Two Experimental Tests of the Halperin-Lubensky-Ma Effect at the Nematic–Smectic-*A* Phase Transition

Anand Yethiraj and John Bechhoefer
Department of Physics, Simon Fraser University, Burnaby, British Columbia, Canada V5A 1S6
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We have conducted two quantitative tests of predictions based on the Halperin-Lubensky-Ma (HLM) theory of fluctuation-induced first-order phase transitions. First, we explore the effect of an external magnetic field on the nematic–smectic-*A* transition in a liquid crystal. Second, we examine the dependence of the first-order discontinuity as a function of mixture concentration in pure 8CB and three 8CB-10CB mixtures. We find the first quantitative evidence for deviations from the HLM theory.

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One of the most important advances made in our understanding of continuous phase transitions has been the modification of critical exponents, due to thermal fluctuations, from the values predicted by mean-field theory [1]. But thermal fluctuations have another effect, one that is less well understood theoretically and studied only to a limited extent experimentally: when two order parameters (or an order parameter and a gauge field) are simultaneously present and interact with each other, the fluctuations of one may drive the phase transition of the other first order. In high-energy physics, for example, an analogous situation occurs in the Higgs mechanism [1]. In condensed-matter physics, over two decades ago, Halperin, Lubensky, and Ma (HLM) [2] predicted that this could occur in two settings: the normal-superconducting phase transition in type-1 superconductors and the nematic–smectic-*A* (NA) transition in liquid crystals. At the NA transition [3–6], the first fluctuating field is the nematic order parameter $Q = S(3 n n - \delta)/2$, while the other order parameter is the two-component smectic-*A* order parameter ψ. In principle, a complete theory must account for thermal fluctuations in the nematic order parameter magnitude S, the nematic director n, and the smectic-*A* order parameter ψ. The de Gennes–McMillan mechanism [3] takes into account S fluctuations but is mean field in n and ψ. The HLM theory, in addition, considers n fluctuations but is mean field in ψ. Deviations from the de Gennes–McMillan mechanism have been quantitatively established by Anisimov *et al.* [7] and Cladis *et al.* [8]. Although their conclusions are consistent with the HLM mechanism, the experiments are at their resolution limits and the full implications of the HLM theory remain to be tested.

In this paper, we conduct the first two quantitative tests of the HLM theory, both leading to significant discrepancies from HLM. (i) Mukhopadhyay *et al.* [9] have made a detailed prediction for the external-field dependence of the HLM effect; we look for this field effect experimentally in the cyanobiphenyl liquid crystal 8CB, as well as in mixtures of 8CB and 10CB. (ii) The first-order discontinuity implied by the HLM theory (which can be characterized by the number $_0 = (_{NA} - {}^*)/{}^*$, where $_{NA}$ is the transition temperature and * is the spinodal point) should also be sensitive to the mixture concentration in the 8CB-10CB system. Here, we make a quantitative study of $_0$ vs

$$\zeta = \frac{\zeta - \zeta_{SN}}{(\langle \bar{I} \rangle - I_{\ldots})^2}, \qquad (2)$$

where ζ