Proposed Science Programs for SPICA Near-Infrared Instrument

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FPC (Focal Plane Camera)

- Near-Infrared Camera: system instrument!

- Two FPCs (Focal Plane Camera)
  - FPC-G: Fine guiding system
    System instrument
    Positional information of identified star

  - FPC-S: Science purpose
    Back-up Instrument of FPC-G: primary function
    Near-IR Imaging & Spectroscopy: secondary function

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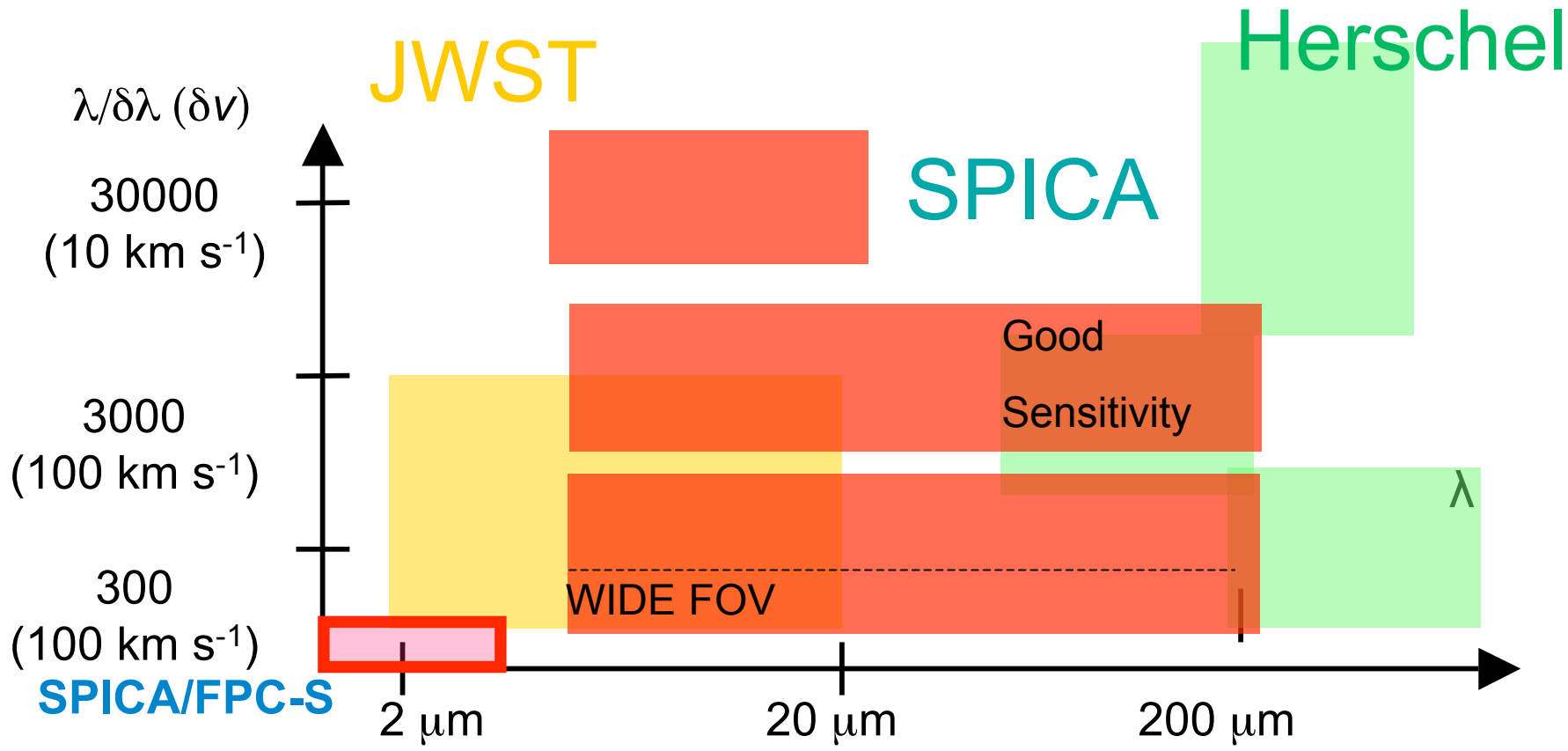
Focal Plane Instruments



Near-Infrared, Wide FOV, Low resolution spectroscopy & Imaging

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Specification of FPC-S

- FoV = **5 arcmin x 5 arcmin** (c.f. JWST: 2.3′ x 4.4′)
- Pixel scale = 0.3″(diffraction limit @ 5μm, telescope limit)
- Wavelength coverage = 0.7 ~ 5.2μm
- 10 filter positions

  Imaging (R~5) & **Low resolution spectroscopy (R~20**)
  - 1 for a back-up of FPC-G (diffuser + I band)
  - 1 blank for dark calibration
  - **3 for LVF (Linear Variable Filter): surface spectroscopy!**

    0.7~1.6μm, 1.4~2.8μm, 2.6~5.2μm
  - 5 for wide band (J, H, K, L and M band)

- QE & optical efficiency = 0.5 (assumed)
- Detector array = InSb 1k x 1k
- Readout noise = 20 electrons (Raytheon data)

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Expected Sensitivity

- **3σ detection limit (100 sec integration, R~5)**

  26.3mag(AB) for point sources

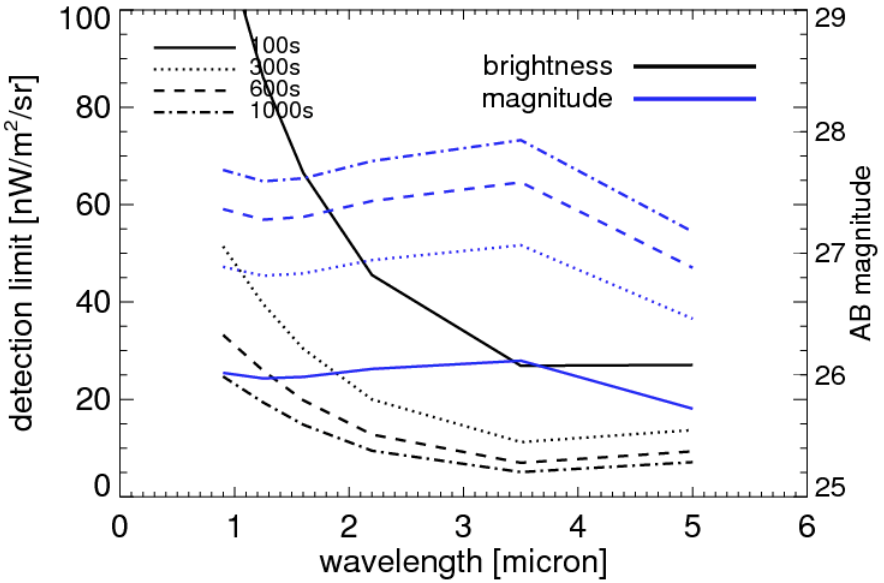
  $81 \cdot \lambda^{-1} \cdot t^{-1}$ *nW.m*$^{-2}$*.sr*$^{-1}$ for extended sources

  Vega magnitude

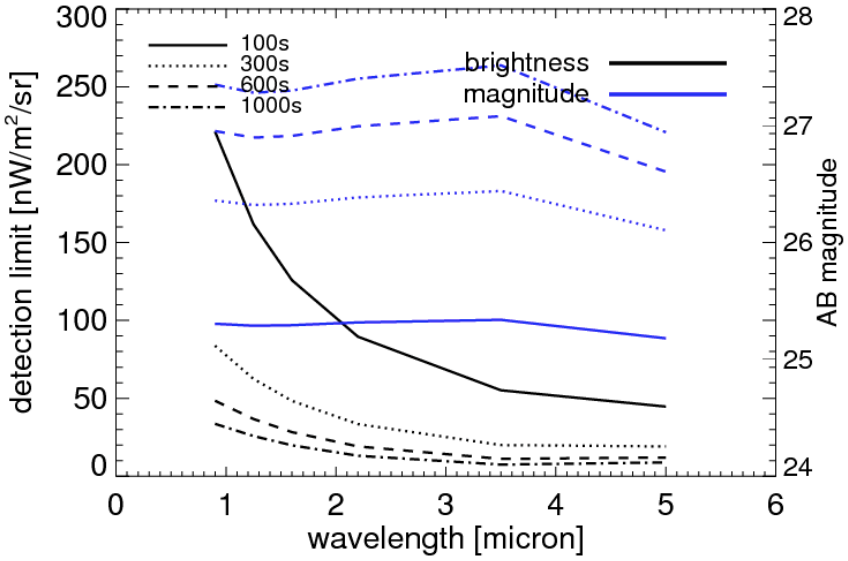
z(0.9μm)	J(1.25μm)	H(1.6μm)	K(2.2μm)	M(5.0μm)
25.6	25.2	24.8	24.2	22.4

∗ Photon noise becomes dominant for integration time > ~100 sec

Wide band filter



LVF



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Scientific Targets

- Legacy Programs
  - **NIRSS**: Near-Infrared Spectroscopic Survey with FPC for Cosmic IR Background and Extra galactic Sciences
  - **Parallel Imaging Survey** for Extragalactic Sciences
- Target of Opportunities
  - Comet Observations
  - Gamma-ray bursts

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NIRSS: Near Infrared Spectroscopic Survey for Extragalactic Studies

- Wide Field Spectroscopic Survey with LVFs (R~20)
  - **Large throughput: ~20 times larger than JWST**
  - **Efficient low resolution surface spectroscopy**
  - **Wide wavelength coverage (0.7~5.2μm)**

  → **advantage to observe diffuse light**

- Primary Science: Cosmic Infrared Background Radiation: Fluctuation and Spectrum

- Secondary Sciences: Lyman Break Galaxies up to redshift 10, Emission Line Galaxies

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NIRSS: Observational Strategy

- **Mode: LVF low resolution spectroscopy at 0.7 – 5.2μm**

1. Spectroscopic observations for CNB

- angular coverage for 1 position: 30 arcsec x 5 arcmin (narrow region)
- 25 pixel step, 100 sec integration, R~10, co-adding 2×10^4 pixels
- 1σ detection limit: $0.86 \times (1\mu m/\lambda)$ nW.m^{-2}.sr^{-1}
  (cf. sky brightness at the J band is 350 nW.m^{-2}.sr^{-1})
- Different ecliptic latitudes, ~37 hours for 3 LVFs
- Short period observations to avoid the seasonal variation of ZL

2. Common field for CNB & other sciences

- angular coverage : 15 arcmin x 15 arcmin
- 25 pixel step, 600 sec integration, R~20
- 3σ detection limit = 26.9 AB mag.
- Total observation time with 3 LVF is ~700 hours

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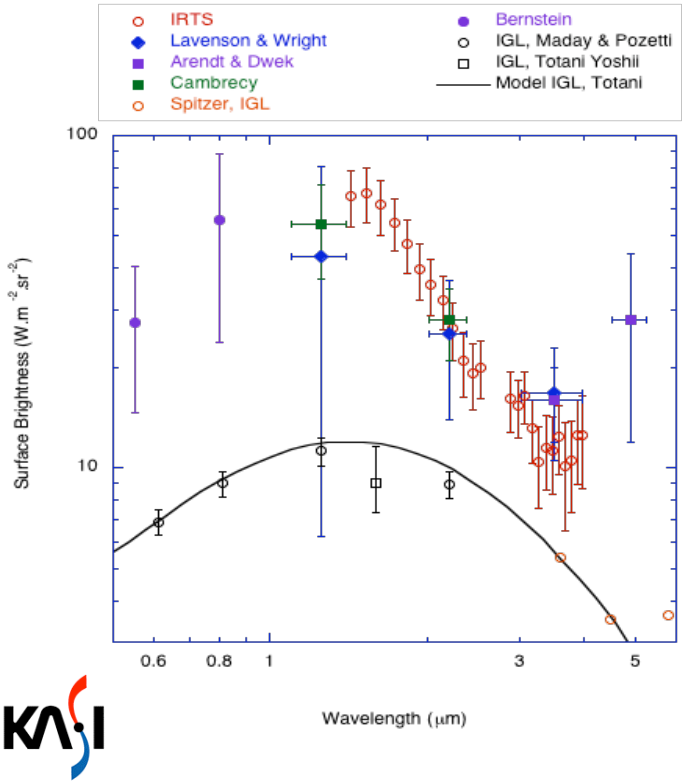
NIRSS 1st: Cosmic NIR background (1/3)

Major Scientific Point 1

Measurement of the spectrum of the sky to examine the nature of the excess background emission

Detection of the peak around 1μm delineates the end of pop.III era

Spectral shape is a measure of the contribution of emission components



- Spectroscopic survey at several ecliptic latitudes with wide wavelength coverage (0.7 – 5.2μm)
- Almost all foreground point sources can be removed
- Modeling of spectrum of zodiacal light makes it possible to subtract accurately

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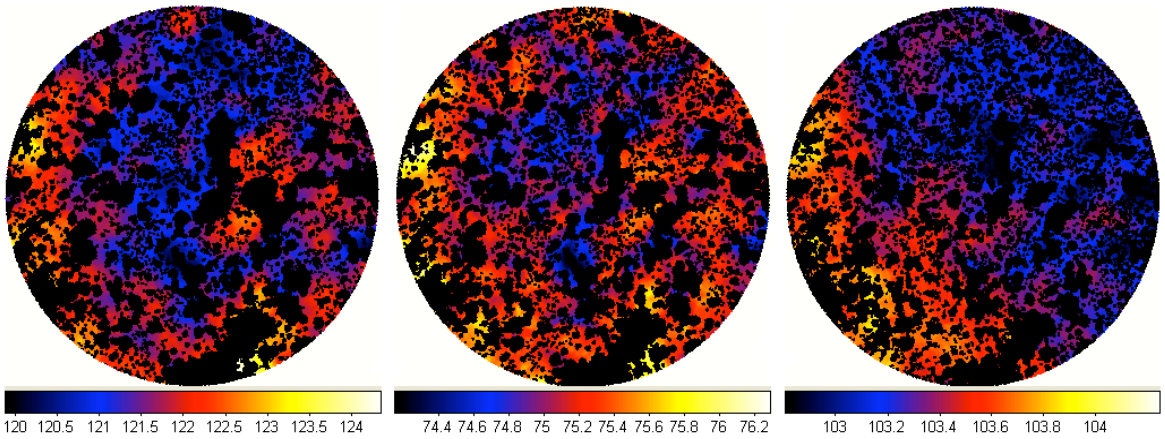
NIRSS 1st: Cosmic NIR background (2/3)

Major Scientific Point 2

Detection of the fluctuation of the sky brightness caused by pop.III stars.

- Zodiacal light is very smooth component (Abraham, Leinert & Lemke 1997; Pyo et al. 2010, in preparation).
- Fluctuation scale indicates the mass of initial halo and the structure formation at pop.III era
- Wavelength dependence of fluctuation is an important clue to understand pop.III star formation



Smoothed image of NEP field observed with AKARI. Angular diameter is 10 arc-minutes. Wavelength band is 2.4, 3.2 and 4.1 μm, from left to right.

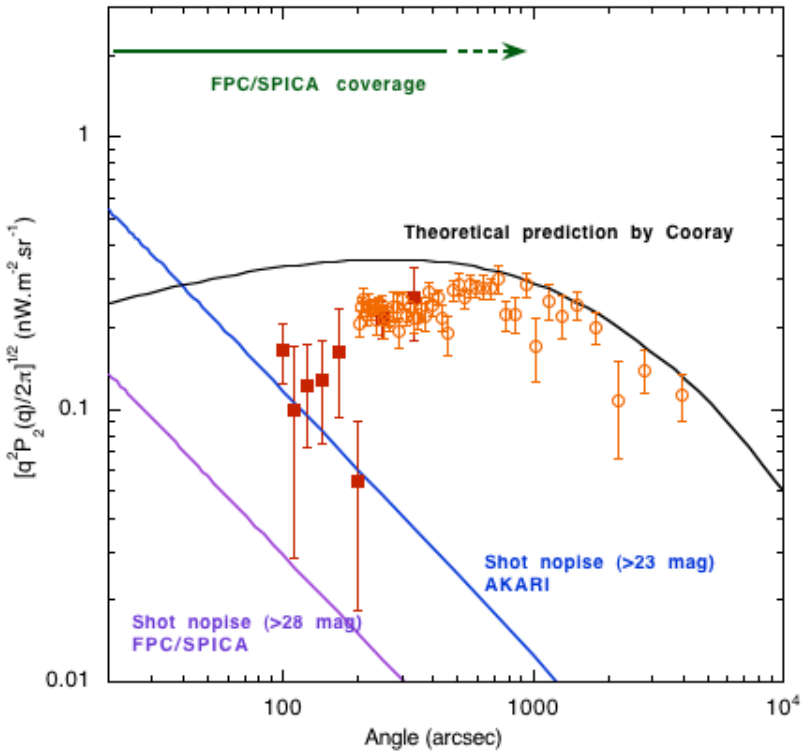
NIRSS 1st: Cosmic NIR background (3/3)

Major Scientific Point 2

Probe the epoch of formation and clustering properties of pop.III stars.

- NIR-MIR-FIR correlation: fluctuation by pop.III & pop.I, II, dust emission
  - Parallel observation with MIR instrument: redshifted Hα
  - CFIRB observation
- Fluctuation measurement up to 10~15 arcsec scale with wide wavelength coverage (LVF)

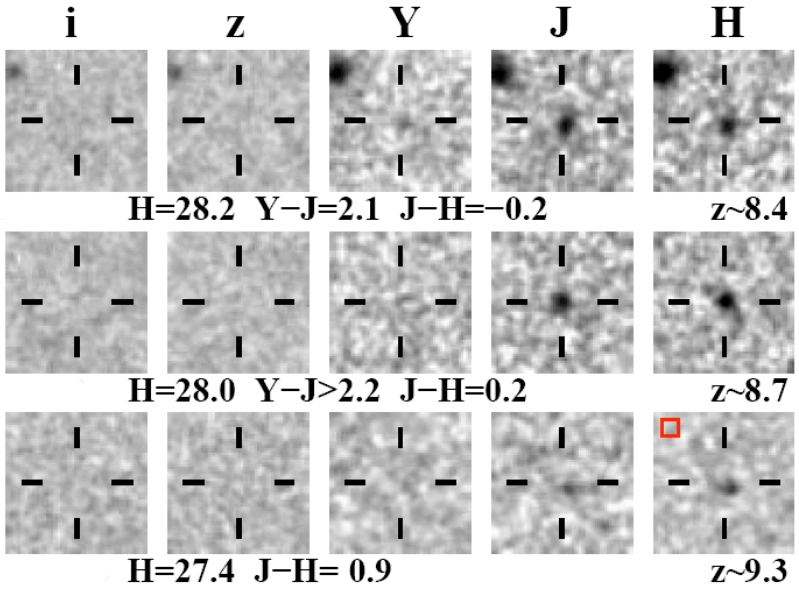
  c.f. degree-scale fluctuation by MIRIS
- Removal of faint galaxies: segregation of shot noise & cluster of galaxies

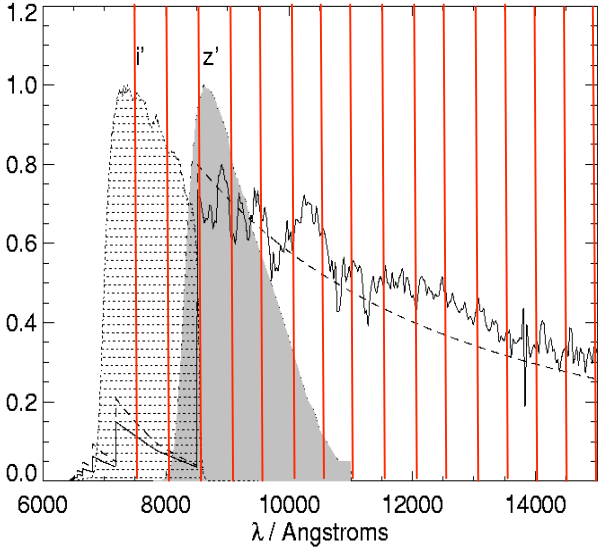


Power spectrum of CNB fluctuation at 2.4μm from AKARI observation

NIRSS 2nd: Lyman Break Galaxies (1/3)

- **Major scientific point**: **Understanding of High redshift s tar formation history of the Universe and the reionizati on**
- LBGs: form stars actively & very bright
- A source will be detected in filters above the break but drop-out of filters below it → This leads to a break in the spectrum
  - V, R, I- drops (z~5.8), … , J, H-drops (z~11)





(Bouwens et al. 2006)

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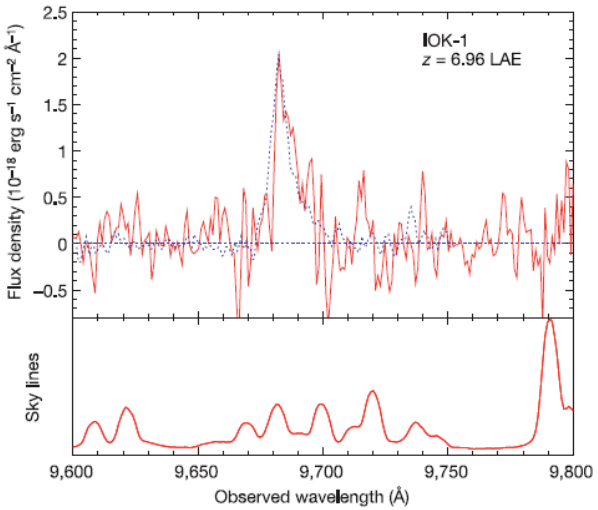
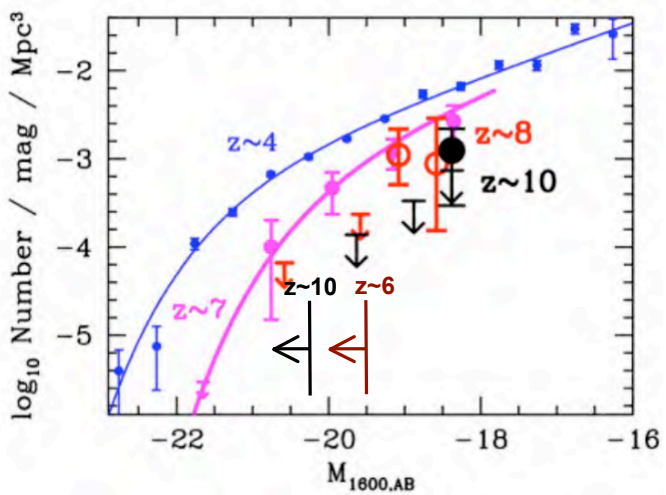
NIRSS 2nd: Lyman Break Galaxies (2/3)

- Recent studies is limited to z~4
- The number of LBGs at high redshift is dramatically decreasing at z~7 (Iye et al. 2006; Bouwens et al. 2007)
- LBGs (z<3) from Spitzer observations (Huang et al. 2005)
  - Dust-attenuated star-forming regions
  - UV-emitting regions
- UV- and infrared-selected populations (Reddy et al. 2005)
- Parallel observations or warm missions
  - large number of samples
  - e.g., balmer break at MIR range
- New populations of LBGs?



Spectroscopically confirmed LAE at z=6.96 (Iye et al. 2006)



(Bouwens et al. 2009)

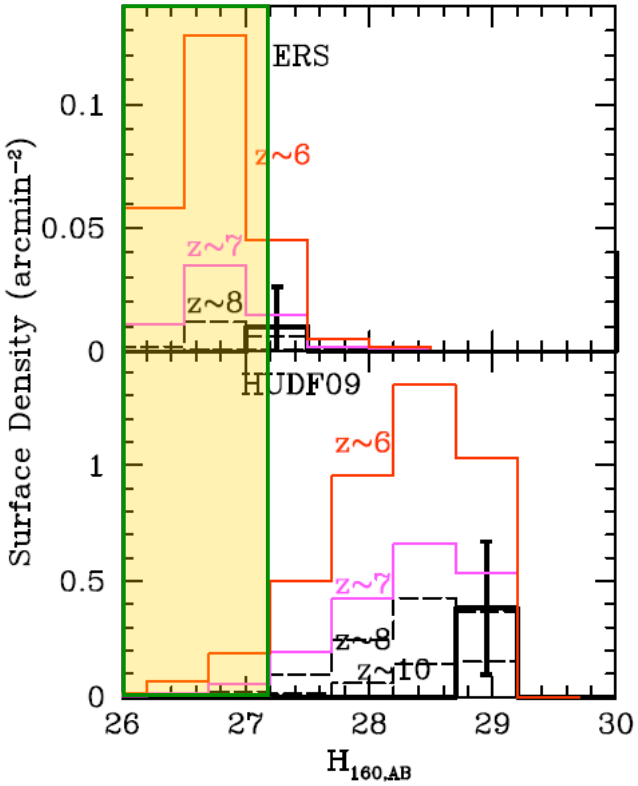
NIRSS 2nd: Lyman Break Galaxies (3/3)

- Detection of Lyman break galaxies with high redshift
  - z~6: 0.8; z~7: 0.2; z~8: 0.02
  - z~10: 0.01 per sq. arcmin

  (Bouwens et al. 2009, 2010)
  - NIRSS: 225 arcmin^2

  → ~ several LBGs @ z>10

- Advantage over JWST
  - Low resolution spectroscopic survey for large area: direct detection of LBGs & emission line galaxies
  - Spectroscopic data for possible extended objects
  - We can cover MIR and FIR wavelengths with other SPICA instruments



(Bouwens et al. 2010)

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Target of Opportunities

- Comets with LVF
  - Determination of molecular abundance H_2O, CO, CO_2 and hydrocarbon in comets at the different heliocentric distances
  - Consideration of the thermal evolution of ice in the solar system

- Gamma-Ray Bursts
  - GRB's are found at very high redshift
  - Lyman break will take place in FPC waveband for high-z GRBs
  - Parallel MIR observations will provide valuable information regarding the emission mechanism

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Summary

- SPICA/FPC-S is the near-IR instrument for scientific observations focused on the extragalactic sciences.
- Low resolution spectroscopy survey (15'x15')
  - Cosmic infrared radiation: spectrum & fluctuation
  - High redshift galaxies (Lyman break galaxies, quasar, …)
  - Emission line galaxies
- Parallel imaging survey
- Target of opportunities: comets, GRBs, …

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