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The effects of tides and an inner core on Mercury's libration

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Abstract

Mercury's longitudinal librations depend on the moment of inertia of its silicate outer part and as such contain information on the interior structure and composition of Mercury. For a correct interpretation of libration observations in terms of Mercury's interior, all effects on the rotation variations of Mercury larger than the measurement precision must be taken into account. Here we study the effect of tides and the existence of a solid inner core on the librations of Mercury.

1 Introduction

The rotation speed of Mercury is not constant but shows small periodic variations. These longitudinal librations are due to the torque exerted by the Sun on the aspherical shape of Mercury. It was realized by Peale [1] that observation of the main libration at 88 days would allow determining whether the core of Mercury is (at least partially) liquid, because that libration is about a factor of two larger for a liquid core than for a solid core. Margot et al. [2], using Earth-based radar observations to estimate the librations, demonstrated that the core is indeed highly likely partially liquid.

An accurate determination of the libration will moreover allow constraining the mantle density and the size, density, and composition of the core, [3, 4]. However, in order to be able to make accurate inferences on the interior structure of Mercury, all possible effects on the libration have to be known more precisely than the observational precision. It is usually assumed that the core is spherically symmetric and that its rotation is not coupled to the rotation of the mantle on the short period of libration. The core, however, can be aspherical and can be coupled to the mantle by various physical mechanisms. Electromagnetic coupling, topographic coupling, viscous coupling [5] and inertial coupling [6] between the liquid core and the mantle have been shown to be sufficiently small so that their influence can be neglected given the current and future spacecraft precision on the libration. Gravitational coupling between the mantle and a solid inner core is thought to have a similarly small influence on the libration amplitude [5], although the influence of the inner core could lead to a noticeable difference in the libration on a timescale of several years [7].

2 Tides

Although several effects on Mercury's libration have been studied, the influence of tides on the librations of Mercury have up to now not been accurately quantified. Tides affect the rotation rate of Mercury because they change the moment of inertia periodically. As a result not only the gravitational torque of the Sun on Mercury is modified but also the rotational response to the gravitational forcing of Mercury is different. We estimate the effects of tides for a large set of interior structure models of Mercury with inner core radius varying between zero and almost the total core radius [4]. The models, which specify composition, density, temperature, and other physical properties as a function of radial distance to the mass center of Mercury, are based on thermoelastic data about mantle minerals and thermoelastic and melting properties of core constituents (assumed to be iron and sulfur). We also include in this study the effect of gravitational coupling between the inner core and the silicate shell of Mercury.

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