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- AGN surveys with SPICA –

Revealing accretion growth history of  
Super Massive Black Hole  
with SPICA

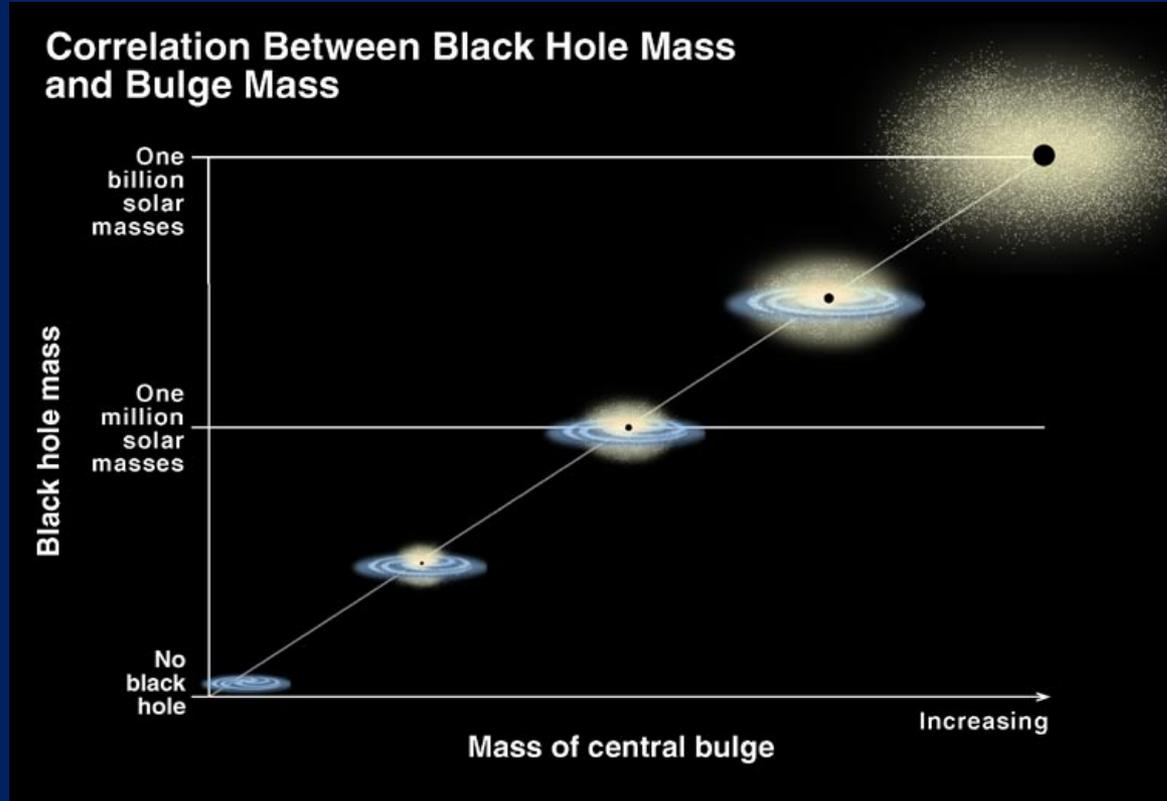
Masayuki Akiyama (Tohoku Univ.)

Shinki Oyabu (ISAS)

SPICA Science Workshop 2009

# Introduction

- After the discovery of ...

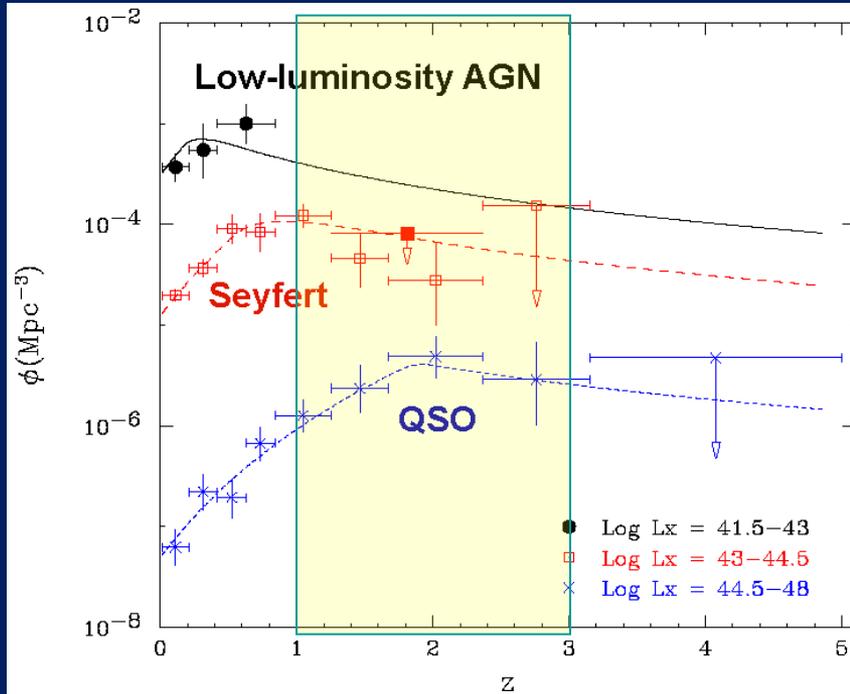


From STSci

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”).

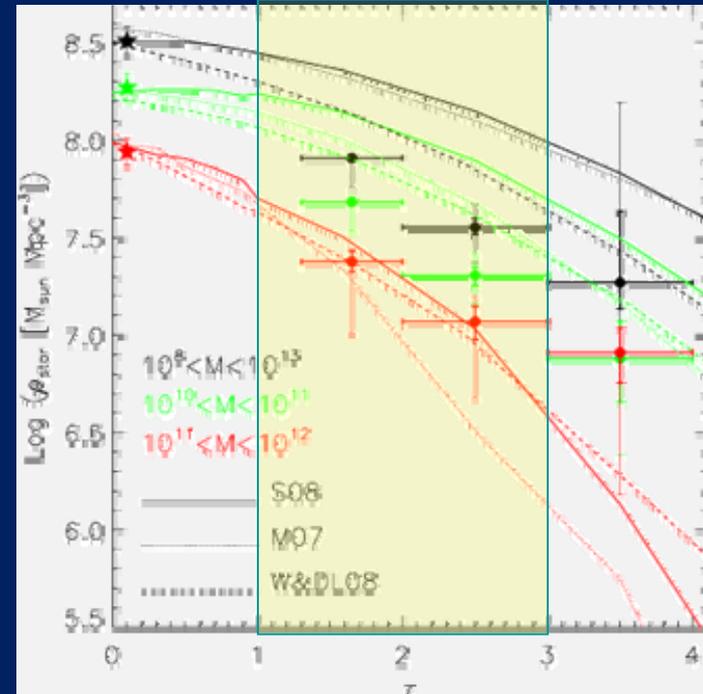
# Introduction: Importance of AGNs at high-redshifts

## Number density of X-ray AGNs



Ueda et al. 2003

## Stellar mass density in galaxies

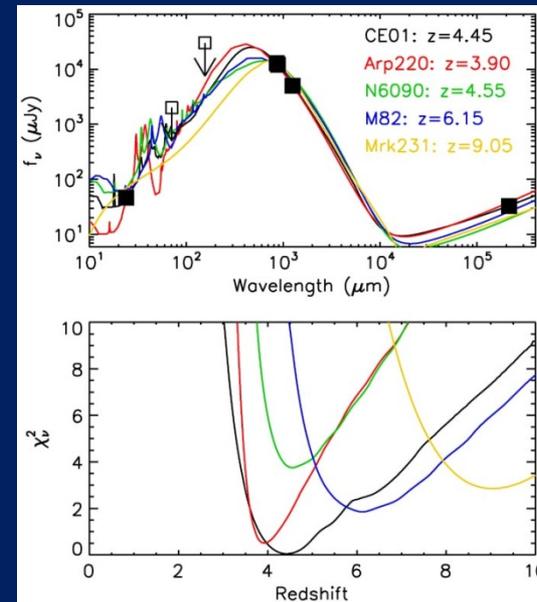
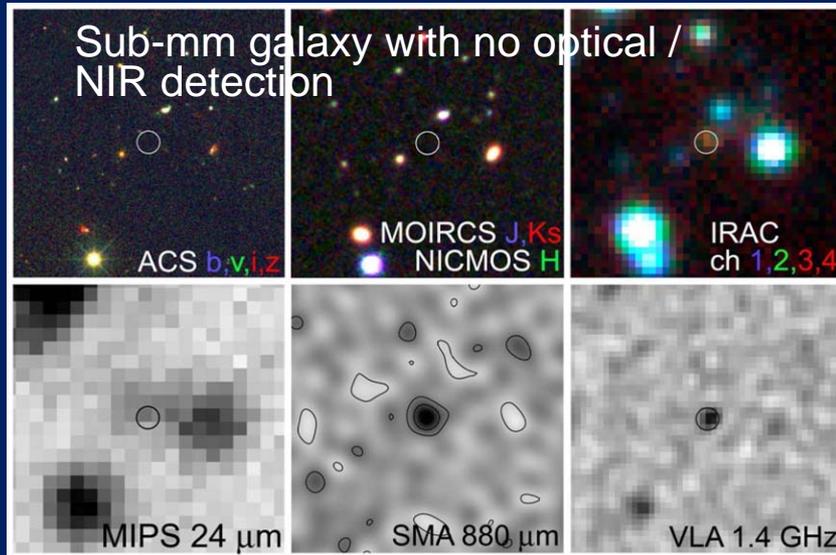


Marchesini et al. 2008

- 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 !!

# At 2017 (what do we expect ?)...

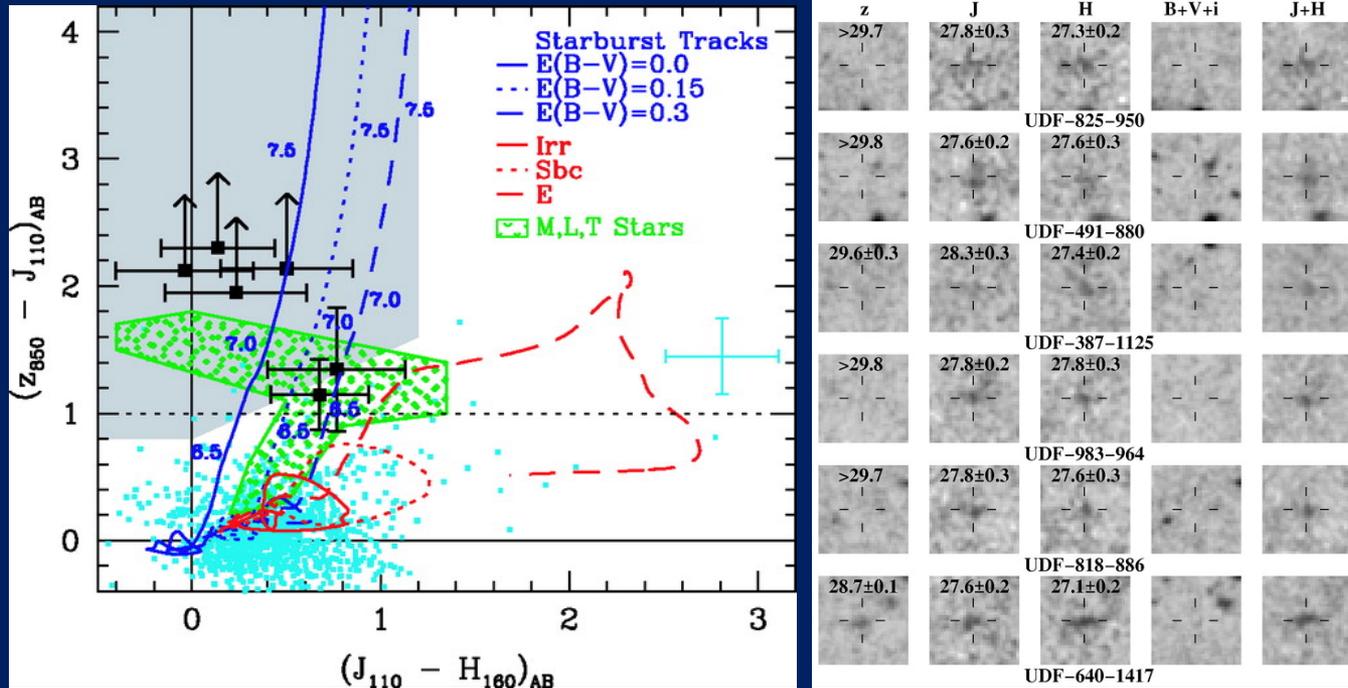
- ALMA started operation since 2012, found large number of dusty starburst galaxies at  $z > 5$ .



Wang et al. 2009, ApJ, 690, 319

# At 2017 (what do we expect ?)...

- WFC3 on HST conducted (relatively) large area survey in the NIR wavelength



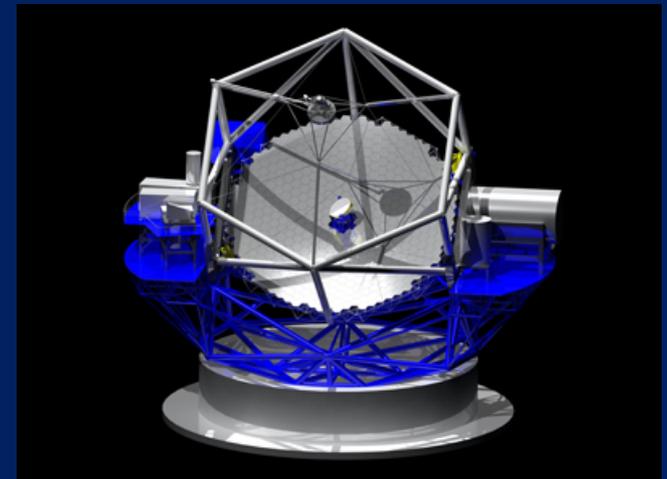
Bouwens et al. 2004, ApJ, 616, L79

- JWST was launched 2014, found large number of galaxies at  $z > 10$  ??

## At 2017 (what do we expect ?)...

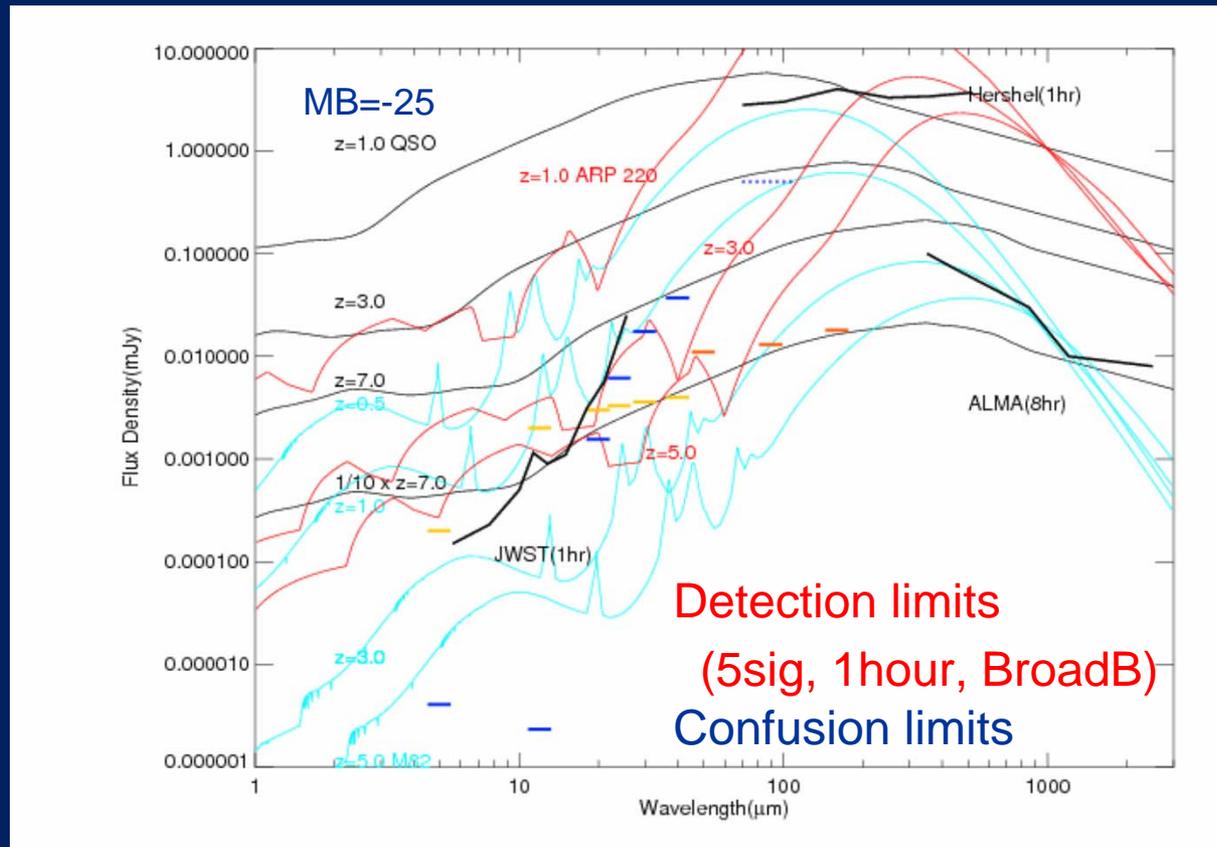
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- *Large area imaging surveys with wide field optical (Subaru/HyperScam 2011- :LSST 2015-) and NIR (UKIRT/WFCAM-UKIDSS : VISTA 2010- : etc.etc.) imagers found AGNs/QSOs at  $z>6$  by optical or NIR dropout selection.*
- *Large area NIR spectroscopic surveys of galaxies at  $z=1-3$  with Subaru/FMOS completed ?*
- *TMT will soon start science operation with first light instruments (NIR IFU, NIR MOS, Opt MOS) (2018-).*



# Baseline

- What can we do with SPICA ?



- *Detect ULIRGs up to  $z < 3(-4)$  below 40 μm*
- *Detect luminous AGNs up to  $z \leq 7$  below 40 μm*

*At 2017 (what do we expect ?)...*

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- *Still unknown !!*

*MIR properties of the high-redshift AGNs/galaxies.*

*Especially above 20 $\mu$ m, rest-frame 5 $\mu$ m for  $z=3$   
AGNs/galaxies.*

*Number density of **obscured** luminous (rare)  
AGNs/QSOs at  $z>6$*

- *(As far as I can imagine..sorry they are obvious...)*

## *Two extremes...*

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1. *Statistics of obscured AGNs among galaxies at  $z=1-3$  ?*
  - ▣ *Locating IR AGNs / starbursts among  $z=1-3$  galaxies with MIR spectroscopic survey.*
  
2. *Understanding  $z>6$  obscured AGN population.*
  - ▣ *Search for rare objects by MIR wide area survey.*

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We already have large sample of high-redshift galaxies with photometric redshift estimation from large area multi-bands surveys (for example GOODS-N+S, COSMOS, SXDF, etc.).

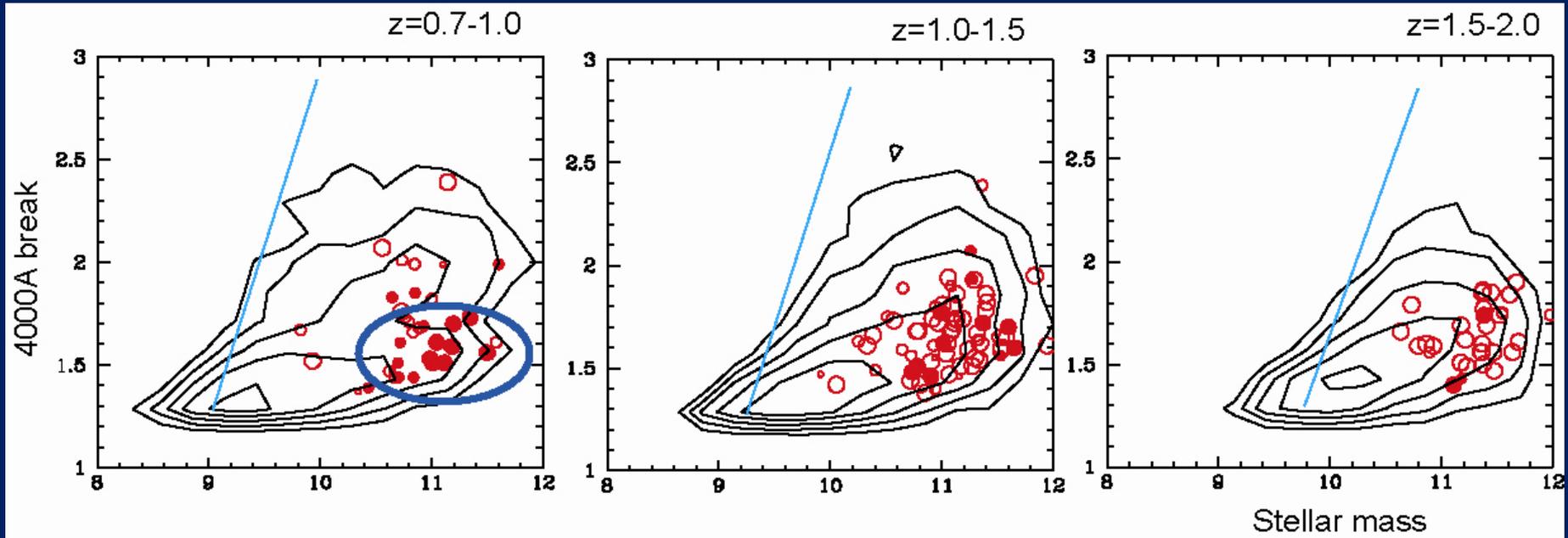


MOIRCS Deep Survey image in GOODS-N region.

# Locating AGNs among field galaxies

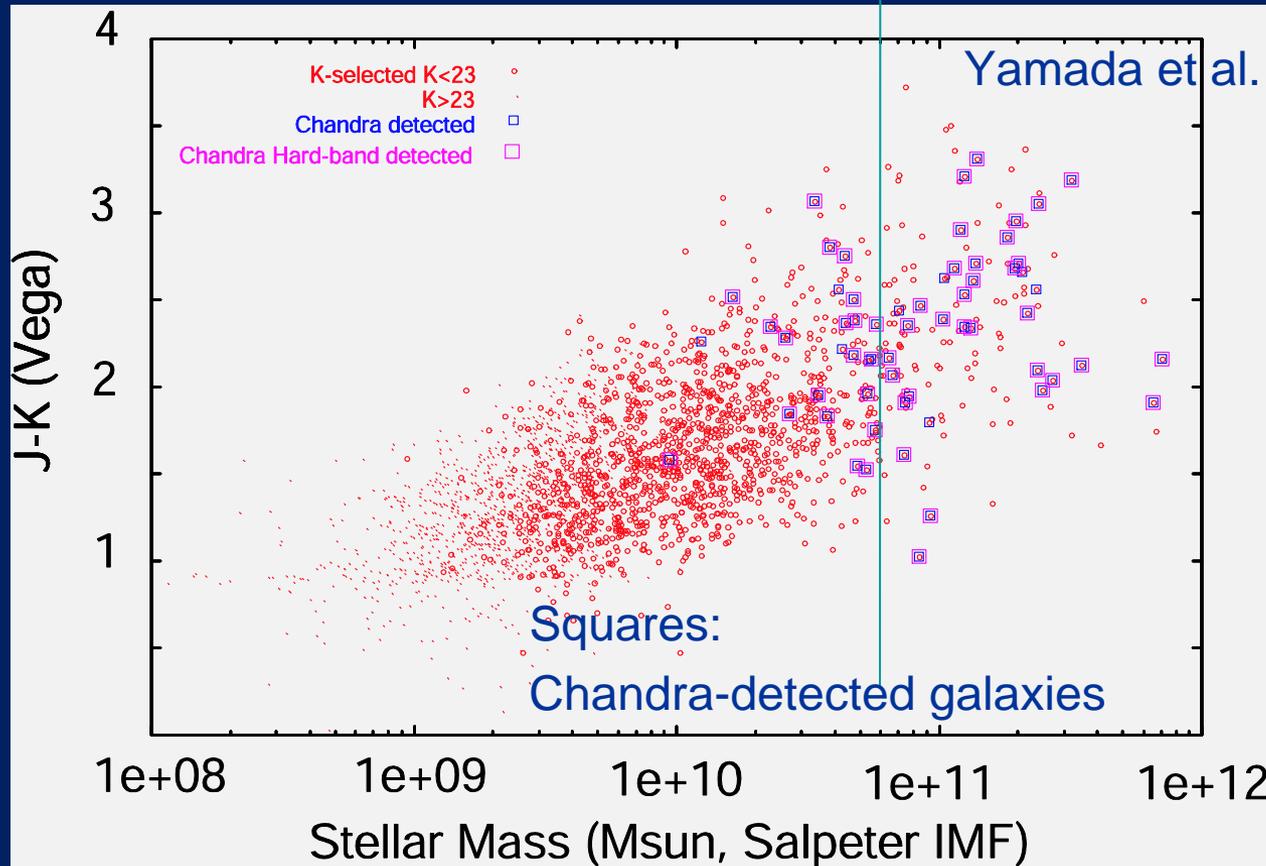
## X-ray AGNs among field galaxies in SXDS

Akiyama et al. 2009 in prep.



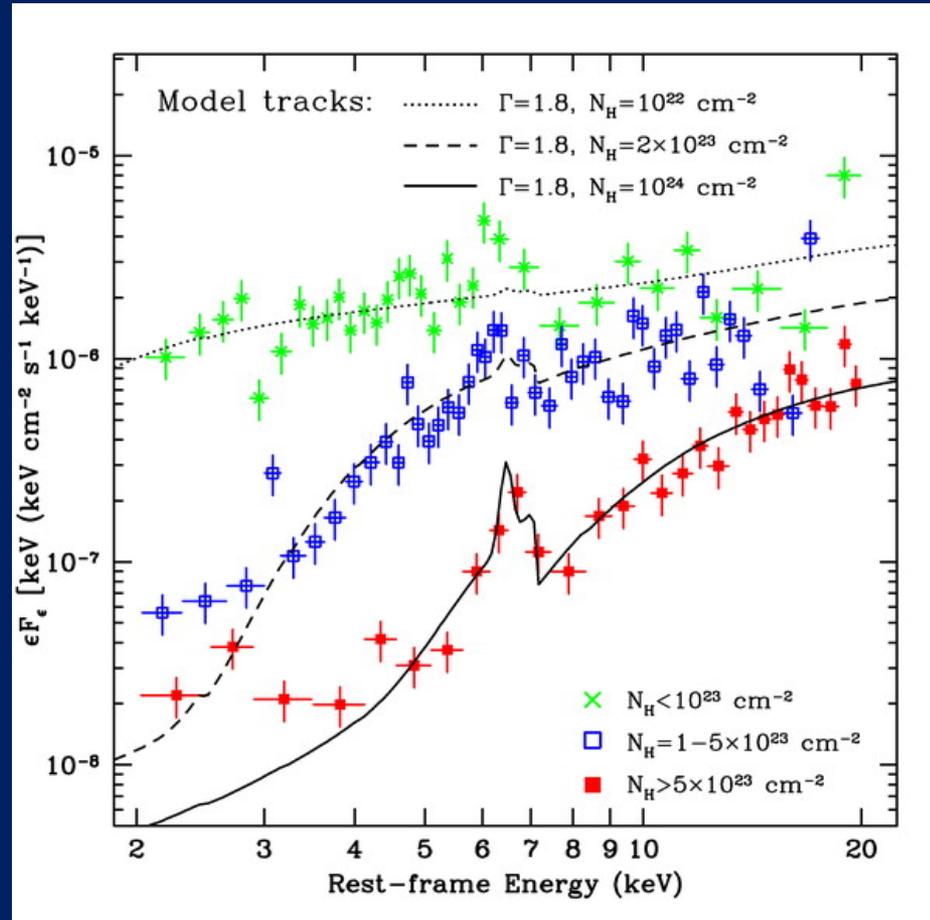
# Locating AGNs among field galaxies

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



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

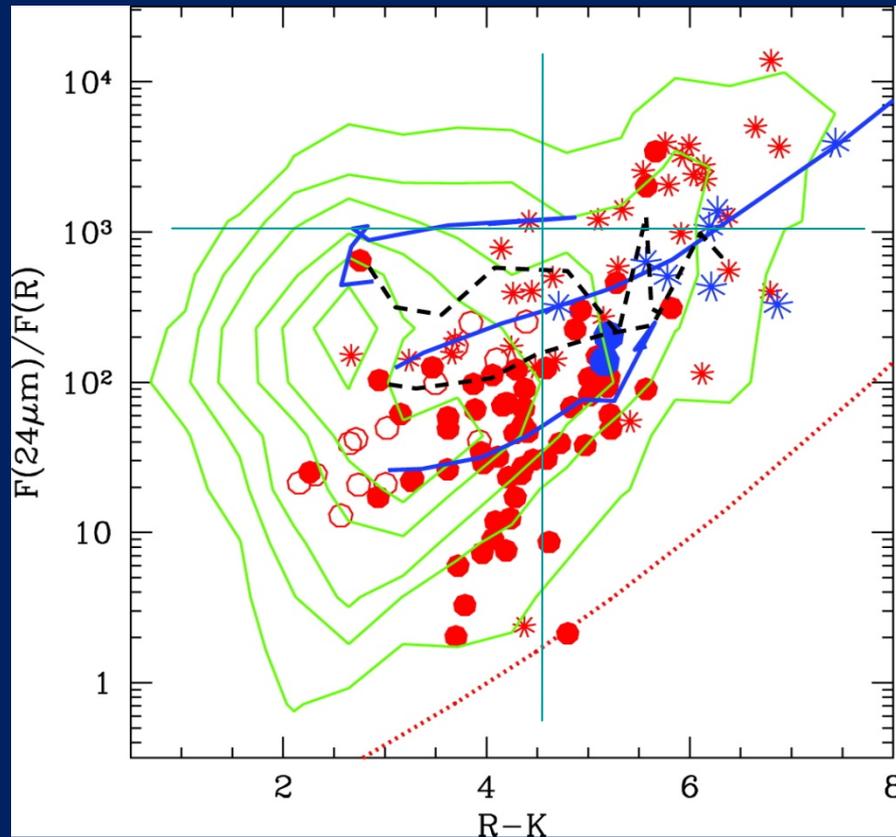
# Compton-thick AGNs among high-z galaxies ?



Alexander et al. 2005, ApJ, 632, 736

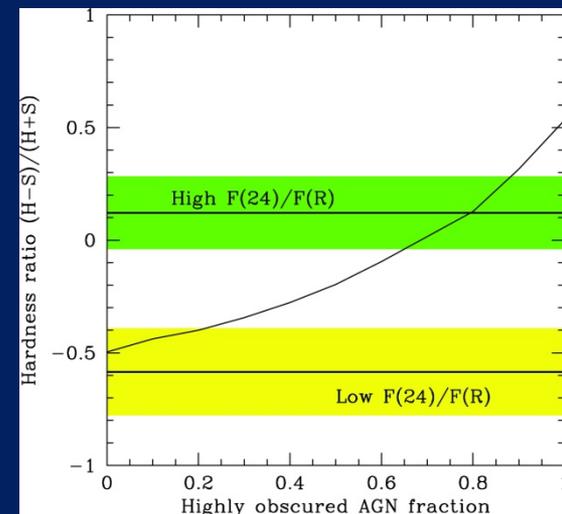
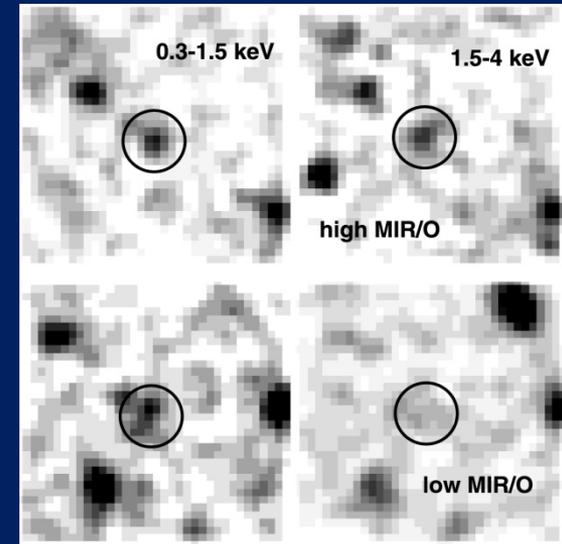
Stacked X-ray spectrum of sub-mm galaxies indicate significant fraction of sub-mm galaxies contain AGNs.

# Compton-thick AGNs among high-z galaxies ?

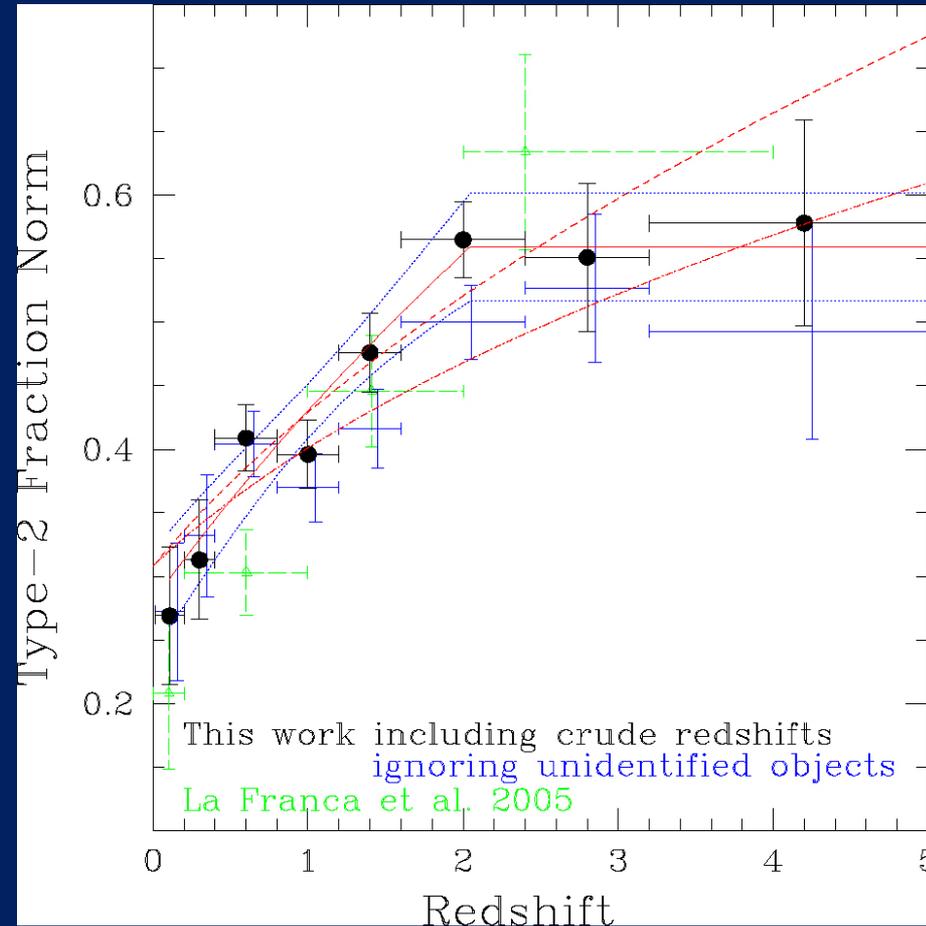
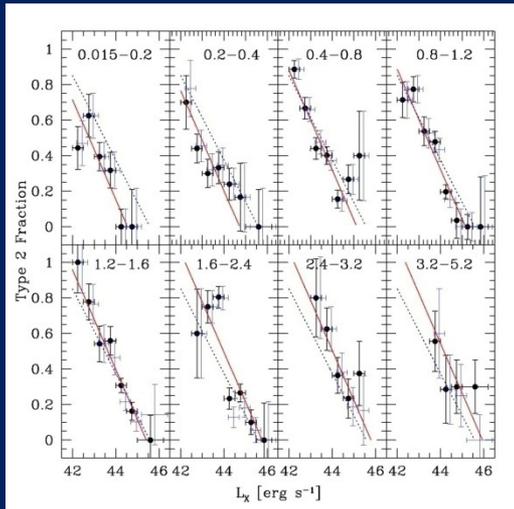


Fiore et al. 2008, ApJ. 672, 94

Stacked X-ray images of large  $F_{24}/F_R$  and red  $R-K$  color objects show hard X-ray spectra.



# Fraction of obscured AGN as a function of redshift



Hasinger 2008, A&A, 490, 905

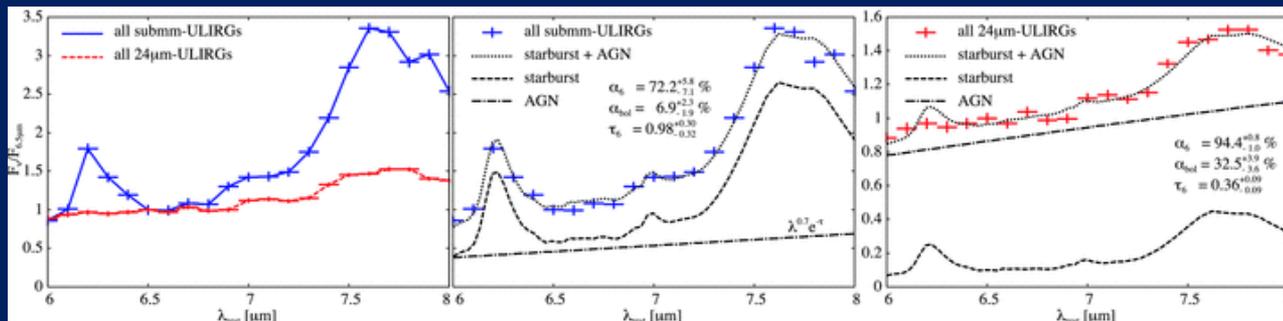
Increased fraction of absorbed AGNs at high-redshifts.

# Evaluation of AGN/starburst component in $z=1-3$ galaxies

Look for obscured AGNs among  $z=1-3$  galaxies with MIR observations !

Issue: We want to use MIR information as quantitative indicator of AGN / starburst activities. Can we distinguish AGN / starburst contribution to MIR spectra ?

AGN/starburst decomposition example,,



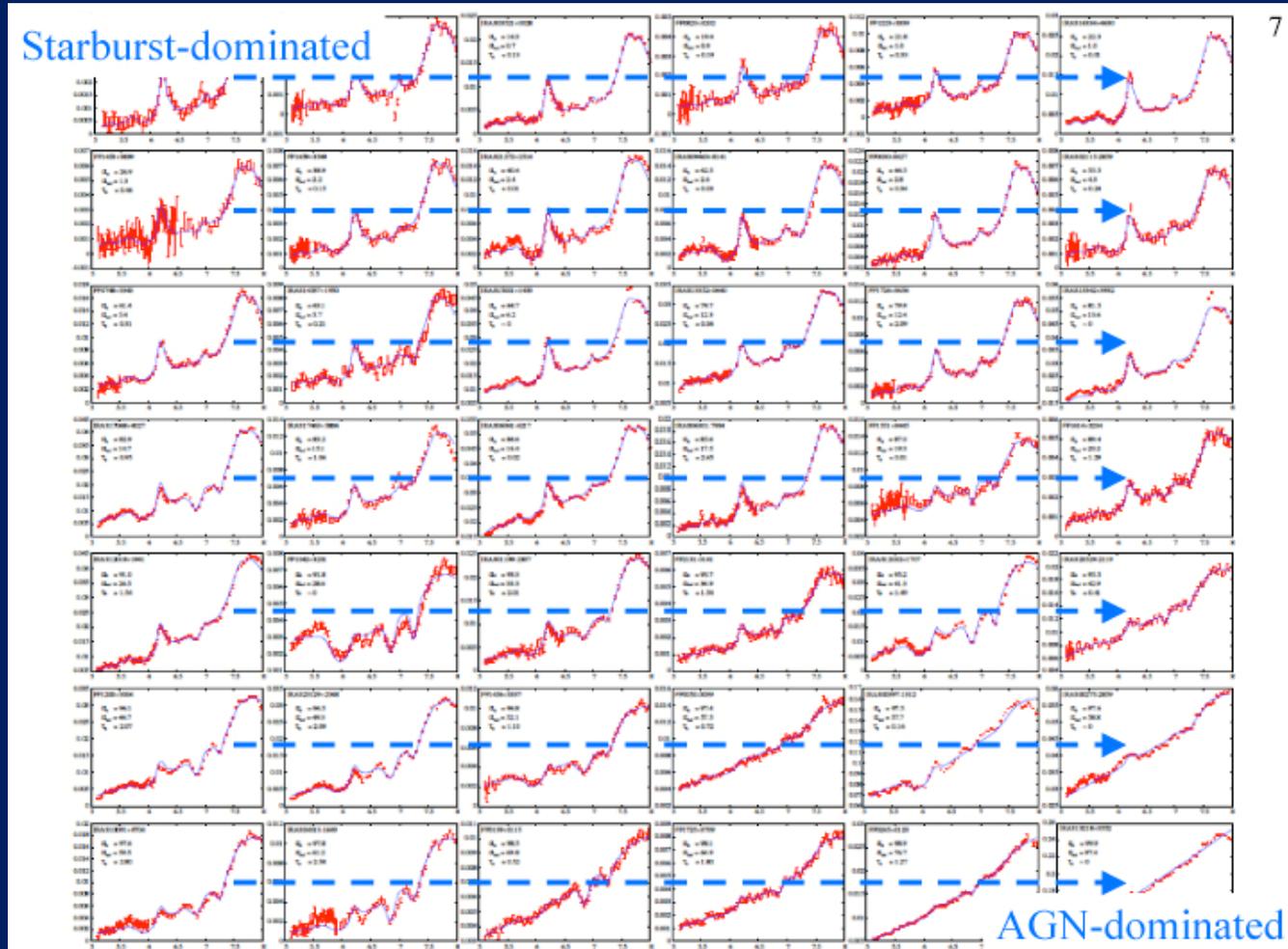
Watabe et al. 2009, MNRAS, 396, L1

(For  $z=3$ , this wavelength range redshifted to 20-30  $\mu\text{m}$ .)

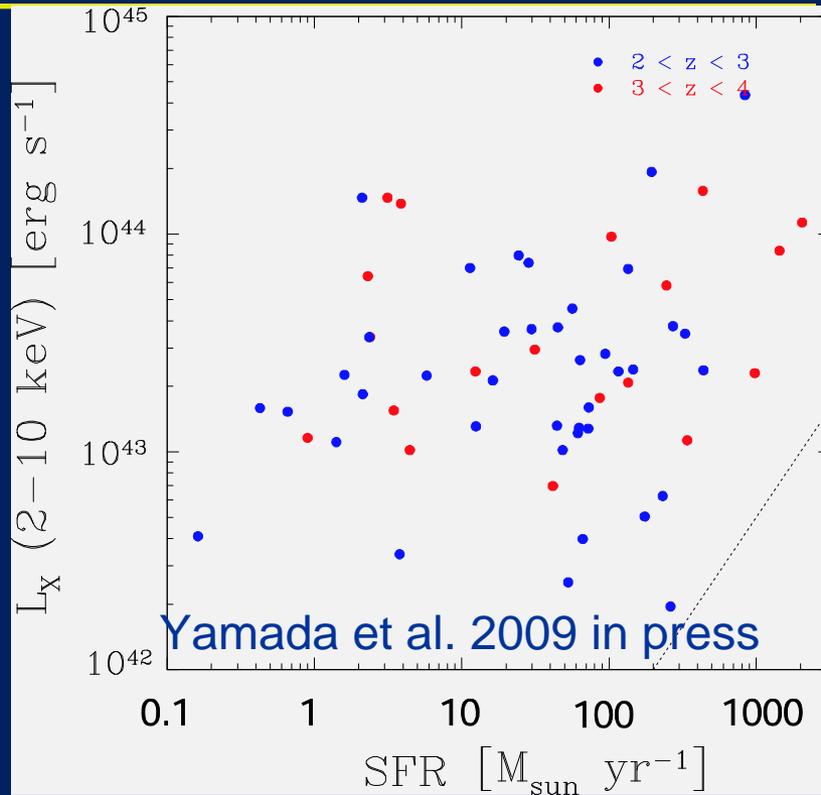
# Evaluation of AGN/starburst component in $z=1-3$ galaxies

MIR (5-8 $\mu$ m Spitzer) spectra of ULIRGs (mostly at  $z < 0.5$ )

R~30-100 spectroscopic survey (R~10 intermediate 10 bands)



# SMBH Accretion rate vs. SFR of AGN host galaxies at $z=2-4$



SFR of AGNs is estimated from rest-frame UV-optical-NIR SED, but there is a large uncertainty due to the contamination of AGN light. If SFR of AGNs is estimated with MIR SED, then we can evaluate mass-accretion rate vs. SFR of galaxies .

## *Important points*

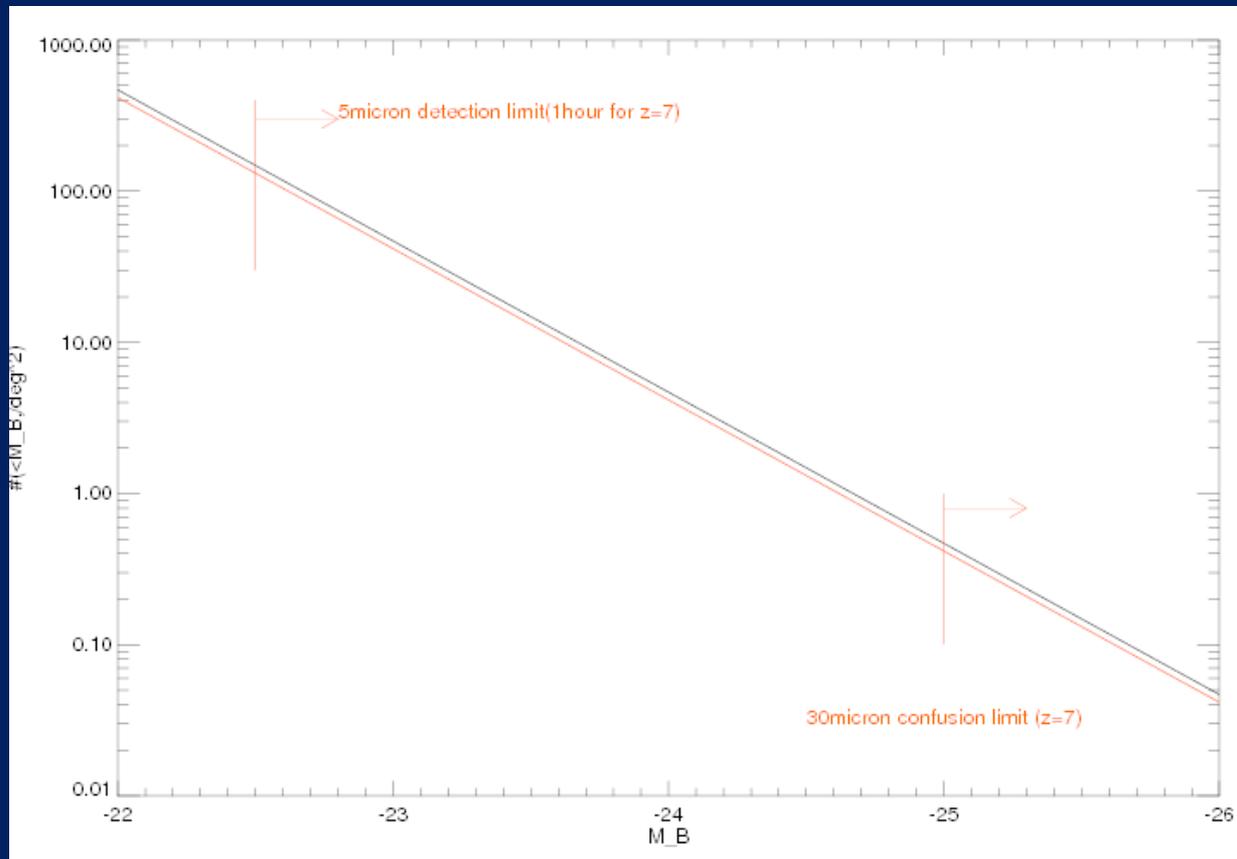
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2. *Understanding  $z > 6$  obscured AGN population.*
  - ▣ *Search for rare objects by MIR wide area survey.*

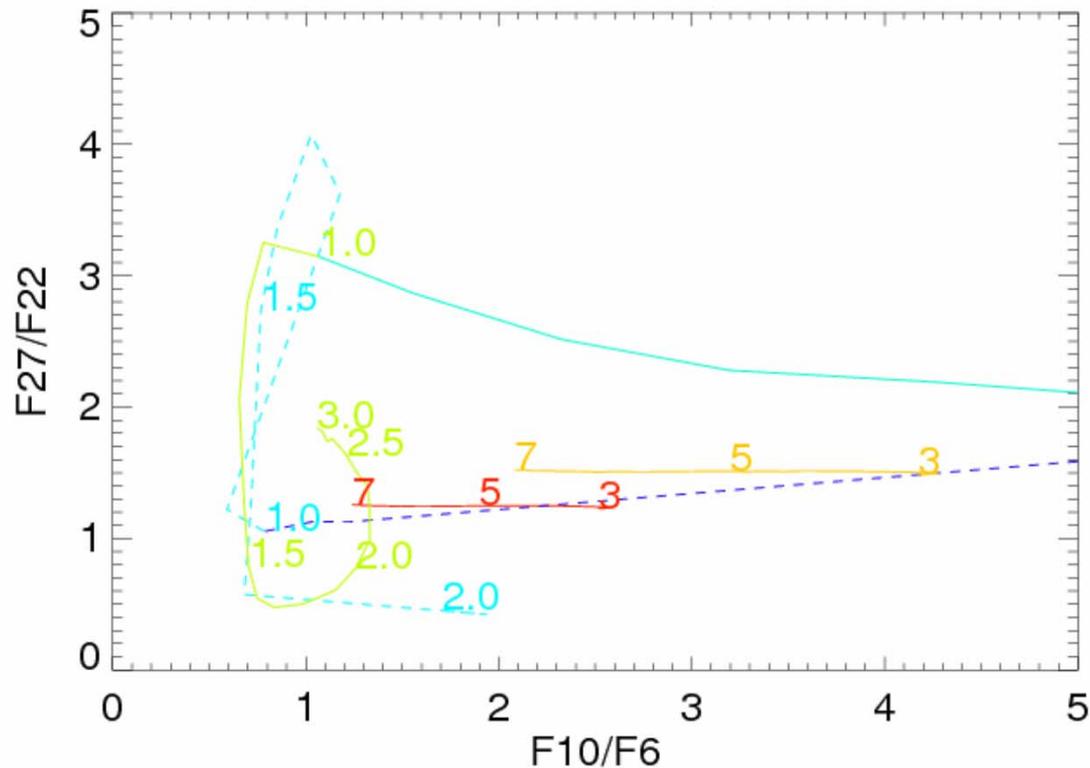
# Search for high-redshift obscured AGNs/QSOs

Wide area surveys ( $>100\text{sq.deg}$ ) in 30 $\mu\text{m}$  can detect  $\sim 100$  QSOs at  $z=6-7$ . The number count estimated with SDSS QSO LF. Selection method of high-redshift AGNs/QSOs candidate is an issue.



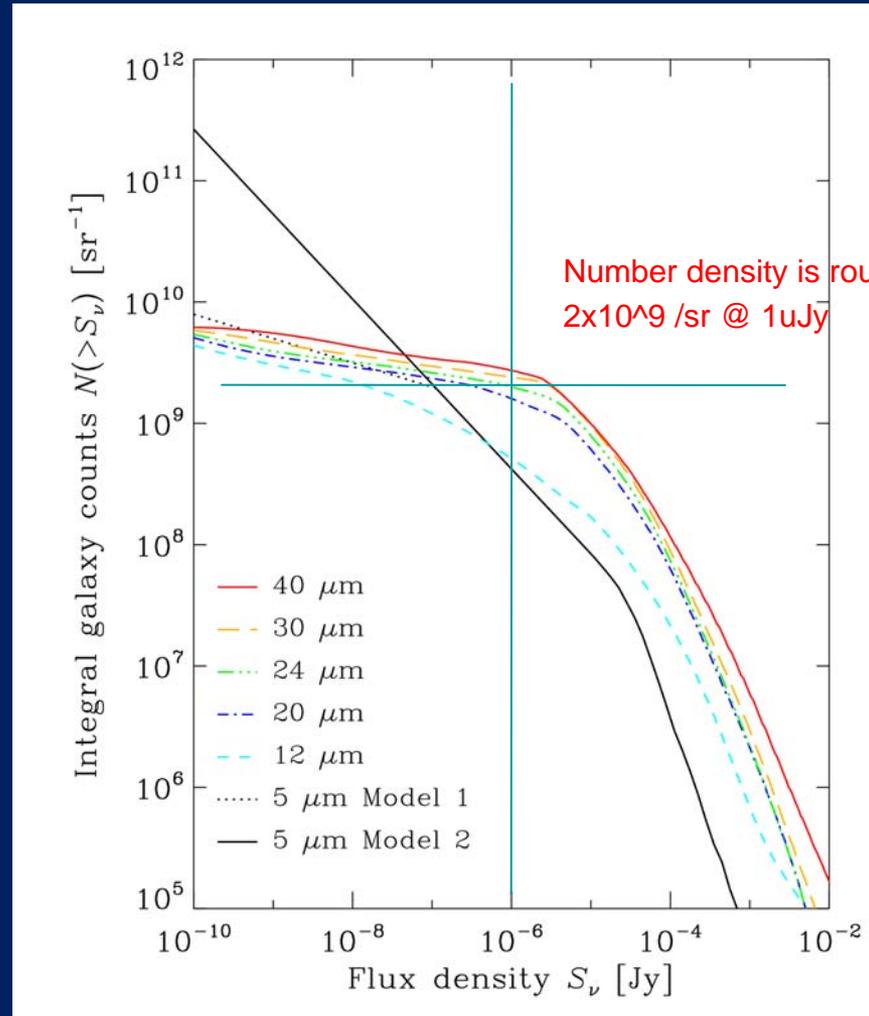
# Search for high-redshift obscured AGNs/QSOs

Color-color selection using 5-30 $\mu$ m colors can select high-redshift QSOs.  $Z < 1$  galaxies can contaminate in the color-color diagram, but they can be eliminated by optical data etc.



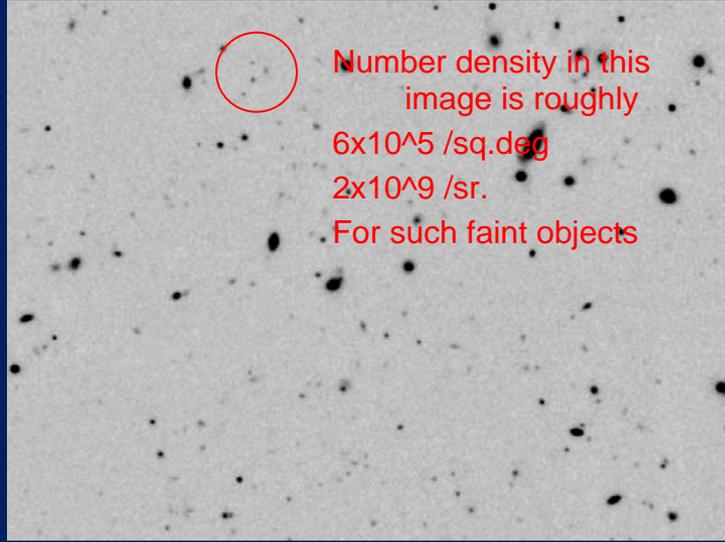
# Beyond confusion limit ?

## MIR number counts from Takeuchi-san's estimate

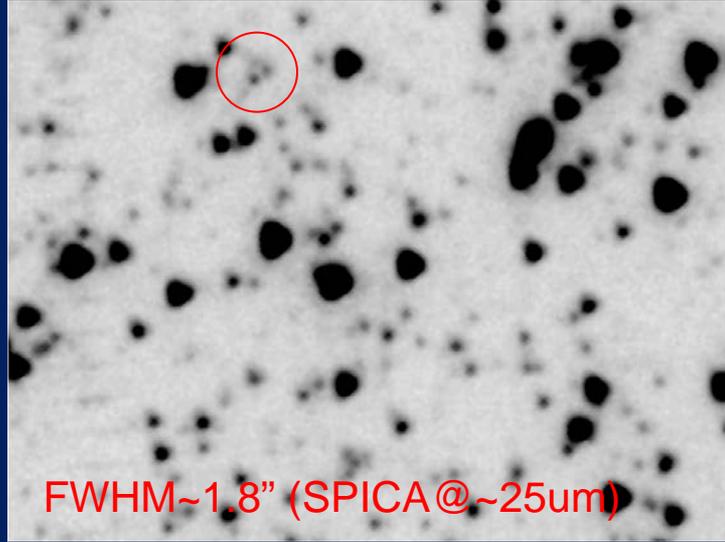


# Beyond confusion limit ?

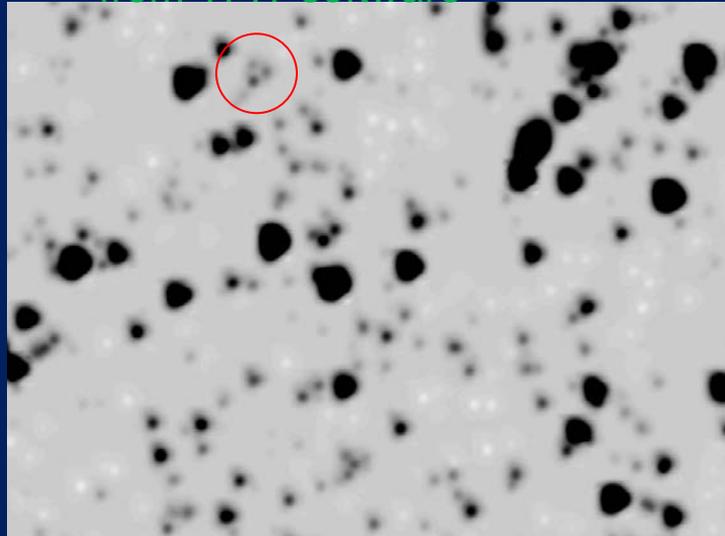
MOIRCS deep image in GOODS



Spitzer 3.6um deep image in GOODS



MOIRCS obj. \* Spitzer PSF from TFIT software



Residual



# Summary

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- *Locating IR AGNs / starbursts among  $z=1-3$  galaxies.*  
MIR properties of
  - ▣  $\sim 1,000$   $z>1$  galaxiesin deep survey fields (GOODS?) to reveal the obscured AGN activity among these galaxies (=hidden growth of SMBH).
- *Complete understanding of  $z>6$  AGNs population.*  
MIR (5-30 $\mu\text{m}$ ) large area multi-color survey in 100sq.deg will find
  - ▣  $>100$ ( $\times$ obscuration factor) QSOs at  $z>6$to reveal the obscured population of AGNs/QSOs at high-redshifts.

# Observation

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- *Locating IR AGNs / starbursts among  $z > 1$  galaxies.*
  - ▣ MIR (10-40 $\mu$ m) low-resolution ( $R < 30-100$ ) slit-scan survey in 6'x6' (x A) area.
  - ▣ 180 (2"-slit) x 1h (confusion lim.) x A / B (number of long-slits in a FoV) =  $180xA/B$  h
- *Complete understanding of  $z > 6$  AGNs population.*
  - ▣ MIR imaging survey in  $> 100$  sq.deg with 1min/fov x 100 fovs x  $\sim 5$  colors = 10h.
  - ▣ Pre multicolor deep imaging data in the optical (and/or NIR) is necessary.