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Exploring the quantum frontier of spin dynamics

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Our familiar classical concept of a *spin* is that of a system characterized by the *direction* in which the spin is *pointing.* In this picture, we may think of the dynamics of a spin as the motion of a *classical gyroscope*, wich we can aptly describe the spin dynamics as the motion of a point on a sphere. This classical description of the spin dynamics, formalized in the Landau-Lifshits-Gilbert equation, has proved extremely successful in the field micro- and nanomagnetism. However, as the size of the system is further decreased (e.g., when considering molecular magnets such as the Fe_8 or Mn_{12} systems, which have a spin S=10), *quantum* effects such as tunneling, interference, entanglement, coherence, etc., play an essential role, and one must adopt a fully quantum mechanical description of the spin system. The landscape in which the system evolves is then no longer a mere sphere, but rather it is the projective Hilbert space (wich is the projective complex space $\leq \mathrm{P}^{2S}$ for a spin S), as space of considerably greater richness and complexity than the sphere of classical spin dynamics. A very appealing tool to describe a quantum spin system is Majorana's stellar representation, which is the extension for a spin S of the Bloch sphere description of a spin $1/2$. I shall discuss how this representation can help us in improving our understanding of fundamental quantum processes and concept such as Landau-Zener transitions, Rabi oscillations, Berry phase, diabolical points and illustrate this on the example of spin dynamics of molecular magnets.