Ce ferromagnets at the quantum critical point

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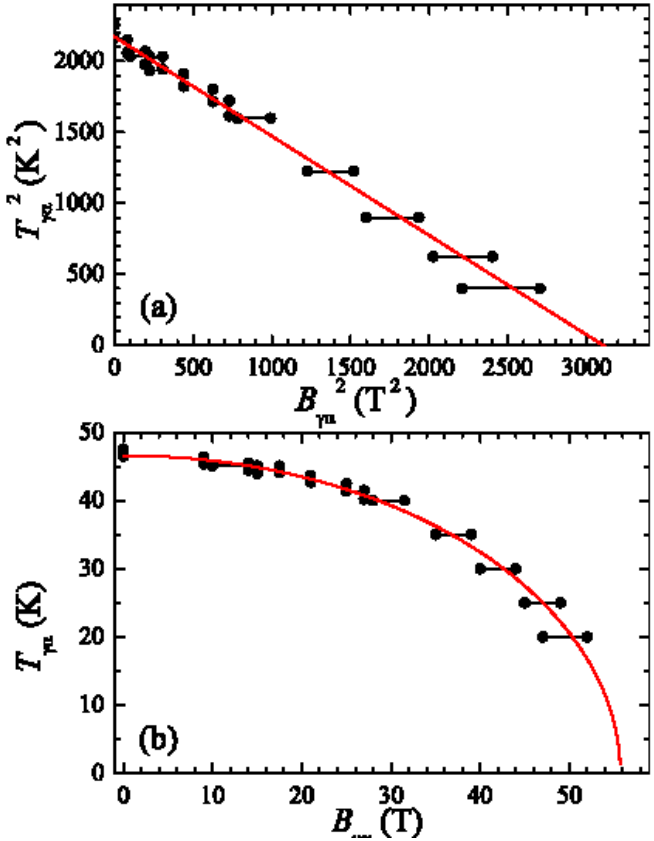
The volume collapse without structure change in elemental Ce has remained a source of theoretical controversy for over 50 years. An alloy of Ce showing this collapse at a temperature of energy scale comparable to magnetic field energies achievable at the NHMFL shows the variation of collapse temperature in applied external fields plotted in two ways here. The red line and curve through the data are accurately gotten from simple atomic parameters, revealing an astonishing and unexpected simplicity underlying this long standing problem. This physics lies as well at the heart of the correlated electron properties of Ce intermetallics.



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Cerium atoms in compounds and alloys can carry atomic moments or not, depending sensitively on local environment details. At the moment/non-moment boundary the physical properties of Ce materials become drastically different, with unexpected low temperature properties. Elemental Ce itself is unusual, undergoing on cooling below room temperature an abrupt volume collapse with no accompanying change in crystal structure, corresponding to loss of atomic moments on the Ce. This γ-α transition has remained a source of theoretical speculation for more than 50 years. We have studied the effect of high magnetic field on the transition temperature of this volume collapse in $Ce_{0.8}La_{0.1}Th_{0.1}$ alloys, where the transition temperature has been reduced to temperatures low enough to be of the order of magnetic field energies of atomic moments in magnetic fields achievable at the National High Magnetic Field Laboratory. The effect of applied magnetic field B in Tesla on the γ-α transition temperature is plotted in two different ways in the above figures. The astonishing B^2 linear in T^2 behavior with slope accurately given by a single ion magnetic energy term (Dzero and Gor'kov) reveals an unexpected and not previously realized simplicity in the physics of this long standing problem.

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Education: One high school student, three graduate students and one post doctoral fellow have been closely involved in the research under this program. The experimental work involves single crystal growth and extensive physical characterization. The search for new materials is an important part of the research effort.

Societal impact: The understanding of Ce containing materials at the magnetic/non-magnetic boundary provides insights into the more complicated physics of transition metal materials which can and will be important in technological applications, for example in spintronics. We have studied doped **FeSi**, a transition metal analogue of the so-called Ce Kondo insulators, and found what seems to be a new class of materials exhibiting large magnetotransport characteristics with potential for application.

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