Molecular spin qudits: a promising ingredient for quantum technologies

S. Carretta[ab*]

[a] *Università di Parma, Dipartimento di Scienze Matematiche, Fisiche e Informatiche, Italy &UdR Parma, INSTM*
[b]*INFN–Sezione di Milano-Bicocca, gruppo collegato di Parma, 43124 Parma,* Italy
*stefano.carretta@unipr.it

The potential to solve problems with large impact on science, society and economy makes the realization of quantum computers one of the hottest topics in current research. However, to deal with problems intractable on classical device, each logical unit must suppress unavoidable errors via quantum error correction. The actual realization of this goal is still far even for the most advanced architectures, based on superconducting qubits or ion traps. In this respect, molecular nanomagnets (MNMs) offer a very promising alternative, opening a new route towards a scalable quantum computer. These magnetic molecules are characterized by a sizeable number of accessible low-energy states that can be coherently manipulated by microwave and radiofrequency pulses, thus opening the possibility use them as molecular qudits.

In my presentation, I review some recent results on molecular qudits/qubits. In particular, I show that MNMs can be exploited to define qubits with embedded quantum error correction in single molecules [1-3], thus circumventing the large overhead in the number of physical units required by standard quantum error correction codes. Moreover, I show that molecular qudits can improve the potential for quantum simulations [4]. Then, I briefly report the characterization of promising molecular qudits using broadband NMR [5] and discuss some recent results on the study of the two main sources of decoherence in MNMs, i.e., interactions with nuclear spins and phonons [6,7].

Finally, I will show how chiral-induced spin selectivity could be harnessed as a useful tool to spin-polarize molecular qubits, thus potentially raising their operating temperature [8].

[1] A. Chiesa, E. Macaluso, F. Petiziol, S. Wimberger, P. Santini, and S. Carretta, J. Phys. Chem. Lett. **11**, 8610 (2020).
[2] E. Macaluso, M. Rubín, D. Aguilà, A. Chiesa, J. I. M. L. A. Barrios, P. J. Alonso, O. Roubeau, F. Luis, G. Aromí, and S. Carretta, Chem. Sci. **11**, 10337 (2020).
[3] A. Chiesa, F. Petiziol, M. Chizzini, P. Santini and S. Carretta, in preparation
[4] F. Petiziol, A. Chiesa, S. Wimberger, P. Santini and S. Carretta, npj Quantum Inf. **7**, 133 (2021).
[5] E. Garlatti, L. Tesi, A. Lunghi, M. Atzori, D. J. Voneshen, P. Santini, S. Sanvito,T. Guidi, R. Sessoli, S. Carretta, Nature Commun. 11, 1751 (2020).
[6] F. Tacchino, A. Chiesa, R. Sessoli, I. Tavernelli, S. Carretta, Molecular spin qudit for simulation of light-matter interaction, J. Mater. Chem. C 9, 10266 (2021).
[7] S. Chicco, A. Chiesa, G. Allodi, E. Garlatti, M. Atzori, L. Sorace, R. De Renzi, R. Sessoli and S. Carretta, Chem. Sci. 12, 12046 (2021).
[8] A. Chiesa, M. Chizzini, E. Garlatti, E. Salvadori, F. Tacchino, P. Santini, I. Tavernelli, R. Bittl, M. Chiesa, R. Sessoli, and S. Carretta, J. Phys. Chem. Lett. **12**, 6341-6347 (2021)

This project has received funding from the European Union through Horizon 2020 research and innovation program under grant agreement No 862893 and the European QUANTERA project SUMO (co-funded by Italian Ministry of University and Research), and from the Italian Ministry of Education and Research through PRIN Project 2017CR5WCH Q-chiSS ``Quantum detection of chiral-induced spin selectivity at the molecular level".