



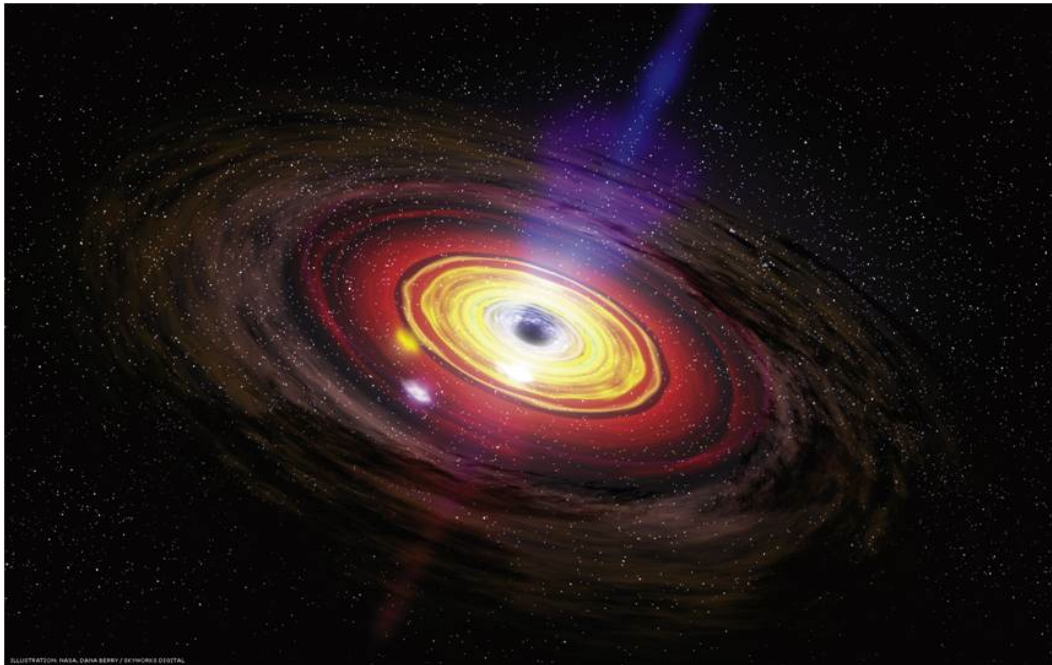
A new survey for ~~radio galaxies with HSC-FIRST~~
dusty AGNs, high-z quasars,
and radio galaxies,
with *Hyper Suprime Cam*

Tohru Nagao (Ehime U.)
on behalf of the HSC-AGN WG

This work is supported by an “open-called research (公募研究)”
under the “Why does the Universe accelerate?” program.



Big questions



We already know:

Most massive galaxies harbor a supermassive black hole (SMBH) at their center. It causes quasar (or AGN) activities through gas accretion. The SMBH mass reaches up to $M_{\text{BH}} \sim 10^9\text{--}10^10 M_{\text{sun}}$.

We still do not know:

- When the first “massive” BHs appeared in the Universe?
- When and how SMBHs grew in the cosmological timescale?
- How the statistical properties of quasars depend on redshift?
- How the SMBH growth is related to the galaxy evolution?



"Co-evolution" of SMBHs and galaxies (2) Quasars

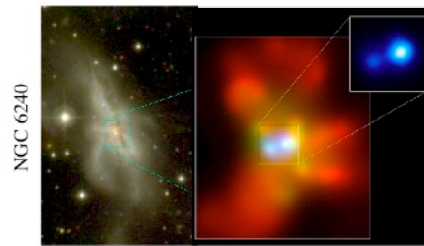
Hopkins et al. (2008)

(c) Interaction/"Merger"



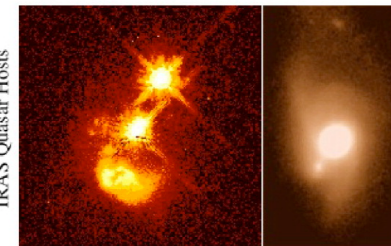
- now within one halo, galaxies interact & lose angular momentum

(d) Coalescence/(U)LIRG



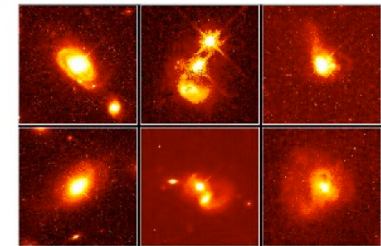
- galaxies coalesce: violent relaxation in core
- gas inflows to center:

(e) "Blowout"



- BH grows rapidly: briefly dominates luminosity/feedback
- remaining dust/gas expelled
- get reddened (but not Type II) QSO: recent/ongoing SF in host
- high Eddington ratios
- merger signatures still visible

(f) Quasar



- dust removed: now a "traditional" QSO
- host morphology difficult to observe: tidal features fade rapidly
- characteristically blue/young spheroid

(1) Dusty AGNs

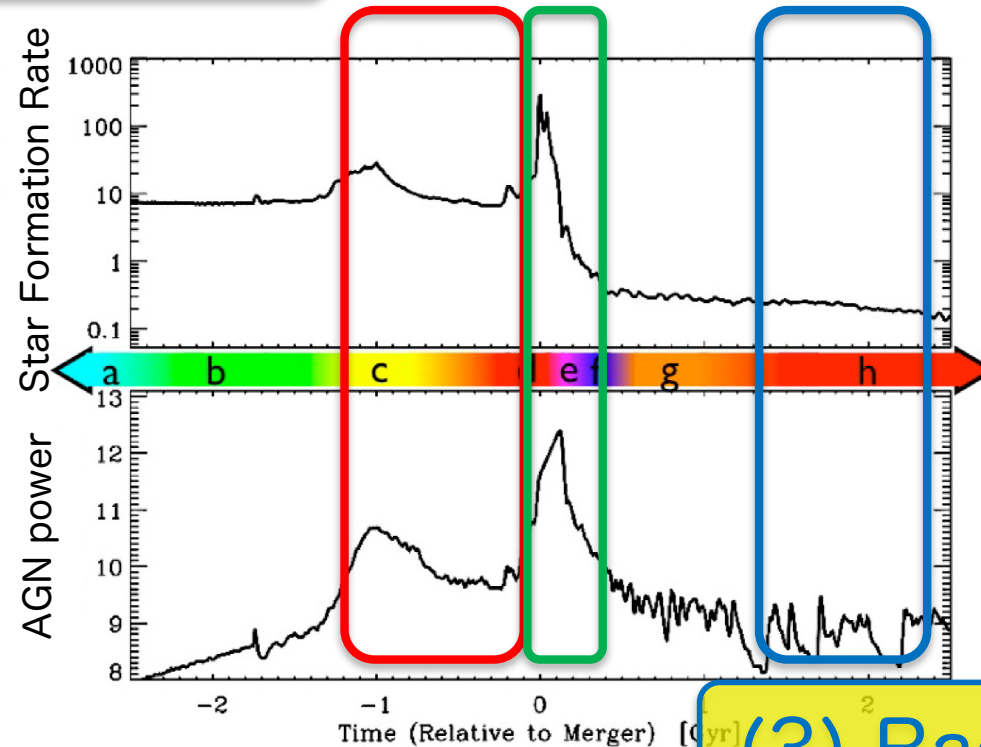


- halo accretes similar-mass companion(s)
- can occur over a wide mass range
- M_{halo} still similar to before: dynamical friction merges the subhalos efficiently

(a) Isolated Disk



- halo & disk grow, most stars formed
- secular growth builds bars & pseudobulges
- "Seyfert" fueling (AGN with $M_B > -23$)
- cannot redden to the red sequence



(g) Decay/K+A



- QSO luminosity fades rapidly
- tidal features visible only with very deep observations
- remnant reddens rapidly (E+A/K+A)
- "hot halo" from feedback
- sets up quasi-static cooling

(h) "Dead" Elliptical



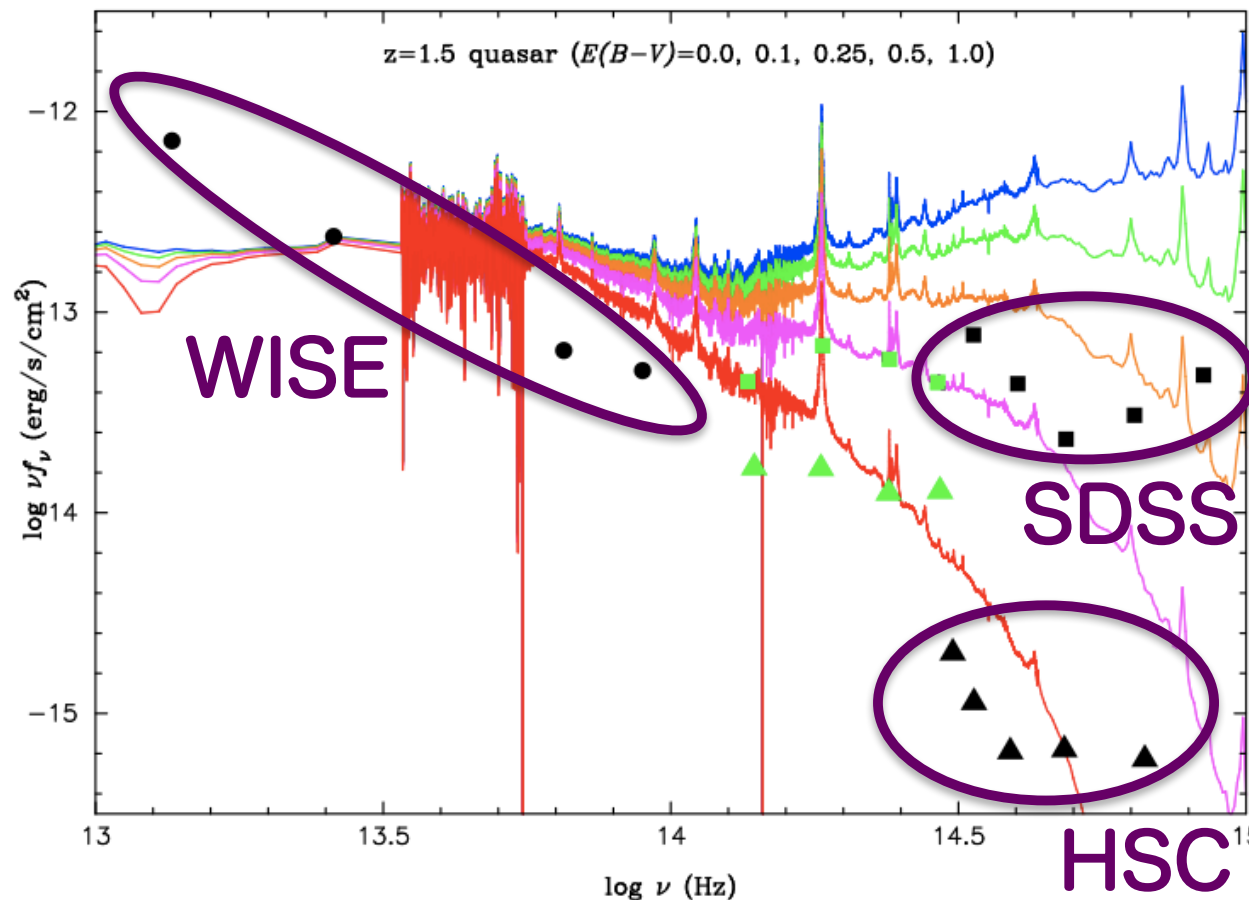
(3) Radio galaxies

- growth by "dry" mergers



Dusty AGNs in “dust obscured galaxies (DOGs)”

- identifying red AGNs with HSC & MIR all-sky data
 - ~ WISE all-sky survey data → Wide & Deep MIR image
 - ~ HSC-SSP data → Wide & Deep optical image



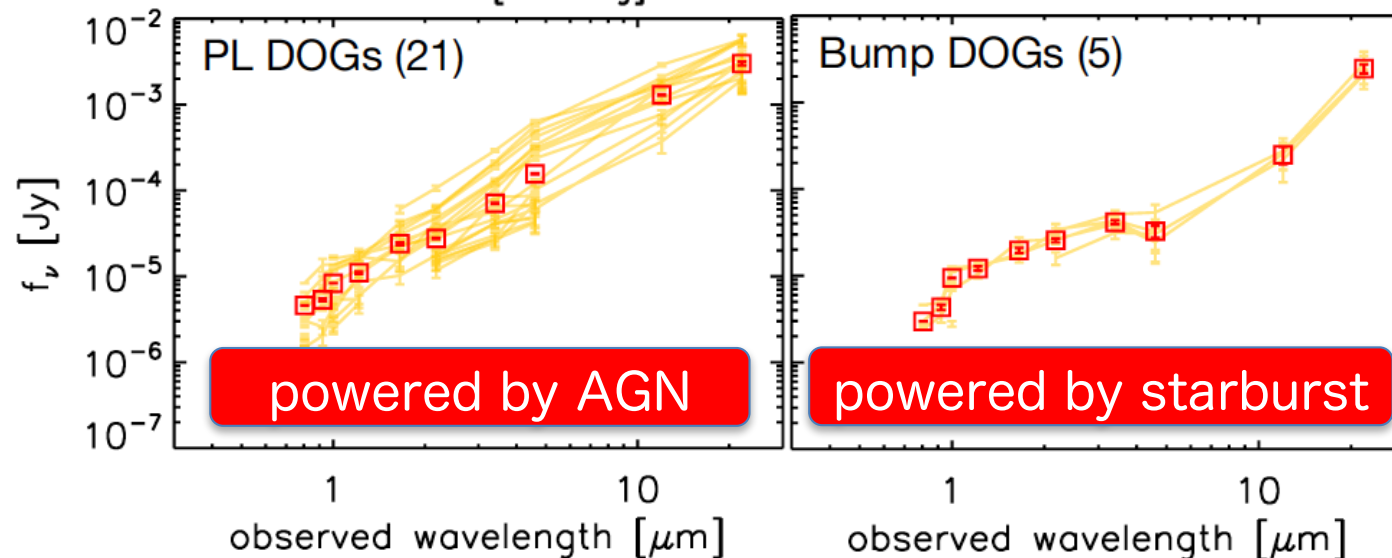
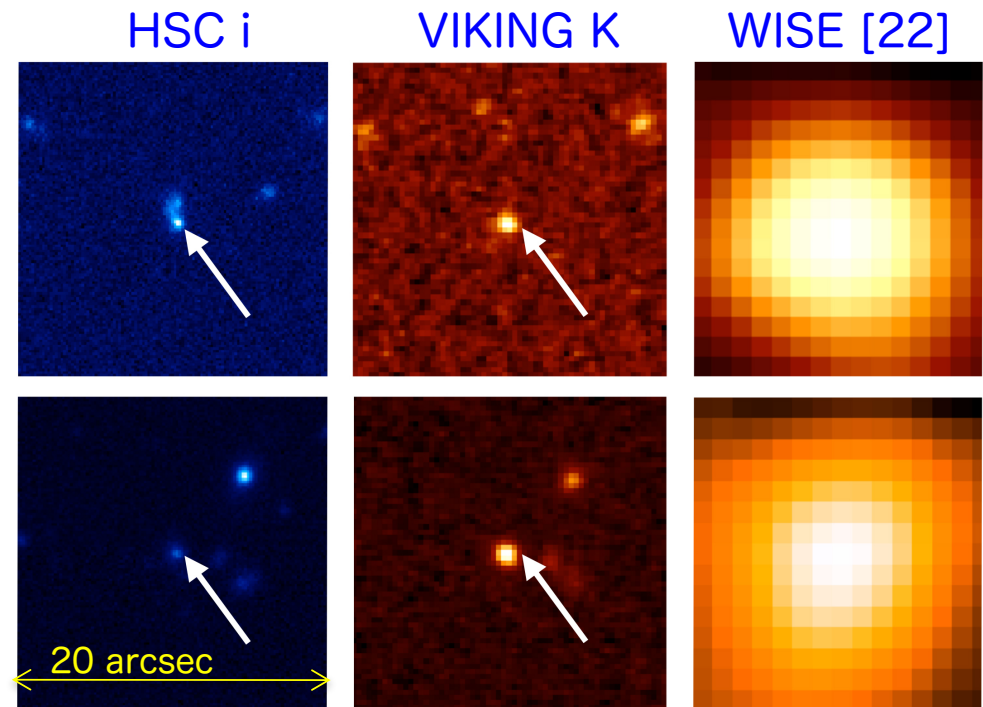
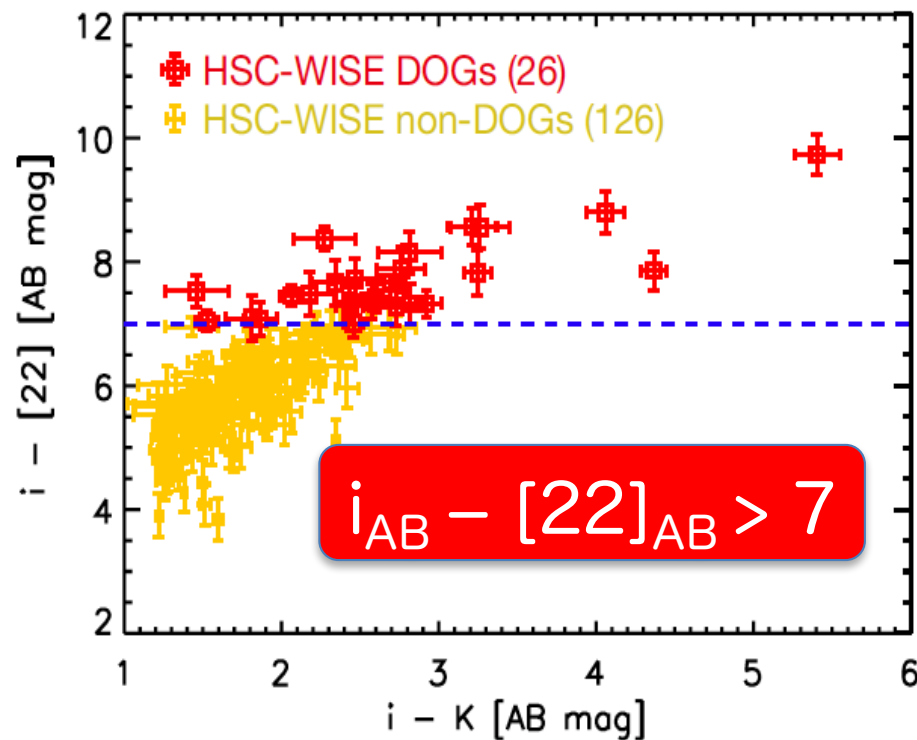
$z=1.5$ quasar spectrum
with various $E(B-V)$

Red WISE-detected
quasars cannot be
detected in SDSS

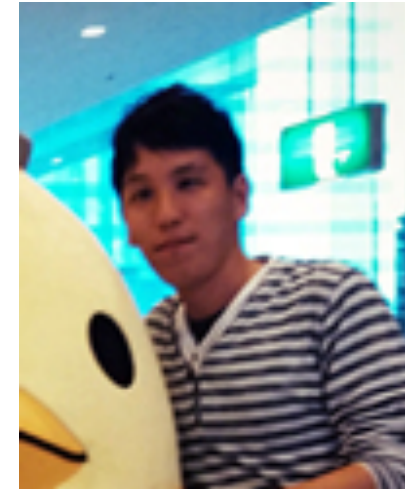
HSC is deep enough
to detect them!



DOGs in the initial 10 deg² of the HSC-SSP



Toba, TN, et al., 15
based on initial
~10 deg² data



Yoshiki Toba
(Ehime → ASIAA)

Press Release



Tweet



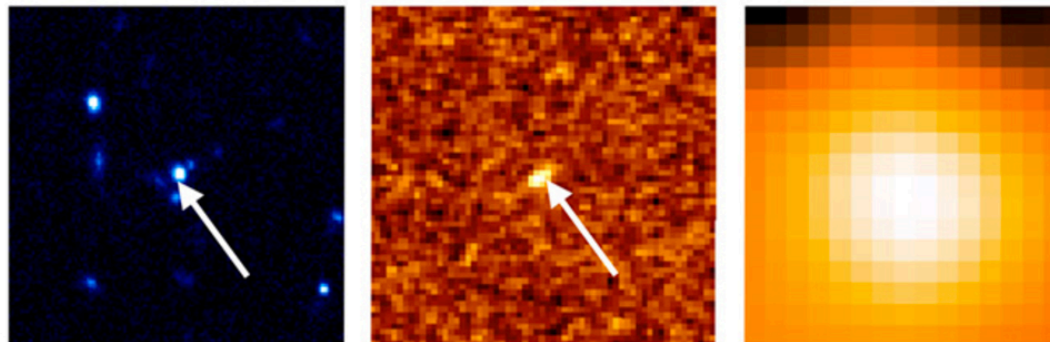
Print This Article

Discovering Dust-Obscured Active Galaxies as They Grow

August 26, 2015

Abstract

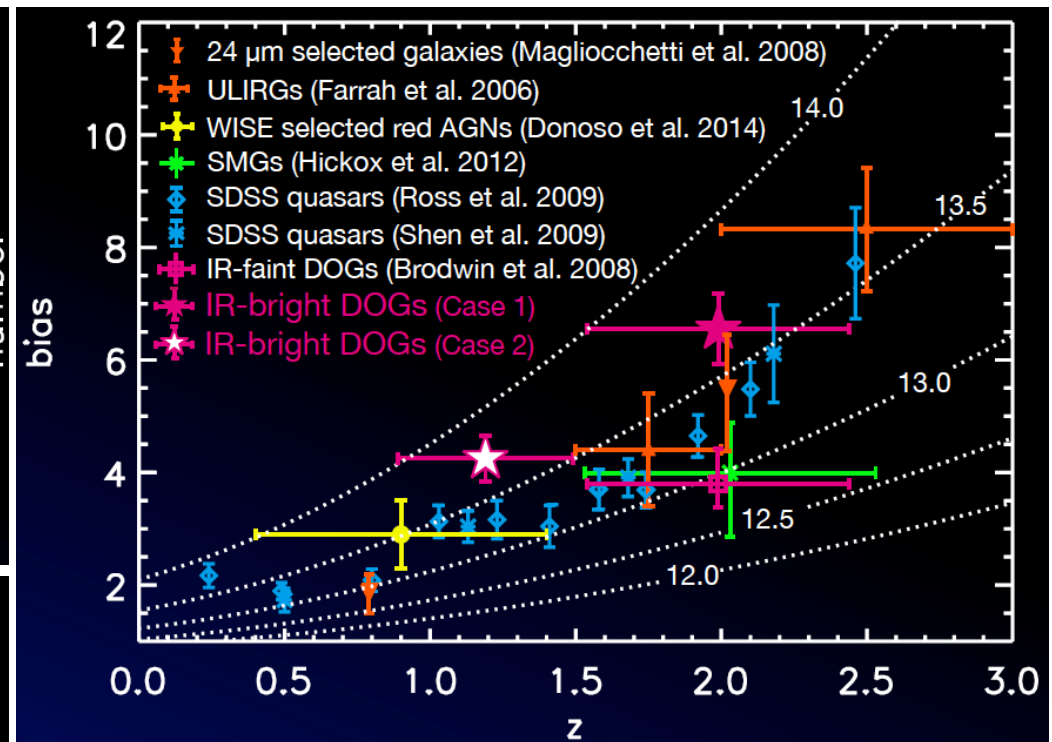
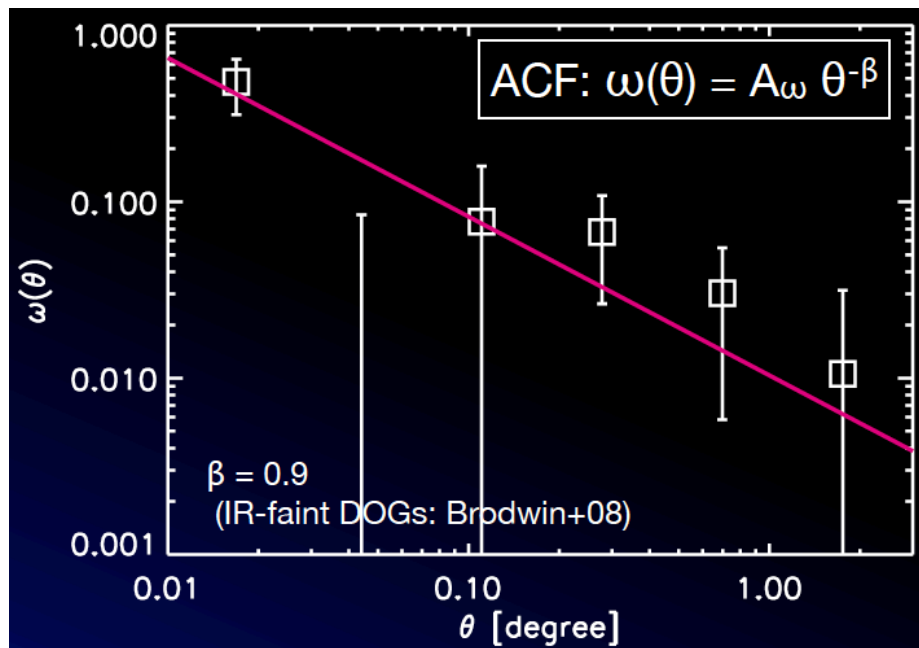
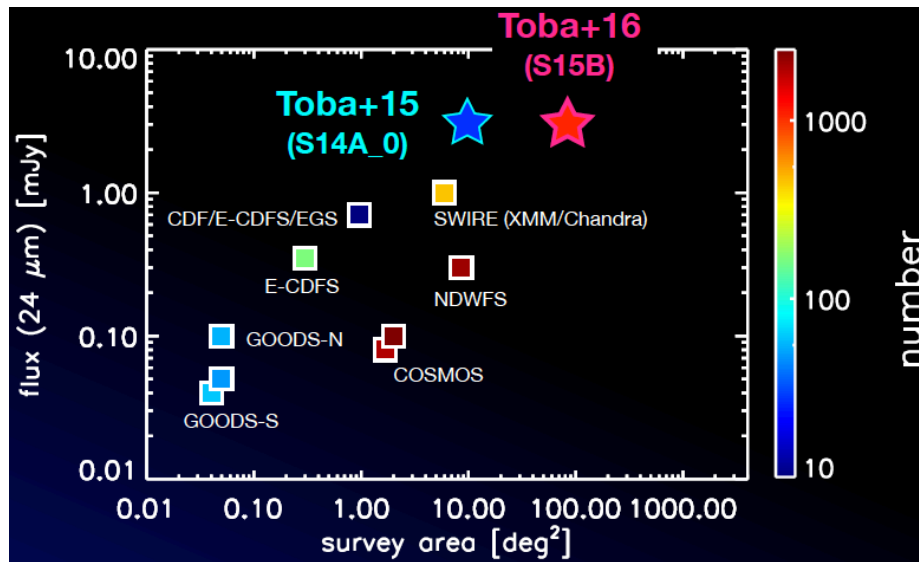
A group of researchers from Ehime University, Princeton University, and the National Astronomical Observatory of Japan (NAOJ) among others has performed an extensive search for Dust Obscured Galaxies (DOGs) using data obtained from the Subaru Strategic Program with Hyper Suprime-Cam (HSC). HSC is a new wide-field camera mounted at the prime focus of the Subaru Telescope and is an ideal instrument for searching for this rare and important class of galaxy. The research group discovered 48 DOGs, and has measured how common they are. Since DOGs are thought to harbor a rapidly growing black hole in their centers, these results give us clues for understanding the evolution of galaxies and supermassive black holes.



Subaru Web Release
on Aug 26, 2015



DOGs in the 100 deg² of the HSC-SSP



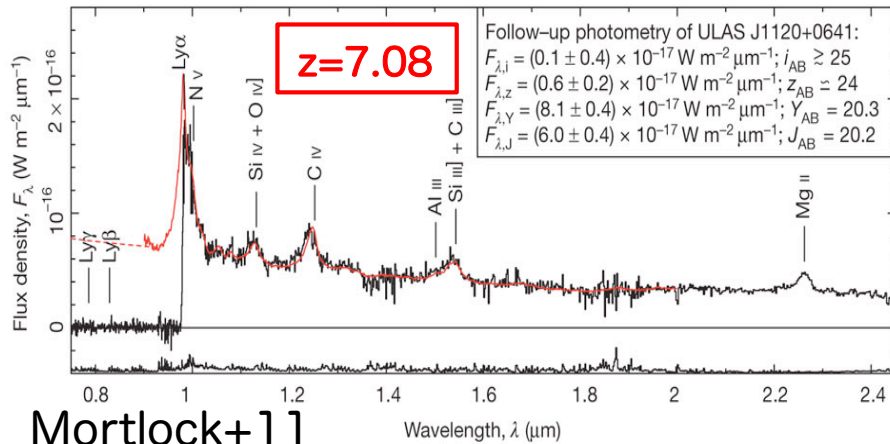
Auto-correlation function of DOGs
derived based on ~1000 HSC-DOGs

→ Large bias, large $M_{\text{DMH}} (\sim 10^{13.5} M_{\text{sun}})$

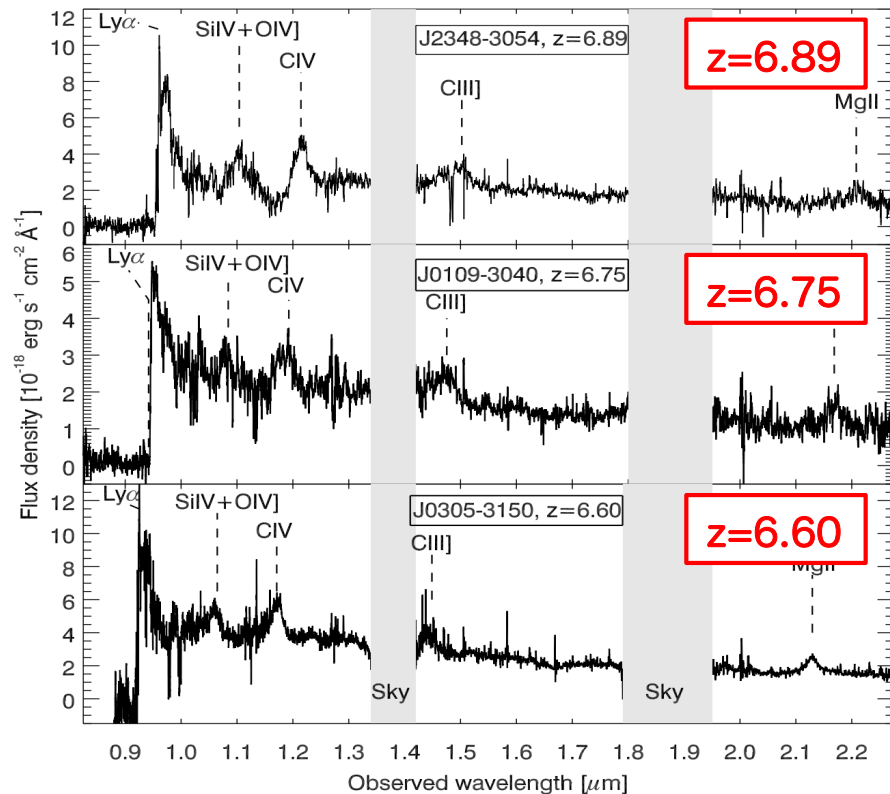
→ Timescale of DOGs: ~40 Myr



Quasars: More objects needed at $z > 6$



Only <10 quasars at $z > 6.5$, from UKIDSS, VIKING, and Pann-STARRS surveys.



NEW Surprises:

- $M_{BH} \sim (1-2) \times 10^9 M_{sun}$ typically
- Strong metallic emission lines

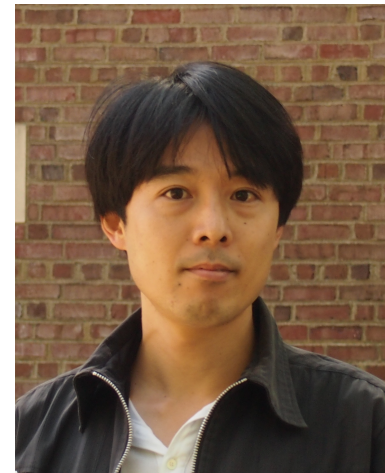
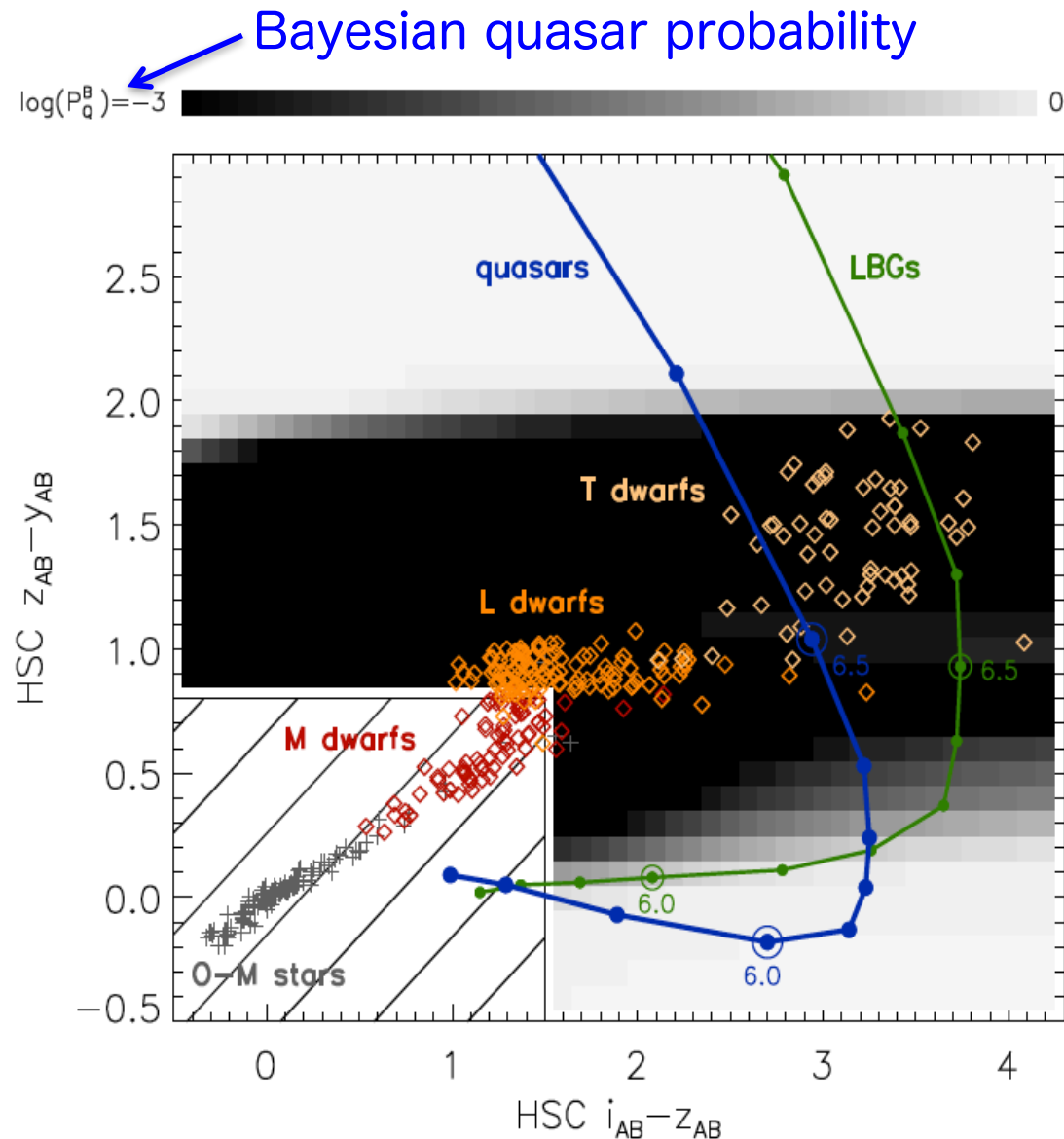
but based on small statistics...
and maybe we are missing
“growing-up” low- M_{BH} quasars
due to the limited sensitivity...

and we have NO quasars at $z > 7.1$

Venemans+13, +15, and some other papers



HSC quasars at $z > 6$: candidate selection



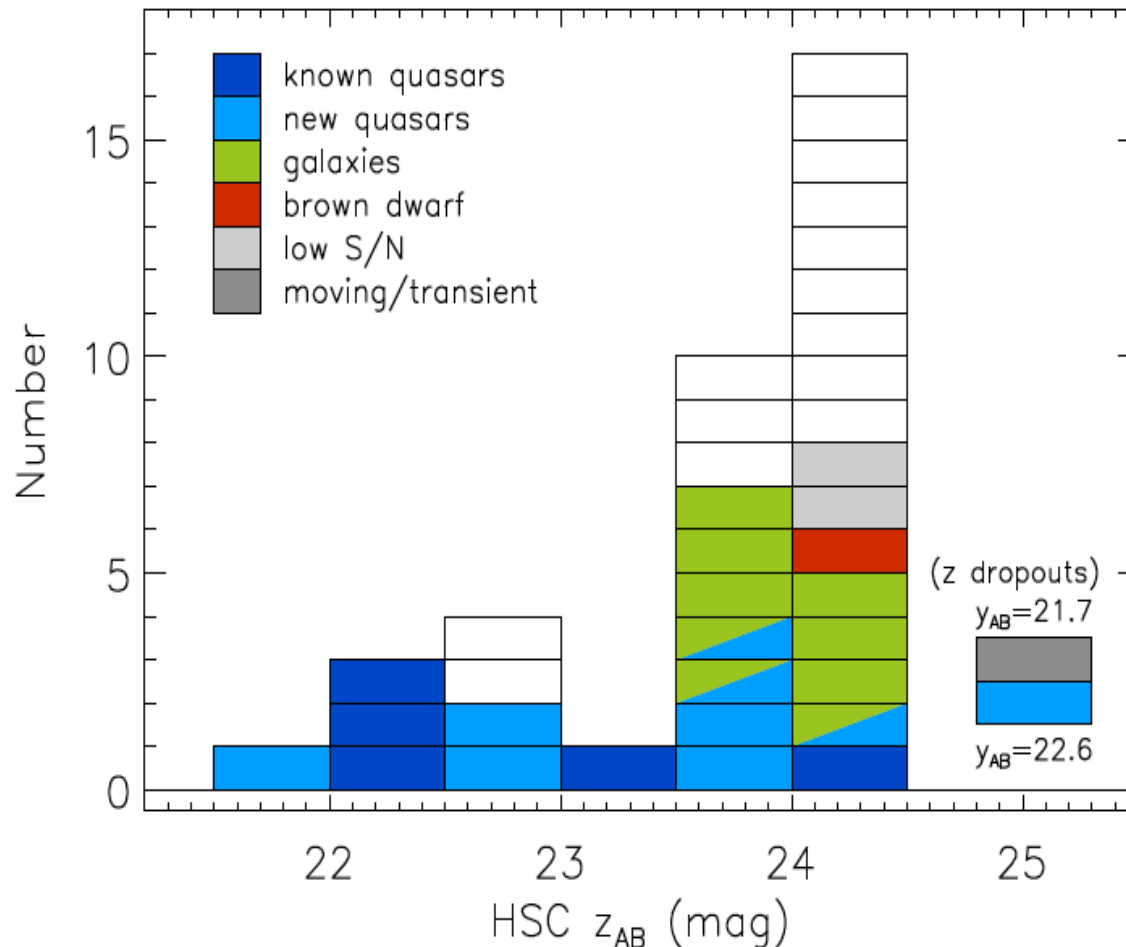
Yoshiki Matsuoka
(NAOJ → Ehime)

Candidates of quasars at $z \sim 6$ are selected with HSC i , z , y photometry (y -band is powerful).

We calculate the Bayesian quasar probability for every point sources, that are used for selecting our spectroscopic targets.



HSC quasars at $z > 6$: success rate



The success rate of our candidate selection is nearly 100% at $z < 23.5$!!

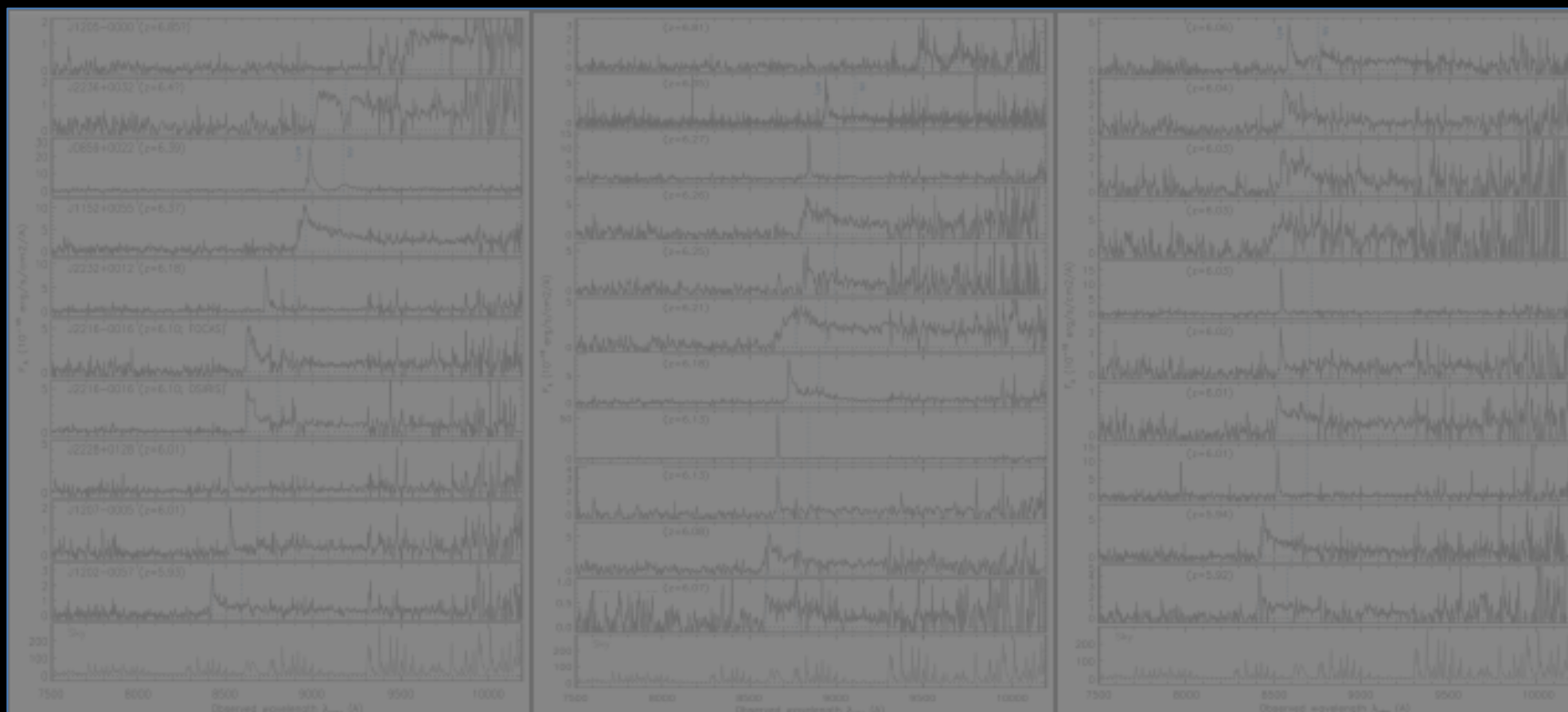
The success rate is still ~50% down to $z \sim 24$, and lower at fainter than $z=24$.

The main contamination source is actually galaxies at similar redshift, not brown dwarf stars. Our estimate of the Bayesian probability works very well.

Matsuoka et al. incl. TN (2016)
based on ~ 80 deg² data

(From Matsuoka-san's presentation)

Quasars

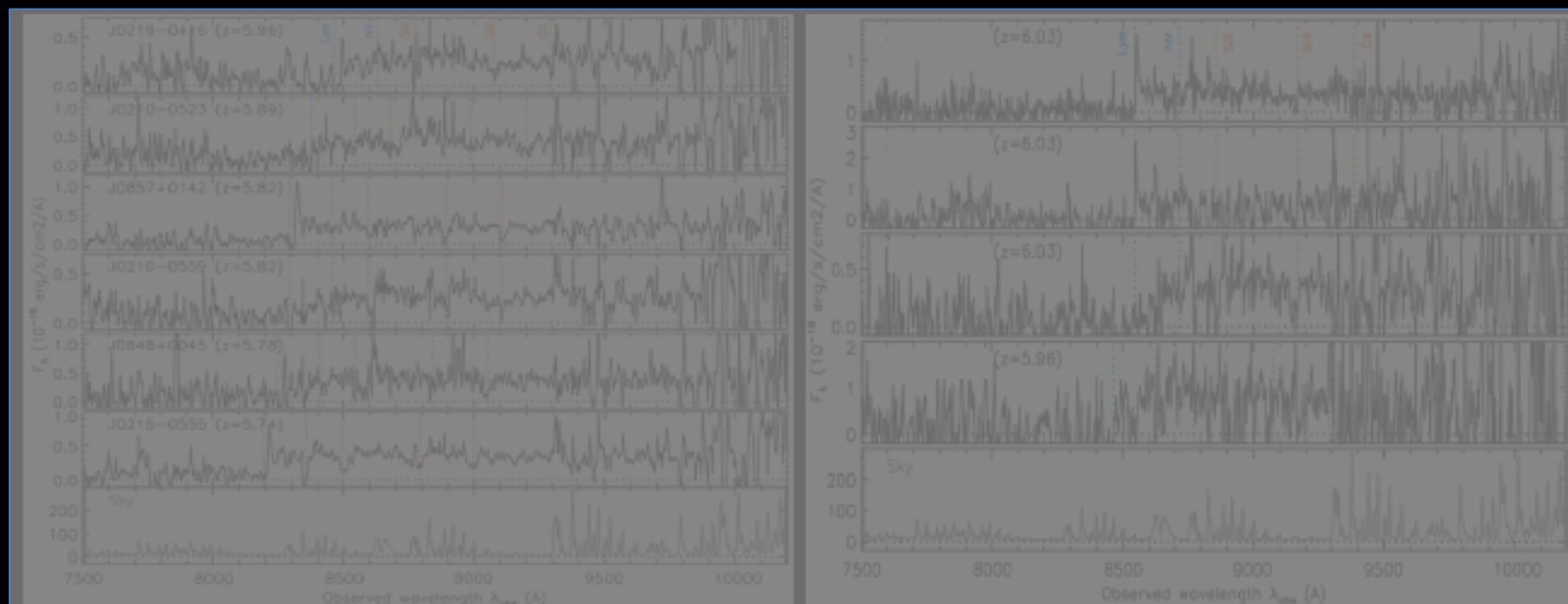


- ★ 30 new quasars at $5.9 < z < 6.9$ (+ 5 quasars recovered) over $\sim 100\text{-}150 \text{ deg}^2$.
- ★ Increasing fraction of absorption features toward higher- z and lower- L ?
- ★ Quasar/galaxy separation is not trivial, even with spectra.

We tentatively classify all the objects with $L(\text{Ly } \alpha) > 10^{43} \text{ erg/s}$ or $\text{FWHM}(\text{Ly } \alpha) > 500 \text{ km/s}$ (uncorrected for IGM absorption) as AGNs or possible AGNs.

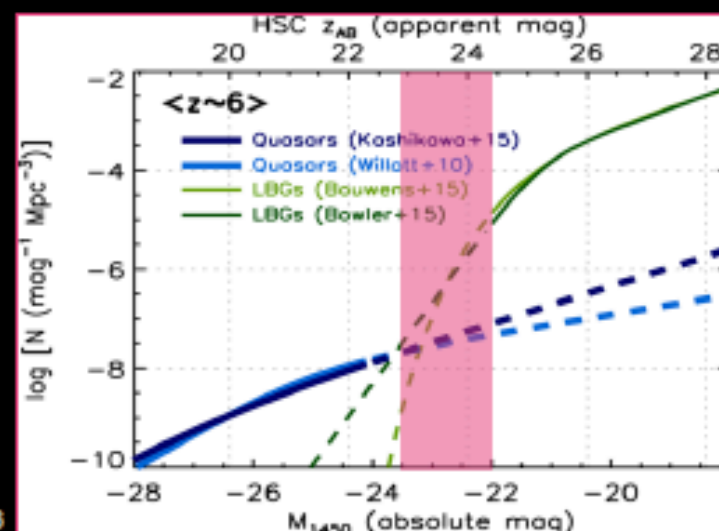
(From Matsuoka-san's presentation)

Galaxies

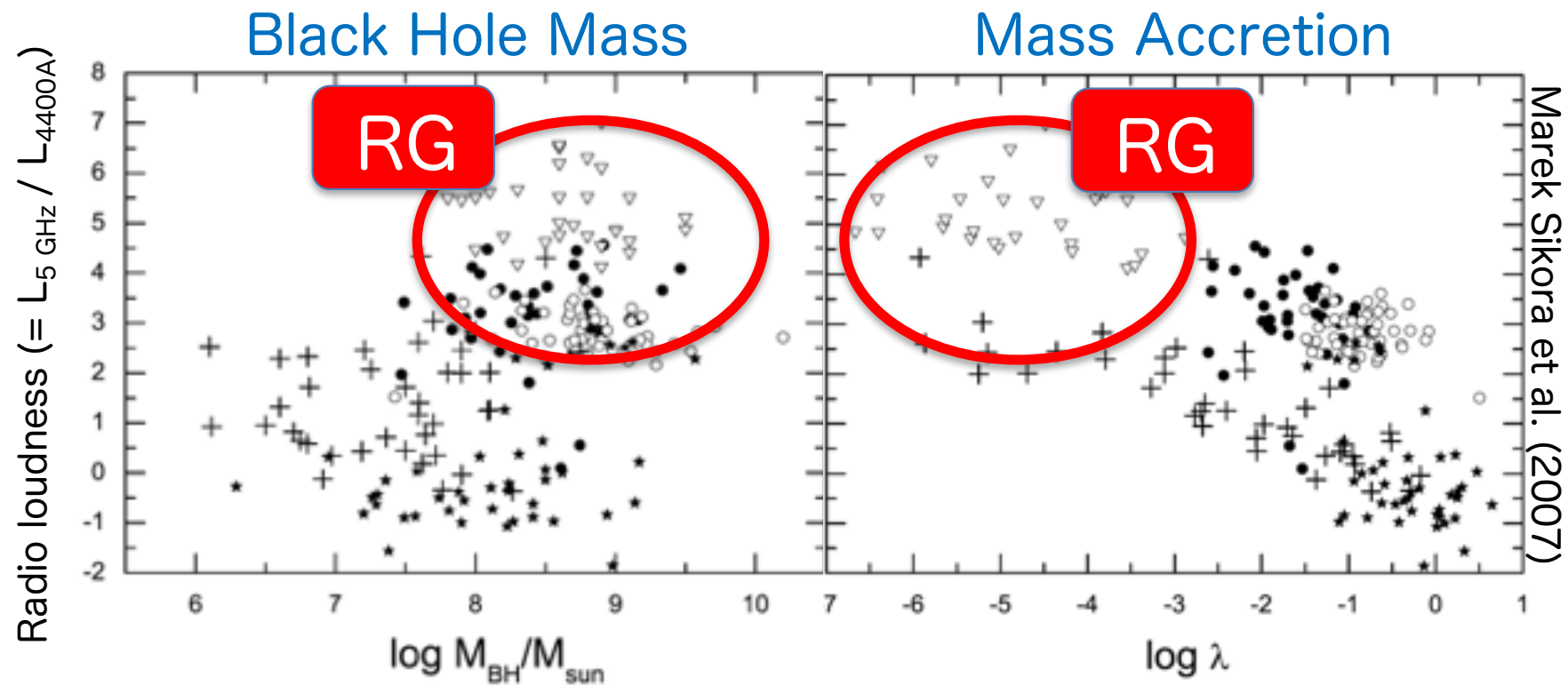


- ★ 9 luminous galaxies at $5.7 < z < 6.1$, with $-23.5 < M_{1350} < -22$ mag.
- ★ We excluded extended sources from our selection, so this result gives us the lower limit of the number density of high- z luminous galaxies.

Matsuoka+16



Radio galaxies: in the final phase of SMBH growth

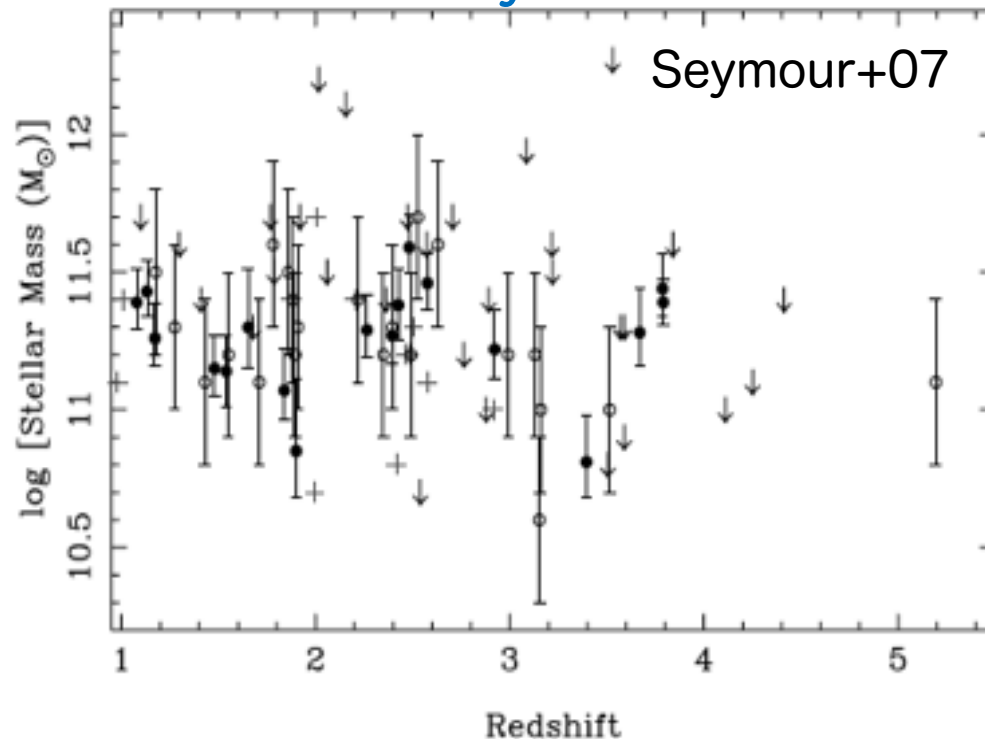


RGs are characterized by high BH mass and low accretion rate
→ RGs are in the final phase of the growth of SMBHs

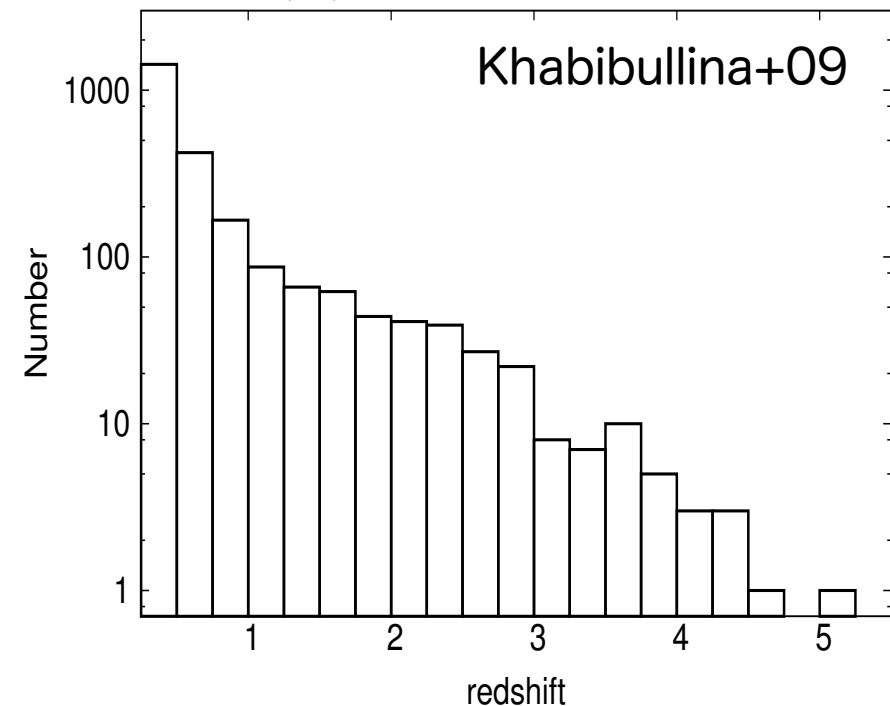


Radio galaxies: in the final phase of galaxy growth

Host Galaxy Mass of RGs



$N(z)$ of known RGs



RGs are generally hosted by massive quiescent galaxies

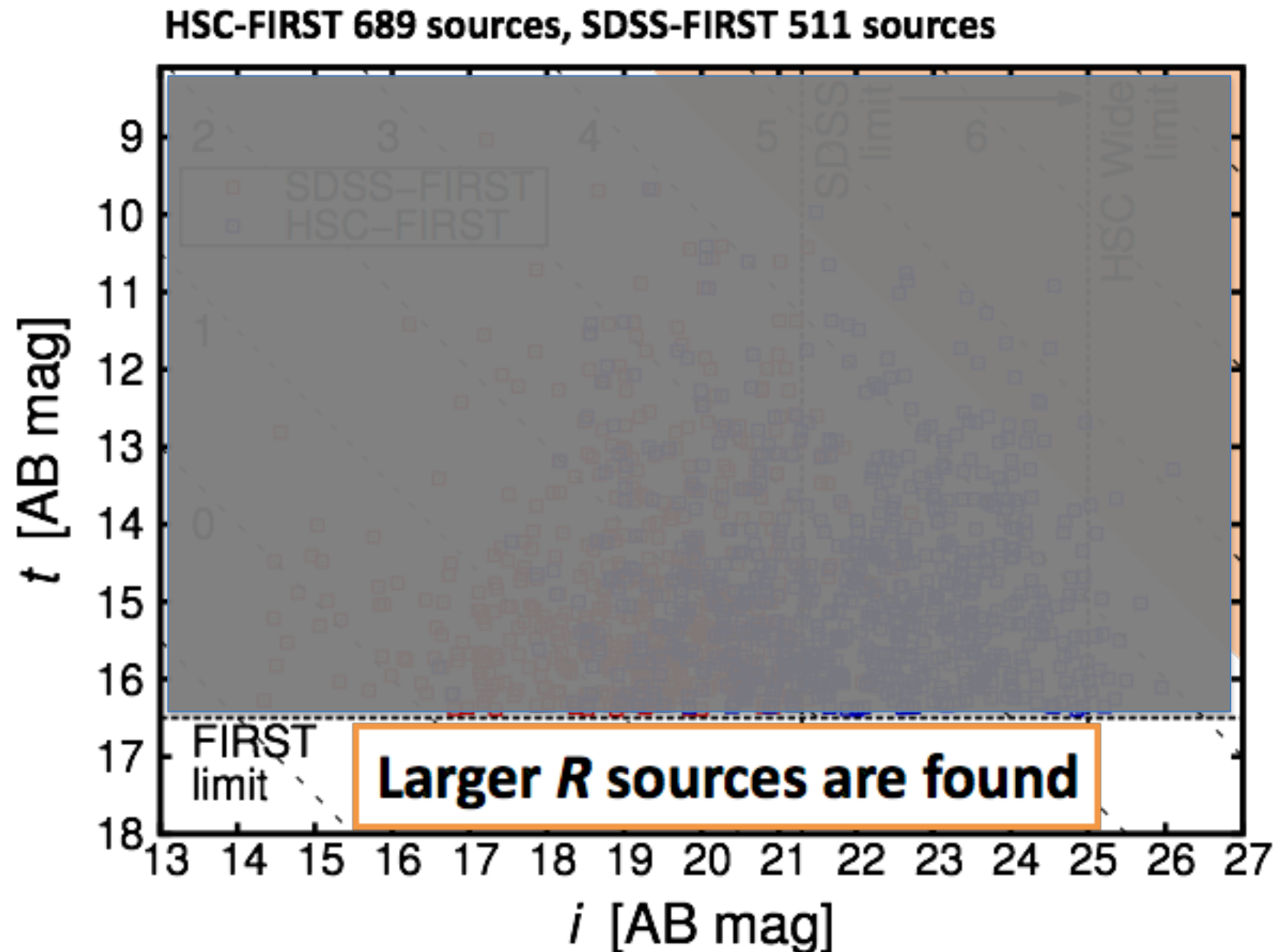
→ RGs are in the final phase of the growth of massive galaxies

Only few RGs have been identified so far...

→ new survey needed !!

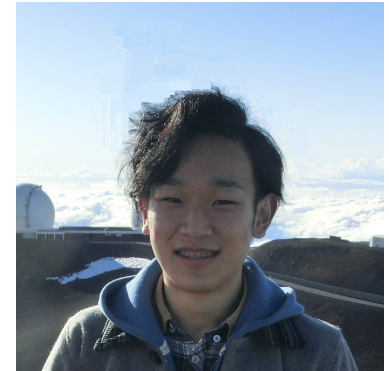
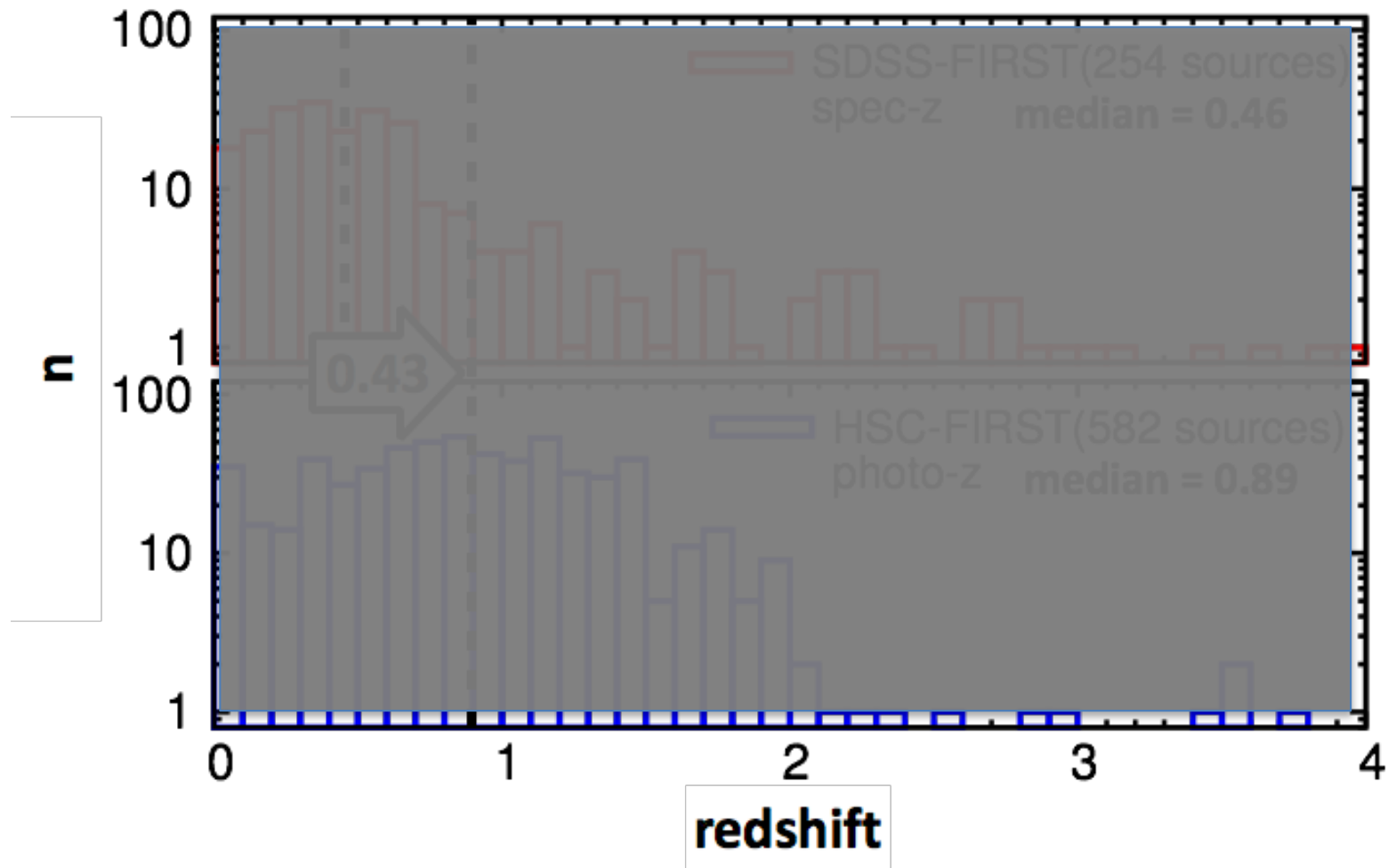


Radio galaxies: SDSS-RGs vs. HSC-RGs





Radio galaxies: SDSS-RGs vs. HSC-RGs



Kodai Nobuhara
(Ehime)



Takuji Yamashita
(ISAS → Ehime)

HSC is good to search for RGs at $z > 1$

At redshift > 3 : waiting for wider HSC images & spectra

(a number of proposals for follow-up spectroscopy submitted)



Summary

- Toward understanding the total picture of the SMBH evolution
 - ~ focusing on dusty AGNs, quasars, and radio galaxies
 - ~ utilizing the HSC-SSP data combined with multi-wav. data
- HSC search for dusty AGNs in dust-obscured galaxies (DOGs)
 - ~ HSC+WISE → DOGs sample → ACF → bias factor
 - ~ $M_{\text{DMH}} \sim 10^{13.5} M_{\text{sun}}$, $\tau_{\text{DOG}} \sim 40 \text{ Myr}$
- HSC search for quasars at $z > 6$
 - ~ new 30 quasars at $z > 6$ and some very luminous galaxies
 - ~ multi-wavelength follow-up observations now on-going
- HSC search for radio galaxies
 - ~ HSC is powerful to find RGs with a larger radio loudness & higher redshift
(spectroscopic observations now being proposed)