- AGN surveys with Subaru –

Toward Complete Understanding of Accretion History in the Universe

and

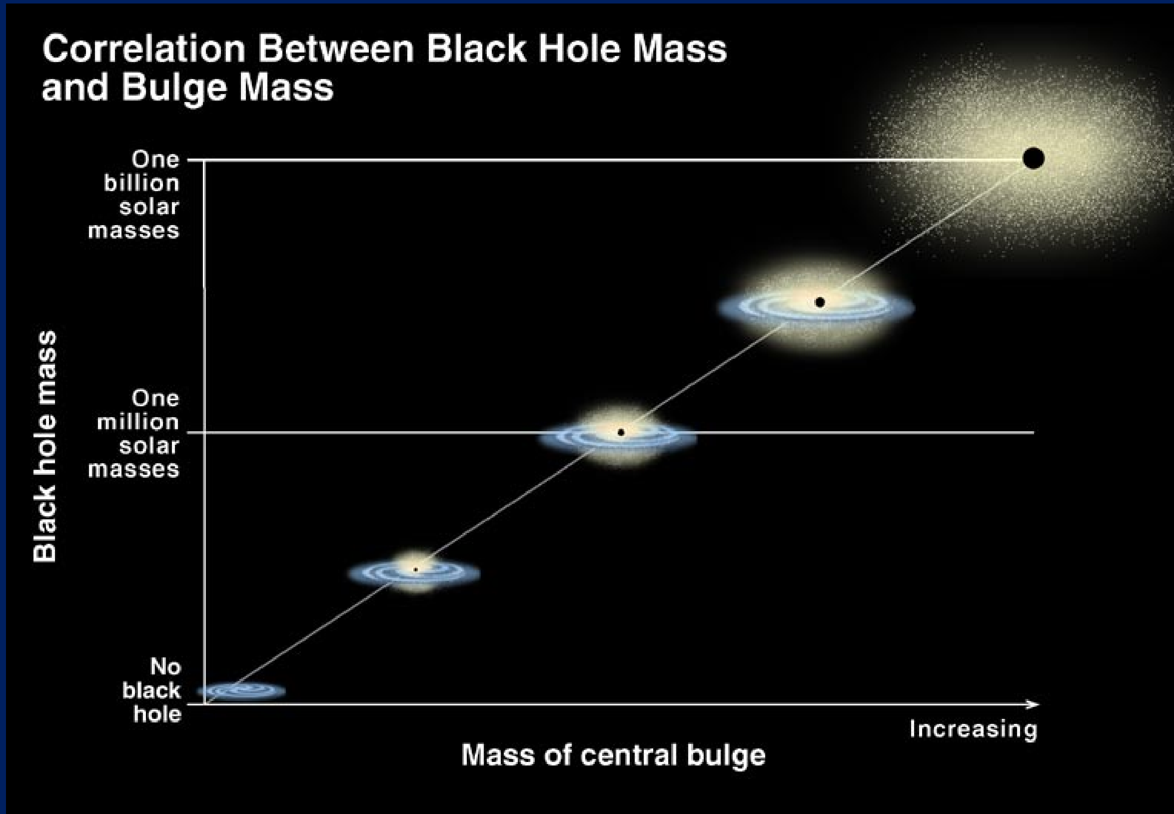
its Relation to the Galaxy Evolution

Masayuki Akiyama (Tohoku Univ.)

Joint Subaru / Gemini Science Conference

Introduction

- After the discovery of …



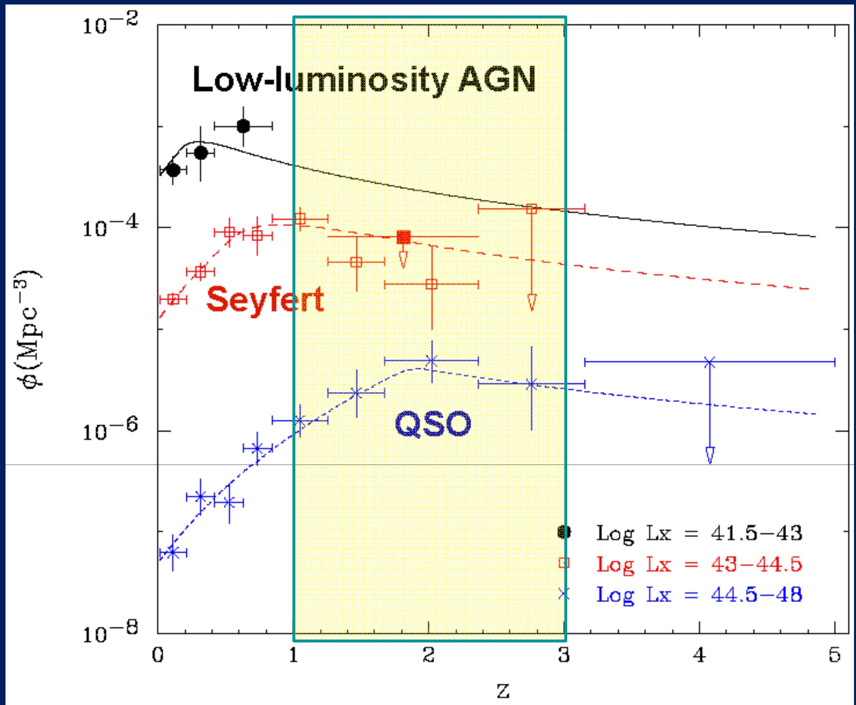
From STSci

early 90s, “revealing the origin of the super-massive blackholes (SMBHs)” became a major driving force for AGN surveys.

Understanding the physical link between AGN phenomena and galaxy evolution also became important (“co-evolution”) .

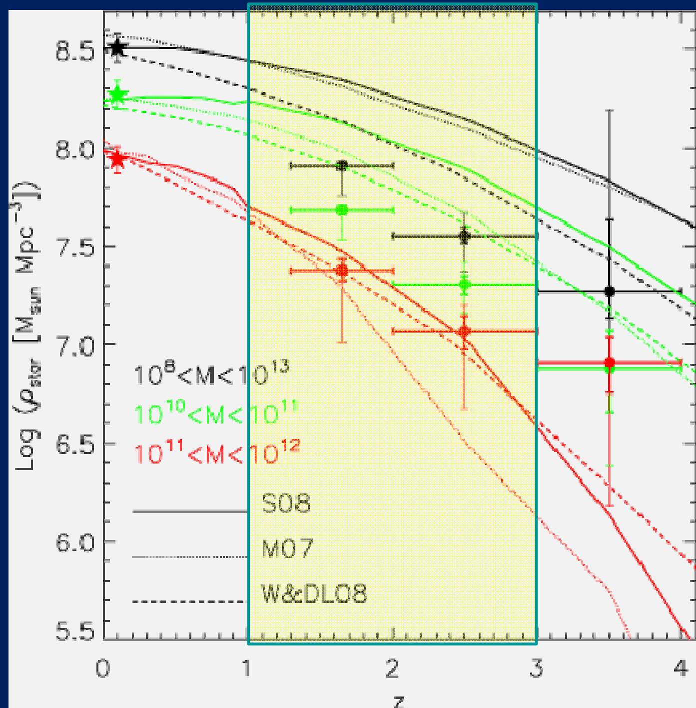
Introduction: Importance of AGNs between z=1-3

Number density of X-ray AGNs



Ueda et al. 2003

Stellar mass density in galaxies



Marchesini et al. 2008

- At z=1-3
  - Number density of AGNs ~10 times larger than in the local universe.
  - Number density of galaxies ~10 times smaller than in the local universe.
- Naïve argument: !! AGN should be 100 times more common among galaxies in the redshift range !!

I will concentrate on 3 topics….

- *Complete understanding of SMBH accretion-growth across cosmic time*
  - Optical/NIR follow-up of X-ray AGN surveys and importance of obscured populations
- *Evolution of MBH-Mbulge relation across cosmic time*
  - Host galaxies of obscured / non-obscured AGNs
- *Locating AGNs among normal galaxies*
  - Fraction of AGNs among each galaxy population

Focusing on z=1-3.

These points are key “items” to understand “co-evolution”.

I will introduce Subaru related results…

- *Complete understanding of SMBH accretion-growth across cosmic time*
  - Suprime-cam and FOCAS wide field AGN survey in the Subaru XMM-Newton Deep Survey (SXDS) field
  - MOIRCS NIR multi-object spectroscopy in the GOODS-North region
- *Evolution of MBH-Mbulge relation across cosmic time*
  - SXDS results
  - New AO188 + IRCS observations of QSO hosts at z~3
- *Locating AGNs among normal galaxies*
  - MOIRCS deep imaging (MODS) in the GOODS-North region

Collaboration

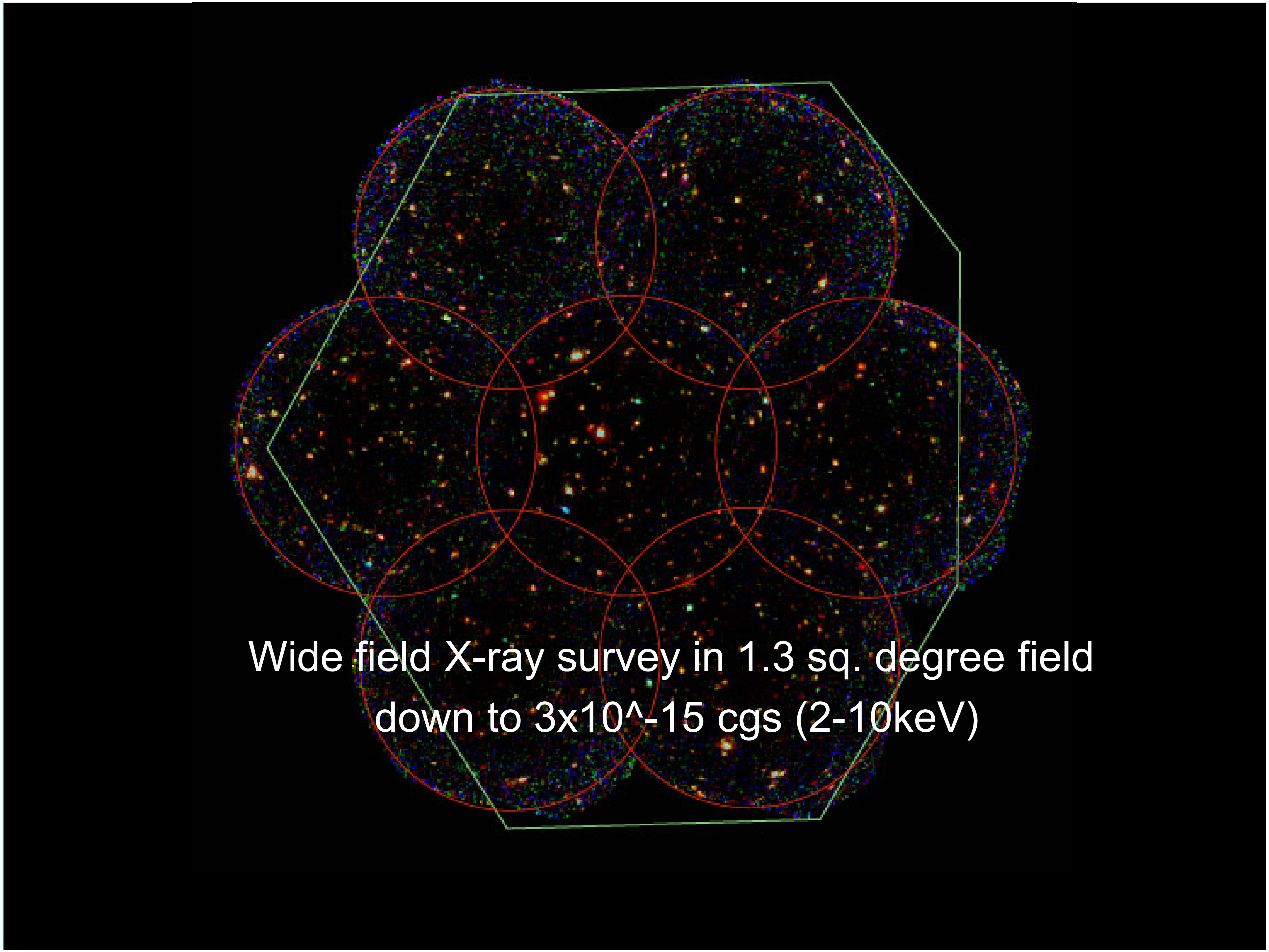
- *Complete understanding of SMBH accretion-growth across cosmic time*
  - Suprime-cam + FOCAS wide field AGN survey
    - Y.Ueda, K.Sekiguchi, and SXDS team members.
  - MOIRCS NIR multi-object spectroscopy
    - T.Yoshikawa and MODS team members.

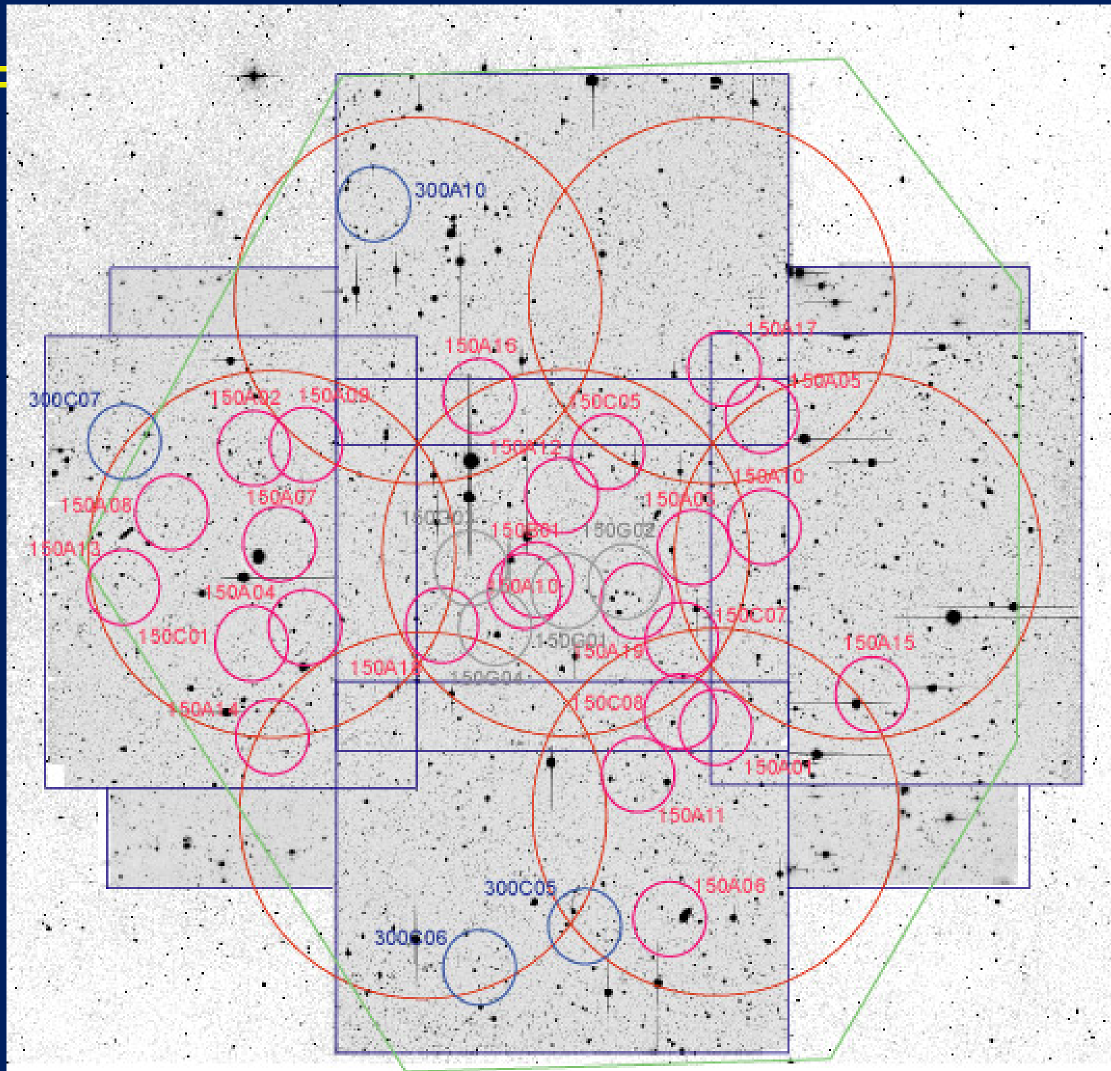
- *Evolution of MBH-Mbulge relation across cosmic time*
  - New AO188 + IRCS
    - M.Schramm, K.Ohta

- *Locating AGNs among normal galaxies*
  - MOIRCS deep imaging (MODS)
    - M.Kajisawa, T.Yamada, and MODS team members.

Section 1.

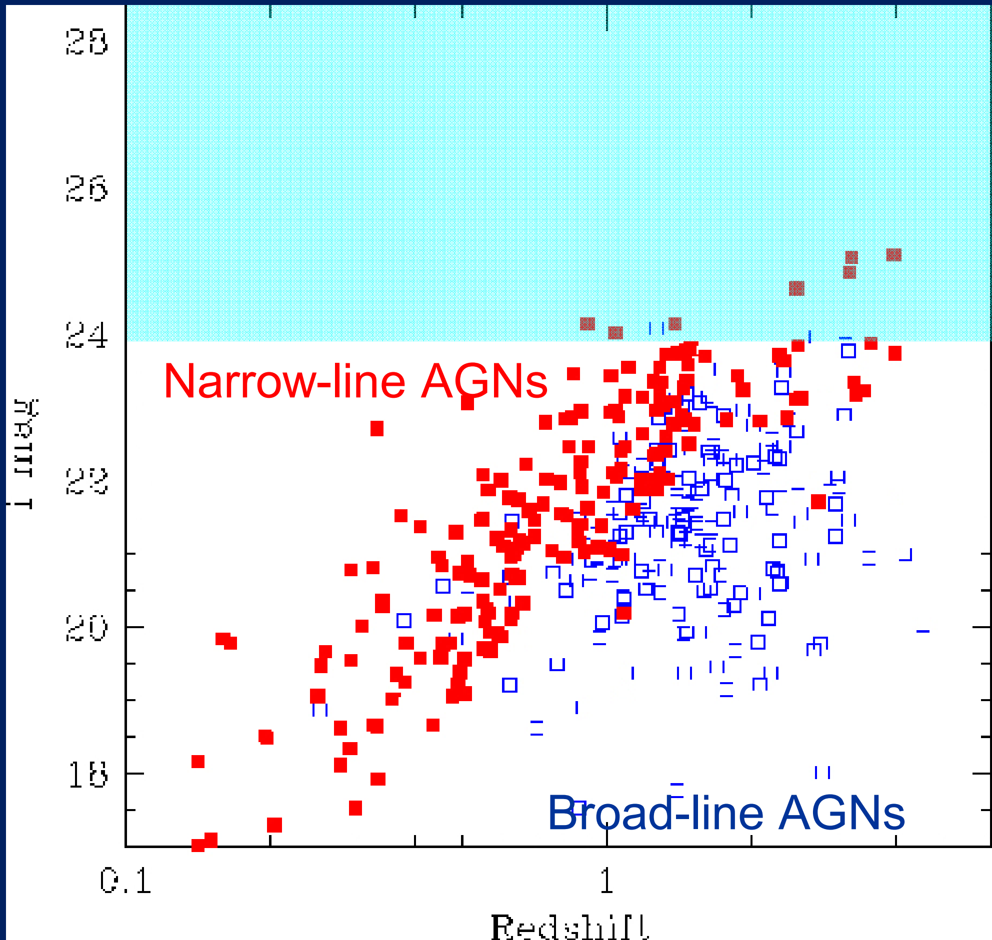
- *Complete understanding of SMBH accretion-growth across cosmic time*
  - Suprime-cam + FOCAS wide field AGN survey in the Subaru XMM-Newton Deep Survey (SXDS) field
  - MOIRCS NIR multi-object spectroscopy in the GOODS-North region


Wide field X-ray survey in 1.3 sq. degree field
down to 3x10^-15 cgs (2-10keV)



- Suprime-cam wide field imaging follow up +
- FOCAS (+AAT/2df, VLT/VIMOS, Magellan/IMACS) spectroscopic follow-up

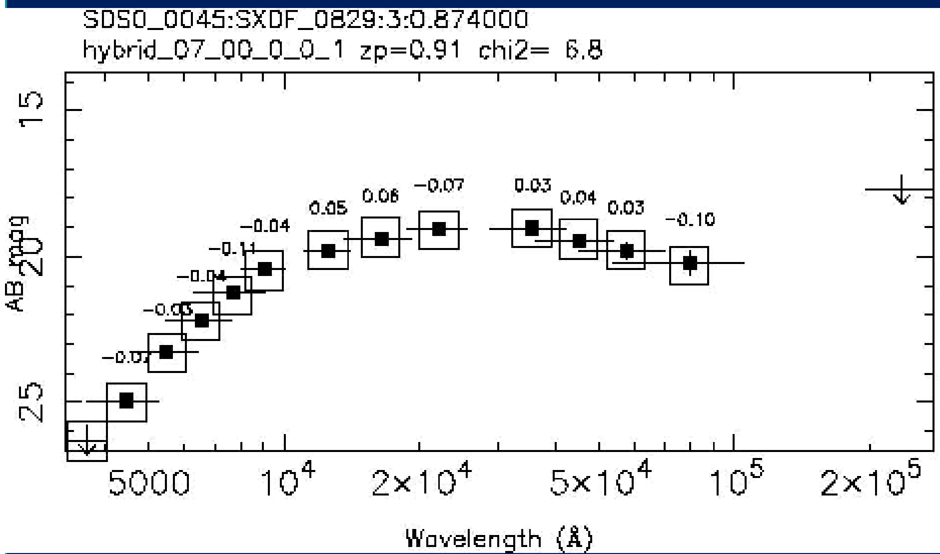
Spectroscopic identification summary

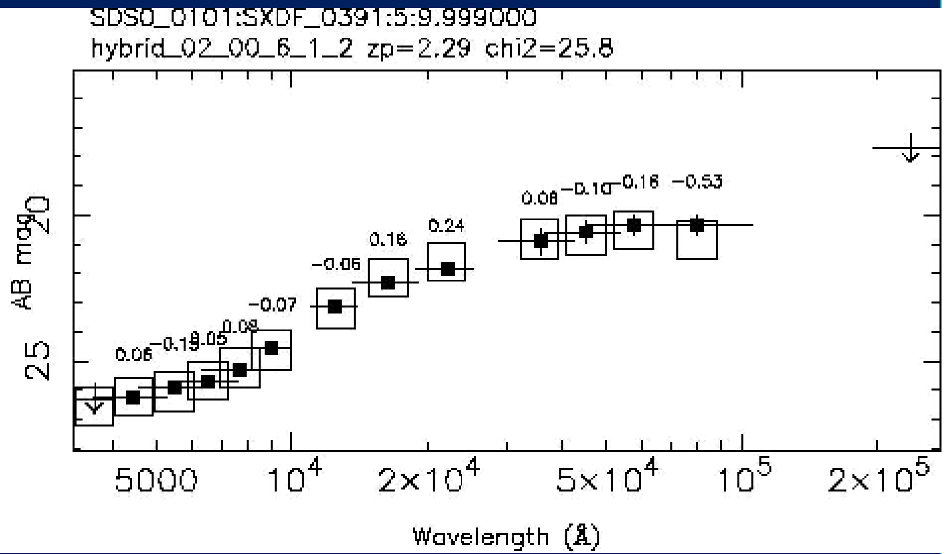


- However, there are large number of optical counterparts beyond optical spectroscopy limit (i~24).

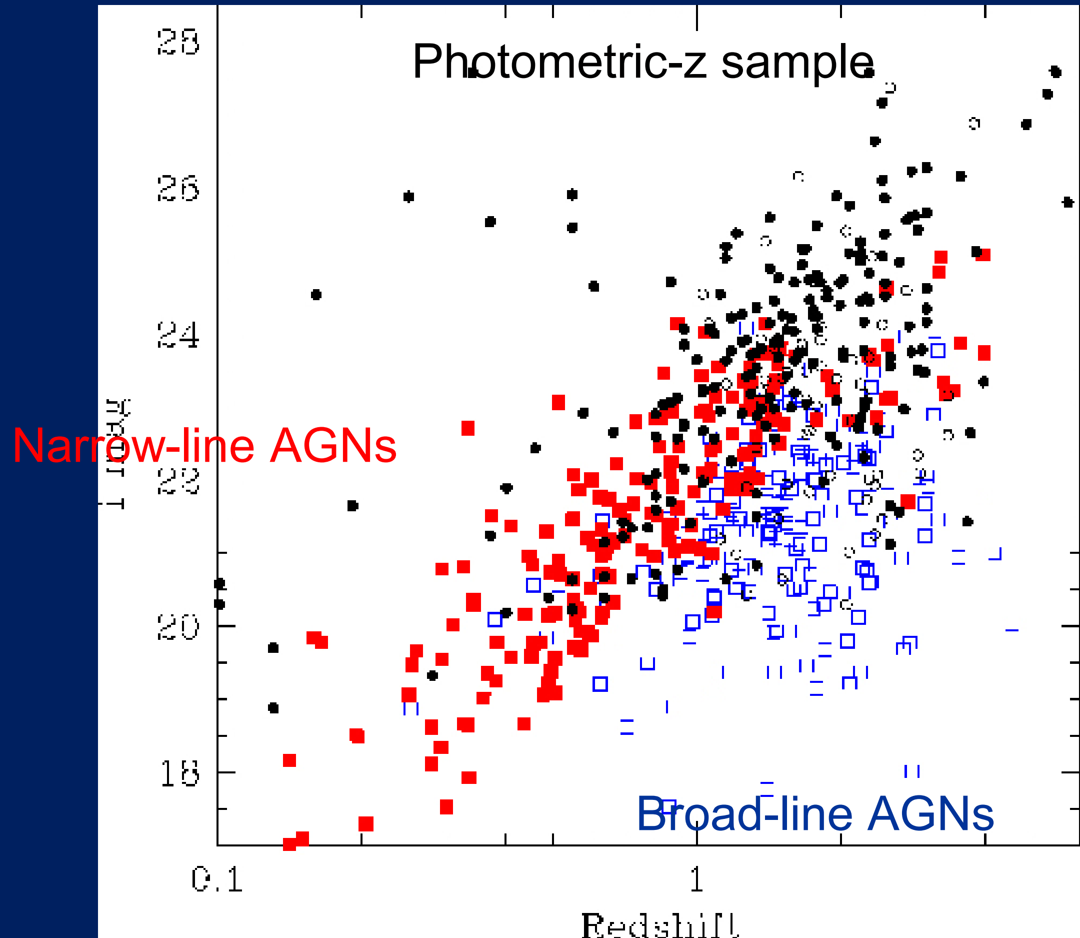
Photometric redshift estimation for optically-faint obj.

Using GALEX NUV/FUV , Suprime u- to z-bands, WFCAM J,H,K-bands, and Spitzer IRAC 4 bands. In total 14 bands.



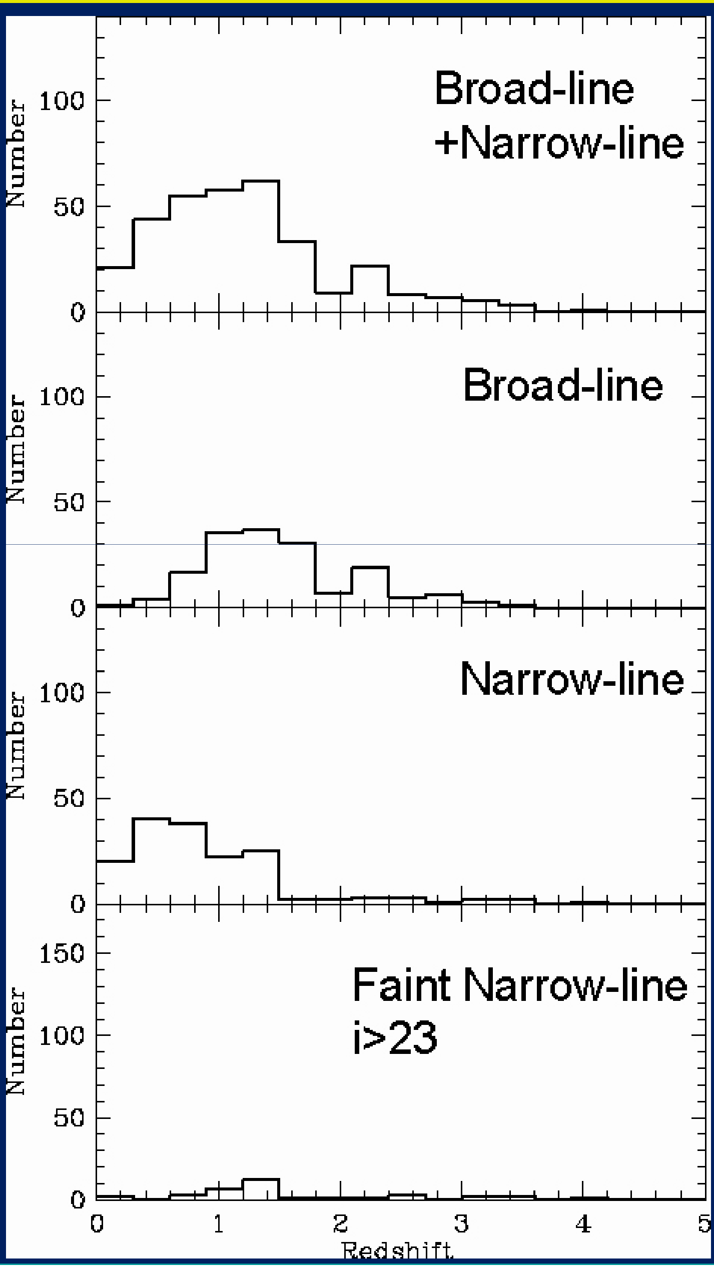


Photometric redshift summary



- Optically-faint objects locate natural extension of narrow-line AGNs at z<~1, thus they are expected to be narrow-line obscured AGNs at z=1-3

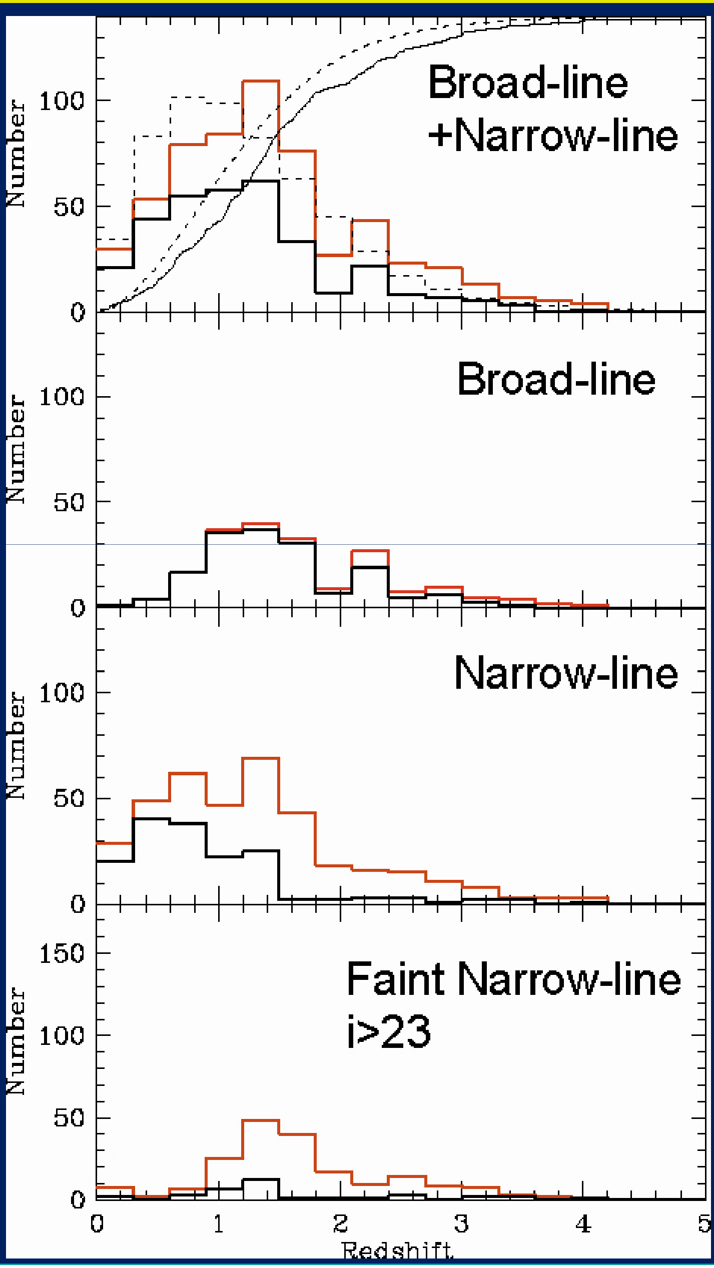
Redshift distribution of the SXDS X-ray AGNs



Black histograms show redshifts of spectroscopically identified hard X-ray sample.

Different redshift distribution between broad - and narrow-line AGNs?

Redshift distribution of the SXDS X-ray AGNs



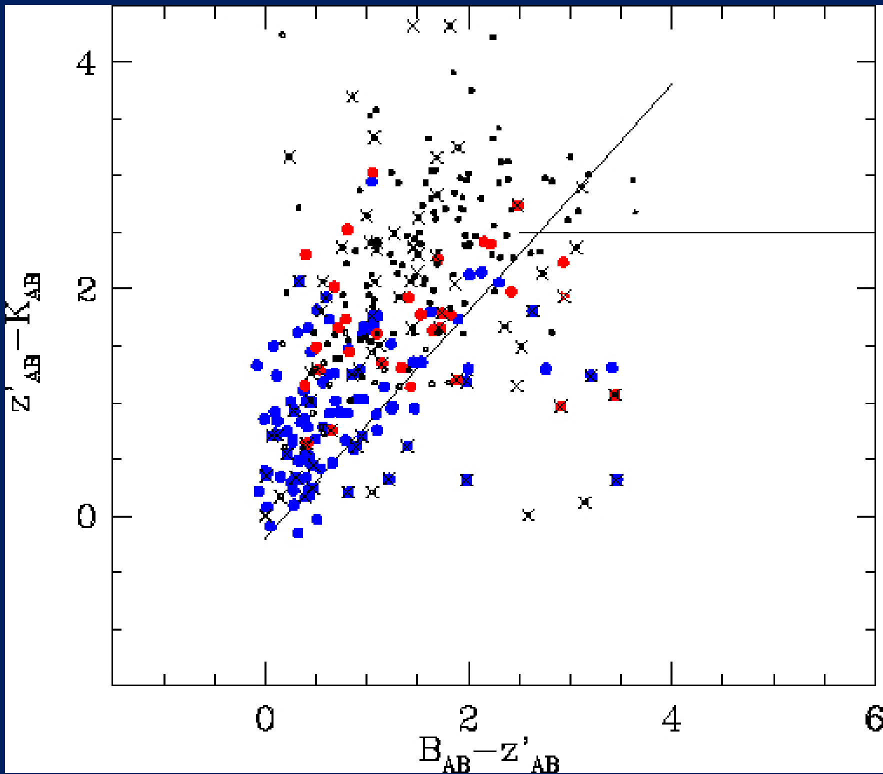
Black histograms show redshifts of spectroscopically identified hard X-ray sample.

Red histogram shows all AGNs including only with photometric redshifts.

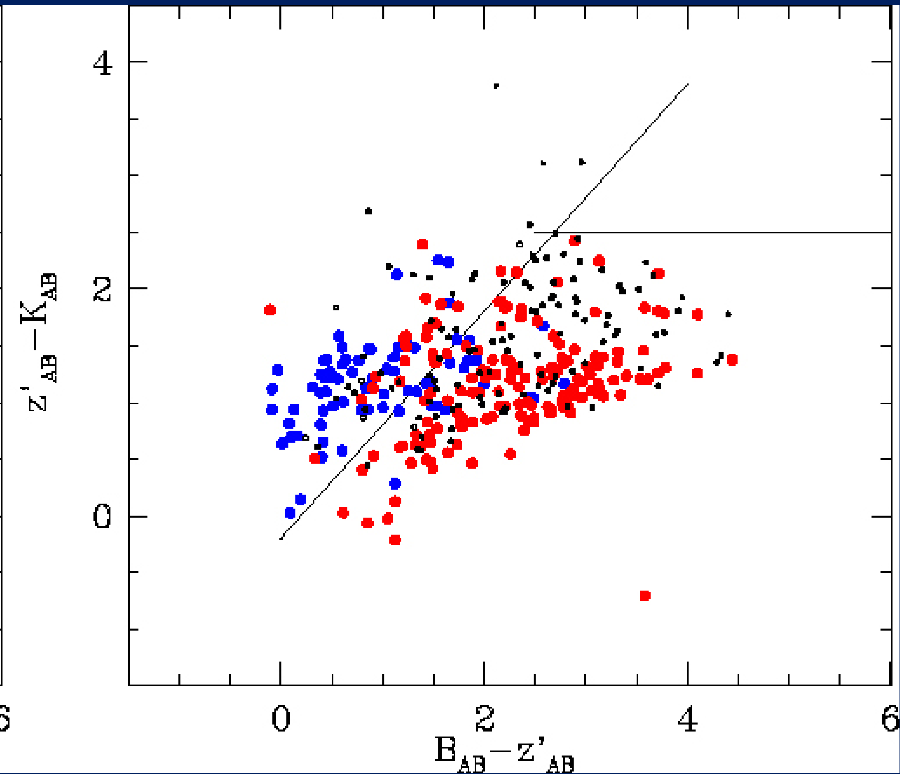
Photometric redshift estimation indicates there are large number of missing z=1-3 narrow-line obscured AGNs with faint optical magnitude.

X-ray AGNs on BzK diagram

z(spec) or z(phot) > 1.4



z(spec) or z(phot) < 1.4

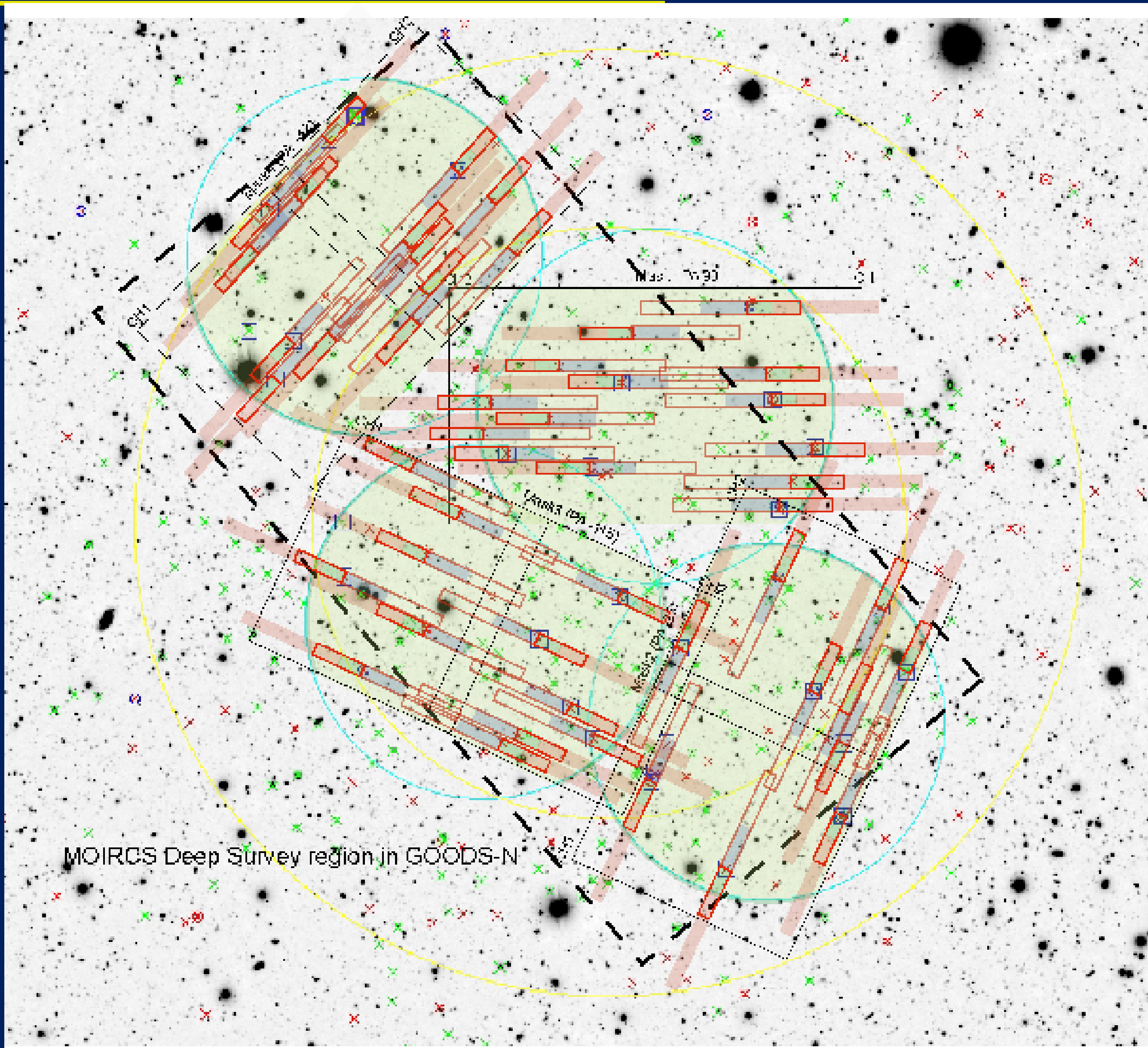


Optically-faint sources have similar color to red sBzK galaxies (expected to be z>1.4, consistent with photmetric redshift estimate)

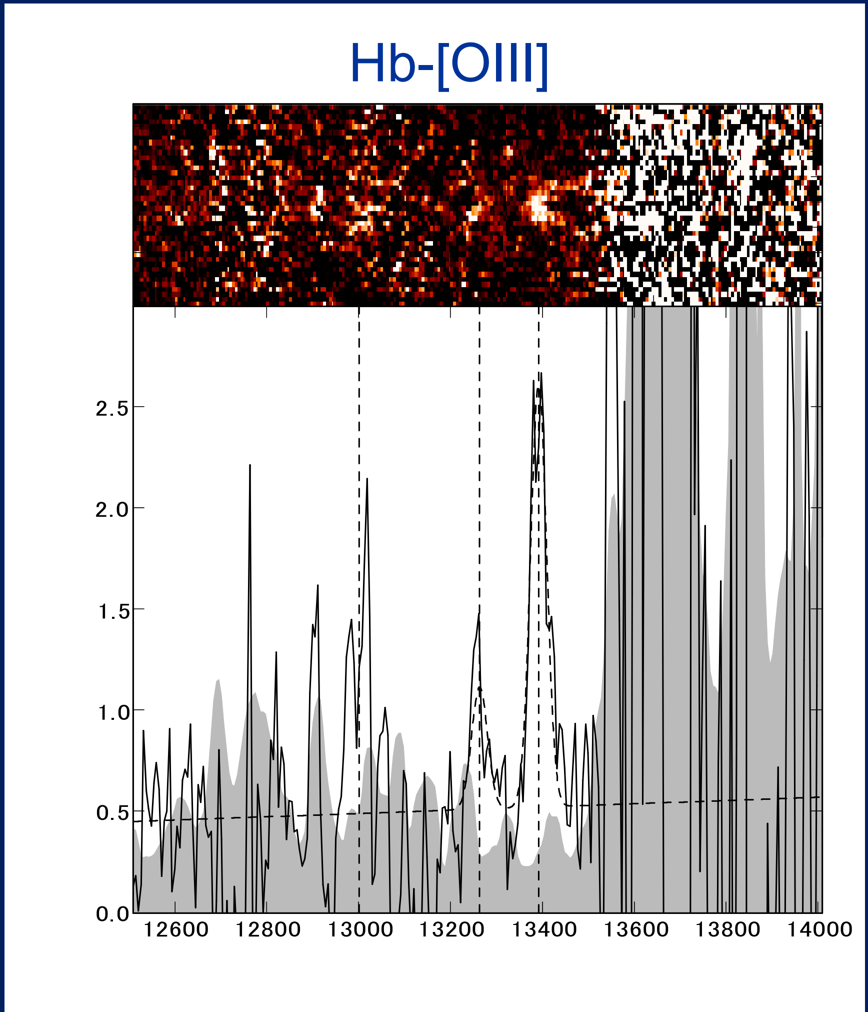
They have red optical – NIR colors, i.e. bright in the NIR wavelength

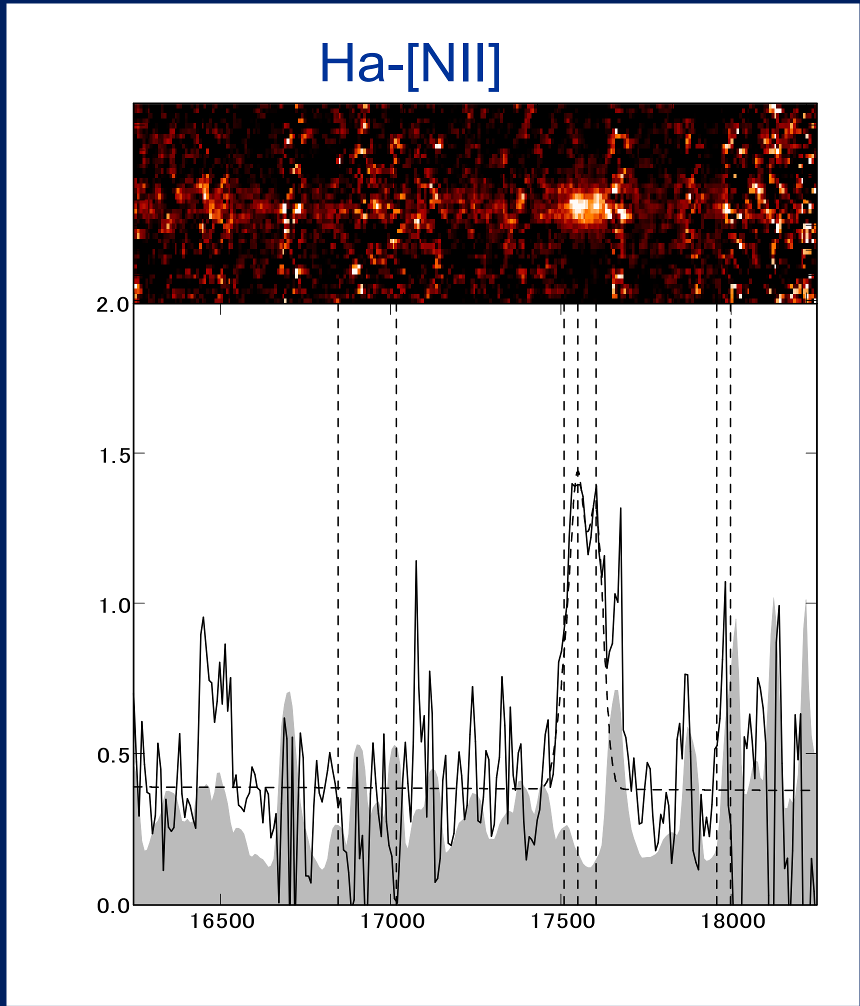
NIR Spectroscopic follow-up of optically-faint objects

With MOIRCS



An example of NIR identification



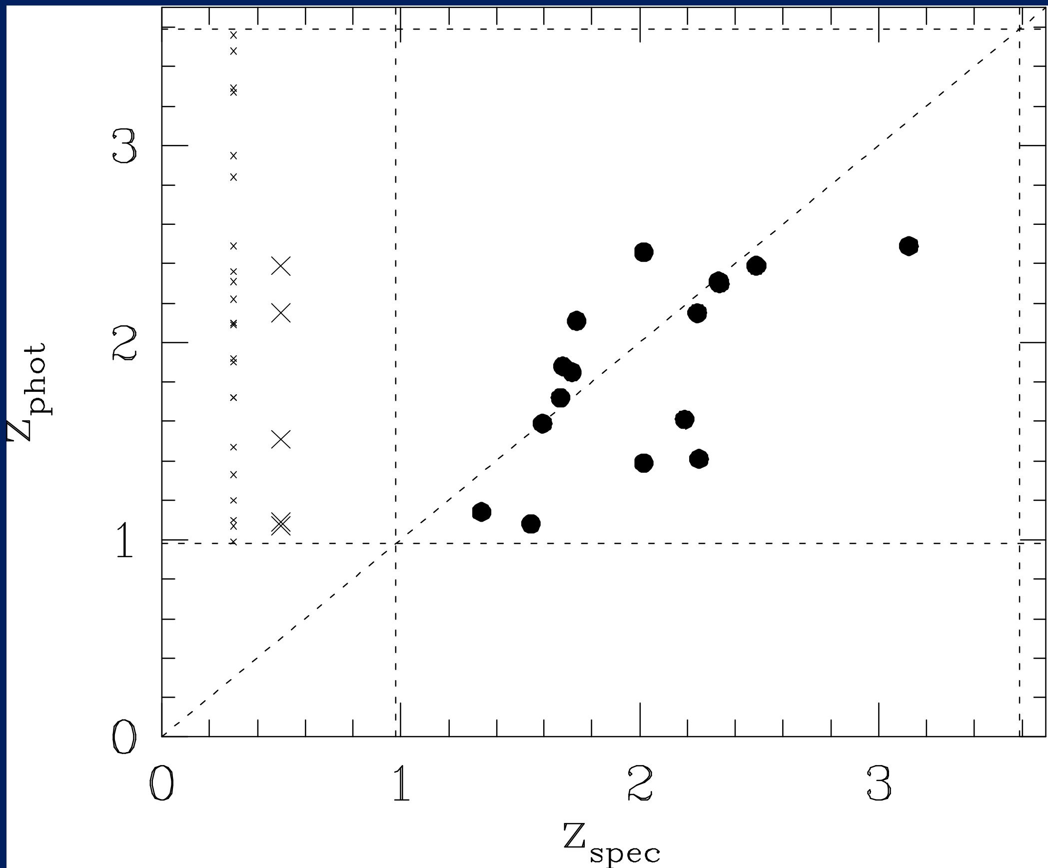


Strong Ha line, strong [NII] line, and strong [OIII] lines

Type-2 Object at z=1.57.

Summary of NIR-spectroscopy

16/21 (76%) KAB<22.5 are identified with AGNs at z=1-3,



Black dots: spectroscopic identification

Large cross : objects with KAB<22.5 no spectroscopic identification

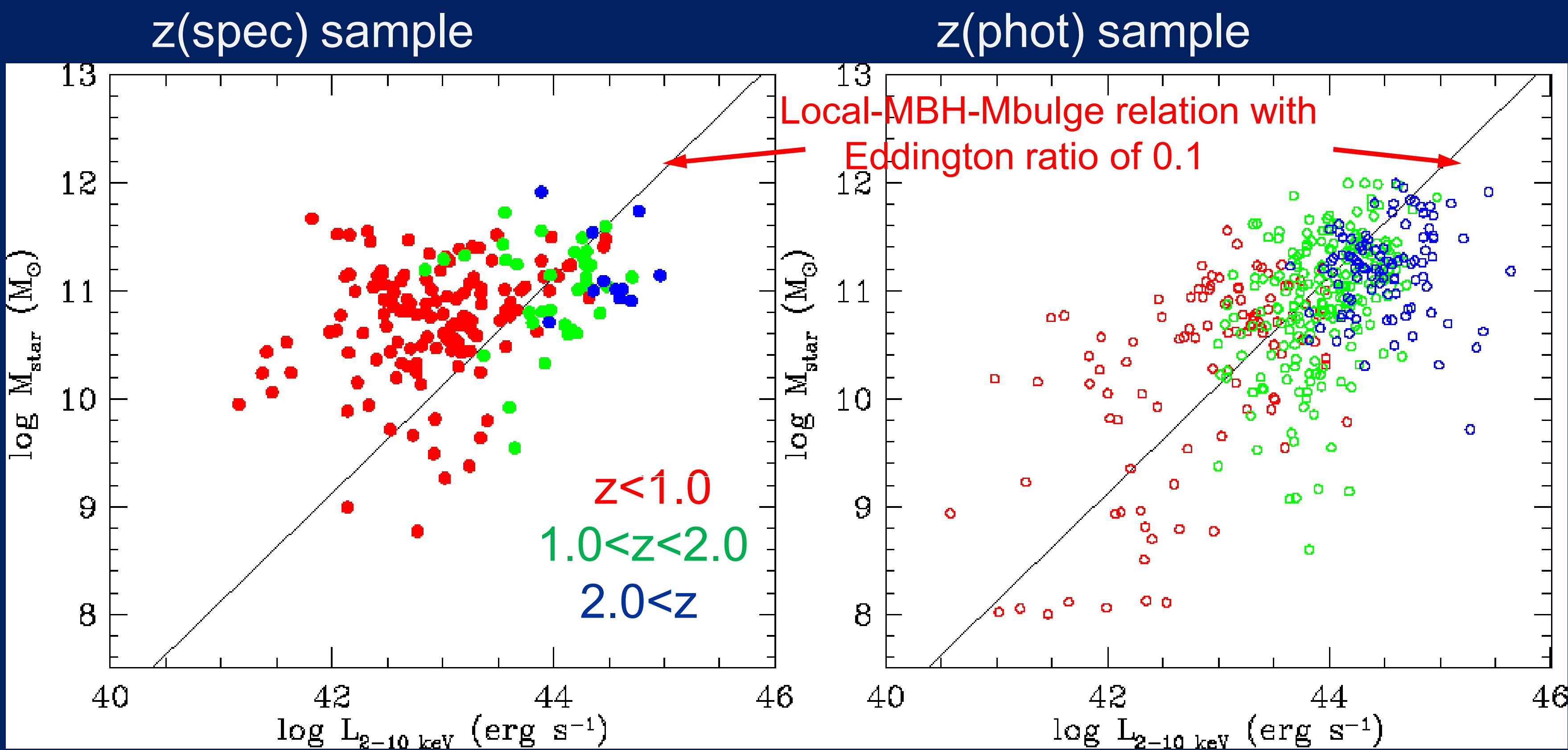
Small cross : objects with KAB>22.5 no spectroscopic identification

Section 2.

Evolution of MBH-Mbulge relation across cosmic time

- SXDS results
- New AO188 + IRCS observations of QSO hosts at z~3

Stellar mass of host galaxies of obscured AGNs in SXDS



Stellar mass of the host galaxies are roughly constant in the large luminosity and redshift range.

High-luminosity AGNs are consistent MBH-M(bulge)

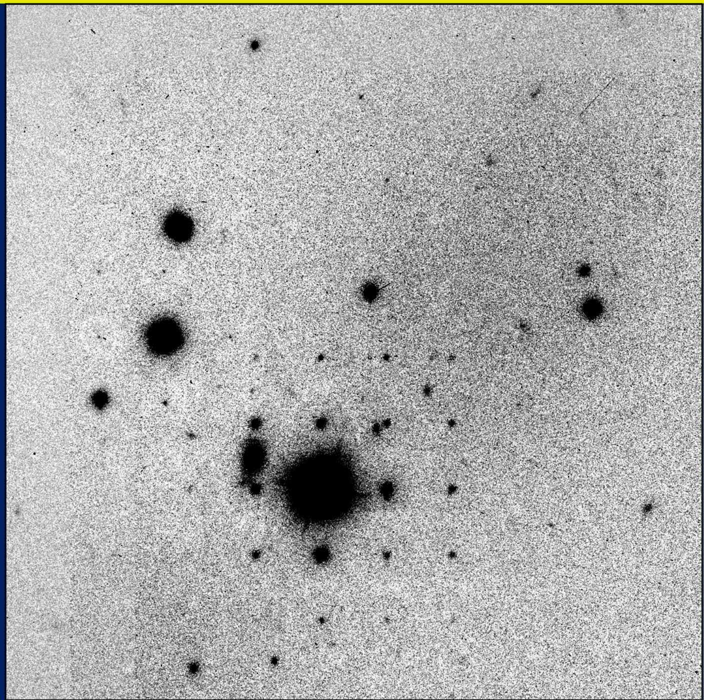
Low-luminosity AGNs have different Eddington ratio (or large M(galaxy), small MBH) ?

Examining MBH-Mbulge relation at high-redshifts

For obscured narrow-line AGNs, stellar mass of their host galaxies can be estimated with relatively small uncertainty. But, estimation of BH mass has uncertainty (we need to assume Eddington ratio).

For broad-line AGNs, we can estimate their BH mass with smaller uncertainty using broad-line width and optical luminosity. Thus, examining MBH-Mbulge relation by investigating the host galaxies of broad-line AGNs at high-redshifts using Adaptive Optics system is complimentary to the narrow-line AGN study.

new AO188 imaging survey of high-redshift QSOs

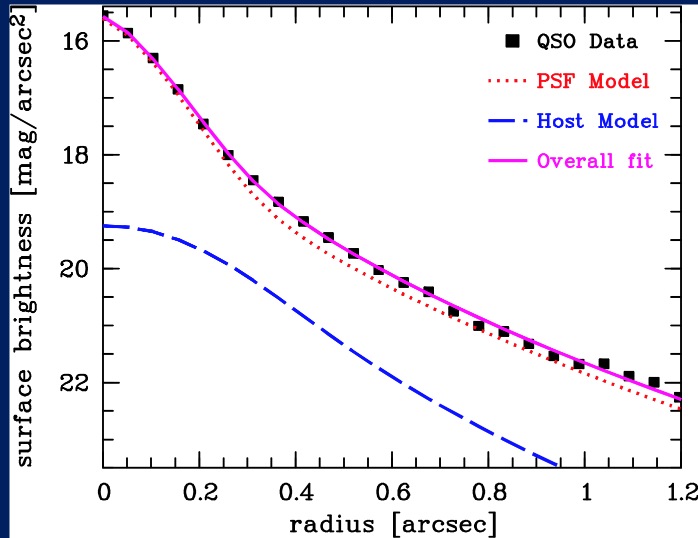


AO188+IRCS image of a QSO field

Estimated stellar mass is 2x10^11Msolar,

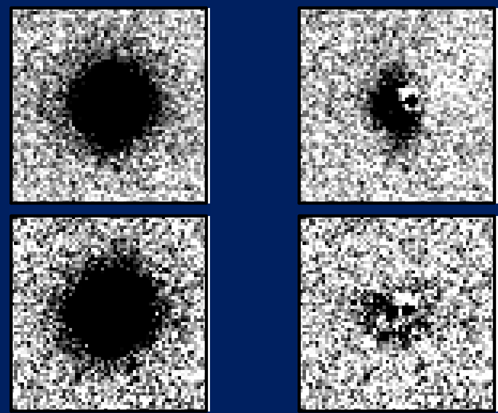
consistent with MBH-Mbulge

Schramm et al. on-goging



K-band

H-band



QSOimg

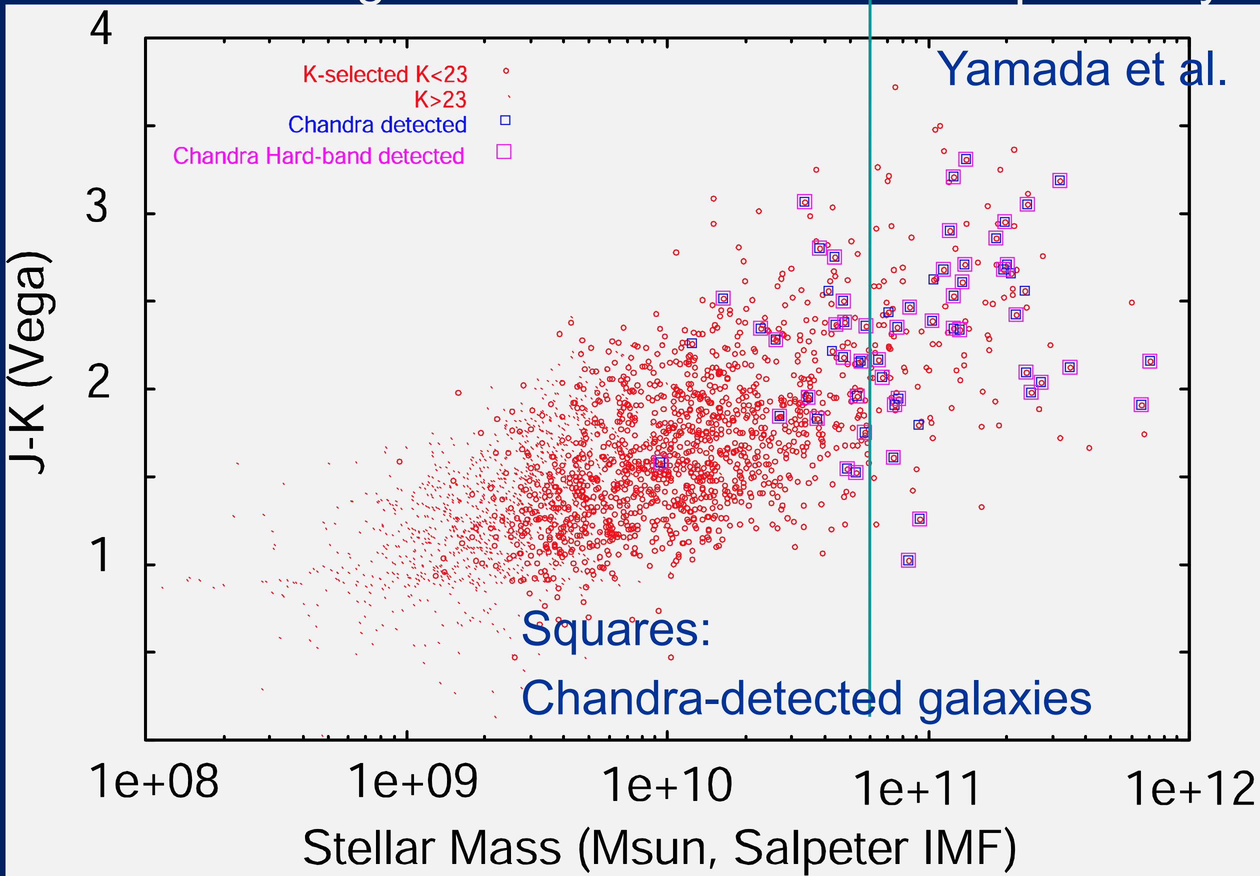
PSF subtracted

Section 3.

- *Locating AGNs among normal galaxies*
  - MOIRCS deep imaging (MODS) in the GOODS-North region

Locating AGNs among field galaxies

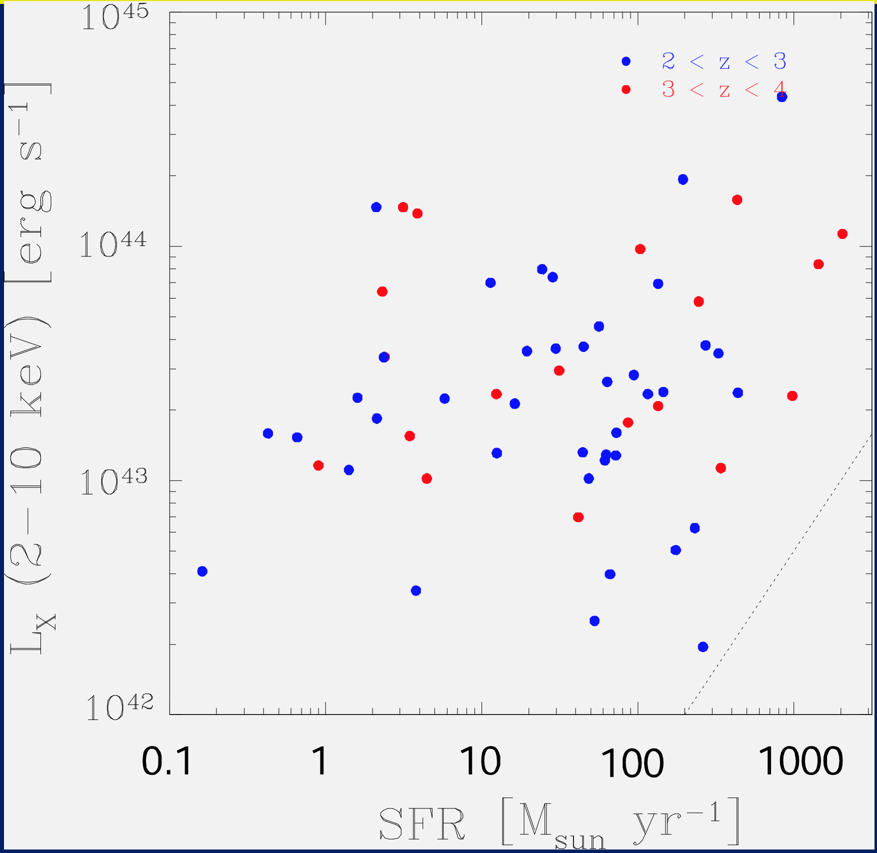
K-selected 2<z<4 galaxies from MOIRCS Deep Survey

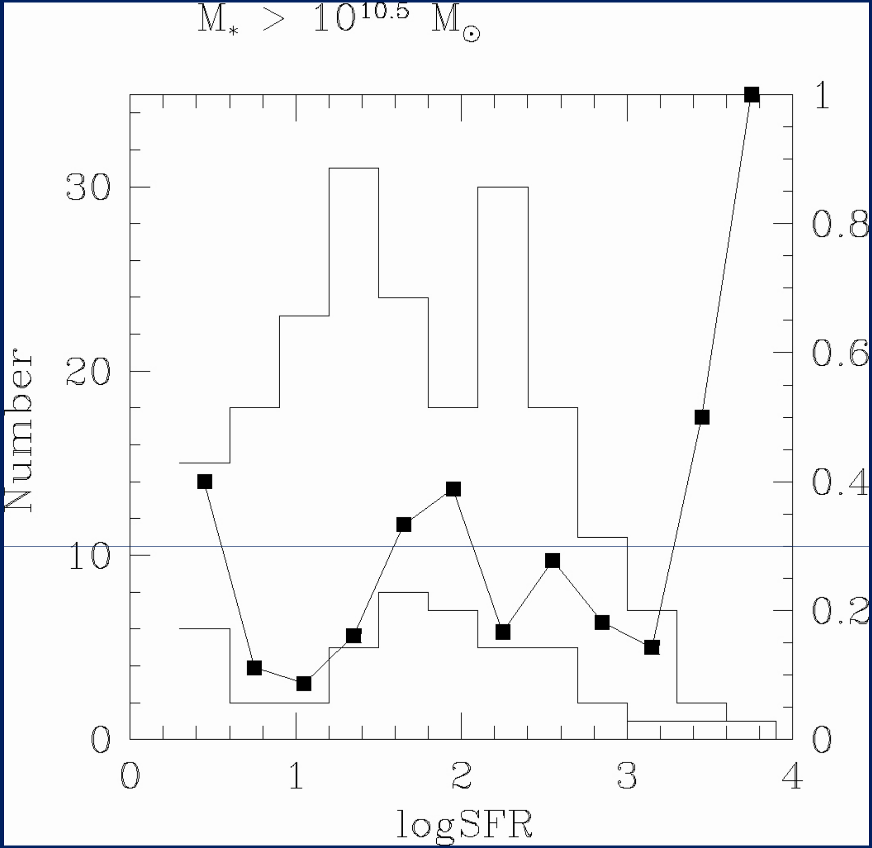


Yamada et al. 2009 in press

At 2<z<4,1/3 of the high stellar mass galaxies are detected in deep Chandra image (estimated hard X-ray luminosity L(2-10keV)=10^42-10^45erg/s, i.e. Seyferts and QSOs).

Accretion rate vs. SFR





For each AGN, estimated SFR is >10 times smaller than the expected SFR from MBH/Mbulge ratio and mass accretion rate.

For massive galaxies, there is no difference in the SFR distribution between AGN – non-AGN galaxies.

Summary

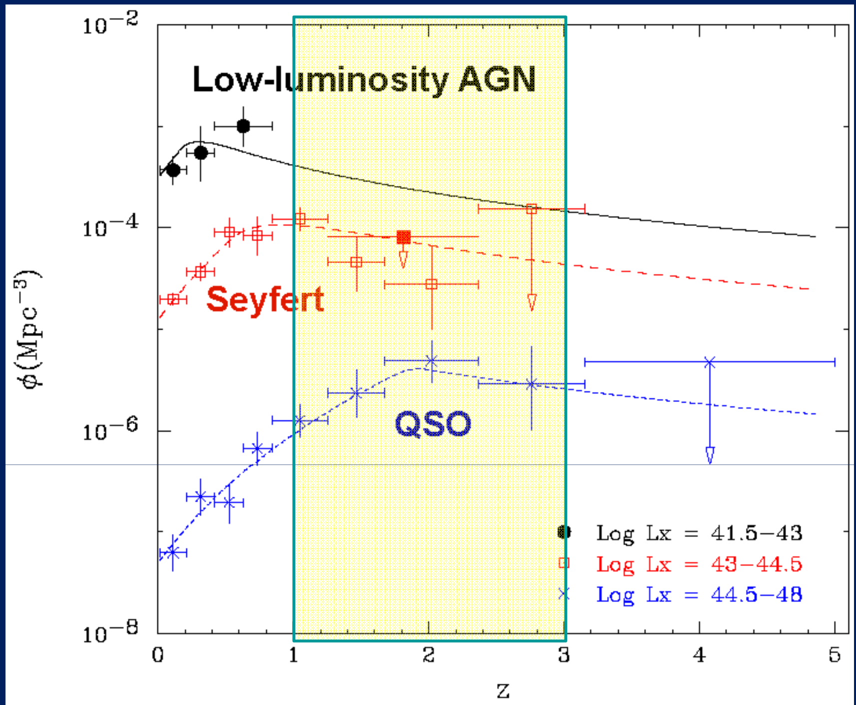
- *Complete understanding of SMBH accretion-growth across cosmic time*
  - Large number of obscured AGNs at z=1-3 found with wide-field multi-band imaging and NIR MOS.

- *Evolution of MBH-Mbulge relation across cosmic time*
  - No significant evolution necessary up to z=3 to explain the estimated M* of host galaxies using multi-band imaging and AO-imaging.

- *Locating AGNs among normal galaxies*
  - 1/3 of massive galaxies at z=2-4 hosts luminous AGNs. SFR is smaller than Macc x Mbulge/MBH.

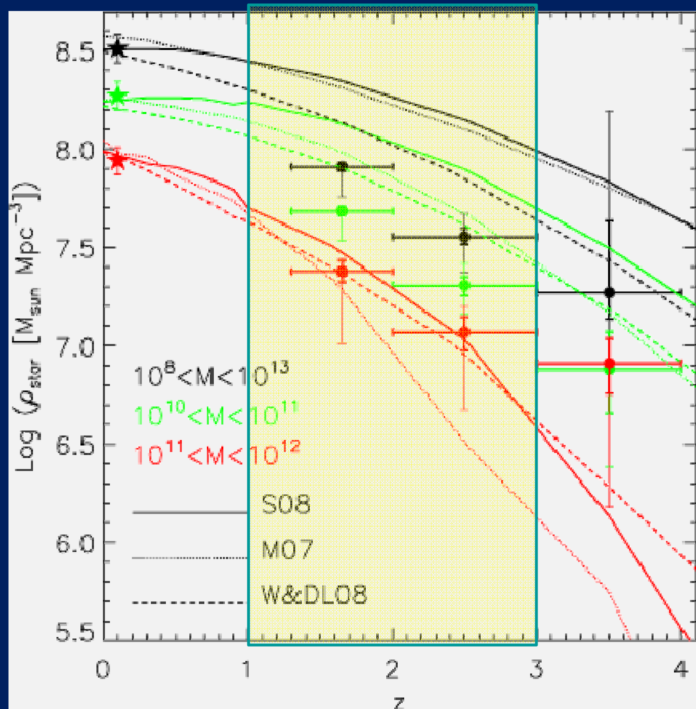
Yes, AGNs are more common !

Number density of X-ray AGNs



Ueda et al. 2003

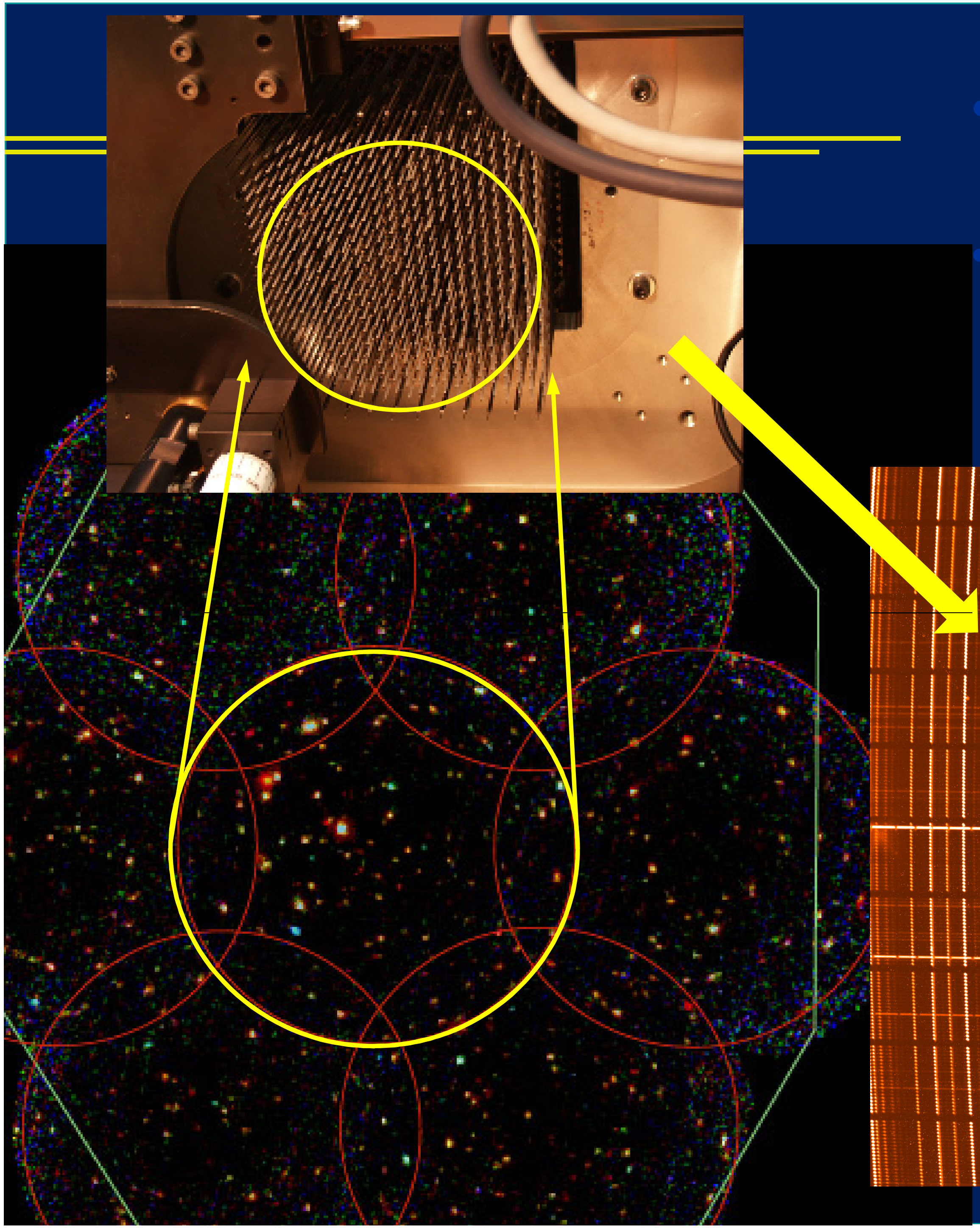
Stellar mass density in galaxies

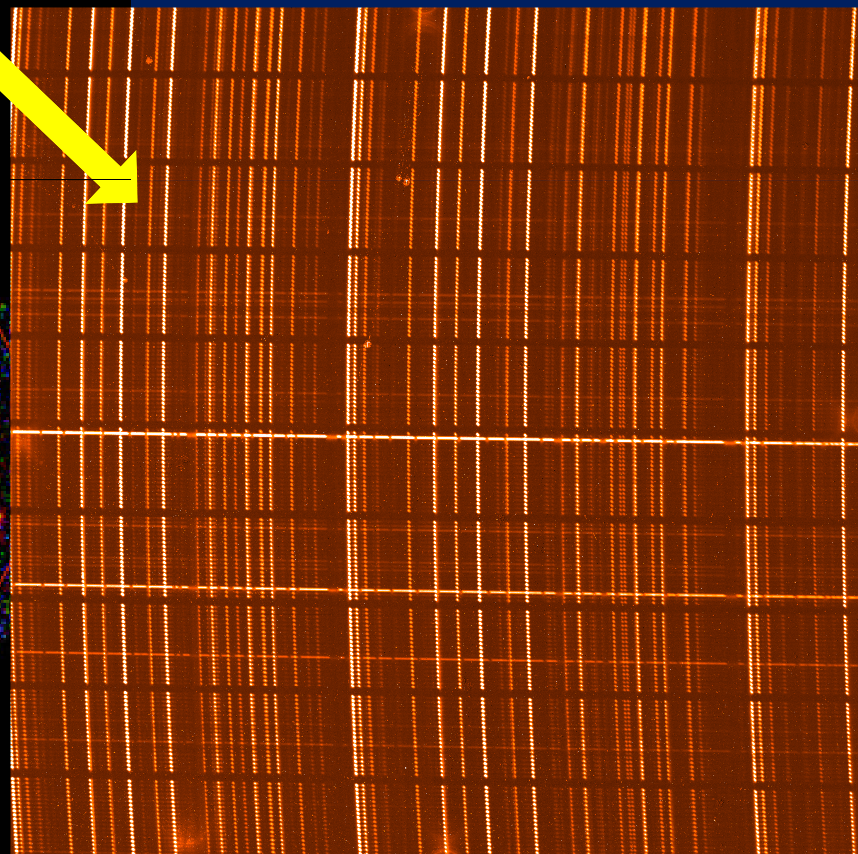


Marchesini et al. 2008

- At z=1-3
  - Number density of AGNs ~10 times larger than in the local universe.
  - Number density of galaxies ~10 times smaller than in the local universe.
- Naïve argument: !! AGN should be 100 times more common among galaxies in the redshift range !!

- Next Step:
- Importance of wide-field NIR spectroscopic follow-up with FMOS





- *Thank you for your attention.*