COULD GIANT IMPACTS CRIPPLE CORE DYNAMOS OF SMALL TERRESTRIAL PLANETS?

J. Arkani-Hamed, Department of Physics, University of Totonto, 60 St. George Str., Toronto, Canada, W5S-1A7, jafar@physics.utoronto.ca

Introduction: The small terrestrial planets have giant impact basins created by large impacts at around 4 Ga. The largest confirmed impact basin of Mars, Utopia, has a ~3380 km diameter, that of Mercury, Caloris, has a ~1550 km diameter, and that of Moon, Aitken, has a ~2400 km diameter. We investigate the effects of these impacts on the mantle dynamics and core dynamos of the planets. We first estimate the impact heating of the planets using Pierazzo et al.'s [1] average shock pressure distribution model and Watters et al.'s [2] foundering shock heating model. This enables us to calculate the mantle dynamics of the planets induced by the impact heating. We then investigate the effects of direct impact heating of the core on the core dynamos of the planets.

Impact Induced Mantle Dynamics: We consider 2D axi-symmetric convection in a spherical shell with temperature dependent viscosity and thermal conductivity, pressure dependent thermal expansion coefficient, and internal heating by radioactive elements. A fixed temperature at the surface and a cooling core-mantle boundary is considered, while the core remains adiabatic temperature as it cools. The thermal evolution model starts at 4.6 Ga but the impact occurs at 4 Ga. The hot and very buoyant upper mantle created by the impact heating quickly ascend and generate a strong upwelling of the mantle directly beneath the impact site. The upwelling sweeps away the impact heated base of the mantle and replaces it with the cold surroundings which have never received shock heating.

Cooling of a Stratified Core: The impact heating is limited to the small uppermost part of the core in the sub-impact region for Mars and Mercury, while that of the Moon penetrates to the entire core, though the impact temperature increase is very small. In all three planets, the core is heated differentially and becomes quite unstable. It overturns and re-distributes the shock-heated fluid onto spherically symmetric isothermal surfaces with increasing temperature as a function of distance from the center, resulting in a stable thermal stratification within about a few tens of years [3]. Because of very low core viscosity of 10^{-2} m^2/s adopted in this study, convection develops in the outer part of the core and heat is transferred to the mantle by convection. Part of the impact heat is conducted from the outer part to the inner part of the core, which retains thermally stratified inner core. The convecting outer core gradually penetrates to deeper parts and eventually establishes a global convection.

Evolution of the Core Dynamos: Once a core is stratified and the core convection diminished, a pre-existing core dynamo decays in time through magnetic diffusion. Using 5×10^5 Sm^{-1} for the electrical conductivity of the core, to be similar to that of the Earth's core [4], the decay times of the dipole fields of Mars, Mercury and Moon are calculate to be 5.8, 8.51, and 0.25 Kyr, respectively. It is expected that a core dynamo is regenerated inside the convecting outer core with increasing intensity as the convecting zone thickens in time. The evolution of the mean magnetic field intensity inside the convecting zones of the cores shows that there is no appreciable magnetic field near the surface of the planets to magnetize the crust before the resumption of global core convection. It takes about 17, 4.6, and 4.5 Myr for Mars, Mercury and Moon to re-establish global convection in the core and possibly regenerate a strong core dynamo.

Conclusions: It is shown that the impacts that have created giant basins on Mars, Merucury and Moon could have heated the interior of the planets significantly. The superheated isobaric sphere in the upper mantle created by an impact quickly ascends and induces vigorous mantle convection. The differential heating of the core by the shock waves transmitted to the core sets up a strong thermal overturn which stratifies the core and suppresses the pre-existing thermal convection, consequently crippling a possible pre-impact thermally-driven core dynamo. Subsequent cooling of the stratified core generates convection in the outer core which gradually penetrates deeper in the core. A weak dynamo is generated inside the convecting outer core and gradually increases in intensity and becomes a strong dynamo when the entire core starts convecting globally. It takes about 17, 4.5, and 4.6 Myr for the cores of Mars, Mercury, and Moon to exhaust the impact heat and develop global convection and possibly power strong new core dynamos.

References: [1] Pierazzo, E. et al. (1997) *Icarus,* 127**,** 408–423. [2] Watters W.A. et al. 2009) *JGR*, 114, E02001. [3] Arkani-Hamed, J. and P. Olson (2010) *JGR*, 115, E07012. [4] Stacey, F.D. (2007), Encyclopedia of Geomagnetism and Paleomagnetism. Springer, Netherlands, pp. 116–117.