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Single spin resonance magnetometry with scanning tunneling microscopy

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Harnessing the quantum behavior of spins on surfaces [1,2] has become a central task in the field of surface science. Consequently, there has been a growing interest in developing techniques to explore magnetism at the nanoscale. In this talk, we highlight the capabilities of Electron Spin Resonance with Scanning Tunneling Microscopy (ESR-STM) [3] as an absolute magnetometer [4], and we present two compelling examples that showcase the possibilities of ESR-STM.

In the first example, we propose a protocol to certify the presence of entanglement in artificial on-surface atomic and molecular spin arrays [5]. We first generalize the theorem that relates global spin susceptibility as an entanglement witness to the case of anisotropic Zeeman interactions, relevant for surfaces. We then propose a method to measure the spin susceptibilities of surface-spin arrays combining ESR-STM with atomic manipulation. We show that entanglement can be certified in antiferromagnetically coupled spin chains using state of the art spectral resolution of ESR-STM magnetometry.

The second example, which is also the main focus of this talk, involves the study of fractionalization. The emergence of effective S=1/2 spins at the edges of S=1 Haldane spin chains [6] represents one of the simplest examples of fractionalization. We utilize ESR-STM to map the stray field created by the fractional S=1/2 edge spin in a Haldane spin chain [7]. Additionally, we propose efficient methods to invert the Biot-Savart equation, allowing us to obtain the edge magnetization map. This approach enables us to unambiguously determine the two outstanding emergent properties of fractional degrees of freedom, namely, their fractional magnetic moment and their localization length ξ.

[1] Chen, Y., Bae, Y., & Heinrich, A. J. (2023). Advanced Materials, 35(27), 2107534.
[2] Heinrich, A. J.,…, Fernandez-Rossier J. et al. (2021). Nature nanotechnology, 16(12), 1318-1329.
[3] Baumann, Susanne, et al. Science 350.6259 (2015): 417-420.
[4] Choi, T. et al (2017). Nature nanotechnology, 12(5), 420-424.
[5] del Castillo, Y., & Fernández-Rossier, J. (2023). Physical Review B, 108(11), 115413.
[6] F. D. M. Haldane, Physics Letters A 93, 464 (1983).
[7] del Castillo, Y., & Fernández-Rossier, J. (2023). arXiv preprint arXiv:2311.15720.