低温物理学

勝本信吾 - 福山　寛

2009.4.9 - 2005.7.4

Syllabus

物質を極低温に冷却したときに現れるさまざまな量子現象を解説する。具体的には、金属や液体ヘリウムの超伝導や超流動、微細加工した系のコヒーレンスや単電子制御、2次元系の電子局在や量子ホール効果などを扱う。

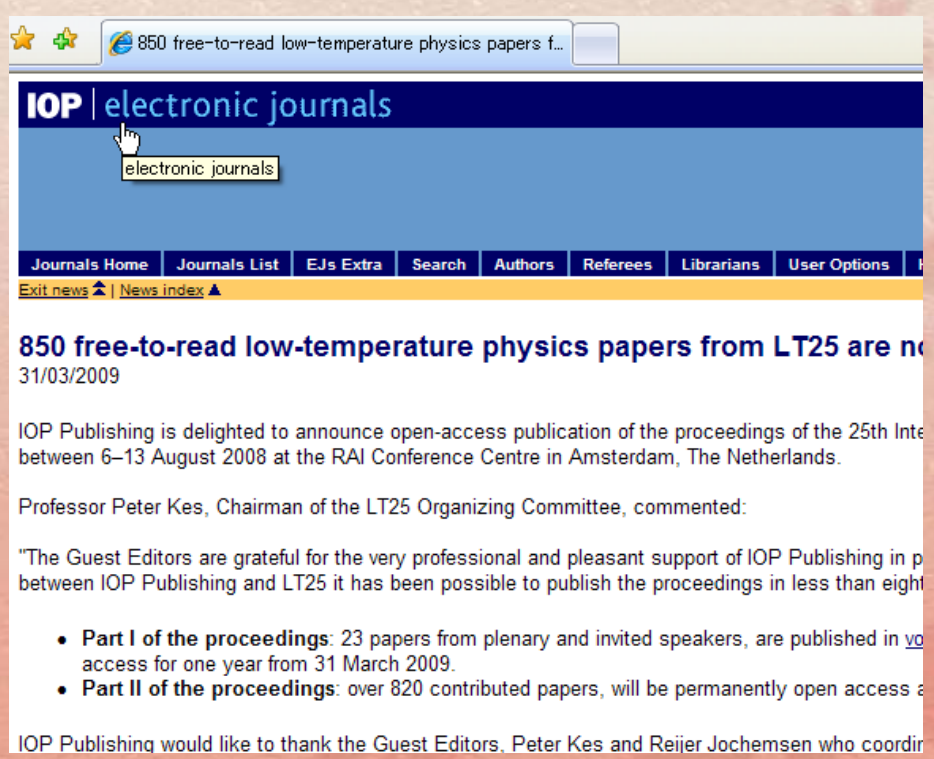
1. 序論
2. ボース・アインシュタイン凝縮
3. 単電子効果
4. 量子輸送現象と量子ホール効果
5. 液体ヘリウムの超流動
6. フェルミ液体論
7. スピン三重項BCS状態

成績評価は「レポート」（2回）で行う。

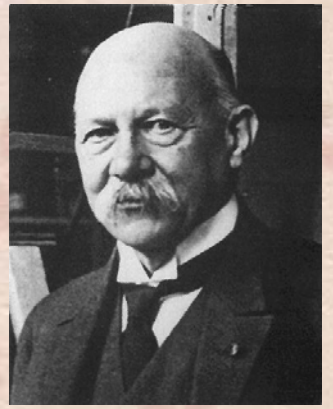
講義ノート等

http://kats.issp.u-tokyo.ac.jp/

http://www.iop.org/EJ/news/-topic=1400

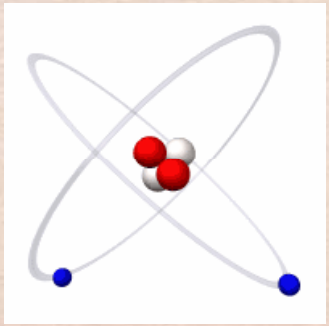


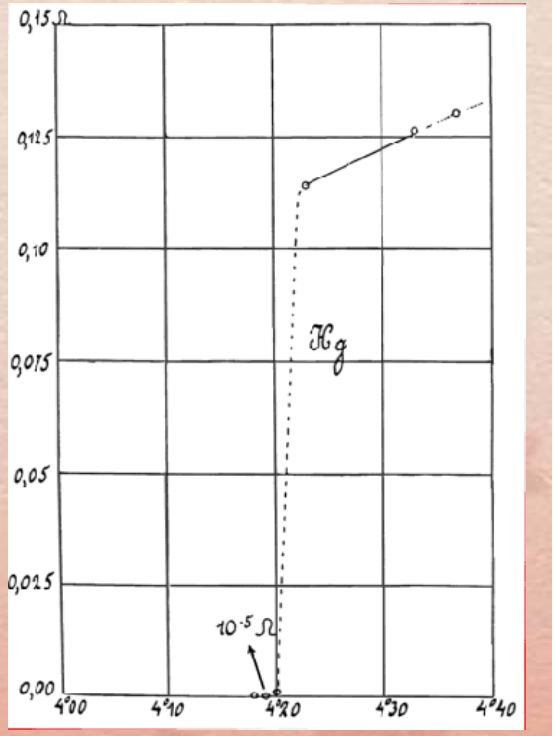
Introduction (Low Temperature Physics)

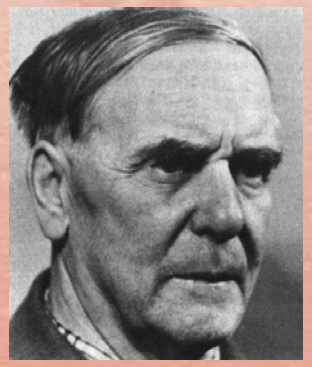


Heike Kamerlingh Onnes

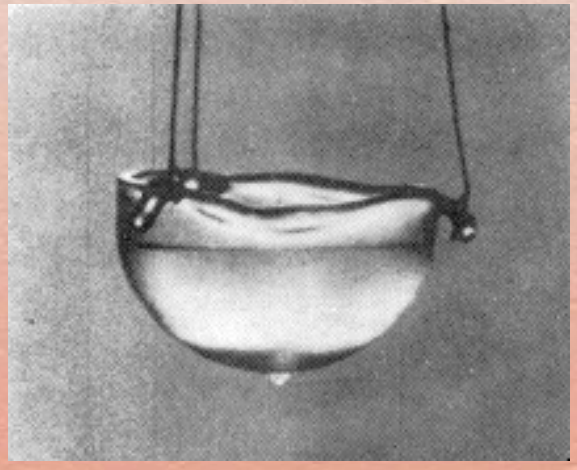
- 1908 7/10 Liquefaction of Helium 4
- 1911 Superconductivity of Hg







Pjotr Leonidovich Kapitza

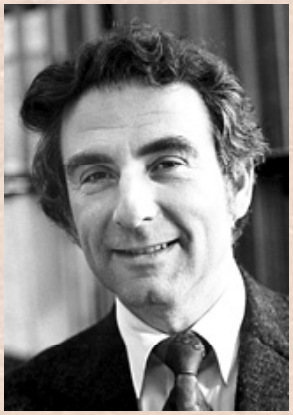


Lev Davidovich Landau

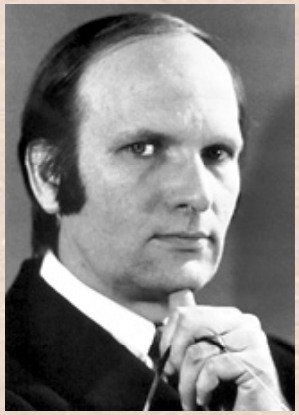
- 1937 Superfluidity of Helium 4

Advances in Low Temperature Physics (1)

John Bardeen

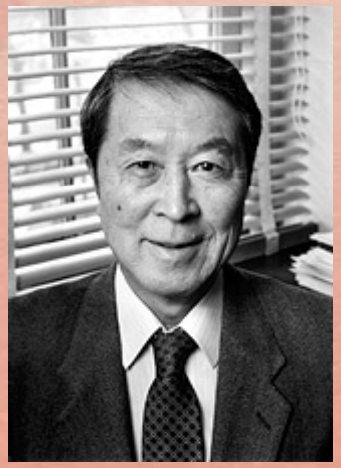


Leon Cooper



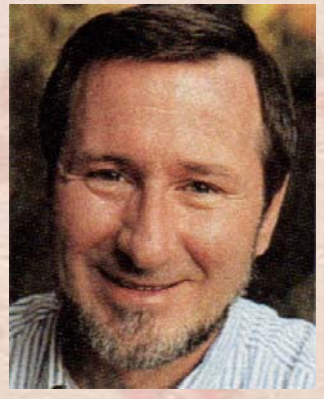
Robert Schrieffer

- 1957 BCS Theory of Superconductivity



- 1960 Spontaneous Symmetry Breaking

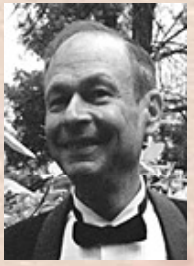
Advances in Low Temperature Physics (2)



Douglas Osheroff

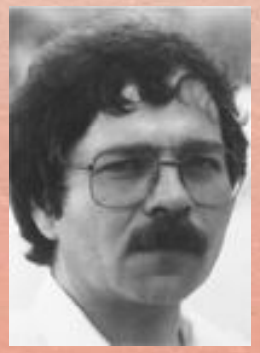
- Superfluidity of ^{3}He

D. M. Lee

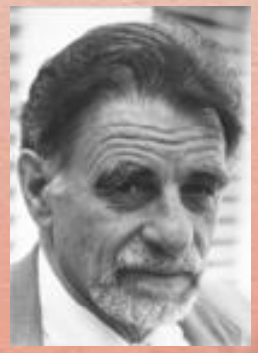


R. C. Richardson

- 1986 Discovery of a High-Tc material

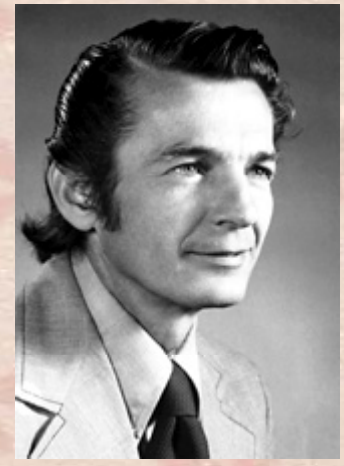


J. Georg Bednorz



K. Alexander Müller

Advances in Low Temperature Physics (2)

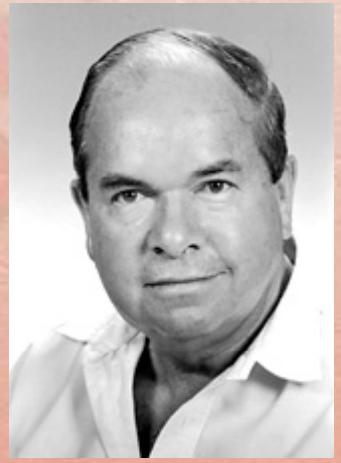


Ivar Giaever

Tunneling Phenomena

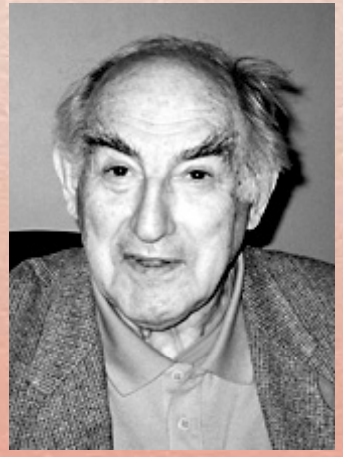
Brian Josephson

Josephson Effect



Alexei Abrikosov

Votex Lattice



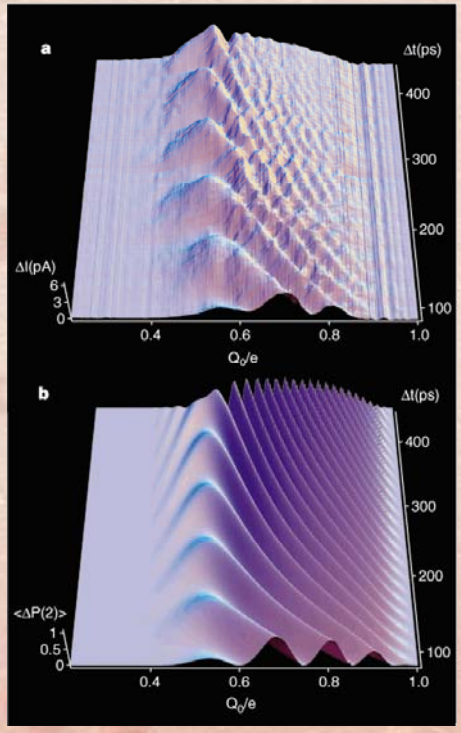
Vitaly Ginzburg

GL Theory

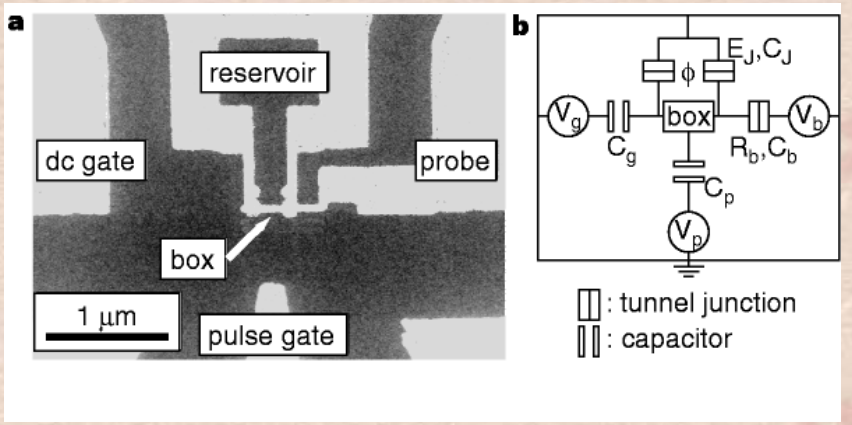
Anthony Leggett

Helium 3 Theory

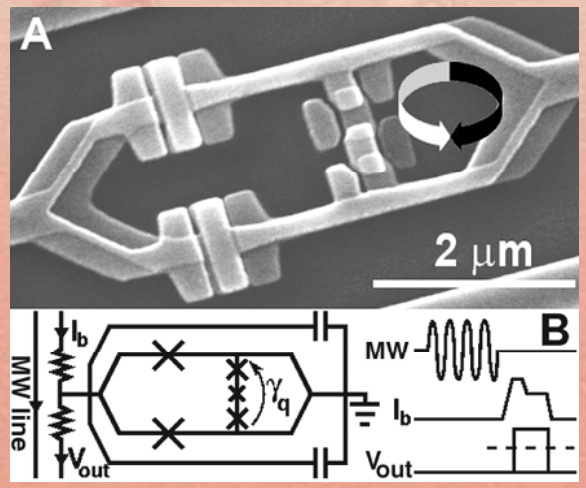
Quantum Coherence and Information Processing

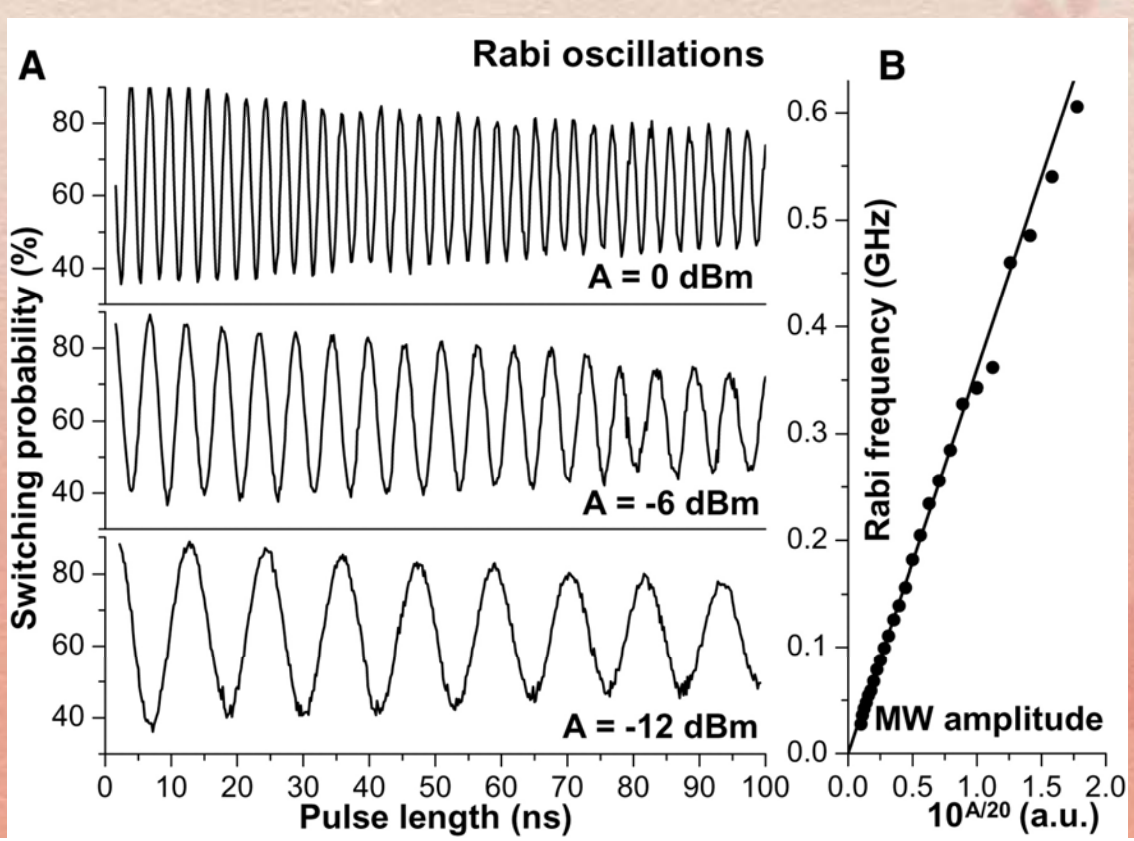


Charge Qubit

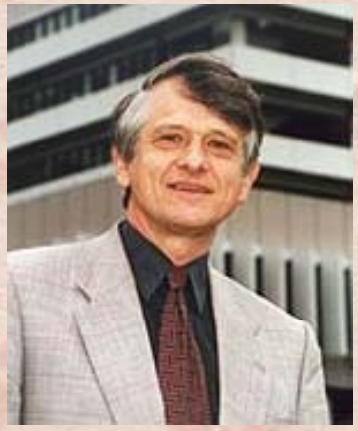


Flux Qubit

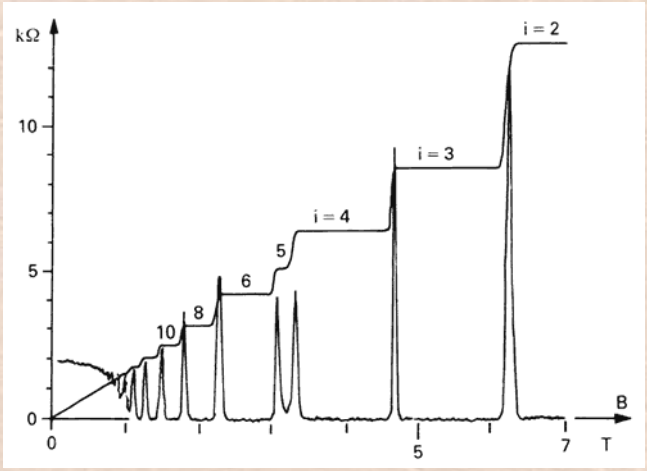




Advances in Low Temperature Physics (3)



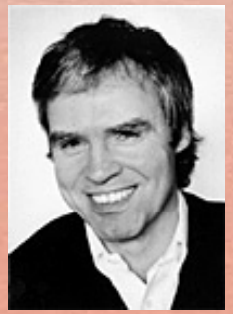
Klaus von Klitzing



- 1980 Discovery of quantum Hall effect

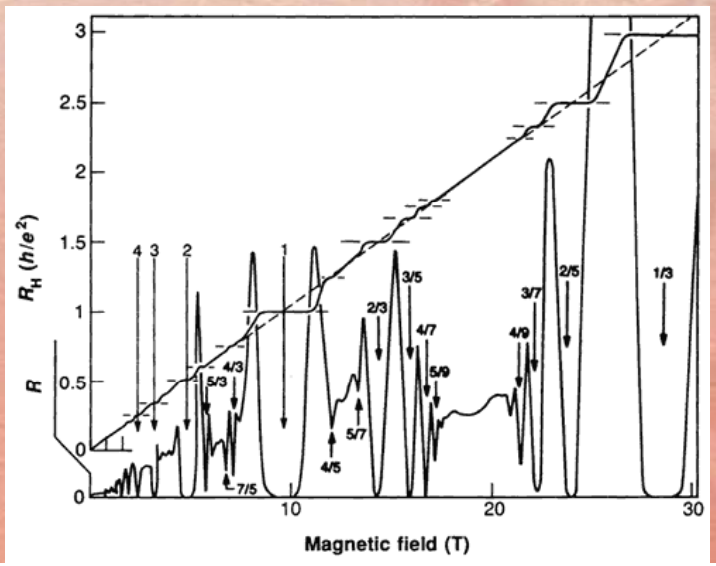
- 1982 Discovery of fractional quantum Hall effect

Robert B. Laughlin

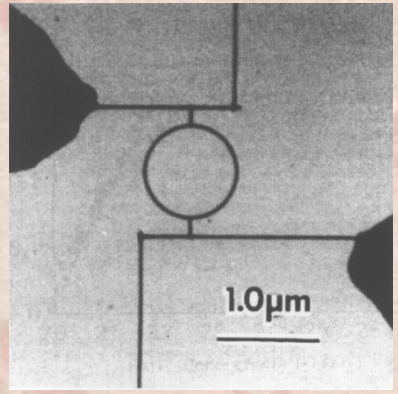


Horst L. Störmer

Daniel C. Tsui

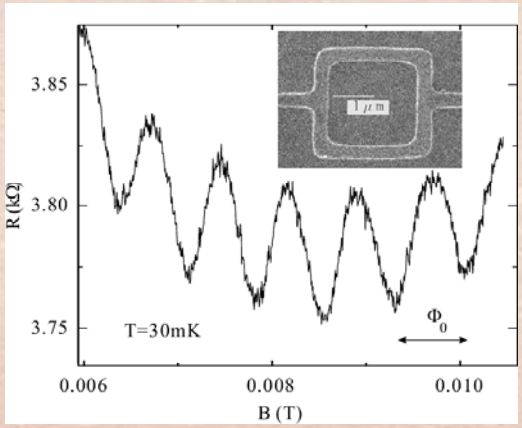


Mesoscopic Systems

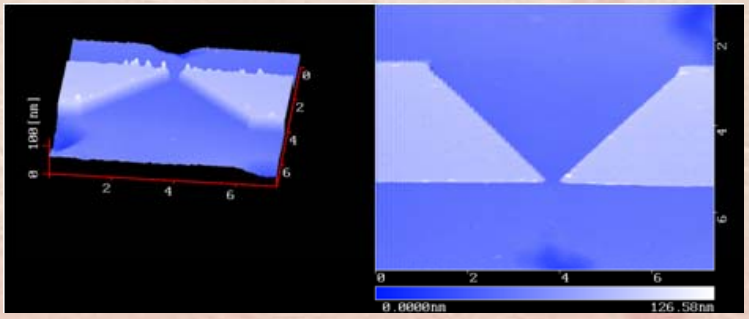


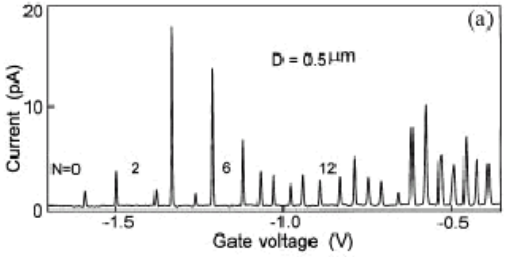
R. A. Webb et al. PRL 54, 1610 (1985).

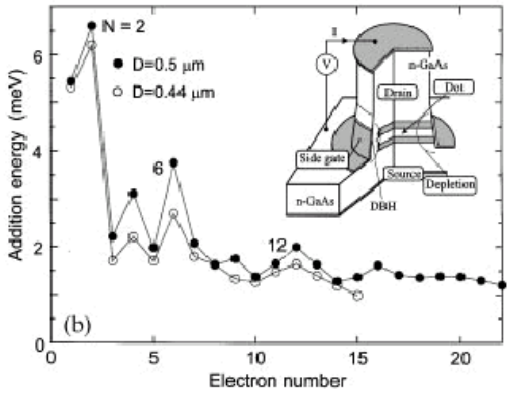
Aharonov-Bohm effect



Quantum Point Contact (1989)

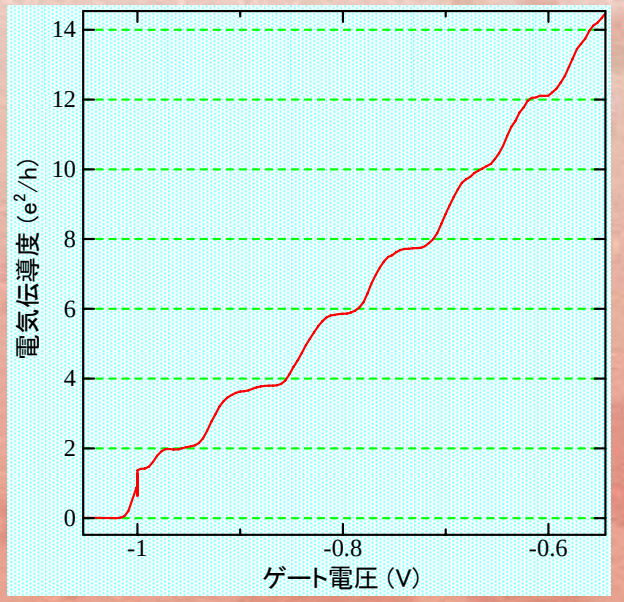






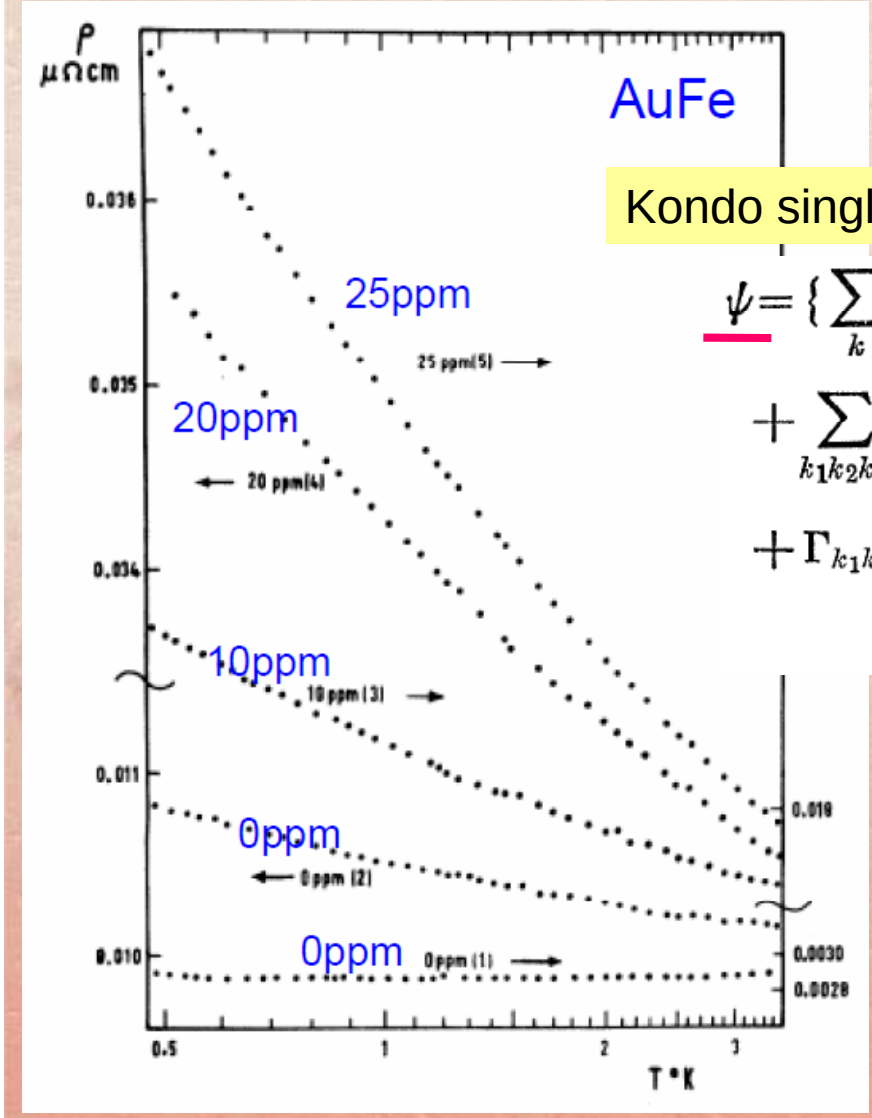
Artificial Atom

S. Tarucha et al.
Phys. Rev. Lett. **77**, 3613 (1997).



The Kondo effect

Jun Kondo



Kondo singlet

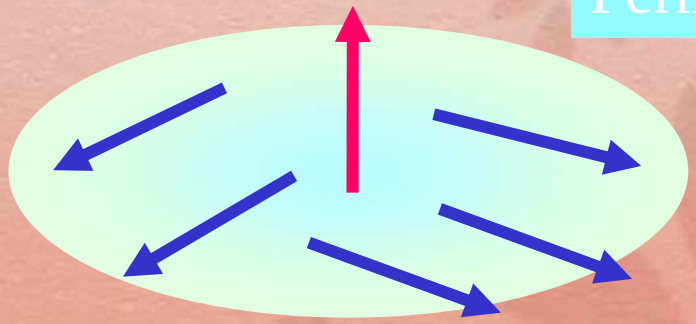
$$\psi = \{\sum_k [\Gamma_k{}^{\alpha} a_{k\downarrow}{}^{\dagger}\alpha + \Gamma_k{}^{\beta} a_{k\uparrow}{}^{\dagger}\beta] \longrightarrow \left(|s\uparrow\rangle|d\downarrow\rangle - |s\downarrow\rangle|d\uparrow\rangle\right)$$

$$+ \sum_{k_1k_2k_3} [\Gamma_{k_1k_2k_3}{}^{\alpha\downarrow} a_{k_1\downarrow}{}^{\dagger} a_{k_2\downarrow}{}^{\dagger} a_{k_3\downarrow}\alpha + \Gamma_{k_1k_2k_3}{}^{\beta\uparrow} a_{k_1\uparrow}{}^{\dagger} a_{k_2\uparrow}{}^{\dagger} a_{k_3\uparrow}\beta$$

$$+ \Gamma_{k_1k_2k_3}{}^{\alpha\uparrow} a_{k_1\downarrow}{}^{\dagger} a_{k_2\uparrow}{}^{\dagger} a_{k_3\uparrow}\alpha + \Gamma_{k_1k_2k_3}{}^{\beta\downarrow} a_{k_1\uparrow}{}^{\dagger} a_{k_2\downarrow}{}^{\dagger} a_{k_3\downarrow}\beta]$$

$$+ \cdots\}\psi_v, \quad (1)$$

Fermi State



Magnetic impurity : Screened by a Kondo cloud

Loramet al., PRB 2, 857 (1970)

The Kondo problem

2nd order Born approx. $R = R_B\left(1 + 2\frac{J_{sd}\rho}{N}\log\frac{k_B T}{D}\right)$ diverges at T=0

Most divergent terms approximation the resistance diverges at

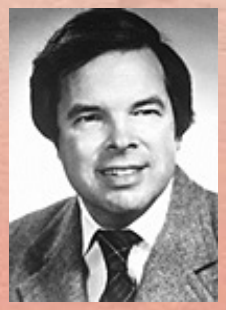
$$k_B T_k = D\exp\left(\frac{N}{J_{sd}\rho}\right)$$ (the Kondo temperature)

the Nobel prize in physics

Phil Anderson

Anderson impurity model

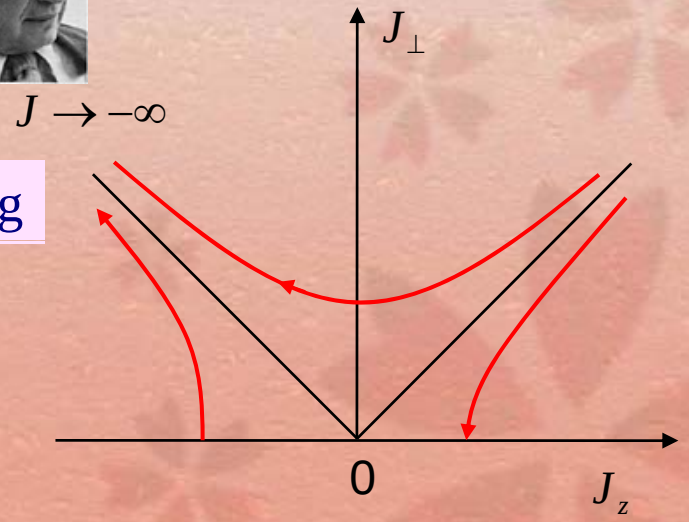
Renormalization group



Ken Wilson

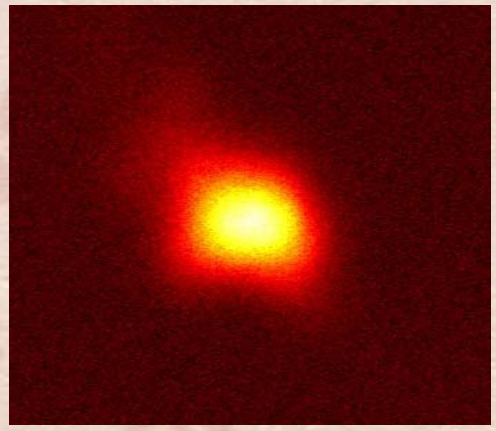
Asymptotic Strong Coupling

Gross, Politzer, Wilczek



Asymptotic Freedom, quantum chromo-dynamics

Advances in Low Temperature Physics (4)

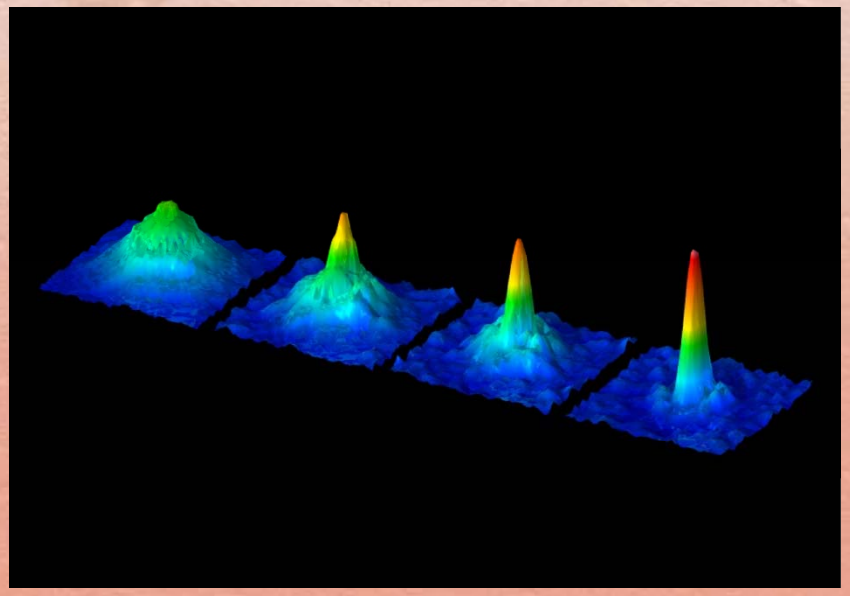


Laser cooling
cold cesium atoms in a magneto-optical trap

Steven Chu

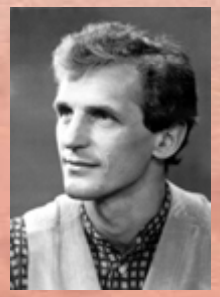
Claude Cohen-Tannoudji

William D. Phillips



- 1995 Bose-Einstein condensation

Eric A. Cornell

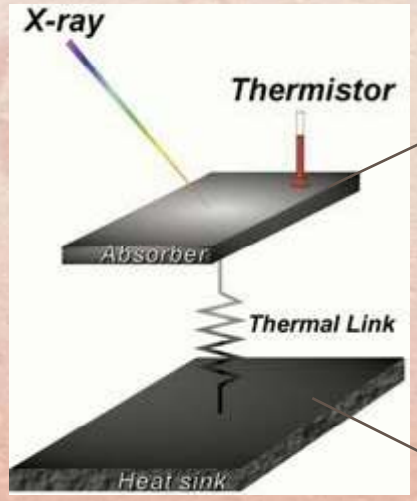


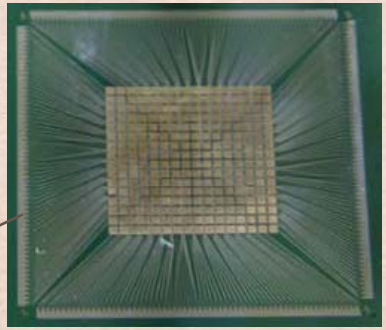
Wolfgang Ketterle

Carl E. Wieman

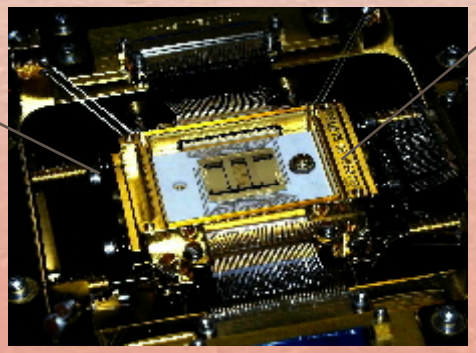
Advances in Low Temperature Physics (5)

Application to astronomy and particle physics





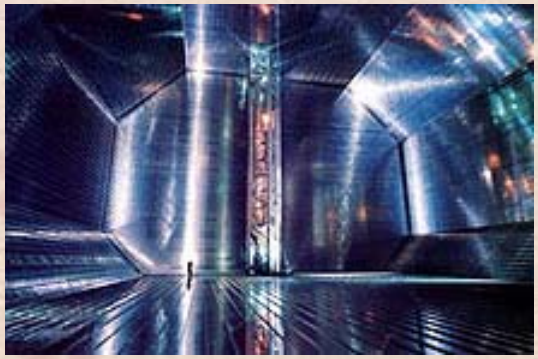
TES micro calorimeter



Refrigerator in Astro-E satellite

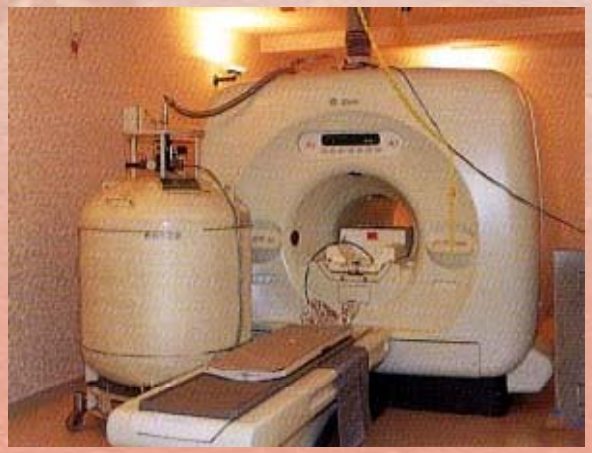
JAXA宇宙研 満田研究室HPより

Application of Low Temperature Technique



LNGタンカーの内部:巨大デュワー

LNGタンカー



MRI