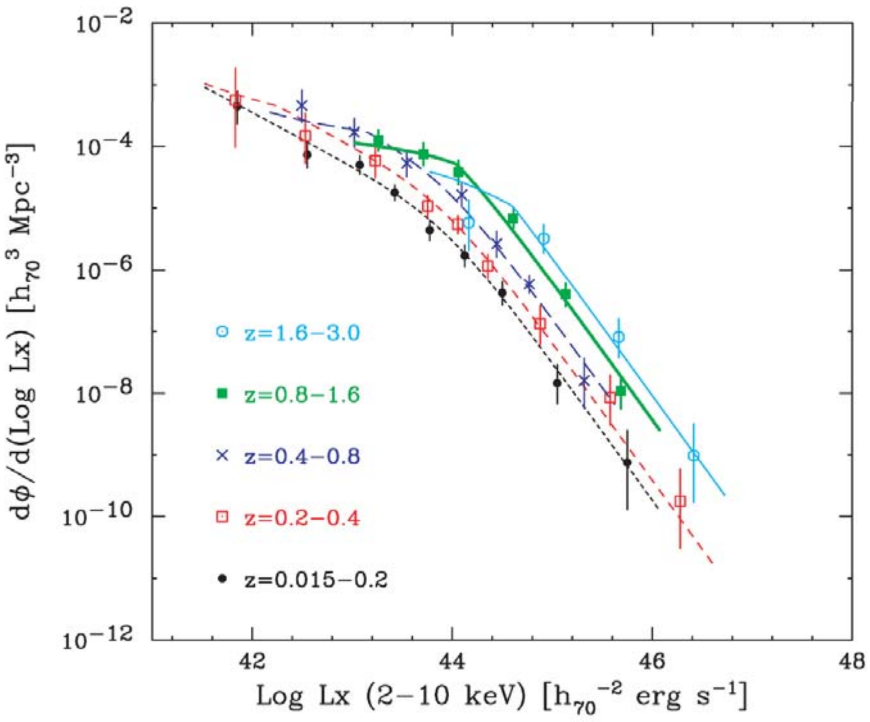
Active Black Hole Mass Function @ z~1.4 in SXDS with FMOS GTO

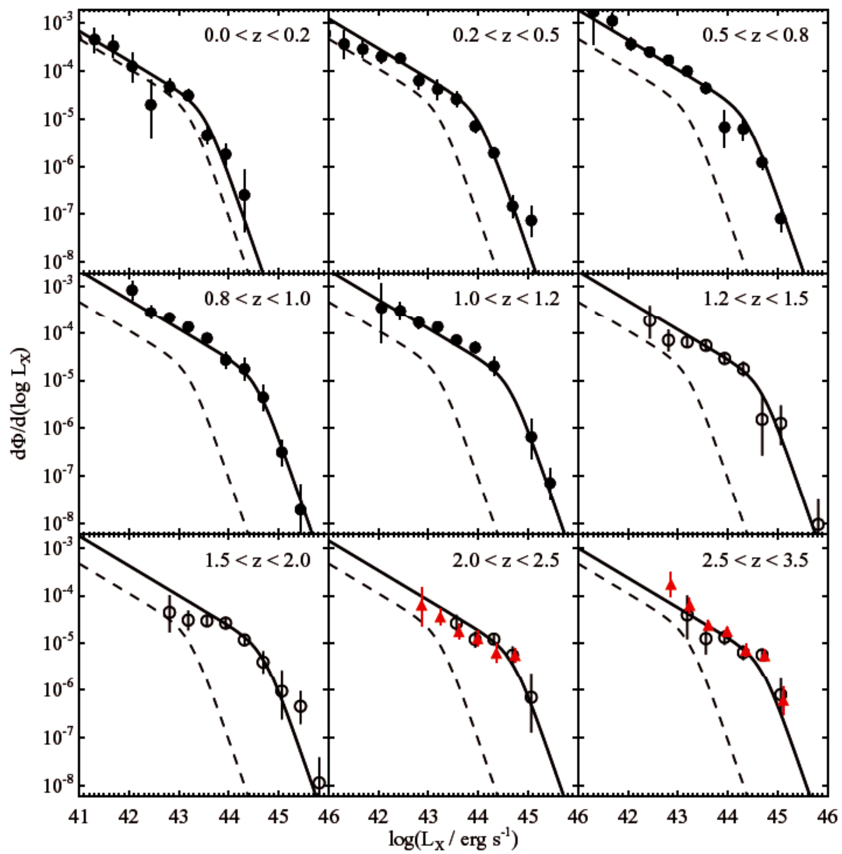
Masayuki Akiyama, Kazuya Nobuta (Tohoku Univ.)
Yoshihiro Ueda, Kazuo Hiroi (Kyoto Univ.)
John Silverman (IPMU)
FMOS GTO team, SXDS team

Nobuta M-thesis, Nobuta et al. in prep.

What does the evolution of AGN LF physically reflect ?



Ueda et al. 2003



Aird et al. 2010

Luminosity Dependent Density Evolution (LDDE) model ? Or
Luminosity And Density Evolution (LADE) model ?

Growth curve of Super Massive BHs

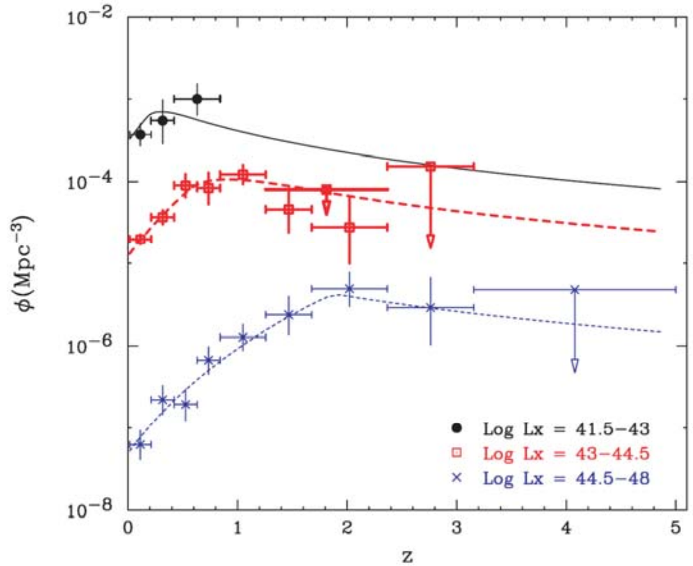
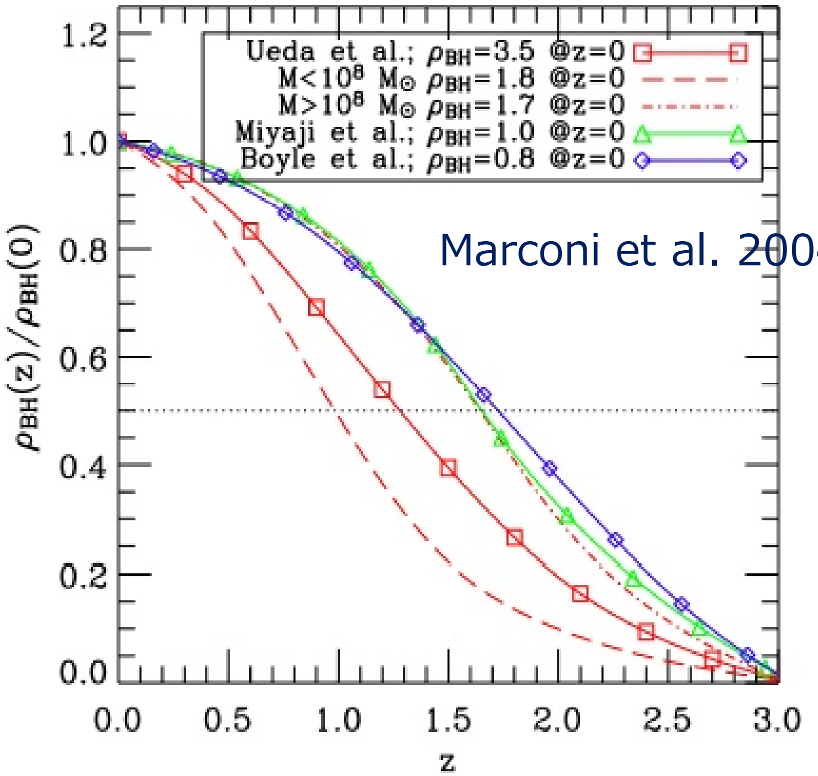


FIG. 12.—Comoving spatial density of AGNs as a function of redshift in three luminosity ranges, log L_X = 41.5–43 (*upper black curve*), 43–44.5 (*middle red curve*), and 44.5–48 (*lower blue curve*). The lines are calculated from the best-fit model of the HXLF. The errors are 1 σ, while the long arrows denote the 90% upper limits (corresponding to 2.3 objects). The short arrow (marked with a red filled square) corresponds to the 90% upper limit on the average spatial density of AGNs with log L_X = 43–44.5 at z = 1.2–2.3 when all the unidentified sources are assumed to be in this redshift bin.

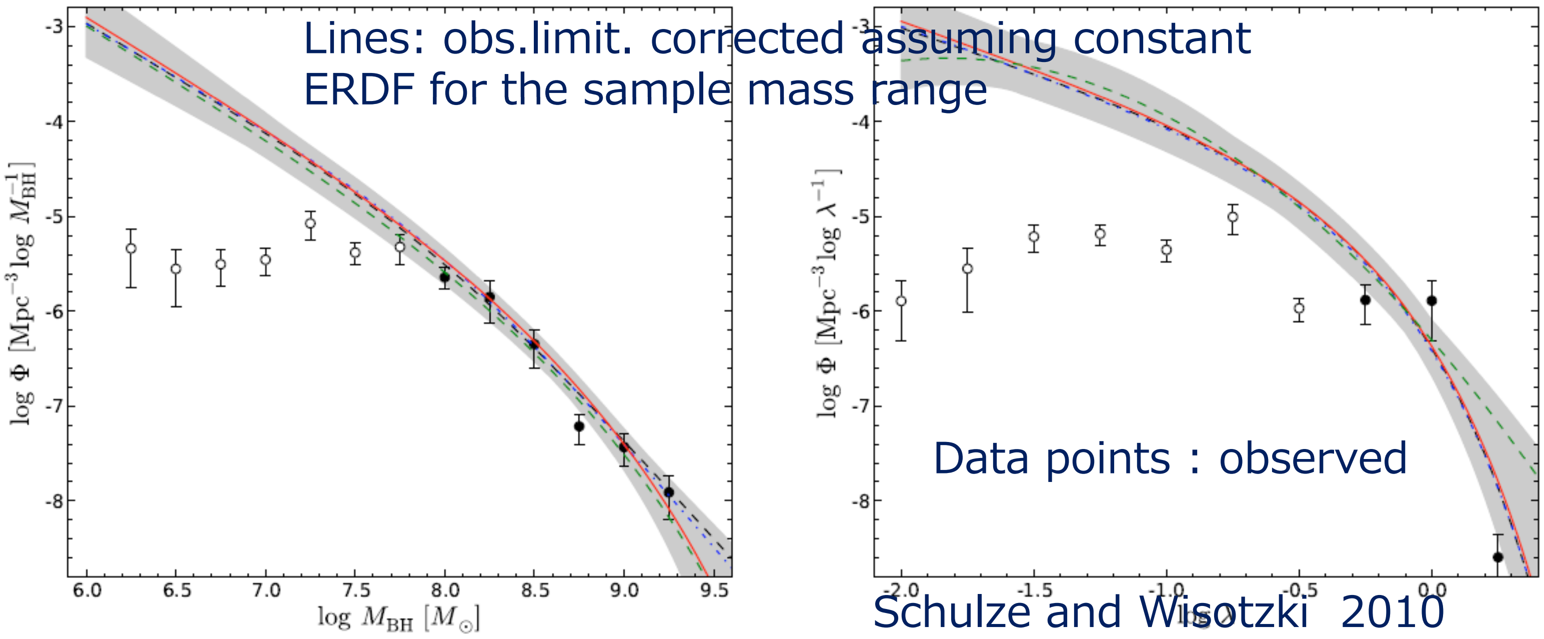


Marconi et al. 2004

Based on redshift evolution of X-ray luminosity function of AGNs, growth curves of SMBHs have been evaluated.

But such calculations are done assuming constant Eddington ratio for entire AGN population (luminosity = mass). For quantitative understanding of growth curve of SMBHs, mass and accretion rate of AGNs need to be examined.

Local Active BH Mass Function and Eddington Ratio Distribution Function

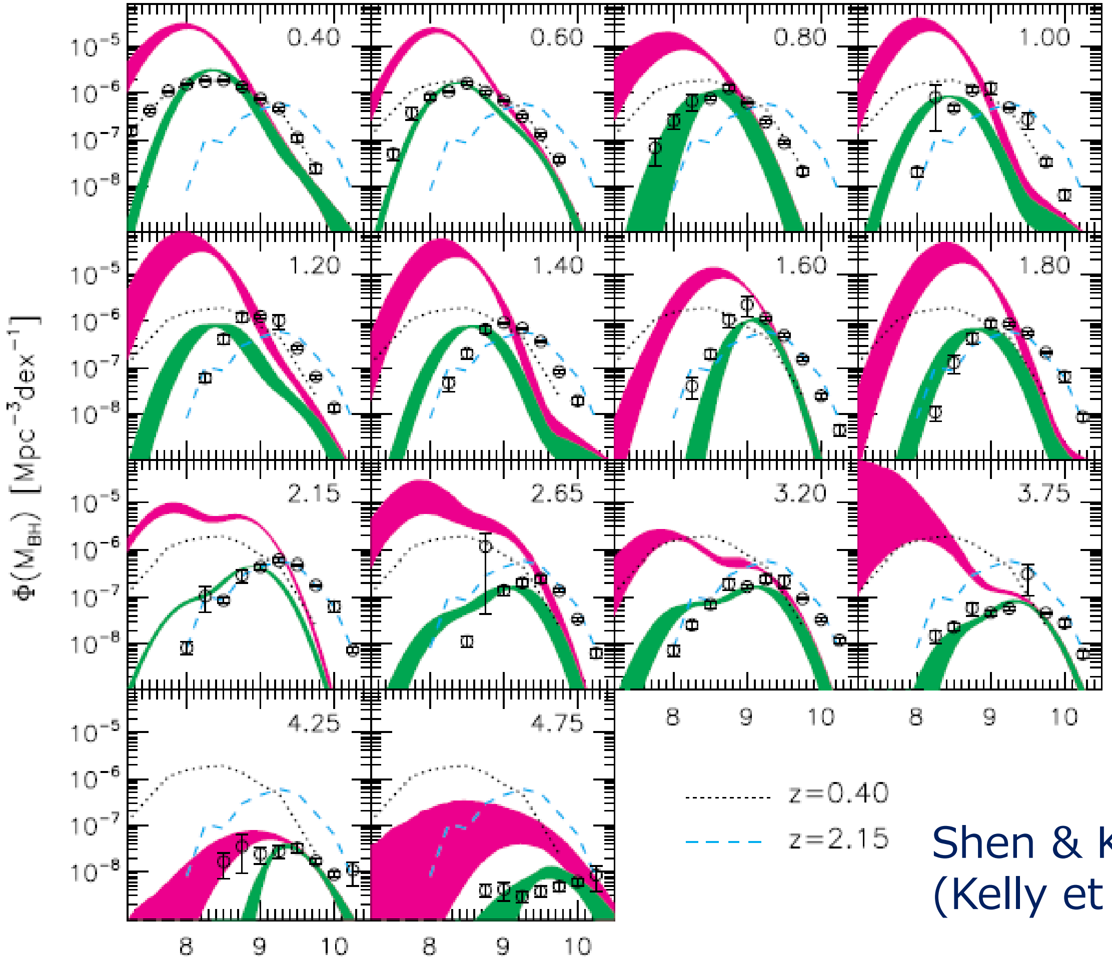


Schulze and Wisotzki 2010

Rather steep active BH mass function and Eddington ratio distribution function mean no typical active black hole mass or no typical Eddington ratio in the local universe.

How about violent era (z=1-2) of the universe ?

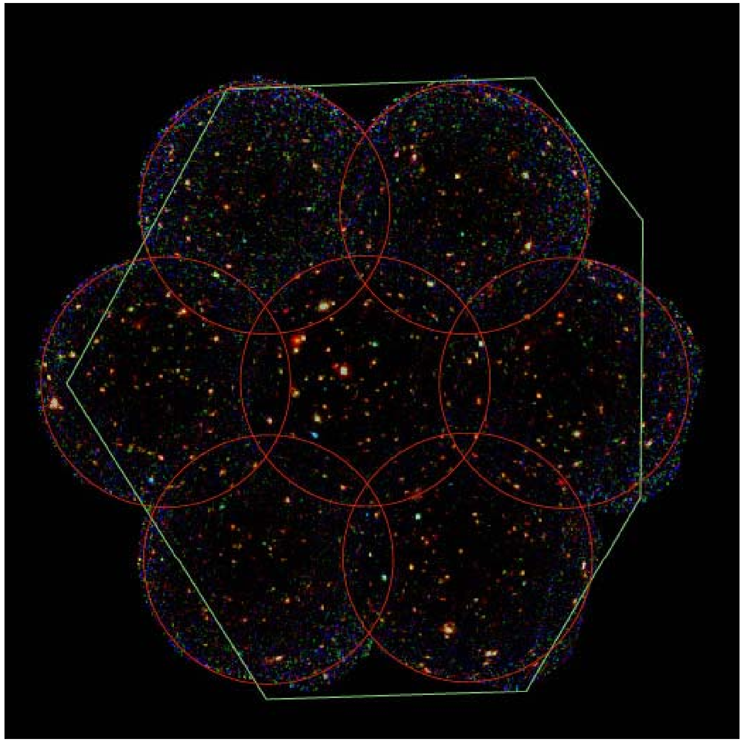
Active BH Mass Function from SDSS



Shen & Kelly 2012
(Kelly et al. 2009, 2010)

SDSS sample only covers most massive BHs with high-Eddington (~1) ratio. In order to understand the AGNs dominating accretion growth of SMBHs, it is necessary to reveal fainter AGNs (~knee of X-ray logN-logS).

SXDS sample



945 sources detected in XMM-Newton – Suprime-cam/Subaru overlapping area (Ueda et al. 2008).

Removing cluster and galactic star candidates, 896 sources remain as candidates of AGNs.

Optical spec covers: 590 sources

FMOS GTO NIR spec covers: 851 sources

586 sources have spectroscopic-redshifts

296 out of 310 remaining sources have secure photometric redshifts determined with photometry in the wavelength range between 1500A to 8um.

SXDS sample in 1.18<z<1.68 (z~1.4)

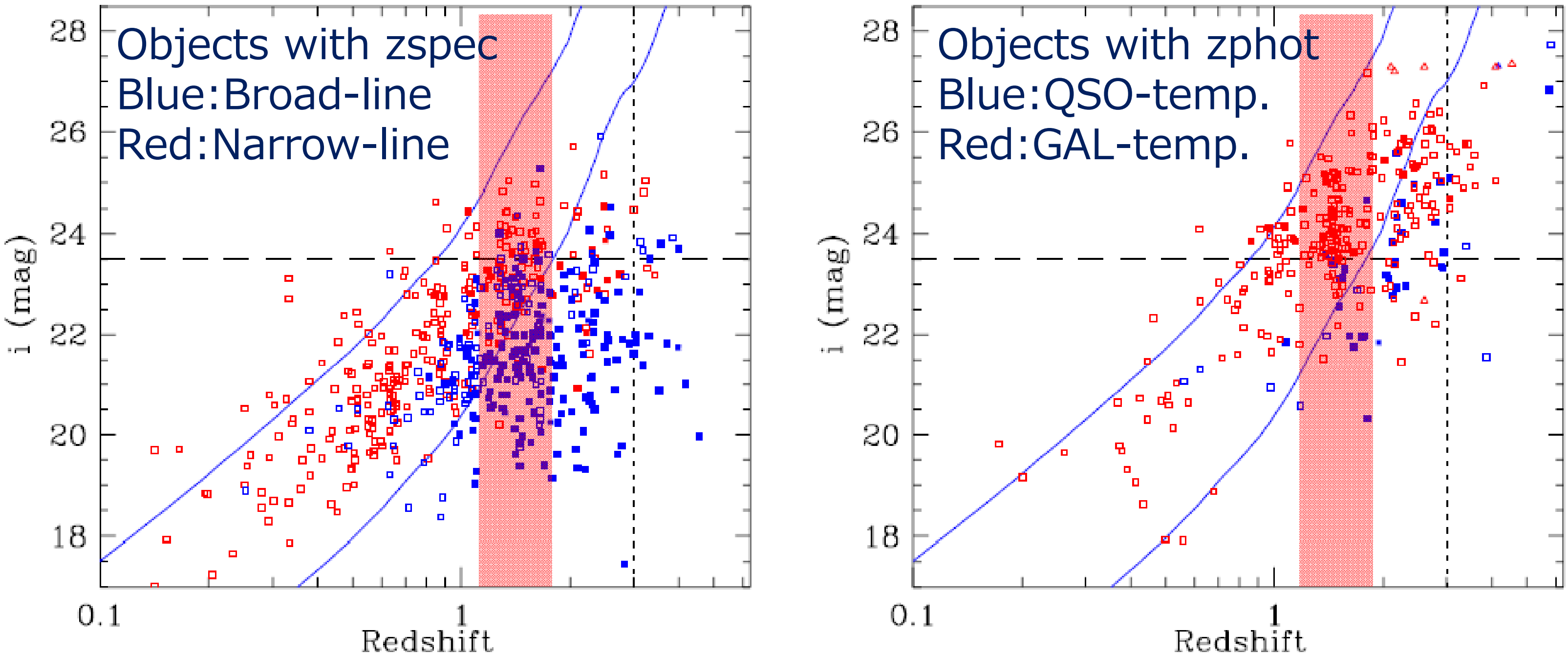


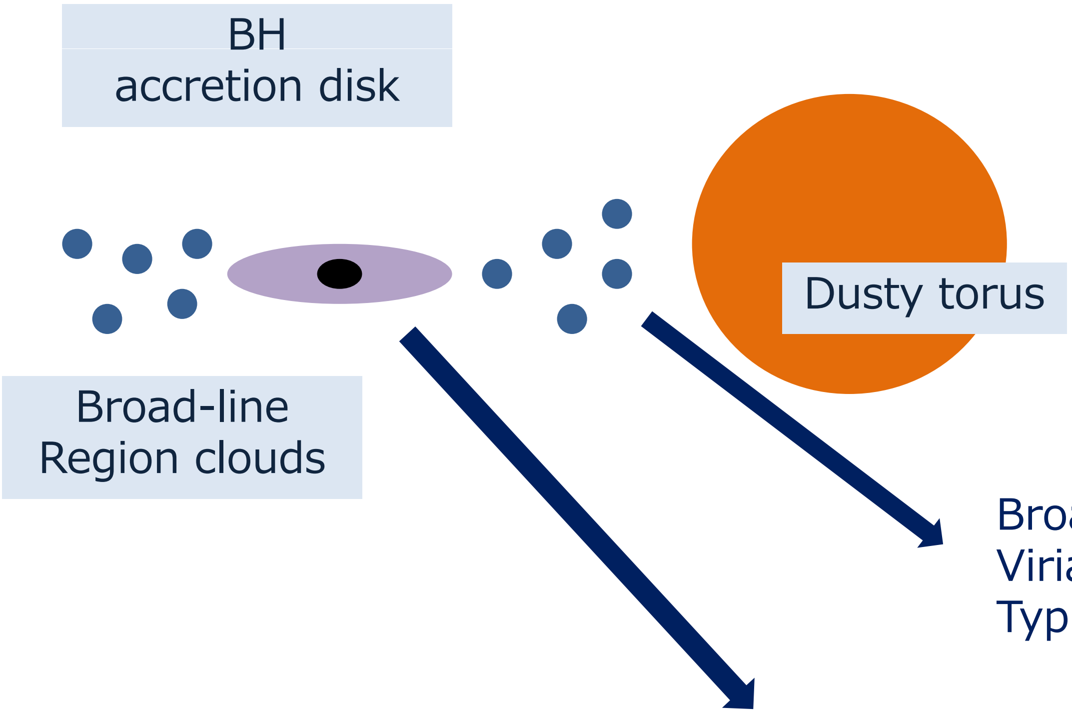
FIG. 7.— Redshift vs. i-band magnitude for spectroscopically identified sources. Blue and red symbols represent NEM and BEM identifications, respectively. Filled symbols indicate stellar object. Stellarities are examined with i-band FWHM less than 0.9 arcsec for objects with $i < 20$, and . Almost all of the stellar objects fainter than i=20.0mag are at $z > 1$ and most of them are BEM, i.e. QSOs. Therefore in the photometric redshift determination, $i > 20$ stellar objects are fitted only with templates at $z > 1$.

Broad-line AGN : with zspec 118 objects, zphot only 10 objects
Narrow-line AGN : with zspec 66 objects, zphot only 92 objects

In this study, we select target redshift range considering the FMOS wavelength coverage.

The sample is highly complete for broad-line AGNs, most of zphot only 10 objects in this redshift range are unlikely in the redshift range, because they do not show strong broad Halpha in the FMOS observation.

Black Hole Mass Estimation



Broad-emission lines:
Virialized velocity structure
Typical emitting region size ~ L^0.5

Continuum emission:
Bolometric luminosity

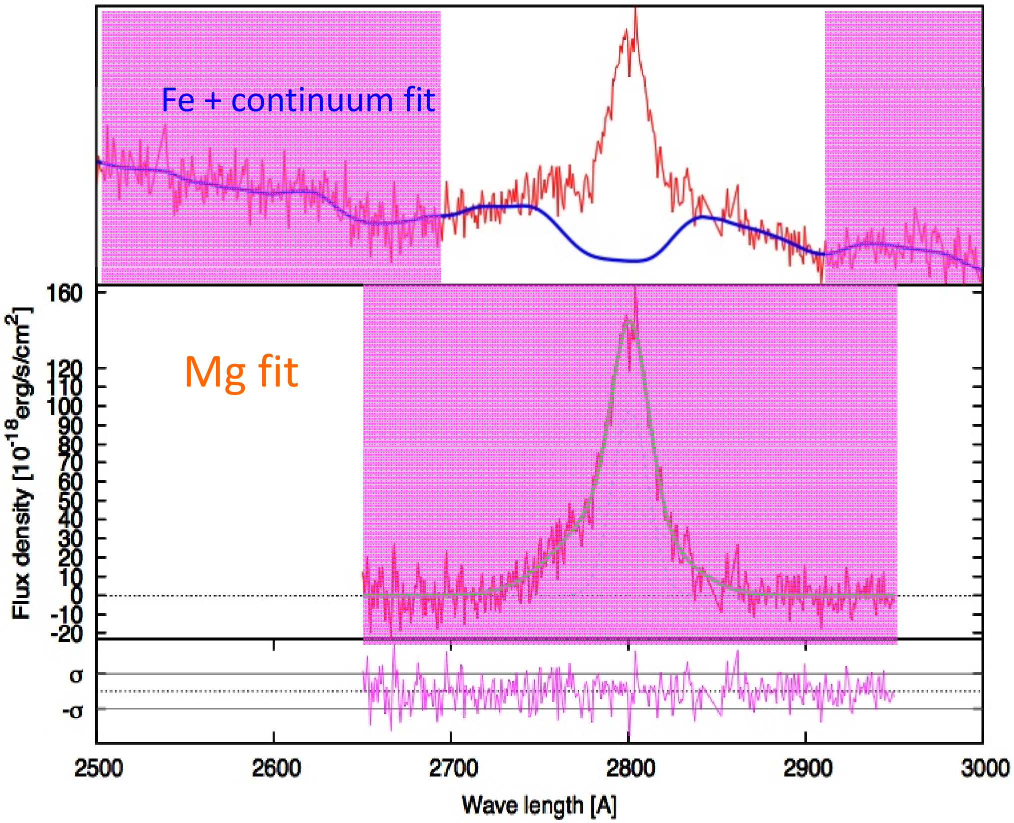
Broad-line width + Continuum luminosity + Assuming virialized velocity structure = Black Hole Mass

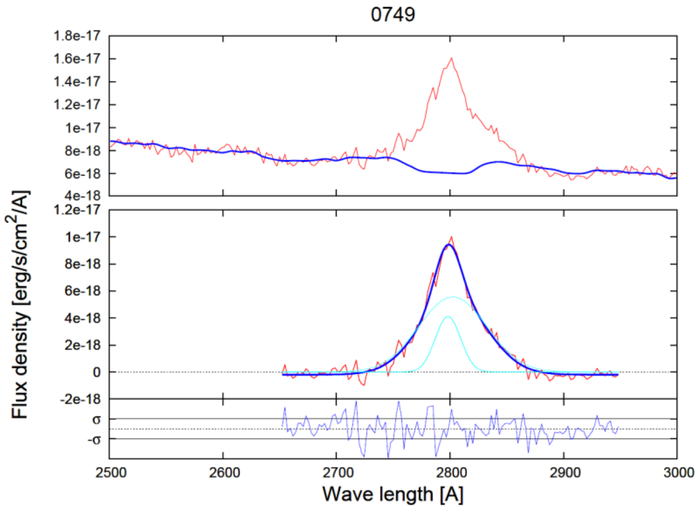
Continuum luminosity ~ Bolometric luminosity ~ Accretion Rate

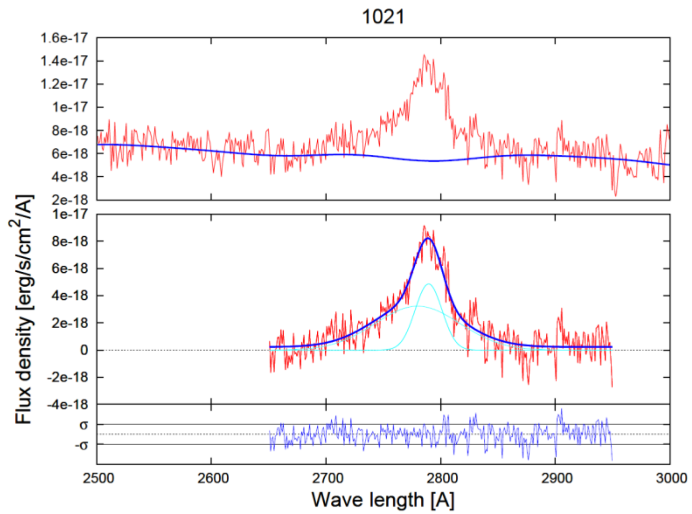
Luminosity / Eddington Luminosity (Black Hole mass) = Eddington ratio

MgII FWHM measurements

(188 objects in total) 97 objects out of 118 broad-line AGNs at z=1.18-1.68

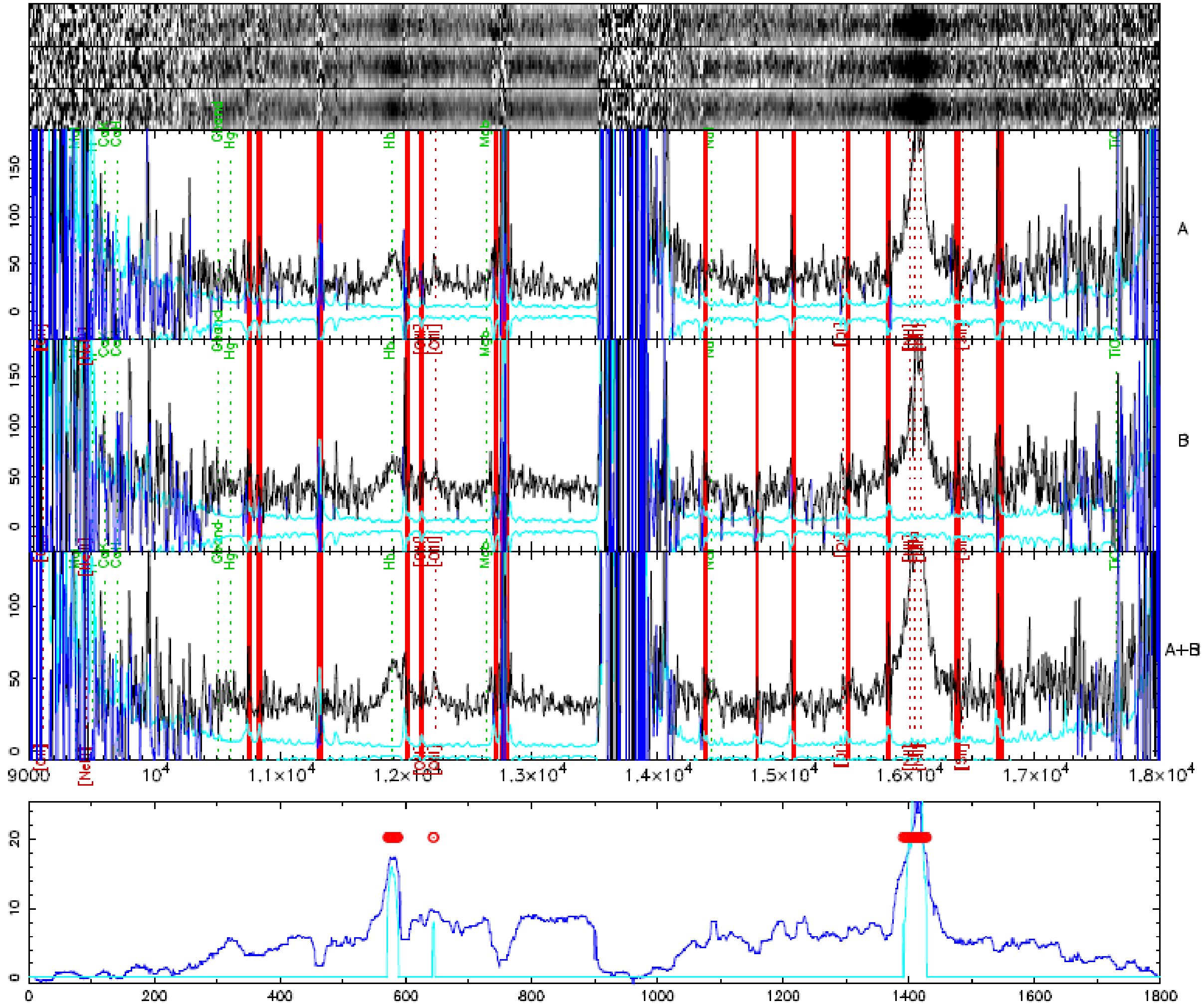






Halpha FWHM with FMOS

(81 objects in total) 19 additional objects out of 21 broad-line AGNs at z=1.18-1.68 w/o MgII FWHM measurement



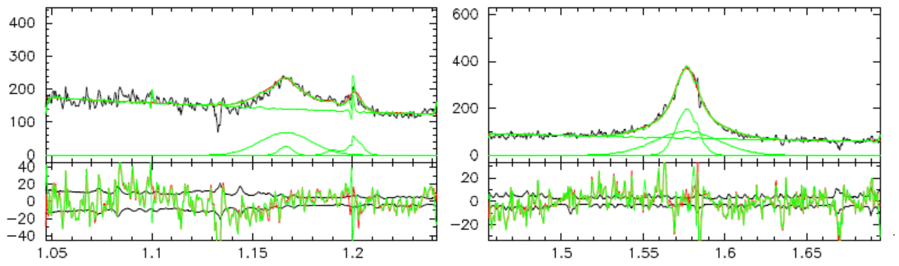
0014_0735 1.445000 BEM OLDID,HαBL,HbBL

20101217_SXDS12/irs1_SXDS12 Apos=81 Bpos=82 SDS0_0014=SXDF_0735 AGN1,zs=1.445,zp=1.660,H=19.44

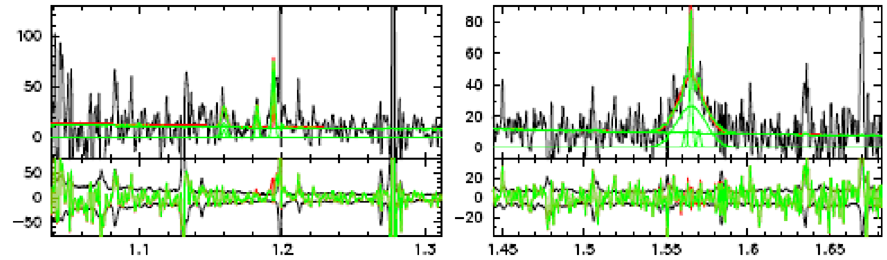
Halpha FWHM

(81 objects in total) 19 additional objects out of 21 broad-line AGNs at z=1.18-1.68 w/o MgII FWHM measurement

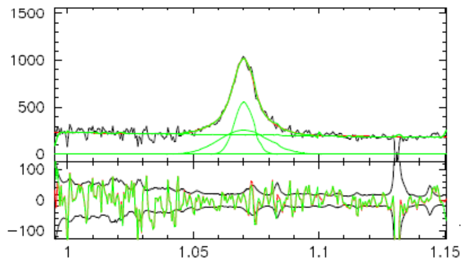
SXDS8_0003_0817_AB



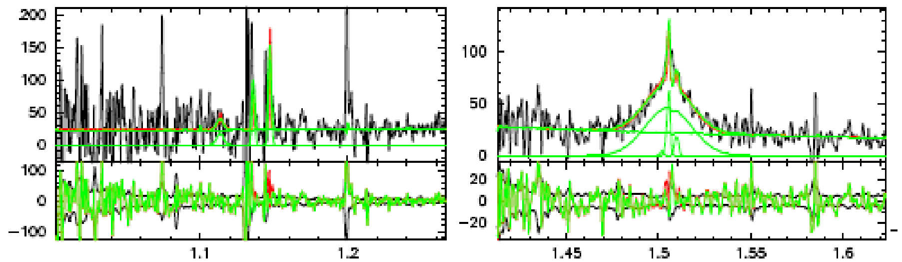
SXDS2_0908_0332_AB



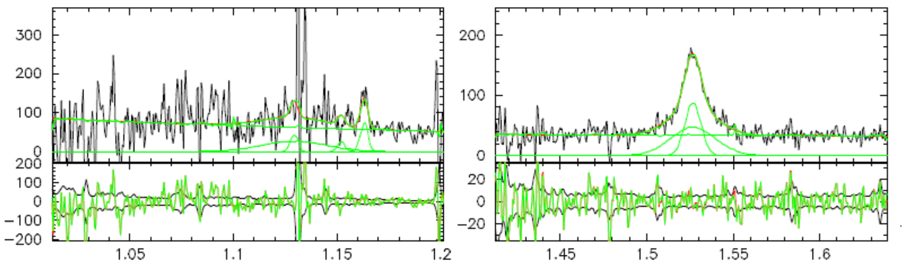
SXDS20_0283_1082_AB



SXDS24_1115_0630_AB



SXDS20_0487_1136_AB

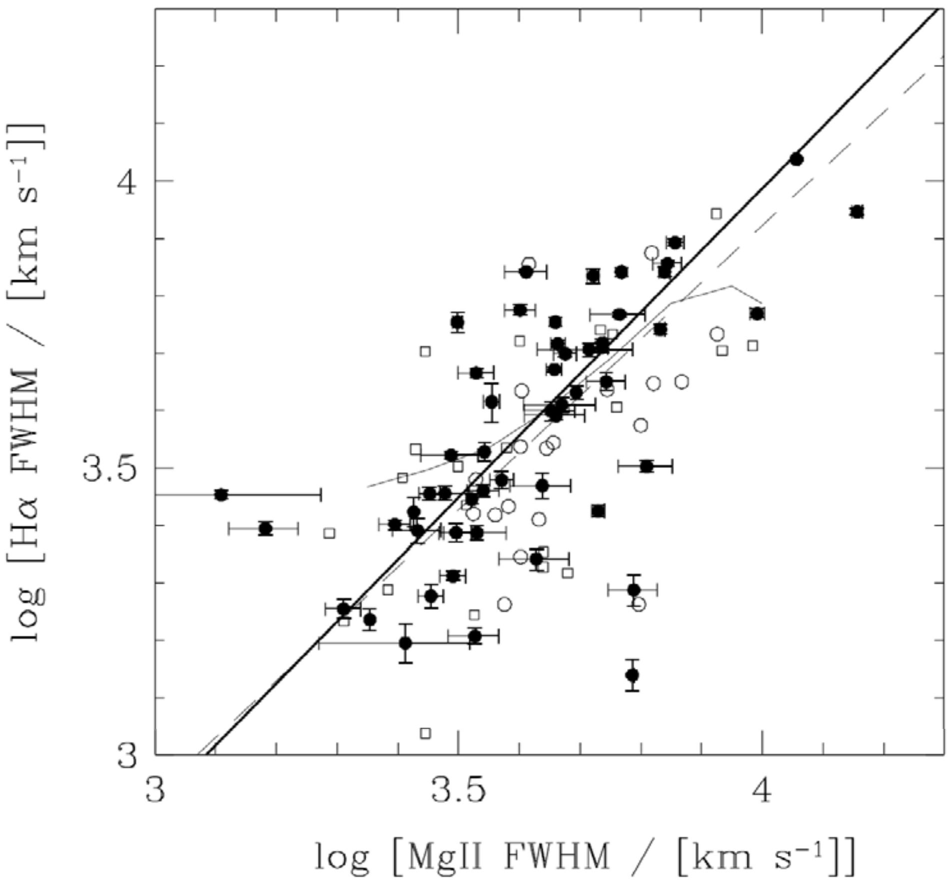


H-beta in left, H-alpha in right panels

Halpha FWHM

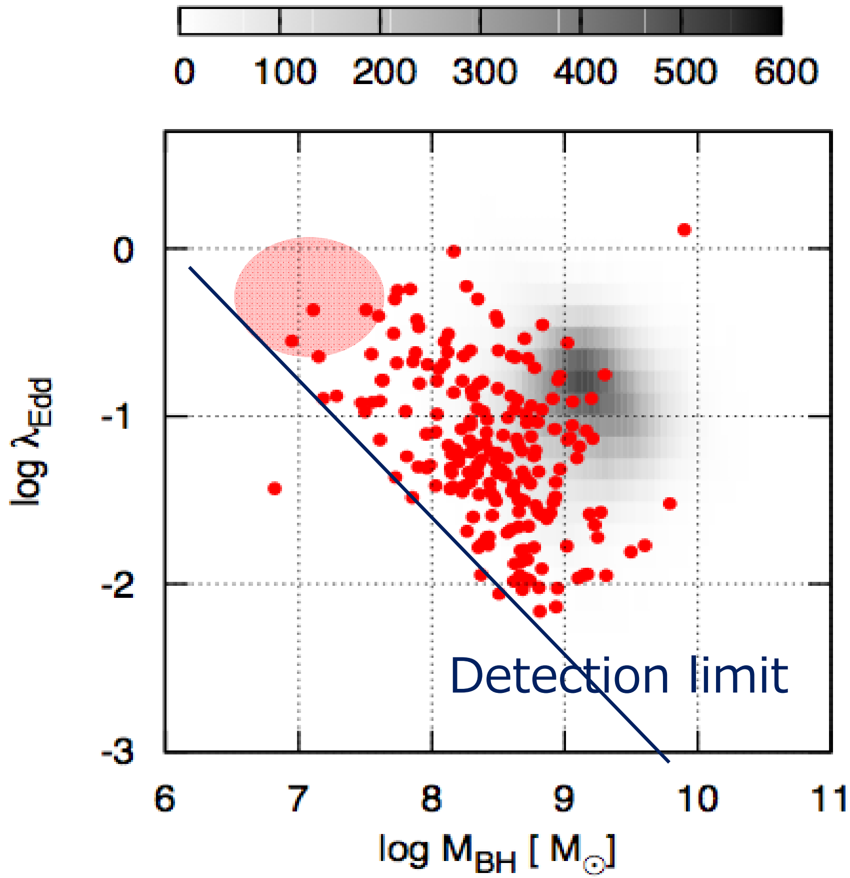
(81 objects in total) 19 additional objects out of 21 broad-line AGNs at z=1.18-1.68 w/o MgII FWHM measurement

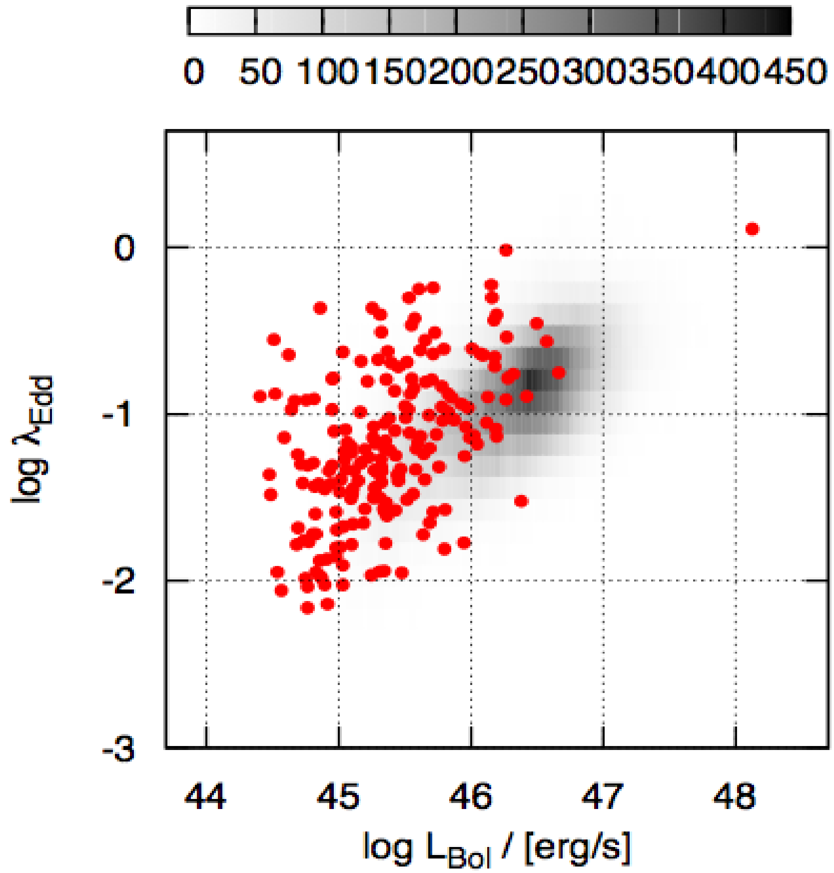
Because Halpha and Mg+ ionization potentials are similar, broad Halpha emission is expected to be emitted in the similar region of MgII emitting region.



Black Hole Mass and Eddington Ratio

Broad-line AGNs in 1.18 < z <1.68

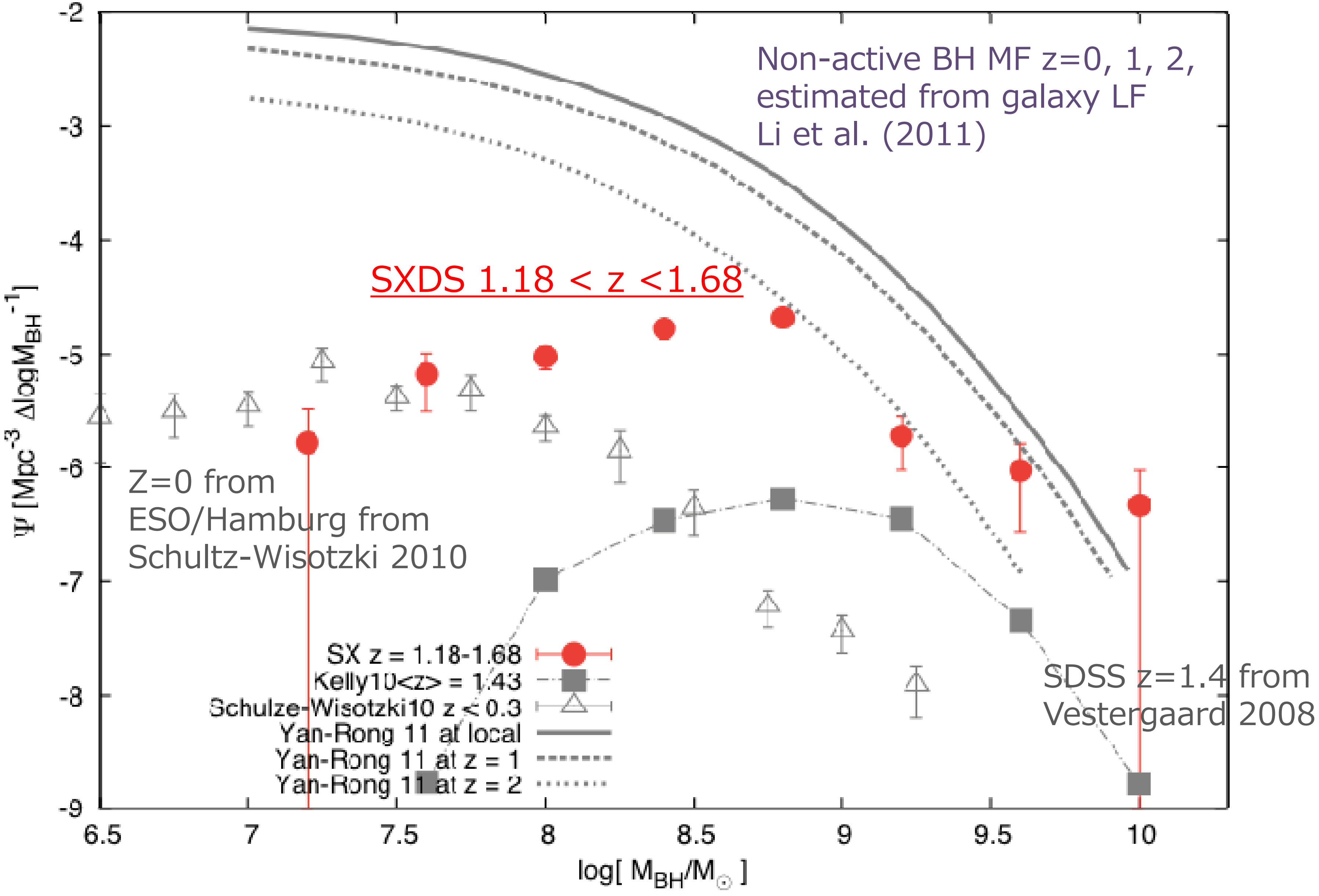




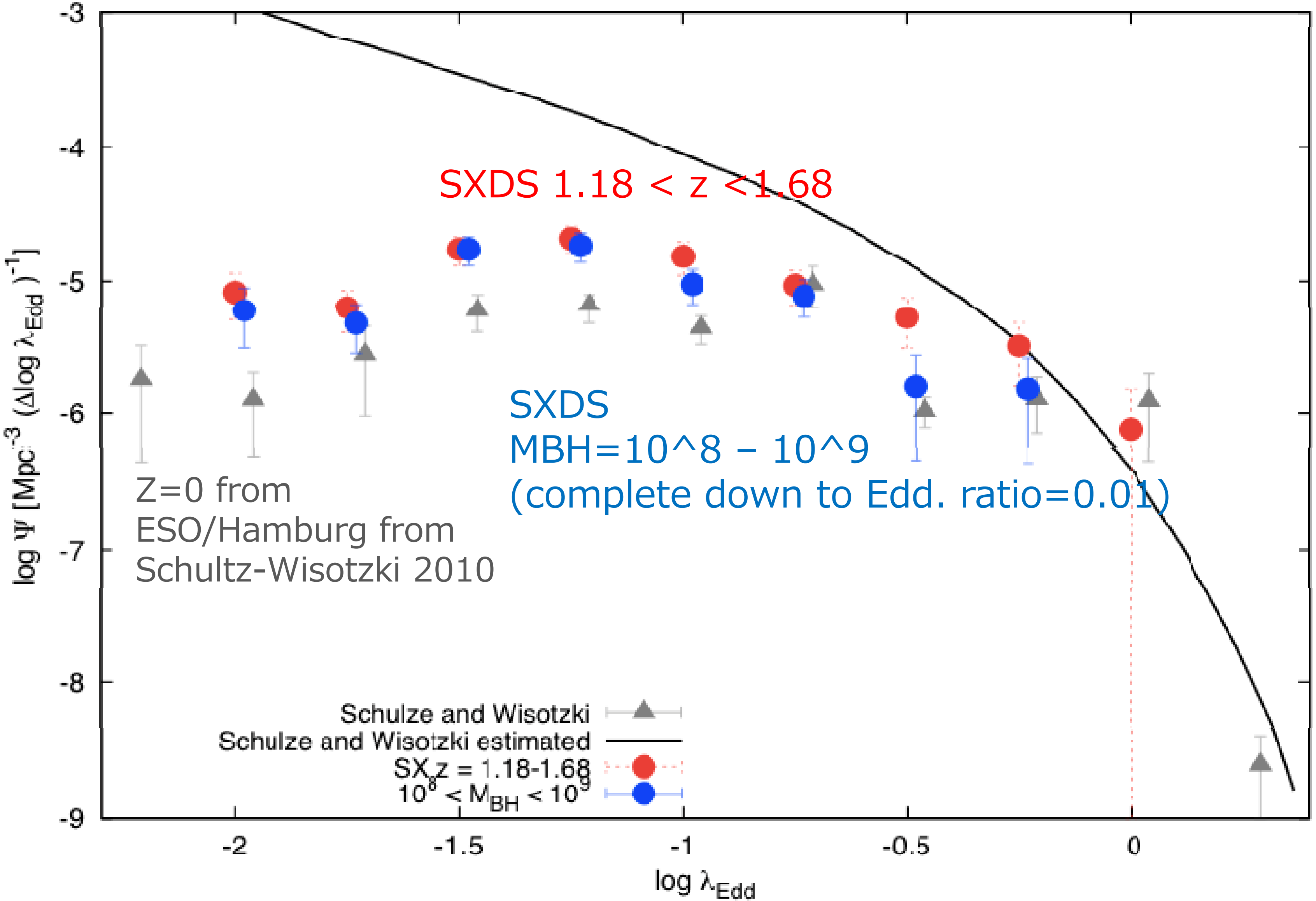
Broad-line AGNs in SXDS (red) and SDSS (gray scale)

Lack of high Eddington ratio AGNs with 10^7 Msolar ?

Active Black Hole Mass Function (Soft sample)

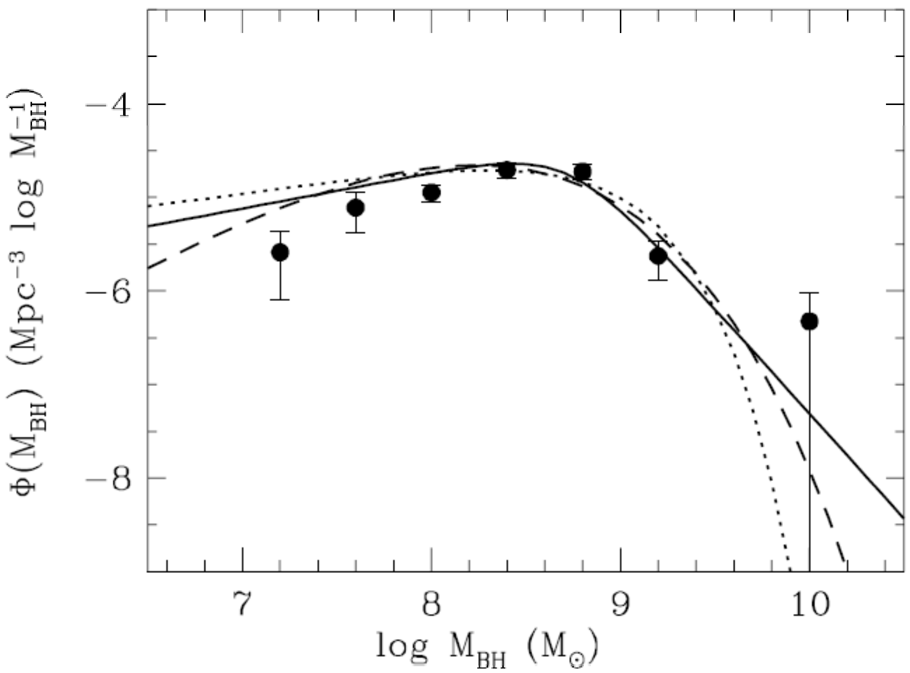


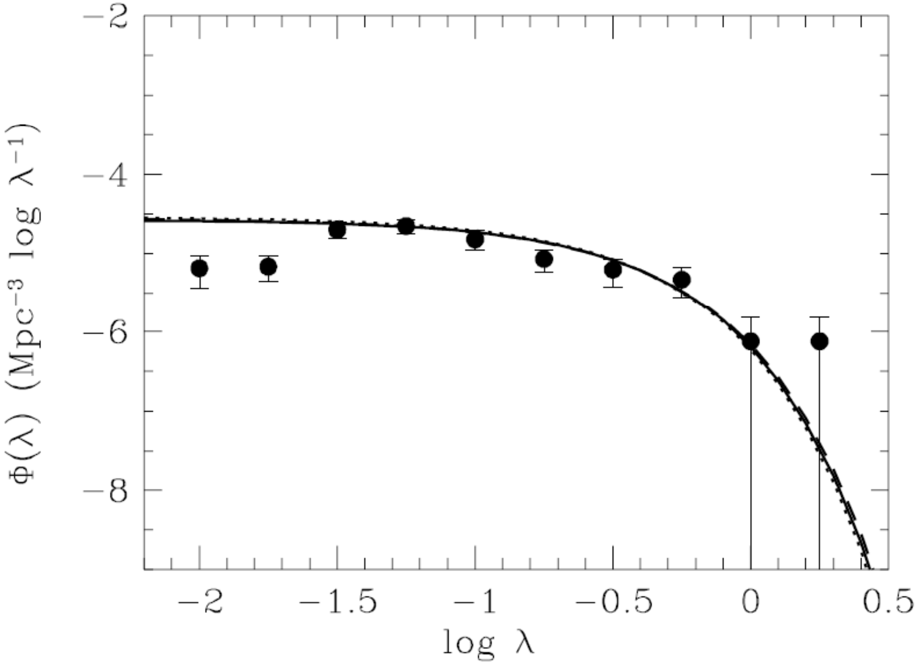
Eddington Ratio Distribution Function



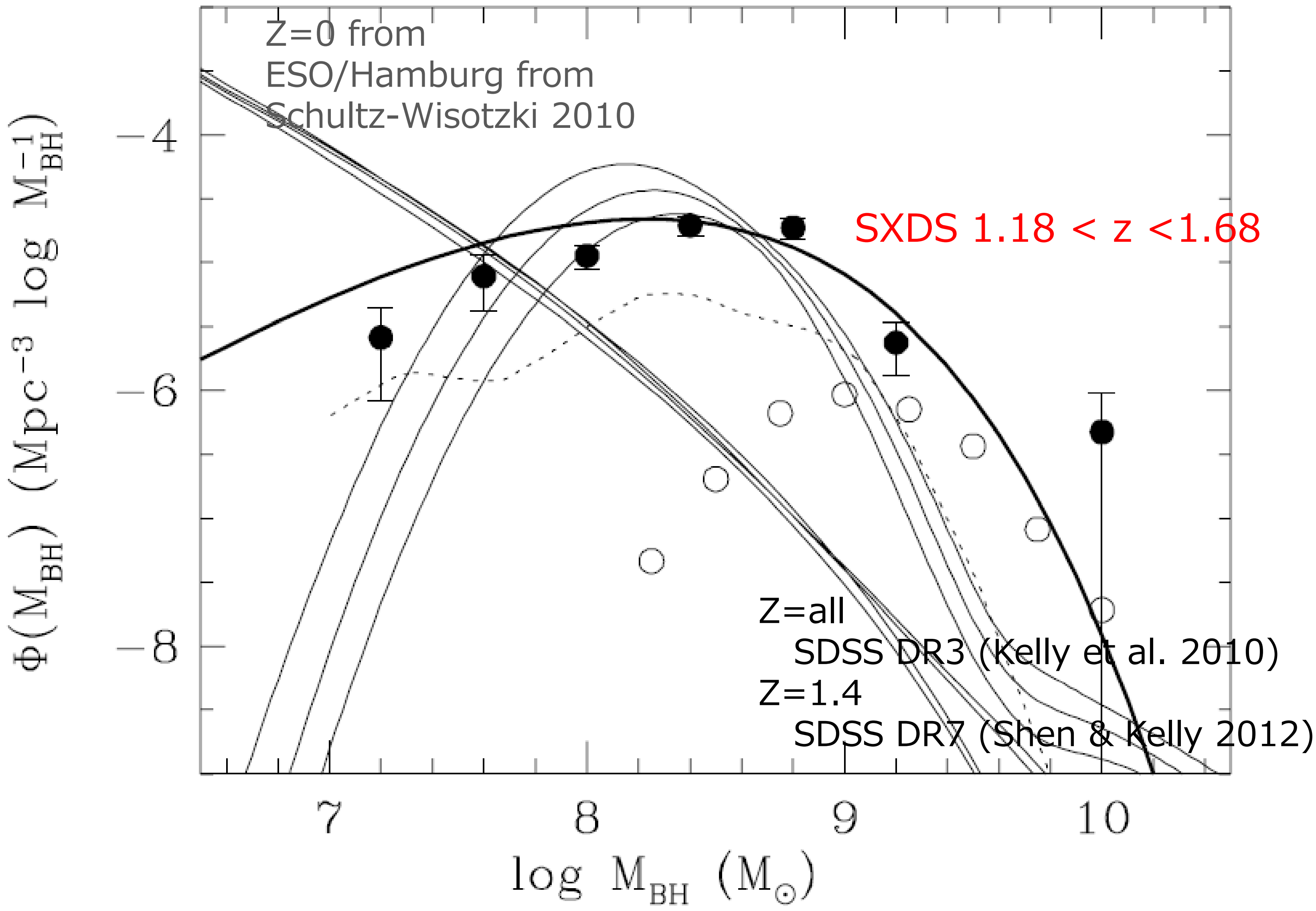
Similarity of the z~1.4 ERDF to the z=0 ERDF.

Maximum Likelihood Estimation

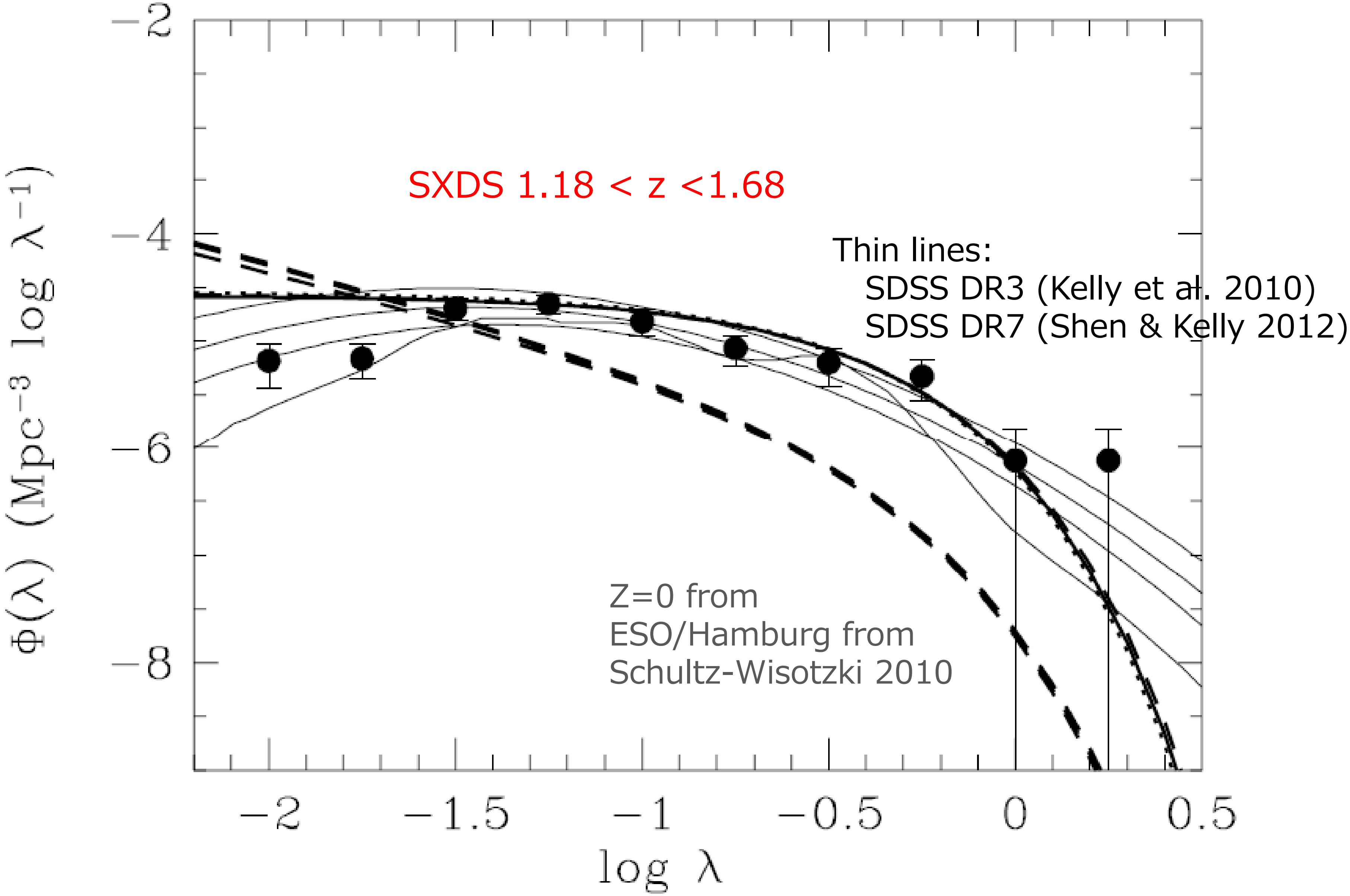




Intrinsic Active BHMF at z=1.4 vs. z=0.0

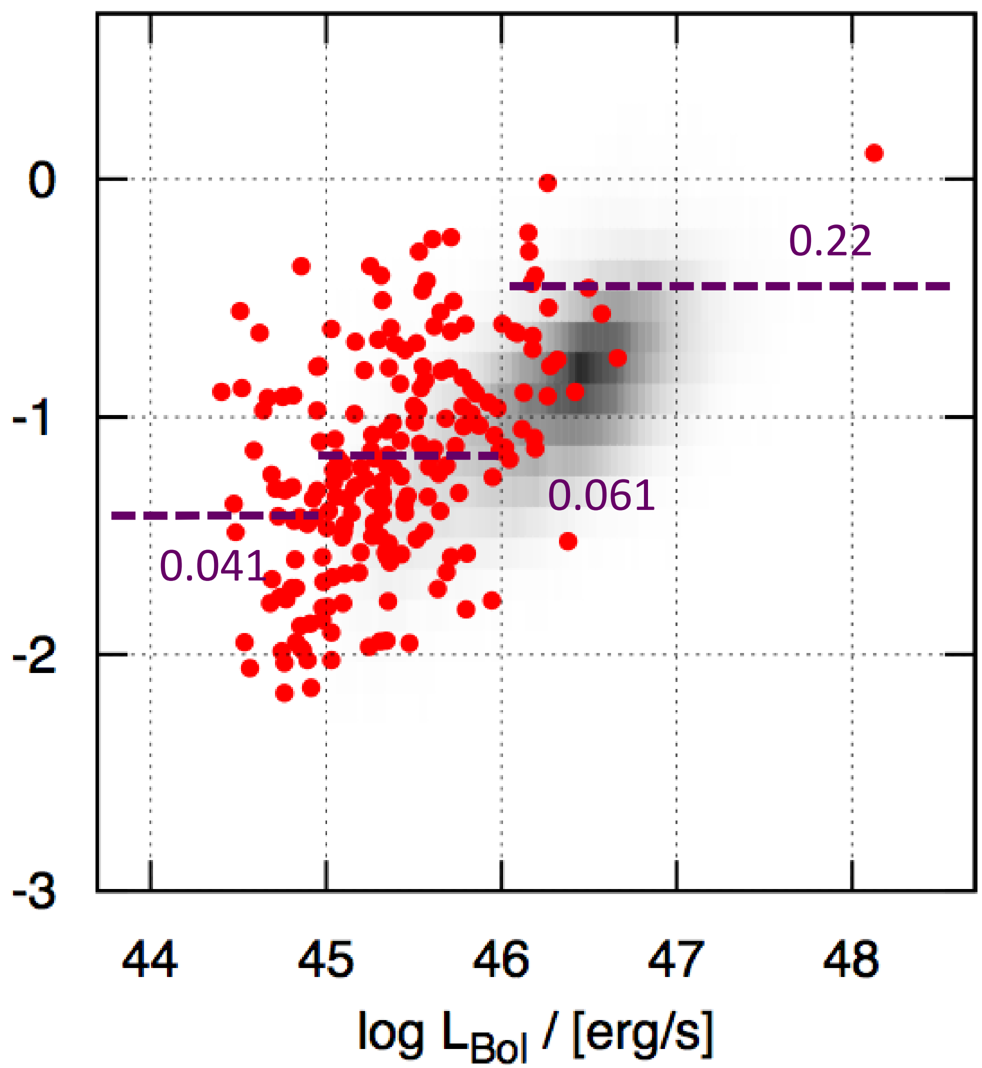


Eddington Ratio Distribution Function



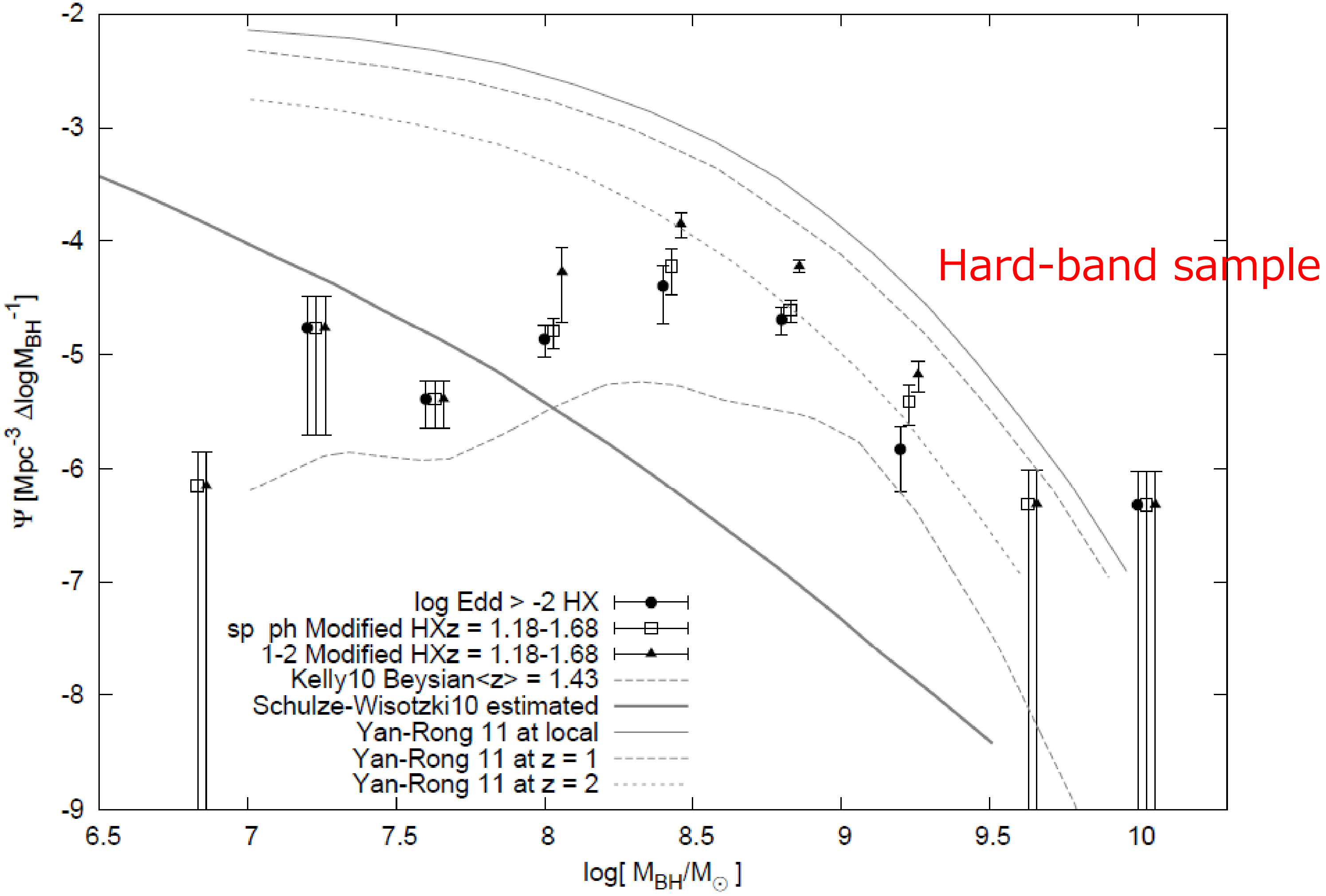
ERDF evolution between z=0.0 and z=1.4

Contribution of obscured narrow-line AGNs



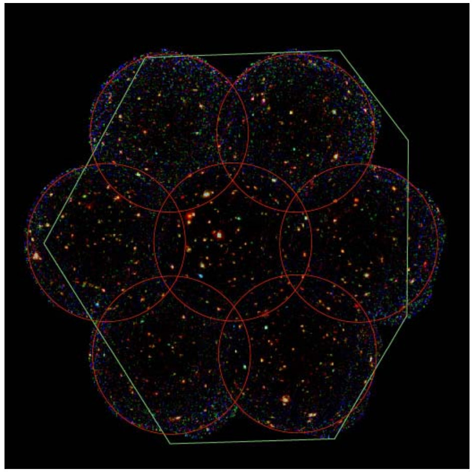
BH mass of obscured narrow-line AGNs are estimated assuming constant Eddington ratio for each luminosity range.

Contribution of obscured narrow-line AGNs



Black hole mass function for 2-10keV selected sample.

Filled triagnles: mass function including contribution of obscured narrow-line AGNs.



Summary

• We examined BH masses and Eddigton ratios of z~1.4 (z=1.18-1.68) broad-line AGNs in SXDS.

• Observed z~1.4 active BH mass function already exceeds that estimated from SDSS dataset with Bayesian method assuming constant Eddington ratio distribution among AGNs at different redshifts and BH masses.

• Observed z~1.4 Eddignton ratio distribution function is similar to that in the local universe, no evolution in the Eddington radio distribution. Therefore, the evolution of the AGN luminosity function is explained with evolution of the active BH mass, higher mass at higher redshifts, i.e. down sizing ?

• If contribution from obscured AGNs considered, the fraction of active BH among entire SMBHs should be fairly high at z~1.4 (order of ~10%).

Next Steps ?

- Higher-z (z~2)
  - Good SN MgII in >8000A range – Keck DEIMOS ?
  - CIV ?

- Archival data survey
  - SDSS + XMM
  - XMM-Medium
  - Chandra deeps

- Bias in X-ray selection (ex. Against NLSy1?)

- Other wavelength = radio-quiet BHMF vs. radio-loud BHMF, quasar-mode feedback vs. radio-mode feedback

- AGN SED atlas (like population synthesis model in galaxy evolution model)

- PFS

-