Electron liquid crystals: a Materials science minefield

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Our understanding of metals was pioneered by Paul Drude, who imagined it as a gas of free electrons contained in a can. This model was refined by Lorentz and Sommerfeld and corroborated by Landau's Fermi Liquid theory, which successfully accounted for all properties of metals. This textbook explanation has been challenged by discovering "strange metal" behavior in high-T_c cuprates — the resistivity scaling linearly with temperature and magnetic field. This is attributed to the electron correlations, strong enough to invalidate the FL picture. An even more spectacular departure is the spontaneous breaking of the rotation symmetry in the electron fluid, first observed in cuprates but subsequently in other correlated-electron materials such as Fe-pnictides and chalcogenides, Sr_2RuO_4, and twisted double-layer graphene (TDLG).

In principle, the most direct way to detect electronic nematicity is the measurement of the components of the resistivity tensor. However, one must beware of artifacts; symmetry breaking may be due to various extrinsic factors. This calls for careful experimentation, extensive statistics, and some meticulous Materials science. The latter includes characterization by STEM, RHEED, LEEM/PEEM/LEED, AFM, synchrotron-based XRD, XRF, and XAS, THz dichroism, Second-harmonic generation, Cross-polarized Raman scattering, as well as the angle-resolved measurements of transverse resistivity and magnetoresistance.

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