PHYSICS DEPARTMENT COLLOQUIUM

"Topological Quantum Computing"

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The central issue in quantum computing is how to build a universal quantum computer. If the history of the transistor be a guide, this engineering fate should not be left only to engineers. A new paradigm pursued by our Microsoft Station Q (http://stationq.ucsb.edu) to achieve such an engineering wonder is through the discovery and/or engineering of topological phases of matter. Topological phases of matter are exotic states of matter with topological quantum field theory (TQFT) as effective theory. The only currently known examples are the fractional quantum Hall (FQH) liquids.

I will explain the proposal for building a quantum computer with the finer plateaus of FQH liquids at filling fractions 5/2 and 12/5. 5/2 (also 7/2 with same physics) are the only known even denominator fractions. While the theoretical origin of 5/2 is still under debate, the Moore-Read Pfaffian states have emerged as the leading candidates for the ground states. If so, then the elementary excitations=quasi-particles=particles in the 5/2 liquid will have electric charge e/4, and the statistics of these particles will be non-abelian: when such particles are pinned at certain positions, the ground state will be still degenerate, and the adiabatic exchange of a pair of particles will induce a matrix, rather than a phase on the ground states. These matrices will be the gates for topological quantum computation. Unfortunately, topological gates from exchanging 5/2 particles are not sufficient to implement all unitary matrices, even approximately, i.e. not universal. To get a universal topological quantum computer, 12/5 is a candidate.

In FQH quantum computing, 75 mK temperature is too hot, not to mention the 5T intensity magnetic field. It would be nice to have "high temperature" topological phases. Theoretical possibilities include the so-called doubled TQFTs. Atomic gas or Josephson Junction arrays might lead their creations in the future.

An easy introduction is the April cover article of Scientific American: Computing with quantum knots. http://info.phys.unm.edu/~thedude/topo/sciamTQC.pdf

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