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The moment-of-intertia factor of Mars revisited: Consequences for the composition and structure of the Martian interior

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Important geophysical constraints on the bulk composition and interior structure of Mars are provided by the knowledge of its mean density ρ and polar moment-of-inertia (MoI) factor C/MR_p^2. Whereas the former can be calculated from the planet's mass M and radius R_p and has been known relatively well for a long time, the polar moment of inertia C has been derived only recently from a combined analysis of Mars Global Surveyor tracking and Mars Pathfinder and Viking Lander range and Doppler data. A re-analyis of the data resulted in the most recent value of C/MR_p^2= 0.3650 $\pm$0.0012 [1], a significantly lower value than the most often used value of C/MR_p^2= 0.3662 $\pm$0.0017 [2]. The improved value is consistent with the model of a hydrostatic planet with non-hydrostatic contributions to the MoI factor entirely related to the axisymmetric distribution of topographics loads about Tharsis [3]. Using the improved value of C/MR_p^2 and accounting for minor contributions due to Tharsis, we find a mean MoI factor of I/MR_p^2= 0.3635 $\pm$0.0012 [4]. That value suggests a stronger concentration of mass toward the center than previously thought with consequences for the planet's bulk chemistry and interior structure, possibly a denser or a larger core.

We consider spherically symmetric, three-layered models of Mars consisting of a basaltic crust, a silicate mantle, and a metallic core. It is assumed that the chemical composition of the Shergotty-type meteorites is representative of the entire crust and that the mantle composition can be derived from the SNC meteorites [e.g., 5]. It is further assumed that the core is made of the two components Fe and FeS with core densities ranging between those of both end-members. We calculate key chemical parameters, such as the Mg/Si ratio and the molar magnesium number Mg# for

the Martian crust and mantle along with the bulk-planet iron-to-silicon ratio Fe/Si as functions of core density and crust thickness for models with a mean MoI factor of $I/MR_p^2 = 0.3635 \pm 0.0012$ and consider the effects of the error bounds. We compare our results to those of previous models [e.g., 6].

The new lower value of the MoI factor of Mars suggests several tens of kilometers larger core radii if other parameters like core density, crust density, and crust thickness remain unchanged. Mass balance constraints require that the core density decreases with increasing crust thickness for cores of a given size. In contrast, the Mg/Si ratio and the molar Mg# of the planet's silicate portion are mostly determined by the density and thickness of the crust because of the compositional differences between crust and mantle and change little with the MoI value in the range considered. The new MoI factor also results in mantle densities that are up to a few 100 kg m^{-3} smaller, thereby suggesting a smaller Fe content of the mantle. This makes the Martian mantle more earth-like than previously thought.

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