Tracing the accretion growth history of super massive black holes “monsters”

with wide-field surveys

Masayuki Akiyama (Tohoku Univ.)

Acknowledgement

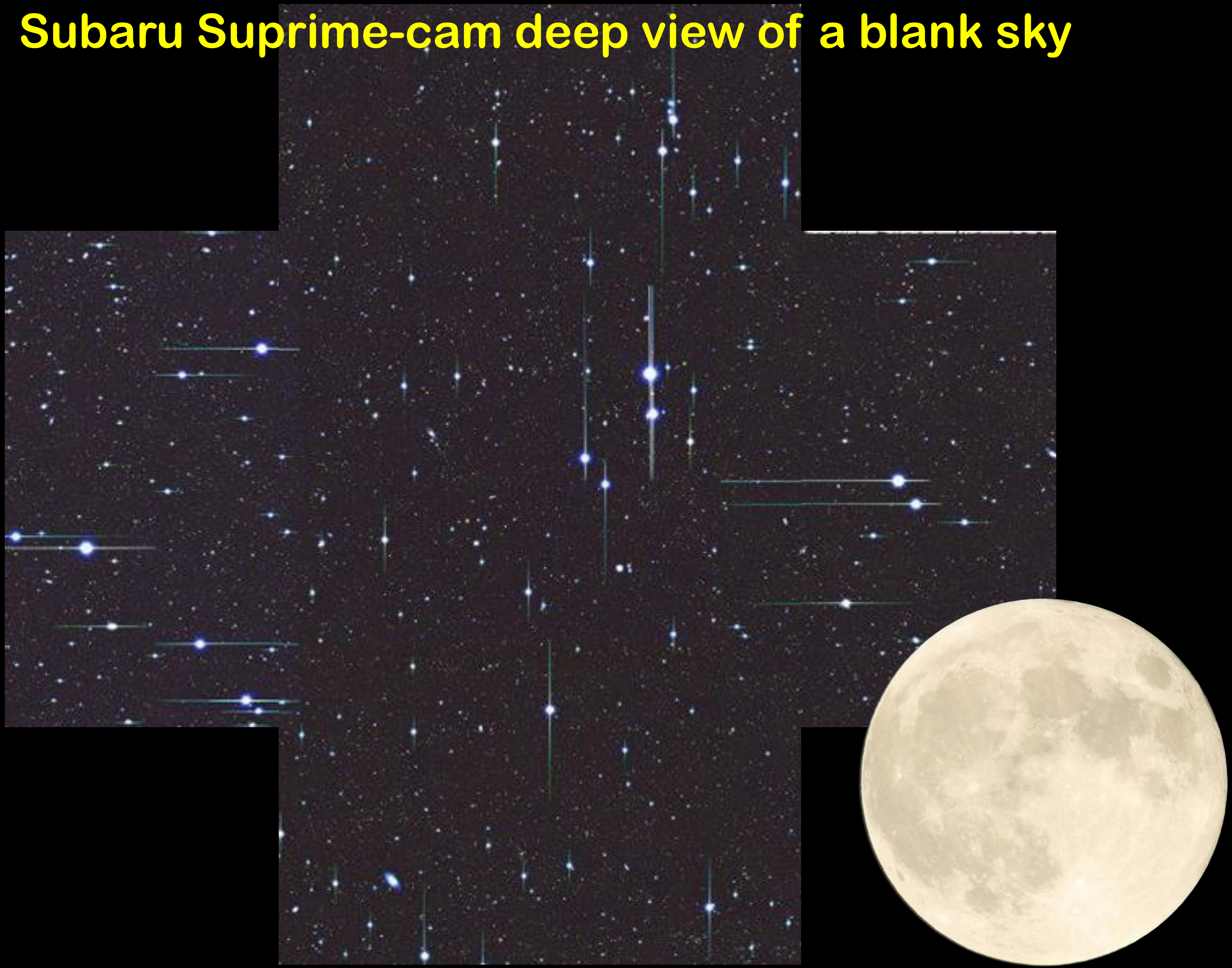
When I moved to Subaru 1998, telescope mirror just arrived to the summit,

everyone was so busy to complete the construction except me (a free Ph.D. student)

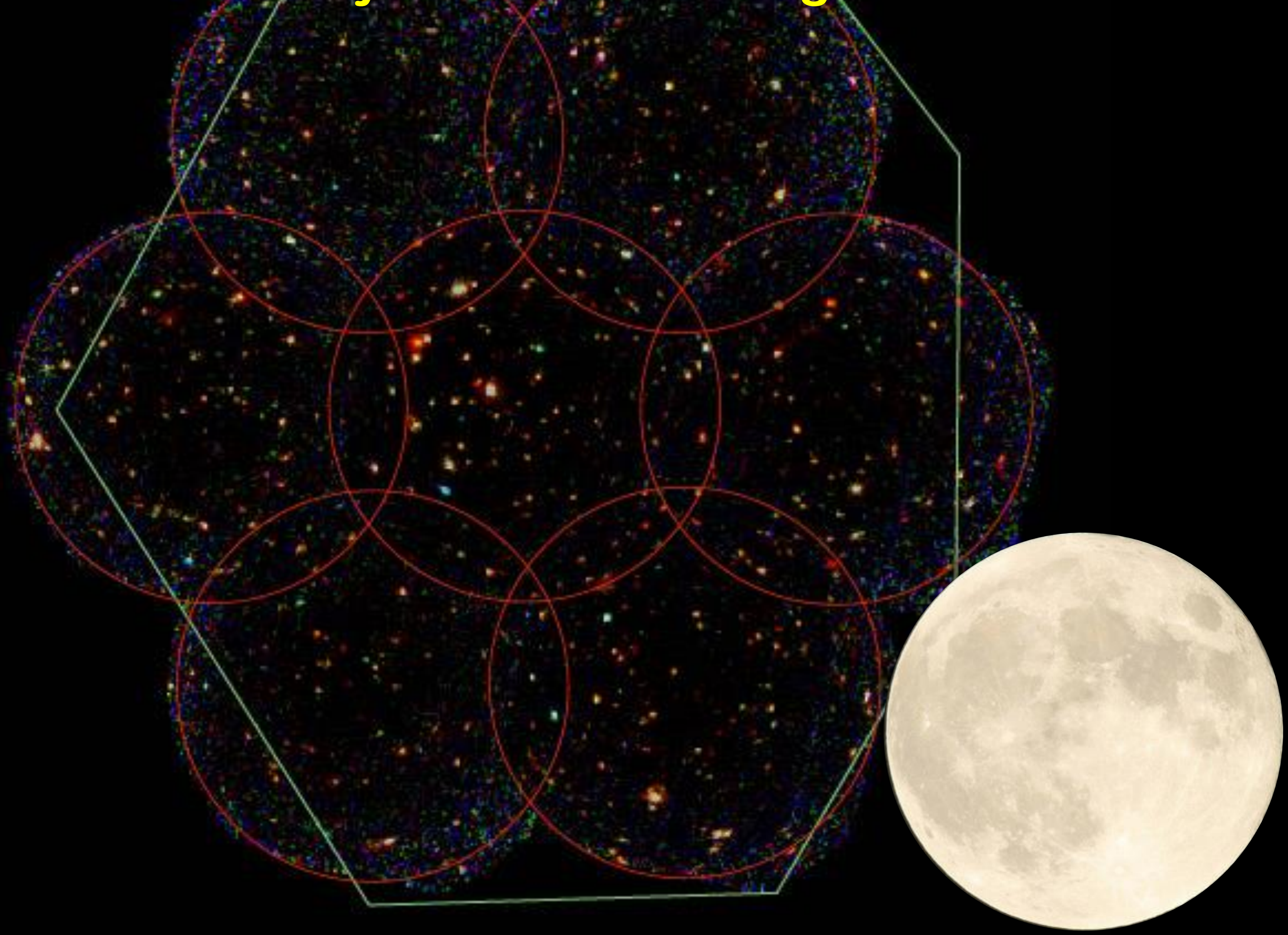
I would like to thank Norio Kaifu san and staff members who kindly welcomed me to the observatory.

I hope young students enjoy the research life in the observatory.

Subaru Suprime-cam deep view of a blank sky

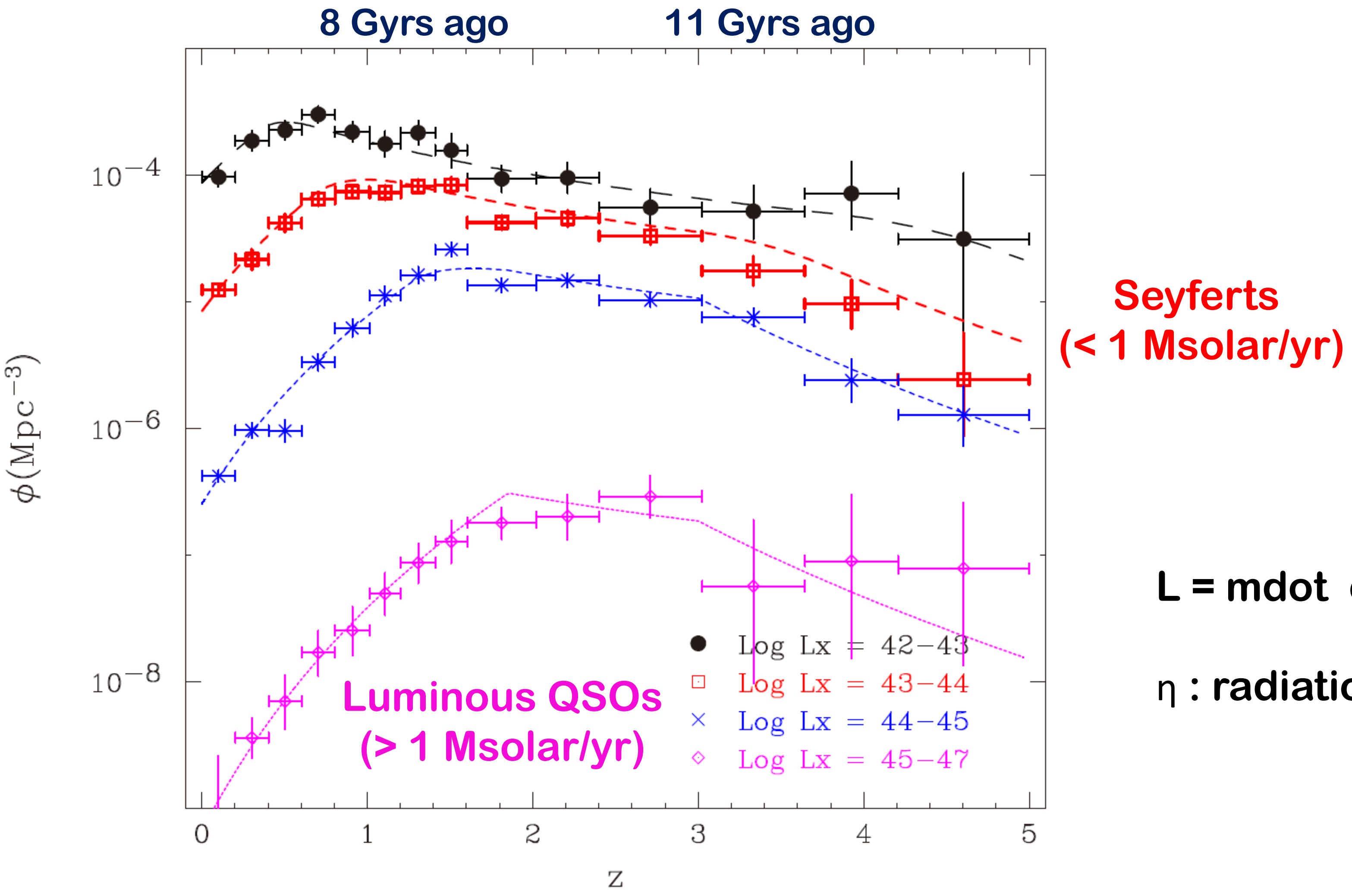


Wide and deep X-ray view of the field
X-ray emission from many AGNs = accreting monster black holes



Cosmological evolution of QSO/AGN number density

The number density evolution indicates the cosmological accretion growth history of the super massive black holes.

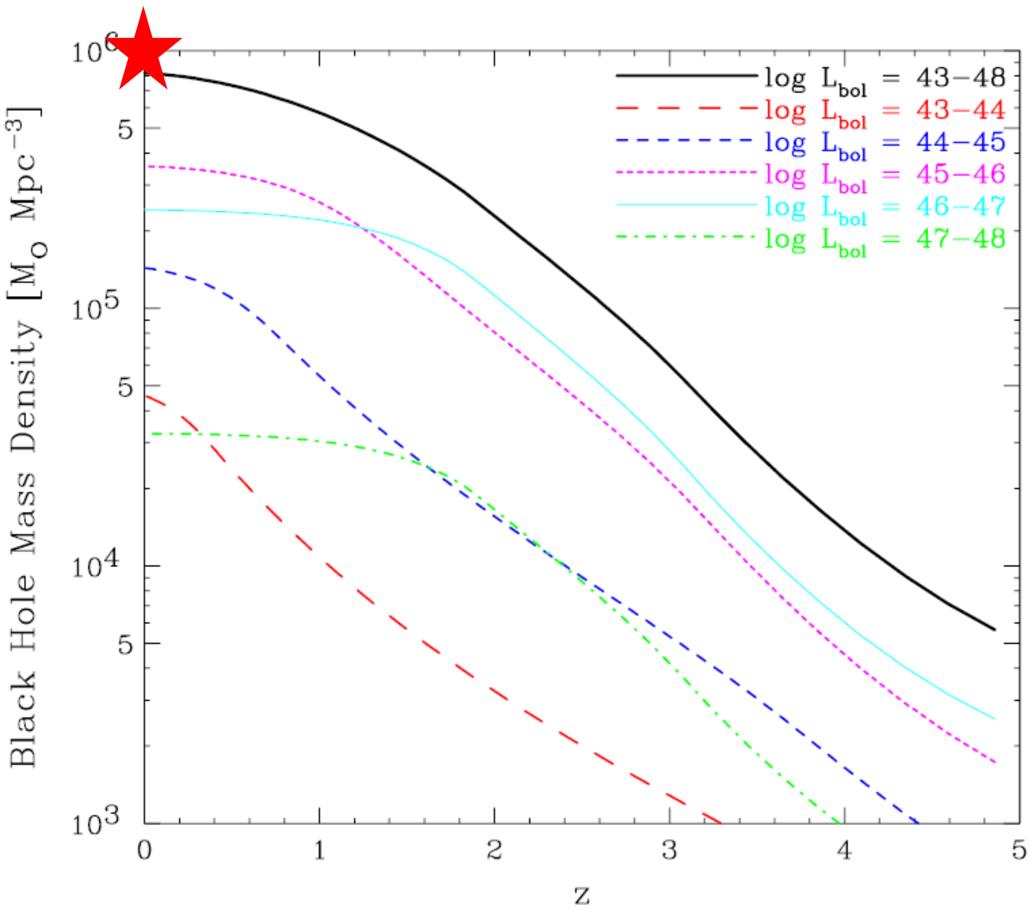


$L = \dot{m}\, c^2\, \eta$ (L = mdot c^2 η)

η : radiation efficiency

Ueda, Akiyama, et al. 2014

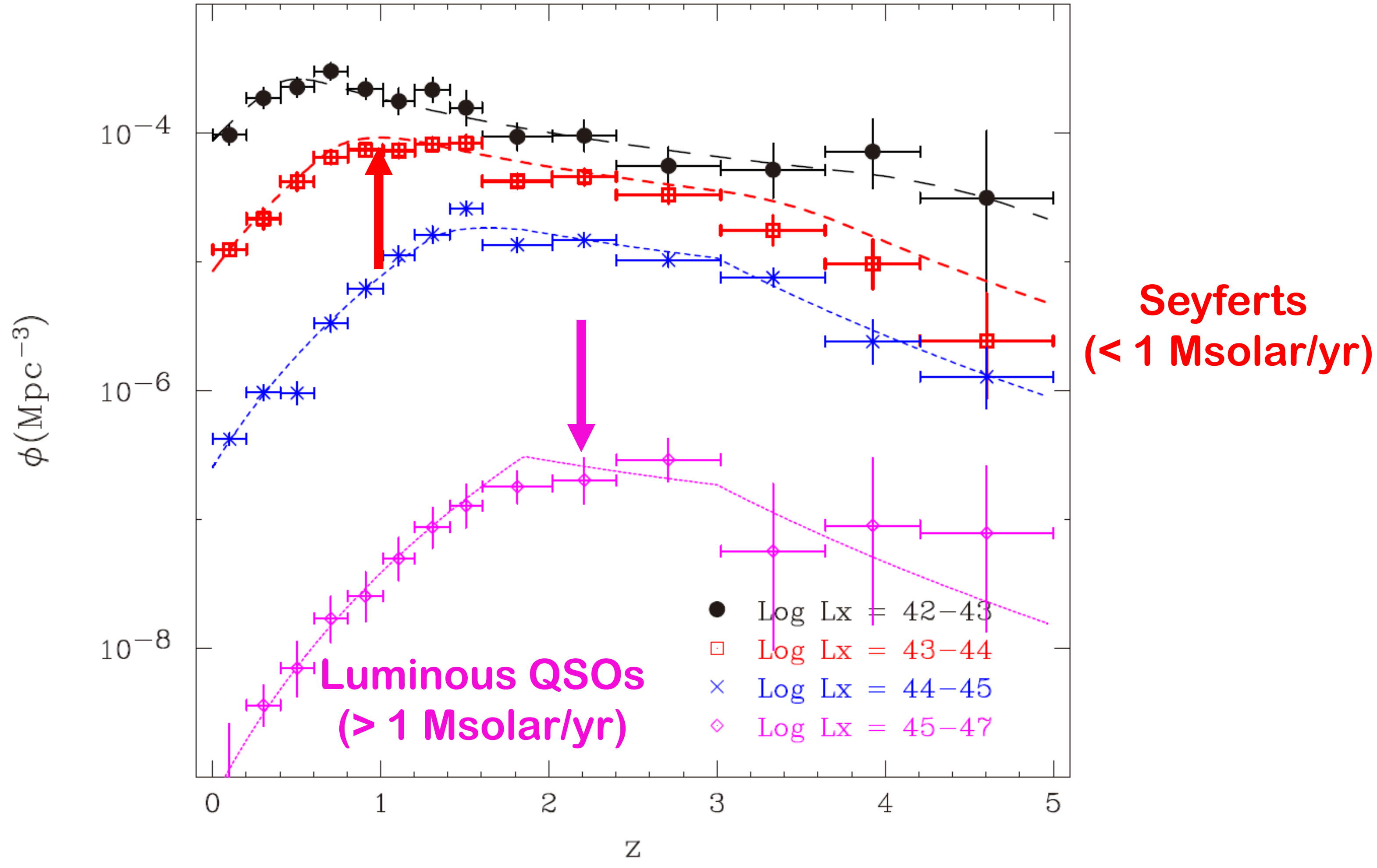
If we integrate all of the accretion ~ super massive black hole mass density around us [Soltan's argument (1982)]



Ueda, MA, et al. 2014
See Yu & Tremeine 2002, Marconi 2004

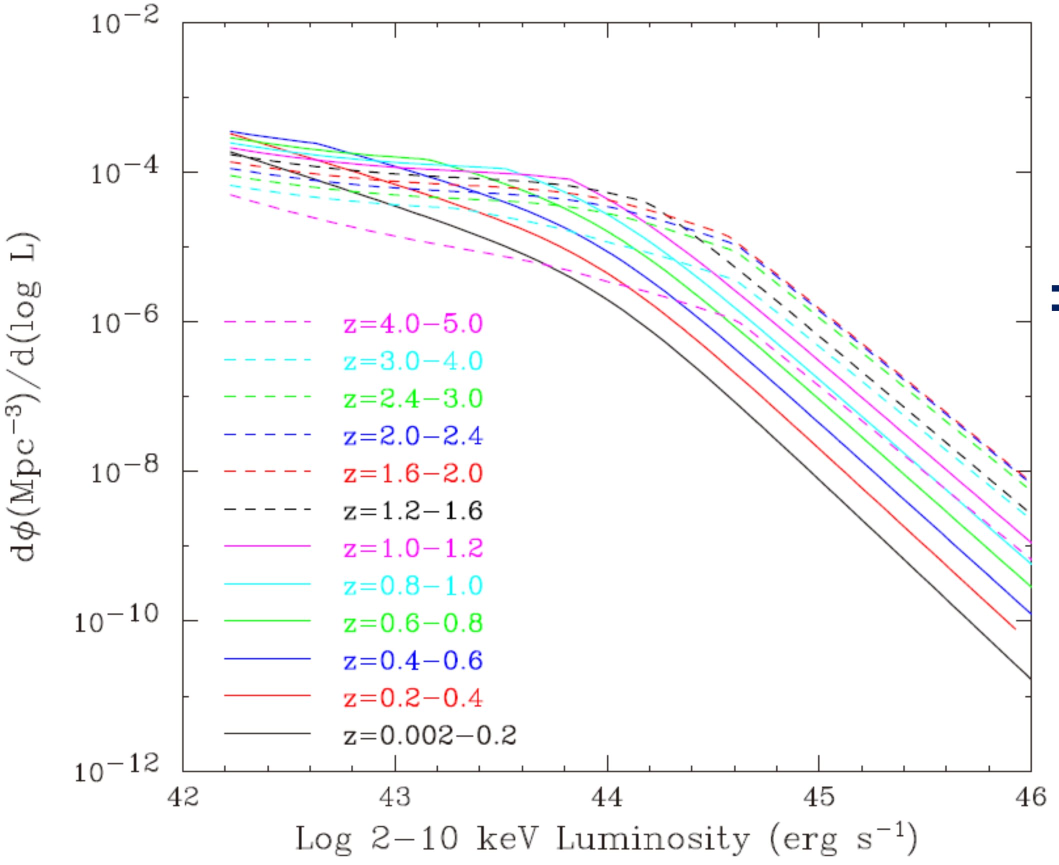
“Down-sizing” evolution of QSO/AGN number density

Unti-hierarchical assembly of structure ?



Ueda, Akiyama, et al. 2014

“Down-sizing” evolution of QSO/AGN luminosity function



Ueda, Akiyama, et al. 2014

=

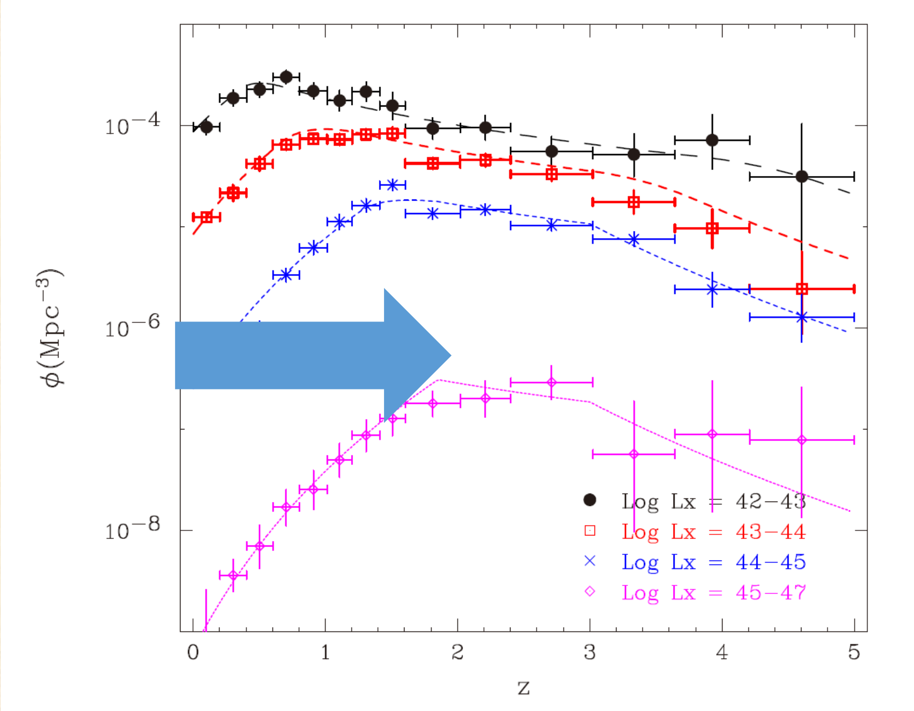
accreting SMBH Mass Func.

⊗

Eddinton Ratio Dist. Func.

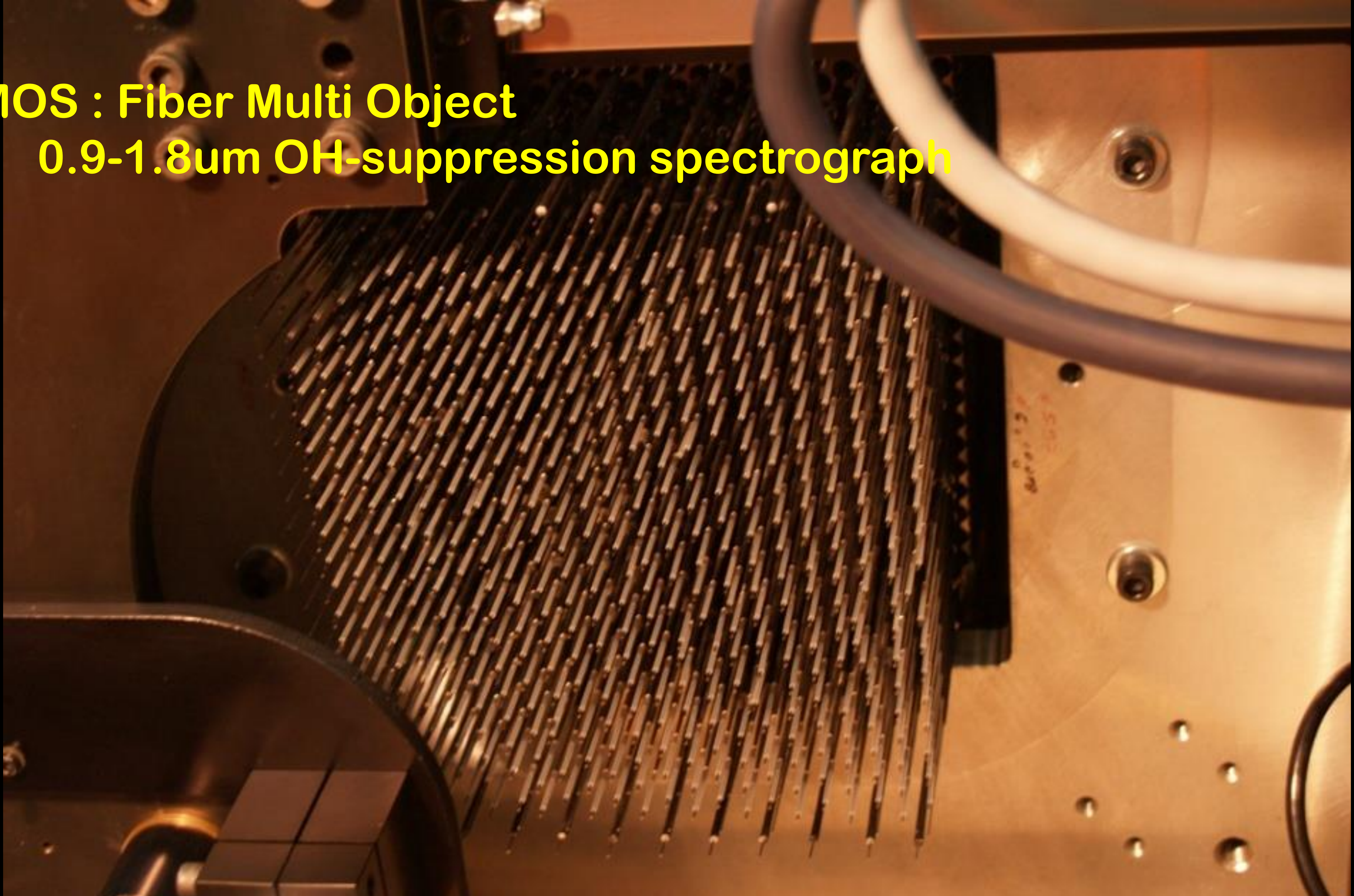
(Ratio to the Eddington limited accretion

~1/mass doubling time scale)

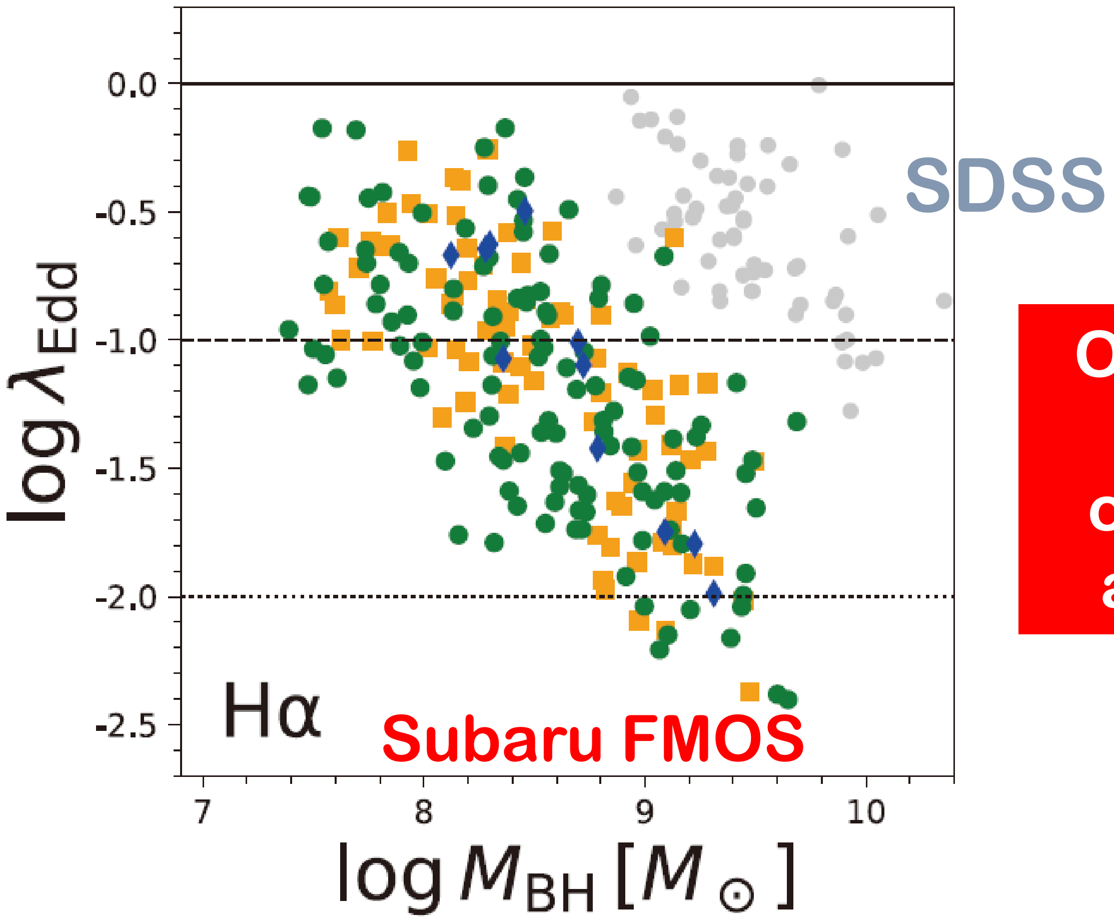


PART I. BACK TO THE PEAK OF THE MONSTERS

FMOS : Fiber Multi Object
0.9-1.8um OH-suppression spectrograph



Black Hole Mass and Eddington Ratio distribution of Broad-line AGNs @ peak of the monsters (z=1-2)

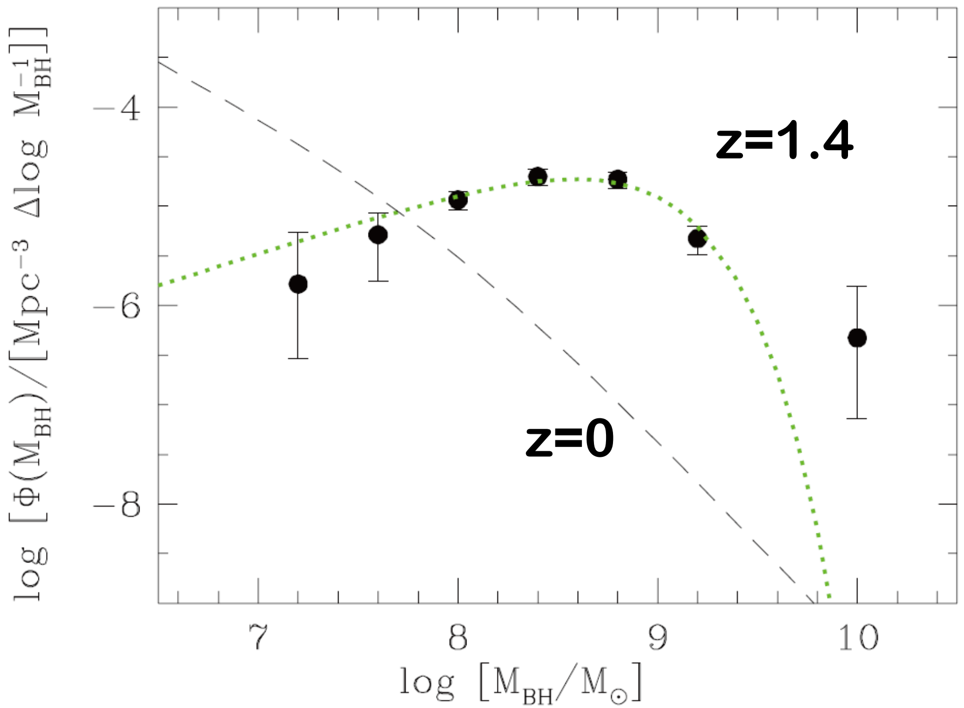


Objects with lower luminosity = typical objects in the era cover both of the lower MBH and Eddington ratio regions

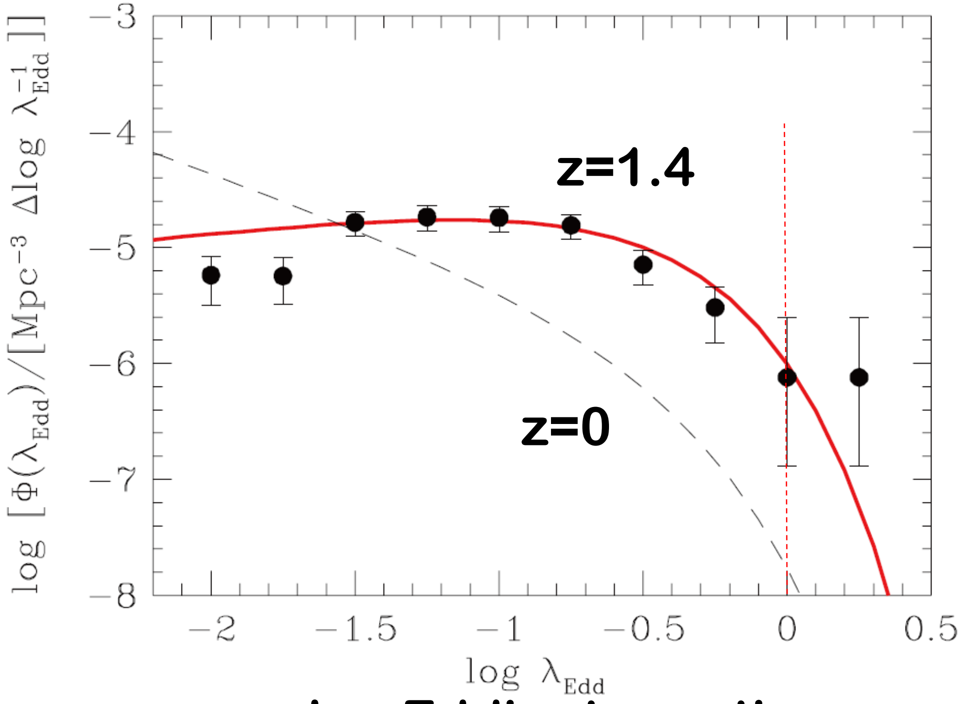
Schulze, MA, et al. 2018
See also
Nobuta, MA, et al. 2012, Matsuoka et al. 2013, Suh et al. 2015

Cosmological evolution of active BHMF and ERDF to the peak of quasar activity

"Down-sizing" trend in the luminosity function caused by the "down-sizing" in the active BH mass and decline in the Eddington-ratio distribution function.
The fraction of Eddington-limited accretion is higher in the peak of the accretion activity.
What regulate the decline of the accretion activity ?



log MBH

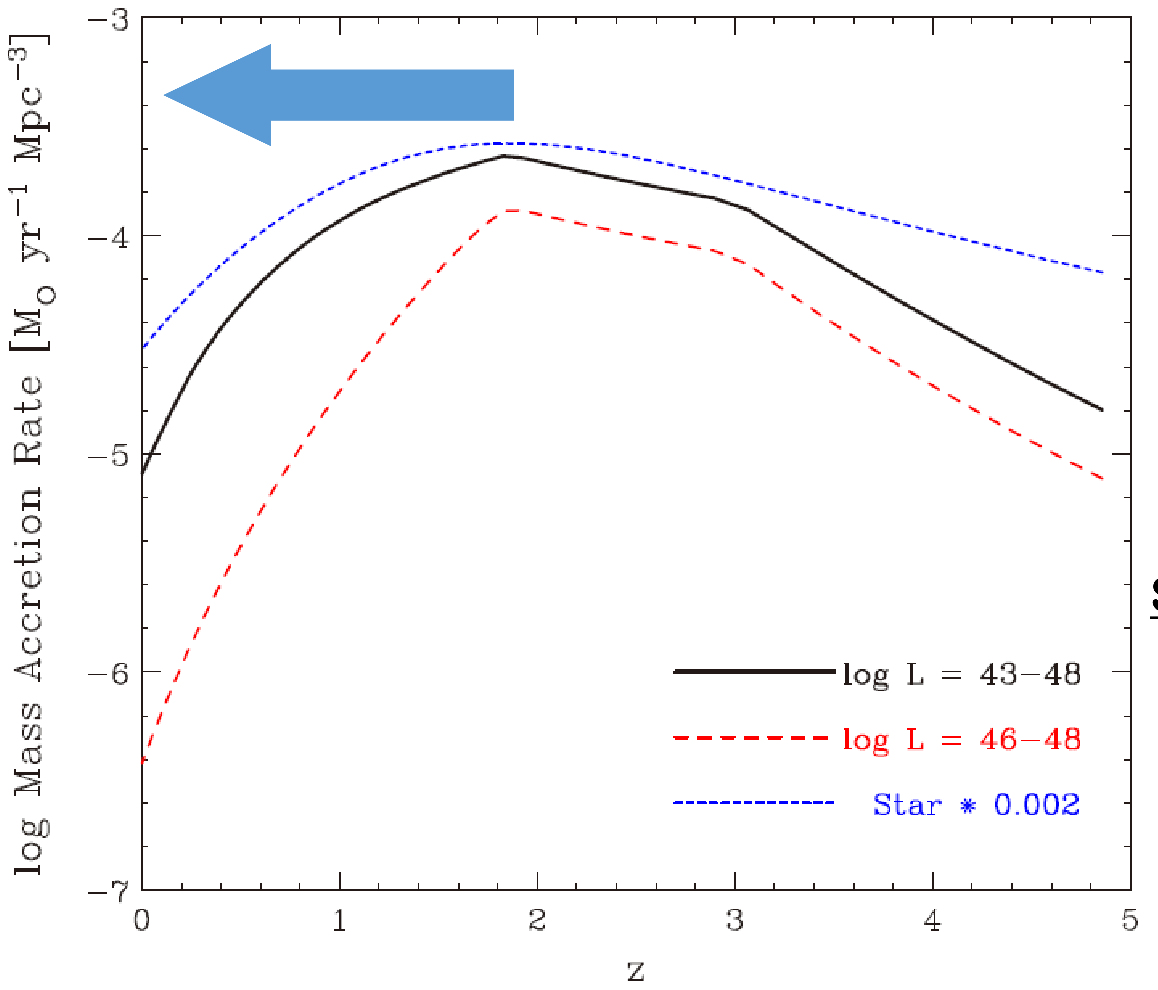


log Eddington ratio

Nobuta, MA, et al. 2012
See also Schulze et al. 2015

Decline of the accretion rate and SFR

Cosmic accretion rate density to SMBHs (black) shows similar cosmological decline to the star formation rate density of galaxies (blue).



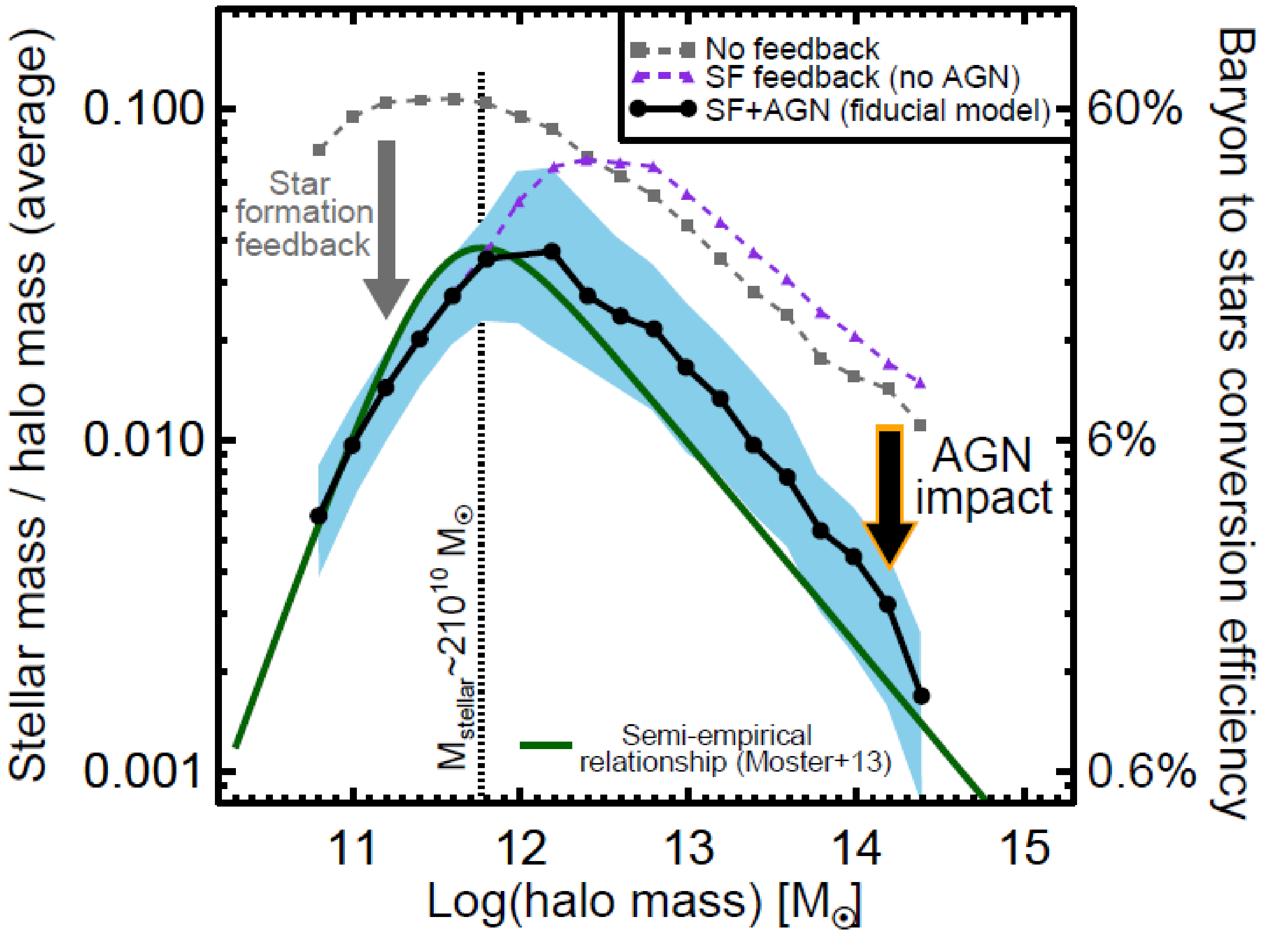
Ueda 2015

<u>AGN accretion</u>
Ueda, MA, et al, 2014, ApJ, 786, 104

<u>SFR density</u>
Madau&Dickinson 2014 ARAA, 52, 415

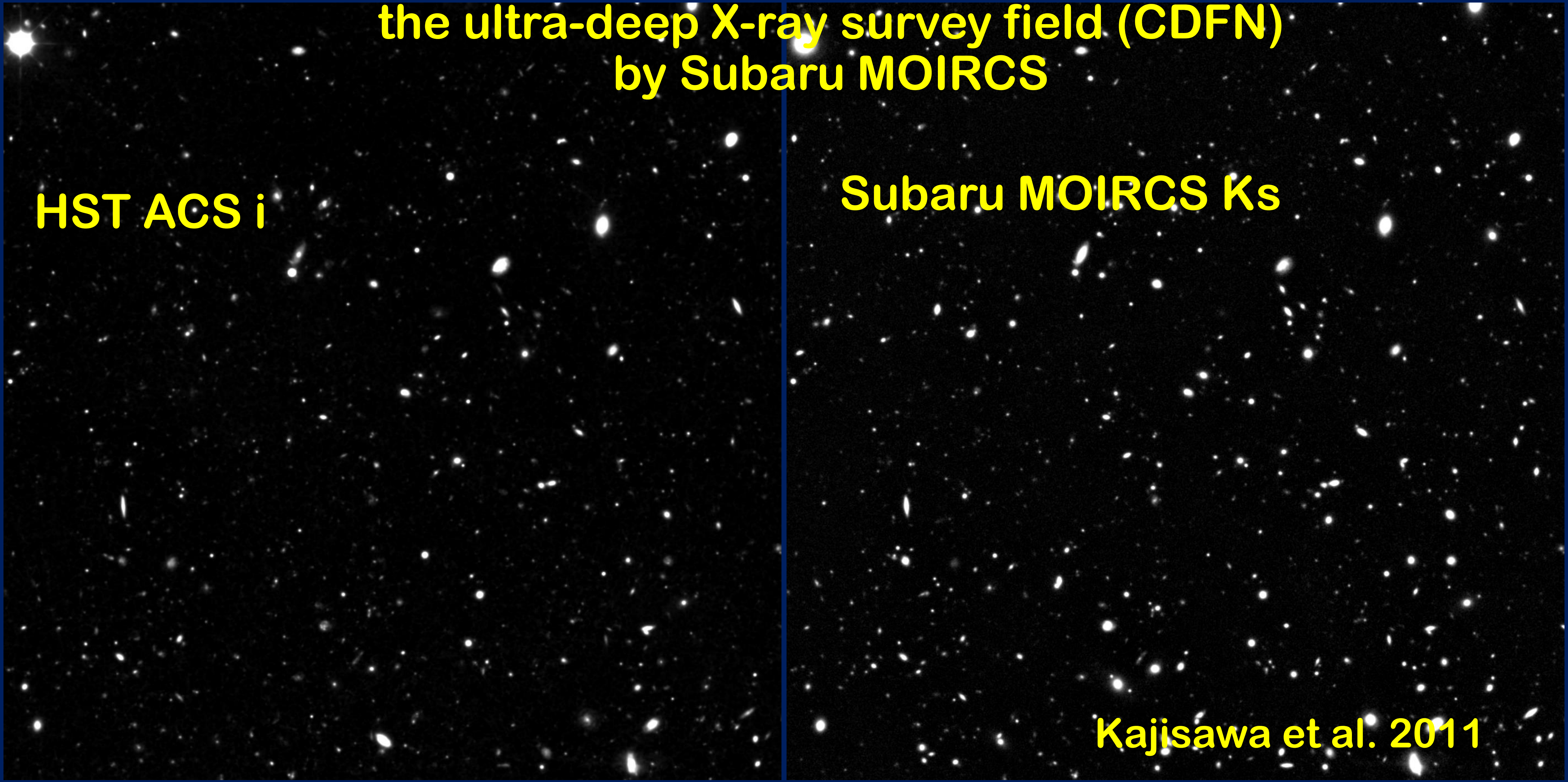
Quenching of star formation activity by AGNs ?

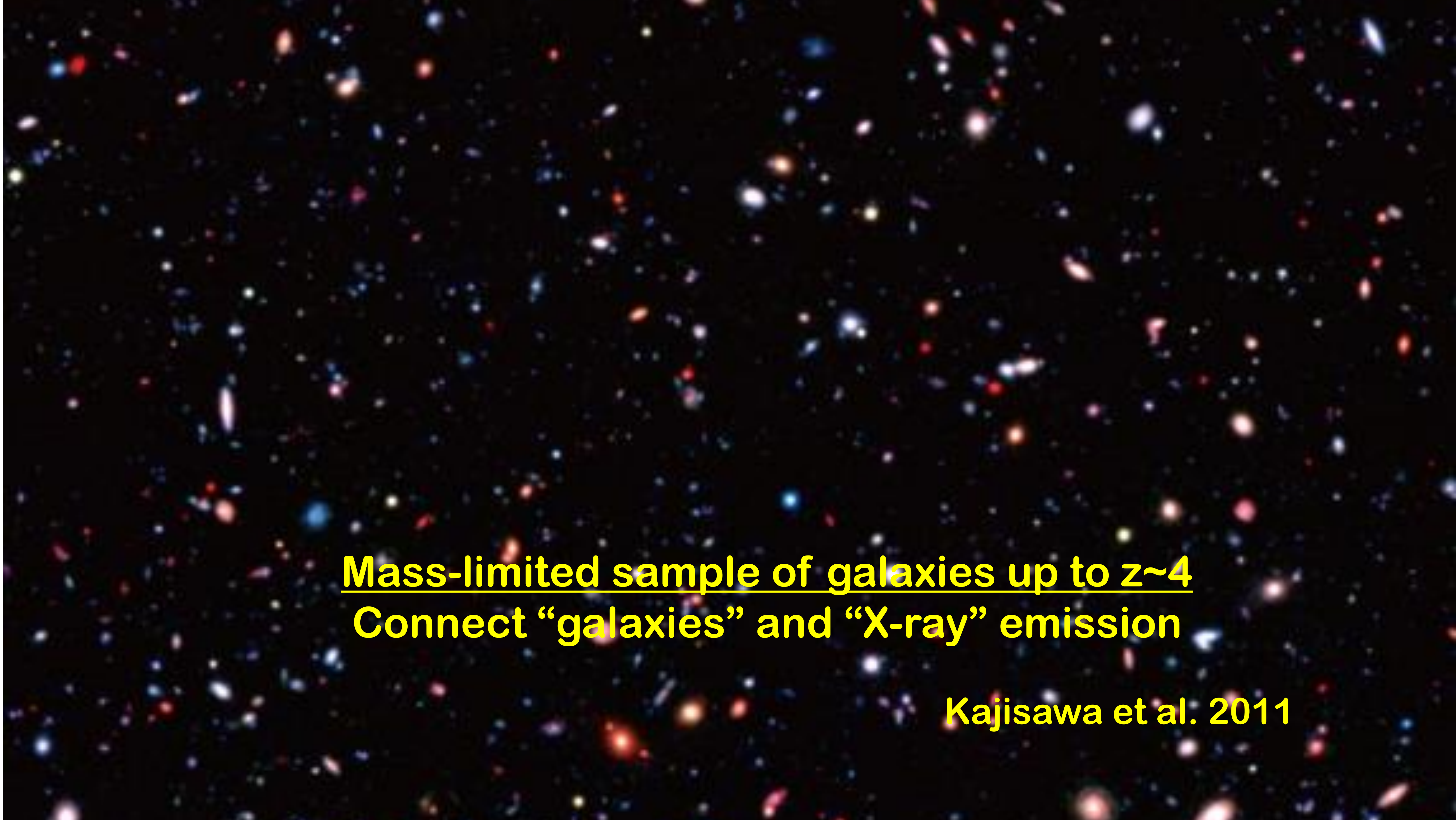
- **Comparison between the observed star formation efficiency in the dark matter halos and simulated one suggests feed back from SN and QSO- / radio(-jet)- mode feedback effects are necessary to explain the observed efficiency.**



Harrison 2017 review
Harrison's talk

Ultra-deep and wide NIR image of the ultra-deep X-ray survey field (CDFN) by Subaru MOIRCS





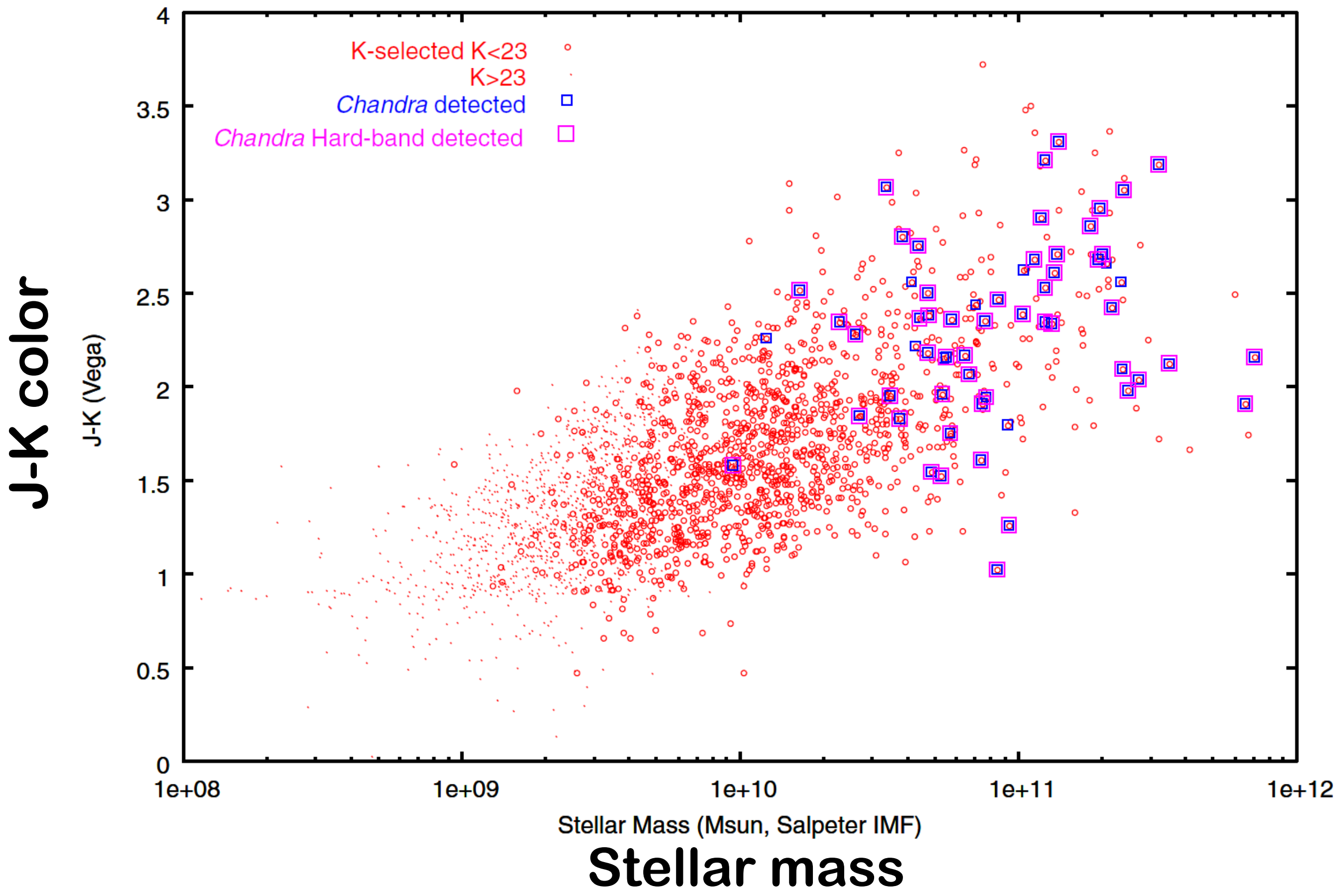
Mass-limited sample of galaxies up to z~4

Connect "galaxies" and "X-ray" emission

Kajisawa et al. 2011

“Most” of the massive galaxies experienced AGN phase

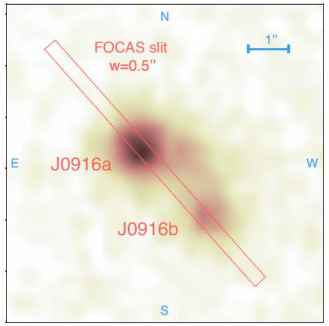
- 33% of massive (>10^{11}Msun) galaxies at z=2-4 are detected in X-ray (Lx>10^{42} erg s^{-1}, mostly Seyferts and QSOs)



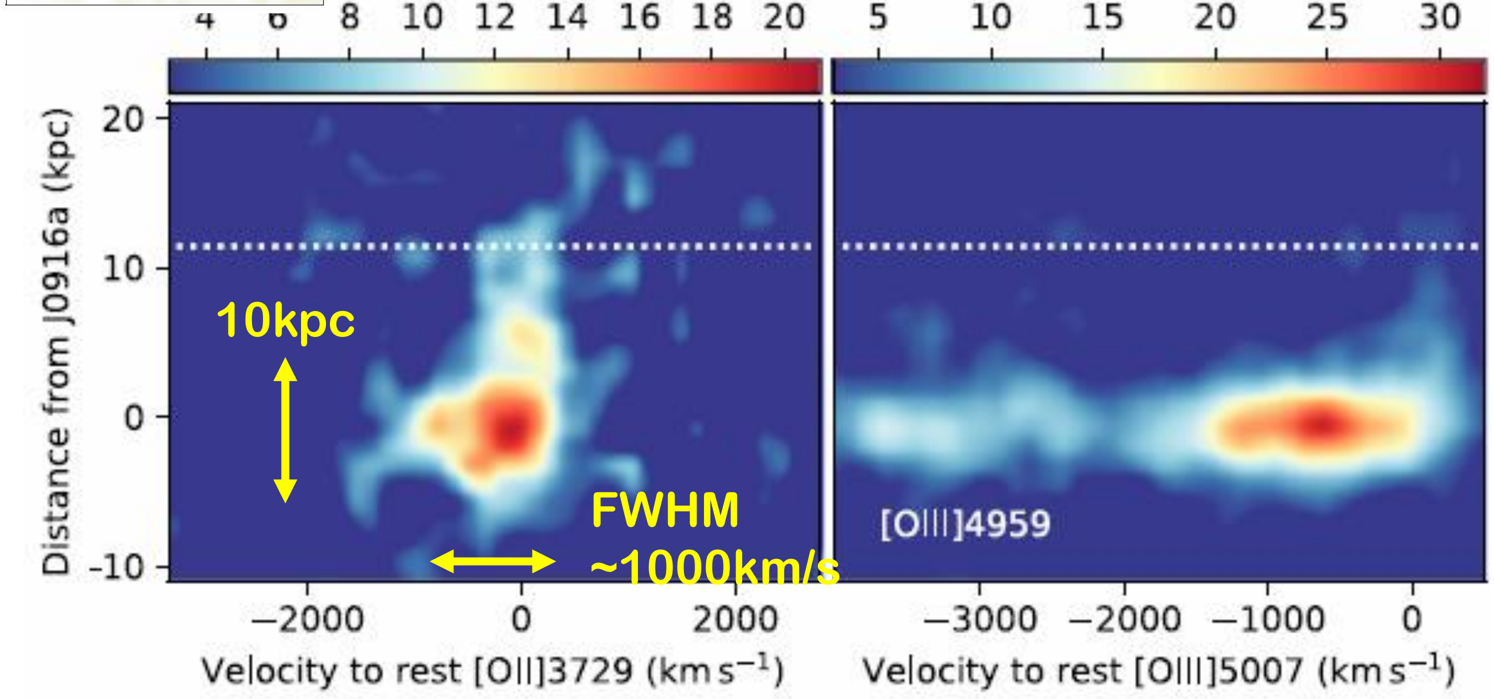
Yamada et al. 2009

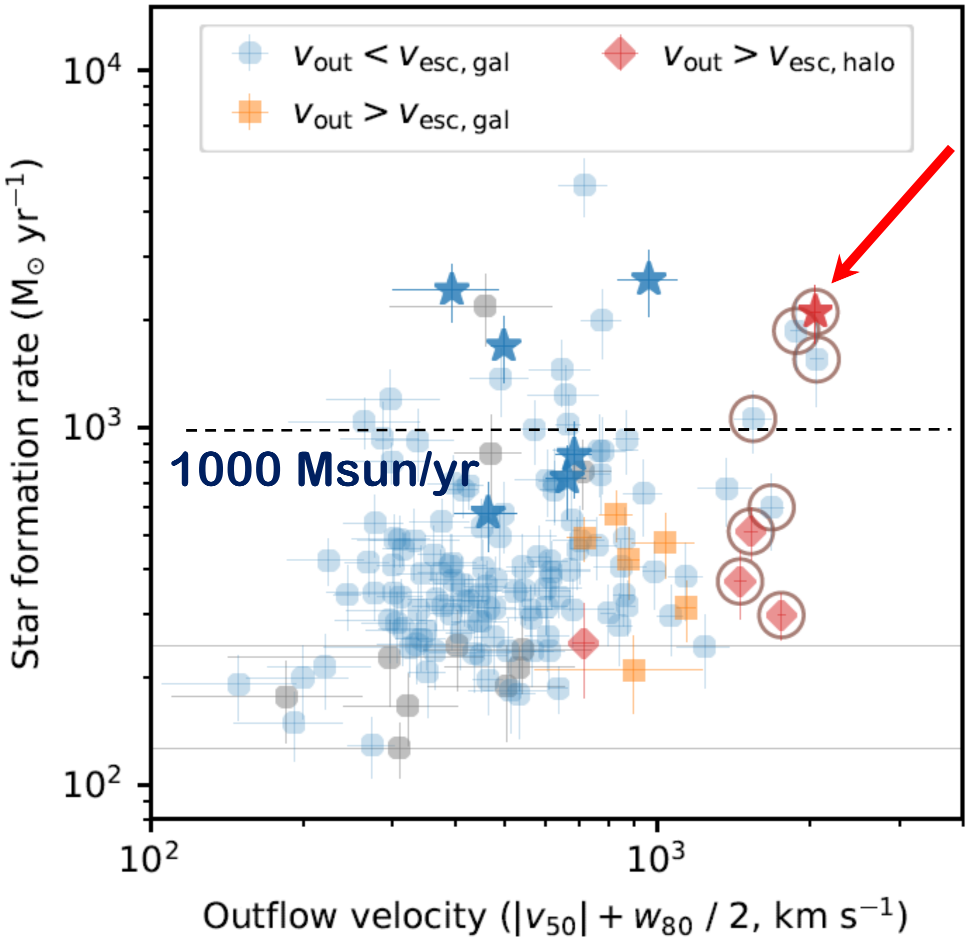
Does AGN quenching of star formation really work ?

- Subaru FOCAS observation of an optically-faint AKARI FIR source reveals a co-existence of strong galaxy-scale outflow and extreme starburst in a ULIRG at z~0.5.



Chen, MA, et al. 2018
Chen, MA, et al. 2019, submitted arXiv:1911.04095

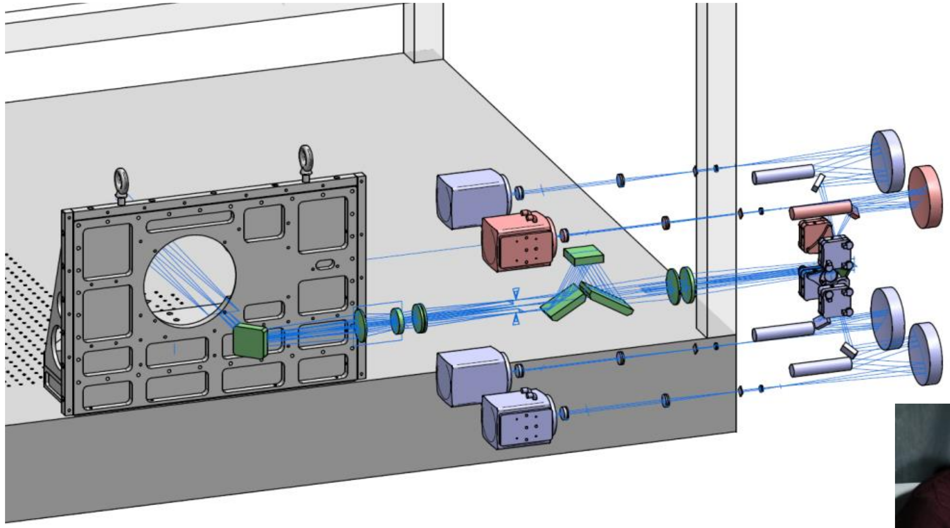


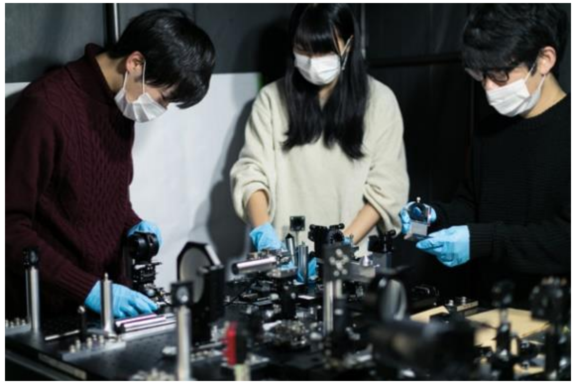


ULTIMATE-START

Explore the physical mechanism behind the co-existence with optical high-spatial IFU observation

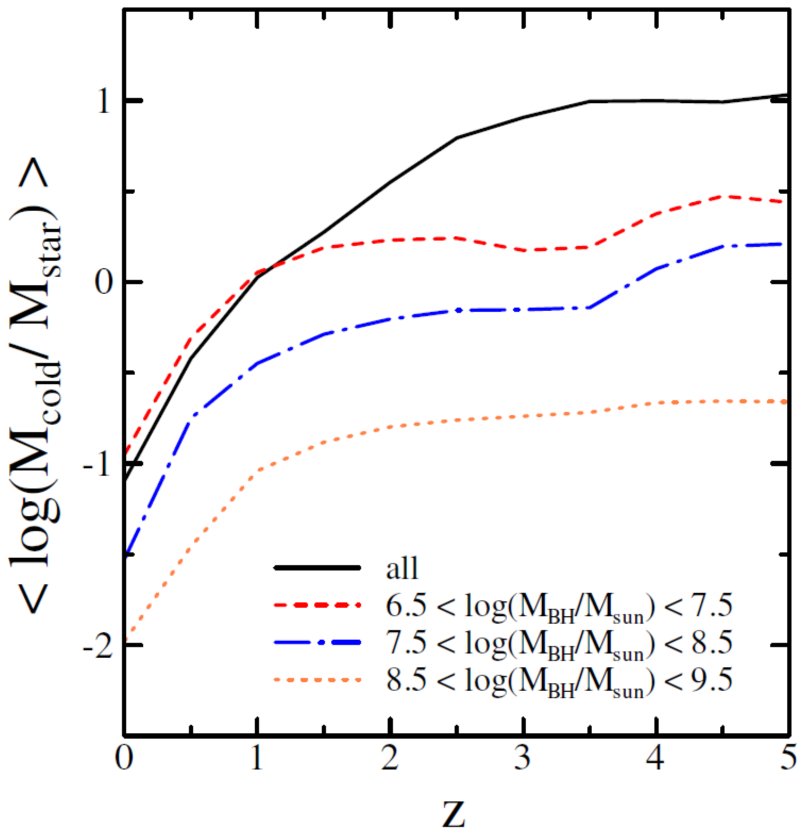
- Subaru Tomography Adaptive Optics experiment develops multi-laser guide star laser tomography AO system behind the existing AO188 and feed 3DII optical IFU spectrograph.

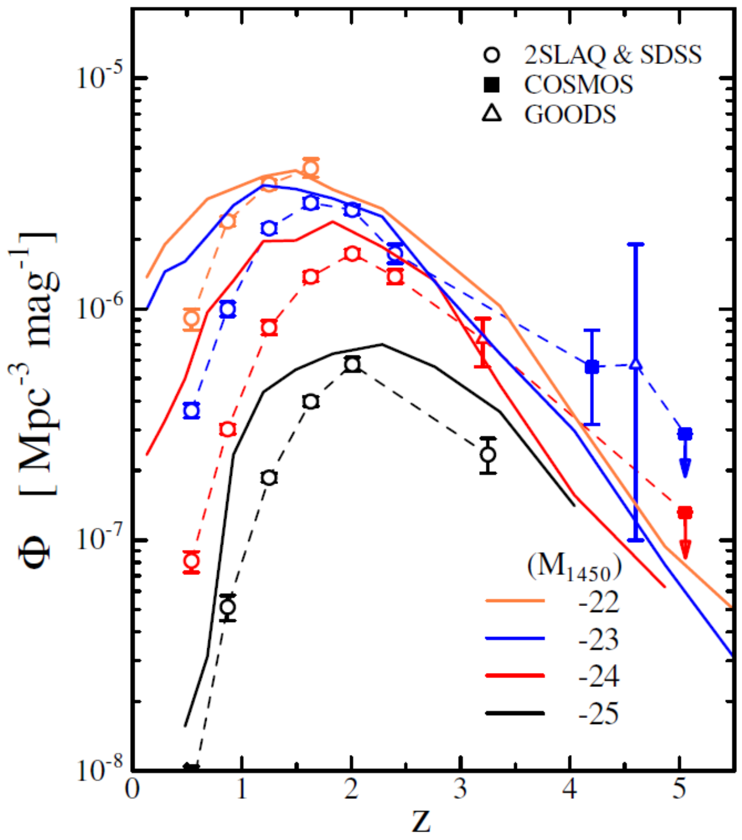




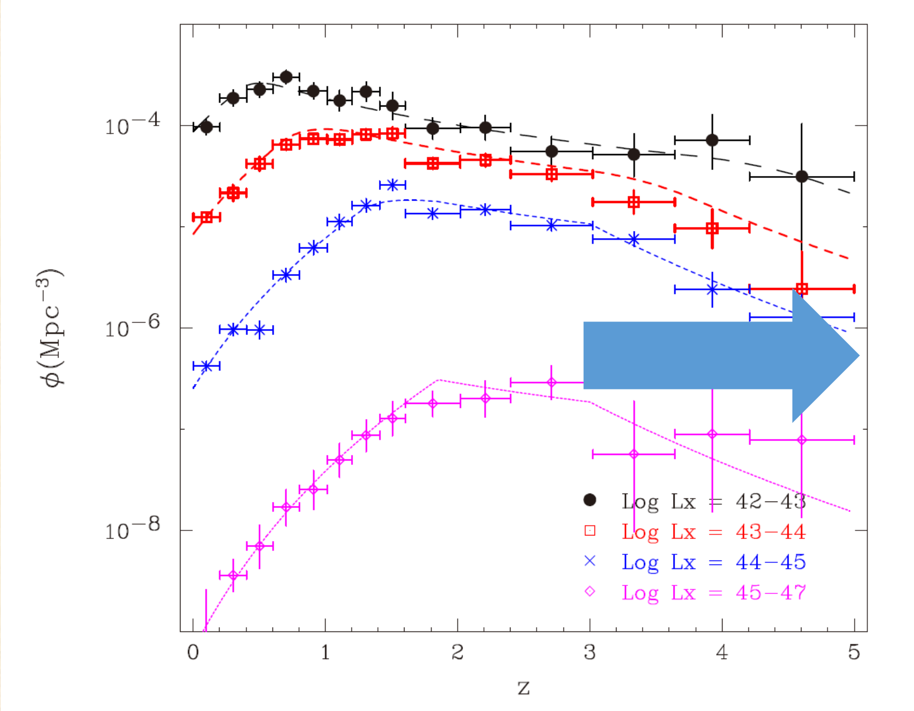
Decline with "down-sizing" can be related to overall consumption of "cold gas"

Semi-analytic modeling of AGN(/galaxy) population can reproduce the "down-sizing" trend, under condition that consumption of cold gas and shutdown of supply decrease the fraction of gas-rich "wet" mergers.





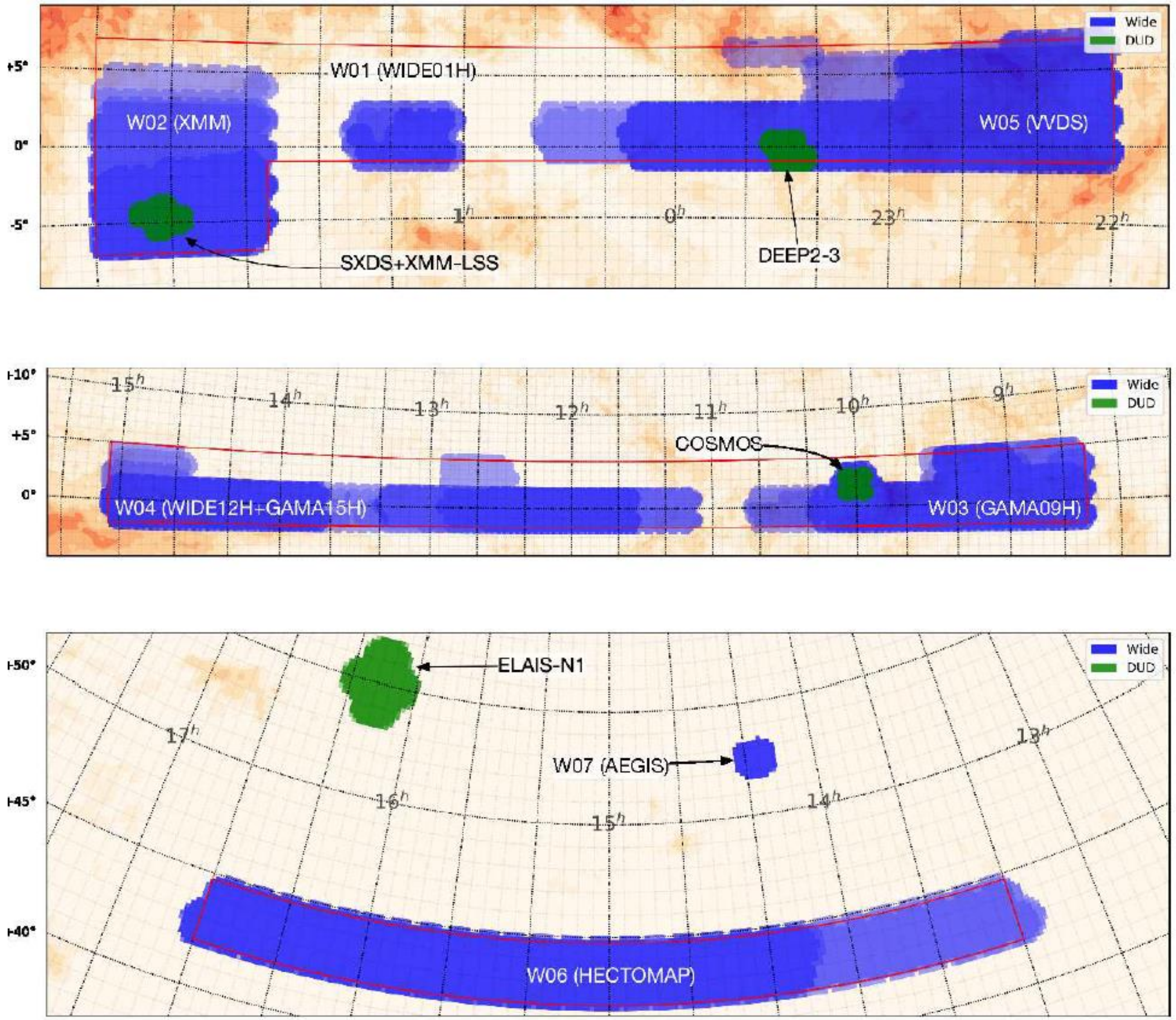
Enoki et al. 2014, see also Shirakata et al. 2019, Harrison's talk.



PART 2. EARLY GROWTH OF THE MONSTERS BEYOND THE PEAK

Subaru Hyper Suprime Cam wide imaging survey

SXDS

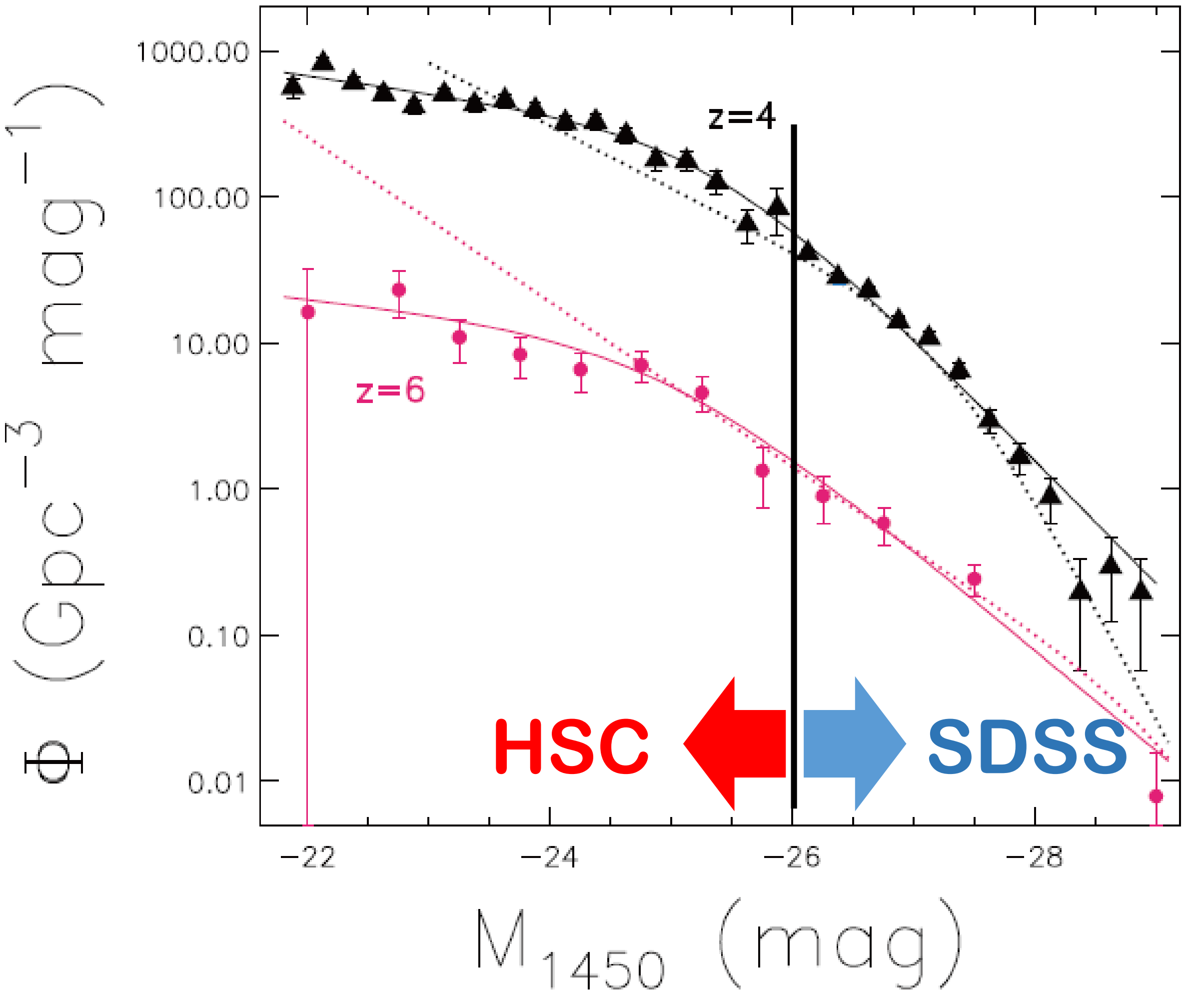


Wide:
1,400 sq.deg
5 broad-bands
5 sigma :
g=26.8mag
r=26.4mag
i=26.2mag
z=25.4mag
y=24.7mag

Aihara et al. 2019

HSC surveys on quasars in the early universe

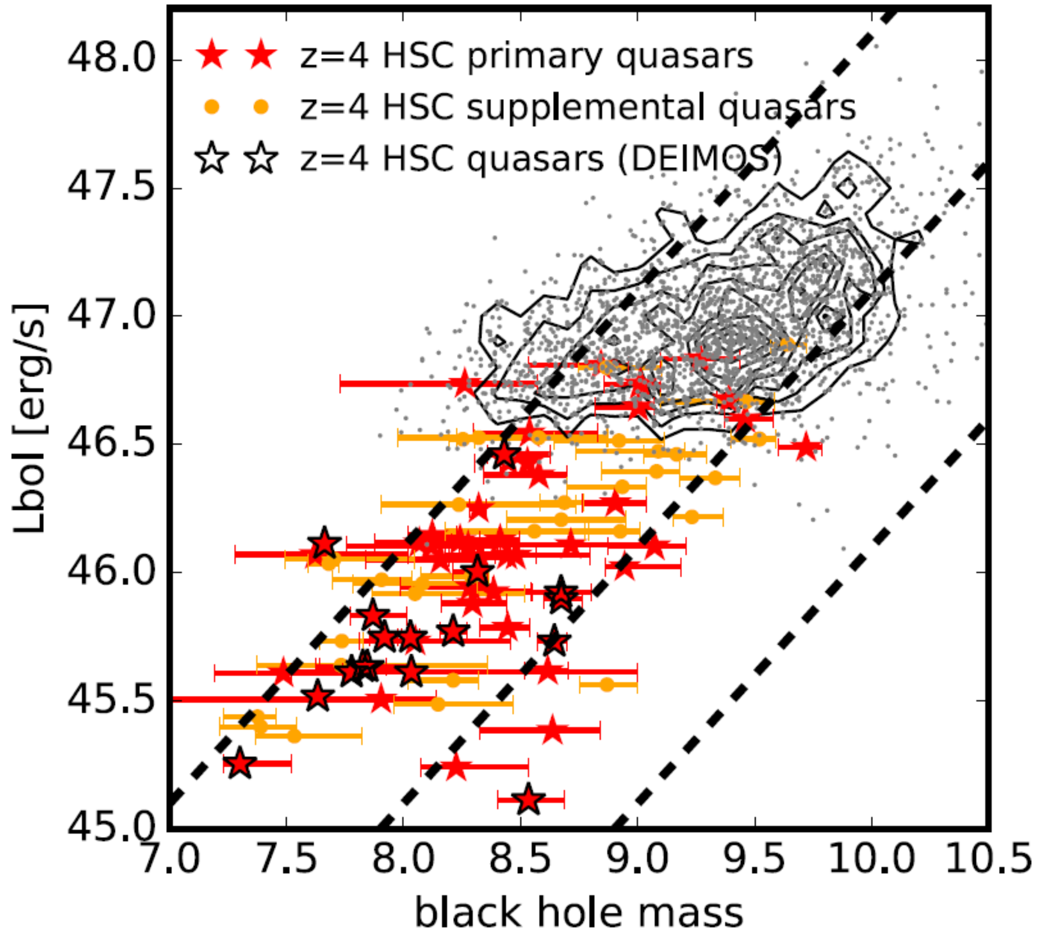
HSC probes "knee" of the luminosity function. HSC QSOs are typical QSOs in those redshift range, and they show flat faint end slope.



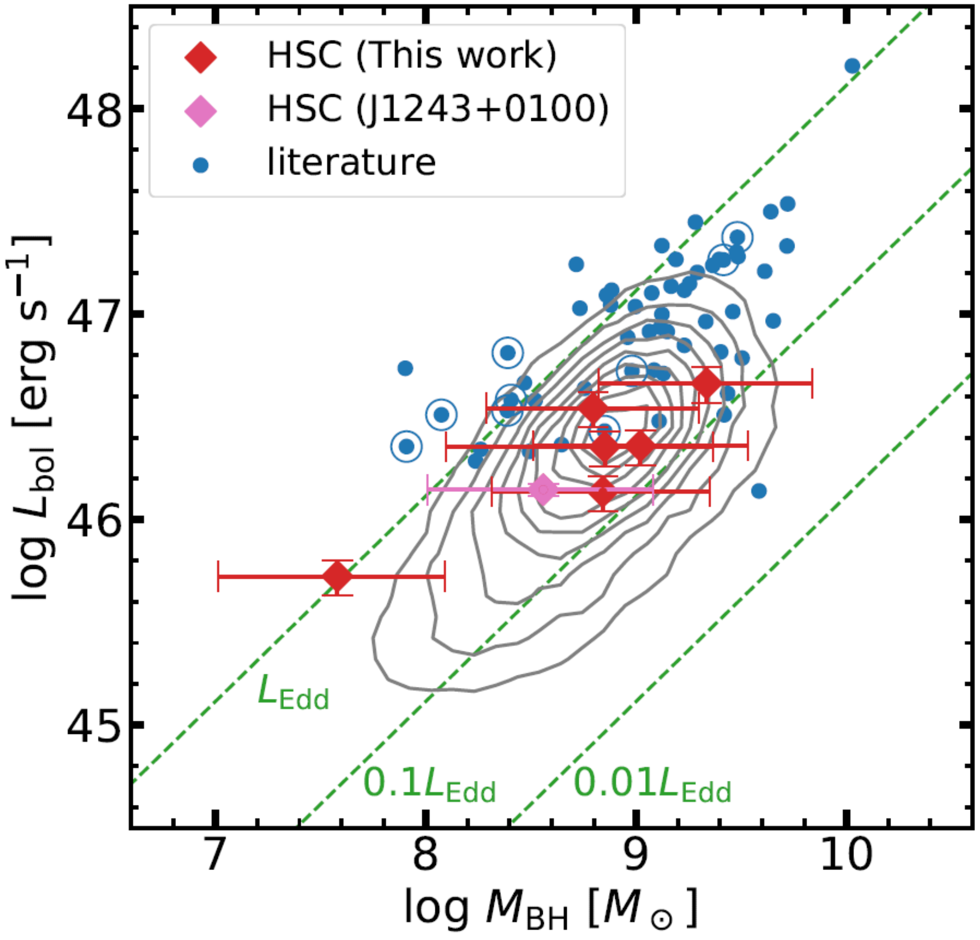
SHELLQs:
Matsuoka et al. 2018

z~4: Akiyama et al. 2018

Black hole mass of the QSOs at z=4 and z=6



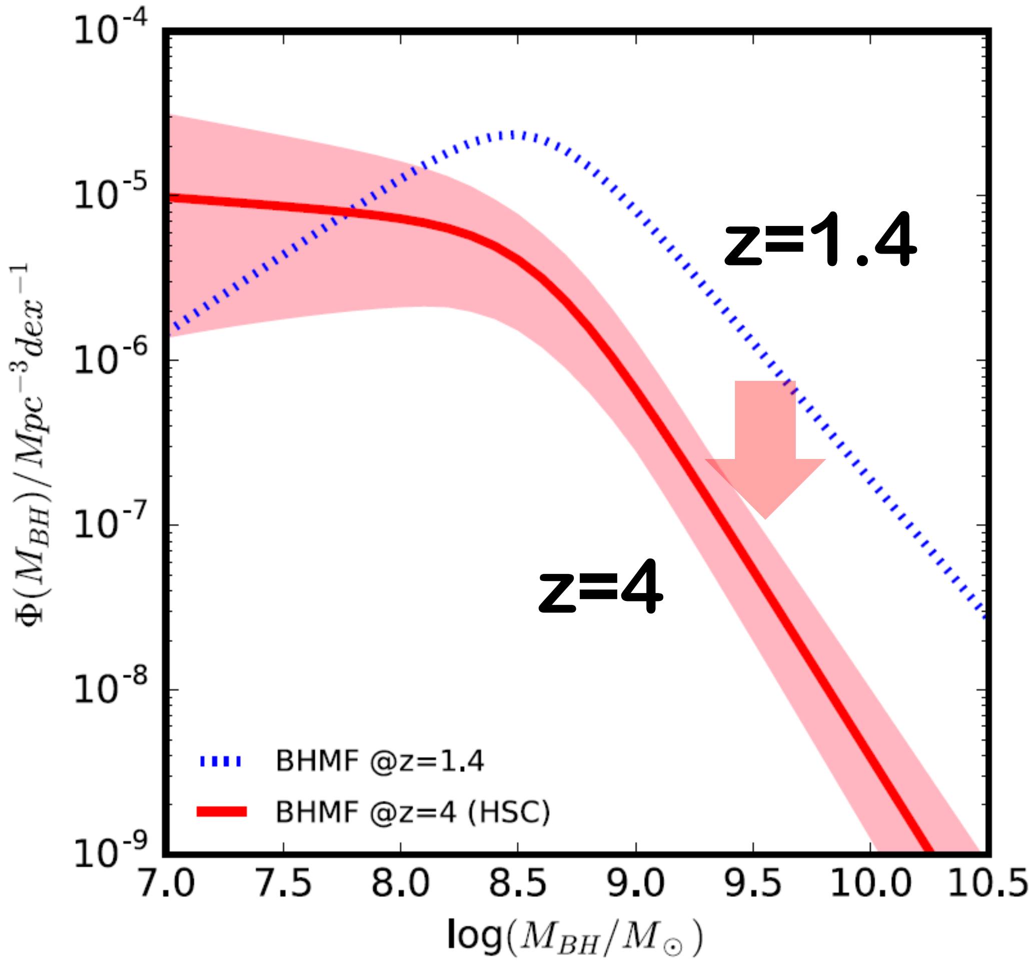
with CIV lines : Wanqiu He Ph.D. thesis 2019

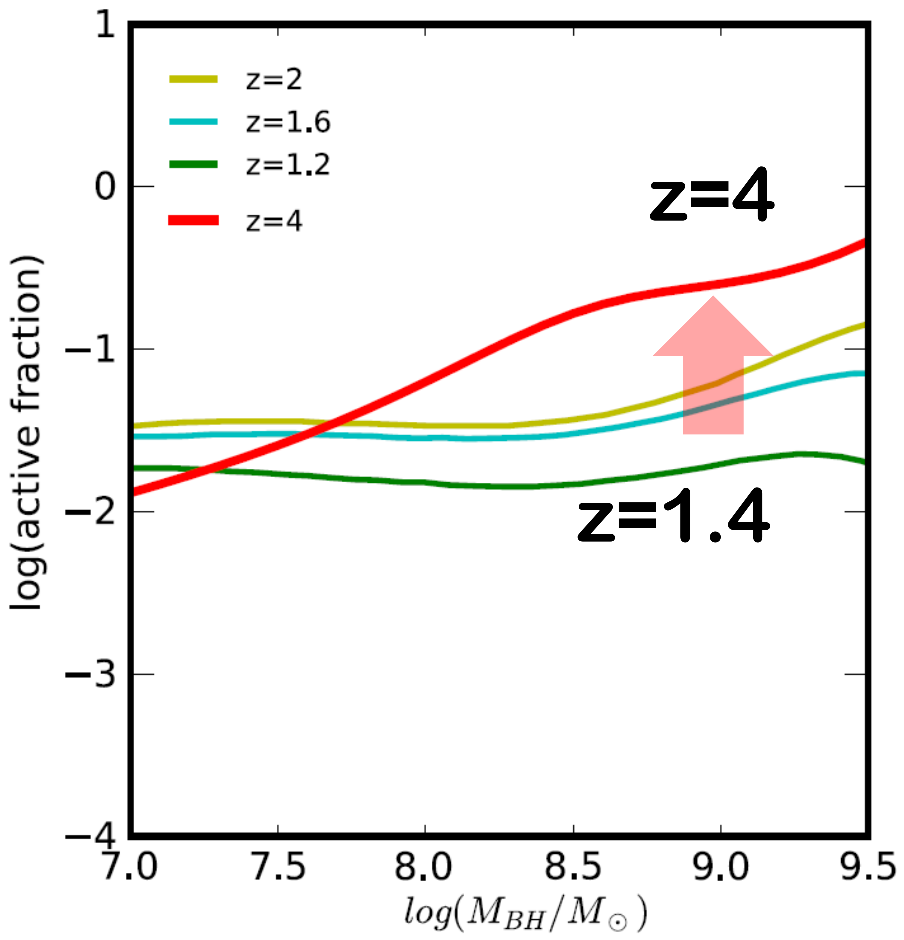


with MgII lines : Onoue et al. 2019
Onoue's talk

Active BH mass function at z=4

Compared to z=1-2, co-moving number density decrease toward z=4, but fraction among massive galaxies can be higher (note: depends on various assumption).

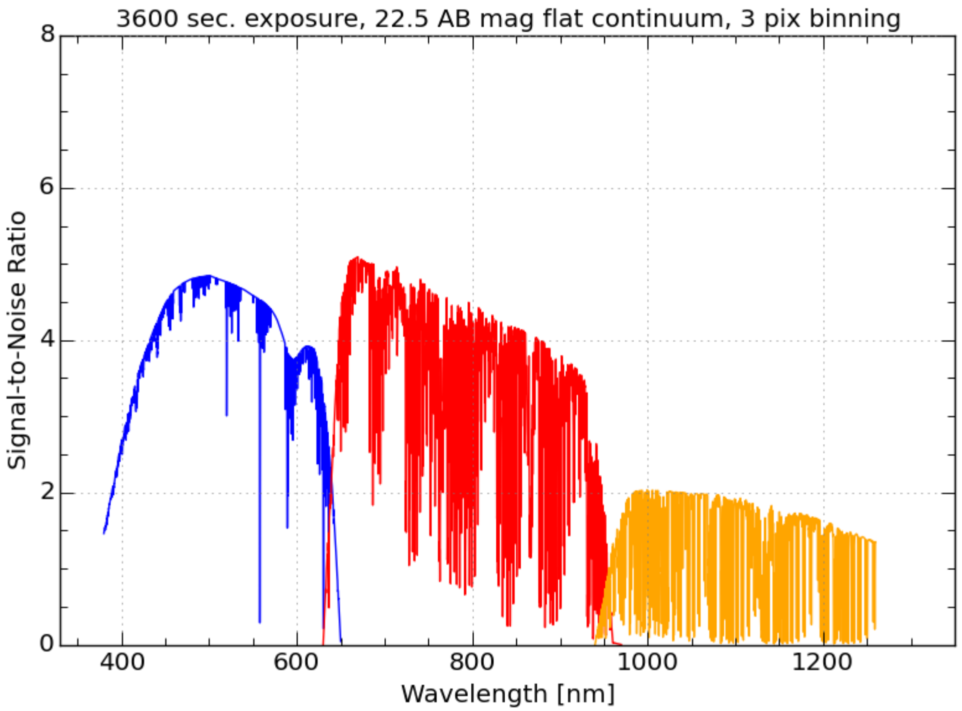


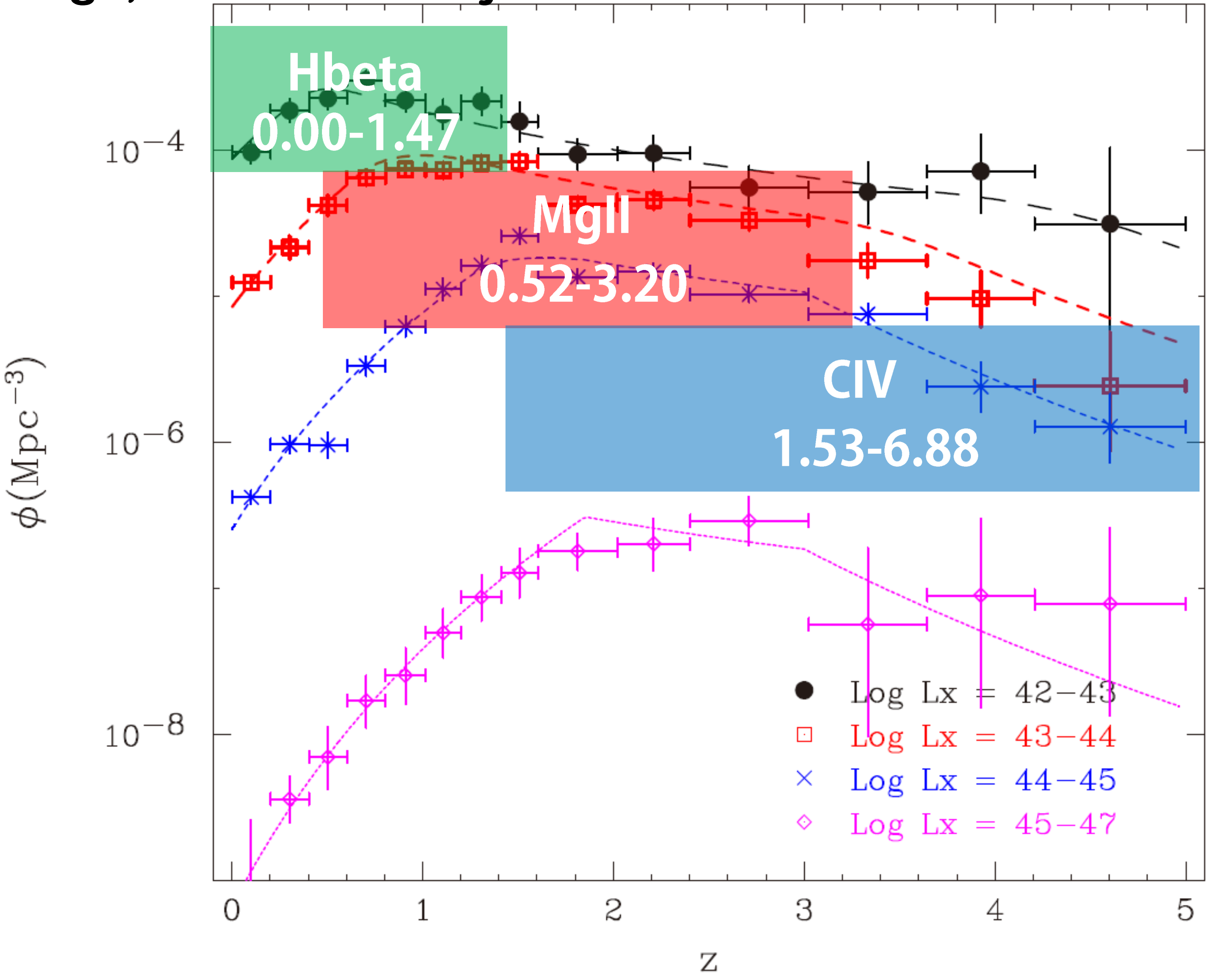


Wanqiu He Ph.D. thesis 2019

But the current sample is too limited to draw continuous picture covering the entire high-z universe: PFS-SSP survey will conclude the accretion growth history

Wide simultaneous wavelength coverage of PFS is powerful to cover quasars with multiple broad-lines in wide redshift range, simultaneously.

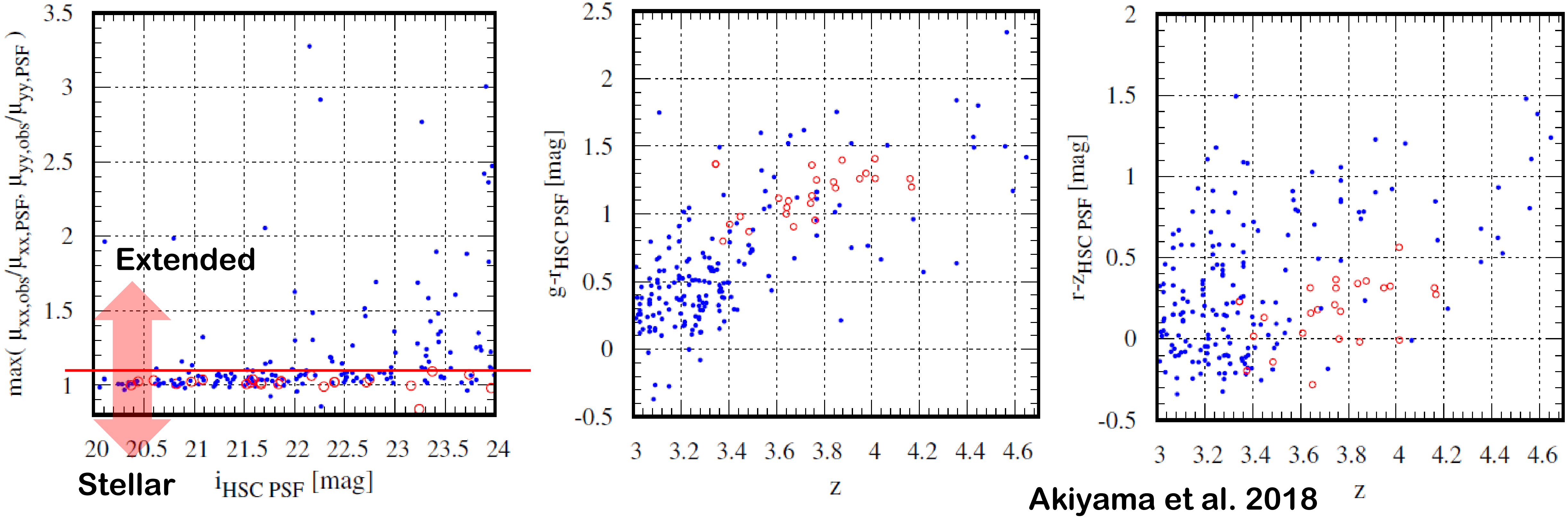




If we consider multi-λ surveys of quasars, we are still missing obscured AGNs !

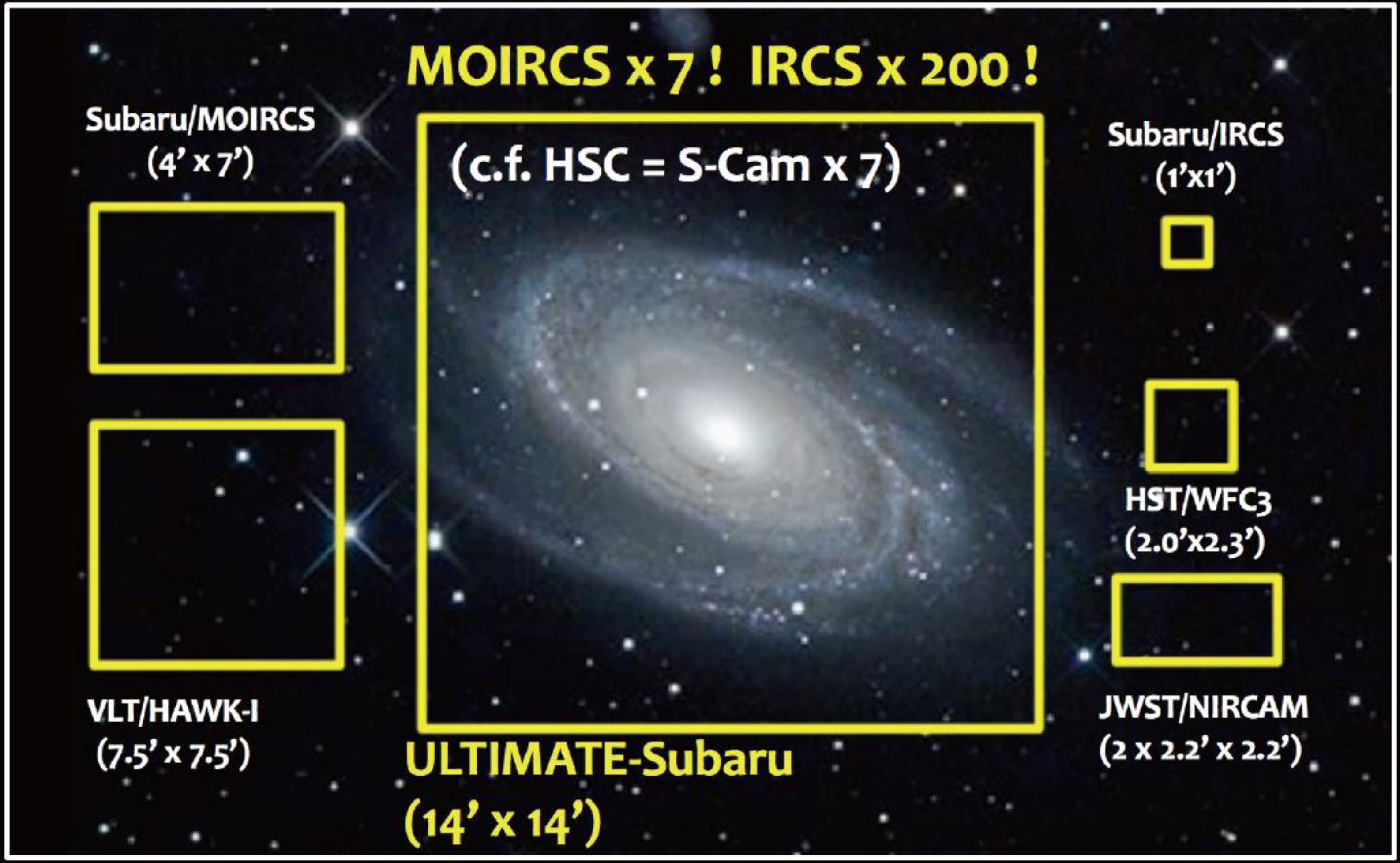
X-ray-selected z~4 candidates : selected with HSC (red circles) and not selected with HSC (blue dots)

Obscured / faint AGNs whose optical emission is dominated by host galaxies have extended morphology and red color, and they are hard to be selected in the optical QSO selection.

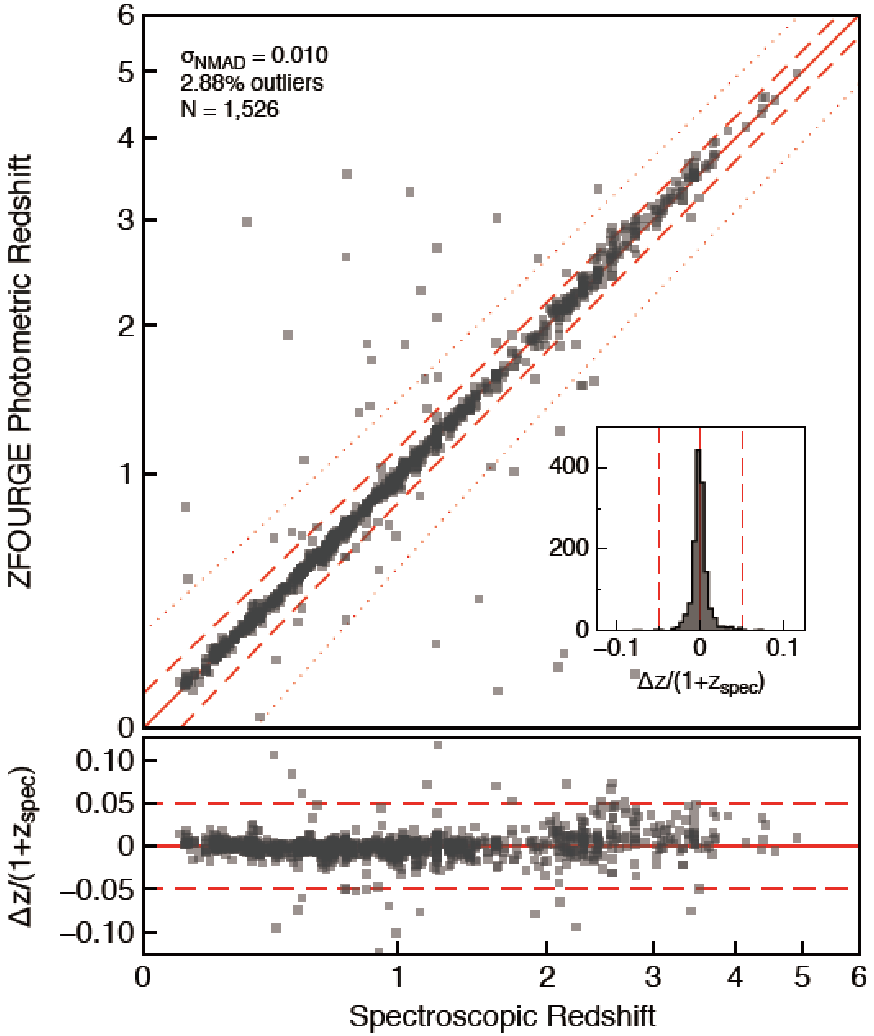


Akiyama et al. 2018

Constructing obscured AGN sample based a “mass-limited” galaxy sample at z>4 with ULTIMATE-Subaru, and examine their X-ray / IR emission to constrain their AGN activity

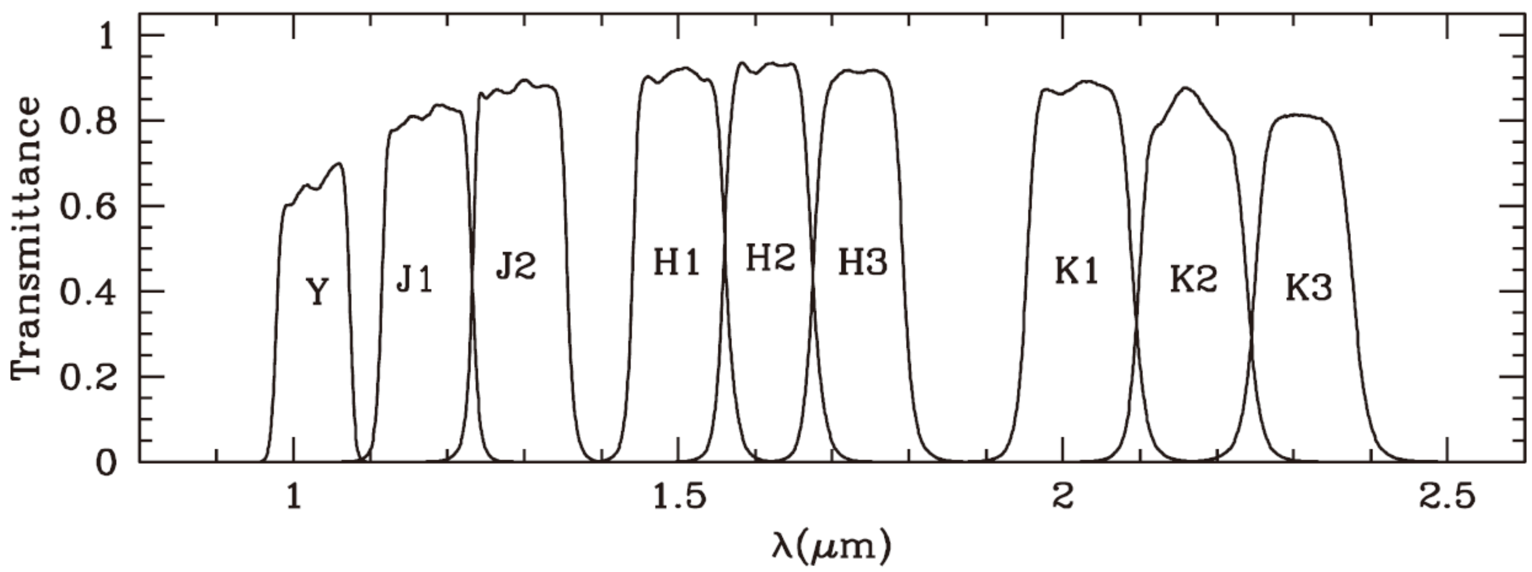


ULTIMATE-SUBARU



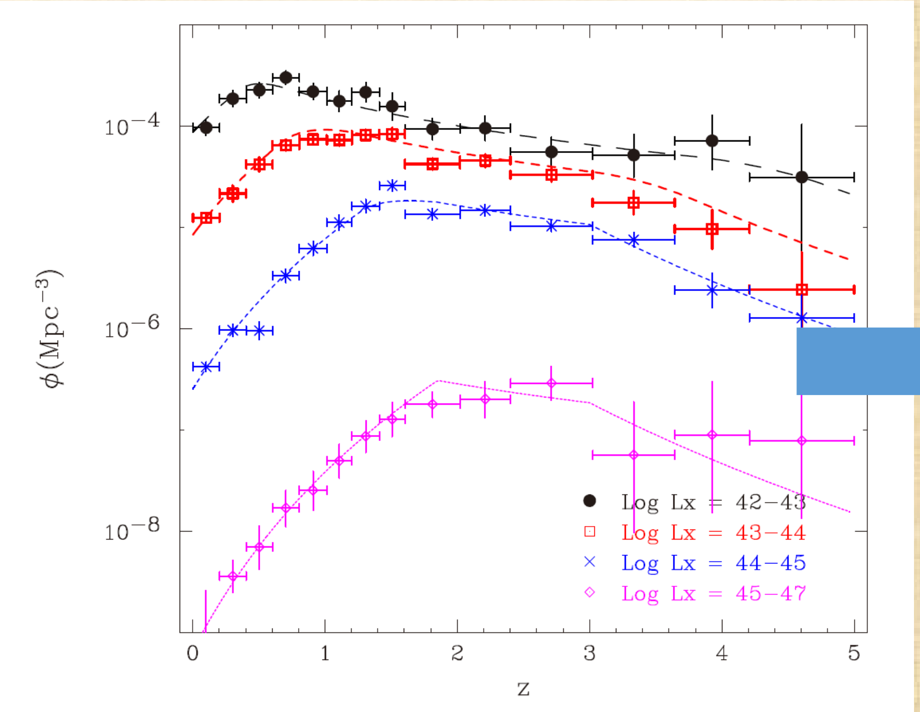
COSMOS20 with Scam(Taniguchi et al. 2015)

Extend to NIR



See Kodama's, Whitaker's talks

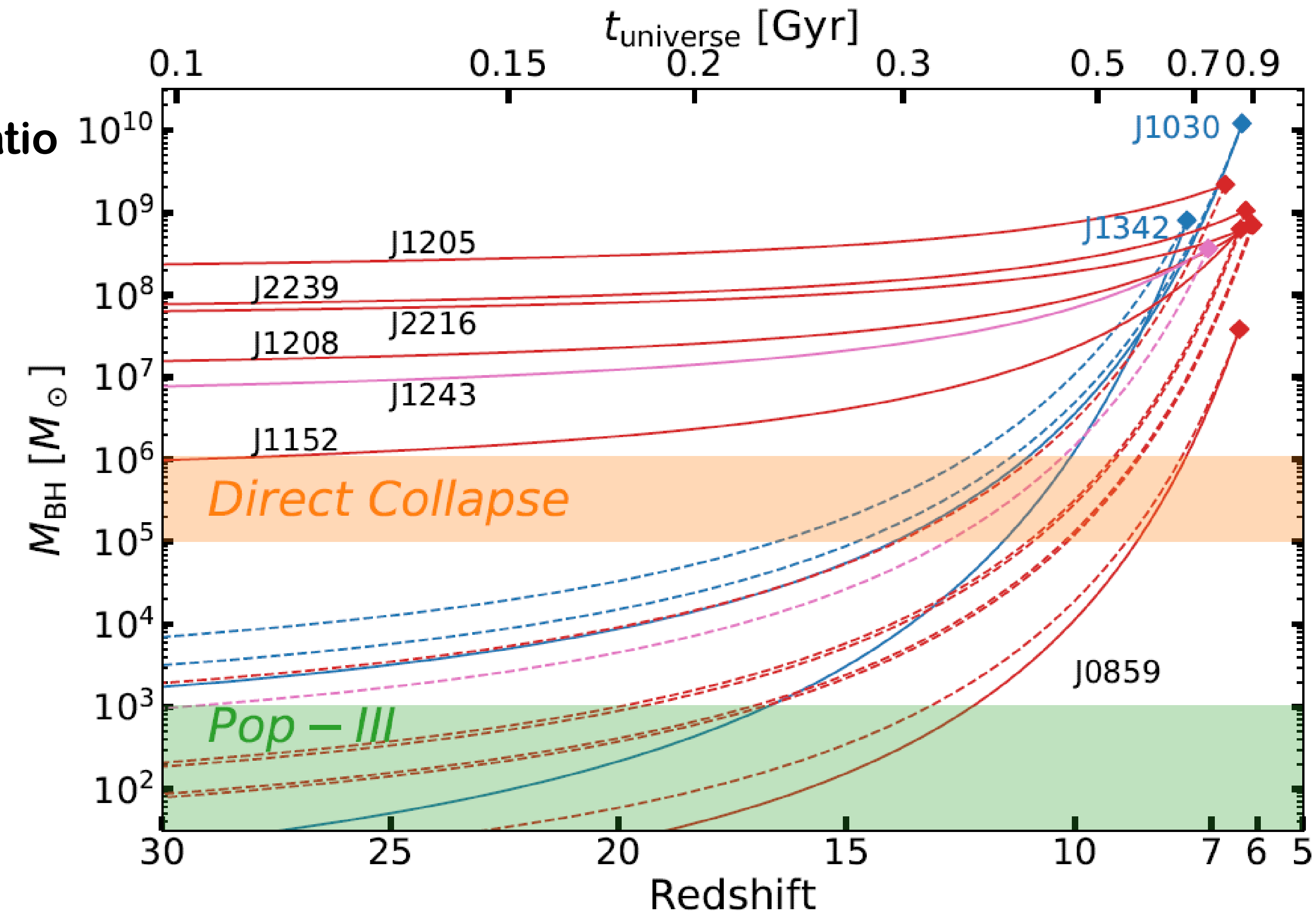
Credit: ZFORGE project



PART 3. BIG QUESTION ON BABY MONSTERS: STELLAR MASS ? OR HEAVY SEED ?

Possible accretion growth path of z~6 QSOs

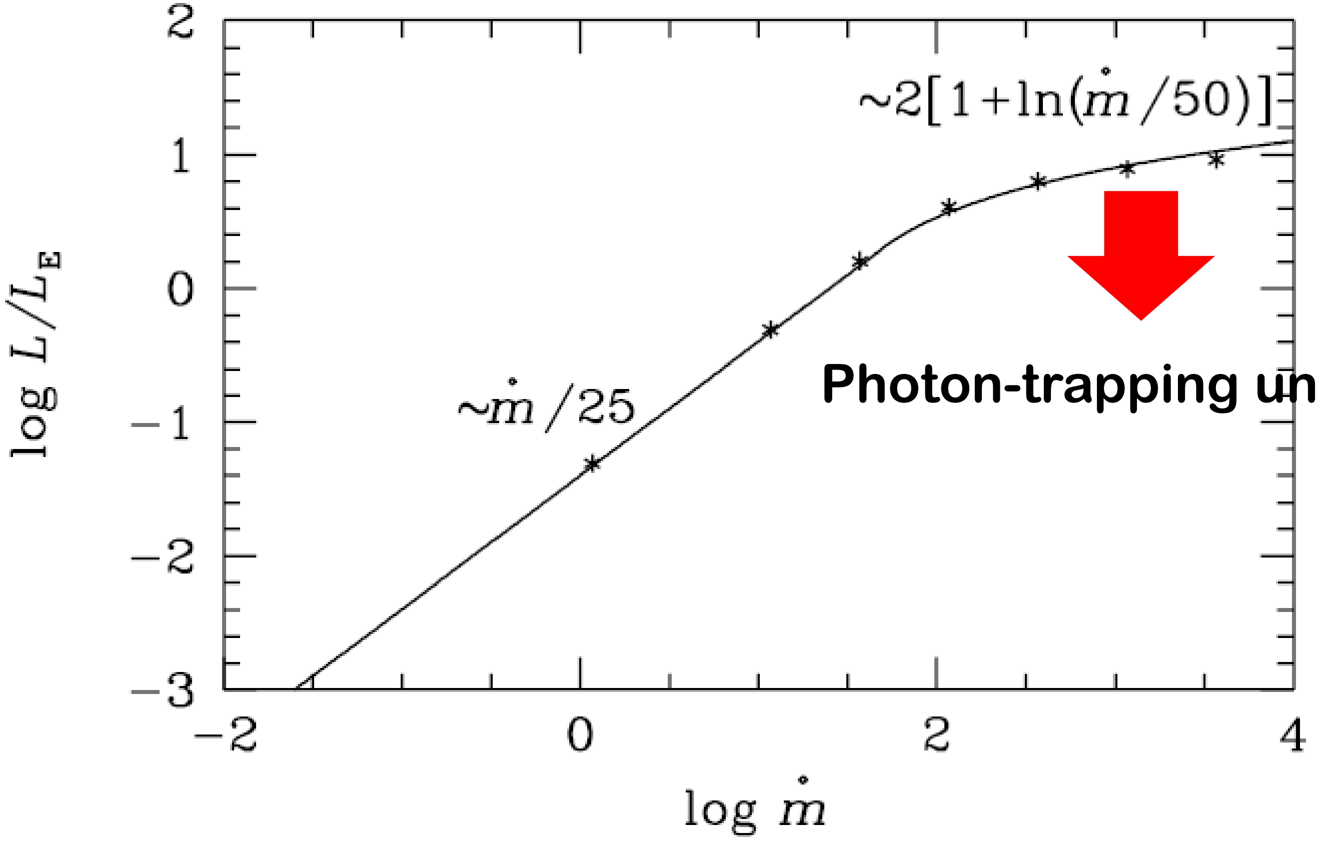
100% duty-cycle with
solid : observed Eddington ratio
dashd : Eddington limited



Onoue et al. 2019, see Onoue's talk

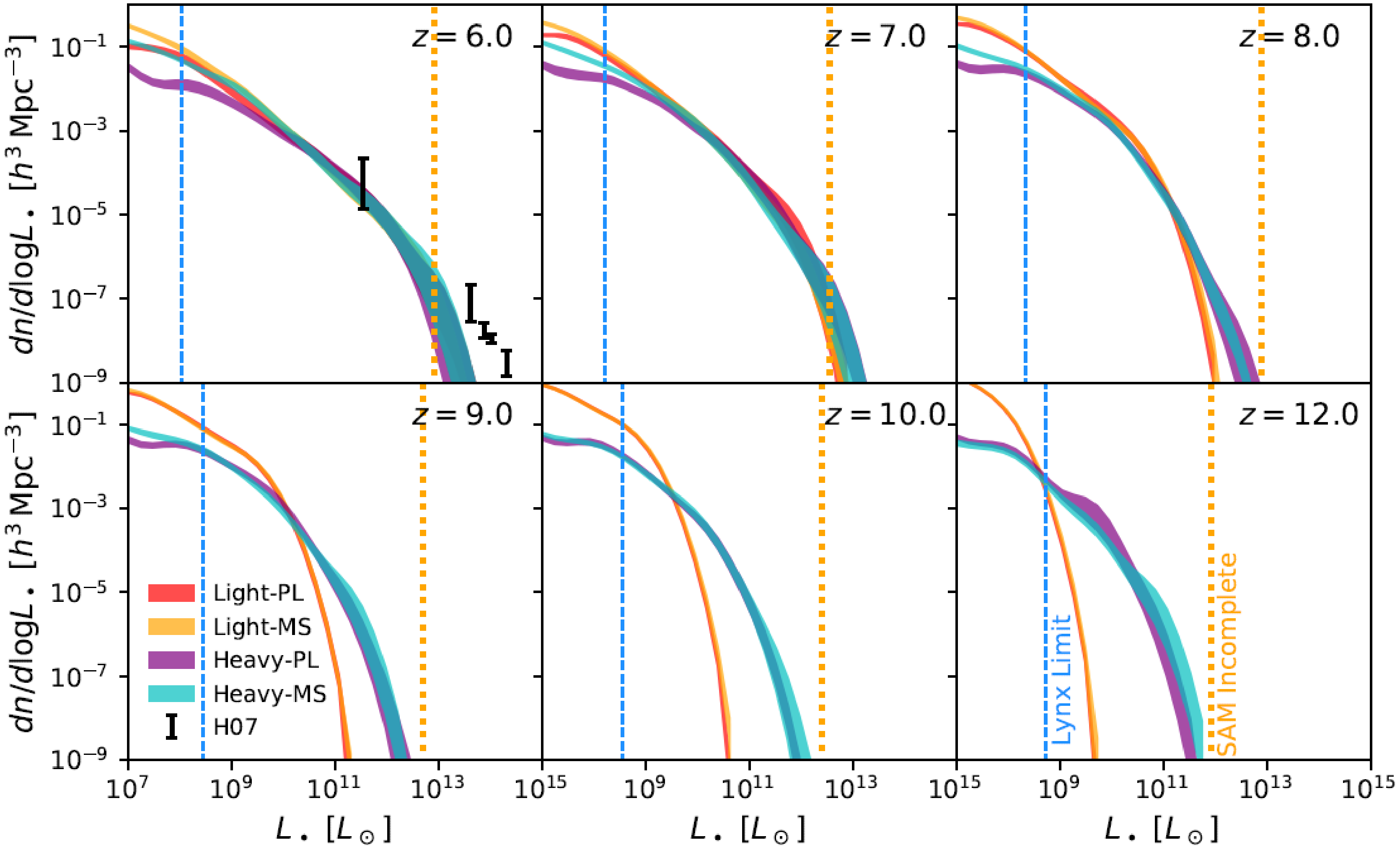
We (observers) need to note:

In the high mass accretion rate regime, luminosity may not be a good indicator of the mass accretion rate.



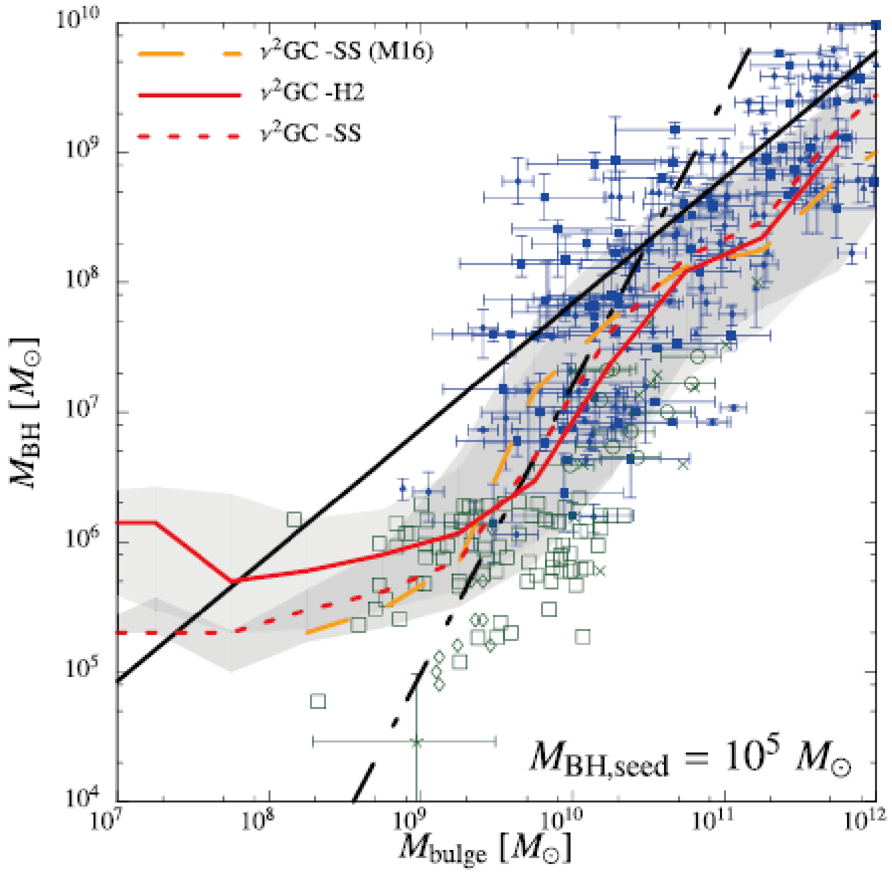
Mineshige et al. 2000
see also Kawaguchi 2003, Ohsuga & Mineshige 2007

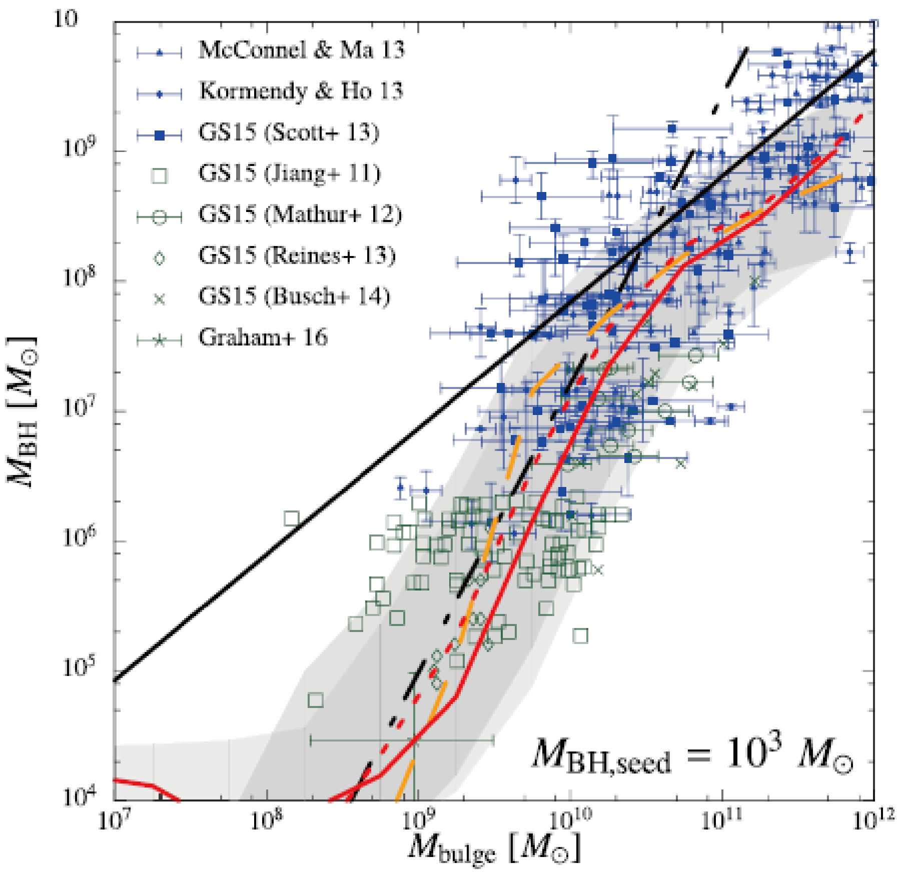
The difference in seed mass disappears even at z~8



Ricarte & Natarajan 2018

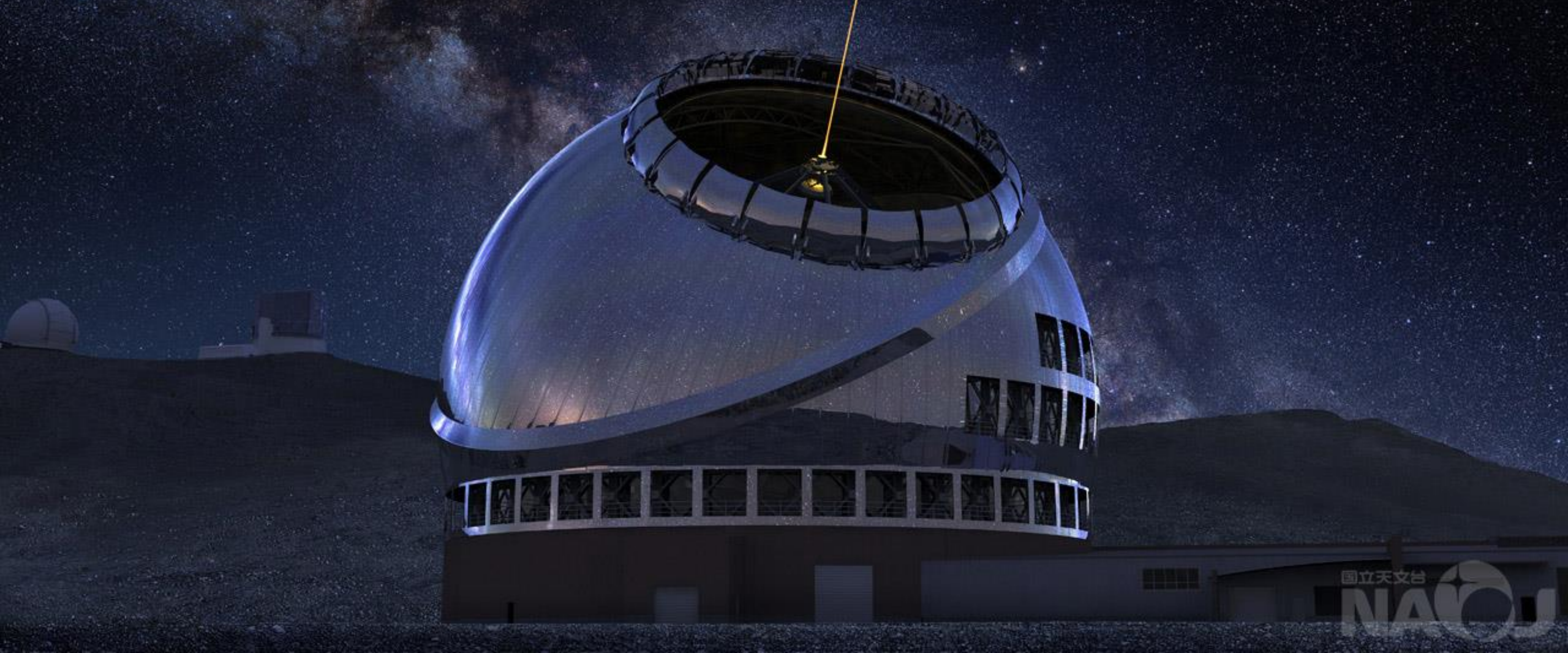
The difference in the seed mass remains in the low-mass end of the MBH-Mbulge relation in the nearby universe





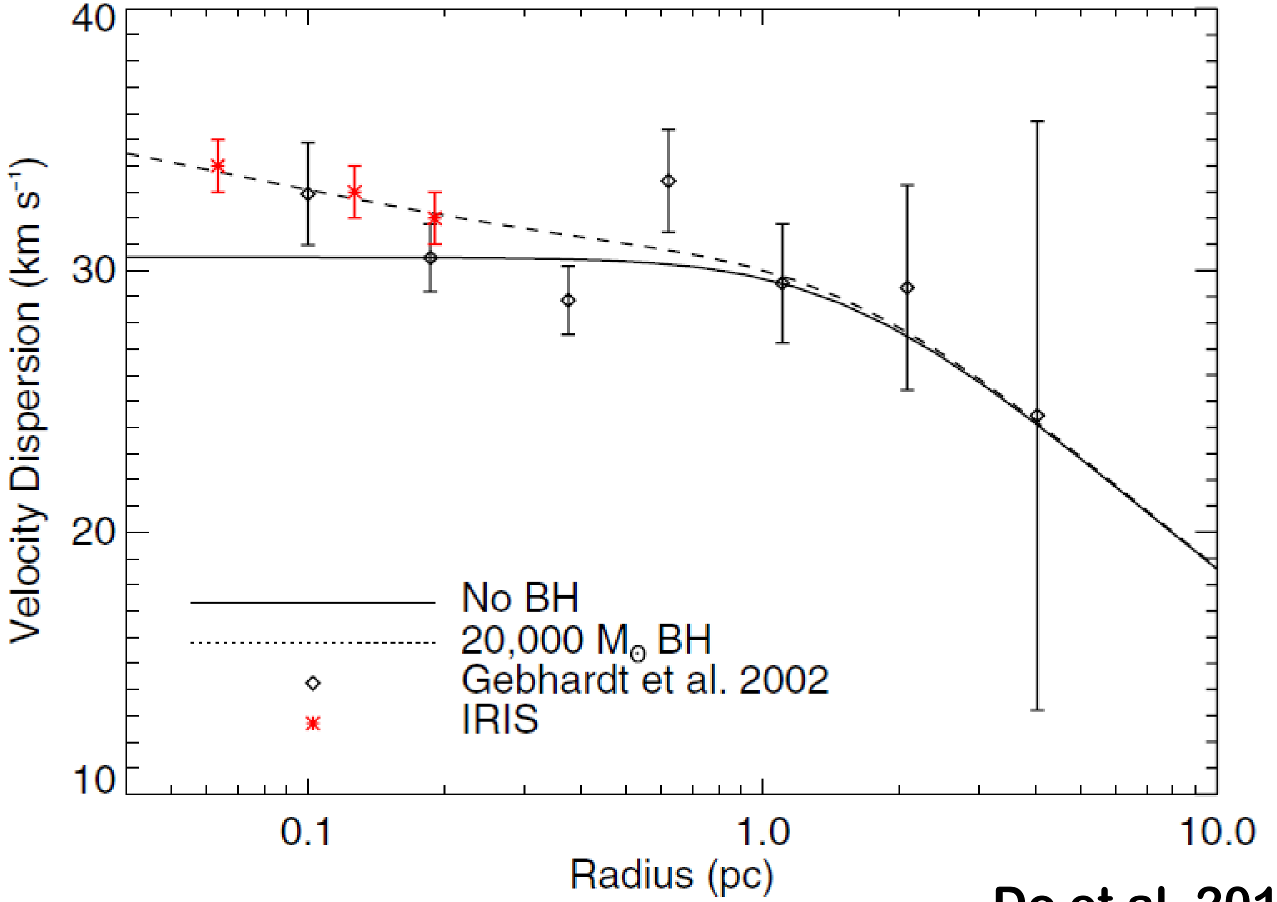
Shirakata et al. 2016

Statistical exploration of low mass SMBHs in the nearby galaxies with high spatial and spectral resolution observation with TMT



Massive star cluster

Prediction with the TMT IRIS observations of $8x10^6$ Msun star cluster at 770kpc (M31) with $2x10^4$ Msun black hole.



Do et al. 2014

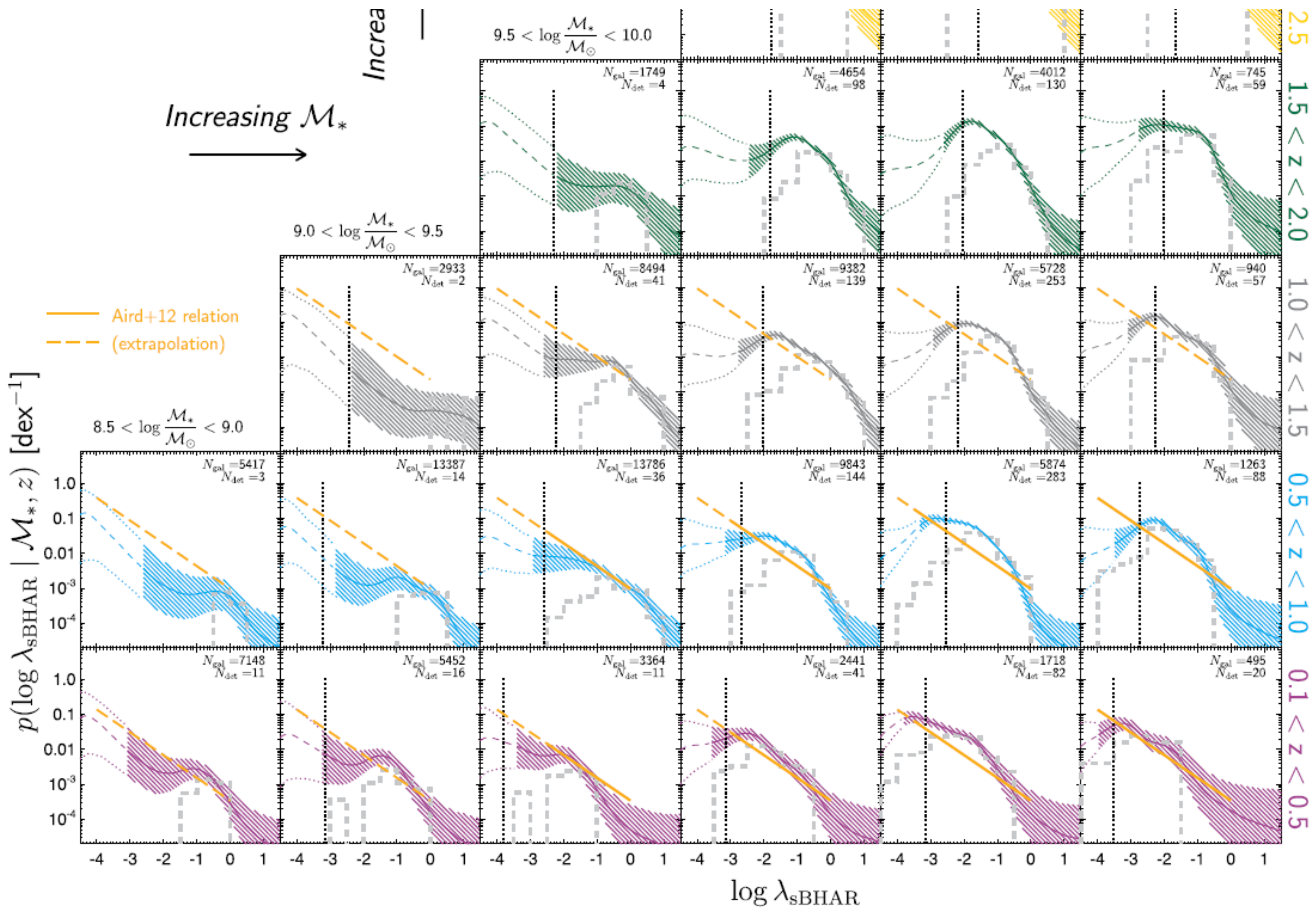
Celebrate 20 years of wide-field surveys with
Suprime-cam / FMOS / MOIRCS / HSC
and
look forward to next 20 years of massive surveys with
PFS / ULTIMATE


I hope human exploration based on
Maunakea continues stepping forward.
マウナケアを起点とした探求の
ますますの発展を祈っています。

additional slides

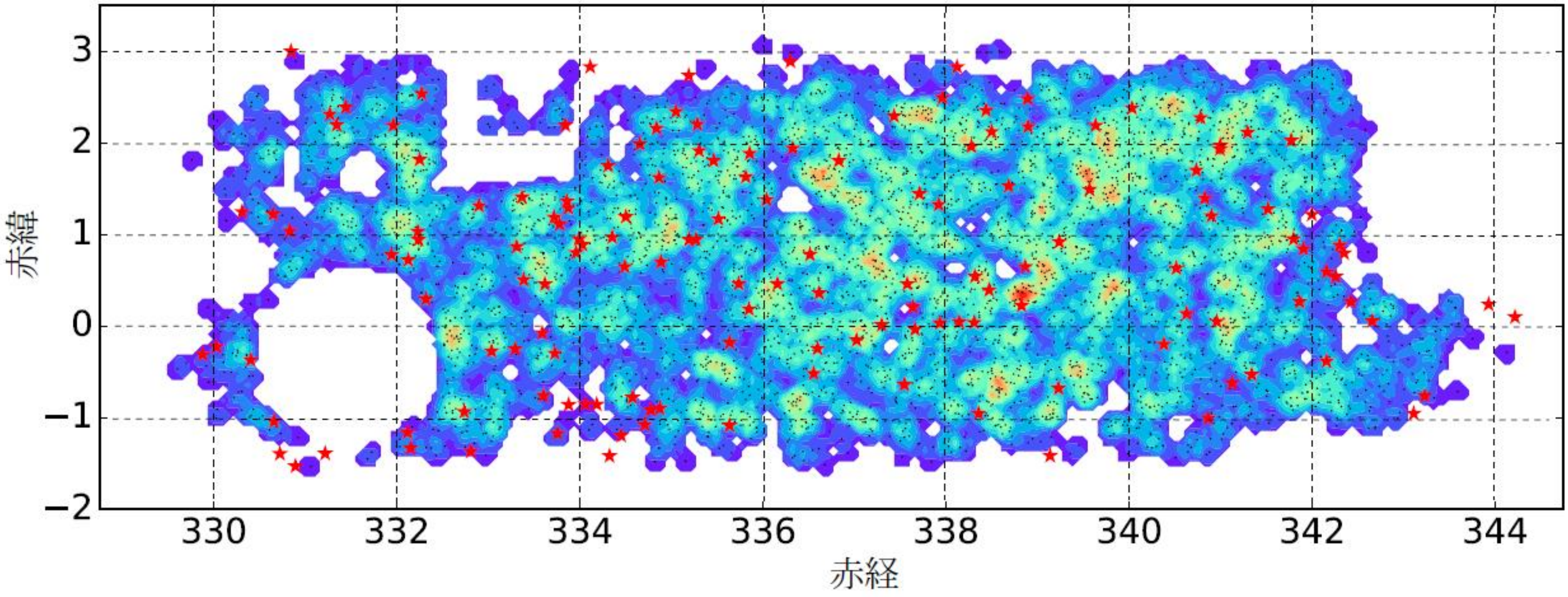
Probability in each activity phase

- Once we have a mass-limited galaxy sample, we can derive distribution of the Eddignton ratio in each stellar mass and redshift bin, assuming local relation between MBH – Mgal in all of the redshift range (and this is a large uncertainty).



Aird et al. 2018

Deep and wide HSC data enable us to locate quasars in the large scale structure of the early universe



He et al. 2017

Even the most luminous z=4 SDSS quasars live in “typical” environment similar to LBGs

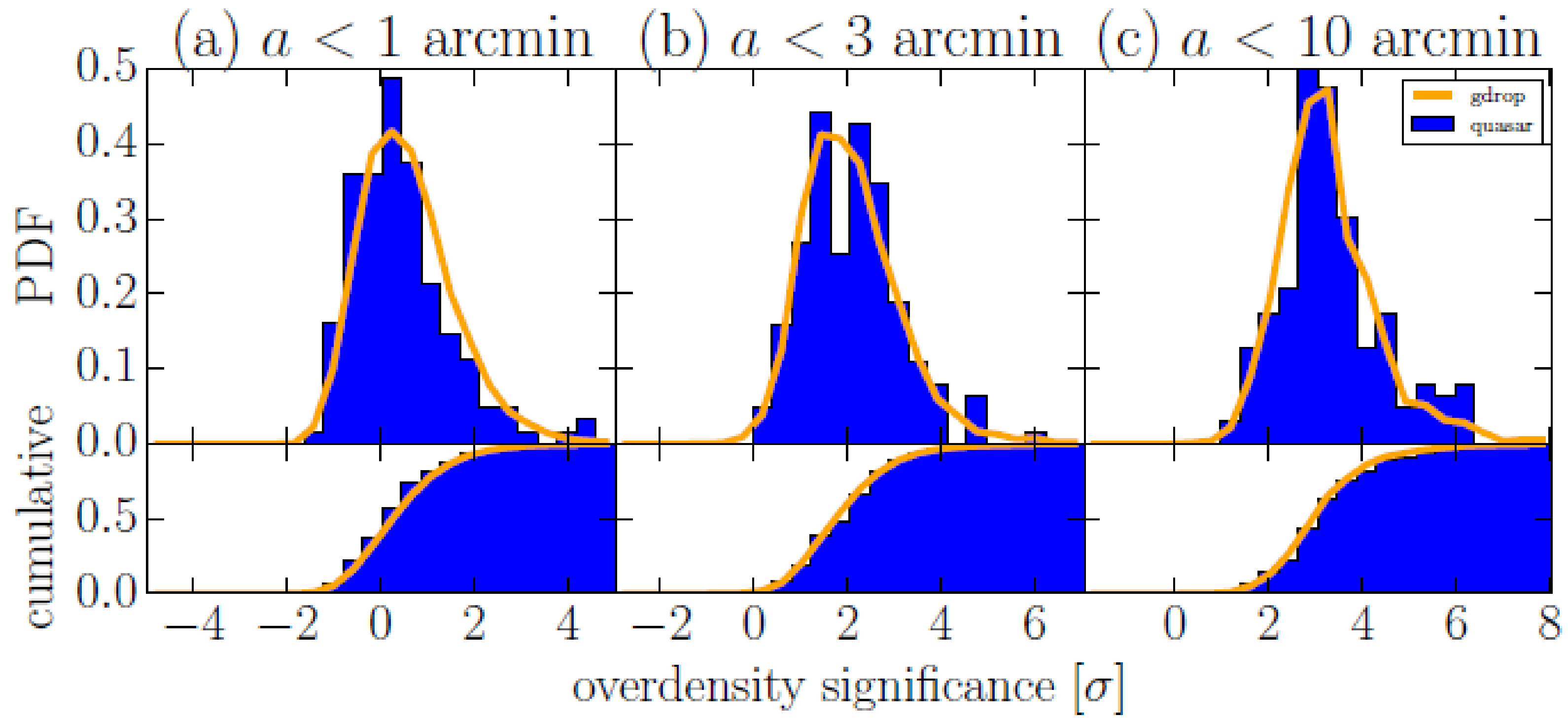


Fig. 3. Histogram of overdensity significance of quasars (blue histograms) and g-dropouts (orange lines). The panels (a), (b) and (c) show the histograms of the maximum overdensity significance centered on quasars and g-dropouts with the radius of 1 (0.42), 3 (1.25), and 10 (4.2) arcmin (pMpc), respectively. On the vertical axis we show the probability distribution function (PDF) and the cumulative PDF.

Uchiyama et al. 2017