Correlation between LAE and IGM HI distributions at z~2 based on Subaru/HSC

(Liang+20, submitted to ApJ.)

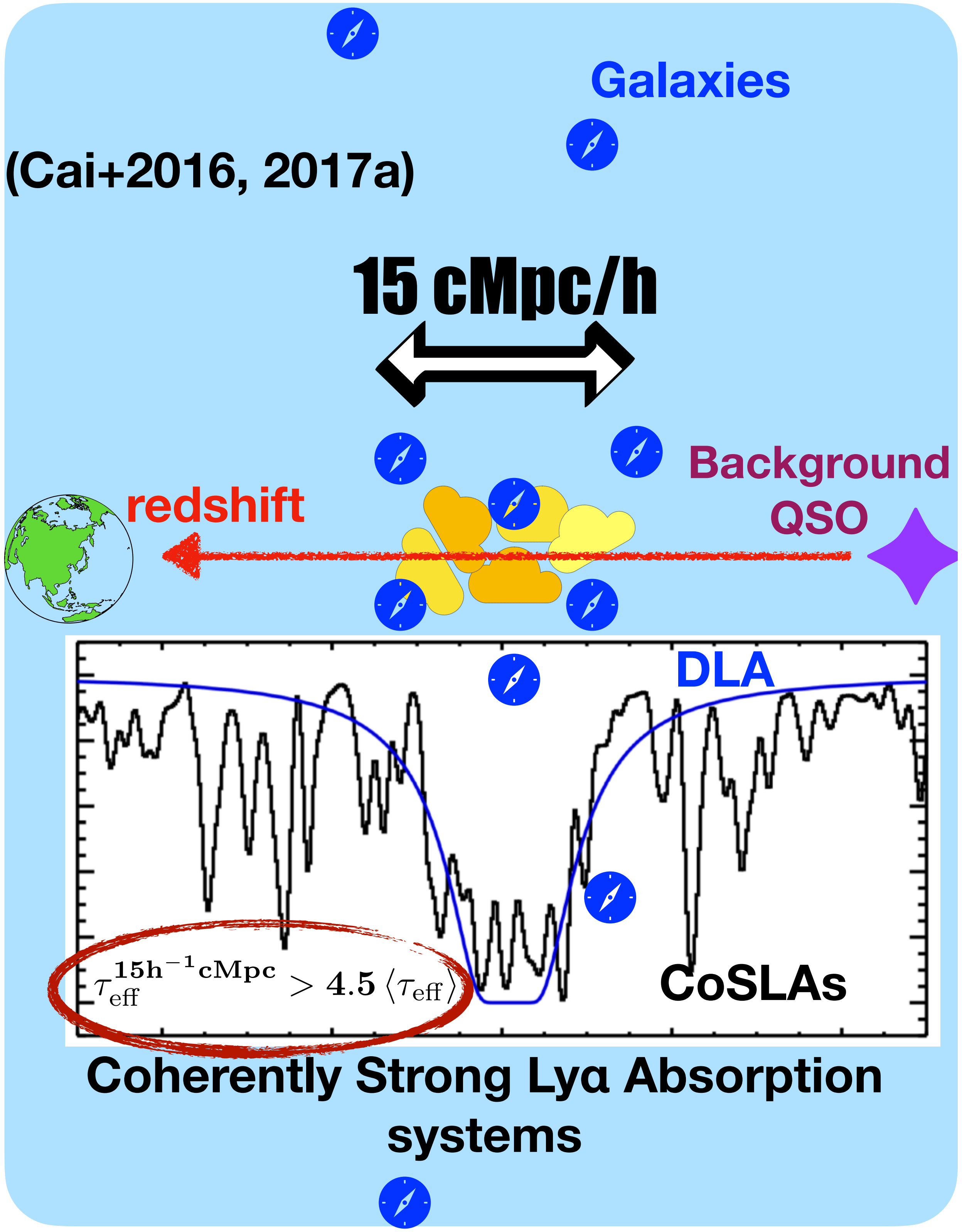
Yongming Liang (SOKENDAI / NAOJ)

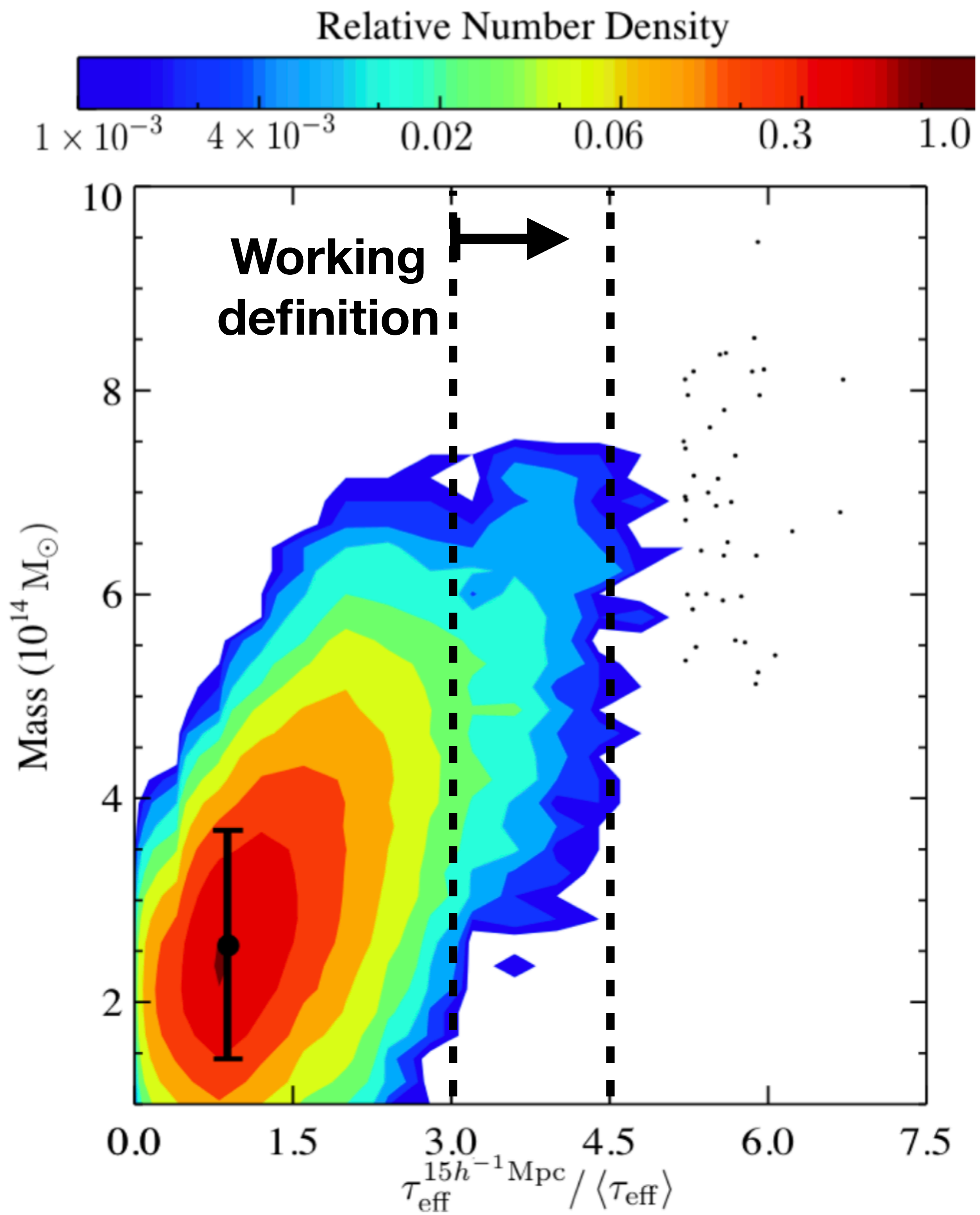
Collaborators:

N. Kashikawa, Z. Cai, X. Fan, J. X. Prochaska, K. Shimasaku, M. Tanaka, H. Uchiyama, K. Ito, R. Shimakawa, K. Nagamine, I. Shimizu, M. Onoue, J. Toshikawa

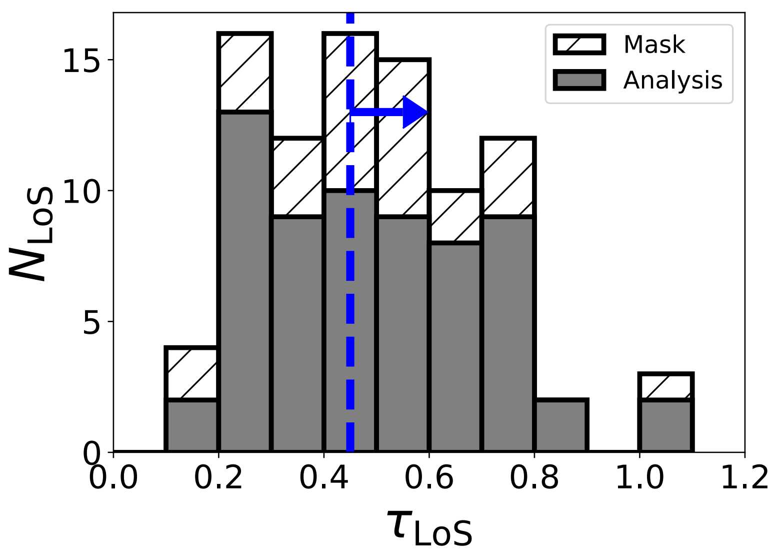
(Galaxy-IGM Workshop 2020/08/05)

Basic idea of MAMMOTH





* LoS sample:

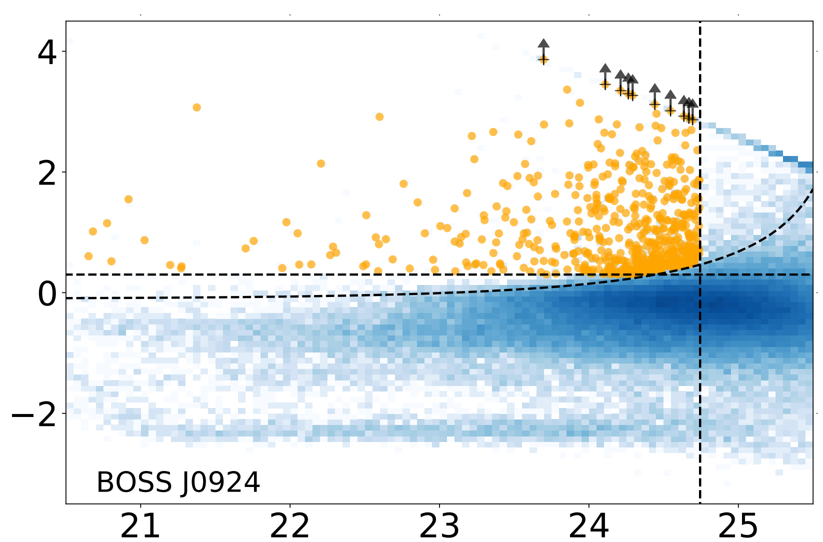


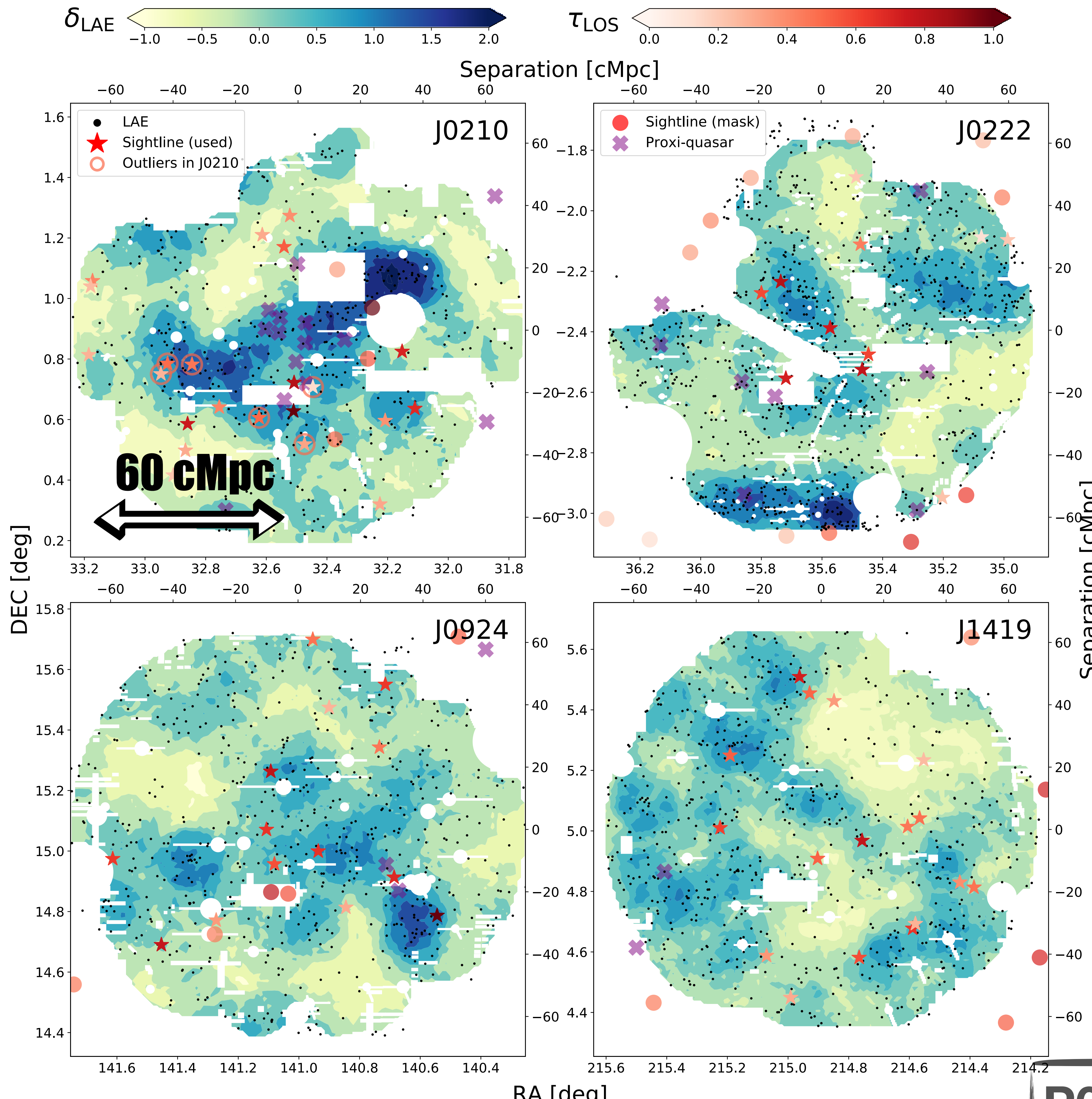
* z=2.18 LAE sample:

2,642 over 5.4 deg²

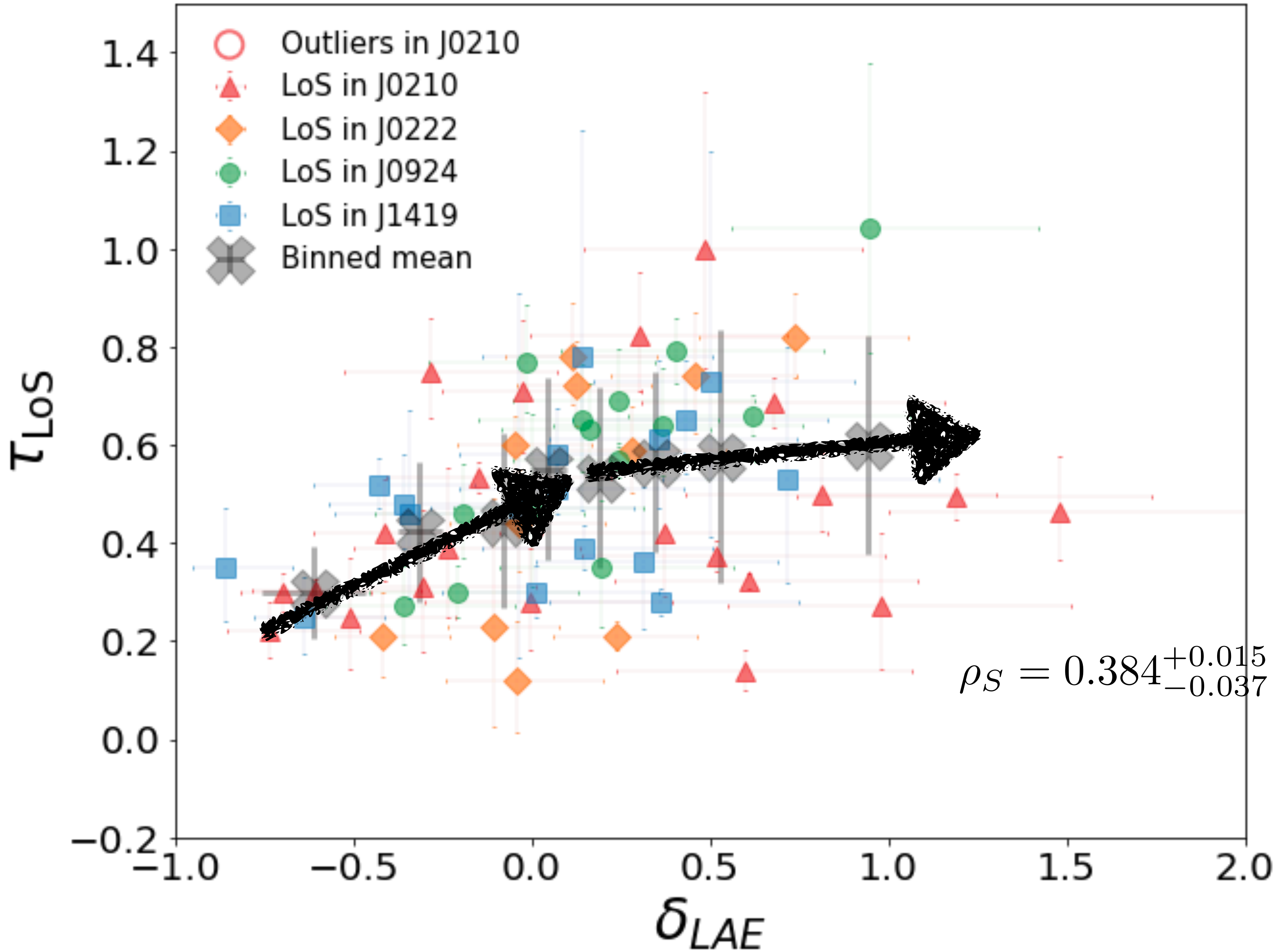
Selection criteria:

$$\begin{aligned} 20.5 &< \mathrm{NB387} \lesssim \mathrm{NB}_{\mathrm{lim},5\sigma}, \\ g - \mathrm{NB387} &> 0.3, \\ g - \mathrm{NB387} &> 2\sigma(\mathrm{NB387}) - 0.1. \end{aligned}$$



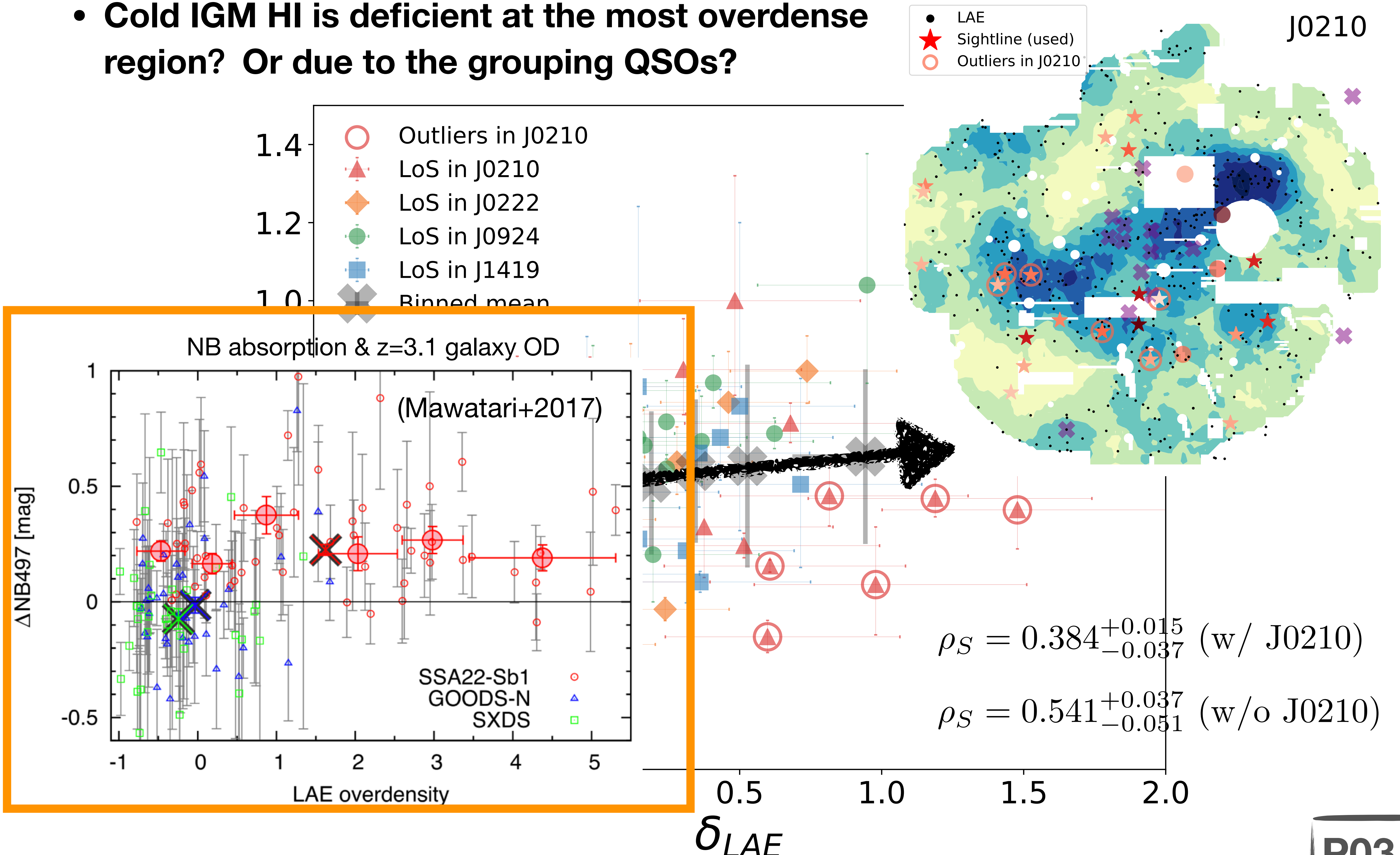


- **A moderate to strong positive correlation (√)**



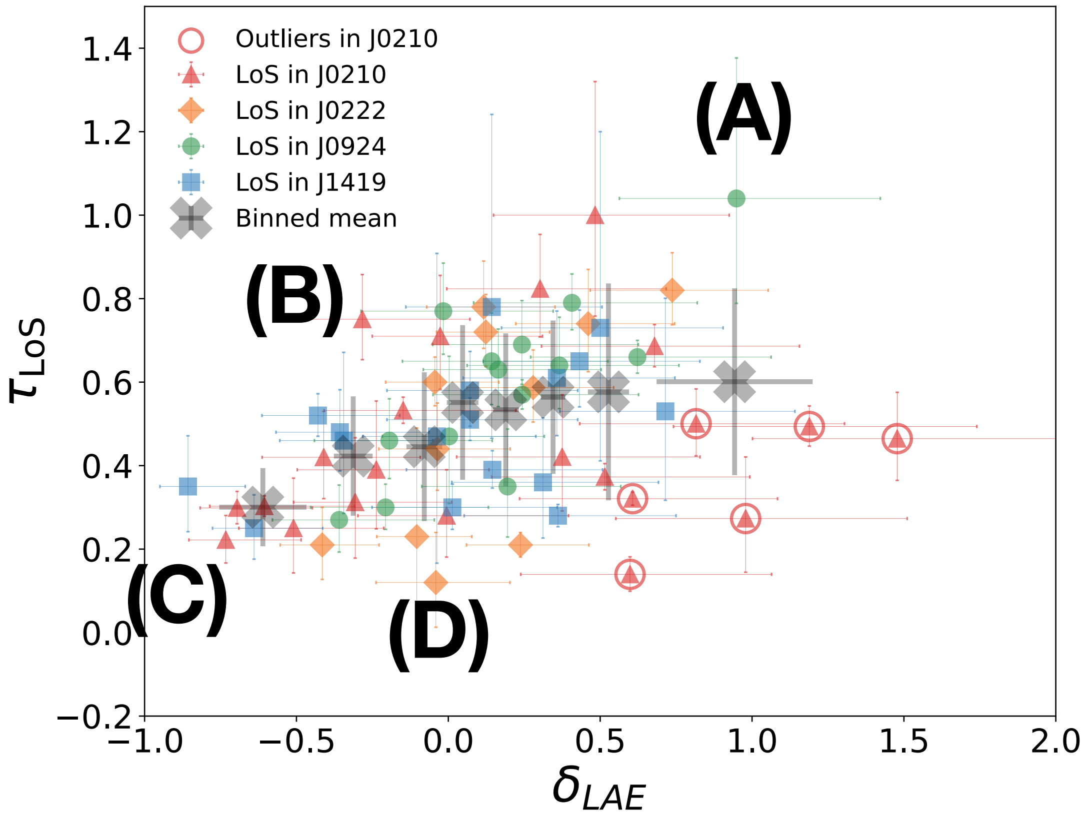
$$\rho_S = 0.384^{+0.015}_{-0.037} \text{ (w/ J0210)}$$

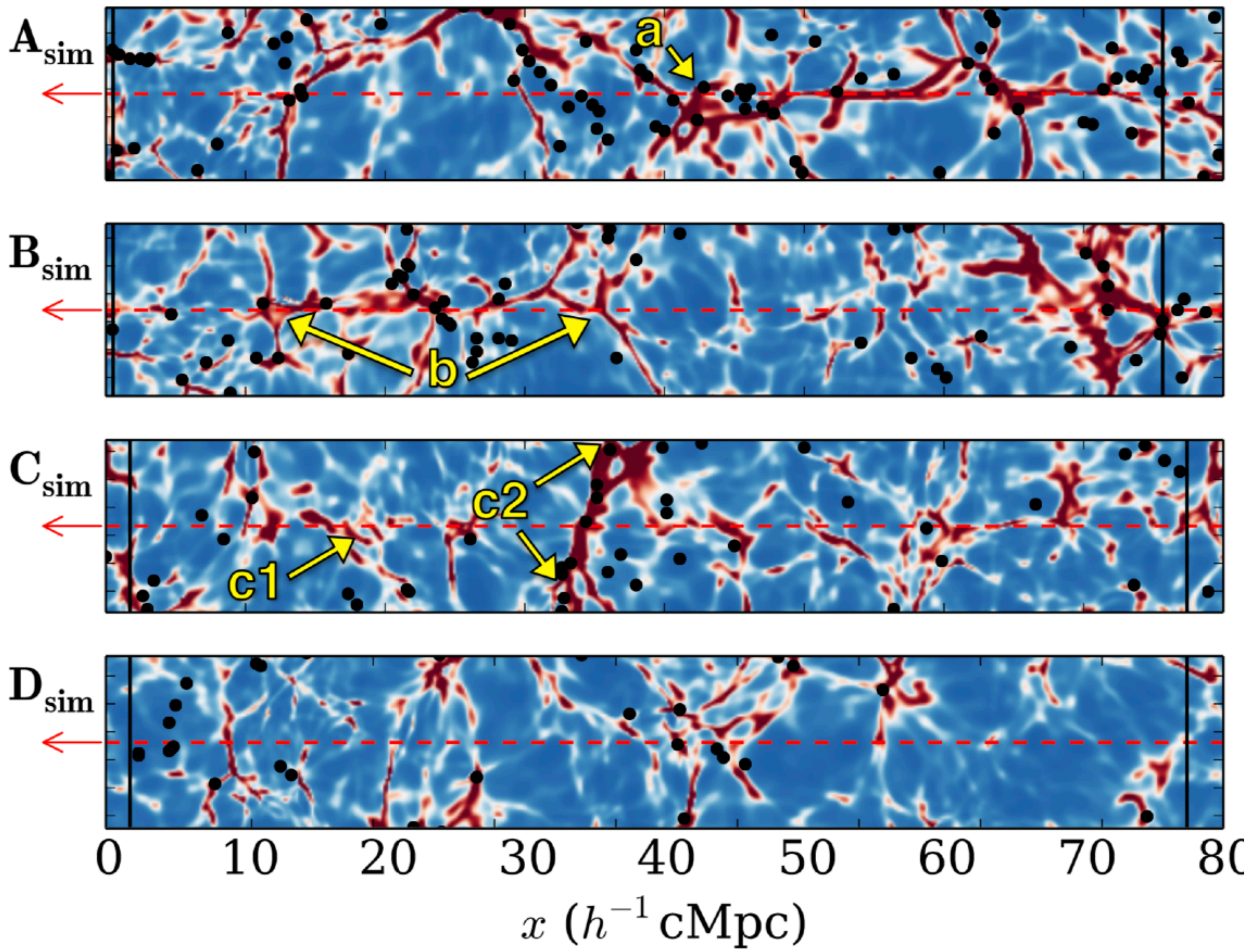
- **A moderate to strong positive correlation.**
- **Cold IGM HI is deficient at the most overdense region? Or due to the grouping QSOs?**



- **Scatter may help to pinpoint unique structures**

(Mukae+2017)





Morphology origin?

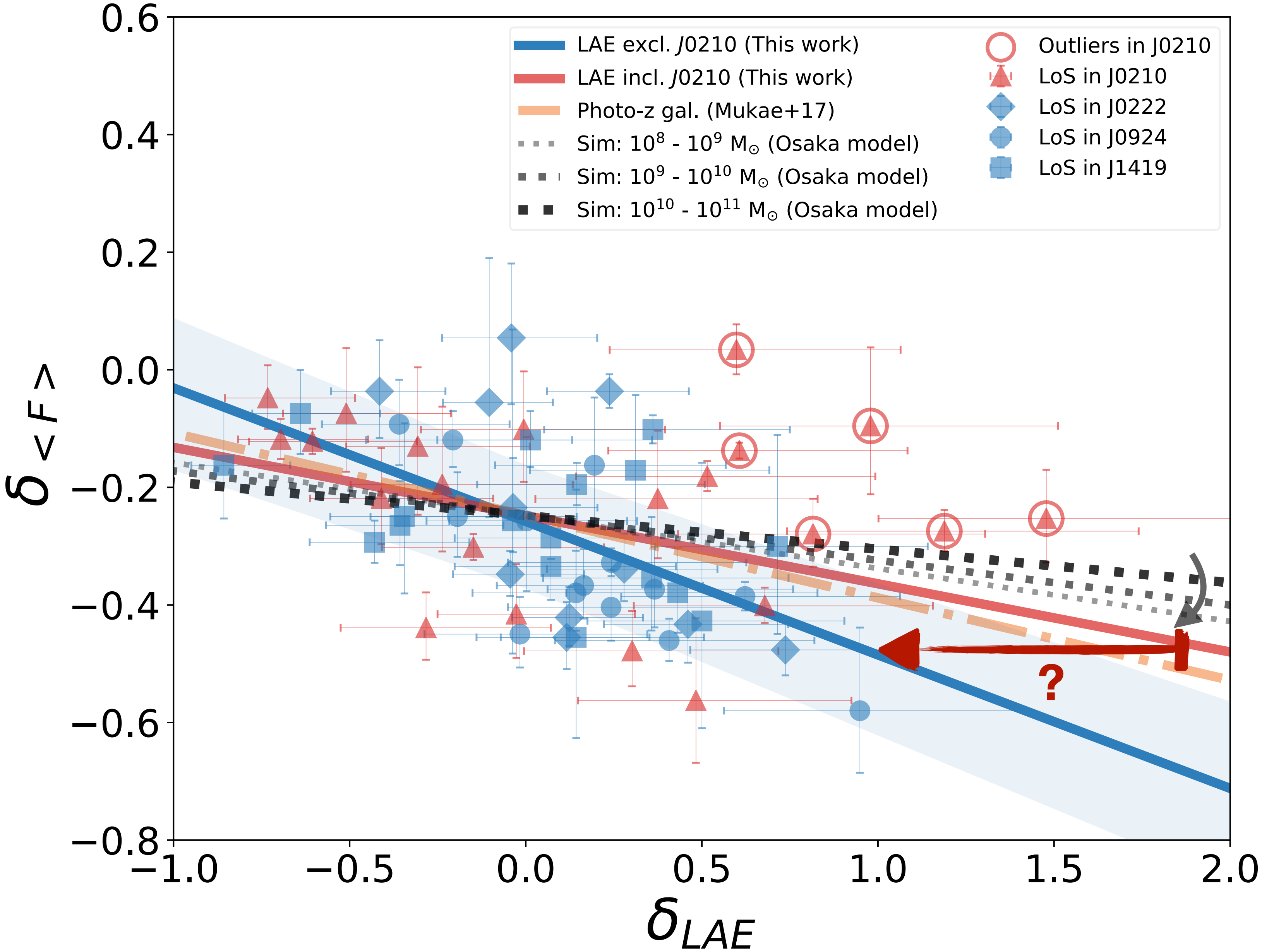
(A) Large OD & absorber.

(B) Along gas filaments but not the galaxy ones.

(C) Large voids; perpendicular gas filament.

(D) Orthogonal low density filaments.

- **Compared with z=2-3 photo-z gal. & GADGET-3 OSAKA models**



$$\delta_{\langle F\rangle} \equiv \frac{\langle F\rangle_{dz}}{F_{\cos}(z)} - 1$$

- **Incl. J0210:** consistent with photo-z gal.
- **Excl. J0210:** Steeper than photo-z gal.

***If excl. J0210 is typical**

→ LAE are less massive?

→ Not likely from Osaka models.

→ Lyα suppression in the HI rich region may be crucial to LAEs.

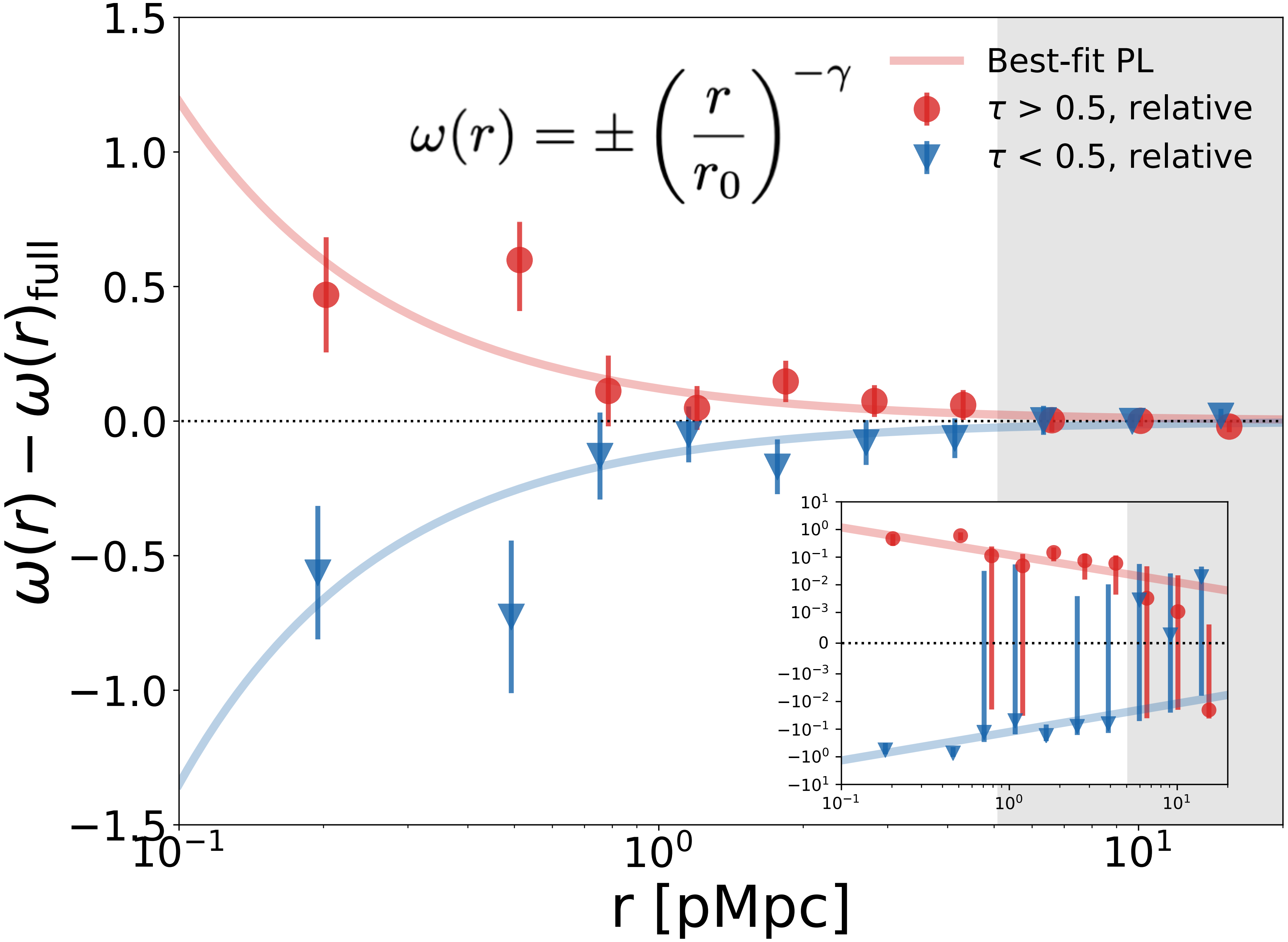
→ Excl. J0210 is rather the biased case?

Incl. J0210 $\delta_{\langle F\rangle} = -0.116^{+0.018}_{-0.022} \times \delta_{\rm LAE} - 0.248^{+0.082}_{-0.093}$

Excl. J0210 $\delta_{\langle F\rangle} = -0.227^{+0.026}_{-0.023} \times \delta_{\rm LAE} - 0.258^{+0.096}_{-0.114}$

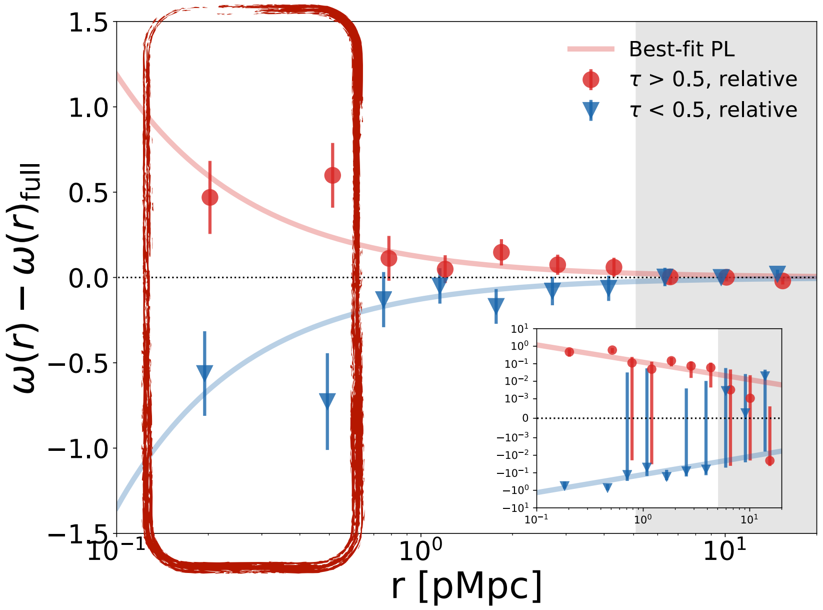
- **CCF bwt LAEs with LoSs (high τ_{LoS} and low τ_{LoS})**

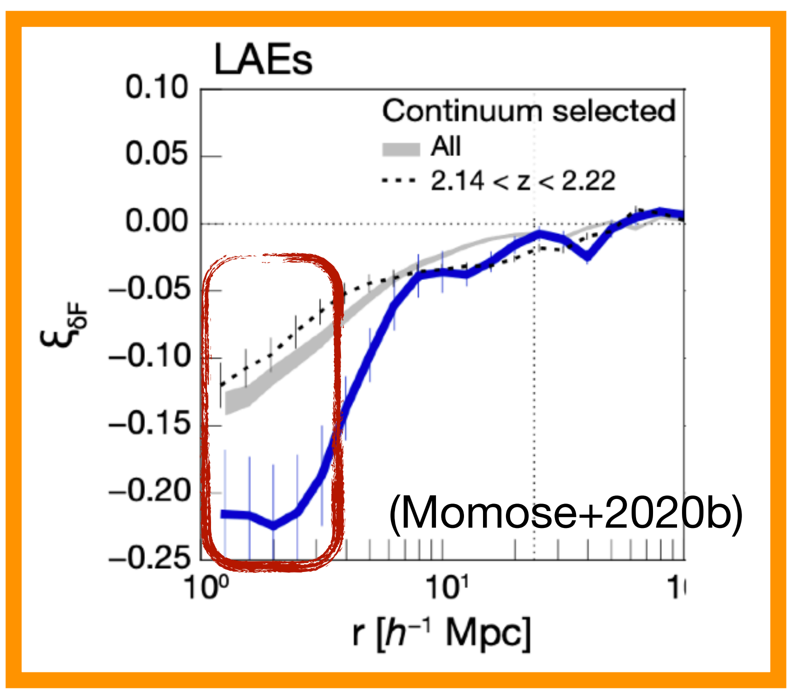
- LAE → high τ_{LoS} (HI-rich);
  → avoid low τ_{LoS};
- The signal found up to ~4±1 pMpc (~13±3 cMpc).
- r_0 ~ 0.1 pMpc, an order of magnitude smaller than typical galaxy clustering.
  (ref. Momose+20b: 0.35 pMpc)



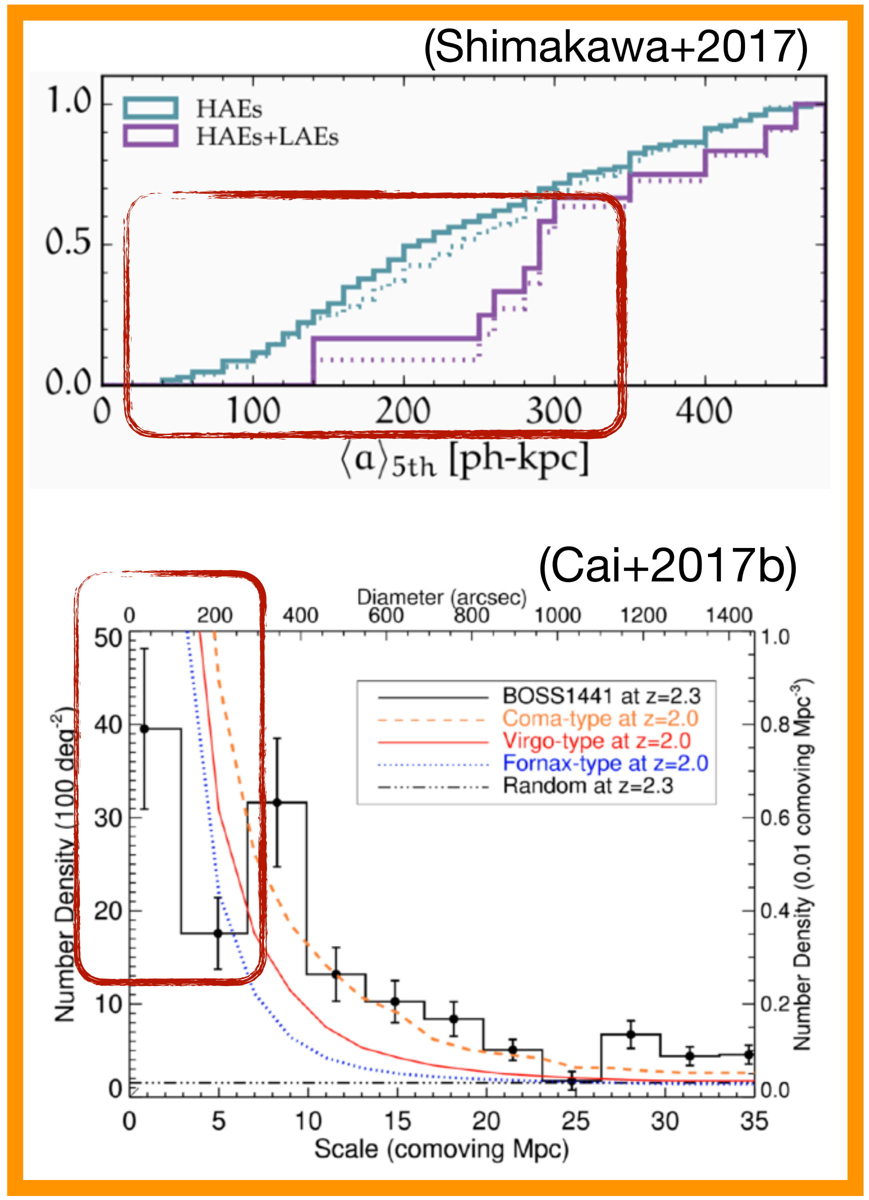
- **LAE deficit in the most overdense region**

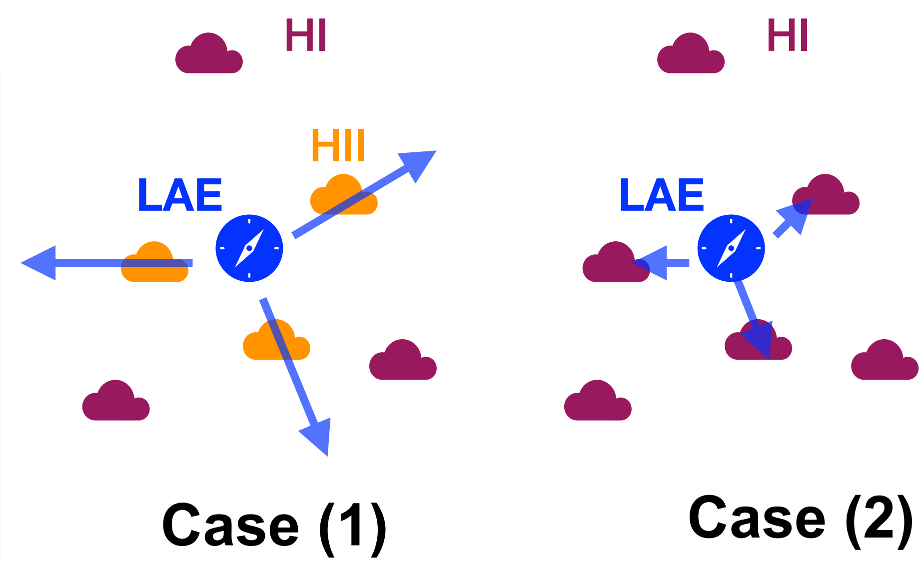
- LAEs & IGM HI





- LAEs & other galaxies





(1) HI ionizied around LAEs?

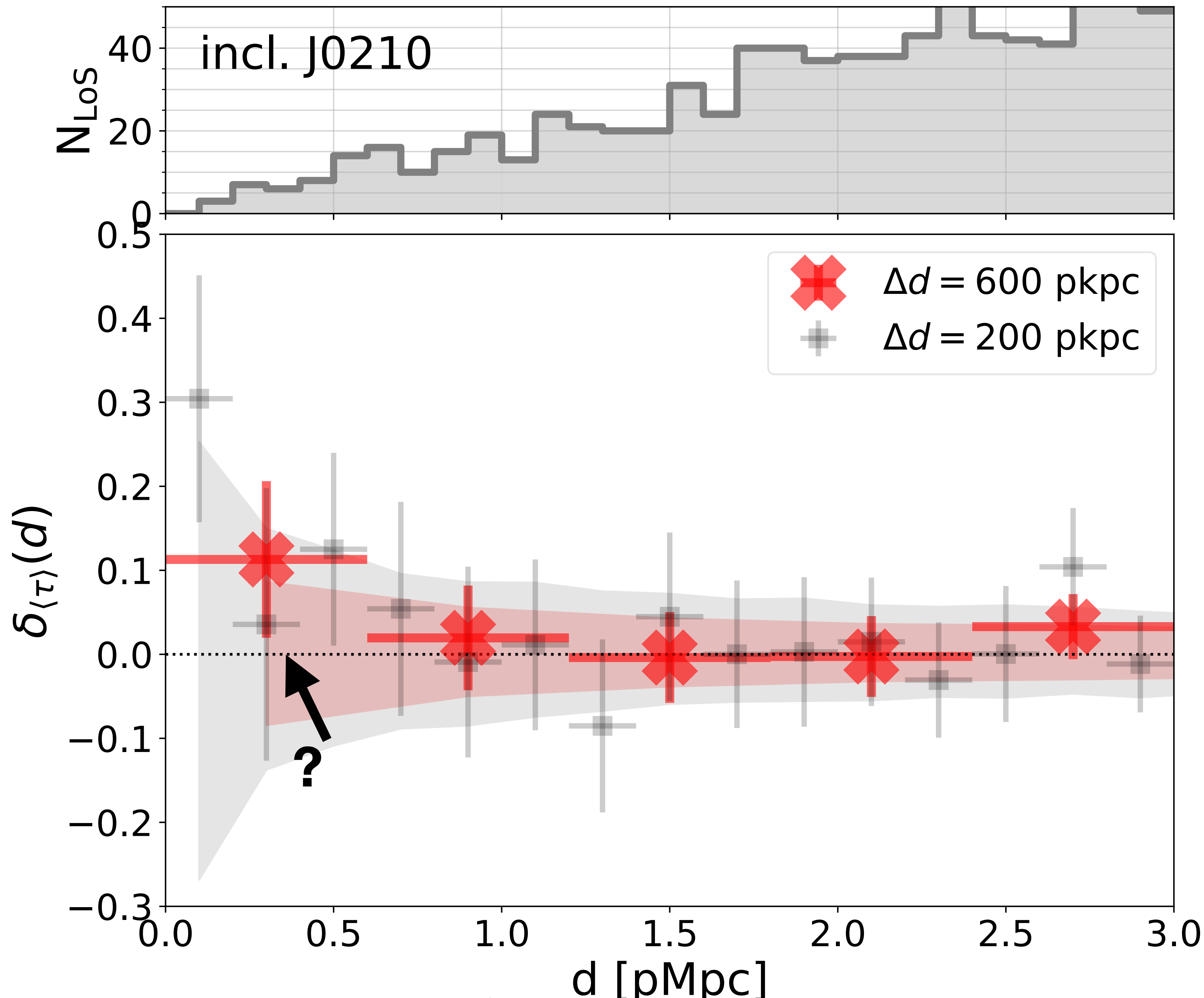
(2) Lyα suppressed at the overdensity peak?

(3) …

Future observations for RT-free tracers
(e.g., Hα emitters (HAEs) with Subaru/MOIRCS?)

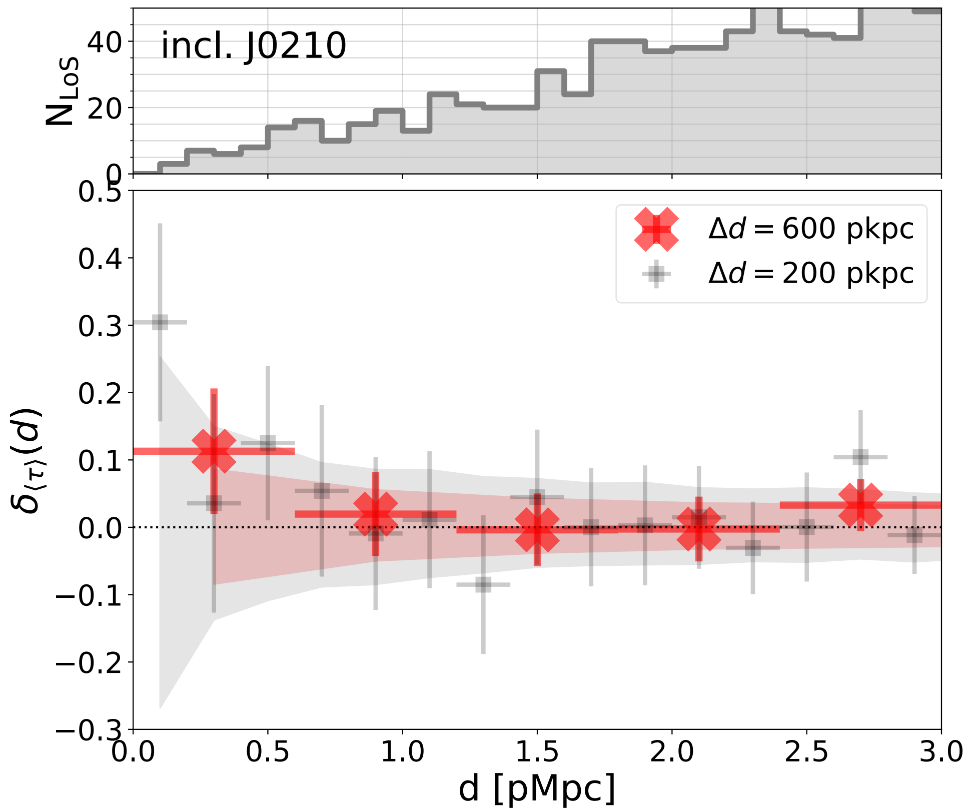
- **Average optical depth as a function of projected distance to LAEs**

$$\delta_{\langle\tau\rangle}(d) = \frac{\langle\tau\rangle\,(\mathrm{d}) - \langle\tau\rangle_{\rm tot}}{\langle\tau\rangle_{\rm tot}}$$



- 2σ 30% excess @ d<200 pkpc: LAE CGM from abs. in statistics.
- 1σ 13% excess @ 400<d<600 pkpc: tend to be in IGM regime

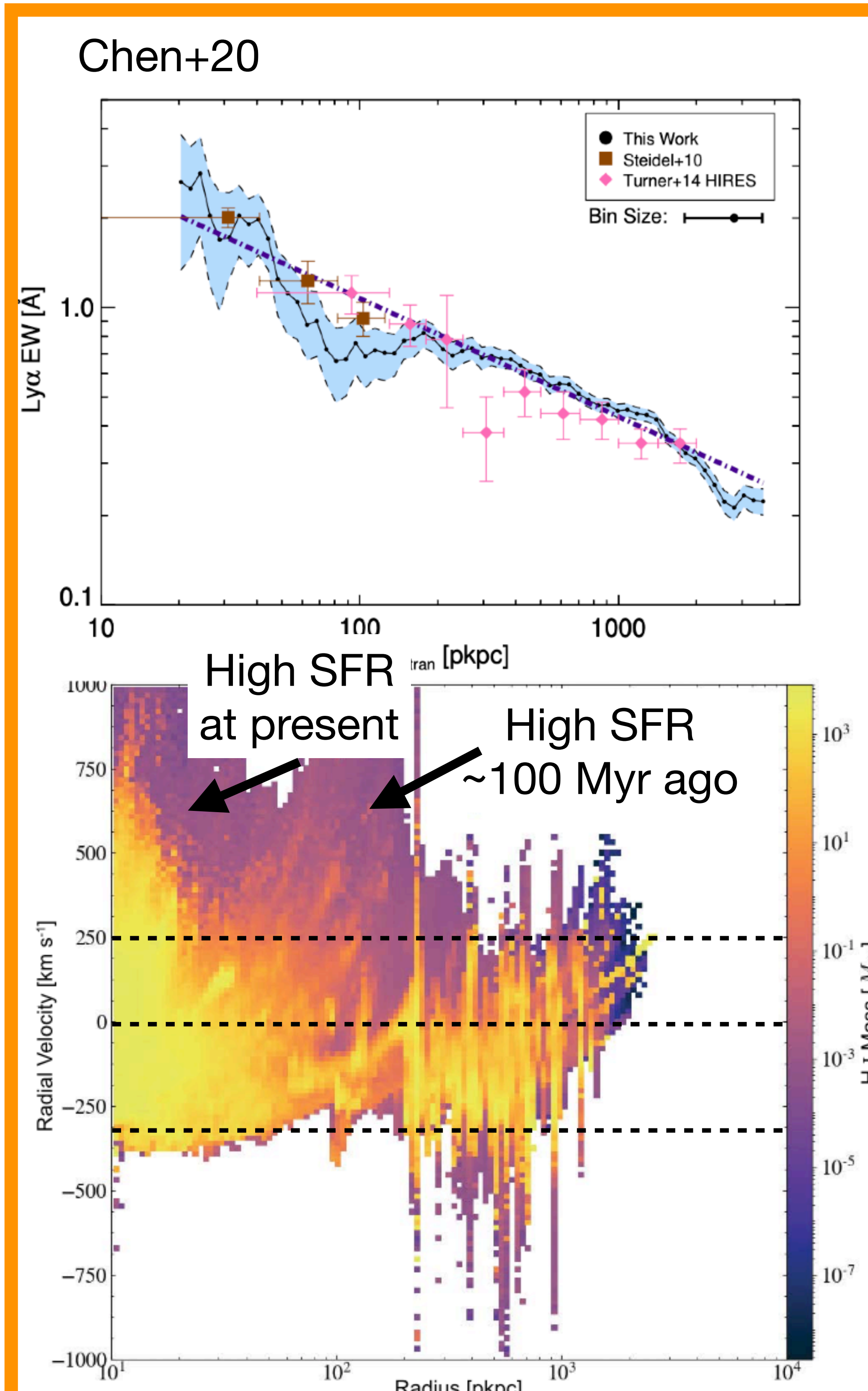
- What makes a dip at 200 < d < 400 pkpc ?



* **Inferences:**

- Chen+20: also found a dip, but @ ~100 pkpc
  → Transition region of inflow & outflow
  → FIRE sim. shows a relation with SF activities
- LAE younger, less massive
  → Stronger SF & shallower potential well
  → Stronger outflow to make the transition region more distant than LBGs?

* **Larger sample in need to say something.**



Liang et al. (2020), ApJ., submitted.

- We target four HSC fields traced by grouping LoSs with strong absorption or grouping QSOs.
  - 2,642 LAEs @ $z = 2.18$ over 5.4 deg^2 in diverse environments.
  - 64 clean LoSs from SDSS/(e)BOSS, especially many own the high $\tau_{\rm LoS}$.
- A moderate (strong) positive correlation between $\tau_{\rm LoS}$ and $\delta_{\rm LAE}$ with (without) J0210.
  IGM HI still traces well LSSs at the Cosmic noon.
  - Outliers in J0210 can indicate a fully ionized or preheated overdensity.
  - The scatter in correlation can help to pinpoint unique structures.
  - Lyα suppression is probably not trival to LAEs even at $z \sim 2$.
- CCF analysis finds the LAEs tend to reside in regions rich in IGM HI up to a scale of 4 ± 1 pMpc.
  - r_0 is one order of magnitude smaller than that of galaxy clustering.
  - The plateau in the inner bins suggest the LAE deficit around overdense peak on small scale.
- The $\delta_{\langle\tau\rangle}$ profile detect a 30% excess at 2σ level at $d < 200$ pkpc, suggesting the CGM of LAEs.
  - A sudden dip at $200 < d < 400$ pkpc may indicate the transition of inflow and outflow of LAEs is lager than LBGs.