Spin temperature and hyperpolarization in disordered magnets.

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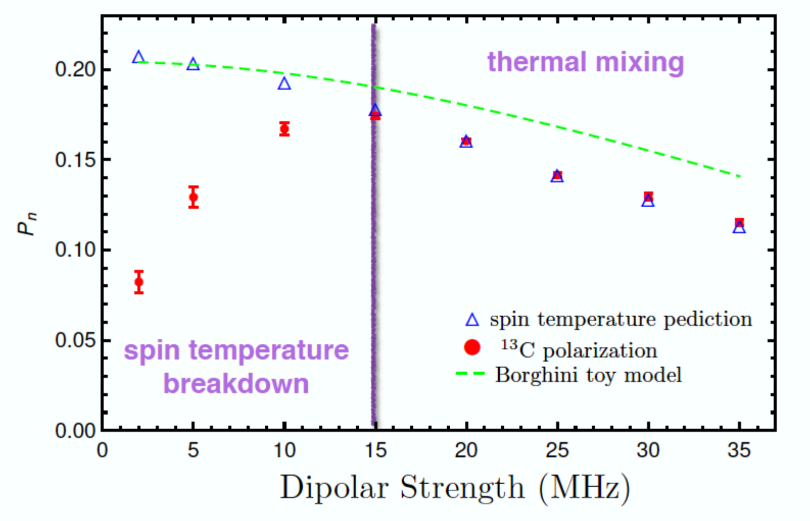
Dynamic Nuclear Polarization (DNP) is to date the most effective technique to increase the nuclear polarization opening disruptive perspectives for medical applications. However, our understanding of the physical mechanisms that trigger hyperpolarization is still poor. In DNP, the nuclear spins are driven to a hyperpolarized state by microwave saturation of a collection of electron spins interacting with the nuclear spin system. A striking experimental evidence is the thermal mixing of the ensemble of different nuclear spins (13C, 15N, 89Y…): their enhanced polarizations are well described by a single spin temperature possibly one thousand time smaller than the temperature of the bath. But how can a quantum system appear thermal and colder when irradiated by microwaves? In which way the spin temperature can be controlled acting on the experimental parameters?



In our work we show that the spin temperature concept is directly connected to quantum ergodicity and that the resulting stationary state strongly depends on the ergodicity properties of the spin many-body eigenstates. In particular

dipolar interactions compete with disorder induced by local magnetic fields resulting in two distinct dynamical phases: while for weak interaction, only a small enhancement of polarization is observed, for strong interactions the spins collectively equilibrate to an extremely low effective temperature that boosts DNP efficiency. Our central finding is that the nuclear hyperpolarization increases steadily upon reducing the Dipolar strength. Interestingly, the highest polarization is reached at a point where the establishment of a spin temperature is just about to break down due to the incipient many-body localization transition in the electron spin system. A very recent experiment seems to confirm our main prediction (Bodenhausen group).

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