Berezinskii-Kosterlitz-Thouless transitions in a ferromagnetic superfluid

A. P. C. Underwood[a], A. J. Groszek[b,c], X. Yu[d,a], P. B. Blakie[a], and L. A. Williamson[b]

[a] *Department of Physics, Centre for Quantum Science and Dodd-Walls Centre for Photonic and Quantum Technologies, University of Otago, Dunedin, New Zealand.*

[b] *ARC Centre of Excellence for Engineered Quantum Systems, School of Mathematics and Physics, University of Queensland, Saint Lucia QLD 4072, Australia.*

[c] *ARC Centre of Excellence in Future Low-Energy Electronics Technologies, School of Mathematics and Physics, University of Queensland, Saint Lucia QLD 4072, Australia.*

[d] *Graduate School of China Academy of Engineering Physics, Beijing 100193, China.*

The Berezinskii-Kosterlitz-Thouless (BKT) transition describes the formation of topological order in low dimensional systems with continuous symmetries. The vast majority of research so far has focussed on systems with a single U(1) symmetry; much less is known about systems with multiple U(1) or higher order continuous symmetries. Spinor Bose gases boast complex continuous symmetries and hence are an exciting new system to explore BKT physics. In this work we carefully characterise BKT transitions in an easy-plane and isotropic ferromagnetic spin-1 Bose gas. In the easy-plane phase we identify two distinct BKT transitions. The higher temperature transition is associated with superfluidity of the mass current with coherence predominantly determined by a single spin component. The lower temperature transition is associated with superfluidity of the axial spin current, quasi-long-range order of the transverse spin density and binding/unbinding of polar-core spin vortices (PCVs). Above the spin superfluid transition we identify a vortex plasma phase, whereby PCVs separate into constitutive components in analogy to a colour plasma in high energy physics [1]. At zero quadratic Zeeman energy the system is in an isotropic ferromagnetic phase with SO(3) symmetry. This manifold supports defects fundamentally distinct from U(1) systems and the superfluid ordering is in general not well understood [2-5]. We present strong evidence of a BKT transition in this phase, with spatial correlations of spin scaling as $G(r) \sim r^{-1/2}$ at the transition point, rather than the conventional $G(r) \sim r^{-1/4}$ scaling in U(1) systems.

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