Massless phases for the Villain model in d>=3

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The XY and the Villain models are mathematical idealization of real world models of liquid crystal, liquid helium, and superconductors.
Their phase transition has important applications in condensed matter physics and led to the Nobel Prize in Physics in 2016. However we are still far from a complete mathematical understanding of the transition.
The spin wave conjecture, originally proposed by Dyson and by Mermin and Wagner, predicts that at low temperature, large scale behaviors of these models are closely related to Gaussian free fields. I will review the historical background and discuss some recent progress on this conjecture in d>=3. Based on the joint work with Paul Dario (CNRS).