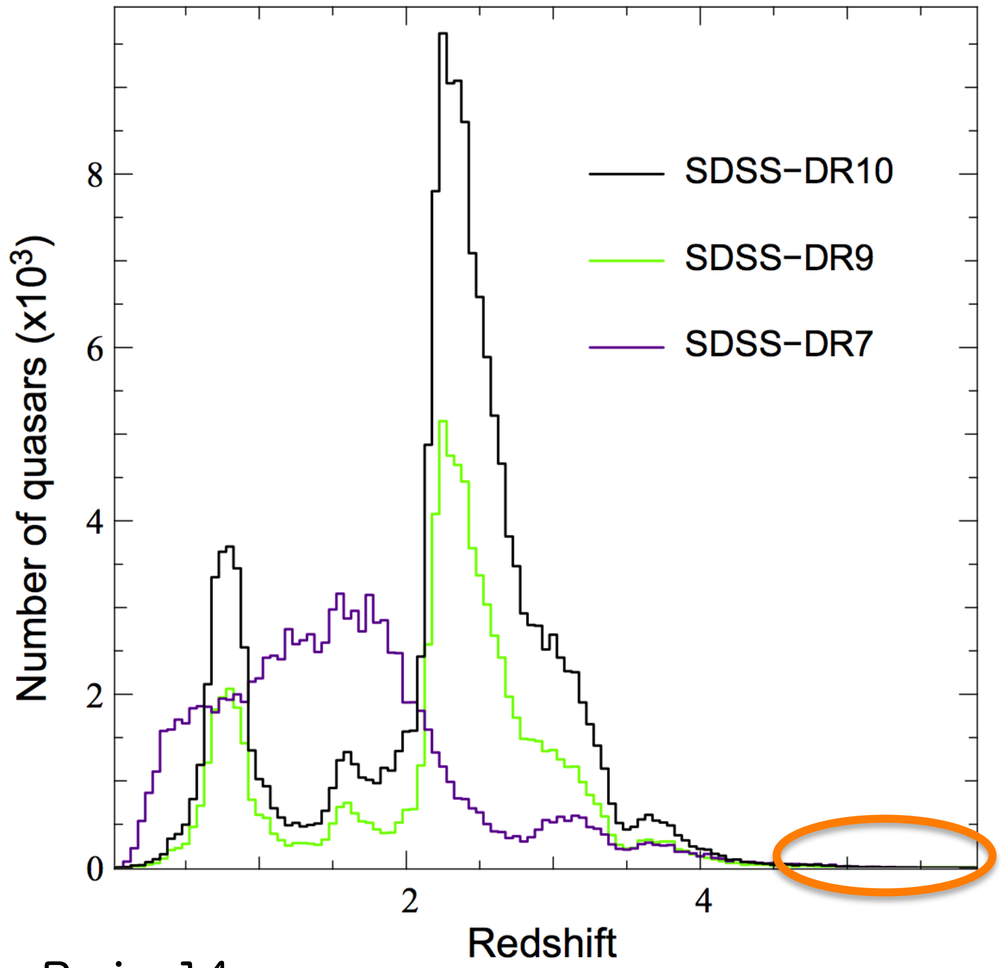
Subaru Wide-Field AGN Survey (SWANS) with Hyper Suprime Cam

Tohru Nagao
Ehime Univ.

愛媛大学
EHIME UNIVERSITY

SMBH-REC workshop vol.2
3-4 November 2014, RCCP, Tsukuba U.

Why new quasar survey?



Paris+14

SDSS and BOSS have already discovered numerous quasars

166,583 quasars in DR10

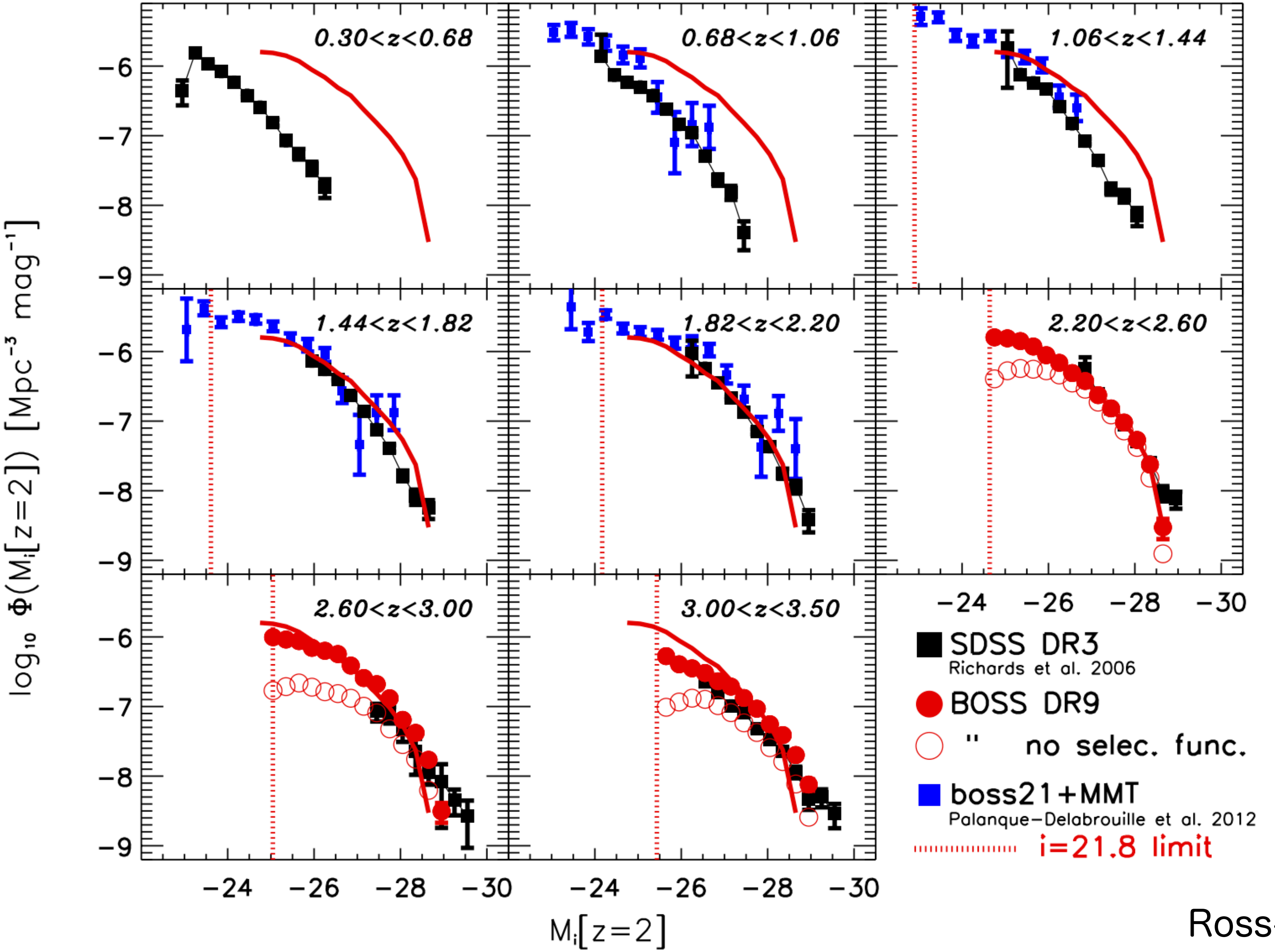
obvious next step is z>6 !!

~ need new surveys
~ see Kashikawa-san's and Matsuoka-san's talks

thousands of quasars at z<5

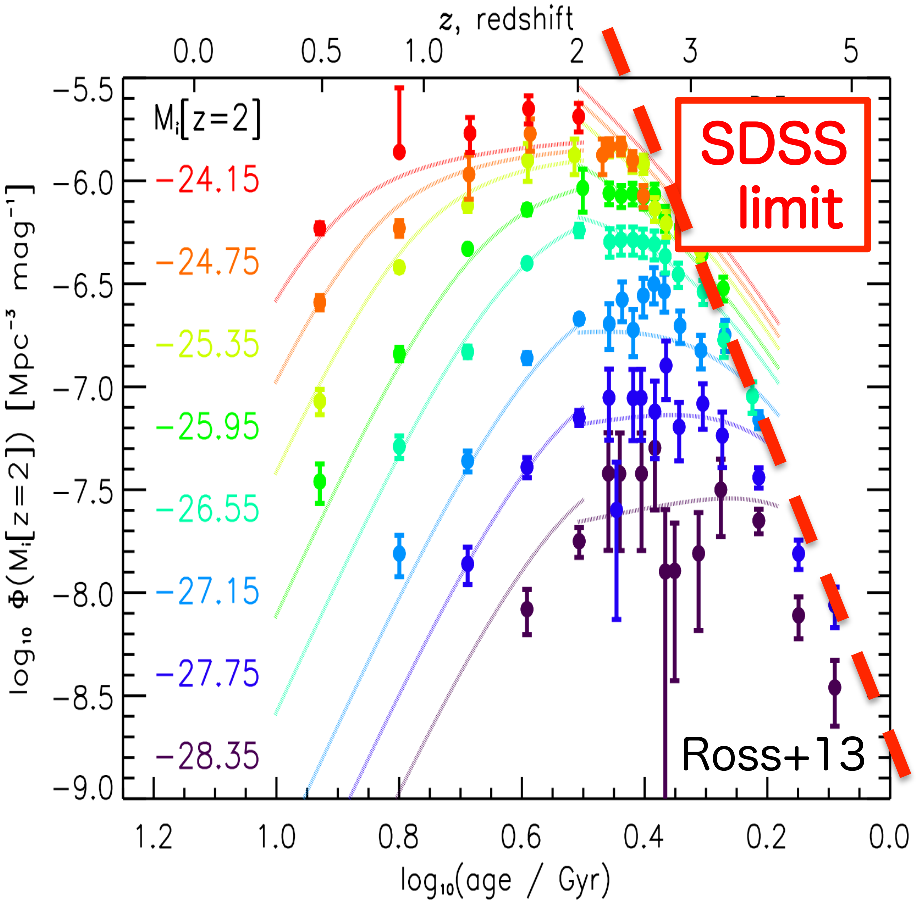
~ are they enough?
~ no more problems?

SDSS quasar luminosity function (QLF)



Ross+13

"Luminosity dependent" evolution of the QLF



Number density evolution of SDSS III quasars. Different colors denote different luminosity ranges.
See also, e.g., Croom et al. (2009); Ikeda, Nagao, et al. (2011, 2012).

More luminous SDSS quasars show the peak of their number density evolution at higher redshifts.

Luminosity-dependent density evolution of quasars, that may be consistent to the picture of the so-called "downsizing" evolution.

Caveat: the number density is not clear at higher z & lower luminosity. Downsizing really holds also at higher z?

Previous quasar surveys: a brief summary

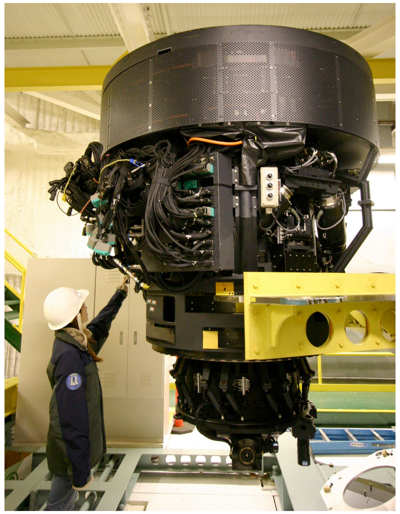
- Evolution of the quasar number density was examined
  - ~ the number density peak of luminous quasars at z~2-3
  - ~ luminosity dependent density evolution (or "down-sizing")
  - ~ number density of low-luminosity quasars at z>3 still unknown

- A few dozen of quasars at z~6 were discovered
  - ~ incomplete reionization was identified at z~6
  - ~ possible spatial variation has not been explored
  - ~ SMBH mass had already reached up to ~10^9 M_{sun} even at z~6
  - ~ low-mass SMBHs not identified; the mass function is unclear

- Only a few quasars were found at z~7 (UKIDSS, VIKING)
  - ~ very massive SMBHs (M_{BH}>10^7 M_{sun})? High metallicity AGNs?
  - ~ but statistically larger sample is definitely needed

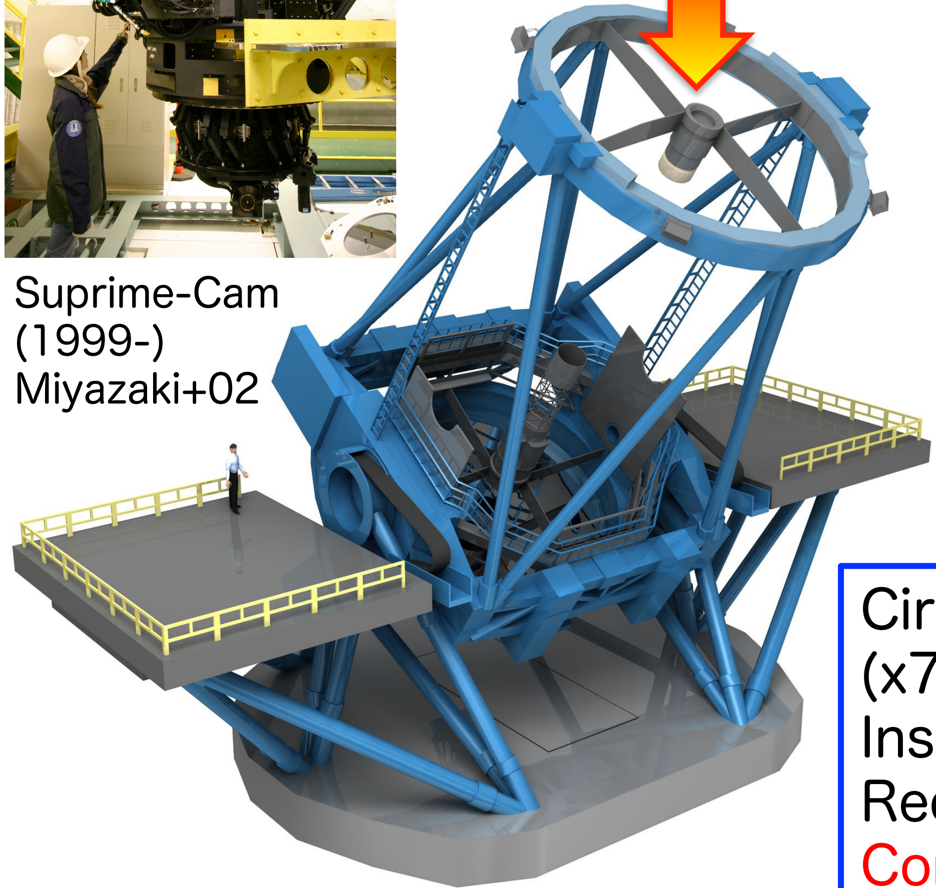
New wide and deep quasar surveys are necessary.

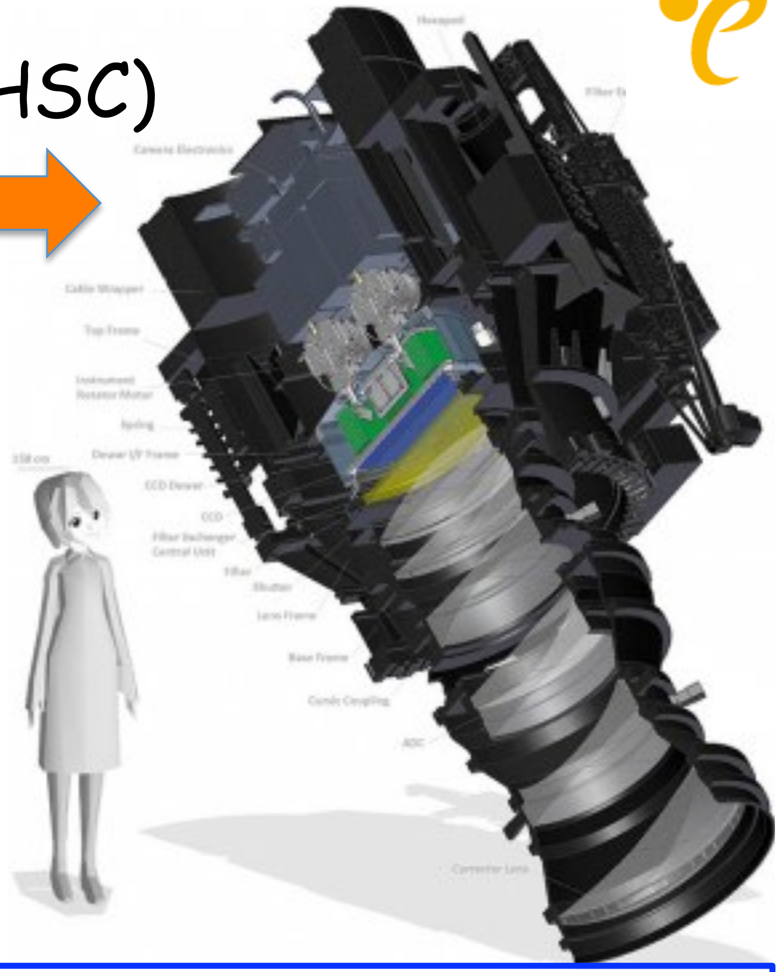
Subaru Hyper Suprime-Cam (HSC)



Suprime-Cam
(1999-)
Miyazaki+02

Prime Focus



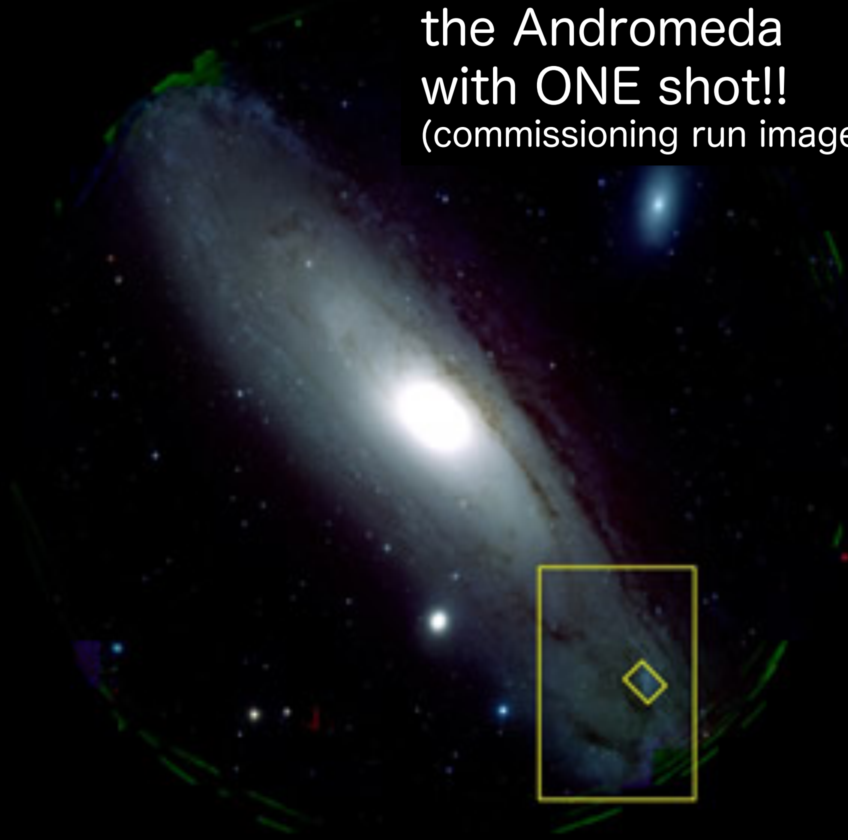


Circular FoV with a 1.5 deg diameter
(x7 wider FoV than Suprime-Cam)
Instrumental PSF: <0.1” (for the whole FoV)
Red-sensitive detectors
Constructed through collaboration among NAOJ, Taiwan, & Princeton U.

HSC: very wide field-of-view

FoV of a Cassegrain camera on Subaru

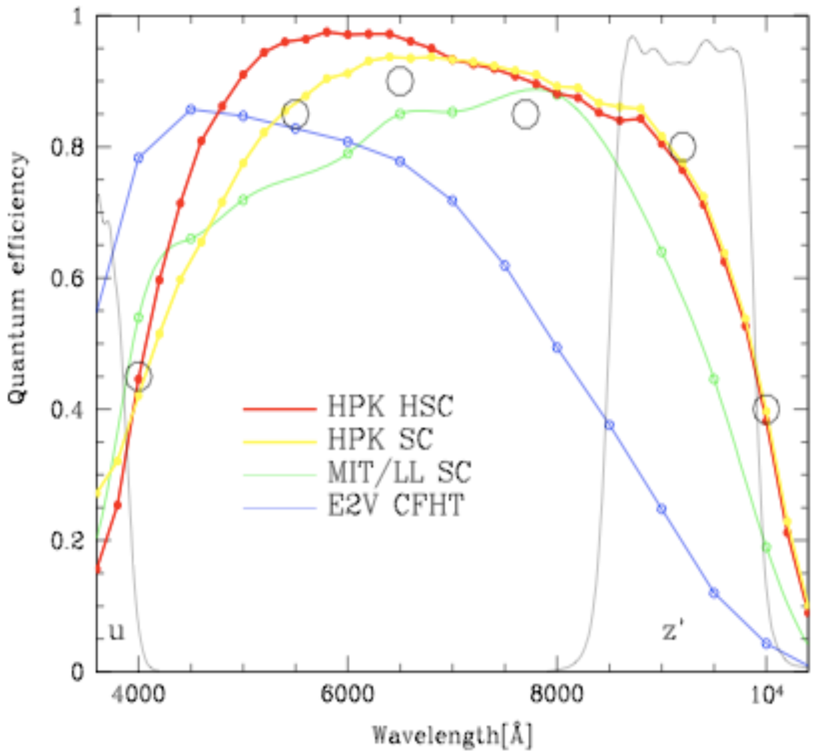
Suprime-Cam
FoV: 27’x34’

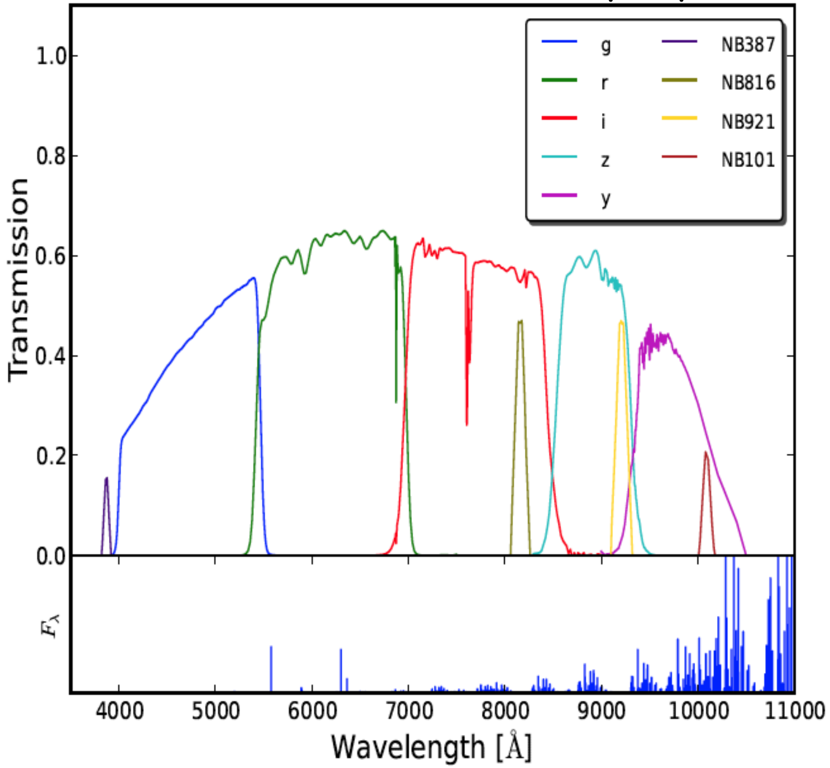


Hyper Suprime-Cam
1.5 degree diameter

HSC: red-sensitive detecters

from the HSC-SSP proposal



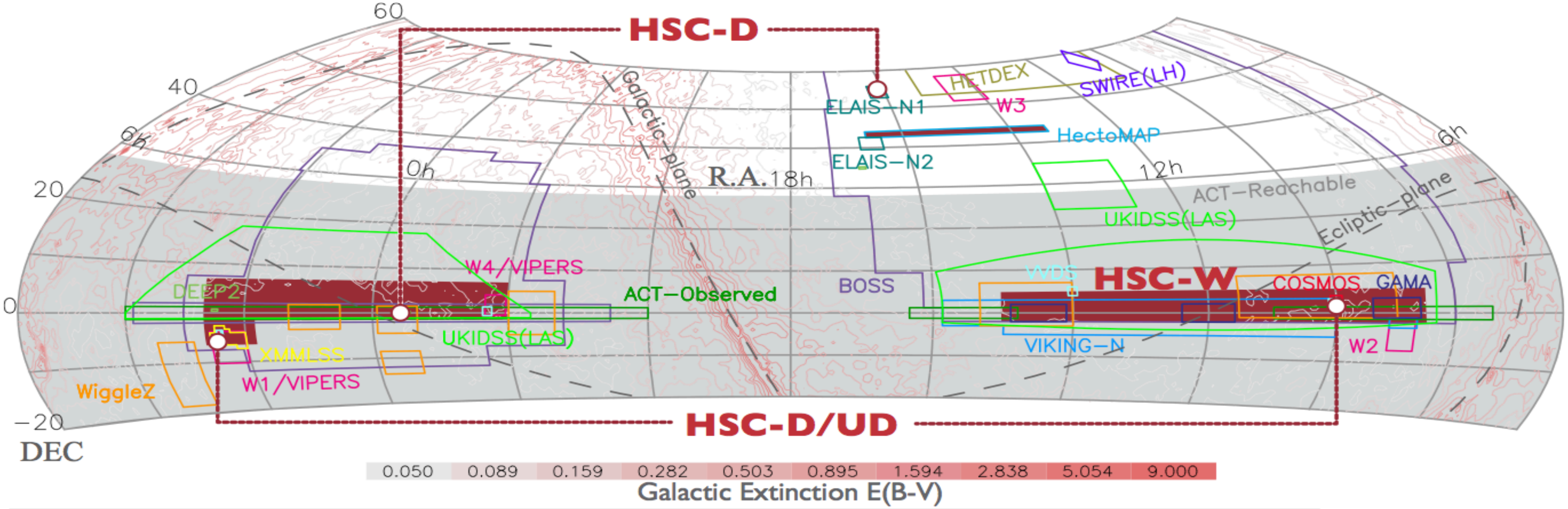


Moderately sensitive even at 1um; x2 more sensitive than old Suprime-Cam detectors.

Thanks to the sensitivity at red, HSC has y-band filter at the longer side of z-band.

from the HSC-SSP proposal

Subaru strategic program (SSP) with HSC

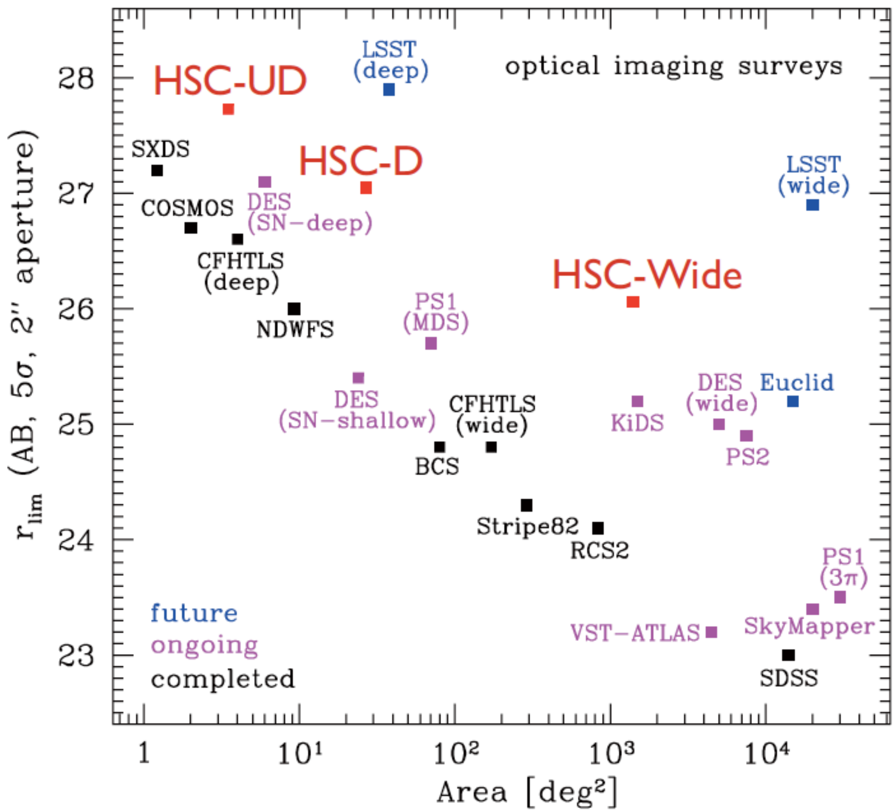


Layer	Filter	Exp.[a] (# of epochs)	Total[b] nights	Lim. mag.[c] (5σ, $2''$)	Moon[d] phase	Requirement(s)[e]	Main scientific driver(s)[f]
Wide	g, r	10 min (3)	53	26.5, 26.1	d	photo	photo-z, $z \lesssim 2$ gals, QSO
Wide	i	20 min (6)	53	25.9	d	FWHM $\lesssim 0.7''$	WL, $z \lesssim 2$ gals, QSO
Wide	z, y	20 min (6)	108	25.1, 24.4	g	photo	photo-z, clusters, $z \sim 1$ gals, $z \sim 6$–7 QSO
Deep	g, r	1.4 hrs (10)	7.3	27.5, 27.1	d	cadence	SNeIa
Deep	i	2.1 hrs (10)	5.4	26.8	d	FWHM $\lesssim 0.7''$, cadence	WL calibration, SNeIa
Deep	z	3.5 hrs (10)	9.1	26.3	g	cadence	$z \lesssim 2$ gals, ionization topology, SNeIa, QSO
Deep	y	2.1 hrs (10)	5.4	25.3	g	cadence	$z \lesssim 2$ gals, SNeIa, QSO
Deep	$N387$	1.4 hrs ($\simeq$10)	3.6	24.5	d	photo	$z \simeq 2.2$ LAEs & LABs
Deep	$N816$	2.8 hrs ($\simeq$ 10)	7.2	25.8	g/d	photo	ionization topology, $z \simeq 5.7$ LAEs & LABs
Deep	$N921$	4.2 hrs ($\simeq$ 10)	11	25.6	g/d	photo	ionization topology, $z \simeq 6.6$ LAEs & LABs
UD	g, r	7 hrs (20)	4.8	28.1, 27.7	d	cadence	$z \gtrsim 2$ gals, SNeIa
UD	i	14 hrs (20)	4.8	27.4	d	cadence	$z \gtrsim 2$ gals, SNeIa, QSO
UD	z, y	18.9 hrs (20)	13	26.8, 26.3	g	cadence	$z \gtrsim 2$ gals, SNeIa, QSO
UD	$N816$	10.5 hrs ($\simeq$ 10)	3.6	26.5	g/d	photo	$x_{\rm HI}(5.7)$, $z \simeq 5.7$ LAEs & LABs
UD	$N921$	14 hrs ($\simeq$ 10)	4.8	26.2	g/d	photo	$x_{\rm HI}(6.6)$, $z \simeq 6.6$ LAEs & LABs
UD	$N101$	17.5 hrs ($\simeq$ 10)	6.1	24.8	g/d	photo	$x_{\rm HI}(7.3)$, $z \simeq 7.3$ LAEs

300 nights in total
2014.02 – 2019.01
(already approved)

HSC-SSP proposal, at a glance

from SSP proposal



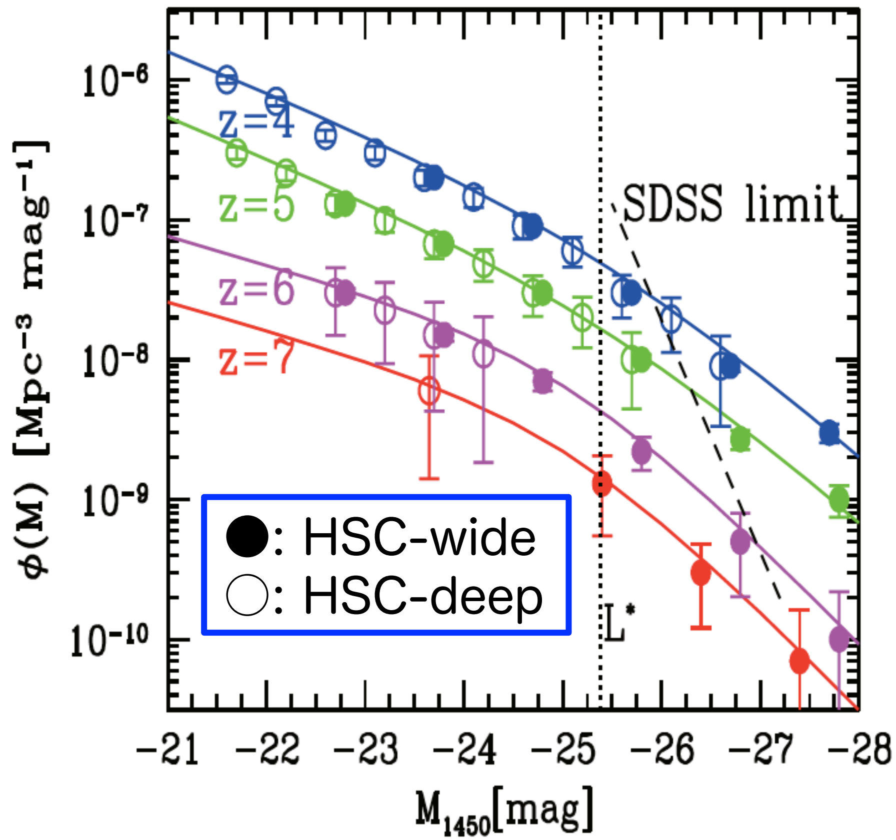


Table 7: Quasar Samples

	Wide (1400 deg^2)				Deep (27 deg^2)			
redshift	3.7–4.6	4.6–5.7	5.9–6.4	6.6–7.2	< 1	3.7–4.6	4.6–5.7	6.6–7.2
mag. range	$r < 23.0$	$i < 24.0$	$z < 24.0$	$y < 23.4$	$i < 25.0$	$i < 25.0$	$i < 25.0$	$y < 25.3$
number	6000	3500	280	50	2000	200	50	3

※ based on 5-yr data

S14B HSC run: Further observations

Schedule for November 2014

Sun	Mon	Tue	Wed	Thu	Fri	Sat
						Nov 01
						S14B-097 Kuzuhara IRCS+AO188
Nov 02	Nov 03	Nov 04	Nov 05	Nov 06 ○	Nov 07	Nov 08
Obs COMICS Eng IRCS+AO188	UH-30B Lu IRCS+AO188		Keck Melis COMICS	Obs MOIRCS Service MOIRCS	Obs MOIRCS TBD	Eng SCExAO
Nov 09	Nov 10	Nov 11	Nov 12	Nov 13	Nov 14 ◑	Nov 15
Eng SCExAO	UH-19A Hagelberg SCExAO+AO188		Obs SCExAO+AO188	Eng HSC	StrObs HSC	S14B-060I Chiba HSC
Nov 16	Nov 17	Nov 18	Nov 19	Nov 20	Nov 21 ●	Nov 22
S14B-060I Chiba HSC	StrObs HSC	S14B-060I Chiba HSC		StrObs HSC	S14B-060I Chiba HSC	StrObs HSC
Nov 23	Nov 24	Nov 25	Nov 26	Nov 27	Nov 28 ◐	Nov 29
S14B-098 Takada HSC	StrObs HSC	S14B-048 Tominaga HSC		StrObs HSC	Eng HSC	
Nov 30						
Eng HSC						

Schedule for January 2015

Sun	Mon	Tue	Wed	Thu	Fri	Sat
				Jan 01	Jan 02	Jan 03
				TBD S14B-003 Matsuoka FOCAS	Eng SCExAO	UH-19A Hagelberg SCExAO+AO188 UH-26C Liu SCExAO+AO188
Jan 04 ○	Jan 05	Jan 06	Jan 07	Jan 08	Jan 09	Jan 10
UH-19A Hagelberg SCExAO+AO188 UH-26C Liu SCExAO+AO188	S14B-013 Tadaki MOIRCS	StrObs HiCIAO+AO188			Gemini de Mooij HDS	S14B-097 Kuzuhara HiCIAO+AO188
Jan 11	Jan 12 ◑	Jan 13	Jan 14	Jan 15	Jan 16	Jan 17
S14B-097 Kuzuhara HiCIAO+AO188	S14B-001 Maier FMOS			StrObs HSC	UH33A Hu HSC	
Jan 18	Jan 19 ●	Jan 20	Jan 21	Jan 22	Jan 23	Jan 24
UH33A Hu HSC		StrObs HSC	S14B-101 Okamoto HSC		S14B-123 Suenaga HSC	
Jan 25	Jan 26 ◐	Jan 27	Jan 28	Jan 29	Jan 30	Jan 31
S14B-034 Yoshida HSC	StrObs HSC	S14B-096 Nozawa COMICS	TBD S14B-142 Maeda IRCS+AO188	S14B-078 Schramm IRCS+AO188	S14B-055 Kasaba IRCS+AO188	S14B-007 Imanishi IRCS+AO188

HSC-AGN "registered" sciences

01) Checking the quality of the photometry for quasar target selection; Strauss+
02) The HSC colors of known quasars; Strauss+
03) Quasar selection by cross-matching with wide-field X-ray data; Terashima+
04) Search for peculiar AGN populations by combining HSC and X-ray; Terashima+
05) Search for extreme red quasars using HSC and mid-infrared data; Aoki+
06) A search for optical counterparts of AKARI/WISE all sky survey sources; Goto+
07) Search for growing-up BHs in the dust obscured galaxies at z~2; Toba+
→ see Toba-san's talk
08) WISE host galaxies; Greene+
09) Evolution of radio galaxies in SDSS stripe 82; Lin+
10) Cross-matching the HSC-wide optical and FIRST radio data; Nagao+
→ see the later slides
11) Properties of variability-selected AGNs; Morokuma+
12) Long-term variability of SDSS quasars; Kokubo+
13) Variability in nuclear activity of SDSS active and inactive galaxies; Kawaguchi+
14) Photometric redshifts for AGNs/QSOs; Tanaka+
15) Search for lensed QSOs in the HSC survey: based on color & morphology; Coupon+

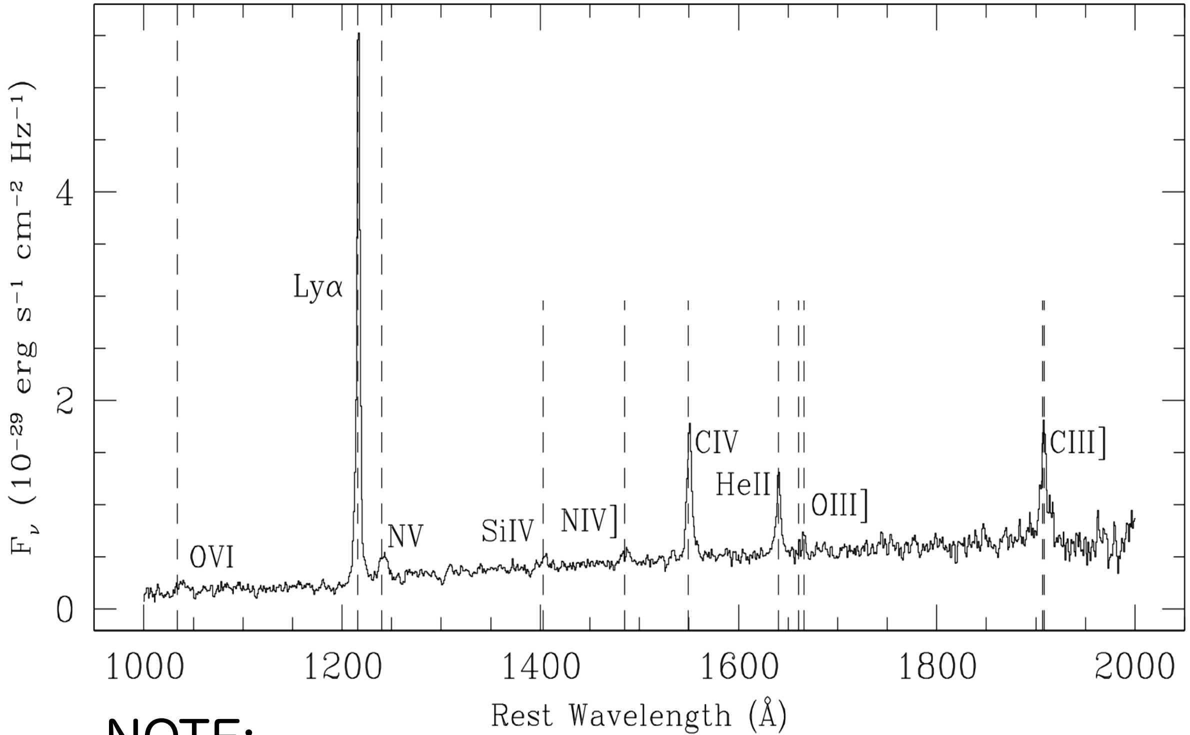
HSC-AGN "registered" sciences (contd.)

16) Search for lensed QSOs in the HSC survey: candidate classification; Suyu+
17) Locating QSOs among luminous *g*-dropout LBGs at $z \sim 4$; Akiyama+
18) The environment of quasars at intermediate redshifts; Strauss+
19) Search for quasars at $z>6$; Y.Matsuoka+
    → see Matsuoka-san's talk
20) Reionization probed by high-z quasars; Kashikawa+
    → see Kashikawa-san's talk
21) Supermassive blackhole masses and Eddington ratios of $z=6\text{-}7$ QSOs; Imanishi+
22) Environment of QSOs at $z>6$; Foucaud+
23) Chemical evolution of quasars at $z>6$; Asami+
24) Exploring the nature of Galactic brown dwarfs; Y.Matsuoka+
25) Quasar luminosity function at fainter side at $z \sim 4\text{-}5$; Ikeda+
26) Search for dual-NB emitters at high redshifts; Nagao+
    → see the later slides
27) Investigating HSC-detected galaxies around SDSS QSOs with DLAs; Ogura+
28) Metallicity of low-luminosity AGNs at $3<z<5$; K.Matsuoka+
29) Systematic Survey of Cold Dust Disk in AGN Galaxies; Okabe+
30) Investigation of rest FIR-Submm properties of $z=6\text{-}7$ QSO-host galaxies; Izumi+
    → see Tamura-san's talk

HSC-AGN “registered” sciences: example 1

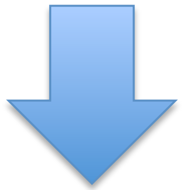
~ Color selection is not good for type 2 AGNs...
~ But they are needed to know the “total” AGN number density
~ Can we search also for type 2 AGNs with HSC data?

Hainline+12; stacked spectra of 33 z~2-3 type 2 AGNs



Strong narrow lines in rest-UV spectra!!

EW_{rest}(CIV) ~ 16A
EW_{rest}(CIII]) ~ 14A



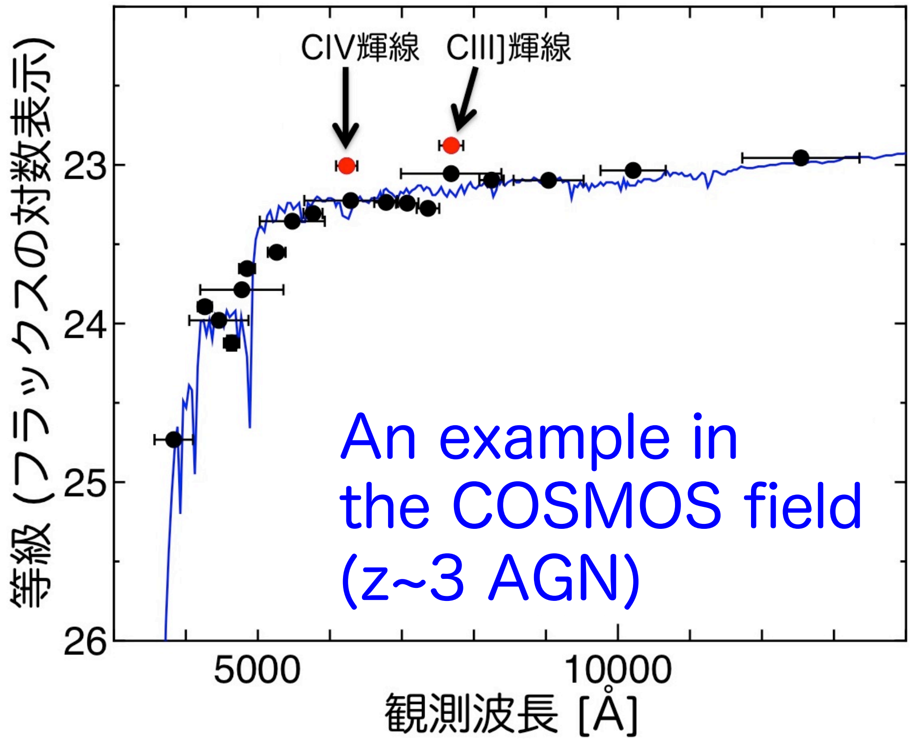
at z~4

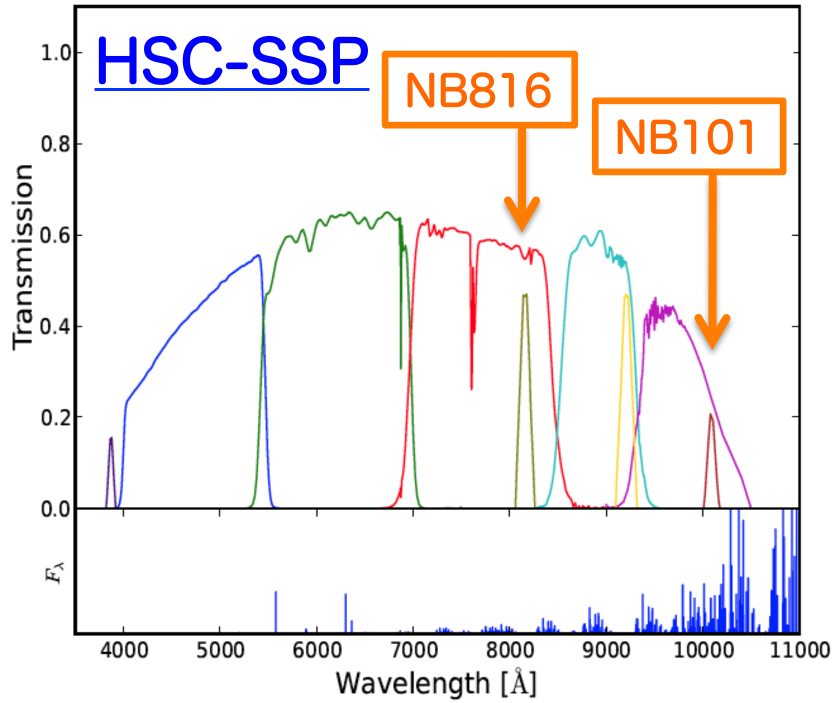
EW_{obs}(CIV) ~ 80A
EW_{obs}(HeII) ~ 70A

NOTE:

CIV is seen only in AGNs (no star-forming galaxies show CIV)
→ CIV is a definite sign for type 2 AGNs
(type 1 AGNs also show CIV but with much smaller EWs)

HSC-AGN "registered" sciences: example 1 (contd.)





CIV in NB816 @ z=4.23-4.31
CIII] in NB101 @ z=4.26-4.31

search for "dual" emitters (= type 2 AGNs) !!

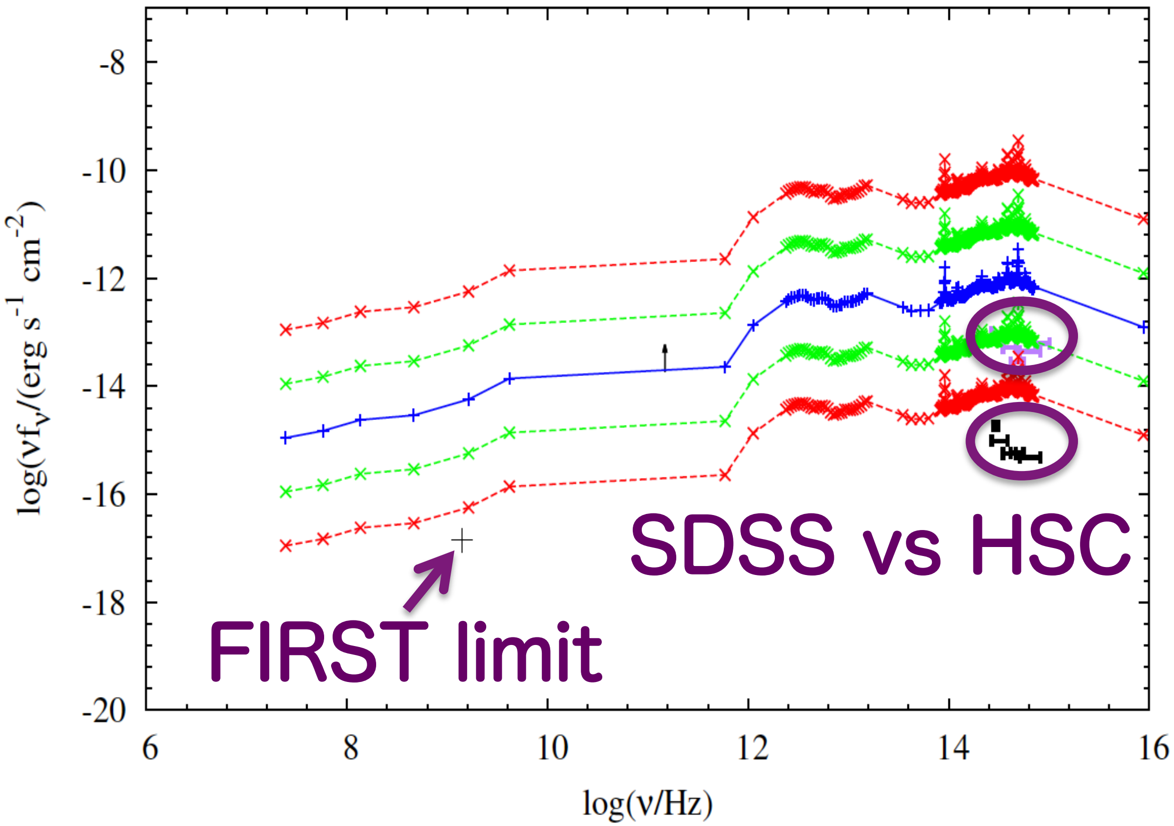
NOTE:

EW_{obs}=80A in NB816 → ⊿m~0.6 mag
EW_{obs}=70A in NB101 → ⊿m~0.6 mag
...easily detectable with the HSC-SSP data!

HSC-AGN "registered" sciences: example 2

Optical counterparts of FIRST wide-sky survey sources

~ FIRST catalog contains 10^7 radio sources
~ 40% of FIRST sources have no SDSS optical counterparts...
~ many missing radio-loud populations? HSC can address this!



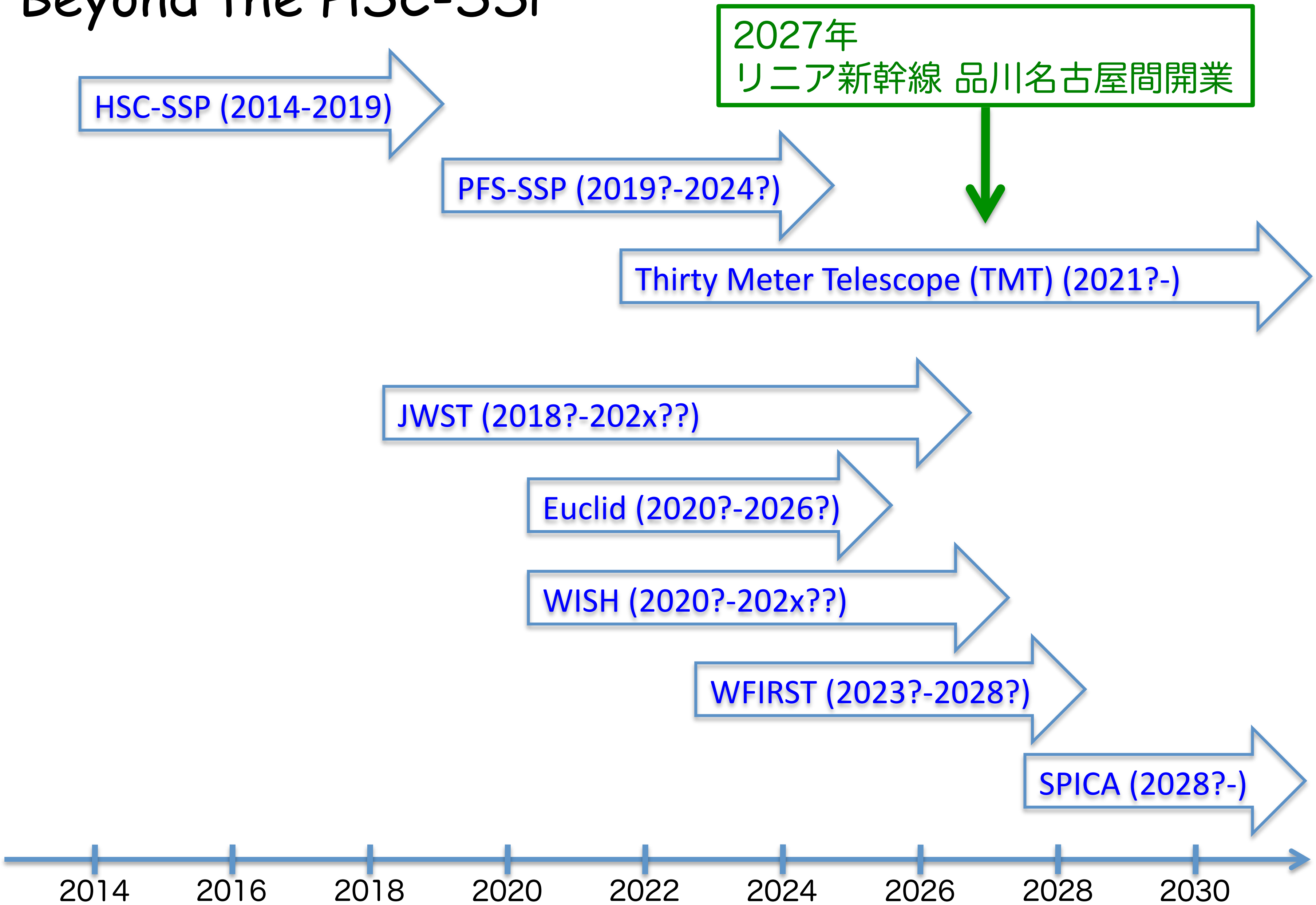
z=4 radio-loud quasar spectrum with various luminosity

High-z low-L radio-loud quasars are detected in the FIRST data but not in the SDSS data

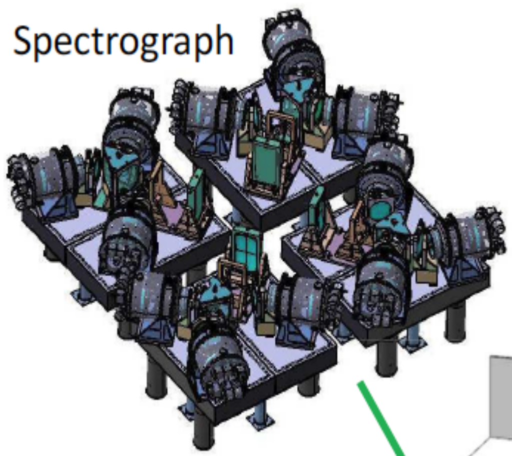
HSC is deep enough to detect them!

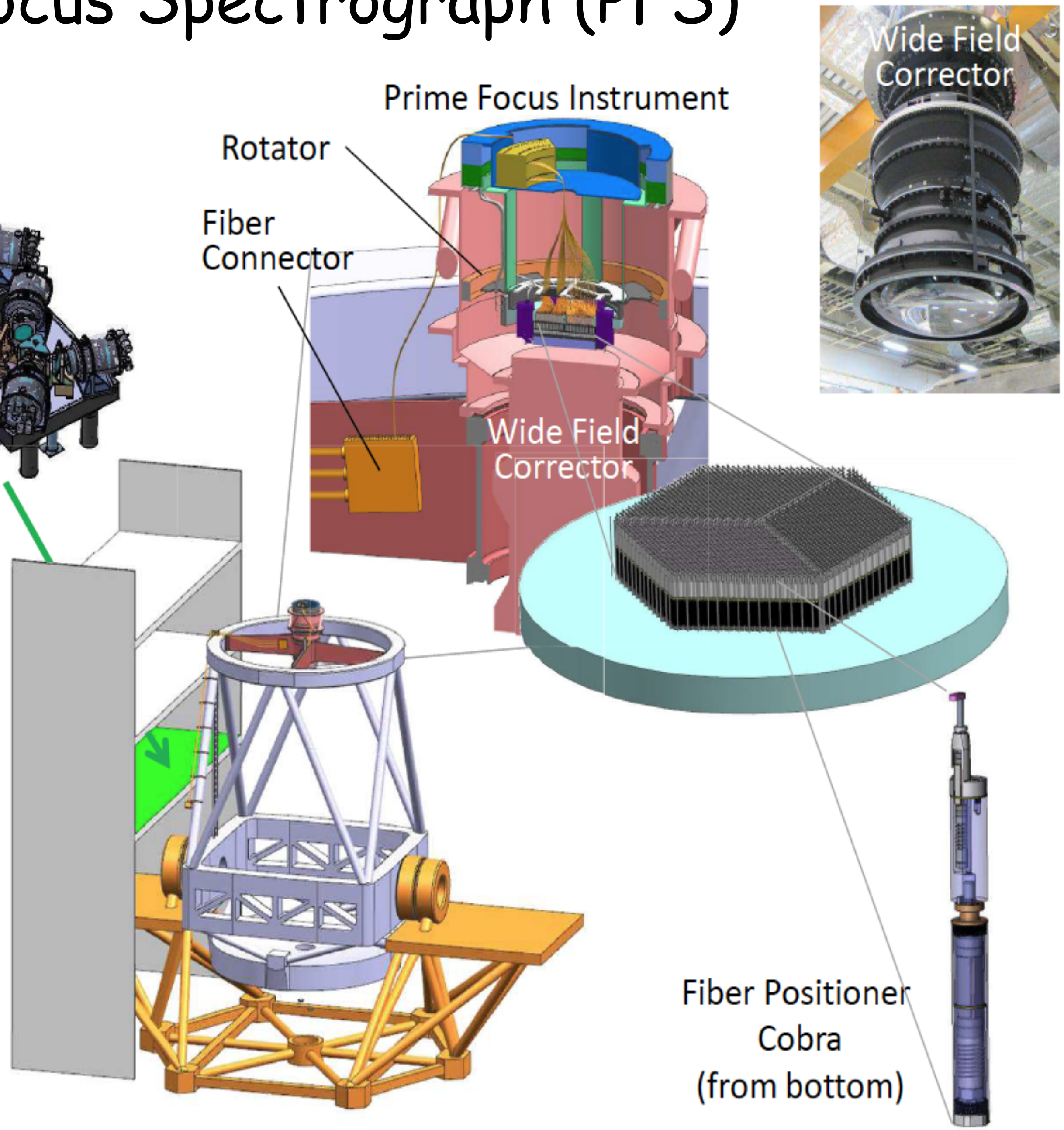
from the HSC white paper

Beyond the HSC-SSP



Subaru Prime Focus Spectrograph (PFS)





PFS Partners:

- ~ NAOJ/U.Tokyo
- ~ Princeton U.
- ~ ASIAA (Taiwan)
- ~ Caltech/JPL
- ~ Johns Hopkins U.
- ~ Marseille
- ~ Brazil
- ~ Max Planck

Takada, Ellis, et al. (2014)

PFS parameters

Takada+14

Number of fibers	2400 (600 for each spectrograph)		
Field of view	1.3 deg (hexagonal – diameter of circumscribed circle)		
Field of view area	1.098 $\deg^2$		
Fiber diameter	$1.13''$ diameter at the field center; $1.03''$ at the edge		
	Blue arm	Red arm	IR arm
Wavelength coverage [nm]	380–670	650–1000	970–1260
Spectral resolution $\lambda/\Delta\lambda$	1900	2400	3500
Pixel scale [Å/pix]	0.71	0.85	0.81
Read-out noise [e^- rms/pix]	3	3	4[a]
Detector type/read-out mode	CCD	CCD	HgCdTe/SUTR
Thermal background [e^-/pix/sec]	None	None	0.013
Dark current [e^-/pix/sec]	3.89×10^{-4}	3.89×10^{-4}	0.01
Spectrograph image quality [μm rms/axis]	14	14[b]	14

IR arm, not only blue & red arms

→ no "redshift desert" ([OII] for z<2.3, Lyα for z>2.2)

Multi-layer survey (not yet fixed)

~ cosmology component (15 min x 2 visits for >1000 $\deg^2$)

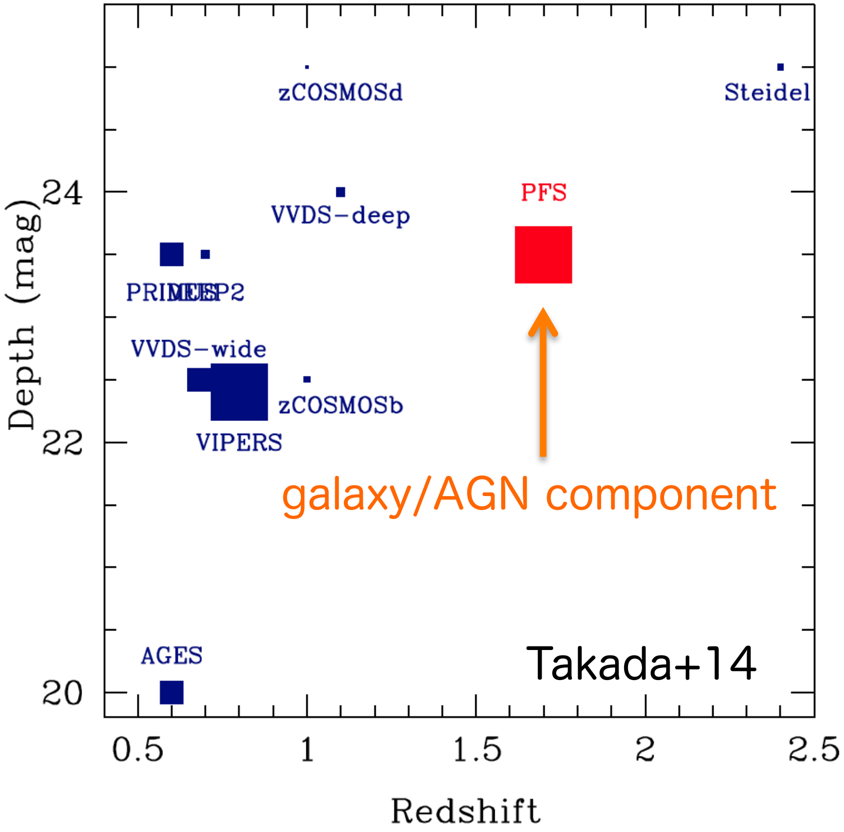
~ galaxy/AGN component (longer exposure for 10-30 $\deg^2$)

~ Galactic archaeology component (for specific fields)

First light hopefully in 2018, legacy survey will start in 2019 (?)

~ depending also on the funding situation

Subaru/PFS survey plan (still under discussion)



Comparison with other large spectroscopic surveys. The symbol size corresponds to the area of the target fields.

Principal Investigator (PI)

Hitoshi Murayama	Kavli Institute of the Physics and Mathematics for the Universe (Kavli IPMU, WPI), Japan; Physics Department, University of California, Berkeley; Lawrence Berkeley National Laboratory, Berkley, USA

Co-Chairs of the PFS Survey Committee

Richard Ellis	Caltech, USA
Masahiro Takada	Kavli IPMU, Japan

Co-Chairs of the PFS Science Working Groups

PFS Cosmology WG

Masahiro Takada	Kavli IPMU, Japan
Christopher Hirata	Caltech, USA
Jean-Paul Kneib	LAM, France

PFS Galactic Archaeology WG

Masashi Chiba	Tohoku University, Japan
Judith Cohen	Caltech, USA
Rosemary Wyse	JHU, USA

PFS Galaxy WG

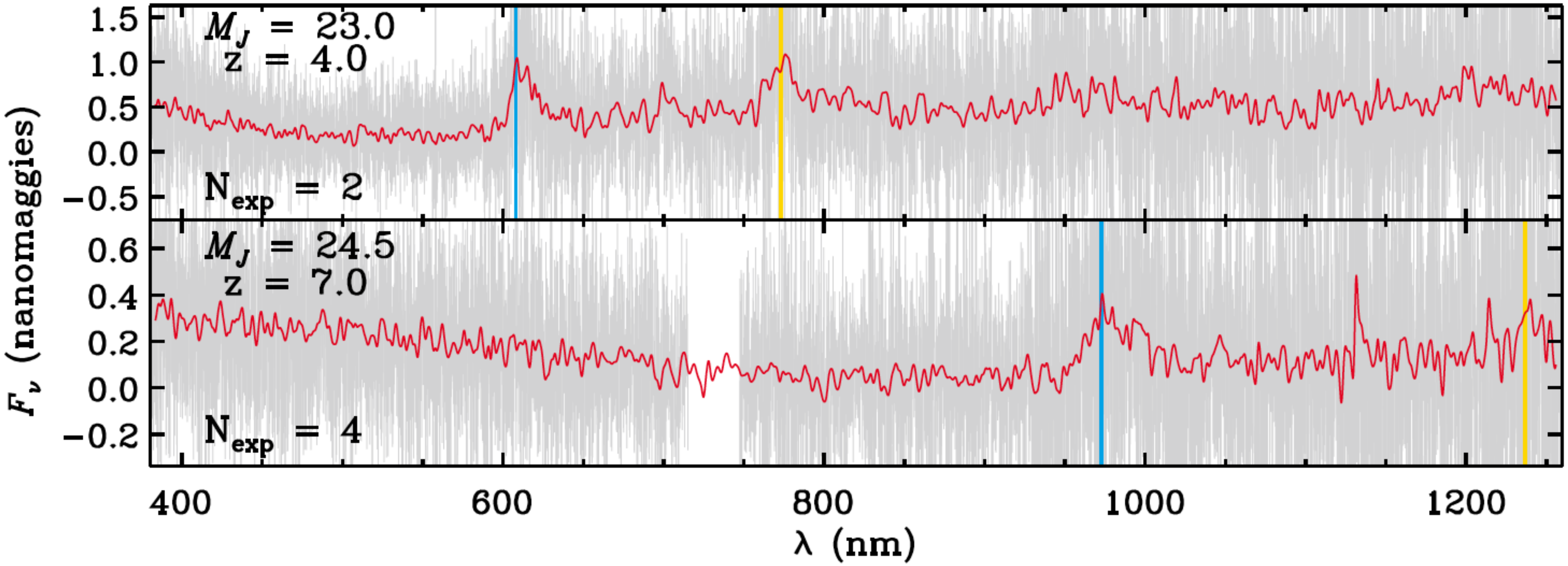
Jenny Greene	Princeton University, USA
Kevin Bundy	Kavli IPMU, Japan
John Silverman	Kavli IPMU, Japan
Masami Ouchi	The University of Tokyo, Japan

PFS AGN/QSO WG

Tohru Nagao	Kyoto University, Japan
Michael Strauss	Princeton University, USA

Simulated PFS spectra of quasars

Takada+14



Top: 15 min x 2 exposures for a z=4.0 quasar with J_{AB}=23.0
Bottom: 15 min x 4 exposures for a z=7.0 quasar with J_{AB}=24.5
Gray: simulated PFS spectra, before the binning (R~2000-3500)
Red: after the binning (effective resolution of R~300)

Summary

- Quasar surveys in the last decade were successful
  - ~ but high-z low-luminosity part was still unexplored
  - ~ no statistical sample for z~7
- Subaru/HSC has come!
  - ~ legacy survey (SSP) has already started in March 2014
  - ~ 300 nights in the coming 5 years
  - ~ searching for z~7 quasars and low-luminosity ones at z~3-6
  - ~ combination with MIR & radio all-sky data also interesting
  - ~ the obtained data are really amazing
  - ~ see the later talks by Kashikawa-san, Matsuoka-san, Toba-san
- Subaru/PFS in preparation
  - ~ for follow-up spectroscopy of the HSC-SSP survey
  - ~ with 2400 filters covering 380nm – 1260 nm (from U to J !!)
  - ~ hopefully coming soon, in a couple of years (~2019-?)

Acknowledgements to the HSC-AGN members

M.Akiyama (Tohoku), K.Aoki (Subaru), N.Asami (Japan Prof. Sch. of Edu.), J.Coupon (Geneva/ASIAA), M.Enoki (TKU), S.Foucaud (NTNU/ASIAA), T.Goto (NTHU), J.Greene (Princeton), T.Hashimoto (NAOJ), Y.Hashimoto (NTNU), H.Ikeda (ASIAA/Ehime), M.Imanishi (Subaru), K.Imase (GUAS/NAOJ), N.Inada (Nara Collage of Tech.), T.Ishiyama (Tsukuba), Y.Ishizaki (GUAS/NAOJ), K.Iwasawa (Barcelona), N.Kashikawa (NAOJ), T.Kawaguchi (NAOJ), N.Kawakatsu (Kure Collage of Tech.), I.Kayo (Toho), M.A.R.Kobayashi (Ehime), M.Kokubo (Tokyo), S.Kouzuma (Chukyo), Y.Lin (ASIAA), K.Matsuoka (Kyoto), Y.Matsuoka (Princeton/NAOJ), T.Misawa (Shinshu), T.Morokuma (Tokyo), T.Murayama (Tohoku), T.Nagao (Ehime), T.Nakagawa (ISAS), M.Nagashima (Bunkyo), M.Niida (Ehime), M.Nomura (NAOJ), K.Ogura (Ehime), M.Oguri (Tokyo), K.Ohsuga (NAOJ), Y.Ohyama (ASIAA), N.Oi (ISAS), M.Onoue (GUAS/NAOJ), T.Oogi (Bunkyo), S.Oyabu (Nagoya), T.Saitoh (ELSI), H.Sameshima (ISAS), Y.Shirasaki (NAOJ), J.Silverman (IPMU), M.Strauss (Princeton), A.Sun (Princeton), S.Suyu (ASIAA), M.Tanaka (NAOJ), Y.Taniguchi (Ehime), Y.Terashima (Ehime), Y.Toba (Ehime), Y.Ueda (Kyoto), M.Umemura (Tsukuba), Y.Urata (NCU), K.Wada (Kagoshima), A.Wagner (Tsukuba), A.Yonehara (Kyoto Sangyo)

Green: Taiwan-based astronomers
Blue: Princeton-based astronomers
Orange: Theoretical astronomers