ULTIMATE-SUBARU: Science Cases

Ikuru Iwata (Subaru Telescope, NAOJ)

Subaru next-gen AO working group + Collaborators

- *Subaru / NAOJ:* Yutaka Hayano, Shin Oya, Yosuke Minowa, Tadayuki Kodama, Nobuo Arimoto, Takashi Hattori, Olivier Lai, Hideki Takami, Naruhisa Takato, Ichi Tanaka
- *Japanese Univ.:* Masayuki Akiyama, Yoshito Ono (Tohoku Univ.), Kentaro Motohara (Univ. of Tokyo)
- *NRC Canada:* Alan McConnachie, Luc Simard, David Anderson, John Pazder, David Crampton, et al.
- *Australian Astronomical Observatory / University of Sydney:* Andrew Sheinis, Chris Lidman, John Lawrence, Andrew Hopkins, et al.
- *ASIAA Taiwan:* Shiang-Yu Wang, Wei-Hao Wang, et al.

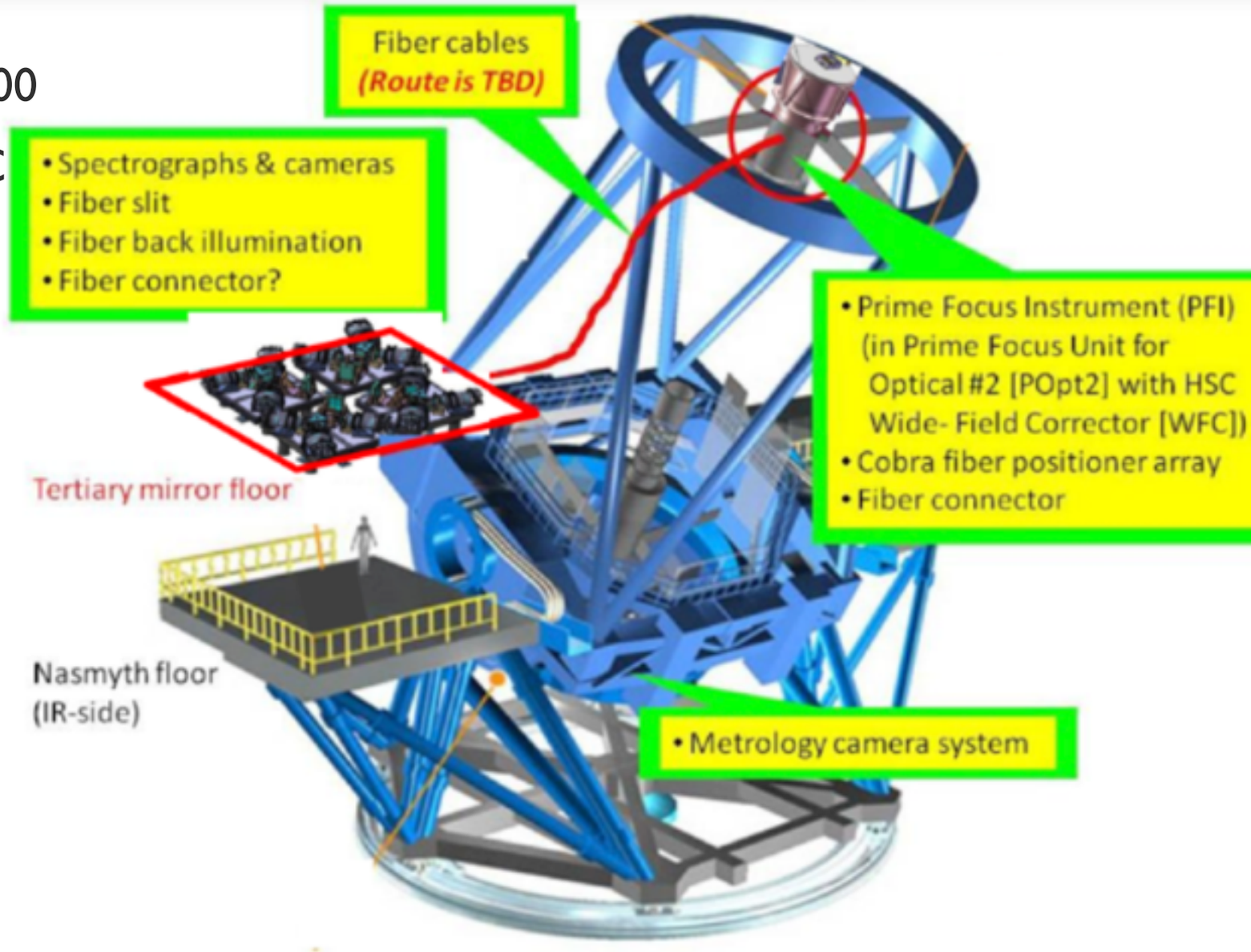
Subaru Telescope Instrument Plan toward 2020s

Hyper Suprime-Cam has started open-use in March 2014

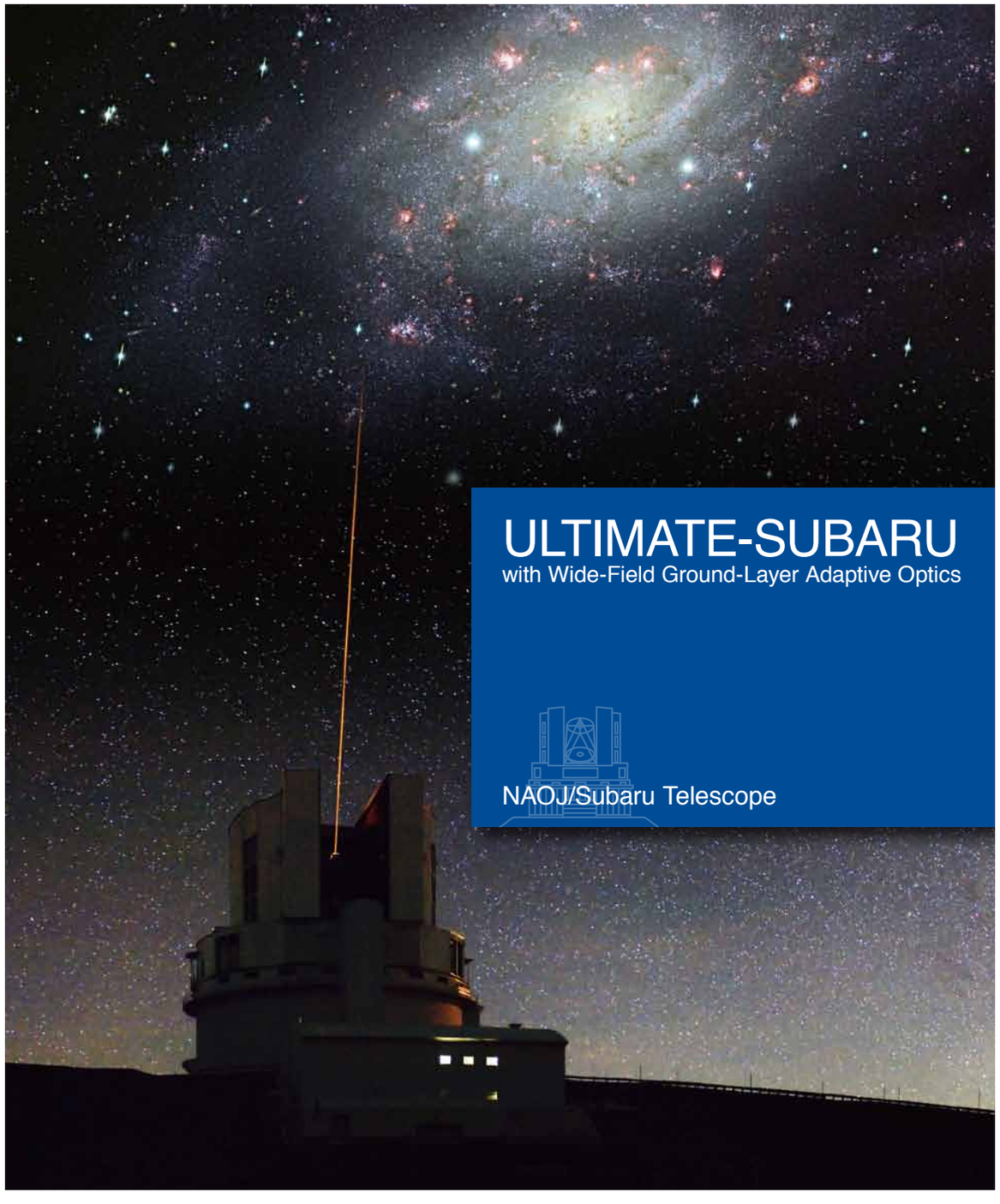
- 1.5 degrees Field-of-View with 104 Science CCDs
- Subaru Strategic Program: 300 nights, 5 years

On-going New Instrument: Prime Focus Spectrograph

- 2,400 fibers, 0.38 - 1.26μm, R~3,000
- Sharing the same POpt2 with HSC
- Four spectrographs
- International team led by IPMU, University of Tokyo
- Expected Engineering First Light in 2017



Project under considerations: ULTIMATE-SUBARU



- Adaptive Secondary Mirror
- Seeing Improvement (about 1/2 image size)
- >10arcmin Field-of-View at Cassegrain
- http://www.naoj.org/Projects/newdev/ngao/
- New Wide-field Near-IR Instrument(s)
- CoDR planned this fiscal year
- Incremental Development of instrument(s) and GLAO
    - Expected start science observations around end of 2010s / beginning of 2020s

ULTRA-WIDE-FIELD LASER TOMOGRAPHIC IMAGER and MOS with AO for TRANSCENDENT EXPLORATION by SUBARU TELESCOPE.

Subaru's Three Pillars - Emphasis on Wide-Field Surveys

HSC

PFS

ULTIMATE-
SUBARU

Why ULTIMATE-SUBARU is Crucial to Subaru

- HSC and PFS are (mainly) optical instruments. We need competitive infrared instruments.
- Time-exchange programs with Keck, Gemini, and possibly others:
  - Balance between dark nights and bright nights
- Synergy with TMT / Unique Strengths of Subaru
  - Wide-Field Survey Oriented Instruments
  - Rigid Telescope, Excellent Image Quality

ULTIMATE-SUBARU: history

- Subaru Advisory Committee Recommendations
- Working Group Formed in 2011
- Science Workshops
  - Sept. 2011 in Osaka
  - Oct. 2012 in Hilo, Hawaii
- June 2013 in Sapporo (with Canadians and Taiwanese)
- July 2014 in Mitaka, Tokyo (with Australians)

ULTIMATE-SUBARU Key Specifications

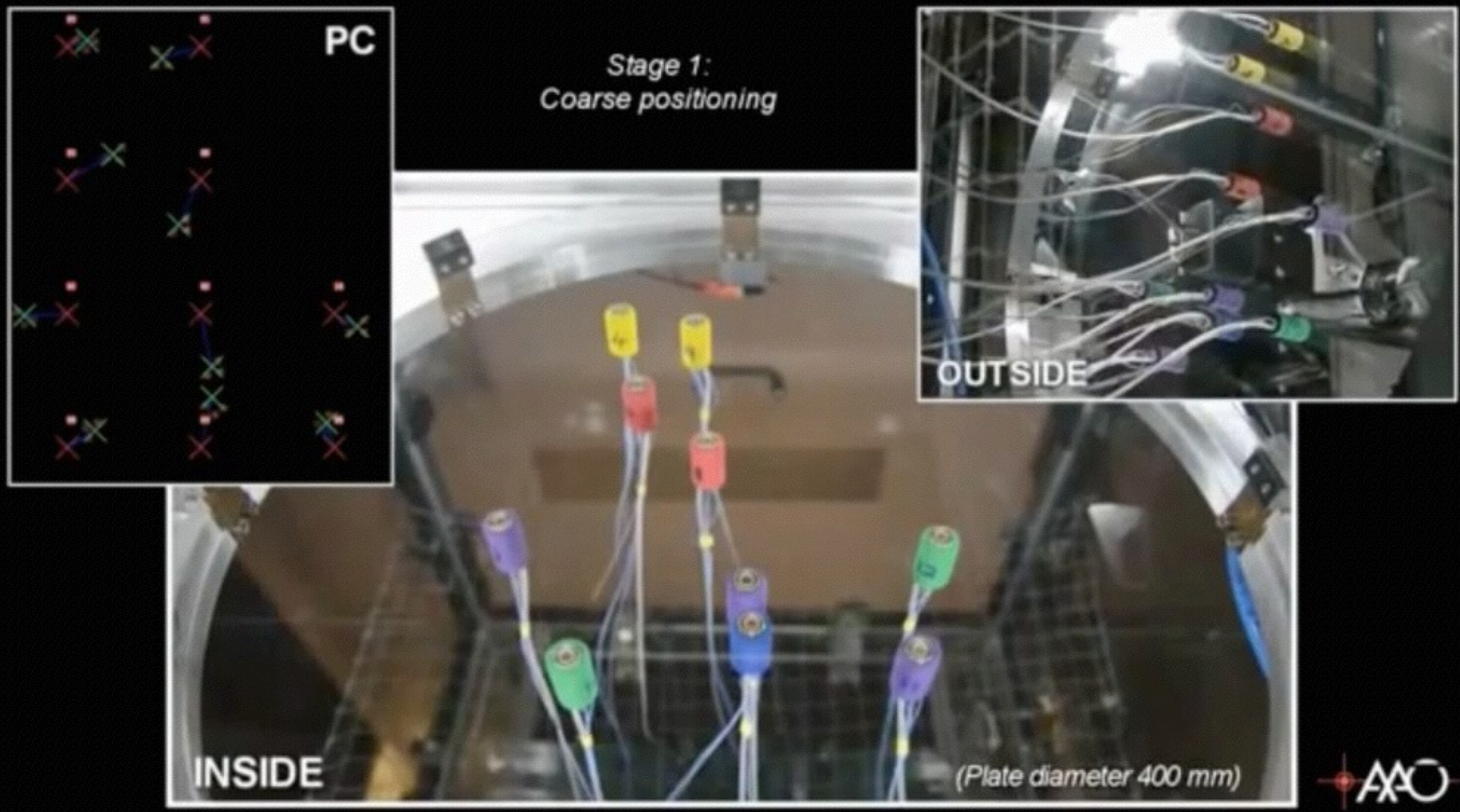
Key Specifications: Ground-Layer AO

Field of View	15 arcmin
Focus	Cassegrain
Corrector	Adaptive secondary, 33 actuators across the diameter
Sky Coverage	Almost all sky

FWHMs at 'Moderate' condition

	GLAO	Natural
K-band	0.20"	0.44"
H-band	0.23"	0.49"
J-band	0.27"	0.51"
R-band	0.41"	0.65"

Starbugs for Multi-IFU Spectrograph



Key Specifications:
Multi-Object Integral-Field Spectrograph

Phase 1

Number of Fibres per Bundle	61
Spatial Sampling	0.2 arcsec/fibre
Bundle Sky Diameter	1.8 arcsec
Number of Bundles	16
Field of View	6' → 13'
Spectral Resolution	~3,000
Detectors	2 x H2RG
Wavelength Coverage	0.9 - 2.0μm

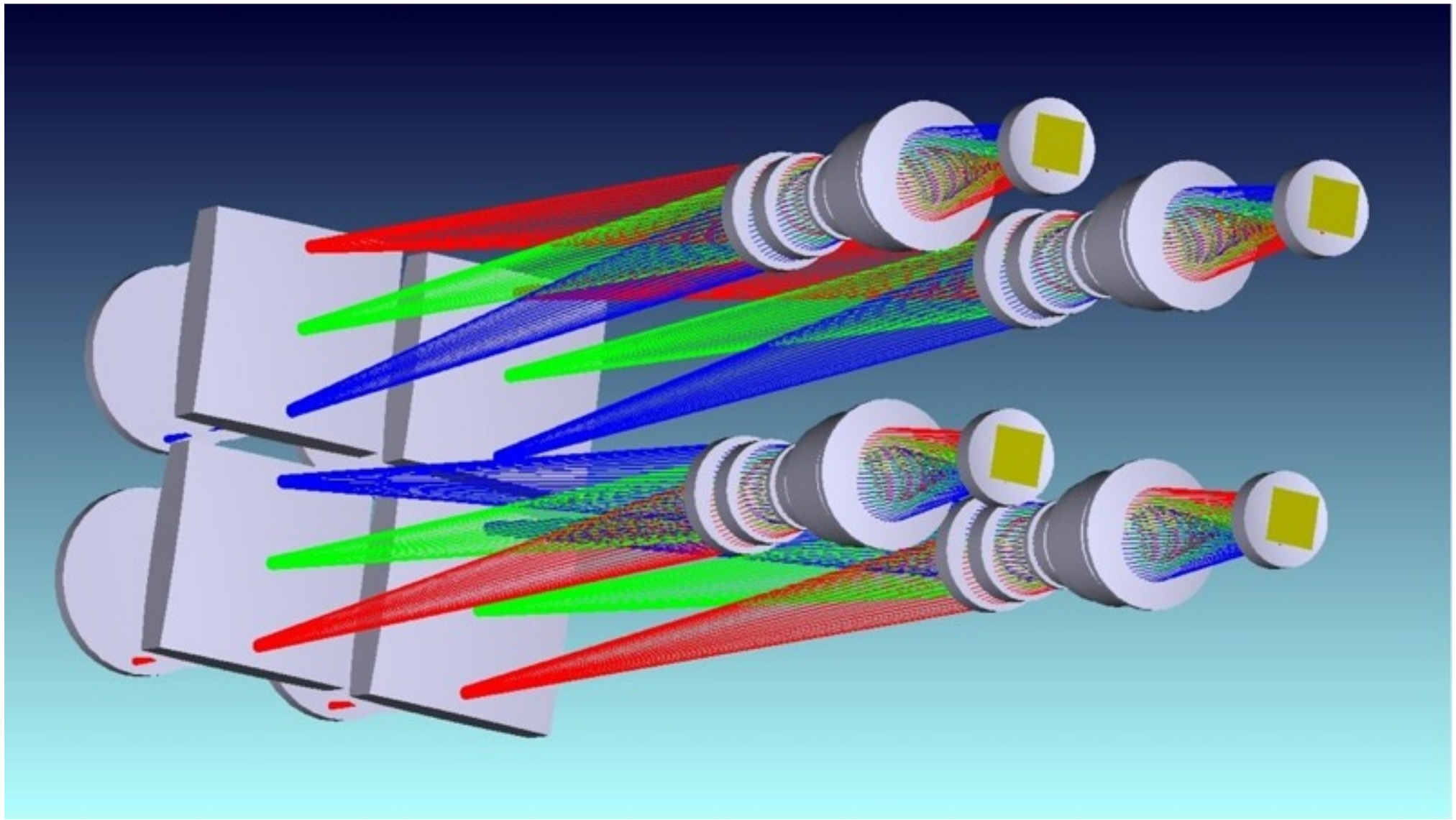
Phase 2

Number of Bundles	>32
Field of View	13'
Detectors	2 x H4RG? (TBD)

Key Specifications:
Wide-Field Near-IR Imager

Field of View	9.6’ x 9.6’ (TBD)
Spatial Sampling	0.07” / pixel
Detectors	4 x H4RG
Wavelength Coverage	0.8um - 2.5um
Filters	Broad-band and Narrow-band

‘Four Barrel’ Optical Design
by John Pazder (NRC Canada)

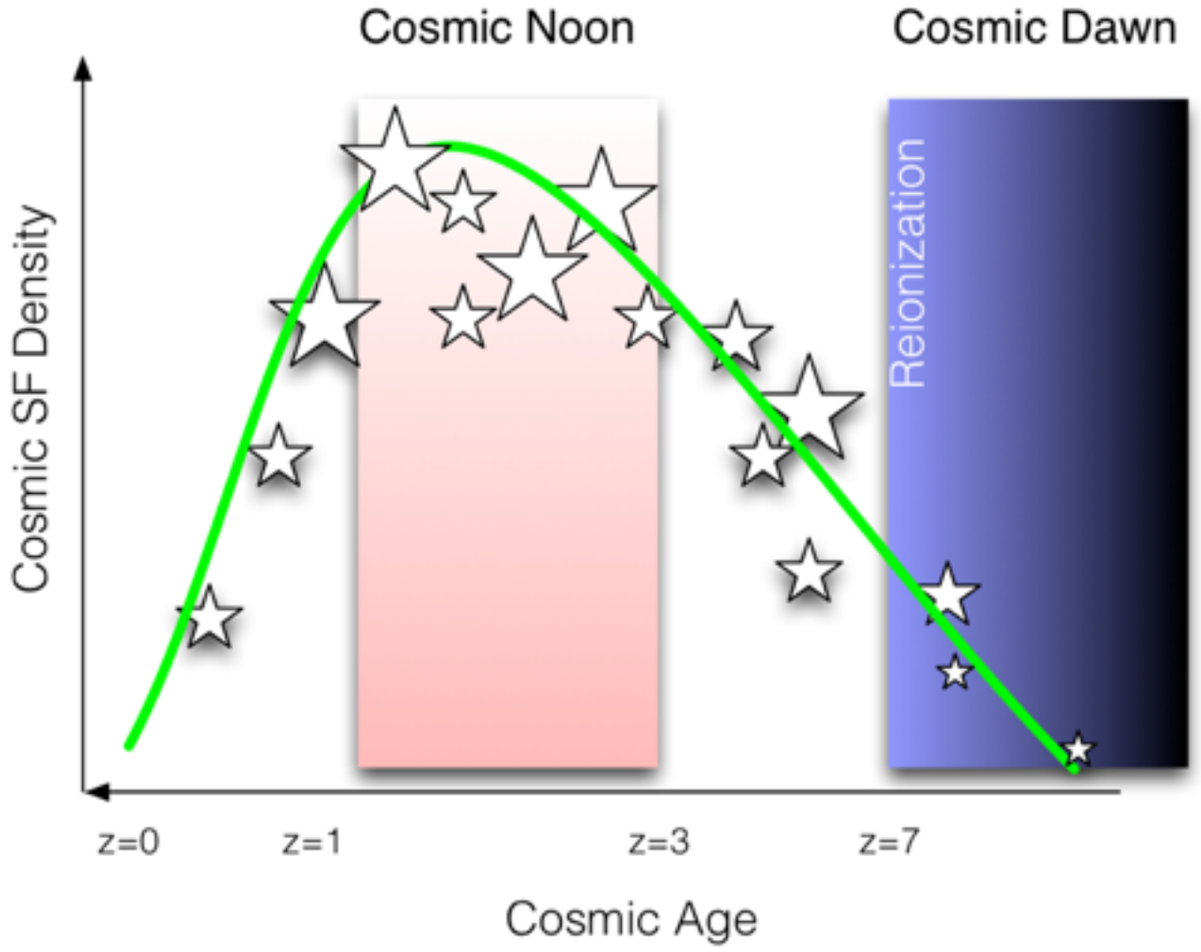


* This optical design assumes wider clearance of Cassegrain focus. We need to revise the design according to available clearance of Subaru Cs (~13’ x 13’).

Science Goals

Primary Science Goals

- *Complete Census of the Galaxy Evolution*
  - 'Cosmic Noon' (1<z<3)
  - Galaxy Anatomy
- *Exploring Very High-Redshift Universe*
  - 'Cosmic Dawn' (z>7)
- *Strong Synergy with TMT*
  - Feed Targets for IRIS +NFIRAOS and WFOS



Primary Science Goal #1:
Complete Census of the Galaxy Evolution with Large-Scale Near-IR Surveys

Complete Census of the Galaxy Evolution with Large-Scale Near-IR Surveys

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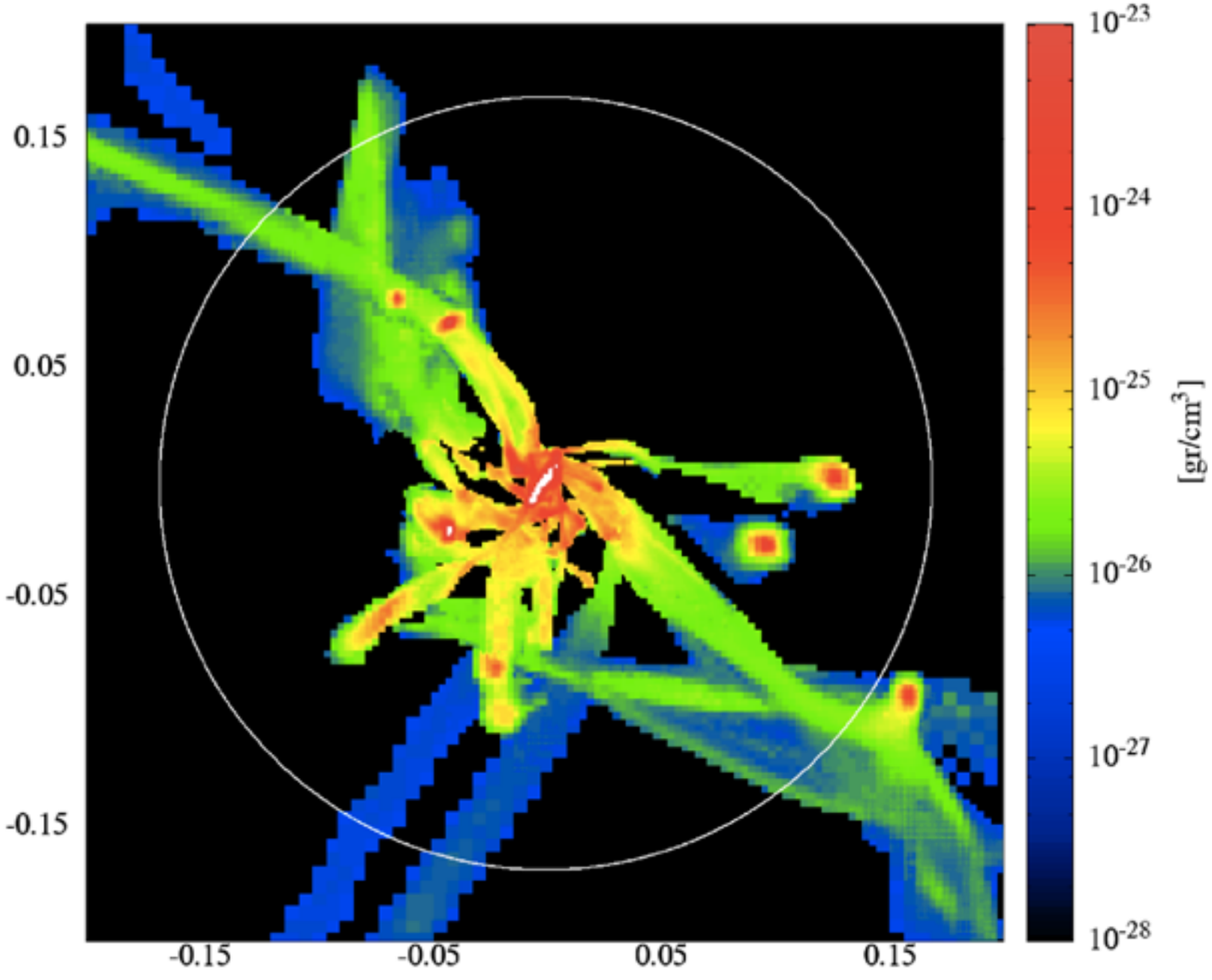
- *What are the key parameters to drive the galaxy evolution?*
- *What determines morphologies of the galaxies?*

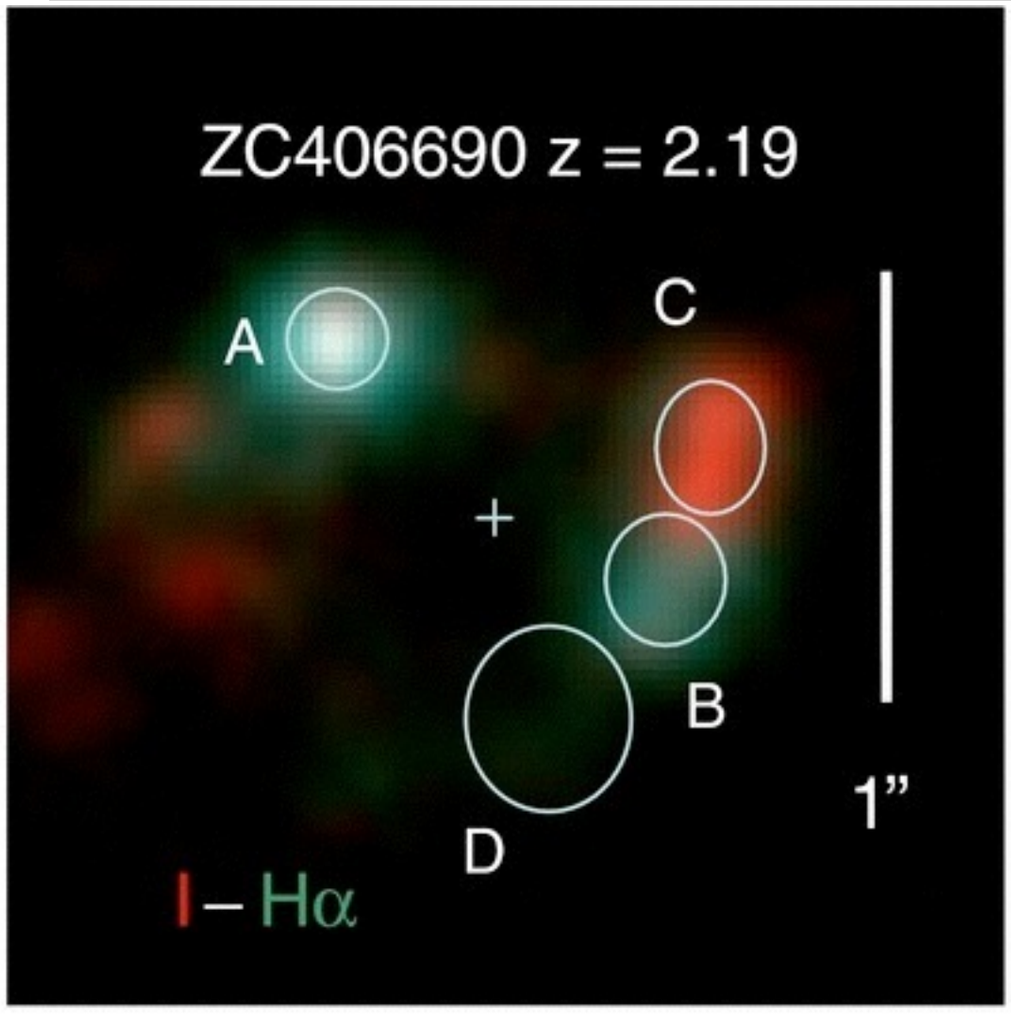
- Current observations of the galaxies in the peak epoch of star formation ($1<z<3$) are limited in both number of sample galaxies and in range of parameters (limited to brightest ones).
- Deeper and larger surveys in Near-Infrared (=rest-frame optical) with Multi-IFU is essential.

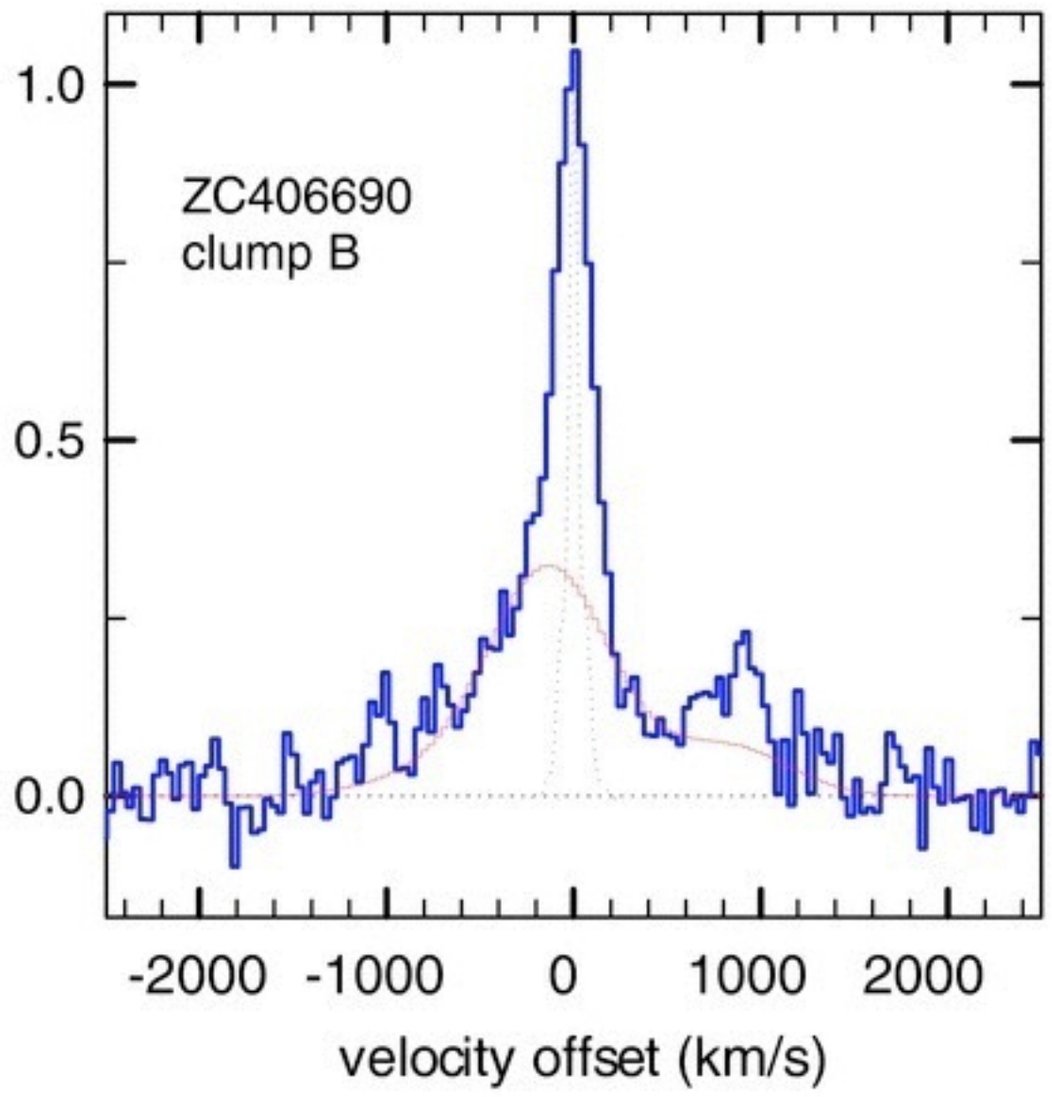
Inflows



- Cold Streams (Kereš et al. 2005; Dekel and Birnboim 2006)
- Could be a main mode of galaxy evolution (rather than major mergers)

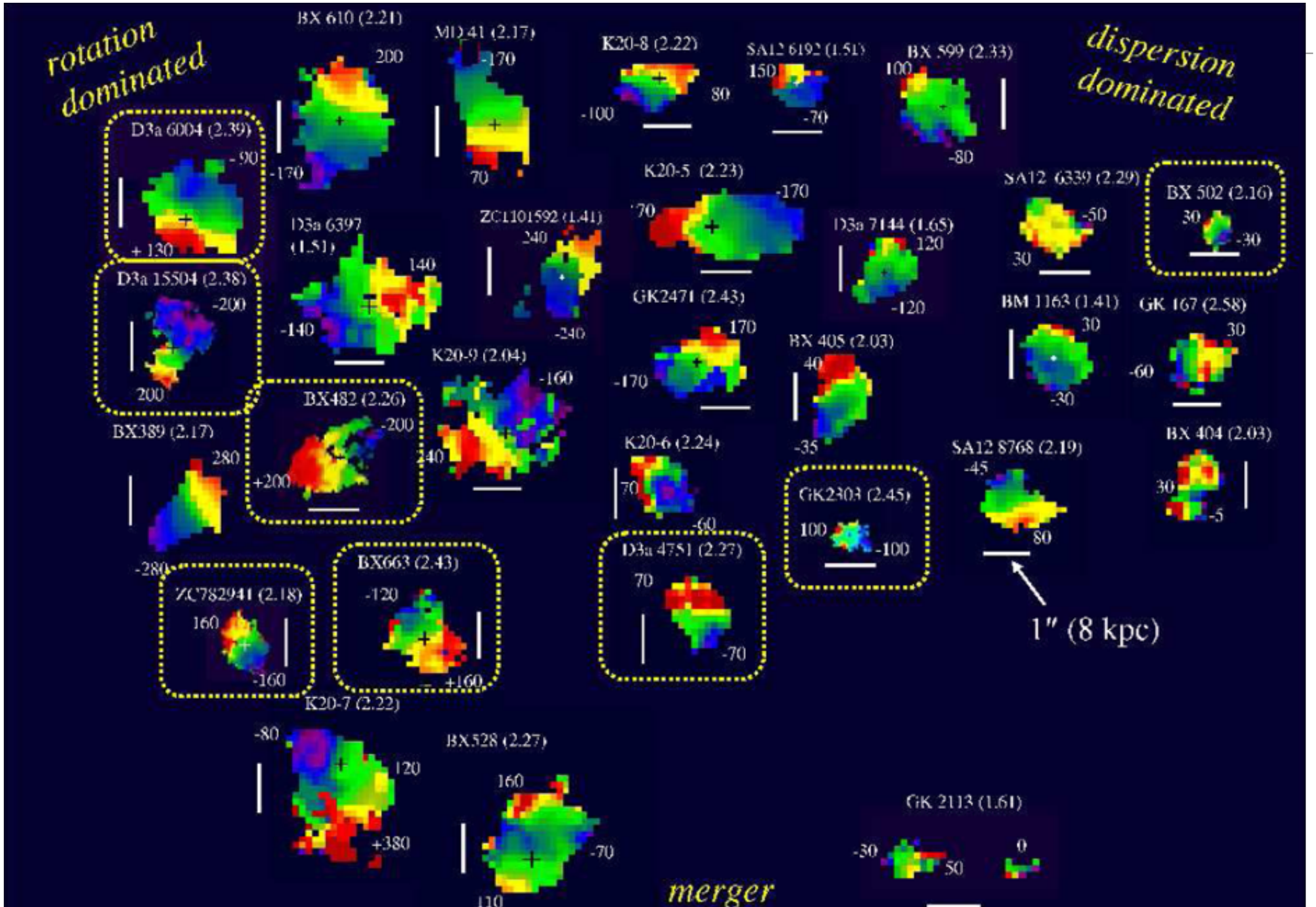
Outflows



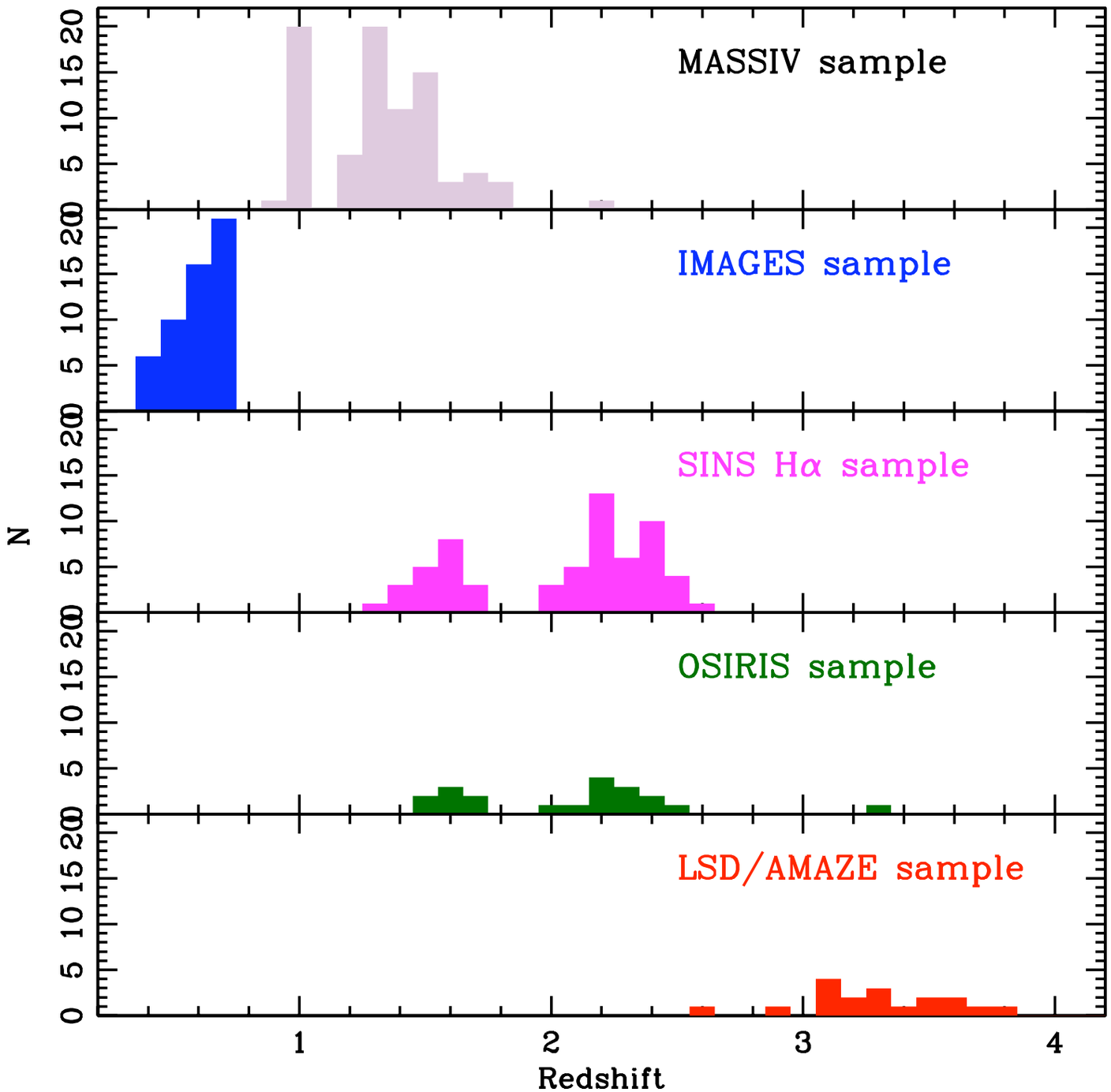


- Genzel et al. 2011: kinematics of SF clumps in z~2 galaxies
- Outflow - loss of SF gas and migration into the center?

VLT SINFONI - SINS Survey

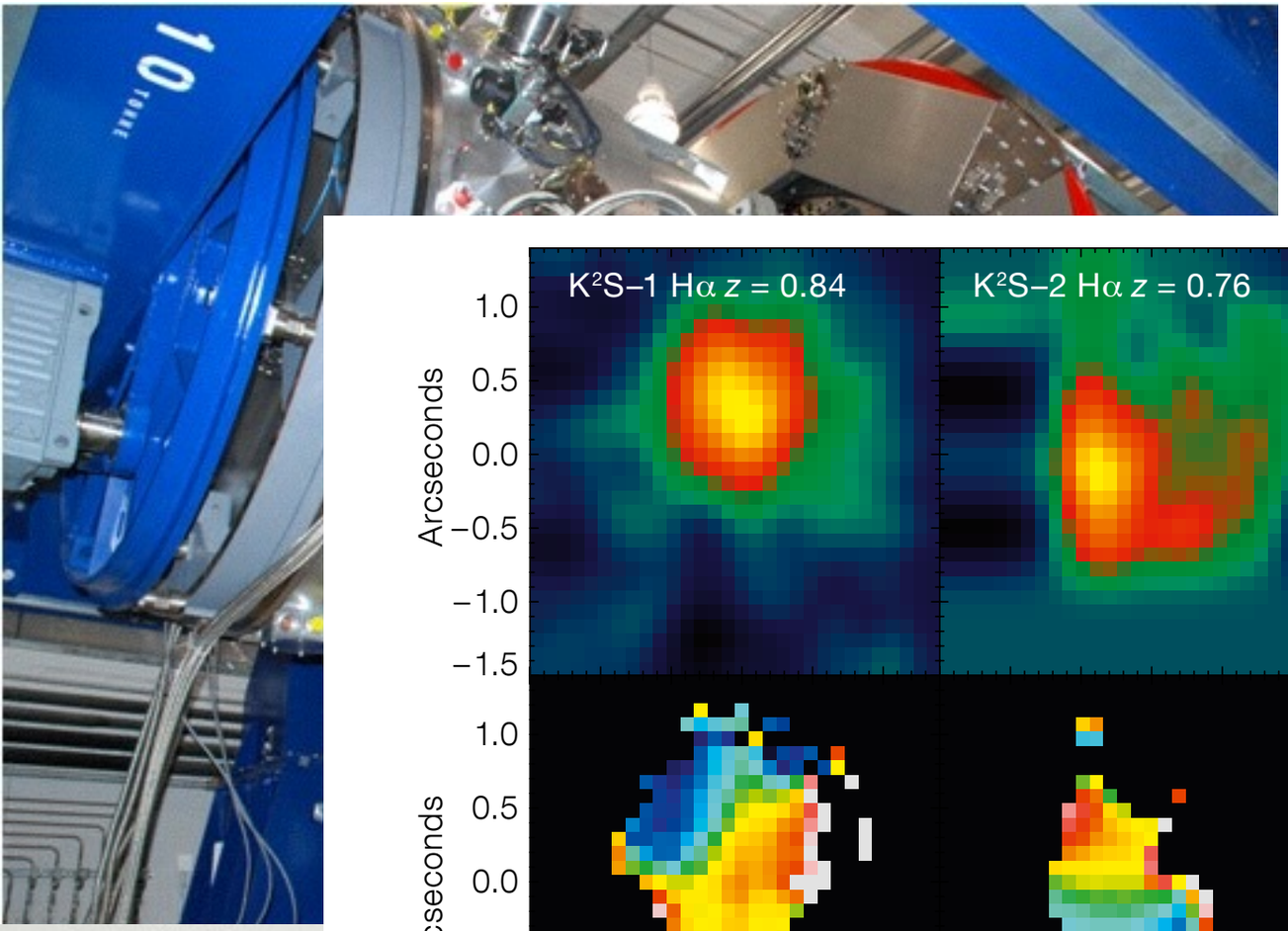


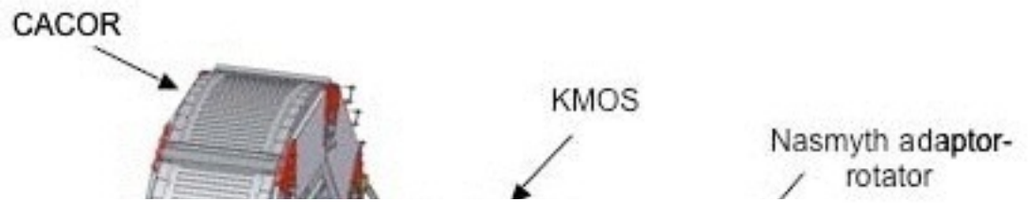
Current Sample of Distant Galaxies with 3D Spectra



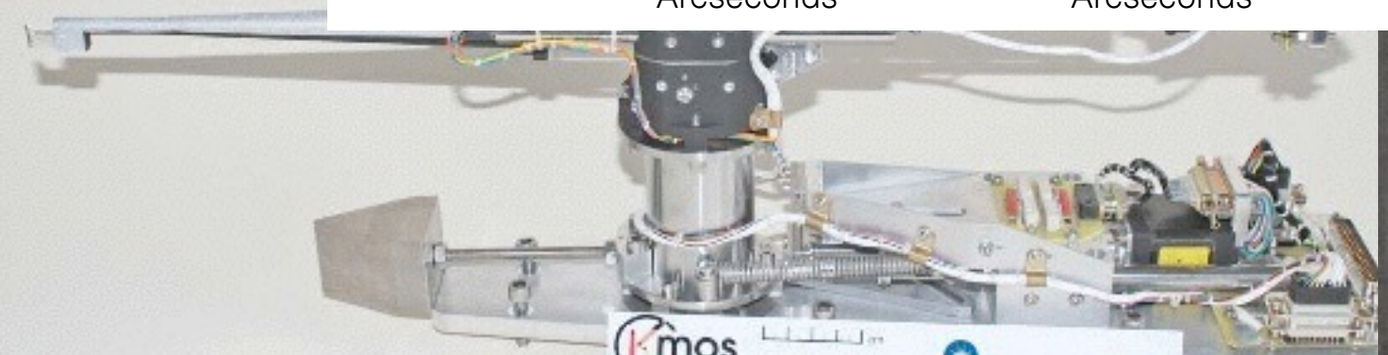
- Contini et al. 2012
- IFU surveys with VLT/SINFONI and Keck/OSIRIS for galaxies at $0<z<4$

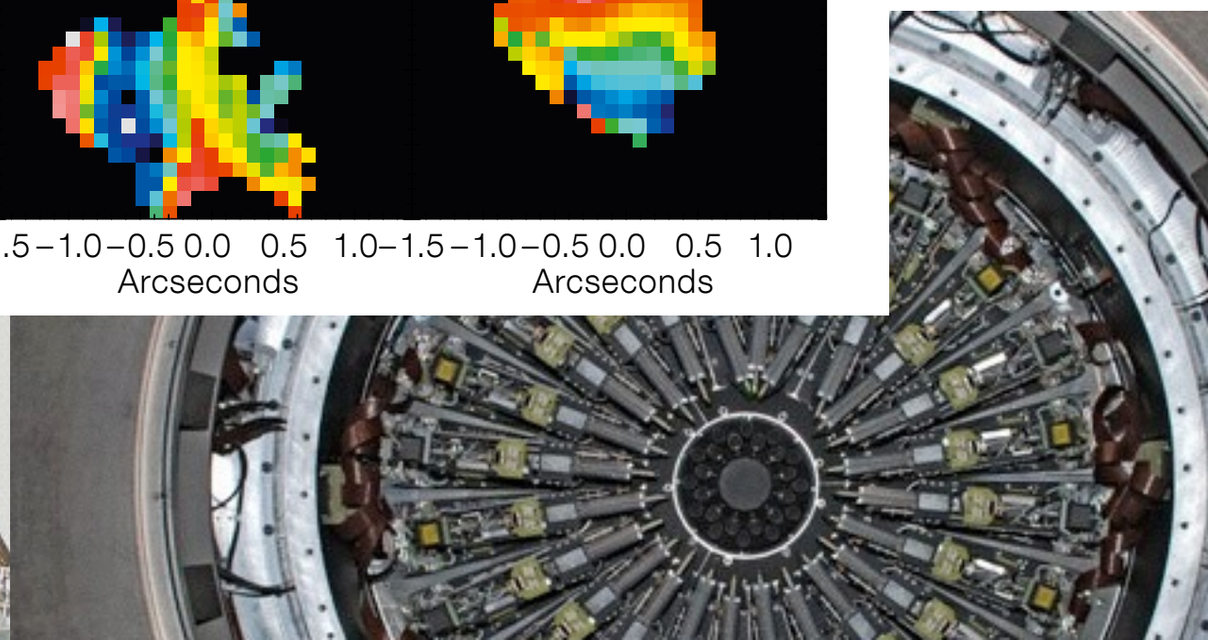
VLT KMOS


10 FEET


CACOR
KMOS
Nasmyth adaptor-rotator

K²S–1 Hα z = 0.84
K²S–2 Hα z = 0.76
K²S–3 Hα z = 1.0
K²S–4 Hα z = 1.0
Arcseconds
1.0
0.5
0.0
−0.5
−1.0
−1.5
−1.5 −1.0 −0.5 0.0 0.5 1.0


kmos



Complete Census of the Galaxy Evolution with Large-Scale Near-IR Surveys

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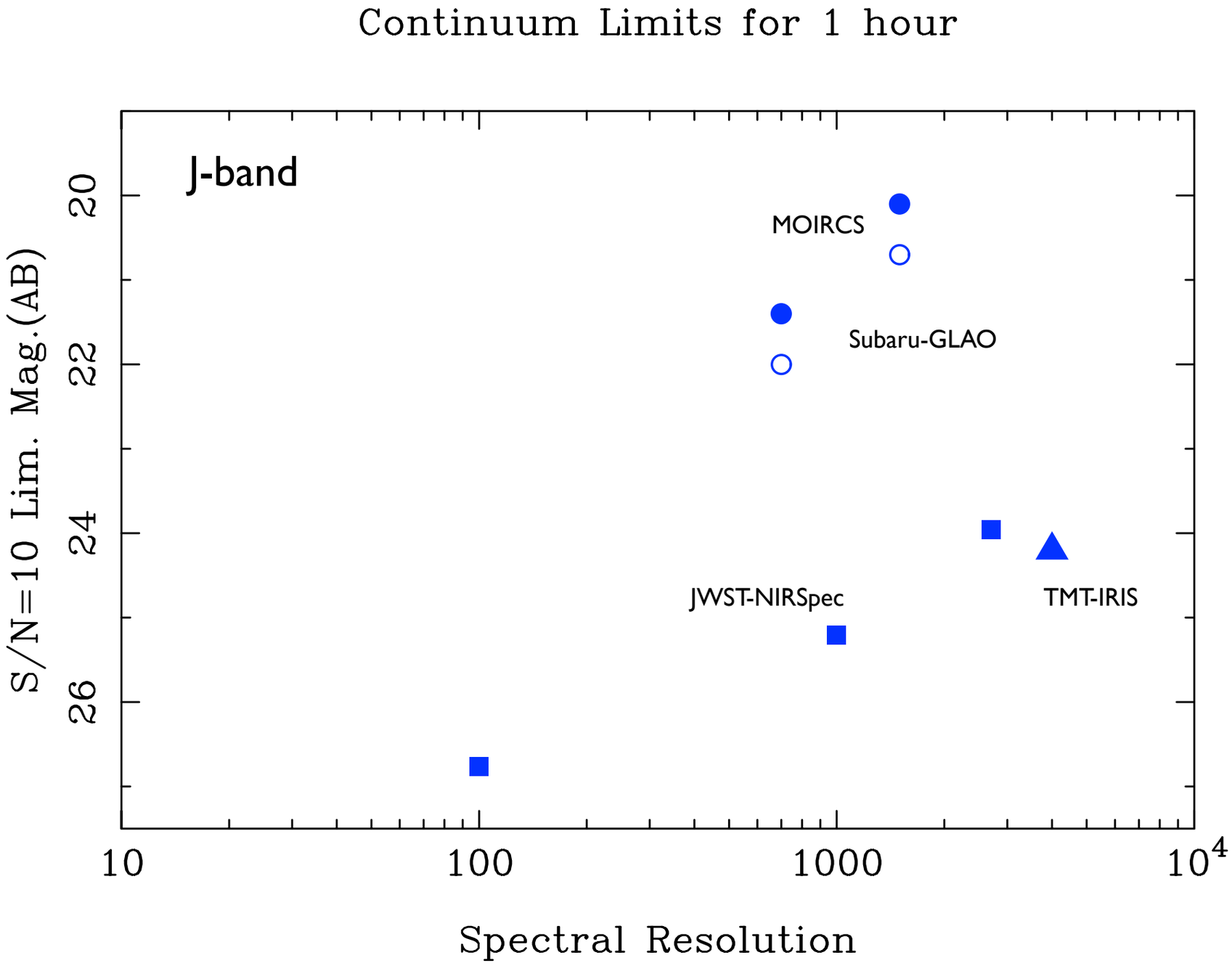
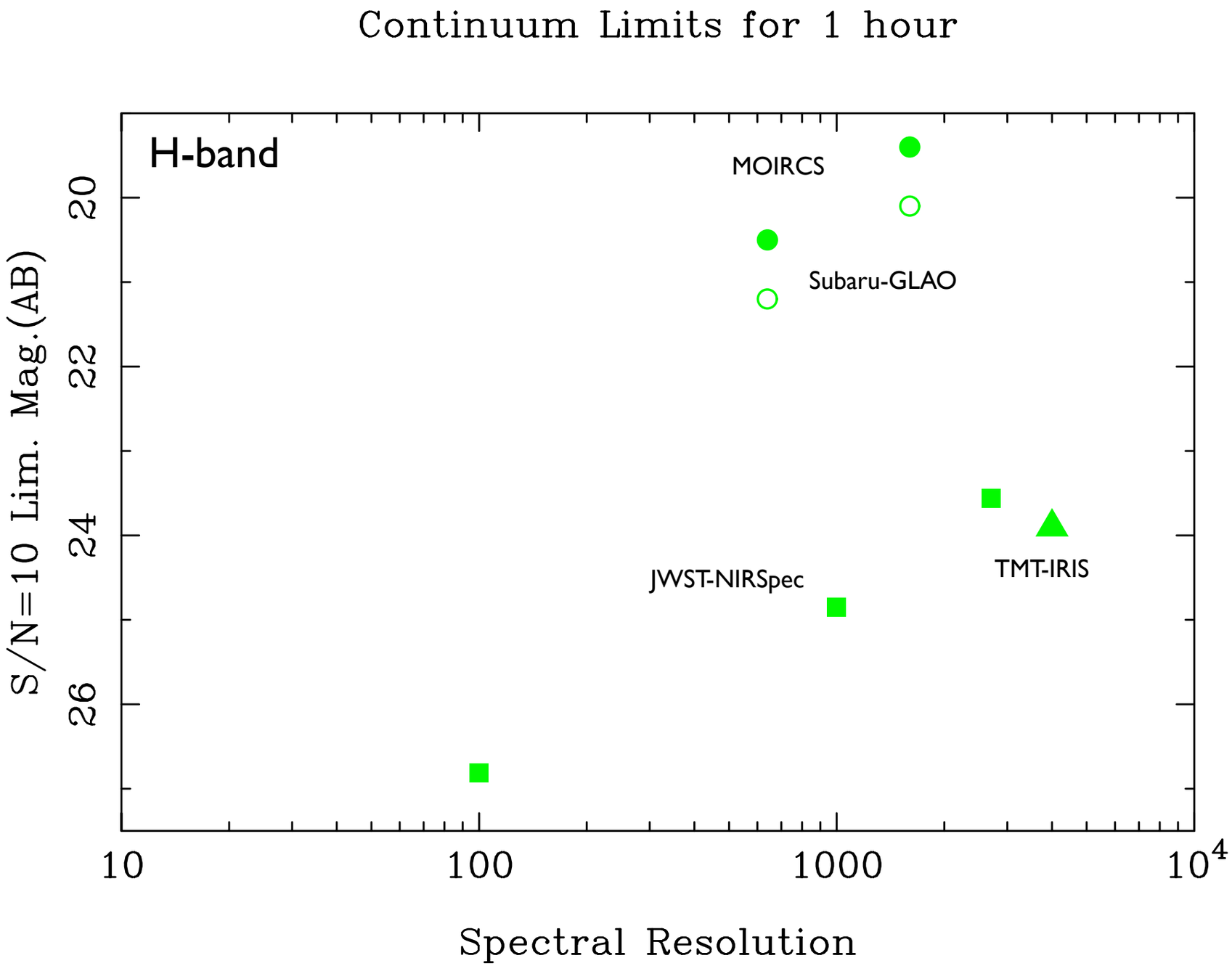
- *Imaging*: Morphological information (size, radial profiles, color distributions)
  - 0.2” FWHM - Spatial resolution comparable to HST
  - Narrow-band imaging survey to trace Hα lines
    - Higher resolution: Geometry of SF regions
    - Wider FoV: Large-scale structure and environmental effects (proto-clusters, groups, fields)
- *Spectroscopy*: Kinematics, Inflows and Outflows, SFR, Chemical compositions, Ionization states
  - Multi-IFS with GLAO could be a powerful and unique instrument - VLT/KMOS is not AO assisted.

Spectroscopic Sensitivity (Preliminary)

Spectroscopy: Continuum Sensitivity (Point Sources)



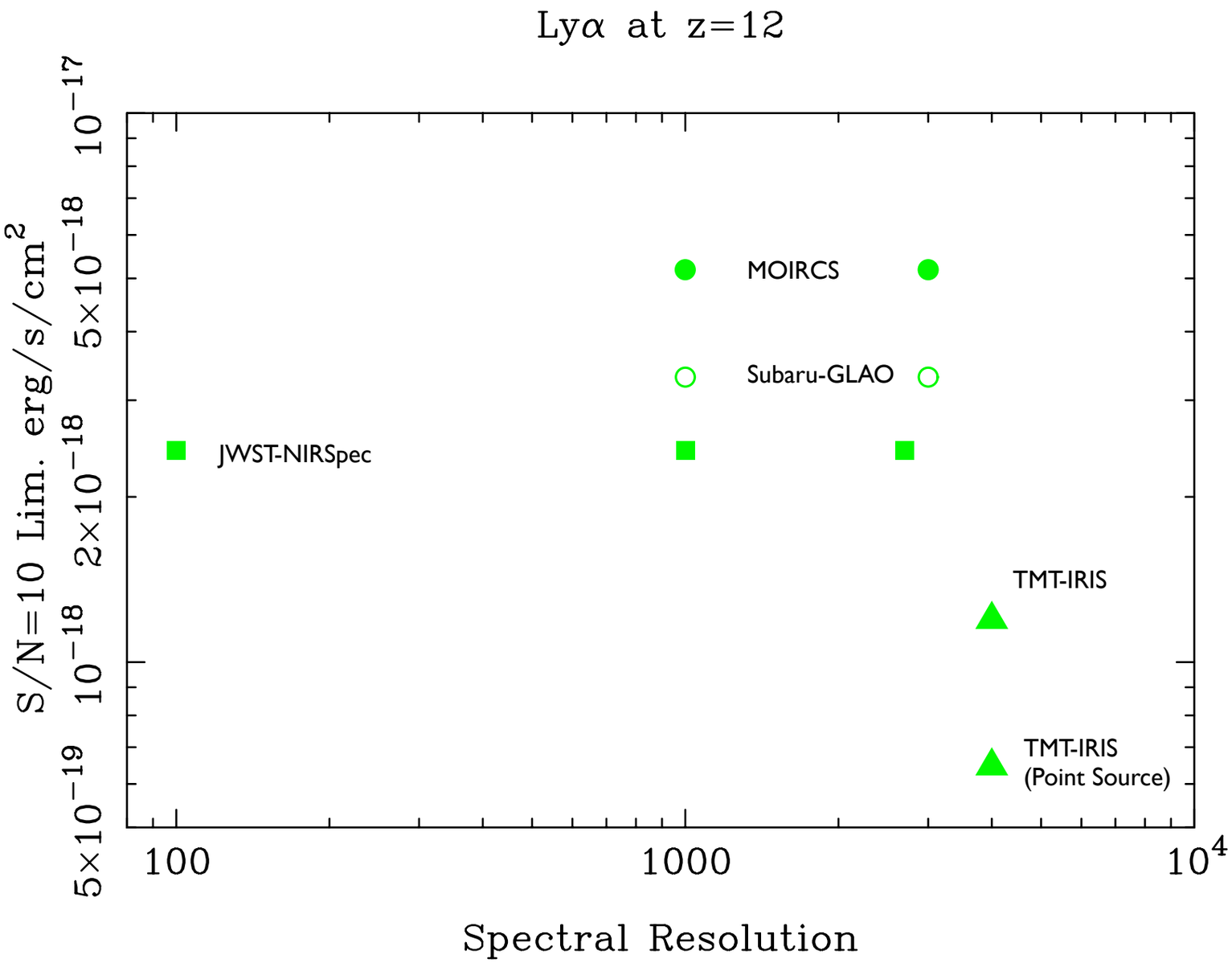
Spectroscopy: Continuum Sensitivity (Point Sources)



JWST and TMT have much higher sensitivities

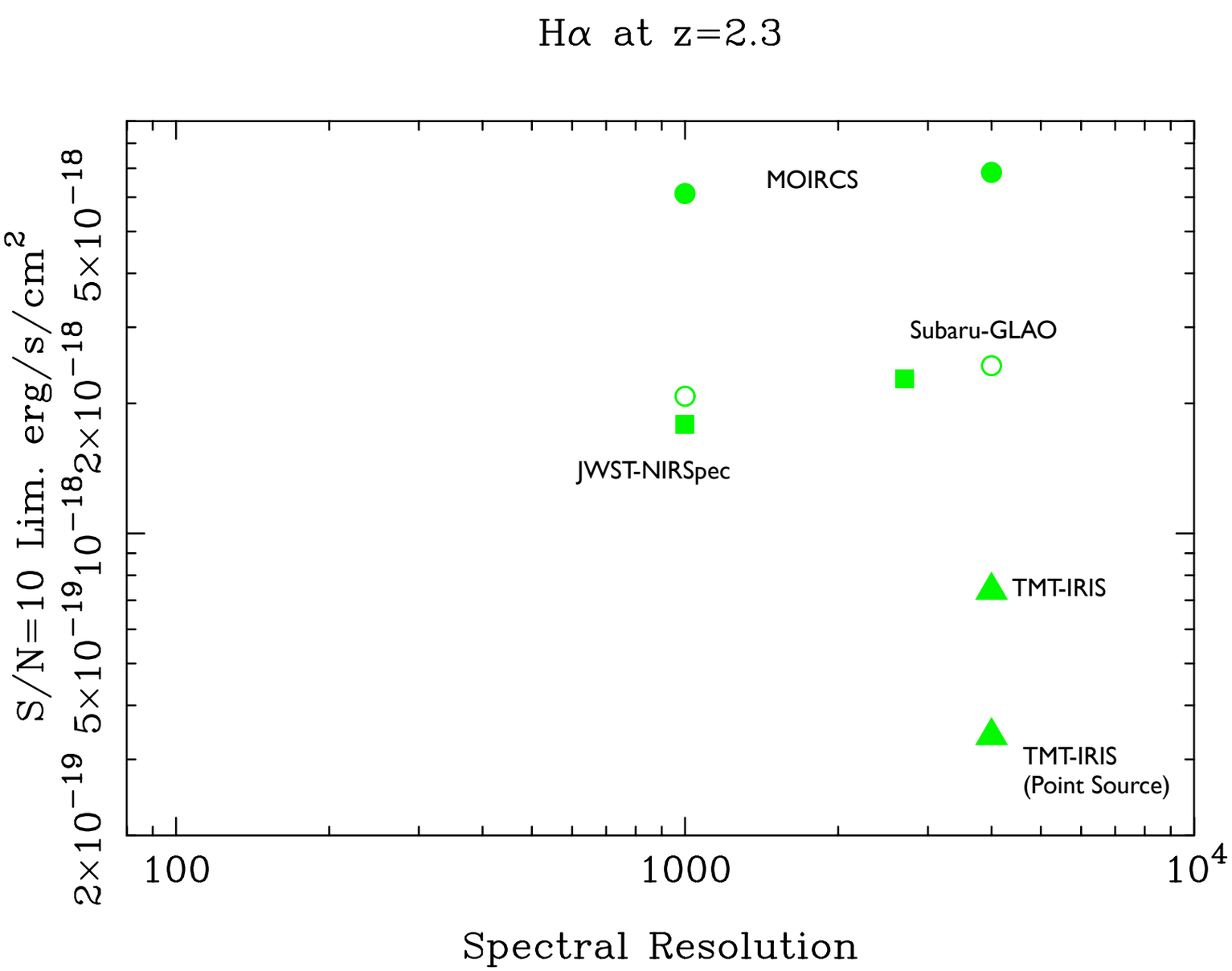
Spectroscopy: Sensitivity for Emission Lines

1 hours, ~0.25" extended source



Spectroscopy: Sensitivity for Emission Lines

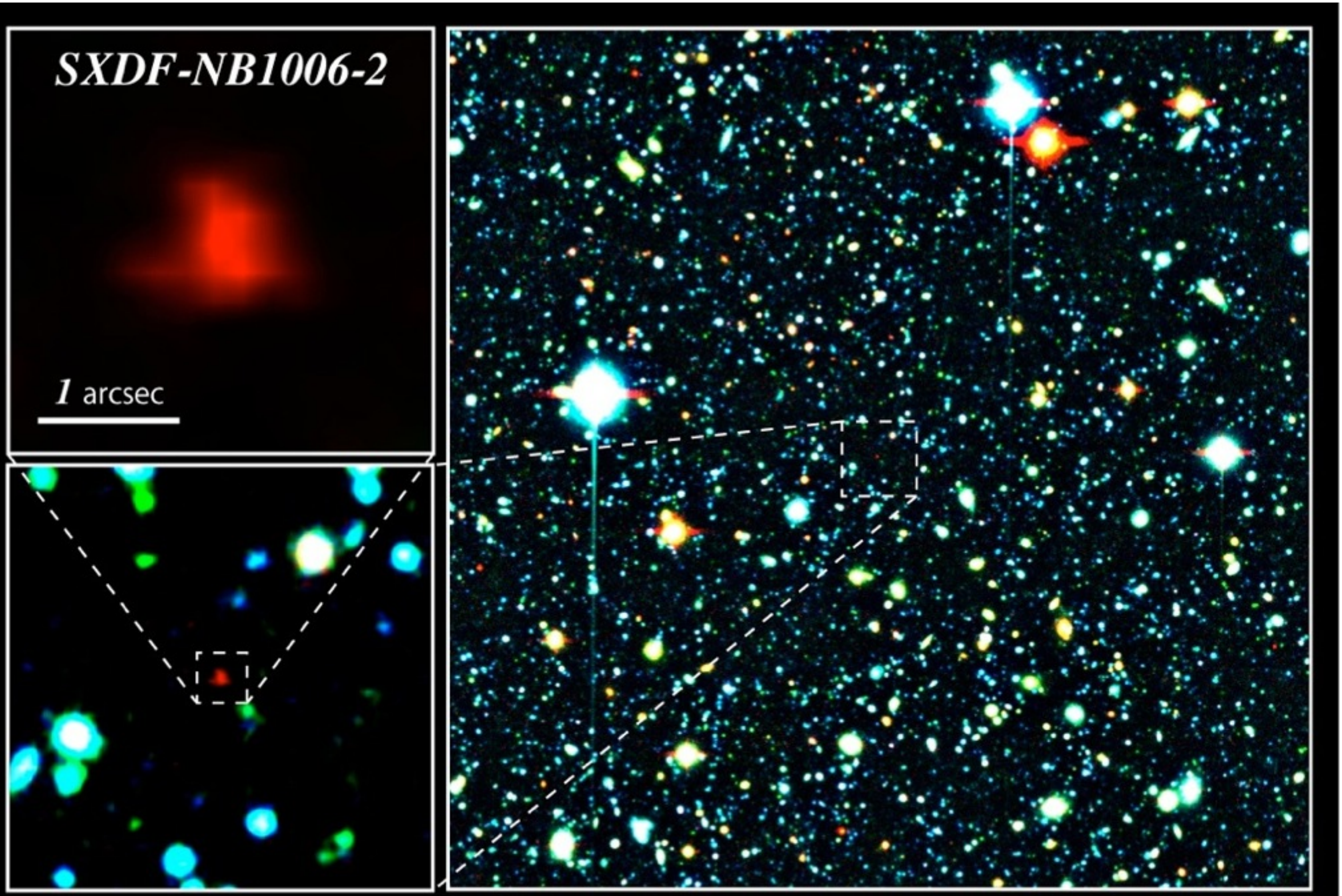
1 hours, ~0.25" extended source



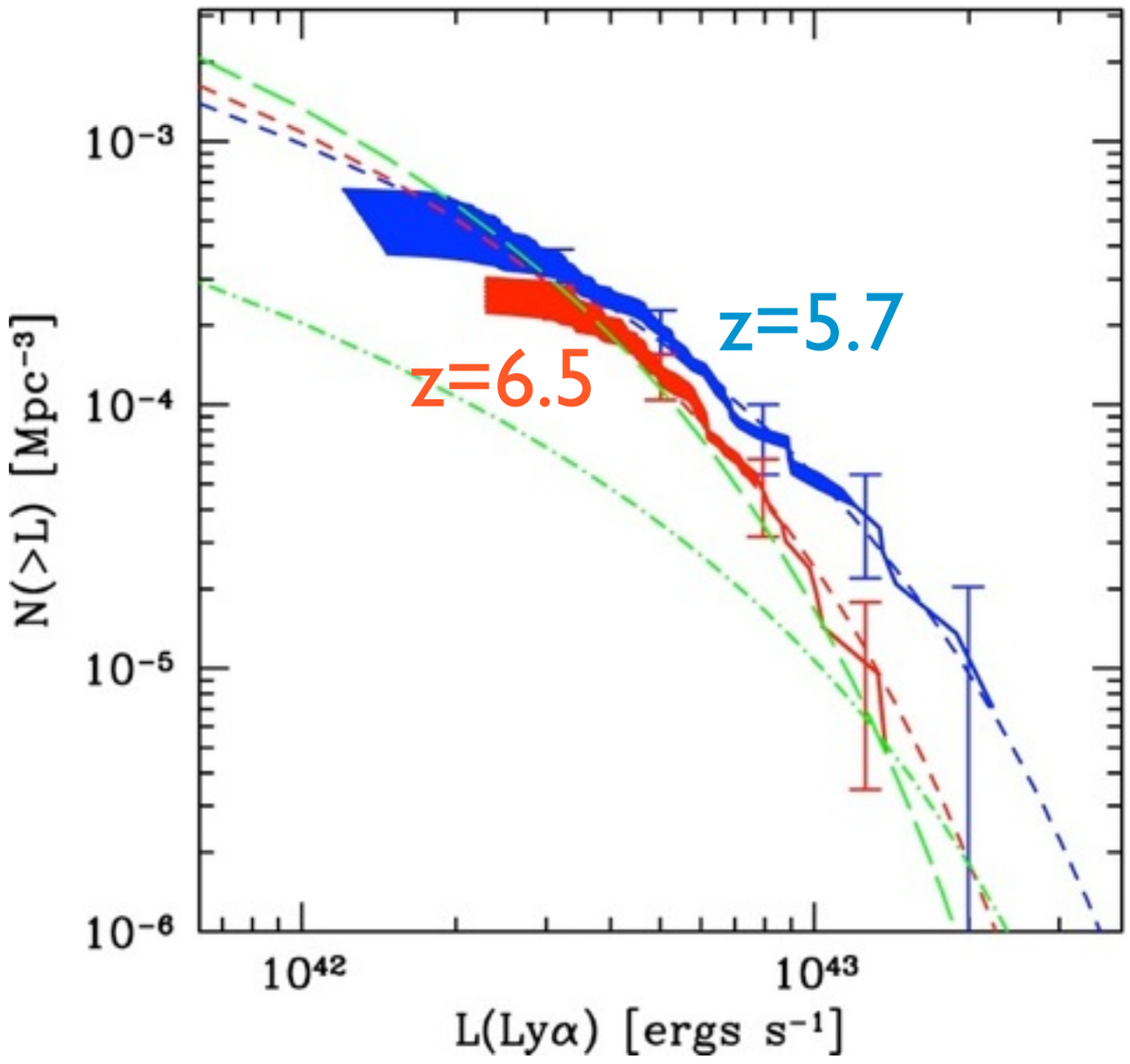
Competitive Sensitivity for Emission Lines

Primary Science Goal #2:
Discovery of the Most Distant Galaxies and Understanding of the Cosmic Reionization

z=7.215 Discovered by Subaru/Suprime-Cam (Shibuya+ 2012)



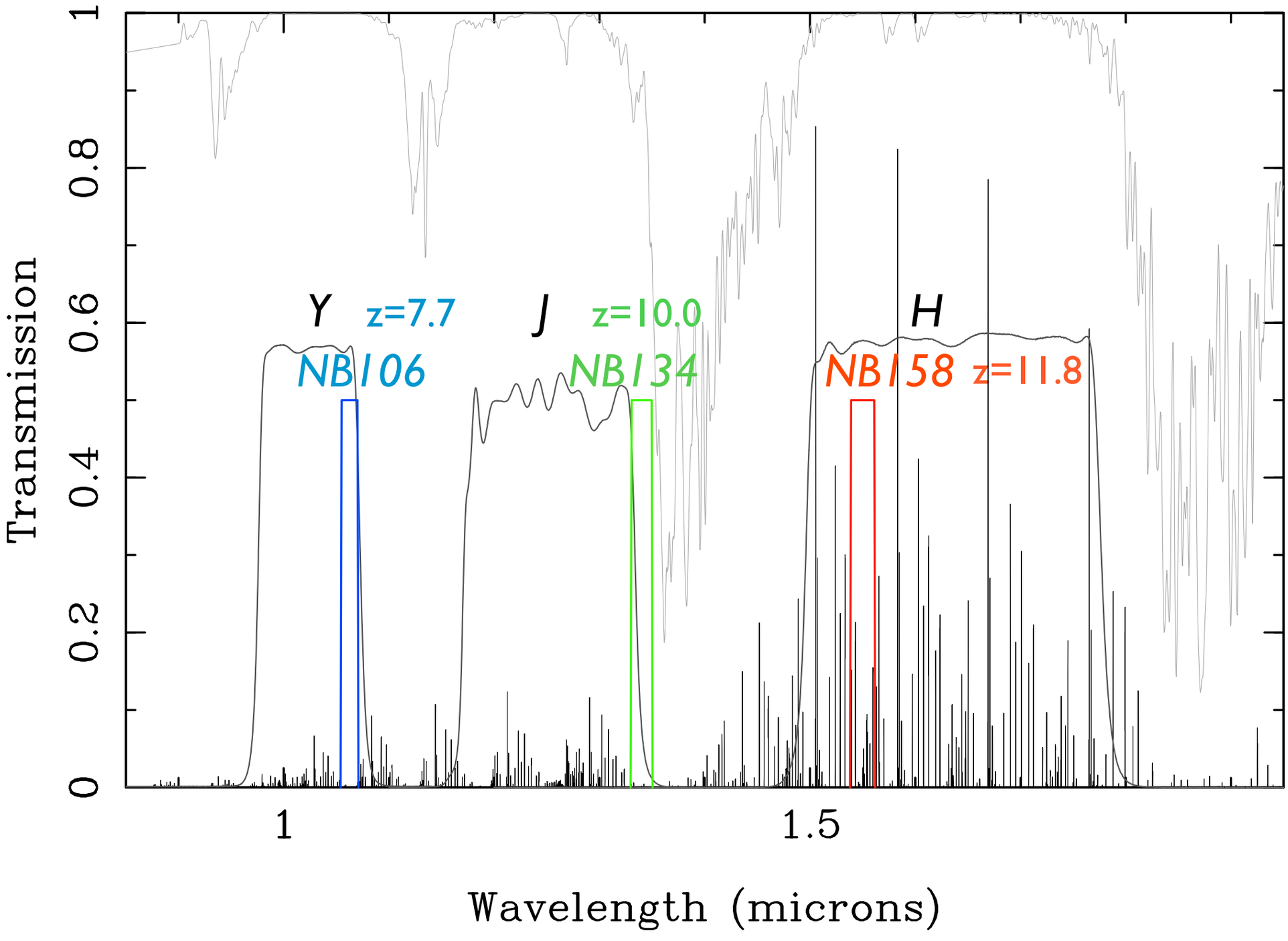
LAE LF at z=5.7 and 6.5

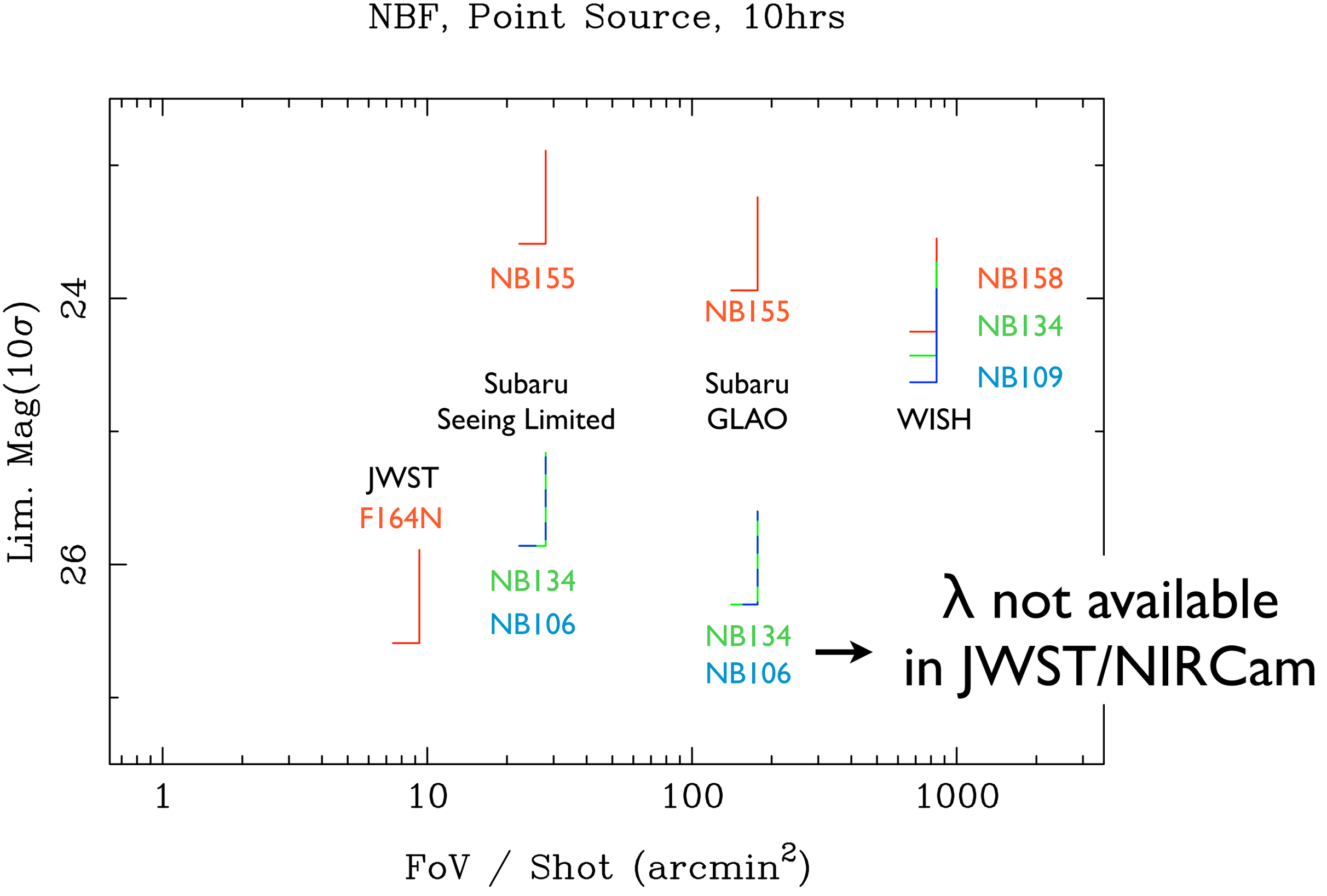


Kashikawa et al. 2011 ApJ 734, 119

Extend Suprime-Cam/HSC surveys toward higher redshift

ULTIMATE-SUBARU NBFs Transmissions, Atmospheric Transmissions, and Sky Lines




NBF, Point Source, 10hrs
Lim. Mag(10σ)
24
26
NB155
Subaru
Seeing Limited
NB155
Subaru
GLAO
NB158
NB134
NB109
WISH
JWST
F164N
NB134
NB106
NB134
NB106
λ not available
in JWST/NIRCam
1
10
100
1000
FoV / Shot (arcmin²)

Expected Numbers per FoV for On-source 10hrs Exposures

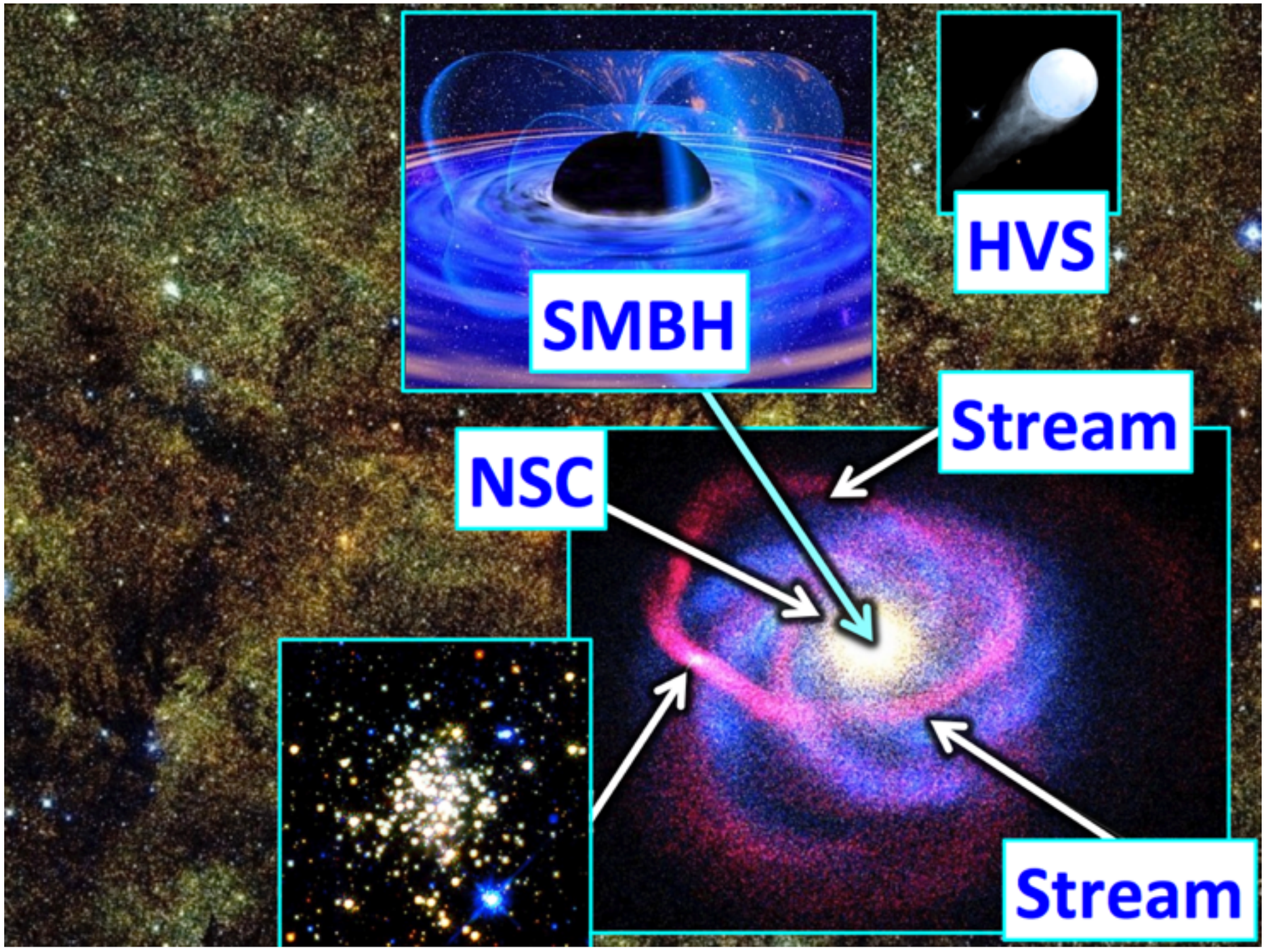
No Evolution from z=6.5 i.e., ~Maximum Number

	Number / FoV		
	Seeing	GLAO	JWST
z~8	0.5	8.3	--
z~10	0.2	3.3	--
z~12	3E-08	8E-06	0.3

Based of Semi-Analytic Model by Kobayashi et al.

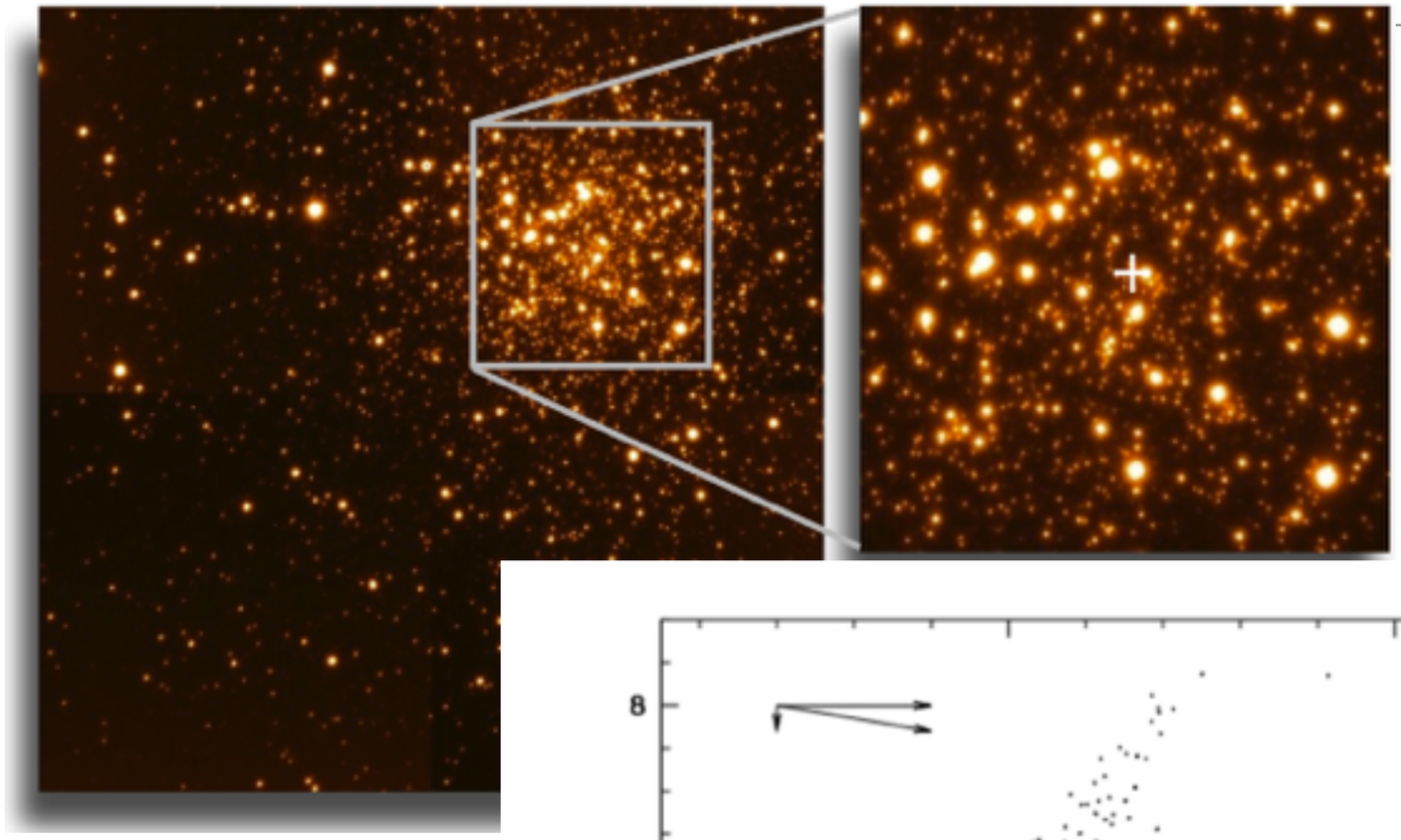
		Number / FoV	
	Seeing	GLAO	JWST
z~8	2.4	3.9	--
z~10	0.2	0.5	--
z~12	~0	~0	0.003

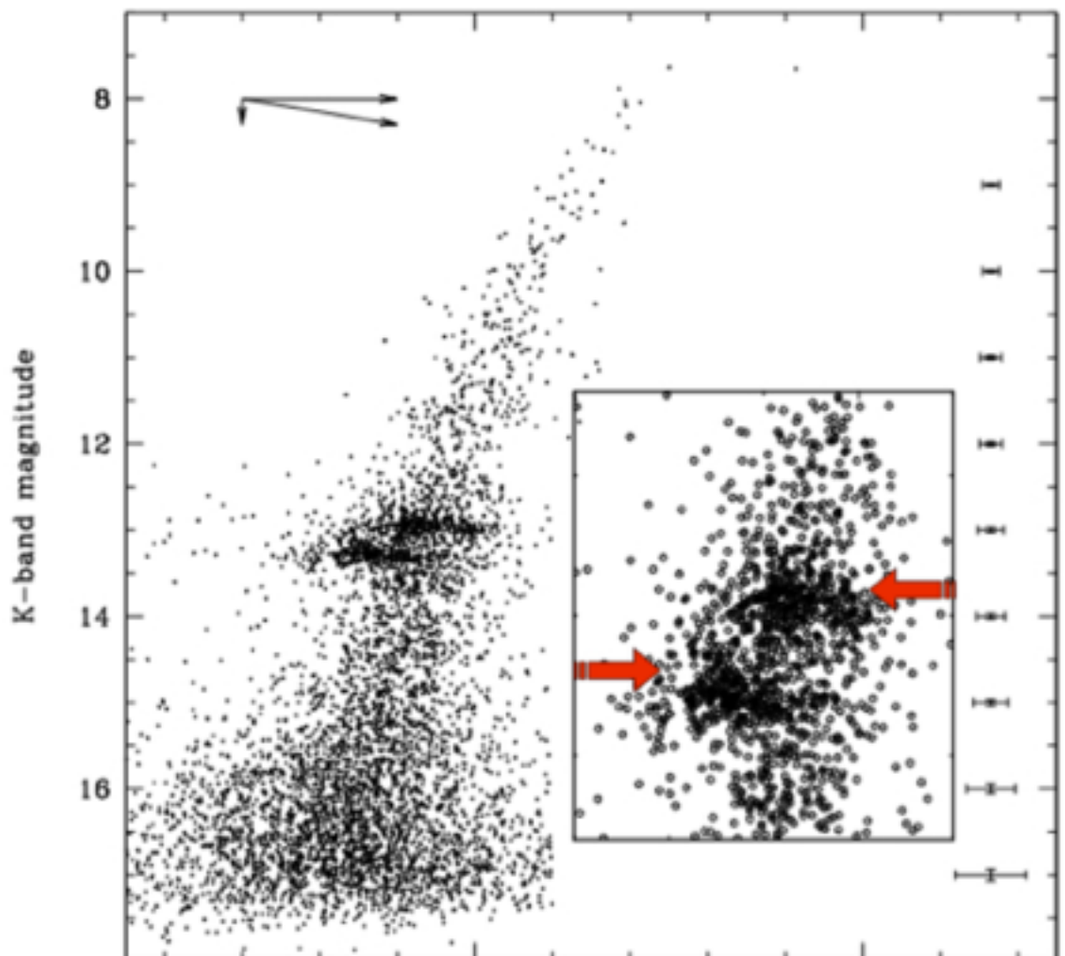
Other Science Cases Discussed in Japanese Community: Galactic Center: Link between SMBH and Galaxy Formation



- Nishiyama (Miyagi Univ. of Edu.) et al.

Other Science Cases Discussed in Japanese Community: Galaxy Archaeology: Bulge formation history from GCs





- Chiba (Tohoku Univ.) et al.

Summary

- ULTIMATE-SUBARU is one of Key Facility Instruments toward 2020s.
- GLAO + New near-IR instruments
  - ASM has a potential to be used by other AOs, e.g., ExAO
  - Incremental instrument development plan
- Two primary science cases
  - *'Cosmic Noon'*: Multi-IFS survey for Complete Census of the Peak Epoch of Galaxy Formation
  - *'Cosmic Dawn'*: Narrow-band Imaging Survey to find z>7 Galaxy Candidates
- Strong Synergy with TMT
- 'Niche' Capabilities - Emission line sensitivities, AO-assisted Multi-IFS, Narrow-band imaging (between OH lines)