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Fermi Liquid Berry Phase Theory of the Anomalous Hall Effect[1]

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Charged Fermi liquids with broken time-reversal symmetry have an intrinsic anomalous Hall effect that derives from the Berry phases accumulated by accelerated quasiparticles that move on the Fermi surface. The intrinsic Hall conductivity is given by a new fundamental geometric Fermi liquid formula that can be regarded as the derivative with respect to magnetic flux density of the Luttinger fomula relating the density of mobile charge carriers to the k-space volume enclosed by the Fermi surface. This formula can be derived by an integration-by-parts of the Karplus-Luttinger free-electron band-structure formula to yield a topological (QHE) part plus a geometrical part expressed completely at the Fermi surface, and which has a natural generalization to interacting Fermi liquid quasiparticles (QP's). The QP Berry phases are properties of the *eigenstates* of the (exact) single-particle Green's function at the Fermi surface, which is a Hermitian matrix with Bloch-state eigenvectors; the Berry phases derive from the variation on the Fermi surface of the spatially-periodic factor of the QP Bloch state that characterizes how the total QP amplitude is distributed among the different electronic orbitals in the unit cell. In the case of 3D ferromagnetic metals, the Berry phases derive from the interplay of exchange splitting with spin-orbit coupling (both must be present). Remarkably, the new formula also applies to Fermi-liquid analogs such as the 2D composite fermion (CF) fluid in the half-filled lowest Landau level: in this case, the QP is a bound electron+vortex composite and not a Bloch state. This QP structure varies on the CF Fermi surface in a way that exactly gives the expected result $\sigma^{xy} = e^2/2h$, unaffected by any Fermi surface anisotropy, thus explaining how a quantized value of σ^{xy} persists even though the CF Fermi liquid is *not* an incompressible FQHE state. The geometric anomalous Hall effect formula suggests a more intrinsic geometric description of the Fermi surface, where the Fermi vector $k_F(\mathbf{s})$ is only one of a number of properties that vary on a curved $(D-1)$-dimensional Fermi surface manifold parametrized by curvilinear coordinates $\mathbf{s}$; other properties include the Berry curvature field $\mathcal{F}(\mathbf{s})$, quasiparticle mean free path $\ell(\mathbf{s})$,*etc.* The new formula also naturally takes into account non-trivial (multiply-connected) Fermi surface topology and open orbits.

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