galaxy environment
quasar environment

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Environment

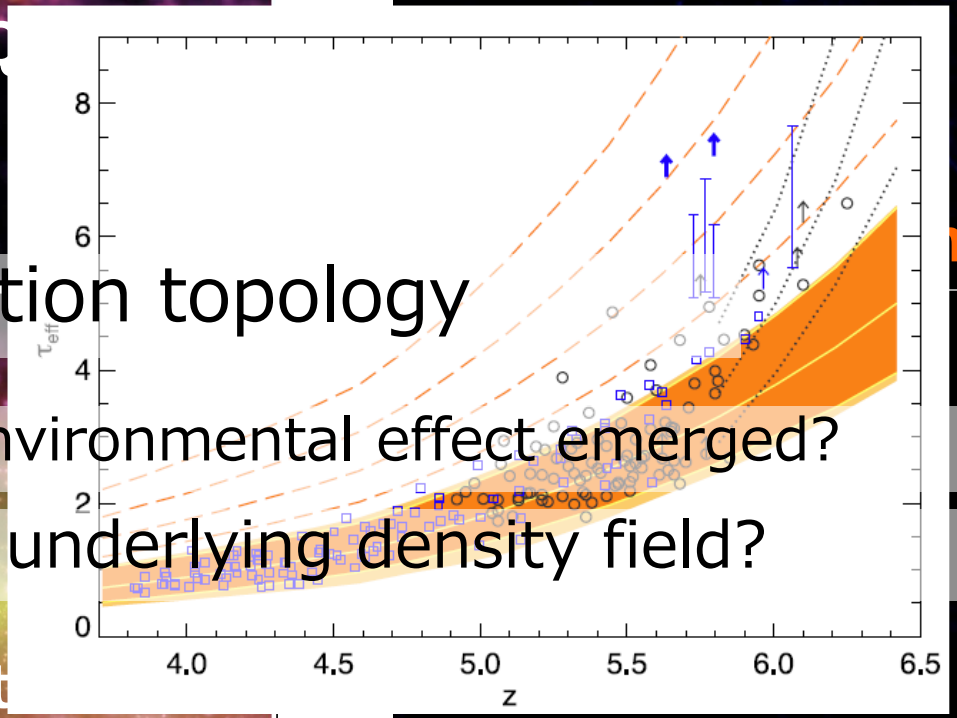
Is quasar activity preferentially triggered in the density peaks?

How does quasar radiation affect on surrounding environment?

Reionization topology

When and how was galaxy environmental effect emerged?

Does gas also trace underlying density field?

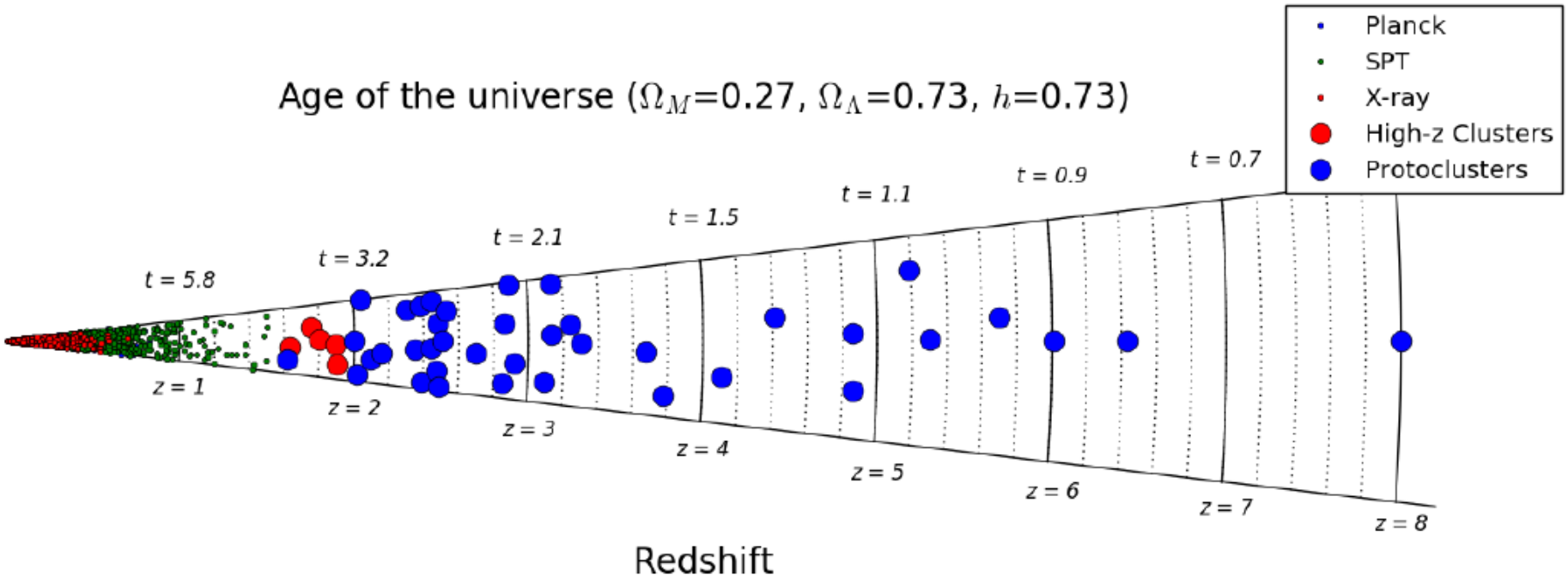


Millenium

Underdense region

High-z protoclusters

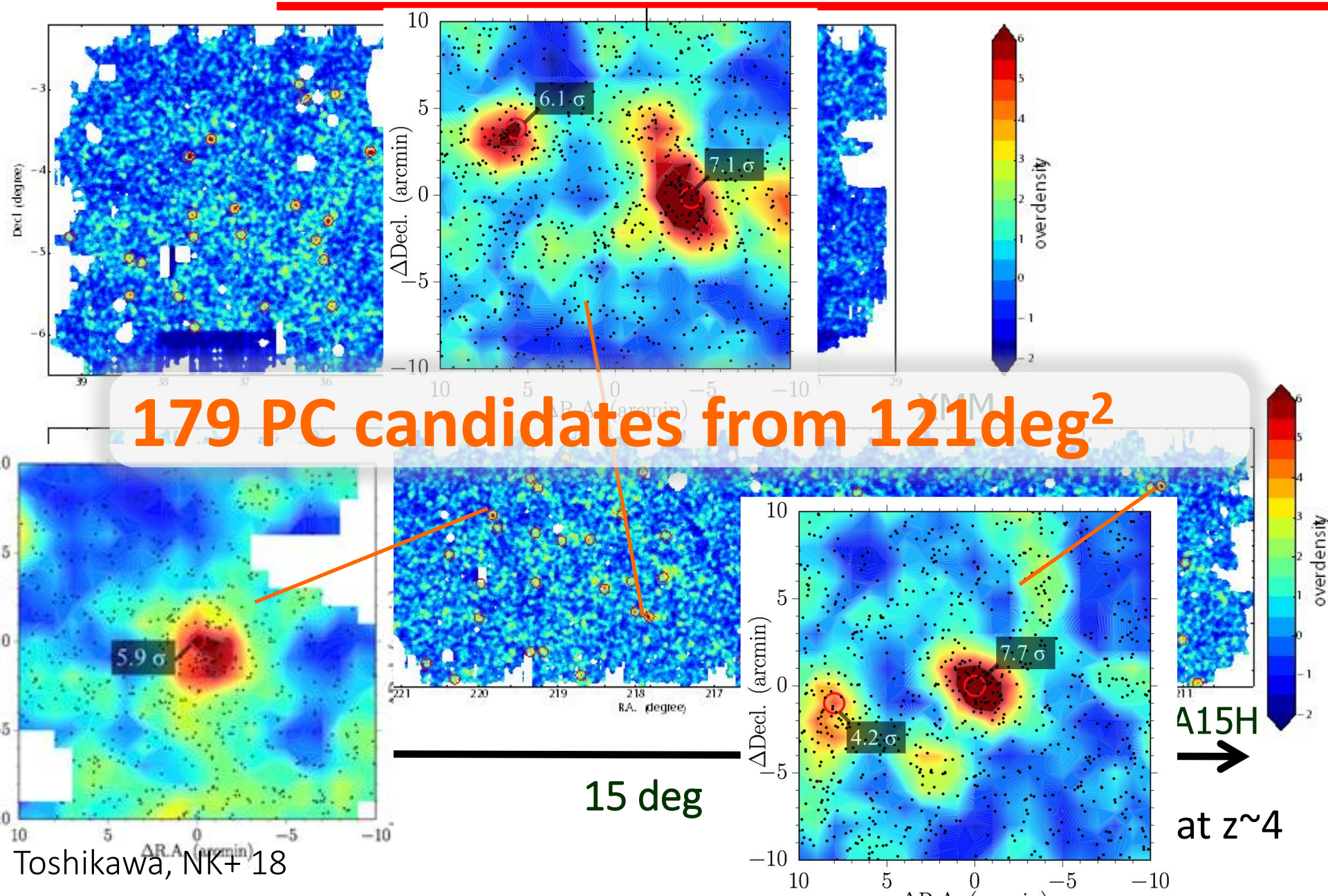
- **Very rare**
- Not enough sample of protoclusters beyond z=3
- Most of them are found around RGs/QSOs



Only ~20 PC at z>3

Overzier+ 16

HSC Protocluster search @z~4



179 PC candidates from 121deg²

15 deg

A15H

at z~4

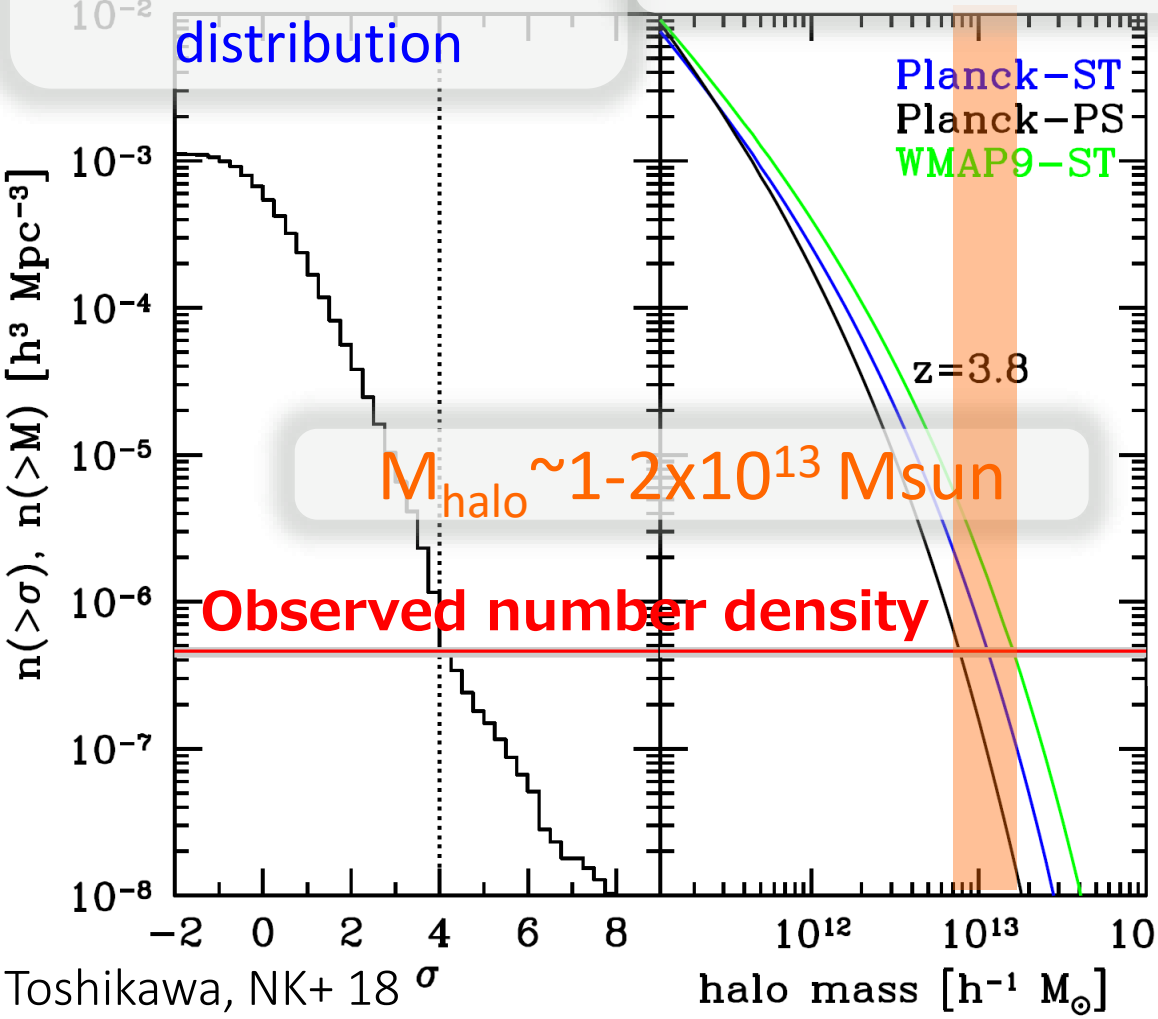
Toshikawa, NK+ 18

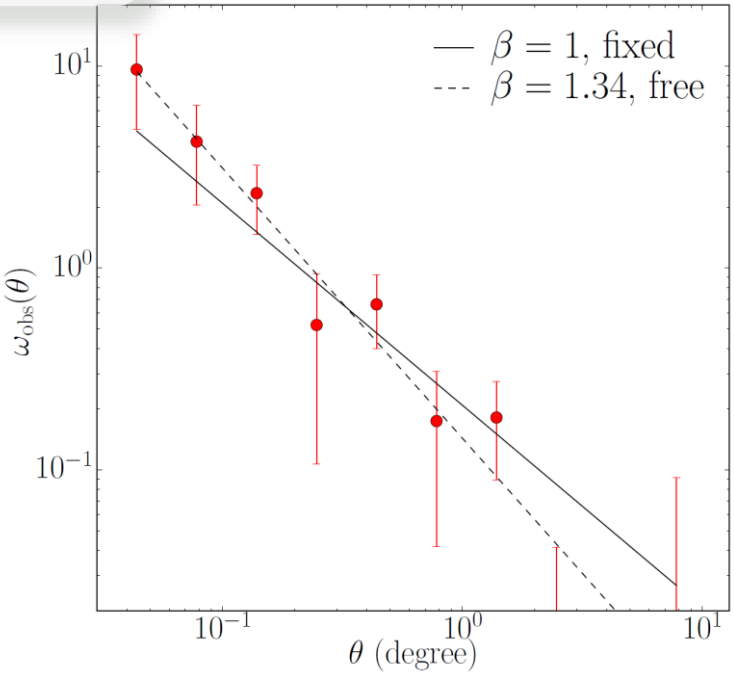
Mass of z~4 PCs

- **Abundance matching**
- **Clustering of PCs**

Observed overdensity distribution

Predicted Mass function





$$r_0 = 35.0^{+3.0}_{-3.3}\, h^{-1}\,\mathrm{Mpc}$$

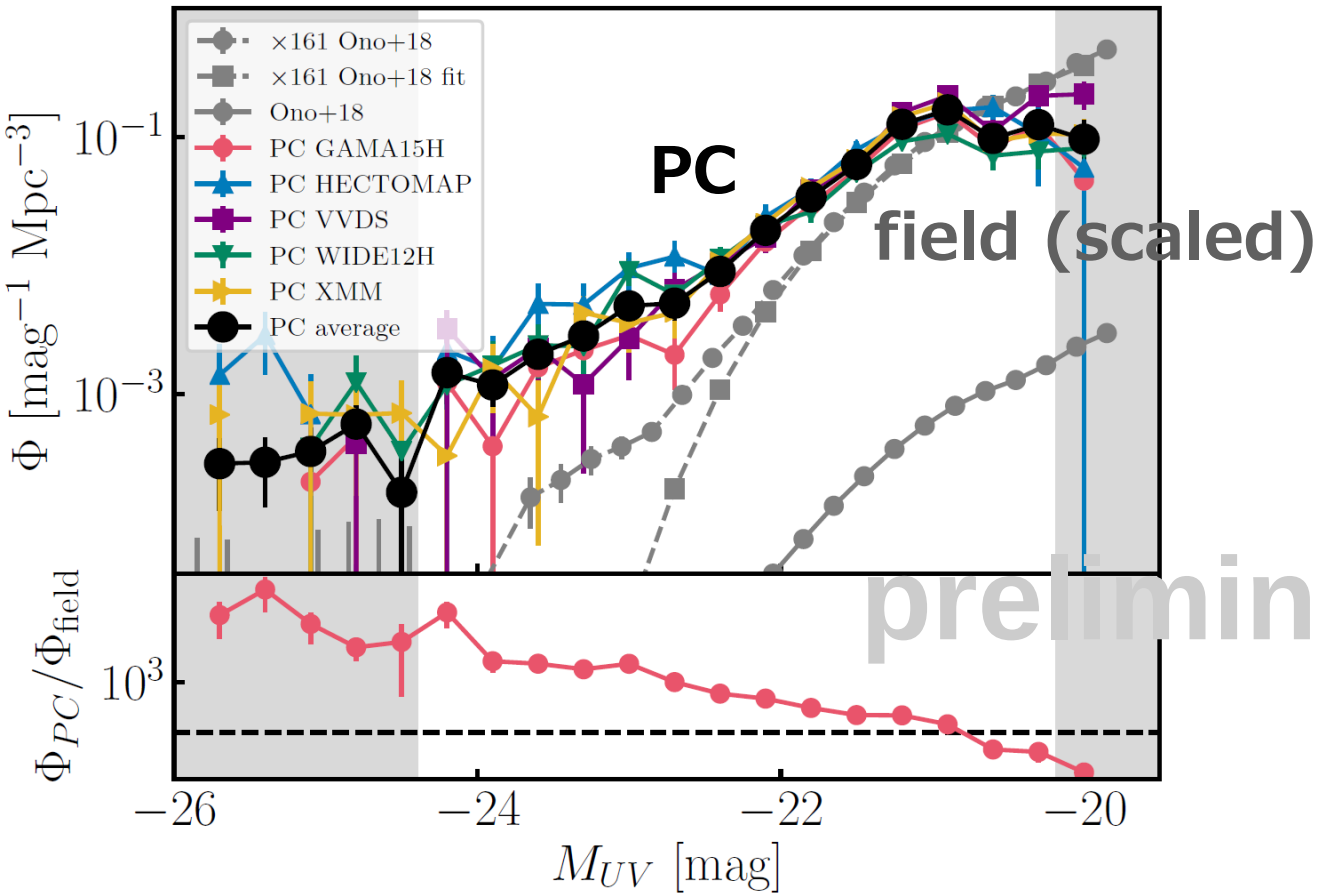
$$\langle M_h \rangle = 2.3^{+0.5}_{-0.5} \times 10^{13}\, h^{-1}\mathrm{M}_\odot$$

Toshikawa, NK+ 18

Descendant halo mass at z=0: $\langle M_h \rangle = 4.1^{+0.7}_{-0.7} \times 10^{14}\, h^{-1}\mathrm{M}_\odot$

Rest-UV LF of PC galaxies at z~4

- Significant excess at the bright end
- PC members are twice as massive as their field counterparts at the same redshift
- galaxy growth was accelerated in dense environments.



Ito, NK+ in prep.

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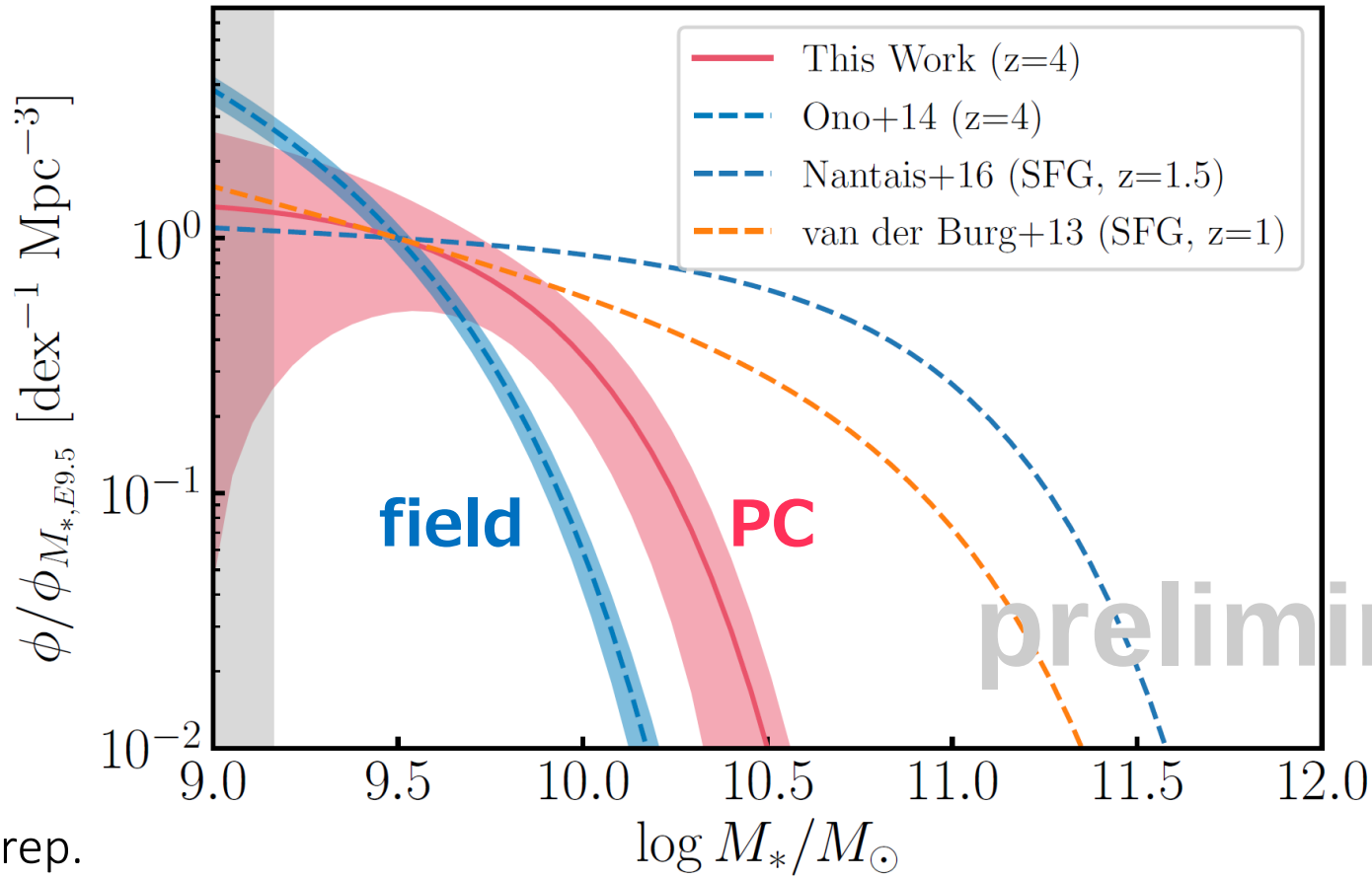
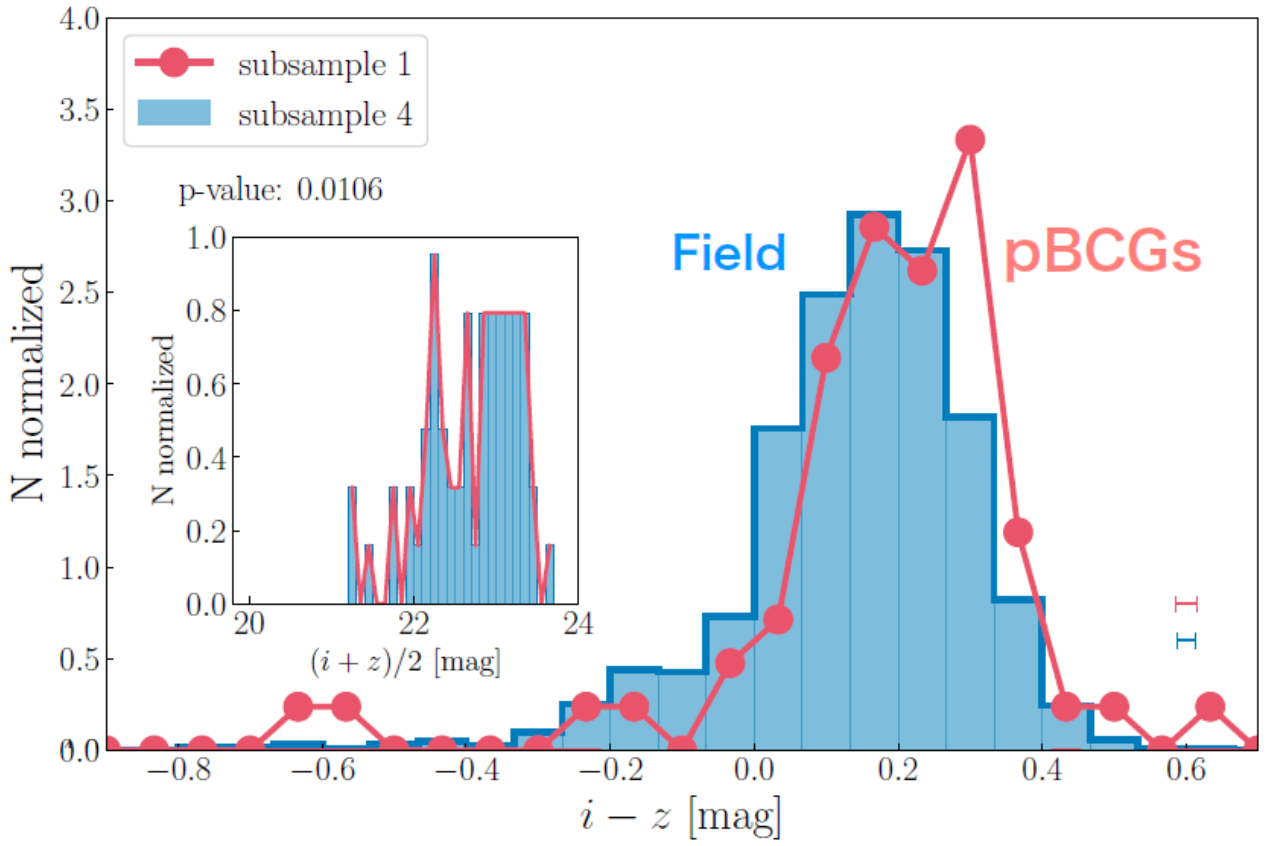


Ito, NK+ in prep.

proto-BCGs (Brightest Cluster Galaxies)

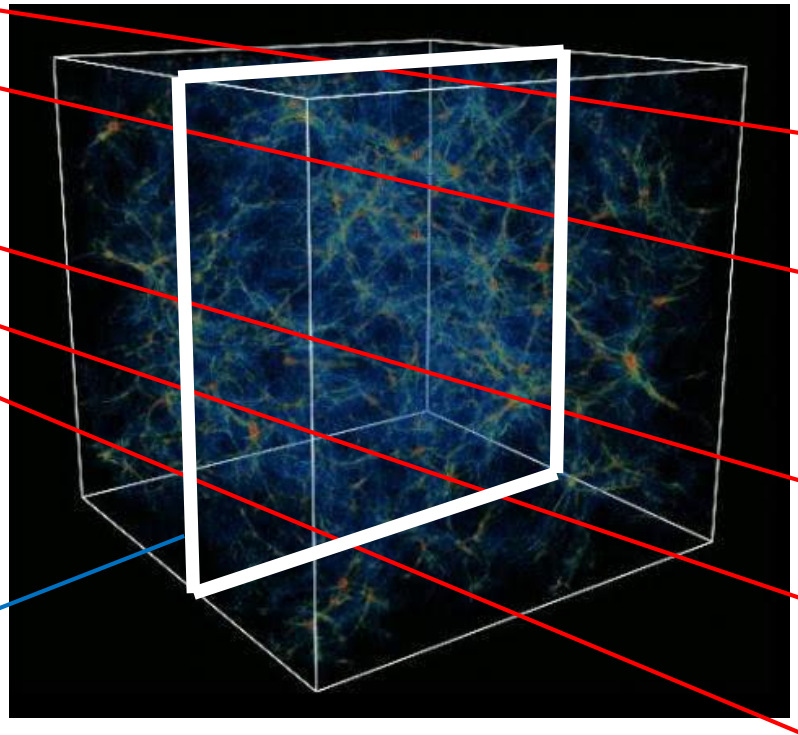
- 63 proto-BCG candidates
- Proto-BCGs and surrounding LBGs at z~4 are redder (dustier A_{UV}~0.7mag) than field LBGs and other cluster LBGs
- More matured (earlier galaxy formation) in proto-BCG environments?



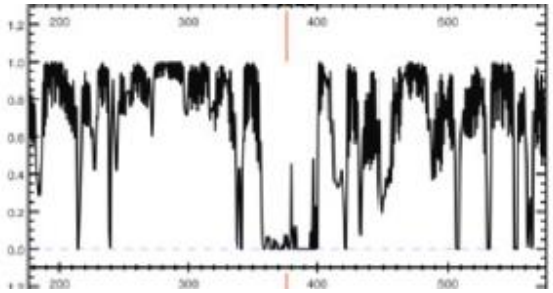
Ito, NK+ 19

HI and protoclusters

- Background quasars: ~160000 BOSS quasars at z>2.2 over 10,000 deg^2 (~1Gpc^3)



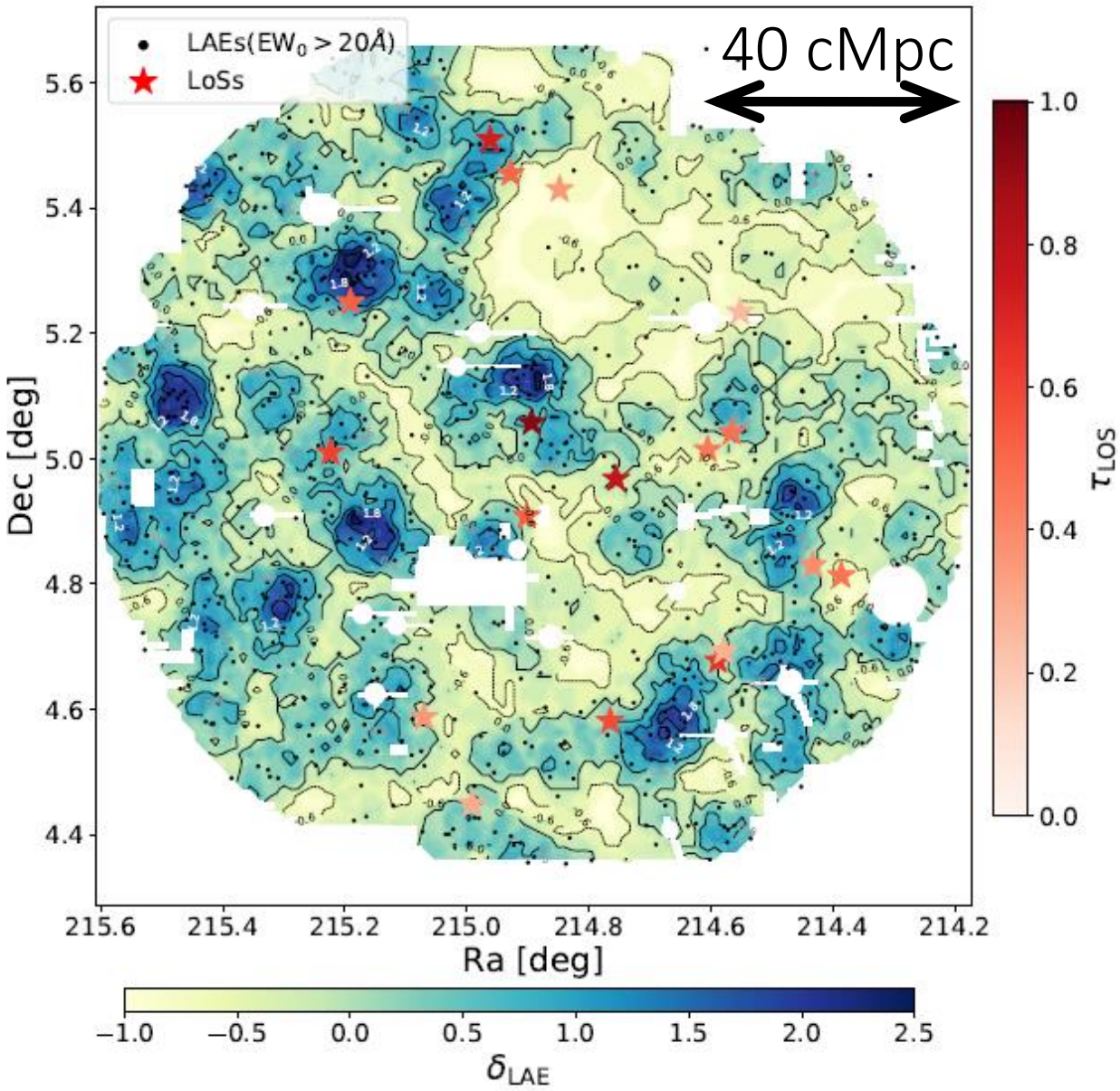
- identify overlapped multiple Lyα forests that originated from the IGM overdensity in a protocluster (Cai+16)



- Subaru/HSC NB observation to map the galaxy (LAE) structure

A statistical sample to unveil correlation between galaxy and IGM/CGM gas at z>2 on **a scale of >100 cMpc**

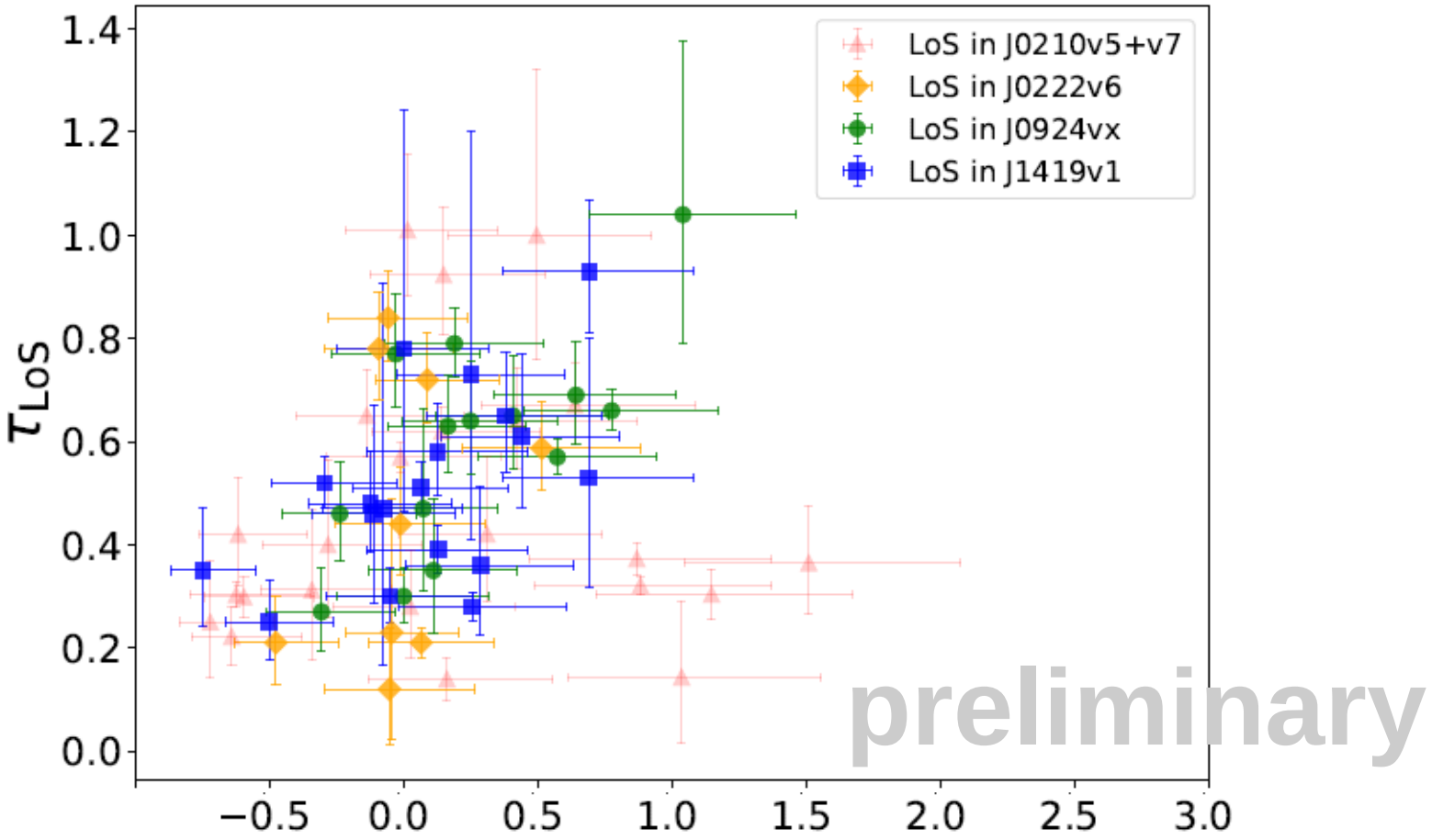
HI and protoclusters



Liang, NK+ in prep.

OD-OD relation

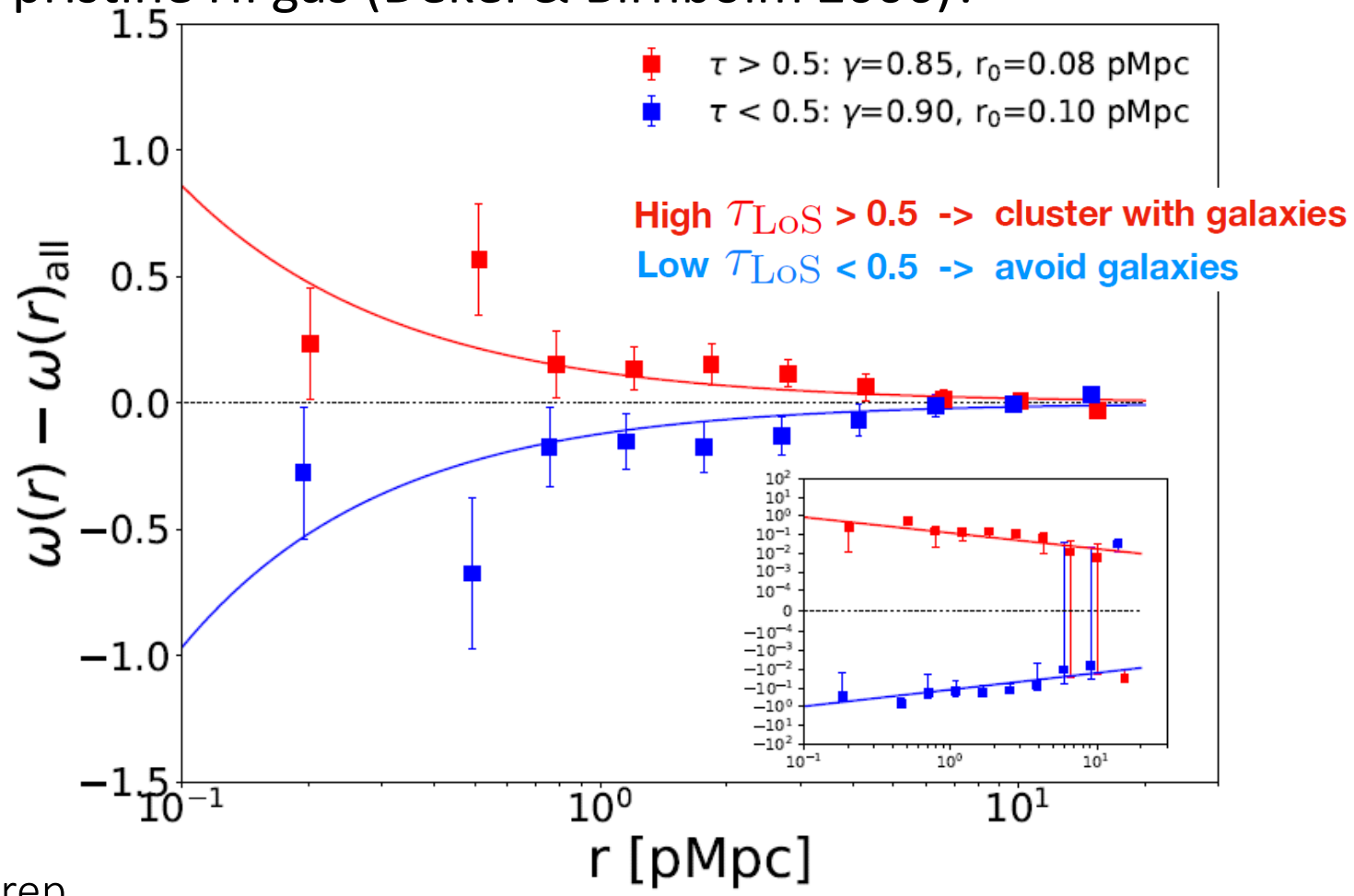
- Optical Depth and Over-Density are positively correlated up to >100cMpc at z~2
- galaxies are clustering in a region associated with large amount of HI gas.



Liang, NK+ in prep.

Cross correlation between τ and galaxy

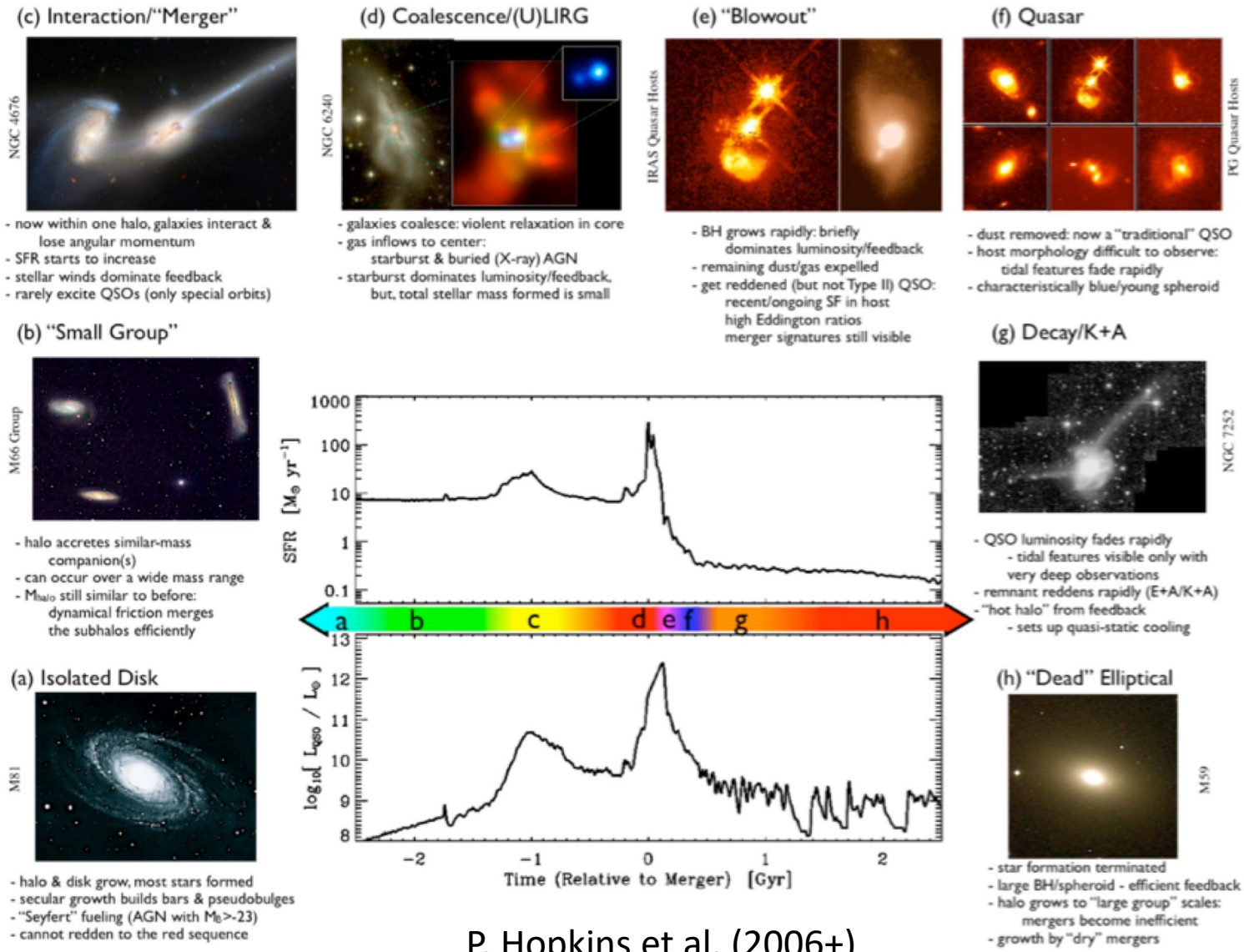
- Higher τ LoSs tends to clustering around galaxies, while the lower one is opposite at up to 4 pMpc scale
- ionization or feedback from galaxies is not sufficient enough? Or cold stream of pristine HI gas (Dekel & Birnboim 2006)?



Liang, NK+ in prep.

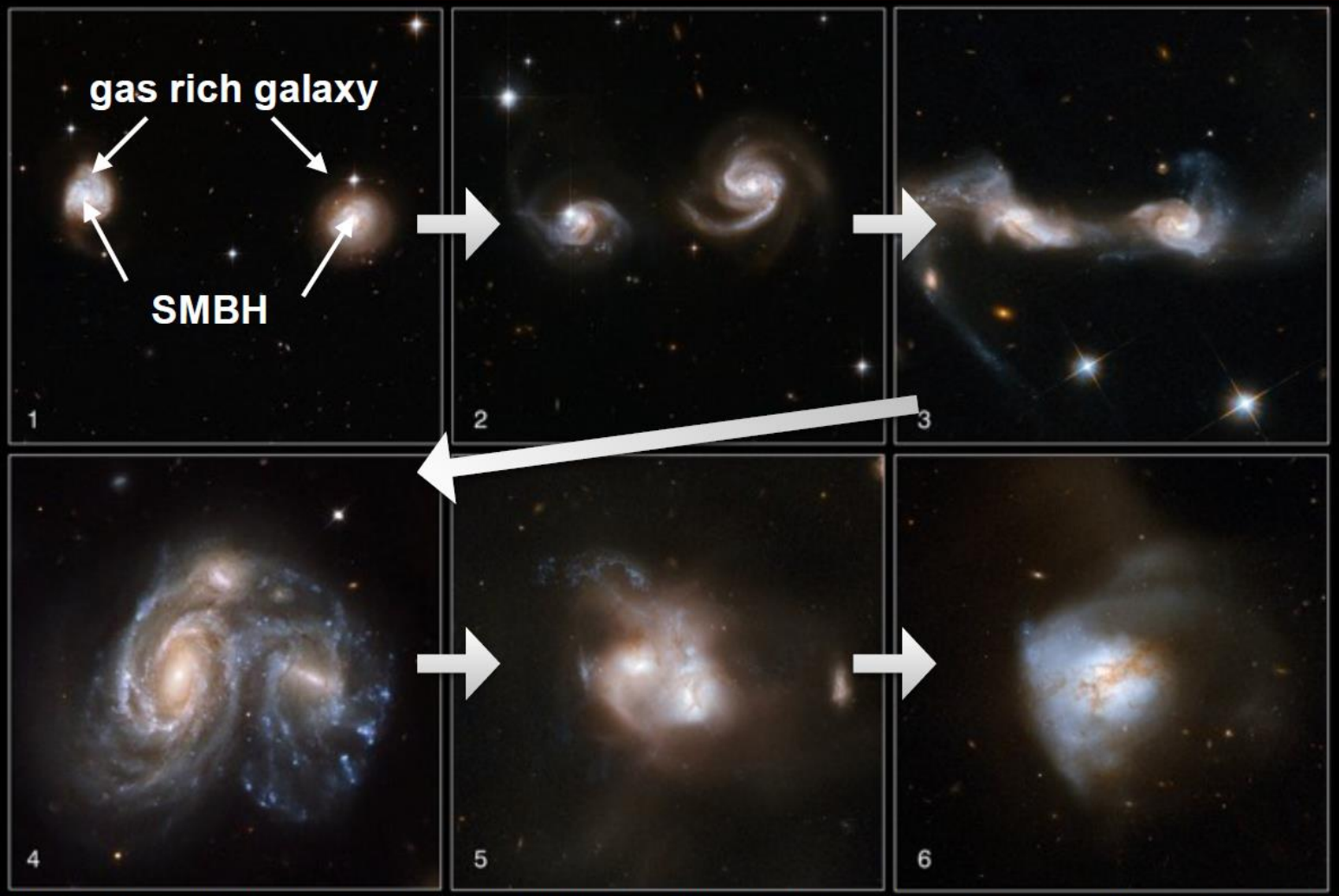
Quasar environment

Is AGN activity triggered by galaxy-galaxy mergers?



P. Hopkins et al. (2006+)

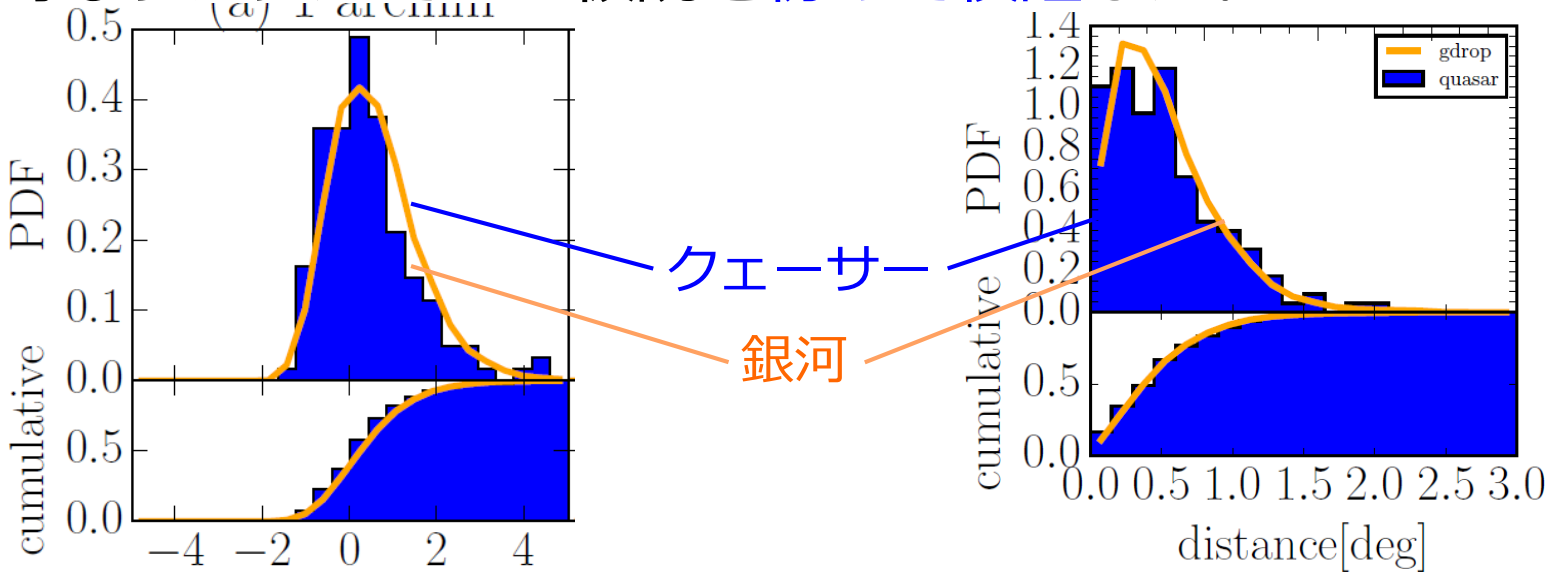
クェーサーはどうやってできるのか？



- 銀河同士がぶつかってクェーサーができる
  → 銀河がたくさんいるところにクェーサーは生まれやすい
  → 銀河団のようなところでクェーサーは生まれる???

原始銀河団とクェーサーの関係

- これまで、クェーサーの活動性は銀河衝突・銀河合体によって生じると考えられてきた。
  → 銀河団のような高密度領域でクェーサーは発現する。
- 統計的なサンプルでこの仮説を初めて検証した。

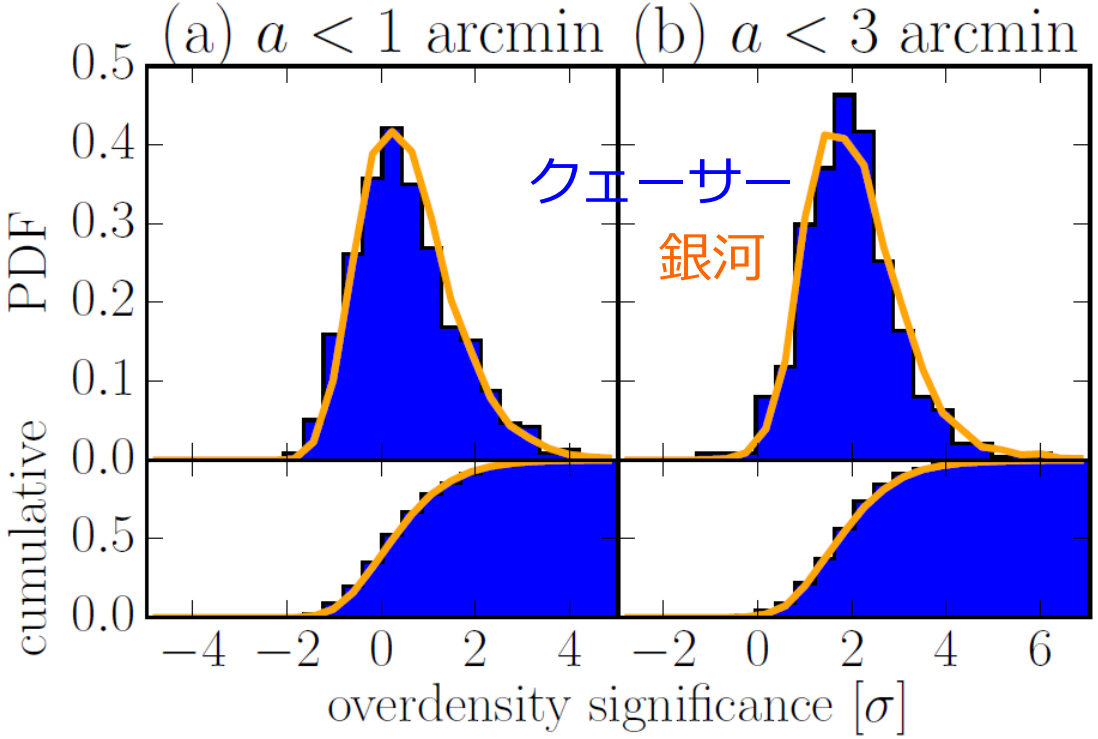


  - 179原始銀河団中にクェーサーが存在する領域は2領域のみ。
  - クェーサー位置の銀河密集度は平均値程度。
  - クェーサーから一番近い原始銀河団までの距離も平均値程度。
- クェーサーは必ずしも高密度領域で発現するわけではない。
- クェーサーの発現はその環境に依存しない。

Uchiyama, NK+ 18

原始銀河団とクェーサーの関係

- SDSSより4mag暗い z~4HSC quasars570個も高密度領域にはいない。

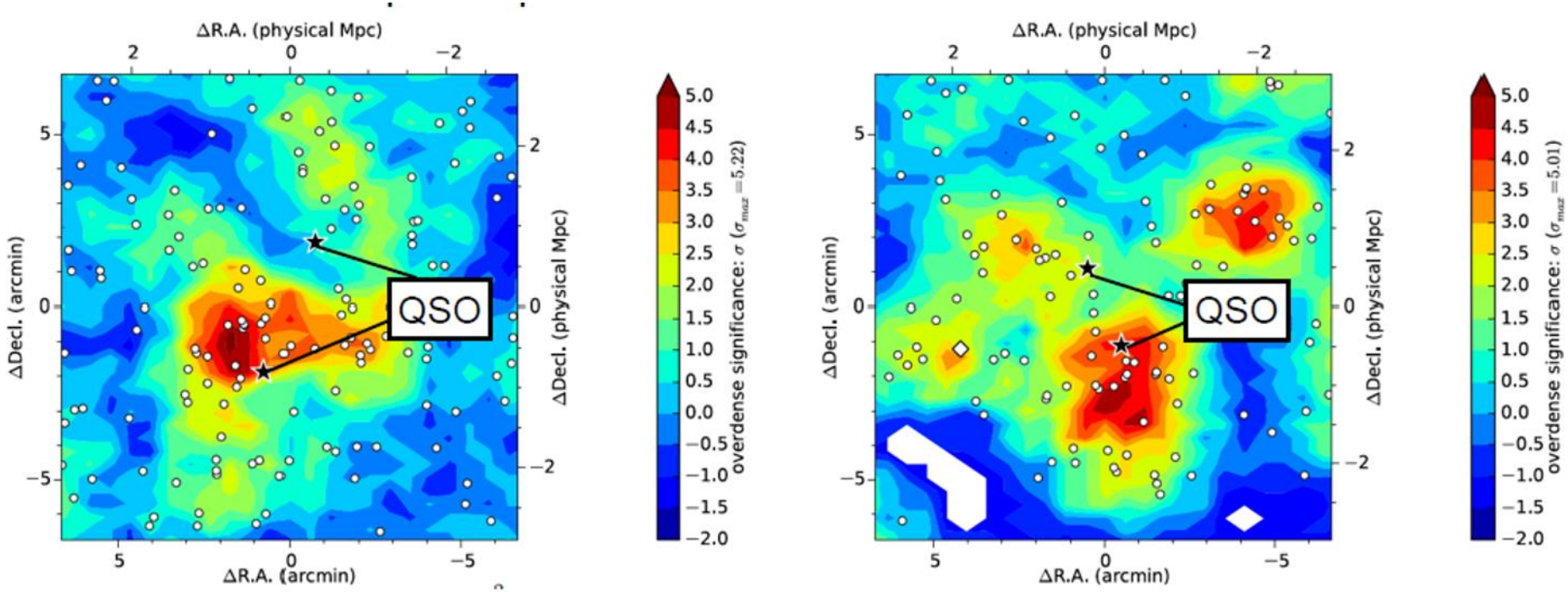


- 570個中高密度領域にいるクェーサーは4個のみ。
- クェーサー位置の銀河密集度は平均値程度。
- クェーサーから一番近い原始銀河団までの距離も平均値程度。

Uchiyama, NK+ in prep.

Pair quasars and protocluster

- Pair quasars at z~4 with <2 Mpc separation are related to a galaxy overdensity region with ~4.5σ (not richest)

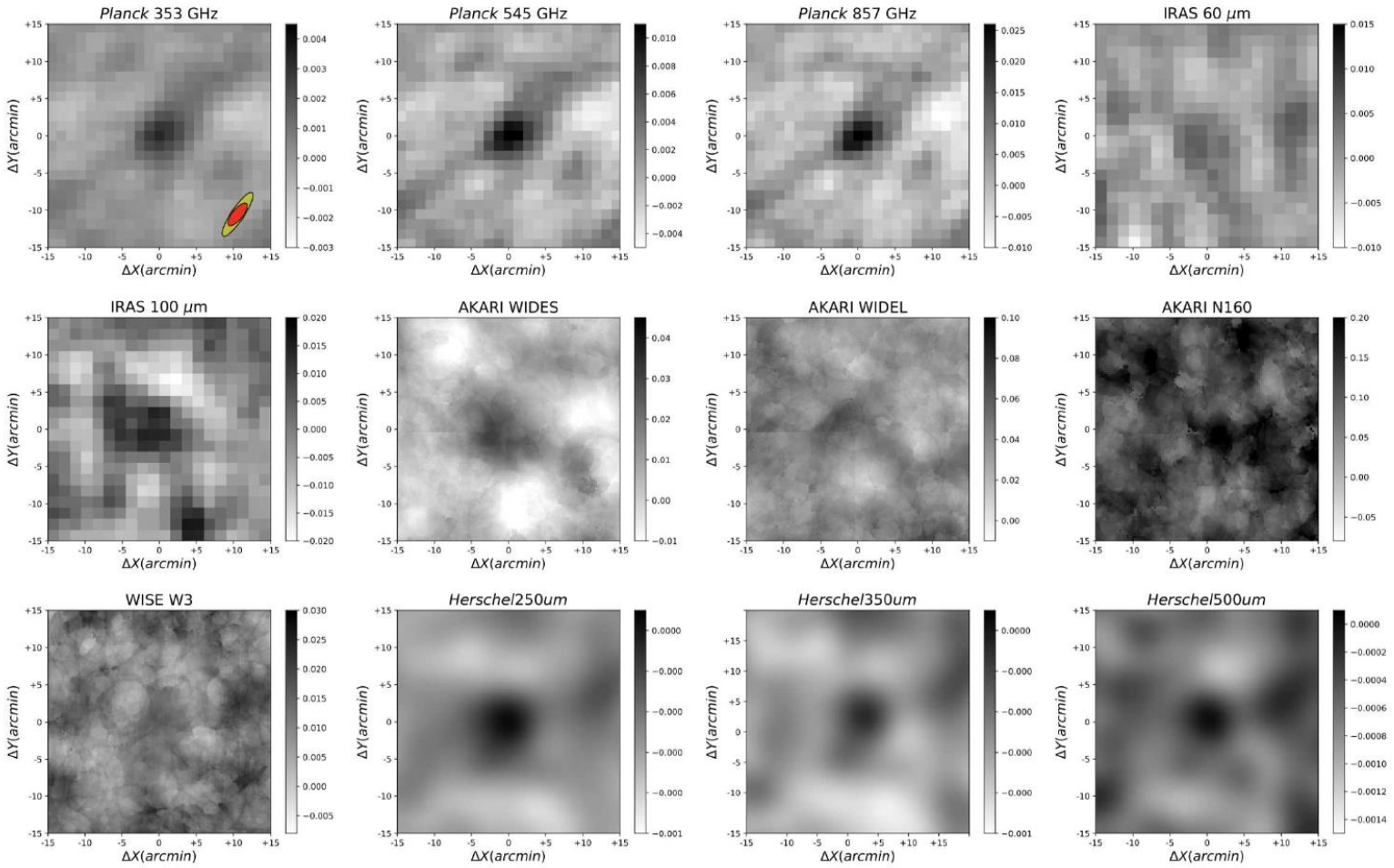


- ~20% of the z~1 pairs are within massive (> 4σ) environments.
- Quasar pairs tend to reside in overdense regions unlike single quasars.

Onoue, NK+ 18

Planck FIR detection of z~4 PCs

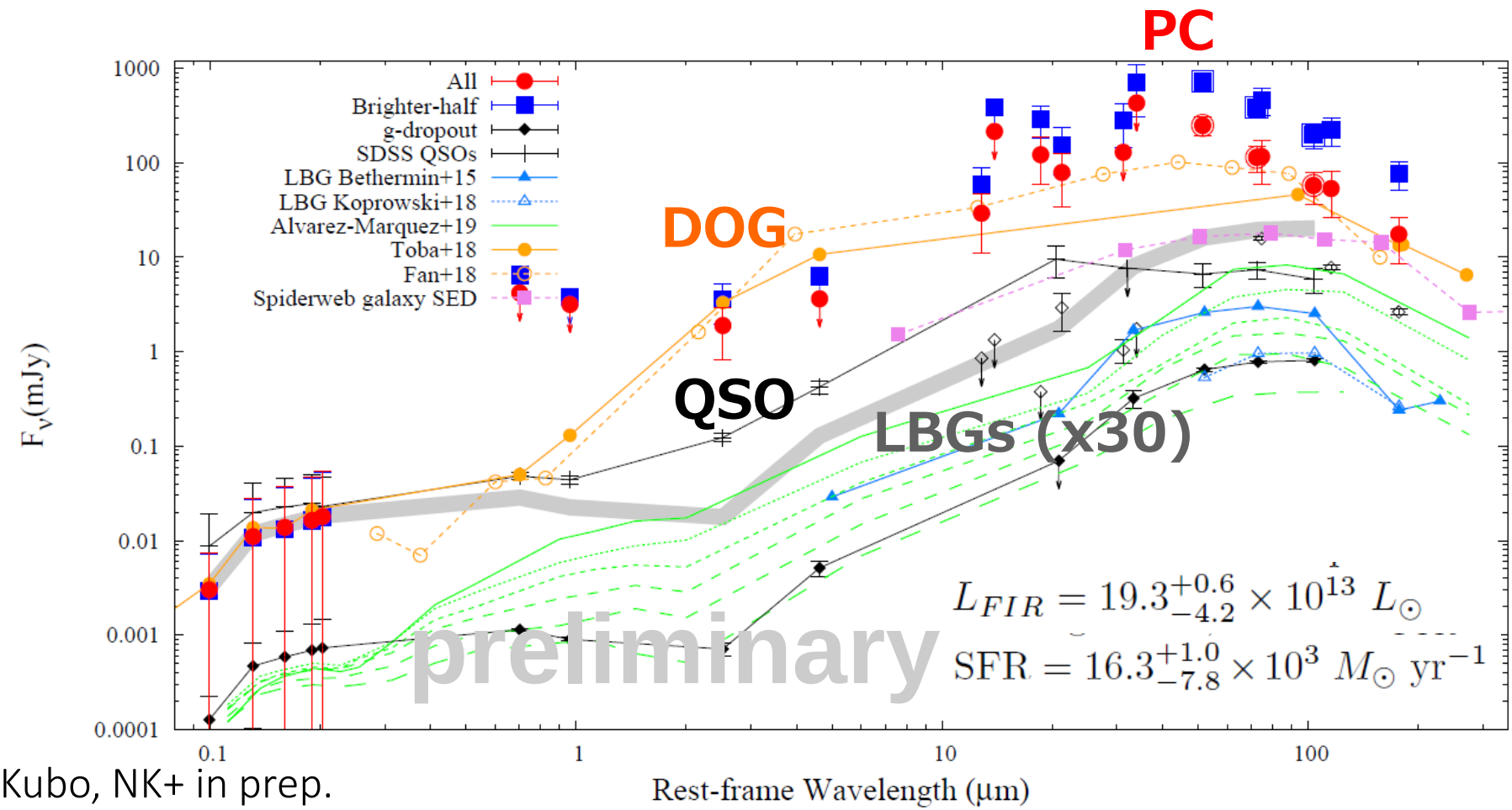
- Stacking the images of the 179 z~4 PC candidates, the FIR emission in the observed 12 – 850 μm wavelength range is, for the first time, successfully detected.



Kubo, NK+ in prep.

Planck FIR detection of z~4 PCs

- The observed IR SEDs of the PCs exhibit significant excess compared to that expected from typical star-forming galaxies .
- The z ~ 4 PCs may host obscured AGNs missed by the selection of PC members in the optical.

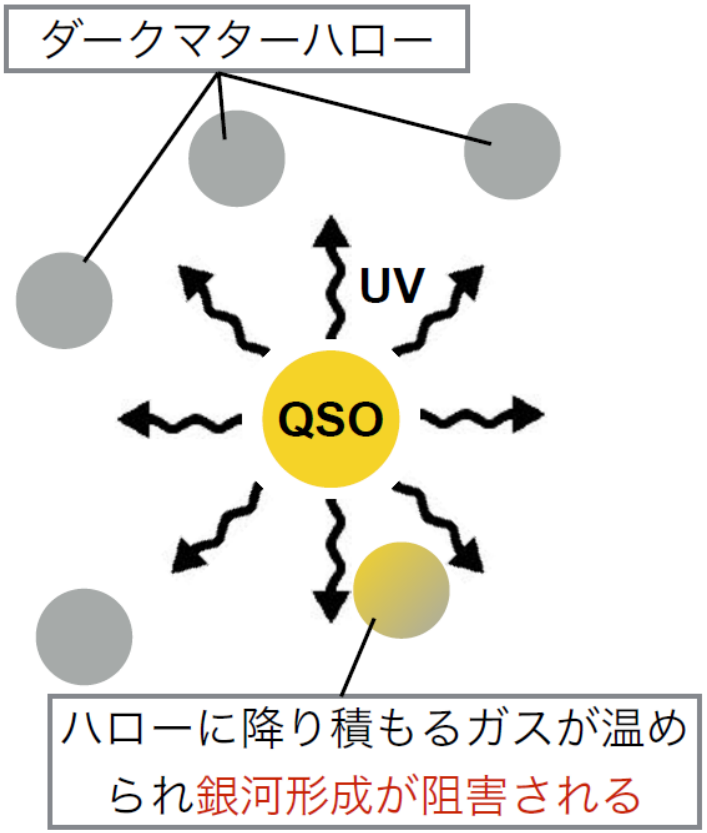


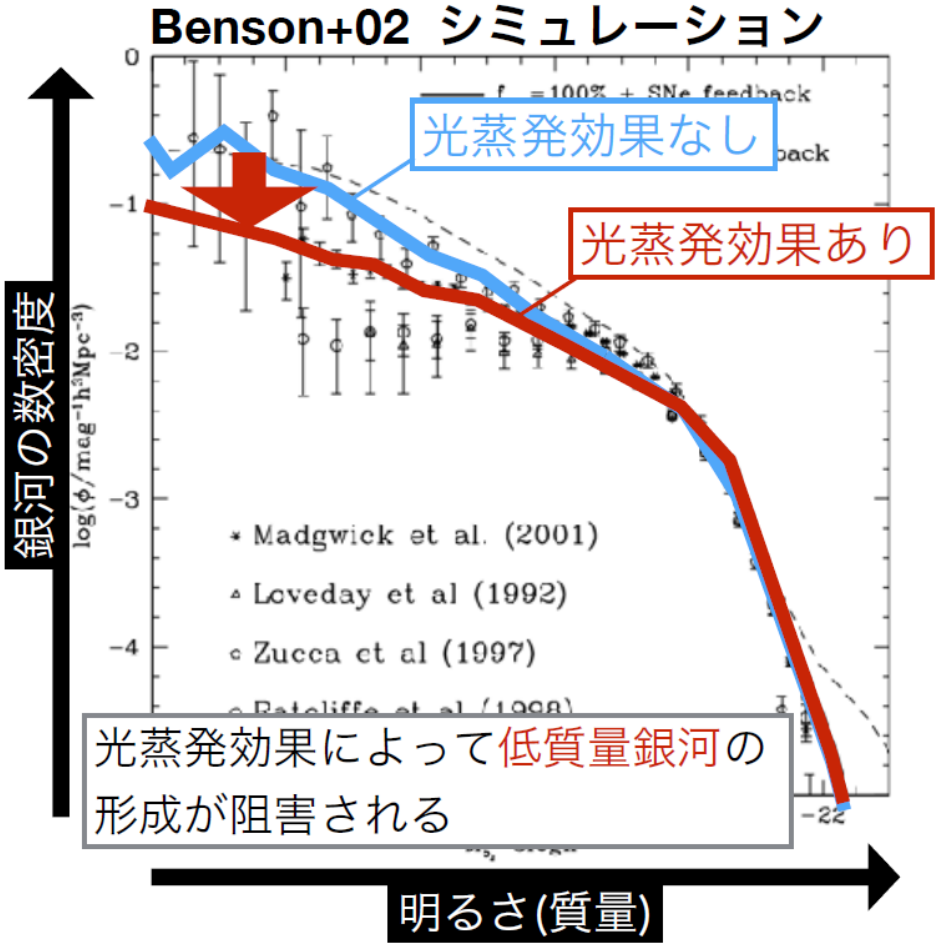
Kubo, NK+ in prep.

QSO周囲の銀河形成阻害

QSOによる光蒸発効果 → 強いUV放射により周辺ハローでのガス冷却妨害

→ 周辺銀河形成抑制

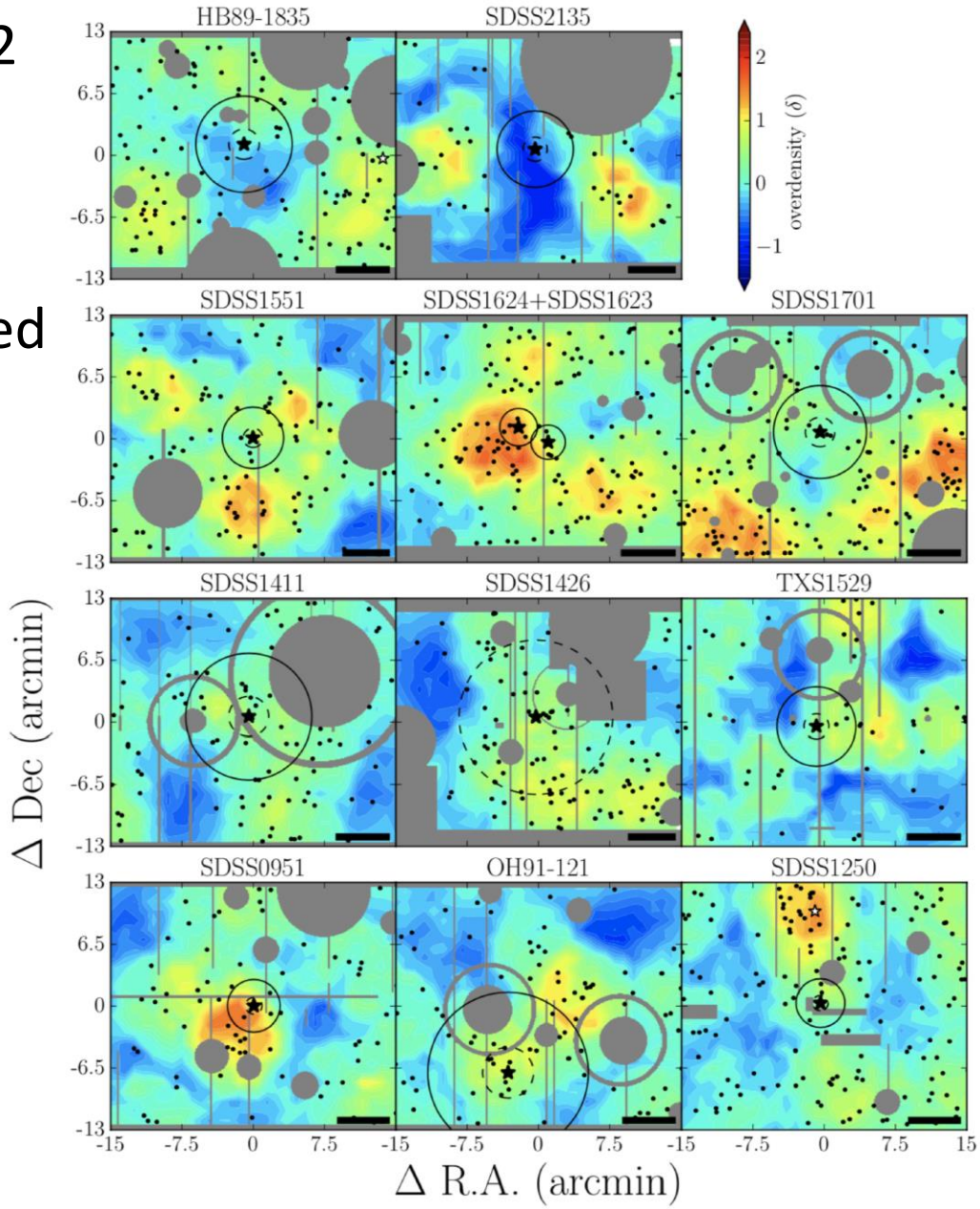




SF suppression around quasars

- 12 quasar regions @z=2.2-3.2
- Scam/NB imagings to detect surrounding LAEs (low-mass galaxies)
- Quasar redshifts are measured by OIII/Hβ
- J_{21}>1: Local UV background ontensity J_{21} is higher than cosmic average

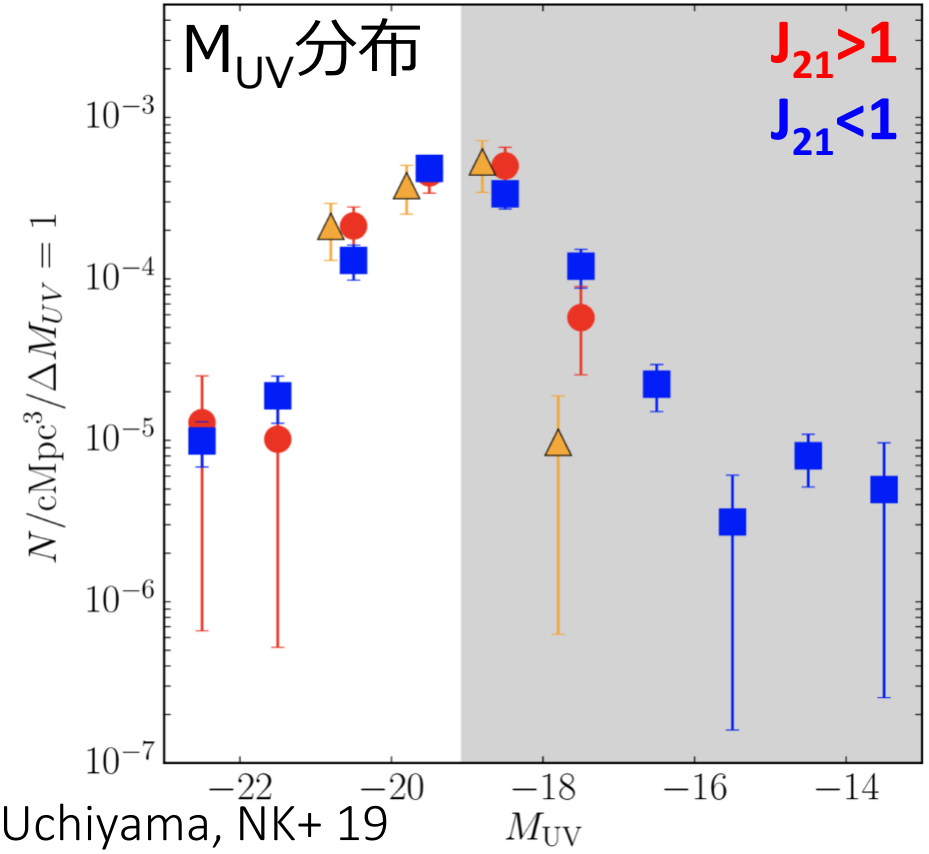
$$J(\nu) = J_{21}\left(\frac{\nu}{\nu_L}\right)^{\alpha} \times 10^{-21}\ \mathrm{erg\ cm^{-2}\ s^{-1}\ Hz^{-1}\ sr^{-1}}$$

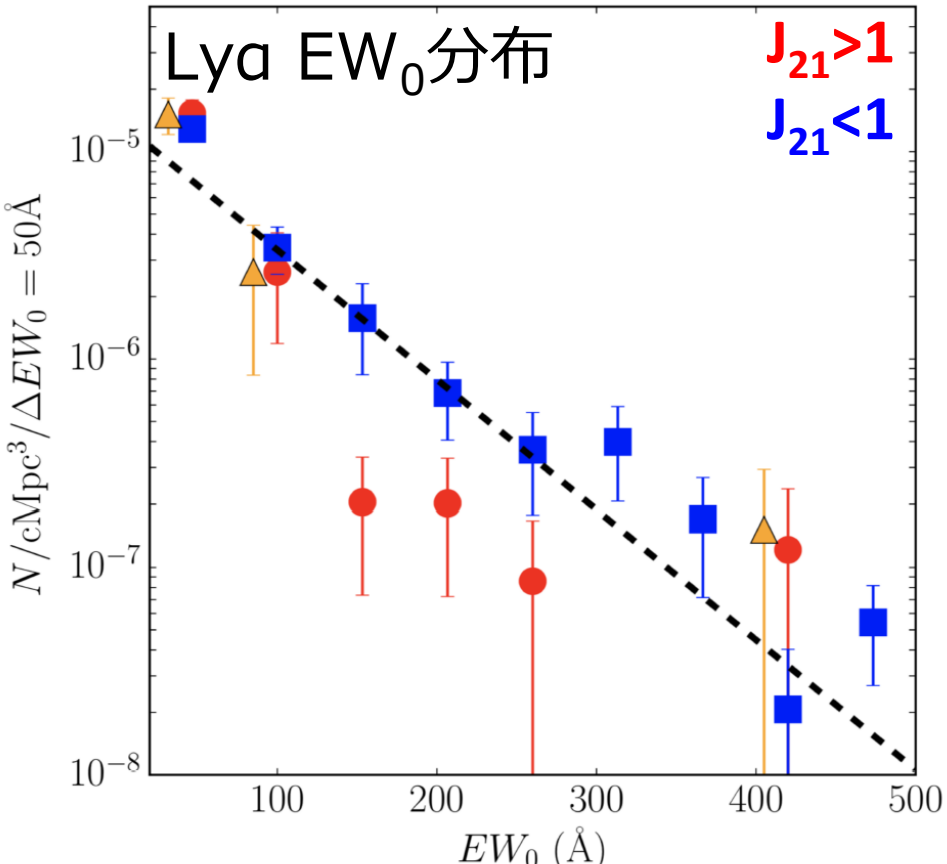


Uchiyama, NK+ 19

SF suppression around quasars

- LAEs with high Lyα EW_0 of $\gtrsim 150$˚A, corresponding to low stellar mass ($\lesssim 10^8 M_\odot$), are predominantly scarce in the quasar proximity zones, suggesting that quasar photoionization effects may be taking place.
- The predicted delay in star formation is about > 20 Myr, which is longer than the expected age of LAEs with EW_0 of $\gtrsim 150$˚A

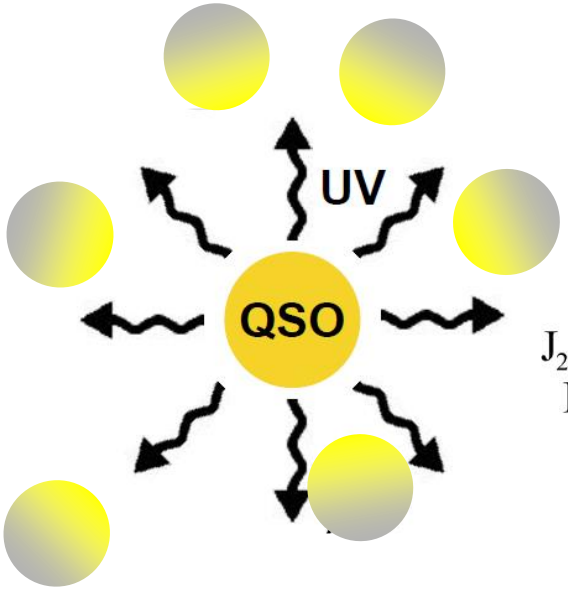




Uchiyama, NK+ 19

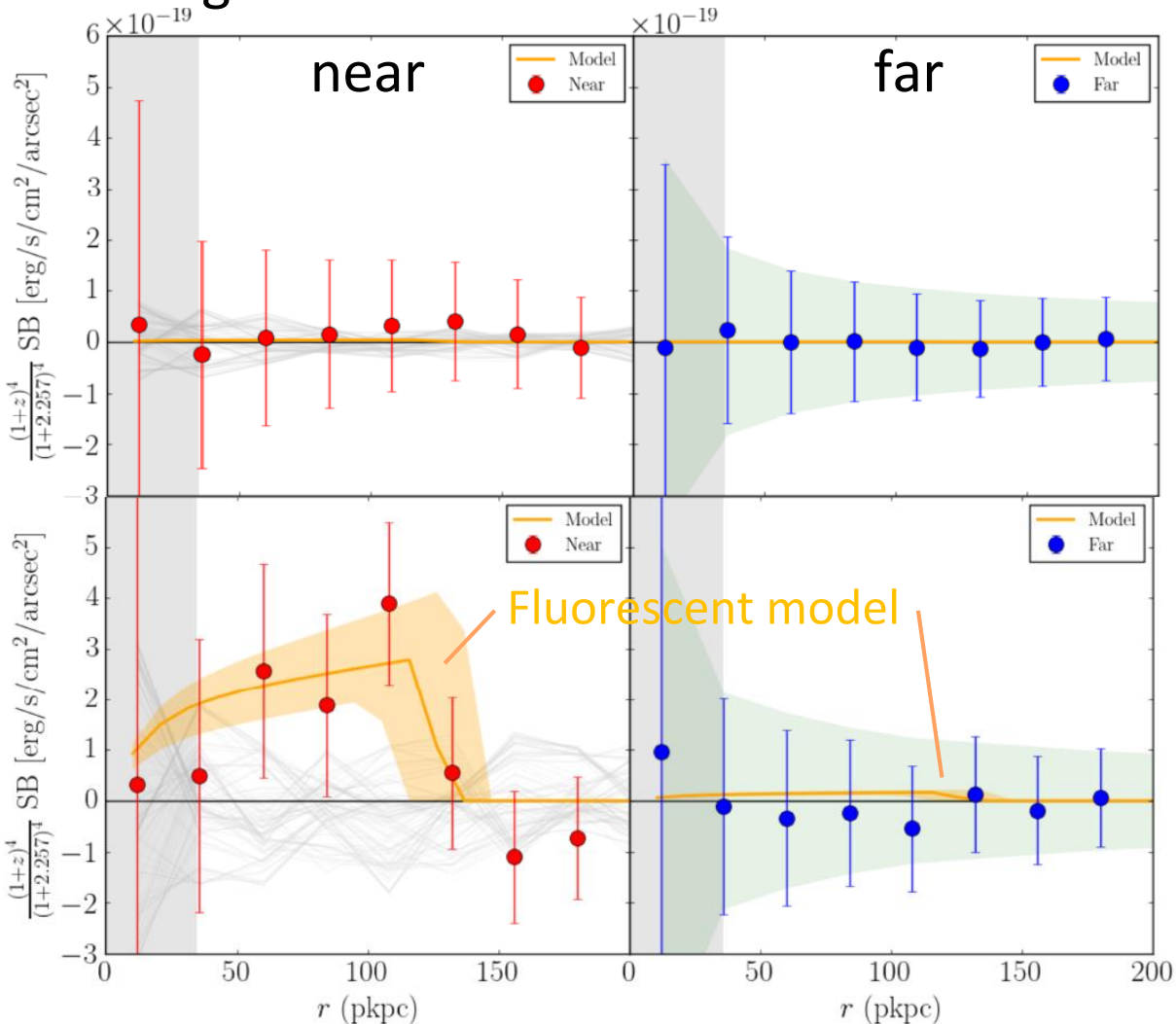
Galaxy CGM around quasars

- The oriented Lyα images of LAEs along the projected directions towards quasars were stacked.
- The flux excess is ~ 4×10^{-19} erg s^{-1} cm^{-2} arcsec^{-2} with 1.5σ significance



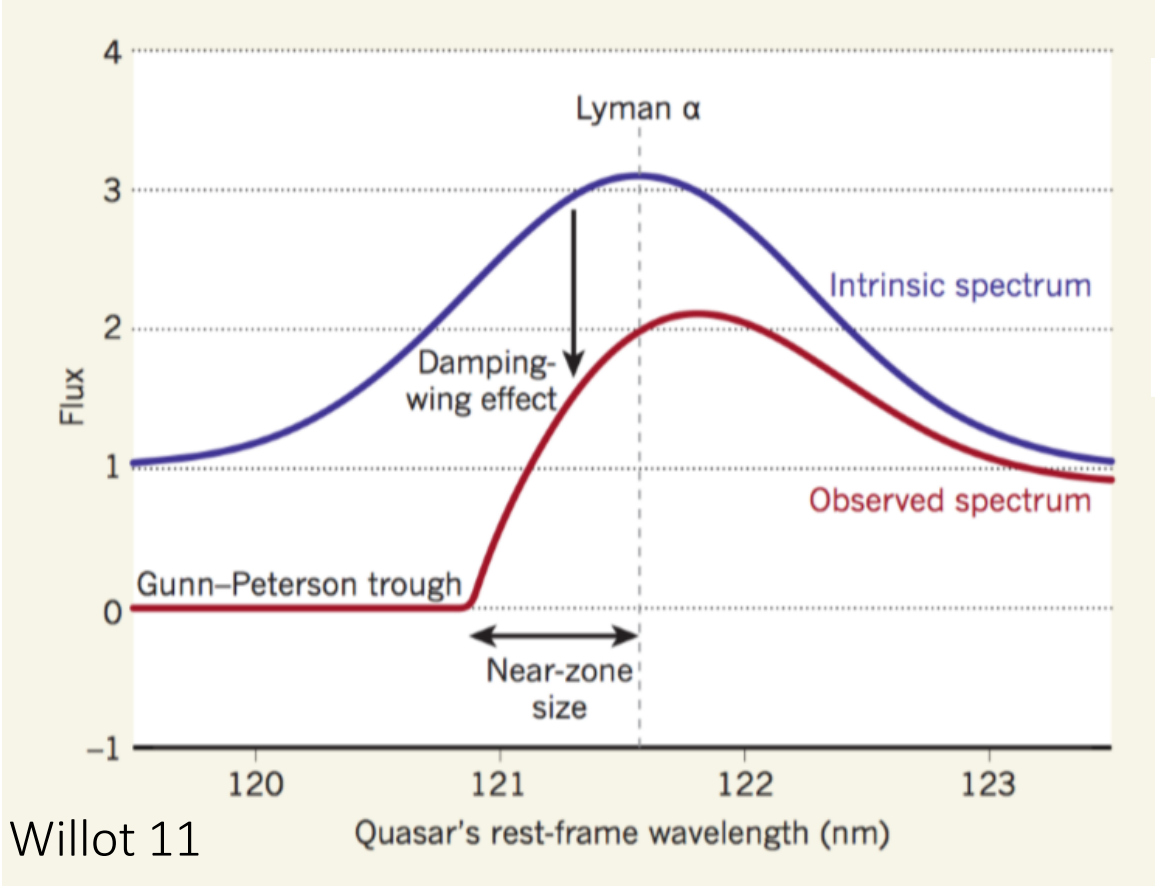
$J_{21} < 10$ LAE

$J_{21} > 10$ LAE



Uchiyama, NK in prep.

quasar near-zone size



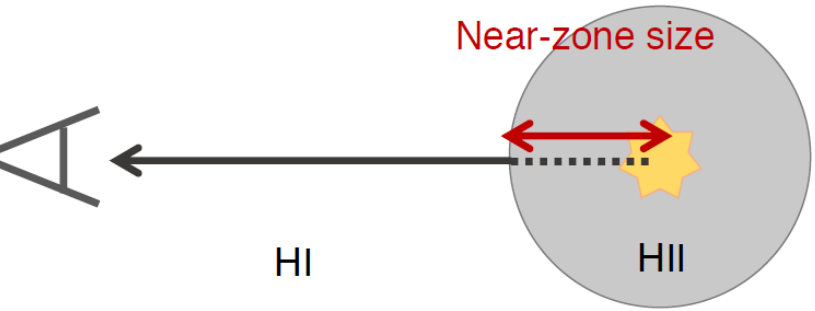
Willot 11

$$R_{\rm ion} = \left(\frac{3\dot{N}_{\rm ion} t_{\rm q}}{4\pi n_{\rm H} x_{\rm HI}} \right)^{1/3}$$

$x_{\rm HI}$: neutral fraction

$\dot{N_{ion}}$: quasar emissivity

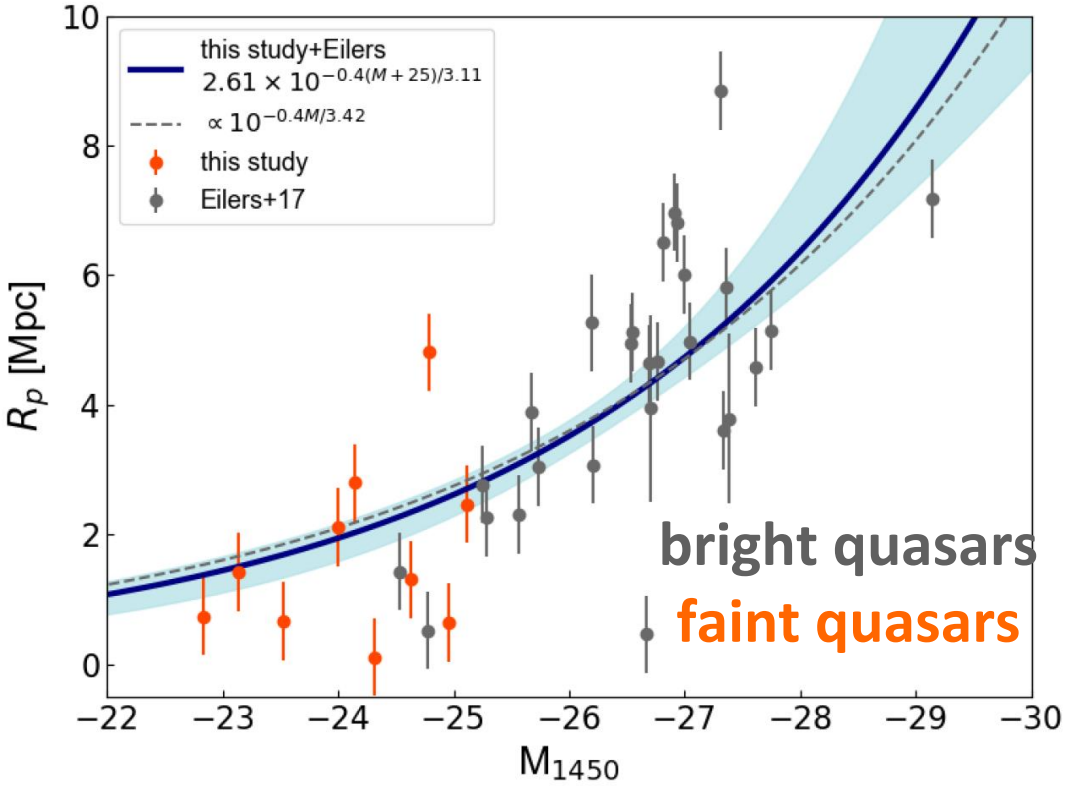
t_q : quasar age



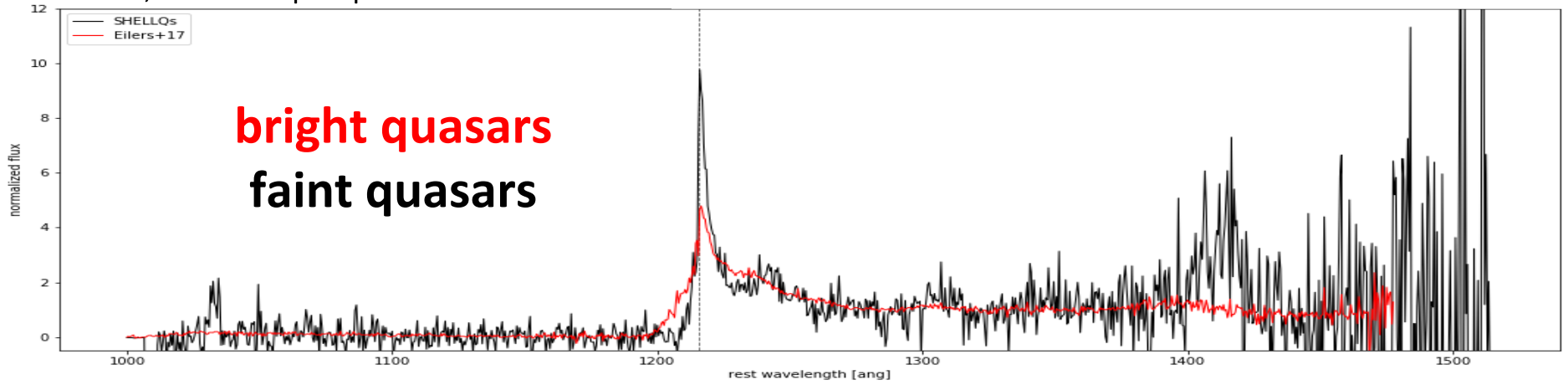
quasar near-zone size

- 10 HSC faint quasars
- Accurate z measurements
- Broad L range

- HSC faint quasars have systematically small Rp as predicted.

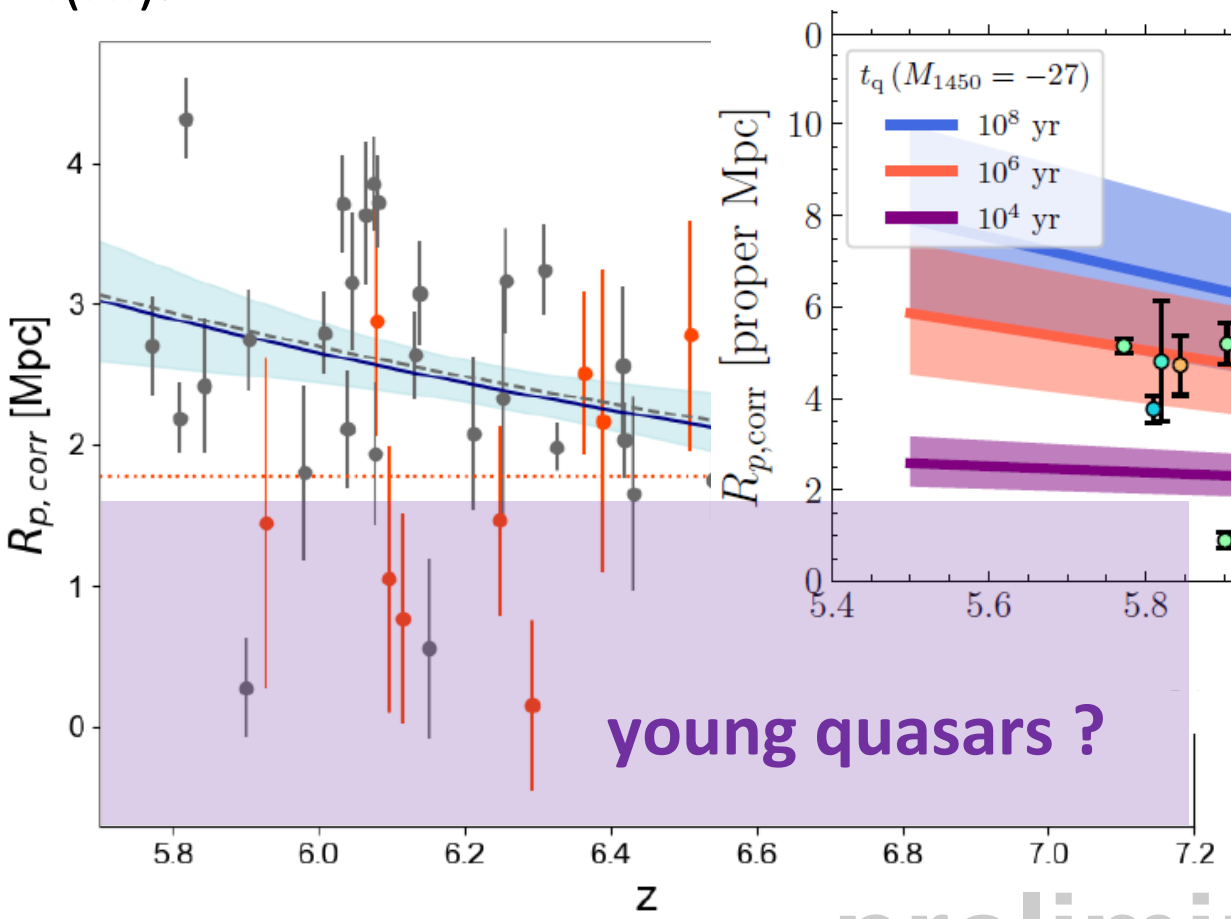


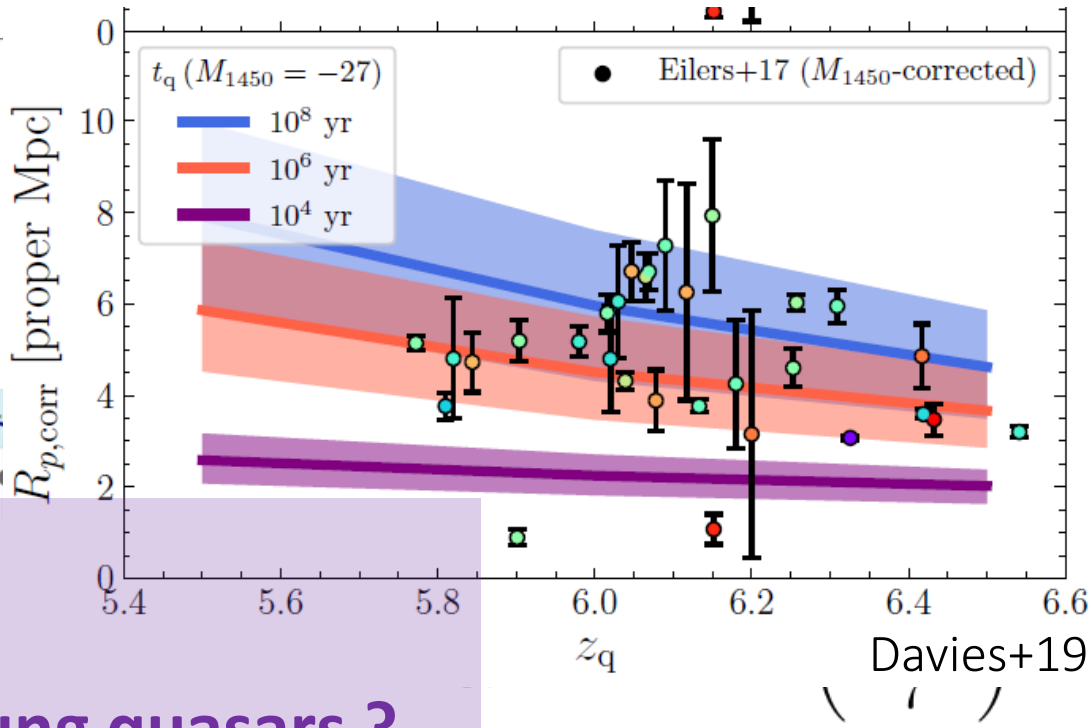
Ishimoto, NK+ in prep.



quasar near-zone size

- Shallow redshift evolution, suggesting that NZ size is insensitive to f(HI).

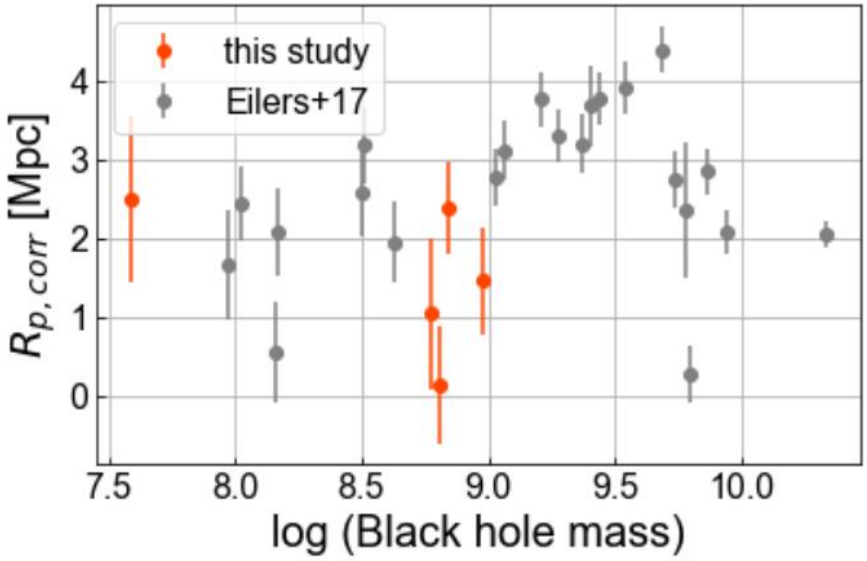


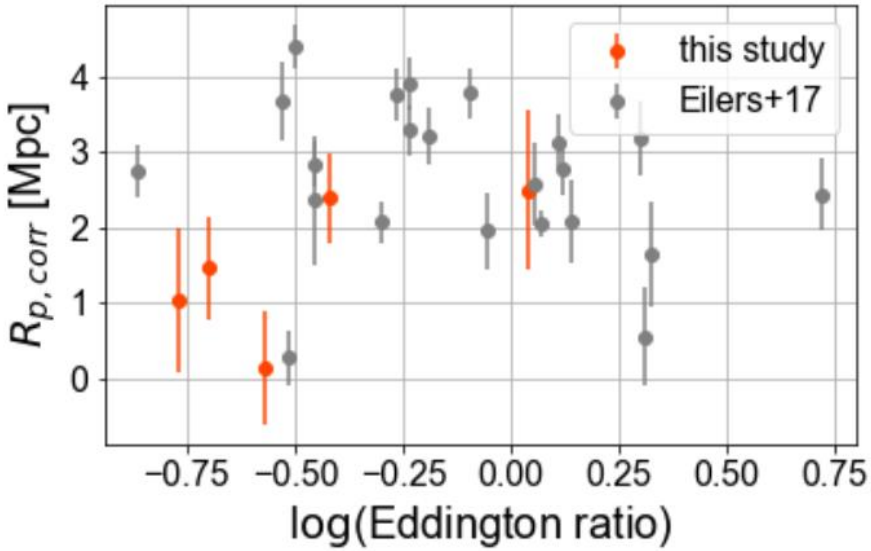


preliminary

Ishimoto, NK+ in prep.

quasar near-zone size





Ishimoto, NK+ in prep.

Summary

- galaxy environment
  - 179 z~4 PC candidates from 121deg^2 by HSC
  - dark halo mass: $\langle M_h \rangle = 2.3^{+0.5}_{-0.5} \times 10^{13}\, h^{-1} \mathrm{M}_\odot$
  - massive & dusty galaxies in PCs: galaxy growth was accelerated in dense environments.
  - galaxies are clustering in a region associated with large amount of HI gas.

- quasar environment
  - luminous quasars do not live in overdense regions of LBGs at z~4
  - The z ~ 4 PCs may host obscured AGNs
  - quasar local photoionization & fluorescent effects may be taking place
  - young quasars at z~6 ?