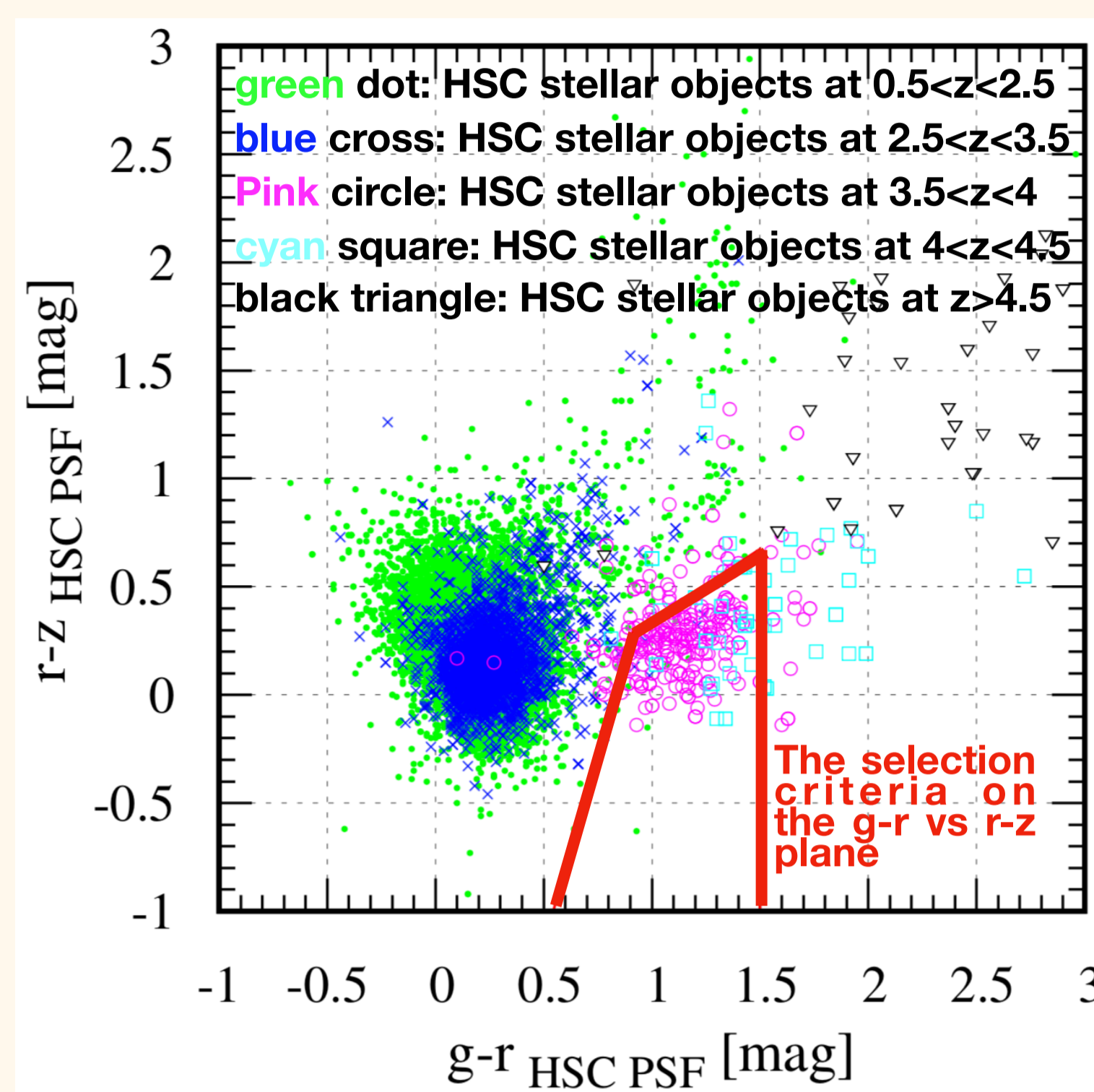# Probe the early growth of the Supermassive Black Holes with Subaru HSC-SSP wide field imaging.

Wanqiu He, Masayuki Akiyama and the HSC-AGN collaborators
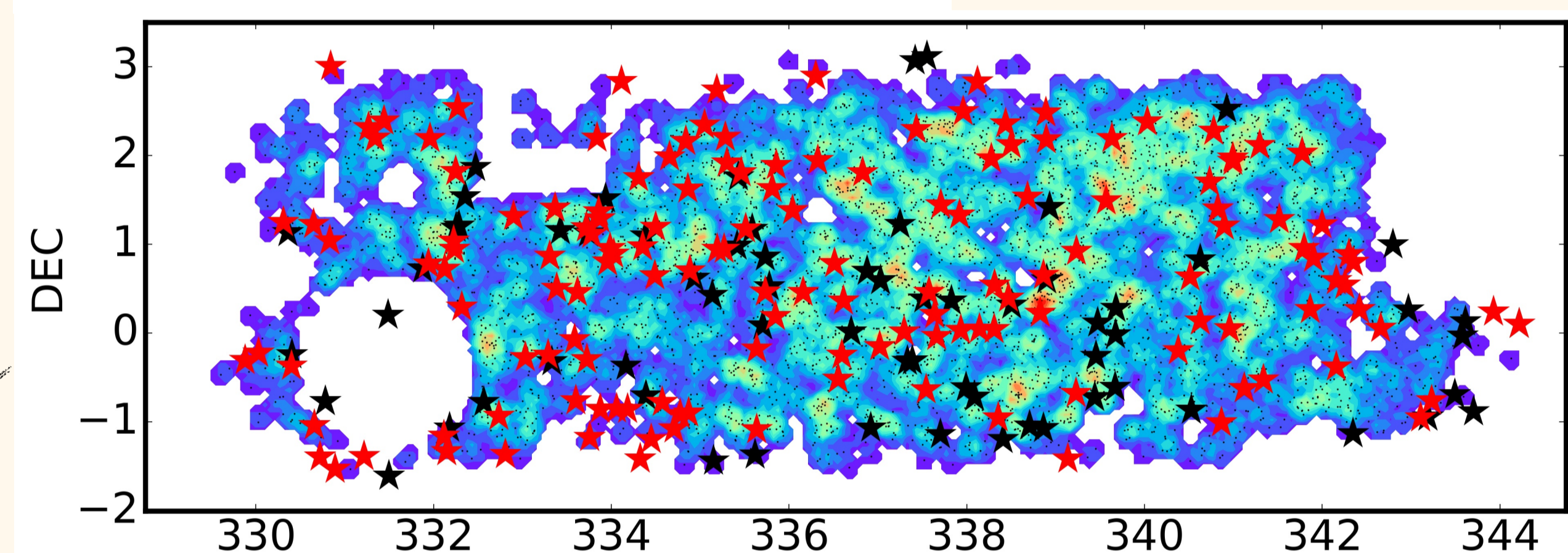
TOHOKU UNIVERSITY

z=4 quasar sample

The wide and deep multi-band imaging dataset of the *Subaru Hyper Suprime-Cam Strategic Survey Program (HSC-SSP*: Aihara et al. 2018a) enables us to examine the **environment** around **high-redshift quasars** in **a wide luminosity range**.

green dot: HSC stellar objects at 0.5<z<2.5
blue cross: HSC stellar objects at 2.5<z<3.5
Pink circle: HSC stellar objects at 3.5<z<4
cyan square: HSC stellar objects at 4<z<4.5
black triangle: HSC stellar objects at z>4.5

The selection criteria on the g-r vs r-z plane

The z~4 quasar sample is selected by the **g-drop (lyman break) color+stellar morphology**

z=4 quasarS	SDSS	HSC
M1450	<-23.9	-24.7~-22.2
N	342	901

A sub-region of the HSC-SSP Wide Field.

Red star: HSC low-luminosity z~4 quasars
Black star: SDSS luminous z~4 quasars
Black dot: HSC z=4 LBGs

Clustering of the z=4 quasar

To trace the environment of high-redshift quasars, we estimated their **angular cross-correlation function (CCF)** with the LBG sample, and measured their **bias** in relative to the underlying dark matter.
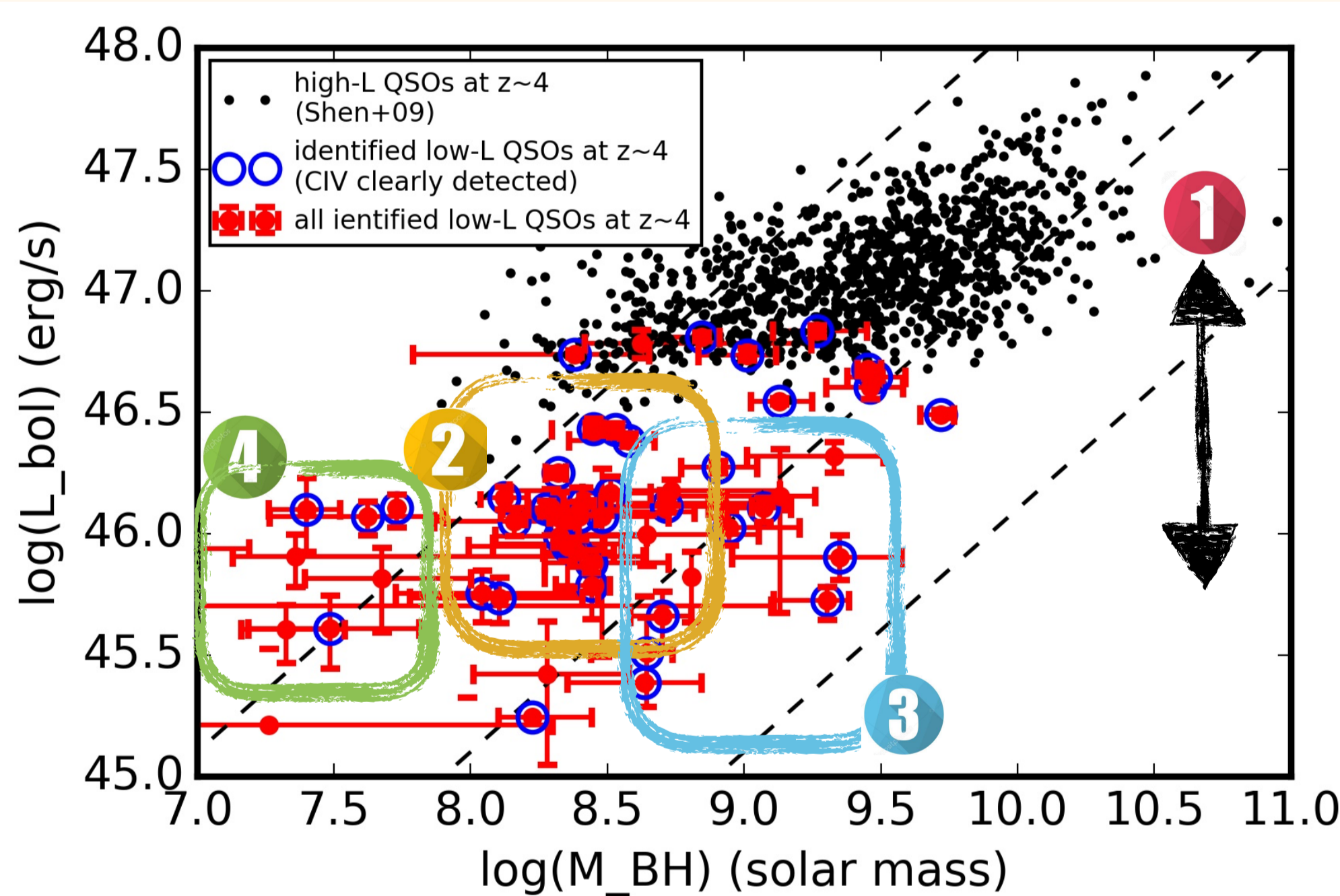

This work
Hopkins+07 model
Halo clustering (Sheth+01)
Quasars Muv>-25
Quasars Muv<-25

ACF / CCF

z=4   z=2
high-L   →
low-L   →   SMBH
halo

Deficit of QSO-LBG pair

SDSS QG CCF ω_{obs}
fit ω_{QG}=2.99 $\theta^{-0.86}$ ω_{obs}
fit ω_{QG}=3.94² ω_{DM}
fit ω_{QG}=4.48² ω_{DM}
expected CCF
fit ω_{QG}=11.63 $\theta^{-0.86}$, 40"<d<160"
fit ω_{QG}=4.64 $\theta^{-0.86}$, 40"<d<1000"
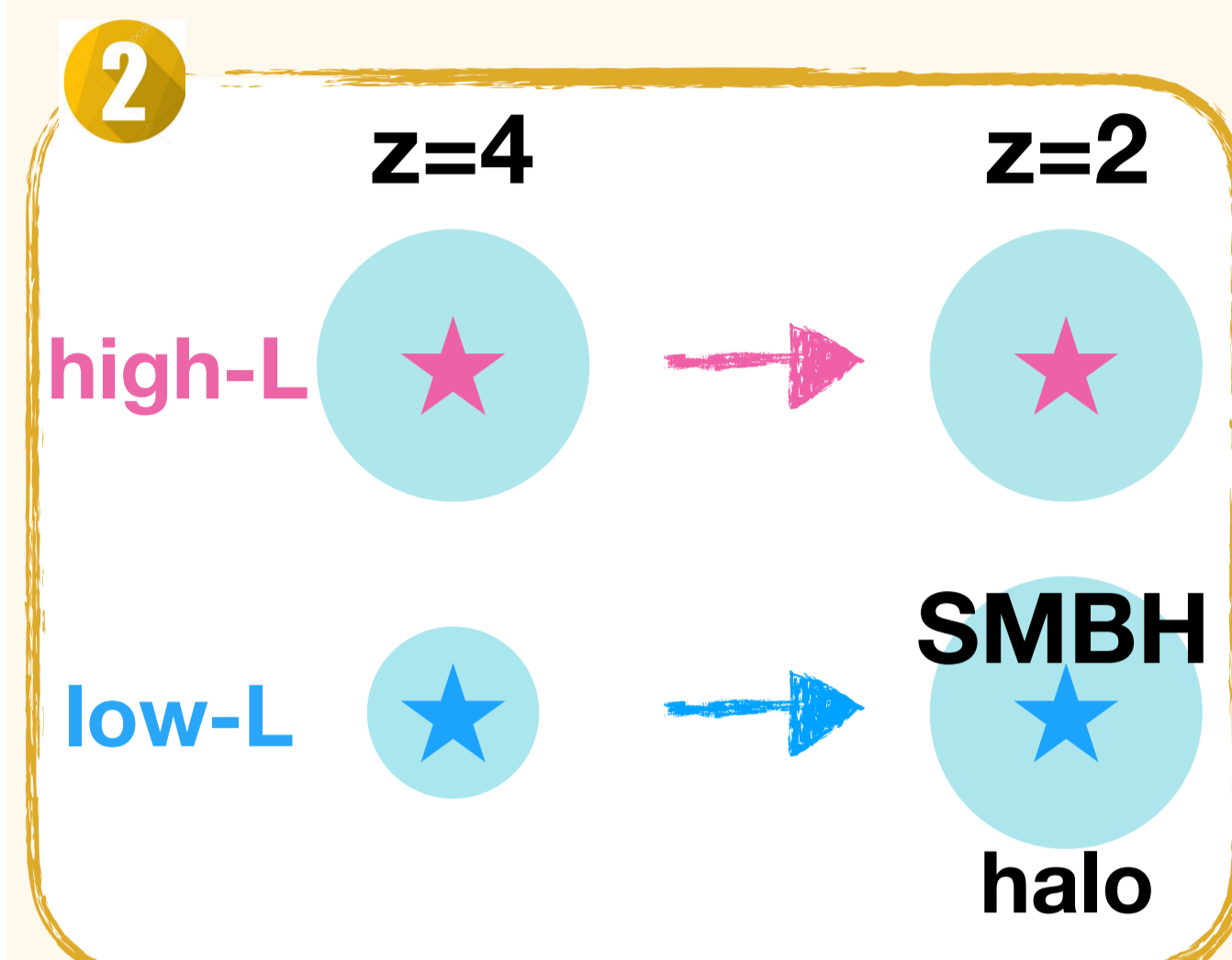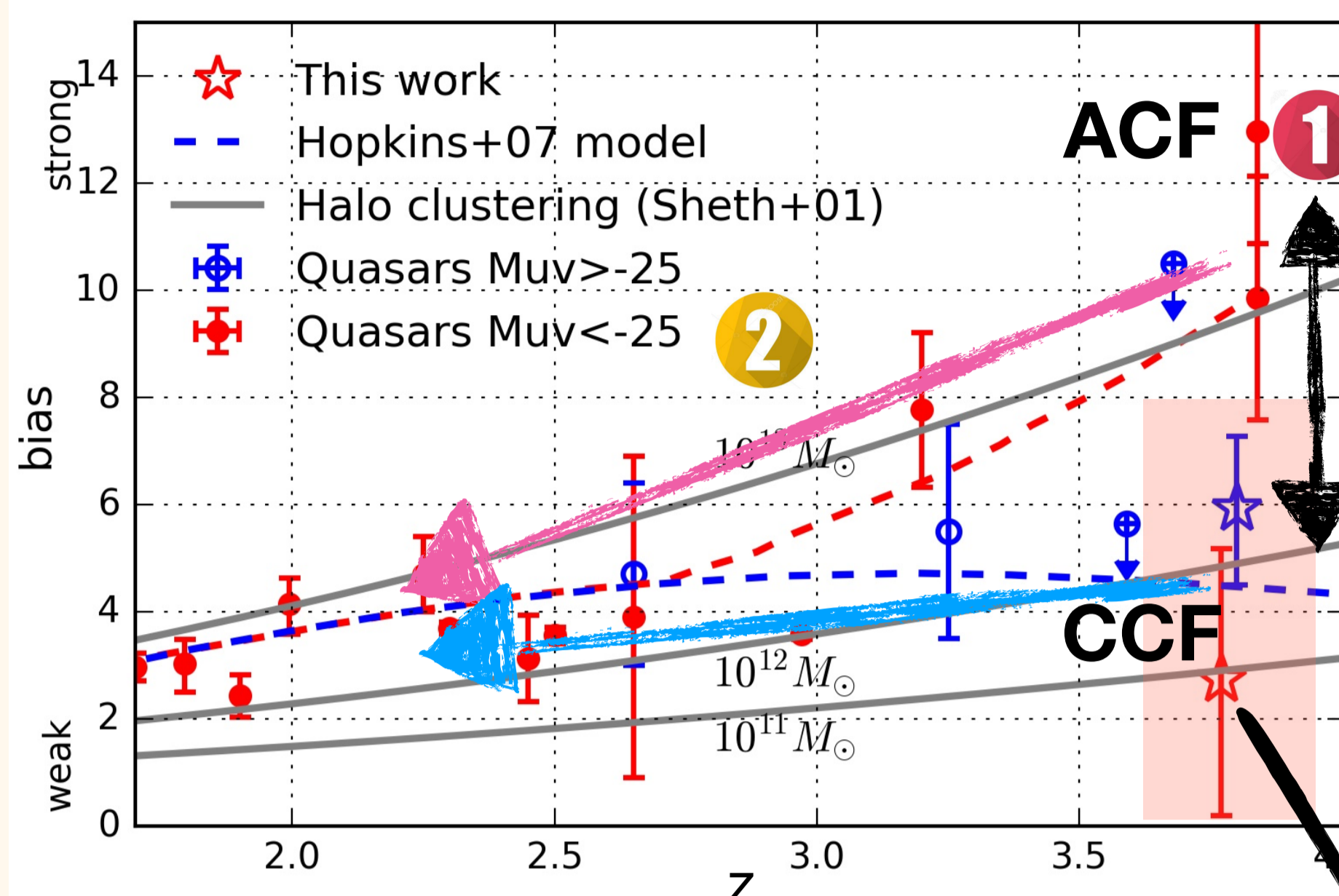
The **clustering** of z~4 low-luminosity quasars is investigated **for the first time**:

1 at z=4, **low-luminosity quasars** are **less clustered** in **less-massive halos** compared to the luminous ones from the SDSS;

2 from z=4 to z=2, the host halo of less-luminous quasars keeps growing, while the **luminous quasars** always reside in **the most massive halos** (~10^13 solar mass);

3 the **luminous quasars** do not tightly correlated with the LBGs at z=4, especially in **the small scales** (<40"), resulting in a much **weaker clustering** compared to their ACF. Feedback...?
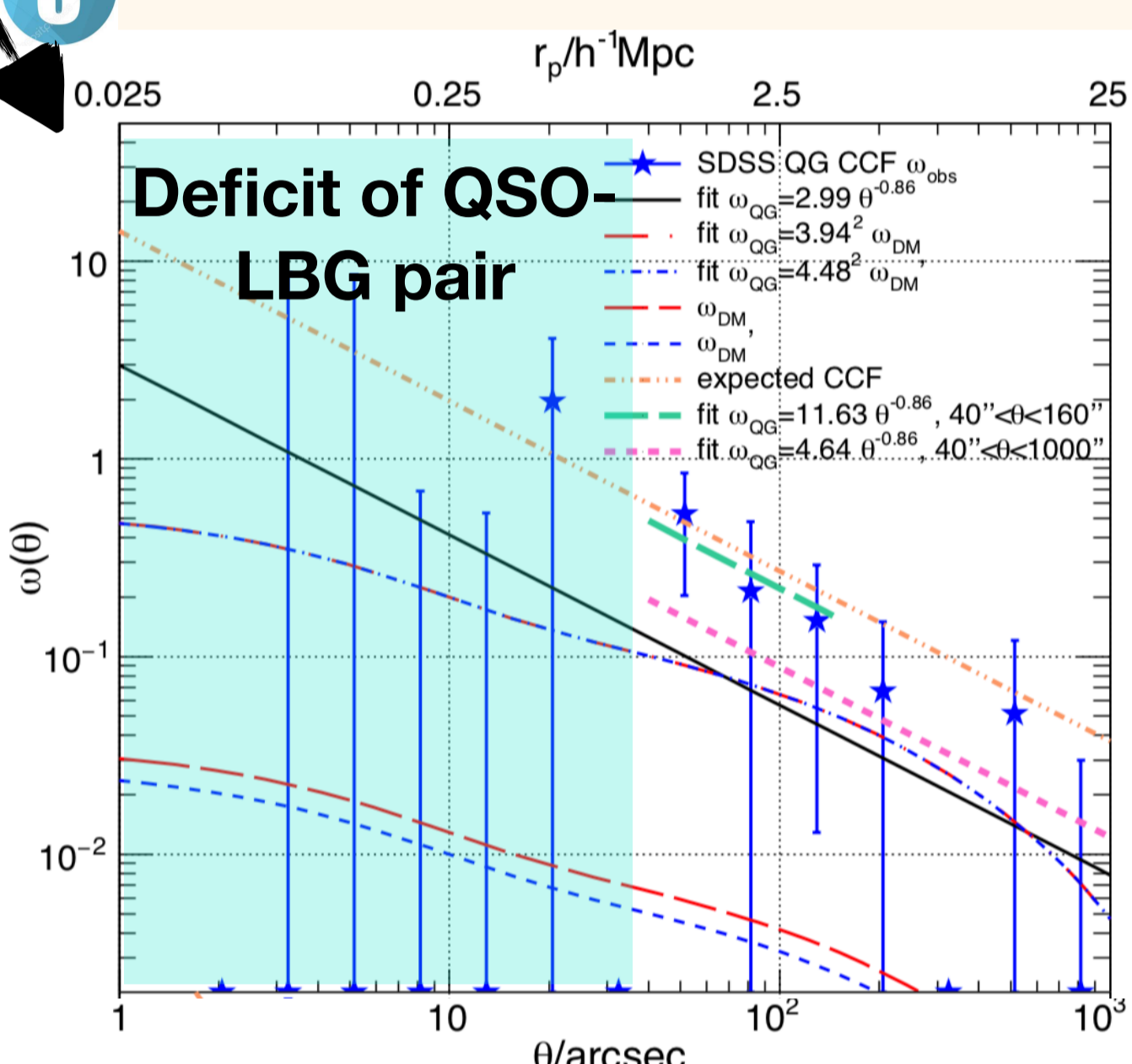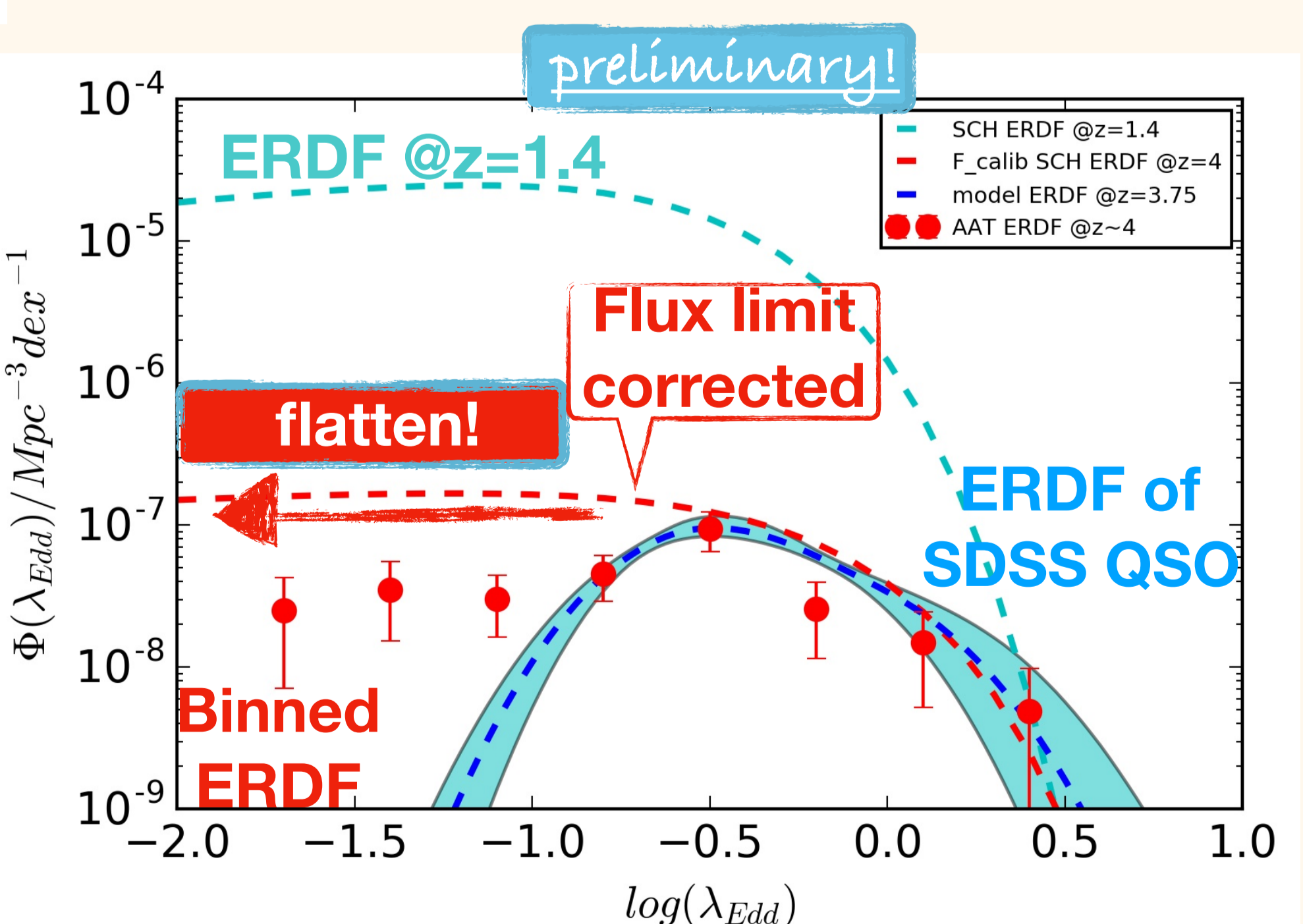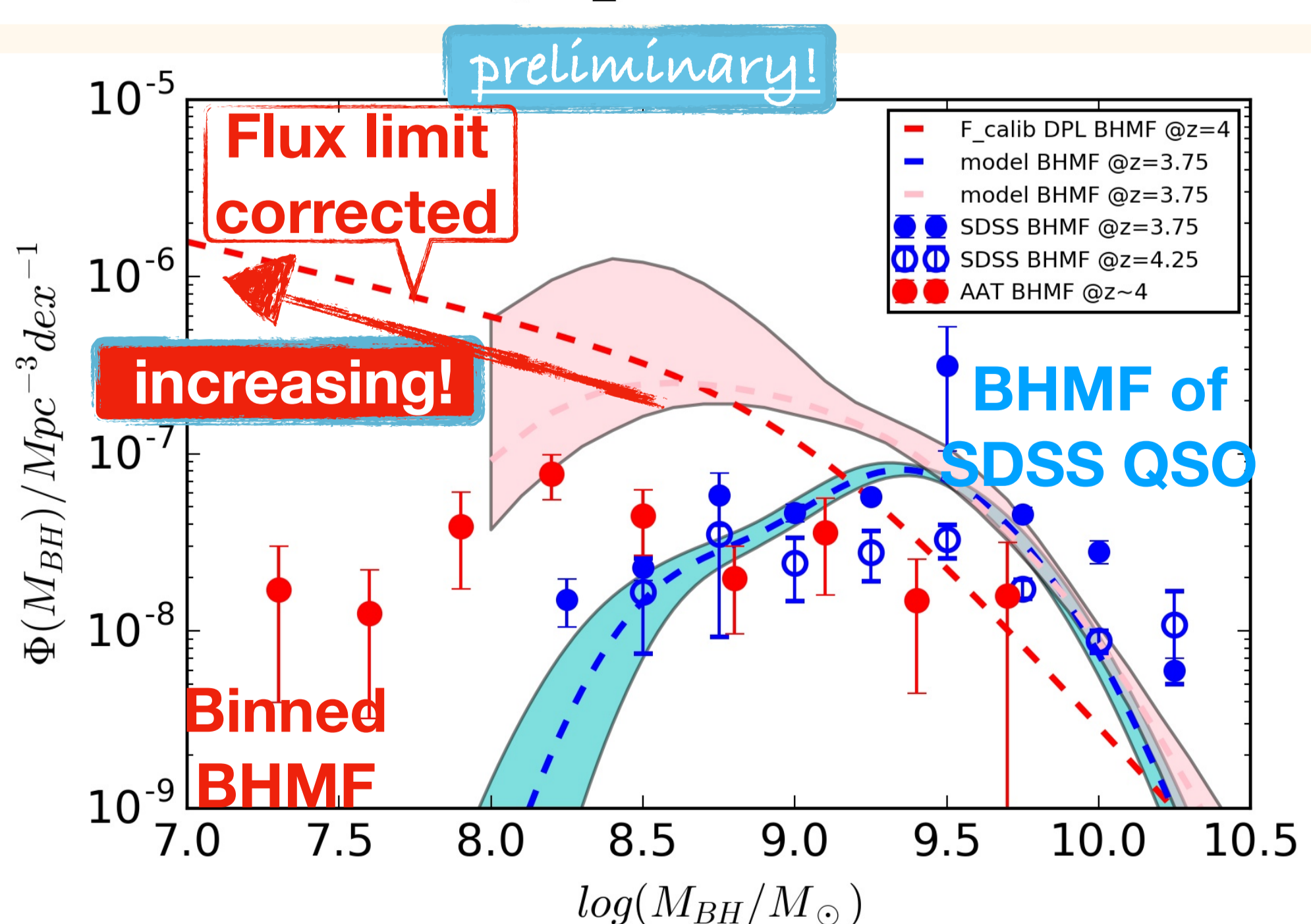
Black mass function & Eddington ration function

The spectroscopic follow-up of the **low-luminosity z=4 quasars** was carried out with the ***2dF-AAOmega spectrograph*** mounted on the 3.9m Anglo-Australian Telescope (AAT). Among the **84** allocated quasar candidates, **68** objects are identified to be quasars. We measure their mass and accretion rate through the **width** and **continuum** of the **CIV(1549)** emission line.

high-L QSOs at z~4 (Shen+09)
identified low-L QSOs at z~4 (CIV clearly detected)
all ientified low-L QSOs at z~4

1 **~1 order of magnitude fainter** than the current SDSS luminous quasar sample;

2 The mass peaks at 10^{8.3}, and the Eddington ratio peaks at 10^{-0.5};

3 A sub-sample of SMBHs are found to have **small accretion rate** (~0.01-0.1), which is typical in the local universe;

4 A small fraction of quasars are **beyond the Eddington limit**, which is consistent with high accretion rate found in the high-redshift quasars.

preliminary!

Flux limit corrected
increasing!
BHMF of SDSS QSO
Binned BHMF

F_calib DPL BHMF @z=4
model BHMF @z=3.75
SDSS BHMF @z=3.75
SDSS BHMF @z=4.25
AAT BHMF @z~4

preliminary!

ERDF @z=1.4
flatten!
Flux limit corrected
ERDF of SDSS QSO
Binned ERDF

SCH ERDF @z=1.4
F_calib SCH ERDF @z=4
model ERDF @z=3.75
AAT ERDF @z~4

high mass/**large** accretion rate end—> **consistent** with the luminous quasars

low mass/**small** accretion rate end
—> the BHMF **increases significantly**
—> the ERDF keeps **constant**, which is **similar to the local universe**

better constraints for checking evolution, especially at less-massive end

Future...

Construct **the semi-analytic model** of galaxy and quasar evolution with the state-of-the-art N-body simulation—v2GC (Ishiyama et al. 2015);

Investigate how **the low-luminosity z=4 quasars** are associated with their **host galaxies/"absent" surrounding galaxies**.

A z~4 quasar pair in a dense region.

z=3.795
z=3.796

density count
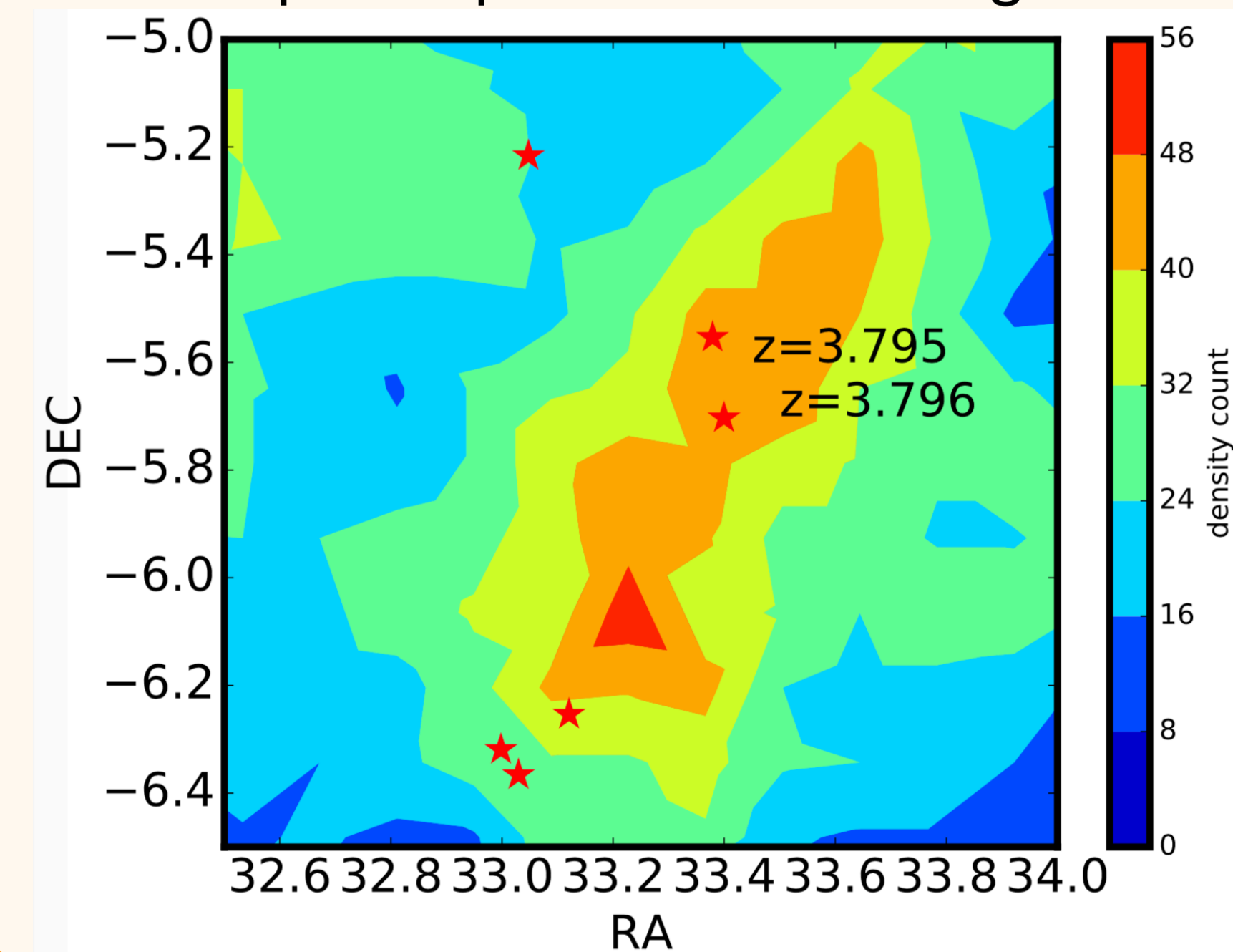
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See more details in our paper!