Mid-Infrared Asteroid Survey: From *AKARI* to *SPICA*

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ABSTRACT

The physical properties of asteroids, including Main-belt asteroids (MBAs), Near-Earth asteroids (NEAs), Jovian Trojans (JTs), irregular satellites, are fundamental to understanding the formation of our solar system, since they are remnant of planetesimals and seem to preserve clues of the initial conditions of our solar nebula 4.6 Gyr ago. The size distribution of these small bodies is the most basic and useful tool to obtain an insight into their original mass and collisional history of our solar system. The radiometric method with the infrared space telescopes (e.g., *IRAS*, *MSX*, *ISO*, *Spitzer*, *AKARI*, *WISE*, and *Herschel*) can determine the size and albedo of asteroids. The sensitivity of *SPICA* is much higher than those of previous observations, especially in 20 μm or longer wavelength, and it can detect faint asteroids, for example, down to ~50 m MBAs. It is important to comprehend the population of such small asteroids also from standpoint of the "spaceguard". Observations at far-infrared wavelengths will allow us to study Trans-Neptunian objects (TNOs) and Centaurs in the outer regions beyond the giant planets. Their size distribution, as well as bulk densities of binary systems, become as important key elements for the history of our solar system.

1. SIZE OF ASTEROIDS MEASURED BY THERMAL INFRARED OBSERVATIONS

Size is one of the most basic physical quantities of asteroids. However, little is still known about the size distribution of asteroids, because there are millions of asteroids, ranging widely in size from > 1000 km across to < 10 m (more than five order of magnitude). Size distribution can help us to understand the current mass distribution in the asteroid belt, the collisional evolution of asteroids and asteroidal families, the production ratio of interplanetary dusts, all of which are linked to planet formation in our solar system. Based on size information, it is enabled to study correlation between size, albedo, thermal inertia, color, surface material, and orbital element of asteroids. This will also contribute to future Rendezvous / sample return missions of small objects.

One of the most effective methods for determining the size of asteroids is through combining radiometric measurements at visible and thermal infrared wavelengths. The radiometric measurements from space allow a large number of objects to be observed in a short period of time. The first systematic survey of asteroids using a space telescope was made by *IRAS* (Tedesco et al. 2002). *AKARI* made the next generation asteroid survey based on the 16-month infrared all-sky survey observation (Usui et al. 2011). *WISE* also completed an all-sky survey with high sensitivity detectors and its database includes more than 130,000 asteroids (Mainzer et al. 2011, and subsequent papers).

2. OBJECTIVES

2.1. Asteroid Survey

The sensitivity of *SPICA* is much higher than those of previous observations. With *SPICA*/MCS, much fainter asteroids in the range of undiscovered size can be detected (see Figure 1). It is a new frontier for asteroid study.

Expected number of known/unknown asteroids detected by systematic survey with *SPICA*/MCS is 6.5 / FOV for MBAs, 0.5 / FOV for JTs, and 0.1 / FOV for TNOs, which corresponds d > 0.1 km, > 0.5 km, and > 100 km, respectively (Yoshida & Nakamura 2007, 2008; Fuentes et al. 2009, also see Figure 2), where d means the diameter of asteroid. To complete this survey program, we will observe the selected sky at the ecliptic latitude of 0°, ±5°, ±10°, ±15°, and ±20° during 10 months (avoiding the galactic plane), which require the total observation time of

$$(1 \text{ hr} \times 2 \text{ times}) \times 9 \text{ positions} \times 10 \text{ months} = 180 \text{ hrs} .$$

It should be noted that we may share imaging data with the zodiacal light observations (Ootsubo et al., this volume) to increase the observational efficiency.

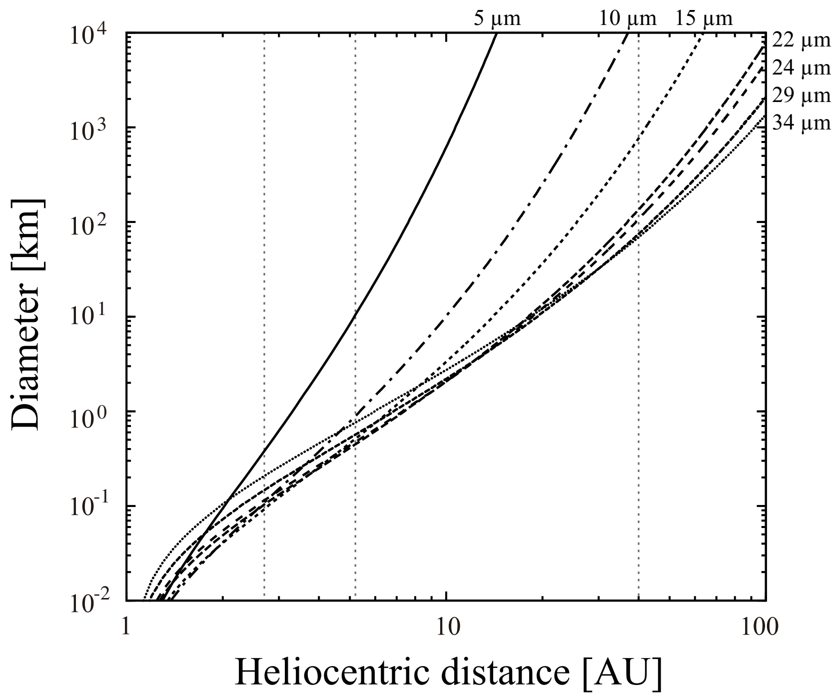

Figure 1. Estimated detection limit of size of objects with *SPICA* (5σ, 100 sec exposure) against the heliocentric distance.

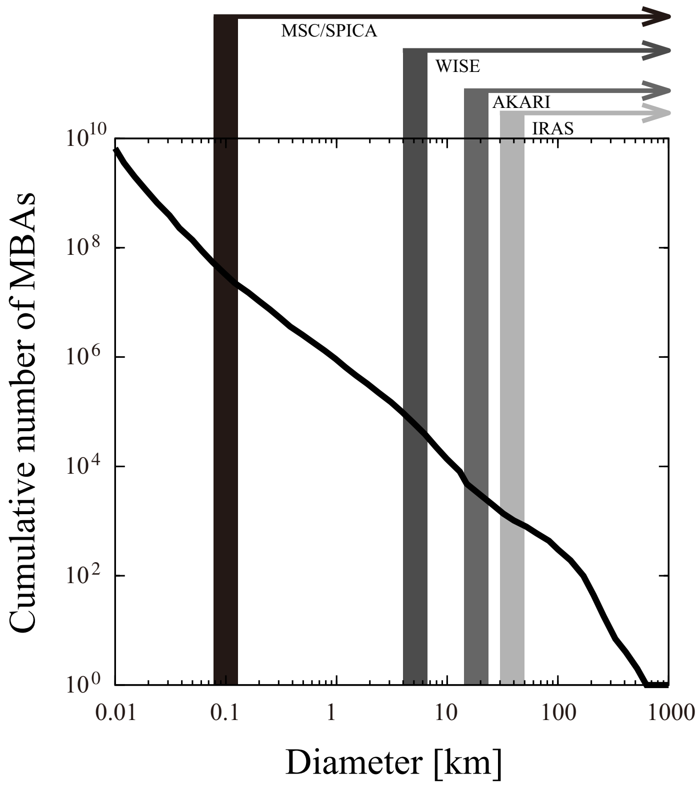

Figure 2. Cumulative size frequency distribution of MBAs and detectability with *IRAS* (Tedesco et al. 2002), *AKARI* (Usui et al. 2011), *WISE* (Mainzer et al. 2011), and *SPICA*.

2.2. TNOs Study

TNOs represent the primitive remnants of the planetesimal disk from which the planets formed. *Herschel* made observations of TNOs/Centaurs of ~130 objects within 373 hrs (Müller et al. 2009). *SPICA* will detect most discovered TNOs (and TNOs to be discovered by HSC/Subaru, Pan-STARRS, and LSST in the future) by photometric-mode of SAFARI, at far-infrared wavelengths. Spectroscopic observation with SAFARI is also essential for studying surface material of TNOs. With *SPICA*, we will make pointed observations for selected targets of the known TNOs with

$$(1 \text{ hr} \times 2 \text{ times}) \times (250 \sim 500) \text{ objects} = (500 \sim 1000) \text{ hrs (at maximum)}\,.$$

2.3. Spectroscopic Observations of JTs

JTs are mostly D-type asteroids, which have close relation with the comet nuclei. For some JTs, 10 μm emission feature was detected with *Spitzer* (Emery et al. 2006), while no 1 μm absorption was detected with IRTF/SpeX (Yang & Jewitt 2011). These results suggest that some JTs have iron-poor (Mg-rich) material and have a thin layer of fine silicate grain, which may be related to past / on-going cometary activity.

With *SPICA*, observations of 10 μm emission feature of comets have been proposed (Kawakita et al., this volume; Furusho et al., this volume). It is worth extending the same procedure to JTs for investigating the surface property of JTs. $d \sim 1$ km for JTs can be detected in grism mode (SG2) with 5σ, 100 sec. Since there is a plan for sample return mission from JTs by the Solar Power Sail spacecraft in 2020s, it is important to have knowledge of JT's surface before the mission.

2.4. Natural Satellites in Orbit around Giant Planets

Regular / irregular satellites of giant planets are also interesting for considering planetary formation and evolution. As the same way of size determination of asteroids described in Section 2.1, we will survey physical information for known natural satellites. The number of *SPICA*'s detectable satellites is ~ 70 of Jupiter, ~ 60 of Saturn, ~ 30 of Uranus, and ~ 15 of Neptune, which correspond $d > 1$ km, $>$ (several) km, > 10 km, and $>$ (several $\times$ 10) km, respectively. Also satellites of Pluto can be detected. It should be noted that detailed feasibility study of these observations is needed to avoid stray light from the planets.

REFERENCES

Emery, J. P., Cruikshank, D. P., & van Cleve, J. 2006, Icarus, 182, 496
Fuentes, C. I., George, M. R., & Holman, M. J. 2009, ApJ, 696, 91
Mainzer, A., et al. 2011, ApJ, 731, 53
Müller, T. G., et al. 2009, Earth Moon and Planets, 105, 209
Tedesco, E. F., et al. 2002, AJ, 123, 1056
Usui, F., et al. 2011, PASJ, 63, 1117
Yang, B., & Jewitt, D. 2011, AJ, 141, 95
Yoshida, F., & Nakamura, T. 2007, Planetary and Space Science, 55, 1113
— 2008, PASJ, 60, 297