Japan Geoscience Union Meeting 2012
(May 20-25 2012 at Makuhari, Chiba, Japan)

PPS23-P01 Room:Convention Hall Time:May 24 17:15-18:30

Mission proposal for asteroid Phaethon

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A mission proposal for asteroid Phaethon and related asteroids is presented.

Keywords: Asteroid, Phaethon, comet, Solar system evolution, Geminid Meteor Stream

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PPS23-P02 Room:Convention Hall Time:May 24 17:15-18:30

Return to Itokawa: Impact experiment on the rubble-pile asteroid

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Asteroid Itokawa is a small rubble-pile body once explored by Hayabusa-space craft, and the only asteroid that the surface sample was returned to the Earth. So, we now accumulated a lot of scientific knowledge related to this asteroid, but simultaneously the more questions are raised and waiting to be solved. Then, we propose a new possibility for the exploration of Itokawa from the point of view of re-exploration and an impact experiment on the asteroid surface.

The purpose of this mission is to deeply understand the scientific knowledge that we obtained from Hayabusa mission by means of the re-exploration of Itokawa. There is a huge advantage for the re-exploration of Itokawa compared to the exploration of the first arrival asteroid. Because we already have a detail information of geography and gravity field on Itokawa, so we can select and optimize instruments for the measurements especially for Itokawa. In this re-exploration of Itokawa, we propose an impact experiment on the surface in order to clarify the impact physics on asteroid with very low gravity field and to study the internal structure of a rubble-pile body by means of this active exploration.

The impact experiment will be conducted by using a improved Small Carry-on Impactor (SCI) developed for Hayabusa 2 space-craft. In the case of Itokawa, we already know the surface geography, and so we can determine the impact point before the exploration exactly. The improved SCI should have a self controlled system for its posture and will impact the exact point with the precision of 10m. In this moment, Muses sea is the best candidate for the cratering experiment by the SCI to study the effect of gravity on the cratering process and construct a mechanical model of the subsurface layer of rubble-pile body. This result will be an anchor for the future impact study and it should be referred to extrapolate the laboratory study to the planetary scale impact.

The artificial impact crater by the SCI will be observed by a sub-satellite for in-situ observation equipped with cameras, a dust counter and a dust LIDAR. We also plan to use a penetrator equipped with a seismometer to observe a seismic vibration by the SCI impact. The three penetrators will be set on Itokawa surface to construct a network of the seismometers and they are used to analyze the internal structure of Itokakwa and to obtain the information of dynamics of granular materials under very small gravity field. In addition to the seismic observation, a radar investigation will be very effective to look through the interior of Itokawa. The sample return from Itokawa was already successful in Hayabusa, but the amount of the sample was not enough large to measure the physical properties of bulk sample. Therefore, we try to recover the sample from Itokawa surface for the study of the bulk physical properties, e.g. pebbles of Muses sea.

According to theses measurements, we will construct a physical model of planetesimal, which is a virtual body in the solar nebula with an internal structure like a rubble-pile body.

Keywords: Itokawa, re-exploration, Impact experiment, Hayabusa

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PPS23-P03 Room:Convention Hall Time:May 24 17:15-18:30

Exploration of Trojan asteroids and interplanetary dust complex by a solar sail mission

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"Asteroids couldn't grow up to be planets. Why?" This is one of the most fundamental and important question in planetary science. In order to answer this question, we need to study two problems, i.e.;

* Why did the collisional growth of planetesimals turn into disruption? Jupiter formation caused the transition?

* The effect of compositional variation of the planetesimal across the "snow line"

Therefore, Trojan asreoids are key objects, but traditional spacecraft cannot reach them without onboard radioisotope thermoelectric generators. In this presentation, we propose a solar sail mission to Trojan asteroids. In-situ and remote sensing observations of Interplanetary dust particles (IDPs) will be made en route. The "clear sky" free from IDPs beyond the asteroid main belt would enable us to observe the cosmic infrared background emission from early universe. This mission provides an ideal synergy of planetary science and astronomy.

Keywords: Solar sail, asteroid, comet, Interplanetary dust

Japan Geoscience Union Meeting 2012
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PPS23-P04 Room:Convention Hall Time:May 24 17:15-18:30

Elemental analysis instrument for landed lunar and planetary explorations: Laser-induced breakdown spectrometer (LIBS)

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In general, lunar and planetary explorations are carried out through the processes of remote sensing by orbiting satellites, in-situ observation by landers and rovers, sample return, and manned exploration. Lunar and planetary explorations of each country will shift to a sample return phase. However, the results of past remote-sensing explorations show that moons and planets in the solar system have complicated and various surfaces. This clearly indicates that we cannot know the origin and evolution of a planetary body from a sample that is recovered from anywhere on it. The necessity of in-situ observations by landing to multiple sites and the importance of understanding the geological context of landing sites are suggested from the experience of the past planetary explorations, especially the landed explorations on Mars. Therefore, a landed geological exploration as a prior phase of sample return is indispensable. In such a case, a wide range of movability by a rover with a quick and efficient elemental analysis method is necessary. Laser-induced breakdown spectrometer (LIBS) is an elemental analysis instrument that is appropriate to such lunar and planetary surface explorations.

The measuring principle of LIBS is as follows: Samples are irradiated with pulsed laser beams in order to generate plasmas of a small amount of a sample. When atomic and ionic species excited in the plasmas are deexcited, the emission of lights occurs according to the difference in energy levels before and after the deexcitation. These lights are measured with a spectrometer as emission lines on spectra. The wavelength of emission lines is unique to each element, and the intensity of emission lines is correlated with the elemental abundance. Both qualitative and quantitative analyses, such as elemental abundance determination and mineral classification, are carried out by analyzing the acquired spectra.

LIBS has several advantages such as (i) capability of remote analysis (up to ten meters or more depending on laser intensity), (ii) rapid data acquisition (a few second to a few minutes), (iii) ability to analyze almost all elements including light elements, (iv) high spatial resolution (several tens to several hundred of micrometers), (v) unnecessity of sample preprocessing, and (vi) unnecessity of an radiation source. On the other hand, LIBS have a weak point of slightly worse determination precision than other elemental analysis methods usually used. However, recent studies show that the use of multivariate analysis methods such as partial least squares regression as a spectral analysis method improve the determination precision.

LIBS is basically composed of a laser, a spectrometer, and optical system. Various configurations are possible according to the size of a landing explorer (a rover or a lander) or the objective of an exploration. For example, "Measured-distance-variable remote LIBS", in which focusing of both the laser beams and emitted lights are conducted through a measured-distance-variable telescope, can measure distant samples. Rapid data acquisition for multiple samples is possible without moving a rover or a lander. Since this configuration requires a telescope with large diameter lens, a drive mechanism for the telescope, and a laser with high output power, the size and weight of this type of LIBS tends to be large. "Measured-distance-fixed near LIBS" measures samples with small laser and simple optical system equipped on a robot arm of a rover or a lander. Since neither a telescope with large diameter lens nor drive mechanism for the telescope are needed, this type of LIBS can be small and lightweight.

LIBS exerts its capability when it is equipped on a rover. Rapid analysis of distant samples makes the selection of interesting sites where a rover moves to possible. In a future sample return mission LIBS will be a suitable instrument for searching appropriate samples to recover.

Keywords: elemental analysis, geological exploration, planetary exploration, LIBS, Moon, Mars

PPS23-P05 Room:Convention Hall Time:May 24 17:15-18:30

Operataion test of LIBS onboard lunar and planetary rover

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We are developing Laser Induced Breakdown Spectroscopy (LIBS) instrument for lunar and planetary exploration. We manufactured a prototype model in 2011. It is composed of a high-energy pulse laser, optics for focusing light at the surface of the target, an image sensor, and spectrograph. We attended the field roving test of one of the prototype of lunar and planetary exploration rover, Micro-6 at the top of Mt. Aso in Kumamoto from 7 to 9 in November, 2011. We used a prototype LIBS model without a pulse laser to demonstrate the performance of auto-focus mechanism because there are many tourists and we had to avoid injuring their eyes without eye-safe glasses. After that, we performed the test with a high energy pulse laser with mini-rover in the room in Sagamihara campus of ISAS/JAXA We confirmed that it is difficult to install the LIBS on the gimbal at the top of the mast of the rover because of its weight and the data rate is too low to control our prototype. In this presentation, we report our test result and introduce the renewed design of LIBS for lunar and planetary exploration.

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PPS23-P06 Room:Convention Hall Time:May 24 17:15-18:30

Development of an in-situ K-Ar dating instrument for landing planetary missions

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We propose an instrument that conducts the in-situ age measurement of rocks during landing missions. The absolute age of a geological unit is one of the most important information for the planetary science. However, the absolute chronology of Mars is poorly constrained due to the lack of directly dated samples. The uncertainty is as large as 1 billion years, preventing us from quantitative understandings of the Martian history. In order to obtain accurate and precise age, sample return missions are of course ideal but such a mission must face many technical challenges and huge budget as compared to sending a robot to the planet. Additionally, sampling place will be limited because of the cost. Therefore the main goal on Mars mission is to the calibrate absolute chronology by in-situ age measurement on Mars.

Our interest also includes future lunar landing missions. One of the most important objectives is that contribution to the sample-return mission from the Moon because such a mission is more realistic than that of Mars. Our instrument will be able to provide information whether a rock underwent resetting event after its formation. We can choose primitive rock samples on the Moon, maximizing the scientific value of the sample return mission.

The instrument determines the K-Ar age of rock samples on a rover in the following way. Laser-induced breakdown spectroscopy (LIBS) and quadrupole mass spectrometry (QMS) are coupled with each other to measure K and Ar, respectively, and it is named LIBS-QMS system. The instrument consists of a vacuum chamber, pulsed laser, an X-Y stage, a CCD camera to observe the measured site, a spectrograph, a QMS, a getter to purify the extracted gas, and a vacuum pump, which is unnecessary for lunar missions. An outstanding feature is that the spot analyses using laser beam enable isochron measurements, which improves the accuracy and precision of age determination.

In order to establish the K-Ar in-situ dating instrument, the following items need to be achieved: (1) improving the accuracy of K measurement by overcoming the matrix effect, (2) improving the detection limit for both K(~1000 ppm) and Ar(^{40}Ar~10^{-11} cc, ^{36}Ar~2x10^{-11} cc) by an order of magnitude, and (3) inventing proper sample handling system, that is, how to pick up rocks, put them into the vacuum chamber, and how to measure them.

We show the current strategy to resolve such issues. First, the matrix effects are shown to be removed to some extent by the multivariate analytical techniques (e.g., partial least squares regression method, neural network analysis). Such statistical techniques will be introduced to our signal processing method. Secondly, we have improved the experimental conditions by optimizing the light collection system in order to enhance the observed intensity of K emission lines. We also replaced our previous detector system, which consisted of a 75 cm spectrograph and an ICCD camera, to a compact spectrograph (~ 500 g in weight) equipped with an ordinary CCD detector. Our preliminary experimental results show that the K emission lines from ~4000 ppm K2O sample are detected by such spectrographs. Improving the limit of detection by an order of magnitude seems to be possible. To improve the detection limit of Ar, the conditions of laser beam (e.g., beam diameter, pulse energy, and beam profile) are required to be optimized. Reducing the blank level of QMS is essential as well. We are now building an oil-free exhaust system. The sensitivity of QMS will be enhanced by reducing the volume of the vacuum system. Finally, the sample handling procedures will be considered with some experts in this area. We are going to establish our method in 2012 and build a compact breadboard model by the end of 2013.

Keywords: In-situ dating, K-Ar dating, Landing mission, LIBS-QMS

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PPS23-P07 Room:Convention Hall Time:May 24 17:15-18:30

Equipments for life search exploration on Mars

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Among the planets and giant satellites in our solar system, the characteristics of Mars are most similar to those of Earth. This may suggest that it may be possible for life similar to terrestrial life to arise and to survive on Mars.

Here we propose a new life detection project on Mars to search for methane-oxidizing microbes by fluorescence microscopy combined with amino acid analysis and mass spectrometry. We propose to search for cells from a depth of about 5 - 10 cm below the surface, which is feasible with current technology. Microscopic observation can be done using low mass equipment with low electric power consumption, and has the potential to detect single cells. The subsequent analysis of amino acids will provide the in-formation needed to define the origin of the cell.

Keywords: Mars, Life search, Fluorescence microscope, Amino acid analysis, Mass spectroscopy, Methane oxidizer

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PPS23-P08 Room:Convention Hall Time:May 24 17:15-18:30

Investigation of Martian surface and interior structure by penetrator probe

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We propose a mission to investigate the Martian surface environment and internal structure by multiple instrumented penetrator probes. The Mars penetrator has two parts, a slender forebody and finned afterbody, connected by an umbilical cable. At the impact, the forebody penetrates into the surface material, whereas the afterbody remains on the surface with a flared terra-brake. As for scientific instruments, a slightly broadband seismometer, thermal conductivity sensor, gamma-ray sensor, and water-detection sensor are housed in the forebody together with most of the electronics parts and a battery package for power supply. A meteorological sensor package and a radio source for geodetic experiment are installed in the separated afterbody. For the purpose of a long-lived geophysical observation, solar panel arrays might be stuck on the facets of flared structure. In addition, the atmospheric density, pressure and temperature will be derived using entry and descent data, and then, an accelerometer profile will be used to determine the impact velocity, depth of penetration and the mechanical properties of surface layers at impact site. The four identical penetrators will land within 100 to 300 km of each other on the Elysium region or Tharsis province; the former is assumed to be most recently active in volcanism, the latter is located in a vast fault zone. Both the two candidate sites have not yet been landed by soft-landers. Primary goal is to demonstrate the penetrator technology that will enable future science missions and, in particular, geophysical network observations. Secondary goal is to determine the seismicity of Martian interior as well as meteoroid impact flux. Third, a continuous monitoring of surface environment(atmospheric temperature, pressure and magnetic field) is essential for the analysis of seismic data and for the advanced design of future geophysical instrument package. After separation of penetrators, the orbital spacecraft will fly over daily and communicate with each penetrator probe for data-relay and measurement of libration parameters of Mars. And also, An impact monitoring camera onboard the spacecraft would detect a number of impact craters and landslides occurred during the mission operation and we could make good use of imaging data in 1~10 meter scale as known locations of Mars quake foci in order to investigate the crust/upper mantle structure.

Keywords: Mars, Surface enviroment, Internal structure, penetrator

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PPS23-P09 Room:Convention Hall Time:May 24 17:15-18:30

Development of optical seismometers for observations at extreme environments

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Seismic observation is useful for investigating interior structure of the Moon and planets. Especially for global structure including deep structure, broadband seismic observation is required. Although short-period seismometers have been used for seismic surveys in the Moon and Mars, broadband seismometers on the surface environment would open up new interior information. Similarly on the earth, broadband seismometers in the deep borehole enable us to observe near a seismic region at low background-noise environment. Hence, broadband seismometers for extreme environment in temperature, cosmic rays, limited power/space, and impact by launch/installation would be essentially required for future seismic surveys. For this purpose, we have been developing optical seismometers that can be used at extreme environment; a laser interferometer, which can operate in such environment, senses pendulum motion with high sensitivity.

We developed a prototype (dimension: W200mm H210mm D115mm) and have confirmed its stable operation, broadband performance (1mHz-50Hz), and self noise level. Optical fibers are used to transmit laser light. In parallel, we have carried out a high-temperature test for the laser interferometer, and confirmed normal operation up to 290 degrees centigrade.

Currently, we have started making a smaller model and developing an automatic operation system. Because optical sensors can be operated in various environments with flexible configuration, they are also useful for planetary explorations on Venus, Mercury, icy satellites of outer planets at extreme temperatures.

Keywords: seismometer, broadband, planetary exploration, laser, interferometer