Spin-nematic Phase in the S = 1/2 Antiferromagnet $LiCuVO_4$ Probed by NMR at 45 T

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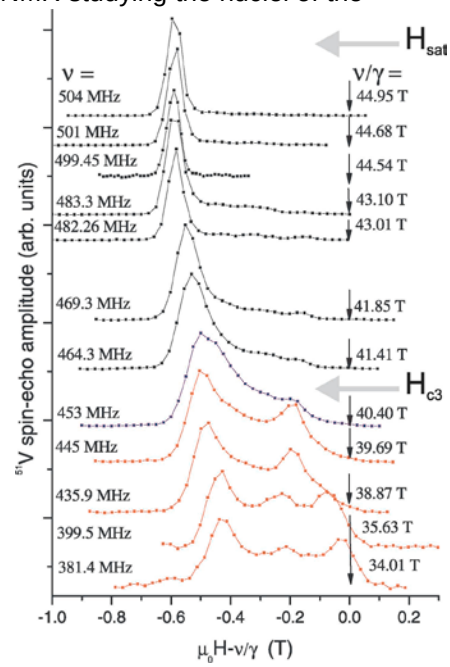
Introduction

From the well known values of the exchange integrals of the Cu^{2+} ions in $LiCuVO_4$ a long-range ordered spin-nematic phase for applied magnetic fields H in the vicinity of $\mu_0 H_{sat}$ = 45 T is predicted theoretically [1]. In this project we elucidate the fingerprint of spin-nematics with the local probes of NMR studying the nuclei of the nonmagnetic ions Li and V. For the spin-nematic phase a single-line shaped NMR spectrum is expected, where the NMR resonance field follows the magnetization M of the sample.

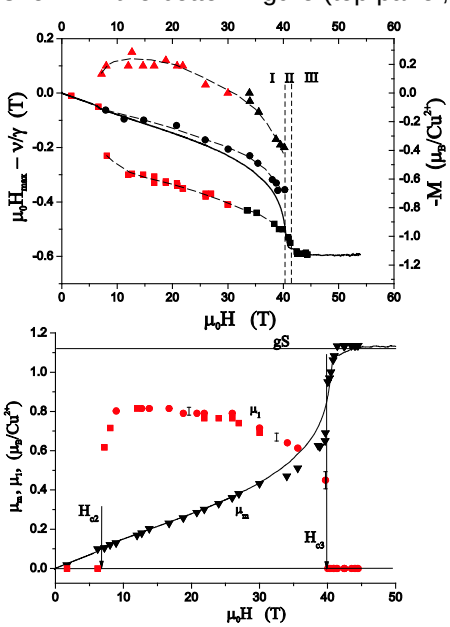


Experimental

We performed our NMR experiments of the ^{7}Li and ^{51}V nuclei using spin-echo techniques with a pulse sequence 3μs-τ-3μs in the hybrid magnet of the DC field facility, NHMFL, Tallahassee. All spectra were collected with τ=15μs by sweeping the applied magnetic field H at constant frequencies. Temperatures down to T = 380 mK were achieved within a ^{3}He cryostat.

Results and Discussion

The right figure shows the ^{51}V NMR spectra of the magnetically ordered phase at 380 mK within the range 34 < $\mu_0 H$ < 45 T of the applied magnetic field H oriented H || c. The origin at 0 T gives the diamagnetic reference field of the line shift. The double-horn shaped pattern for lower fields H at the bottom resemble our previous results [2], where we established the spin-modulated magnetic structure in $LiCuVO_4$. Around the value of the applied magnetic field $\mu_0 H$ = 40.4 T (cf. arrows in the Fig.) the double-horn shape starts to disappear in favor of a single-line pattern with one solitary spectral line towards higher fields H. The transition takes place in a narrow field range, probably due to demagnetization fields of the single-crystalline sample. The single-line shaped pattern is maintained up to 45 T. The field dependence of the resonance positions of the ^{51}V spectra are shown in the bottom figure (top panel, left axis). These local fields trace the magnetization data (top panel, right axis, [3]) up to fields $\mu_0 H$ ~ 41.4 T. For higher fields H the magnetization M is field dependent, whereas the NMR resonance is field independent. In the bottom figure (bottom panel) μ_m is the mean magnetic moment of Cu^{2+} and μ_1 is the modulation strength of the spin-modulated structure.



Conclusions

Our NMR experiments establish the parameters of the spin-modulated phase in the full field range. At higher fields $H > H_{c3}$, the ^{51}V NMR line is single-line shaped, as it is expected for the spin-nematic phase. Additionally, μ_m detected from NMR spectra follows μ_m obtained from magnetization data only up to $\mu_0 H$ ~ 41.4 T. This evidences that spin-nematic correlations in $LiCuVO_4$ are active in the narrow field range 40.4 < $\mu_0 H$ < 41.4 T. Herein, the magnetization of the sample changes by 15…20 % of H_{sat}, satisfying theoretical predictions for 1D spin-chains [4].

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References [1] Zhitomirsky, M.E., *et al.*, H., Europhys. Lett., **92**, 37001 (2010); Sato, M., *et al.*, arXiv:1208.2235v1 (2012). [2] Büttgen, N., *et al.*, PRB, **85**, 214421 (2012). [3] Svistov, L, *et al.*, JETP Letters **93**, 21 (2011). [4] Heidrich-Meissner, F., *et al.*, PRB, **80**, 144417 (2009).