Incommensurate spin excitations in $BiCu_2PO_6$

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We report detailed inelastic neutron scattering experiments on the newly discovered spin-1/2 ladder compound $BiCu_2PO_6$. Our measurements were performed on the C5 DUALSPEC triple axis spectrometer at the Canadian Neutron Beam Centre at Chalk River Laboratories. $BiCu_2PO_6$ has an orthorhombic unit cell,space group Pnma with a = 11.755 , b = 5.16 , c = 7.79 at 6 K[1]. The ladder legs and rungs oriented along the crystallographic b and c axis respectively [Fig. 1]. Frustration is introduced by competing nearest (J_1) and next-nearest-neighbour (J_2) antiferromagnetic interactions on the ladder leg.

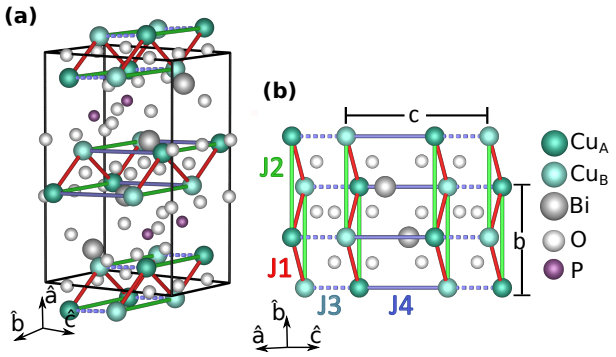

FIG. 1. (a) Schematic representation of the crystal structure of $BiCu_2PO_6$. (b) Perspective view of the ladder unit in the b-c plane. Along the chains Cu^{2+} ions interact via NN exchange J1 and NNN exchange J2. The chains are coupled along the c axis via superexchange interactions J3 and J4.

Experiments were carried out on a 4.5 g single crystal sample grown using the traveling floating zone method. The sample was mounted in the $(0kl)$ scattering plane and the spectrometer was operated at a fixed final energy of 14.56 meV, using a focusing pyrolytic graphite monochrometer (PG) and graphite analyzer with a horizontal collimation sequence of [33'-48'-51'-144']. Two sets of PG filters were placed in the scattered beam to eliminate higher order reflections. Temperature control was provided by a closed cycle cryostat with a base temperature of 6 K. All data was corrected for higher-order wavelength neutrons in the incident beam monitor[2]. Intensities were placed on an absolute scale by normalization with the integrated intensity of a transverse acoustic phonon measured near the (004) Bragg peak.

The spin excitation spectrum in $BiCu_2PO_6$ was mapped out through a series of constant momentum transfer scans. Throughout the Brillouin zone we observe two steeply dispersing modes. Representative scans are shown in Fig. 2.

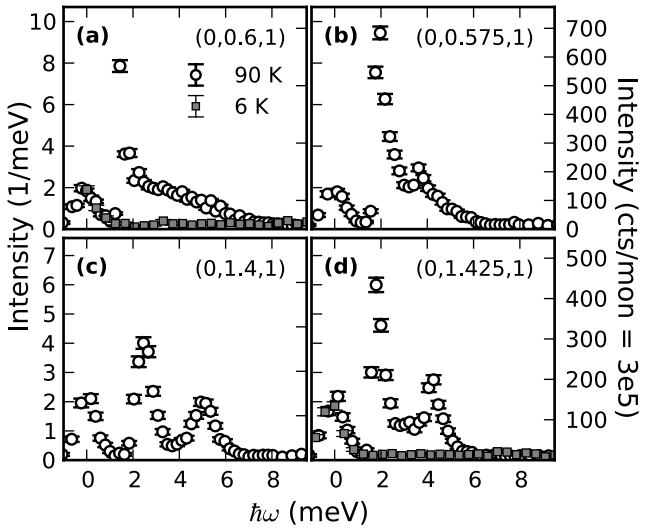

FIG. 2. Representative constant-**q** scans collected on C5, at T = 6 K and T = 90 K.

The inelastic intensity decreases with increasing temperature and vanishes above 60 K, corresponding with the turnover observed in the magnetic susceptibility[3]. Extensive sampling of **q**-values throughout reciprocal space enabled the construction of a map of the dynamic structure factor $S(\mathbf{q},\omega)$ shown in Fig. 3.

No evidence for elastic magnetic scattering was found indicating the absence of magnetic long-range order in $BiCu_2PO_6$. Two branches of long-lived magnetic excitations disperse along both the $\mathbf{b}^*$ and $\mathbf{c}^*$ directions. The modes are gapped throughout the Brillouin zone and the excitation minimum occurs at an incommensurate wavevector. The excitation bandwidth was observed to be $\sim$ 12 meV along the ladder leg, $\mathbf{b}^*$, direction and $\sim$ 2 meV along the ladder rung, $\mathbf{c}^*$, direction.

Our neutron scattering data are consistent with a J_1-J_2-J_4 two-leg ladder model including small interladder exchange J_3. Competing interactions J_1 and J_2 drive the dynamic correlations to an incommensurate wavevector.

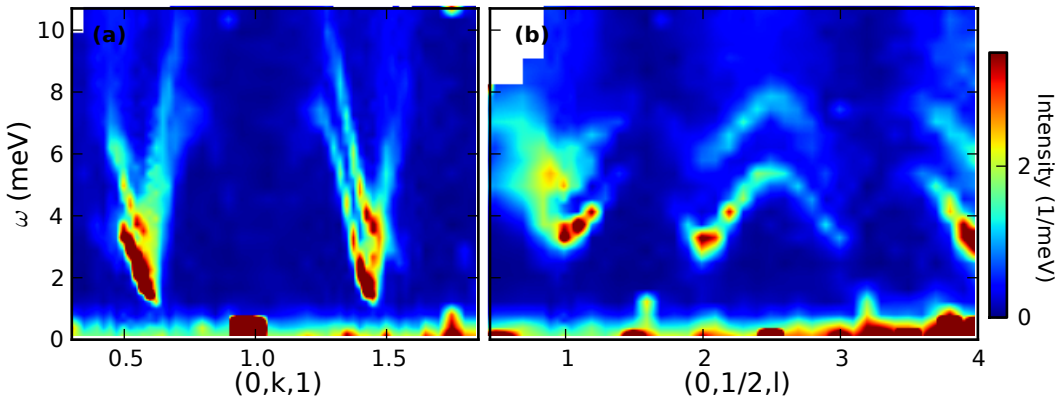

FIG. 3. Map of the dynamic structure factor $S(\mathbf{q},\omega)$ measured at T = 6 K. Neutron scattering intensities were corrected for higher order wavelength contamination in the incident beam monitor and the isotropic Cu^{2+} form factor. Intensity maps were constructed by linear interpolation of a series of constant-$\mathbf{q}$ scans.

In contrast to the single triply degenerate excitation normally observed in spin ladders, we observe two-branches of excitations. The appearance of two modes may be due to the presence of significant anisotropic interactions which split the degeneracy of the triplet in zero field.

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