PFSによる輝線診断で切り拓く
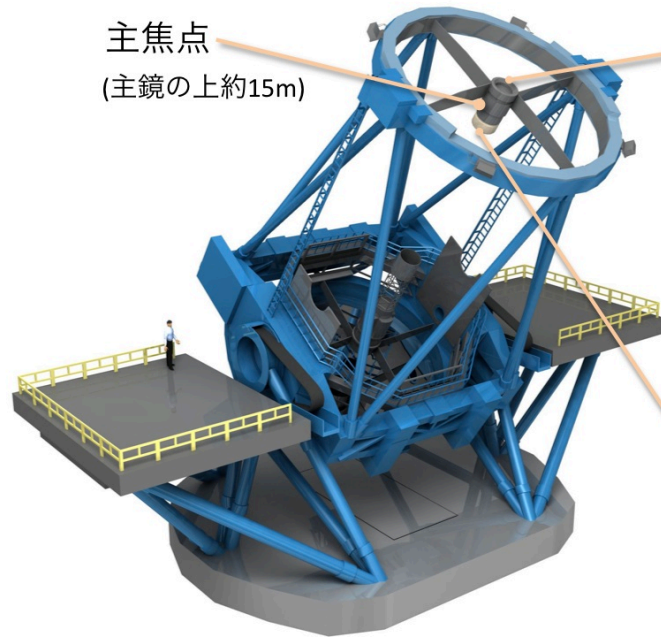# 銀河と活動銀河核のサイエンス

Tohru Nagao
(Ehime U.)

Partly based on inputs from

Kouta Kawasaki (Ehime U.)
Yoshiki Matsuoka (NAOJ)
Masayuki Tanaka (NAOJ)
Yoshiki Toba (Ehime U.)

愛媛大学
EHIME UNIVERSITY

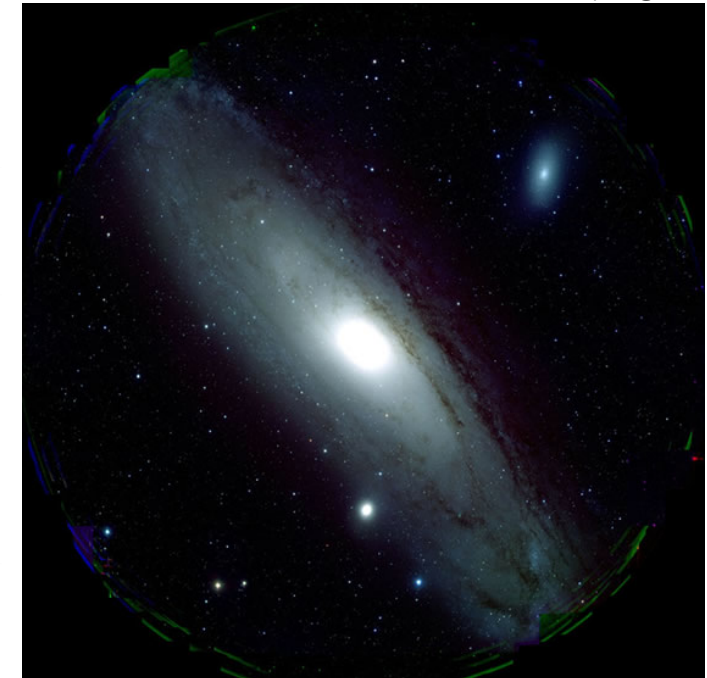# Now we have Hyper Suprime Cam !!

from the Subaru webpage

主焦点
(主鏡の上約15m)

すばる望遠鏡

Hyper Suprime-Cam
(高さ約３m、重さ約３トン)

~ press release of the Andromeda image in Jul. 2013
~ HSC "Subaru Strategic Program" started in Mar. 2014
    -- total 300 nights in the coming 5 years
    -- wide 1400 deg^2, deep 28 deg^2, ultradeep 3.5 deg^2
~ first HSC-SSP internal data release in Sep. 2014

HSC science papers have already come !!
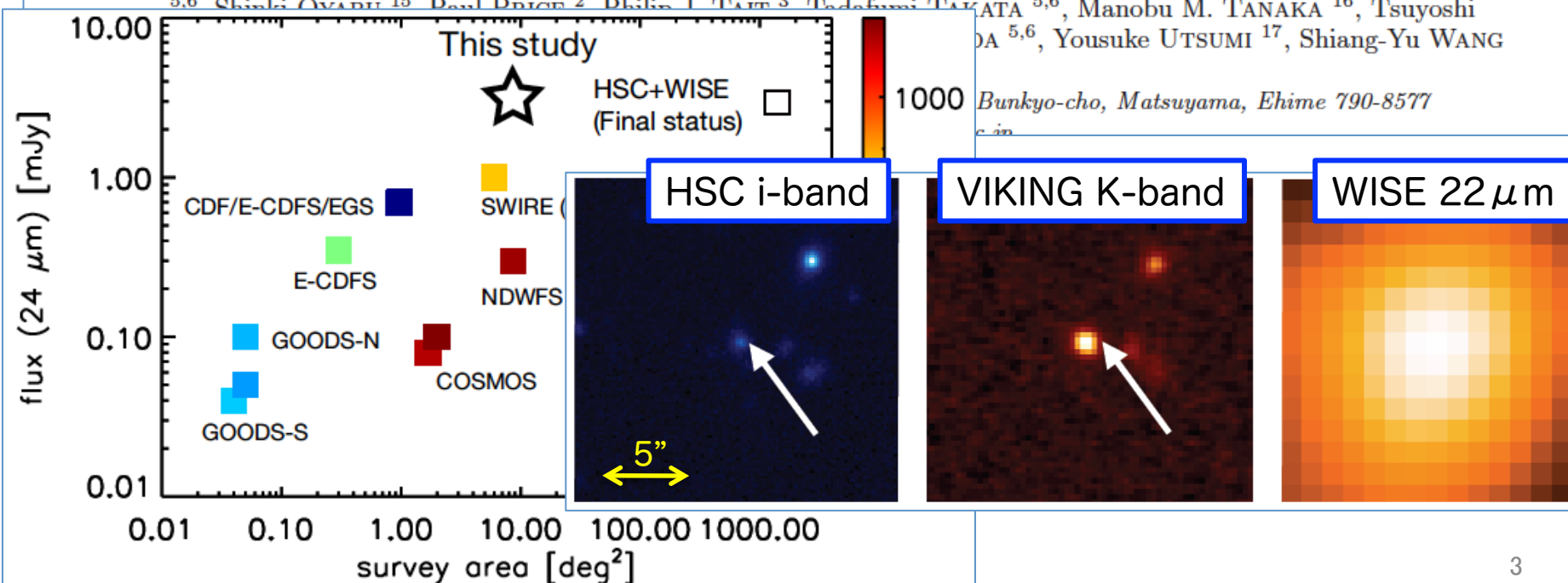
arXiv:1506.00320
Toba, TN, Strauss, et al., in press
(PASJ Subaru special issue)

Hyper-luminous Dust Obscured Galaxies discovered by the Hyper Suprime-Cam on Subaru and WISE*

Yoshiki TOBA [1], Tohru NAGAO [1], Michael A. STRAUSS [2], Kentaro AOKI [3], Tomotsugu GOTO [4], Masatoshi IMANISHI [3,5,6], Toshihiro KAWAGUCHI [7], Yuichi TERASHIMA [8], Yoshihiro UEDA [9], James BOSCH [2], Kevin BUNDY [10], Yoshiyuki DOI [3], Hanae INAMI [11], Yutaka KOMIYAMA [5,6], Robert H. LUPTON [2], Hideo MATSUHARA [12,13], Yoshiki MATSUOKA [5], Satoshi MIYAZAKI [5,6], Tomoki MOROKUMA [14], Fumiaki NAKATA [3], Nagisa OI [12], Masafusa ONOUE [5,6], Shinki OYABU [15], Paul PRICE [2], Philip J. TAIT [3], Tadafumi TAKATA [5,6], Manobu M. TANAKA [16], Tsuyoshi ...DA [5,6], Yousuke UTSUMI [17], Shiang-Yu WANG
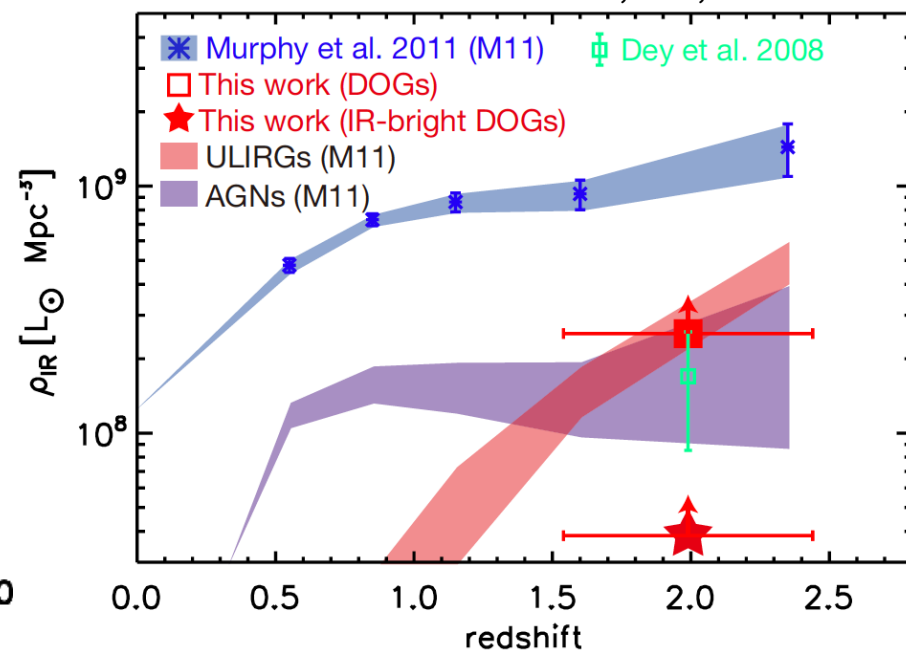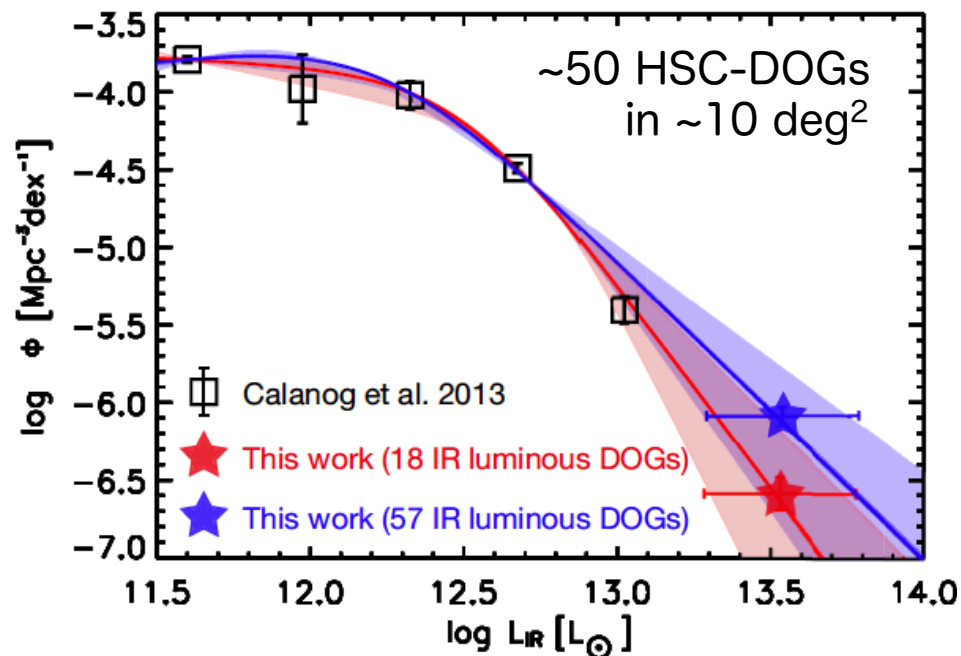
...Bunkyo-cho, Matsuyama, Ehime 790-8577

HSC i-band

VIKING K-band

WISE $22\,\mu m$

5"

HSC science papers have come, BUT...

~50 HSC-DOGs in ~10 deg^2

Calanog et al. 2013

★ This work (18 IR luminous DOGs)

★ This work (57 IR luminous DOGs)

Murphy et al. 2011 (M11)   Dey et al. 2008
This work (DOGs)
This work (IR-bright DOGs)
ULIRGs (M11)
AGNs (M11)
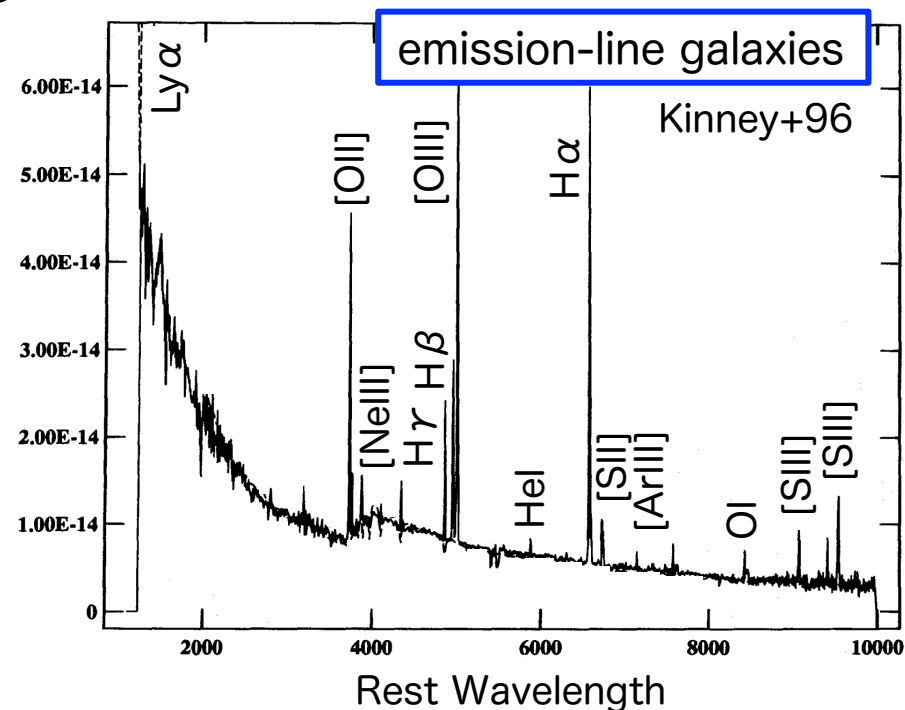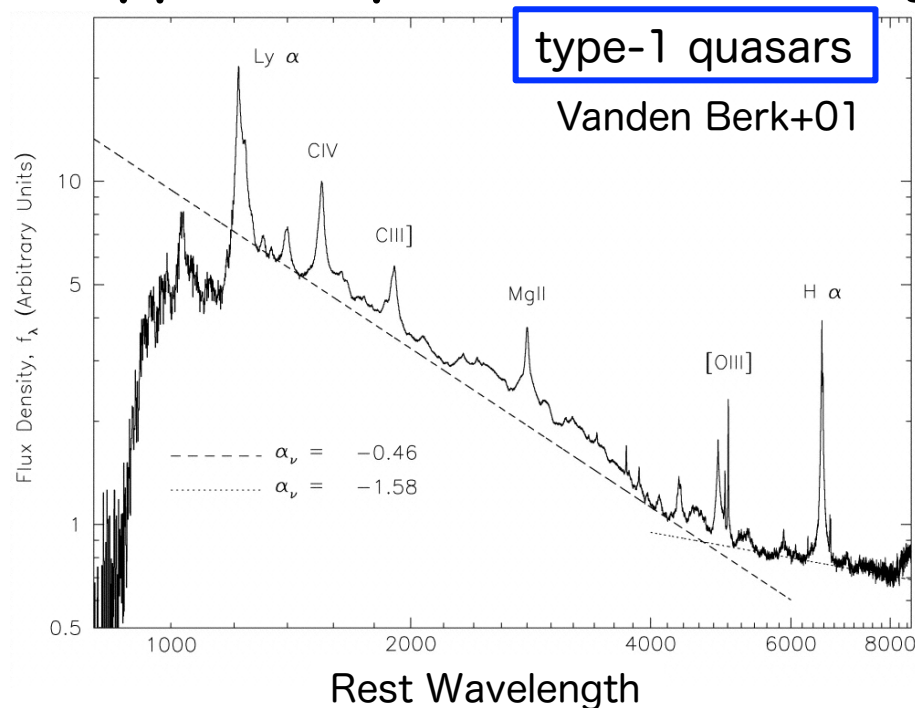
~ double-PL LF → close connection to the SMBH growth
~ DOGs' contribution to the IR density is similar to ULIRGs

~ but no spectra
~ redshift distribution? presence of AGNs? SMBH mass?
~ wide spectroscopic survey is crucial, not only for DOGs

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Typical spectrum of SF-galaxies and AGNs

type-1 quasars

Vanden Berk+01

emission-line galaxies

Kinney+96

~ many features in UV & optical
~ useful for measuring z, M_{BH}, Z_{BLR}
~ Matsuoka-san's talk (high-z)
~ Akiyama-san's talk (M_{BH})
~ Niida-san's poster (Lum. Func.)
~ Oogi-san's poster (clustering)

~ no strong lines between Lyα and [OII]
~ Lyα at $z > 2.1$ ($\rightarrow$ Ouchi-san)
~ [OII] at $z < 2.3$
~ PFS: powerful for measuring z
~ line diagnostics at $z < 1.5$

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Emission-line diagnostics, BUT...

~ gas density
     -- [SII]6717/6731
     -- [OII]3726/3729

~ gas temperature ←??
     -- [OIII]4363/5007
     -- [NII]5755/6584
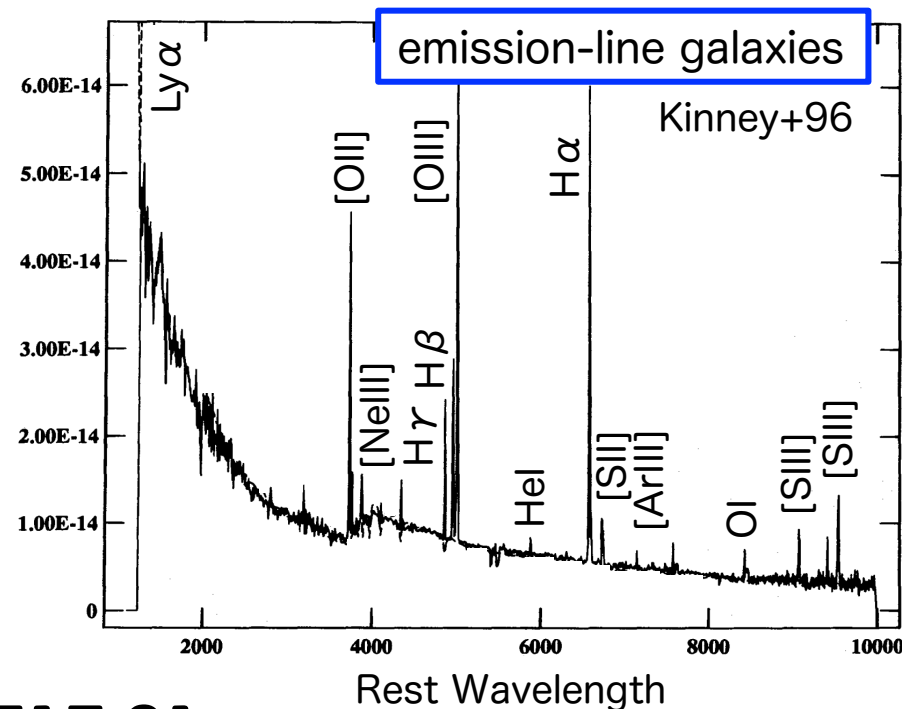   -- [SIII]6312/9069,9532

~ gas ionization ←??
     -- [OIII]5007/[OII]3727
     -- [SIII]9069,9532/[SII]6717,31

~ gas metallicity ←??
     -- [NII]6584/Hα6563
     -- ([OII]+[OIII])/Hβ4861

~ dust extinction ←??
     -- Hα6563/Hβ4861

emission-line galaxies

Kinney+96

Rest Wavelength

A caveat:

Is this object star-forming galaxy or type-2 AGN ??

So-called BPT diagram

Baldwin+81, Veilleux+87

Symbols

- ● Seyfert 2
- ■ NLRG
- ▲ Liner
- ✳ NELG
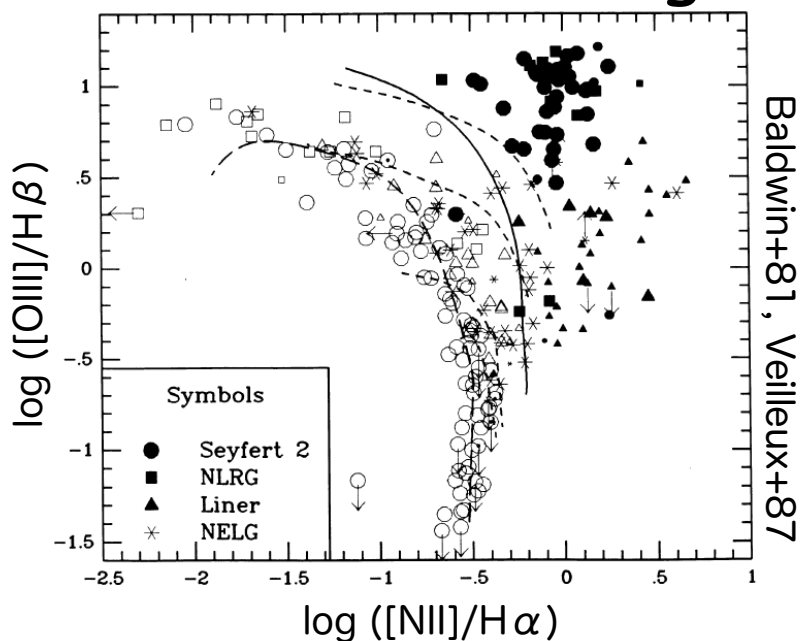
Kewley+01,06, Kauffmann+03, Groves+06

Seyfert Galaxies

Star-forming Galaxies

LINERs

BPT with SDSS
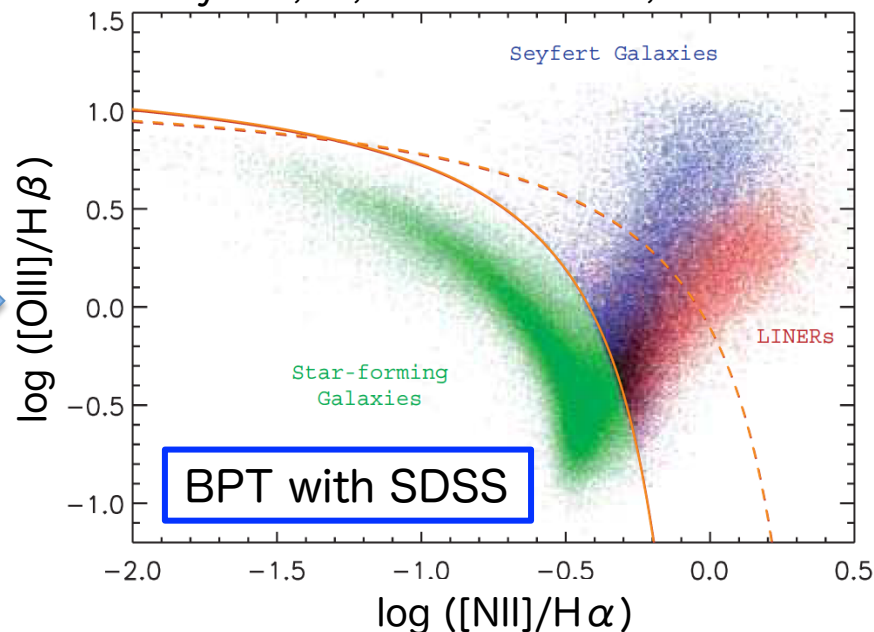
In the PFS survey:

BPT available up to z~0.9
Blue-BPT up to z~1.5

Lamareille+04,10

Seyferts

LINERS

composites

star-forming galaxies
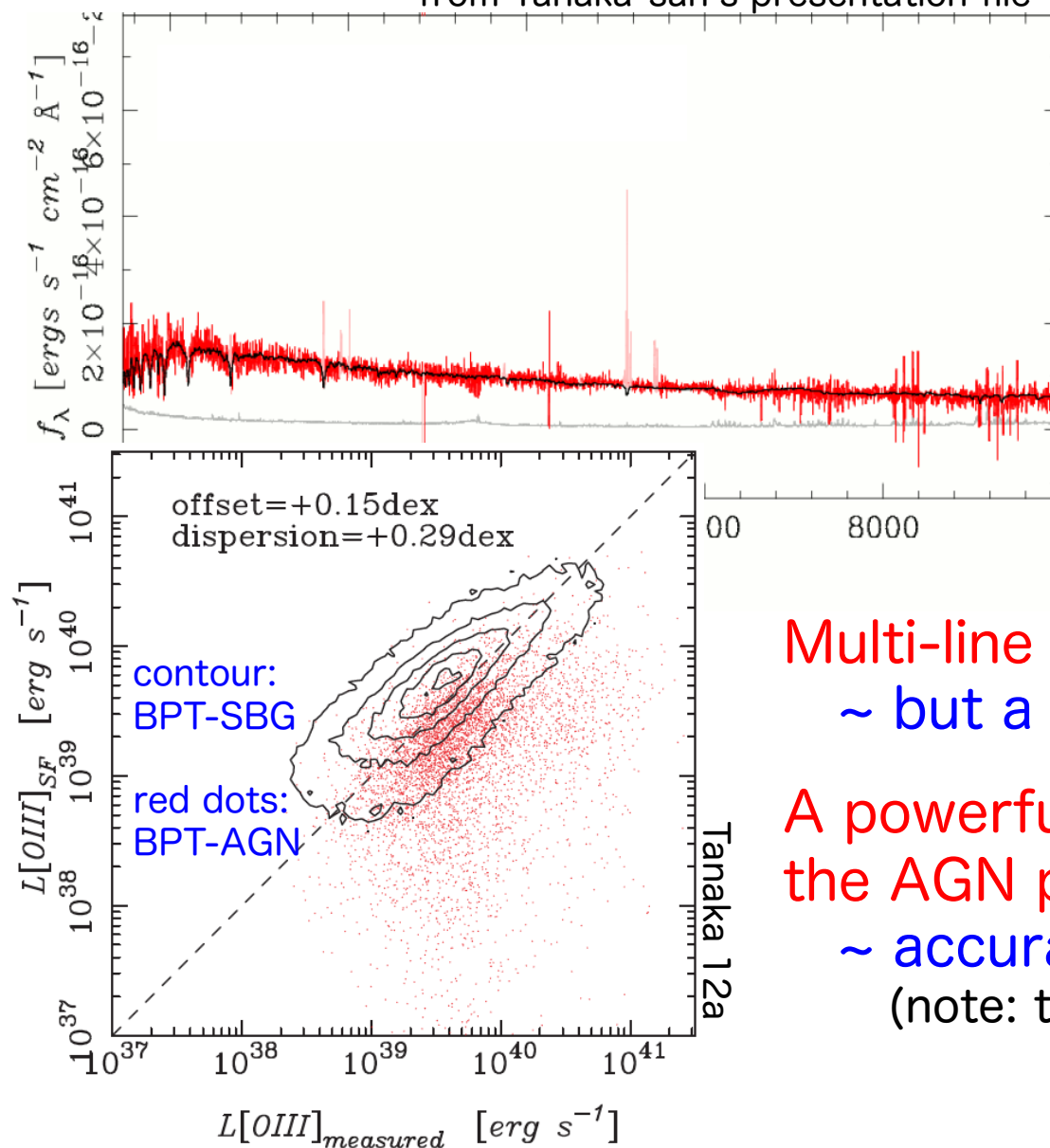
blue BPT
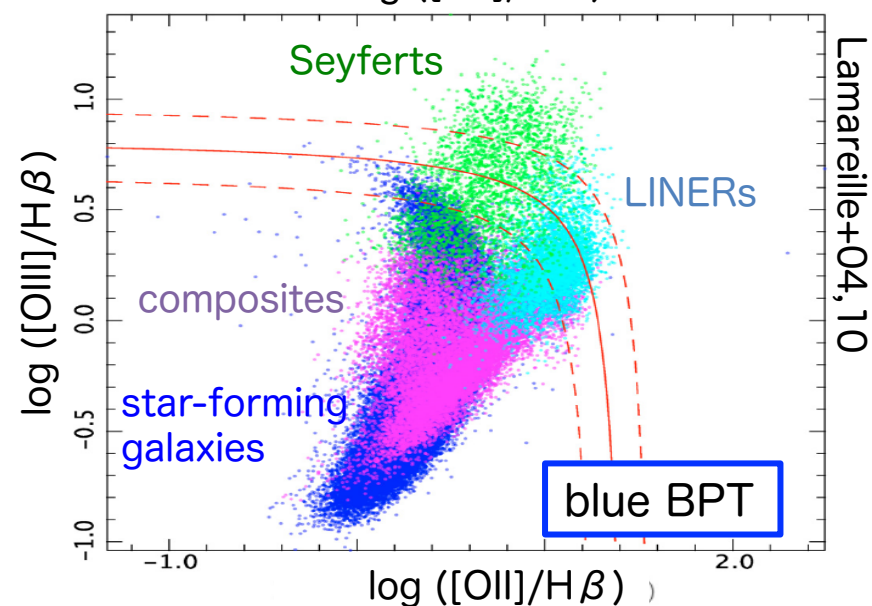
So-called Tanaka method

from Tanaka-san's presentation file

continuum fitting
→ SFR, reddening
→ predicted line fluxes
→ comparing with F_{obs}
→ are there excess flux?
→ if yes, then AGN

(Tanaka 12a,12b)

offset=+0.15dex
dispersion=+0.29dex

contour:
BPT-SBG

red dots:
BPT-AGN
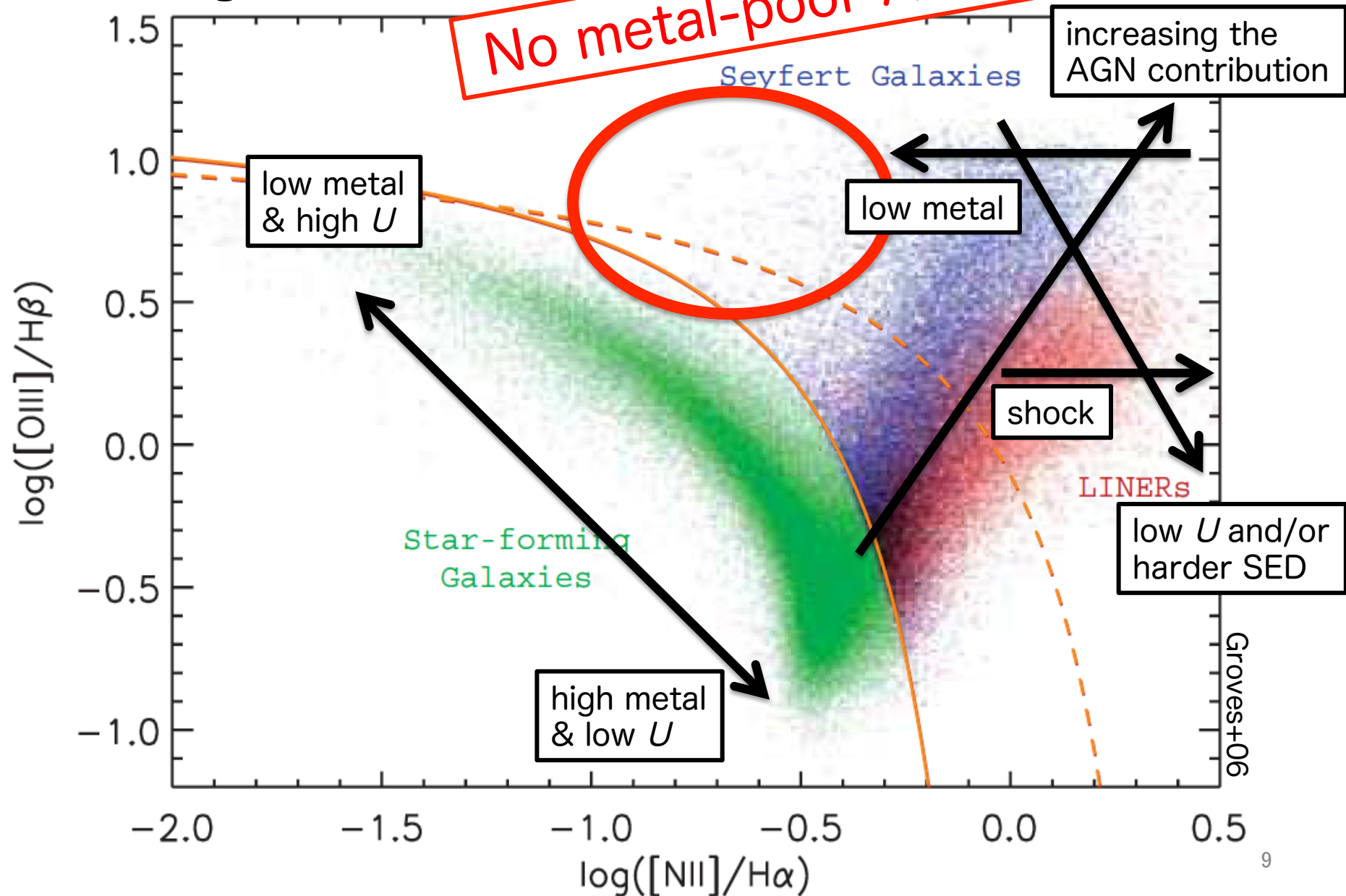
Tanaka 12a

Multi-line detection is not needed
~ but a wide λ-range required

A powerful approach to diagnose
the AGN presence in PFS surveys
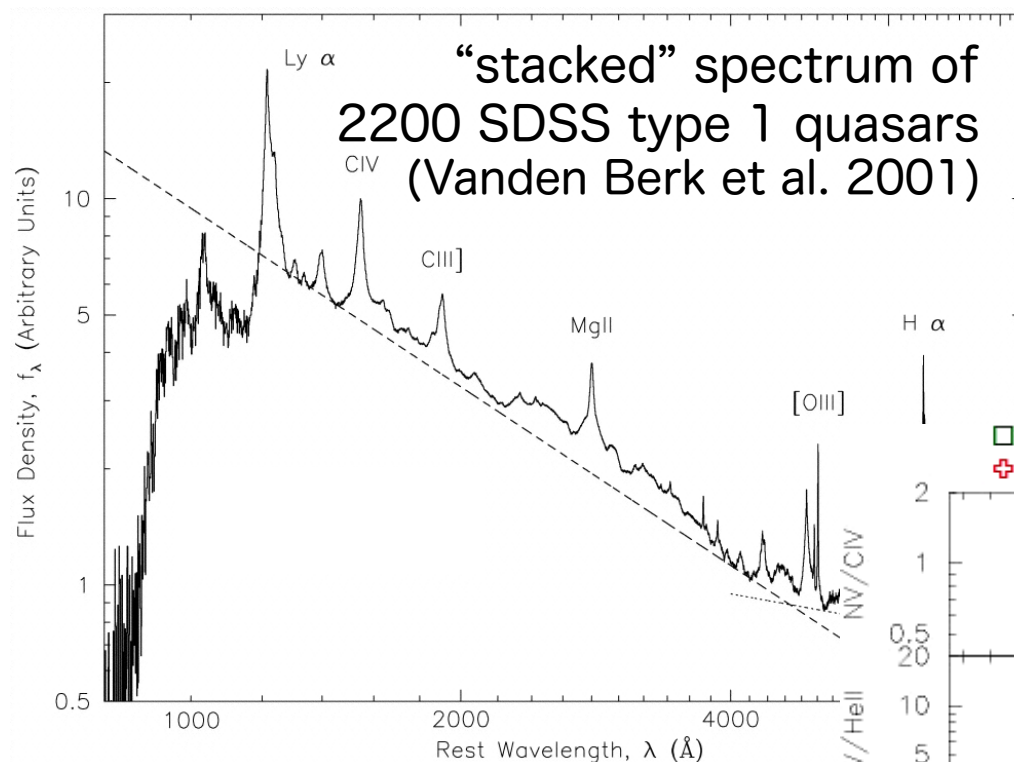~ accurate flux calib is a challenge
(note: the PFS fiber diameter is ~1")

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BPT diagram, revisited

No metal-poor AGNs?

Seyfert Galaxies

increasing the AGN contribution

low metal & high *U*

low metal

shock

LINERs

low *U* and/or harder SED

Star-forming Galaxies

high metal & low *U*

log([OIII]/Hβ)

log([NII]/Hα)

Groves+06

Metallicity of the ISM in AGNs; a BLR view

"stacked" spectrum of 2200 SDSS type 1 quasars (Vanden Berk et al. 2001)

type-1 AGNs show various strong metalic lines
→metallicity measurements are relatively easy even at high redshifts

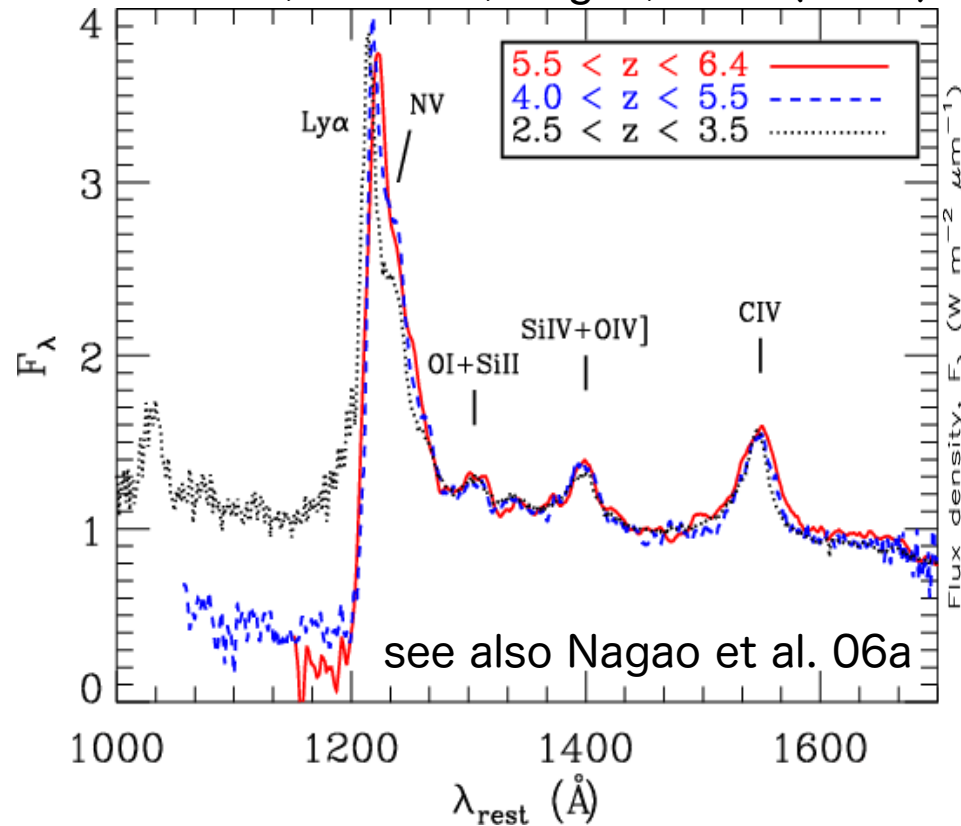luminous quasars show $Z_{BLR} \sim$ 5-10 Z_{sun}, without any redshift evolution at z ~ 2 - 5
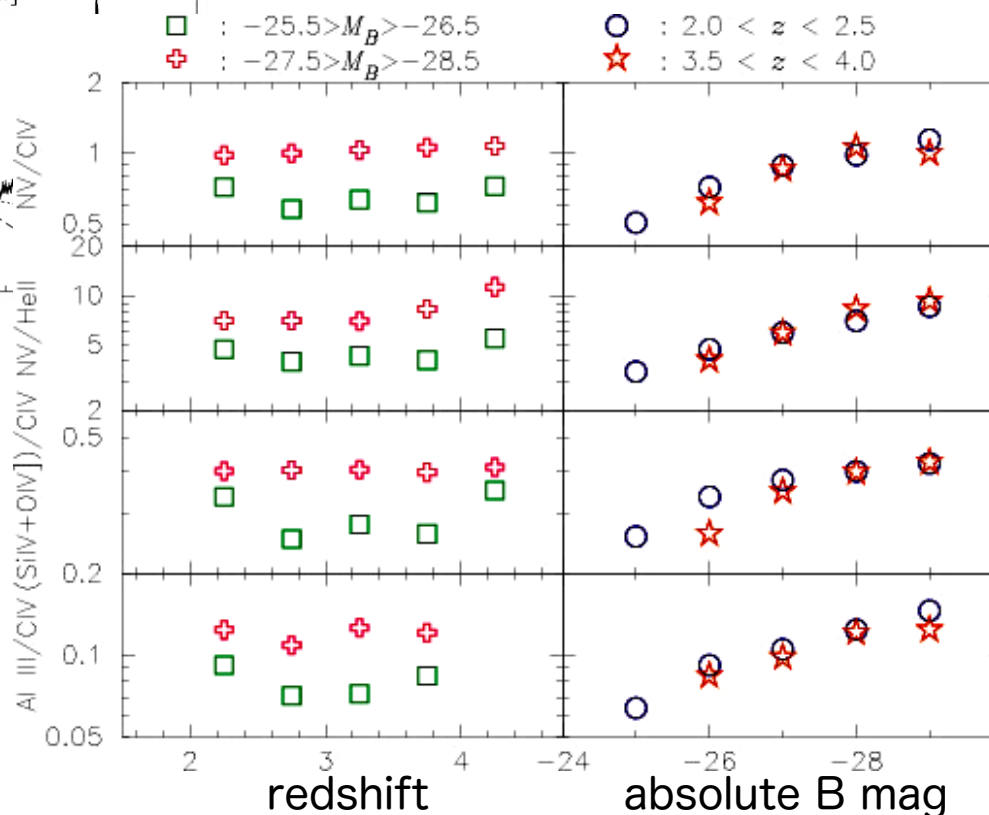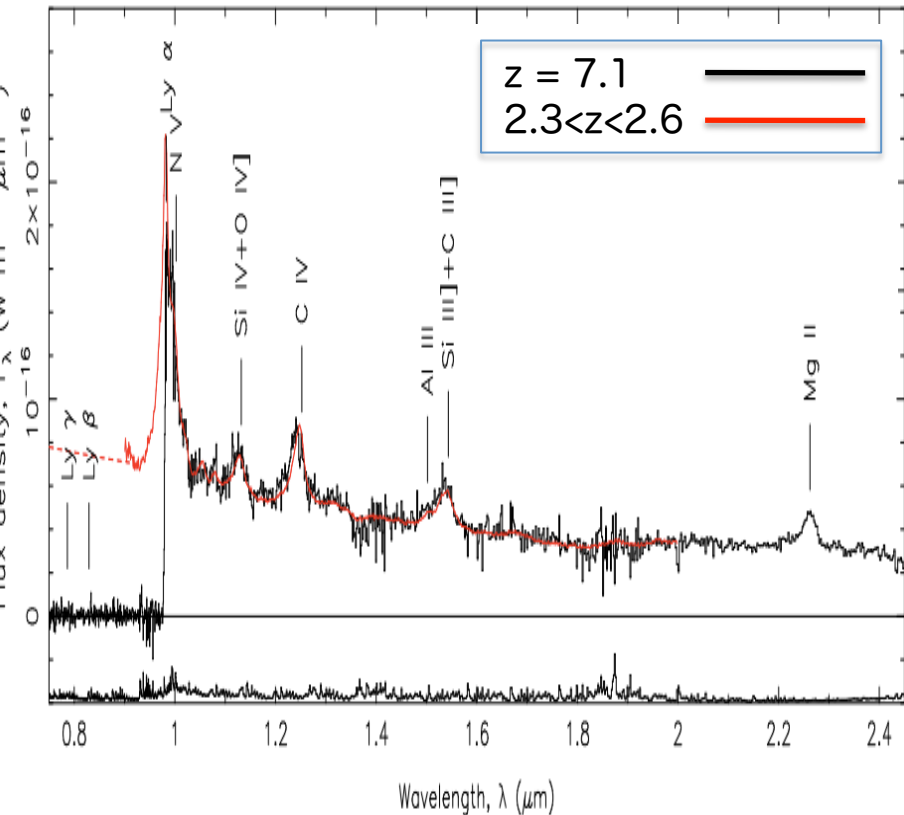
Nagao, Marconi, & Maiolino (2006a)

Metallicity of the ISM in AGNs; a BLR view
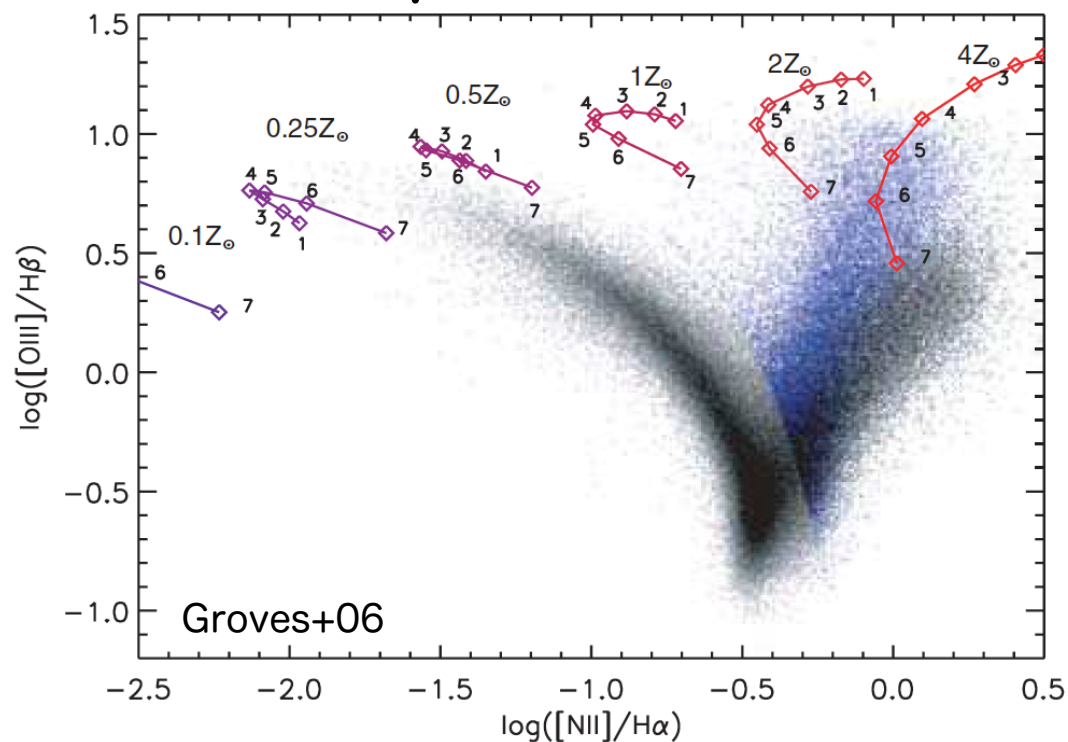
Juarez, Maiolino, Nagao, et al. (2009)

Mortlock et al. (2011)

➤Quasars are chemically matured even at z~6-7
~ should be tested with HSC/PFS (→ Matsuoka-san's talk)
~ no low-metallicity AGNs?

No metal-poor (i.e., chemically young) AGNs?

Groves+06

Photoionization model says there are only few AGNs with $Z_{AGN} \lesssim 1\text{-}2\ Z_{sun}$, but due to the selection bias? (shallow depth of SDSS)

TN+01

Note: very high-U AGNs also show similar emission-line flux ratios...

Sensitive PFS surveys for faint AGNs will be powerful to search for metal-poor, chemically-young AGNs

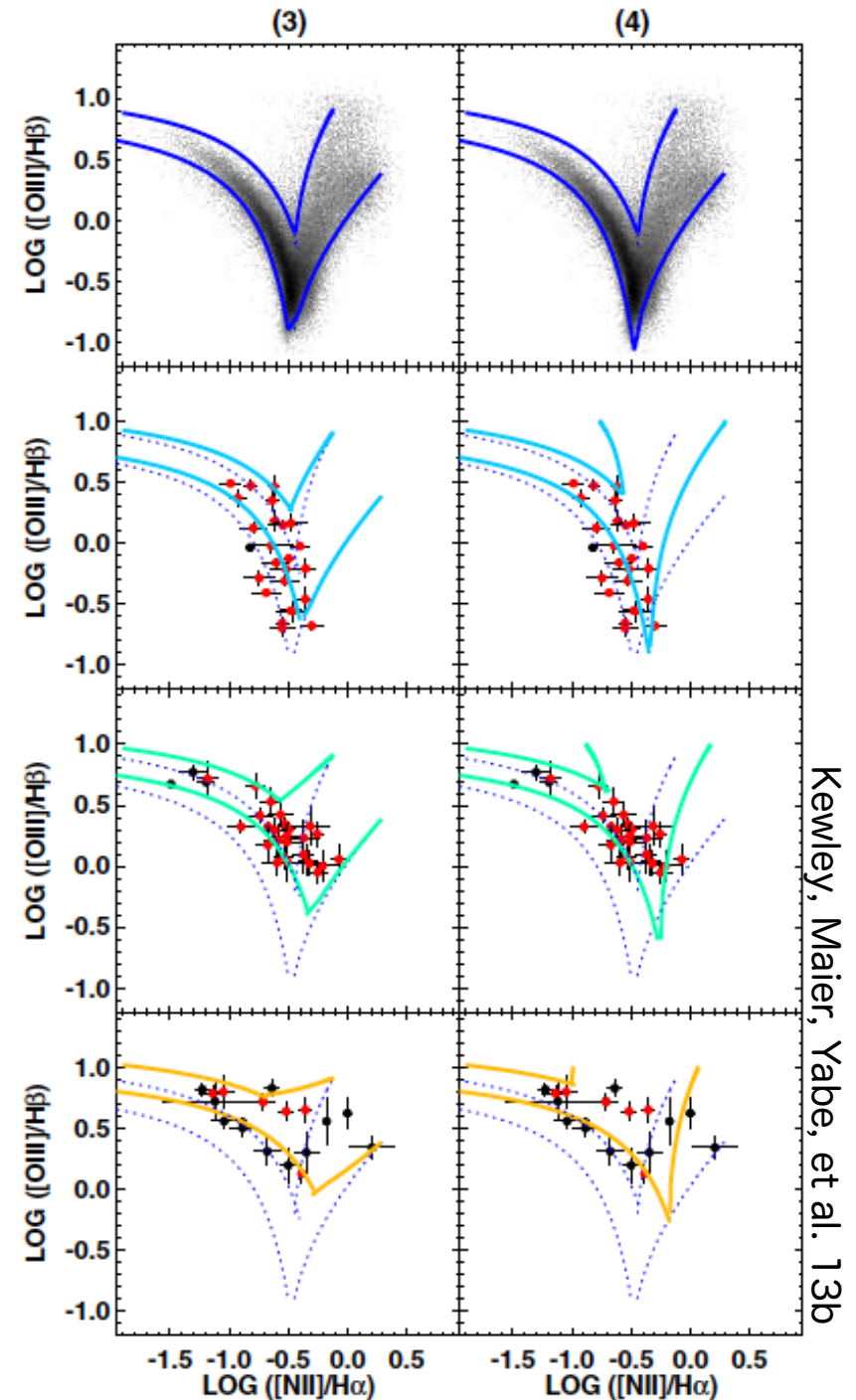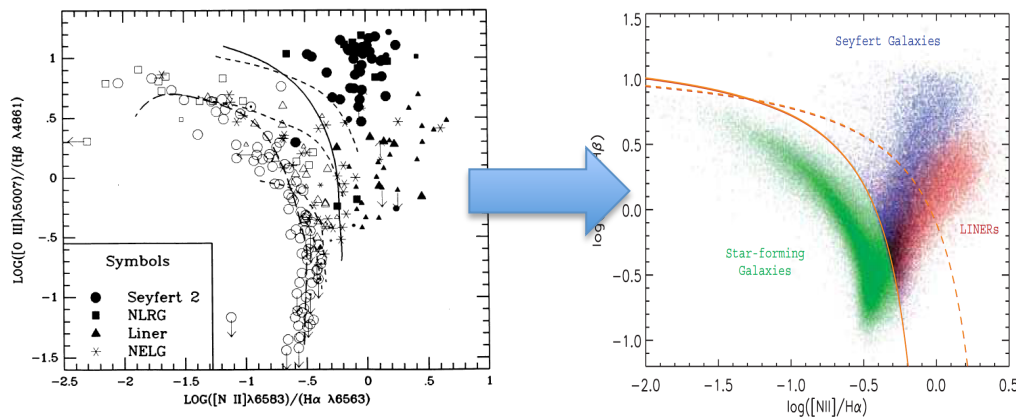# Cosmic BPT

Kewley+13a

Kewley+13a
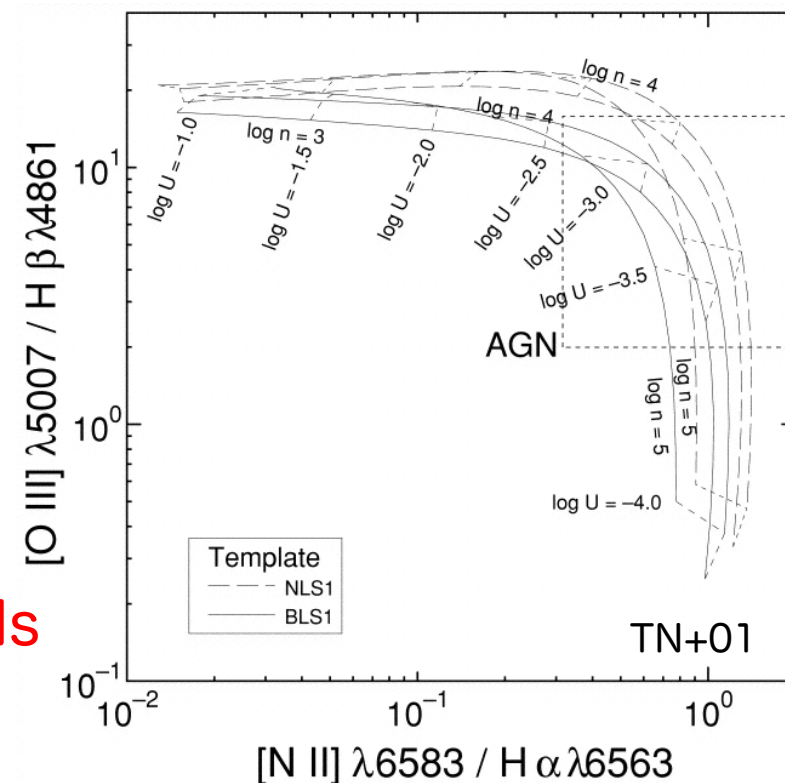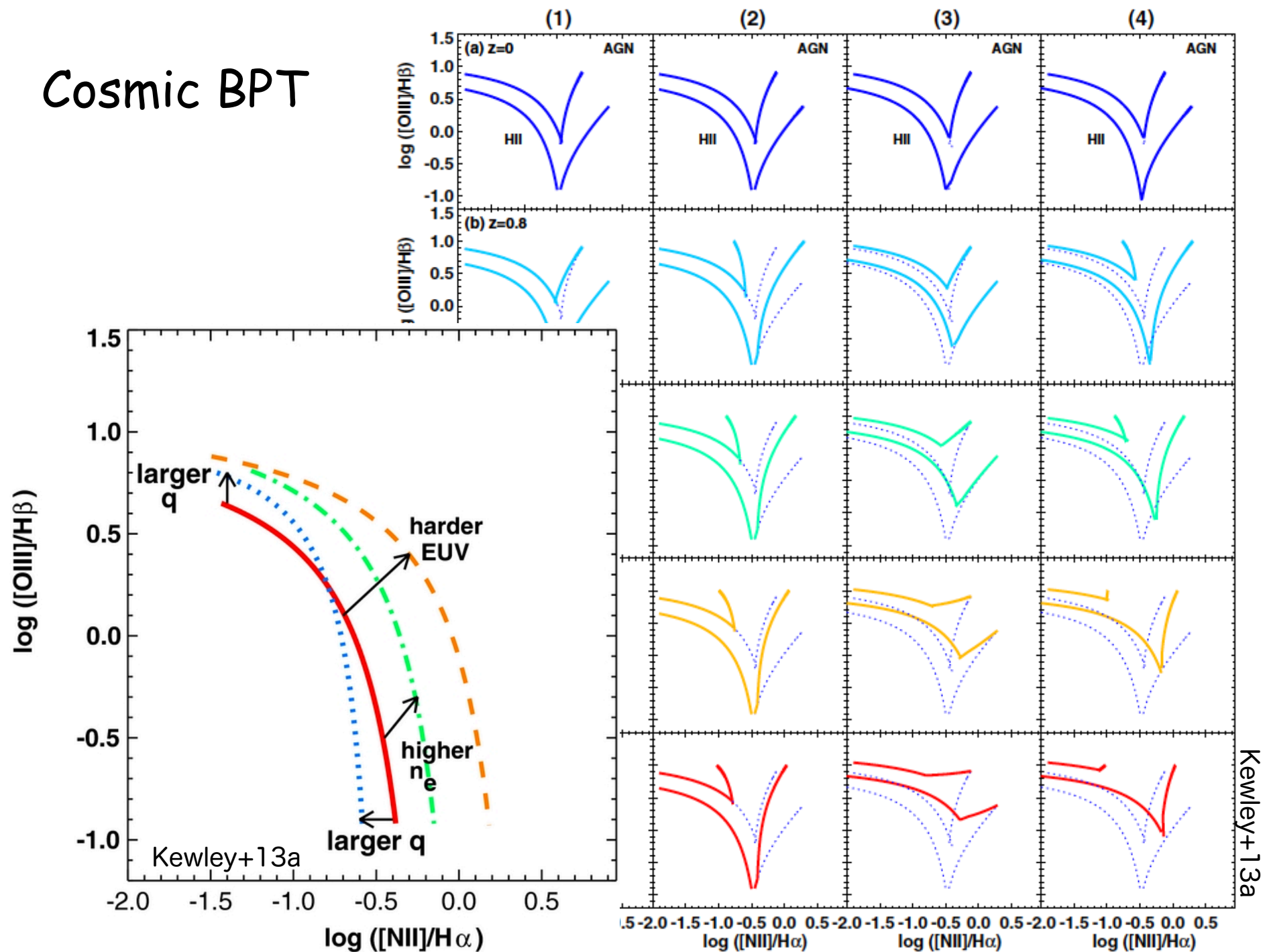
Cosmic BPT: PFS required !!

How the ISM evolved?

Current data are insufficient to discriminate possible scenarios...

The PFS survey can tackle this:
- ~ BPT available up to $z \sim 0.9$
- ~ blue-BPT up to $z \sim 1.5$

- ~ preparative model works needed
- ~ AGN/SB should be discriminated
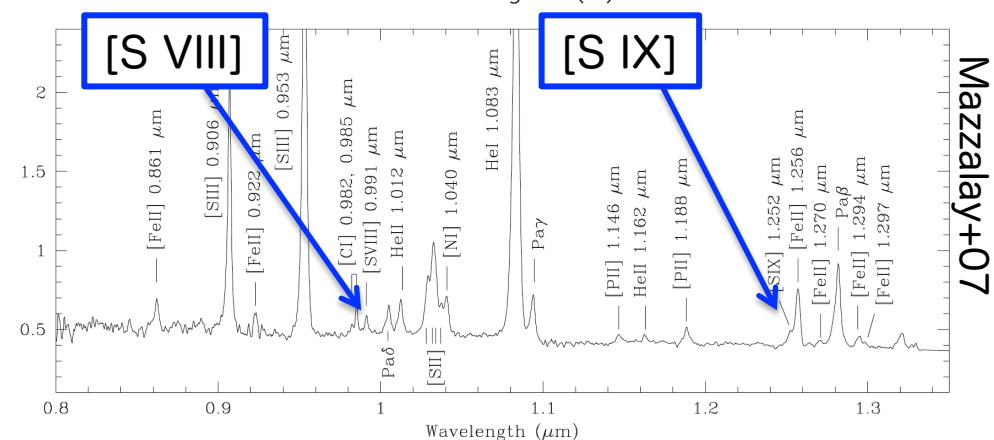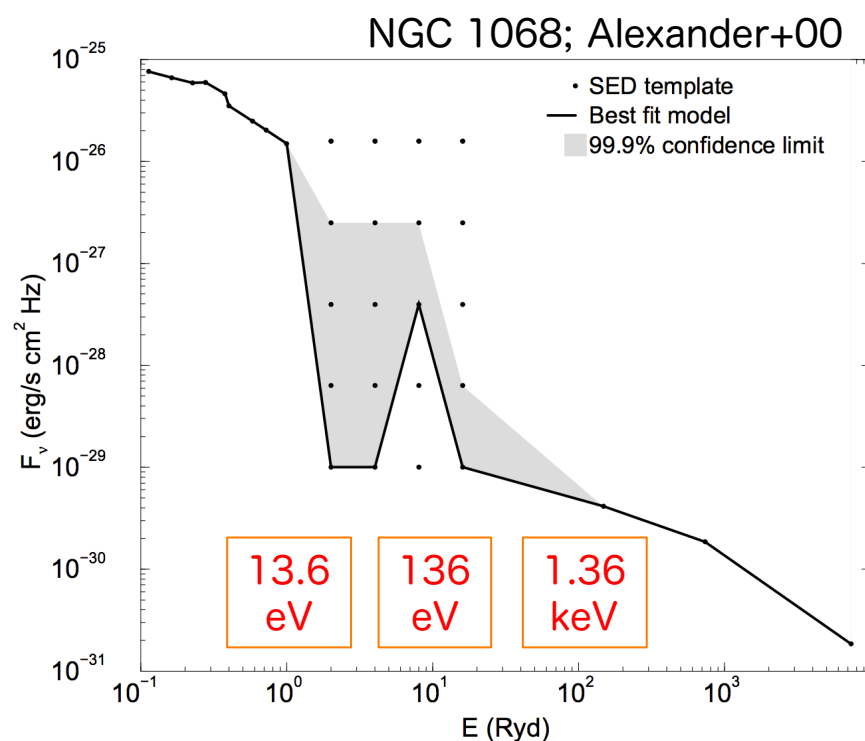- ~ HeII 4686, [NeV] 3426, ...
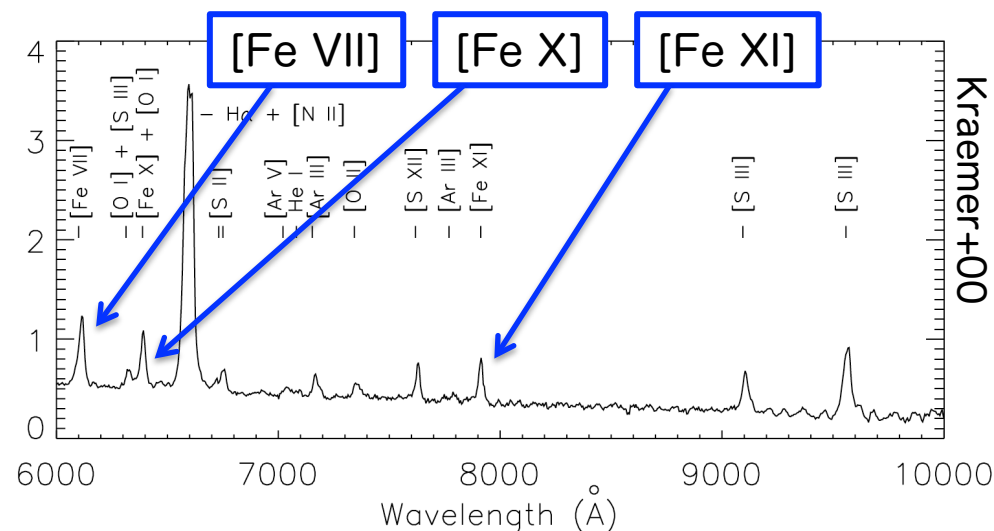

Kewley, Maier, Yabe, et al. 13b

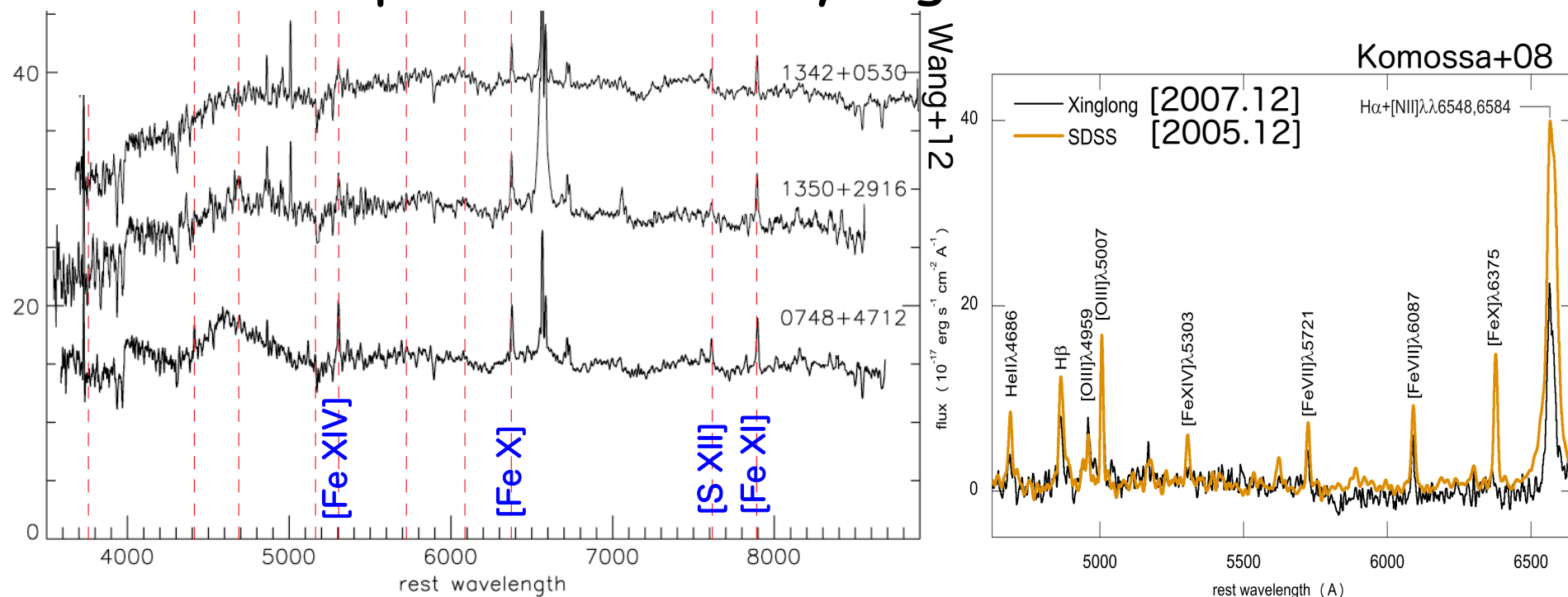# High-ionization lines in AGNs (ionization potential > 100 eV)

[Fe VII] 3760,5159,5721,6087
[Fe X] 6374,   [Fe XI] 7892
[Fe XIII] 1.075, [Fe XIV] 5303
[Ne V] 3346,3426
[Ar XIV] 4414
[S VIII] 9910,   [S IX] 1.252
[S XII] 7611

Kraemer+00

NGC 1068; Alexander+00

Mazzalay+07

Useful to trace the invisible part of the ionizing radiation

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Tidal disruptions traced by high-ionization lines

Wang+12

Komossa+08

-- Strong high-ionization lines are sometimes seen
-- Non-AGNs also show these lines !? (but extremely rare)
-- Non-AGN high-ionization lines show clear time variations
-- Fading to the zero flux in a few years
-- Interpreted by the tidal disruption of a star around SMBH
   (predicted rate: 10^{-4}-10^{-5} galaxy^{-1} yr^{-1}; e.g., Rees 1988)
-- Interesting to study SMBHs in distant non-AGN galaxies → PFS!

Summary

➢ **HSC has come !!**
  - ~ but spectra needed for further studies in many cases

➢ **PFS will bring us numerous spectra of galaxies**
  - ~ type 1 AGNs (quasars) → see following talks
  - ~ narrow-line galaxies: SF galaxies & type 2 AGNs

➢ **galaxy-AGN separation is crucial**
  - ~ BPT diagram available up to z~0.9, "blue BPT" to z~1.5
  - ~ "Tanaka method" will be powerful in PFS surveys

➢ **AGN metallicity**
  - ~ chemically-young AGNs will be surveyed by PFS

➢ **Cosmic BPT evolution**
  - ~ models predict "evolving" BPT from z~0 to z~1-2
  - ~ PFS will reveal the ISM evolution in star-forming galaxies

➢ **PFS will find extremely rare events**
  - ~ stellar tidal disruption around SMBH, even in non-AGNs
  - ~ that will be identified through high-ionization lines