"Decoherence in Many-Spin Systems: a Quick View of the NMR Contribution from our Group"

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The control of coherent dynamics in open quantum systems has a fundamental relevance for fields ranging from Quantum Information Processing (QIP) to Nanotechnology. Any system in interaction with an environment suffers a degradation of its quantum dynamics known as "decoherence". Moreover, as we conclude from our experiments, this process can be assisted by the own system's complexity [1].
We found that Nuclear Magnetic Resonance (NMR) is a wonderful technique to study decoherence and a great part of the scientific community working on Chaos and Quantum Instabilities in Quantum Mechanics is trying to learn from it. Some of the advantages come from the good isolation of the nuclear spins which allows for long enough times to produce external perturbations and precise observations of their dynamics with today technology. Besides, the possibility to implement "average Hamiltonians" that can lead the evolution of the systems at will comes from the old days in NMR [2].
Our first NMR tool was the sequence to generate polarization echoes (PE) a form of a many-body Loschmidt echo that achieves the time reversal of a quite complex polarization dynamics. The polarization echoes are generated when the evolution of a local spin excitation, governed by the dipolar spin interaction, is reversed [3]. Their temporal attenuation represents the failure of the quantum interferences to rebuild the local excitation, i.e., the fragility or hypersensitivity to perturbations of the increasingly spread entangled state. We will show experiments where the intrinsic (reversible) dynamics and the coupling with the environment (perturbations) are modified in a controlled way. More recently, we started to use another powerful tool: the sequences to excite and detect multiple quantum coherences in solids [4]. We will also discuss many recent surprises found in our way, as a dynamical phase transition occurring when the dynamics of a simple two-spin system is frozen by the interaction with the environment through the Quantum Zeno effect [5].
Puzzling results on magnetically diluted systems, of relevance for the QIP community, where very long coherence times (tens of seconds) seemed to appear triggered a lot of excitement. However, after some measurements in our laboratory, we proved that there were not long lived coherences but longitudinal polarization enabled, among other things, by the localization inherent to a diluted disordered system [6].

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