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Non-hydrostatic effects on Mars' nutation

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Abstract

Mars' tidally forced nutation can be resonantly amplified owing to a rotational normal mode called the Free Core Nutation (FCN) which exists because the mantle and fluid part of the core can have a relative rotational motion [1]. The period of the FCN and the amplitude of the nutation depend on the moments of inertia of the mantle and core, as well as on the deformation of the planet due to rotation rate variations and tidal forcing. One of the goals of the RISE experiment on InSight [2] and of the future LaRa experiment on ExoMars 2020 is to infer the core radius of Mars by measuring nutation. Precise core radius determination from the FCN period requires knowledge of the core shape. Here we study how non-hydrostatic core shape models affect the FCN and discuss to what extent the shape of the core could be inferred if its radius were known.

1. Method

We assume that the non-hydrostatic (n.h.) degree-two shape of the planet and core result from a surface topographic load and internal loads located at the crust-mantle interface or below. The n.-h. topographic load is determined from the n.-h. surface topography and the internal loads are selected such that the n.-h. degree-two gravity field coefficients correspond to the observed values. We assume that the deep interior behaves like a fluid on long timescales. The mechanical model of the planet therefore assumes an elastic lithosphere overlying a fluid lower mantle and core. The effect of the surface and internal loading is calculated with the Love number formalism.

To assess the effect of a n.h. core on nutation amplitudes and on the FCN period we use a large set of plausible interior structure models with a non-elastic mantle rheology that are compatible with the most recent determinations of the moment of inertia [3] and tidal Love number k_2 [3, 4].

2. Results

Our results show that non-hydrostatic models have a FCN period that is about 10% larger than the same models would have if they were hydrostatic (Fig.[1]). An effect that is large enough to be detected by RISE and LaRa. N.-h. models that agree with k_2 have an FCN period that is close to the retrograde $\frac{1}{3}$-annual forcing period. As a consequence, their nutation at that period can be amplified by up to $100\mathrm{mas}$ whereas models assuming a hydrostatic shape are amplified by less than $10\mathrm{mas}$.

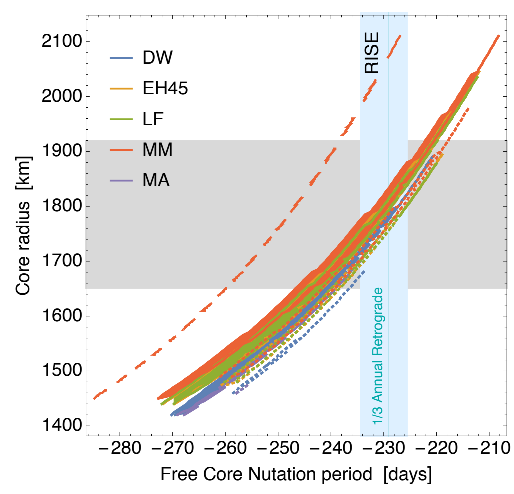

Figure 1: Core radius as a function of FCN period. Non-hydrostatic models are shown by full curves and the hydrostatic MM model is represented by a dashed curve. The blue shaded area is the expected precision by RISE on the FCN and models within the gray area agree with the k_2 at 3σ

With the expected precision of RISE and LaRa an independent estimation of the core radius can be obtained that is comparable to the present-day estimate obtained from the tidal Love number [5, 6] at 2σ and a combination of the latter with nutation measurements will provide constraints about the shape of the core.

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