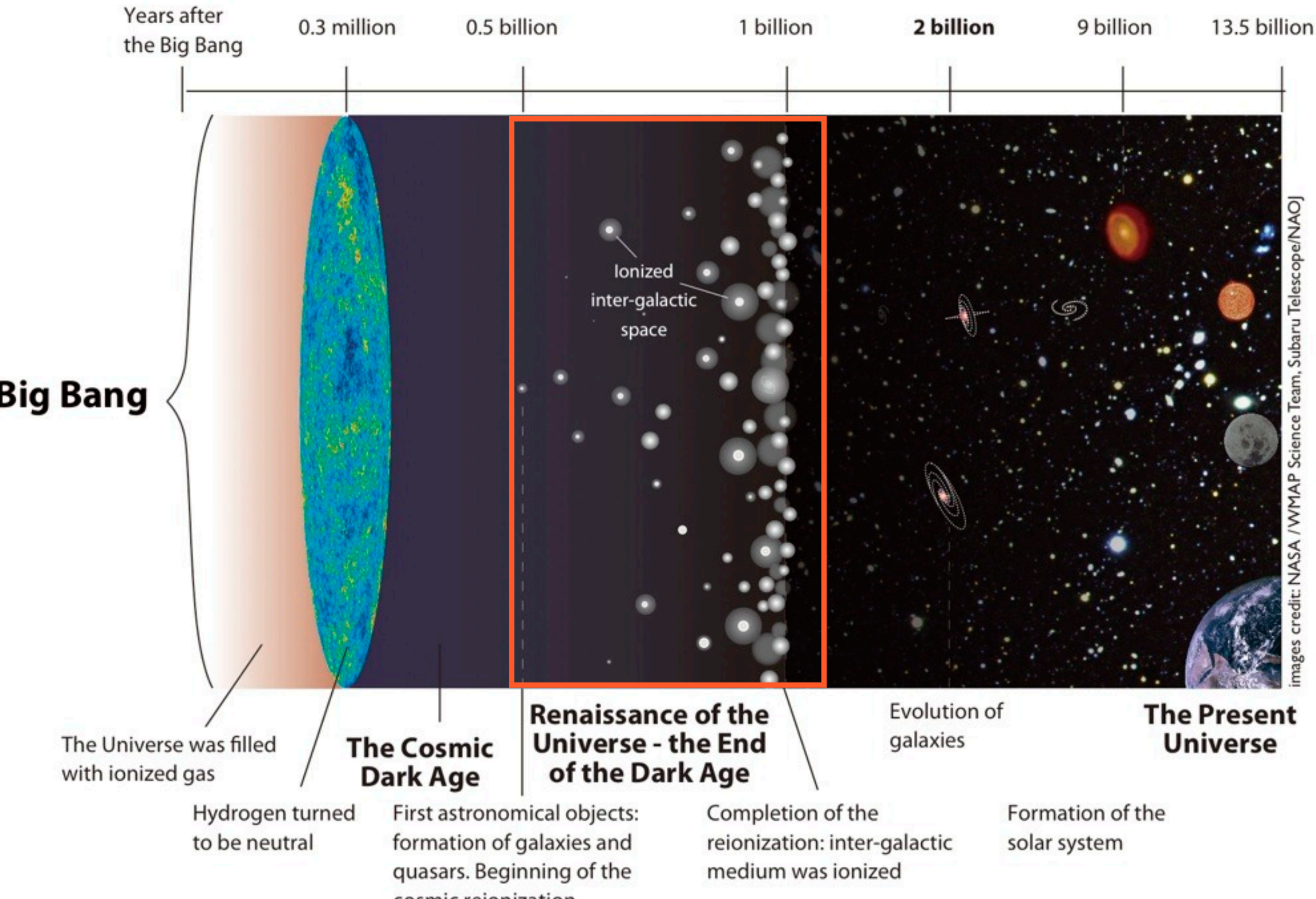
# Study of Extremely High-z Galaxies: SPICA/FPC-S and WISH

岩田 生 Ikuru Iwata (National Astronomical Observatory of Japan)

Kiyoto Yabe (Kyoto U), Mark Kobayashi (NAOJ), Toru Yamada (Tohoku U),
Kouji Ohta (Kyoto U), Takehiko Wada (ISAS) and WISH team

# Cosmic Reionization - Dawn of the Universe



# SPICA / FPC-S

- Near-Infrared Camera for SPICA
  - 5’ x 5’ Field of View (1k x 1k InSb detector)
  - Linear Variable Filters
  - 8 Science Filters
- SPICA: Extremely Cold Space Mission
- NO instrument thermal background in near-IR

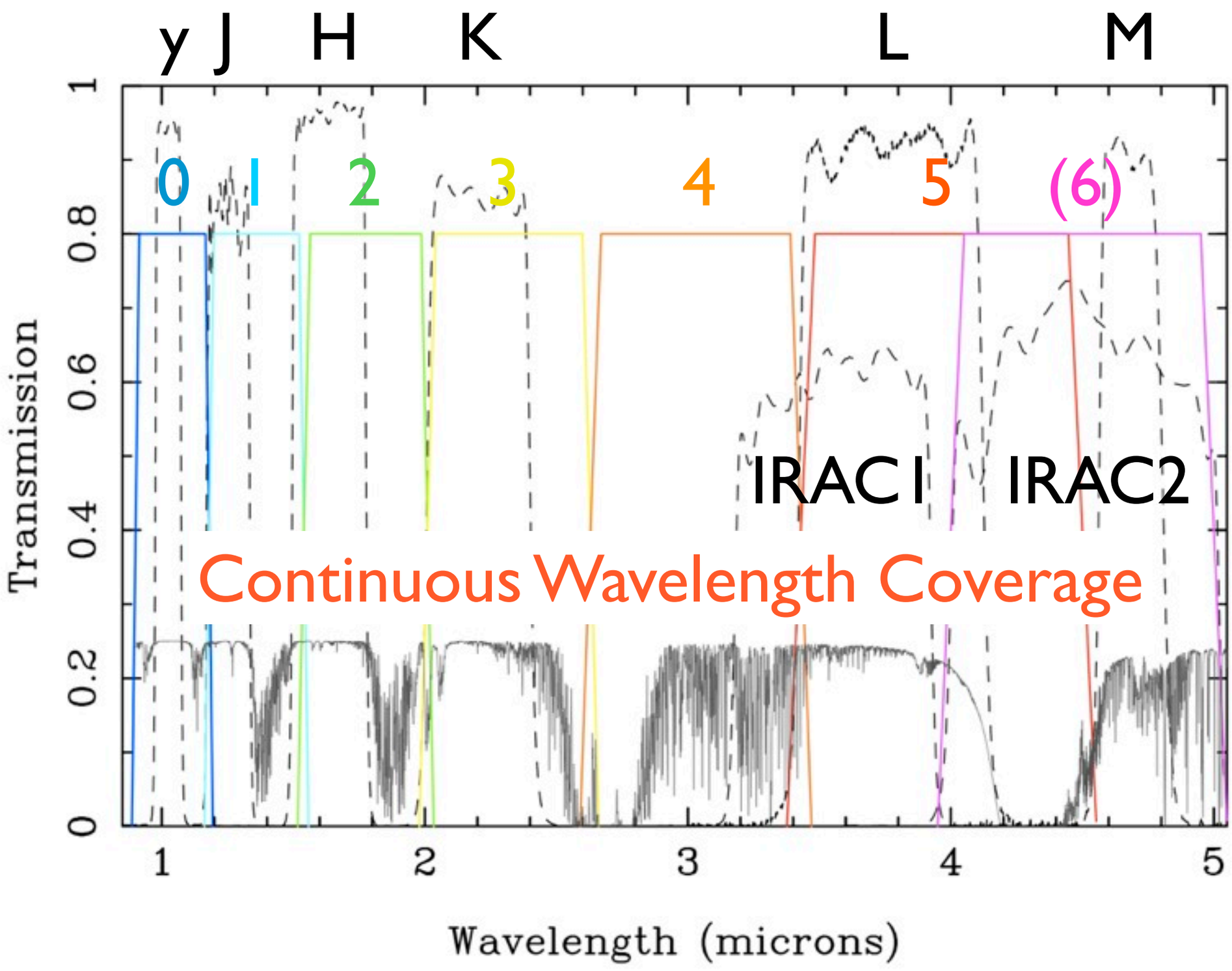
Although near-IR is not the core wavelength,
it potentially provides an opportunity of
probing extremely high-z galaxies.

# WISH: Wide-field Imaging Surveyor for High-redshift

- 1.5m Space Telescope at S-E L2
- 840 arcmin$^2$ Wide-field Camera
- 6 Broad-band filter from 1.0μm to 5.0μm
- 0.15”/pixel, diffraction limit at 1μm
- Passive cooling optimized for near-IR
- JAXA/ISAS Working Group from 2008 - P.I. Toru Yamada (Tohoku Univ.)

http://wishmission.org

# WISH Broad-band Filter Set

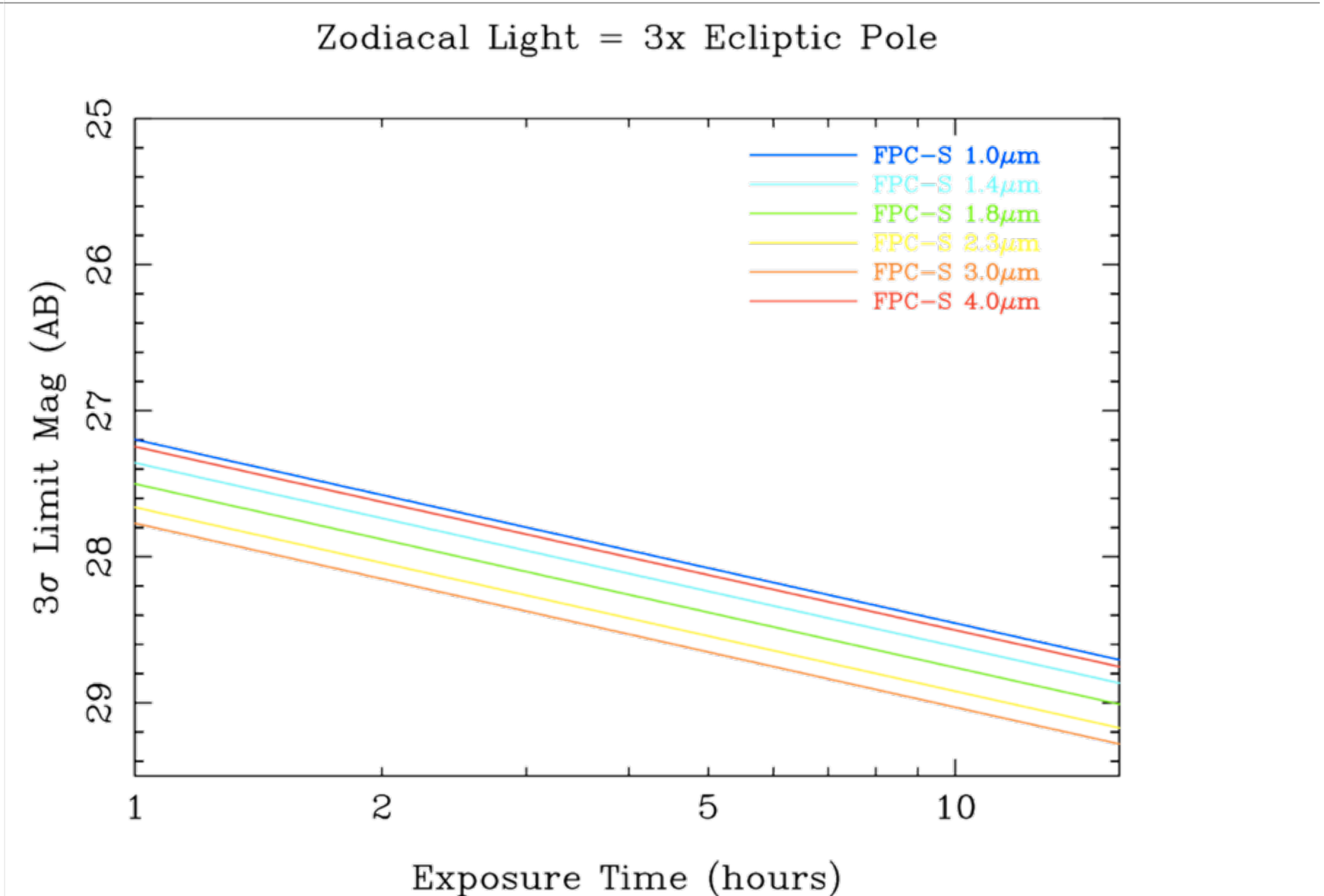


# SPICA/FPC-S: Expected Sensitivity for Point Sources

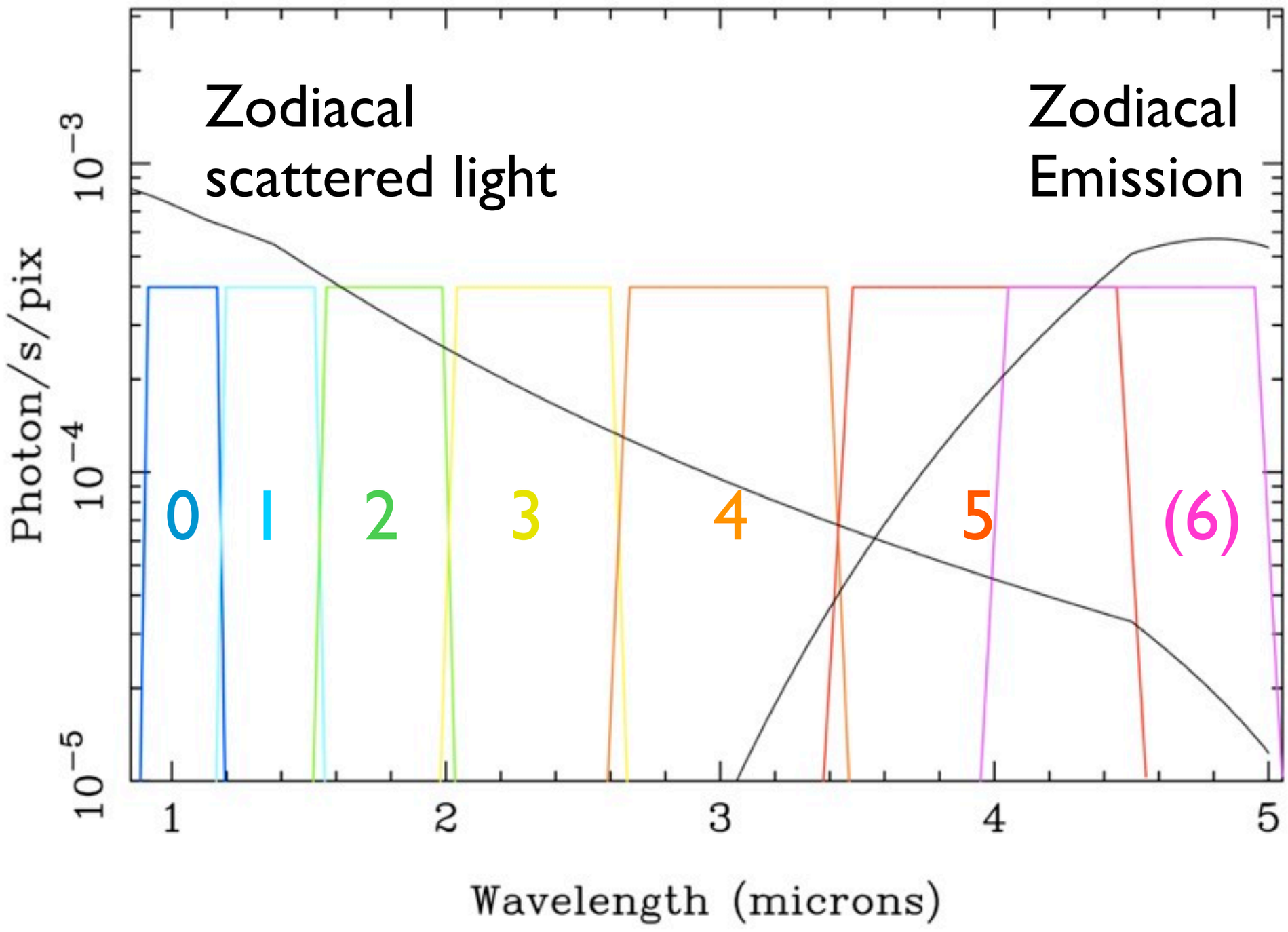
- Assumptions:
  - FWHM = 0.35 arcsec for all wavelengths, Aperture=0.6 arcsec
    - Better image quality, better sensitivity
  - Zodiacal background: 3x of the values in Ecliptic poles
  - WISH broad-band filter set: optimized for high-z galaxy search
    - Camera optics throughput: 65%
    - Single exposure time: 120 seconds
    - Read-out-noise: 20e-

- Sensitivity is background-limited.

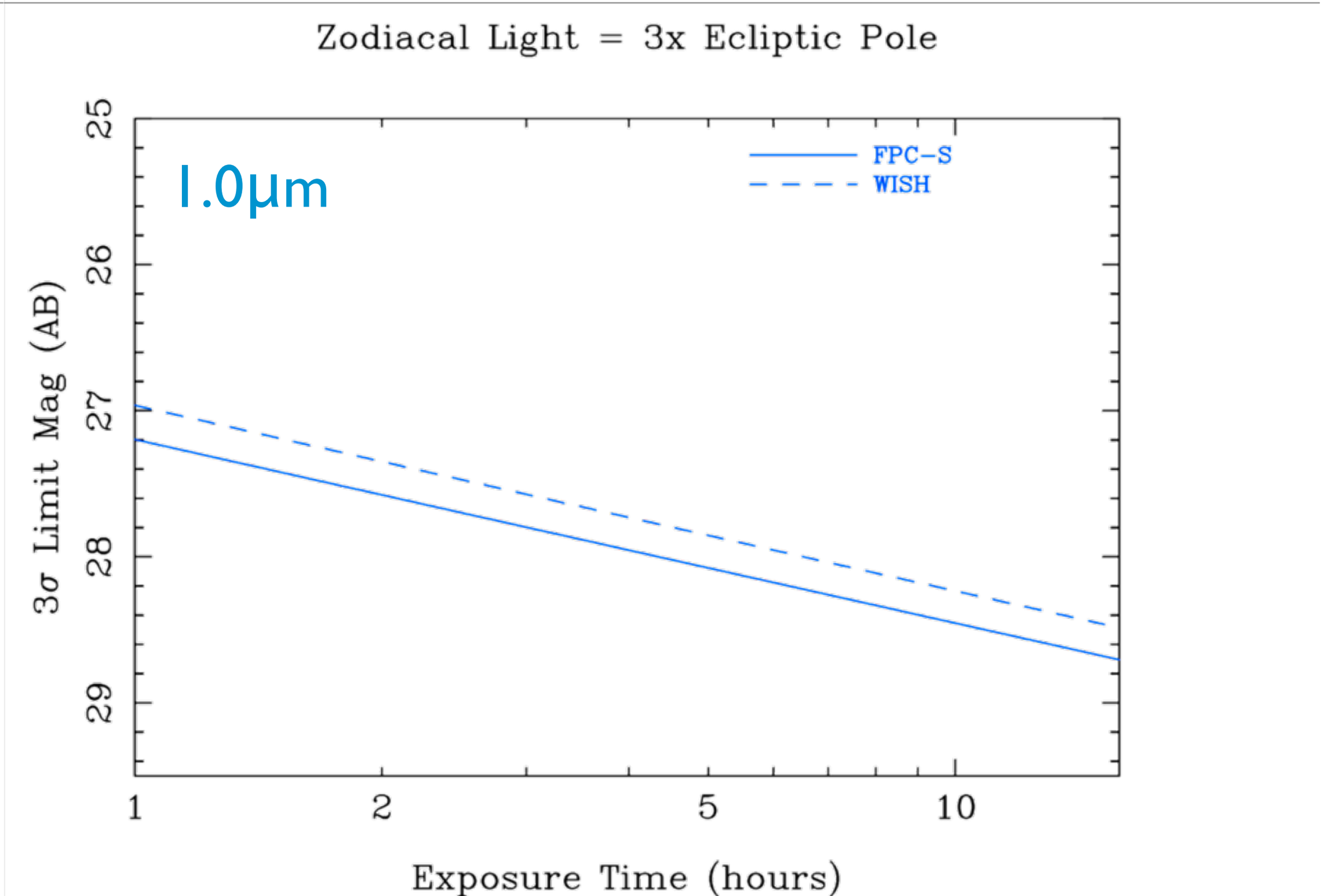
# FPC-S Expected Sensitivity for Point Sources



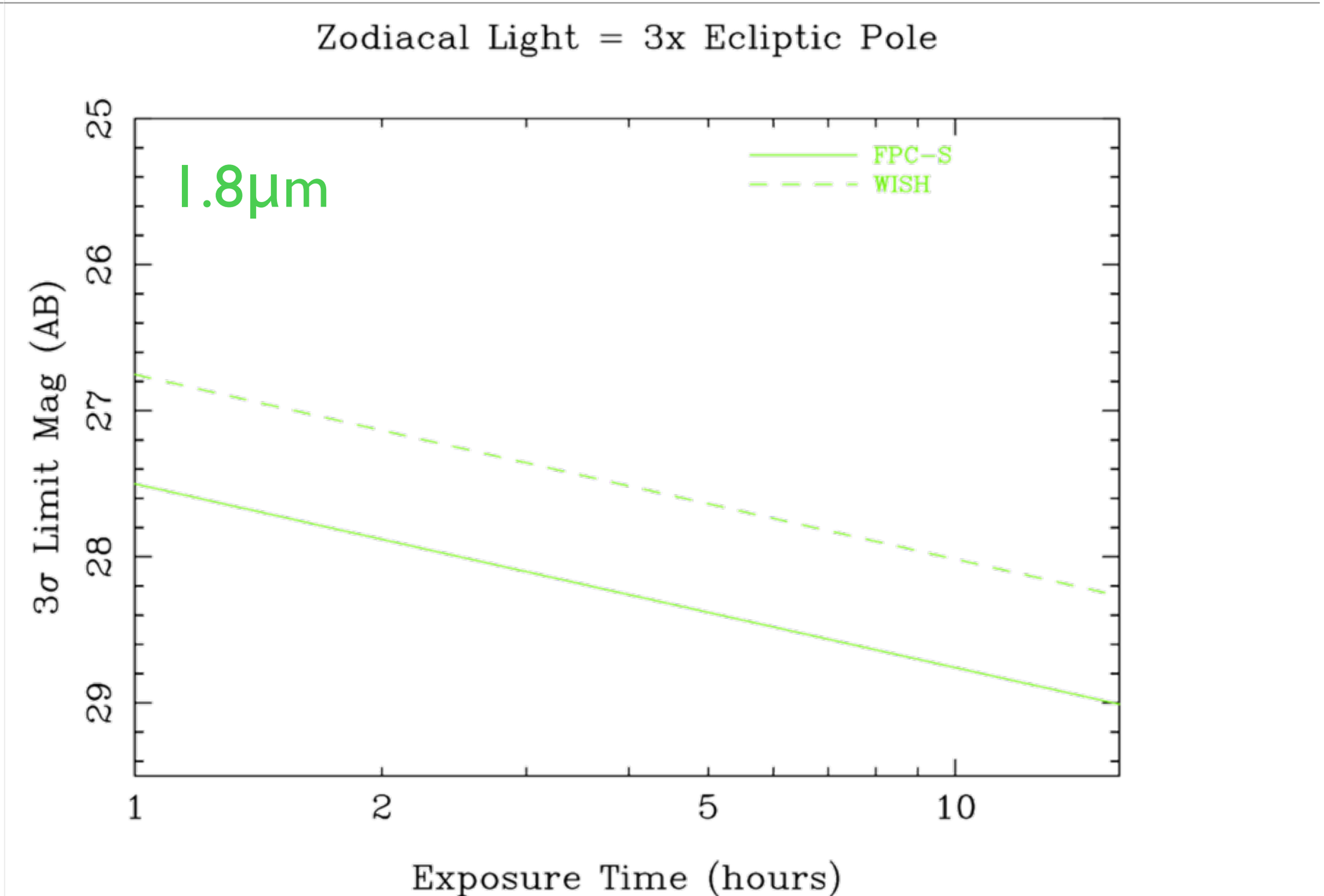
# WISH Broad-band Filter Set



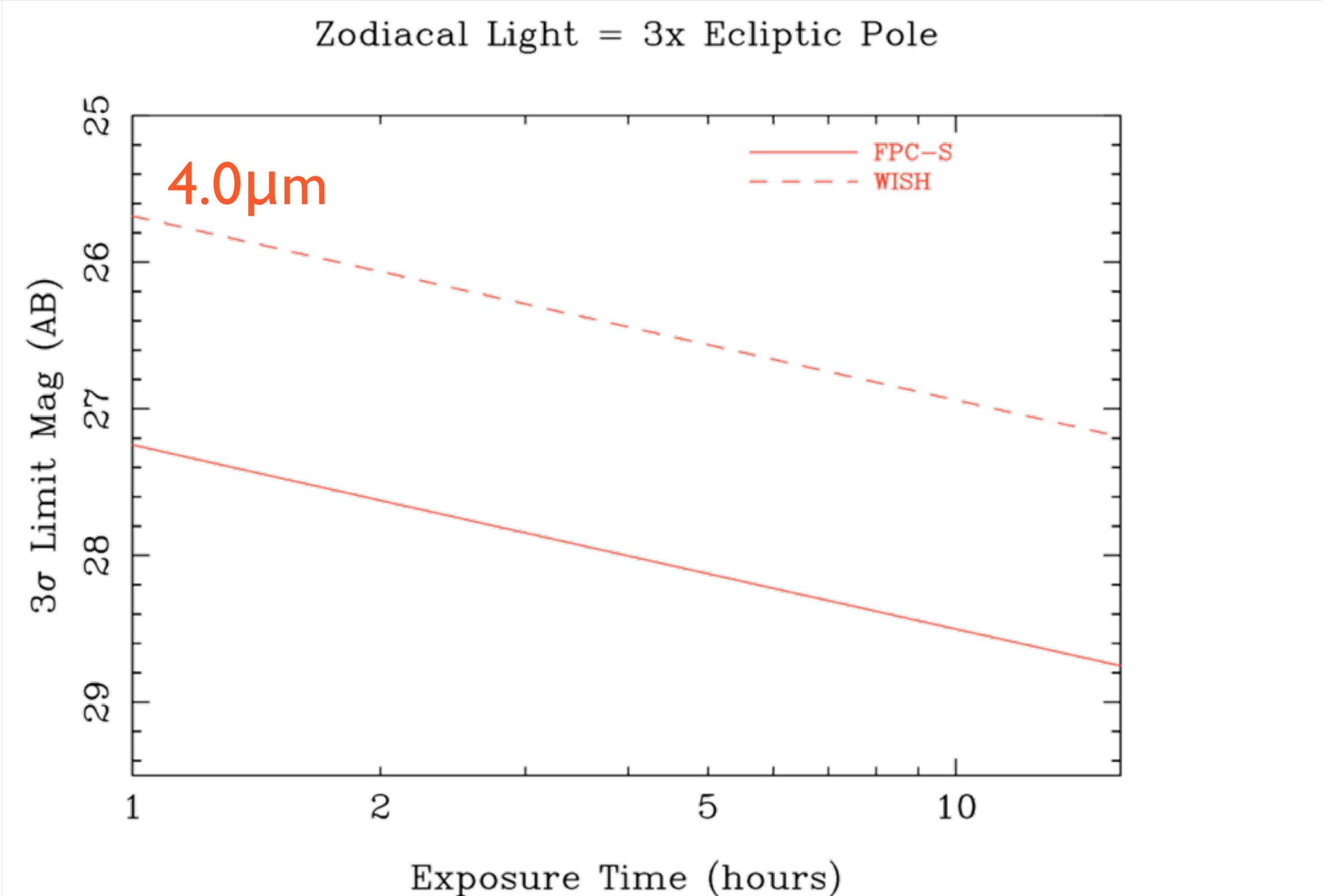
# FPC-S vs. WISH at 1.0μm



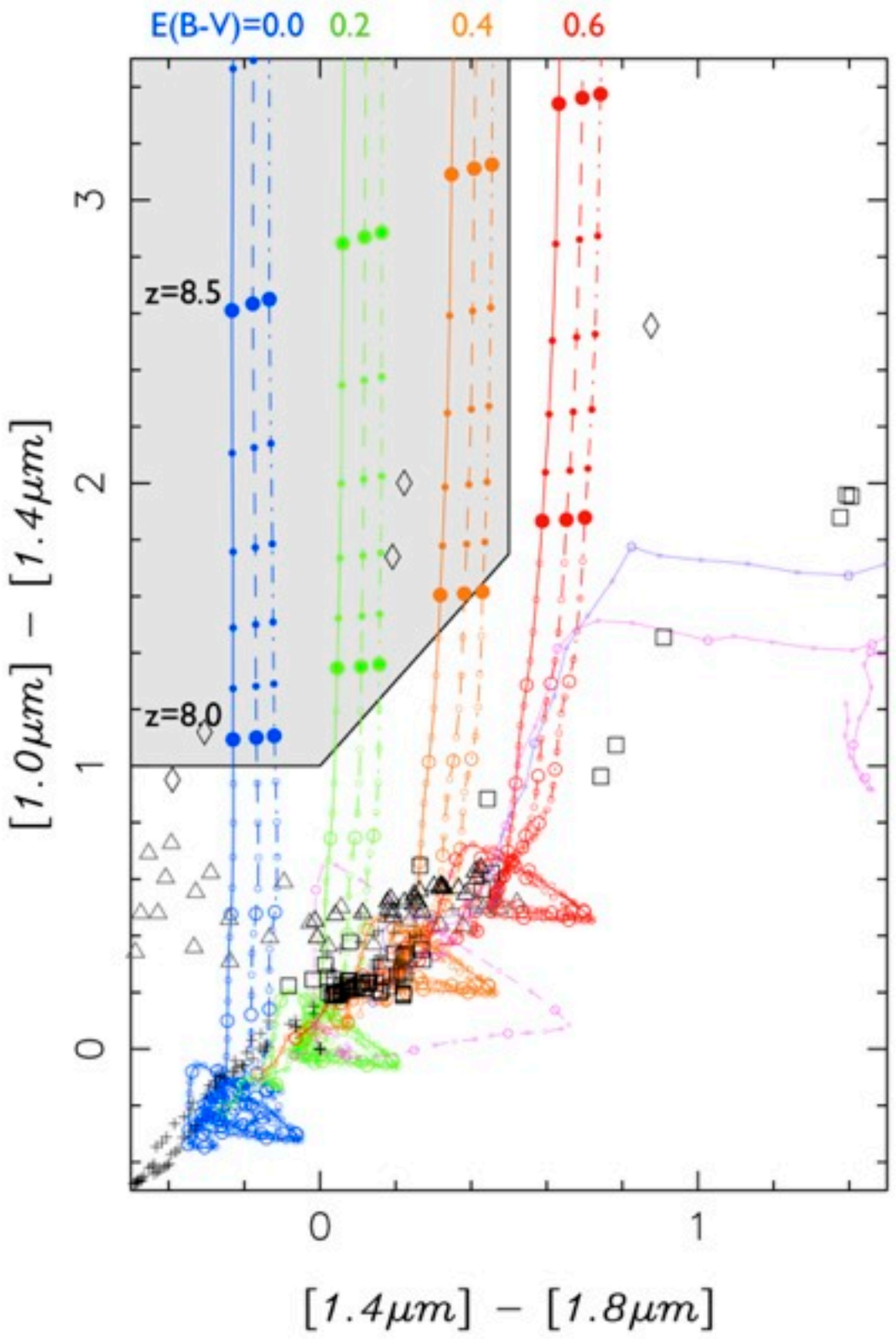
# FPC-S vs. WISH at 1.8μm

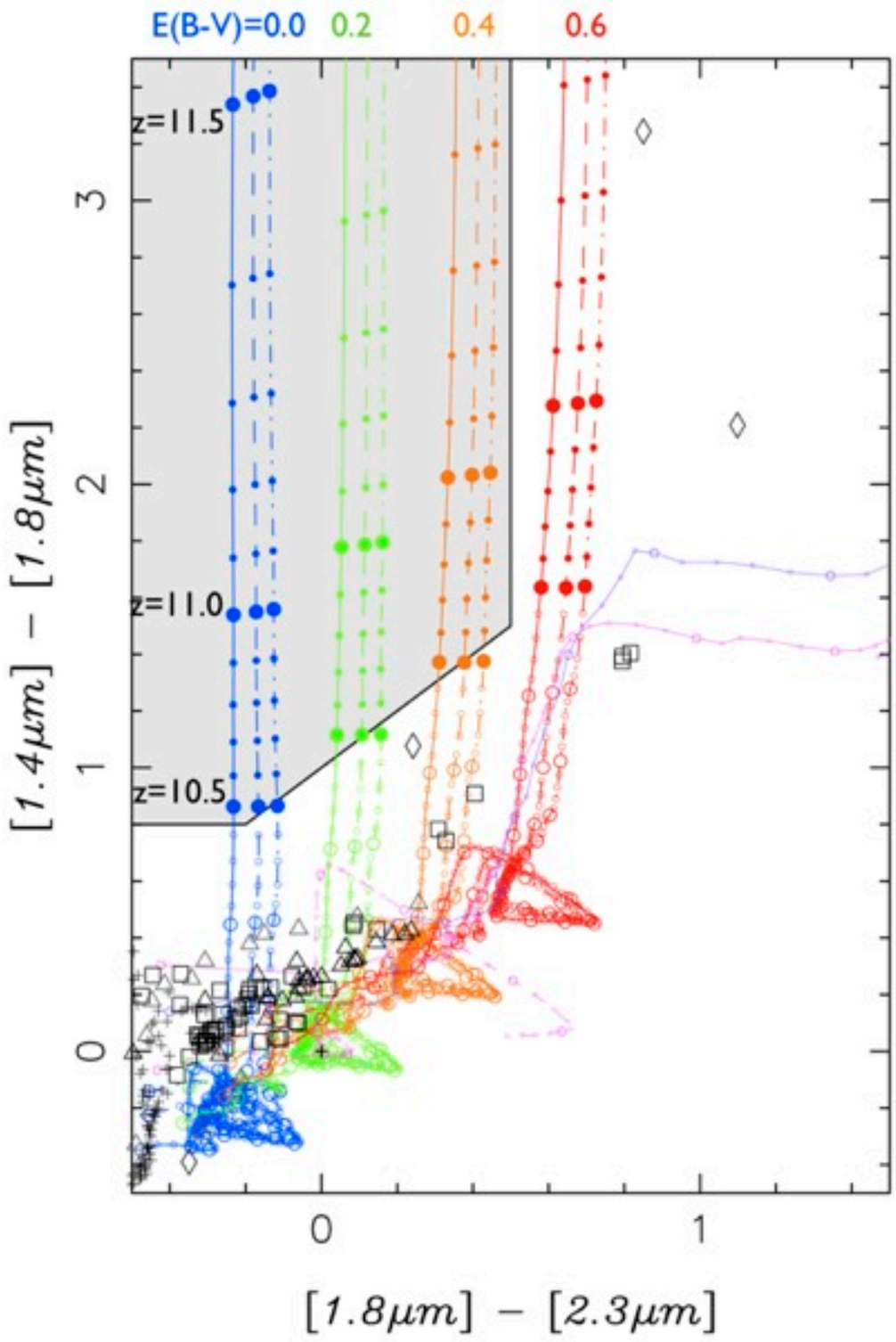


# FPC-S vs. WISH at 4.0μm

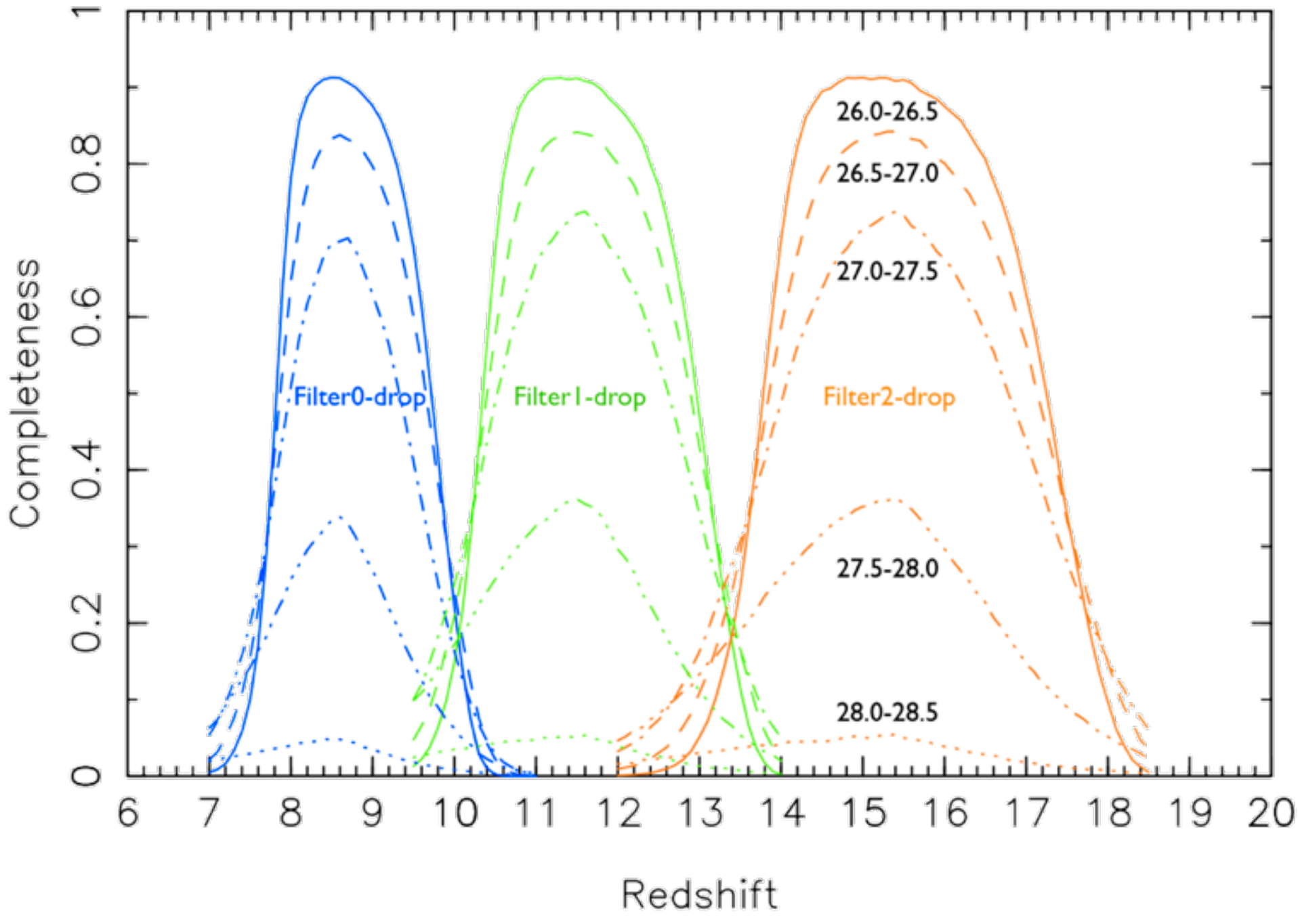


# Selection of High-z Galaxies with Two-Colors



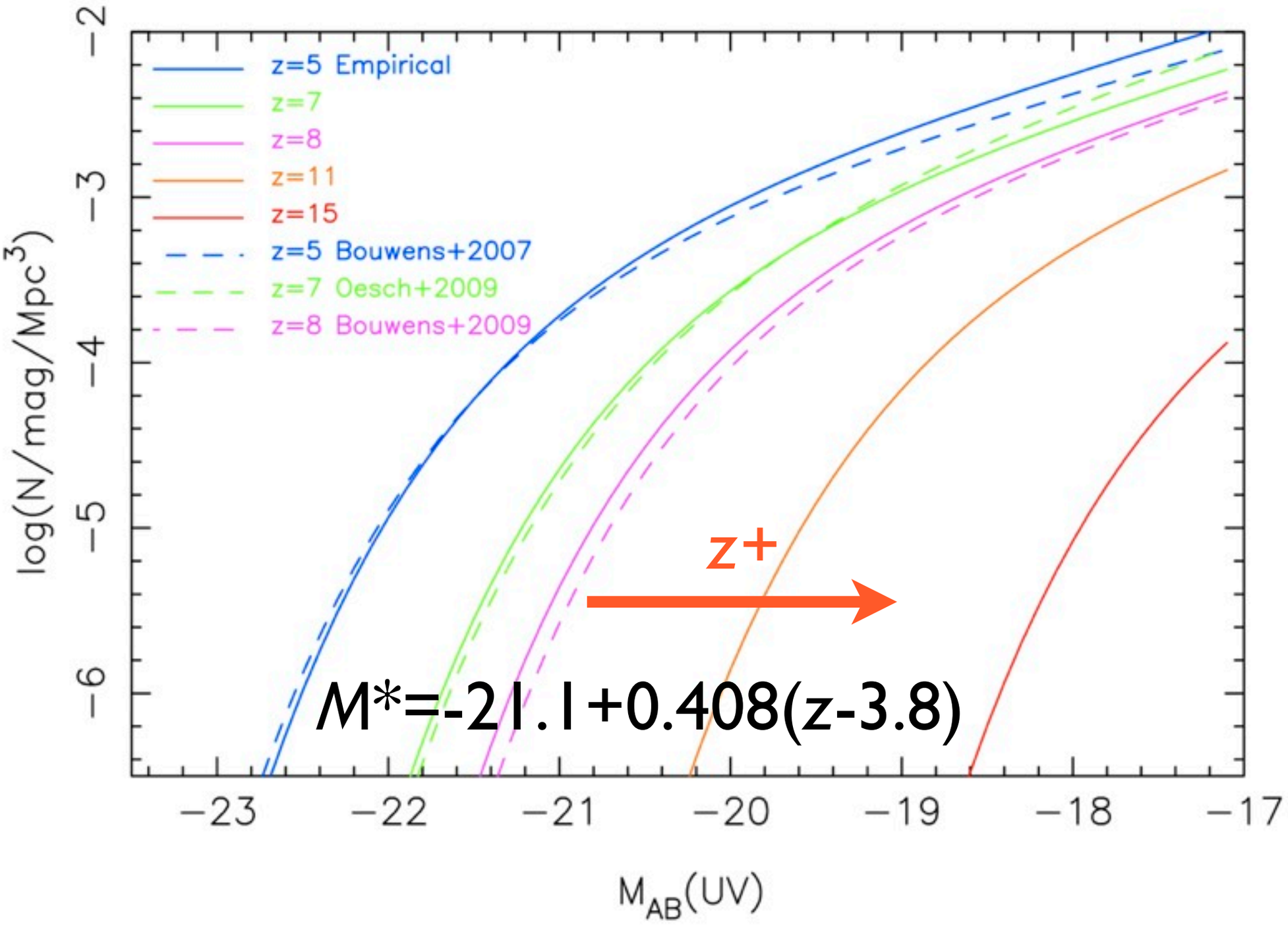



# Completeness Estimates

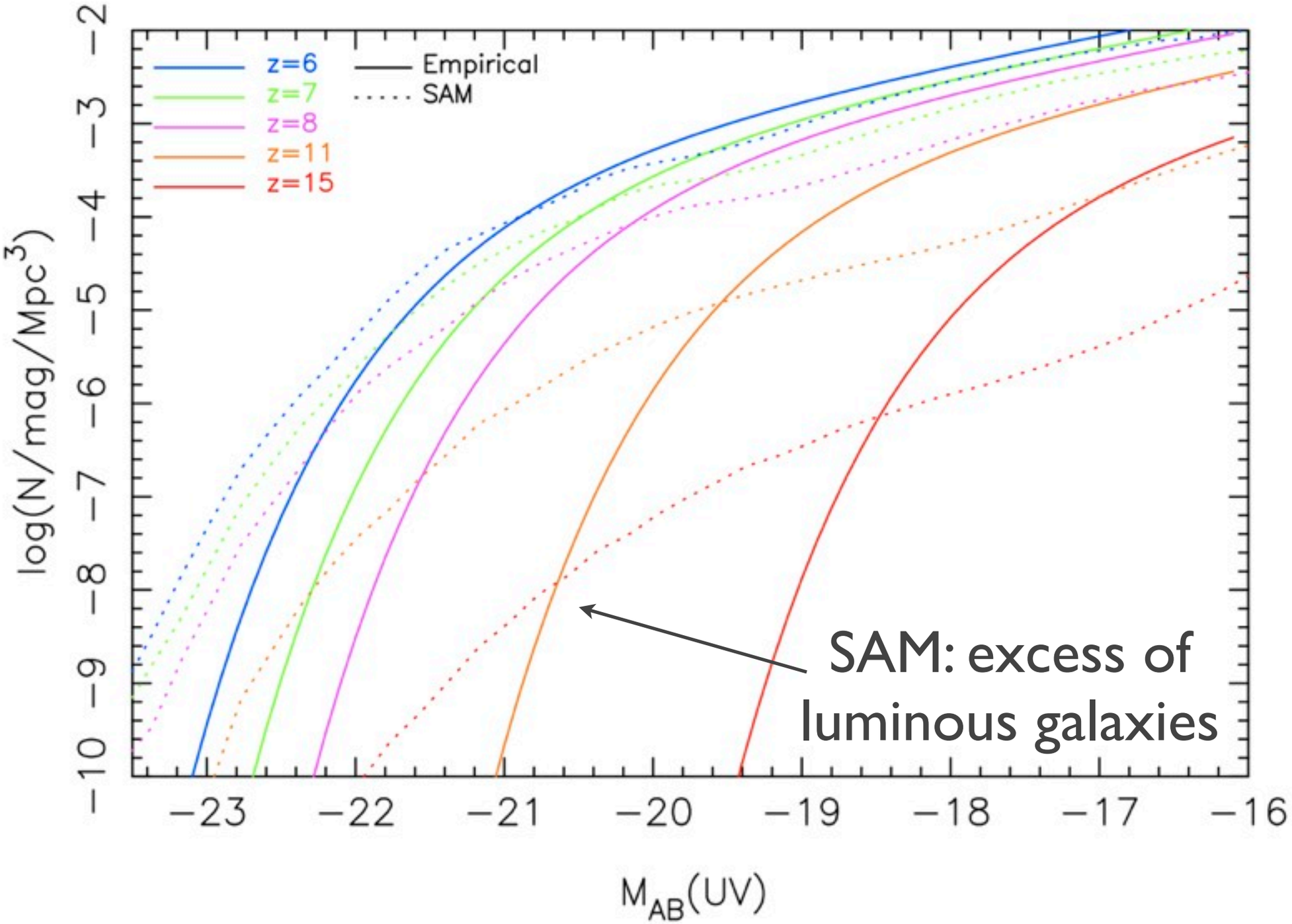



for the case of WISH (Lim. Mag. = 28AB)

# 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 of High-z Galaxies with FPC-S

- Example(1): 100 FoV (~0.7 sq. deg.) Survey with 5 filters from 1.0μm to 3.0μm
  - Limiting magnitudes 28AB (point source, 3σ)
  - Total 16.9 hours per FoV (incl. 25% overhead) - 70 days for 100 FoV

| | z=8-9 | z=10-12 |
|---|---|---|
| Empirical Ev. | 1173 | 72 |
| SAM | 438 | 35 |

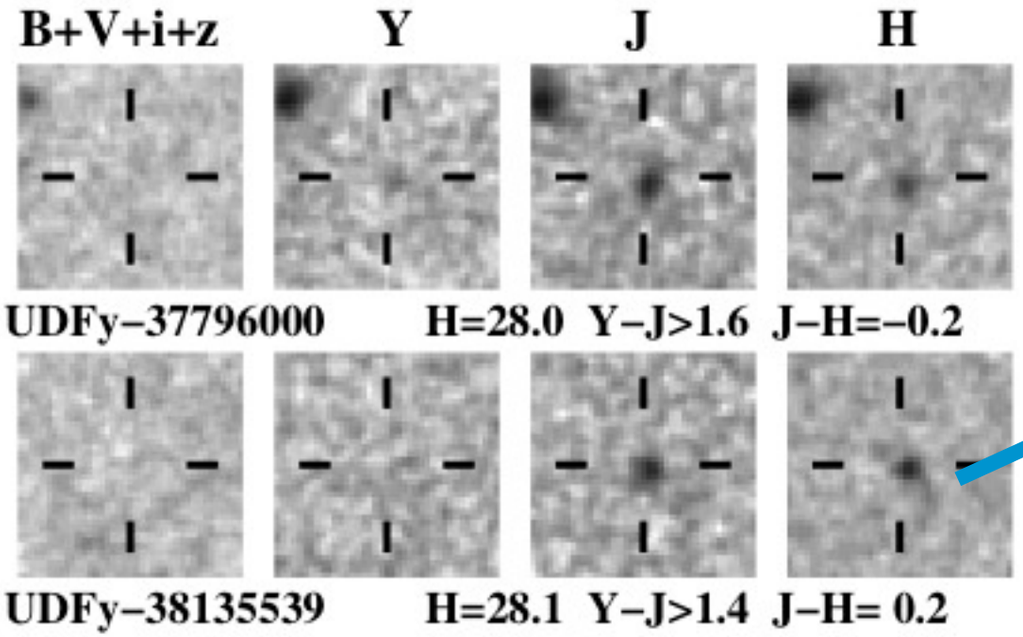
- Example(2): 500 FoV Survey with 3 filters from 1.8μm to 3.0μm
  - Limiting magnitudes 28AB (point source, 3σ)
  - Total 7.4 hours per FoV (incl. 25% overhead) - 153 days for 500 FoV

| | z=13-17 |
|---|---|
| Empirical Ev. | 2.5 |
| SAM | 3.7 |

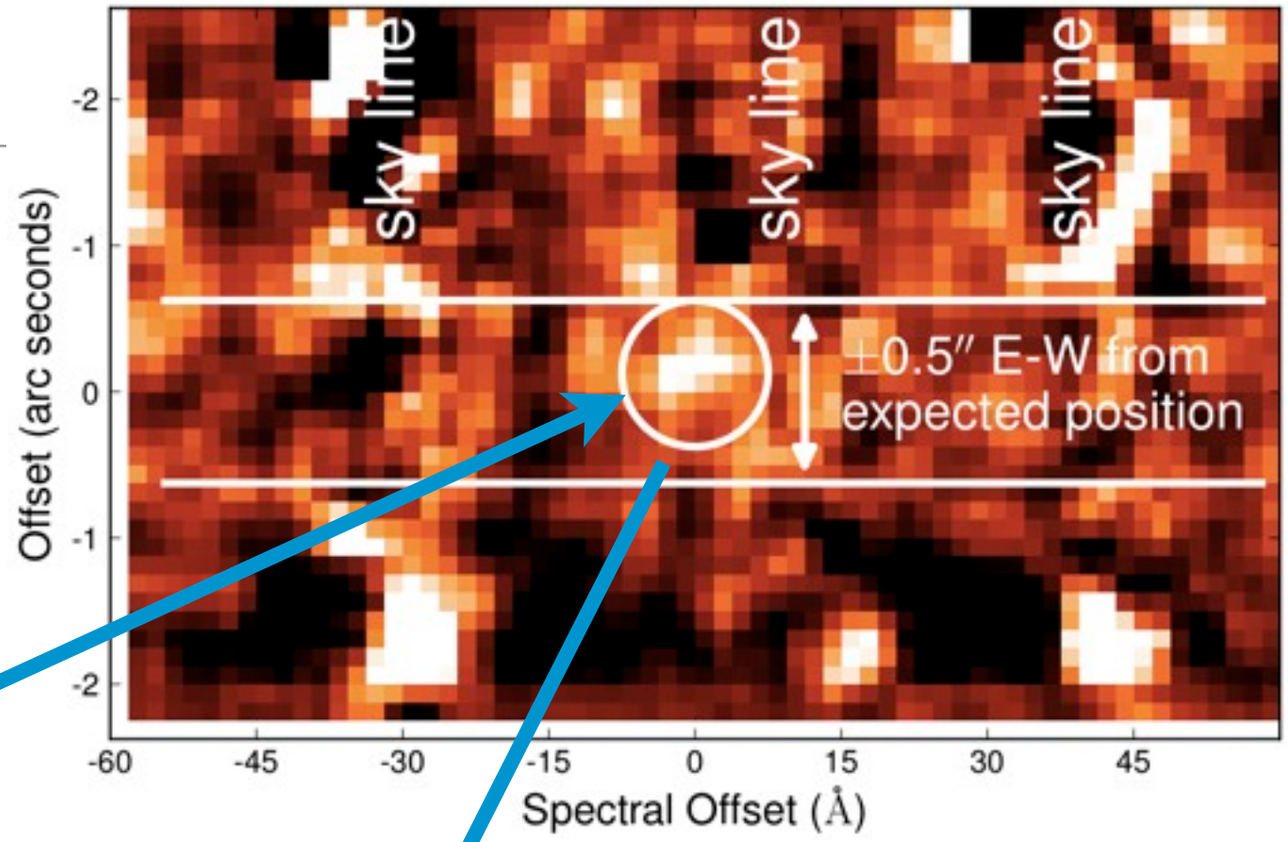
# How about JWST?

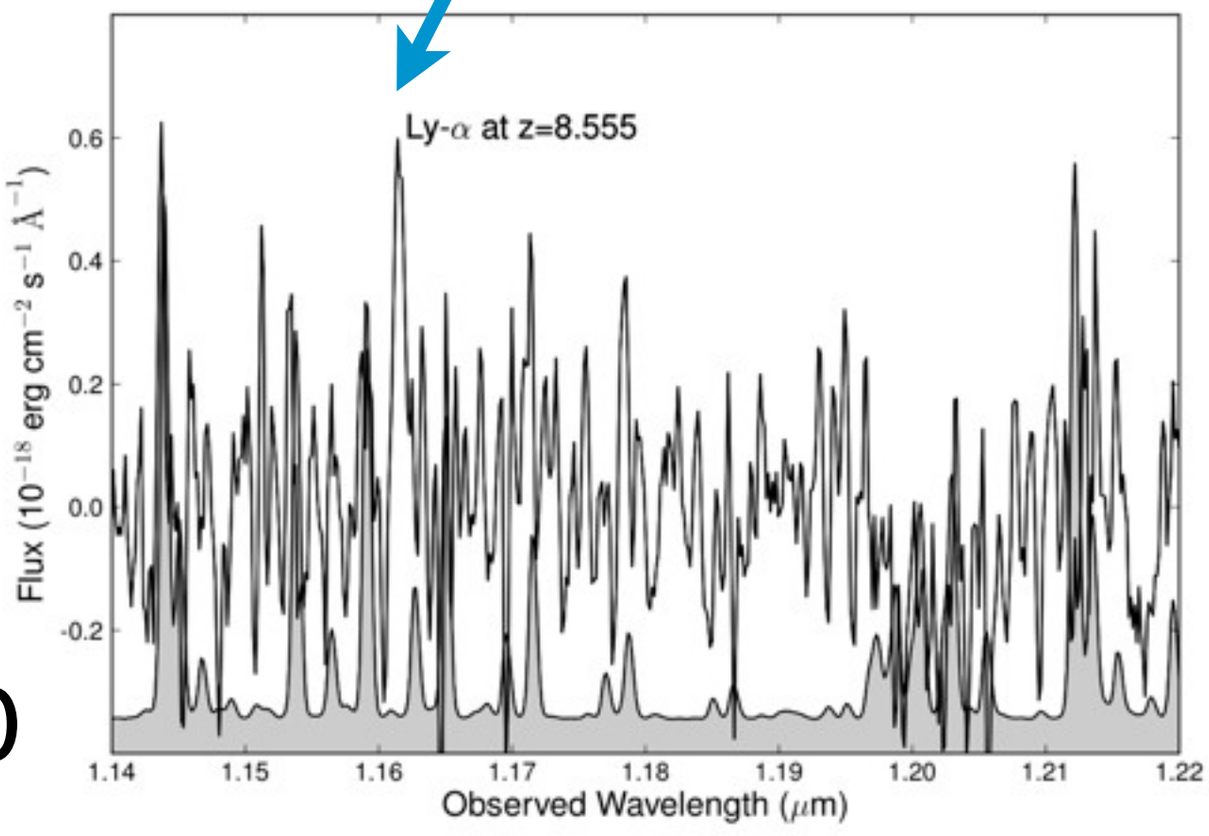
- JWST / NIRCam should have a better sensitivity and image quality
- Numerous extremely high-z galaxy candidates would be detected
- THEY ARE TOO FAINT!

# HST/WFC3




Bouwens+2010




Lehnert+2010

# How about JWST?

- JWST / NIRCam should have a better sensitivity and image quality
- Numerous extremely high-z galaxy candidates would be detected
- THEY ARE TOO FAINT!

- Even the current candidates at z~9 with HST/WFC3 are too faint (m>28AB) for 8-10m telescopes, and continuum detection would be very hard even with next-generation large telescopes.
- We need to search for rare luminous galaxies with Wide-area surveys.
- With larger Field-of-view, survey with SPICA / FPC-S will have a capability to provide large sample of luminous high-z galaxy candidates which can be spectroscopically identified with large telescopes such as TMT.
  - Parallel observations with other instruments such as Mid-IR camera and spectrograph
  - Legacy survey in 'Warm Mission' phase

# Field of View

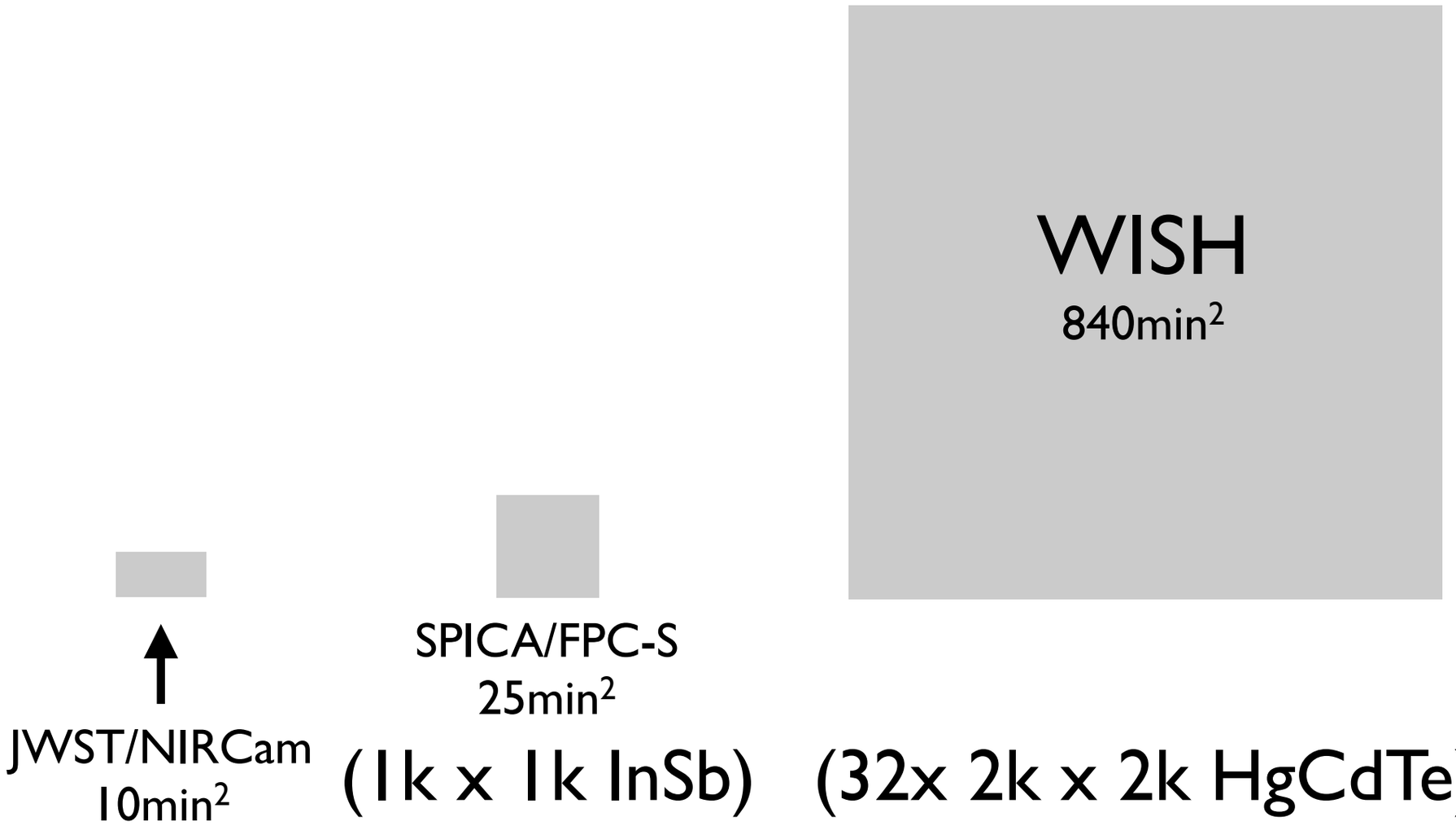
JWST/NIRCam

2.2’ x 4.4’

SPICA/FPC-S

5’x5’

# Field of View



# 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 |

# Summary

- With FPC-S, there is an opportunity to search for extremely high-z "luminous" galaxies, which should be good targets for spectroscopy with extremely large telescopes such as TMT.
- Based on the studies on high-z galaxy survey with WISH, we examined the expected number of high-z galaxies with a survey using FPC-S. Several tens of galaxies at z=10-12 would be detected with ~1 sq. deg survey, and there is a chance to detect galaxies at z>13 with a wider survey, say ~5 sq. deg.
- Well designed, continuous coverage of wavelength is important for clean selection of drop-out galaxies.
- Critical issue for FPC-S would be image quality. Especially, smaller PSF should improve the sensitivity at shorter wavelengths and increase the chance to detect high-z galaxies. Also, under sampling problem should be avoided.

- WISH is a project optimized for extremely high-z galaxies. WISH + TMT is a promising combination to reveal the nature of first galaxies.

http://wishmission.org