Local Moment, Itinerancy and Deviation from Fermi Liquid Behavior in Na_xCoO_2 for $0.71 \leq x \leq 0.84$

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Introduction

We report the observation of Fermi surface (FS) pockets via the Shubnikov de Haas (SdH) effect in Na_xCoO_2 for $x = 0.71$ and 0.84, respectively. Our observations indicate that the FS expected for each compound intersects their corresponding Brillouin zones, as defined by the previously reported superlattice structures [1], leading to small reconstructed FS pockets, but only if a precise number of holes per unit cell is *localized*. For $0.71 \leq x < 0.75$ the coexistence of itinerant carriers and localized $S = 1/2$ spins on a paramagnetic triangular superlattice leads at low temperatures to the observation of a deviation from standard Fermi-liquid behavior in the electrical transport and heat capacity properties, suggesting the formation of some kind of quantum spin-liquid ground state.

Experimental

We performed electrical transport measurements in $Na_{0.71}CoO_2$ and $Na_{0.84}CoO_2$ using the hybrid magnet in conjunction with a ^{3}He refrigerator and a rotating sample holder in order to detect Shubnikov de Haas oscillations. Results for x = 0.71 are shown in Fig. 1. While Heat capacity and resistivity measurements at low fields were performed by using a PPMS (Fig. 2).

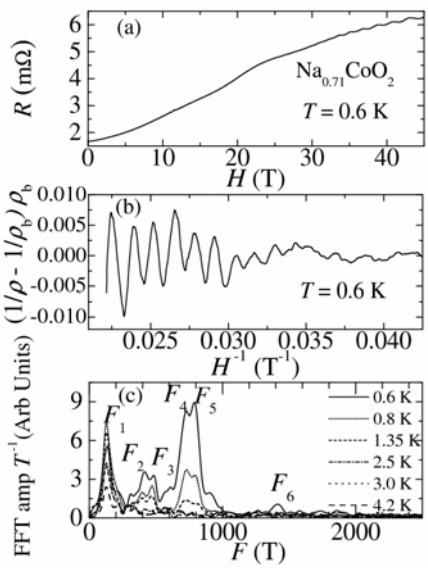

Fig 1 (a) Resistance R as a function of field H for a $Na_{0.71}CoO_2$ single crystal at $T = 0.6$ K. (b) The SdH effect or the oscillatory component of R in (a) as a function of $H_i 1$. (c) Amplitude of the fast Fourier transform normalized by temperature T for several values of T. At least six frequencies are detected: $F_1 = 125$ T, $F_2 = 400$ T, $F_3 = 475$ T, $F_4 = 725$ T, $F_5 = 800$ T, and $F_6 = 1413$ T.

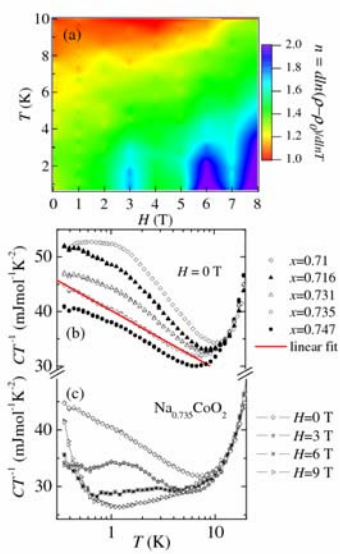

Fig. 2(a) The evolution of the exponent of the resistivity as a function of field H for a $Na_{0.735}CoO_2$ single crystal. (b) Heat capacity normalized by temperature C/T as a function of T for several Na concentrations x in a semi-log scale. Straight line represents a linear fit to the $x = 0.735$ data over the temperature range $0.35 \leq T \leq 7$ K. (b) $C=T$ as a function of T for $x = 0.735$ and for several values of the field H.

Results and Discussion

The SdH oscillations can only be understood by the intersection of the original Fermi surface of these materials with the superlattice induced Brillouin zone, if for both concentrations at least one hole per superlattice unit cell is localized. Thus for x = 0.71 one has 2.5 itinerant holes coexisting with a localized moment per each 12 cobalts within the superlattice unit cell and 1 itinerant holes and one localized moment per 13 cobalts within the superlattice unit cell.

Conclusions

In summary, deviation from standard Fermi-liquid behavior is observed in the paramagnetic state of Na*x*CoO2 as $x = 0.75$, and as a result of the interplay between itinerancy and localized $S = 1/2$ moments on a triangular superlattice. The upturn in the low temperature specific heat and the anomalous scattering in the resistivity both point to the existence of a novel kind of low energy excitations. That these excitations appear to be suppressed by a magnetic field suggests that these are spin fluctuations. One suggestion [1] is that the local moments form a spin liquid state which co-exists with itinerant electrons. While our data does not allow us to draw any firm conclusion on the origin of the anomalous behavior, it is clear that the cobaltates offer a new window into possible novel ground states in a system with coupled local moments and itinerancy.

Acknowledgements

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References

[1] F. C. Chou *et al.*, cond-mat:0709.0085.