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Infrared Surveys Planned for ASTRO-F

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Abstract. The next survey mission, ASTRO-F, is scheduled for launch in 2005. This is the first Japanese satellite dedicated to infrared astronomy. The primary purpose of this project is to investigate the birth and evolution of galaxies in the early universe through deep, wide-field surveys at wavelengths ranging from 2 to 200 microns. In the far-infrared wavelength band, ASTRO-F will conduct an all-sky survey like the IRAS survey with several tens of times higher sensitivity and several times better spatial resolution. In the near- and mid-infrared, wide area sky-surveys will be conducted over pre-selected portions of the sky in 13 bands ranging from 2-200microns. In addition to these photometric surveys, low-resolution spectroscopic capabilities are available for all wavelength bands. The ASTRO-F mission will produce a fundamental database for the next generation of advanced observatories, for example Herschel, and JWST, and will complement the SIRTF mission by virtue of its wide sky coverage.

1. ASTRO-F Outline

ASTRO-F is the first Japanese satellite dedicated to infrared astronomy (Shibai 2003). The wavelength coverage is from 2 to 200 μm. The project was started in 1997, succeeding a small, survey-type telescope, the IRTS (Infrared Telescope in Space, Murakami et al. 1996). It follows twenty years on from the IRAS survey (Neugebauer et al. 1984). A new infrared survey with higher quality is believed to be undoubtedly important as a fundamental database in astronomical researches.

The ASTRO-F satellite weighs approximately 970 kg, the maximum weight for a Sun-synchronous orbit when launched by the Japanese launch vehicle, M-V rocket. The telescope is cooled to 5.8 K to reduce the instrumental thermal emission. The effective aperture is 670 mm in diameter. The primary and secondary mirrors are fabricated by using a newly-developed, lightweight SiC mirror technique. The image quality of the telescope is better than 1 arcsecond.

ASTRO-F is a hybrid-type cryostat satellite incorporating a mechanical cooler as well as cryogen. Because of this hybrid cooling system, the cryogen volume and the size of the vacuum vessel can be reduced, and therefore, a large aperture telescope fits into a small cryostat. The telescope and the focal plane instruments are cooled to 2 K by super-fluid helium (180 litre tank). By employing a mechanical cooling system (Stirling cycle cooler), most of the heat load on the cold part is compensated. The expected cryogen life is nominally one and a half years. Even after the helium cryogen has run out, near-infrared observations using the InSb array can be continued, using only the mechanical cooling system.

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Survey

Band	wavelengths	pixel	format	
N60	50 - 75μm	30"	20x2	Ge:Ga
WIDE-S	50 - 110μm	30"	20x3	Ge:Ga
WIDE-L	110 - 200μm	50"	15x3	stressed Ge:Ga
N170	150 - 200μm	50"	15x2	stressed Ge:Ga

Spectroscopy

Imaging Fourier Transform spectrometer
50 - 200μm (WIDE-S & -L)
0.4 cm^{-1} resolution

Figure 1. FIS photometric bands and arrays.

2. Scientific Capability

ASTRO-F has two unique focal plane instruments, FIS (Far-Infrared Surveyor) and IRC (Infrared Camera). Their design and performance are described by Kawada (1998) and Wada et al. (2003), respectively.

2.1. Spectral Coverage

The FIS has four wideband photometric channels (Figure 1); Wide-S (50-110 μm), Wide-L (110-200 μm), N60 (50-75 μm), and N170 (150-200 μm). The two wider bands are aimed for detecting the faintest FIR sources, and the two narrower channels are for better determination of the colour of detecting sources. IRAS has the 100 μm band for its longest wavelength band. However, as demonstrated by ISO, important FIR sources often have their peaks at longer than 100 μm, and therefore, the survey with the Wide-L and N170 bands are unique and undoubtedly important. The Wide-S and N60 are expected to determine the color temperature of warm FIR sources, such as AGNs and ULIRGs.

On the other hand, IRC covers photometrically from 1.8 to 26 μm with 9 bands (Figure 2). As the number of bands is twice of that of IRAC/SIRTF, it will be able to characterize SEDs of distant and/or obscured galaxies much more precisely compared with IRAC. In particular, IRC has 4 bands beyond 8 μm. Photometric redshift determination using the UIR features may be a powerful tool for the investigation of distant starburst galaxies.

2.2. Spectral Resolution

ASTRO-F is unique for low-resolution spectroscopic capability throughout the spectral range (Figure 3). IRC has grism/prism channels with the resolving power of 100-200. By using a narrow and short slit for targets, spectroscopic data can be obtained. In the far-infrared wavelength band, FIS can act as an imaging

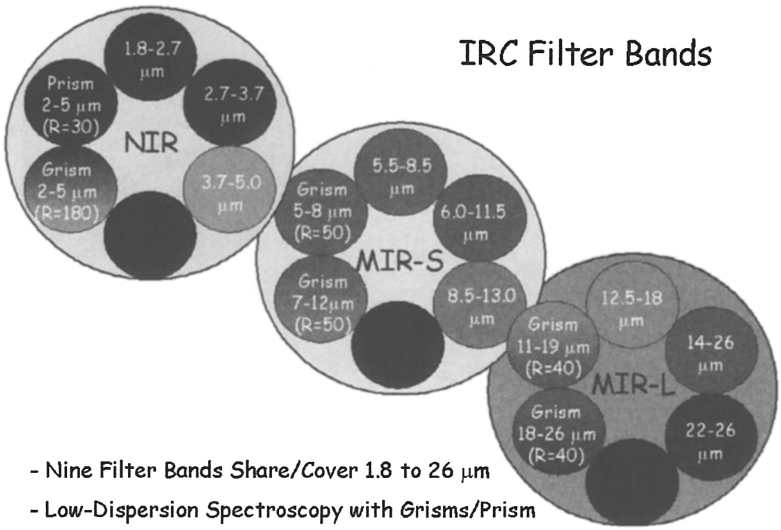

Figure 2. IRC filter bands.

Fourier transform spectrometer with Martin-Puplett type interferometer. The spectral resolution is 0.3 cm^{-1}.

2.3. Sky Coverage

The orbit and attitude operation of ASTRO-F are similar to those of IRAS. Therefore, although all-sky coverage can be accomplished in a half-year in the sense of attitude operation, complete coverage of the whole sky is quite difficult due to several constraints on the data quality (SAA, Moon-shine, etc.). However, it is expected that far more than half of the sky will be covered with good data quality. In addition to the all-sky survey, ASTRO-F has a pointing mode. The attitude stability is better than 1 arcsecond and the duration of one run is 10 minutes maximum. By coordinating the pointing mode, we will be able to make wide-area surveys for selected sky regions described in section 3.

2.4. Sensitivity

Figure 4 shows the point source sensitivity expected for ASTRO-F. In the all-sky survey, the 5 sigma sensitivity is 50-100 mJy for point sources in all six bands. The sensitivity of the WIDE-L and N170 is limited by the cirrus confusion, and that of other bands is by the detector noise. On the other hand, by using the pointing mode in which the 10 minutes integration can be used, the sensitivity is significantly improved; a few μJy in NIR, few tens μJy in MIR, and a few mJy in 50-100 μm. The sensitivity values are almost comparable to those of SIRTF.

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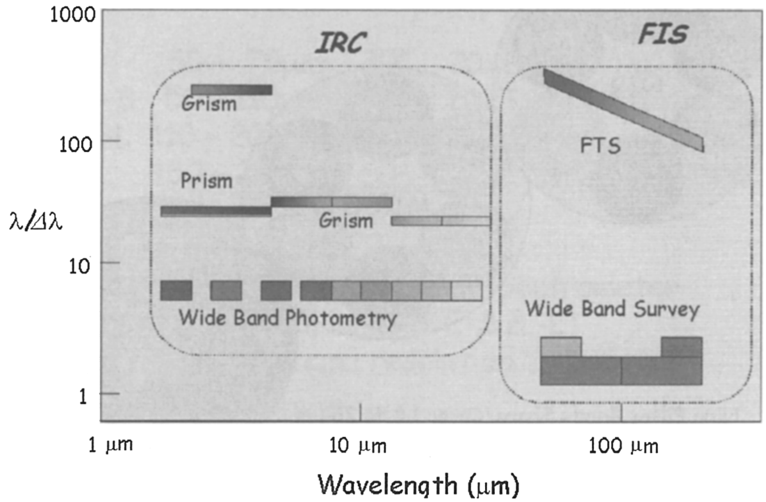

Figure 3. Spectral coverage and resolution of ASTRO-F

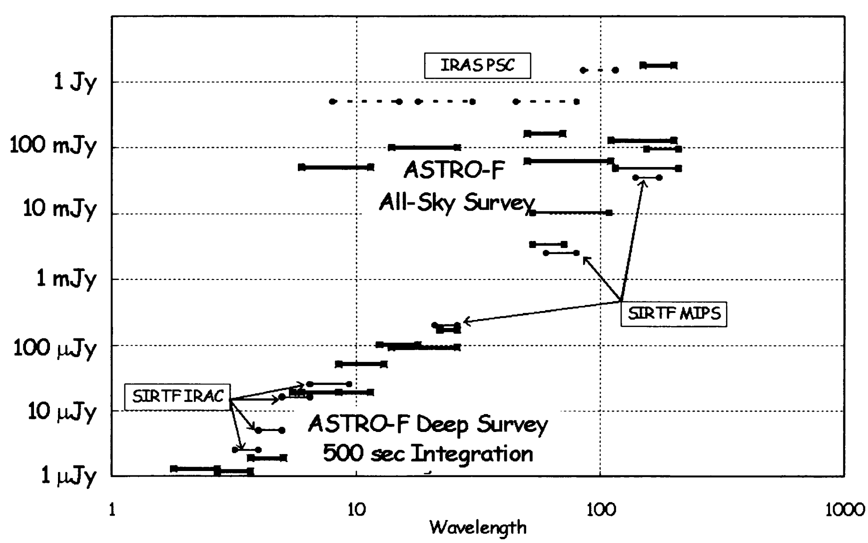

Figure 4. Point source sensitivity of *ASTRO-F* (5σ) compared with *IRAS* PSC limit (Neugebauer et al. 1984) and SIRTF (5σ, 200 sec integration, Werner et al. 2002).

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3. Survey Strategy

The current plan of the survey program is briefly reviewed in the following subsections. This plan might be revised in future, although it is the default one at present.

3.1. All-Sky Survey

In the mid- and far-infrared wavelength region, *ASTRO-F* will execute an all-sky survey like the *IRAS* survey with a sensitivity of 100 mJy (5σ) and several times better spatial resolution (30-50 arcsecond). Moreover, spectral bands were added at longer than 100 micron, where most important types of objects have their peaks. The final point source catalog is expected to include distant ultra-luminous galaxies, starburst galaxies, proto-planetary disks, and other sources. The expected number of detected point sources, mainly external galaxies, is more than ten million. The data of the all-sky survey are reduced and analyzed for the archive by a dedicated team including not only Japanese astronomers but also Korean, UK, and Dutch astronomers. Several data products, *ASTRO-F* Flux Catalog at *IRAS* Point Sources, Point Source Catalog at High Latitudes and at Low Latitudes, and All-Sky Images, are planned to be released as soon as possible.

3.2. Large Area Shallow Survey

The field of views of IRC are larger than those of SIRTF. To exploit this advantage, the large area, shallow survey is planned. One of the best targets for this mode is the Large Magellanic Cloud (LMC). As it is located near the South Ecliptic Pole, it can be observed once per satellite revolution during almost half of the total period with the pointing mode. Far-infrared is automatically well-covered by the all-sky survey because of its location. We will be able to obtain the full image of the LMC in all infrared bands with diffraction-limited resolution.

3.3. Deep Survey

The regions near the North and South Ecliptic Poles can be surveyed many times. Therefore, we can execute a highly sensitive survey by repeating pointing mode observations of a small sky area many times. The sensitivity can reach to almost the confusion limit level even in the NIR. According to the current plan, the 1 square degree field around the North Ecliptic Pole will be deeply surveyed. At the South Pole, the survey is to be made for the LMC, not for the SEP itself.

3.4. Very Wide NIR Survey

The cryogen life is expected to be one and a half years. After the cryogen boil-off, we can continue the NIR observation by the mechanical cooling system. Therefore, very wide area survey, 100 square degree per year or more is possible. The sensitivity remains high enough (Figure 4) and the spatial resolution is 1.2 arcsecond. This will be the largest NIR survey with very high sensitivity and resolution at that time.

4. International Collaboration

ASTRO-F has a severe constraint in its pointing direction: the telescope must be directed within ± 1 degree from the great circle perpendicular to the direction of the Sun. Therefore, operation planning is not so versatile. Because of this limited freedom of operation, most of the observing time will be used for the continuous all-sky survey and for pointing observations made by the *ASTRO-F* project team. The observation programming is continued by a dedicated team. However, 30% of the pointing time will be open to the Japanese community (20%) and to the European community (10%). The call for open-time proposals will be announced in 2004.

5. Summary

ASTRO-F will be a unique and powerful telescope for the research of the interstellar medium, complementary to the observatory-type large telescopes, such as, *SIRTF* (Werner et al. 2002), *SOFIA* (Becklin & Moon 2002), *Herschel* (Pilbratt 2003), *JWST* (Seery 2003), and *SPICA* (Nakagawa 2002). *ASTRO-F* is to be launched in 2005.

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