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The internal structure of Mars inferred from nutation

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Scope

Knowledge about the rotation of Mars provides insight about its global scale atmosphere dynamics and interior structure. In particular, inferences about the core of Mars can be made by observing its nutation as foreseen by the forthcoming RISE and LaRa experiments on InSight and ExoMars. Nutation can be resonantly amplified if the planet's core is liquid and the amplification depends on the core's polar moment of inertia, figure, and capacity to deform. By combining measured nutation amplitudes with the already well known polar moment of inertia and tidal Love number the size of the core and its material properties can be determined more precisely than from the latter quantities alone.

Here, we use models of Mars' interior structure that agree with its moments of inertia, tidal Love number, and global dissipation to predict the nutations of the real Mars. Our models have been constructed from depth-dependent material properties and use recent thermoelastic and melting properties of plausible core constituents. For each model we assess what constraints on the interior structure of the core can be expected from RISE and LaRa.

1. Mars interior structure modeling

- crust density $[2700, 3100]\mathrm{kg/m^3}$ and average thickness $[30, 90]\mathrm{km}$ (Wieczorek and Zuber, 2004)
- a hot and a cold end-member mantle temperature profile from thermal evolution studies (Plesa et al., 2016) and 5 plausible mantle compositions (DW, EH45, LF, MM, MA) (Taylor, 2013; Sanloup et al., 1999; Lodders and Fegley, 1997; Mohapatra and Murty, 2003; Morgan and Anders, 1979)
- viscoelastic mantle rheology (Jackson and Faul, 2010) that agrees with $Q(\tau_{\mathrm{Phobos}} = 5.56\mathrm{h}) = 96 \pm 21$ (Lainey et al., 2007)
- liquid convecting Fe-S core
- models agree with degree 2 gravity field (Konopliv et al., 2016) and surface topography and are compatible with the elastic tidal Love number: $k_2 = 0.165 \pm 0.007$ (Konopliv et al., 2016; Genova et al., 2016)

2. Results

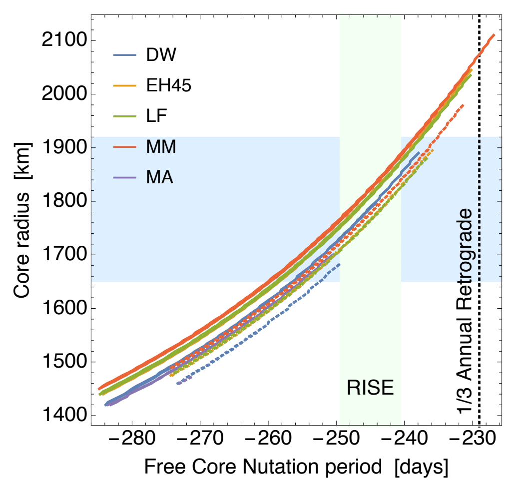

Figure 1: Core radius as a function of Free Core Nutation rotation normal mode. Models that agree with k_2 are located within the blue shaded area and the expected precision of RISE is indicated by the green shaded area.

- nutations are resonantly amplified because of Mars' large liquid core
- viscoelastic effects of the mantle reduce the FCN period by up to 1.72 days%
- nutations provide independent constraints on the core size and composition if its shape is known

- the expected precision on the core radius by RISE/LaRa improves on that obtained from k_2 (3σ)
- a combination of RISE and LaRa data will further reduce the uncertainty on the core radius

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References

Genova, A., Goossens, S., Lemoine, F. G., Mazarico, E., Neumann, G. A., Smith, D. E., and Zuber, M. T. (2016). Seasonal and static gravity field of Mars from MGS, Mars Odyssey and MRO radio science. *Icarus*, 272:228–245.

Jackson, I. and Faul, U. H. (2010). Grainsize-sensitive viscoelastic relaxation in olivine: Towards a robust laboratory-based model for seismological application. *Physics of the Earth and Planetary Interiors*, 183(1–2):151 – 163.

Konopliv, A. S., Park, R. S., and Folkner, W. M. (2016). An improved JPL Mars gravity field and orientation from Mars orbiter and lander tracking data. *Icarus*, 274:253–260.

Lainey, V., Dehant, V., and Pätzold, M. (2007). First numerical ephemerides of the Martian moons. *Astronomy and Astrophysics*, 465:1075–1084.

Lodders, K. and Fegley, B. (1997). An Oxygen Isotope Model for the Composition of Mars. *Icarus*, 126:373–394.

Mohapatra, R. K. and Murty, S. V. S. (2003). Precursors of Mars: Constraints from nitrogen and oxygen isotopic compositions of martian meteorites. *Meteoritics and Planetary Science*, 38:225–242.

Morgan, J. W. and Anders, E. (1979). Chemical composition of Mars. *Geochimica et Cosmochimica Acta*, 43:1601–1610.

Plesa, A. C., Grott, M., Tosi, N., Breuer, D., Spohn, T., and Wieczorek, M. A. (2016). How large are present-day heat flux variations across the surface of Mars? *Journal of Geophysical Research: Planets*, 121(12):2386–2403.

Sanloup, C., Jambon, A., and Gillet, P. (1999). A simple chondritic model of Mars. *Phys. Earth Planet. Inter.*, 112:43–54.

Taylor, G. J. (2013). The bulk composition of Mars. *Chemie der Erde - Geochemistry*, 73(4):401–420.

Wieczorek, M. A. and Zuber, M. T. (2004). Thickness of the Martian crust: Improved constraints from geoid-to-topography ratios. *J. Geophys. Res. (Planets)*, 109(E18):E01009.