Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

U07-01 Room:105 Time:May 19 09:25-09:40

Characteristics and Significant Exploration of Small Solar System Bodies

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Characteristics and significant exploration of the small Solar System bodies are summarized as follows:

1)Small bodies of the Solar System are primordial materials to form the planets by the impact processes.

2)Small bodies of the Solar System are remained as nano-solid materials after air-liquid phases during impact processes.

3)Impacts on heterogeneous surfaces penetrate light elements of carbon and water hydrogen to the interior and be stored for magmatic melting with lift-up eruption of volcano-like process.

4)Light elements on the present Earth are not used for the small bodies, because the Earth is changed so much by ocean water system.

5)Monomer carbons of organic compounds are formed everywhere if shock-wave reaction is generated there. However, to form high molecules of supra- to giant-molecules for organic life compounds are required for stable and long high temperature condition, which is not impact condition process in smaller bodies in the Solar System .

In short,
1)Sample return plan with carbon and hydrogen is significant to our Earth due to be loss by in-situ exploration.

2)Life carbon organic compounds are not expected on smaller bodies due to difficulty of measurements, because shock-wave reaction makes any monomer organic compounds.

3)Thus there are no scientific significance except sample returning,if engineering supports are not expected.

Keywords: Smaller bodies, Characteristics, Exploration, Carbon and water, Life organic compounds, Mini bubble texture

U07-02 Room:105 Time:May 19 09:40-09:55

Laboratory Experiment on Impact Process of Granular Target under Microgravity: Drag Equation of Projectile Penetration

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Regolith and boulders are observed on the surface of asteroids. These objects could be formed by impact and reaccumulation. For example, images taken by Hayabusa showed that the surface of asteroid Itokawa was divided into rough terrain, mostly consisting of numerous boulders, and smooth terrain composed of fragmental debris with grain sizes (Fujiwara et al. 2006). Itokawa is 300-m sized small asteroid, which has the escape velocity of 10 to 20 cm s^{-1} from the surface and microgravity of 0.1mm s^{-2}. Reaccumulation process would have occurred below the escape velocities, i.e., asteroids of similar size to Itokawa would have reaccumulated at a velocity as low as cm s^{-1} to m s^{-1}. Crater formation process and ejection mechanism under such condition are not fully understood. In this study, to understand reaccumulation process on the surface of asteroids, we conducted low velocity impact experiments of granular target, that is simulated asteroid surface, under microgravity. In this presentation, we focus on drag equations of projectile to understand penetration of boulders into regolith surface of small asteroids.

Glass beads (sphere) and sand (irregular shape) were used as targets. The grain sizes ranged 90-106 micro meters and 355-500 micro meters for glass beads, and 100-180 micro meters and 300-600 micro meters for sand. Aluminum cylinder with diameter of 5 mm and length of 15 mm with a hemispherical tip was used as a projectile. Impact experiment was conducted by a drop tower in Braunschweig University of Technology, Germany. By dropping a projectile and a container filled with the target material with a time interval, low velocity impact under microgravity was achieved (Beitz et al., 2011). Two high-speed cameras are also dropped with the target. Impact velocities were ~5cm s^{-1}, 23cm s^{-1}, ~50cm s^{-1} and ambient pressures in the chamber were ~20 Pa and ~500 Pa.

Ejecta cone was not clearly observed for sand target whereas it was observed clearly for glass bead target. We measured the distance between the rear edge of projectile and the surface of target on high speed camera images and analyzed the deceleration process of projectile. The result showed that projectile was decelerated more effectively in sand target than in glass bead target. As a first analysis, we applied three equations of motion; drag force is proportional to square of projectile velocity; drag force is proportional to velocity; drag force is proportional to a constant and independent of velocity. The deceleration curve of the drag force proportional to velocity fitted the experimental data better than the other curves. Drag force proportional to velocity was also shown in an impact experiment and numerical simulation of plastic sphere into glass bead target at initial velocity of 70 m s^{-1} (Nakamura et al. 2013). We discuss how the deceleration process depends on target material, grain size of target and impact velocities.

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U07-03 Room:105 Time:May 19 09:55-10:10

Experimental study on impact into sand under simulated reduced gravities

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The geographical feature of the surface of asteroids, which is largely covered by regolith, is mostly governed by the collision phenomenon. Because gravitational acceleration at the asteroid surface is very small, when considering the evolutional process of the asteroids surface, it is important to understand the impact crater formation under microgravity condition.

However, not many impact cratering experiments under microgravity condition have been conducted. As one of few examples, Gault and Wedekind (1977) conducted the experiment in which the target was hung by springs of constant force with different spring constants and was dropped to achieve smaller gravitational acceleration than the earth's gravitational acceleration. The acceleration of the target was varied over a range of 0.1-1 G. The impact velocity was between 0.4 and 8.0 km/s, and the target material was quartz sand. The crater diameter was proportional to -0.165 power of the acceleration. On the other hand, Takagi et al. (2007) conducted a series of microgravity experiments by using a drop tower. The gravitational acceleration for the target was less than 10^-5 G, impact velocity was between 45 and 360 m/s and the target material was soda-lime glass beads with mean diameter of 0.08 to 0.9 mm. The crater diameter formed under microgravity was not different from the crater diameter formed under 1 G, which was contradictory to the result of Gault and Wedekind (1977). Because there is little experimental data, the reason of the difference between these results is not fully understood, and further experiment is required.

Therefore, we started to conduct a new impact experiments of low velocity under simulated smaller gravities by dropping the target with springs of constant force. As a preliminary experiment, sea sand (grain diameter is approximately 0.1 mm) in a container was used as a target, and we changed the acceleration by changing the weight attached to the container. The acceleration was measured by an accelerometer and was determined with a fluctuation of +/-6*10^-3 G.

We will present the result of impact experiments conducted at reduced gravity using this device.

Keywords: impact experiment, microgravity, crater

U07-04 Room:105 Time:May 19 10:10-10:25

Fragmentation degree of impactor in collision with asteroid regolith

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Introduction: Many of meteorites are fragments of disrupted asteroids, therefore we can get the information of early stages of the Solar System, because it is considered that thermal activity was stopped in the early stage in the parent bodies of chondrites. However, there are meteorites in which the components from various parent body origins are mixed. These meteorites contain the fragments of the different bodies' material and are brecciated. For example, it was reported that the fragments of carbonaceous chondrite are contained in Tsukuba meteorite and Almahata Sitta meteorite (Nakashima et al. 2003, Jenniskens et al. 2009). HED meteorites are known to be originated from asteroids (4) Vesta. HEDs generally contain the carbonaceous chondrite to 5vol. % (Zolensky et al. 1996), and on the Vesta surface there is a crater that was probably formed by the carbonaceous chondrite impact (Reddy et al. 2012). Thus, brecciated meteorites containing the fragments of other bodies' material were probably formed by impacts of smaller bodies into boulders or regolith of another bodies to have been captured in the regolith. The regolith containing the fragments was lithified by further impacts (e.g. Rubin et al. 1983). In addition, a 6 m-sized black boulder on the surface of Itokawa (Hirata and Ishiguro 2011) may also be carbonaceous chondrite of other body origin. Therefore, taking the material of other bodies has likely been a universal process on asteroid surface. In this study, we investigated the fragmentation degree of projectile by laboratory impact experiments in order to clarify the fragmentation degree of a meteorite in collision with asteroid regolith.

Experiment: Basalt projectiles simulating meteorites were impacted on regolith like silica-sand-target. We previously conducted the experiment at velocities of 167 to 960 m/s (Nagaoka et al., the Japanese society for planetary science, fall meeting, 2012). In this study, we conducted the experiment at velocities of 2 to 5 km/s that simulated the mean impact velocity in the asteroid belt, which is ˜4.4 km/s (Bottke et al. 1994). The experiments were performed by a two-stage light-gas-gun facility at the ISAS/JAXA. Recovered fragments were sorted out by 0.5 mm size meshes.

Result: We studied the relation of the largest fragment mass fraction to the non-dimension impact pressure (in this study, it was defined as the initial peak pressure divided by the tensile strength of projectile). It was found that projectile began to break at pressure of ten times greater than the tensile strength of projectile that corresponded to about 200 MPa. Moreover, the largest fragment mass fraction was larger than that expected from the impact experiments at velocities of a few 100 m/s. This may be explained by the increase of the dynamic strength of projectile according to a strength-strain rate relation (Grady and Kipp 1980).

Keywords: asteroid, meteorite, impact

U07-05 Room:105 Time:May 19 11:00-11:15

Numerical simulation on trajectories of crater ejecta from a small asteroid

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An artificial impact cratering experiment is planed in the Hayabusa-2 mission by a small carry-on impactor. Trajectory of ejecta from the crater shows complex behavior due to an asymmetric gravitational field of the small and irregular-shaped asteroid and solar radiation pressure. We examine the trajectories and fate of impact ejecta around the asteroid using numerical simulation. Gravitational field of the asteroid is estimated by a polyhedron method with a polygon shape model of the asteroid. Solar radiation pressure to small ejecta grains is modeled by a cannon-ball method. Size-frequency distributions and velocity-frequency distribution of ejecta particles are considered to estimate a time development of ejecta distributions around the asteroid.

Keywords: Hayabusa 2, 1999JU3, asteroid, crater, ejecta

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U07-06 Room:105 Time:May 19 11:15-11:30

Reflectance spectroscopy of CM2 chondrite (Nogoya) using the Hayabusa2 ONC-T Flight Model

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Hayabusa successfully brought samples from the S-type asteroid Itokawa. Based on the technology of Hayabusa, Hayabusa-2 is designed to collect samples of surface material from the near-Earth asteroid 1999JU3 and return them to Earth. 1999JU3 is classified as a C-type asteroid, which differs from S-type asteroids in their degree of thermal metamorphism. There is a possibility that primitive samples exist on 1999JU3, because C-type asteroids are less thermally metamorphosed than S-type asteroids. Ground-based observations have indicated, the presence of hydrated materials on 1999JU3's surface. However, these materials are not distributed over the entire surface of the asteroid. To bring the primitive samples to Earth, we observed the asteroid using the optical navigation camera (ONC) mounted on Hayabusa-2. ONC-T's effective wavelength are same as those of the Hayabusa Asteroid Multiband Imaging Camera(AMICA); however, it differs from AMICA in the 430 and 750 nm wavelengths, and the neutral density (ND) filter. Hayabusa-2 ONC-T has seven filters and one glass cover, with effective wavelengths of 390, 480, 550, 589.5, 700, 860, and 950 nm. Hayabusa-2 enables to find the place on the asteroid surface where aqueously altered minerals are concentrated, observing the absorption band of phyllosilicate around 700nm. This will be helpful for us to decide the landing point of Hayabusa2. We examined the Hayabusa-2 ONC-T calibration and imaged meteorites via multi-band imaging. The purpose of this study is to determine the feasibility of detecting primitive rocks on 1999JU3 using Hayabusa-2 ONC-T. we also examined the spectral reflectance properties of the meteorite Nogoya, which is similar to C-type asteroids. We directly Compared ONC-T's images with the spectroscopic data; our results indicate that ONC-T can detect an absorption feature centered near 700 nm.

Keywords: Hayabusa2, ONC, meteorite, Nogoya

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U07-07 Room:105 Time:May 19 11:30-11:45

Sciences prospected from the results of ground tests for NIRS3: the Near Infrared Spectrometer on Hayabusa-2

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NIRS3: the Near Infrared Spectrometer is one of the candidate scientific instruments which will be equipped on Hayabusa-2 mission. It aims to observe near infrared spectroscopy at the wave length band of 1.8-3.2 micrometer to detect specific molecular absorption lines, including the absorption by hydrated minerals at 3 micrometer, on the target C-type asteroid. The major purpose of NIRS3 is to observe the absorption bands of hydrated minerals in the 3 micrometer band on the candidate target C-type asteroid 1999JU3, which has been reported in ground observations to have an absorption band of hydrated minerals at 0.7 micrometer. C-type asteroids are thought to be mother celestial bodies of carbonaceous chondrites (C-chondrites). C-chondrites have been classified into sub-groups by their composition, organization, and isotope ratio of oxygen. The spectra of C-type asteroids have also been classified into sub-types by their inclination and the existence of absorption bands detected in ground observations. However, the relationship between the sub-groups of C-chondrites and the sub-types of C-type asteroids has not been clarified due to the effects of solar radiation and space weathering. Therefore, we will directly observe the surface of a C-type asteroid without the terrestrial atmospheric absorption in the 3 micrometer band using NIRS3. Detecting younger terrain by global mapping of the asteroid and the ejecta of new crater by the Small Carry-on Impactor (SCI) will also provide the spectra of surface less affected by space weathering. To estimate the quantities of the hydrated minerals with accuracies of 1 to 2 wt%, we designed the NIRS3 system to have a signal-to-noise ratio (SNR) exceeding 50 at 2.6 micrometer for global mapping.

The critical design of NIRS3 started in August, 2011. We performed ground properties tests and environmental tests using the engineering model of NIRS3-S and NIRS3-AE including the newly developed InAs sensor and the shutter. Results of SNR property tests implied that the rapid increase of the dark current in the InAs sensor degrades the SNR when the integration time exceeds 200 microsecond at 193K. Therefore, we improved the SNR by (1) cooling the sensor to below 187K to reduce the dark current low sufficiently for 400 microsecond integration, (2) sampling three-times of 400 microsecond integration in one shutter-open period, and (3) spectral binning of two channels. The adjusted SNR remains above 50 at 2.6 micrometer during a sufficient period for global mapping. The later sensor property tests of flight model produced the better qualities for noise and linearity (Nakauchi et al., this meeting), which suggests the on-board SNR will provide enough performance. Thus, NIRS3 will shed light on the initial composition, aqueous alternation, thermal metamorphism, and space weathering on the surface of a C-type asteroid.

Keywords: Hayabusa-2, asteroid, 1999JU3, NIRS3, near infrared, spectrometer

U07-08 Room:105 Time:May 19 11:45-12:00

Development of Thermal Infrared Imager onboard Hayabusa2

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Thermal Infrared Imager (TIR) onboard Hayabusa2 will take a mid-infrared image, or thermograph, of C-class Near-Earth Asteroid 1999JU3. TIR is based on two dimension un-cooled micro-bolometer array and images the asteroid in the wavelength of 8 to 12 um. Its field of view covers 16 deg by 12 deg (320 by 240 effective pixels) with 0.05 deg resolution per pixel, corresponding to about 20m per pixel when observed from Home Position, 20km altitude from asteroid. Thermal radiation depends on the temperature and thermal emissivity of asteroid surface. The latter is represented by that of carbonaceous chondrites. In 8 to 12 um, low diversity of thermal emissivity (0.96+/-0.02) affects surface temperature by only +/- 2 degC error. Thermal inertia relies on heat capacitance and thermal conductivity. For rocks, thermal inertia is influenced by porosity. Porous rock shows 1000 to 2000 in SI unit, while higher than 2000 for condensed rock. For fine particles, sands, or pebbles, both of porosity and particle size influence the thermal inertia. It is typically less than 100 for fine sands, 100 to 200 for millimeter-sized sands, 200 to 400 for centimeter-sized pebbles.

Maximum and minimum peak temperatures on asteroid surface as well as the delay time to reach peak temperature varies by those such as surface thermal inertia, albedo, geographical latitude, and asteroid rotation period. Thermal inertia at each site on asteroid is determined by comparison of observation with calculated thermal emission. Asteroids ever explored show a variety of surface conditions or geologic features, so as for 1999JU3. Huge boulders that originated from its parent body might show condensed state in the past whether it is still porous and primordial or dense and compacted. Flat area, crater ejecta, or pond-like feature is formed by sedimentation, and its particle size (fine sands or pebbles) and regional distribution indicates the granular flow or sedimentation processes. Large crater directly shows the inside of asteroid, which informs whether asteroid interior consists of porous materials or rubble-pile boulders. They are distinguishable by thermal inertia mapping. Comparison of thermal imaging by TIR with ground-based observation and calculated thermal model will increase the asteroid thermal model and the effect of thermal emission by surface roughness.

Here we report the current status of TIR development. Although TIR is based on LIR onboard Akatsuki, there are something different such as mechanical and thermal environments to be experienced, temperature range to be observed, and digital electronics for onboard data handling. Now the flight model of TIR has been manufactured to be tested and verified. Using a proto model, mechanical environment test on spacecraft has been completed in January 2013. Thermal calculation is conducted for the case of cruising and touchdown to asteroid. Focal length of TIR optics has been adjusted using a specific target and a flat panel heater. In the initial integration test, all the commands, telemetries and functions of TIR has been checked successfully, although some interface still remains unchecked. Automatic observation operation modes will be tested in the late stage of IIT. After IIT, TIR component environment tests will be conducted, and performance and calibration of TIR will take place for scientific purpose.

Keywords: Hayabusa2, asteroid, thermal inertia, planetary surface process, thernal emission, temperature

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U07-09 Room:105 Time:May 19 12:00-12:15

Simulation of thermal inertia measurement of an asteroid by Thermal Infrared Camera onboard HAYABUSA 2

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The asteroid explorer HAYABUSA 2 launched in 2014 will visit a C-type asteroid 1999JU3 which may preserve composition when the solar system was formed. One of the scientific purposes of the HAYABUSA 2 mission is to infer the surface physical properties and internal structure of the asteroid by measuring its thermal inertia. In this study observation of the asteroid surface by Thermal Infrared Camera onboard HAYABUSA 2 was simulated by an experiment. Surface temperatures of a rock, grave and sand of feldspar were measured by a commercial infrared camera, and accuracy of thermal inertia derived from the temporal variation of the surface temperature was examined. Albedo of the samples and spectral luminosity of a halogen lamp were measured by a spectrometer. The surface temperature of the sample was obtained from temperatures of two aluminum plates simultaneously measured by thermocouples and their gray levels in the infrared image obtained by the infrared camera, and thermal inertia of the sample was derived. The experiment was performed for two cases in which the angle subtended by the lamp and infrared camera seen from the sample was about 10 and 45 degrees. As a result the thermal inertia of same material depends on sample size; it increases from sand, grave to a rock. This simulation experiment shows that HAYABUSA 2/TIR is able to derive thermal inertia of an asteroid by measuring its surface temperature variation due to rotation and to provide information on surface physical properties and internal structure of the asteroid.

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U07-10 Room:105 Time:May 19 12:15-12:30

Detection of dust around 1999JU3 using Hayabusa-2 LIDAR

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The surface of an airless object suffers from bombardments of micrometeoroids. The bombardments produce small fragments, or dust grains, on and around the surface of the object. Dust grains on the surface could ejected from the surface due to some reasons such as seismic shaking, another impact, electric repulsion, etc. Lateral transport of dust particles at the surface of the object is likely very important for formation of local morphology. Also, vertical transport of dust is critical for interpretation of irradiation age of comic rays and implantation of solr wind elements which could constrain orbital evolution of the object. We are planing to detect dusts around the target object of Hayabysa-2 mission, 1999JU3, by using Hayabusa-2 LIDAR.

Hayabusa-2 LIDAR is one of four remote sensing instruments onboard Hayabusa-2. It measures distance between the space-craft and a target by taking a time of flight of LASER pulse. The threshold level in optical receiver changes in 8 steps. Dust grains with radius of ten micron meters and spacial density of a few grains per cc is expected to be detected from an altitude of 20km (Hayabusa-2 home position), but it depends not only on the physical properties of dust grains but also on sensitivity of receivers for faint signal. Thus we need to verify the performance of dust detection mode of Hayabusa-2 LIDAR.

We develop a new device which simulates a faint reflected light from dust clouds. When a trigger signal is received, it irradiate LASER with a pre-programed pattern. The time resolution of the pattern is ten nano seconds and energy changes in 7 steps. The maximum energy of LASER is adjusted by using ND-filter.

In this presentation we will present a strategy to verify the perfomance of dust detection mode of Hayabusa-2 LIDAR, and discuss the possibility of dust detection around 1999JU3.

Keywords: dust, LIDAR, Hayabusa-2

U07-11 Room:105 Time:May 19 14:15-14:35

Engineering Aspect of Small Body Exploration -Hayabusa2 and Future

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The second asteroid sample return mission "Hayabusa-2" is now under development. It is to be launched in the end of 2014 to set out on a round-trip voyage for a C-type asteroid 1999 JU3. The Hayabusa2 mission is regarded as a series of the Japanese programmatic exploration of small body. In order to stably and strongly evolve our small body explorations, the best blend of new technologies and heritage-based technology should always be pursued. This talk reviews the mission scenario of Hayabusa2; what are mission enablers and what are technological challenges in it, and then discusses several future strawman missions than can be realized with our present and near-future engineering capabilities.

Keywords: Planetary Exploration, Spacecraft, Asteroid, Sample Return

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U07-12 Room:105 Time:May 19 14:35-14:50

Development Status of Hayabusa-2 Deployable Camera (DCAM3)

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Collisions between primitive planetary bodies are one of the most important physical processes in the planetary accretion from planetesimals to planets. Asteroids are small primitive bodies on the way to the larger bodies or the fragment bodies such as rubble piles of the evolved bodies, so that the asteroids are possibly be recognized as fossil bodies showing the accretion process in the solar nebula. Impact studies on the asteroid, such as the impact scaling rules related to the cratering and the disruption, are important to reveal the actual manner of planetary accretions in early stage of the evolution.

Small Carry-on Impactor (SCI) on Hayabusa-2 is a small detachable instrument that launches an artificial projectile and simulates planetary impacts on the asteroid 1999JU3. A copper-disk projectile is deformed by explosive in the SCI and forms a semi-spherical shell, and is accelerated to approx. 2 km/s. The tiny asteroid 1999JU3 is a good analogue of planetesimals and suitable to study the effect of micro-gravity on the impact process and elucidate the mechanical properties of planetesimals. The Deployable Camera (DCAM3) is a miniaturized detachable camera inherited from DCAMs in the Japanese IKAROS mission. The DCAM3 is currently under development for observations of the SCI impact. For avoiding a risk that the mother ship encounters high-speed ejecta from the asteroid, a separable instrument is necessary to obtain close up views of the impact while the mother ship is hiding in a safe region far from the impact point.

The scientific observations are performed by DCAM3-D that is a high-resolution visible observation subsystem in the miniaturized DCAM3 body. Scientific objectives of this camera are summarized as (1) clarifying the sub-surface structure, and (2) constructing the impact scaling rule applicable to the surface of asteroid 1999JU3. Observation objects of the camera are ejecta and a subsequent crater of the SCI impact, and a relative position of the SCI to the asteroid when it is launched. DCAM3-D can determine the size and the angle of the ejecta curtain, and the speed of the ejecta spreading or fragment spattering, which are the key information for the above objectives. In addition, low-speed ejecta (dust) spreading will possibly be observed around the DCAM3 in a few hours after the impact.

So far, we conducted the conceptual examinations to specify the required specification of the camera and a communication device. Engineering models were prepared for all components of DCAM3, and verification tests were conducted with them. Currently flight models are in tests for the observation and communication performances. The DCAM3-D sensor consists of a 2000 x 2000 pixels and 8 bit CMOS imager with a wide-angle optics (74 x 74 deg), which takes sequential images of the ejecta spreading with 1 frame/sec at maximum. The digital communication device can send the image data to the mother ship with 4 Mbps. DCAM3-D instruments in the mother ship receive and store all data taken by the deployed camera which continues to produce data for a few hours until batteries runs out or the DCAM3 falls and crashes on the asteroid. Total size of image data is estimated to be approximately 5 Gbits with image compression.

In this presentation, we show the science and the development status of the DCAM3 scientific part.

U07-13 Room:105 Time:May 19 14:50-15:05

Hayabusa-2 sampler: Surface variety of near-Earth C-type asteroid

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Samples from C-type asteroids, which are abundantly present in the asteroid belt and of which reflectance spectra resemble those of carbonaceous chondrites, may well preserve the information covering the long history of the solar system, compared to other bodies such as comets and Itokawa-like bodies. Their scientific values will be significantly increased for return samples obtained with detailed geological contexts. Moreover, surface samples from near-Earth C-type asteroids will provide insights into the space weathering of C-type asteroids and the surface thermal processes due to irradiation of sunlight, which cannot be obtained from meteorites and interplanetary dust particles. The Hayabusa-2 is a sample return mission from a near-Earth C-type asteroid 1999JU3 (2014-2020). Here we describe a sampling system of the Hayabusa-2 spacecraft to obtain samples from multiple surface locations of the asteroid with minimal contamination and a possible sampling strategy.

Keywords: Hayabusa-2, asteroid, sample return, space exploration

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International Campaign of (162173)1999 JU3 Lightcurve Observation

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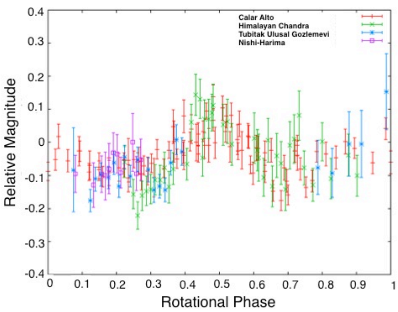
The observations were carried out at 32 nights during 2011-2012 apparition using 13 telescopes. The telescopes we used are as follows: the University of Hawaii 88-inch (2.2-m), Lulin Observatory (1.0-m), Nishi-Harima Astronomical Observatory Nayuta telescope (2.0-m), Himalayan Chandra Telescope (2.0-m), Tenagra II (0.8-m), Bosque Alegre (1.5-m), Magellan Baade (6.5-m), Calar Alto (1.2-m), Tubitak Ulusal Gozlemevi (1.0-m), MOA-I and II (0.6-m and 1.8-m), IRSF (1.4-m) and ESO/MPI (2.2m). We would like to emphasis that low solar phase angle (Sun-Asteroid-Observer's angle) data were acquired during 2011-2012 apparition which were not covered by 2007-2008 data. The new data sets enable to derive the accurate absolute magnitude and albedo.

(162173) 1999 JU3 (hereafter 1999 JU3) is a target asteroid of Hayabusa 2 sample return mission. The primary goal of the mission is to bring back samples from a C-type asteroid, which is considered to contain organics and hydrous minerals. It is scheduled to launch in 2014 arrive at 1999 JU3 in 2018. Some physical properties of 1999 JU3 were determined during the last apparition in 2007-2008. It is classified into C-type asteroid through optical spectroscopic observations (Binzel et al. 2001; Vilas 2008). Lightcurve observations indicated that 1999 JU3 has a synodic rotational period of 7.6272 +- 0.0072 hr (Abe et al. 2008). From the mid-infrared observations, it was found that the asteroid has an effective diameter of 0.87 +- 0.03 km (Muller et al. 2011). The pole orientation derived by the lightcurve observations still has a large uncertainty (Kawakami 2009; Muller et al. 2011). We had another observational opportunity in 2011-2012 when the apparent magnitude was bright enough to derive absolute magnitude and lightcurve with 1-2 m class telescopes. Since this is the last observational opportunity before the spacecraft launch, we, Hayabusa 2 Ground-based Observation group, conducted a global observational campaign to acquire the optical magnitude. In this presentation we report the results based on the campaign data.

We analyzed the photometric data using IRAF. As the results, we firstly derived the synodic rotational period of 7.631 +- 0.0072 hr. The result coincides with the previous result to an accuracy of our measurement. We found that the amplitude of the lightcurve was subdued with an amplitude of ~0.05 mag. Because the amplitude had been always small regardless of the observing angles (parameterized by 'phase-angle-bisector'), 1999 JU3 must have nearly spherical shape, which make us difficult to determine the pole orientation. In collaboration with experts in asteroid shape model and thermal model, Dr. J. Durech and T. Muller, some physical parameters were studied using our data. As the results, it is found that (i) the absolute magnitude is 19.20+-0.12, (ii) the geometric albedo is 0.057+-0.025 typical for C-type asteroids, (iii) and the thermal inertia is 200+-100 [J m-2 s-0.5 K-1] with the combination of mid-infrared data. As of 2013 February, we could not get conclusive result for the pole orientation, although the inclined pole solutions show better match to the observational data.



Japan Geoscience Union Meeting 2013
(May 19-24 2013 at Makuhari, Chiba, Japan)

U07-15 Room:105 Time:May 19 15:20-15:35

Ground-based observations of visible spectroscopic properties of 1999 JU3

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Asteroid 1999 JU3 is among the few C-type asteroids that can be reached with small delta-V from the Earth. This makes this asteroid a very attractive target for a near future sample-return mission. In fact, 1999 JU3 is currently chosen for the primary exploration target of JAXA's Hayabusa 2 and the secondary target for both OSIRIS-REx mission by NASA and Marco-Polo mission by ESA. Thus, detailed investigation of this NEA is very important for near future planetary mission projects.

In particular, both spatial inhomogeneity and temporal variation in the spectral properties of the mission target NEA would give a large impact on remote sensing strategy and sampling site selection processes. In this study, we observe visible spectrum of 1999 JU3 over multiple spin phases to examine how much spatial inhomogeneity is present and analyze newly obtained and literature spectrum of 1999 JU3 closely to infer material properties.

A series of visible spectroscopic observations of 1999 JU3 were conducted with the 8.1-m-aperture Gemini-South telescope in Chili using GMOS instrument on June 24, 26, and July 5. The apparent visible magnitude of 1999 JU3 was between 19.13 and 19.66 during our observations. The phase angle was relatively small between 22.7 and 30.3 deg. Two standard stars (HD142801, SA107-998) were used for calibration. Although the three observations cover a wide rotational phases, the observation on July 5th suffered from background star contamination.

The comparison between meteorites and the great variety of 1999 JU3 spectra reveal that the spectrum observed by Binzel et al. (2001) in May 1999, that by Vilas (2008) in Sept. 2007, and those in this study in June to July 2012 can be fit well by Murchison chondrite samples heated at different temperatures ranging from 650 to 900 deg.

Keywords: asteroids, reflectance spectroscopy, Hayabusa-2 mission, remote sensing, primitive bodies

U07-16 Room:105 Time:May 19 15:35-15:54

Interdisciplinary science of Hayabusa 2 mission

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The Hayabusa 2 mission, an asteroid exploration rendezvousing at a C-type near-Earth asteroid 1999 JU3, dropping off an explosively formed impactor colliding the surface to excavate a crater, and retrieving samples of the surface to the earth, is now developing the spacecraft and payload instruments aiming at a proposed launch in December 2014. The payload scientific instruments are a near IR spectrometer (NIRS3), a thermal IR imager (TIR), an optical navigation camera (ONC-T), a laser altimeter (LIDAR), a sampler (SMP), a small carry-on impactor (SCI), a separation digital camera (DCAM-D), and a small lander (MASCOT). ONC-T is a multi-band imager with seven band-pass filters (one of which is a narrow band-pass Na D line filter). MicrOmega, a hyperspectral microscope mounted on MASCOT, has a resolution of 20 um and covering wavelength from 0.9 to 3.5 um. Observation, experiments, and sampling by Hayabusa 2 needs a sound base of integrated science through each instrument.

In succession to activities of the Hayabusa 2 Task Force under the ISAS Space Science Committee, the Hayabusa 2 project set up the Interdisciplinary Science Team in the end of 2012. The objectives of the team are (1) drawing the entire picture of sciences of the mission, (2) finding cross-cutting themes derived from integration of scientific data by each instrument, (3) clarifying scientific constraints on mission scenario in process of creation, and (4) expanding the range of the project science under the mantra of ”planetary science from asteroids”.

The agenda is as follows: the method of selection of touch-down points from remote-sensing data, scientific strategy according to possible surface conditions of the asteroid, observation planning of the SCI crater, strategy for analyses of retrieved samples, refinement of the mission scenario, modeling of the origin and evolution of 1999 JU3 (by solar system dynamics and observational facts), mechanism of material transfer from the Main Belt to the earth.

Keywords: asteroids, 1999 JU3, remote sensing, cosmic and planetary material science, science of collision phenomena, planetary exploration

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Evolution of small bodies: The role of collision

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Collisions change the mass distributions of small bodies. When two small bodies collide, they will become bound to form a bigger body, lose mass by fragmentation and ejection, or be disrupted into smaller pieces. It has been recognized that larger rocky bodies are weaker due to a larger probability of relatively weak cracks. However, observational data indicate that small bodies have various porosities suggesting that they have experienced various degrees of thermal metamorphism and aqueous alteration. We conducted laboratory collisional disruption experiments for rock and homogeneous porous targets by changing the size scale of the target and projectile. Our porous target showed no obvious size dependence in the disruption threshold, in contrast to a size-dependent disruption threshold for the rock targets. If this tendency can be applied to the evolution of small bodies, it could be that mass distributions with different thermal metamorphism stages or different degrees of aqueous alteration evolved along different evolutional tracks or different timescales.

Collision modifies the structure of small bodies. Collisions initiate and promote crack growth and consequently reduce the strength of the small bodies. Collisions make the small bodies more compact and reduce the porosity. They also increase the temperature of a body and cause it to lose porosity and gain strength via thermal evolution. Collisional disruption and re-accumulation can even change a continuum body into a granular, rubble-pile body.

Collision changes the surface material of small bodies. Mature surface materials exposed to interplanetary space are ejected by collision, refreshing the surface. Collision brings exotic material to the surface as seen on the surface of Asteroid 4 Vesta and the spatial variation of surface material. Vibration produced in a rubble-pile body by collision induces migration and segregation of grains on the surface. Eventually, it may modify the reflectance spectrum and thermal emission of the surface.

Here we discuss our current understanding of the above three roles of collision in small body evolution and discuss this alongside recent results of laboratory experiments.

Keywords: small bodies, collision, evolution

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U07-18 Room:105 Time:May 19 16:35-16:55

Collisional fragmentation and dynamics of asteroids, and the solar system origin revealed by them

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Planets are formed via collisions of kilometer size of larger planetesimals such as asteroids. Collisional outcomes (coagulation or fragmentation) are very important to reveal the origin of the solar system. In spit of many efforts, we still have uncertainty of collisional physics for such large bodies. The size distribution of bodies are affected by collisional outcomes and hence the size distribution of asteroids may give a clue to clarify collisions of such large bodies and the origin of the solar system.

Keywords: Origin of the solar system, asteroids, collisional physics, dynamics

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Material diversity of C-type asteroids with reference to their reflectance spectra

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The target asteroid of Hayabusa 2 mission is Near-Earth asteroid 162173 (1999JU3) with a size of 0.87 +/- 0.03 km and a low albedo 0.070 +/- 0.006 (Muller et al. 2011). It is a C-type asteroid whose reflectance spectrum shows a 0.7 micron absorptipon band (Vilas, 2008), similar to CM-type carbonaceous chondrite meteorites. However, recent telescopic observations of JU3 failed to detect the 0.7 micron band, which probably indicates material diversity of the JU3 surface.

In the early solar system, rocky particles were accreted with icy particles to form C-type asteroids. Internal heating due to the decay of short-lived radionuclide 26Al has taken place within 5 million years after the birth of CAIs and molten ice to facilitate water-rock reactions. The deeper portions of the asteroids suffered high temperature heating and thus heavy aqueous alteration, while shallow layers experienced low-degree of alteration at low temperatures. This leads to the formation of zoned sturature from heavy altered interior to weakly altered surface. The aqueous alteration reactions ceased sometime between 10 to 100 million years after CAI farmation.

However, if we assume that JU3 formed with a size of 1km, which is comparable to current size, at 2 Myr after CAI formation, the internal temperature cannot reach melting temperature of ice by the decay heat of 26Al.In this case, aqueous alteration has never taken place in JU3, which contradicts the detection of hydrous minerals from JU3. Thereofere, JU3 might have been much larger than current size when it formed and later disaggregated. This suggests that JU3 is a rubble pile asteroid and the zoning structure of alteration is expevted to observe.

During 4.6 billion years after formation, surfaces of JU3 have been subject to impacts. Dust particles, the largest population is 200 microns, and solar winds continuously hit the surface of the asteroids, which results in changes of materials, callled "Space weathering". We have simulated dust-particle impacts on C-type asteroids experimentally. Pulse laser heating on the CM chondrite surfaces succeeds to reproduce "bluing" of the reflectance spectra (Matsuoka et al. 2013), which is observed from space-weathered C-type asteroids. The blueing agents are probably nano-particles of iron sulfides and amorphization of Fe-rich serpentine.

Along with micrometeorite bombardments, large scale impacts occur occasionally on the asteroids which leads devolatilization of hydrous material. In fact, many C-type asteroids show reflectance spectra similar to dehydrated carboncaeous chondrites. Recent mineralogical investigation of such dehydrated CM chondrites revealed a wide variation of mineralogy in terms of dehydration (Nakato et al. 2013).

Keywords: Reflectance Spectra, C-type asteroids

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Post-Hayabusa2 mission

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Hayabusa mission was finished and Hayabusa follow-on mission Hayabusa2 has started. Hayabusa2 will be launched in 2014 and come back to the earth in 2020. And now, we are planning a mission next to Hayabusa2. A few years ago, we already studied post-Hayaubsa2 mission, which was called Hayabusa-Mk2. It was a sample return mission from a D-type asteroid or a dormant comet, such as Wilson-Harrington. We made a mission plan. However, the situation has changed now and we are reconsidering this plan. The new plan that we are studying now is a mission to Trojans. In this presentation, we summarize the current study about this new idea.

Keywords: Asteroid, Exploration, Hayabusa

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U07-21 Room:105 Time:May 19 17:30-17:45

Scientific Observations during Cruising and Rendezvous Phases of the Solar Power Sail

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Following successful demonstration of deep space solar sail technique by IKAROS, the solar power sail is a deep space probe with hybrid propulsion of solar photon sail and ion engine system that will enable Japan to reach out deep interplanetary space beyond the main asteroid belt. For over the last decade, we have been investigating interdisciplinary space science areas that will benefit respective scientific premises from such a deep space observation platform mainly during its cruising phase. They include: (1) infrared astronomy to observe the first generation stars as the IR cosmic back ground radiation being discriminated from the foreground scattering of zodiacal light due to (2) cosmic dust, which at the same time hit a large cross section of the solar sail membrane dust detector, concentrating inside the main asteroid belt, and (3) gamma-ray astronomy to identify burst sources by taking advantage of an extremely long baseline with the terrestrial observatories as counterparts. Recently, the mission design has extended from cruising and fly-by only to rendezvous and sample return options from Jovian Trojan asteroids, en route Jovian gravity assist. Then, scientific observation opportunities gain for (4) Jovian magnetosphere interacting with the solar wind, (5) multiple flybys of asteroids at the main belt and the Jovian Trojan region, and (6) semi-intact sampling of both interplanetary dust at 5.2 AU heliocentric distance and surface compositions of a most-likely D-type asteroid in the Trojan clan. We also investigate possible synergy effects among these interdisciplinary observation plans and respective available instruments, such as IR and dust, gamma-ray and solar wind.

Keywords: Solar Power Sail, Infrared Astronomy, Gamma-ray Astronomy, Zodiacal Light Dust, Jovian Magnetosphere, Jovian Trojan Asteroids

U07-22 Room:105 Time:May 19 17:45-18:00

IKAROS and Solar Power Sail Mission for a Round Trip to Outer Solar System

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A Solar Sail is a space yacht that gathers energy for propulsion from sunlight pressure by means of a membrane. A solar sail can move forward without consuming propellant as long as it can generate enough energy from sunlight. A Solar Power Sail is a Japanese original concept that gets electricity from thin film solar cells on the membrane in addition to acceleration by solar radiation. The Japan Aerospace Exploration Agency (JAXA) made the world's first solar power sail demonstration of photon propulsion and thin film solar power generation during its interplanetary cruise by IKAROS (Interplanetary Kite-craft Accelerated by Radiation Of the Sun).

A solar power sail craft can save the fuel using a solar sail and it can also gain the necessary electric power using a vast area of thin film solar cells on the membrane even when it is away from the sun. It can be a hybrid propulsion system with a solar sail by activating the ultra-high specific impulse ion engines with the power generated by thin film solar cells. This paper proposes an solar power sail mission for a round trip to outer solar system. It demonstrates a variety of key technologies requisite for future outer solar system exploration as well as solar power sail technology. This innovative spacecraft is used not only for the cruise science observation but for dust in the outer solar system and Trojan asteroids sample return for the first time in the world.

Keywords: Solar sail, Solar power sail, Outer solar system, Round trip, Sample return