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Lateral core mantle boundary heat flux variations as a model of Martian paleomagnetic field

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Abstract

The presence of a strong crustal magnetization [1] on Mars indicates an ancient magnetic field. The dichotomy in the crustal magnetization between the northern and southern hemisphere supports the idea of a hemispherical magnetic field at the late stage of the dynamo action. The flow in the underlying core is strongly influenced by the mantle convection. A significant feature of the Martian mantle dynamics is low degree mantle convection [2] leading to a lateral inhomogeneous heat flux at the Core Mantle Boundary (CMB) and affect the dynamics of the liquid iron core. We explore the dynamo action in this scenario imposed by low degree mantle convection and investigate the effect on the morphology of the magnetic field.

We model the Martian dynamo, which is imposed by a degree-one lateral variation of the heat flux at the CMB, as a spherical shell of conducting fluid in a full MHD numerical simulation. The flow is driven only by volumetric internal heating, since we assume no solid inner core. The lateral heat flux variations at the CMB are considered as a degree-1 heat flux perturbations with small amplitude. We systematically investigate the dependence of the amplitude of the perturbation and its tilt angle with respect to the rotation axis on the dynamo field configuration. In the hemisphere of higher heat flux the vigor of the dynamo action is amplified when on the other hemisphere the temperature gradient driven thermal convection is weakened.

The mechanism can be explained with perturbation orientating along the rotation axis, with weaker cmb heat flux in the north and stronger in the southern hemisphere. As a consequence an equatorial asymmetric temperature anomaly is established, since the cooling is more efficient in the southern hemisphere. Acting of the coriolis force on advection along this latitudinal temperature gradient (meridional circulation) forces strong zonal winds, which are retrograde in the north and prograde in the south. Most of the kinetic energy is just axisymmetric and toroidal motion. The dipole character of the magnetic field reduces due to inhibiting the columnar motion. Additionally, shearing in the boundary between the zonal wind cells, produces strong magnetic field, which moves downwards, if the relative perturbation increases. So the north-south symmetry of the dynamo ceases and a hemispherical configuration is preferred.

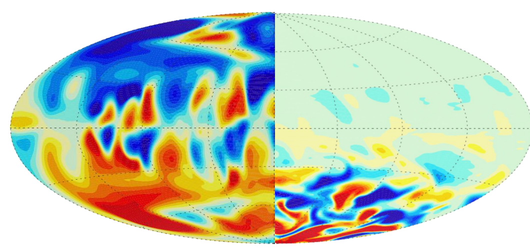

Figure 1: Radial magnetic field at the core mantle boundary for the reference case (constant flux) on the left half, and the strong perturbed system on the right.. The dipolar morpholgy is lost, and a hemispherical dynamo is established.

References

[1] Acuna,A. et al. : Global Distribution of Crustal Magnetization Discovered by the Mars Global Surveyor MAG/ER Experiment, Science, Vol. 284, Iss. 5415, p. 790, 1999

[2] Roberts, J.H. and Zhong, S.: Degree-1 Mantle Convection and the Origin of the Martian Hemispheric Dichotomy, 37th Annual Lunar and Planetary Science Conference, March 13-17, 2006, League City, Texas, abstract no.1447, 2000.