EPSC Abstracts
Vol. 13, EPSC-DPS2019-1334-3, 2019
EPSC-DPS Joint Meeting 2019

EPSC
EPSC-DPS Joint Meeting 2019
15–20 September 2019 | Geneva, Switzerland

The rotation of Io

Tim Van Hoolst (1, 2), Rose-Marie Baland (1), Antony Trinh (1), and Francis Nimmo (3)
(1) Royal Observatory of Belgium, Belgium, (tim.vanhoolst@oma.be), (2) KU Leuven, Belgium, (3) University of California Santa Cruz, California, USA

Abstract

The gravitational force exerted by Jupiter on Io deforms the satellite and periodically changes its rotation. The gravitational interaction between Jupiter and Io in its precessing orbit also leads to the satellite having a small but finite obliquity. Both the tides and the rotation characteristics (librations and obliquity) depend on the interior structure of Io. Here we evaluate the rotation for various models of the interior of Io, which take into account observational constraints from magnetic induction observations and astrometry. In particular, we assess the signature of a magma ocean on the librations and obliquity.

1. Introduction

Galileo magnetometer data show that the volcanically active satellite Io has a global, partially molten asthenosphere or a fully molten magma ocean [1]. Tidal measurements can differentiate between full and partial melt [2]. We here evaluate whether libration and obliquity can be used as an additional tool to determine the status of Io's melt region. Both libration and obliquity can be measured by future spacecraft during multiple flybys of Io as has been done for Enceladus (libration, [3]) and Titan (obliquity, [4]).

As for all large satellites in the solar system, Io's rotation is synchronous with the orbital motion. Due to the gravitational torque of Jupiter, the orientation of the long axis of Io librates around the synchronous orientation at the orbital period of almost 1.77 days, as illustrated in Fig. 1. The gravitational interaction between Jupiter and Io in its fast precessing orbit leads to the satellite having a small but finite obliquity. We here calculate the libration and obliquity for a large set of interior structure models of Io and assess the influence of a subsurface magma ocean and of the rigidity and viscosity of the crust.

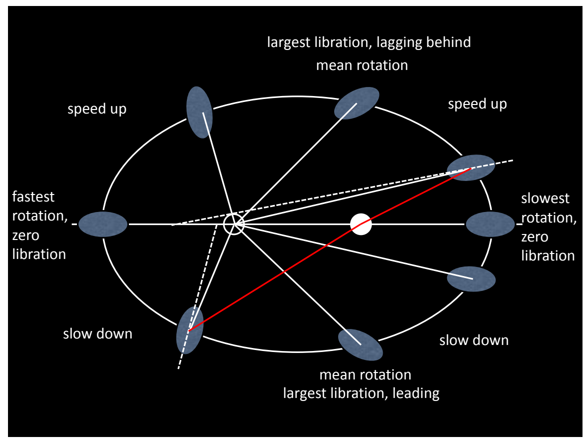

Figure 1: Schematic of the phase of the diurnal libration of Io. White continuous lines represent the approximate orientation of the long axis without libration, dashed lines the orientation including libration.

2. Io's interior

The sectorial degree-two gravitational coefficient determined by the Galileo spacecraft indicates a large mean moment of inertia [5] and a core radius between about 650 km and 950 km [6]. The core is most likely entirely liquid because of the high mantle temperature [7, 1]. Eruption temperatures of Io's silicate volcanism indicate a large melt fraction in Io's upper mantle of 20%-30% [8]. This high melt fraction is confirmed by magnetic induction measurements [1]. Still higher melt fractions and the existence of a magma ocean are consistent with the Cassini magnetic induction measurements but seems to be at odds with the phase of the auroral spot oscillations [9]. We here use models of the interior of Io with a homogeneous core and mantle that have an asthenosphere with a thickness and depth below the surface of 5 km to 100 km.

3. Rotation

A magma ocean strongly increases the libration amplitude compared to an asthenosphere (Figs. 2 and 3). If Io has a magma ocean, its libration amplitude depends sensitively on the thickness of the crust for crust rigidities larger than 10^{10} Pa (Fig. 3). This behaviour is similar to that of Enceladus, although tidal deformation is larger and decreases the libration amplitude much more than for Enceladus [10]. For crust rigidities of about 10^{10} Pa or smaller, the libration amplitude becomes almost independent of the crust thickness, similar to the libration behaviour of large icy satellites, which have a soft shell [11].

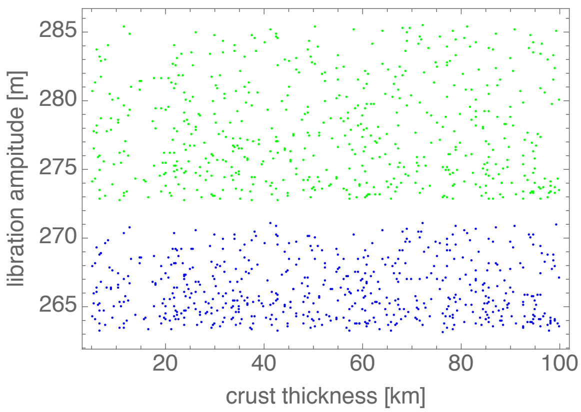

Figure 2: Amplitude of the libration for a partially molten asthenosphere. Rigidities are 6×10^{10} Pa (crust), 2×10^{9} Pa (asthenosphere) and 4×10^{10} Pa elsewhere. Values with deformation included are shown in blue and are below those for rigid solid layers.

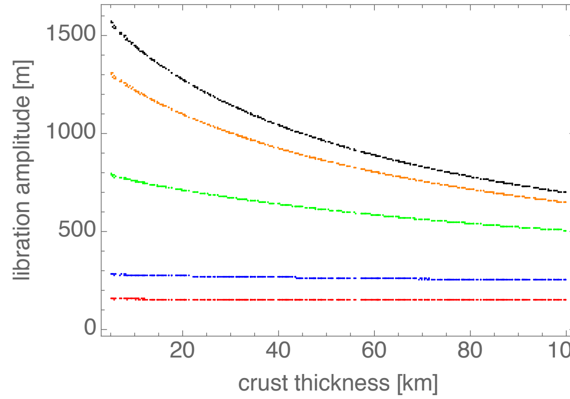

Figure 3: Amplitude of the libration of Io with a magma ocean as a function of the crust thickness for a uniform crust rigidity. Crust rigidity is 6×10^{10} Pa (black), 5×10^{10} Pa (orange), 3×10^{10} Pa (green), 10^{10} Pa (blue), and 5×10^{9} Pa (red).

References

[1] Khurana K. et al., Science, 332, 1186, 2011

[2] Bierson C.J. and Nimmo F. , JGR 121, 2211-2224, 2016

[3] Thomas et al., Icarus 264, 37-47, 2016

[4] Stiles et al., Astron. J. 135, 1669, 2008

[5] Anderson J.D. et al., JGR 106(E12), 32,963-32,970, 2001

[6] Baland R.-M. and Van Hoolst T., Icarus 209, 651-664, 2010

[7] Spohn T., in: Tidal Phenomena, 345-377, 1997

[8] Keszthelyi L. et al., Icarus, 192(2), 491-502, 2007

[9] Roth L. et al., JGR 122, 1903-1927, 2017

[10] Van Hoolst T., Baland R.-M, Trinh A., Icarus 277, 311-318, 2016

[11] Van Hoolst T., Baland R.-M, Trinh A., Icarus 226, 299-315, 2013