Quantum Hall Physics: Introduction and Current Affairs

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Since the experimental discovery of the quantized Hall resistance by Klaus von Klitzing in 1980, quantum Hall systems have become one of the most versatile and best–controlled laboratories for the study of basic concepts in condensed–matter physics. Most commonly realized in two–dimensional electron systems in a perpendicular magnetic field, they offer unique access to understand the competition between disorder and interactions in the quantum realm. Simply by turning a knob that controls the magnetic field, it is possible to realize almost the entire range of correlated–electron effects known to us. Most famous are the exotic quasiparticles that exhibit fractional charge and statistics. Similarly intriguing are the chiral one–dimensional excitations, supported by boundaries of quantum–Hall samples, that exhibit striking non–Fermi–liquid behavior. Recently, quantum Hall systems showing ideal quantum magnetism, p–wave superconductivity, or charge–density–wave ordering were found. Steady progress in sample fabrication leads us to expect more discoveries of novel and surprising physics in new generations of quantum–Hall samples.

I plan to give an introduction to the microscopic origin of quantum Hall effects and their ramifications in transport experiments. It turns out that a quantized Hall resistance is observed when the electron system has an incompressible ground state at a magnetic–field–dependent density. The particular mechanism realizing such an incompressibility must be due to interactions when electrons occupy only states in the lowest Landau level. Commensurability of electron density and magnetic field give then rise to a topological fractional charge of quasiparticles and may support skyrmions in the ground state. Besides the introductory part, in which I intend to briefly discuss the role of disorder, I would like to present an overview of the multitude of correlated electron states that exist in the quantum Hall regime. In closing, I will give a brief outlook on new, unconventional quantum–Hall systems formed by atomic gases in rotating traps.