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Dynamical theory of spin noise and relaxation-prospects for real time measurements

The dynamics of a spin system is usually calculated using the density matrix. However, the usual formulation in terms of the density matrix predicts that the signal will decay to zero, and does not address the issue of individual spin dynamics. Using stochastic calculus, we develop a dynamical theory of spin relaxation, the origins of which lie in the component spin fluctuations. This entails consideration of random pure states for individual protons, and how these pure states are correctly combined. Both the lattice and the spins are treated quantum mechanically. Such treatment incorporates both the processes of spin-spin and (finite temperature) spin-lattice relaxation. Our results reveal the intimate connections between spin noise and conventional spin relaxation. These developments in theoretical aspects of spin noise and relaxation and their interrelationship reveal a modified spin density, distinct from the density matrix, as the necessary object to describe fluctuations in spin systems. These fluctuations are to be viewed as an intrinsic quantum mechanical property of such systems immersed in random magnetic environments and are observed as spin noise in the absence of any radio frequency excitation. With the prospect of ultrafast digitization, the role of spin noise in real-time parameter extraction for spin systems, and the advantage over standard techniques, is of essential importance, especially for systems containing a small number of spins. In this presentation we outline prospects for harnessing the recent dynamical theory in terms of spin-noise measurement, with attention to real-time properties.

Biography

Timothy R Field studied undergraduate mathematics at King's College, Cambridge University, and went on to receive a Doctorate in mathematics from New College and the Mathematical Institute, Oxford University in 1997, where he studied mathematical physics under Sir Roger Penrose. He is an Associate Professor in the Departments of Electrical & Computer Engineering and Mathematics & Statistics at McMaster University. He is fellow of the Institute of Physics and the Institute of Mathematics and its Applications, and twice recipient of NSERC Discovery Awards for research into electromagnetic scattering from random media and related phenomena.

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