Geometric Frustration and Quantum Criticality in Heavy Fermions with the Shastry-Sutherland Lattice

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Geometrical frustration leads to the destabilization of magnetic order, and in some cases to the formation of strongly fluctuating ‘spin liquid’ states with unconventional dynamics and only short ranged correlations. Since frustration arises from competition among short-ranged interactions, its impact is most evident in insulating systems, and is thought to be a weak effect in metallic systems where the phase behavior is likely to be controlled by long-ranged Kondo and RKKY physics. We review here the essential properties of the \( \text{R}_2\text{T}_2\text{X} \) (\( \text{R}= \text{rare earth}, \text{T}= \text{transition metal}, \text{X}= \text{Pb,Sn,SB,Bi} \)) layered compounds, where the \( \text{R} \) atoms lie on triangular units in the geometrically frustrated Shastry-Sutherland lattice (SSL)\cite{[1]} . Depending on the relative strengths of the first and second neighbor exchange interactions, these compounds are separated by a quantum critical point (QCP) into antiferromagnets and spin liquids. The metallic \( \text{R}_2\text{T}_2\text{X} \) compounds present the first opportunity to span the entire SSL phase diagram within a single structure and moment type. Far from the QCP, conventional Kondo and mixed valence behavior is found for \( \text{R}= \text{Ce,Yb} \), while typical SSL phenomena such as magnetization plateau and strong fluctuations are found in the magnetically ordered compounds. \( \text{Yb}_2\text{Pt}_2\text{Pb} \) and \( \text{Ce}_2\text{Pt}_2\text{Pb} \) are of special interest, as they lie very near the quantum critical point. \( \text{Yb}_2\text{Pt}_2\text{Pb} \) orders antiferromagnetically at 2 K, with unusually strong fluctuations in the paramagnetic state. The ordered state is Fermi liquid-like with a Sommerfeld coefficient \( \gamma=0.05 \text{ J/mol-K}^2 \)\cite{[3]} . In contrast, \( \text{Ce}_2\text{Pt}_2\text{Pb} \) appears to be very near the QCP, and here the ground state is heavy fermion-like, with \( \gamma=0.6 \text{ J/mol-K}^2 \).