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Orbital Physics: Colossal Magnetoresistance and Quantum Oscillations in the Mott System $\mathbf{Ca_3Ru_2O_7}$

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$Ca_3Ru_2O_7$ features a Mott transition, colossal magnetoresistance and quantum oscillations. $Ca_3Ru_2O_7$shows strikingly different behavior when the field is applied along the different crystal axes. A ferromagnetic (FM) state with full spin polarization is achieved for B$||a-$axis, but colossal magnetoresistance is realized *only* for B$||b$-axis by avoiding the ferromagnetic state. For B$||c$-axis, Shubnikov-de Haas oscillations are observed and followed by a less resistive state than for B$||a$. Hence, in contrast to standard colossal magnetoresistive materials, the FM phase is the least *favorable* for electron hopping. In addition, for B rotating within the *ac*-plane, slow and strong Shubnikov-de Haas (SdH) oscillations periodic in 1/B are observed for T$\leq$1.5 K in the presence of metamagnetism. These oscillations are highly angular dependent and intimately correlated with the spin-polarization of the ferromagnetic state. For B||[110], oscillations are also observed *but periodic in B* (rather than 1/B) *which persist up to 15 K.* While the SdH oscillations are a manifestation of the presence of small Fermi surface (FS) pockets in the Mott-like system, the B-periodic oscillations, an exotic quantum phenomenon, may be a result of anomalous coupling of the magnetic field to the t_{2g}-orbitals that makes the extremal cross-section of the FS field-dependent.