Our WISH: Feeding z>10 Targets to ELTs

Ikuru Iwata
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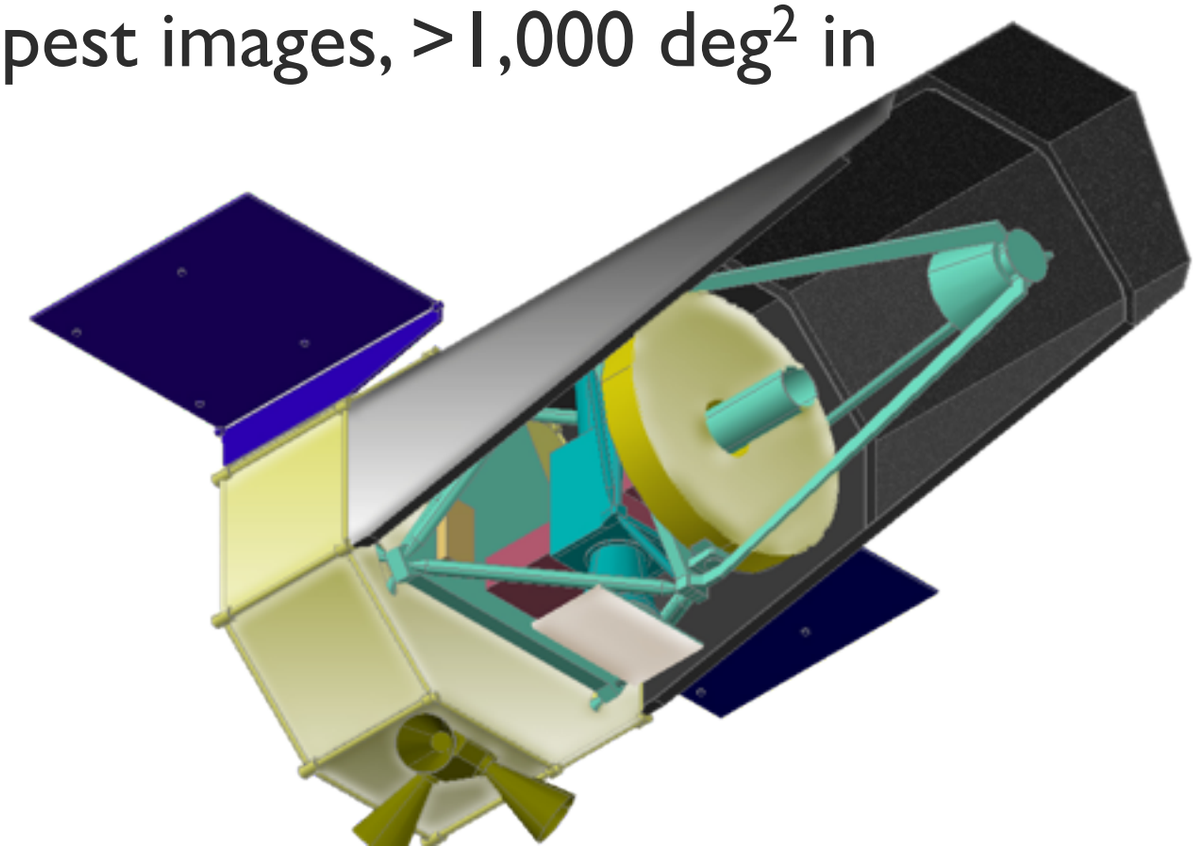
http://wishmission.org

WISH: Wide-field Imaging Surveyor for High-redshift

- Space Telescope Mission with 1.5m Diameter Aperture
- Wide-Field Near-Infrared Camera (0.9 - 5 μm)
- (Passively) Cooled Mission with Sun - Earth L2 Orbit
- Depth - deeper than images with any ground-based telescopes
- Width - 100 square degrees in deepest images, >1,000 deg^2 in shallower surveys



WISH Working Group Members

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- NAOJ: I. Iwata, S. Tsuneta, T. Kodama, Y. Komiyama, M. Imanishi
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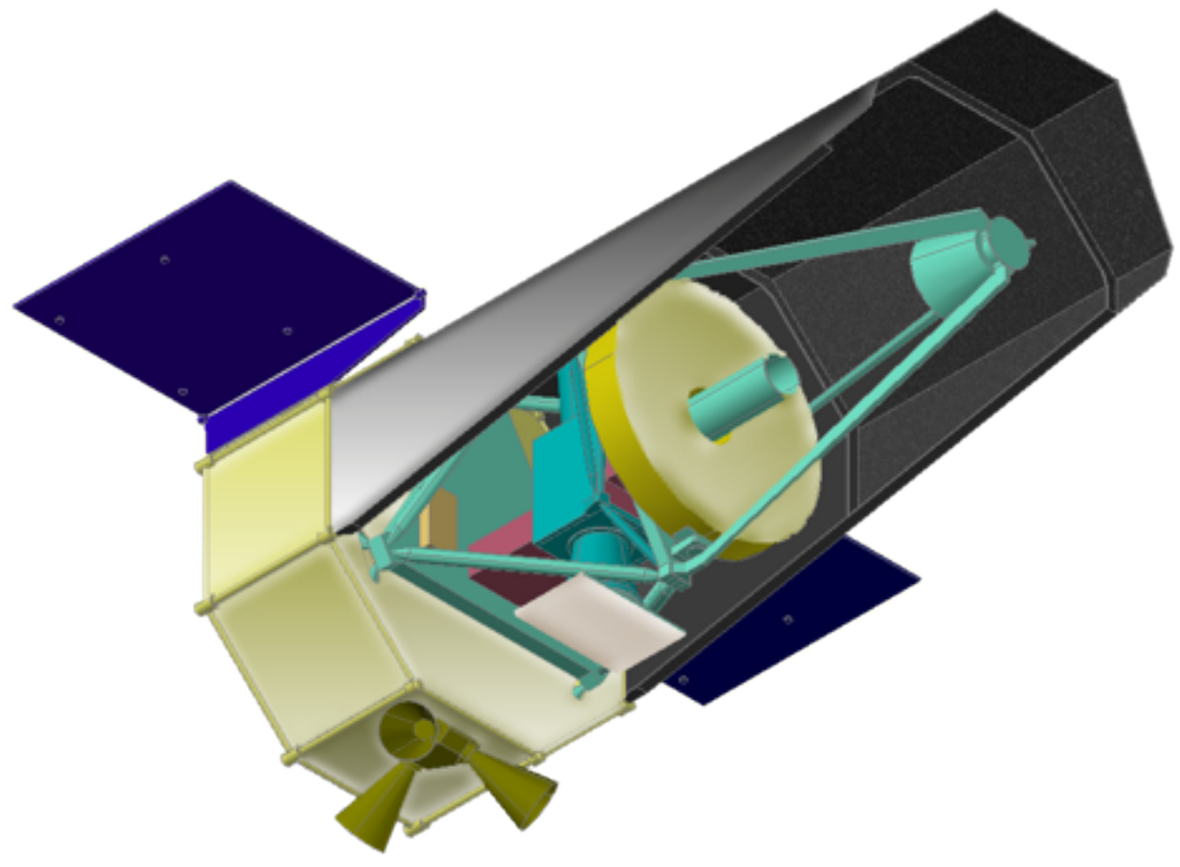
- Tokyo: T. Morokuma, M. Doi, N. Yasuda
- S. Oyabu (Nagoya), N. Kawai (TITech), D. Yonetoku (Kanazawa), A. K. Inoue (Osaka-Sangyo), T. Goto (UH), Y. Ikeda (Photocoding / Kyoto-Sangyo), S. Iwamura (MRJ)

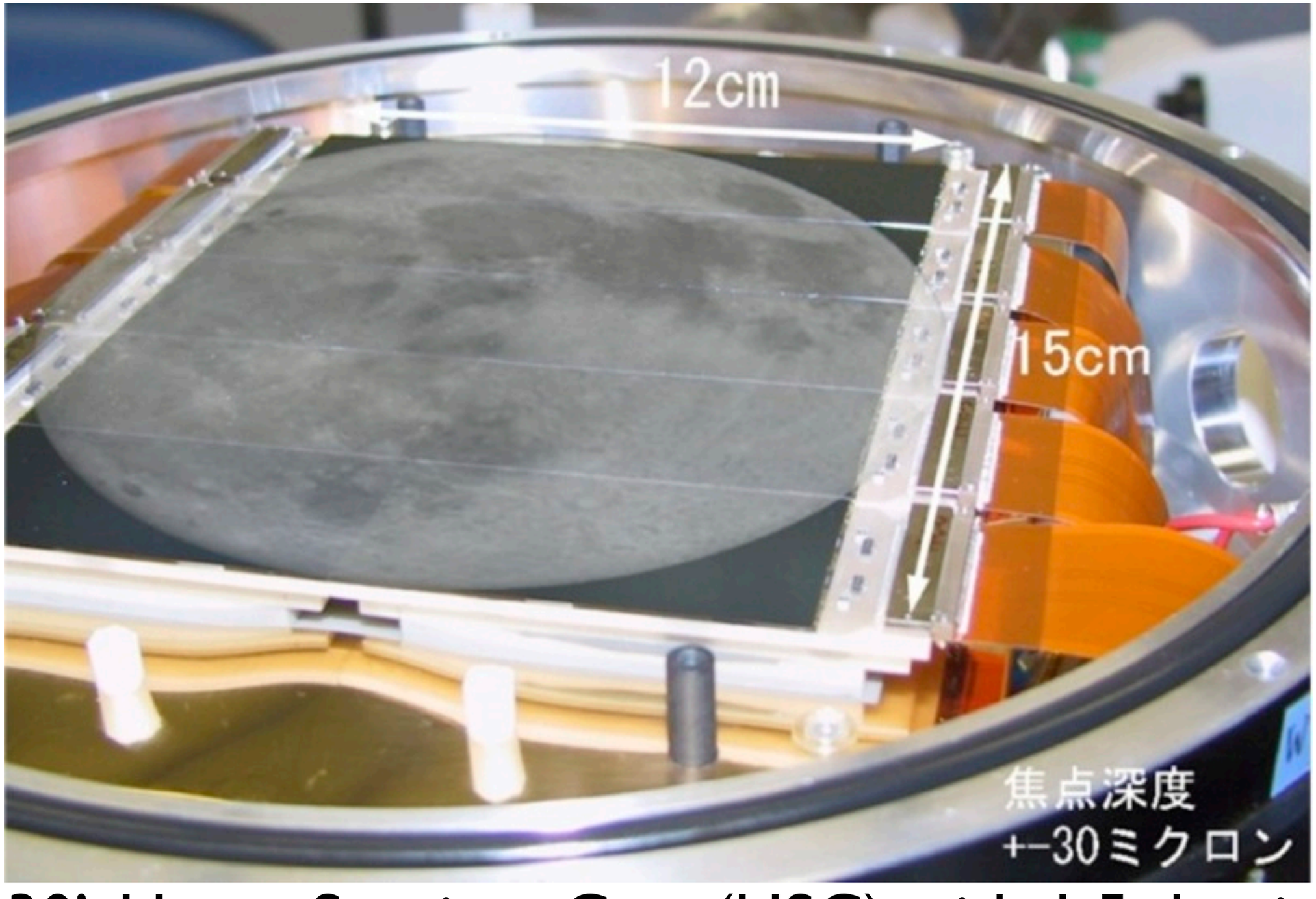


WISH: Scientific Objectives

WISH: Science Objectives

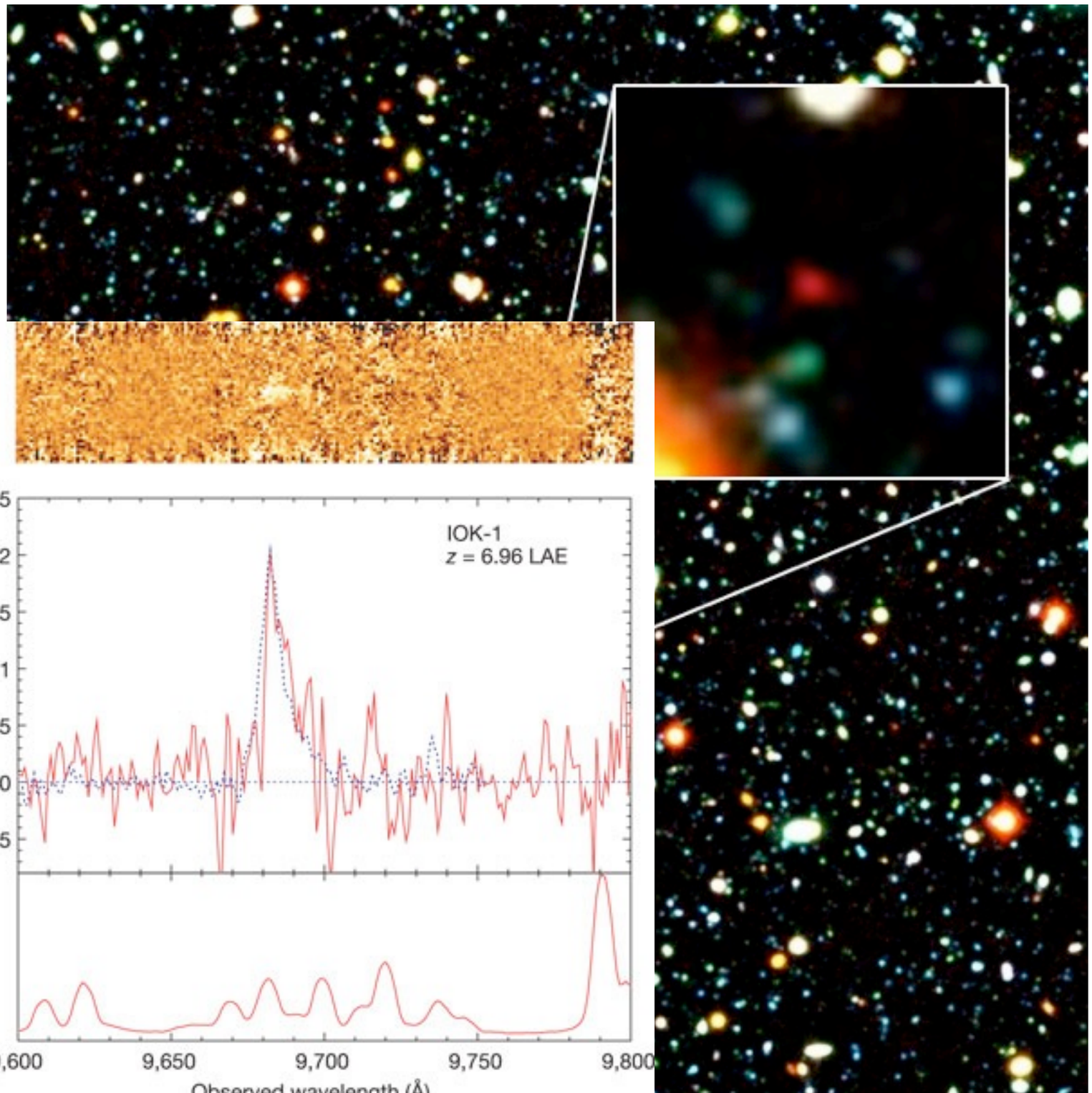
- Unveiling the First Epoch of Galaxy Formation:
  - Detections of Large Sample of First-Generation Galaxies (7<z<15)
  - Explorations of the Cosmic Reionization
- Constraining Dark Energy using Type Ia Supernovae
  - Detection and Light Curve in Rest-frame Near-IR
- Transient Objects such as Gamma-ray Bursts and Luminous Supernovae
- Legacy Near-IR Survey Data with Unprecedented Depth and Area
  - Galaxy Evolution, High-z AGN, Galaxy Stellar Population and more.

Subaru Suprime-Cam



FoV ~30’; Hyper Suprime-Cam (HSC) with 1.5 deg. in 2012

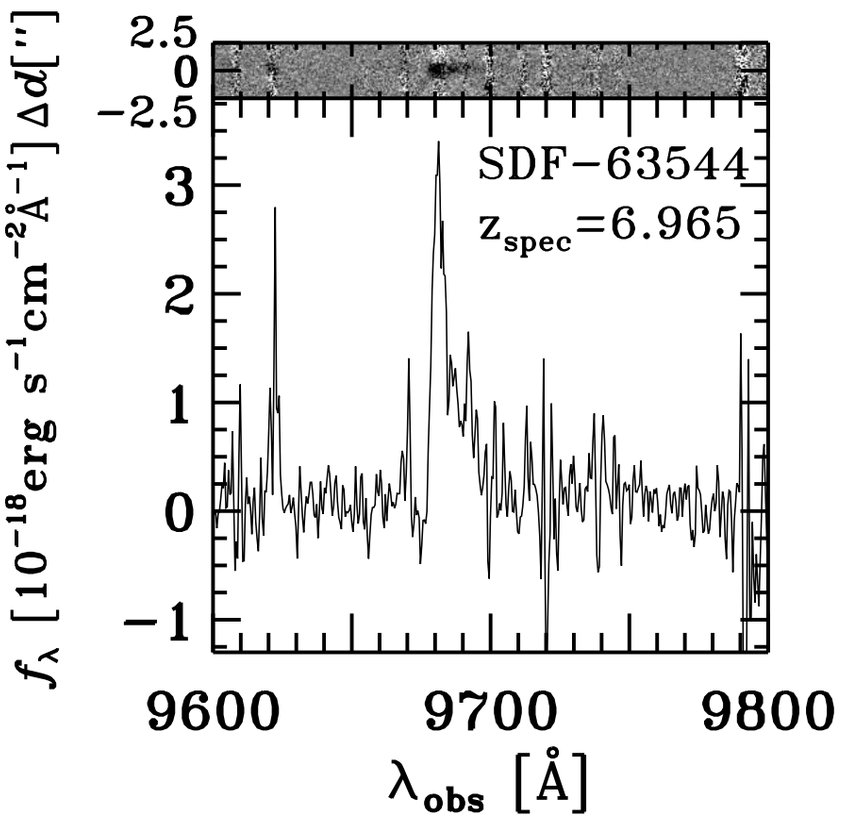
Achievements of Subaru Wide-field Imaging

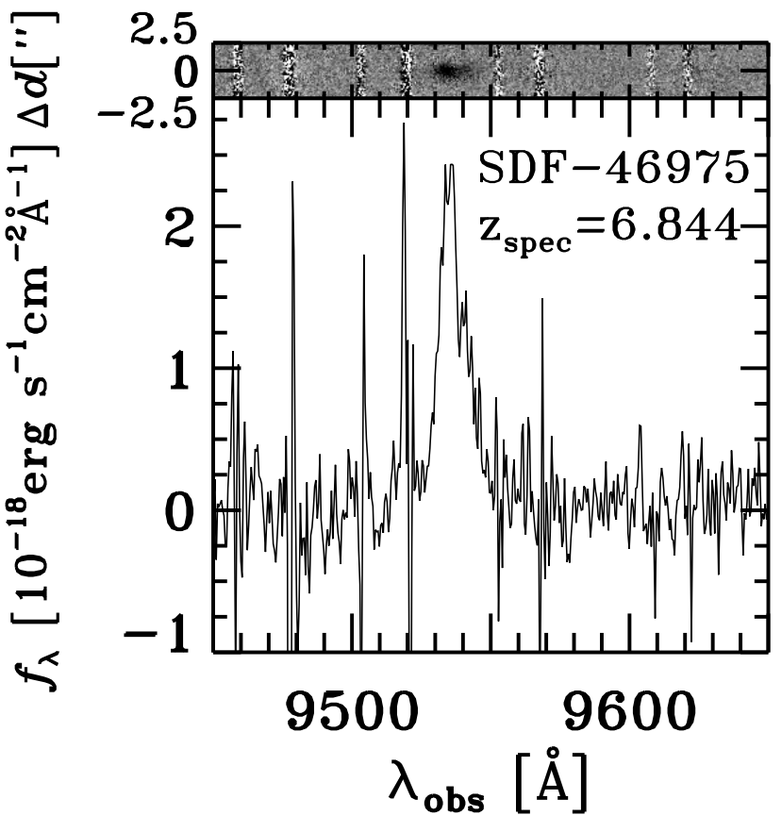


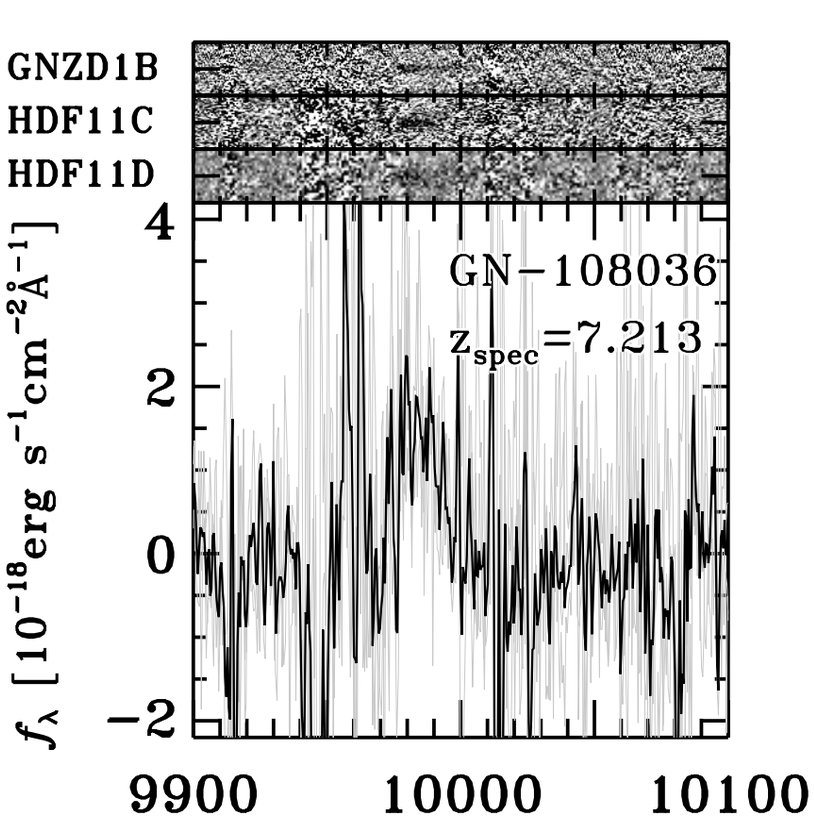
Iye et al. 2006
z=6.964
(Cosmic age=
750 Million years)

Lyα at 0.97μm

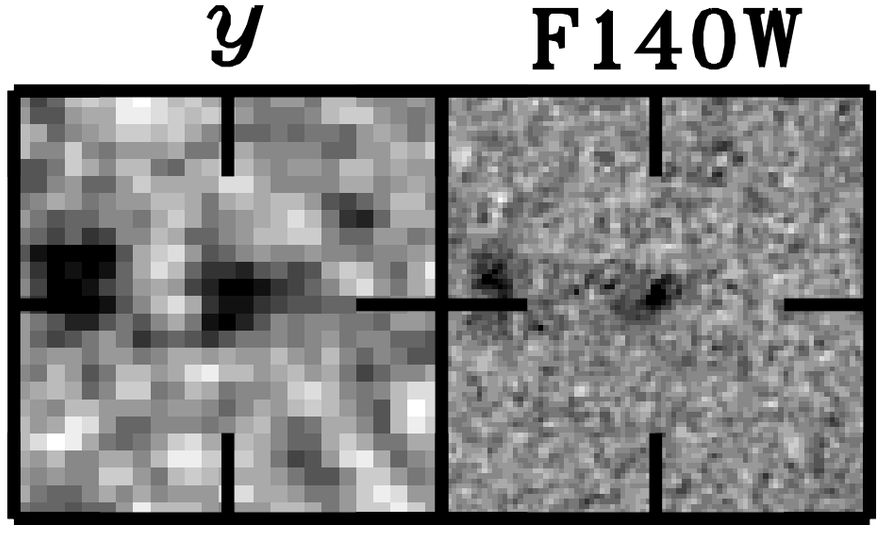
Achievements of Subaru Wide-field Imaging







Ono et al. 2011
z-dropouts



Years after the Big Bang

0.3 million

0.5 billion

1 billion

9 billion

13.5 billion

Big Bang

WISH

ionized inter galactic space

HST and 8-10m Telescopes

images credit: NASA / WMAP Science Team, Subaru Telescope/NAOJ

The Universe was filled with ionized gas

Hydrogen turned to be neutral

The Cosmic Dark Age

First astronomical objects: formation of galaxies and quasars. Beginning of the cosmic reionization

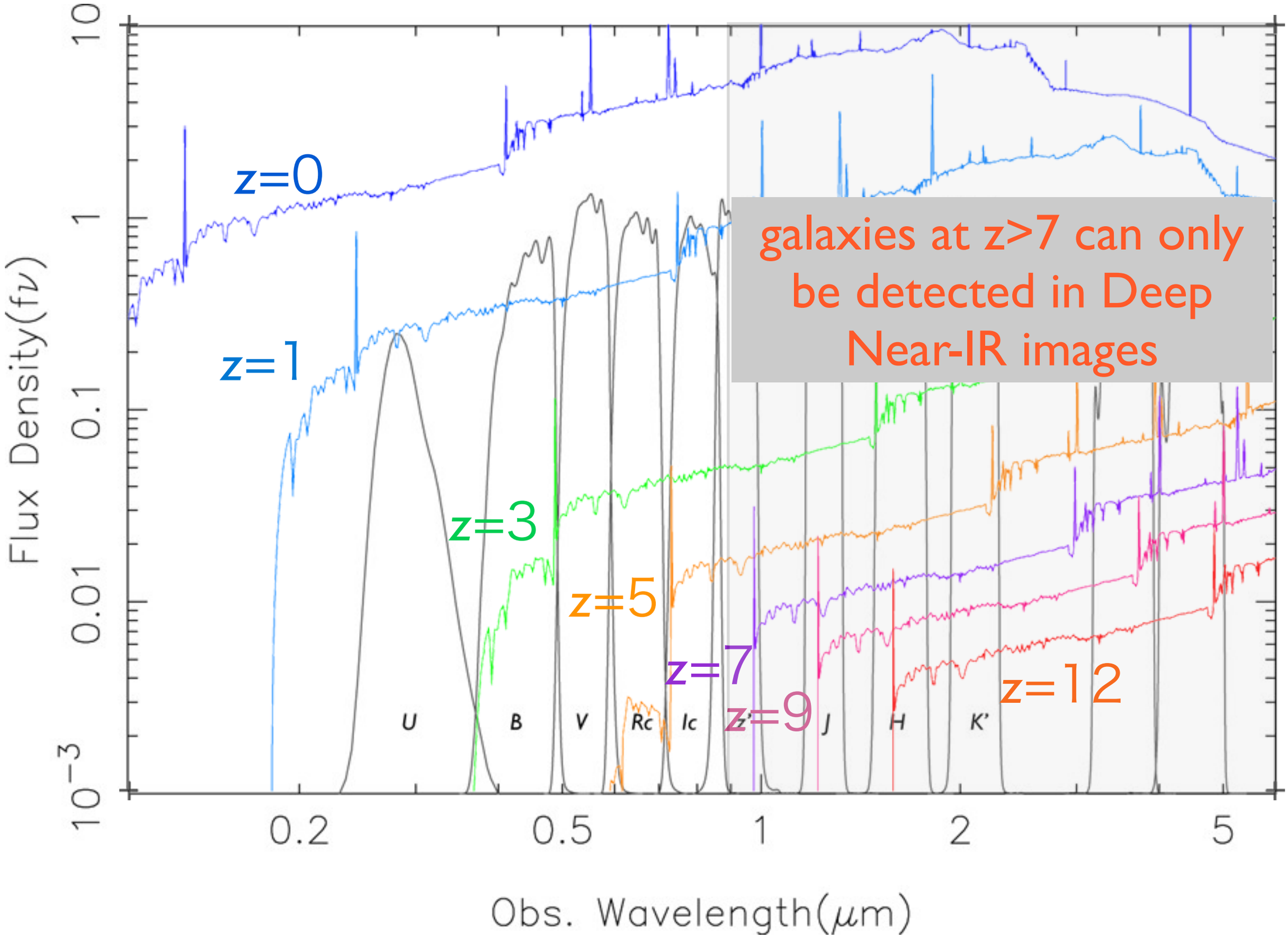
Renaissance of the Universe - the End of the Dark Age

Completion of the reionization: inter-galactic medium was ionized

Evolution of galaxies

Formation of the solar system

The Present Universe


z=0
z=1
z=3
z=5
z=7
z=9
z=12
galaxies at z>7 can only be detected in Deep Near-IR images
U
B
V
Rc
Ic
z'
J
H
K'
Flux Density(fν)
10
1
0.1
0.01
10^{-3}
0.2
0.5
1
2
5
Obs. Wavelength(μm)

ELTs Should Make Spectroscopy of 'First Galaxies'. But Who can Provide the Targets?

Ground-based Telescopes Can't Find 'First' Galaxies

In Near-IR, the Depth of the Broad-band Images is Determined by the Background Radiation. Thermal Noises Prevent Us to Reach >27 AB Mag.

Cooled Space Telescope is Required.

Depth + Survey Area are the Keys.

Point Source, 10^4 sec

2μm

VISTA

MOIRCS

HAWK-I

WISH

TMT/IRIS

JWST/NIRCam

Lim. Mag(5σ)

24

26

28

30

0.1

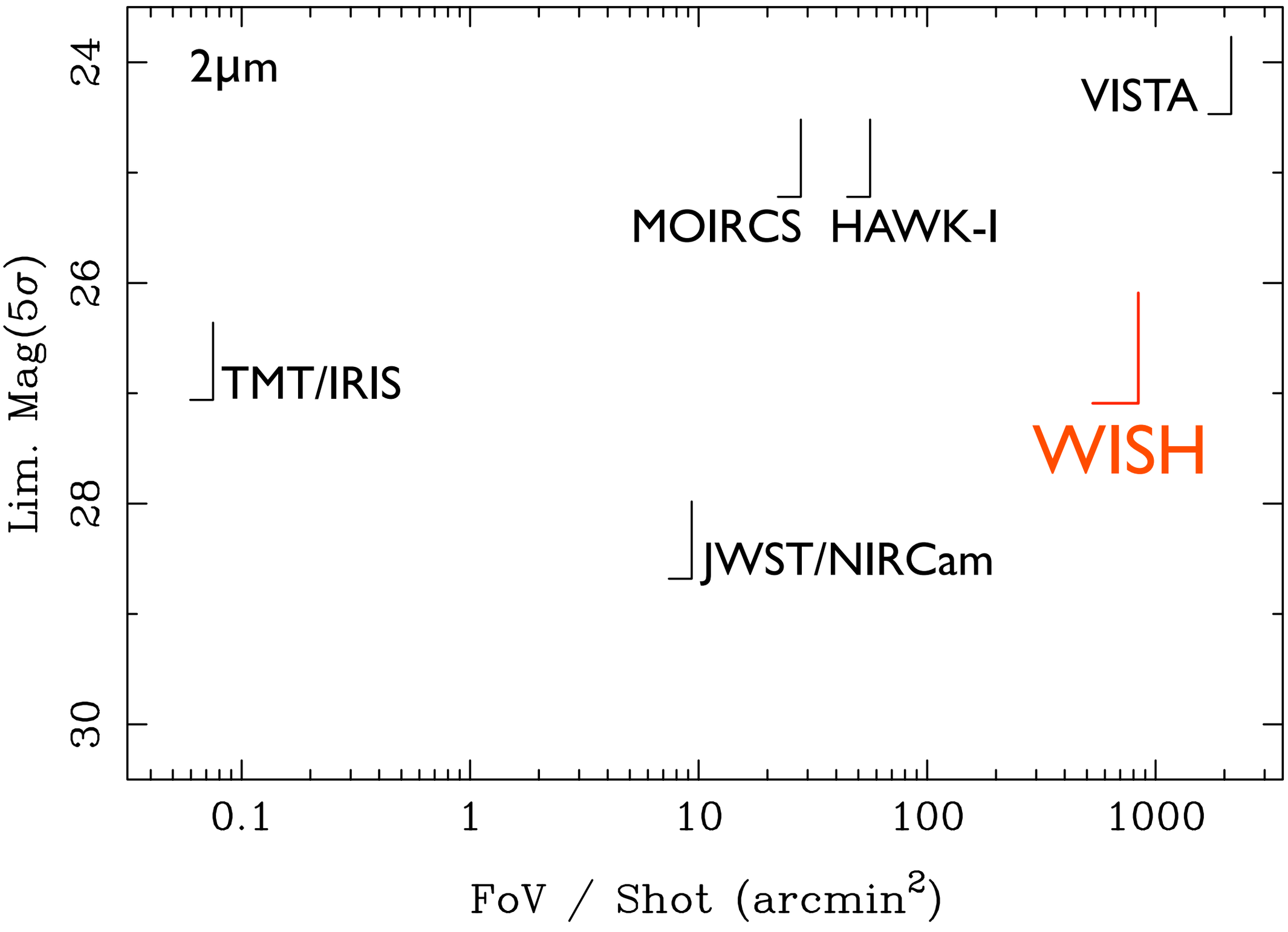
1

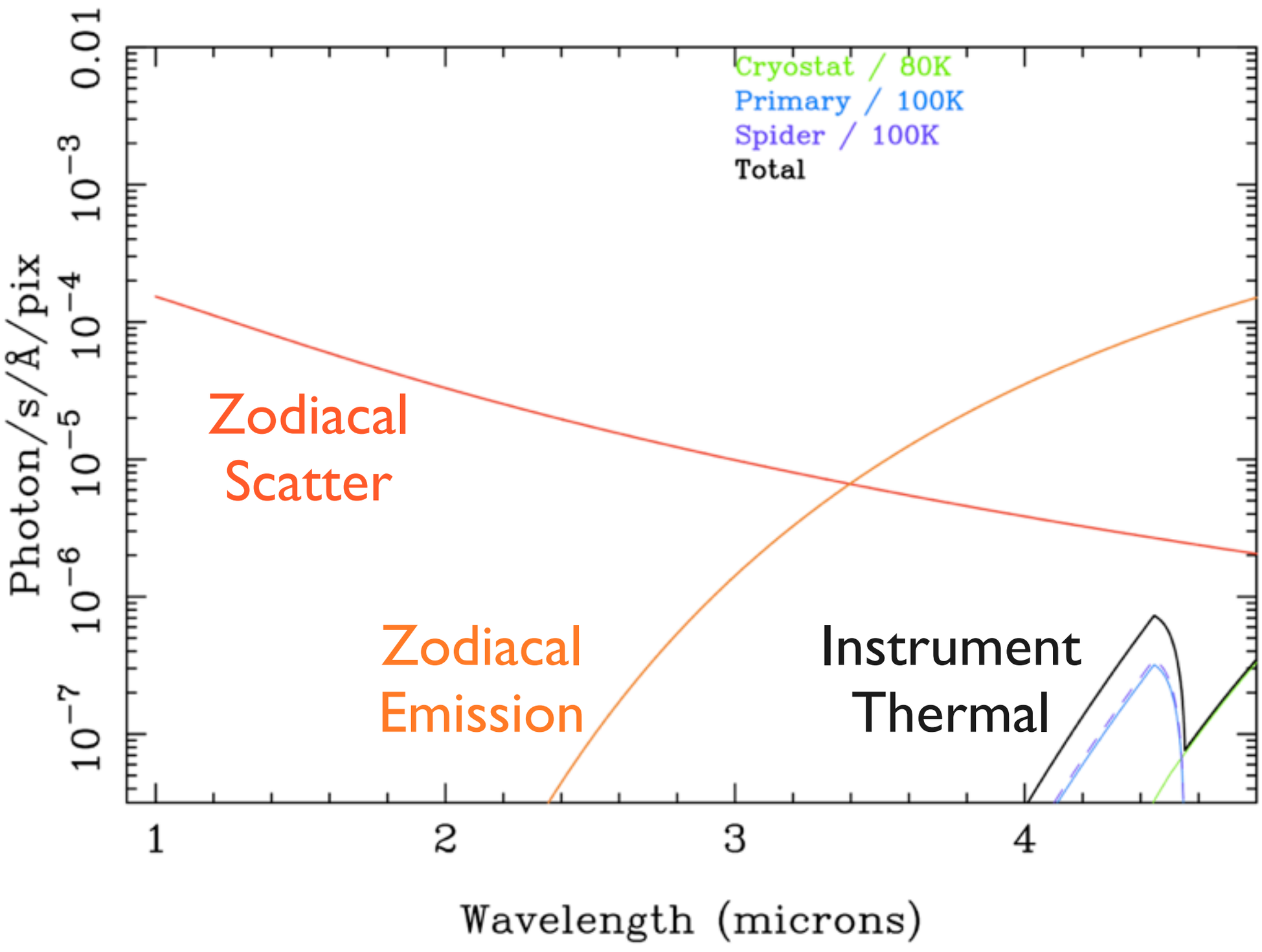
10

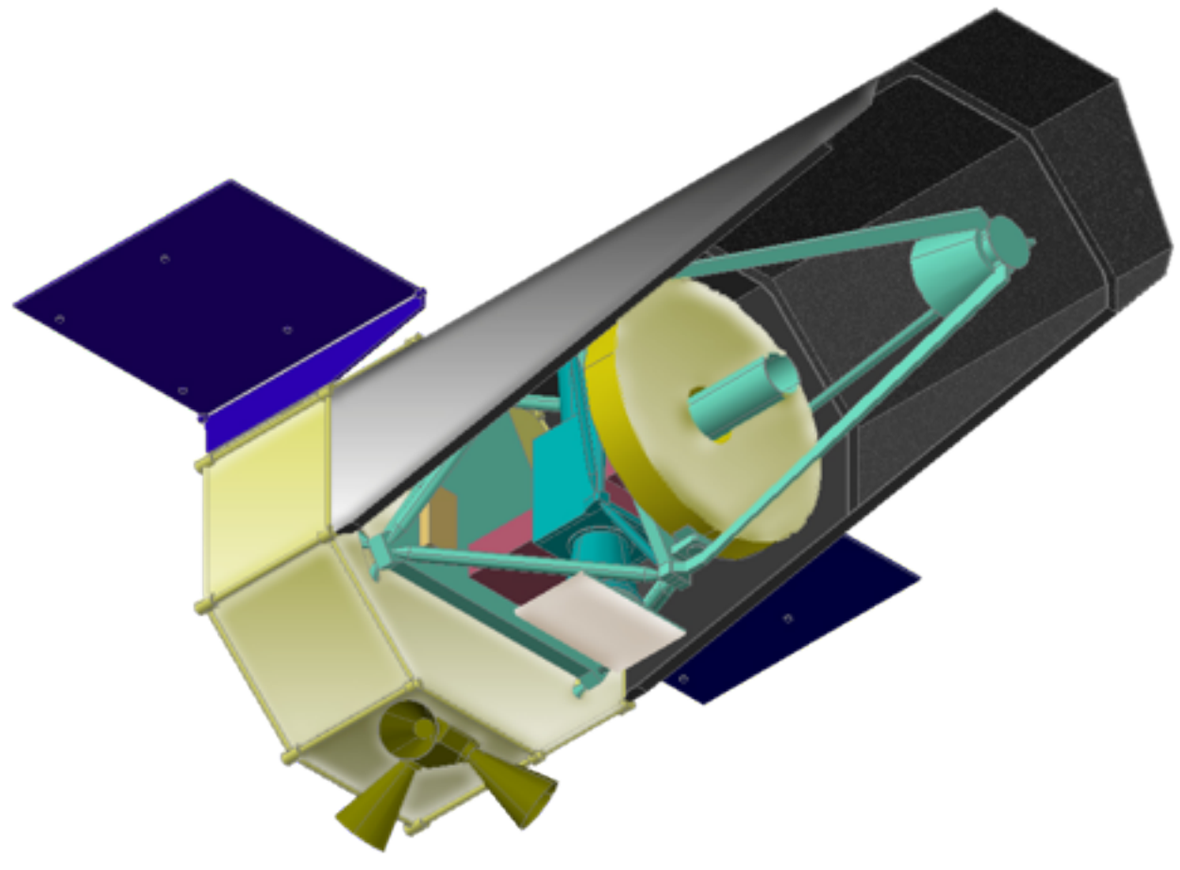
100

1000

FoV / Shot (arcmin^2)


0.5″ Extended Source, 10^4 sec
2μm
VISTA
MOIRCS
HAWK-I
TMT/IRIS
WISH
JWST/NIRCam
Lim. Mag(5σ)
24
26
28
30
0.1
1
10
100
1000
FoV / Shot (arcmin^2)


Filter5 CRYO=80K MIRROR=100K
Cryostat / 80K
Primary / 100K
Spider / 100K
Total
Zodiacal Scatter
Zodiacal Emission
Instrument Thermal
Photon/s/Å/pix
0.01
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
1
2
3
4
Wavelength (microns)

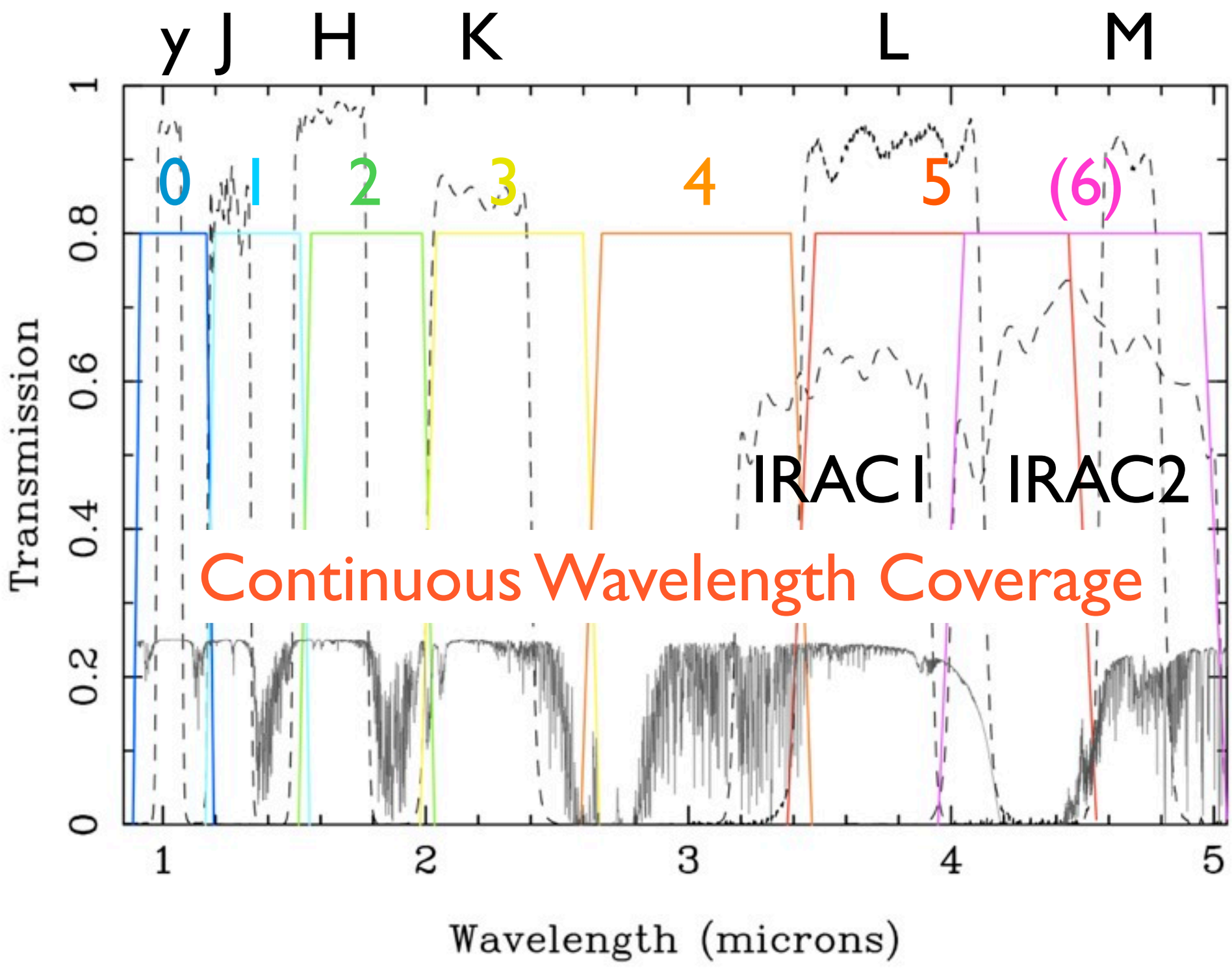


WISH: Expected Number of High-z Galaxies

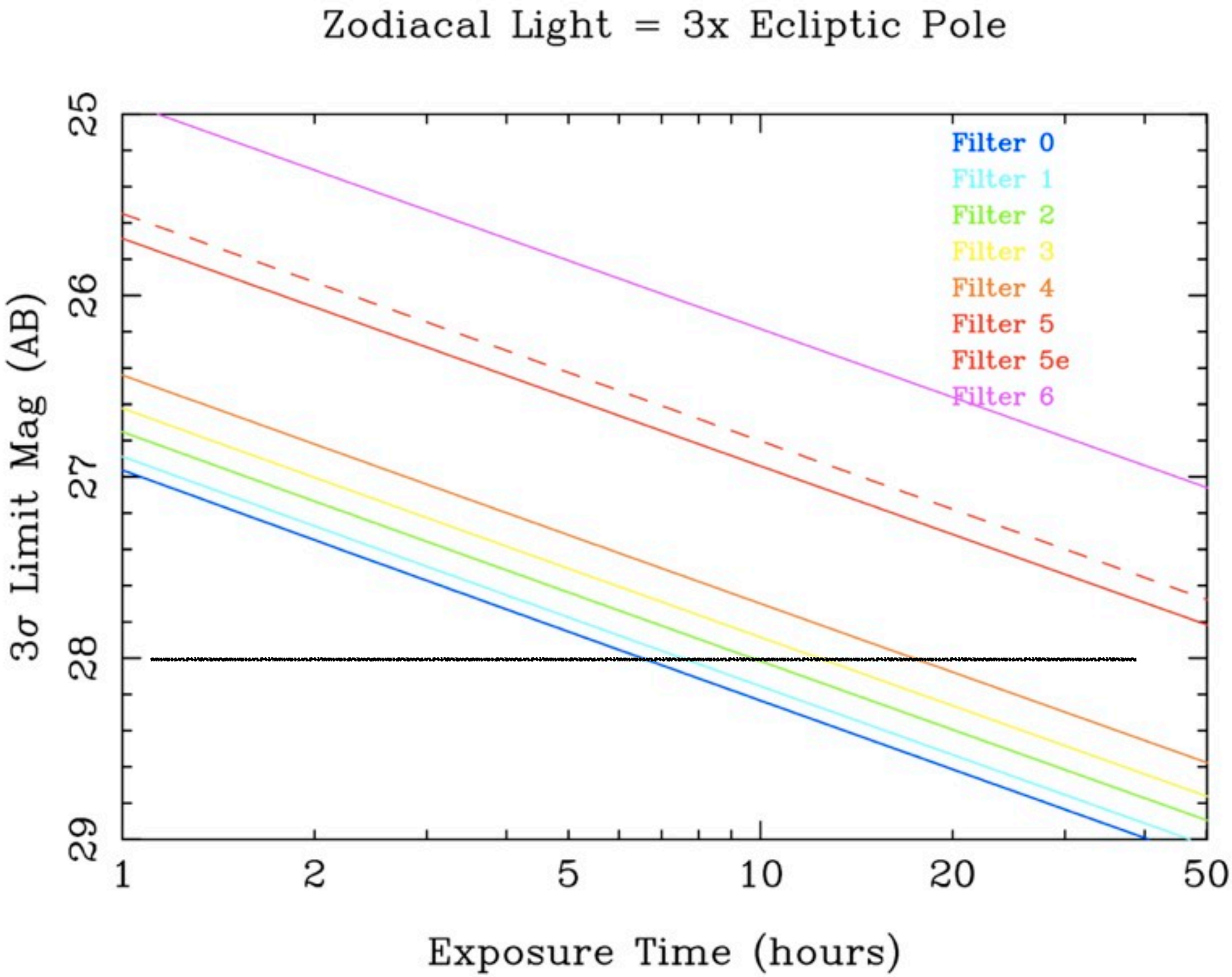
WISH Survey Plan

	Depth [AB mag.]	Area [sq. deg]	Days
Ultra Deep Survey	28.0	100	1,500
Ultra Wide Survey	25.0	1,000	50-100
Extreme Survey	~29.5	~1	<100

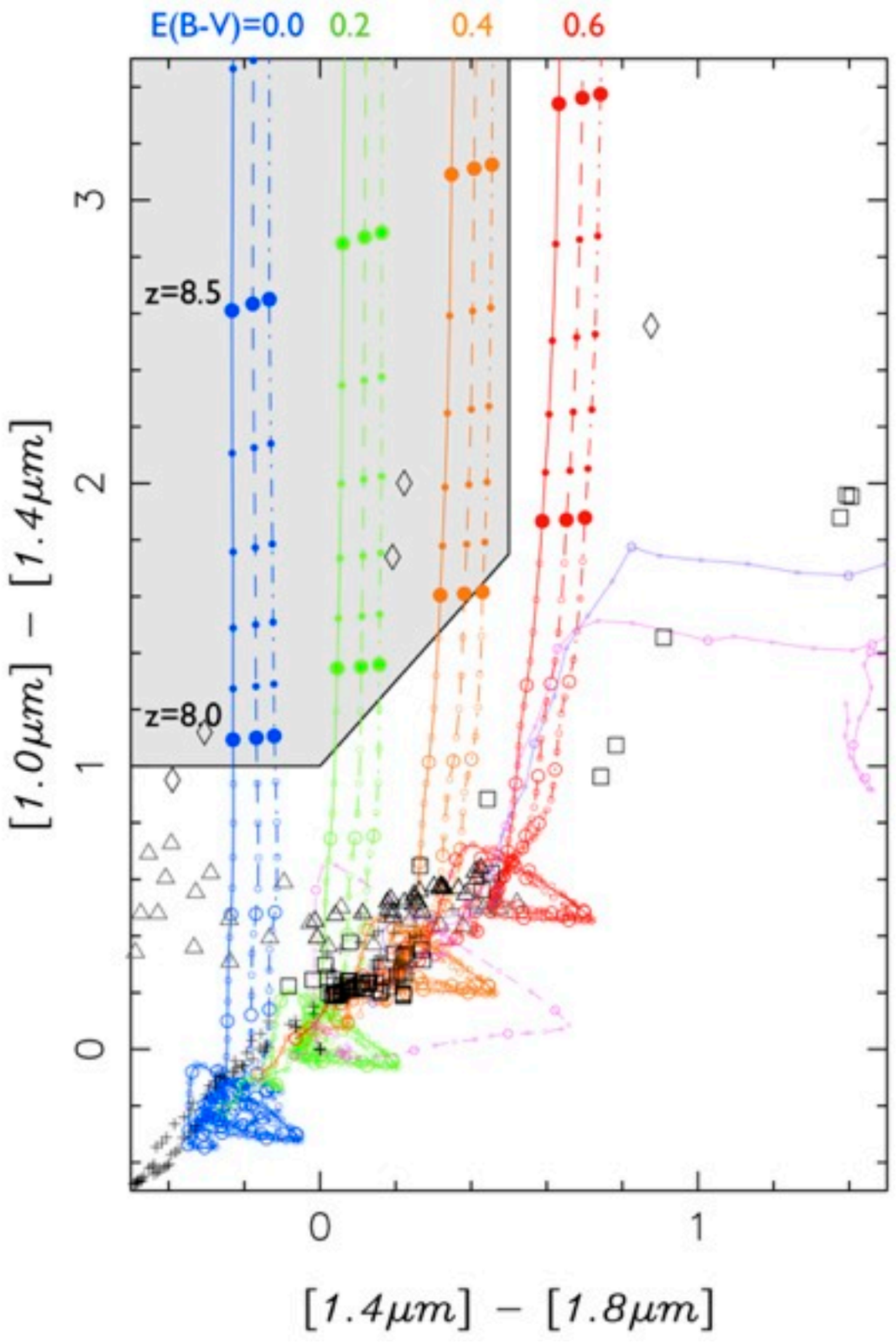
WISH Broad-band Filter Set

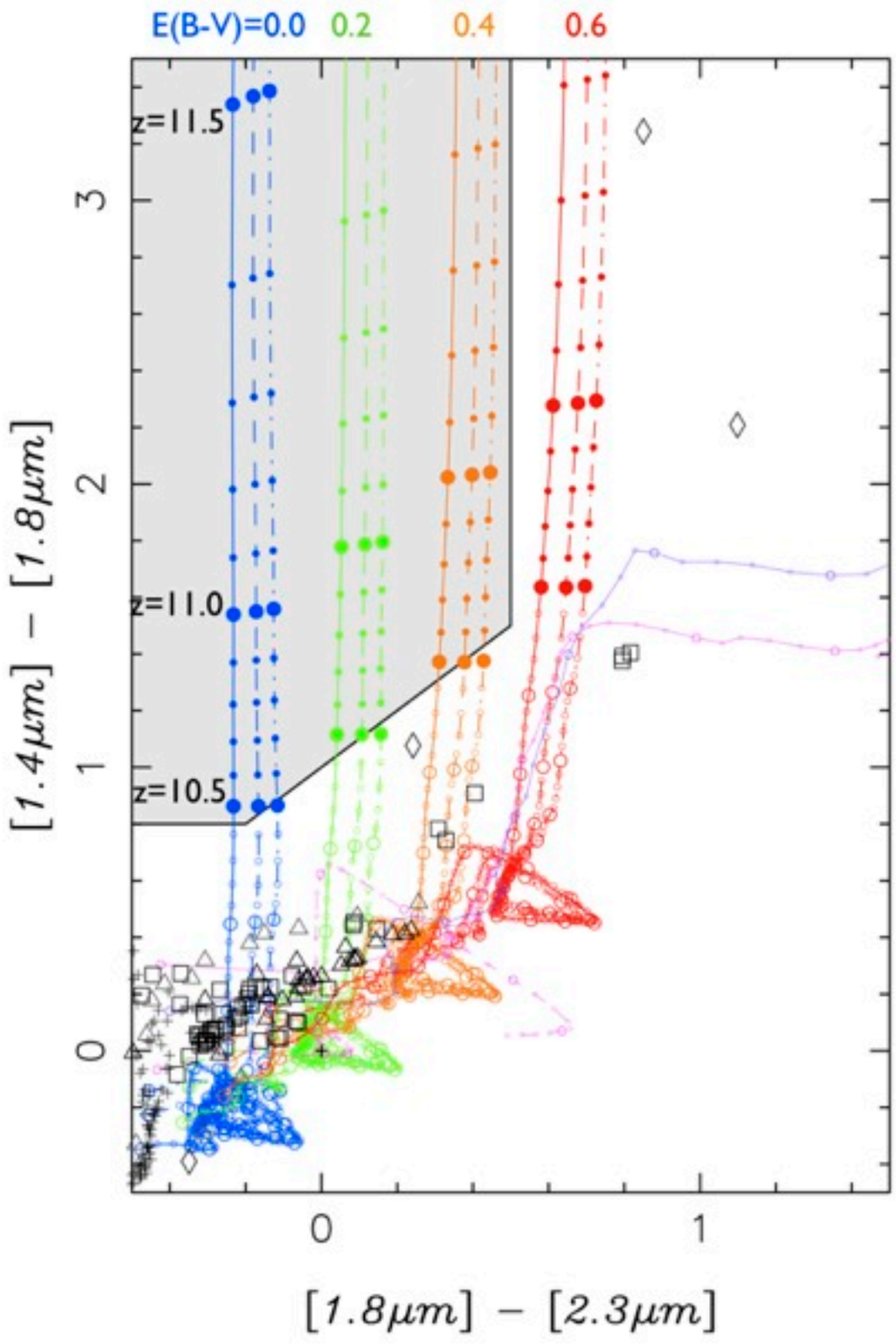


WISH: Expected Sensitivity

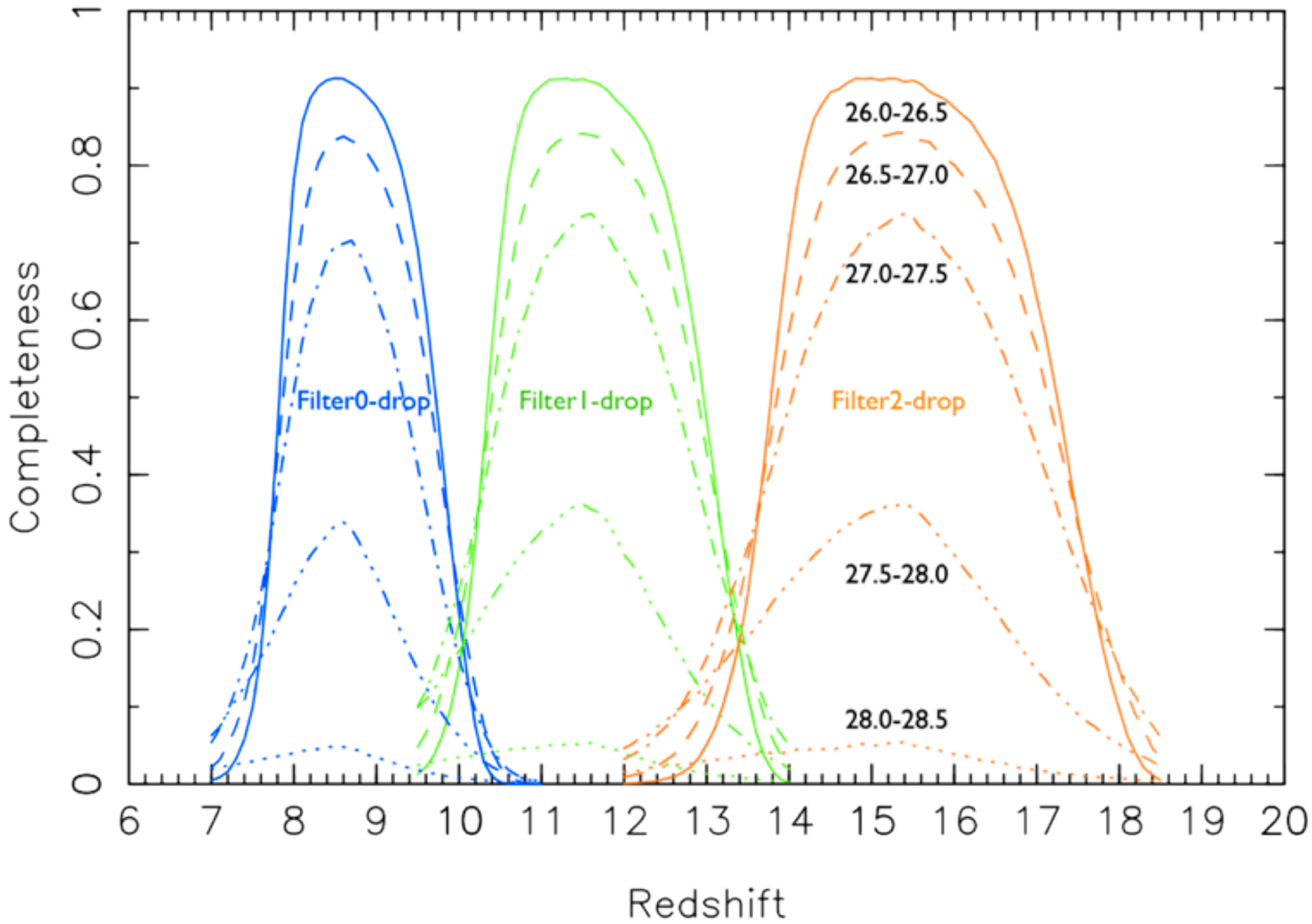


Selection of High-z Galaxies with Two-Colors



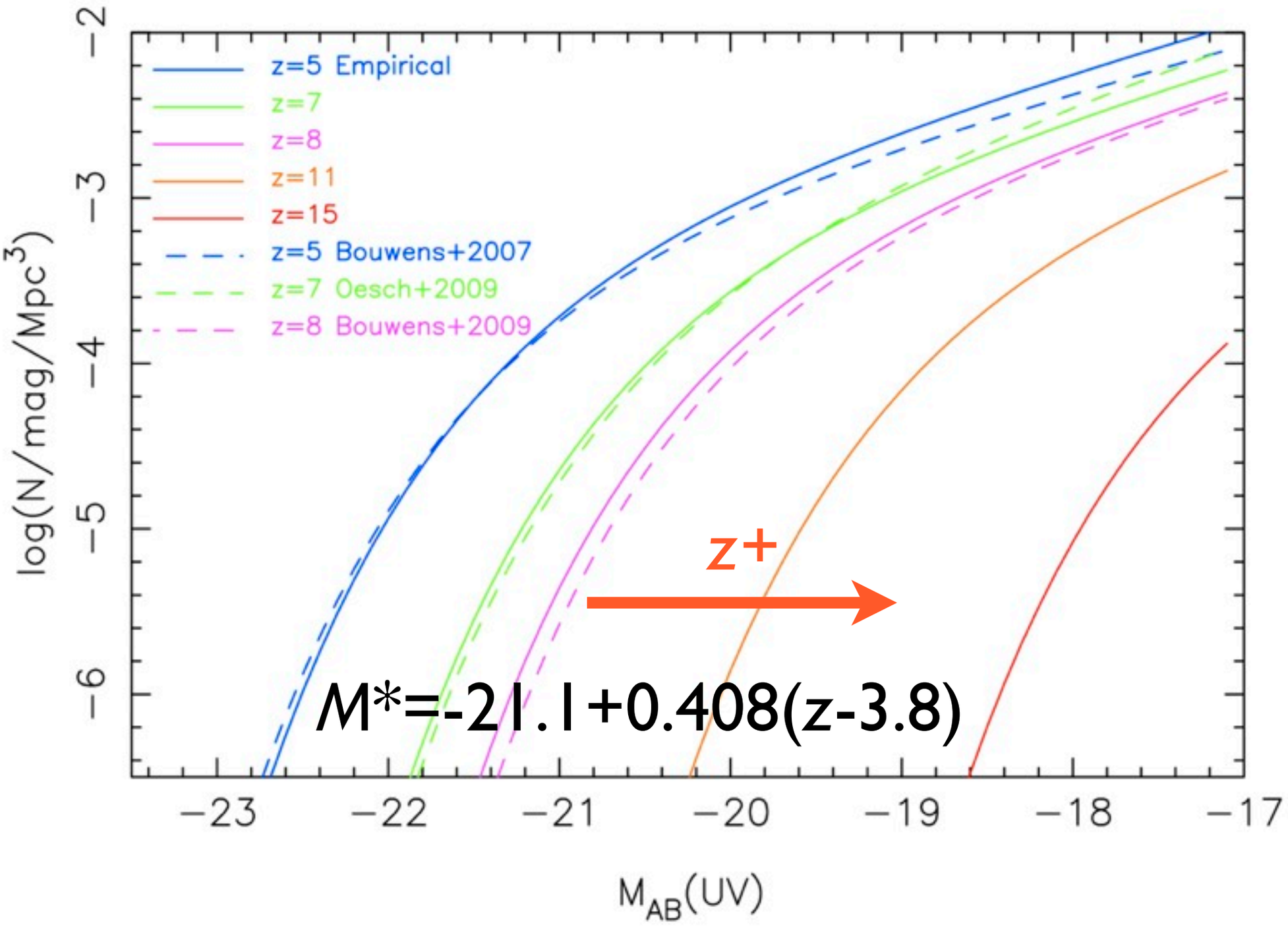


Completeness Estimates

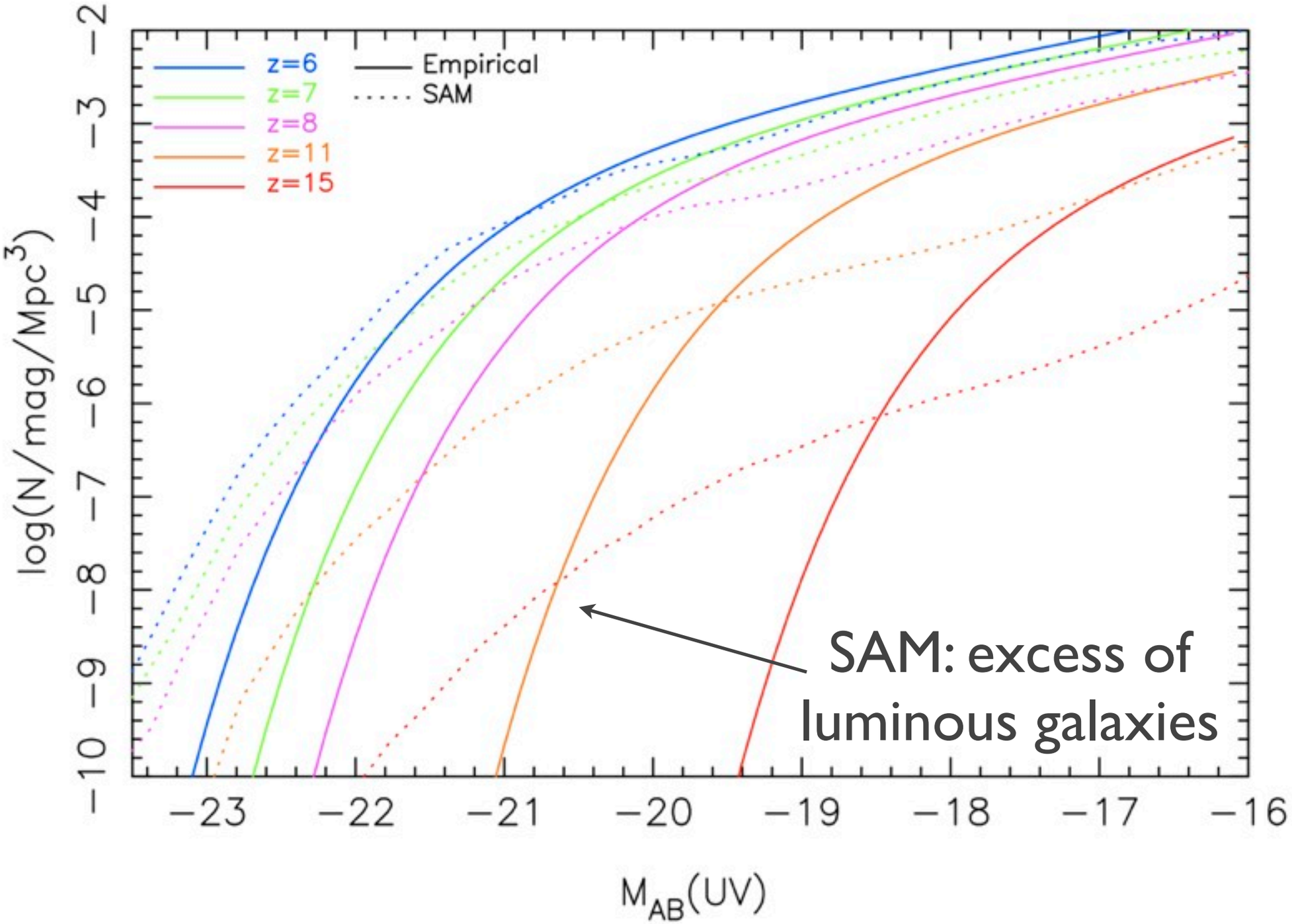


for the case of WISH (Lim. Mag. = 28AB)

Assumption on Evolution of Luminosity Function(1) Empirical Evolution



Assumption on Evolution of Luminosity Function(2) Semi-Analytic Model by Kobayashi et al.



Expected Numbers with WISH Ultra-deep Survey

- 100 sq. deg survey with 5 filters from 1.0μm to 3.0μm
  - Limiting magnitudes 28AB (point source, 3σ)
  - Total 1,500 days

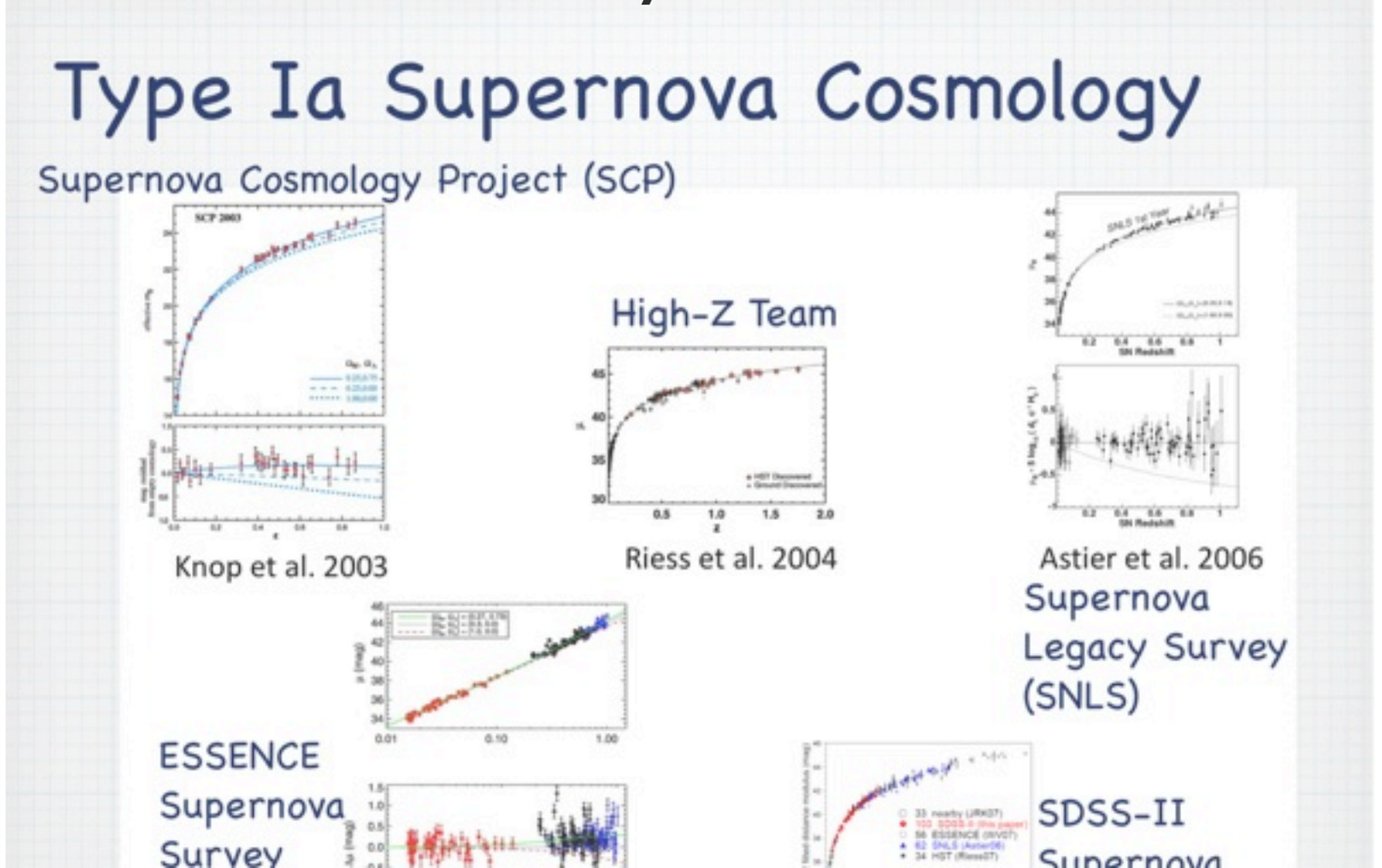
	z=8-9	z=10-12	z=13-17
Empirical Ev.	169,000	10,420	72
SAM	63,120	4,970	107

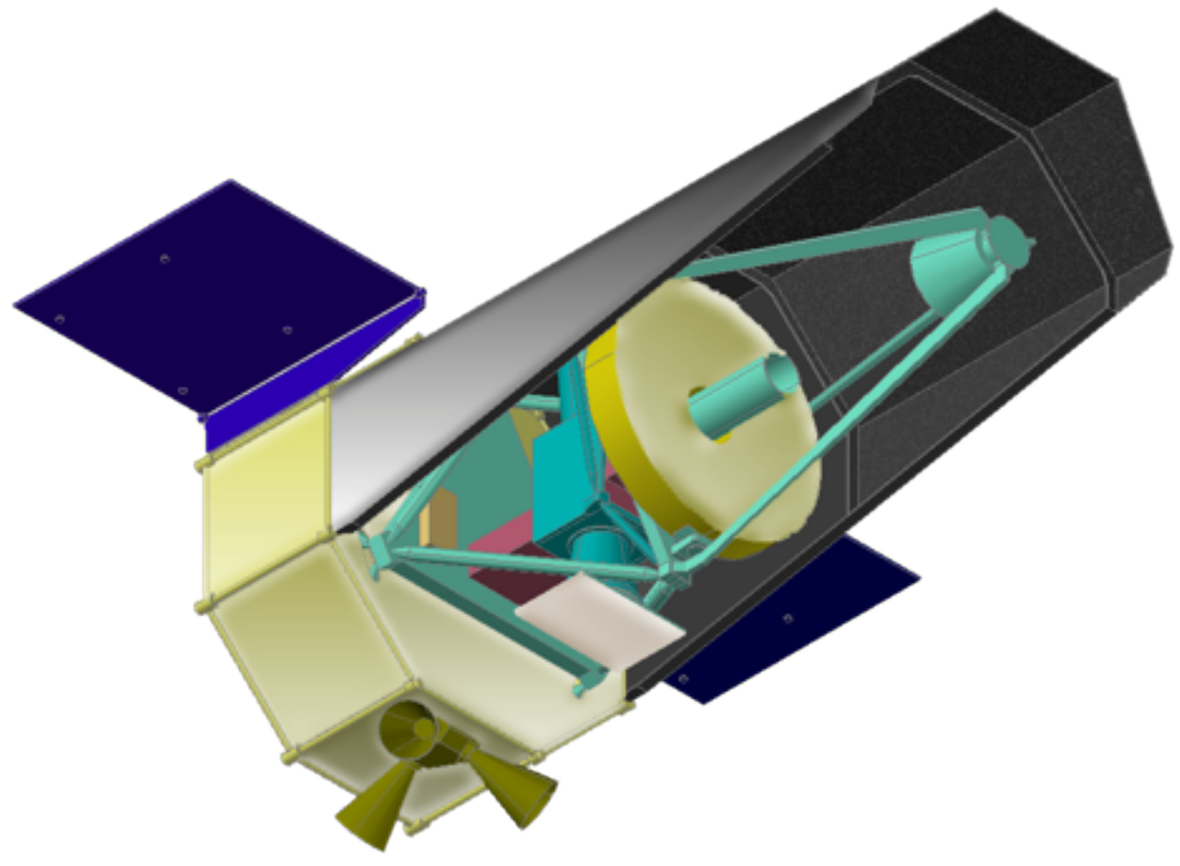
WISH can provide large number of targets to ELTs.

Supernova Survey

- Repeat Observations → Find Transient Objects
- Type-Ia SN Search can be made Simultaneously.
- ~2,000 Type Ia SNe (0<z<2-3) are expected
- Rest-frame IR Light Curve: Less Affected by Dust

Slide by
T. Morokuma

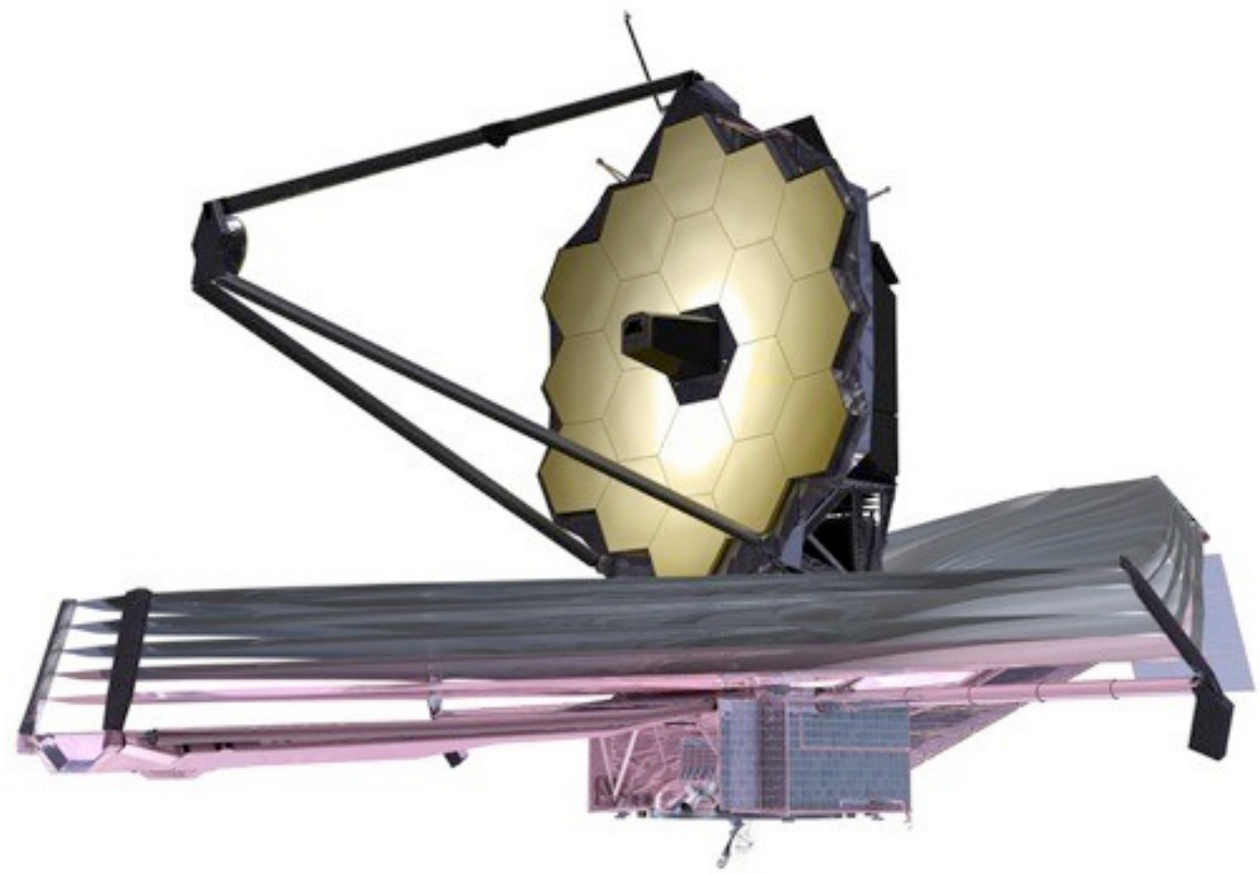




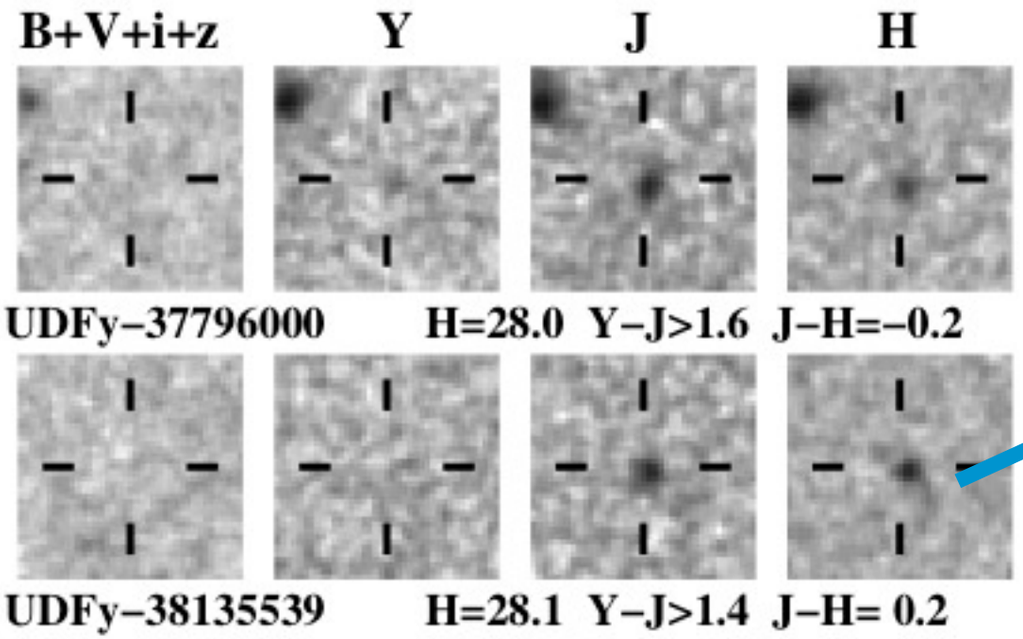
Why WISH is Indispensable

JWST

- 6.5m Deployable Mirror, Passive Cooling at S-E L2
- Four Science Instruments:
  - MIRI: Mid-IR (5 - 28μm)
  - NIRSpec
  - NIRCam
  - TFI: Tunable Filter Imager



HST/WFC3

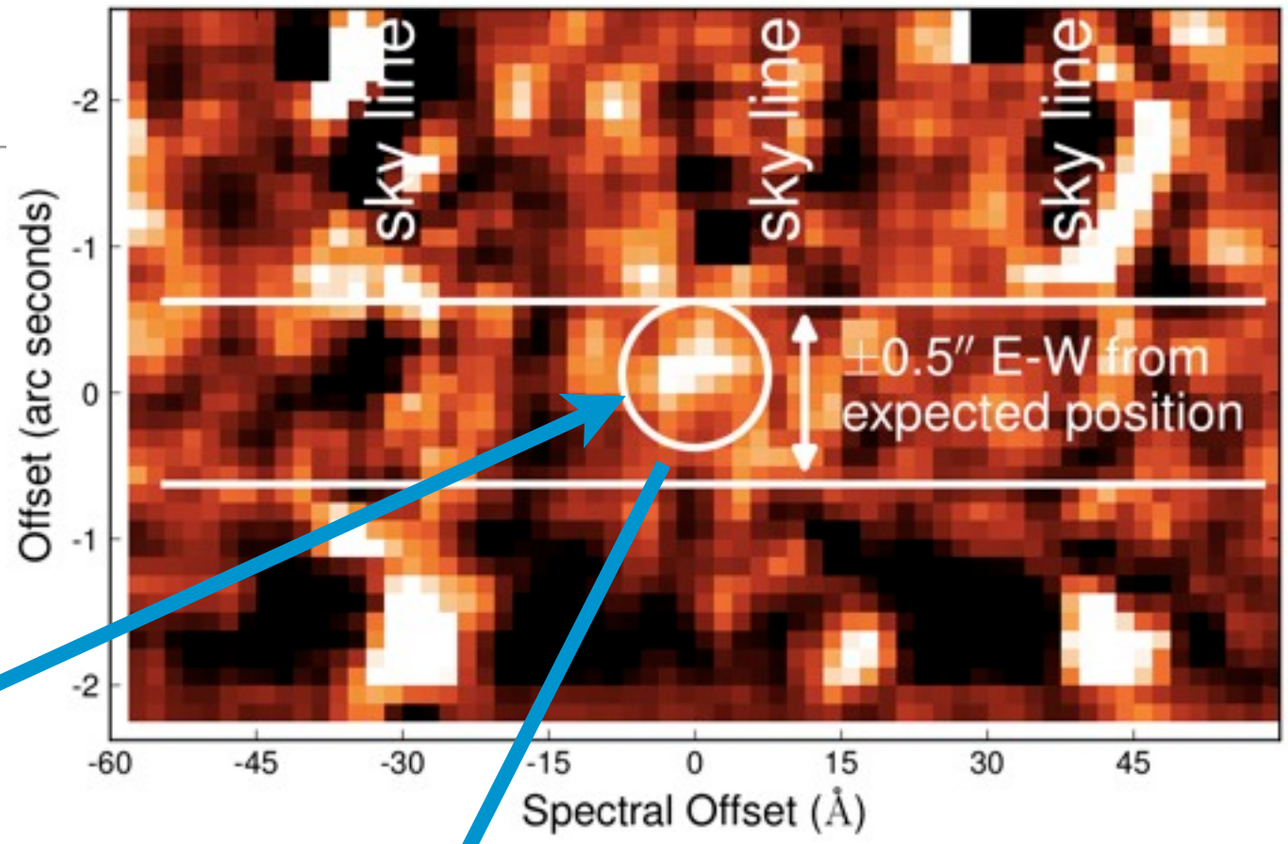


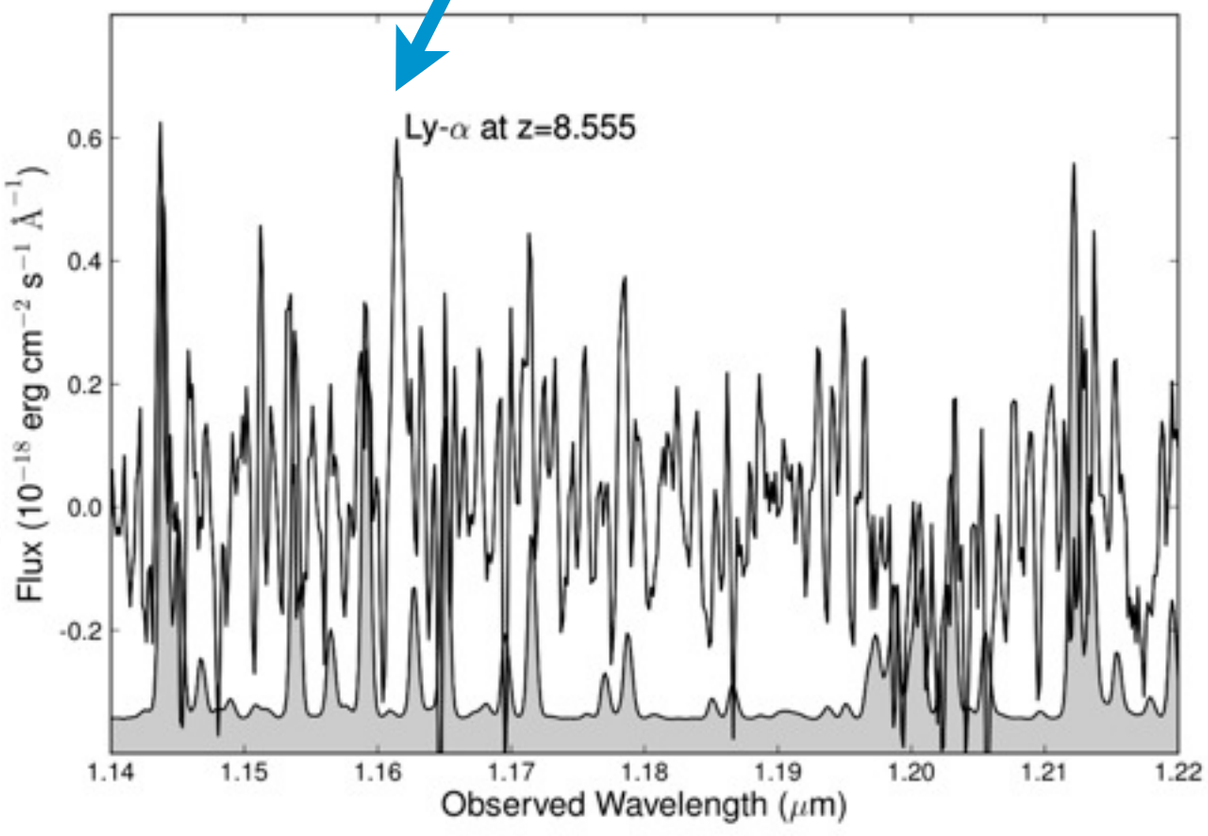
Bouwens+2010

Bunker+ 2010 etc.

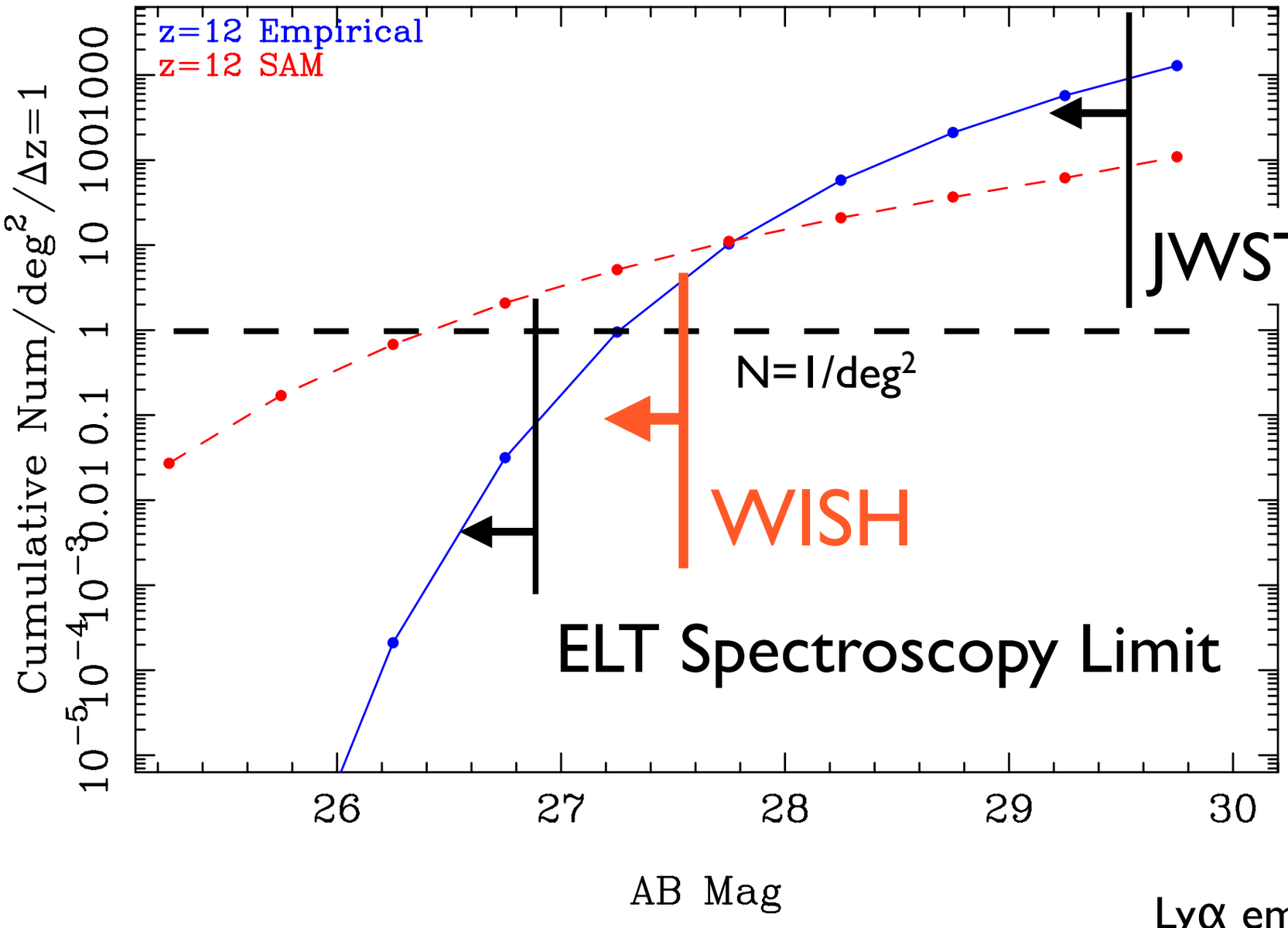
Lehnert+2010

VLT/SINFONI





Number Density of z=12 Galaxies



Lyα emission would not help improving the detection limit with ELTs for extended sources

Field of View

Survey Area

WISH Ultra-Deep Survey
100 deg^2
450 Pointings

JWST/NIRCam
10min^2

WISH
840min^2

Why is WISH So Important?

- JWST will discover numerous candidates of very high-z galaxies, but most of them are too faint to be followed-up with JWST itself and ELTs.
- Narrow FoV of NIRCam makes wide-field surveys very expensive.
- JWST + WISH: Complimentary to constrain UVLF Evolution

- Wide-field + Dedicated Surveyor Enables to Find ‘Luminous’ Galaxies

Euclid, WFIRST, and WISH

	Euclid	WFIRST	WISH
Mirror	1.2m	1.3m	1.5m
FoV	0.5 deg^2	0.3deg^2	0.23deg^2
Visual Imager	RIz	↓	--
NIR Imager	YJH	0.6-2.0μm	0.9-5.0μm
Lim. Mag.	24AB	25.9AB	28AB
Survey Area	20,000 deg^2	>11,000 deg^2	100 deg^2
Primary Science	Dark Energy	DE, Exoplanet, QSO	First Galaxies

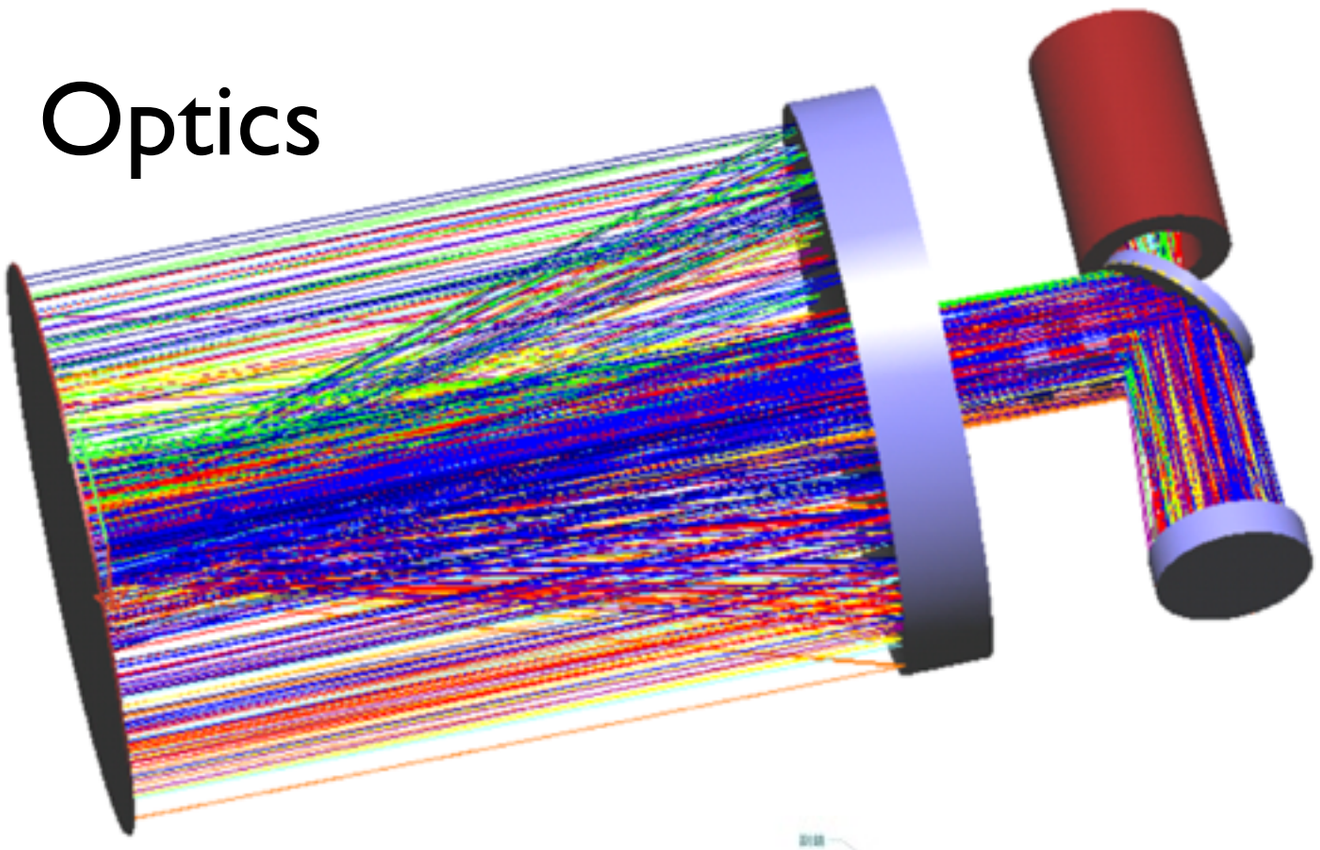
Euclid, WFIRST, and WISH

- Euclid, WFIRST:
  - Precise photometry and Image Quality
  - >10,000 deg^2 Survey
- WISH:
  - Optimized for Detection of Luminous High-z Galaxies to Feed ELTs
  - 1.5m Diameter Mirror Size is Mandatory
    - Image Depth
    - Diffraction Limit (0.15” at ~1μm)
  - Cover λ~5μm

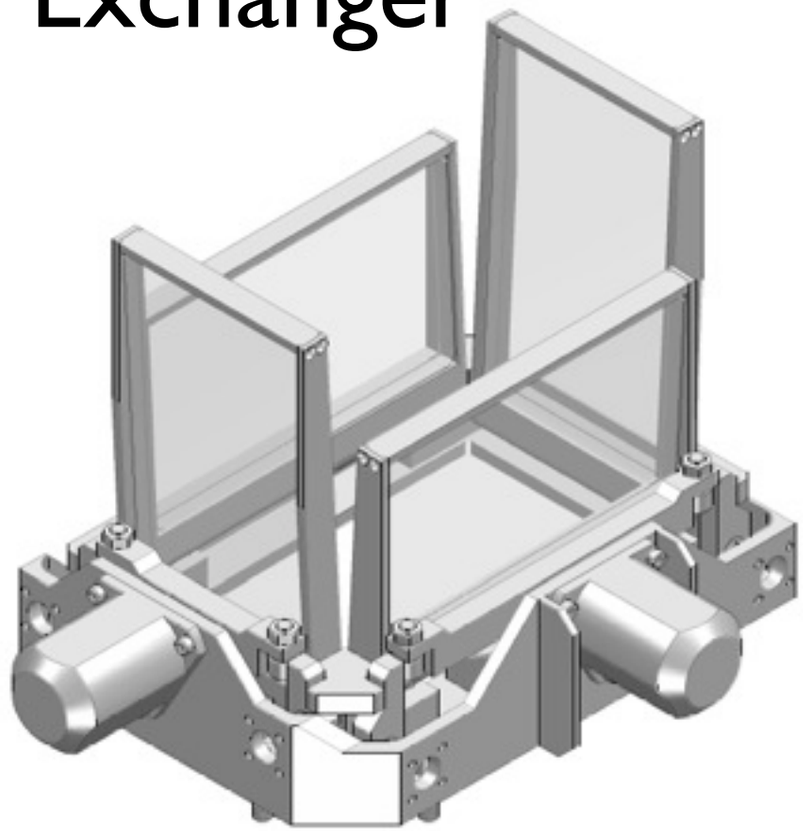
WISH is the Best High-z Sample Feeder for ELTs and Right Strategy to Tackle the Enigmatic Early Stage of the Universe.

R&D

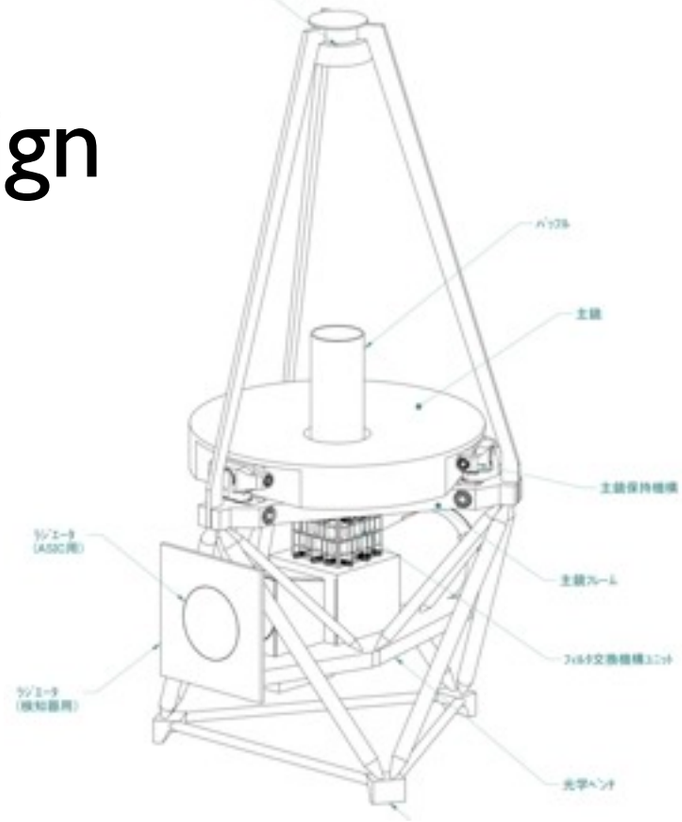
Optics



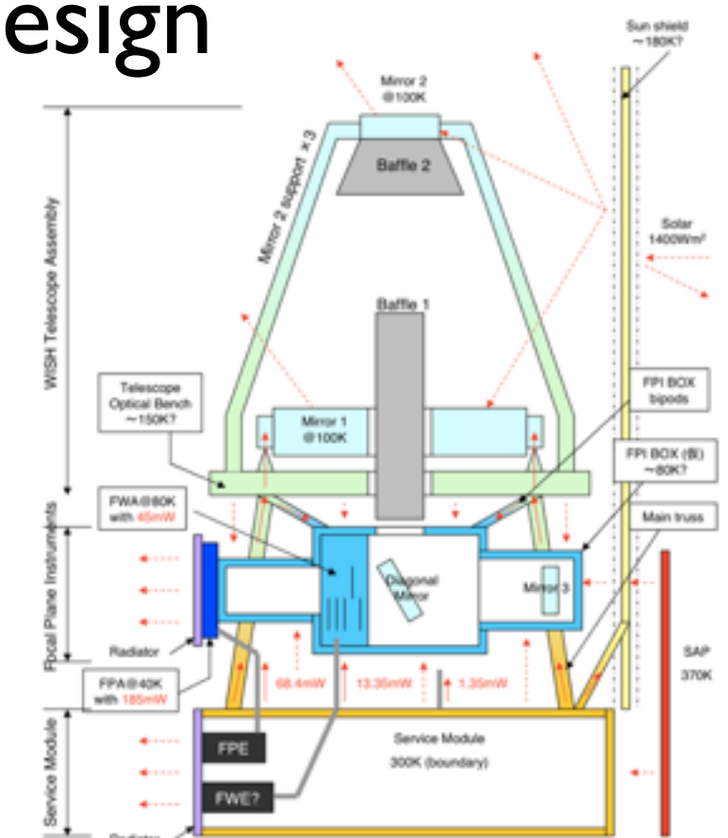
Filter Exchanger



Structure Design



Thermal Design



Make WISH Come True!

- 1.5m Space Telescope Optimized for Hunting Galaxies at z>10
  - 28 AB mag., 100 deg^2
  - λ up to 5 μm
- Provides Thousands of Galaxies at z>10 and Hundreds of Galaxies at z>13
- Now in Basic R&D and Preparing a Mission Proposal to JAXA
- Open for International Collaboration

http://wishmission.org