“固体宇宙”

多电子体系的集体行为

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Emergence

课题组网页

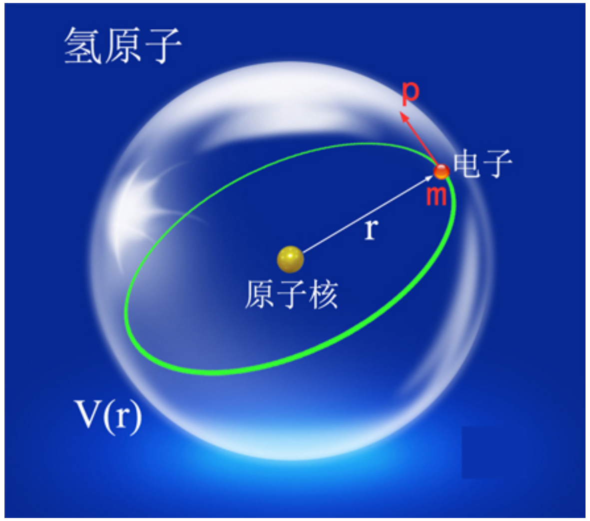
http://hf.iphy.ac.cn

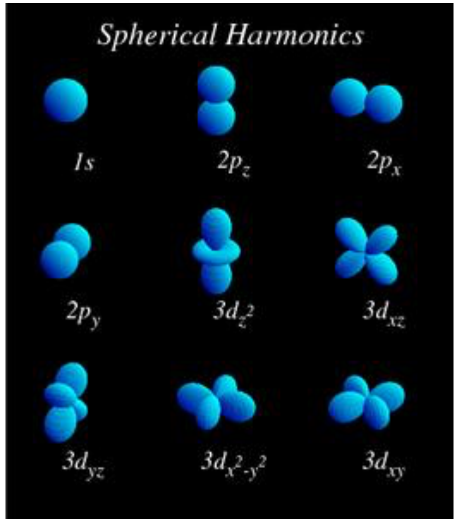
Institute of Physics CAS 1928

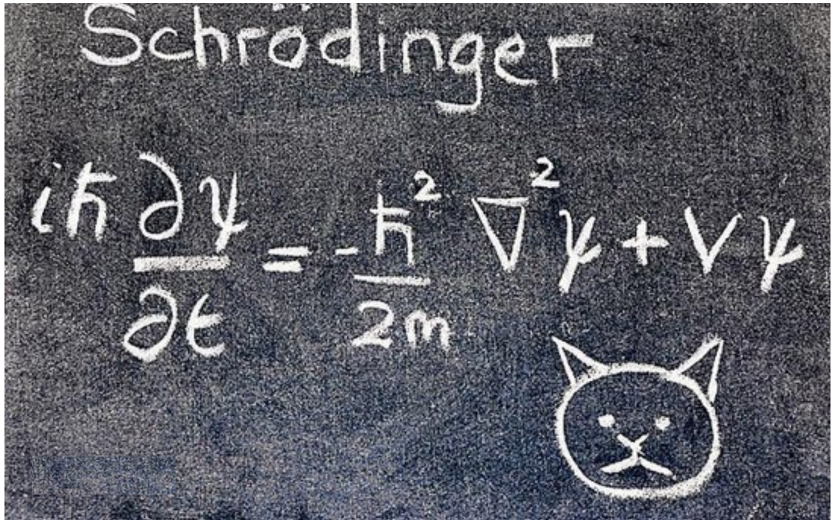
两类本科物理课程

第一类

电动力学、量子力学、原子物理





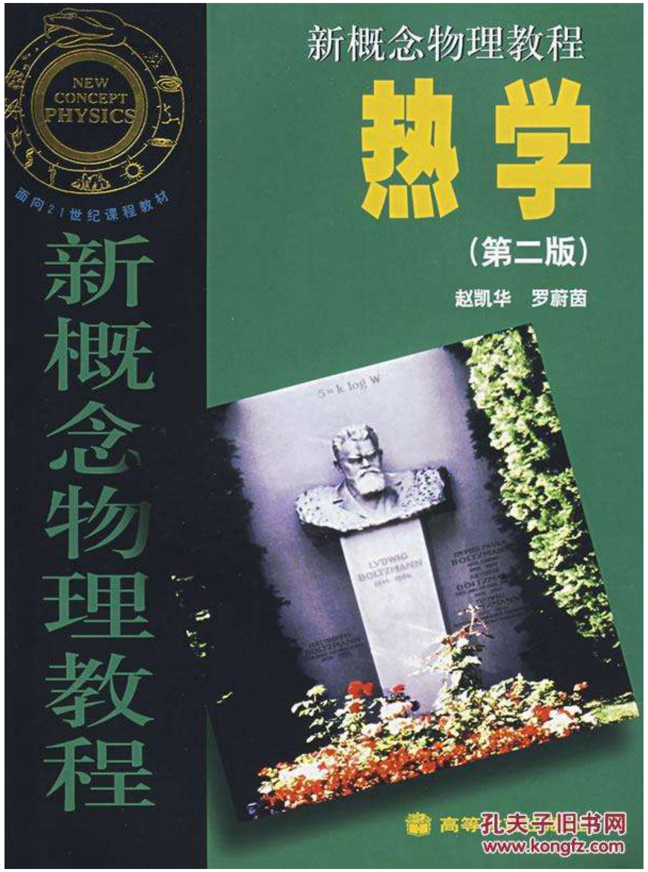


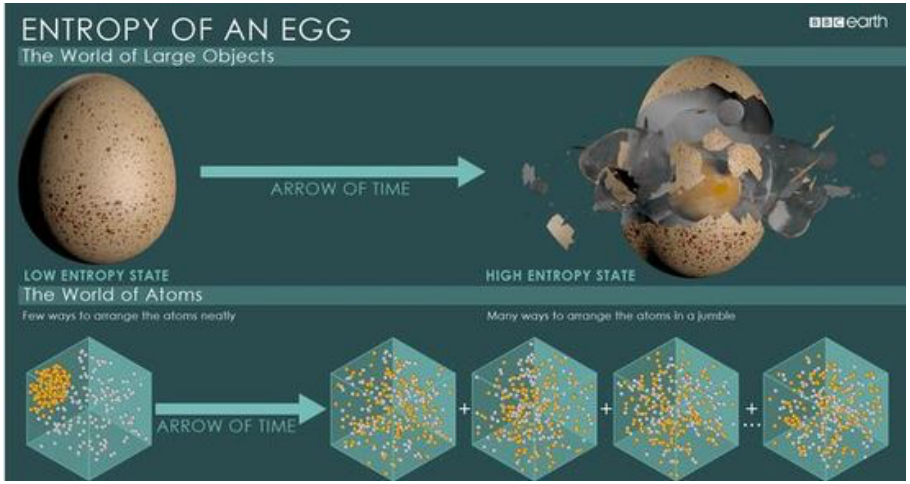
教授世界的最基本的个体的运动规律

两类本科物理课程

第二类

热学、统计物理学

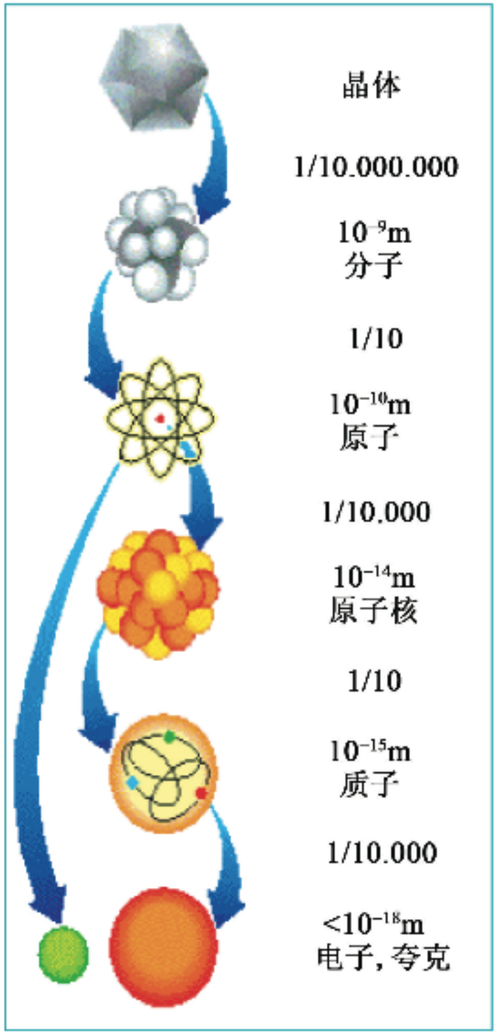




教授大量个体所构成的体系的集体行为规律

认识世界的两种不同途径

一尺之棰，日取其半，万世不竭！



材料科学

化学

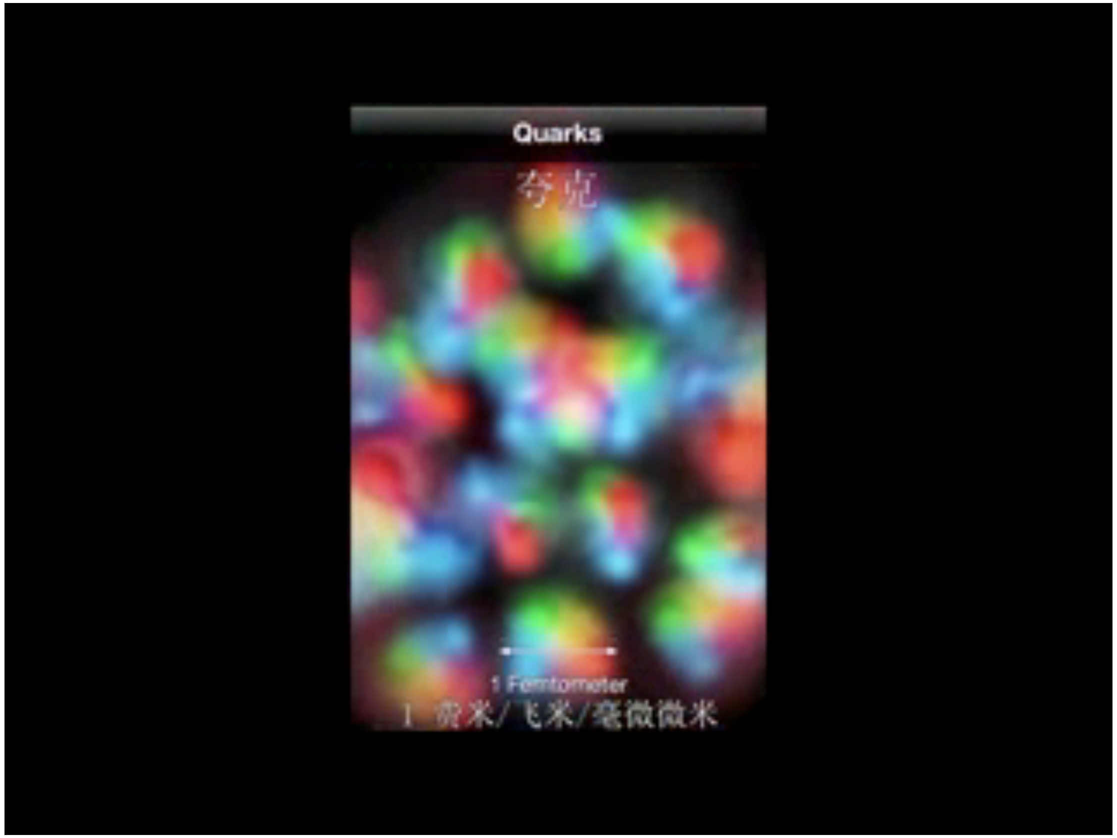
原子物理学

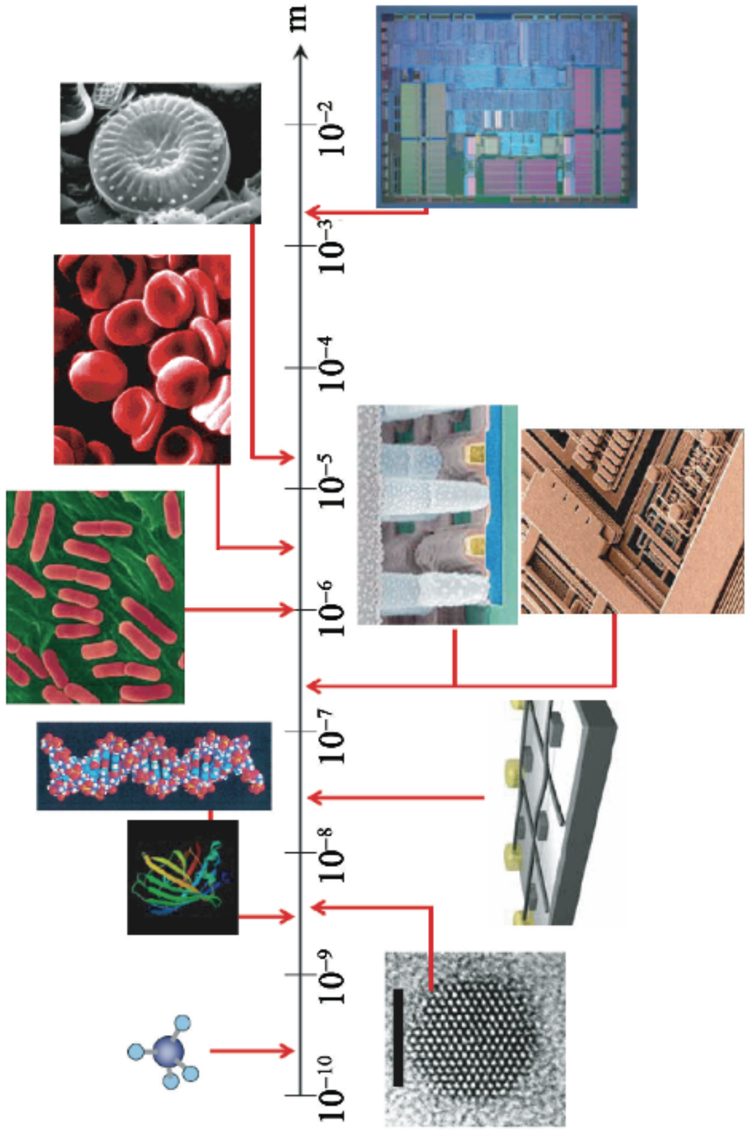
核物理学

粒子物理学

分辨构成世界的最基本的个体

认识世界的两种不同途径



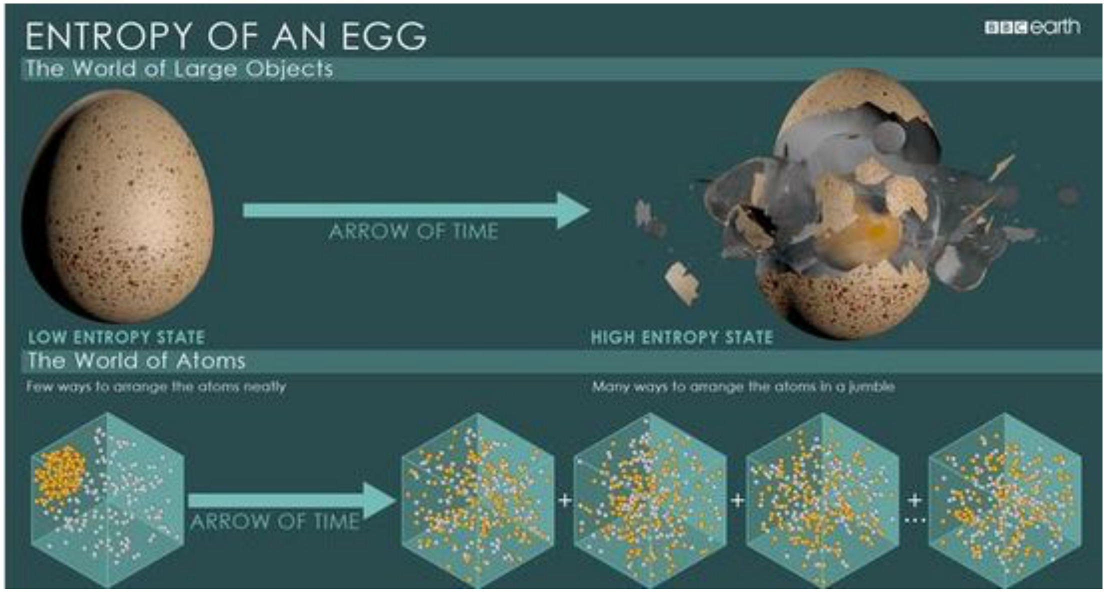


原子－细胞－人－社会

重新构建世界每个层面的行为模式

不同层面的行为模式可能是不同的
难以从低层进行简单推演

More is different !



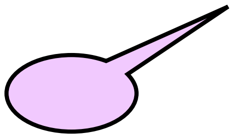
时间箭头

必须具体研究集体的行为模式与演化规律

生物群体的集体行为模式

必须具体研究集体的行为模式与演化规律

大量水分子的集体运动产生的波纹及其干涉现象

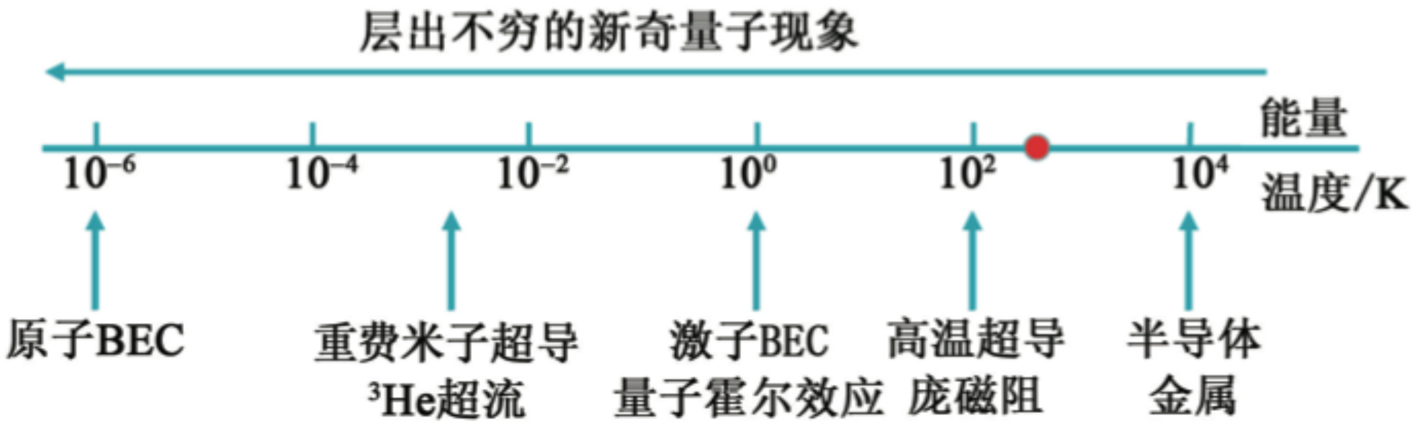


必须具体研究集体的行为模式与演化规律

大量机动车导致的交通阻塞，甚至“幽灵堵车”

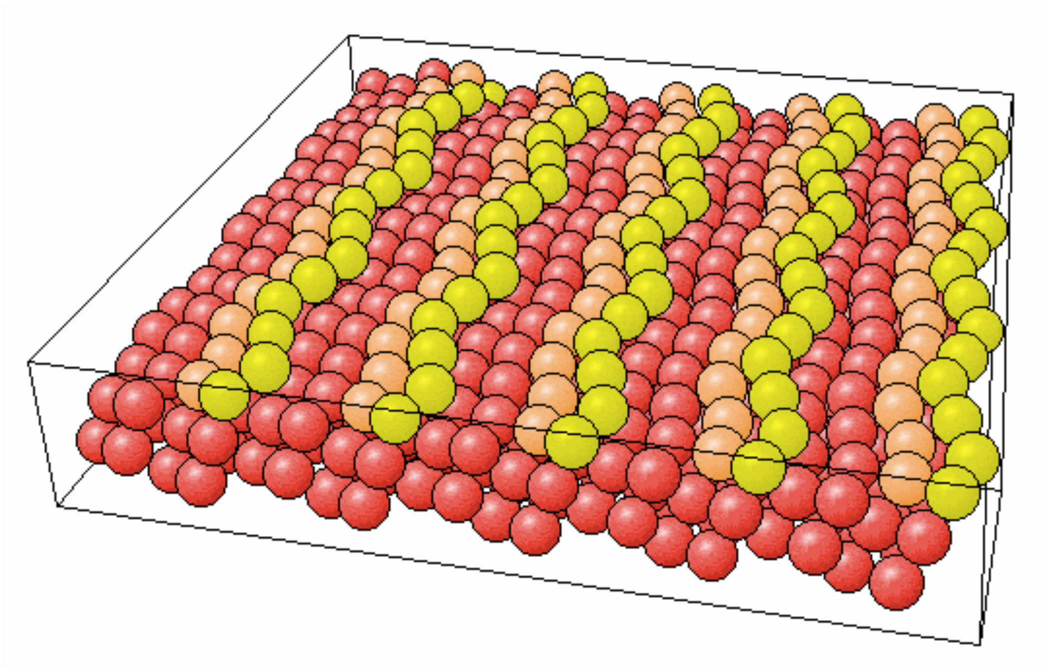
集体行为模式与演化规律

是凝聚态物理的核心研究对象

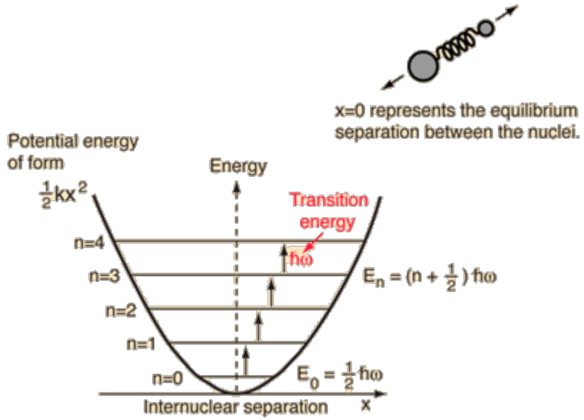


在不同的能量 / 时间尺度上均有新奇的量子现象涌现

晶格振动与声子



声子的Einstein模型

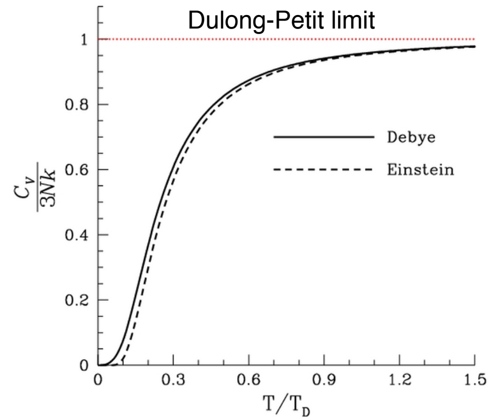


Energy per mole = $3kTN_A$

k= Boltzmann's constant
T= Temperature in Kelvins
N_A = Avogadro's number

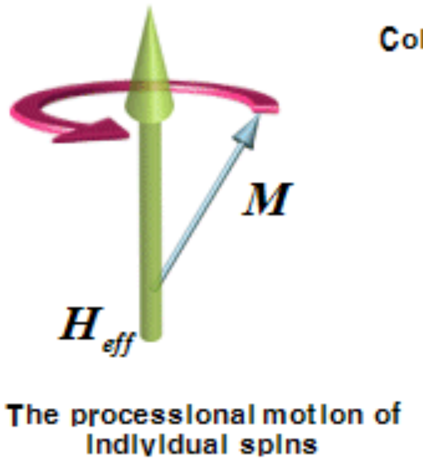
The Law of Dulong & Petit

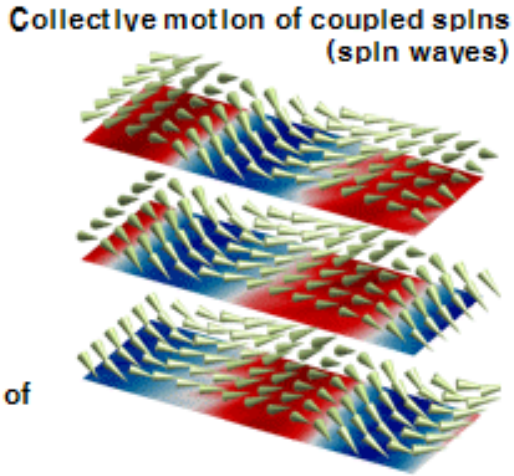
$$C_v = \frac{\partial}{\partial T}(3kTN_A) = 3kN_A\ /\ mole = 24.94J\ /\ mole\ K$$

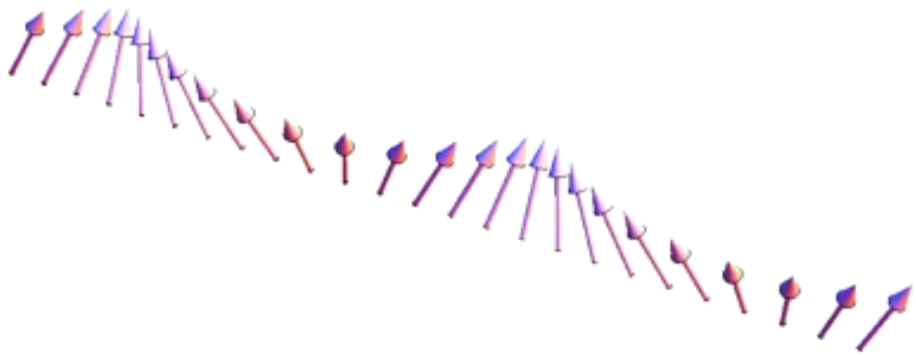


不断放大，最终看到晶格，而不是更小的组成单元

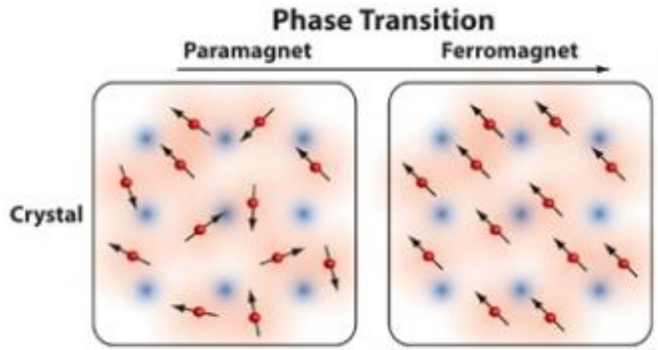
自旋波与磁性相变







磁性相变附近的临界行为

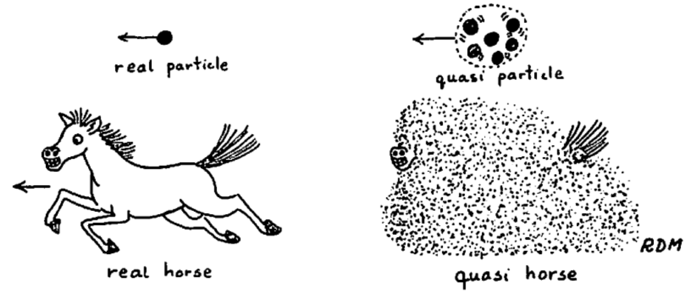


波长 —> ∞

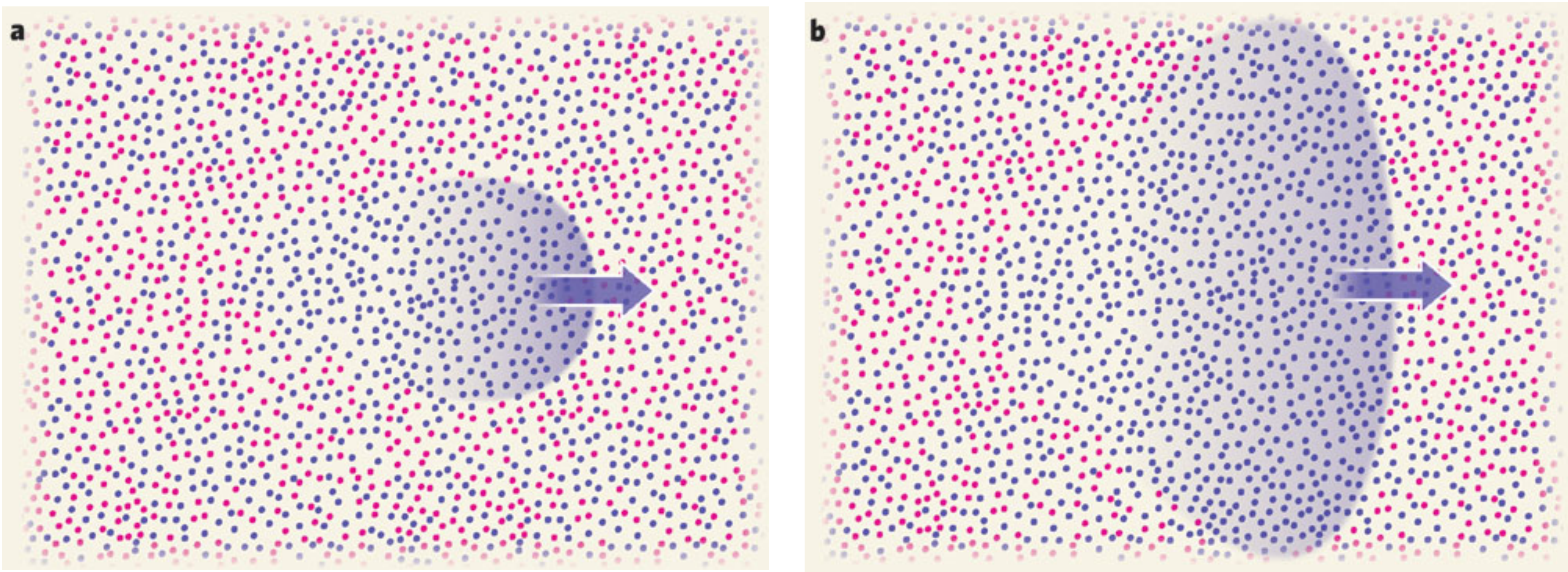
能量 —> 0

自旋波激发决定了磁性转变附近的各种物理性质

自由电子与准粒子



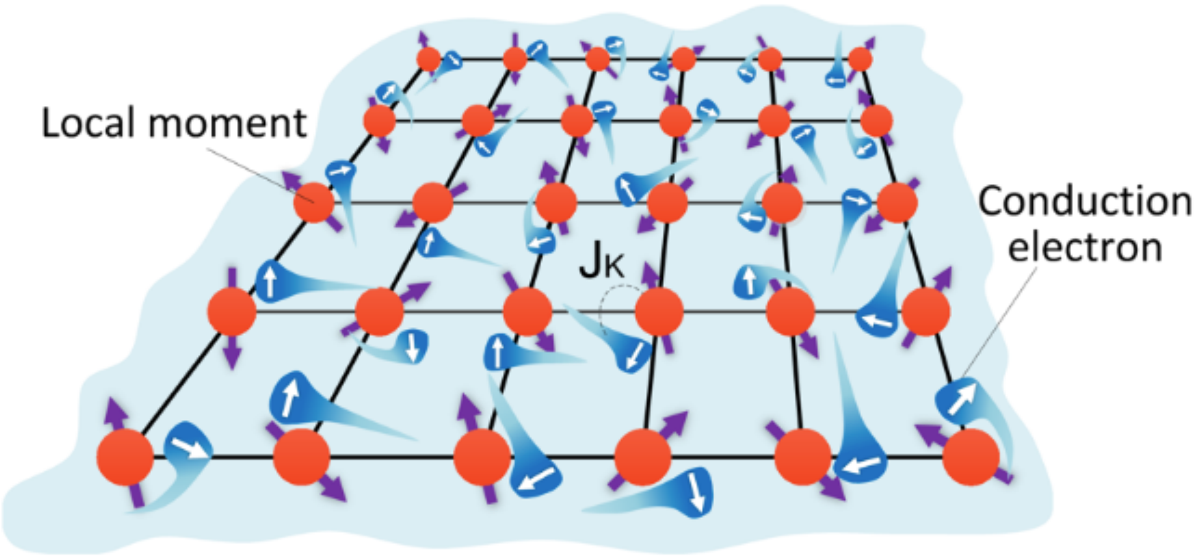
朗道的费米液体理论



每个电子带动周围电子一起运动，形成变胖了的准粒子

可以解释大部分金属的电、热、磁性质

电子与自旋波的复合粒子



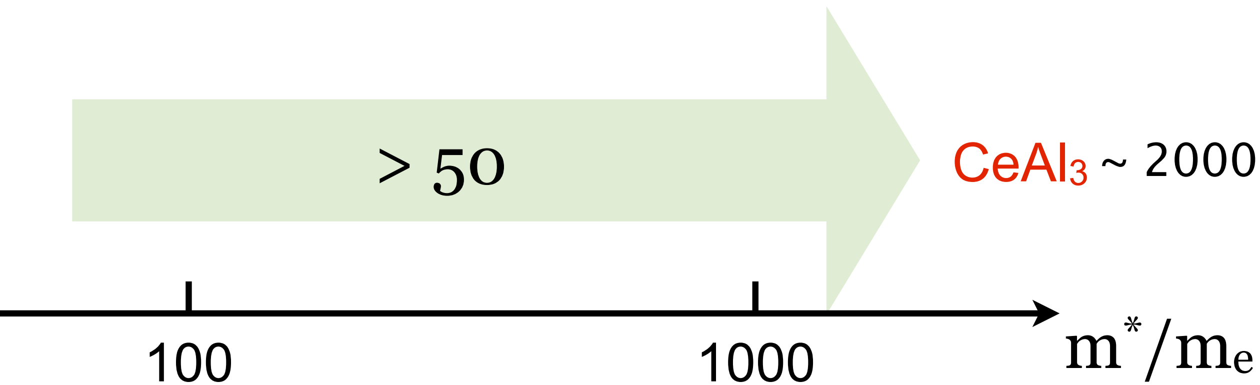
电子＋自旋波＝新的复合费米子

电子：电荷-e，自旋1/2

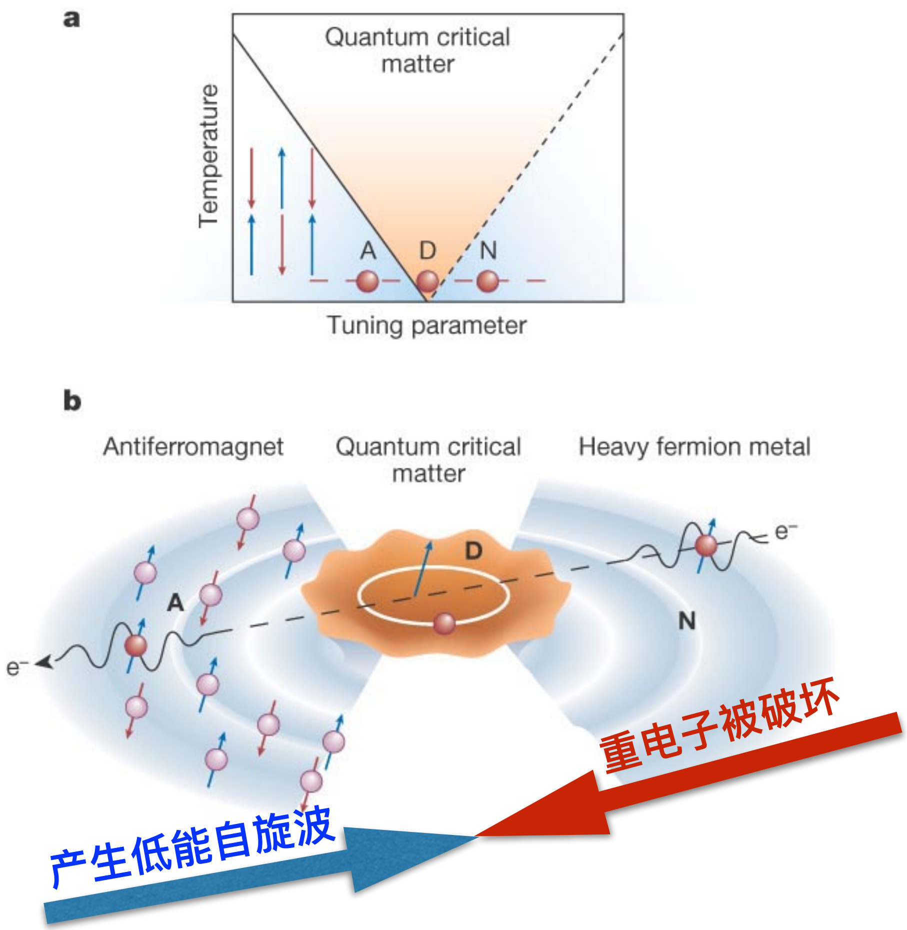
复合费米子：电荷-e，自旋1/2

复合费米子携带着电子的电荷和耦合后的总自旋1/2，类似于电子，但是其有效质量却可以达到质子的质量，称为“重电子”

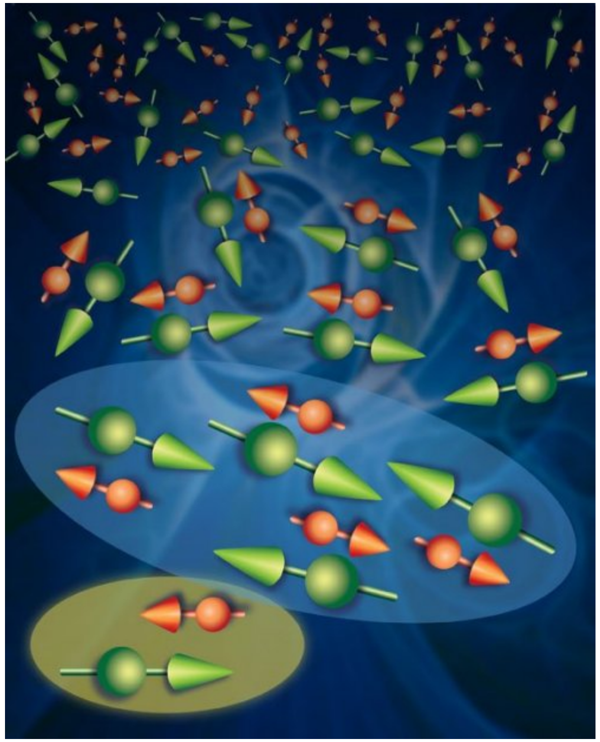
金/铜等

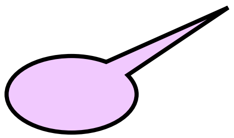


两种相反趋势的竞争



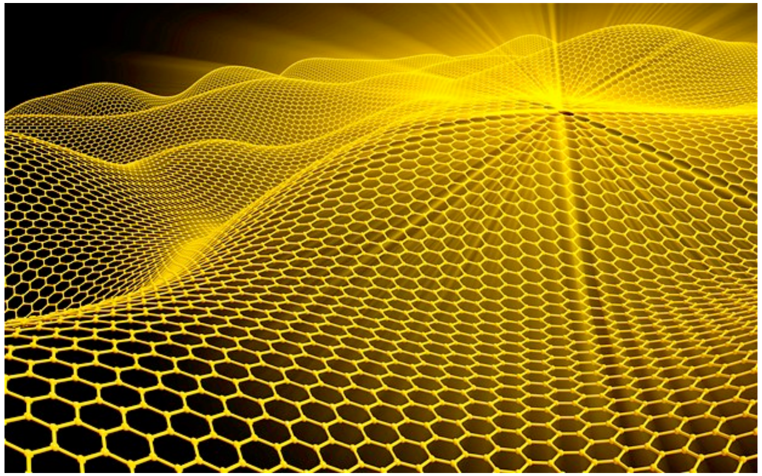
空间与时间上的涨落

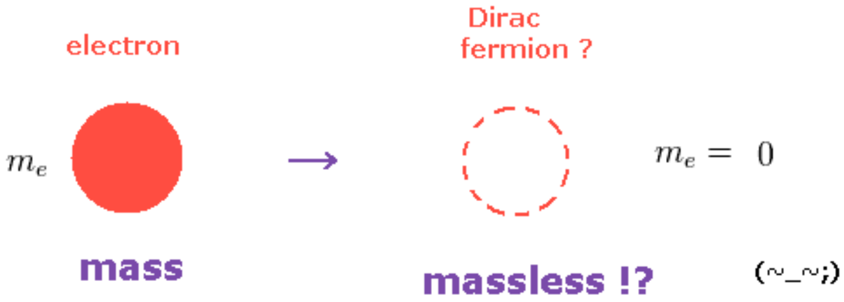




在中间的“量子临界区”，不存在稳定的准粒子，
而是有着各种复杂的瞬时的集体模式。如何描述？非费米液体？

“零质量”电子




electron
Dirac fermion ?
m_e
$m_e = 0$
mass
massless !?
(~_~;)

$E=Pc$

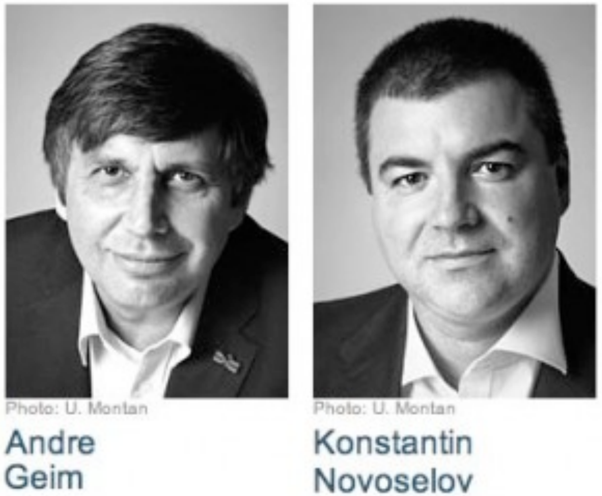
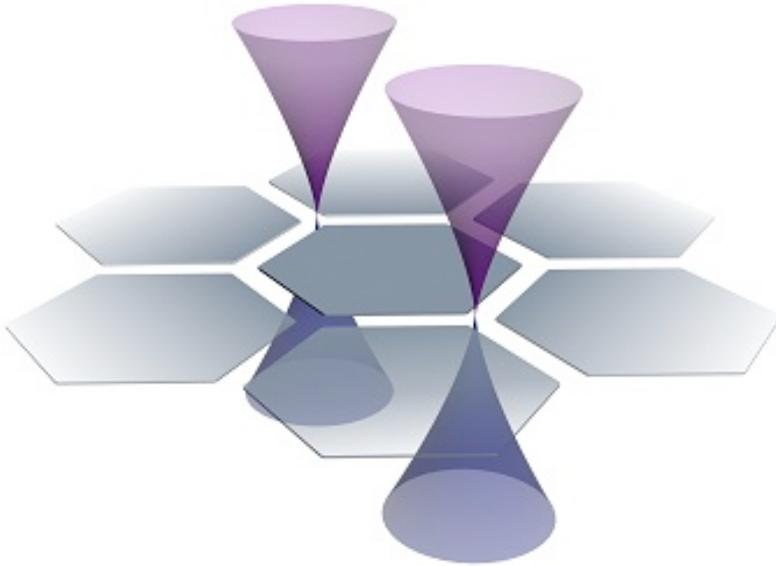
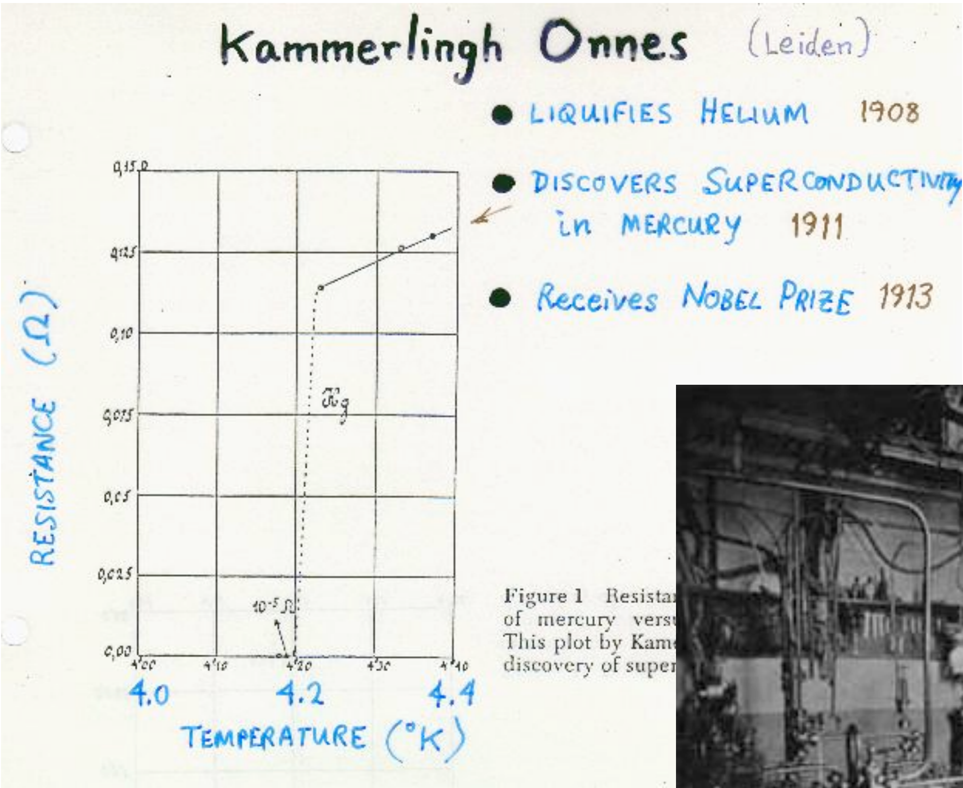


Photo: U. Montan
Andre Geim
Photo: U. Montan
Konstantin Novoselov



一种奇异的集体现象：超导

超导



Kammerlingh Onnes (Leiden)
LIQUIFIES HELIUM 1908
DISCOVERS SUPERCONDUCTIVITY in MERCURY 1911
Receives NOBEL PRIZE 1913
RESISTANCE (Ω)
TEMPERATURE (°K)
4.0
4.2
4.4
Hg
Figure 1 Resista
of mercury versu
This plot by Kame
discovery of super

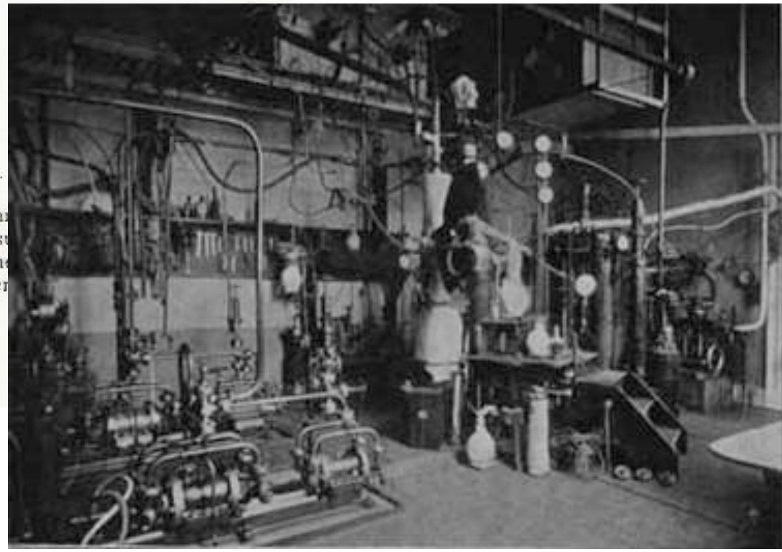
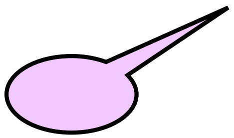


Fig. 1. Albert Einstein, Paul Ehrenfest, Paul Langevin, Heike Kamerlingh Onnes, and Pierre Weiss discussing superconductivity during the "Magnet-Woche" in Leiden in November 1920 (Photo: AIP)



PHYSICAL REVIEW VOLUME 108, NUMBER 5 DECEMBER 1, 1957

Theory of Superconductivity*

J. Bardeen, L. N. Cooper,† and J. R. Schrieffer‡
Department of Physics, University of Illinois, Urbana, Illinois

(Received July 8, 1957)

A theory of superconductivity is presented, based on the fact that the interaction between electrons resulting from virtual exchange of phonons is attractive when the energy difference

one-to-one correspondence with those of the normal phase is obtained by specifying occupation of certain Bloch states and by using the rest to form a linear combination of virtual pair con-

我的导师 David Pines

Nobel Prize 1972

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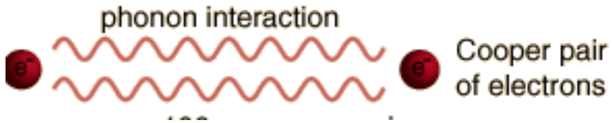
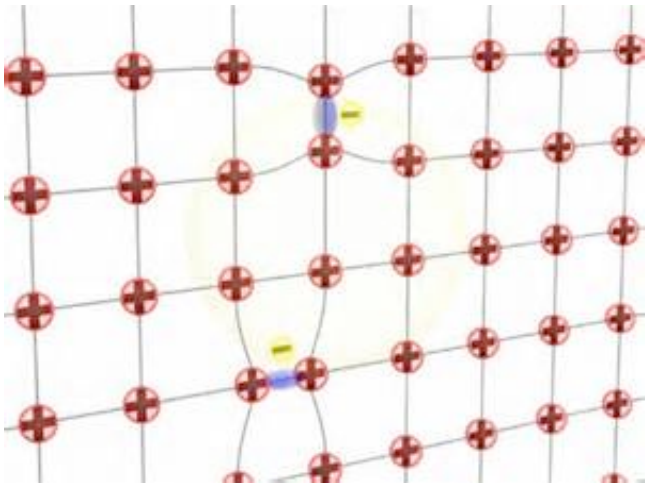
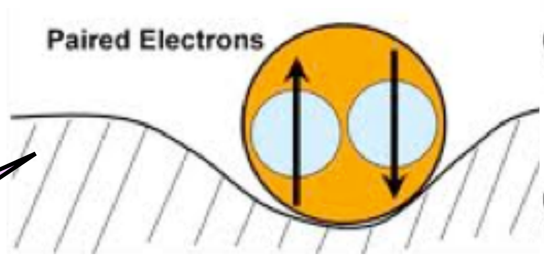
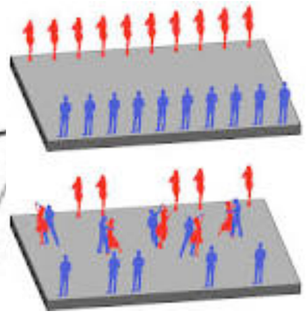
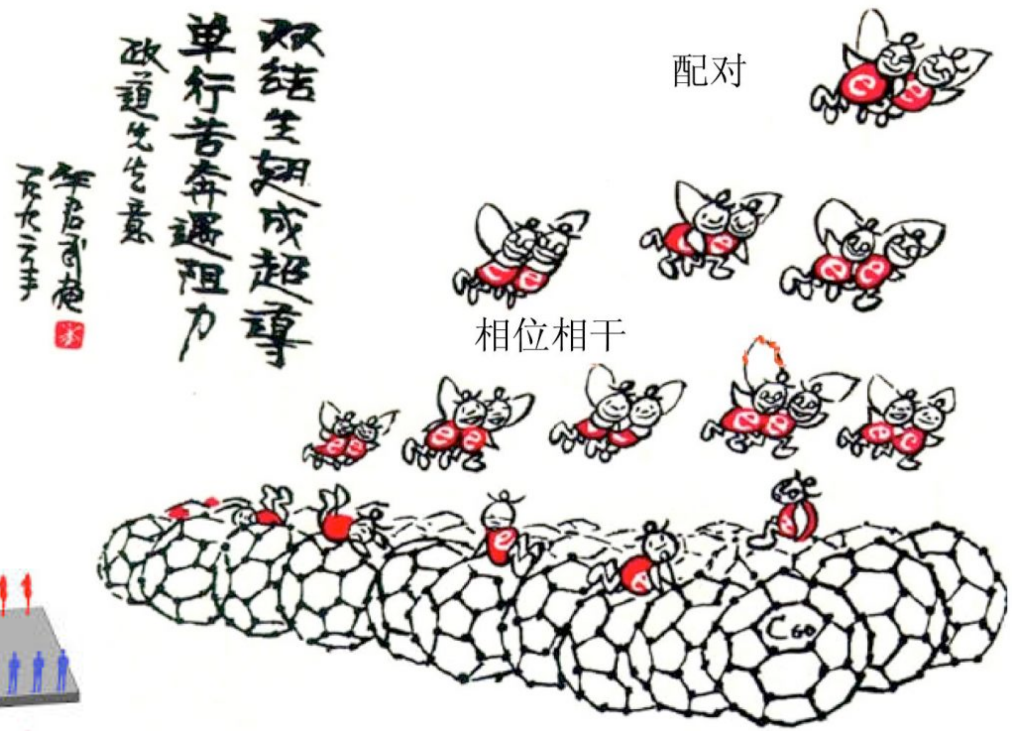




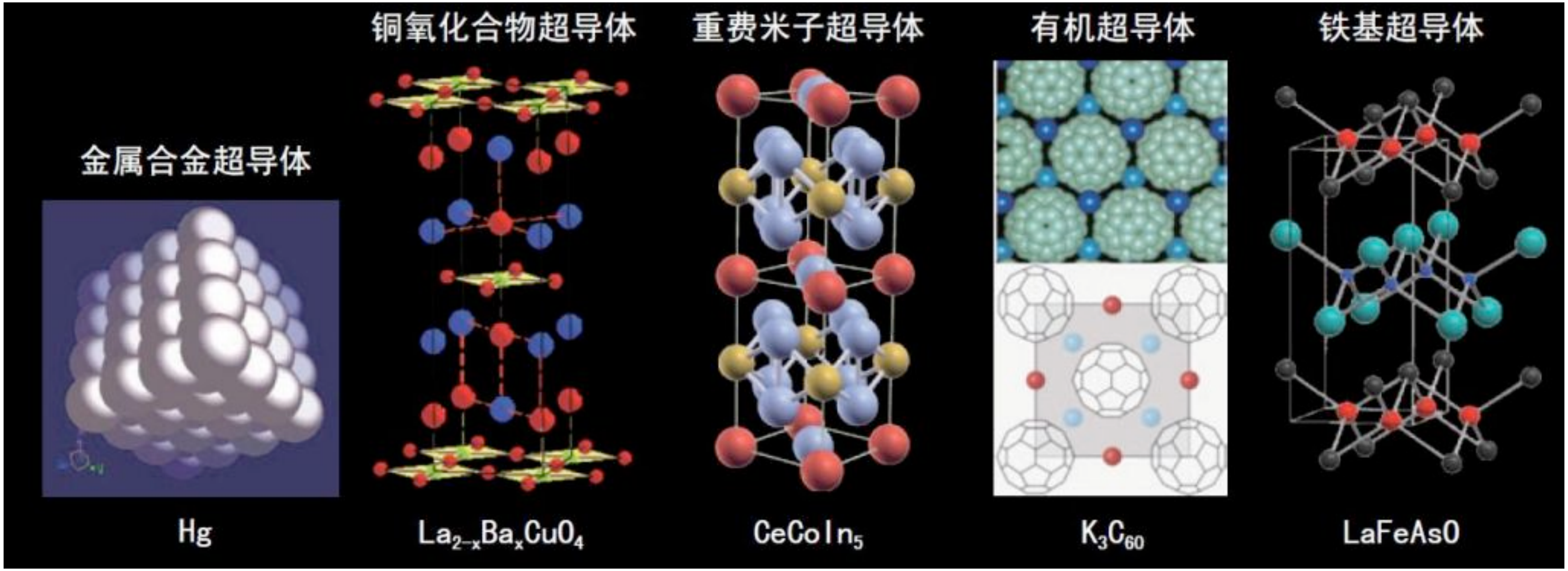






单行苦奔遇阻力，双结生翅成超导

（李政道 创意）



NATURE | NEWS

Superconductivity record breaks under pressure

Everyday compound reported to conduct electricity without resistance at a record-high temperature, outstripping more exotic materials.

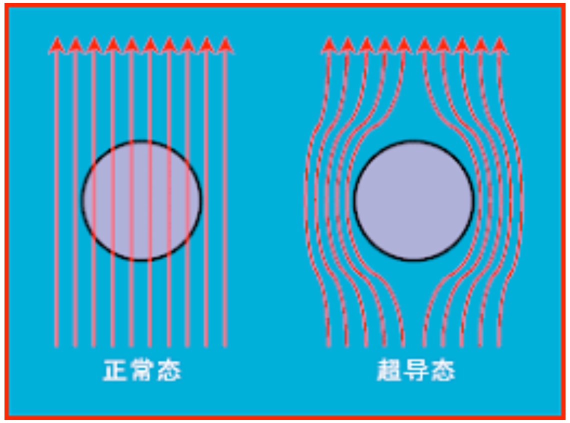
Conventional superconductivity at 190 K at high pressures

A.P. Drozdov, M. I. Eremets*, I. A. Troyan

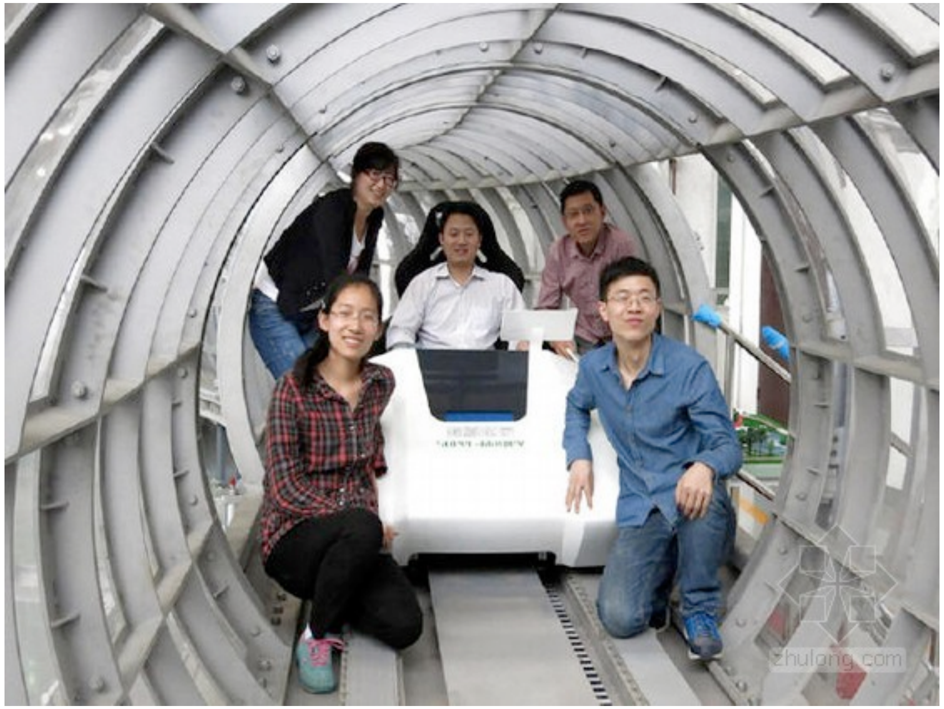
Max-Planck Institut fur Chemie, Chemistry and Physics at High Pressures Group

Postfach 3060, 55020 Mainz, Germany

“臭鸡蛋”的超导

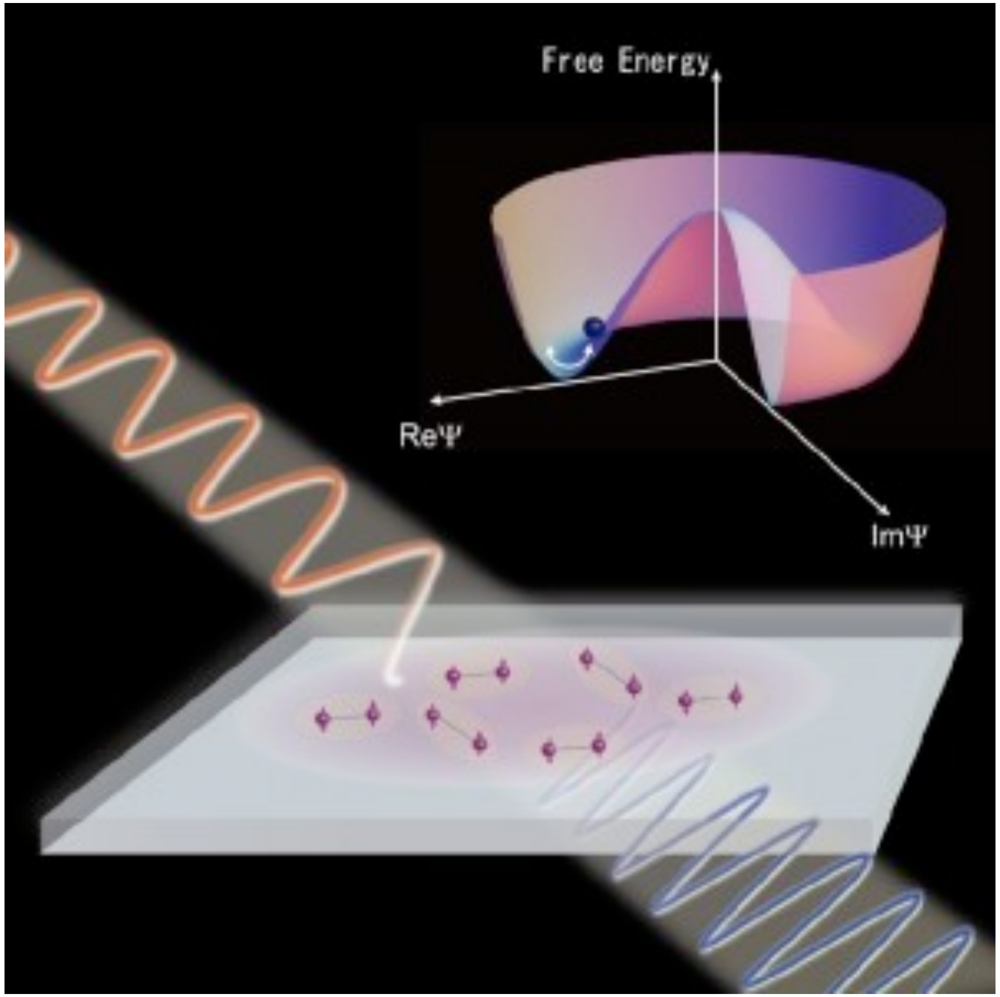


▲在超导磁悬浮平台上的日本相扑运动员
http://www.ru.nl/hfml/research/levitation/

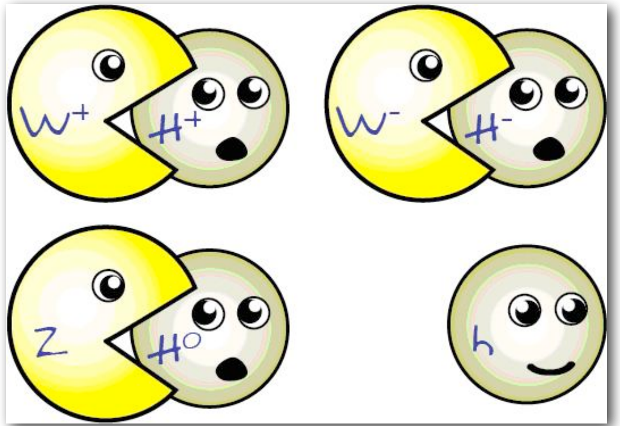


完全抗磁性 / 超导磁悬浮

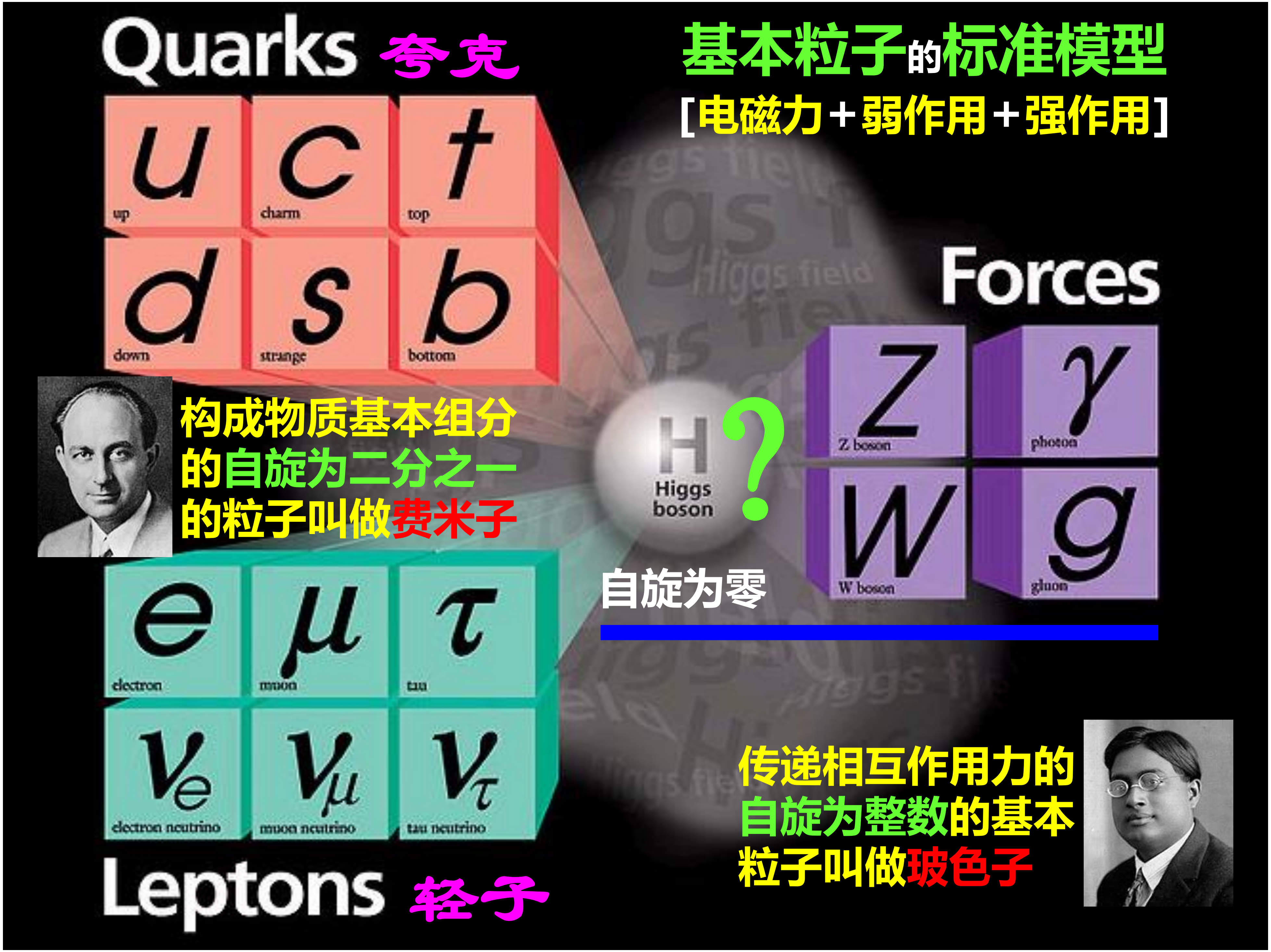
超导与Higgs粒子



Anderson-Higgs机制



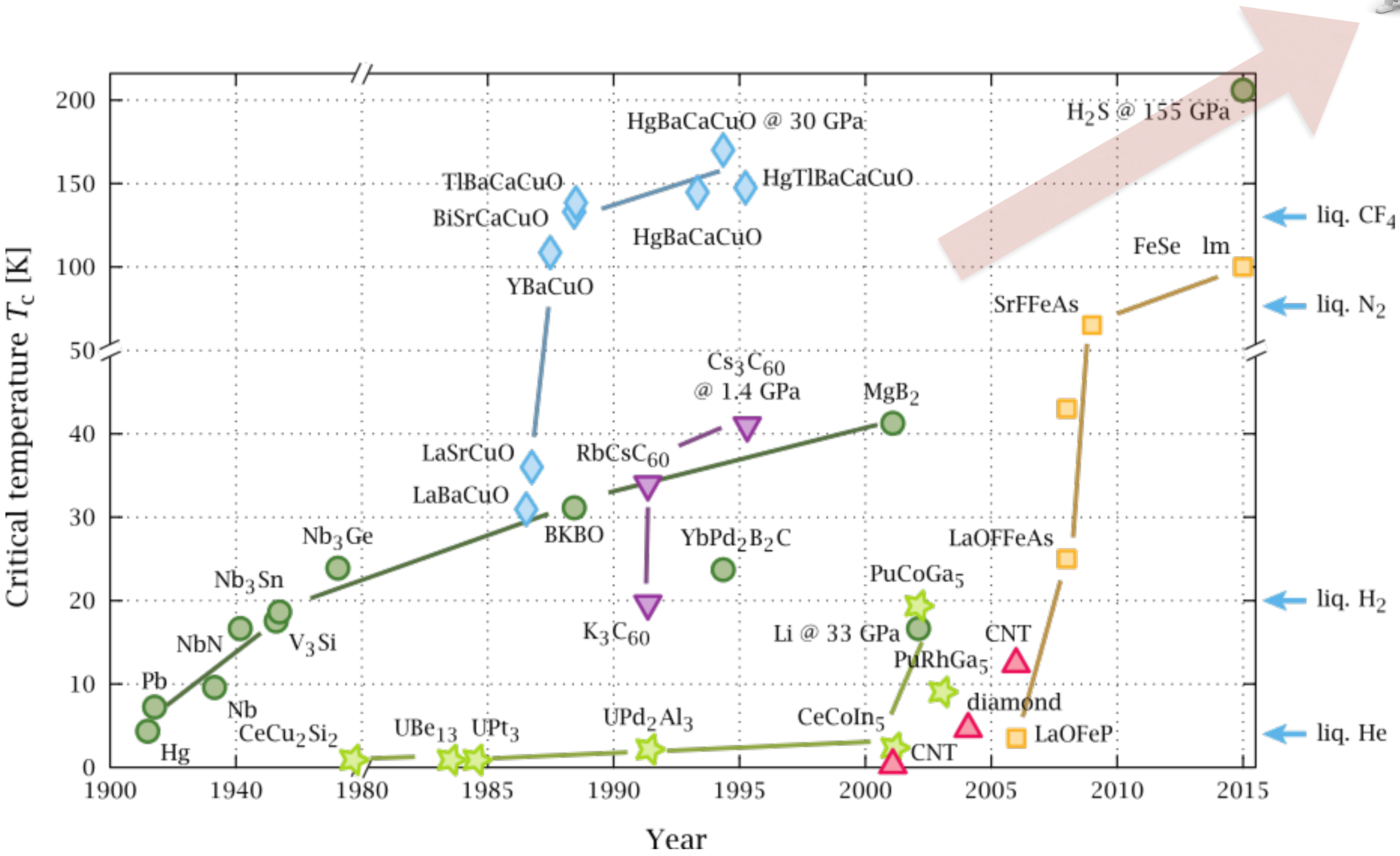
光子获得质量



基本粒子的标准模型
[电磁力＋弱作用＋强作用]
Quarks 夸克
u up
c charm
t top
d down
s strange
b bottom
构成物质基本组分的自旋为二分之一的粒子叫做费米子
e electron
μ muon
τ tau
νe electron neutrino
νμ muon neutrino
ντ tau neutrino
Leptons 轻子
H Higgs boson
?
自旋为零
Forces
Z Z boson
γ photon
W W boson
g gluon
传递相互作用力的自旋为整数的基本粒子叫做玻色子


大型强子对撞机
----能量前沿是发现新物理的平台
----发表一篇文章共有三千人署名
LHC
L et's H ave C offee!
Big Science
霍伊尔：希格斯粒子
964年，三组物理学家差不多同时发现了一个机制
Peter Higg
3
1
Gerald Guralni
古拉尼
Francois Englert
昂格勒
Tom Kibble
Carl Hagen
Robert Brout

非常规超导的机理问题与室温超导



超导相关

Nobel奖

获得者

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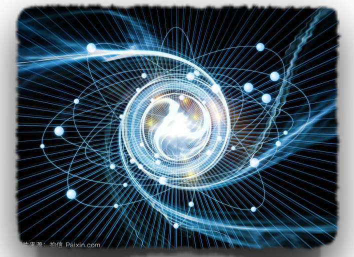
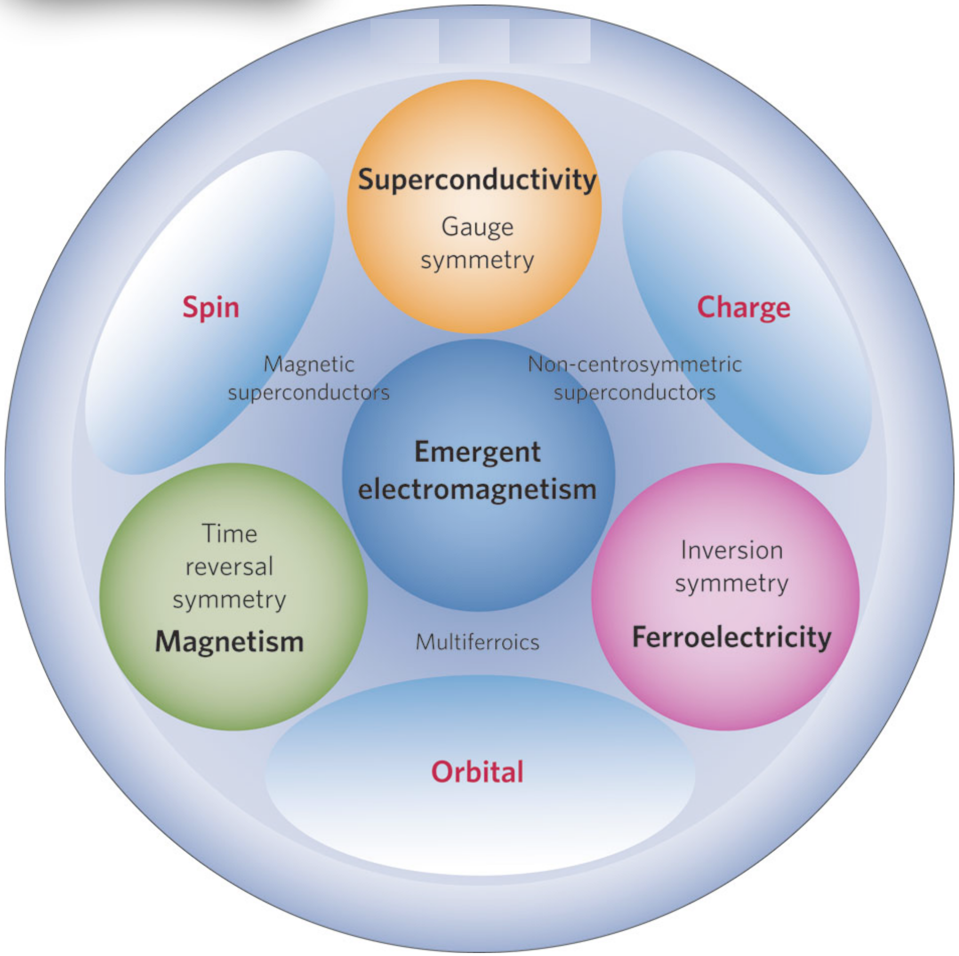
Nobel奖

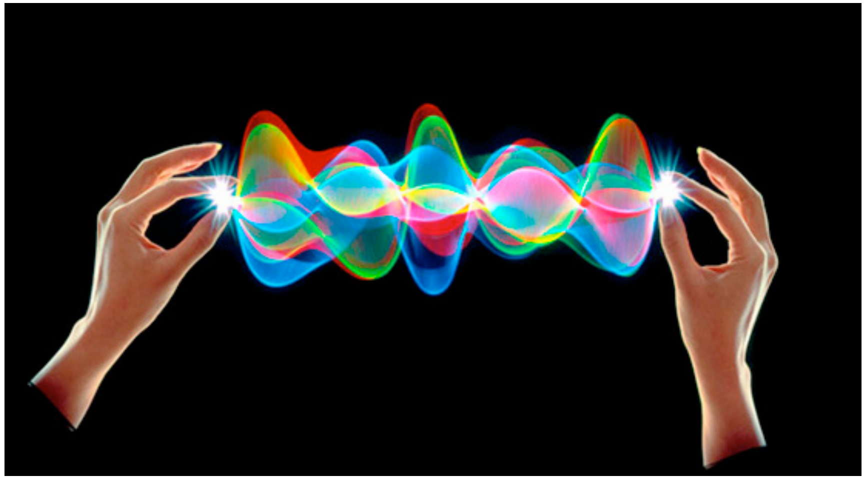
获得者



研究多电子体系的集体行为模式
是凝聚态物理的核心内容



通过电荷、自旋、轨道、晶格等自由度的纠缠，产生复杂集体行为



还有各种新奇量子激发，甚至类似光、引力、超对称等

最重要的

要不满足于**非费米液体**之类的模糊表述，寻找新的物理语言，建立描述这些复杂现象的概念体系和统一理论