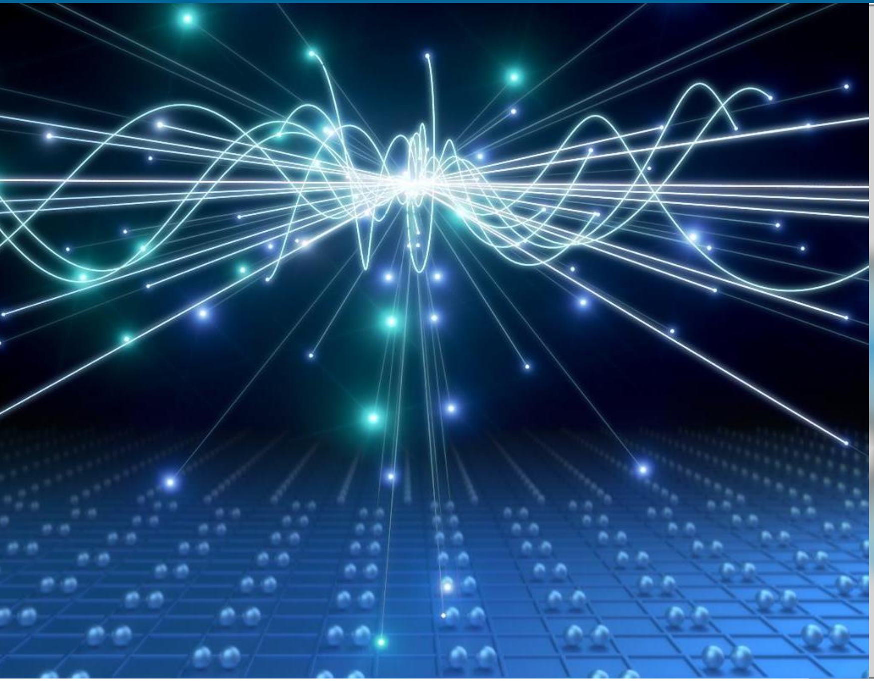
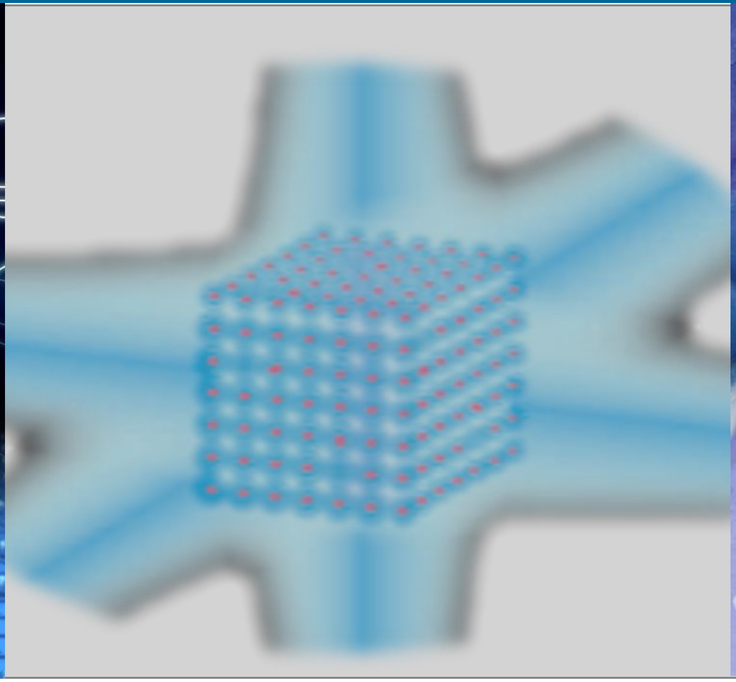



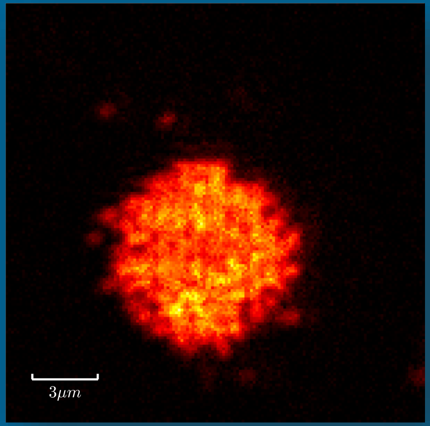

Ultracold Matter and Quantum Science

Zhen-Sheng Yuan，USTC

University of Science and Technology of China

Outline

Ultracold
Atoms

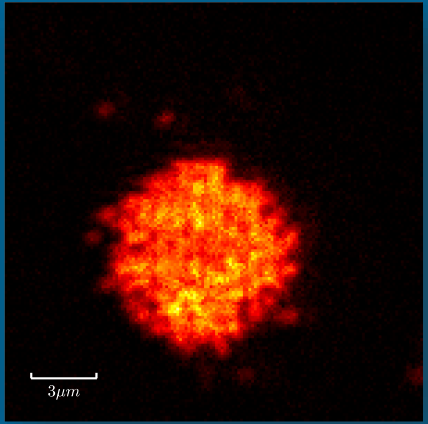


Application
in
Quantum
Science

Our
Team
and
Research

Outline

I. 超冷原子物理

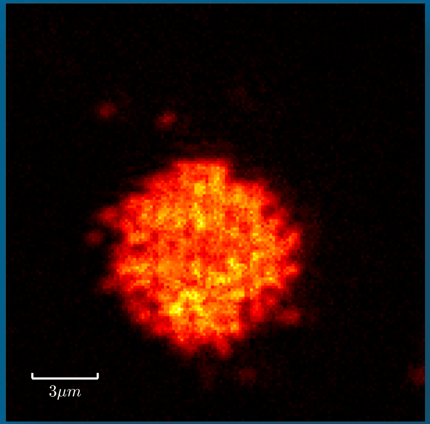


II. 强关联人工量子材料的显微学研究

III. 我们的团队简介

Outline

I. 超冷原子物理



II. 强关联人工量子材料的显微学研究

III. 我们的团队简介

Ballet: La Sylphide

广场舞萌娃

人的舞蹈：人的位置、肢体动作
原子行为：原子的外部模式、原子的内部内能级

舞蹈的编排
自然界的运行规律

报告内容

■ 为什么要精确地控制原子的行为?

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- 微观世界多体系统的行为
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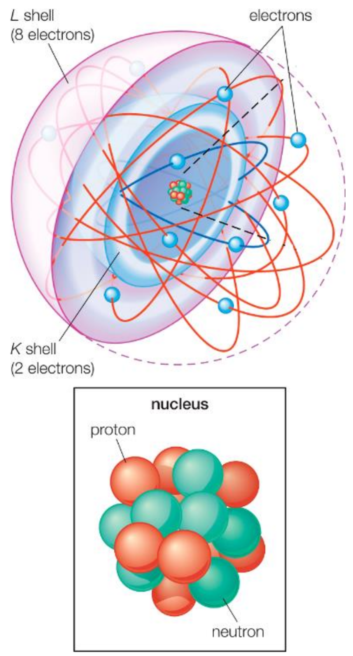
■ 如何实现对原子的高精度调控及测量?

- 激光冷却
- 光镊俘获原子
- 多原子的量子态操控



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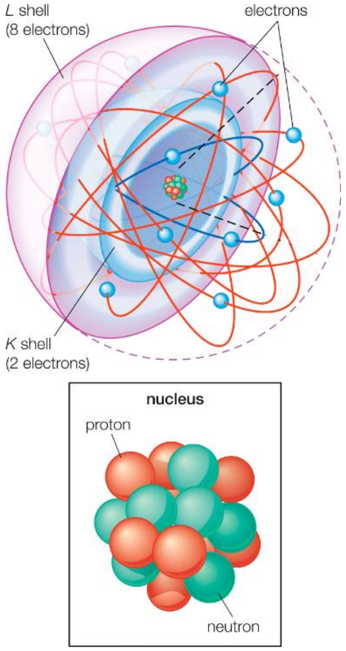

■ 如何实现对原子的高精度调控及测量？

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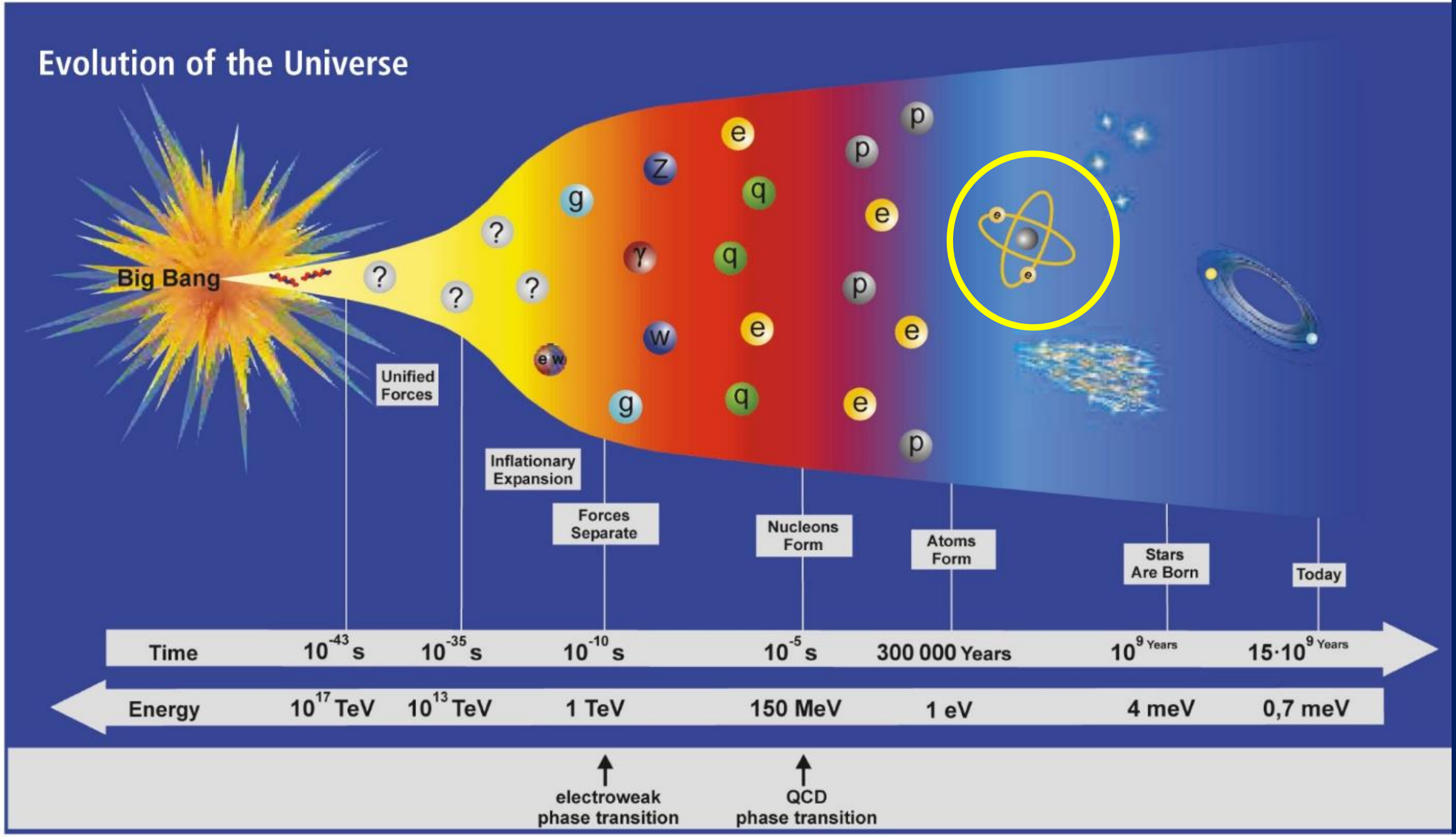
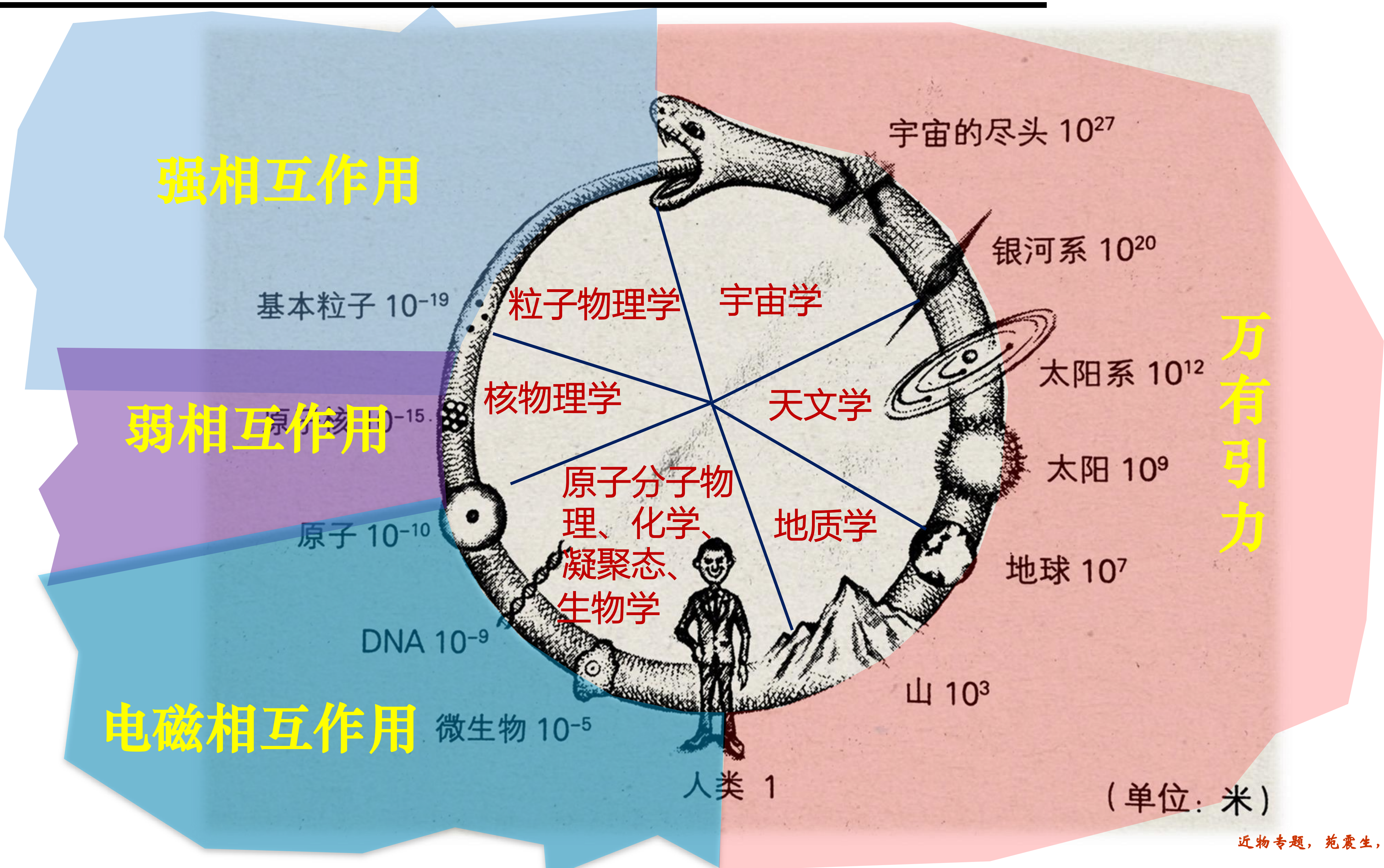
宇宙大爆炸（130多亿年）



- 大爆炸开始的阶段，量子涨落驱动着体系膨胀演化；
- 在暴涨期，各种基本粒子逐渐形成，它们之间的相互作用及转化成为此时的主旋律；
- 之后漫长的岁月中，原子、分子、物质、星云逐渐演化而来，冷却的宇宙中遗留了大爆炸的线索。

宇宙的尺度

标准模型

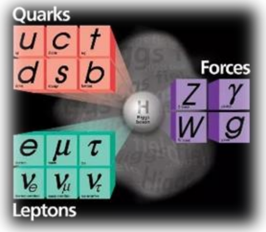


广义相对论

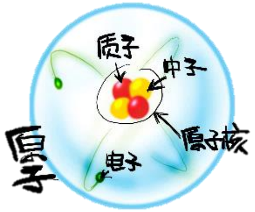
宇宙的尺度

基本粒子到星系宇宙的空间尺度

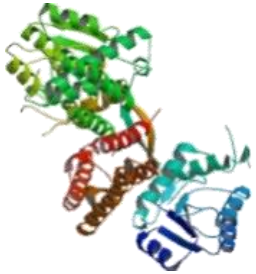
10^{-21}　10^{-14}　10^{-7}　10^{0}　10^{7}　10^{14}　10^{21}　10^{28}



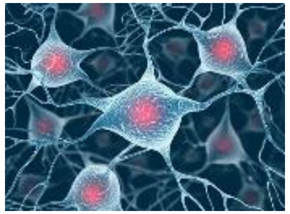
基本粒子



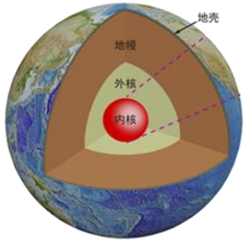
原子分子



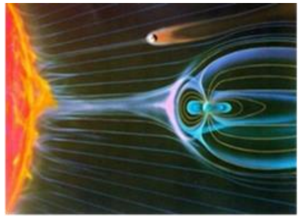
蛋白质



细胞



地球



近地空间

星系宇宙

强相互作用(QCD)
弱相互作用(电弱统一理论)

电磁相互作用
量子力学、
狭义相对论

经典力学
麦克斯韦方程、
经典热力学统计力学

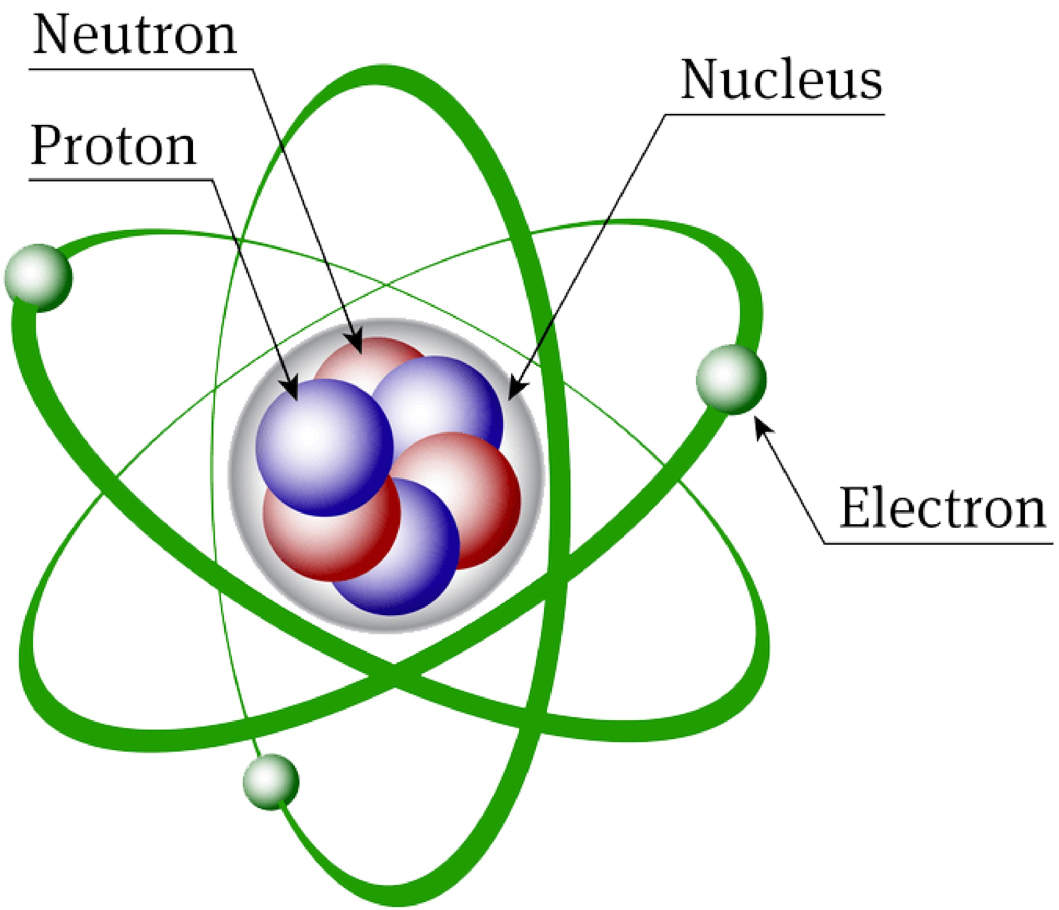
宇宙大爆炸、
标准模型

----强----弱-----电磁---------------------------万有引力-----------

规范场基础上的---标准模型　　　　广义相对论

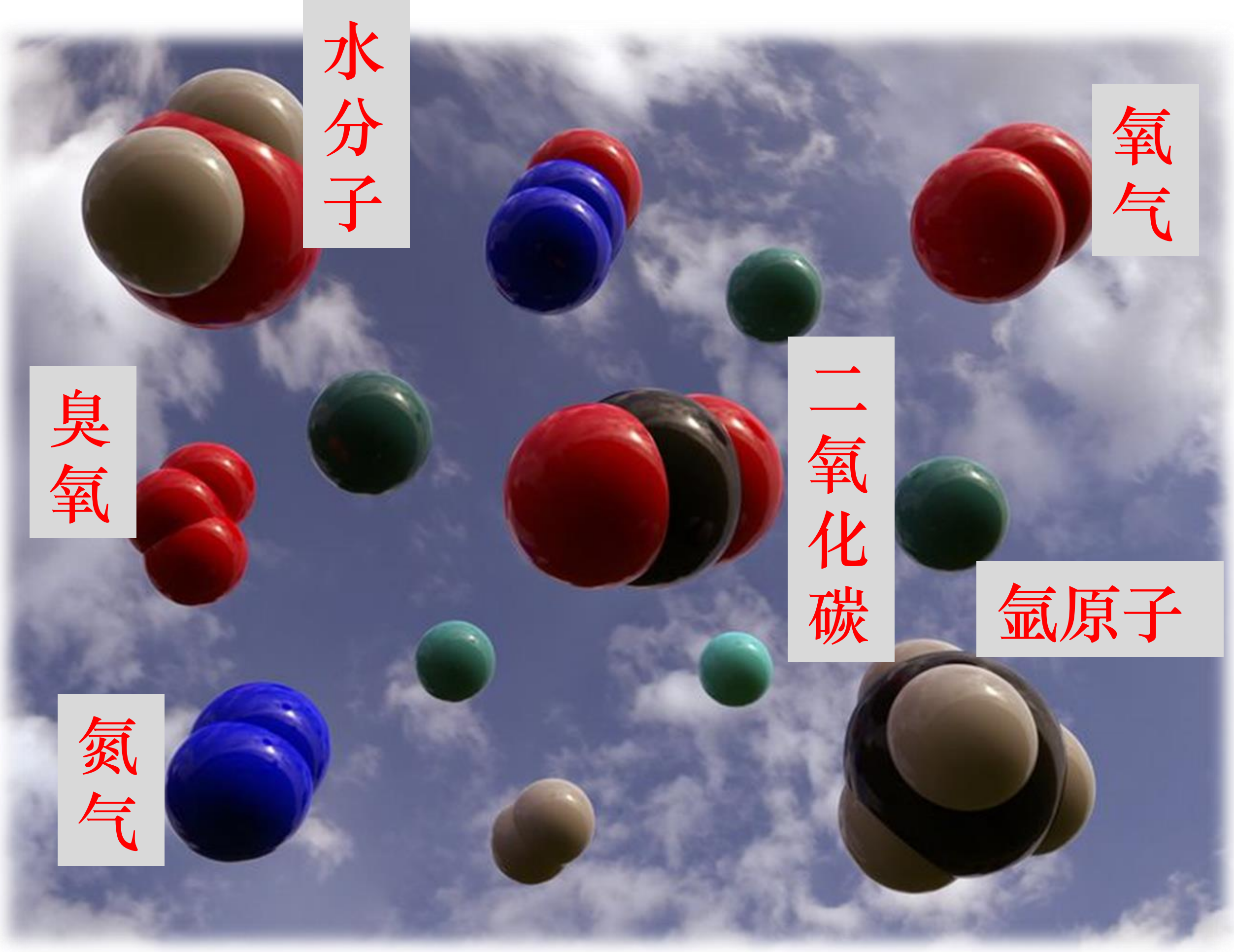
统一的理论是什么？弦论、圈量子引力

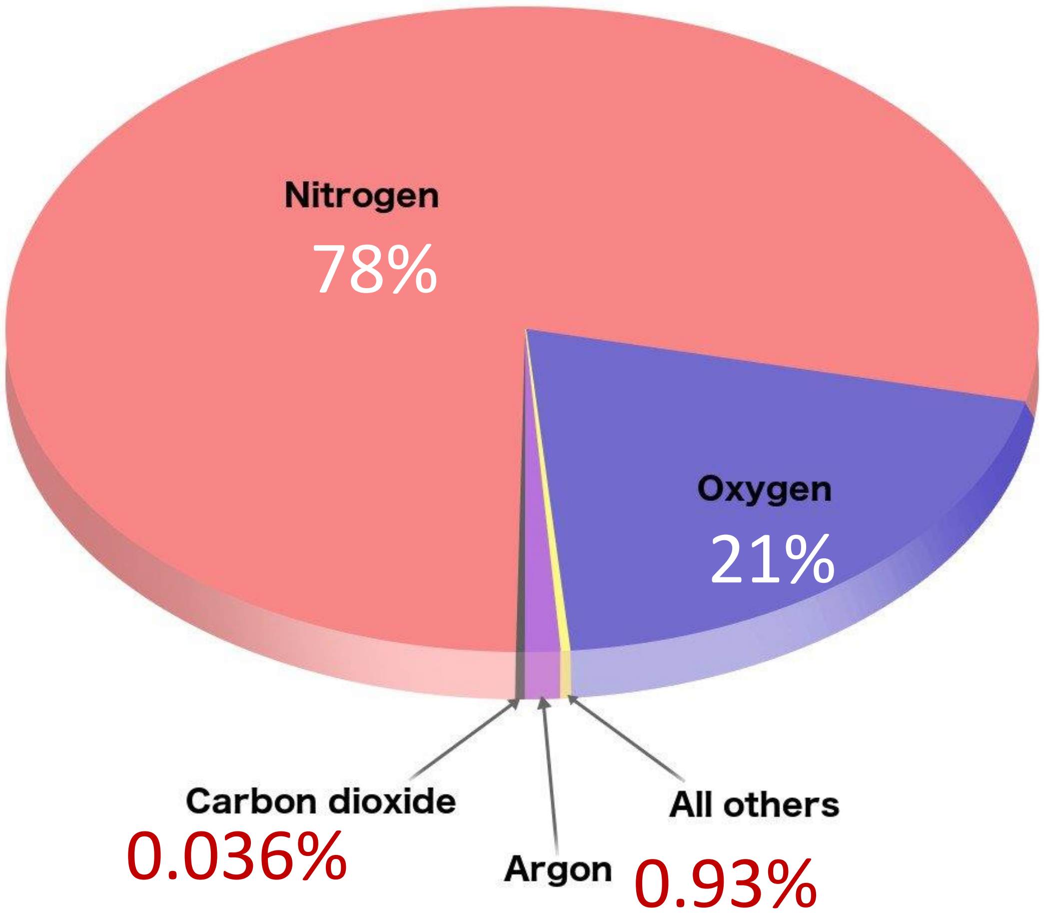
原子的基本结构



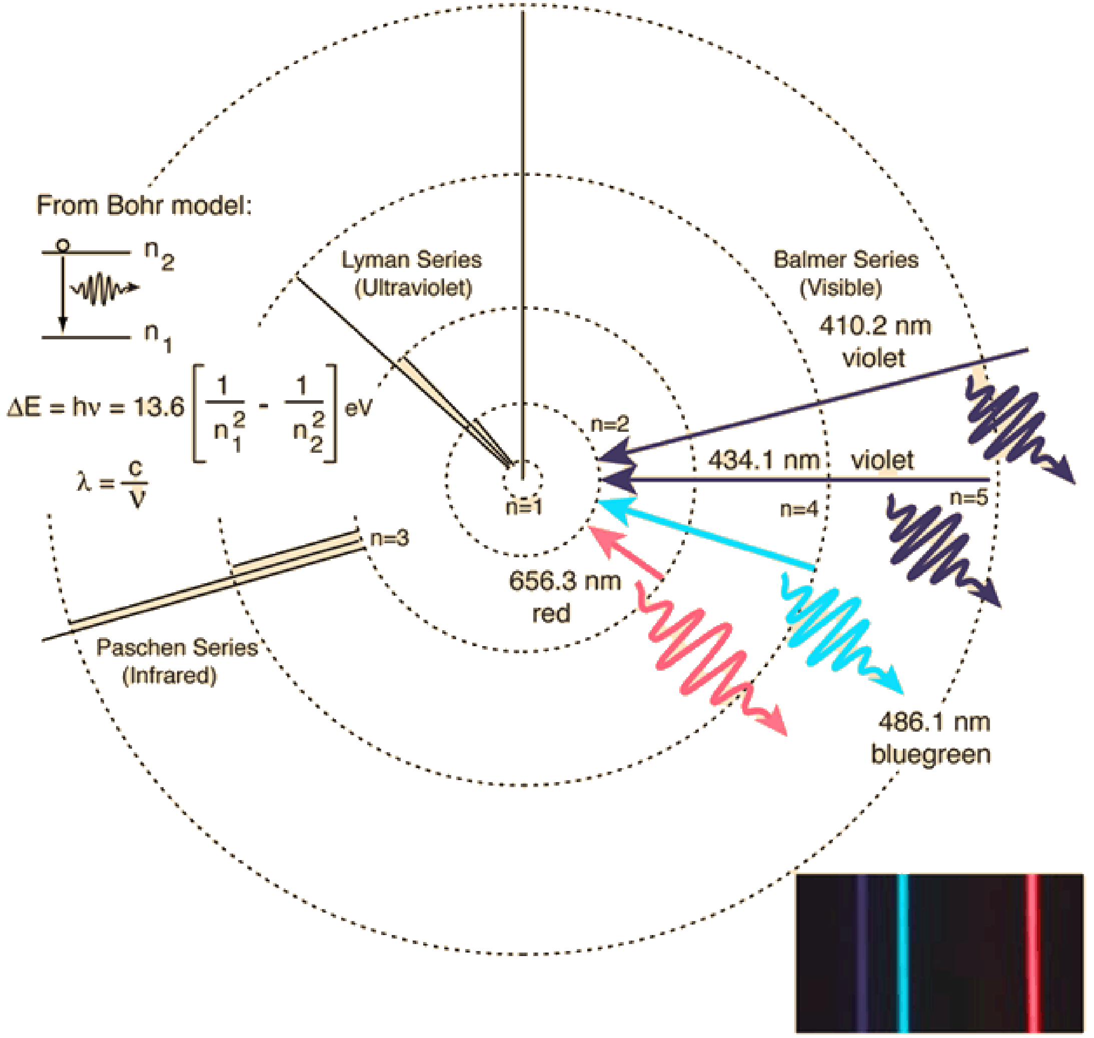
- 中子、质子、电子的自旋都是1/2，半整数，叫做费米子；光子的自旋是1，整数，叫做玻色子；
- 奇数个中子、质子、电子放在一起形成的原子的总自旋仍是半整数，还是费米子
- 偶数个中子、质子、电子放在一起形成的原子的总自旋是整数，是玻色子

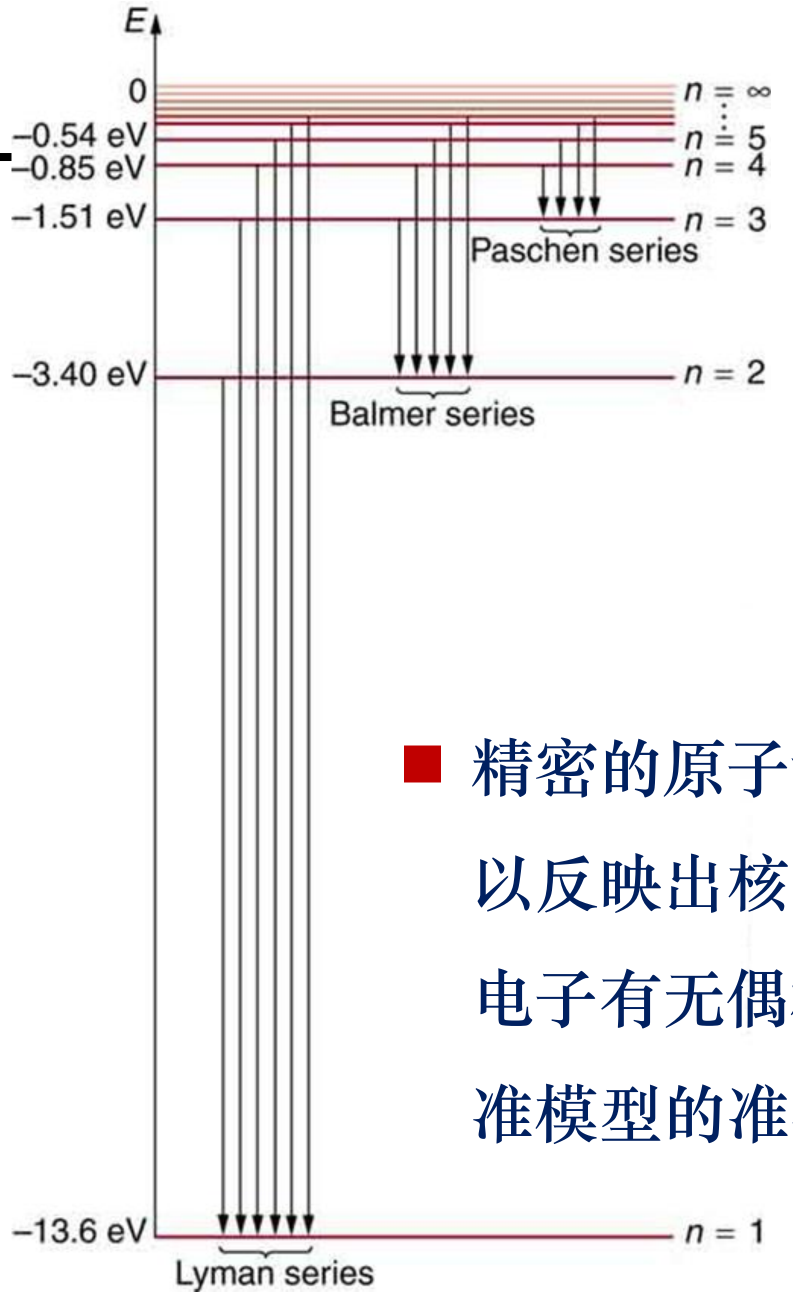
大气的中的原子和分子


水分子
氧气
臭氧
二氧化碳
氩原子
氮气


Nitrogen
78%
Oxygen
21%
Carbon dioxide
0.036%
Argon
All others
0.93%

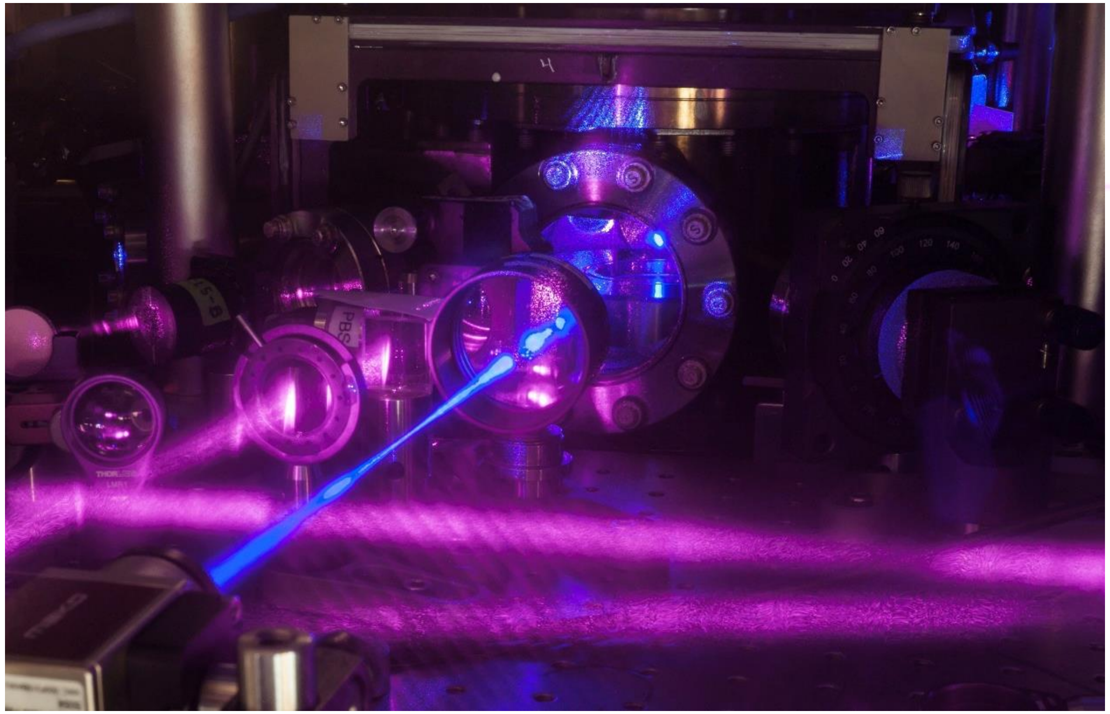
原子的基本结构



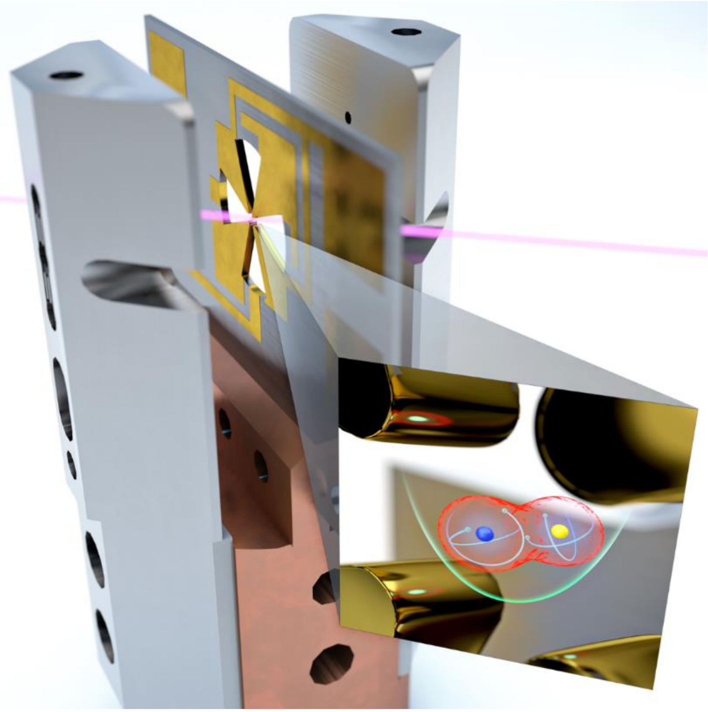


- 精密的原子谱线测量可以反映出核结构信息、电子有无偶极矩关系标准模型的准确与否

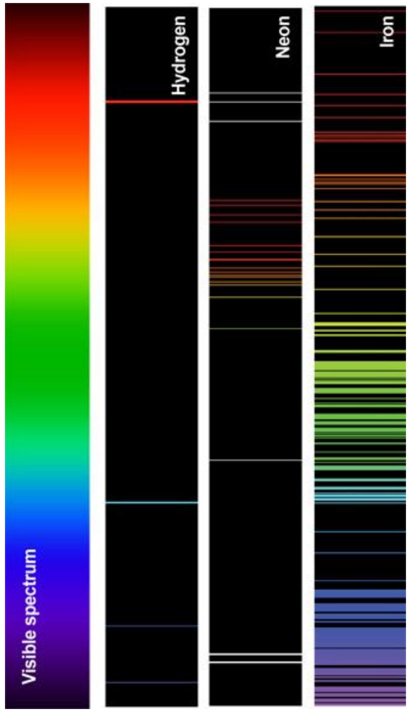
光谱测量--百亿年不差1秒的原子光钟



JILA的原子光钟

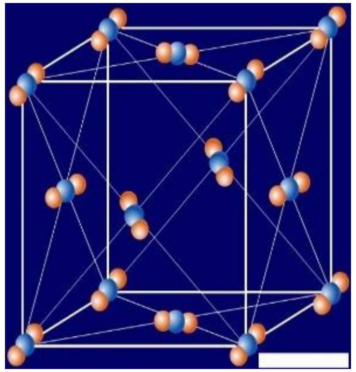


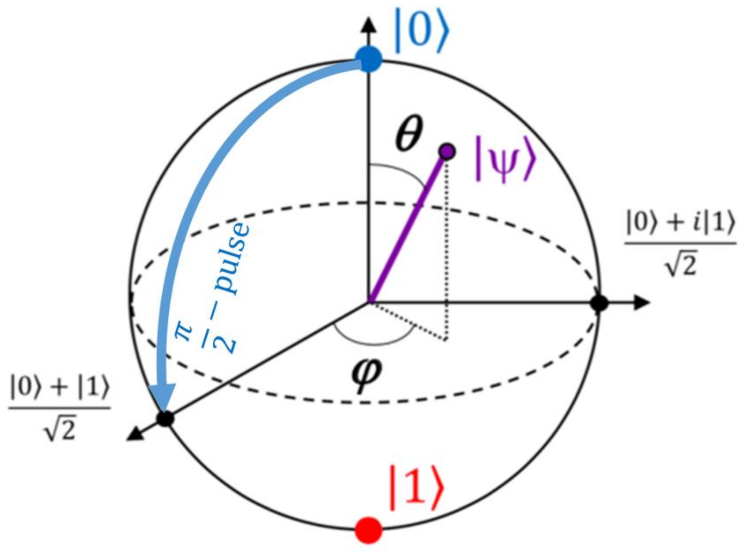
NIST的铝离子光钟



准确的测量光谱

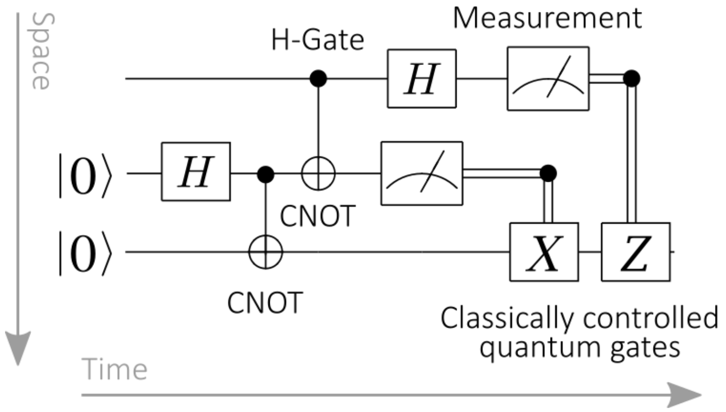
两能级原子编码量子比特





$$|\psi\rangle = \cos\frac{\theta}{2}|0\rangle + e^{i\varphi}\sin\frac{\theta}{2}|1\rangle$$

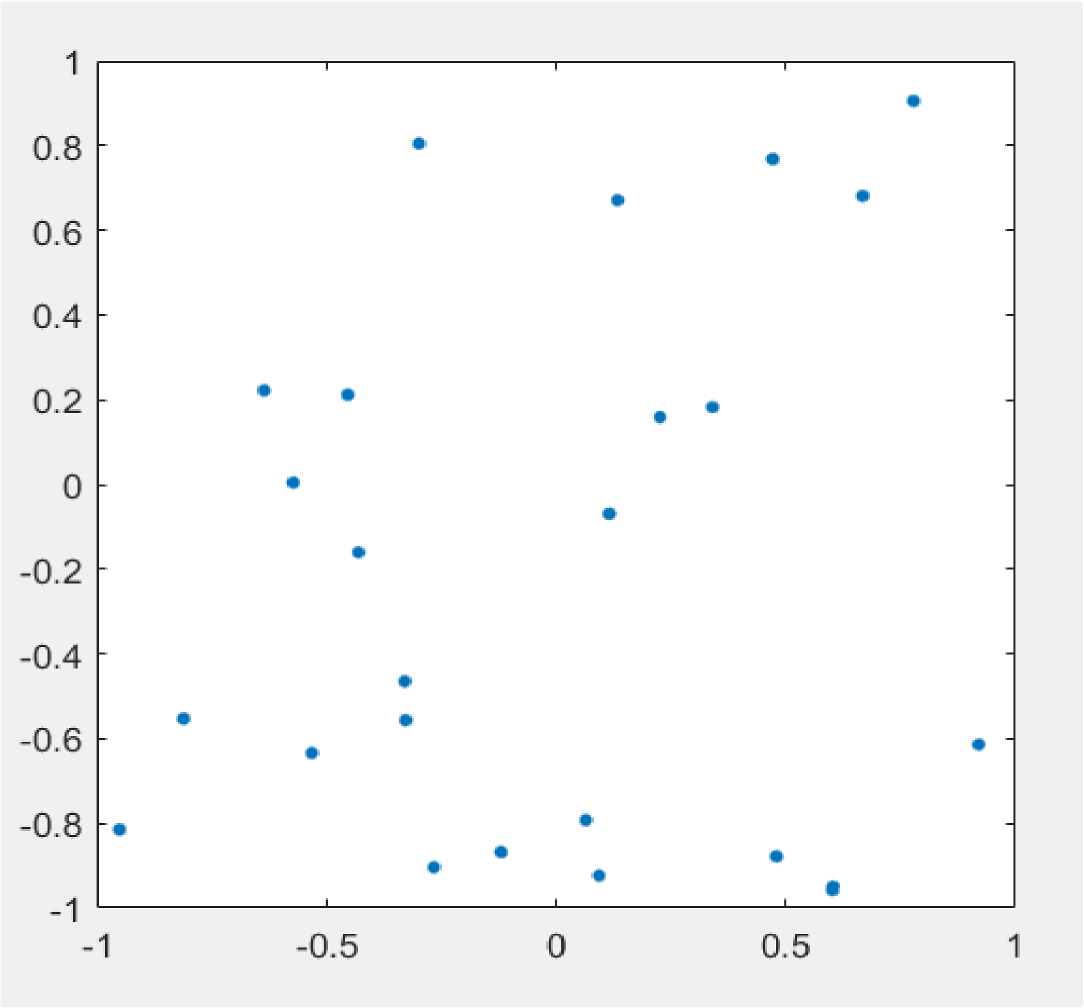
- 使用多个原子比特模拟解决凝聚体中的复杂问题：如高温超导



- 使用原子中的两个能级编码量子比特
- 构建量子电路、开展量子计算

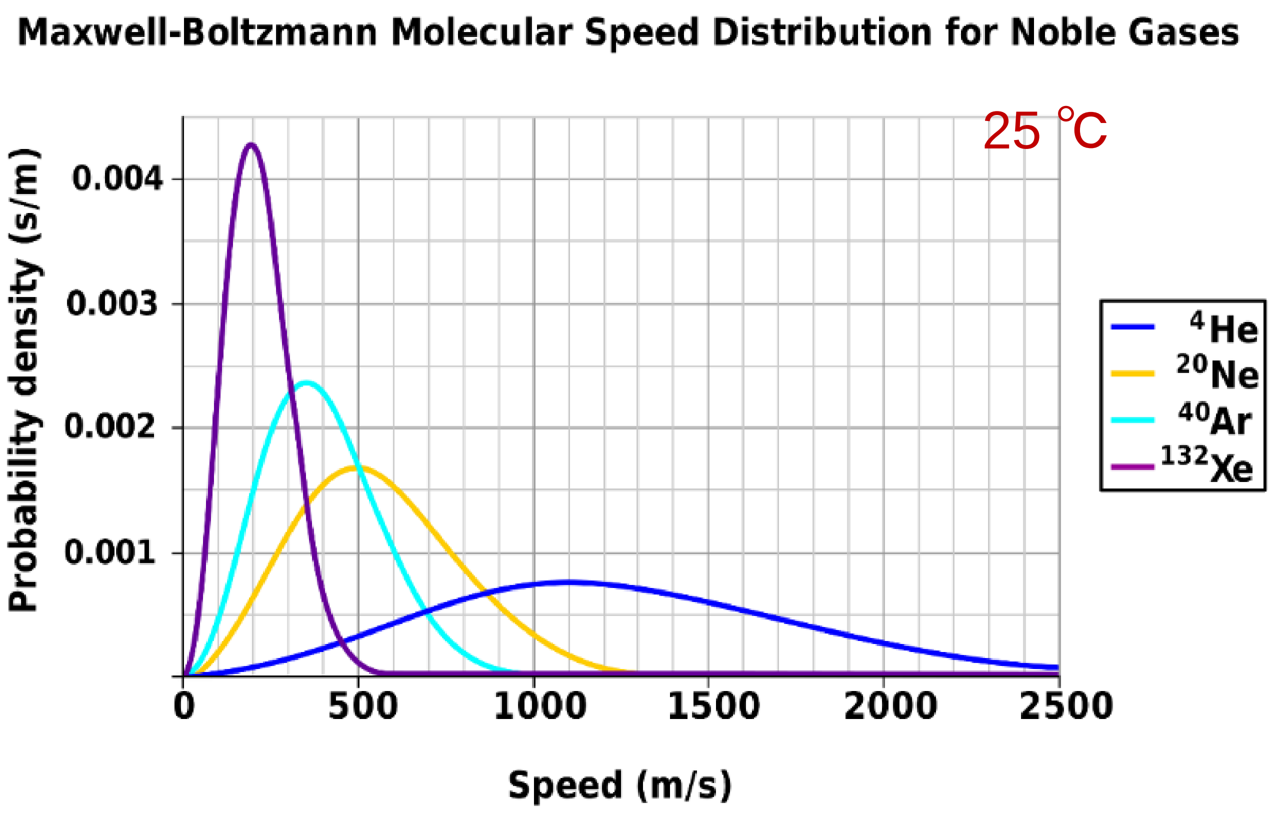
常温下原子不能精确测控

常温下原子/分子的运动?



无规则热运动，乱冲乱撞的野马

麦克斯韦-玻尔兹曼统计

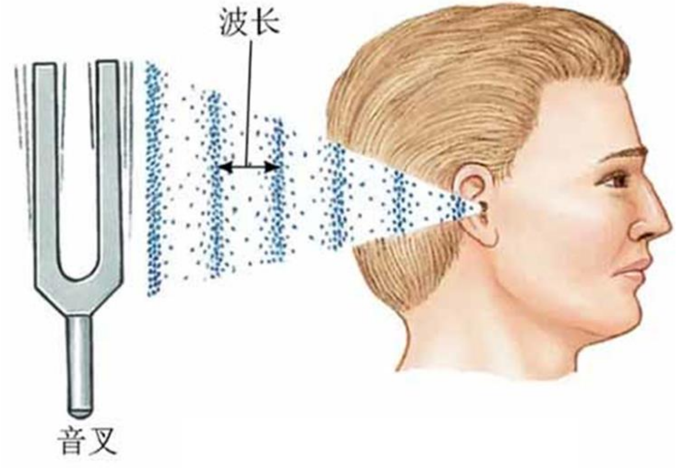


$$\overline{n_i}(\varepsilon_i) = \frac{g_i}{e^{(\varepsilon_i - \mu)/k_B T}}$$

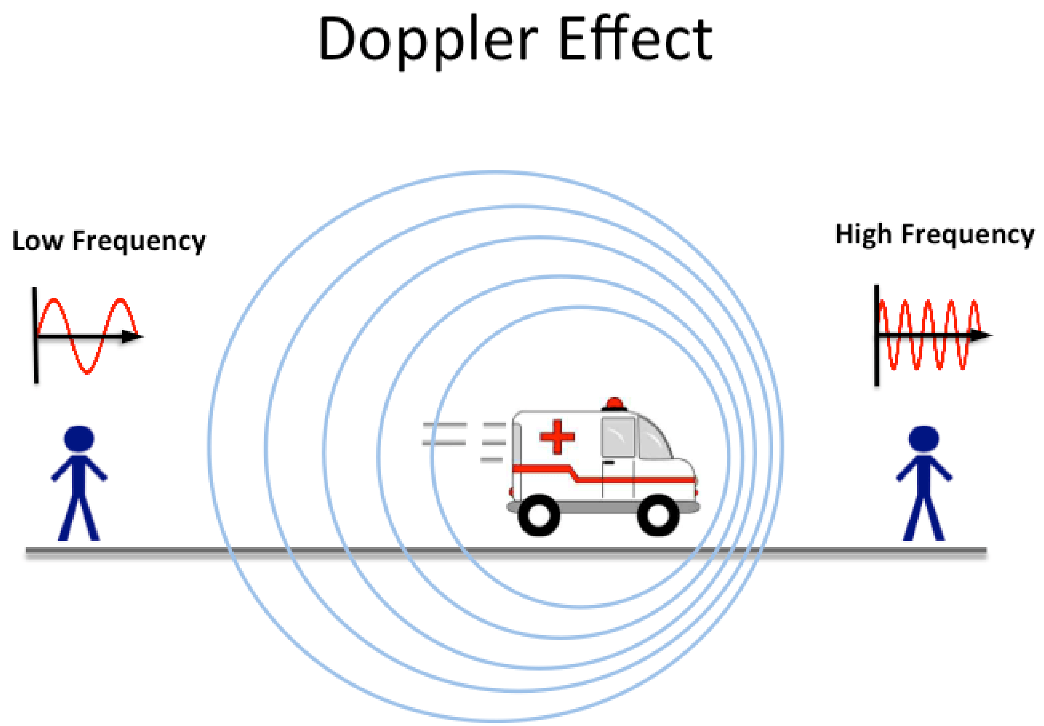
■ 理想气体状态方程

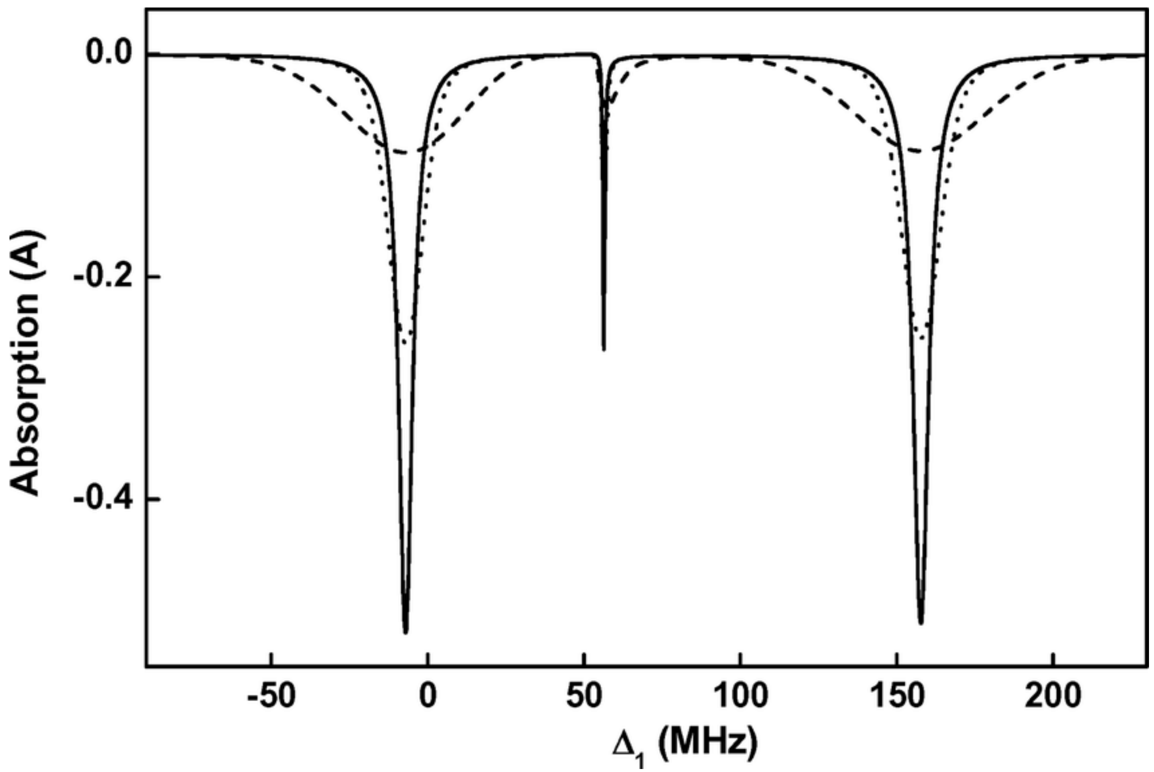
$$pV = nRT$$

■ 声音

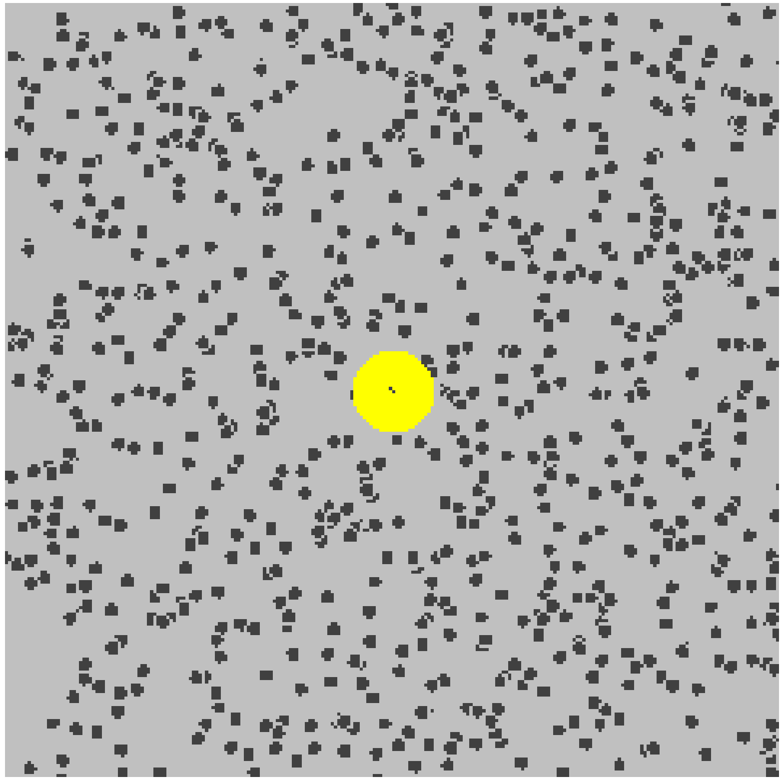


分子运动带来谱线展宽

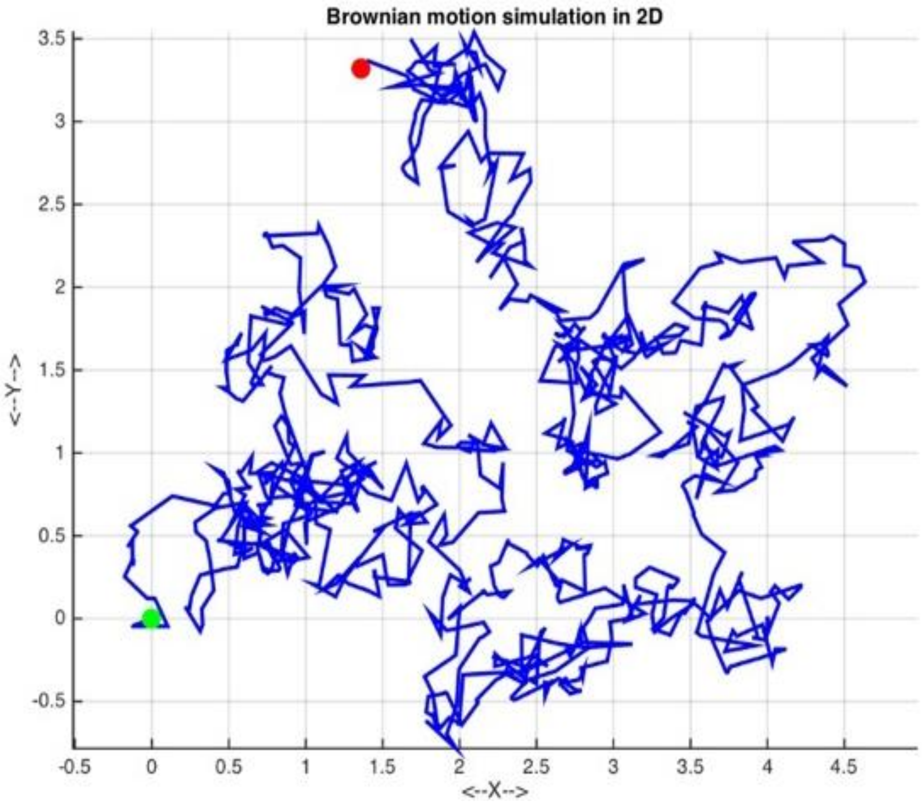

Doppler Effect
Low Frequency
High Frequency


0.0
-0.2
-0.4
Absorption (A)
-50
0
50
100
150
200
Δ1 (MHz)

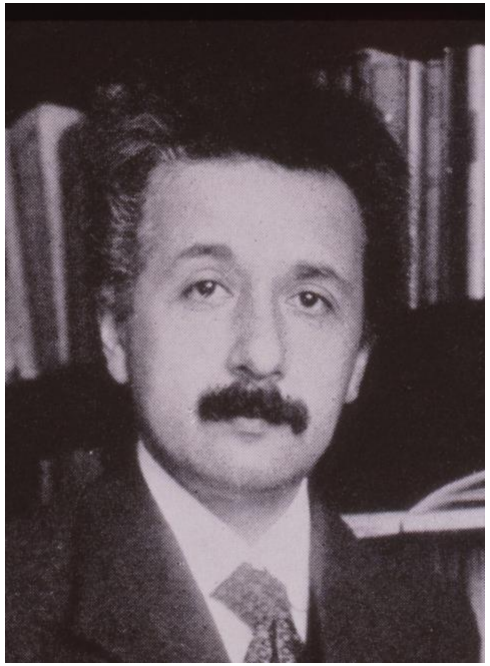
布朗运动与分子大小



微米级别的颗粒在空气或液体中的运动行为



二维空间的布朗运动



爱因斯坦的博士论文：《一种确定分子尺寸的方法》

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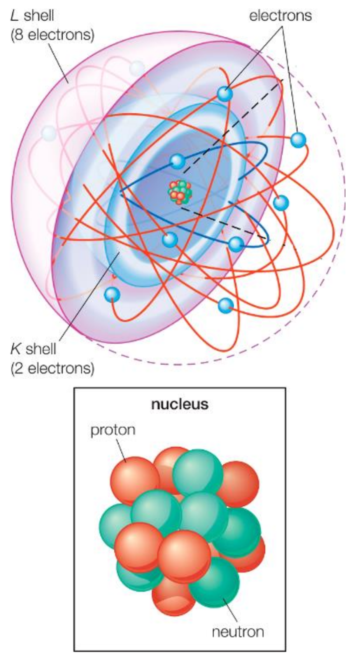
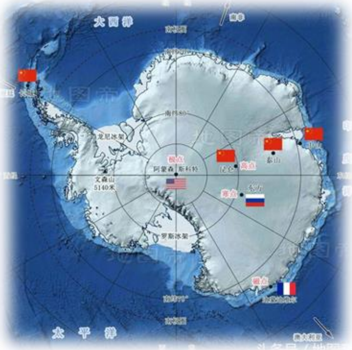
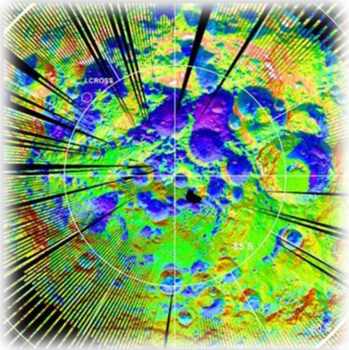


低温世界


冰水混合


南极洲，1983


月球

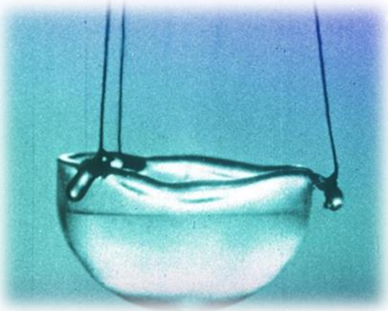

月南极陨石坑

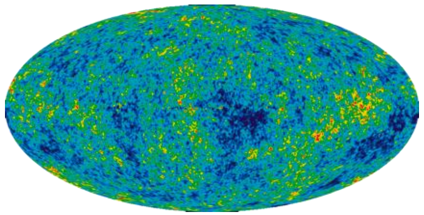
0 ℃, 273 K

-89 ℃, 215 K

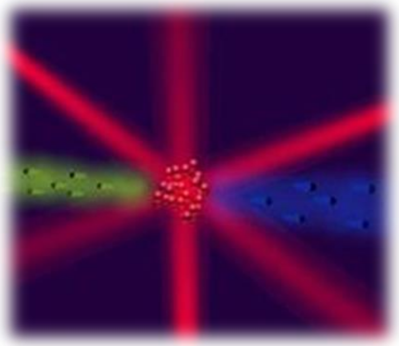
-183~127 ℃, 90 K

-247℃, 26 K


液氦He4, 1 atm


宇宙微波背景


He稀释制冷


激光超冷原子技术

4.2 K, Onnes, 超导

2.7 K

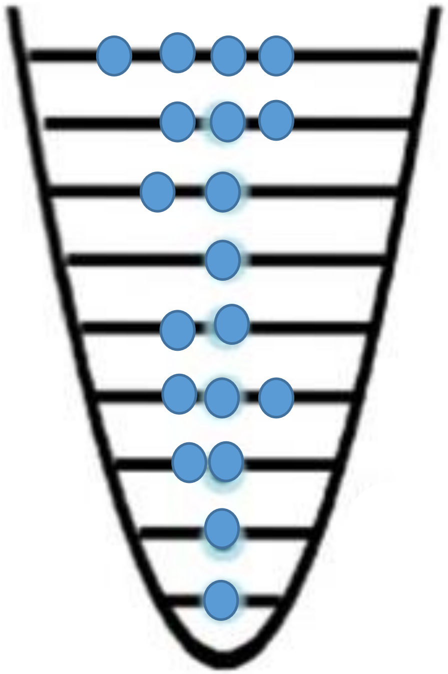
0.3~0.01 K

mK~ pK

超冷原子--统计规律发生变化

- 麦克斯韦-玻尔兹曼统计

$$\bar{n}_i(\varepsilon_i) = \frac{g_i}{e^{(\varepsilon_i - \mu)/k_B T}}$$

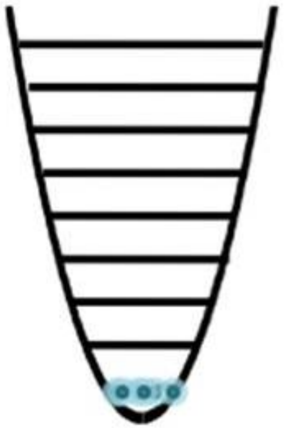


温度T逐渐降低时--原子住在很多层的房间

- 量子统计

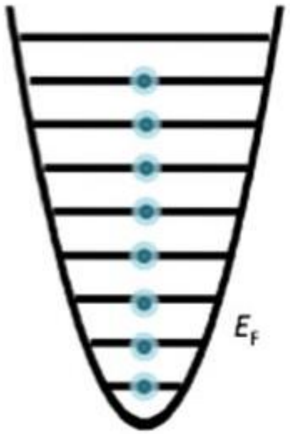
玻色-爱因斯坦统计

$$\bar{n}_i(\varepsilon_i) = \frac{g_i}{e^{(\varepsilon_i - \mu)/k_B T} - 1}$$

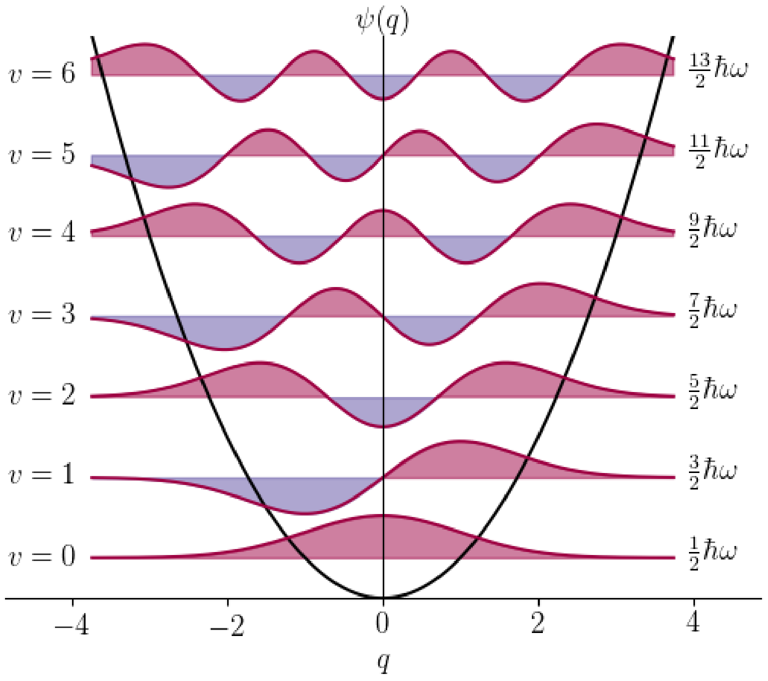


费米-狄拉克统计

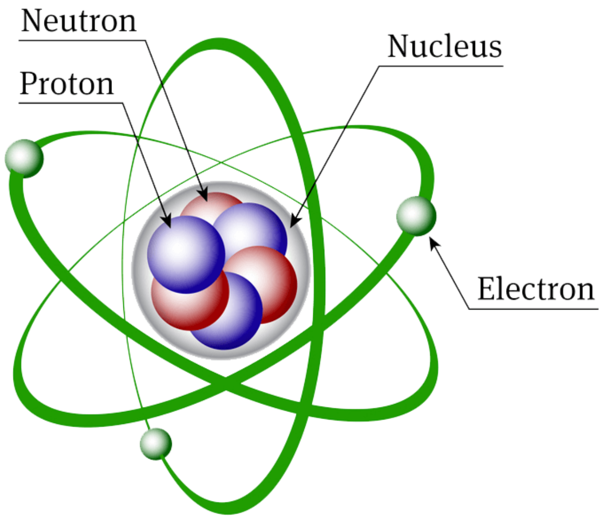
$$\bar{n}_i(\varepsilon_i) = \frac{g_i}{e^{(\varepsilon_i - \mu)/k_B T} + 1}$$

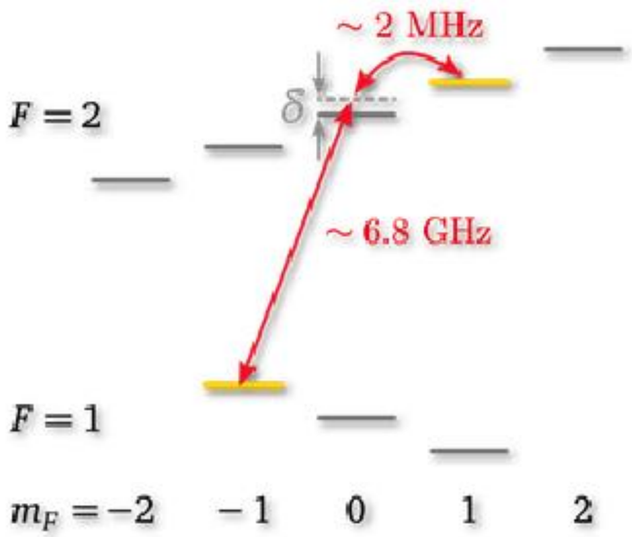


原子的内部和外部能级



原子的外部能级





原子的内部能级

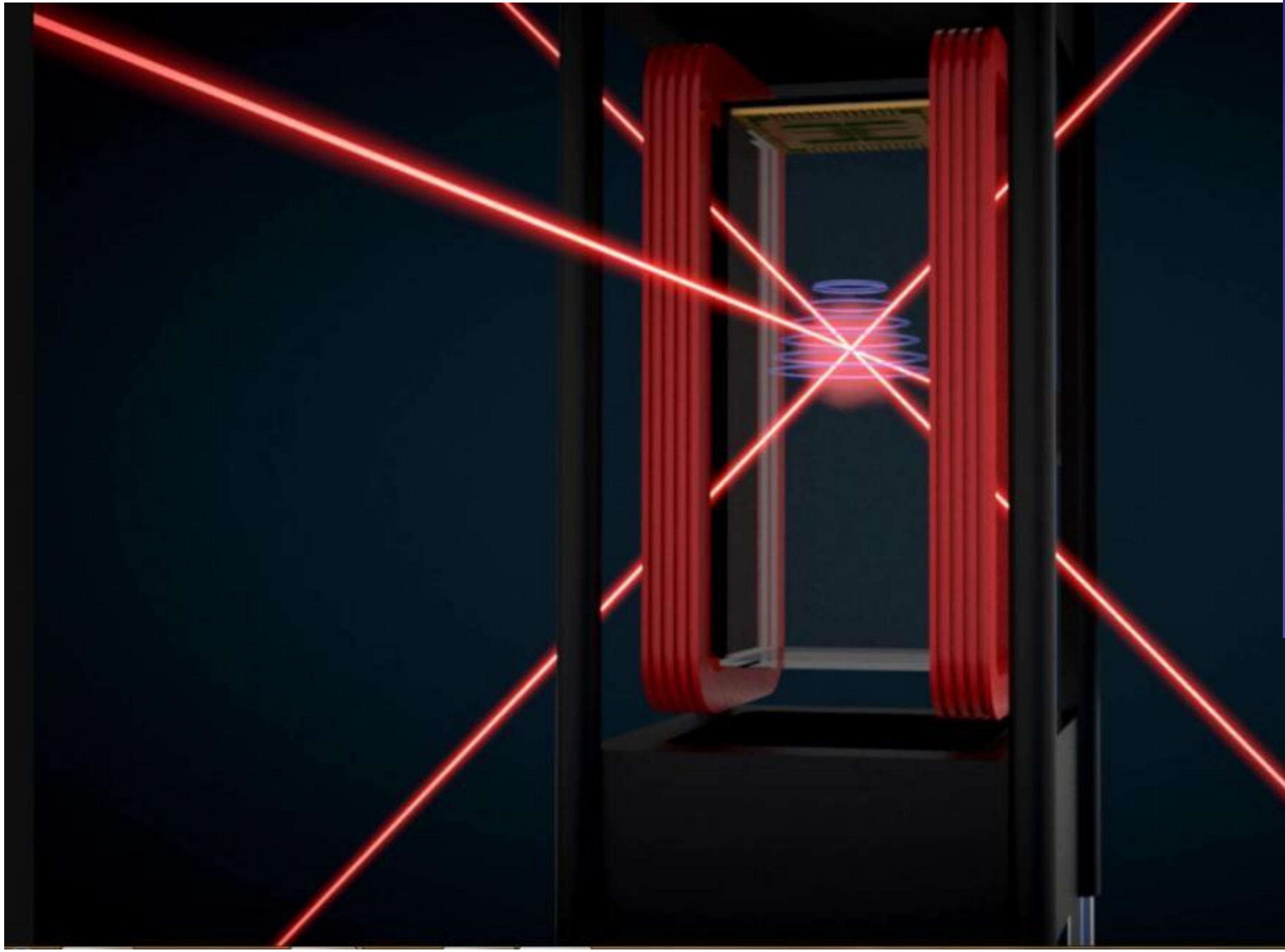
精确操控原子的内、外能级—开展物理学前沿探索

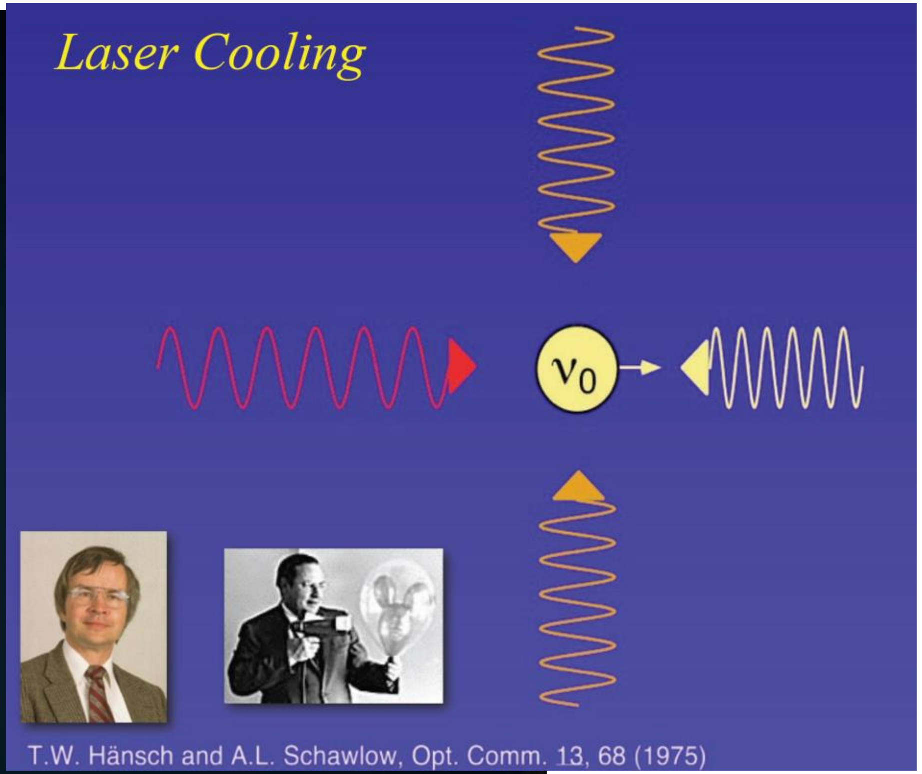
御光之力

Johannes Kepler (1571-1630)

Let us create vessels and sails adjusted to the heavenly ether, and there will be plenty of people unafraid of the empty wastes.

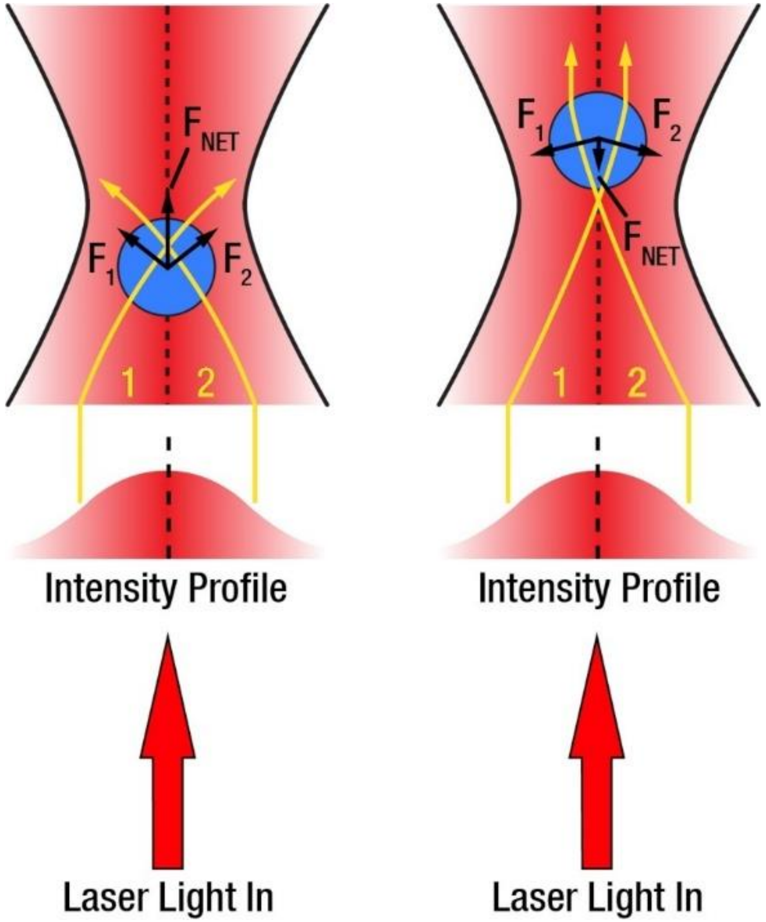
激光冷却

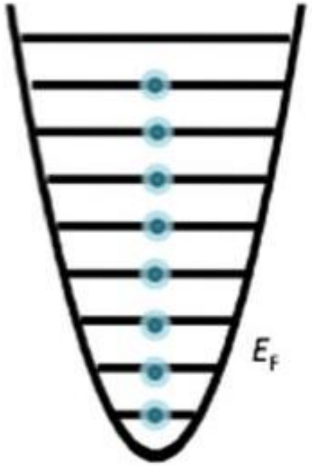


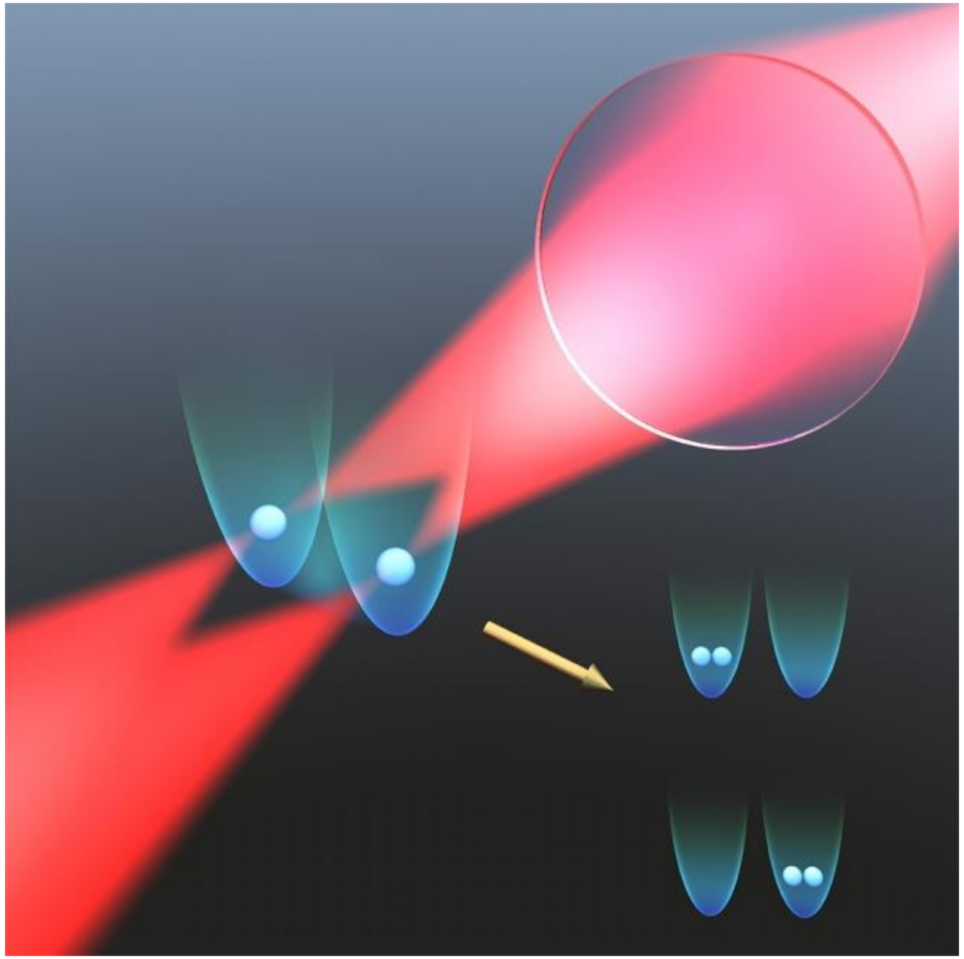

Laser Cooling
ν_0
T.W. Hänsch and A.L. Schawlow, Opt. Comm. 13, 68 (1975)

10000 g

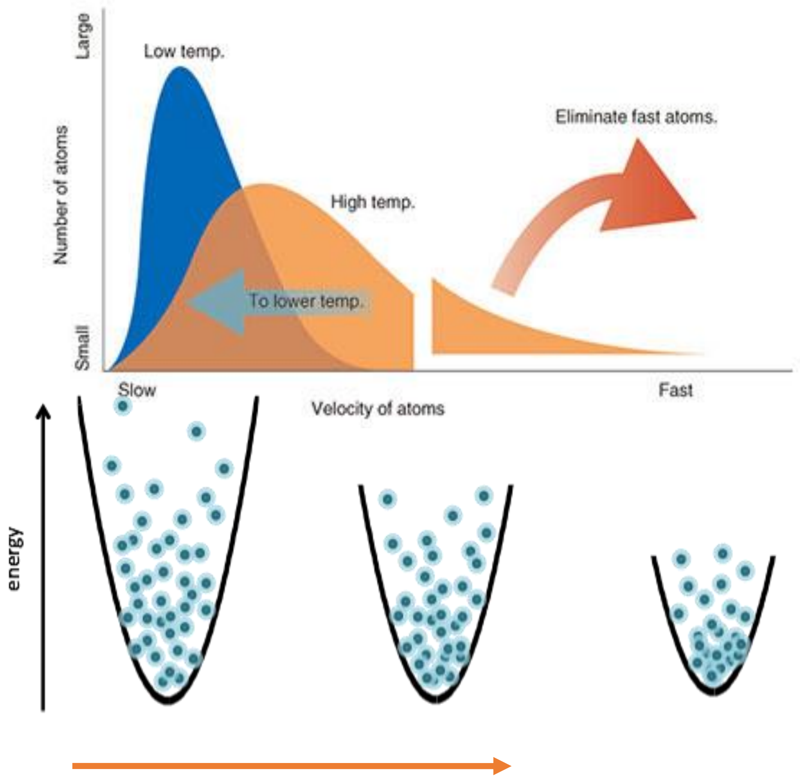
光镊抓住原子


F
NET
F
1
F
2
1
2
Intensity Profile
Laser Light In
F
1
F
2
F
NET
1
2
Intensity Profile
Laser Light In

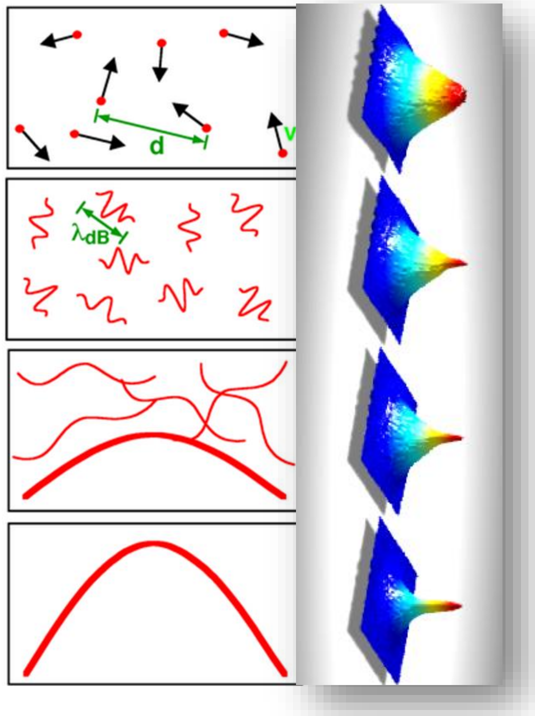

E_F



超冷量子气体的获得



更冷、更稠密



极低的温度 nK

The Nobel Prize in Physics 2001

Photo from the Nobel Foundation archive.

Eric A. Cornell

Prize share: 1/3

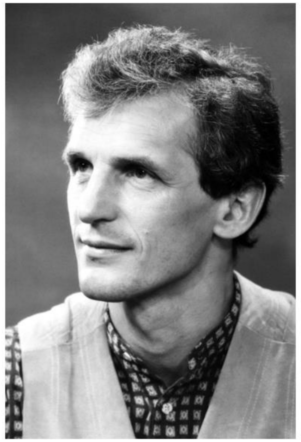


Photo from the Nobel Foundation archive.

Wolfgang Ketterle

Prize share: 1/3

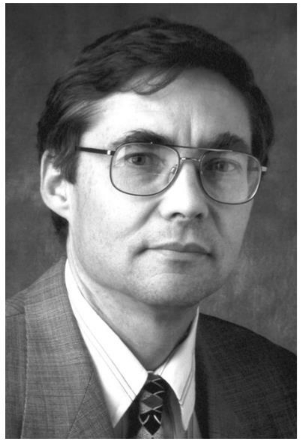


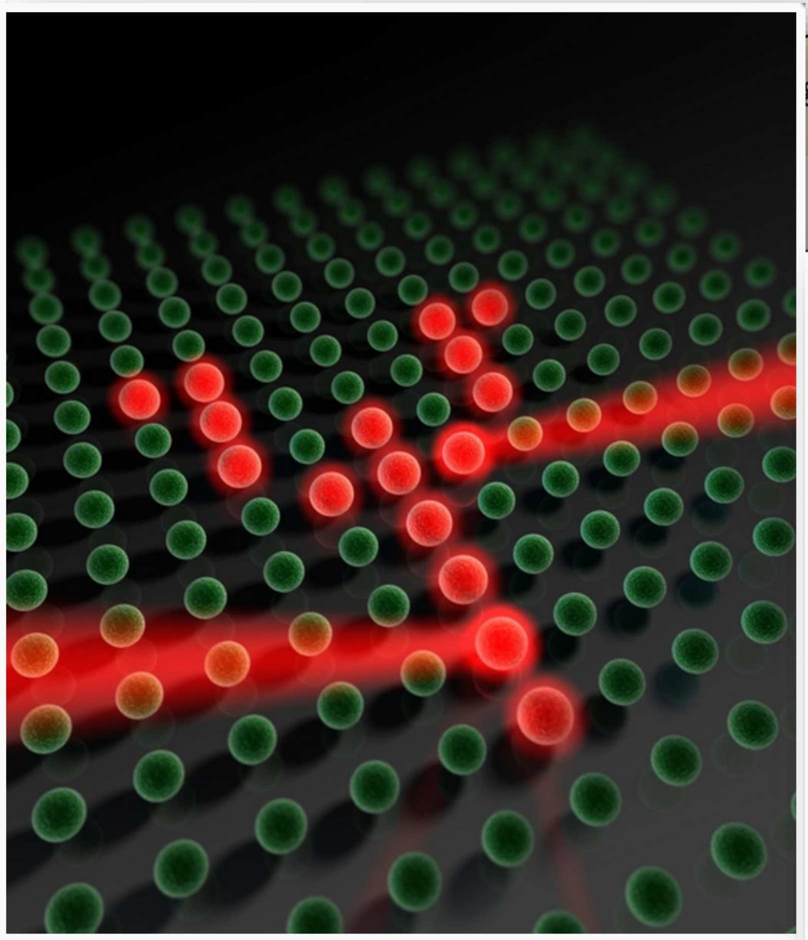
Photo from the Nobel Foundation archive.

Carl E. Wieman

Prize share: 1/3

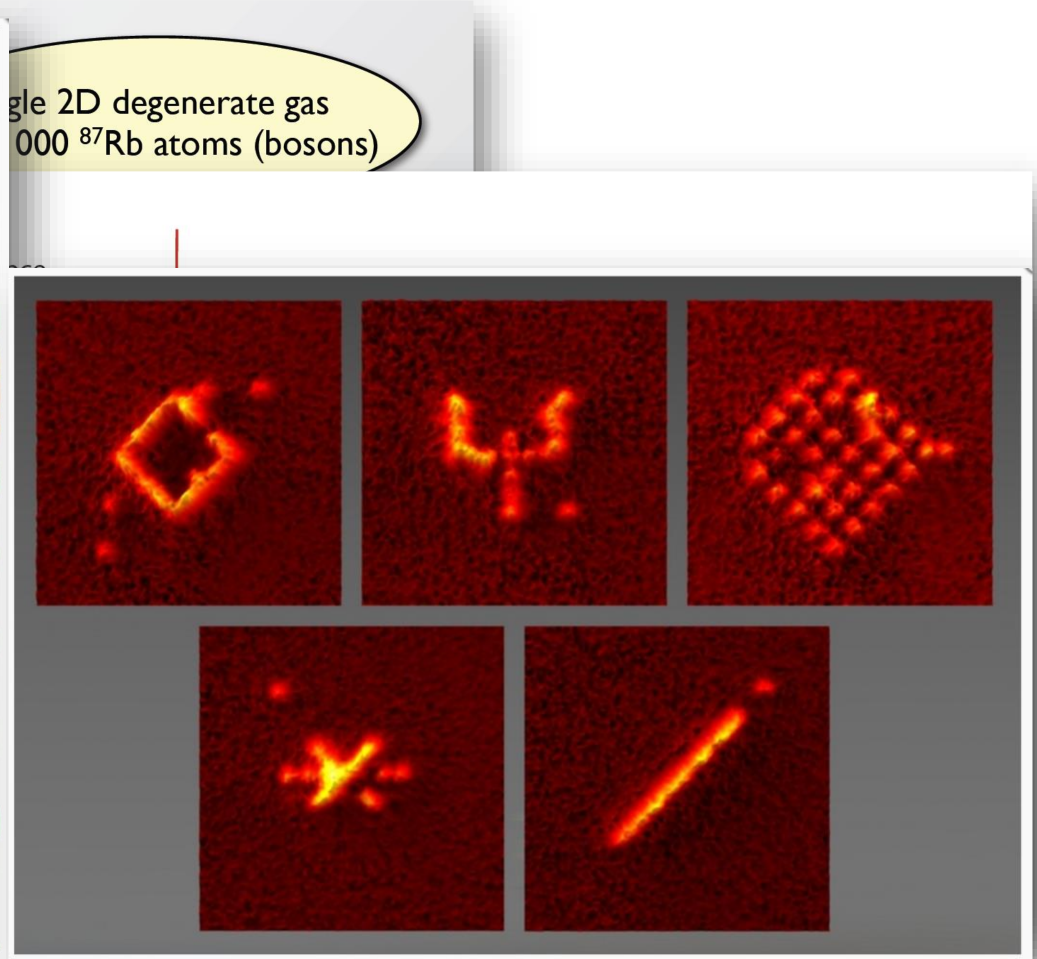
The Nobel Prize in Physics 2001 was awarded jointly to Eric A. Cornell, Wolfgang Ketterle and Carl E. Wieman "for the achievement of Bose-Einstein condensation in dilute gases of alkali atoms, and for early fundamental studies of the properties of the condensates."

国际上的量子气体显微镜



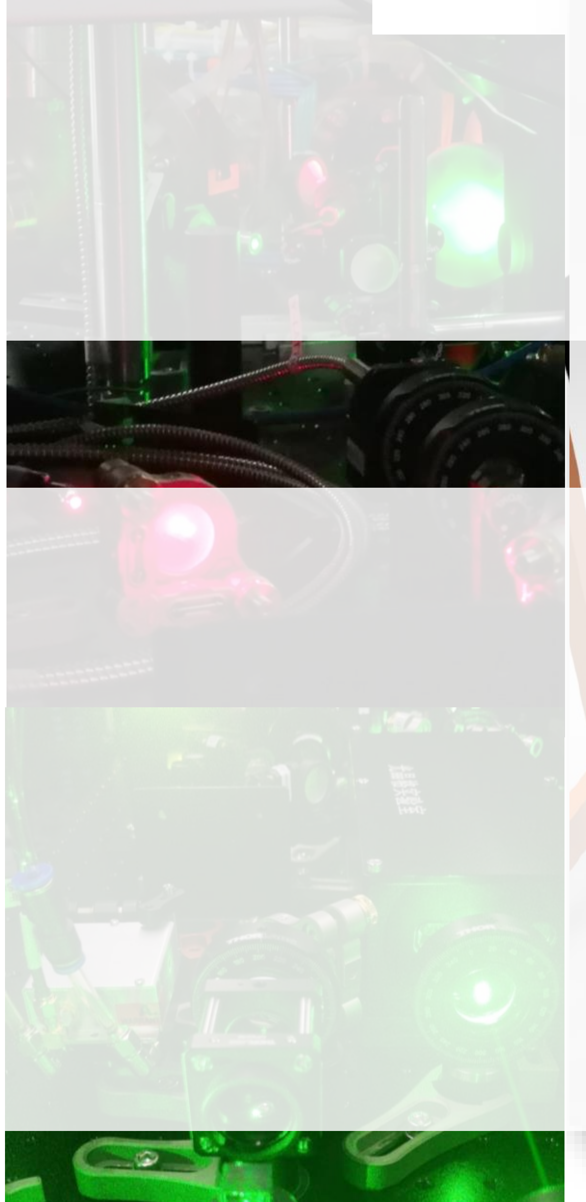
I Bloch@MPQ

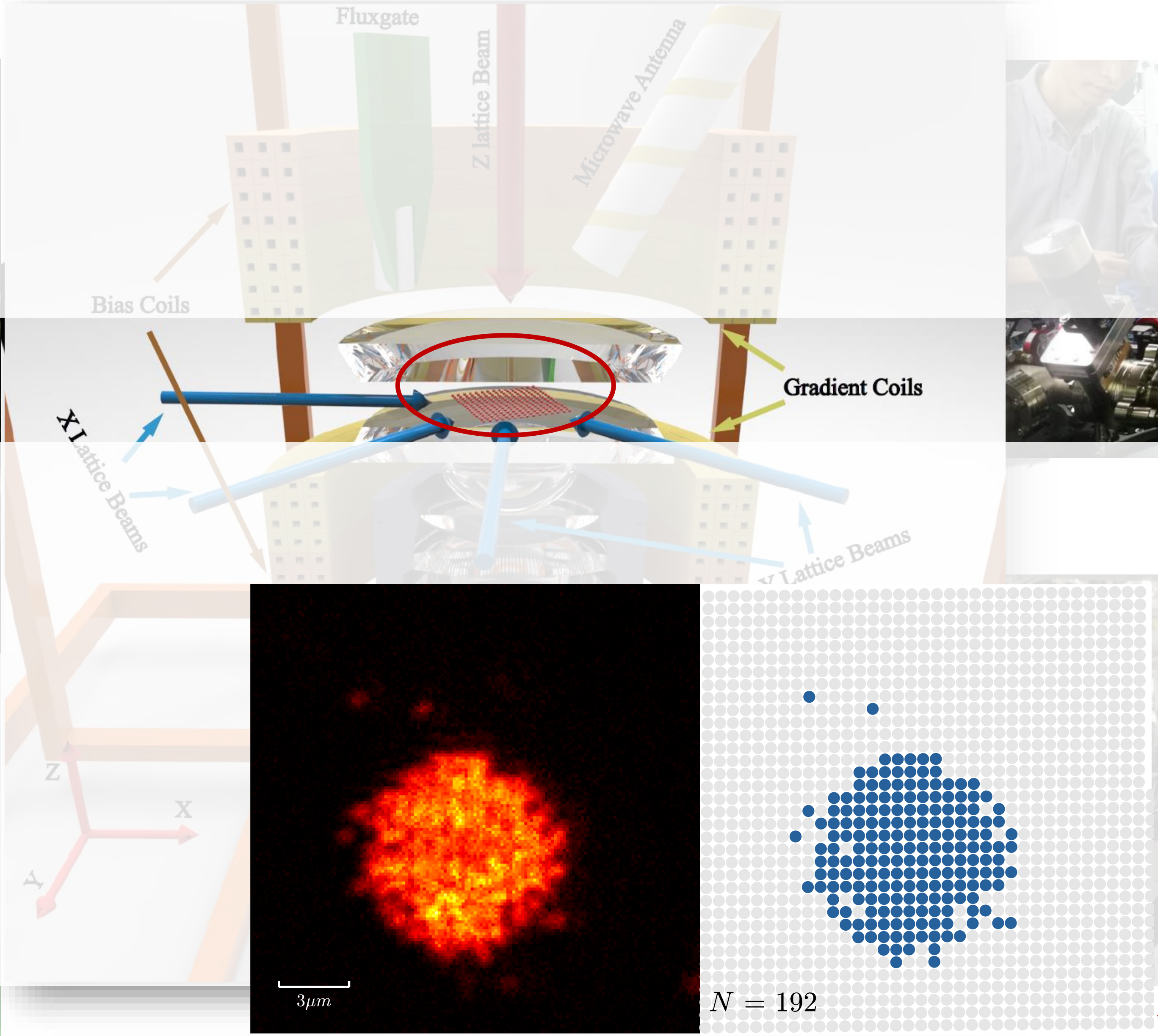
S. Kuhr@Glasgow, M. Zwierlein@MIT



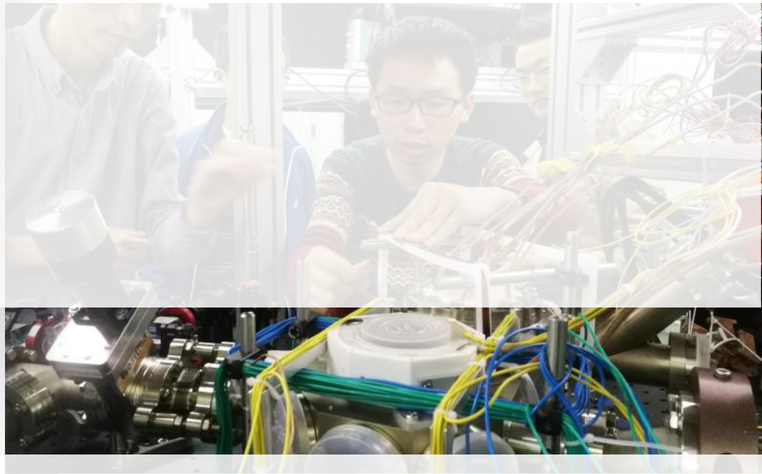
M Greiner@Harvard

实验装置



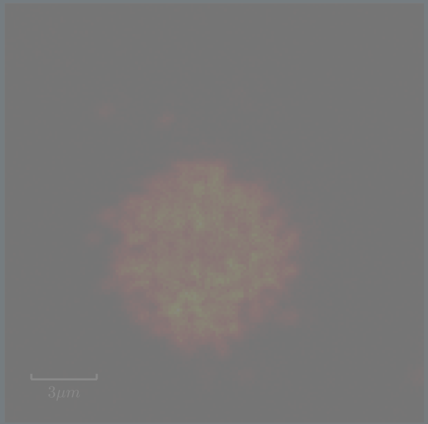


Fluxgate
Z lattice Beam
Microwave Antenna
Bias Coils
Gradient Coils
X Lattice Beams
Z
X
Y
3μm
$N = 192$



Outline

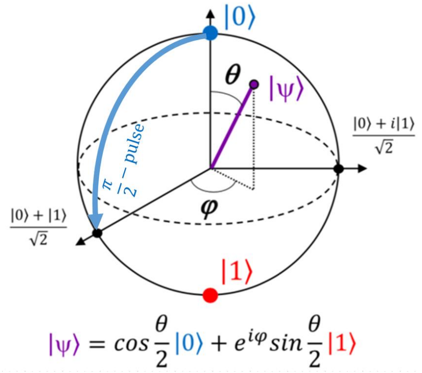
I. 超冷原子物理

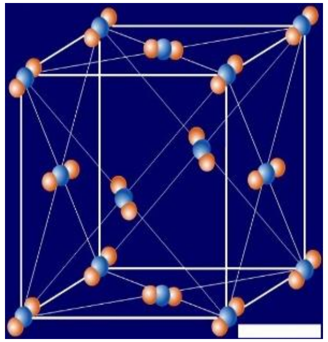


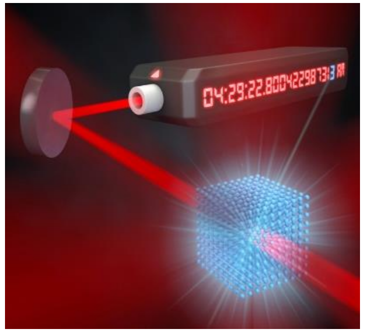
II. 强关联人工量子材料的显微学研究

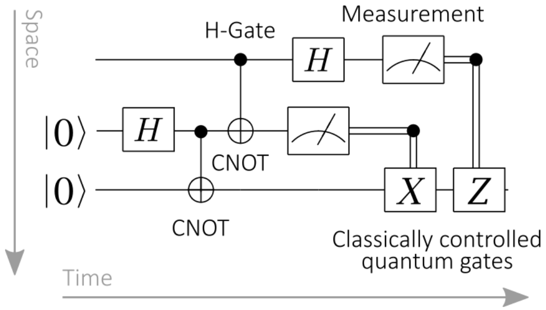
III. 我们的团队简介

Application in quantum information science

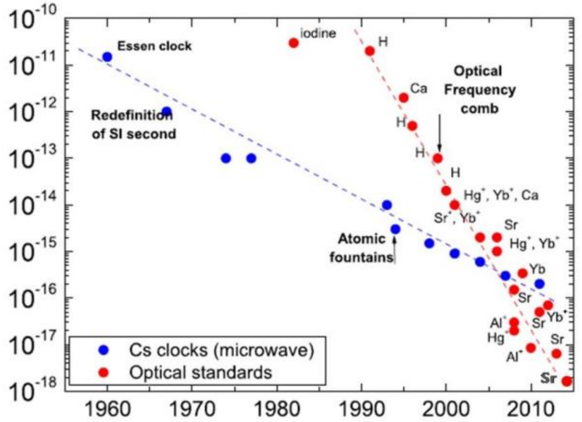








$$
\begin{vmatrix}
H_{11} & H_{12} & H_{13} & \cdots & \cdots & H_{1M} \\
H_{21} & H_{22} & \cdot & \cdots & \cdots & \cdot \\
H_{31} & \cdot & \cdot & \cdots & \cdots & \cdot \\
\vdots & \vdots & \vdots & \cdots & \cdots & \cdot \\
\vdots & \vdots & \vdots & \cdots & \cdots & \cdot \\
H_{M1} & \cdot & \cdot & \cdots & \cdots & H_{MM}
\end{vmatrix}
$$



- **Quantum computation:**
  Quantum bits, gates
  Quantum circuit
- **Quantum simulation:**
  engineering interaction,
  build Hamiltonian, e.g.
  Hubbard model, Spin model
- **Precision measurement:**
  Atomic clock with a
  relative precision of
  10^{-18}

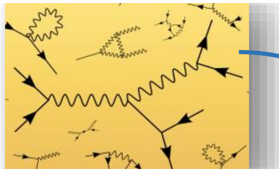
Difficulty

Quantum simulation with ultracold atoms

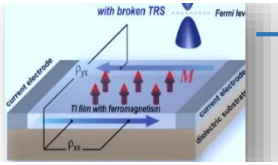
■ **Motivation**： complexity of quantum many-body problem

Diagonalization of H

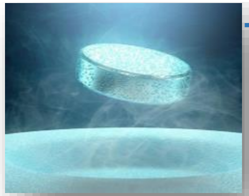
Q. Field theory



Q. Materials



Superconductors



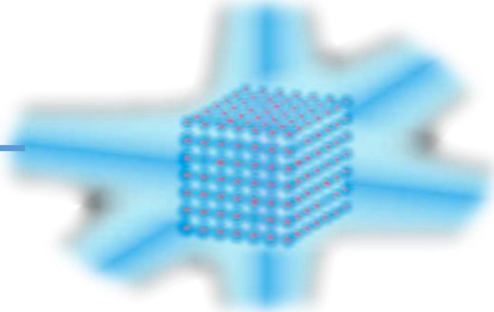
$$\boldsymbol{H} = \boldsymbol{H_0} + \boldsymbol{H_I}$$

$$\begin{vmatrix} H_{11} & H_{12} & H_{13} & \cdots & \cdots & H_{1M} \\ H_{21} & H_{22} & \cdot & \cdots & \cdots & \cdot \\ H_{31} & \cdot & \cdot & \cdots & \cdots & \cdot \\ \vdots & \vdots & \vdots & \cdots & \cdots & \cdot \\ \vdots & \vdots & \vdots & \cdots & \cdots & \cdot \\ H_{M1} & \cdot & \cdot & \cdots & \cdots & H_{MM} \end{vmatrix}$$

$2^M \times 2^M$， ***M*~40**，

The capacity of global information processing

Quantum simulation



Quantum Machine
(Feynman,1981)

■ Requirements： manipulation of many particles at single particle level

A specific-purpose computer

Bohemian Rhapsody, Pipe organ （>100 years old）

Superfluid-Mott Insulator transition

: 81, NUMBER 15 PHYSICAL REVIEW LETTERS 12 OCTOBER 1998

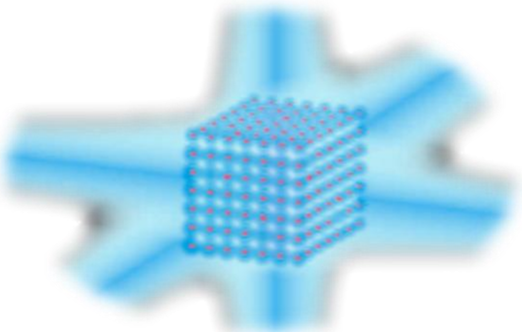
Cold Bosonic Atoms in Optical Lattices

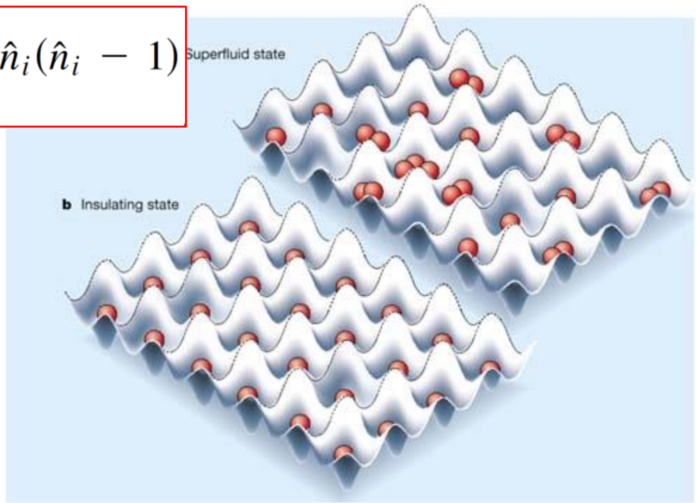
D. Jaksch,[1,2] C. Bruder,[1,3] J. I. Cirac,[1,2] C. W. Gardiner,[1,4] and P. Zoller[1,2]
[1] *Institute for Theoretical Physics, University of Santa Barbara, Santa Barbara, California 93106-4030*
[2] *Institut für Theoretische Physik, Universität Innsbruck, A-6020 Innsbruck, Austria*
[3] *Institut für Theoretische Festkörperphysik, Universität Karlsruhe, D-76128 Karlsruhe, Germany*
[4] *School of Chemical and Physical Sciences, Victoria University, Wellington, New Zealand*

(Received 26 May 1998)

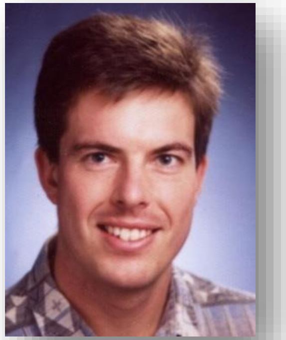
The dynamics of an ultracold dilute gas of bosonic atoms in an optical lattice can be described by a Bose-Hubbard model where the system parameters are controlled by laser light. We study the continuous (zero temperature) quantum phase transition from the superfluid to the Mott insulator phase induced by varying the depth of the optical potential, where the Mott insulator phase corresponds to a commensurate filling of the lattice ("optical crystal"). Examples for formation of Mott structures in optical lattices with a superimposed harmonic trap and in optical superlattices are presented. [S0031-9007(98)07267-6]

$$H = -J \sum_{\langle i,j \rangle} b_i^\dagger b_j + \sum_i \epsilon_i \hat{n}_i + \frac{1}{2} U \sum_i \hat{n}_i (\hat{n}_i - 1)$$





M. Fisher
PRB,1989

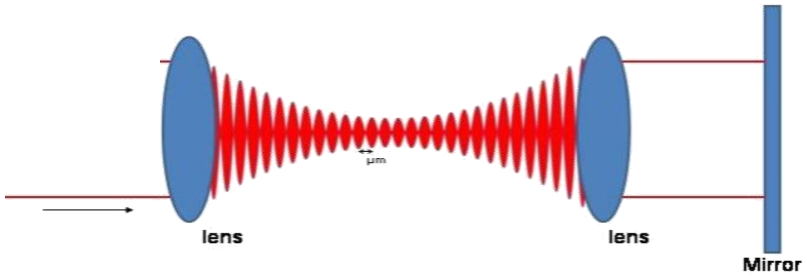


D. Jaksch

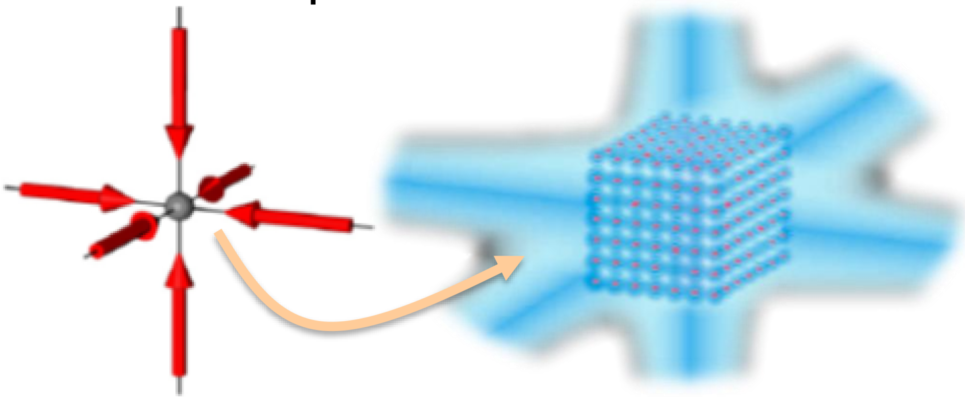
P. Zoller

Optical Lattices and Hubbard Model

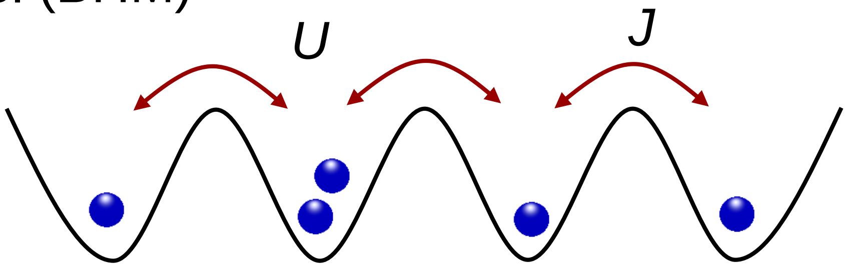
Standing wave of light



3D optical lattice



Bose-Hubbard model (BHM)



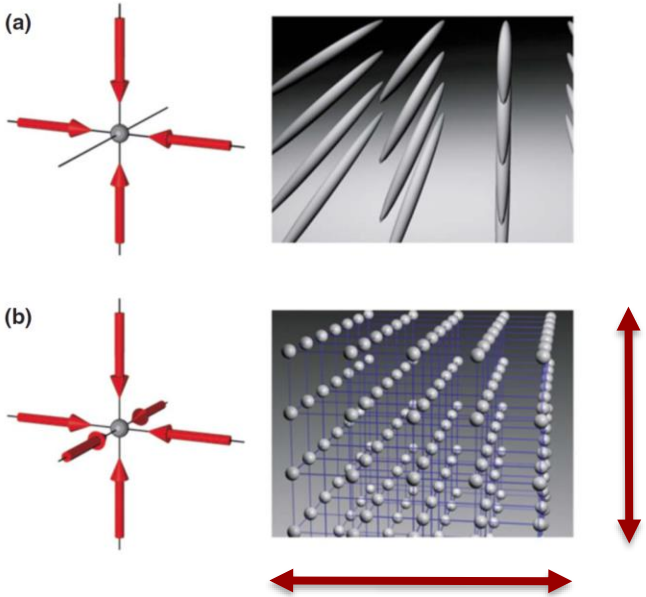
$$\hat{H} = -J\sum_{\langle i,j\rangle}\hat{a}_i^\dagger\hat{a}_j + \frac{U}{2}\sum_i \hat{n}_i(\hat{n}_i - 1) - \sum_i \mu_i\hat{n}_i,$$

J: nearest-neighbor tunneling

U: onsite interactions

Imaging the atoms

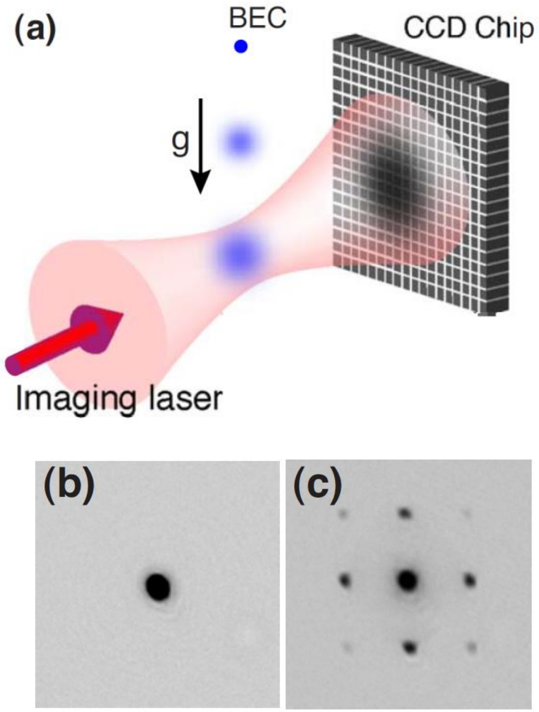
实空间的分布



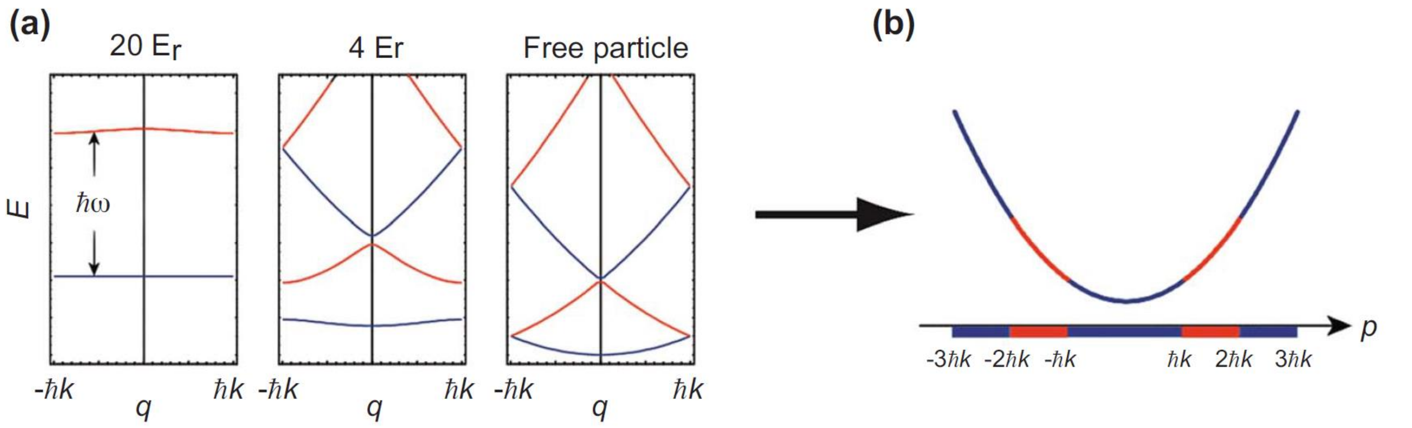
~50 微米

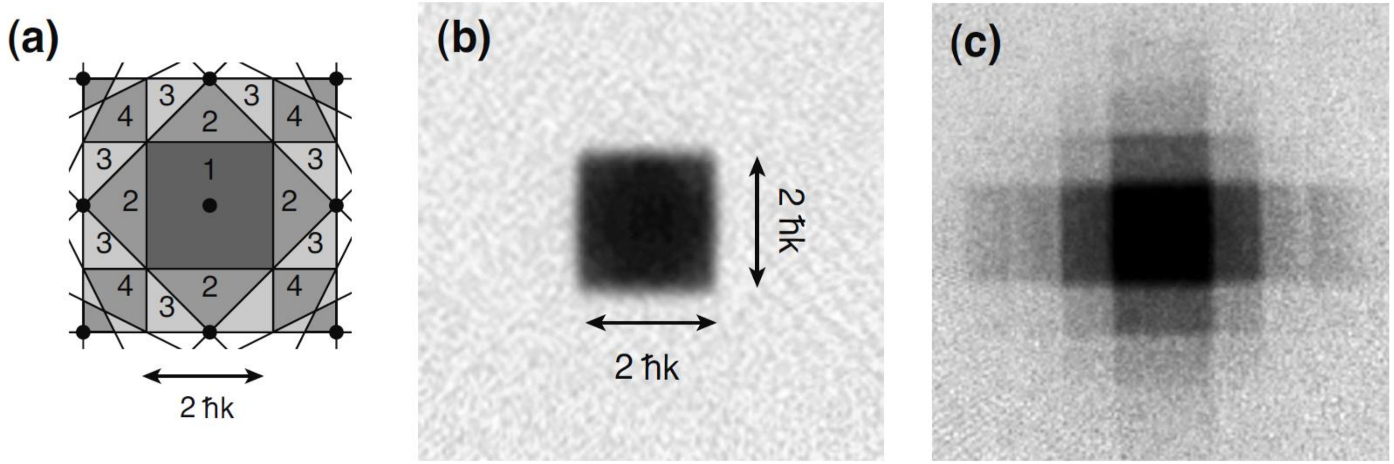
＊ 与晶格中电子的进行类比

时间飞行探测方法—动量空间



Band structure of the lattices





Greiner, M., I. Bloch, M. O. Mandel, T. Hänsch, and T. Esslinger, 2001, Phys. Rev. Lett. 87, 160405

SF-MI transition, experimental realization

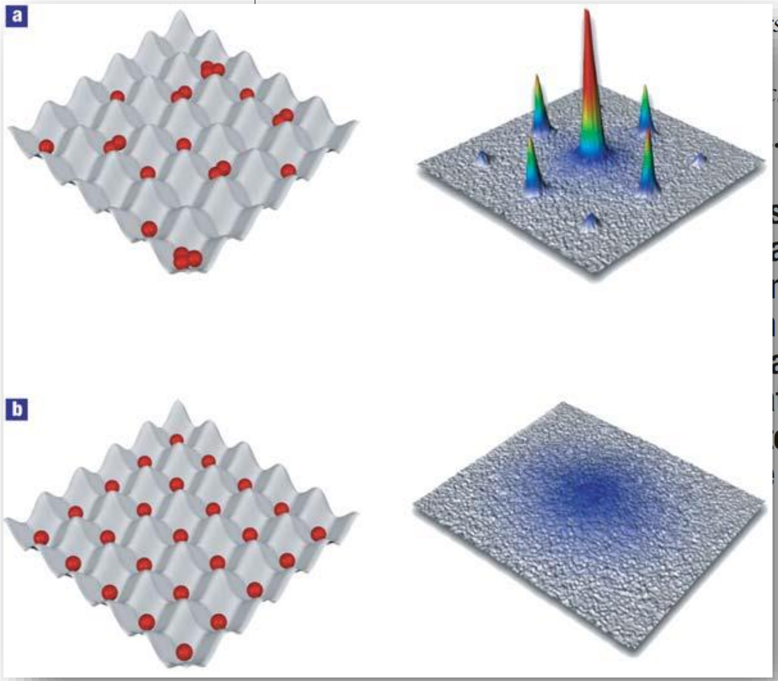
Quantum phase transition from a superfluid to a Mott insulator in a gas of ultracold atoms

Nature 2002

Markus Greiner*, **Olaf Mandel***, **Tilman Esslinger†**, **Theodor W. Hänsch*** & **Immanuel Bloch***

sität, Schellingstrasse 4/III, D-80799 Munich, Germany, and Max-Planck-Institut für Quantenoptik, D-85748 Garching,

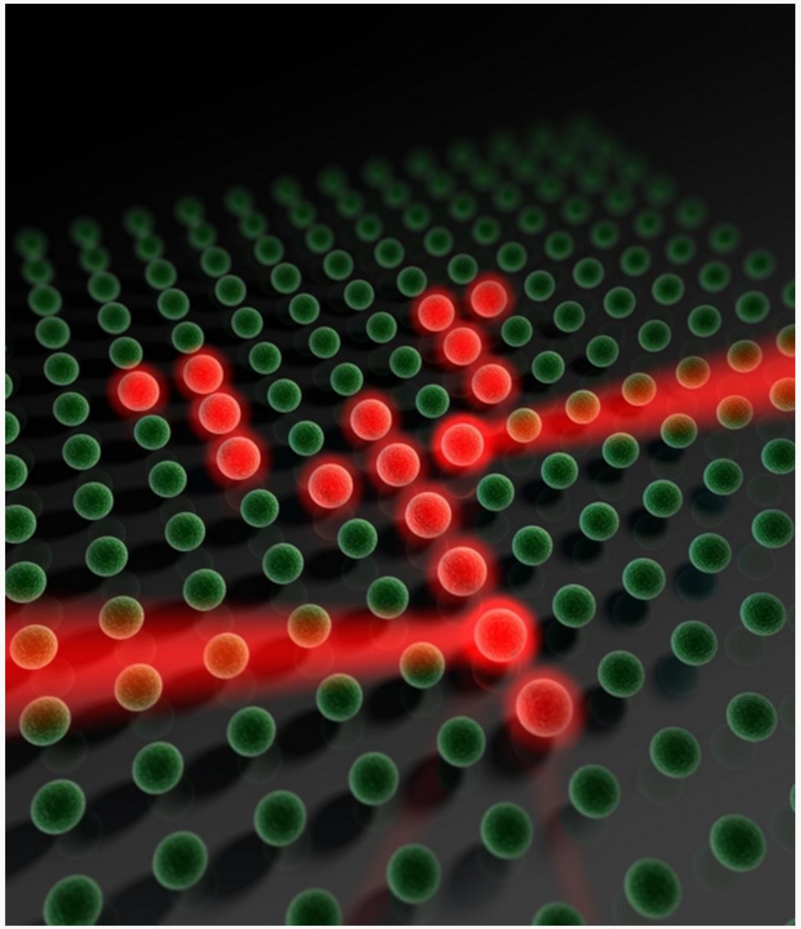
h, Switzerland

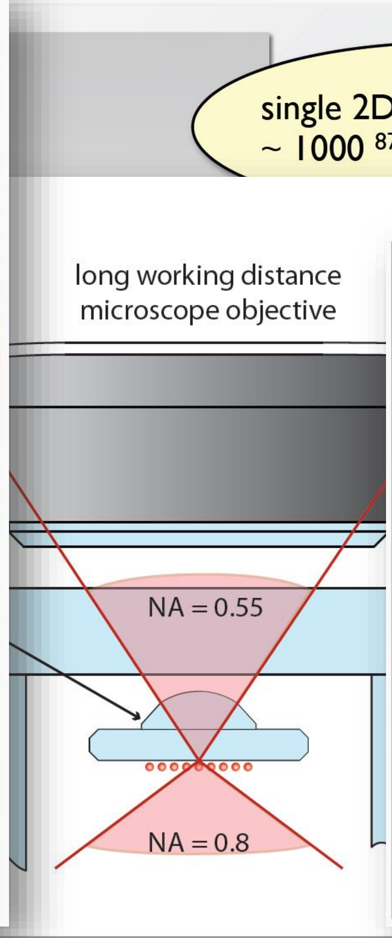


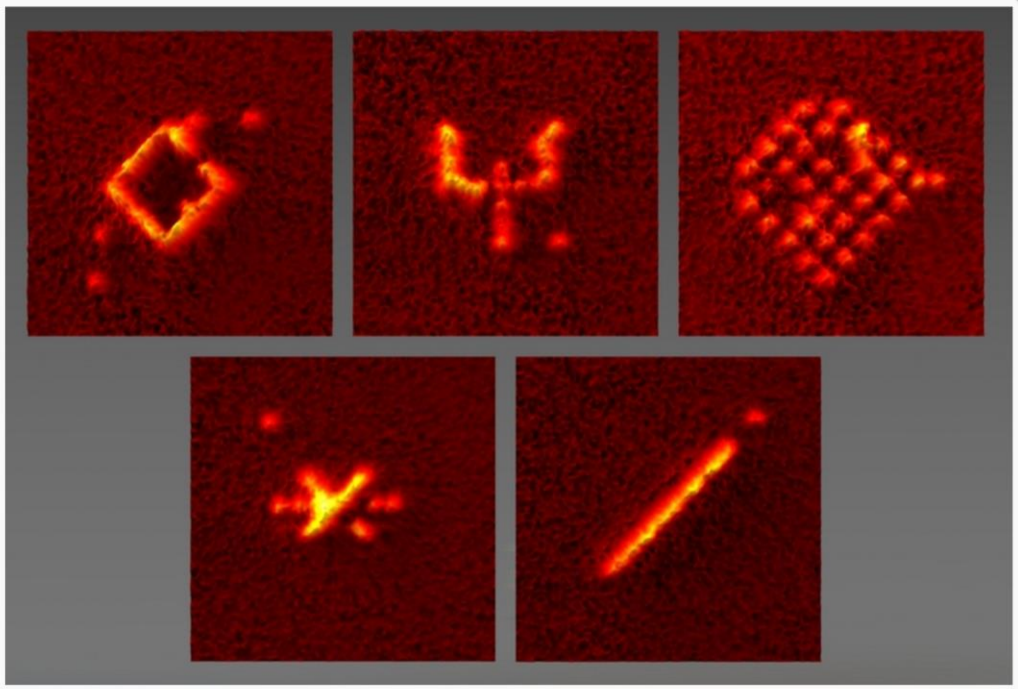
solute zero, all thermal fluctuations are frozen out, while quantum fluctuations prevail. These an induce a macroscopic phase transition in the ground state of a many-body system when the nergy terms is varied across a critical value. Here we observe such a quantum phase transition repulsive interactions, held in a three-dimensional optical lattice potential. As the potential ansition is observed from a superfluid to a Mott insulator phase. In the superfluid phase, each ttice, with long-range phase coherence. But in the insulating phase, exact numbers of atoms es, with no phase coherence across the lattice; this phase is characterized by a gap in the reversible changes between the two ground states of the system.

$$H = -J \sum_{\langle i,j \rangle} b_i^\dagger b_j + \sum_i \epsilon_i \hat{n}_i + \frac{1}{2} U \sum_i \hat{n}_i (\hat{n}_i - 1)$$

Quantum gas microscope





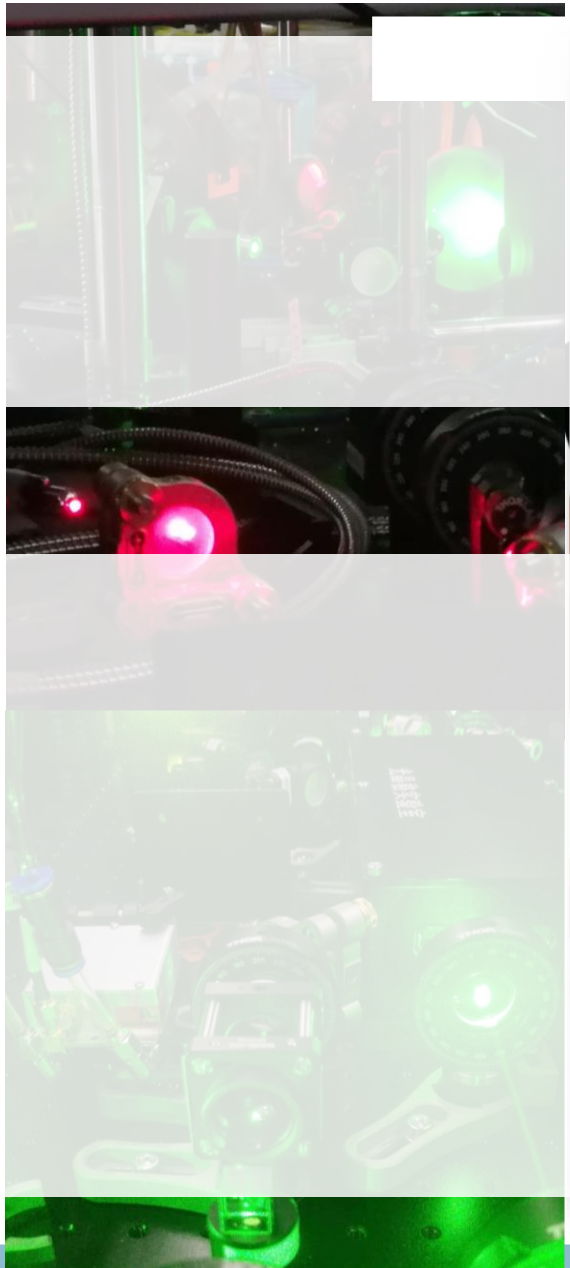


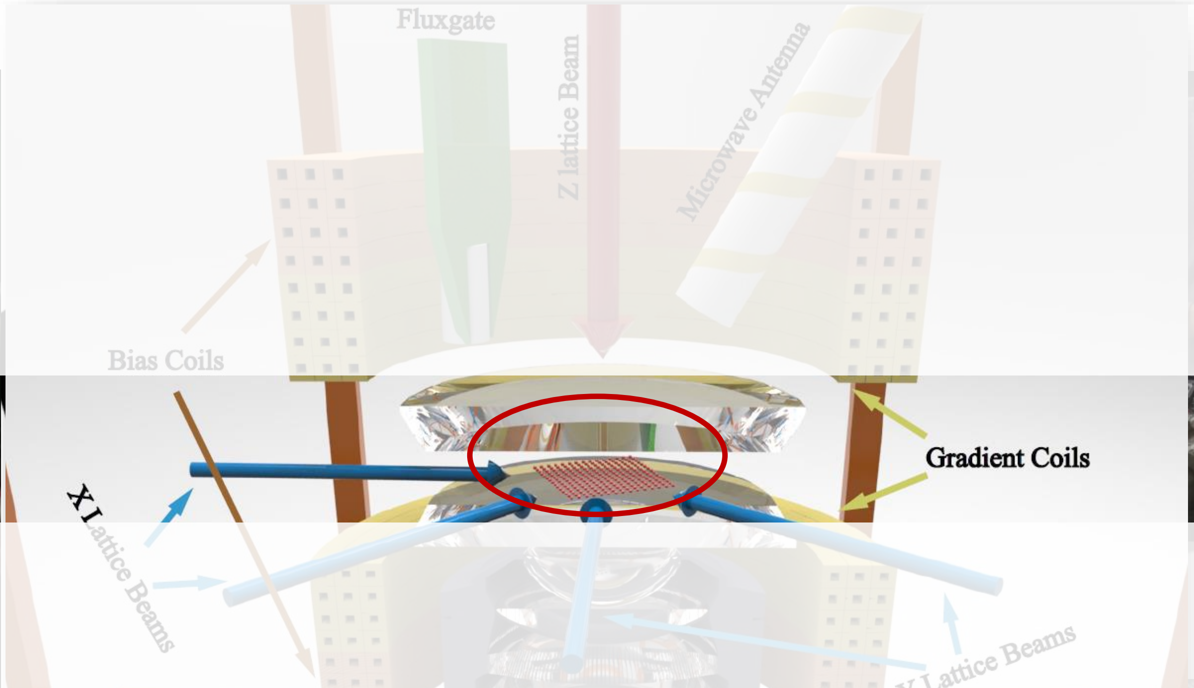
I Bloch@MPQ

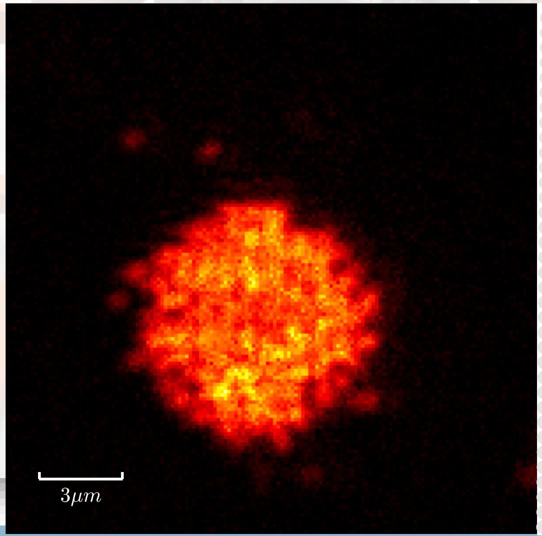
M Greiner@Harvard

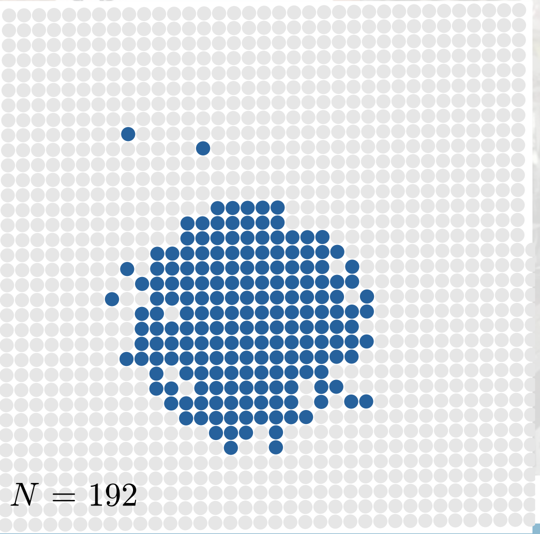
S. Kuhr@Glasgow, M. Zwierlein@MIT

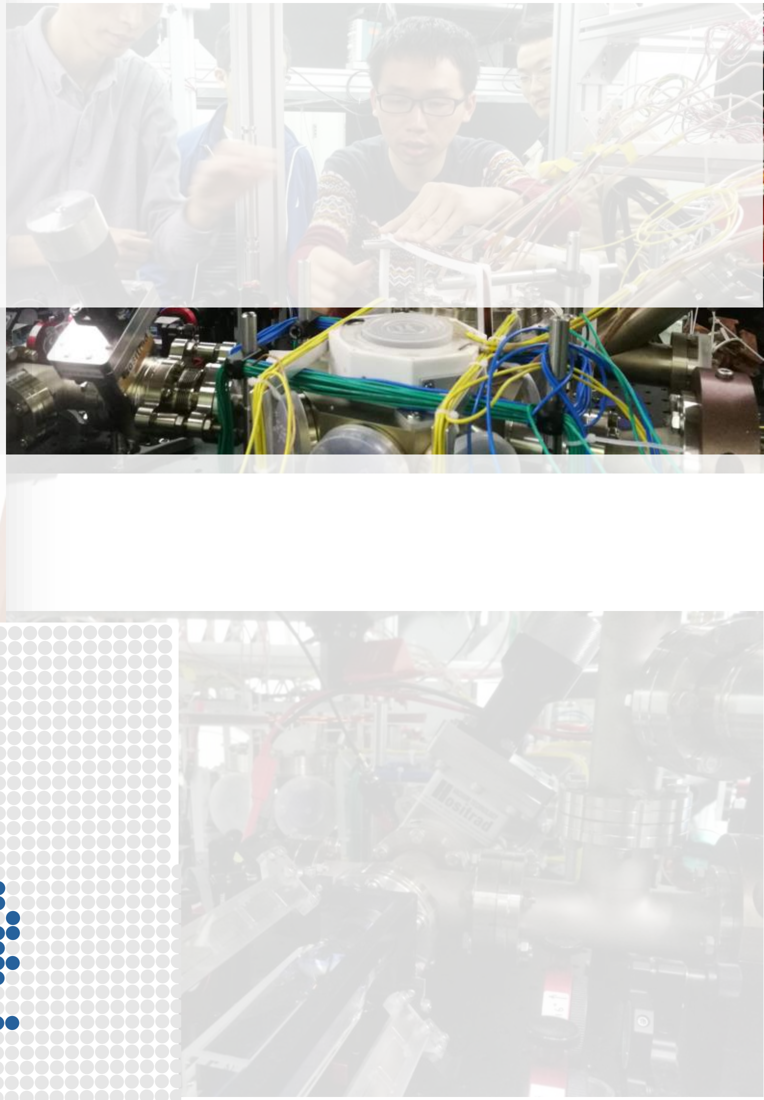
Experimental setup





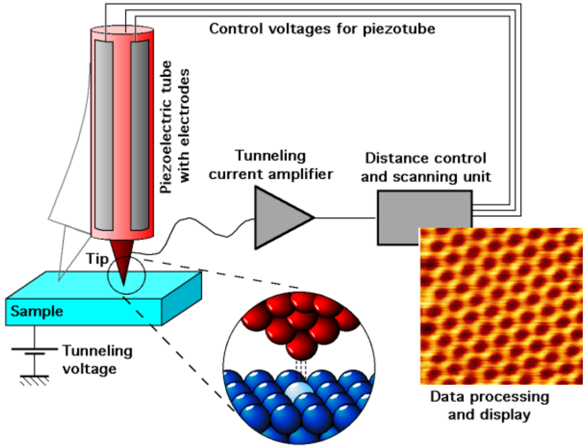






STM v.s. QGM (Quantum gas microscope)

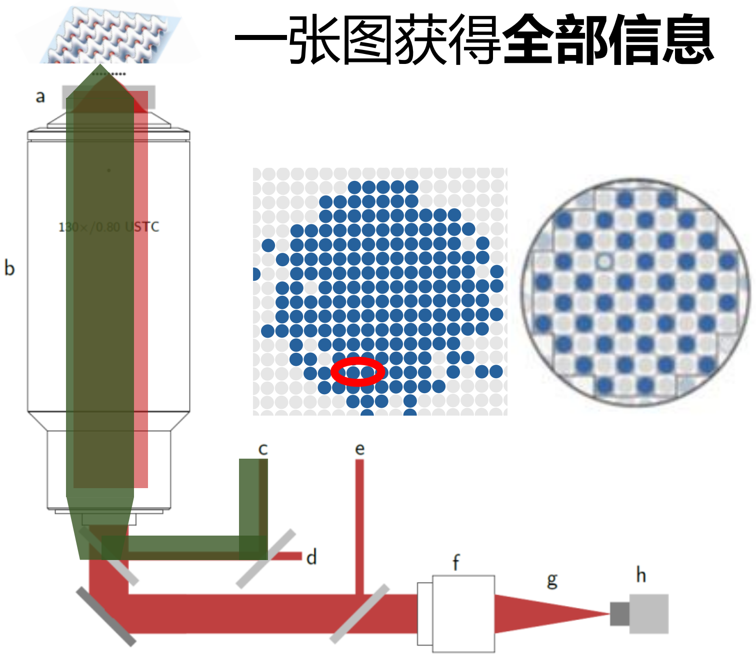
- **STM**：测量针尖与样品表面之间的**隧道电流** → 获得样品**表面形貌图**



☑ 获得电子密度分布的平均值
☒ 电子如何运动?
☒ 电子--电子关联?

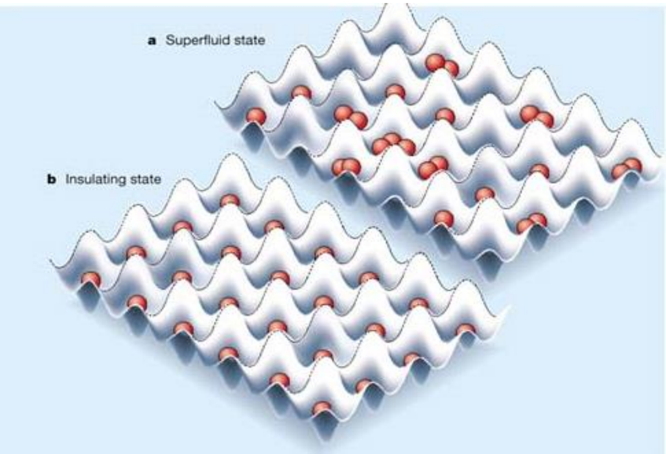
QGM是对STM显微镜的**重要补充**、更是探测量子关联和相干操控量子态的**全新工具**!
面向目标Hamiltonian，可以**即时制备样品**

- **QGM**：全部原子**瞬时冻结成像**
  一张图获得**全部信息**

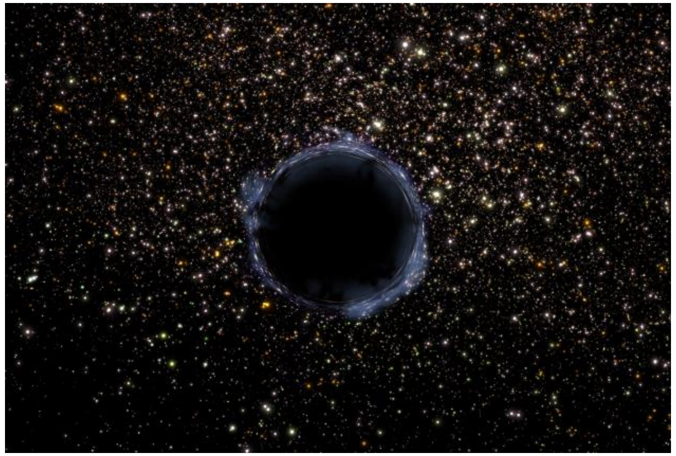


☑ 实空间单格点、单原子分布
☑ 多次成像跟踪原子的实时运动
☑ 实空间原子-原子关联（粒子-空穴、自旋-自旋，近邻和长程，两体，多体）
☑ 反打光相干操控单个或多个原子的量子态

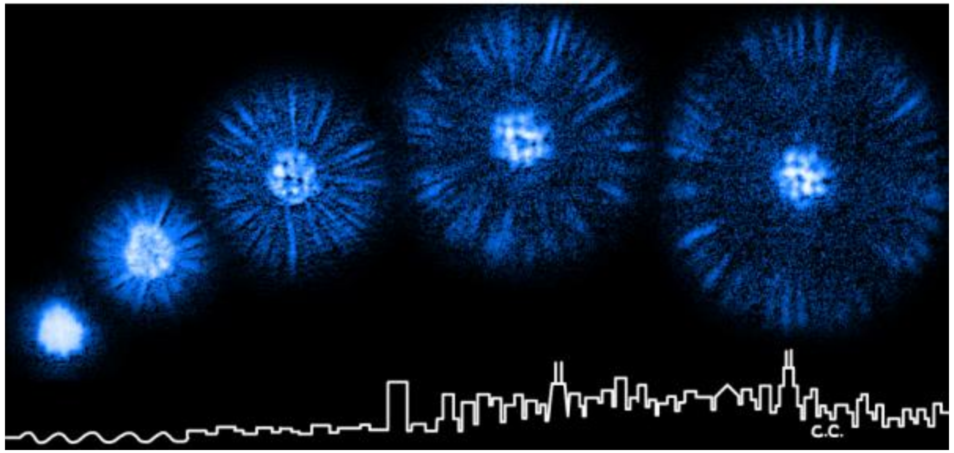
Quantum simulation



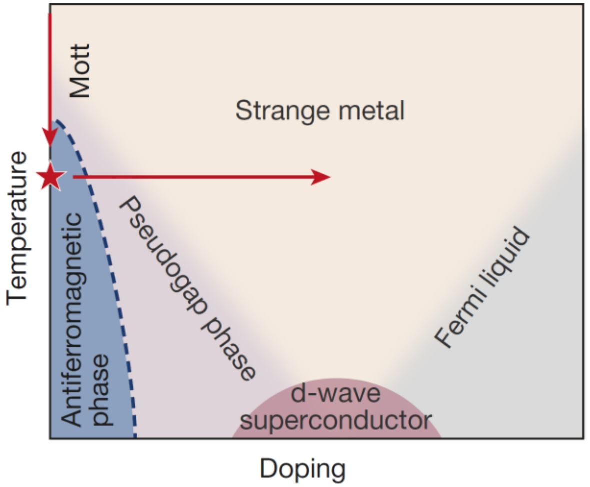
- SF-MI transition (Bloch, Greiner…)



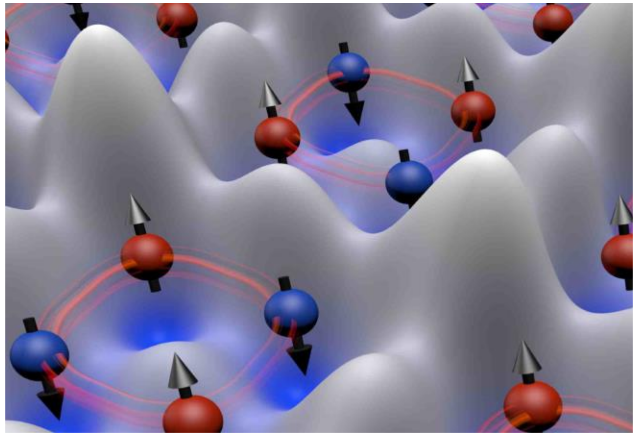
- Hawking radiation (Steinhauer, Haifa)



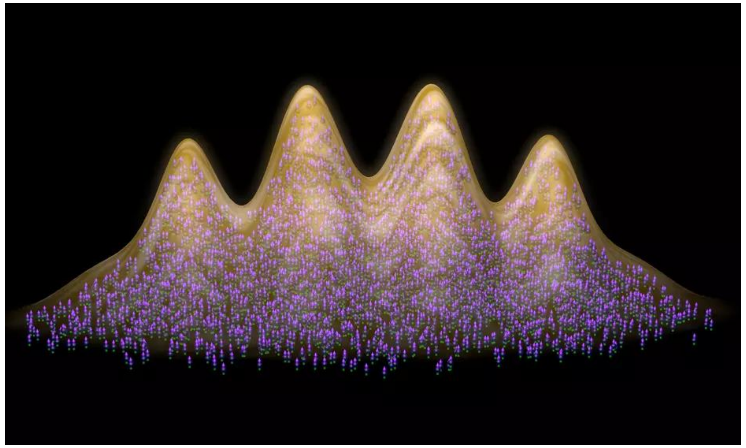
- Jet of matter waves (Cheng Chin, U. Chicago)



- D-Wave superfluidity (Greiner…)



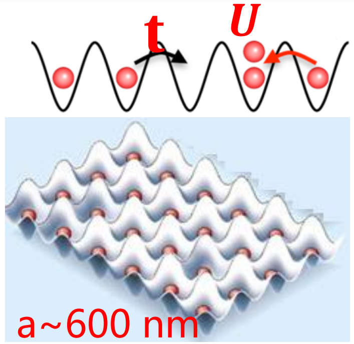
- Topological matter (Yuan, Pan…)



- supersolidity (Ferlaino,Ketterle…)

Quantum simulation

- Quantum simulator： Hubbard Model



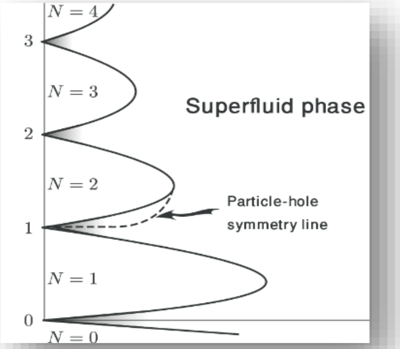
$$\hat{H} = -t\sum_{\langle i,j\rangle}\hat{a}_i^{\dagger}\hat{a}_j + \frac{U}{2}\sum_i \hat{n}_i(\hat{n}_i - 1) - \sum_i \mu_i \hat{n}_i$$

t: Hopping in neighboring sites

U: On-site interaction

μ_i: Chemical potential

t/U competition

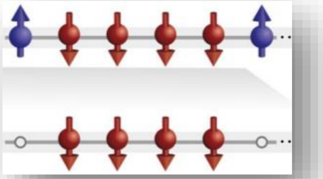


superfluid-insulator transition

U>>t

$$H \sim J_{ex}\vec{S}_i \cdot \vec{S}_j$$

$$J_{ex} = t^2/U$$

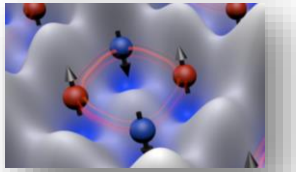


Spin model

U>>t, tune μ_i

$$H \sim J_{\blacksquare}\vec{S}_1 \cdot \vec{S}_2 \cdot \vec{S}_3 \cdot \vec{S}_4$$

$$J_{\blacksquare} = t^4/U^3$$

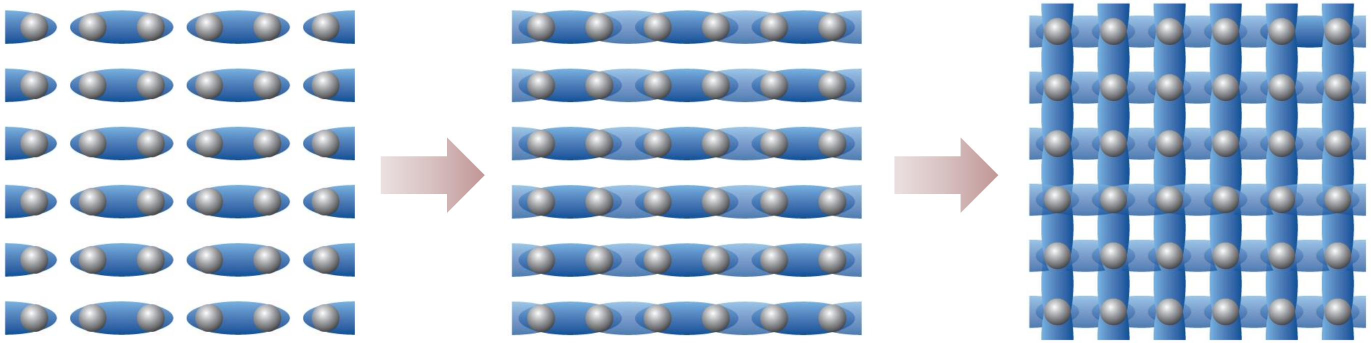


Topological models

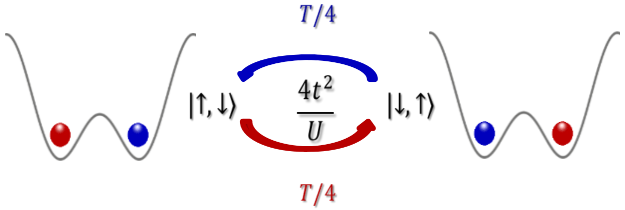
Tool kits for Quantum simulation

Entanglement in optical lattices

Multi-atom entanglement!



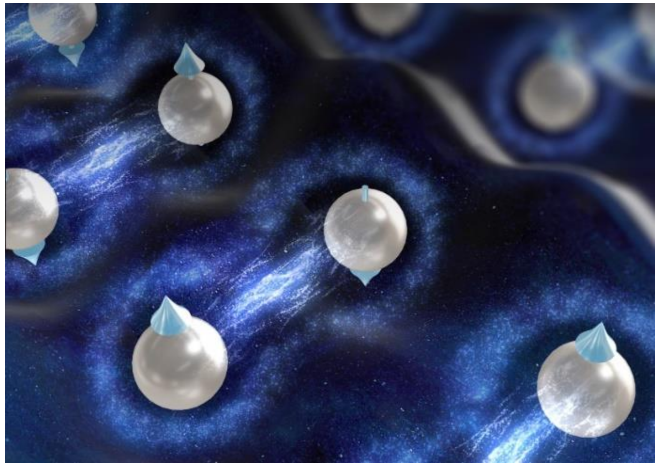
Vaucher *et al*, NJP (2008)



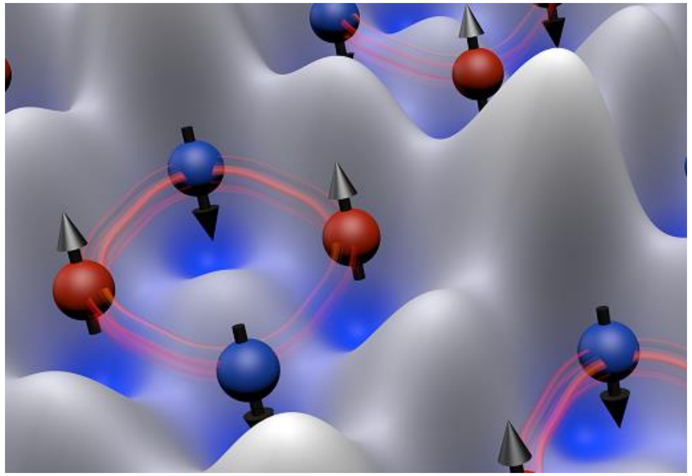
Spin exchange interaction:

Duan *et al*., PRL 91, 090402 (2003)

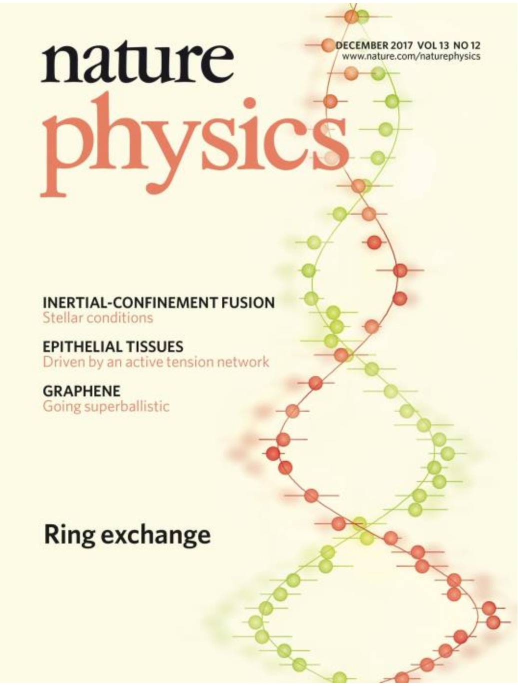
Trotzky *et al*., Science 319, 295 (2008)



Dai *et al*, Nature Physics (2016)

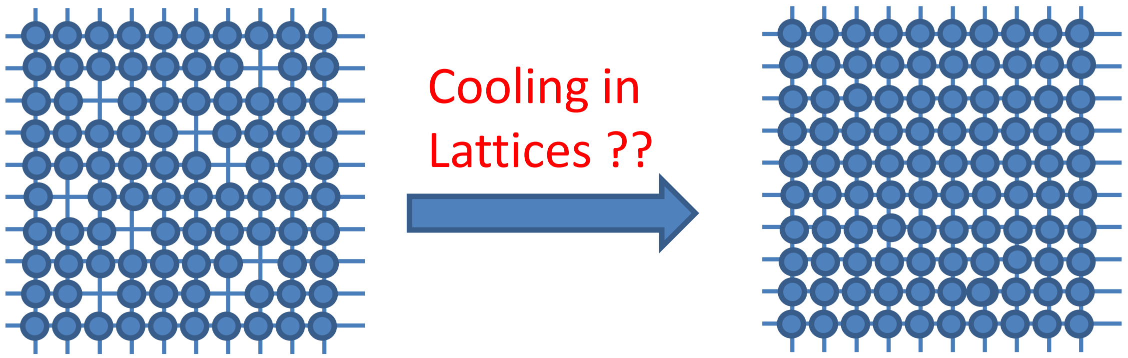


Dai *et al*, Nature Physics (2017)

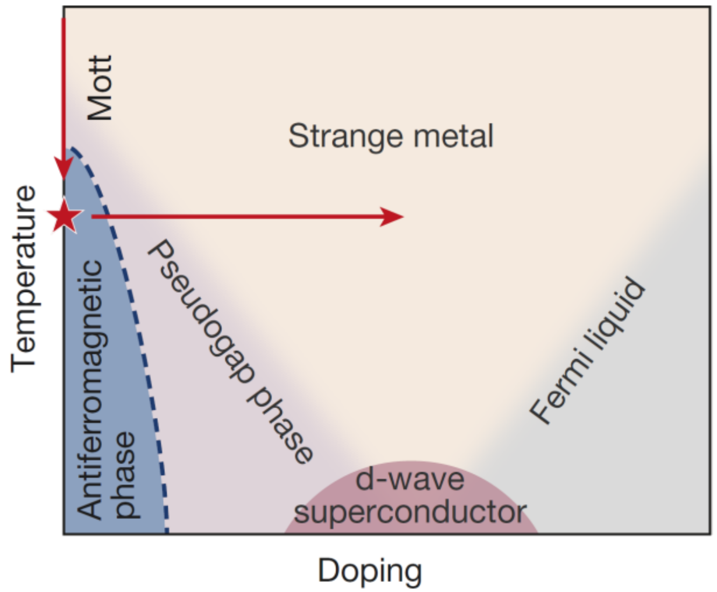


Defects in optical lattices

- **Challenge**: remove defects, cool the atoms in lattices?



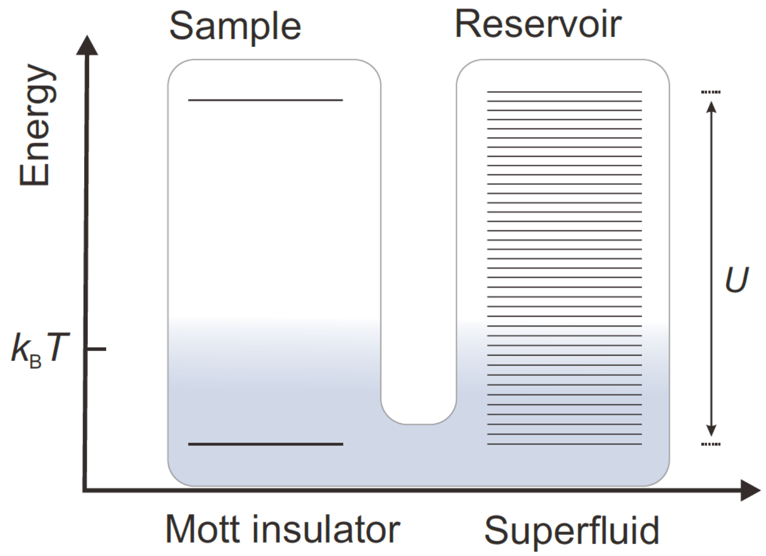
- Doping Fermi-Hubbard model
  High Tc superconductivity

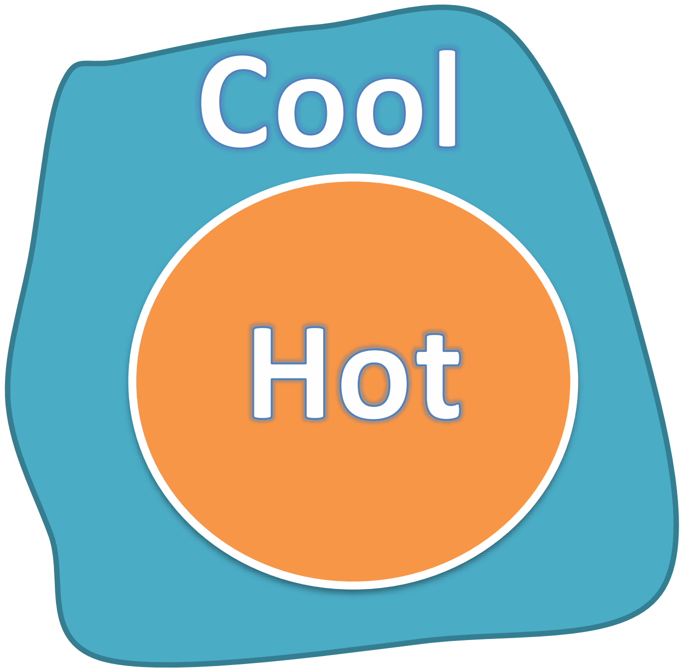


A Mazurenko *et al*, Nature 2017

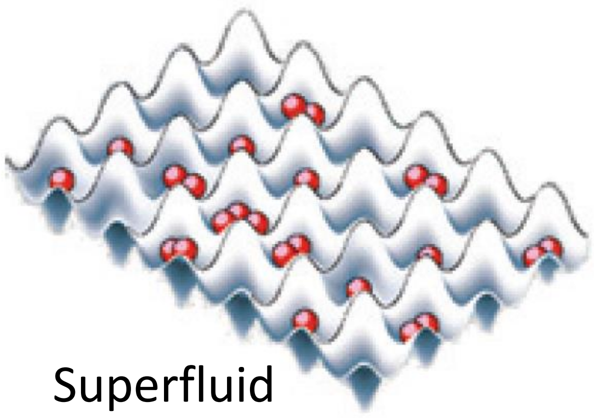
Cooling in Lattice

Deep cooling in optical lattices

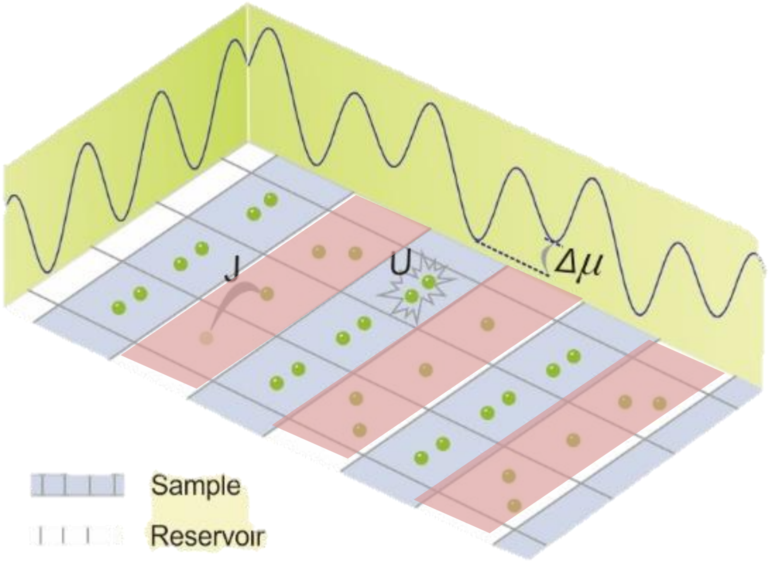




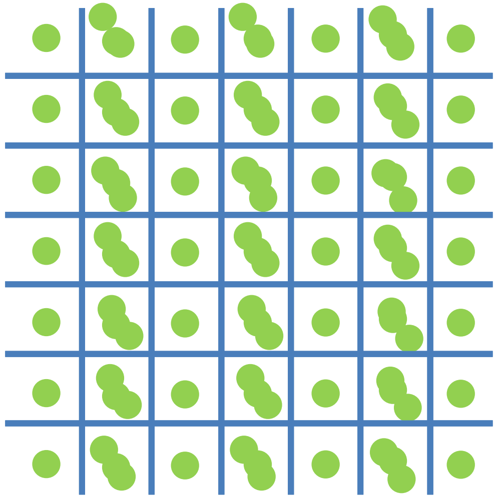
Our scheme for cooling atoms



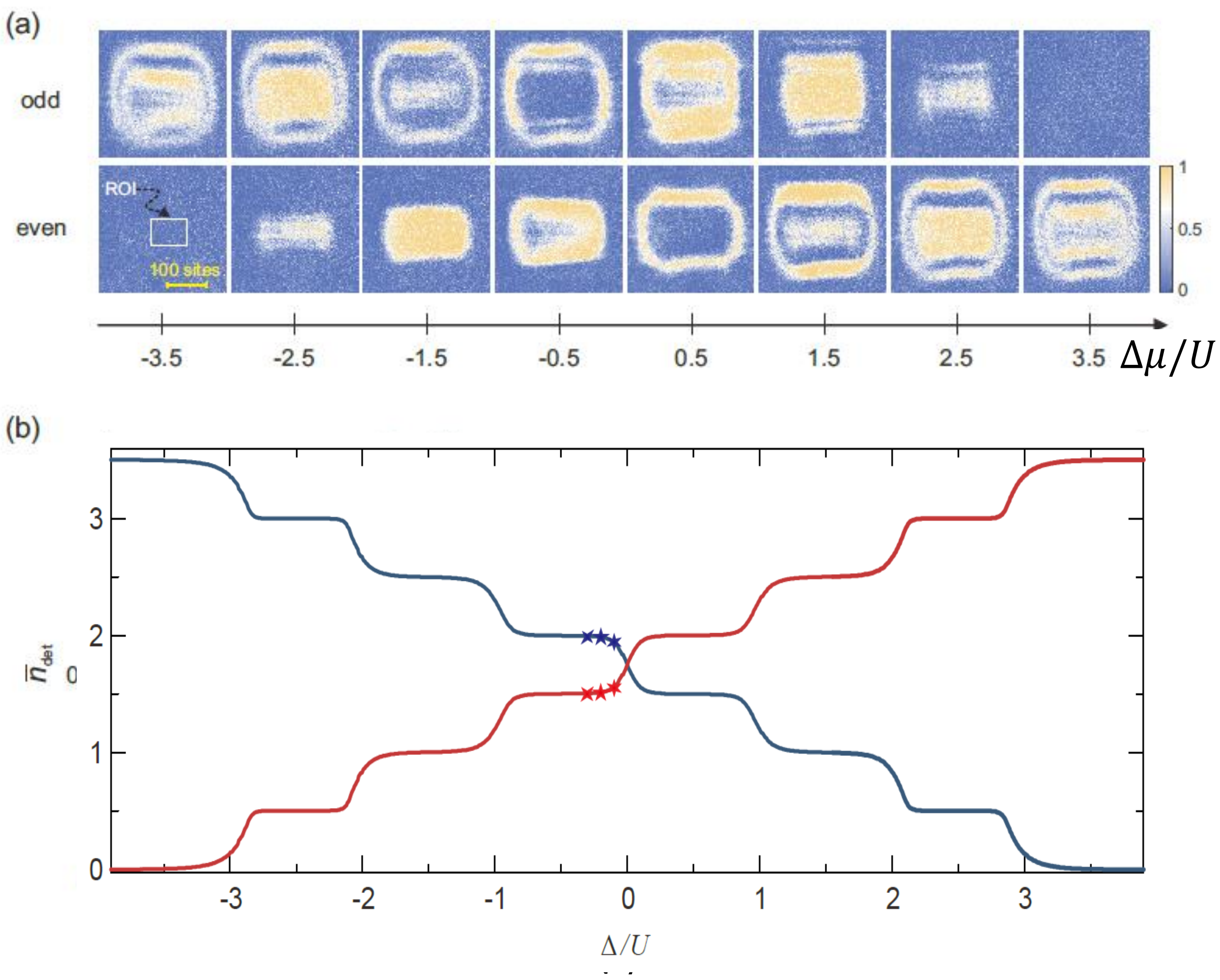
Superfluid

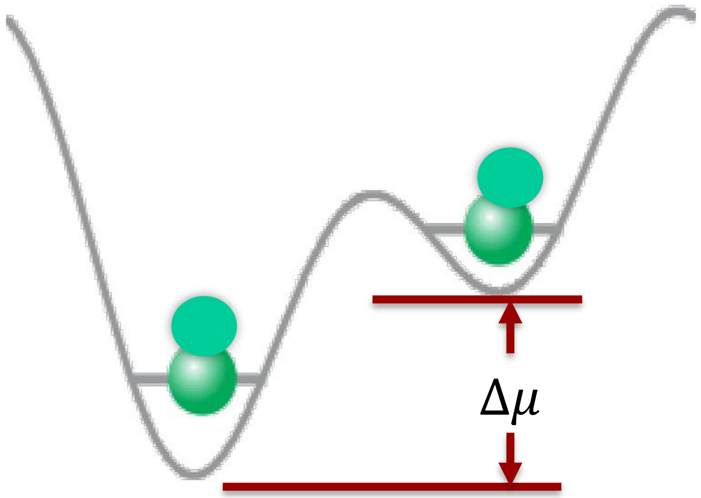


$\Delta\mu$ is varied

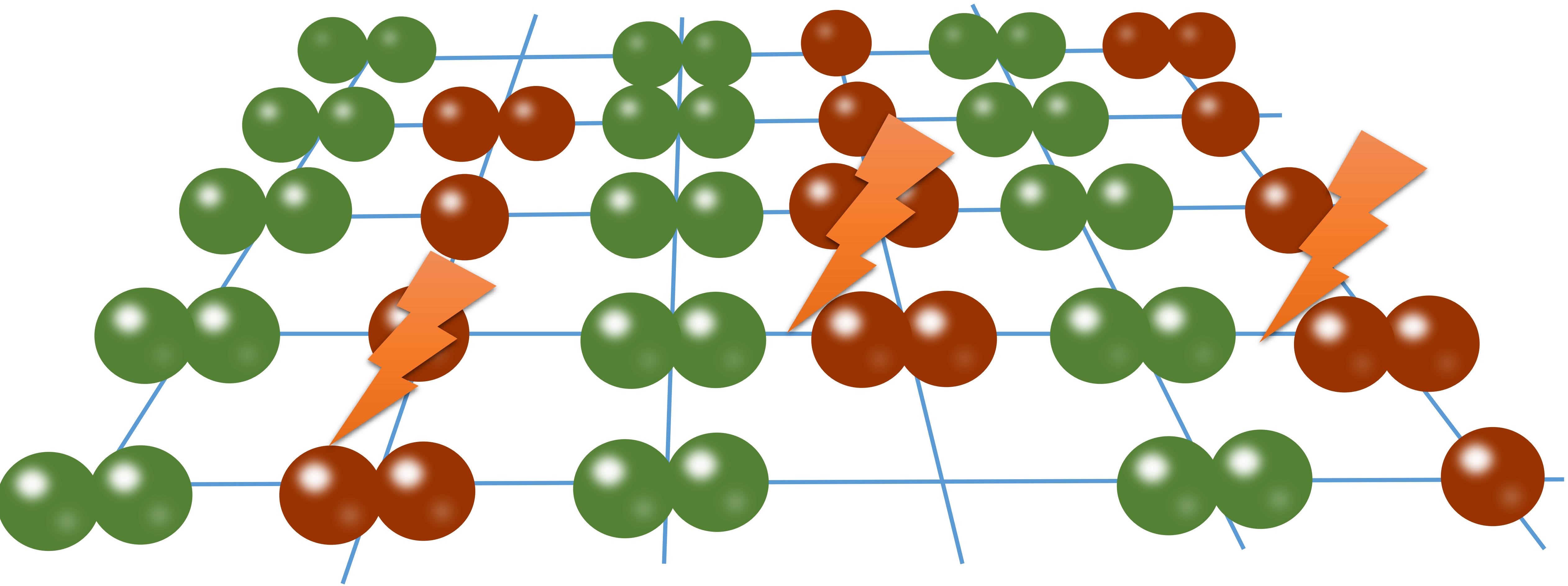


Mass and entropy transport





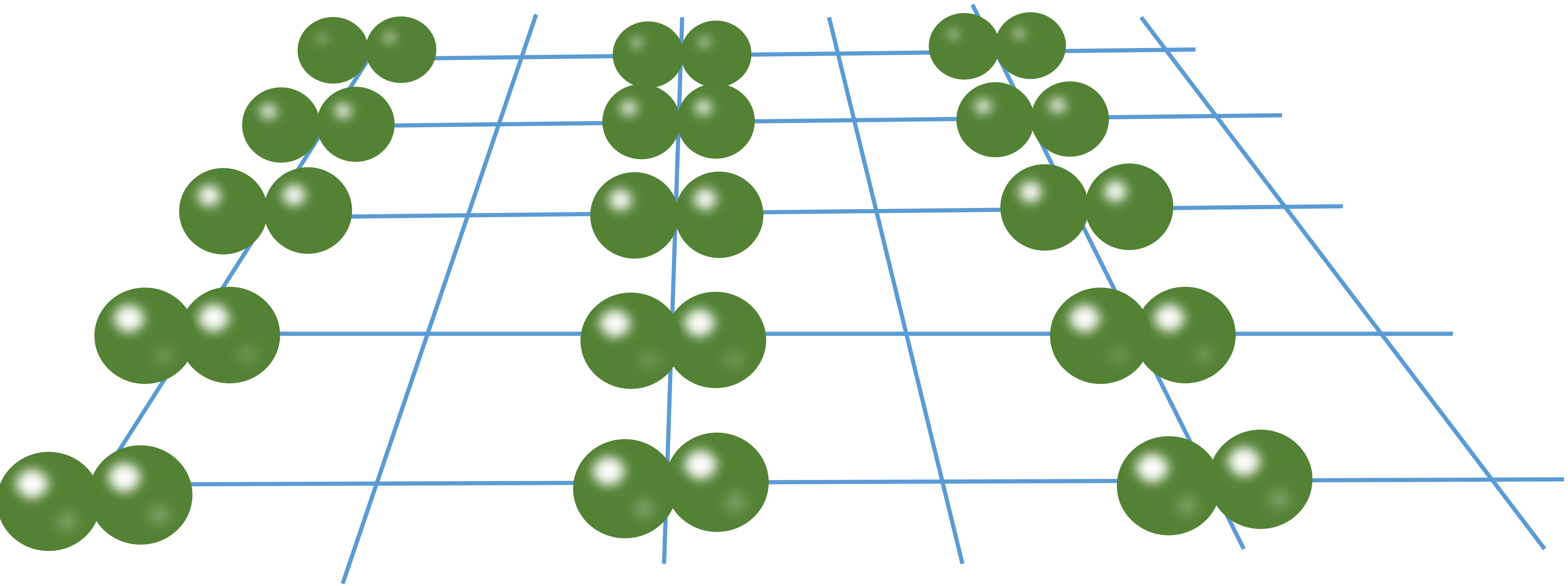
Deep cooling in optical lattices



Mott
Insulator

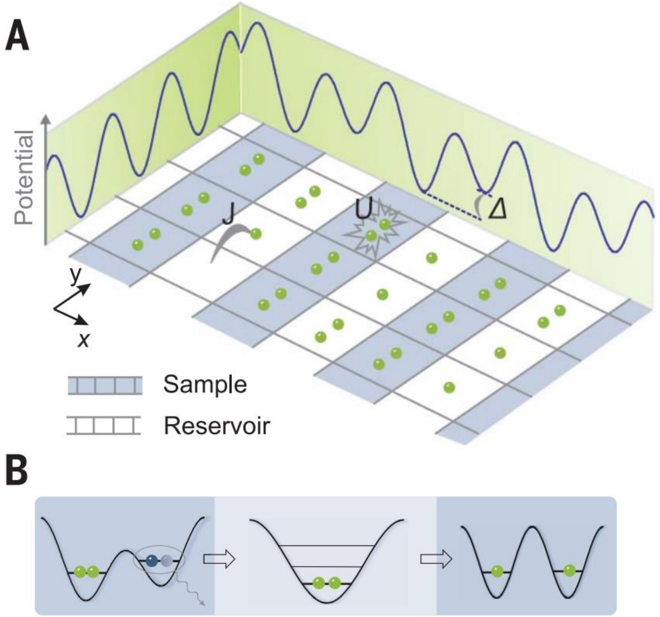
Superfluid

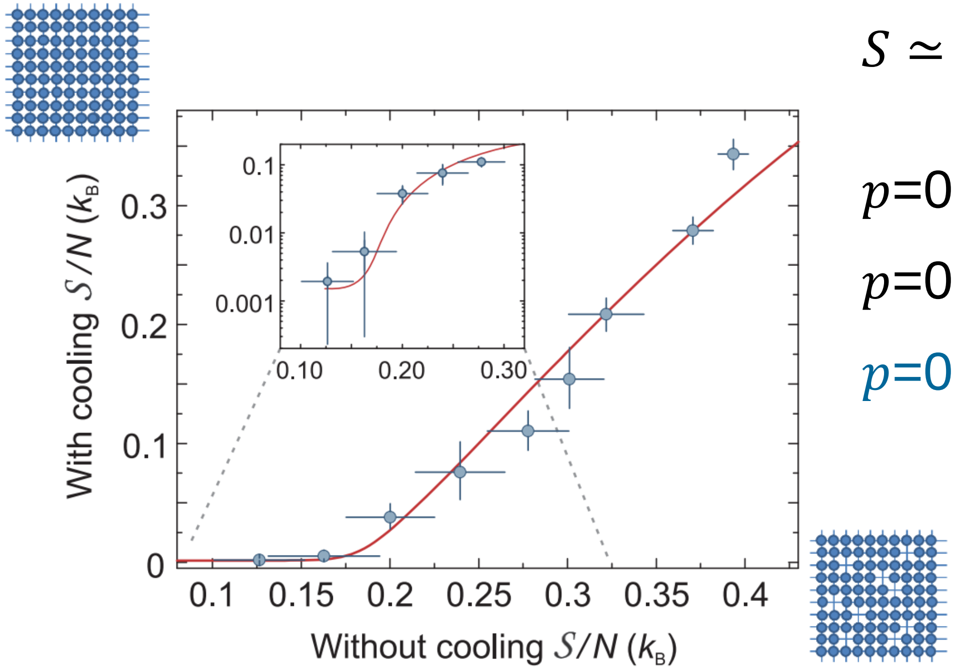
Deep cooling in optical lattices



Entropy →0.0019 k_B/N， 60 times reduction …10%→0.1%

Staggered-immersion cooling





$S \simeq -p \sum_i p_i \log p_i$,

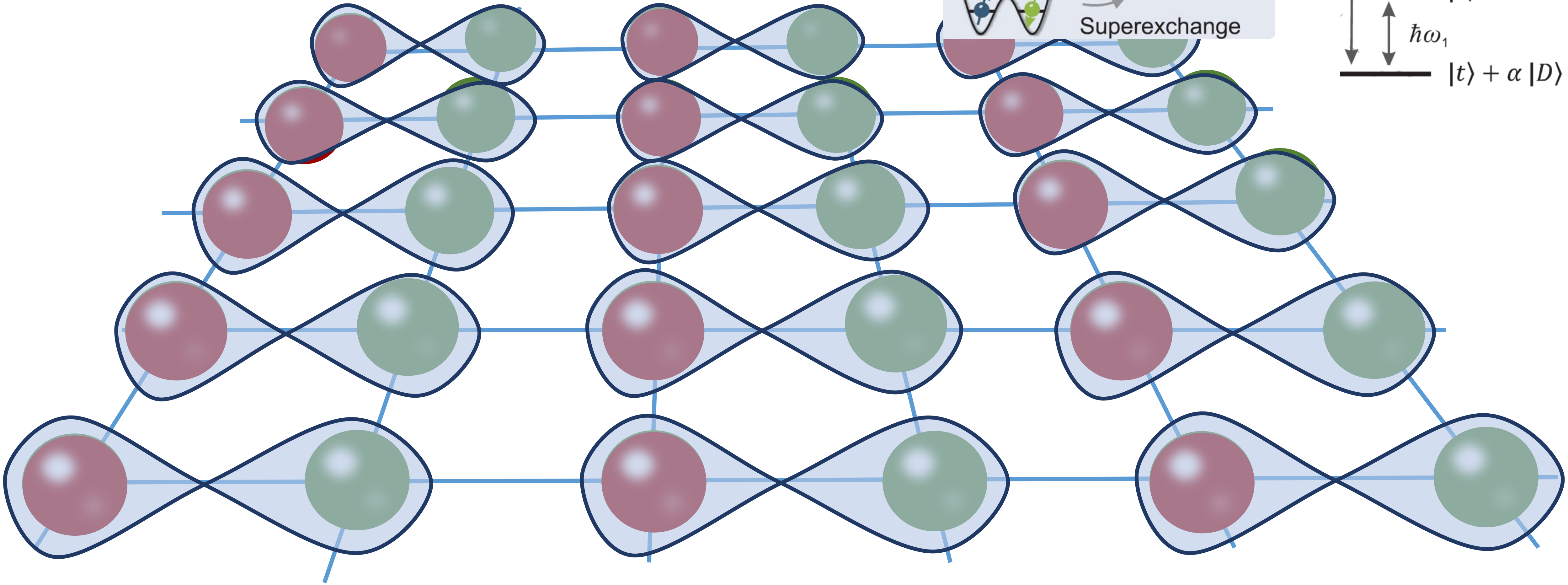
p=0.9, $\frac{S}{N}$~0.2 k_B;

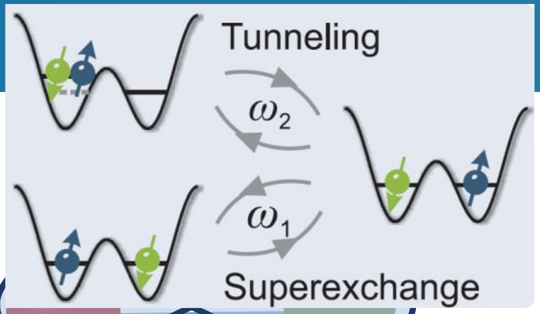
p=0.999, $\frac{S}{N}$~0.008 k_B;

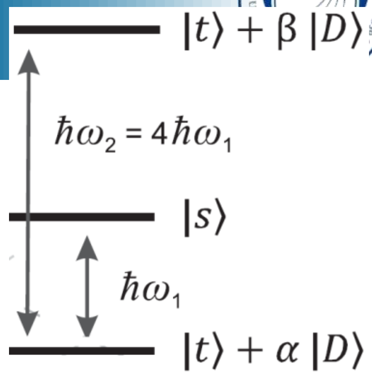
p=0.9997, $\frac{S}{N}$~0.002 k_B;

Yang et al, Science (2020)

Entanglement of atoms

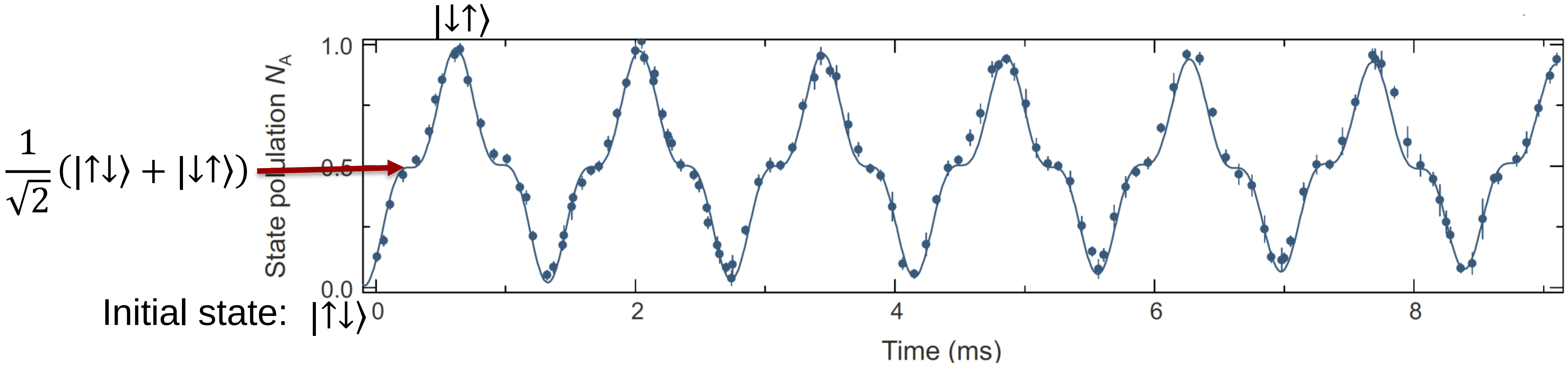


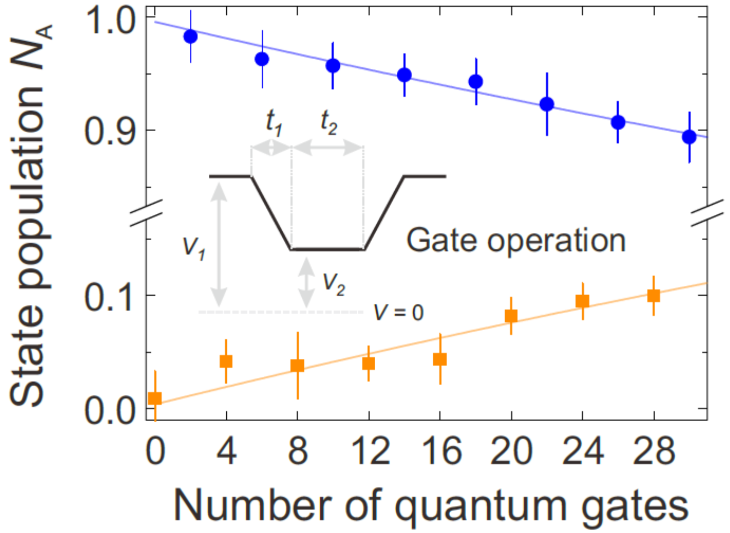




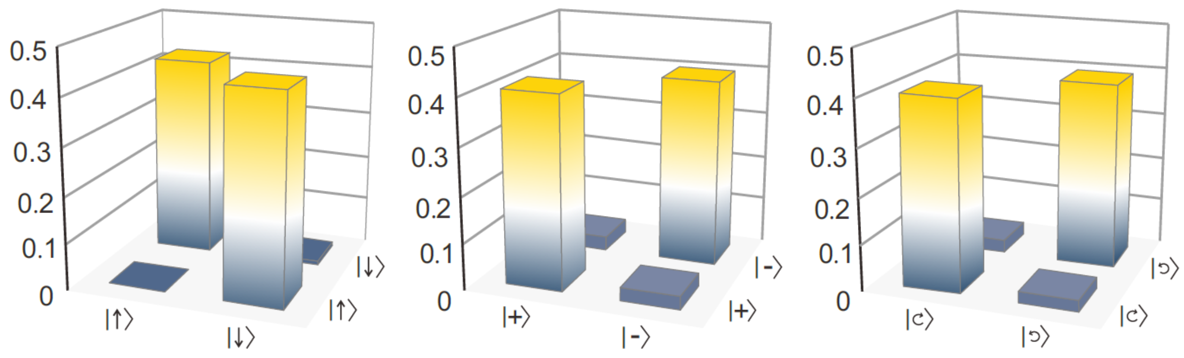
Fast entangling gate

Spin Entanglement



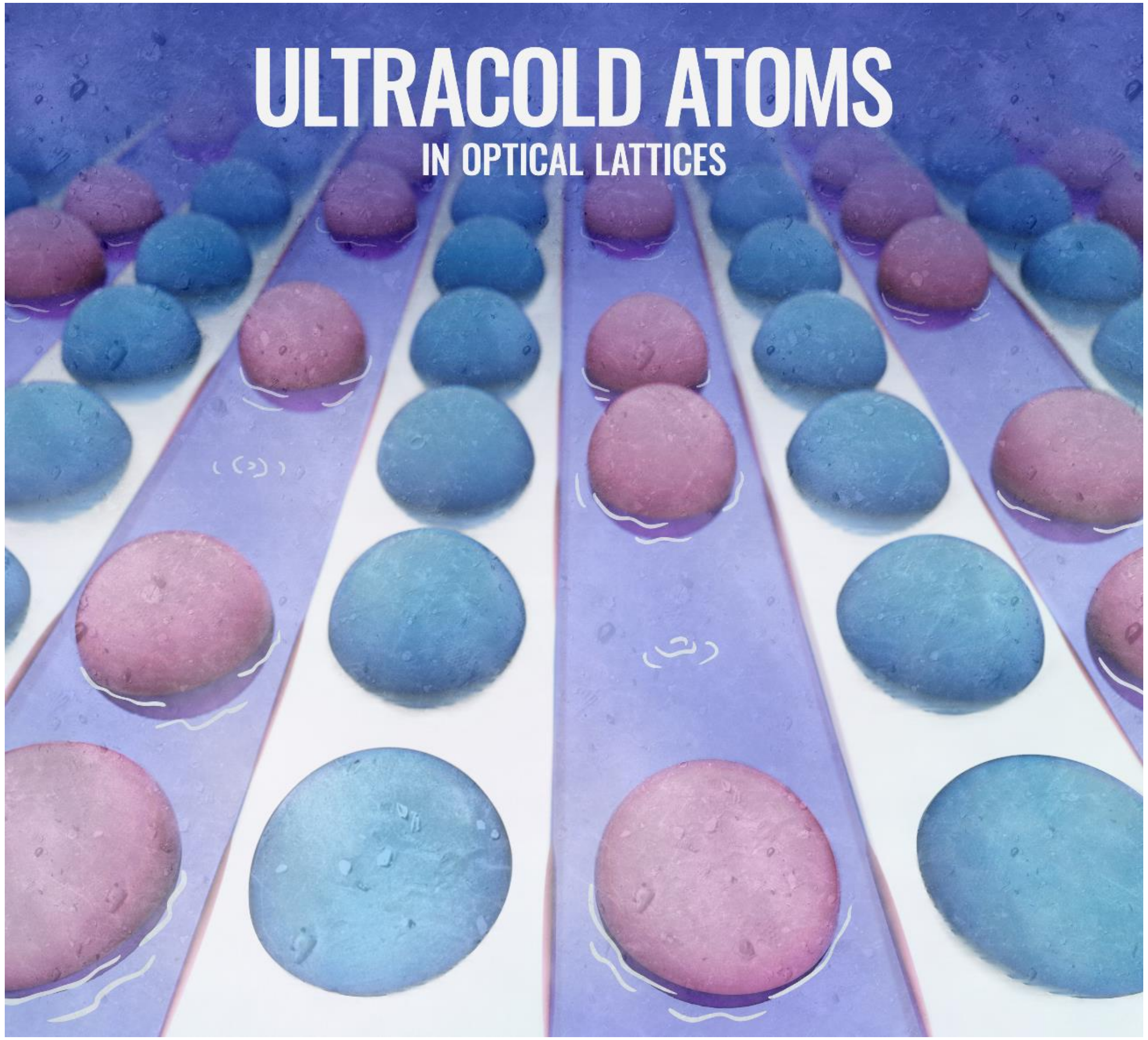


State tomography after 29 gate operations



Fast entangling gate F=99.3%， 1250 pairs

原子的深度冷却和纠缠

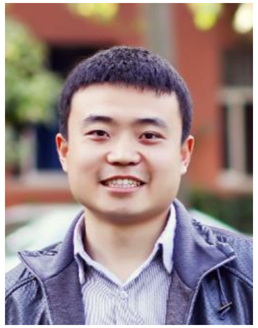


Science (2020)

研究组成员


苑震生


潘建伟


杨兵


孙辉

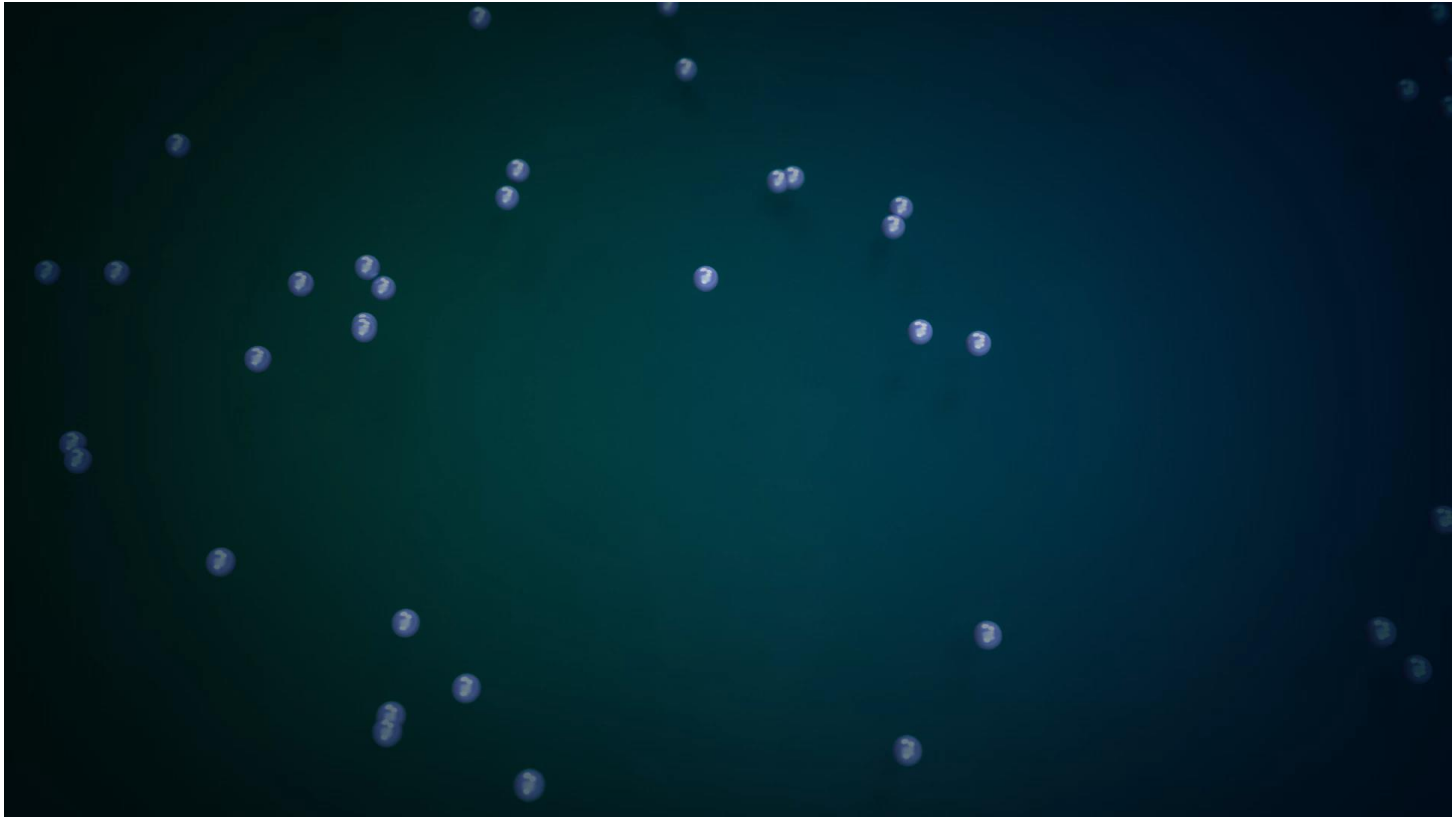

黄春炯


王翰逸


戴汉宁


邓友金

Deep cooling in lattice and atom entanglement



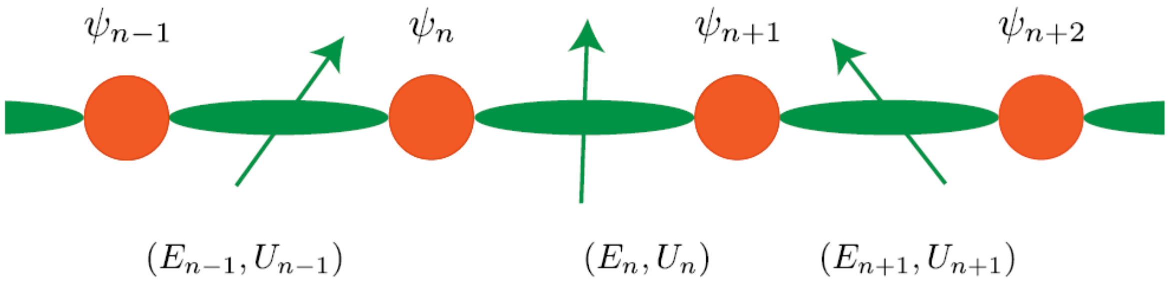
Yang B, ……Yuan Z -S, Pan J- W, Science 2020

动画：梁琰、石千惠、苑震生等

一维格点Schwinger方程

Schwinger Model

$(\hat{E}_n, \hat{U}_n)$ gauge field



Electric field

Matter field

$$\hat{H}_{\mathrm{QED}} = \frac{a}{2}\sum_l (\hat{E}_{l,l+1}^2) - \frac{\mathrm{i}}{2a}\sum_l (\hat{\psi}_l^\dagger \hat{U}_{l,l+1} \hat{\psi}_{l+1} - \mathrm{H.c.}) + \frac{a}{2}\sum_l m(-1)^l \hat{\psi}_l^\dagger \hat{\psi}_l$$

Static electric field

Matter field—Gauge field coupling

Kogut & Susskind, *Phys. Rev. D* 11, 395(1975).

Target Hamiltonian

Matter －gauge interaction

Effective mass；particle-hole

$$\hat{H}_{\mathrm{QLM}} = \sum_l [-\frac{\mathrm{i}\tilde{t}}{2}(\hat{\psi}_l \hat{U}_{l,l+1}^{+} \hat{\psi}_{l+1} - \mathrm{H.c.}) + m\hat{\psi}_l^\dagger \hat{\psi}_l]$$

1D lattice Schwinger model

Target Hamiltonian

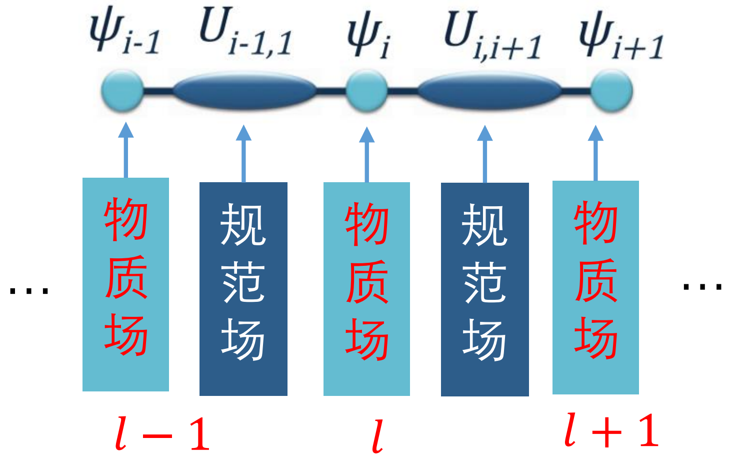
gauge field

matter field, fermionic

$$\hat{H}_{\mathrm{QLM}} = \sum_l [-\frac{\mathrm{i}\tilde{t}}{2}(\hat{\psi}_l \hat{U}^{+}_{l,l+1}\,\hat{\psi}_{l+1} - \mathrm{H.c.}) + m\hat{\psi}^{\dagger}_l\,\hat{\psi}_l]$$

Matter-gauge interaction

变换为实验中的
粒子数产生、湮灭算符



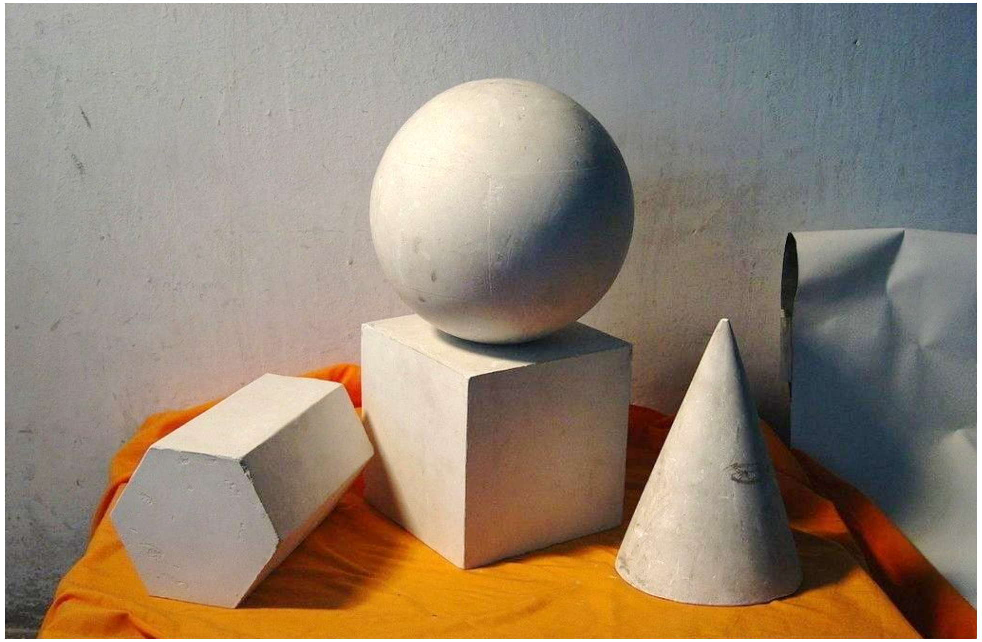
$$\hat{H}_{\mathrm{QLM}} = \sum_l [\frac{\tilde{t}}{2\sqrt{2}}(\hat{a}_l(\hat{d}^{+}_{l,l+1})^2\,\hat{a}_{l+1} + \mathrm{H.c.}) + m\hat{a}^{\dagger}_l\,\hat{a}_l]$$

此即目标Hamiltonian

- $\hat{a}_l$是物质场格点上的算符
- $\hat{d}_{l,l+1}$是规范场格点上的算符，也是单粒子算符，脚标$(l, l+1)$仅代表这两个格点之间的链接

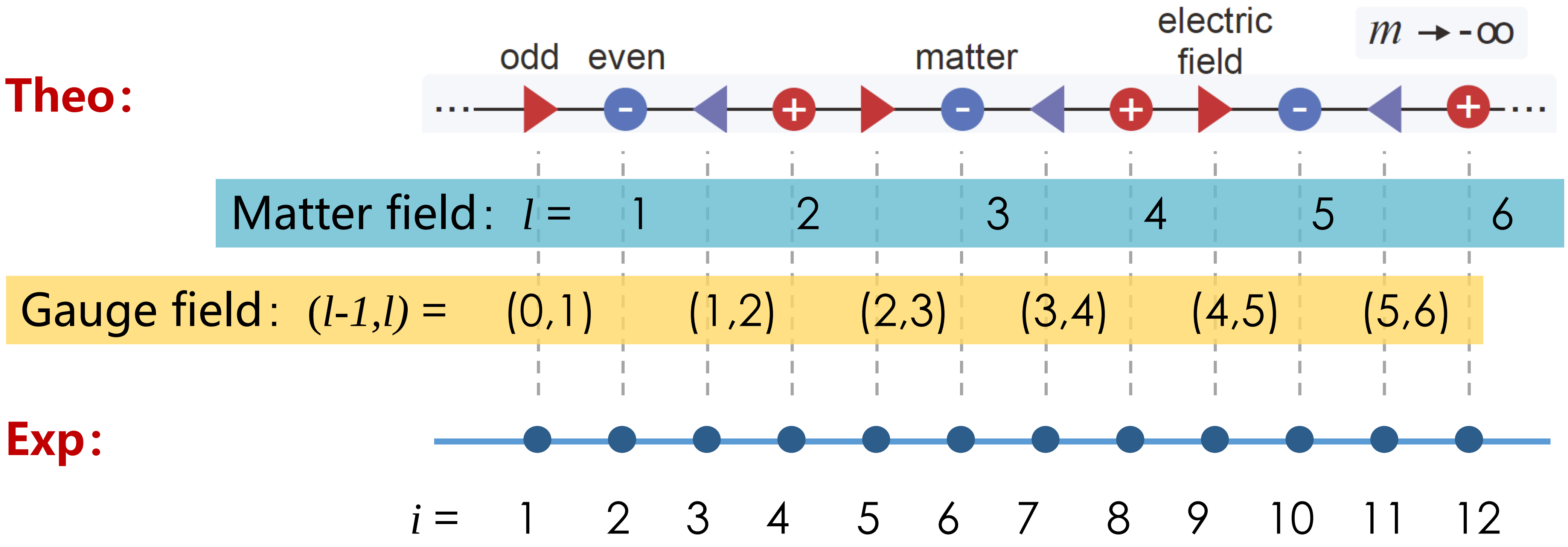
A naïve picture

$$\hat{H} = -J \sum_{\langle i,j \rangle} \hat{a}_i^\dagger \hat{a}_j + \frac{U}{2} \sum_i \hat{n}_i(\hat{n}_i - 1) - \sum_i \mu_i \hat{n}_i,$$

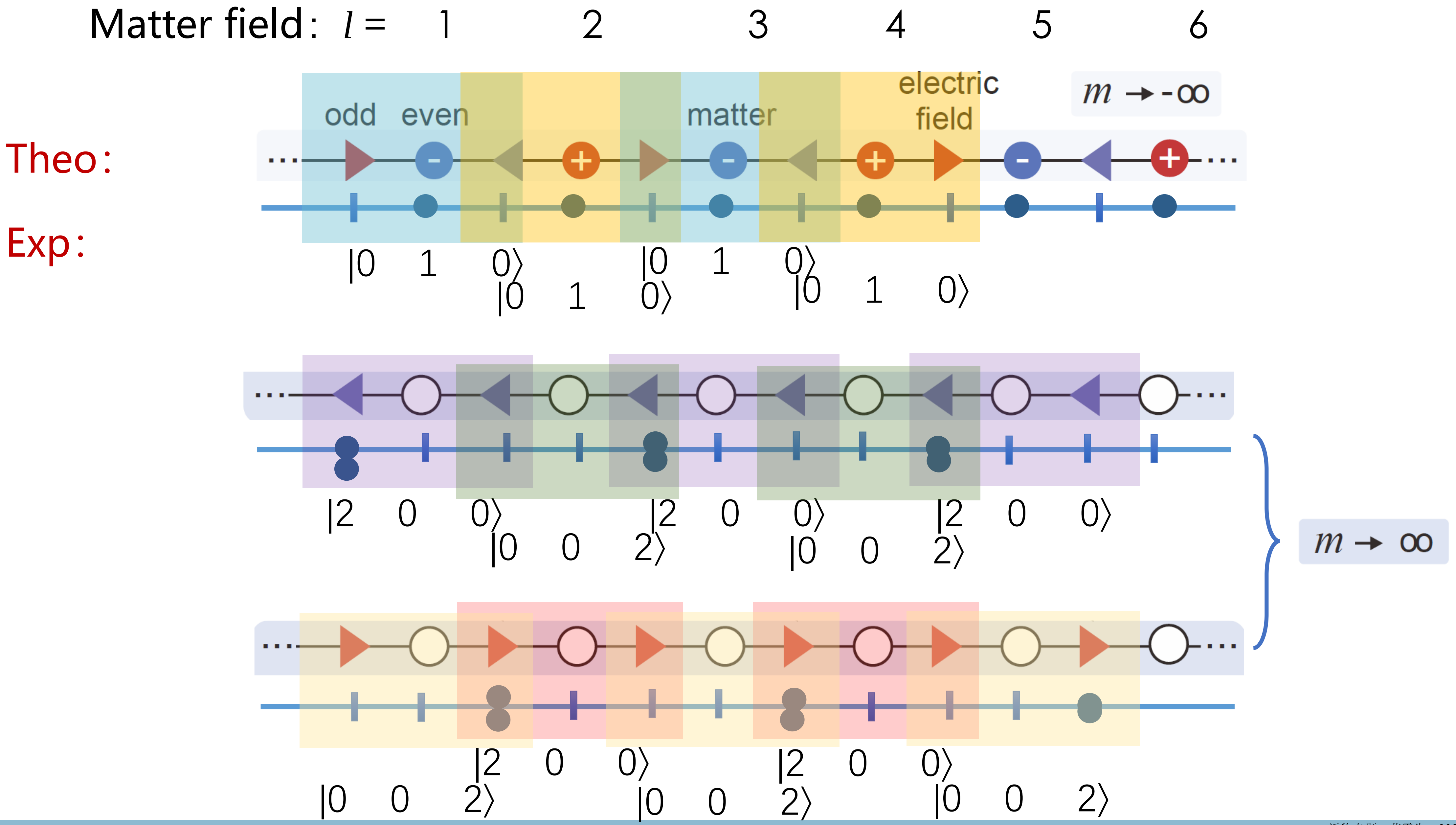


$$\hat{H}_{\mathrm{QLM}} = \sum_l [\frac{\tilde{t}}{2\sqrt{2}} \left(\hat{a}_l (\hat{d}_{l,l+1}^\dagger)^2 \hat{a}_{l+1} + \mathrm{H.c.} \right) + m \hat{a}_l^\dagger \hat{a}_l]$$

Theo --- Exp mapping



Theo --- Exp mapping



Experimental realization

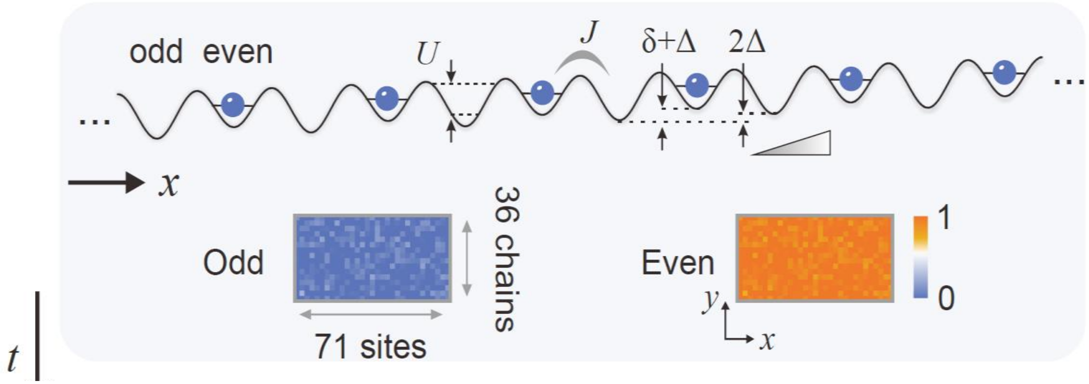
$$\hat{H}_{\mathrm{QLM}} = \sum_{l}[\frac{\tilde{t}}{2\sqrt{2}}\left(\hat{a}_l(\hat{d}^{\dagger}_{l,l+1})^2\,\hat{a}_{l+1} + \mathrm{H.c.}\right) + m\hat{a}^{\dagger}_l\,\hat{a}_l]$$

- 制备初态： $|010101010101\cdots\rangle$

  整条链加线性倾斜，

  $m = \delta - U/2$ δ intra double well

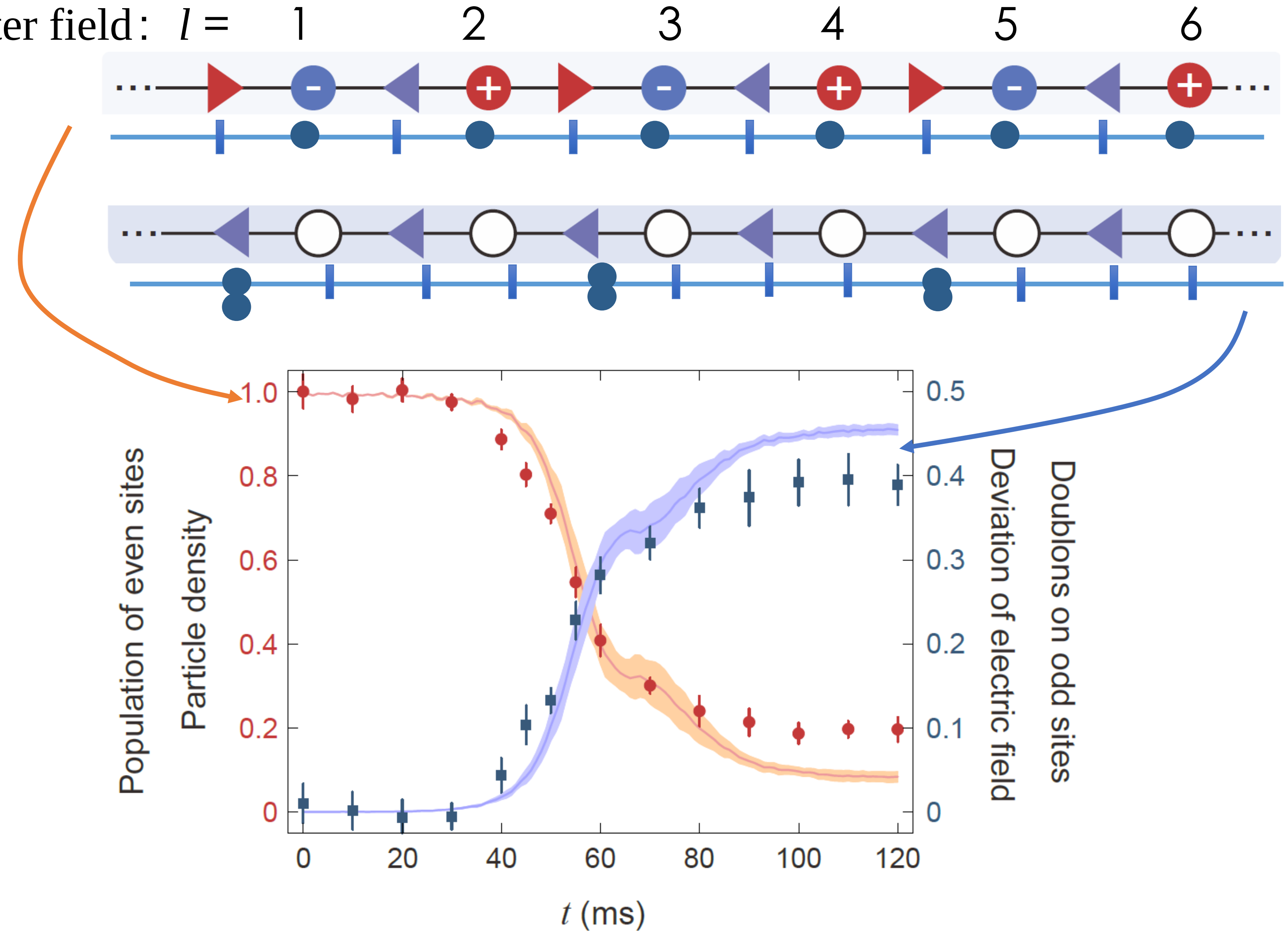
  $\tilde{t} = 8\sqrt{2}J^2/U$ Δ inter double well



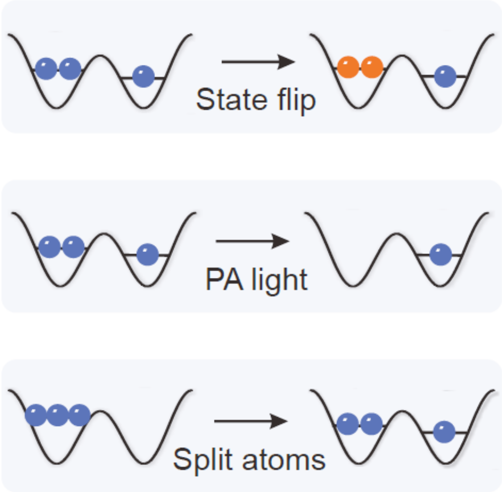
- 在120 ms内绝热改变相互作用U

$$\frac{m}{\tilde{t}}: -\infty \to \ 0 \to \ \infty$$

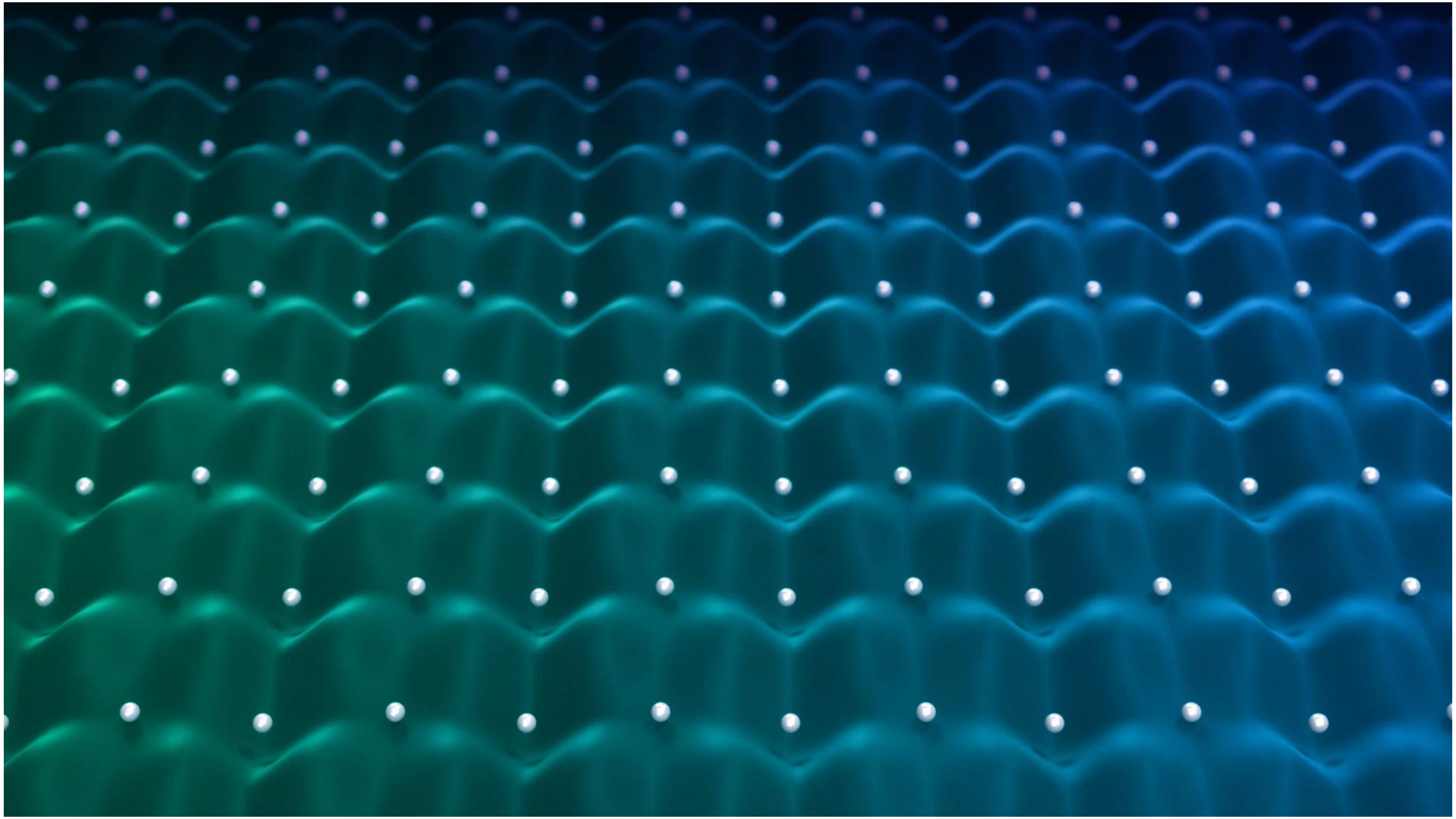
Experimental observation



通过自旋依赖、原子碰撞等方法测量奇偶格点上的原子占据数



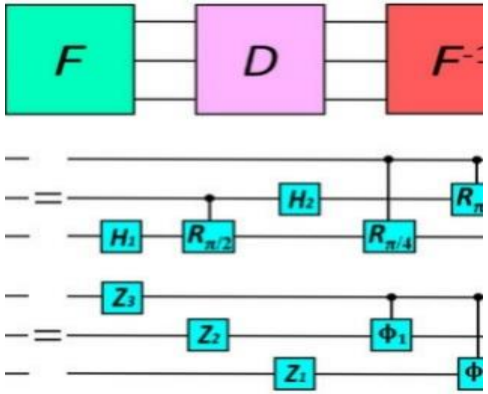
Simulation of lattice gauge field

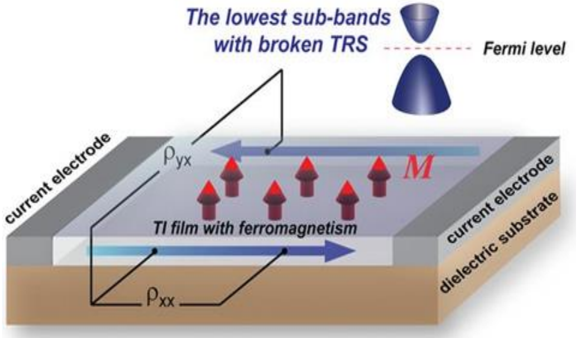


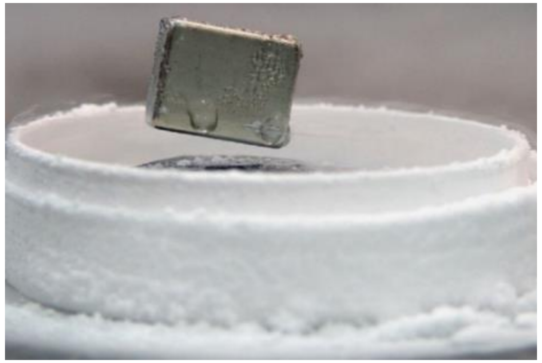
Yang B, ……Yuan Z -S, Hauke P, Pan J- W, Nature 2020

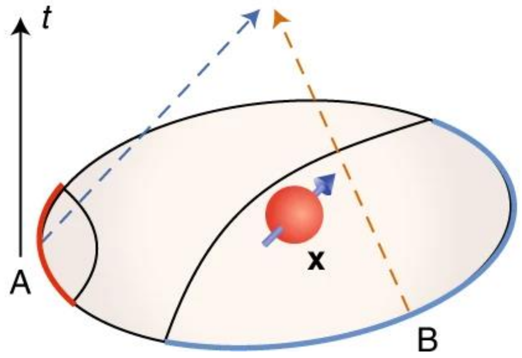
动画：梁琰、石千惠、苑震生等

Outlook—Quantum computation and simulation









- Manipulating atomic qubits，Quantum computation，Demonstration of quantum advantage over classical supercomputers
- Simulation of quantum Hall effect、topological insulators、H-Tc superconductivity, physics of black hole and quantum gravity

Quantum computer quest, Nature 516, 25 (2014)

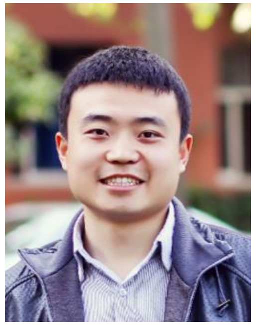
Does gravity come from quantum information? Nature Physics 14, 984 (2018)

Thanks to

Co-PI:

Jian-Wei Pan
(USTC)

Experiment:



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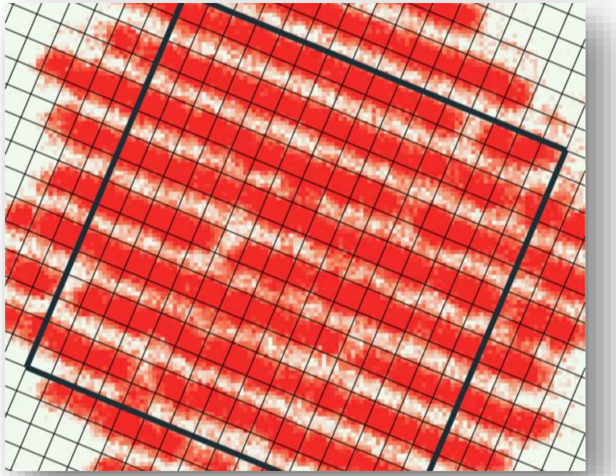
(中科院物数所)

Thanks to—quantum gas microscope group



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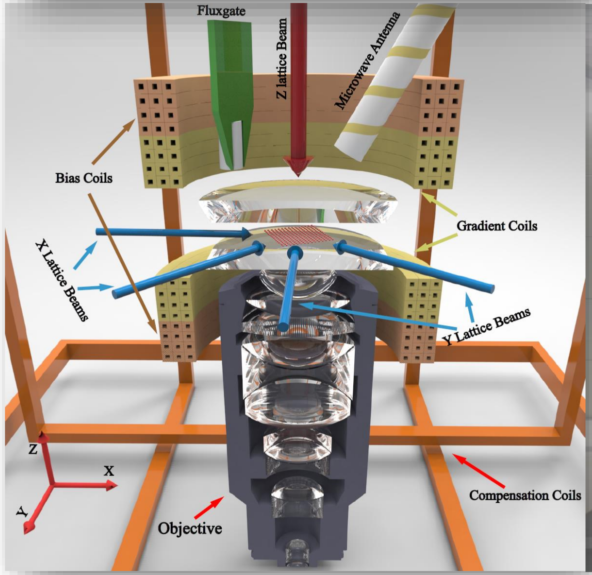
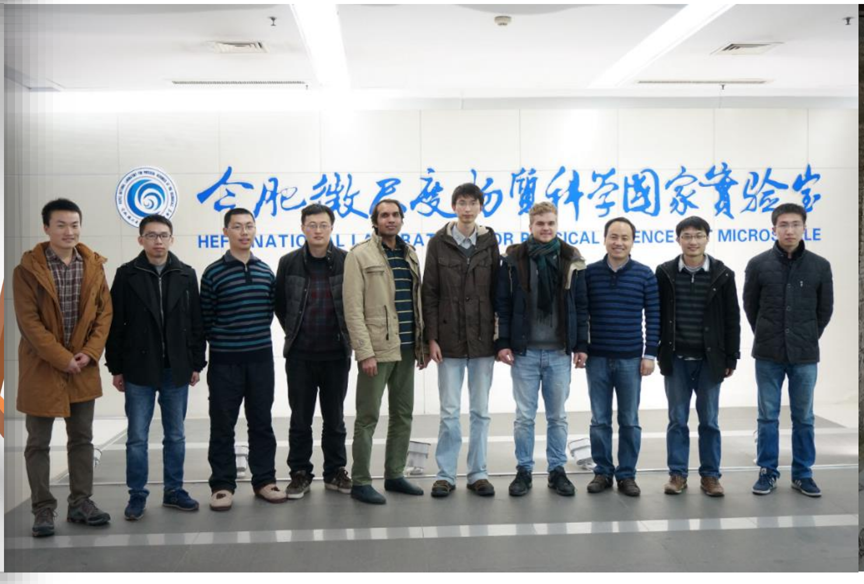
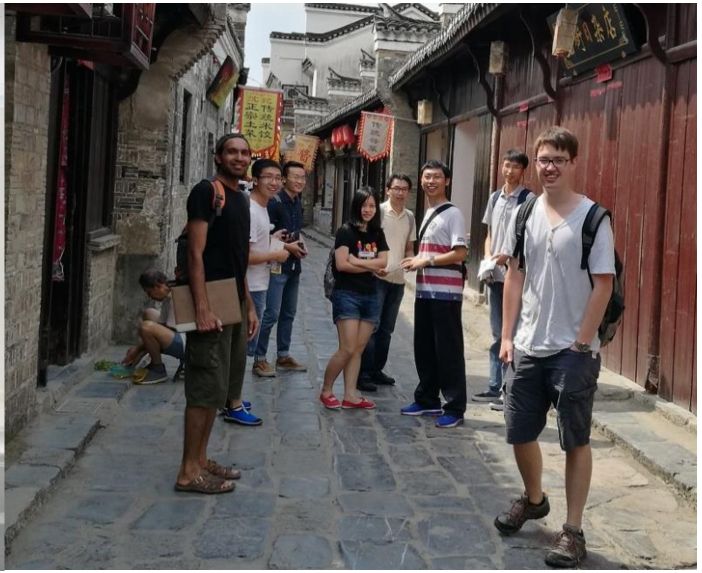
周肇宇、王翰逸、骆安、林婉、刘颖、苏国贤、

禹松涛、朱子杭、何明根、Timo、 ....

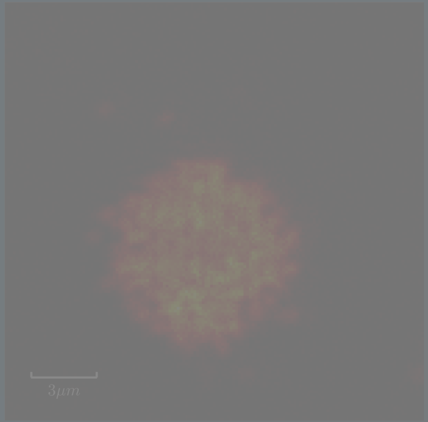






Outline

Ultracold Atoms



Application in Quantum Science

Our Team and Research

Our team

http://quantum.ustc.edu.cn

Hefei National Laboratory of Physical Sciences at the Microscale

中文 English

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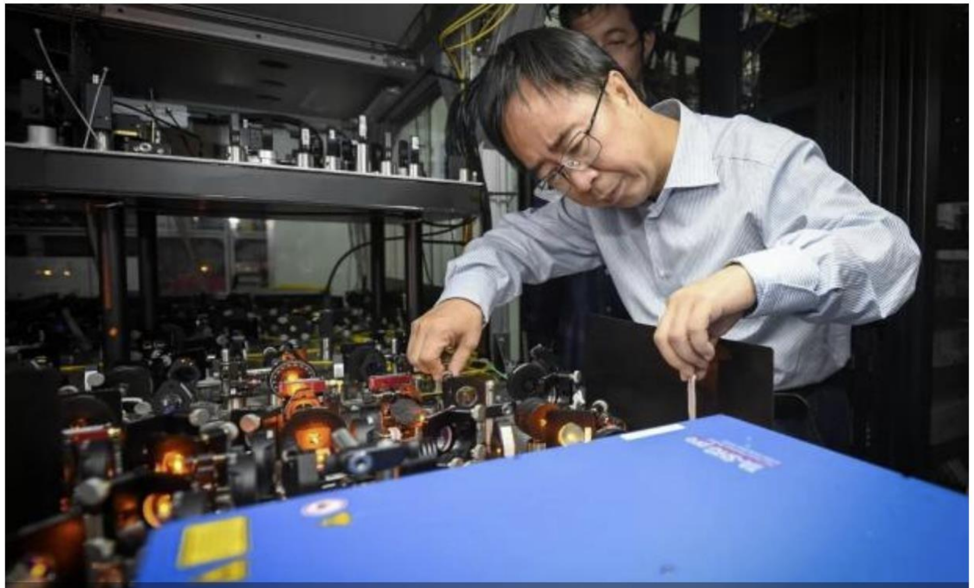


Prof.Pan wins OSA 2019 Wood Prize

News

2020-06-07 It Broke Our Hearts to Lose You, Jon

2019-03-22 Prof.Pan wins OSA 2019 Wood Prize

2019-01-31 Chinese Study on Quantum Communication Wins Newcomb Cleveland Prize

2019-01-18 Collision Resonances between Ultracold Atom and Molecules Visualized fo...

2018-12-17 [Physics] Highlights of the Year

2018-07-04 [Global Times] Chinese Physicists' Quantum Achievement Signals Dawn of ...

2018-01-12 [Anhui News] Pan Jianwei Wins Willis E.Lamb Award

Progress

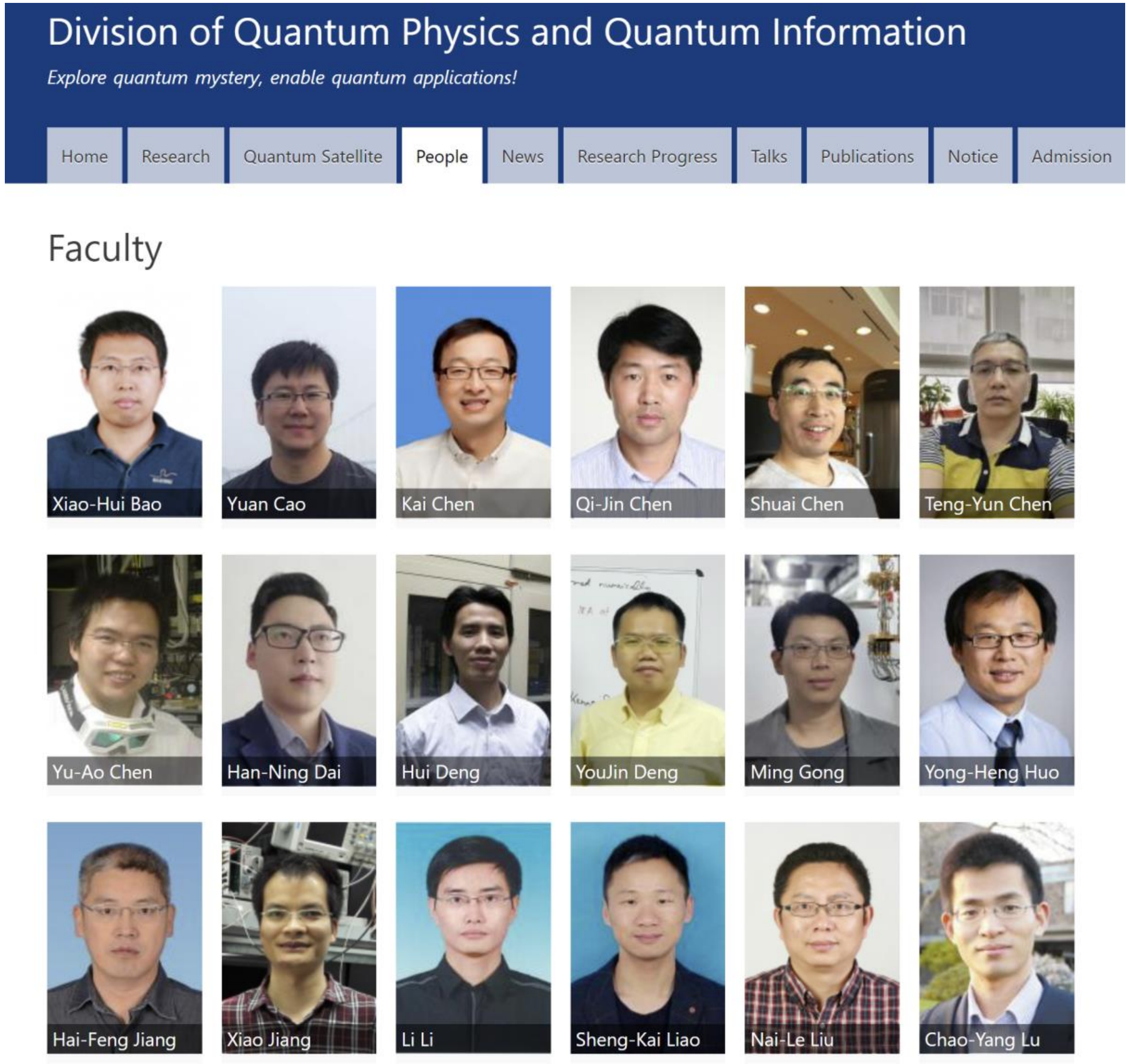
2019-07-01 Observation of Interference between Resonant and Detuned STIRAP in the...

2019-04-28 Experimental Demonstration of High-Rate Measurement-Device-Independend...

2019-04-08 Degenerate Bose gases near a d-wave shape resonance

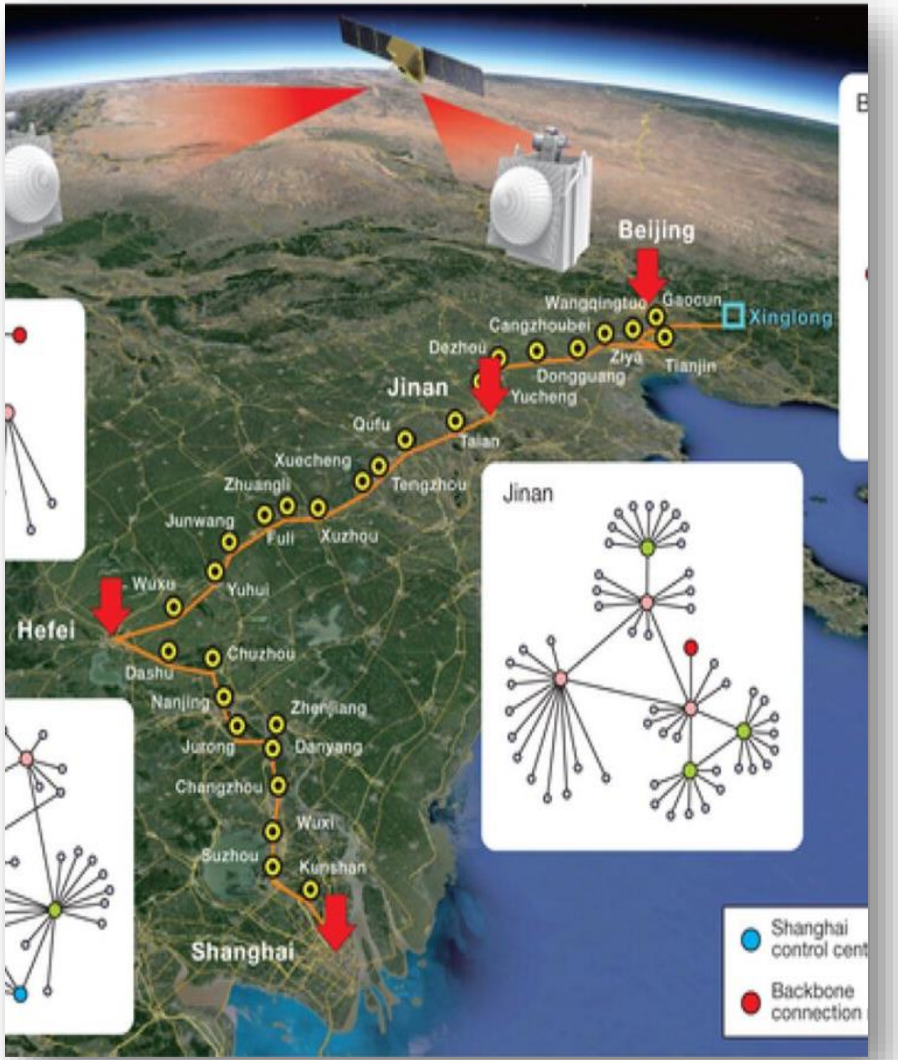
2019-03-27 Synopsis: Entangled Photon Source Ticks All Boxes

Our team (>40 faculty members)



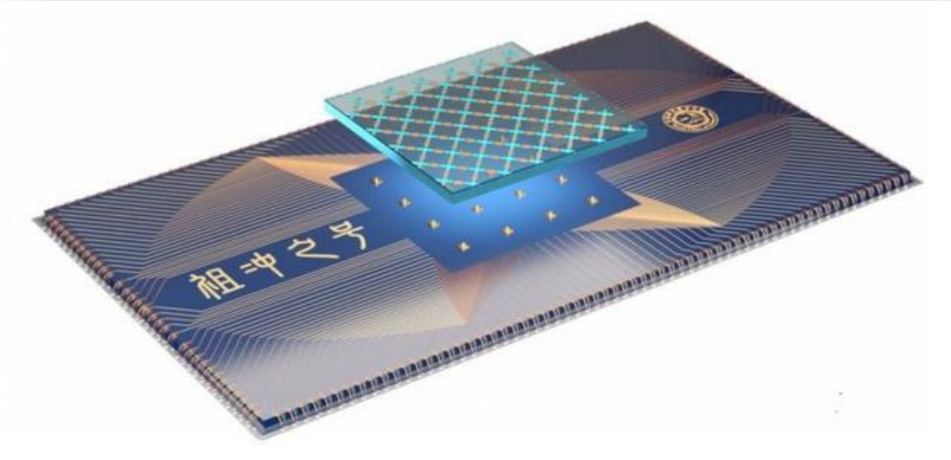
Research topics—Quantum communication

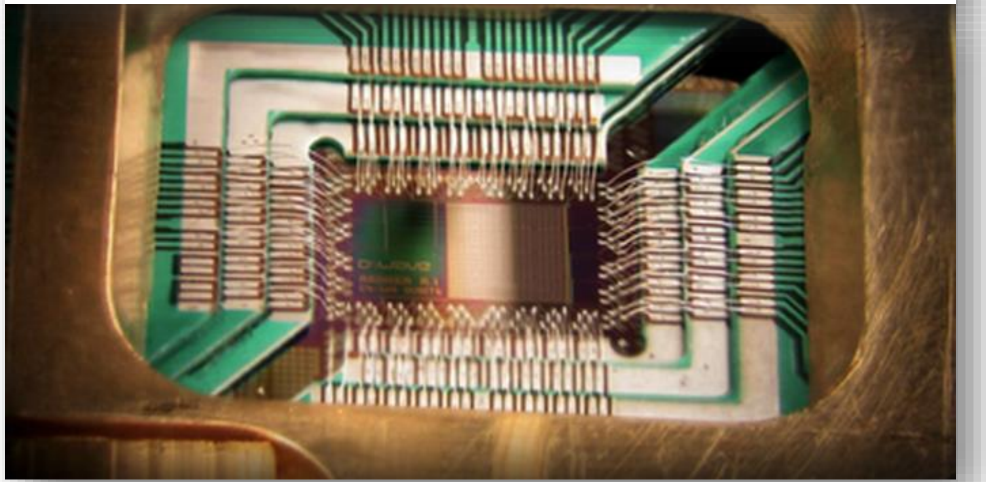
Quantum satellite



Fiber network

Quantum computation

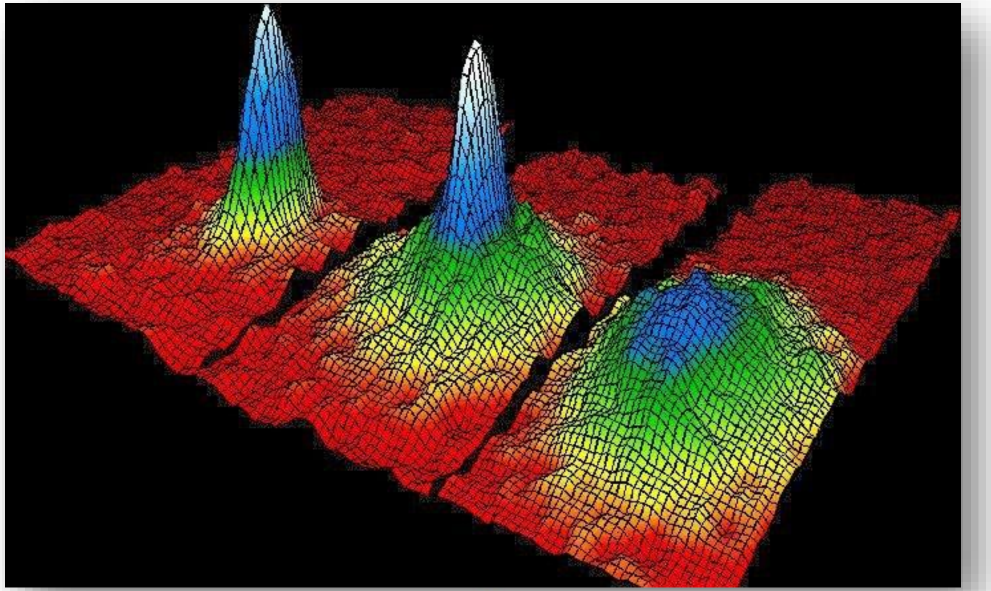


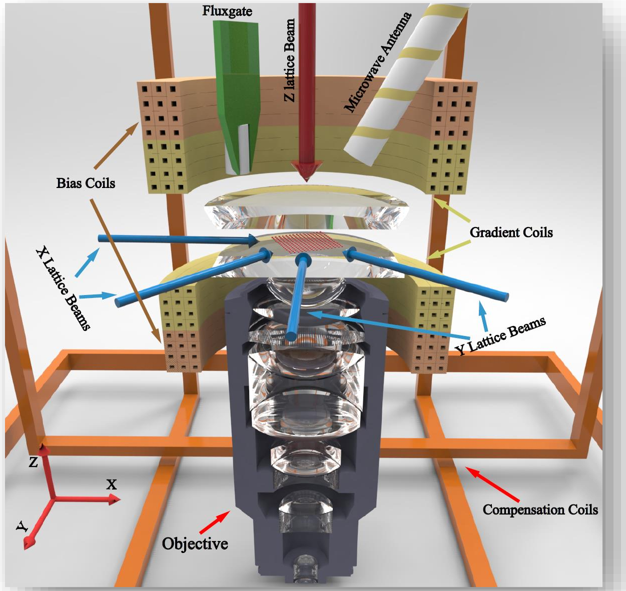


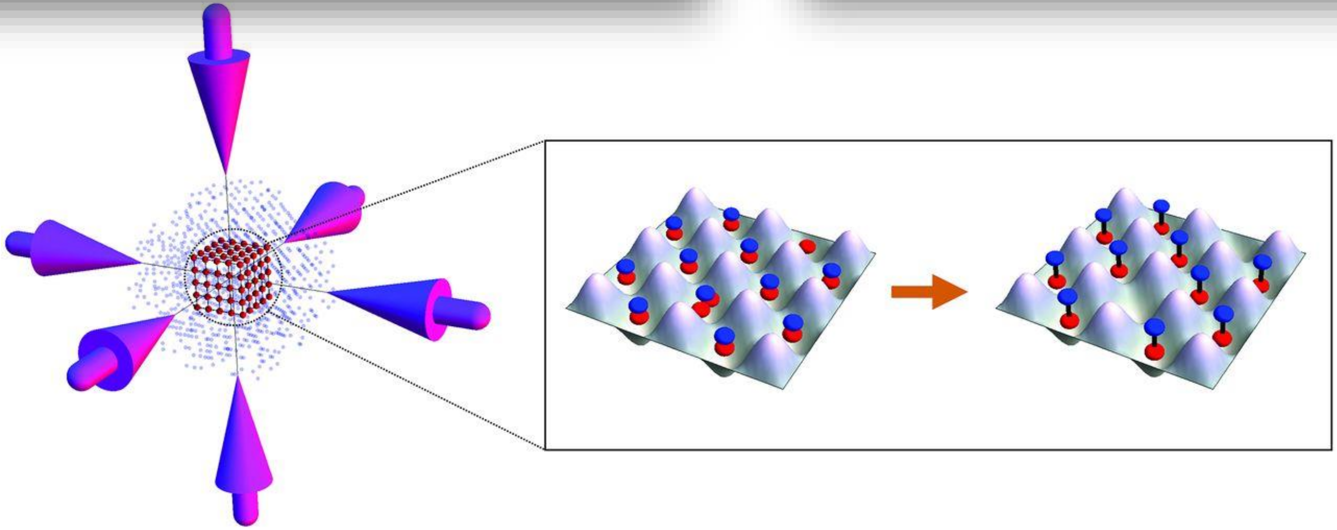
Photonic circuit

Superconducting circuit

Quantum simulation

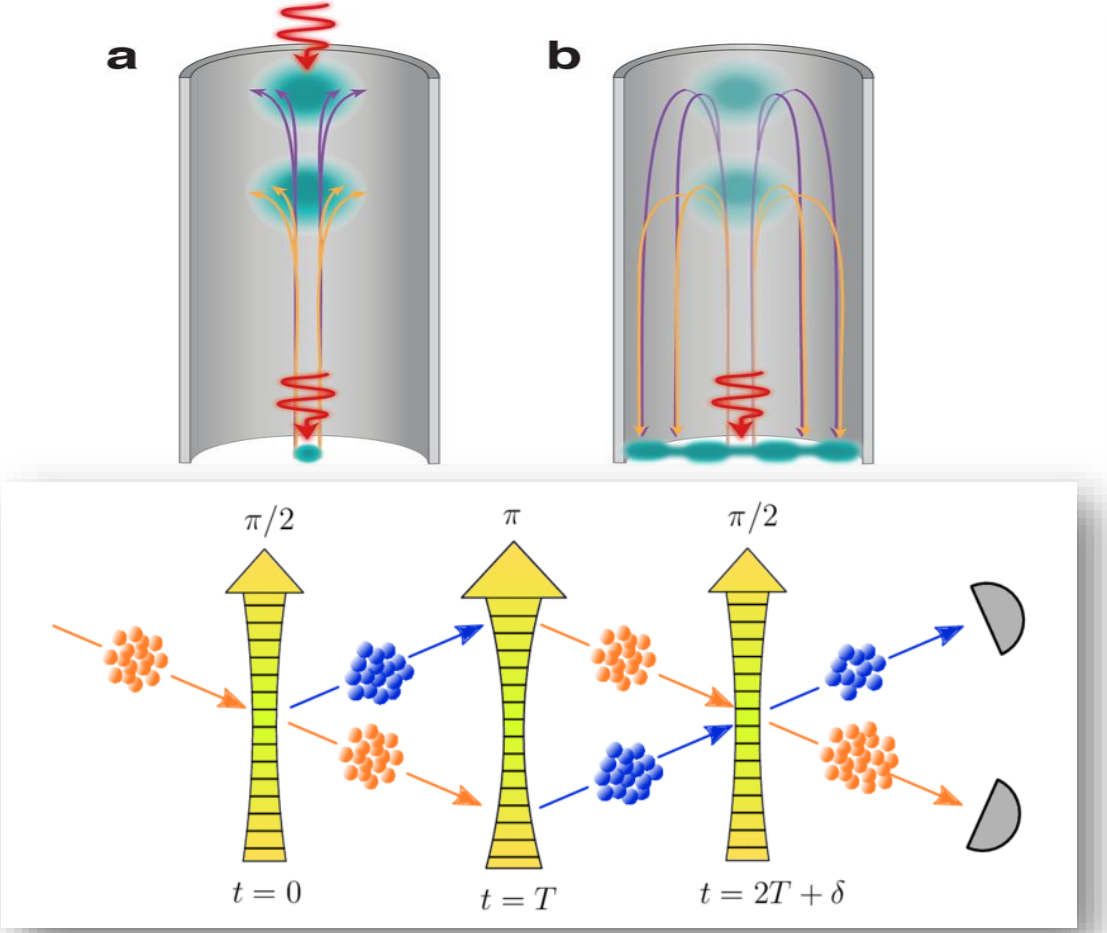




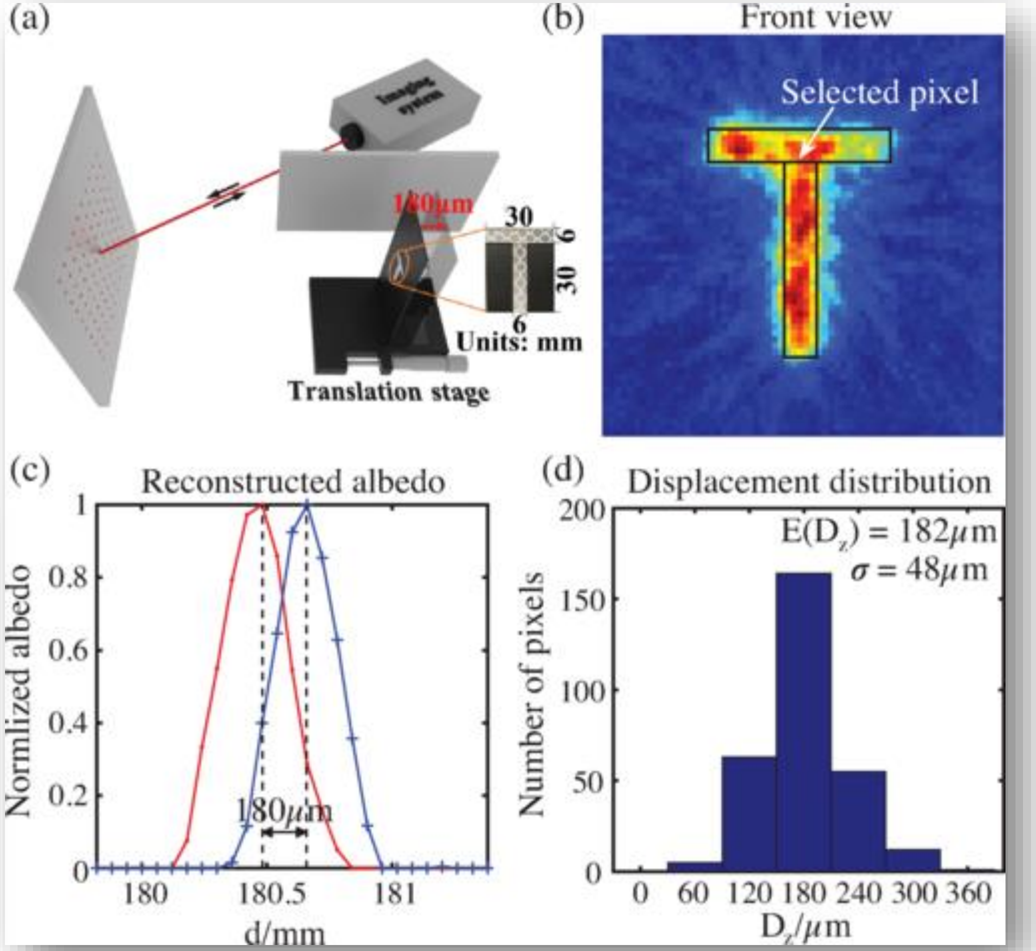


Ultracold atom quantum simulation

Quantum interferometry and imaging

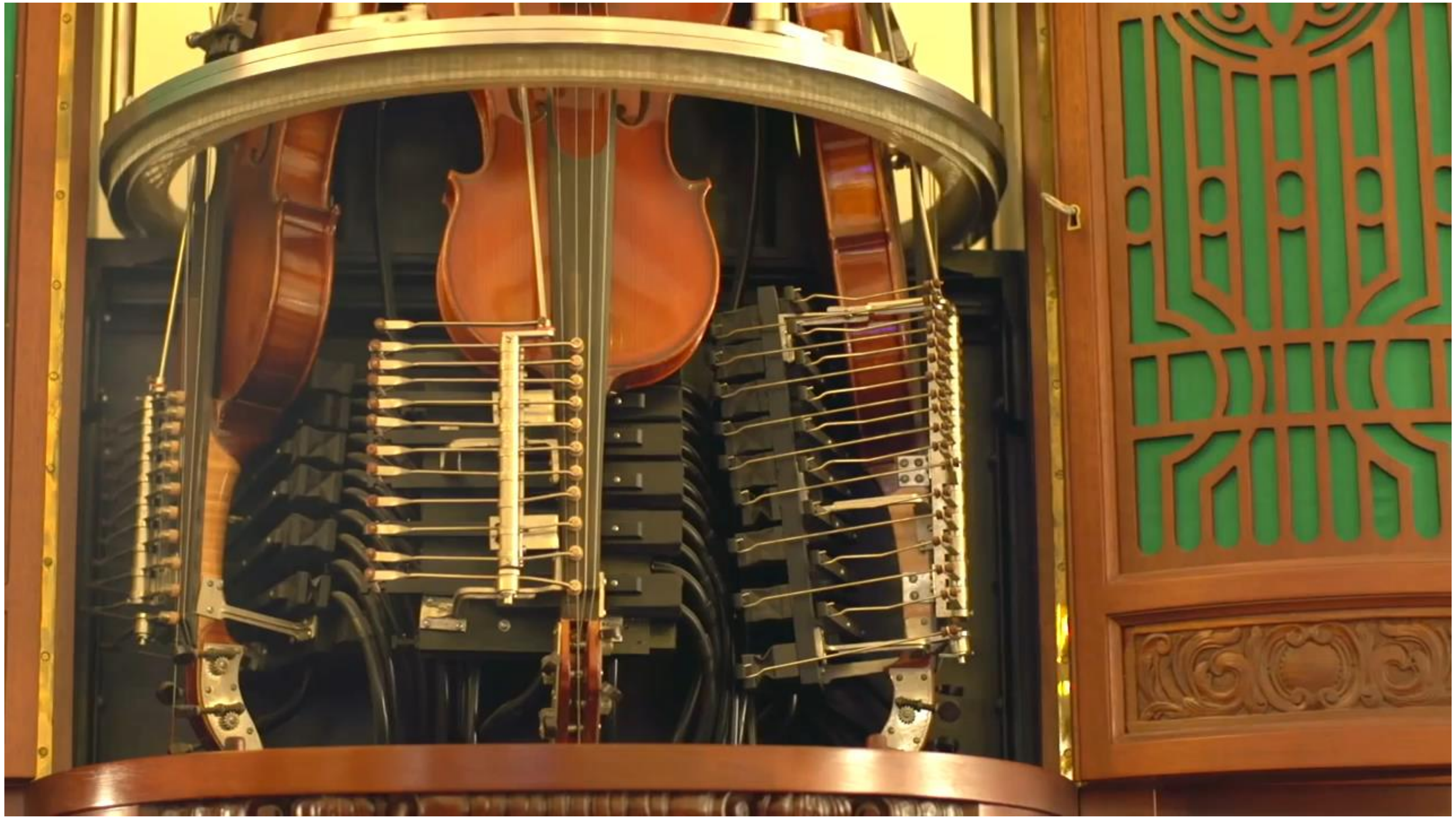


atom interferometer



single-photon imaging

Thanks for your attention



You are welcome to join us!