Experimental report

12/09/2022

Proposal: 4-05-737 **Council:** 10/2018

Title: Spin dynamics in a Tomonaga Luttinger liquid

Research area: Physics

This proposal is a new proposal

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Samples: Ba2Co2V2O8

Instrument	Requested days	Allocated days	From	To
IN5	8	7	09/01/2020	16/01/2020

Abstract:

We propose to investigate the spin dynamics in Ba2Co2V2O8, which may be considered as an experimental realization of a Tomonaga Luttinger liquid at very low temperature and above a magnetic field of 4 T. We especially would like to concentrate on the cross over around 8 T, predicted by theory, from a regime where longitudinal incommensurate correlations dominate towards a regime dominated by transverse and commensurate ones around the antiferromagnetic position. This cross over is in principle encoded in the spin dynamics making inelastic neutron scattering the best tool to study this feature. For this purpose, we apply for 8 days of beamtime on IN5, using the 10 T magnet equipped with a dilution insert.

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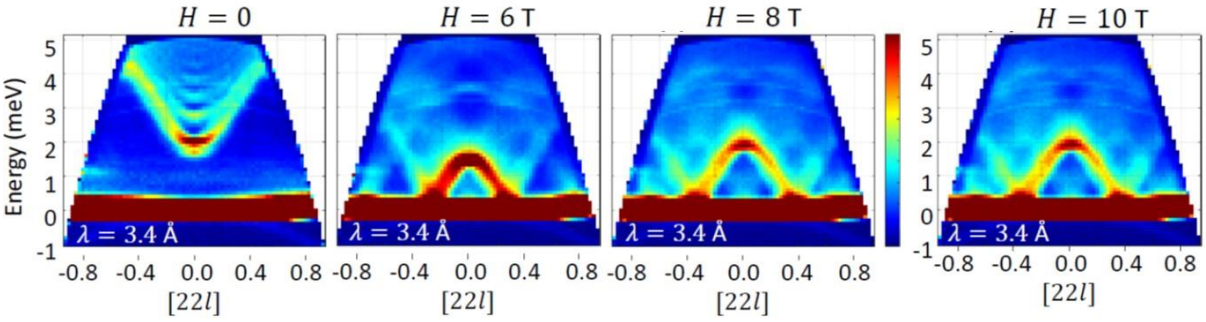
Context: $BaCo_2V_2O_8$ is a canonical model compound to investigate low-dimensional quantum behavior. It consists in screw-chains of magnetic Co^{2+} running along the c-axis, weakly coupled to one another. This coupling produces a three-dimensional antiferromagnetic order (LAF for longitudinal antiferromagnetic) below T_N=5.6 K. $BaCo_2V_2O_8$ is also characterized by a sizable Ising-like magnetic anisotropy of the effective spins 1/2 carried by the Co^{2+}. Remarkably, the spin dynamics consists in spinons bound states (fractionalized excitations analogous to domain walls) gapped by the anisotropy. The confinement potential is due to interchain interactions. They appear as two series of discrete states with transverse and longitudinal fluctuations (with respect to the anisotropy c axis), see also our previous results are describes in the references.

Combining inelastic neutron scattering and numerical simulations, the aim of this experiment was to study $BaCo_2V_2O_8$ in a longitudinal magnetic field, parallel to the chain axis, in particular the region around the critical field corresponding to the spin-flop transition at 9 T. This transition separates two ordered states stabilized by the interchain coupling. At this magnetic field, the magnetic ground state changes from an incommensurate longitudinal spin density wave with the ordered magnetic moments pointing along the c-direction, to a collinear antiferromagnetic phase where the magnetic moments are oriented perpendicular to the magnetic field direction. The critical field also corresponds to the inversion of the Tomonaga-Luttinger exponents, which characterize the power law decay of the spin-spin correlation functions for the longitudinal and transverse parts.

Experiment: Time-of-flight experiments were performed successfully on the IN5 spectrometer in a 10 T vertical magnet using a dilution insert allowing to cool down to 50 mK. The crystal was oriented with the c axis vertical and the horizontal scattering plane (a*, b*). The large vertical covering of the detector allowed to probe a large portion of the reciprocal space along the c* direction. IN5 was operated with 3.4 and 4.8 Angstrom for most of the measurements. Three different wavelengths, 2.3, 3.4 and 4.8 Angstrom were used at 10 T to probe different energy ranges with appropriate resolution. The figure below shows some of our results.



At H=0 in the LAF phase, discrete excitations with energy minimum at reciprocal vector (2, 2, 0) position are observed and attributed to spinon bound states confined by the interchain interaction. Above 3.8 T, the spectral weight concentrates in a low energy arch-like excitation that bridges the incommensurate magnetic satellites of the LSDW order. No abrupt change of behavior is observed at 9 T, where the flop transition occurs. Our IN5 neutron scattering measurements allowed to probe the magnetic orderings and associated spin dynamics through two quantum phase transitions, from LAF to LSDW at 3.8 T and from LSDW to TAF at 10 T. The ongoing analysis of these results follows two directions, with the strong support of Shintaro Takayoshi (Konan University, Japan) and Thierry Giamarchi (Geneva University):

1) performing numerical simulations with a longitudinal magnetic field (density matrix renormalization group. The retarded correlation function is calculated by time evolving block decimation). This work is nearly finished.
2) carefully analyze the dispersion of the bound states as a function of field to determine the weak interchain interactions. This is currently done with the help of spin wave calculations.

References

Topological quantum phase transition in the Ising-like antiferromagnetic spin chain BaCo2V2O8
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Tomonaga-Luttinger liquid spin dynamics in the quasi-one-dimensional Ising-like antiferromagnet BaCo2V2O8
Quentin Faure, Shintaro Takayoshi, Virginie Simonet, et al.
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Solitonic excitations in the Ising anisotropic chain BaCo2V2O8 under large transverse magnetic field
Quentin Faure, Shintaro Takayoshi, Béatrice Grenier, Sylvain Petit, Stéphane Raymond, Martin Boehm, Pascal Lejay, Thierry Giamarchi, and Virginie Simonet
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Tomonaga-Luttinger exponent inversion in the quasi-one dimensional Ising-like antiferromagnet BaCo2V2O8
in preparation