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# FUTURE SPACE INFRARED TELESCOPE MISSION, SPICA

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## ABSTRACT

SPICA (Space Infrared Telescope for Cosmology and Astrophysics) is an infrared astronomical satellite with a 3.5 m cooled telescope which is very powerful in mid- and far- infrared observations and makes complementary role to JWST and Herschel. SPICA will be launched at ambient temperature without any cryogen into the Sun-Earth L2 orbit and cooled down in space to 4.5 K with use of efficient radiative cooling and mechanical coolers. The present status of SPICA and the developments of the satellite system are reported.

*Key words :* infrared — space telescope

## I. INTRODUCTION

Space infrared observations are now an inevitable tool for the astronomy, in particular, to investigate the formation and evolution of galaxies, stars and planetary system. IRAS was the first that showed the importance of the infrared observations in space, and COBE, ISO, and IRTS successfully followed. SPITZER Space Telescope (SST, SIRTF) was recently launched and Japanese mission, ASTRO-F2 will be ready soon. In these missions, cooling of the telescope with super fluid Helium is commonly adopted to avoid the noise due to the thermal emission of the telescope itself. The cryogenics with vacuum system renders serious constraints on the telescope size, that is, the largest telescope is 85 cm aperture of SST. The diffraction limited image makes spatial resolution of infrared observations considerably worse than those at other wavelength bands.

The next generation space infrared telescopes are now being developed, such as ESA's Herschel (3.5 m aperture, HST; Pilbratt 2004) and NASA's JWST (6 m aperture; Seery 2003). These two missions have excellent performance and must provide a breakthrough for the infrared observations, however, telescopes are passively cooled and their temperatures are higher than 50 K. The relatively high telescope temperature makes observations restricted to near infrared and 'submillimeter bands for JWST and Herschel, respectively. In order to achieve similar level of observation in mid and far infrared region, large aperture cold telescope ( $< 5$ K) is required, which is the expected role of the SPICA mission. SPICA is not the approved mission yet, but phase-A studies have been performed in these three years. One of the key technology of the SPICA mission is the thermal design for the efficient radiative cooling and development of the mechanical coolers. In this paper, we present the current mission study of SPICA based on the recent results of the development.

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## II. OUTLINE OF THE SPICA MISSION

We, Japanese infrared astronomers, first launched space infrared telescope, IRTS in 1995. IRTS is a 15 cm aperture cooled telescope dedicated for the observations of diffuse extended sources in the wavelength band from near infrared to submillimeter region. IRTS was very successful and provided significant scientific outputs, such as infrared background, diffuse UIR emission extended over the galactic plane, etc. Furthermore, technologies concerning the space cryogenics were established.

Based on the IRTS heritage, new mission ASTRO-F was proposed and now is being developed. ASTRO-F is a survey mission similar to IRAS but has a capability of much better sensitivity and higher spatial resolution. It is expected that ASTRO-F catalogue with several millions of infrared sources will be widely used in the worldwide astronomy community.

SPICA is a successor of ASTRO-F and is planned to carry out detailed the observations of ASTRO-F sources with higher spatial and spectral resolutions. SPICA is the observatory like SST, Herschel and JWST, and observing programs will be selected based on the peer review.

SPICA is a 3.5 m cooled telescope and a mission much bigger than previous Japanese scientific satellites launched by M-V rocket. We are going to launch SPICA with H-2A rocket of JAXA and to install telescope of the largest possible size in the fairing. The telescope will be launched at the ambient temperature, and will be cooled down in space with efficient radiative cooling and mechanical coolers. The lack of the heavy and large vacuum container makes it possible to install

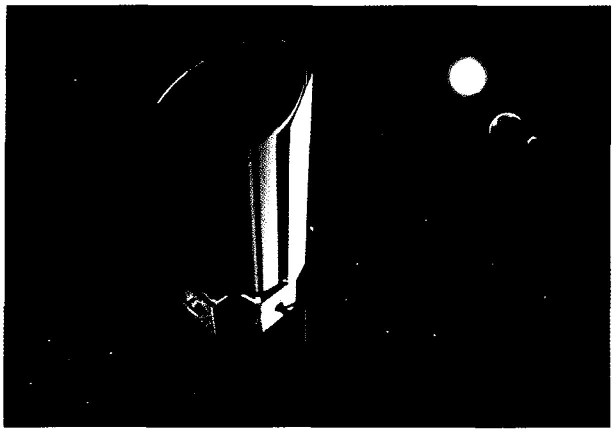

**Fig. 1.**— An artist's view of SPICA at L2 orbit. The sun and the earth can be seen in the same direction with same size.

the large aperture telescope. Furthermore, we do not use a deployable system to make the system simple and to save the cost. Total weight of the satellite system is required to be less than 2.6 ton.

The orbit of infrared satellite is also important issue. We chose Sun-Earth L2 orbit for SPICA like Herschel and JWST. L2 orbit is very preferable from the thermal point of view, since thermal radiation of the earth is negligible and the radiative cooling towards the deep space is very efficient. Fig. 1 shows an artist's view of the SPICA satellite in orbit. The sun and the earth can be seen in the same direction with same size.

Fig. 2 shows the detection limit of SPICA as compared with those of Herschel and JWST. It is clearly found that SPICA has an excellent performance at the wavelength region from 20 to 200 $\mu$m as expected for the cooled telescope.

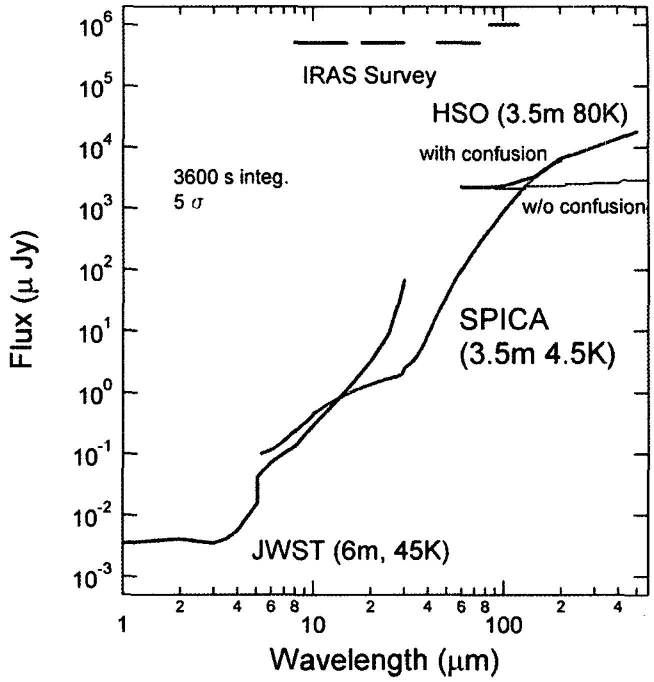


**Fig. 2.**— The detection limit of SPICA is compared Wwith JWST and Herschel(HST). It is clearly found that SPICA is powerful at 10 $\sim$ 200 $\mu$m.

## III. THERMAL DESIGN AND DEVELOPMENT OF MECHANICAL COOLER

The basic structure of the satellite system is shown in Fig. 1. The lower part is a bus system whose temperature is kept at the ambient temperature. The upper part, telescope and focal plane system, is thermally isolated from the bus system, and the telescope is cooled down to 4.5K. One side of the telescope is always exposed to the sun light, whose heat is blocked by a sun shade and three folded radiation shields. Another side of the telescope is faced to the 3 K deep space. The telescope tube in this side and a part of radiation shields are used as radiators for the efficient radiative cooling. The mechanical coolers are placed in the middle of the telescope and the bus system. The output heat of the coolers is radiated to the deep space from the specific radiator placed at the middle part.

Considering the environmental condition at the launch of H2A rocket, the structure of the satellite system is constructed, and the thermal analysis was attained. In this analysis, the heat load from focal plane instruments of 15 mW at 4.5 K, 10 mW at 2.5 and 1.7 K was assumed. Fig. 3 shows the result of the thermal analysis which indicates that there exits a possible system design.

Since the mechanical coolers are key item to realize the SPICA concept, we have devoted considerable effort to developing the mechanical coolers. For the preecooling, a two-stage Stirling cooler was already developed which has a cooling power of 200 W at 20 K. This system is used for ASTRO-F and will be in flight proven soon. For the 4.5 K stage, we developed J-T system with He4 gas. This JT coolers is installed on SMILES onboard the Space Station and will be in flight proven in 2007. The quite new item is 2.5 K and 1.7 K stage coolers. We adopted the J-T system using He3 gas at low pressure operation. We fabricated the bread board model and finally achieved the cooling power of 12 mW at 1.7 K. Fig. 4 shows the photographs of cold head and entire view of the He3 J-T system. The development of the flight model needs more efforts, but we are now confident that the SPICA concept can be technically feasible.

## IV. TELESCOPE AND FOCAL PLANE INSTRUMENTS

The 3.5 m telescope is another important issue for the SPICA development. Based on the experience of

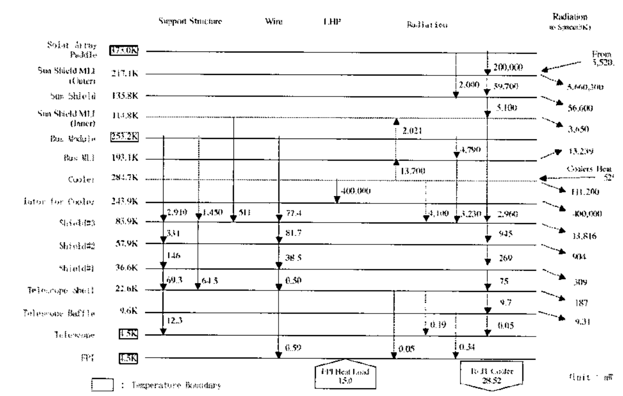

**Fig. 3.**— Heat flow chart of the SPICA thermal design.

the 70 cm mirror made of SiC for ASTRO-F, we are going to develop the light-weighted mirror with similar composite material. The SPICA telescope has the requirements for its total weight to be lighter than 700 kg and for the imaging performance to be diffraction-limited at 5 $\mu$m at 4.5 K. Two candidate materials, silicon carbide (SiC) and carbon-fiber-reinforced SiC (C/SiC composite), are currently under investigation for the primary mirror. A monolithic mirror design will be adopted in both cases because of the technical feasibility and reliability.

The focal plane instruments are also under study. In order to make the best use of the characteristic feature of SPICA, the first priority must be the mid and far infrared instruments. One is a mid infrared camera/spectrometer with diffraction limit image of 0.3″at 5 $\mu$m. Capability of the coronagraph is also considered which could be very powerful in detecting the extra solar planets. The second is a far infrared camera/spectrometer which provides spatial resolution of 3.5″at 50 $\mu$m. The large format array for this instrument is now being developed. The near infrared camera/spectrometer, and submillimeter camera/spectrometer are being studied as an optional instruments. Final selection of the focal plane instruments will be made taking the possible international collaboration into consideration.

## V. FUTURE PROSPECT

We have developed the key technologies for SPICA and now believe that SPICA is a feasible mission. We are going to make a formal proposal to ISAS/JAXA by the end of 2004FY to proceed the development one step further. We welcome international collaboration in any kinds to make the proposal strong and competitive. At present, we are investigating to collaborate with US and European countries on far-infrared and submillimeter spectrometers. Korea also shows a strong interest to provide one of focal plane instruments.

The financial condition of JAXA is not so good now, but we hope to launch SPICA in 2012 in the earliest case.

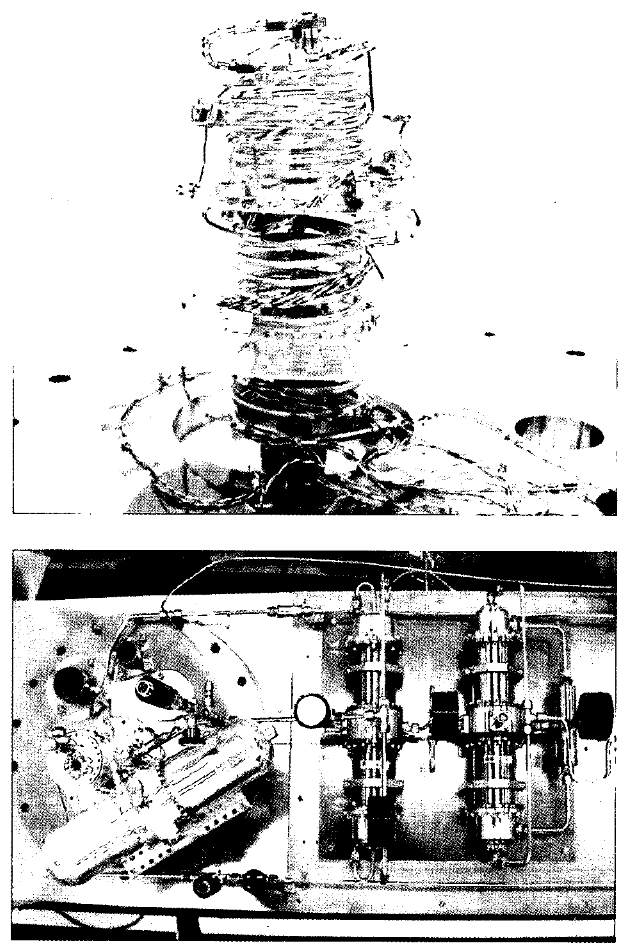

**Fig. 4.**— Photographs of He3 J-T bread board model. Left and right panels indicate side the cold head and heat exchanger, and entire view of the system, respectively.

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