The next-generation Infrared astronomy mission

SPICA
Space Infrared Telescope for Cosmology and Astrophysics

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High-redshift Science Potentials of Next-generation Space Infrared Space Telescope SPICA

Deciphering the Ancient Universe with Gamma-Ray Bursts
19-23 April 2010, Kyoto, Japan
H. Matsuhara, Takao Nakagawa (ISAS/JAXA) on behalf of SPICA pre-project / SPICA task-force / SPICA Science Working Group
Our Scientific Goals

How did the Universe originate and what is it made of?
What are the conditions for stellar and planetary formation?
How did the universe evolve chemically? The emergence of life?
One of the Science Goals:

*How did the Universe originate and what is it made of?*

- **Inflation**
- **Quantum Fluctuations**
- **Birth of 1st Stars**
- **Cosmic Re-ionization**
- **First Stars** about 400 million yrs.
- **Big Bang Expansion** 13.7 billion years
- **Development of Galaxies,Planets, etc.**
- **Pattern 400,000 yrs.**

Credit: NASA
SPICA Overview

- COOLED (<6K) Space telescope
  - 3-m class *monolithic* primary mirror
  - diffraction limited at 5μm
- Space Observatory mission, for mid- & far-IR astronomy (core 5-210μm)
  - JAXA – ESA(Cosmic Vision M-class candidate) Mission, with planned participation from Korea & US
    - Orbit: Sun-Earth L2 Halo
    - Mission Life: 3 years (nominal) 5 years (goal)
    - Launch: FY2018 (H-IIA)
Overview of SPICA

- Weight: 3.7t
- Launching Vehicle: H-IIA (5S fairing)
- 11Mbps downlink in X-band
- TT&C in S-band
Focal Plane Instruments

λ/δλ (δν)

Herschel

10000
(30 km s⁻¹)

MIRHES

1000
(300 km s⁻¹)

JWST

100
(3000 km s⁻¹)

MIRMES

SCI

FPC-S

2 μm

20 μm

200 μm

SAFARI

BLISS

Optional
Flux Limit in $5\sigma$ (Jy) for imaging / photometry

SAFARI Imaging Spectroscopy
R~100, 1hr

SAFARI Broad-band Imaging
In only 10 min (!)

MIRACLE Imaging, 1hr

Confusion limit !!

JWST /MIRI
(3m aperture)
Sensitivity for spectral lines
(1 hour, 5σ)
Uniqueness of SPICA

- Overwhelming Imaging Sensitivity at 20-100 μm (MIRACLE, SAFARI)
  - Overwhelming mapping speed!!
  - MIRACLE should have large FoV as much as possible (at least 4’x4’)
- Capability of spectro-imaging at 35-210μm (SAFARI, 2’x2’ FoV)
- Overwhelming Spectroscopic sensitivity at 20 – 400 μm (MIRMES, SAFARI, BLISS)
- High-dispersion spectroscopy at 4-8, 12-18μm (MIRHES)
Infrared Spectroscopy: Energy Sources

- AGN
- Starburst

NGC 6240: starburst + hidden AGN

- H$_\alpha$ 6.9$\mu$m
- [NeII] 12.8$\mu$m
- [SII] 34.8$\mu$m
- [SII] 33.5$\mu$m
- [OIV] 25.9$\mu$m

Spinoglio et al. 2009
Characterization of galaxies

Herschel and SCUBA-2 → many objects in photometric surveys
Only **SPICA** can reveal nature and role of AGN and star formation

To reveal their nature and physics and chemistry
The first cosmological spectroscopic survey

900 hours Of Obs.

Dark matter vs Barionic Matter

Image Springel et al. 2006
Diagnostics of Obscured Galaxies with FIR line ratio
Nagao, et al., in prep.

metallicity diagnostics

physical properties

Very limited work was possible with ISO data
Only low-z samples can be done with Herschel
Feasibility

[NIII] 57μm is a key
- M82 (dwarf SB): detectable out to z~1 with BLISS
- ULIRGs are detectable out to z~2 with SAFARI
SPICA’s probe for re-ionization Era (z~10)

Probes free from the confusion limit:

- PAH Emitter
- $H_2$ emitter
- Cosmic IR Background Fluctuations
- Gravitational lens
- Dust-obscured hyper-luminous AGN
- Dust-cocooned GRB afterglow

Evidence of Formation of dust / metals in the re-ionization era ULIRGs at z~10: if exit, how they are related to the 1st stars?
Strong PAH emitter search upto $z \sim 10$

- $7.7\mu$m PAH luminosity of $z \sim 2$ SMGs: $\sim 5 \times 10^{10} L_{\odot}$ for the most luminous ones (Pope et al. 2008) \(\Rightarrow\) Requires a flux sensitivity of $\sim 10^{-19}$ Wm$^{-2}$ to detect up to $z \sim 10$ @ R$\sim 20$ is enough with SAFARI

- Blank Field Survey with SAFARI
- Targeted Spectroscopy with BLISS

Courtesy to Eiichi Egami (U. Arizona)
Probing Early Universe with hyper-luminous H$_2$ Emission Lines

Egami et al. (2006)

Z3146 (z=0.29) from Zw3146 (LIRG with \(\sim10^{10}M_{\text{SUN}}\) warm H$_2$ gas)

Do they already exist beyond z=4?

Such galaxies at z=6-7 can be detected with BLISS.

SPICA/BLISS is unique observatory to do H$_2$ line science of early Universe!
A Science Potential of SPICA

Gamma-Ray Bursts (Imaginary Picture)

gamma-rays are produced when the jet (close to the light speed) breaks out from the stellar envelope

A black hole, accretion disk and jet are formed by the gravitational collapse of the stellar core

A very massive star (more than 20 solar mass), whose outer envelope (hydrogen and helium) has been removed

Kyoto University, T. TOTANI

DUST COCOONED GRB AFTERGLOW?
GRB as a probe of high-redshift metal & dust

- Dust in Early Universe may be different from dust in the local Universe
  - Interstellar dust from AGB stars require >1Gyr
  - For $z>5$, core-collapse SNe could dominate the dust formation

- Dust extinction may be probed by rest UV-opt SED of GRB afterglow
- But, so far no clear evidence for dust extinction...

  (GRB at $z\sim 6.3$: Zafar 2010)
GRB afterglow with SPICA

- SPICA can observe the dust emission of high-z GRB afterglow together with rest-MIR spectral lines (diagnostics tools).

- Dust cloud around GRB will be heated by dissipating its kinetic (\& UV\textendash opt. radiation) energy during >1 yr? (in rest frame), \( \text{upto } 10^3 \text{K} \) \( \rightarrow \) SPICA may catch them even at \( z=10 \).

- This may not be necessarily a “ToO”: fast telescope (spacecraft) maneuver is not necessary like rest-optical afterglow?
  - Depending on how much fraction of GRB kinetic energy will heat dust, and the cooling time scale.

*Courtesy to K. Kawara, S. Oyabu et al.*
Sun angle constraint limits the ‘viewing zone’

- Spacecraft maneuver allowed in the ‘viewing zone’:
  - -1 ~ 25 deg toward/away from the Sun for safety
  - maneuver speed: 0.12 deg/sec max., ~30 min over 180deg ( + ~ a few minutes for stabilization )
Conclusion …

- SPICA will undertake the first Cosmological Spectroscopic survey for Obscured high-z sources with overwhelming mid- & far-IR spectroscopic sensitivity.
- Dust-cocooned GRBs are potentially very interesting and worth to be investigated further.

What is essential is invisible to the eye, but visible to SPICA’s HEART

大切なものは目で見えないんだよ。

l'essentiel est invisible pour les yeux