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

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Instrument overview and Japanese contribution to the development of Submillimetre Wave Instrument (SWI) aboard Jupiter

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The Submillimetre Wave Instrument (SWI) is a very high spectral resolution, dual band (600 and 1200 GHz) instrument proposed to form part of the scientific payload instruments for the JUpiter Icy Moons Explorer (JUICE) mission. It will measure atmospheric temperature, winds, water vapor, methane and numerous other molecules with its high-resolution spectrometers on Jupiter, Ganymede, Callisto, Europa and Io.

The SWI is a passive heterodyne microwave spectrometer sensitive for radiation in the two frequency bands of 530-601 GHz and 1082-1271 GHz. Radiation is received through a submillimetre telescope with 30 cm aperture diameter, providing a spatial resolution of 400 and 200 arcseconds (FWHM) at 600 and 1200 GHz, respectively. Two independent double sideband receivers are used to obtain simultaneous observing capability in the two frequency bands. Each receiver is connected to its own high-resolution chirp transform spectrometer (CTS), providing a total bandwidth of 1 GHz at 100 kHz resolution. To allow a larger bandwidth coverage at lower resolution for surface emission measurements of Jupiter's satellites, SWI is equipped with two autocorrelation spectrometers (ACS) (5 GHz bandwidth, programmable 256, 512, 758 or 1024 channels) and two continuum detectors (5 GHz bandwidth) as well. For radiometric calibration, the SWI instrument uses an internal blackbody as hot reference load and the cold sky as external cold reference load. The hot reference load is coupled into the beam internally via a calibration flip mirror. The cold sky is viewed by turning away the telescope from Jupiter respective the satellite under investigation.

Japanese team is responsible for the development of telescope unit consisting of antenna, scanning mechanism, and actuator control for SWI. In this poster, current idea and design of the telescope unit are briefly summarized.

The telescope consists of an off-axis parabolic primary mirror together with a hyperbolic secondary mirror (Cassegrain configuration). It is very similar to the design of the telescope for the MIRO instrument onboard of the Rosetta spacecraft. However, the surface accuracy of the primary reflector for SWI needs to be at least twice as good than for the MIRO reflector, because SWI observes in band 2 within a frequency range with approximately half the wavelength than at 557 GHz.

The actuator control electronics will control the movements of the 3 mechanisms (rotation of primary mirror, tilt of telescope sub-unit and movement of the calibration flip mirror). Radiation hard components will be used.

The design of the scanning mechanism is critical and thus still preliminary. The requirement is to have a pointing step size of less than 30 arcseconds, but to achieve a pointing knowledge of 5 arcseconds. To save mass the baseline approach is not to use an appropriate absolute angular encoder, but instead to aim mechanically for a 5 arcsecond step size and then to count steps relative to a single reference position. A dedicated test model for just the mechanism will be built to demonstrate the feasibility of this concept and to move the decision point for including an angular encoder (adds additional mass) as far as possible towards early phase of the instrument development phase.

Keywords: Jupiter, submillimeter sounder, JUICE

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Development of charged particle instruments for JUICE/CEPAGE and beyond

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JUICE (JUpiter ICy moon Explorer) is a mission to Jupiter for the exploration of Jovian system including magnetospheric dynamics and plasma interaction with moons' surface/atmosphere/ionosphere. The spacecraft is supposed to accommodate scientific instruments for imaging, spectroscopy, sounders/radio sciences, and field and particles. The French institute IRAP leads the CEPAGE consortium (ChargEd Particle Analysers for Galilean Environments) to deliver a charged particle instrument package, in response to ESA's AO. This consortium is an international collaboration among several countries including Japan, and ISAS/JAXA will deliver a high-energy particle analyser (HEP) and a part of a low-energy ion mass analyser (ISATIS). We have designed each instrument in detail so as to meet scientific goals for JUICE. Furthermore, since the design concept is toward broad application for limited spacecraft resources (such as small mass requirement and non-spin attitude control), we consider these instruments/techniques can be applied to various future explorations.

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Accretion of Solid Materials onto Circum-Planetary Disks

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Regular satellites of the giant planets in our solar system are believed to be formed in circum-planetary disks around the planets during the final stage of the formation. Recent hydrodynamic simulations have revealed that gas disks around giant planets are inevitably formed in the course of gas accretion growth phase. However, in order to form satellites, solid materials are necessary in the gas disks and thus should also be accreted onto the circum-planetary disks from proto-planetary disks.

In this study, we performed orbital simulations of solid particles which is rotating in heliocentric orbits in order to investigate accretion efficiency onto circum-planetary disks under the influence of gas accretion flow. We found that the accretion efficiency of the solid particles peaks around 10m-sized particles because energy dissipation of drag with circum-planetary disk gas in this size regime is most effective. The efficiency for particles larger than 10m size becomes lower because gas drag becomes less effective for larger particles. For particles smaller than 10m, the efficiency is lower because the particles are strongly coupled with the back-ground gas flow, which prevent from accretion. We will discuss satellite formation process based on the obtained accretion efficiency of solid particles.

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Transferring Near Earth Objects (NEOs) into a spacecraft for manned interplanetary exploration

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How will human can go beyond Mars to explore Jovian system and finally to reach to the Saturnian moon Titan, to search for life, on which several critical issues of manned interplanetary mission such as ECLSS supporting capability, food and water acquisition, propellant refuel, etc.?

Near Earth Objects or NEOs are comets or asteroids which have potential orbital intersection and closely approach to Earth. Despite many precursor researches have concluded that Near Earth Objects can be future resources of raw materials for building interplanetary spacecraft, this paper indicates utilizing Near Earth Objects itself would a possible transportation vehicle with habitat for manned interplanetary mission due to its plenty in amount and abundant resources (e.g. water ice, rare metals, etc.). Advantages of this proposal are: (a) To procure water by mining ice on NEOs surface or interior for human life support and ECLSS management.; (b) To obtain sufficient Hydrogen and any other possible substances for propellant needs; (c) The paper especially focus on designing of a habitat space by using regolith for an expedition crew (4 to 6 persons) on which NEOs provide efficient surface area to do so. Also, using regolith may provide a solution for cutting cosmic ray causing harmful result to human body while during interplanetary flight.

Candidate model is particularly to pick up an object from a branch of NEOs: Potential Hazardous Objects, known as their Minimum Orbit Intersection Distance (MOID) less than 0.05 AU, shorter period and relatively easily recognized by its high absolute magnitude. Although these celestial bodies have certain possibility to collide to Earth, we are currently monitoring and tracking their positions to ensure they will not come too close for sever damage. This technology may be helpful to locate suitable objects to meet our goal.

Mission profile is considered: (a) Sending a core module with a crew of 4 to rendezvous with PHOs target; (b) Mining and surface modification will be an on-site process, meanwhile, to produce propellant fuel and necessary material for plants to grow (e.g. food) and potable water; (c) During its flyby to Earth, new modules and crew are launched to rendezvous with the asteroid to extend habitat space; (d) To alter its orbit into Hohmann Transfer Orbit to proceed interplanetary flight course. Detailed sequence of asteroids selection and habitat design is included in full paper.

In this paper, reveals that transferring NEOs (near Earth comets or asteroids) into manned interplanetary exploration vehicle would be much reasonable not only is an alternative solution for avoiding designing massive space ship, carrying enormous amount of supplies (i.e. water, food) is unnecessary and cost reducible, but also it opens up a new possibility to procure asteroid resources for human space exploration purpose. This proposal is based on in-situ (in situation) methodology from technology readiness level of space architecture development progress.

In summary, although this research also points out issues that remain to be discussed in near future, it helps to establish further strategies to shape and to achieve certain goals on multidisciplinary efforts.

Keywords: NEOs, Asteroid mining, Human interplanetary exploration, ECLSS, Space settlements

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Short-term intense burst of Saturn's radio emission: Its relationship to the rotation phase and north-south difference

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This paper presents characteristics of short-term intense bursts of Saturn kilometric radiation (SKR) from 2005 to 2006 with the separation between northern and southern SKR. Our result shows the dependence of SKR bursts on rotational modulations of Saturn. This suggests that the internal process of the Kronian magnetosphere mainly drives SKR bursts. We also discovered that most of northern and southern SKR bursts occur independently of one another.

SKR is generated by electron beams accelerated along the auroral field lines via cyclotron maser instability, like auroral kilometric radiation (AKR) at Earth. Since this radiation is emitted at near the local electron cyclotron frequency in their source, the altitude of the radio source can be derived from the spectra. At Earth, AKR spectra show the bursty variations characterized by a sudden increase of the main emission with the extension of their spectra down to lower frequencies, associated with substorms (magnetic reconnection) driven by external (solar wind) drivers. It means that the occurrence of such variations is independent of the terrestrial rotation phase. SKR shows the similar short-term bursts like AKR although they occur on a longer time scale (several hours). In the case of Saturn, its magnetotail activities are affected by both external and internal (planetary rotation) drivers [Cowley et al., 2004]. Jackman et al. [2009] suggested the link between the SKR rotational modulations and the magnetotail reconnections. On the other hand, SKR has the rotational modulations with north-south asymmetric periods [Kurth et al., 2008; Gurnett et al., 2009]. There should therefore be some difference between northern and southern SKR bursts if they reflect strength of the field-aligned current system with distinct two rotational periods in each hemisphere [Andrews et al., 2010].

In this study, we examined the relationship between the short-term intense bursts and the SKR rotational phases with northern and southern SKR spectra observed with the Radio and Plasma Wave Science [Gurnett et al., 2004] on board Cassini spacecraft from 2005 to 2006. During this period, Cassini was traveling in an equatorial orbit, which is suitable to receive radio emissions from both northern and southern polar region. Northern and southern SKR phases are defined based on rotational modulations of SKR from each hemisphere [Lamy, 2011]. We selected 17 short-term intense bursts in northern SKR and 36 in southern SKR with the criteria, which consist of the followings: (1) SKR flux densities at low frequencies and (2) SKR total power must be significantly higher than median values of those during about 60 hours before and after the time of an SKR burst. (3) There must be no spectral gap between SKR main and lower-frequency bands. The result shows that more than 60 percent of bursts took place around time when northern or southern SKR phase was from 300 to 60 degrees, respectively. It clearly suggests that the short-term SKR bursts occur in synchronization with SKR rotational modulations, and supports the result by Jackman et al. [2009]. We suggest that the internal process of the Kronian magnetosphere mainly drives SKR bursts. On the other hand, we got the result that only six pairs of northern and southern SKR bursts we identified took place almost simultaneously (within two hours), that is, there is an asymmetry between northern and southern SKR bursts.

We are also investigating the SKR bursts independent of the rotation, which should be driven by the external (solar wind) effects. In addition, we will compare the results obtained during the southern summer with those after the equinox in 2009 to examine the effect of the long-term variations of SKR. These analysis results will be also presented.

Keywords: Saturn, Saturn kilometric radiation, low-frequency extension, Cassini