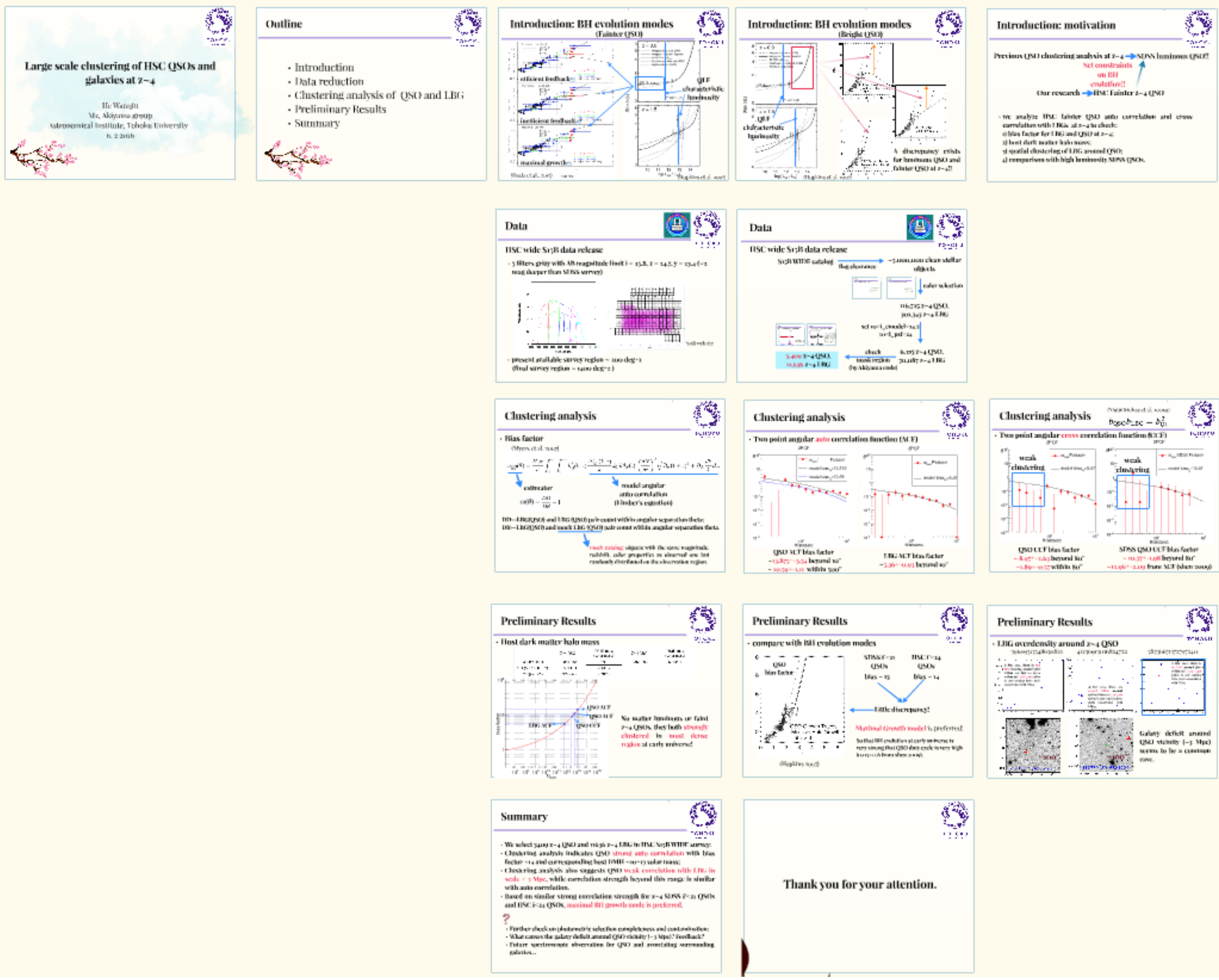
Large scale clustering of HSC QSOs and galaxies at z~4
He Wanqiu
Mr. Akiyama group
Astronomical Institute, Tohoku University
Outline
Introduction
Data reduction
Clustering analysis of QSO and LBG
Preliminary Results
Summary
Introduction: BH evolution modes
Introduction: motivation
Data
Clustering analysis
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Summary
Thank you for your attention.

Large scale clustering of HSC QSOs and galaxies at z~4

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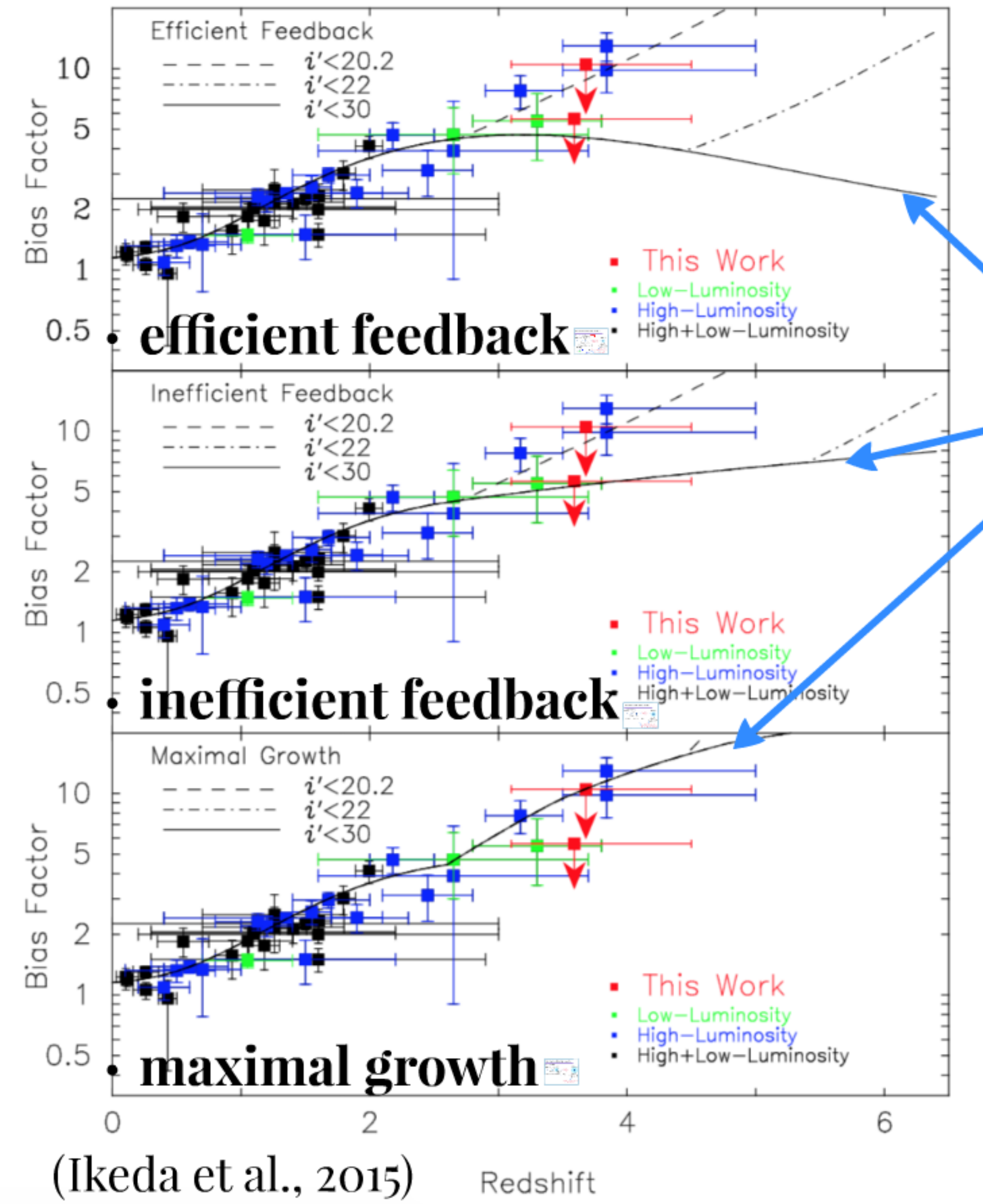
6. 2 2016

Outline

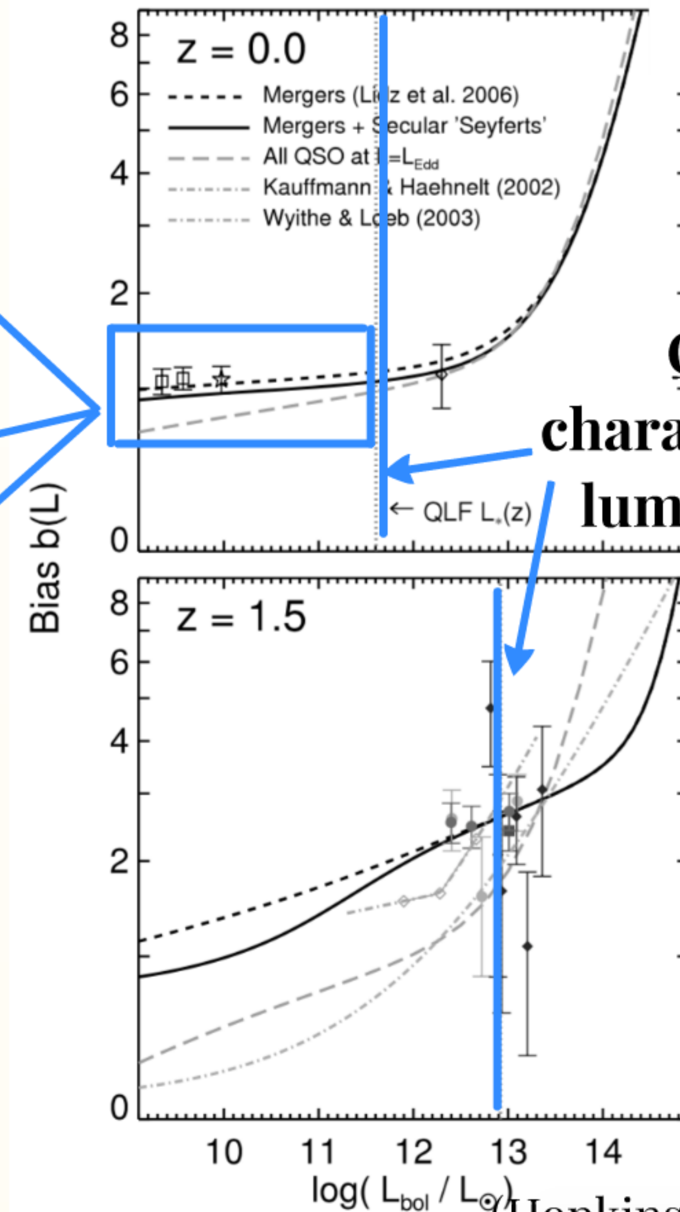
- Introduction
- Data reduction
- Clustering analysis of QSO and LBG
- Preliminary Results
- Summary

Introduction: BH evolution modes
(Fainter QSO)



- efficient feedback
- inefficient feedback
- maximal growth

(Ikeda et al., 2015)



QLF characteristic luminosity

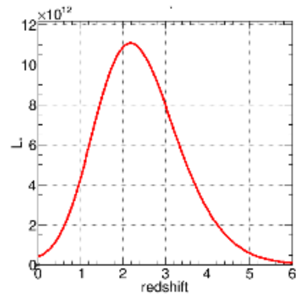
(Hopkins et al. 2007)

Introduction: BH evolution modes

- efficient feedback

BH at z~6

experience a QSO phase (L~L*) at z~4



BH growth shuts down!

BH at z~0

BH mass growth ~L*

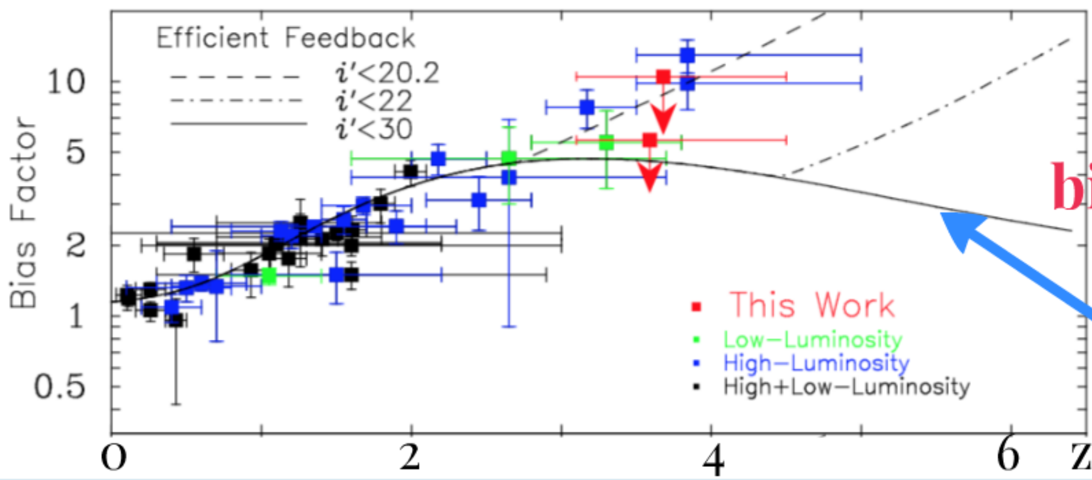
$$3.0\ \lambda^{-1} \times 10^{8}\ M_{\odot}\ (L_{*}/10^{13}\ L_{\odot})$$

BH mass= BH mass + growth

BH mass
~ Host mass
~clustering strength
(bias factor)

bias factor for this BH ~ L* at z~4!

bias factor follows QLF!

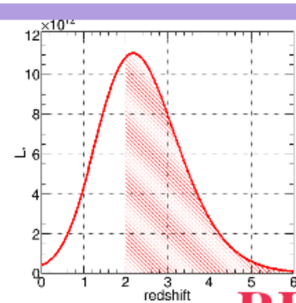


Introduction: BH evolution modes

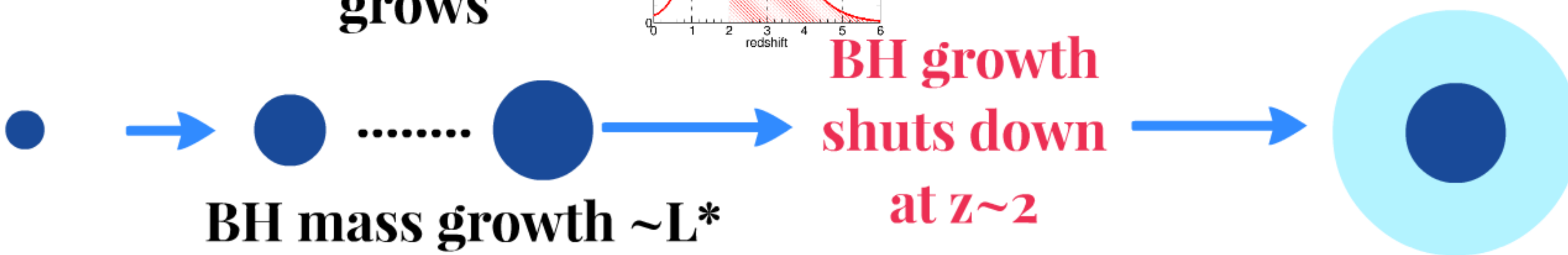
- **inefficient feedback**

BH at z~6

BH continually grows



BH at z~0



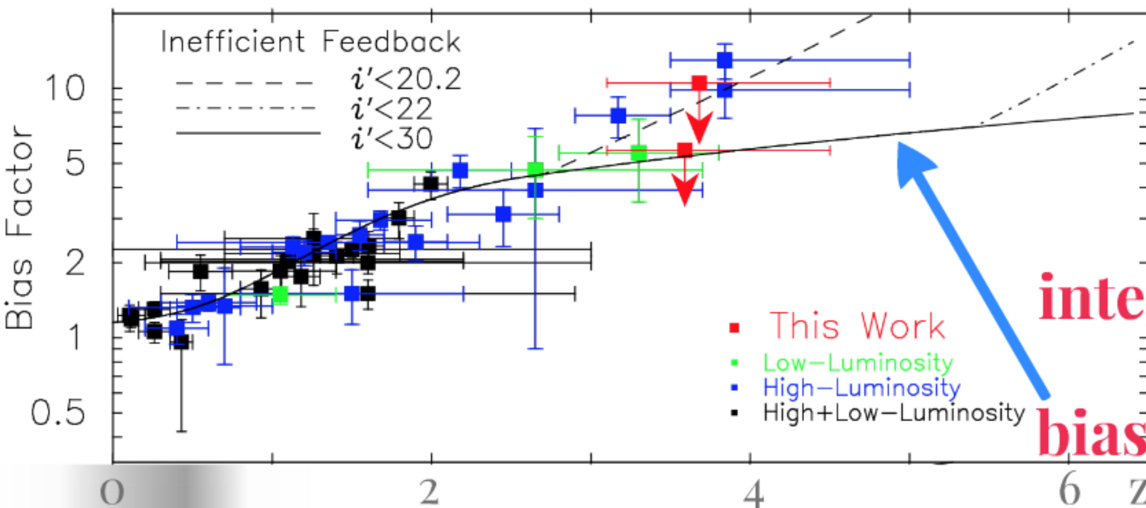
BH growth shuts down at z~2

BH mass growth ~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~6 to z~2!

bias factor follows integrated QLF!

Introduction: BH evolution modes

- **Maximal growth**

BH at z~6

BH and DMH continually grows

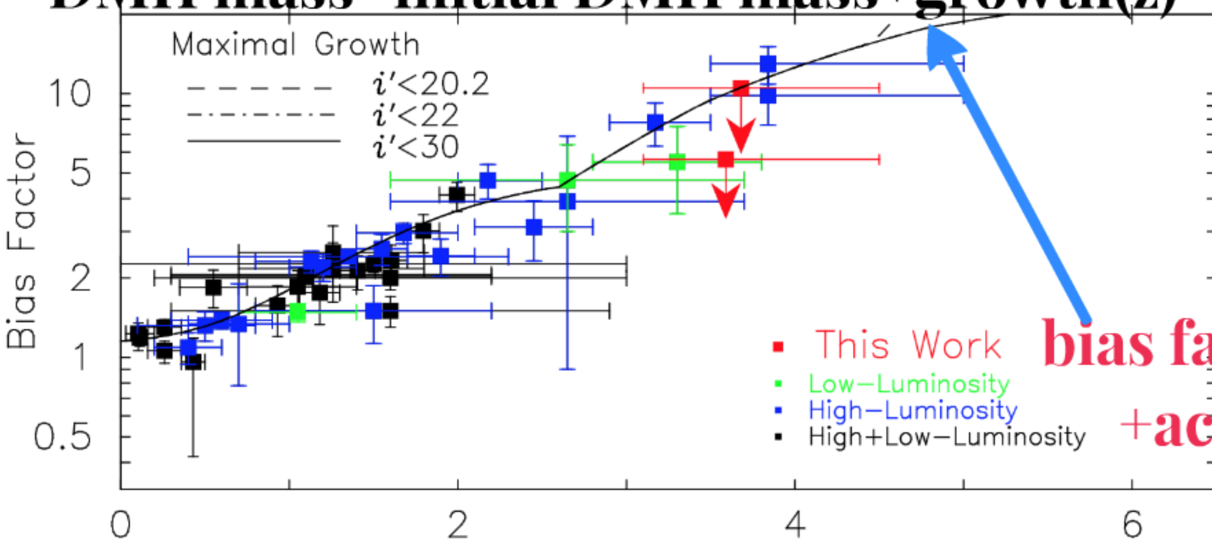
BH growth shuts down at z~2

BH at z~0

BH mass= initial BH mass + growth(z)

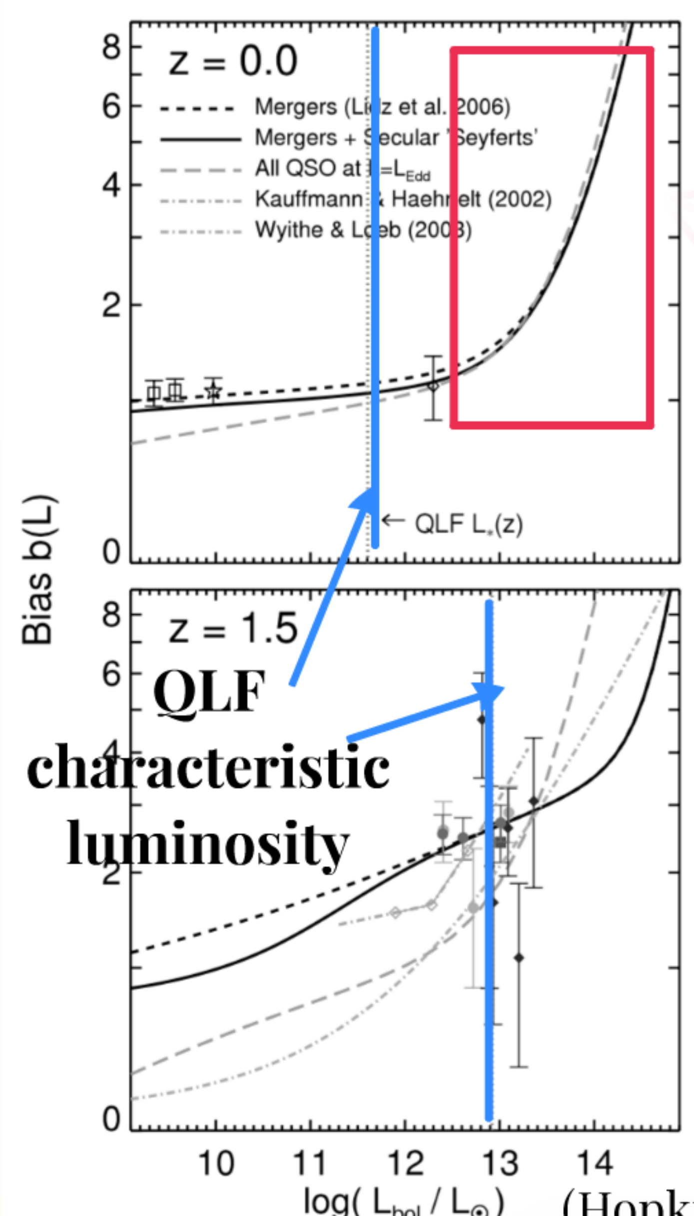
DMH mass=initial DMH mass+growth(z)

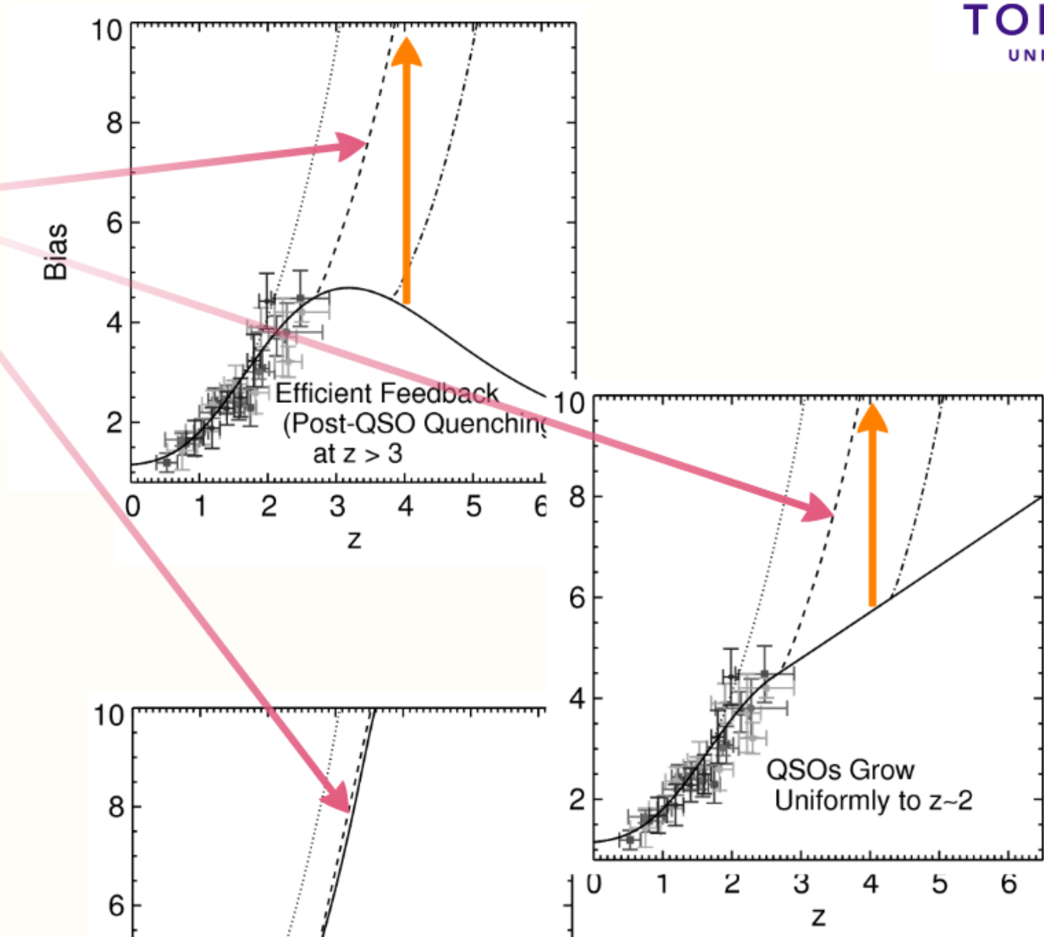
BH mass ~ Host mass ↑ ~clustering strength (bias factor) ↑

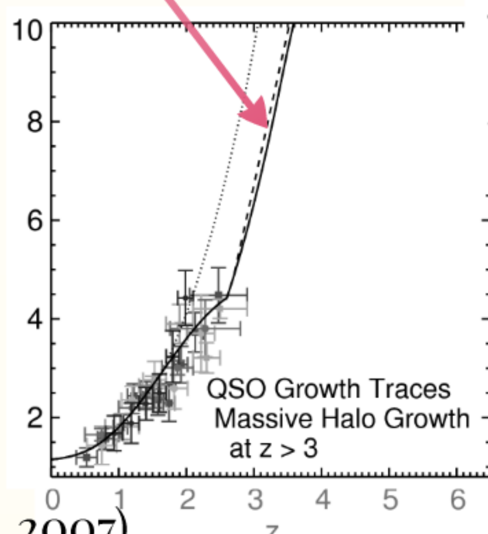


bias factor follows integrated QLF +accumulated DMH growth!

Introduction: BH evolution modes
(Bright QSO)







(Hopkins et al. 2007)

A discrepancy exists for luminous QSO and fainter QSO at z~4!!

Introduction: motivation

Previous QSO clustering analysis at z~4 → SDSS luminous QSO!!

Set constraints on BH evolution!!

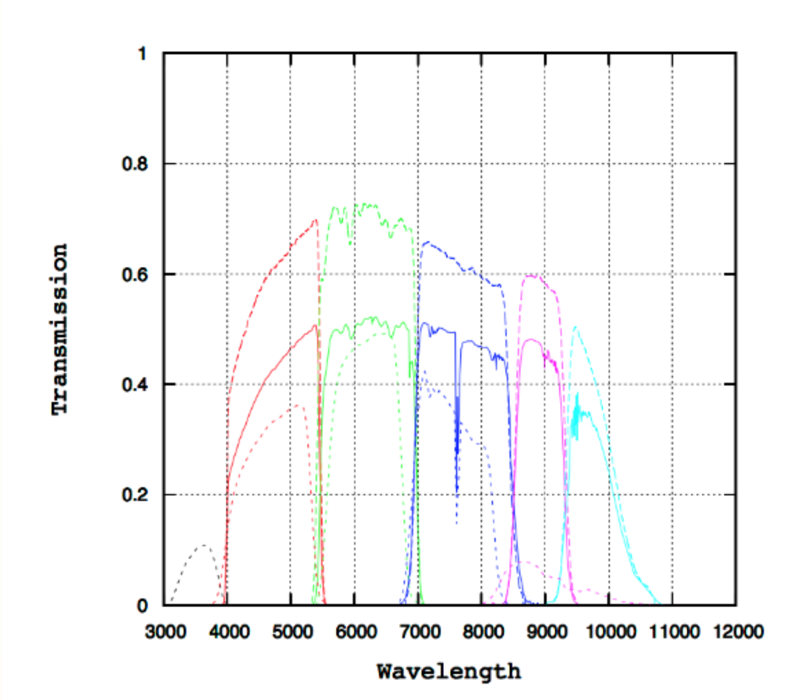
Our research → HSC Fainter z~4 QSO

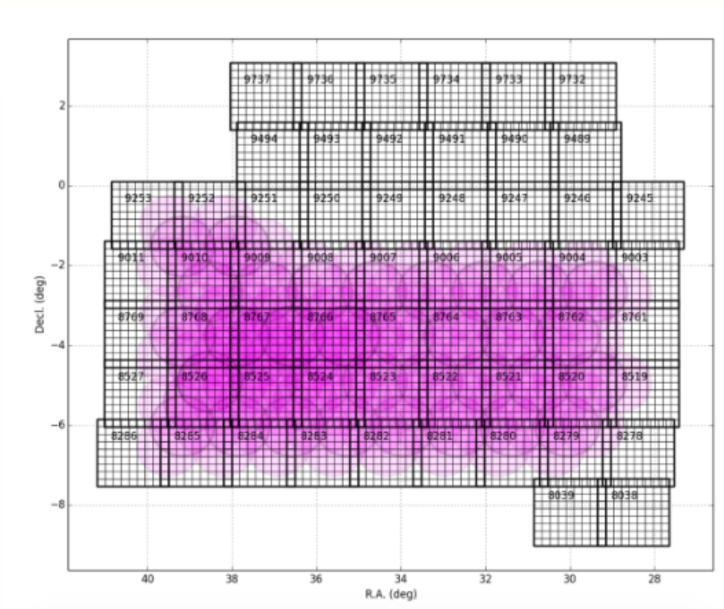
- we analyze HSC fainter QSO auto correlation and cross correlation with LBGs at z~4 to check:
  1) bias factor for LBG and QSO at z~4;
  2) host dark matter halo mass;
  3) spatial clustering of LBG around QSO;
  4) comparison with high luminosity SDSS QSOs.

Data

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)





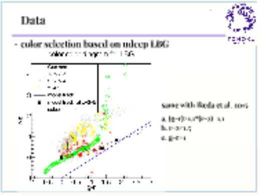
S15B website

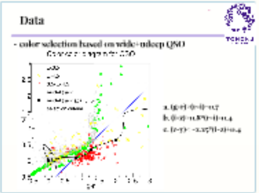
- present available survey region ~ 200 deg^2
  (final survey region ~ 1400 deg^2)

Data

HSC wide S15B data release

S15B WIDE catalog → flag clearance → ~5,000,000 clean stellar objects



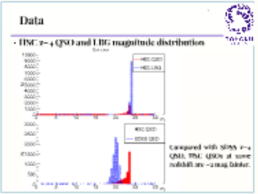


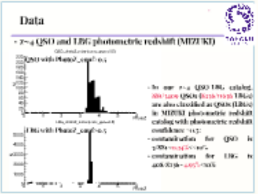
color selection

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



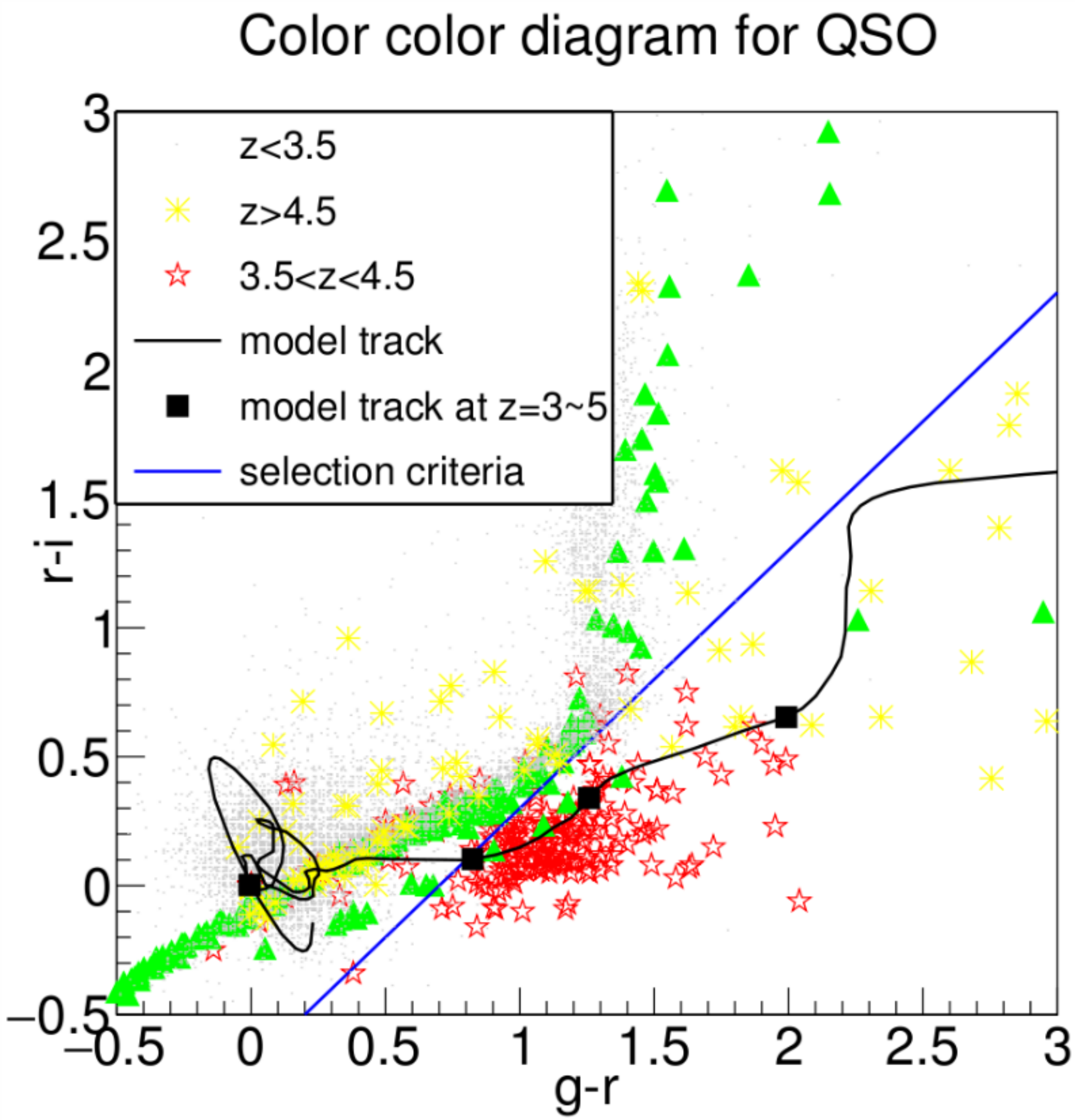


check
mask region
(by Akiyama code)

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

Data

- **color selection based on wide+udeep QSO**



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

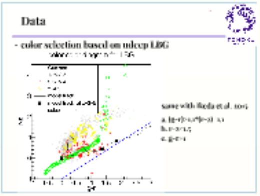
b. (i-z)>0.8*(r-i)-0.4

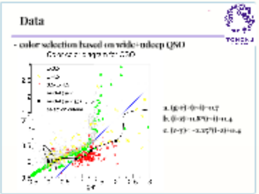
c. (z-y)< -2.25*(i-z)+0.4

Data

HSC wide S15B data release

S15B WIDE catalog → flag clearance → ~5,000,000 clean stellar objects





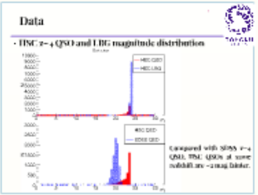
↓ color selection

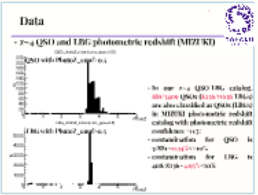
116,725 z~4 QSO,
301,343 z~4 LBG

↓ set 10<i_cmodel<24.5
10<i_psf<24

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

← check mask region (by Akiyama code)

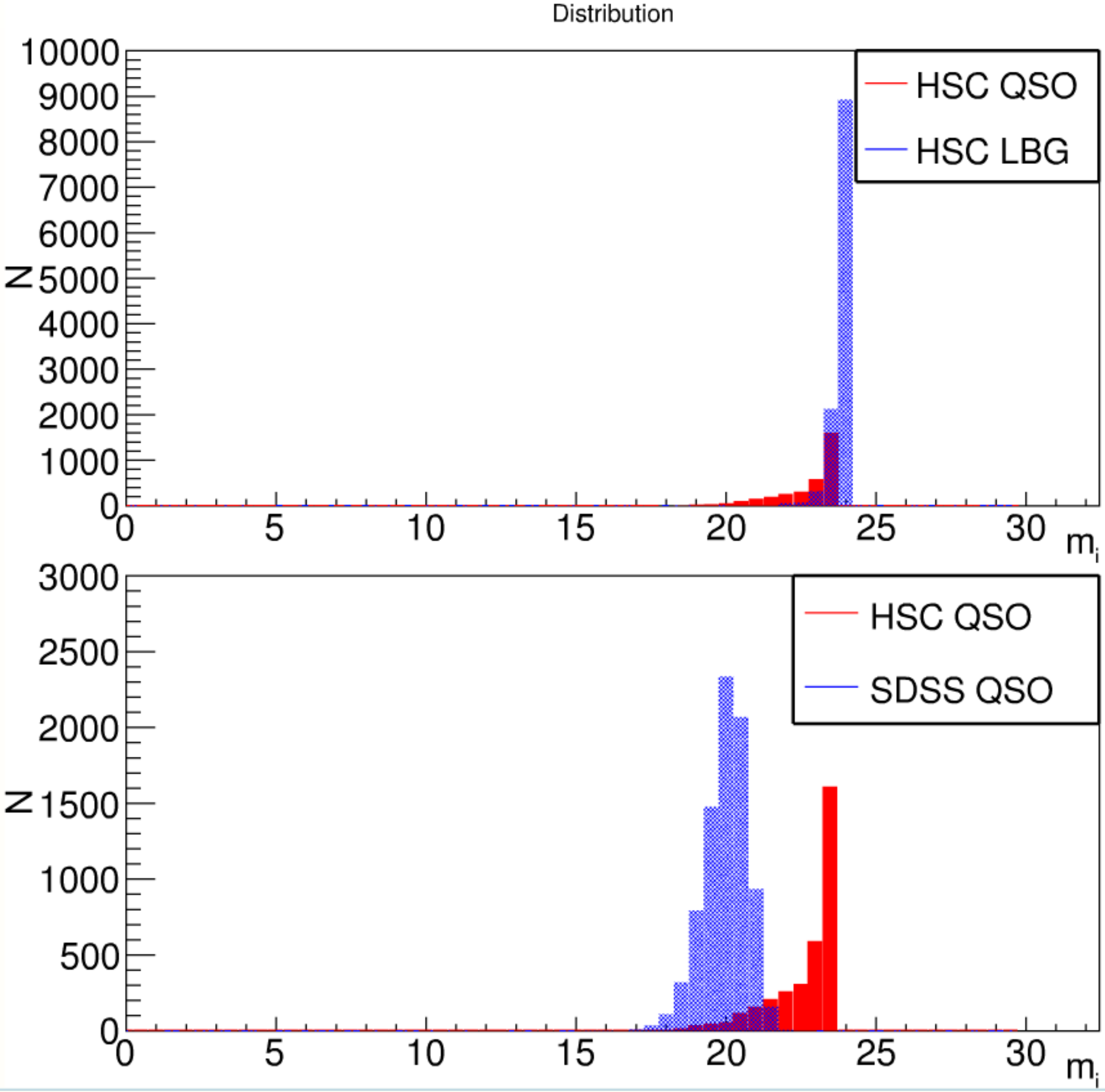




3,409 z~4 QSO,
11,636 z~4 LBG

Data

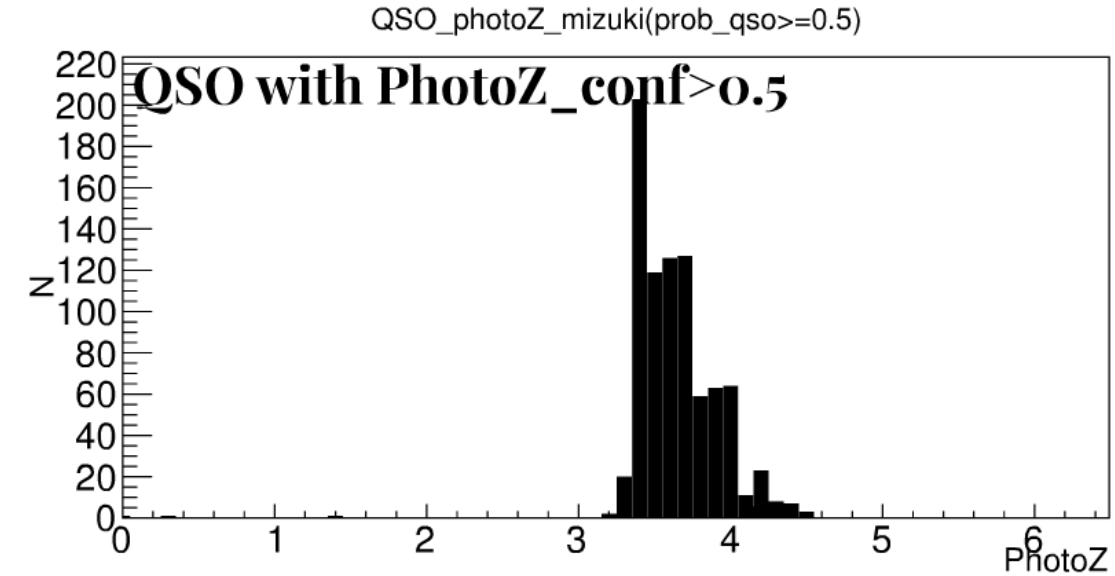
- **HSC z~4 QSO and LBG magnitude distribution**

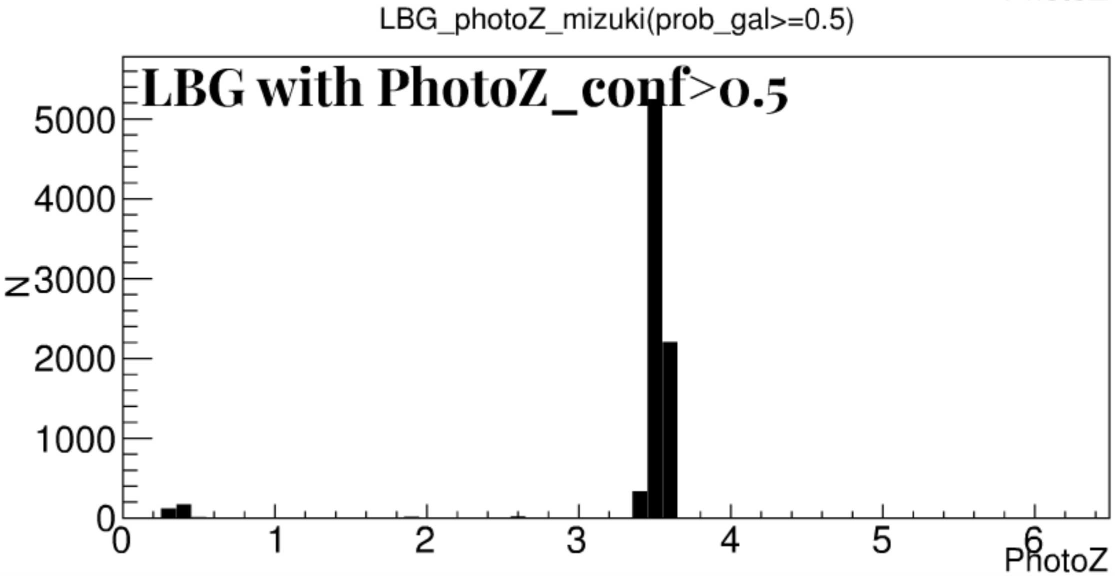


Compared with SDSS z~4 QSO, HSC QSOs at same redshift are ~2 mag fainter.

Data

- z~4 QSO and LBG photometric redshift (MIZUKI)





- In our z~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 3/881~0.34%<<10%
- contamination for LBG is 408/8236~4.95%<10%

Clustering analysis

- **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

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

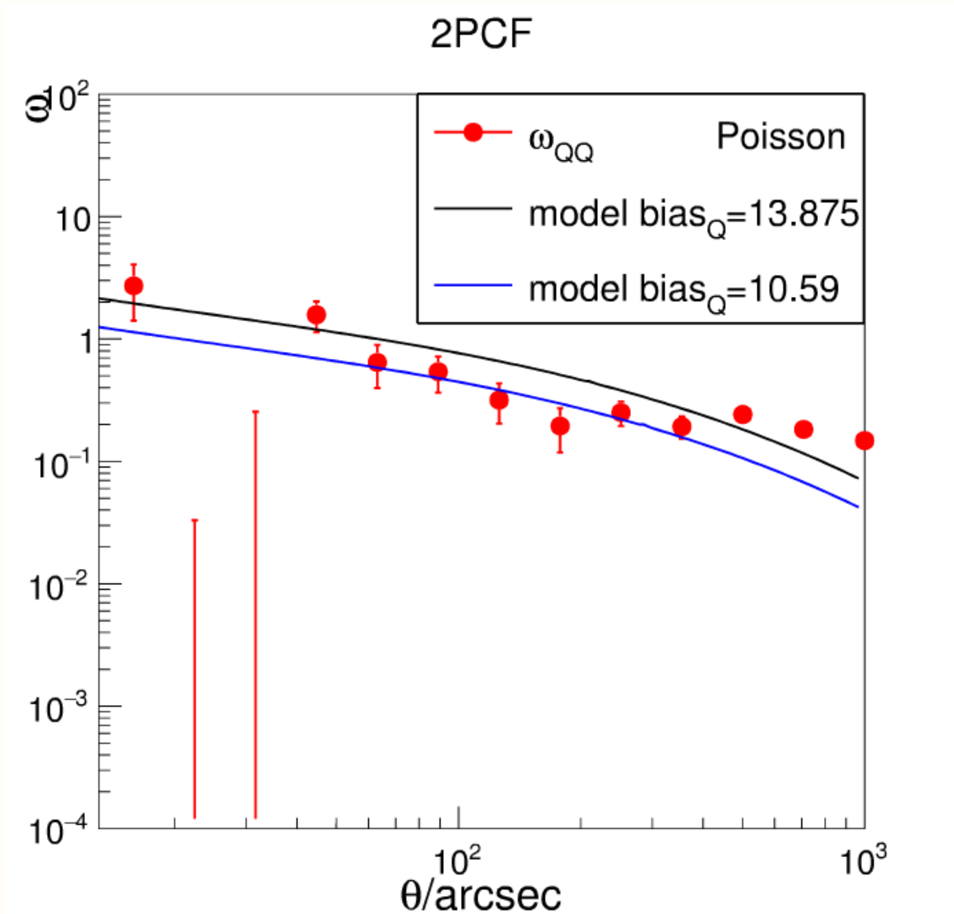
model angular auto correlation (Limber's equation)

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.

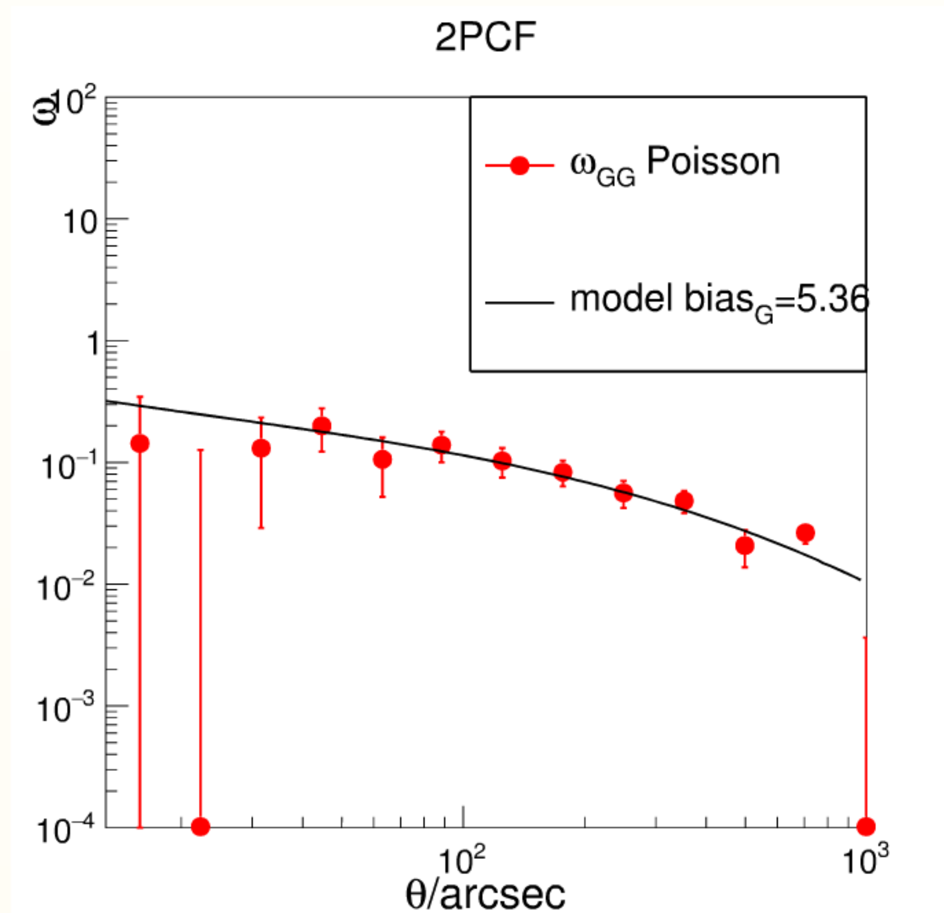
mock catalog: objects with the same magnitude, redshift, color properties as observed one but randomly distributed on the observation region.

Clustering analysis

- Two point angular auto correlation function (ACF)



QSO ACF bias factor
~13.875+-3.54 beyond 10"
~ 10.59+-1.11 within 500"



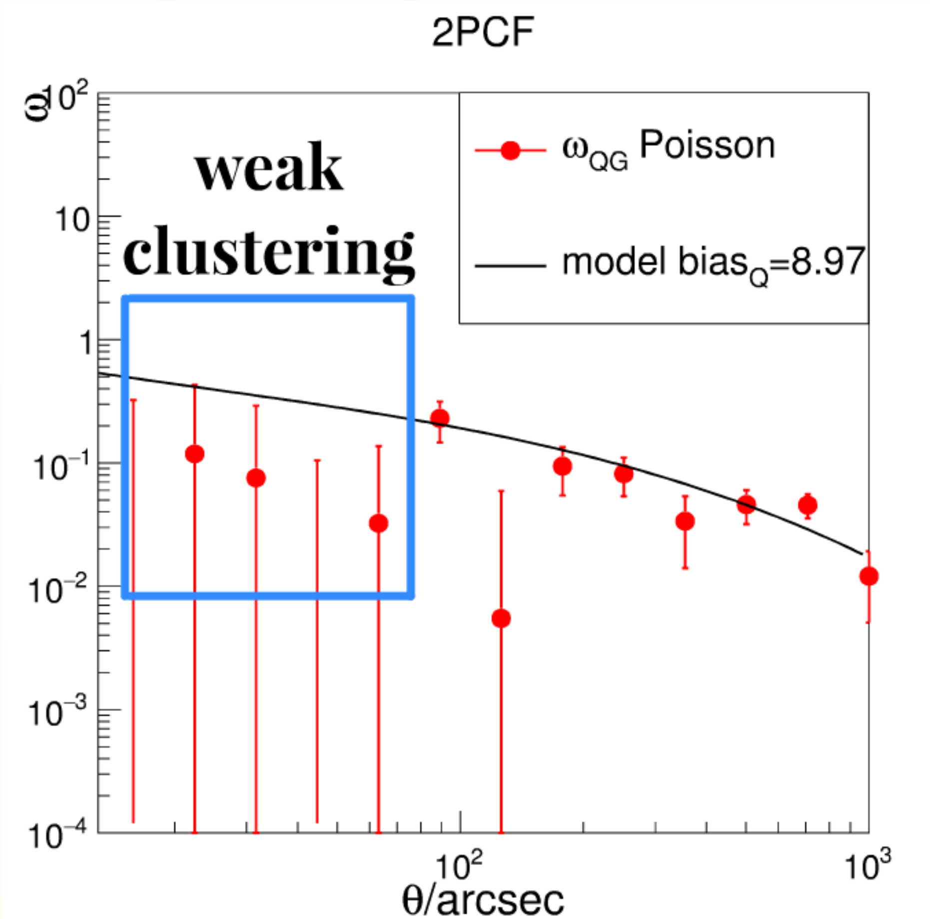
LBG ACF bias factor
~5.36+-0.93 beyond 10"

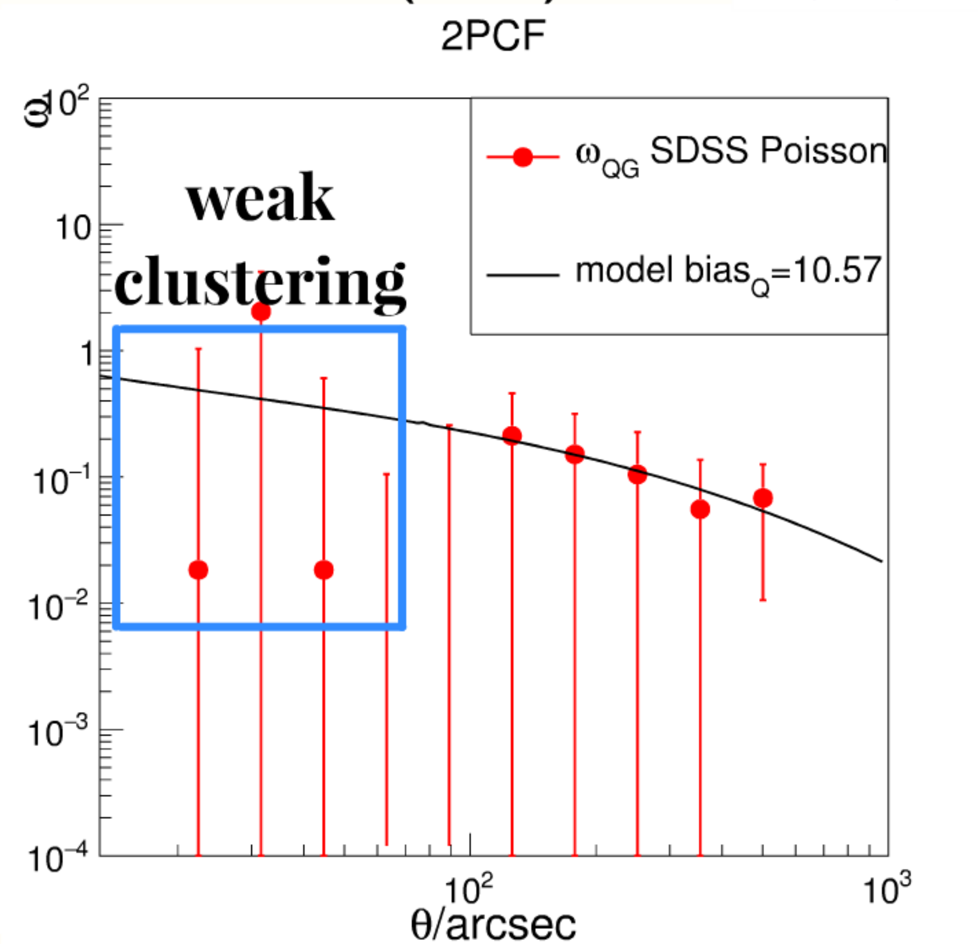
Clustering analysis

(Mountrichas et al, 2009a)

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

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





QSO CCF bias factor

~ 8.97+-2.63 beyond 80"

~1.89+-0.57 within 80"

SDSS QSO CCF bias factor

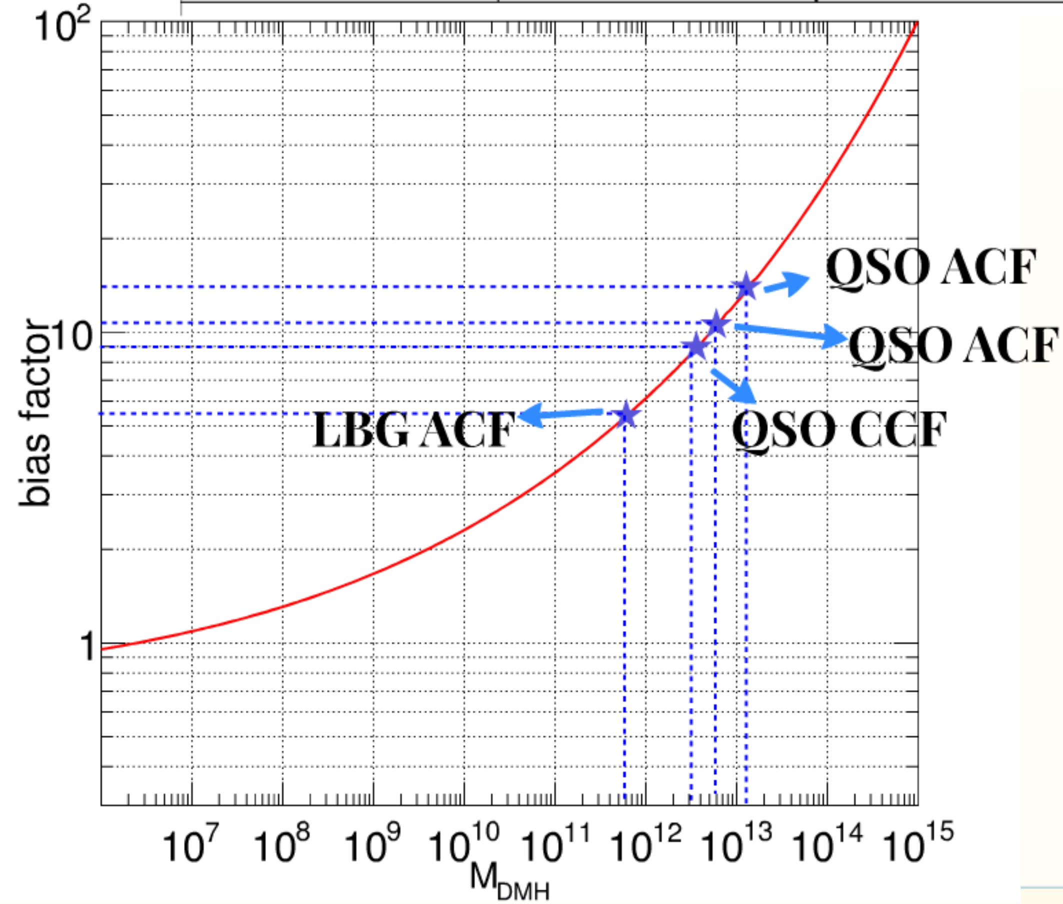
~ 10.57+-1.98 beyond 80"

~12.96+-2.09 from ACF (shen 2009)

Preliminary Results

- Host dark matter halo mass

	Z~4 QSO	DMH mass (solar mass)	Z~4 LBG	DMH mass (solar mass)
ACF(Θ>10″)	13.88±3.54	1.27E13	5.36±0.93	6.09E11
ACF(500">Θ>10″)	10.59±1.11	5.96E12		
CCF(Θ>80″)	8.97±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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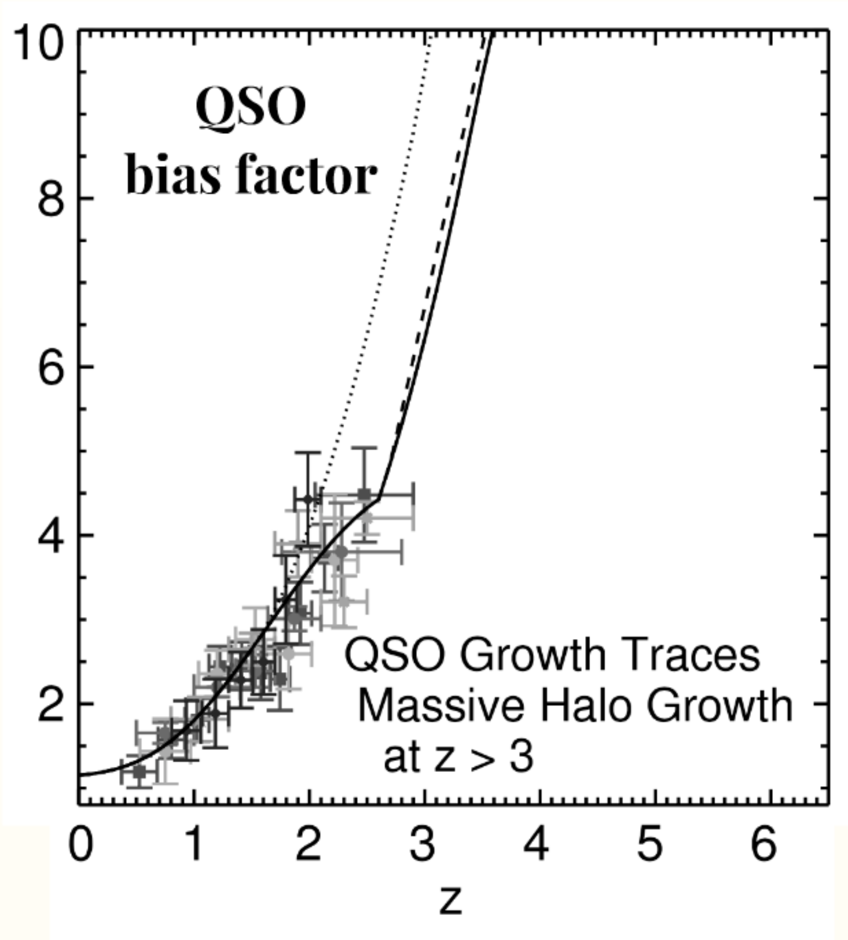
- compare with BH evolution modes



(Hopkins 2007)

SDSS i'<21 QSOs bias ~ 13

HSC i'<24 QSOs bias ~ 14

Little discrepancy!

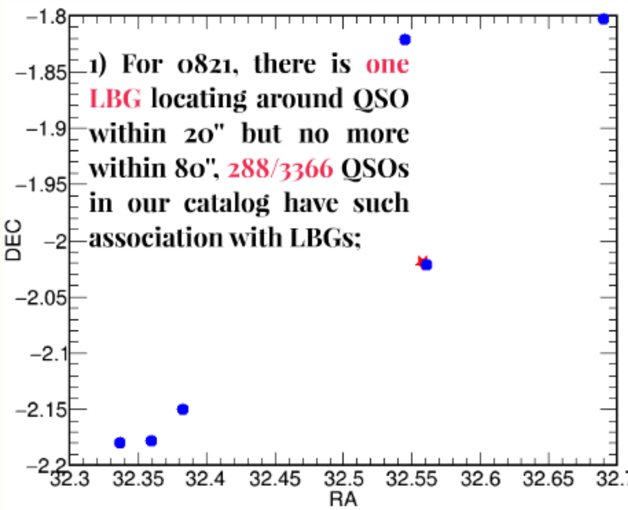
Maximal Growth model is preferred!

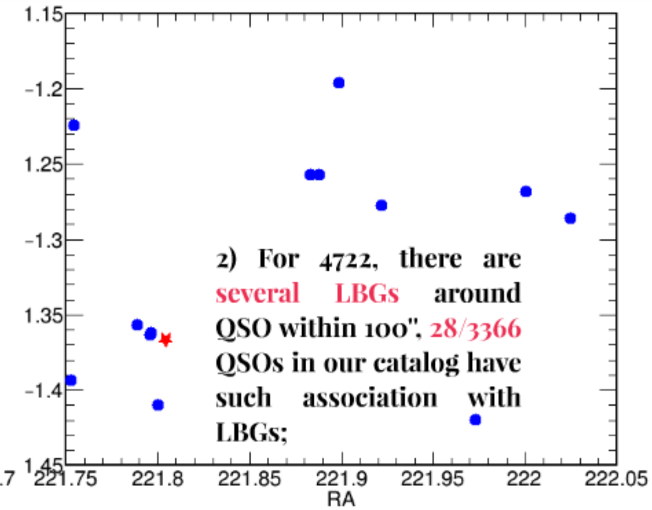
So that BH evolution at early universe is very strong that QSO duty cycle is very high (0.03~0.6 from shen 2009).

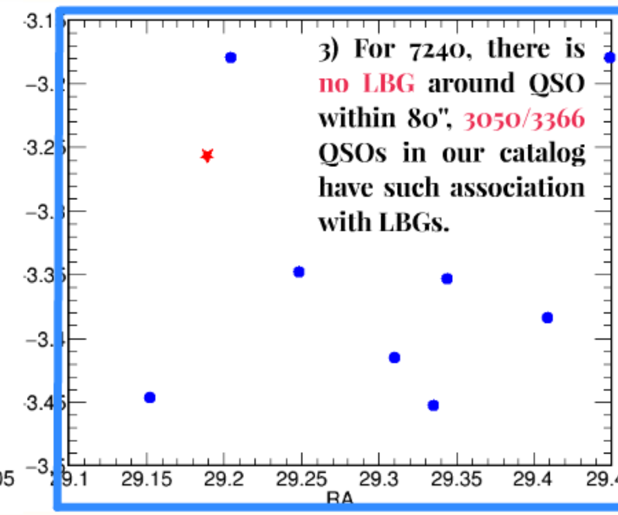
Preliminary Results

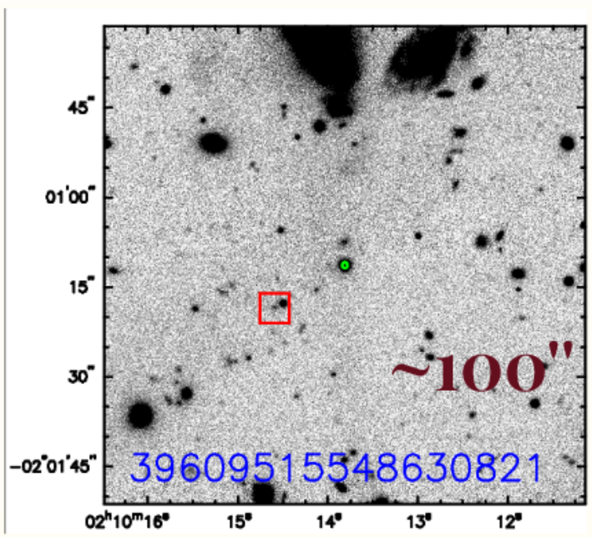
- **LBG overdensity around z~4 QSO**

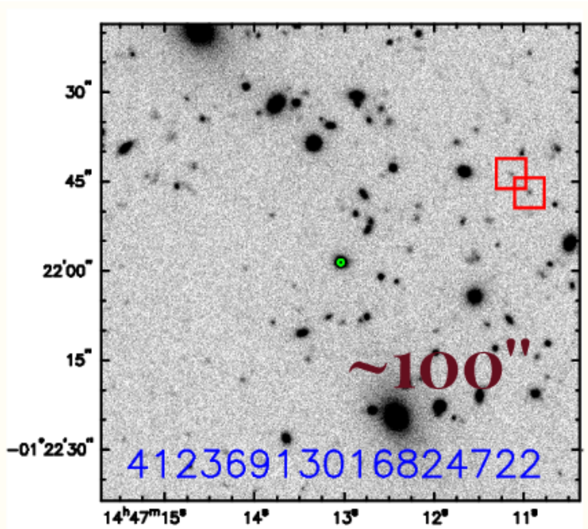
3960951554863082l   41236913016824722   38536671372797240











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

Summary

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- We select 3409 z~4 QSO and 11636 z~4 LBG in HSC S15B WIDE survey;
- Clustering analysis indicates QSO strong auto correlation with bias factor ~14 and corresponding host DMH ~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~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...

Thank you for your attention.