Creation of a magnetic field in a turbulent fluid

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Understanding the origin and behavior of the magnetic fields of planets and stars is the goal of research being carried out by many teams from all over the world. The VKS collaboration (CEA, CNRS, Ecole normale supérieure in Lyon, Ecole normale supérieure in Paris) has succeeded in creating in the laboratory a magnetic field in a highly turbulent flow of liquid sodium.

Although the extreme conditions specific to astrophysical and geophysical environments cannot all be reproduced in the laboratory, the magnetic field observed shows remarkable similarities with magnetic fields observed in the cosmos. The findings represent a significant advance in the understanding of the mechanisms at work in the formation of natural magnetic fields. They are published in *Physical Review Letters* dated 26 January 2007.

Most of the astrophysical objects which surround us (planets, stars and galaxies) have a magnetic field, whose origin is poorly understood. Such magnetic fields can play a major role in the evolution of various structures throughout the Universe. The Earth's magnetic field, which is very probably caused by the movement of liquid iron in the core, not only makes compass needles point north, but also protects us from the harmful effects of cosmic rays and the solar wind.

As early as 1919, Larmor put forward the hypothesis that the Sun's magnetic field is generated by a "dynamo" effect, in other words by the movement of a fluid that conducts electricity. Because of their highly

chaotic (turbulent) nature, the analysis of geophysical and astrophysical flows is beyond the current capacities of numerical simulations, and, until now, has thwarted all attempts at a theoretical approach.

It is only through experimental work that it is possible to reproduce the dynamo phenomenon with parameters that are similar to those that occur naturally. Following experiments carried out in 2000 by teams in Riga and Karlsruhe, the challenge facing the physicists was to show that the fully turbulent motion of a conducting liquid could spontaneously generate a magnetic field.

Since 1998, the VKS collaboration has been studying a highly turbulent flow produced by the movement of two turbines revolving in opposite directions in a cylinder filled with liquid sodium. Liquid sodium is an excellent conductor of electricity, while having a density similar to that of water, unlike many other metals which are much denser. In September 2006, the VKS experiment showed that, when the turbines revolve faster than a critical speed (1020 rpm), the flow spontaneously generates a magnetic field. This is the first time that such results have been observed in a highly turbulent medium.

The result proves that fluid dynamos continue to operate in the presence of strong turbulence of the kinds that occur under natural conditions. The achievement of the dynamo experiment under laboratory conditions opens up many new prospects. In particular, it will make it possible to study the energy balance involved in the production of a magnetic field as well as its dynamics. It may therefore be possible to understand the origin of the pseudoperiodic oscillations in the solar cycle or the irregular reversals of the Earth's magnetic field.

Source: CNRS