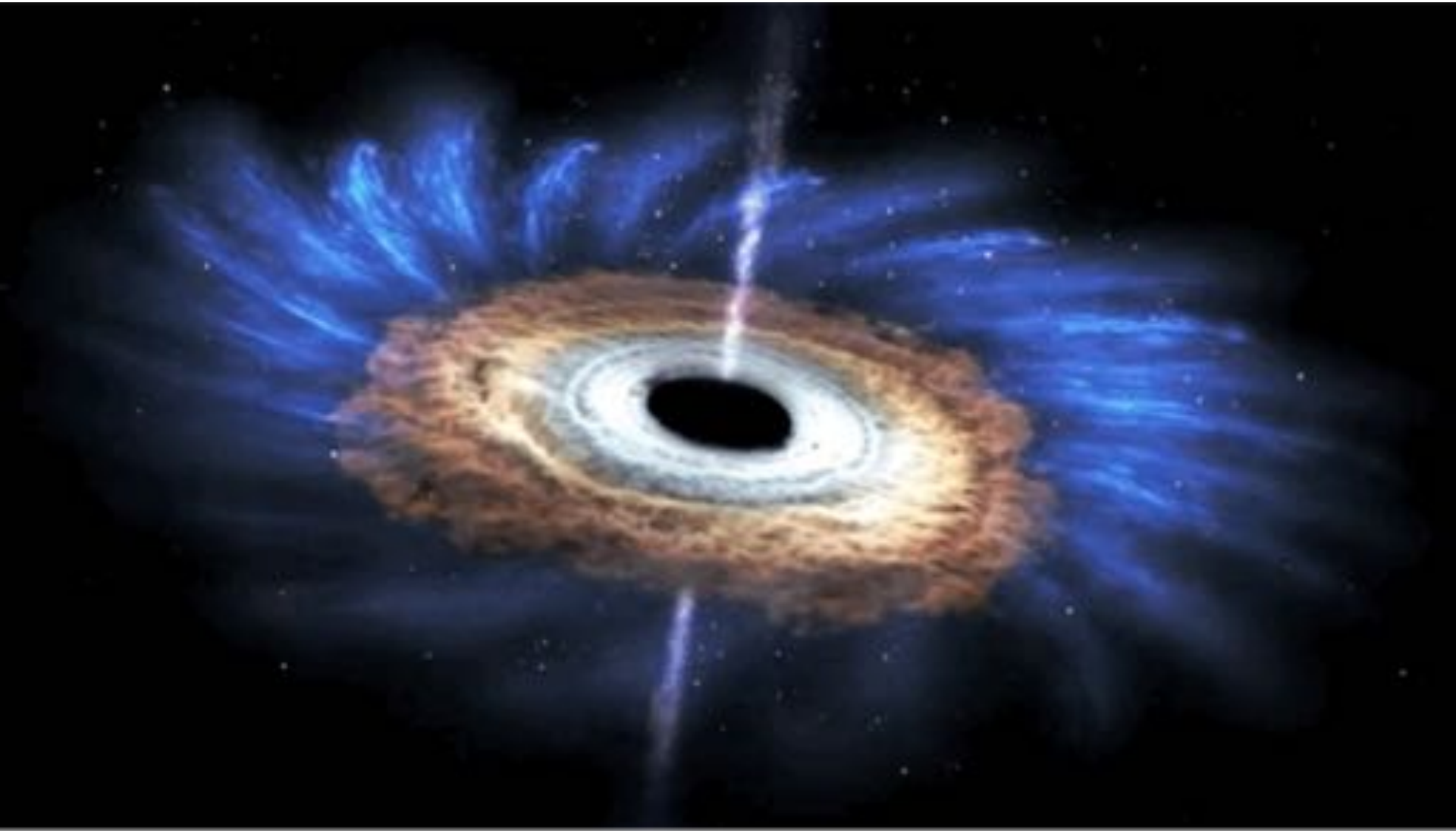
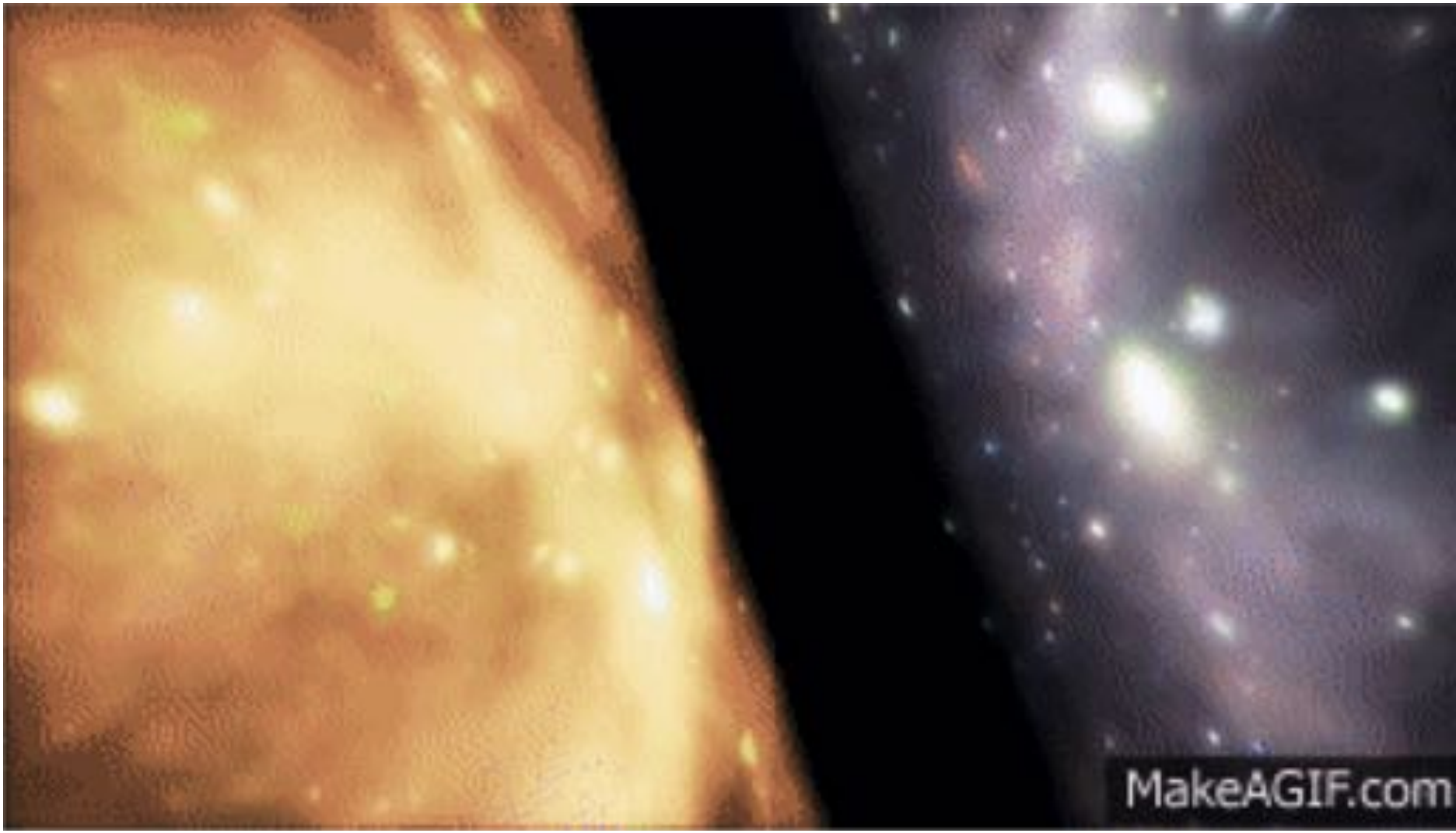
The 7 big mysteries of MODERN PHYSICS

2nd April 2019

INSPYRE 2019, LNF-INFN

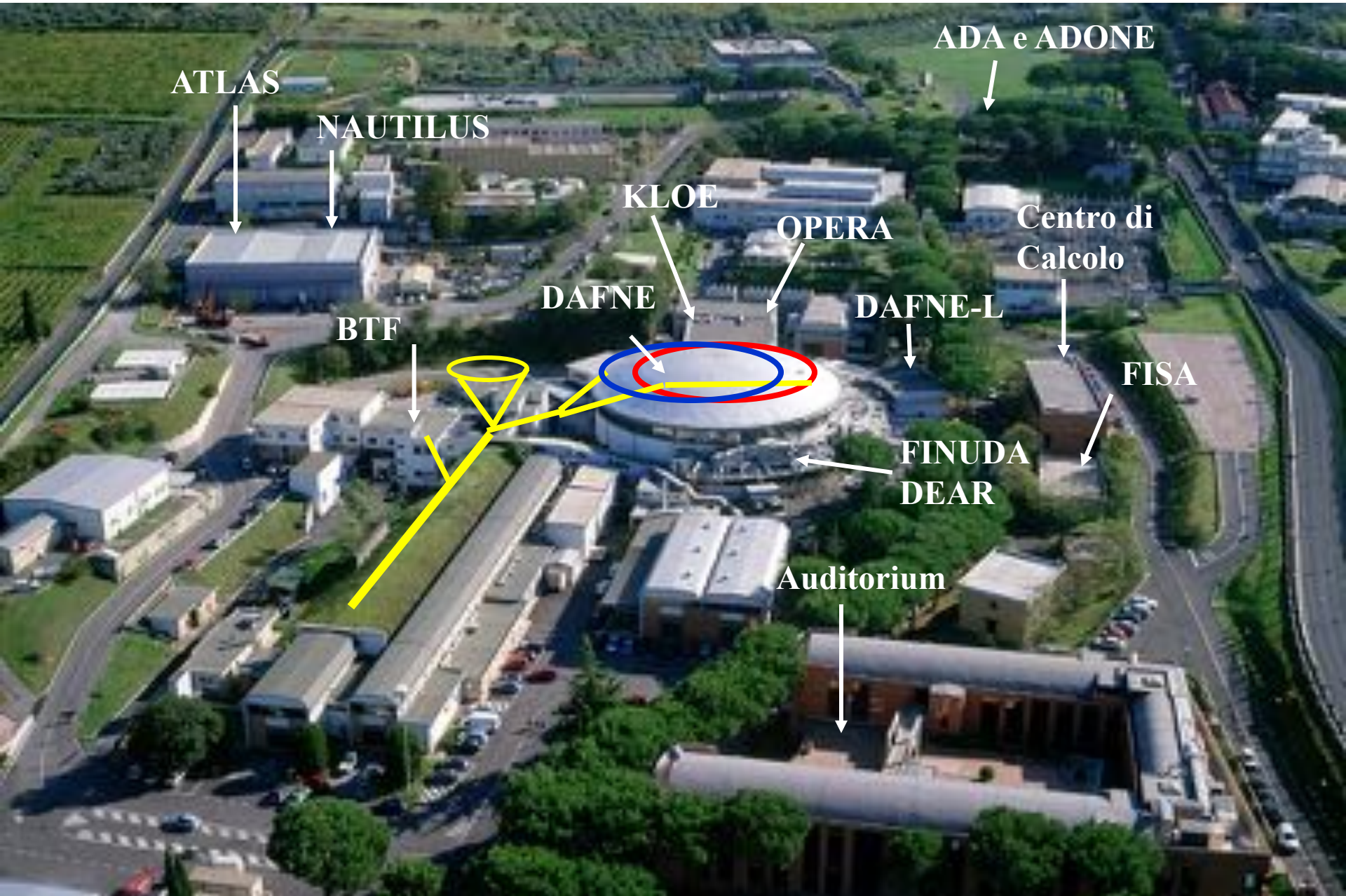
Catalina Curceanu,

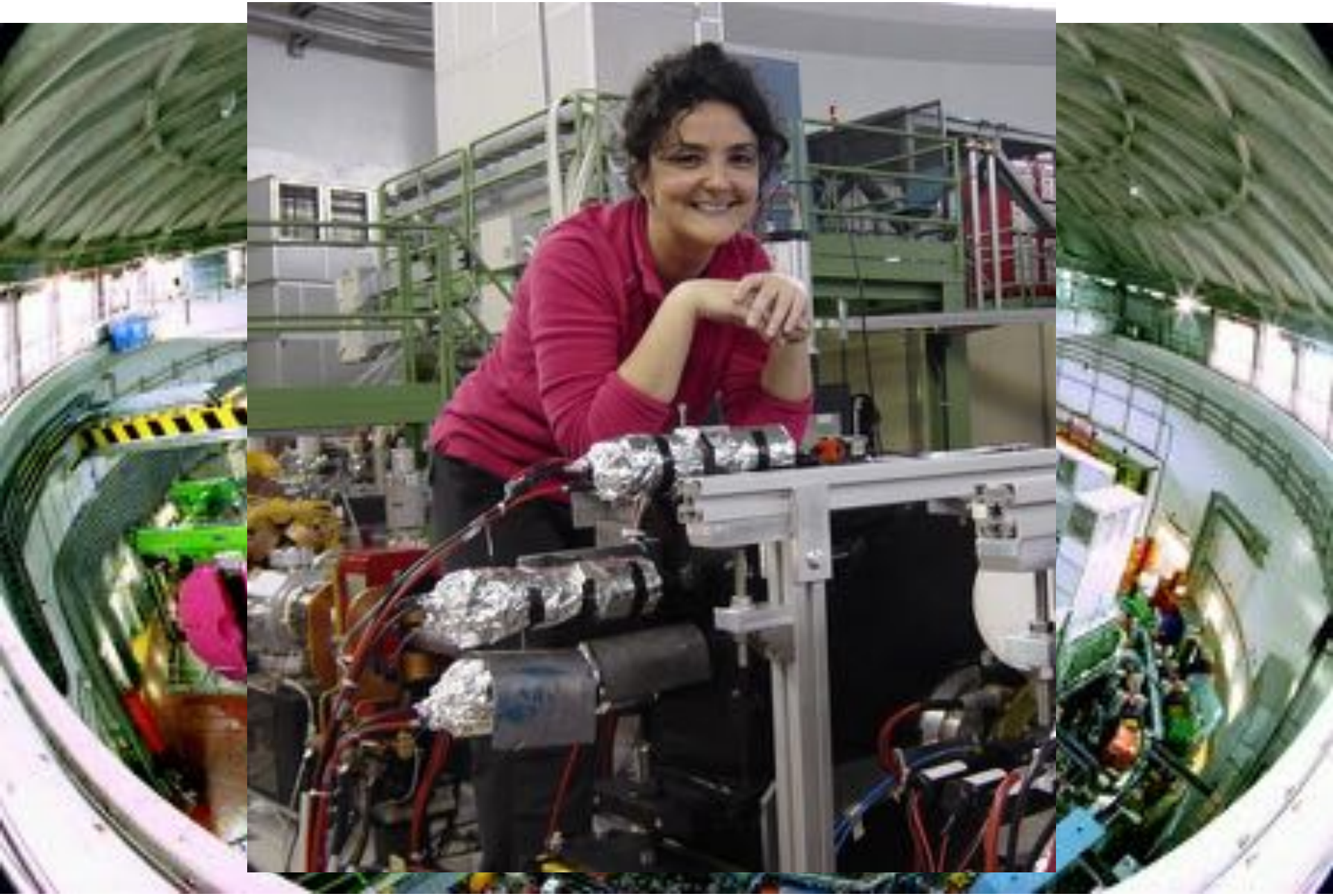



MakeAGIF.com


UKRAINE
Chernivtsi
Satu Mare
Baia Mare
Borşa
Câmpulung Moldovenesc
Botoşani
Suceava
Dorohoi
Debrecen
HUNGARY
MOLDOVA
Oradea
Zalău
Dej
Bistriţa
Piatra-Neamţ
Iaşi
Chişinău
Salonta
Cluj-Napoca
Reghin
Bicaz
Roman
Huşi
Gheorgheni
Turda
Târgu Mureş
Bacău
ROMANIA
Arad
Aiud
Sighişoara
Onești
Bârlad
Alba Iulia
Mediaş
Sibiu
Făgăraş
Gheorghe
Tecuci
UKRAINE
Deva
Sebeş
Timişoara
Lugoj
Hunedoara
Braşov
Săcele
Focşani
Galaţi
Petroşani
Reşiţa
Câmpulung
Sinaia
Brăila
Tulcea
Sulina
Râmnicu Vâlcea
Târgu Jiu
Curtea de Argeş
Buzău
Făurei
Belgrade
Moldova Nouă
Ploieşti
Târgovişte
Piteşti
Drobeta-Turnu Severin
SERBIA
Bucharest
BLACK SEA
Năvodari
Slatina
Medgidia
Călăraşi
Craiova
Videle
Constanţa
Calafat
Alexandria
Giurgiu
Mangalia
Ruse
BULGARIA
© 2011 Encyclopædia Britannica, Inc.

Laboratori Nazionali di Frascati





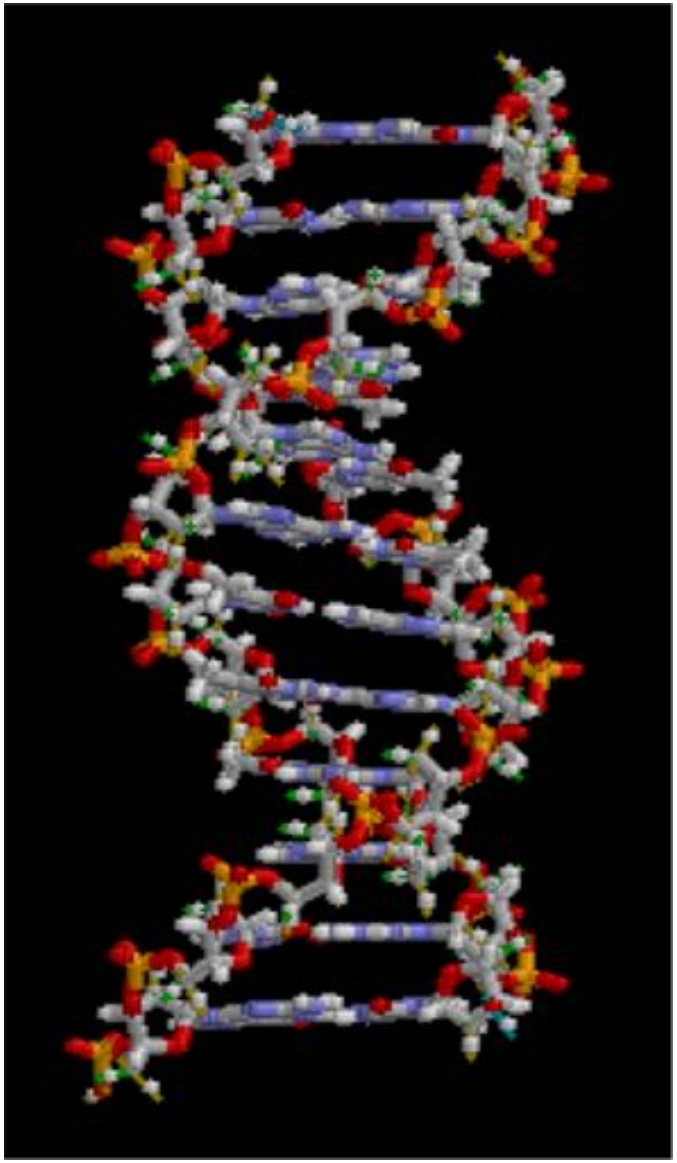
PERIODIC TABLE of the ELEMENTS

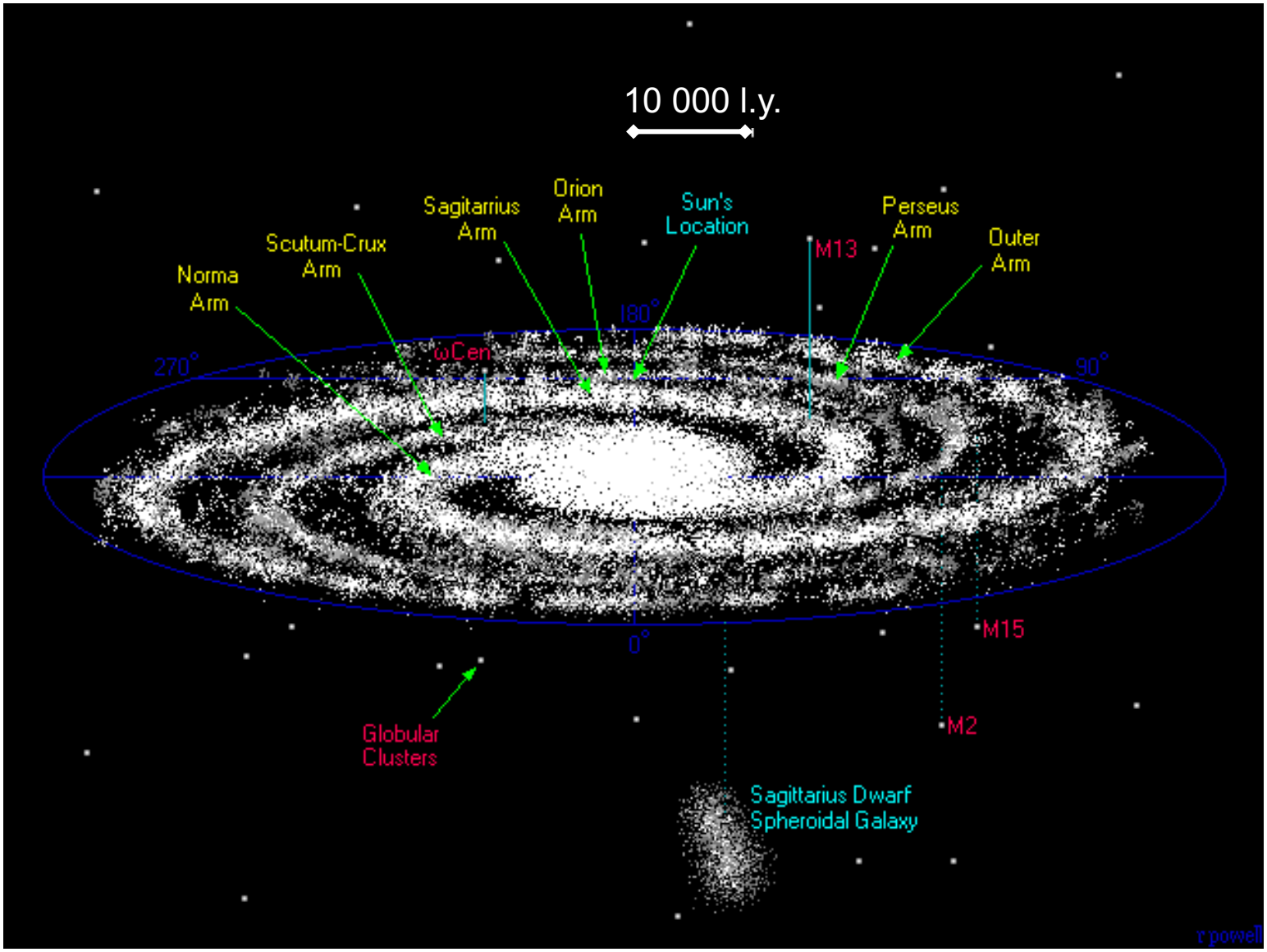
DMITRI MENDELEYEV (1834 – 1907)

H																	He
Li	Be											B	C	N	O	F	Ne
Na	Mg											Al	Si	P	S	Cl	Ar
K	Ca	Sc	Ti	V	Cr	Mn	Fe	Co	Ni	Cu	Zn	Ga	Ge	As	Se	Br	Kr
Rb	Sr	Y	Zr	Nb	Mo	Tc	Ru	Rh	Pd	Ag	Cd	In	Sn	Sb	Te	I	Xe
Cs	Ba	Lanthanide Series	Hf	Ta	W	Re	Os	Ir	Pt	Au	Hg	Tl	Pb	Bi	Po	At	Rn
Fr	Ra	Actinide Series	Rf	Db	Sg	Bh	Hs	Mt									

La	Ce	Pr	Nd	Pm	Sm	Eu	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu
Ac	Th	Pa	U	Np	Pu	Am	Cm	Bk	Cf	Es	Fm	Md	No	Lr

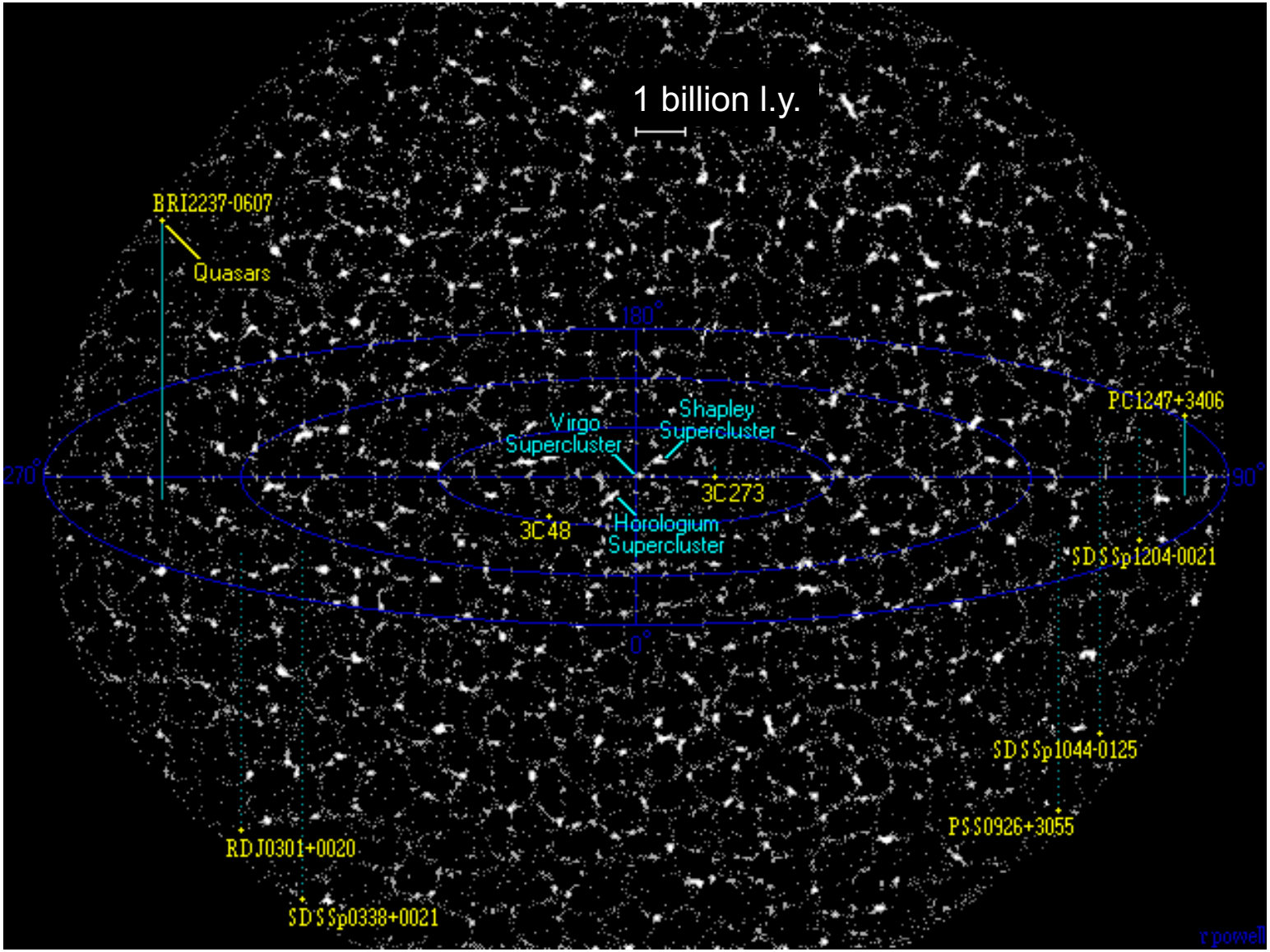

H2O
H
H
O





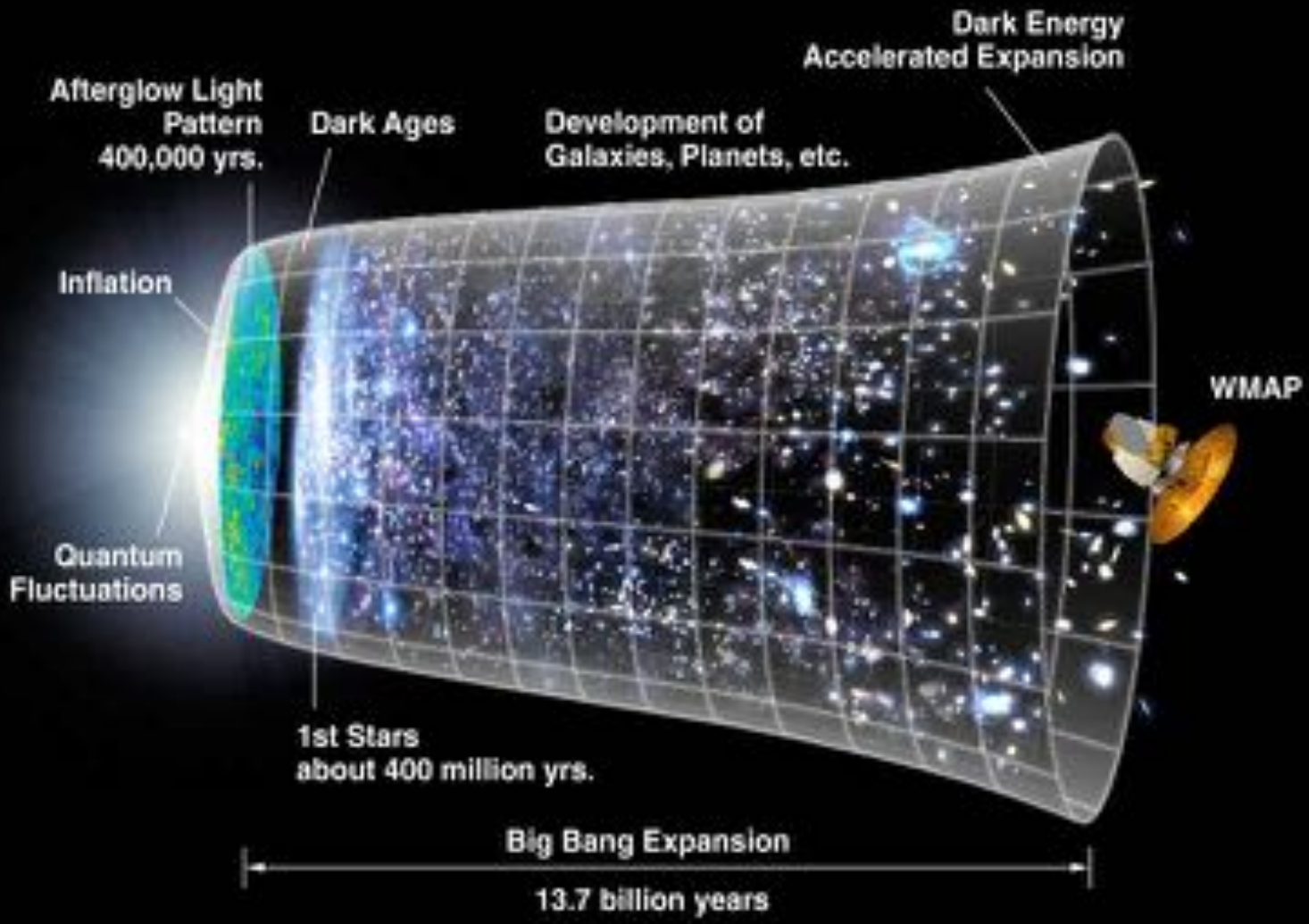
Zoom In x10

Zoom Out x10


1 billion l.y.
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

The Big Bang Model



Modern Physics

Two **"scientific revolutions"** are the pillars of MODERN PHYSICS; both of them born about 100 years ago

Both these theories are going far beyond the so-called "common sense" experience, and happened when physicists dared to look beyond

There two revolutionary theories are:

- **Theory or Relativity**
- **Quantum Mechanics**

Relativity

Used to describe behaviour of **"bodies" moving with high speed (compared to light).**

Special relativity

- No object can move with speed higher than the light
- Mass and energy equivalence

$$E = m c^2$$

General relativity

- Contains effects from gravity; related to black holes, Universe expansion and fate….

Einstein in 1905, age 26

La teoria della Relatività Ristretta

Un po' di matematica.

- Dilatazione dei tempi

$$\Delta t = \frac{\Delta t_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

- Contrazione delle lunghezze

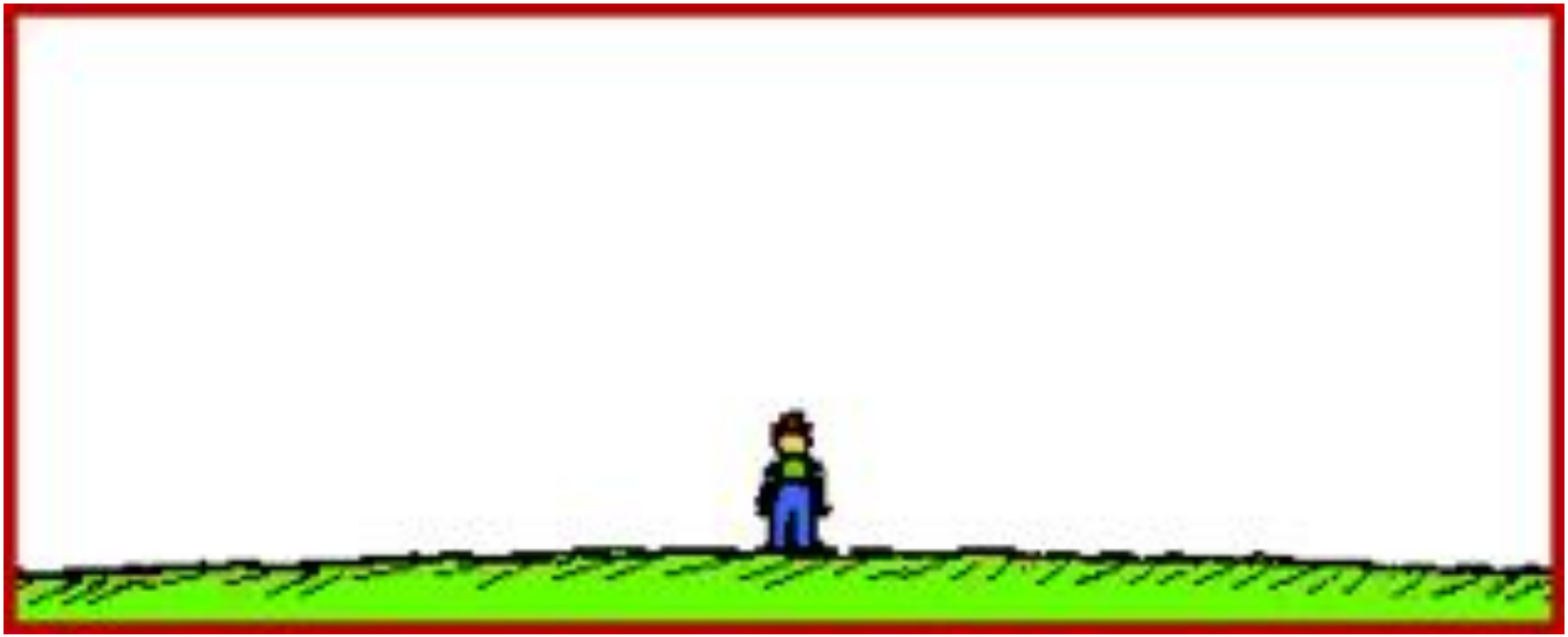
$$l = l_0 \sqrt{1 - \frac{v^2}{c^2}}$$

- Aumento delle masse

$$m = \frac{m_0}{\sqrt{1 - \frac{v^2}{c^2}}}$$

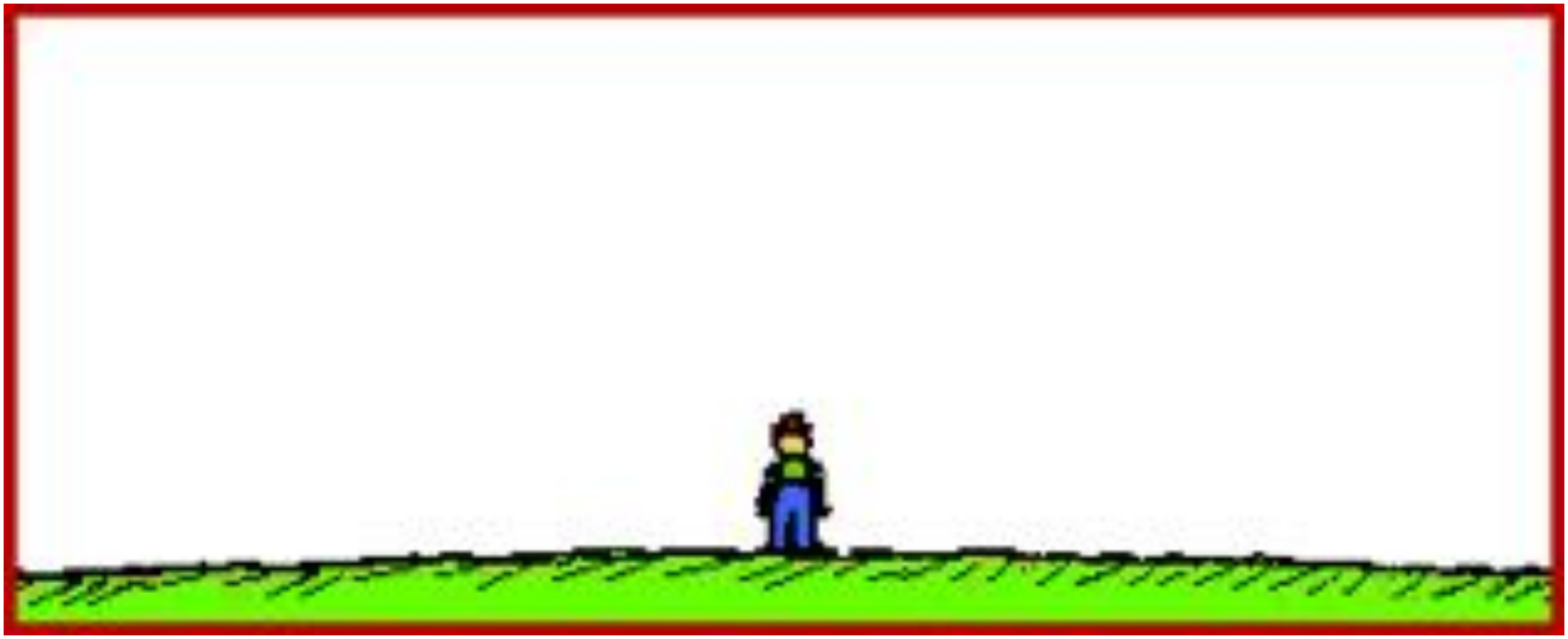
Length contraction

- 10% speed of light



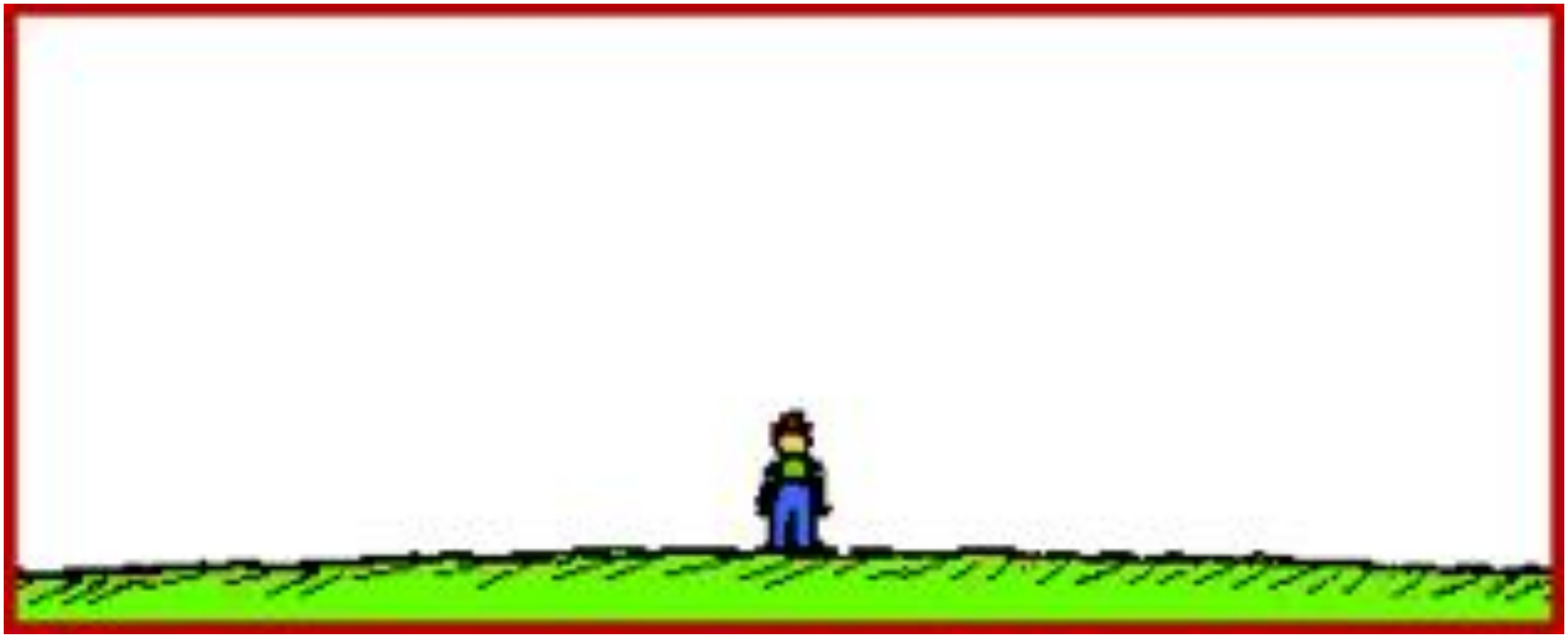
Length contraction

- 86% speed of light



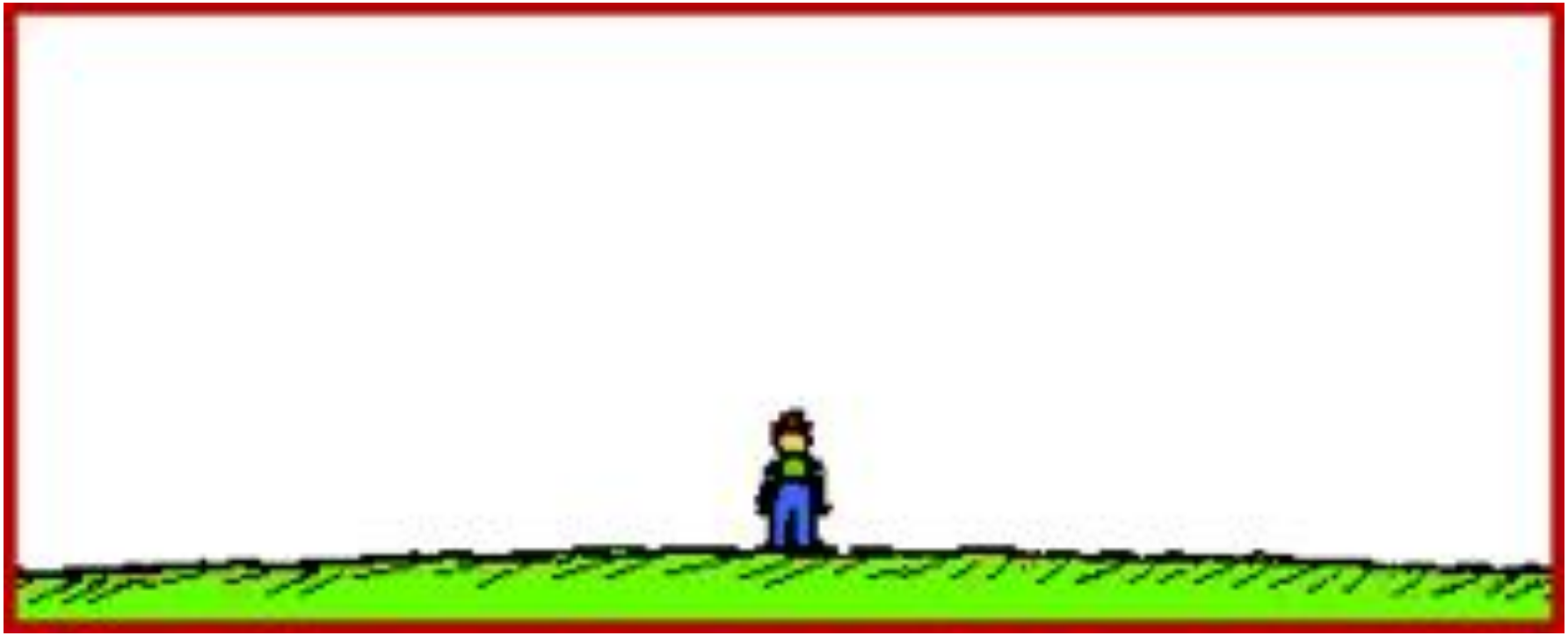
Length contraction

- 99% speed of light



Length contraction

- 99.99% speed of light




BACK
TO THE FUTURE

Quantum Mechanics

Describes the behaviour of **"objects" which are very small (particles…)**

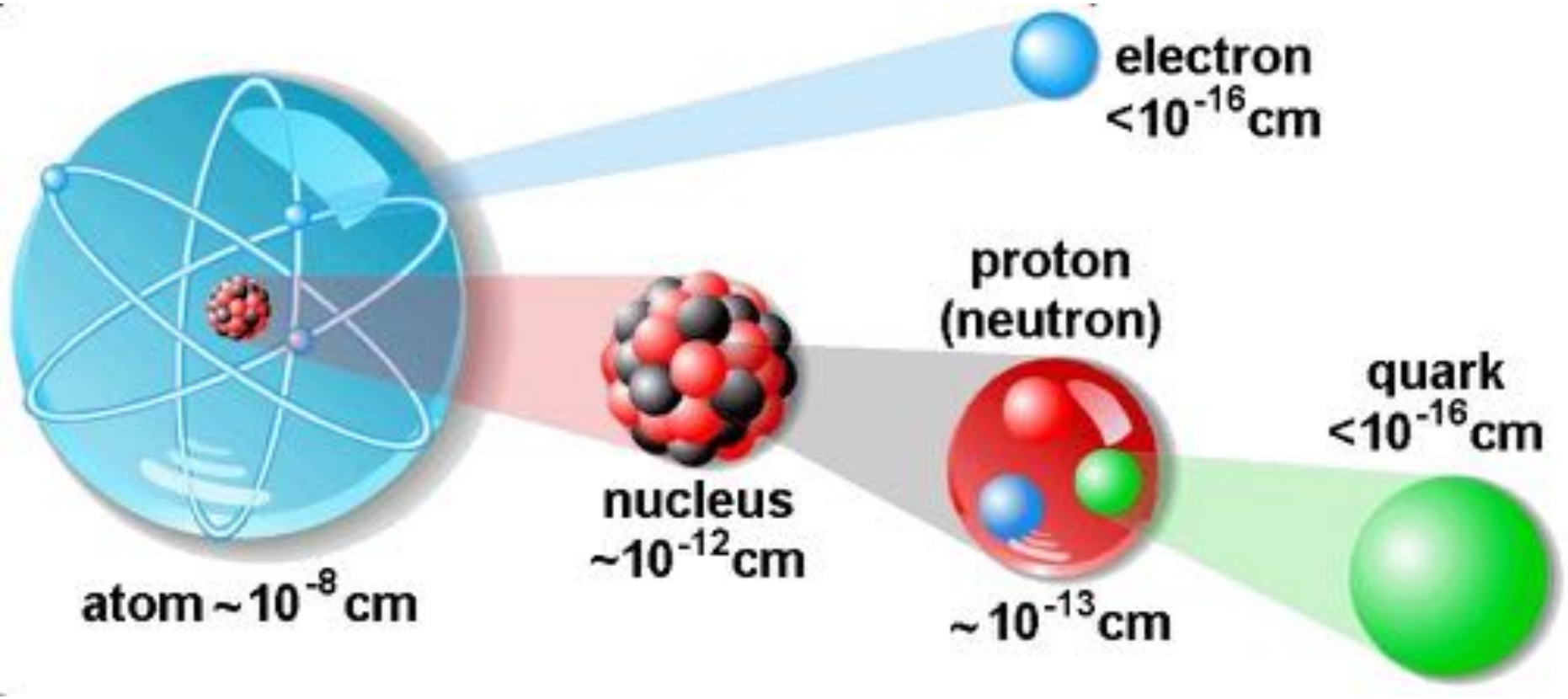
Heisenberg uncertainty principle:

- better we know the position of an object, less we know its speed

To understand and describe particles, nuclei, atoms we need quantum mechanics and relativity (quantum field theory)

Heisenberg in 1925, age 24

Conferenza di Solvay (1927)


electron
<10^-16 cm
proton
(neutron)
quark
<10^-16 cm
nucleus
~10^-12 cm
atom ~10^-8 cm
~10^-13 cm

STANDARD MODEL OF ELEMENTARY PARTICLES

QUARKS

UP
mass 2.3 MeV/c²
charge ⅔
spin ½
u

CHARM
1.275 GeV/c²
⅔
½
c

TOP
173.07 GeV/c²
⅔
½
t

GLUON
0
0
1
g

HIGGS BOSON
126 GeV/c²
0
0
H

DOWN
4.8 MeV/c²
-⅓
½
d

STRANGE
95 MeV/c²
-⅓
½
s

BOTTOM
4.18 GeV/c²
-⅓
½
b

PHOTON
0
0
1
γ

LEPTONS

ELECTRON
0.511 MeV/c²
-1
½
e

MUON
105.7 MeV/c²
-1
½
μ

TAU
1.777 GeV/c²
-1
½
τ

Z BOSON
91.2 GeV/c²
0
1
Z

ELECTRON NEUTRINO
<2.2 eV/c²
0
½
ν_e

MUON NEUTRINO
<0.17 MeV/c²
0
½
ν_μ

TAU NEUTRINO
<15.5 MeV/c²
0
½
ν_τ

W BOSON
80.4 GeV/c²
±1
1
W

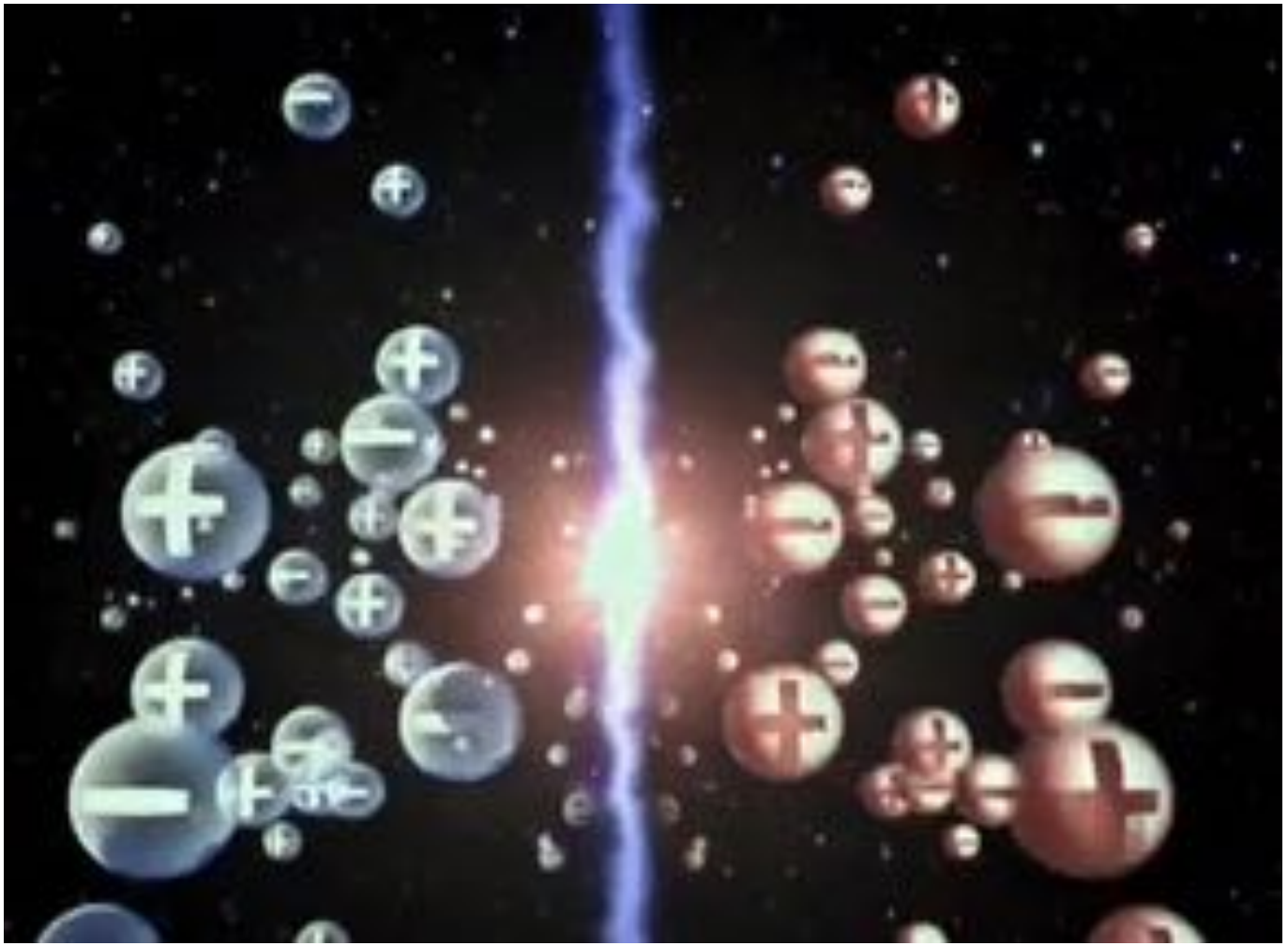
GAUGE BOSONS

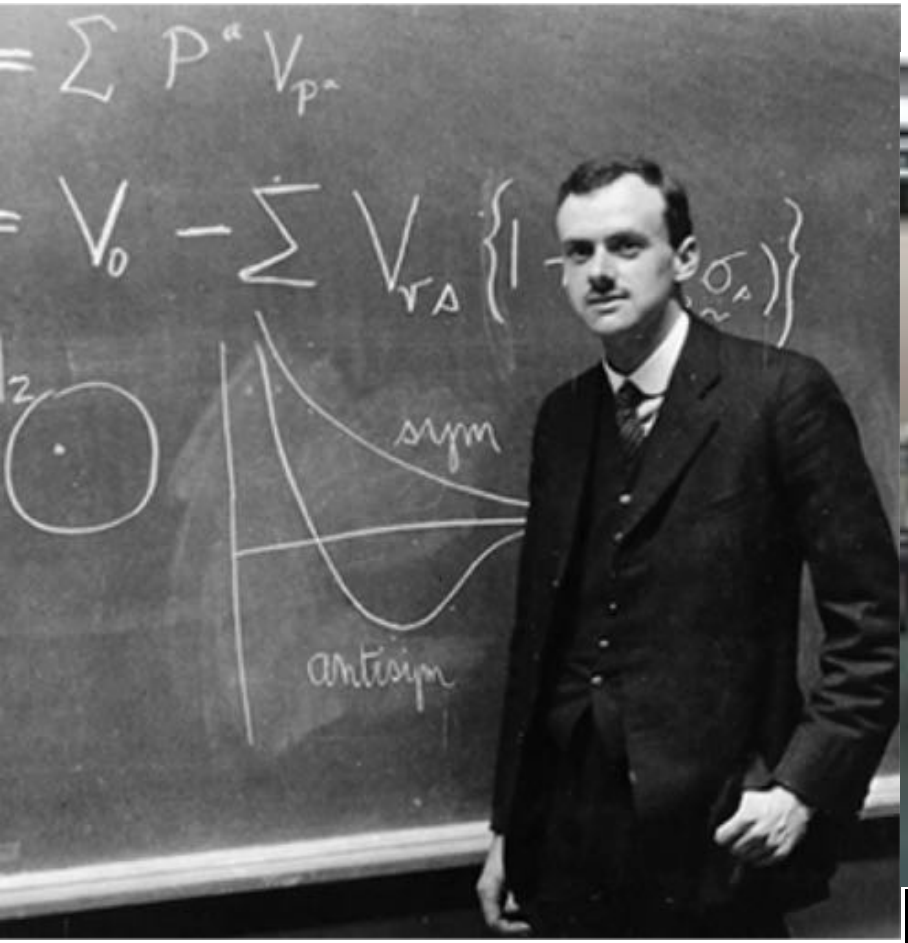
Does not include Gravity!

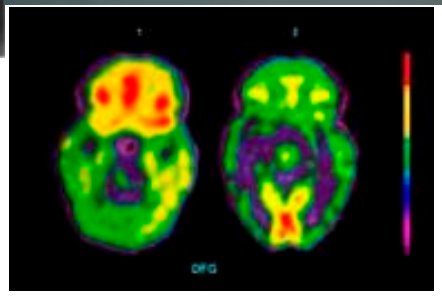
7 mysteries in modern physics:

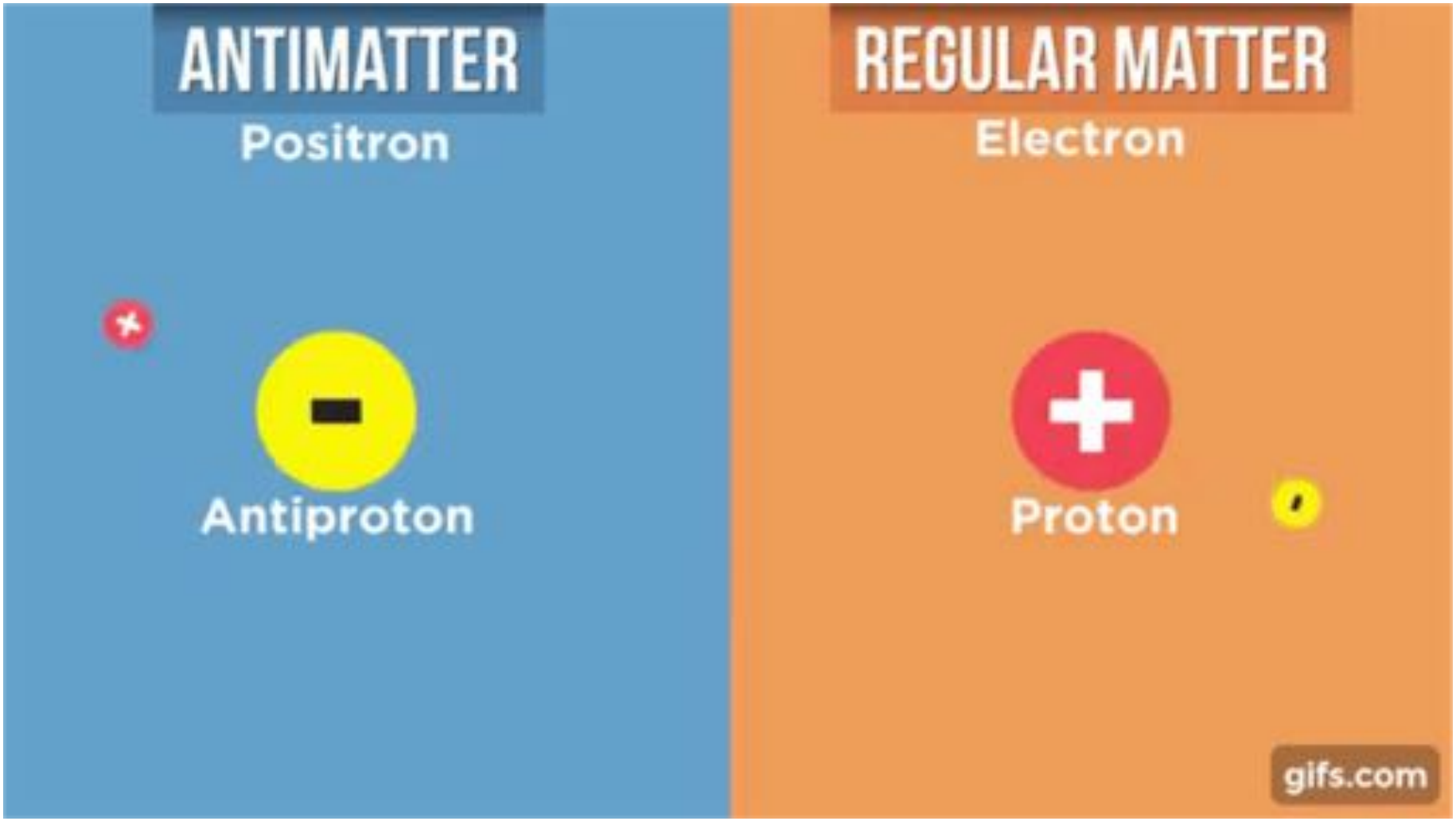
– what happened to antimatter?
– black holes – what happens inside?
– what are the dark matter and dark energy?
– quantum mechanics and the Schroedinger cat paradox – which is the solution?
– the neutron stars structure – is there place for strangeness inside?
– are there other Universes?
- are we alone in the Universe?

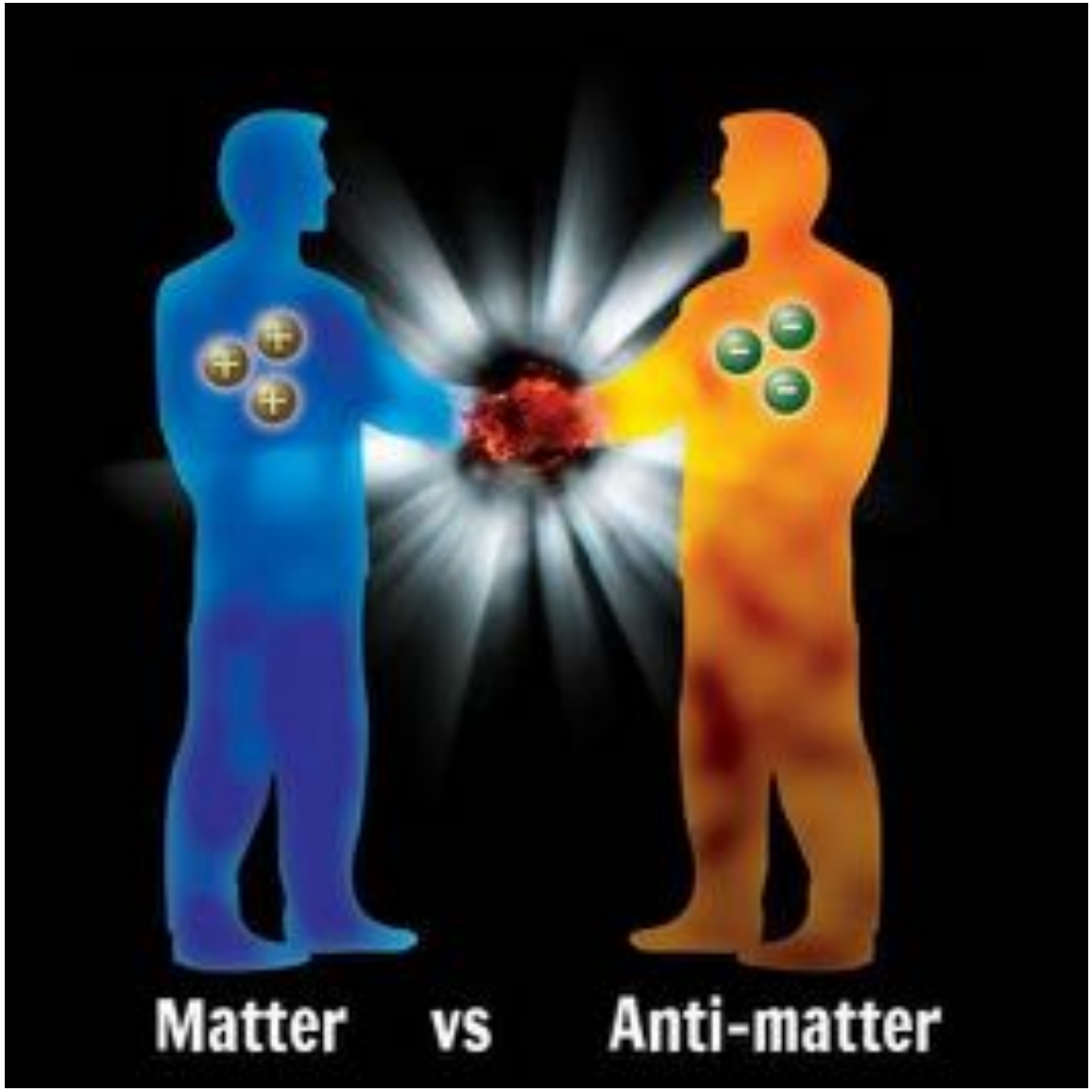
7 mysteries in modern physics:
– what happened to antimatter?



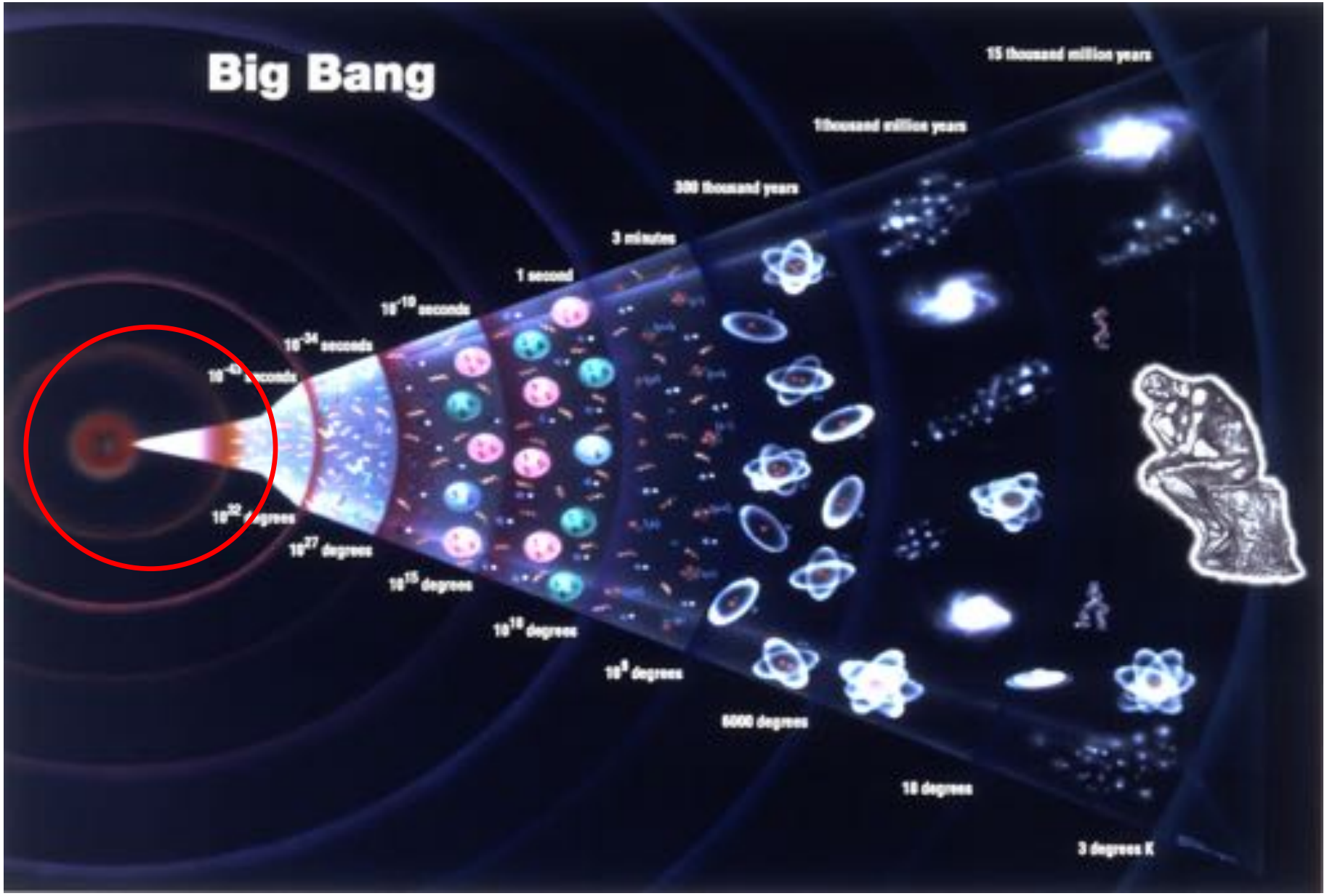

sym
antisym



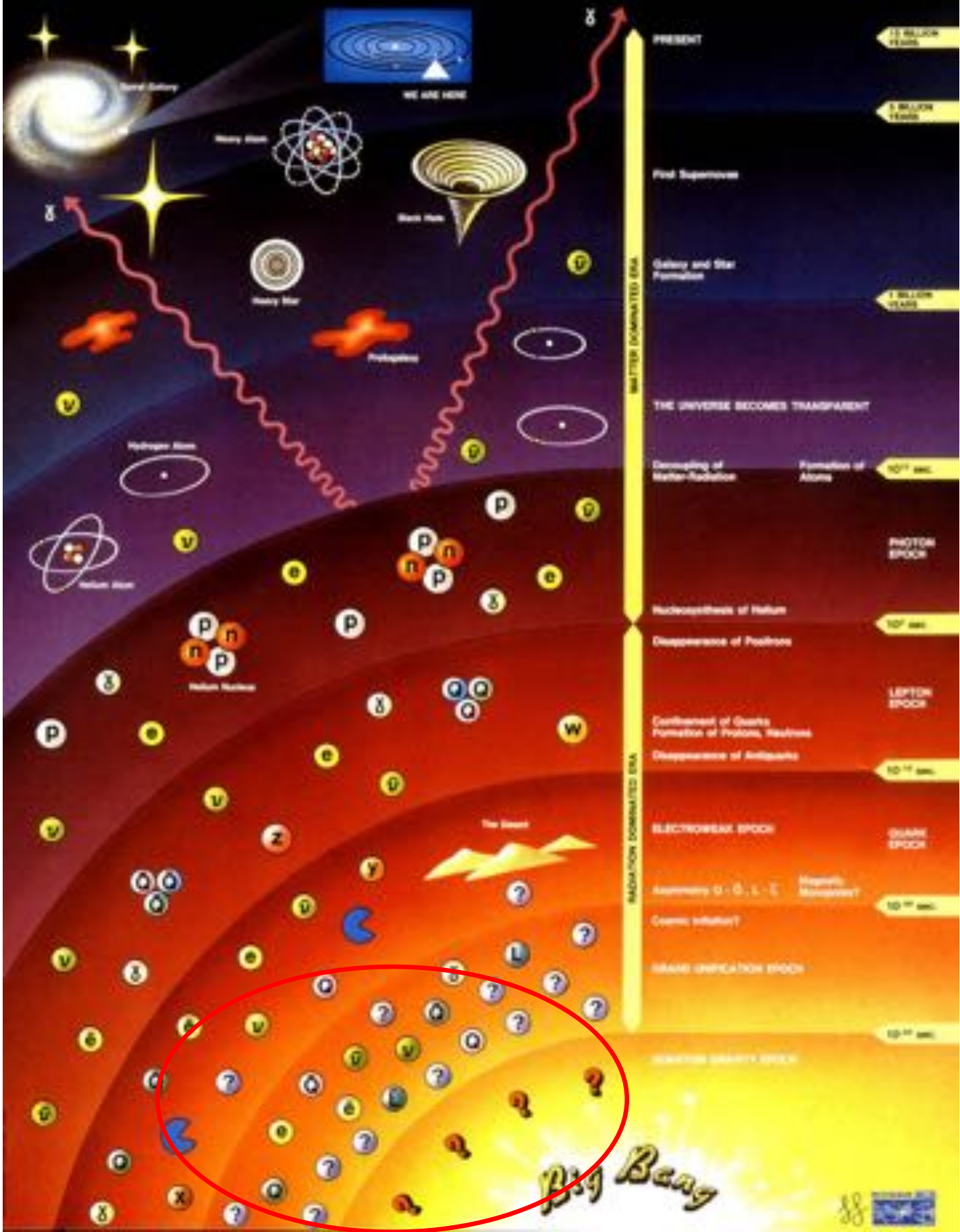

ANTIMATTER
Positron
Antiproton
REGULAR MATTER
Electron
Proton
gifs.com


Matter vs Anti-matter

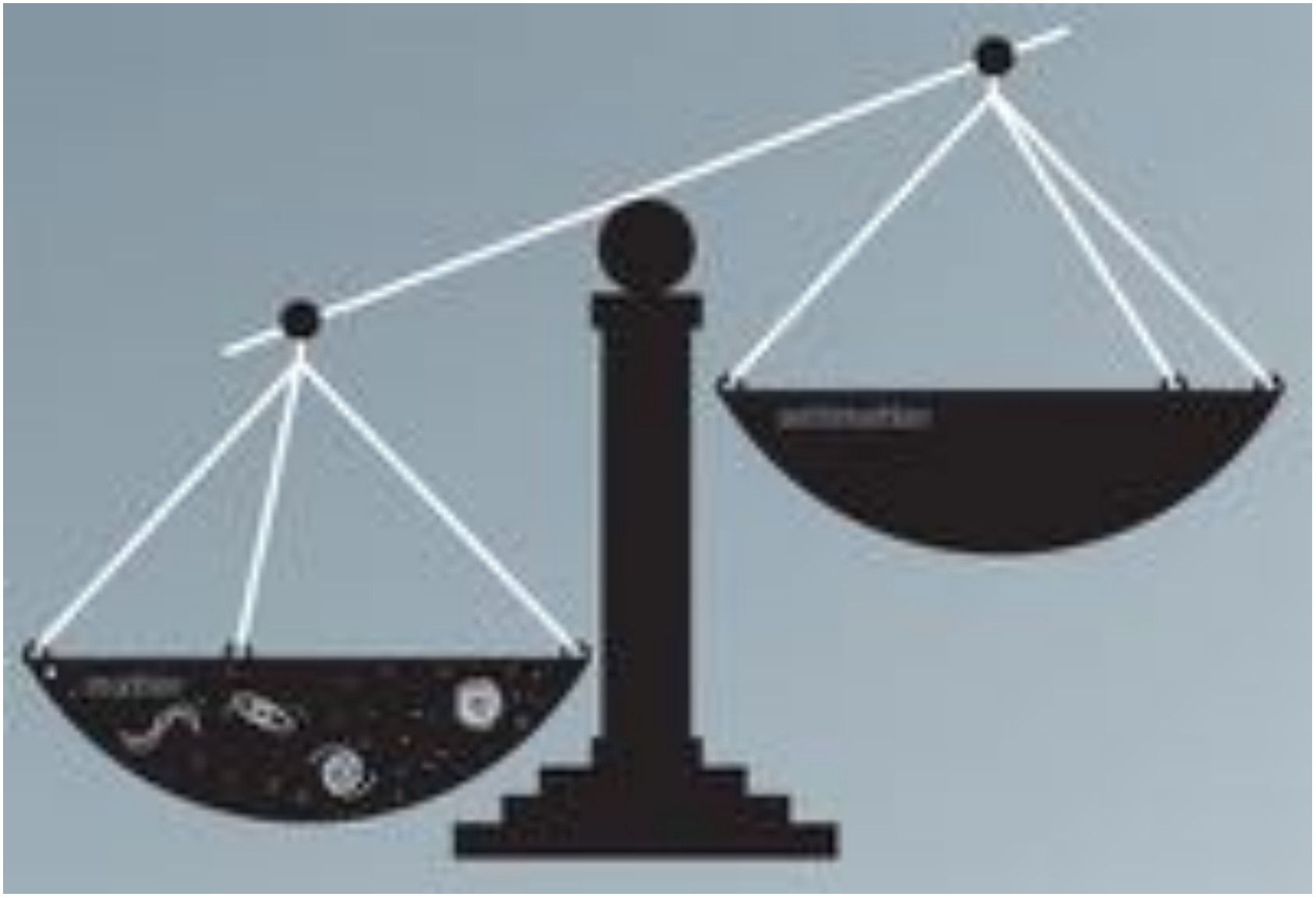
The Big Bang history



History of the Universe

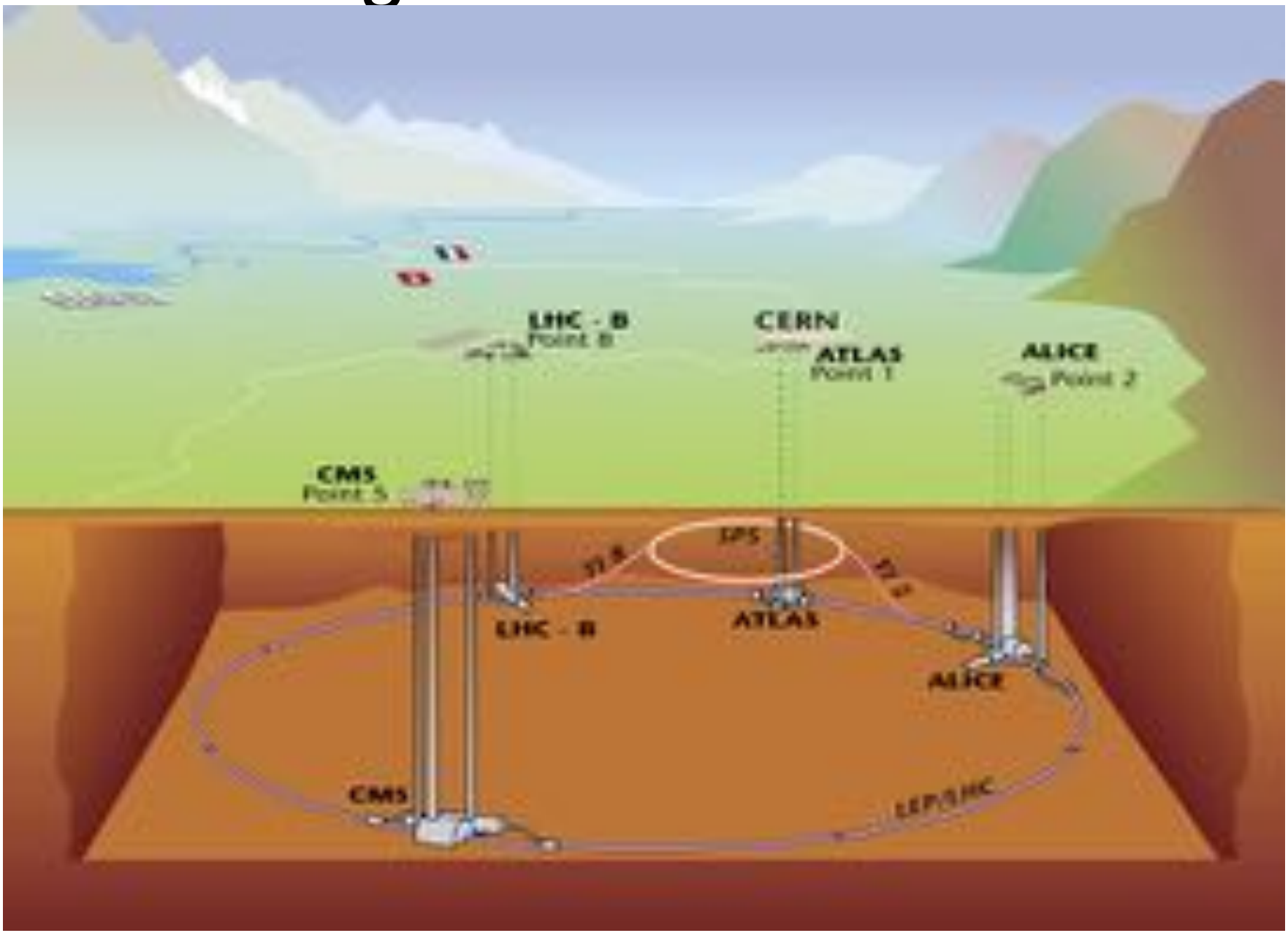



Where is
all the
antimatter?

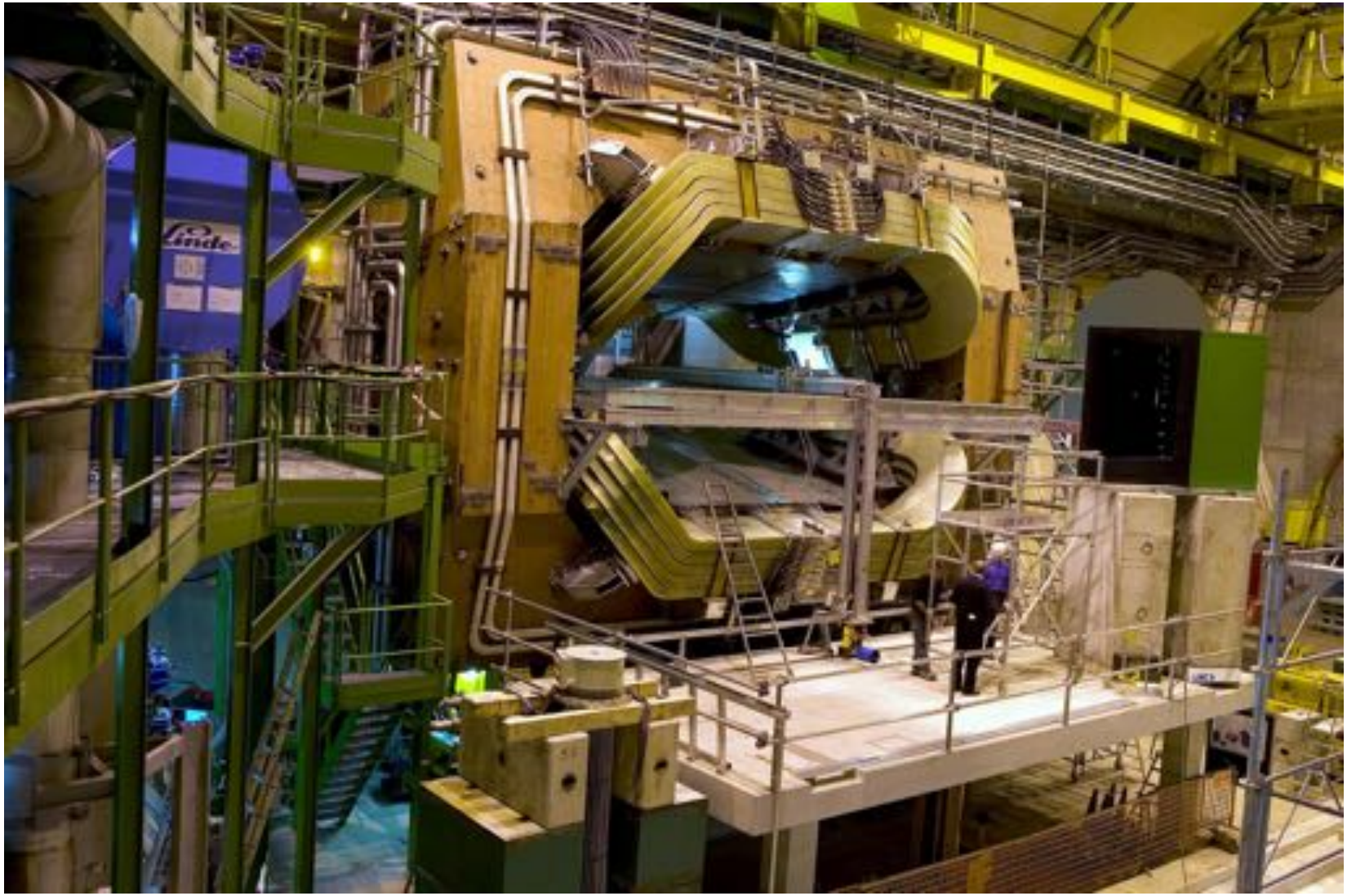


CP violation (CPT)
Assymetry between “laws of matter and laws of antimatter”

Large Hadron Collider

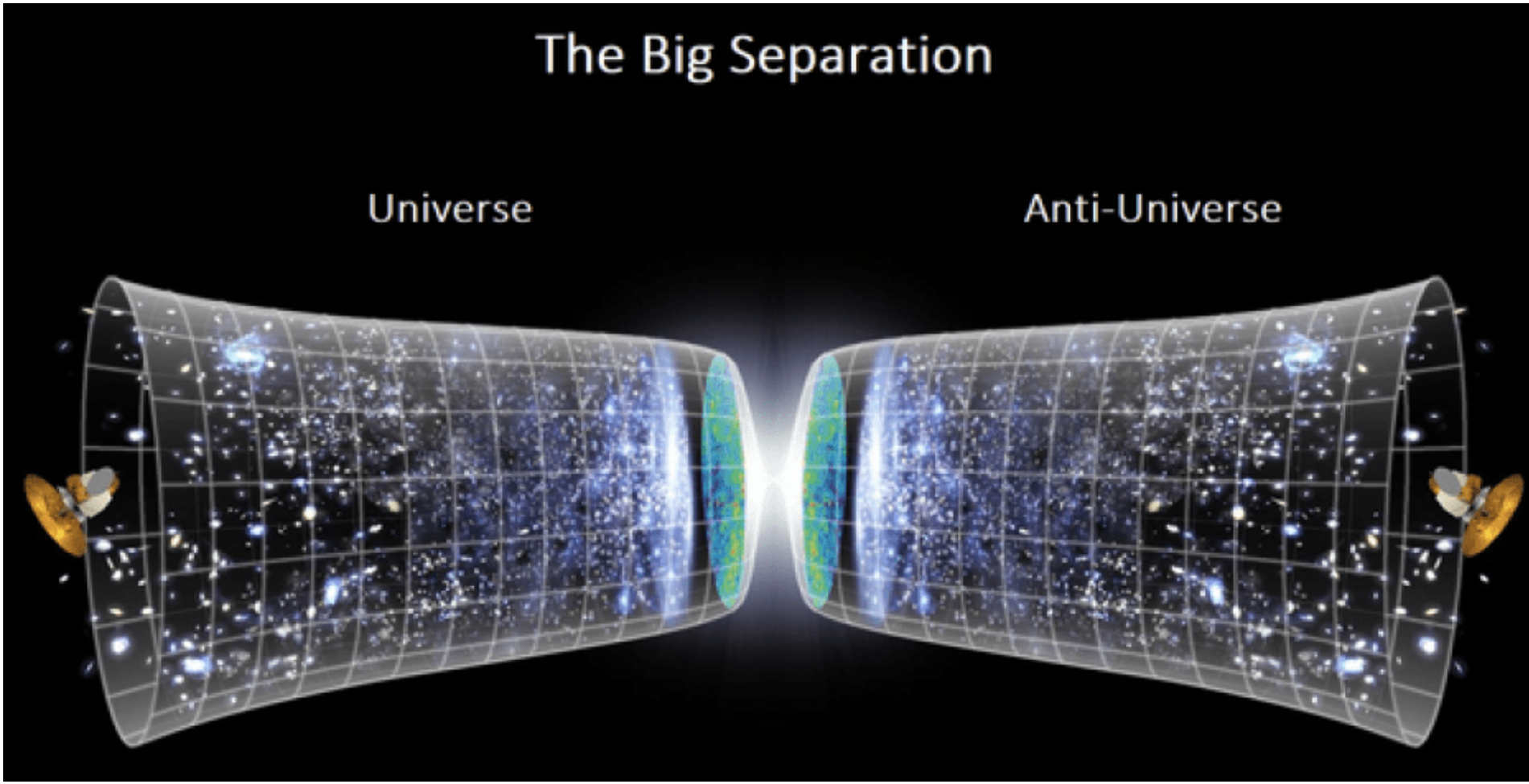


LHCb



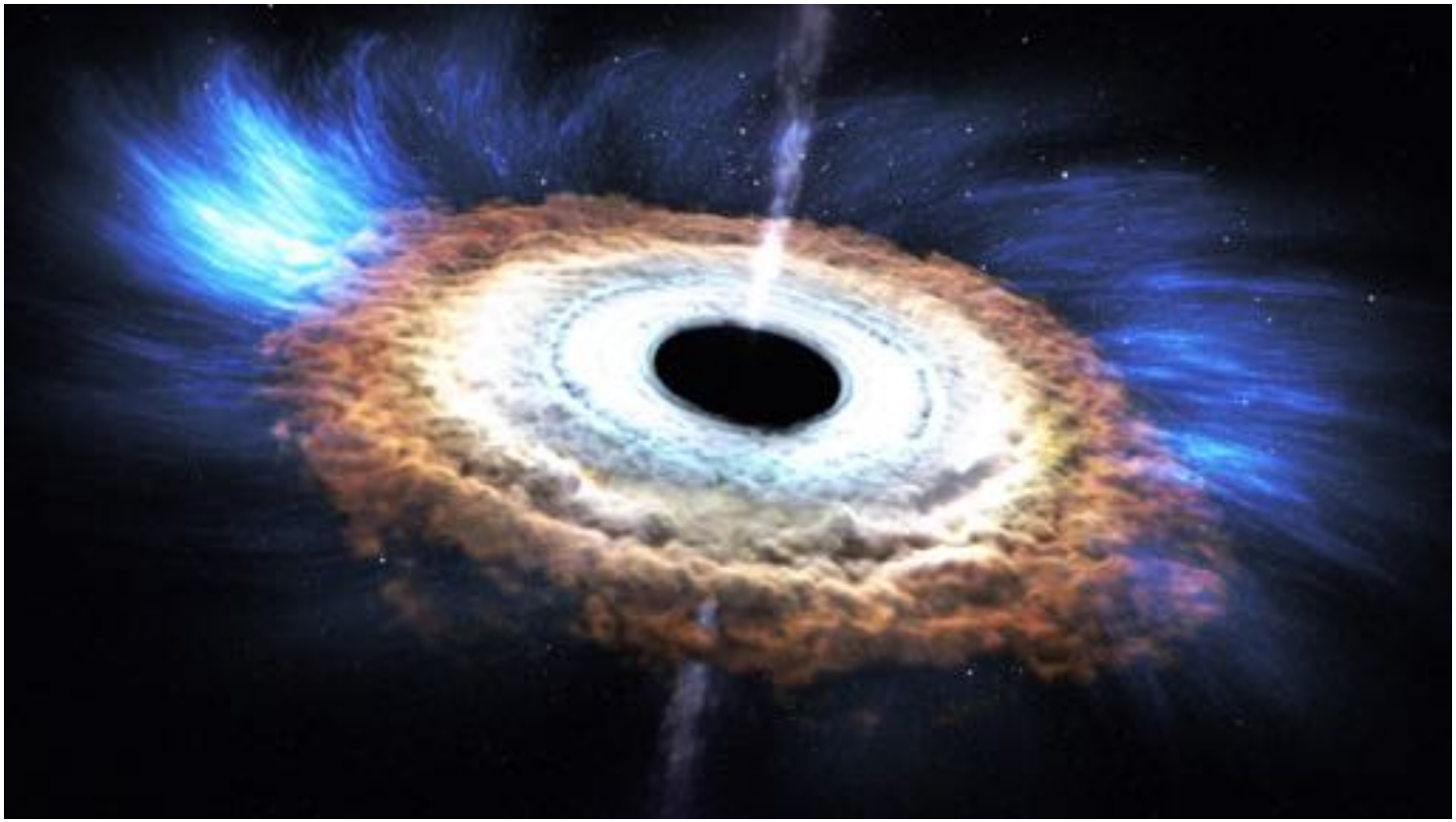
The measured assymetry does not (yet) explain why all antimatter «died»

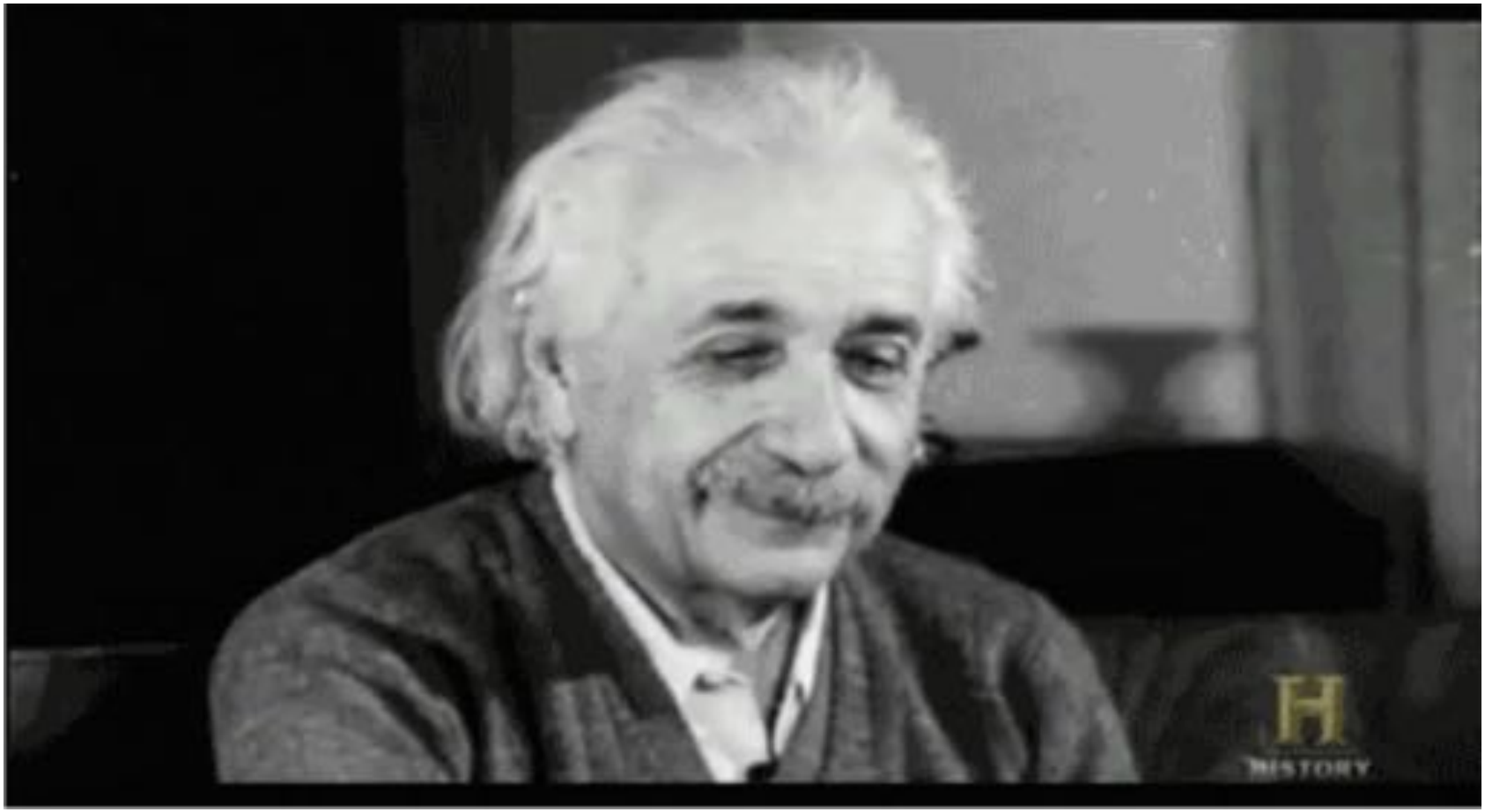
New theory:



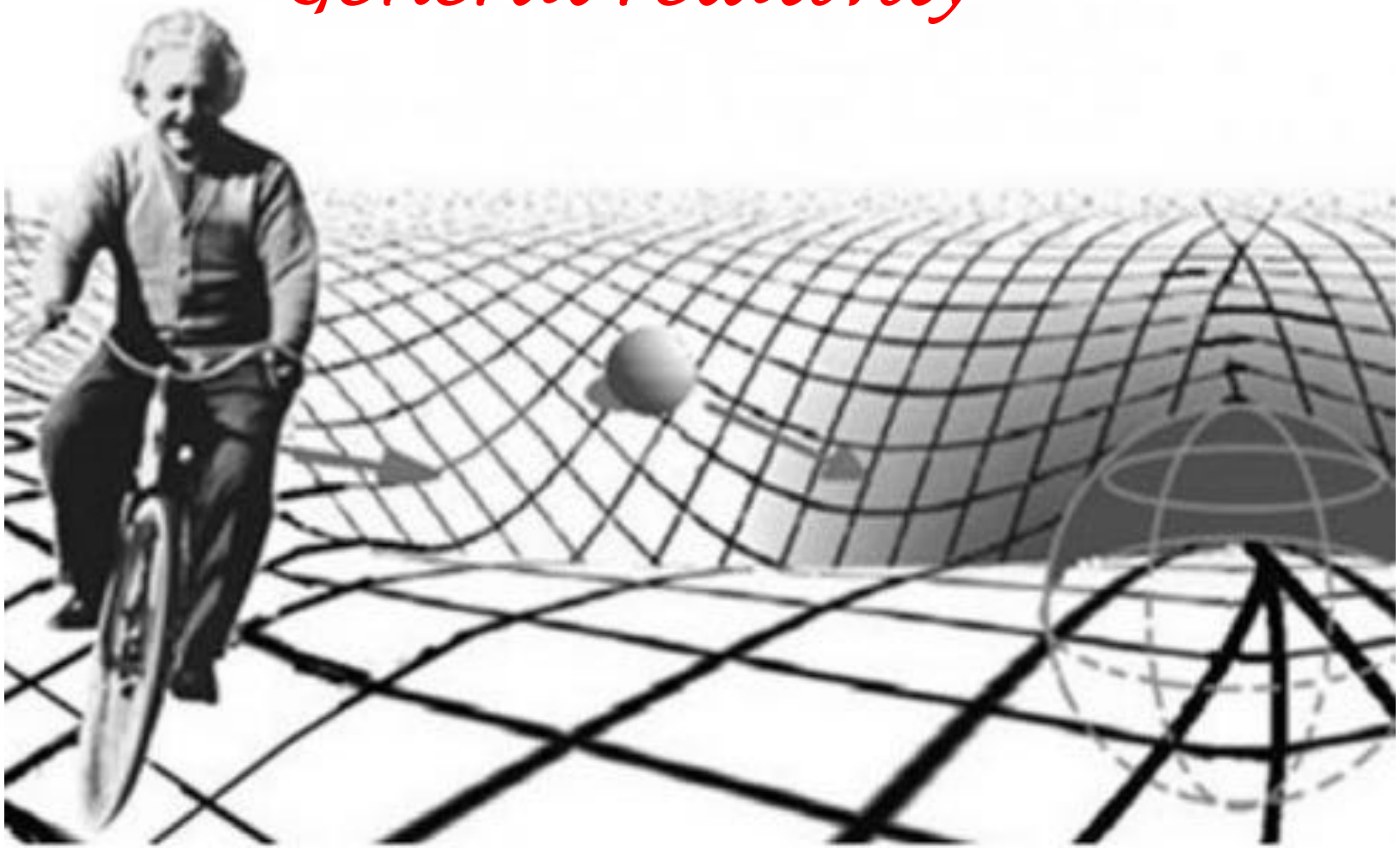
7 mysteries in modern physics:

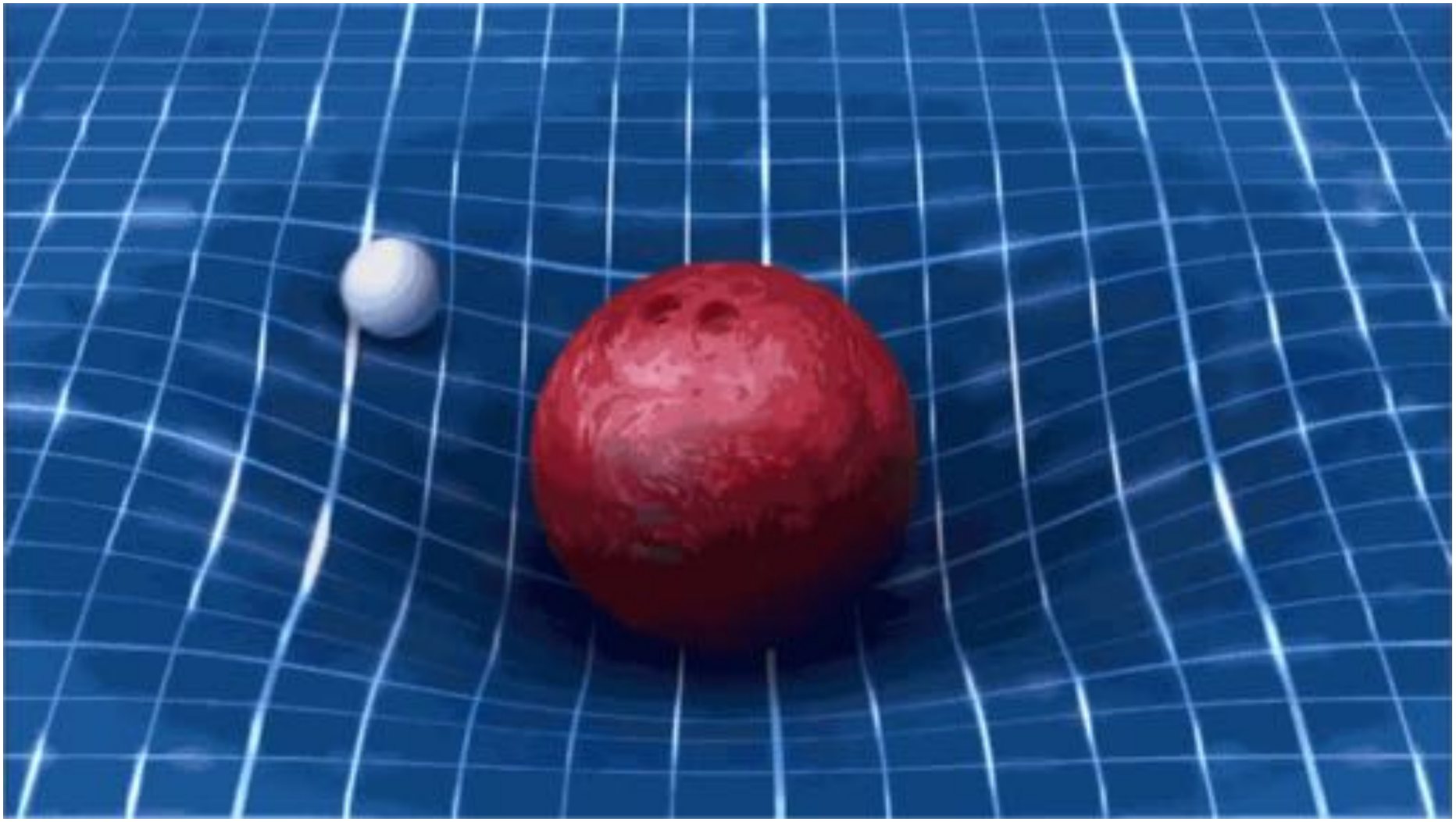
– black holes – what happens inside?



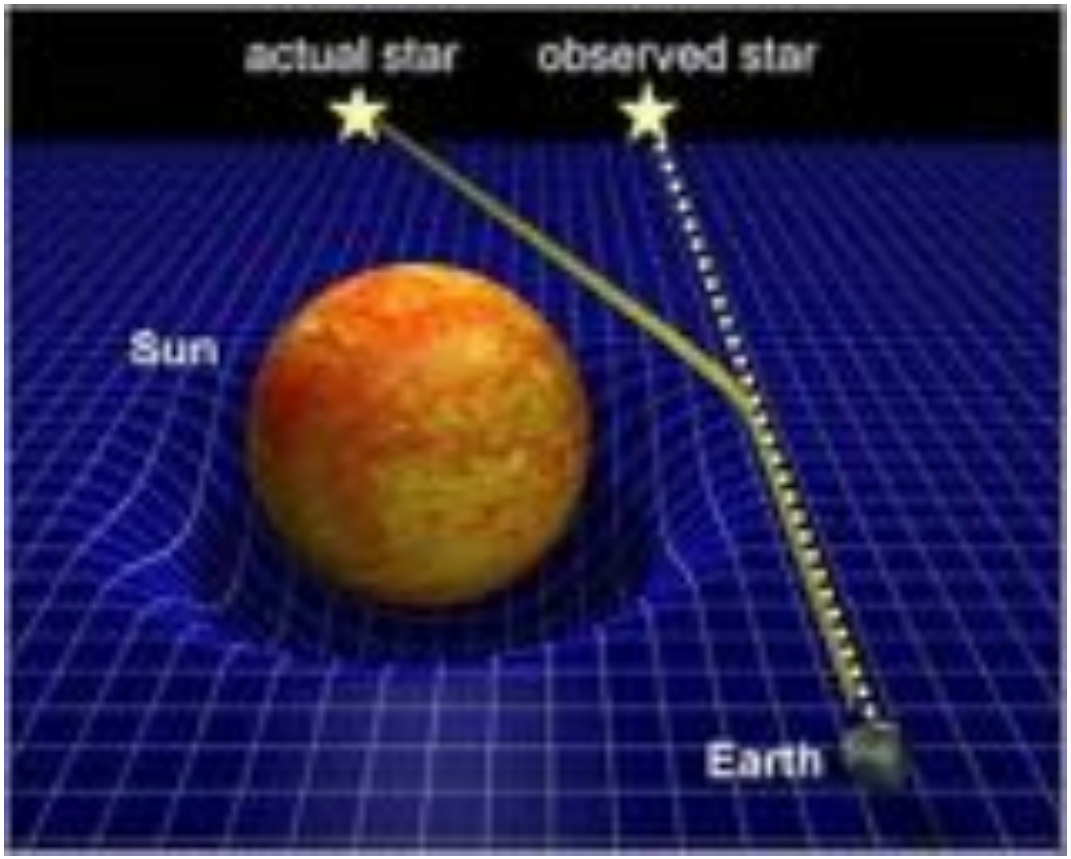

HISTORY

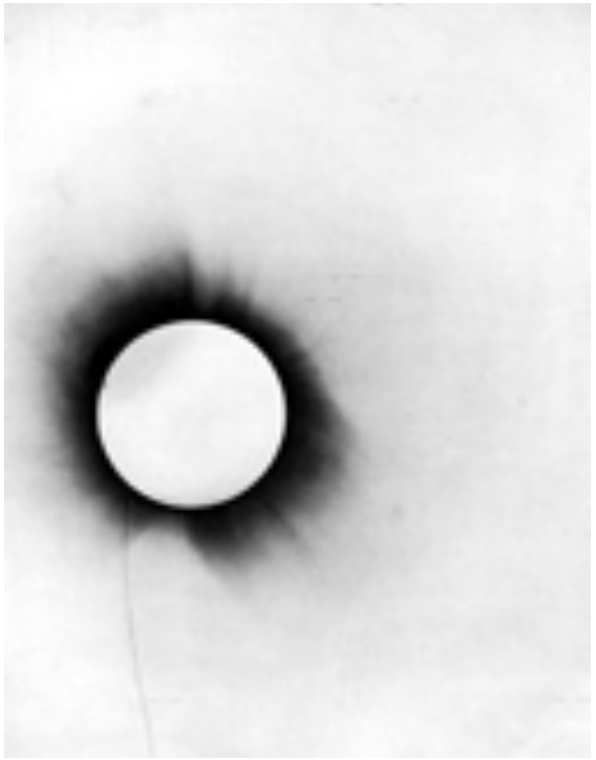
General relativity

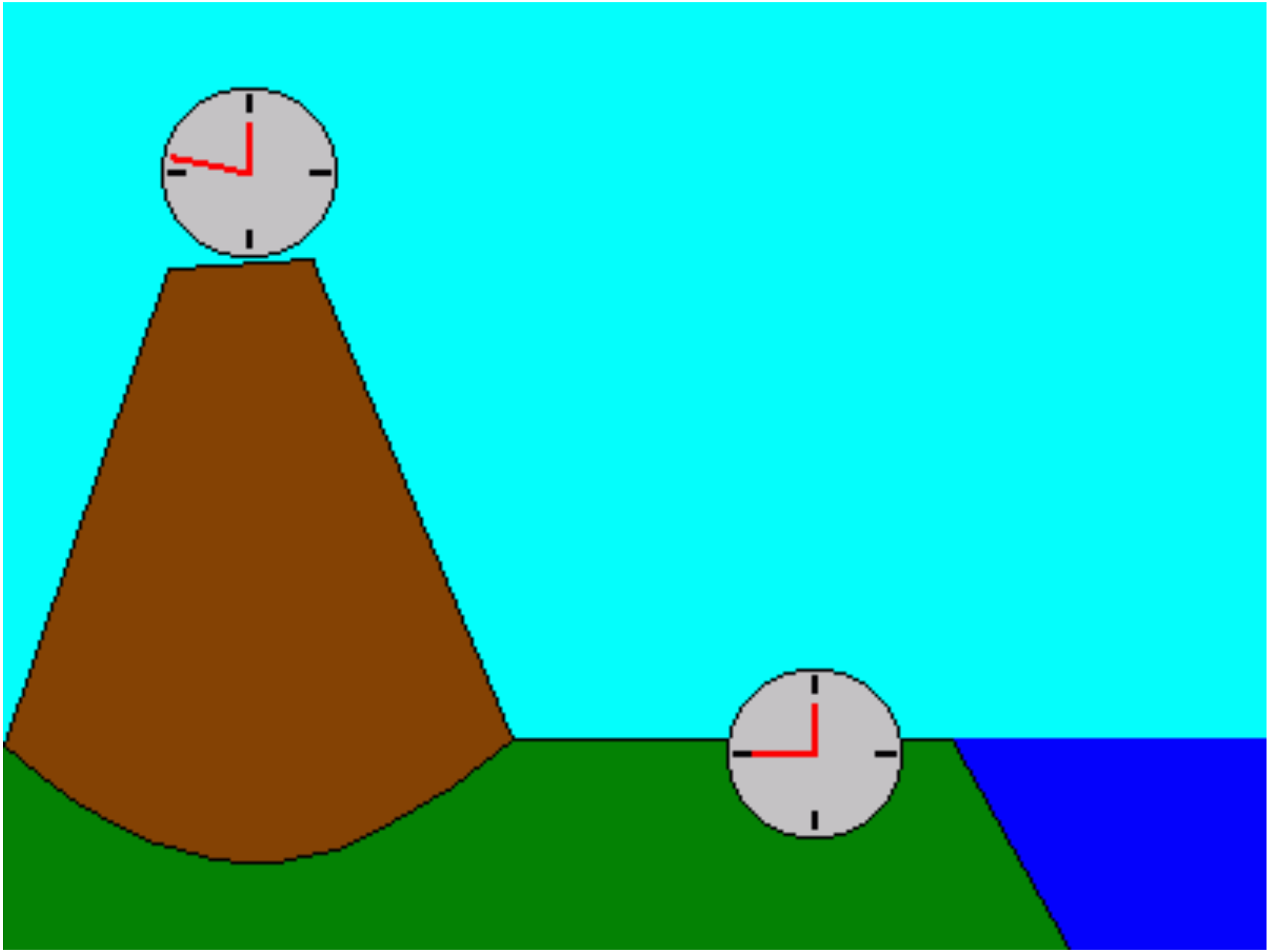


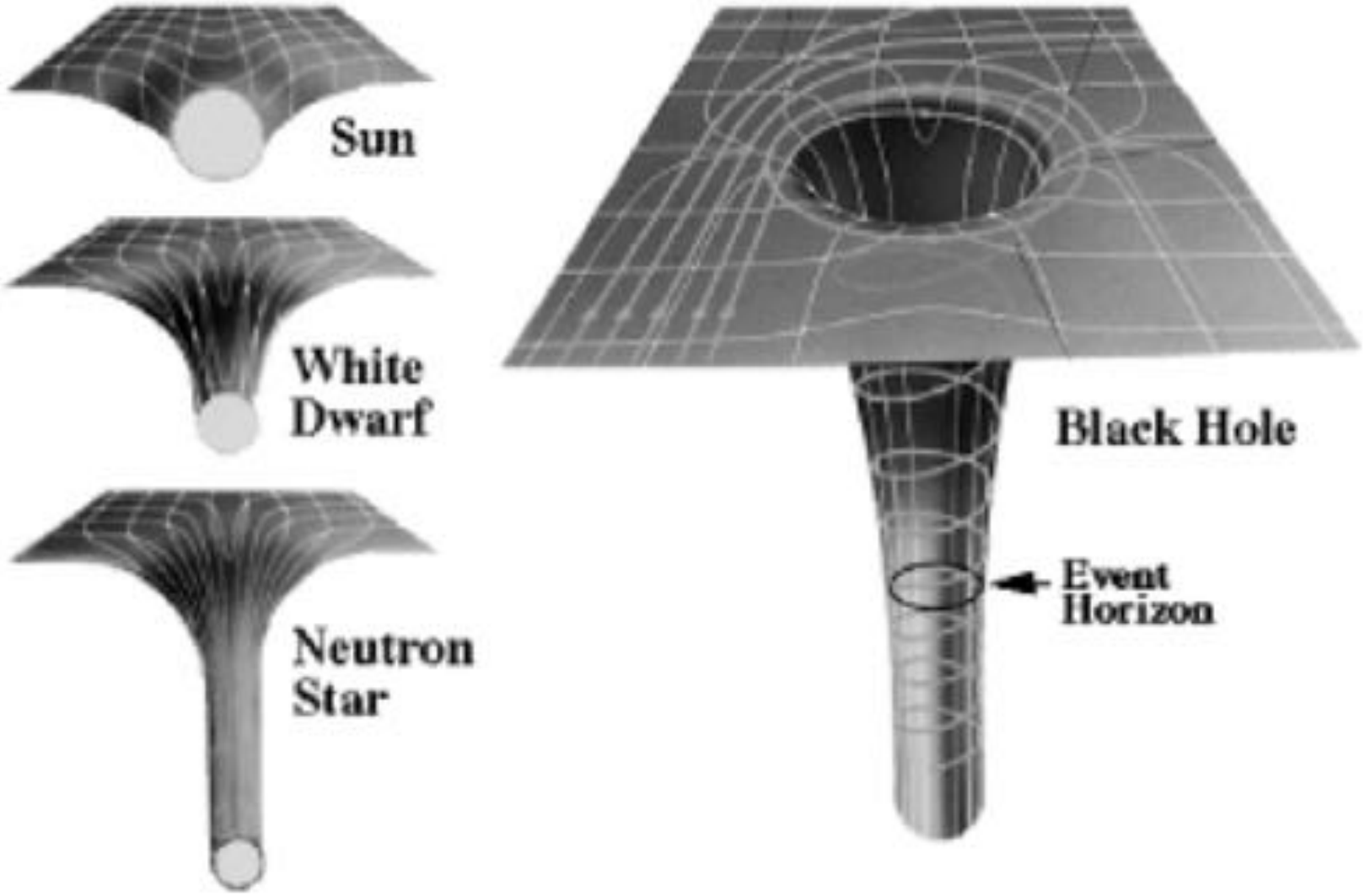



$R_{\mu\nu} - \frac{1}{2} g_{\mu\nu} R = \frac{8\pi G}{c^4} T_{\mu\nu}$
A. EINSTEIN

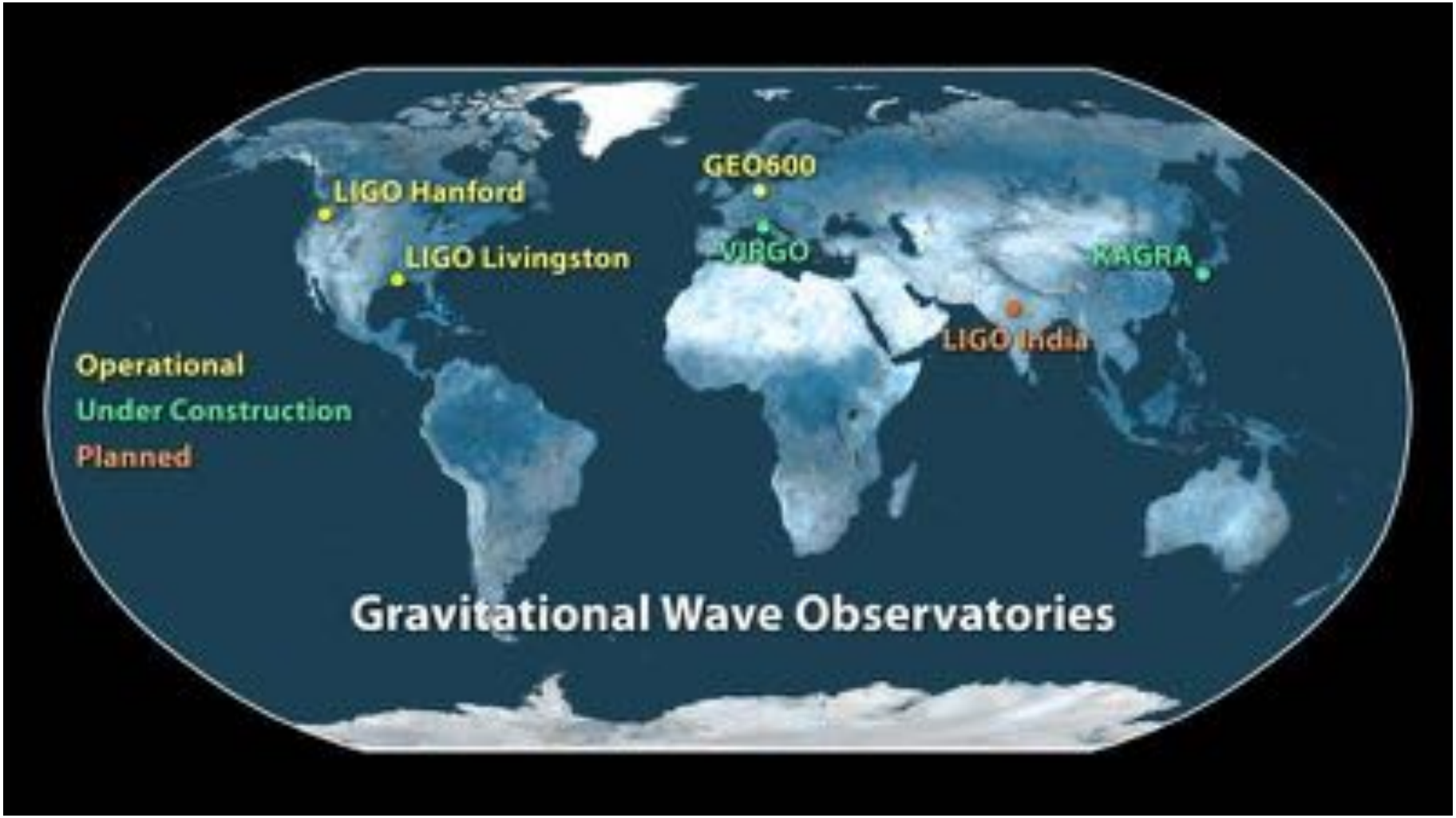

actual star
observed star
Sun
Earth

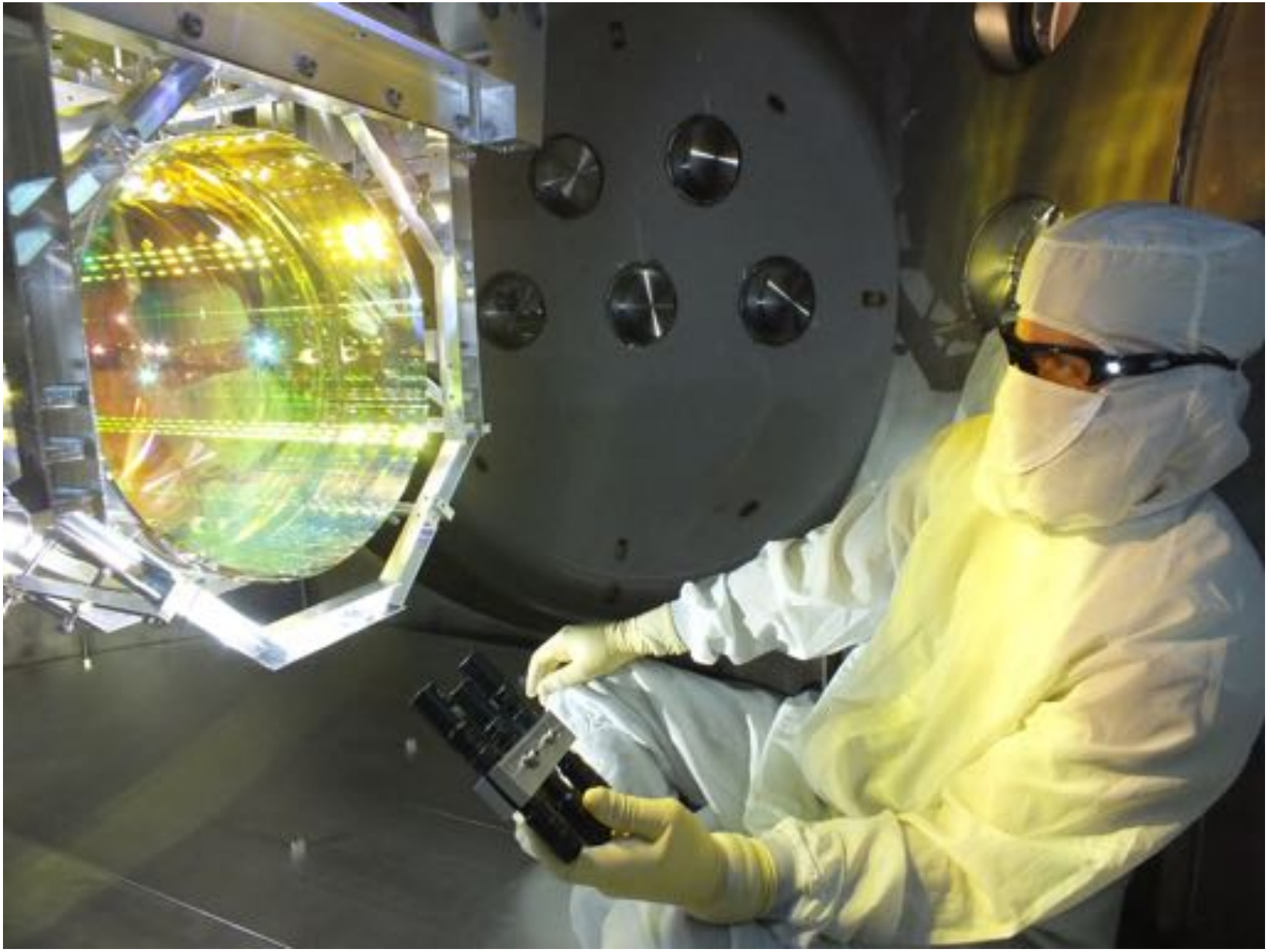


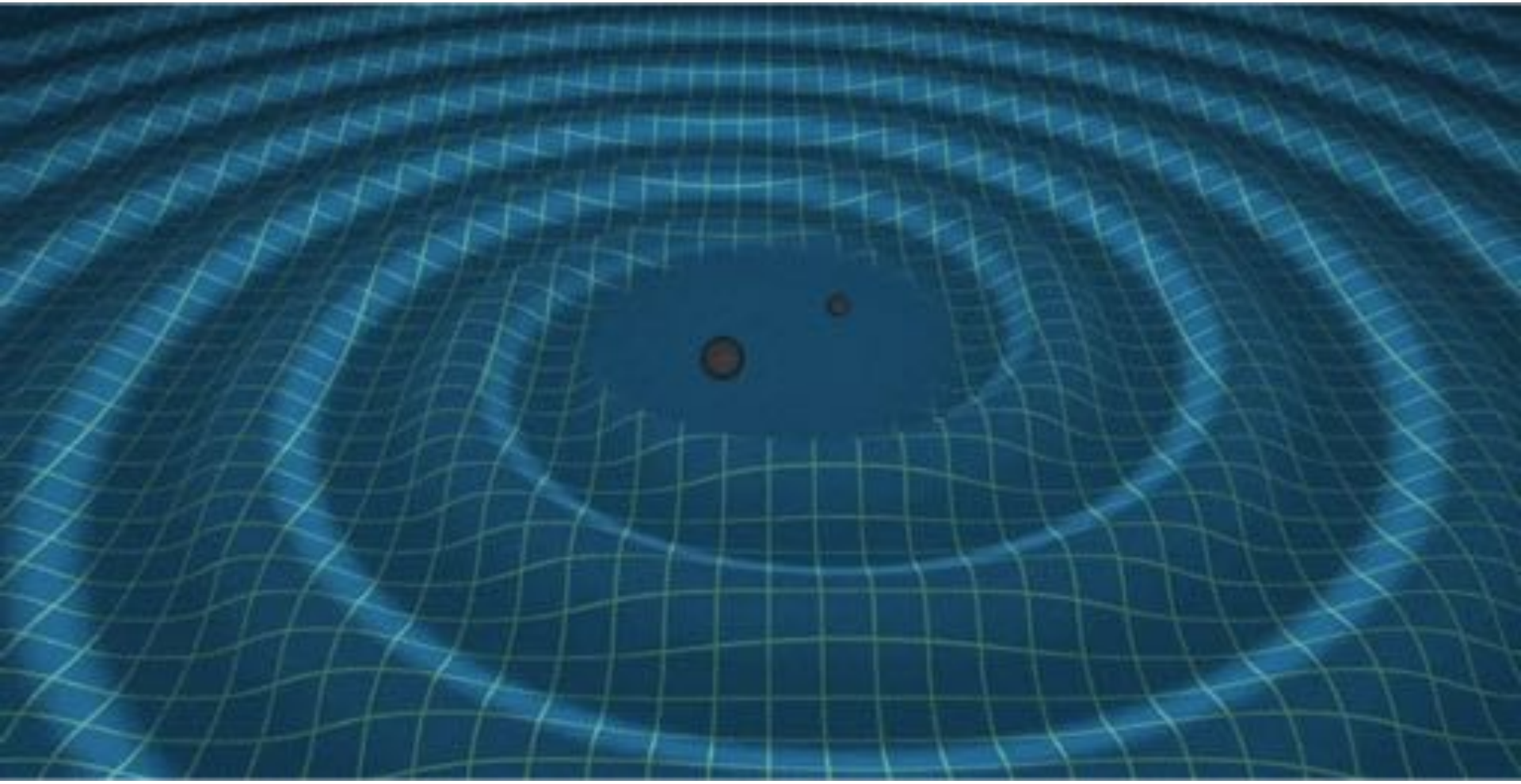


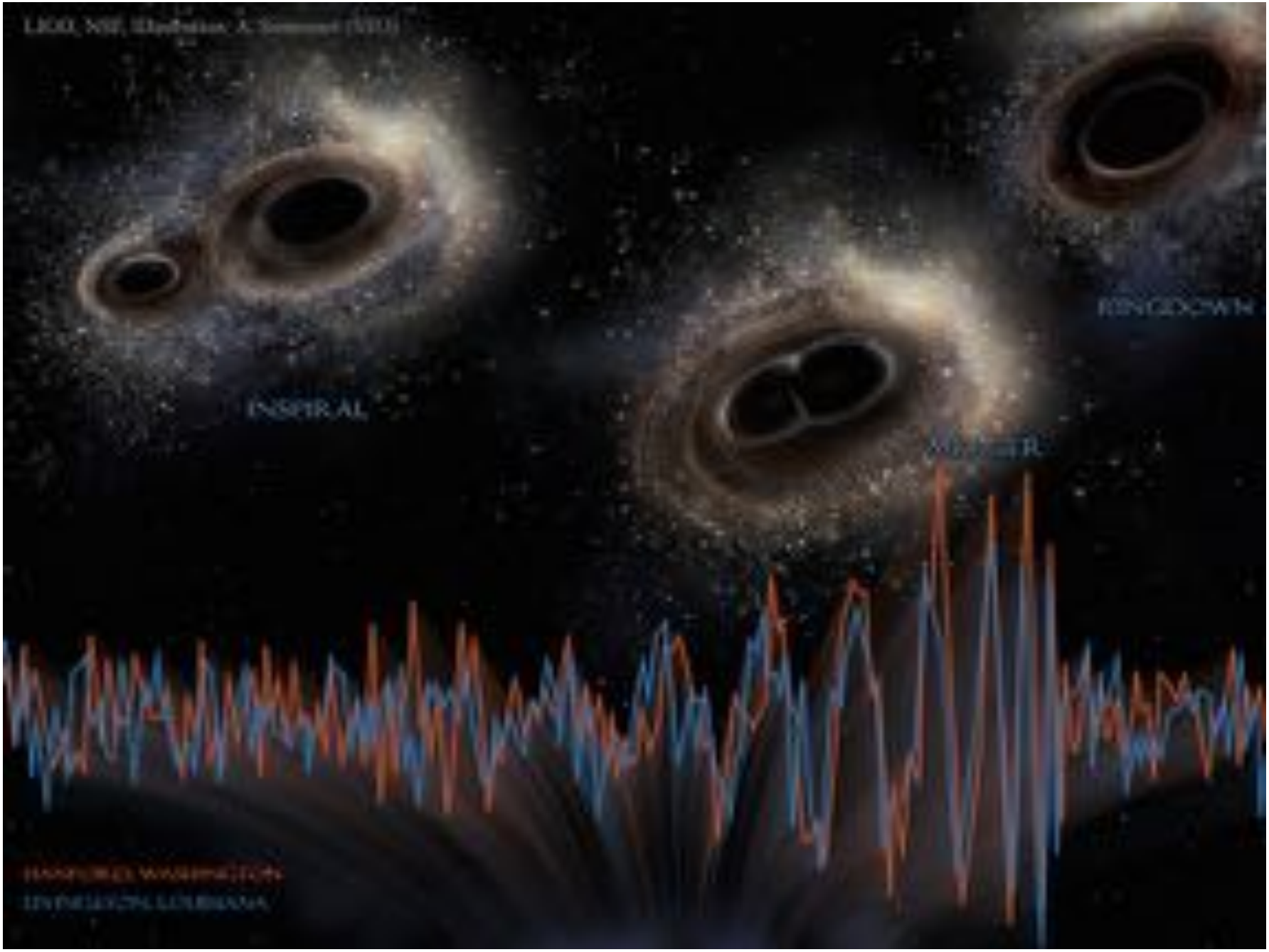


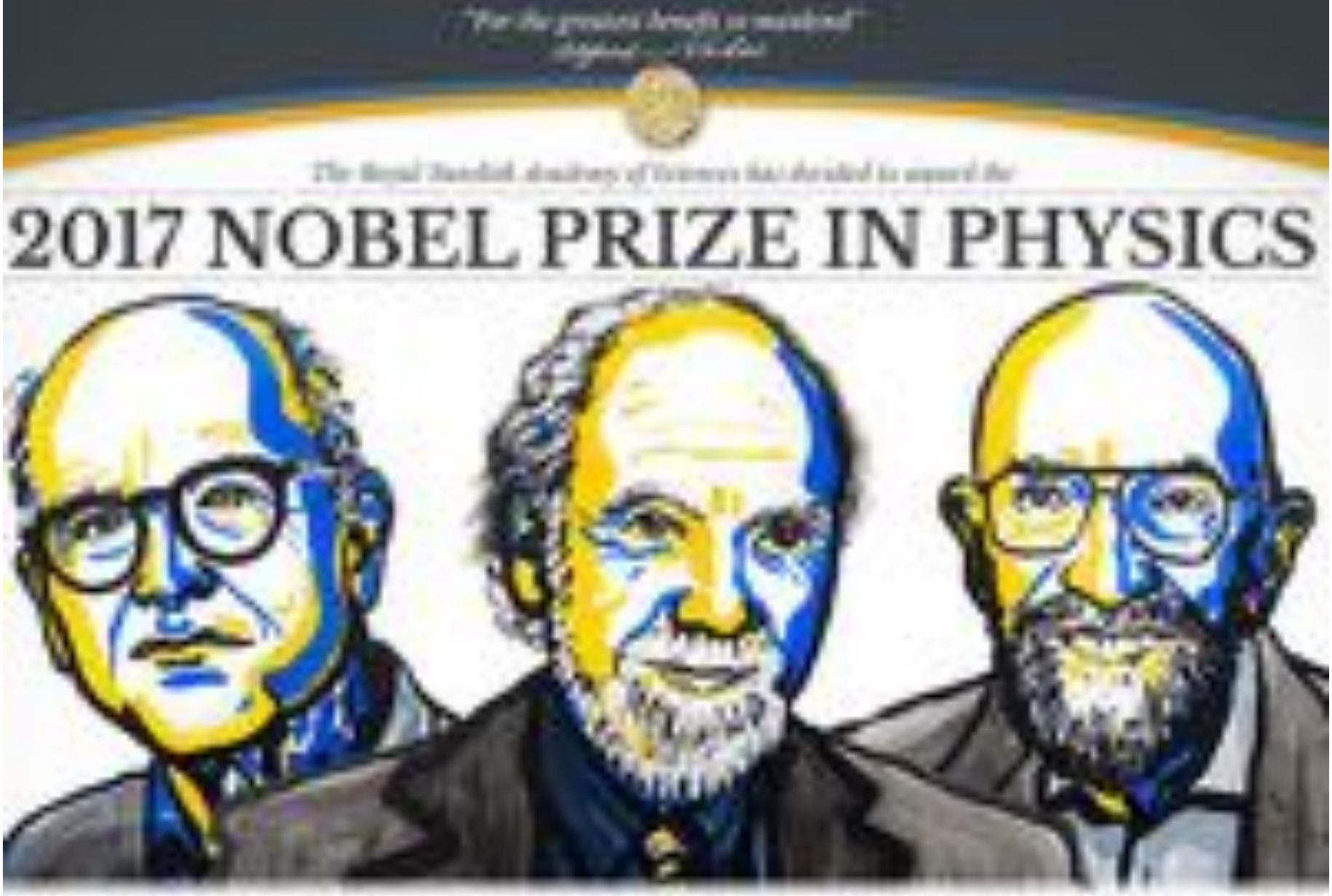
Credit: Adam Apollo


GEO600
LIGO Hanford
VIRGO
KAGRA
LIGO Livingston
LIGO India
Operational
Under Construction
Planned
Gravitational Wave Observatories





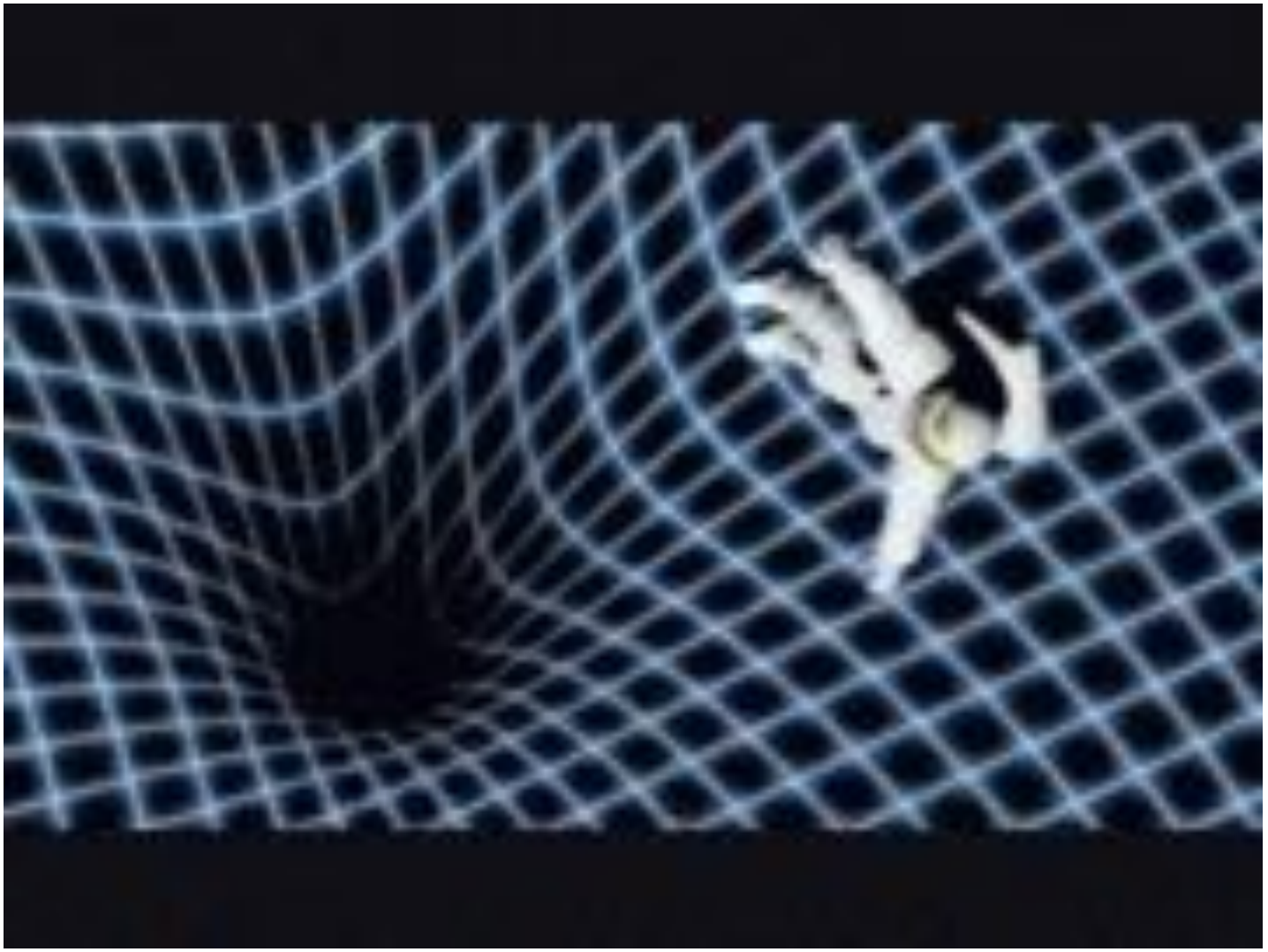

INSPIRAL



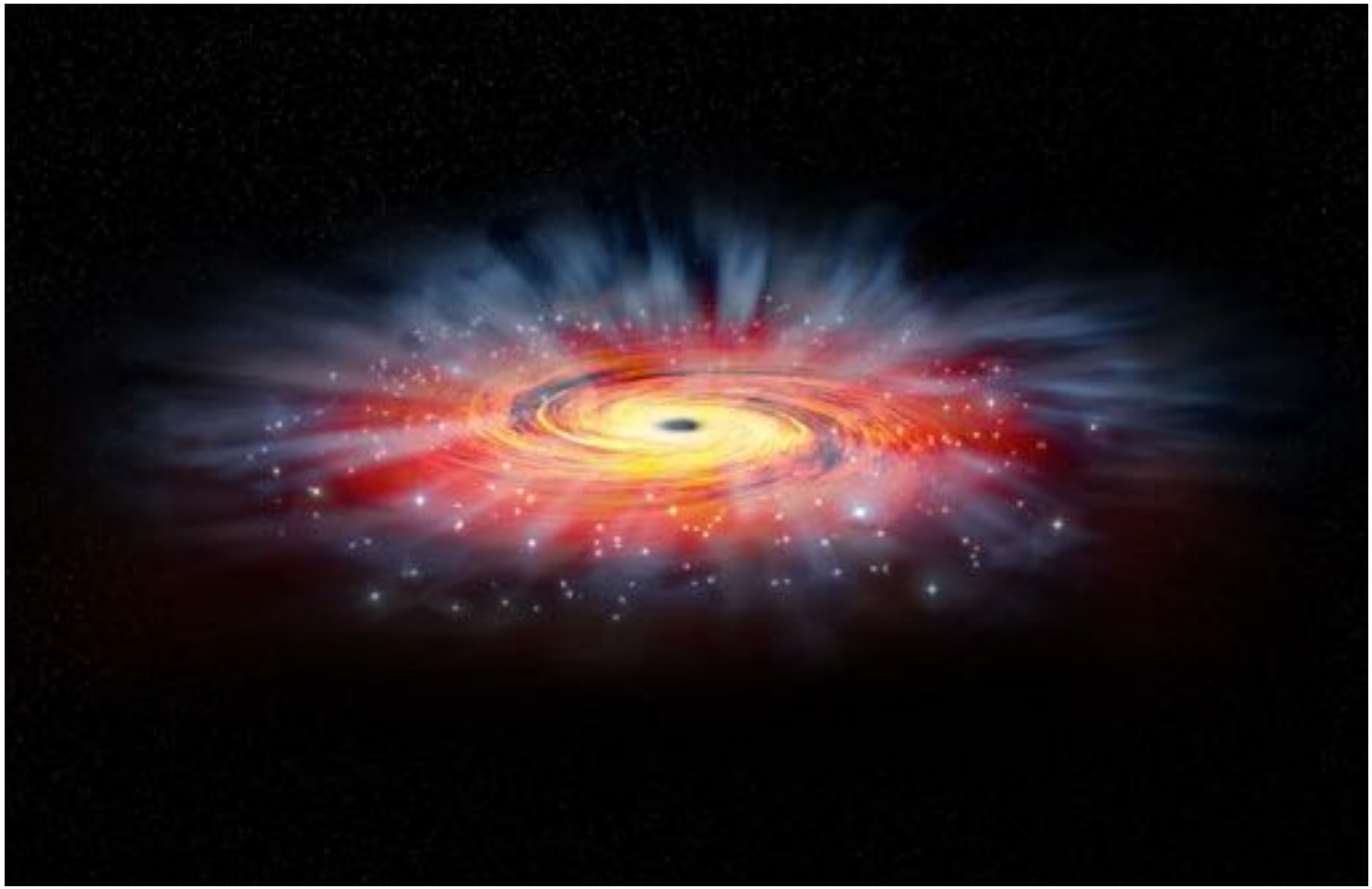
Half: Rainer Weiss and the **other half jointly** to **Barry C. Barish** and **Kip S. Thorne** - LIGO/VIRGO Collb.

Spaghettification!

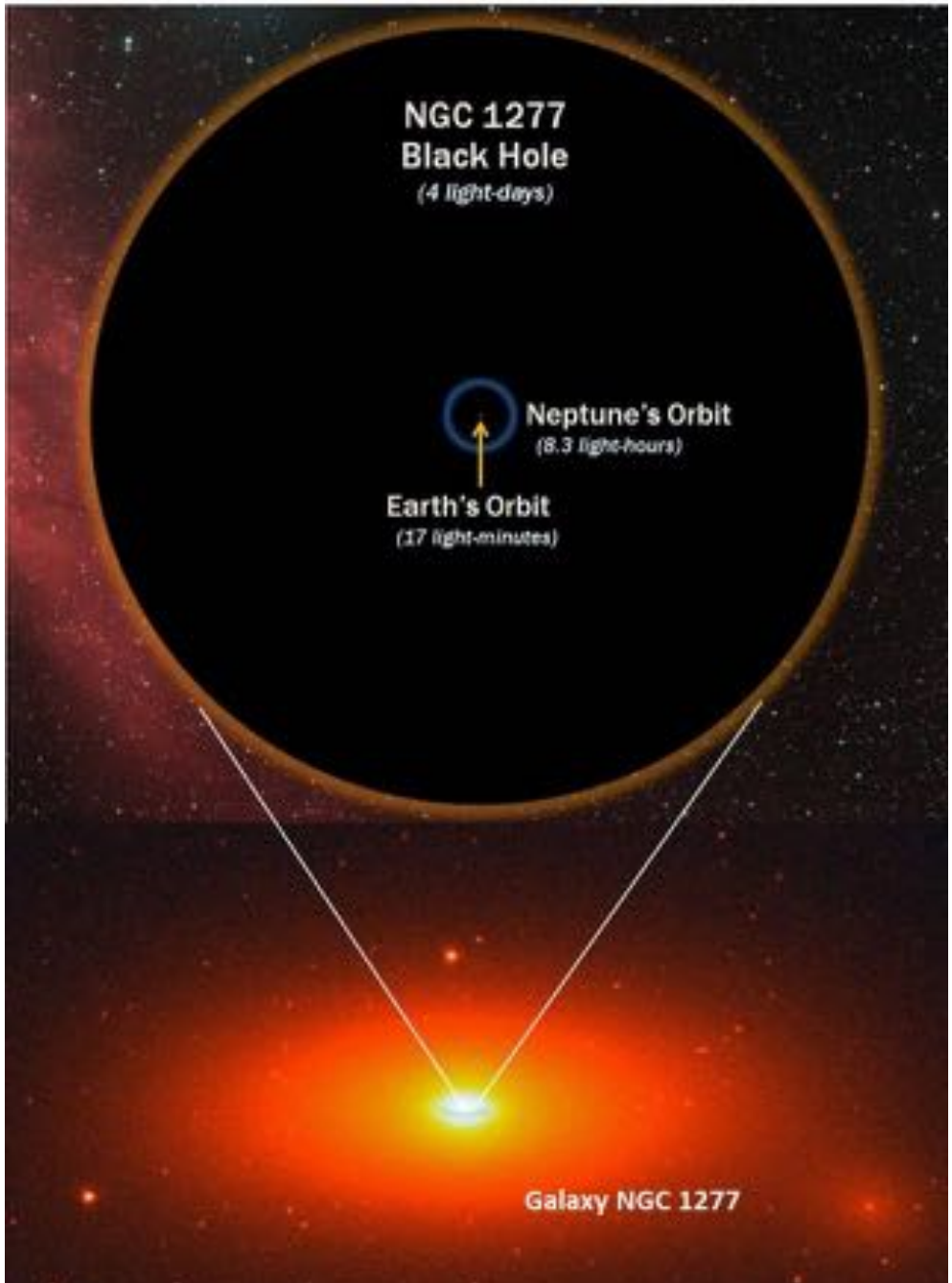
To Black Hole



Huge black holes
no spaghetificaton



Black Hole – mass about 17 billion times Solar mass



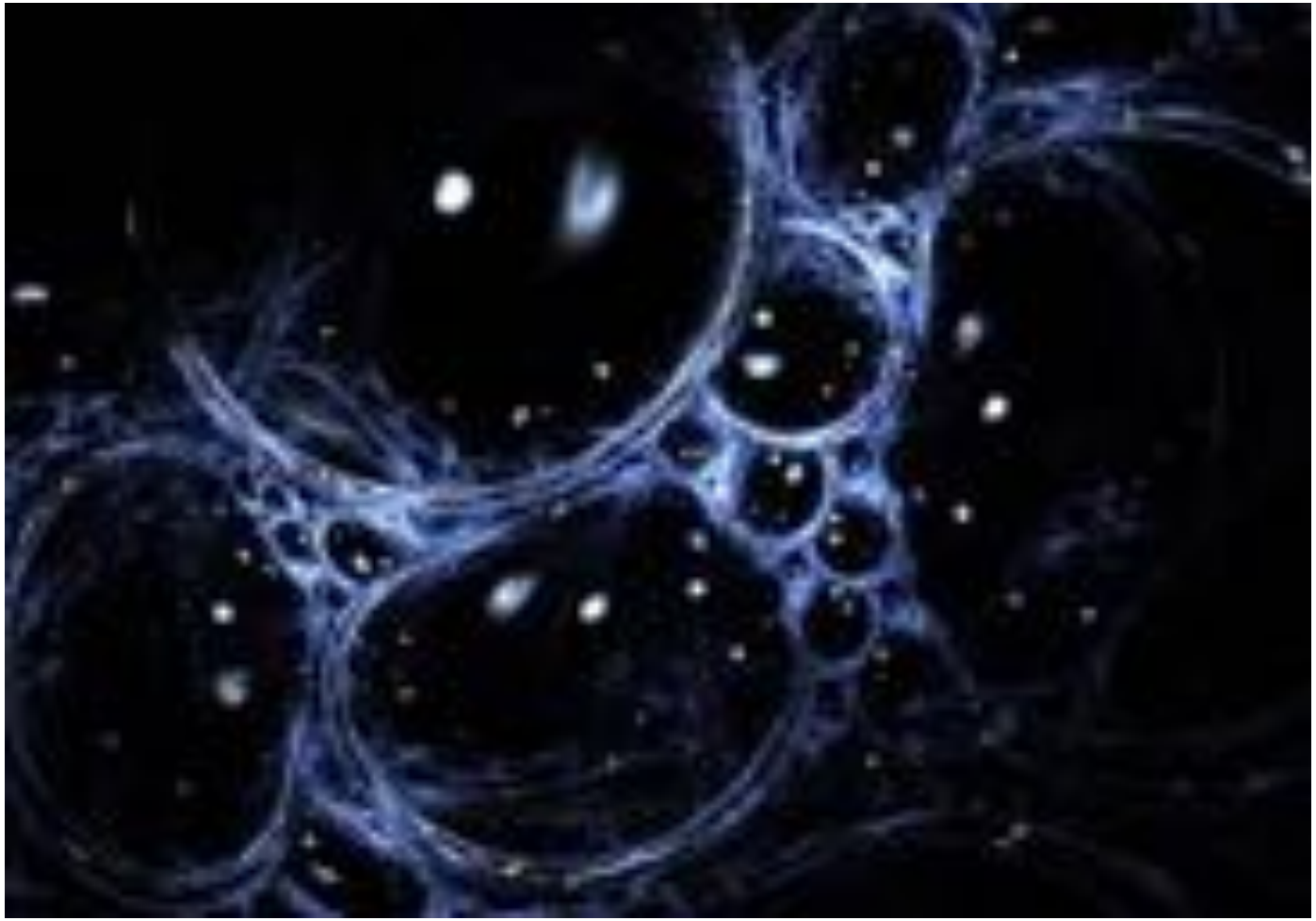
Interstellar??

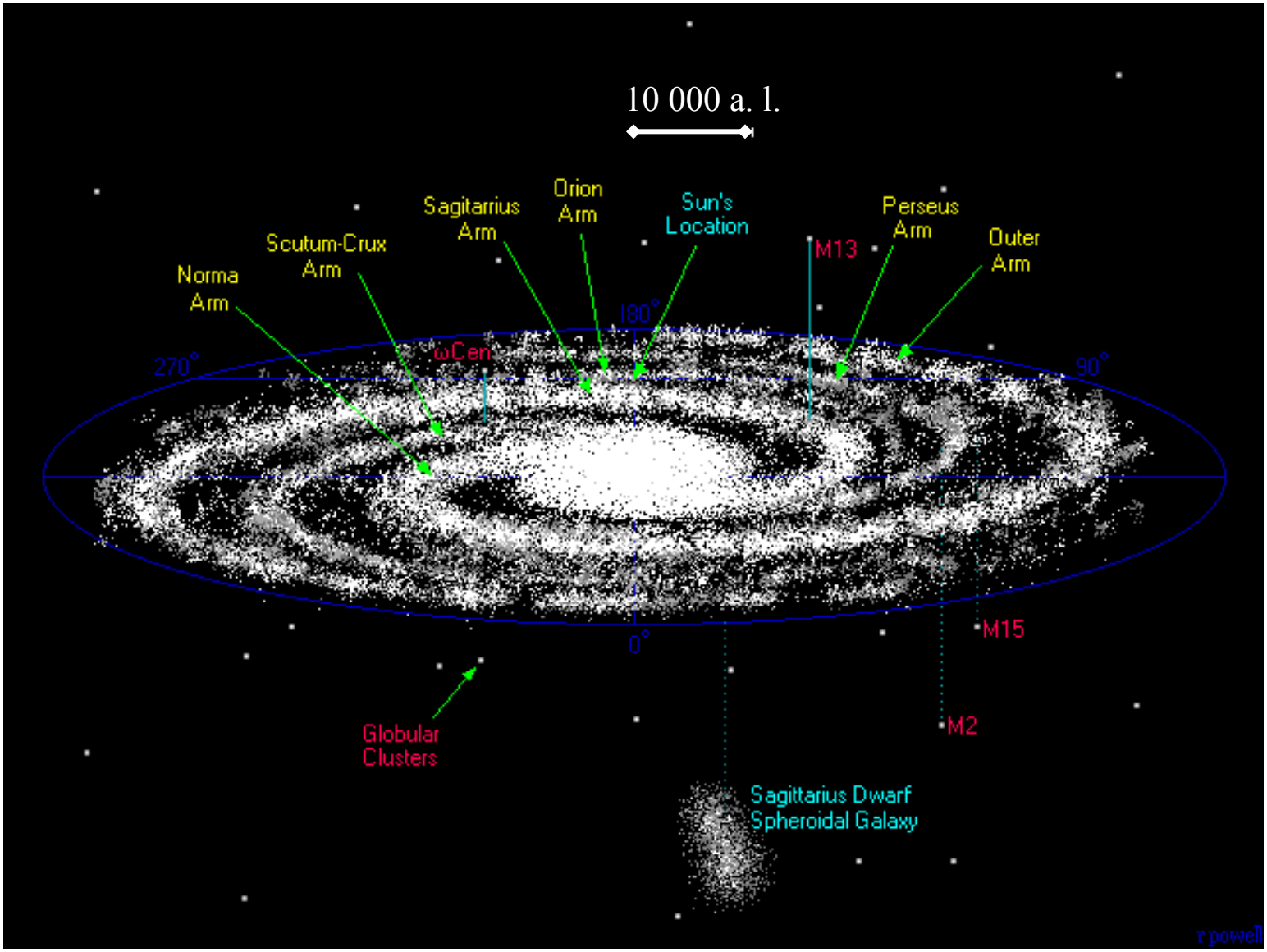

Black Holes Are Passage To Another Universe

Quantum gravity?

7 mysteries in modern physics:

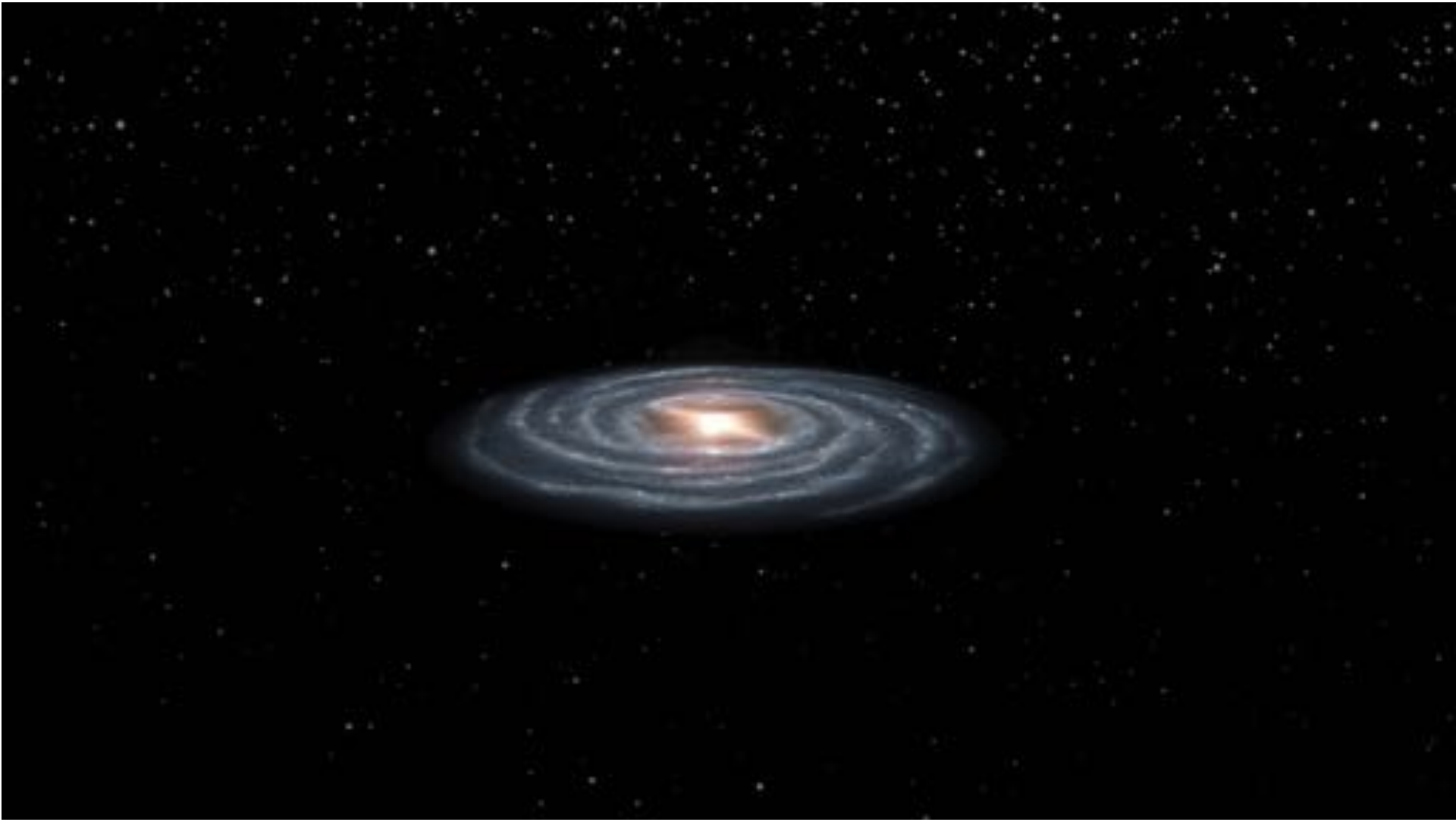
– dark matter and energy

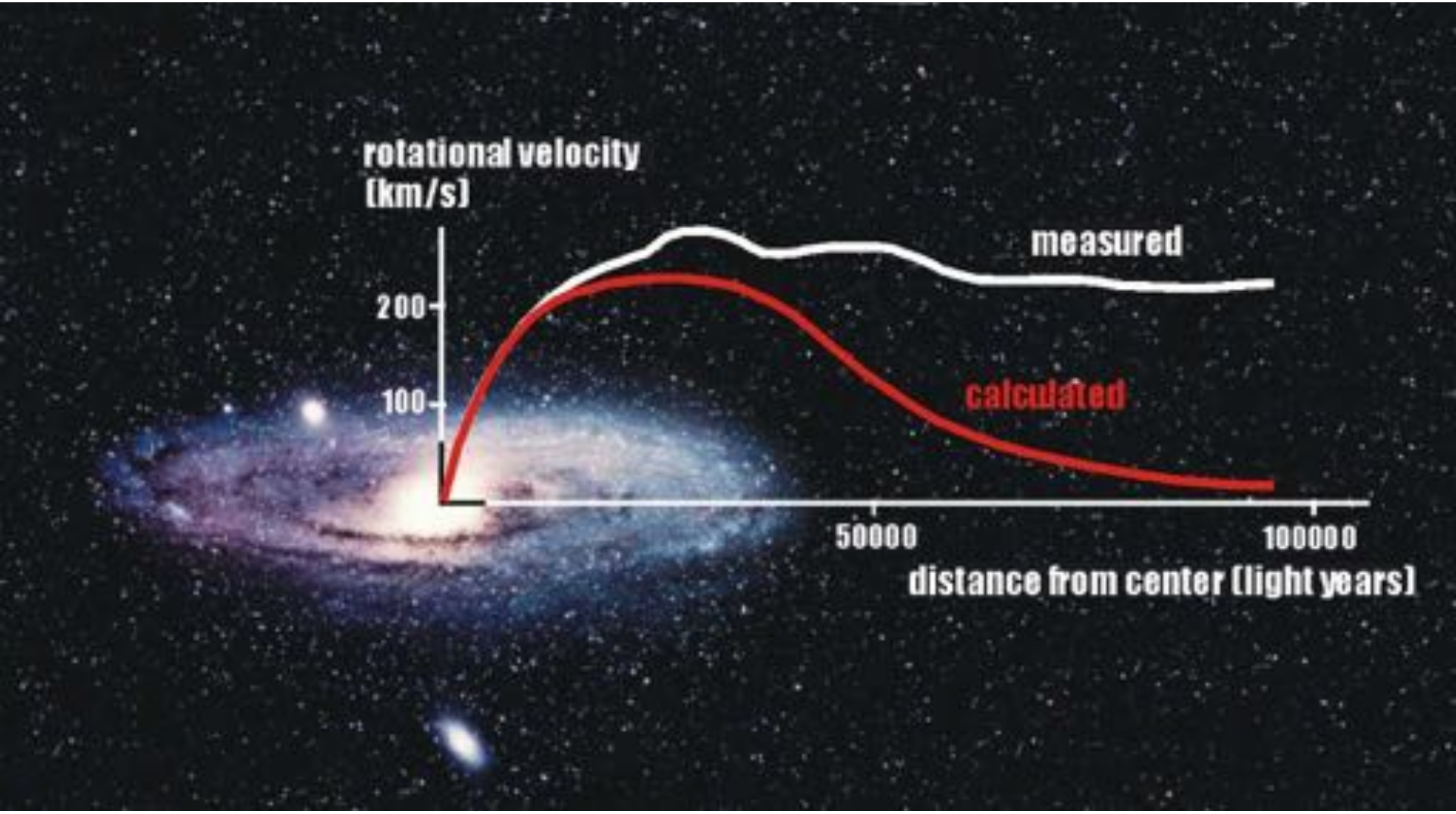


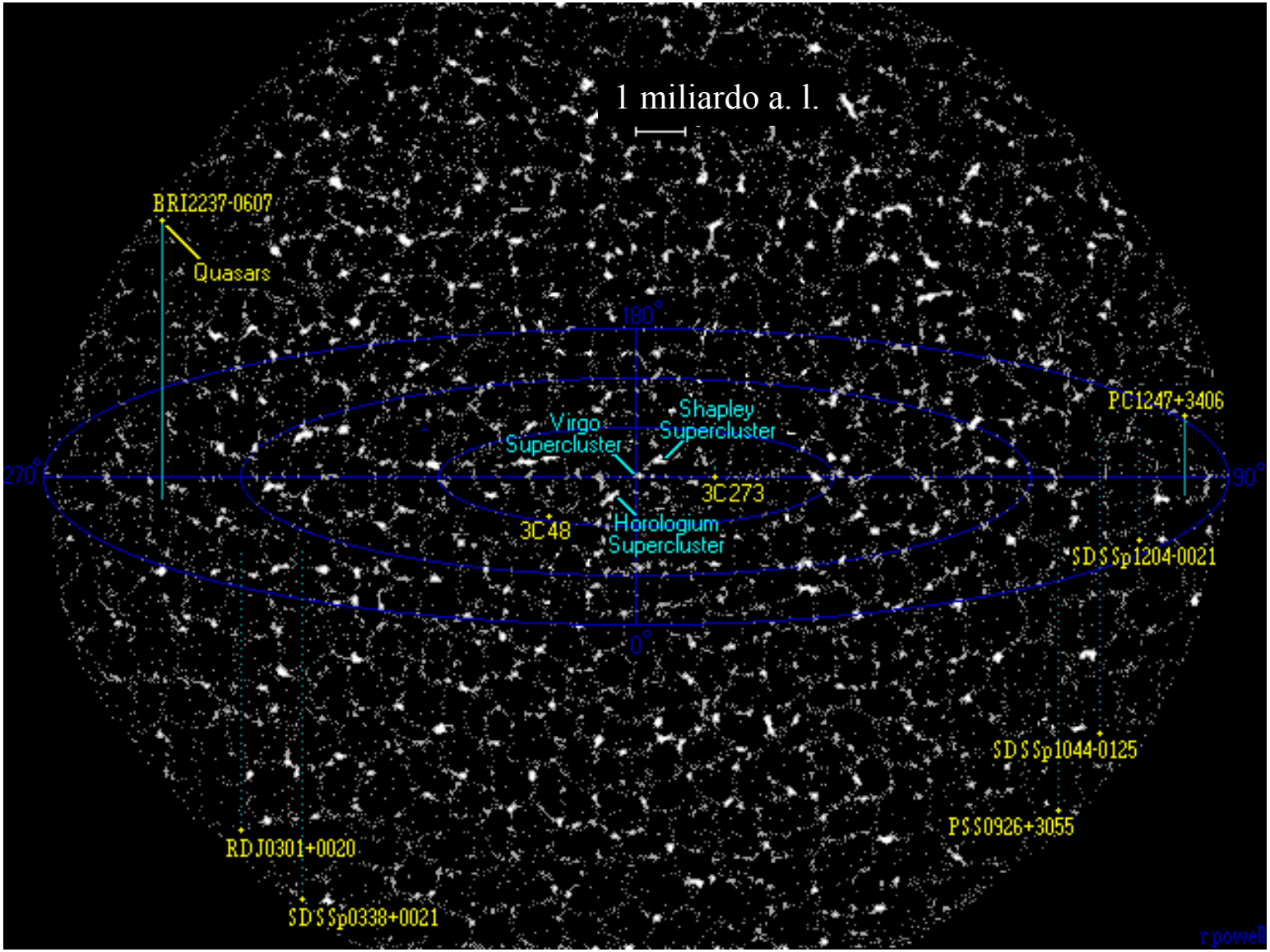


Zoom In x10

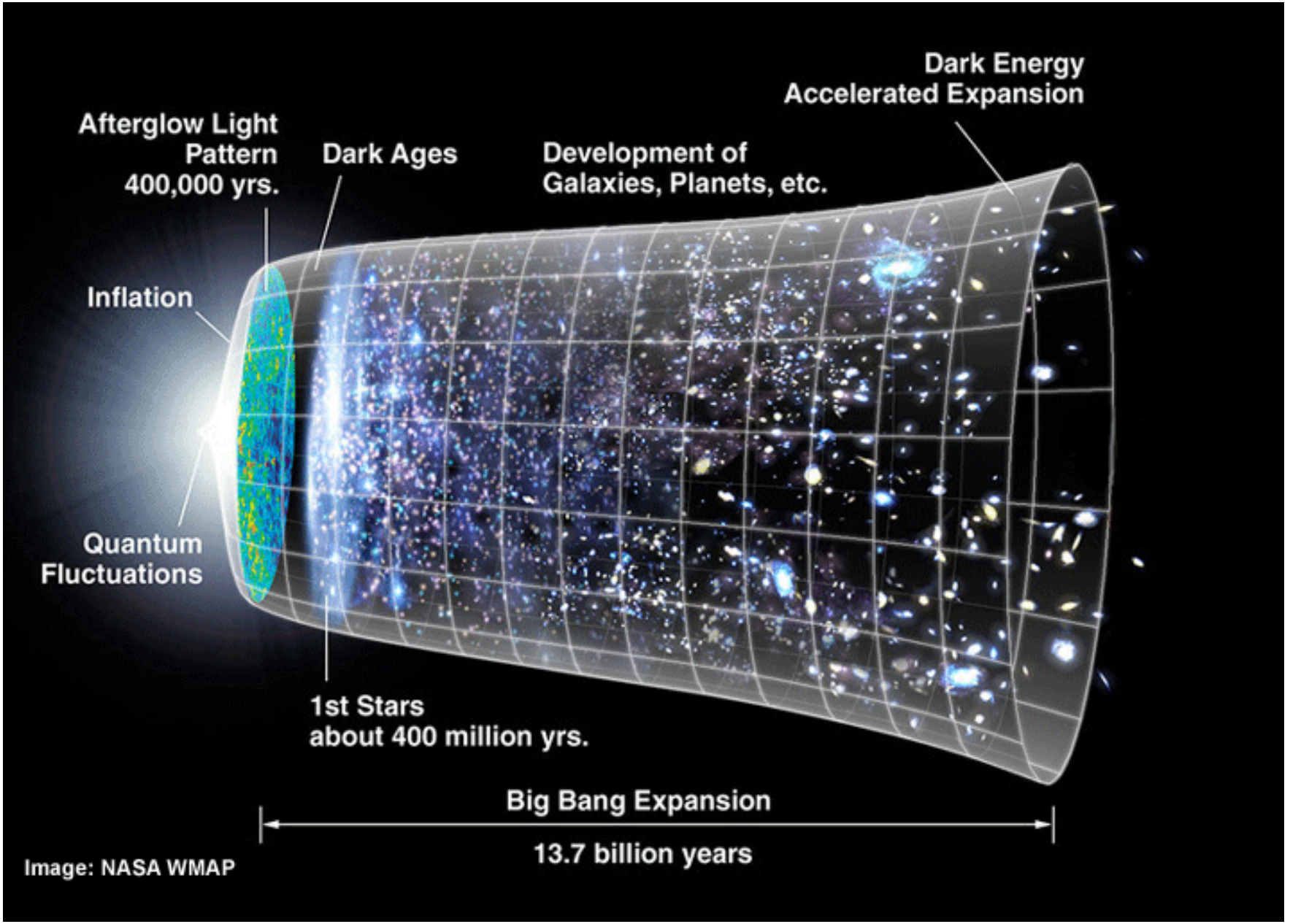
Zoom Out x10

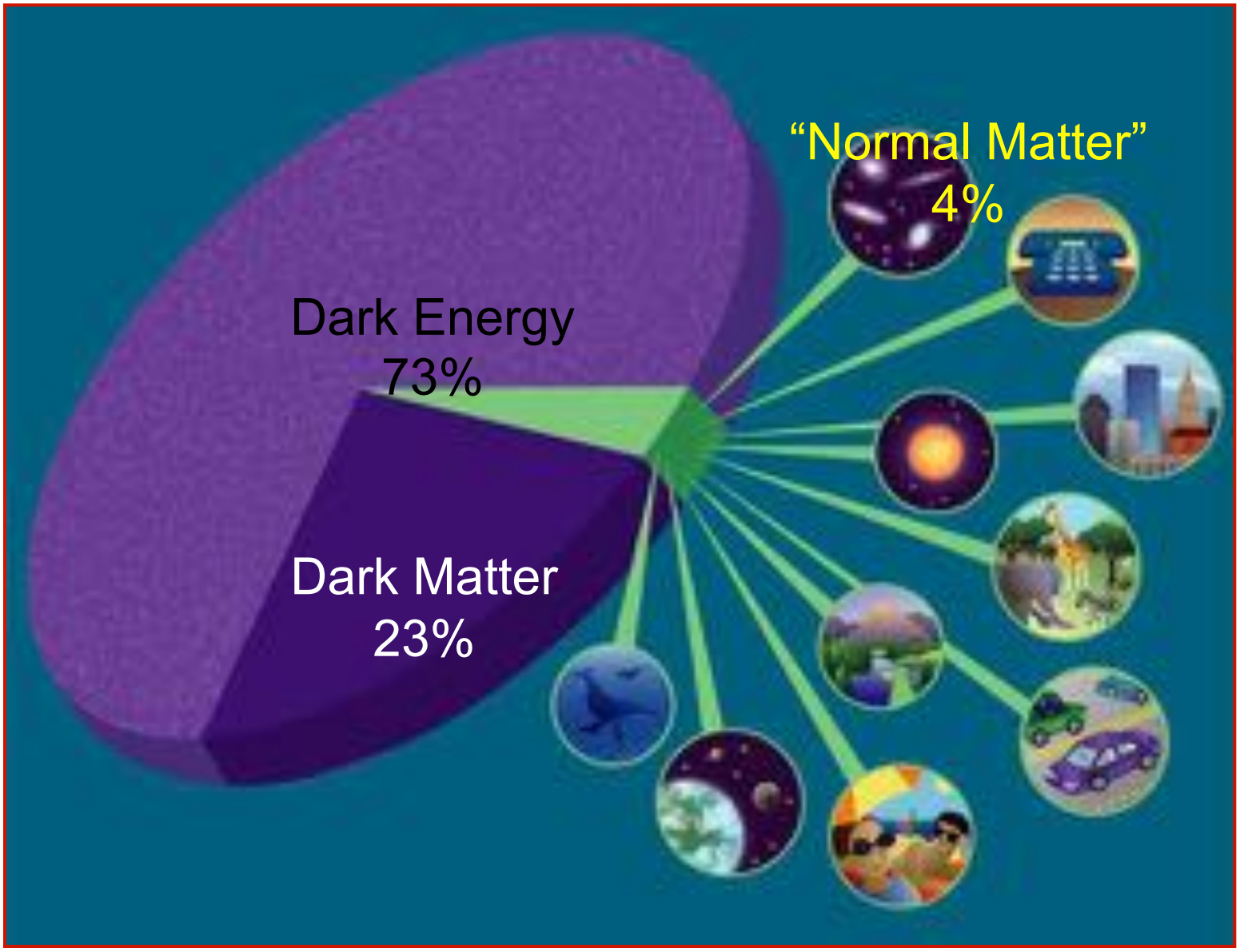



rotational velocity
(km/s)
200
100
measured
calculated
50000
100000
distance from center (light years)

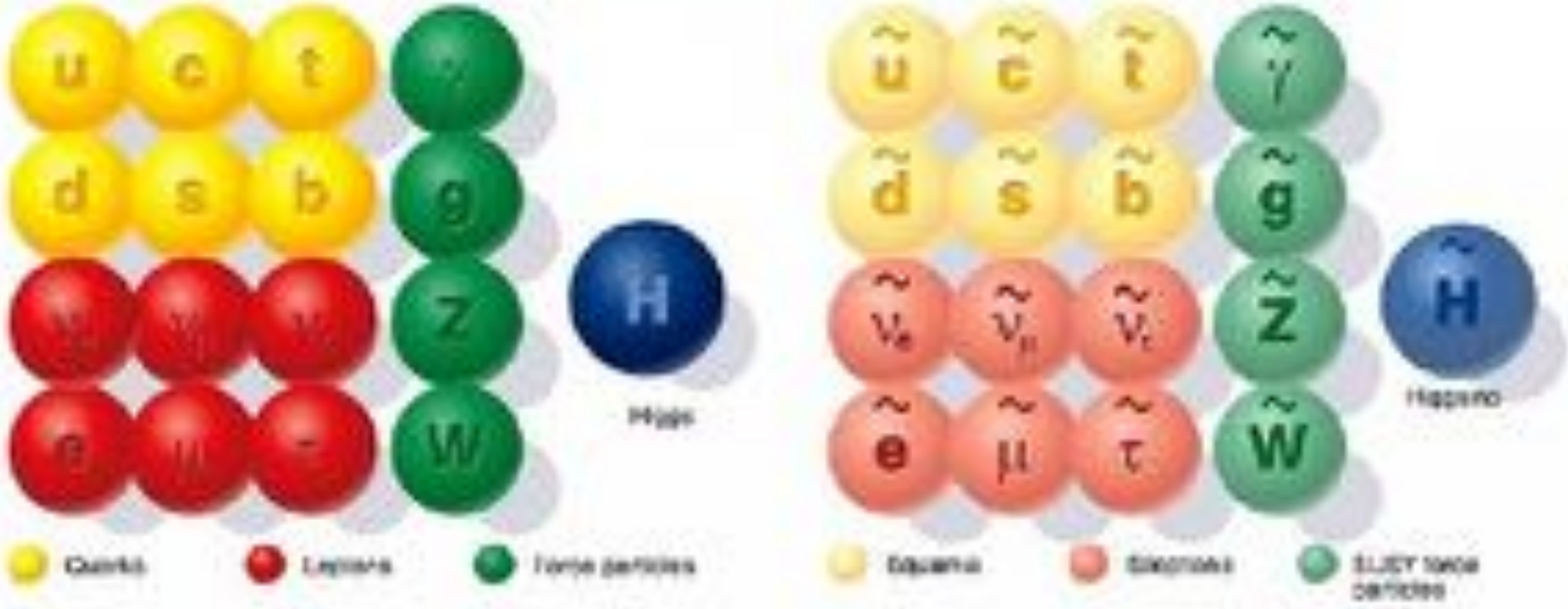

1 miliardo a. l.
BRI2237-0607
Quasars
180°
270°
90°
0°
Virgo
Supercluster
Shapley
Supercluster
3C273
3C48
Horologium
Supercluster
PC1247+3406
SDSSp1204-0021
SDSSp1044-0125
PSS0926+3055
RDJ0301+0020
SDSSp0338+0021
r powell

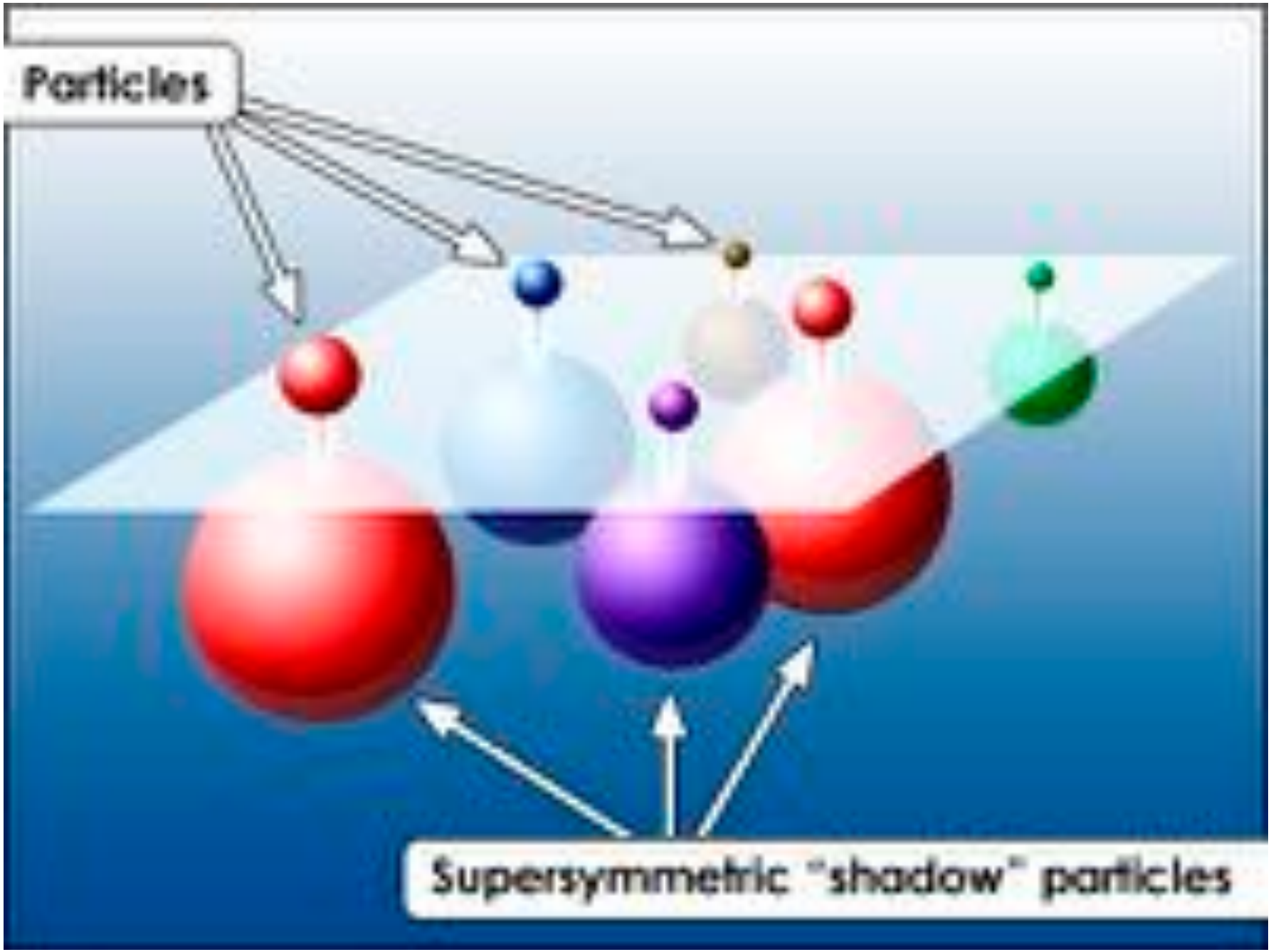
Zoom In x15

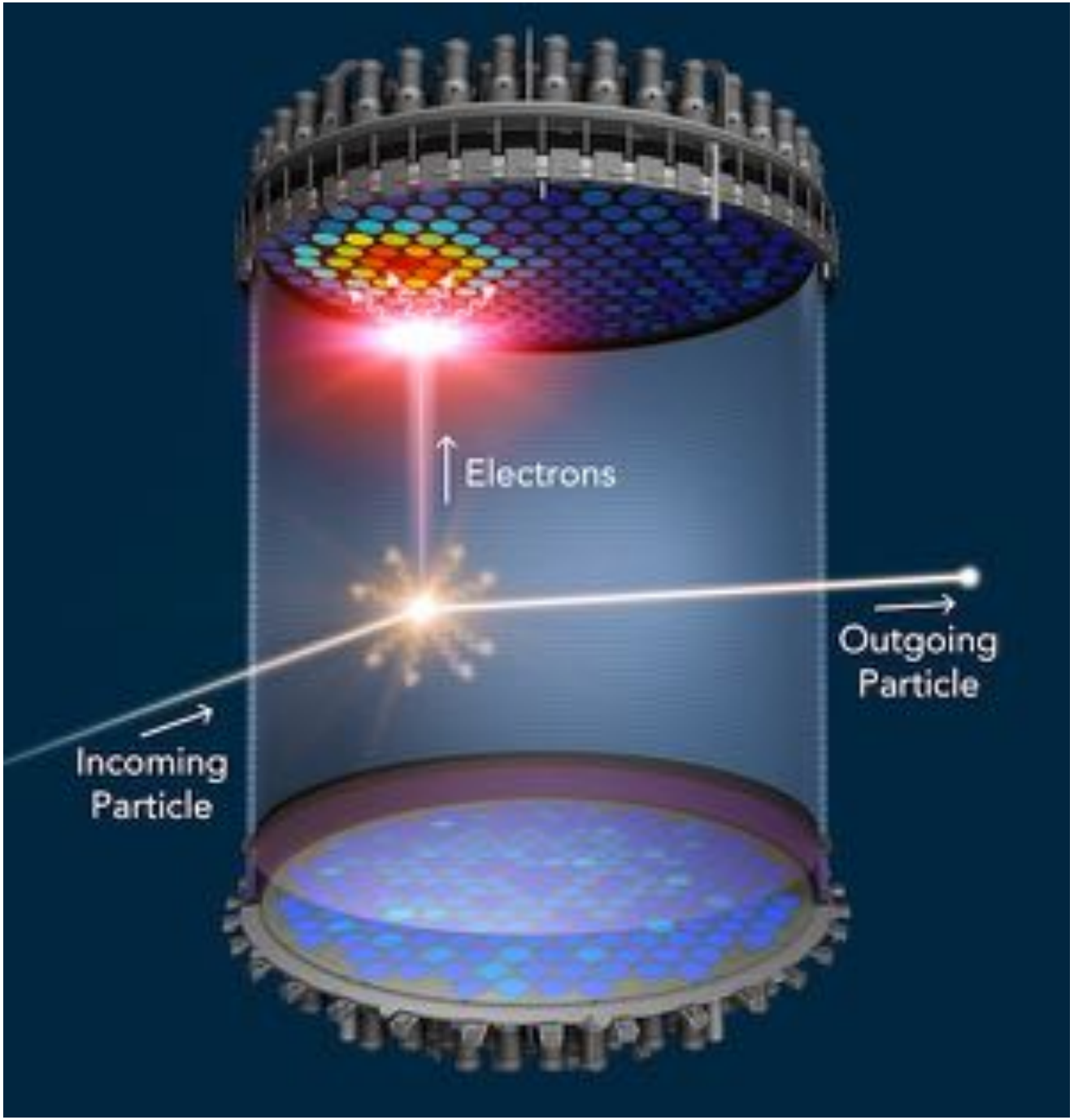

Dark Energy
Accelerated Expansion
Afterglow Light
Pattern
400,000 yrs.
Dark Ages
Development of
Galaxies, Planets, etc.
Inflation
Quantum
Fluctuations
1st Stars
about 400 million yrs.
Big Bang Expansion
13.7 billion years
Image: NASA WMAP

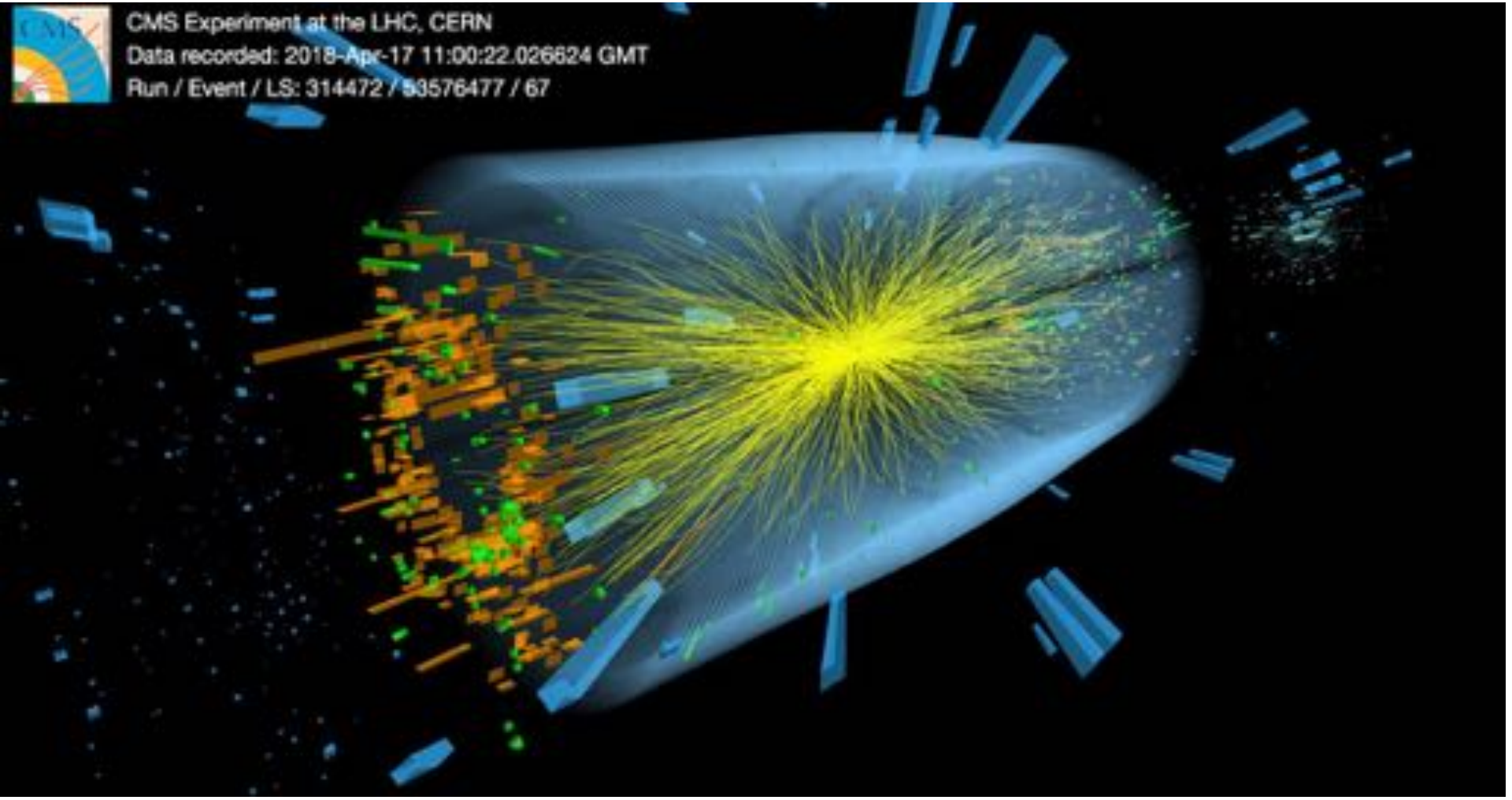

“Normal Matter”
4%
Dark Energy
73%
Dark Matter
23%

SUPERSYMMETRY




Particles
Supersymmetric "shadow" particles


Electrons
Outgoing Particle
Incoming Particle


CMS Experiment at the LHC, CERN
Data recorded: 2018-Apr-17 11:00:22.026624 GMT
Run / Event / LS: 314472 / 93576477 / 67

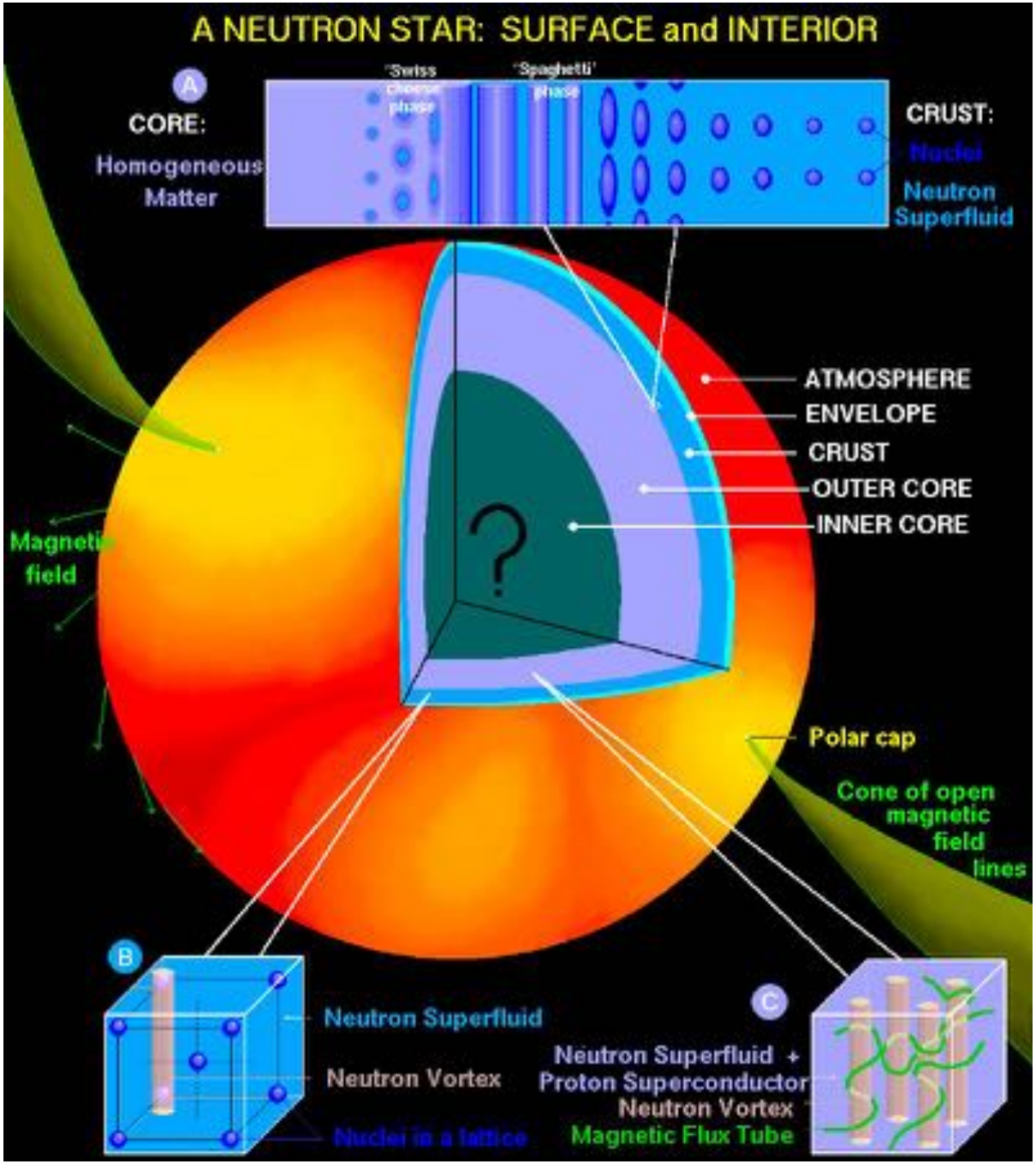
7 mysteries in modern physics:

– neutron stars

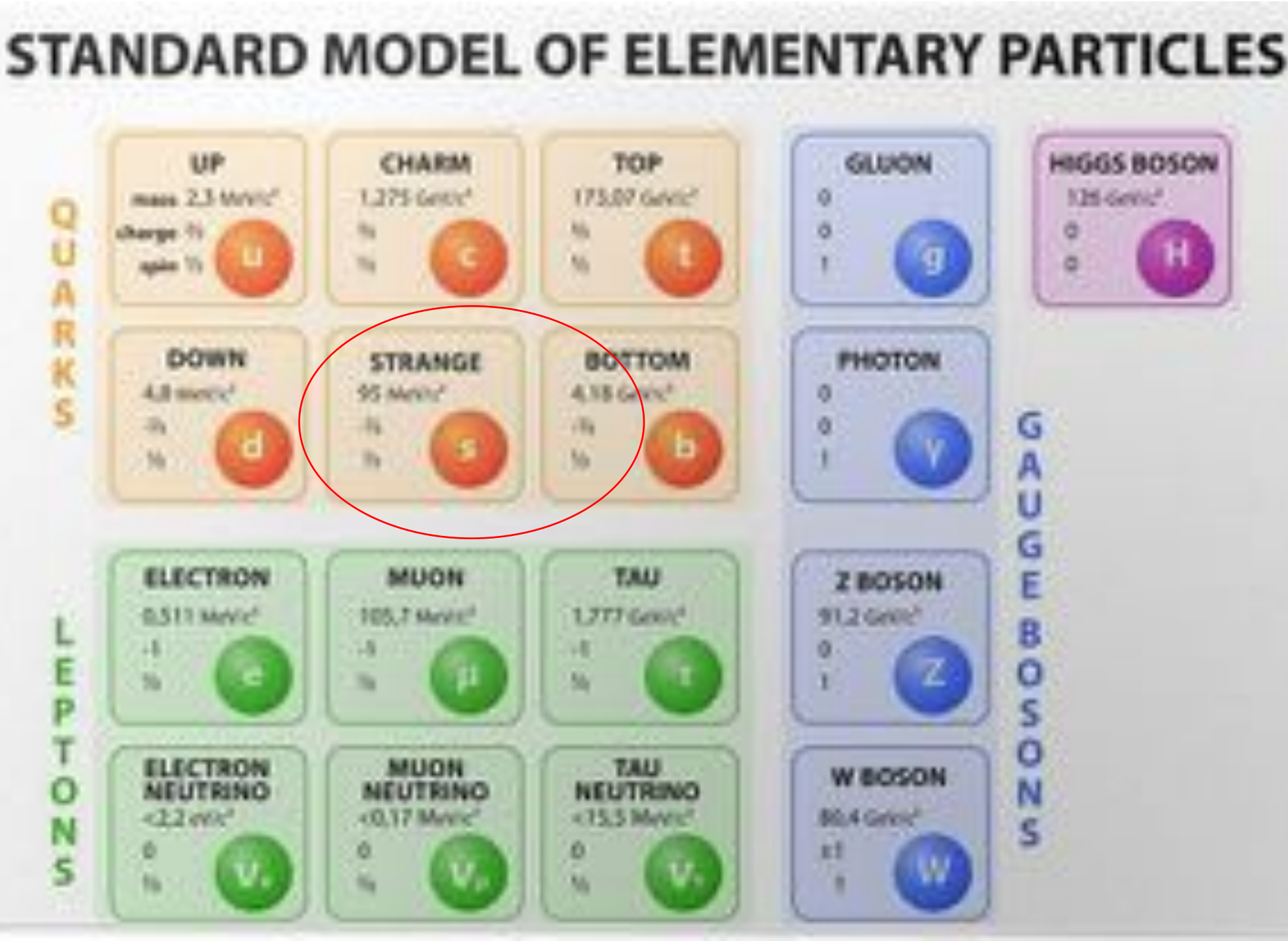

Neutron Star
Vancouver
www.kindaroomy.com

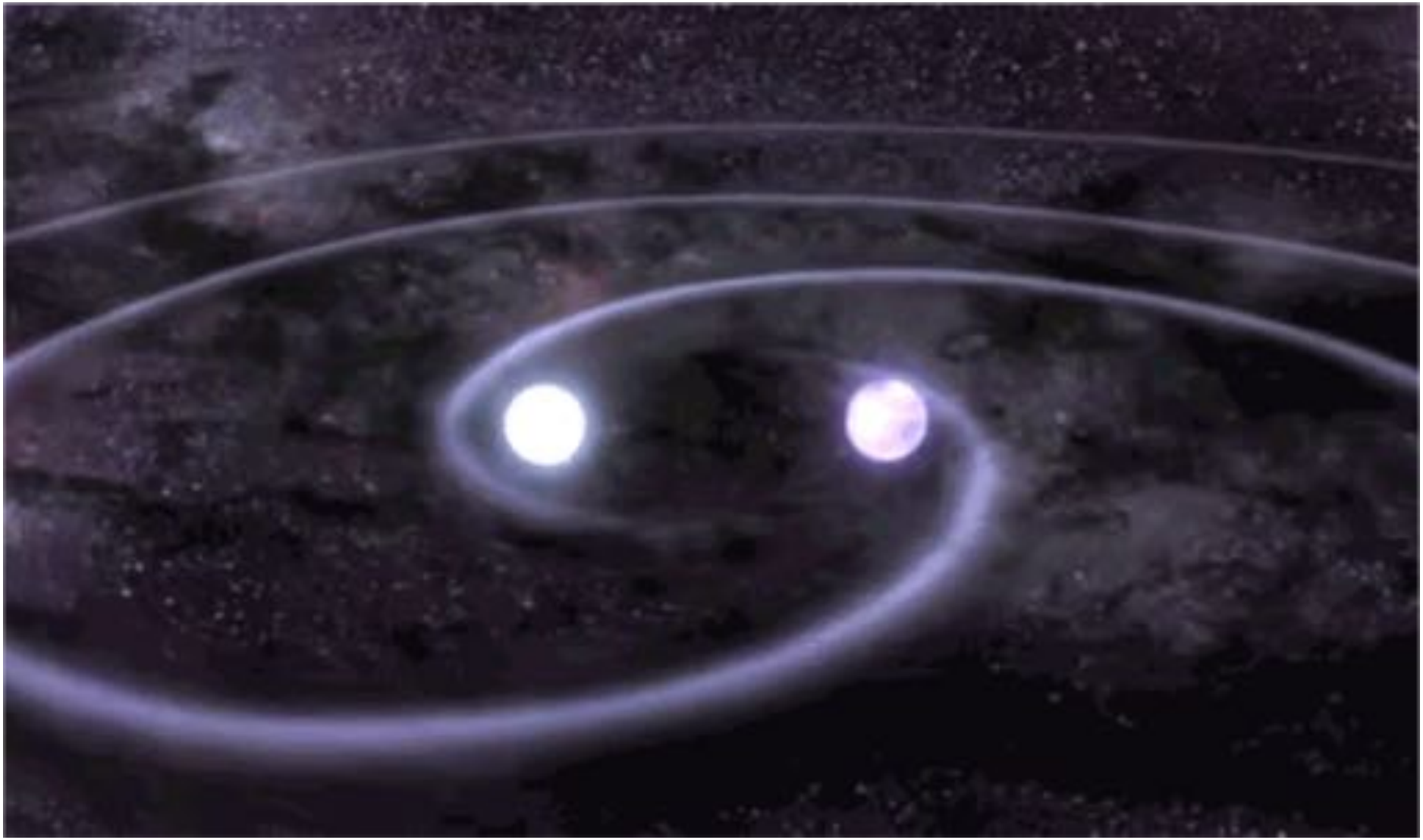
To achieve this density of a neutron star at home, just cram a herd of 50 million elephants into the volume of a thimble.

— Neil deGrasse Tyson —

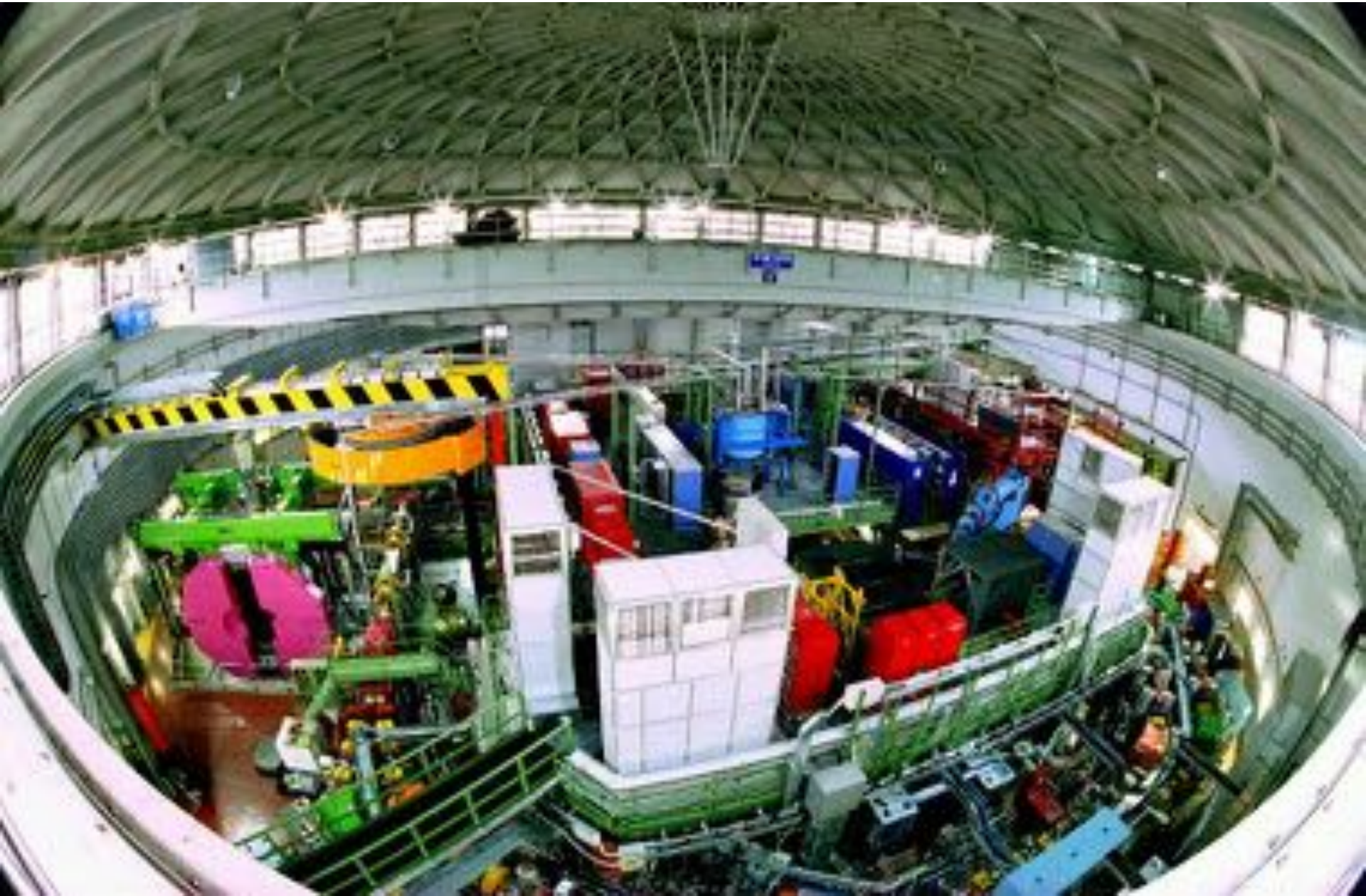

A NEUTRON STAR: SURFACE and INTERIOR
A
CORE:
Homogeneous Matter
'Swiss cheese' phase
'Spaghetti' phase
CRUST:
Nuclei
Neutron Superfluid
ATMOSPHERE
ENVELOPE
CRUST
OUTER CORE
INNER CORE
?
Magnetic field
Polar cap
Cone of open magnetic field lines
B
Neutron Superfluid
Neutron Vortex
Nuclei in a lattice
C
Neutron Superfluid +
Proton Superconductor
Neutron Vortex
Magnetic Flux Tube

STANDARD MODEL OF ELEMENTARY PARTICLES



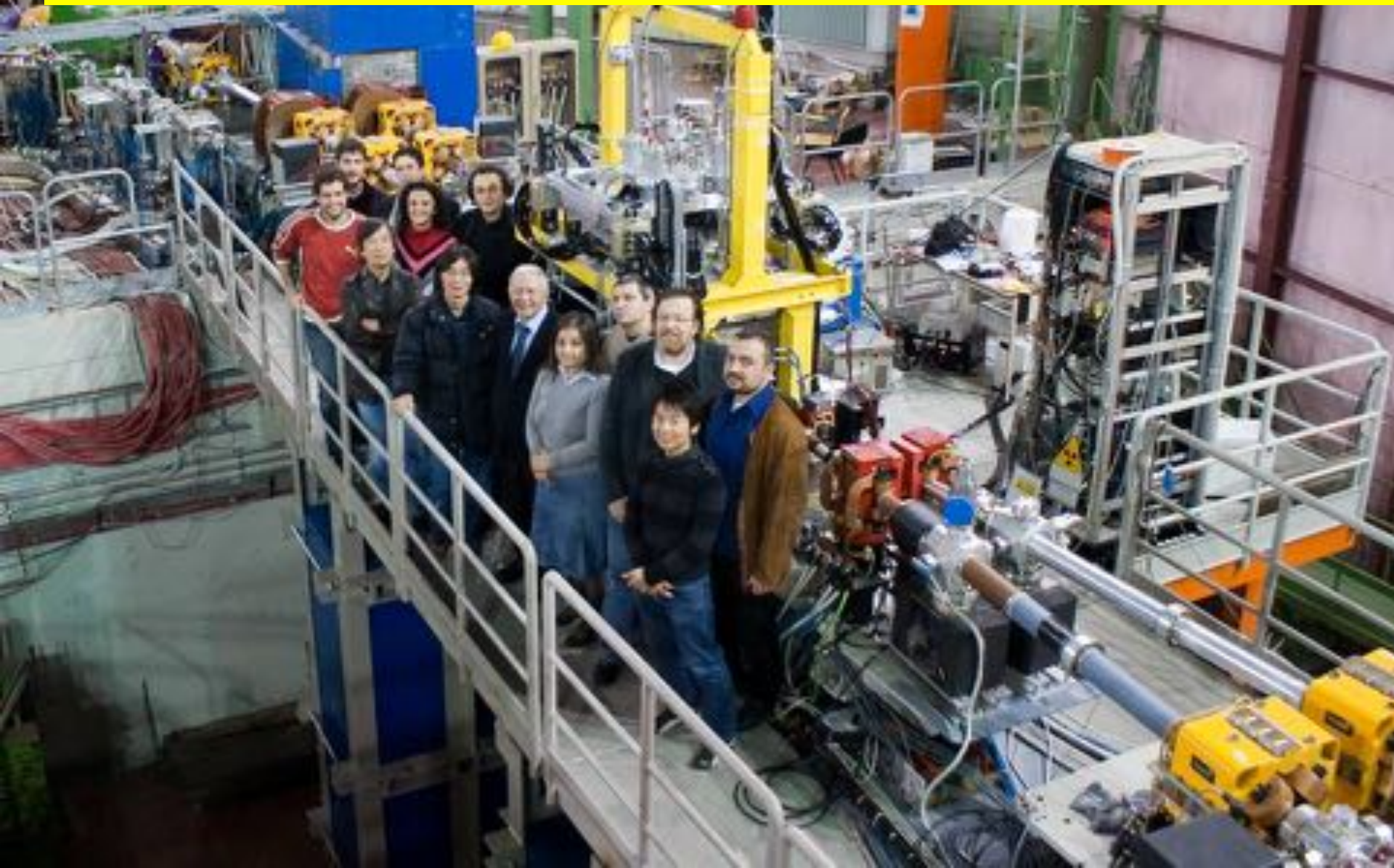


DAΦNE, since 1998

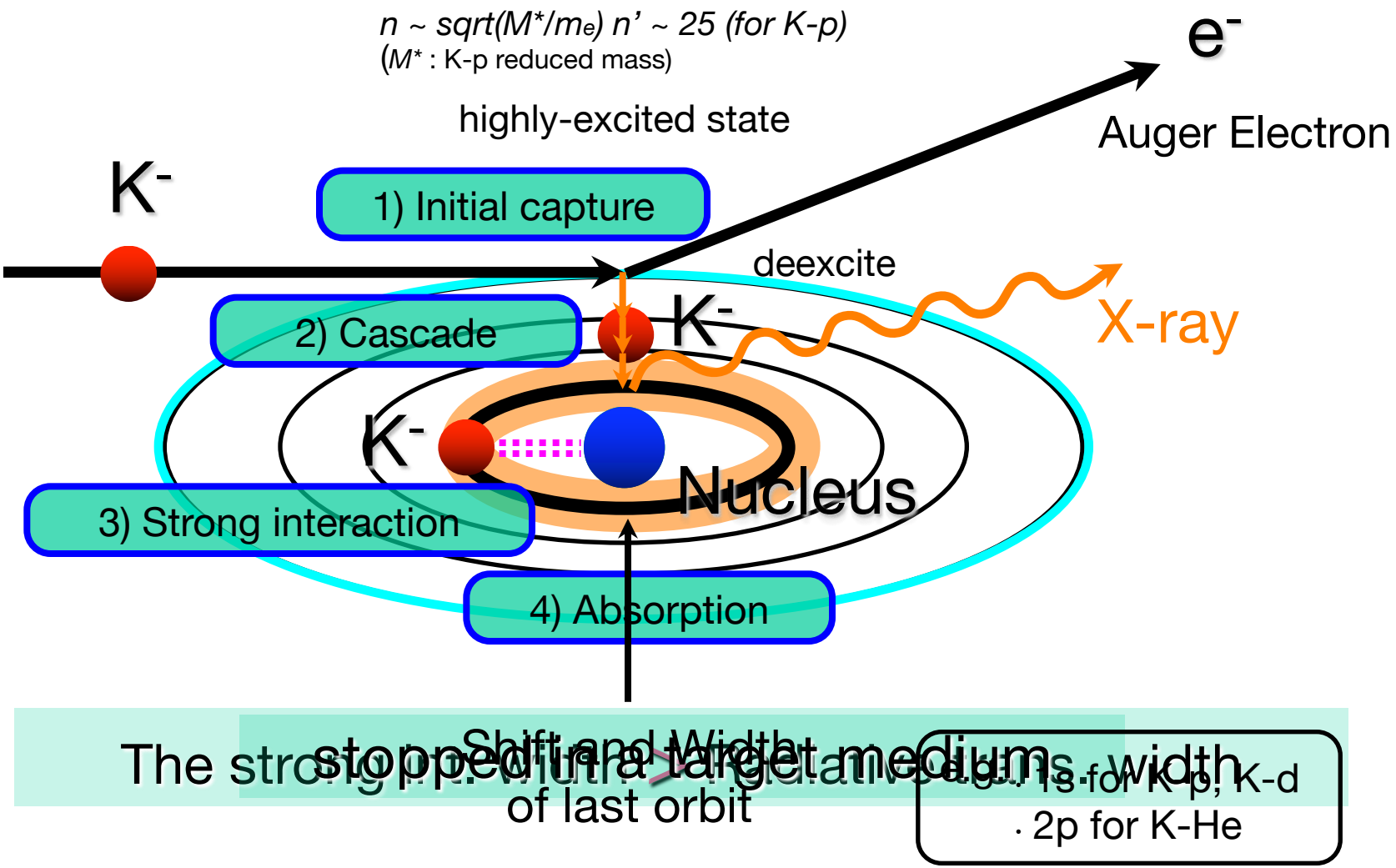


SIDDHARTA

SIlicon Drift Detector for Hadronic Atom Research by Timing Applications



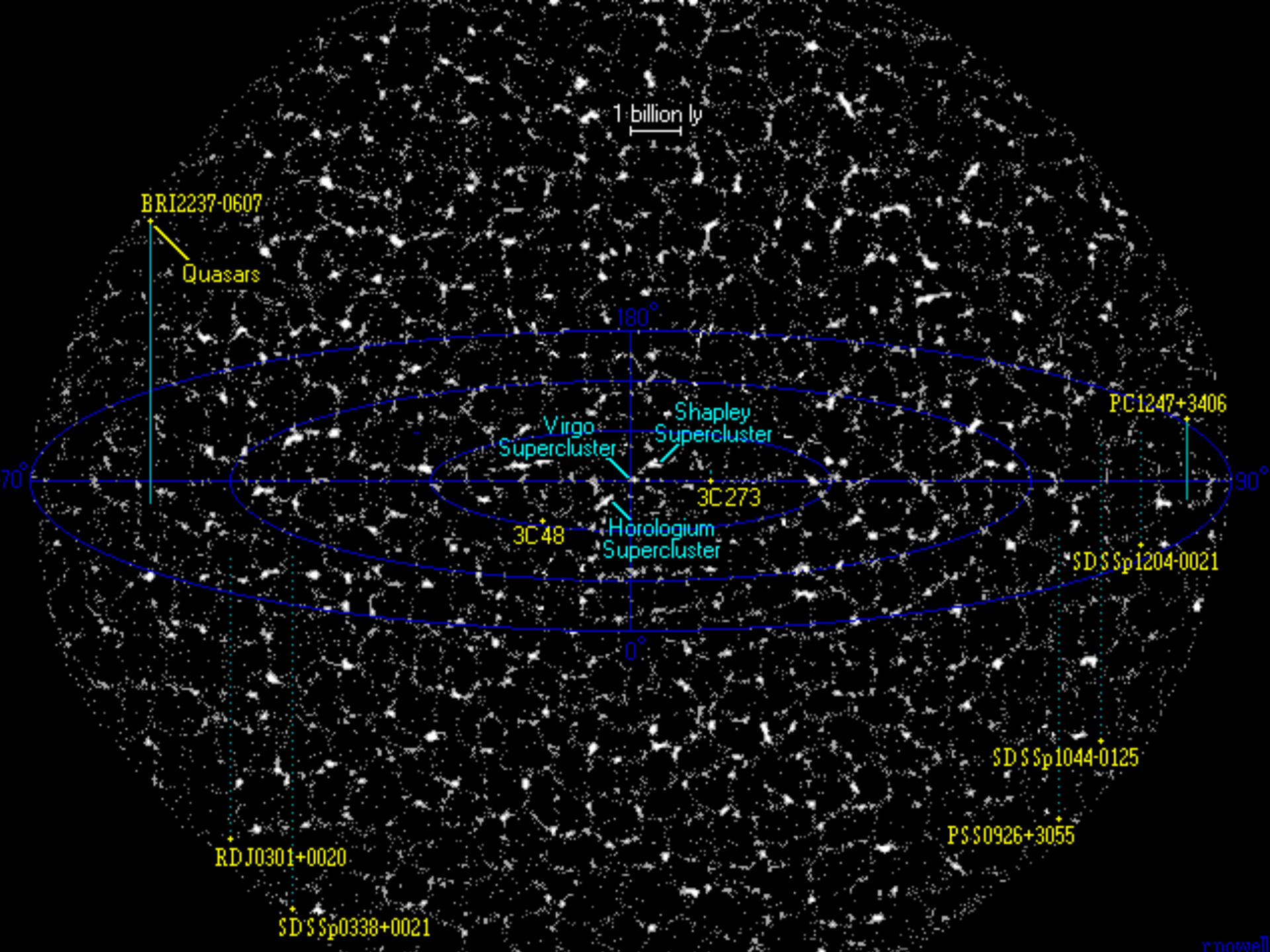
Kaonic atom formation

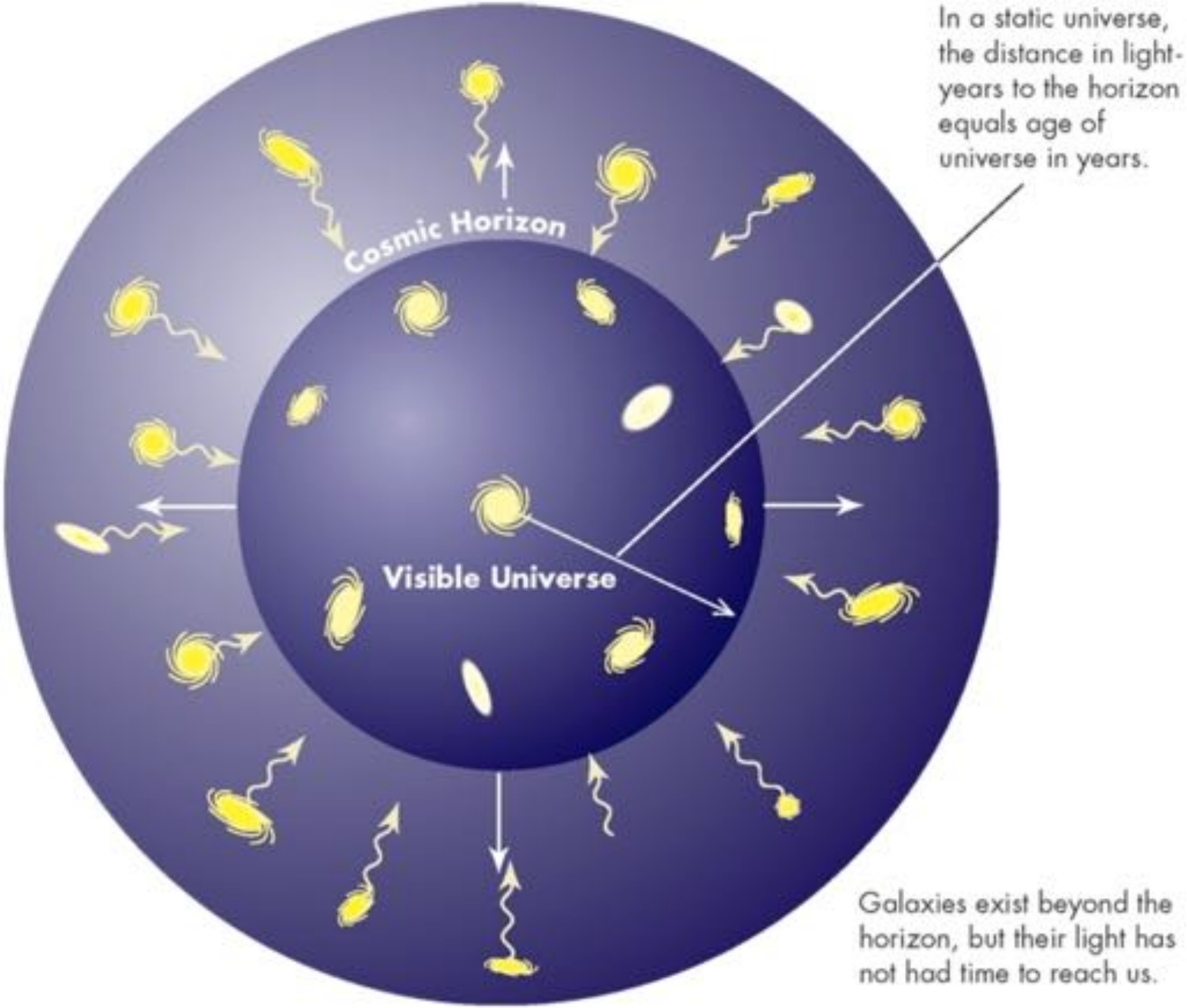


The strong interaction width

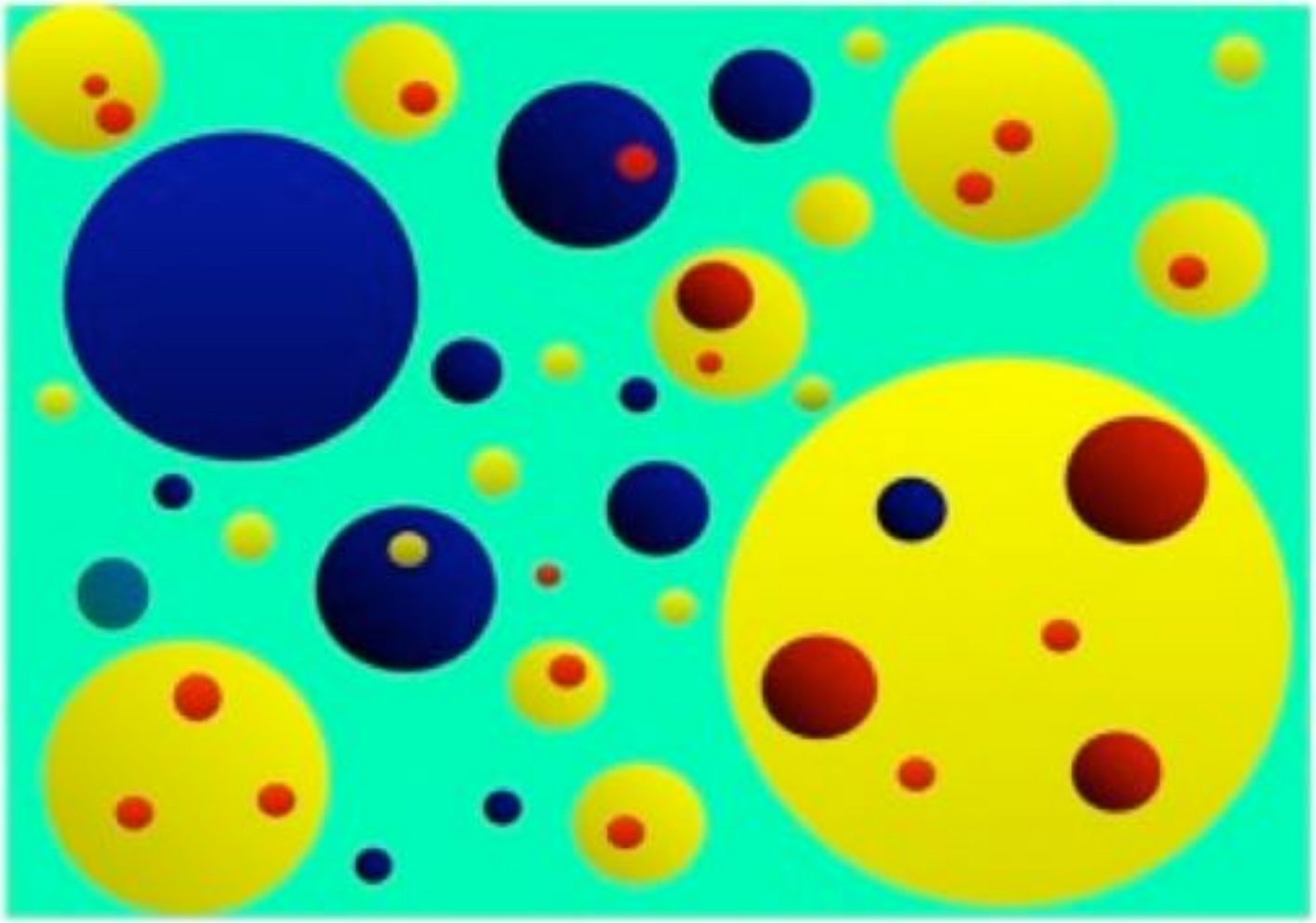
7 mysteries in modern physics:

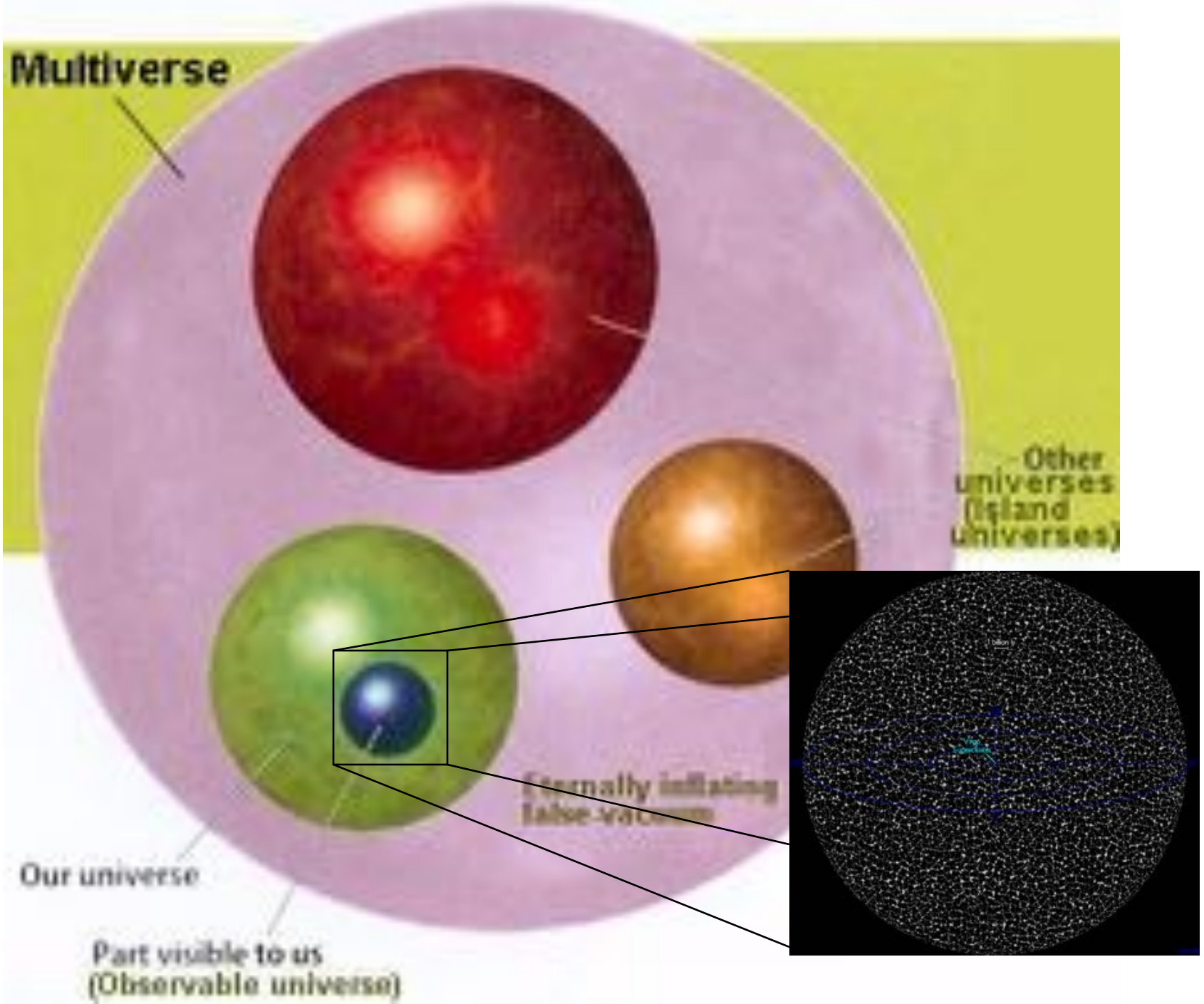
– Schroedinger cat and parallel Universes


1 billion ly
BRI2237-0607
Quasars
180°
70°
90°
0°
Virgo
Supercluster
Shapley
Supercluster
PC1247+3406
3C273
3C48
Horologium
Supercluster
SDSSp1204-0021
SDSSp1044-0125
PSS0926+3055
RDJ0301+0020
SDSSp0338+0021

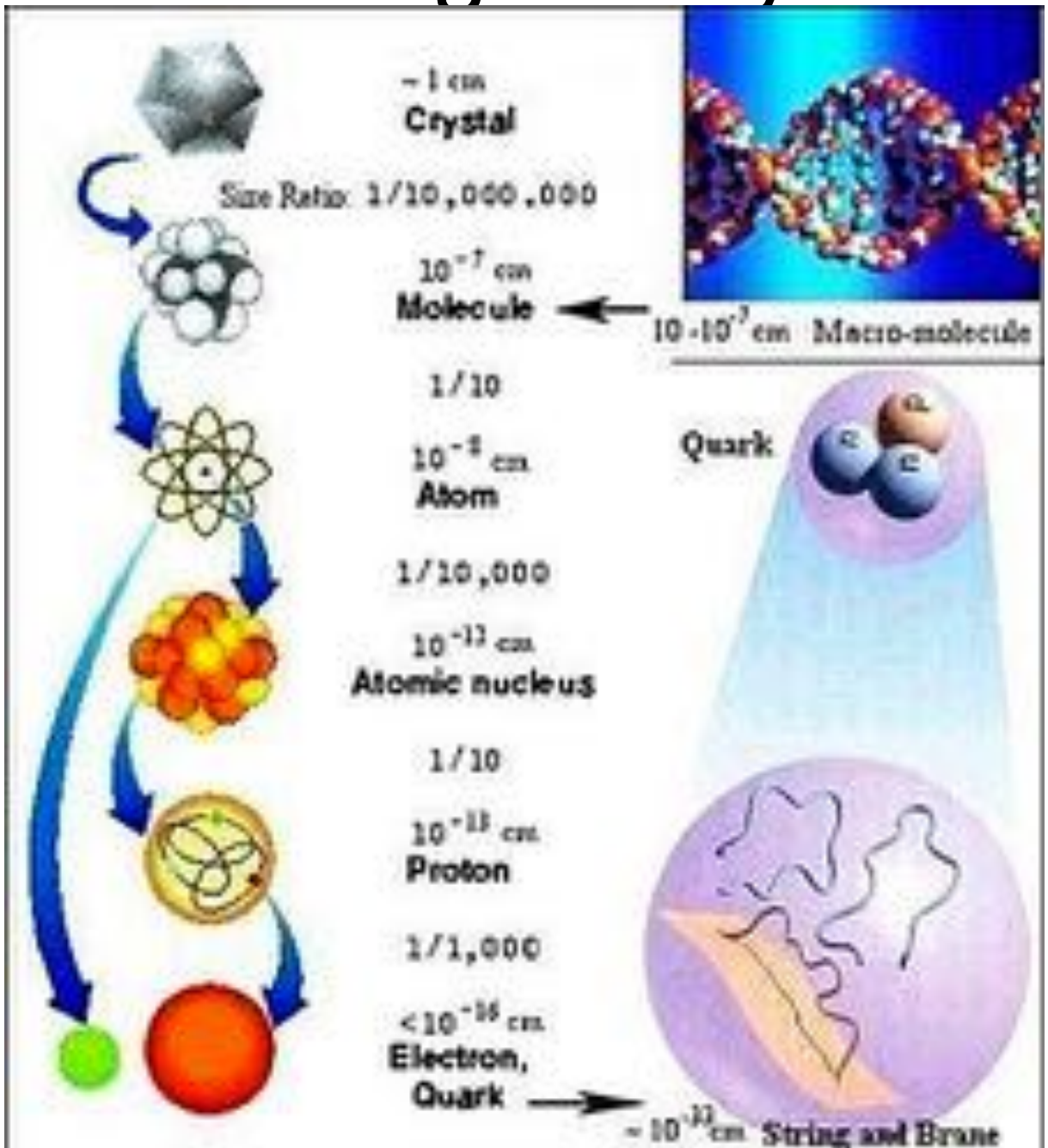

In a static universe, the distance in light-years to the horizon equals age of universe in years.
Cosmic Horizon
Visible Universe
Galaxies exist beyond the horizon, but their light has not had time to reach us.

More Universes with different physics

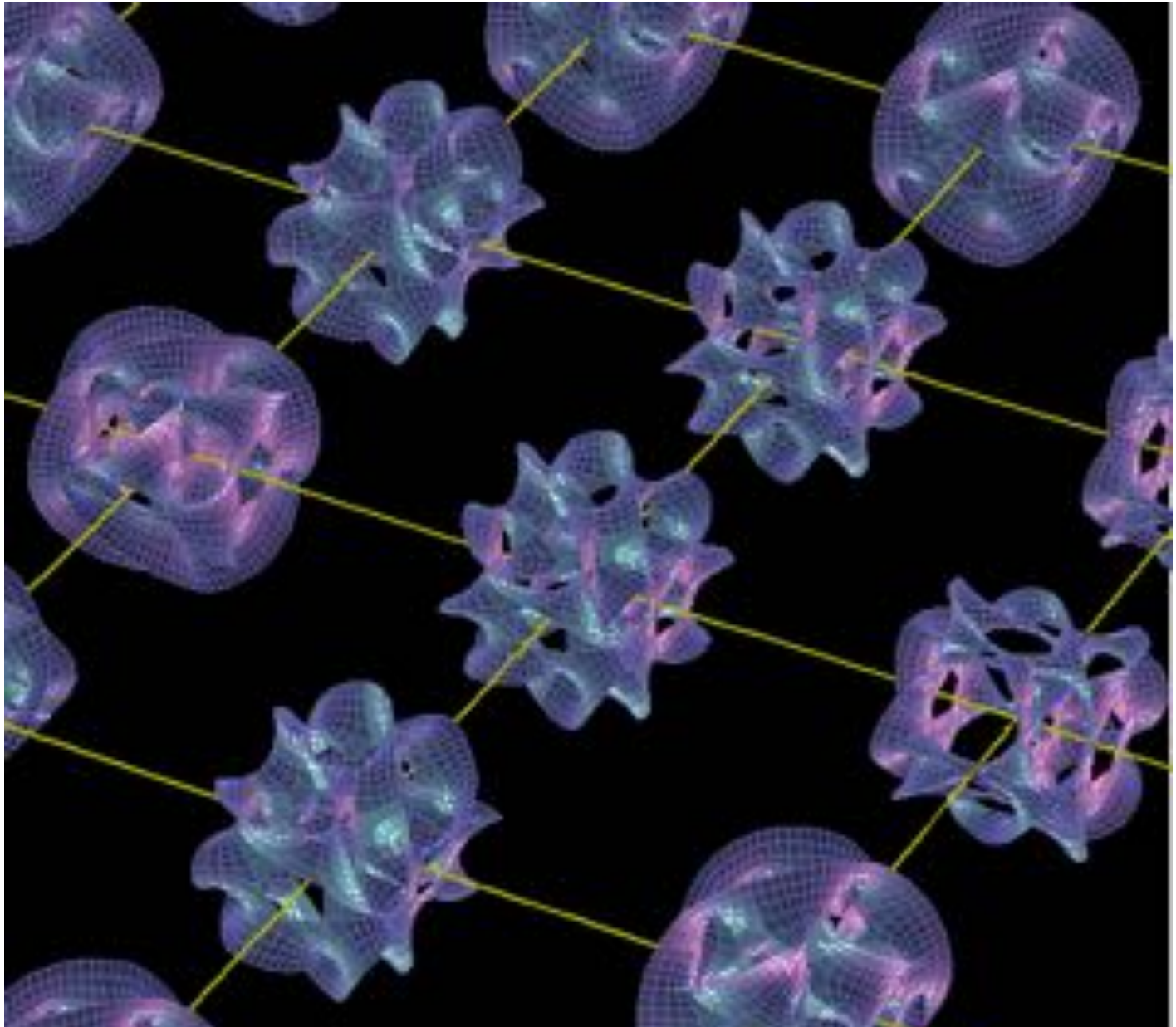



Multiverse
Other universes (Island universes)
Eternally inflating false vacuum
Our universe
Part visible to us (Observable universe)

String theory



String theory



10^{500} parallel universes


GIFsBOOM
.net


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

-De Broglie – Bohm

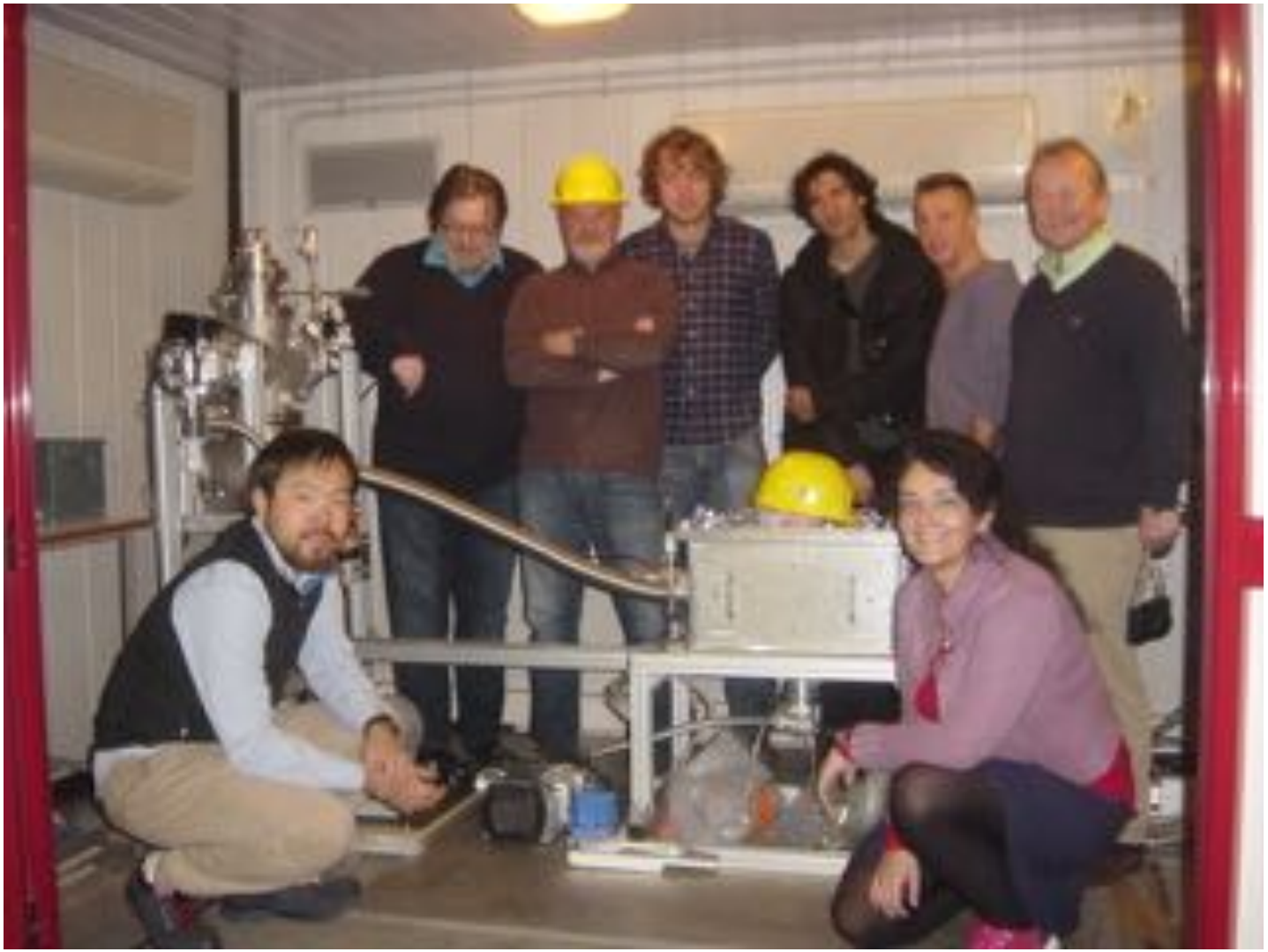
- Many-World Interpretations

-Collpse of the wave function

-.....

Many words interpretation

Underground Gran Sasso laboratory



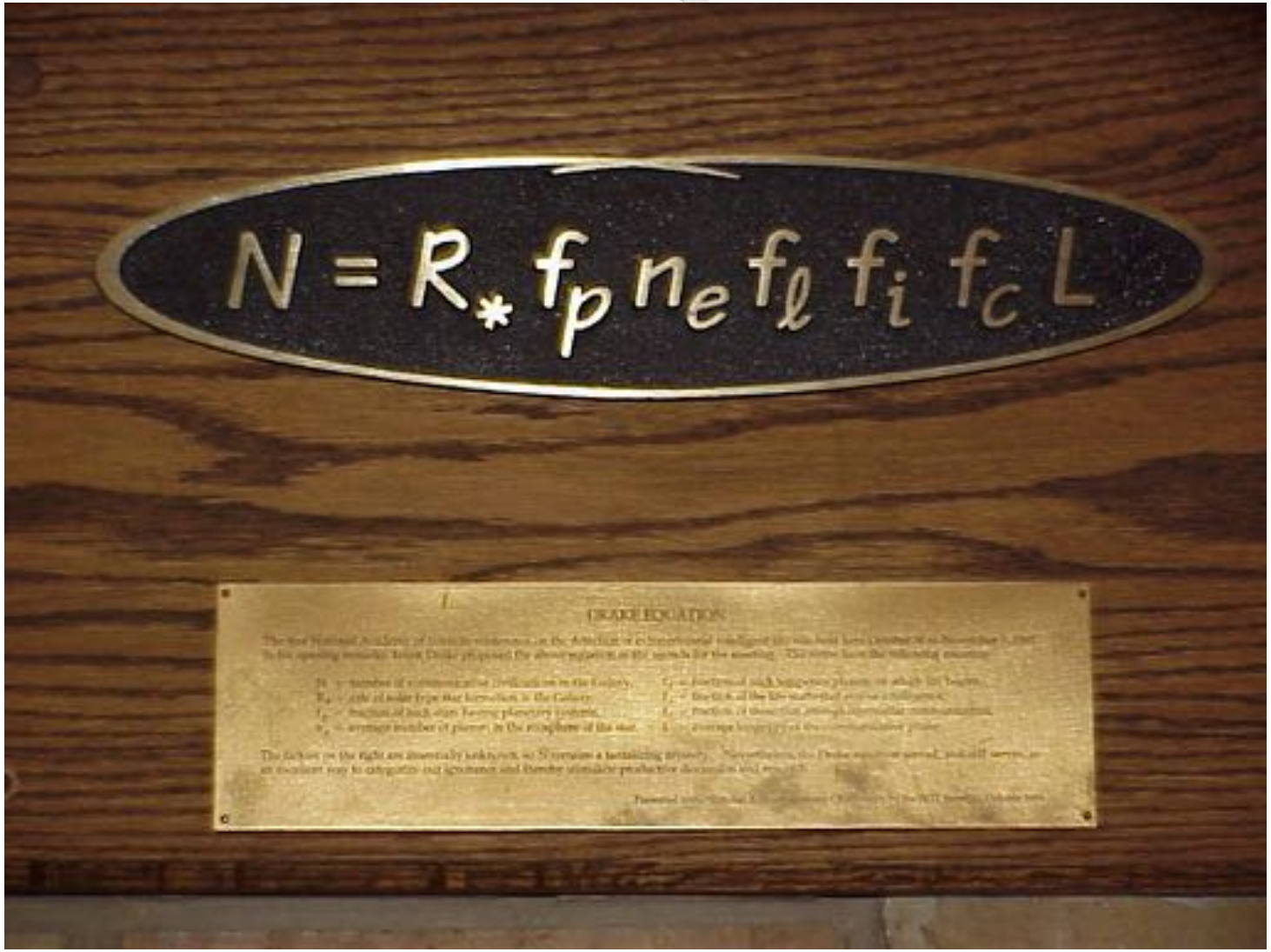
Stawell underground laboratory

7 mysteries in modern physics:

- are we alone in the Universe?


PARADOSSO DI FERMI
"DOVE SONO TUTTI QUANTI?"
SE NELL'UNIVERSO ESISTE UN GRAN NUMERO DI CIVILTÀ ALIENE, PERCHÉ LA LORO PRESENZA NON SI È MAI MANIFESTATA?

Drake's equation:



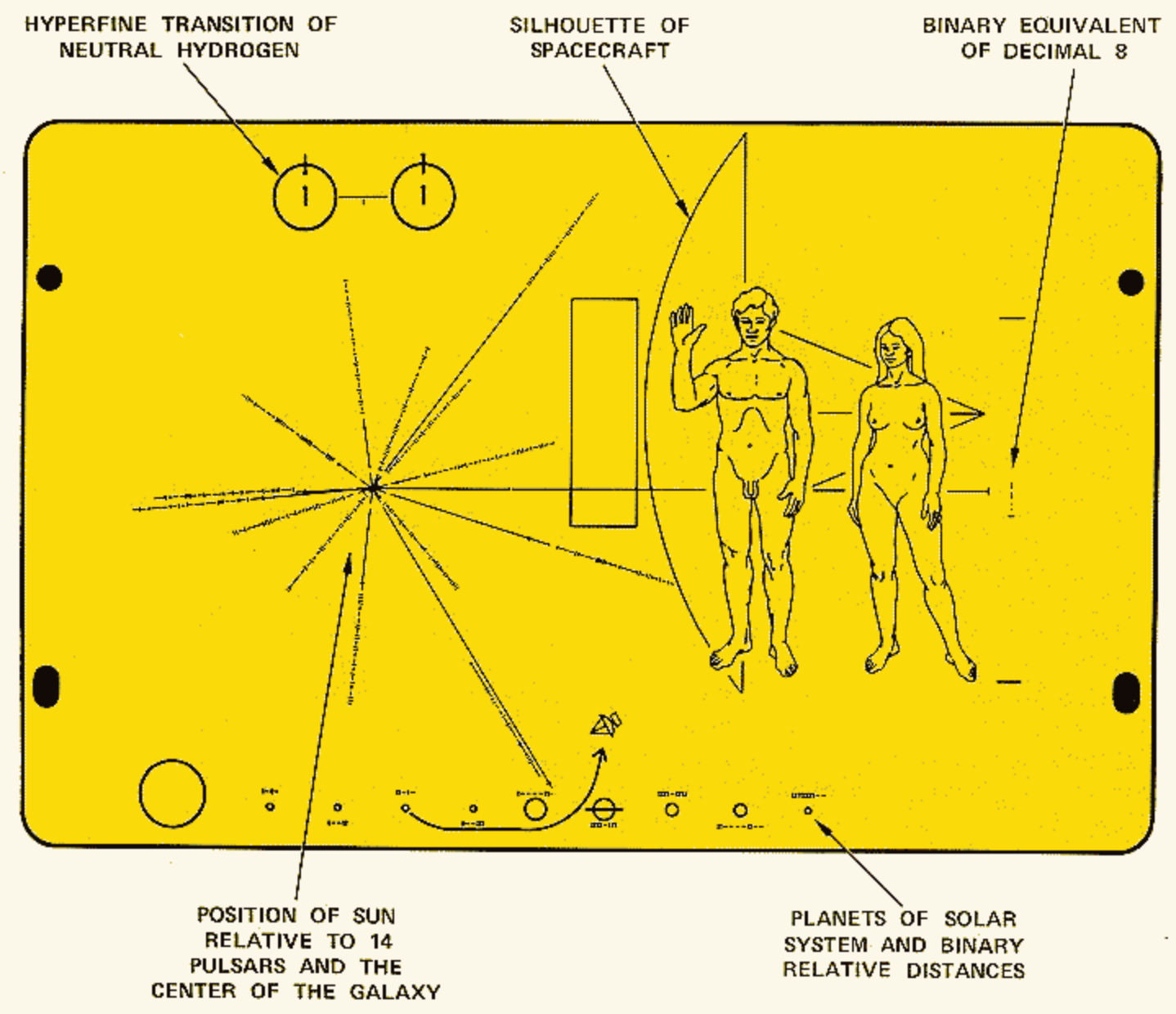

Drake Equation
$N = R \times f_p \times n_e \times f_l \times f_i \times f_c \times L$
R
f_p
n_e
f_l
f_i
f_c
L
fraction of
technology
lifetime of
communications
"have"


Intelligent civilizations in galaxy
Star Formation
Planetary System
Suitable Planet
Life
Intelligence
IQ
Technology
Lifetime

They are here

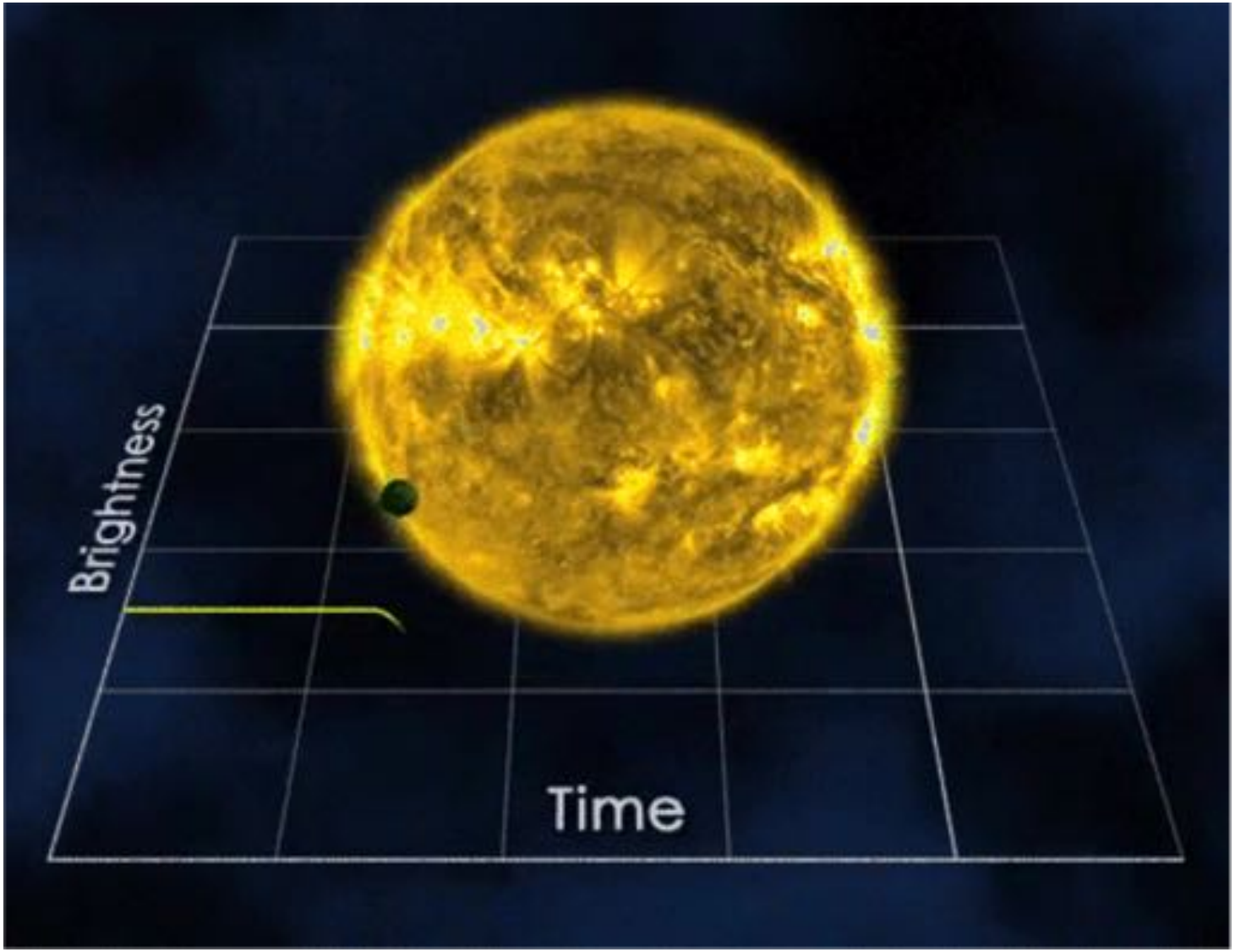
Pioneer 10 (17-10-70) e 11

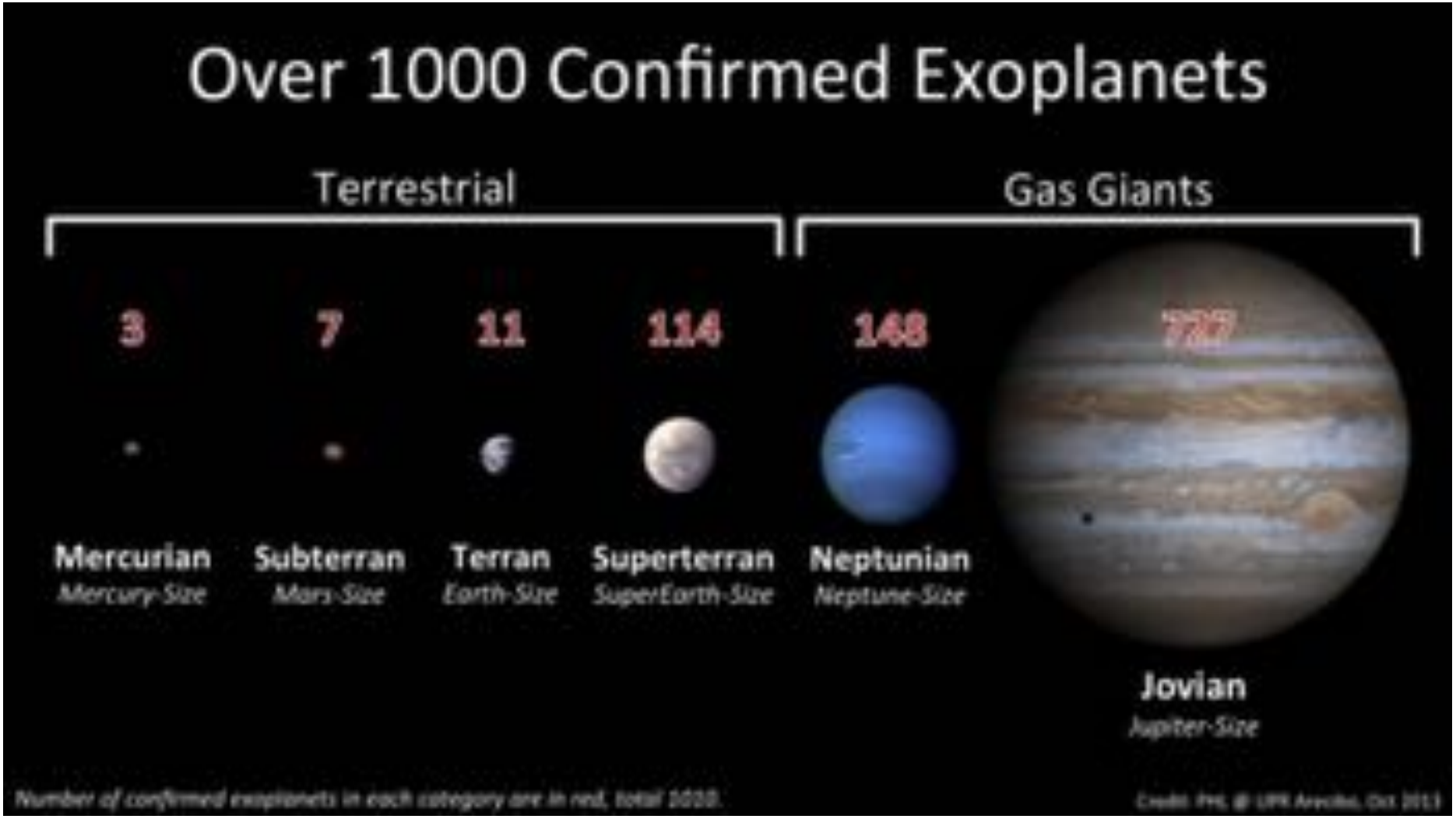
C.
Sagan &
F. Drake




ARECIBO (Puerto Rico)
diam. 305 m,profondita' 51 m

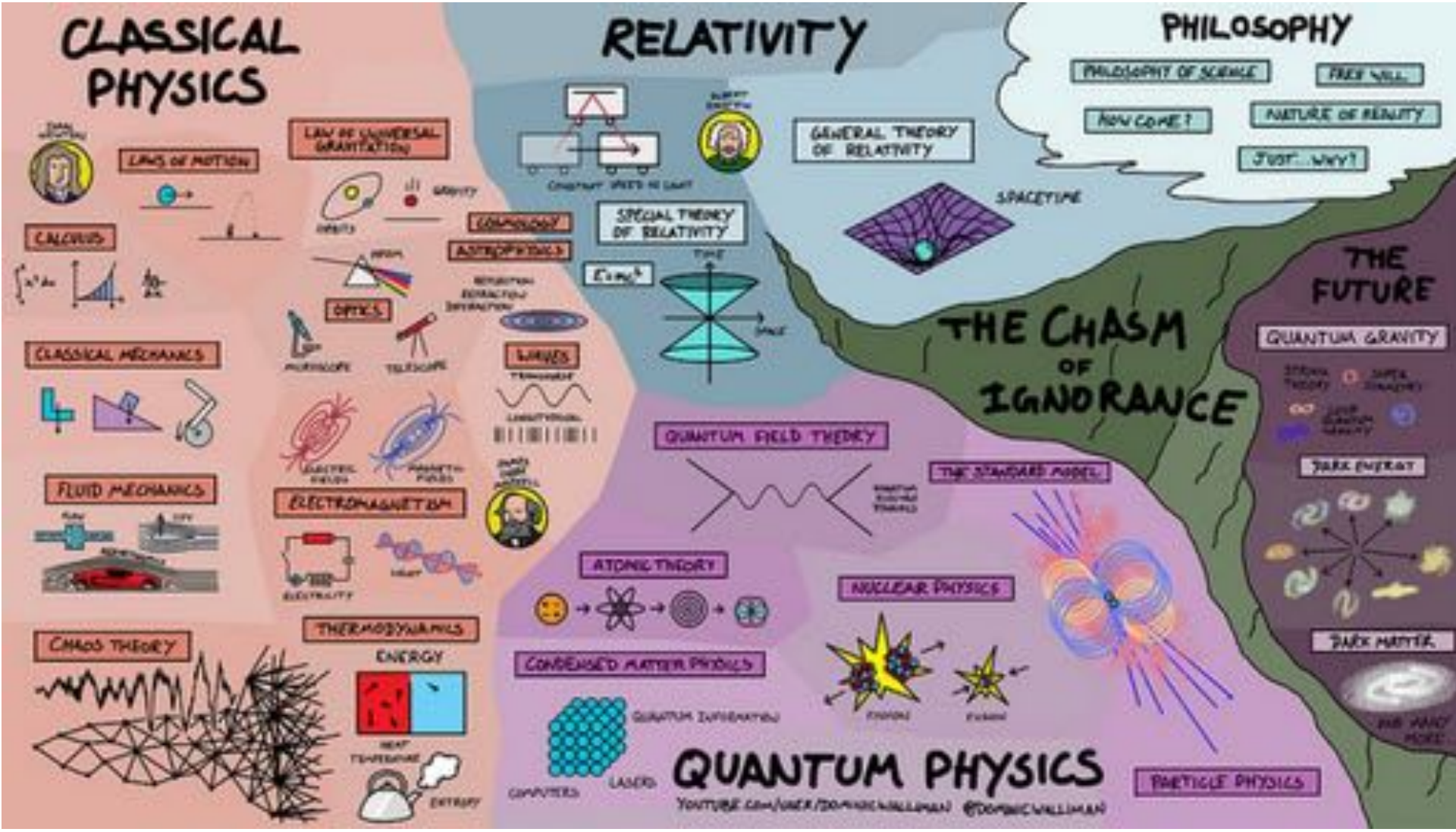
FAST (China), 500m


Brightness
Time

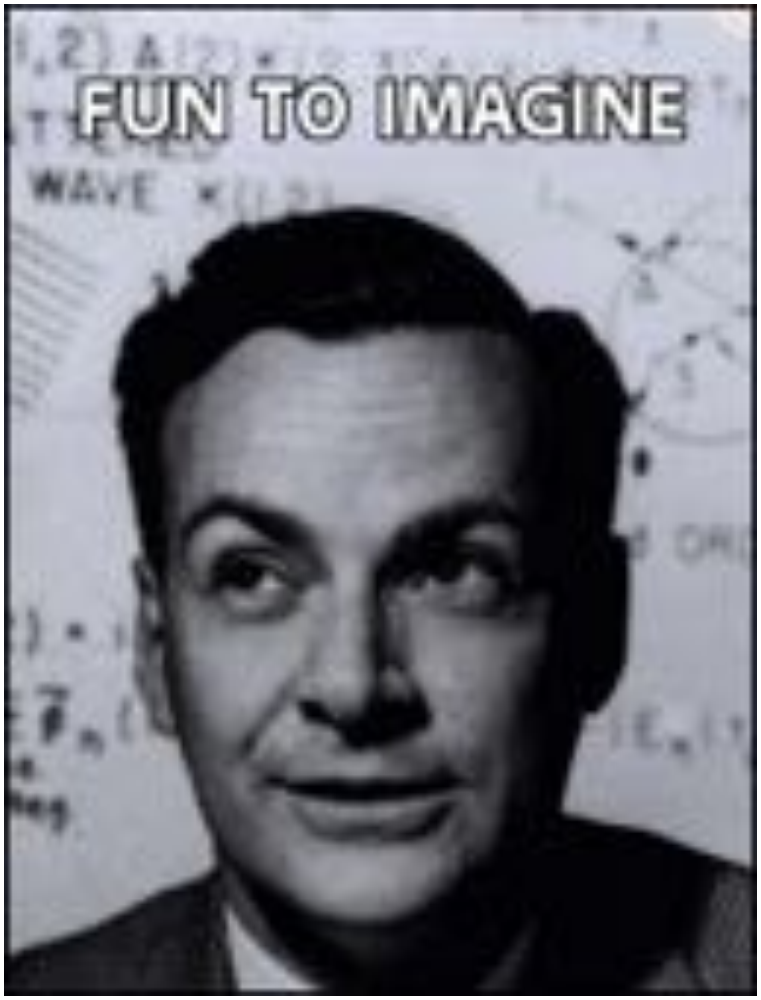

Over 1000 Confirmed Exoplanets
Terrestrial
Gas Giants
3
7
11
114
148
Mercurian
Mercury-Size
Subterran
Mars-Size
Terran
Earth-Size
Superterran
SuperEarth-Size
Neptunian
Neptune-Size
Jovian
Jupiter-Size
Number of confirmed exoplanets in each category are in red, total 1010.


Potential Habitable Worlds in the Universe
#01
KOI 736.01
#02
KOI 494.01
#03
KOI 784.01
#04
KOI 630.01
#05
KOI 947.01
#06
KOI 817.01
#07
KOI 1361.01
#08
KOI 463.01
#09
KOI 701.03
#10
KOI 227.01
#11
KOI 255.01
#12
KOI 854.01
#13
KOI 5026.01
#14
HD 85512 b
#15
KOI 268.01
#16
Gliese 581 d
Scientists are starting to identify potential habitable exoplanets in over 2,000 exoplanets that have been detected so far. Here is the current working list of 16 potential habitable exoplanets candidates ranked by similarity to Earth, from best to worst. All are to scale and can be compared to Earth, Venus, Mars, and Mercury below.
Solar System Terrestrial Planets
Earth
Venus
Mars
Mercury
Updated: Dec 5, 2011
CREDIT: The Habitable Exoplanets Catalog, Planetary Habitability Laboratory @ UPR Arecibo (phl.upr.edu)


alaTerra


CLASSICAL PHYSICS
LAWS OF MOTION
LAW OF UNIVERSAL GRAVITATION
CALCULUS
COSMOLOGY
ASTROPHYSICS
OPTICS
CLASSICAL MECHANICS
WAVES
FLUID MECHANICS
ELECTROMAGNETISM
CHAOS THEORY
THERMODYNAMICS
ENERGY
RELATIVITY
GENERAL THEORY OF RELATIVITY
SPECIAL THEORY OF RELATIVITY
SPACETIME
PHILOSOPHY
PHILOSOPHY OF SCIENCE
FREE WILL
HOW COME?
NATURE OF REALITY
JUST... WHY?
THE CHASM OF IGNORANCE
THE FUTURE
QUANTUM GRAVITY
DARK ENERGY
DARK MATTER
QUANTUM FIELD THEORY
THE STANDARD MODEL
ATOMIC THEORY
NUCLEAR PHYSICS
CONDENSED MATTER PHYSICS
QUANTUM INFORMATION
COMPUTERS
LASERS
QUANTUM PHYSICS
PARTICLE PHYSICS

Feynman – The Value of Science, 1955



Out of the cradle
onto dry land
here it is
standing:
atoms with consciousness;
matter with curiosity.

Stands at the sea,
wonders at wondering: I
a universe of atoms
an atom in the Universe

Thanks to support from:

Farnesina
Ministero degli Affari Esteri
e della Cooperazione Internazionale

cost
EUROPEAN COOPERATION
IN SCIENCE AND TECHNOLOGY

INFN
LNF
Istituto Nazionale di Fisica Nucleare

John
Templeton
Foundation

CENTRO
FERMI
Museo Storico della Fisica e Centro Studi e Ricerche Enrico Fermi

FQXi
Foundational Questions Institute

TEQ

Feynman – Il valore della scienza

Fuori dalla culla
sulla terra asciutta

Feynman– The Value of Science, 1955

Out of the cradle
onto dry land
here it is
standing:
atoms with consciousness;
matter with curiosity.

Stands at the sea,
wonders at wondering: I
a universe of atoms
an atom in the Universe

nza
sità.
are
ria meraviglia: io
mi
erso

Pronti per esplorare la
Terra Incognita
della Fisica Moderna?

Catalina Oana Curceanu

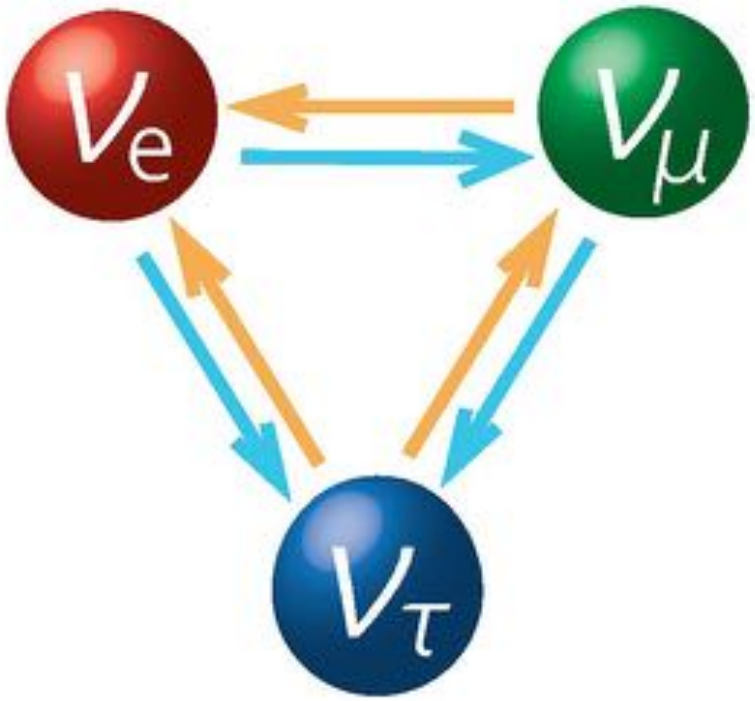
Dai buchi neri all'adroterapia

Un viaggio nella fisica moderna

http://www.springer.com/physics/applied+%26+technical+physics/book/978-88-470-5240-6

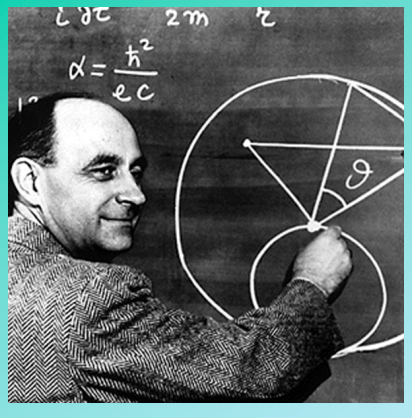
7+1 mysteries in modern physics:

– the fascinating neutrinos – which is their mass?



The Standard Model

Neutrino Facts



Neutrino from Enrico Fermi for "Little neutral one"

ν flux on Earth from Sun

$6.5 \times 10^{14}/(m^2\ s)$

<E> ~ 0.3 MeV

Neutrino from sun will pass through 5 LY of solid lead, with 50% chance of interacting

Average number of solar neutrinos interacting in a person per year

≤ 30!

≤ 1 with 'real energy'

Sun:

$p + p \rightarrow d + e^+ + \nu_e$

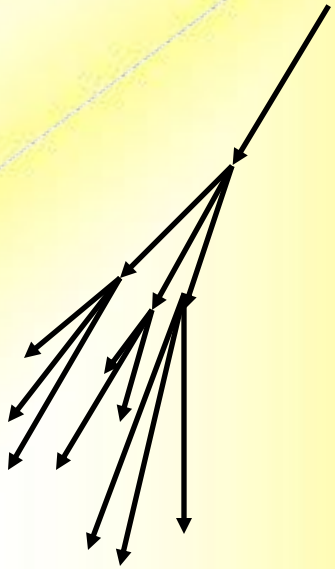
$^8B \rightarrow {}^8Be + e^+ + \nu_e$

$2\times10^{38}\ s^{-1}$

Uranium & Thorium
from Earth crust

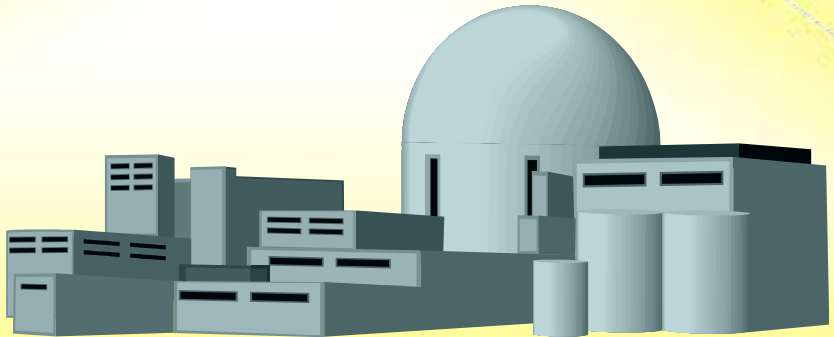
$\sim 5\times10^{10}\ s^{-1}\ m^{-2}$

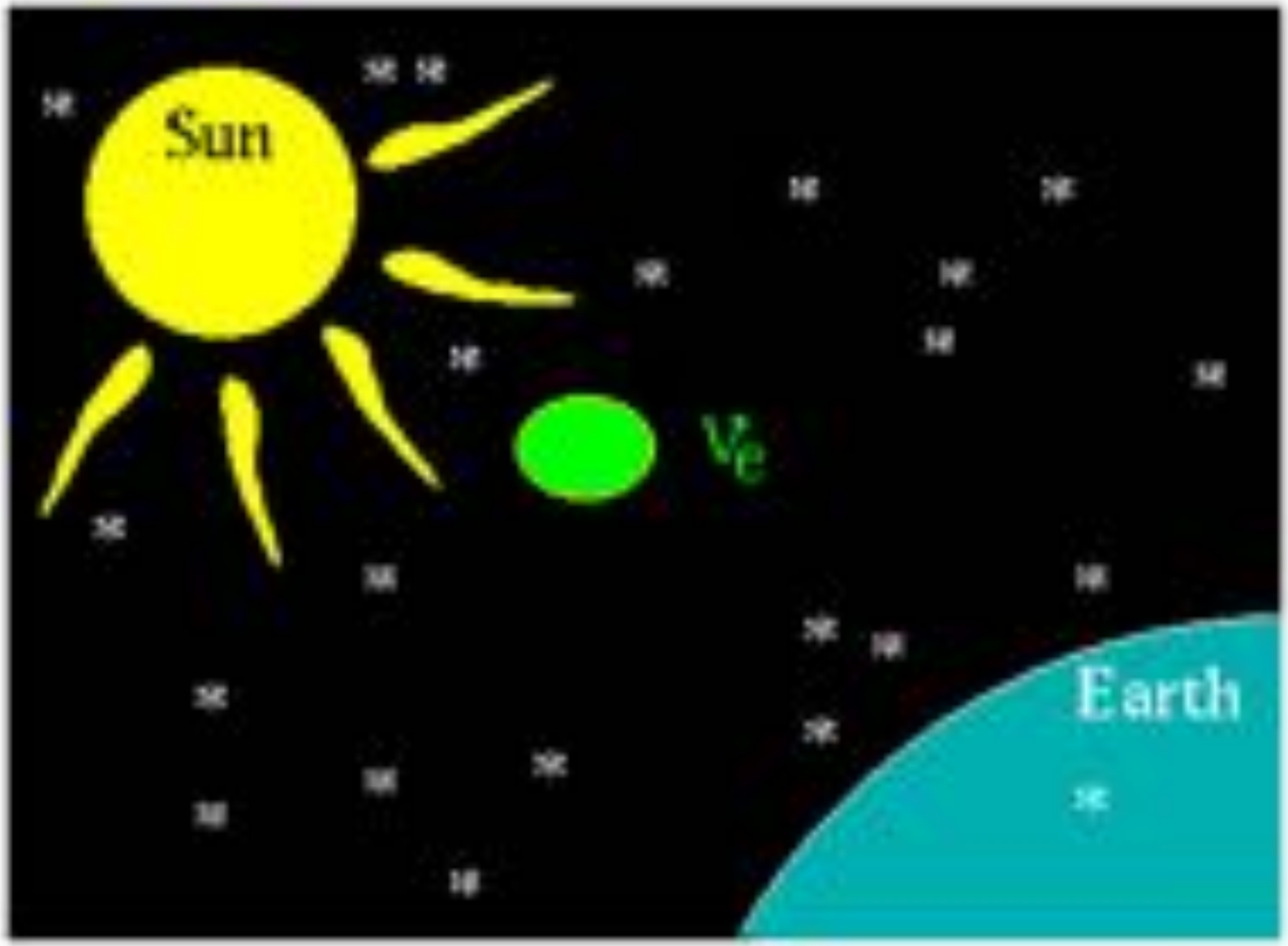
Neutrino sources



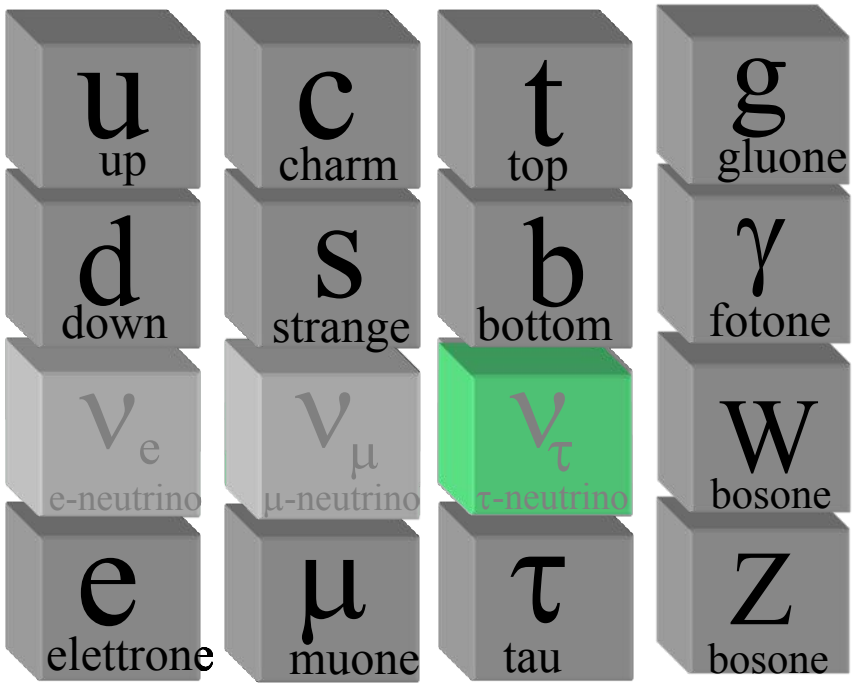
Cosmic Rays
$\sim 100\ m^{-2}\ s^{-1}$

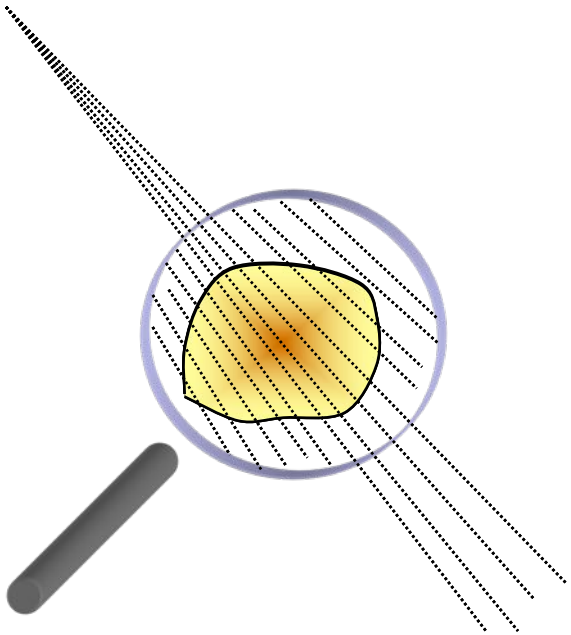
Nuclear power reactors
$\sim 10^{20}\ s^{-1}$



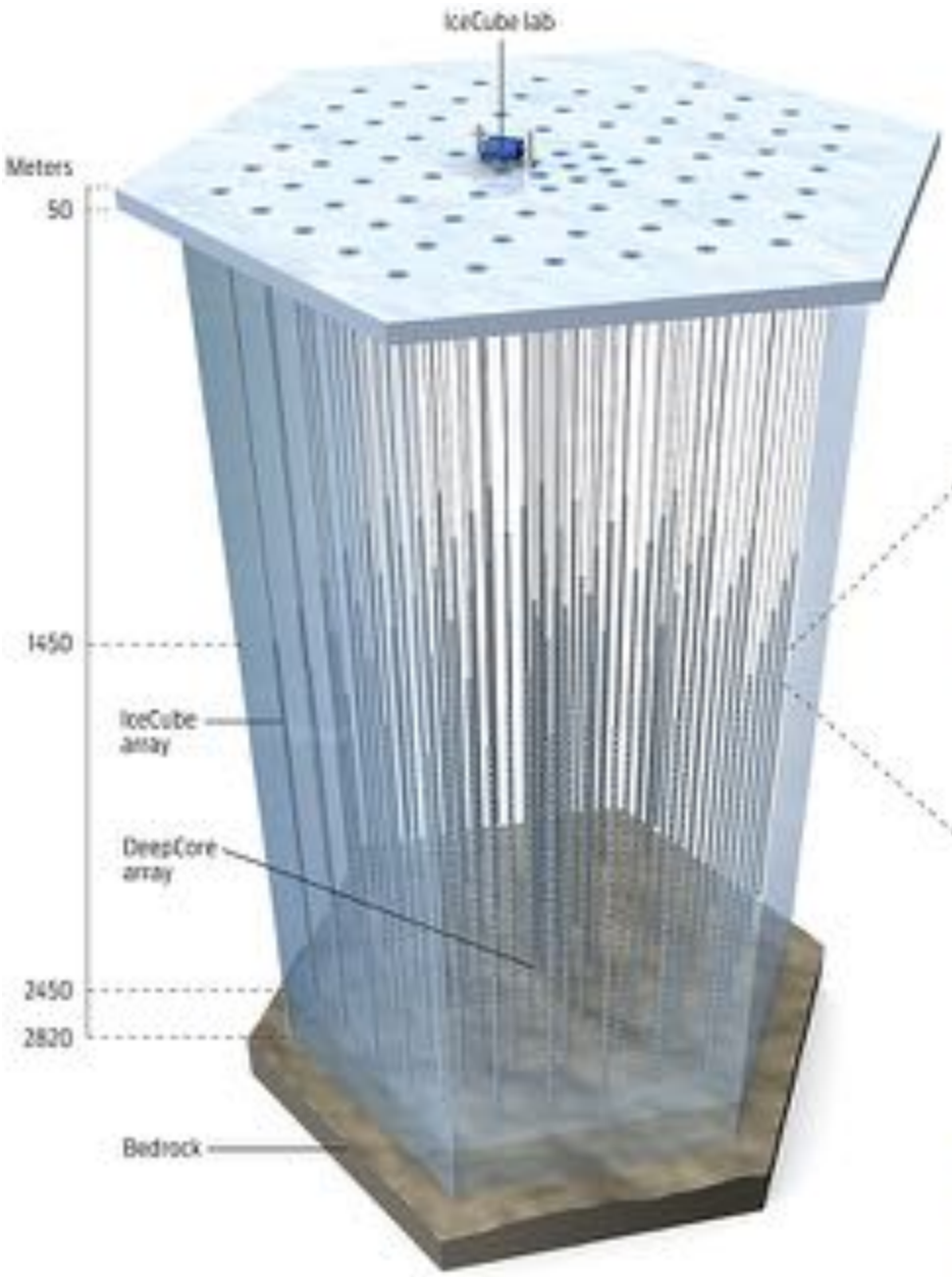

Sun
ν_e
Earth

Neutrinos oscillations

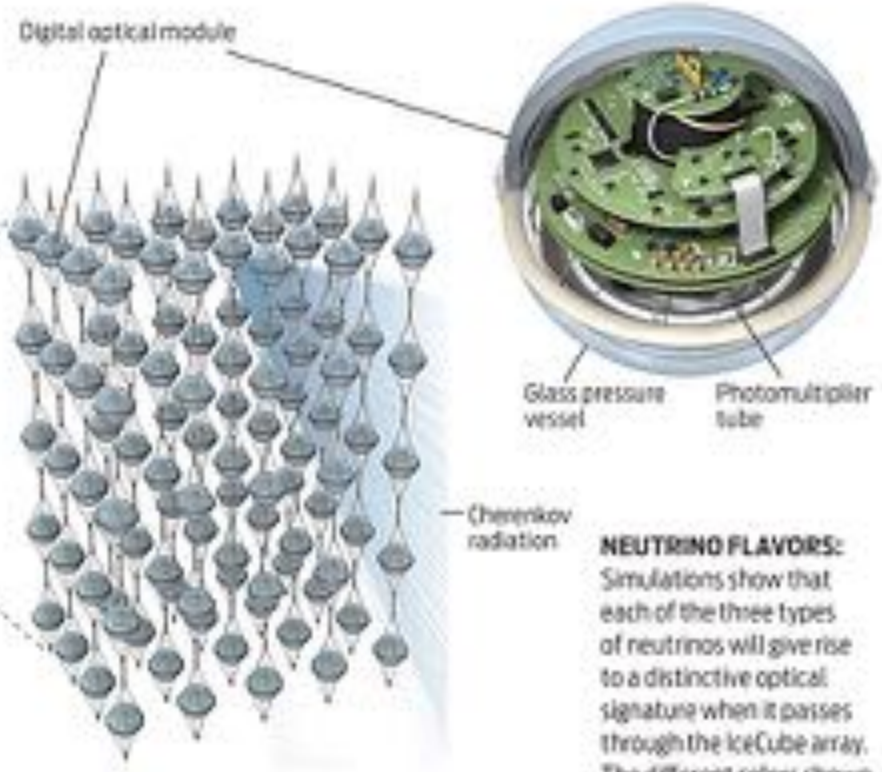




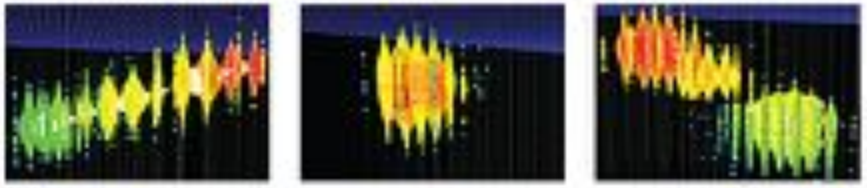
Milioni di neutrini al secondo attraverso un granello di sabbia



ELECTRONIC PEARLS: The digital optical modules used to sense the passage of neutrinos through the ice are encased in spherical pressure vessels made of borosilicate glass. They are attached to their suspending cables at 17-meter vertical intervals, from 1450 to 2450 meters' depth. After a string has been deployed and tested, the surrounding water (left over from drilling the hole) freezes the detectors in place.



NEUTRINO FLAVORS: Simulations show that each of the three types of neutrinos will give rise to a distinctive optical signature when it passes through the IceCube array. The different colors shown here represent detections taking place at slightly different times.



BOREXINO at LNGS