Introduction to the Modern Physics ad to the LNF-INFN activities

Mini-stage in MP, 4-5 August 2014

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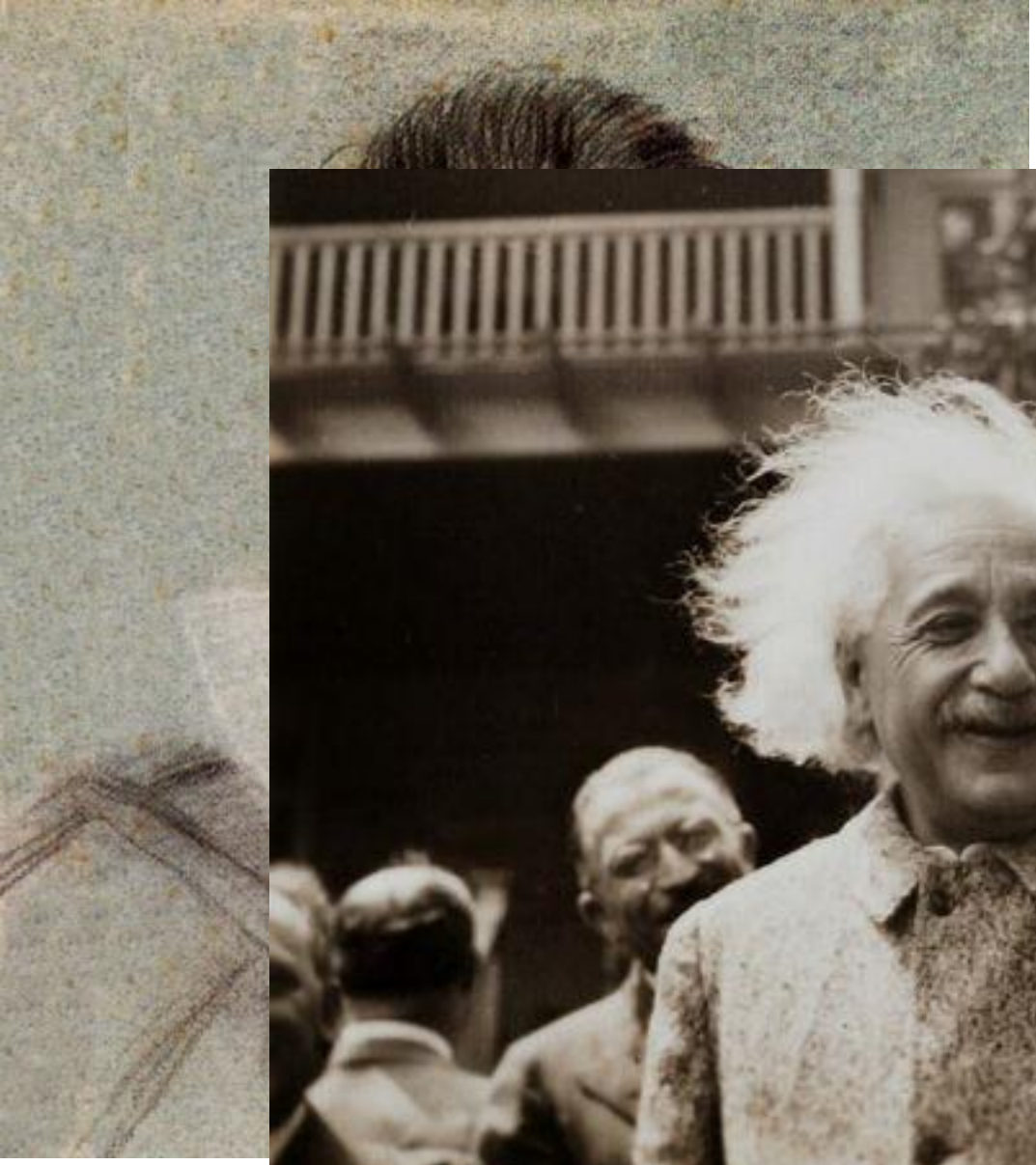
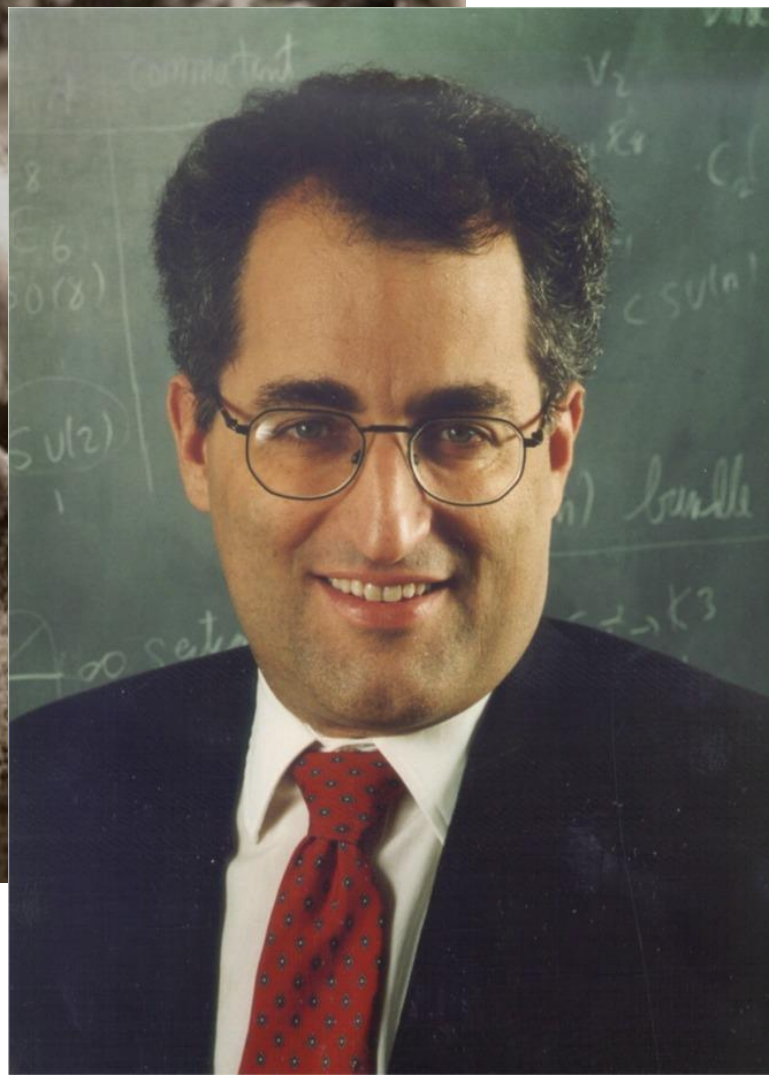
LNF-INFN

INFN
Istituto Nazionale di Fisica Nucleare





Modern Physics

Two **"scientific revolutions"** in the 20th century:

- **Theory of Relativity**
- **Quantum Mechanics**

Relativity

Speaks about events occurring in space and time

Relates these events

for

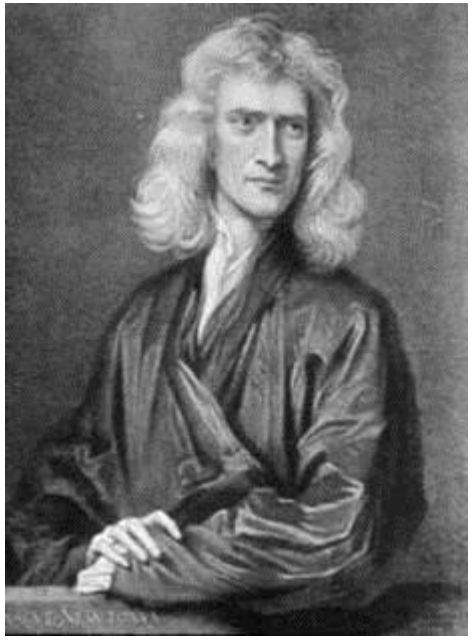
Reference systems

Special Relativity

(1900 ÷ 1905)

Einstein, Lorentz, Poincaré

NEWTON



I. Absolute TIME.

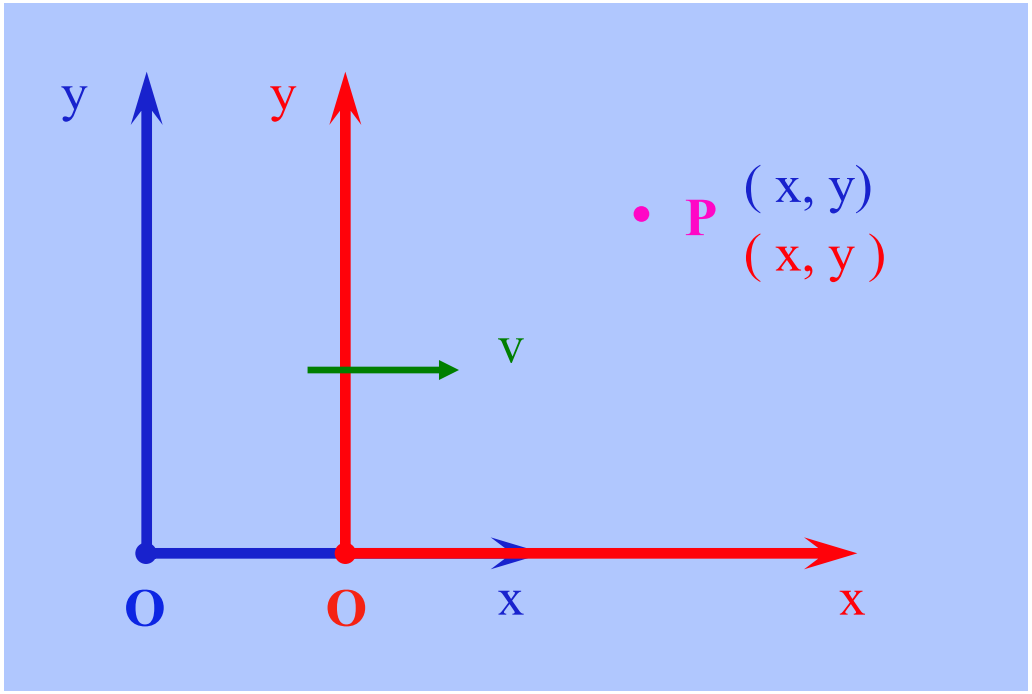
II. Absolute SPACE

GALILEO

Equivalence between 2 inertial reference systems

Same laws of physics in various reference systems

Galileo laws



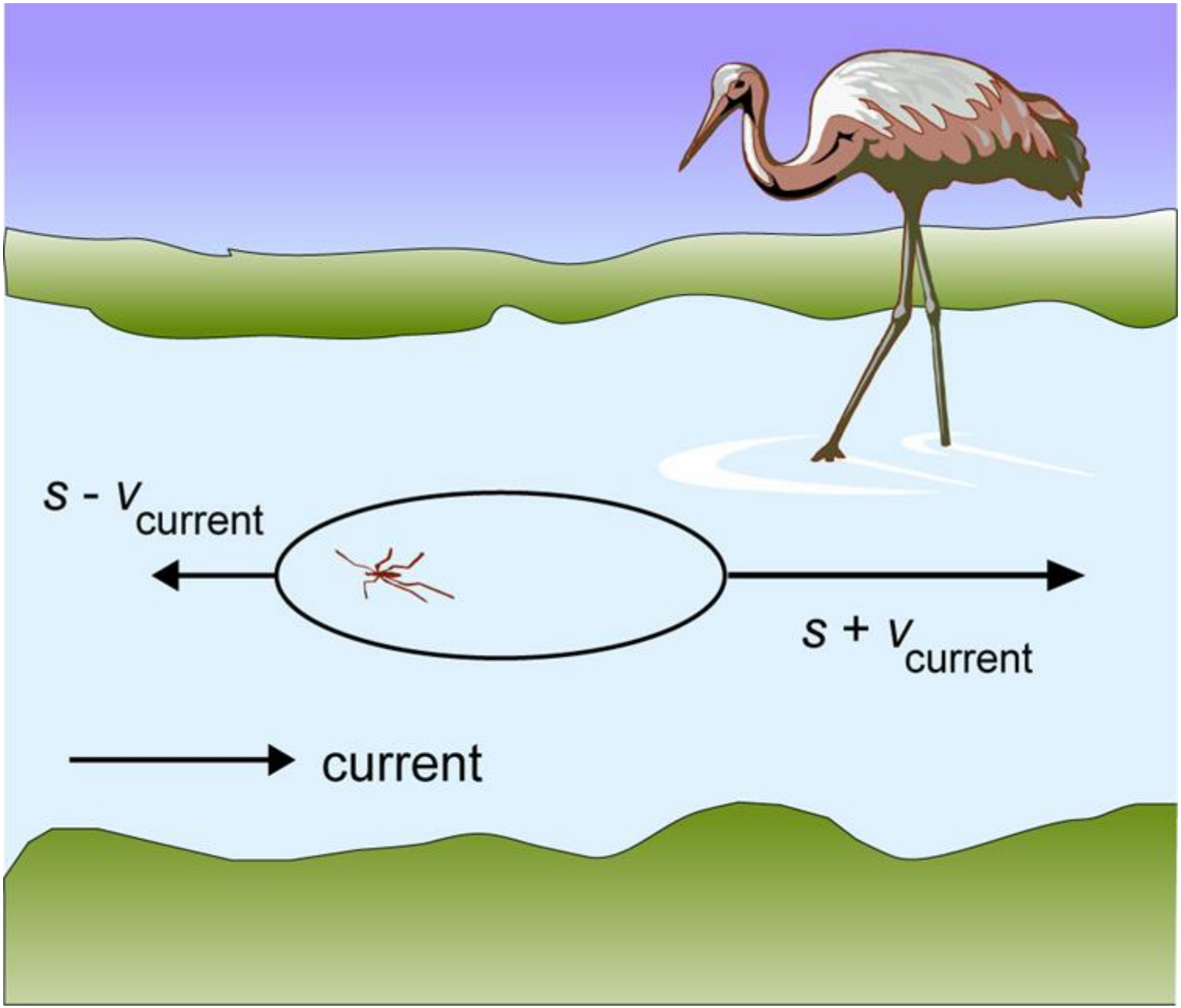
$$x = x - v \cdot t$$

$$y = y$$

$$t = t$$

$(t = 0 \rightarrow O \equiv O)$

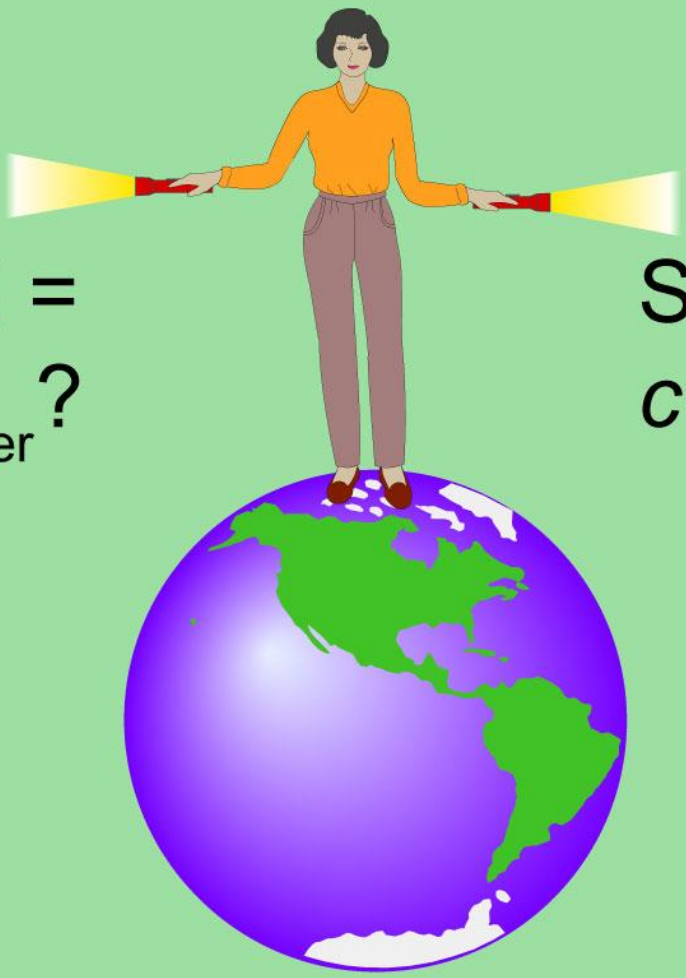
m is the same $\Rightarrow$ $F = m \frac{d^2 x}{d t^2} = m \frac{d^2 x}{d t^2} = F$


s - v current
s + v current
current

BUT at very high speed (-> light speed)

Strange things happen….

Ether?



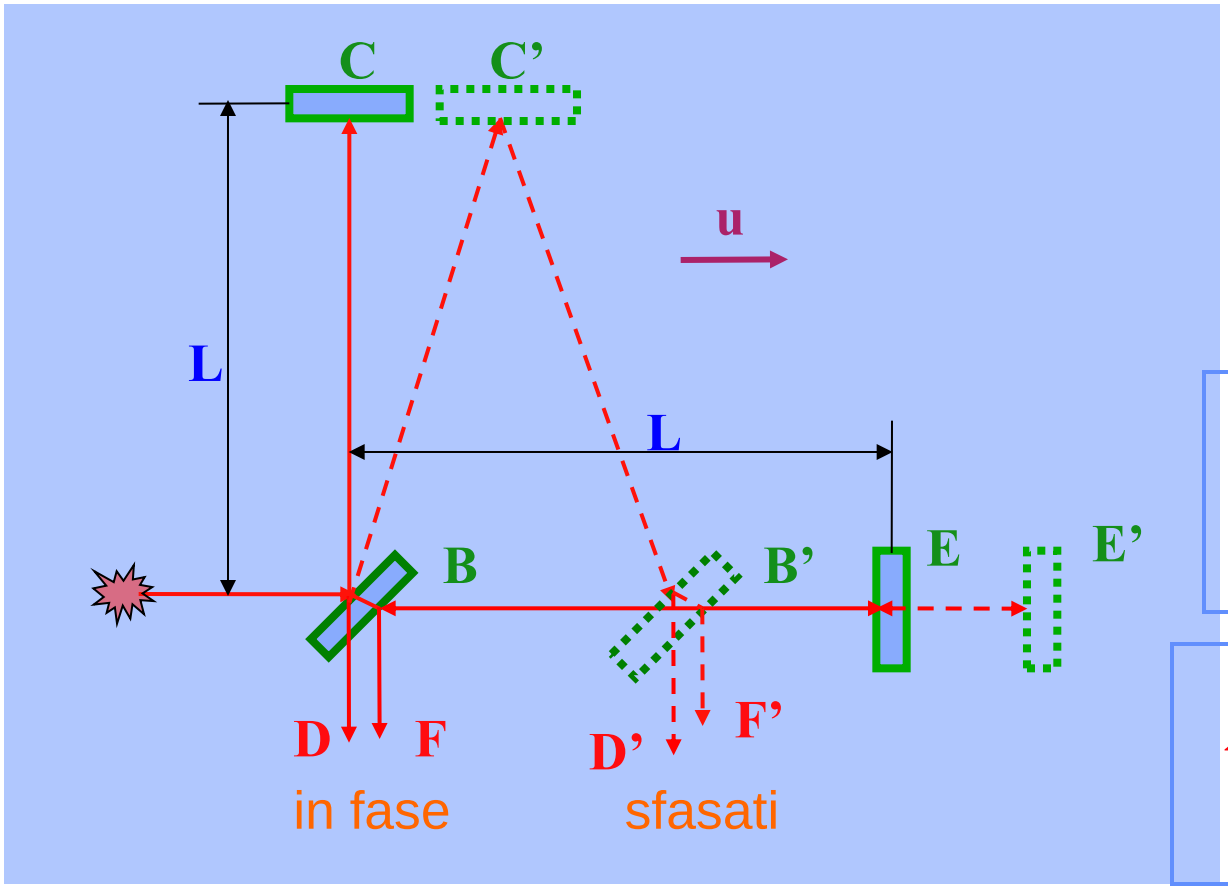
Speed = $c + v_{ether}$?

Speed = $c - v_{ether}$?

Michelson & Morley

(1887)

Earth was supposed to move in ether



Interferometer

t_1 : B – E – B

t_2 : B – C – B

$$t_1 = \frac{2L / c}{1 - u^2 / c^2}$$

$$t_2 = \frac{2L / c}{(1 - u^2 / c^2)^{1/2}}$$

Michelson & Morley

Experimental observation:

$$\Delta t = t_1 - t_2 = 0$$

Light speed is the same → no effect due to Earth moving in ether

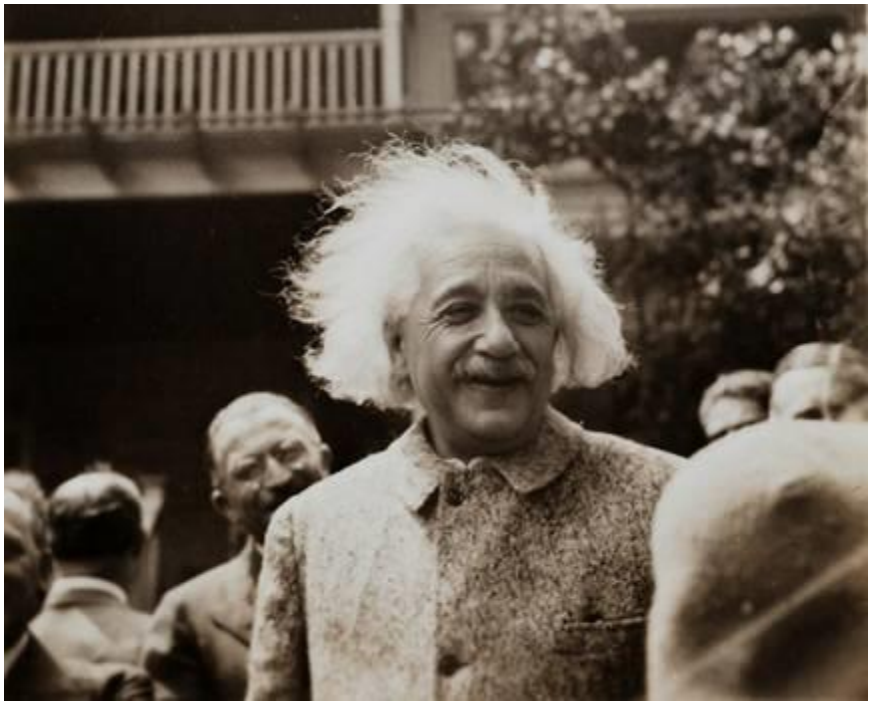
Two possible alternatives:

1) Light does not propagate in the same way in various reference systems – not same physics (Maxwewll laws)

2) Galileian transformations are not valid!

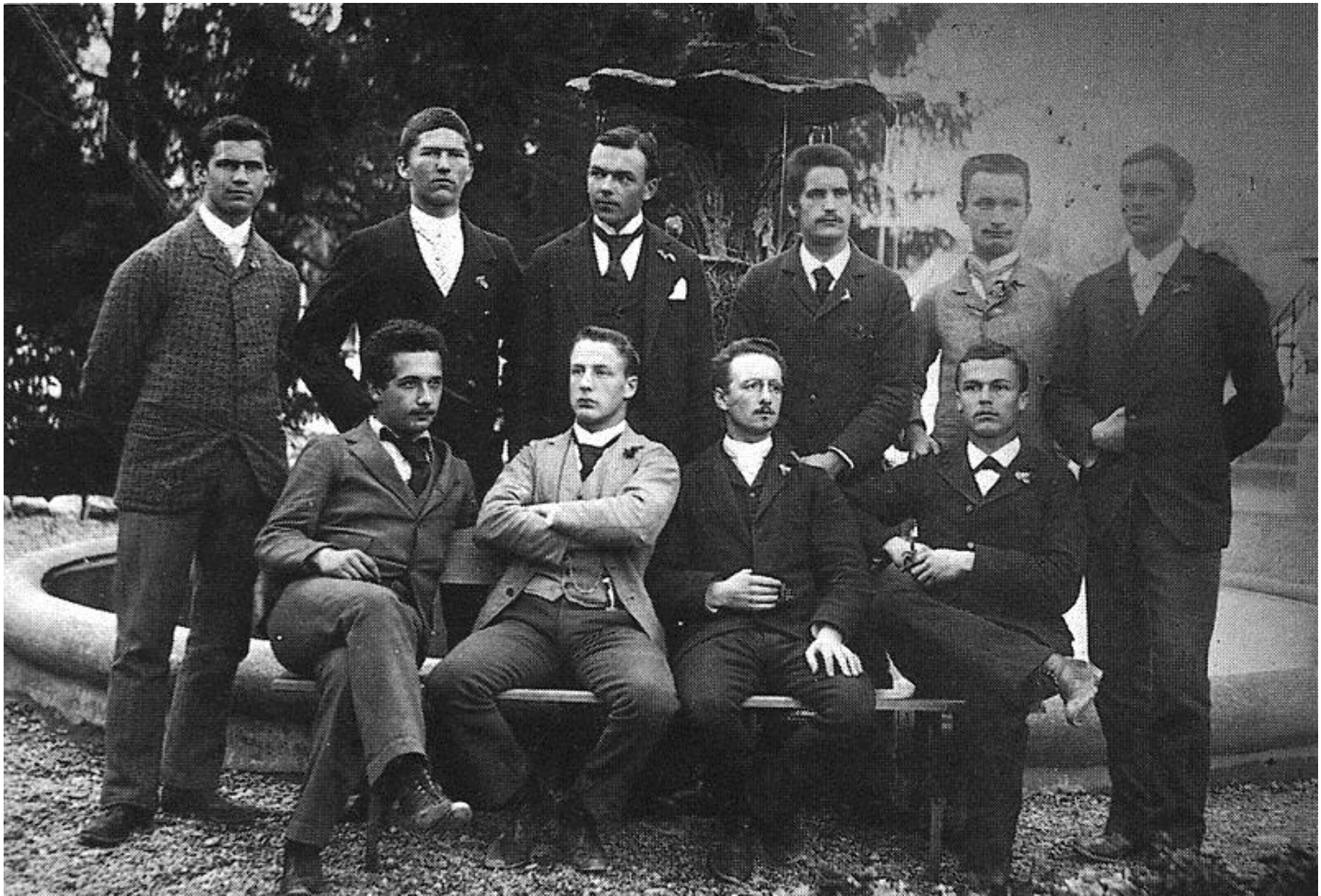
Einstein

(1905)



First picture of Einstein

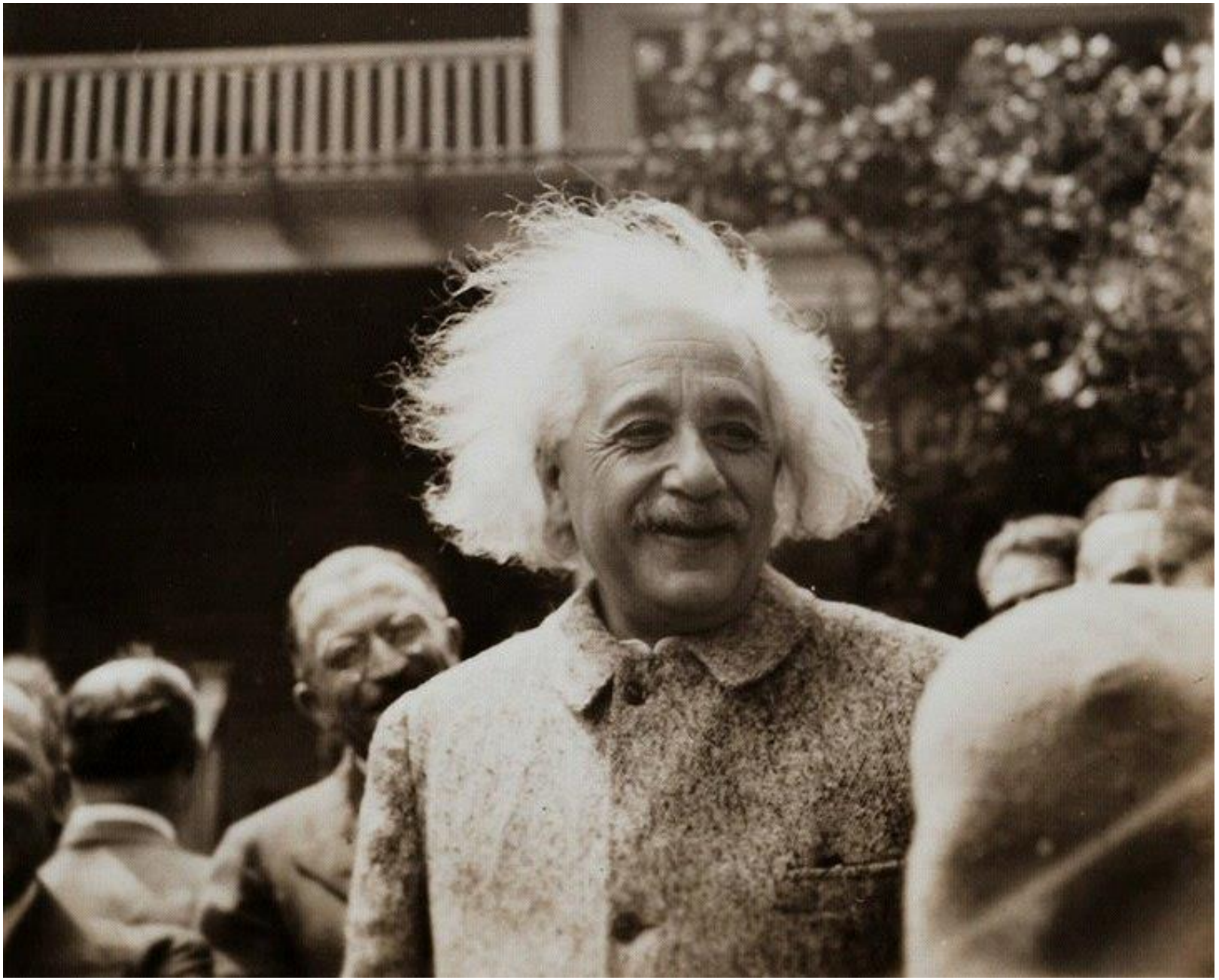
Einstein –Aarau public school



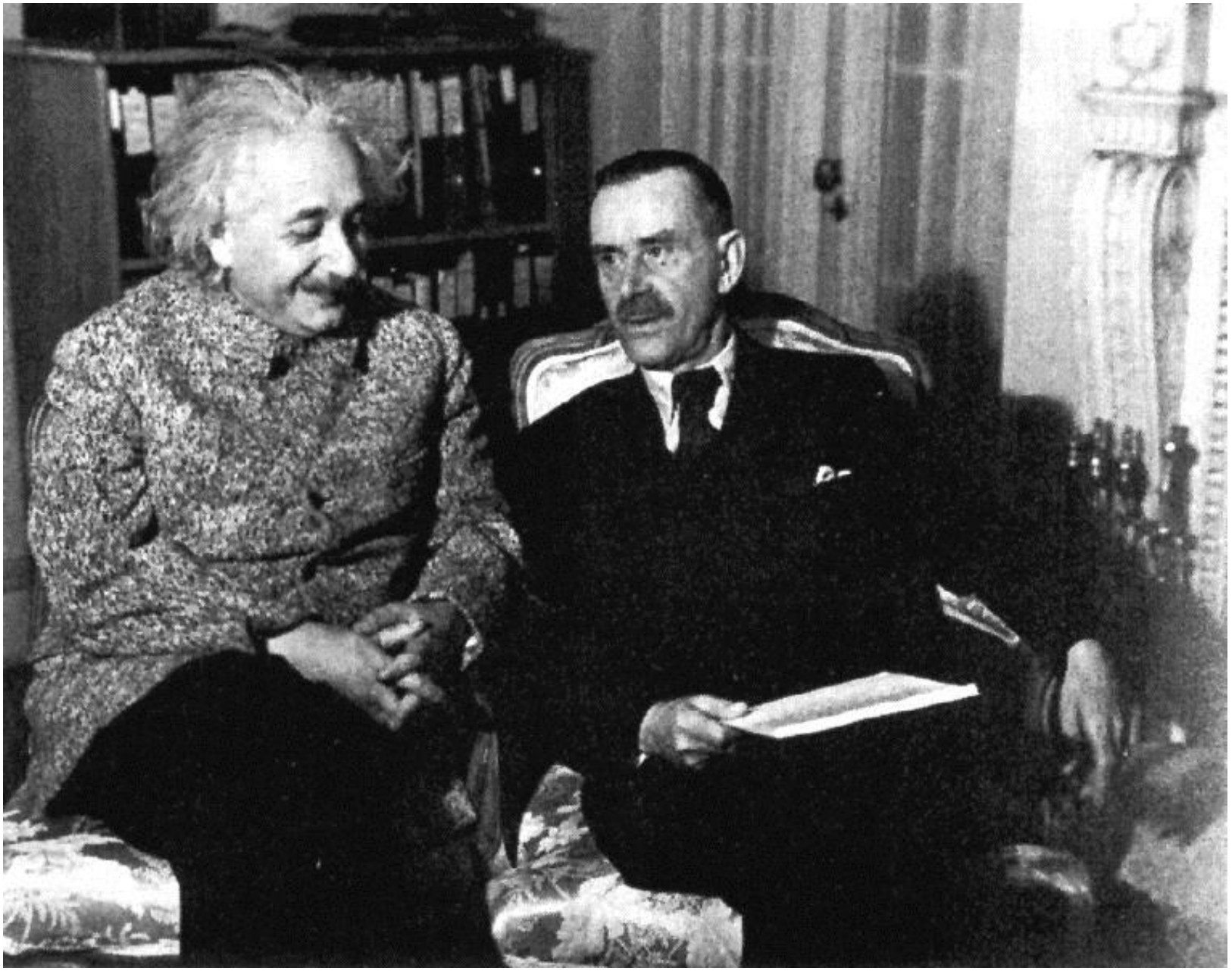
Einstein at Yekes Observatory - 1921

Einstein and music 1929

Einstein:1945

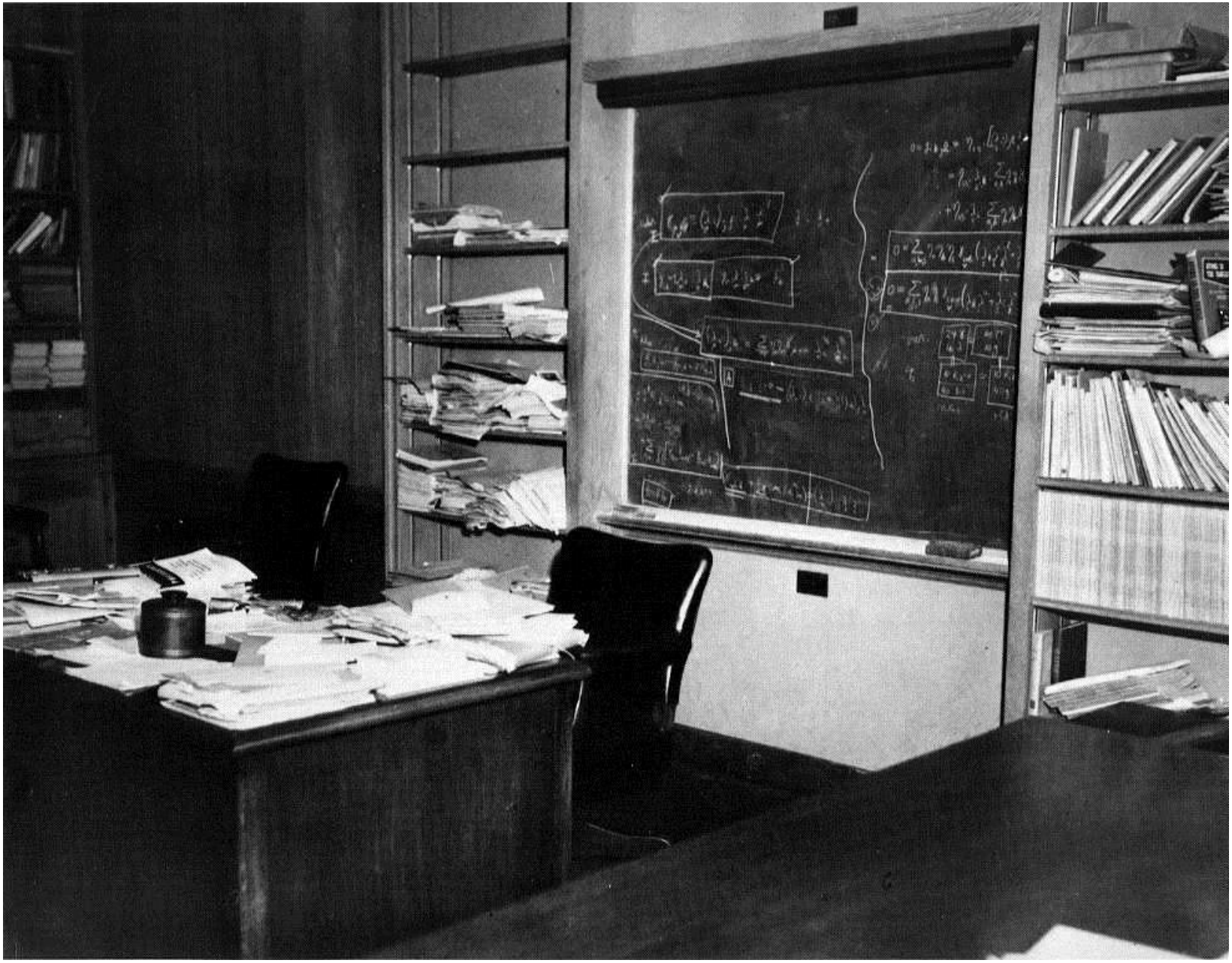


Einstein and Thomas Mann



Einstein and Charlie Chaplin

Einstein – last work



Einstein

(1905)

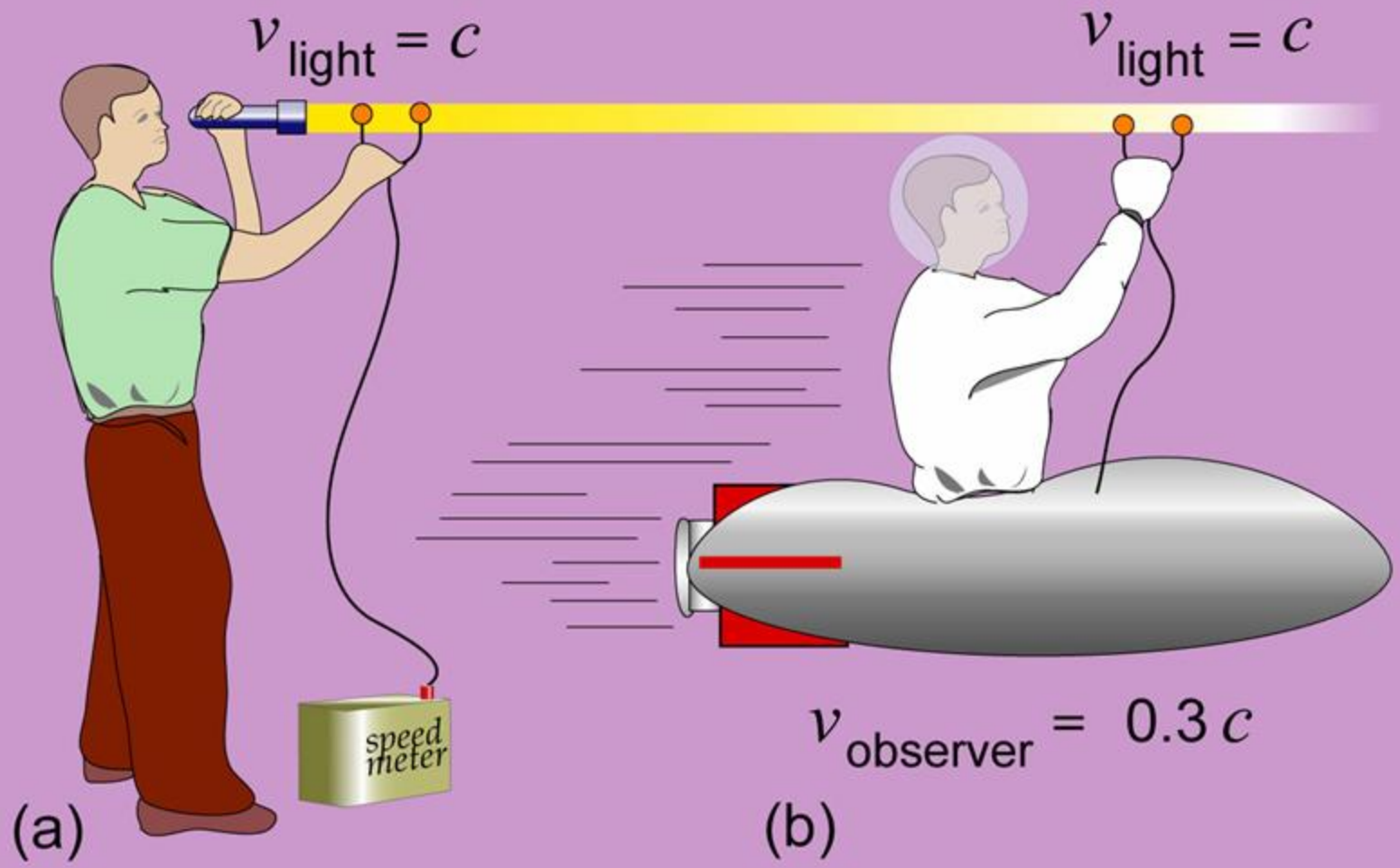
Theory of relativity – postulates:

P1 - laws of physics are the same in all inertial reference systems IRF

Than Maxwell eq. are ok if and only if:

P2 - speed of light is the SAME in all IRS

Ether does not exist (not necessary)


$v_{light} = c$
$v_{light} = c$
speed meter
$v_{observer} = 0.3\,c$
(a)
(b)

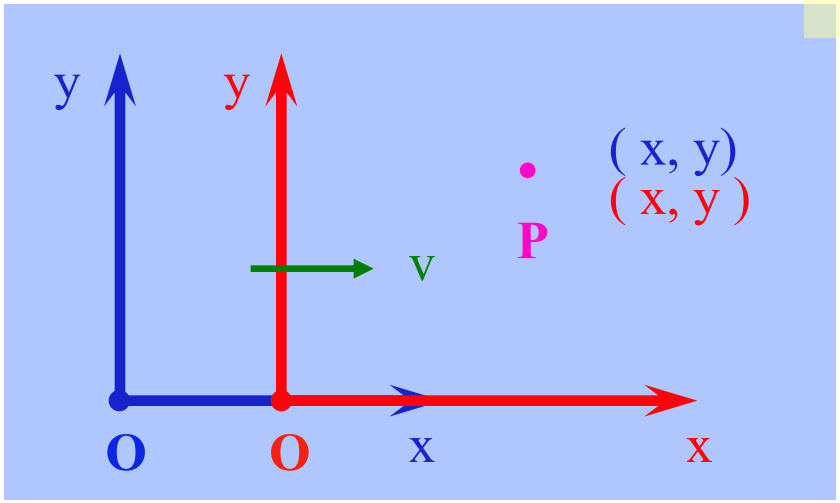
Consequences of P2

Time dilation

Distance contraction

Space and time are part on an unique quantity

Space-time



$$\gamma(>=1) = (1 - v^2 / c^2)^{-1/2}$$

$$x = \gamma (x - v\,t)$$

$$y = y$$

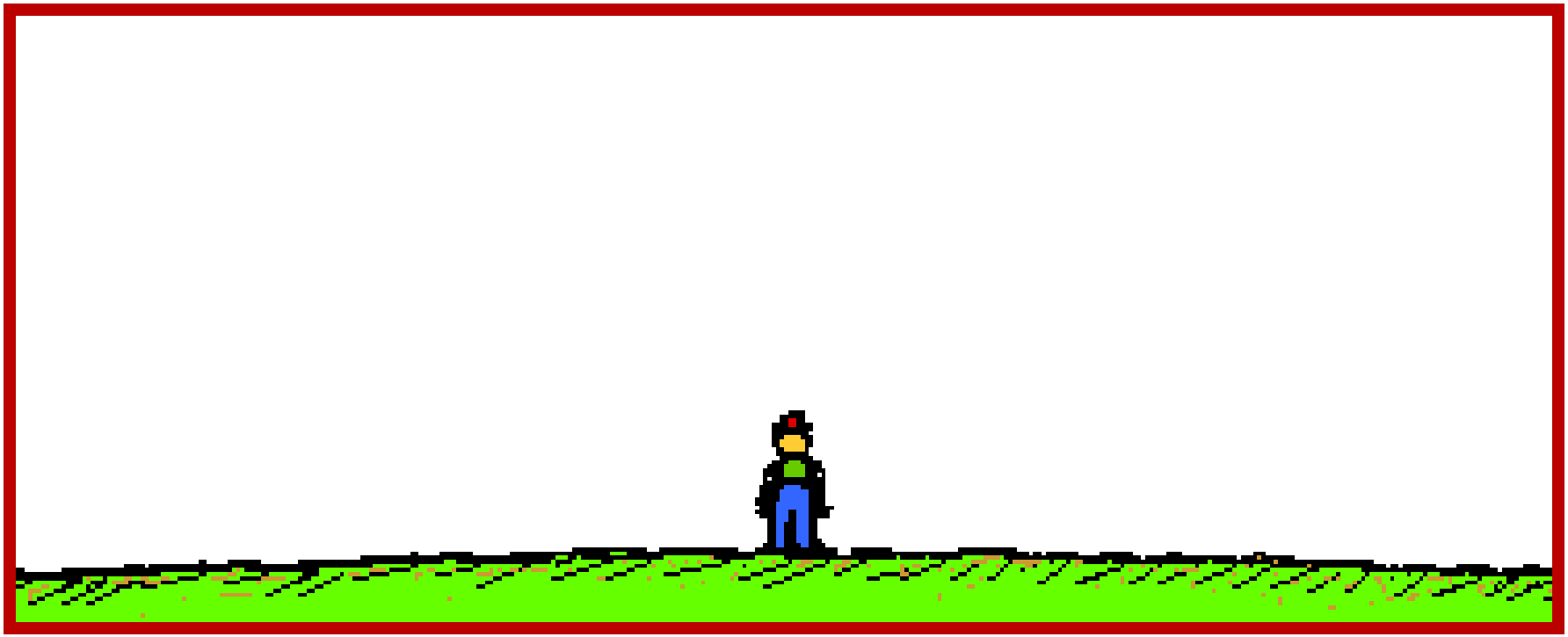
$$t = \gamma (t - v \cdot x / c^2)$$

$$L = L/\gamma$$

$$\delta t = \delta t\, \gamma$$

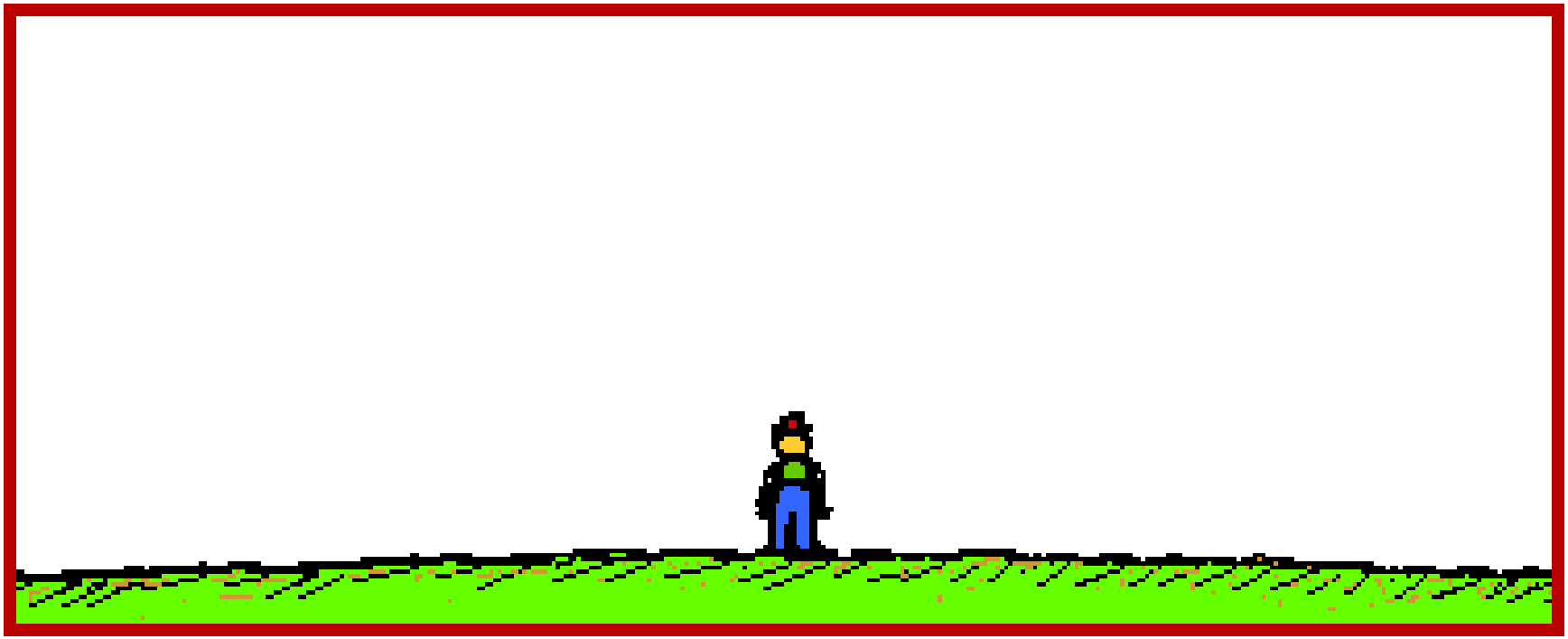
Length contraction

- 10% speed of light



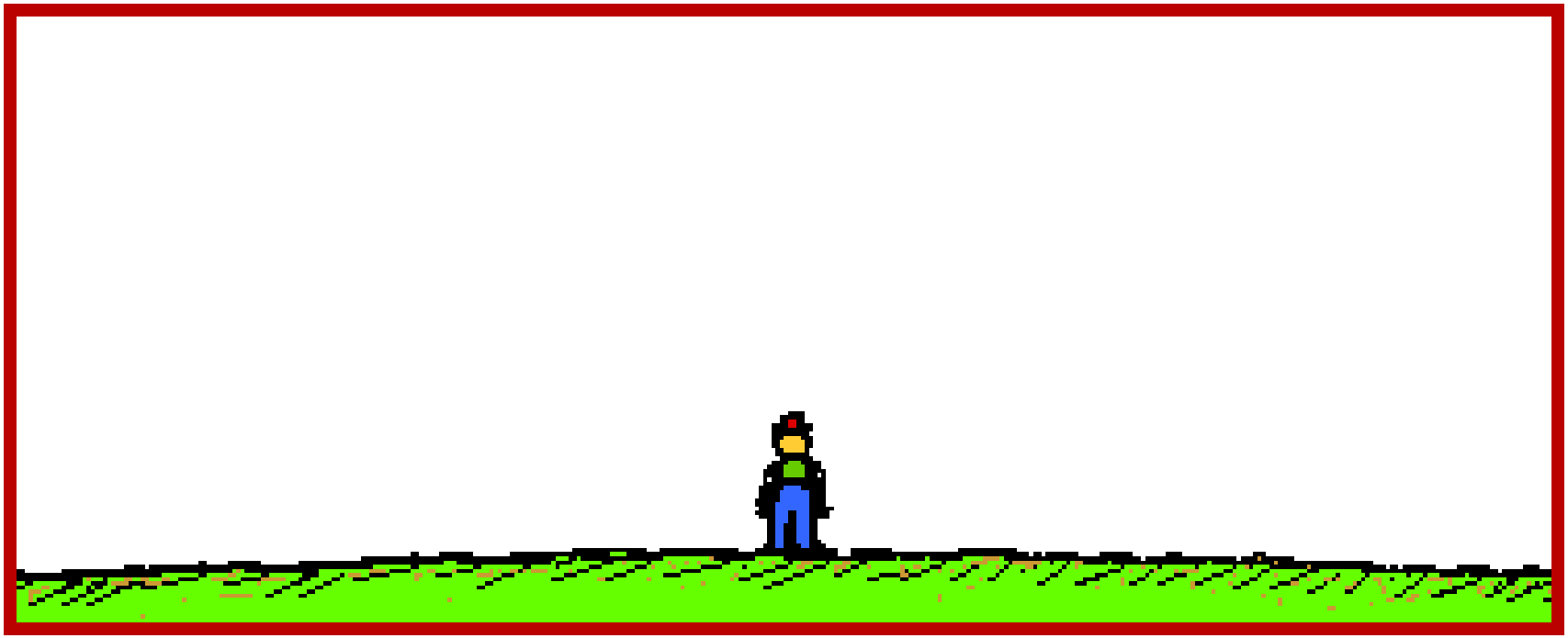
Length contraction

- 86% c



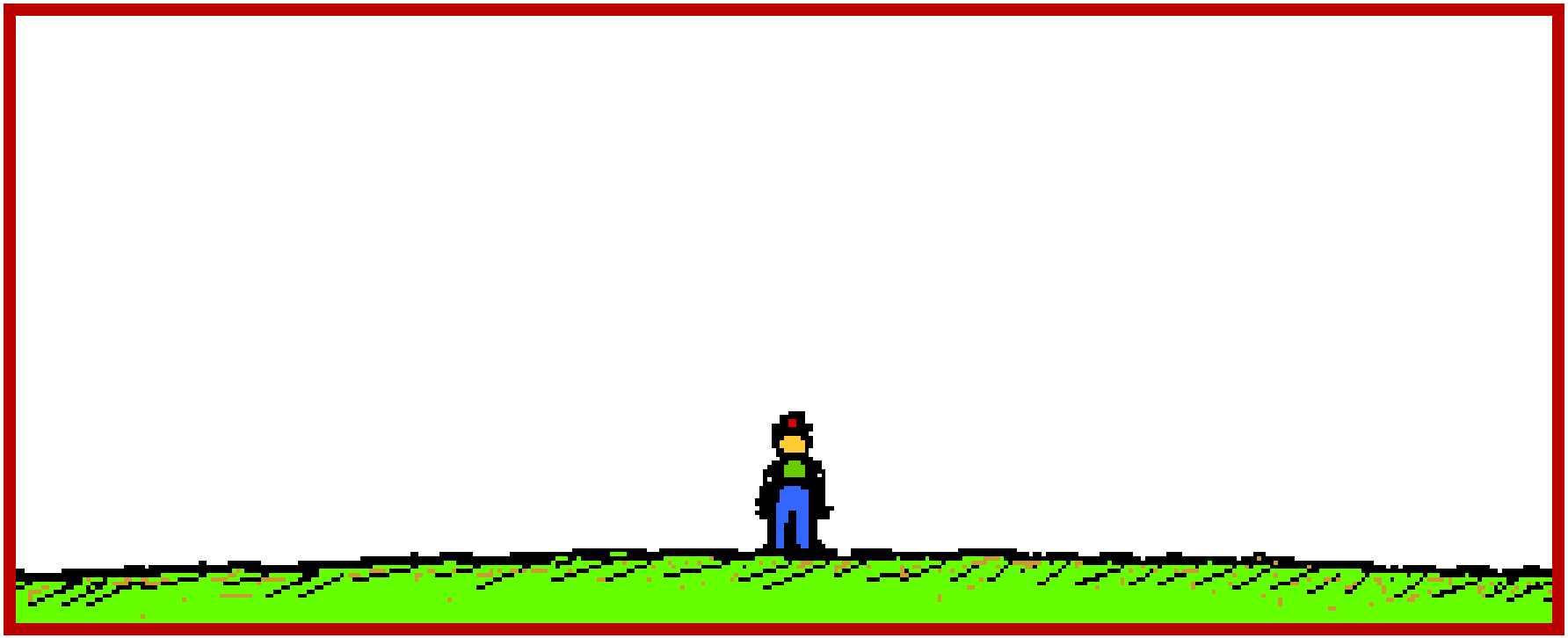
Length contraction

- 99% c



Length contraction

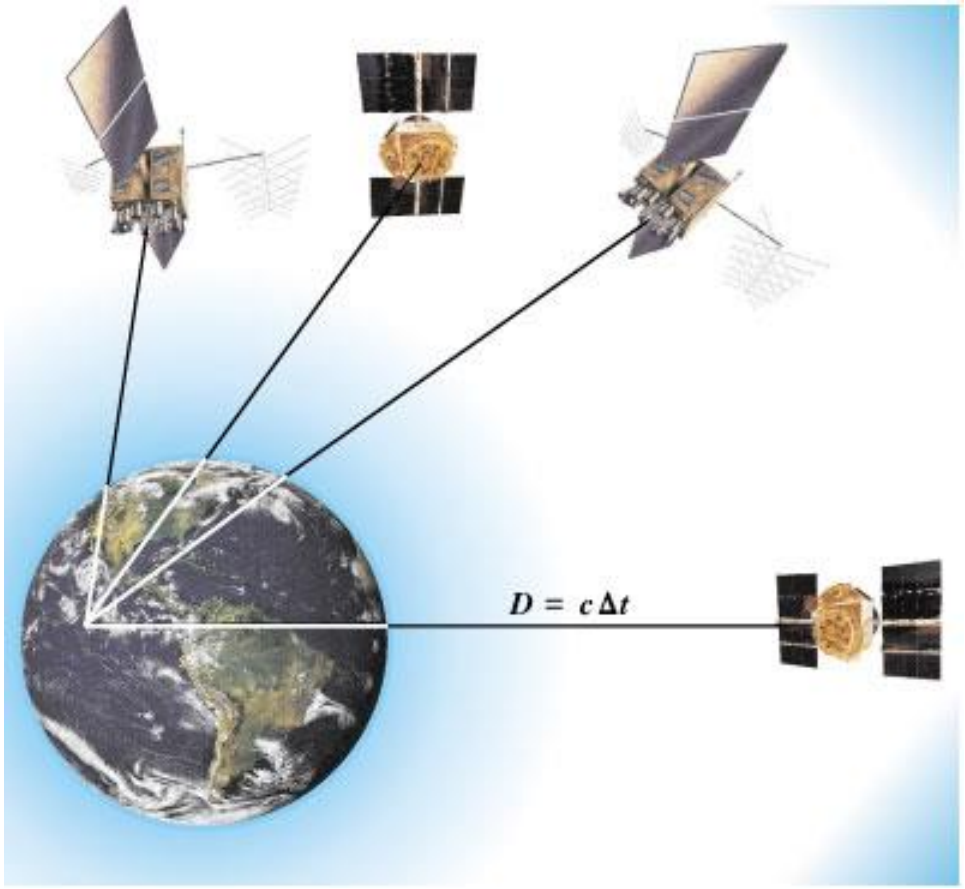
- 99.99% c



Relativity is NOT an exotic theory

IT REALLY WORKS!!!

The Global Position System (GPS)



GPS

Satelites are moving !!!

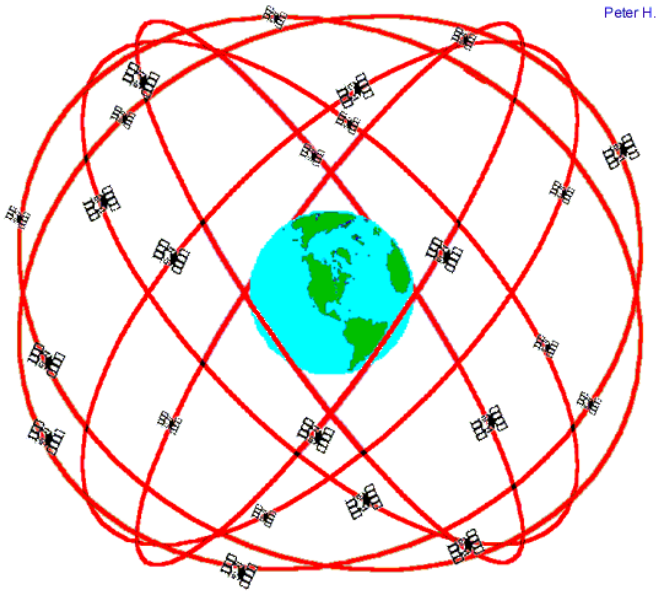
D ~ 20,200 km → $v^2/(D+R_e) = G\ M_e/(D+R_e)$

→ v = 3.87 Km/s

→ $\Delta t - \Delta\ t_0 = (1 - \gamma)\ \Delta t \sim 5\ 10^{-12}$ s

→ Needs relativity

The Global Position System (GPS)



GPS Nominal Constellation
24 Satellites in 6 Orbital Planes
4 Satellites in each Plane
20,200 km Altitudes, 55 Degree Inclination

$v = 3.87$ Km/s

$t_{01} - t_{01}' = (1 - \gamma)\, t_{01}$

1 orbit ~ 12 hours

➔ $t_{01} - t_{01}' \sim 6\ 10^{-8}$ s

➔ $\Delta D \sim 18$ m

And general relativity (gravity)

$\Delta D \sim 100$ m

Particle accelerators

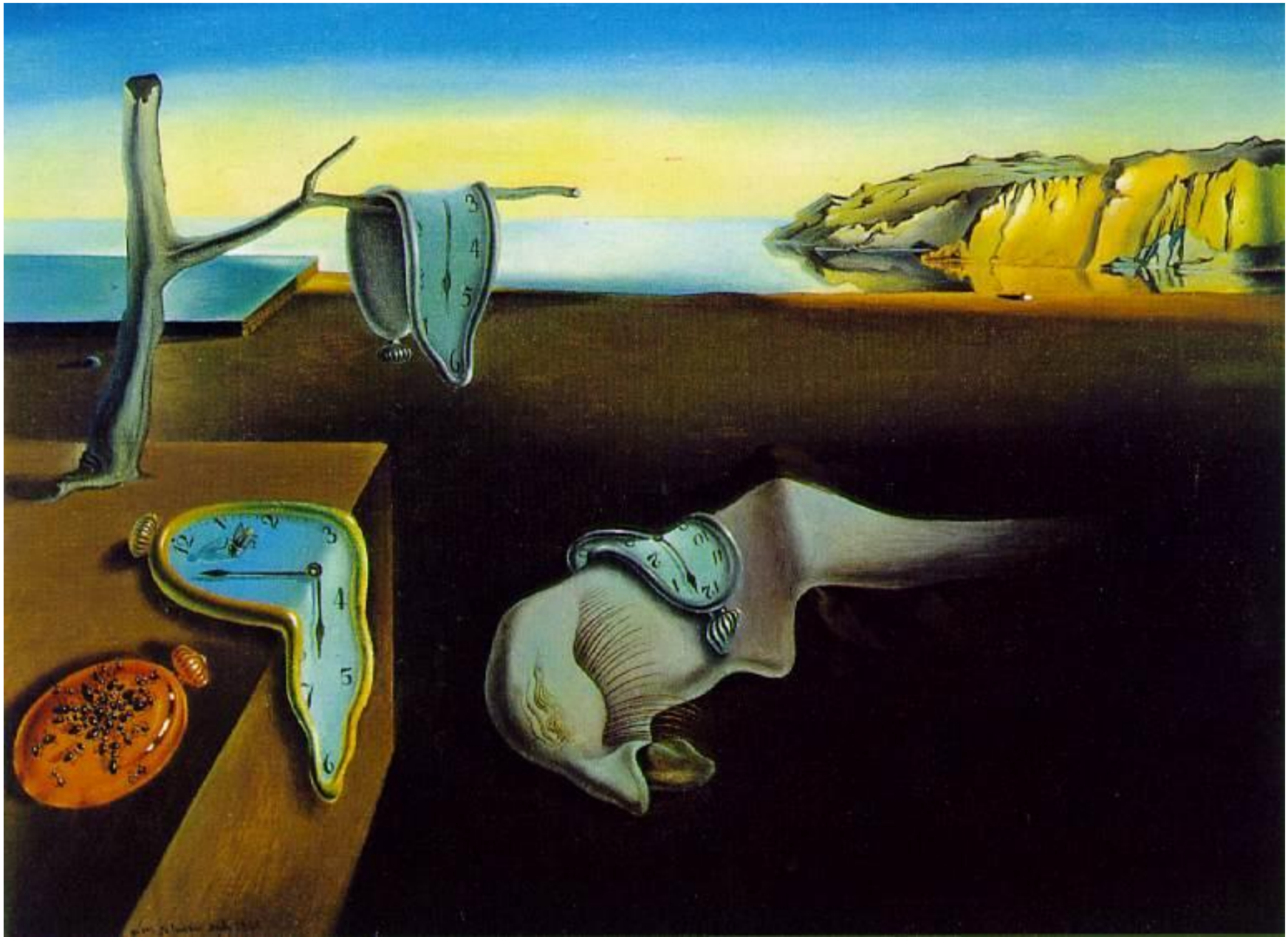
$v > 0.99\ c$


BACK
TO THE FUTURE

Les Demoiselles d'Avignon: Picasso's 1907 exc a fou

Girl in a chair
Picasso's 1907
indagine nella
quarta dimensione

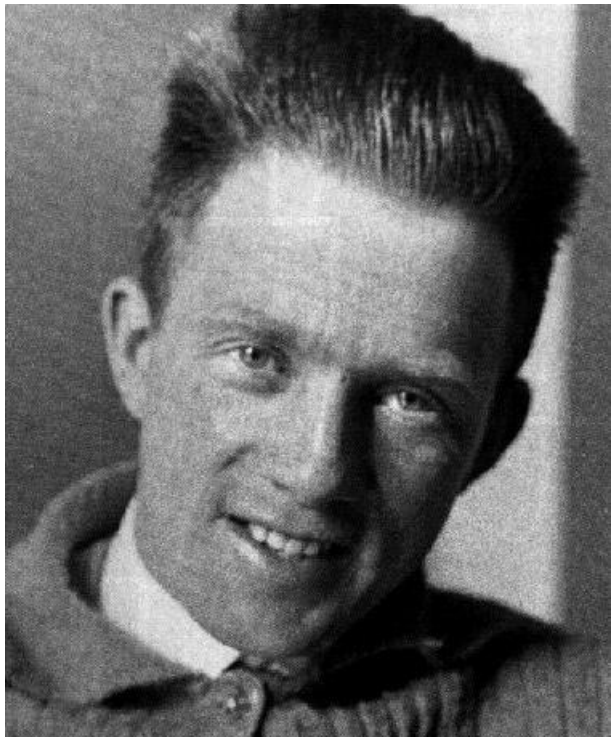
The Persistence of memory, Salvador Dali, 1931



Quantum Mechanics

For very small objects

(as particles, atoms, molecules…)

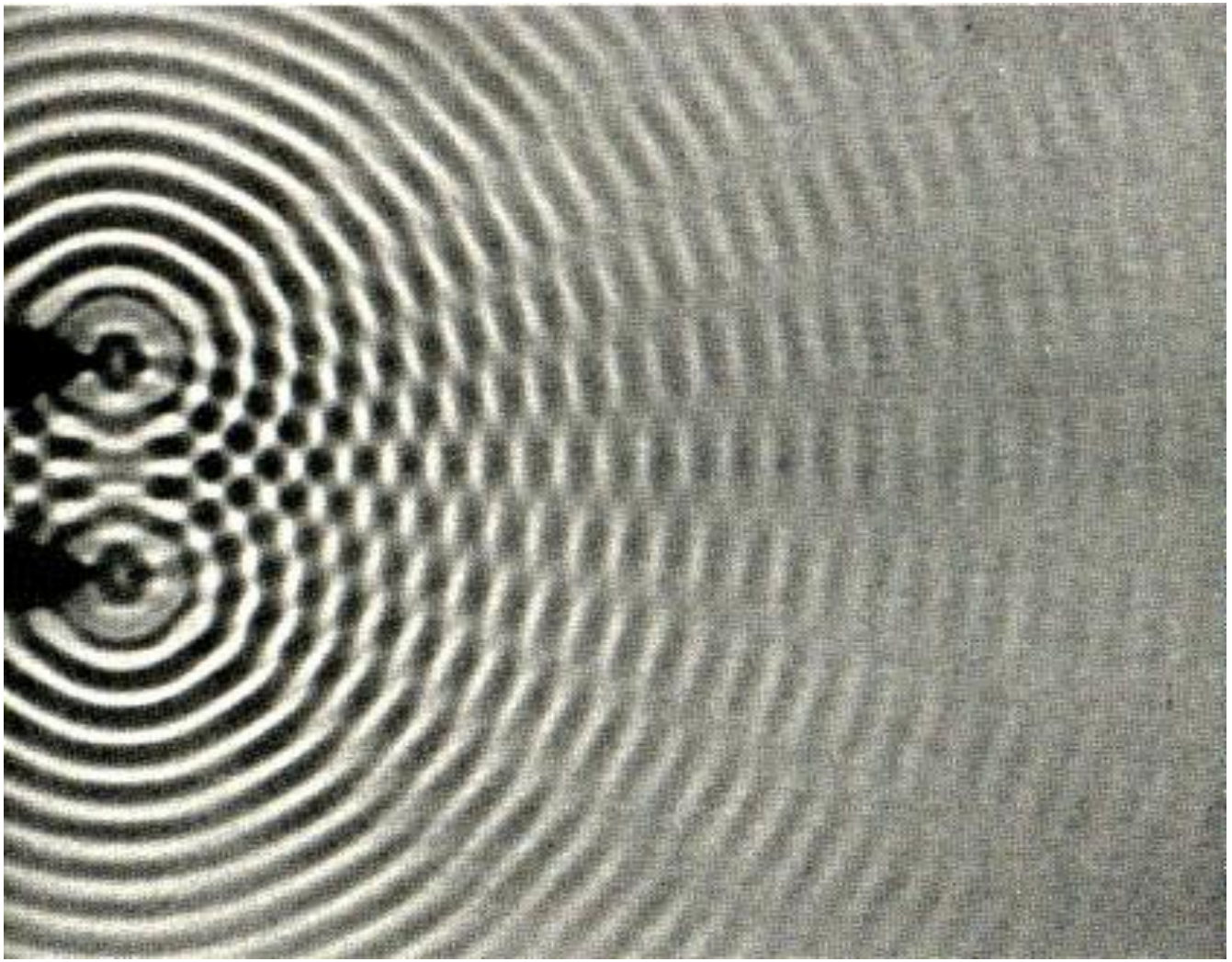


Heisenberg in 1925, 24 years old

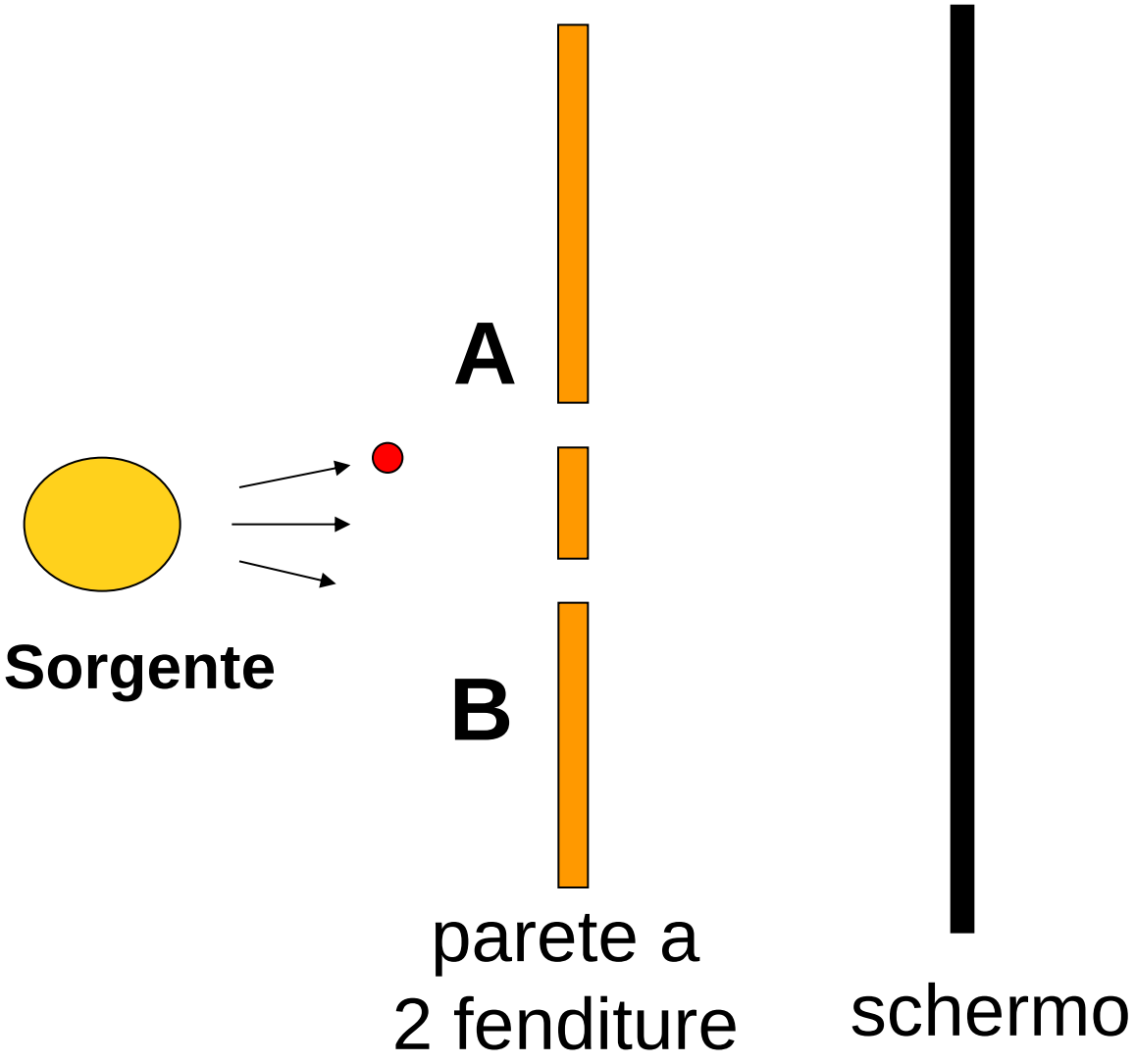
Conferenza di Solvay (1927)

Interference

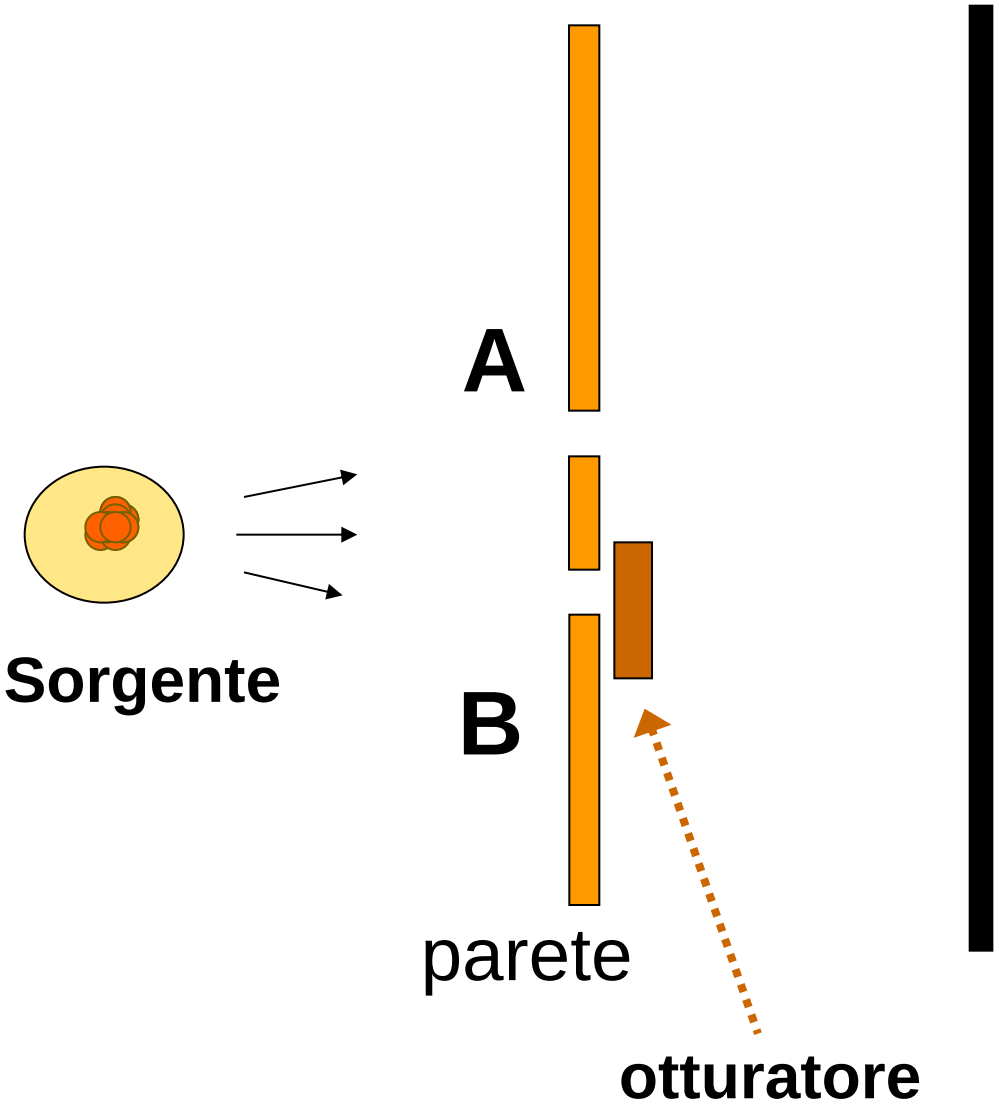
"…the heart of quantum mechanics. In reality it contains the only mystery …" R.P.Feynman (1965)



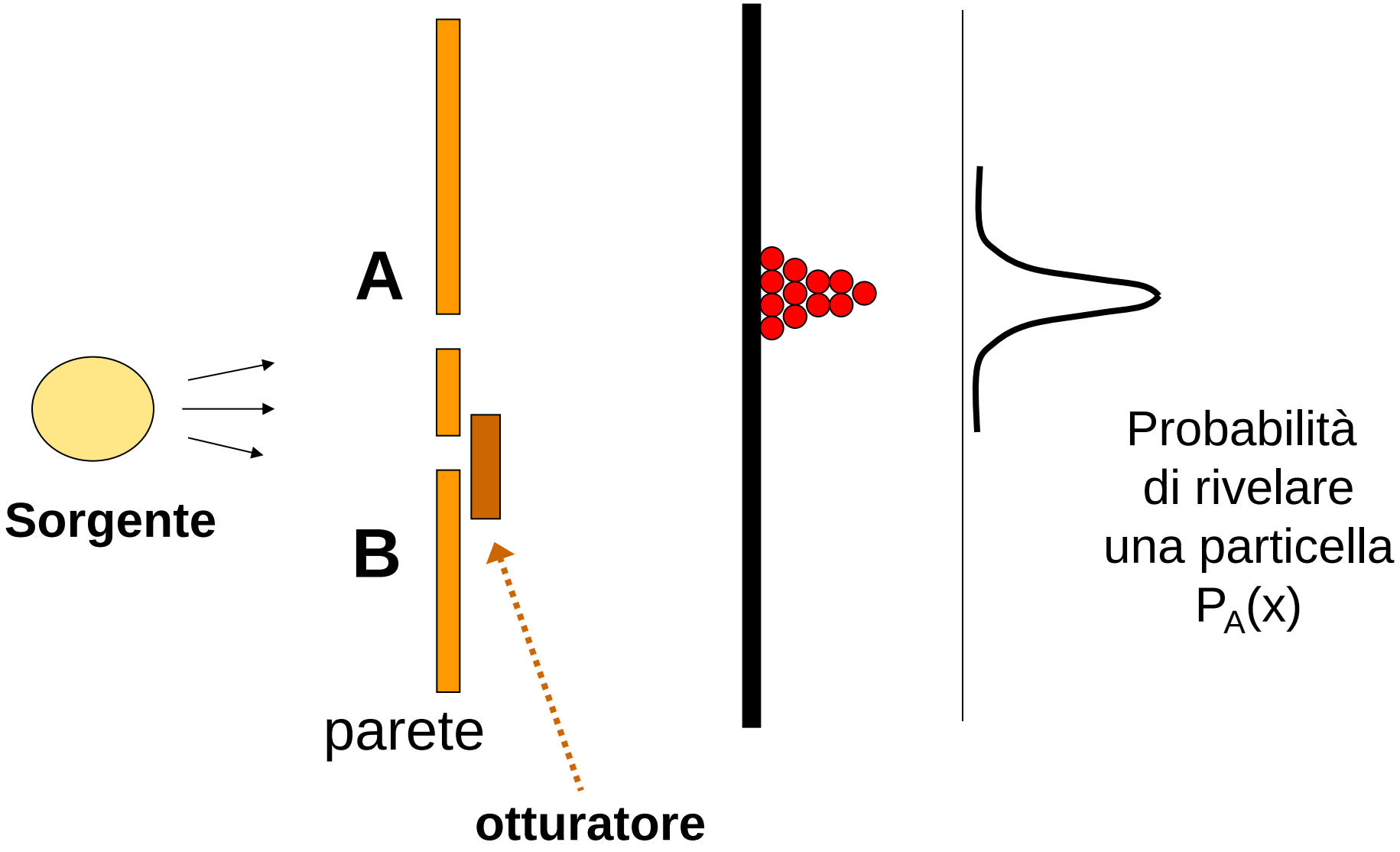
Single particle interference



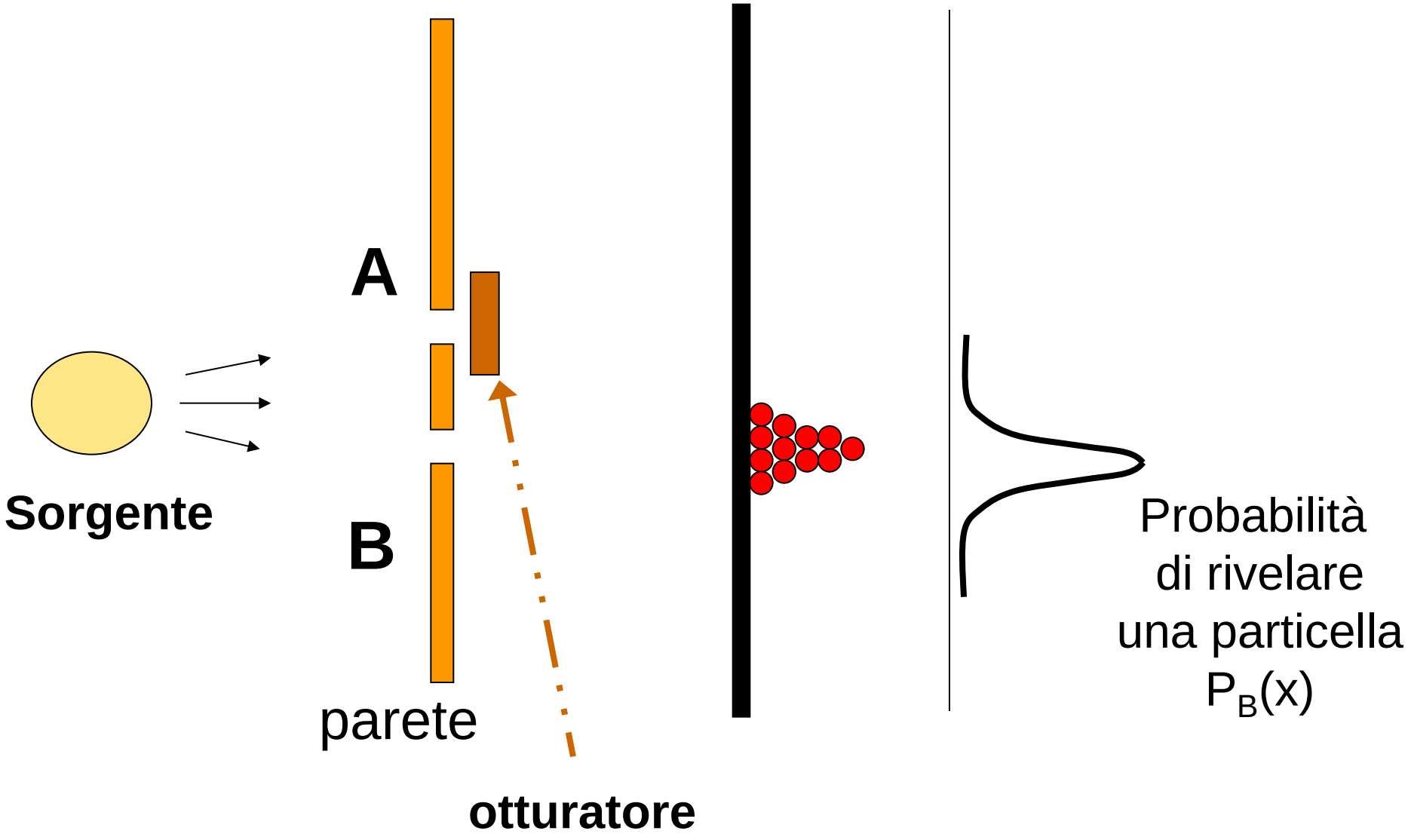
Single particle interference



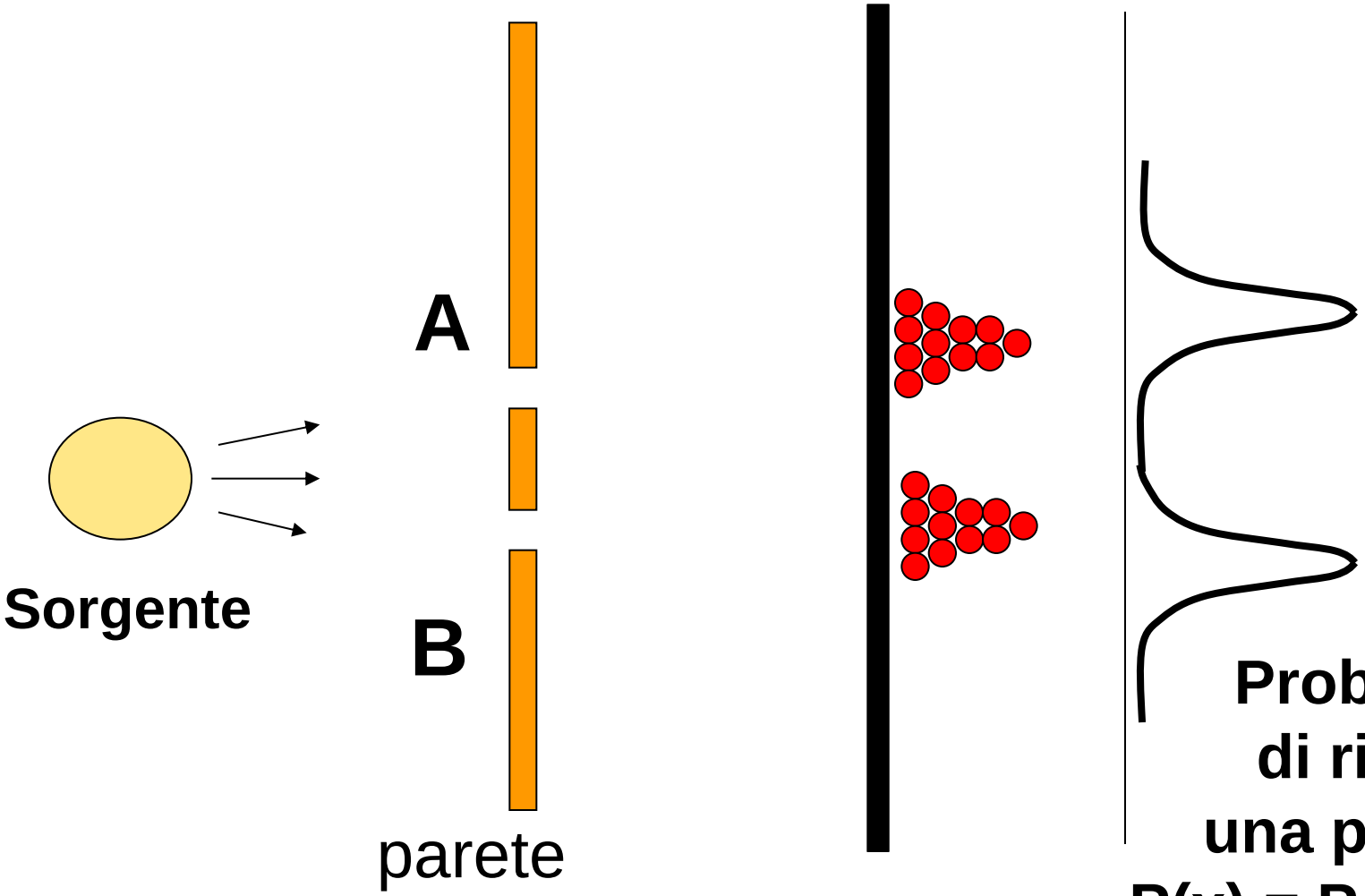
Single particle interference



Single particle interference

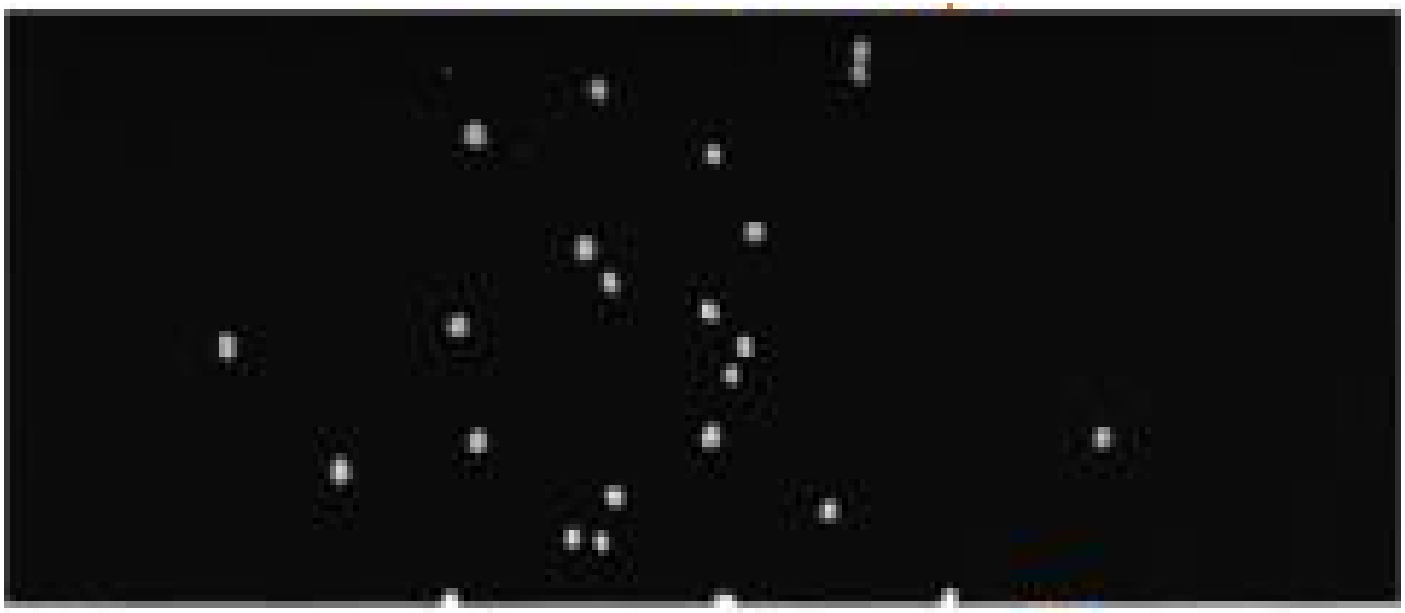


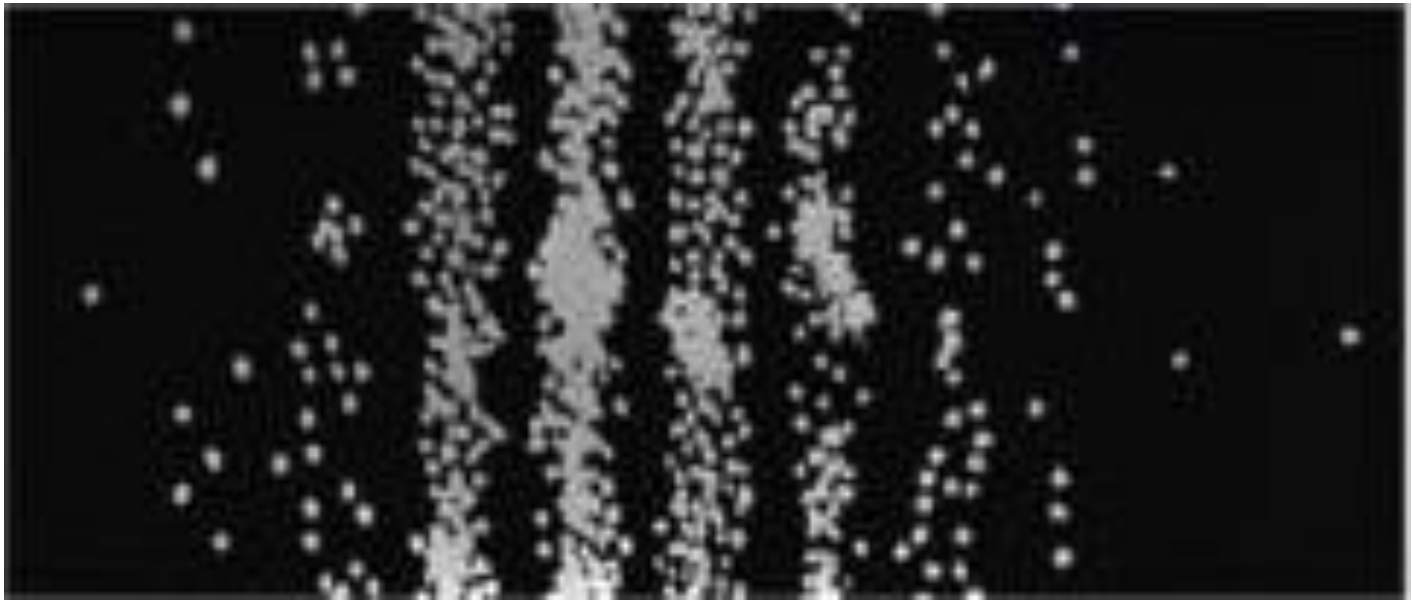
What happens when both “doors” are opened?

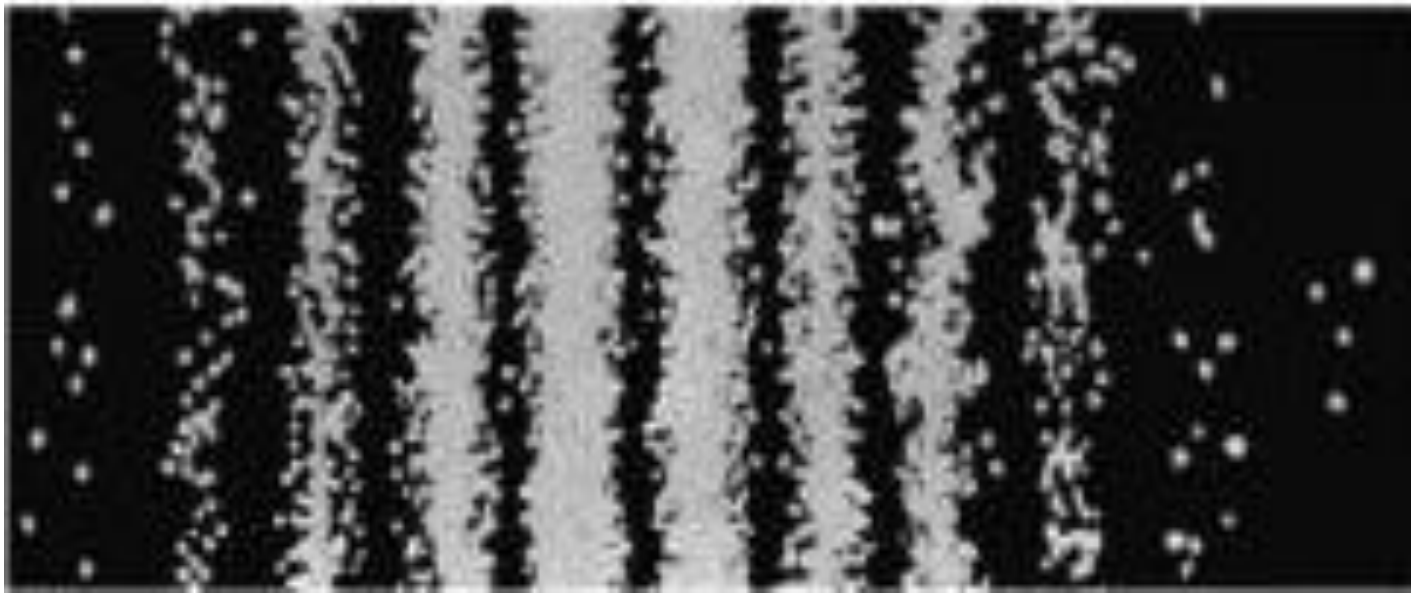


Probabilità di rivelare una particella

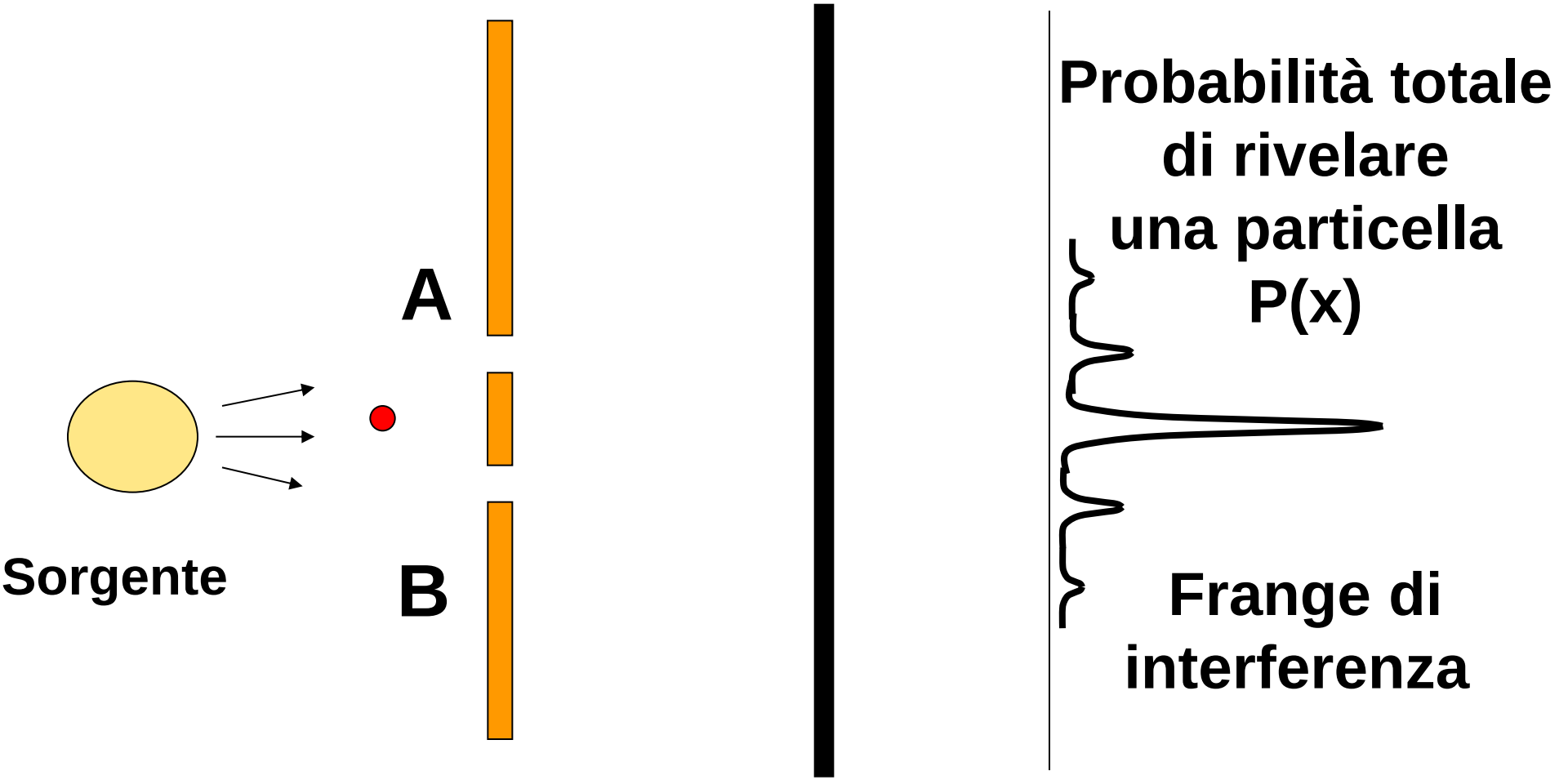
$$P(x) = P_A(x) + P_B(x)$$



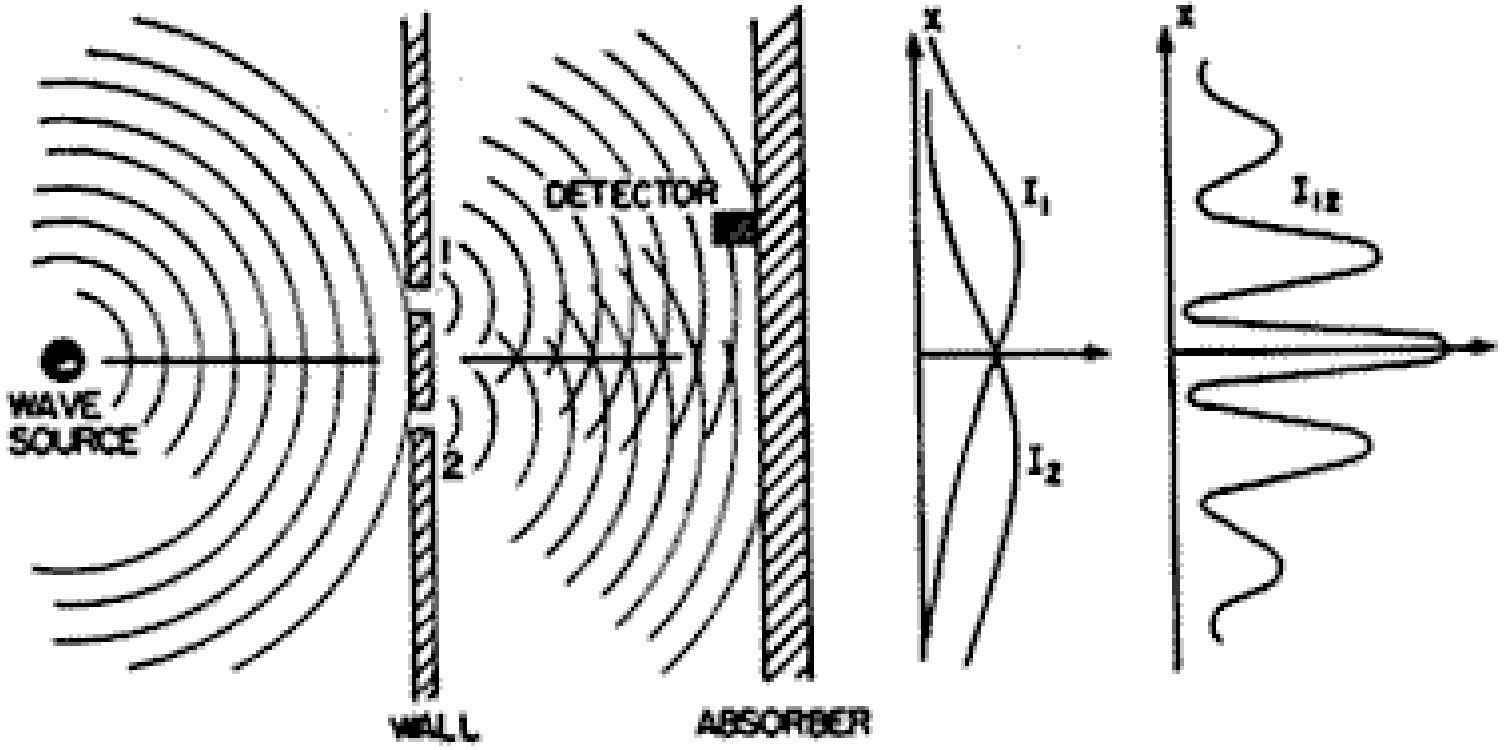


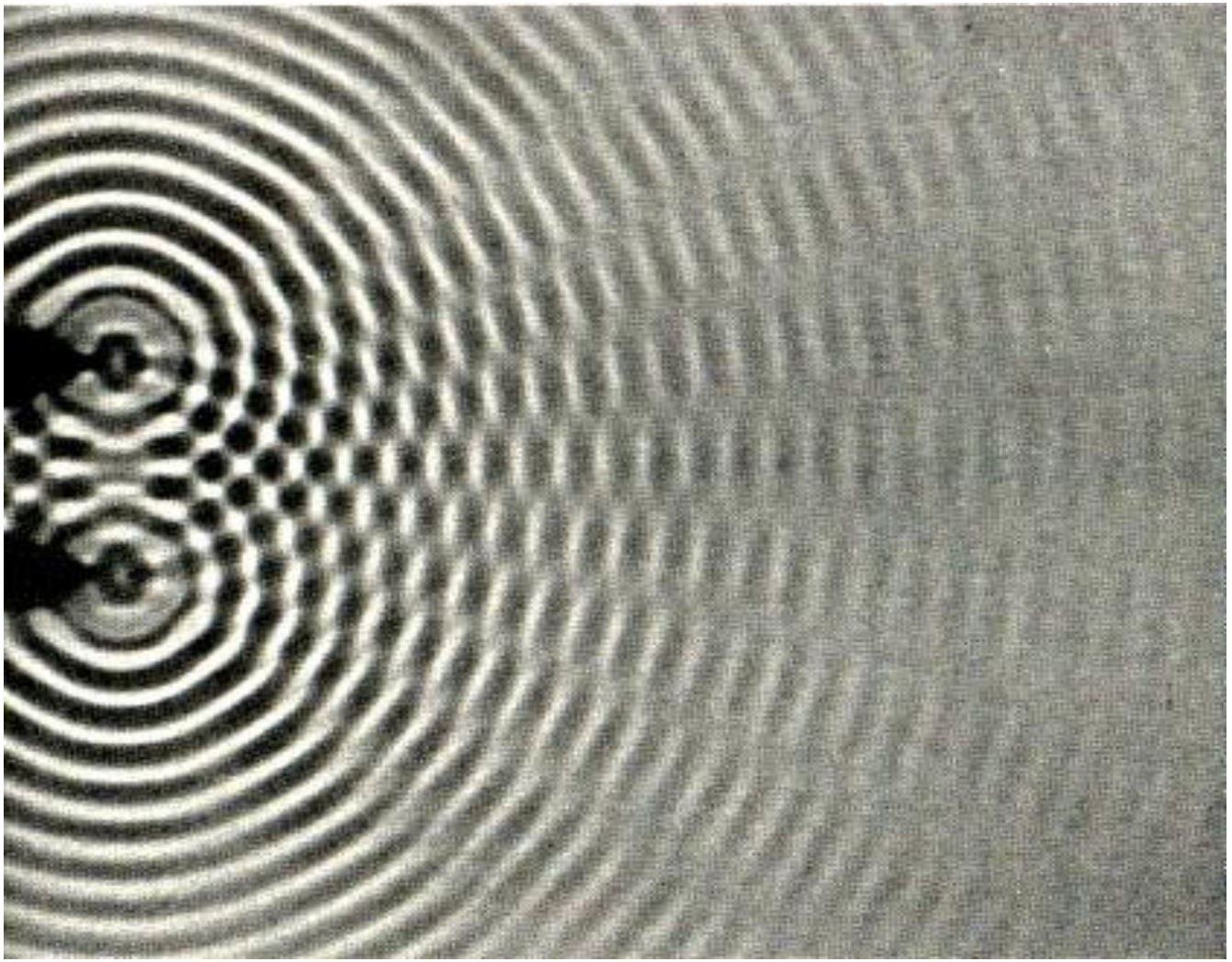


Quantum interference



The particle passes from BOTH doors!!


WAVE SOURCE
1
2
WALL
DETECTOR
ABSORBER
x
I_1
I_2
x
I_{12}



Schrodinger cat

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- qu ere i
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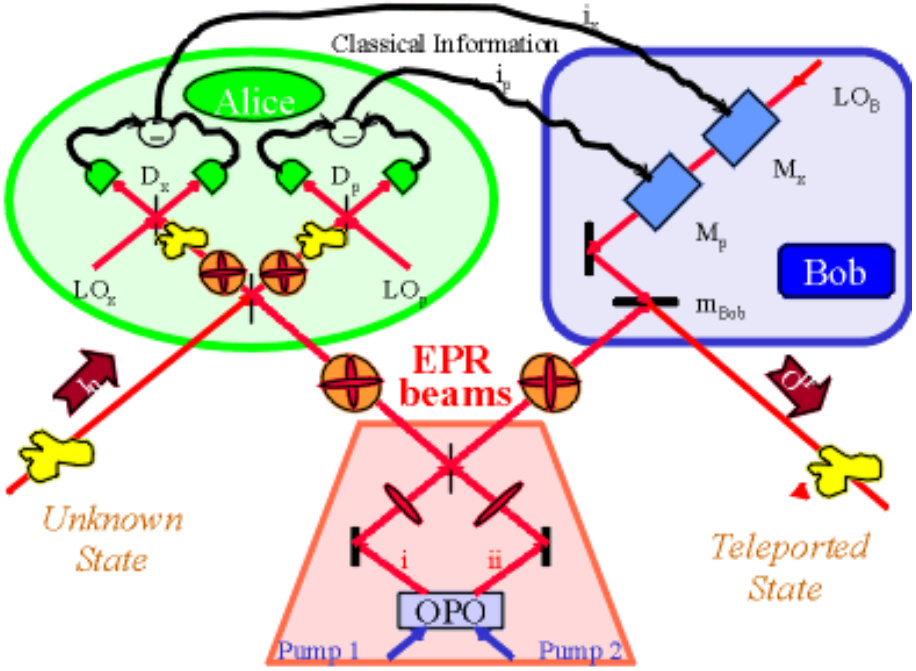
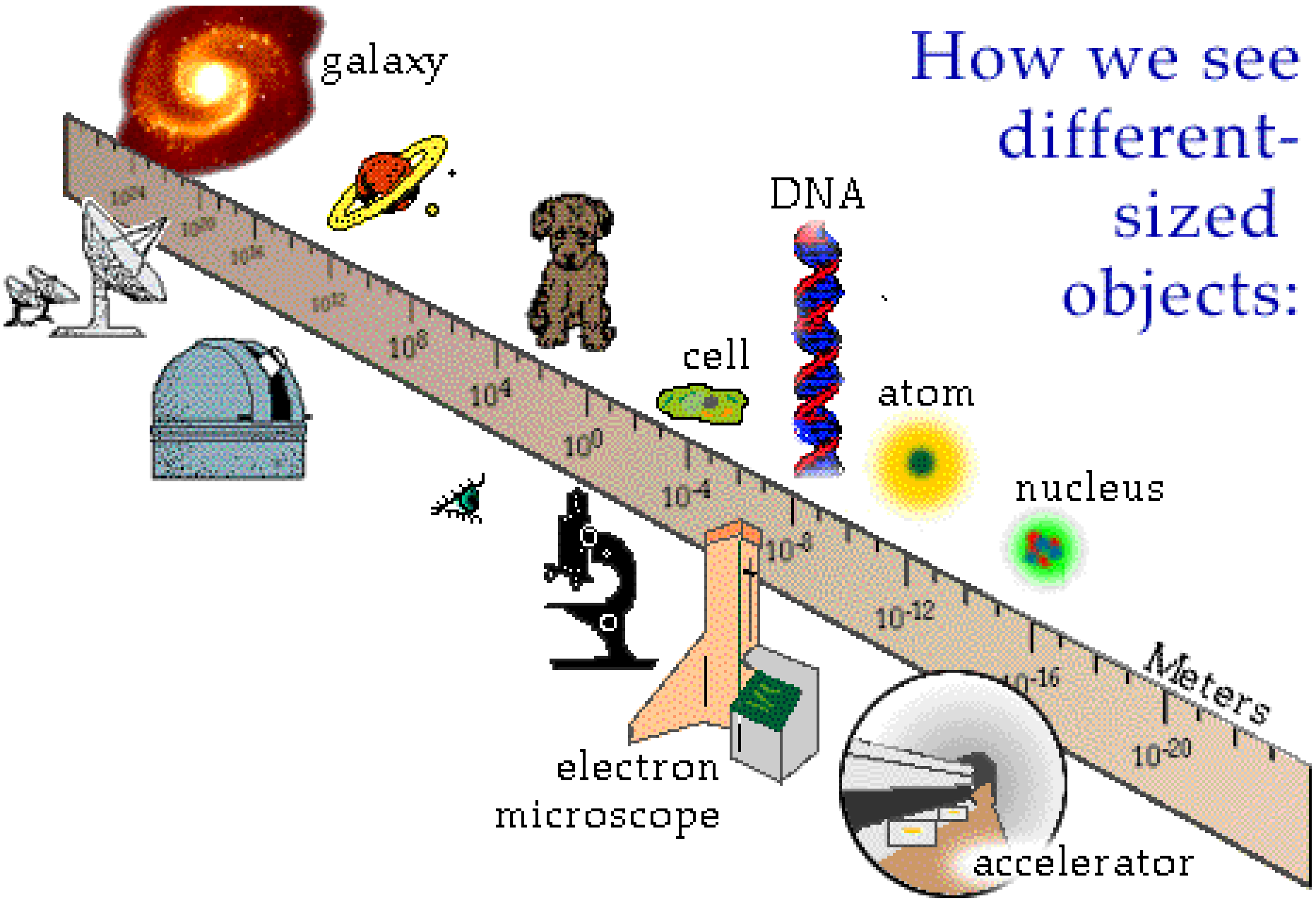
Schrodinger cat – a paradox?

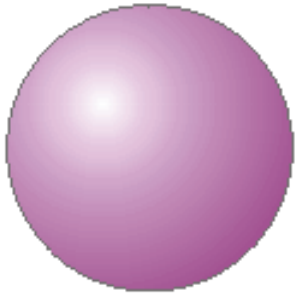
Teleportation: Phantasy or reality?



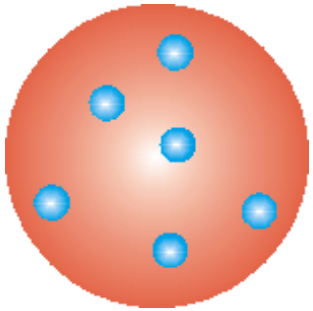
How we see different-sized objects:

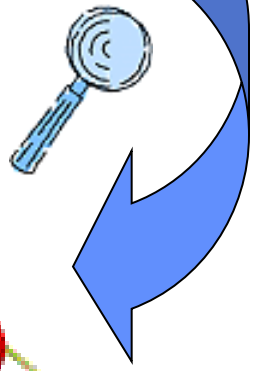


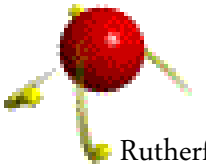
The atom in the beginning of '900



The Thompson's atom

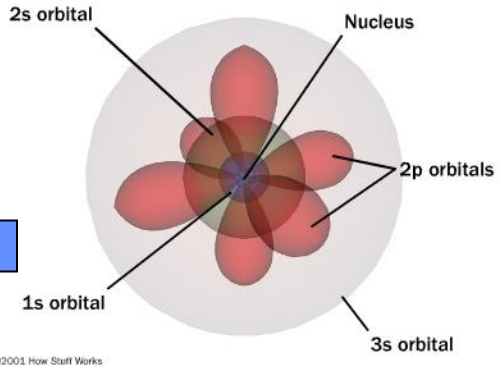


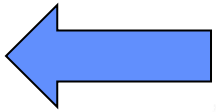


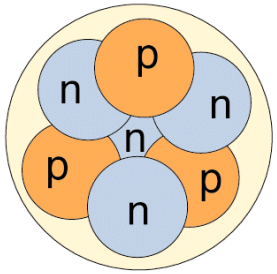


Rutherford e Bohr - atom

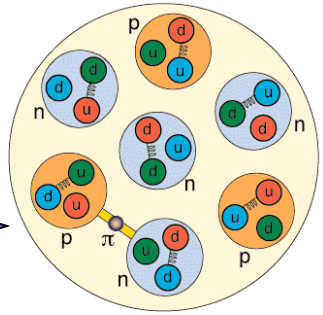
Quantum mechanics - atom





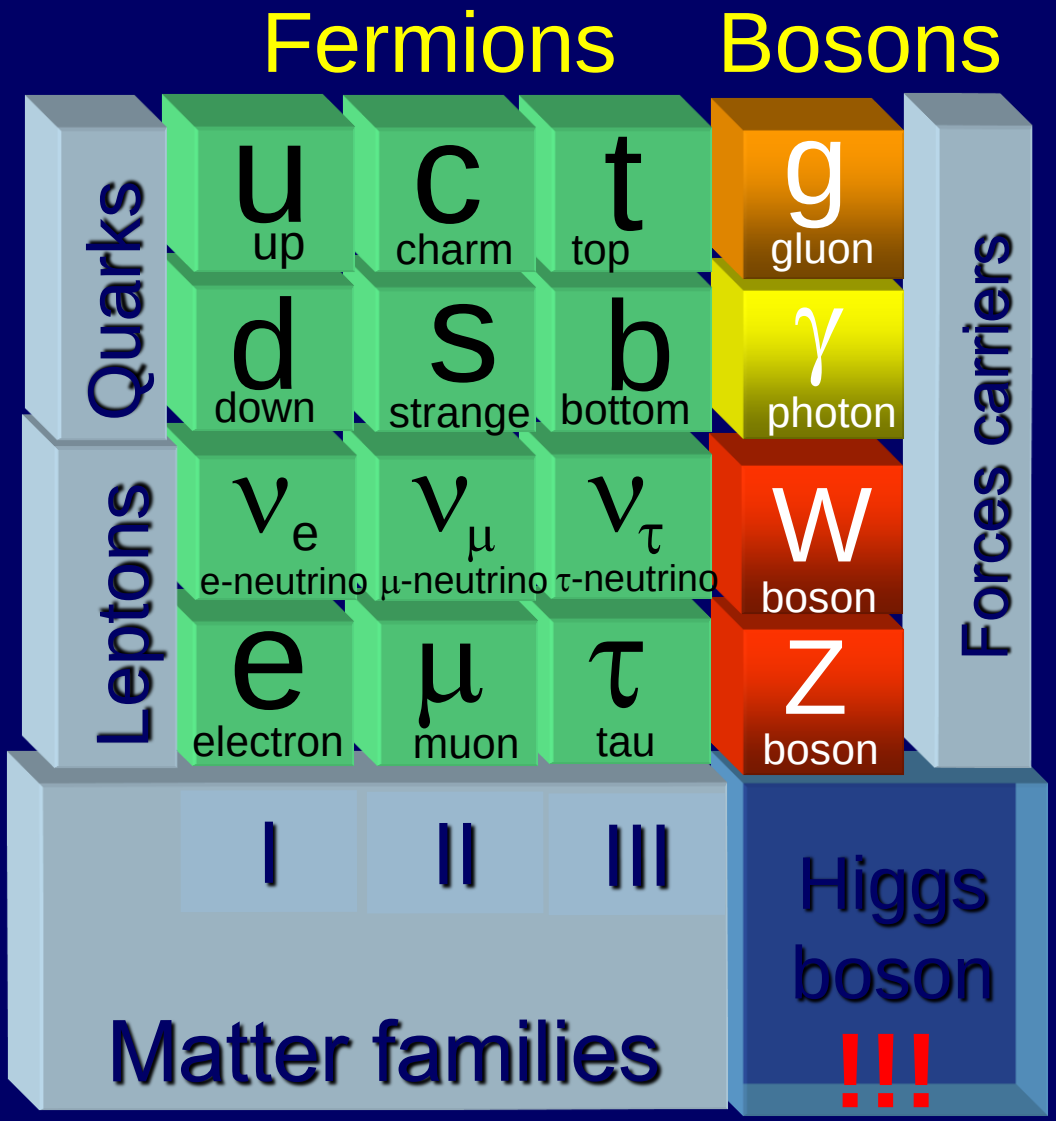


The nucleus structure



The nucleus today

The Standard Model

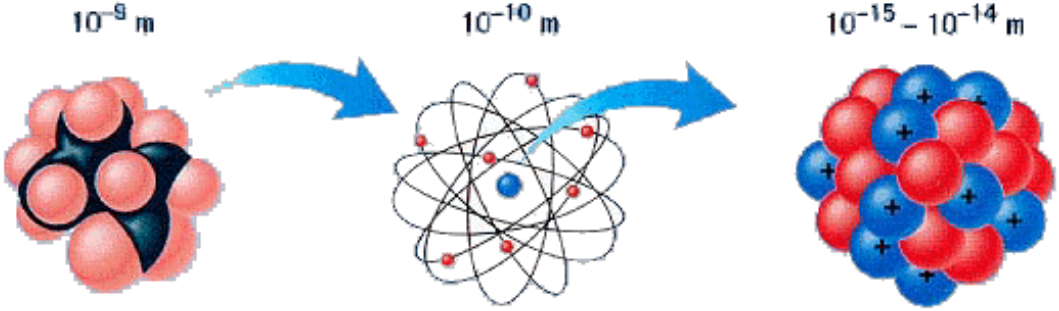


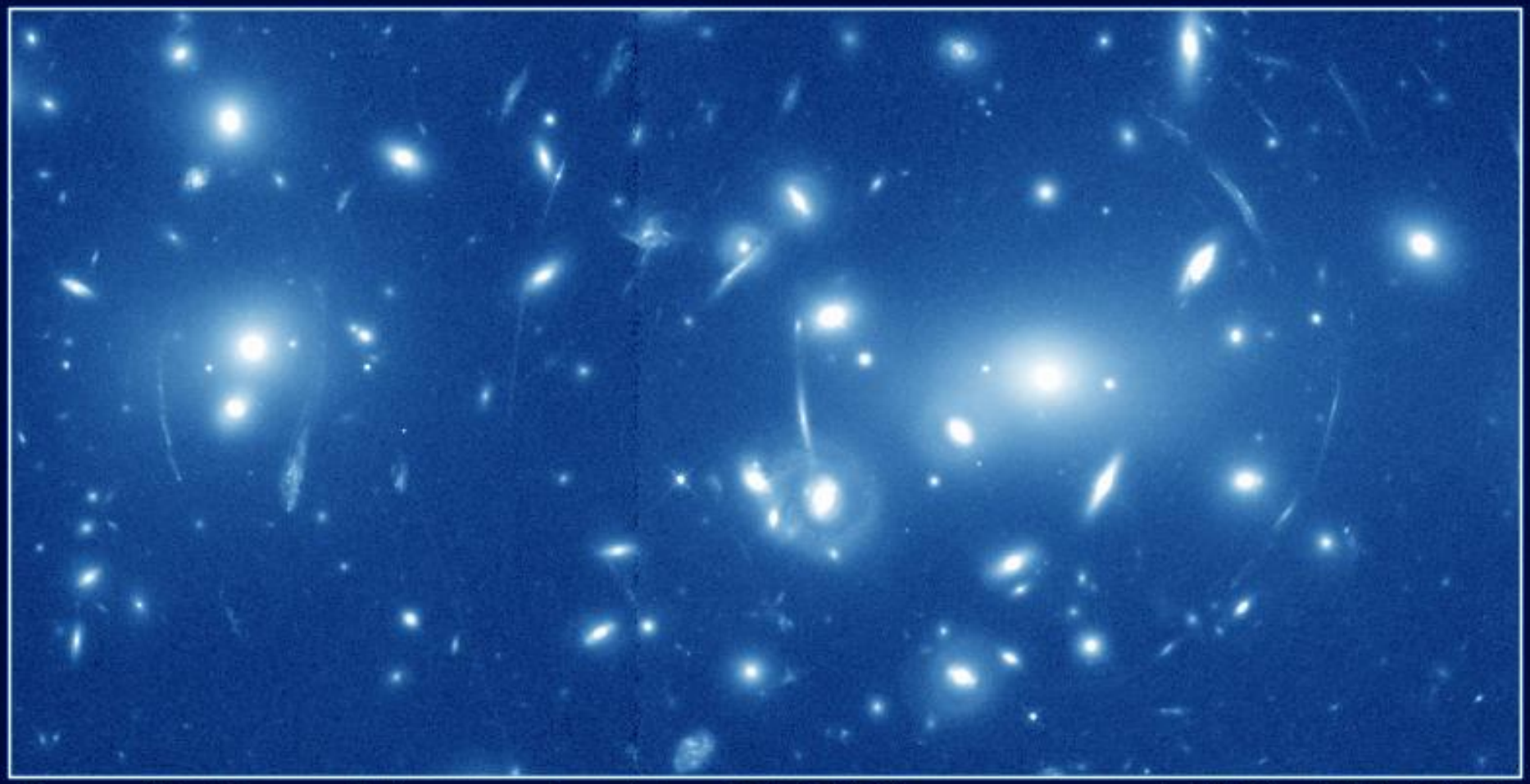
Gravitation

The “Opera ghost”

The fundamental forces

Force	Intensity	Effect
Gravitation	1	*Keeps you on the chair*
Weak	10^{29}	*Weak decays:* $n \rightarrow p + e^- + \nu$
Electromagnetic	10^{40}	*Hold atoms as a whole*
Strong	10^{43}	*Hold nuclei as a whole*





Gravitational Lens in Abell 2218 HST • WFPC2

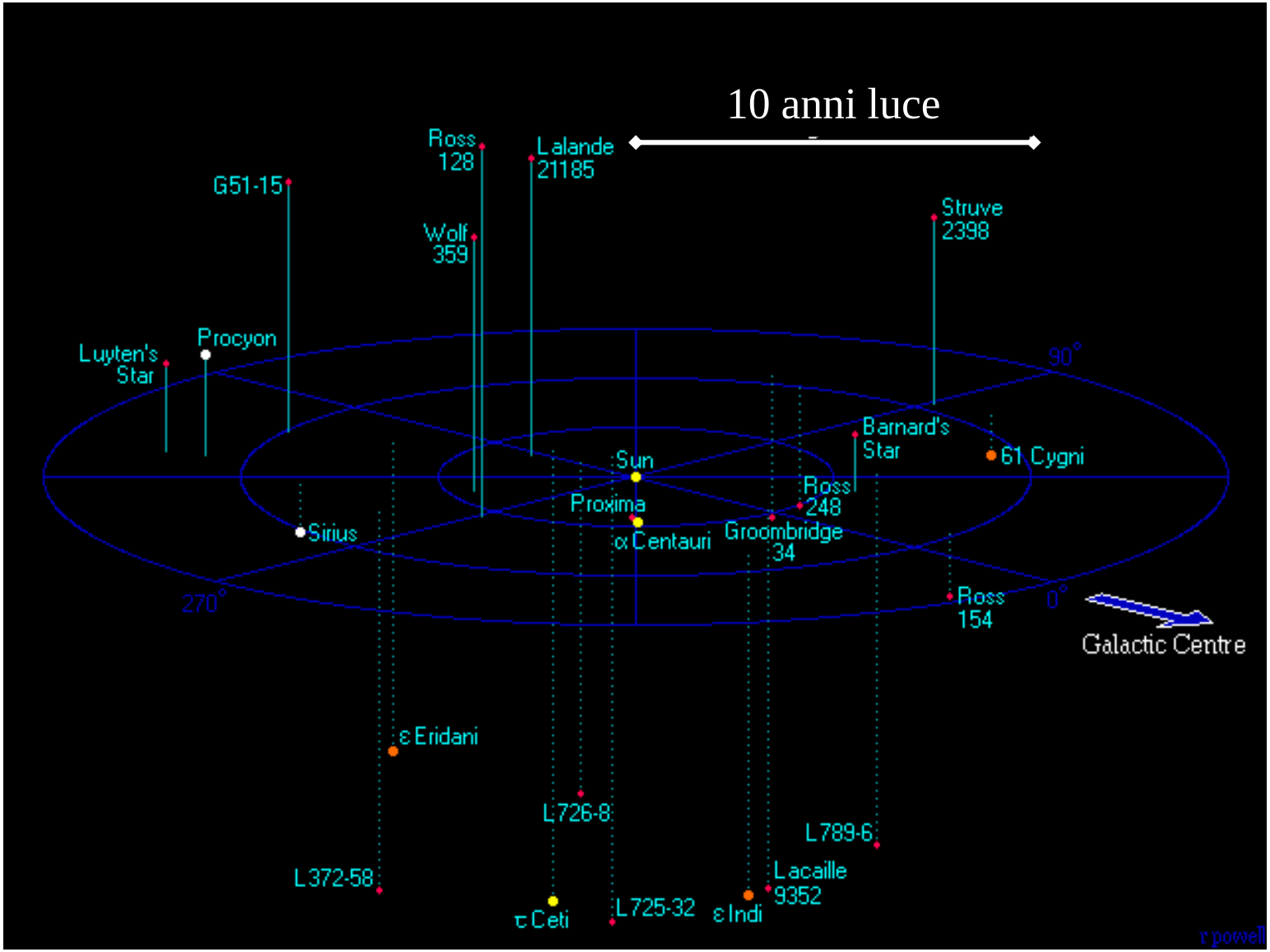
PF95-14 · ST ScI OPO · April 5, 1995 · W. Couch (UNSW), NASA

Galassie a Spirale

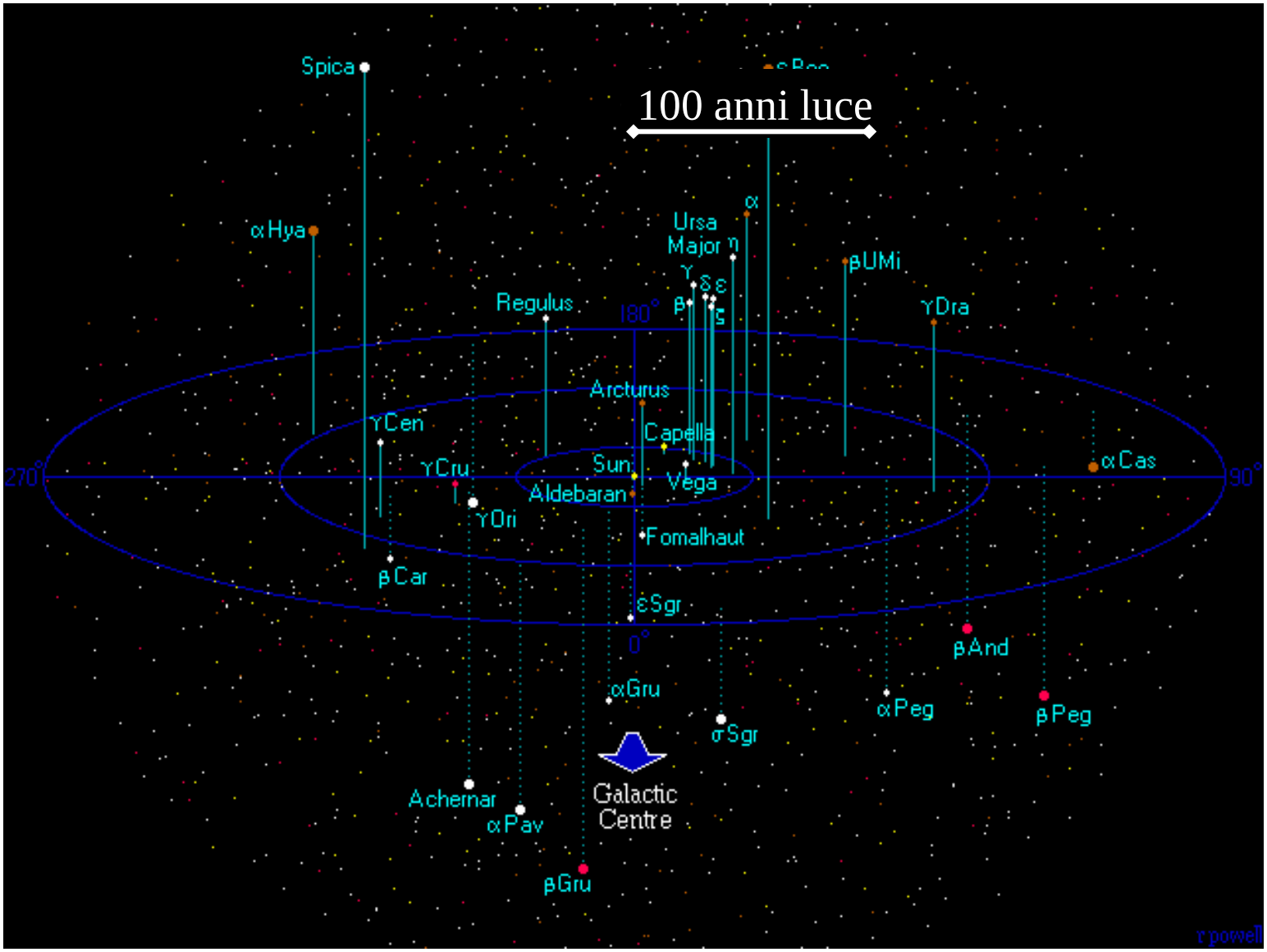
Galassie Ellittiche

Galassie Lenticolari

Galassie Irregolari, come la Nube di Magellano

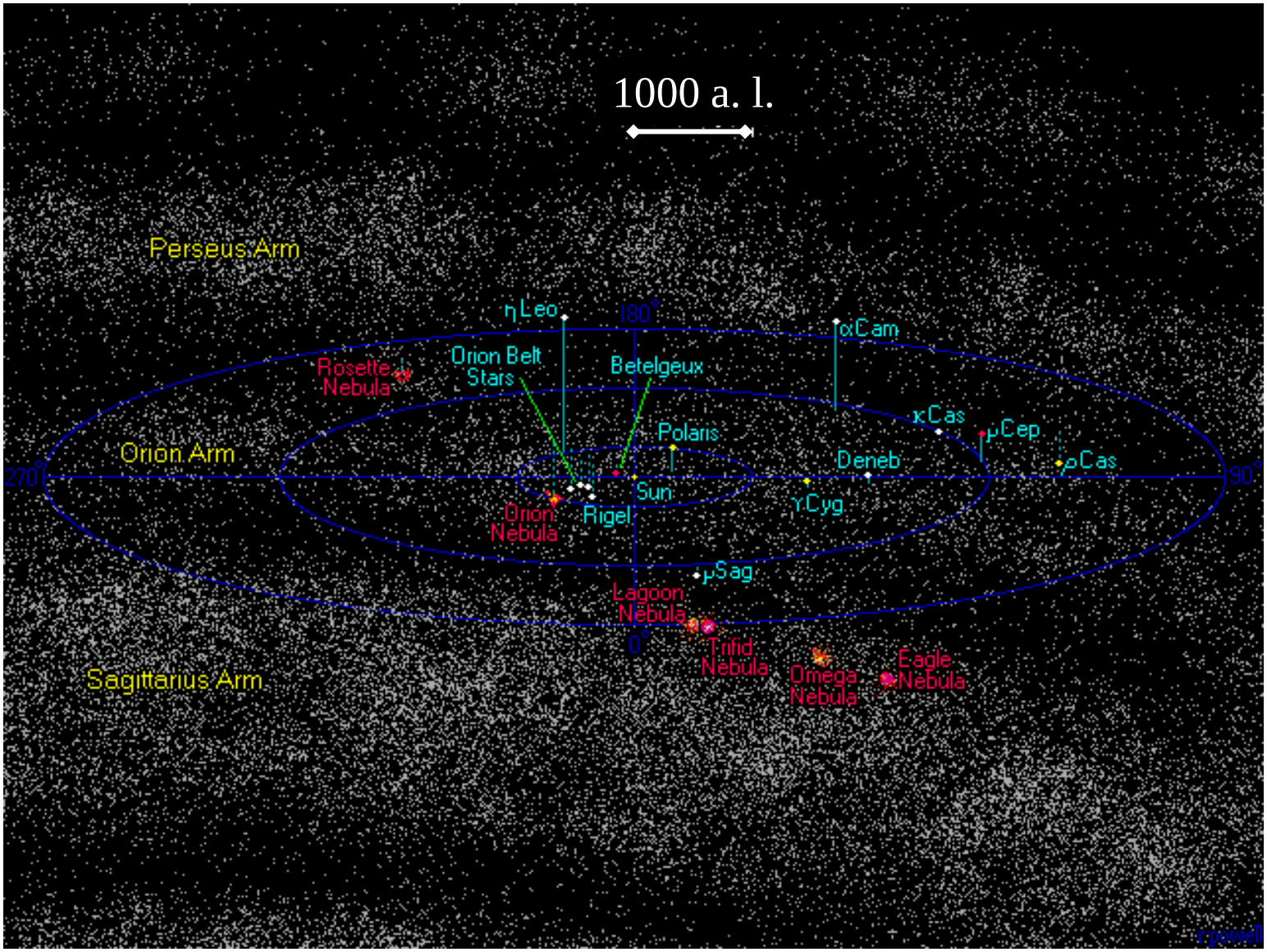

10 anni luce
Ross 128
Lalande 21185
G51-15
Wolf 359
Struve 2398
Luyten's Star
Procyon
90°
Barnard's Star
61 Cygni
Sun
Ross 248
Proxima
α Centauri
Groombridge 34
Sirius
270°
0°
Ross 154
Galactic Centre
ε Eridani
L726-8
L789-6
L372-58
Lacaille 9352
τ Ceti
L725-32
ε Indi
r powell

Zoom Out x20



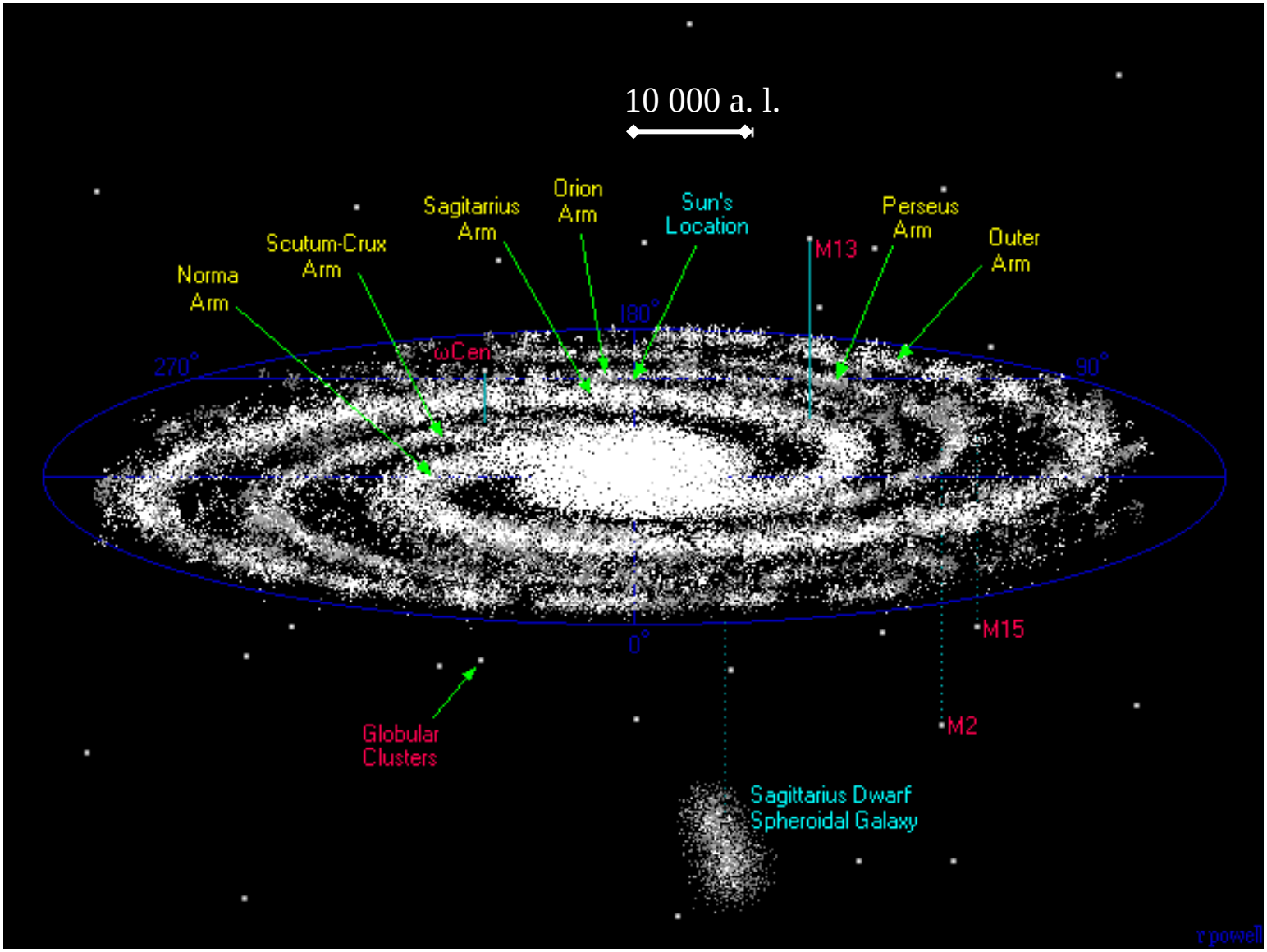
Zoom In x20

Zoom In x20



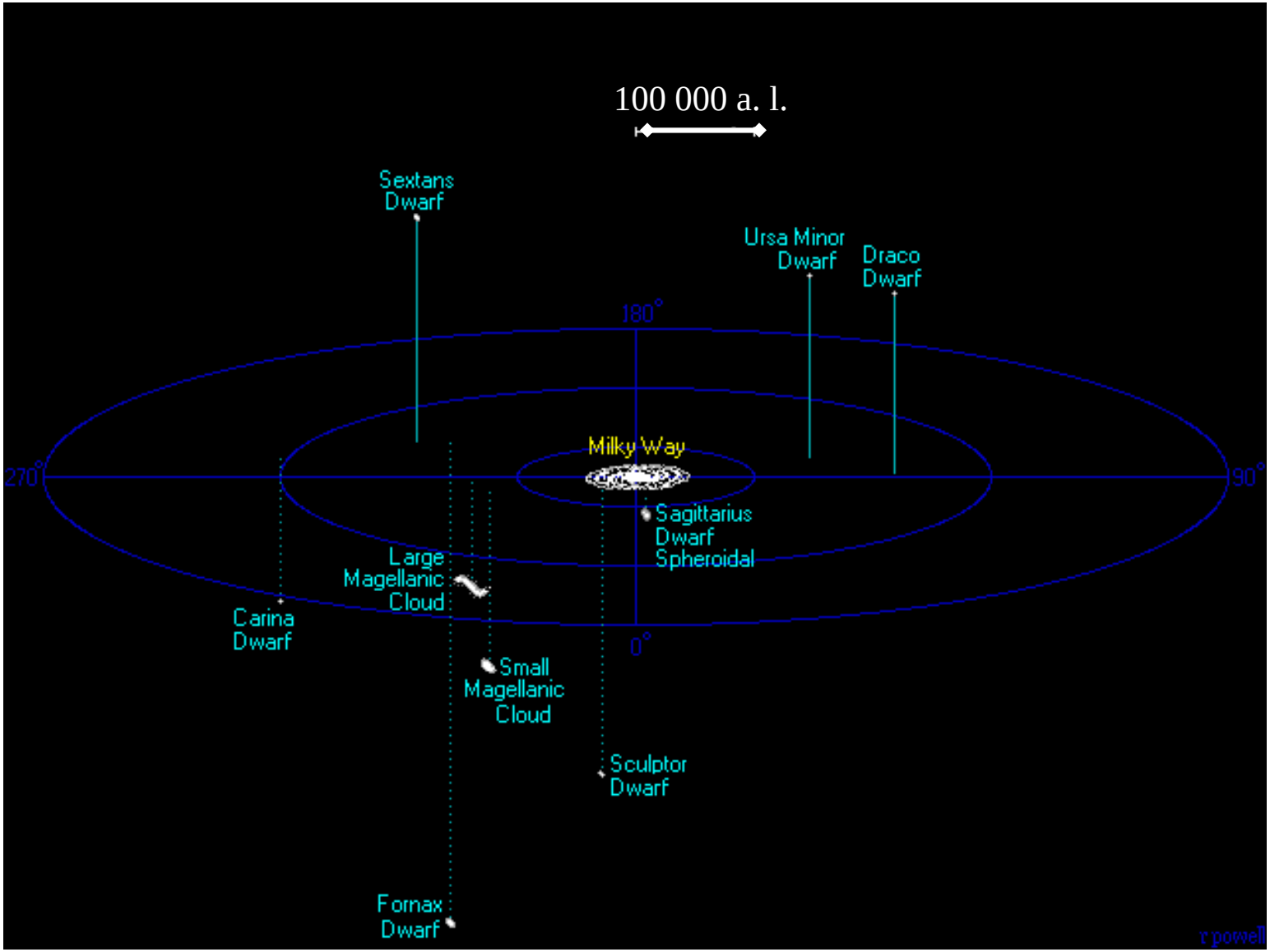
Zoom In x20

Zoom Out x10



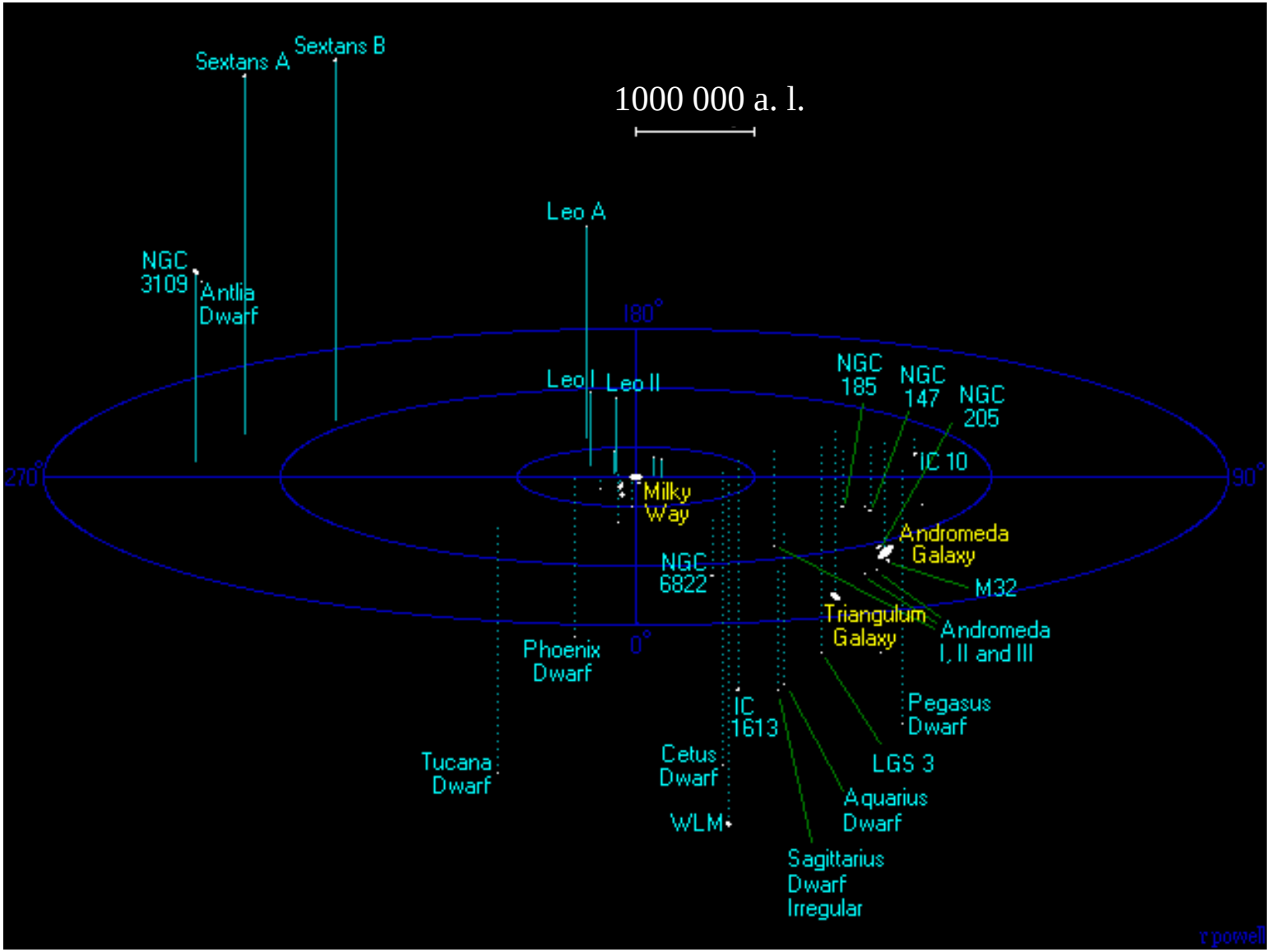
Zoom In x10

Zoom Out x10



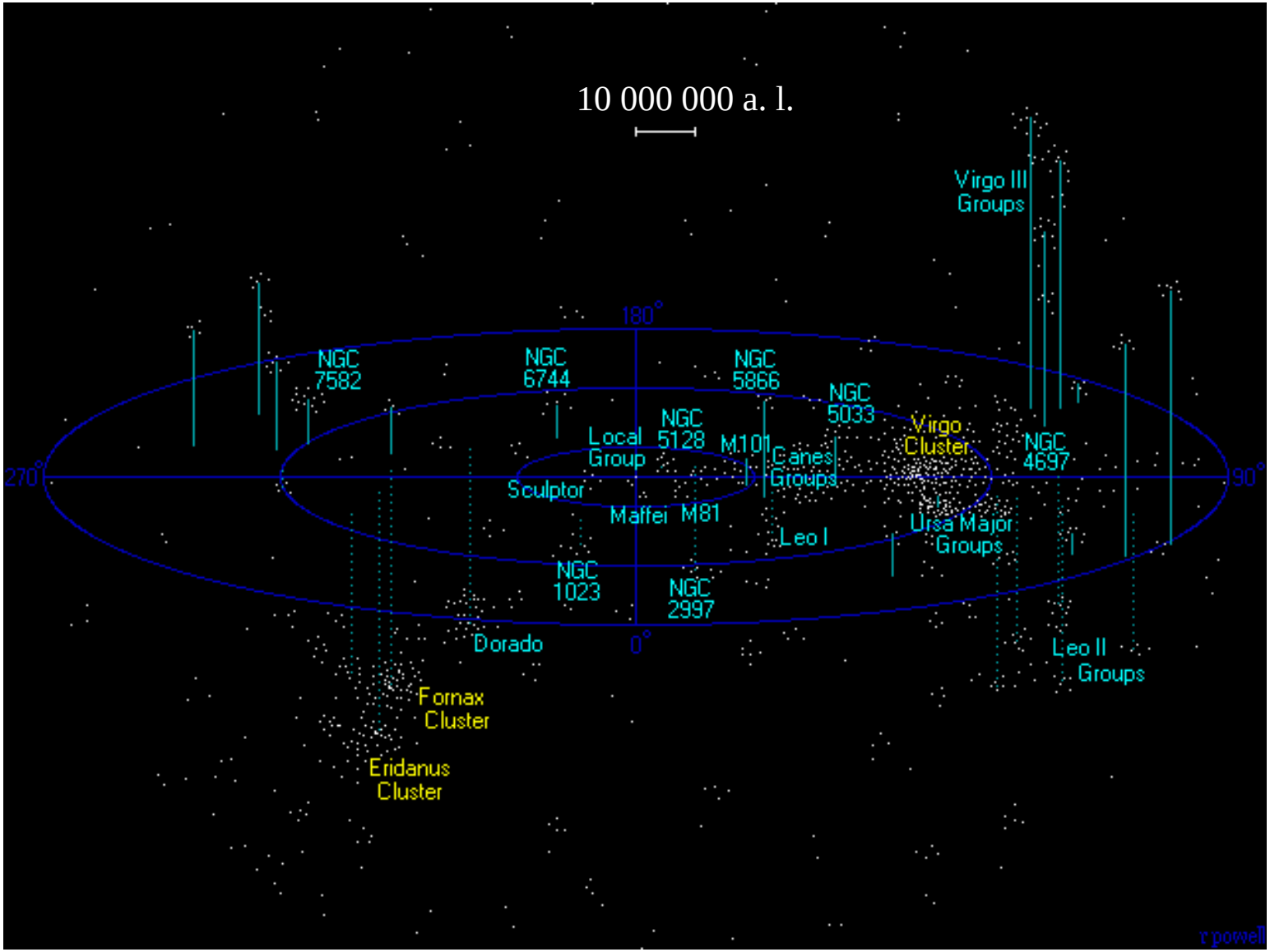
Zoom In x10

Zoom Out x10



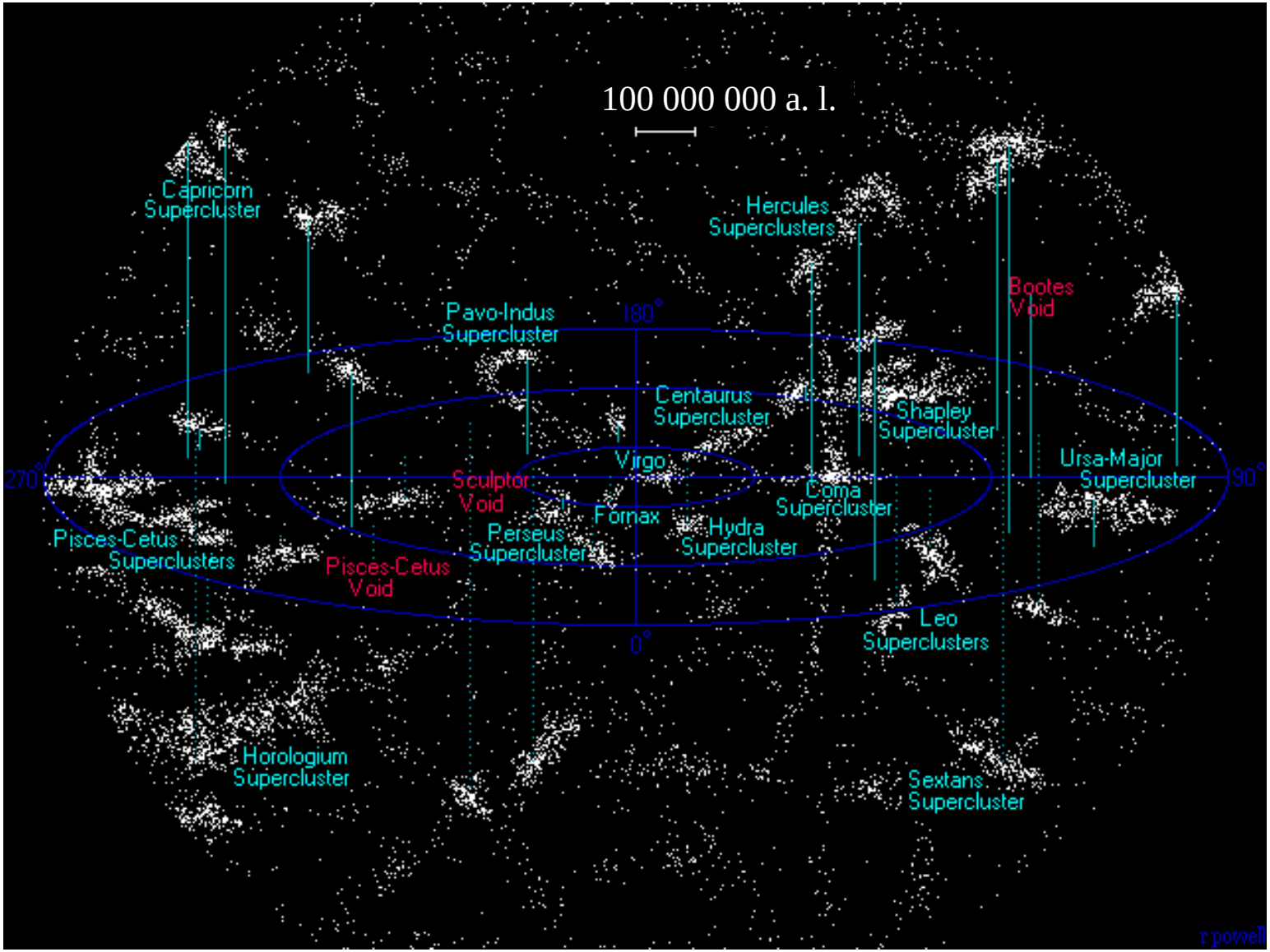
Zoom In x10

Zoom Out x20



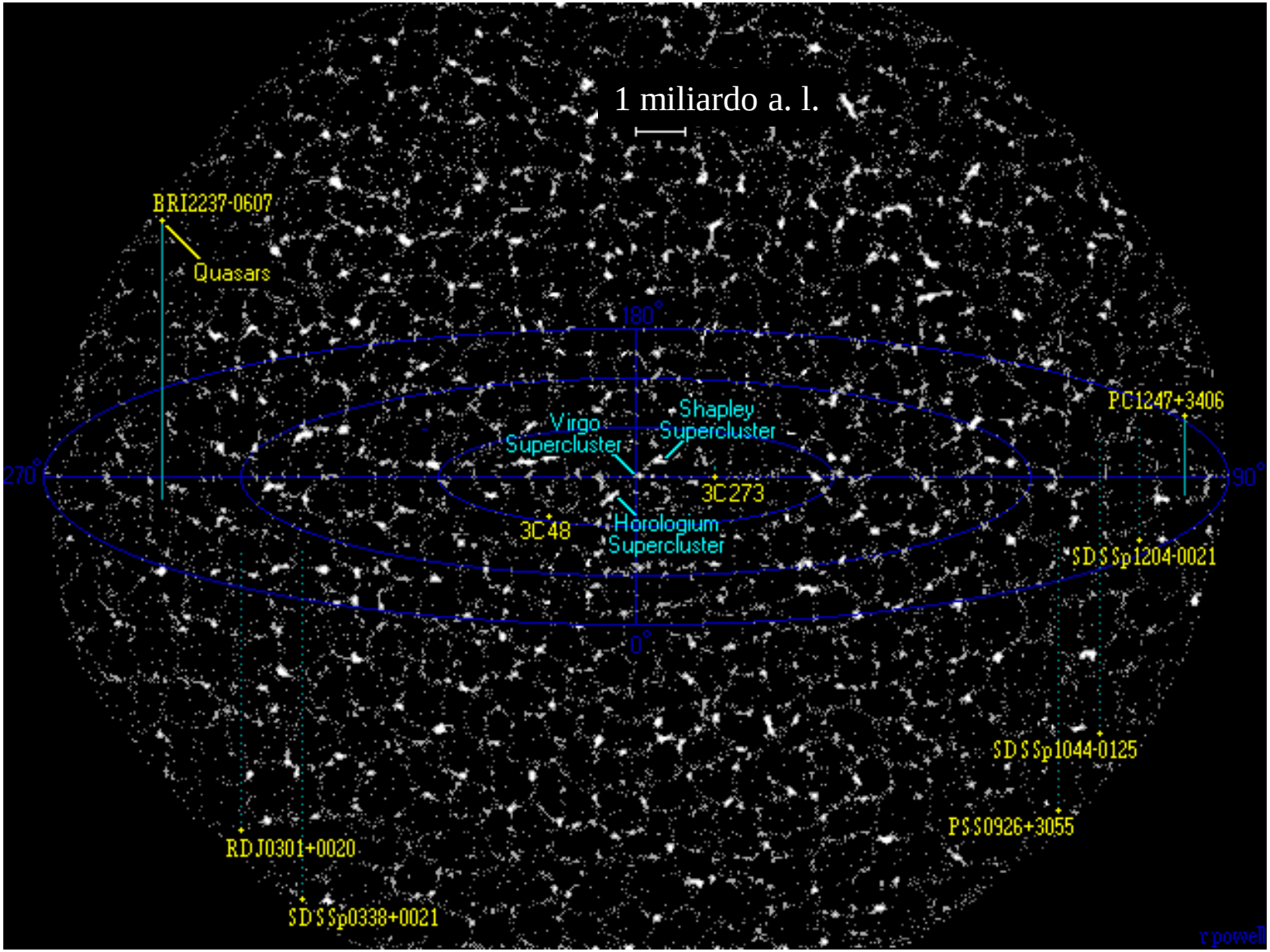
Zoom In x20

Zoom Out x10



Zoom In x10

Zoom Out x15


1 miliardo a. l.
BRI2237-0607
Quasars
180°
270°
90°
0°
Virgo
Supercluster
Shapley
Supercluster
3C273
3C48
Horologium
Supercluster
PC1247+3406
SDSSp1204-0021
SDSSp1044-0125
PSS0926+3055
RDJ0301+0020
SDSSp0338+0021
r powell

Zoom In x15

Istituto Nazionale di Fisica Nucleare

The INFN promotes, coordinates and performs scientific research in the sub-nuclear, nuclear and astroparticle physics, as well as the research and technological development necessaries to the activities in these sectors, in strong connection with the University and in the framework of international cooperation and confrontation

1951

4 University Sections

Milano, Torino, Padova, e Roma

1957

Laboratori Nazionali di Frascati

Frascati

INFN
Istituto Nazionale di Fisica Nucleare

Legnaro

Gran Sasso

VIRGO-EGO

European

Gravitational

Observatory

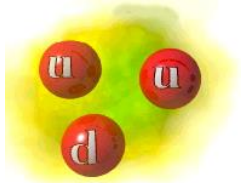
Laboratori del Sud (Catania)

19 Sections

11 Related Groups

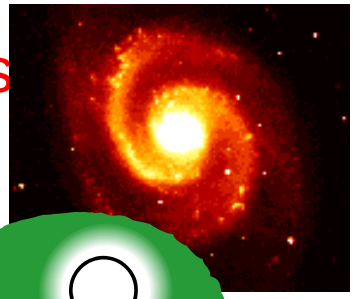
4 National Laboratories

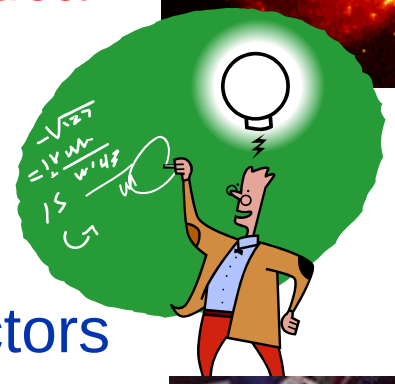
What are the activities performed at Laboratori Nazionali di Frascati?



Fundamental research

- Studies of the ultimate matter structure
- Search for gravitational waves
- Developments of theoretical models





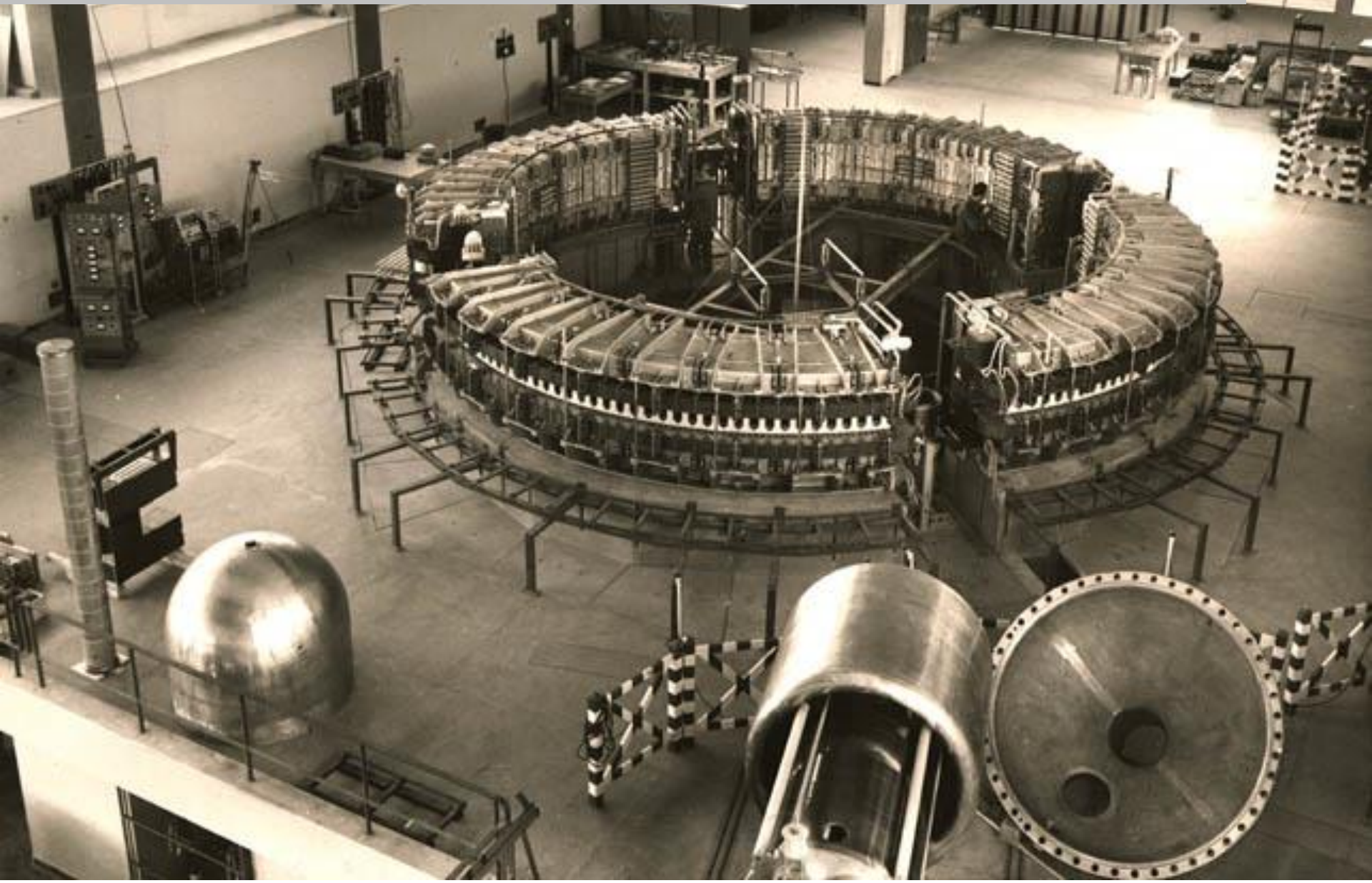
- Development and construction of particle detectors
- Studies and development of accelerating techniques
- Material studies and bio-medical research with the synchrotron light
- Development and support for computing systems and nets

Frascati National Labs (LNF)

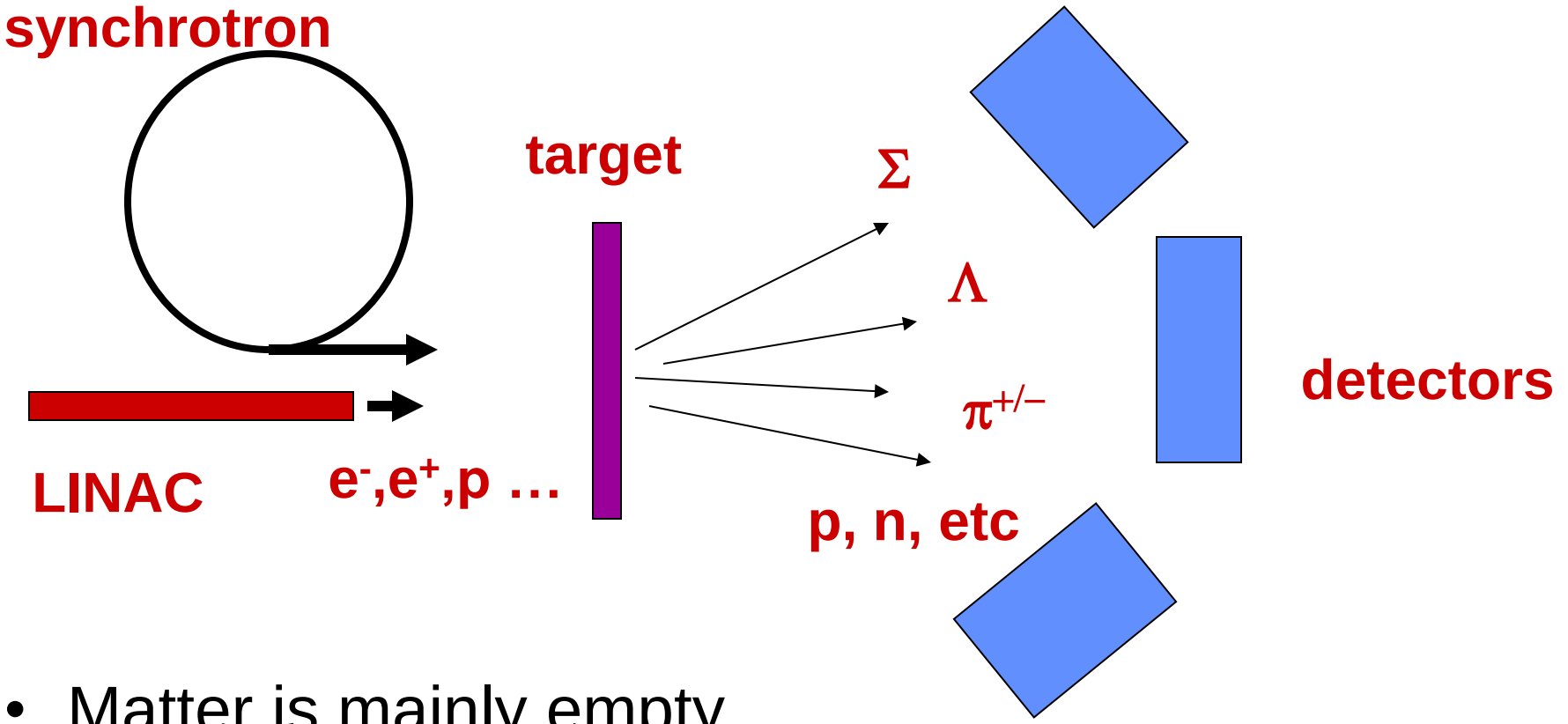
Total Staff of which: **364**	**Researchers** **98**	**Technologist/ Engineers** **57**	**Technicians** **170**	**Administration/ Services** **39**
External Users **546**	***Italian*** **346**		***Foreign*** **200**	
Visitors **3960**	**Stages** **310**	**Conference Workshops** **17**	**Participants to Conf. / Work.** **776**	**Master Courses** **1 (27 positions)**


LNF
DAFNE-light
LINAC
DAFNE
BTF
SPARC
FLAME

Frascati electrosynchrotron 1959-1975

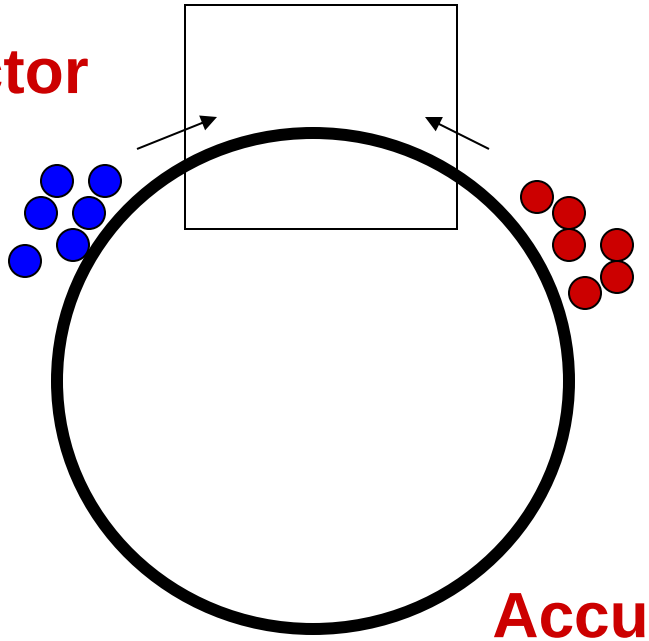


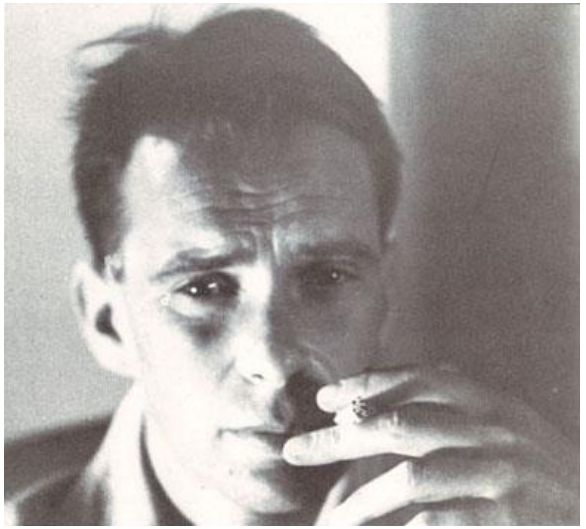
Observing on fixed target



- Matter is mainly empty
- All those particles which did not interact get lost
- Energy loss by moving the center of mass
- Target is complex

First Frascati's idea

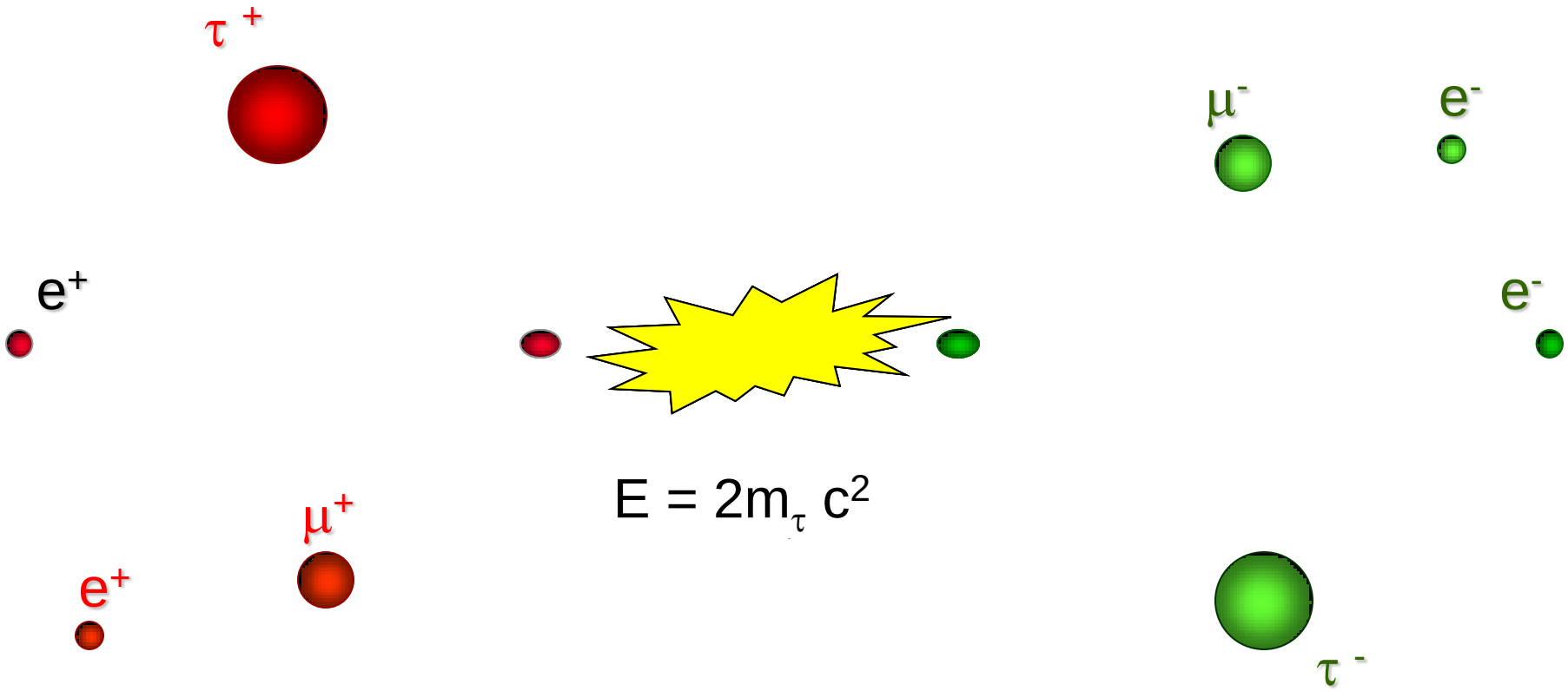




Bruno Touschek

- The non-interacting particles can be re-used in the successive rounds
- Collisions are performed in the center of mass frame
- The circulating particles can be either elementary or complex (nuclei or atoms)

Second Frascati's idea



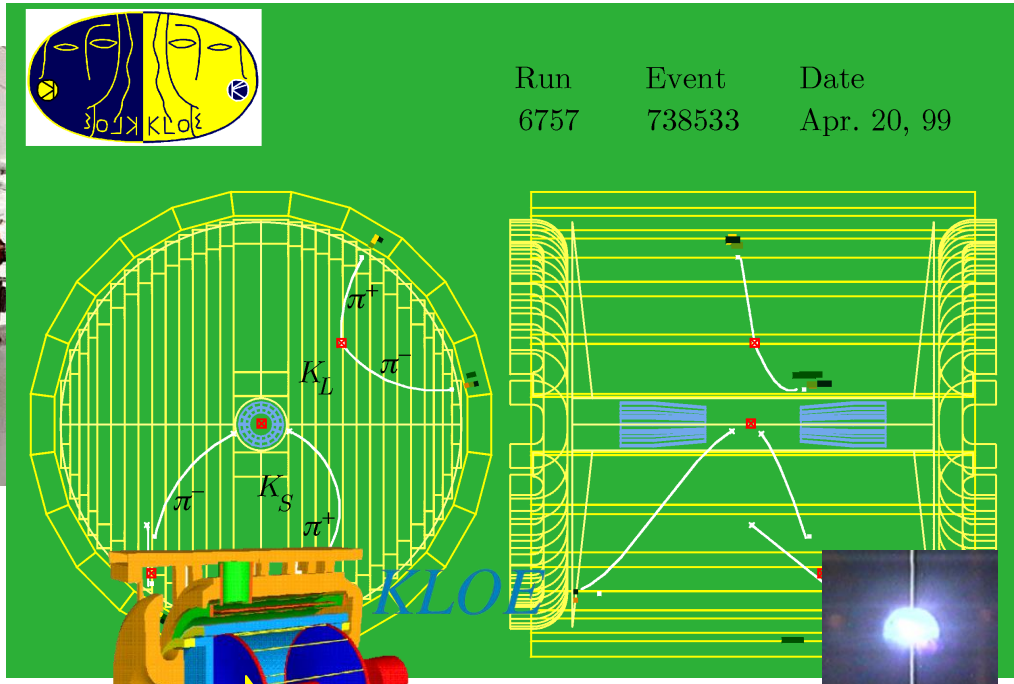
E = m c^2

Bigger the energy is, more and more particles can be studied

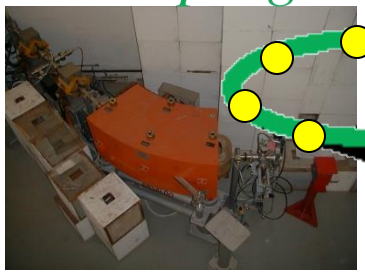
Matter-antimatter colliders

LHC at Cern (pp)

DAΦNE



Damping ring



Test beam

Main rings

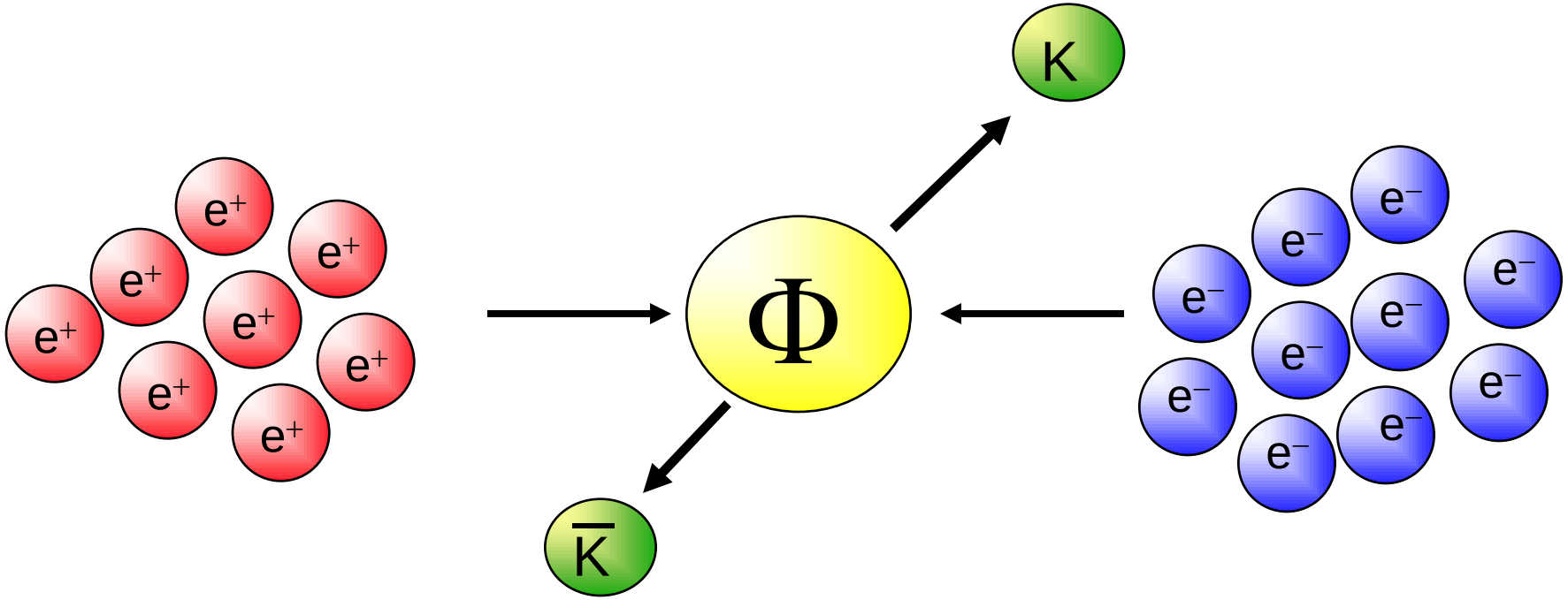
DAFNE-Light

Linac

DEAR
FINUDA

Physics at DAΦNE

Out of the electron – positron collisions the Φ meson can be produced; it decays immediately in other two particles, the *K*-mesons (kaons). The kaons can be both neutrals or charged.

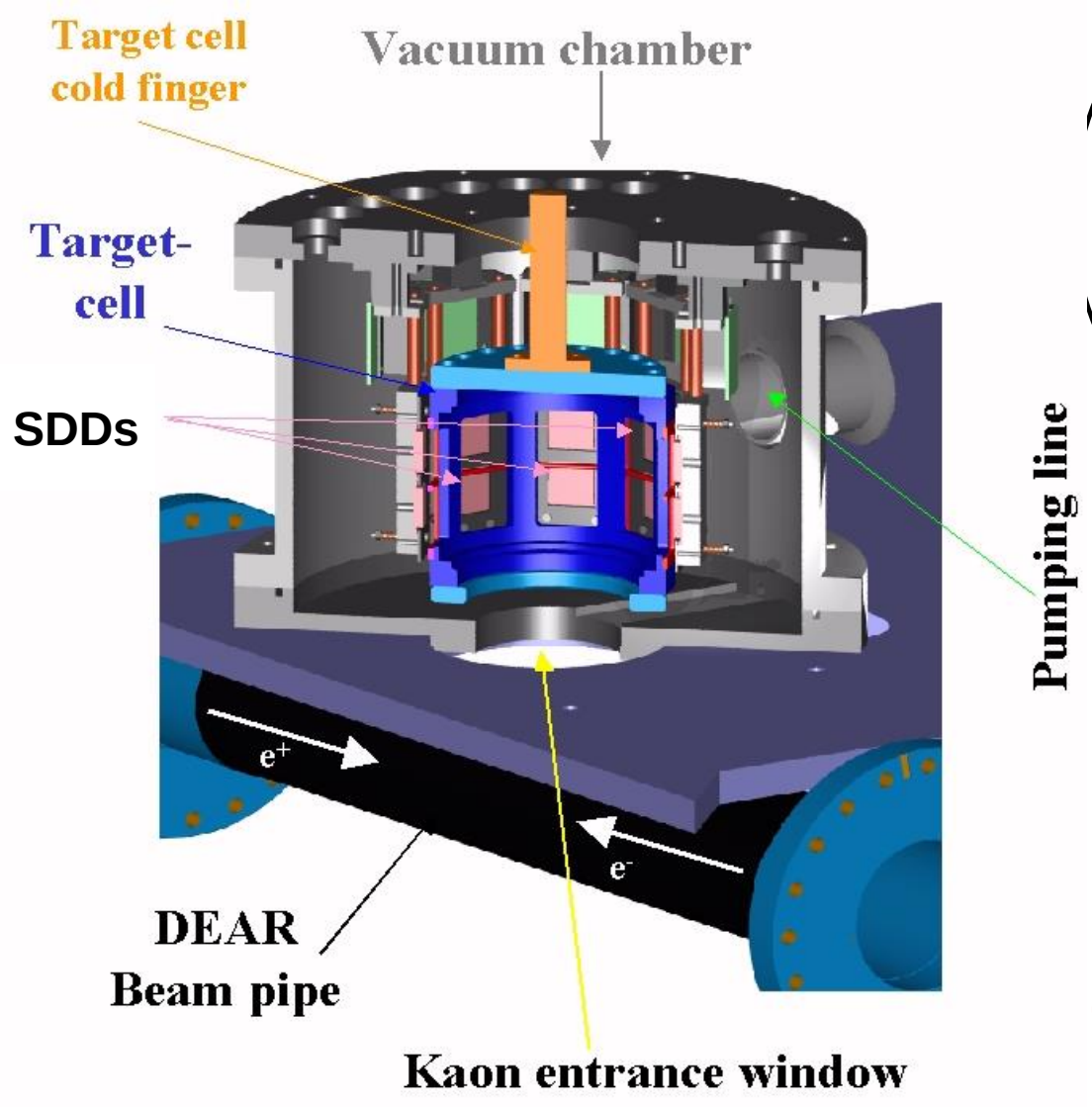


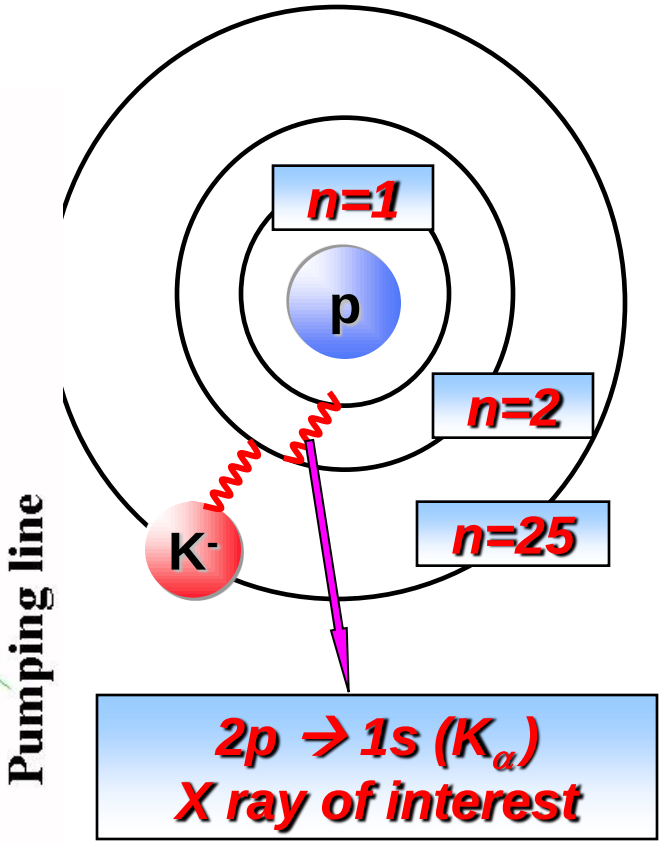
The *K* are the particles used by the three experiments, DEAR, FINUDA and KLOE, to reach their scientific goals. The DAΦNE luminosity allows to produce about 10000 *K* in a second

DEAR/SIDDHARTA

(DAΦNE Exotic Atom Research)

Kaonic hydrogen



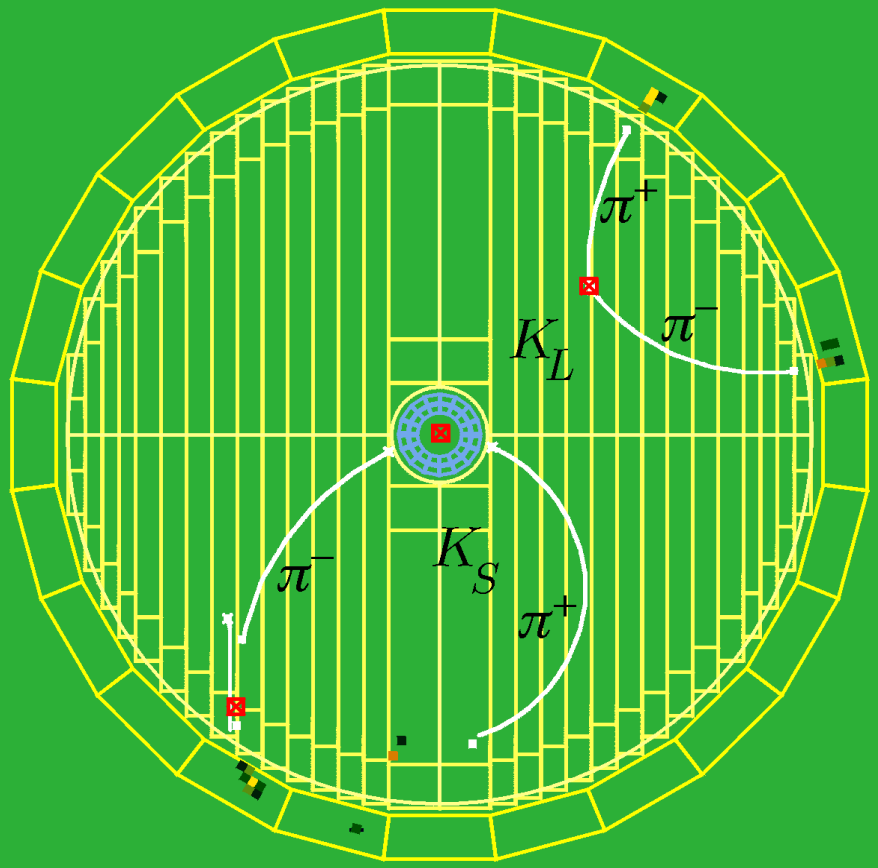


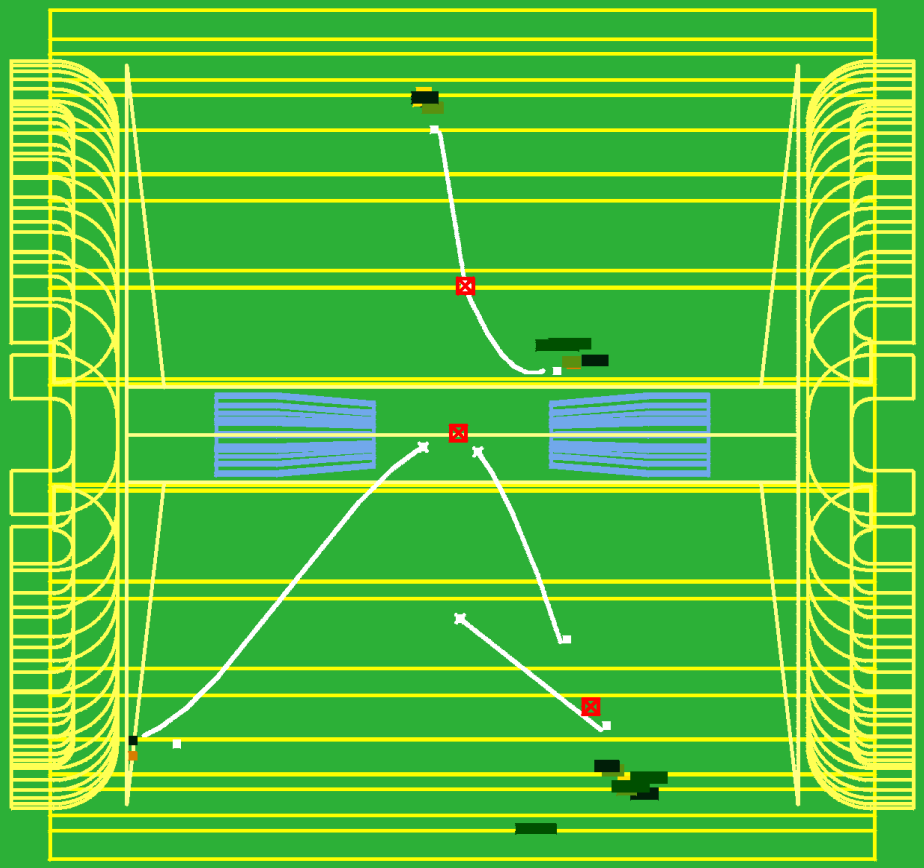
The DEAR experiment investigates the *strong force* by studying the *kaonic atoms* (in which a K^- is substituting an atomic electron).

KLOE

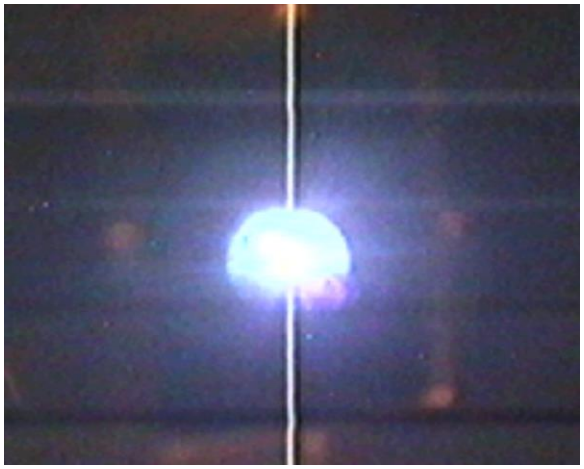
(K LOng Experiment)

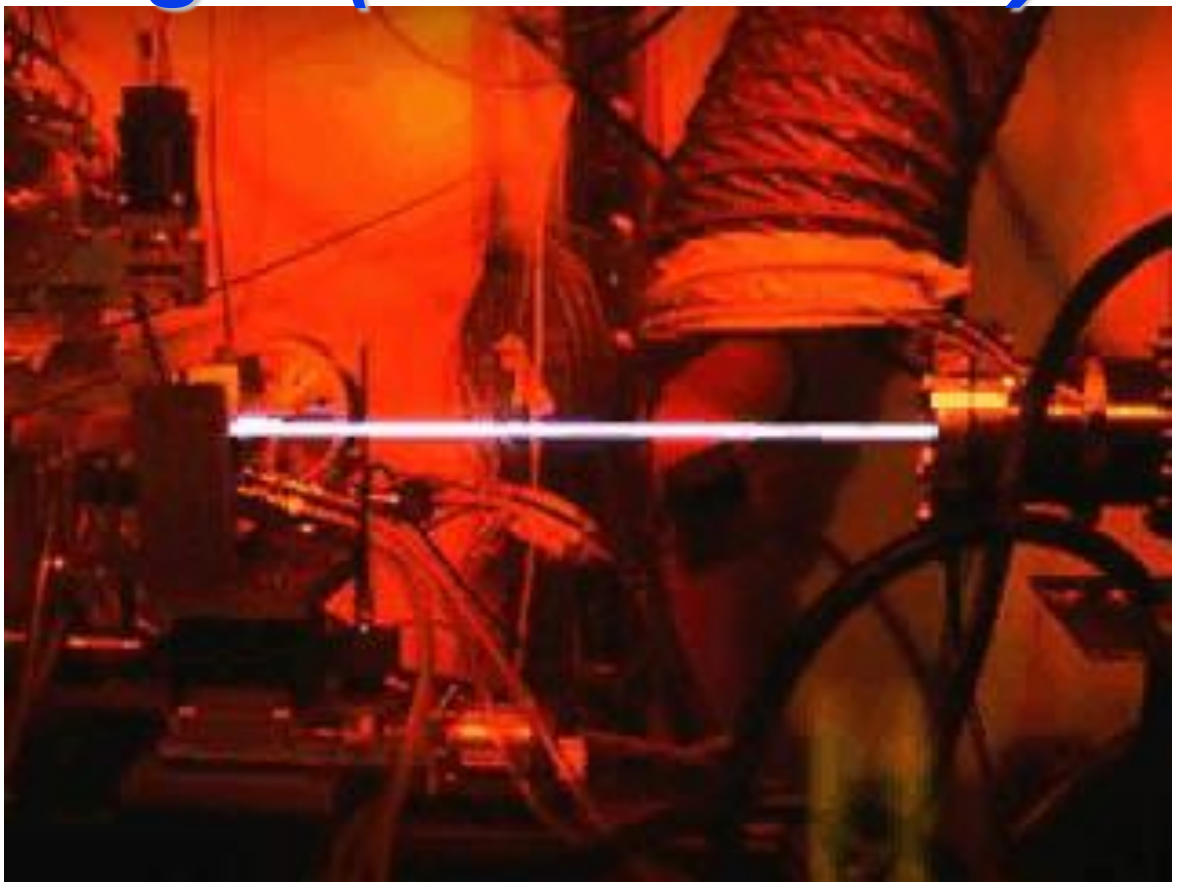
Run	Event	Date
6757	738533	Apr. 20, 99

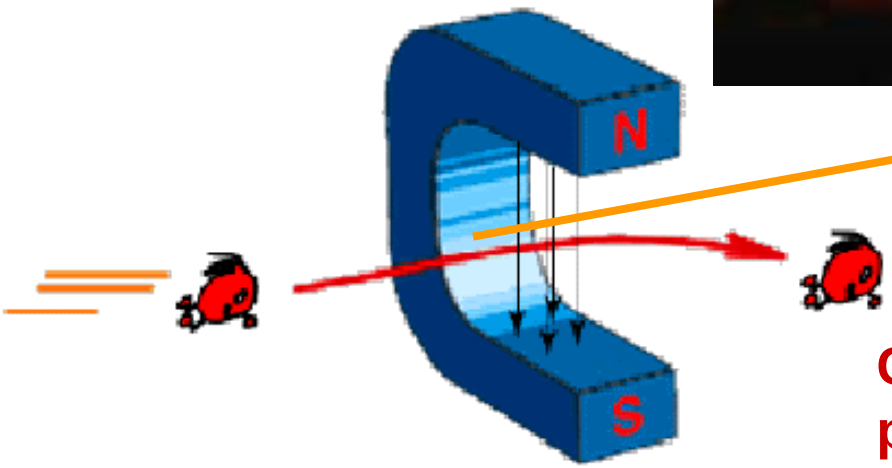




Synchrotron light (DAΦNE-luce)







Light (photons)

European Synchrotron Radiation Facility

Charged particle

FLAME:Frascati Laser for Acceleration and Multidisciplinary Experiments

Laser of high power (> 100 TW), able to produce pulses of 6 J in 20 fs at 10 Hz

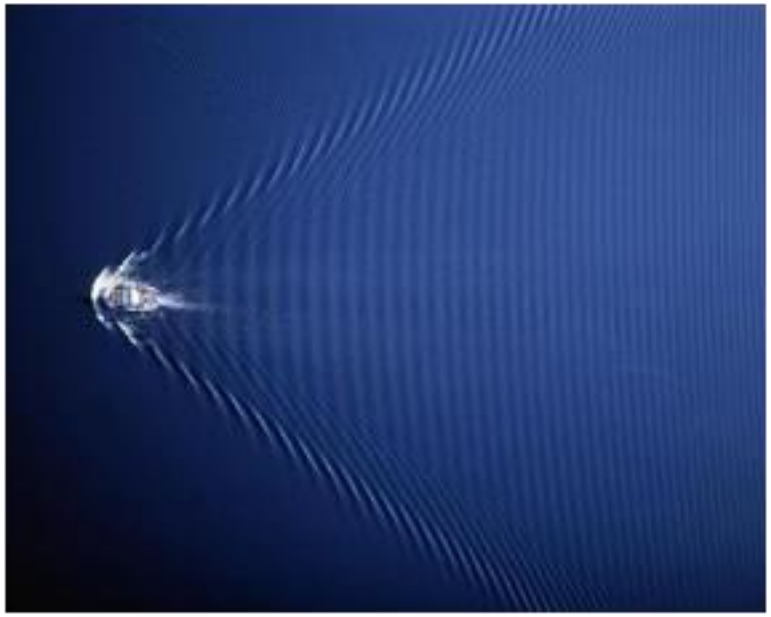
Started December 2010

1)If FLAME beam is injected into a gas the electrons inside get highly accelerated (new acceleration technique)

2)If FLAME beam is colliding head-on with an electron beam (SPARC) an intense source of X rays is produced

1) New acceleration technique

L'impulso laser produce nel plasma un'onda di scia simile a quella che lascia dietro di sè un'imbarcazione



Su quest'onda parte degli elettroni del plasma acquistano energia come un surfista che cavalca un'onda.

In few cm electrons get accelerations as in present accelerators of hundred meters

2) Intense X rays source

Electron beams from Linac (SPARC) with energies about 25-50 MeV collide with FLAME beam

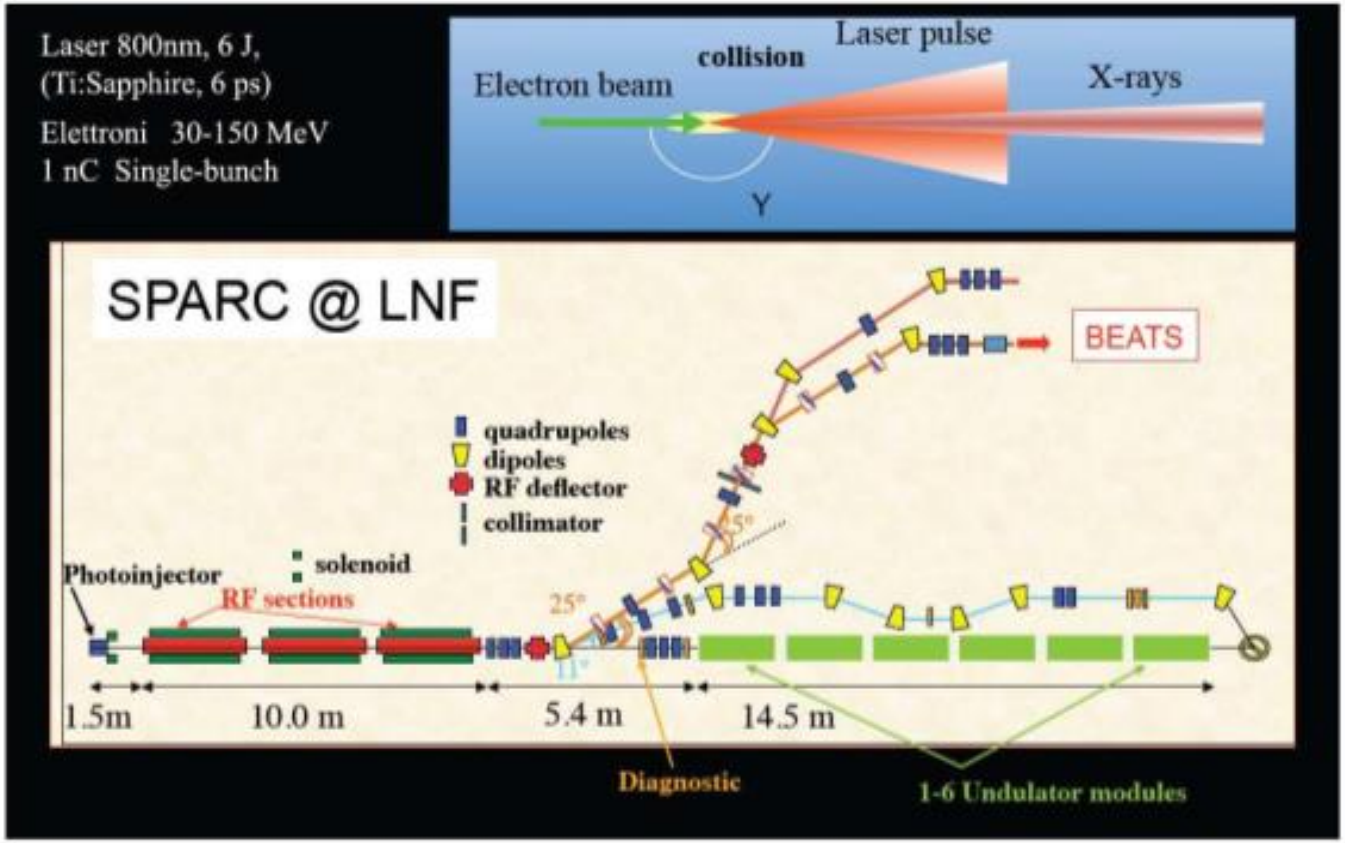


Fig. 1 – Sorgente Thomson ai LNF

Resulting in monochromatic X ray beams with energies between 20 and 800 keV

.

Medical diagnosis and material science

Medical diagnosis

Mamography

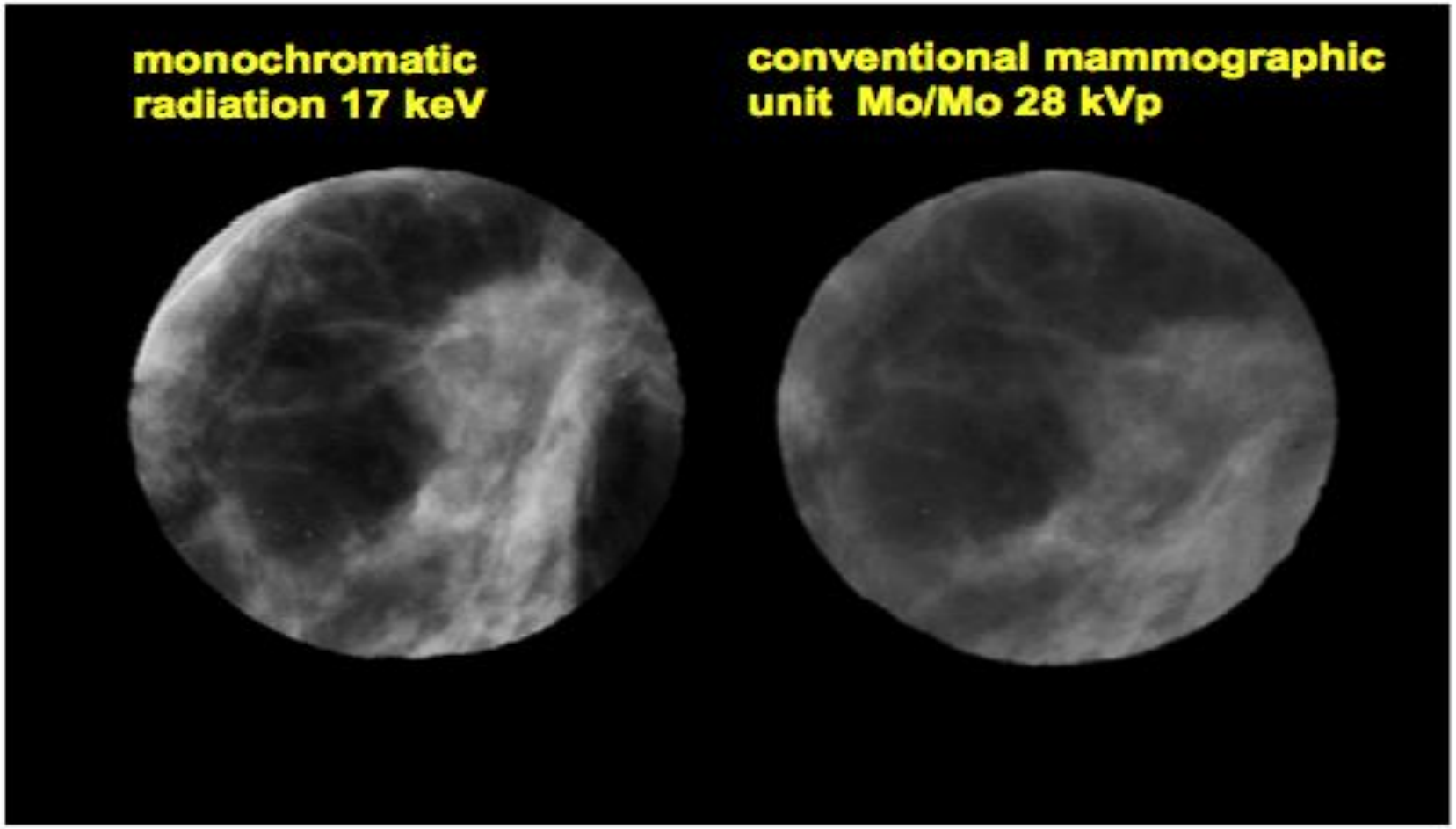
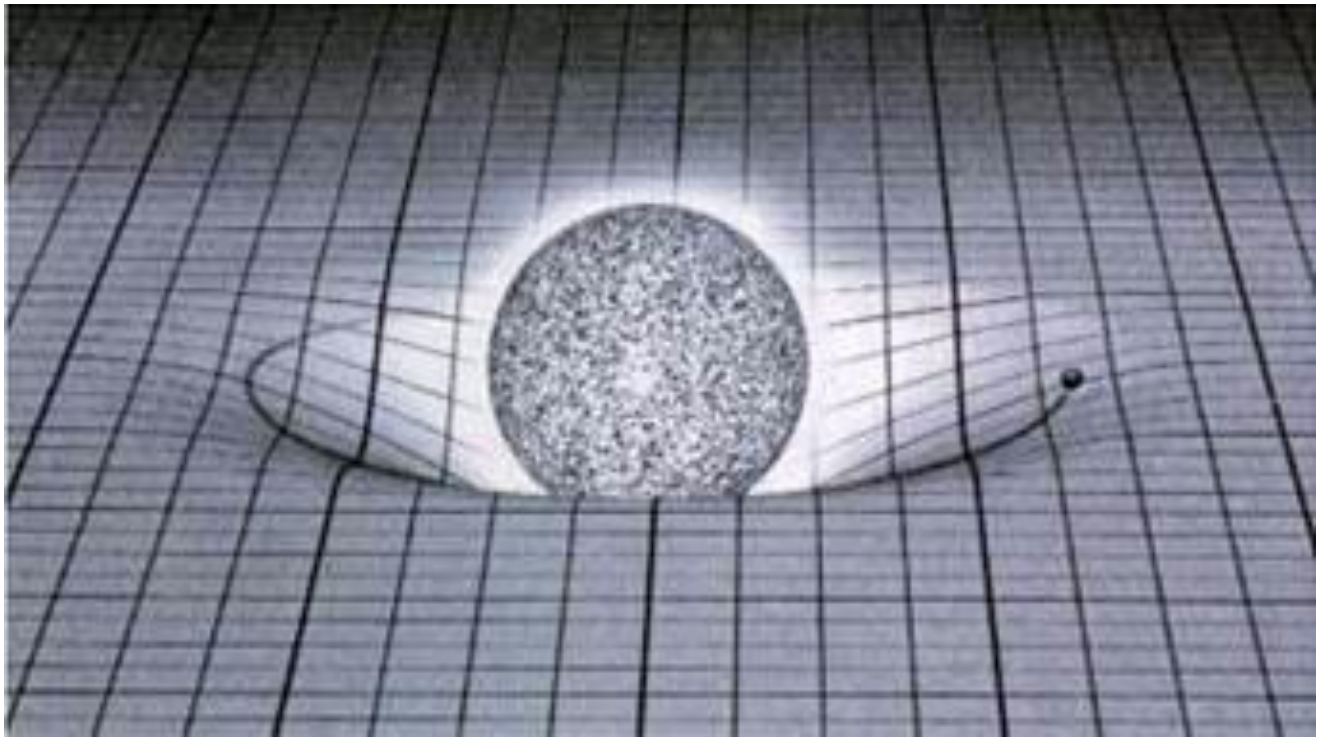


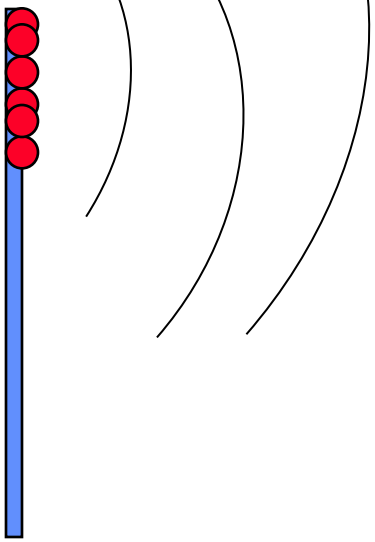
Fig. 3 – Confronto fra una mammografia monocromatica (sinistra) con una tradizionale (destra).

Gravity force`



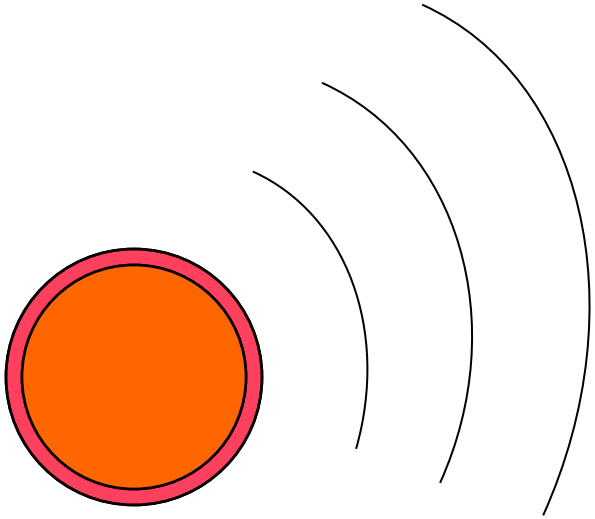
Distortion of space-time

Antenna

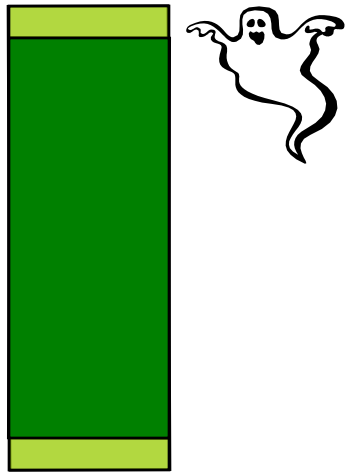


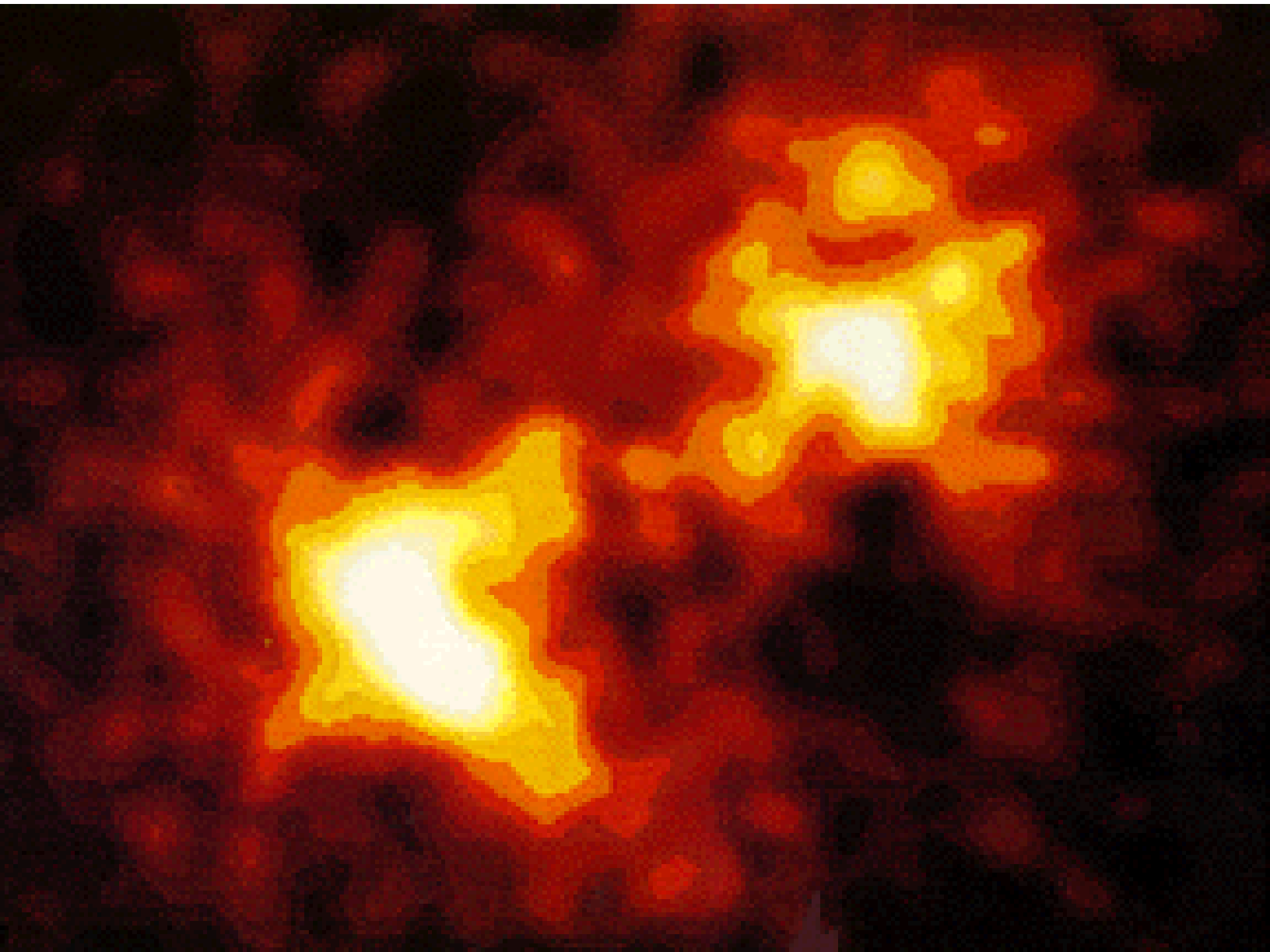
The electromagnetic waves are produced by an electric charge in movement

Gravitational waves: an analogy

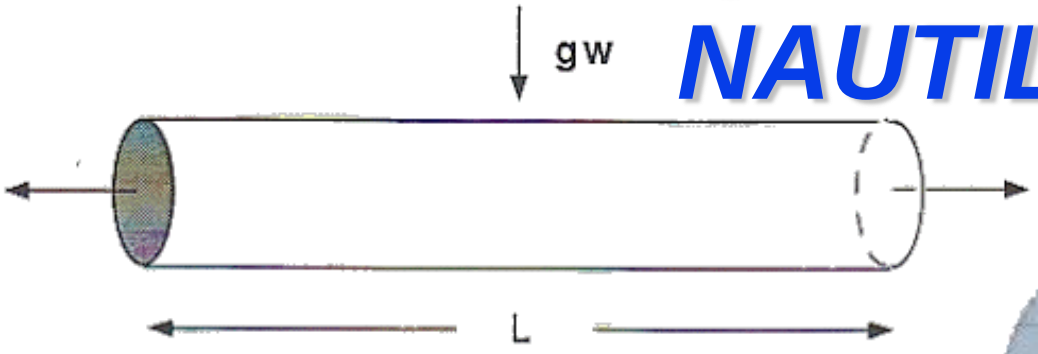


Gravitational waves are produced by masses in movement….





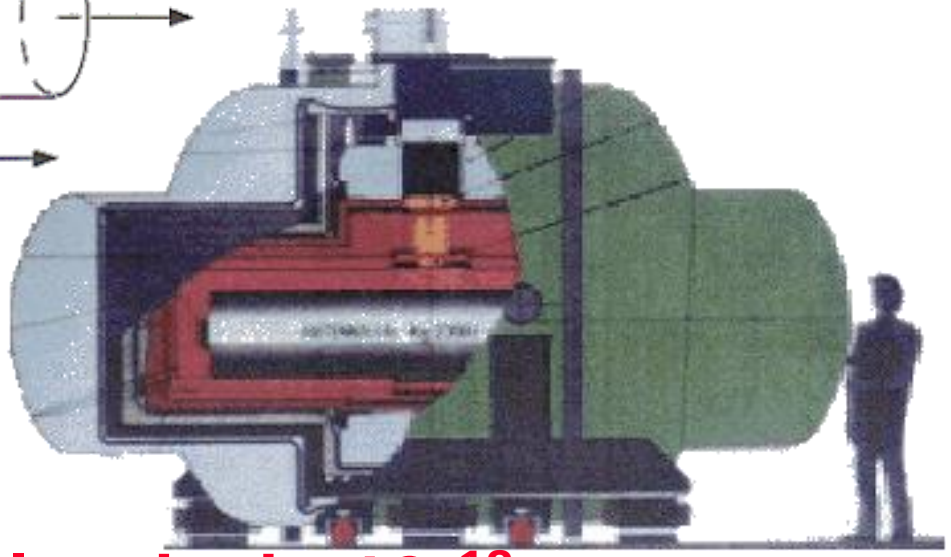
Search for gravitational waves: NAUTILUS



vibrations in the bar

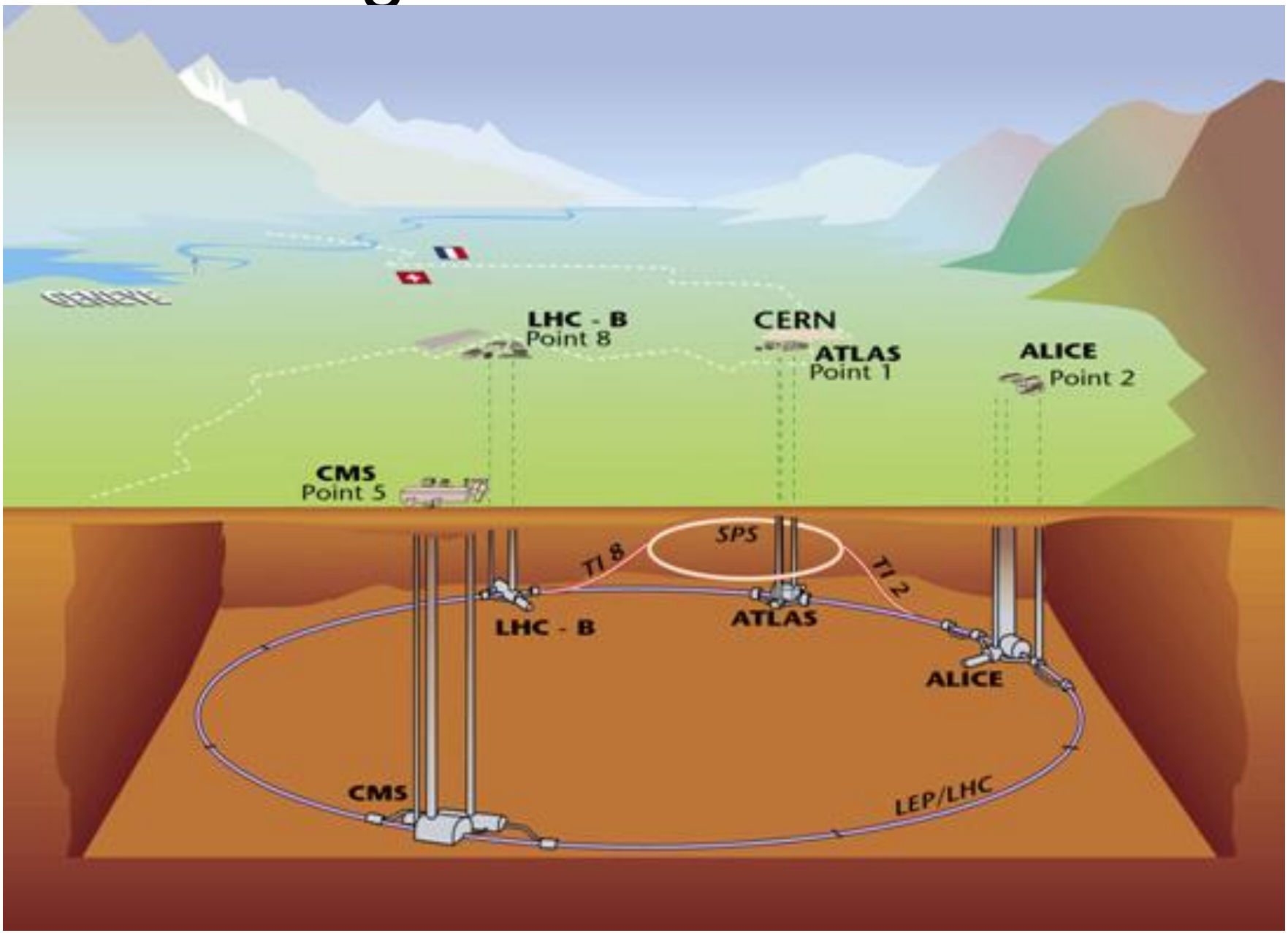
(for Al, L=3 m, f=915 Hz)

$$\frac{\Delta L}{L} \approx h$$



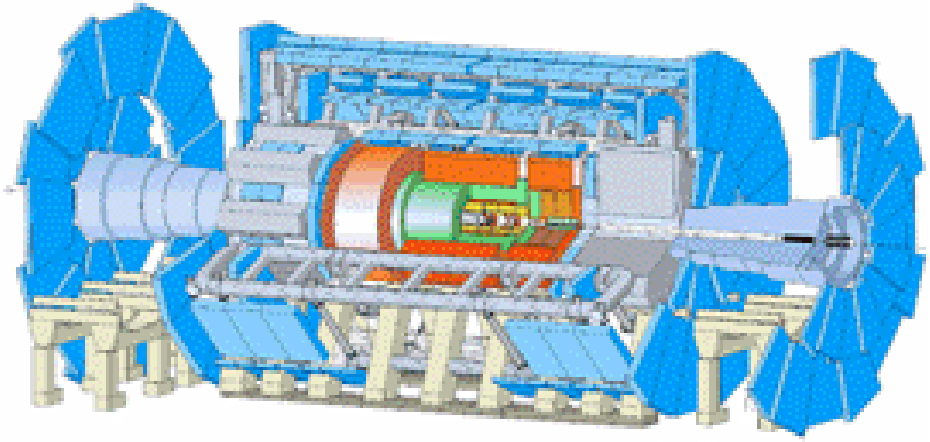
- **Supernova in our Galassia $h=10^{-18}$**
- **Supernova in Virgo $h=10^{-21}$**
- **Thermal noise @ T=300 K, $\Delta L=10^{-16}$ m**
- **Thermal noise @ T=3 K, $\Delta L=10^{-17}$ m**
- **Thermal noise @ T=300 mK → $\Delta L=10^{-18}$ m**

Large Hadron Collider

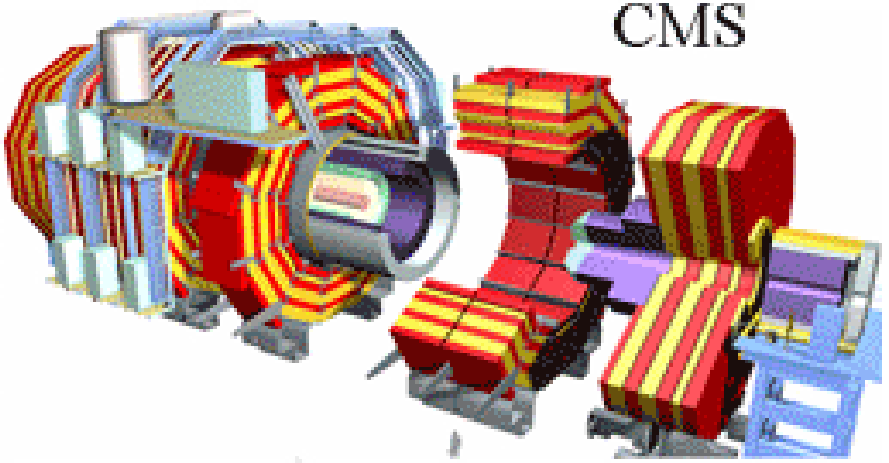


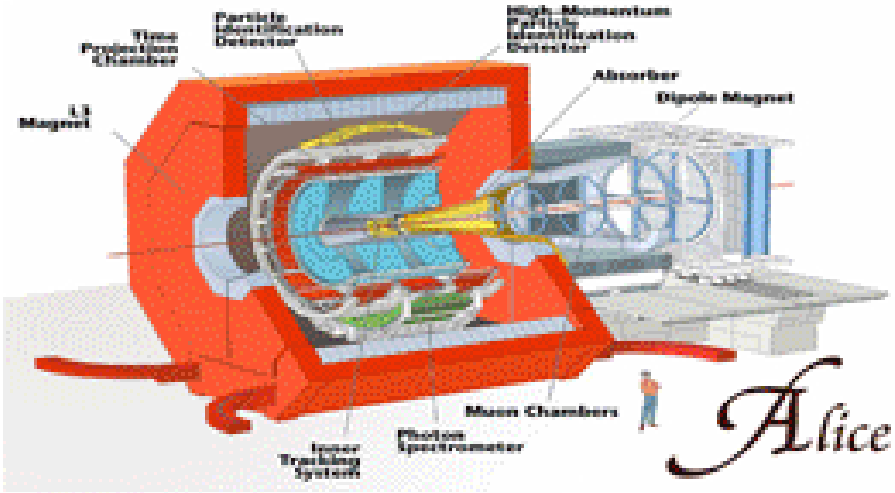
Large Hadron Collider

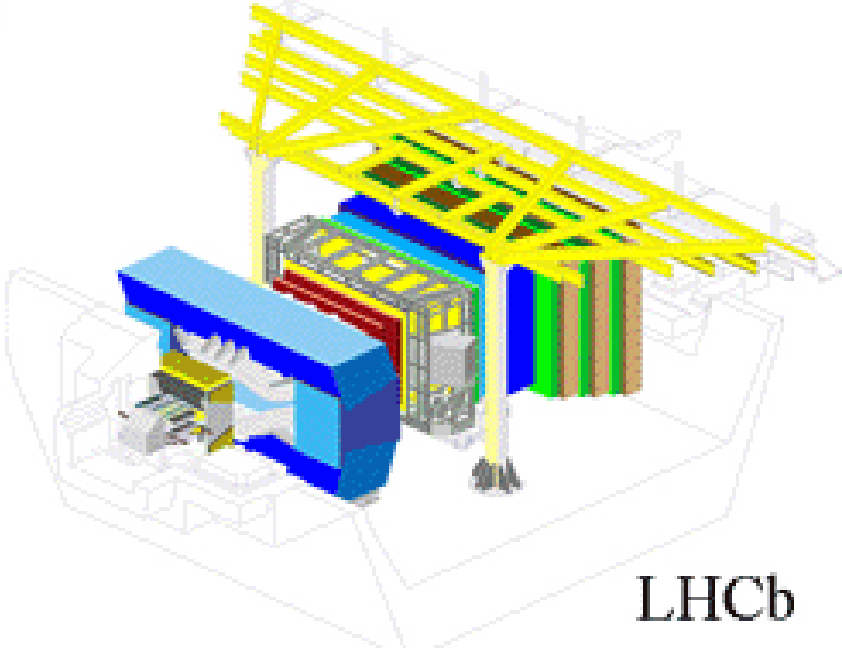
ATLAS



CMS

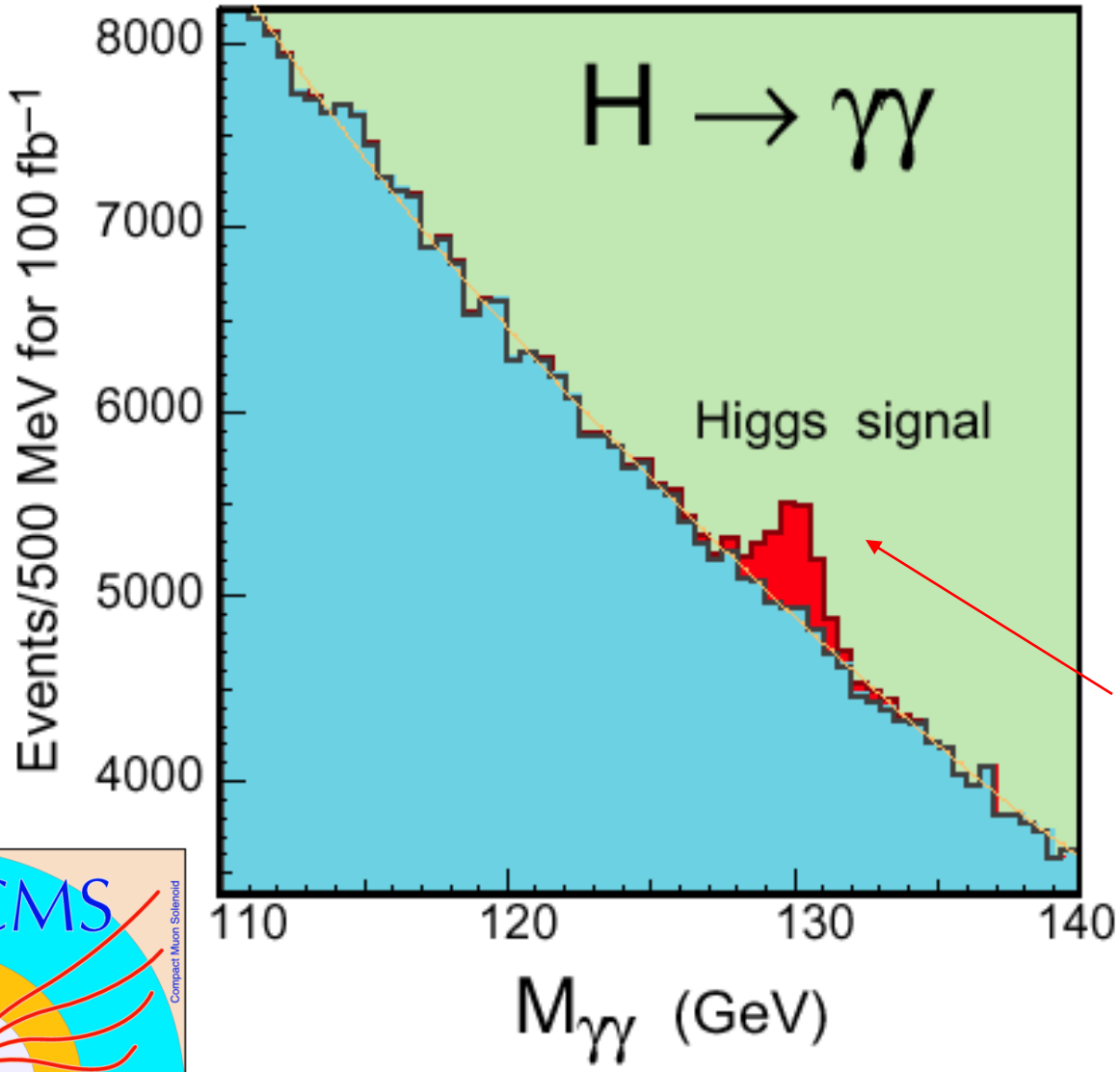




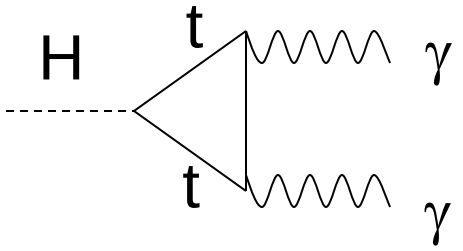


LHCb

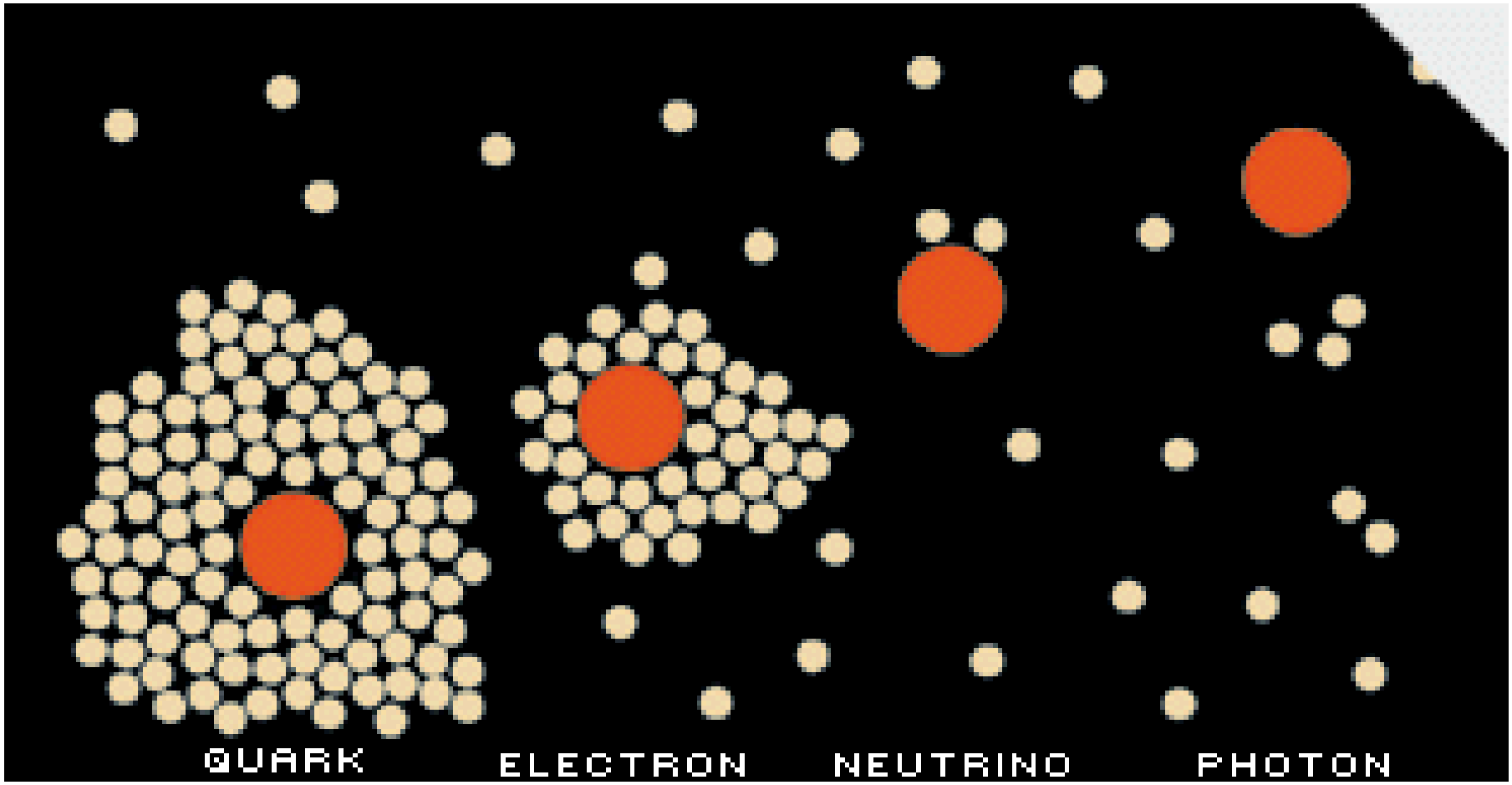
Higgs Decay to Photons



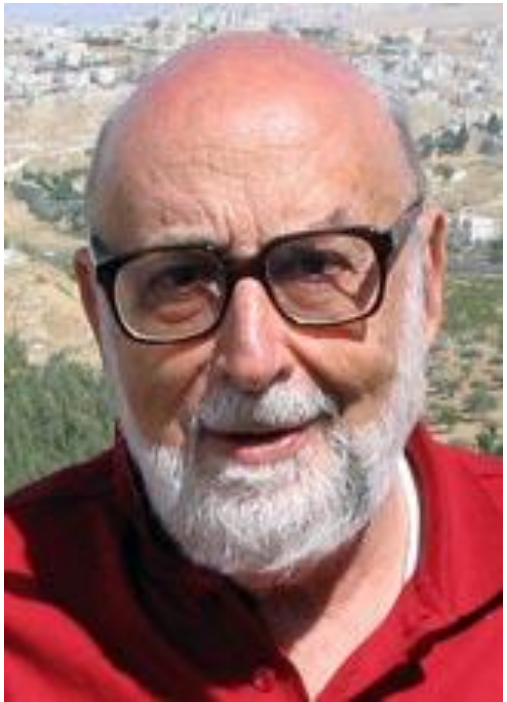
Rare decay in SM

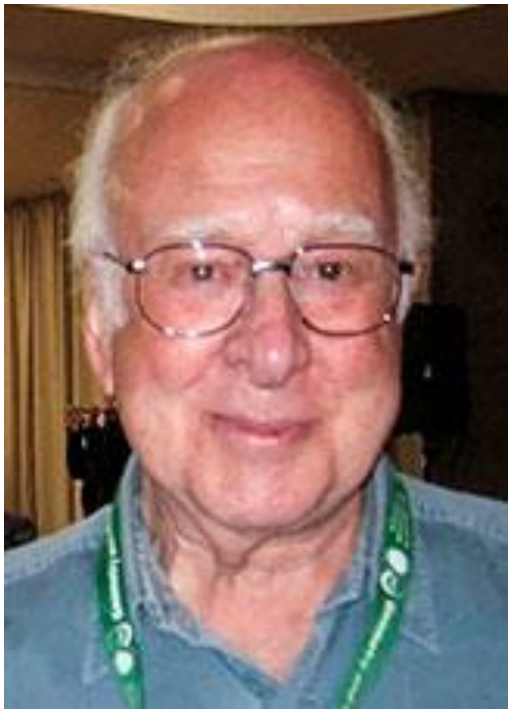


LHC detectors have been optimized to find this peak!

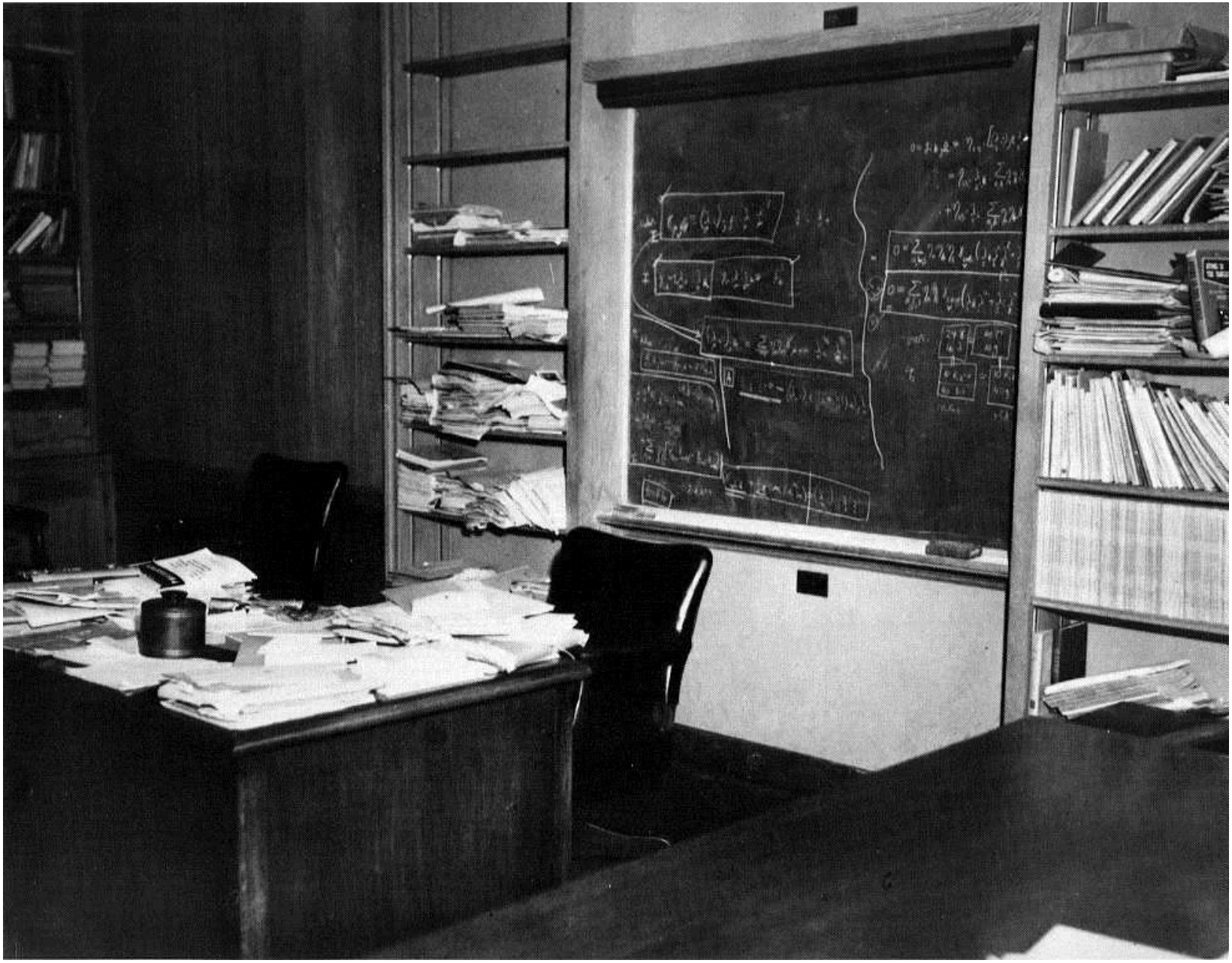

QUARK
ELECTRON
NEUTRINO
PHOTON

The Nobel Prize in Physics 2013 was awarded jointly to François Englert and Peter W. Higgs *"for the theoretical discovery of a mechanism that contributes to our understanding of the origin of mass of subatomic particles, and which recently was confirmed through the discovery of the predicted fundamental particle, by the ATLAS and CMS experiments at CERN's Large Hadron Collider"* – *Francois Englert, Peter Higgs*

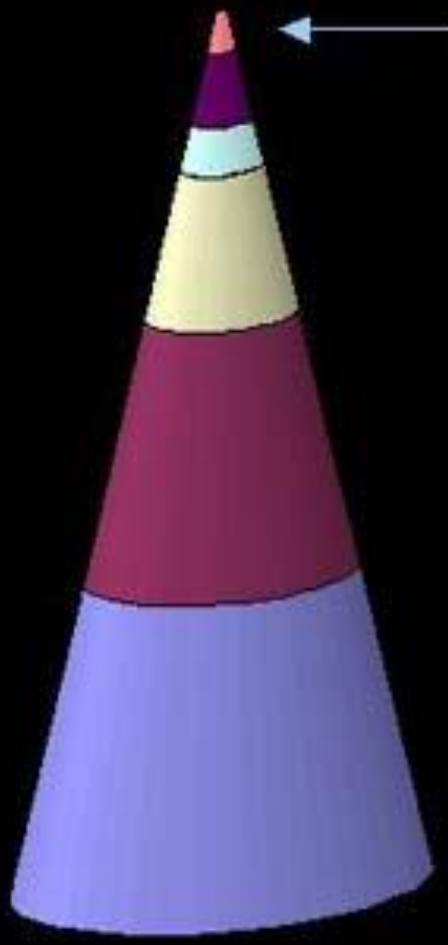




Einstein – last black-board



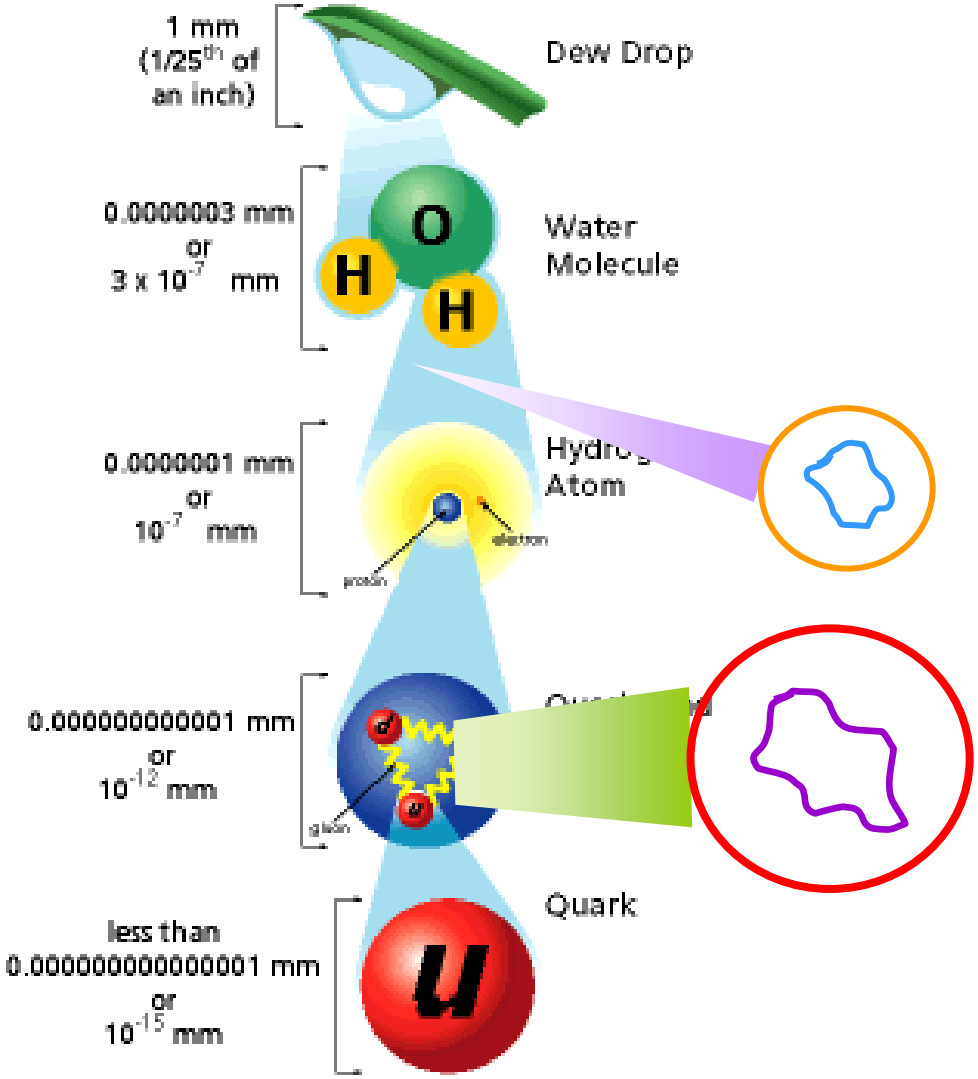
Composizione dell'Universo

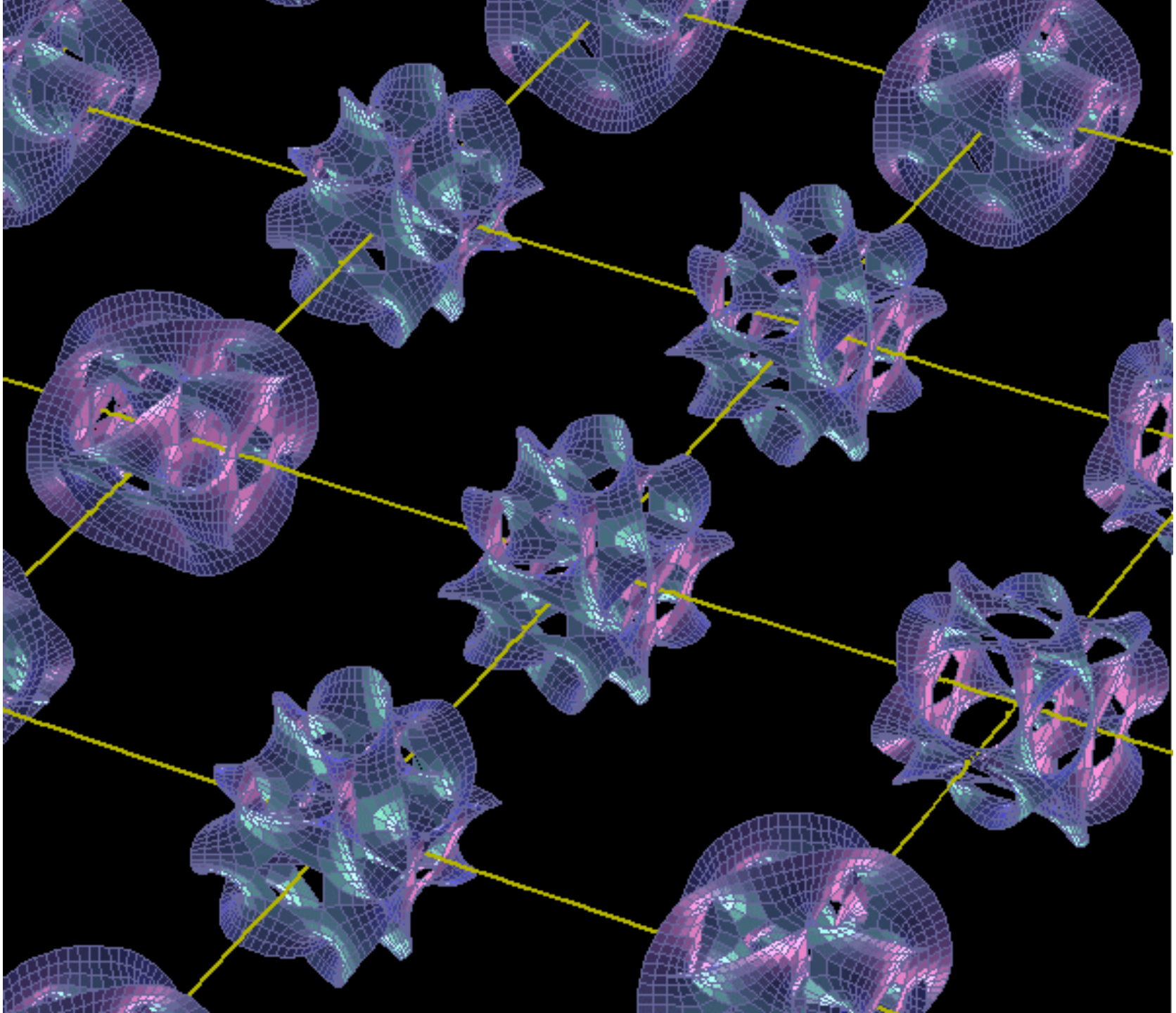


Other elements	0.03%
Neutrinos	0.3%
Stars	0.5%
Free H and He	4%
Dark matter	23%
Dark energy	72%

We do not know what makes up 95% of the universe.

String theory





Einstein quotes

There are two ways to live: you can live as if nothing is a miracle; you can live as if everything is a miracle.

TRY NOT TO BECOME A MAN OF SUCCESS, BUT RATHER TRY TO BECOME A MAN OF VALUE.

Laboratori Nazionali di Frascati, info: http://www.lnf.infn.it/sis/