Really good 2D systems of high purtiy can now be made. The Quantum Hall effect blew minds.

The hall resistance is quanitzed, while the magnetoresistance vanishes (magnetoresistance is where the regular resistance changes in repsonse to applied field.)

electrons

Statistics change from boson to vfemrion and back.

The electrons absorb flux quanta?

Epitaxail growth of semiconductors with different band gaps make thin potnetial wells. GaAs/AlGaAs 2d carriers have mean free path λ of 0.1mm. HUGE

Magnetic fields cause splitting in ladnau levels. Energy now comes in quanta of cyclotron freqeuncy. Spin degerenacy is lifted. degenracy is eB/h states per area.

Cyclotron $\omega = qB/m$.

$\nu = n/d$ The filling factor is actual denisty divided by landau level state density.

$h/e = \phi$ the flux quantum. ν is electron to flux density (Duality between vortices and particles? Circuit duality? Circuit duality with respect to zome reference impedance. Riemann Sphere. Inversion. Poles to zeros). Electrons per flux quantum.

h/e^2 is the resistance quantum

Experimental condition. Measure Current. Measure voltage orthogonal and along. Divide to get maghnetirestance and hall reisstance

Classical hall resistance is $R = B/ne$. Conveneient for measuring n the denisty of conducting electrons.. The quantum hall effect has plateaus that follow around this line. So it does increase roughly linearly.

At vanishing magentoresistance, the system is insulating.

The width of a landau band is visible in the diagram?

FQHE the filling factor is an exact fraction.

Coulomb force drives correlation between electros,

Presence of magnetic field reuqires wavefunction to have as many zeros and flux quantum penetrate per unit area. What is a zero in a many body wavefunction? Fixing all variables except one?

Magnetic Legnth $l = \sqrt{\hbar/eB}$.Each zero of FGHE state "heals" on this legnth scale?

Vortices are charge deficits. That's bad? So they attract electrons. Wait. What? Th vortex is a zero of the electron wavefunction. How can it attract electrons? The other electrons?

Is the inotrudctin of magnetic field moving the electrons such that they cancel the incoming flux?

Vortex generating flux quanta

Composite Fermions. Some shaky way you combine vortices and electrons and then you couple those to more vortices?

0.1 Conductance viewed as transmision

Traidstional view is response to applied electric field. Different view is codnuction as due to injection of electrons at one end.

Semiclasscial thinking dominates traditional thoery. Use qwuantum band structure and quantum sctatering cross sections, but then use classical movement otherwise using distributions in these propgating states. Boltzmann like

Kubo gave first totally quantum verison. Extended thoery of polaization.

Circuit thoery does not give votlage as cause and current as effect. New apporach is current casues self consitsent buildup of charge, hence electric field

Field in tunnelling barrier is localized around barrier. Not mean free path inside contacts.

0.2 Nakahara Homotopy

Homotopy is the study of maps from well understood spaces to complicated ones. S1 is the circle, which maps to loops in the space. Continuous defomrations between images

Arcwise connectedness: If there exist a path between any two points

Means fundamental group is indepdnant of basepoint

Conjugation by the connection path

Topologically distnct states of fields -

COnsider the following geometry. You have a function defined in space S(x). You can divide the space into distinct classes by specifying surfaces S<a. This is the analog of topologically inequivlaent field configurations $F[\phi] < k_B T$, divides the function space into diffrent classes. For actions, you can only borrow something something hbar of action. Of you can only borrow such and such energy for a time that is under the heisneberg uncertainty. Or momentum for a space less than hbar.

The mixing of the topology of the domain (Balls of various dimensionality - loops spheres etc) going into

Two field configurations are physically (homeomorhpic, homotopic) if they can be deformed into one another while never passing through a state of energy greater than kT.

The functional integral (volume integral) may be subdivided into an integral of loops (sum of tubes) or an integral of spheres (sum of shells).

Berry phase is kind of like an order parameter. The degeneracy points are the vortex cores of paramatezied hamiltonians

Model mh,mailtonains as order parameters

r dimensionals contours external to a core a of d' dimension + 1 radial direction = d of space.

On the contour (Whihc is S_r) we map to the order parater (Which is often $S_{d'}$ for n vector models, but could be a projective space for nematic crystals or whatevs). Therefore, each core gets a member of the homotopy group assigned to it.

Magnetic field. Vecotr potential due to magnetic field. Some sort of potential for A? In gauge $\nabla \cdot A = 0$, then A = $\nabla \times C$. Hence C= coulomb of B, A = biot savart of B, just like sliding down one using A,B,J.

If we have two wires move around each other, the ensuing loop integral of B is analogous to phase

Phase dynamics

$\nabla \times A + \dot{F} = B$

$\nabla \times F + \dot{A} = E$

Abelianized homotopy = homology

Edge groups and ability to contract