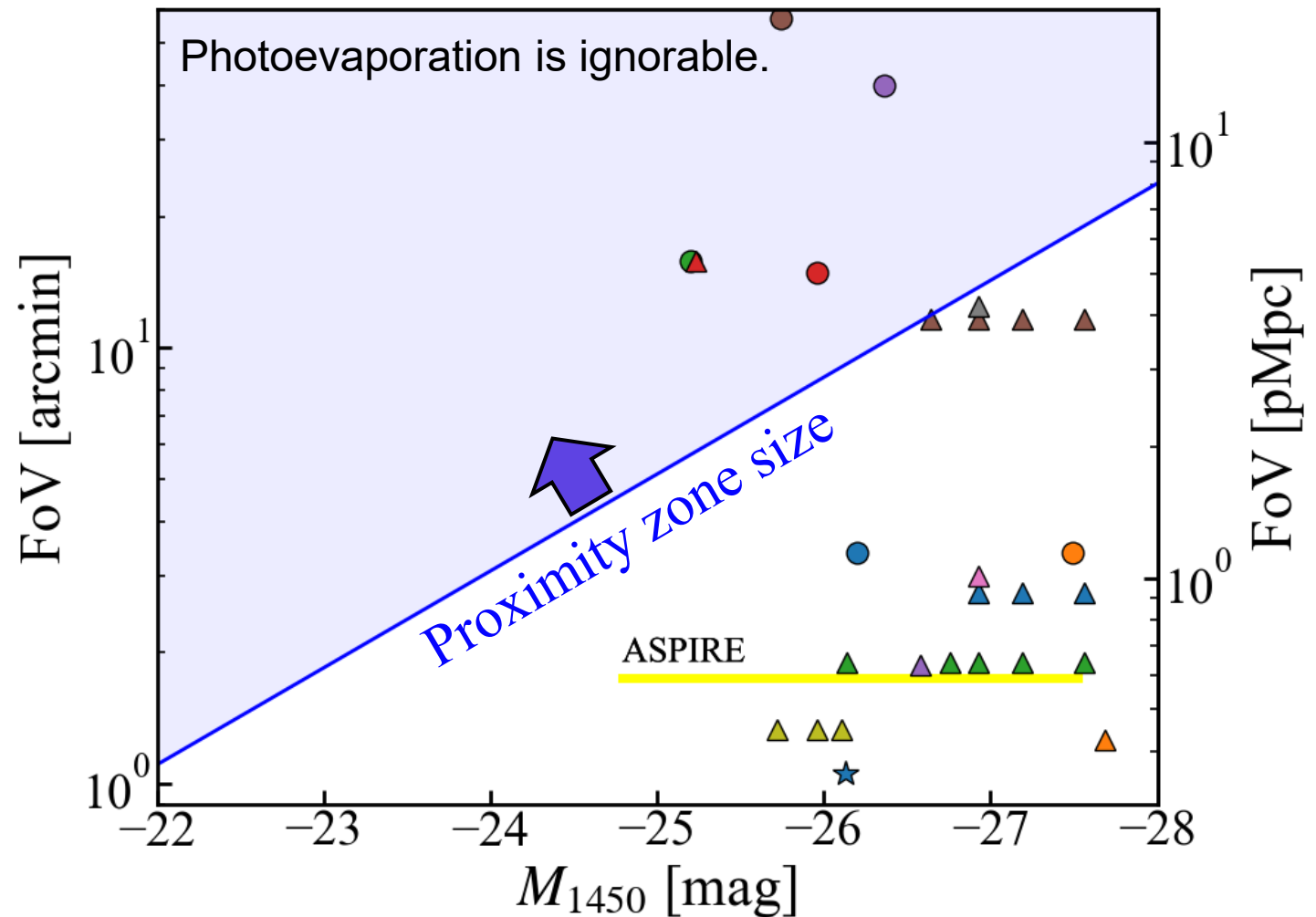
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- The **HSC FoV** can fully cover the expected overdensity scale.



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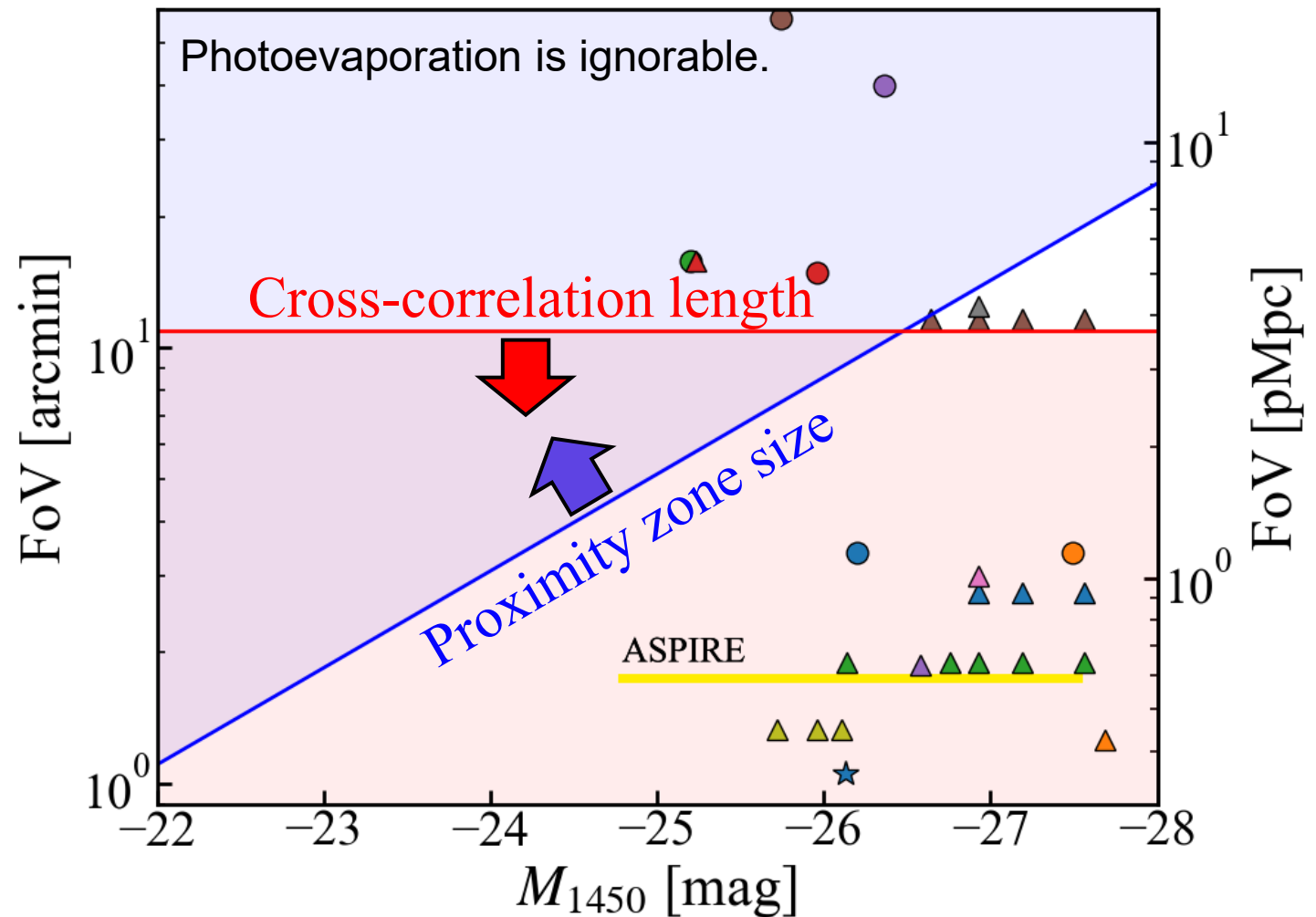
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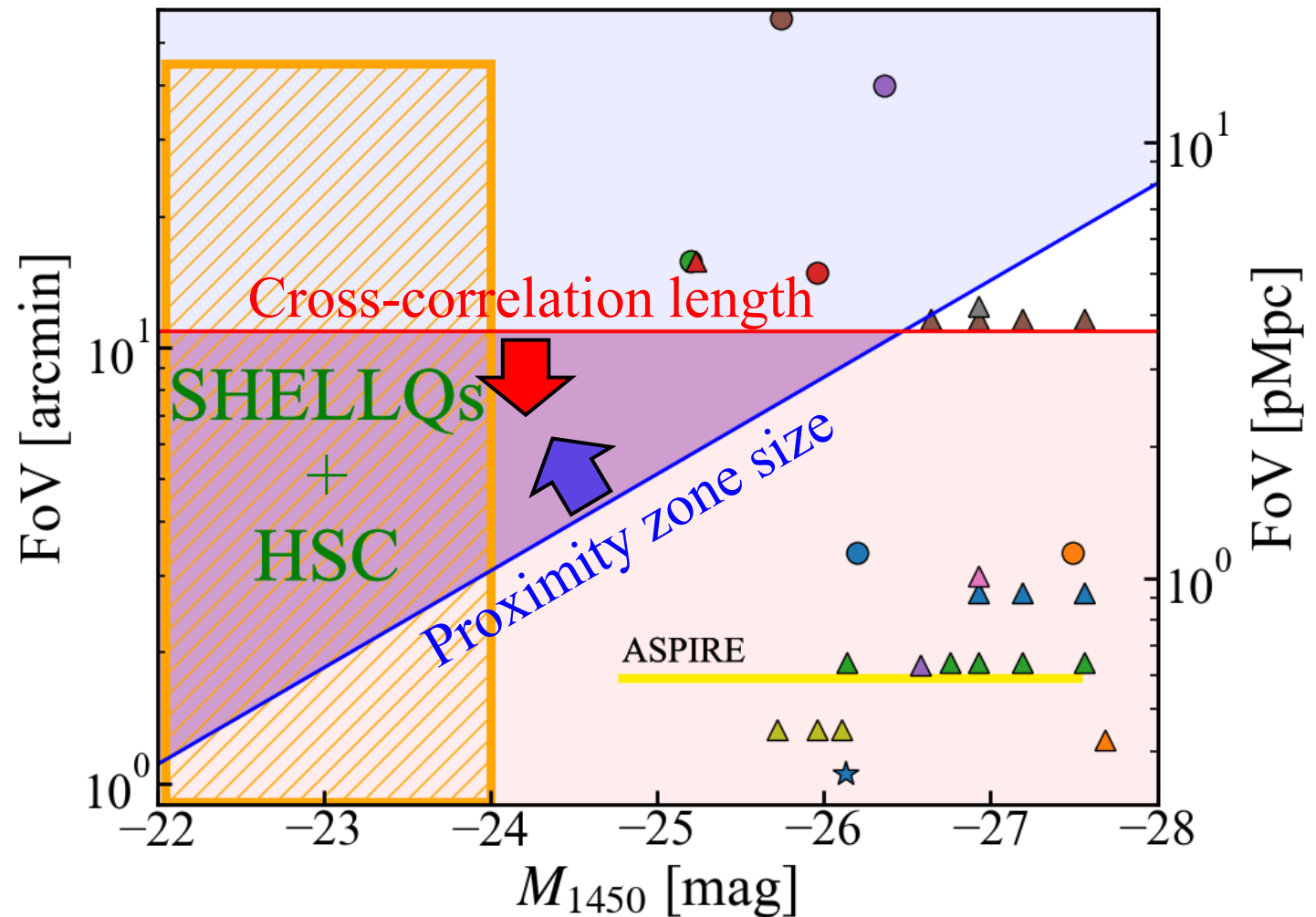
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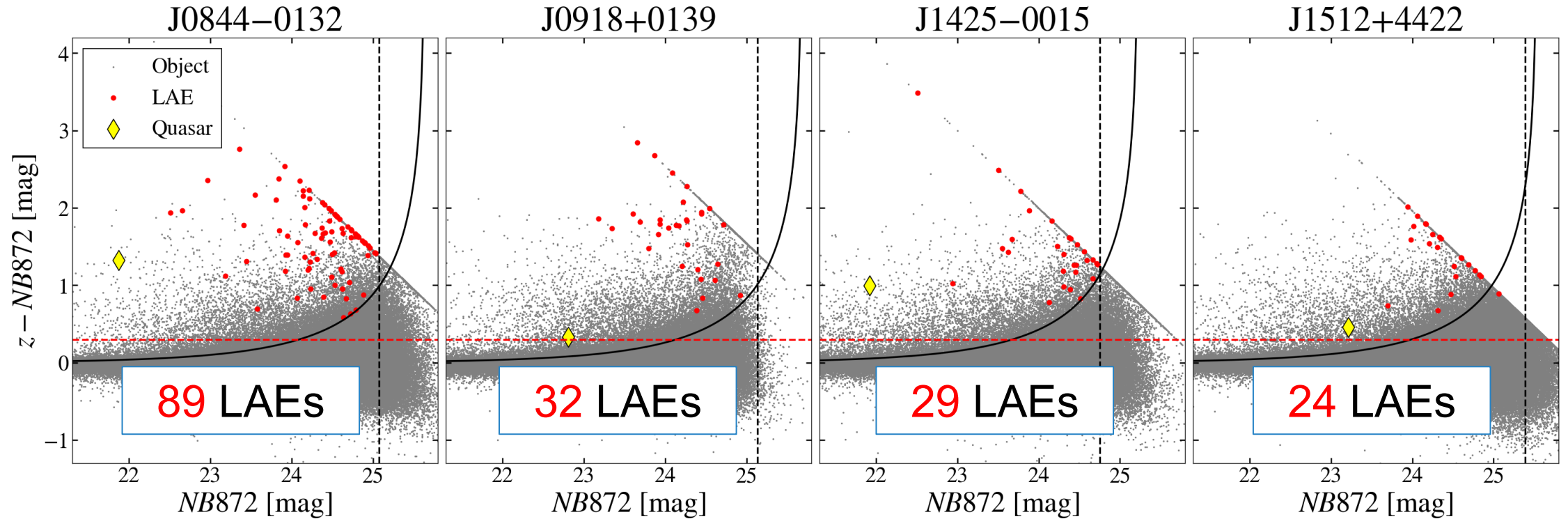
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LAE selection using NB872



□ HSC observations with i , z , and NB872 from 2024 Nov. to 2025 Jul. (S24A-090, S25A-023; PI: J.Arita).

□ Color selection of LAEs with $\text{EW} > 15 \text{ \AA}$:

$$(\text{NB872} < \text{NB872}_{5\sigma}) \wedge (z - \text{NB872} > 0.3) \wedge (i - z > 2.2 | i > i_{3\sigma})$$

LAE overdensity

□ LAE overdensity at the quasar position

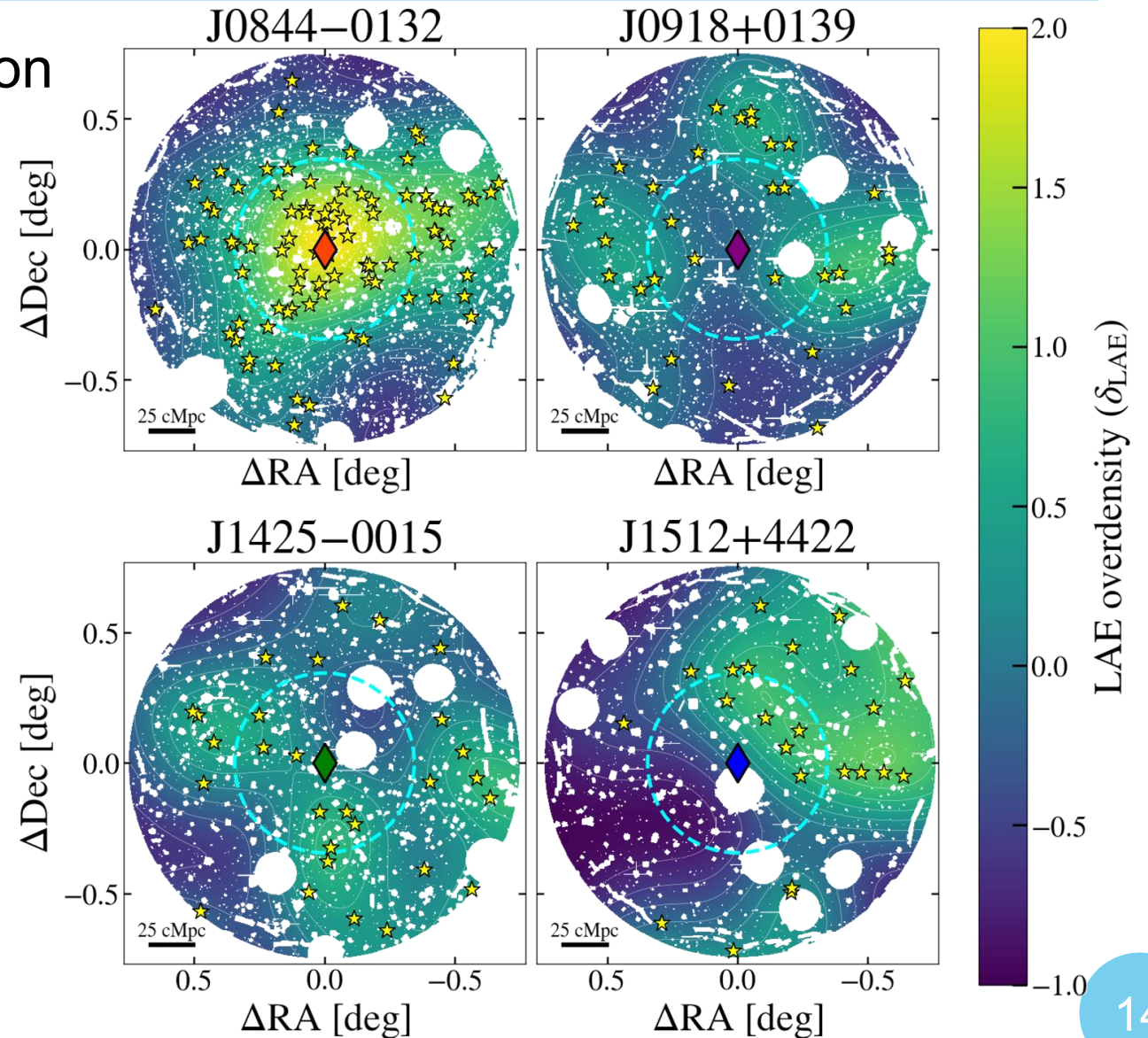
$$\delta_{\text{LAE}} = \frac{\Sigma_{\text{LAE}}}{\langle \Sigma_{\text{LAE}} \rangle} - 1$$

(Σ_{LAE} is estimated by KDE.)

- **J0844-0132**: $\delta_{\text{LAE}} = 1.97 \pm 0.40$
- **J0918+0139**: $\delta_{\text{LAE}} = -0.11 \pm 0.14$
- **J1425-0015**: $\delta_{\text{LAE}} = 0.16 \pm 0.23$
- **J1512+4422**: $\delta_{\text{LAE}} = 0.01 \pm 0.23$

□ Only **J0844-0132** field shows LAE overdensity.

□ What causes diverse δ_{LAE} ?



Effect by photoevaporation

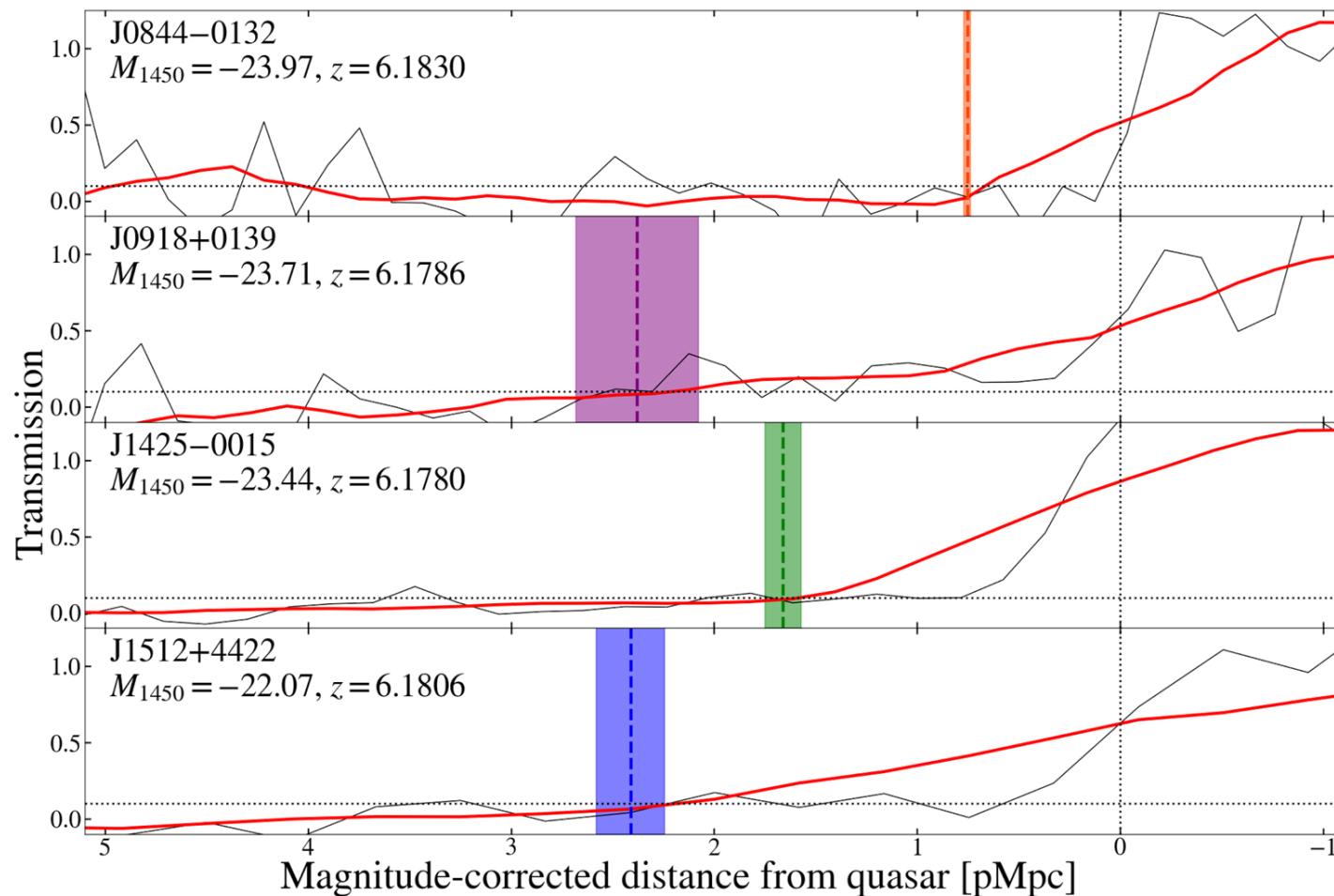
□ Proximity zone size (R_p)

- **J0844-0132**: $R_p = 0.4449 \pm 0.0093$ pMpc
- **J0918+0139**: $R_p = 1.230 \pm 0.156$ pMpc
- **J1425-0015**: $R_p = 0.7478 \pm 0.0404$ pMpc
- **J1512+4422**: $R_p = 0.5387 \pm 0.0373$ pMpc

□ No LAEs are detected within R_p .

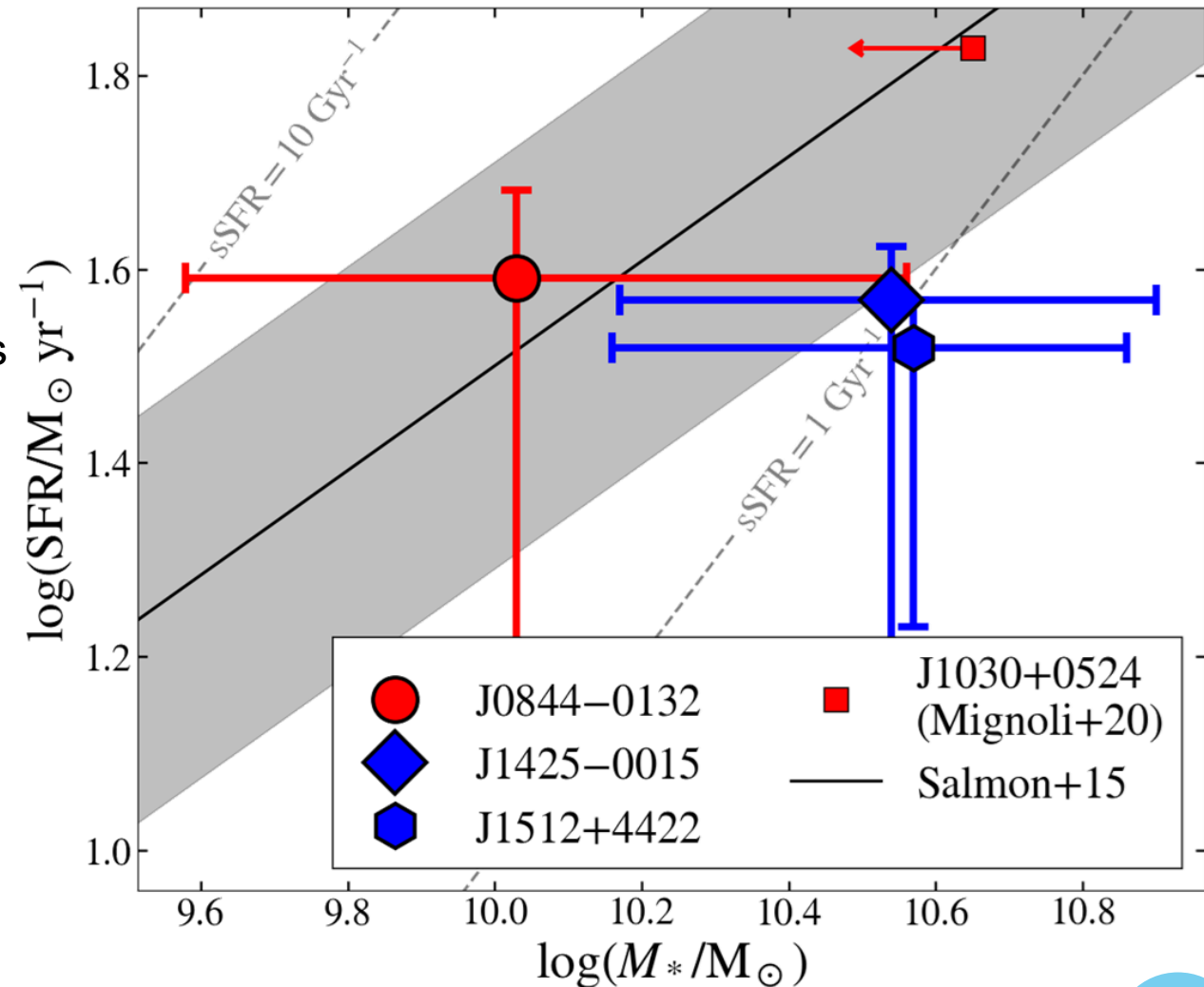
- **J0844-0132**: consistent with the expected number of LAEs
- Others: LAE overdensity is not observed outside R_p .

→ Photoevaporation does not have a large impact on LAE overdensity.



Relation b/w host galaxy properties and δ_{LAE}

- $M_* - M_{\text{halo}}$ relation (e.g., Behroozi+19) suggests that quasars with high M_* show high LAE overdensities.
- Properties of quasars' host galaxies
 - M_* (Ding+25): decomposition of NIRCam images
 - SFR (Phillips+25): Extended H α luminosity
- Quasars with high M_* do not always show high LAE overdensity.
 - Large scatter in $M_* - M_{\text{halo}}$ relation
 - Caution: small sample, and narrow M_* range



red : overdensity/blue : non-overdensity

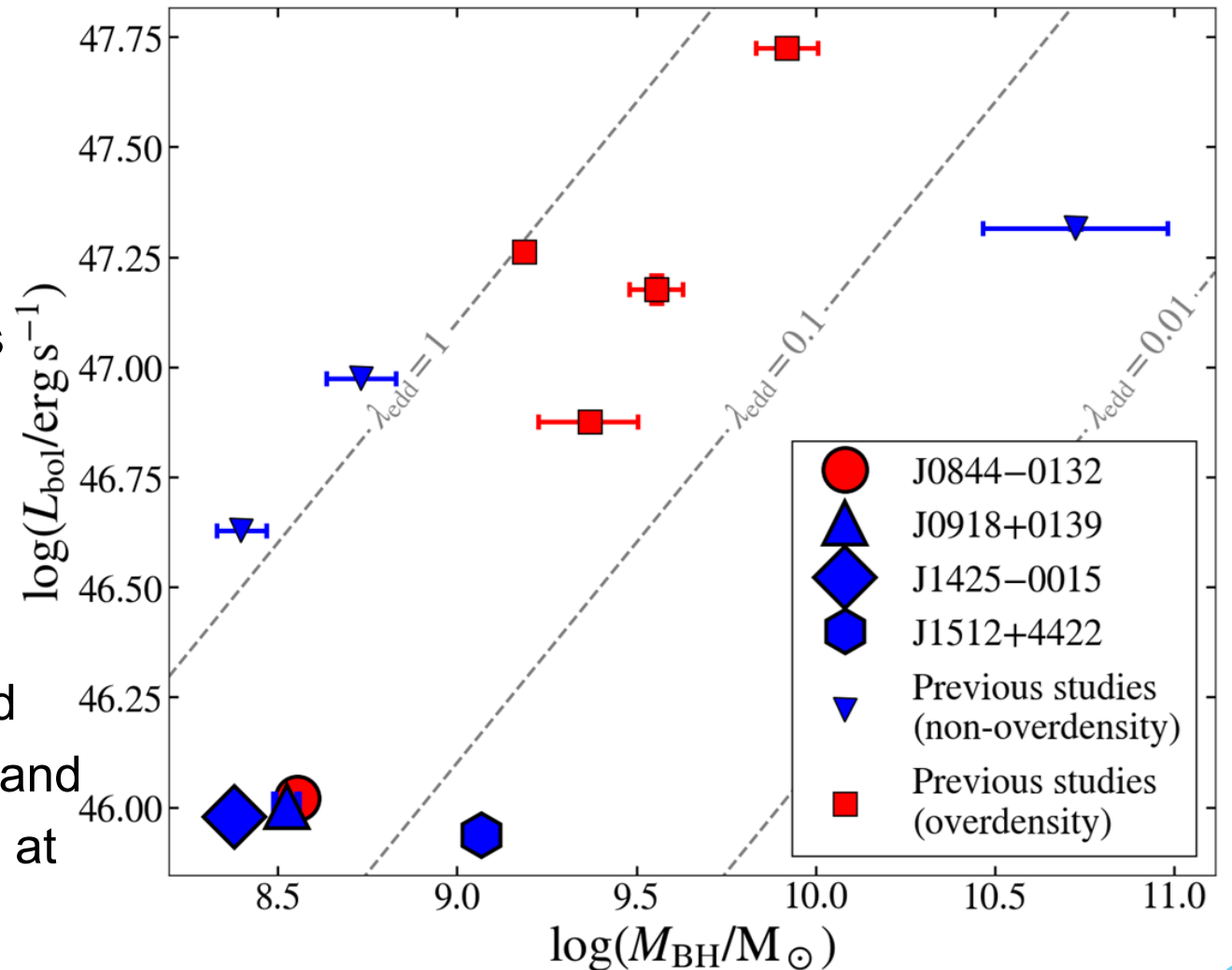
Relation b/w SMBH properties and δ_{LAE}

□ Properties of SMBHs

- BH mass, Eddington ratio, Eddington ratio:
Onoue et al. in prep.

□ Quasars at $5.7 < z < 7$ targeted by previous studies on quasar environments (Banados+13; Goto+17; Ota+18; Mignoli+20; Overzier+22; Wang+24; Lambert+24)

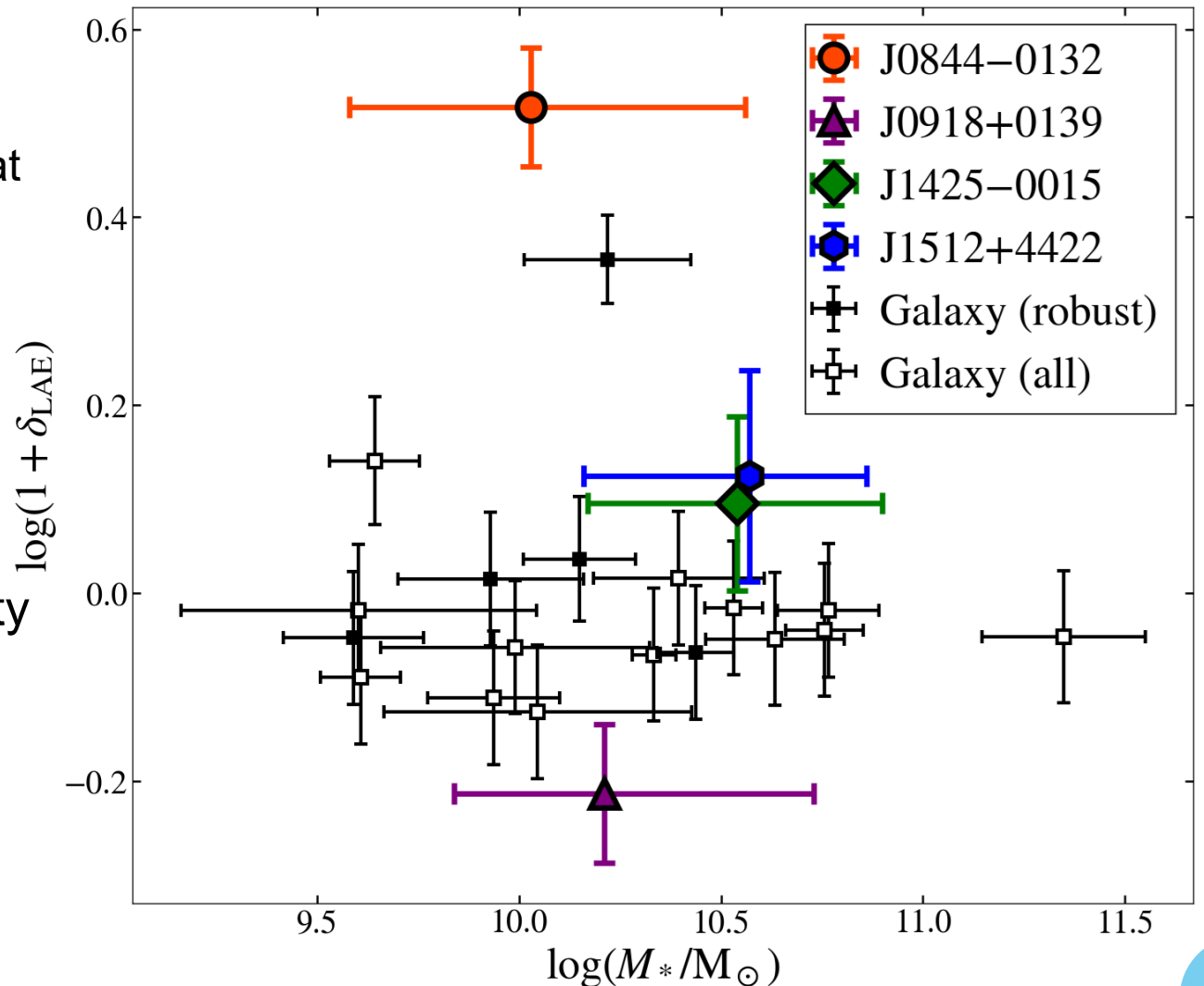
□ **No strong correlation** between LAE overdensities and SMBH properties → Consistent with Lin+25, which reported no correlation between HAE overdensity and SMBH properties of low-luminosity AGNs at $3.9 < z < 6$



red : overdensity/blue : non-overdensity

δ_{LAE} of non-AGN galaxies with similar M_*

- Galaxies with similar M_* to our quasars
 - COSMOS spec-z catalog (Khostovan+26)
 - 18 galaxies with $9.5 \leq \log(M_*/M_\odot) \leq 11.5$ at $5.65 \leq z \leq 5.75$
- LAE (SC4K: Santos+16; Sobral+18)
 - NB816 selection ($5.65 \leq z_{\text{Ly}\alpha} \leq 5.75$)
 - 37 LAEs with $\text{NB816} < 24.5$
- J0844-0132** shows higher LAE overdensity than galaxies with similar M_*
 - Enhancement by quasar? (e.g., Zana+22)
 - Large scatter in $M_* - M_{\text{halo}}$ relation
- Other quasars show comparable LAE overdensity to non-AGN galaxies.



What makes quasar environment diverse?

□ Large scatter in M_* – M_{halo} relation

- M_{halo} can vary widely even with the similar stellar mass

□ Population of the tracer galaxy (**galaxy conformity**)

- LAEs are generally young (a few Myr), low-mass galaxies.
- J1512+4422 is hosted by a post-starburst (~ 150 Myr), which is older than typical LAEs.
- Observations of various tracers (e.g., [OIII] emitter, HAE, LBG) are necessary.

□ Triggering mechanisms of quasars (e.g., Fontanot+25)

- Disk instability: a physical process that can occur regardless of the environment
- Galaxy merger: prone to occur in overdense environments

□ Cosmic variance

- Observing more quasar fields with wider FoV is important.

Summary

- We observe four SHELLQs quasar ($-24 < M_{1450} < -22$) fields with i, z, and NB872 on Subaru/HSC to calculate the LAE overdensity.
- Only **J0844-0132** shows high LAE overdensity ($\delta_{\text{LAE}} = 3.77 \pm 0.97$), and our results suggest that high-z quasar environments are intrinsically diverse.
- Other quasar fields do not show LAE overdensity over proximity zone size, which suggests that photoevaporation does not have an impact on the LAE overdensity.
- No correlation between LAE overdensity and host/SMBH properties
- **J0844-0132** has higher LAE overdensity than galaxies with similar M_* .