

# 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

Katsumoto Group - Windows Internet Explorer

http://kats.isspu-tokyo.ac.jp/

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勝本信吾

Shingo Katsumoto

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自己紹介

現在の研究テーマ

論文リスト

「ポケットに電磁気を」が単行本になりました

出版された書籍

「低温物理学」講義ノート (2009 Apr.-May)

「低温物理学」講義ノート (2005 Apr.-May)

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

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850 free-to-read low-temperature physics papers from LT25 are now available

31/03/2009

IOP Publishing is delighted to announce open-access publication of the proceedings of the 25th International Conference on Low Temperature Physics (LT25) between 6-13 August 2008 at the RAI Conference Centre in Amsterdam, The Netherlands.

Professor Peter Kes, Chairman of the LT25 Organizing Committee, commented:

"The Guest Editors are grateful for the very professional and pleasant support of IOP Publishing in publishing the proceedings between IOP Publishing and LT25 it has been possible to publish the proceedings in less than eight weeks."

- Part I of the proceedings: 23 papers from plenary and invited speakers, are published in open access for one year from 31 March 2009.
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IOP Publishing would like to thank the Guest Editors, Peter Kes and Reijer Jochemsen who coordinated the proceedings.

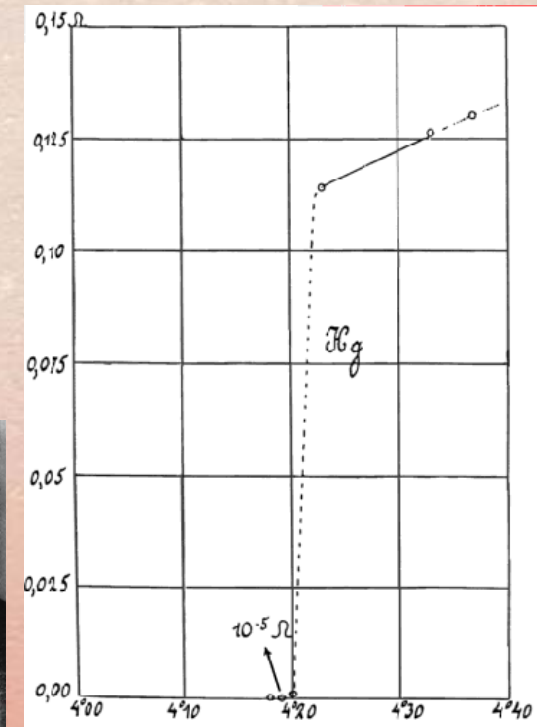
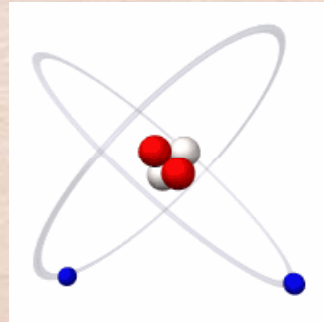


# Introduction (Low Temperature Physics)

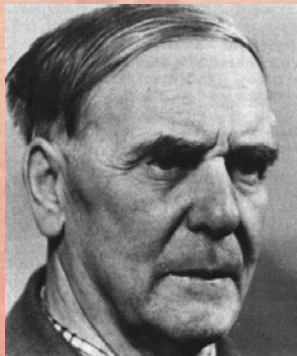


Heike Kamerlingh Onnes

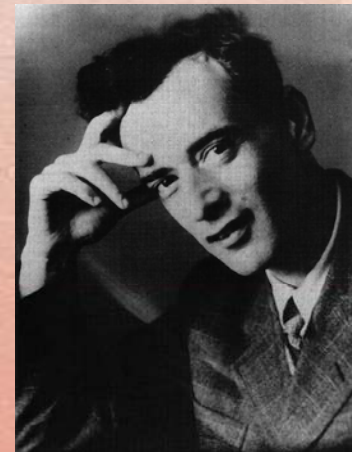
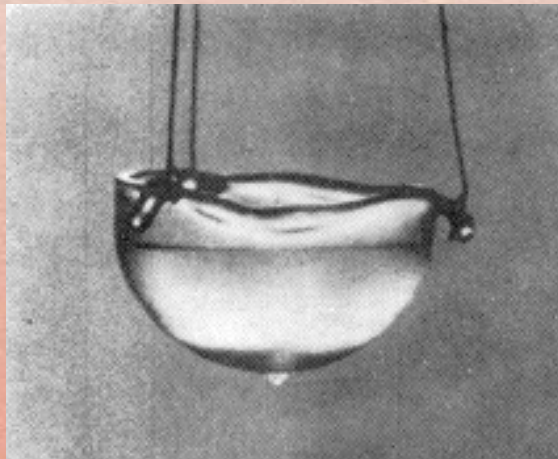
- 1908 7/10 Liquefaction of Helium 4
- 1911 Superconductivity of Hg



Lev Davidovich Landau



Pjotr Leonidovich Kapitza



- 1937 Superfluidity of Helium 4

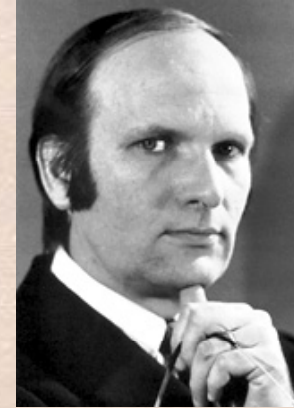
# Advances in Low Temperature Physics (1)



John Bardeen

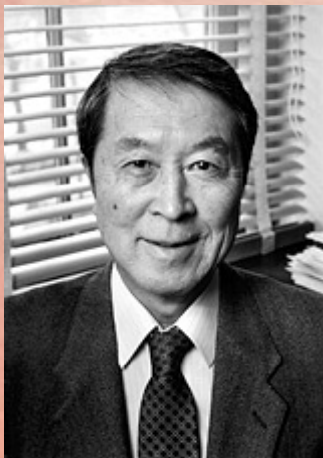


Leon Cooper



Robert Schrieffer

■ 1957 BCS Theory of Superconductivity



■ 1960 Spontaneous Symmetry Breaking



## Advances in Low Temperature Physics (2)



Douglas Osheroff



### ■ Superfluidity of $^3\text{He}$



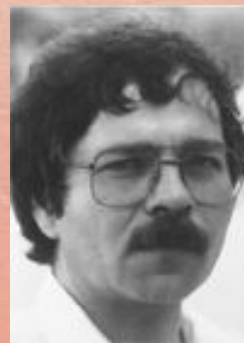
D. M. Lee



R. C. Richardson



### ■ 1986 Discovery of a High-Tc material

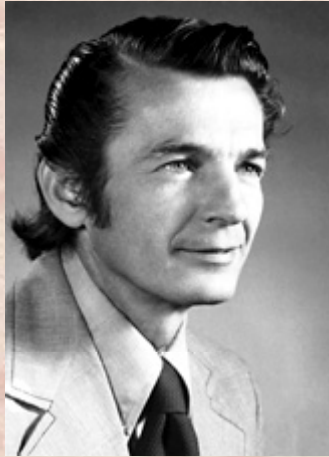


J. Georg Bednorz



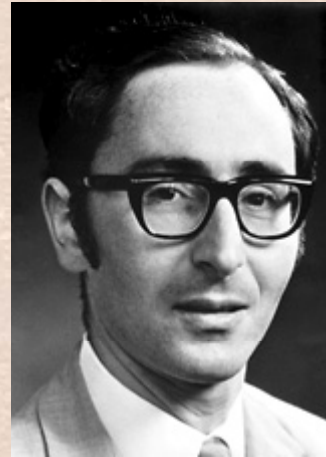
K. Alexander Müller

## Advances in Low Temperature Physics (2)



Tunneling  
Phenomena

Ivar Giaever



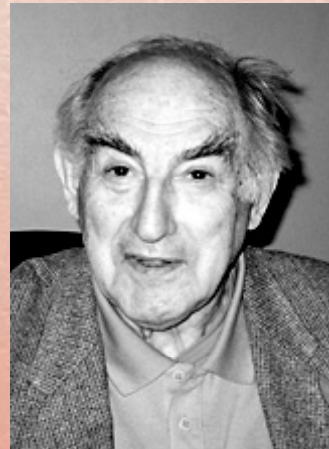
Josephson Effect

Brian Josephson



Alexei Abrikosov

Vortex Lattice



Vitaly Ginzburg

GL Theory



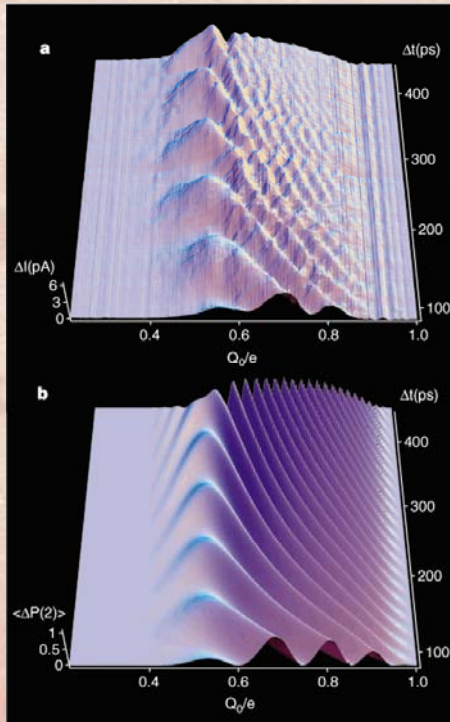
Anthony Leggett

Helium 3 Theory

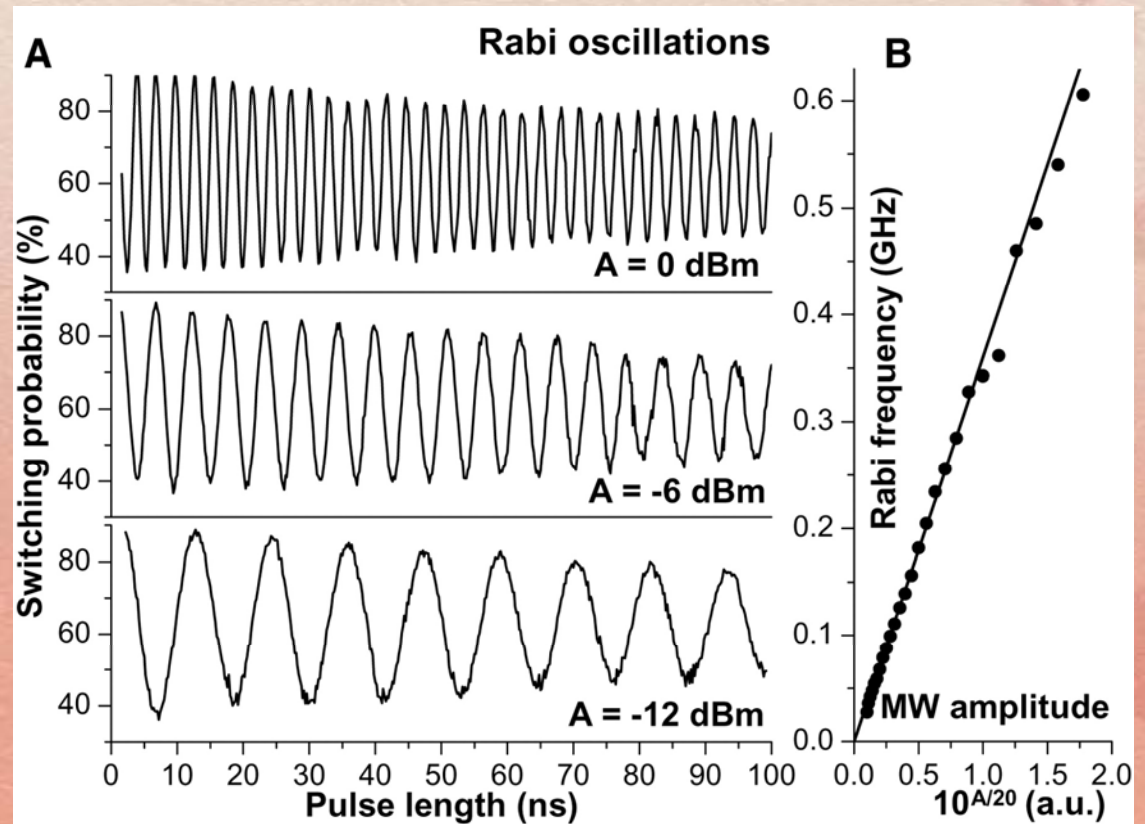
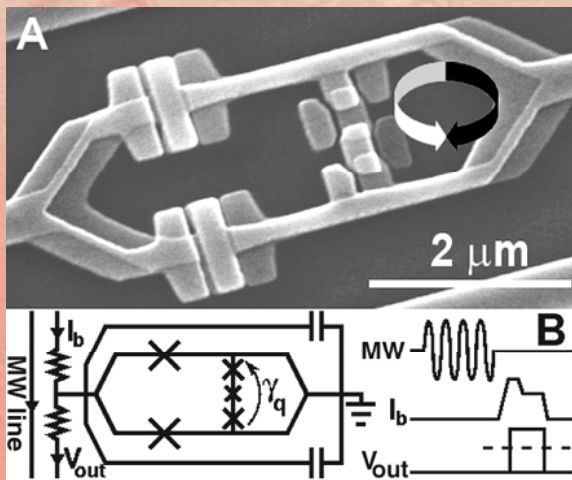
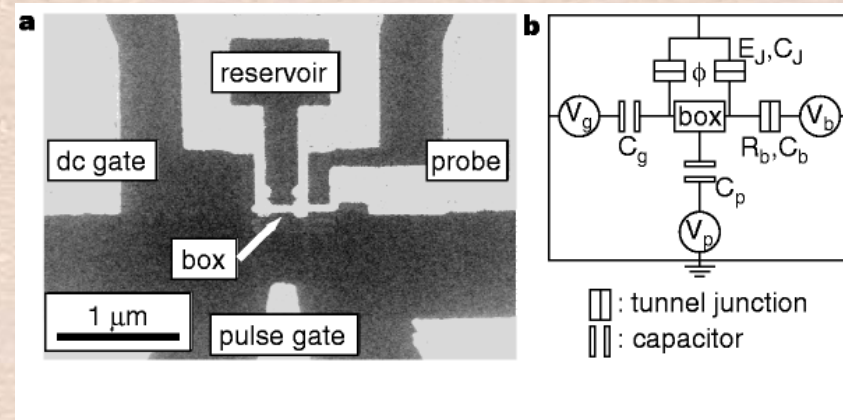


# Quantum Coherence and Information Processing

Charge Qubit



Flux Qubit

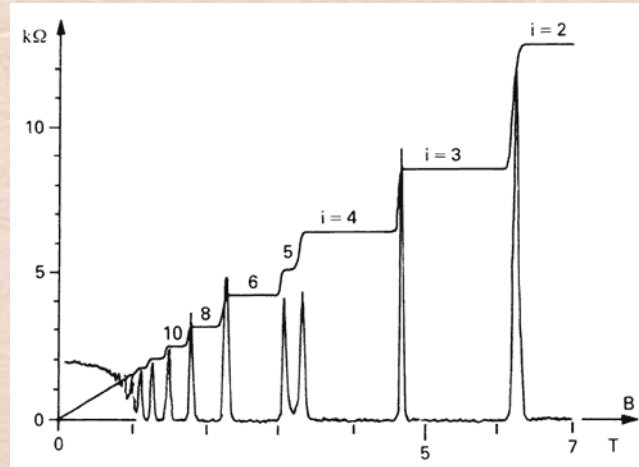




# Advances in Low Temperature Physics (3)



Klaus von Klitzing



■ 1980 Discovery of quantum Hall effect

■ 1982 Discovery of fractional quantum Hall effect

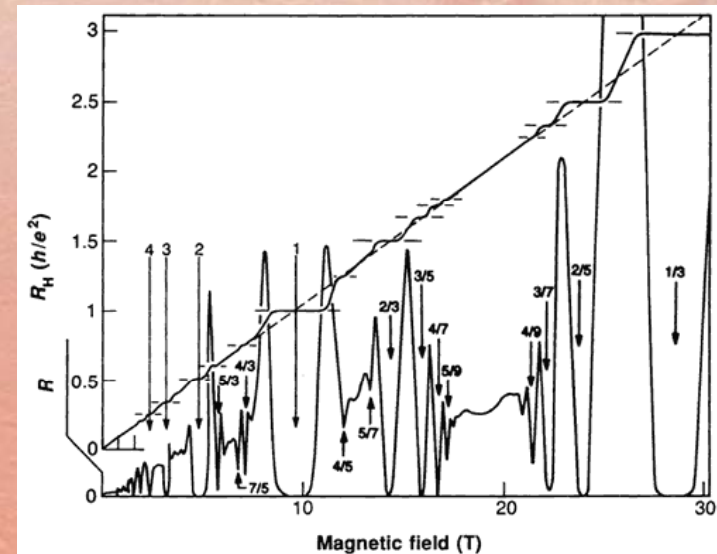
Robert B. Laughlin



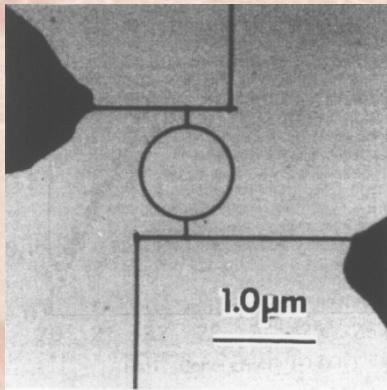
Daniel C. Tsui



Horst L. Störmer

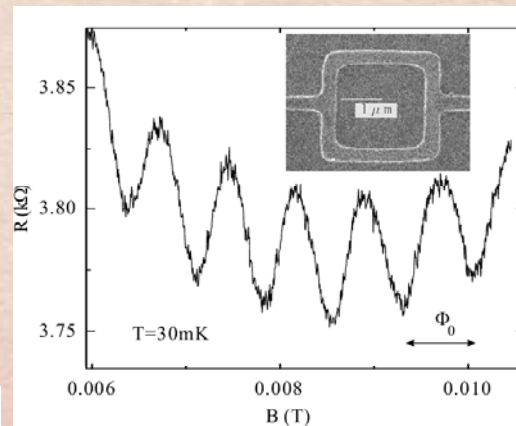


# Mesoscopic Systems

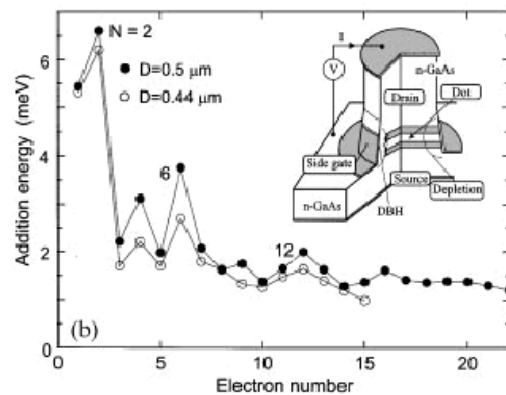
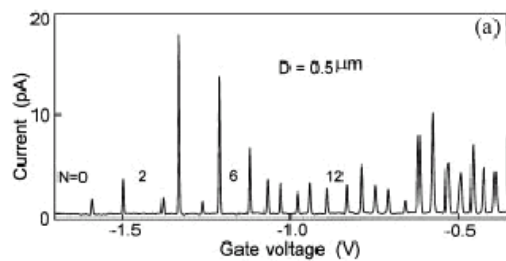
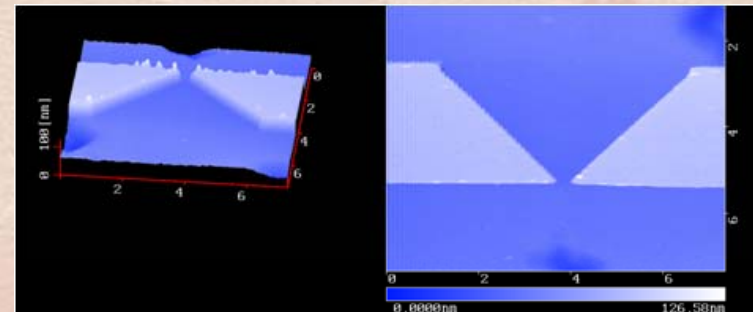


R. A. Webb et al. PRL 54, 1610 (1985).

## Aharonov-Bohm effect

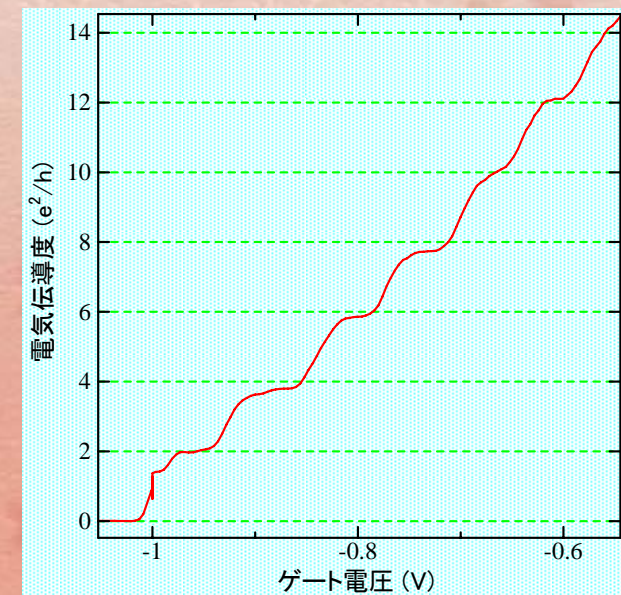


## Quantum Point Contact (1989)



## Artificial Atom

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

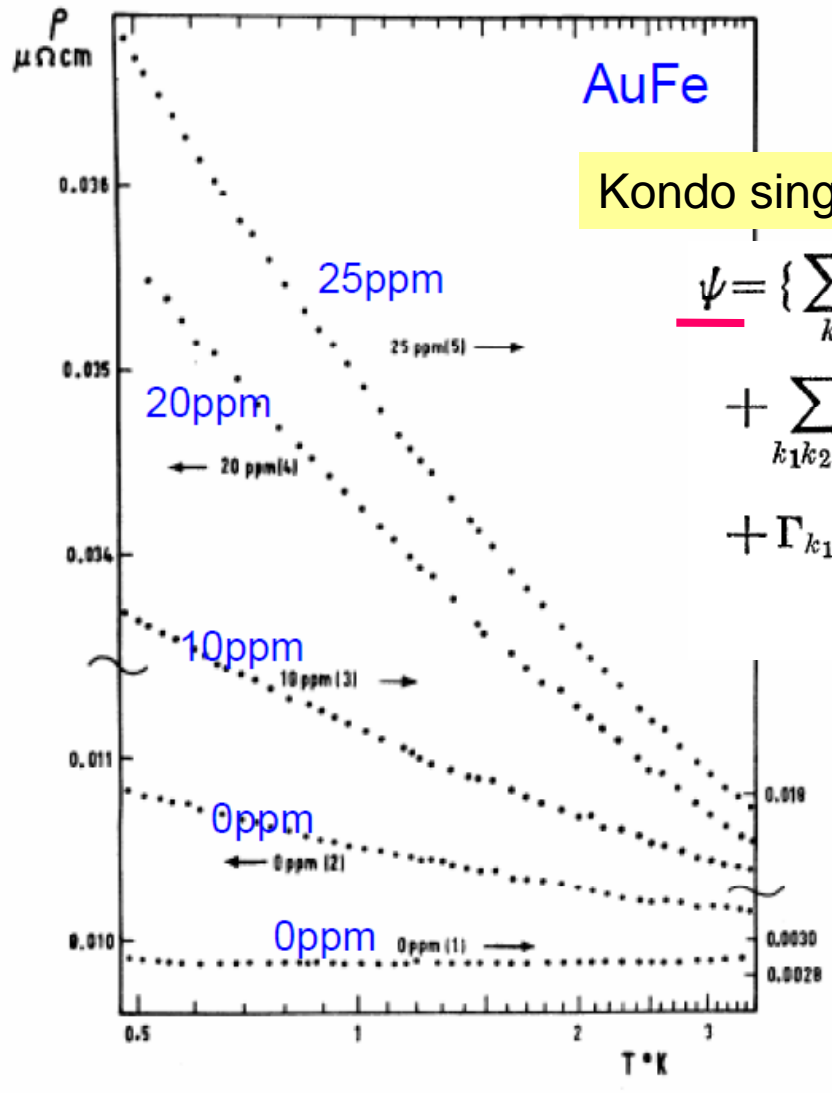




# The Kondo effect



Jun Kondo

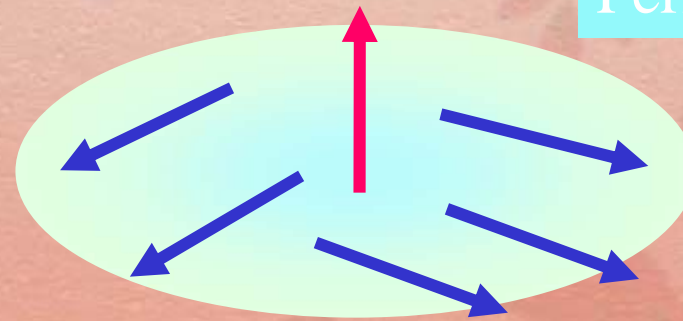


AuFe

Kondo singlet

$$\begin{aligned}
 \psi = & \left\{ \sum_k [\Gamma_k^\alpha a_{k\downarrow}^\dagger \alpha + \Gamma_k^\beta a_{k\uparrow}^\dagger \beta] \rightarrow (|s\uparrow\rangle|d\downarrow\rangle - |s\downarrow\rangle|d\uparrow\rangle) \right. \\
 & + \sum_{k_1 k_2 k_3} [\Gamma_{k_1 k_2 k_3}^{\alpha\downarrow} a_{k_1\downarrow}^\dagger a_{k_2\downarrow}^\dagger a_{k_3\downarrow} \alpha + \Gamma_{k_1 k_2 k_3}^{\beta\uparrow} a_{k_1\uparrow}^\dagger a_{k_2\uparrow}^\dagger a_{k_3\uparrow} \beta \\
 & \left. + \Gamma_{k_1 k_2 k_3}^{\alpha\uparrow} a_{k_1\downarrow}^\dagger a_{k_2\uparrow}^\dagger a_{k_3\uparrow} \alpha + \Gamma_{k_1 k_2 k_3}^{\beta\downarrow} a_{k_1\uparrow}^\dagger a_{k_2\downarrow}^\dagger a_{k_3\downarrow} \beta] \right. \\
 & \left. + \dots \right\} \psi_v, \quad (1)
 \end{aligned}$$

Fermi State



Loramet et al., PRB 2, 857 (1970)

Magnetic impurity : Screened by a Kondo cloud

# 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

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



the Nobel prize in physics



Phil Anderson

Anderson impurity model

Renormalization group

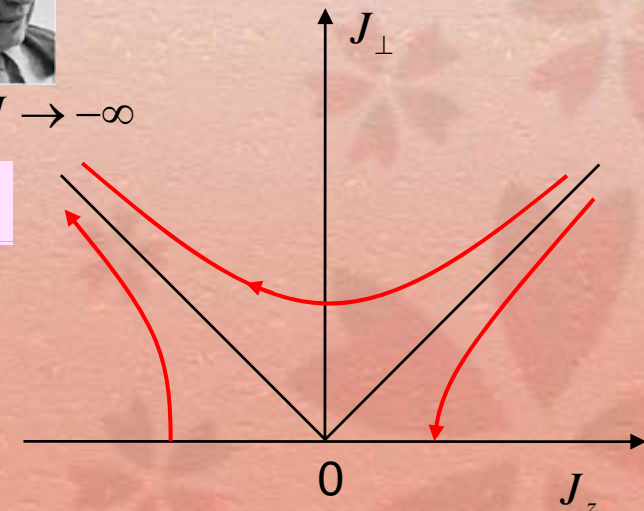


Ken Wilson

Asymptotic Strong Coupling



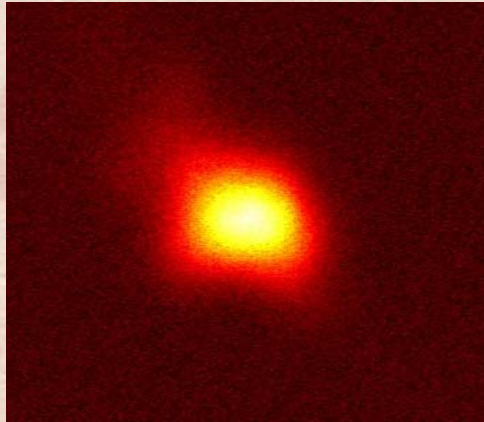
Gross, Politzer, Wilczek



Asymptotic Freedom, quantum chromo-dynamics



# Advances in Low Temperature Physics (4)



Laser cooling  
cold cesium atoms in a magneto-optical trap



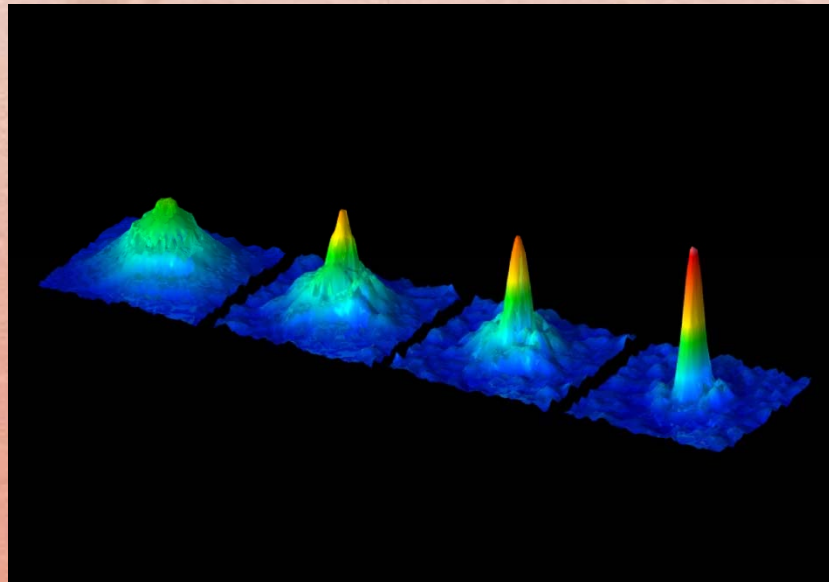
Steven Chu



Claude  
Cohen-Tannoudji



William D. Phillips



■ 1995 Bose-Einstein  
condensation



Eric A. Cornell



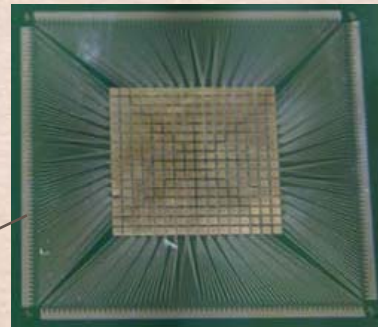
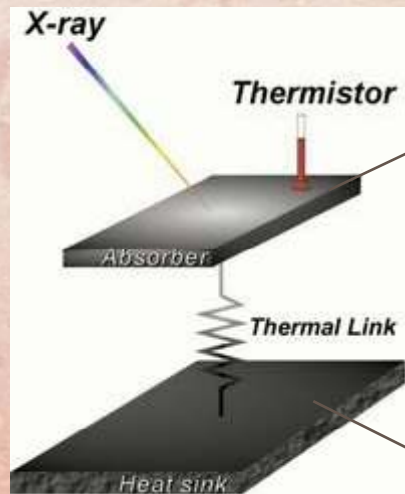
Wolfgang  
Ketterle



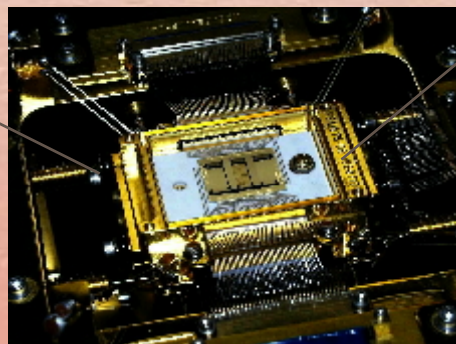
Carl E. Wieman

# Advances in Low Temperature Physics (5)

Application to astronomy and particle physics



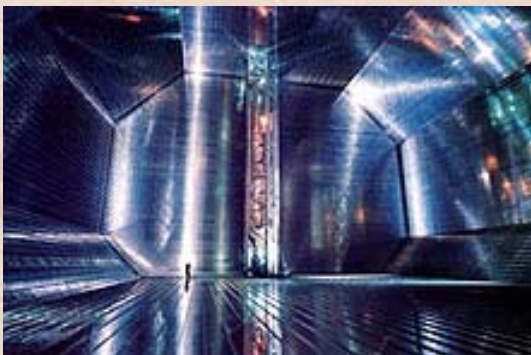
TES micro calorimeter



Refrigerator in Astro-E satellite



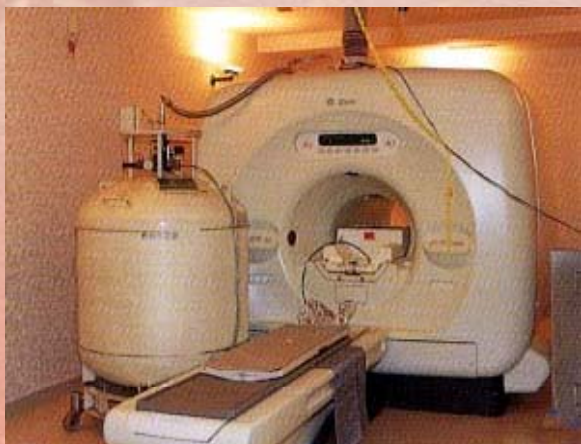
# Application of Low Temperature Technique



LNGタンカーの内部:巨大デュワー



LNGタンカー



MRI