Generation of the Earth's magnetic field. Experimental modelisation with liquid sodium

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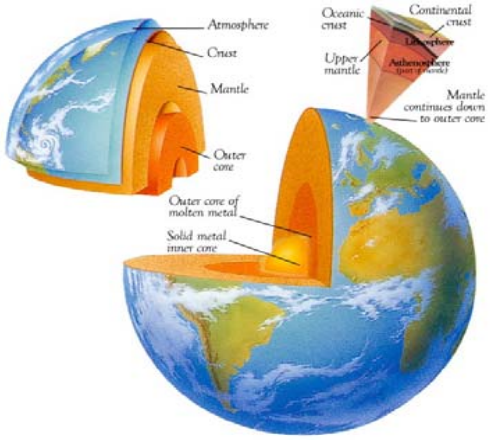
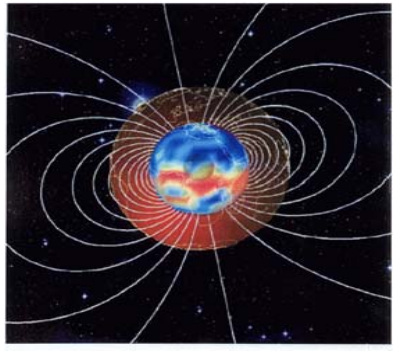
THE STRUCTURE OF THE EARTH

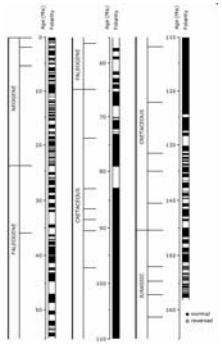


Below the crust and the rocky mantle of the Earth, the liquid outer core is a big ocean of liquid iron with a solid inner core in its center.

THE DEEP EARTH AND ITS MAGNETIC FIELD



Schematic of the dipolar magnetic field lines emerging from the Earth's outer core.



Paleomagnetic time scale. Black : normal period, white : reverse period

The liquid iron of the Earth's core is in motion, mainly due to thermal convection. Associated electrical currents are huge in the outer core and give rise to the large scale magnetic field measurable at the Earth's surface.
This motion have been self-sustaining the Earth's magnetic field for more than three billion years by the so-called DYNAMO process. The Earth's magnetic field is mainly dipolar, aligned with the Earth's rotation axis and its polarity reverses aperiodically through the geological time.

MANY QUESTIONS

Several basics questions are still open concerning the physics of the outer core and the role of the Earth's magnetic field, *e.g.* :
•How do the fluid motion organize in the core to generate a dynamo ? Is this organization identical to the one in other planets hosting a dynamo?
•What does drive a reversal of the Earth's magnetic field ? Why are the reversals aperiodic ? What is the origin of the several periods with no reversals at all through the Earth history ?

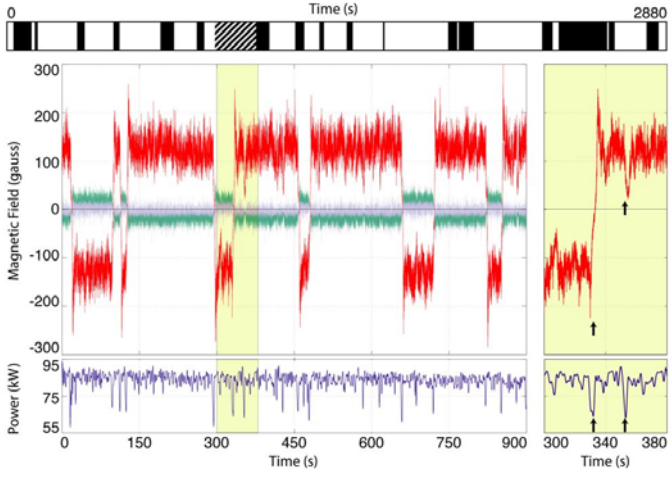
DIFFERENT WAYS TO ANSWER

***Theory* :The Earth's core is a fluid dynamic system in rotation (with the Earth) in as spherical shell under the presence of a large magnetic field. Theoretical studies investigate this very peculiar situation. The equations of the Earth's core magnetic dynamo are known for more than half a century.**

***Numerical computations* : A lot of progress have been made in the last decade regarding the numerical simulation of the geodynamo. The results of the simulations are astonishingly close to the real situation although the physical parameters used in those calculations are very far from the real ones of the Earth' core.**

***Experiments :* Laboratory modelisation of the dynamo is challenging since it requires to drive a large amount of liquid sodium in motion. The goal is to reproduce in a laboratory, in a relatively small container, a close balance of the physical forces acting in the Earth's core.**

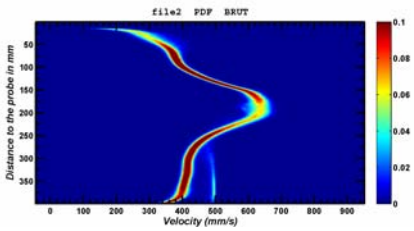
The first successful experimental dynamos were obtained quasi-simultaneously in Riga and Karlsruhe, in 2000. Recently an experimental dynamo was observed for the first time with a reversing magnetic field during the experiment !



Measured magnetic field during a dynamo experiment (VKS, Berhanu et al. 2007)

"GEODYNAMO" TYPE EXPERIMENTS

An experiment in Grenoble, DTS (Derviche Tourneur Sodium), has been running for a few years in an Earth's like configuration with liquid sodium in motion between an outer sphere and an inner sphere. Technological progress in measurements have been made to capture the physics of such flow in sodium (150°C). Recent results points out an unexpected fluid flow composed of azimuthally traveling waves in the spherical shell filled with liquid sodium.



Top : Sodium velocities measured by ultrasonic measurements in the bulk of the rotating outer sphere in DTS.

Left : DTS geodynamo type experiment running in Grenoble.

The 3-meters diameter sphere filled with liquid sodium is expected to run soon in the University of Maryland.
http://complex.umd.edu/dynamo/3m.html

This unprecedented huge experiment could certainly lead to an Earth's like geodynamo.

CONCLUSION

The international scientific community is extremely active around the understanding of the deep Earth processes, and in particular the understanding of the dynamo. The complementary numerical and experimental approach is extremely promising for the near future. The present very accurate satellite data measurements of the Earth's magnetic field gives a fantastic opportunity to constrain the modelisation of the Earth's dynamo.