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The convective origin of hemispherical dynamos

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The dichotomy in the magnetisation of the Martian crust may have an internal origin due a hemispherical magnetising field. The absence of a solid inner core in Mars and a low-degree core mantle boundary (CMB) heat flux pattern are two characteristic features of the early Martian core dynamics. Here we combine both in a new numerical model of an internally heated dynamo with degree-one perturbations of the superadiabatic heat flux at the core mantle boundary. In these scenarios an equatorially antisymmetric and axisymmetric (EAA) convective regime is favored, which gives rise to a hemispherical magnetic field.

If the tilt angle between the degree-1 heat flux anomaly is zero, the heat flux is reduced at the northern pole and increased at the southern pole. The differences in heat loss efficiency establishes a strong latitudinal temperature gradient, which leads to a large scale meridional circulation that connects northern and southern hemisphere. The Coriolis force converts these flows into two strong thermal wind cells directed retrograde in the northern and prograde in the southern hemisphere. Small scale, turbulent convection occurs only at the southern pole and the surrounding area.

For a homogeneous cmb heat flux poloidal and toroidal fields are both produced in the individual convective columns due to the helical flow (alpha-effect) therein. Induced by the CMB heat flux perturbations, the cessation of the columns by the EAA mode weakens the production of poloidal and toroidal field simultaneously, while in the shear layer between the northern and southern thermal wind cells the omega-effect-like induction of toroidal field is highly efficient. Poloidal magnetic field is then only locally induced in the southern upwellings, where helical flow in the sense of small scale convection is present. This concentration of poloidal (radial) magnetic field production yields into a hemispherical magnetic field configuration.

We vary both the relative amplitude of the heat flux perturbation and it's tilt angle with respect to axis of rotation to model arbitrary locations of cmb heat flux heterogeneities caused by low-degree mantle convection or giant impacts. Starting from small perturbations allows to study the onset of the EAA mode and it's ability to sustain hemispherical dynamos.