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Uncertainty on the core radius of Mars from nutation estimation

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Summary

The presence of a liquid core inside Mars affects nutations: nutation amplitudes can be resonantly amplified because of the existence of an eigen mode, the free core nutation (FCN). We quantify the effect of the size of the core on the nutation amplitudes. Present day core size estimates suggest that the effect is the largest on the prograde semi-annual and retrograde ter-annual nutation.

We solve the inverse problem assuming a given precision on the nutation amplifications or the transfer function parameters provided by an extensive set of geodesy measurements and we estimate the precision on the core radius.
Such measurements will be available in the near future thanks to the geodesy experiments RISE (InSight mission) and LaRa (ExoMars mission).

1. Nutation and the transfer function

Nutation amplitudes for a rigid planet like Mars can be written as the sum of different prograde p and retrograde r nutations or as nutation in obliquity ϵ and in longitude ψ.
The frequencies of the 4 largest are the harmonics of the Martian year (Roosbeek 1999).

The amplification by the liquid core can be modeled by a **transfer function** with 2 parameters: the core factor F and the Free Core Nutation (FCN) frequency σ_0 (Folkner et al. 1997).

The retrograde ter-annual r_3 nutation (-229 days) can be resonantly amplified by the presence of a liquid core. The other most affected nutations are p_2, p_3 and r_1.

2. Prior functions

The prior functions for the two parameters of the transfer function is shown as a function of the core size on Figures 1 and 2. We use a large set of plausible interior structure models of Mars with five mantle mineralogies and a hot and a cold mantle temperature end-members (see Panning et al. 2016).

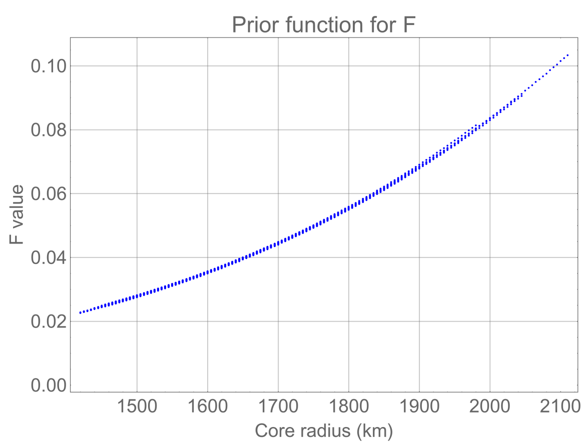

Figure 1: Core factor F of the transfer function as a function of the core size.

3. Method

We do a Bayesian inversion of the synthetic nutation amplitudes or transfer function parameters taking into account the uncertainties on these parameters.

We assume
- the nutation amplifications p_2, r_1, r_3 and p_3 are estimated with an uncertainty of X mas
- or the transfer function parameters are estimated with an uncertainty of 0.013 for F and $0.023°$/day for σ_0.

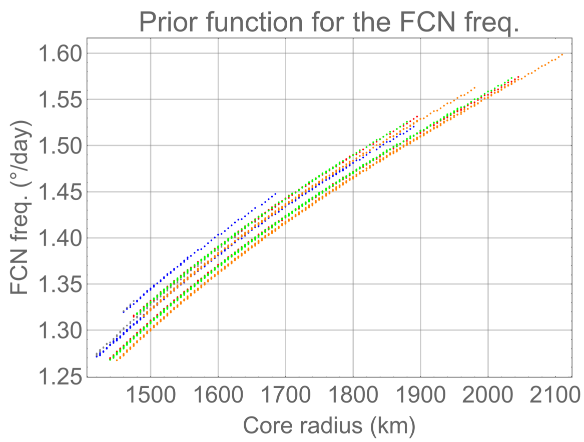

Figure 2: Prior function for the Free Core Nutation (FCN) frequency, as a function of the core size.

Such measurements will be available in the coming years thanks to 2 transponders: the RISE experiments onboard the InSight mission and LaRa experiment onboard the ExoMars2020 mission.

4. Results

- The precision on the core radius is very dependent on the proximity of the FCN period to the ter-annual forcing (-229 days) and on the precision with which the nutation will be measured.

- Combining different nutations reduces the uncertainty on the core radius, particularly if p_2 and r_3 are used.

- To go beyond the present day estimate of the core size, a precision smaller than 5 mas is needed on the nutation amplitudes.

References

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