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Free librations of the two-layer Moon and the possibilities of their detection

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Abstract

Based on the forthcoming second stage of the Japanese Lunar mission ILOM (2013), when an optical telescope will be set on the surface near one of the Lunar poles, the possibility to detect free Lunar modes (Chandler-like wobble and free-core nutation) is considered. The difference between the Lunar Eulerian and Chandler-like wobble is explained. The terms "arbitrary libration" and "free libration" are discussed. The geometrical and physical interpretations of the free polar motion over the Lunar surface are considered from the viewpoints of Lunar surface-based observations and the Lunar Navigation Almanac. The dependencies of the free libration period on the core's radius, density, and ellipticity are modelled and discussed.

Keywords: Lunar free libration; Chandler-like wobble; Free Core Nutation; Polar motion; ILOM

1. Introduction

Our current knowledge of the internal structure of the Moon is very limited and is mainly based on observations of its gravity field. Our intention is to detect fine variations in its rotation caused by a complex stratigraphy of the Lunar interior, using high-precision astronomical observations of the Lunar rotation in the forthcoming mission ILOM (Hanada et al., 2005; Noda et al., 2008; Kawano et al., 2003). In order to investigate the interior structure of the Moon, a preliminary study of its free librations must be conducted. On one hand, from libration observations, a considerable rotational dissipation was detected. As a result, the free modes should have long been damped. On the other hand, the same observations showed the presence of free modes in the present state of the Moon. This emphasizes the importance of the spin–orbit interaction. In particular, the resonant interaction with Venus, as well as a two- or three-layer model of a non-rigid Moon with a tidal dissipation or turbulent dissipation at the core–mantle boundary (CMB) needs to be developed. A model of a two-layer Moon is to become the first step in this direction. The Hamiltonian formalism provides a powerful tool for the study the rotation.

The Lunar rotation is sensitive to its interior structure. Numerical models of the Lunar physical libration (LPhL) (Newhall and Williams, 1997; Williams et al., 2001), satisfying the modern Lunar laser data (LLR), necessarily include complex internal startigraphy of the Lunar body. To do this in the framework of an analytical theory is much more difficult. The main advantage of the analytical approach over the LPhL theory is an opportunity to separate the forced and free libration. Precision data of a laser location of the Moon give a good basis for determination of amplitudes and phases of the free libration. Yet the opportunity to study the rotation of a celestial body from its surface in the framework of the planned experiment, ILOM, opens even greater prospects in this direction.

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