TIDAL EXCITATION OF THE CORE DYNAMO OF MARS. J. Arkani-Hamed[1], B. Seyed-Mahmoud[2], and K. Aldridge[3], [1]Department of Physics, University of Toronto. Toronto, Canada, M5S 1A7 (jafar@physics.utoronto.ca), [2]Physics Department, University of Lethbridge, Lethbridge, Canada, T1K 3M4, (seyeb0@uleth.ca), 3 Graduate Program in Earth and Space Science, York University, Toronto, Canada, M3J 1P3 (keith@yorku.ca)

Introduction: The lack of appreciable magnetic anomalies inside giant impact basins, inside the northern low lands, over the Tharsis bulge, and over the Tharsis and Olympus mounts suggest that the core field ceased to exist by about 4 Gyr ago [(1,2)]. One explanation is that the core dynamo was maintained by a vigorously convecting liquid core. Once Mars became a one-plate planet, the stagnant lithosphere hampered heat loss from the mantle and subsequently from the core. The core dynamo ceased because of the reduction of heat loss that decreased the vigor of the convection [(3).]

The giant impact basins Hellas, Isidis, Utopia and Argyre are located on a great circle, within +-6 degree, suggesting that the basins were most likely produced by fragments of a large asteroid that broke apart as it entered the Roche limit of Mars[(4)]. The asteroid was at least ~9.8×10^{20} kg. This scenario offers a causative relationship between the formation of the giant basins and the cessation of the core dynamo. It provides an interesting alternative for the generation of the core dynamo, through tidal excitation of elliptical instability in the Martian core by the asteroid. The breaking of the asteroid and its final impact on Mars eliminated the excitation and thus killed the dynamo. Here we investigate this scenario in detail.

Elliptical Instability of Martian Core: Recent laboratory observations of a parametric instability of a rotating incompressible fluid, contained in a flexible-walled spherical cavity, confirm the possibility that an early Martian dynamo could have been powered by tidal straining. Elliptical deformation of otherwise circular streamlines in a Martian fluid core could have been tidally produced by an orbiting asteroid. In our experiments, deformation of the contained fluid's outer boundary models the core-wide elliptical straining produced by the orbiting asteroid.

Two possible scenarios for the orbiting asteroid are considered, each with its counterpart in the interpretation of our current laboratory experiments. First, an asteroid captured by Mars corresponds to an ongoing elliptical deformation of the boundary containing the fluid in our laboratory experiment. In this case, our observations confirm the onset of a parametric instability corresponding to an approximately semi-diurnal tide as long as the instability's rate of growth which is proportional to external straining, exceeds its dissipation rate, a condition readily satisfied in our experiments. In the second scenario, the asteroid is in a heliocentric orbit so that it can only produce significant tidal straining when it is near Mars. For this scenario we model the proximity straining by the asteroid, by switching on the boundary deformation for a fraction of the time needed to produce the instability already seen in the first scenario. It is shown that for short durations of perturbation, corresponding to a highly elliptical orbit of the asteroid, the instability will be excited if a large number of orbits is completed.

For numerical modeling of the instability, we assume that tidal forces configure the figure of the core into a tri-axial ellipsoid. The linear-equations of motion in an inviscid liquid core lead to an eigenvalue problem[5] indicating that the motion is an instability which grows at the rate of $e^{\varepsilon\Omega\ t/2}$, where Ω is the angular velocity of rotation and ε is the tidally-induced ellipticity of the core. Figure 1 shows the growth time of the instability ($2/\varepsilon\Omega$) as a function of distance of the 9.8×10^{20} kg asteroid from Mars. The growth rate of the instability in the Martian core is at least twice as large as that in Earth's core due to the Earth-Moon interaction. It is therefore quite possible that a magnetic dipole was induced in the Martian core as a result of the instability [6].

We also investigate the dynamics of an asteroid orbiting Mars taking into account their spin-orbit coupling due to tidal interactions. A prograde asteroid recedes from Mars if it is captured at distances greater than about 21,000 km, but evolves toward Mars if it is captured at shorter distances (Figure 2). On the other hand a retrograde asteroid always evolves toward Mars regardless of its initial distance from Mars (Figure 3).

References:
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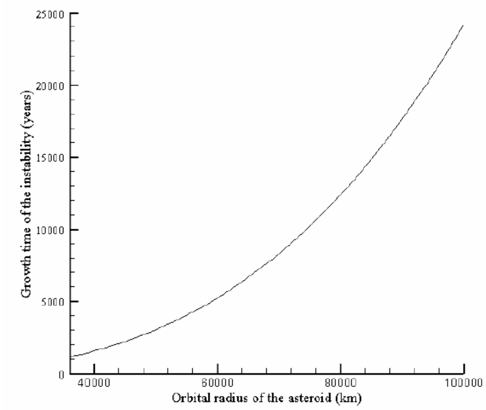

Figure 1. The growth time of the instability

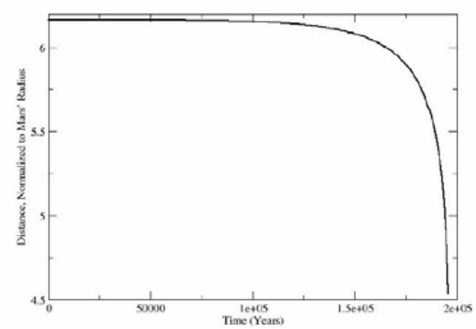

Figure 2. A prograde asteroid captured at 20897 km distance from Mars.

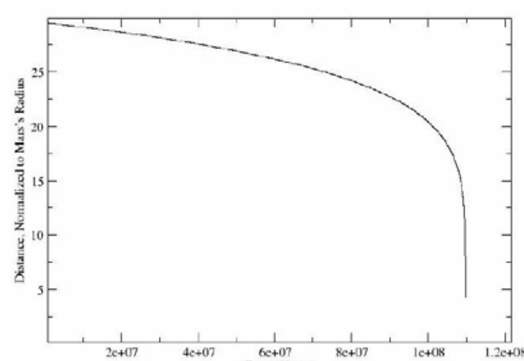

Figure 3. A retrograde asteroid captured at 100000 km distance from Mars.