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Dynamics of Bound Monopoles in Artificial Spin Ice: How to store energy in Dirac Strings.[1]

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Magnetism of two-dimensional dipolar spin ices (2D-DSI) is an exploding and innovative field of science. Recent developments in 2D-DSI research concern the defects also known as "magnetic monopoles" connected by a Dirac string. The ultimate goal of 2D-DSI research is creation of a magnetic analog of Spintronics using monopoles and Dirac strings as acting elements. Main stream of investigations on 2D-DSI concerns the behavior of unbound magnetic monopoles with vanishing tension of Dirac strings. Here, it is shown that in the regime of bound monopoles (BM) with non-vanishing Dirac string tension one-dimensional Dirac strings rather than point-like monopoles are effective degrees of freedom [1]. Particularly, BMs do not obey the Coulomb law and can be attracted or repulsed depending on the tension-to-mass ratio. Dirac string tension in strongly coupled 2D-DSI is found to be a fundamental quantity, which is bounded by the fine-structure constant and lattice specific parameters only. A measurable prediction of path-time dependence of endpoints of stretched and then released Dirac strings is made and verified via simulations. It is demonstrated that this kind of string dynamics may be used to achieve spontaneous currents of confined monopoles and to store energy. Interestingly, the current duration can be increased by geometrical means, e.g. increasing the length of a sample as will be shown in an experimental demonstration. Nanoscale realization of this effect will open novel technological avenues and change our understanding of magnetism in 2D-DSI fundamentally. [1] E. Y. Vedmedenko, Phys. Rev. Lett. 116, 077202 (2016).

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