Experimental report

09/10/2019

Proposal: **7-01-482** **Council:** 10/2018

Title: Anomalous lattice dynamics of the elemental superconductor niobium

Research area: Physics

This proposal is a new proposal

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Sonja HOLM-DAHLIN

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Samples: Ni.(C(2)D(8)N(2))2.NO(2).ClO4

Instrument	Requested days	Allocated days	From	To
IN5	7	4	23/09/2019	27/09/2019

Abstract:

Phonon lifetimes in BCS superconductors provide information on the details of the electron-phonon coupling mechanism. In 2008, high-resolution neutron inelastic scattering experiments revealed anomalies in the lifetimes of transverse acoustic modes in the elemental superconductors Pb and Nb. These experiments were performed using a resonant spin-echo technique. To date no quantitative explanation for these anomalies has been forthcoming. Here we propose to use IN5 to investigate phonon lifetime effects arising from electron-phonon coupling in Nb over a large swathe of reciprocal space. In addition to providing an important check of the surprising behaviour of the transverse acoustic modes, we will investigate non-Lorentzian lineshapes, and obtain a high-resolution survey of the longitudinal acoustic modes where new features may be expected. These data will be compared with ab initio calculations to be performed by one of the proposers using CASTEP.

Multimagnon and intra-band excitations in the Spin-1 Haldane chain

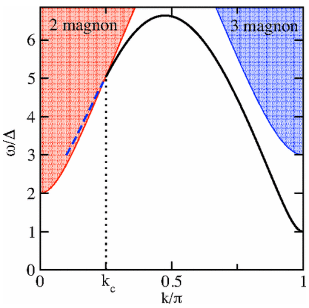
The spin-1 Heisenberg antiferromagnetic (HAFM) chain is a canonical model system in quantum magnetism. The existence of the Haldane gap to the lowest energy excitations has been demonstrated in many experimental realisations. However, the nature of the multimagnon continua is much less clear. We propose to fully measure the one- and multi- magnon spectra as a function of wave vector along the chains and frequency, $S(q, \omega)$, in the classic $S = 1$ HAFM chain compound, NENP, and compare the results with calculations for the multimagnon continua in the low temperature limit. We then propose to investigate the very recent prediction of thermally induced magnon scattering below the one-magnon dispersion.

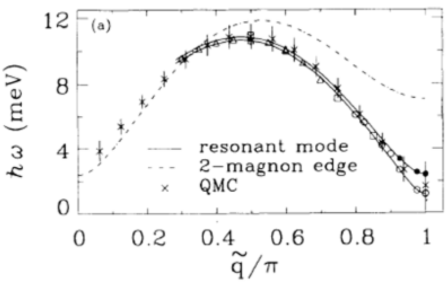
The d-NENP sample

$Ni(C_2D_8N_2)_2NO_2ClO_4$ (d-NENP) is a $S = 1$ Heisenberg antiferromagnet with two Ni sites per unit cell along b and an in chain coupling of J = 46 K = 4.0 meV.
Pnma orthorhombic space group: a = 15.223 Å, b = 10.300 Å, c = 8.295 Å, α, β, γ = 90°.
The 2.3 g sample was mounted on an aluminum holder with wire, no glue, and aligned in with (010) and (001) in the horizontal plan.

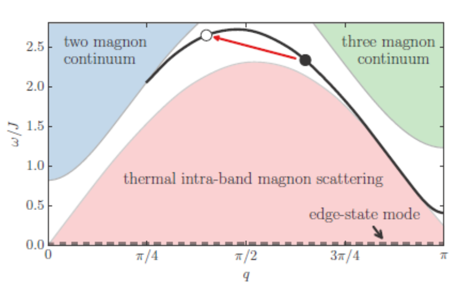
Two main objectives

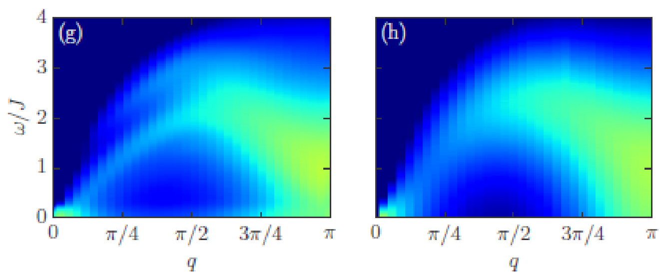
1. Measure $S(q, \omega)$ in d-NENP at 2 K, corresponding to an energy much smaller than the gap Δ, to be effectively in the low temperature limit, and seek evidence for two- and three- magnon continua as shown in the figure below [1]. The second figure is TAS data of the dispersion [2].





2. Investigate the recent prediction of thermally induced magnon scattering below the one-magnon dispersion. Measure at three additional temperatures, up to $k_B T = 46$ K $\approx J$, to investigate the prediction of thermally induced magnon scattering as shown in the schematic drawing and the calculated thermally induced magnon scattering at 46 K [3].





Results

The spectrum of $S(q,\omega)$ has been measured with two different incident energies (λ_0 = 2.2 Å and 3.5 Å) and at three different temperatures (T = 1.7 K, 18.4 K and 46 K). It is clear form the data that a detailed data analysis is needed in order to separate the 1D magnetic signal from the 3D phonons. The acoustic phonons are clearly present between 4 and 8 meV and the lowest ling optical phonons start at roughly 9 meV as seen in figure 1. There seems to be a splitting of the magnon at $q = \pi$ of about 2 meV; this signal is however an artifact of the integration range cutting the acoustic phonon in a skewed fashion.

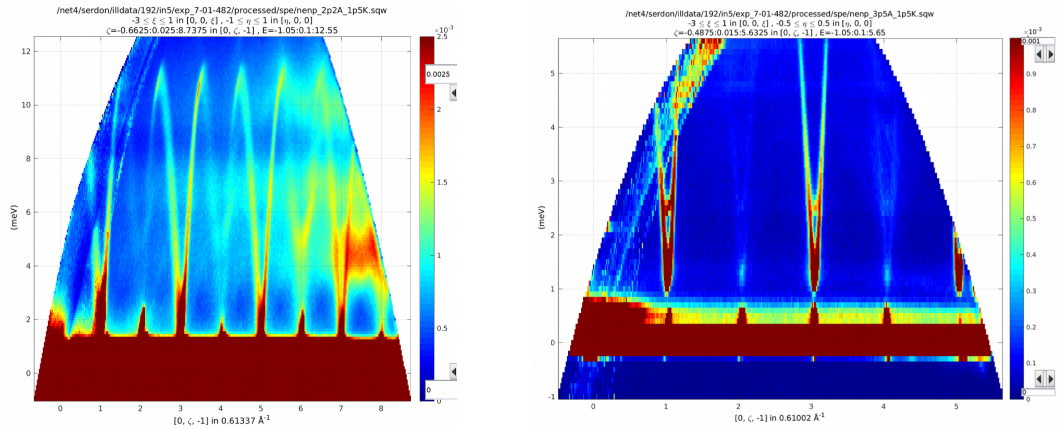


Figure 1: The dispersion relations measured at 1.7 K. The incident wavelength is λ_0 = 2.2 Å on the left, and λ_0 = 3.5 Å on the right.

When the sample is heated to a temperature equal to the coupling in the system $J = 46$ K the magnetic signal becomes broad as seen in figure 2.

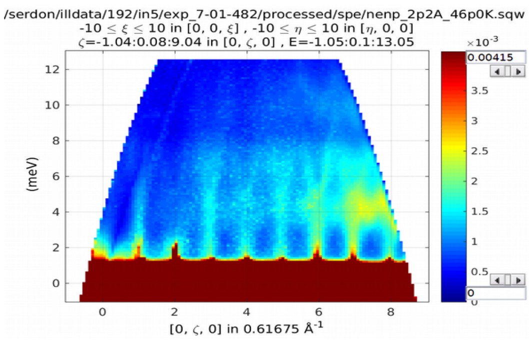


Figure 2: The dispersion relations measured at 1.7 K and λ_0 = 2.2 Å.

References

[1] S.R. White and I. Affleck, Phys. Rev. B 77, 134437 (2008)

[2] S. Ma et al., Phys. Rev. Lett. 69, 3571 (1992)

[3] J. Becker et al., Phys. Rev. B 96, 060403(R) (2017)

The report was written on October 8, 2019 by Dr. Sonja Holm-Dahlin.