Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-01 Room:503 Time:April 28 09:00-09:15

On activities in the interdisciplinary science of Hayabusa-2

KOBAYASHI, Naoki[1*] ; WATANABE, Sei-ichiro[2] ; THE INTERDISCIPLINARY SCIENCE TEAM, Hayabusa-2[1]

[1]ISAS/JAXA, [2]Division of Earth and Planetary Sciences, Graduate School of Science, Nagoya University

Hayabusa-2 is an asteroid sample return mission of which target asteroid is 1999JU3, a near Earth asteroid of type C, and it is scheduled to be launched late in this year. As on-board scientific instruments, Hayabusa-2 has a near infrared spectrometer (NIRS3), thermal IR imager (TIR), optical navigation camera (ONC-T) used as a multi-band imager with seven band-pass filters, laser altimeter (LIDAR), sampler (SMP), small carry-on impactor (SCI), separation digital camera (DCAM-D), and small lander (MASCOT). Using these instruments, we try to characterize the surface properties and materials of 1999JU3 and select three sampling points from which material samples will be obtained to reveal physical and chemical processes on the asteroid and its history from the formation to the present. Thus scientific success of Hayabusa-2 strongly depends on a strategy for characterizing the surface and selecting sampling sites, which can be achieved making the best use of data from the above all sensors. We, for this purpose, organize a working team called as the Interdisciplinary Science Team (IDST) of Hayabusa-2. In this presentation, we introduce the activity of the IDST.

The IDST was established in the first meeting held on Dec. 2012. Its purposes are to obtain the general picture of a scientific scenario of Hayabusa-2, define interdisciplinary science themes and contribution of individual instruments to the themes, define scientific constraints and validations on the mission scenario, and promote planetary sciences and think out planetary sciences from a standpoint of the asteroid mission. The discussion in the IDST is open to the project members. So far, we have discussed deeply a strategy in return sample analyses, heterogeneity detection by the remote sensing sensors, surface temperature detection, crater chronology, morphology produced by meteoroid impacts, reflectance spectra of C-type asteroids, space weathering, and so on. As a result of these discussion, we produce a logical flow chart to characterize the surface material and property. In the chart, mutual relations between basic observation quantities, quantities inferred by multiple sensors, their indexes, identified characters and general inferences on primitiveness are described. Contributions from each sensor are clarified in the chart. In addition, we also depicted an operational picture of SCI which is a grand experiment for an impact process in the low gravity space and exposes material in a depth that can be less suffered by space weathering, but SCI is wasteful of the satellite resources. It is necessary to polish up the operation plan of SCI from the view point of the system resources.

The logical flow chart is a guiding principle in the science of the Hayabusa-2 mission. We continue to refine the chart and complete the logic. For this purpose, we make several working groups to reinforce the logic flows. As closing the development phase of on-board instruments, we now rush up to make the IDST of Hayabusa-2 more active. We think that the activity in the IDST is a key point to succeed in the science mission and promote planetary sciences and explorations in Japan.

Keywords: Hayabusa-2, asteroid, exploration, surface material, interdisciplinary science, sample return

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-02 Room:503 Time:April 28 09:15-09:30

Detectability of 0.7 um absorption band of hydrous minerals using the Hayabusa2 ONC-T Flight Model

KAMEDA, Shingo[1*] ; AKITO, Takei,[1] ; SATO, Masaki[1] ; OKUMURA, Yu[1] ; CHO, Yuichiro[2] ; ONC, Science team[3]

[1]Rikkyo University, [2]The University of Tokyo, [3]JAXA

Hayabusa2 has three cameras for optical navigation to the asteroid 1999JU3. ONC-T is one of them and it can be used also for reflectance spectroscopy. The results of the ground-based observation suggested that hydrous materials might remain on the 1999JU3 but on the small part of the surface. To bring them to the Earth, we should perform reflectance spectroscopic observation near the asteroid using ONC-T to locate the point where hydrous mineral is rich.

In this presentation, we will report the result of final calibration test of ONC-T and discuss the detectability of hydrous minerals on 1999JU3.

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-03 Room:503 Time:April 28 09:30-09:45

Development and tests of Hayabusa-2 LIDAR

NAMIKI, Noriyuki[1*] ; MIZUNO, Takahide[2] ; SENSHU, Hiroki[1] ; YAMADA, Ryuhei[3] ; NODA, Hirotomo[3] ; SHIZUGAMI, Makoto[3] ; HIRATA, Naru[4] ; IKEDA, Hitoshi[5] ; ABE, Shinsuke[6] ; MATSUMOTO, Koji[3] ; OSHIGAMI, Shoko[3] ; YOSHIDA, Fumi[3] ; HIRATA, Naoyuki[7] ; MIYAMOTO, Hideaki[7] ; SASAKI, Sho[8] ; ARAKI, Hiroshi[3] ; TAZAWA, Seiichi[3] ; ISHIHARA, Yoshiaki[2] ; KOBAYASHI, Masanori[1] ; WADA, Koji[1] ; DEMURA, Hirohide[4] ; KIMURA, Jun[9] ; HAYAKAWA, Masahiko[2] ; KOBAYASHI, Naoki[2] ; MITA, Makoto[2] ; KAWAHARA, Kousuke[2] ; KUNIMORI, Hiroo[10]

[1]PERC/Chitech, [2]ISAS/JAXA, [3]NAOJ, [4]The University of Aizu, [5]ARD/JAXA, [6]Nihon University, [7]The University of Tokyo, [8]Osaka University, [9]Tokyo Institute of Technology, [10]NICT

The Japanese first asteroid mission, Hayabusa, visited at the small asteroid 25143 Itokawa in September, 2005. Images taken by Hayabusa are combined with other remote sensing observations and revealed that the asteroid as small as 500 m in the longest axis is the first rubble-pile body identified in our solar system. Despite of several serious failures of the spacecraft occurred during and after rendezvous, Hayabusa successfully retrieved samples from the surface of 25143 Itokawa to the Earth in 2010 to disclose unpredicted nature of a very small asteroid.

JAXA and collaborating scientists are now developing the second asteroid mission named ”Hayabusa-2”. Hayabusa-2 is based on a heritage of the first Hayabusa. At the same time, Hayabusa-2 is intended to improve engineering and scientific achievements of the first Hayabusa, and also to challenge new technologies. Furthermore, target asteroid is different from that of the first Hayabusa. The asteroid 25143 Itokawa is a silicate-rich S-type. On the other hand, Hayabusa-2 is visiting a C-type asteroid, (162173) 1999 JU3. Needless to say, C-type is more primitive than S-type, therefore is expected to be a key to understand chemical evolution of the early solar system.

LIDAR measures altitudes of the spacecraft from the surface of the asteroid by taking a time of flight of laser pulse. As a part of Attitude and Orbit Control System (AOCS), the LIDAR data are used for navigation of the spacecraft. The data are particularly important during touchdown operation. Besides, the LIDAR data are served for scientific analysis of the shape, mass, and surface properties of the asteroid in order to elucidate physical evolution of minor bodies such as impact fragmentation and coagulation. We also wish to expand outcomes of Itokawa exploration by examining uniformity and variation of porosity within rubble-pile body and detecting dusts levitating above the surface of asteroid. The remote sensing observations of Hayabusa-2 will be carried out from Home Position (HP), middle altitude, and low altitude whose distances from the asteroid surface are nominally 20 km, 5 km, and 1 km, respectively. We report recent progress of LIDAR development anticipating the launch in December 2014.

Keywords: Hayabusa, asteroid, exploration, LIDAR

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-04 Room:503 Time:April 28 09:45-10:00

A strategy to estimate thermal properties using Thermal Infrared Imager on board Hayabusa-2.

SENSHU, Hiroki[1*] ; TAKITA, Jun[2] ; TANAKA, Satoshi[3] ; OKADA, Tatsuaki[3]

[1]PERC/Chitech, [2]Graduate School of Science, Tokyo University, [3]ISAS/JAXA

Thermal InfraRed imager (TIR) on board Hayabusa-2, an upcoming japanese mission to C-type asteroid 1999JU3, is non-cooled bolometer which image mid-infrared thermal emission from the asteroidal surface. The field-of-view (FOV) of TIR is 16x12 degrees and ts effective pixels are 320x240. So the spacial resolution, which depends on distance from the suface, is about 18m from an altitude of 20km (Home position) and less than 1m from an altitude of 1km.

By comparing the temperature distribution obtained by TIR and thermal evolution model, we can get thermophysical properties such as thermal inertia and emissivity. These parameters are diagnostic for the characteristic size of surafce grain.

In this presentation we will present our strategy to estimate the thermophysical properties from TIR observation.

Keywords: hayabusa-2, thermal infrared imager, surface temperature, thermal properties, thernal inertia, emissivity

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-05 Room:503 Time:April 28 10:00-10:15

Relationship on Surface Morphology of Small Asteroids and Geopotential

HIRATA, Naru[1*] ; MATSUMOTO, Koji[2] ; KIMURA, Jun[3]

[1]ARC-Space/CAIST, The University of Aizu, [2]RISE Project, The National Astronomical Observatory of Japan, [3]The Earth-Life Science Institute (ELSI) of Tokyo Institute of Technology

We compared the distribution of smooth terrains with the geopotential map of the asteroid Itokawa, and demonstrate that the distribution of smooth terrains on Itokawa is strongly controlled by the geopotential distribution. Because the geopotential distribution of an asteroid can be estimated from its shape, rotation state and density, we can predict the distribution of smooth terrains on the asteroid from these observations.

Keywords: Asteroid, geopotential, smooth terrain, Itokawa, 1999JU3

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-06 Room:503 Time:April 28 10:15-10:30

Spectral evolution of s-type asteroids suggested by principal component analysis of multi-band images of Itokawa

KOGA, Sumire[1*] ; SUGITA, Seiji[1] ; KAMATA, Shunichi[2] ; ISHIGURO, Masateru[3] ; HIROI, Takahiro[4] ; SASAKI, Sho[5]

[1]Graduate School of Frontier Sciences, The University of Tokyo, [2]Dept. of Earth and Planetary Sci., UC Santa Cruz, [3]Depertment of Physics and Astronomy, Seoul National University, [4]Depertment of Geological Science, Brown University, [5]Department of Earth and Space Science, Graduate School of Science, Osaka University

Objective

Itokawa is covered with materials from the same initial material with different degree of space weathering[1,2]. However, it has not been verified sufficiently if there is other factors that change the spectra. Our analyses of principal component analysis (PCA) using multi-band images taken by Hayabsa's AMICA (Asteroid Multi-band Imaging CAmera) so far have provided the results that a component of spectral reddening, a typical trend of space weathering effect, is the first principal component (PC1) with comparison to laser-irradiated meteorites spectra. The comparison with main-belt asteroids suggests how the spectra of the asteroids develop in their PC space with weathering (by micrometeorites bombardment[3])[4]. However, further analysis had been impeded by electromagnetic noise. In this study, we remove the noise and examine spectral change trends caused by processes other than space weathering.

Methods

We used 2 sets of images of six visible bands (Central wavelengths of 381, 429, 553, 700, 861, 960 nm) taken by AMICA. Periodic electromagnetic noise is imposed on most of the images. We removed it by subtracting superposition of sine waves. The images were calibrated following [4] and coresistrated. Normalized ratio images were obtained by dividing the images by those of 553 nm.

We performed PCA on the normalized reflectance spectra. We used a set of images of a Itokawa semisphere and another set including a dark rock (Black Boulder). Shock darkening is indicated as a possible origin of it [5].

We also performed PCA on spectra of main-belt asteroids obtained in ECAS [6] and each Itokawa spectrum superimposed. Because AMICA and ECAS filter wavelengths are approximately same, we can compare the Itokawa surface in the PC space defined by ECAS data set.

Results

The PC1 of spectra of only Itokawa had a shape rising to the right with a steep rise in 430-700nm. The PC1 score spatial distribution was consistent with the distribution of space weathering degree obtained by [7]. PC2 had positive coefficients at the wavelengths except 553nm, and the spectrum shape was upward to both sides. The PC2 is different from sillicate spectra, therefore interpretation in a context of material science is difficult. We found a feature that PC1 score is low and PC2 score high in boulder-rich regions, but the muximum area of PC2 score lay around a boulder where PC1 score were minimum. Proportion of variance of PC1 and PC2 was 60-75% and 20-30%.

In the ECAS-defined PC space, the spectra of Black Boulder were distributed apart from the cluster of the other parts.

Discussion

The proportions of variance of PC1 and PC2 would suggest that the heterogeneity in Itokawa surface spectrum is dominated by two processes. The PC1 and PC2 score distribution might suggest that the process which changes PC2 score occurs where space weathering has moderately developed. We have observed only a part of the surface, and features observed in a global analysis will be reported in our presentation.

The fact Black Boulder spectral trend is different from that of the other parts suggests that another process than space weathering (shock darkening is a candidate) is the origin of its peculiar spectrum.

In this analysis, another trend than the general space weathering was captured. Consideration of an evolution caused by larger impacts together as well as the space weathering caused by micrometeorites bombardment may enable us to constrain the spectral evolution processes of asteroids and derive relationships among asteroids of different spectral classes.

References

[1] Abe, M et al. (2006) Sci. 312, 1334. [2] Hiroi, T. et al. (2006) Nature 443, 56. [3] Sasaki, S. et el. (2001) Nature 410, 555-557. [4] Koga, S. et al. (2014) 45th LPSC, Abstract #1721 [5] Ishiguro, M. et al., (2010) Icarus,207, 714. [6] Hirata, N. and Ishiguro, M., (2011) 42nd LPSC, Abstract #1821. [7] Tedesco, E.F. et al. (1982) Astron.J. 87, 1585. [8] Ishiguro, M. et al. (2007) MAPS 42, 1791.

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-07 Room:503 Time:April 28 11:00-11:15

Small carry-on impactor of Hayabusa2

SAIKI, Takanao[1*] ; IMAMURA, Hiroshi[1] ; SAWADA, Hirotaka[1] ; ARAKAWA, Masahiko[2] ; TAKAGI, Yasuhiko[3] ; KADONO, Toshihiko[4] ; WADA, Koji[5] ; HAYAKAWA, Masahiko[1] ; SHIRAI, Kei[1] ; OKAMOTO, Chisato[1] ; OGAWA, Kazunori[6] ; IIJIMA, Yuichi[1]

[1]Japan Aerospace Exploration Agency, [2]Kobe University, [3]Aichi Toho University, [4]University of Occupational and Environmental Health, [5]Chiba Institute of Technology, [6]University of Tokyo

Small Carry-on Impactor of Hayabusa2

A Japanese spacecraft, Hayabusa2, the successor of Hayabusa, which came back from the Asteroid Itokawa with sample materials after its 7-year-interplanetary journeys, is a current mission of Japan Aerospace Exploration Agency (JAXA) and scheduled to be launched in 2014. Hayabusa2 is a similar sample return mission to Hayabusa, however the type of the target asteroid is different from that of Hayabusa. Asteroid Itokawa, explored by Hayabusa is a rock-rich S-type one. Hayabusa2 will go to a C-type asteroid. Both C-type and S-type asteroids consist of rocks, but C-type asteroids are considered to have organic and water materials. Hayabusa2 has two objectives to discover: organic matters and water in the solar system and relationship between life and ocean water. C-type asteroids are the most common variety and many of them are in the outer part of the asteroid belt beyond 2.7 AU. An asteroid, called 1999 JU3, is chosen as the target of Hayabusa2 mission because it is considerably easy to reach. It has a similar orbit as that of Itokawa and it is in the orbit that occasionally comes close to the earth orbit.

The design of Hayabusa2 basically follows Hayabusa. Its configuration, size and weight are almost same as Hayabusa and the touch-down operation will be performed in much the same way. However, it is planned to be equipped with some new components. Small Carry-on Impactor (SCI) is one of the new challenges. The observations by Hayabusa discovered that Itokawa was rubble-pile body with the macro-porosity. No direct observational data as for their internal structures and sub-surface materials were available, however. One of the most important scientific objectives of Hayabusa2 is to investigate chemical and physical properties of the internal materials and structures in order to understand the history of formation of small bodies such as small, un-differentiated asteroids. In order to achieve this objective, the SCI is required to remove the surface regolith and create an artificial crater on the surface of the asteroid. Different from other impact missions, Hayabusa2 can make a detailed observation of the resultant crater after the impact. Observing the size of the crater is very important to investigate the physical properties of the asteroid. Additionally, Hayabusa2 will try to touchdown near the crater to get the fresh material of the asteroid.

It is very difficult to create a meaningful crater on the asteroid. High kinetic energy (i.e. about 2km/s impact speed and 2kg impact mass) is required to make a crater, but the high speed is difficult to realize. The famous impact mission, Deep Impact was the direct impact mission, which used the interplanetary velocity for the impact speed. Consequently, the impact energy became very high. On the other hand, SCI of Hayabusa2 is a carry-on type impactor and it should accelerate itself after the separation from the mother spacecraft. Therefore, how to accelerate the impact body is a big challenge of SCI. The traditional acceleration devices such as rocket motors and thrusters are difficult to hit the asteroid without a guidance system because the acceleration distance is large. To overcome this difficulty, the powerful explosive is use in SCI. The special type of shaped charge makes it possible to accelerate the impact head in a very short amount of time (less than 1 millisecond) and it becomes possible to crash into the asteroid.

The development of SCI is now almost finished. A lot of tests were conducted during the development period. The overview of the small carry-on impactor system and the results of the development tests will be presented in the conference.

Keywords: Hayabusa2, Impactor, Artificial Crater

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-08 Room:503 Time:April 28 11:15-11:30

Small Carry-on Impactor Elucidates the Nature of Craters and the Evolution of our solar system

WADA, Koji[1*] ; SCI, Team[2] ; DCAM3, Team[2]

[1]PERC/Chitech, [2]Hayabusa-2 Project

Hayabusa-2, the Japanese next asteroid exploration mission, equips Small Carry-on Impactor (SCI) to launch a decimeter scale projectile on an asteroid surface. This is a novel apparatus to excavate the asteroid surface, and hopefully it will enable us to observe a fresh surface without space weathering and thermal alteration. Furthermore, we will be able to recover the asteroid sample excavated from several 10 cm depth at the deposit of the impact ejecta. The SCI impact on the asteroid is very good chance to examine the projectile scale on the crater scaling law in addition to the study on the gravity effect on the crater formation process. In this presentation, I will introduce the scientific goals of Hayabusa-2 mission using SCI and the scientific problems to be solved in the near future to maximize the scientific outputs of the SCI impact.

Keywords: Hayabusa-2, SCI, impact, asteroid

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-09 Room:503 Time:April 28 11:30-11:45

The final impact tests of Small Carry-on Impactor(SCI) equipped on HAYABUSA-2

HAYAKAWA, Masahiko[1*] ; SAIKI, Takanao[1] ; IMAMURA, Hiroshi[2] ; SHIRAI, Kei[2] ; WADA, Koji[3] ; ARAKAWA, Masahiko[4] ; OKAMOTO, Chisato[2] ; TSUDA, Yuichi[1] ; TAKAGI, Yasuhiko[5] ; KADONO, Toshihiko[6] ; NAKAZAWA, Satoru[2] ; IIJIMA, Yuichi[1] ; YANO, Hajime[2] ; KAMITOMAI, Hideo[7] ; MATSUZAKI, Shinichi[7]

[1]ISAS/JAXA, [2]JSPEC/JAXA, [3]Planetary Exploration Research Center/Chiba Institute of Technology, [4]Graduate School of Science, Kobe University, [5]Aichi Toho University, [6]University of Occupational and Environmental Health, [7]NIPPONN KOHKI Co. ltd

HAYABUSA-2(the next Japanese Aseroid Sumple Return Explorer) is now at the final integrated test. Before this test, all sub-systems experienced final test individually. The Small Carry-on Impactor:SCI has been adopted the new sub-system of HAYABUSA-2, it is one of the self forging fragment which will be able to eject the 2kg projectile by 2km/sec velocity by detonation.

In this paper we show the outline and results of the final performance test of the SCI explosive part on Oct. 2013. The test bodies have be made by the same rot of flight model, and experienced environmental stress tests. The projectiles formed explosion impacted on the sand target and made craters.

A point of view of understunding of impact phenomina, these tests are larger scale impact experiments than thats made in labolatory, between space scale and labolatory scale. Therefore we observed and measured the crater formation prosesses by two high-speed video cameras, a infrared video camera, accelerometers, geophons, and digital handy video cameras. We succeeded to obtaine five cratering prosesses.

Keywords: HAYABUSA-2, Small Carry-on Impactor, impact experiment, crater, explosion

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-10 Room:503 Time:April 28 11:45-12:00

Optical performance verification of DCAM3-D/Hayabusa 2

ISHIBASHI, Ko[1*] ; ARAKAWA, Masahiko[2] ; IIJIMA, Yuichi[3] ; OGAWA, Kazunori[4] ; SHIRAI, Kei[3] ; WADA, Koji[1] ; HONDA, Rie[5] ; SAWADA, Hirotaka[3] ; SAKATANI, Naoya[6] ; KADONO, Toshihiko[7] ; KOBAYASHI, Masanori[1] ; NAKAZAWA, Satoru[3] ; HAYAKAWA, Hajime[3] ; IKEDA, Yuji[8]

[1]Chiba Institute of Technology, [2]Kobe University, [3]Japan Aerospace Exploration Agency, [4]University of Tokyo, [5]Kochi University, [6]The Graduate University for Advanced Studies, [7]University of Occupational and Environmental Health, [8]Photocoding

Small Carry-on Impactor (SCI) is one of the instruments carried on Hayabusa-2 space craft. It will be used for an active exploration on the surface of asteroid 1999JU3. The SCI consists of a disk impactor made of copper. This disk will be accelerated to a velocity of ˜2km/s for the collision onto the asteroid surface, creating an artificial crater on 1999JU3. Then, samples in the crater and/or around the crater will be recovered by the Hayabusa-2 mother ship. Observation of the crater is expected to reveal the surface structure of 1999JU3. This SCI impact also has an aspect of an ”impact experiment” on an asteroid that elucidates the impact phenomena on small bodies.

A miniaturized optical camera unit (DCAM3) is being developed for observations of the SCI impact. DCAM3 will be detached from Hayabusa-2 mother ship and obtain a close-up image of the SCI impact. The detached part of DCAM3 has two cameras; one is an analog camera (DCAM3-A) and the other is a digital camera (DCAM-3D). The purposes of DCAM3-D are (1) the detection of SCI explosion and impact on the asteroid and (2) the observation of ejecta created by the SCI impact.

DCAM3-D optical system has to satisfy strict required specifications to fulfill these purposes: it requires a large view angle (74 deg) to detect both the SCI and the asteroid, high imaging capability for whole sensor area, a bright optical system (F $>$1.7) to detect dark SCI and ejecta, resistance to radiation, and limited size and weight . Moreover, these conditions have to be accomplished without active temperature control.

In this presentation we report the results of the optical performance verification of a flight model of DCAM3-D. The optical performance verification tests consist of electrical test, collimator test, and integration sphere test. The electrical test evaluated the performance of the CMOS sensor. In the collimator test, lens-sensor distance and lens-sensor angle were adjusted. Then, imaging capability (i.e., ensquared energy), spatial resolution, and distortion were evaluated under vacuum condition ($<$1 torr) with various temperatures, wavelength regions, and angles of view. In the integration sphere test, sensitivity, limb darkening, and stray light were evaluated. We confirmed that the results of these evaluations were favorable and that the strict required specifications of the optical system are almost satisfied.

Keywords: asteroid, planetary exploration, Hayabusa-2, scientific payload

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-11 Room:503 Time:April 28 12:00-12:15

The effect of substrate structure of rubble-pile bodies on cratering process

TATSUMI, Eri[1*] ; SUGITA, Seiji[1]

[1]Graduate School of Frontier Science, The University of Tokyo

Introduction: Hayabusa obtained many high-resolution images and revealed that this asteroid has many unique morphological features which are not seen on other small planetary bodies. One of the most symbolic configurations are quasi-circular depressions (QCD) on boulder-rich surfaces, which are inferred as impact craters (Hirata et al,. 2009). If the QCDs are impact craters, then the surface crater retention age of Itokawa can be estimated based on crater chronology approach. However, age estimates has great uncertainty: 75Myr-1Gyr (Michel et al., 2009). The uncertainty in age results mostly from the uncertainty in crater scaling formed on the boulder-rich surface observed on rubble-pile bodies. The impact energy required for forming a crater on a small body is much smaller than that on a large body because of the limitation of catastrophic disruption energy (Benz and Asphaug, 1999). Impact cratering with such small energy on rubble-pile bodies are expected to follow a scaling low between the strength-regime rates and the gravity-regime cratering. The impactor destroys a surface boulder and dissipates its energy, then leading to a smaller crater: an armoring effect.

Moreover, impact induced mass loss is a critical value for estimating the life time of small bodies. The escape velocity of small bodies is very small. For example, Itokawa has an escape velocity of 10-20cm/sec. Thus, small bodies can easily lose their mass upon impact cratering.

As mentioned above, crater size and ejecta mass are important parameters for calculating the life-time of small bodies. However, these values for the rubble-pile bodies are not constrained well. Cratering process may be influenced greatly by the substrate structure of small bodies. In this study, the effect of the substrate structure of the rubble-pile bodies on the impact process is examined experimentally.

Experiment: Sintered glass beads blocks crashed into 8-15 mm chips and 200 micro meter glass beads are used as boulder simulants and regolith simulant in our experiments, respectively. We employ two types of targets: one consists of all boulders simulants (target 1) and the other consists of a surface layer of boulders simulants and regolith substrate (target 2). Polycarbonate projectiles 10mm diameter were launched at 160-180 m/sec of velocities. The impact cratering process was observed by a high-speed camera. We also measured the size of final crater and the ejecta mass.

Result: Crater size of target 1 is smaller by $\sim$20% than target 2, and ejecta mass of target 1 is smaller than by a factor of five than target 2. High-speed camera observations revealed that the surface boulders are destroyed by the impactor more heavily in the target 1. This difference occurs because the shock impedance of boulder simulants are larger than that of regolith simulant by a factor of ten and much stronger reflected stress waves comes back to the surface boulders for target 1, but the stress wave transmits efficiently from surface boulders to legolith layer in target 2.

These results suggest that the substrate structure of small bodies changes the impact process greatly. Crater size varies by $\sim$20% depending on substrate layers: boulders or regolith. Crater forming on bodies consisting of only boulder is smaller than bodies with regolith substrate but still much larger than crater on monolith (i.e., the scaling in strength-regime scaling). Consequently, the surface age of Itokawa could be on the younger side of the previous estimates as 75Myr-1Gyr with the strength-regime crater scaling. Furthermore, the substrate structures of the rubble pile bodies change the ejecta mass by 5 times. Rubble-pile bodies consisted of boulders possibly live longer.

Keywords: rubble-pile bodies, impact cratering, mass loss, fragmentation

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-12 Room:503 Time:April 28 14:15-14:35

Computer Vision in Space: Optical Navigation Technology Development for Hayabusa-2

OHTA, Naoya[1*]

[1]Gunma University

Computer vision (CV) is a research field aiming to establish technologies by which information of objects is extracted from their images. Using CV technologies, our research group are developing methods to construct shape model of an asteroid for Hayabusa-2 navigation. We report this activity in this article. In addition, applying CV technologies to space environment has a potential to drive CV itself to a new research direction. We also touch on this observation.

For Hayabusa-2 navigation, we need to know shape of the destination asteroid, but the long distance between the asteroid and the earth prevent us from measuring it from the earth. Therefore we have to measure it after the arrival to the asteroid. Because active measurement methods need too much power, we are developing methods using images taken from the spacecraft.

Our project is mainly run by Dr. Seiji Sugita at Univ. of Tokyo and Dr. Naru Hirata at Aizu Univ., who are researchers in planetary science. However, because shape reconstruction techniques using images have intensively been studied in CV and CG (computer graphics) areas, the project is contributed by Dr. Hiroshi Ishikawa at Waseda Univ. and the author from CV area, and Dr. Shigeo Takahashi at Univ. of Tokyo from CG area.

We have applied a structure from motion technique developed in CV without modifications to the shape reconstruction of asteroids. We have had a minimum result required for Hayabusa-2 navigation, but more precise model is needed to make the navigation more certain and flexible. Therefore, we are combining photometric stereo to it.

Photometric stereo is a shape reconstruction method utilizing reflectance information of objects. However, we cannot directly apply such techniques developed in CV to the asteroid, because the conditions assumed in CV are fairly different from our case. The CV techniques assume that a number of images are taken from the same position, but the spacecraft cannot be controlled in such a way because it requires too much fuel. In addition, the reflectance models are different; Lambertian and Phong, for example, are used in CV, but we need algorithms based upon models such as Hapke and Minnaert, which describe reflectance of planet materials. Therefore, we are developing new algorithms that match the space environment for Hayabusa-2 navigation.

Looking at the origin of CV, it was regraded as a part of artificial intelligence research and has been motivated by artificially realizing functions of visual systems of human beings, or creatures in general. It seems that, from this reason, methods developed in CV tend to be general-purpose, and also that environments on the earth are implicitly assumed. Therefore, algorithms in CV are sometimes not applicable to problems in space science. However, viewing the situation from a different point, it may inspire CV itself to a new research direction by giving clear purposes.

When assuming usage in space, the following peculiarities are observed. The light source is usually only the sun, so it often suffice to consider only parallel light as the illumination. We can develop algorithms fully taking advantage of this simplicity. As mentioned above, reflectance models special to planet are used. If the process is executed in spacecrafts, the amount of computation is very limited, so the view point to develop a minimum algorithm to fulfill the objective becomes important. On the other hand, if images are transferred to the earth, the number of images is limited, but usually no limitation exists in amount of the computation. In such a case, CG-CV loop where a CG model is iteratively modified so that the generated images match to the observed images becomes to have reality. In addition to stated above, computing other information needed for space science than shape, estimating error information (variance), and so on, are important tasks for space science. We believe developing these techniques is an important direction of CV research.

Keywords: image measurement, shape reconstruction, optical navigation, Hayabusa-2

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-13 Room:503 Time:April 28 14:35-14:55

Analytical chemistry of organic compounds in the Solar System: An attempt to link with planetary science

YABUTA, Hikaru[1*]

[1]Osaka University, Department of Earth and Space Science

Analytical chemistry of organic compounds in the Solar System small bodies is a microscopic approach for understanding of the origin and evolution of building blocks of the Solar System and life, which has a complementary relationship with macroscopic approaches such as observational and theoretical astronomy. This approach would provide a significance of considering organic compounds in the planetary formation theory, which has been constructed only by silicate and ice dusts. Indeed, significant roles of organic compounds in the early Solar System are explained by (1) high abundances of C, H, O, N in the Solar System, (2) major components of dusts in interstellar clouds, (3) high reactivity to heat, light, shock, water, and minerals (chemical indicator recording the processes in the Solar System), (4) possible contribution to accretion of dusts, due to their stickiness (Kouchi et al. 2002), and (5) possible contribution to redox imbalance in solar nebula (that determined the chemical compositions of chondrules) (Yurimoto and Kuramoto, 1998). Despite these significant roles, however, organic cosmochemistry was not a very popular field in planetary science until several years ago. One of the reasons may be because of difficulty in visualization of organic compounds, i.e., drawing of a big picture. In this point, I attempt to show a simple example. When starch-syrup is heated, how is it changed. One would tell that the color is changed from colorless to brown, the originally sticky syrup becomes less sticky candy, and water-soluble syrup becomes an insoluble solid. These descriptions are based on visuality and are easy to understand. On the other hand, if these phenomena are translated to organic analytical chemistry, the description becomes quite different from the former; hydroxyl groups of glucose changes to carbonyl groups via dehydration as well as aromaticity increases with heating. However, it should be noted that two ways of descriptions explain exactly the same phenomenon. That demonstrates that physical properties (color, stickiness, and solubility) are determined by molecular chemical structures. Likewise, analytical chemistry of organic compounds in the Solar System has a potential to reveal the molecular science that determines physics of macroscopic planetary formation, such as the color of asteroids (albedo). This will become possible by improvements of the in-situ organic analyses such as spectromicroscopy (e.g., STXM), electron microscopy (TEM), and ion probe mass spectrometry (e.g., nanoSIMS), through visualization of the distributions of organics and minerals in the Solar System materials which record the chemical evolution from dusts to planetesimals.

Keywords: Organic compounds, Solar System, Analytical chemistry, small bodies, planetary formation, visualization

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-14 Room:503 Time:April 28 14:55-15:15

Formation Process of Complex Organic Molecules in Protoplanetary Disks

NOMURA, Hideko[1*]

[1]Tokyo Institute of Technology

It is believed that chemical reactions in protoplanetary disks will lead the origin of materials in our Solar System. Recently, many complex organic molecules (COMs) have been found in molecular clouds by radio observations of molecular transition lines. Meanwhile, amino-acids are found in a comet and meteorites in our Solar System. In this work we investigate the synthesis of complex organic molecules in protoplanetary disks using a large gas-grain chemical network together with a 2D steady-state physical model of a disk irradiated by UV and X-rays from the central star. We find COMs are efficiently formed on cold and warm grains in the disk midplane via grain-surface reactions through efficient migration of icy species on grain surface. Radiation processing on ice forms reactive radicals and helps build further complexity. We find the grain-surface abundances predicted by our calculations are consistent with those derived from cometary comae observations. We also predict line spectra of COMs, which are partly photodesorbed into gas from grain surface, will be observable in nearby protoplanetary disks with ALMA. In this talk I would like to discuss further on formation process of COMs on grains in the asteroid belt region, too.

Keywords: protoplanetary disks, formation of organic molecules

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-15 Room:503 Time:April 28 15:15-15:30

Status report of curation of Hayabusa-returned samples

YADA, Toru[1*] ; ABE, Masanao[1] ; UESUGI, Masayuki[1] ; KAROUJI, Yuzuru[1] ; ISHIBASHI, Yukihiro[1] ; OKADA, Tatsuaki[1] ; SATAKE, Wataru[1] ; FUJIMOTO, Masaki[1]

[1]Japan Aerospace Exploration Agency

Hayabusa spacecraft returned samples from S-type Near-Earth Asteroid (NEA) Itokawa in June 2010. After the return, Extraterrestrial Sample Curation Team (ESCuTe) of JAXA have recovered particles from a sample catcher of Hayabusa, and more than 400 particles initially described have been presented in public (Yada et al., 2014a). In this presentation, we review the recovery and initial description of Hayabusa-returned samples and mention their future schedule.

A sample container had been extracted from the reentry capsule of Hayabusa and cleaned in cleanrooms of the Extraterrestrial Sample Curation Center (ESCuC) of JAXA. It was introduced into a clean chamber No.1 and opened in vacuo, and then a sample catcher, which enclosed samples captured on the surface of asteroid Itokawa, was extracted to be transferred to a clean chamber No.2 which is designed to handle Hayabusa-returned samples in highly purified nitrogen condition. The sample catcher is mainly composed of a rotational cylinder through which captured samples had been transferred, a room A in which samples obtained by the second touchdown on Itokawa and a room B in which captured those of the first one. At first, we had prepared quartz glass disks of the same size with covers of the room A and B, on which particles inside each room were fallen by tapping. The particles on the quartz disks have been picked up one by one with a specially designed electrostatically-controlled micromanipulator to be placed onto a SEM holder which can seal the samples in nitrogen condition and initially described by SEM-EDS. Then they sent back to the clean chamber No.2 to be placed onto gridded quartz glass slides to be given their ID and preserved. In fiscal year of 2013, we started to describe particles on a cover of the room B with SEM-EDS directly, utilizing a SEM holder specially designed for the cover of the catcher (Yada T. et al., 2014b).

The initial description method using the quartz glass disks has disadvantages in inefficiency and risk of particles transportation one by one with the micromanipulator. In order to resolve these disadvantages, we have developed metal disks which particles can be fallen on by tapping and can be set to the SEM holder designed for the covered of the catcher in fiscal year of 2013. We are planning to start sample recovery by the metal disks in fiscal year of 2014, and going to confirm vast majority of particles inside the catcher for more than two years (Yada T. et al., 2014a).

The ESCuTe of JAXA started the international AO for Hayabusa-returned samples in the beginning of 2012. In the international AO, worldwide researchers can apply their proposals and the committee composed manly of top scientists outside JAXA reviews the proposals to determine which proposal the precious samples should be distributed. The AO have been published approximately annually, and the third AO will be published in the beginning of fiscal year 2014. The research results of the AOs are presented in the international symposium held by JAXA, named as ”Hayabusa 2013: Symposium of Solar System Materials”, and its proceedings will be published in the international journal.

Particles having rare features have not been provided to the international AOs, but to consortium studies led by ESCuTe of JAXA until 2013. So far, four consortia, including the maximum-sized particle, a NaCl-bearing one, an iron sulfide one, and ones containing phosphates Uesugi et al., 2013; Yada et al., 2013; Karouji et al., 2013). Particles having other rare features will be provided to consortium studies in future.

References:

Abe M. et al. (2011) LPS XLII, Abstract #1638.
Karouji Y. et al. (2013) 76th Ann. Meteorit. Soc. Meeting, Abstract #5148.
Uesugi M. et al. (2013) 76th Ann. Meteorit. Soc. Meeting, Abstract #5186.
Yada T. et al. (2013) 76th Ann. Meteorit. Soc. Meeting, Abstract #5150.
Yada T. et al. (2014a) LPS XLV, Abstract #1759.
Yada T. et al. (2014b) MAPS, in press.

Keywords: Hayabusa, asteroid, curation, sample return

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-16 Room:503 Time:April 28 15:30-15:45

Examination of the origin of carbonaceous particles in Hayabusa-returned samples

UESUGI, Masayuki[1*] ; NARAOKA, Hiroshi[2] ; ITO, Motoo[3] ; YABUTA, Hikaru[4] ; KITAJIMA, Fumio[2] ; TAKANO, Yoshinori[3] ; MITA, Hajime[5] ; KEBUKAWA, Yoko[6] ; YADA, Toru[1] ; KAROUJI, Yuzuru[1] ; ISHIBASHI, Yukihiro[1] ; SATAKE, Wataru[7] ; OKADA, Tatsuaki[1] ; ABE, Masanao[1]

[1]Japan aerospace exploration agency, [2]Department of Earth and Planetary Sciences, Kyushu University, [3]Kochi Institute for Core Sample Research JAMSTEC, [4]Osaka University, Department of Earth and Space Science, [5]Fukuoka Institute of Technoology, Faculity of Engineering, Department of Life, Environment and Mater, [6]Department of Natural History Sciences Hokkaido University, [7]Department of Earth and Planetary Science, University of Tokyo

Extraterrestrial Sample Curation Team (ESCuTe) recovered more than 50 carbonaceous particles from the sample catcher of the Hayabusa spacecraft. Those carbonaceous materials, named as category 3, were found in the form of particles with similar size range of the silicate particles those confirmed as Itokawa regolith particles. Initial description by the SEM-EDS analysis shows variable textures and chemical compositions of them, suggesting the multiple origins of the carbonaceous materials.

Preliminary examinations of category 3 particles were carefully processed in parallel with those of silicate materials. However, we could not obtain the information for the origin of category 3 particles before the opening of international announcement of opportunity (A/O). The ESCuTe and preliminary examination team of category 3 particles have continued the investigations. In this paper, we report the several recent results obtained from the sequential analyses.

Samples allocated for the preliminary examinations of category 3 are RA-QD02-0008, RA-QD02-0120, RA-QD02-0180, RB-QD04-0001, RB-QD04-0037-01 and RB-QD04-0047-02. RA-QD02-0008 was lost during the manipulation at first preliminary examination. Three samples, RA-QD02-0120, RB-QD04-0001, and RB-QD04-0047-02, were pressed on the Au plate and fixed without any adhesive materials. We analyzed H, C and N isotopic composition by nano-SIMS in the beginning of the sequential study, in order to investigate the isotopic anomaly which is a direct evidence of extraterrestrial origin of organic materials [8]. FT-IR and micro-Raman spectroscopy were also applied for the pressed samples [9]. After ToF-SIMS analysis of those particles, the samples were sliced by FIB in order to investigate the fine structure of the samples by XANES and TEM/STEM [10].

We performed those analyses with determining the effect on the subsequent analyses, such as sample damages and contaminations. The rest two particles, RA-QD02-0180 and RB-QD04-0037-01 were pressed on indium plates, because significant disturbance by Au on the ToF-SIMS analyses was found. We will also report the construction of the sequential analysis flow of tiny carbonaceous particles.

In parallel with the Hayabusa-returned particles, we processed observation and analysis of insoluble organic matter (IOM) of A881458 (CM2) and several possible materials of the origin of the category 3 particles, such as viton, silicon rubber, vectran and particles collected from the Hayabusa2 clean room.

We did not obtain any signature of extraterrestrial origin from category 3 particles so far. We are planning to continue the preliminary examination of category 3 by the end of March 2014. We are also planning to open the category 3 particles to the future International A/O, with the data of preliminary examinations before the end of 2014.

References: [1] Yada et al. 2011. Meteoritics & Planetary Science 32:A74. [2] Nakamura et al. 2011. Science 333:1113-1116. [3] Yurimoto et al. 2011. Science 333:1116-1119. [4] Ebihara et al. 2011. Science 333:1119-1121. [5] Noguchi et al. (2011) Science 333:1121-1125. [6] Tsuchiyama et al. 2011. Science 333:1125-1128. [7] Nagao et al. 2011. Science 333:1128-1131. [8] Ito et al. 2013. Abstract of Hayabusa Symposium, [9] Kitajima et al., 2013 Abstract of Hayabusa Symposium, [10] Uesugi et al. 2013. Abstract of Hayabusa Symposium

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-17 Room:503 Time:April 28 15:45-16:00

H, C and N isotopic compositions of HAYABUSA Category 3 organic samples

ITO, Motoo[1*] ; UESUGI, Masayuki[2] ; NARAOKA, Hiroshi[3] ; YABUTA, Hikaru[4] ; KITAJIMA, Fumio[3] ; MITA, Hajime[5] ; TAKANO, Yoshinori[6] ; KAROUJI, Yuzuru[2] ; YADA, Toru[2] ; ISHIBASHI, Yukihiro[2] ; OKADA, Tatsuaki[2] ; ABE, Masanao[2]

[1]Kochi Institute for Core Sample Research, JAMSTEC, [2]Japan Aerospace Exploration Agency, [3]Department of Earth and Planetary Sciences, Kyushu University, [4]Osaka University, Department of Earth and Space Science, [5]Fukuoka Institute of Technology, Department of Life, Environment and Materials Science, [6]Institute of Biogeosciences, JAMSTEC

Hayabusa spacecraft had brought back asteroid Itokawa particles to the Earth on June 2010. More than 1,500 mineral particles were identified on the Qz glass after the compulsive free fall, and most of them were very small ranging from 10 to 300 μm but are mostly smaller than 50 μm (Nakamura et al., 2011). In addition several amount of carbonaceous materials were found that is called Category 3. Based on FE-SEM and EDS observations at JAXA Extraterrestrial Sample Curation Team, those samples mainly composed of C, N, O and some of them contain NaCl and KCl (JAXA Hayabusa sample catalogue).

H, C and N isotopic compositions of extraterrestrial organic materials in Stardust cometary samples (McKeegan et al., 2006), IDPs (Messenger, 2000), IOM (Busemann et al. 2006) and nanoglobules in primitive chondrite (Nakamura-Messenger et al., 2006) provide a clue for understanding of origin and nature of the Solar System. Large D and 15N isotopic enrichments were observed, and C isotope is slightly enriched in 13C in extraterrestrial organic materials (Pizzarello, 2005). Those data suggest that extraterrestrial organics are probably interstellar material that was survived through formation processes (planetesimals) of the Solar System (Sanford et al., 2001), and may also have material that formed in the cold molecular cloud region of the protoplanetary disk (Aikawa et al., 2002).

Here we report H, C and N isotopic measurement of organic materials from Hayabusa Category 3 samples, RB-QD04-0047-02, RA-QD02-0120 and RB-QD04-0001, by an ion imaging with the JAMSTEC NanoSIMS ion microprobe. The purposes of this study are to evaluate terrestrial contaminations in the Hayabusa spacecraft and in the JAXA curation facility, and to find extraterrestrial organic materials on the basis of H, C and N isotope measurements.

Each Hayabusa organic sample was pressed on Au plate together with terrestrial organic standards of 1-hydroxybenzotriazole hydrate and BBOT with known H, C and N isotopic compositions. Following the SEM study to check the sample condition, texture and morphology, the samples were analyzed for H, C and N isotopic compositions by an isotopic imaging with the JAMSTEC NanoSIMS 50L at Kochi Institute for Core Sample Research.

We studied three Hayabusa organic samples, RB-QD04-0047-02, RA-QD02-0120 and RB-QD04-0001. All of the samples have been initially investigated by a FE-SEM and EDX observation at JAXA Hayabusa curation facility, and the EDX spectra of the samples contain C, N and O; the dominant elements are C, and N (Hayabusa sample catalogue).

Based on NanoSIMS isotopic images of H, C and N in RB-QD04-0047-02, RA-QD02-0120 and RB-QD04-0001, all three samples show homogeneous and terrestrial H, C and N isotopic compositions within an error (δD = 60 $\pm$ 13 permil, δ13C = 3 $\pm$ 3 permil and δ15N = -4 $\pm$ 2 permil for RB-QD04-0047-02; δD = 81 $\pm$ 54 permil, δ13C = -20 $\pm$ 8 permil and δ15N = 2 $\pm$ 2 permil for RA-QD02-0120; δD = 135 $\pm$ 32 permil, δ13C = -20 $\pm$ 9 permil and δ15N = 16 $\pm$ 12 permil for RB-QD04-0001).

The IOMs in CI and CM chondrites show heterogeneous distributions of delta-D at the molecular (Remusat et al. 2009) and micron scale level (Busemann et al., 2006). The IOMs of CR, CM and CI have D and 15N isotopic enrichments in micron-sized regions (hot spots). The IOMs in ordinary chondrites are heterogeneous, however, they do not show many micron-scale anomalies as IOMs in carbonaceous chondrite (Remusat et al., 2013). It is obvious that H, C and N isotope signatures of Hayabusa organic samples are different from those of IOMs in carbonaceous and ordinary chondrites: i.e., No hot spots, terrestrial values for H, C and N isotopes.

We have not found strong evidence of extraterrestrial origin because isotope compositions of H, C and N in Hayabusa organic samples show terrestrial values, and homogeneous distributions of H, C and N in the samples, which are unlike to IOM in various types of chondrites.

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-18 Room:503 Time:April 28 16:15-16:35

Albedo properties of main belt asteroids based on the infrared all-sky surveyors

USUI, Fumihiko[1*]

[1]University of Tokyo

Presently, the number of asteroids is known to be more than 620,000, and more than 90% of asteroids are classified as the main-belt asteroids (MBAs). The spatial distribution of compositions among MBAs is of particular interest, because the main belt is the largest reservoir of asteroids in the solar system. Asteroids are thought to be the remnants of planetesimals formed in the early solar system, and have a clue to study the formation and evolution of asteroids, origin of meteoroids and the near-Earth asteroids, as well as the formation of the solar system. Size and albedo are one of the most basic physical quantities of asteroid. Knowledge of size and albedo is essential in many fields of asteroid research, such as chemical composition and mineralogy, the size-frequency distribution of dynamical families and populations of asteroids, and the relationship between asteroids in the outer solar system and comets.

Several techniques have been developed to determine the size of asteroids. One of the most effective methods for measuring asteroidal size and albedo indirectly is through the use of radiometry, where a combination of the thermal infrared flux and the absolute magnitude as the reflected sunlight. Using radiometric measurements, a large number of objects can be observed in a short period of time, providing coherent data for large populations of asteroids within the asteroid belt. Infrared observations can be made still better under ideal circumstances, from space. The first space-borne infrared telescope is the Infrared Astronomical Satellite (IRAS; Neugebauer et al. 1984), launched in 1983 and performed a survey of the entire sky. To date, there are two other infrared astronomical satellites dedicated to all-sky survey: the Japanese infrared satellite AKARI (Murakami et al. 2007), and the Wide-field Infrared Survey Explorer (WISE; Wright et al. 2010). Based on the all-sky survey data obtained by IRAS, AKARI, and WISE, the largest asteroid catalogs containing size and albedo data were constructed (e.g., Tedesco et al. 2002; Usui et al. 2011; Mainzer et al. 2011). The total number of asteroids detected with size and albedo information with these three surveyors is 138,285, which is 22% of currently known asteroids with orbits.

In addition, several outstanding works have provided the taxonomic classification of asteroids (e.g., Tholen 1989; Bus & Binzel 2002; Lazzaro et al. 2004; Carvano et al. 2010), based on ground-based spectroscopic observations within optical and near-infrared wavelengths. Along with these taxonomic classifications, size and albedo data also contribute to our understanding of asteroid compositions. In general, the albedo of C-types is considered as low and that of S-types is high (e.g., Zellner & Gradie 1976). The relationship between taxonomic types and albedo is, however, complex and type determinations cannot be made on the basis of albedo values alone. Recently albedos of C- and S-type asteroids are found to vary widely, especially for sizes smaller than several tens km (Usui et al. 2013). Furthermore, in spite of the albedo transition process like space weathering, the heliocentric distribution of the mean albedo of asteroids in each taxonomic type is found to be nearly flat. In the total distribution, on the other hand, the mean albedo value gradually decreases with increasing the semimajor axis, presumably due to the compositional mixing ratios of taxonomic types.

In this talk, we present the details of data compiling of size, albedo, and taxonomy of MBAs, and discuss the compositional distribution in the main belt regions.

Keywords: asteroids, main belt, infrared surveys, size and albedo, taxonomic classifications

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-19 Room:503 Time:April 28 16:35-16:50

Lightcurve Survey of Vestoids in the Inner Asteroid Belt

HASEGAWA, Sunao[1*] ; MIYASAKA, Seidai[2] ; MITO, Hiroyuki[3] ; SARUGAKU, Yuki[1] ; OZAWA, Tomohiko[4] ; KURODA, Daisuke[5] ; YOSHIDA, Michitoshi[6] ; YANAGISAWA, Kenshi[5] ; SHIMIZU, Yasuhiro[5] ; NAGAYAMA, Shogo[5] ; TODA, Hiroyuki[5] ; OKITA, Kouji[5] ; KAWAI, Nobuyuki[7] ; SEKIGUCHI, Tomohiko[8] ; ISHIGURO, Masateru[9] ; ABE, Masanao[1]

[1]Institute of Space and Astronautical Science, Japan Aerospace Exploration Agency, [2]Tokyo Metropolitan Government, [3]Kiso Observatory, Institute of Astronomy, The University of Tokyo, [4]Misato Observatory, [5]Okayama Astrophysical Observatory, National Astronomical Observatory, [6]Hiroshima Astrophysical Science Center, Hiroshima University, [7]Graduate School of engineering, , Tokyo Institute of Technology, [8]Asahikawa Campus, Hokkaido University of Education, [9]Department of Physical and Astronomy, Seoul National University

We have made the lightcurve observation of 13 vestoids ((1933) Tinchen, (2011) Veteraniya, (2508) Alupka, (3657) Ermolova, (3900) Knezevic, (4005) Dyagilev, (4383) Suruga, (4434) Nikulin, (4796) Lewis, (6331) 1992 FZ_1, (8645) 1998 TN, (10285) Renemichelsen, and (10320) Reiland).

Lightcurves in the R-band of rotation periods were found for (1933) Tinchen, (2011) Veteraniya, (2508) Alupka, (3657) Ermolova, (3900) Knezevic, (4005) Dyagilev, (4383) Suruga, (4796) Lewis, (6331) 1992 FZ_1, (8645) 1998 TN, and (10320) Reiland.

The distribution of rotational rates of 59 vestoids in the inner main belt, including 29 members of the Vesta family that are regarded as ejecta from the asteroid (4) Vesta, is inconsistent with the best-fit Maxwellian distribution.

This inconsistency may be due to the effect of thermal radiation Yarkovsky- O'Keefe-Radzievskii-Paddack (YORP) torques, and implies that the collision event that formed vestoids is sub-billion to several billion years in age.

Keywords: asteroid, vesta

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-20 Room:503 Time:April 28 16:50-17:05

Near-infrared spectral measurements of zodiacal light by CIBER rocket experiments

MATSUURA, Shuji[1*] ; ARAI, Toshiaki[1] ; ONISHI, Yosuke[1] ; SHIRAHATA, Mai[1] ; TSUMURA, Kohji[1] ; MATSUMOTO, Toshio[2] ; BOCK, James[3] ; CIBER, Team[3]

[1]JAXA, [2]ASIAA, [3]Caltech

We have observed the cosmic near-infrared background light as the integrated light along the line of sight, which is the near-infrared diffuse radiation in wide range of the cosmic structure from the solar system to extragalactic universe, with the CIBER (Cosmic Infrared Background ExpeRiment) rocket experiments. One of scientific objectives of CIBER is to measure the zodiacal light in the near-infrared, which is the scattered sun light by interplanetary dusts. From the results of CIBER, we first observed the zodiacal light spectrum and its polarization in the near-infrared range from 0.8 to 2 mincrons. In this paper, we present the observation results.

CIBER is an international collaboration study among Japan, US and Korea, and a sounding rocket program by NASA. In a term from 2009 to 2013, we have carried out four times of launch and obtained high quality data at the altitudes above 200 km with no contamination by the earth atmosphere. In order to measure the extragalactic background light, we selected the observation field to have solar elongation over 90 degrees with relatively low brightness. We extracted the zodiacal light component from the total sky brightness by using the ecliptic latitude dependence. As the result, we could obtain information of spectrum, polarization and seasonal variation of the zodiacal light.

The observed infrared spectrum shows neither ecliptic latitude dependence nor time variation, and reddened color compared with the solar spectrum at wavelengths below 1.5 microns. From this result, size of interplanetary dust is larger than the order of micron, and there may be absorption of dust minerals at shorter wavelengths. We found the polarization of 20-25% at the maximum at the north ecliptic pole, which is higher than that previously observed in the visible wavelength range. The polarization result also suggest that the majority of the dust size is much larger than the observation wavelength.

In this paper, we report the observation result, and we discuss the optical properties of interplanetary dust by comparing our result with the spectral reflectance of meteorites and cometary dust.

Keywords: zodiacal light, interplanetary dust, infrared, observation

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-21 Room:503 Time:April 28 17:05-17:20

Reflectance Spectra of Jovian Small Satellites and Implication of their Origin

TAKATO, Naruhisa[1*] ; TERADA, Hiroshi[1] ; YOSHIDA, Fumi[1] ; OHTSUKI, Keiji[2]

[1]National Astronomical Observatory of Japan, [2]Kobe Univ.

Abstract

Jupiter has many small satellites other than the four giant Galilean satellites. Four of them revolve inside Io's orbit and others revolve outside Calisto's orbit. Based on the similarities of their photometric and orbital properties, these small satellites are thought to be captured asteroids. However, it is still unknown where and when these satellites were captured by Jupiter. We can reveal the dynamic history of our solar system evolution by investigating these questions.

Here, we have made optical spectroscopies of 11 small satellites which were not yet taxonomically classified by spectroscopy so far. We compared the number ratio of C- and X-type to D-type of the 11 satellites, and the Hilda and Trojan groups observed recently by Grav et al. (2012) as a function of diameter. We found that the diameter-(C,X)/D relation of the Jovian irregular satellites is similar to that of Hilda's, not Trojan's. This result suggests that the Jovian irregulars and the Hilda members originate from the same source of asteroids.

We also observed the 3.05 μm narrow-band photometry of the inner small satellite Thebe and found that there is absorption. This can be attributed to hydrated minerals.

Keywords: satellites, Jupiter, spectrum, Hilda group, Trojan

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-22 Room:503 Time:April 28 17:20-17:35

Weathering effect of solar wind proton on hydrated silicate minerals

NAKAUCHI, Yusuke[1*] ; ABE, Masanao[2] ; KITAZATO, Kohei[3] ; TSUCHIYAMA, Akira[4] ; YASUDA, Keisuke[5]

[1]The Graduate University for Advanced Studies, [2]Japan Aerospace Exploration Agency, [3]University of Aizu, [4]Kyoto University, [5]The Wakasa Wan Energy Reserch Center

NIRS3 is an on-board near infrared spectrometer of Hayabusa-2 project which is aimed at returning samples from C-type asteroid 1999 JU3. In this project, it is important to characterize mineralogical and heterogeneities on the asteroid surface for the sampling site selection. Observing wavelength of NIRS3 is including the 3 μm band which is charactering C-type asteroid (*Rivkin et al. LPSC 2002, Milliken et al. 2007*). The NIRS3 will measure reflectance spectra of asteroid surface in the wavelength range of 1.8 - 3.2 μm. This wavelength region includes features mainly related to OH and H_2O.

The spectral properties of the surface, however, would have different trend to the subsurface, because the surface of asteroids would be exposed to solar wind and micrometeorite. As for the reflectance spectrum of the moon, the absorption feature from 2.8 μm to 3.0 μm was reported in M^3 data (*Pieters et al. 2009*). It is thought that the implantation of solar wind proton is one of the causes (*McCord et al. 2011*). The solar wind protons will affect the spectral shape of 3μm region of air less bodies. Thus we study effect of irradiation of solar wind protons on near-infrared reflectance spectra by laboratory experiment.

We executed the simulation of irradiation of solar wind protons using ion implantation device at the Wakasa Wan Energy Research Center (WERC), Fukui. This device can irradiate $H_2{}^+$ beam with 10 keV in a vacuum (under 1×10^{-5} Pa). The total amount of $H_2{}^+$ was about 10^{18} ion/cm^2. Three samples were prepared; olivine (San Carlos, Arizona), antigorite (Sangenchaya, Kyoto), saponite (synthetic: Kunimine Industries Co., Ltd.). Antigorite and saponite were sieved between 50 μm and 75 μm and olivine served between 75 μm and 105 μm, and then they were heated for 24 hours at 423 K. They were packed into Cu cups and formed pellets. After irradiated the spectra were measured using FTIR, which resolution was 2.0 cm^{-1} in wavenumber. We adopted the analysis method of *Ichimura et al. (2012)*, which is to compare the reflectance spectra of altered sample, R, with unaltered sample, R_0, to determine the alteration ratio of spectra, R/R_0, without absorption water.

The alteration ratios of irradiated samples were different between minerals. The alteration ratio of olivine showed increasing of broad absorption feature from 2.8 μm to 3.8 μm due to OH/H_2O production. In antigorite and saponite, the alteration ratio, additionally, showed characteristic change related to coupling state of -OH. In the alteration ratio of antigorite, stretching of -OH bonded water molecule (-OH $\cdots$ ^{H}OH) at 2.77 μm and stretching of -OH $\cdots$ ^{H}OSi at 2.85 μm was increased conspicuously. On the other hands, the alteration ratio of saponite was changed conspicuously at 2.77 μm.

We think that the difference of the bands which showed conspicuously change is related with structure of minerals. Antigorite have -OH into the crystal. Therefore the irradiated protons broke bonds of Si-O and produced newer hydrogen bonds which are -OH $\cdots$ ^{H}OH or -OH $\cdots$ ^{H}OSi. Saponite has H_2O as interlayer water. It would be similarly broken bands of Si-O and produced newer hydrogen bonds which are -OH $\cdots$ ^{H}OH. These spectral changes can explain same process. These features support that the irradiated protons react with bonds of Si-O in the crystal.

In this study, we showed that the alteration of feature related with OH/H_2O is different from each mineral. Next step, we will examine the other minerals against determination minerals and the amount of water from reflectance spectra.

Keywords: Hayabusa-2, space weathering, solar wind, OH/H_2O, C-type Asteroid, proton implantation

Japan Geoscience Union Meeting 2014
(28 April - 02 May 2014 at Pacifico YOKOHAMA, Kanagawa, Japan)

U06-23 Room:503 Time:April 28 17:35-17:50

The effect of coexisting iron sulfide on space weathering by nanosecond pulse laser irradiation

OKAZAKI, Mizuki[1*] ; SASAKI, Sho[1] ; HIROI, Takahiro[2]

[1]School of Science, Osaka University, [2]Brown University

High-velocity impacts of micrometeorites and solar-wind particles change the surface optical properties of airless silicate bodies such as asteroids and the Moon. This process is called ”space weathering”. Experiments using nanosecond pulse laser confirmed the prediction that the formation of nanometer-size metallic iron particles should cause darkening, reddening and attenuation of absorption bands in visible and near infrared reflectance. The space weathering may explain the spectral mismatch between S-type asteroids and ordinary chondrites.

Previously sulfur depletion from asteroid surface was advocated on the basis of low sulfur abundance on Eros.

Recently on the surface of dust particles from Itokawa’s surface returned by Hayabusa, a thin layer containing nano particles of FeS over amorphous zone containing nano iron particles. A 10 micron size FeS crystal is also found in one Itokawa-derived grain.

To examine the effect of FeS on the space weathering, we conducted simulation experiments of the space weathering of silicate-FeS mixture using nanosecond pulse laser irradiation.

Then S is rich in volatility, so we guessed if sulfur has a certain influence on space weathering at the astronomical surface, and the experiments on chondrites with S by using nanosecond pulse laser.

We prepared pellet samples of powdered olivine and pyroxene (45-75 micrometer) mixed with iron sulfide particles (of 10, 20wt%) with same (and smaller) size range. We also prepared olivine pellet samples containing metallic iron particles of 10 to 20 wt%.

We found that the addition of Fe should enhance reddening and also darken near infrared reflectance (about 20% in the case of 10-20wt % FeS)., as compared with the case of the addition of Fe.

Although it was space weathering which has so far attracted attention from reddening, such as reddening by weathering in case Fe is contained, in the case where FeS is added, darkening was also seen and it has checked that space weathering became strong. Although existence of nano iron particulates can be considered about reddening, about overall darkening, it is under examination.

The samples were irradiated by nano-second pulse laser.

Keywords: space weathering, iron sulfide, experiments using pulse laser, asteroids, Itokawa