

Large scale clustering of HSC QSOs and galaxies at $z \sim 4$

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Outline

- Introduction
- Data reduction
- Clustering analysis of QSO and LBG
- Preliminary Results
- Summary

Introduction: BH evolution modes (Fanfarer QSO)

Introduction: BH evolution modes (Bright QSO)

Introduction: motivation

Previous QSO clustering analysis at $z \sim 4$ → SPSS luminous QSO?

Not consistent on BH evolution?

Our research → HSC Fanfarer $z \sim 4$ QSO

- We analyze HSC Fanfarer QSO auto correlation and cross correlation with LBG at $z \sim 4$ to check bias factor for LBG and QSO at $z \sim 4$
- to test dark matter halo mass
- if spatial clustering of LBG around QSO
- comparisons with high luminosity SPSS QSOs.

Data

HSC wide SSB data release

- 10 filters, g16 with 10 magnitude limit $z = 25.8, r = 24.5, i = 23.4, z = 23.0$ and deeper than 30 filter survey

present available survey region = 300 deg² (final survey region = 3000 deg²)

Data

HSC wide SSB data release

10 filter survey → 1000000000 clear stellar objects

filter selection

10 filter → QSO, 10 filter → LBG

check 10 filter → QSO, 10 filter → LBG (if Akaika's model)

Clustering analysis

Bias factor

observed vs. expected

estimator

weak angular auto correlation (Holler's estimator)

HSC-Fanfarer QSO and LBG QSO (pre-processed with angular separation filter)

HSC-Fanfarer QSO and LBG QSO (pre-processed with angular separation filter)

check catalog edges with the same magnitude, redshift, color properties as observed one, but randomly distributed on the observation region.

Clustering analysis

Two-point angular auto correlation function (M.F)

QSO LBG bias factor
= 1.47 ± 0.22 beyond 10''
= 0.20 ± 0.05 within 10''

LBG QSO bias factor
= 2.30 ± 0.40 beyond 10''

Clustering analysis

Two-point angular cross correlation function (M.F)

QSO LBG bias factor
= 1.47 ± 0.22 beyond 10''
= 0.20 ± 0.05 within 10''

LBG QSO bias factor
= 2.30 ± 0.40 beyond 10''

Preliminary Results

Dark matter halo mass

No matter halos or faint $z \sim 4$ QSOs, they both strongly clustered in small scales, across multiple of early universe.

Preliminary Results

compare with BH evolution modes

Minimal growth mode is preferred.

So far BH evolution of early universe is very strong, but QSOs and LBGs are very high bias and low halo mass.

Preliminary Results

LBG overdensity around $z \sim 4$ QSO

Galaxy deficit around QSO vicinity (→ Mpc) seems to be a common case.

Summary

- We select $z \sim 4$ QSO and $z \sim 4$ LBG in HSC SSB data
- Clustering analysis indicates QSO strong auto correlation with bias factor > 1 and cross correlation best (M.F) > 1 solar mass.
- Clustering analysis also suggests QSO to be correlated with LBG in scale > 10 Mpc, while correlation strength beyond this range is similar with randomization.
- Based on similar strong correlation strength for $z \sim 4$ SPSS $z \sim 4$ QSOs and HSC $z \sim 4$ QSOs, maximal BH growth mode is preferred.
- Further check consideration to select completeness and contamination.
- What causes the galaxy deficit around QSO vicinity (→ Mpc)? feedback?
- Future spectroscopic observation for QSO and revealing surrounding galaxies...

Thank you for your attention.



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Large scale clustering of HSC QSOs and galaxies at $z \sim 4$

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Astronomical Institute, Tohoku University

6. 2 2016



Outline



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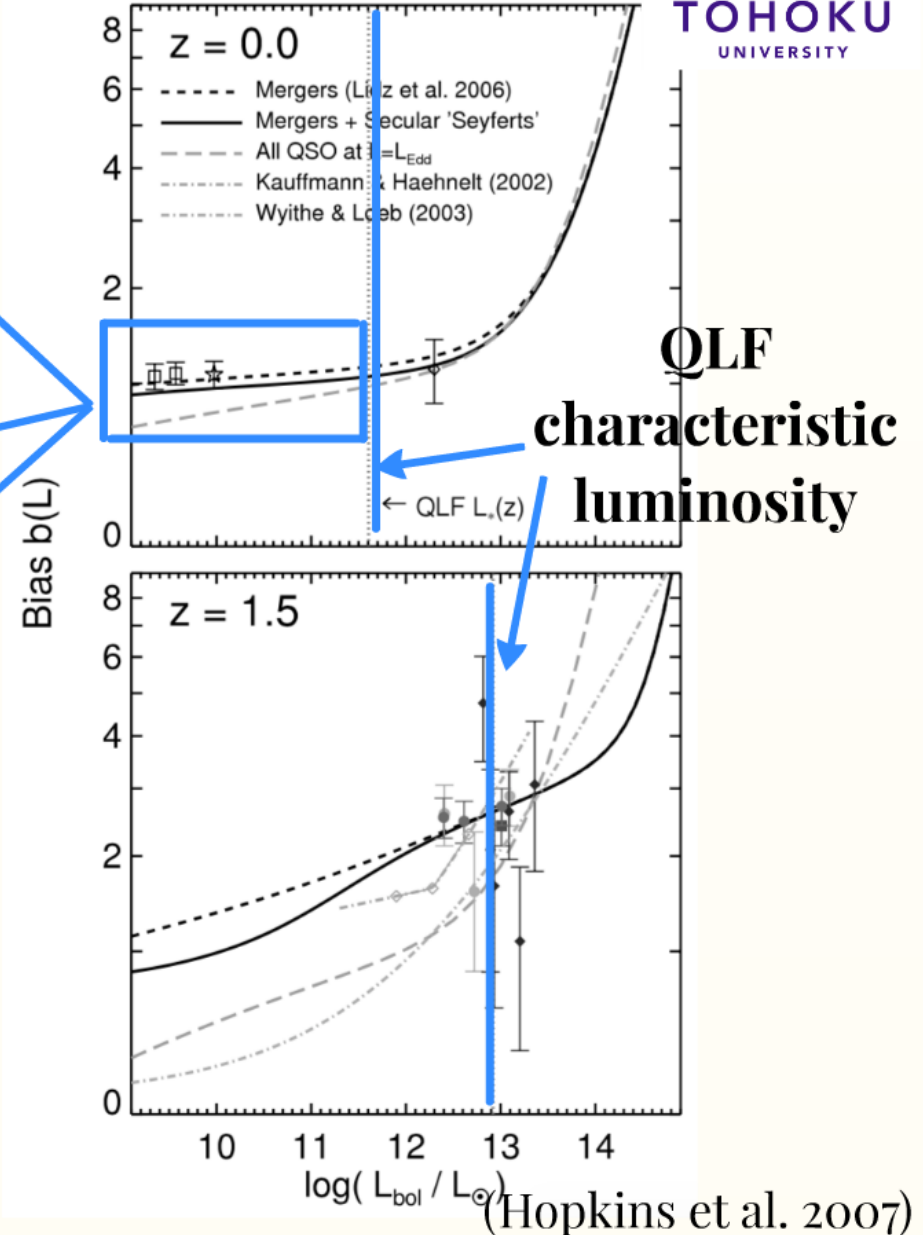
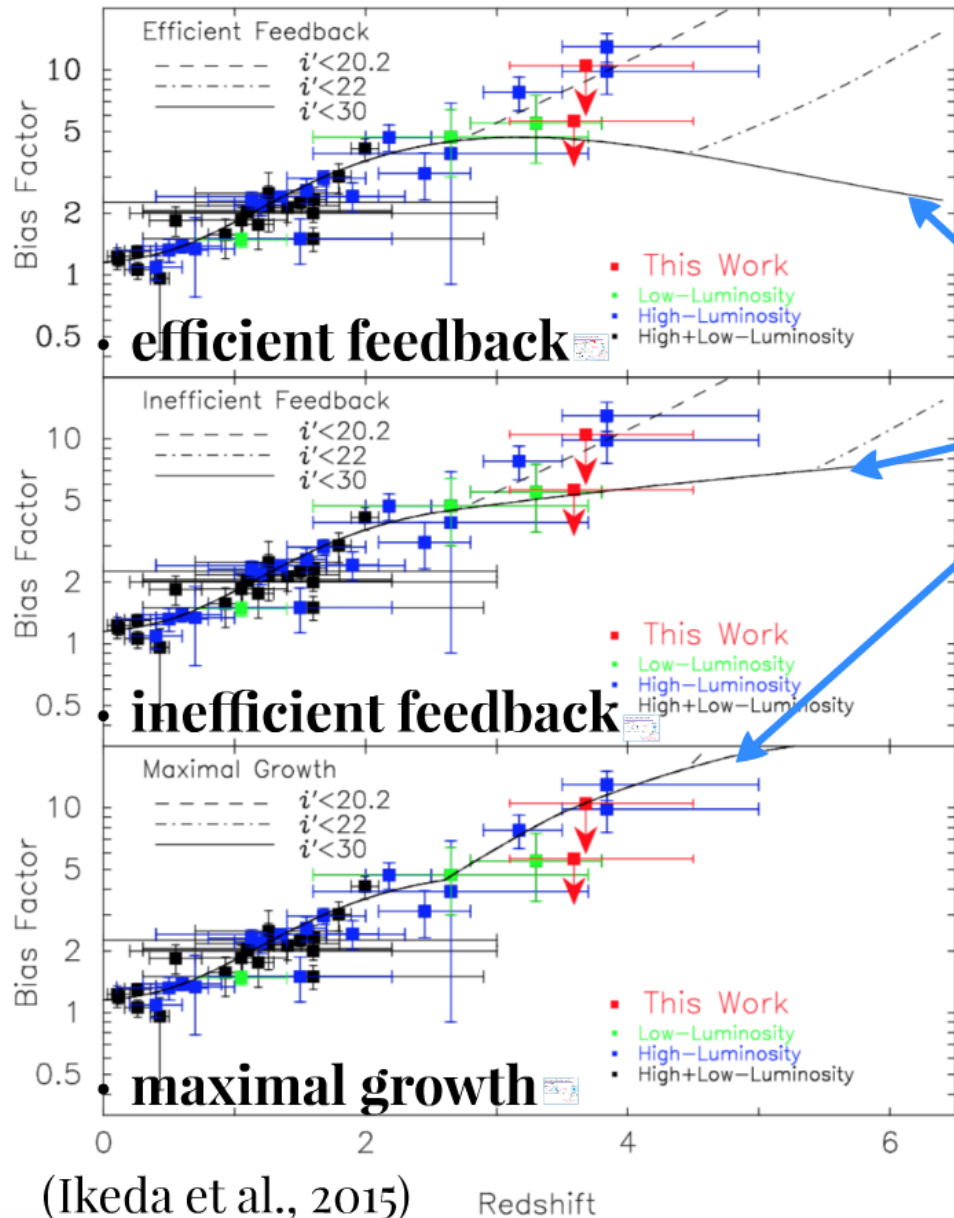
- Introduction
- Data reduction
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- Summary



Introduction: BH evolution modes (Fainter QSO)



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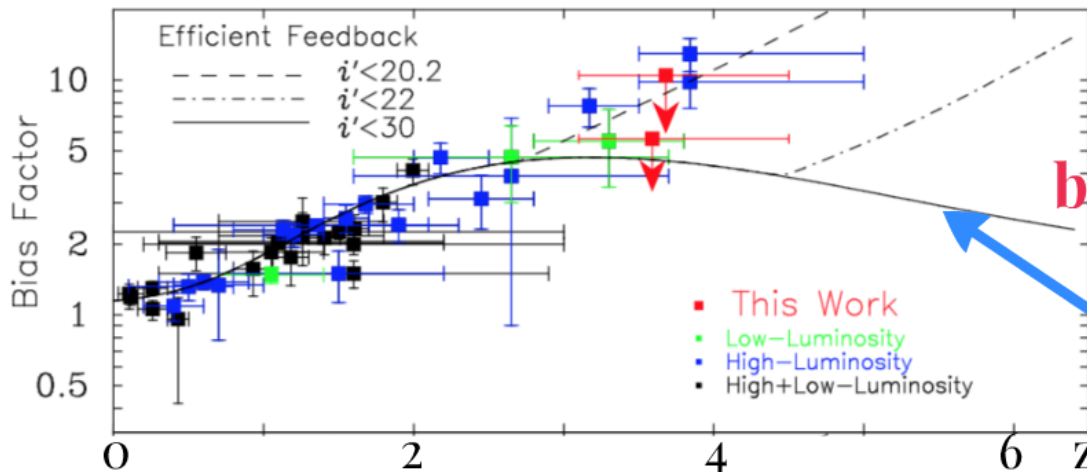
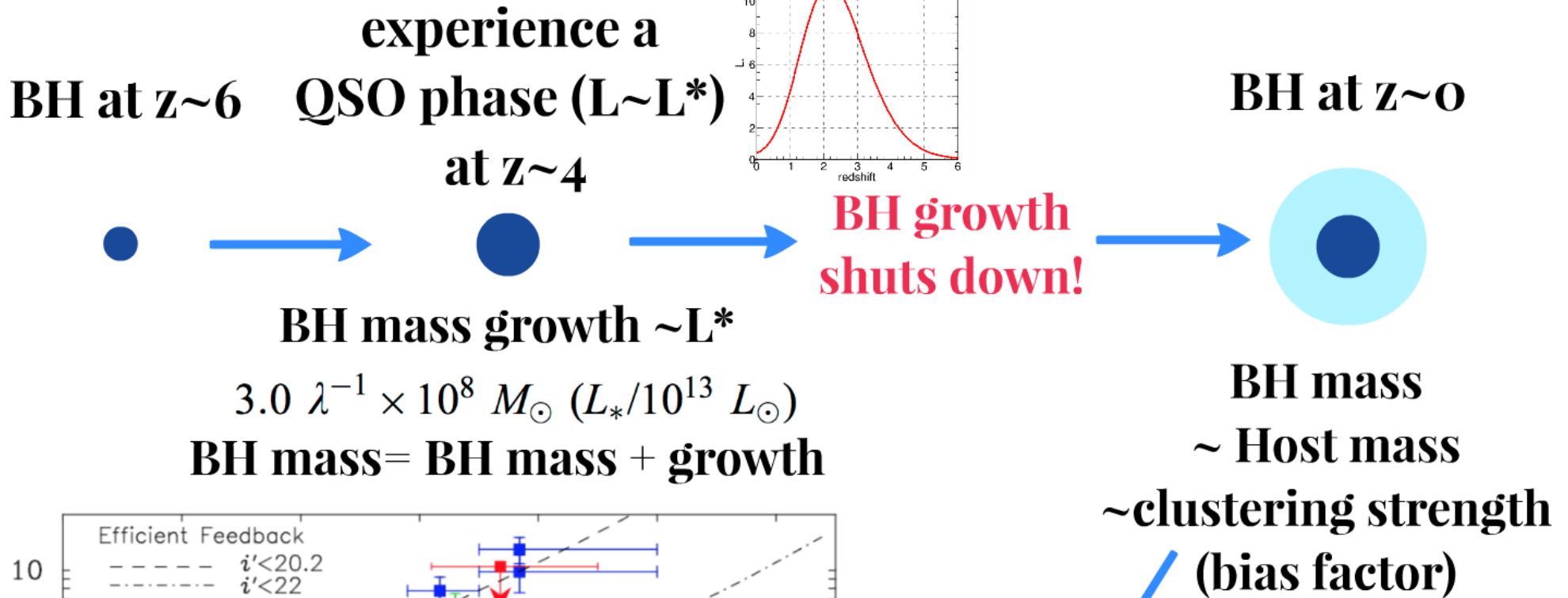


Introduction: BH evolution modes



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- efficient feedback



bias factor for this BH $\sim L^*$ at $z \sim 4$!
 bias factor follows QLF!

Introduction: BH evolution modes

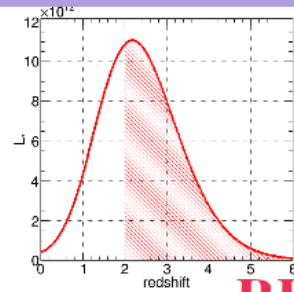


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- inefficient feedback

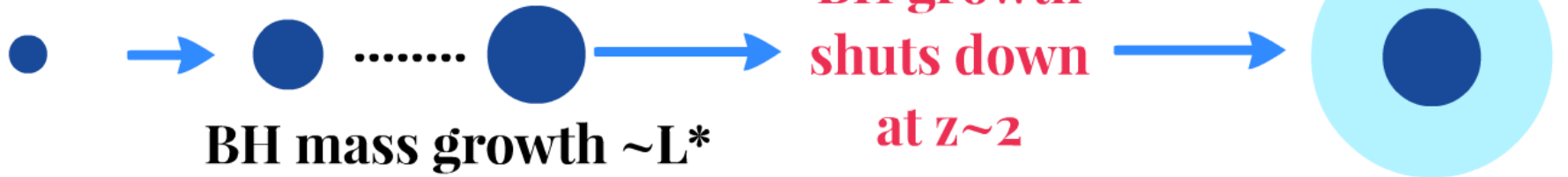
BH at $z \sim 6$

BH continually grows



BH growth shuts down at $z \sim 2$

BH at $z \sim 0$



BH mass growth $\sim L^*$

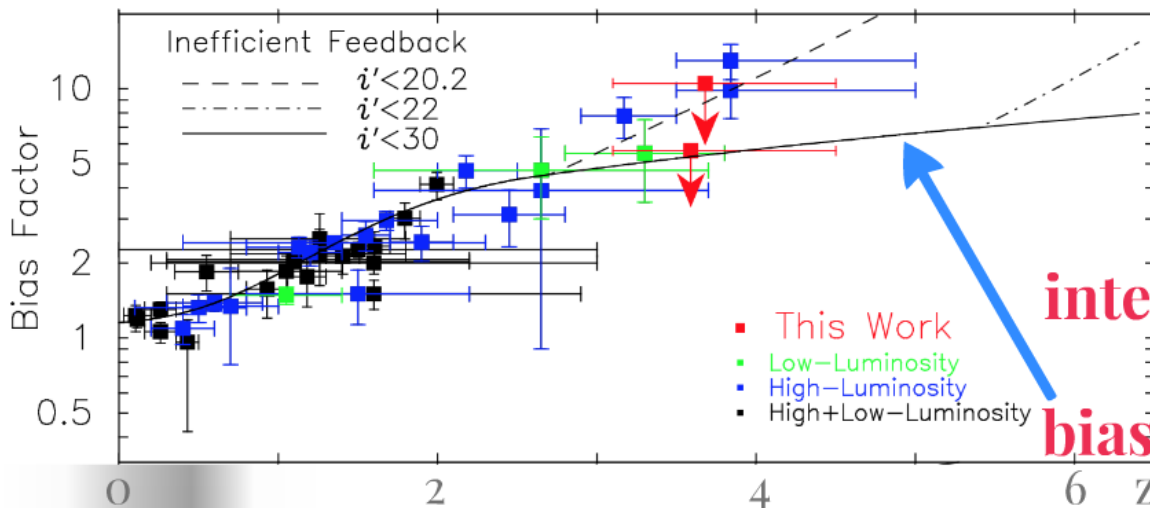
$$3.0 \lambda^{-1} \times 10^8 M_{\odot} (L_*/10^{13} L_{\odot})$$

BH mass = initial BH mass + growth(z)

↑ BH mass

~ Host mass ↑

~ clustering strength (bias factor) ↑



bias factor for this BH ~ integration for L^* from $z \sim 6$ to $z \sim 2$!

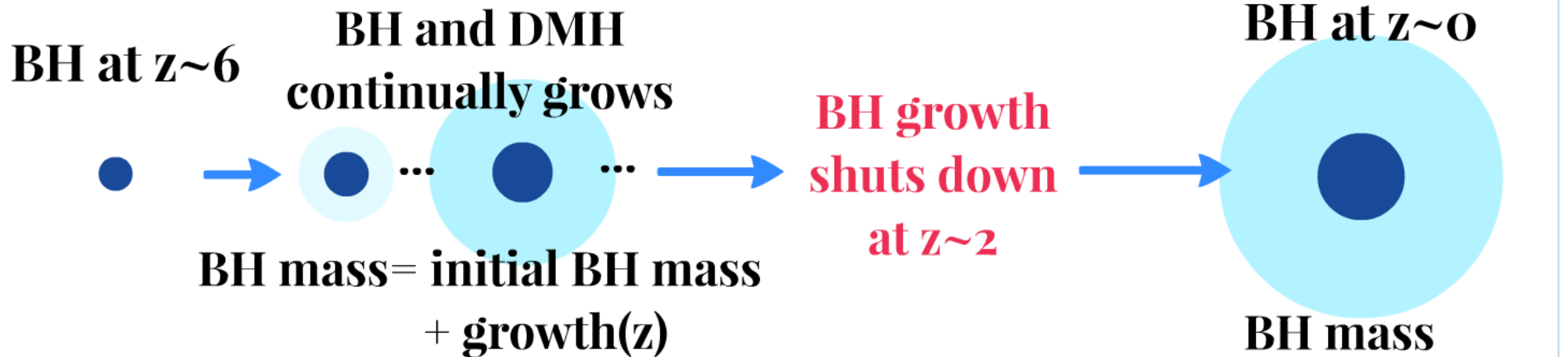
bias factor follows integrated QLF!

Introduction: BH evolution modes

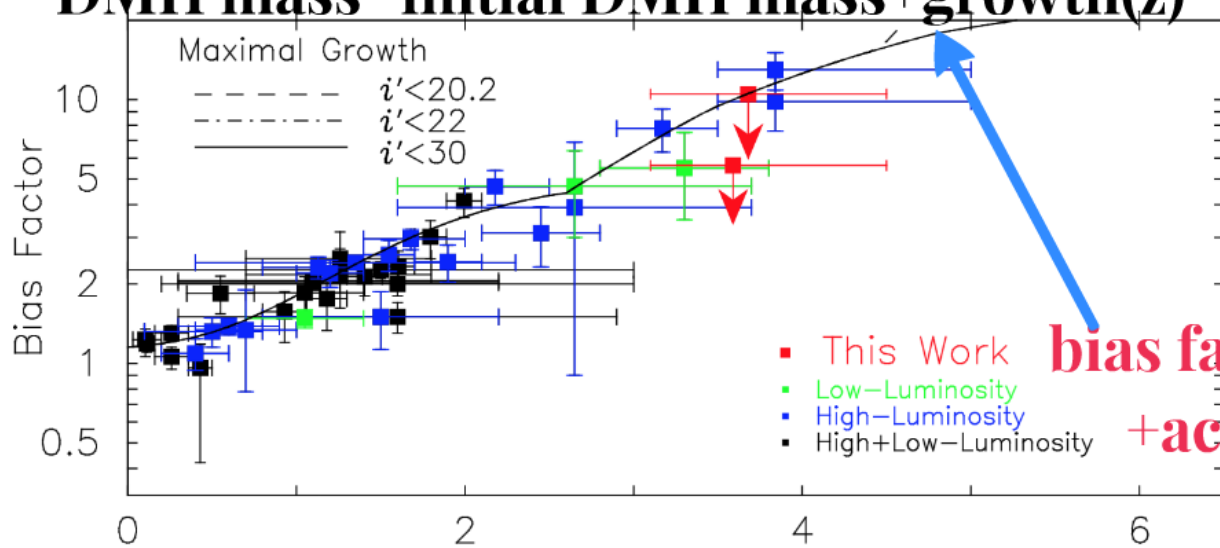


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• Maximal growth



DMH mass = initial DMH mass + growth(z)

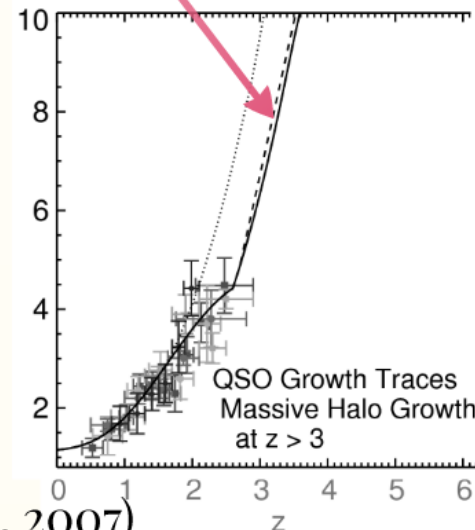
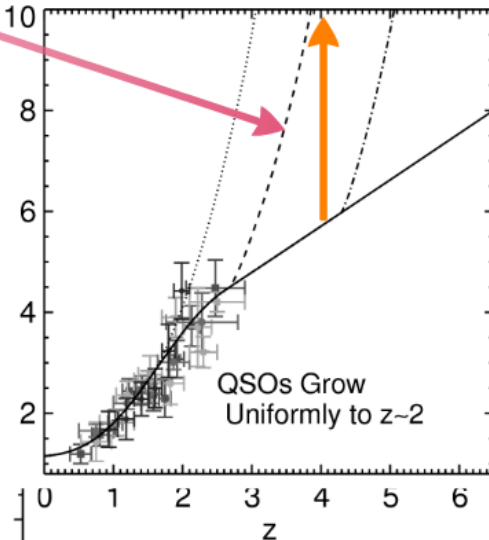
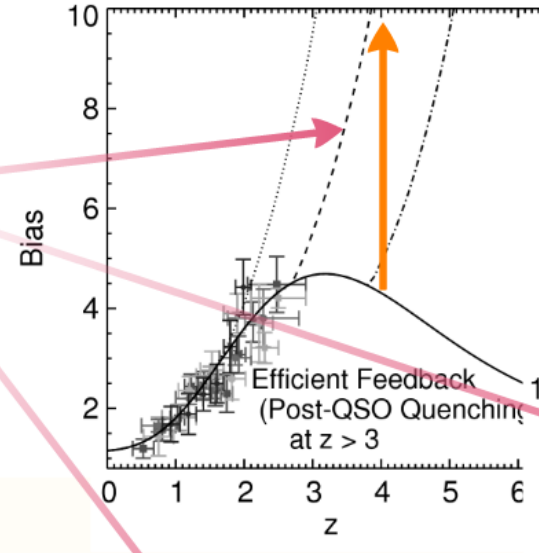
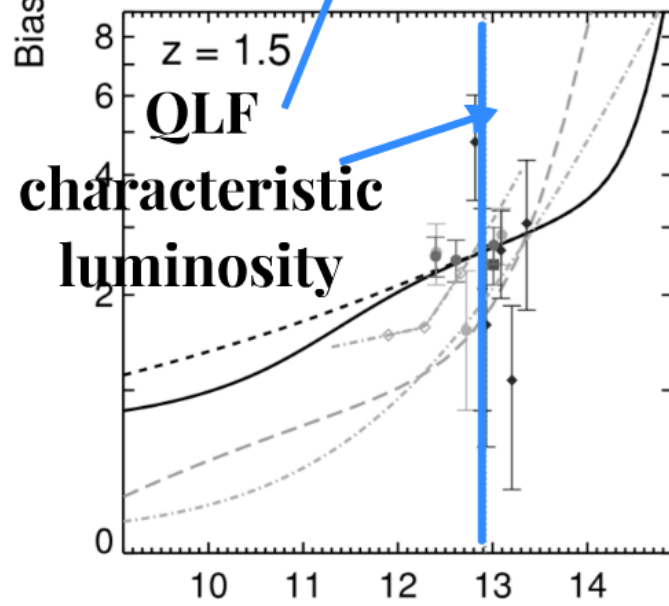
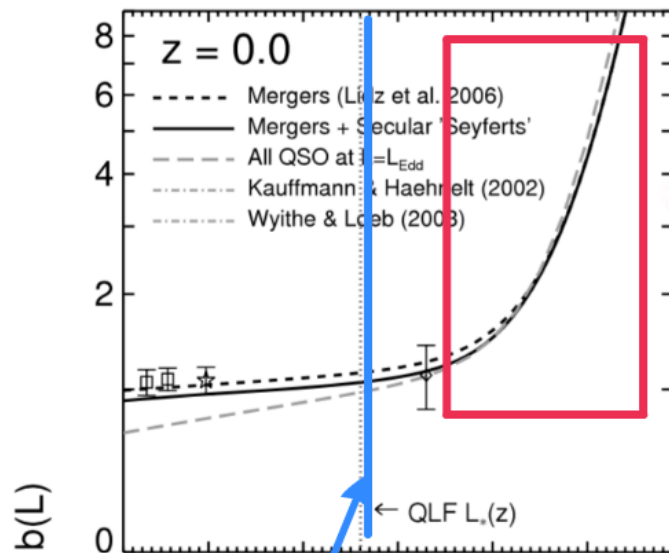


bias factor follows integrated QLF + accumulated DMH growth!

Introduction: BH evolution modes (Bright QSO)



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A discrepancy exists for luminous QSO and fainter QSO at $z \sim 4$!!

(Hopkins et al. 2007)

Introduction: motivation



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Previous QSO clustering analysis at $z \sim 4$ → SDSS luminous QSO!!

Set constraints
on BH
evolution!!

Our research → HSC Fainter $z \sim 4$ QSO

- we analyze HSC fainter QSO auto correlation and cross correlation with LBGs at $z \sim 4$ to check:
 - 1) bias factor for LBG and QSO at $z \sim 4$;
 - 2) host dark matter halo mass;
 - 3) spatial clustering of LBG around QSO;
 - 4) comparison with high luminosity SDSS QSOs.

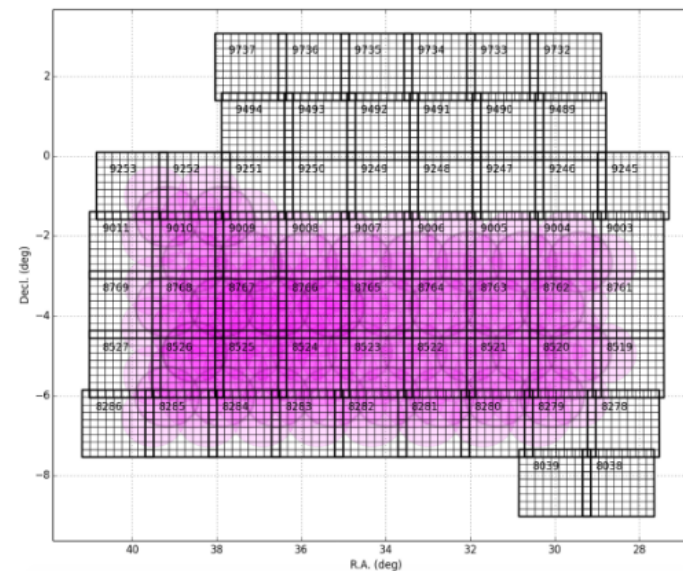
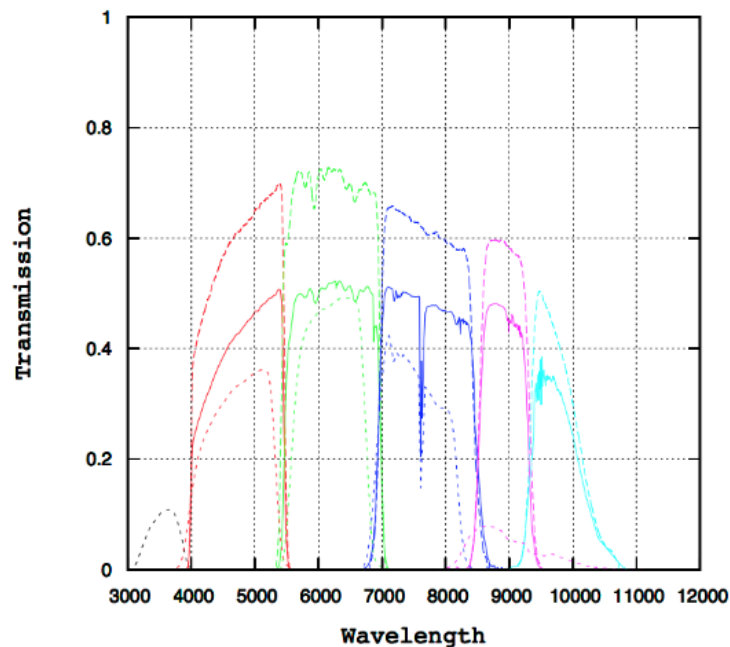
Data



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HSC wide S15B data release

- 5 filters grizy with AB magnitude limit $i = 25.8$, $z = 24.7$, $y = 23.4$ (~ 2 mag deeper than SDSS survey)



S15B website

- present available survey region $\sim 200 \text{ deg}^2$
(final survey region $\sim 1400 \text{ deg}^2$)

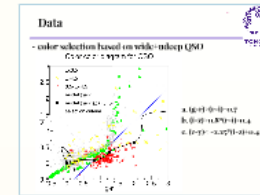
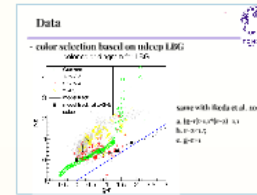
Data



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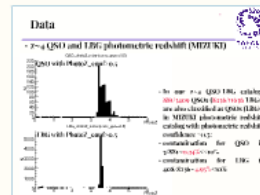
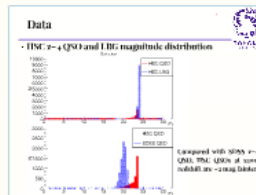
HSC wide S15B data release

S15B WIDE catalog $\xrightarrow{\text{flag clearance}}$ $\sim 5,000,000$ clean stellar objects



\downarrow color selection

116,725 z~4 QSO,
301,343 z~4 LBG



set $10 < i_cmodel < 24.5$
 $10 < i_psf < 24$



6,215 z~4 QSO,
50,087 z~4 LBG

\leftarrow check
mask region
(by Akiyama code)

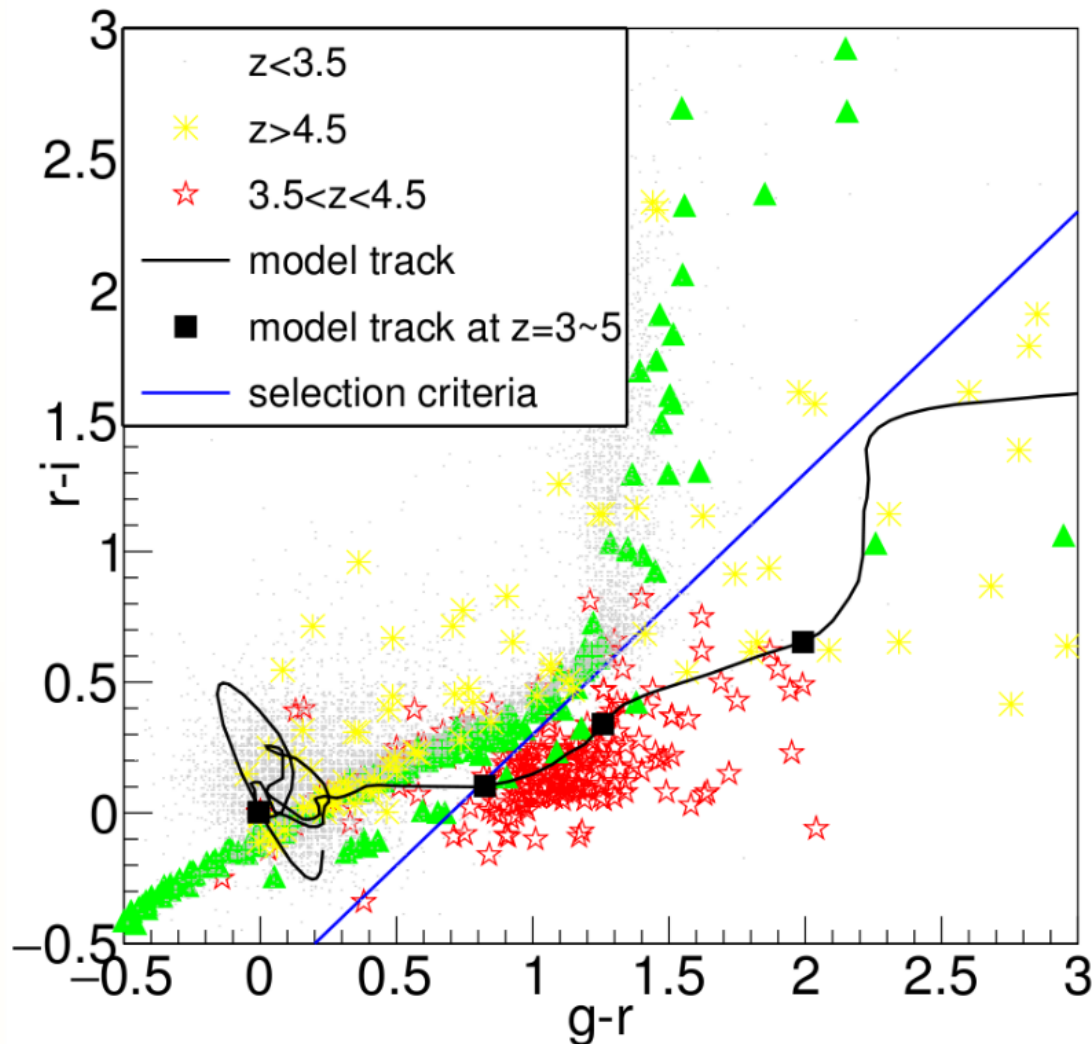
3,409 z~4 QSO,
11,636 z~4 LBG



Data

• color selection based on wide+udeep QSO

Color color diagram for QSO



a. $(g-r) > (r-i) + 0.7$

b. $(i-z) > 0.8 * (r-i) - 0.4$

c. $(z-y) < -2.25 * (i-z) + 0.4$

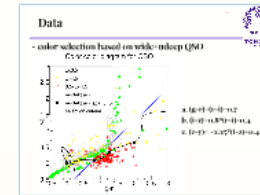
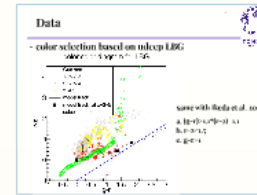
Data



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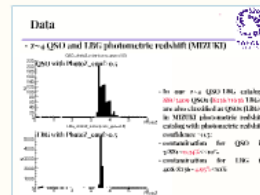
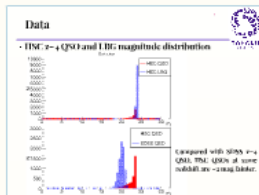
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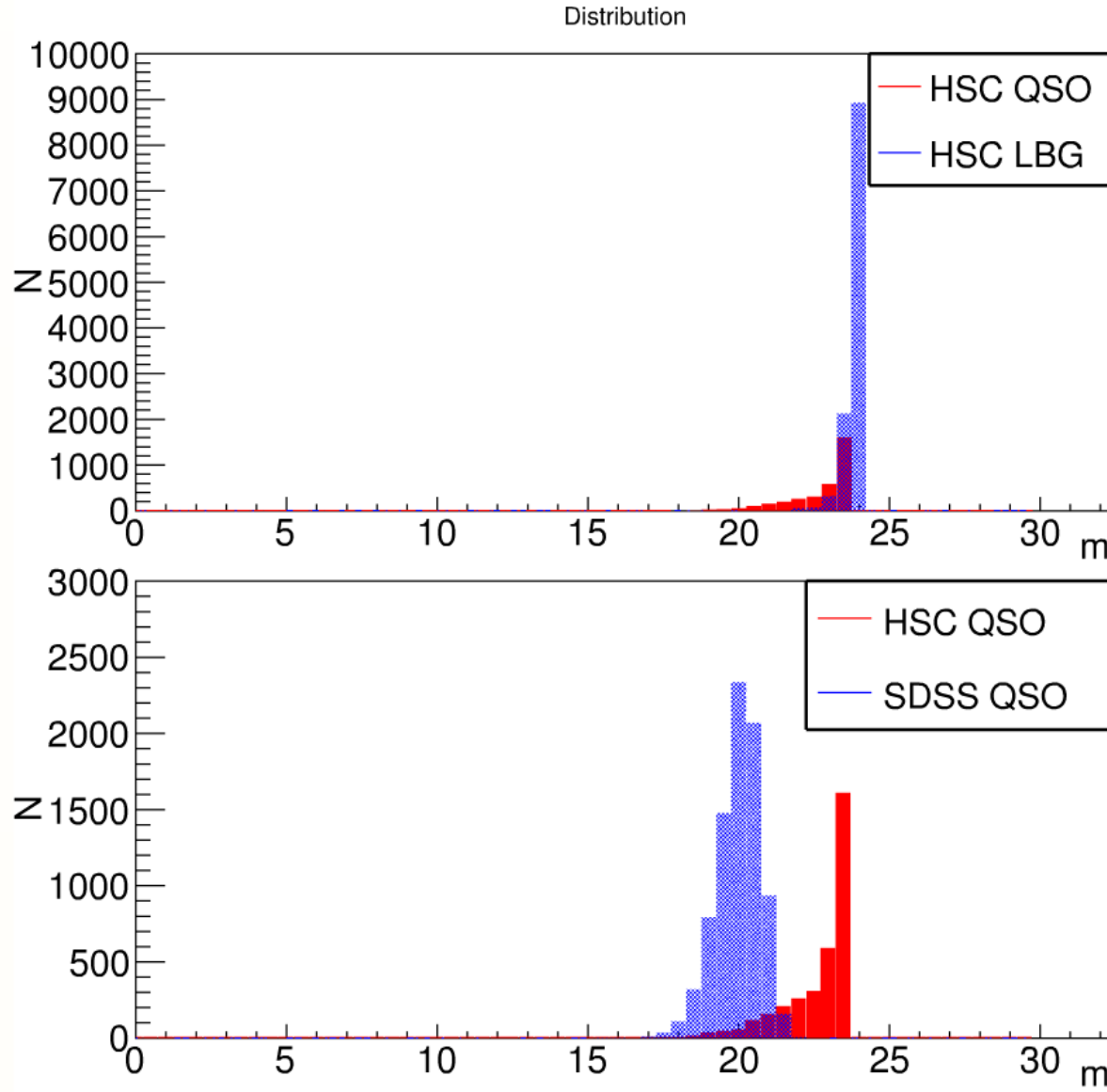
\leftarrow check
mask region
(by Akiyama code)

3,409 z~4 QSO,
11,636 z~4 LBG



Data

• HSC $z \sim 4$ QSO and LBG magnitude distribution



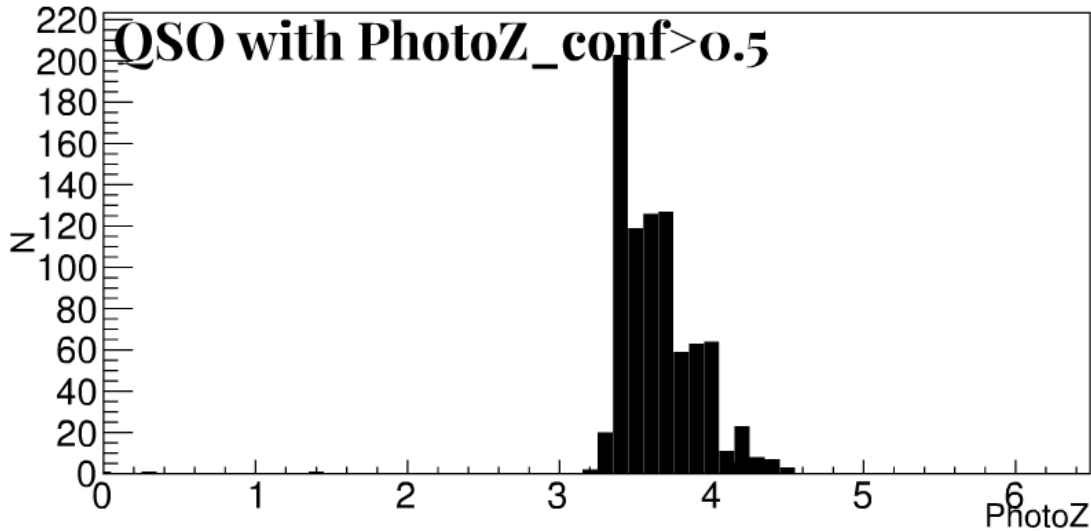
Compared with SDSS $z \sim 4$ QSO, HSC QSOs at same redshift are ~ 2 mag fainter.



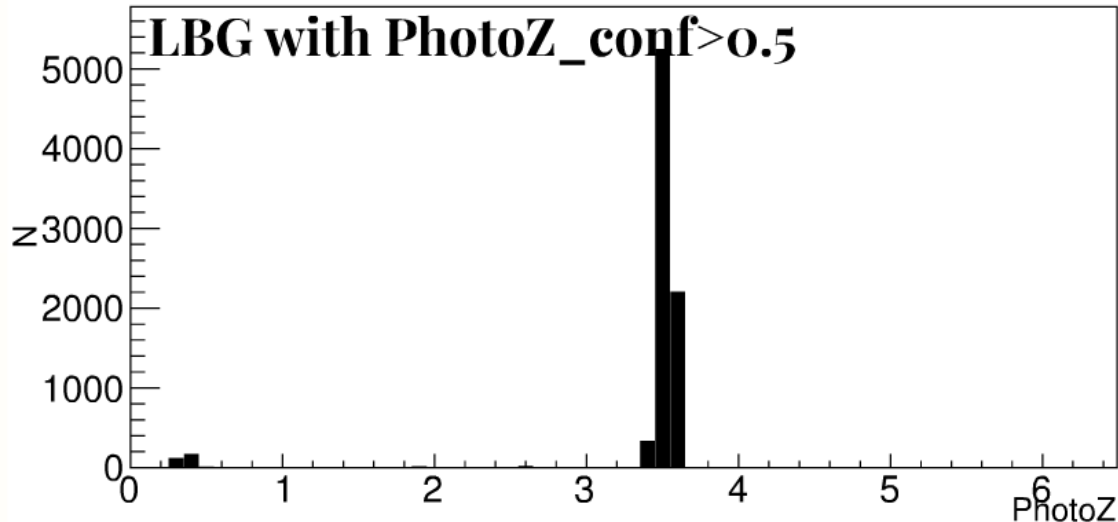
Data

• $z \sim 4$ QSO and LBG photometric redshift (MIZUKI)

QSO_photoZ_mizuki(prob_qso \geq 0.5)



LBG_photoZ_mizuki(prob_gal \geq 0.5)



- In our $z \sim 4$ QSO/LBG catalog, **881/3409** QSOs (**8236/11636** LBGs) are also classified as QSOs (LBGs) in MIZUKI photometric redshift catalog with photometric redshift confidence > 0.5 ;
- contamination for QSO is $3/881 \sim 0.34\% \ll 10\%$
- contamination for LBG is $408/8236 \sim 4.95\% < 10\%$

Clustering analysis



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• Bias factor

(Myers et al. 2007)

$$\omega_{QQ}(\theta) = \frac{H_0 \pi}{c} \int_0^\infty \int_0^\infty b_Q^2(k, z) \frac{\Delta_{NL}^2(k, z)}{k} J_0[k\theta\chi(z)] \left(\frac{dN}{dz}\right)^2 \sqrt{\Omega_m(1+z)^3 + \Omega_\Lambda} \frac{dk}{k} dz.$$

estimator

$$\omega(\theta) = \frac{DD}{DR} - 1$$

model angular
auto correlation
(Limber's equation)

DD--LBG(QSO) and LBG (QSO) pair count within angular separation theta;
DR--LBG(QSO) and mock LBG (QSO) pair count within angular separation theta.

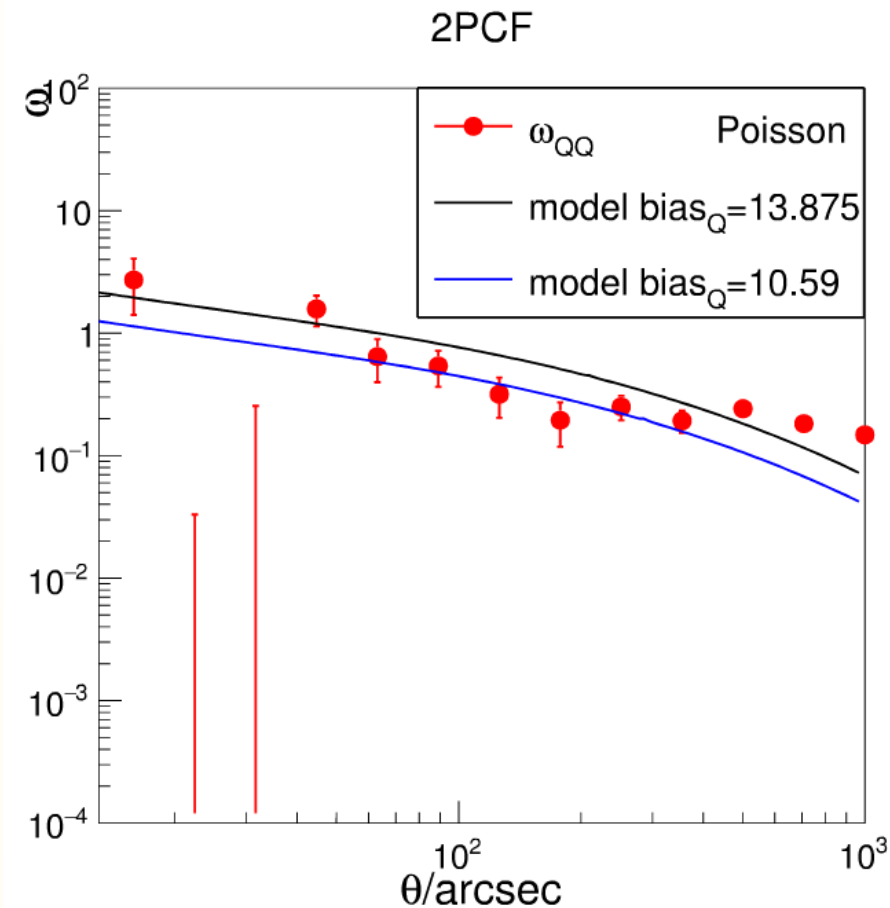
mock catalog: objects with the same magnitude, redshift, color properties as observed one but randomly distributed on the observation region.

Clustering analysis

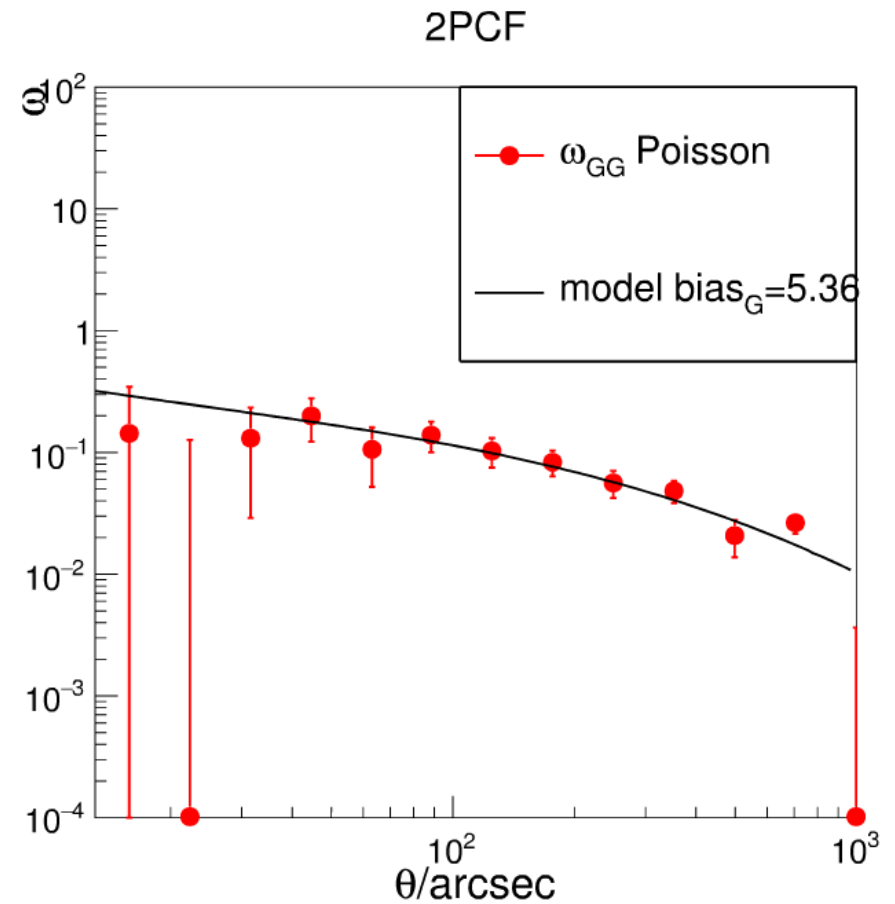


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- Two point angular **auto** correlation function (ACF)



QSO ACF bias factor
 $\sim 13.875 \pm 3.54$ beyond $10''$
 $\sim 10.59 \pm 1.11$ within $500''$



LBG ACF bias factor
 $\sim 5.36 \pm 0.93$ beyond $10''$

Clustering analysis

(Mountrichas et al, 2009a)

$$b_{\text{QSO}} b_{\text{LBG}} = b_{\text{QL}}^2$$

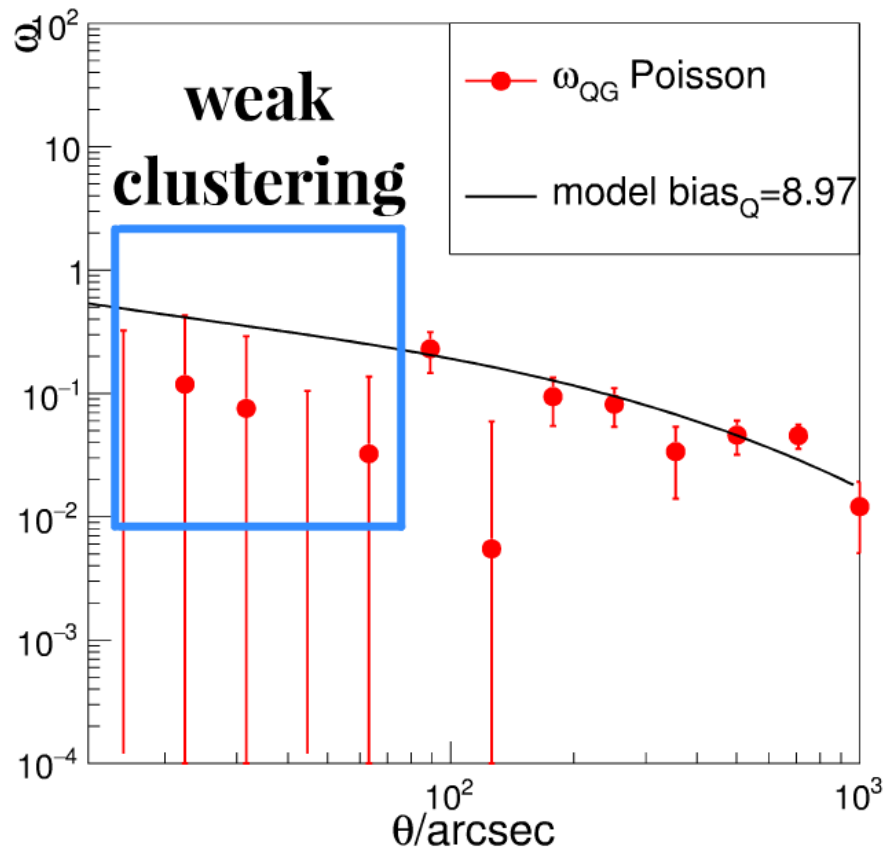


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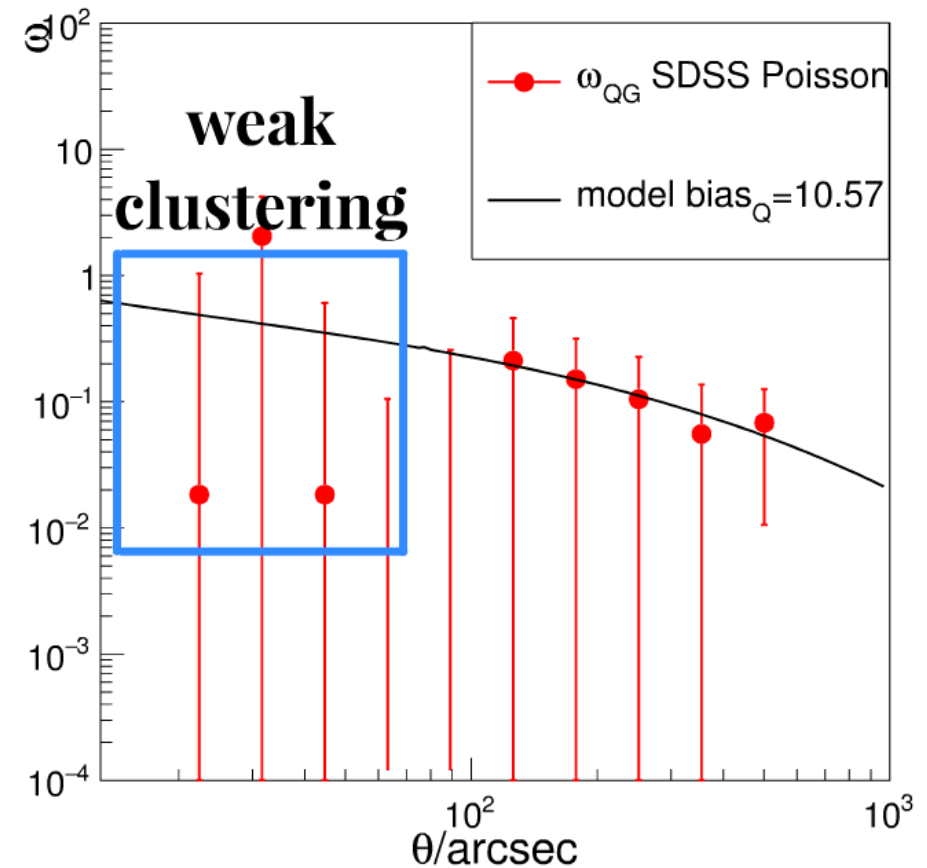
- Two point angular **cross** correlation function (CCF)

2PCF

2PCF



QSO CCF bias factor
 $\sim 8.97 \pm 2.63$ beyond 80"
 $\sim 1.89 \pm 0.57$ within 80"



SDSS QSO CCF bias factor
 $\sim 10.57 \pm 1.98$ beyond 80"
 $\sim 12.96 \pm 2.09$ from ACF (shen 2009)

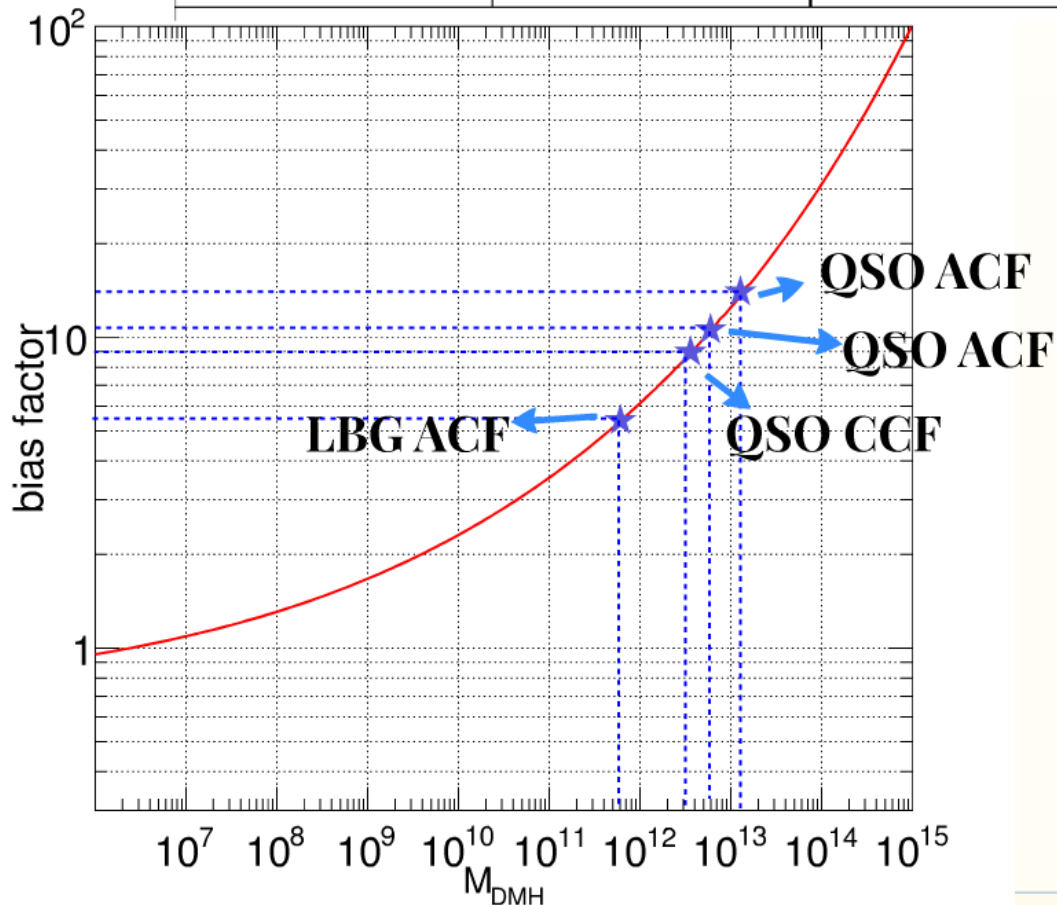
Preliminary Results



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• Host dark matter halo mass

	Z~4 QSO	DMH mass (solar mass)	Z~4 LBG	DMH mass (solar mass)
ACF($\Theta > 10''$)	13.88 \pm 3.54	1.27E13	5.36 \pm 0.93	6.09E11
ACF(500'' $>$ $\Theta > 10''$)	10.59 \pm 1.11	5.96E12		
CCF($\Theta > 80''$)	8.97 \pm 2.63	3.59E12		



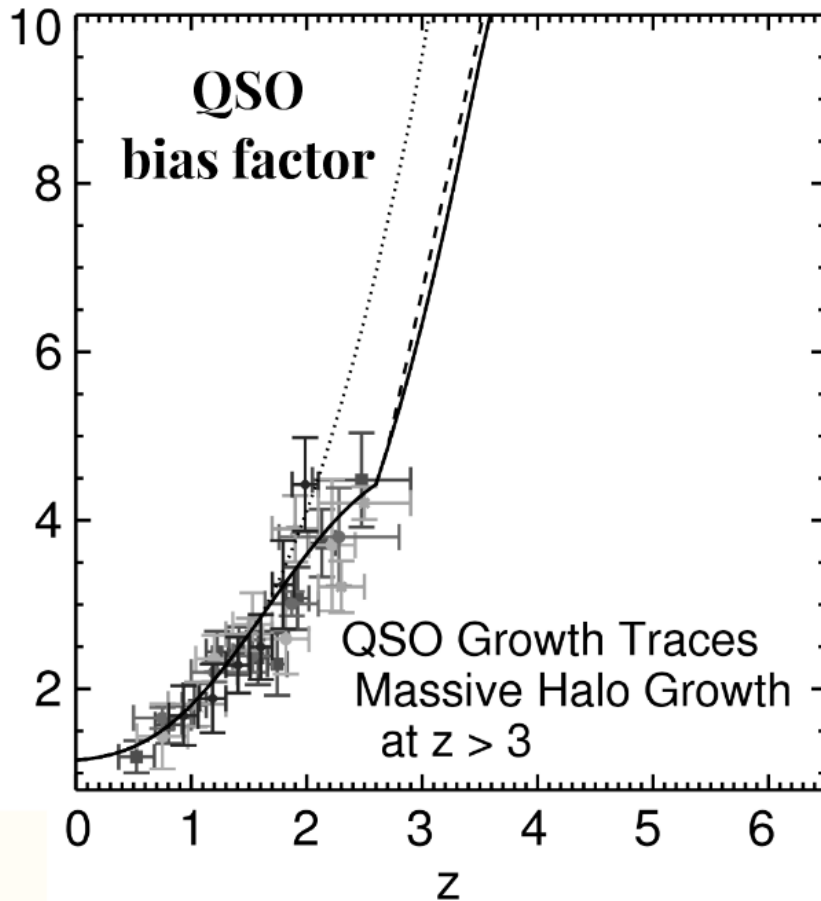
No matter luminous or faint
z~4 QSOs, they both **strongly**
clustered in **most dense**
region at early universe!

Preliminary Results



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- compare with BH evolution modes



(Hopkins 2007)

SDSS $i' < 21$
QSOs

bias ~ 13

HSC $i' < 24$
QSOs

bias ~ 14

← Little discrepancy!

Maximal Growth model is preferred!

So that BH evolution at early universe is very strong that QSO duty cycle is very high (0.03~0.6 from Shen 2009).

Preliminary Results



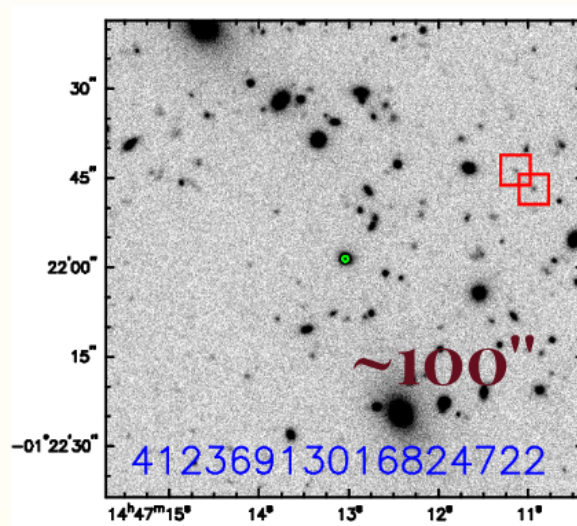
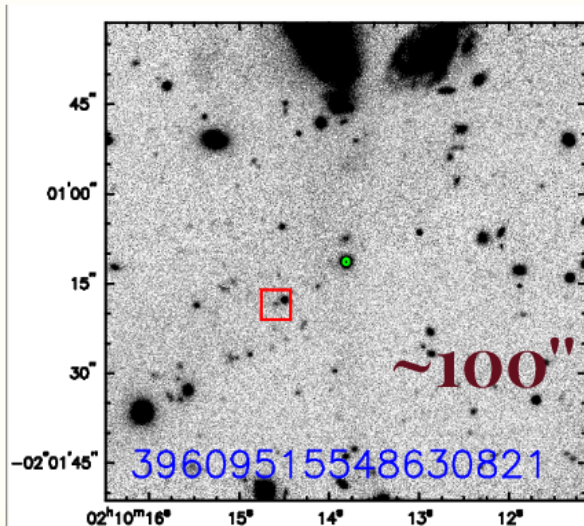
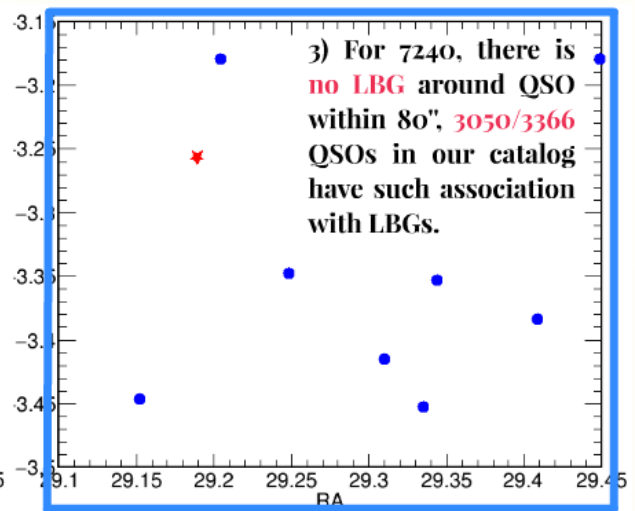
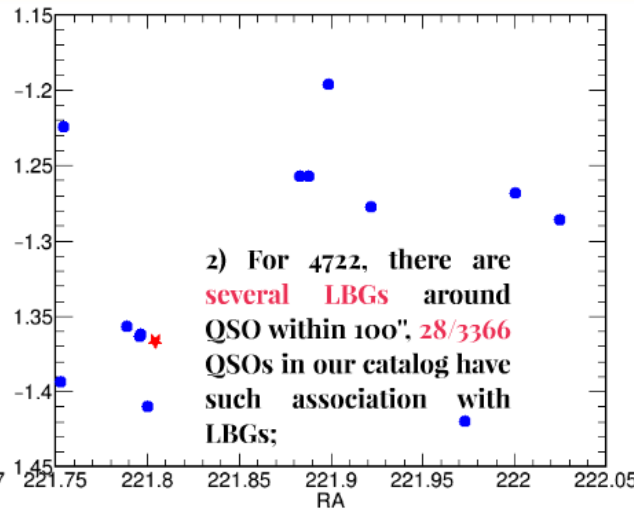
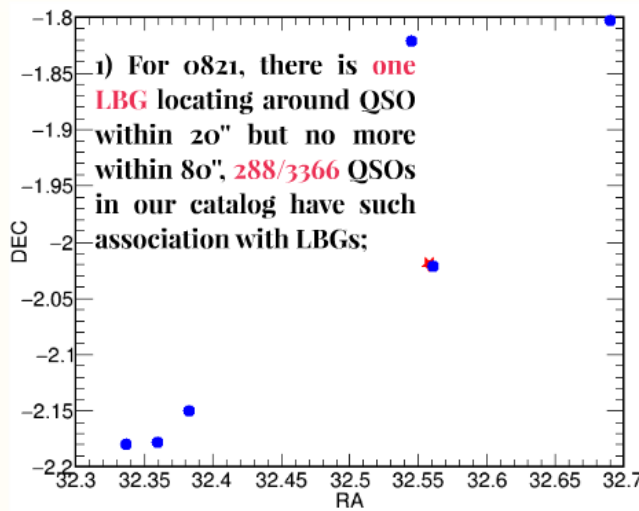
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• LBG overdensity around $z \sim 4$ QSO

39609515548630821

41236913016824722

38536671372797240



Galaxy deficit around QSO vicinity (~ 3 Mpc) seems to be a common case.

Summary



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- We select 3409 $z \sim 4$ QSO and 11636 $z \sim 4$ LBG in HSC S15B WIDE survey;
- Clustering analysis indicates QSO **strong auto correlation** with bias factor ~ 14 and corresponding host DMH $\sim 10^{13}$ solar mass;
- Clustering analysis also suggests QSO **weak correlation with LBG in scale < 3 Mpc**, while correlation strength beyond this range is similar with auto correlation.
- Based on similar strong correlation strength for $z \sim 4$ SDSS $i' < 21$ QSOs and HSC $i < 24$ QSOs, **maximal BH growth mode is preferred.**



- Further check on photometric selection completeness and contamination;
- What causes the galaxy deficit around QSO vicinity (~ 3 Mpc)? Feedback?
- Future spectroscopic observation for QSO and associating surrounding galaxies...



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Thank you for your attention.

