The Institute of Space and Astronautical Science
Report SP No.14, December 2000

Focal Plane Instruments onboard HII/L2 Mission (SPICA)

By

Munetaka UENO*, Hideo MATSUHARA†, Hiroshi MURAKAMI†, and Takao NAKAGAWA†

(November 1, 2000)

Abstract: Current idea of focal plane instruments onboard HII/L2 (SPICA) mission is described. To squeeze out maximum scientific output, the instruments cover 2-200 μm in both imaging mode and spectroscopic mode.

1. INTRODUCTION

The strong demand of interesting science is, of course, the motive behind new instruments. For example spectroscopic studies of very distant galaxies, galaxy counts toward the scale showing the curvature of the universe, spectroscopy of interstellar medium to understand properties of solid bodies or direct imaging of extra-solar planets may trigger it. This is very straightforward approach and we should take this at any time but in order to get maximum scientific output, adding of a spoon of strategemma may be important. We know what kind of projects are undergoing in the world. We know what we want now, but with our limited considerations. We are going to launch ASTRO-F mission (Murakami 1998; Shibai 2000). We will make a whole sky survey. We are keen on extending our studies absolutely. The HII/L2 (SPICA) (Nakagawa et al. 2000) mission is scheduled as the next step of ASTRO-F mission.

2. DESIGN CONCEPT

HII/L2 employs cooled telescope, and whose aperture size is 3.6 meter. The optical accuracy of the telescope is proposed to realize a diffraction limit at 5 μm. Active or slow-speed adaptive optics is proposed to be employed to allow a high resolution imaging and an accurate pointing for the stellar corona-graph. Taking these specifications into account, HII/L2 has advantages on middle- and far-infrared observations compared to NGST (Mather 2000) or FIRST (Pilbratt 2000) missions. HII/L2 will not be entered into a near-Earth orbit but will be placed

* Department of Earth Science and Astronomy, Graduate School of Arts and Sciences, University of Tokyo, Komaba 3-8-1, Meguro, Tokyo, 153-8902, JAPAN; ueno@provence.c.u-tokyo.ac.jp
† The Institute of Space and Astronautical Science, Yoshinodai, Sagamihara, Kanagawa, JAPAN

at the L2 point of the sun and Earth. The near-Earth orbit has many advantages but also has weak-points. Radiation from the sun, Earth and the moon drastically limit the operation and exposure length for infrared missions in near-Earth orbit. A telescope at the L2 point points the sun and the earth in the same direction, and their viewing angles are also small compared to the case of near-Earth orbit. Use of the L2 point makes the operation so flexible that it allows a very long exposure, which enables us to make spectroscopic observations with enough photons. Spectroscopic observations with very deep sensitivities will push the observational horizon beyond the present world.

3. INSTRUMENTS

Basic idea of HII/L2 instruments is the following.

NIR camera and spectrometer
MIR-S camera and spectrometer
MIR-L camera and spectrometer
FIR-S camera and spectrometer
FIR-L camera and spectrometer

Sub-mm instruments, beyond 200 μm range, are still under consideration. The cooled telescope has less advantage in sensitivities than a large telescope with warm temperature because the spatial resolution will limit the sensitivities at sub-mm range.

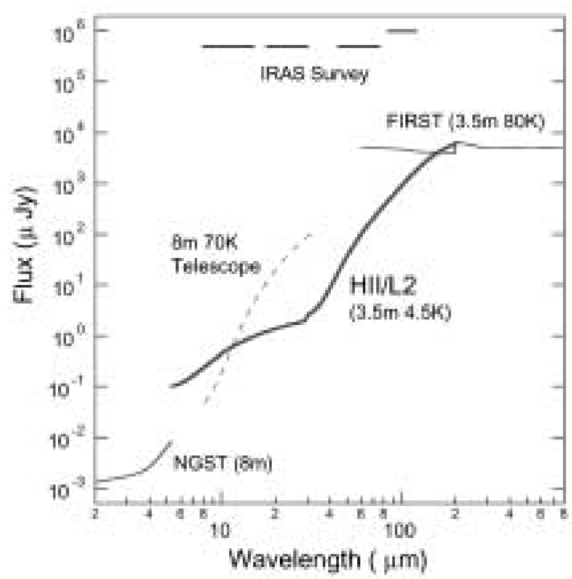

Fig. 1: Detection limit of HII/L2 instrument

3.1 Near-infrared (NIR) Camera and Spectrometer

Near-infrared camera and spectrometer is rather optional instrument because the telescope is not optimized below 5 μm range. Still it is notable that sensitivities in 2-5 μm range are excellent. NIR channel is very useful unless it causes severe constraint for the system design.

Detector

InSb is a leading device in 2-5 μm range. To cover the wide field of view with diffraction-limited resolution, a large format array like 2048 $\times$ 2048 pixels, is necessary for the instrument. 512 $\times$ 412 InSb array has been developed for ASTRO-F (Matsuhara et al. 1998; Ueno et al. 1999) by Raytheon (Hoffman 1998). The device is realized by specially designed multiplexer for low temperature uses. We need a larger format multiplexer using the same kind of technology.

Table 1: Detector for NIR camera and spectrometer

	Specification
Wavelength	2-5 μm
Detector	InSb
Detector format	2048 $\times$ 2048
	(1024 $\times$ 1024 $\times$ 2 $\times$ 2)
Operating temperature	7-10 K

Mode and Specifications

Wide band imaging will extend the SED of faint objects very widely, while spectroscopic observation is very powerful to detect emission lines of very distant object.

Table 2: Mode and specification of NIR channel

NIR imaging mode	Specification
Wavelength	2-5 μm
Pixel scale	$0''.18$/pixel
Field of view	$6'.1 \times 6'.1$
Filter bands	T.B.D.
NIR spectroscopic mode	Specification
Mode	a long slit spectrograph
Wavelength	2-5 μm
Pixel scale	$0''.18$/pixel
Slit length	$6'.1$
Spectral resolution	T.B.D.

3.2 Mid-infrared (MIR) Camera and Spectrometer

MIR camera and spectrometer is a very important instrument for HII/L2. MIR channel is designed to realize ultimate sensitivities in 5-25 μm region aiming to detect very faint objects.

Detector

Si:As detector covers this range up to 27 μm. Development of a large format Si:As detector is one of the key technology for the mission. MIR-S channel uses 2 by 2 mosaic array while MIR-L channel uses a single chip.

Table 3: Detector for MIR camera and spectrometer

	Specification
Wavelength	5-26 μm
Detector	Si:As
Detector format	2048 × 2048 for MIR-S
	(1024 × 1024 × 2 × 2)
	1024 × 1024 for MIR-L
Operating temperature	4-8 K

Mode and Specifications

MIR channel has three mode of observations. Diffraction limited imaging is a primary mode of the instrument. The pixel resolution is optimized at shorter wavelength and will allow us to trace the point spread function of the optical system. Long slit spectrograph is also important. Detection of emission line is primary target for the spectrograph with moderate spectral resolution. High resolution spectrograph will be realized by Fabry-Perot filters. A corona-graphic imaging at 5-25 μm is a powerful tool. To observe faint region around the bright central object, the optics requires enough suppression of stray light and internal diffractions. Slow adaptive optics will maintain the precise pointing to put the central star on the occulting disk. A center null interferometer will be also effective to suppress the bright central object.

Table 4: Mode and specification of MIR channel

MIR imaging mode	Specification
Wavelength	5-12 μm for MIR-S
	12-26 μm for MIR-L
Pixel scale	$0''.18$/pixel for MIR-S
	$0''.36$/pixel for MIR-L
Field of view	$6'.1 \times 6'.1$
Filter band	T.B.D.
MIR spectroscopic mode	**Specification**
Mode	a long slit spectrograph
Wavelength	5-26 μm
Pixel scale	$0''.18$/pixel for MIR-S
Pixel scale	$0''.36$/pixel for MIR-L
Slit length	$6'.1$
Spectral resolution	T.B.D.
MIR stellar corona-graphic mode	**Specification**
Wavelength	5-26 μm
Pixel scale	$0''.05$/pixel for MIR-S
Pixel scale	$0''.10$/pixel for MIR-L
FOV	$51'' \times 51''$ for MIR-S
FOV	$102'' \times 102''$ for MIR-L

Table 5: Detection limit of MIR channel for one hour exposure and 5σ sensitivities

Imaging	Sensitivity
7 μm	0.16 μJy
9 μm	0.32 μJy
11 μm	0.53 μJy
15 μm	0.93 μJy
20 μm	1.3 μJy
25 μm	1.6 μJy
Spectroscopy	Sensitivity
5 -8.5 μm	7.9 $\times 10^{-21}$ Wm^{-2}
8.5-12 μm	4.4 $\times 10^{-21}$ Wm^{-2}
12 -18.5 μm	4.1 $\times 10^{-21}$ Wm^{-2}
18.5-25 μm	3.3 $\times 10^{-21}$ Wm^{-2}

3.3 Far-infrared (FIR) Camera and Spectrometer

Detector

A hybrid array of Ge:Ga detector (Hiromoto et al. 1998), which covers 50-100 μm, has been developed for ASTRO-F. The technology will allow us to use a larger format detector up to 128 $\times$ 128 pixels. The 100-200 μm region is situated in slightly difficult condition in detector technology but is very important range since quite a large number of spectral lines including the famous [CII] 158 μm line are within this range. Stressed-Ge:Ga device (Doi et al. 2000) is the leading detector in 100-200 μm but we need a breakthrough in structure of the device since the format size is very limited in the current architecture. Quantum dot detector (Komiyama et al. 2000) has big potential as the future device in this range, however, it will take certain amount of time to fabricate it into a big device.

Table 6: Detector for FIR camera and spectrometer

Wavelength	50-100 μm for FIR-S
	100-200 μm for FIR-L
Detector	Ge:Ga for FIR-S
	Stressed-Ge:Ga for FIR-L
Pixel size	0.5 mm for FIR-S
	1 mm for FIR-L
Detector format	128 $\times$ 128 for FIR-S
	64 $\times$ 64 for FIR-S
Operating temperature	2.5 K for FIR-S
	1.7 K for FIR-L

Mode and Specifications

FIR channel has two modes of observation, diffraction limited imaging and mid- and high-resolution spectrograph. The pixel resolutions are optimized at shorter wavelength and will

Table 7: Mode and specification of FIR channel

FIR imaging mode	Specification
Wavelength	50-100 μm for FIR-S
	100-200 μm for FIR-L
Pixel scale	$1''.8$/pixel for FIR-S
	$3''.6$/pixel for FIR-L
Field of view	$3'.8 \times 3'.8$
FIR spectroscopic mode	**Specification**
Mode	a long slit spectrograph
Wavelength	50-200 μm
Pixel scale	$1''.8$/pixel for FIR-S
Pixel scale	$3''.6$/pixel for MIR-L
Slit length	$3'.6$
Spectral resolution	R=1000 (Grating)
	R=20000 (Grating with Fabry-Perot)

allow us to trace the point spread function of the optical system. Long slit spectrograph is employed to detect emission lines with moderate spectral resolution. High resolution spectrograph will be realized by Fabry-Perot or Fourier interferometer.

4. KEY TECHNOLOGIES

Development of two dimensional detector for 30-50 μm region is one of the important technological issue for the mission. The 30-50 μm region is the zone of avoidance in the current design. Development of Si:P IBC detector will extend the coverage into slightly longer wavelength at around 40 μm. Development of large format array for 100-200 μm region is also key technology. To realize optics of the instruments with high image quality within very limited space as well as to employ adaptive optics for the corona-graphic mode are also very important.

REFERENCES

Doi, Y. et al. 2000, Experimental Astronomy, 10, 393

Hiromoto, N. et al. 1998, SPIE Proc., 3354, 48

Hoffman, A. W. 1998, SPIE Proc., 3354, 24

Komiyama, S. et al. 2000, Nature, 403, 405

Mather, J. C. 2000, in: ASP Conf. Ser. 207, NGST Science and Technology Exposition, ed. E. P. Smith & K. S. Long (San Francisco: ASP), 18

Matsuhara, H. et al. 1998, SPIE Proc., 3354, 915

Murakami, H. 1998, SPIE Proc., 3356, 471

Nakagawa, T. et al. 2000, this volume

Pilbratt, G. L. 2000, in: IAU Symp. 204, The Extragalactic Infrared Background and its Cosmological Implications, ed. M. Harwit (San Francisco: ASP), in press

Shibai, H. 2000, in: IAU Symp. 204, The Extragalactic Infrared Background and its Cosmological Implications, ed. M. Harwit (San Francisco: ASP), in press

Ueno, M. et al. 1999, SPIE Proc., 3698, 612