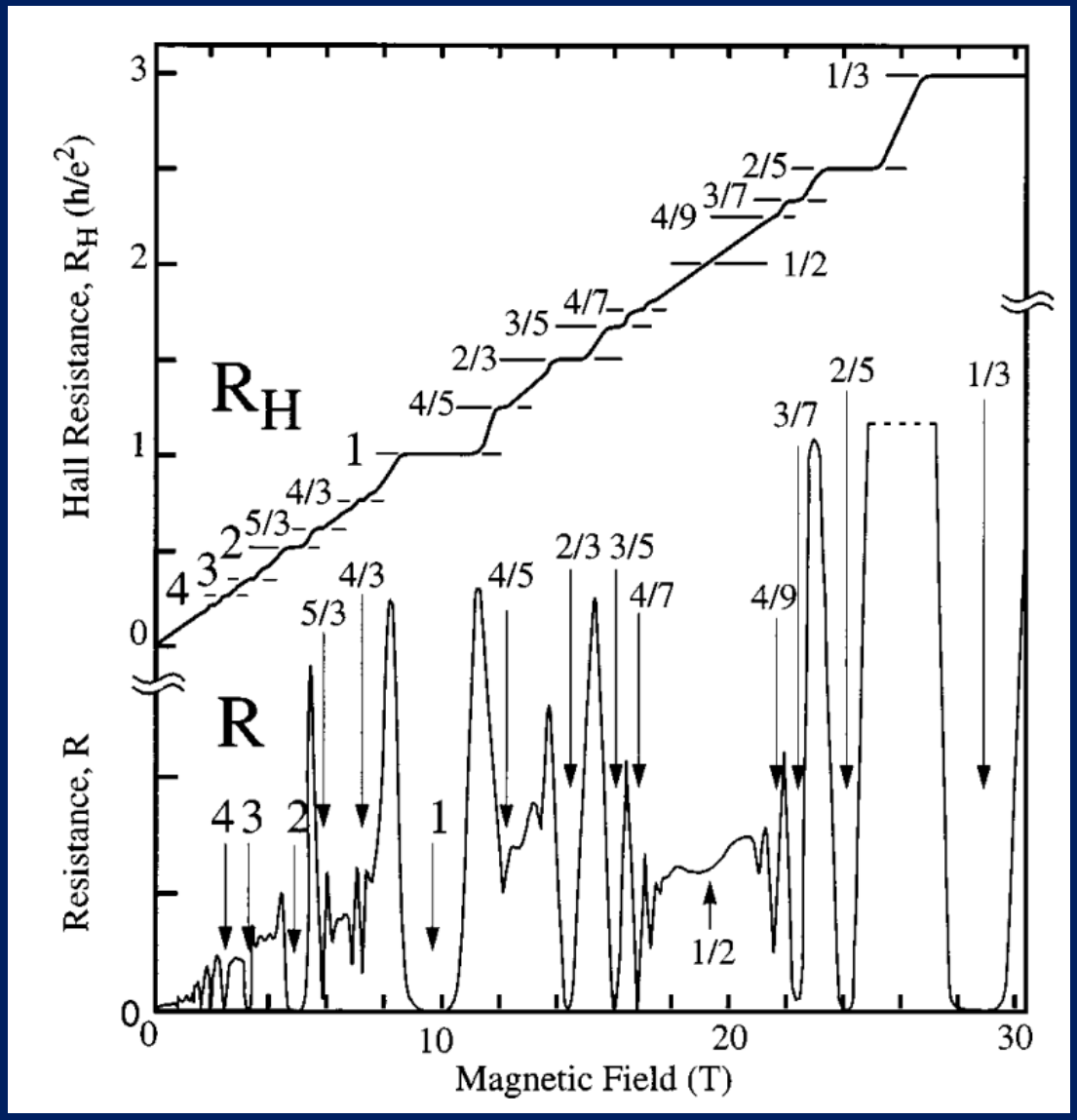
Quantum Hall Effect

Celia Burstein

June 26, 2012

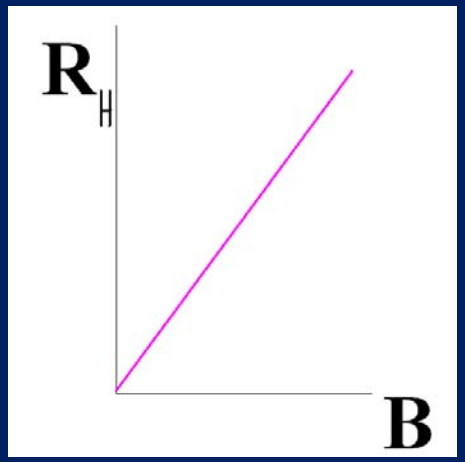
- 2D electron system→Integer Quantum Hall Effect
- 2D electron system + electron interactions→ Fractional Quantum Hall Effect
- Disorder and Quantum Hall Effect

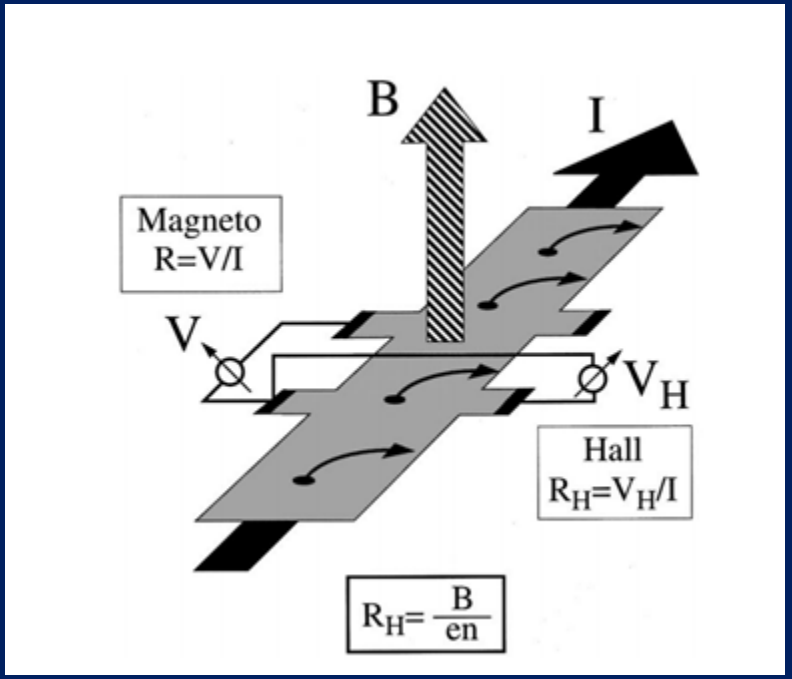


H. L. Stormer, Nobel Lecture, 1999

Hall Effect

- V=voltage along current path
- V_H=voltage across current path
- V_H caused by Lorentz force
- R_{xx} and R_{xy}

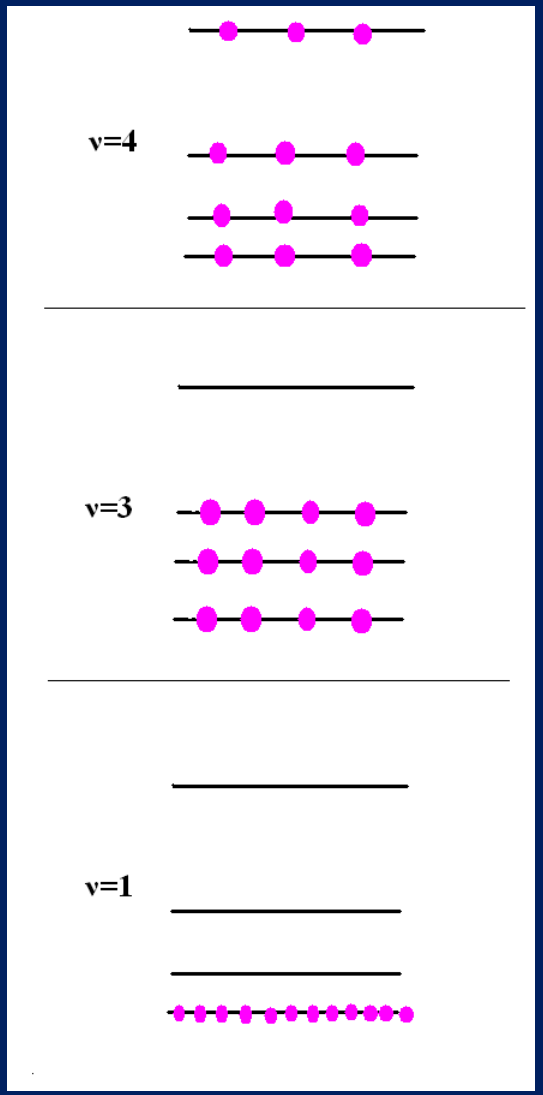




H. L. Stormer, Nobel Lecture, 1999

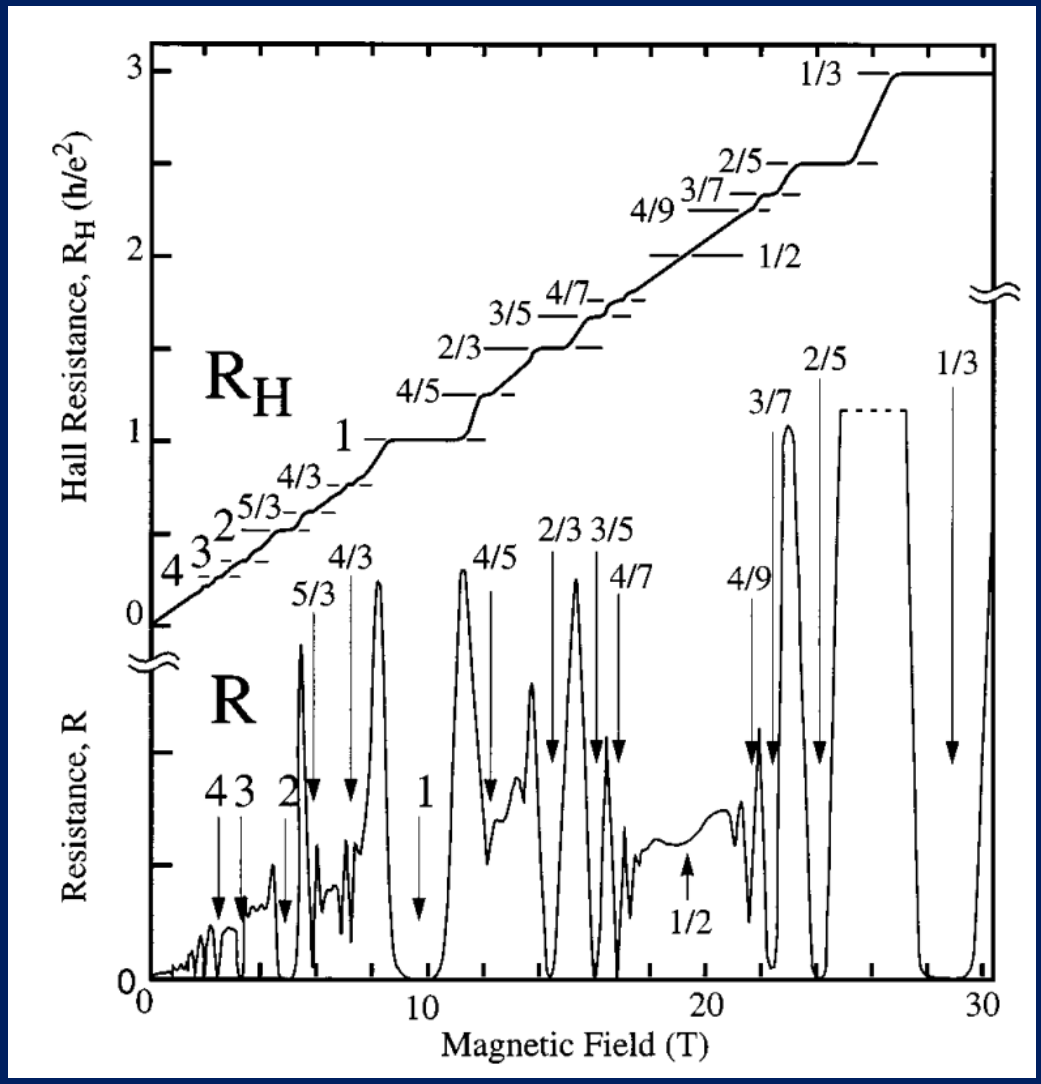
Quantization

- Energy of electrons is quantized in magnetic field
- Higher magnetic field:
  - Increase degeneracy
  - Lower filling factor, ν
- Magnetic Quantum Limit: ν=1



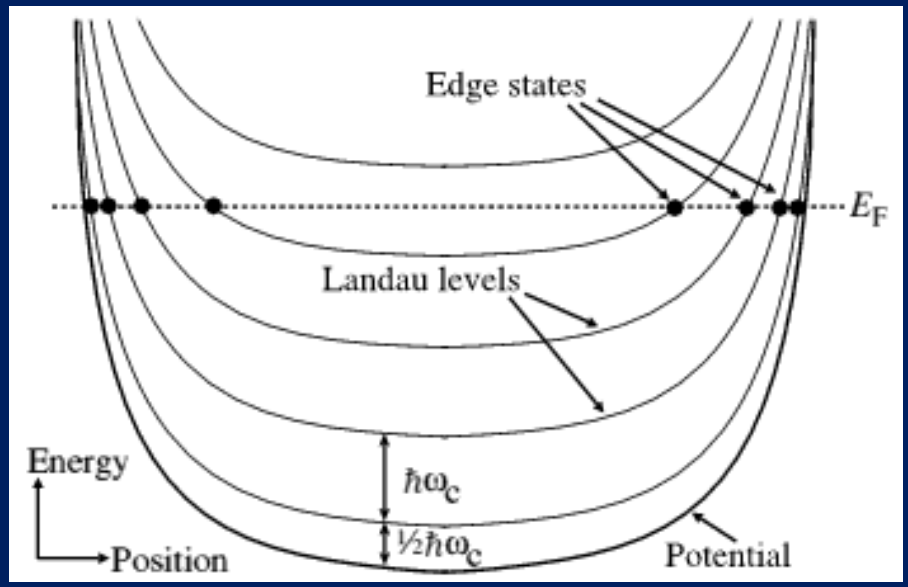
Integer Quantum Hall Effect

- Can be described with single electron
- $\nu \geq 1$
- R_{xy} plateaus when R_{xx} minimizes



Hall Resistance

- Does not depend on length or area
- Depends on Fermi Energy Level
- Quantized when Fermi Energy Level lies within landau level at edge states: $R_{XY}=h/(ie^2)$



University of Cambridge, Semiconductor Physics Group, 2012

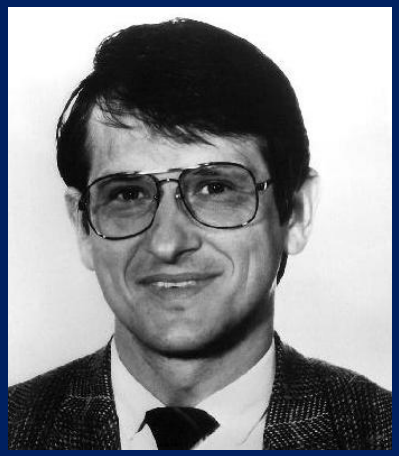
2D Electron Gas (2DEG)

- Motion in third dimension fills energy gaps (IQHE is less dramatic)
- Molecular Beam Epitaxy to create GaAs/AlGaAs sandwich
- Modulation doping: Silicon is source of conduction electrons
- Low temperatures

N. Samkharadze et al, Integrated Electron Transport, 2011

n-body Problems

- 2-body problems with classical mechanics
- 3-body problems with classical mechanics
- n-body problems with quantum mechanics



Klaus von Klitzing

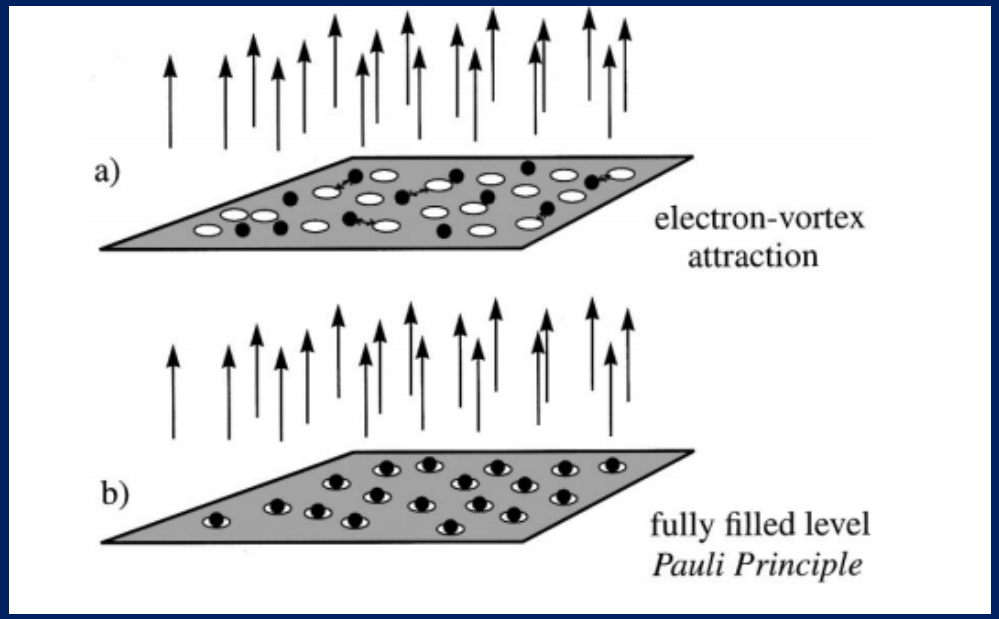
Robert B. Laughlin

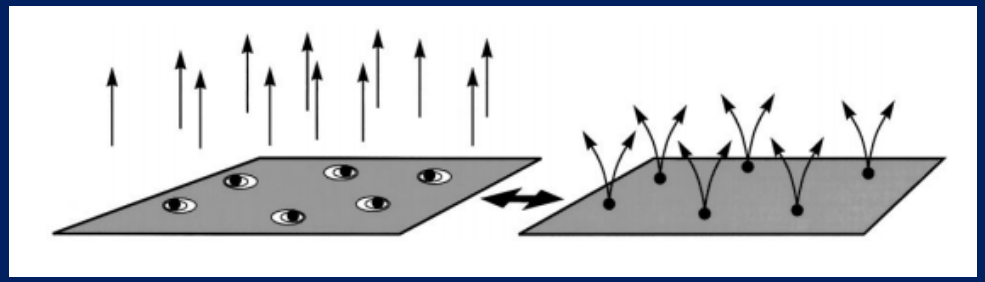
Horst L. Störmer

Daniel C. Tsui

Fractional Quantum Hall Effect

- Many-particle effect in which Coulomb interactions play a role
- Flux Quanta attached to carriers to create composite particles
- Composite Fermions and non-Abelian states

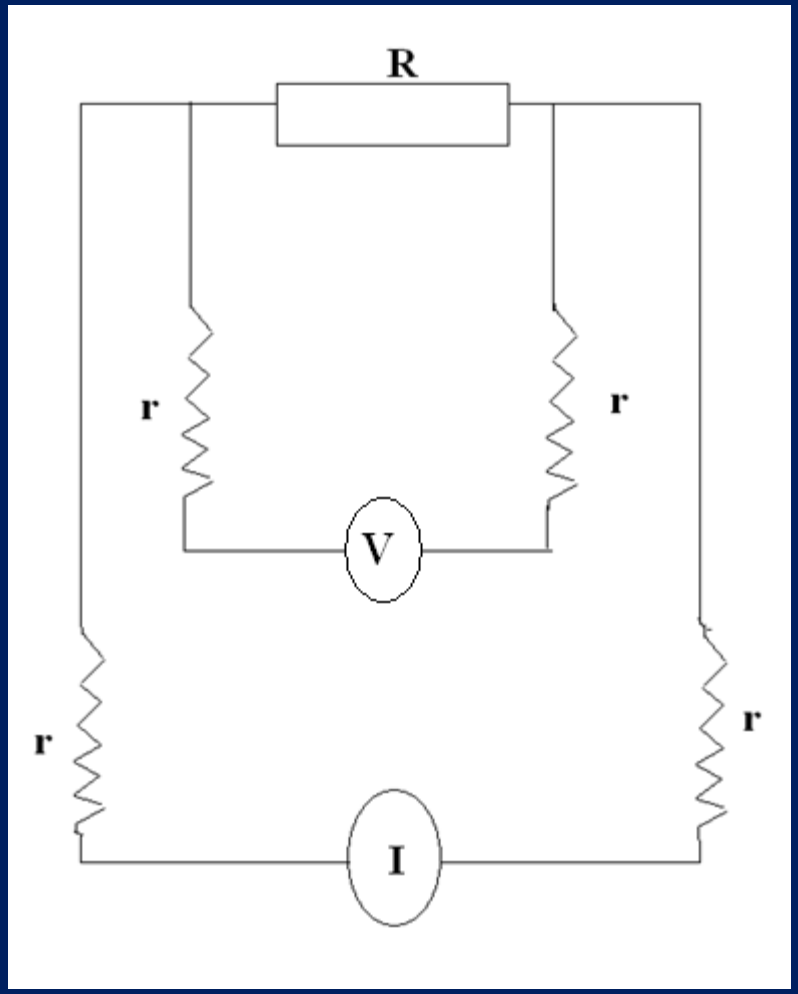


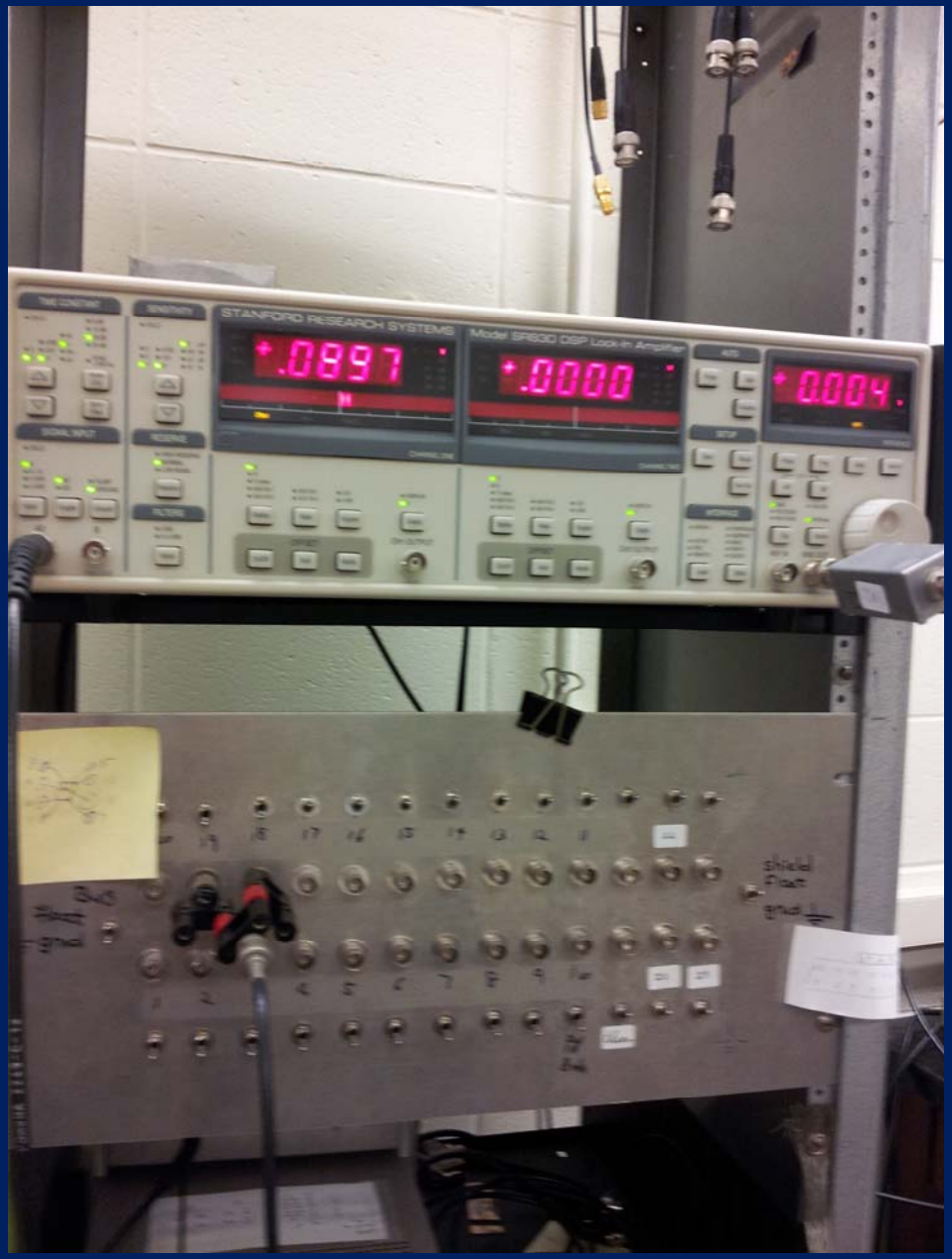


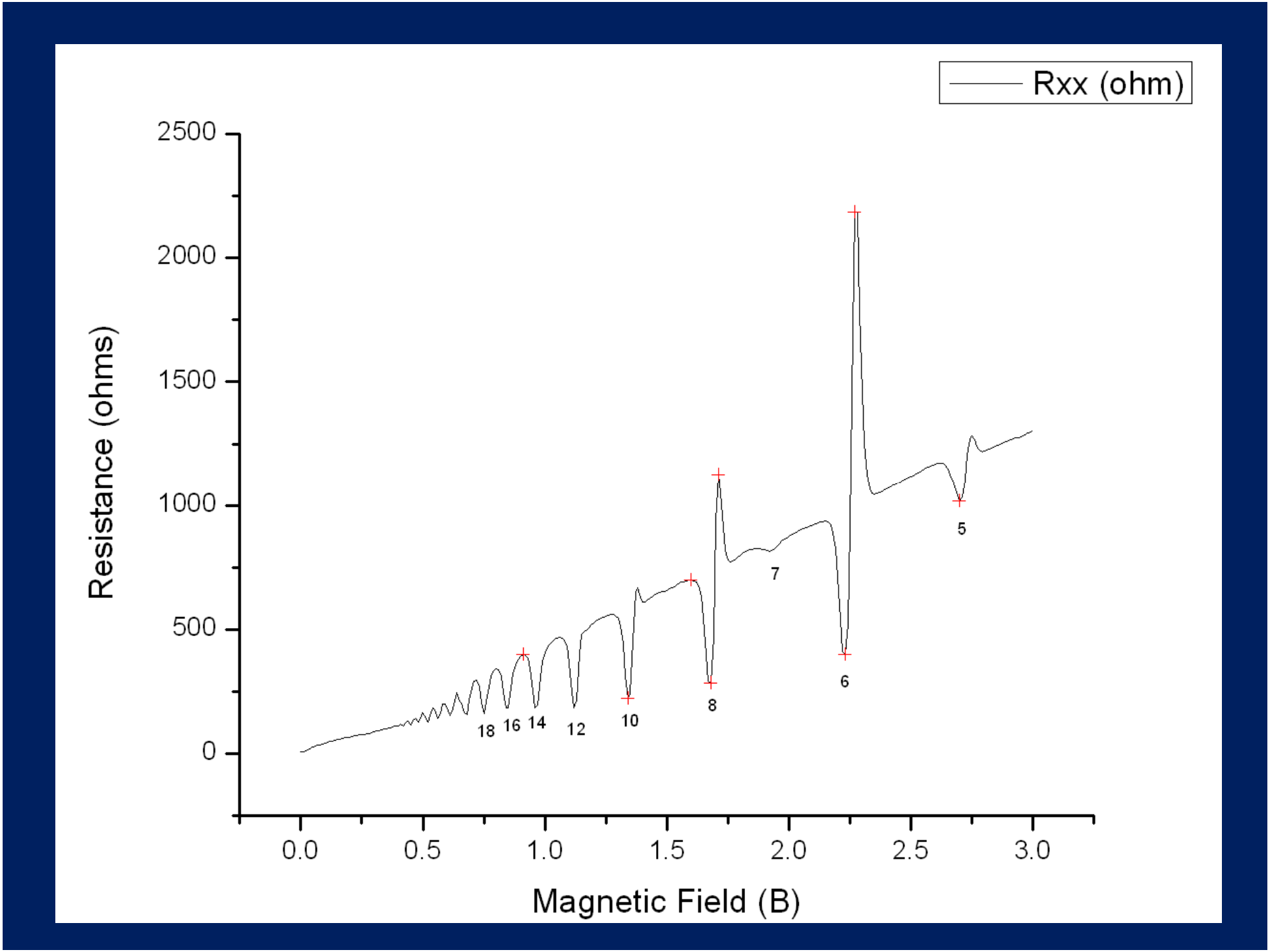
H. L. Stormer, Nobel Lecture, 1999

Resistance Measurement

- Use He Dewar to cool down AlGaAs/GaAs sample
- 4-probe measurement with lock-in amplifier
- Find correspondence between R_{xx} minima and states
- Determine density of electrons: n=vBe/h

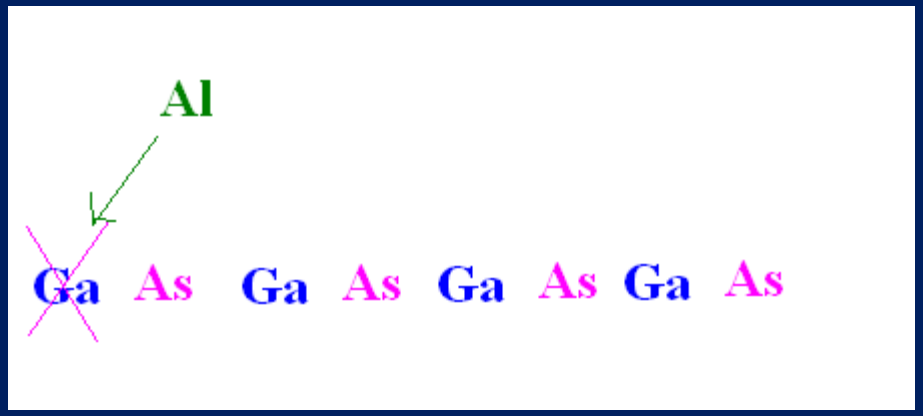


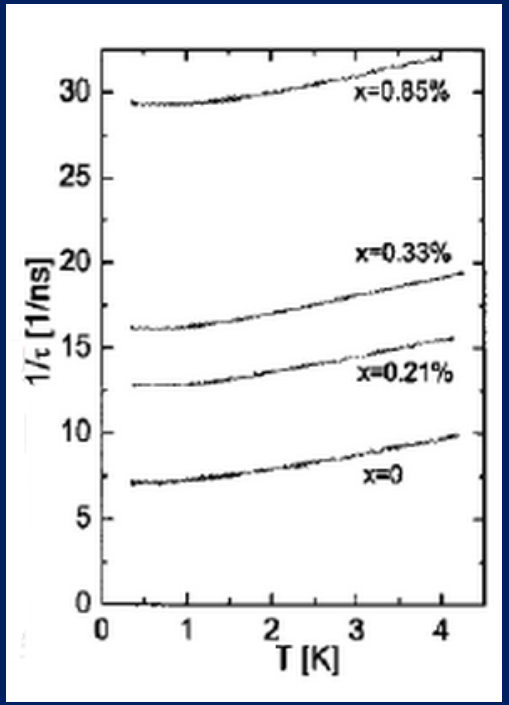

STANFORD RESEARCH SYSTEMS
Model SR830 DSP Lock-In Amplifier
+.0897
+.0000
+0.004
shield
float
gnd


Rxx (ohm)
Resistance (ohms)
2500
2000
1500
1000
500
0
0.0
0.5
1.0
1.5
2.0
2.5
3.0
Magnetic Field (B)
18
16
14
12
10
8
7
6
5

Disorder

- Neutral Disorder Source: Alloy scattering can be studied by adding small amount of Al impurities to GaAs
- Different states respond differently to same disorder





W. Li, G. A. Csathy et al, APL, 2003