

VLBI mission proposed for SELENE-2 and its contribution to constrain the lunar internal structure

MATSUMOTO, Koji^{1*}, KIKUCHI, Fuyuhiko¹, Sander GOOSSENS², KAMATA, Shunichi⁴, IWATA, Takahiro³, HANADA, Hideo¹, ISHIHARA, Yoshiaki¹, YAMADA, Ryuhei¹, SASAKI, Sho¹

¹National Astronomical Observatory of Japan, ²NASA Goddard Space Flight Center, ³JAXA, ⁴University of Tokyo

Internal structure and composition of the Moon provide important clue and constraints on theories for how the Moon formed and evolved. The Apollo seismic network has contributed to the internal structure modeling. Efforts have been made to detect the lunar core from the noisy Apollo data (e.g., [1],[2]), but there is scant information about the structure below the deepest moonquakes at about 1000 km depth. On the other hand, there have been geodetic studies to infer the deep structure of the Moon. For example, LLR (Lunar Laser Ranging) data analyses detected a displacement of the lunar pole of rotation, indicating that dissipation is acting on the rotation arising from a fluid core [3]. Bayesian inversion using geodetic data (such as mass, moments of inertia, tidal Love numbers k_2 and h_2 , and quality factor Q) also suggests a fluid core and partial melt in the lower mantle region [4]. Further improvements in determining the second-degree gravity coefficients (which will lead to better estimates of moments of inertia) and the Love number k_2 will help us to better constrain the lunar internal structure.

Differential VLBI (Very Long Baseline Interferometry) technique, which was used in the Japanese lunar exploration mission SELENE (Sept. 2007 - June 2009), is expected to contribute to better determining the second-degree potential Love number k_2 and low-degree gravity coefficients. In SELENE, the VLBI radio sources (called VRAD) were on board the two sub-satellites, Rstar and Vstar. The differential VLBI data, when both the radio sources were within the beam-width of the ground antennas, were of particular importance because they are highly accurate with atmospheric and ionospheric disturbances almost cancelled out by the simultaneous observation. Such tracking data, i.e. "same-beam differential VLBI data" were useful for precision orbit determination [5] and also used to develop an improved lunar gravity field model SGM100i [6].

SELENE will be followed by the future lunar mission SELENE-2 which will carry both a lander and an orbiter. We propose to put the VRAD-type radio sources on these spacecraft in order to accurately estimate k_2 and the low-degree gravity coefficients. By using the same-beam VLBI tracking technique, these parameters will be retrieved through precision orbit determination of the orbiter with respect to the lander which serves as a reference. The VLBI mission with the radio sources is currently one of the mission candidates for SELENE-2.

We have conducted a preliminary simulation study on the anticipated k_2 accuracy. With the assumed mission duration of about 3 months (84 days) and the arc length of 14 days, the k_2 accuracy is estimated to be better than 1 %, where the uncertainty is evaluated as 10 times the formal error considering the errors in the non-conservative force modeling and in the lander position.

Through forward model calculation, we will show that the k_2 error as small as 1 % is sensitive enough to the change in the liquid core radius of about +/-40 km. We will also show that the k_2 accuracy has sensitivity to possible partial melt layer and contribute to narrow the range of the plausible internal structure models. Although k_2 by itself can not distinguish the effect of core size from that of partial melt layer, it is expected that the combination with other geophysical data such as seismic data as well as geochemical data will establish a realistic lunar interior model.

References

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