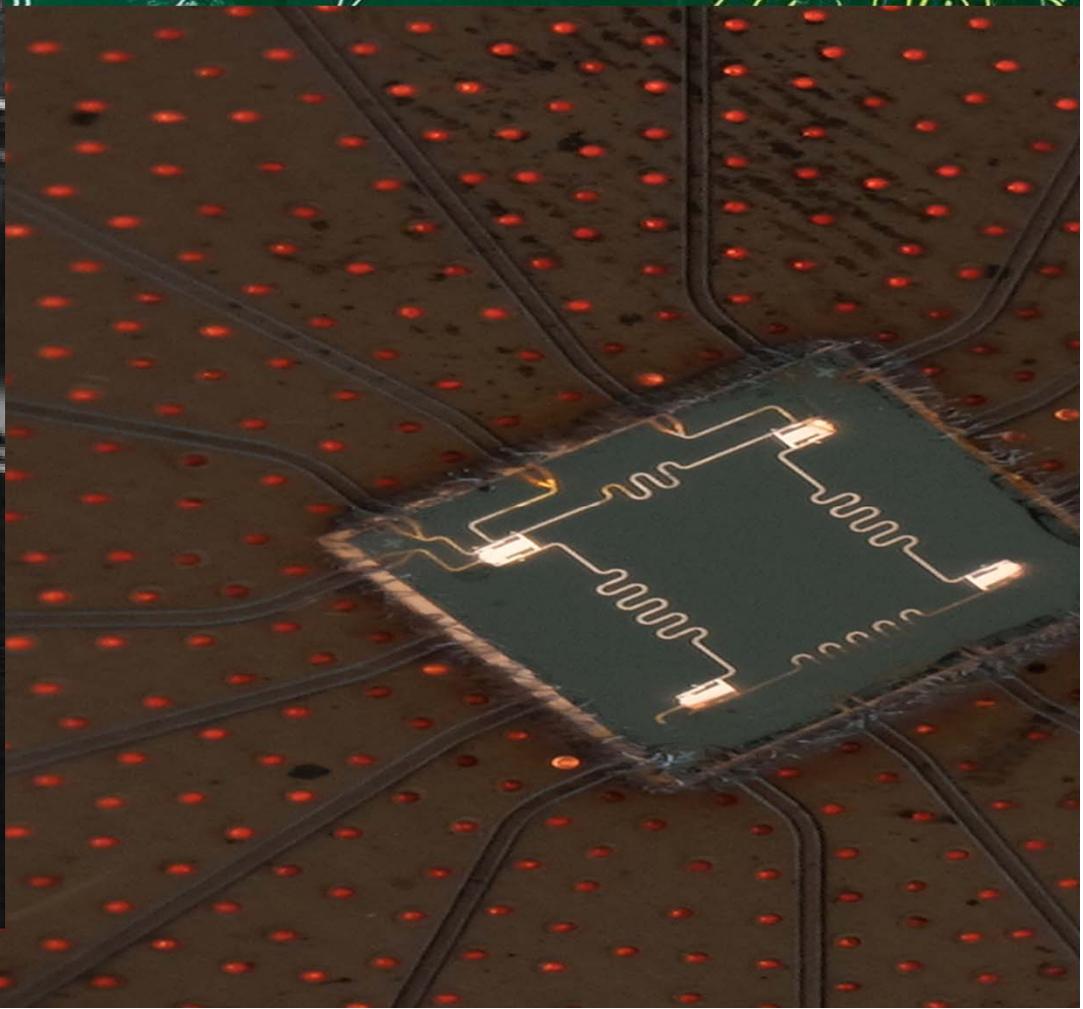
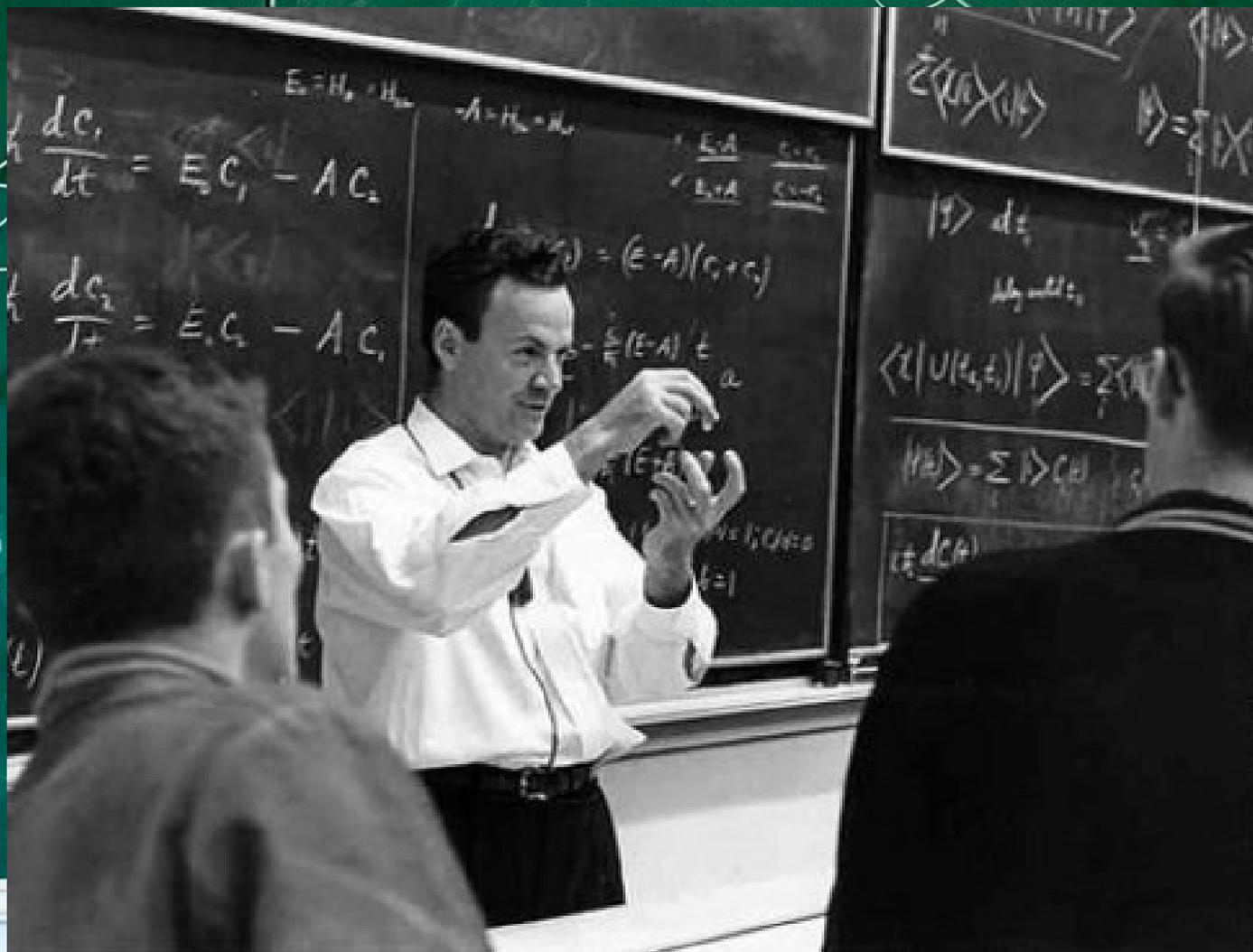


Technologies quantiques: un changement de paradigme?

Richard Boudreault P.Phys.

1 'There's Plenty of Room at the Bottom'



$$\frac{1}{\mathcal{N}} \int \mathcal{P}(\mathbf{h}, \mathbf{m}, \mathbf{n}) \mathcal{Z}(\mathbf{h}, \mathbf{m}, \mathbf{n})$$

$$+ \int \delta_{\phi} \delta_{\mathbf{m}, \mathbf{n}} \mathcal{P}_2(\cdot)$$

$$\sum_{abc} \dots = m \delta_{\mathbf{m}, \mathbf{n}, 0}$$

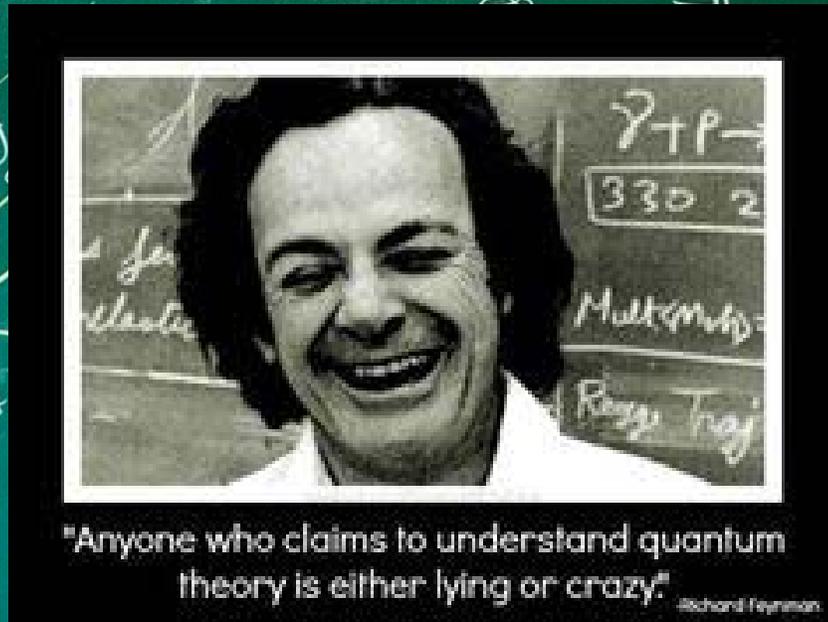
Free Boson

$$\frac{\partial \mathcal{L}}{\partial \phi} = 0$$

$$h = -1$$

$$j_c = 0$$

$$[-1, 1]^n$$



$$E \quad L_0 + \bar{L}_0$$

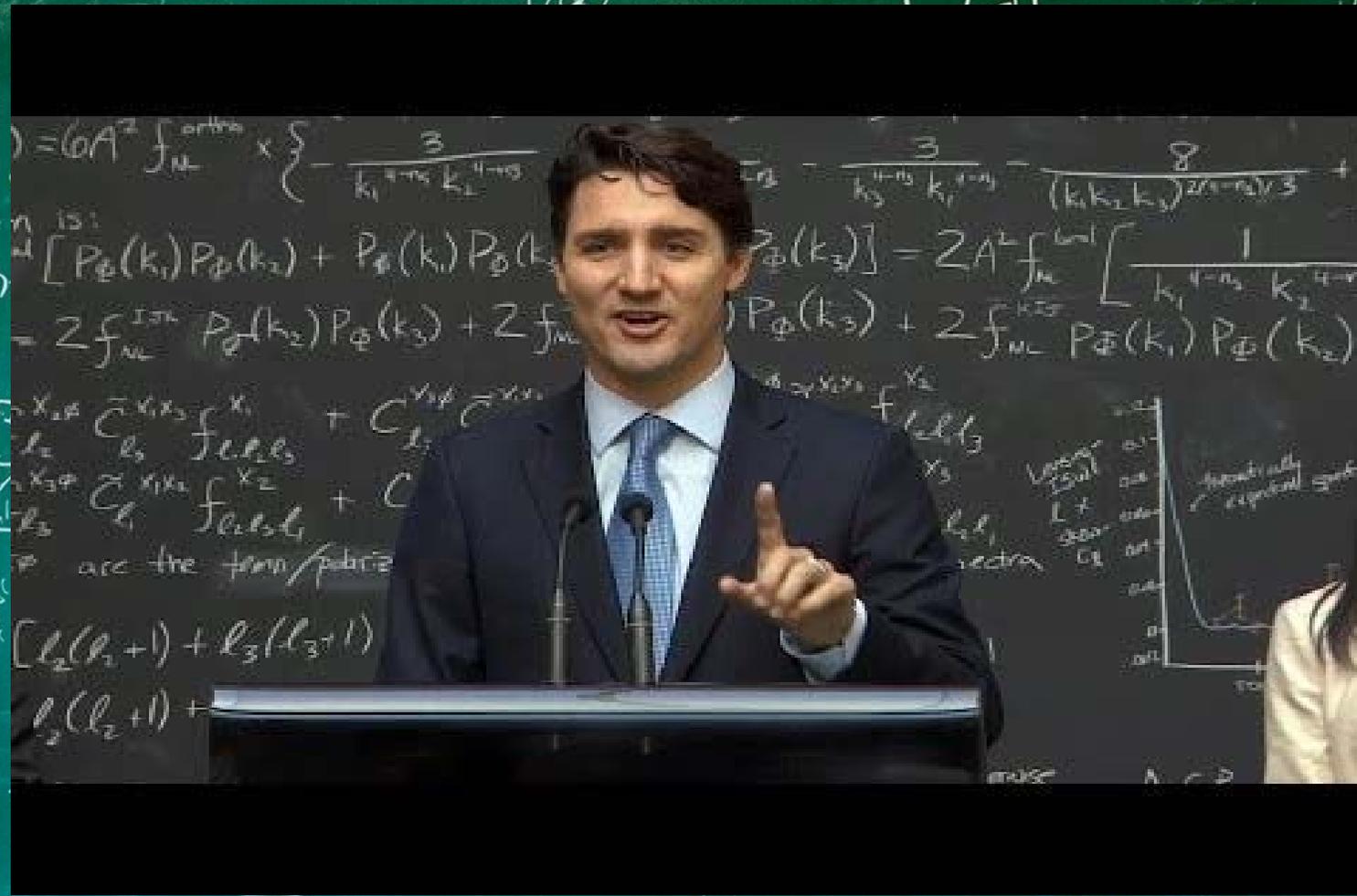
$$L_{-n} |0\rangle$$

$$L_{-1} |0\rangle$$

Handwritten notes and diagrams on a chalkboard:

- Diagram showing a vertical line labeled E and a horizontal line labeled $j(z)$.
- Equation: $4 \langle f(\tau) f(0) \rangle$
- Equation: $\langle f(\tau) f'(0) \rangle$
- Equation: $\sum_{k=1}^{\infty} \frac{1}{i\omega_n - \epsilon_k}$
- Equation: $\Gamma_x(\psi_+ + \psi_-)$
- Equation: $\int \Gamma_x(\tau) \Gamma_y(0)$
- Equation: $\rightarrow L_0 = \frac{1}{2} \sum_{m \neq 0} \alpha_{-m} \alpha_m$
- Equation: $\alpha_{-1} \alpha_1 \times \alpha_{1/4} \alpha_{-1/4} - m$

Sommaire de Mr. Trudeau

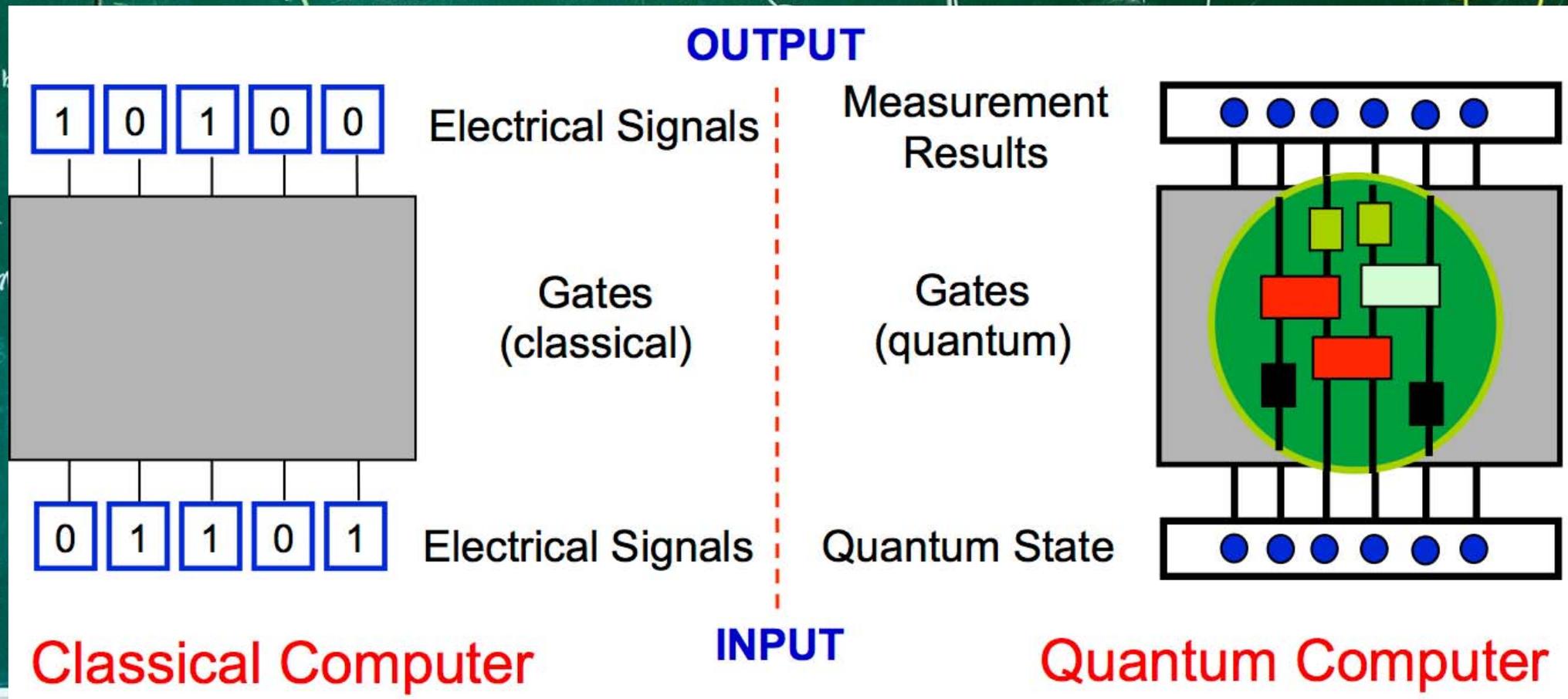


What is Quantum Computing?



```
010101001  
010100  
1001001000  
1001010100  
00010010111  
0010111100  
1110010010  
10101001  
01001
```

La différence entre les formes ordiniques



Where did this idea come from?

A Recent History



1982

Richard Feynman envisions quantum computing

1994

Peter Shor develops algorithm that could be used for quantum code-breaking

2000

Eddie Farhi at MIT develops idea for a diabatic quantum computing

2013

D-Wave Two, 512 qubits



1985

David Deutsch describes universal quantum computer



1999

D-Wave Systems founded by Geordie Rose

2010

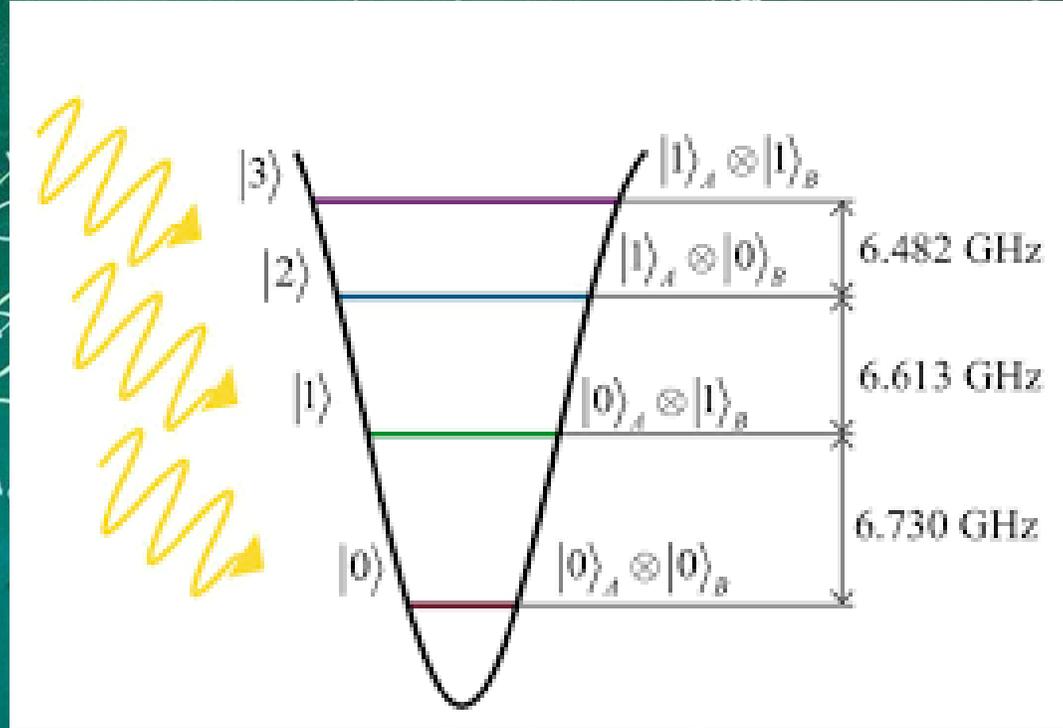
D-Wave One: first commercial quantum computer, 128 qubits

Sans Équations ?

$$i\hbar \frac{\partial}{\partial t} \Psi = \hat{H} \Psi$$

$\delta \langle P(\hbar, m, p) \rangle_{m+n} + \delta \langle \phi \rangle_{m+n, 0} \cdot P_2(\dots)$
 $\sum_{abc} \dots$
 $= m \delta_{m+n, 0}$
 Virasoro
 $J_{m+n} + \dots$
 Free Boson
 $\frac{\partial \mathcal{L}}{\partial \alpha} = 0$
 \dots
 $J_{-1} = -1$
 $J_0 = 0$
 $[-1, 1]^m$
 $L_0 = \dots$
 $L_{-n} |0\rangle = 0$
 $L_{-1} |0\rangle = 0$
 E
 $L_0 |0\rangle = 0$
 $L_{-1} |0\rangle = 0$
 $j(z)$
 $4 \langle f(\tau) f(0) \rangle$
 $\langle f(\tau) f(0) \rangle$
 $\sum_{k=1}^{\infty} \frac{1}{i\omega_n - \epsilon_k}$
 $\Gamma_x(\psi_+ + \psi_-)$
 $\int \Gamma_x(\tau) \Gamma_y(0)$
 \dots
 \dots
 \dots

Puits quantique

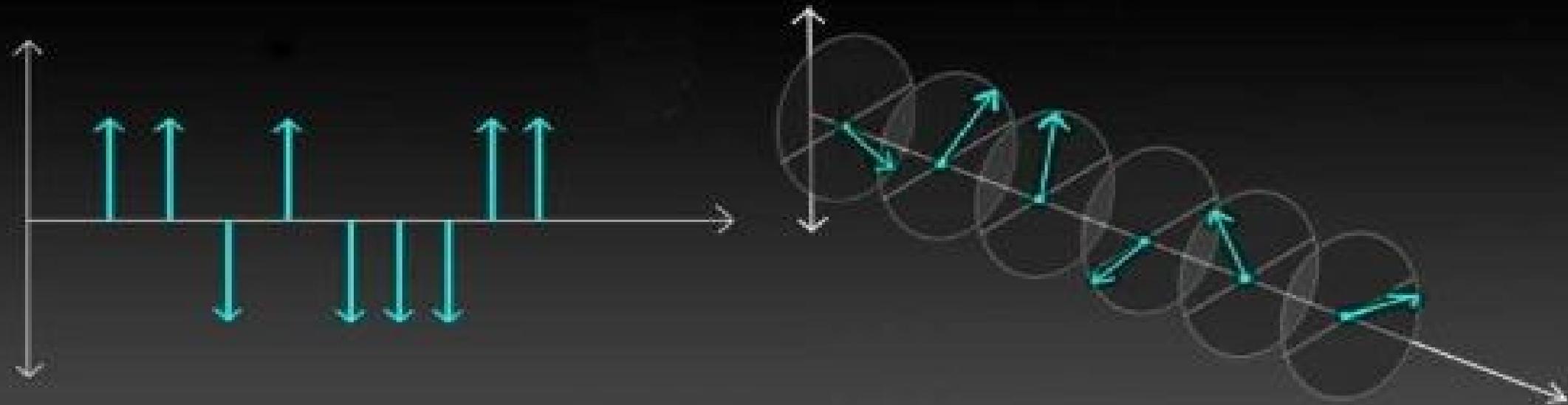


Handwritten notes on the chalkboard include:

- $\rho(\mathbf{r}, \mathbf{r}', t)$
- $\delta\phi \delta_{m+n, 0} \rho_2(\dots)$
- $E \rightarrow L_0 \bar{L}_0$
- $L_{-n} \rightarrow |0\rangle$
- $L_{-1} \rightarrow |0\rangle$
- $\sum_{abc} \dots$
- $\sum_{m+n, 0} J_{m+n}$
- Free Boson
- $\frac{\partial \mathcal{L}}{\partial \phi} > 0$
- $\frac{1}{2} \dots$
- $h = -1$
- $j_c = 0$
- $[-1, 1]^m$
- $j(z)$
- $\sum_{k=1}^{\infty} \frac{1}{i\omega_n - \epsilon_k}$
- $\Gamma_x(\psi_+ + \psi_-)$
- $\int \Gamma_x(\tau) \Gamma_y(0)$
- Γ_x
- Γ_y
- \dots

Classical bit Vs Qubit:

- Classical bit: {0, 1}
- Qubit: {0, 1, superposed states of 0 and 1}



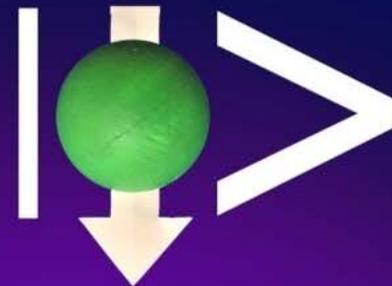
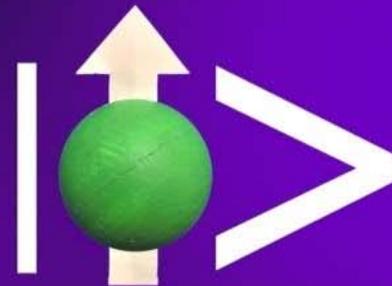
Classical bits Vs Quantum bits

En état quantique ne peut être mesuré

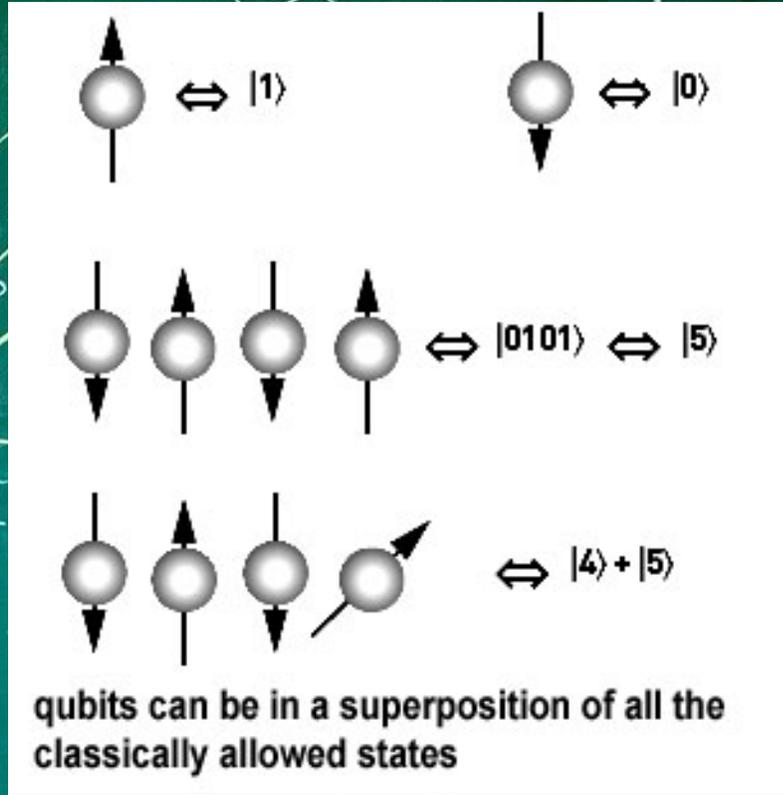


1

0



Spintronique

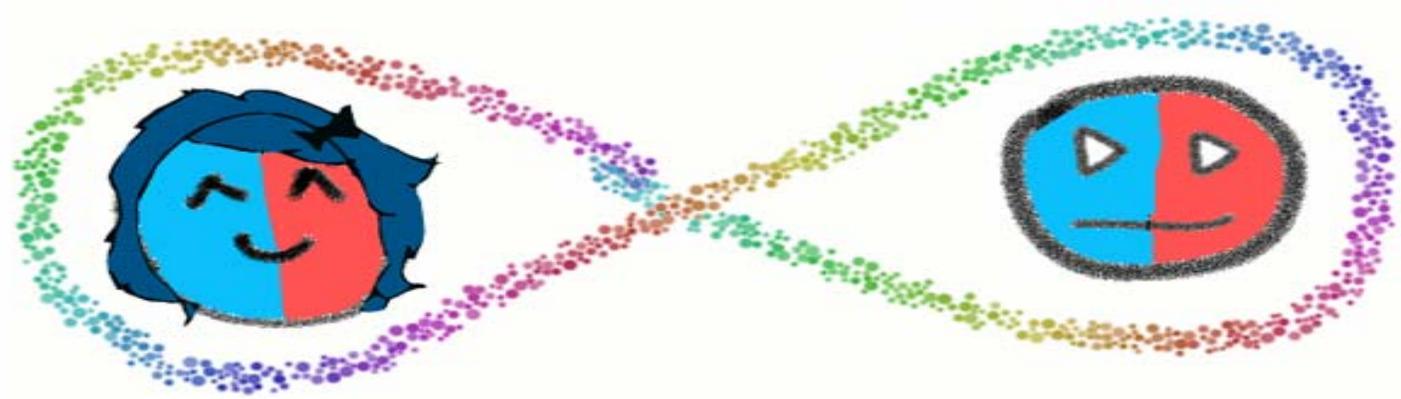


$\psi = \sum_{m,n} P(m,n) \chi_{m+n}$
 $+ \int \delta\psi \delta_{m+n,0} P_2(\dots)$
 $E = L_0 + \bar{L}_0$
 $L_{-n} \rightarrow |0\rangle$
 $L_{-1} \rightarrow |0\rangle$
 $\sum_{m,n} \dots$
 $\sum_{k=1}^{\infty} \frac{1}{k} i\omega_k - \xi_k$
 $\Gamma_x(\psi_+ + \psi_-)$
 $\int \Gamma_x(\tau) \Gamma_y(0)$
 $\sum_{m,n} \dots$
 $\sum_{k=1}^{\infty} \frac{1}{k} i\omega_k - \xi_k$
 $\Gamma_x(\psi_+ + \psi_-)$
 $\int \Gamma_x(\tau) \Gamma_y(0)$
 $\sum_{m,n} \dots$
 $\sum_{k=1}^{\infty} \frac{1}{k} i\omega_k - \xi_k$
 $\Gamma_x(\psi_+ + \psi_-)$
 $\int \Gamma_x(\tau) \Gamma_y(0)$

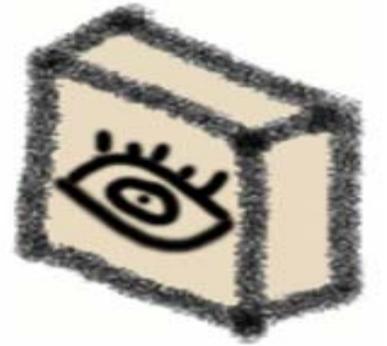
La Superposition



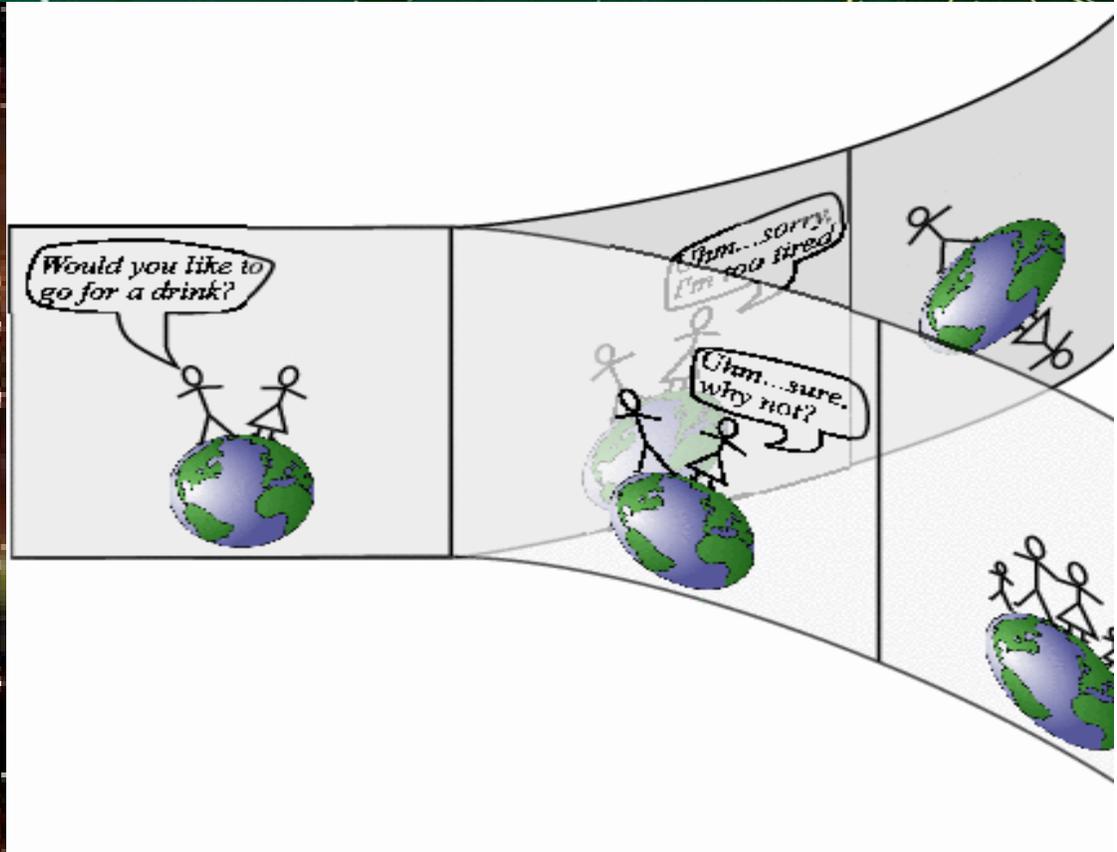
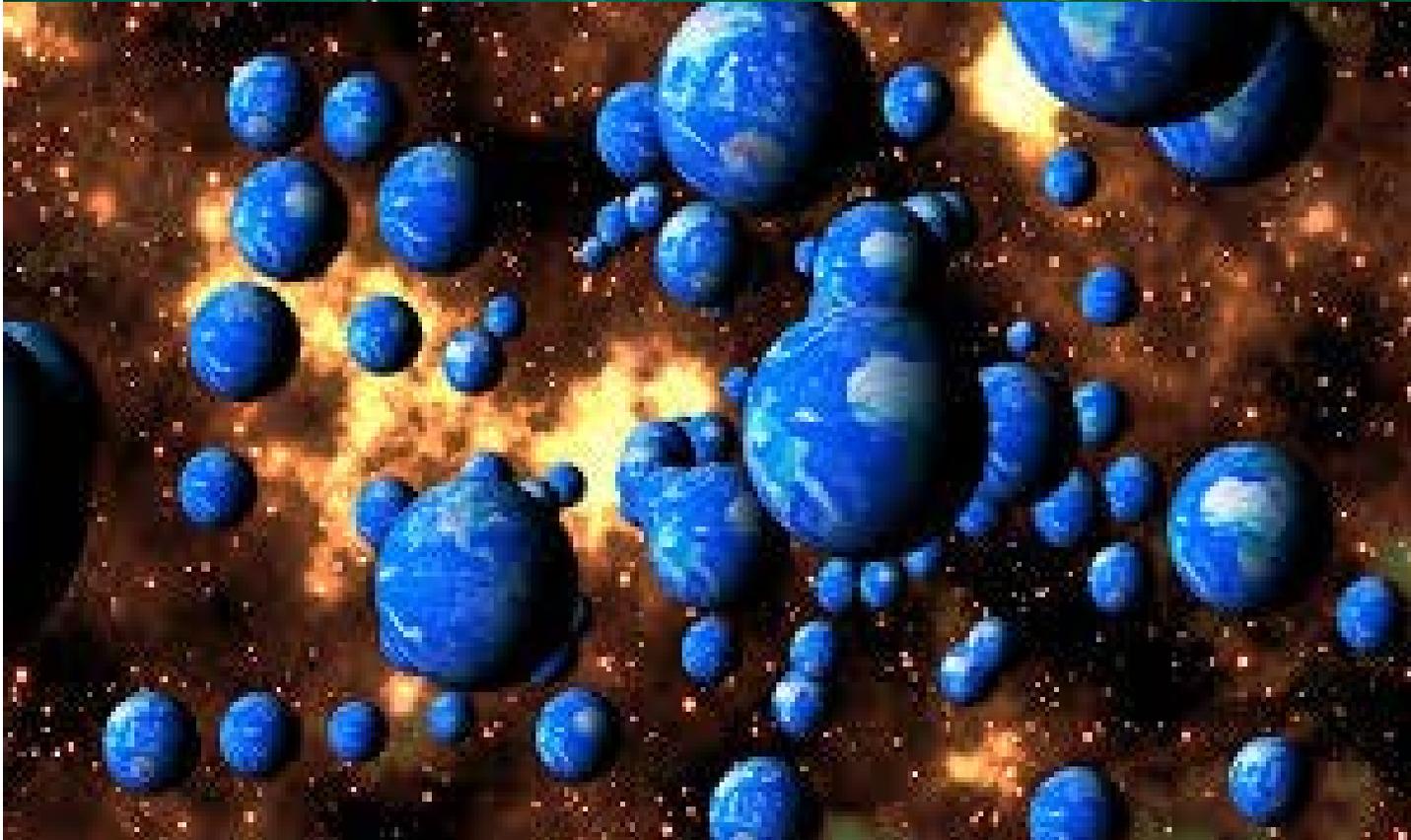
Quantum coherence



Quantum decoherence

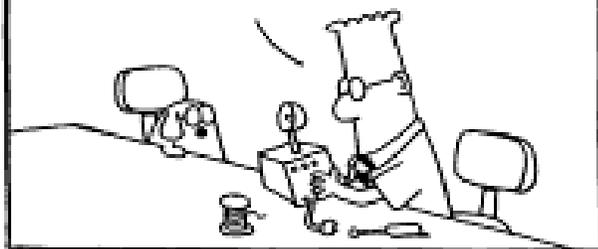


Univers multiples et parallèles



Univers?

I'VE INVENTED A QUANTUM COMPUTER, CAPABLE OF INTERACTING WITH MATTER FROM OTHER UNIVERSES TO SOLVE COMPLEX EQUATIONS.

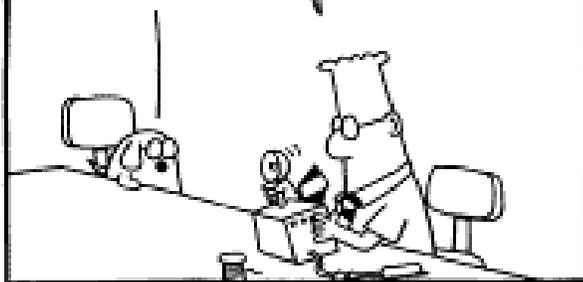


ACCORDING TO CHAOS THEORY, YOUR TINY CHANGE TO ANOTHER UNIVERSE WILL SHIFT ITS DESTINY, POSSIBLY KILLING EVERY INHABITANT.

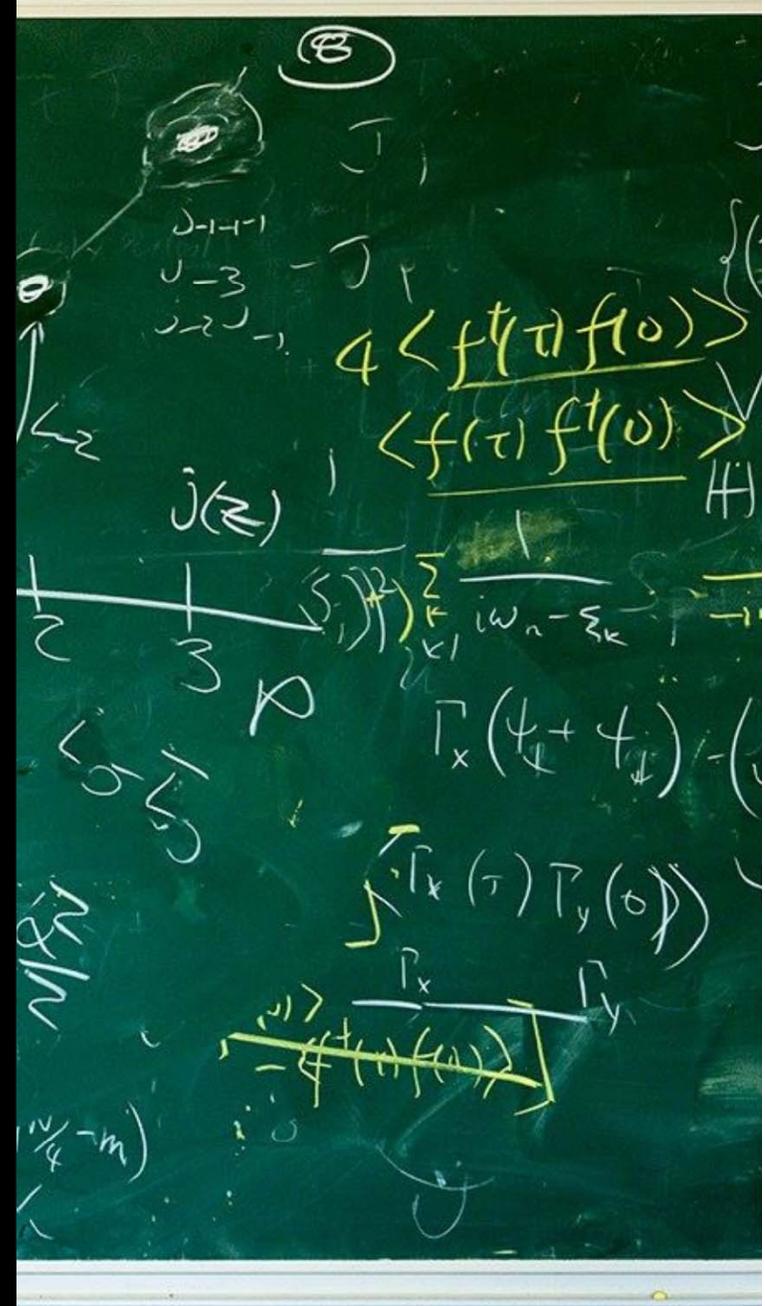
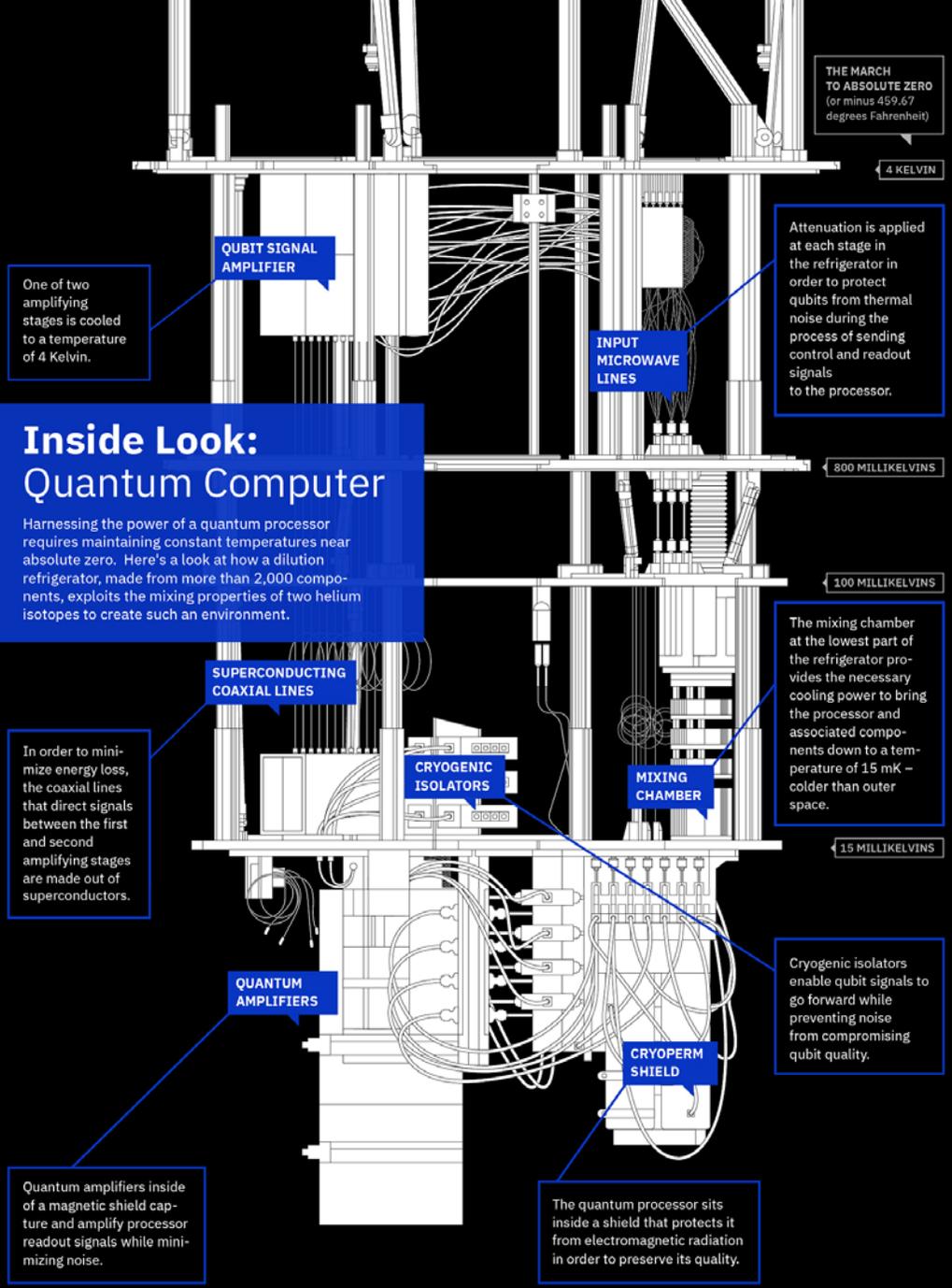


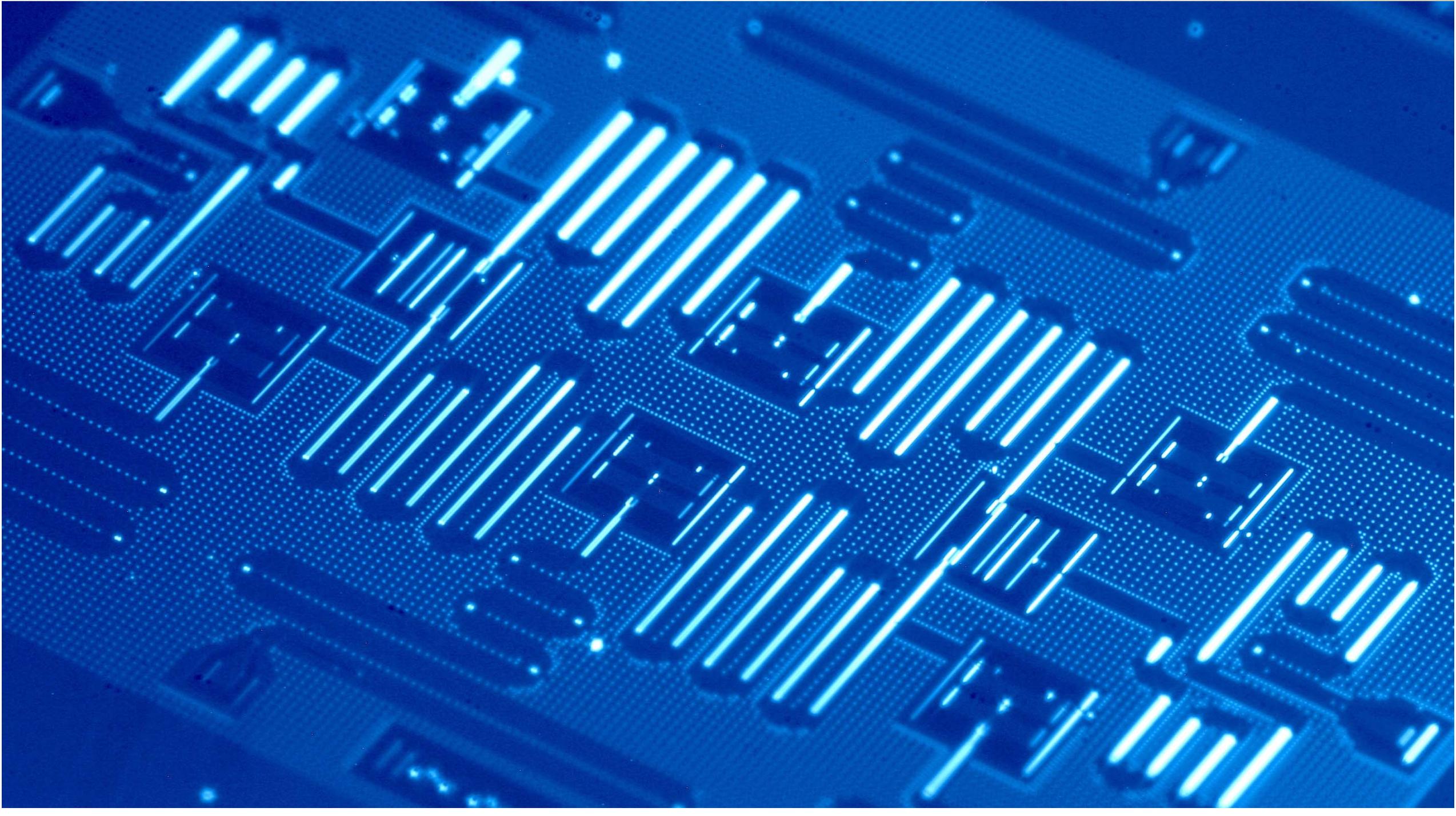
SHIFT HAPPENS.

FIRE IT UP.



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$$\frac{1}{\mathcal{P}(h, m, p)} \int_{h, m, p}$$

$$+ \delta_{\phi\phi} \delta_{m+n, 0} \mathcal{P}_2(\dots)$$

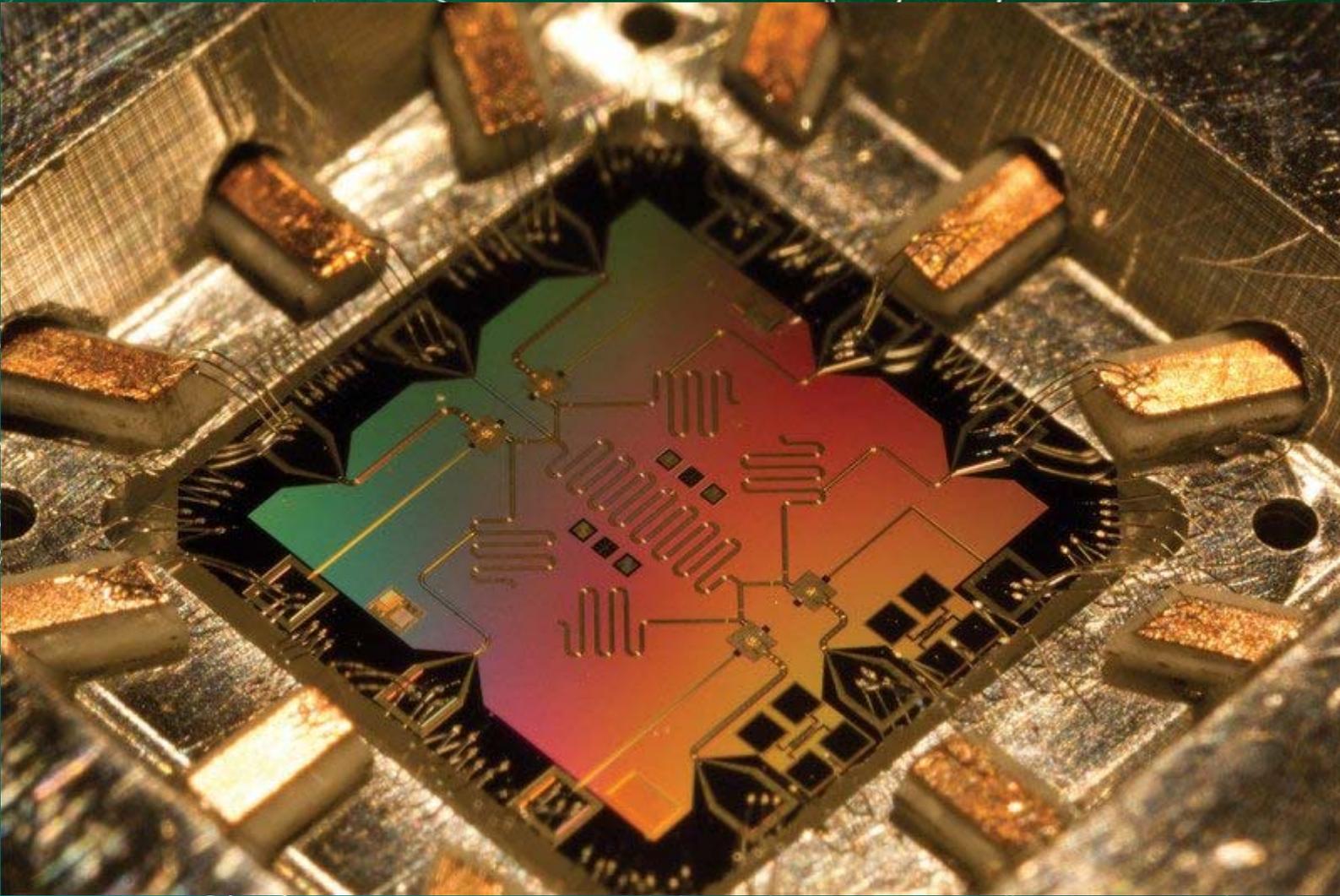
$$E \text{ Lot } \bar{L}_0$$

(8)

$$\sum_{abc} \dots$$

$$= m \delta_{m+n, 0}$$

$$V_{\text{resoro}}$$



$$4 \langle f(\tau) f(0) \rangle$$

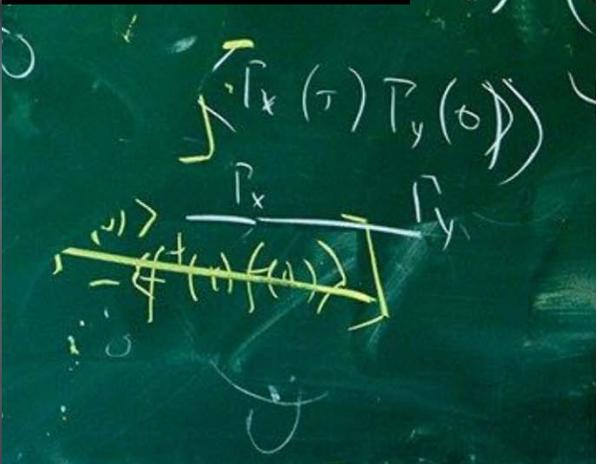
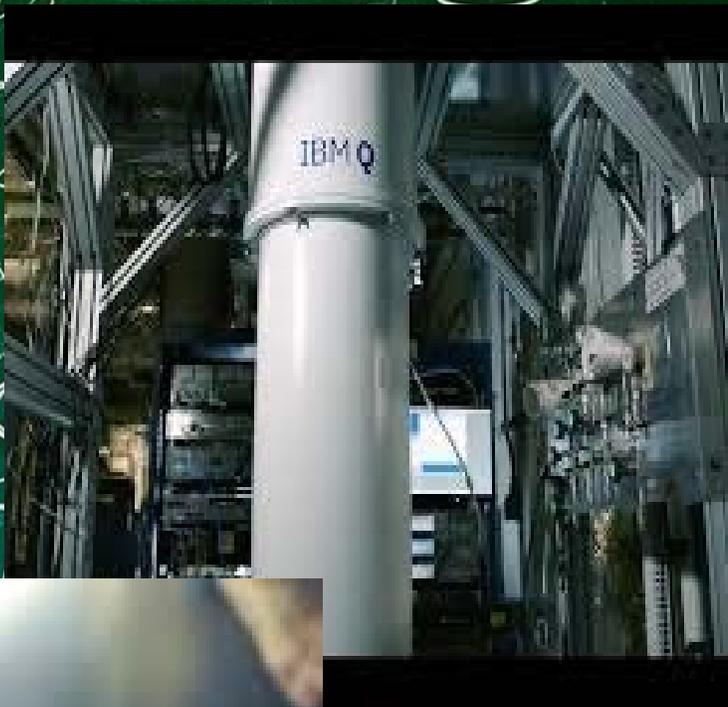
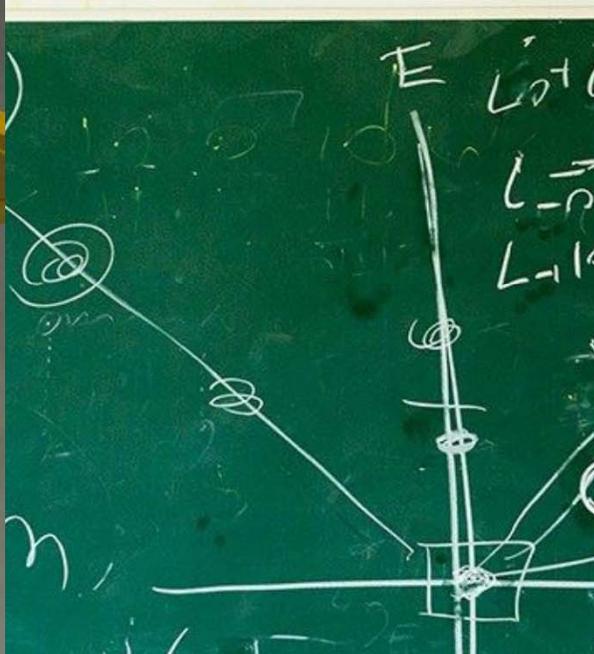
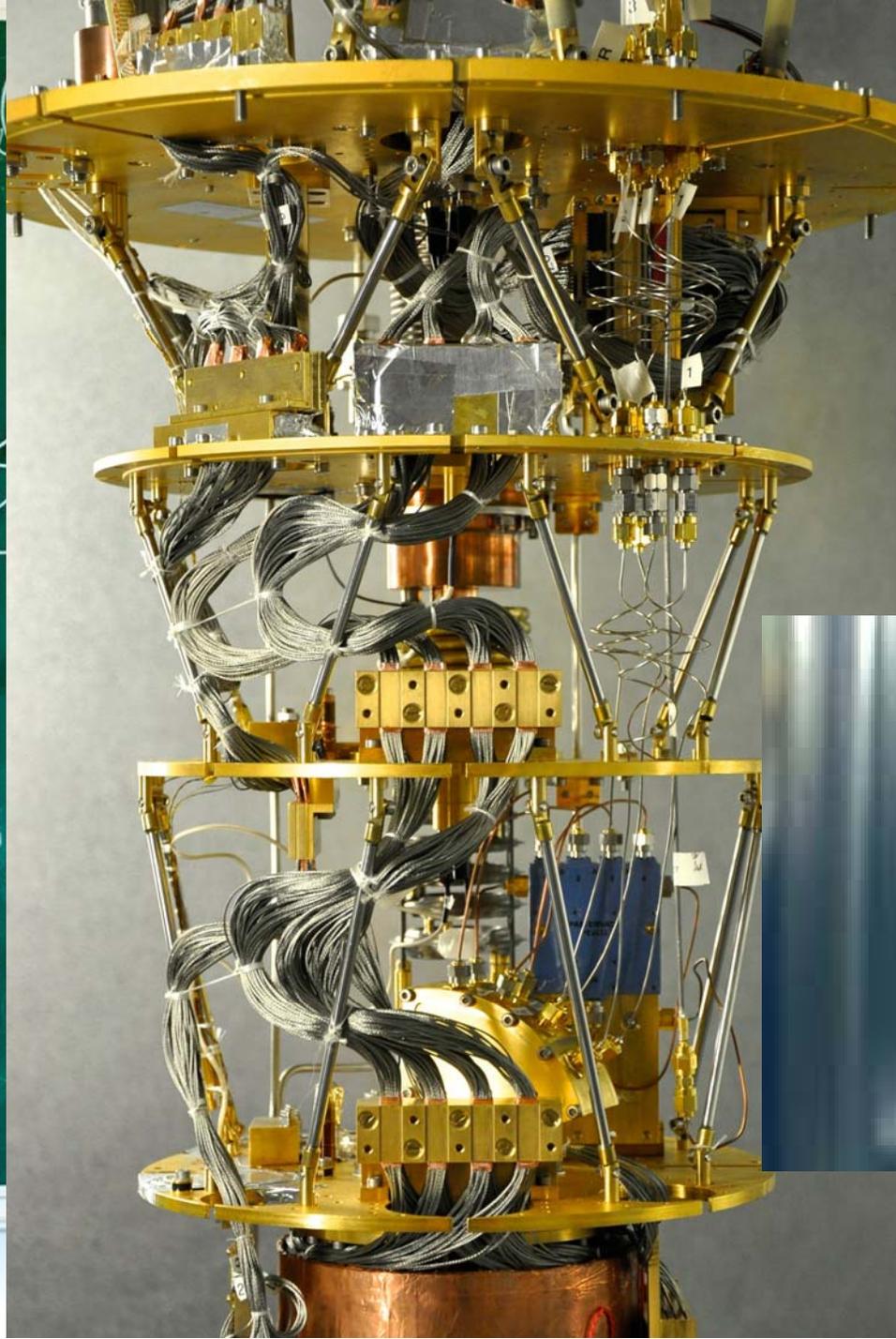
$$\langle f(\tau) f(0) \rangle$$

$$\sum_{k=1}^{\infty} \frac{1}{i\omega_n - \epsilon_k}$$

$$T_x(\psi_+ \psi_-)$$

$$T_x(\tau) T_y(0)$$

$$T_x \quad T_y$$



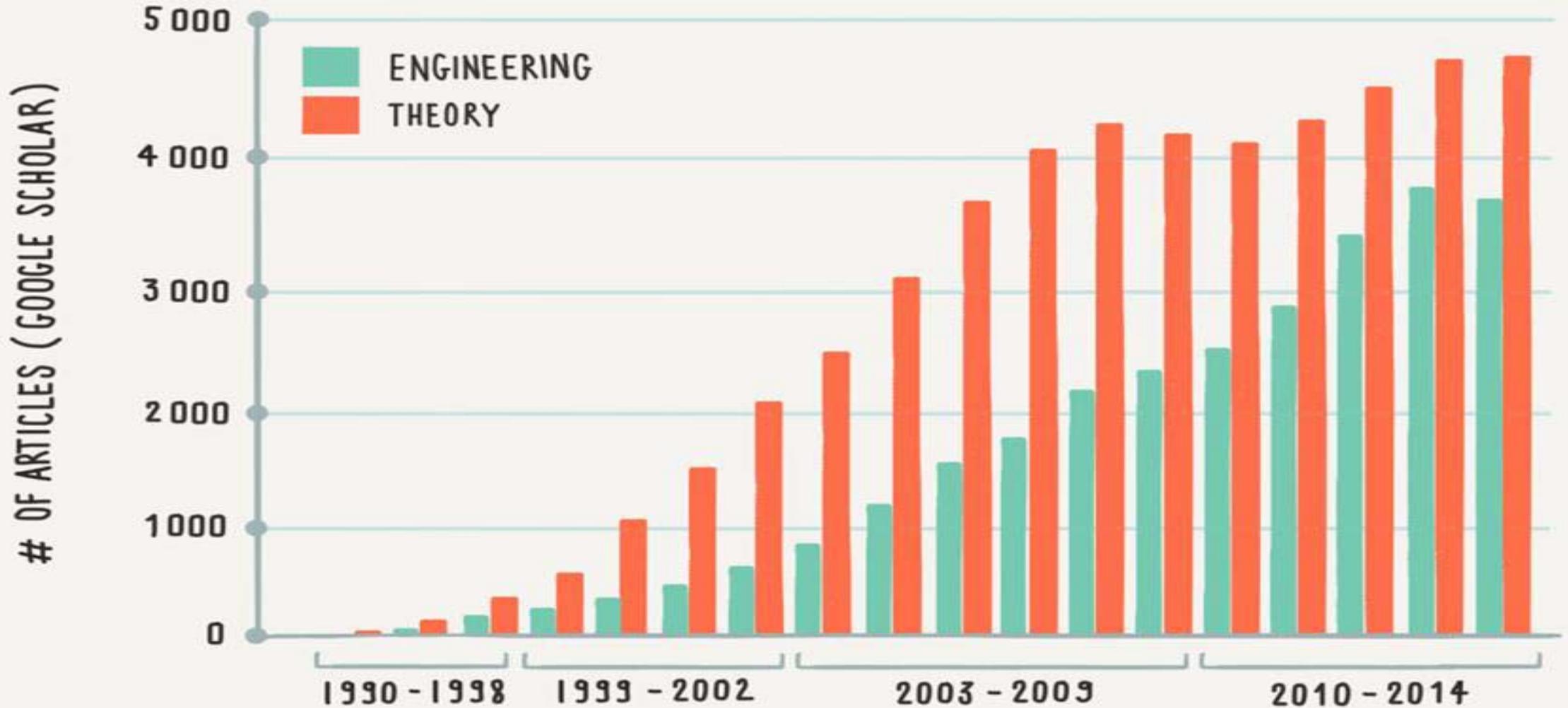
$\frac{1}{\sqrt{2}} [P(\hbar, m, p)] \psi_{m+n}$ + $\delta_{\phi\psi} \delta_{m+n, 0} P_2(\)$ $E \text{ Lot } \bar{L}_0$ $1 \rightarrow 10$ \textcircled{B}

$\sum_{abc} \dots$
 $= m \delta_{m+n}$
Virasoro

$f(\tau) f(0)$
 $(\tau) f'(0)$
 $i\omega_n - \sum_k$
 $(\psi_{\downarrow} + \psi_{\uparrow})$
 $(\tau) T_y(0)$



QUANTUM COMPUTING AND QUANTUM INFORMATION ARTICLES PER YEAR



Innovations

Technology

ONLY GOD CAN COUNT THAT FAST – THE WORLD OF QUANTUM COMPUTING

The progress seen in IT over the last few years is truly mind-boggling. And yet the computational power of classical computers appears to be limited. Therefore everyone whose sights are set on boundless technological advances turns their attention to a technology promising to deliver another big breakthrough – quantum computing.

**ONLY GOD CAN COUNT THAT
FAST – THE WORLD OF
QUANTUM COMPUTING**

**MACHINE LEARNING.
COMPUTERS COMING OF AGE**

**THE INVISIBLE WEB THAT
SURROUNDS US, I.E. THE
INTERNET OF THINGS**

**ACCORDING TO OUR
COMPUTERS... YOU DON'T
EXIST**

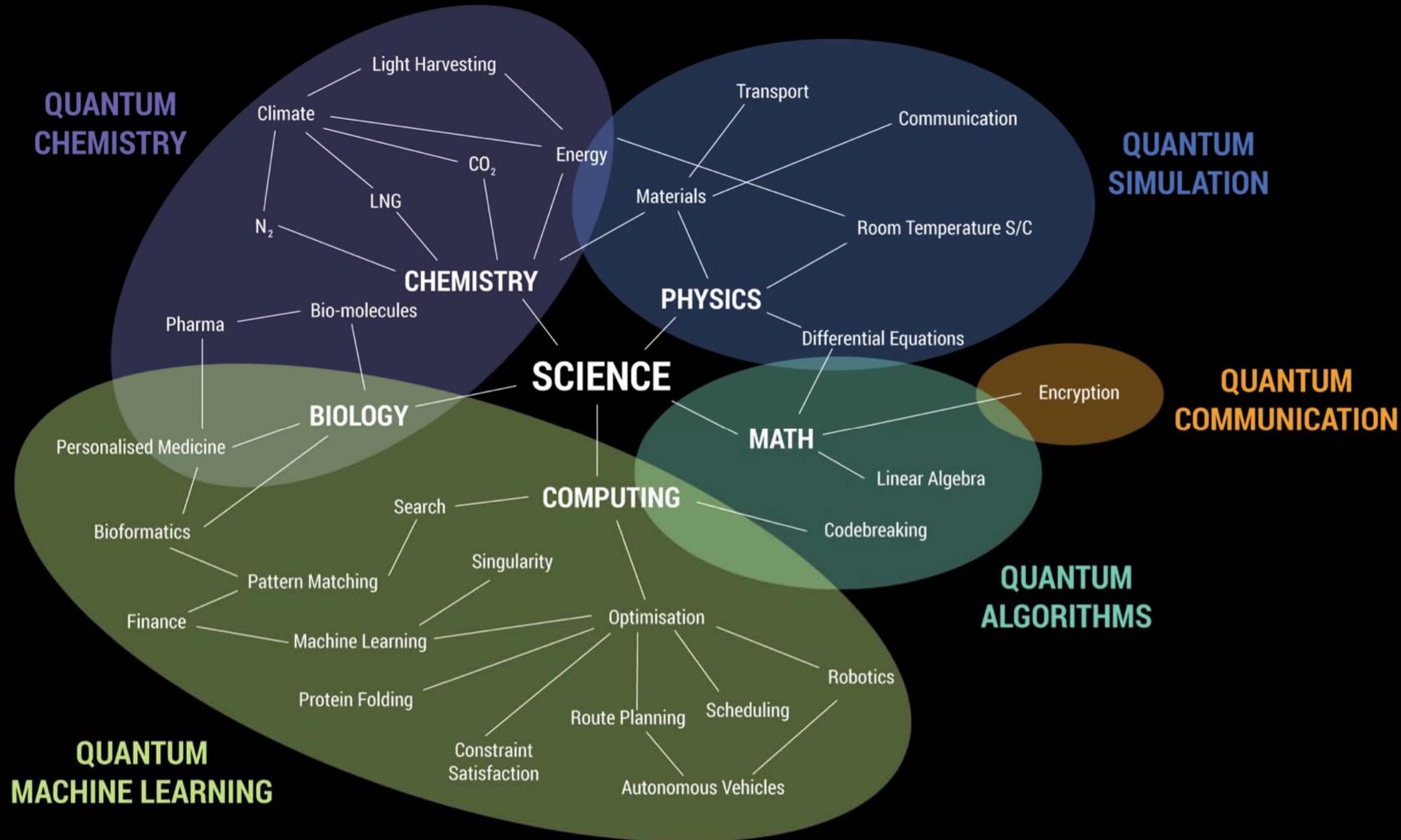
QUANTUM CHEMISTRY

QUANTUM SIMULATION

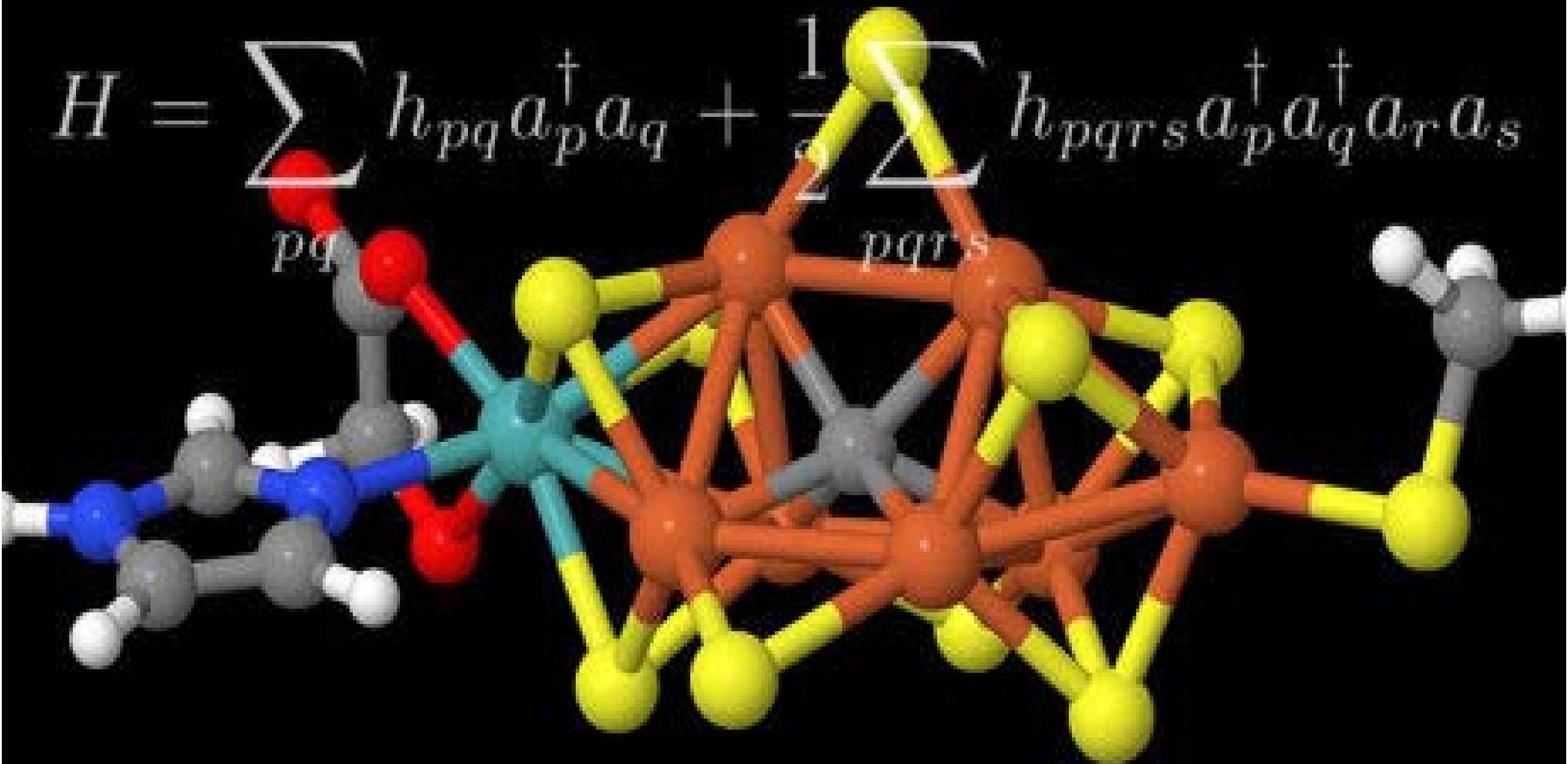
QUANTUM COMMUNICATION

QUANTUM ALGORITHMS

QUANTUM MACHINE LEARNING



$$H = \sum_{pq} h_{pq} a_p^\dagger a_q + \frac{1}{4} \sum_{pqrs} h_{pqrs} a_p^\dagger a_q^\dagger a_r a_s$$



$$\frac{1}{\sqrt{1 + \frac{1}{\mu^2}}}$$

$$+ \delta_{\phi\phi} \delta_{m+n,0} r P_2(\dots)$$

$$E \text{ Lot } \bar{L}_0$$

$$L \rightarrow 10$$

$$\sum f^{abc}$$

$$J^c_{m+n}$$

$$= m \delta_{m+n,0}$$

Free Bos

$$\frac{\partial \mathcal{L}}{\partial \psi} = 0$$

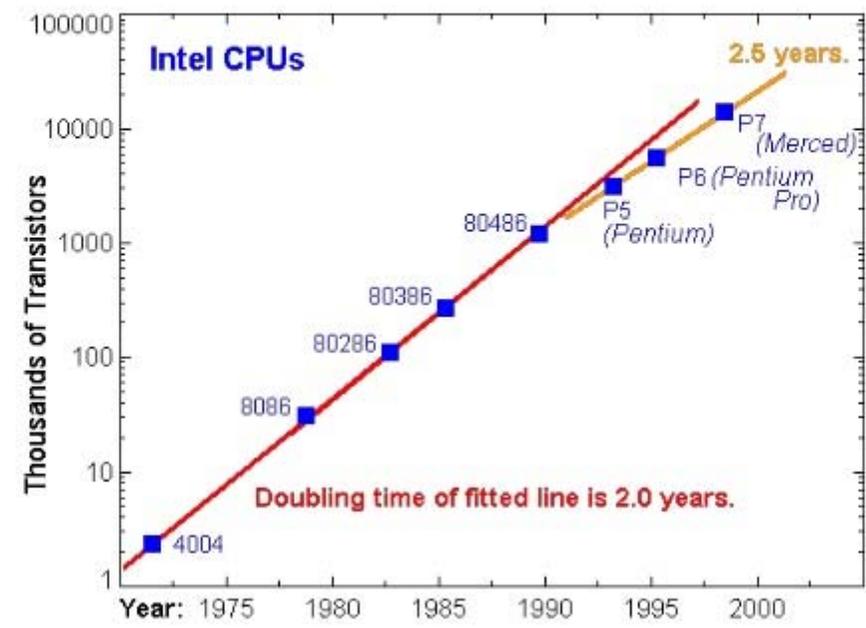
$$h = -1$$

$$j_c = 0$$

$$[-1, 1]^m$$

Virasoro

The Future



$$4 \langle f(\tau) f(0) \rangle$$

$$\langle f(\tau) f'(0) \rangle$$

$$j(z)$$

$$\sum_{k=1}^{\infty} \frac{1}{\omega_n - \xi_k}$$

$$T_x(\tau) T_y(0)$$

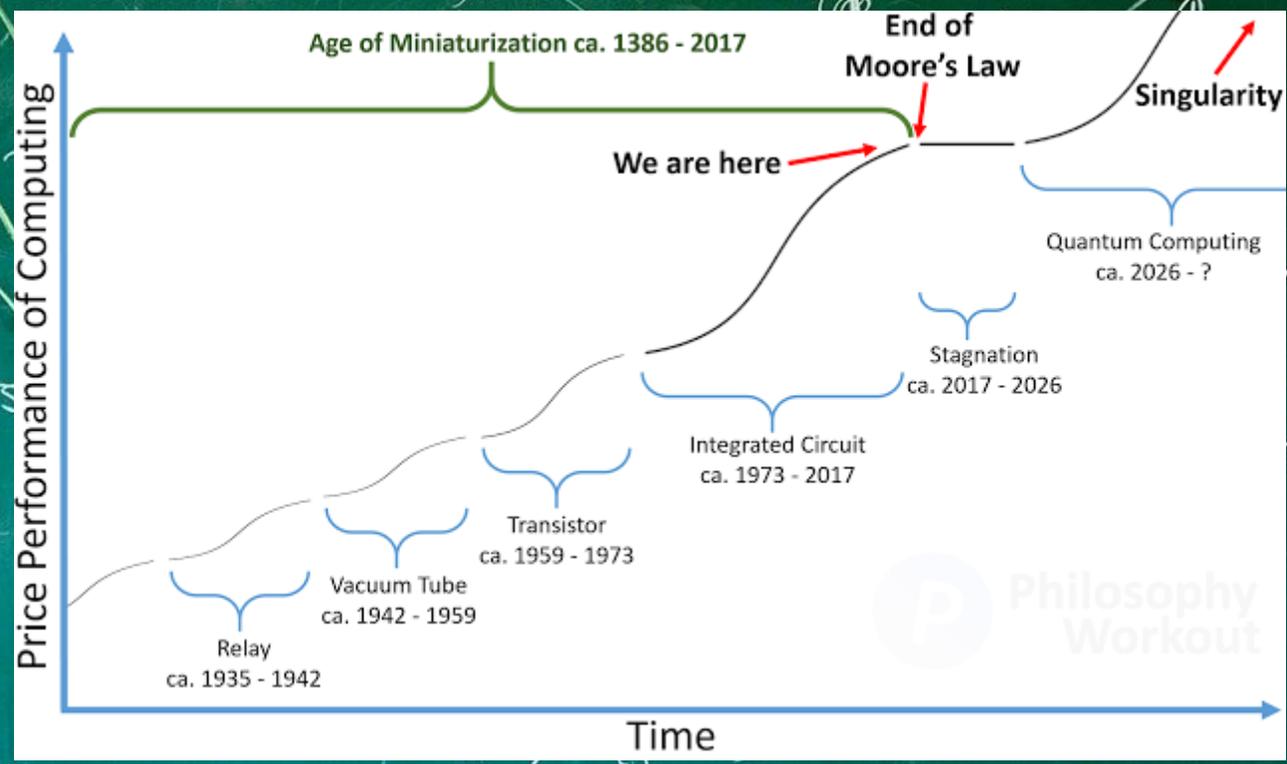
$$T_x(\tau) T_y(0)$$

$\frac{1}{P(h, m, n)}$
 \sum_{abc}
 $= m \sum_{m+n, 0}$
 $V. r. s. o. r. o.$

$+ \delta \phi \delta_{m+n, 0} r P_2(\cdot)$
 J_c
 J_{m+n}
 Free Boson
 $\frac{\partial \mathcal{L}}{\partial \psi}$
 $h = -1$
 $J_c = 0$
 $[-1, 1]^m$

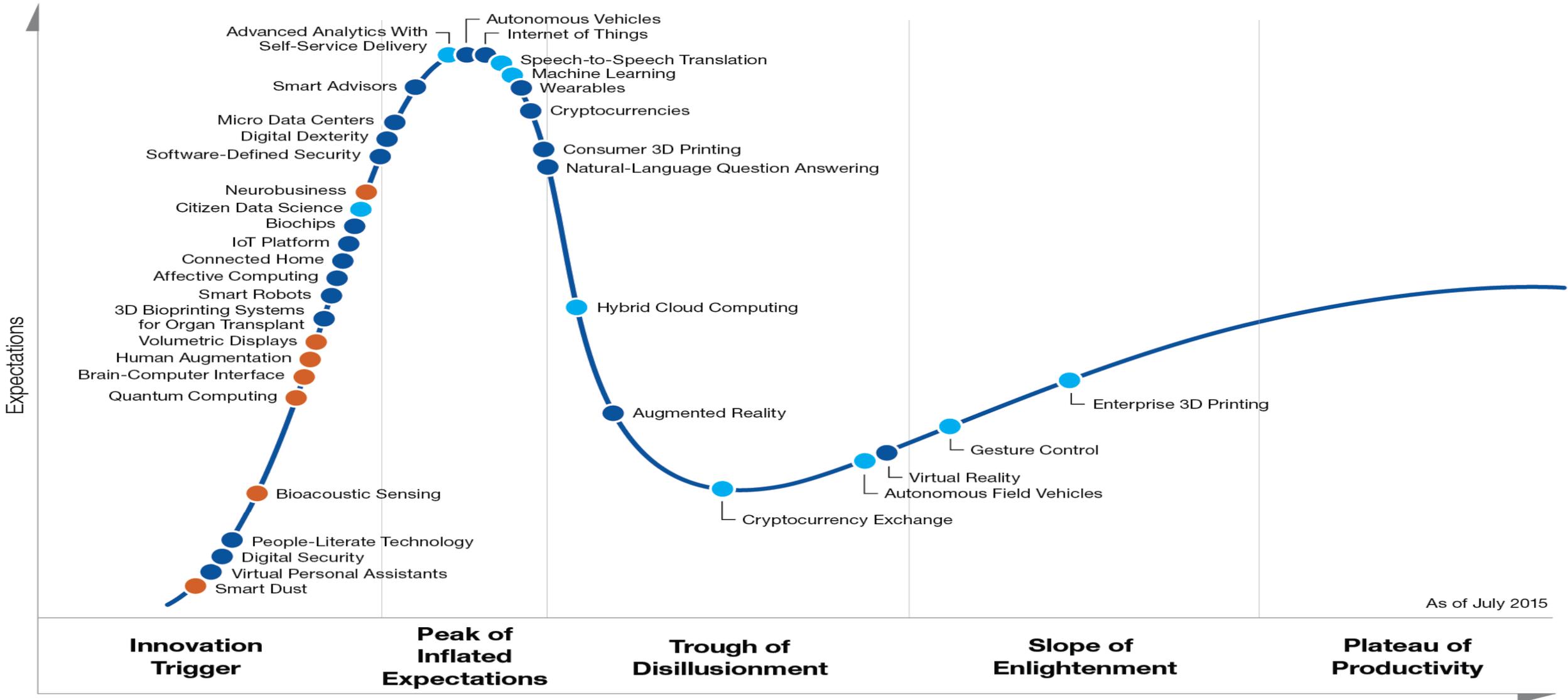
E
 $L \rightarrow L_0$
 $L \rightarrow 10$
 $L \rightarrow 10$

$\langle f(\tau) f(0) \rangle$
 $\langle f(\tau) f'(0) \rangle$
 $j(z)$
 $\sum_{k=1}^{\infty} i \omega_k - \xi_k$
 $P_x(\psi_+ \psi_-)$
 $P_x(\tau) P_y(0)$
 P_x
 P_y

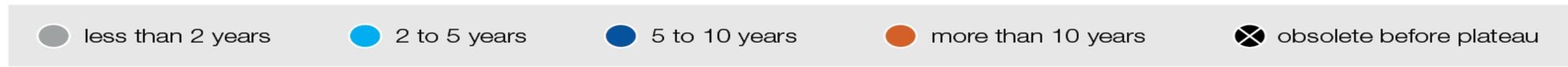


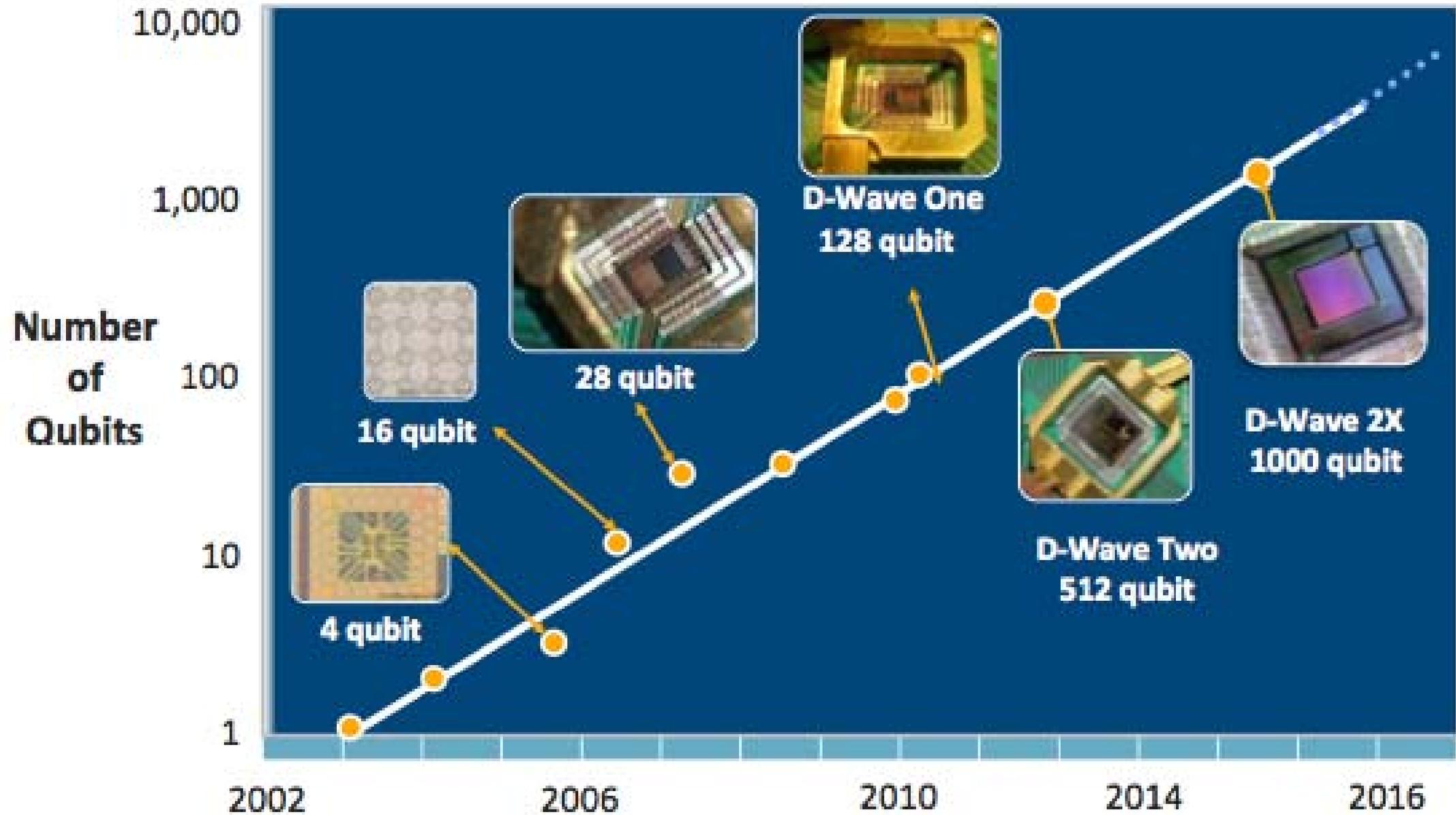
$r(m) \times \frac{1}{4} - m$

Emerging Technology Hype Cycle



Years to mainstream adoption:

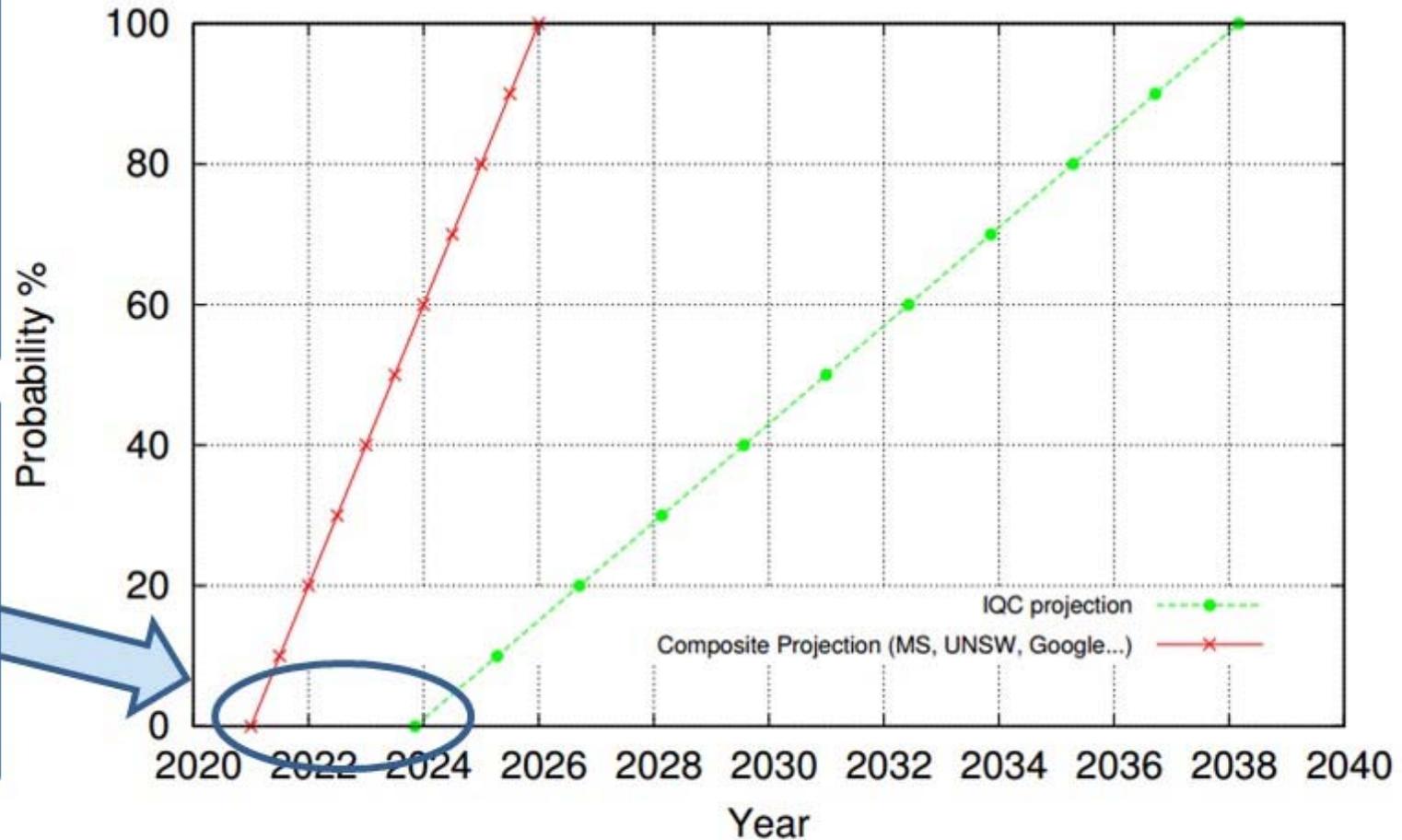




Projected Probability of General Purpose Quantum Computers Arriving By Year

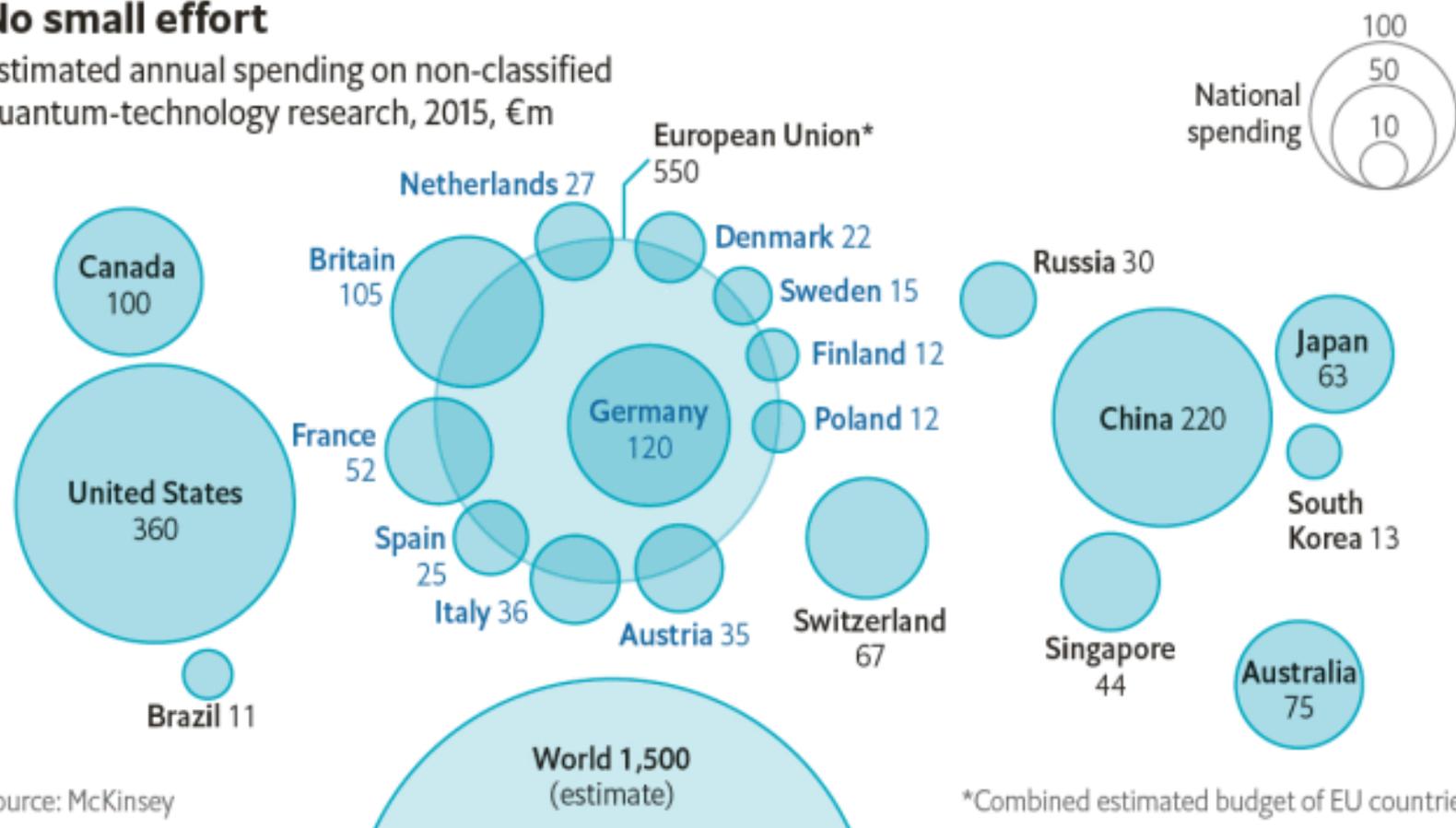
The green graph is based on data from the IQC (Institute for Quantum Computing) provided earlier in 2015. The red graph is based on data after significant breakthroughs were achieved (Microsoft, UNSW, IBM, Google, etc.) since the beginning of 2H15.

*Critical infrastructure and industries with fiduciary responsibilities **MUST** be re-tooled when the threat window opens!*



No small effort

Estimated annual spending on non-classified quantum-technology research, 2015, €m



Source: McKinsey

*Combined estimated budget of EU countries

$\frac{1}{\sqrt{2\pi}} \int_{-\infty}^{\infty} P(\hbar, m, n) \chi_{\hbar, m, n} \chi_{\hbar, m, n}^{\dagger} d\hbar$

\sum_{abc}

$= m \delta_{m+n, 0}$

Virasoro

$+ \delta_{\phi\phi} \delta_{m+n, 0} \chi_{\hbar, m, n}^{\dagger} \chi_{\hbar, m, n}$

$E \text{ Lot } \bar{L}_0$

$\langle f(\tau) f(0) \rangle$

$\langle f(\tau) f'(0) \rangle$

$\sum_{k=1}^{\infty} \frac{1}{k} \omega_k - \sum_{k=1}^{\infty} \omega_k$

$\Gamma_x(\psi_{\uparrow} + \psi_{\downarrow}) - (\dots)$

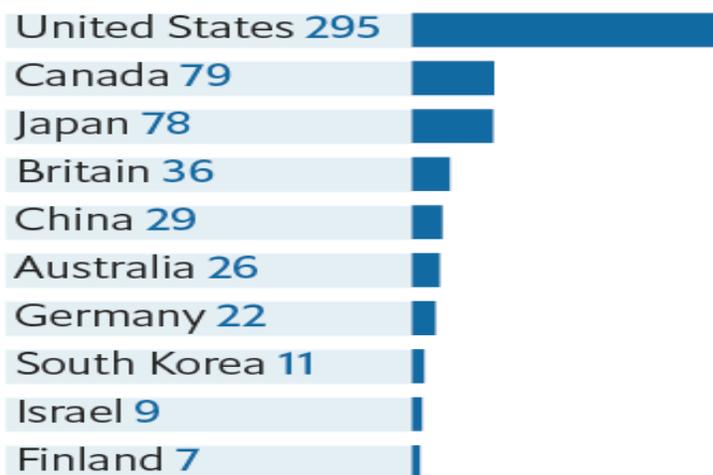
$\int \Gamma_x(\tau) \Gamma_y(0)$

$\int \Gamma_x(\tau) \Gamma_y(0)$

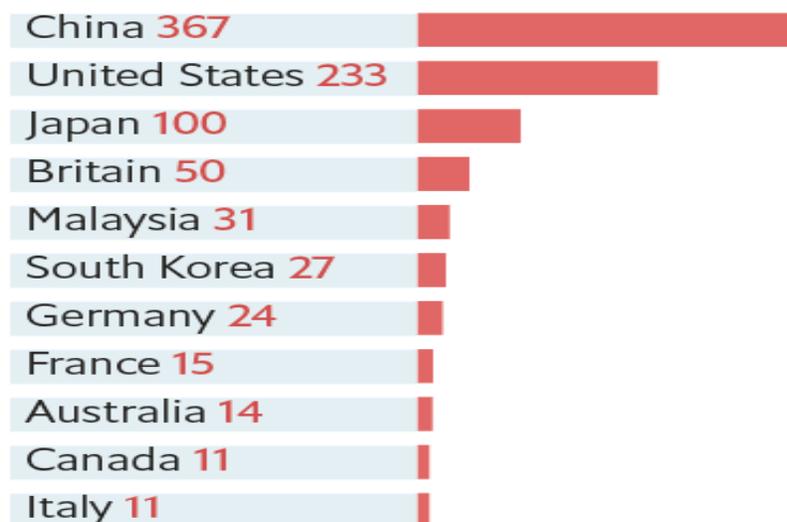
Excited states

Patent applications to 2015, in:

Quantum computing



Quantum cryptography

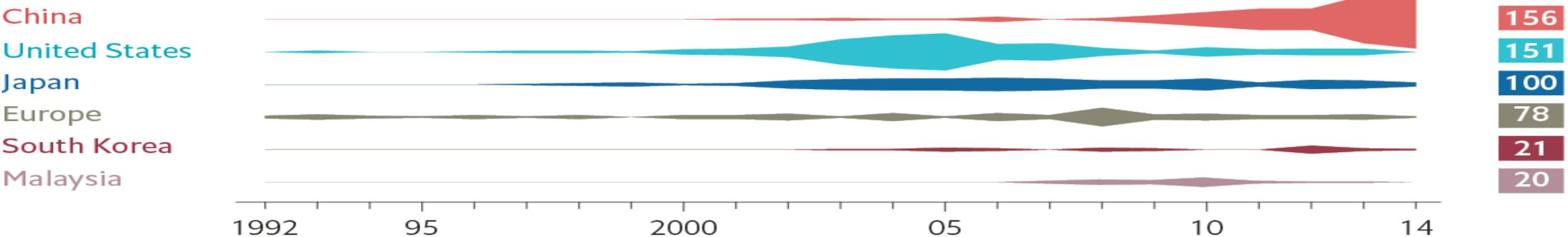


Quantum sensors



Quantum-key distribution

Patent applications by country*

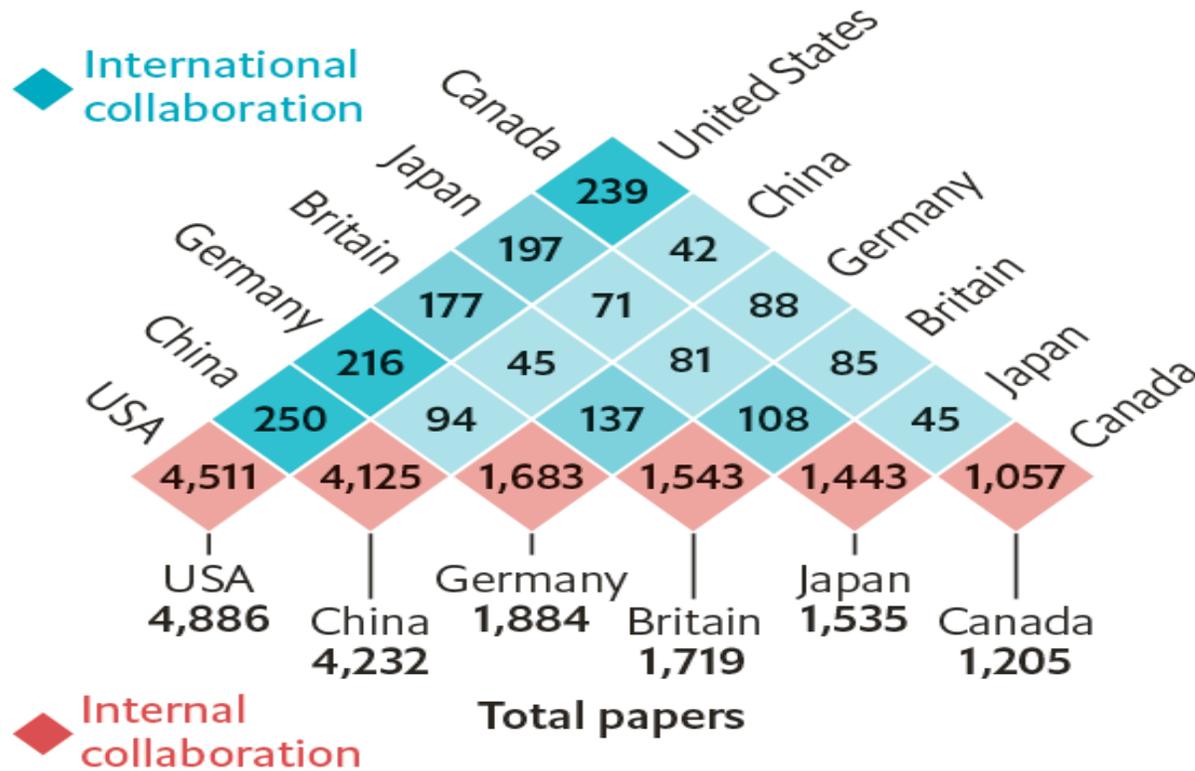


Sources: UK Intellectual Property Office; European Commission

*By location of corporate headquarters

Foreign entanglements

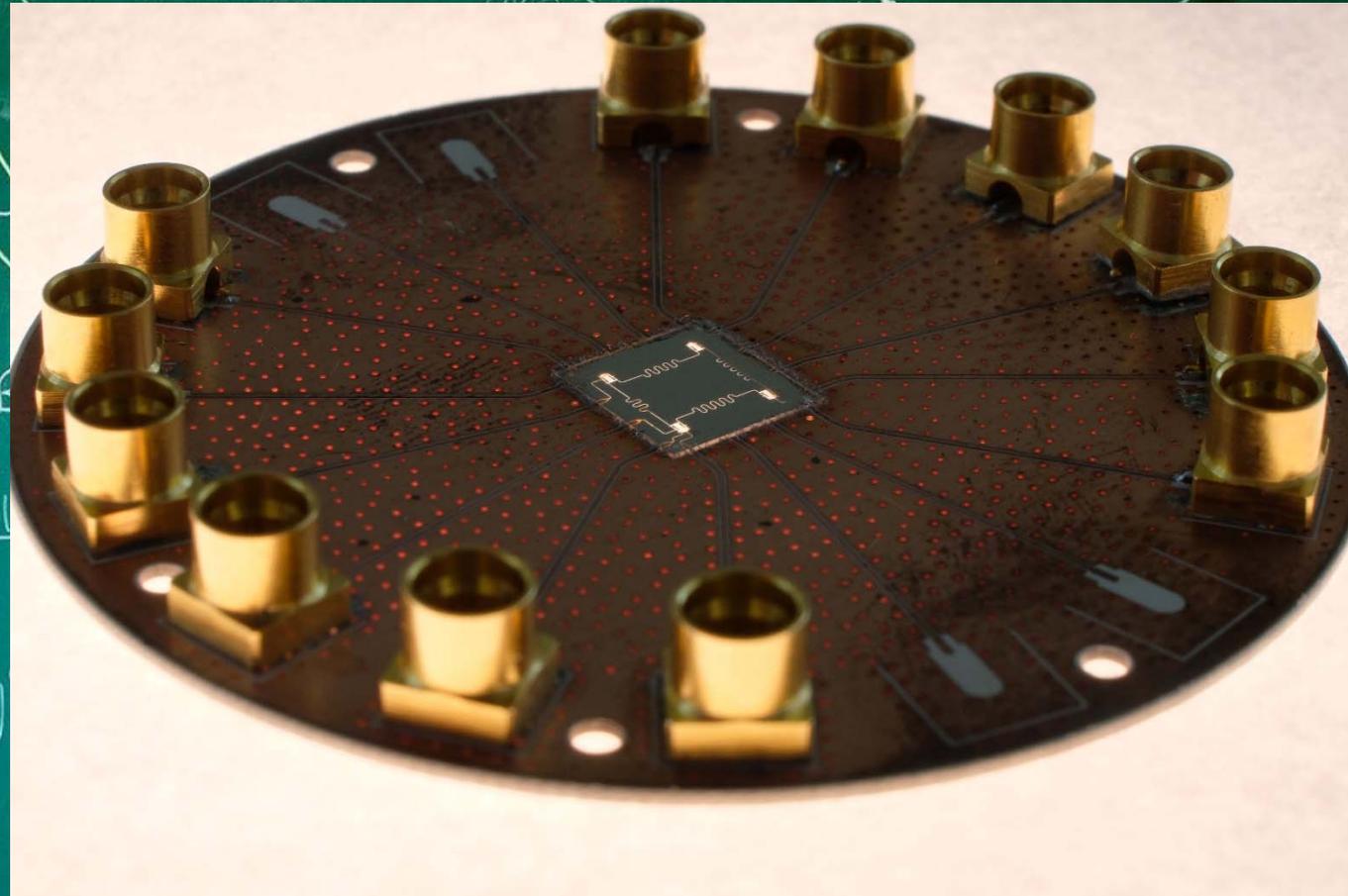
Authorship of papers on quantum computing by nationality of authors*, top 6 nations 2004-13



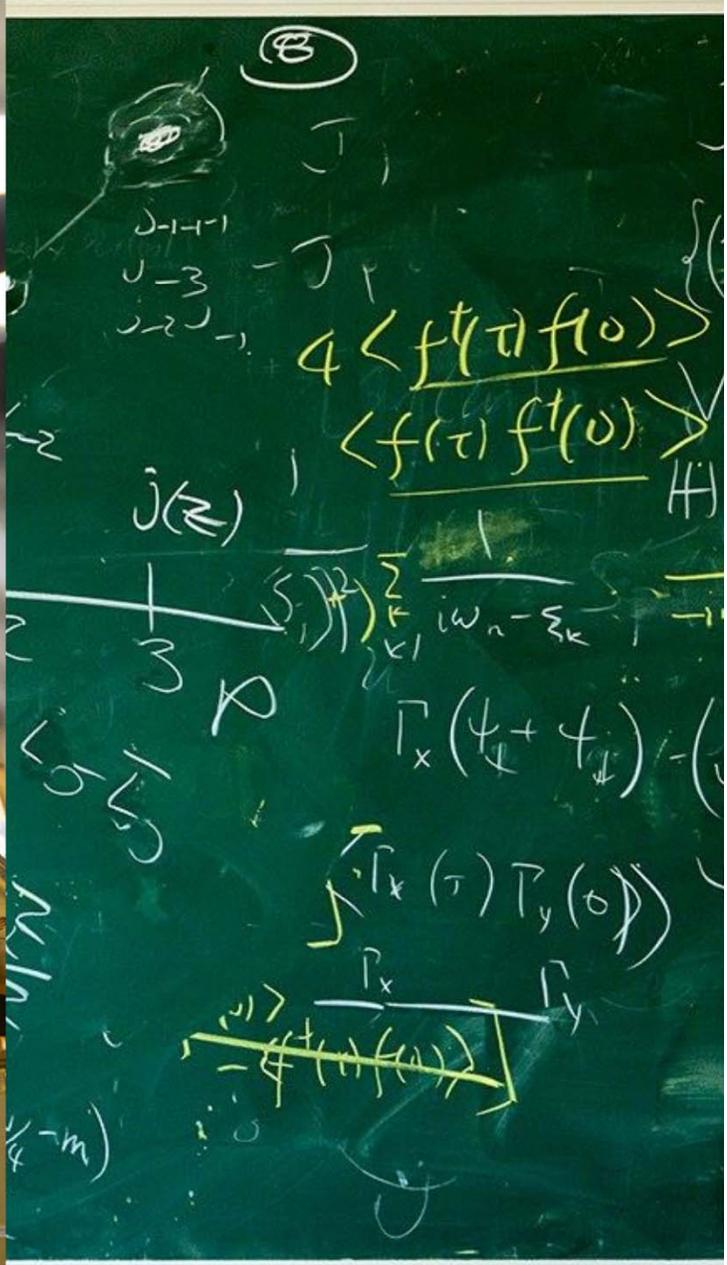
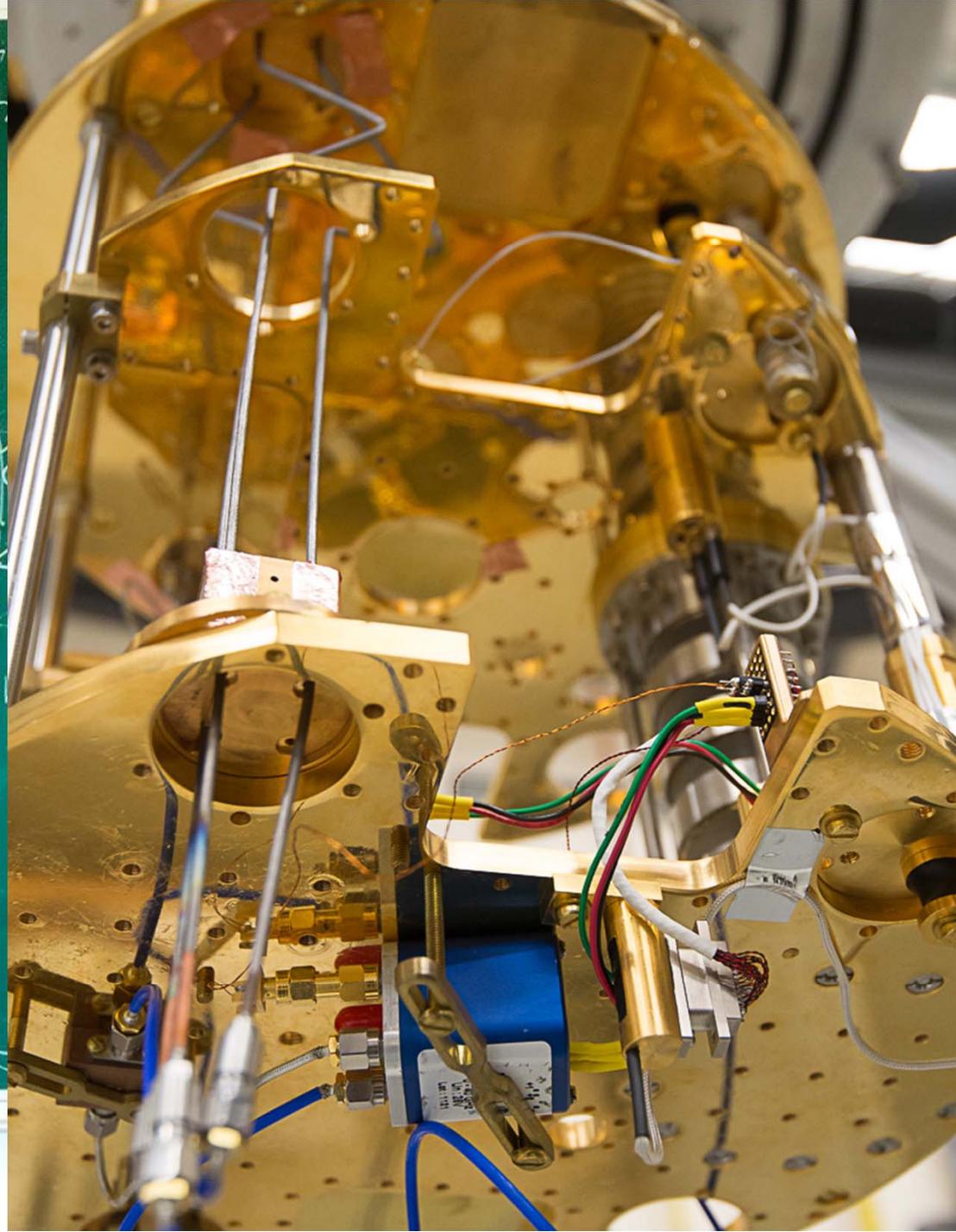
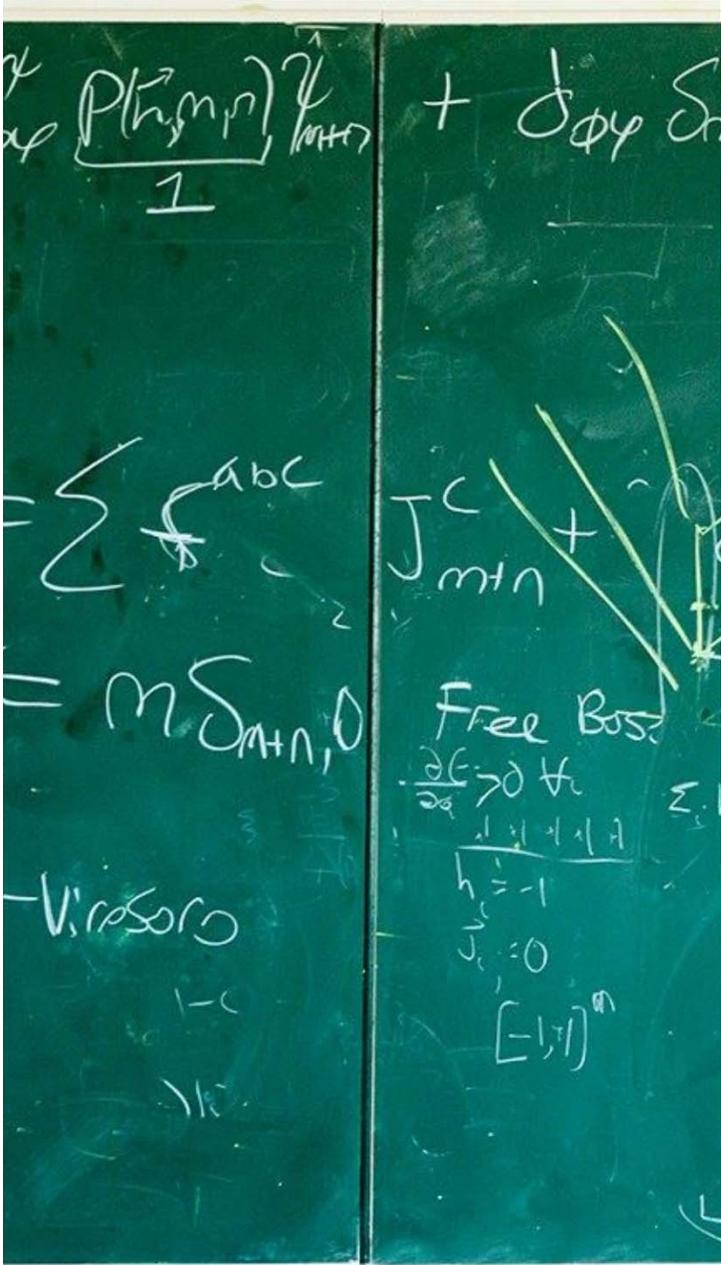
Sources: Digital Science; Clarivate

*Collaborations between more than two countries may be counted multiple times

Au Québec ?

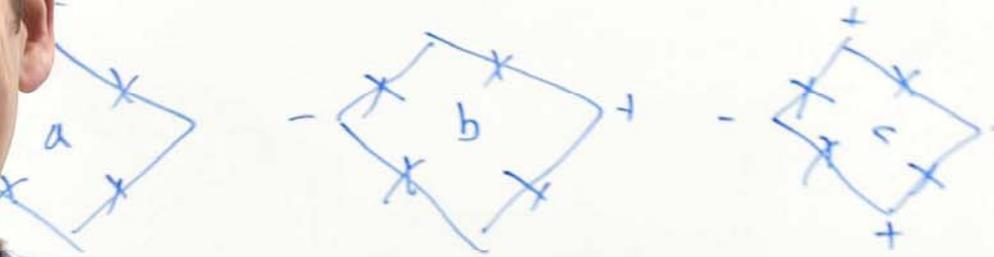
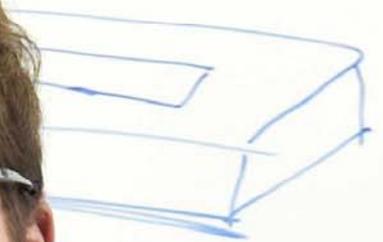
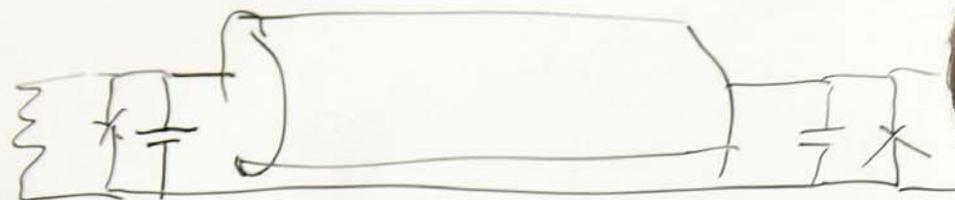


$P(\hbar, m, n)$
 $+ \delta_{\phi} \delta_{m+n, 0} P_2(\dots)$
 $E \quad L \rightarrow \bar{L}_0$
 $L \rightarrow |0\rangle$
 $L \rightarrow |0\rangle$
 $4 \langle f(\tau) f(0) \rangle$
 $\langle f(\tau) f(0) \rangle$
 $\sum_{k=1}^{\infty} \frac{1}{i\omega_n - \xi_k}$
 $\Gamma_x(\psi_+ + \psi_-)$
 $\int \Gamma_x(\tau) \Gamma_y(0)$
 Γ_x
 Γ_y
 $[-1, 1]$
 J_c
 J_{m+n}
 $Free$
 $\frac{\partial \mathcal{L}}{\partial \psi}$
 $h_c = -1$
 $J_c = 0$
 abc
 \sum
 $m \delta_{m+n, 0}$
 V, ρ, σ, τ
 $1-c$
 $1/c$

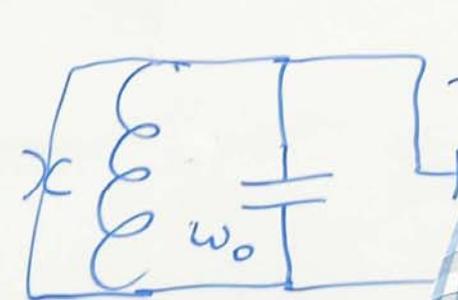


Alexandre Blais U. de Sherbrooke

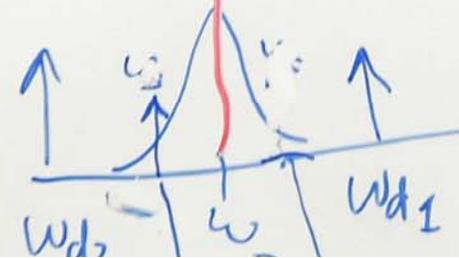
Line \rightarrow LC \rightarrow JRM



$$\omega_0 a^\dagger a + \lambda (a^\dagger a)^\dagger + \epsilon_{dL}^2 a$$



$$\omega_g = \frac{\omega_{d1} + \omega_{d2}}{2}$$



$$\frac{a[\omega_g]_{out}}{a[\omega_g]_{in}}$$

$$+ \omega_b b^\dagger b + \omega_c c^\dagger c$$

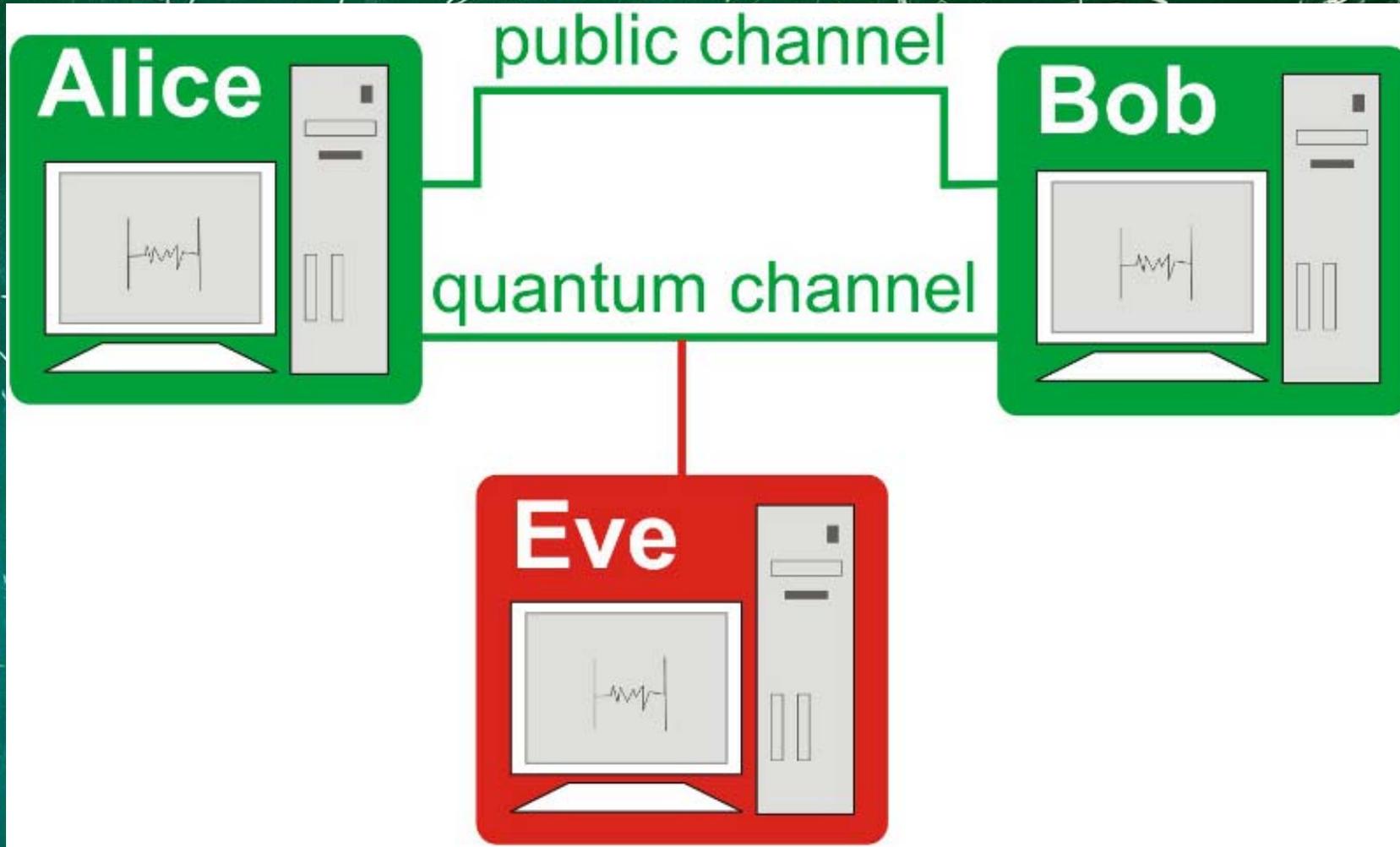
$$(a + a^\dagger) \dots (c + c^\dagger)$$

Sw

vacuum

OOPS un état quantique ne peut être mesuré



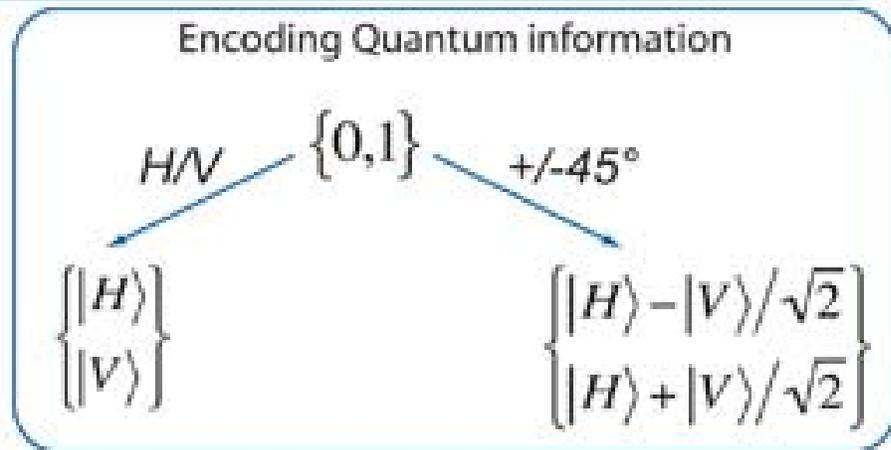
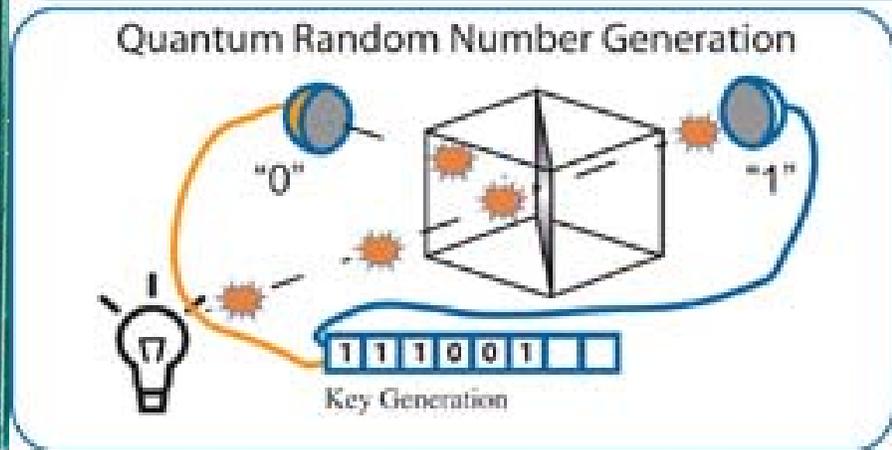
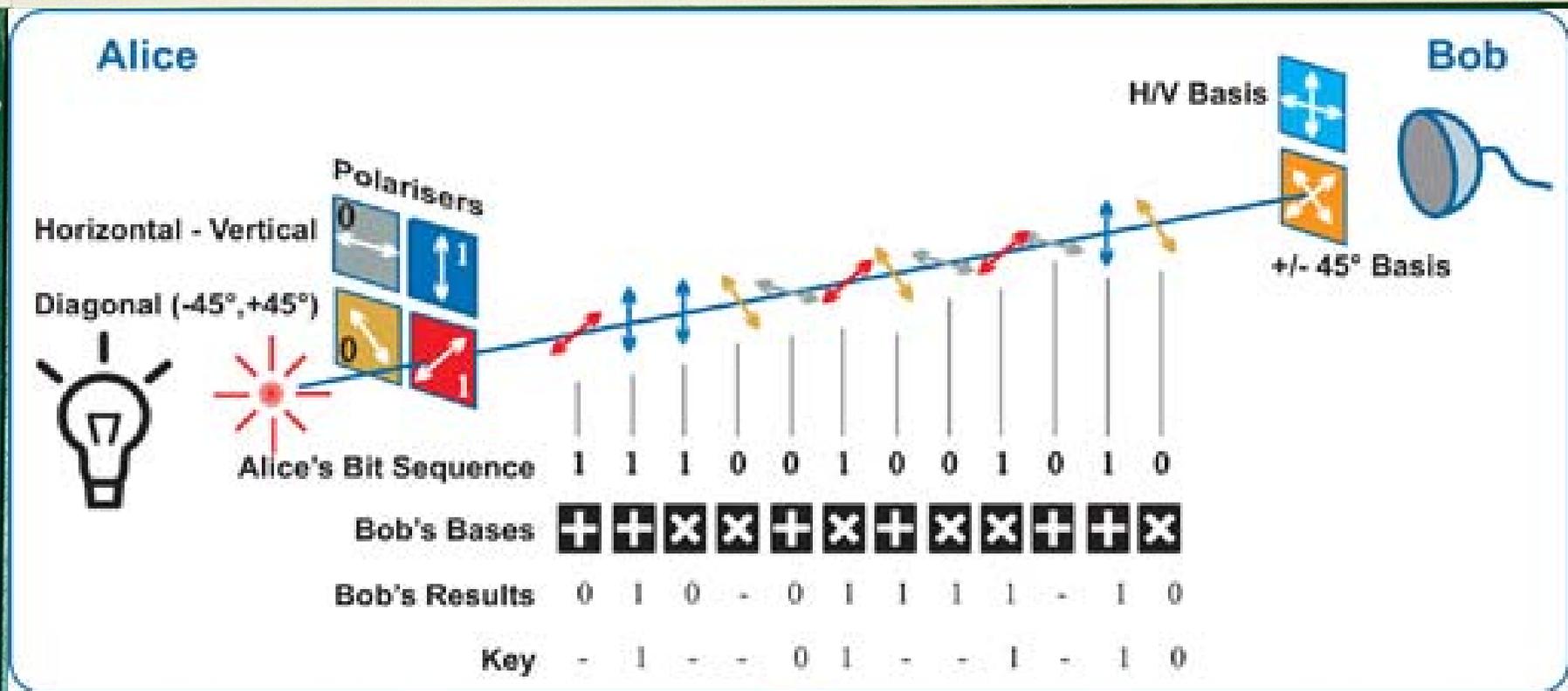


$\rho_{\text{ph}, m, n}^{\text{ph}}$
1
 \sum_{abc}
 $= m \delta_{m+n, 0}$
Virasoro
1-c
1/c

$+ \delta_{\text{ph}} \delta_{m+n, 0} \rho_{\text{ph}}^{\text{ph}}$
E Lot \bar{L}_0
⑧

$4 \langle f(\tau) f(0) \rangle$
 $\langle f(\tau) f(0) \rangle$
 $\sum_{k=1}^{\infty} \frac{1}{\omega_n - \epsilon_k}$
 $\Gamma_x(\psi_+ \psi_-)$
 $\int \Gamma_x(\tau) \Gamma_y(0)$
 Γ_x
 Γ_y

$\rho = \sum_{i,j} P_{ij} |i\rangle\langle j|$
 $\frac{1}{2}$
 $\sum_{i,j} \dots$
 \dots
 \dots

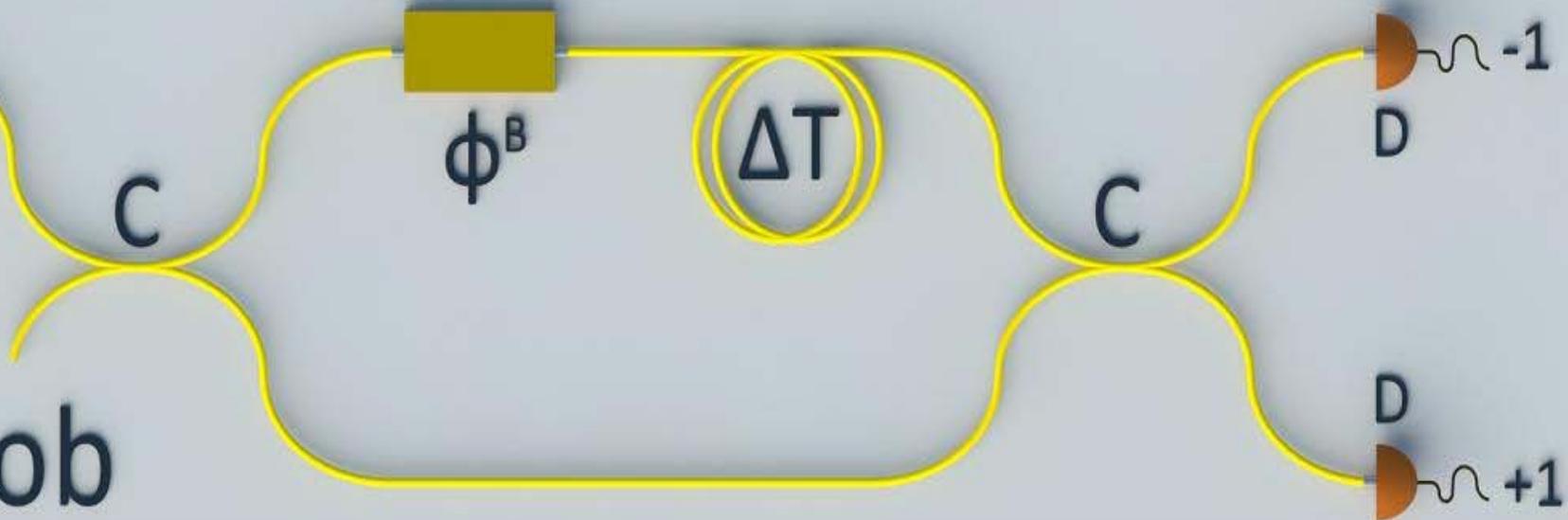


$\langle f(\tau) f(0) \rangle$
 $\langle f(\tau) f'(0) \rangle$
 \dots
 \dots
 \dots

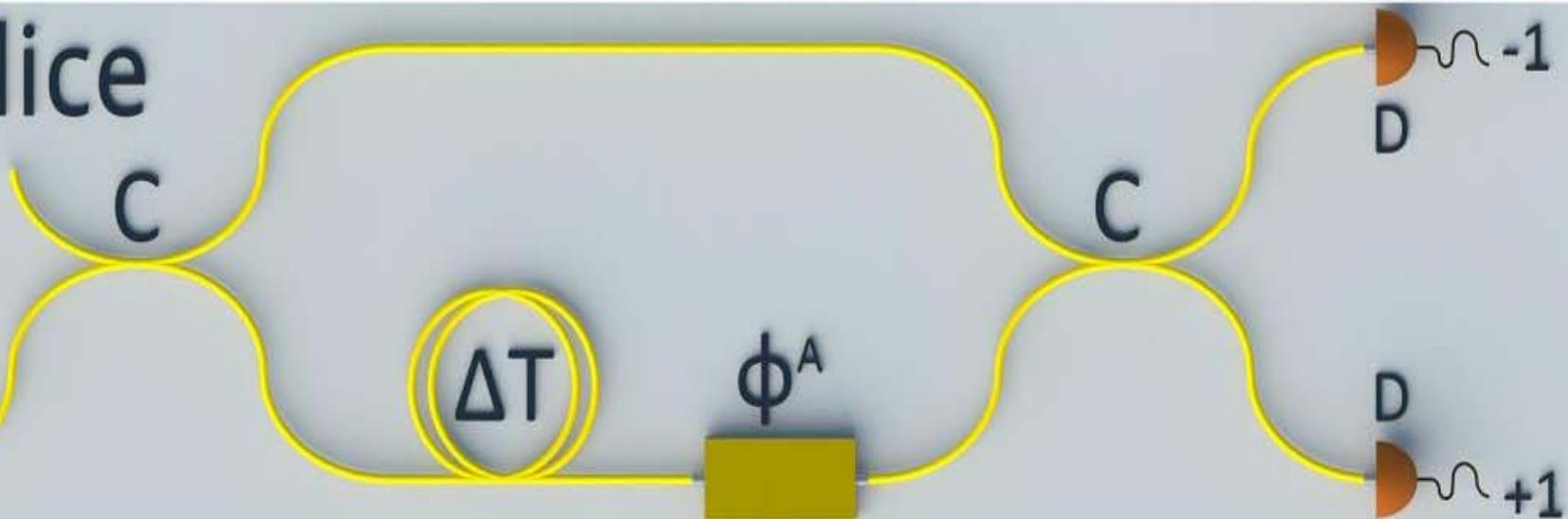
Source



Bob

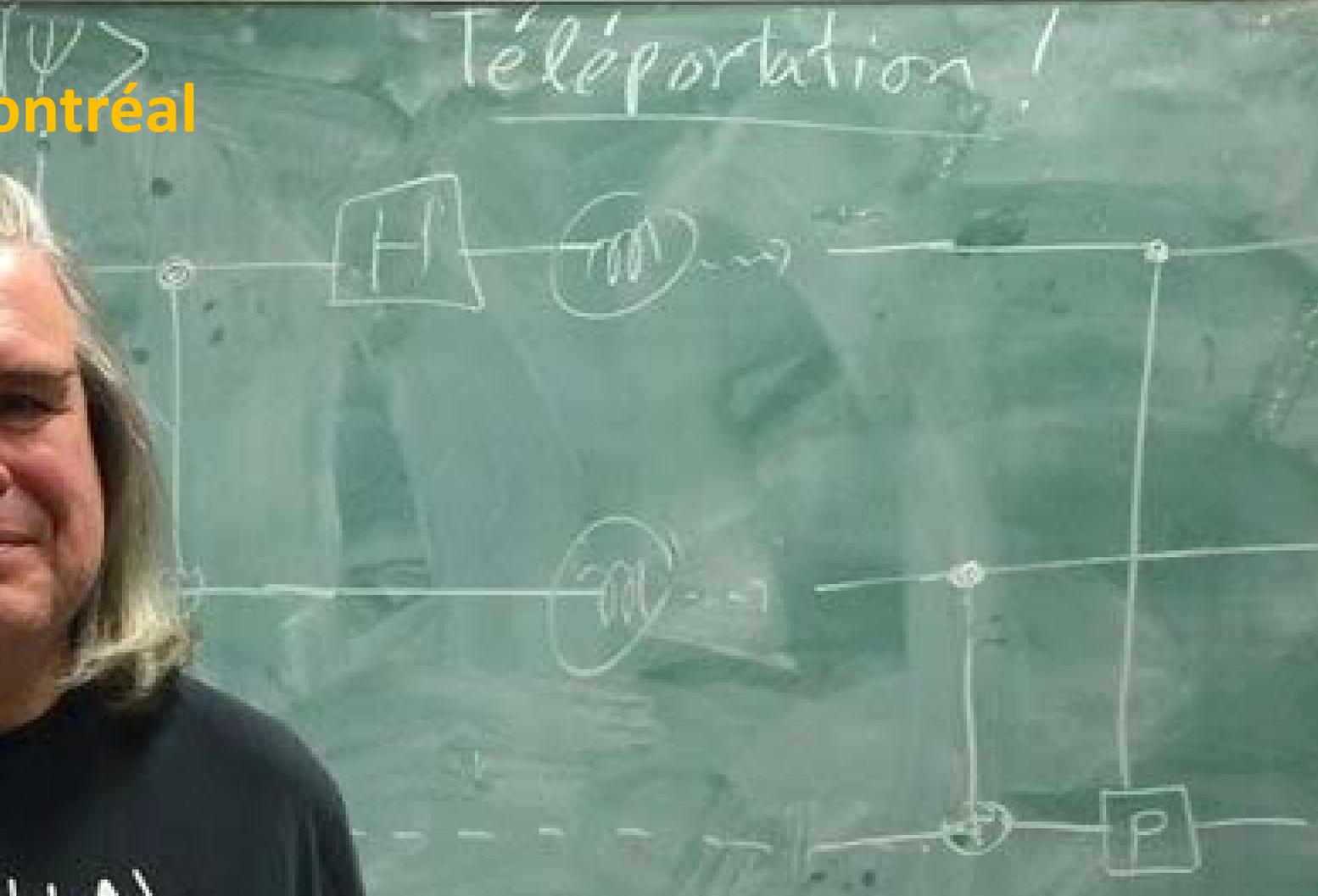
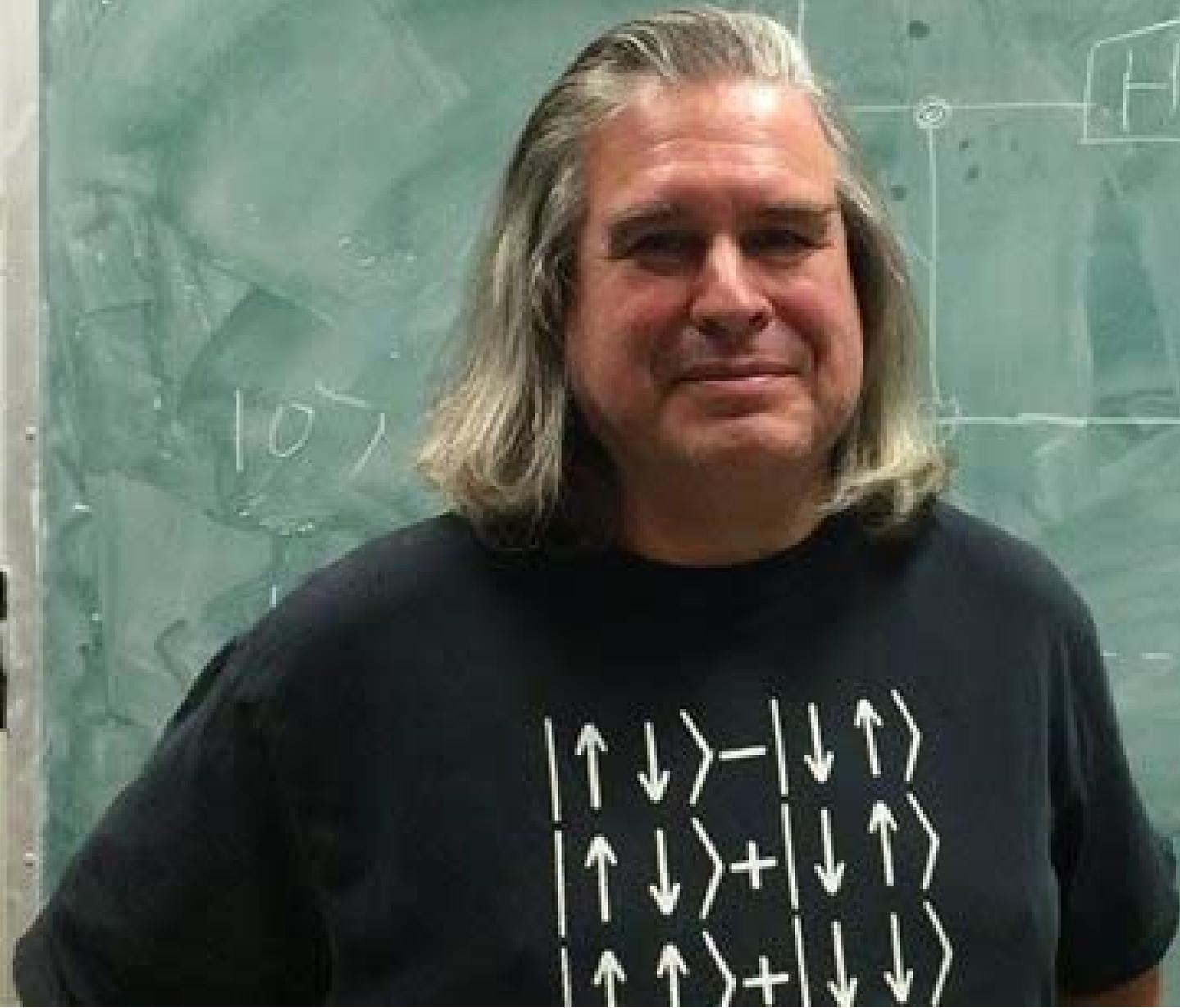


Alice



Gilles Brassard U de Montréal

Téléportation!



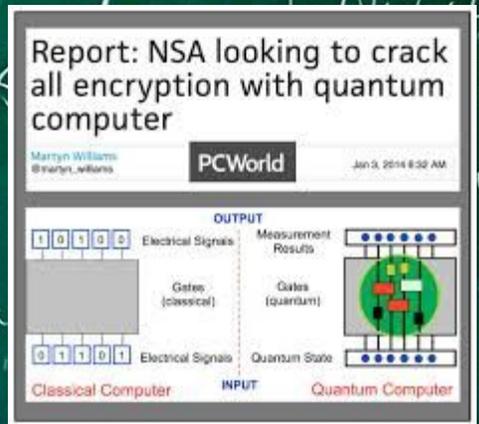


Delingha

Lijiang

NSA Says It "Must Act Now" Against the Quantum Computing Threat

The National Security Agency is worried that quantum computers will neutralize our best encryption – but doesn't yet know what to do about that problem.



Technologies quantiques: un changement de paradigme?

OUI!

Richard Boudreault P.Phys.

$\frac{1}{2} P(\hbar, m, n)$
 \sum_{abc}
 $= m \delta_{m+n, 0}$
 Virasoro
 $h = -1$
 $j_0 = 0$
 $[-1, 1]^m$

$+ \delta_{\phi\psi} \delta_{m+n, 0} P_2(\dots)$
 $J_{m+n} + \dots$
 Free Boson
 $\frac{\partial \mathcal{L}}{\partial \alpha} = 0$
 $\sum_i h_i + \sum_j J_j > 0$
 $L_0 = \dots$
 $L_{-n} |0\rangle = 0$
 $L_{-1} |0\rangle = 0$
 $L_0 = \dots$
 $L_1 = \dots$
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 $L_{99} = \dots$

Êtes vous prêt à l'ère quantique?

Ils se préparent

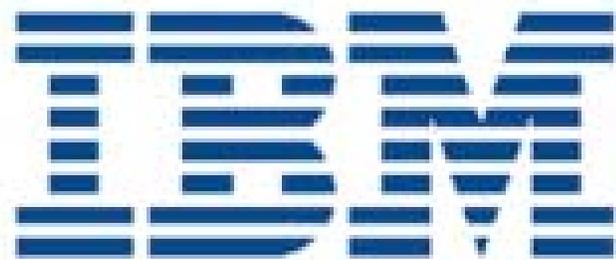


Alibaba Group

Raytheon

LOCKHEED MARTIN

Booz | Allen | Hamilton

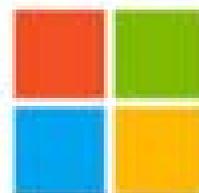


TOSHIBA

BT



NTT



Microsoft

SK telecom

Google



kpn

