SIMULATION OF THE SIZE AND FLATTENING OF THE LUNAR CORE FOR SYNCHRONIZATION WITH DATA ON LASER OBSERVATIONS

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Introduction: Space lunar experiments have provided high quality data on the Moon's internal structure. In the course of measuring the parameters of physical libration by the methods of long-term lunar laser ranging it was possible to determine the characteristics of the lunar core (its shape, chemical composition [1]) and to construct empirical series for the parameters of the physical libration of the Moon (PLM), which provided its analytical description [2]. Satellite gravimetric measurements allowed to refine the values of the gravitational field parameters, Love coefficients, which characterize the viscoelastic properties of the lunar body [3–4]. To analyze the size and compression of the core, observations of free core nutations (FCNs) are used: in the parameters of the rotation of the Moon with a liquid core, additional modes appear due to the mismatch between the axis of rotation of the core and the one of the mantle. However, due to the slow rotation and small size of the core, FCNs for the Moon have a long period of ~300 years and small amplitudes – less than 10 milliseconds [5–6]. Therefore, it is very difficult to reveal this mode in the series of observations. Barkin et al. [7] developed the world's first analytical theory for the Moon with a liquid core and compared its results with empirical series [2]. As a result, a number of terms caused by the presence of the core were identified in the analytical solution. Their amplitude is found to be less than 30 ms [8]. We developed a computer simulation method by which we managed to compare the theory with observations and to clarify the size and falttening of the Moon's core.

Methods: The computer simulation method developed by us is focused on determining the parameters of the free nutation of the lunar core and observing stars using the lunar automated zenith telescope [9]. Firstly, the modeling involves solving a direct problem using the PLM theory: calculating the "observed" selenographic coordinates of stars at any given moment and time interval. Secondly, the inverse problem is solved: according to the "observed" selenographic coordinates, the program calculates the PLM parameters. We show that when the lunar telescope is placed at latitudes of 30°–45°, selenographic coordinates are equally sensitive to librations in longitude and latitude. The main idea is to calculate selenographic coordinates based on empirical series [2] with an accuracy of 1 ms of arc. In this case, low-amplitude harmonics should contribute to the values of the measured coordinates. If this assumption is confirmed, then we proceed to solving the inverse problem and estimating how the nutation of the core will manifest in the planned experiment in PLM.

Results: The process of modeling the parameters of the lunar core is based on the use of our PLM theory for the two-layer Moon [10]. In the process of modeling the parameters of the lunar core and comparing them with the results of calculations using semi-empirical series, the conditions were determined under which a minimum was reached in the residual differences for frequencies defined as harmonics of unknown nature. According to the conclusions of Y.V. Barkin's analytical theory, it is these harmonics that confirm the presence of the liquid core. As a result of modeling, the optimal values for the radius and falttening of the core were obtained, and the values of the period of FCNs were refined. These data increased the probability of detecting core parameters in PLM observations.

Conclusions: As a result of the study, we obtained information on the possibility of detecting harmonics in the PLM observations, confirming the presence of the lunar core. By modeling the parameters of the core, the dynamics of such harmonics was studied and the prospects for the planned experiments involving lunar telescopes were determined for their use in measuring the selenographic coordinates of stars when finding the parameters of FCN and refining its characteristics.

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