SPICA焦点面観測装置： 米国主導観測装置の開発

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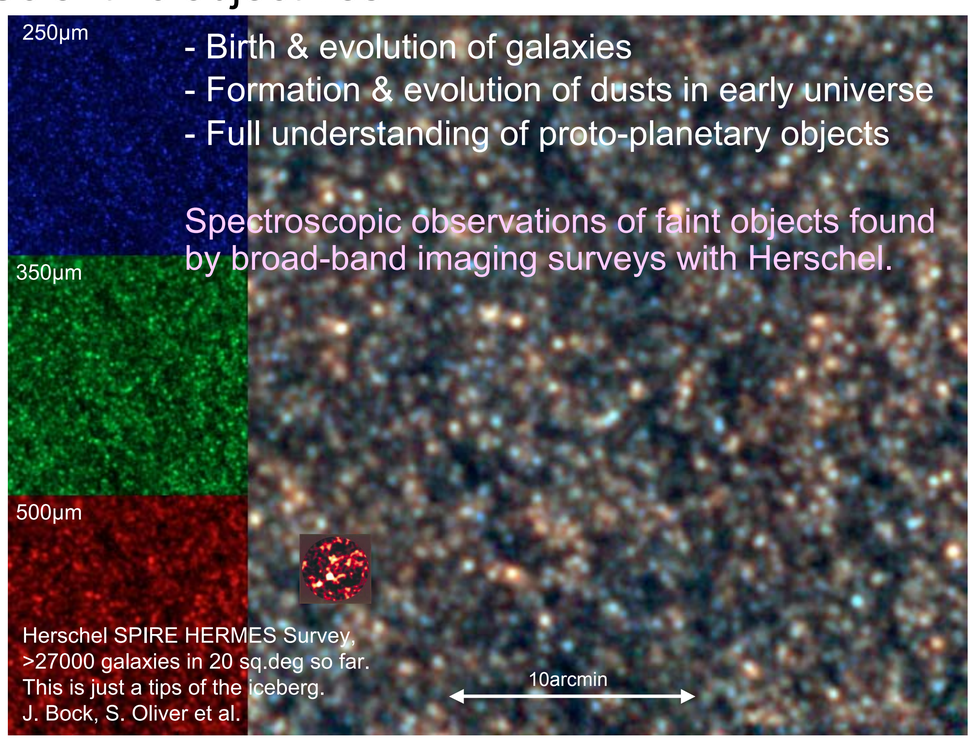
— 概要 — SPICA米国主導観測装置(US instrument)は、米国が主導して開発を行なうSPICAへの搭載観測装置である。NASAのとりまとめにより米国内で装置提案の公募を行なった結果、BLISS, μ-Spec, WISPIRと名付けられた3つの装置提案が採択され、搭載装置候補として検討機会が与えられた。提案されたいずれの装置も、遠赤外・サブミリ波の波長域において中程度の分解能で分光観測を行うものであり、欧州主導で提案されている観測装置SAFARIよりも高い検出感度を達成する設計となっている。また、点源分光に重きをおいた設計とし、撮像装置であるSAFARIとは相補的である。その高い感度は、SPICAの主たる科学目的である銀河や原始惑星系などの進化解明に強力な手段となるだけでなく、宇宙初期天体の検出をも可能にする。これまでに、すべての候補装置についての最終報告書がNASAに提出された。今後、NASAから米国主導観測装置としてひとつの提案が推薦される予定である。

US proposed instrument(s)

- NASA called for proposal to study a full US-led SPICA instrument（NRA ROSES 2009）.
- Selected 3 proposals
  - **BLISS for SPICA**: Sensitive Far-IR Spectroscopy Reveals the Cosmic History of Galaxies and Organic Elements
    PI: Charles(Matt) Bradford (Caltech/JPL)
  - **μ-Spec**: A Revolutionary Far Infrared Spectroscopic Capability for SPICA
    PI: Samuel(Harvey) Moseley (NASA/GSFC)
  - **WISPIR**: Wide-field Imaging SPectrograph for the InfraRed
    Co-PI: Lee Mundy (University of Maryland) and Dominic Benford (NASA/GSFC)
  - FIR/sub-mm spectrometers with dispersion elements
  - Super-conducting detectors with ultra-high sensitivity
  - Optimized for spectral line detection of point source, complementary with SAFARI (imaging FT)
- Aug 2010: The US Decadal Survey (astro2010) committee strongly recommends US participation to SPICA.
- Sep 2010: Final study reports, discussing about implementation of the US instrument.

Scientific objectives

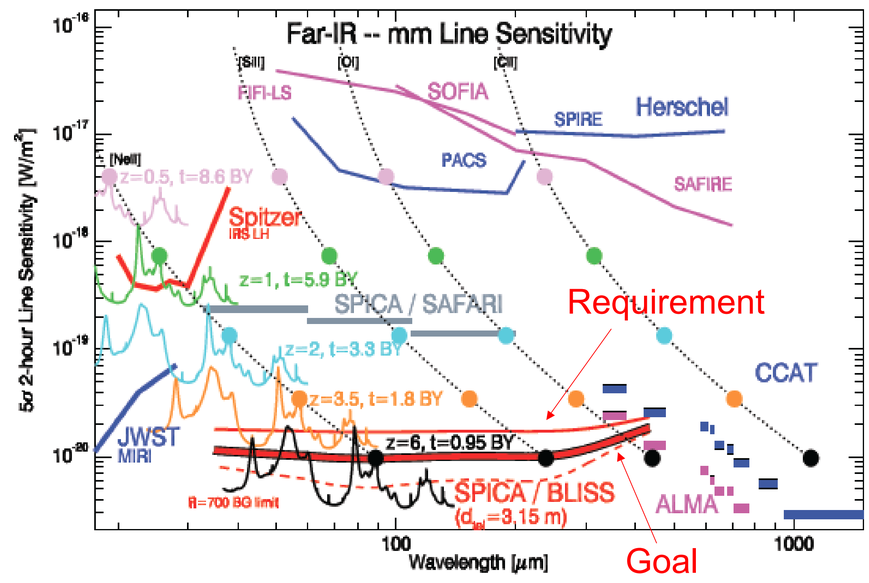


BLISS overview

BLISS (The Background Limited Infrared Submillimeter Spectrograph)
: Sensitive Far-IR Spectroscopy Reveals the Cosmic History of Galaxies and Organic Elements

- BLISS is a 38-433 μm grating spectrometer (R=700)
  - Fills gap between JWST / SPICA-MIR and ALMA with comparable sensitivity.
- The BLISS grating architecture provides maximum sensitivity.
  - BLISS-SPICA is the only way to study a meaningful sample of the tens of thousands of high-redshift galaxies and protoplanetary systems now being discovered with Herschel and other imaging systems.
- BLISS is compact, low mass, and has simple interfaces.
  - Only moving part is a chopping mirror.
  - Cold mass less than 30 kg, size 45x40x40 cm, bolts to 4.5 K instrument bench and rejects heat to SPICA 1.7 K cold finger.
- BLISS uses TES bolometer arrays with a now-standard SQUID multiplexer.
  - Systems issues proven in several scientific instruments.
  - Clear path to achieving the uniquely sensitive bolometers required for BLISS.

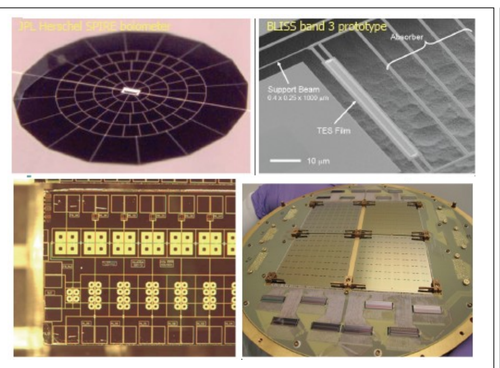
BLISS sensitivity



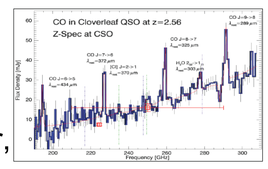
- BLISS can detect spectral features by dusts in galaxies at z=6 !
- High sensitivity of BLISS is owing to high sensitivity of superconducting TES bolometer and new technology of wave-guide grating spectrometer.

BLISS technology

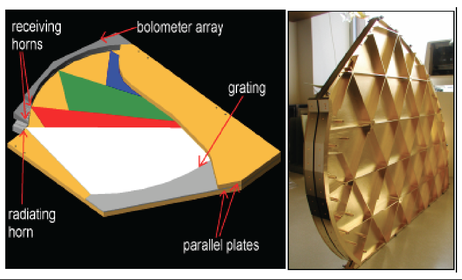
- Detector（TRL 4-6）
  - Caltech/JPL TES bolometers, BICEP2, SPIDER
  - MoCu (Tc=65mK) + Ti (Tc=450mK)
  - NEP < 1x10^{-19} W/√Hz
- Readout（TRL 6）
  - NIST SQUID Time-Domain 32ch MUX (left)
  - 512 pixels TES for CMB pol (right)



- Spectrometer
  - 38-433μm, 5 bands, R=700, diffraction-limited single beam
  - <120μm：Cross-disperser + Echelle grating spectrometer, Spitzer（TRL 9）
  - >120μm：Waveguide grating spectrometer, Z-Spec（TRL 6）



Z-Spec result example



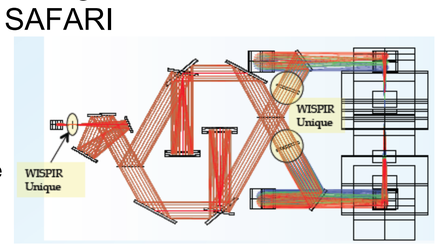
WISPIR overview

WISPIR: Wide-field Imaging Spectrometer for the InfraRed

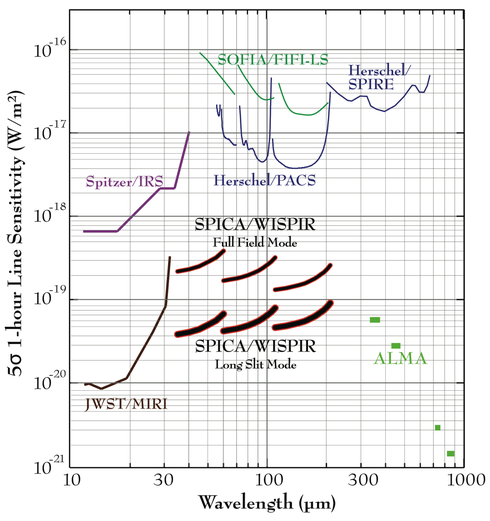
- Objectives: high-z galaxies & molecular lines in local universe
- Imaging FT spectrometer
- 35-210μm（3 bands）, R=1000-6000
- GSFC TES bolometer & SQUID MUX
- NEP~4x10^{-20} W/√Hz
- 50mK/300mK tandem cooler (ASTRO-H)
- High sensitivity with slit+grism
  - Improvement of SAFARI

Mach-Zender FTS (COBE/FIRAS)

Slit + grism
Reduction of photon noise
---> very high sensitivity detector



sensitivity

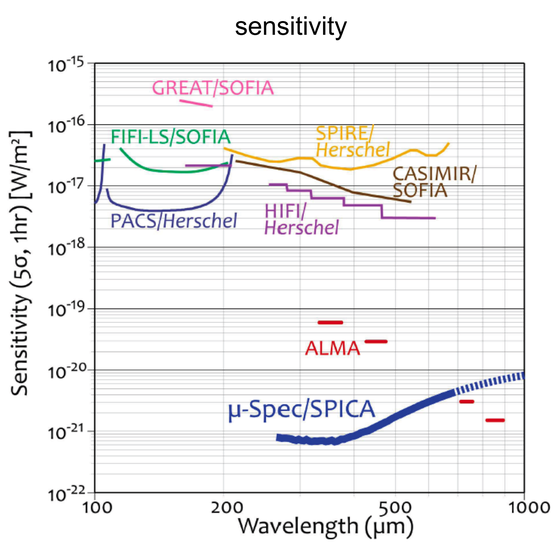


μ-Spec overview

μ-Spec: A revolutionary Far Infrared Spectroscopic Capability for SPICA

- Objectives: similar to BLISS
  - Very high redshift objects（out to z~10）
  - H_2O, O_2 molecular lines in ISM
- Ultra-high sensitivity & high resolution with compact system
- Novel technologies
  - λ = 250—700μm
  - Micro-strip delay-line spectrometer（R~1500）
  - MKID（Microwave Kinetic Inductance）, several times higher sensitivity than TES
  - Ultra compact spectrometer module fabricated on a ~100mm(!) Si-wafer
- 50mK ADR / 300mK ^{3}He tandem cooler system (ASTRO-H)

sensitivity

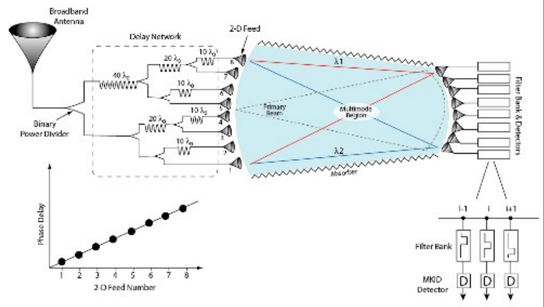


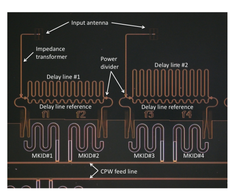
μ-Spec technology

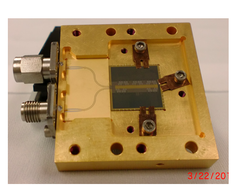
- New technologies
  - MW(RF) microstrip delay-line spectrometer
  - RF filter bank
  - MKIDs, NEP~1x10^{-20} W/√Hz
  - HEMT amplifier, 3-6GHz readout

specifications

Line sensitivity (5σ, 1h)	1×10^{-21} Wm^{-2}
Resolving power (R=λ/Δλ)	1500
Spectral coverage	250-700 μm
Number of beams	1-7 TBD, Diffraction ltd.
Detector format	~4000
Detector sensitivity	1×10^{-20} W/√Hz
Detector technology	MKID
Readout	Microwave HEMT
Spectrometer	Delay line spectrometer
Cooler	<300mK TBD







Proto-type delay-line