Available online at www.sciencedirect.com
ScienceDirect
Advances in Space Research 42 (2008) 341–346
ADVANCES IN SPACE RESEARCH
(a COSPAR publication)
www.elsevier.com/locate/asr

VLBI for better gravimetry in SELENE

H. Hanada [a,*], T. Iwata [b], N. Namiki [c], N. Kawano [a], K. Asari [a], T. Ishikawa [a], F. Kikuchi [a], Q. Liu [a], K. Matsumoto [a], H. Noda [a], S. Tsuruta [a], S. Goossens [a], K. Iwadate [a], O. Kameya [a], Y. Tamura [a], X. Hong [d], J. Ping [d], Y. Aili [e], S. Ellingsen [f], W. Schlüter [g]

[a] *National Astronomical Observatory of Japan, 2-12 Hoshigaoka, Mizusawa, Oshu, Iwate 023-0861, Japan*
[b] *Japan Aerospace Exploration Agency/Institute of Space and Astronautical Science, 3-1-1 Yoshinodai, Sagamihara, Kanagawa 229-8510, Japan*
[c] *Kyushu University, 6-10-1 Hakozaki, Higashi-ku, Fukuoka 812-8581, Japan*
[d] *Shanghai Astronomical Observatory, Chinese Academy of Sciences, 80 Nandan Road, Shanghai 200030, China*
[e] *Urumqi Astronomical Observatory, Chinese Academy of Sciences, No. 40-5 South Beijing Road, Urumqi, Xingjiang 830011, China*
[f] *University of Tasmania, Private Bag 37, Hobart, Tasmania 7001, Australia*
[g] *Bundesamt für Kartographie und Geodäsie, Fundamentalstation Wettzell, D-93444 Kötzting, Germany*

Received 31 October 2006; received in revised form 25 October 2007; accepted 1 November 2007

Abstract

The Japanese lunar explorer SELENE (SElenological and Engineering Explorer), to be launched in 2007, will for the first time utilize VLBI observations in lunar gravimetry investigations. This will particularly improve the accuracy to which the low degree gravitational harmonics and the gravity field near the limb can be measured, and when combined with Doppler measurements will enable three-dimensional information to be extracted. Differential VLBI Radio sources called VRAD experiment involves two on-board sub-satellites, Rstar and Vstar. These will be observed using differential VLBI to measure the trajectories of the satellites with the Japanese network named VERA (VLBI Exploration of Radio Astrometry) and an international VLBI network.

We will use a multi-frequency VLBI method to measure the angular distance between the two sub-satellite radio sources Rstar and Vstar. The observations will be at three frequencies in S-band, 2212, 2218 and 2287 MHz, and one in X-band, 8456 MHz. This method uses low power consumption carrier waves, and is suitable for the positioning of spacecraft. The Japanese domestic VLBI network, VERA, will conduct VLBI observations for the whole mission period of one year. In addition, we will conduct two periods of intensive observations, each one month in duration, which will also include the international stations, Shanghai, Urumqi (China), Hobart (Australia) and Wettzell (Germany). These observations will measure the phase delay to an accuracy of better than 0.17 rad (10 deg) in X-band. For a baseline length of 2000 km this is equivalent to a positioning accuracy of about 20 cm on the Moon. Combining the data from the tracking of the 3 SELENE satellites (main orbiter, Rstar and Vstar) at different altitudes and from four-way Doppler measurements, and by making long term observations of the sub-satellites (in excess of one year without any maneuvering), we will be able to improve the accuracy to which the lunar gravitational field is known by an order of magnitude.

We have completed the development of on-board instruments, and are carrying out pre-flight tests under a variety of conditions. We have also undertaken test VLBI observations of orbiters such as Geotail, Nozomi and Smart-1 with the international network.
© 2007 COSPAR. Published by Elsevier Ltd. All rights reserved.

Keywords: SELENE; Lunar gravity field; VLBI

1. Introduction

Measurements of the gravity field of the Moon and planets allow us to study their interior, whereas remote sensing observations, with the exception of magnetome-

* Corresponding author. Tel.: +81 197 22 7149; fax: +81 197 25 6619.
E-mail address: hanada@miz.nao.ac.jp (H. Hanada).

0273-1177/$34.00 © 2007 COSPAR. Published by Elsevier Ltd. All rights reserved.
doi:10.1016/j.asr.2007.11.003

ters or radar sounders only probe surface or near-surface properties. Recent advances in lunar gravity field modeling have come from (1) reanalysis of historical data using more modern computational techniques (Konopliv et al., 1993; Lemoine et al., 1997) and precise force and measurement modeling that have been refined since the Apollo era, (2) new data from the Lunar Prospector mission, which has allowed a spherical harmonical expansion up to degree 150 due to dense data coverage over the near side (Konopliv et al., 2001), (3) the analysis of high-resolution local gravity fields on the near side (Sugano and Heki, 2004; Goossens et al., 2005).

The bulk of the tracking data has been radiometric (Doppler and range measurements by radio waves), and mostly two-way Doppler measurements (transmitting and receiving stations are the same), although some limited three-way Doppler data (transmitting and receiving stations are different) has also been obtained. The Doppler sensitivity diminishes as the spacecraft orbits the limb of the Moon as seen from Earth, and the gravity field in this region is less well determined. New VLBI data will help to constrain the orbit during the face-on orbit geometries (when the orbital plane is perpendicular to the line of sight from the Earth) when the Doppler measurements are less sensitive. VLBI data are complementary and sometimes orthogonal to the Doppler ranging, and has been used for interplanetary navigation of spacecrafts such as Mars Pathfinder, Geotail, Nozomi, Hayabusa and Huygens (Folkner et al., 1997; Kikuchi et al., 2004; Konopliv et al., 2006; Witasse et al., 2006).

It is also possible to use lunar laser ranging (LLR) to access the low degree harmonics and the internal structure through study of the internal librations (Dickey et al., 1994; Williams et al., 2001, 2007).

The SELENE project is a Japanese lunar exploration mission using an H-2A rocket that will be launched in 2007. It will make precise observations of the gravitational field of the Moon utilizing both four-way Doppler observations through a relay satellite (RSAT experiment), and differential VLBI observations of two satellites (VRAD experiment), as well as through the 13 other scientific instruments that are part of the mission (Namiki et al., 1998; Kato et al., this issue). The purpose of these observations is to address the inadequacies in existing data, and hence obtain a highly accurate lunar gravity model.

This paper describes the scientific objectives, mission instruments, developed technologies, mission plan and performance tests of the gravimetric observations of SELENE related to VLBI. New technical developments, such as the multi-frequency VLBI method (Kono et al., 2003), the same beam VLBI method (Kikuchi, 2006) and a new method of measuring the phase characteristics of an antenna (Liu et al., 2004), which have been established to enable more precise orbital determination, are also introduced.

2. Scientific objective

The expected improvement from the SELENE gravity field model is important because it contributes not only to our understanding of the structure near the surface by analyzing the high-degree gravity field, but it is also able to place strong constraints upon the deep interior through the low-degree terms. For example, by comparing the gravitational and topographic data we can estimate the elasticity of the crust and the mantle and by combining the low degree gravitational harmonics with the amplitudes of the lunar physical librations we can then constrain the density of the lunar core through the moment of inertia (MOI).

Simulations by Hanada et al. (2000) investigated whether the measurements of the MOI can constrain the core density or not, by using a three-layer Moon model using the crustal densities based on Hood and Jones (1987). Without information on the crustal or mantle density, it is not possible to place any limits on the core density, even if the MOI is known to high accuracy. It is possible to constrain the core density if some assumptions. If we assume that crustal density lies in the range 2.9–3.1 g/cm^3, the depth of the crust–mantle boundary is 87 km, the core radius is 450 km, and the mean MOI 0.391 $\pm$ 1%, then the core density must be in the range from 5.7 to 9.5 g/cm^3 (about 50%). If the accuracy of the MOI were 0.1% and the crustal depth takes the minimum value of 55 km, then the range of possible values for the core density will be from 6.6 to 7.7 g/cm^3 (about 15%), much narrower. As a result, it will be possible to estimate the core density for the first time with an accuracy of 15% by improving the accuracy of the MOI from 1% to 0.1% (Hanada et al., 2000). Furthermore, we will be able to obtain information about the difference between the MOIs with respect to different axes, and about the effect of topography and crustal thickness if we know the MOI to better than 0.1% accuracy (because these effects are influential at about the 0.1% level). An accuracy for the MOI better than 0.1% is essential for the studies of the interior of the Moon, but the present accuracy to which we know the MOI does not attain 0.1% due to possible systematic errors in the gravitational harmonics (Hanada et al., 2000). We are aiming to improve the accuracy of the low degree gravitational harmonics by one order of magnitude compared to LP100J, and to determine the moment of inertia to an accuracy better than 0.1% by making VLBI observations in addition to the Doppler measurements.

We will make VLBI observations of the SELENE satellites by using the Japanese VERA stations (Mizusawa, Iriki, Ishigaki and Ogasawara), throughout the one year mission period. Each week there will be three observing sessions, each of eight hours. In order to improve the accuracy of the observed lunar gravity field we will also include two international VLBI campaigns, each of one month duration. In these campaigns four international stations (Shanghai, Urumqi, Hobart and Wettzell) will participate, complementing the VERA network. In order to maximize

Download English Version:

https://daneshyari.com/en/article/1766738

Download Persian Version:

https://daneshyari.com/article/1766738

Daneshyari.com