Japan Geoscience Union Meeting 2011
(May 22-27 2011 at Makuhari, Chiba, Japan)

PPS022-01 Room:IC Time:May 26 16:30-16:45

Thermal infrared (TIR) imager onboard Hayabusa-2

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A mid-infrared or thermal infrared (TIR) imager is a nominal remote-sensing instrument onboard HAYABUSA-2, to investigate physical properties of the surface of C-class asteroid 1999JU3. The instrument is based on the LIR (long-infrared imager) onboard AKATSUKI (former Planet-C), a Japanese Venus climate orbiter launched in 2010. Science objectives and current situation of the instrument are briefly reported.

HAYABUSA-2 is the follow-on mission after the Japanese asteroid explorer HAYABUSA and primarily an NEO sample-return mission, but remote sensing have much importance to characterize global features of the target body, complementary with the analysis of returned samples. Since the target body is a C-class asteroid, optimal set of instruments should be different from that of HAYABUSA. Telescopic (multi-band) imagers, laser ranger (LIDAR = Light detection and ranging), near-infrared spectrometer to identify 3 micron absorption band, and a thermal infrared imager are selected as nominal instruments. In HAYABUSA, measurement of thermal emission from asteroid has been done using the radiator of the XRS, but in HAYABUSA-2 the thermal infrared imager will take the role.

The original LIR instrument on AKATSUKI has been developed for mapping Venus clouds at the temperature range of 220-250K. The instrument is applicable to mid-infrared imaging to investigate thermal inertia of asteroid surface. The instrument uses a non-cooled bolometer as detector. The instrument has a field of view of 16 x 12 degree, detector of 344 x 260 pixels, and its detection temperature range of 250 to 400K. The total mass is about 3.5 kg including the detector, hood, electronics.

The main scientific missions are to investigate the global and local areal distribution of the surface physical properties. Surface physical properties are determined in 10 m spatial resolution from Home-Position. Images of higher resolution are taken by observation at lower altitude during the descent. Thermal inertia represents the surface physical condition. The surface thermal inertia is small ($<$50) for sandy material, moderate (100˜300) for pebbles, and higher (1000) for monolithic rocks, respectively.

The TIR imager will contribute to giving an information for the selection of sampling site by its surface physical condition and for the temperature range important for touchdown operation of spacecraft.

The development of the thermal infrared (TIR) imager for Hayabusa-2 is just started. This instrument should help understand the nature of the asteroid 1999JU3.

Keywords: Hayabusa2, asteroid, thermal property, mid-infrared imager, remote sensing, thermal inertia

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PPS022-02 Room:IC Time:May 26 16:45-17:00

Scientific targets of the LIDAR onboard Hayabusa2

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The asteroid explorer Hayabusa2 will carry a LIDAR that is an instrument for laser ranging between the spacecraft and the asteroid. Although its primal purpose is navigation and guidance of the spacecraft, LIDAR data also will be valuable for scientific analyses. Scientific aim of the Hayabusa 2 LIDAR includes to give an accurate position of the spacecraft relative to the target asteroid; to determine the mass of the asteroid; and to measure albedo of the asteroid surface.

Keywords: asteroid, LIDAR, Hayabusa 2, gravity field, density, internal structure

Japan Geoscience Union Meeting 2011
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PPS022-03 Room:IC Time:May 26 17:00-17:15

Surface science with small landing robots in Hayabusa-2

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Hayabusa-2 is an asteroid sample-return mission to C-class asteroid 1999JU3 and the returned samples are only from a few points on the asteroid. Global features of asteroid by remote sensing and the milimeter to submilimeter scale detailed observation by the surface package are complementary to sample analysis.

In addition to sample analysis, asteroid context infromation is essential such as global shape, surface geomorphology, mineralogy, particle size and distribution and condition, internal structure and average density. Detailed geologic context at landing site is most important to interpret the sample.

On the other hand, surface condition, particle size, stiffness, chemical and mineral composition is critical to investigate and comapre with the results from sample analysis and remote sensings.

In Hayabsa 2, two kinds of landing robots (INERVA-II and MASCOT) is planned to observe the surface. We present here the scientific observation of these robots are considered.

MINERVA-II is based on the heritage of MINERVA on Hayabusa, a small hopping robot of 1.5kg. It is organized by the consortium based on UNISEC (academic community) MINERVA-II has three compact cameras, two for stero viewing and another for telescopic image. Temperature sensors are equipped at the top of pin-shaped bars to directry contact the surface while temperature is measured. Other candidate experiment is that an LED is prepared to shine the rock surface and image the fluorescence from organic material.

MASCOT is based on the heritage of Philae lander on Rosetta, a small lander of 10kg including mothership element. It is an international collaboration with DLR (Germany), CNES (France), and JAXA (Japan). MASCOT will have a wide angle camera WAC with 12 point multi-band filter wheel or mulit-color LEDs for landscape and geologic context around the landing site. Visible to near-infrared imaging spectrometer MicrOmega is to take surface features and mineralogy in tens of micrometer scale at the same time. Laser-induced breakdown spectrometer LIBS is to analyze major and volatile elements to characterize the materials. A small magnetometer is proposed to mount for inform the asteroid magnetism and the interaction with solar wind that depends on the porosity as magnetic permiability and the abundance of metal phase materilas as electric conductivity. Other instruments for house-keeping are temperature sensers, accelarometer, clinometer, which are also useful for scientific measurements.

Detailed design and scientific instrumentation is under discussion but final configuration will be determined soon.

Keywords: Hayabusa2, Asteroid Exploration, surface experiment, microscopy, elemental analysis

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PPS022-04 Room:IC Time:May 26 17:15-17:30

Scientific Objectives of the Impactor on board Hayabusa 2

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The asteroid explorer "Hayabusa 2" following "Hayabusa" has an impactor device in addition to the sampling device, remote sensing instruments. The device can impact a 2 kg metallic body to the asteroid with 2 km/sec. Phenomena on the asteroid 1999JU3 by the impact, observation methods of the phenomena, and expected scientific outcomes will be presented.

Keywords: small body exploration, impact phenomena, primitive material

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PPS022-05 Room:IC Time:May 26 17:30-17:45

Laboratory experiments simulating for sample recovery in the Hayabusa-2 mission.

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Sample return mission from C-type asteroid 162173 1999JU3 is planned as the Hayabusa-2 mission. The sampling method is 'impact sampling', which was adopted in the Hayabusa mission. We have performed impact experiments using simulants of a carbonaceous chondrite, which may corresponds to the surface material of the target asteroid, to increase the amount of samples by improving the impact conditions.

We carried out laboratory experiments using a gunpowder gun, which will be used in the Hayabusa-2 mission. The projectiles were hemisphere shaped tantalum (d=10mm,4.6g) and impact velocity was about 200 m/s. The simulants, which was used as targets in the experiment, were synthesized by sintering a mixture of soda lime glass beads of 250-355 microns (simulating chondrules) and $<$20 microns (simulating matrix). The mixing ratio of these glass beads was 20 or 50 volume %. The tensile strength of carbonaceous chondrites is in the range from about 0.1 to 10 MPa (Tsuchiyama et al., 2009.) By controlling the sintering temperature and duration, simulants with such strengths were obtained. We also used firebricks and glass beads as the targets.

Different mass distribution of fragments, ejection velocity of fragments and size of the crater were obtained for simulants with different strengths.

Keywords: Hayabusa-2, sampling, impact

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PPS022-06 Room:IC Time:May 26 17:45-18:00

Estimating the composition and the degree of space weathering of asteroids 6 Hebe, 433 Eros, and 25143 Itokawa

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Visible and near-infrared reflectance spectroscopy has been a useful method for remotely detecting mineralogy of planetary surface materials. However, there have been two problems in the analysis.

(1) On airless bodies such as asteroids, there exists a phenomenon called space weathering which is a process of alteration due to exposure to the harsh space environment including solar wind and micrometeorite bombardments. Their surface reflectance spectra show reddened continua, lowered albedos, and attenuated absorption features [Pieters et al., 1993], which makes it more difficult to analyze their spectra.

(2) In the reflectance spectra of solid planetary surfaces, we often find that each component mineral shows multiple broad bands which overlap with one another and with those of other minerals, making it very difficult to deconvolve them and assign the deconvolved bands into individual mineral components.

The purpose of this study is to solve these two problems.

First, this study made a progress toward solving the problem (1) by modeling the light-scattering property of a regolith particle having a vapor coating containing nanophase reduced iron ($npFe^0$) particles.

Next, the absorption spectra of silicates were studied. As a method of deconvolving the complex absorption spectra of silicates into individual absorption bands, the modified Gaussian model (MGM) is commonly used [Sunshine et al., 1990]. In this study, we investigated the relationships between the chemical composition and the absorption band parameters of major rock-froming minerals: olivine, low-Ca pyroxene, and high-Ca pyroxene, and also determined the band center, width, and relative strength of plagioclase. These relationships were utilized in MGM calculations. In this way, we solved the problem (2).

Utilizing the above two models and a mineral mixing model, we have constructed a unified model for estimating the mineral assemblage, chemical compositions of the component minerals, mineral grain size, and the degree of space weathering from the visible and near-infrared reflectance spectrum of a given airless celestial body.

This new model has been applied to the visible and near-infrared reflectance spectra of asteroids 6 Hebe, 433 Eros, and 25143 Itokawa. The results indicate that their surface compositions correspond to those of H chondrites (6 Hebe) and LL chondrites (433 Eros and 25143 Itokawa) which are abundant in our meteorite collections. Although such results had been also given by past studies, this study has also determined their Mg numbers, mineral mixing ratios of four major minerals of olivine, low-Ca pyroxene, high-Ca pyroxene, and plagioclase, mineral grain sizes, and the degree of space weathering from their visible and near-infrared reflectance spectra only. These model calculations have demonstrated that there are differences in the thickness of vapor coating layer and the concentration of $npFe^0$ in the coating layer among the asteroids. The former indicates that airless celestial bodies having boulders and coarse regoliths may be more space-weathered than those having fine regoliths. The reason behind this may be that the surface of larger asteroids having stronger gravity are gardened and renewed more frequently. The latter is a new finding that the Fe concentration in the impact vapor varies among the three asteroids, which can be explained by the difference in the metallic iron abundance on these ordinary chondrite like asteroid surfaces. This is consistent with the fact that H chondrites contain significantly more metallic iron than LL chondrites, and the recognition that 433 Eros which is much larger than 25143 Itokawa should have a regolith which is fine enough to separate metallic iron particles from the remaining silicates in the LL chondrite mineral assemblage and the separated metallic iron may be concentrated on the top of the regolith, which may constitute the ponds on 433 Eros observed by NEAR spacecraft.

Keywords: spectroscopy, space weathering, asteroid, modified Gaussian model

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PPS022-07 Room:IC Time:May 26 18:00-18:15

Surface processes on small bodies: Implications to the internal structures of asteroids and their explorations

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Recent missions reveal that significant varieties exist in the shapes and surface states of small bodies in the solar system. These are partly results of surface processes including cratering, reaccumulations of ejecta, migrations of gravels, and space weathering. Recently, we find an impact crater on the unusually smooth-looking surface of a small saturnian satellite, Atlas, whose enigmatic shape is explained by accumulations of particles from the A-ring of Saturn. This finding as well as geologic and electro-static analyses indicate that the surface of Atlas is covered by fine particles, which electro-statically levitate, migrate, and deposit to erase surface features, including craters. Such process is likely active on other small satellites of Saturn if they are 1) in the region outside the orbit of Titan, and 2) in the region that lies within A-, B-, and C-rings, including the orbits of Atlas and Pan. Also, this process might be important even for near-earth asteroids, especially if large amount of fine particles are supplied on their surfaces.

We consider this process is another example that the surface states of small bodies can be more active than relatively larger bodies, such as the Moon. In this talk, we will review the surface processes on the surface of small bodies and discuss their implications to the internal structures of asteroids. We also present the current status of our development of a Ground Penetrating Radar for future asteroid mission, which is probably the most effective way to explore the near-surface structures of asteroids.

Keywords: asteroid, Hayabusa, satellite, surface processes

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Search for Hayabusa Re-entry Capsule and Parachute after Landing by the Formosat-2 Remote Sensing Instrument

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Hayabusa is the Japanese asteroid sample return mission launched in 2003. The sampling capsule reentered the earth atmosphere at approximately 11.20pm 13th June (JST). The capsule was discovered around 23:56 p.m. and retrieved in the Woomera Protected area, Australia. at 16:08 on June 14th, 2010 (JST). The expected landing area was imaged by using Remote Sensing Instrument (RSI) on Formosat-2 satellite in the morning of Juln 13th and 14th to find the capsule and parachute on the ground. Several change detection techniques have been applied to the image pair, but no significant variation was found on the actual location of the capsule and parachute identified on the airborne images. We demonstrate from this experiment, however, that satellite imaging could be a contingency plan for capsule retrieval of future sample return missions if we utilize a space-borne sensor with sub-meter spatial resolution and accurate radiometric calibration.

Keywords: hayabusa, remote sensing, change detection, asteroid

Japan Geoscience Union Meeting 2011
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PPS022-09 Room:IC Time:May 27 08:30-08:45

Ejection Velocity and Angle of the Fast Ejecta from Impact of Small Bodies

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Ejection from impact between solid projectiles and targets has been investigated in laboratory with focus on the relationships between ejecta velocity and position and ejecta velocity and mass. Based on the laboratory data, the ejecta scaling laws are proposed. However, little is understood for relations of ejecta velocity and ejection angle versus impact velocity and impacting bodies.

We conducted impact experiments using two-stage light-gas guns at ISAS. We used rocks and nylon blocks which are easier to be vaporized. Projectile materials were metals, glass, and nylon. We took images of pre- and post impact using two high-speed cameras. Ejecta velocity and ejection angle measured from the surface normal to the targets were investigated on the images.

We found that the maximum ejection velocity increases with the initial shock pressure and is dependent upon projectile materials. There are no difference between the ejection velocity from the serpentine blocks and dunite rocks, i.e., no effect of dehydration of serpentine was found on the velocity of the fastest ejecta. Ejecta from the shots with nylon projectiles were faster than the theoretical limit of the solid ejecta. It suggests that nylon vapor probably accelerates the solid ejecta. The ejection angle decreases with initial shock pressure for some projectiles.

Keywords: small bodies, impact, ejecta, velocity

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PPS022-10 Room:IC Time:May 27 08:45-09:00

The measurements of restitution coefficient for glass beads at low collision velocity under microgravity.

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Some icy small bodies in the solar system have porous internal structure. Such porous structure may have been built through reaccumulation process of fragments once ejected by impact. In our previous study, we performed impact disruption experiments of porous sintered glass-beads targets and investigated the relation between static strength plus internal structure and impact strength of porous small bodies. Since restitution coefficient of the beads is one of the basic data for future numerical simulation of the impact process of sintered glass beads, we conducted measurement of the restitution coefficient under microgravity.

The experiments were performed twice at ZARM Drop Tower in Bremen on Nov. 12, 2010. There is a tube 110 m in height inside the tower. During the experiments the tube was evacuated under 10 Pa. In this work, we chose the catapult operation to obtain longer duration of 9.3 seconds under microgravity of 10^{-5} to 10^{-6} g. One of three pairs of sample folder and high-speed camera fixed in the sample chamber was used. The sample folder was filled with 32 beads of 4.7 mm in diameter. The collision images were taken through a beam splitter by the high-speed camera with frame rate of 500 frames/s and shutter speed of 1/5000 s. The restitution coefficient of the beads was obtained from the analyses of the images with two different projections and the calculation of collision velocity for each collision with the three-dimensional coordinate data.

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PPS022-11 Room:IC Time:May 27 09:00-09:15

A numerical model for the shape distribution of fragments in brittle targets

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Dynamic fragmentation is a complex physical phenomenon in many natural systems. The shape of fragments is one of the most interesting aspects of dynamic fragmentation. That is, in laboratory impact experiments, the shape of fragments over a broad size range is distributed around the mean value of the axial ratio 2: square root of 2: 1, which is independent of a wide range of experimental conditions. The shape distributions of the boulders on asteroid Eros and the small- and fast-rotating asteroids (diameter $<$200 m and rotation period $<$1h) are similar to those of laboratory fragments (Michikami et al., 2010). However, there are few studies to explain the shape distribution of fragments. No simple fragmentation model can reproduce the experimental shape distribution satisfactory. Many geometric approaches have focused on the size distribution of fragments. In this study, a geometric approach by numerical simulation has been performed, but we consider the effect of faults and the growth of cracks on the shape of fragments. Our model can reproduce the experimental shape distribution. The results show that the shape distribution is independent of target's shape, the growth of cracks and the number of inherent faults in the target.

Keywords: brittle target, shape of fragments, impact

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PPS022-12 Room:IC Time:May 27 09:15-09:30

Impact Experiments on High Porosity Sintered Targets: Penetration Depth and Track Morphology

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It is considered that primordial bodies in the solar system, such as planetesimals and comets, have high porosity. When small bodies or dusts impact those primordial bodies, the process of penetration, destruction or compaction should be controlled by the porosity, the strength, and the structure of target bodies.

We prepared high porosity targets, which are consists of soda-lime acid silicate hollow glass beads. We sintered this material to get targets with porosity of about 95%. The bulk density is ~0.14 g/cm3. First, the targets are impacted at low velocity (~250m/s) using a small light-gas gun at Kobe University. We determined the drag coefficient at low velocity (Okamoto et al. 2010, annual meeting of Japanese Society for Planetary Sciences). Then we conducted impact experiments at high velocity at ISAS using two-stage light-gas gun and high speed cameras. The impact velocities were ~2.5, 4.0, 7.0km/s. The projectiles were glass and titanium spheres.

We examined the penetration depth and track morphology by X-ray micro tomography at Osaka University. We develop a deceleration model of the projectile from both penetration depth data obtained by the tomography and those of the projectile velocity at the rear side of the target obtained by one of the high speed cameras.

Keywords: porosity, sinter, impact experiment

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PPS022-13 Room:IC Time:May 27 09:30-09:45

Micrometeoroid Flux inside 1 AU Heliocentric Distance Measured by IKAROS-ALADDIN

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IKAROS(Interplanetary Kite-craft Accelerated by the Radiation Of the Sun), a 20-m-across solar sail demonstration spacecraft was launched by H-IIA rocket in May 2010. As the world's first solar sail in deep space, IKAROS carries ALADDIN (Arrayed Large-Area Dust Detectors for INterplanetary space) dust detector made of 0.54 m^2 PVDF sensors which deploy on its 7.5 micron polyimide sail membrane. As the first deep space dust detectors developed and built in Japan, ALADDIN continuously measures dust flux in the viscinity of the Earth to that of Venus within its first 6-month cruising and now in its extended mission period. On its thin sail membrane, a large-area but still light-weight dust detector arrays made of 8 channels of 9-20 micron-thick PVDF were attached in order to count and time hypervelocity impacts by micrometeoroids larger than a few micron size during its interplanetary cruise. The sensors filter electronic, thermal and vibration noises and record time, peak hold value, and relax duration of signals of micrometeoroid impacts. Inside the orbit of the Earth (~1.0 AU) down to the vicinity of Venus (~0.7 AU), ALADDIN has measured abundant dust flux each of which separated by a 24-hour bin, thus enabling to discuss heliocentric dependency of the flux variation around >10^-12 g mass range in the finest detail among any previous spacecraft such as Helios-1/2 and Galileo. The ALADDIN dust flux in 2010 is generally consistent with flux trends of Helios in 1980's and Galileo in 1990's but some fine structures are observed.

Keywords: Micrometeoroids, In-situ Measurement, Solar Sail, Inner Region of the Solar System, Impact Flux

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PPS022-14 Room:IC Time:May 27 09:45-10:00

First results from the 2009-2010 MU radar head echo observation programme for sporadic and shower meteors: the Orionids

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The aim of this presentation is to demonstrate the capabilities of a new automated analysis scheme developed for meteor head echo observations by the interferometric Shigaraki Middle and Upper atmosphere (MU) radar in Japan (34.85 degrees N, 136.10 degrees E). Meteors, or colloquially shooting stars, are caused by particles from space that are heated up and shattered in the atmosphere. Meteor head echoes are radio waves scattered from the intense regions of plasma surrounding and co-moving with meteoroids during atmospheric flight.

Our analysis procedure computes meteoroid range, velocity and deceleration as functions of time with unprecedented accuracy and precision. This is crucial for estimations of meteoroid mass and orbital parameters, as well as investigations into meteoroid-atmosphere interaction processes. We collected an extensive set of data (>500 h) between June 2009 and December 2010. The data set contains both shower and sporadic meteor detections. Sporadic meteors are those that cannot be directly ascribed to a parent body. Sporadics are the most numerous among our observed particles, and the main contributors to the mass influx into the Earth atmosphere.

Here, we present initial results from data taken 2009 October 19-21. More than 600 of about 10 000 head echoes recorded during 33 hours were associated with the 1P/Halley dust of the Orionid meteor shower. The Orionid activity within the MU radar beam reached about 50 per hour during radiant culmination. The rate of sporadic meteors in the MU radar data, coming primarily from the direction of the Earth's apex, peaked at about 700 per hour during the same observations.

Head echoes of shower meteors are quite rare in modern high-power large-aperture (HPLA) radar data, primarily because sporadics outnumber shower meteors in the low-mass regime observable with these radar systems. The small collecting area of an HPLA radar system further limits successful observation of shower meteors. Analysis performed on a limited data set may, therefore, contain no or only a few shower meteors due simply to low statistical probability. In this work, we have estimated the MU radar collection area, calculated the flux of Orionid meteors, and show that the Orionid meteoroid stream activity could be accurately tracked with the MU radar when the radiant is at least 10 degrees above the local horizon.

Keywords: meteor, meteoroid, HPLA radar, head echo

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PPS022-15 Room:IC Time:May 27 10:00-10:15

Jovian impact flashes and their implication to small bodies

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Optical flashes on the surface of Jupiter were observed by amateur astronomers in June and August 2010. It is thought that these phenomena were bright meteors caused by the collision of small celestial bodies of a few to 10 m, and that they seemed to be more frequent than expected. If the frequency and the scale of these phenomena are investigated, the size distribution down to size of a few m can be decided at around the giant planet region. If the systematic observation is achieved, it will be a unique attempt to use the giant planets as a natural detector of small bodies.

The collision to the giant planets, especially the Jupiter is a phenomenon that often occurs as comet Shoemaker-Levy 9 in 1994. A trace of such impact was discovered by many amateur astronomers including Japan in July, 2009 (T. Mishina, in Astronomical Herald, August 2010). The follow up observation with Hubble Space Telescope etc. was promptly performed. It was presumed that it was a small body of about 500m-1km (A. S?nchez-Lavega et al. 2009, H. Hammel et al. 2010). Because this impact occurred in the opposite side, the impact flash was not observed. In June 2010, a optical flash of about two seconds in June, 2010 was caught by two amateur astronomers in Australia and the Philippines independently during their video observations of Jupiter. It is thought that this was caused by an impact of small body of about 8-13m diameter, without leaving any trace in the atmosphere (Hueso et al. 2010).

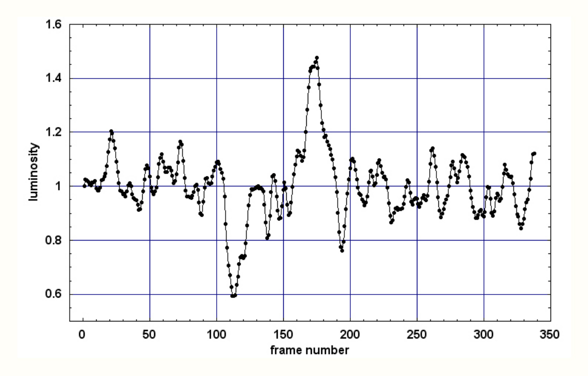
Only two month later, four amateur astronomers in Japan recorded a flash at 3h22m12s on August 21 (UT). The coordinate is 140.4 and +21.1degrees in system II. The duration was about two seconds, and the brightness was 6.2 magnitudes. This data is presumed to be an equivalent or slightly smaller scale than that in June.

In case of Earth, the brightness of meteors depends not only on sizes but also on the entry velocity. However, in the case of Jupiter, the entry velocity becomes almost similar value (60-64km per second) which is almost independent on the direction of the orbits of bodies because of the strong gravity of Jupiter. We do not have any uncertainty for estimating size of impacting bodies from the brightness of the flashes.

On the other hand, we have large uncertainty in the size distribution of small bodies in the giant planet region, because we cannot see directly any bodies of less than 1km. There is an unbridgeable gulf in the size distribution at 1km or less though presumptions from the crater count on the surface of the satellites. Estimation from the satellite of Uranus and Jupiter has one-order difference in 0.1km size. There is two-order or more difference compared to the size distribution extended from the trans-Neptunian objects (Zahnle et al. 2003). If we thinks only two samples observed in 2010, the collision probability of 10m size on the Jupiter becomes about 0.5-10 per year, somewhere between the size distribution presumed by the Crater count of the satellite of Uranus and by the trans-neptunian objects.

However, it should be a lower limit. By a systematic monitoring observation, we may have larger value. Anyway, this is certainly a powerful means that we can derive information on the distribution of the size of small bodies of 1km or less. The result may be a feedback to the Crater chronology. As for craters that remain on the surface of the planet in an internal region in the solar system, the size distribution is relatively consistent, but those in the icy satellites in the giant planets have wide variety, which suggests complicated processes. As for the meaning to make the understanding of the vicinity advance, the meaning of such phenomena is significant.

We try to construct a network of monitoring observations of Jupiter and Saturn together with skilled amateur astronomers, and to detect more small-scale impact flashes with large telescopes in order to investigate frequency and scale of such impact flashes.



Keywords: impact, flash, Jupiter, size distribution, Crater

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Dynamical Evolution of Haumea Collisional Family: General Properties and Implications for the Trans-neptunian Belt

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Recently, the first collisional family was identified in the trans-neptunian belt, thus revealing the importance of collisions between trans-neptunian objects (TNOs). The family consists of the dwarf planet Haumea and at least nine other ~100 km-sized TNOs. Here, we modeled the long term orbital evolution of an ensemble of family fragments over 4 Gyr. First, we obtained collisional families that reproduced the currently known Haumea's family. In particular, ninety percent of the fragments survived the integrations concentrated in wide regions with the following orbital element ranges: a ~ 6-12 AU, e ~ 0.1-0.15 and i ~ 7-10 deg. Most of the survivors populated the so called classical and detached regions of the trans-neptunian belt, whilst a minor fraction entered the scattered disk reservoir (<1%) or was captured in Neptunian resonances (<10%). In addition, the great majority of fragments displayed negligible long term orbital variations. This implies that the orbital distribution of the intrinsic Haumea's family can constrain the orbital conditions and physics of the collision that created the family billions of years ago. Finally, ~25-40% of the original Haumea family was lost due to planetary ejections or collisions over 4 Gyr.

Keywords: Edgeworth-Kuiper belt, Solar system, Haumea, Collisional family objects, Neptune, Trans-Neptunian objects (TNOs)