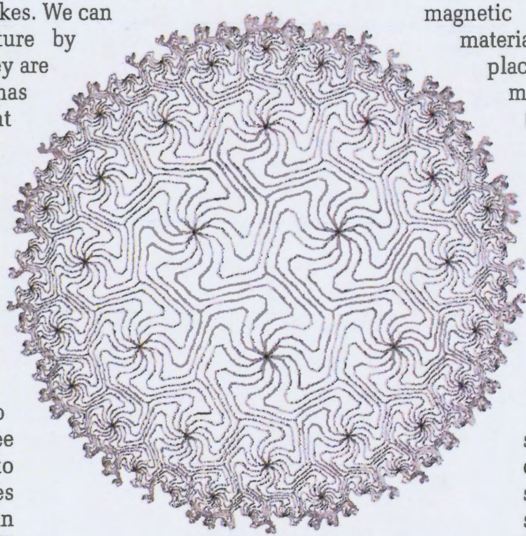
# Quarks, symmetry and cold electrons

Symmetry is all around us – witness the beautiful symmetric forms of crystals and snowflakes. We can learn and understand much about Nature by studying her symmetries, but sometimes they are less than obvious. A new symmetry has recently been found in two very different natural phenomena, indicative of a curious connection between them. These phenomena are: Quantum chromodynamics (QCD) – the force that binds quarks, among the smallest known constituents of matter, inside protons and neutrons; and the strange behaviour of very cold electrons in semiconductors – the quantum Hall effect (QHE).

QCD is named after quantum electrodynamics, its close cousin. The term chromo (colour) is used in analogy with the three primary colours: as red, blue and green mix to white, so quarks can have one of three types of colour charge which add to zero. One can imagine hypothetical worlds where QCD would be different: the strength of the colour charge could be bigger than in our Universe, for example. A remarkable fact was recently discovered in some simplified mathematical models of QCD: the predicted physical properties of many of these hypothetical worlds are very similar – there is a symmetry relating them.



*A Poincaré disc: think of points inside the disc as representing hypothetical worlds in QCD or plateaux in the QHE – any two points which can be related to each other by the symmetry of the picture have similar physical properties (copyright 1990-1999 by The Geometry Center, University of Minnesota; used by permission - see http://www.geom.umn.edu/admin/copyright.html).*

The Hall effect occurs in semiconductors placed in a magnetic field. When a slab of semiconducting material, carrying a current along its length, is placed in a magnetic field, the field pushes the moving charged particles left or right (depending on the sign of their electric charge) building up a voltage across the slab's width. Normally this voltage is proportional to the magnetic field but, surprisingly, for pure, very thin samples in high magnetic fields and extremely low temperatures, the voltage increases in a series of steps or plateaux which are precise fractions of a basic unit. This is the QHE. Experiment shows that the physical properties of many of these plateaux are very similar – there is a symmetry relating them. Herein lies the connection between QCD and the QHE – they share the same symmetry! This symmetry is similar to that of a Poincaré disc, seen in the illustration.

One aim of my research is a deeper mathematical understanding of this connection – what can we learn about QCD from the QHE and vice versa?

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