Department of Physics
Condensed Matter Physics
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UNIVERSITY OF OXFORD

CONDENSED MATTER PHYSICS SEMINAR

Thursday 19 November at 14:30
Simpkins Lee Seminar Room, Department of Physics
(https://maps.app.goo.gl/WjG71uLF2D48n85B6)

Quantum Spin Liquid Noise

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No state of matter can be defined by what it is not; yet magnetic quantum systems e.g. quantum spin liquids, are often conjectured to exist based only on nonexistence of magnetic order. An emerging concept designed to circumvent this ambiguity is to identify each type of non-ordered quantum magnetism by its spontaneous quantum spin noise spectrum.

For example, the kagome lattice of spin-1/2 Cu atoms in herbertsmithite ($ZnCu_3(OH)_6Cl_2$) is conjectured to sustain a quantum spin liquid (QSL) state with spinon quasiparticles. Each kagome plane is separated from its homologues by a layer of spinless Zn atoms. Providentially, however, some spin-1/2 Cu atoms substitute randomly onto these inter-kagome Zn sites. We reconceptualized these 'impurity' atoms as 'witness-spins' that provide an exceptional new interrogative of the QSL state.

To explore herbertsmithite witness-spin dynamics in this context we recently introduced quantum spin noise sensing[1-4] to QSL studies. It reveals the existence, slowing and intensification of spin noise, prefatory to a sharp transition at $T^* \approx 260$ mK. Below T^* the spin-noise power spectral density $S(\omega, T) \propto \omega^{-\alpha(T)}$ stabilizes at $\alpha \approx 1$; the spin noise variance $\sigma_M^2(T)$ diminishes precipitously; the ultra-low-field magnetic susceptibility $\chi(T)$ undergoes a sharp transition into a phase exhibiting an Edwards-Anderson order-parameter and ultra-slow spin-state ageing.

To understand these phenomena we use a model of QSL spinon-mediated witness-spin interactions and, when compared to empirical phenomenology of witness-spin noise, it reveals the spinon spectrum in herbertsmithite. Time permitting I will discuss other types of quantum spin noise spectroscopy.

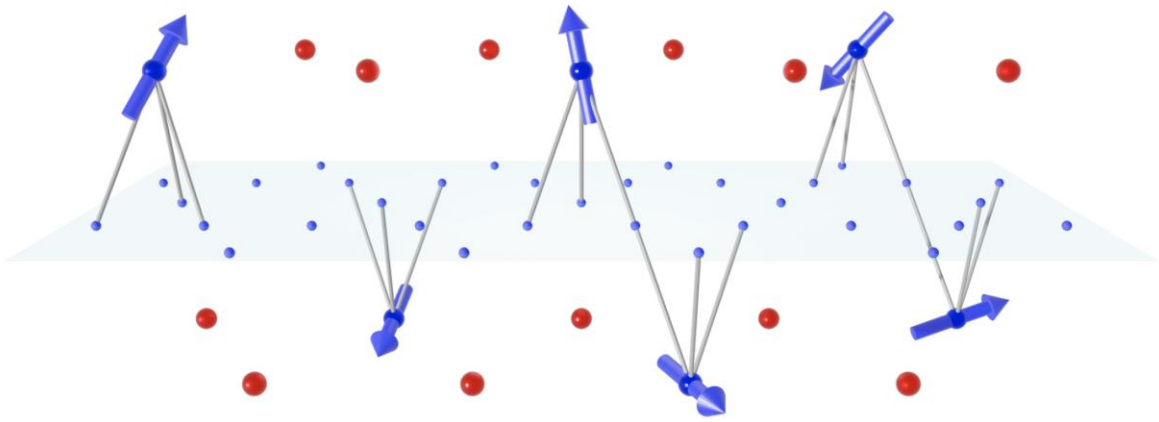


Figure 1: Spinon Mediation of Witness-Spin Dynamics in Herbertsmithite

[1] Dusad *et al.* ***Nature*** **571**, 234 (2019).
[2] Hsu *et al.* ***PNAS.*** **121**, e2320384121 (2024).
[3] Takahashi, H. *et al.* ***PNAS*** **122** e2422498122 (2025)
[4] Takahashi, H., *et al*. ***Nat. Phys.*** **22**, 1071–1078 (2026).

Host: Professor Amalia Coldea