

Wish



# Wide-field Imaging Surveyor for High-redshift

超広視野初期宇宙探査衛星計画



Toru Yamada (Tohoku University /  
ISAS visiting professor)

On behalf of  
JAXA/ISAS WISH Working Group

WISH is a concept of future JAXA/ISAS space mission to be proposed and launched in early 2020's (~2021)

LiteBird



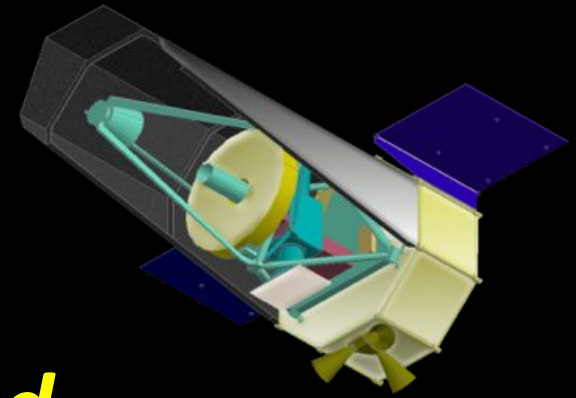
Solar-C

SPICA

WISH

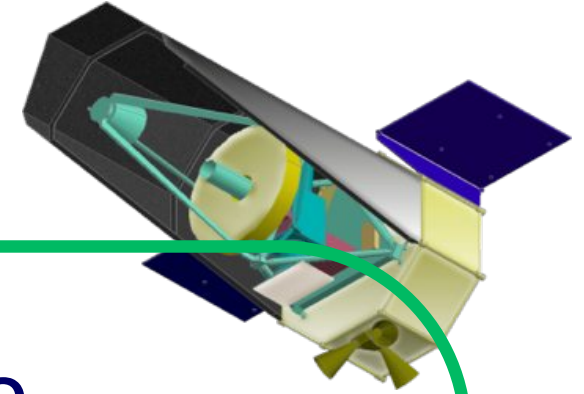
Status: JAXA/ISAS 'Steering Committee for Space Science'  
WISH Working Group (pre-Phase A)

# WISH Science Goals



1. Exploring the Galaxies *beyond*  
**the Epoch of Cosmic Reionization  $z=8-15$**   
*(Primary Science Case)*
2. NIR search and light curves of type-Ia SNe  
History of cosmic expansion  
***Dark Energy***
3. Deep and Wide NIR Survey @  $1-5\mu\text{m}$

# WISH Reference Model

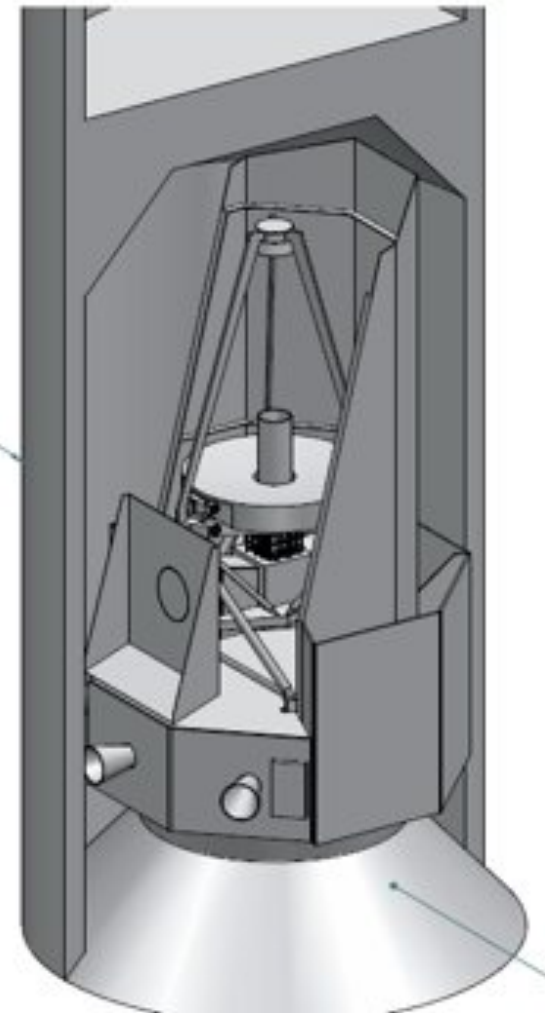
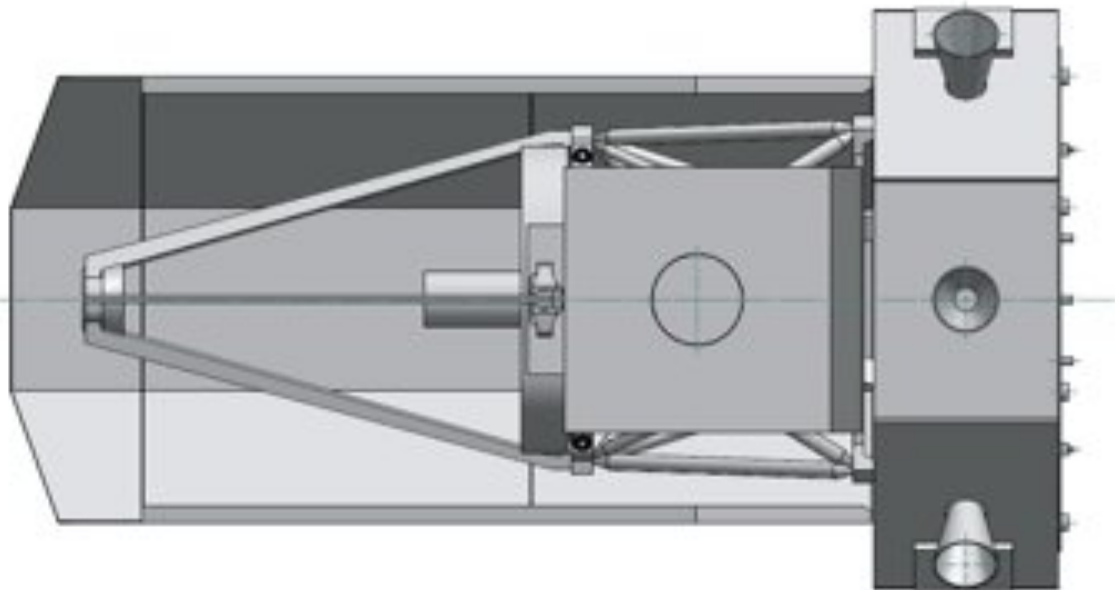
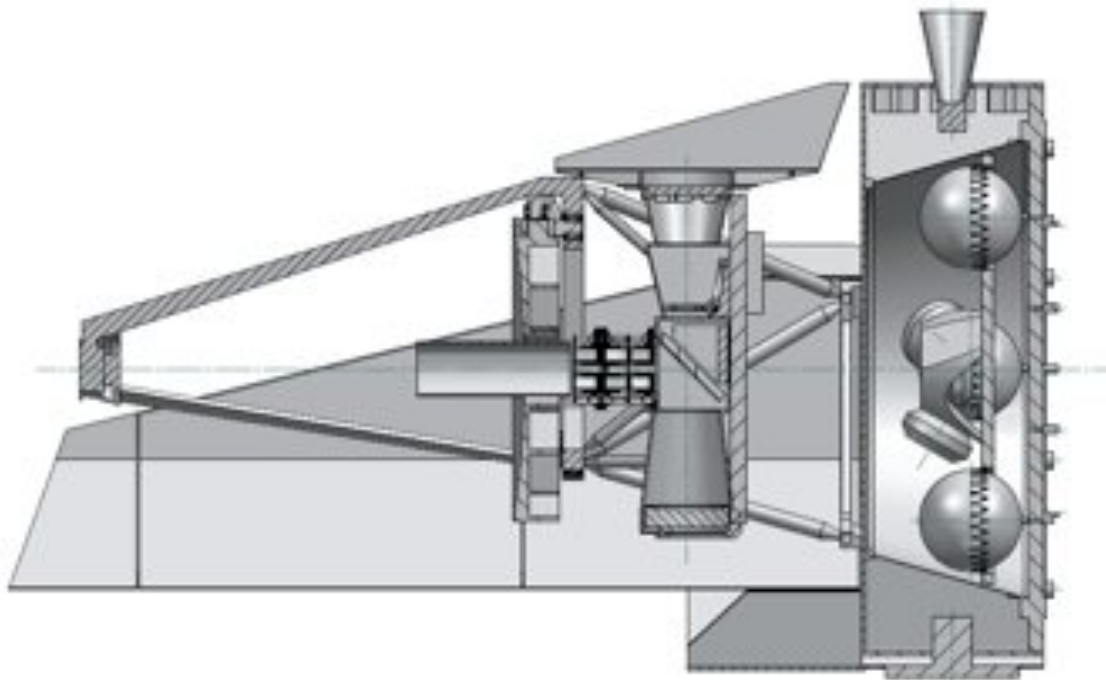


- 1-5  $\mu\text{m}$  wavelength range
- 1.5m diameter telescope
- Very Wide-Field Imager
  - ~850  $\text{arcmin}^2$  FoV
- pixel scale: 0.155" / 18 $\mu\text{m}$  (f/16)
- Cooled to 90K (telescope)
- SE-L2, JAXA HIIA

Size : (HII-A) 4/4D-LC

Mass :  $\sim 1.4\text{t}$

Power: 1.2kW





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LiteBird



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WISH Working Group (pre-Phase A)

# JAXA (Japanese Space Agency)



└ ISAS (Space Science Institute)

└ Steering Committee for Space Science

Working Groups for R&D



Mission Proposal

WISH  
~ \$1.2M in total

Mission Definition Review  
System Definition Review

Recommend Candidate Mission to ISAS



# JAXA/ISAS WISH Working Group (2008~)

---

Toru Yamada (Tohoku)

Ikuru Iwata、Kiyoto Yabe、Masayuki Tanaka、Nobunari Kashikawa、

Taddy Kodama, Yutaka Komiyama, Hidehiko Nakaya (NAOJ)

Hideo Matsuhara, Takehiko Wada, Yoichi Sato, Atsushi Okamoto,

Makiko Ando (JAXA)

Akio Inoue (Osaka Sangyo), Nobuyuki Kawai (TiTeck), Kouji Ohta (Kyoto)

Tomoki Morokuma, Mariko Kubom, Naotaka Suzuki, Mamoru Doi,

Naoki Yasuda, Ryo Tsutsui (Tokyo)

Shinki Oyabu (Nagoya), Daisuke Yonetoku (Kanazawa), Tomo Goto (NTHU)

Jun Toshikawa (Soukendai/NAOJ), Chihiro Tokoku, Ken Mawatari (Tohoku)

Yuji Ikeda (Photocoding), Satoru Iwamura (MRJ)

+

WISH Science ML Members



Ikuru Iwata



Kiyoto Yabe

# WISH International Collaboration

## US-collaboration (SAO, Giovanni Fazio)

- Proposal submitted for NASA SALMON2 MoO 2012  
(PI: G. Fazio, Smithsonian Astrophysical Observatory)
- Testing and Providing Focal Plane Arrays / ASIC electronics
- DSN antennas

**Focal Plane Arrays  
testing and procuring  
+ DSN antennas**

## France-collaboration (LAM, Denis Burgarella)

- Proposal Submitted for CNES Missions of Opportunity Program
- IFU Spectrograph as an optional instrument
- possibly utilizing the LAM new chamber for testing
- CNEs could provide downlink antennas
- French internal WISH workshop at IAP (Oct 3)

## Canada(Marcin Sawicki)

- possibility: Filter Exchange Unit

**“WISHSpec”  
adding spectroscopic capability  
- parallel operation  
during imaging survey  
+ CNES antenna**

(informal prospect of )

Announcement of Opportunity  
for Strategic Large-Class Mission (<\$300M)

target launch date : early 2020's

Likely to be:

released within this calendar year

due date may be the end of February, 2015

WISH WG is taking its efforts to submit  
the proposal for this coming AO

# ISAS Road Map “draft” 2013/09

SPICA >2028

2013

2018

2023

2028



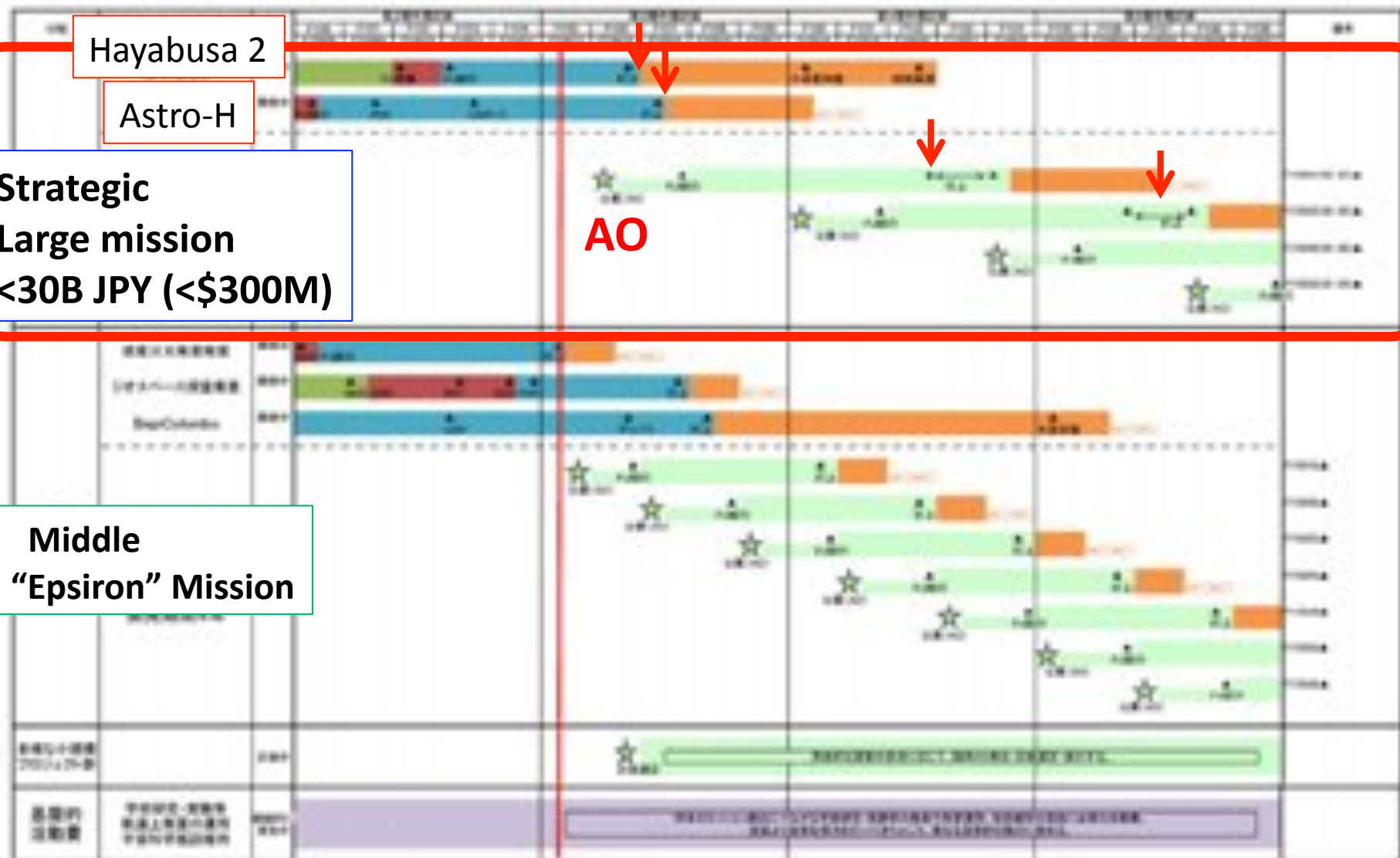
Hayabusa 2

Astro-H

**Strategic  
Large mission  
<30B JPY (<\$300M)**

AO

**Middle  
“Epsilon” Mission**



Mission Concepts

**Working Group  
phase-1**

Pre-Phase A

Mission Definition Review

AO

**Working Group  
phase-2**

Conceptual study

Pre-Phase A

~1 year

System Requirement Review

**Pre-Project**

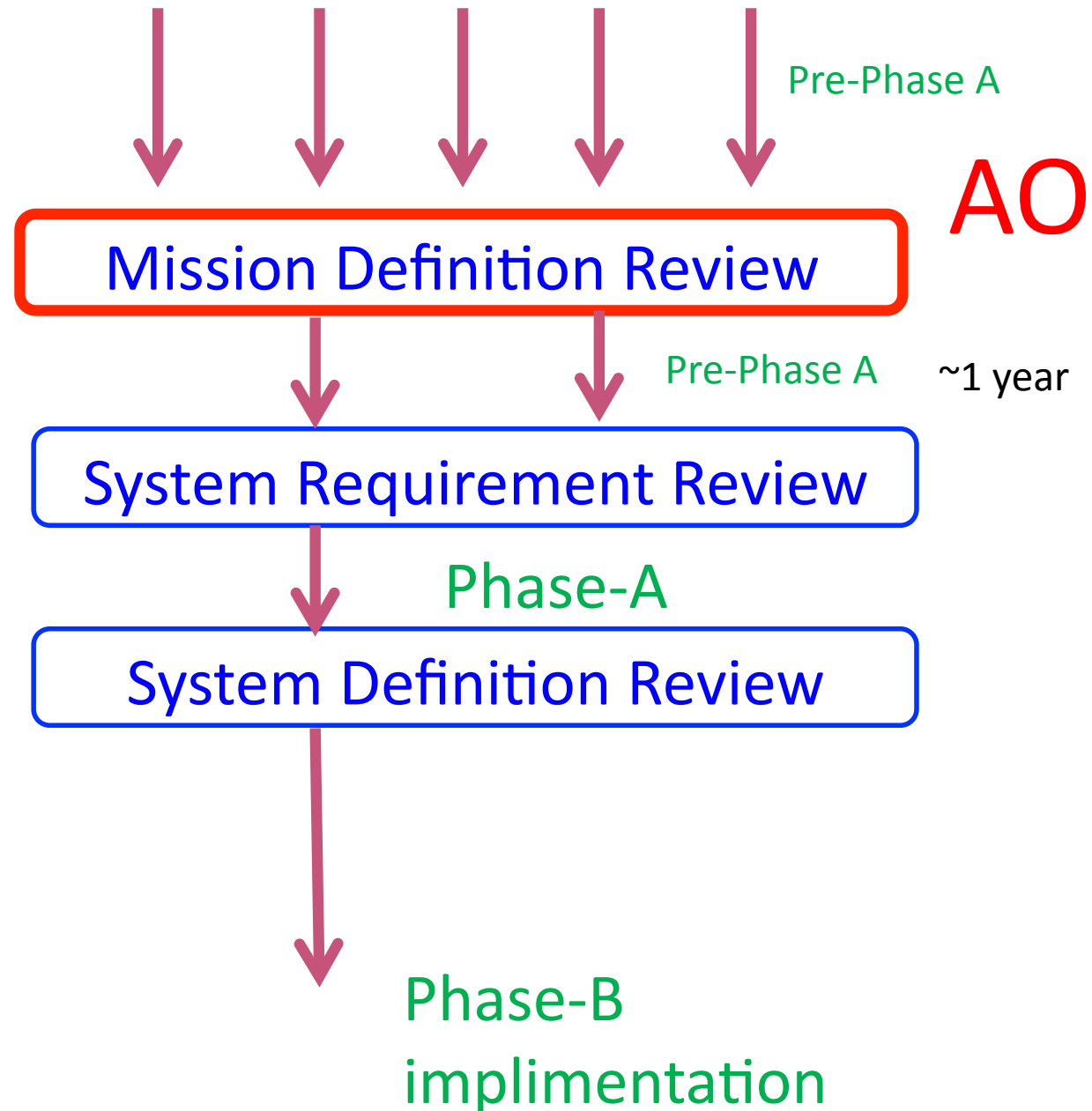
Conceptual design

Phase-A

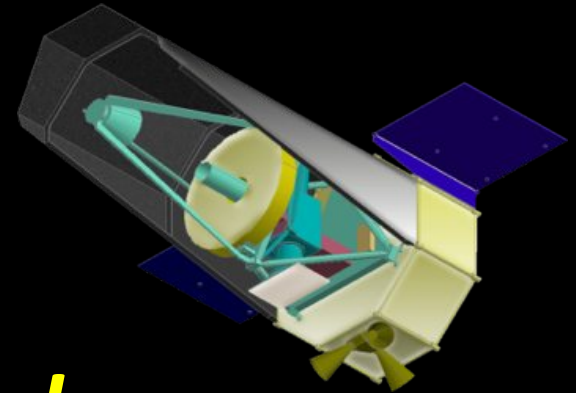
System Definition Review

**Project**

Phase-B  
implimentation

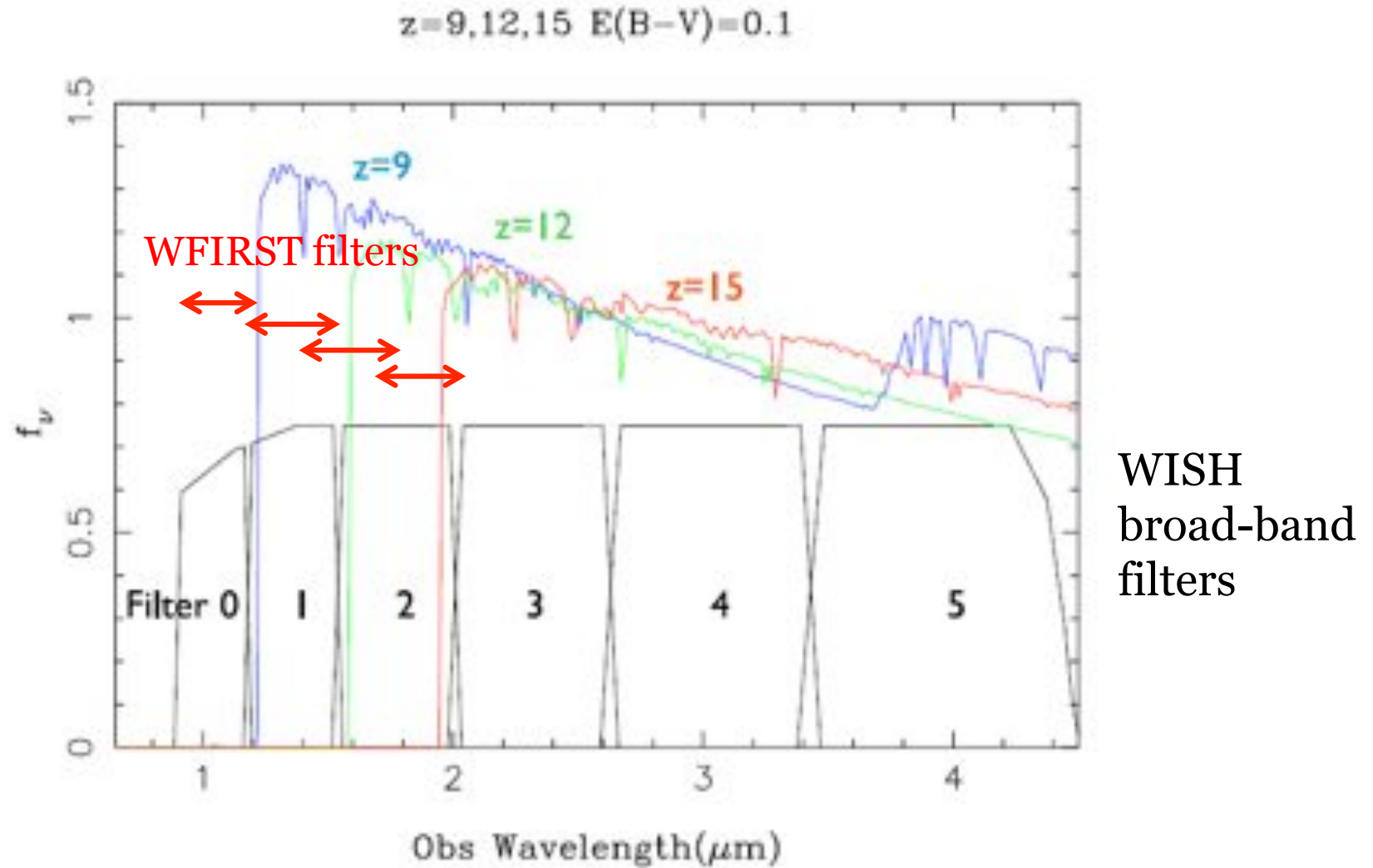


# WISH Science Goals



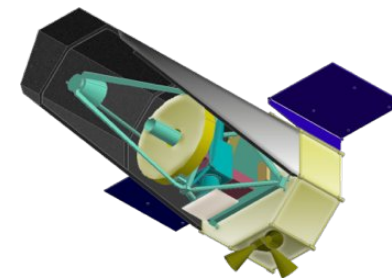
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History of cosmic expansion  
*Dark Energy*
3. Deep and Wide NIR Survey @  $1-5\mu\text{m}$

# Basic Plan: 6 Broad-band filters





# WISH: Survey Dedicated Mission



## WISH Base-Line Imaging Survey Plan

**80% of 5yr Mission**

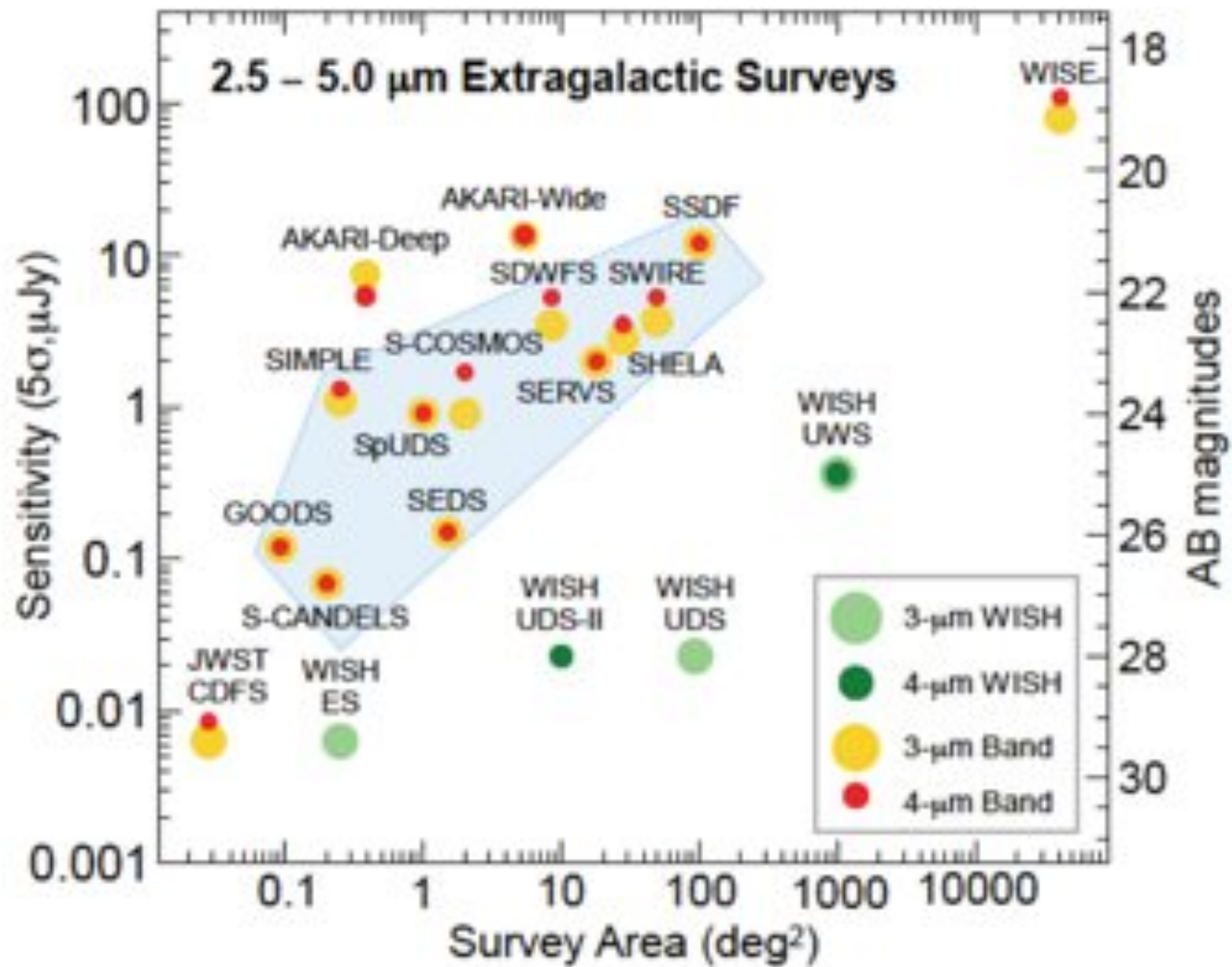
|                                    | Depth ( $3\sigma$ )<br>(AB mag) | Area                       | Example of the Filters $\lambda_0$<br>(a plan, to be determined) |
|------------------------------------|---------------------------------|----------------------------|------------------------------------------------------------------|
| <b>Ultra Deep Survey<br/>(UDS)</b> | <b>28</b>                       | <b>100 deg<sup>2</sup></b> | <b>1.0, 1.4, 1.8, 2.3, 3.0<br/><math>\mu\text{m}</math></b>      |
| <b>+ Filter 5</b>                  | <b>~27</b>                      | <b>~100deg<sup>2</sup></b> | <b>4.0<math>\mu\text{m}</math></b>                               |
| <b>Ultra Wide Survey<br/>(UWS)</b> | <b>24-25</b>                    | 1000 deg <sup>2</sup>      | 1.4, 1.8, 2.3, <b>3.0, 4.0</b>                                   |
| <b>Extreme Survey</b>              | <b>29-30</b>                    | 0.25 deg <sup>2</sup>      | 1.0, 1.4, 1.8                                                    |

UDS 1500days (with 50% overhead)

UWS 50-60 days Filter5 150 days

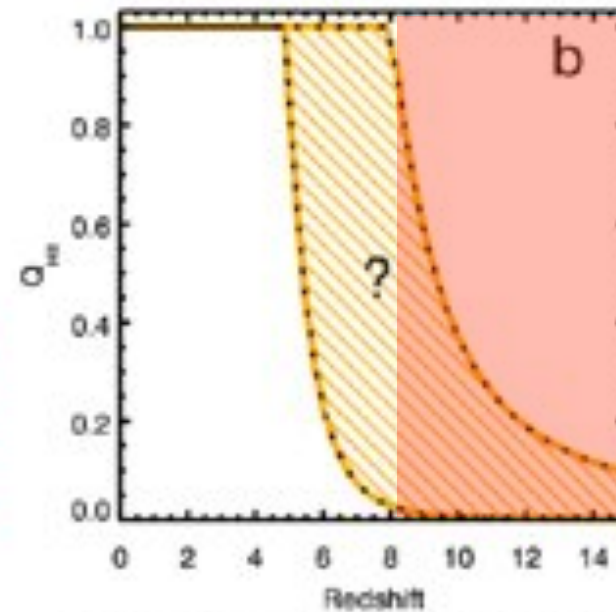
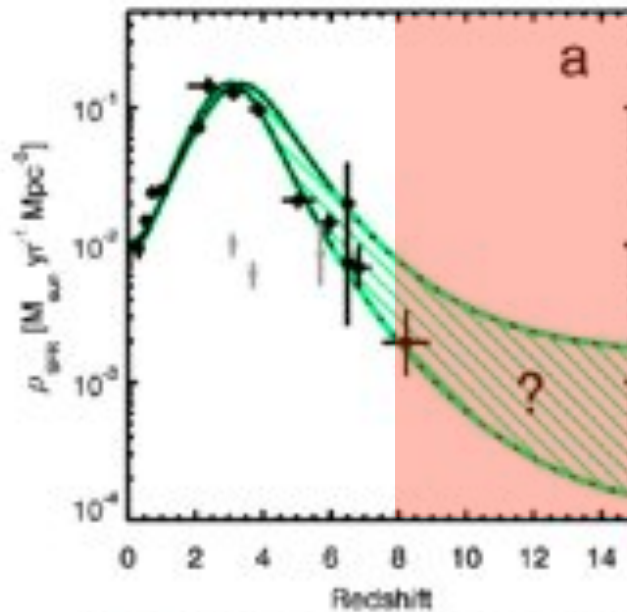
ExS 20 days/FoV

Nominal Five Years



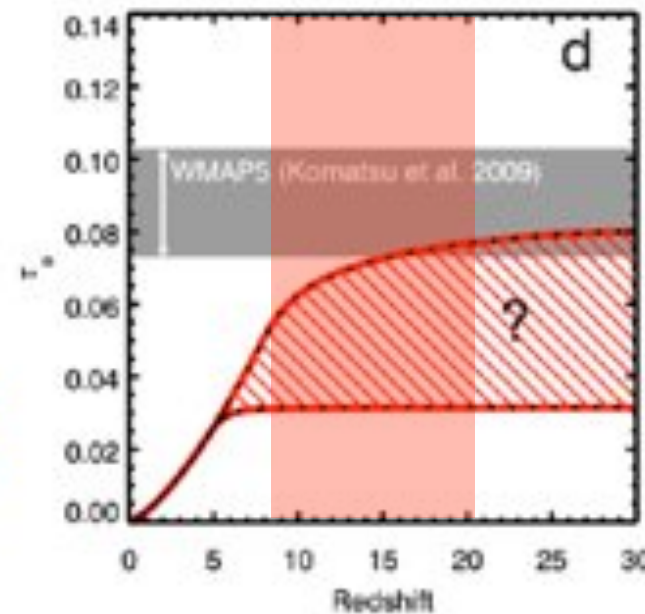
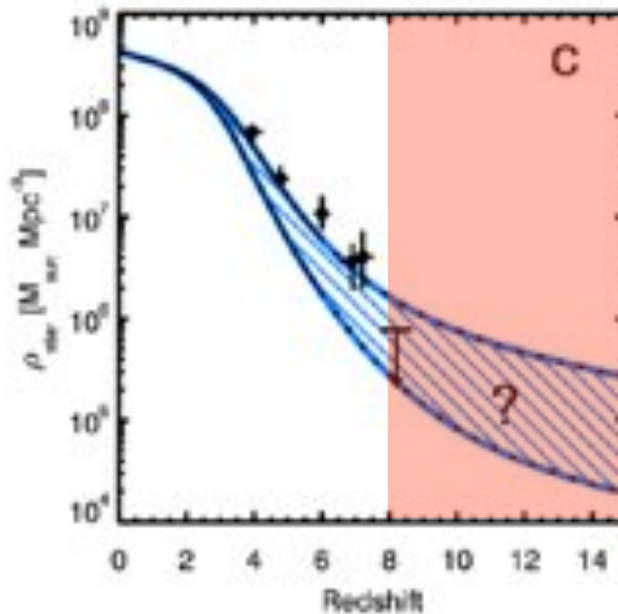
# A schematic picture Robertson et al. 2010

SFR  
density



Ionization  
degree

Stellar mass  
density



Electron  
scattering  
optical depth

# WISH for Galaxies *beyond* Epoch of Cosmic Reionization

- Exploration (detection, physical parameters)
- UV luminosity function  $z=8-15$   
(UDS.. Bright end / ExS.. Faint End + JWST .. Very faint end)
- Spatial distribution  
(marking structure at  $z>8$ , clustering, reionization topology)
- Rest-frame UV spectra  
(rest frame 0.1-0.45 $\mu\text{m}$  for  $z\sim 10$  galaxies)
- Spectroscopic Targets for ELTs, JWST
- Correlation with HI21cm

# WISH Science Goals

Expected number of the *observed*  
very high-redshift galaxies

|                  |          | Number Density [objects per 1 deg <sup>2</sup> ] for AB < 28.0 |           |     |       |
|------------------|----------|----------------------------------------------------------------|-----------|-----|-------|
|                  | redshift | No Evolution                                                   | Empirical | SAM | DMH   |
| 1.0 $\mu$ m-drop | 8-9      | 4,000                                                          | 1,700     | 630 | 850   |
| 1.4 $\mu$ m-drop | 11-12    | 2,400                                                          | 100       | 50  | 4.1   |
| 1.8 $\mu$ m-drop | 14-17    | 1,200                                                          | 0.72      | 1.1 | 0.003 |

Numbers for 1 deg<sup>2</sup> , <28AB

# WISH for distant SNe

## Ultra Deep Survey (100 deg<sup>2</sup>, ~28AB)

- *recurrent* observations
- *simultaneous* deep and wide search for *transients*
- **type-Ia** (reducing systematic errors in cosmology)
  - high photometric accuracy, homogeneity
  - rest-frame NIR search and light curve ( $z = 0.5-1.5$ )
  - high-redshift objects (rest-frame optical  $z \sim 2$ )

**~2000 type-Ia SNe in UDS**

- **Ultraluminous SNe** e.g., type-II n

# Proposed spectroscopic capabilities

- **WISH Spec (parallel IFU)**

(Denis Burgarella's talk)

- \* utilizing the beam 'not used' in wide-field imaging
- \* parallel mode operation
- \* IFU / no moving part
- \*  $\sim 1 \times 1 \text{ arcmin}^2$ ,  $R \sim 1000$ 
  - ➔ unique spectroscopic survey for bright galaxies
  - ➔ limited number of targeted spectroscopy

- **Narrow-band** (see “**Filter Exchanger**”) max 5 filters

- **Wide-field grism slitless spectroscopy** (risky option)

- \* using the beam for wide-field image,  $R=100$



# WISH Campaign Science Cases ( $<20\%$ of Mission Lifetime)

- Narrow Band / Grisms Survey
- Targeted spectroscopy

## Variety of Science Cases

- Bulge Campaign astrometry  
w/ JASMINE Project
- Galactic Plane Campaign clusters / variables
- Transit Exoplanet Campaign
- Lensing Exoplanet Campaign
- Solar System Icy Minor Planets Campaign

Etc.....

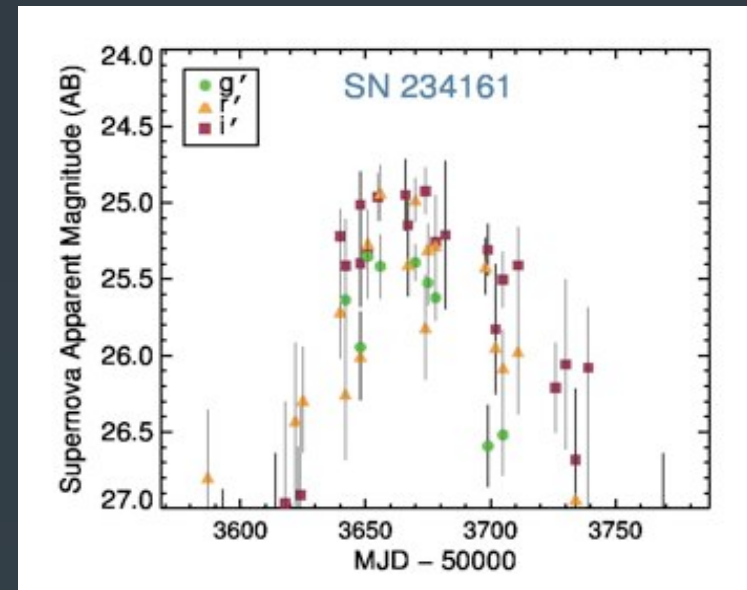
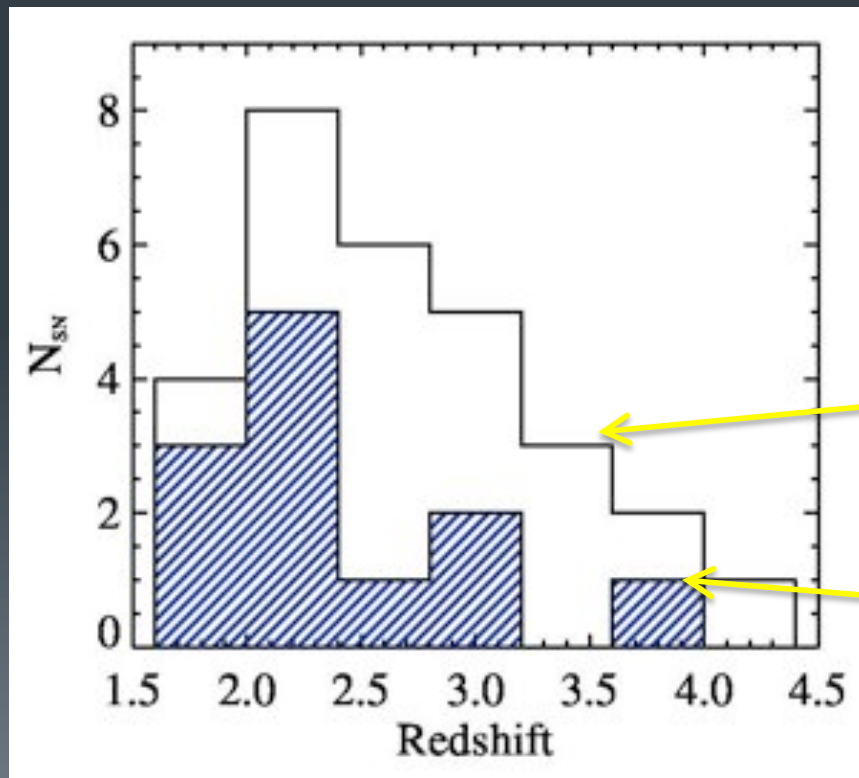
# WISH Science Workshop 2013 December

<http://wishmission.org/sciws2013/Welcome.html>  
(or google, “wishmission” and check the banner)



# High-z High-Luminosity SNe

From Jeff Cooke  
WISH Science WS 2013

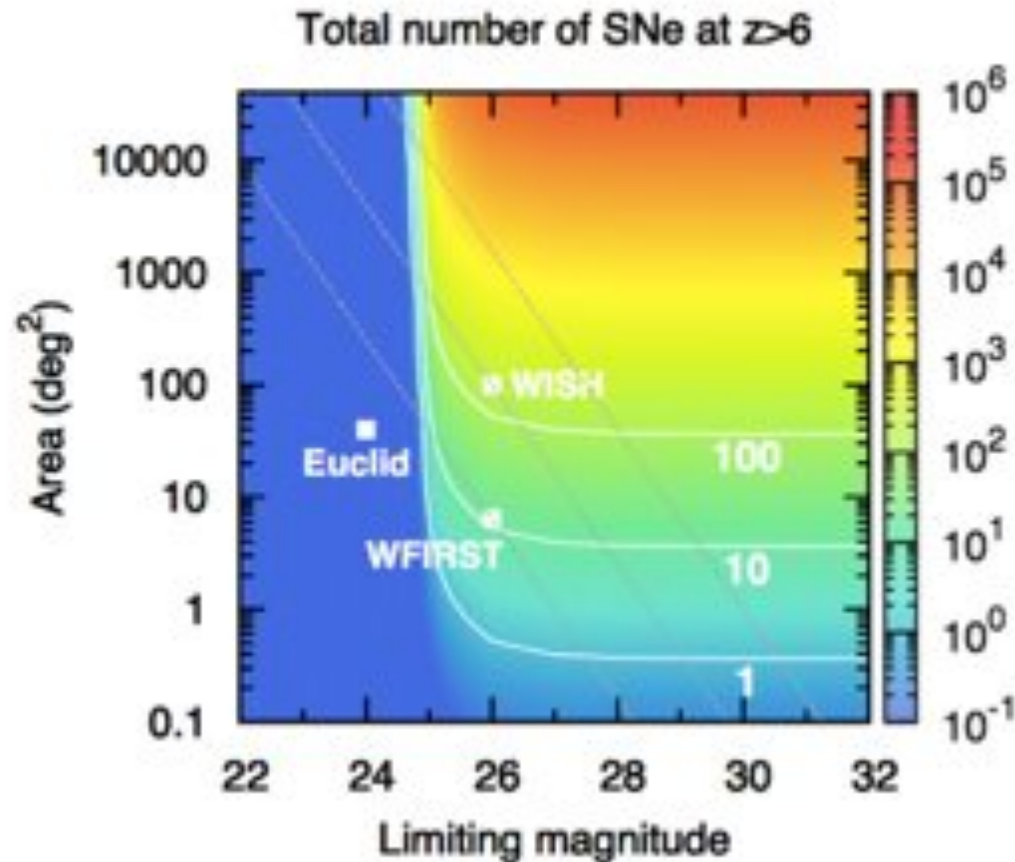


photometric candidates

spectroscopic sample;  
many events show late-time  
supernova emission

# WISH UDS $>100$ $z>6$ SNe

Beyond  $z=6$ : Monte Carlo LC simulation

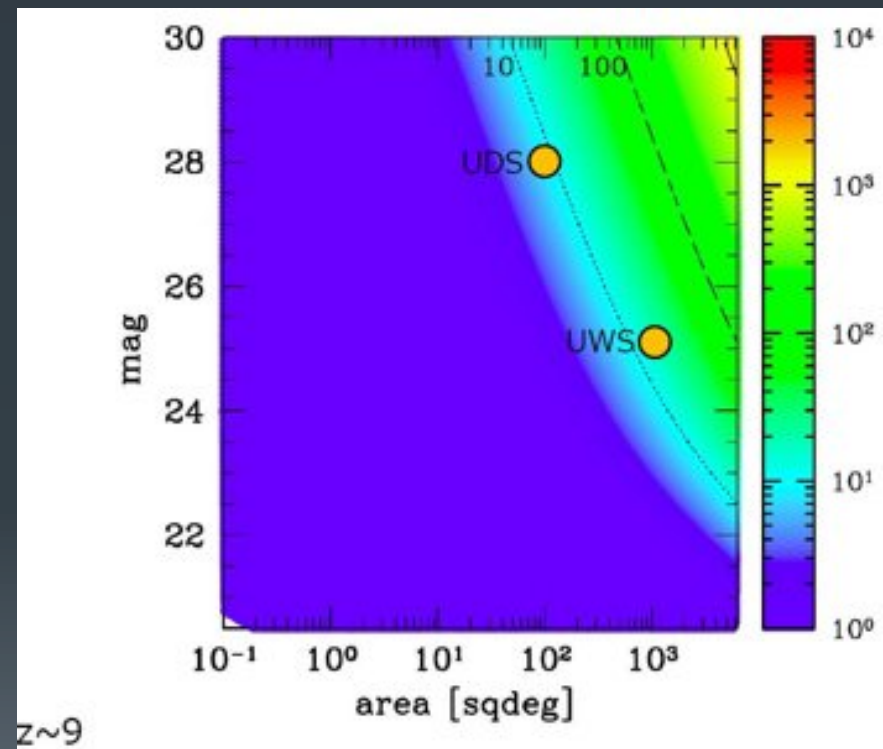
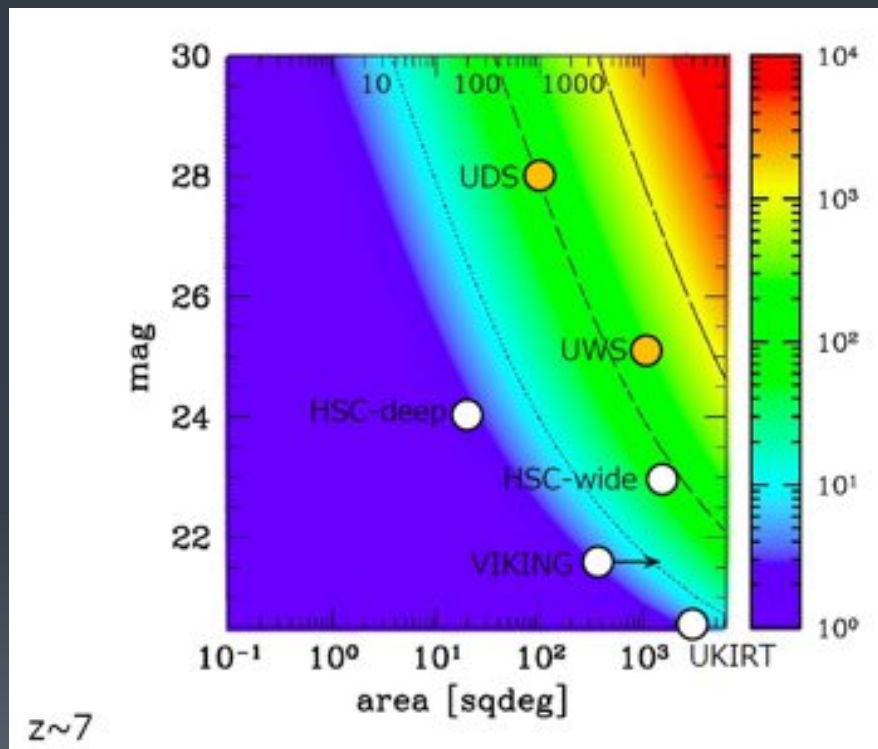


Tanaka, Moriya, Yoshida et al. (2013)  
from Naoki Yoshida WISH Science Workshop 2013



# WISH and First Quasars

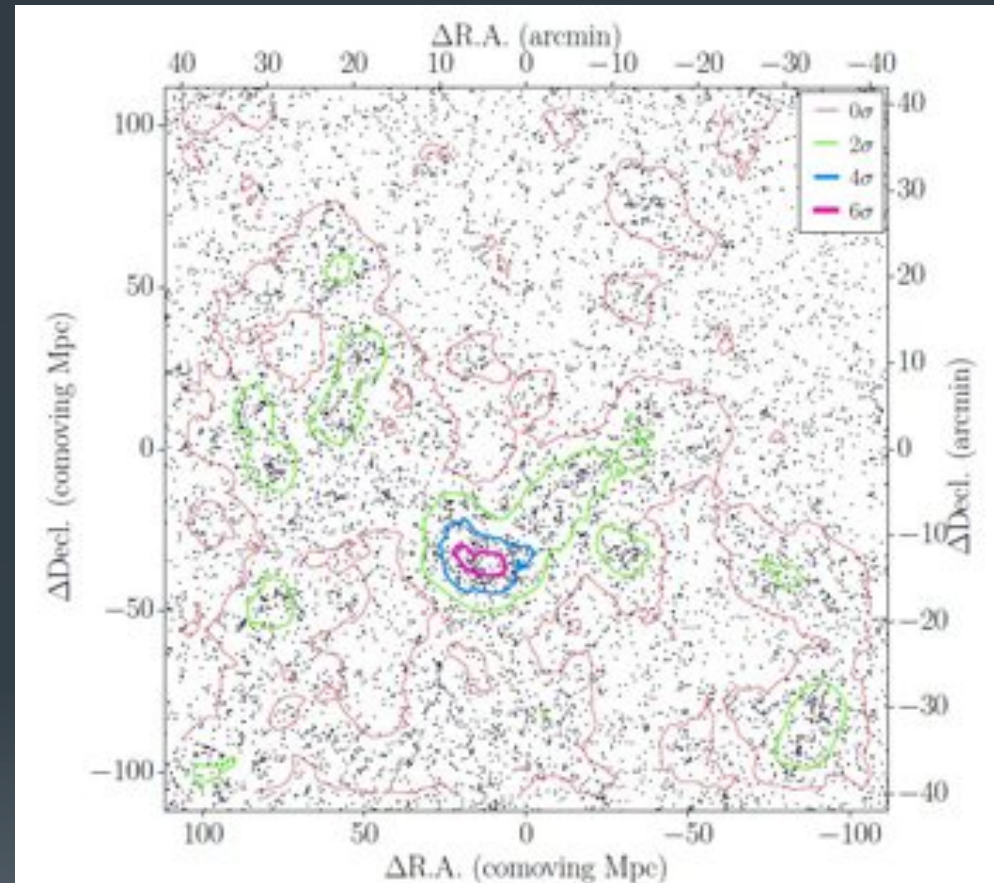
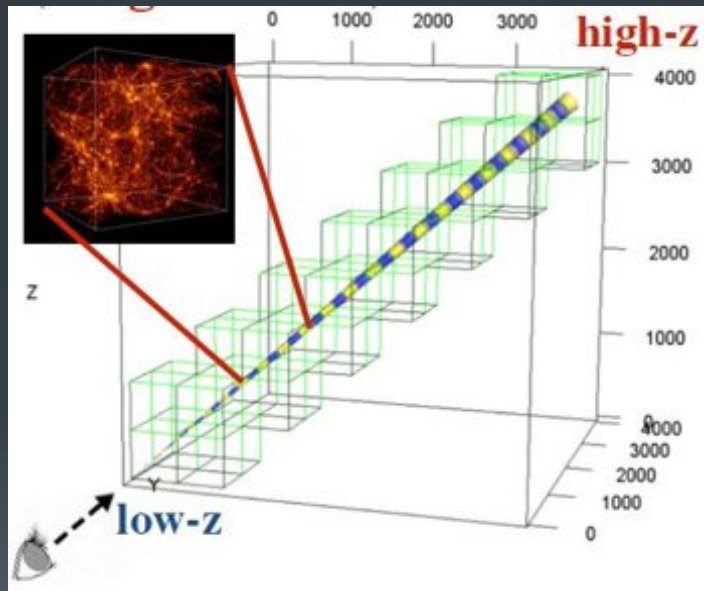
~100  $z \sim 7$  QSOs and ~10  $z \sim 9$  QSOs in UDS and UWS



Nobunari Kashikawa WISH Science Workshop 2013  
And update in 2014 August

# WISH and First Protoclusters

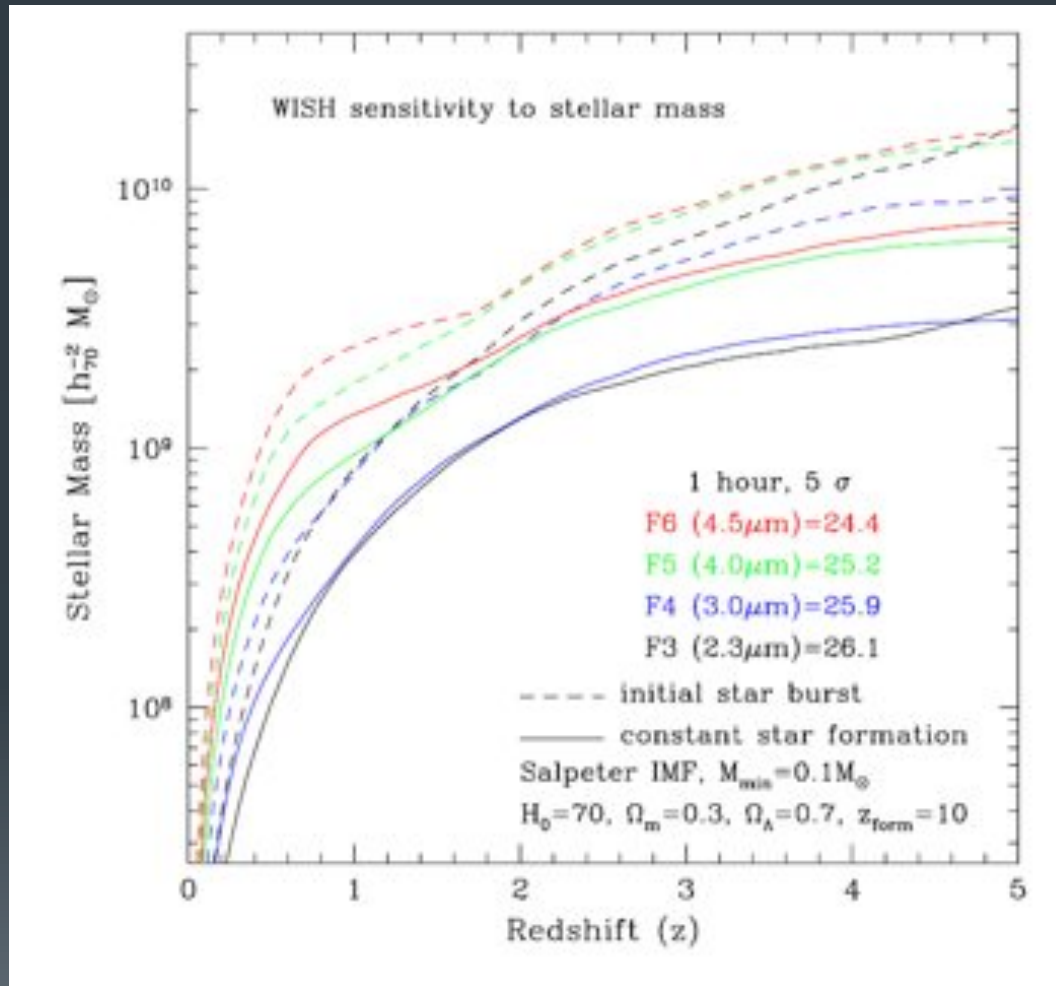
UDS-like mock catalog  
of  $z \sim 8$  galaxies



Jun Toshikawa, Nobunari Kashikawa  
WISH Science Workshop 2013  
And update in 2014 Aug

$>4\sigma$  peak (LBG  $m < 28$ )  
 $\sim 10\text{-}14 M_{\odot}$  @  $z=0$   
 $0.6/\text{deg}^2$

# WISH and galaxy stellar mass



1-hour limit

$10^9 M_{\text{sun}}$

Taddy Kodama  
WISH SW 2013



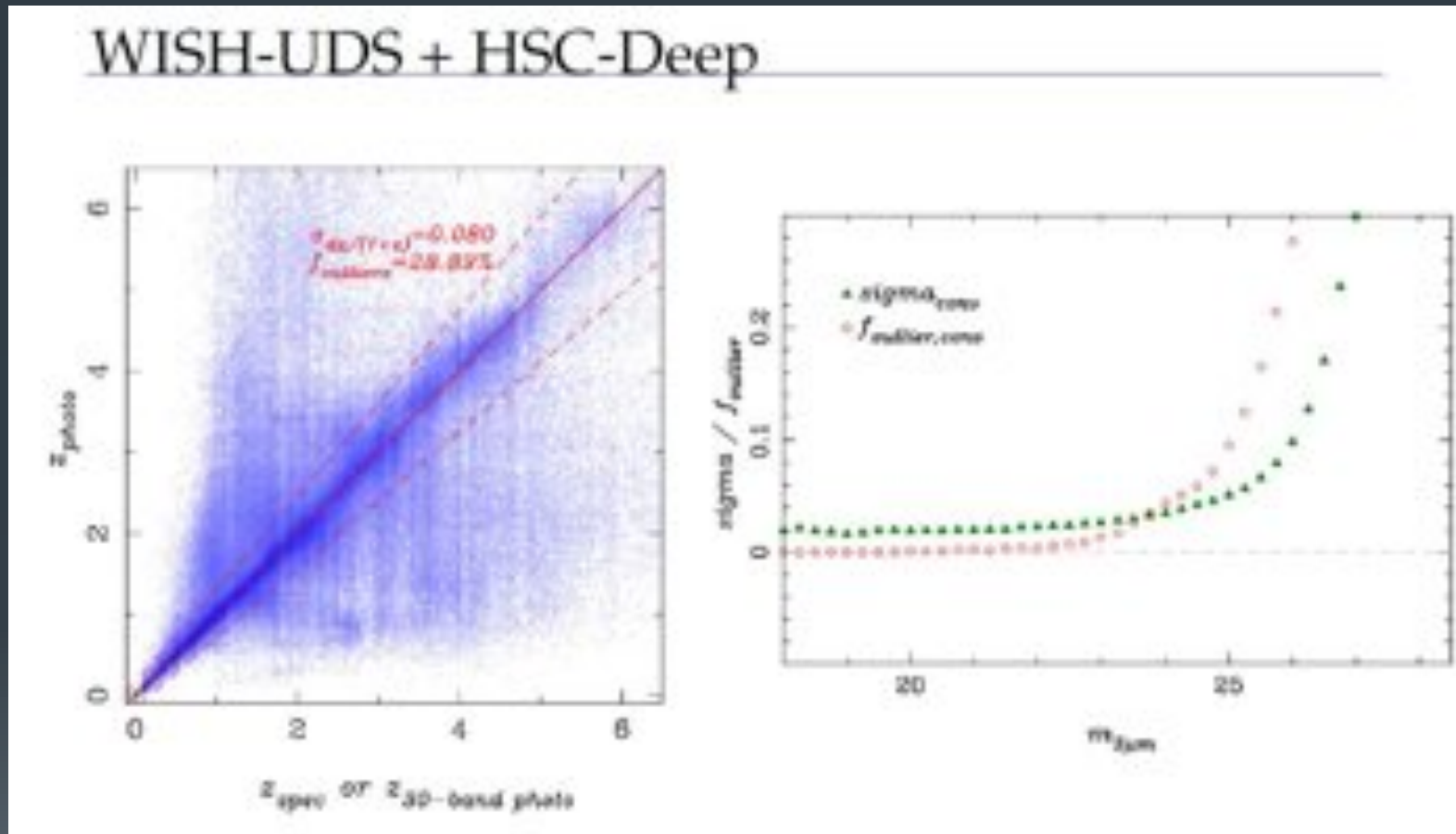
# WISH for Narrow Band

## *WISH-7 Survey* for $1.5 < z < 8$



- 「7」 sq. deg.  
     $\sim 7 \times 10^7 \text{ Mpc}^3 / (\Delta z = 1)$   
         $\sim 10$  progenitors of Coma class clusters at every  $z$   
    NB:  $3.5\text{--}7 \times 10^6 \text{ Mpc}^3 / (\Delta z = 0.05\text{--}0.1)$   
         $\sim 1$  progenitor of Coma class cluster per filter  
    30 WISH pointings (0.24 sq. deg. / FoV)
- Exposure times needed  
    BB: 1 hrs  $\times$  6 filters  $\times$  30 p = 180 hrs  
    NB: 6 hrs  $\times$  4 filters  $\times$  30 p = 720 hrs  
    900 hrs in total (or 1200 hrs including overheads)

# WISH+HSC Photometric Redshift



Masayuki's WISH Mock Catalog (m~28 mock catalog)

Masayuki Tanaka WISH Science Workshop 2013

# WISH

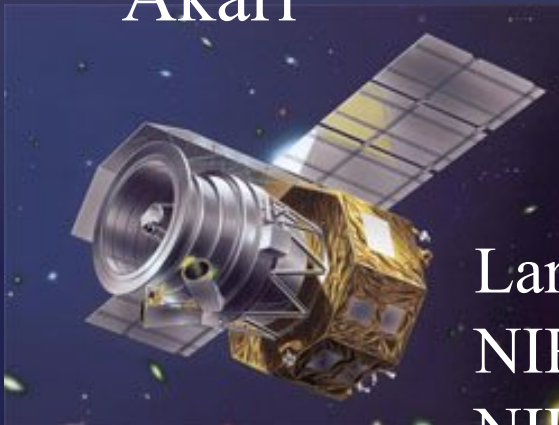
in Japanese Astronomy Roadmap

Subaru



Wide-field deep imaging  
Opt → NIR  
Higher redshift

Akari

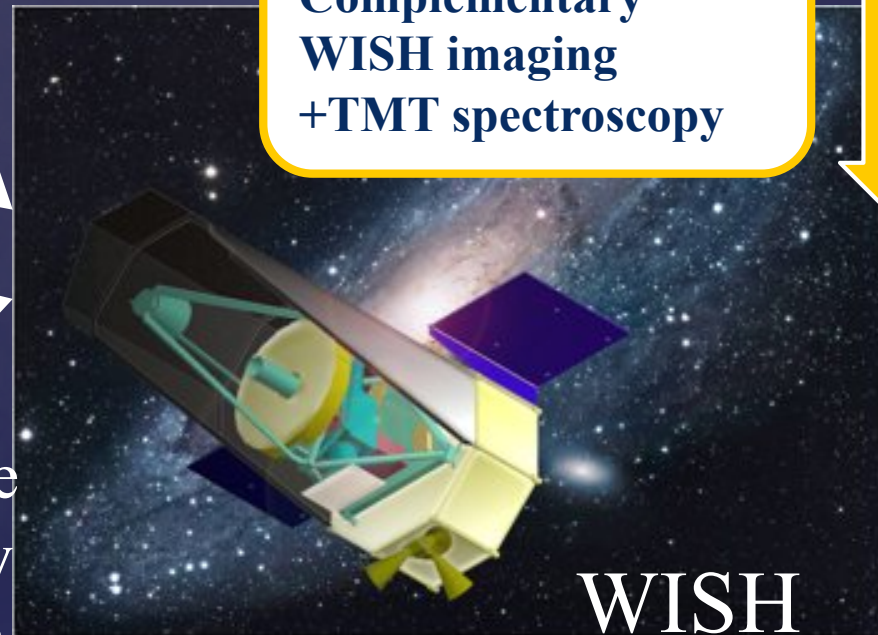


Larger aperture  
NIR sensitivity  
NIR resolution

TMT



Strong Synergy  
Complementary  
WISH imaging  
+TMT spectroscopy



WISH



# Complimentarity with JWST (NIR imaging)

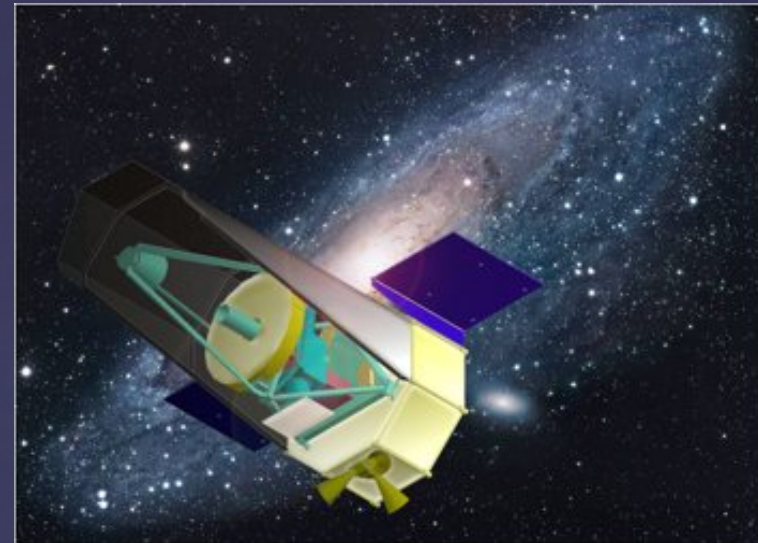


JWST NIRCам

$$2 \times 2.2 \times 4.3 = 19 \text{ arcmin}^2$$

JWST NIRRIS

$$2.2' \times 2.2' = 4.5 \text{ arcmin}^2$$



WISH VWFI

$$850 \text{ arcmin}^2 = \sim 40 \times \text{NIRCам}$$

**dedicated**

**Assuming the natural background-limited observations,**

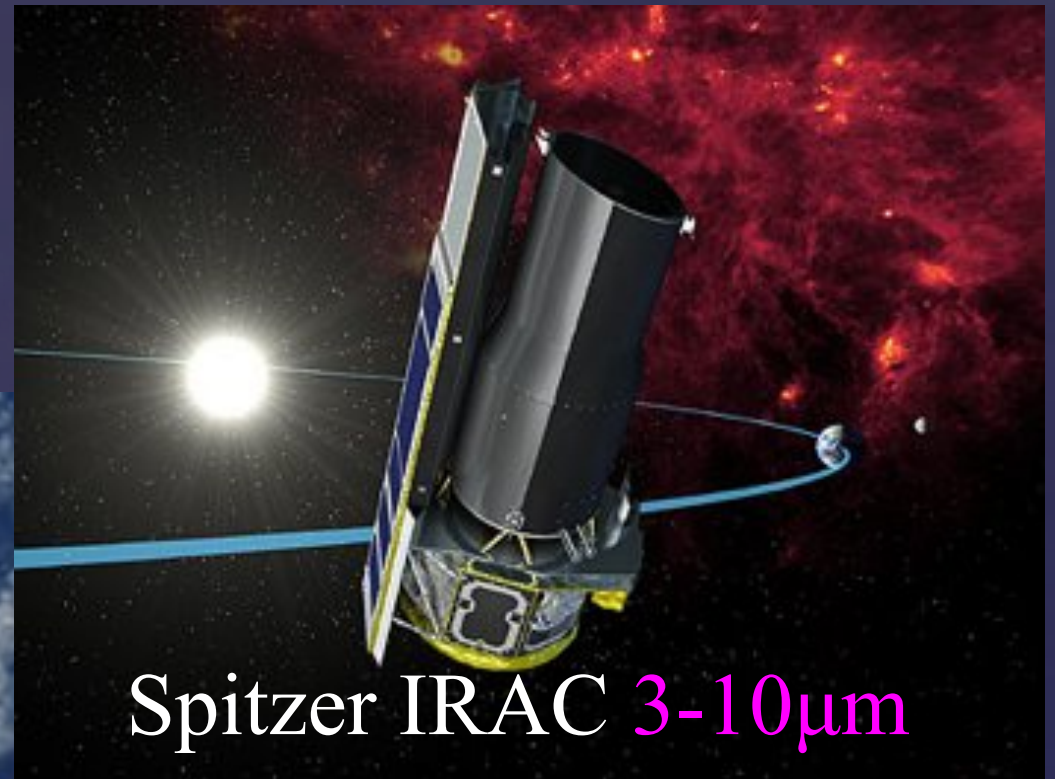
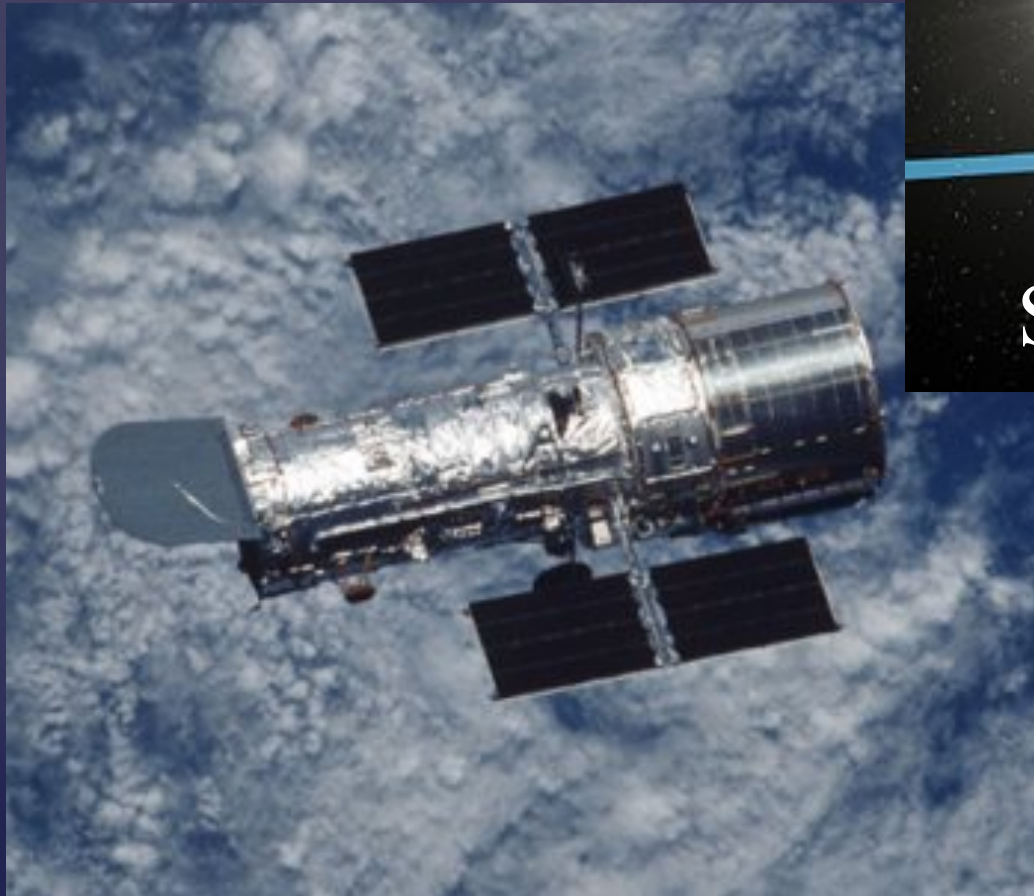
**‘Survey speed’ (time to observe same area with same S/N ratio) is:**

**Point Sources JWST NIRCам = 9 x**

**Extended Sources (fixed large aperture) WISH = 2x (shorter wavelength)**

**many high-z (bright) galaxies may be extended to ~0.2-0.5”**

Hubble  
**0.1-1.8 $\mu\text{m}$**



Spitzer IRAC **3-10 $\mu\text{m}$**



Akari IRC NIR **2-5 $\mu\text{m}$**



Euclid  
0.4-1.8 $\mu\text{m}$



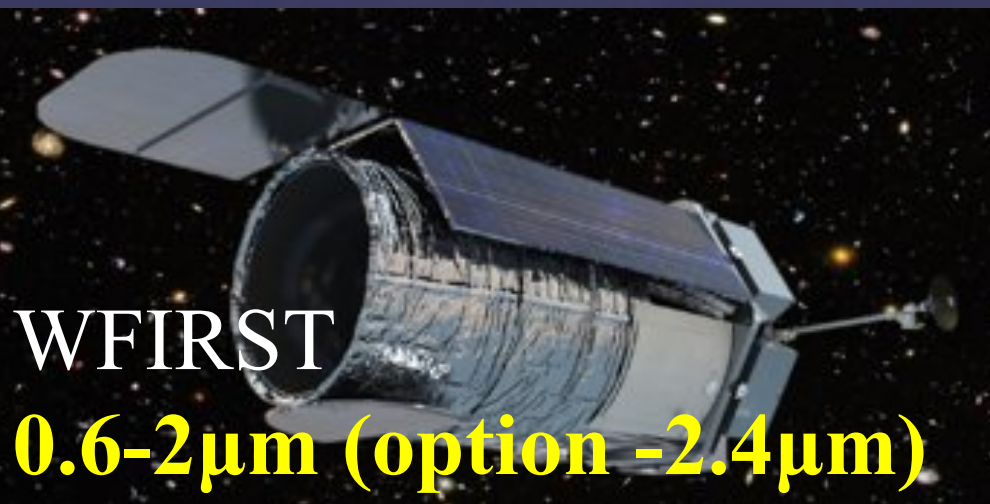
WISH  
1-5 $\mu\text{m}$



Wide field  
dedicated



WFIRST~AFTA  
Wide-Field Infrared Survey Telescope



WFIRST  
0.6-2 $\mu\text{m}$  (option -2.4 $\mu\text{m}$ )





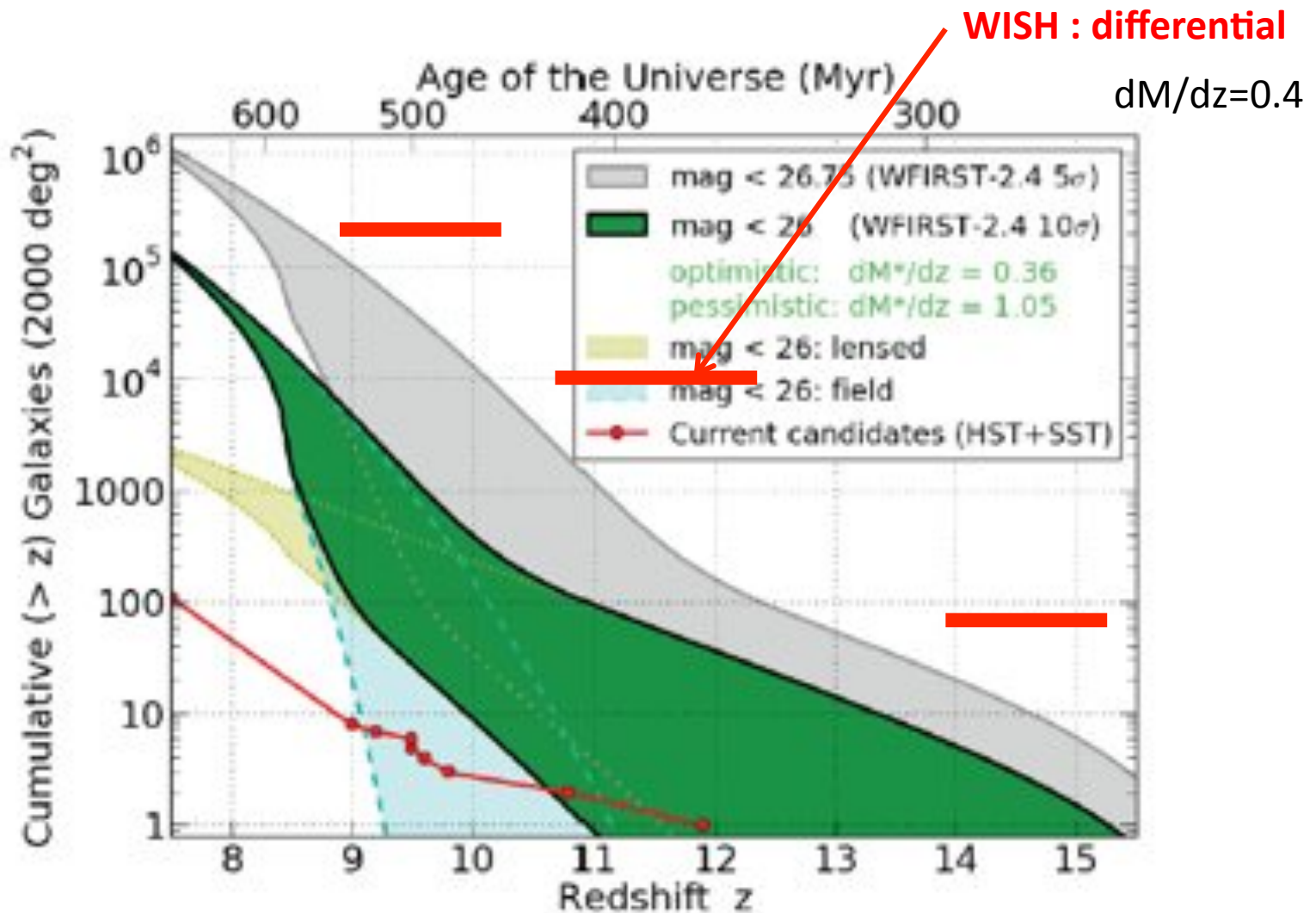
# Comparison of **NIR IMAGING** Capability

|                     | Euclid                | WFIRST                           | WISH                  |
|---------------------|-----------------------|----------------------------------|-----------------------|
| Mirror              | 1.2m                  | 2.4m                             | 1.5m                  |
| Wavelength Coverage | 0.9-2 $\mu$ m         | 0.8-2 $\mu$ m                    | 1-5 $\mu$ m           |
| FoV                 | 0.5deg <sup>2</sup>   | 0.28deg <sup>2</sup>             | 0.23deg <sup>2</sup>  |
| Pixel Scale         | 0.3arcsec             | 0.11arcsec                       | 0.155arcsec           |
| Num. Pixels         | 64Mpix                | 4RG,288Mpix                      | 128Mpix               |
| Filters             | YJH                   | 4BB                              | 6BB+NB                |
| Survey Area Deep    | 40deg <sup>2</sup>    | ?                                | 100deg <sup>2</sup>   |
| Survey Depth Deep   | 26AB                  | ?                                | 28AB                  |
| Survey Area Wide    | 20000deg <sup>2</sup> | HL >2000deg <sup>2</sup>         | >1000deg <sup>2</sup> |
| Survey Depth Wide   | 24AB                  | 26-27AB                          | 24-25AB               |
| Primary Science     | Dark Energy           | Dark Energy<br>Exoplanets<br>QSO | First Galaxies        |

2011 SDT report

**Note:** WISH is a dedicated imaging surveyor  
while Euclid / WFIRST has wide-field NIR spectroscopy (Euclid / WFIRST),  
optical imaging (Euclid), IFU spectroscopy (WFIRST), and coronagraph (WFIRST)

WISH UDS (100 deg<sup>2</sup>) can detect 10x-100x galaxies of  
WFIRST-2.4m 2000 deg<sup>2</sup> High Latitude Survey



Euclid  
26mag(5σ)  
40deg<sup>2</sup>  
(X1/50)

WFIRST SDT report

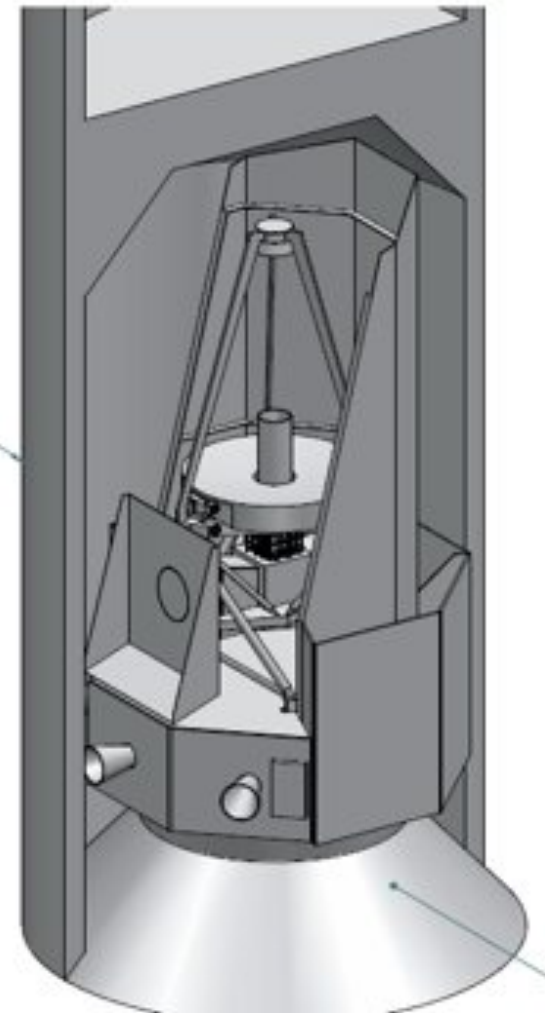
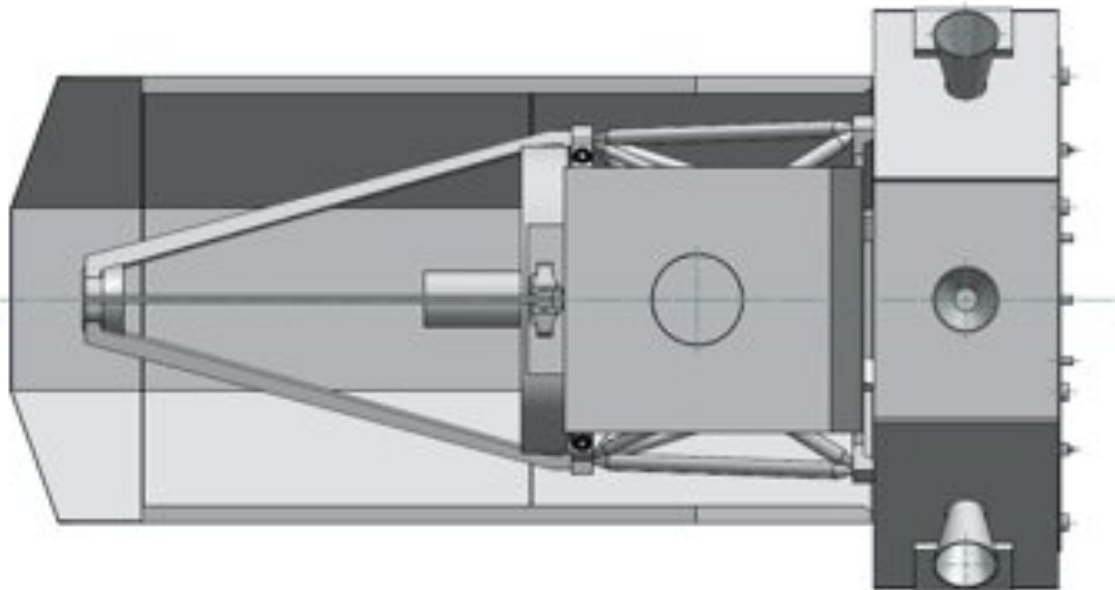
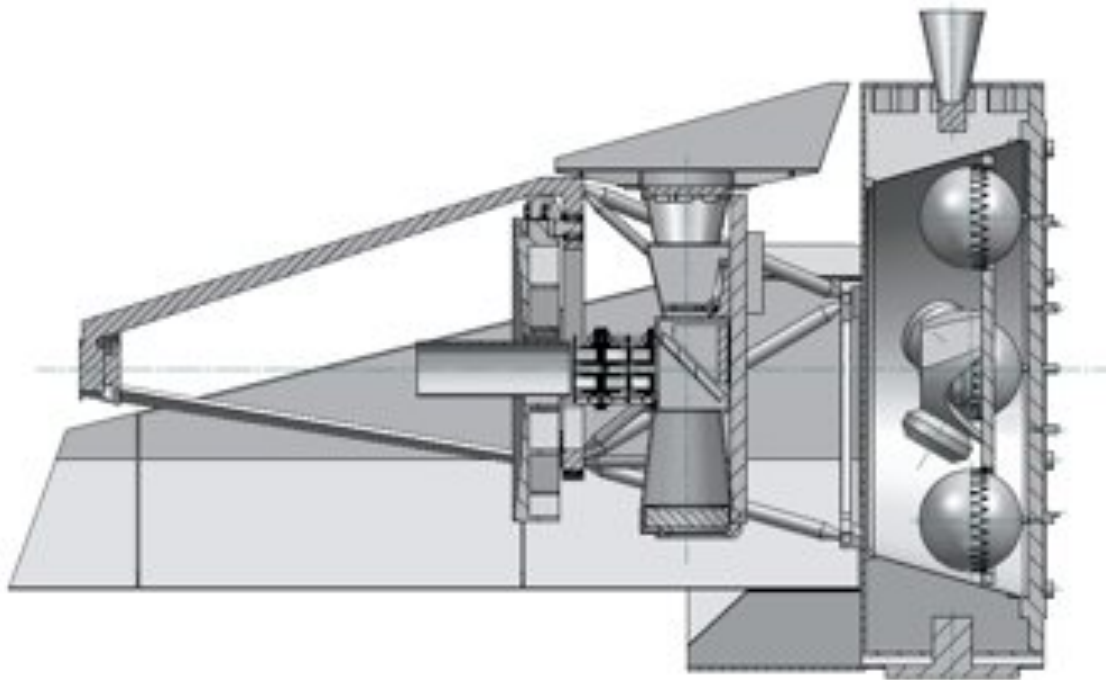
## Base Design Model

- **1.5m** light-weighted glass primary mirror
- CFRP structure @**90-100K**
- Diffraction limited image at **1-5 $\mu$ m** over the flat focal plane
- H2RG 32x2kx2k 128Mpix
- **0.155''**/pixel(18 $\mu$ m-pitch), **850arcmin<sup>2</sup>**/FoV
- Light weight: **1.4t** (WET) (w/o optional spectrograph)
- optional spectrograph (collaboration with French group)

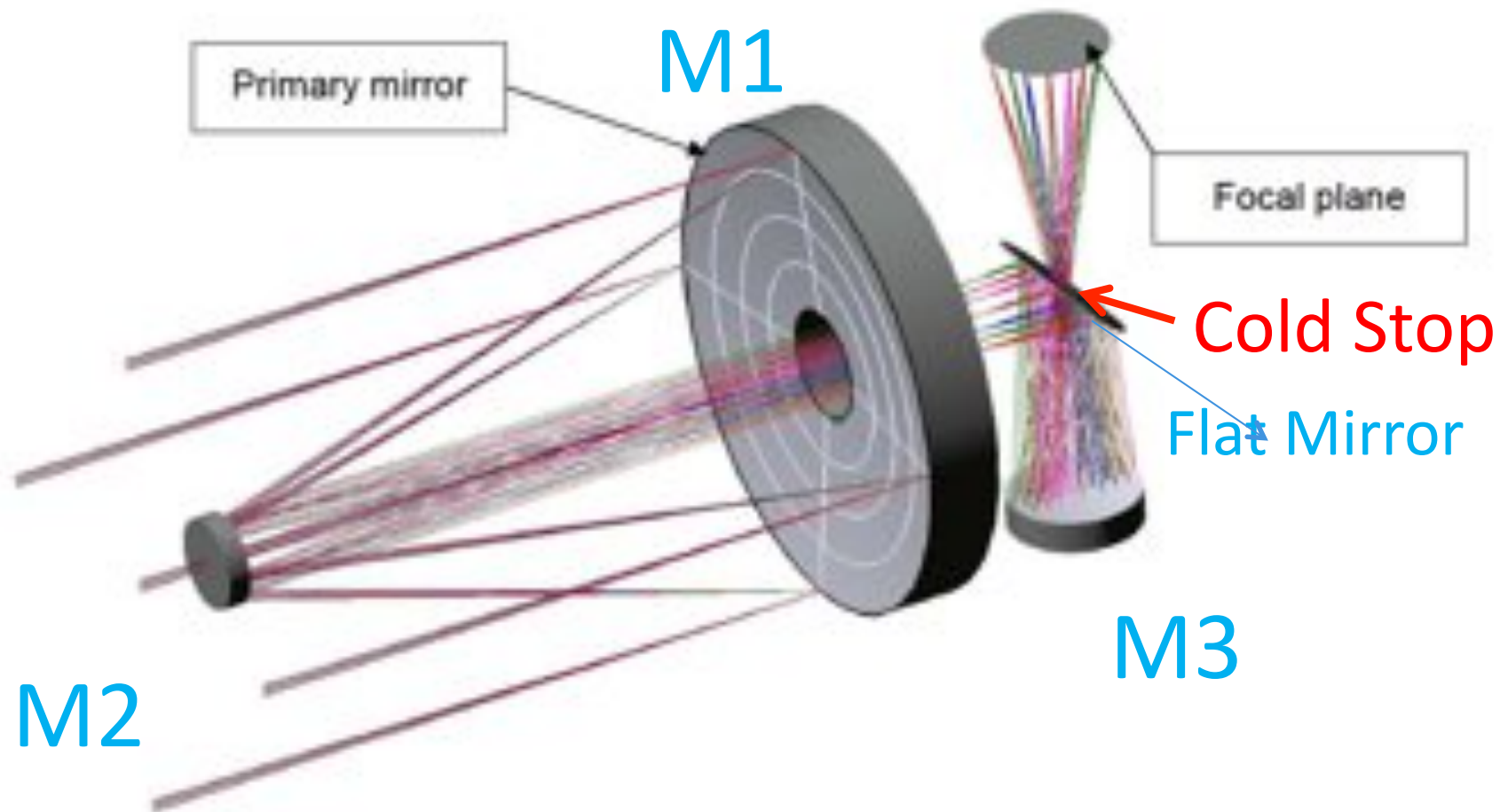
Size : (HII-A) 4/4D-LC

Mass :  $\sim 1.4\text{t}$

Power: 1.2kW

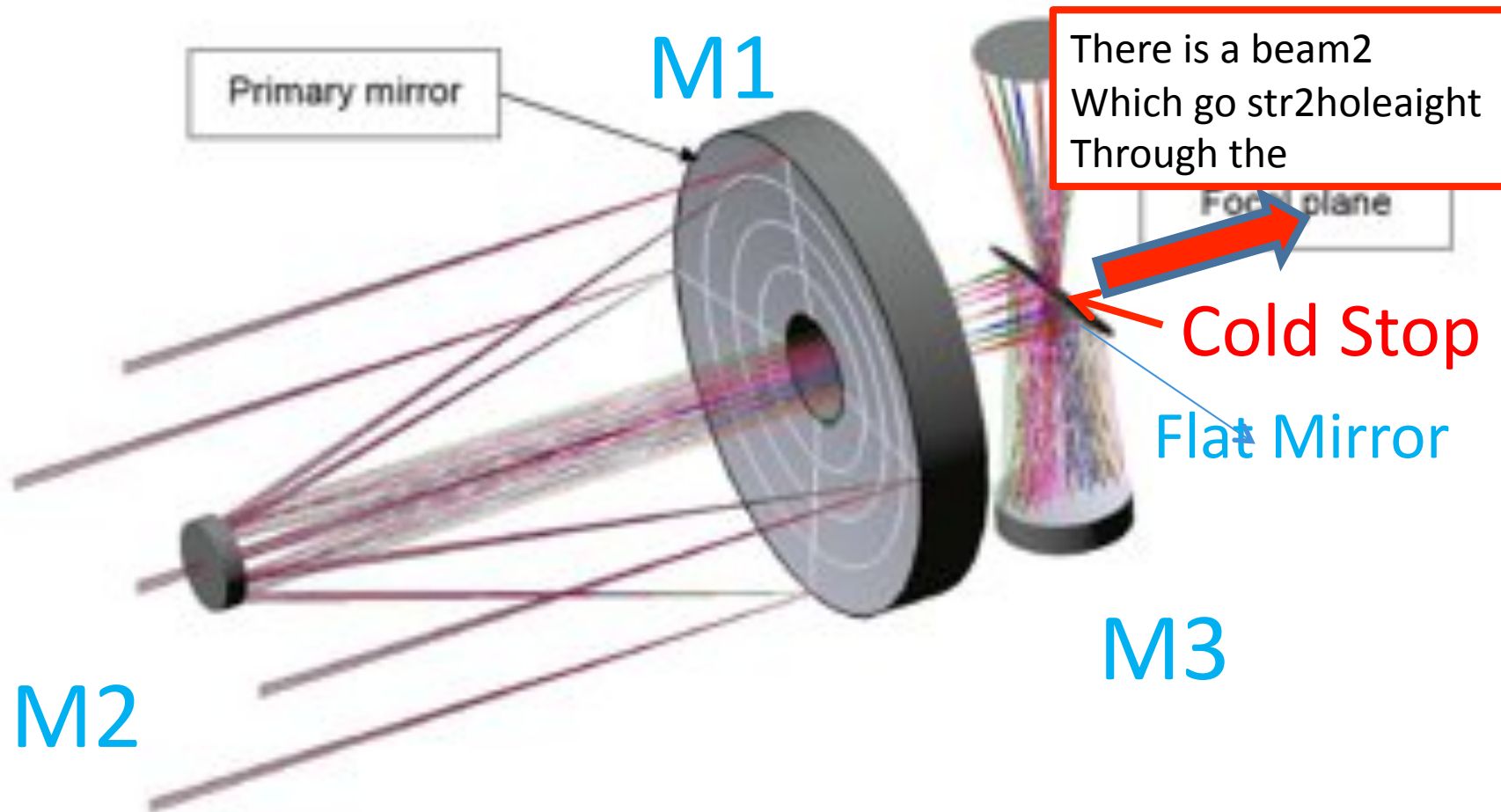


# WISH Optical Layout

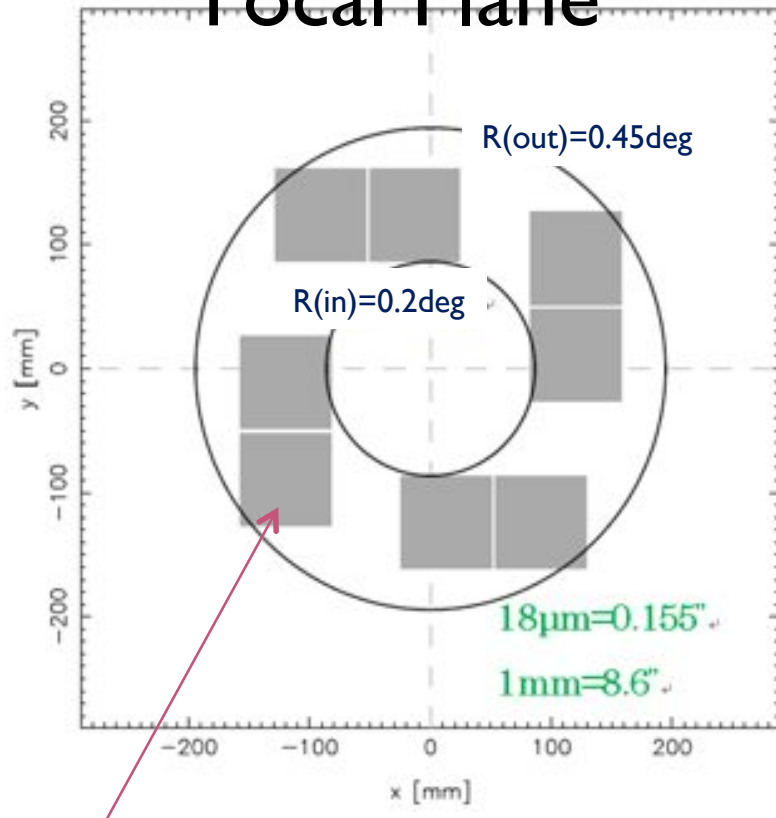




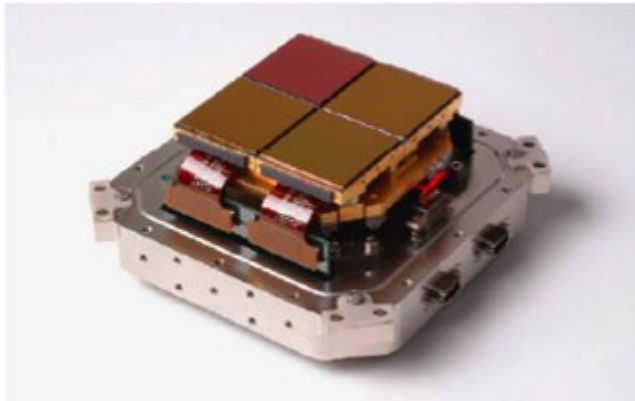
# WISH Optical Layout



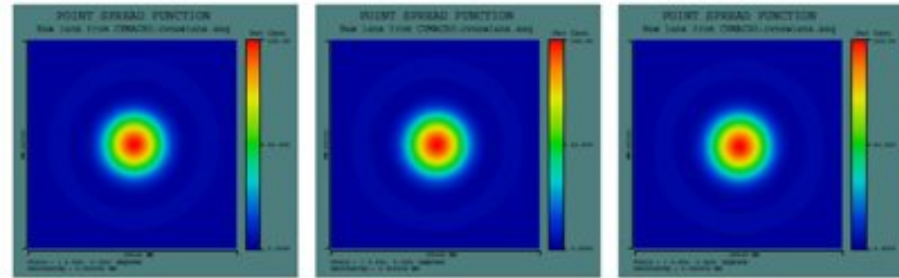
# Focal Plane



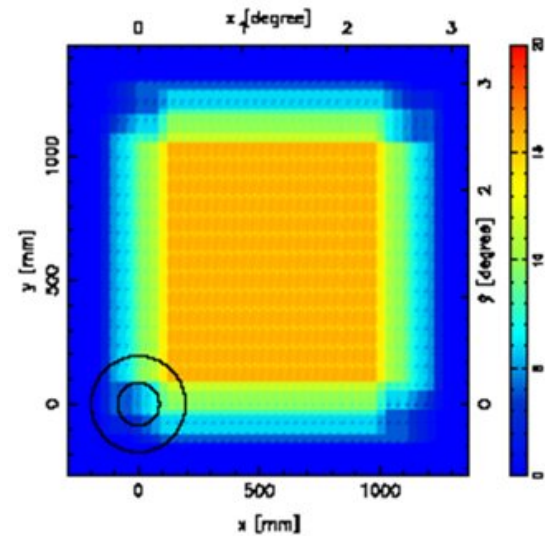
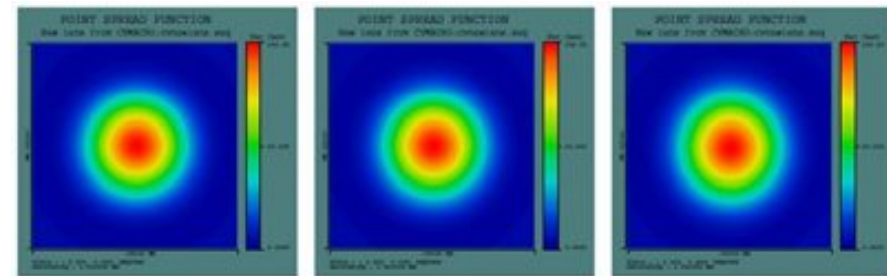
4 x 2kx2k FPA



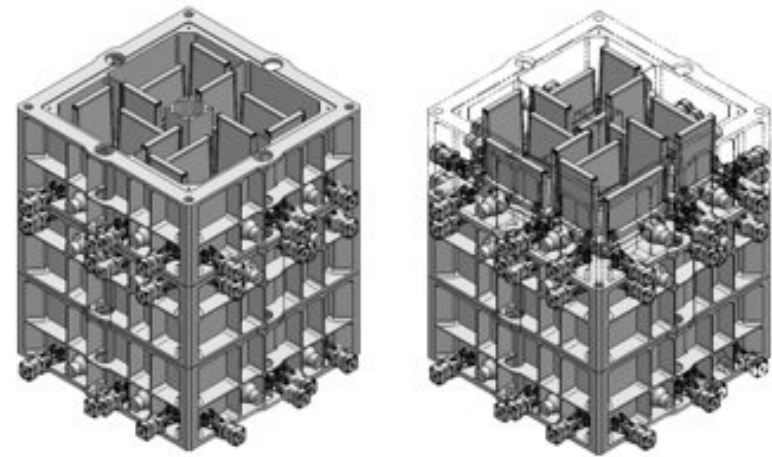
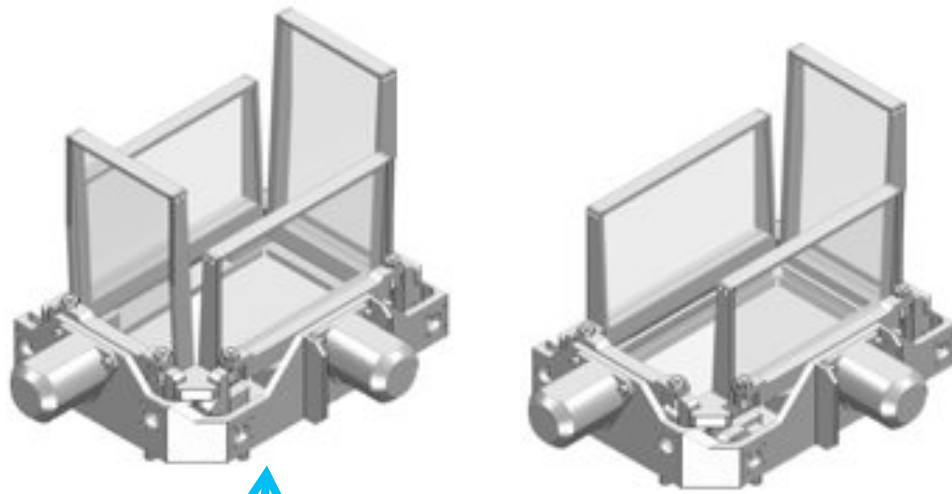
R=0.2, 0.325, 0.4 deg @ 1.25 $\mu\text{m}$



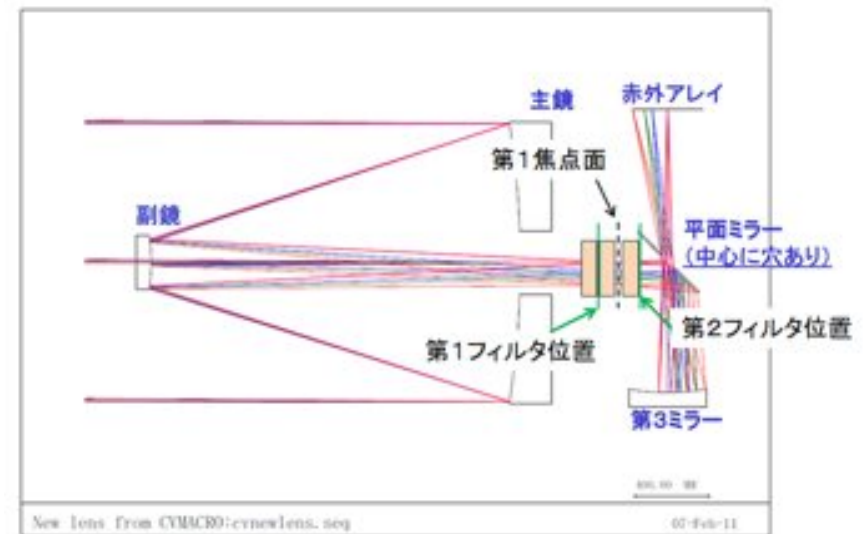
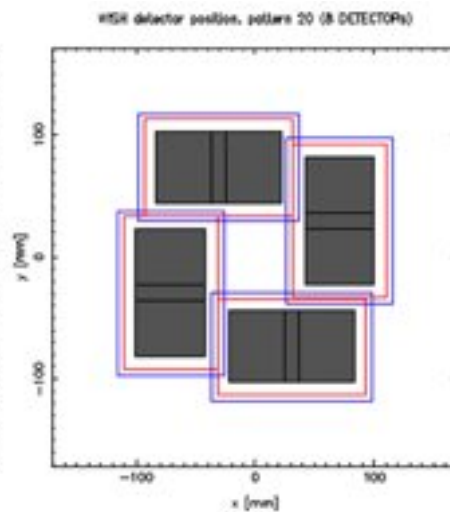
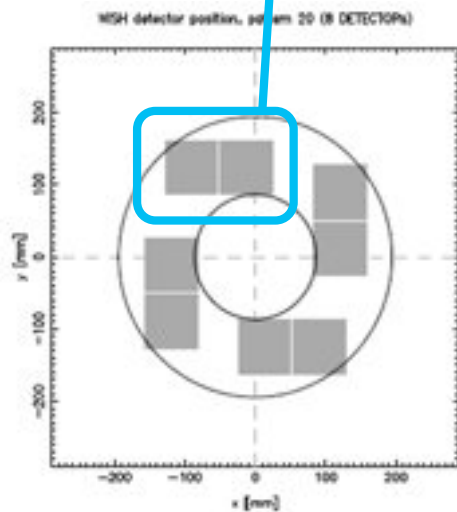
R=0.2, 0.325, 0.4 @ 2.2 $\mu\text{m}$



# WISH Flip-type Wide-field Filter Exchange System



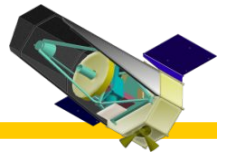
フィルタ交換機構ASSY 概要図







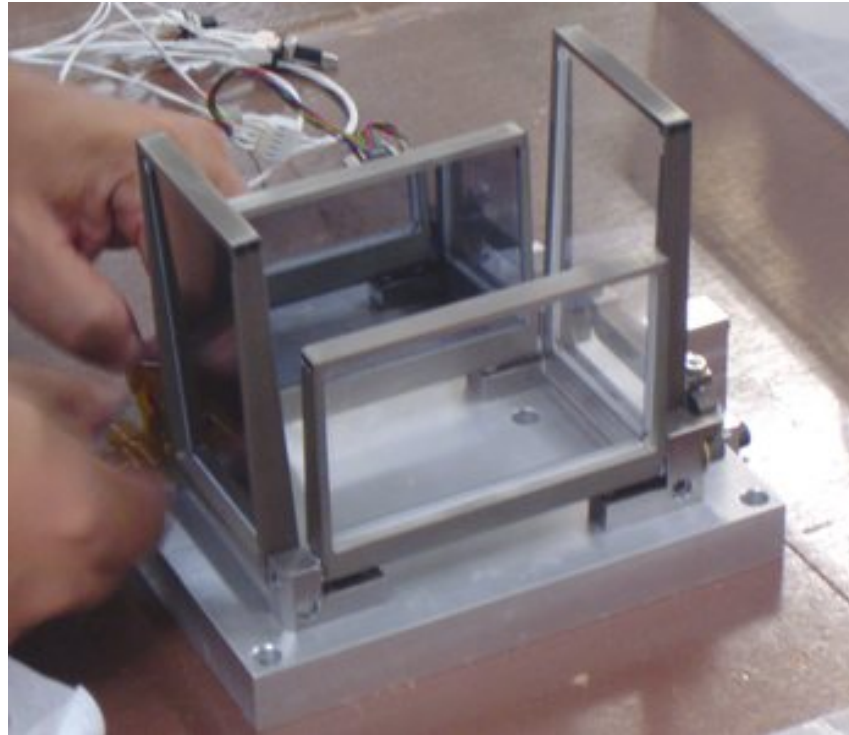
# Filter Exchange Unit: Vibration Test



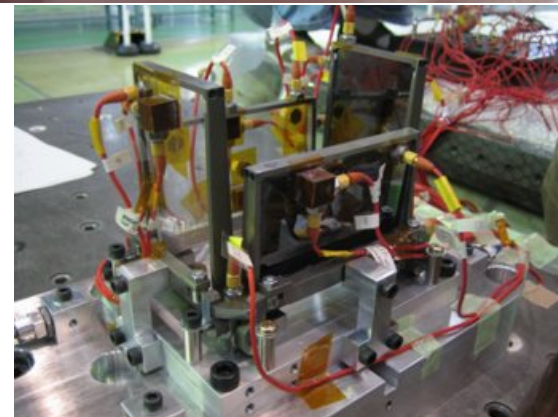
2010年11月16－19日  
JAXA/ISAS Vibration Test Facility

Dummy Filters

ECSS-E-10-03A  
“Testting” guideline  
Generic levels of vibration

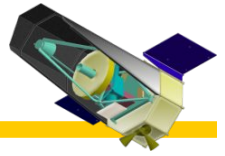


Successfully Passed



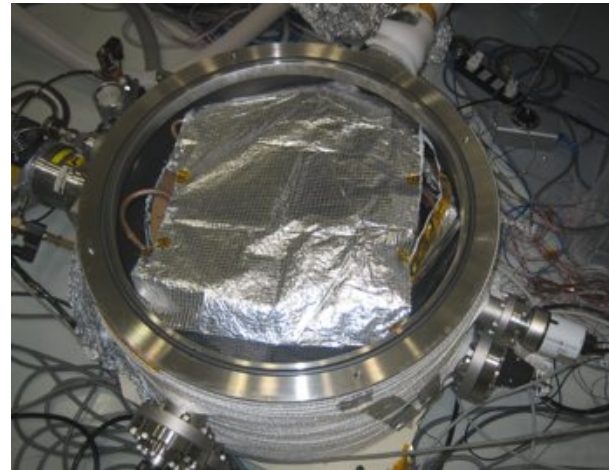


# Filter Exchange Unit: Robustness Test

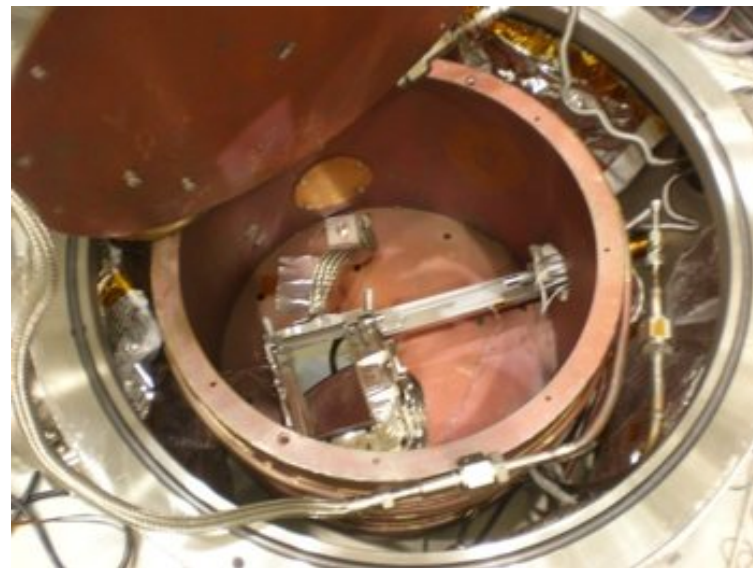


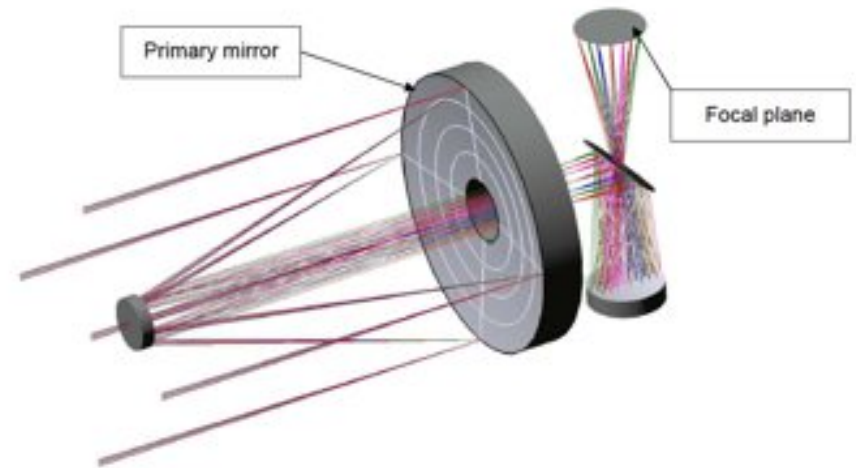
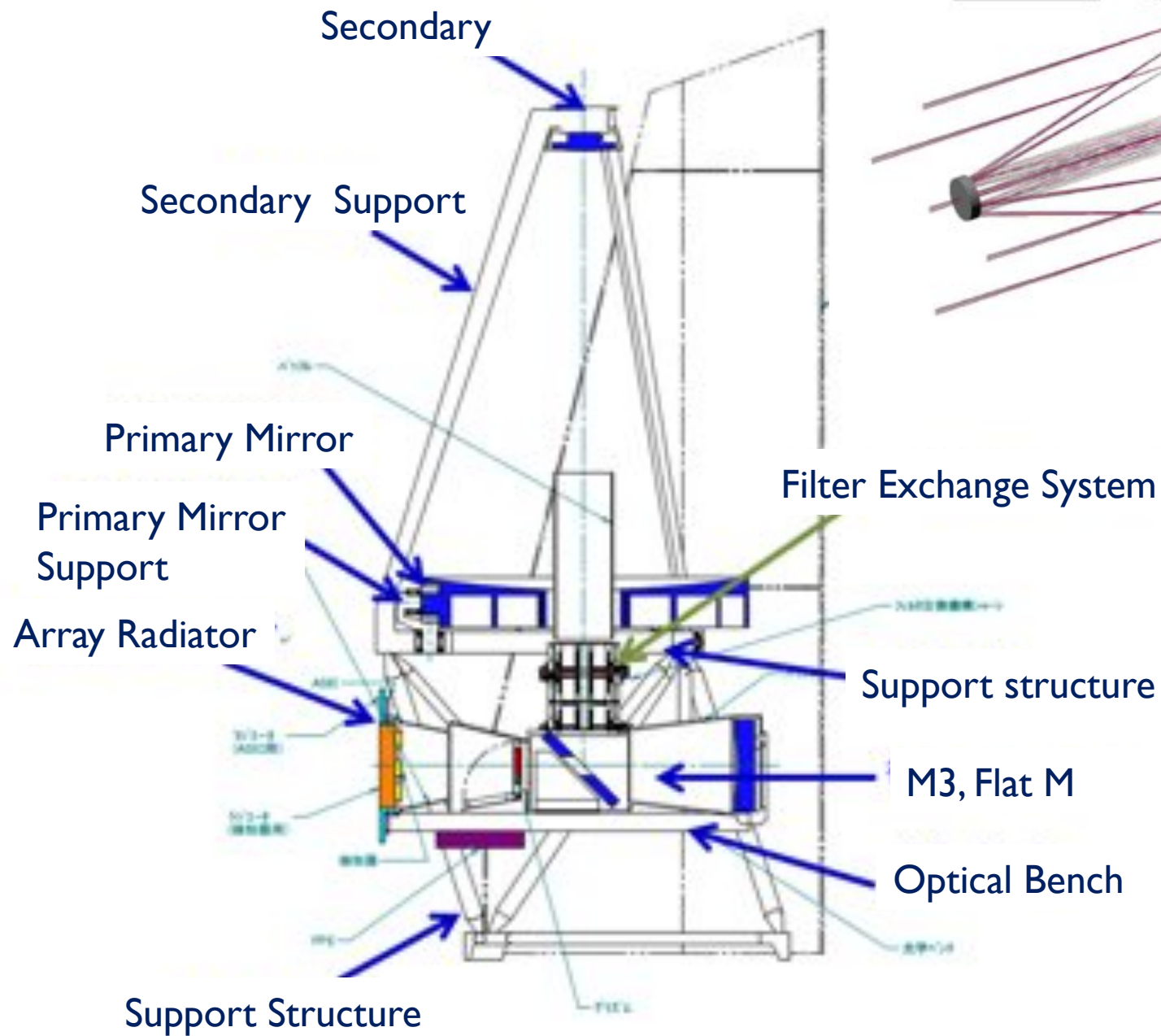
@ NAOJ  
Clean Room

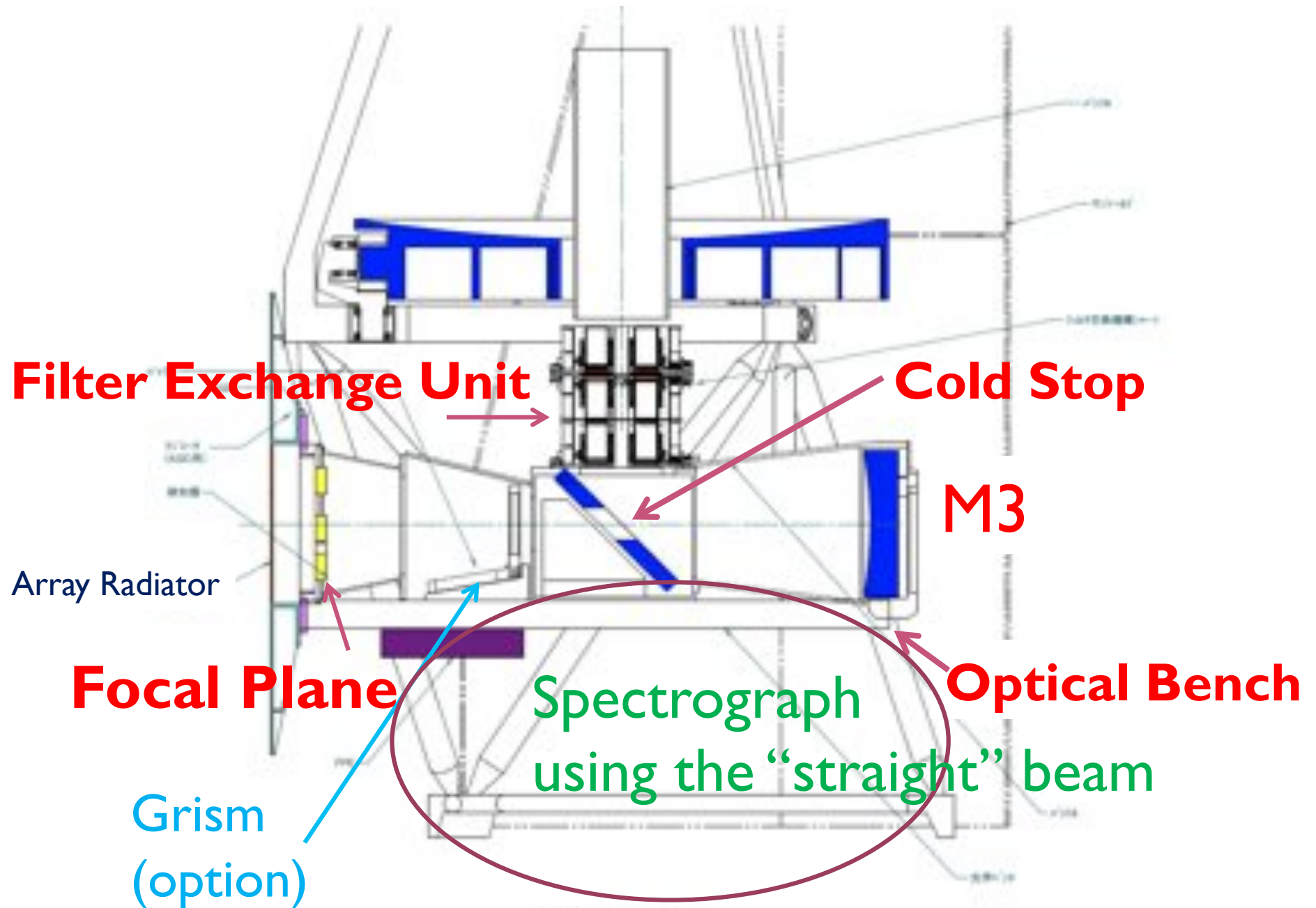
Cooled to 100-120K in a small chamber  
Test body temperature 120-150K



Successfully operated  
more than 100000 times





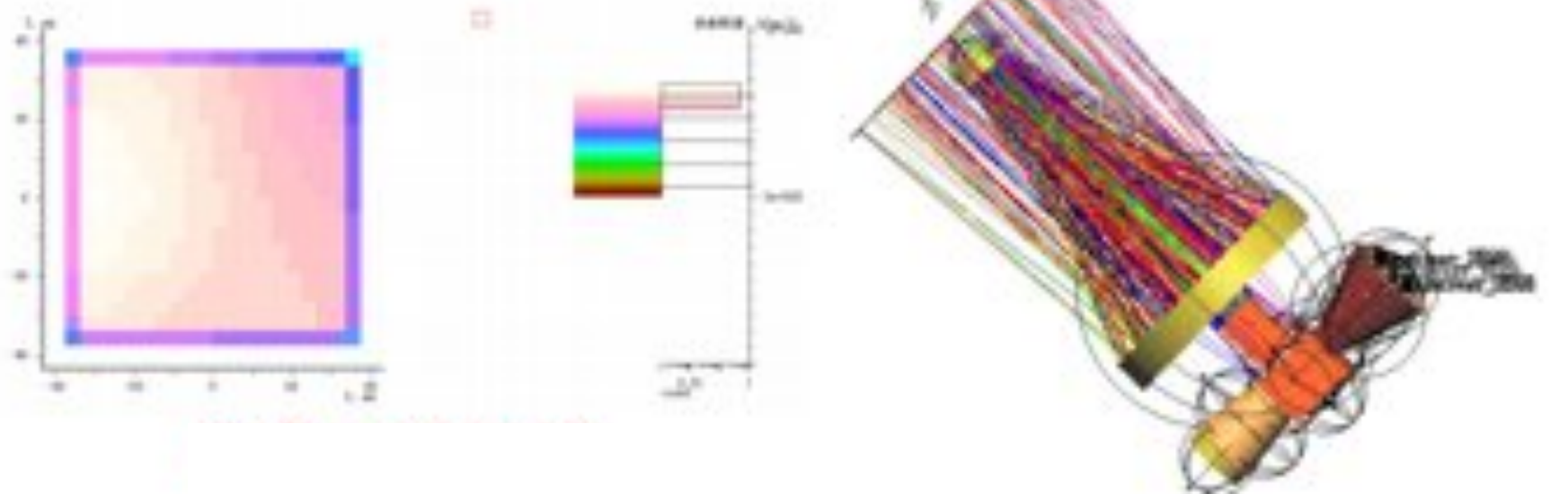


望遠鏡 断面図

# Thermal Design

WISH requires the natural background limited observations

- Evaluating the thermal radiation seen by the detectors
- Ray trace simulation



## Current Status

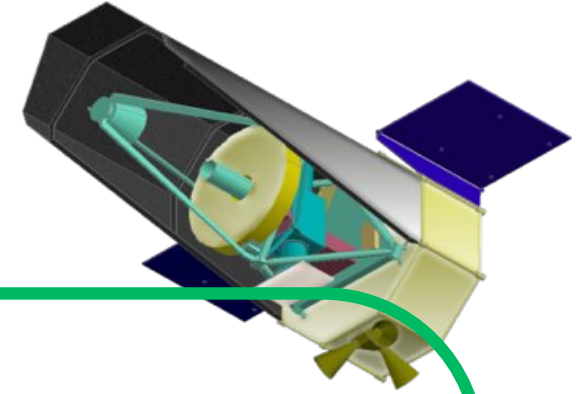
- JAXA/ISAS WISH Working Group since 2008 (**pre Phase A**)
- More than 20 astronomers/engineers have been working for R&D
- JAXA/ISAS R&D budget (~1M\$, without including man power cost)
- **WISH Mission Proposal Draft distributed (500pages, in Japanese, 2012)**
- **Potential international Partners: SAO (USA), LAM (France), Canada**
- Proposed Schedule: 2014 Mission Definition Review,  
2016 System Definition Review, Launch by early ~2020's
- JAXA Cost Cap (incl. launch, operation, data facility) ~300M\$  
+ any external budget (international collaboration /

NAOJ)

launch: HII dual launch ~ \$30-50M



# Summary



- NIR **Deep** and **Wide-field** Imaging Surveyor
- Exploring the 1<sup>st</sup> generation galaxies
- Dedicated,  **$\sim 100 \text{ deg}^2$ , 28AB ( $\sim 25 \text{ nJy}$ )**
- **$\sim 10^4$  galaxies at  $z=8-9$ ,  $\sim 3-6 \times 10^3$  at  $z=11-12$ ,  
and  $\sim 50-100$  galaxies at  $z=14-17$**
- Concept developed under JAXA/ISAS WG  
to be launched by  $\sim 2020$

# WISH Schedule (proposed)

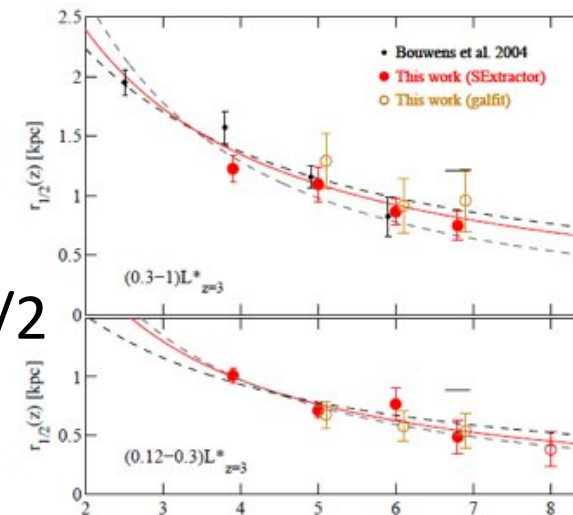
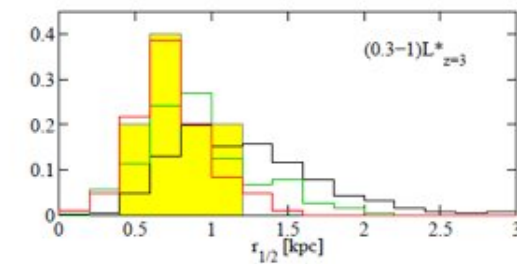
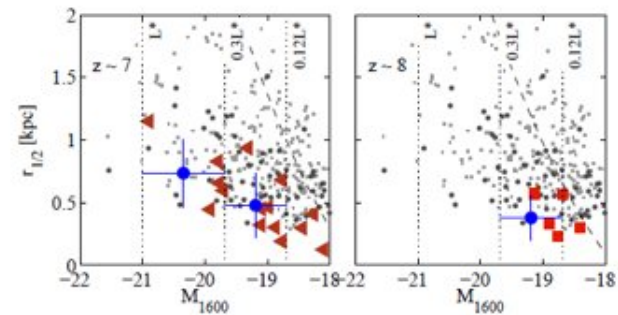
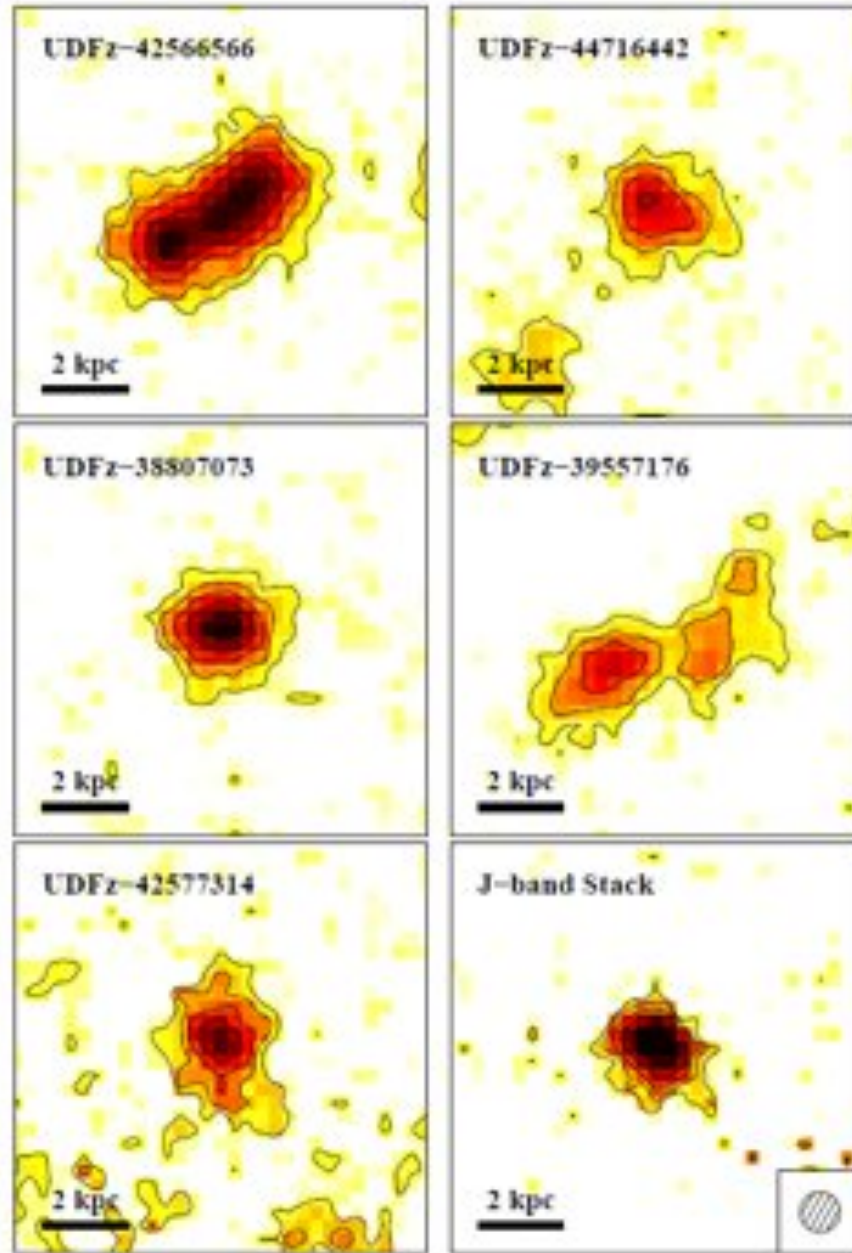
| FYr                 | Items                                                                                                       |
|---------------------|-------------------------------------------------------------------------------------------------------------|
| FYr0<br>(2008)      | Project launched<br>JAXA/ISAS Working Group<br>Conceptual Study for Specification                           |
| FYr1-6 (2009-2014)  | Conceptual Study, R&D<br>Mission Proposal<br>Mission Requirement/Definition Review → 2014?                  |
| FYr6-7              | Phase A / Proto Models                                                                                      |
| FYr7-8              | Preliminary Design Review<br>Proto Models / Test                                                            |
| FYr9-10             | Proto Models /Test<br>Critical Design Review<br>Primary Mirror / Detector fabrication start<br>Flight Model |
| FYr11               | Flight Model / Test                                                                                         |
| FYr12<br>(NET 2020) | Flight Model / Test<br>Launch                                                                               |

| Overall Parameters |                                          |                                                   |
|--------------------|------------------------------------------|---------------------------------------------------|
| Launch Date (plan) | NET 2017                                 | Mission Life Time<br>> 5yr                        |
| Launcher           | H-IIA<br>4/4D-LC lower case<br>PAF 2360S | Capable to launch 1.5t<br>(dual launch, SE-L2)    |
| Size               | $\phi$ 3.3m x 5.2m                       | Launch Configuration<br>Including the startracker |
| Mass               | @launch (WET) 1.3t                       | margin 0.2t                                       |
| Orbit              | Sun Earth L2 Halo                        |                                                   |
| Power              | Max 1.2 kW                               | SAP power<br>1.6kW (BOL)<br>1.4kW (EOL)           |

| Mission Part       |                                                                                                                                                                            |                                                                                                                                                                                                                                                             |
|--------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Optics             | M1 $\phi$ 1.5m ellipsoidal<br>M2 $\phi$ 0.28m hyperboloid<br>M3 $\phi$ 0.41m ellipsoidal<br>Deff..limit at 1-5 $\mu$ m<br>Fov $\phi$ 0.2-0.7deg<br>0."15/18 $\mu$ m(pixel) | <ul style="list-style-type: none"> <li>• Cooled to 100K</li> <li>• flat mirror also works as the cold stop</li> <li>• <b>light going through the flat mirror hole: option</b></li> <li>• slitless grism spectroscopy at 1-2.5 <math>\mu</math> m</li> </ul> |
| Focal Plane Arrays | HgCdTe (HAWAII-2RG)<br>2K x 2K 32 chips (128Mpix)                                                                                                                          | 0.9-5.3 $\mu$ m<br>1pixel=18 $\mu$ m                                                                                                                                                                                                                        |
| Filter Exchanger   | Flip-type exchanger<br>11 filters + Cold Shutter                                                                                                                           | Test module pass the robustness test<br>(120K, >100000 moving) and oscillation test                                                                                                                                                                         |
| Cooling            | M1 100K<br>Other telescope and instrument<br>structure: 80-100K<br>Detector 40-50K<br>Passive radiative cooling                                                            | No mechanical cooler                                                                                                                                                                                                                                        |

|                                  |                                                                                             |                                                                                                             |
|----------------------------------|---------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| BUS                              |                                                                                             |                                                                                                             |
| SAP                              | Fixed, 2 wings<br>1.6kW (BOL) 1.4kW (EOL)                                                   |                                                                                                             |
| Sun shield                       | Al panels + <b>MLI 30/30</b>                                                                | SPICA R&D heritage                                                                                          |
| Positional Control               | STT-IRU Strap down system<br>RW high accuracy<br>(tork-balance )                            | "internal accuracy" (w/o thermal flexure)<br><0.03" r.m.s. (300sec)<br><br>Guiding using the science arrays |
| Thruster                         | 一液触媒式ブローダウン方式<br>fuel >162kg<br>thruster 3Nx8 23Nx4                                         | Φ504mm tank 4                                                                                               |
| Data link<br><br>Data processing | X-band (Data, 16Mbps),<br>S-band (telemetry)<br>BUS < 50Mbps<br>(Space Wire)<br>DR 48GB x 2 | Ka-band (32Mbps): option                                                                                    |

# Size distribution of the galaxies at $z \sim 7$



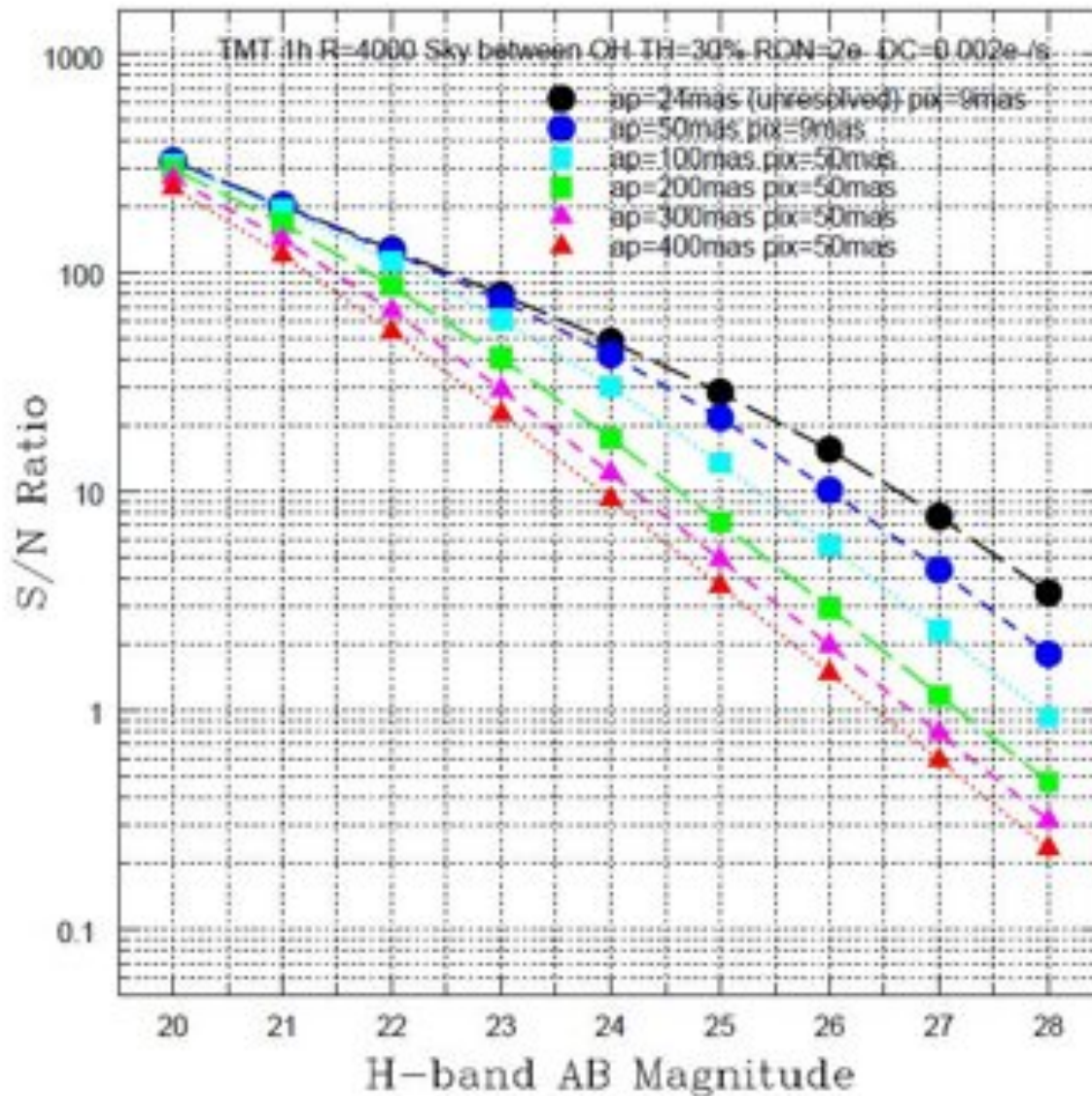
$R_{1/2}$

$z=7$

Oesch et al. 2009



# WISH and ELTs



TMT 1h spectroscopy  
(between OH lines)

R~4000

200mas aperture  
10h, R~400  
AB~28 → S/N~3

TY