GEOPHYSICAL CONSTRAINTS ON THE COMPOSITION AND STRUCTURE OF THE MARTIAN INTERIOR.

F. Sohl[1], G. Schubert[2] and T. Spohn[1], [1]Institute of Planetary Research, German Aerospace Center, Rutherfordstrasse 2, D-12489 Berlin, Germany, Frank.Sohl@dlr.de, [2]Dep. Earth and Space Sci., UCLA, Los Angeles, Ca 90024, USA, schubert@ucla.edu.

Introduction: 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 [1]. 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].

Most recent Martian interior structure models frequently use the polar MoI C as a constraint although the mean moment of inertia, I, should be used for constructing spherically symmetric models. The corresponding MoI factors are related to each other by [e.g. 4] $I/MR_p^2 = C/MR_p^2 - 2/3\ J_2$, where $J_2 = -C_{20}$ is the planet's gravitational oblateness. Using the improved value of C/MR_p^2 and accounting for minor contributions due to Tharsis of the order of 8/3 J_{22}, we find a mean MoI factor of $I/MR_p^2 = 0.3635 \pm 0.0012$ [5]. 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.

Model: Models of planetary interiors suffer from an inherent non-uniqueness since there are usually fewer constraints than unknowns. If the planet's mean density ρ and mean MoI factor I/MR_p^2 are used as constraints then even two-layer structural models have more unknowns, the core density ρ_c; the core radius R_c; and the mantle density ρ_m. However, as illustrated in Fig. 1, a precise knowledge of the MoI factor strongly constrains the core density for $\rho_m < \rho$ and $\rho_c \sim \rho$ (e.g., Mercury), and the mantle density if $\rho_m \sim \rho$ and $\rho_c > \rho$ (e.g., the Moon). Even for Mars, however, ρ_m is not much affected if ρ_c is varied within reasonable limits. In the following, we additionally account for a basaltic crust of constant density (2900 kg m^{-3}) but variable thickness. It is assumed that the chemical composition of the Shergotty meteorites is representative of the entire crust and that the mantle composition can be derived from the SNC meteorites [6]. 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 also compare our results to those of previous models.

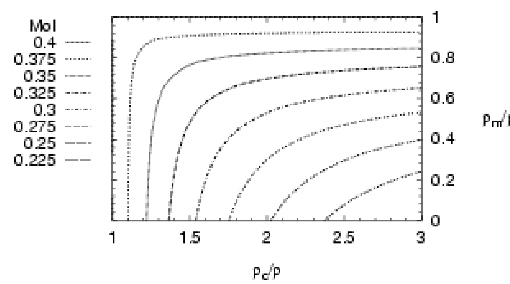

Fig. 1: Contours of MoI factor for two-layered structural models as a function of the ratio of core and mantle density ρ_c and ρ_m, respectively, to mean density ρ.

Results and Discussion: 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 (Fig. 2). This is because dense mantle material will be replaced by less dense crust material. The rate of change (absolute value) of the core density with crust thickness decreases with decreasing MoI factor (compare panels in Fig. 2). The increase in core size significantly affects the bulk planet Fe/Si ratio which is found to be larger by typically about 10%. The Martian core is sufficiently large such that even small changes in core size result in significant changes of core volume. Since the core contributes most of the iron, a significant change in core volume results in a significant modification of the bulk planet Fe/Si ratio (compare panels in Fig. 3). 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.

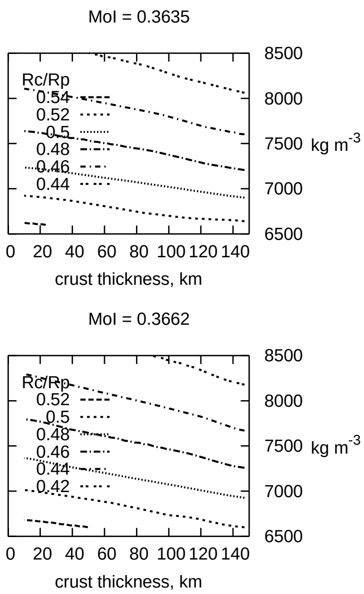

Fig. 2: Comparison of contours of core radius relative to the surface radius R_c/R_p as a function of crust thickness and core density for MoI factors of 0.3635 (above) and 0.3662 (below).

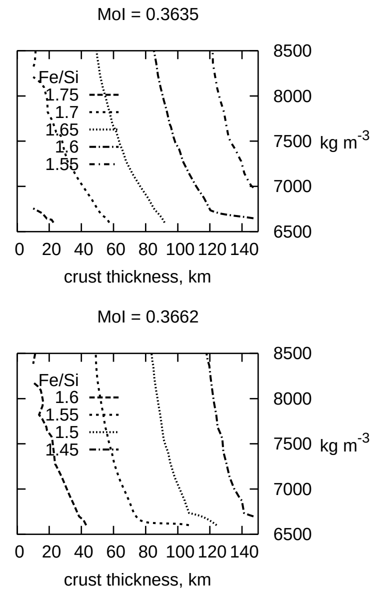

Fig. 3: Comparison of contours of bulk planet Fe/Si ratio as a function of crust thickness and core density for MoI factors of 0.3635 (above) and 0.3662 (below).

References: [1] Yoder C. F. et al. (2003) *Science, 300,* 299–303. [2] Folkner W. M. et al. (1997) *Science., 278,* 1749-1751. [3] Kaula W. M. (1979) *Geophys. Res. Lett.,* 194–196. [4] Sohl F. and Spohn T. (1997) *J. Geophys. Res., 102,* 1613-1635. [5] Schubert G. (2004) *Proc. Kobe Int. Nat. School Planet. Sci.*, 69-105. [6] Dreibus G. and Wänke H. (1985) *Meteoritics, 20,* 367-381.