Quantum applications and INFN

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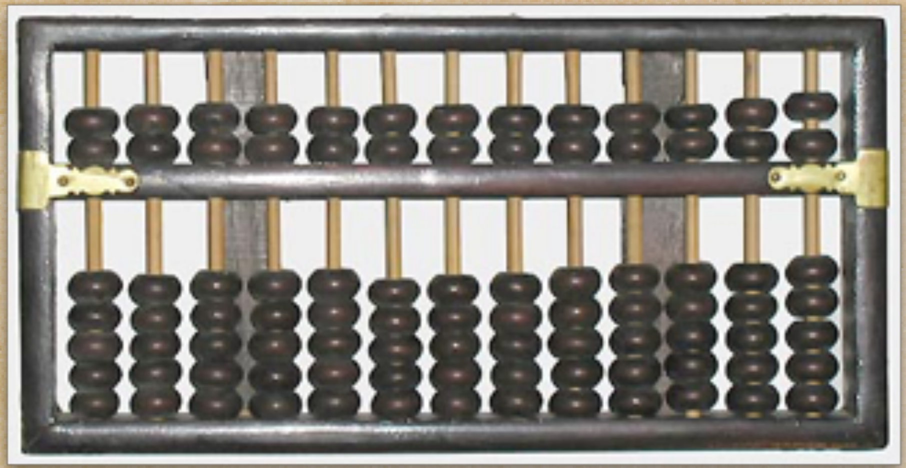
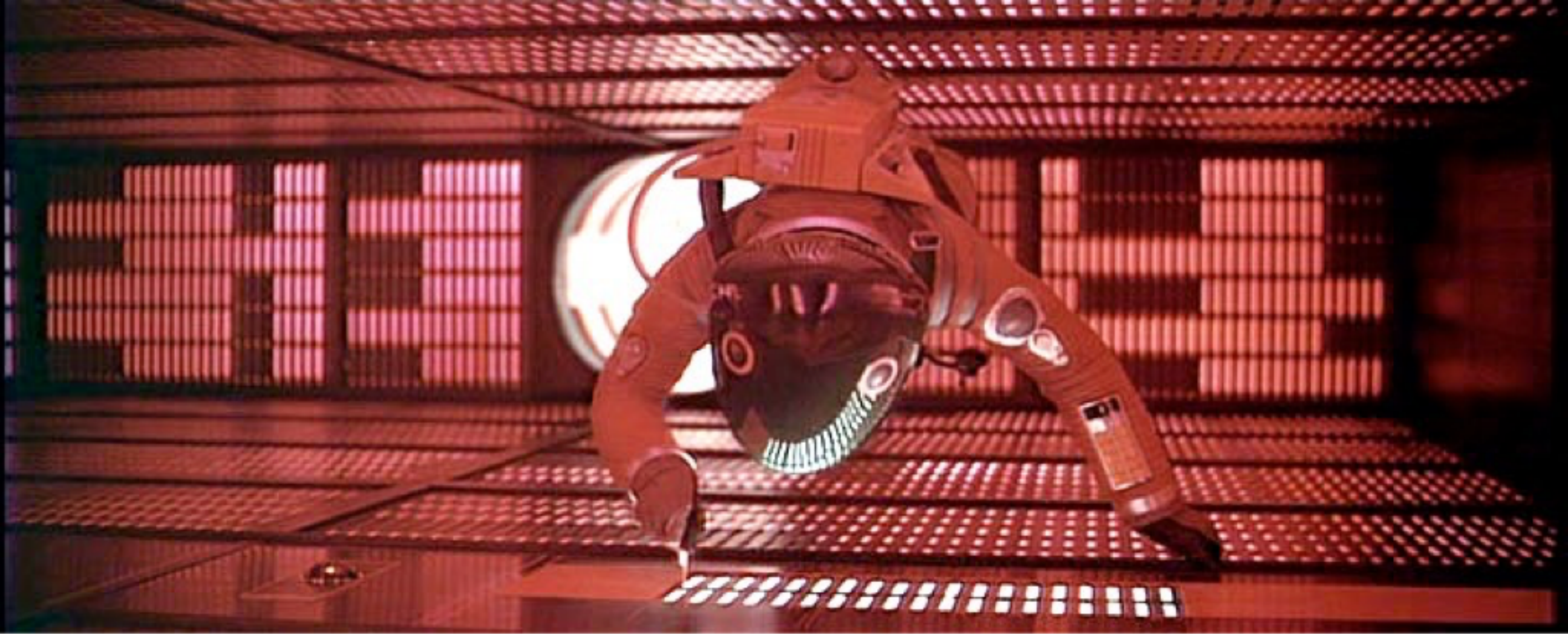
LNGS, L'Aquila, 12 October 2019





HAL 9000

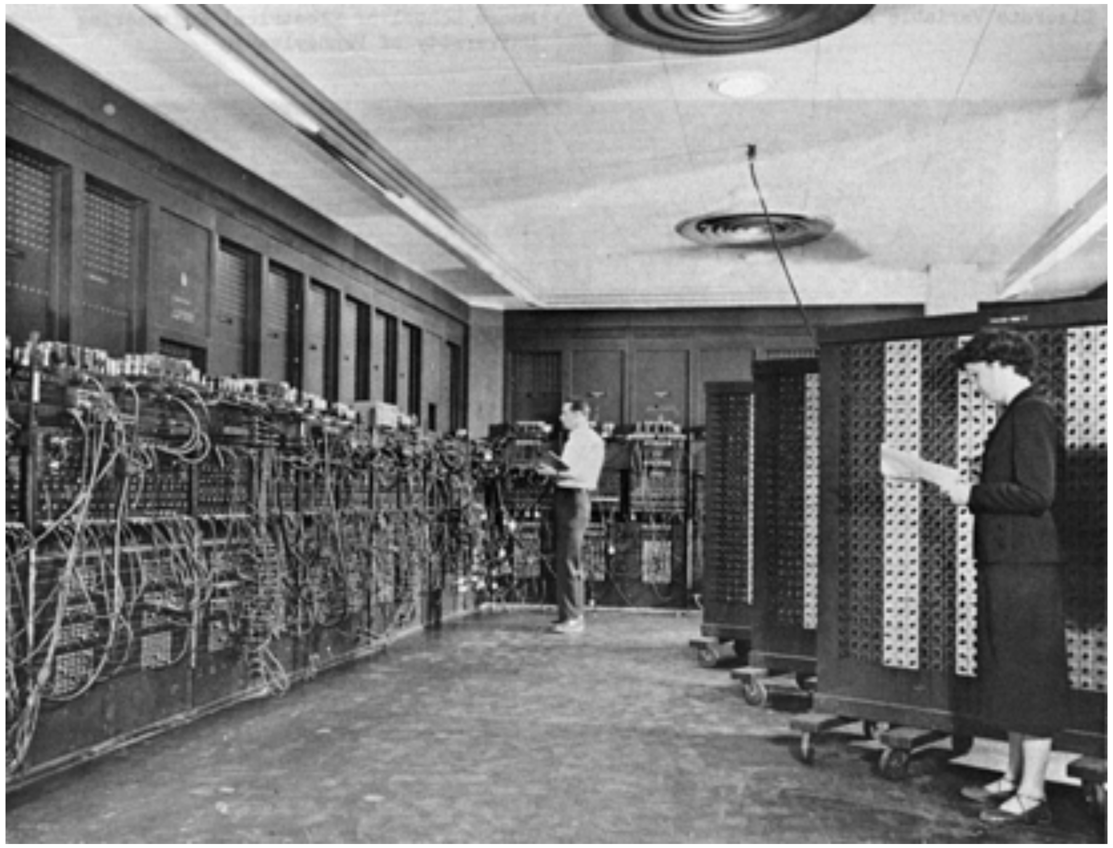
2001 A Space Odyssey

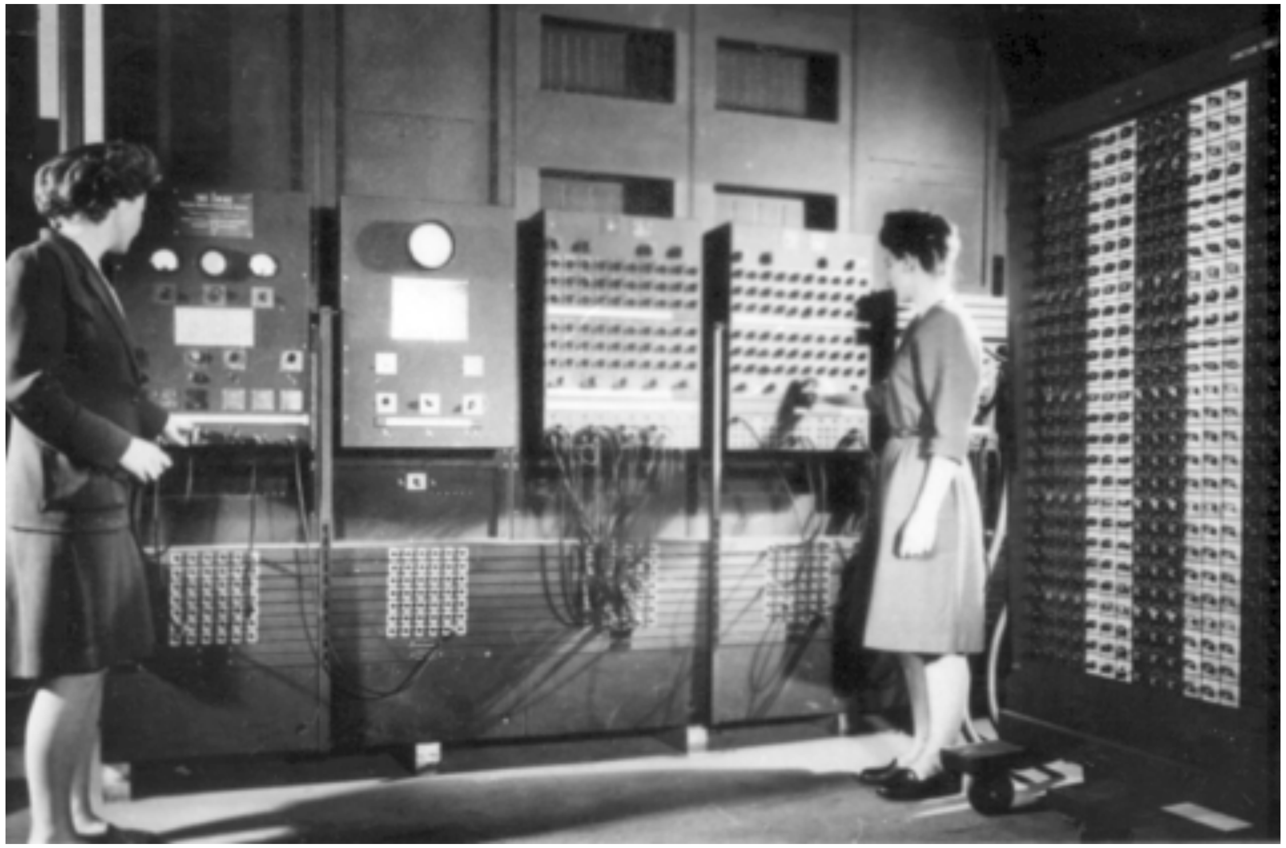
(1968)

ENIAC

Electronic Numerical Integrator and Computer

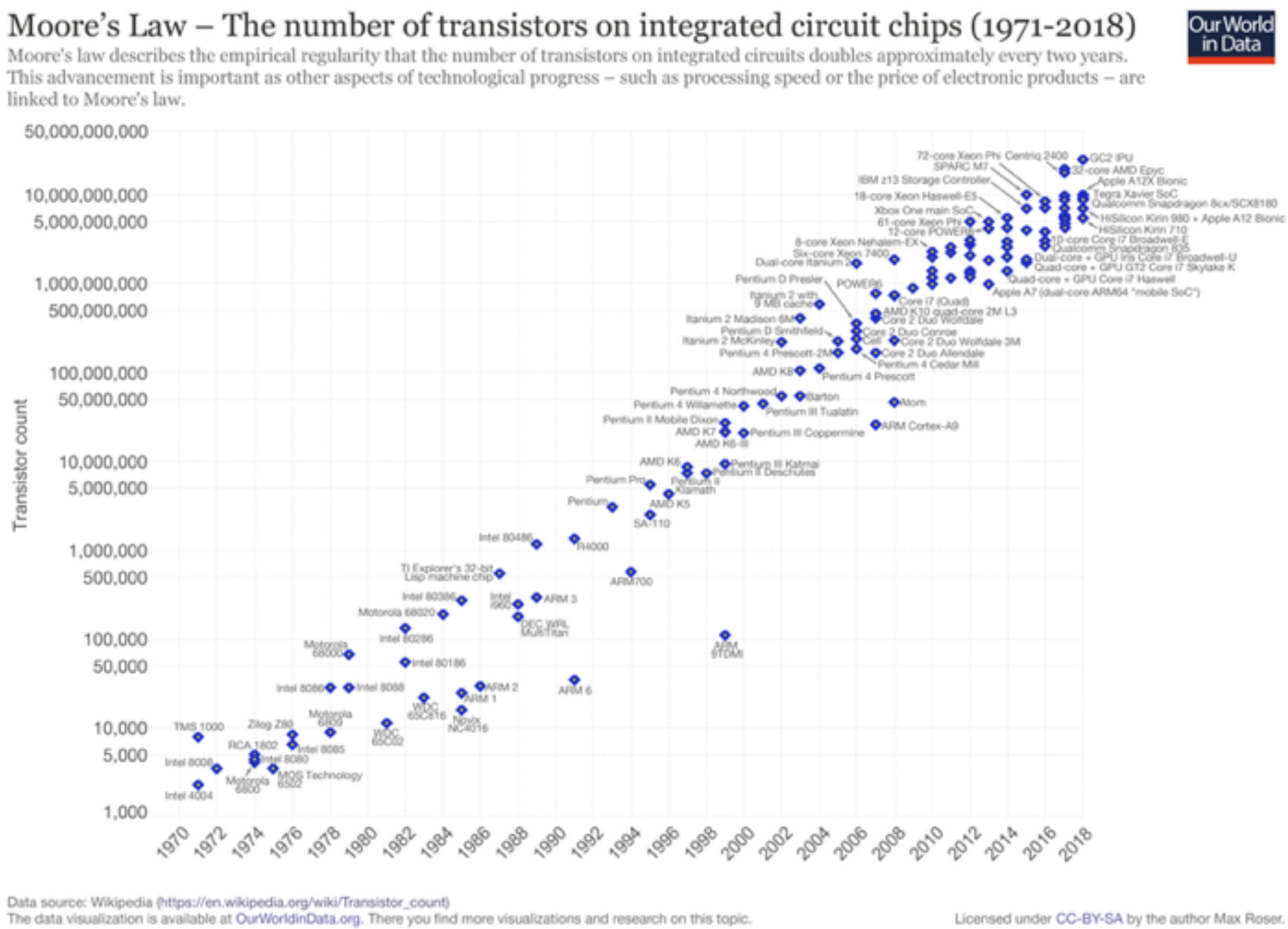
Turing-complete





It contained 20,000 vacuum tubes; 7,200 crystal diodes; 1,500 relays; 70,000 resistors; 10,000 capacitors; and approximately 5,000,000 hand-soldered joints.
It weighed more than 30 short tons (27 t), was roughly 2.4 m × 0.9 m × 30 m in size, occupied 167 m^2 and consumed 150 kW electricity

Smaller and smaller:
one has to apply the rules of quantum mechanics



resources: physics vs mathematics and informatics

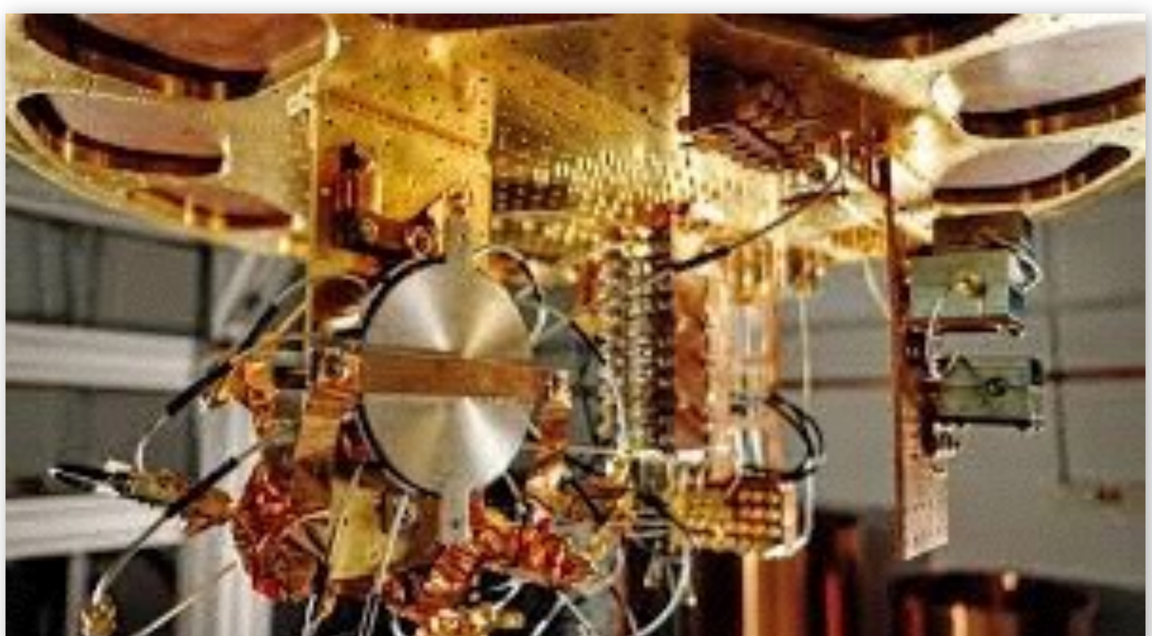
Feynman

"...trying to find a computer simulation of physics, seems to me to be an excellent program to follow out...and I'm not happy with all the analyses that go with just the classical theory, because nature isn't classical, dammit, and if you want to make a simulation of nature, you'd better make it quantum mechanical, and by golly it's a wonderful problem because it doesn't look so easy."

since nature is quantum,
it is better simulated on a quantum computer

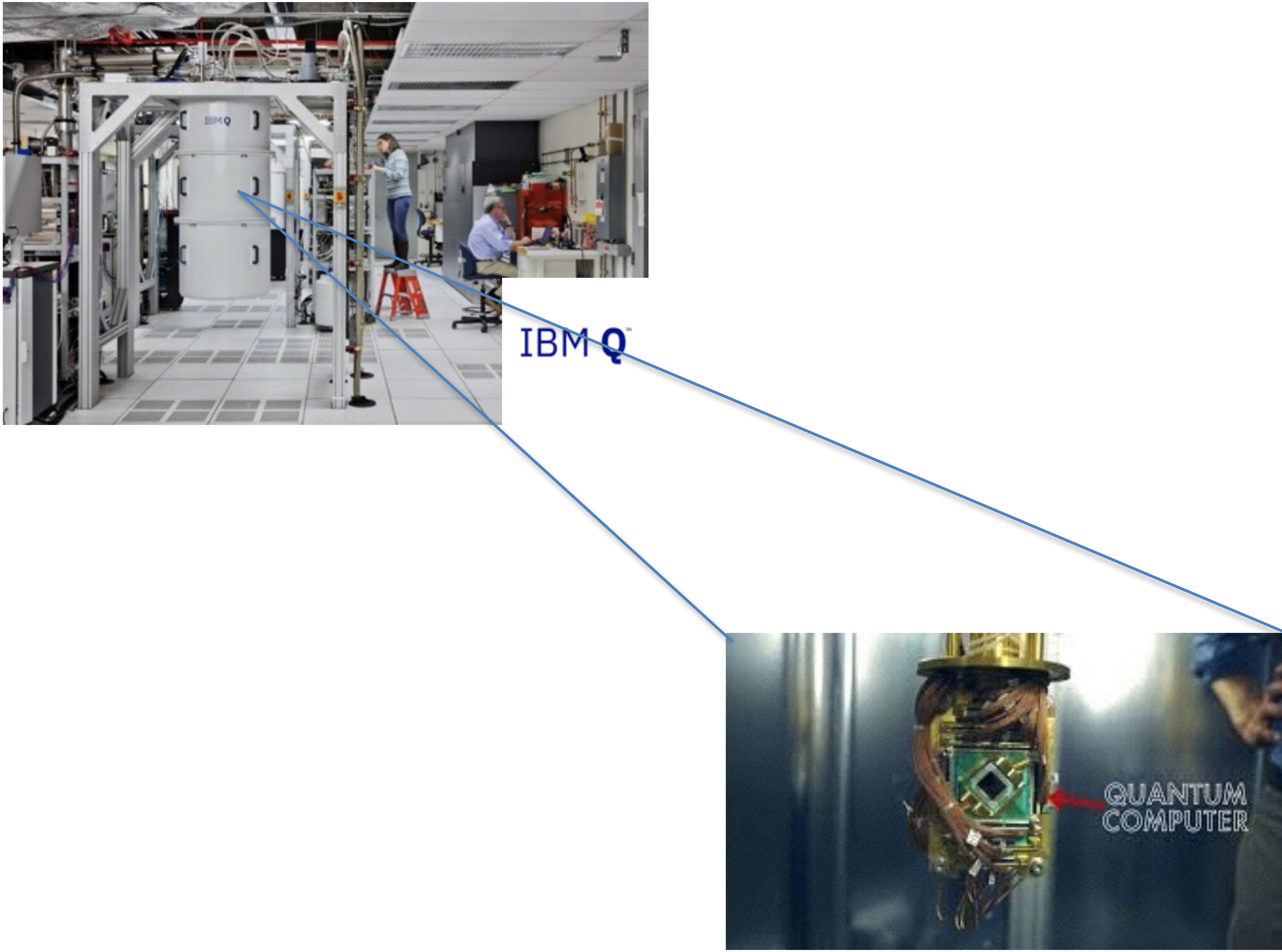
R. P. Feynman, "Simulating Physics with Computers"
Int. J. Theor. Phys. 21, 467 (1982)

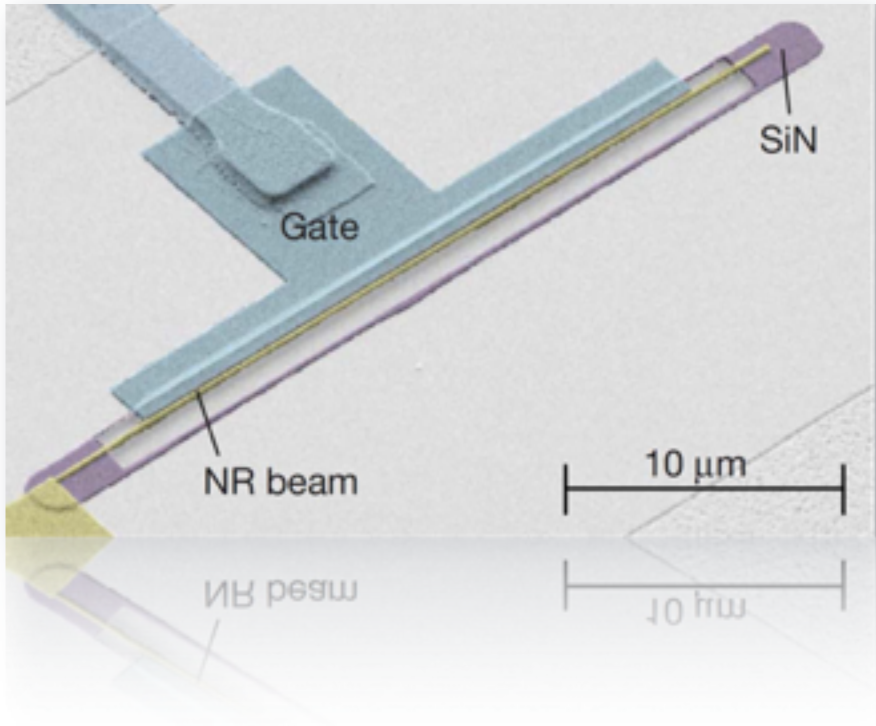
Quantum Computers

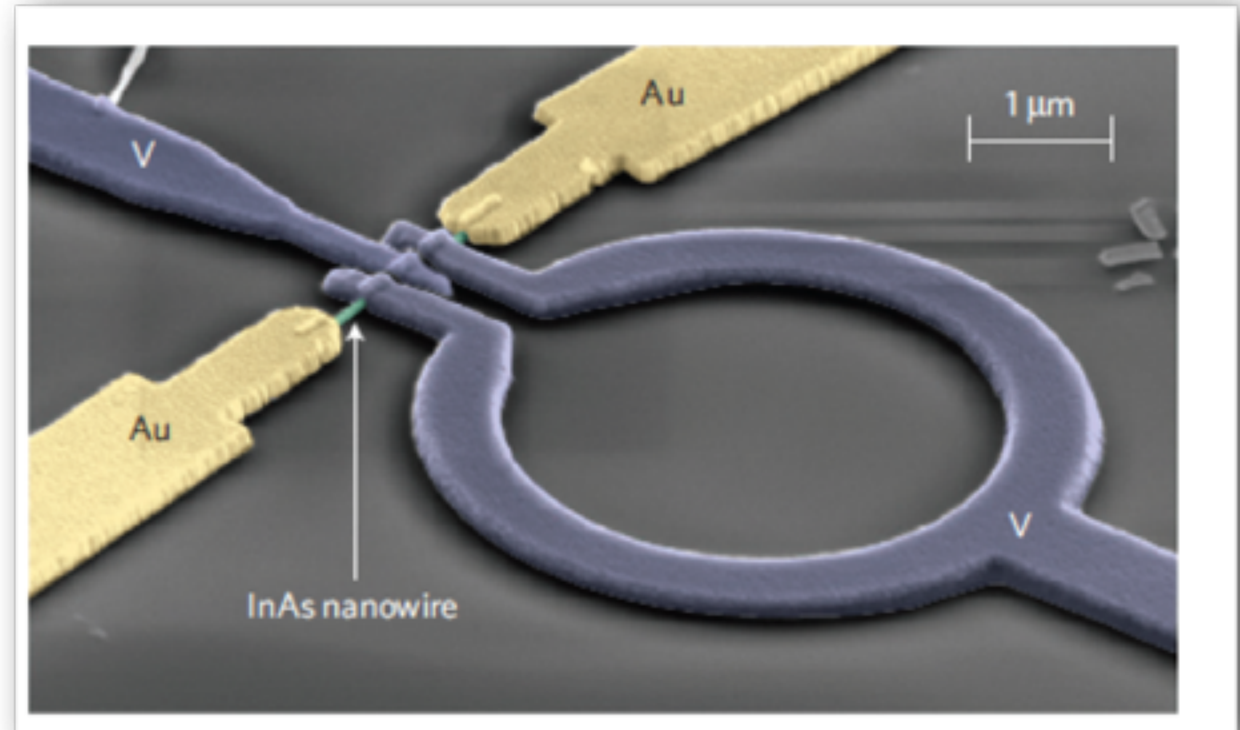


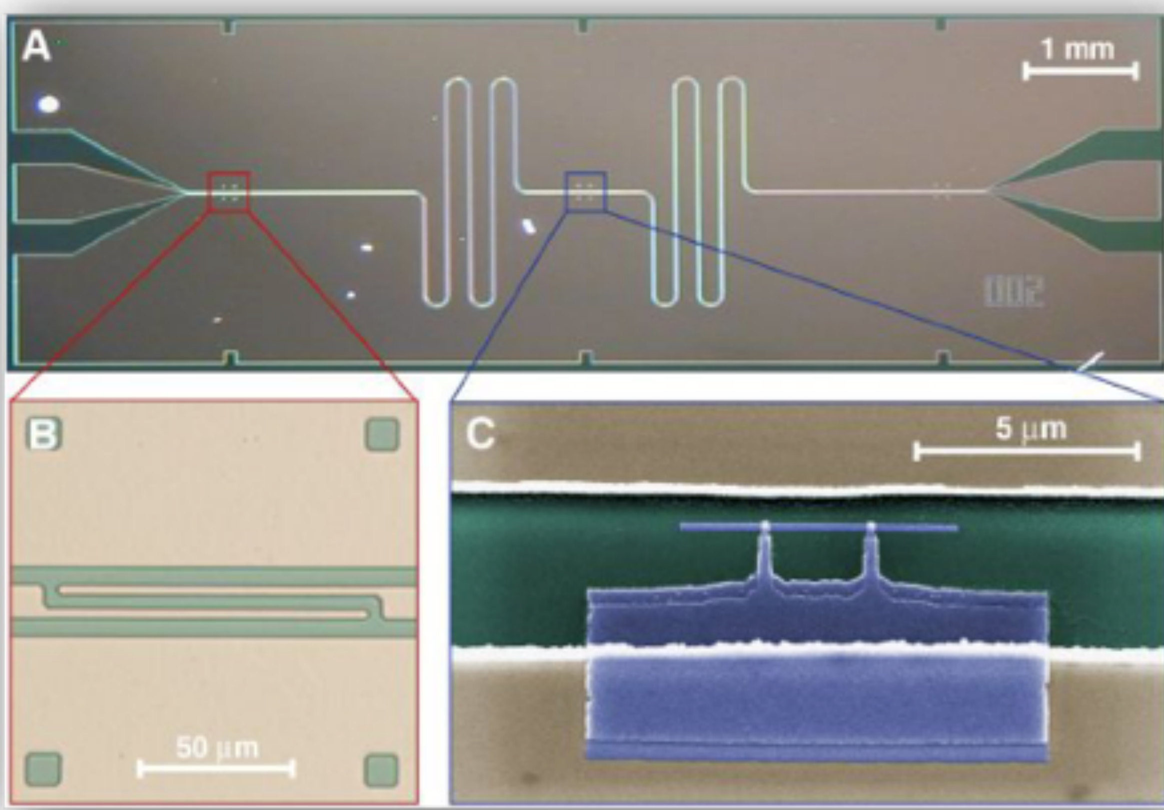
Google

rigetti


IBM Q™
QUANTUM
COMPUTER


SiN
Gate
NR beam
10 μm

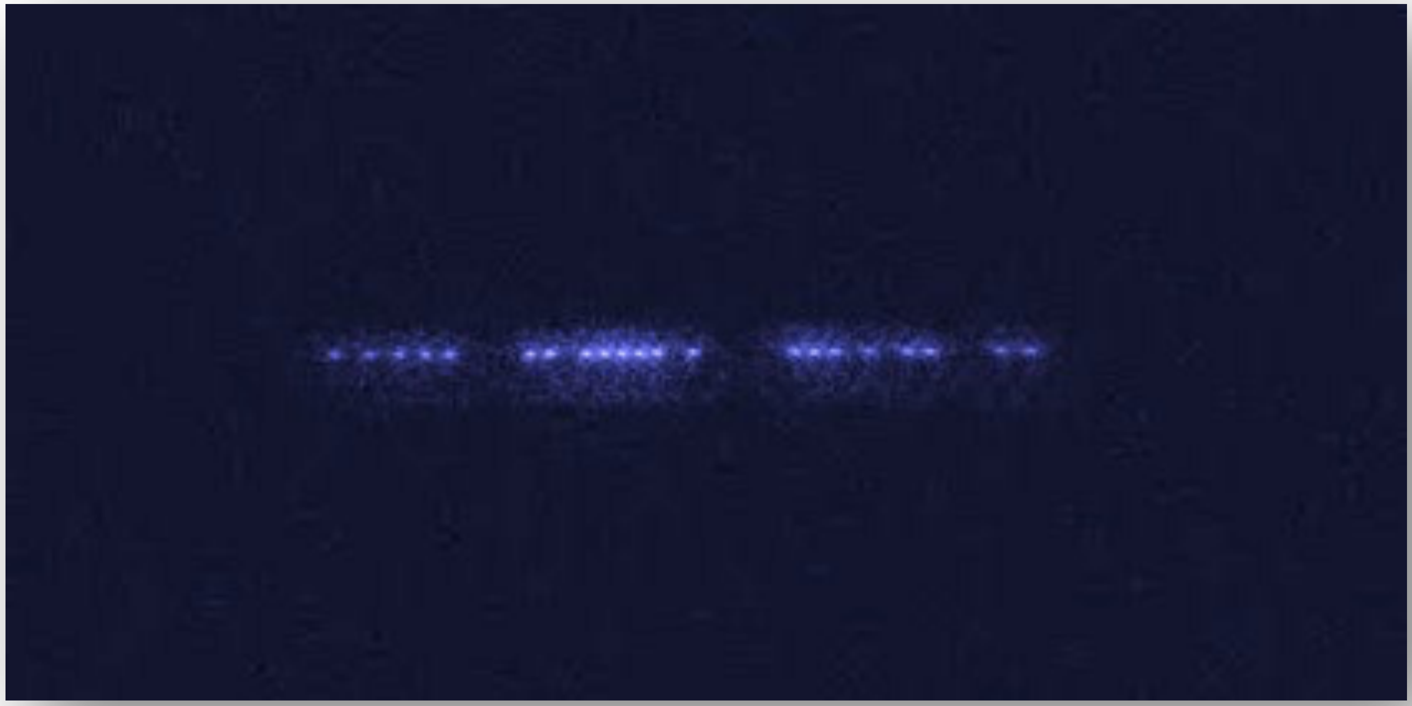

Au
1 μm
V
Au
V
InAs nanowire

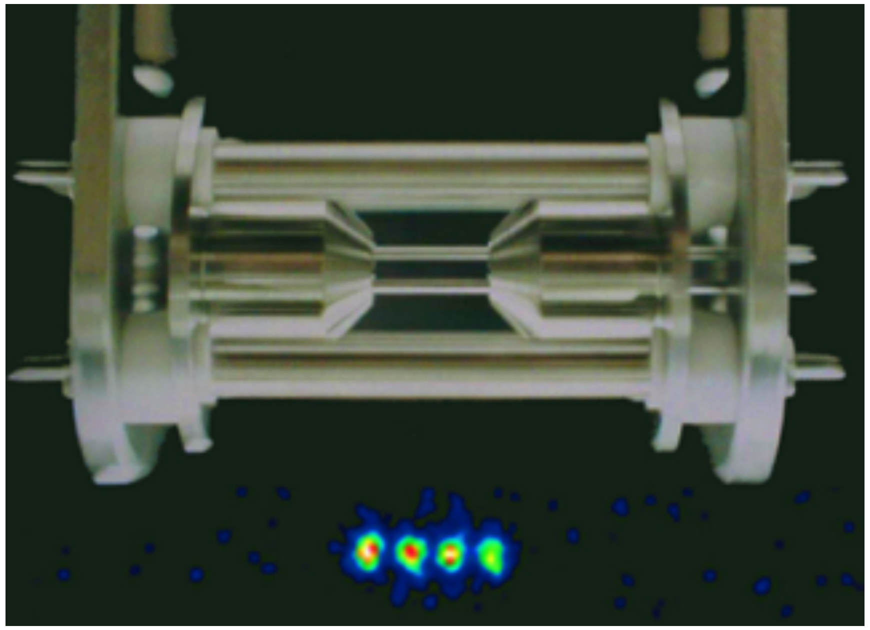

A
1 mm
B
50 μm
C
5 μm

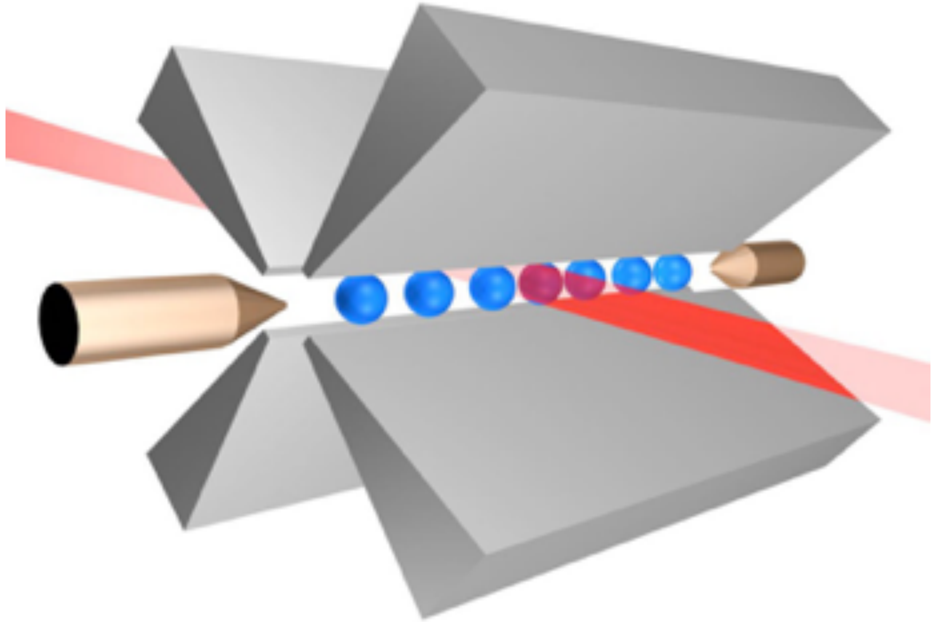
trapped ions

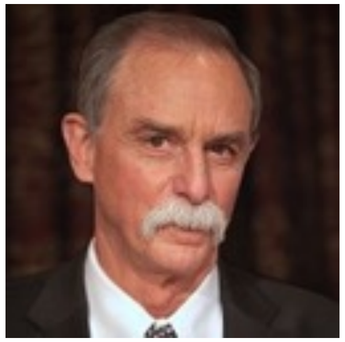
Cirac

Zoller





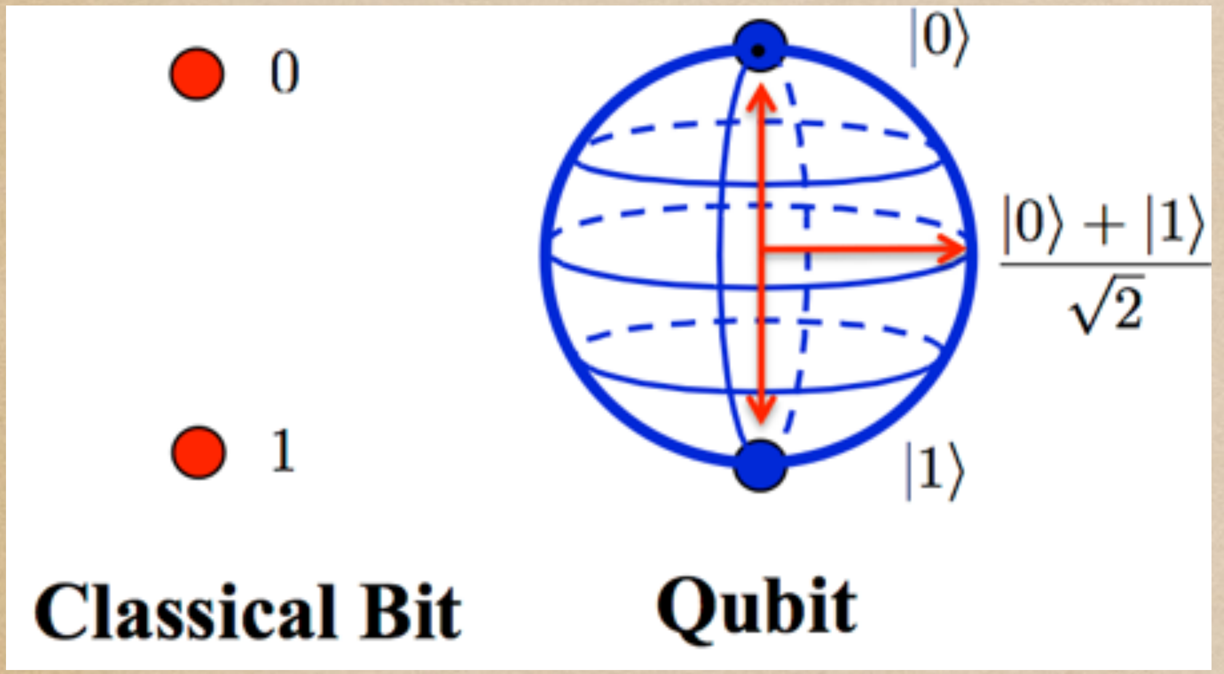


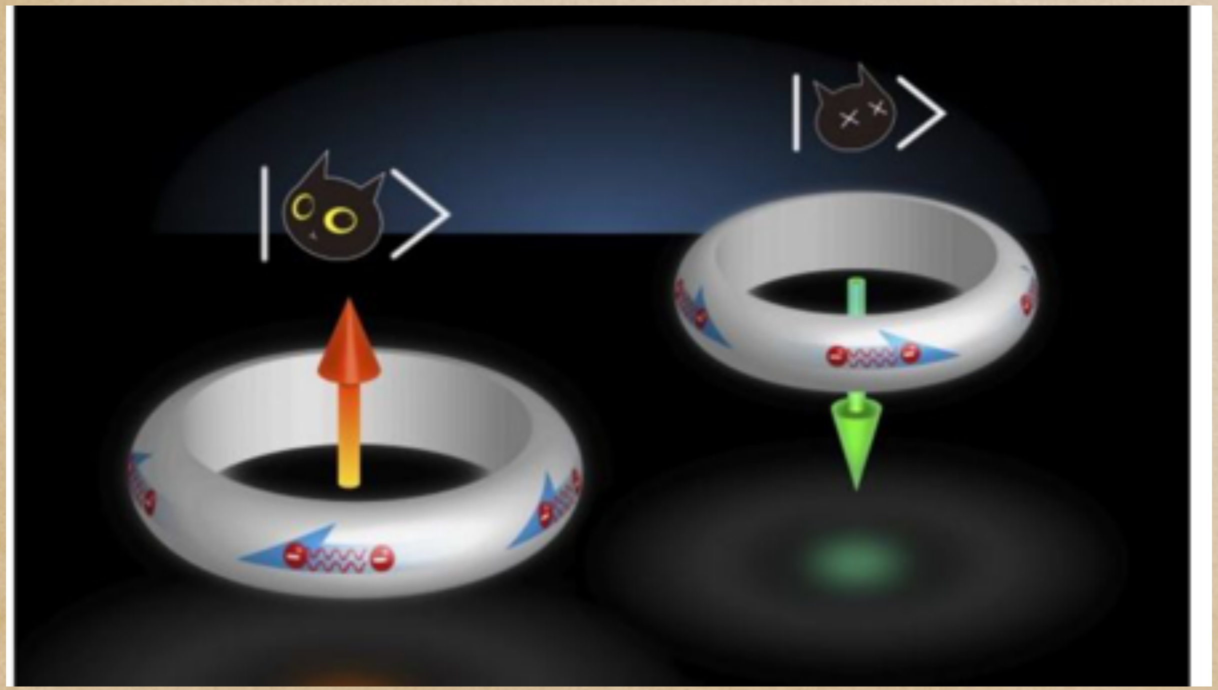


Wineland

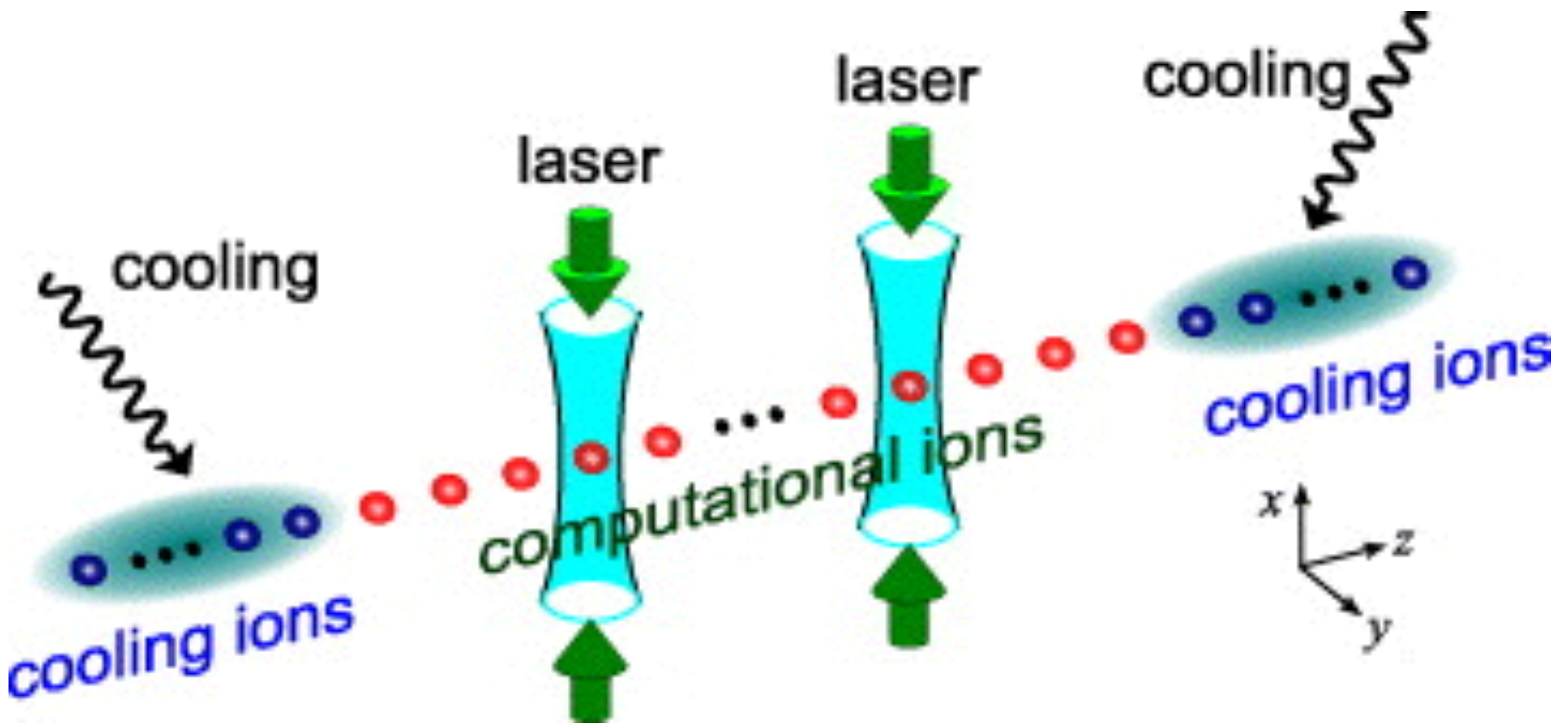
Blatt

qubit


0
1
Classical Bit
$|0\rangle$
$\frac{|0\rangle + |1\rangle}{\sqrt{2}}$
$|1\rangle$
Qubit



30 trapped ions



$$2^{30}(!)$$

roadblocks

la coerenza (della fisica 2)

“easy”

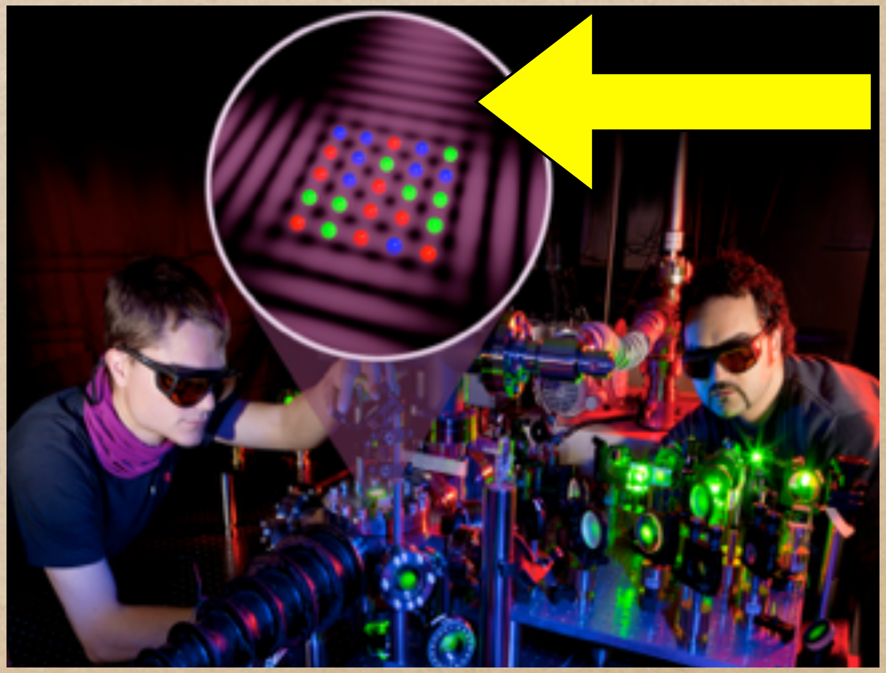
Ψ

“difficult”

classical computer

Ψ

“easy”

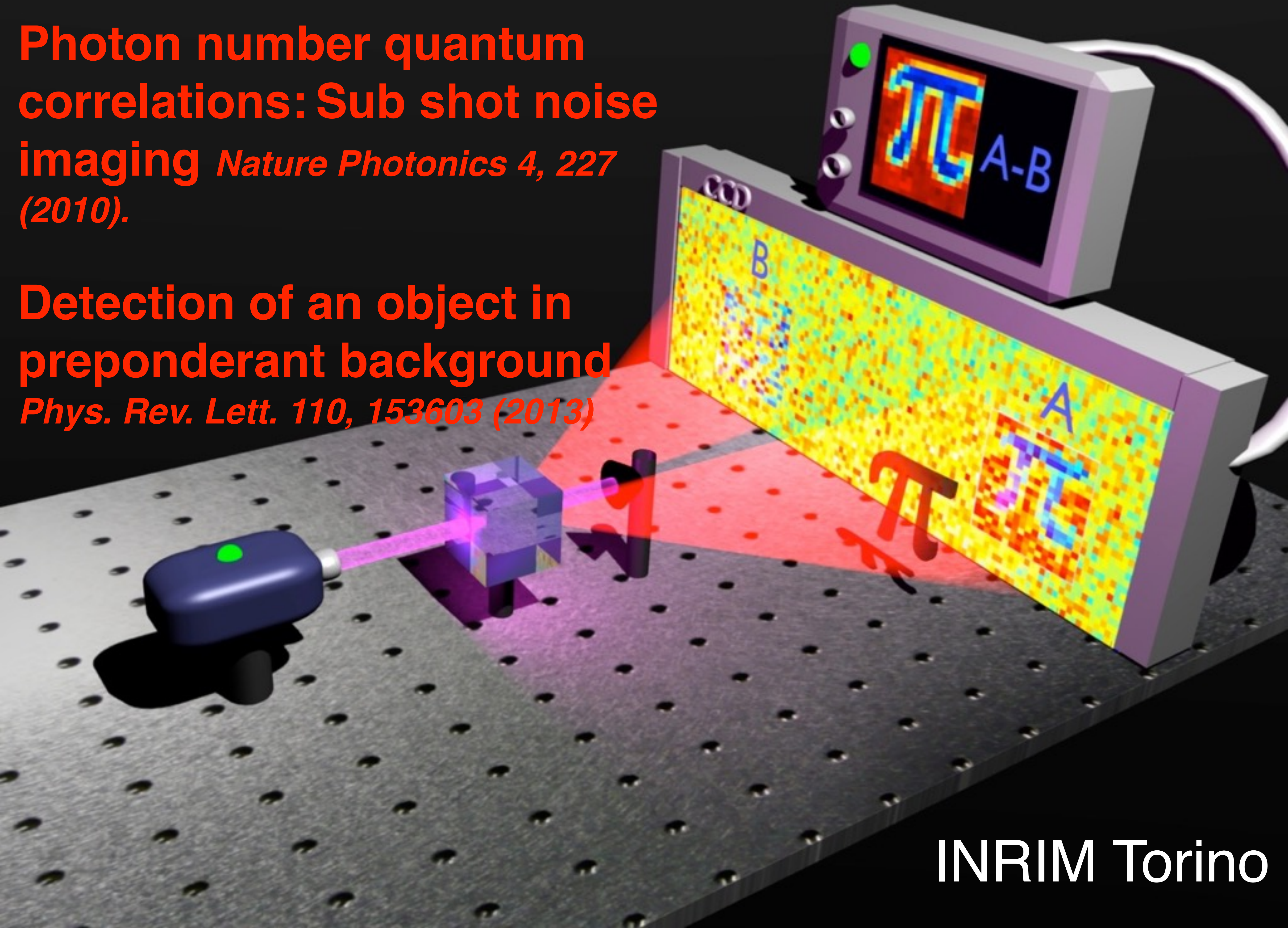


ψ

quantum computer

Photon number quantum correlations: Sub shot noise imaging *Nature Photonics 4, 227 (2010).*

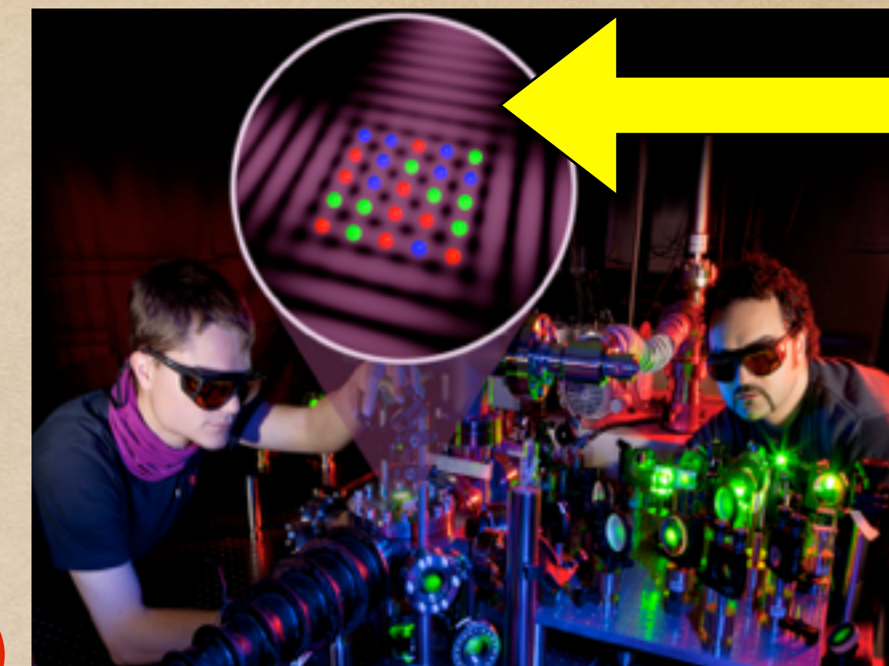
Detection of an object in preponderant background
Phys. Rev. Lett. 110, 153603 (2013)



INRIM Torino

Ψ

“easy”
(polynomial)



ψ

quantum simulator

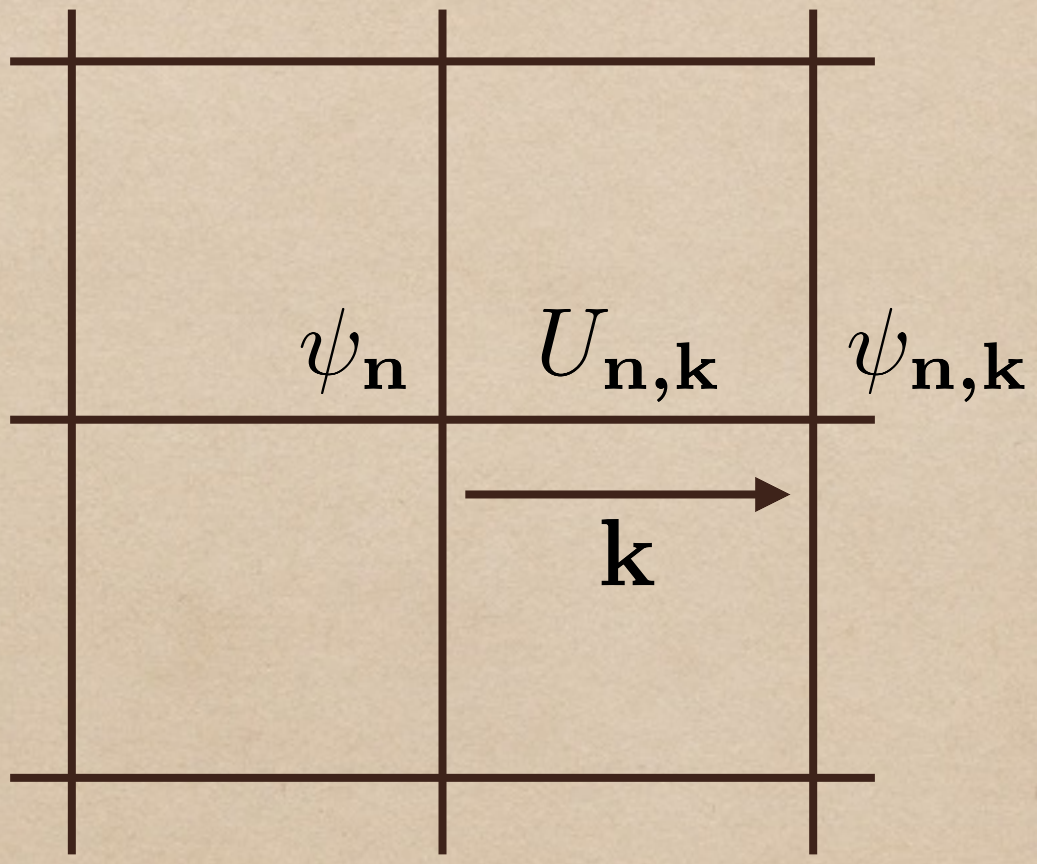
Quantum Hamiltonian engineering in table-top setups

Cirac and Zoller, Nat. Phys. 2012
Inguscio and Fallani, Atomic Physics (Oxford, 2013)
M. Lewenstein et al., Ultracold atoms in optical lattices (Oxford, 2012)

engineering: focus on what the simulator can do
(advice: not on what the simulator cannot do)

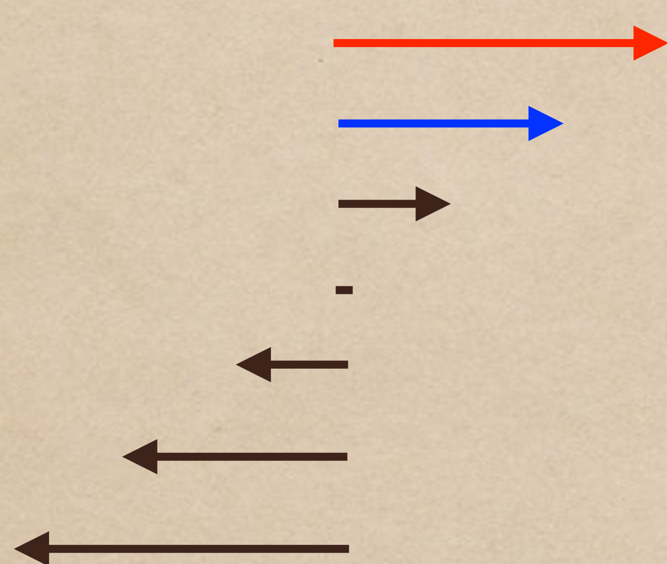
example: mass + hopping terms (Schwinger's model)

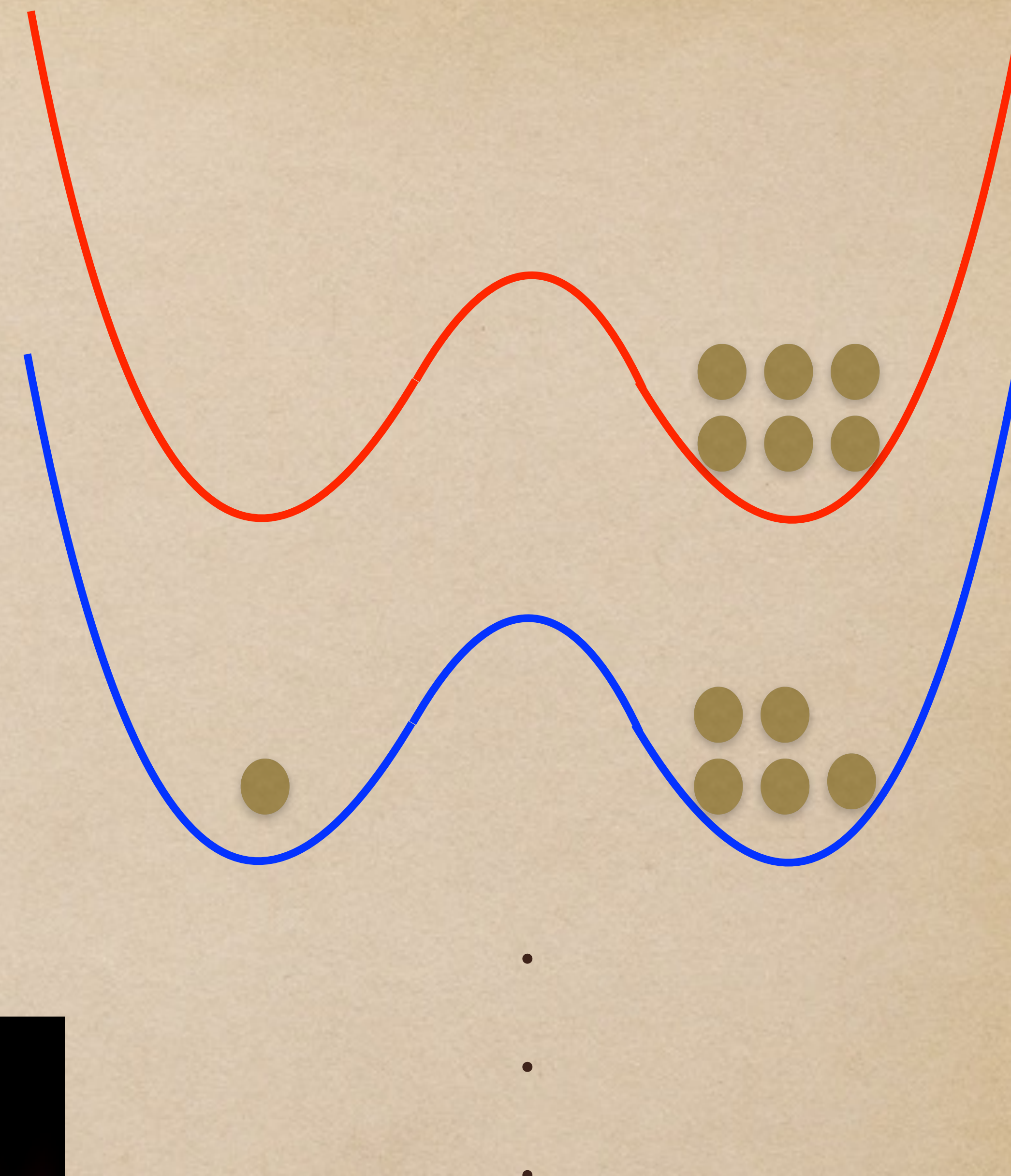
$$H = \sum_{\mathbf{n}} M_{\mathbf{n}} \psi^\dagger_{\mathbf{n}} \psi_{\mathbf{n}} + t \sum_{\mathbf{n}} (\psi^\dagger_{\mathbf{n}} U_{\mathbf{n},\mathbf{k}} \psi_{\mathbf{n},\mathbf{k}} + \text{H.c.})$$



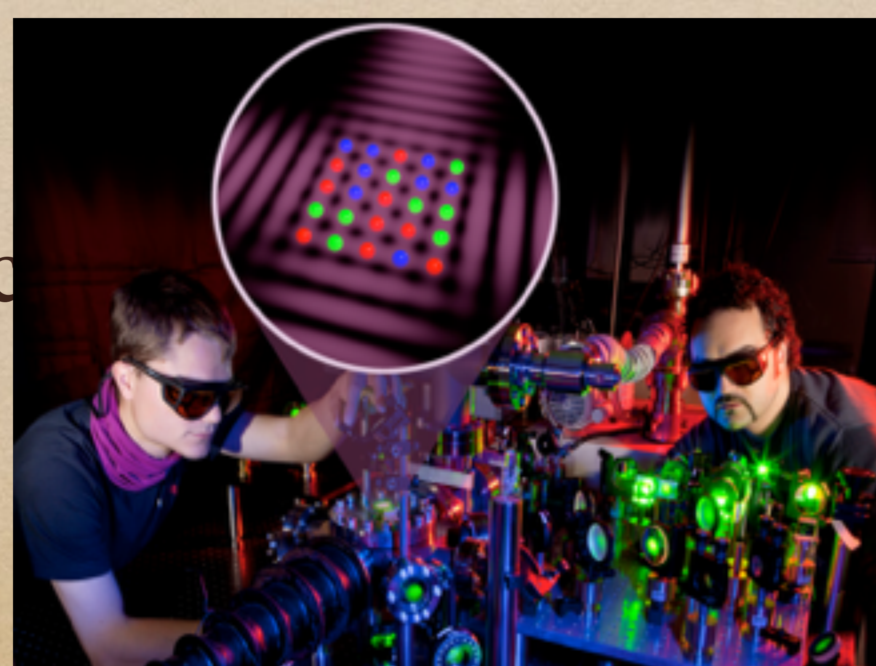
$U_{\mathbf{n},\mathbf{k}}$ is the connection

careful…





elec



and so on…

quantum simulator

ft.com

Fatto Q Alitalia Repubblica INFN Dipartimento di Fisica uniba_cdf – C...rea in Fisica Overleaf, Onl... LaTeX Editor SSL VPN Service Waseda SIBA arXiv Library Genesis Petition · Sal... · Change.org Electronic library bookzz ASN

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Google claims to have reached quantum supremacy

Researchers say their quantum computer has calculated an impossible problem for ordinary machines

Madhumita Murgia and Richard Waters SEPTEMBER 20 2019

159

Save

Google claims to have built the first quantum computer that can carry out calculations beyond the ability of today's most powerful supercomputers, a landmark moment that has been hotly anticipated by researchers.

A paper by Google's researchers seen by the FT, that was briefly posted earlier this week on a Nasa website before being removed, claimed that their processor was able to perform a calculation in three minutes and 20 seconds that would take today's most advanced classical computer, known as Summit, approximately 10,000 years.

The researchers said this meant the "quantum supremacy", when quantum

Feedback

The Abdus Salam International Centre for Theoretical Physics

Antonello Scardicchio

Contextual Navigation

NEWS HIGHLIGHTS

Google Grant

ICTP scientist wins prestigious research award from search engine giant

23/02/2017 - Trieste

ICTP condensed matter physicist Antonello Scardicchio

ICTP condensed matter physicist Antonello Scardicchio has been awarded a Google Faculty Research Award for work related to quantum computing. The US$72,000 in seed funding will be used to support graduate students and postdoctoral associates working in his group.

Quantum computing has the potential to revolutionize the speed and efficiency of computers because of the way it processes information: as quantum bits, or qubits. Unlike classic computers, where information is stored as bits and each bit is either zero or one, quantum computing's qubits are made of quantum particles that can exist in a superposition of both values at the same time. This could allow quantum computers to process information millions of times faster than today's supercomputers.

The algorithms used in quantum computing presumably are faster than algorithms used on classical computers because they take advantage of the speed offered by interference of matter waves, a peculiar quantum phenomenon. To confirm the performance superiority of quantum algorithms would help to define which problems can benefit significantly from using a quantum computer instead of a classical one. This is what Scardicchio's research aims to do, using techniques developed in statistical mechanics and condensed matter, in particular the analysis of differences of quantum and classical dynamics. By understanding in which situations quantum interference can speed up the