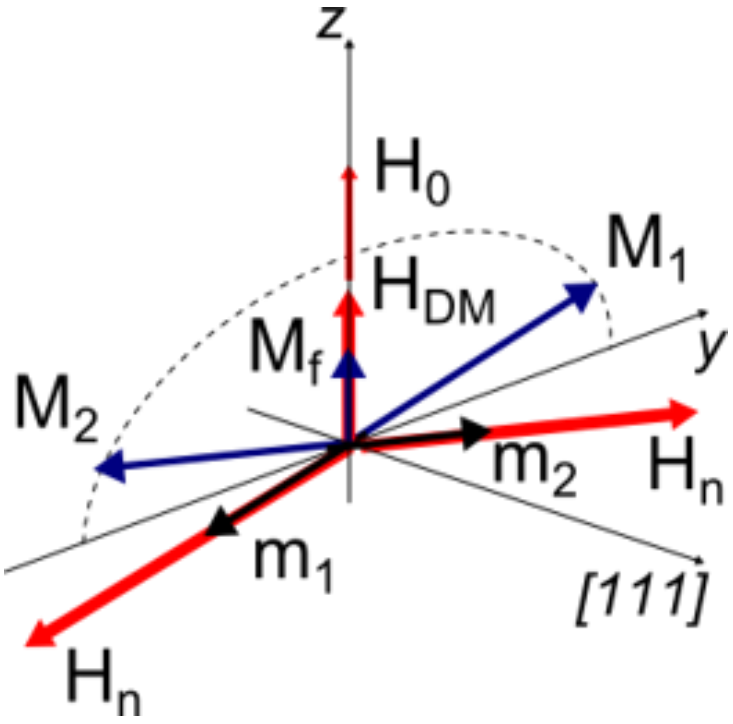
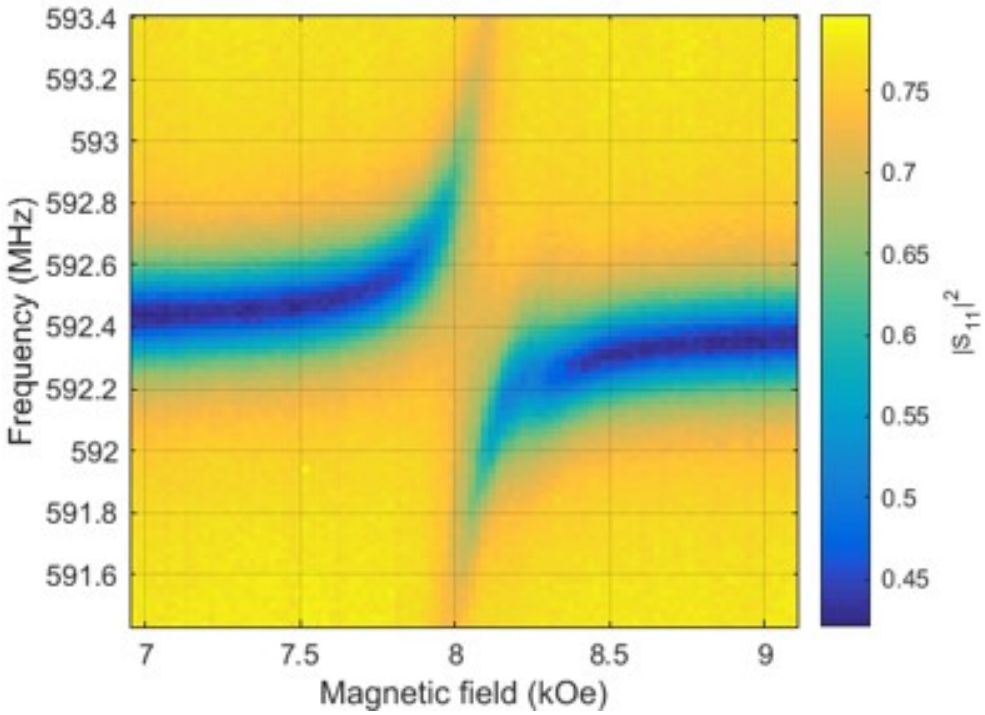
Coupled Electron-Nuclear Spin Ensembles



In some magnetically ordered materials, the interaction between electron and nuclear spins can be so large that the hyperfine field seen by a nuclear spin can be as large as 100 Tesla. Of particular interest to us is $MnCO_3$ (for which we have a sample!), a two-sublattice antiferromagnet with a weak antiferromagnetic moment in its basis plane (see diagram). The hyperfine field strongly modifies properties of the nuclear system in such materials, and this can lead to some fascinating phenomena such as the dynamical shift of NMR frequency, frequency-modulated and parametric spin echoes, as well as possibility for the Bose-Einstein Condensation (BEC) of nuclear spin waves.

Strong coupling of nuclear spin ensemble to a microwave resonator

Usually, the interaction of a nuclear spin with electro-magnetic field is significantly weaker than for an electron spin because of much smaller magnetic moment. However, in the coupled spin systems considered here this interaction can be significantly (~100 times) enhanced due to the coupled precession of electron and nuclear spins.



In our experiments, we exploit the amplification of coupling between the nuclear spin ensemble in a $MnCO_3$ sample and an electro-magnetic mode of a microwave loop-gap resonator to reach the regime of strong coupling interaction. Using this method, we explore possibility for using nuclear ensembles in such materials for quantum information applications, such as quantum memory.

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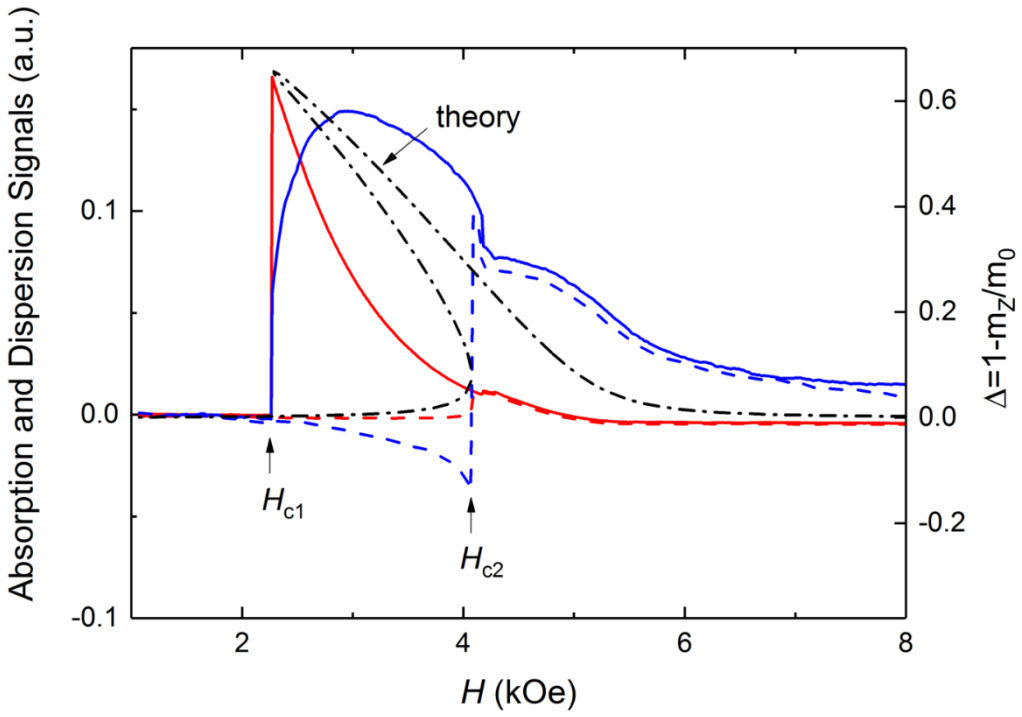
Phys. Rev. Lett. 114, 226402 (2015)

Non-linear NMR and BEC of nuclear spin waves

Dynamical shift ("pulling") of NMR frequency in coupled electron-nuclear ensembles can lead to strongly non-linear NMR signals. Study of such signals can provide important information about dynamics of nuclear magnetization vector m and test different scenarios and models.



In our experiments, we study non-linear NMR signals (both absorption and dispersion) in a $MnCO_3$ sample. An example of such strongly non-linear siganls are shown here. In particular, we are interested in testing an idea that, under a strong NMR pumping, the nonequilibrium nuclear spin waves condenses to a BEC state characterized by a coherent precession of all nuclear spins, similar to what happens in superfluid ^{3}He.

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Phys. Rev. B 97, 024425 (2018)

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JETP Letters 112, 95 (2020)