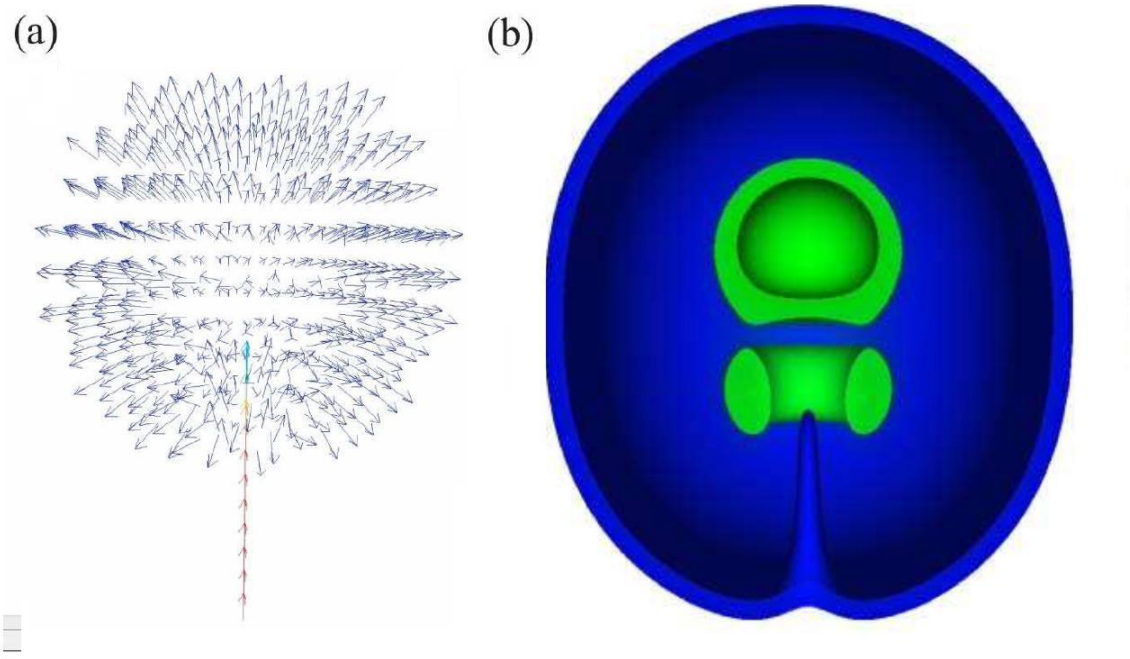
Reaching for magnetic monopoles – an analogy for a point source of magnetic field to be created?

Two researchers at Helsinki University of Technology (Finland) and University of New South Wales (Australia) have found a way to create so-called Dirac monopoles in Bose-Einstein condensates using methods routinely employed in experiments. The results have been just published in Physical Review Letters.

The condensate is only tens of micrometers in diameter and composes of dilute alkali atom gas cooled below one millionth of a degree above the absolute zero. Monopoles are created into an optically-trapped condensate simply by changing currents in nearby conductors.



Caption: (a) Vorticity of the condensate which is analogous to the magnetic field of the magnetic monopole. The monopole is at the point, from which the blue arrows are pointing outwards. (b) Cross section of the condensate particle density in two regions. The blue color corresponds to low and the green to high densities.

"The Dirac monopole is a theoretical model which describes, for example, a point source of magnetic field. However, these magnetic monopoles have not been found and the magnetic field is typically assumed to be free of sources", Dr. **Möttönen** explains. "The method we have found is probably going to lead at last to the first experimental realization of an ideal analogy for a magnetic monopole", he continues.

A similar but slightly simpler method has been already used in experiments to create the first multiply quantized vortices, quantized whirlpools, in the world. With a technically small change to this method, it is now possible to create the first ideal analogy for a magnetic point charge. The realization of this method would be an enormous advancement in monopole physics possibly enabling the studies monopole interactions, decay, and dynamics. To date, there are no technical or fundamental obstacles in sight, and hence the experimental realization of Dirac monopoles could be witnessed in a one-year timeframe if one of the many top experimental groups started to study it.

“If the realization of this analogy for the magnetic point charge is a success, it will be an enormous advancement in monopole physics possibly enabling the studies monopole interactions, decay, and dynamics”, tells Möttönen. “Maybe after this there would be enough interest to create a so-called non-Abelian monopole, on the possible realization of which we have published another theoretical article. This monopole is more complex than the Dirac monopole since it has a U(2) gauge degree of freedom”, he continues with visions of future impact.

According to the present understanding, an electron is a point-like particle carrying the elementary charge. Thus it is a source of electric field, that is, an electric monopole. Corresponding particle for magnetic field has not been found and the magnetic field is typically free of sources. For example, a bar magnet can be modelled by two monopoles with opposite charges in the ends of the bar. However, if the bar is cut into two, new north and south poles are being created implying that the poles cannot be separated.

The existence of magnetic monopoles is not forbidden in the present theory. For example, the cool down and phase transitions of the universe may have given rise to the formation of magnetic monopoles. Despite decades of experimental work, they have not been found. Thus analogies for magnetic monopoles have been searched in other quantum mechanical systems, in superfluid ^{3}He for example, without success. However, the new studies reported here show that this kind of monopoles can be created in Bose-Einstein condensates.

Creation of Dirac monopoles in spinor Bose-Einstein condensates
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