Time-domain terahertz probes of $RuCl_3$

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The Mott insulator $RuCl_3$ is proving to be an ideal platform for testing theoretical predictions regarding the Kitaev class of quantum spin liquids (QSLs). Although spins in $RuCl_3$ order at 7 K, they can be tuned to a disordered phase by application of magnetic field (B). This allows for a direct test, using time-domain THz spectroscopy (TDTS), of a B-induced transition to a QSL phase [1]. A "smoking gun" for such a transition would be a dynamic spin susceptibility that evolves from sharp magnon resonances to a continuum associated with fractionalized quasiparticles. In this talk, we report TDTS measurements of in $RuCl_3$ as a function of B, temperature, and photon energy from 0.3 to 8.3 meV. At all fields we resolve sharp peaks that are clearly identified as a magnon resonances on the basis of their temperature dependence. From fits to a simple Lorentzian lineshape, we obtain the frequency, damping factor, and spectral weight of these antiferromagnetic resonance (AFMR) modes as a function of the magnitude and direction of B, as well as the relative orientation of B and the terahertz magnetic field. A key point is that the static or dc susceptibility associated with well-defined magnons can be determined from the AFMR spectral weight through application of the thermodynamic sum rule. Comparison with directly measured values of dc susceptibility places a quantitative bound on the contribution arising from a continuum associated with fractionalized quasiparticles. Based on this analysis, we find that the contribution to the static spin susceptibility from a continuum remains at most 30% of that from magnons. Crucially, this fraction does not grow with approach to the critical field at which the transition to the spin-disordered state occurs. This observation indicates that there is no direct evidence for fractionalization of quasiparticles with zero wavevector and spin=1 at the putative transition from an antiferromagnetic to QSL phase. While the absence of this smoking gun does not rule out that $RuCl_3$ is a QSL above a critical field, it does places severe constraints on theories of the B-induced transition to a spin disordered state.

[1] A. Little, Liang Wu, P. Lampen-Kelley, A. Banerjee, S. Patankar, D. Rees, C. A. Bridges, J.-Q. Yan, D. Mandrus, S. E. Nagler, J. Orenstein, Phys. Rev. Lett. 119, 227201 (2017).