

2022年诺贝尔物理学奖解读

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MSCA ITN fellowship

2021-至今 维也纳大学 物理系 博士在读

2017-2020 日本京都大学 电子科学工程系 修士学位

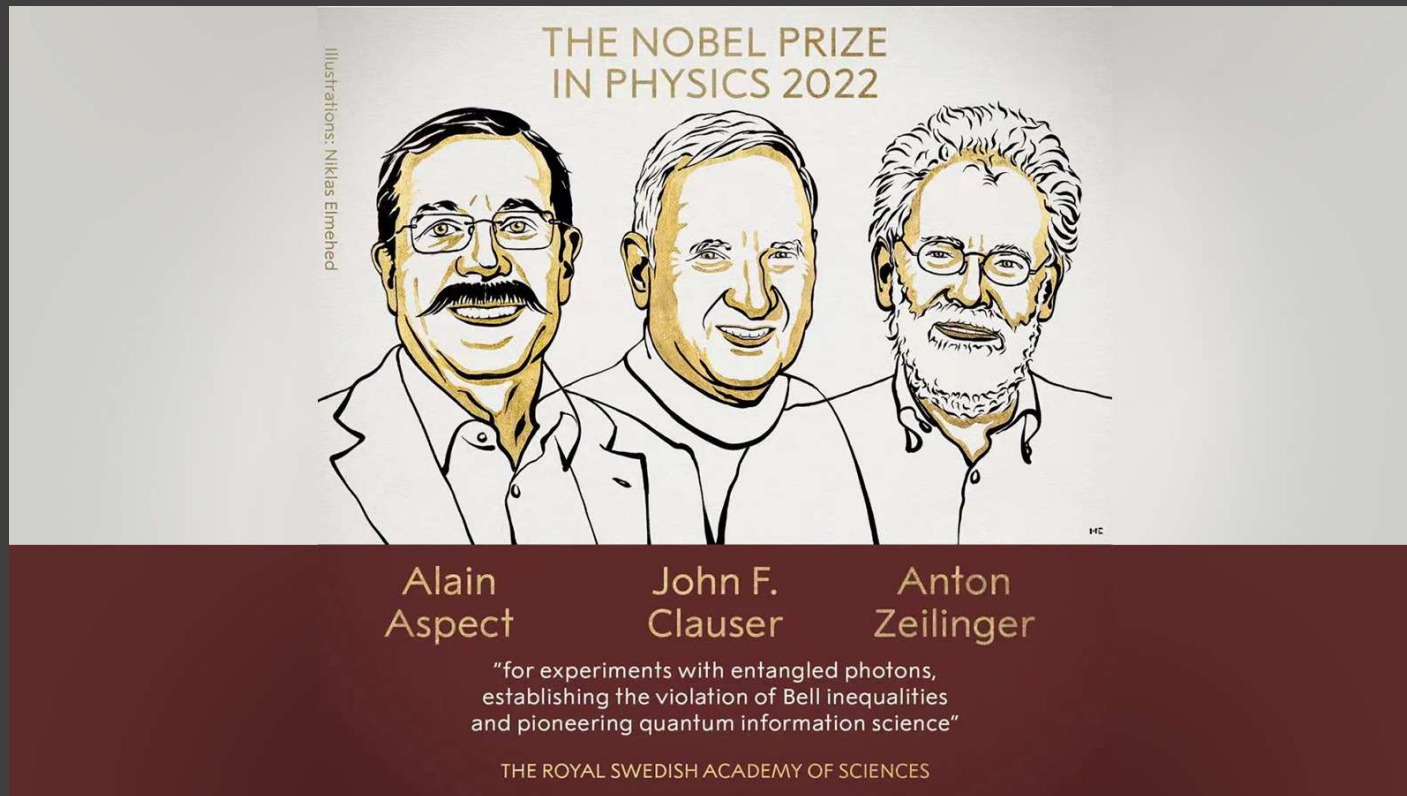
2013-2017 南京大学 物理学 学士学位 (马小松课题组)

目前研究: 量子计算, 量子机器学习, 光电集成

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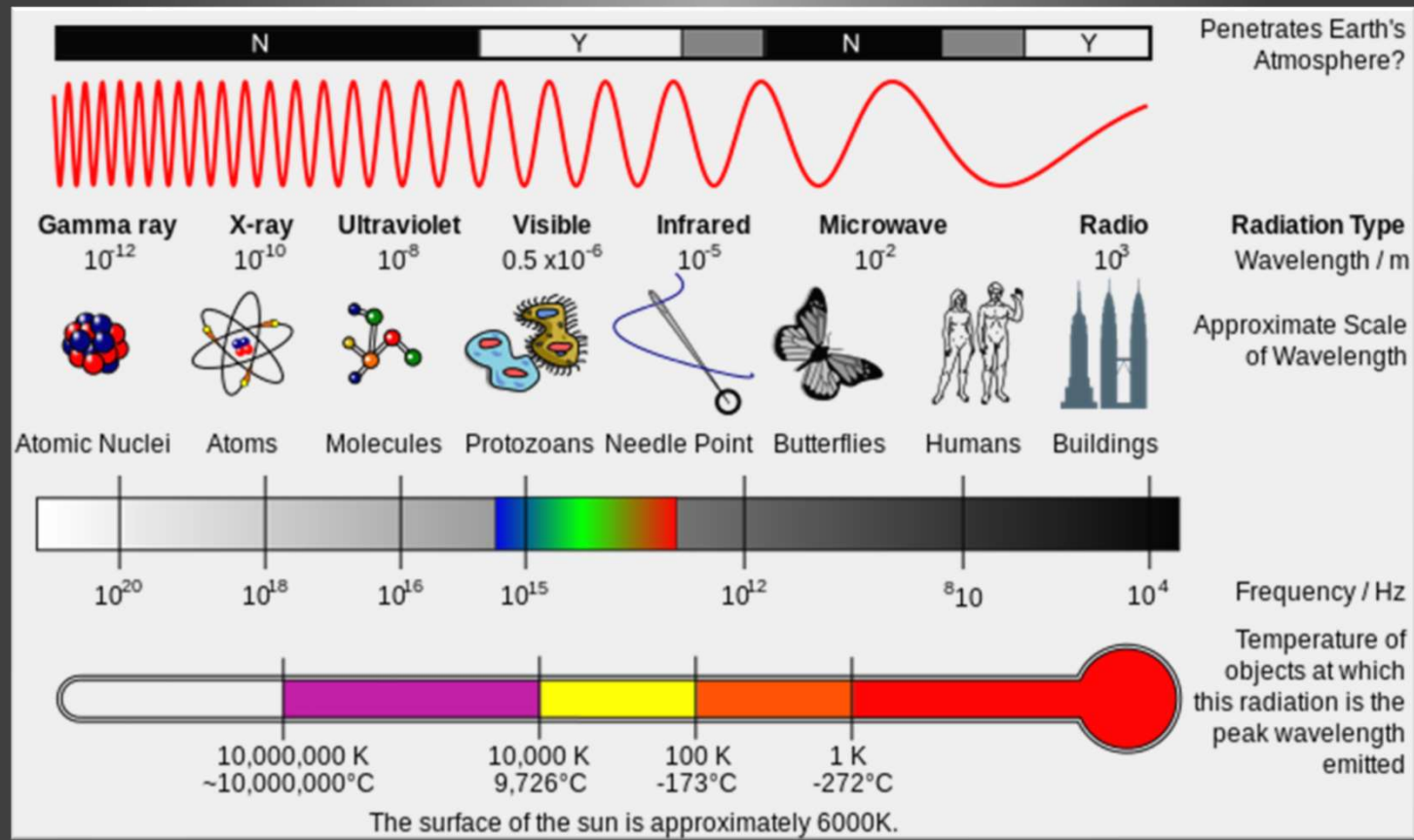




“因其纠缠光子实验、验证违反贝尔不等式和开创量子信息科学”

- 量子力学简单介绍
- 何谓量子纠缠?
 - 哥本哈根诠释
 - 爱因斯坦以及EPR佯谬
 - 贝尔不等式以及CHSH不等式
- 诺奖得主介绍及其实验证明
- 近期量子科学发展

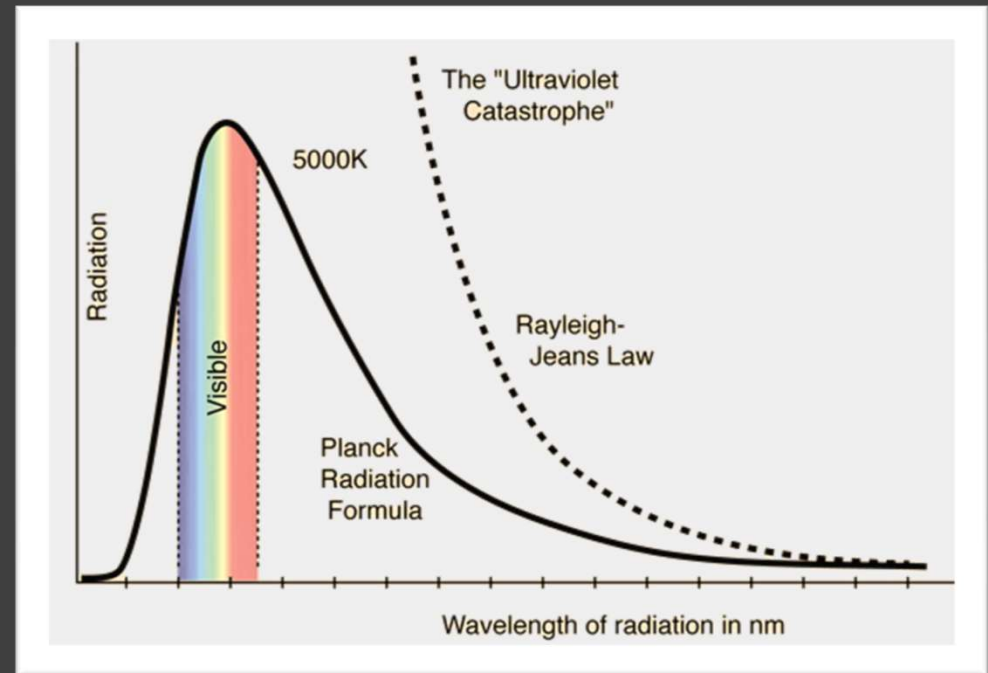
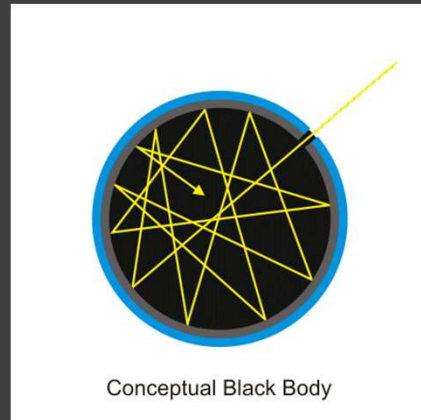
从人类世界
到原子世界





Max Planck

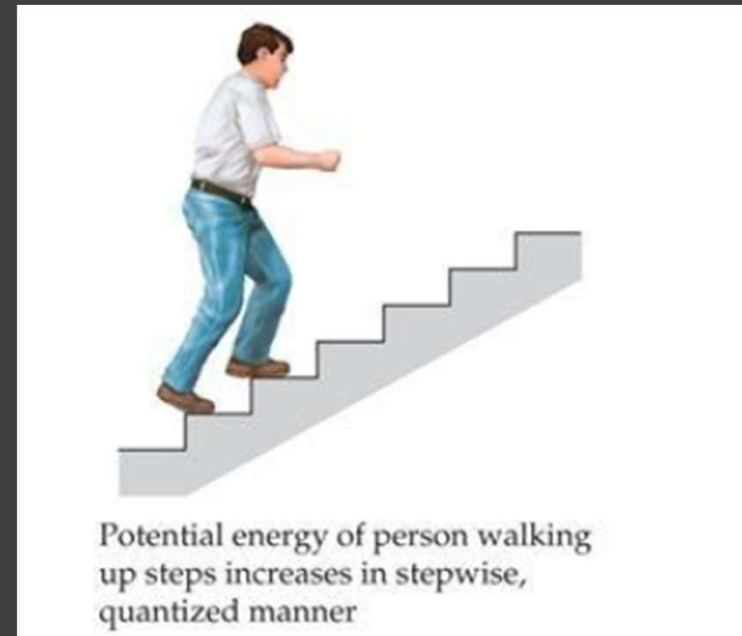
黑体辐射



能量量子 (Energy quanta)



经典力学

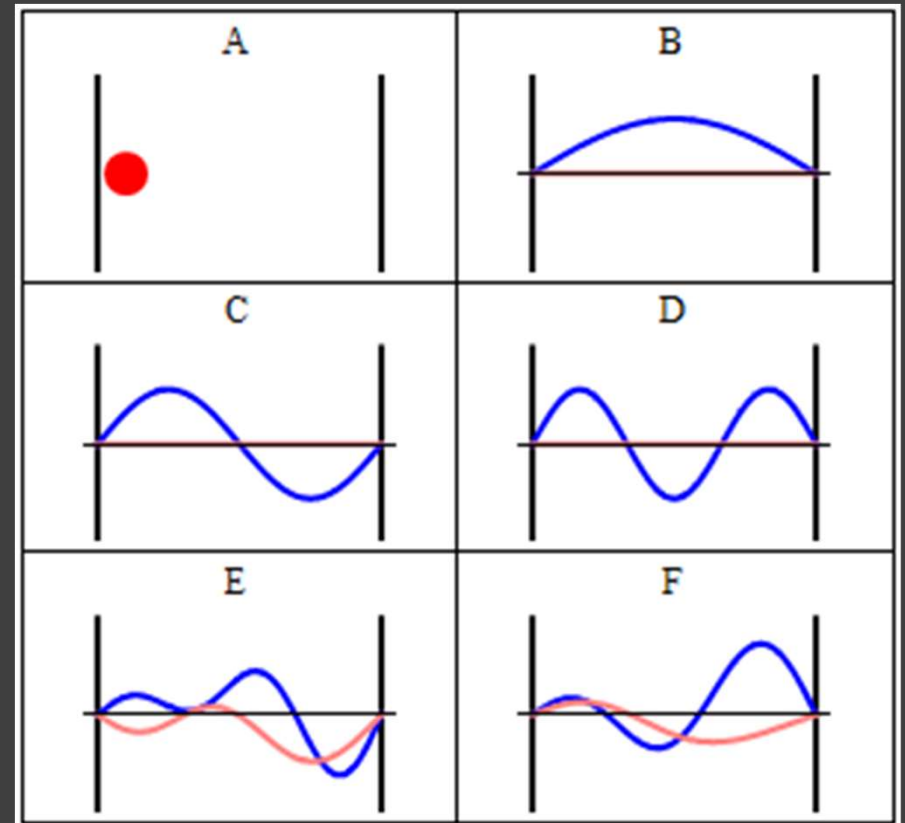


量子力学

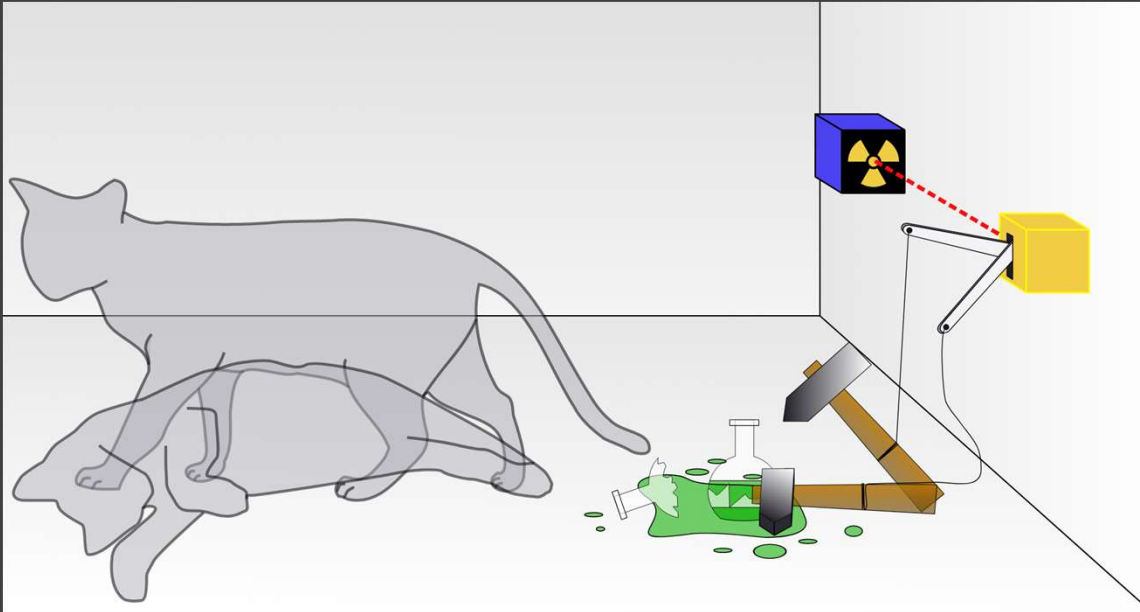
量子力学的源起之二：不确定性 (Uncertainty)



Erwin Schrödinger

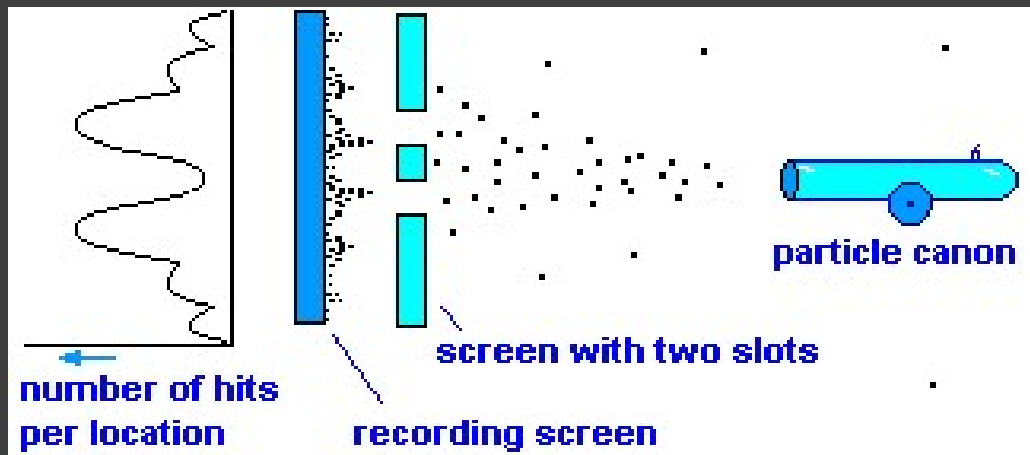


薛定谔猫佯谬

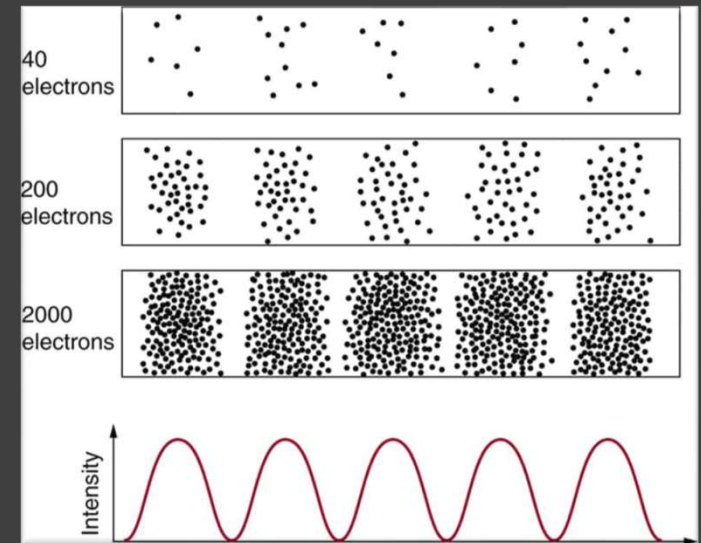


状态：是死是活？即死又活？
测量：死活只能二选一

不确定性客观存在，但当
时还没有统一的解释
(Zeeman 实验)





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统计学意义上，两者相互统一

量子纠缠 (Entanglement) ?

 : 1 或 0

  : 11, 10, 01, 00

是否存在一个状态, 只包含00与11两个状态 (正关联)
或10与01 (反关联) ?

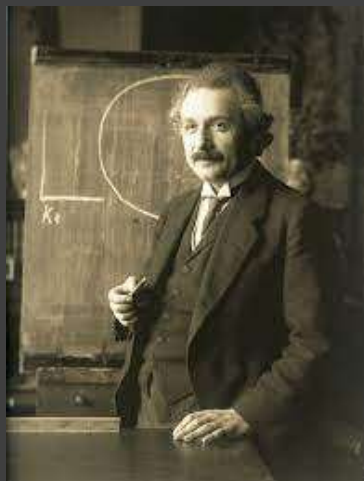
如果存在, 是不是可以分发两个粒子?



那么, 0与0, 1与1, 一定“同时”存在
这是否意味着超光速相互作用?

不存在, “上帝不掷骰子”

同时也不存在超过光速的相互作用



Albert Einstein



Boris Podolsky



Nathan Rosen

EPR佯谬: 隐变量



不存在超过光速的相互作用 ->
存在一个隐变量 (hidden variable) , 在分发之初就决定了测量结果,
状态其实已经决定, 只是并未被测量

哥本哈根诠释: 叠加态 (Superposition)



存在，并且是量子力学又一特质，状态改变只在测量时发生



John Stewart Bell

ON THE EINSTEIN PODOLSKY ROSEN PARADOX*

J. S. BELL[†]*Department of Physics, University of Wisconsin, Madison, Wisconsin**(Received 4 November 1964)*

1. Introduction

THE paradox of Einstein, Podolsky and Rosen [1] was advanced as an argument that quantum mechanics could not be a complete theory but should be supplemented by additional variables. These additional variables were to restore to the theory causality and locality [2]. In this note that idea will be formulated mathematically and shown to be incompatible with the statistical predictions of quantum mechanics. It is the requirement of locality, or more precisely that the result of a measurement on one system be unaffected by operations on a distant system with which it has interacted in the past, that creates the essential difficulty. There have been attempts [3] to show that even without such a separability or locality requirement no "hidden variable" interpretation of quantum mechanics is possible. These attempts have been examined elsewhere [4] and found wanting. Moreover, a hidden variable interpretation of elementary quantum theory [5] has been explicitly constructed. That particular interpretation has indeed a grossly non-local structure. This is characteristic, according to the result to be proved here, of any such theory which reproduces exactly the quantum mechanical predictions.

统计学意义上将两种假设区分开



John Clauser

PROPOSED EXPERIMENT TO TEST LOCAL HIDDEN-VARIABLE THEORIES*

John F. Clauser†

Department of Physics, Columbia University, New York, New York 10027

and

Michael A. Horne

Department of Physics, Boston University, Boston, Massachusetts 02215

and

Abner Shimony

Departments of Philosophy and Physics, Boston University, Boston, Massachusetts 02215

and

Richard A. Holt

Department of Physics, Harvard University, Cambridge, Massachusetts 02138

(Received 4 August 1969)

A theorem of Bell, proving that certain predictions of quantum mechanics are inconsistent with the entire family of local hidden-variable theories, is generalized so as to apply to realizable experiments. A proposed extension of the experiment of Kocher and Commins, on the polarization correlation of a pair of optical photons, will provide a decisive test between quantum mechanics and local hidden-variable theories.

贝尔不等式

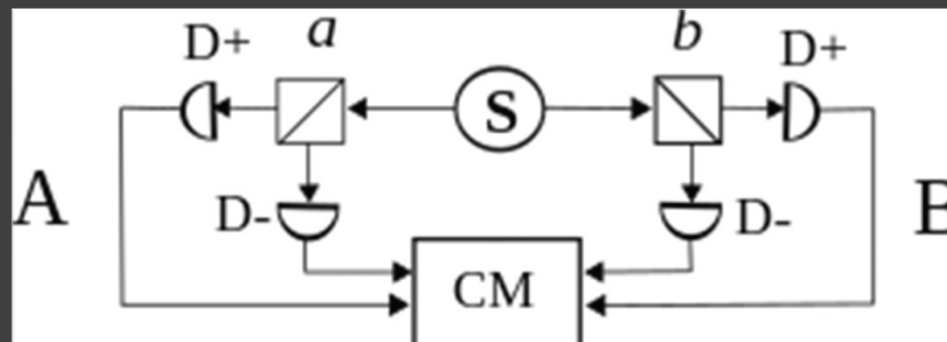
$$|P(a, b) - P(a, c)| < 1 + |P(b, c)|$$



CHSH不等式

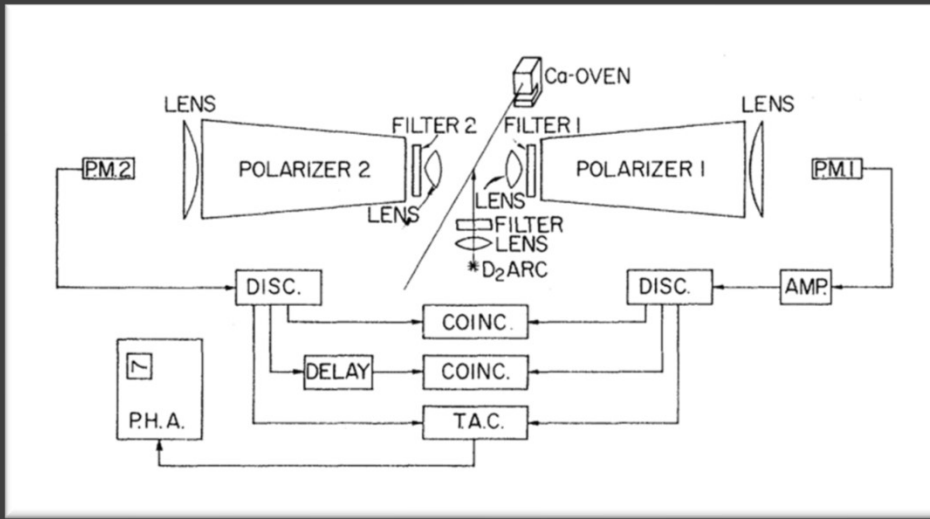
$$P(a, b) - P(a, a') + P(b', b) + P(b', a') < 2$$

量子力学的理论上限为 $2\sqrt{2} = 2.828$



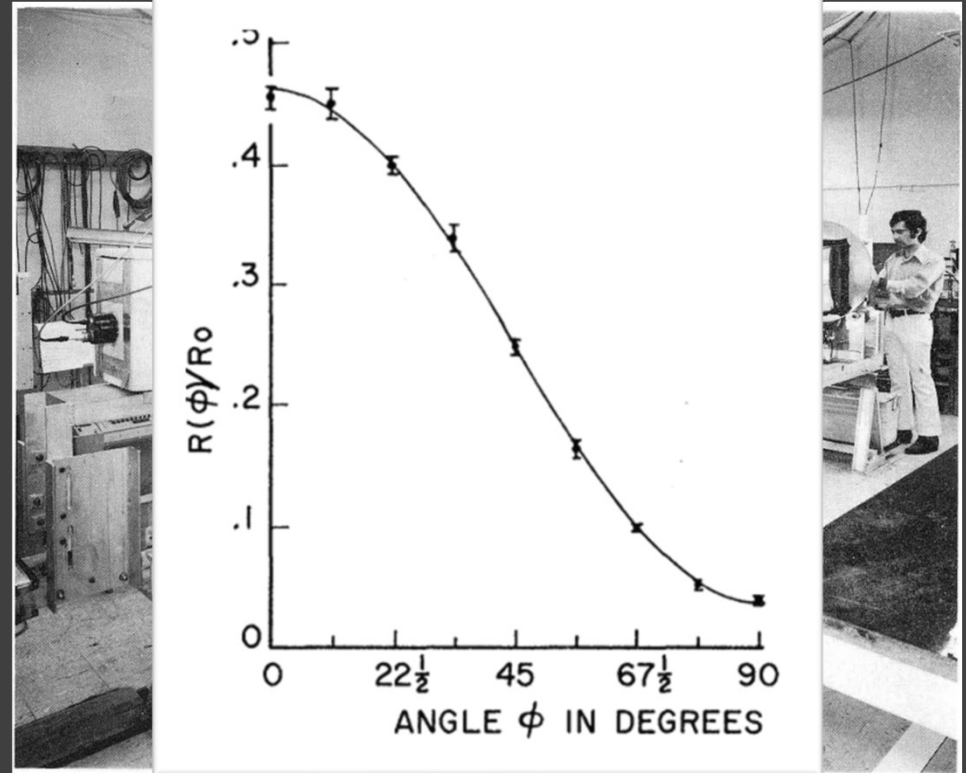
Clauser Ca 原子实验

Lawrence Berkeley Laboratory, USA, 1972



PRL. 28 (14): 938-941

$$\sin\phi|00\rangle + \cos\phi|11\rangle$$



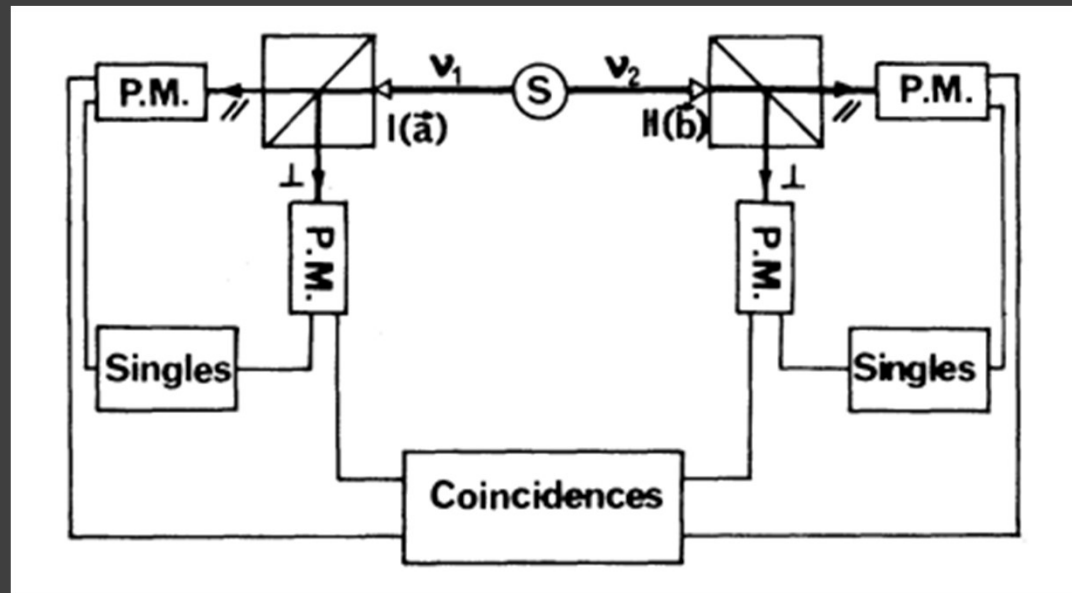
违反量 0.050 ± 0.008

Aspect Ca40 原子实验

Institut d'Optique and Ecole Polytechnique, France, 1982



Alain Aspect

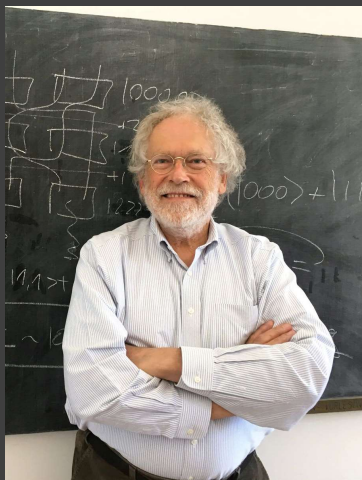


Phys. Rev. Lett. 49, 1804

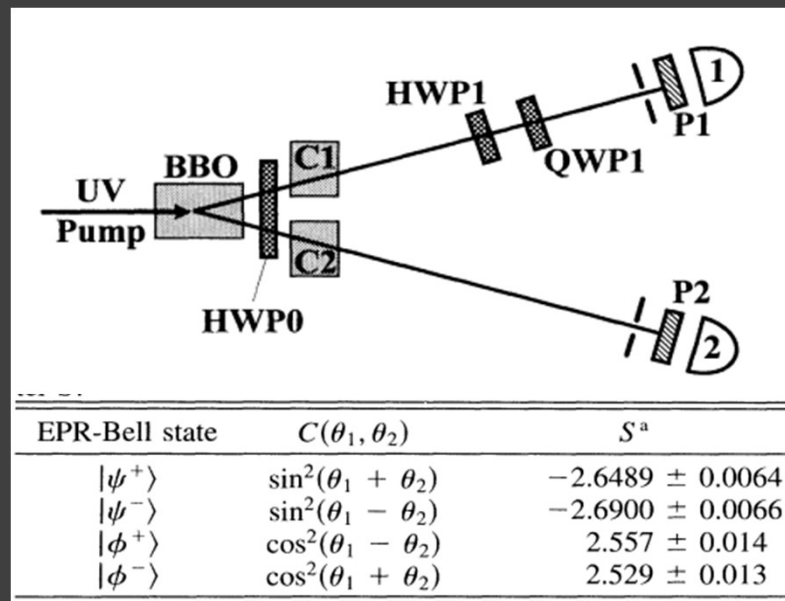
$$P(\perp, \parallel) - P(\parallel, \parallel) + P(\perp, \perp) + P(\parallel, \perp)$$

违反量 0.697 ± 0.015

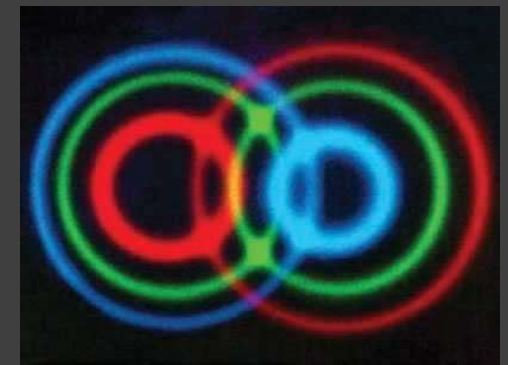
University of Innsbruck, Austria, 1995



Anton Zeilinger



Physical Review Letters 75 (24), 4337



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量子隐形传态 (Quantum teleportation)

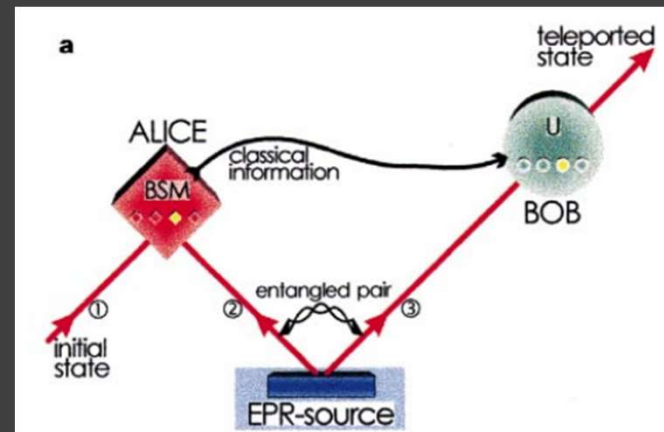
University of Innsbruck, Austria, 1997

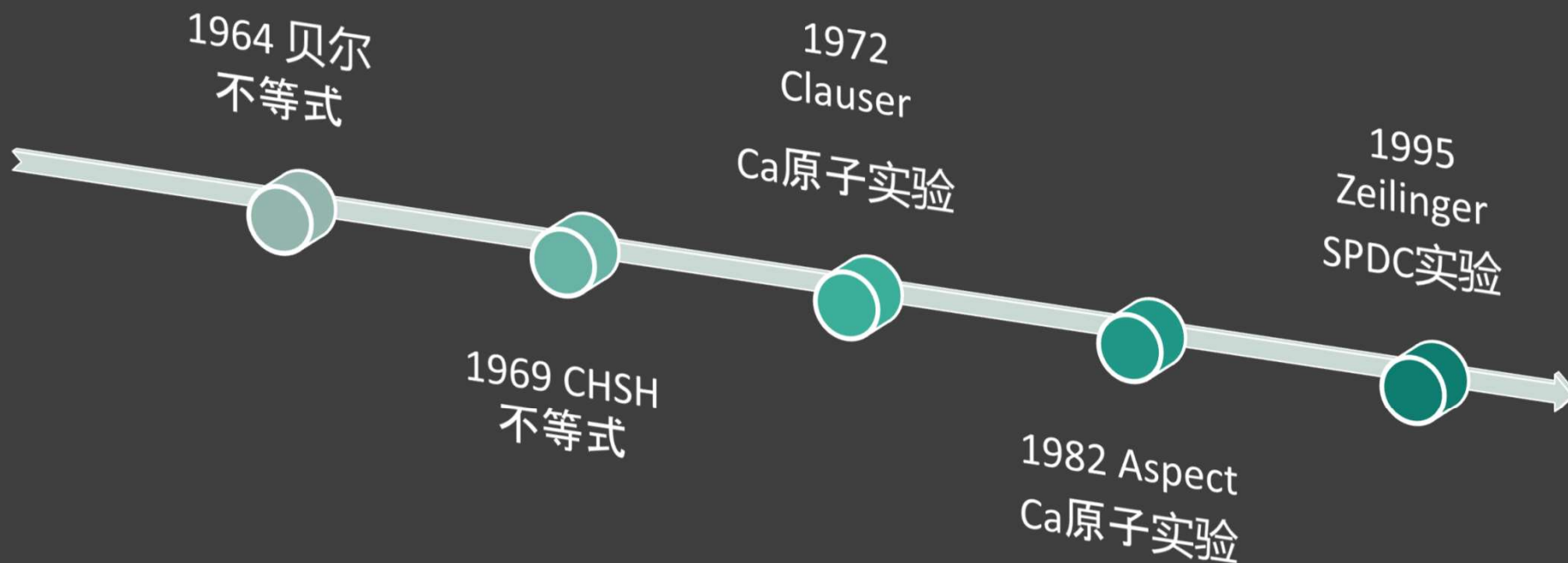


Dirk Bouwmeester



潘建伟





叠加态时量子力学的重要性质!

“不可克隆定理”

- ✓ 军事国防安全
- ✓ 政务保密通信
- ✓ 金融信息加密

京沪干线

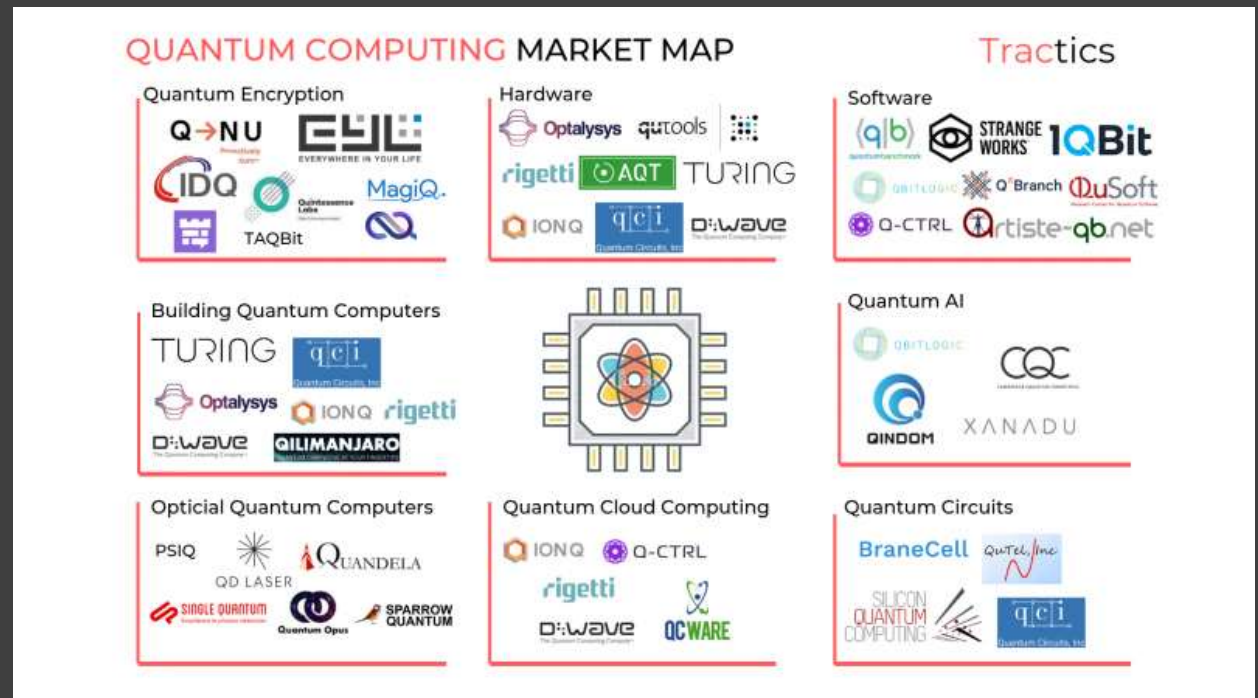
“实现了连接北京、上海，贯穿济南和合肥全长2000余公里的量子通信骨干网络”



量子卫星 (维也纳-北京 加密通话)



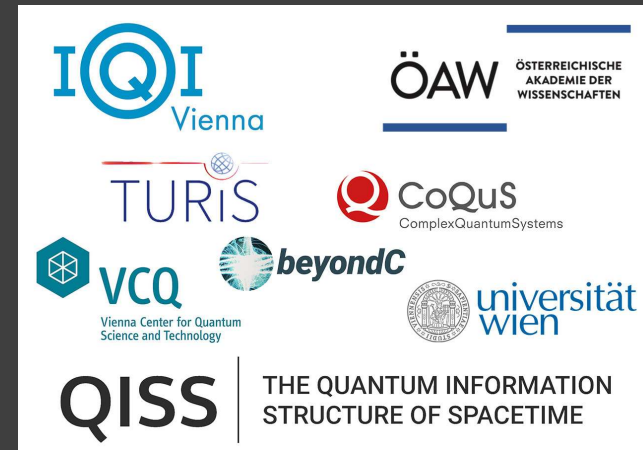
- ✓ 复杂物理模型求解
- ✓ 生物医药研发
- ✓ 经典密码破解 (RSA)
- ✓ 金融模型预测



[QC Companies of 2022: Guide Based on 4 Ecosystem Maps \(aimultiple.com\)](https://aimultiple.com)



The screenshot shows the VCQ website homepage. At the top left is the VCQ logo and the text "Vienna Center for Quantum Science and Technology". A navigation menu includes "HOME", "ABOUT", "RESEARCH", "PHD PROGRAM", "NEWS & EVENTS", and "PUBLICATIONS". The main banner features a blue-toned image of fiber optics and text: "EACH SEMESTER, VCQ OFFERS A COLLOQUIUM WITH VARIOUS TOPICS ON QUANTUM PHYSICS: TAKE A LOOK HERE" and "VCQ COLLOQUIUM". Below the banner, the VCQ logo is displayed again, followed by a paragraph: "The Vienna Center for Quantum Science and Technology (VCQ) is a joint initiative of the University of Vienna, the Vienna University of Technology, the Austrian Academy of Sciences, and the Institute of Science and Technology Austria, which unites quantum physicists of Vienna's research institutions in one collaborative center. VCQ will set new impulses for research and teaching through its unique spectrum of research topics – from fundamental quantum physics to novel quantum technologies."



A collection of logos for partner institutions: IQI Vienna, ÖAW (Österreichische Akademie der Wissenschaften), TURiS, CoQuS (Complex Quantum Systems), VCQ (Vienna Center for Quantum Science and Technology), beyondC, universität wien, and QISS (The Quantum Information Structure of Spacetime).

谢谢大家!

