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Scientific Objectives and Detection Capabilities of HII/L2 Observation for Asteroids and Edgeworth-Kuiper Belt Objects

By

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Abstract: The HII/L2 Mission (Nakagawa 1998, 2000) is Japan's future infrared astronomical satellite following IRTS (Murakami et al. 1996) and ASTRO-F (Murakami 1998, 2000). This paper estimates detection limits of minor bodies in the solar system using the HII/L2 telescope, and proposes scientific objectives which can only be accomplished by that mission.

1. INTRODUCTION

Albedos, diameters, and surface regolith conditions of minor bodies in the solar system such as asteroids and Edgeworth-Kuiper belt objects (EKBOs) are important information for studies of the origin and evolution of the solar system. However, it is not easy to attain them due to following reasons. Firstly, apparent sizes of most asteroids are smaller than the spatial resolution of even the largest telescopes (e.g. SUBARU and VLT). The second reason is that the absolute magnitude of minor bodies, which is the magnitude at zero phase angle in the unit heliocentric and geocentric distances, is a function of albedo and surface area, neither of which can be obtained independently.

There have been several techniques previously development to measure the albedo and diameter of asteroids, including the photometric model method (Bowell et al. 1989), the polarimetric observation method (Dollfus & Zellner 1979), the radar observation method (Ostro 1989), and the stellar occultation method (Mills & Dunham 1989). Also employed are direct observation methods such as measurements using large ground-based telescopes with speckle interferometry (Drummond & Hege 1989) and adaptive optics (Saint-Pe et al. 1993), space telescope (e.g. Hubble Space Telescope) observations, and *in-site* measurements by spacecraft (e.g. Galileo, NEAR Shoemaker, Deep Space 1, Rosetta, and MUSES-C). Yet, many of these methods require too longer observation times (photometric and polarimetric methods) and rely on opportunistic occasions (*in-site* observation, radar, and stellar occultation).

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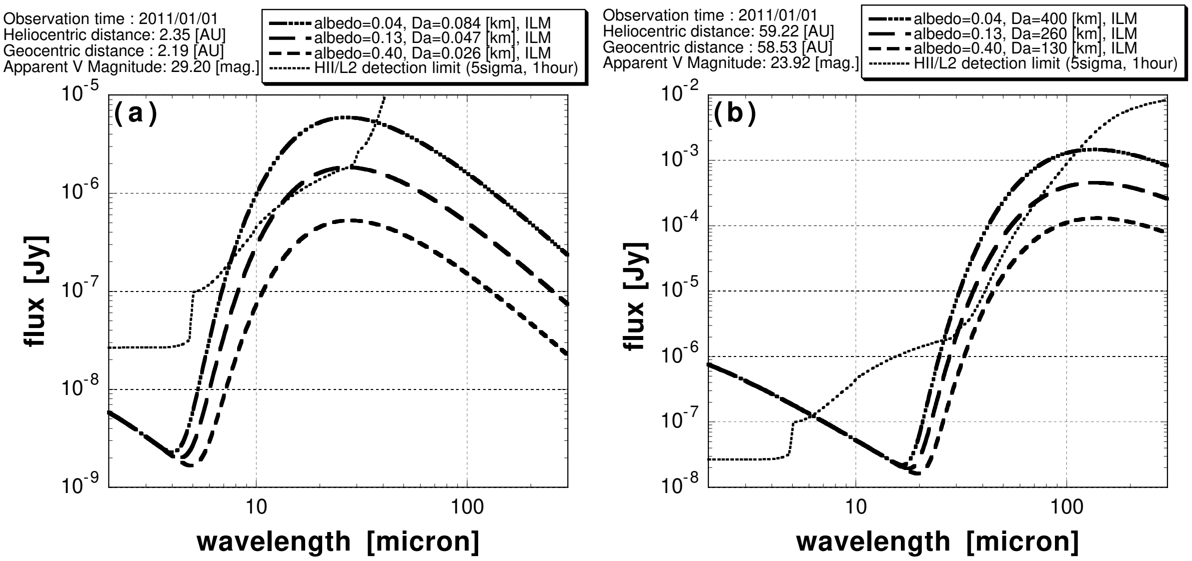

Fig. 1: Flux estimates of solar system minor bodies. (a):Amor asteroid '1996MQ'. (b): Edgeworth-Kuiper Belt object (scatter disk object) '2000CR105' (with the farthest aphelion among discovered EKBOs as of April 1, 2000)

One promising method for the determination of albedos and diameters of asteroids is the thermal infrared observation (Lebofsky & Spencer 1989) since it does not require the above conditions. In addition, at present this method is the only effective method to measure the albedos and diameters of minor bodies which are far from the sun such as EKBOs. Therefore, this method is the most effective method for estimating albedos, diameter, and surface regolith conditions of minor bodies in the solar system.

The HII/L2 Mission (Nakagawa 1998, 2000) which will follow IRTS (Murakami et al. 1996) and ASTRO-F (Murakami 1998, 2000) is an infrared telescope with a 3.5 meter primary mirror. This telescope will have good sensitivity throughout the infrared region, and achieve supreme sensitivity especially in mid- to far-infrared regions. Hence, this mission will suit well measurements of albedos, diameters, and surface regolith conditions of distant and small size objects within the solar system. The following sections describe detection capabilities, number counts, and scientific objectives for solar system objects observed by HII/L2

2. DETECTION CAPABILITIES OF HII/L2 OBSERVATIONS OF SOLAR SYSTEM OBJECTS

The wavelength range of the HII/L2 Mission covers the reflected light region and thermal radiation region of asteroids. Figure 1 shows estimated fluxes for asteroids and EKBOs for various combinations of albedo and diameter that give identical signatures in reflected light. This study was used the isothermal latitude model (Lebofsky & Spencer 1989) which is the highest thermal inertia model among other thermal models because cold bodies such as EKBOs have higher thermal inertia than warmer bodies and the thermal inertia of asteroids increases with the diminution of asteroid size (Hasegawa 1998). The HII/L2 sensitivity assumed for a 3.5 meters aperture and 5 sigma flux in 3600-second integration period. Table 1 shows the summary of delectable diameter limits in kilometers for minor bodies using HII/L2, as a function of heliocentric distance and wavelength. Values in parentheses indicate that reflected light regions surpass thermal radiation in the flux density. The units of reflected light regions are magnitude in the V band. As can be seen, the HII/L2 Mission has significant capability to study distant and small sized solar system bodies.

Table 1: Detectability of minor bodies in the solar system by using HII/L2.

distance	diameter[km]					
[AU]	10μm	20μm	50μm	75μm	100μm	200μm
1.5(NEO)	0.017	0.017	0.10	0.44	0.95	4.5
2.0(MBA)	0.044	0.032	0.20	0.71	1.4	7.0
2.5(MBA)	0.10	0.055	0.32	1.0	2.2	10
3.0(MBA)	0.14	0.084	0.45	1.4	2.8	14
3.5(MBA)	0.26	0.11	0.55	2.0	3.2	17
5.2(Jupiter)	1.0	0.32	1.0	3.2	6.3	28
9.6(Saturn)	14	1.0	3.0	8.4	17	55
19(Uranus)	(22V)	10	11	28	44	170
35(EKBO)	(22V)	140	45	89	140	390
40(EKBO)	(22V)	(19V)	63	120	170	550
45(EKBO)	(22V)	(19V)	85	140	220	630
50(EKBO)	(22V)	(19V)	100	170	260	710
55(EKBO)	(22V)	(19V)	140	220	320	890
60(EKBO)	(22V)	(19V)	200	280	350	1000

♯ (–V) indicates the magnitude of reflected light in the V band.

3. NUMBER COUNTS OF SOLAR SYSTEM OBJECTS NEAR THE ECLIPTIC PLANE IN FIELD OF VIEW OF HII/L2

The HII/L2 telescope will be able to observe very small and distant objects in the solar system. For examples, 20 meter-sized near-Earth asteroids (NEAs) and 60 meter-sized main belt asteroids (MBAs) at 20μm wavelength, and 300 meter-sized MBAs and 85 kilometer-sized EKBOs at 50μm wavelength will be detected by this telescope. As a result, it is reasonable to expect that HII/L2 will detect a large number of solar system objects. However, for astronomers who are not interested in minor bodies in solar system, these objects might be regarded as obstacles for observing their target. Therefore, this section estimates number counts of those near the ecliptic plane in the field of view of HII/L2.

Population models of MBAs and EKBOs were adapted from Durada, Greenberg, & Jedicke (1998) and Davis & Farinella (1997), respectively. Figures 2 and 3 show cumulative numbers of MBAs and EKBOs as a function of their diameter. At the detection limit of the HII/L2 telescope, total numbers of MBAs are about 5×10^7 at 20μm and 3×10^6 at 50μm, while total counts of EKBOs is about 3×10^6 at 50μm.

It is assumed that all MBAs and EKBOs are equally distributed in the space ± 30 degrees latitude. Fields of view of MIR and FIR cameras onboard the HII/L2 telescope are proposed to be $6.1' \times 6.1'$ and $3.8' \times 3.8'$, respectively (Ueno et al. 2000). Thus, observing within ± 30 degrees, about 30 MBAs will be found in field of view of the MIR camera at 20μm, and 0.6

MBAs and 0.6 EKBOs will be taken in field of view of the FIR camera at 50 μm.

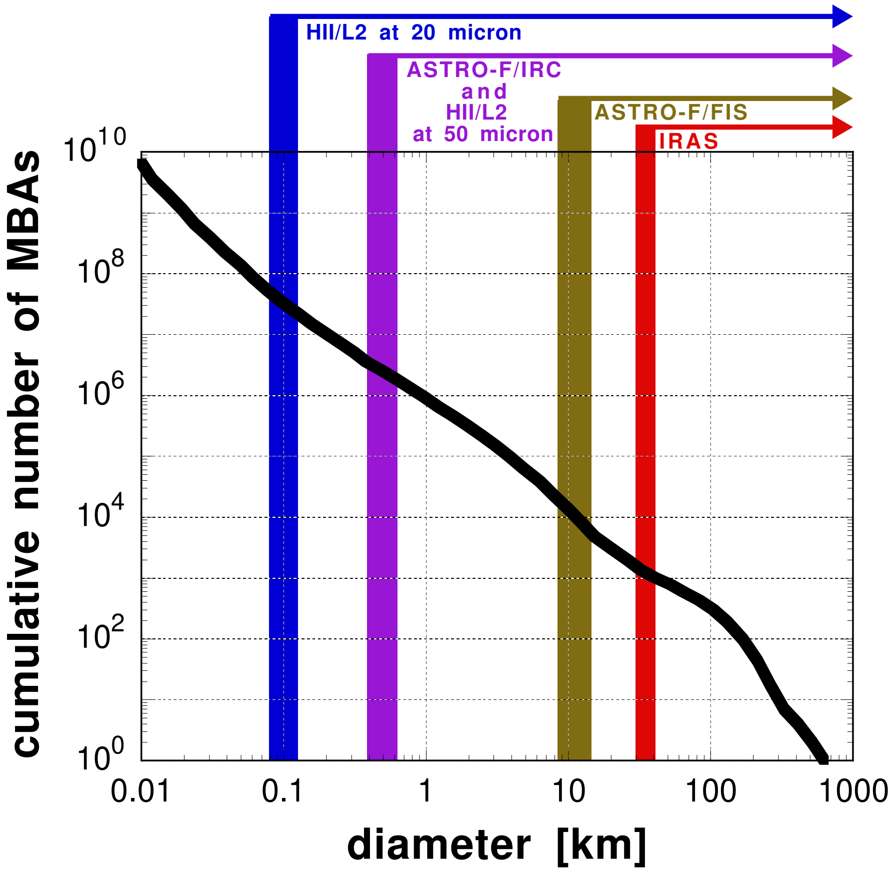

Fig. 2: Cumulative number of main belt asteroids as a function of diameter. The solid line is the number estimated from Durada, Greenberg, & Jedicke (1998). Vertical lines to the right indicate the detection limit of asteroids at 3.5 AU heliocentric distance by IRAS, ASTRO-F/FIS, ASTRO-F/IRC and HII/L2 at 50μm wavelength, and HII/L2 at 20μm.

4. SCIENTIFIC OBJECTIVES OF OBSERVATION FOR EDGEWORTH-KUIPER BELT OBJECTS BY HII/L2

It is generally recognized that EKBOs are planetesimals created in the early proto-planetary disk and have survived over 4.5 Gyr due to their long distance from the Sun such that the solar heat does not sufficiently reach them. Therefore, planetary scientists suppose that albedo, size distribution, and surface condition of those objects may provide direct hints for the formation and evolution of the early solar system. The initial mass distribution of the Kuiper Belt can be estimated from the present EKBOs' size distribution, while their albedo and surface conditions might give us information on what those planetesimals are made of. Also, a relationship between albedo and size of EKBOs will constrain their surface material evolution and origin of short period comets and Centaurus objects.

Past infrared satellites such as IRAS (Neugebauer et al. 1984) and IRTS (Murakami et al. 1996) did not detect the thermal radiation of EKBOs. ISO (Kesseler et al. 1996) succeeded to

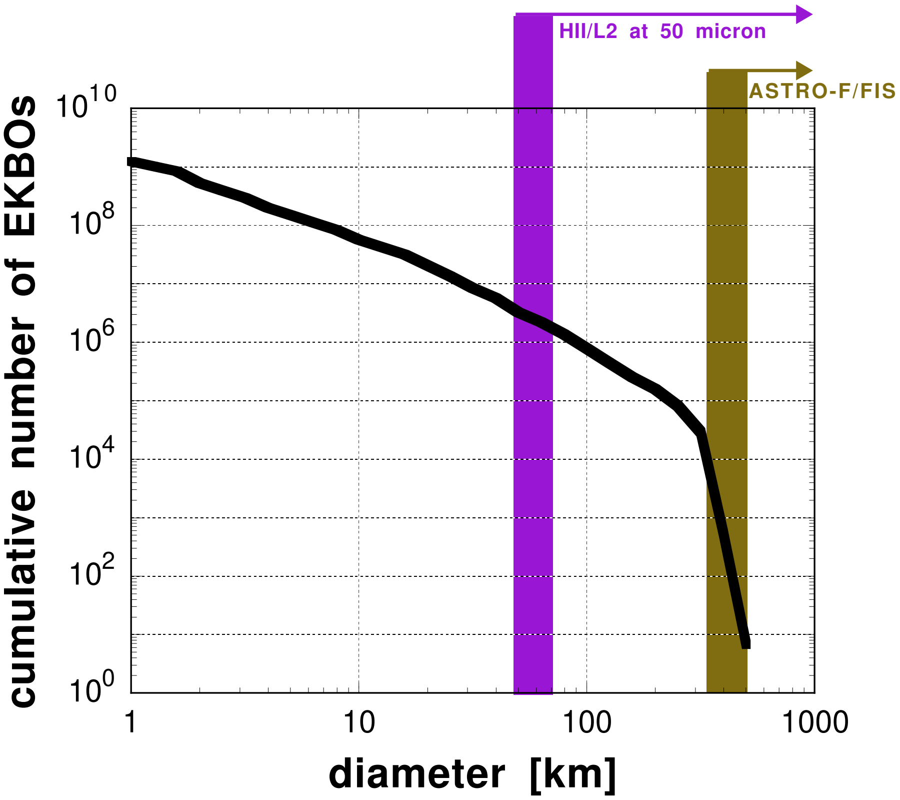

Fig. 3: Cumulative counts of Edgeworth-Kuiper belt objects versus diameter. Vertical lines indicate the detection limit of EKBOs by ASTRO-F/FIS and HII/L2 camera at 50μm. This figure is adapted from Davis & Fallinera (1997).

observe only two EKBOs, '1993SC' and '1996TL66', in far-infrared region and obtained albedo and diameter of them (Thomas et al. 2000). Future infrared satellites such as SIRTF (Fanson et al. 1998), which will be launched in 2001, and ASTRO-F (Murakami 1998, 2000) in 2004 will be able to observe EKBOs in far-infrared regions. Detectable size limits of EKBOs obtainable by SIRTF and ASTRO-F are 300 - 500 kilometers in diameter (Hasegawa et al. 2000), which is presumed to be their maximum size range (Davis and Farinella 1997). The albedo and size are relations within EKBOs can not be obtained by SIRTF nor ASTRO-F, and neither is their initial mass distribution, surface material evolution, and the relationship among Centaurus objects, comets, and EKBOs.

On the other hand, the HII/L2 telescope will be able to observe 50-kilometer-sized EKBOs at 35 AU of the heliocentric distance, and 100-kilometer-sized EKBOs at 50 AU. Thus, albedo and size relationship of EKBOs will be able to be studied by the HII/L2 mission.

5. SCIENTIFIC OBJECTIVES OF OBSERVATION FOR MAIN-BELT AND NEAR-EARTH ASTEROIDS BY HII/L2

Most of the larger than 40-kilometer-sized in diameter MBAs were observed by the IRAS satellite (Tedesco 1992) and ASTRO-F/FIS (Kawada 2000), which is designed primarily to perform an all-sky survey like IRAS, will detect most of the larger than 10 kilometer diameter objects (Hasegawa *et al.* 2000). ASTRO-F/IRC (Onaka 2000) is not a survey type instrument but an imaging instrument for selected sky regions; it can detect MBAs as small as 500 meters across (Hasegawa et al. 2000). On the other hand, the HII/L2 MIR camera will be able to observe MBAs of 50 meters across at 2.5 AU, which is one order of magnitude larger than those to be obtained by ASTRO-F/IRC.

Asteroids smaller than 50 meters are broken up into meteorites in the upper atmosphere of the Earth, when they intercept the planet (Morrison, Chapman, & Slovic 1994). Therefore, asteroids of such sizes in inner asteroid belt to be observed by the HII/L2 MIR camera will be equivalent to "parent-meteoroids".

Ordinary chondrites are the most abundant meteorites collected on the ground. However, from spectroscopic evidence, parent bodies of ordinary chondrites of meteorites collected in the terrestrial environment seen very rare or even absent among the MBAs. This is one of the most puzzling aspects of current asteroid investigations. Space weathering process (alteration process of optical properties of the uppermost regolith of asteroids surface due to bombardments of micro-meteoroids, exposure to cosmic rays, and/or proton implantation of solar wind) and meteoroid delivery process to Earth are candidates for the lack of asteroids with ordinary-chondritic spectrum but it is not obvious which is the cause of the lack of MBAs with ordinary chondritic spectrum. Therefore, a spectroscopic study combined with observations of geometric albedo and surface regolith conditions of the smallest MBA, as "parent-meteoroids" by HII/L2 will provide an important clue to solve this problem.

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