Role of the electronic spins in a novel superconductor $CeCoIn_5$

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A series of $CeMIn_5$ (M = Rh, Co and Ir) has the highest superconducting (SC) transition temperature $T_c = 2.3$ K for heavy fermion materials. Such a high SC transition temperature can be realized by strong antiferromagnetic (AFM) fluctuations. Pure $CeRhIn_5$ exhibits an incommensurate AFM phase below $T_N = 3.8$ K, with the modulation of $q_h = (1/2, 1/2, 0.297)$.[1, 2, 3] In this phase, a helical spin density wave (SDW) state is suggested to appear. It is expected that a quantum critical point (QCP) exists at $x \sim 0.75$ with strong magnetic fluctuations, and the AFM phase vanishes here. On the other hand, the superconductivity appears in $x \geq 0.4$. Therefore, the SC phase in this family lies near the QCP, and coexists with the AFM phase in the intermediate x region. In order to understand the role of the magnetic spins for the superconductivity in these systems, we performed neutron scattering measurements on $CeRh_{1-x}Co_xIn_5$.

Single crystals of $CeRh_{1-x}Co_xIn_5$ with $x = 0.3$, 0.4, 0.6, 0.7 and 0.75 were prepared. Elastic and quasi-elastic neutron scattering experiments were carried out at 4G (GPTAS). (*hhl*) was selected as the scattering plane. The $x = 0.3$, 0.4 and 0.6 samples were cooled down to 1.5 K by using a ^{4}He cryostat, and the $x = 0.7$ and 0.75 ones were cooled down to 0.7 K with a 1K cryostat. The neutron momenta of $k = 3.814$ Å^{-1} and 2.67 Å^{-1} were selected for the measurements on the $x = 0.3$, 0.4 and 0.7 samples and the $x = 0.6$ and 0.75 samples, respectively.

In the $x = 0.7$ and 0.75 systems, which are near the QCP, neither magnetically ordered phase nor the magnetic fluctuation is observed. On the other hand, the $x = 0.6$ system exhibits a magnetically ordered state below 2.8 K. Fig. 1 shows the elastic neutron scans at $q = (1/2, 1/2, l)$ for the $x = 0.6$ system, with l ranging from 0.25 to 0.55. For $0.45 \leq l \leq 0.55$, the scan at $q = (1/2, 1/2, 1 + l)$ is shown instead of $q = (1/2, 1/2, l)$ to exclude Bragg peaks from mosaic. The open and closed circles indicate the results obtained at 5 K and 1.5 K, respectively. A Bragg peak is observed at $q_c = (1/2, 1/2, 1/2)$, indicative of the appearance of a commensurate AFM phase. The helical SDW phase, which is observed in the pure $CeRhIn_5$, with a propagation vector $q_h = (1/2, 1/2, 0.297)$ is already vanished here. Thus, the SC phase coexists with the commensurate AFM phase. The present study suggests the significant relationship between these two phases.

References

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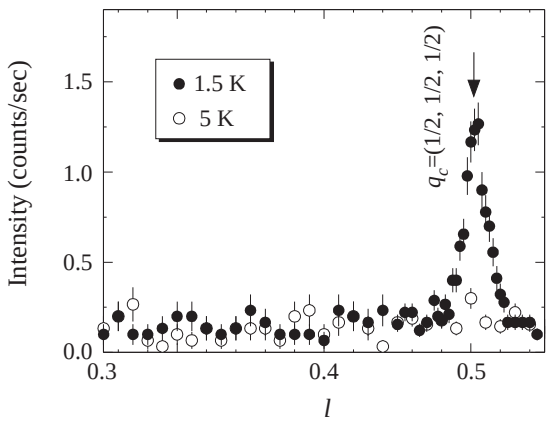

Fig. 1. Elastic neutron scans for $CeRh_{0.4}Co_{0.6}In_5$. Open and closed circles indicate the results at 5 K and 1.5 K, respectively.