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Titolo del Seminario: Molecular spin qudits: a viable path for Quantum information Processing

Abstract: Molecular spins represent a very promising platform for the physical implementation of quantum information processing (QIP). Indeed, combined efforts of Physicists and Chemists allow for tuning their properties at the synthetic level and to design suitable QIP protocols [1]. What could make these systems competitive even with the most advanced architectures is the natural availability of a multi-level (qudit) structure in which we can encode logical qubits with embedded quantum error correction (QEC) [2,3]. This makes the control of the hardware much easier compared to multi-qubit encodings, potentially representing a breakthrough for the field, and tracing a route towards the realization of an effectively working quantum machine. I will overview recent progress in the design and realization of a molecular-spin quantum processor, showing advantages and challenges of this approach [1]. Among the former, I will present a fault-tolerant scheme suppressing dephasing almost exponentially with the qudit size [3,4] and the first experimental demonstration of a quantum simulator based on a molecular spin qudit [5]. The main challenge is related to the readout of individual spins, and it is naturally tackled by coupling molecules to superconducting resonators, analogously to superconducting qubits [6]. A promising alternative is based on the chirality-induced spin selectivity (CISS) effect, where the electron moving through a chiral bridge is filtered depending on its spin projection. Based on our recent observation of this intriguing phenomenon in electron-transfer processes [7], I will illustrate schemes for initialization and readout of individual spins through a spin-to-charge conversion mechanism enabled by the CISS effect [8].

[1] Rep. Progr. Phys. 87, 034501 (2024). [2] J. Phys. Chem. Lett. 11 8610 (2020). [3] J. Phys. Chem. Lett. 13, 6468 (2022). [4] https://arxiv.org/abs/2307.10761 (2023). [5] J. Am. Chem. Soc. 146, 1053 (2024). [6] Phys. Rev. Appl. 19, 064060 (2023). [7] Adv. Mater. 35, 2300472 (2023). [8] Science 382, 197-201 (2023).