Experimental report

02/08/2021

Proposal: **4-03-1742** **Council:** 4/2020

Title: Quasi-elastic scattering in the stoichiometric non-Fermi liquid system CeCo2Ga8

Research area: Physics

This proposal is a resubmission of 4-03-1740

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Samples: CeCo2Ga8

Instrument	Requested days	Allocated days	From	To
IN5	9	4	19/08/2020	23/08/2020

Abstract:

The quantum critical point (QCP) governs many novel dynamics at finite temperature with a quantum critical fluctuation region. For strong correlated heavy-fermion materials in this region, the energy of spin fluctuations scales with temperature, called ω/T scaling, where the critical exponent give important information about the type of QCP. However, most of present study on QCP in heavy fermions focus on the quasi-2D or 3D systems, and high pressure or magnetic field have to be applied to induce the QCP, giving big challenge to inelastic neutron scattering.A recently stoichiometric quasi-1D Kondo lattice system CeCo2Ga8, suggest possible naturally non-Fermi-liquid behaviors and possible in the vicinity of QCP. To study the magnetic excitations in this material, we have proposed an experiment at IN5 and done recently (Proposal No.: 4-03-1734).We have found a typical quasi-elastic signal of spin dynamics. Due to Due to limit beamtime (4 days), we were not able to get more data above 10 K to finish the w/T scaling. Thus we request continue beamtime on CeCo2Ga8 at IN5 for more measurement up to 300 K.

Exp. Report: Quantum critical scaling in the quasi-1D heavy fermion $CeCo_2Ga_8$

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A quantum critical point (QCP) is a continuous phase transition from an order state to a paramagnetic state. The quantum critical fluctuations associated with the QCP will give rise to non-Fermi-liquid behaviours and some other novel phases, such as superconductivity. Heavy-fermion materials exhibit rich quantum critical phenomena and are excellent platforms to study QCPs [1-3]. For a long-ranged magnetic ordered system, the QCP is defined as the point with transition temperature graduately approaching zero. Its properties differ from those on either side of the quantum transition (e.g. Landau Fermi liquid sate) and often exhibit unusual dependence on the temperature and energy (so called Non-Fermi-liquid state), These socalled non-Fermi liquid (NFL) materials exhibit characteristic low temperature properties such as $C/T \sim -lnT$ and so on. The presence of E/T scaling in their dynamical spin susceptibility, with an anomalous exponent α, is another remarkable feature of some of the NFL systems that is characteristic of a strongly interacting quantum critical point [4]. Recently, a quasi-1D Kondo lattice system CeCo2Ga8 has been reported to exhibits NFL and QCP behavior without doping at ambient pressure [5]. Therefore we proposed to measure the energy and temperature dependence of spin excitations in single crystals of CeCo2Ga8 to examine the quantum critical scaling behavior of the dynamical susceptibility [6].

We have grown about a total mass of 10 grams of crystals to meet the requirement of inelastic neutron scattering experiment. Since it is very difficult to distinguish the orientation in ab-plane, we simply co-aligned them on copper plates along c-axis to measure the spin excitations along L direction and in the ab-plane. With a series rotation of sample along L axes and peroendicular to L axes from +30° to -30° with 1° /step, the excitation signals can be obtained up to 2.5 meV. As shown in Fig.2, we can see an antiferromagnetic excitations around L = 0.5. Besides, for the 1D cut along L, we can see the spin excitation is incommensurate and the two incommensurate peaks merge into one peak with the increase of the energy. While the reason of this strange downward dispersion is not clear. We measured the excitations at 1.5K, 4.5K, 12.6K, 35.5K and 100K. By integrating the intensity in the first Brillouin zone after background subtraction and form factor correction, we get the energy dependence of the spin excitations at different finite temperatures. We find a clear evidence of E/T scaling in the imaginary part of the dynamic susceptibility. The $\chi''(\omega,T)$ obtained is shown in Fig. 2(d) as $\chi''(\omega,T)T^{\alpha}$ versus E/T plot. The $\chi''(\omega,T)$data between 0.2 and 2 meV at $1.8K \leq T \leq 100K$ collapse onto a single curve. This confirms the universal E/T scaling behavior of $\chi''(\omega,T)$ data are well described by the scaling relation $\chi''(\omega,T)T^{\alpha} \sim f(\omega,T)$ with $\alpha = 0.21$ [7]. The solid curve in Fig. 2(d) represents the scaling function $\chi''(\omega,T)T^{\alpha} = (k_BT/\omega)^{\alpha}\tanh(bE/k_BT)$ for $\alpha = 0.21$ and $b = 0.37$.

References:

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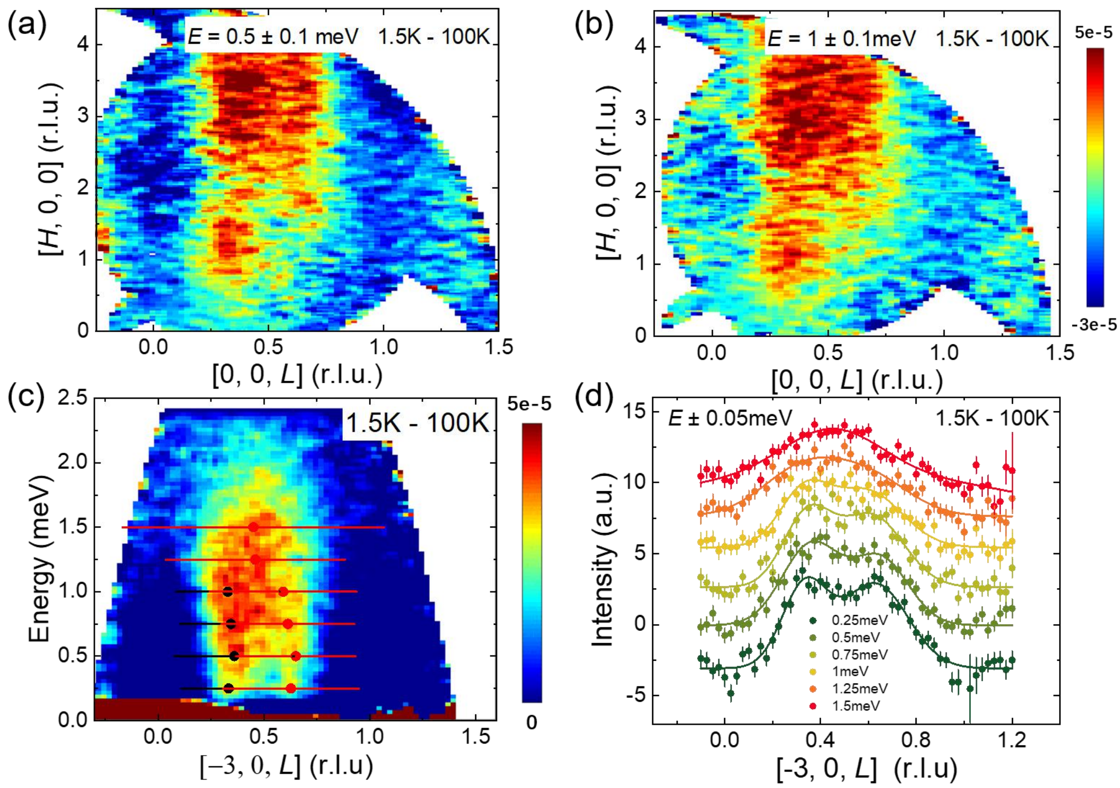

Fig.1 (a)-(d) The spin excitation of CeCo2Ga8 in the $[H,0,L]$ scattering plane at 0.5meV and 1meV; (b) The energy dependence of $S(Q,E)$ of spin waves along the $[-3,0,L]$ direction; (d) 1D cut of the scans at different energy.

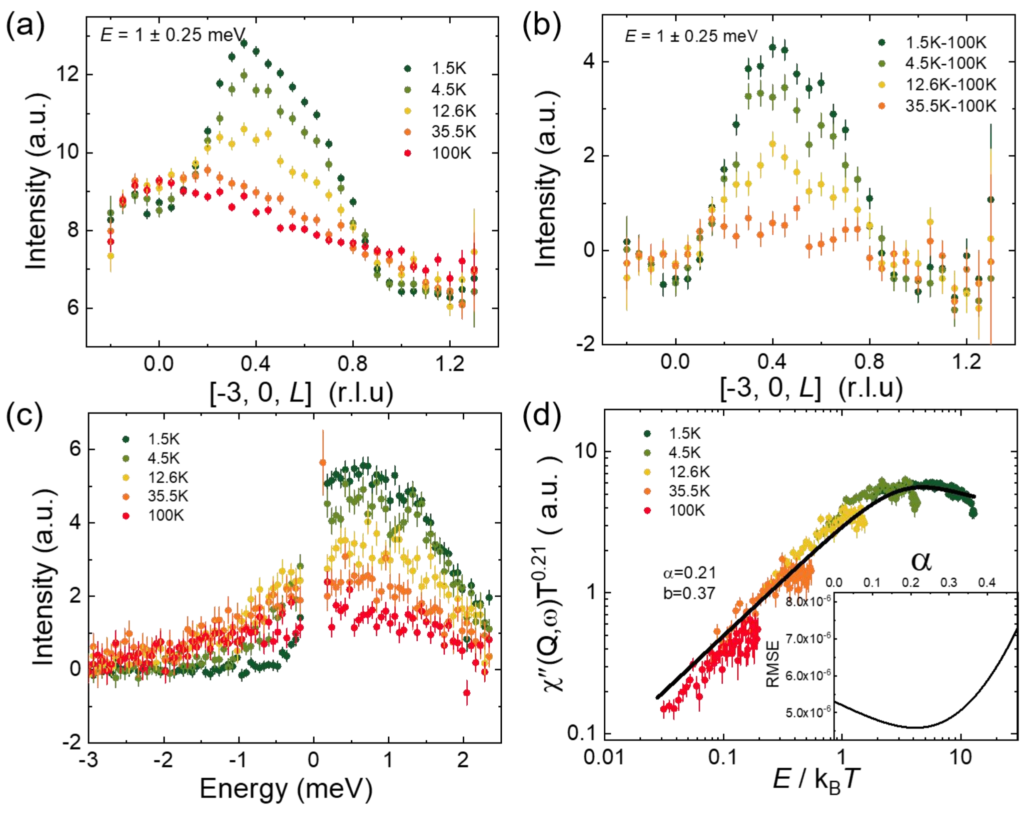

Fig.2 (a) 1D cut at different temperature; (b)The data after background subtraction and the background here is the data of 100K; (c) The energy dependence of $S(Q,E)$ at different temperature; (d) E/T scaling of spin excitations and the solid line is fitted as $\chi''(\omega,T)T^{\alpha} = (k_BT/\omega)^{\alpha}\tanh(bE/k_BT)$ with $\alpha = 0.21$ and $b = 0.37$.