EXPLORATION OF DEEP INTERIOR OF THE MOON FROM MEASUREMENTS OF CHANGES OF LONG-WAVELENGTH GRAVITY AND ROTATION. S. Sasaki, F. Kikuchi[1], K. Matsumoto[1], H. Noda[1], H. Araki[1], H. Hanada[1], R. Yamada[1], S. Goossens[1,#], H. Kunimori[2], T. Iwata[3], N. Kawaguchi[1], Y. Kono[1] , [1]National Astronomical Observatory of Japan 2-12 Hoshigaoka, Mizusawa, Oshu 023-0861 Japan (sho@miz.nao.ac.jp), [2]NICT, Koganei, Japan, [3] ISAS/JAXA, Sagamihara, Japan, [#]Now at Goddard Space Flight Center/NASA, USA.

Introduction: Precise measurements of gravity and rotation of planets as well as seismic measurement are important for the discussion on their deep interior. The Moon revolves around the Earth once in a month synchronously with its rotation. It is tidally deformed by the Earth, which would excite irregular motion of the lunar rotation with small amplitude, which is called forced librations. Additionally, free libration is excited by impacts, liquid core, and orbital resonance. Dissipation of the libration terms of lunar rotation may depend on the interior structure of the Moon, especially the state of the core and lower mantle [1, 2]. Effect of tidal deformation can be detected by low-degree gravity change, although surface height change is as small as 10cm. Long-term (> a few months) gravity measurements can provide information of the lunar tidal deformation. One important scale of tidal deformation is degree 2 potential Love number k_2, which could constrain the state of the core (solid or liquid) and viscosity of the lower mantle of the Moon [3].

VLBI gravity measurement: In KAGUYA (SELENE) mission, multi-frequency differential VLBI observations (S/X bands) are used for the precise determination of orbits of satellites leading to increase in the accuracy of lunar gravity field [4]. However, the accuracy of low-order gravity and its change are limited. The same-beam VLBI observation is only possible when the separation angle between the two radio sources is smaller than the beamwidth of the ground antennas. The relatively large shape of Rstar's orbit (100 km x 2400 km) did not allow the same-beam observation all the time.

SELENE-2 is planed as a follow-on mission of KAGUYA. The spacecraft is to be launched in 2010's. SELENE-2 lands on the nearside of the Moon and investigates the surface and the interior of the moon. In SELENE-2 mission, we will have VLBI radio (VRAD) sources both in the lander and the orbiter. Vstar-like orbit (100 km x 800 km) will almost always keep the separation angle smaller than the S-band beamwidth of domestic VERA stations since one of the radio sources is fixed on the near-side lunar surface. Also, for continuous tracking of the orbiter both by S and X bands, we started development of two-beam S/X receivers which will allow larger separation angle between radiosources.

The k_2 is sensitive to the state of deep interior. When the core radius is 350 km, k_2 changes by about 5% between liquid and solid cores. Using same-beam (or two-beam) multi-frequency VLBI observation of , we will determine orbits of the orbiter precisely, measure low-order gravity changes, and estimate k_2 with uncertainty below 1%. If the core size is constrained by SELENE-2 seismometer, contributions of lower mantle and core on k_2 would separated.

LLR: We also propose a Lunar Laser Ranging (LLR) reflector on SELENE-2 lander. Instead of conventional corner cube reflector (CCR) array, we plan a larger single reflector in SELENE-2. The new reflector should be somewhere in the southern hemisphere on the nearside Moon. With pre-existed reflectors, latitudinal component of lunar libration and its dissipation can be measured precisely. The dissipation between the solid mantle and a fluid core was discussed. LLR observation has also provided information of moment of inertia and tidal Love number of the Moon. However, among LLR parameters, k_2 and core oblateness is coupled. Once k_2 is fixed, we can determine core oblateness, which would also constrain the core and lower mantle states.

ILOM (In-situ Lunar Orientation Measurement) The ILOM is an experiment to measure the lunar physical librations on the Moon with a star-tracking small telescope [2]. Since observation of ILOM is independent of the distance between the Earth and the Moon, the effect of orbital motion is clearly separated from the observed data of lunar rotation. This is the advantage of ILOM over the ground-based methods such as LLR and VLBI. The crucial issue that should be overcome is the survival of lunar night and thermal effect of solar illumination on the zenith tube.

References: [1] J. G. Williams et al. (2001) *JGR* **106** 27933-27968. [2] H. Hanada et al. (2005) *Proc. Int. Ass. Geod.* Springer, pp.163-168. [3] K. Matsumoto et al., (2011) Geophysical Research Abstracts 13, EGU2011-2032-1. [4] S. Goossens, et al. (2011) J. Geodesy, 85, 205-228.