

Introduction to Physics Research

Origin of Universe and Ourselves

Katsushi Arisaka

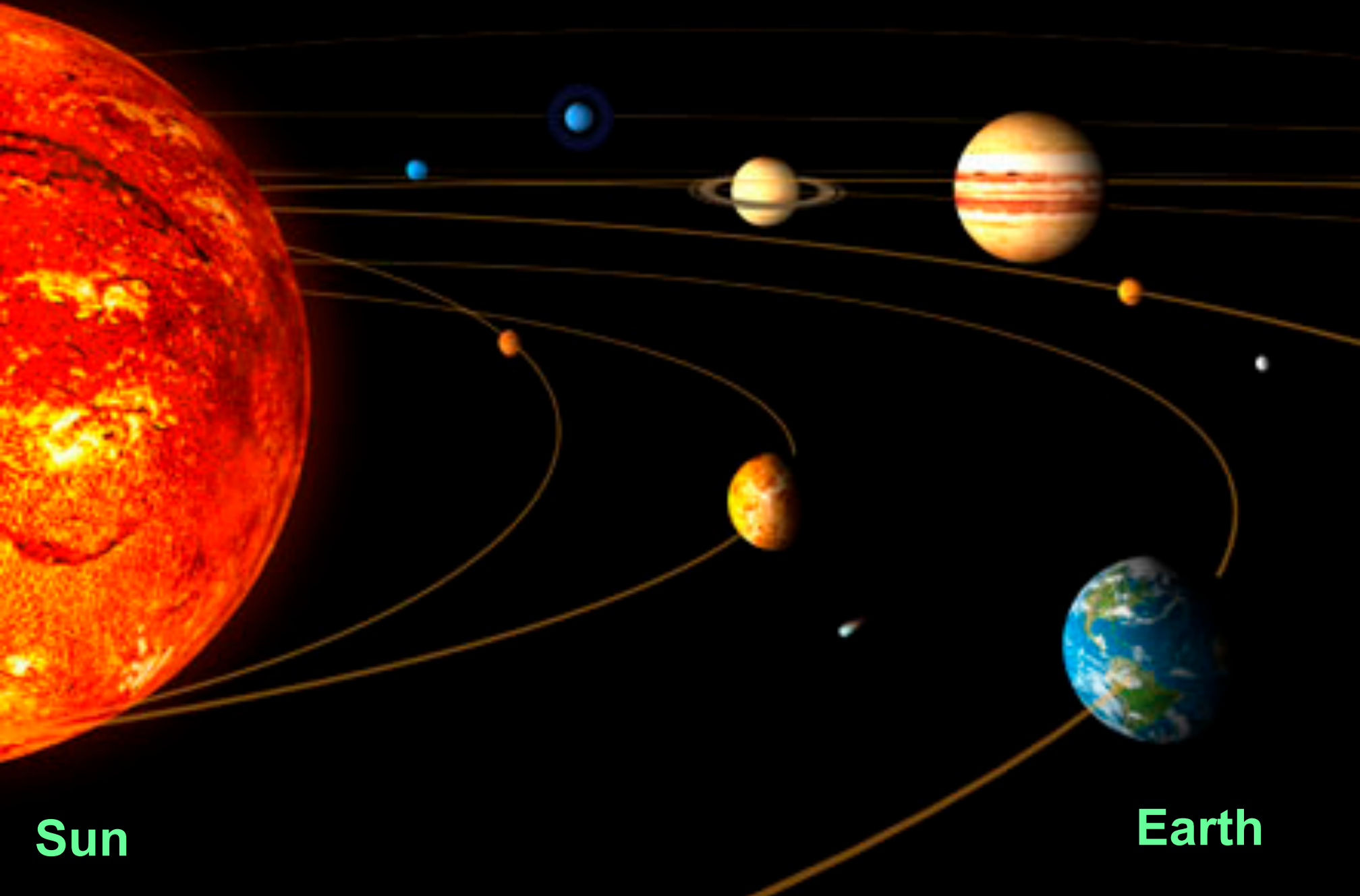
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Department of Physics and Astronomy

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Why are we here?

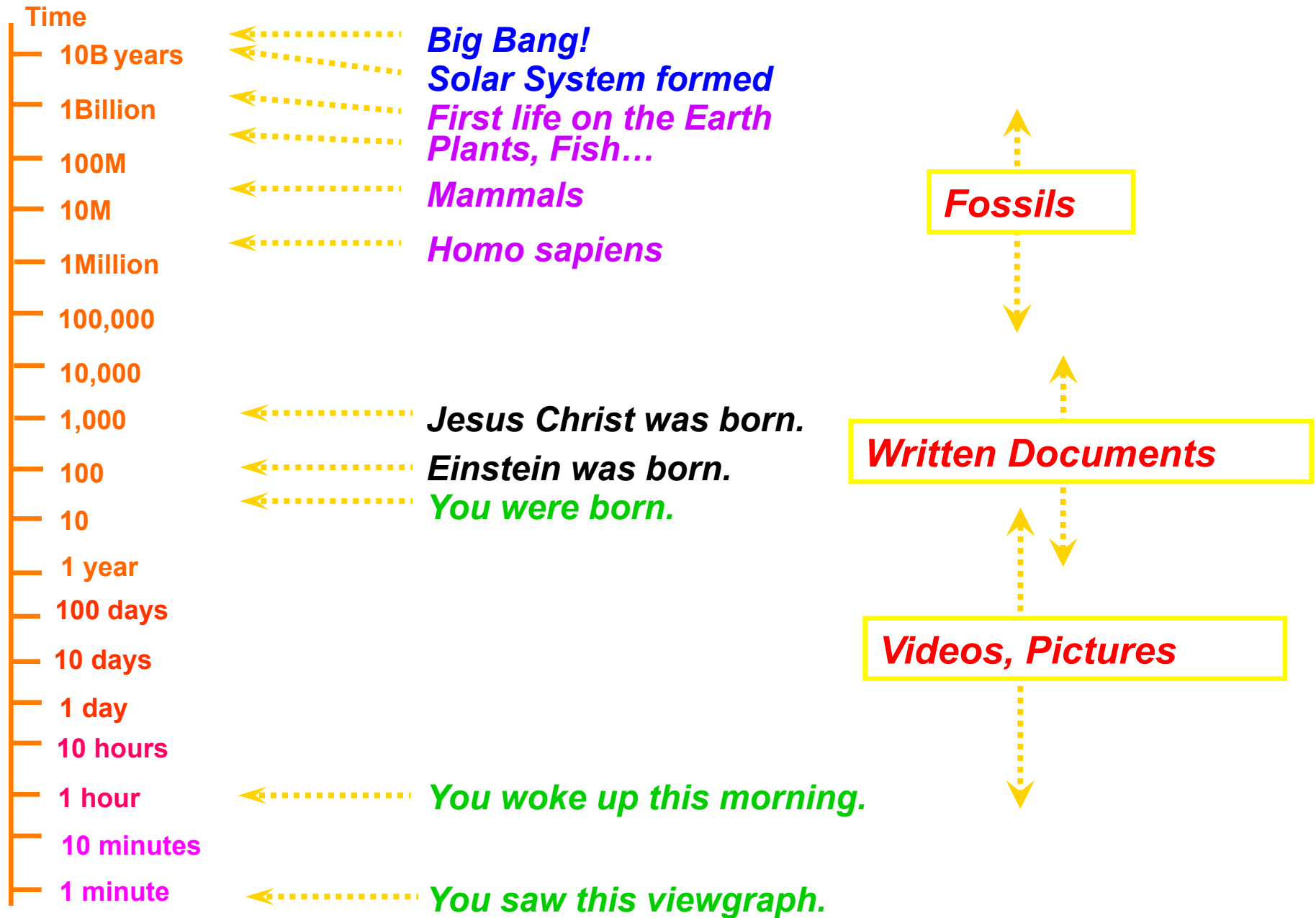
Solar System



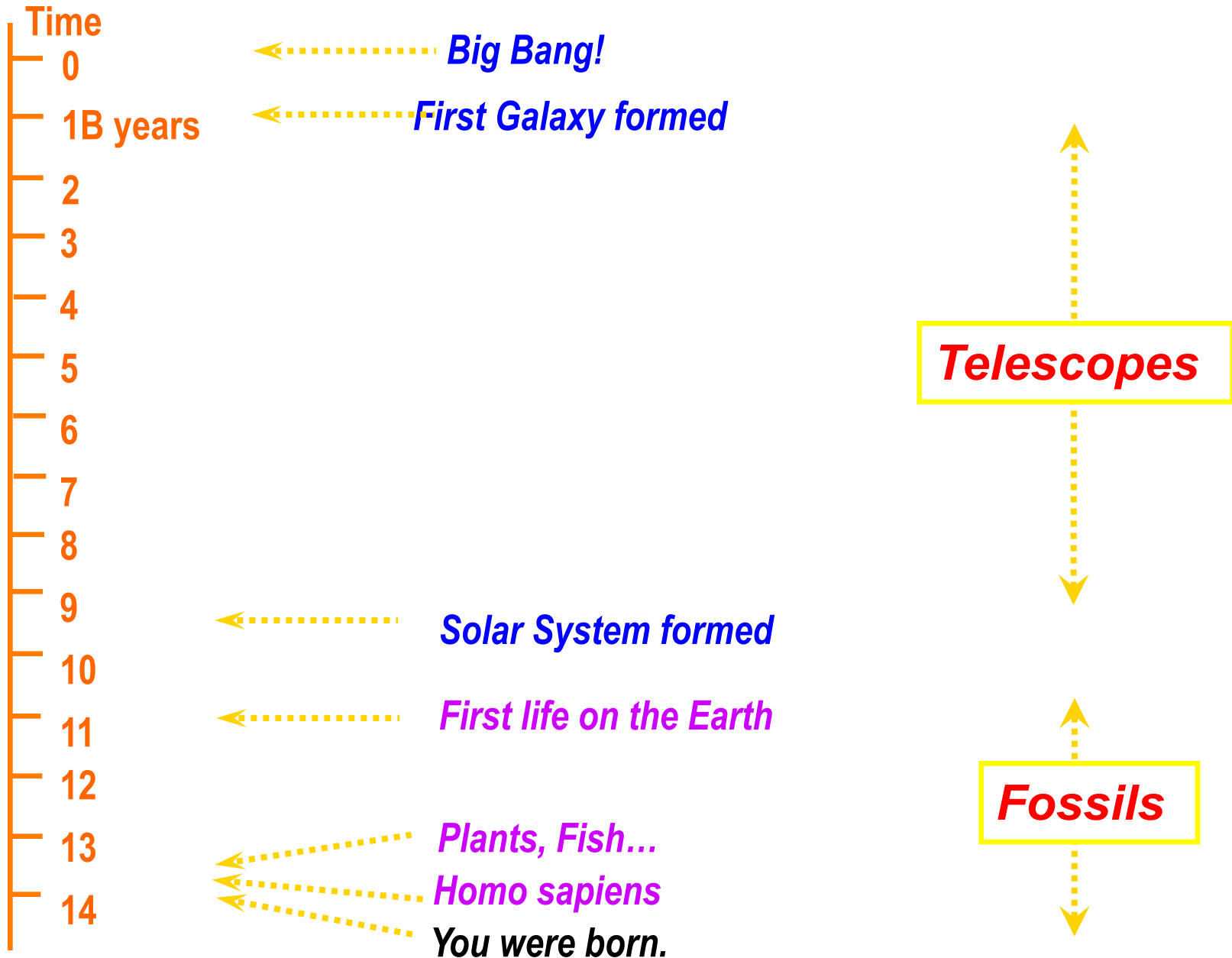
Sun

Earth

History of Life and the Human beings



Brief History of Universe and Life



Andromeda

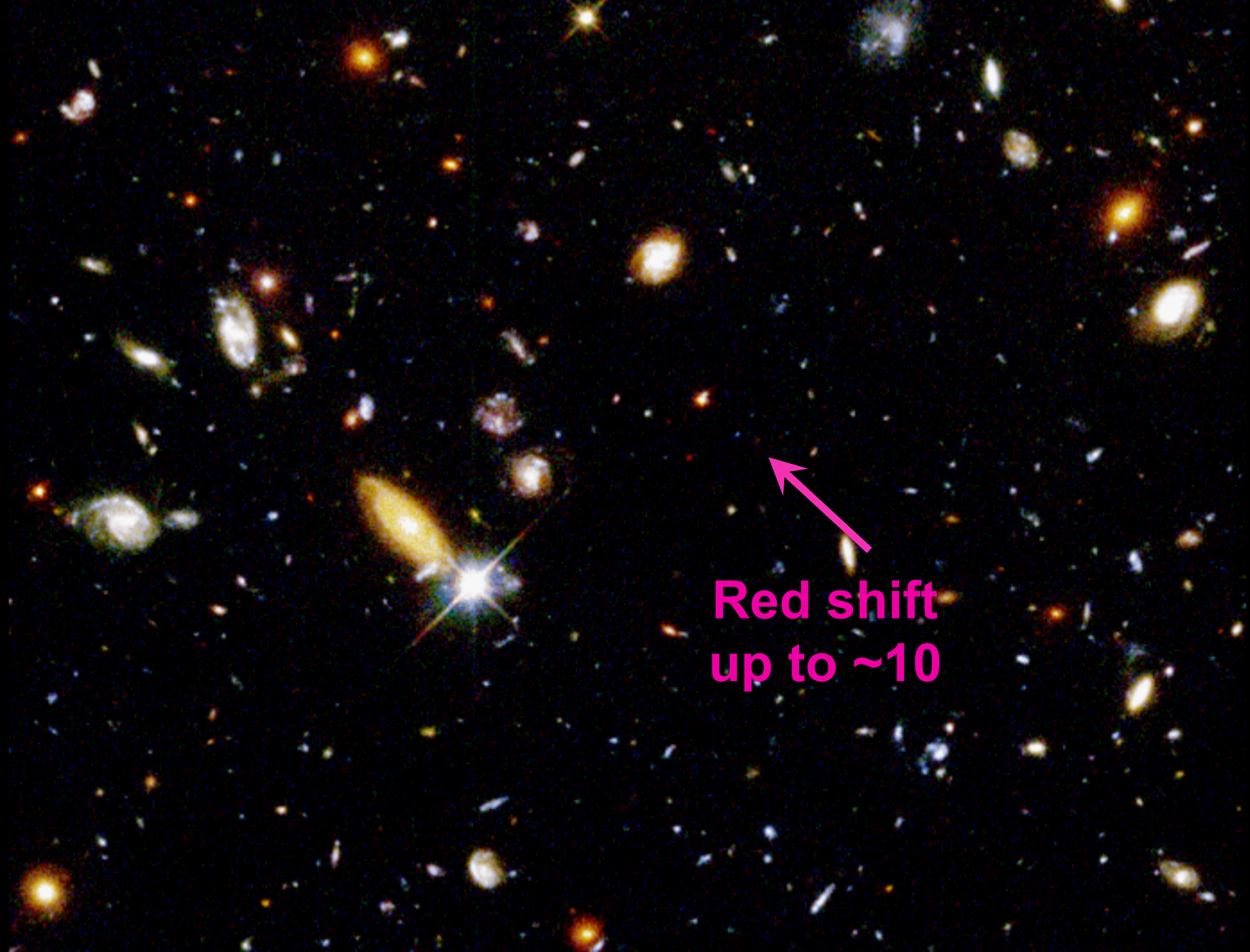


~100 Billions Stars in a Galaxy

Hubble Deep Field

The image displays a dense field of galaxies, including various types such as spirals, ellipticals, and irregular shapes, scattered across a dark background. The galaxies are concentrated in the central and lower-left regions, with some appearing as bright, distinct points of light and others as faint, diffuse structures. The overall appearance is that of a rich, multi-colored stellar population.

~100 Billion Galaxies

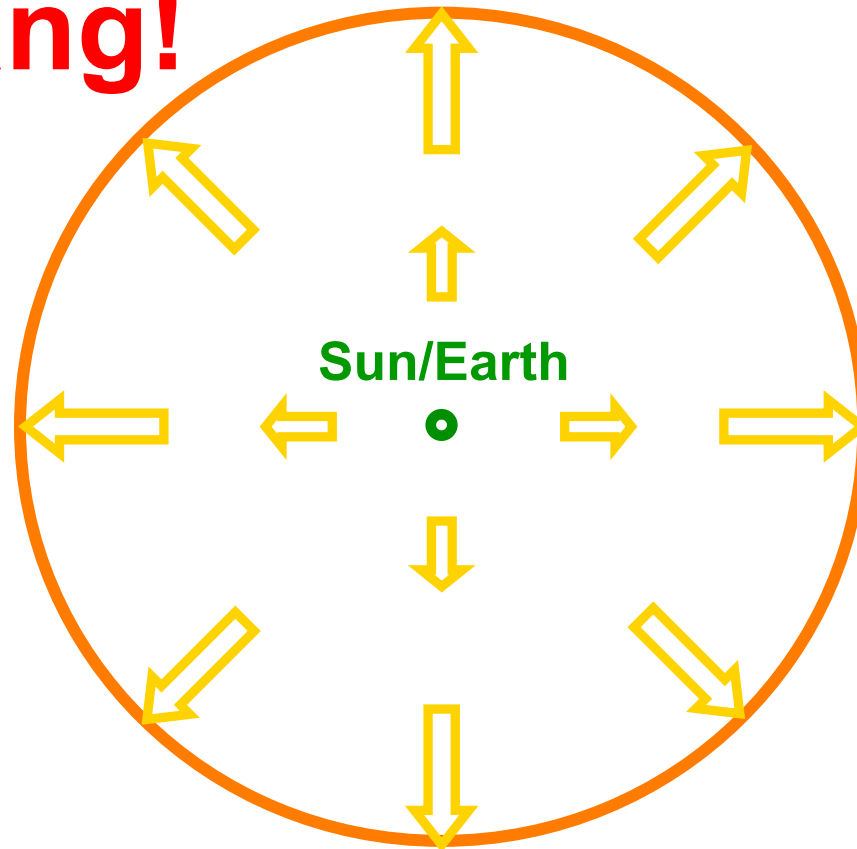


**Red shift
up to ~10**

Hubble's Law: Expansion of the Universe

Big Bang!

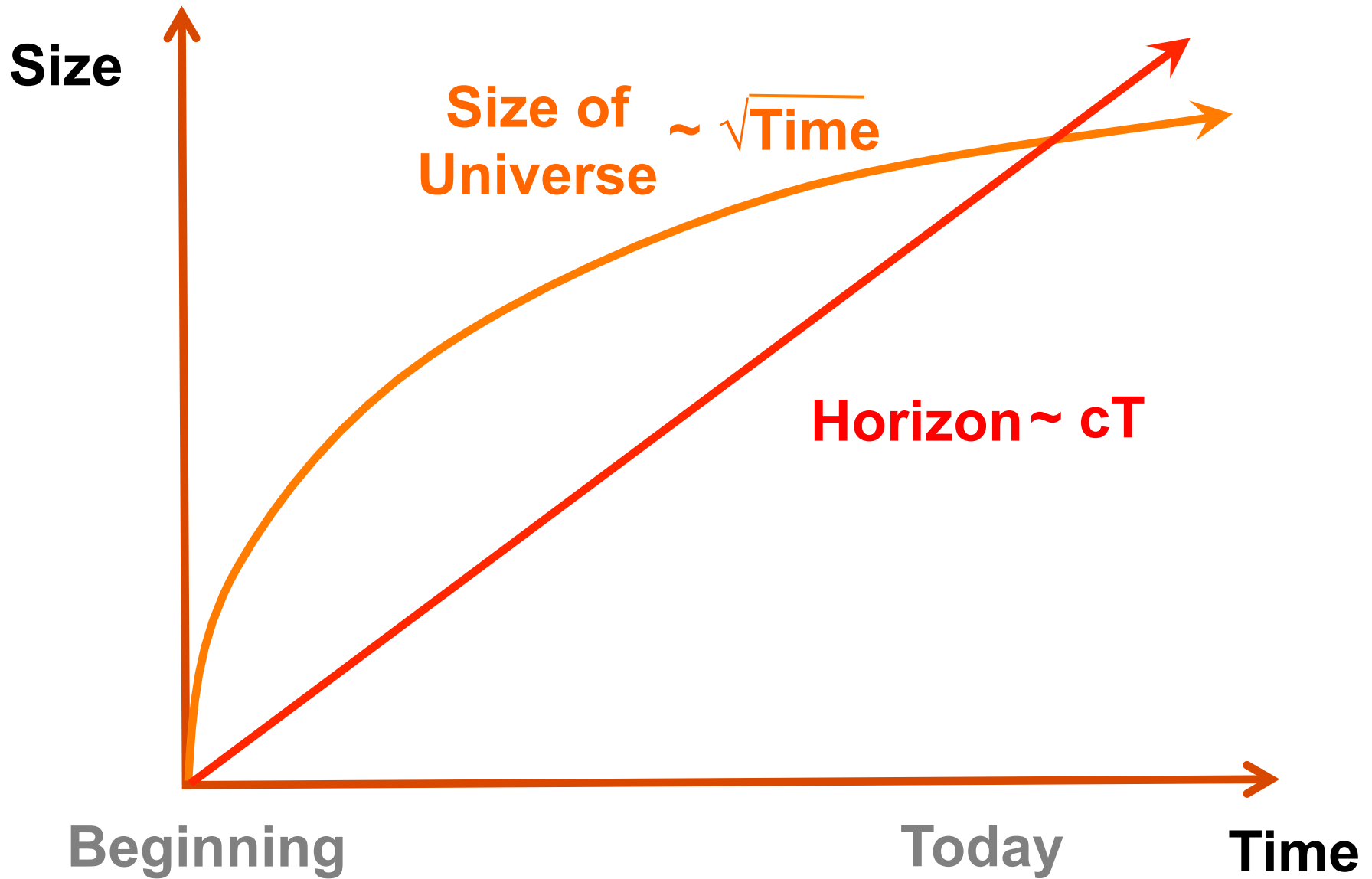
Horizon
of Universe



14 Billion
Light Years

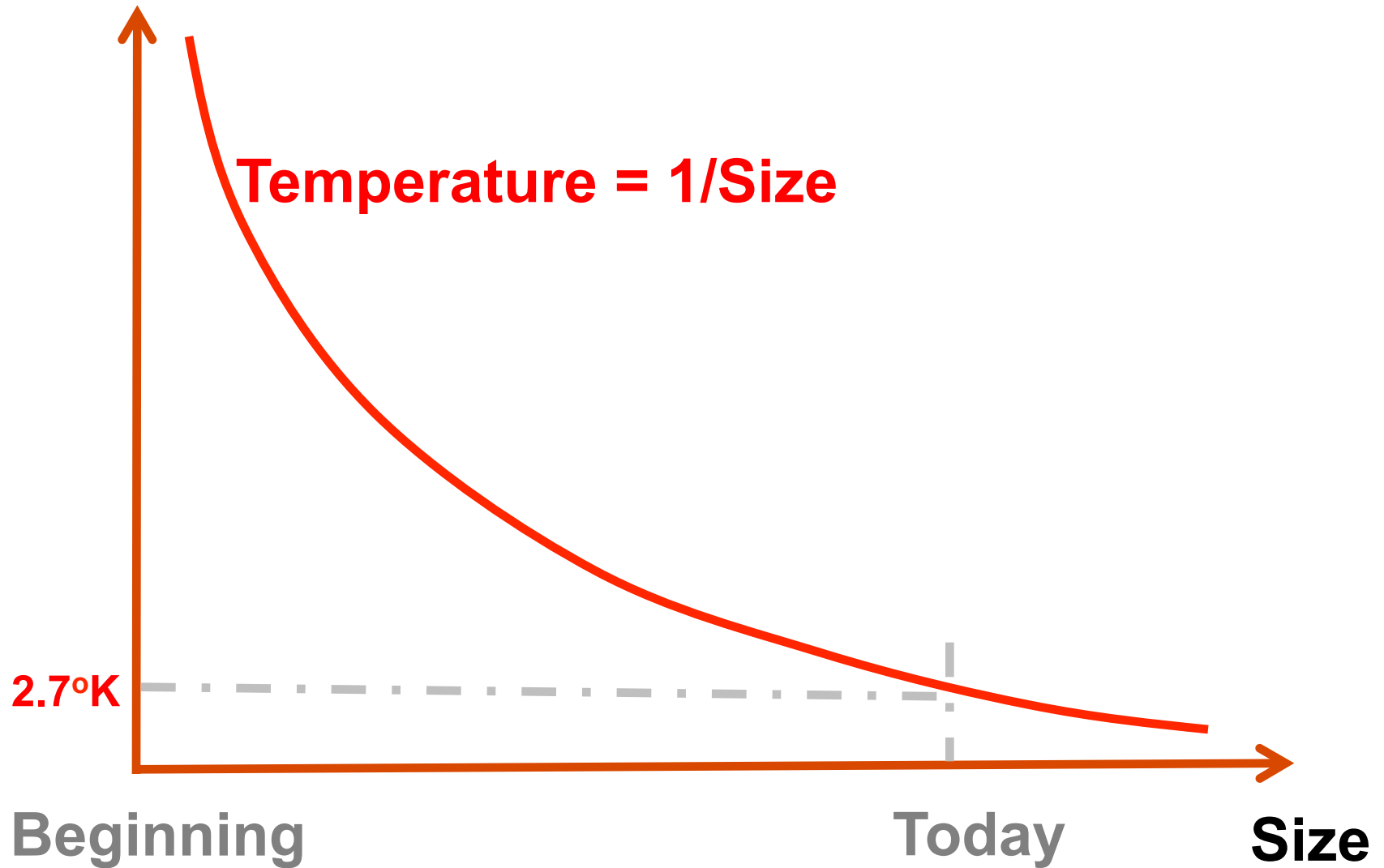
Moving Away
at Speed of Light

Expansion of Universe



Temperature of Universe

Temperature

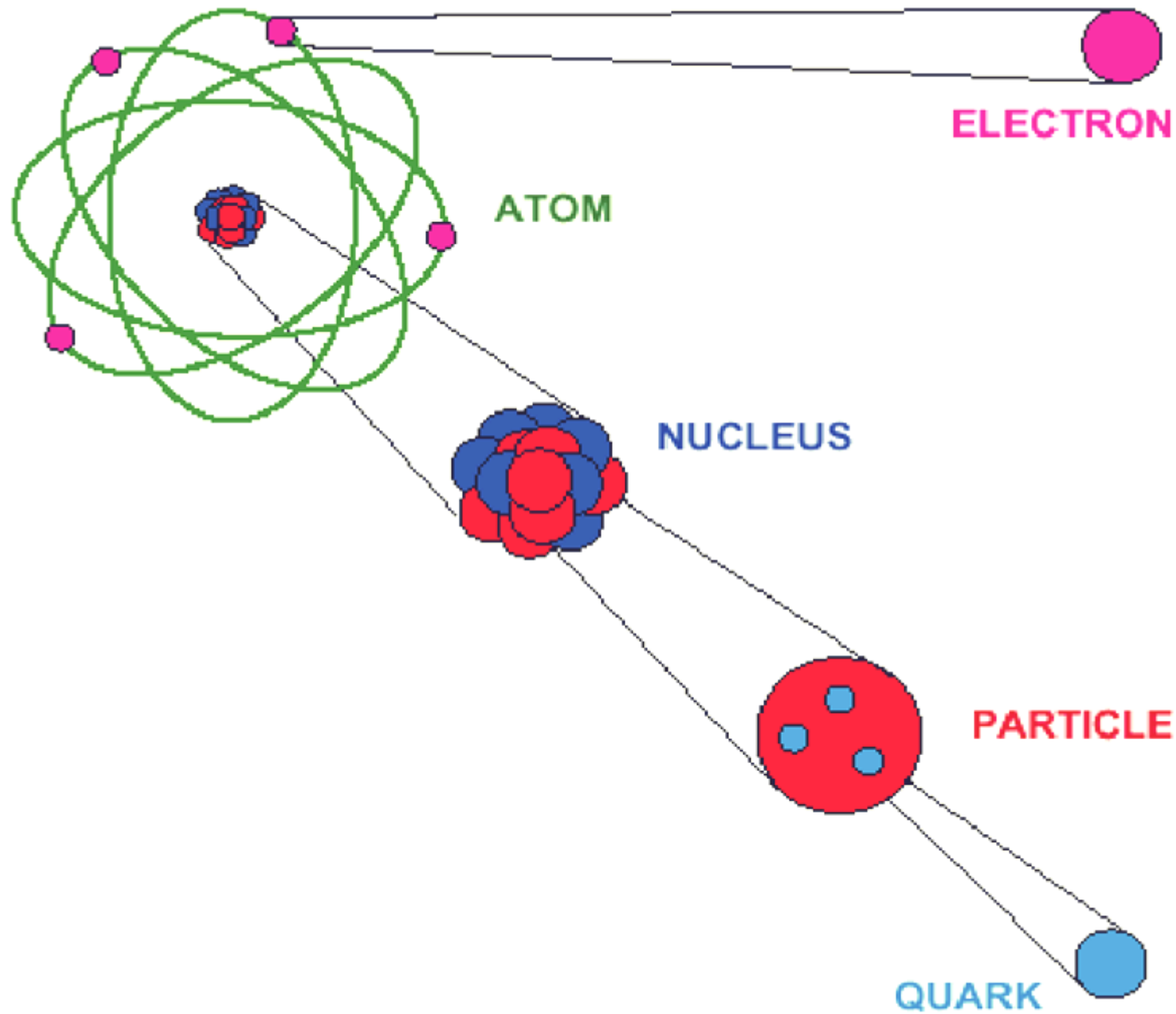


Tevatron at Fermi Lab near Chicago (1980 – 2010)



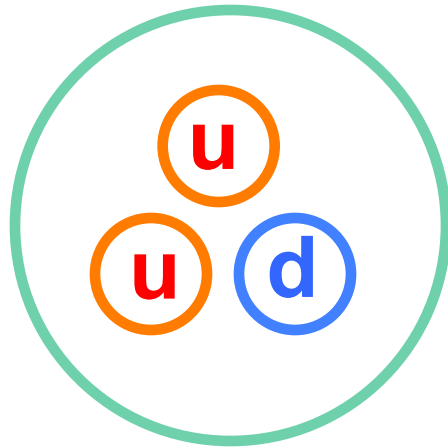
6km Circumference

Elementary Particles



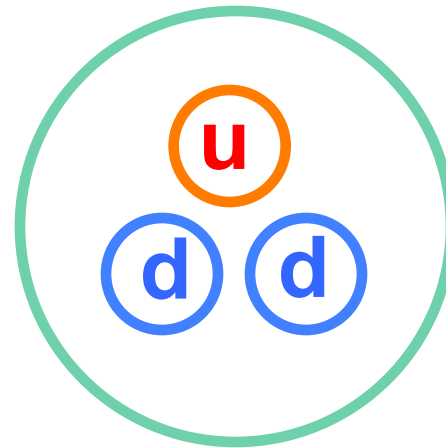
Quark Model

Proton



$$+ 2/3 + 2/3 - 1/3 = 1$$

Neutron



$$+ 2/3 - 1/3 - 1/3 = 0$$

Elementary Particles

		Fermion			Boson			
Charge							Charge	
+2/3	Quarks	<i>u</i> up	<i>c</i> charm	<i>t</i> top	<i>γ</i> photon	<i>g</i> gluon	0	0
		<i>d</i> down	<i>s</i> strange	<i>b</i> bottom				
-1/3	Leptons	<i>ν_e</i> electron neutrino	<i>ν_μ</i> muon neutrino	<i>ν_τ</i> tau neutrino	<i>Z</i> Z boson	<i>W</i> W boson	0	0
0		<i>e</i> electron	<i>μ</i> muon	<i>τ</i> tau				
-1								
		I	II	III				
		Three Families of Matter						



+ Anti-particles

Elementary Particles and Forces

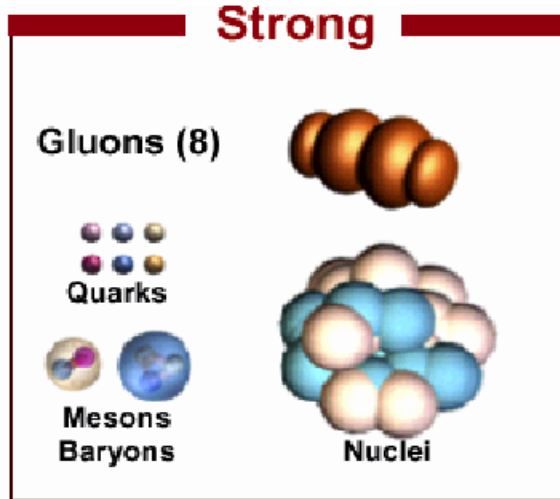
Strong

Gluons (8)

Quarks

Mesons
Baryons

Nuclei

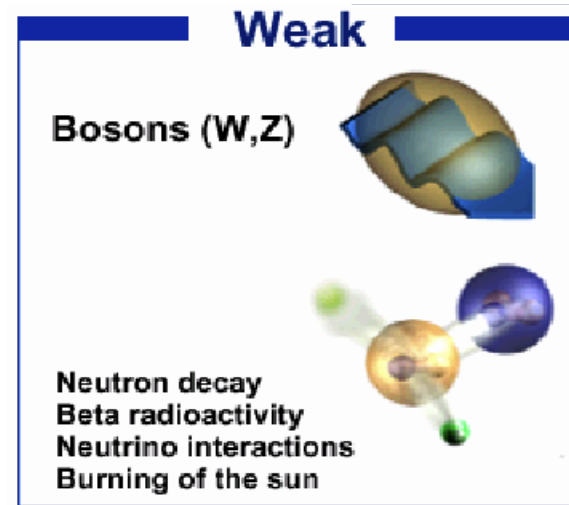
The diagram for the strong force shows various components. At the top, eight orange spheres represent gluons. Below them, six small colored spheres (red, green, blue, anti-red, anti-green, anti-blue) represent quarks. Further down, two pairs of quarks are shown: one pair in a meson and one pair in a baryon. At the bottom, a cluster of quarks represents a nucleus.

1

Weak

Bosons (W,Z)

Neutron decay
Beta radioactivity
Neutrino interactions
Burning of the sun

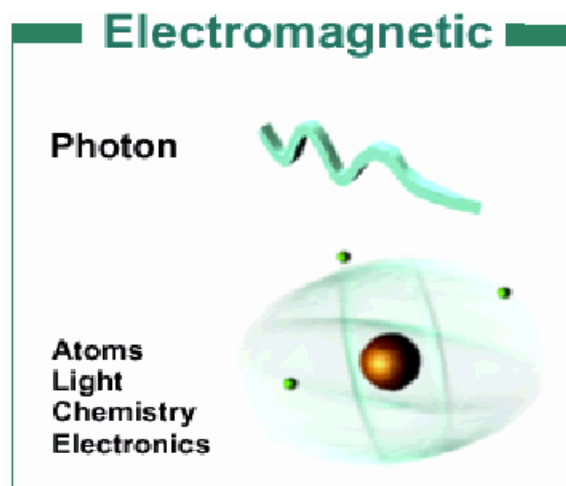
The diagram for the weak force shows two bosons, W and Z, represented as blue and green spheres. Below them, a neutron is shown decaying into a proton and an electron, with a neutrino also present. This illustrates beta radioactivity and neutrino interactions.

10^{-13}

Electromagnetic

Photon

Atoms
Light
Chemistry
Electronics

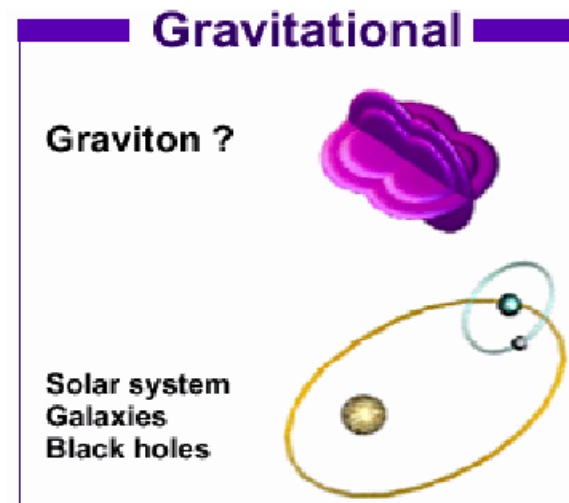
The diagram for the electromagnetic force shows a photon as a wavy green line. Below it, an atom is depicted with a central nucleus and orbiting electrons, illustrating the force's role in chemistry and electronics.

10^{-2}

Gravitational

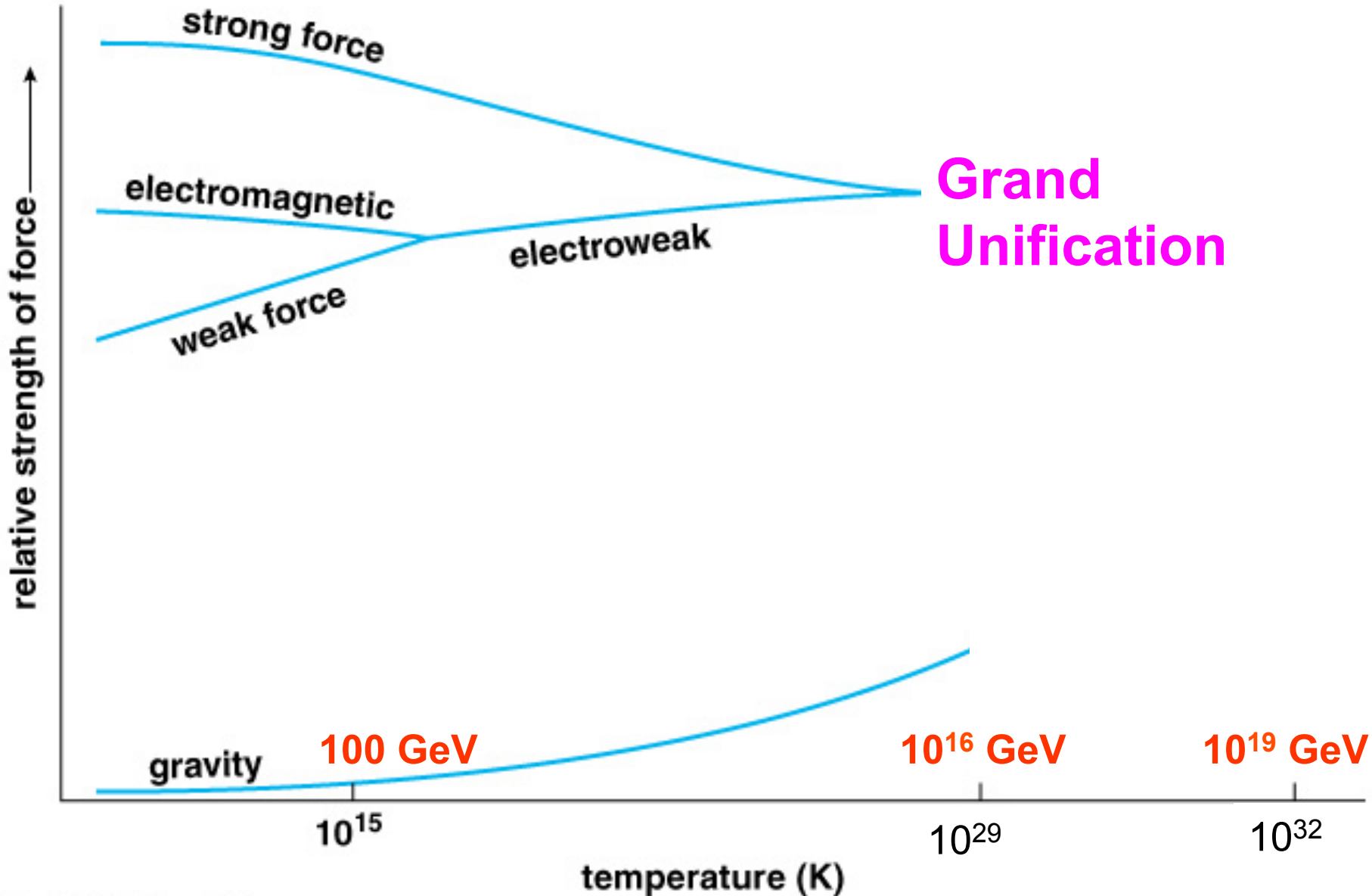
Graviton ?

Solar system
Galaxies
Black holes

The diagram for the gravitational force shows a graviton as a purple cloud-like shape. Below it, a solar system with a central star and orbiting planets is shown, along with a galaxy and a black hole, illustrating the force's role in celestial mechanics.

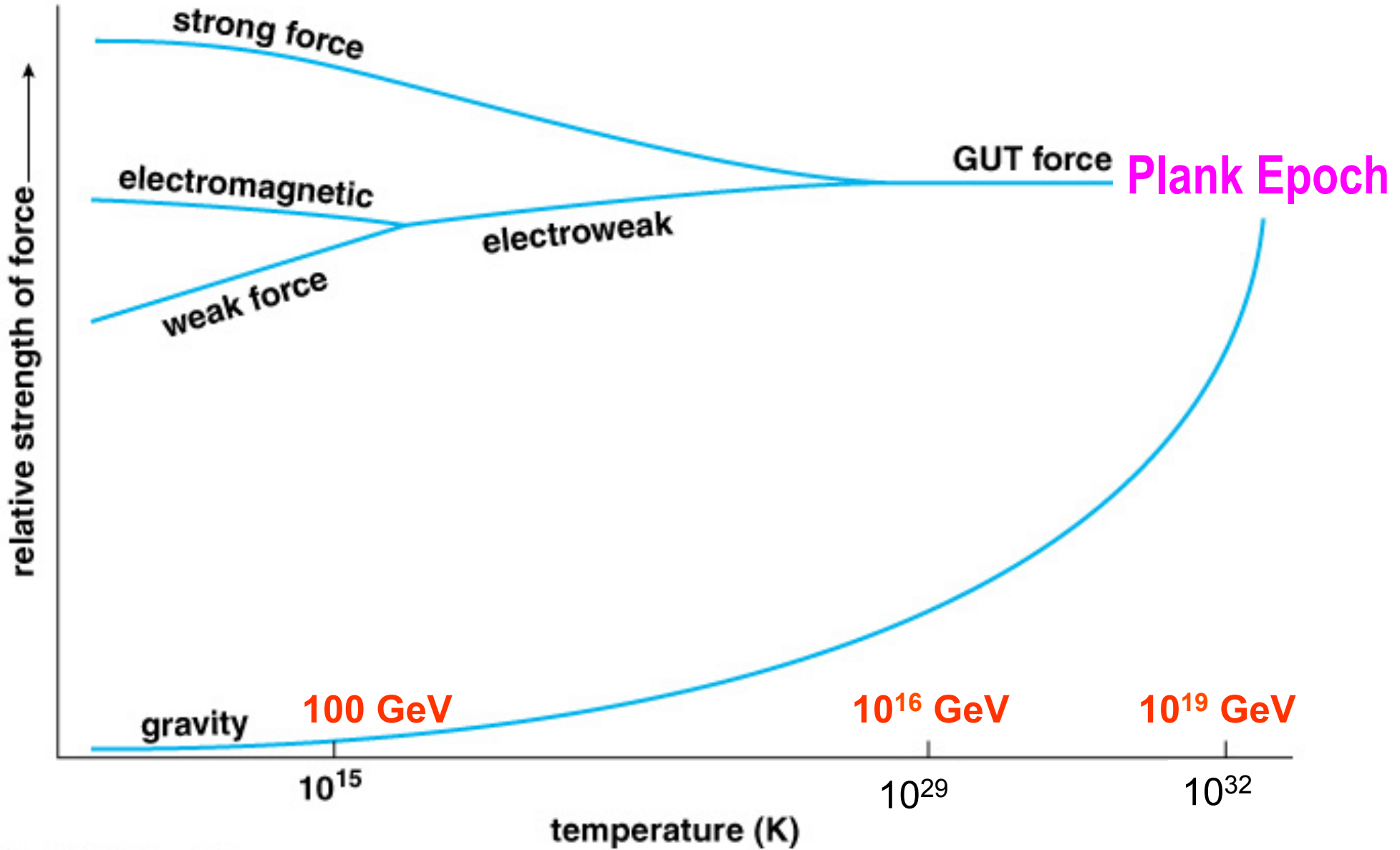
10^{-38}

Unification of Forces (1980)



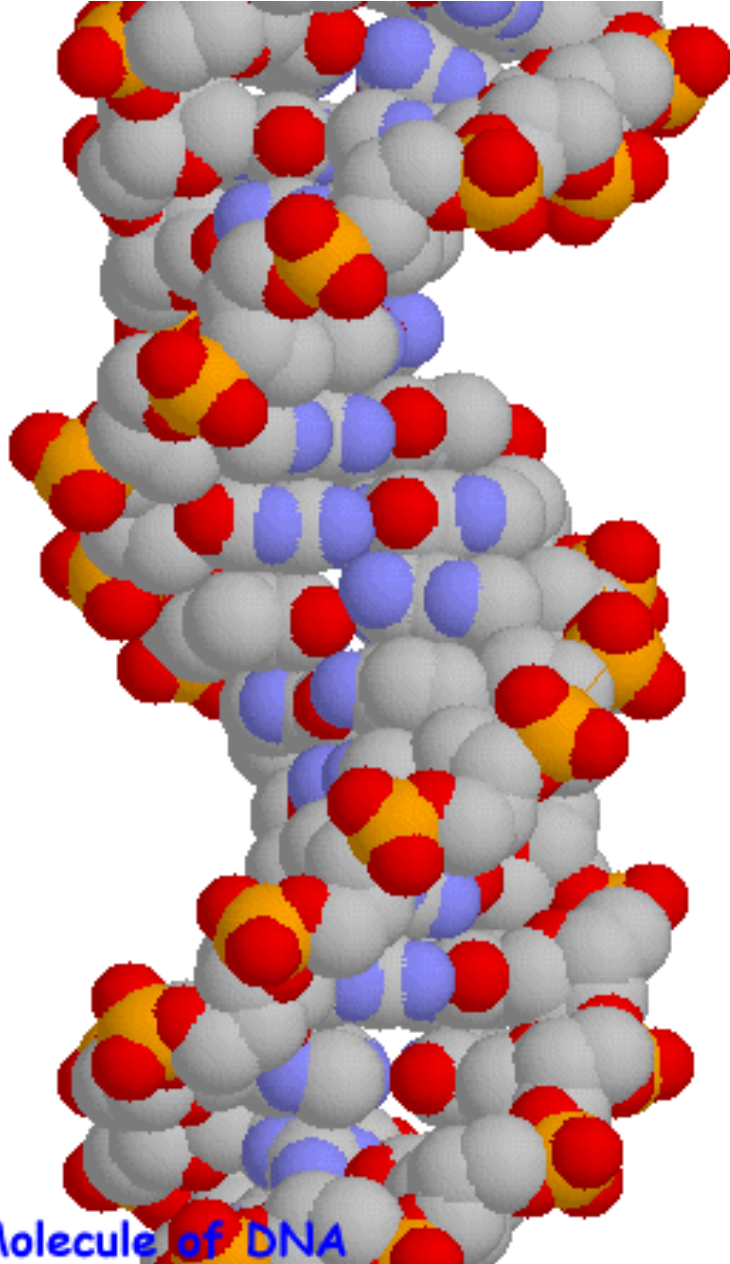
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Unification of Forces (1980)

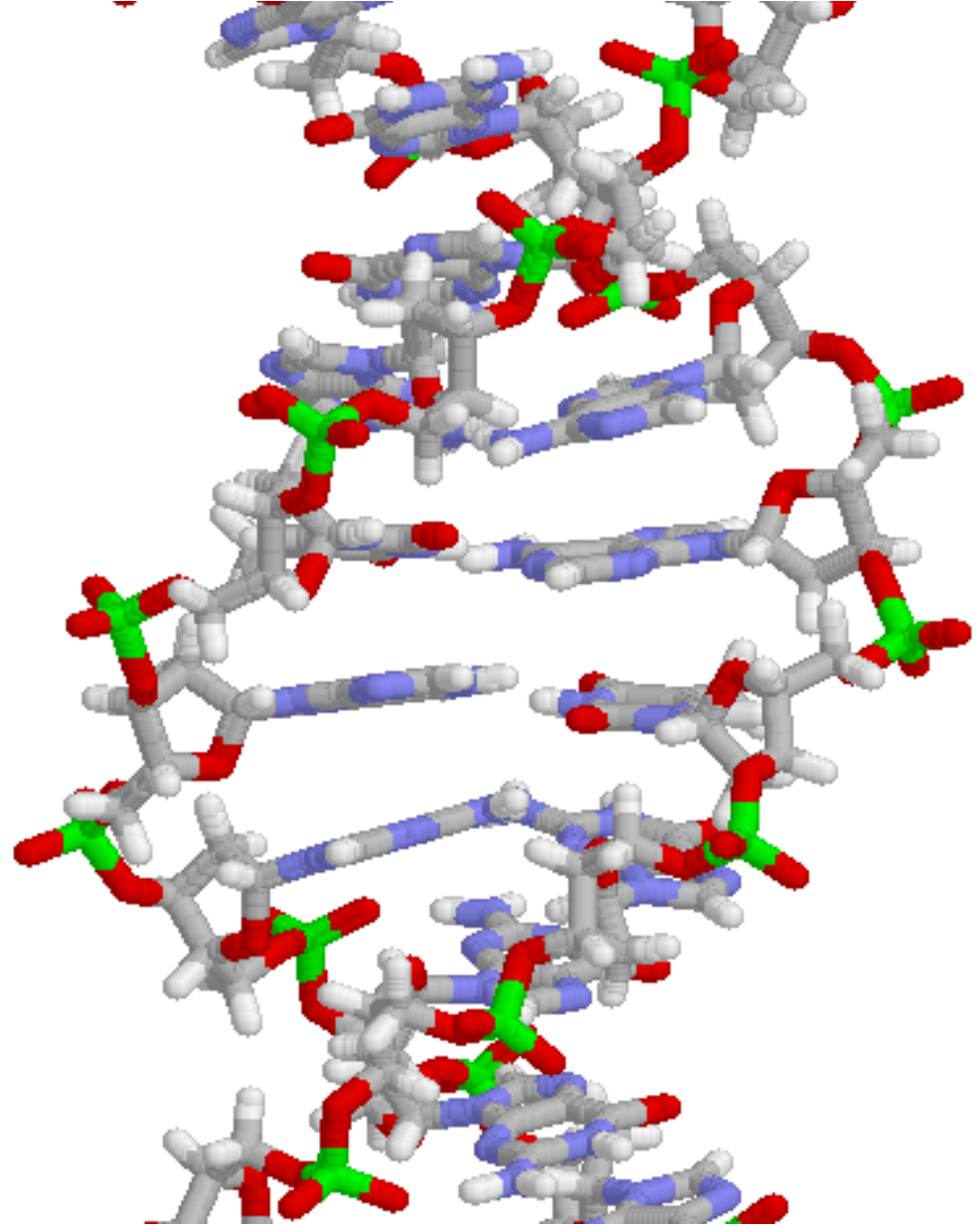


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Structure of DNA

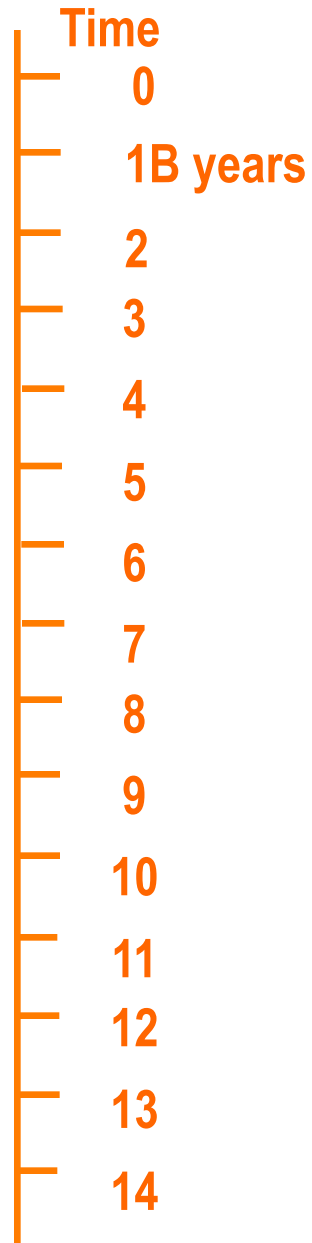


©Rothamsted Experimental Station, 1997, 1998



Molecule of DNA

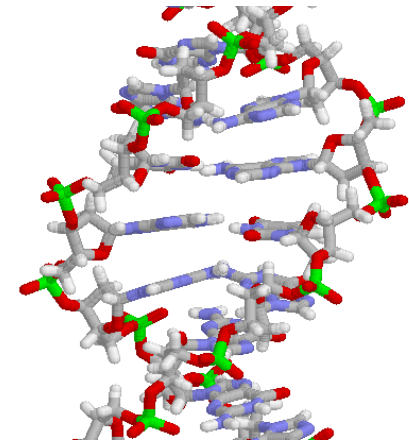
Symmetry Breaking



Simple

*Symmetry
Break Down*

Complex



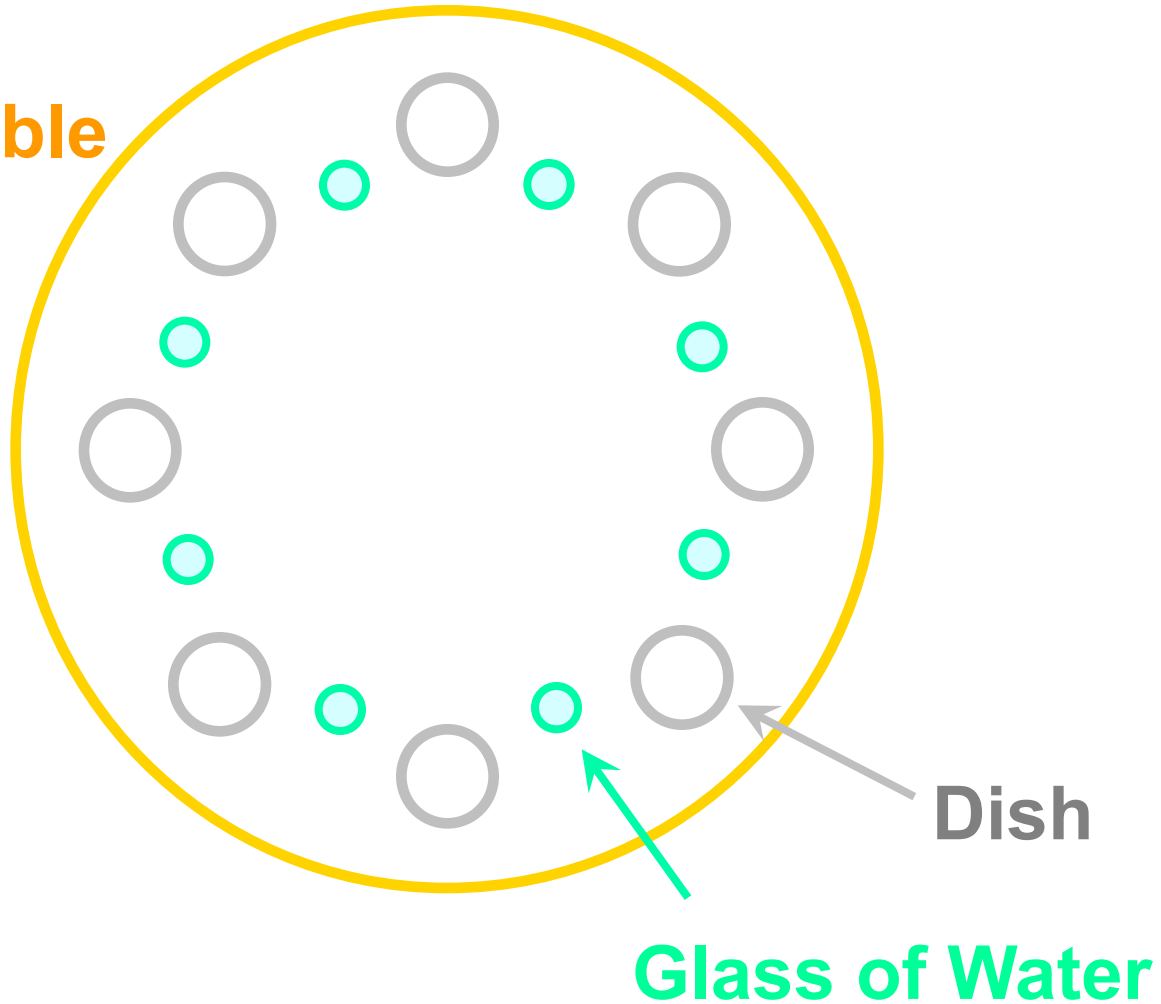
The Beginning

- Everything was the same → Perfect symmetry.
 - All the particles are the same as photons.
 - All four forces are the same.
- The Universe was 10 dimension.



Spontaneous Symmetry Breakdown at a Dinner Table

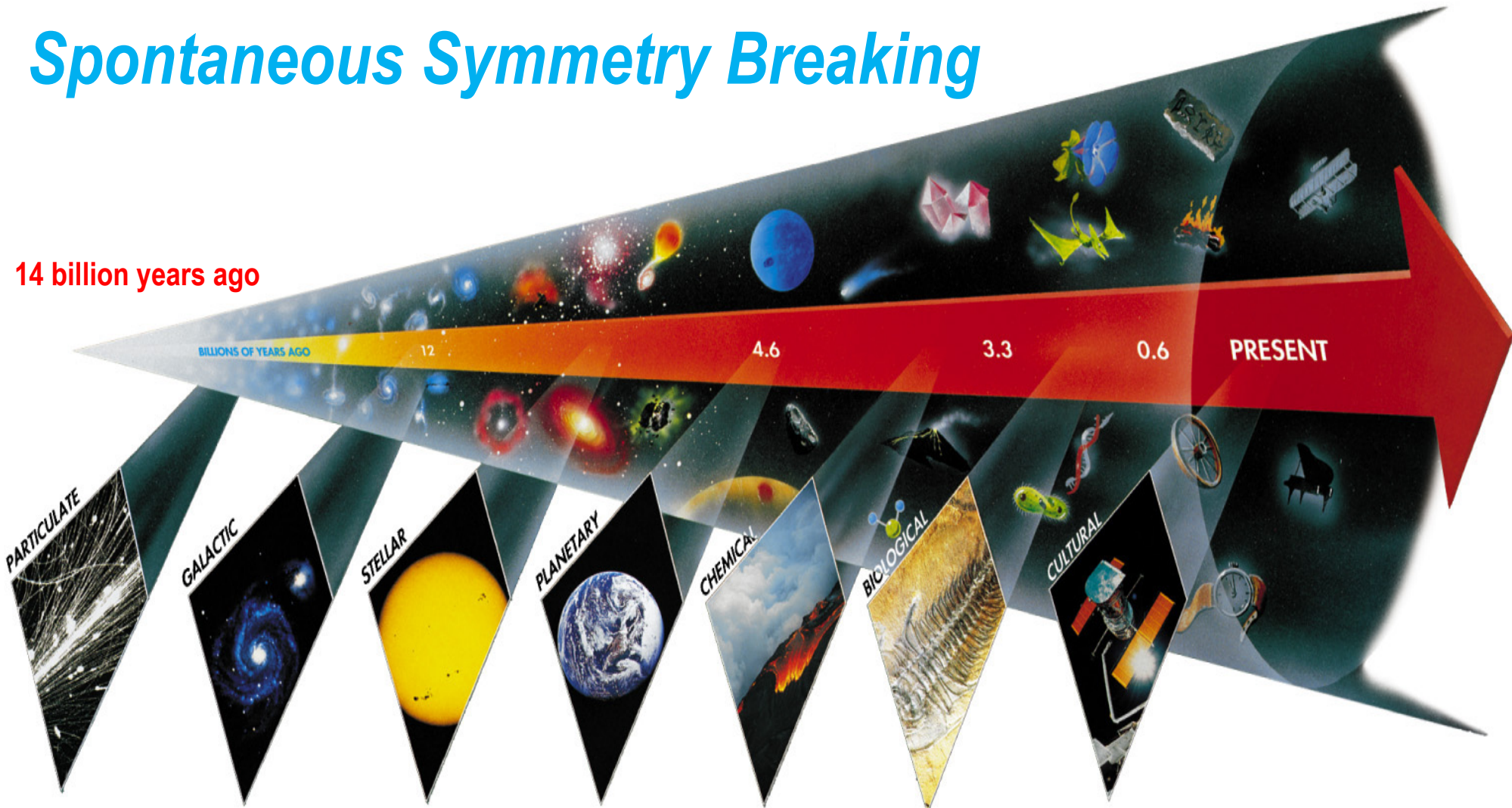
Dinner Table



by Nambu Yoichiro

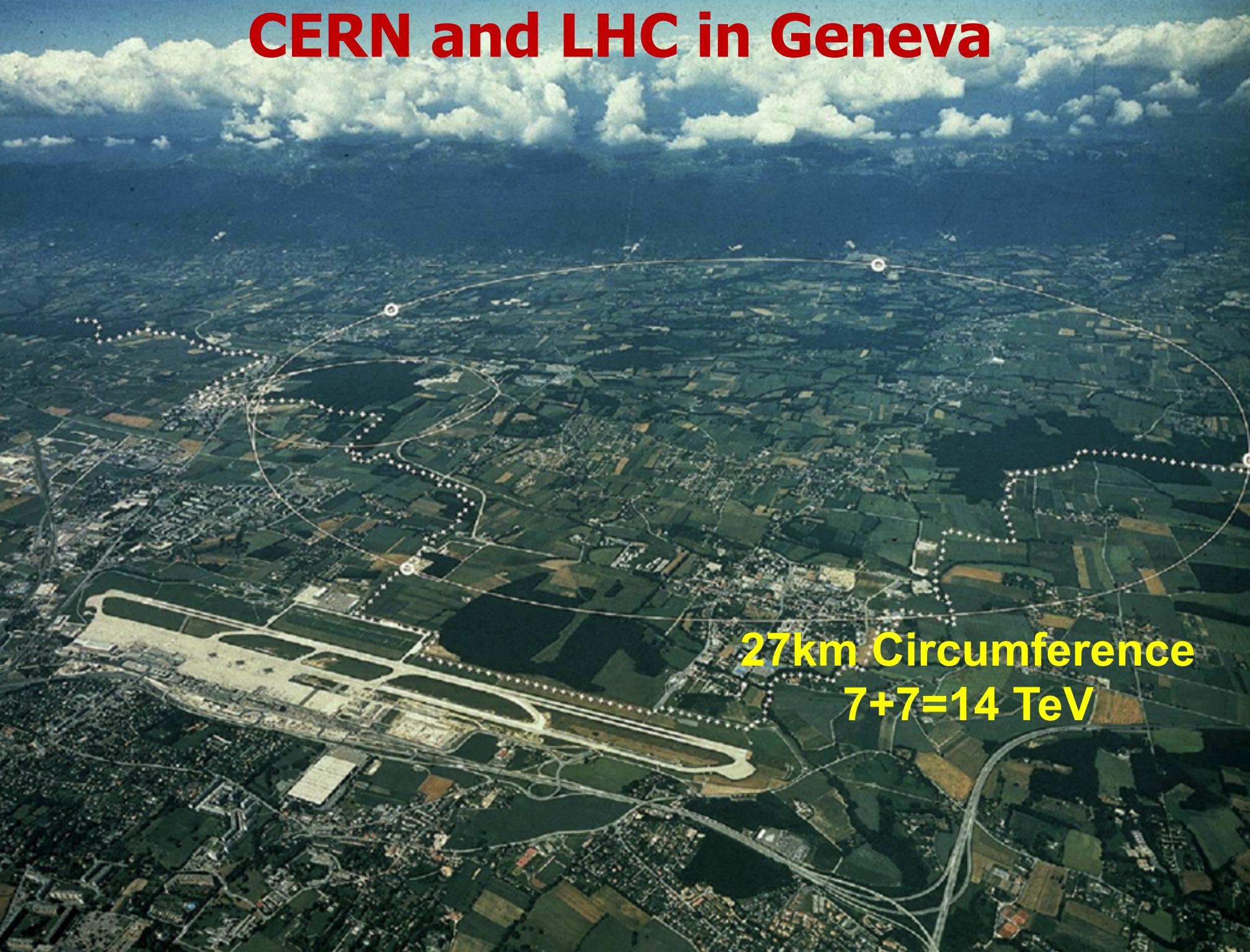
Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking



Origin of
Particles

CERN and LHC in Geneva



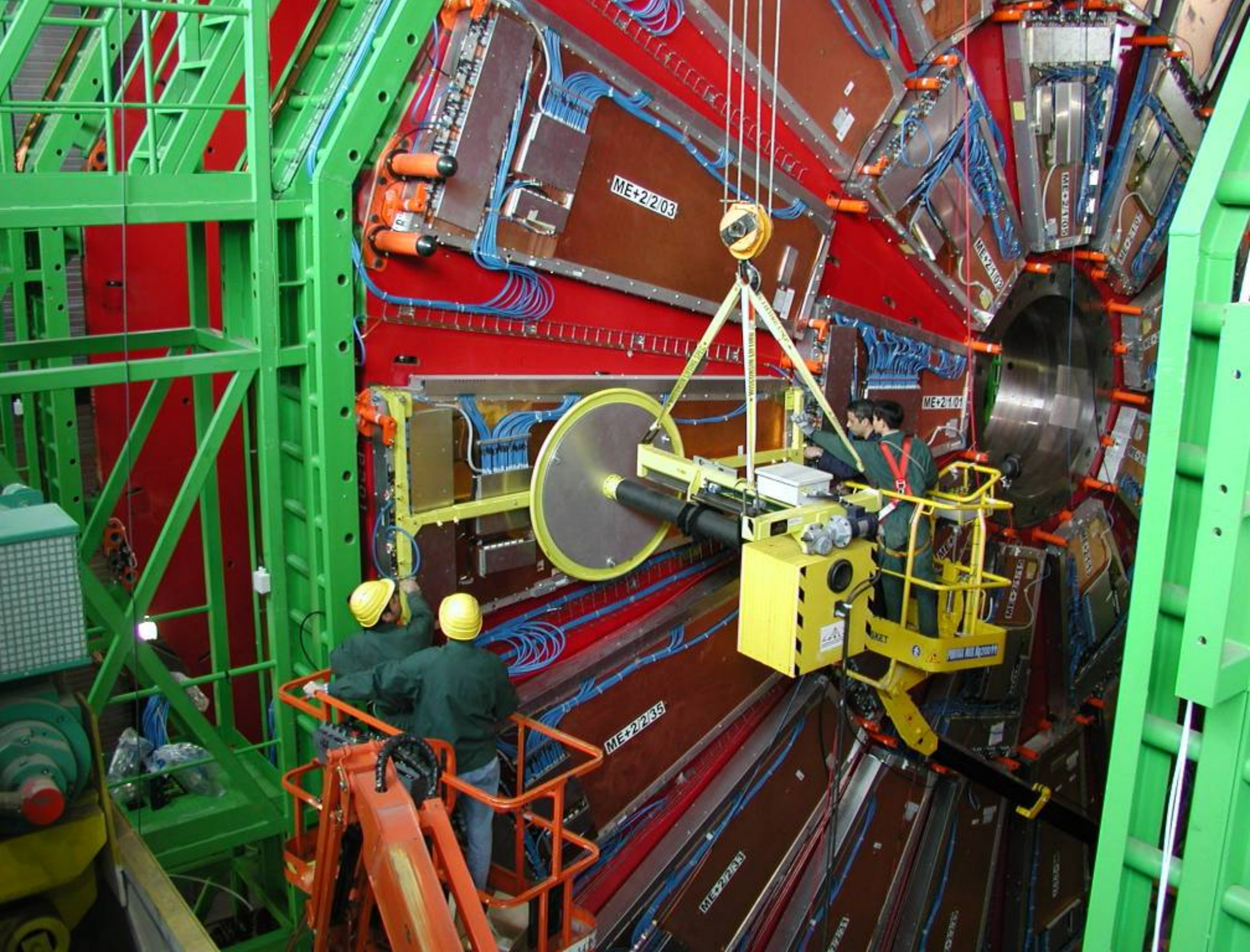
27km Circumference
7+7=14 TeV

LHC Tunnel with Magnets



CMS Barrel Yoke





ME+2/2/03

ME+2/1/01

ME+2/2/05

ME+2/2/08

ME+2/2/10

ME+2/2/12

ME+2/1/02

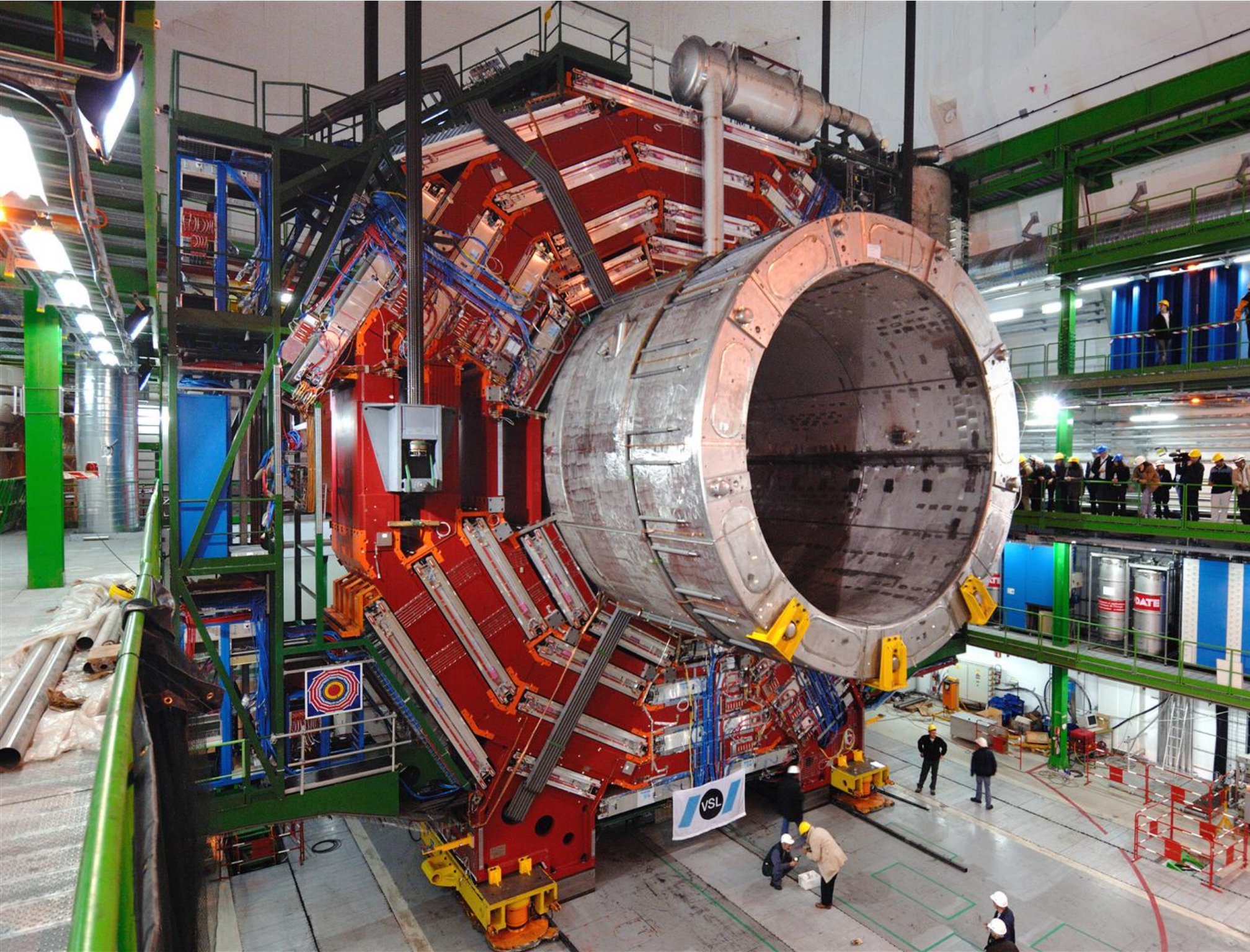
ME+2/1/03

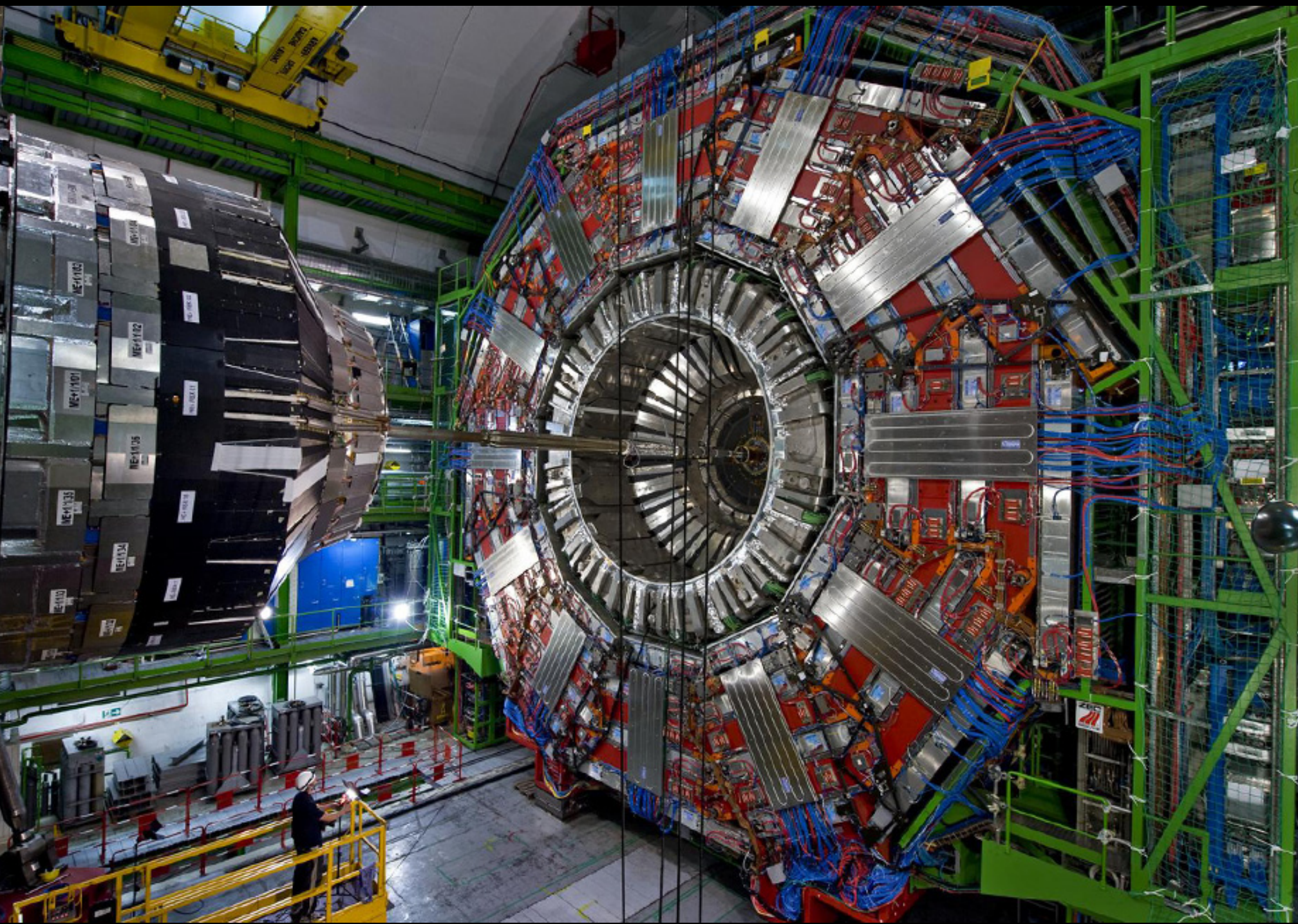
ME+2/1/04

ME+2/1/05

ME+2/1/06

ME+2/1/07





Newsweek

The Biggest Experiment Ever (And It's European)



Particle detectors constructed at Westwood, now at LHC, CERN



newswk.com SEPTEMBER 15, 2008 PHOTOGRAPH BY MARTIAL TREZZINI-AP

The new CERN collider in Geneva



Albania	Lek 600	Finland	€4.40	Israel	NIS 20.00	Netherlands	€4.40	Slovenia	€3.40
Austria	€4.40	France	€4.40	Italy	€4.40	Norway	Kr 41.00	Spain	€4.40
Belgium	€4.40	Germany	€4.40	Kazakhstan	\$4.40	Poland (incl tax)	PLN 12.30	Sweden	SKr 34.00
Bulgaria	BGL 4.50	Gibraltar	€2.90	Latvia	€4.40	Portugal Cont	€4.40	Switzerland	SF 7.70
Croatia	KN 22.00	Greece	€4.40	Lithuania	\$4.40	Romania	Lei 11.00	Turkey	YTL 4.00
Cyprus	€2.58/€4.40	Hungary	FL 700.00	Luxembourg	€4.40	Russia	€4.40	Ukraine	€4.40
Czech Republic	Czk 115.00	Iceland	IKR 390.00	Malta	Lm 1.70/€3.96	Serbia	DIN 240	United Kingdom	€2.80
Denmark	Kr 38.00	Ireland (incl tax)	€4.40	Montenegro	DIN 240	Slovakia	SK 120.00/€3.98	U.S. Forces	\$3.25

Sept 15, 2008 Issue

CMS Experiment, CERN

Data_taken 2009-11-07 19:12:36.880368 GMT

Run_no 120015

Event_no 8

Lumi_sec 1

Orbit 584946

Crossing 2603

<http://iguana.cern.ch/isy/>

L1 Triggers:

L1_DoubleHEBitCountsRing1_P1N1

L1_DoubleHEBitCountsRing2_P1N1

L1_ETM20

L1_ETM30

L1_MinBias_HTT10

L1_Mu3QE8_Jet6

L1_SingleEG1

L1_SingleEG10

L1_SingleEG12

L1_SingleEG15

L1_SingleEG20

L1_SingleEG25

L1_SingleEG30

L1_SingleEG35

L1_SingleEG40

L1_SingleEG45

L1_SingleEG50

L1_SingleEG55

L1_SingleEG60

L1_SingleEG65

L1_SingleEG70

L1_SingleEG75

L1_SingleEG80

L1_SingleEG85

L1_SingleEG90

L1_SingleEG95

L1_SingleEG100

L1_SingleEG105

L1_SingleEG110

L1_SingleEG115

L1_SingleEG120

L1_SingleEG125

L1_SingleEG130

L1_SingleEG135

L1_SingleEG140

L1_SingleEG145

L1_SingleEG150

First Event at LHC – Recreation of the Big Bang! (Nov 7, 2009)

WORLD U.S. N.Y. / REGION BUSINESS TECHNOLOGY SCIENCE HEALTH SPORTS OPINION
ENVIRONMENT SPACE & COSMOS

Physicists Find Elusive Particle Seen as Key to Universe



Pool photo by Denis Balibouse

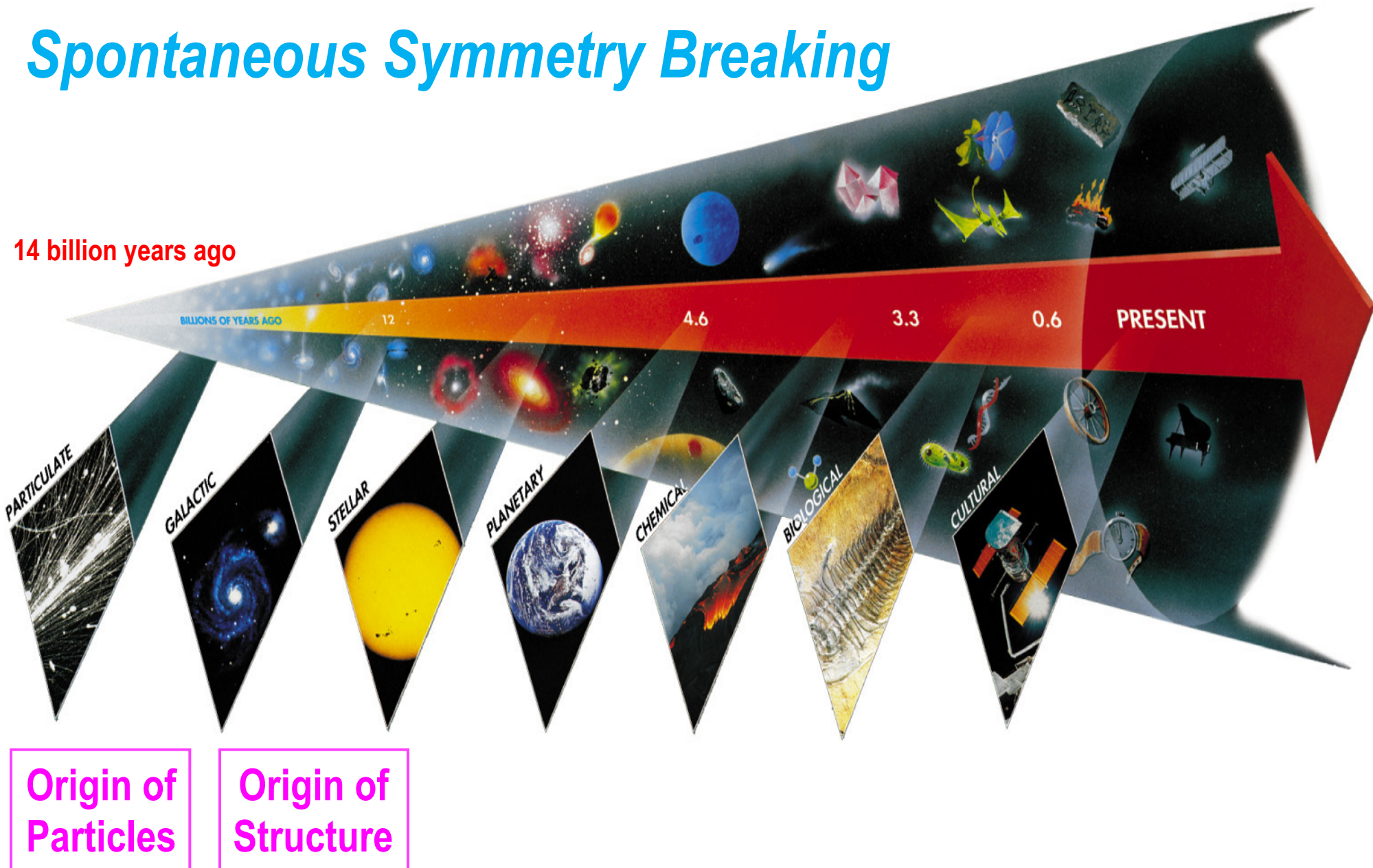
Scientists in Geneva on Wednesday applauded the discovery of a subatomic particle that looks like the Higgs boson.

By DENNIS OVERBYE

Published: July 4, 2012 |  122 Comments

Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking

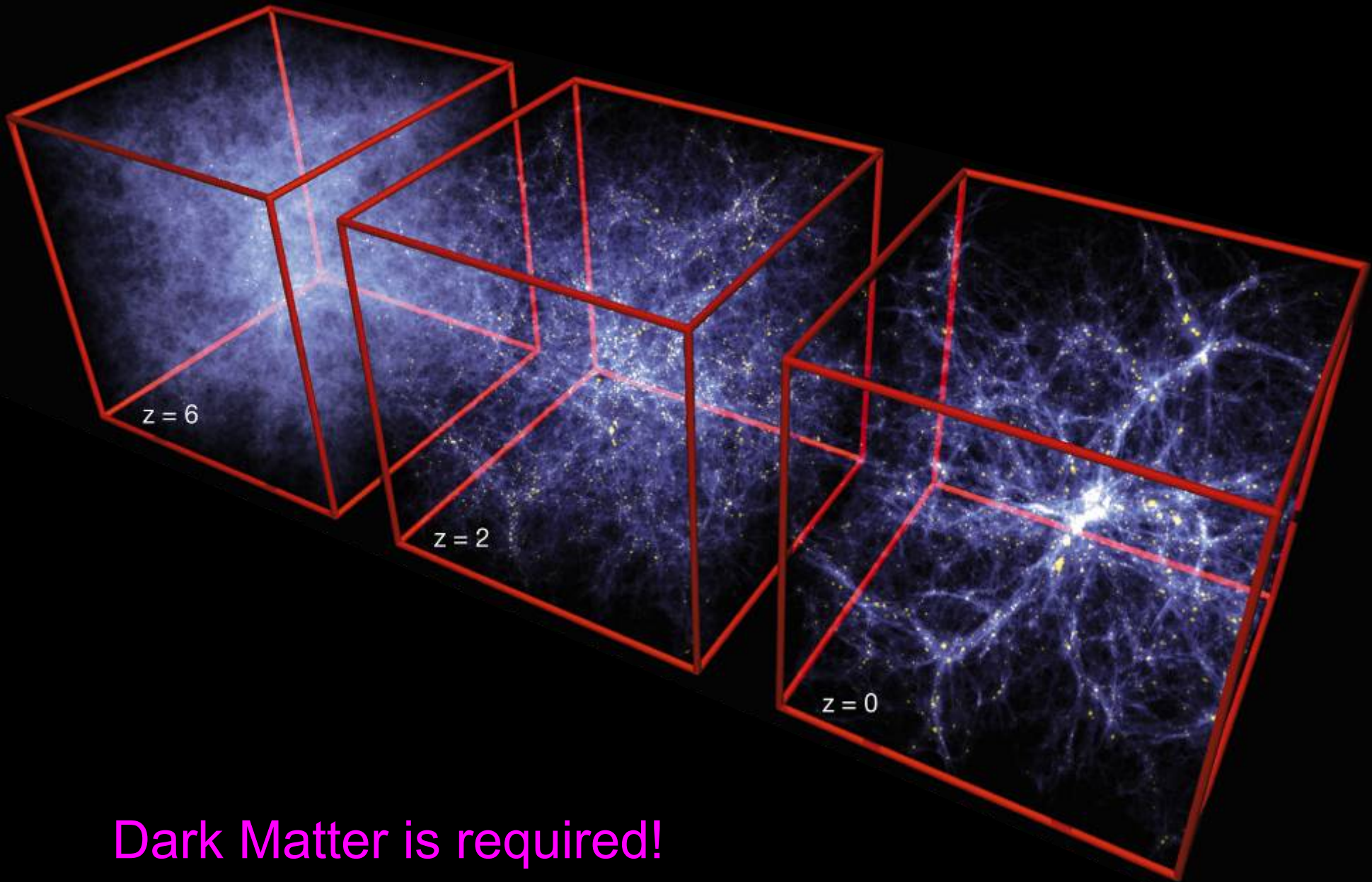




Dark Matter is required!

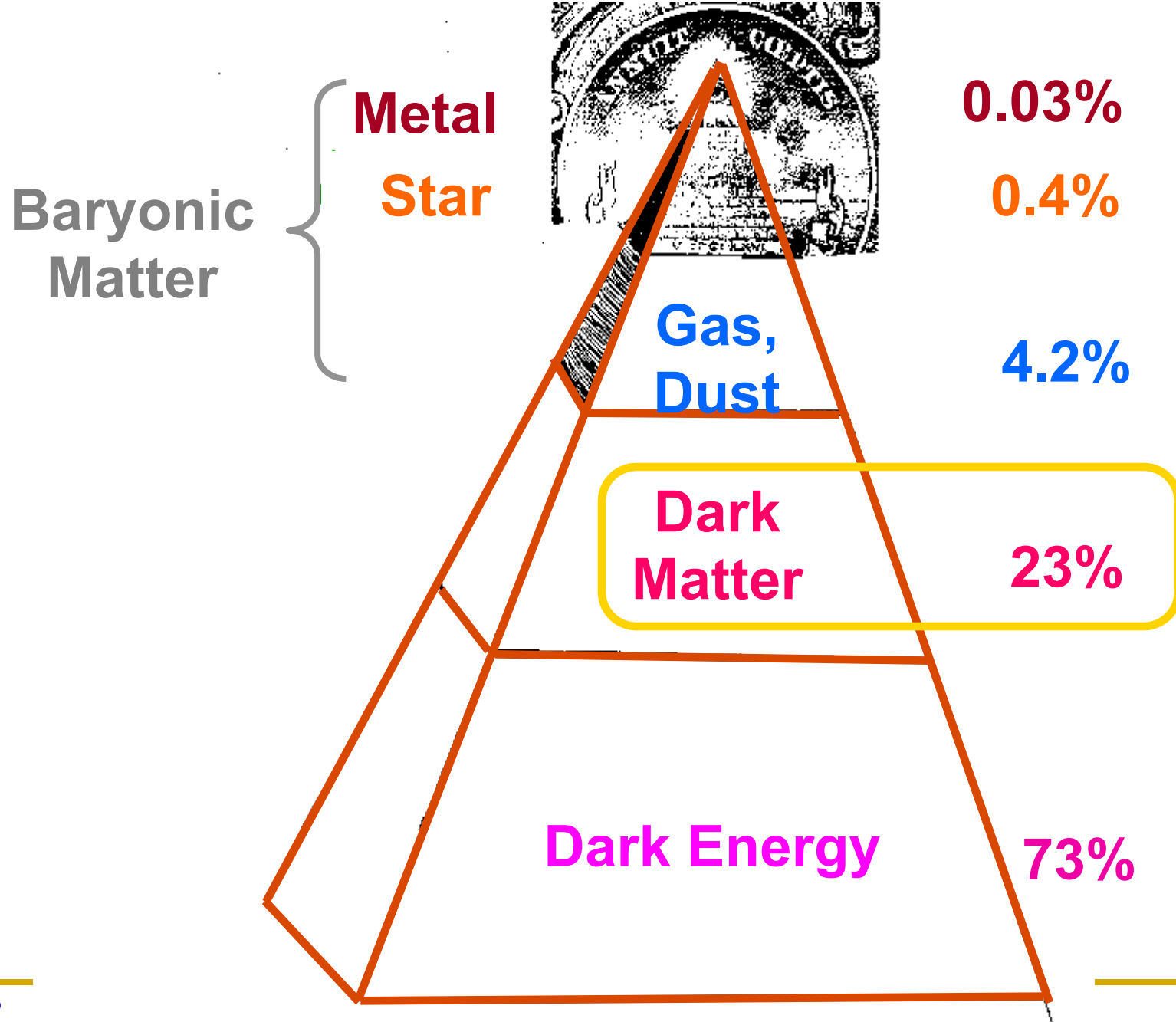
ANDROMEDA
GALAXY.

Formation of Structure in the Universe

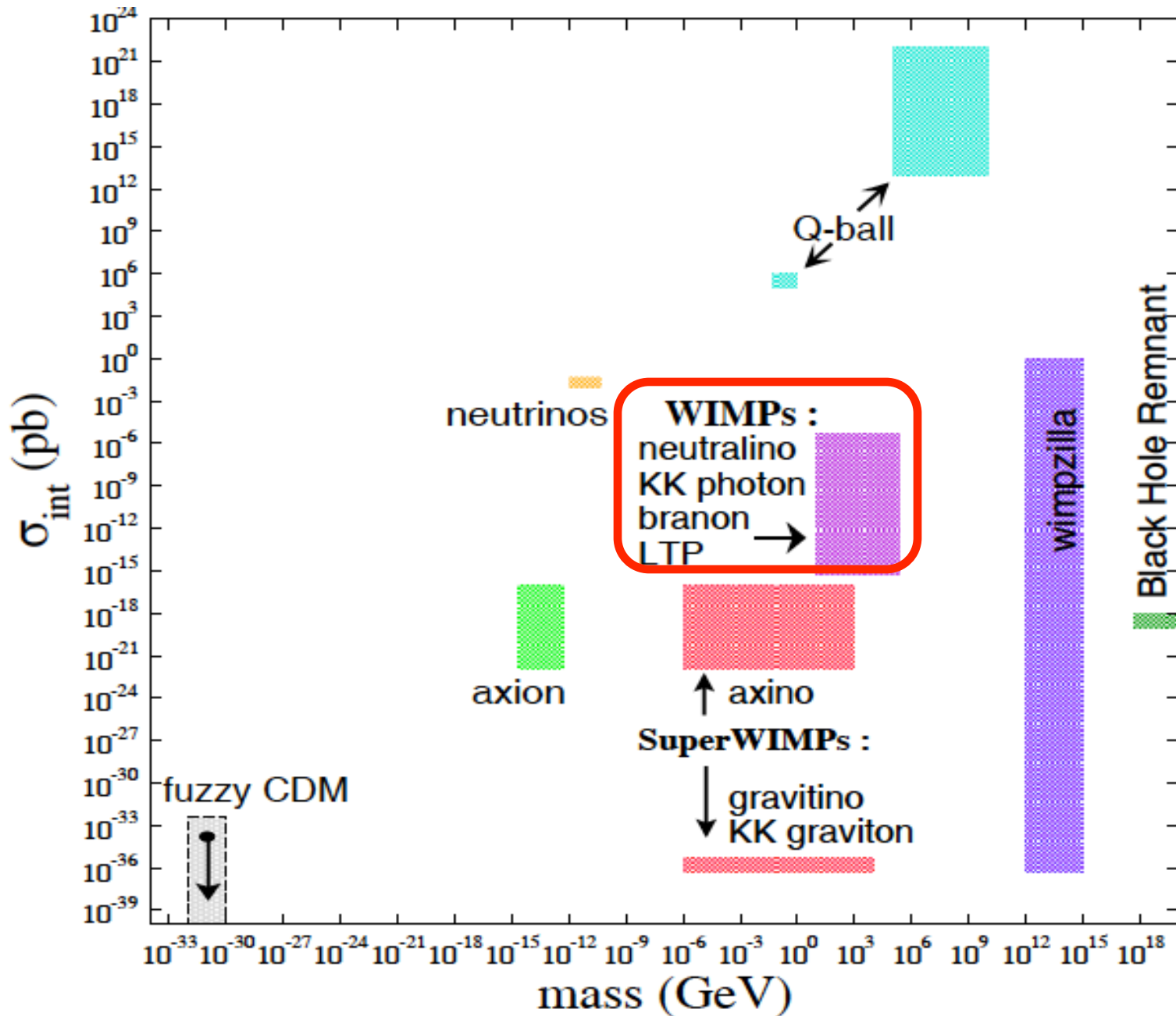


Dark Matter is required!

Cosmic Pyramid

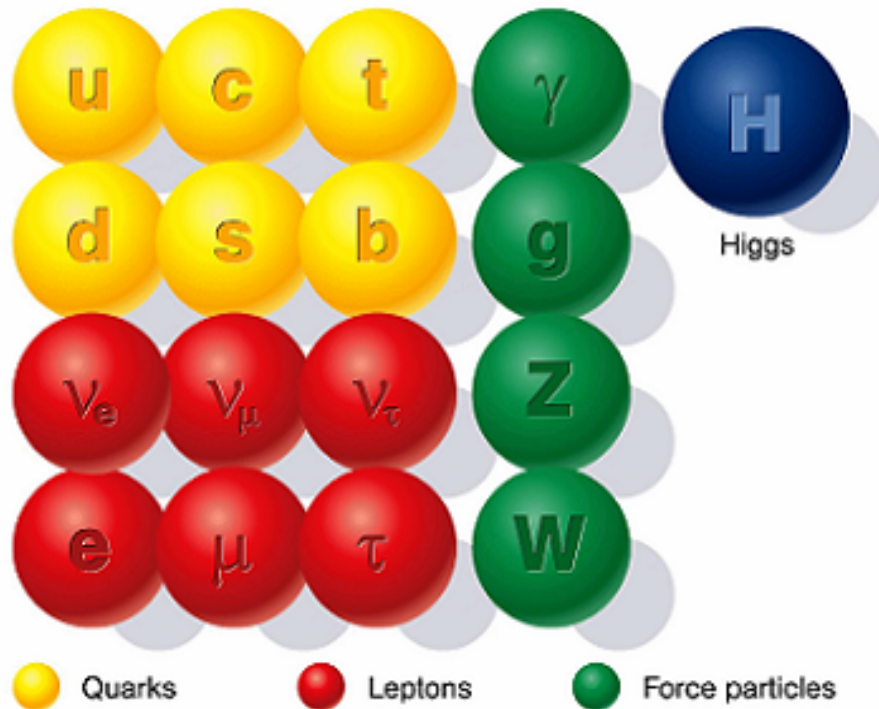


What is Dark Matter?



SUSY Particles and Neutralino

Standard particles



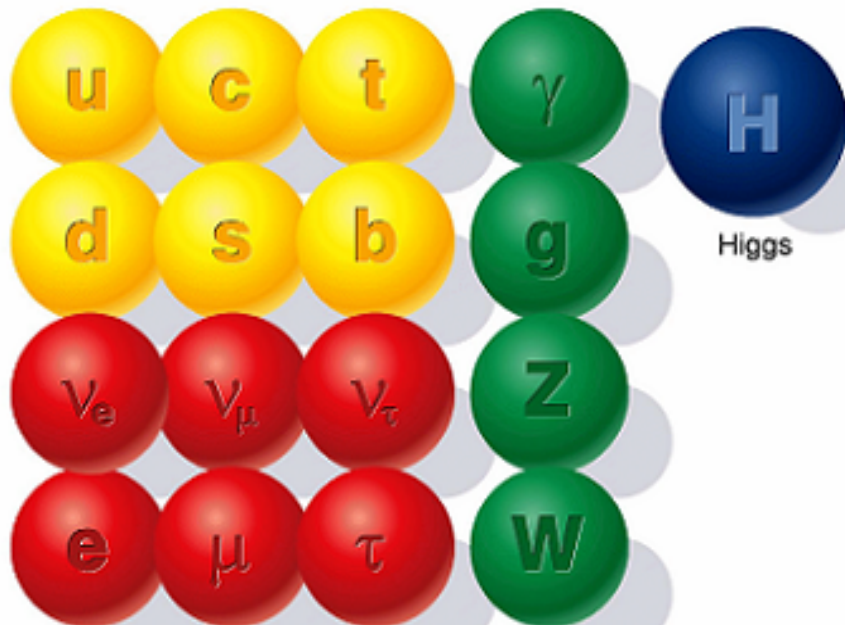
Spin 1/2 1 0

SUSY Particles and Neutralino

Super Symmetry

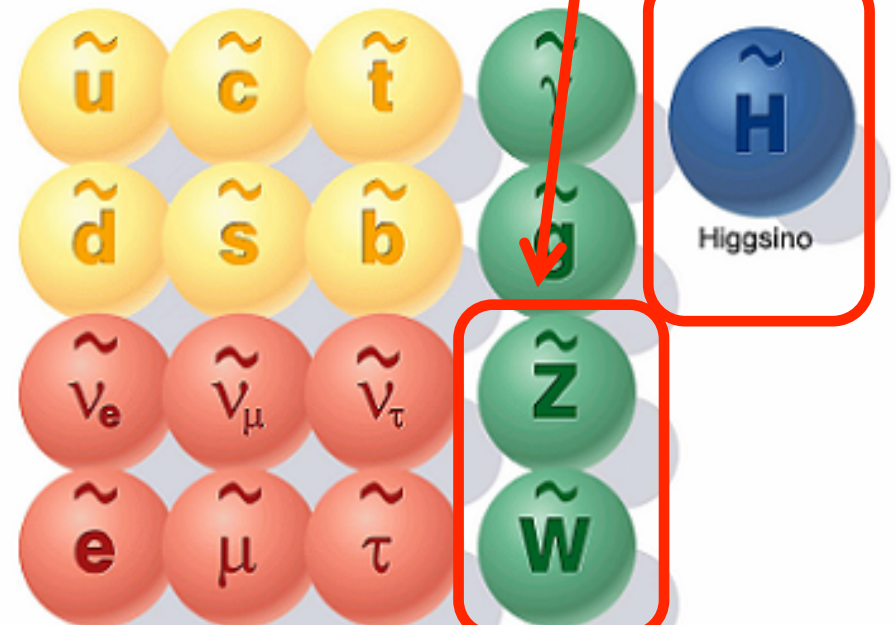
Neutralino

Standard particles



Yellow circle: Quarks Red circle: Leptons Green circle: Force particles

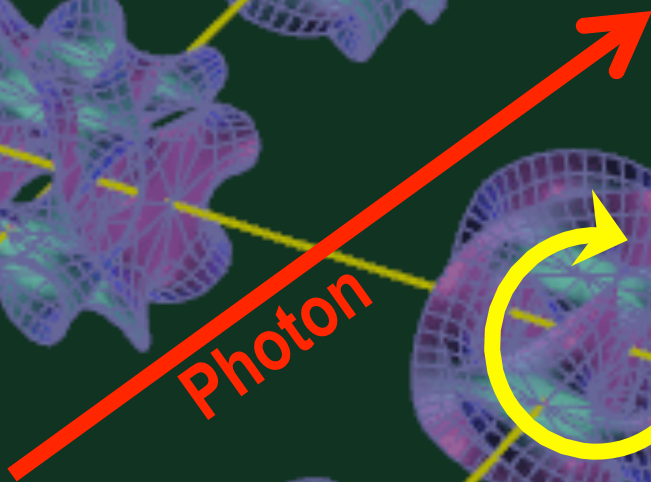
SUSY particles



Yellow circle: Squarks Red circle: Sleptons Green circle: SUSY force particles

Spin 1/2 1 0 0 1/2 1/2

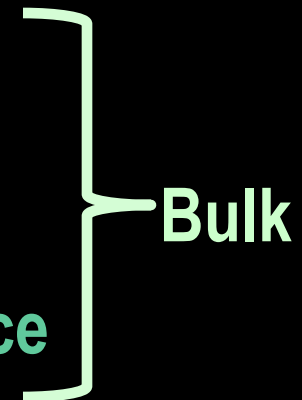
Extra Dimensions



KK Photon

Extra
Dimensions

Our 3D Space
(= Brane)

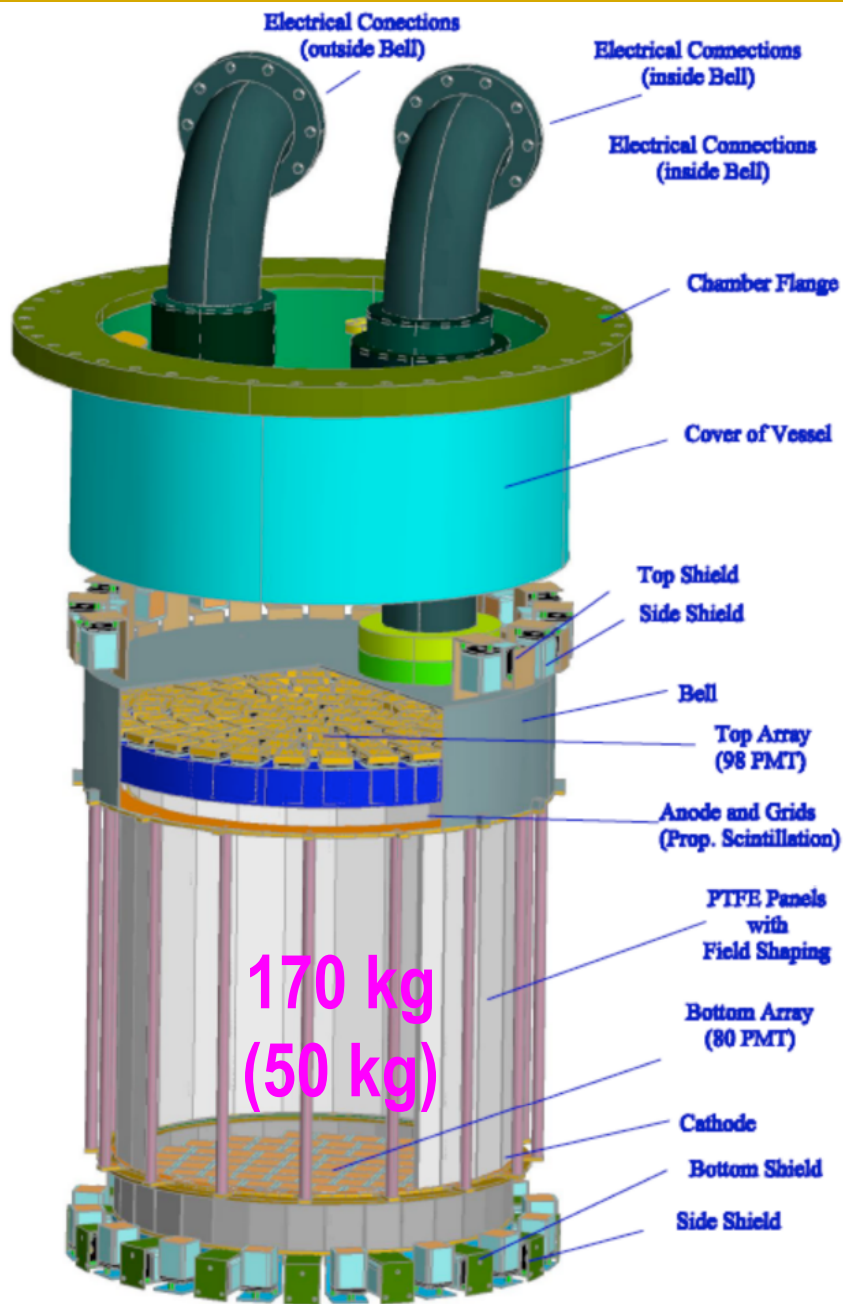


Laboratori Nazionali del Gran Sasso, Italy

LNGS 1400 m Rock (3100 w.m.e)



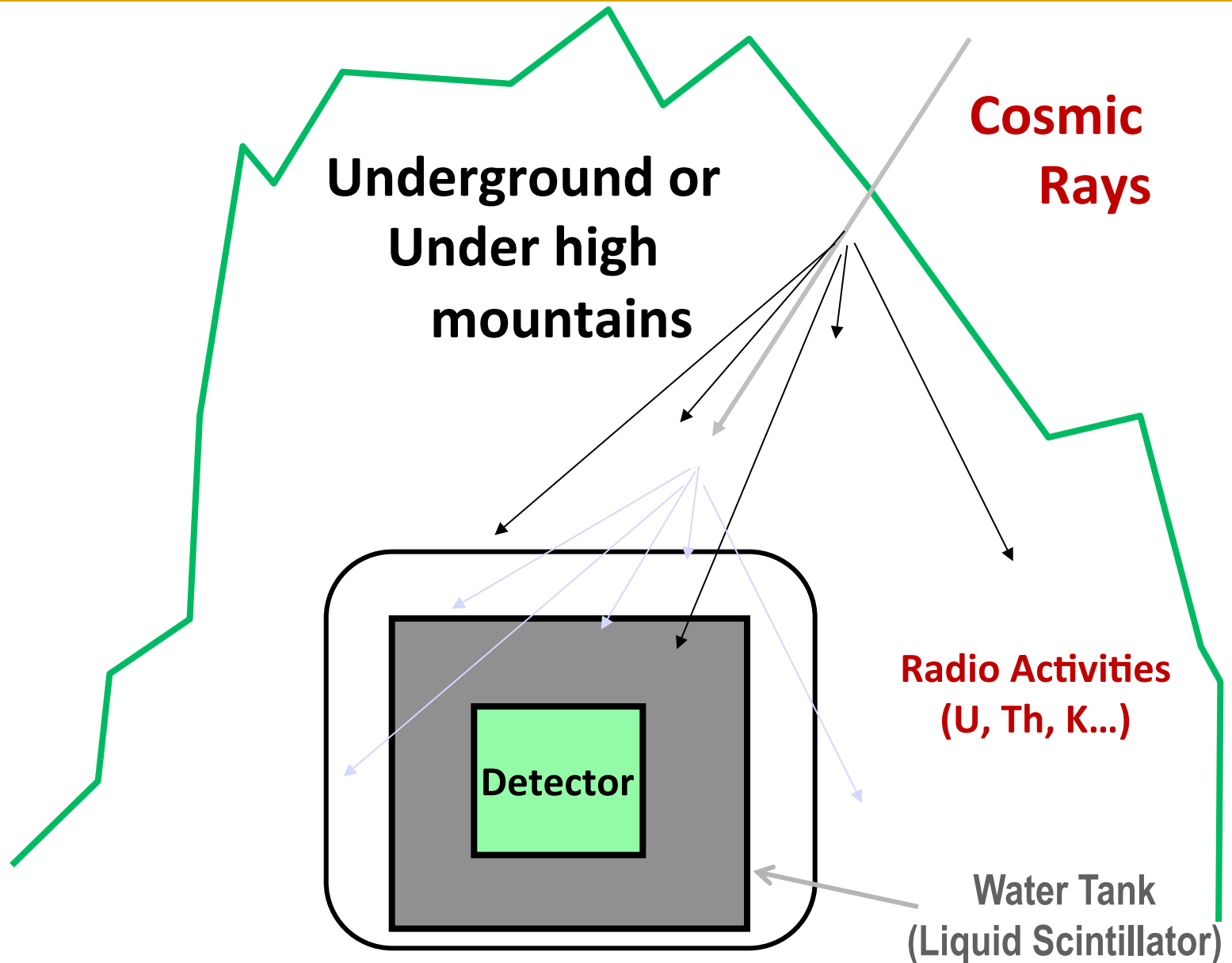
XENON100 Detector



XENON100 Detector (2009)



Where backgrounds come from?



Ultimately photon detectors are the major source of backgrounds.

Comparison of Photon Detectors from Hamamatsu

R11065 (Ar)
R11410 (Xe)
3 inch

XENON1T
DarkSide50

QUPID
3 inch

MAX
XAX

R8520
1 inch

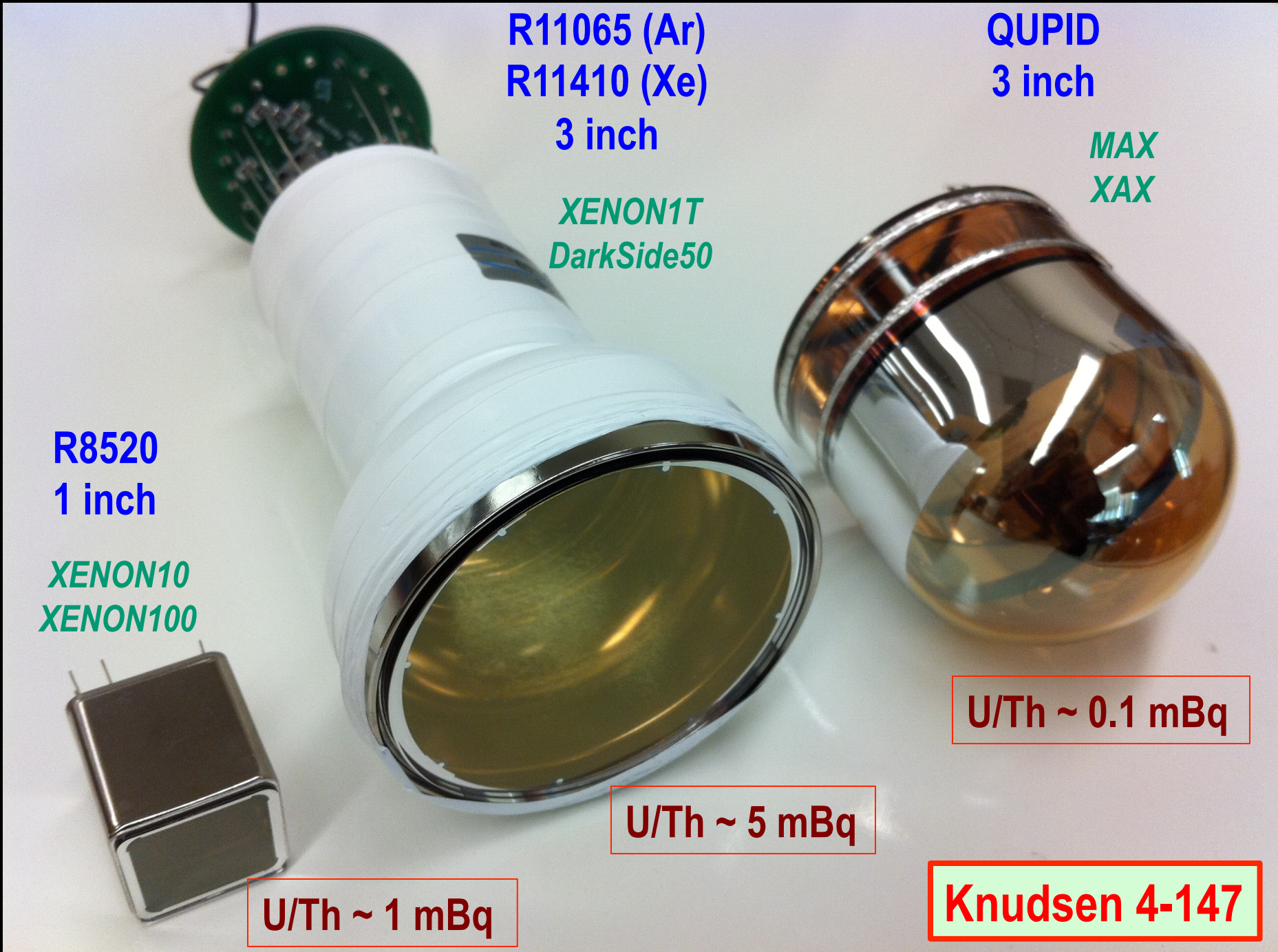
XENON10
XENON100

U/Th ~ 0.1 mBq

U/Th ~ 5 mBq

U/Th ~ 1 mBq

Knudsen 4-147



Control Panel

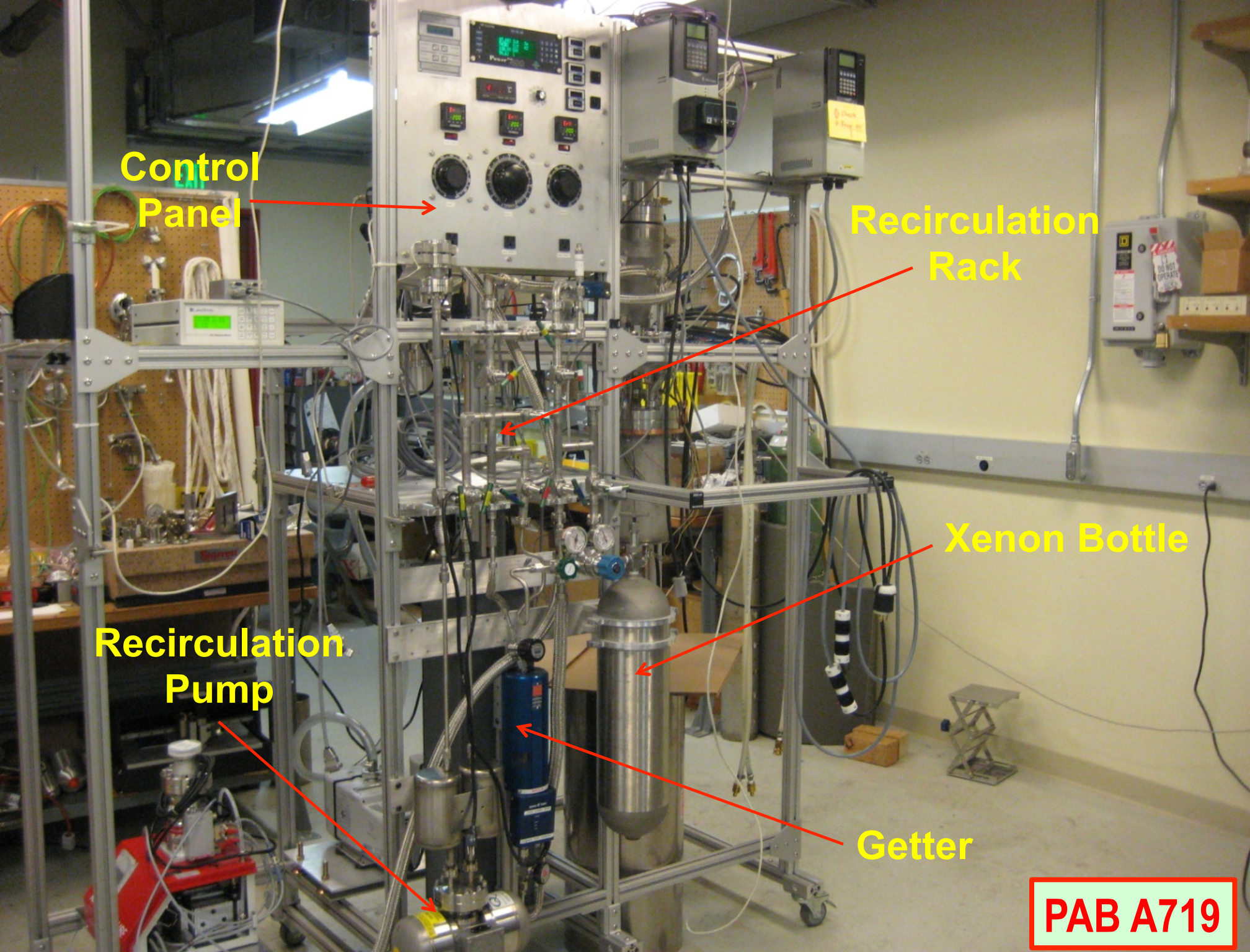
Recirculation Rack

Xenon Bottle

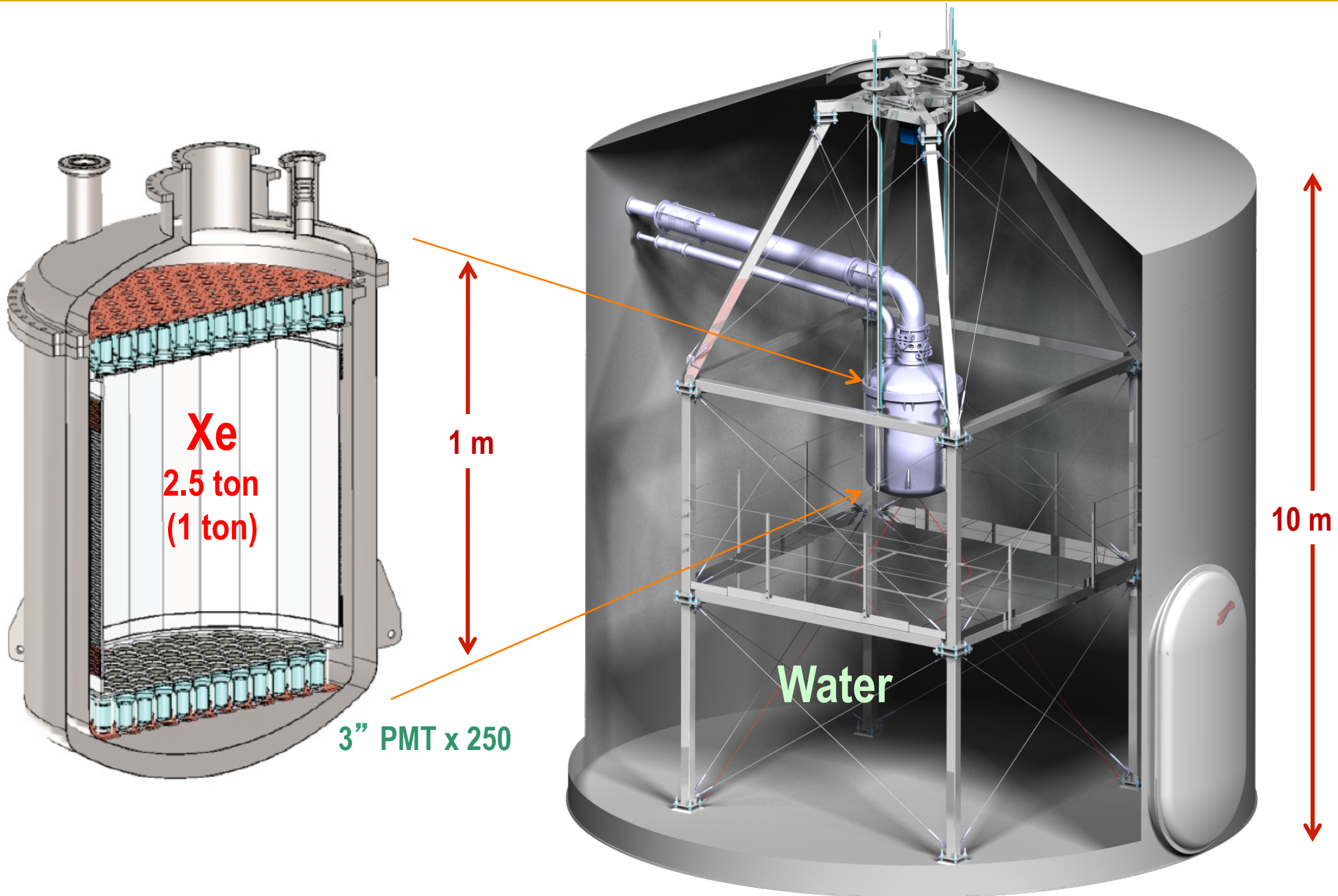
Recirculation Pump

Getter

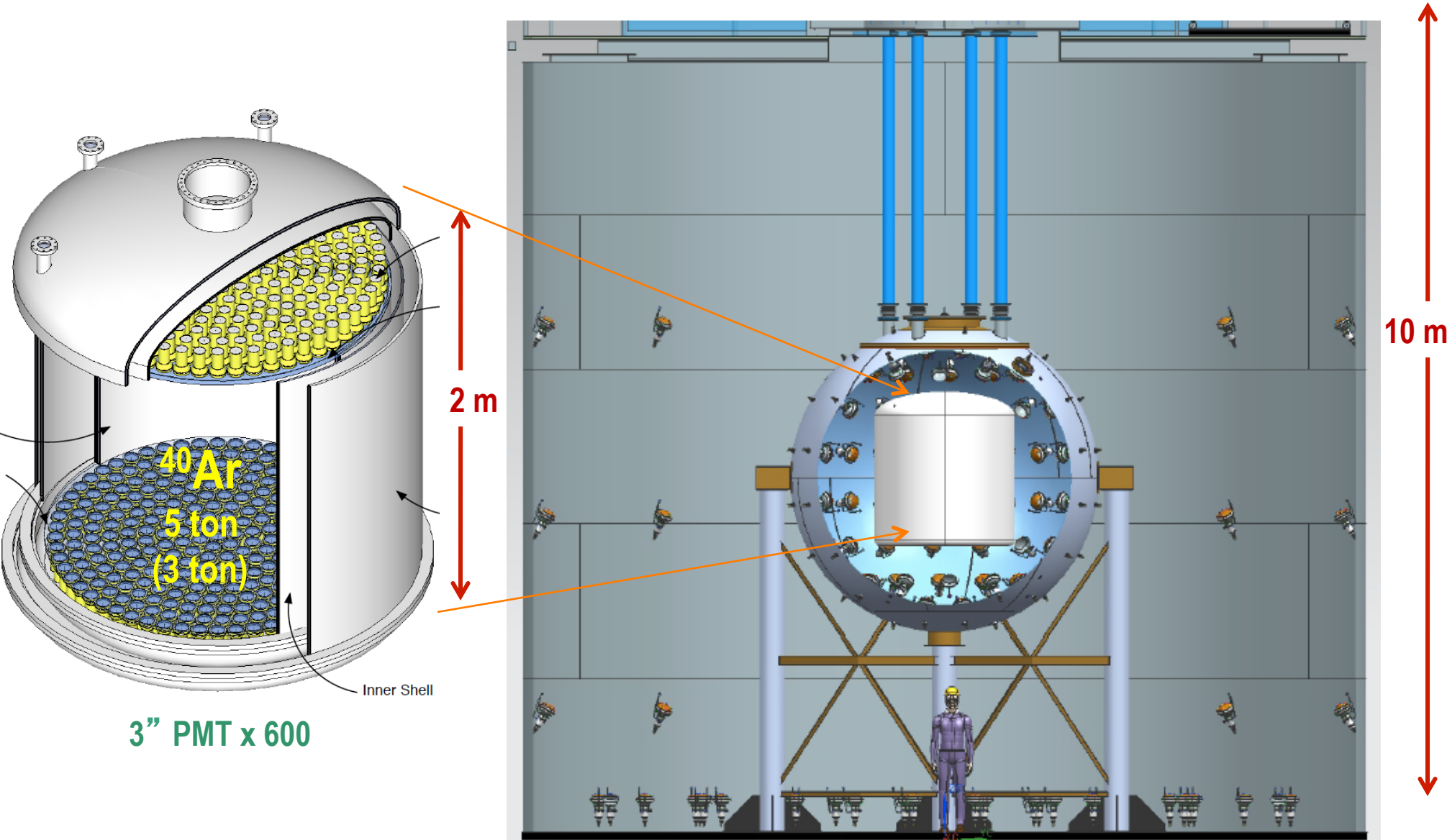
PAB A719



XENON1T at LNGS

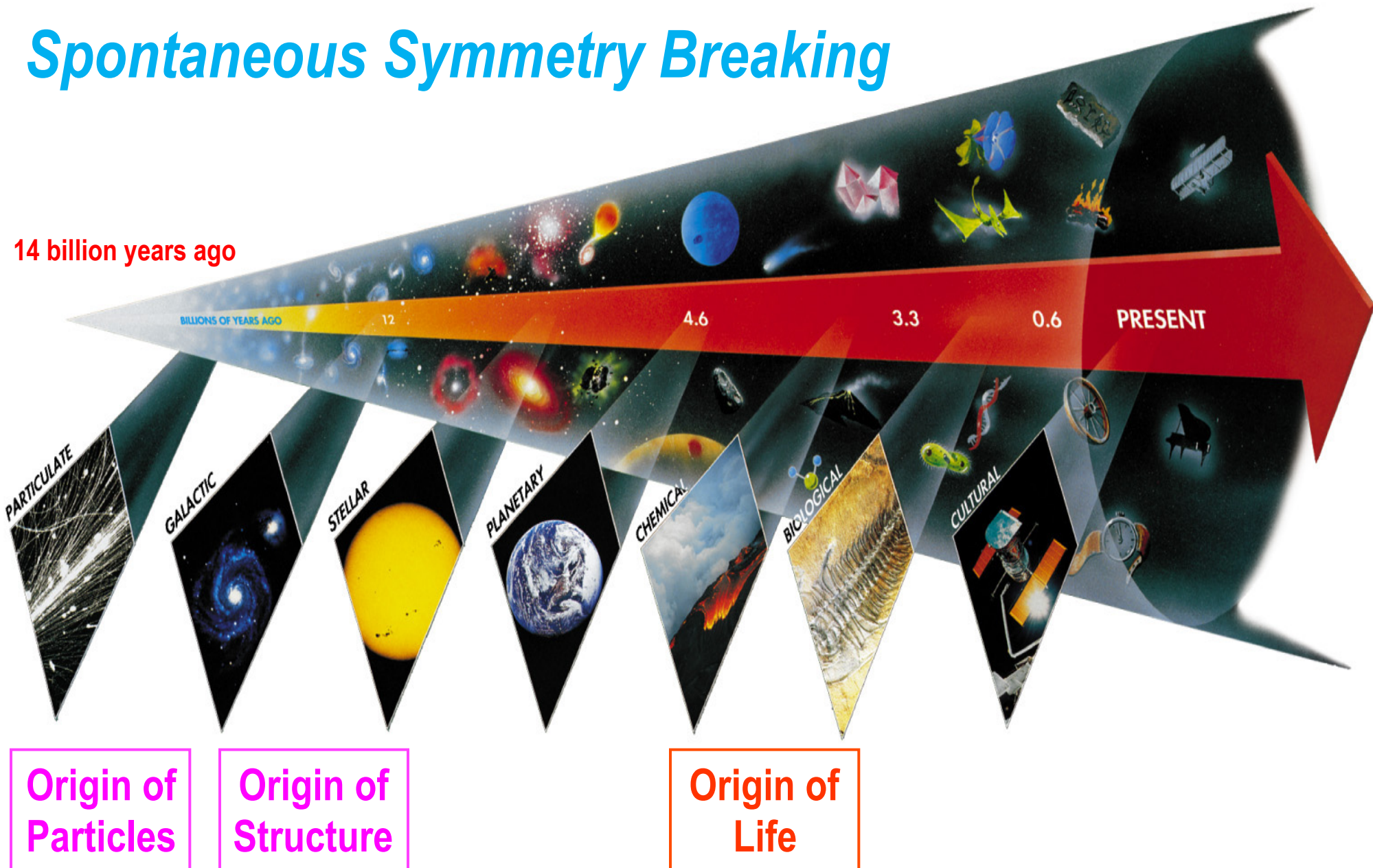


DarkSide 5T at Gran Sasso

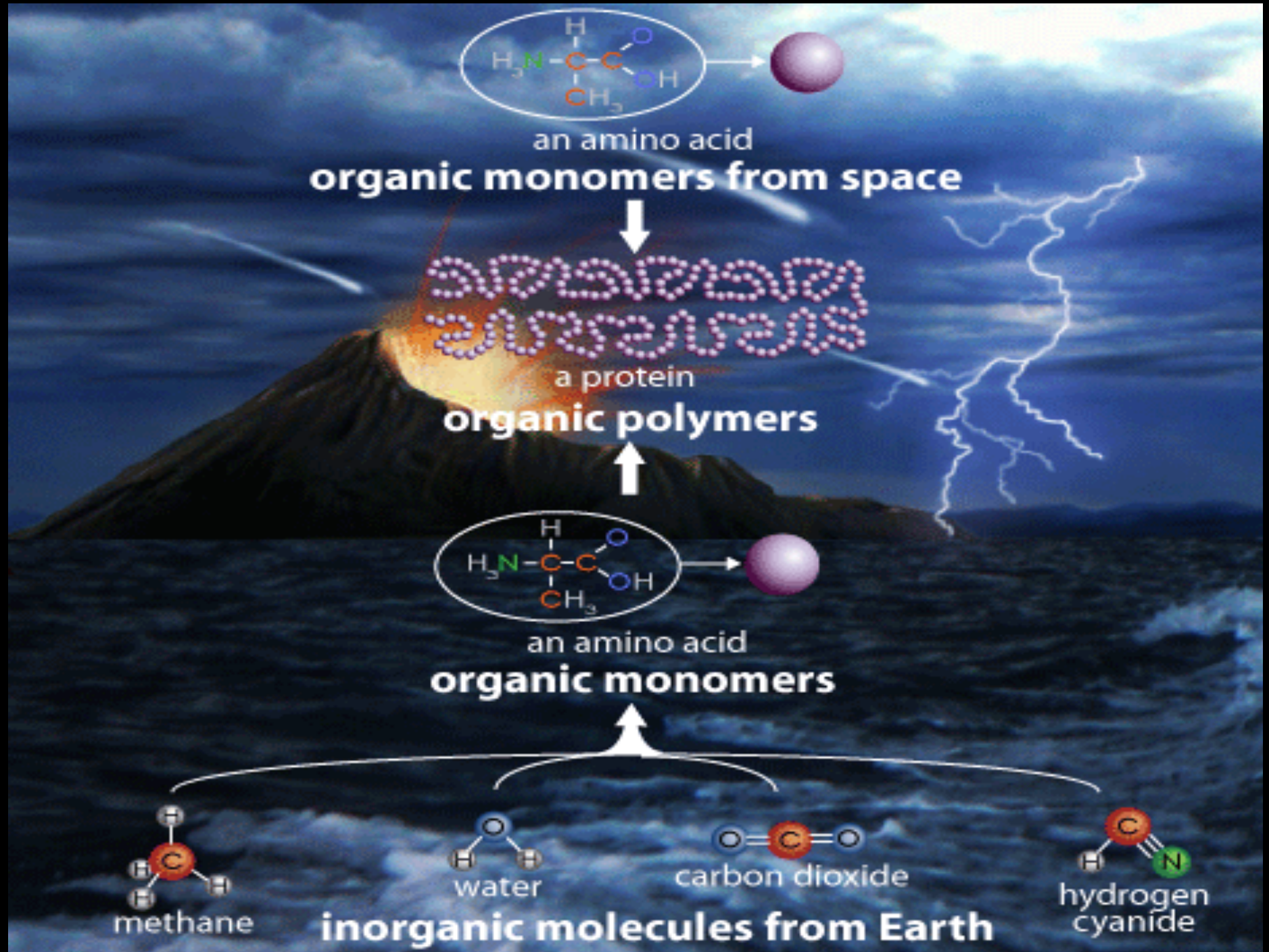


Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking

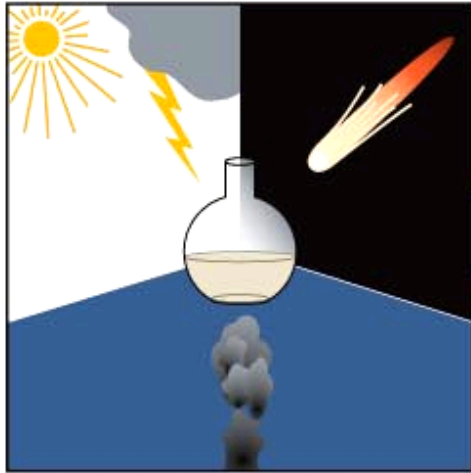


Organic Polymers (4.5B → 4B years)

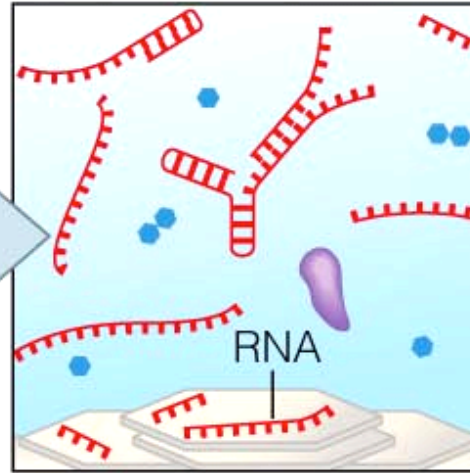


RNA World (4B → 3.5B years ago)

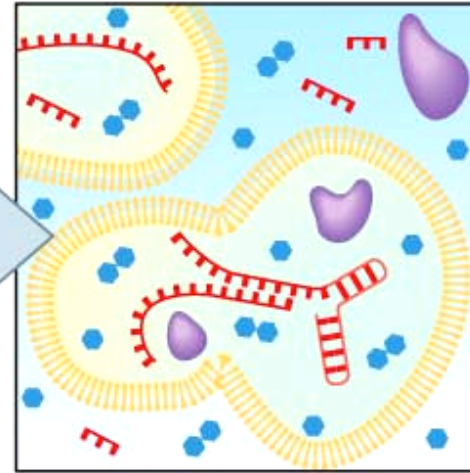
1. Organic precursor molecules appear.



2. RNA molecules become self-replicating.

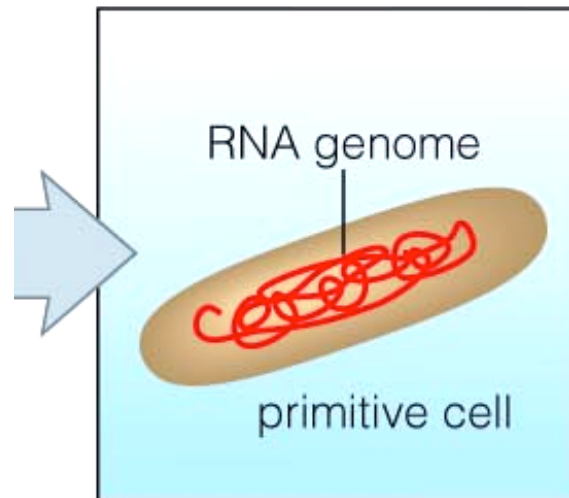


3. Membrane-enclosed pre-cells arise.

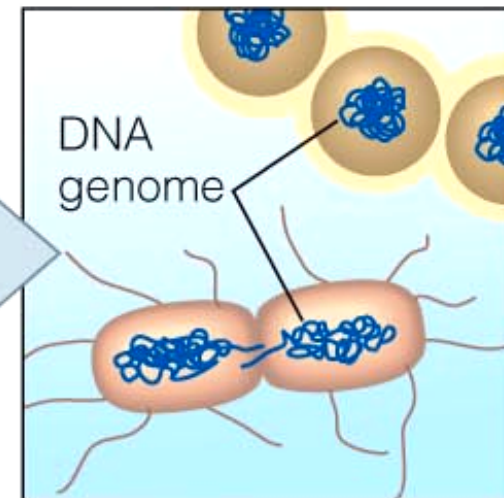


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4. True cells with RNA genome appear.



5. Modern cells with DNA genome evolve.



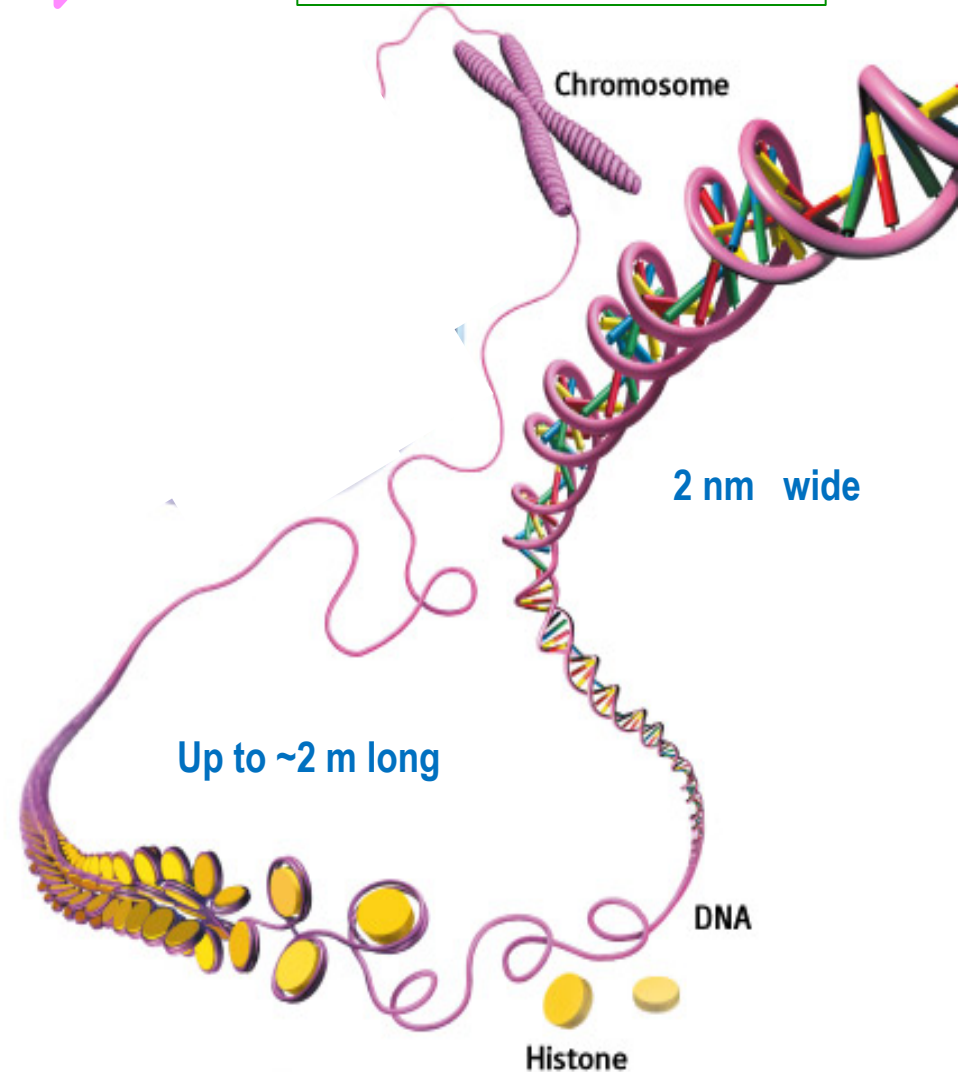
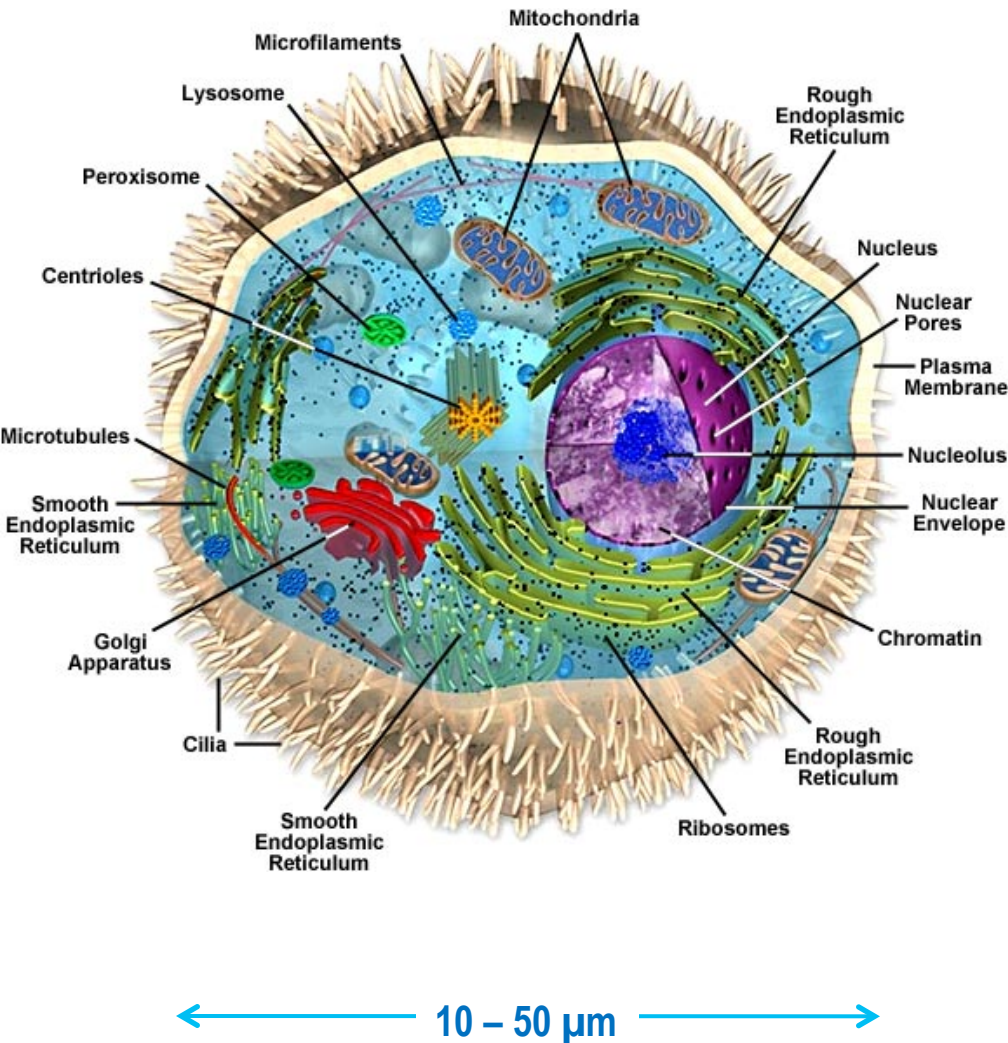
Eukaryote (~2B years ago)

Symmetry breaking

Cell made by proteins



Gene made by DNA



How to observe the “Origin of Life”

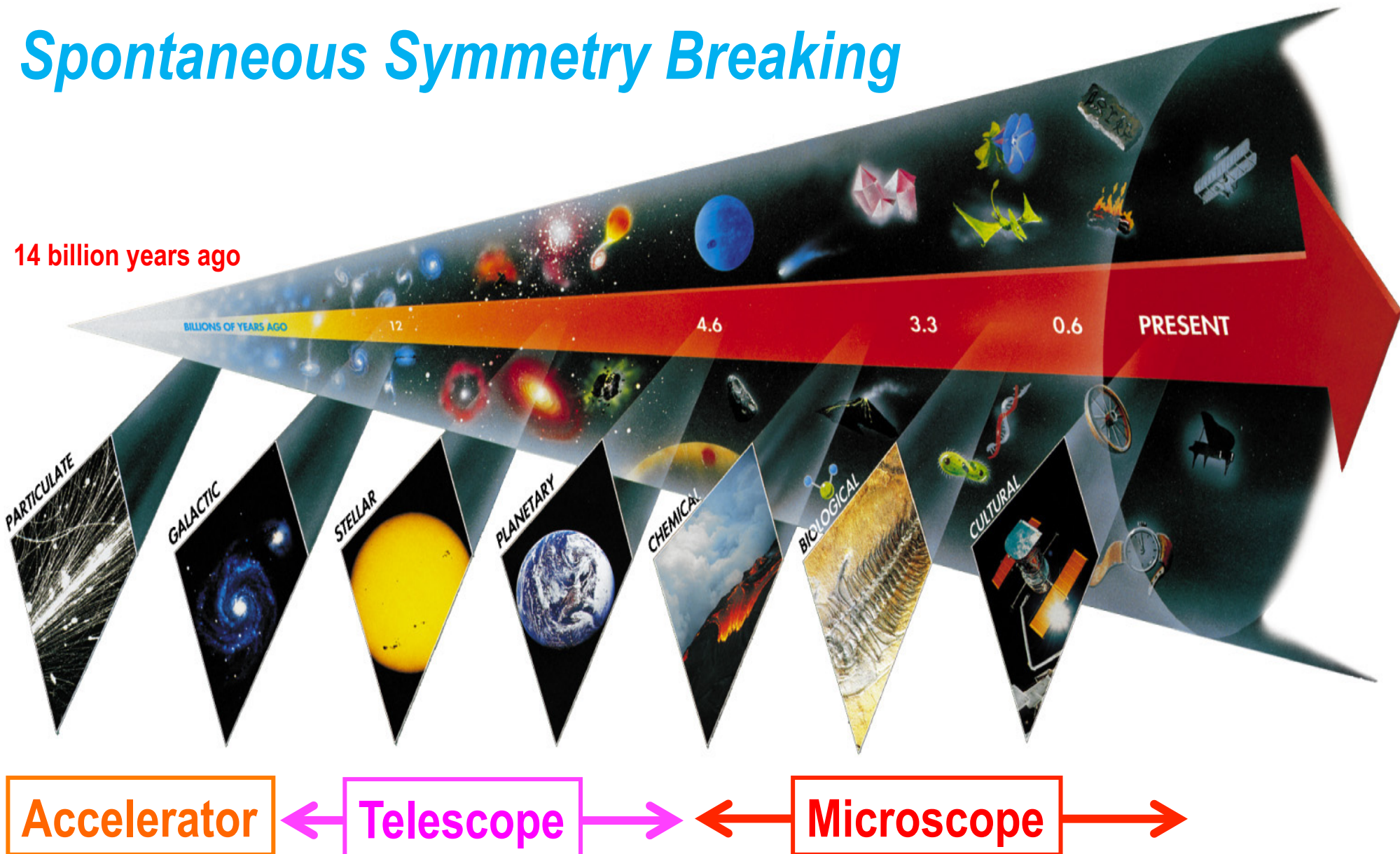
- Exactly the same way as we look for the “Origin of Universe”

Telescope vs. **Microscope**

- We must look for “**Live Life**”
- Take advantages of the state of art “**Photon Detectors**” in particle physics.

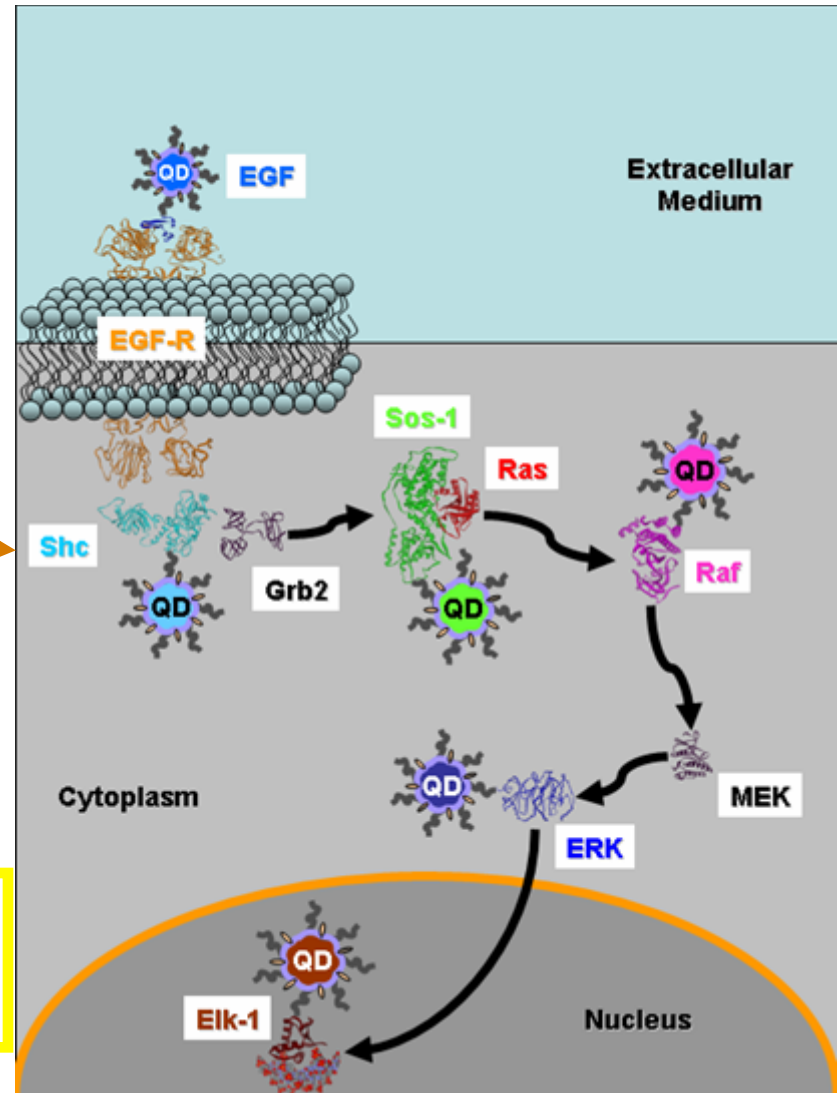
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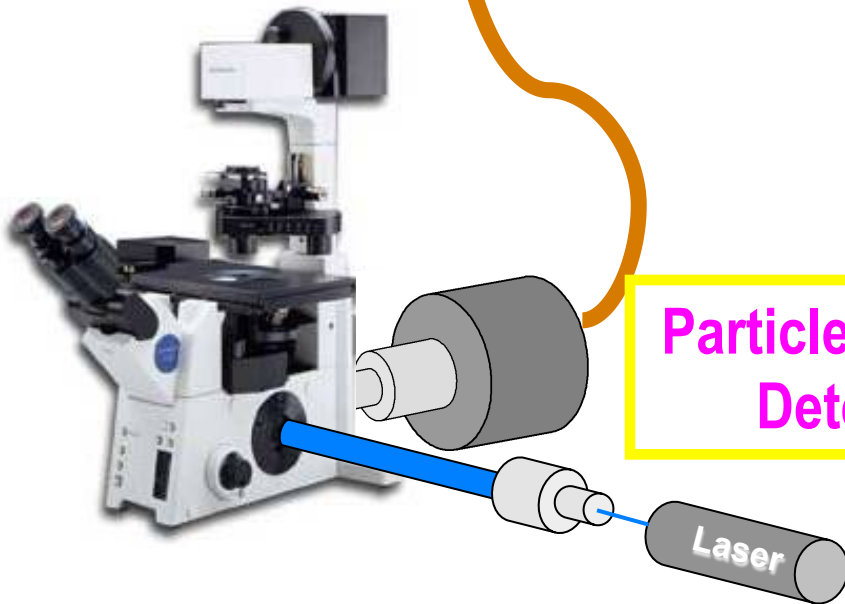


Single Molecule Imaging

Nano Technology



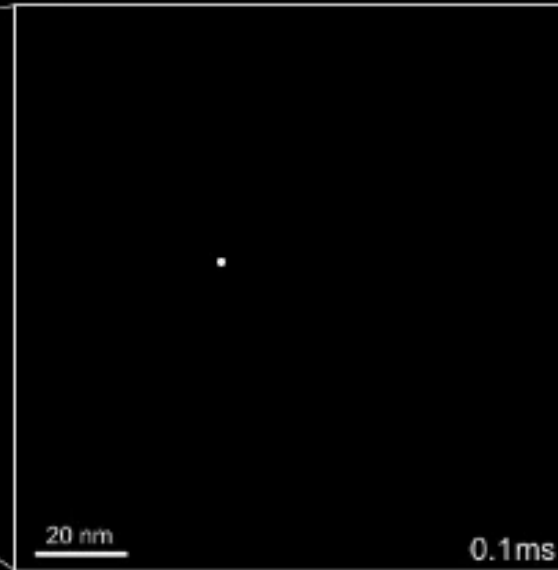
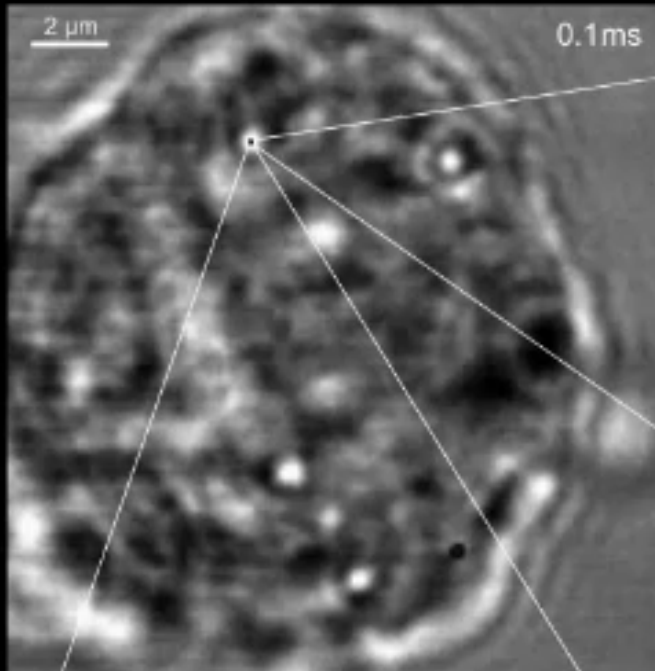
Particle Physics
Detector



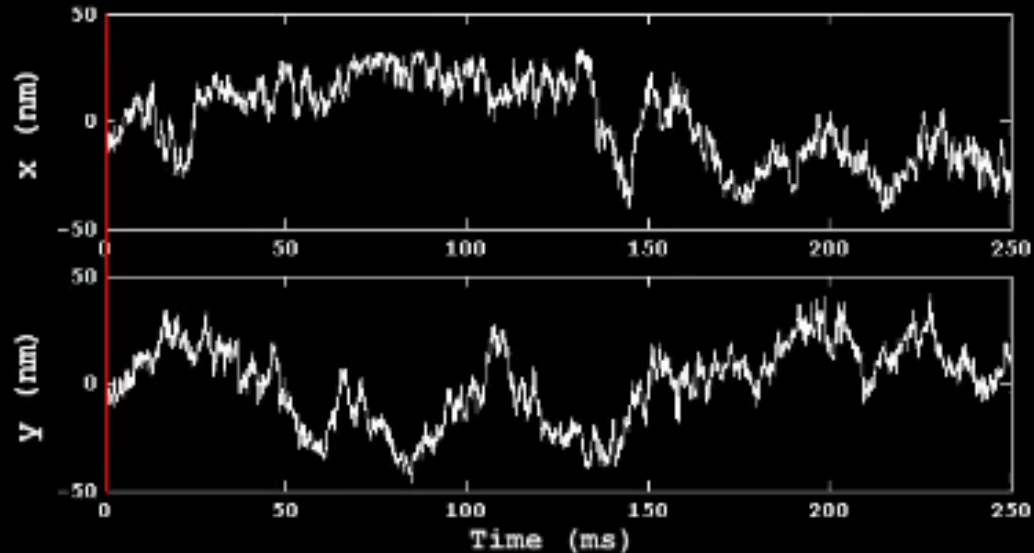
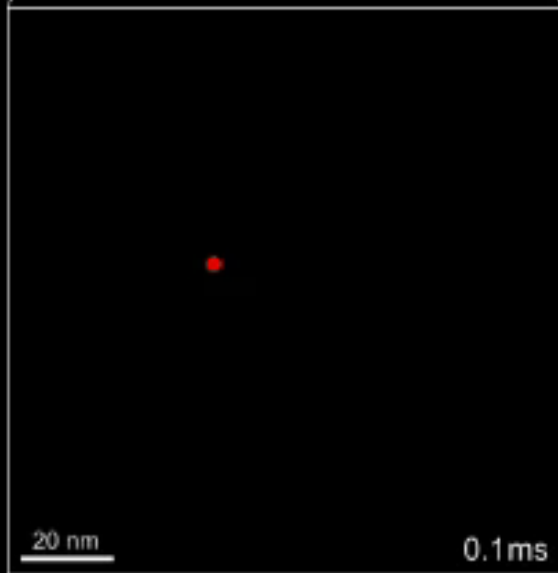
Prof. Shimon Weiss

Gold nano particle (40nm) attached to Transferrin Receptor (TfR) on Cancer Cell

Prof. Manuel Penichet (Oncology)



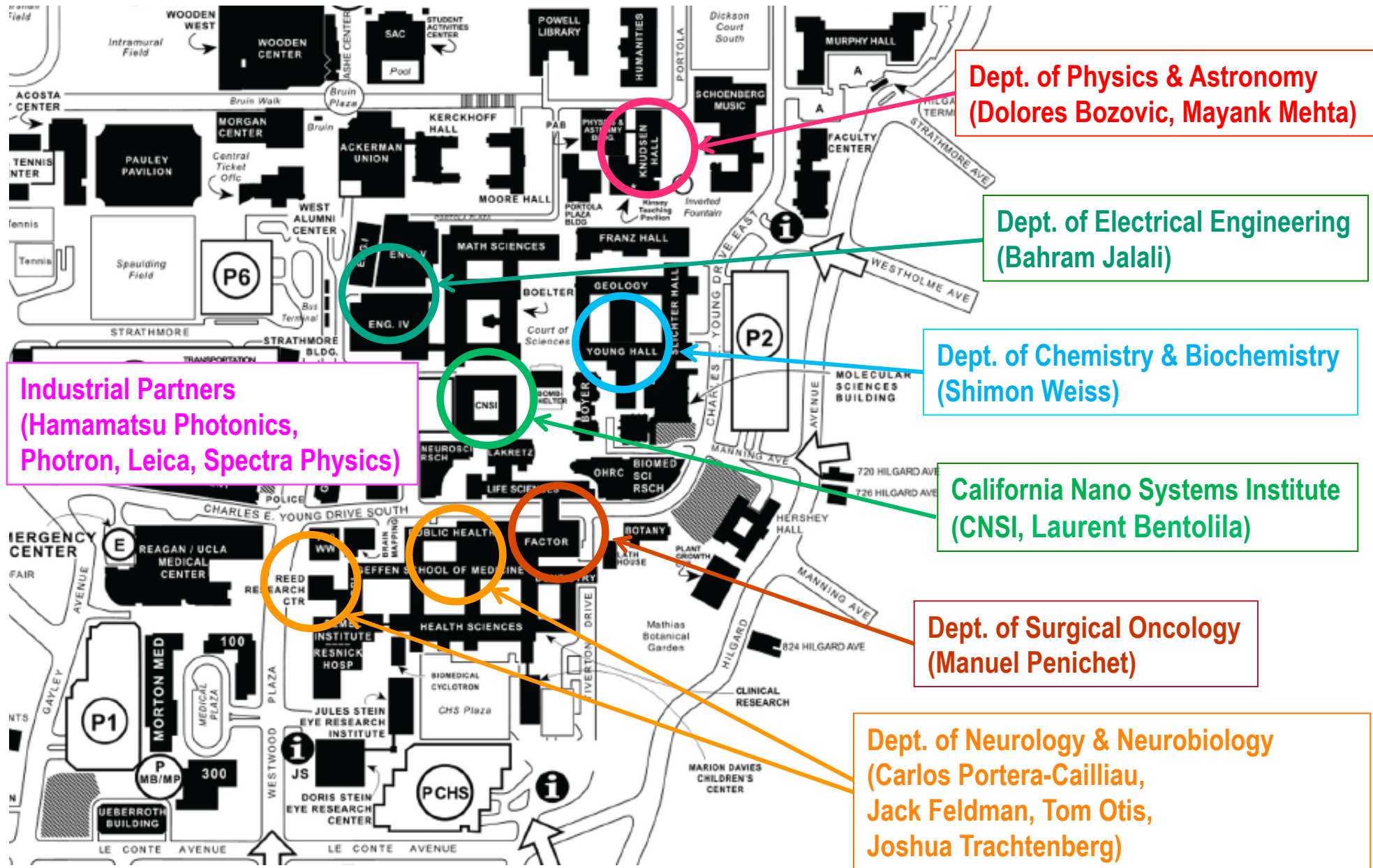
(10,000 frame/sec)



UCLA Fast Bio-Imaging Group

L. Fredrickson, J. Rodriguez, A. Cheng, K. Jewhurst, J. Miao, K. Arisaka

Arisaka's Campus-wide Collaborations on High-Speed Bio-imaging



User-shared Core Facility of High-speed Microscopes at CNSI

Tour in July



4D Nano Biophysics

High-speed Confocal Microscope with ICMOS at CNSI

(1,000 frame/s)

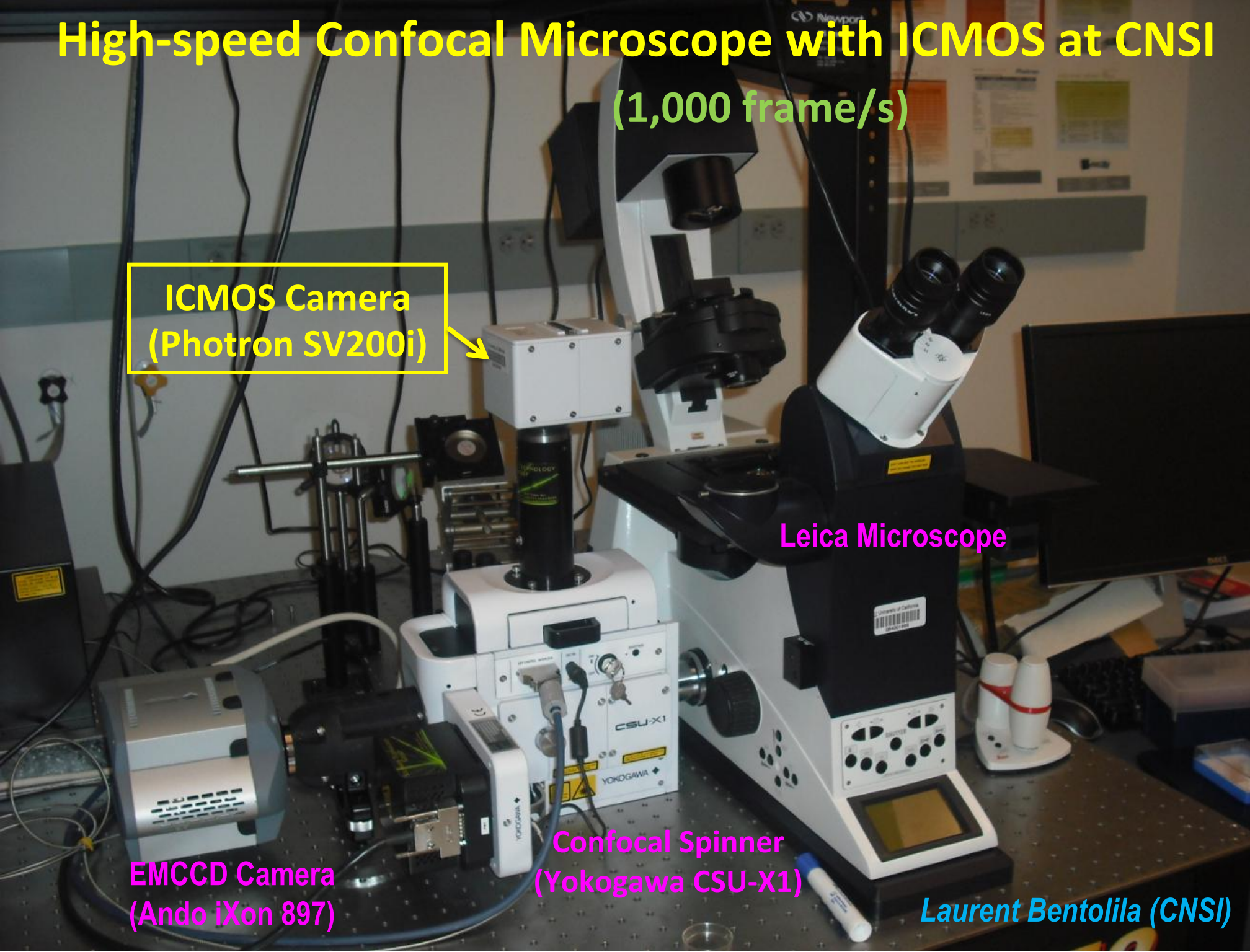
ICMOS Camera
(Photron SV200i)

Leica Microscope

EMCCD Camera
(Ando iXon 897)

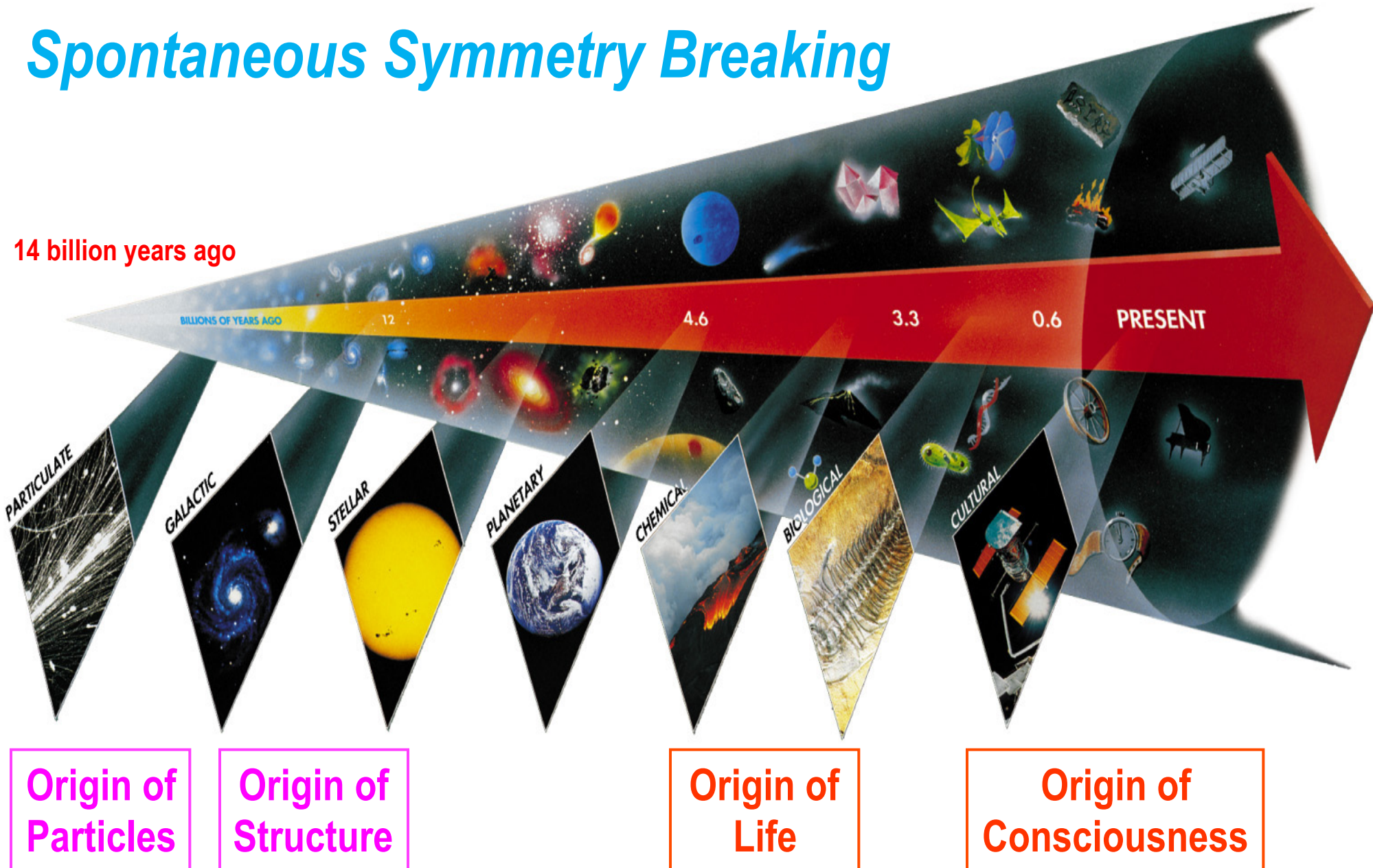
Confocal Spinner
(Yokogawa CSU-X1)

Laurent Bentolila (CNSI)



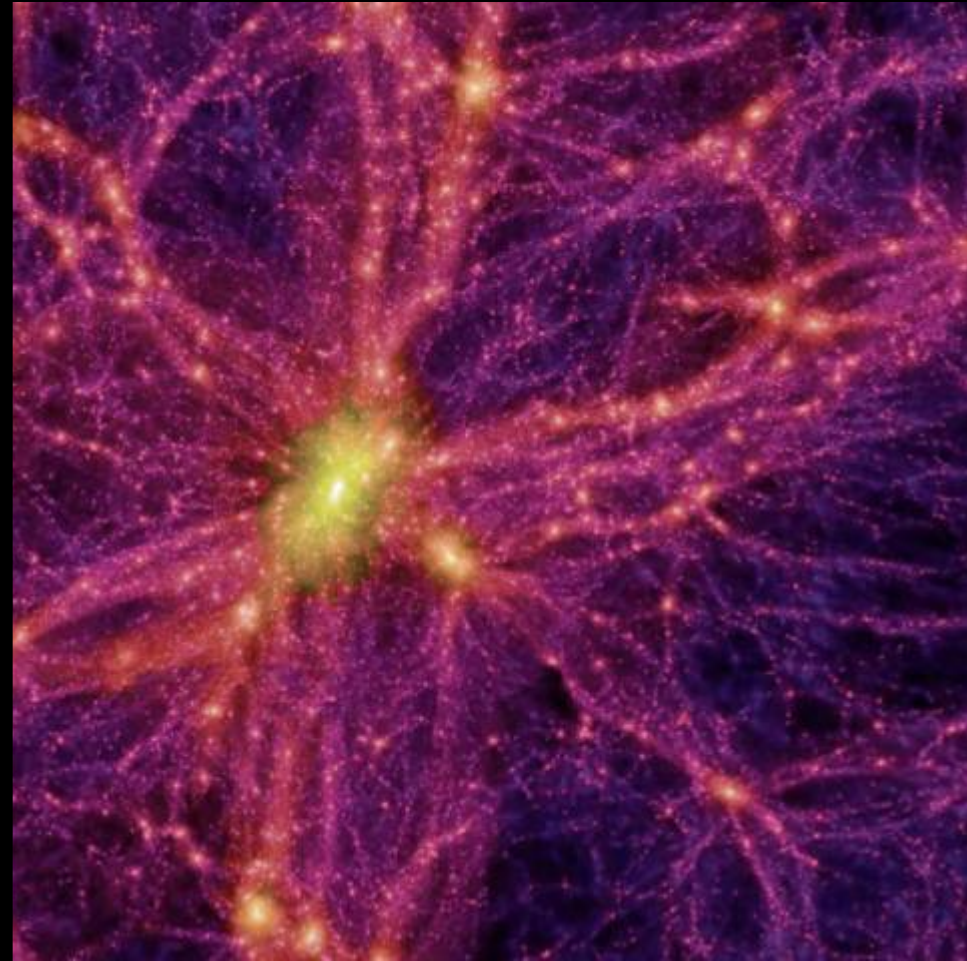
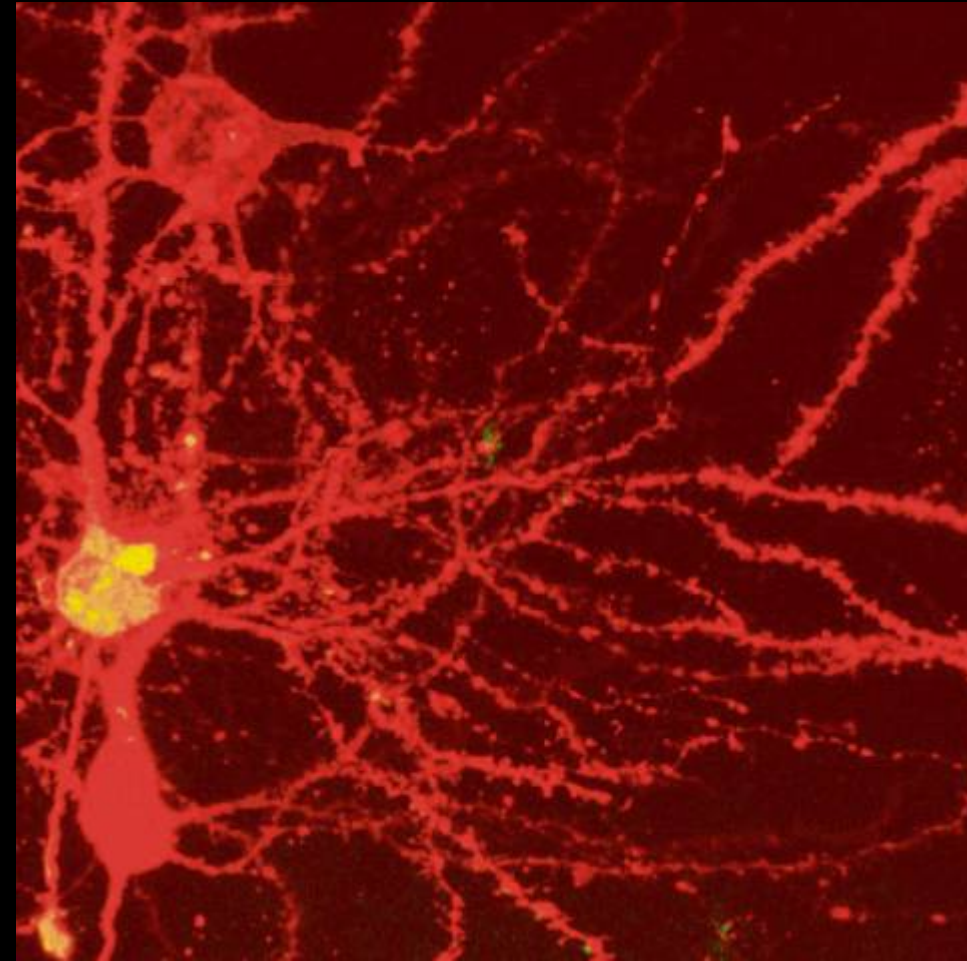
Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking



Brain

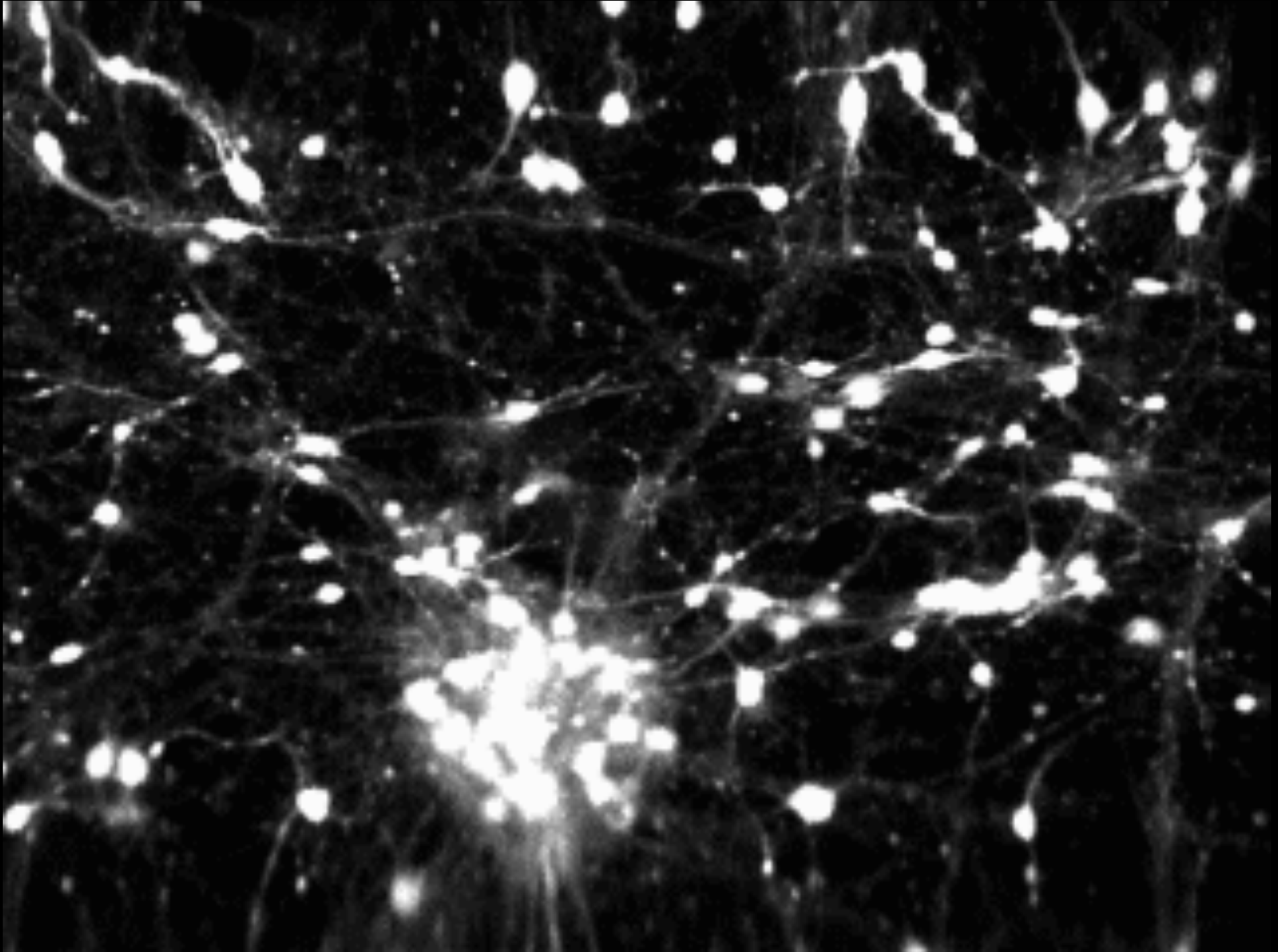
Universe



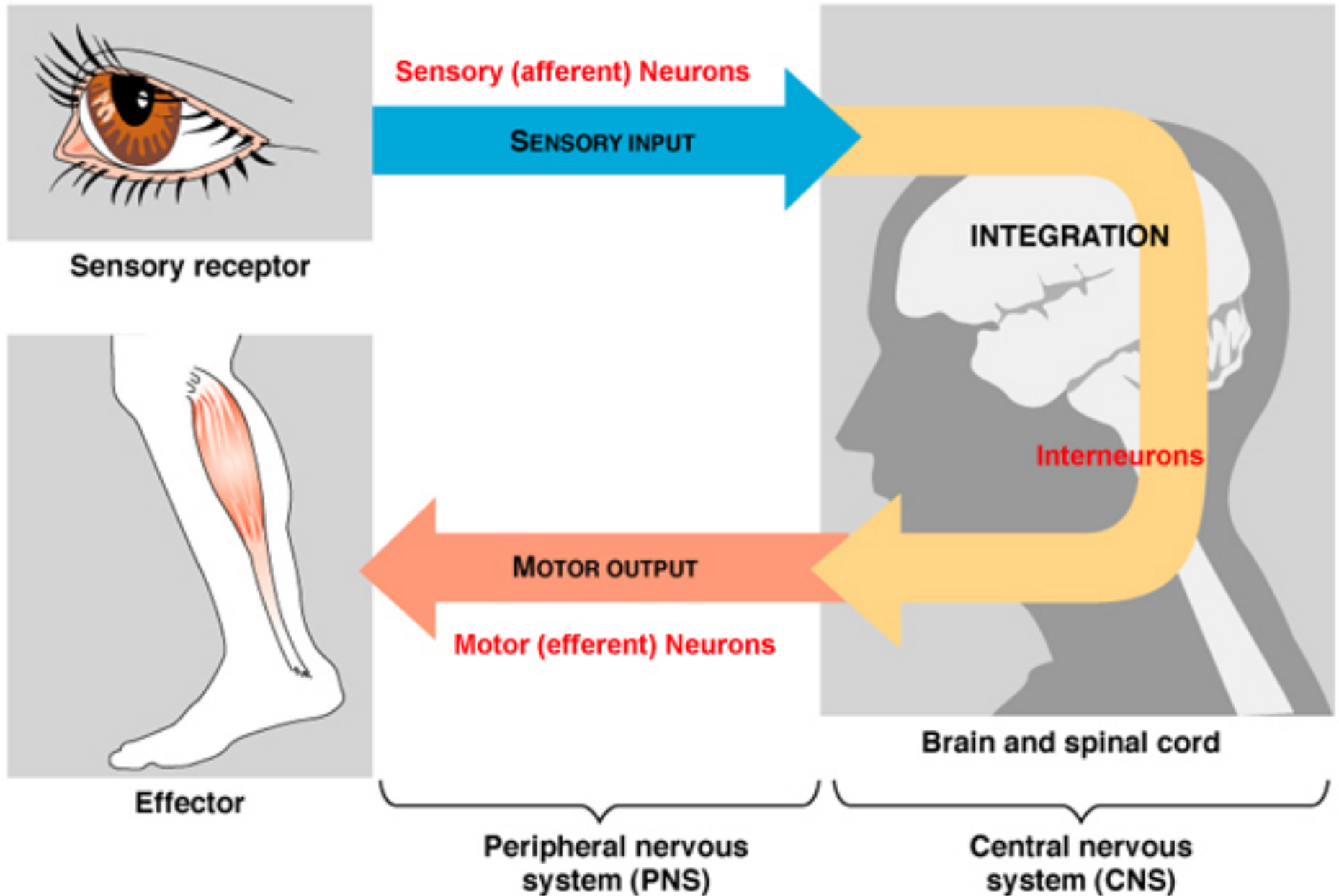
100 Billions Neurons

100 Billions Galaxies

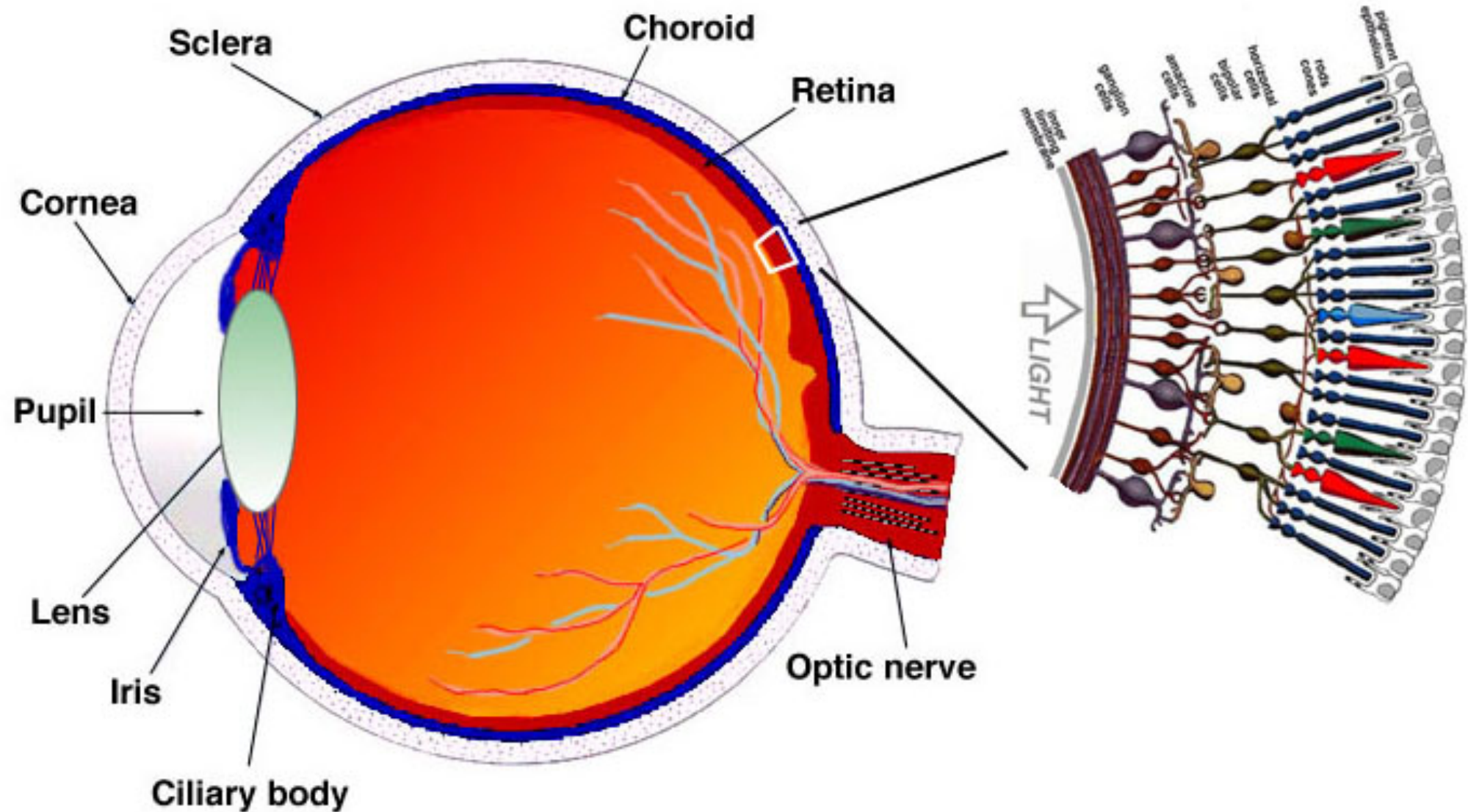
Ca²⁺ Signal in cultivated Rat's Brain



Assembly of cortical circuits during development



Human Eyes



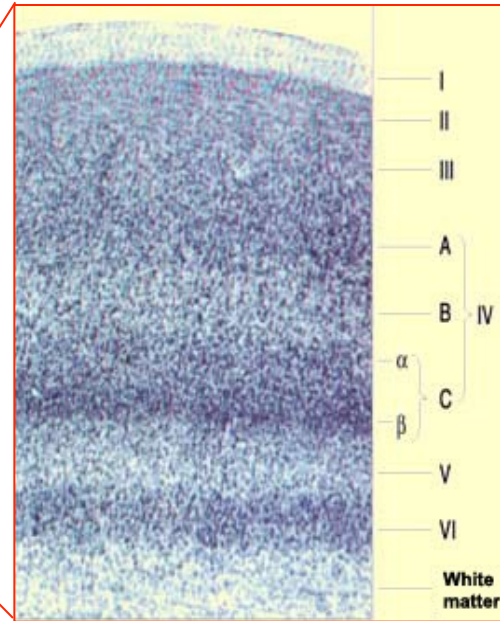
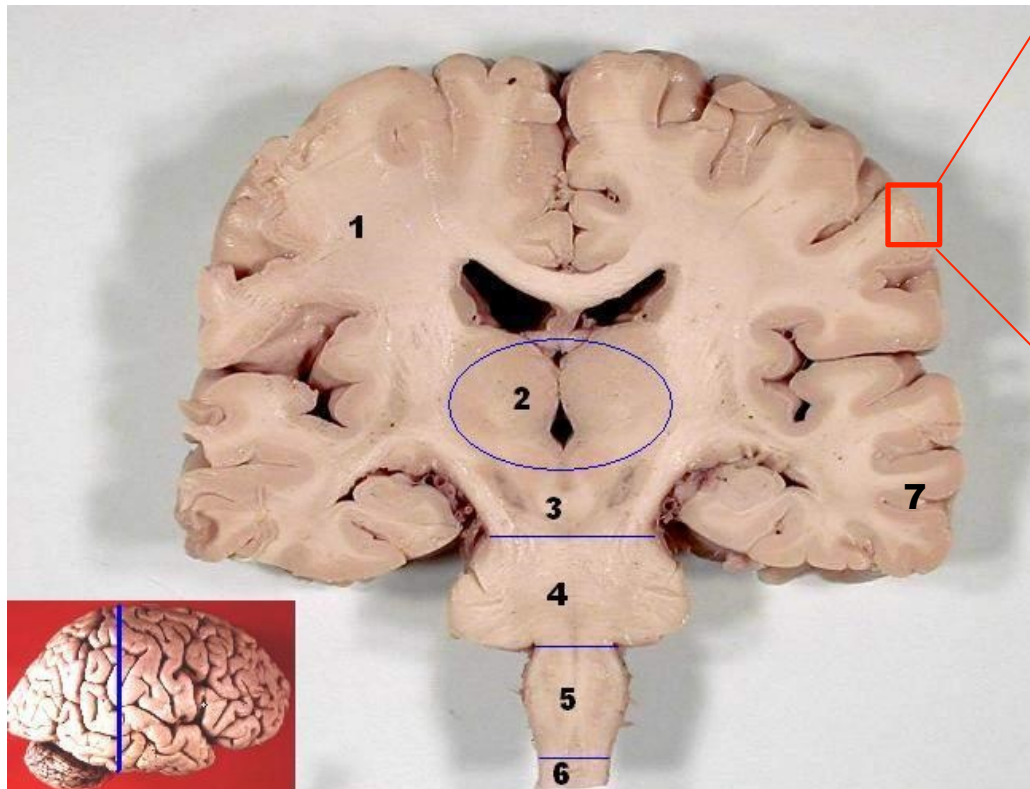
How can I recognize a woman so far away?



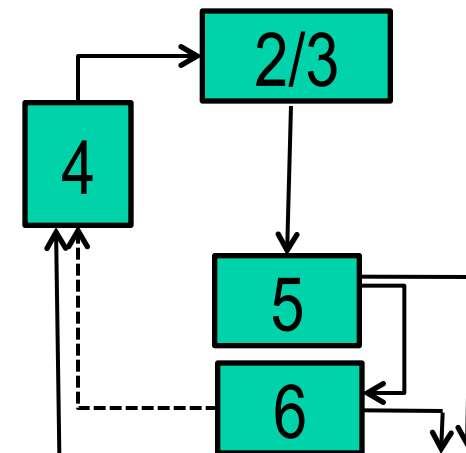
- Genetically encoded?
- Learning and memory?

The Cerebral Cortex

Conscious



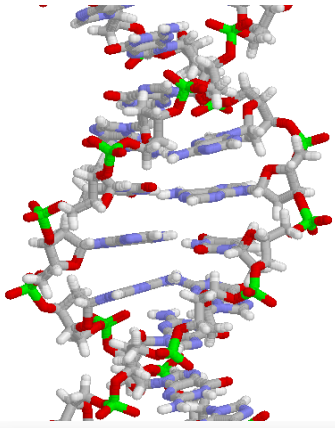
Unconscious



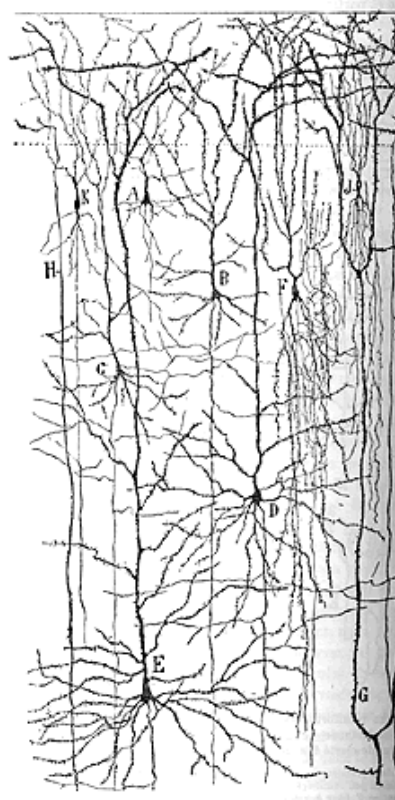
Thalamus

Subcortical areas

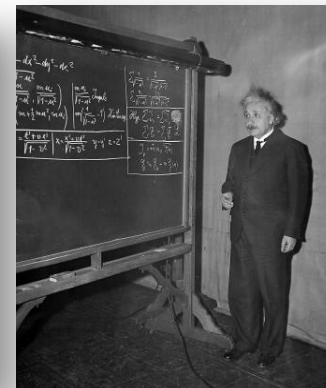
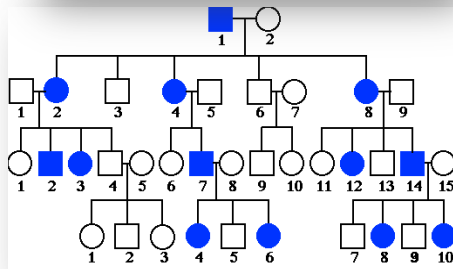
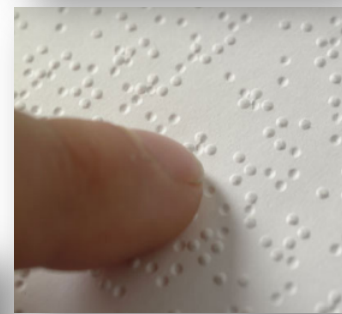
Nature vs. Nurture



Nature



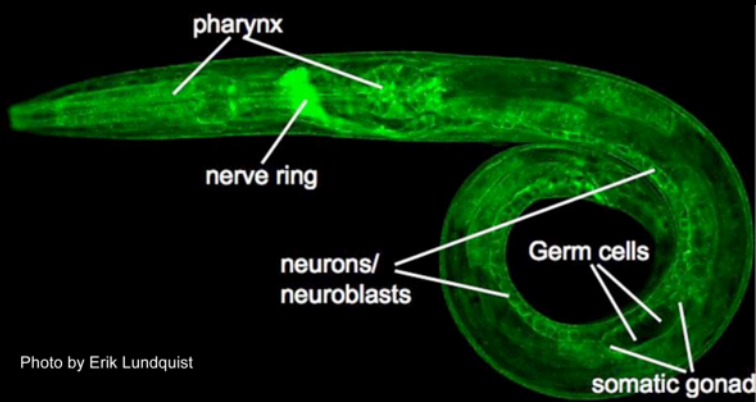
Nurture



From No Brain to Big Brain



Paramecium (Single Cell)



C. elegans (302 neurons)



Zebrafish (~10,000 neurons)



Bullfrog (~10⁷ neurons)



Rat (~10⁸ neurons)

Introduction

Why C. Elegans ?

➤ Why are we here?

- C. Elegans is a half way from the big bang to the human being

➤ Origin of Life

- C. Elegans is the simplest animal from the complete genetic information (97 Mbp) to the entire cell structure (959 cells)

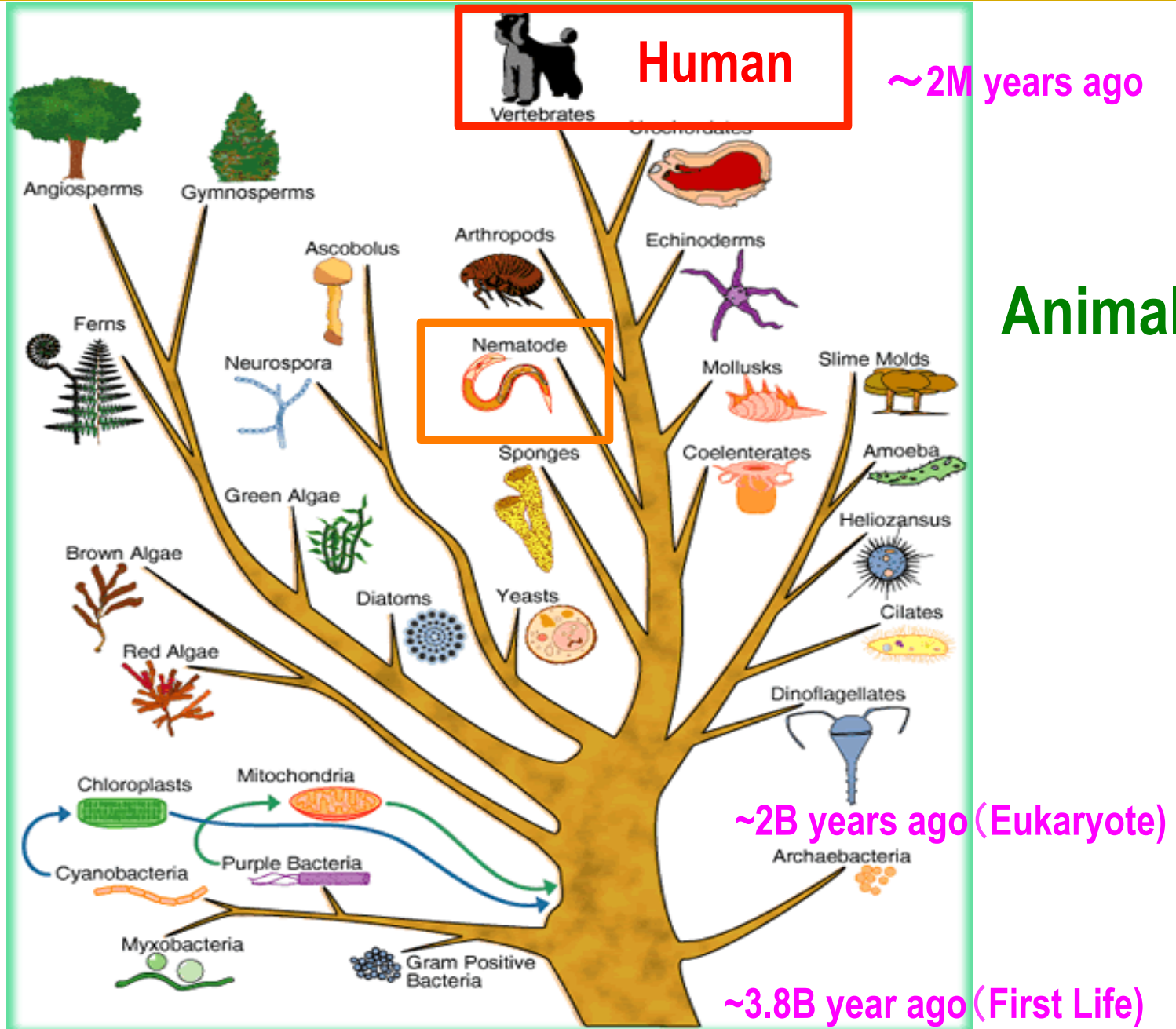
➤ Origin of consciousness

- C. Elegans is the simplest animal with known neural network (302 neurons)

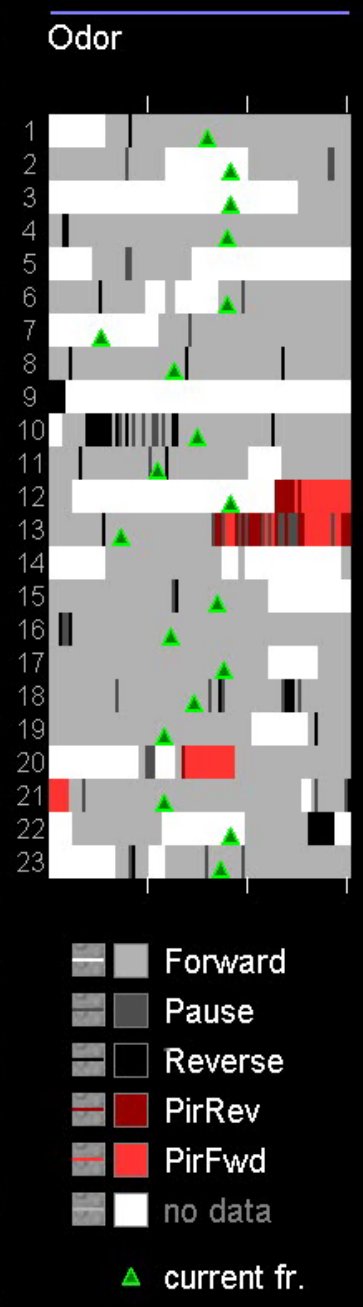
Tree diagrams of evolution

Plants

Animals



High-content behavioral analysis

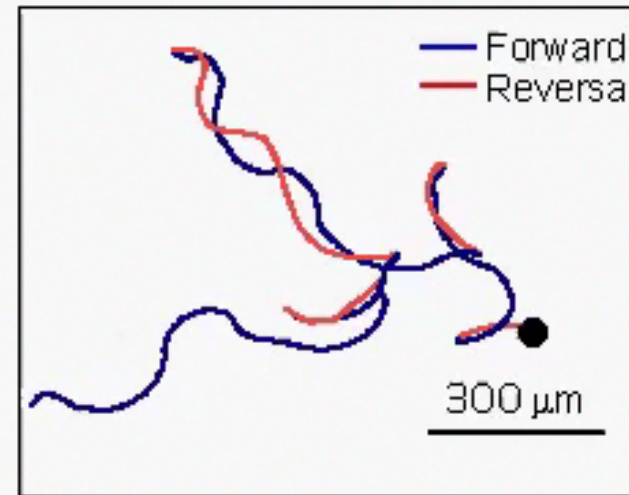


Supplemental movie 3

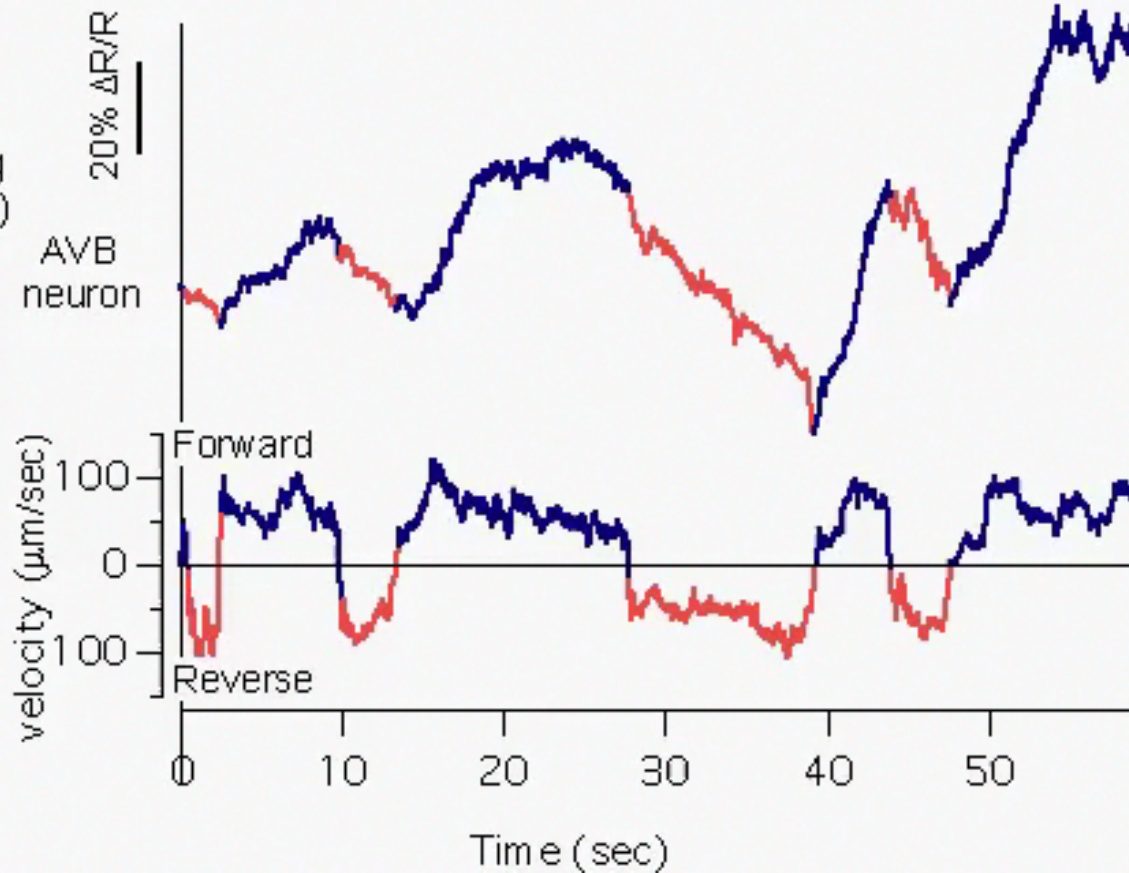
Spotting Camera (4X)

Faumont *et al.*, 2011

Track

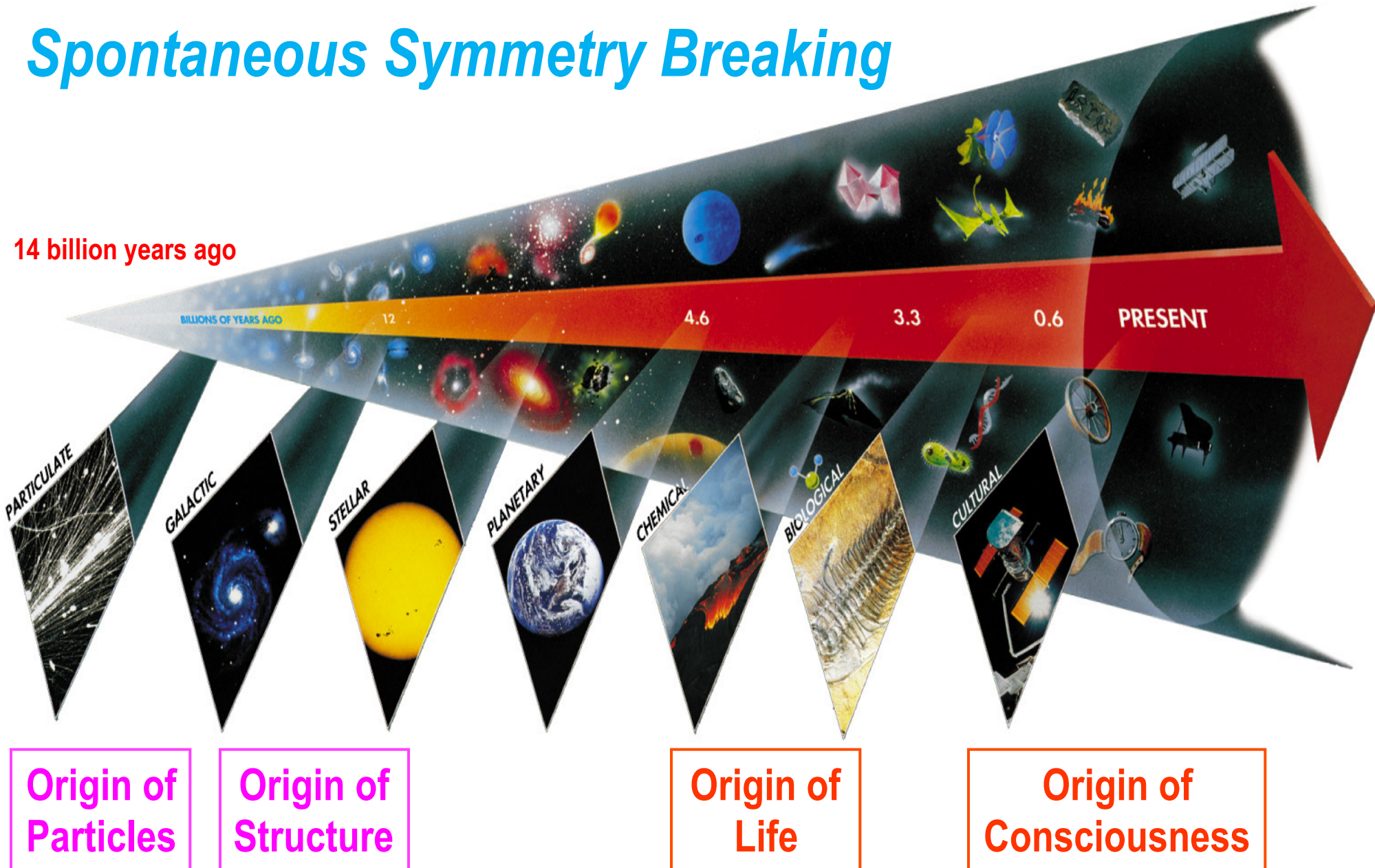


Ca²⁺ imaging camera (63X)



Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking

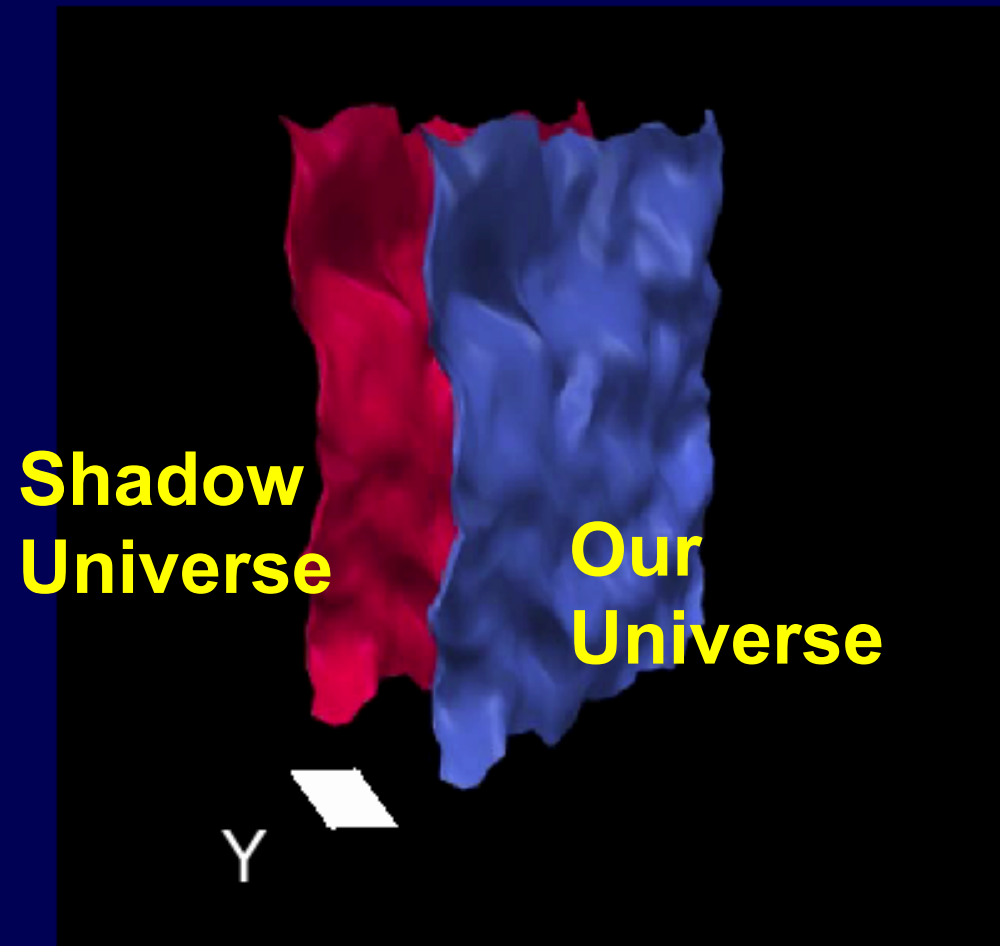
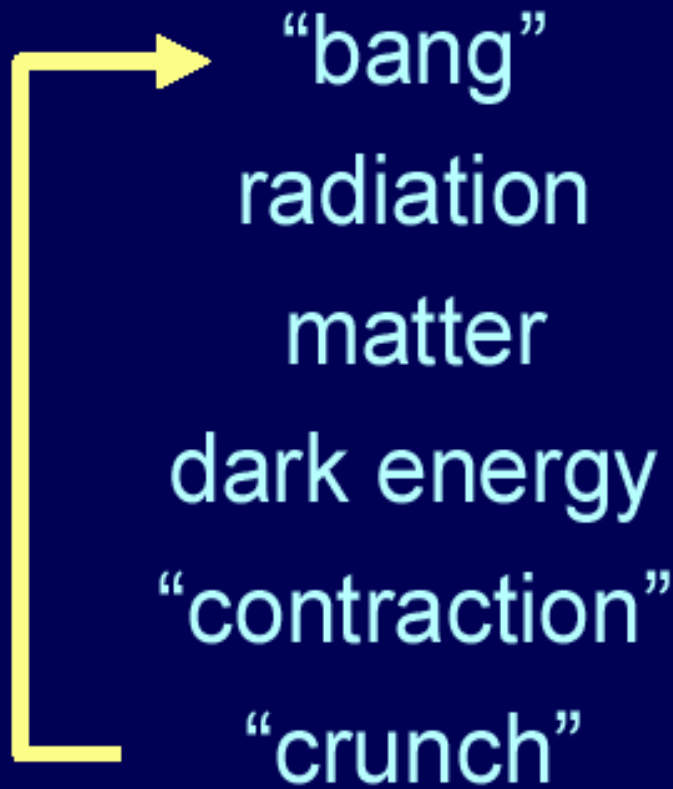




Why are we here?

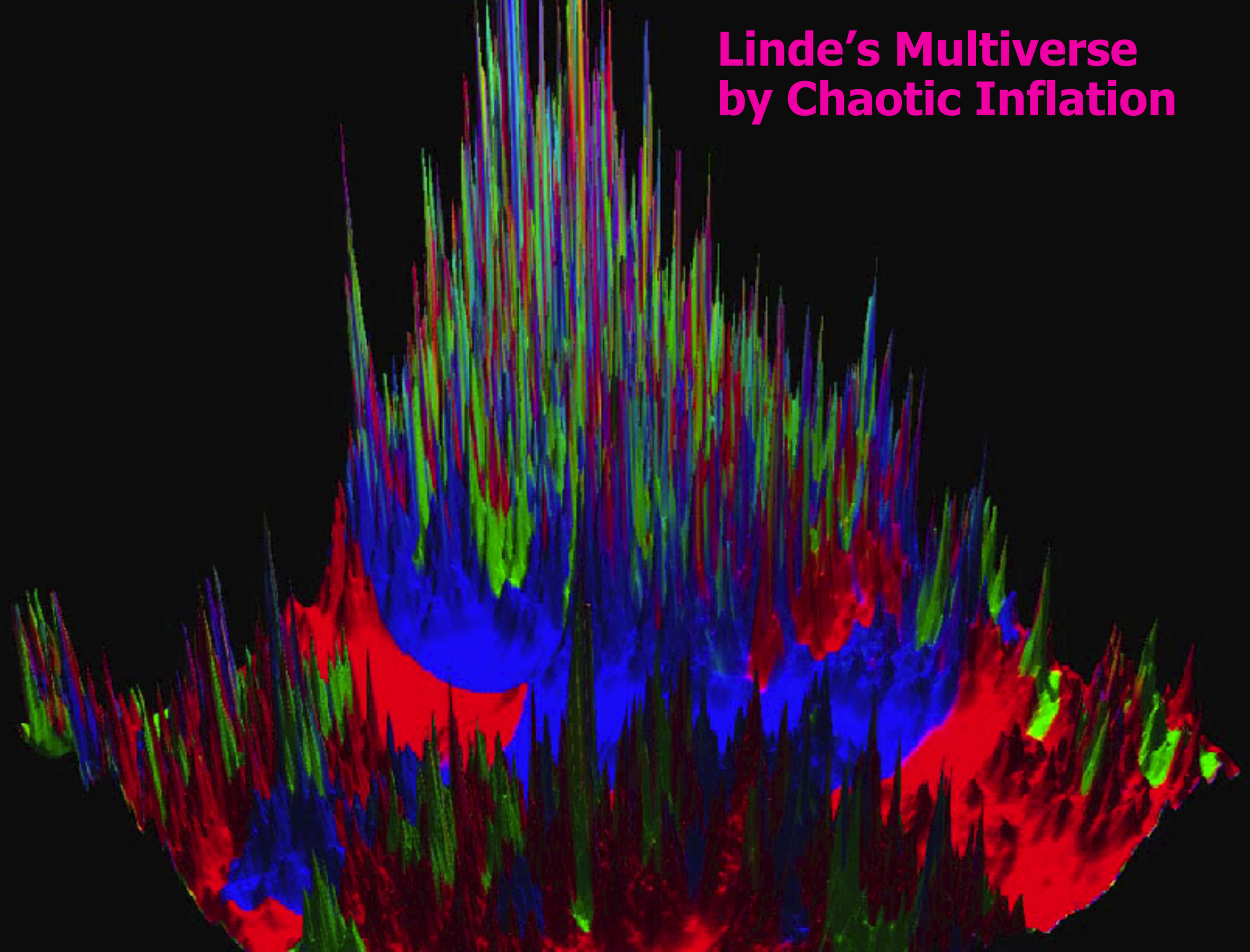
Cyclic Model

M theory



**Are there more than
one Universe?**

Linde's Multiverse by Chaotic Inflation



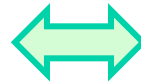


There may be ~100 Billion Universes.

Four Major Science

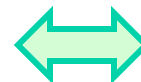
Origin of Particles
Particle Physics

Origin of Universe
Cosmology



Origin of Life
Molecular Biology

Origin of Consciousness
Neurophysics



Welcome to Physics World at UCLA

➤ **Feel free to stop by my office any time.**

- **Katsushi Arisaka**
- **Knudsen 4-145**
- **(310) 825-4925**
- **arisaka@physics.ucla.edu**

➤ **This talk will be posted at:**

<http://www.physics.ucla.edu/~arisaka/home>

➤ **Lab Tours:**

- **Today → Dark Matter Lab**
- **In July → CNSI (California Nano System Institute)**