SLITLESS SPECTROSCOPY OF SMALL SOLAR SYSTEM BODIES ON A DARK CLOUD CURTAIN. F. Yoshida[1], M. Yagi[1], Y. Komiyama[1], F. Nakata[1], H. Furusawa[1] T. Ohno[2], S. Okamura[2] and T. Nakamura[3] [1]National Astronomical observatory of Japan (2-21-1, Osawa, Mitaka, Tokyo 181-8588 Japan, fumi.yoshida@nao.ac.jp, [2]Univesity of Tokyo, [3]Teikyo Heisei University.

Introduction: Recently, knowledge of small solar system bodies (SSSBs) has been growing rapidly by following reasons: (1) large telescopes enable us to obtain detailed physical properties of relatively small objects, (2) numerical simulations enable us to calculate orbital/collisional evolutions in detail, (3) in-situ observations by spacecrafts show us highly-resolved asteroid surfaces (topography, craters, mineralogy, colors, etc.). Especially, the survey observations with 8m class telescopes are a powerful tool to investigate such SSSBs. The survey with Subaru telescope + Suprime-Cam during only 3 nights in 2001 detected many sub-km Main Belt Asteroids (MBAs) and Jupiter Trojan asteroids (JTs) of a few-km size and supplied their size distributions [1][2][3][4][5][6][7]. These imaging observations contributed to construct a new view of the early stage of the solar system, for example, by presenting a clue of possible cause of the Late Heavy Bombardment [8]. However, follow-up observations have hardly been made for these small asteroids in order to investigate their physical properties. This is because they are faint, and more importantly, because their orbits were not determined. A wide field slitless spectroscopy circumvents the difficulty of the orbit determination and realizes the detection and the spectrophotometry of such faint asteroids simultaneously.

New tool and new idea !: Two grism filters; G-A-B030 (blue grism) and G-A-R030 (red grism) of S-prime-Cam are available for slitless spectroscopic observations. The throughput of both grism are ~50% and resolution is $\lambda/\delta\lambda$ ~40. The wavelength range of blue grism is 4500-7000Å and that of red grism is 6250-8600Å.

One of the difficulties in the slitless spectroscopy is the overlap of more than two objects. In order to overcome the problem, we introduced a new idea of using a Galactic dark cloud as a "curtain". Considering the Suprime-Cam FOV (0.25 deg^2) and ecliptic latitude (SSSBs concentrate near ecliptic plane), we selected the ρ Oph cloud as a best curtain from the dark clouds catalog by Dobashi et al. (2005) [9].

We observed the ρ Oph region with the grisms in a single night in 2009 May. The idea using the ρ Oph as a curtain was proved to work quite well. The faintest objects detected in each exposure have ~ 23 Rmag (AB). The S/N of spectra of such faint objects are ~1.5 in 6-min exp. image of blue grism data, and ~1 in 3-min exp. image of red grism data. A total of 140 objects (most of detected moving objects were MBAs, but 6 new TNOs, 9 JTs, 8 Hilda group) with R<25 mag were detected in R-band calibration image, and spectra of ~50 objects with R<23 mag were obtained with the grism. Most of the spectra are free from overlapping (see Figure 1). Figure 2 shows preliminary spectra of bright (14-20 mag) moving objects.

Some interesting science topics:

(a) Investigating origin of meteorites: Comparing figure 2 with spectra of different asteroid types (figure 3), we are convinced that we are able to determine several asteroid types (S, Q, C, D, see Figure 3) with the slitless spectroscopy. We can use this classification using grism spectra for searching for meteorite reservoirs in the main belt. Most of meteorites are classified as ordinary chondrites which have similar spectra with Q-type asteroids. Q-type asteroids are regarded as collisional fragments of S-type asteroids because (1) intermediate spectra between S-type and Q-type have been found in the Near Earth Asteroids (NEAs) group and (2) it has been confirmed by laboratory experiments that space-weathering process varies Q-type spectra to S-type spectra [10]. It is reasonable to assume that Q-type asteroids which fall on the earth become meteorites. Our question is "where were Q-type asteroids created?" Collisional probability at the near-Earth region looks not high enough. Thus, it is natural to assume that the Q-type came from the main belt through a usual supply route of NEAs. However Q-type is very rare in the main belt. Only two Q-type asteroids were discovered so far [11] in the extremely young asteroid family, Datura family, which was created 450 kyr ago [12]. Regarding the NEAs, Binzel et al. (2004) [13] suggested that Q-type begins to dominate at D<5km. We think that Q-type is generally smaller than S-type, because they are fragments. If we can detect smaller asteroids in the main belt, we may find more Q-types there. If there is a Q-type cluster in the main belt, it must be a meteorite reservoir. With S/N>10 in each spectral resolution unit, classification of S-type and Q-type is possible (Figure 2, 3).

(b) Investigating small Jupiter Trojans: Additional interesting topics are on Jupiter Trojans (JTs). At our observation in 2009, we expected ~20 Jupiter's (L5) Trojans on the basis of the estimations of Yoshida and Nakamura 2005, 2008 [4][6], and Jewitt et al. 2000 [14], although their estimates were based on survey observations of L4 JTs. However, we found only 9 L5 JTs. This may suggest that there is a difference of the spatial distribution between L4 and L5 JTs populations. It is also an interesting work to confirm a differ-

ence of the size distribution between large JTs (found by Jewitt et al.[14]) and small JTs (found by Subaru telescope[4][6]) suggested by Yoshida and Nakamura 2008 [6].

Very recently, Fernandez et al. (2009) [15] found that the median R-band albedo of small JTs (5km<D<24km) is much higher (0.12) than that of "large" Trojans with D>57 km (0.04). This means that there is a possibility that small Trojans show different spectral-type from large Trojans. So far, there is no spectral information of JTs of a few to several tens km in size. We can detect such objects and obtain their spectra with the slitless spectroscopy.

All science topics mentioned above are feasible only with the wide field slitless spectroscopy at 8-m telescope. The combination of Subaru, Suprime-Cam and the grism filters is the only one that enables us to pursue such exciting science. A statistically unbiased set of spectra of a large number of SSSBs obtained by this slitless spectroscopy will give a significant impact to SSSBs research.

Motivated by this successful pilot observation in 2009, we will carry out slitless spectroscopy of small solar system bodies again in the ρ Oph cloud region in 3 nights in 2010 June.

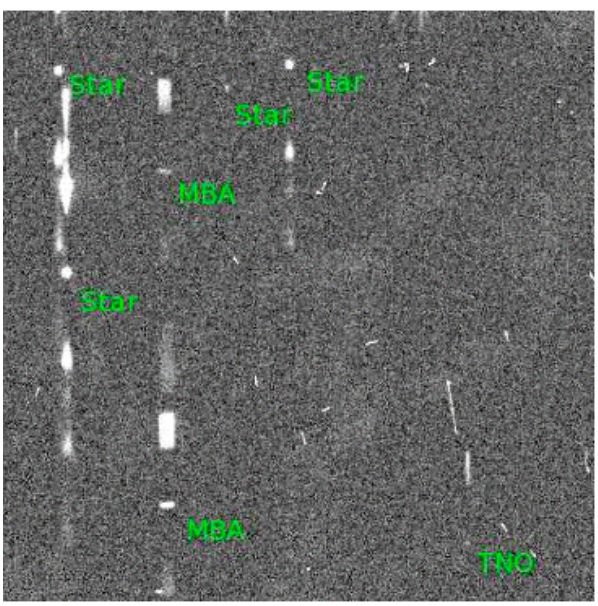

Figure 1: Result from 2009 observation. Example of slitless spectra of a single exposure with the blue grism in 80 arcsec square field. A TNO (22.3mag) and two MBAs (19.6, 21.0) are detected without overlapping. Contaminating cosmic rays will be removed by coadding.

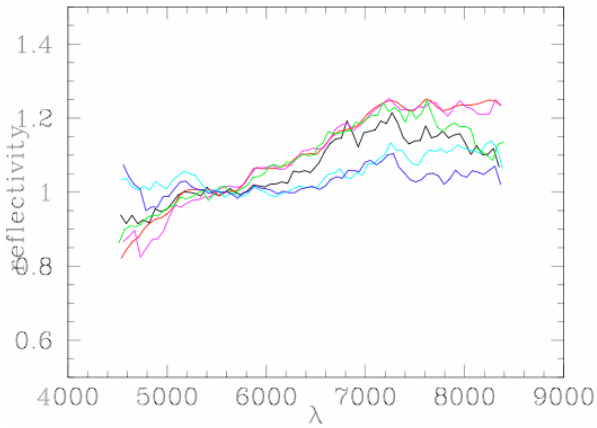

Figure 2: Preliminary spectra of 6 bright (14-20 Rmag) MBAs from our observation in 2009. The spectra are converted to reflectivity and normalized at 5500Å. The difference of slopes is recognized.

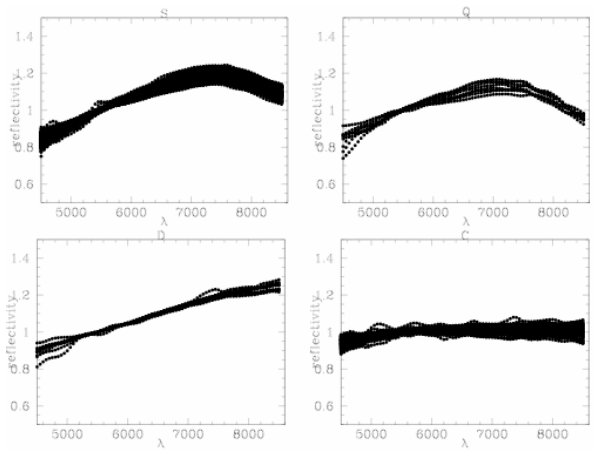

Figure 3: Spectra of known asteroids in SMASSII [16]. S, Q, D, and C types are plotted from left to the right normalized at 5500Å. Spectra are taken from BB02 and B04, smoothed with the grism resolution, and resampled by 50Å in 4500Å-8600Å. The difference of S and Q is seen in the slope at >7500Å.

References: [1] Yoshida et al. 2001, *PASJ*, 53, L13. [2] Yoshida et al. 2003, *PASJ*, 55, 701. [3] Yoshida and Nakamura 2004, *AdSpR*, 33, 1543. [4] Yoshida and Nakamura 2005, *AJ*, 130, 2900. [5] Yoshida and Nakamura 2007, *P&SS*, 55, 1113. [6] Yoshida and Nakamura 2008, *PASJ*, 60, 297. [7] Nakamura and Yoshida (2008) *PASJ*, 60, 293. [8] Strom et al., *Science*, 2005, 309, 1847. [9] Dobashi et al. (2005) *PASJ*, 57, S1. [10] Sasaki et al. (2001), *Nature*, 410, 555. [11] Mothe-Diniz and Nesvorny, 2008, *A&A*, 486, L9. [12] Nesvorny, et al. 2006, *Science*, 312, 1490. [13] Binzel et al. (2004) *Icarus*, 170, 259 (B04). [14] Jewitt et al. (2000) *AJ*, 120, 1140. [15] Fernandez et al. 2009, *AJ*, 138, 240. [16] Bus, S.J. and Binzel, R.P. (2002) *Icarus*, 158, 146 (BB02)