Dynamics of emergent magnetic monopoles in the magnetoelectric spin ice $Dy_2Ti_2O_7$

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Abstract

In systems with competing interactions frustration can create complex ground states with exotic excitations. Spin-ice is a solid manifestation of such a degenerate ground state in which magnetic degrees of freedom carry zero point entropy in analogy water ice[1]. Recently it has been found that excitations in spin-ice behave like magnetic monopoles[2]. In a magnetic field along [111] direction the density of these monopoles is a function of temperature and magnetic field and the corresponding phase diagram exhibits a phase transition which resembles the gas-liquid. Accordingly there exists a critical end-point for the monopole condensation[3]. It also has been postulated that the emergent magnetic monopoles in addition carry electric dipole moments[4].
Using dielectric spectroscopy we demonstrate the existence of such an electric dipole moment coupled to magnetic monopole excitations. Furthermore we are able to examine the monopole dynamics via this magnetoelectric coupling. We can track the relaxation time of the electrically dipolar contribution down to low temperatures in the mK-range as a function of an external magnetic field along the crystalline [111] direction. Analyzing the dynamics at temperatures above the critical end-point we see the crossover from the conventional slowing down of the fluctuation dynamics to an critical speeding up.

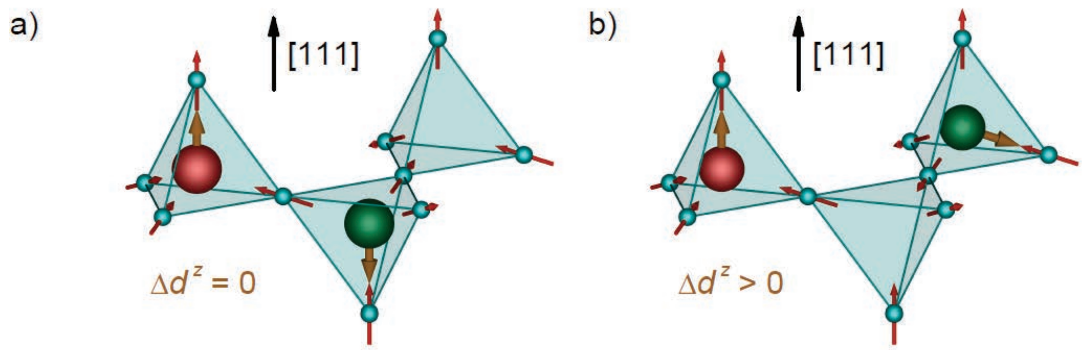

Figure 1: Magnetic and dielectric configuration of monopoles in the corner sharing network of Dy-tedrahedra. Red arrows denote the Dy-spins, yellow arrows denote the induced dielectric dipole moments connected to the magnetic mono- and anti-monopoles (red and green balls). The hopping a) to b) of the "green" monopole corresponds to the flipping of the connective spin between the two tetrahedra and results in a non-vanishing net electric dipole moment Δd^z along the field direction.

References:

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