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Quantum spin dynamics and coherence in solids

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Even while their existence as individuals is fundamentally quantum mechanical, derivable from atomic physics, for many purposes the spins in solids behave as classical objects. In particular, virtually the entire science of solid state magnetism, including phenomena as diverse as phase transitions, domain walls, and magnons can be understood in terms of classical rotors, subject to varying anisotropic potentials determined by external as well as internal (crystal) fields, coupled to each other via dipolar and exchange interactions. Even so, there has long been theoretical suspicion that when the interactions are antiferromagnetic rather than ferromagnetic, quantum mechanics might manifest itself on scales larger than the interatomic spacings associated with crystal fields and exchange interactions. Recent experiments on antiferromagnets, where the quantum fluctuations are enhanced by coupling to mobile electrons or by geometric factors such as system dimensionality, reveal this suspicion to be justified. Some of the materials, including even the simple two- dimensional Heisenberg antiferromagnet, display anomalous spin wave amplitudes and dispersion, while for others, classical order itself is replaced by mesoscopic quantum order or coherence. Apart from their intrinsic interest as magnets with strong quantum fluctuations, systems of this type are also of more general importance as they include both the heavy fermion metals and high temperature superconductors, many of whose interesting properties are thought to be derived from the same fluctuations. Work is currently supported by a Wolfson Royal Society Fellowship and the Basic Technologies Progamme of the UK Research Councils.