Switching the magnetic order in CaBaCo2Fe2O7 using magnetic field

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The layered kagome system in the hexagonal Swedenborgite structure displays similarly to the Pyrochlores a highly frustrated network of tetrahedral coordinated magnetic ions. However, its broken inversion symmetry raises further the complexity of ordering due to non-vanishing Dzyaloshinski-Moriya (DM) interactions. The crystallographic structure of the compound $CaBaCo_2Fe_2O_7$ was successfully refined in $P6_3mc$ symmetry (a = 6.36 Å and c = 10.28 Å) and determined to be structural invariant under temperature within the resolution limits. Neutron scattering evidenced the coexistence of a seemingly commensurate K-type and long periodic (lp) modulation within the AFM phase (below 160 K). The latter one can be described with the 3-q star q_s^* of the propagation vector $q_s = (0.342, 0.342, 0)$ noted in the crystallographic unit cell. This corresponds to a splitting of $\delta \approx 0.017\,\text{Å}^{-1}$. Based on information from polarization analysis a spin structure was established using a model of superimposed cycloidal waves along each arm of the star q_s^*. The structure factor of the resulting spin structure corresponds semi-quantitatively with the observations. This model of the spin structure itself is an AFM skyrmion-lattice with a winding number of $w \approx -1$ indicating a topologically protected swirling.
In contrast to most ferromagnetic skyrmion-lattices, here no external magnetic field was applied to stabilize the long periodic modulation. This rises the question for the nature on the intrinsic stabilization mechanism. Magnetization measurements evidenced a non-vanishing field-hysteresis concluding a net magnetic moment at all measured temperatures (2 K up to room temperature). Depending on the sample's magnetic field history two different state exist (basically zero or non-vanishing net moment). In a more recent neutron scattering experiment, the intensity close to the K-point was discovered to be split, too, and corresponds to another lp modulation with a longer periodicity (inner $l_i \approx 1100$ Å and outer lp $l_o \approx 320$ Å). Furthermore, these two different lp modulations appeared to coexist in a wide temperature range within the AFM phase (cf. Fig. 1a). In correspondence with magnetization results, two states could be distinguished below 20 K: coexistence of two lp modulations (state A) or only the one with shorter periodicity remains (state B). Previous neutron scattering experiments hinted at the possibility to influence the magnetic order with an external field. In that experiment at the start the state A was observed, however applying an oscillating, decreasing magnetic field at room temperature led to a stabilization of state B. Yet, this change could not be reversed with magnetic fields up to 2 T.
The samples measured in the present experiment have been in state B at the start of the experiment, showing a coexistence at 80 K (see Fig. 1a) and a single lp modulation at 4 K (see Fig. 1b). The application of 5 T parallel and anti-parallel to the c-axis did not have any notable influence in the temperature range 4 to 80 K, however cooling in an applied field of 5 T from 160 K slightly changed the scattering pattern at low temperatures (see Fig. 1c). While, a complete switch to A could not be achieved, with the outer lp remaining dominant, this still underlines the possibility of a switch from state B to A.
Thanks to the improved resolution and decreased background, the two different modulations could be told apart clearly

and even the peak splitting of the inner modulation was resolved. Selected magnetic peaks have been measured at various temperature steps. From the 2D fits of these scattering maps we extracted not only the splitting magnitude but also the peak intensities of each individual peak. The resulting temperature dependence evidences the clear change of the dominant lp modulation for a sample in state B (see Fig. 1d). Since the inner lp modulation nearly vanishes at low temperatures, it can be hardly fit. Otherwise, both modulations' periodicity slightly increases with decreasing temperature, indicating both modulations to be incommensurate. Furthermore, for the first time an electric field of up to 0.5 kV/mm was applied along the high symmetry c-axis, however, at this field strength no change was observed in the scattering pattern.

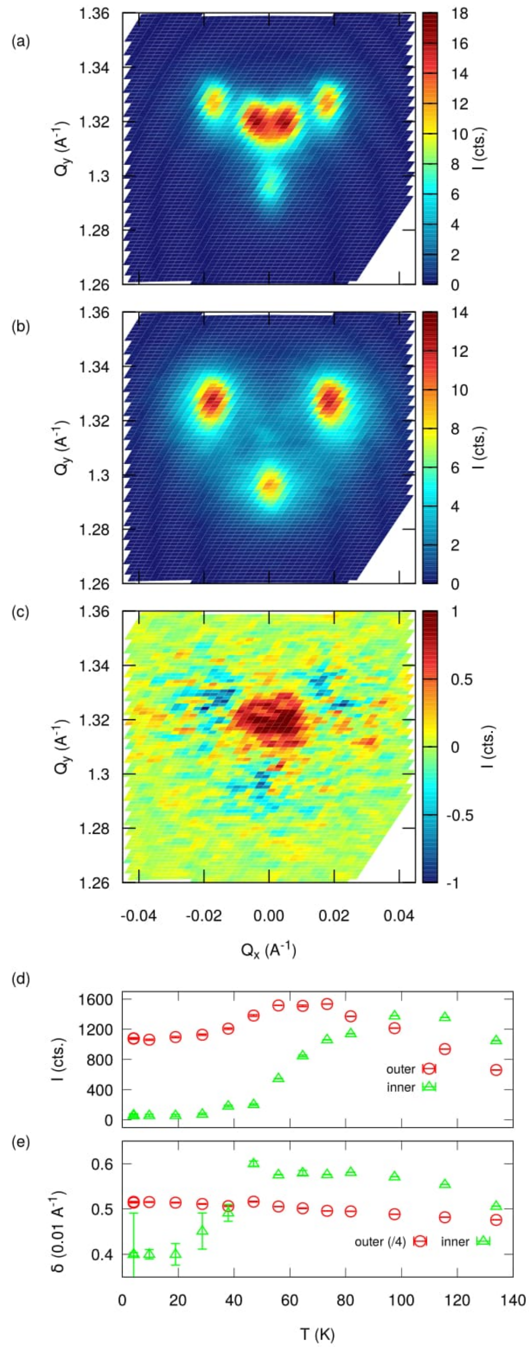

Fig. 1. Magnetic peak (2/3, 2/3, 0). (hk0)-scattering map at 80 K (a) and 4 K (b). (c) (hk0) map of the difference between measurements using FC and ZFC at 4 K. T dependence of the lp modulations' peak intensities (d) and splitting (e).