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SPICA: A 3.5 m space infrared telescope for mid- and far-infrared astronomy

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Abstract

The Space Infrared Telescope for Cosmology and Astrophysics (SPICA) mission is a Japanese astronomical infrared satellite project optimized for mid- to far-infrared observations. It will be launched at ambient temperature and cooled down on orbit by mechanical coolers on board with an efficient radiative cooling system, a combination of which allows us to have a 3.5-m class cooled (4.5 K) telescope in space. SPICA will give us deep insights into a number of key problems in present-day astronomy, ranging from the star-formation history of the universe to the formation of planets, owing to its high spatial resolution and unprecedented sensitivity in the mid- to far-infrared. We have made successful progress in the development of mechanical coolers, whereas silicon carbide and carbon-fiber reinforced silicon carbide have been extensively investigated as primary candidates for the SPICA telescope mirrors. We present the current status of the SPICA project as well as the results of technology developments.

Keywords: Space-based infrared telescopes; Infrared; Far infrared; Space cryocoolers

1. Overview of SPICA mission

In the mid- (MIR) to far-infrared (FIR) region thermal emission dominates in the background noise and thus cryogenically cooled space-based telescopes bring a tremendous gain in the sensitivity. On the other hand, the source confusion noise, set by the number of detectable sources in a spatial resolution element, becomes a dominant noise source in the FIR because of the relatively large diffraction-limited resolution size. Past and currently-ongoing space infrared missions all employ a large cryogen tank system, which limits the aperture size of the telescope to less than ~1 m. A large cooled space telescope thus, if realized, provides an ideal facility for MIR to FIR astronomy. It will give us a first opportunity to make MIR to FIR observations with unprecedented sensitivity and arcsecond spatial resolution. An example of the magnitude of the gain by improvement of the spatial resolution is indicated in Fig. 1.

The Space Infrared Telescope for Cosmology and Astrophysics (SPICA) is an infrared satellite project that adopts a warm launch design without a cryogen tank (Nakagawa et al., 2004). It will be brought into a sun–earth libration L_2 halo orbit. Owing to the large distance from the earth, mechanical coolers on board together with an efficient radiative cooling system enable to avoid large cryostat shrouds that enclose the telescope and scientific instruments. This allows to have a 3.5 m class cooled telescope in space (see Fig. 2). The target launch date of SPICA is early 2010s, to be operated in a time frame similar to the Herschel Space Observatory (HSO; Pilbratt, 2003) and the James Webb Space

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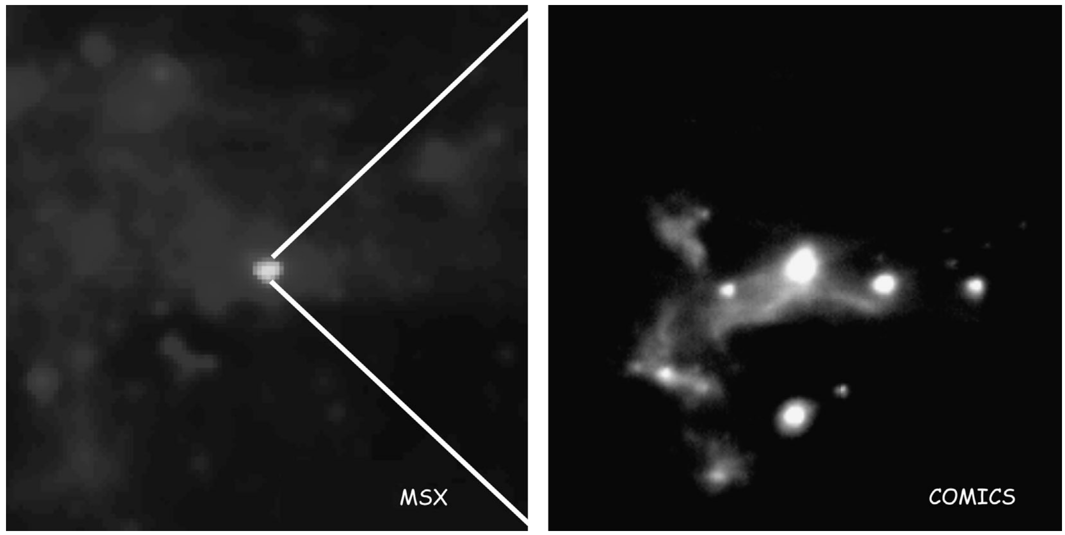

Fig. 1. Example of the benefit of high spatial resolution. The MIR image of the Galactic center by Midcourse Space Experiment (MSX) observations at 8.2 μm with the spatial resolution of 18″ (left; Price et al., 2001) and the image taken by the COMICS on the 8.2 m Subaru telescope at 8.8 μm with the spatial resolution of 0.3″ (right; Okada et al., 2003). The MSX image was obtained from the MSX image server at the Infrared Processing and Analysis Center (IPAC). FIR observations of currently available cooled telescope have spatial resolutions similar to the MSX observation of 8.2 μm. SPICA can carry out FIR observations with arcsecond spatial resolutions as well as MIR observations with the spatial resolution similar to the COMICS observation for much fainter objects.

Telescope (JWST; Seery, 2003). Fig. 3 shows the sensitivities expected for SPICA observations performing wide-band photometry of point sources together with those of other missions. HSO and JWST both will have passively cooled telescope systems, whose expected temperatures are in the range 40–80 K. Thermal emission from the telescope system in both missions will significantly limit the sensitivities in the spectral region where SPICA will be optimized and perform most efficient observations. A coronagraphic capability in the MIR is also being planned to be on board SPICA (e.g. Enya et al., 2004). SPICA will have higher sensitivities (by more than an order of magnitude) than the Spitzer Space Telescope (SST; Werner et al., 2004) and the ASTRO-F (Matsuhara et al., 2005), providing images of the universe deepest ever in 20–200 μm.

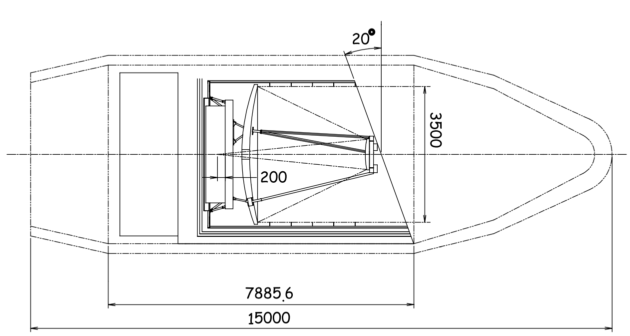

Fig. 2. Illustrative view of the SPICA telescope system in the H-IIA rocket fairing. This figure indicates a baseline dimension of the telescope system. Details of the design, such as the supporting structures, are shown only for the illustrative purpose.

SPICA can make crucial observations for a number of key problems in present-day astronomy. They range from the study of the early universe, where in such very

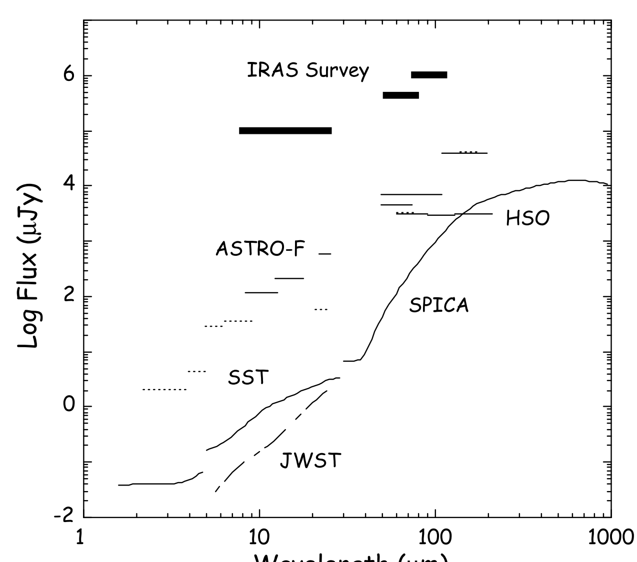

Fig. 3. Sensitivities of the SPICA mission (thick lines; 5σ for 1 h integration) together with other missions for point source detections; JWST (dot-dashed lines), HSO (PACS, thin solid lines), ASTRO-F (solid lines), SST (IRAC and MIPS, dotted lines), and the IRAS survey detection limits (very thick solid lines). For the ASTRO-F the sensitivities are estimated for one pointing observation (5σ; Matsuhara et al., 2005). Note that those for $\lambda > 50$ μm are set by confusion limits. For the SST, the sensitivities for the IRAC are shown for those with the 200 s frame time (Fazio et al., 2004), while the source density confusion limits taken from Dole et al. (2004) are plotted for the MIPS.