

MAGIC⁺ WORKSHOP

Magnetism, Interactions and Complexity

Invited

2D and 3D topological charges: from magnetic skyrmions to hopfions

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Topological solitons of a vector field describing an order parameter can be classified by using maps from the coordinate space (\mathbf{r}) to the order parameter space. The vector order parameter for a ferromagnetic media is its net magnetization $\mathbf{M}(\mathbf{r})$. The magnetization field in 3D space represented by the unit field vector $\mathbf{m}(r_\alpha) = \mathbf{M}(\mathbf{r})/|\mathbf{M}(\mathbf{r})|$ depends, in general, on three spatial coordinates r_α , $\alpha=1,2,3$. The theory of topological charges in 1D and 2D space is well developed and used for the classification of topological magnetic solitons such as domain walls (kinks), vortices and skyrmions. Topological charges describe degrees of mappings (homotopy invariants) of 1D- (S_1) or 2D coordinate space (S_2) to the unit sphere $\mathbf{m}^2 = 1$ in the magnetization space $S_2(\mathbf{m})$, *i.e.*, $S_1 \rightarrow S_2(\mathbf{m})$, $S_2 \rightarrow S_2(\mathbf{m})$. There is interest nowadays in 3D inhomogeneous magnetization configurations classified by a linking number of the preimages of two distinct points in $S_2(\mathbf{m})$ on the 3D sphere S_3 , *i.e.*, by the Hopf index. The corresponding configurations are called "hopfions". The Hopf index can be represented as some integral of the expression composed by a continuous field and its spatial derivatives.

A hedgehog or Bloch point is a point-like 3D magnetization configuration in a ferromagnet. Regardless of widely spread treatment of a Bloch point as a topological defect, its 3D topological charge has never been calculated. Here, applying the concepts of the emergent magnetic field and Dirac string, we calculate the 3D topological charge (Hopf index) of a Bloch point in a spherical soft magnetic particle and show that due to the magnetostatic energy contribution it has a finite, non-integer value. Thus, Bloch points form a new class of hopfions - 3D topological magnetization configurations. The calculated Bloch point non-zero gyrovectoread leads to important dynamical consequences such as the appearance of topological Hall effect.

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