Two-dimensional Ising model with competing interactions as a model for interacting π-rings

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A chain or a planar array of electrically isolated π-rings could be treated as a set of magnetic moments oriented perpendicular to the plane (i.e. as Ising spins) and interacting via magnetic dipole forces. Due to this dipole character of the interaction between the orbital moments, it is necessary to include the next-nearest neighbor interactions in addition to those between the nearest neighbors.

We propose a two-dimensional Ising model with competing nearest-neighbor and diagonal interactions on a square lattice as a model for interacting π-rings. It is now well accepted that such a model with nearest-neighbor (J) and next-nearest neighbor (J') interactions on the 2D square lattice exhibits two phases with magnetic long-range order; a semi-classical Néel-like magnetic order at small J' and a antiferromagnetically coupled ferromagnetic chains (vertical or horizontal stripes) large J'. These two ordered phases are separated by an intermediate quantum paramagnetic phase without the long-range order, the nature of which is still under discussion.

We show that this model exhibits an additional low temperature disordered phase due to the proximity of the lowest energy excited states to the ground state. Exact diagonalisation is used for small lattices and Monte Carlo simulations is used for larger lattices where we measure several potential order parameters for the model. We compare the results from exact diagonalisation and Monte Carlo simulations with experimental results.

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