Vortices and other two–dimensional topological solitons in magnetic nano–particles

Konstantin L. Metlov

Institute of Physics ASCR, Na Slovance 2, Prague 8, Czech Republic 18221

Similarly to superconductors the topologically charged states are very common in ferromagnets.

The specialty of magnets is the vectorial character of the order parameter (magnetization), which is the three–dimensional vector with fixed magnitude. It had been known for along time (since the groundbreaking work by Belavin and Polyakov [1]) that topologically charged states are metastable in ferromagnets due to the exchange interaction between spins. Nevertheless, there were only a few direct experimental observations of magnetic vortices in extended magnetic samples, and not everyone in the field accepts them. There were also considerable theoretical problems in building the local theory of magnetic vortices, as the vortex solutions appeared to be stable only when some exotic higher order local terms are added to the Lagrangian, and otherwise collapse into the point singularity due to the magnetic anisotropy. Recently, the magnetic vortices with measurable size [2] were observed as a typical ground state of magnetic nano–particles (with the sizes of the order of 100nm or less) and it was understood [3] that the long–range non–local dipolar interactions are essential for their stability.

In this talk an approximate (but general, simple and straightforward to apply) theory [4] of magnetic topological solitons in magnetic nano–cylinders of arbitrary shape (not necessary having an axial symmetry) is presented. It is based on the theory by Belavin and Polyakov, but additionally takes into account the boundary conditions on the finite surface of the particle. It allows to reduce the problem of finding the equilibrium distribution of magnetization vector within the particle to the solution of Riemann–Hilbert boundary value problem, and to express the result explicitly through the derivative of the conformal map of the cylinder's face to the unit disk. Simple analytical expressions for the structures of magnetic solitons in the cylinders of common shapes (circular, triangular, rectangular [5]) are presented. They also describe non–vortex magnetic structures [4]. Based on these expressions it is possible to compute the magnetic phase diagrams of small particles, study the stability [6] of various magnetic solitons and pinpoint the range of particle geometrical dimensions where the magnetic vortices can or cannot be found [7]. The complete magnetic phase diagram of a circular nano–cylinder will be presented and discussed.

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