FROM SCHRÖDINGER'S CAT TO QUANTUM TECHNOLOGIES: A REVOLUTION UNFOLDING

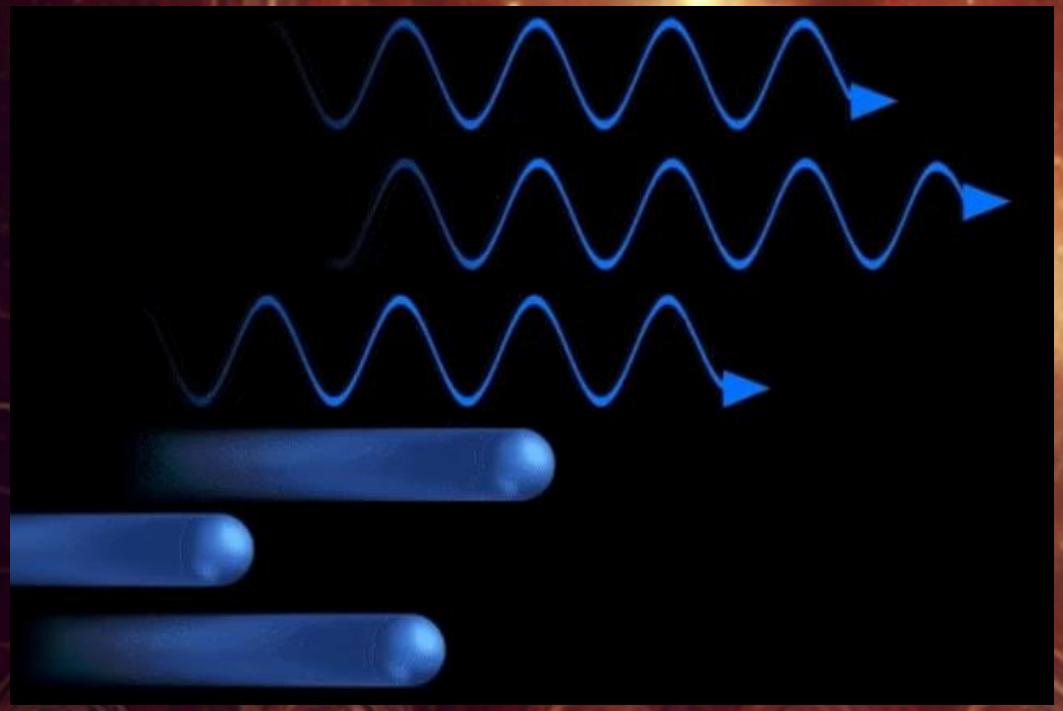
Catalina Curceanu, LNF-INFN

Public Lecture – MESON 2026 - Krakow

28 June 2026,

Quantum physics is already here

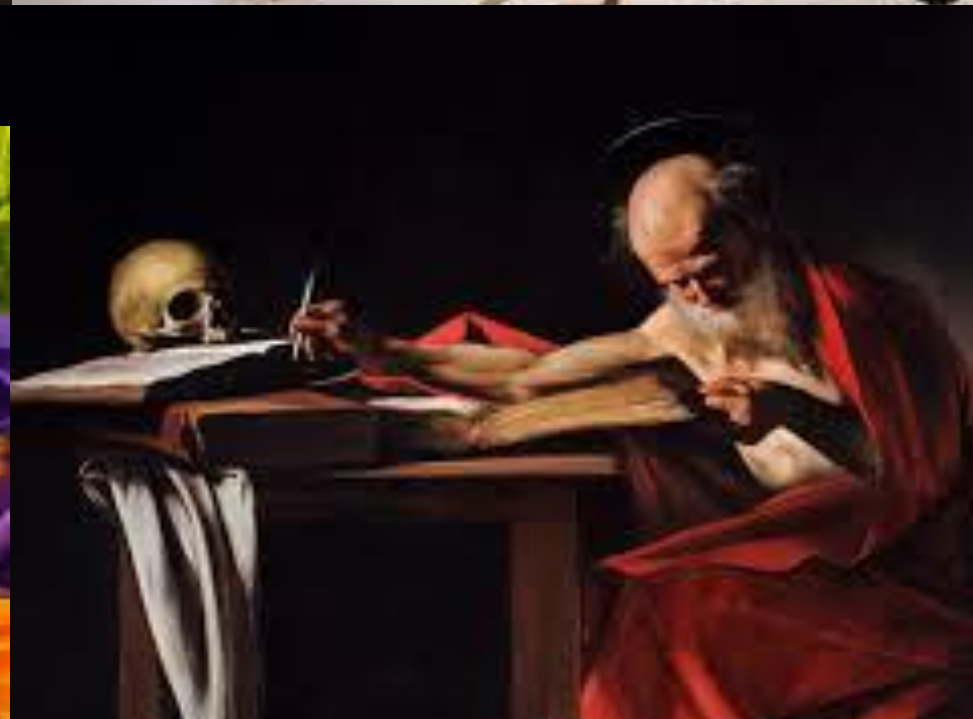

© Foto: Andrei Paul, Primaria Brasov



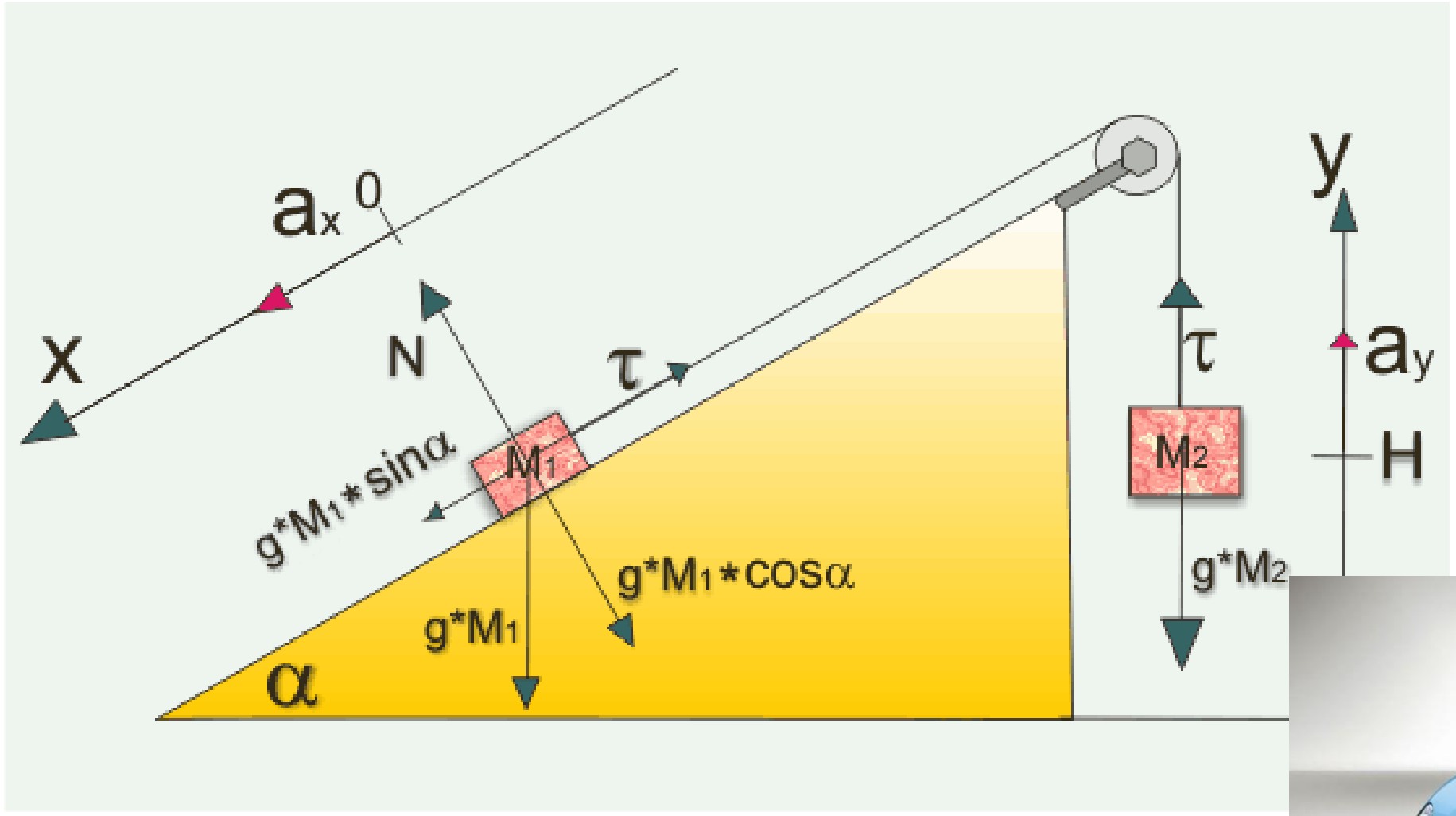


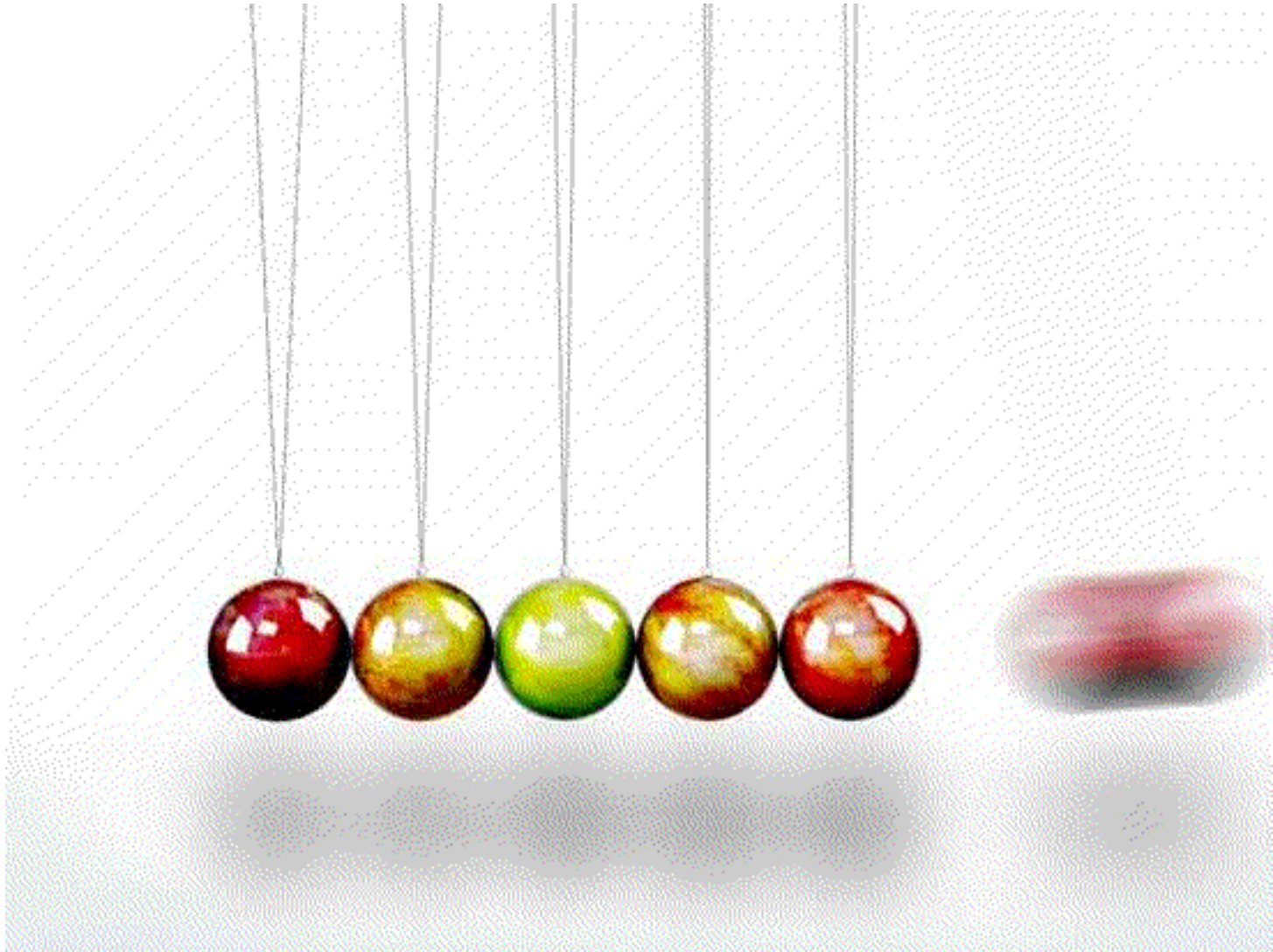


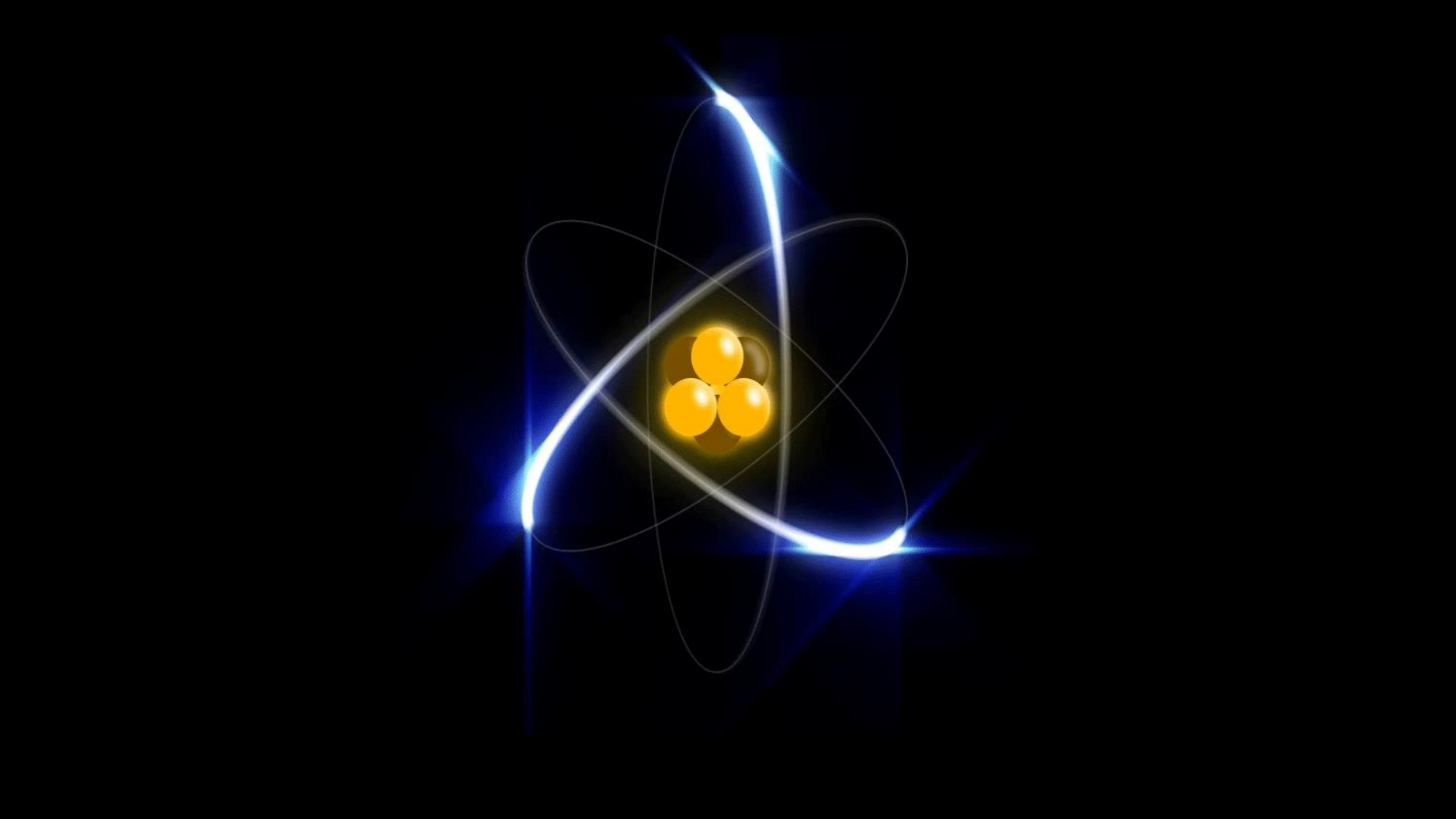




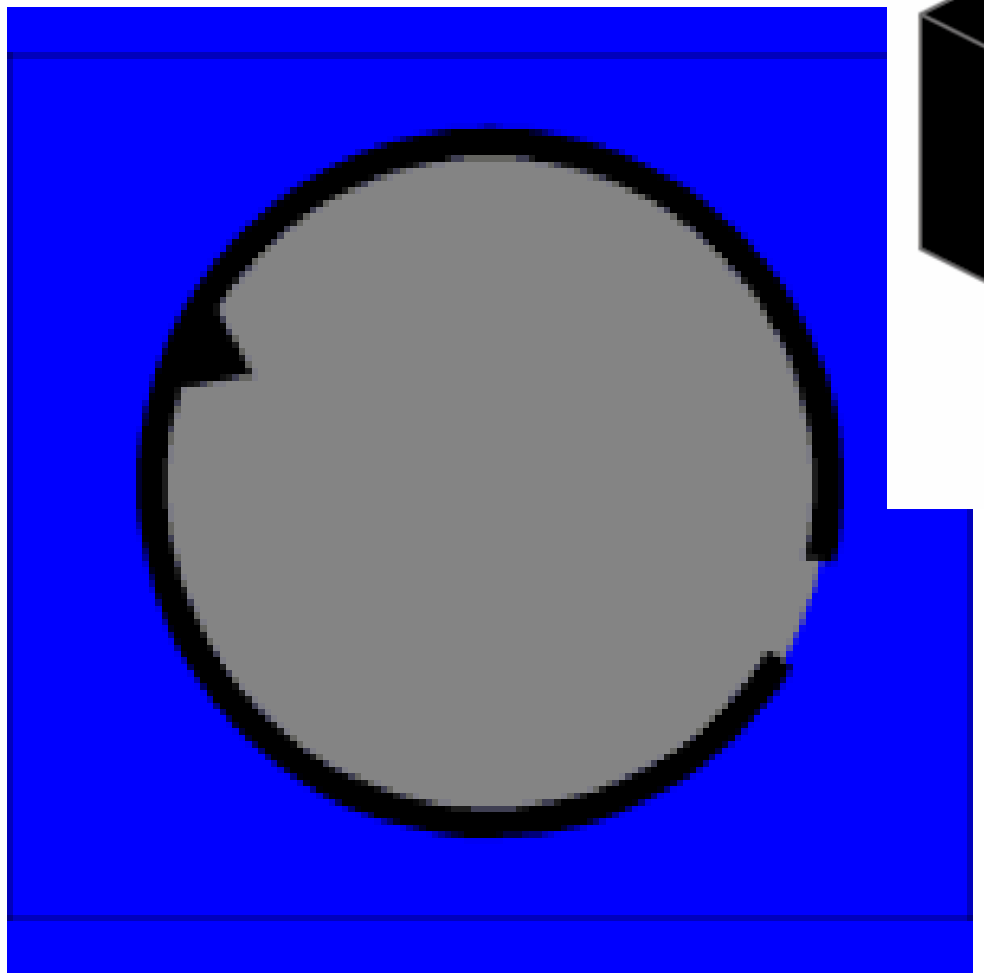
Classical Mechanics



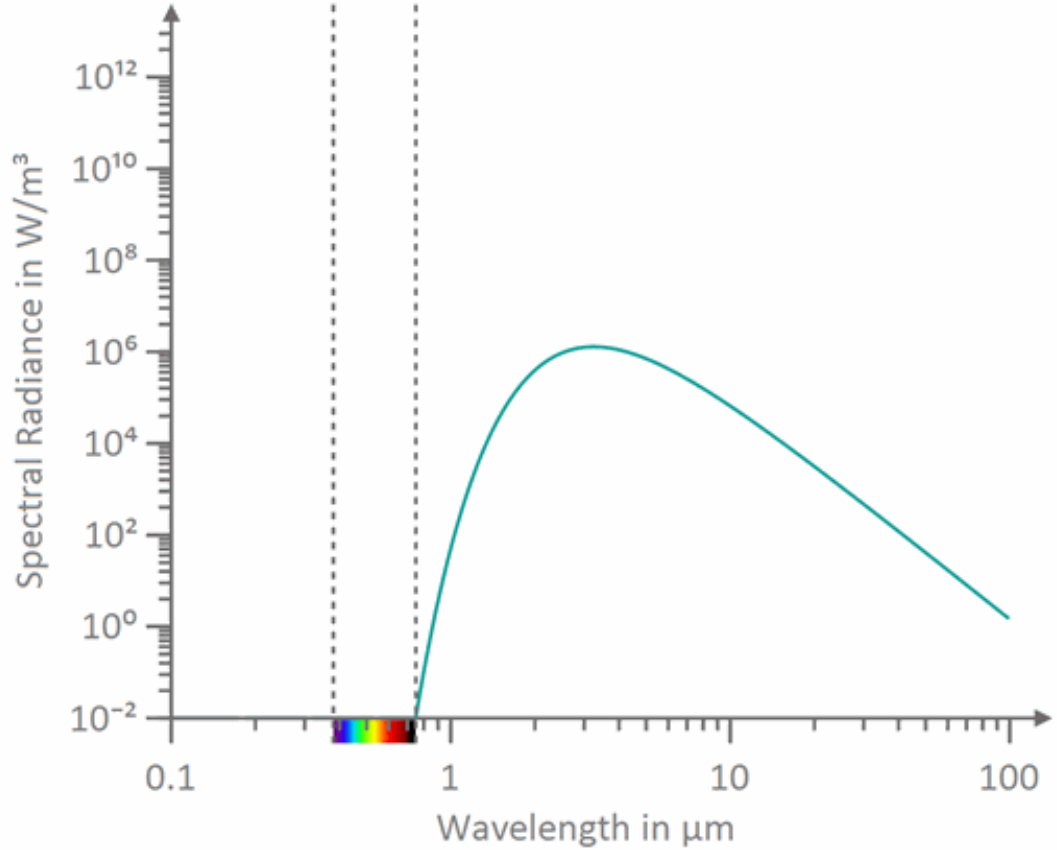




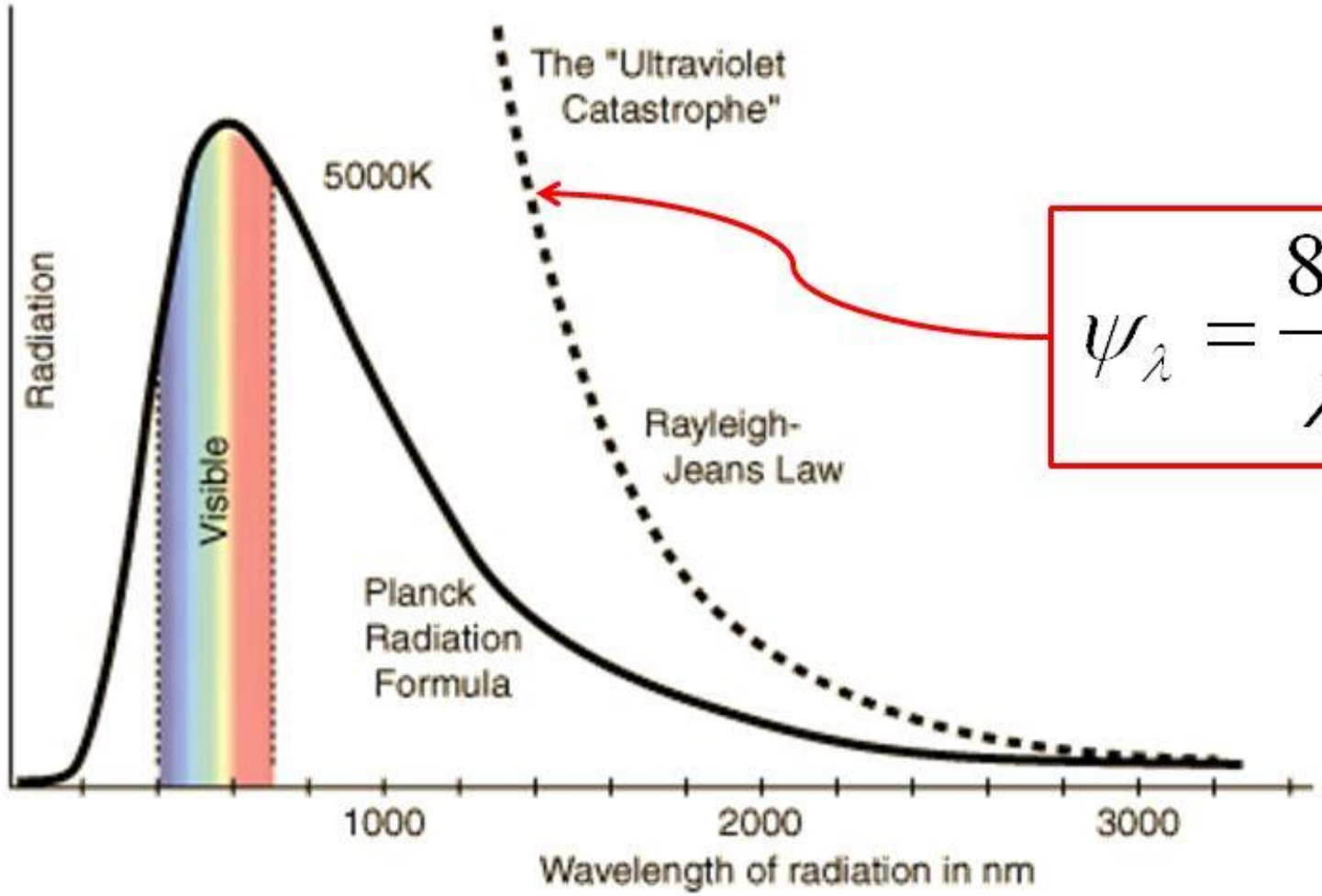
Black Body Radiation



Temperature = 280K



La “catastrofe ultravioletta”



$$\psi_\lambda = \frac{8\pi}{\lambda^4} kT$$

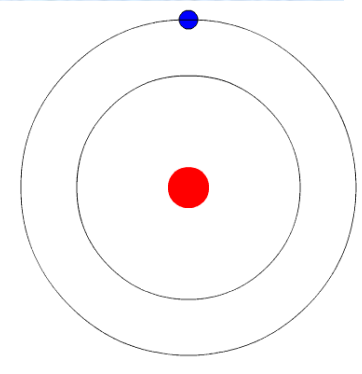
- Wien : formula empirica e valida solo a piccole λ
- Rayleigh-Jeans : formula coerente, ma valida solo ad alte λ

Max Planck hypothesized that energy is not emitted as a continuous flow but in discrete packets, called quanta.

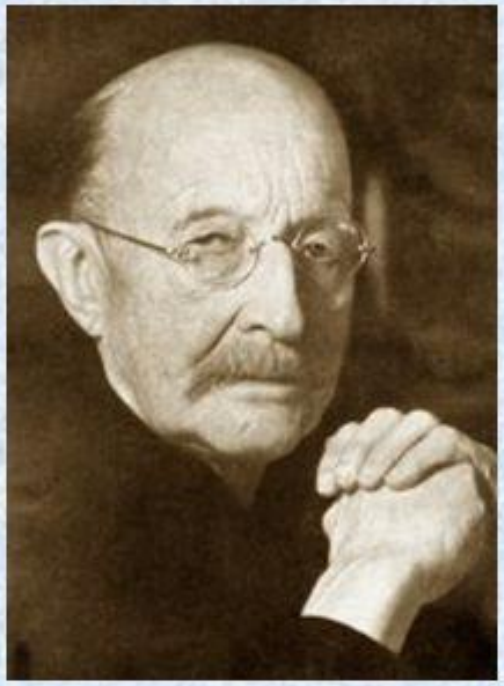
The energy of each quantum is

$$E = hf,$$

where $h = 6.626 \times 10^{-34}\,\mathrm{J\,s}$.



"The whole procedure was an act of desperation, because a theoretical interpretation had to be found at any price, no matter how high that might be. I was ready to sacrifice every one of my previous convictions about physical laws.“



Vienna 14 dicembre 1900

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SOLVAY CONFERENCE 1927

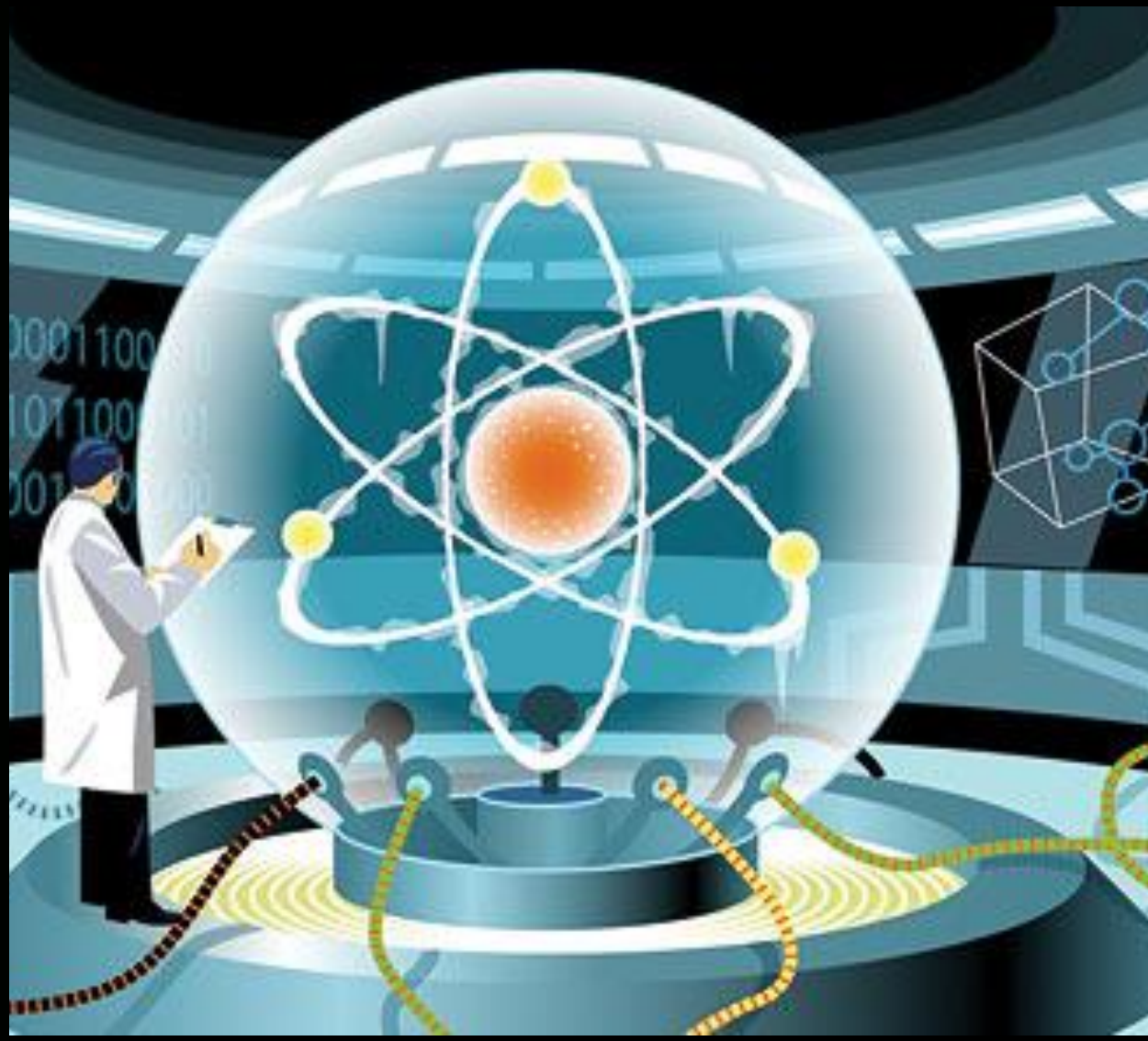
A. PICARD E. HENRIOT P. EHRENFEST Ed. HERSEN Th. DE DONDER E. SCHRÖDINGER E. VERSCHAFFELT W.PAULI W. HEISENBERG R.H FOWLER L. BRILLOUIN

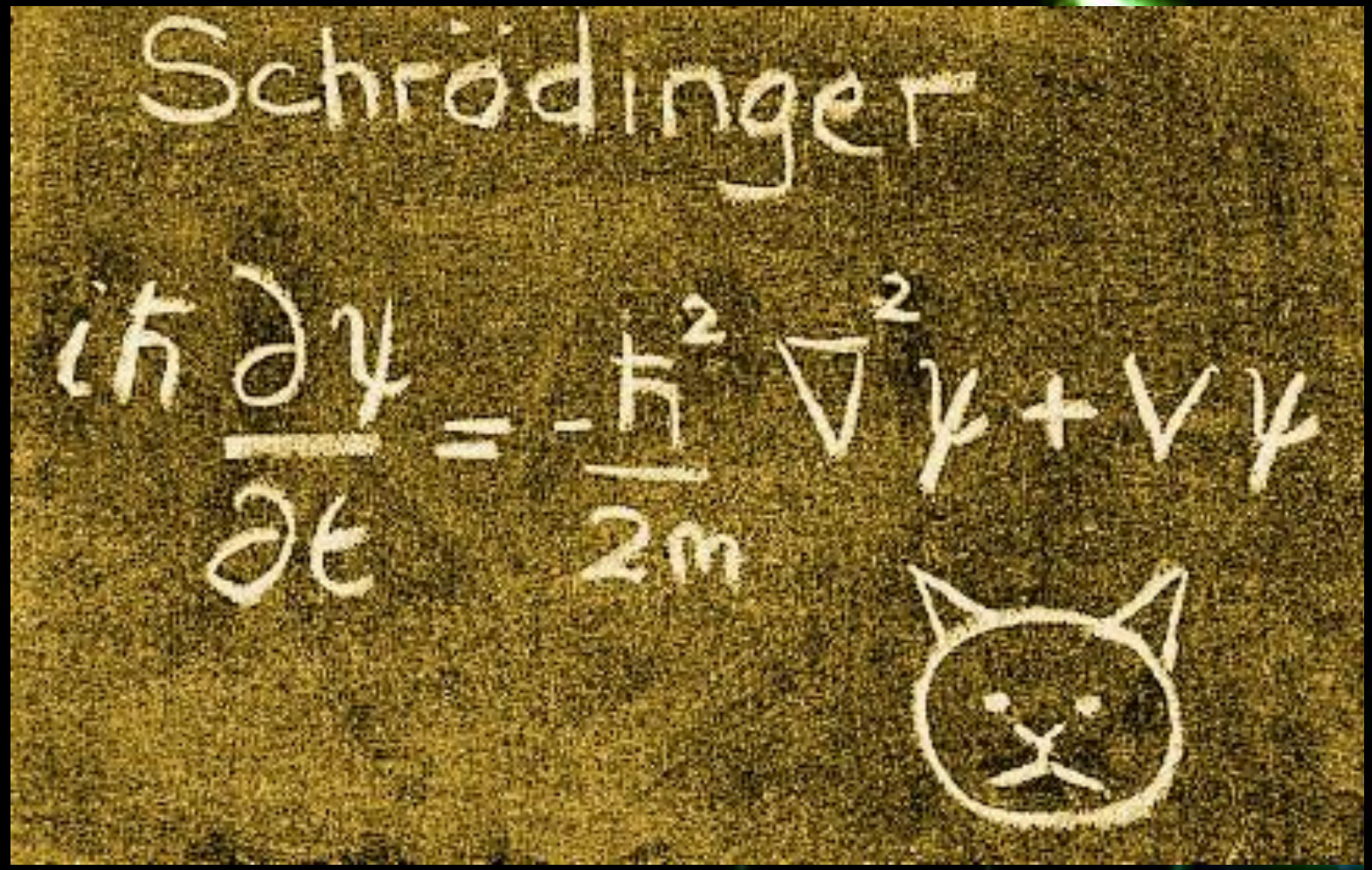
P. DEBYE M. KNUDSEN W.L. BRAGG H.A. KRAMERS P.A.M. DIRAC A.H. COMPTON L. de BROGLIE M. BORN N. BOHR

I. LANGMUIR M, PLANCK Mme CURIE H.A.LORENTZ A. EINSTEIN P. LANGEVIN Ch.E. GUYE C.T.R. WILSON O W, RICHARDSON

Absents : Sir W.H. BRAGG, H. DESLANDRES et E. VAN AUBEL

$$\Psi_{\text{kitty}} = \frac{1}{\sqrt{2}}\Psi_{\text{alive}} + \frac{1}{\sqrt{2}}\Psi_{\text{dead}}$$



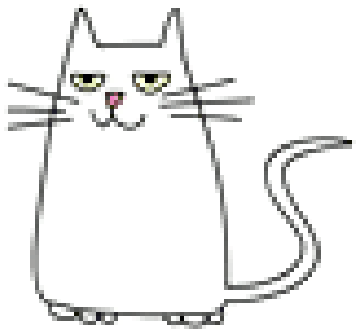


$$\Psi = c_1 \psi_1 + c_2 \psi_2 + \ldots$$

Quantum Wonders/Resources

- Superposition of States
- Entanglement
- Quantum tunnelling

Superposition of States

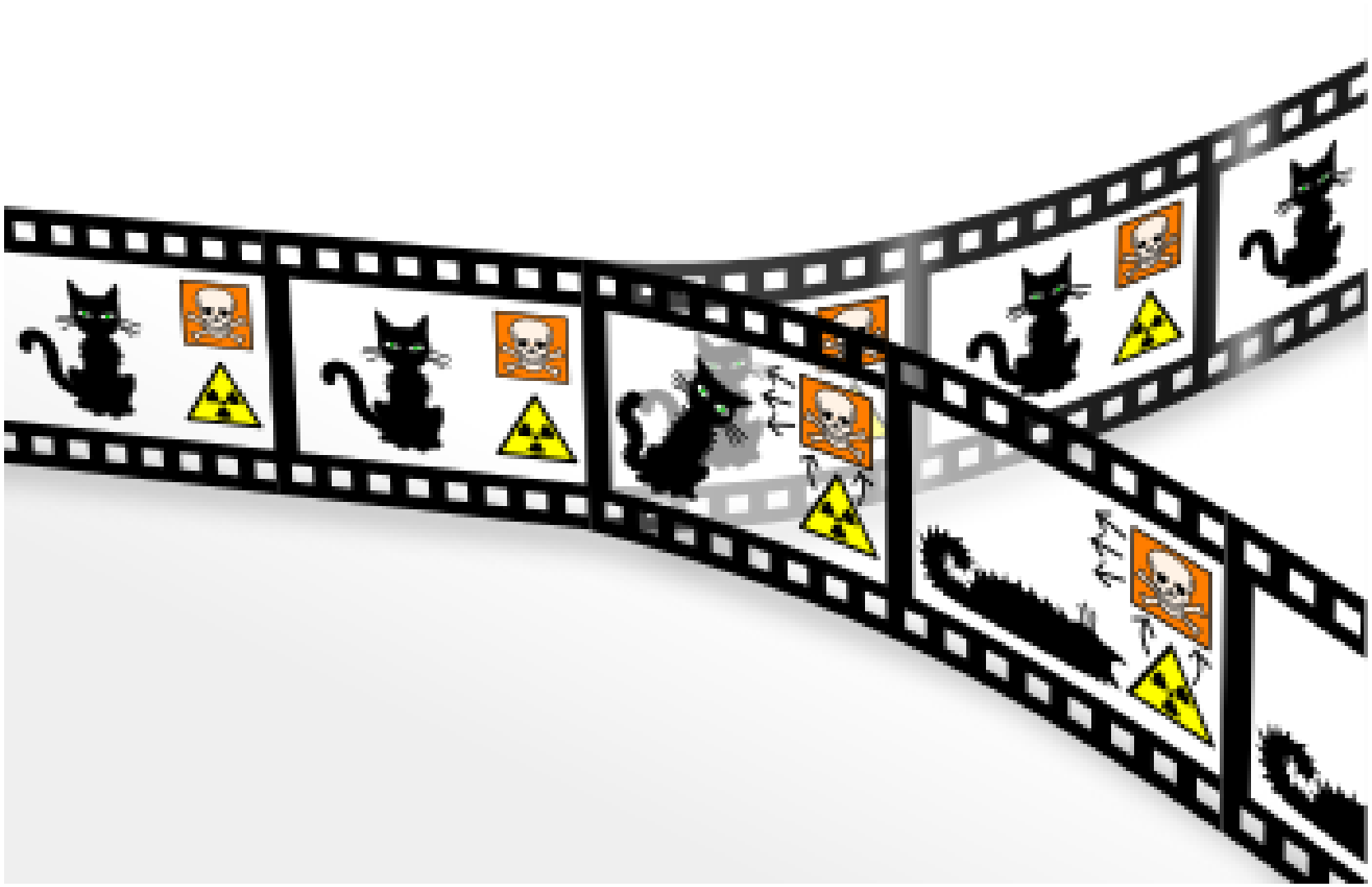


Possible Solutions:

-De Broglie – Bohm

- Many-World Interpretations

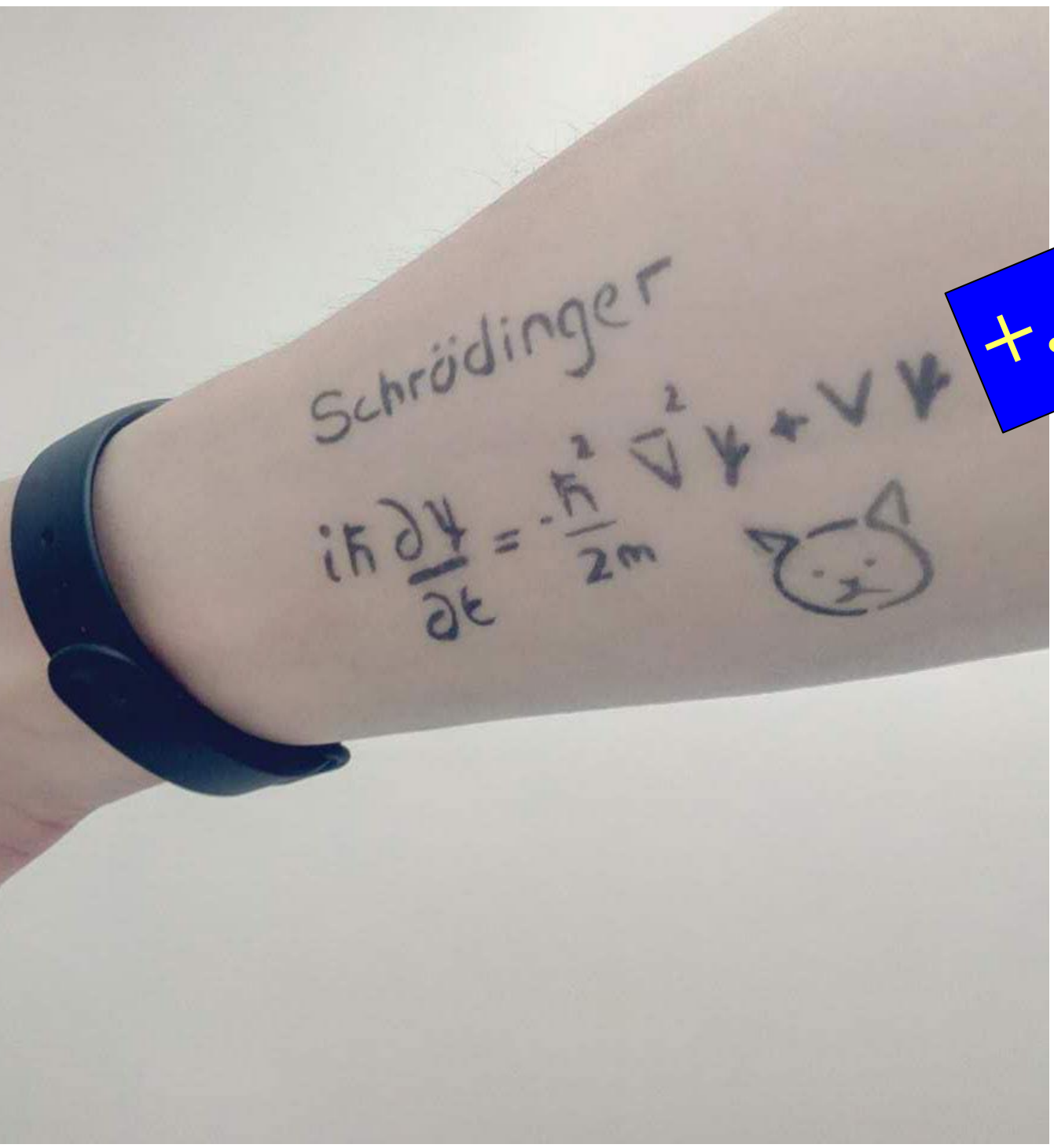
-.....



Possible Solutions:

-Collapse of the Wave Function

-.....


Schrödinger
$i\hbar \frac{\partial \Psi}{\partial t} = -\frac{\hbar^2}{2m} \nabla^2 \Psi + V \Psi$
+...

Spontaneous emission in the γ-rays regime

- **CSL - s. e. photons rate:**

$$\left.\frac{d\Gamma}{dE}\right|_t^{CSL} = \frac{\hbar\lambda}{4\pi^2\epsilon_0 c^3 r_C^2 m_0^2 E}\left(N_p^2 + Ne\right)$$

- **DP - s. e. photons rate:**

$$\left.\frac{d\Gamma}{dE}\right|_t^{DP} = \frac{G}{12\pi^{3/2}\epsilon_0 c^3 R_0^3 E}\left\{N_p^2 + N_e\right\}$$

the photon w.l. λ_γ is intermediate between the nuclear dimension and the lower atomic orbit radius -> protons emit coherently, electrons emit independently

λ - collapse strength

r_C - correlation length

see e. g. S. L. Adler, JPA 40, (2007) 2935, Adler, S.L.; Bassi, A.; Donadi, S., JPA 46, (2013) 245304.

R_0 - size of the particle mass density. See e.g. Diósi, L. J. Phys. Conf. Ser. 442, 012001 (2013)., Penrose, R. Found. Phys. 44, 557–575 (2014).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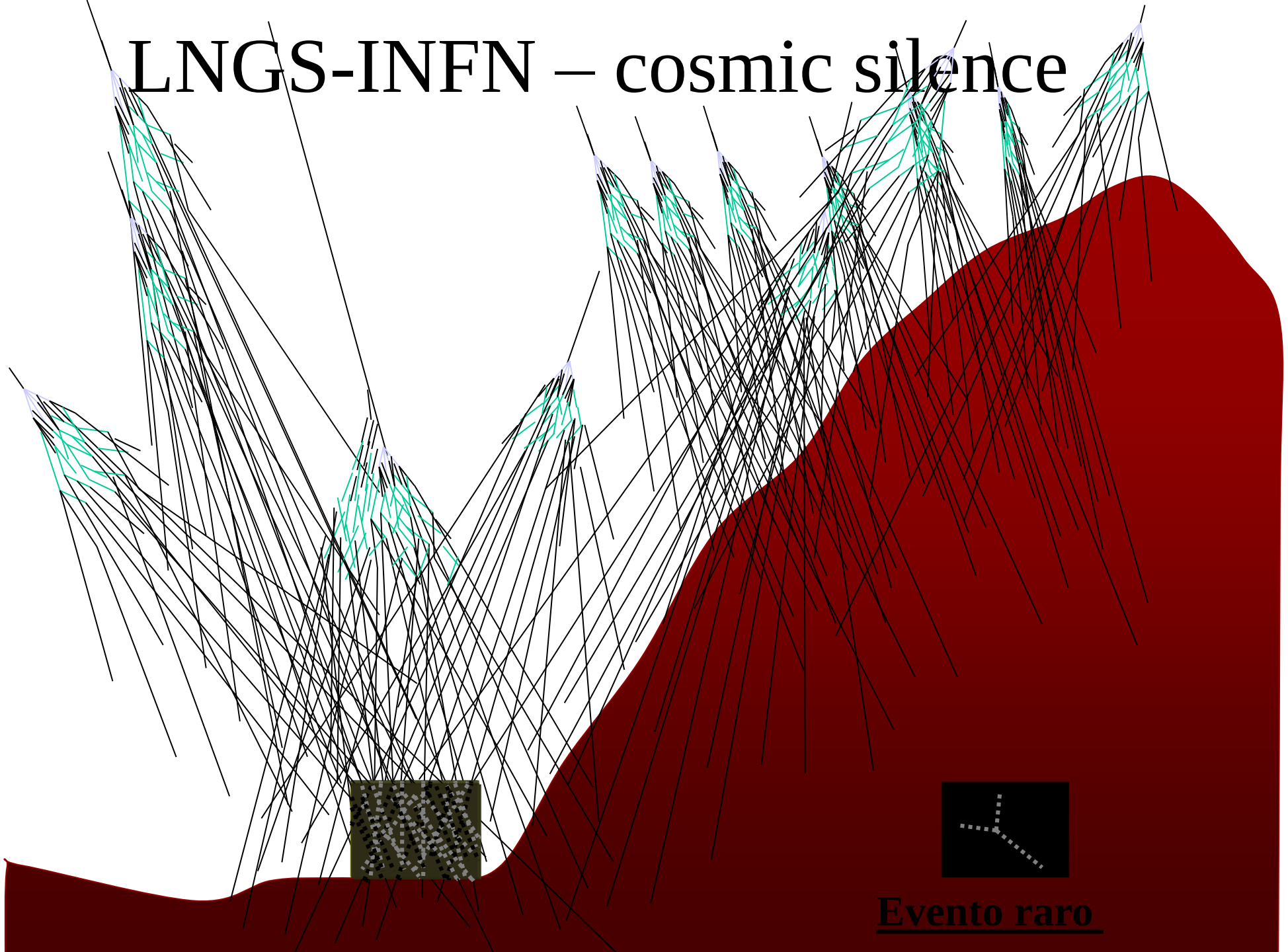
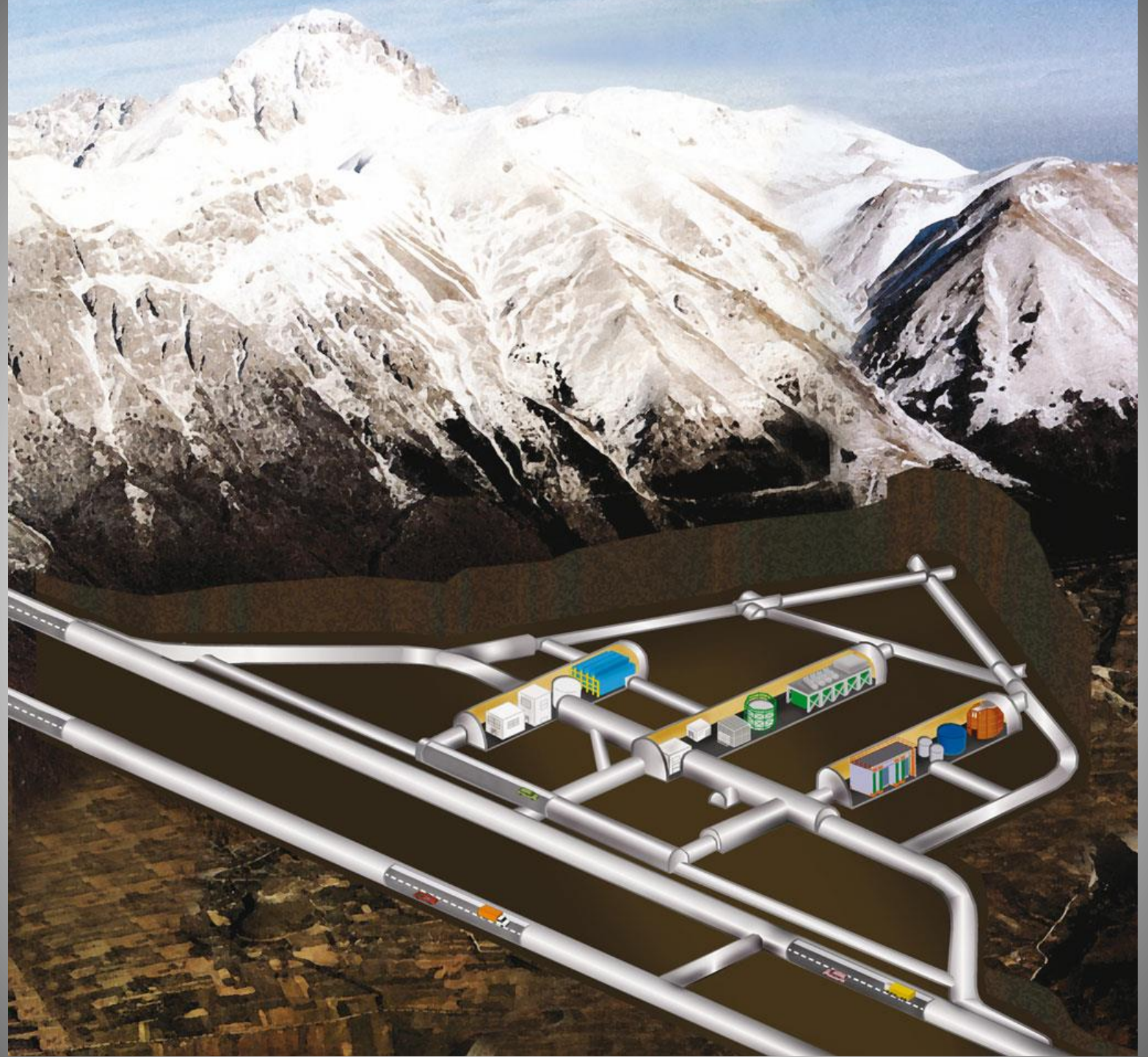
LNGS-INFN – cosmic silence

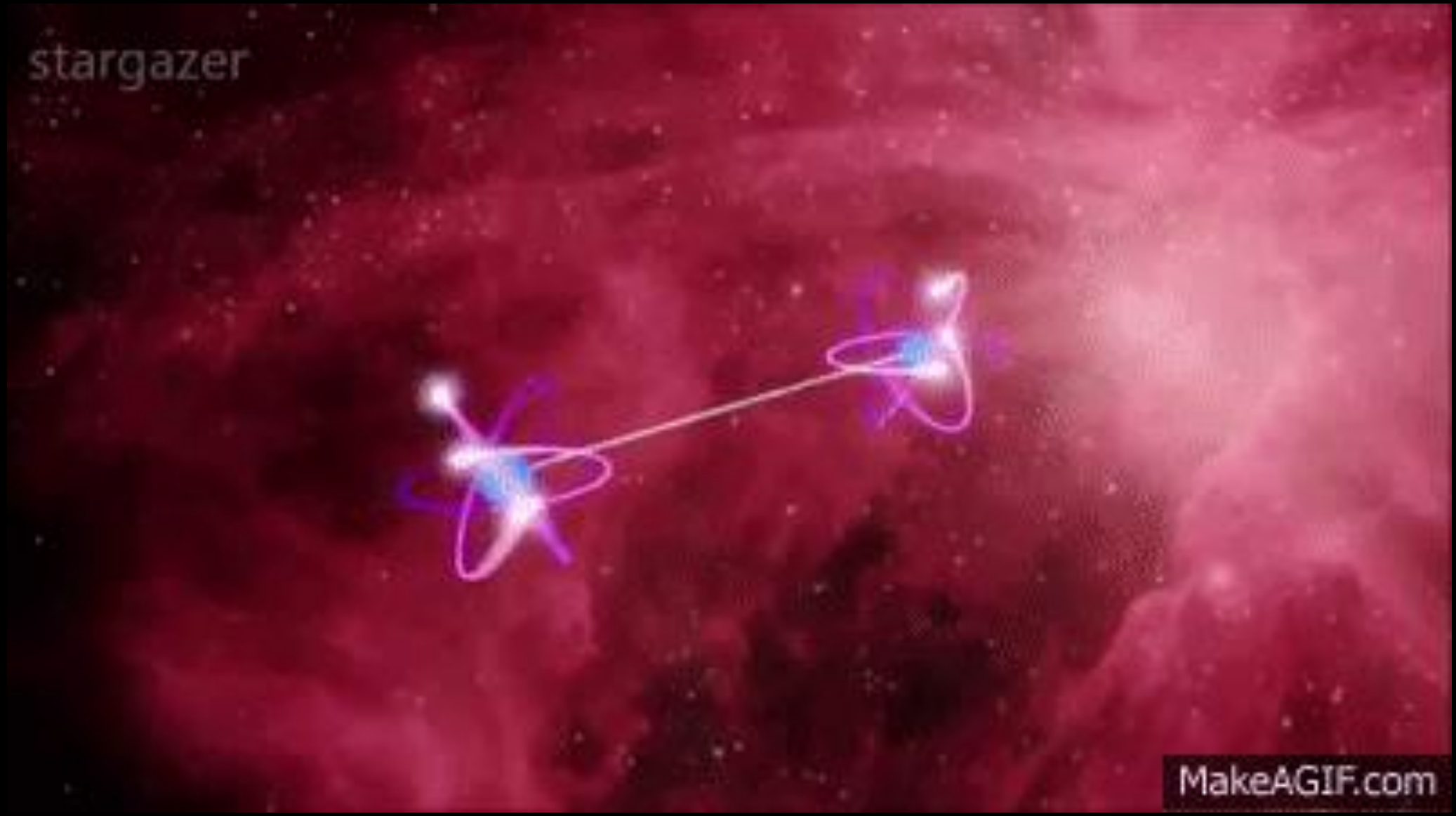




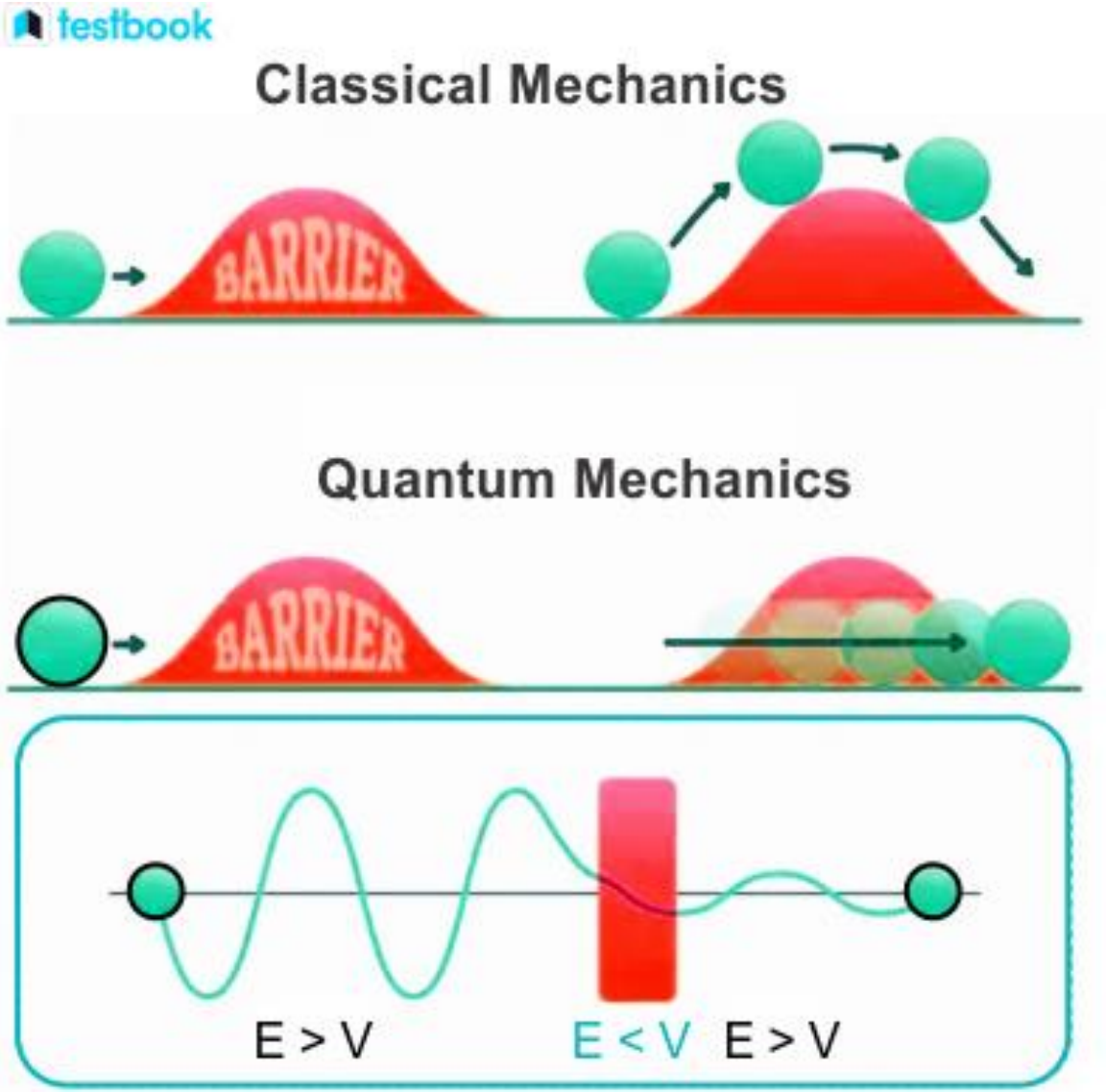

INFN-LABORATORI
NAZIONALI
DEL GRAN SASSO
DAMA
F40D

At LNGS – with my group we study possible modifications of quantum mechanics

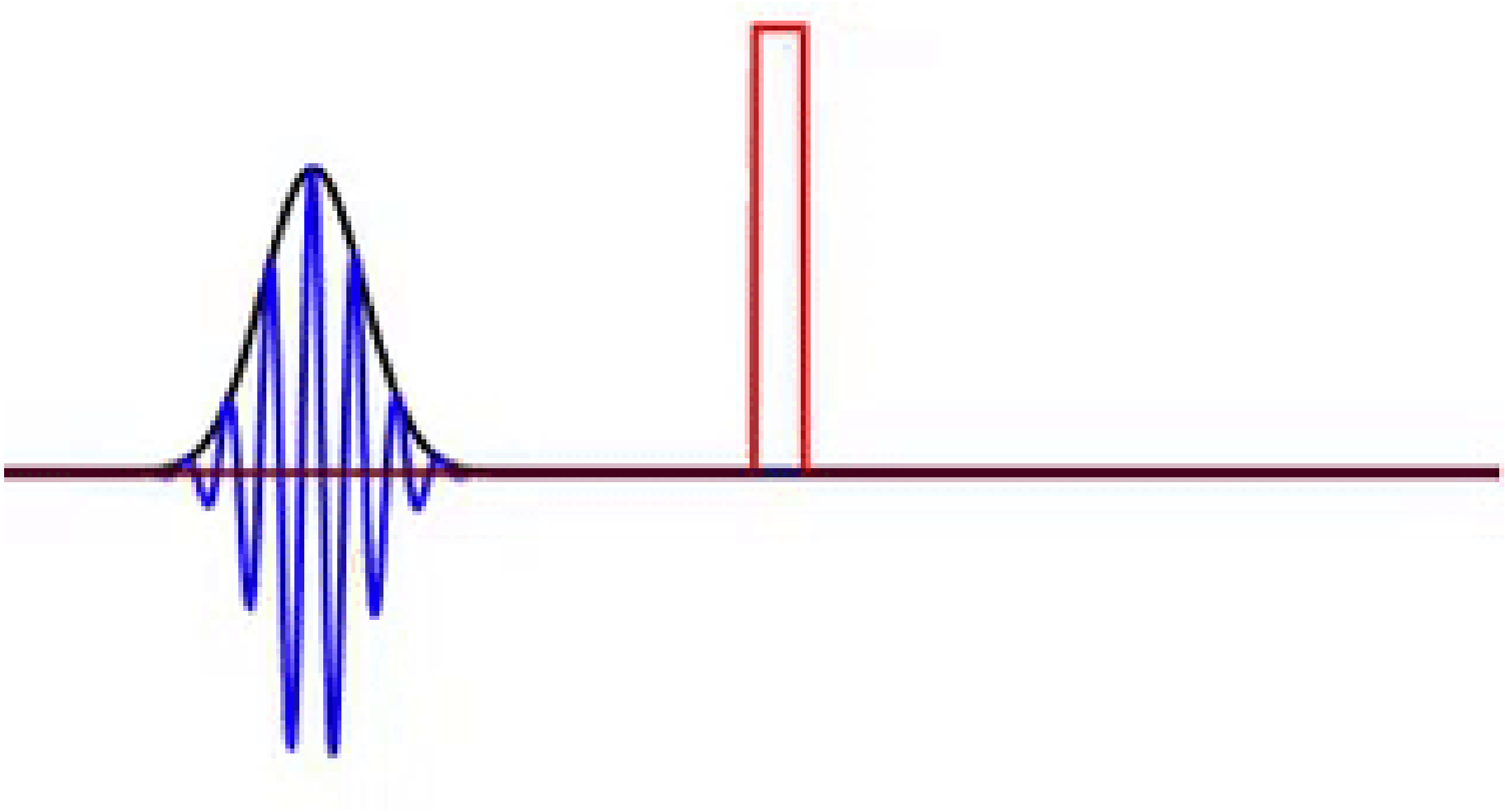
Entanglement



Quantum tunnelling

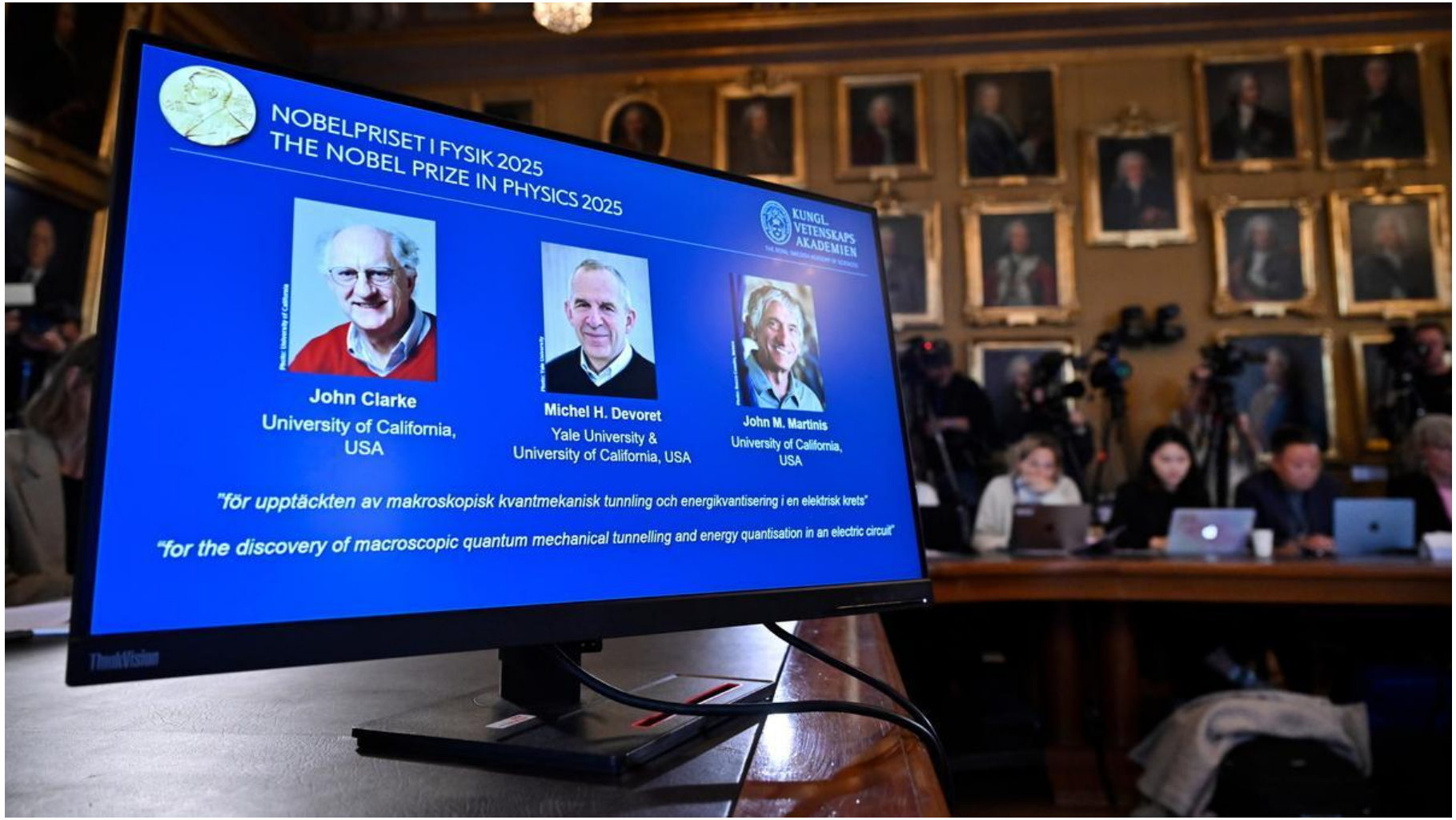


Quantum tunnelling



Nobel in Physics 2025

- for the discovery of macroscopic quantum mechanical tunnelling and energy quantisation in an electric circuit.



Quantum Technologies

the second quantum revolution

Quantum Technologies

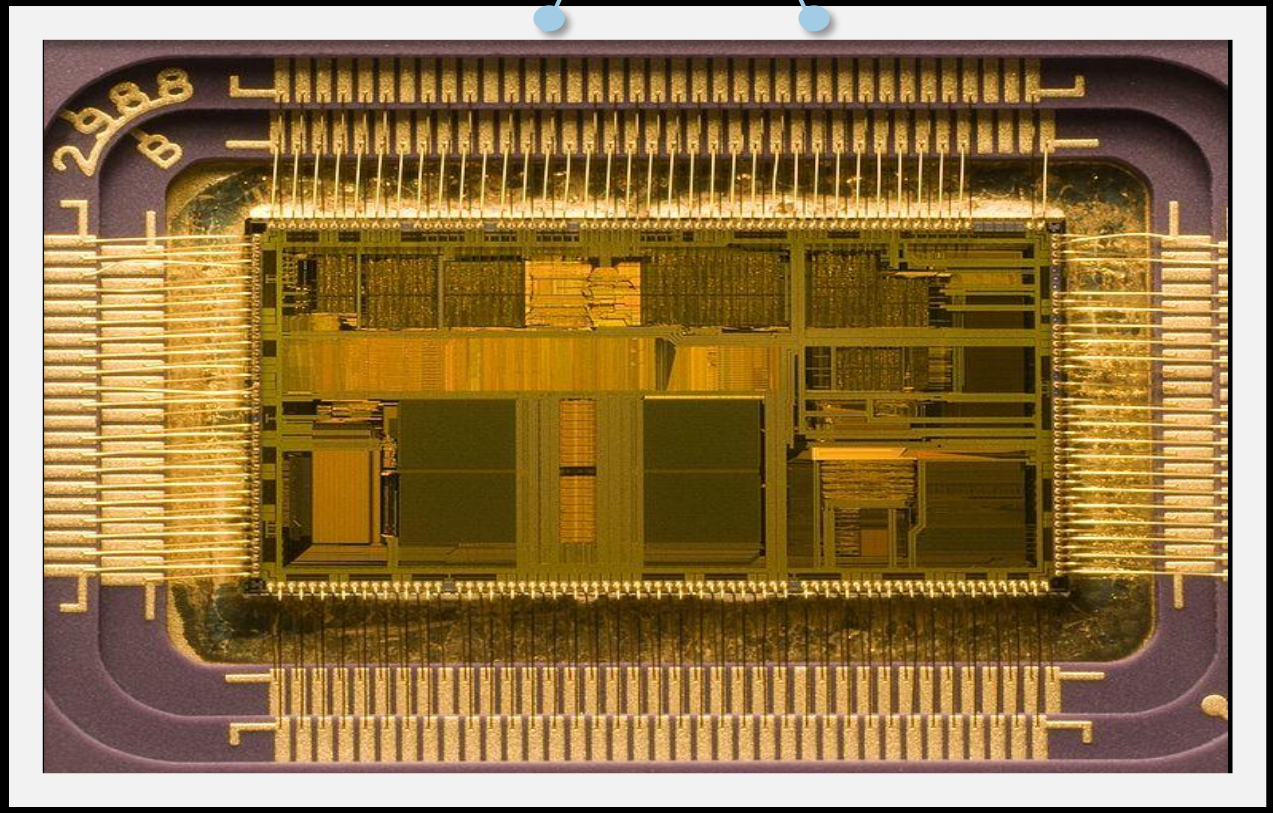
THE TRANSISTOR

Photo Source: By ArnoldReinhold (Own work) via Wikimedia Commons

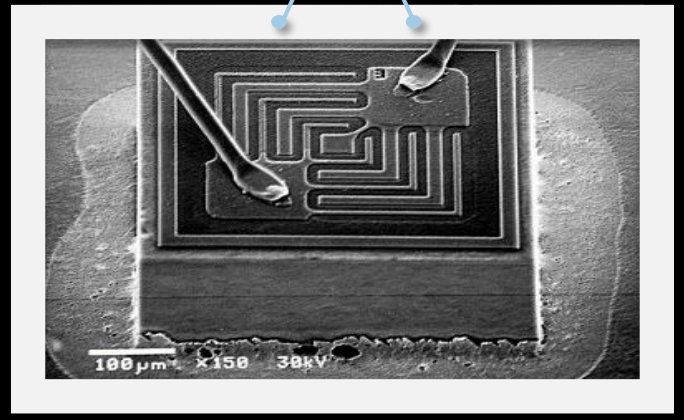
GAME CHANGERS

Photo Source: By AT&T; photographer: Jack St. via Wikimedia Commons

2.4mm

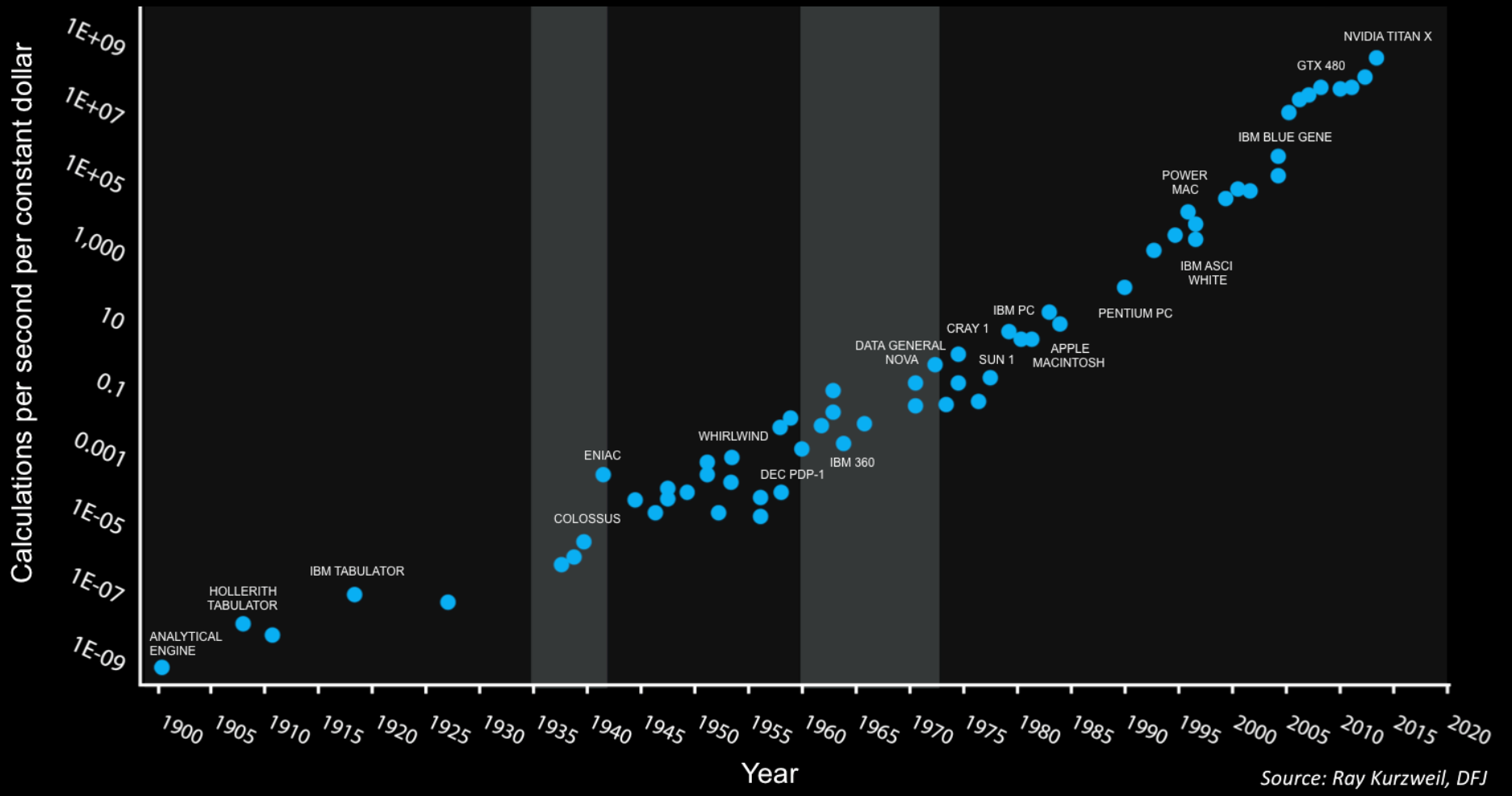


1nm

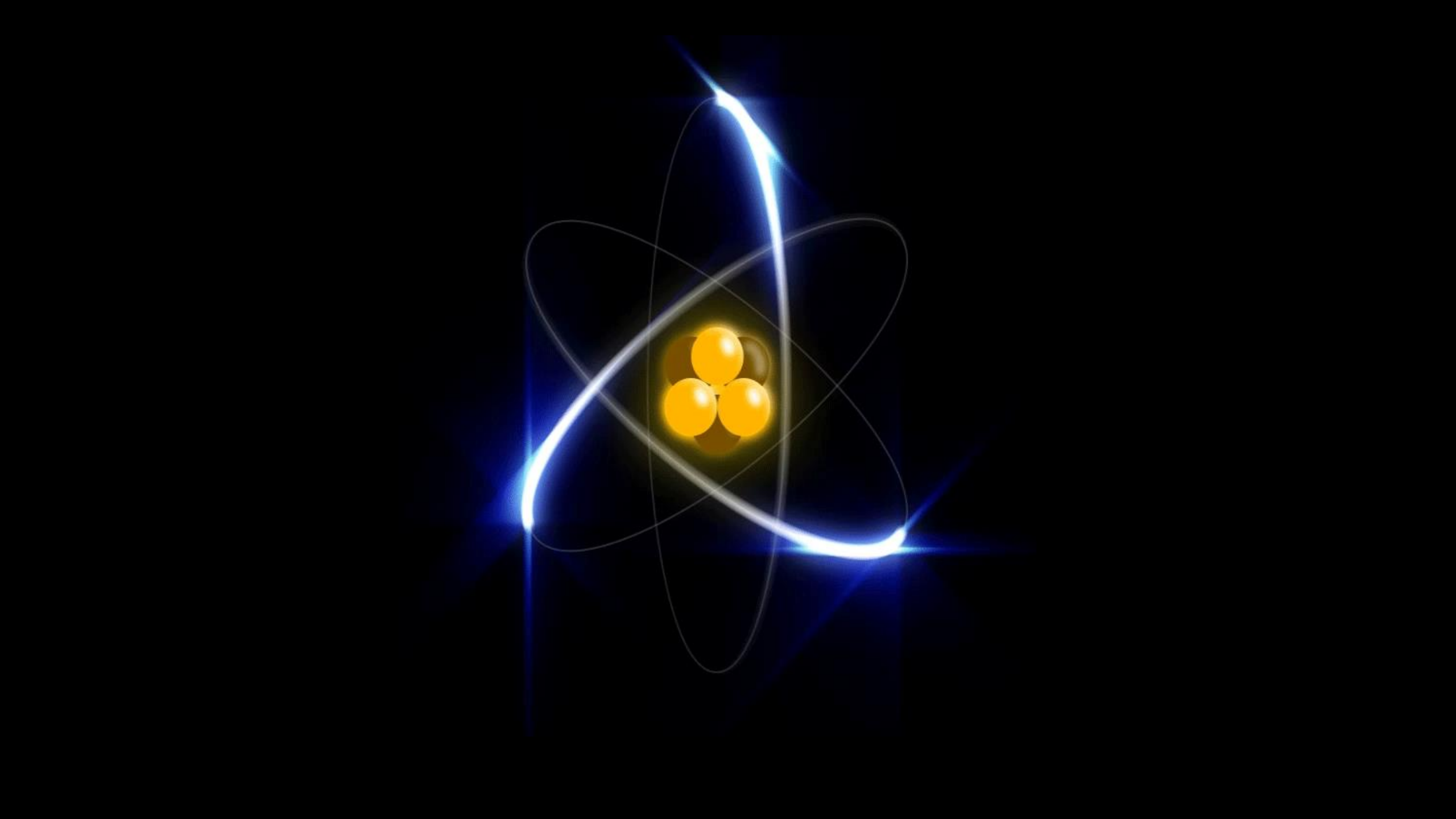


Moore Law

Limit: atomic scale
(Quantum Mechanics)



Source: Ray Kurzweil, DFJ



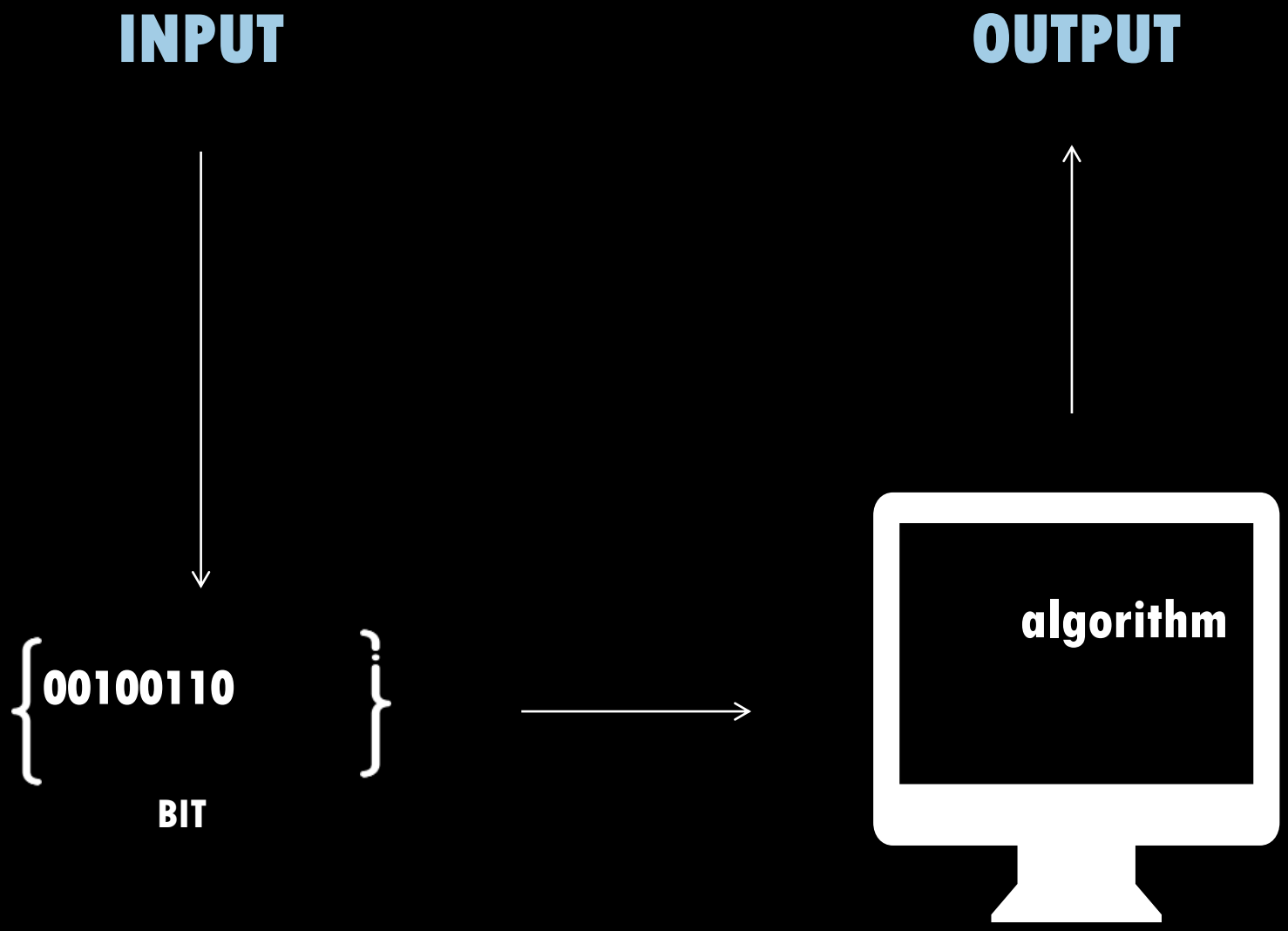
Quantum superposition

$$\Psi = c_1 \psi_1 + c_2 \psi_2 + \ldots$$

RICHARD FEYNMAN

DAVID DEUTSCH

How present computer works

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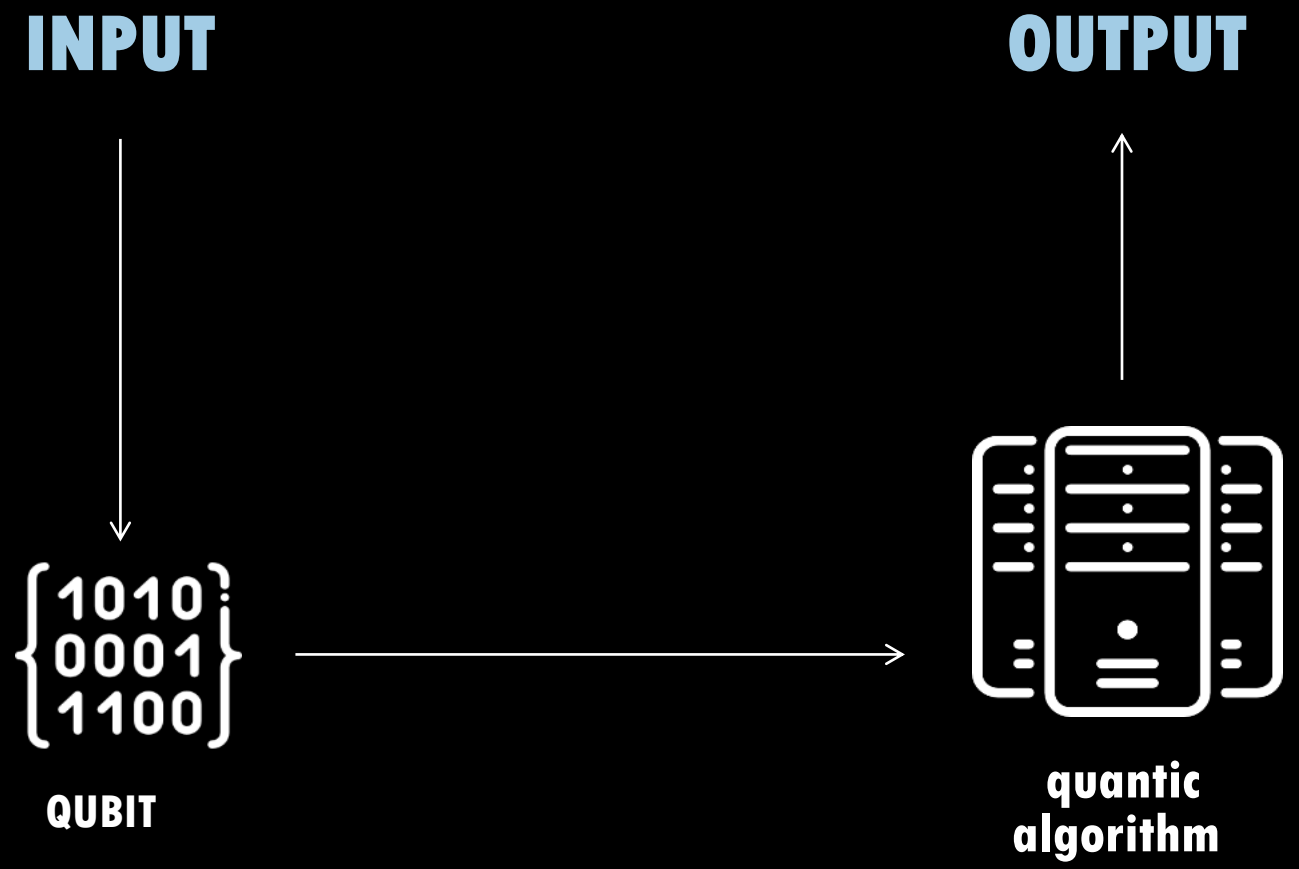
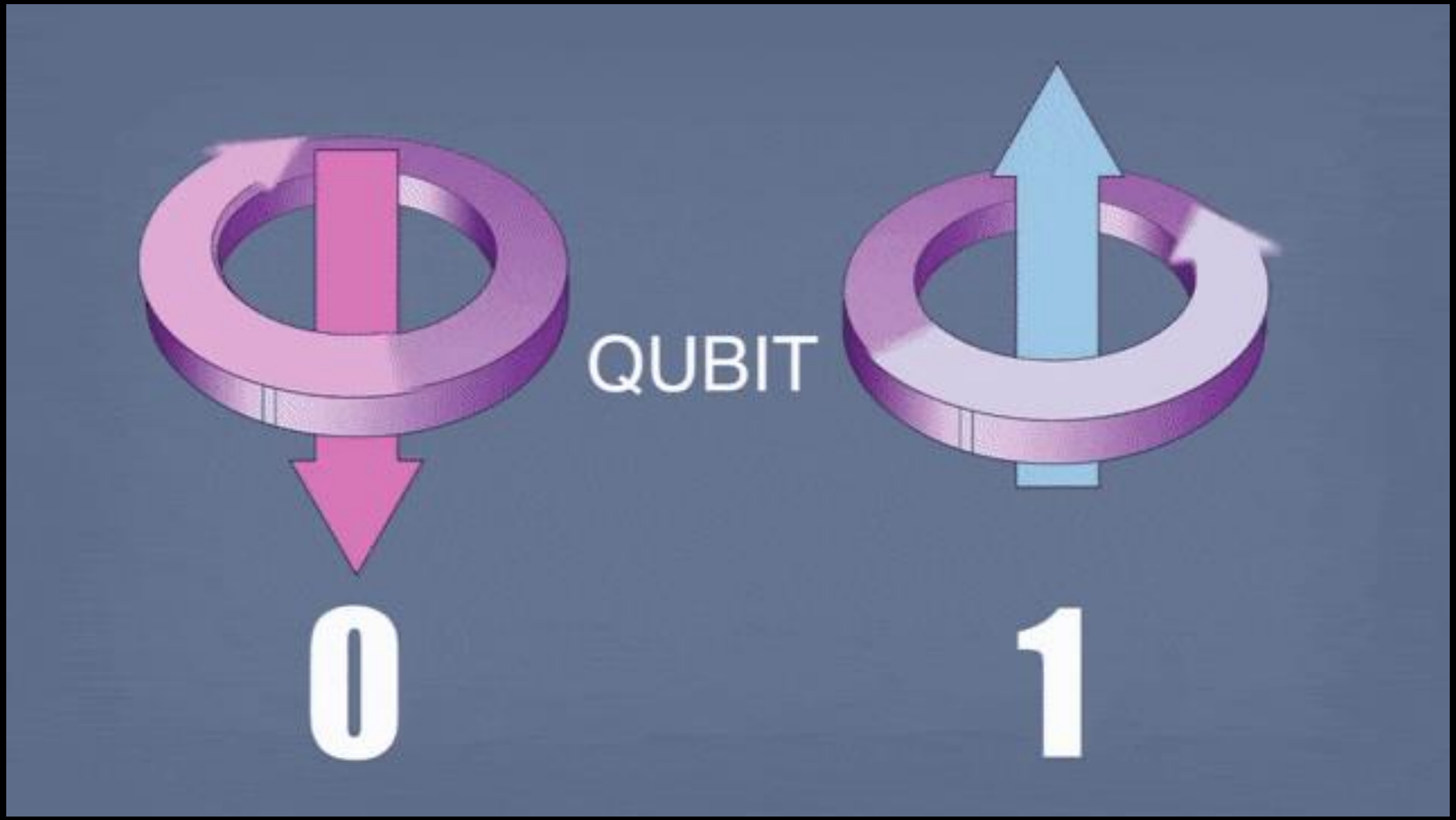
How a quantum computer works




Qubits can exist in a state of
1 or 0 simultaneously



gfycat

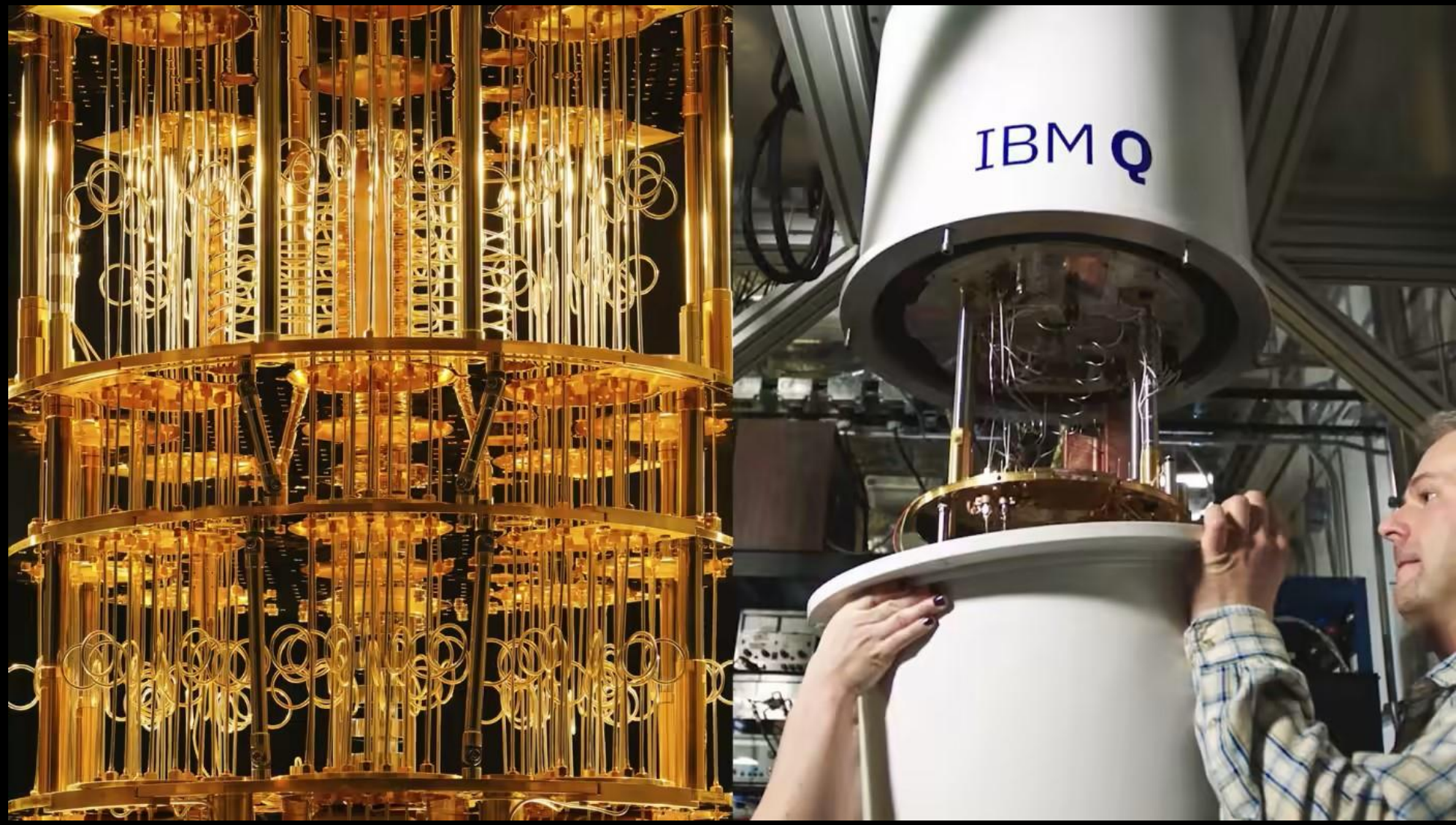
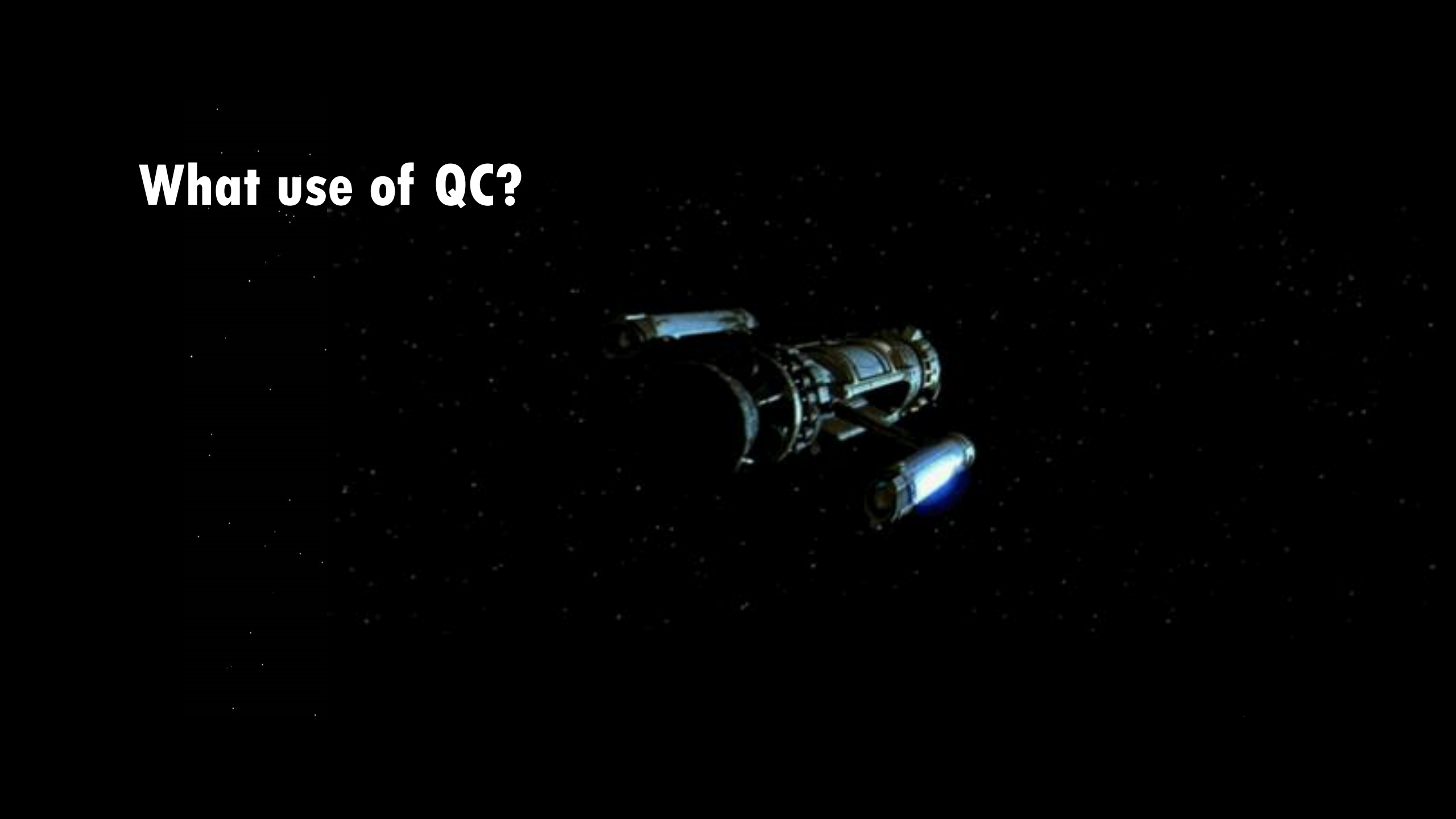


Photo courtesy of IBM

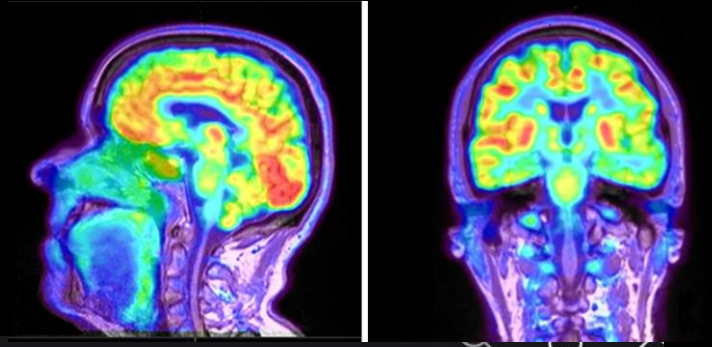
We need to fight against decoherence – errors and be sure quantum mechanics is a valid theory at all scales!

What use of QC?

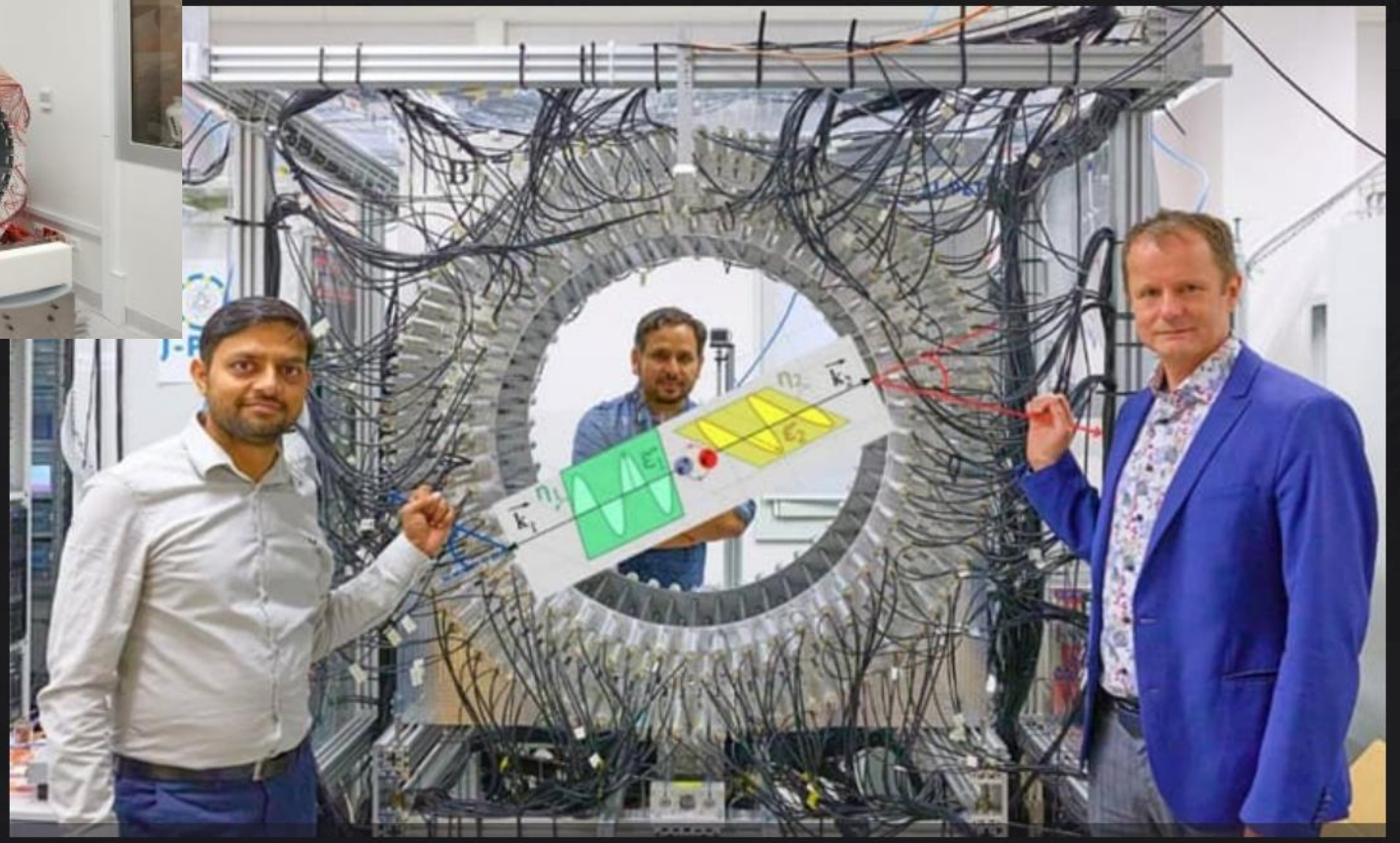


Virtual Reality
Artificial Intelligence

J-PET in Krakow



https://www.asfnr.org/what-is-pet-imaging.

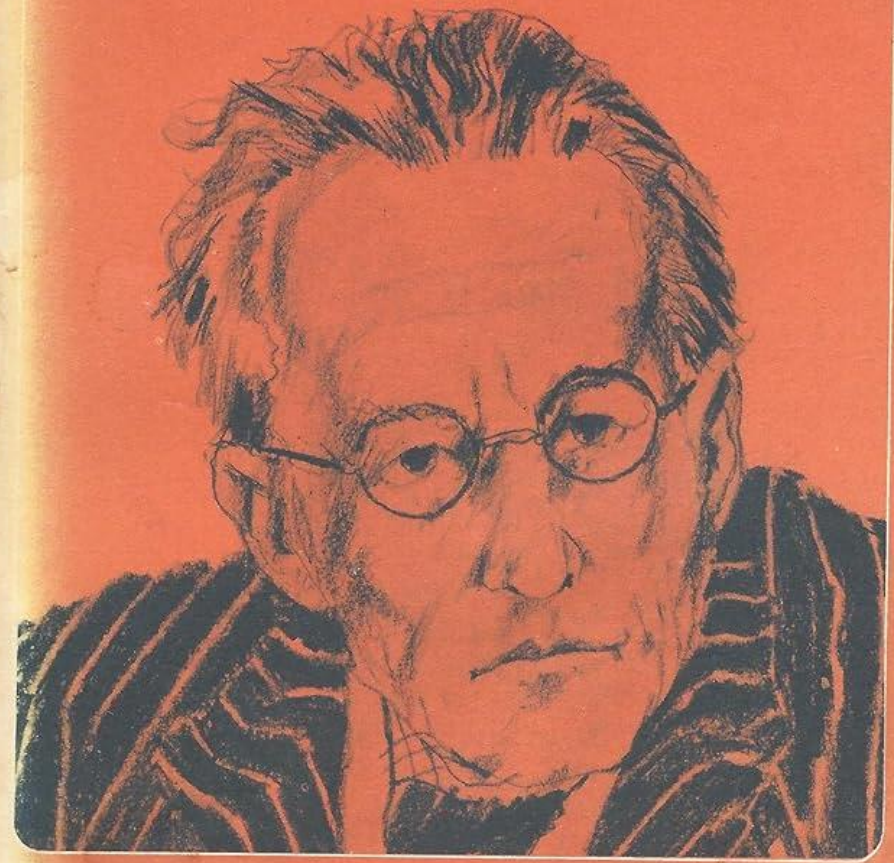


tory prototype The J-PET scanner used in the discovery of non-maximal entanglement, with (left to right) Deepak Kumar, Sushil Sharma and Pawel Moskal. The central
am shows the annihilation of an electron with a positron and the resulting photons with their polarization planes. (Courtesy: Damian Gil and Deepak Kumar)

https://physicsworld.com/a/towards-quantum-pet-harnessing-the-diagnostic-power-of-positronium-imaging

Erwin Schrödinger

What is Life? & Mind and Matter



CAMBRIDGE UNIVERSITY PRESS 13s (65p) net in U.K.

WHAT IS LIFE?

The Physical Aspect of the Living Cell

BY

ERWIN SCHRÖDINGER

SENIOR PROFESSOR AT THE DUBLIN INSTITUTE FOR ADVANCED STUDIES

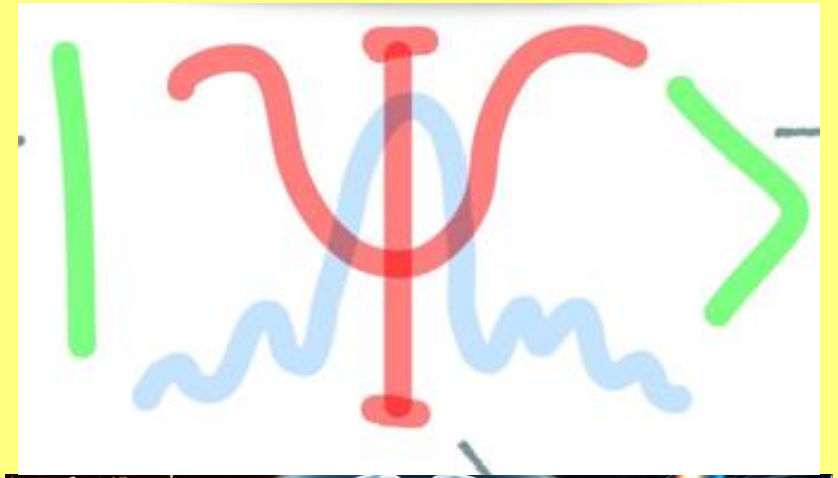
Based on Lectures delivered under the auspices of the Institute at Trinity College, Dublin, in February 1943

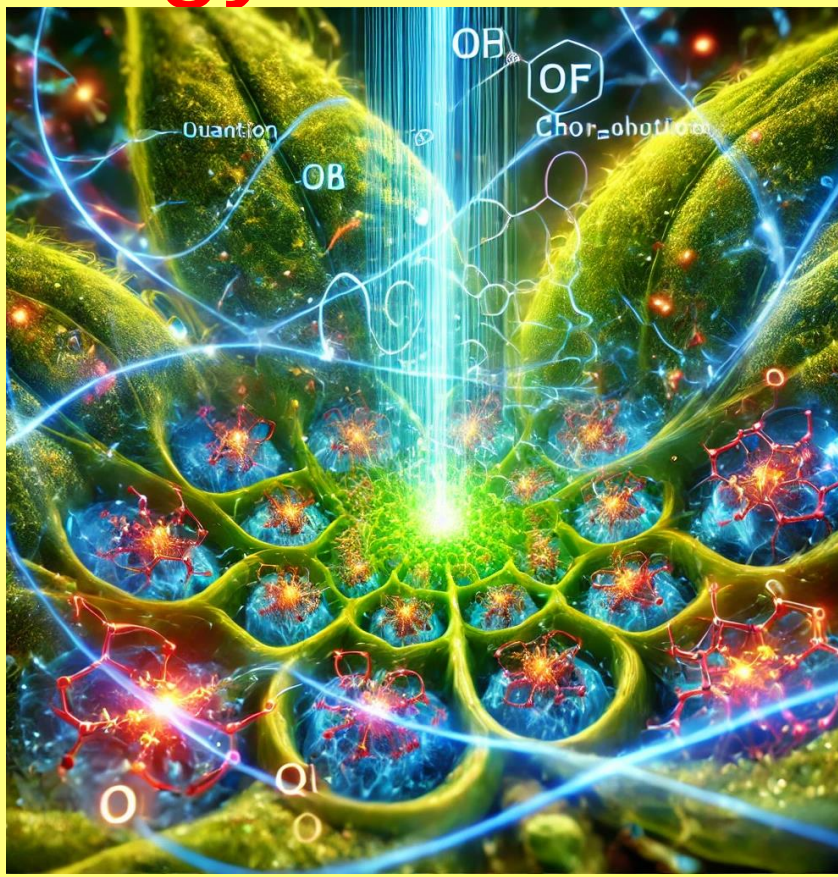
CAMBRIDGE

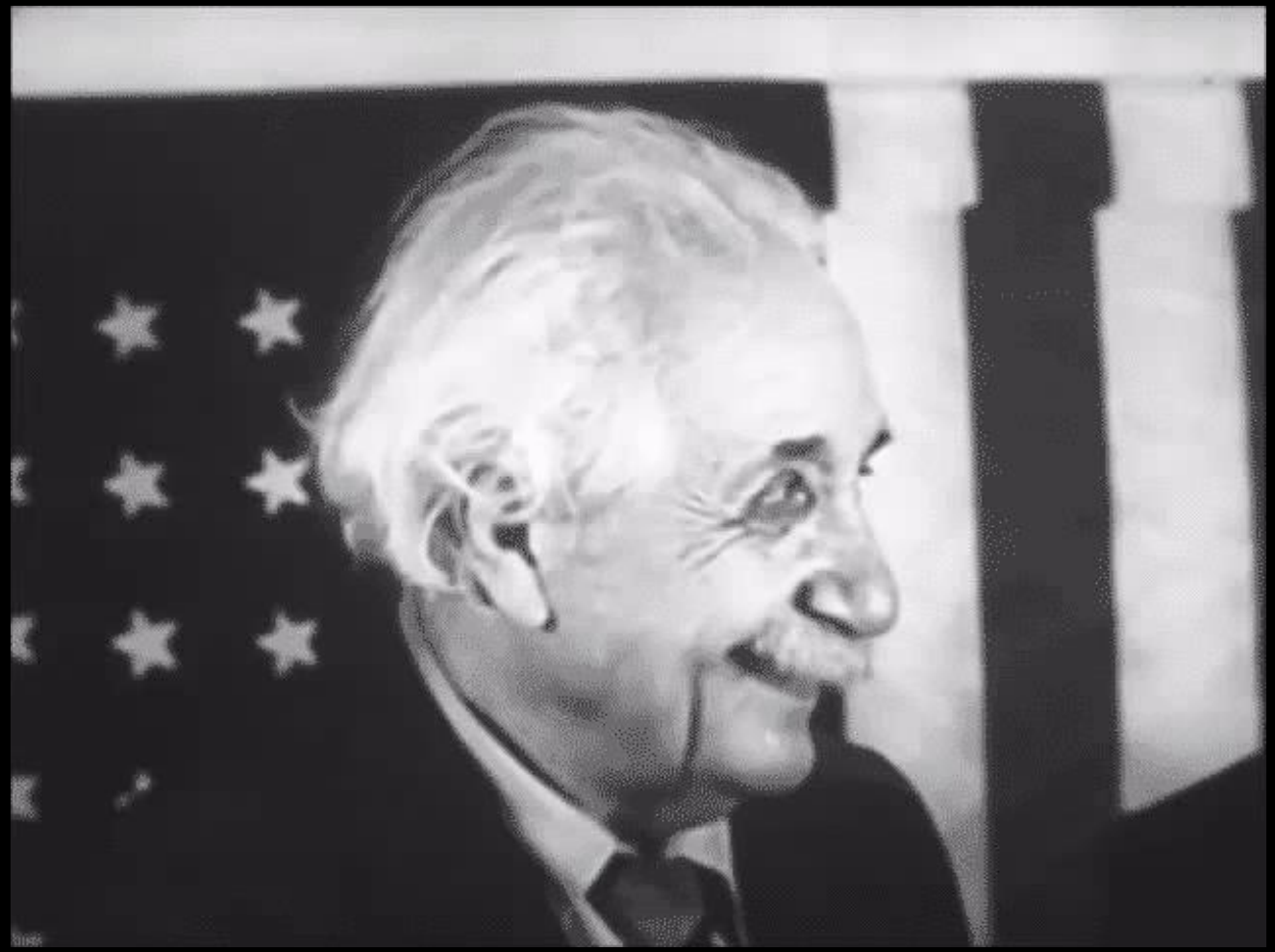
AT THE UNIVERSITY PRESS

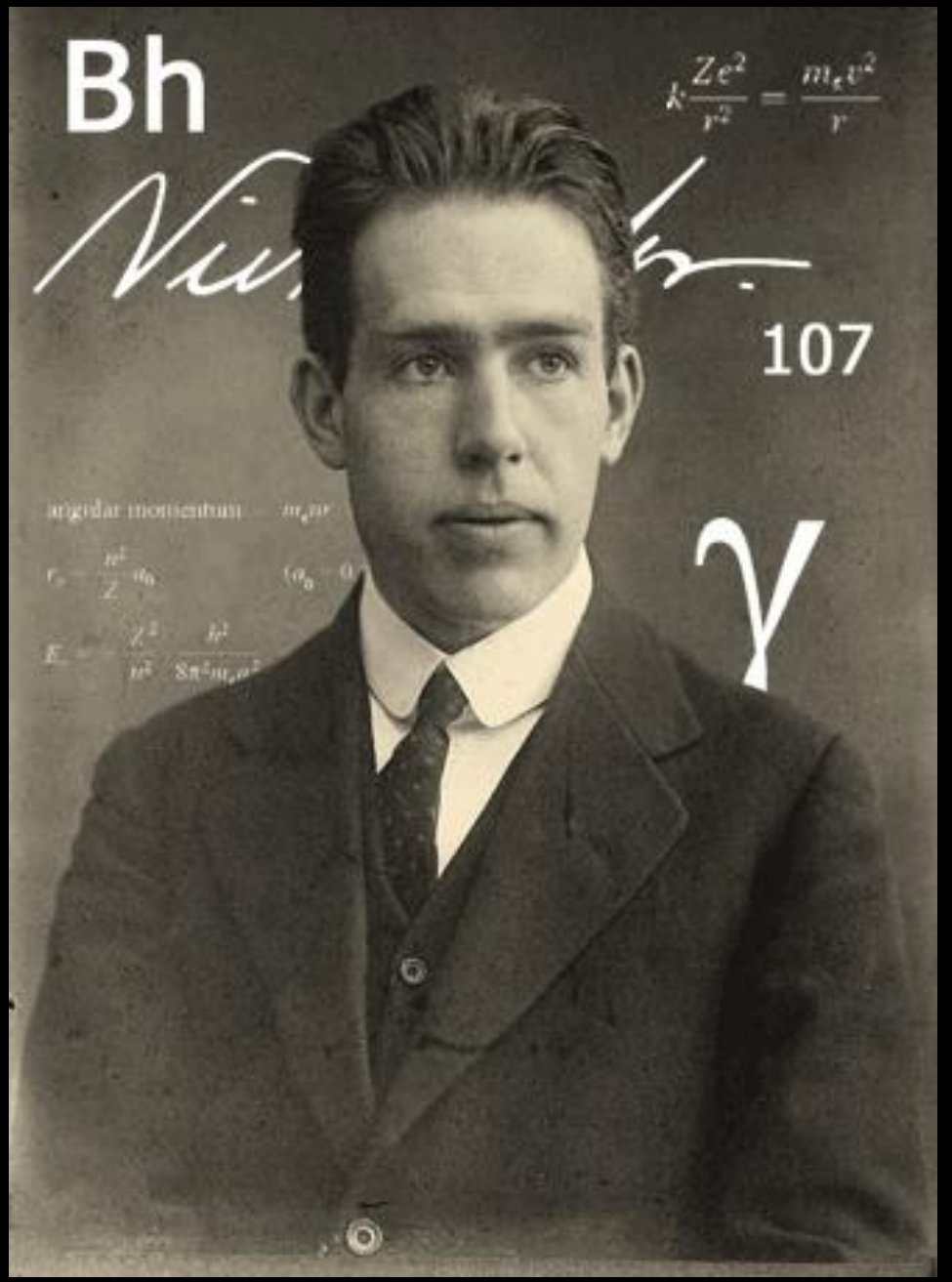
1948

Towards Quantum Biology?








Bh
107
$k\frac{Ze^2}{r^2} = \frac{m_e v^2}{r}$
angular momentum $m_e vr$
γ

I was not spared the shock which every physicist, accustomed to the classical way of thinking, experienced when he came to know of Bohr's « basic postulate of quantum theory » for the first time (Wolfgang Pauli)


The Future is not something
we enter.
The Future is something
we create.

For those who wish to contact me:
Catalina.Curceanu@LNF.INFN.IT

Testing Quantum Physics underground

Gian Carlo Ghirardi

Un'occhiata alle carte di Dio

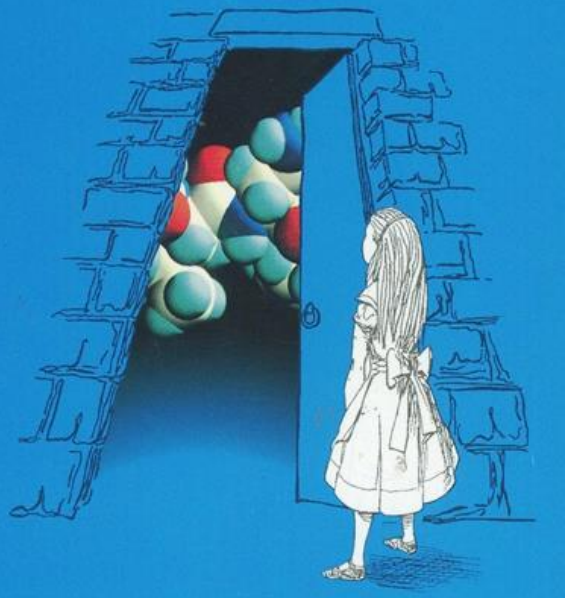
Gli interrogativi che la scienza moderna pone all'uomo

ilSaggiatore

Raffaello Cortina Editore

Robert Gilmore
Alice nel paese dei quanti

Le avventure della fisica



Scienza e Idee

Collana diretta da Giulio Giorello

Anton Zeilinger

Il velo di Einstein

Il nuovo mondo della fisica quantistica

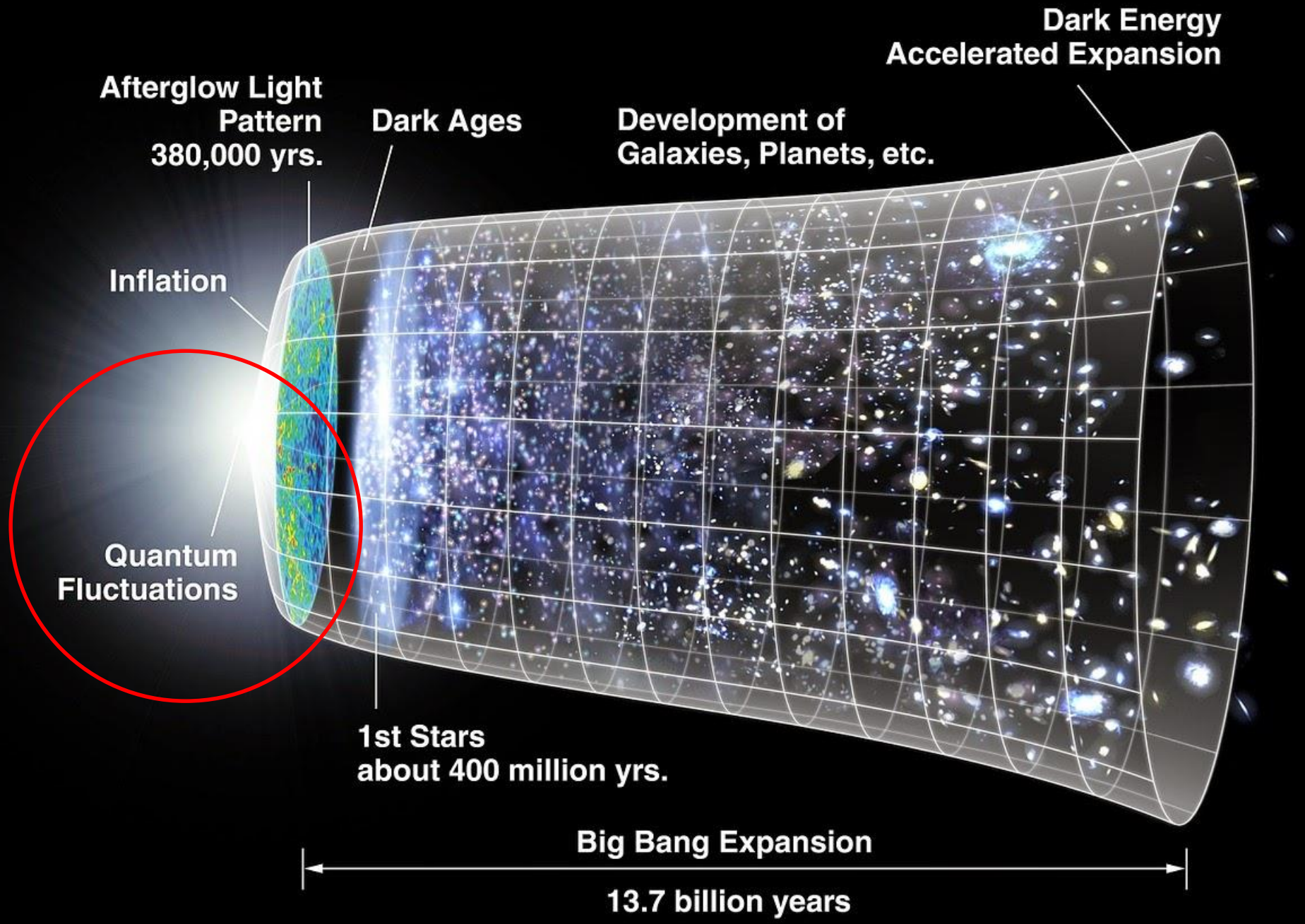
ET

Einaudi

Feynman – Il valore della scienza

Fuori dalla culla
sulla terra asciutta
eccolo
in piedi:
atomi con la coscienza
materia con la curiosità.
In piedi davanti al mare
meravigliato della propria meraviglia: io
un universo di atomi
un atomo nell'universo

Pronti per le nuove meraviglie
Del Mondo Quantistico?


Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
380,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years

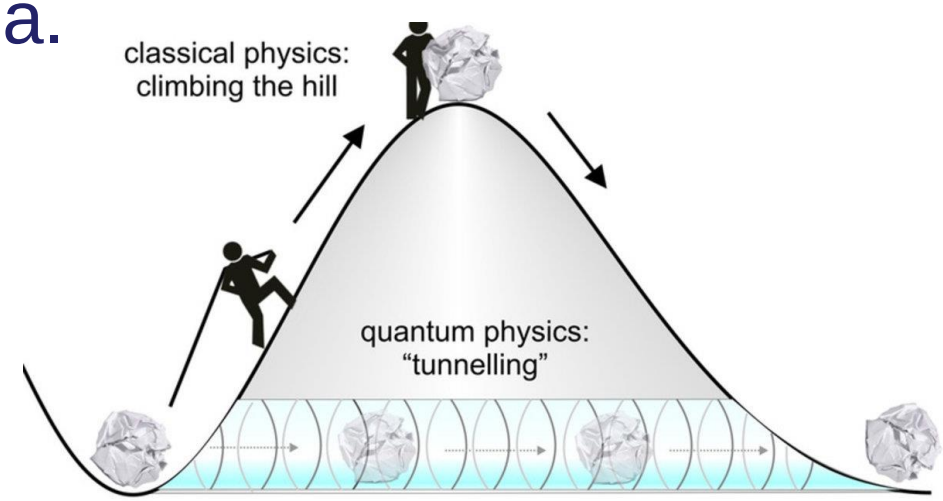
SIDDHARTA-2 sull'acceleratre DAFNE ai Laboratori Nazionali di Frascati dell'INFN

Bussola quantistica

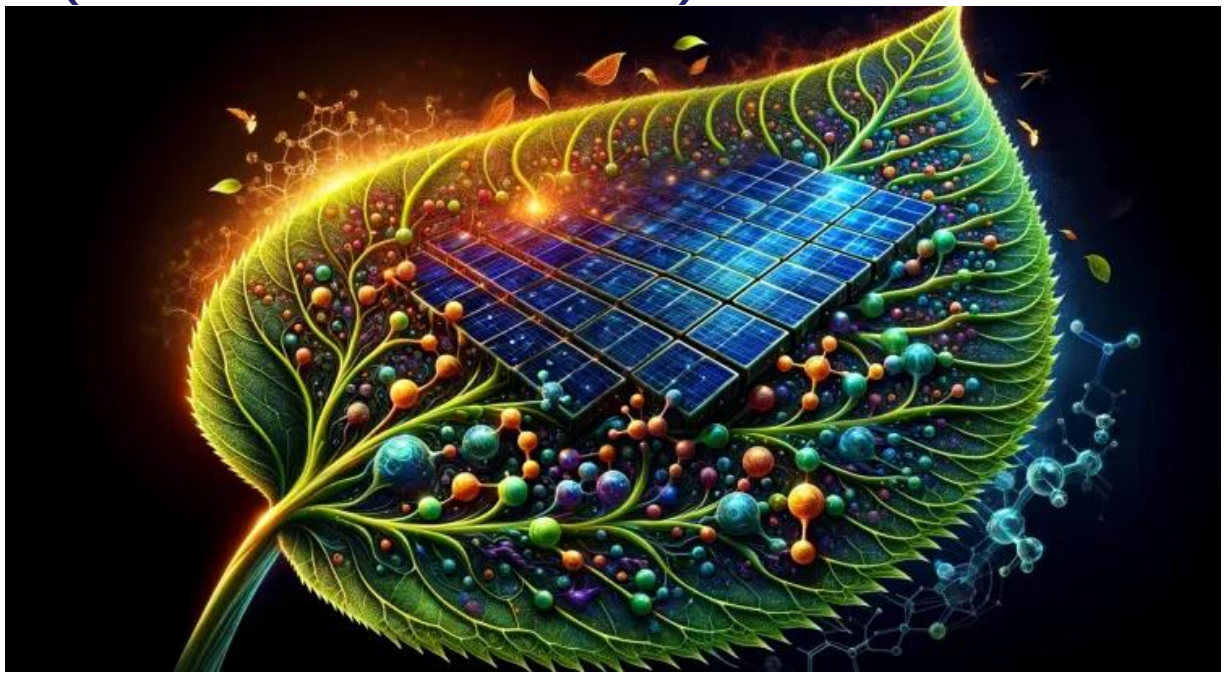
Gli uccelli migratori, come i pettirossi europei, sembrano utilizzare un meccanismo di navigazione basato su effetti quantistici per percepire il campo magnetico terrestre. Questo fenomeno è noto come magnetoricezione quantistica e coinvolge il principio della coerenza quantistica all'interno di una proteina chiamata criptocromo, presente negli occhi degli uccelli. Gli studi hanno dimostrato che i pettirossi europei possono mantenere effetti quantistici nei loro occhi per un massimo di 20 microsecondi, una durata più lunga rispetto a quella ottenuta in alcune condizioni di laboratorio.

Recenti ricerche suggeriscono che la meccanica quantistica potrebbe giocare un ruolo nel sistema olfattivo, in particolare attraverso la teoria vibrazionale dell'olfatto. Questa teoria propone che il nostro senso dell'olfatto non dipenda solo dalla forma delle molecole odorose, ma anche dalle loro frequenze vibrazionali. Quando una molecola odorosa si lega a un recettore olfattivo, potrebbe facilitare il trasferimento di elettroni **tramite il tunneling quantistico**, influenzato dall'energia vibrazionale della molecola.

(ancora dibattuto...)

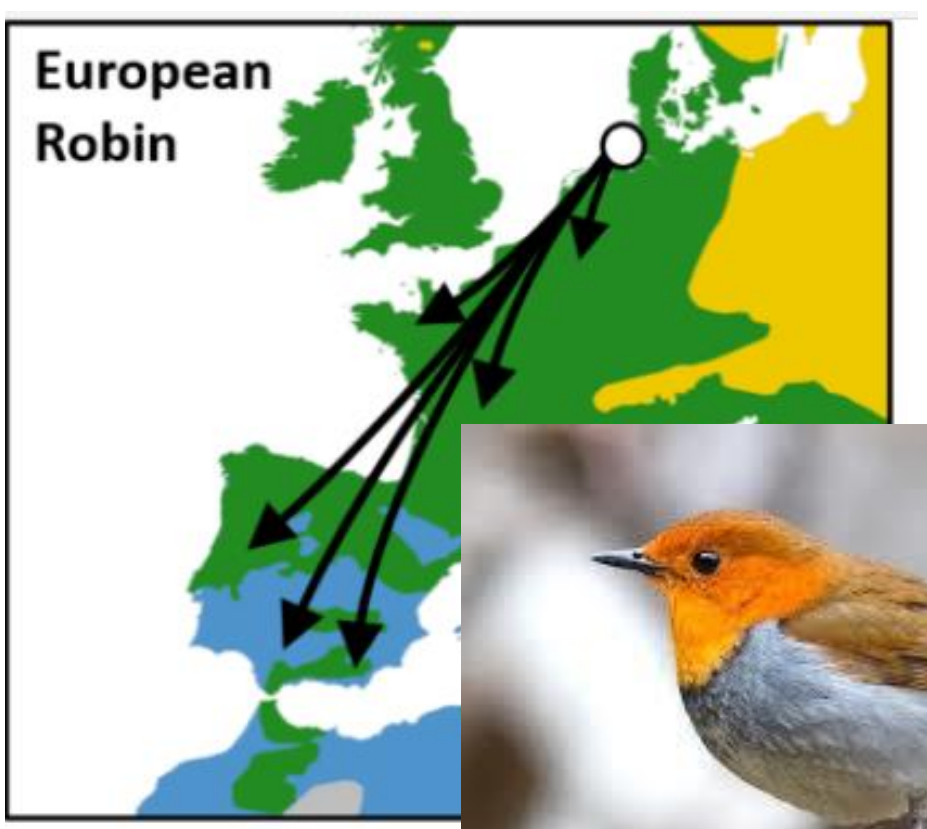


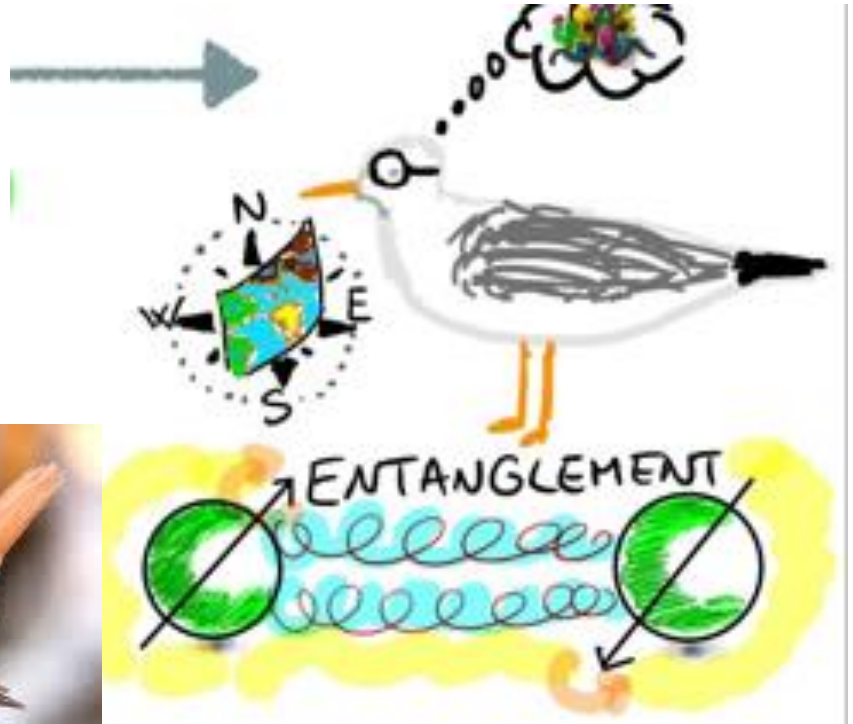
La sovrapposizione quantistica potrebbe essere la chiave. Nella fotosintesi **l'eccitone potrebbe percorrere contemporaneamente tutte le strade possibili fino al centro di reazione**. La sovrapposizione quantistica offre una valida spiegazione del motivo per cui la fotosintesi è altamente efficiente nel convertire la luce solare in energia.(ancora dibattuto...)



https://andrewggibson.com/2024/04/21/quantum-coherence-in-photosynthesis-natures-quantum-computers/

Senso (quantistico) dell’ orientamento negli uccelli





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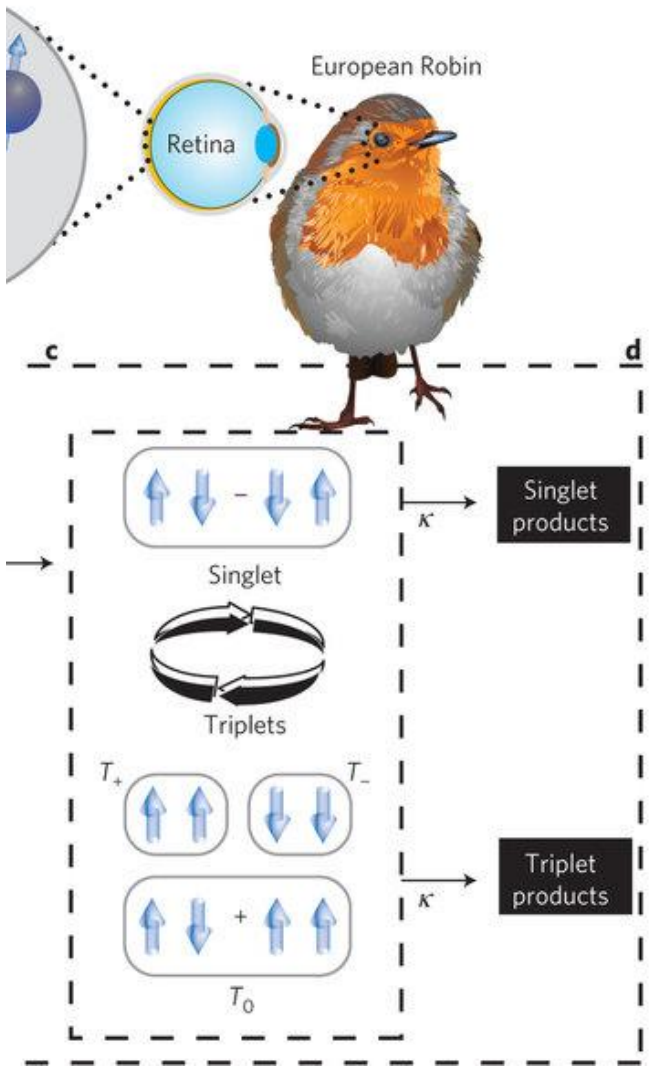
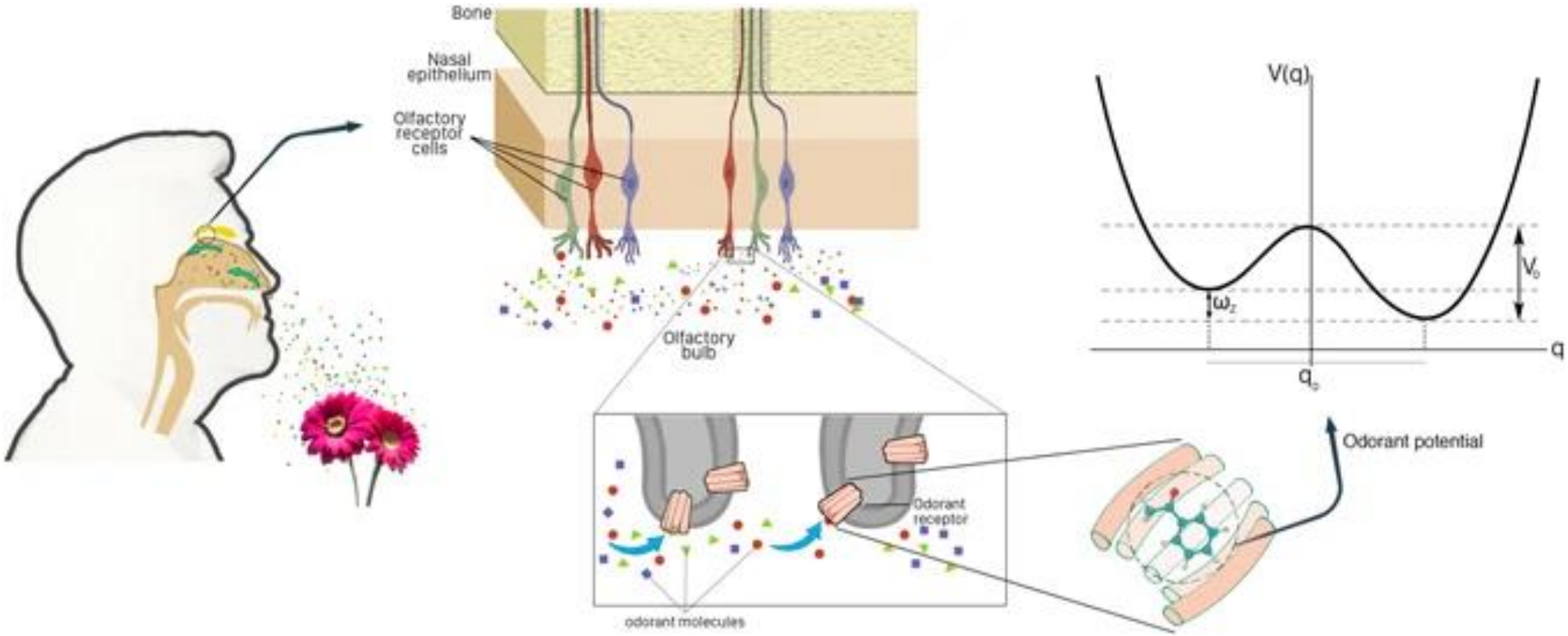


Researchgate.net

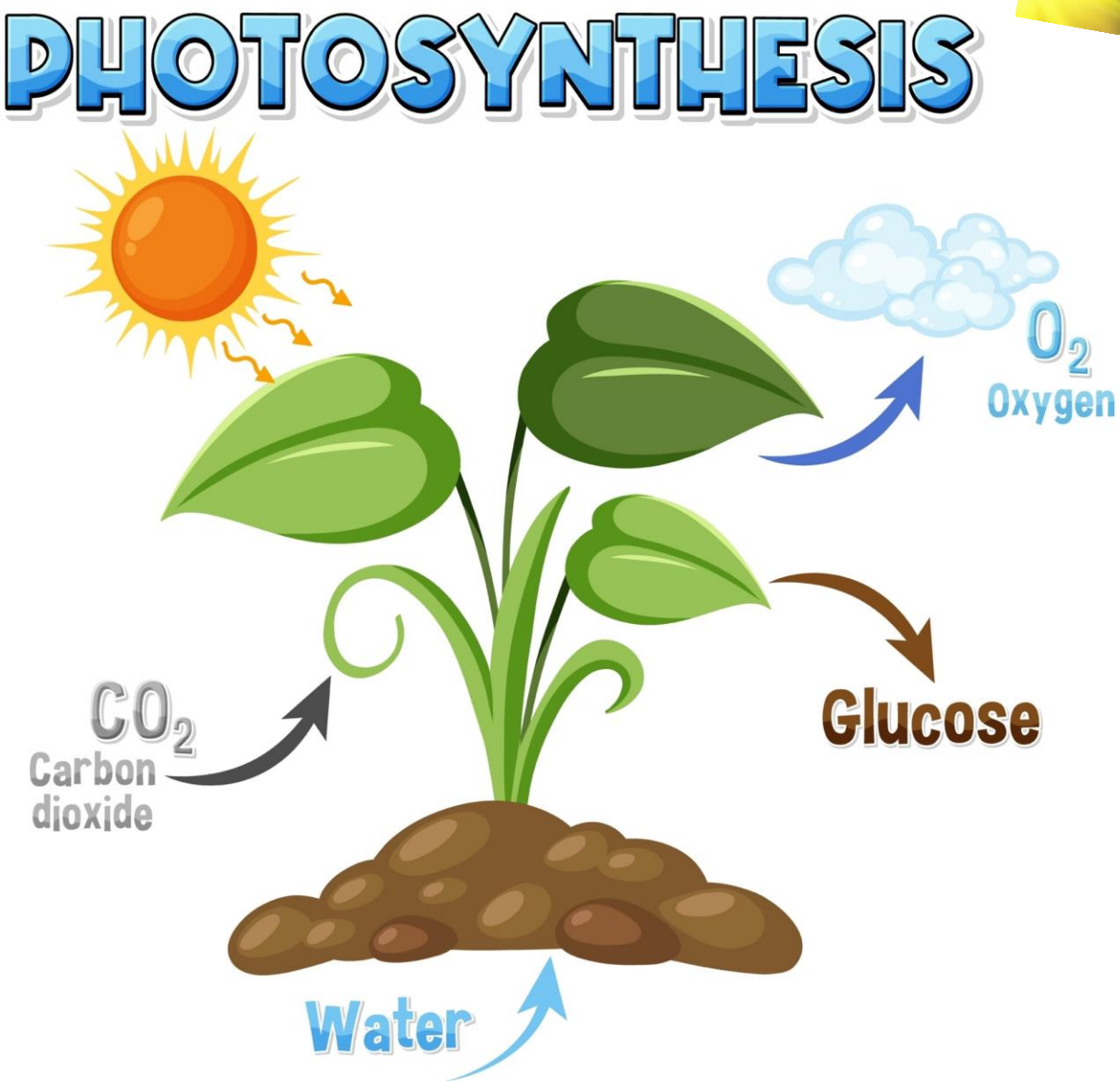
Senso sell’olfatto (quantistico?)

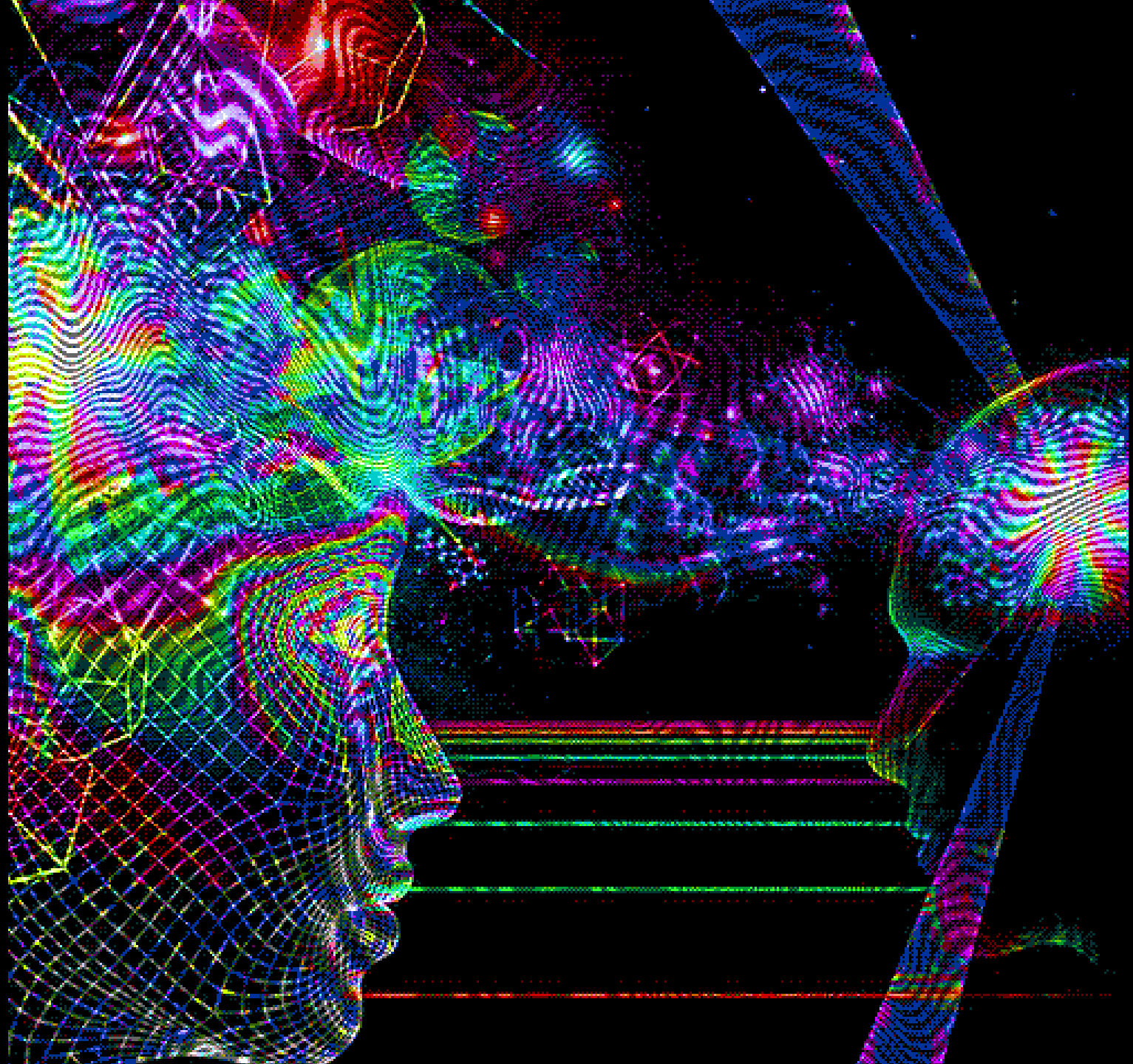
Validity Examination of the Dissipative Quantum Model of Olfaction



Scientific Reports volume 7, Article number: 4432 (2017)

Fotosintesi (quantistica?)





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Physics of Life Reviews 42 (2022) 8–14

PHYSICS of LIFE reviews

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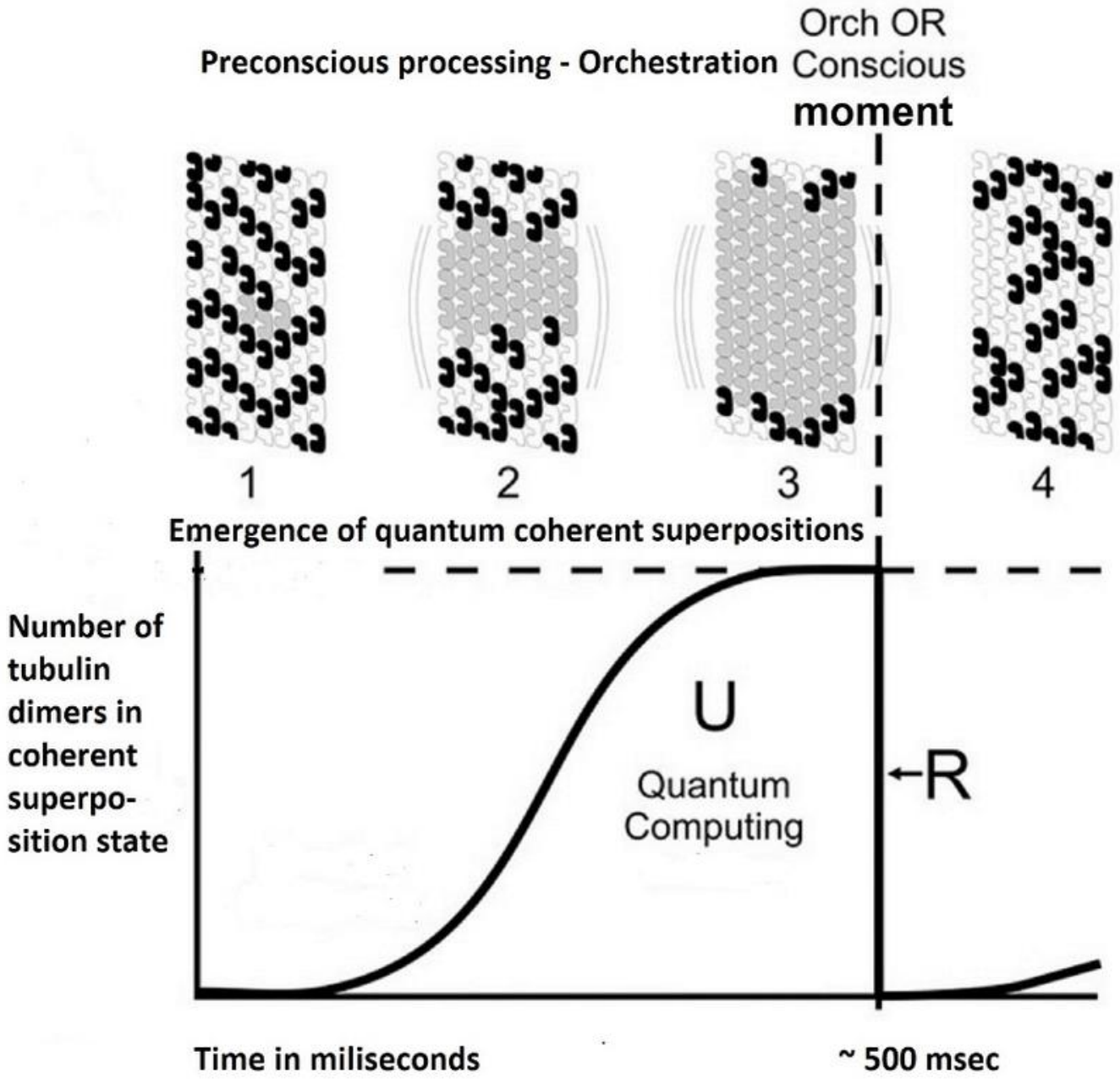
Review

At the crossroad of the search for spontaneous radiation and the Orch OR consciousness theory

Maaneli Derakhshani [a], Lajos Diósi [b,c], Matthias Laubenstein [d], Kristian Piscicchia [e,f,*], Catalina Curceanu [f]



I risultati ottenuti non sono coerenti con quanto ci aspettiamo dal modello Diósi-Penrose

Non possiamo rifiutarlo, ma se esiste non è così semplice.

Unraveling quantum coherences mediating primary charge transfer processes in photosystem II reaction center

Science Advances, 6 Mar 2024

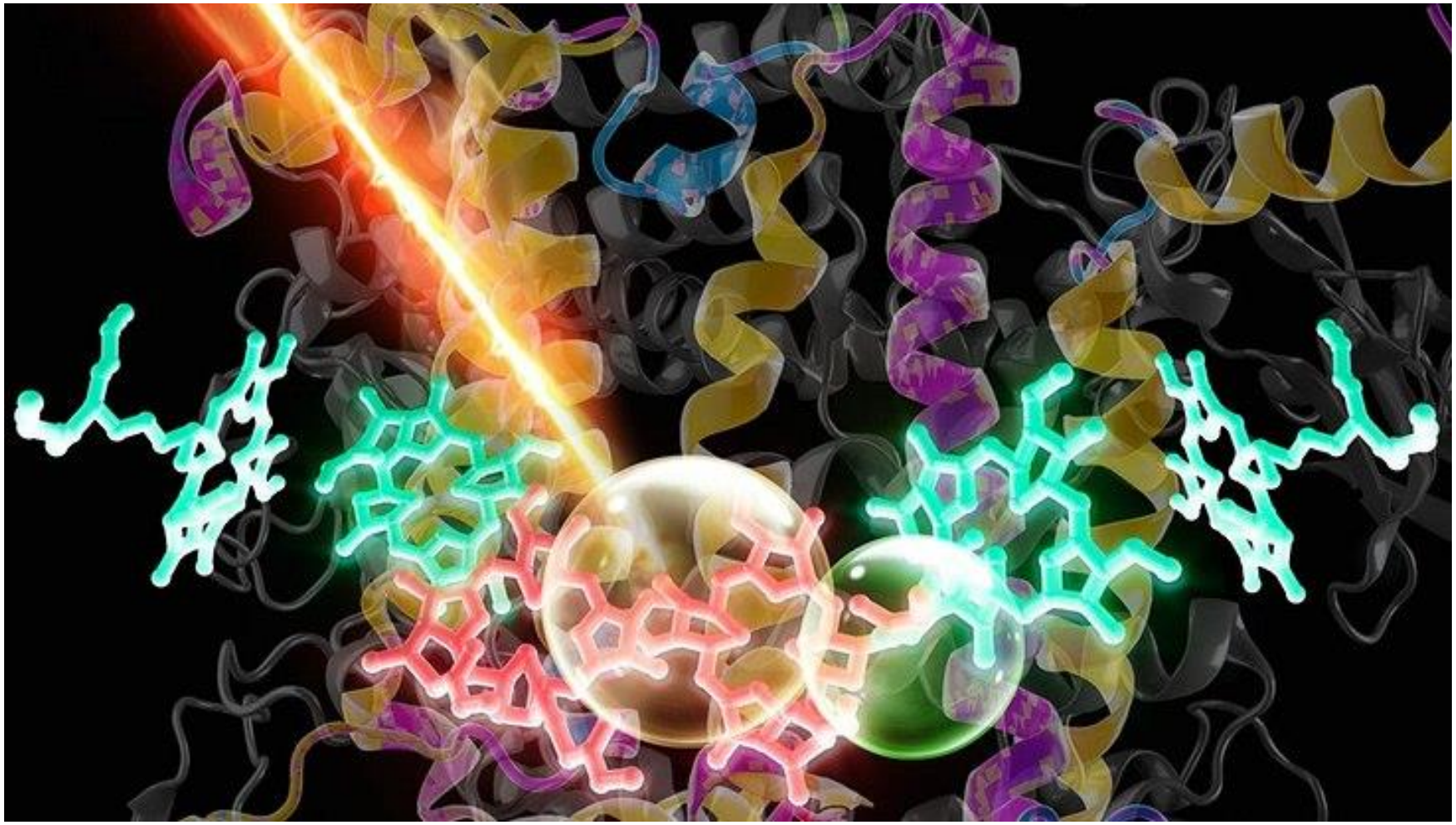
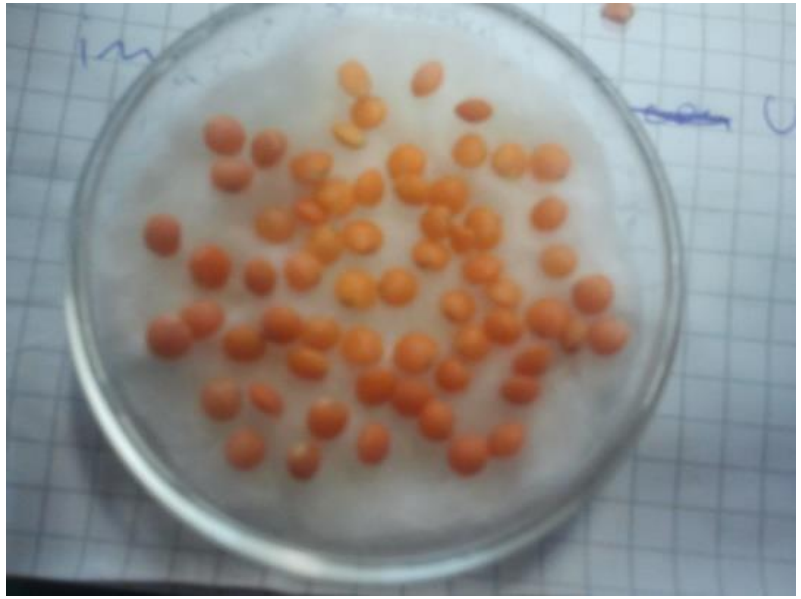
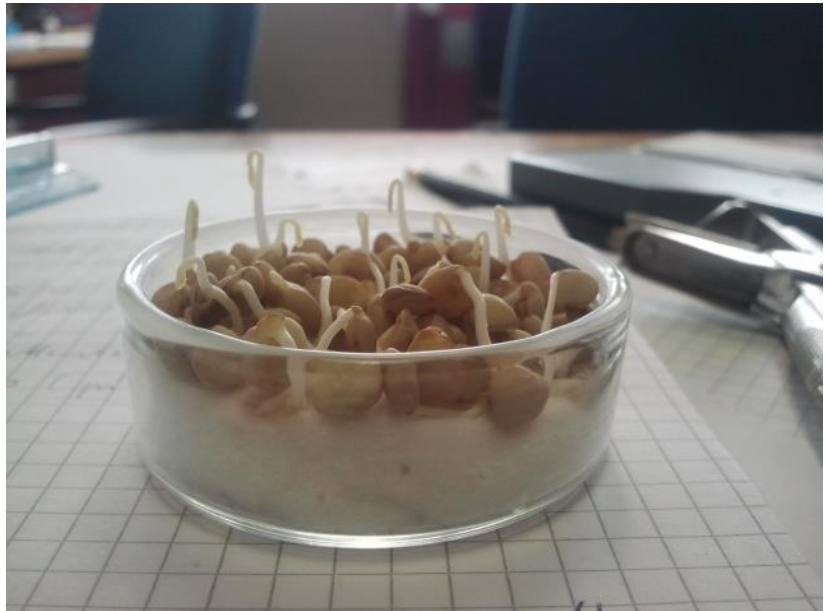


Photo: A. Jha and H.-G. Duan

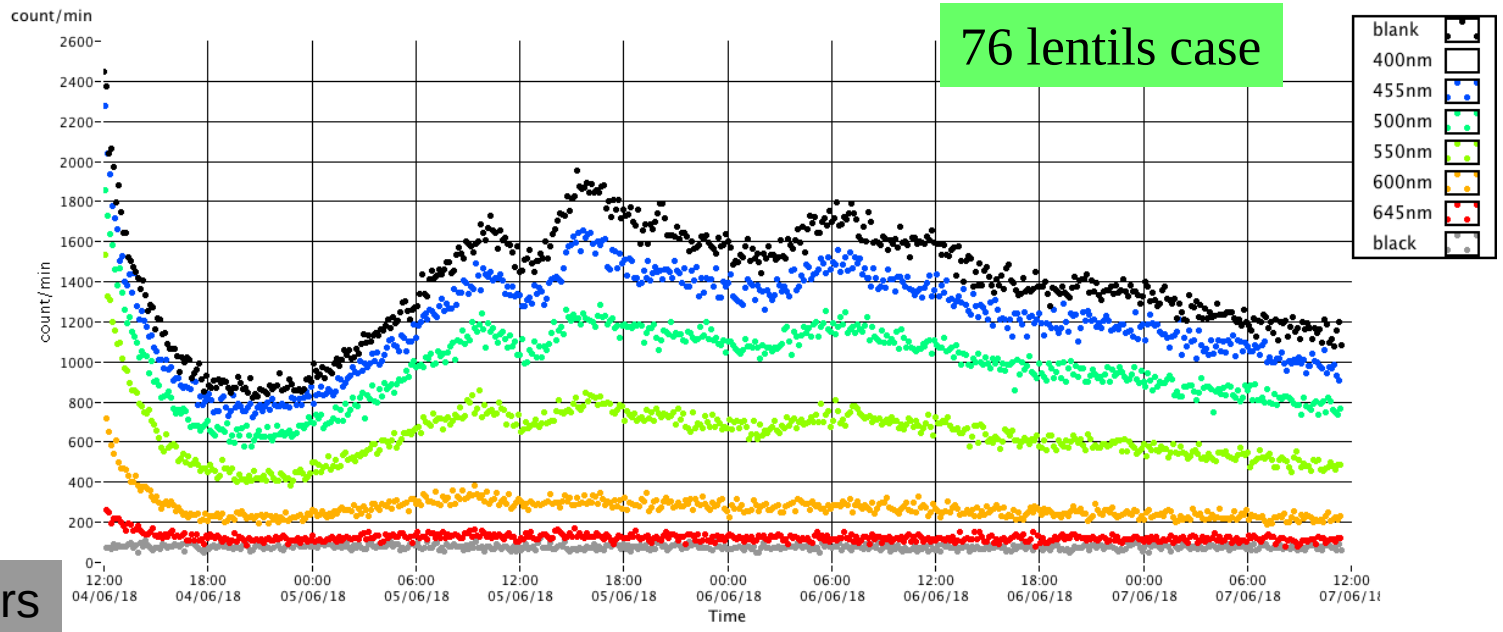
Biofotoni – piante che stanno germinando

L’esperimento

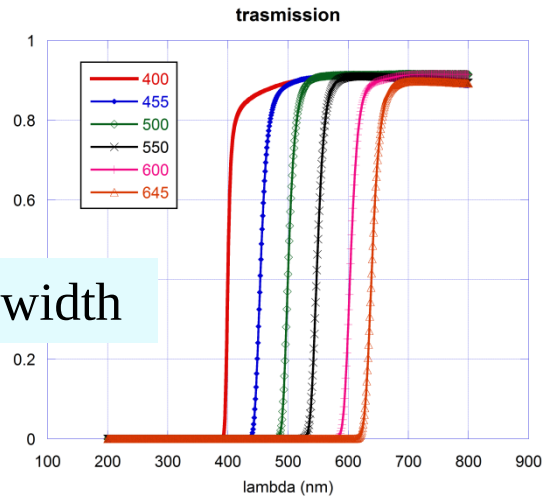




time dependence of the different spectral components



Time : hours
days



Filters bandwidth

the energy resolution
is of the order of

$$\frac{\Delta E}{E} \sim 0.1$$

entropy M. Benfatto et al. Entropy 23, 554 (2021) MDPI

Article

Biophotons and Emergence of Quantum Coherence—A Diffusion Entropy Analysis

Maurizio Benfatto [1,*], Elisabetta Pace [1], Catalina Curceanu [1], Alessandro Scordo [1], Alberto Clozza [1], Ivan Davoli [2], Massimiliano Lucci [2], Roberto Francini [3], Fabio De Matteis [3], Maurizio Grandi [4], Rohisha Tuladhar [5] and Paolo Grigolini [6,*]

Biophotons: New Experimental Data and Analysis

by Maurizio Benfatto [1,*], Elisabetta Pace [1,*], Ivan Davoli [2], Roberto Francini [3], Fabio De Matteis [3], Alessandro Scordo [1], Alberto Clozza [1], Luca De Paolis [1], Catalina Curceanu [1,*] and Paolo Grigolini [4]

Entropy 2023, 25(10), 1431;

L'analisi dei dati sui biofotoni emessi dai semi di lenticchie supporta modelli per l'emergere di una sorta di **'intelligenza' vegetale**, in cui i biofotoni trasportano informazioni e potrebbero quindi essere utilizzati dalle piante come mezzo di comunicazione

Effetti quantistici?

Altri organismi?

La possibilità di nuovi trattamenti delle patologie?