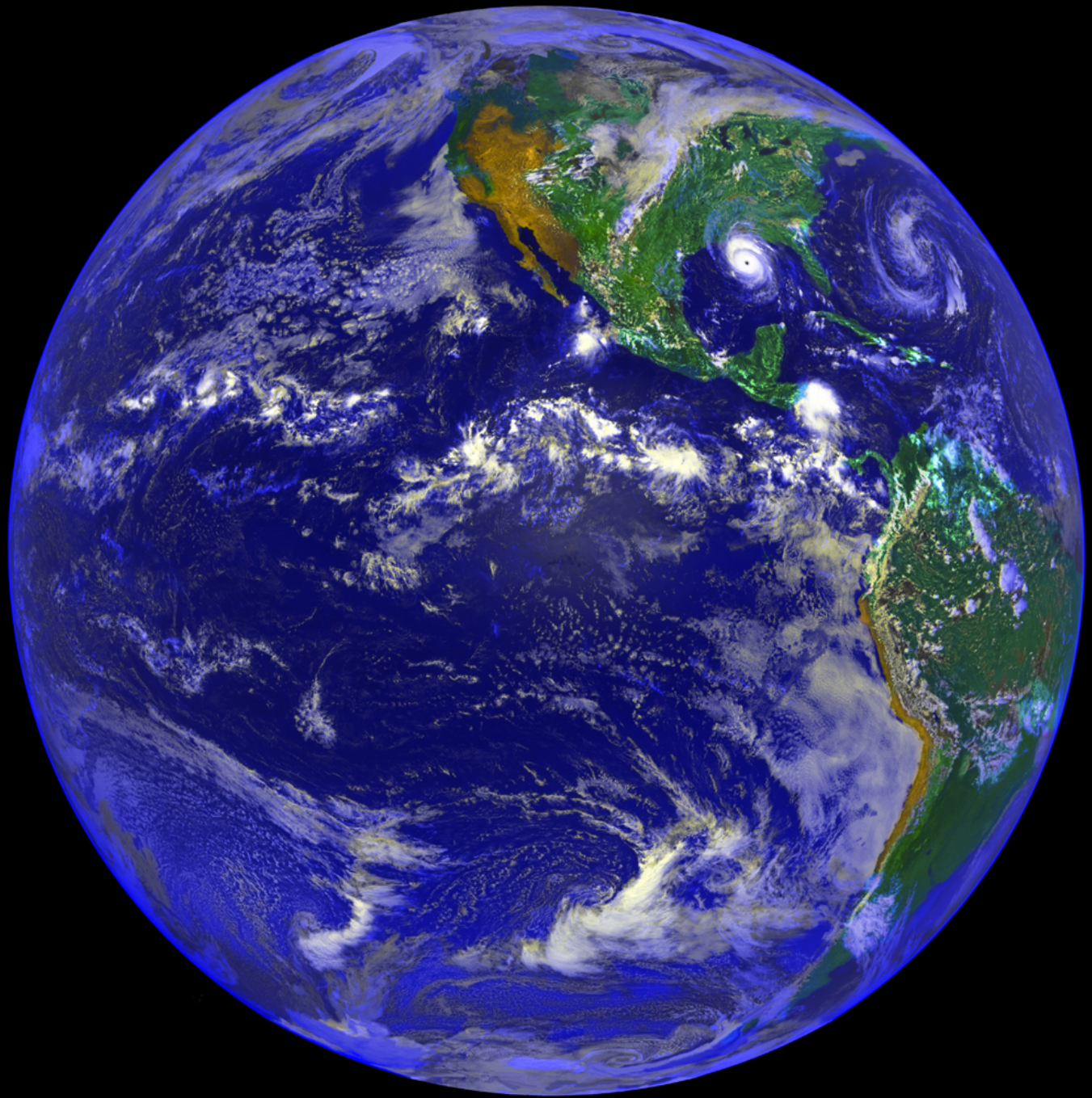
Introduction to Physics Research
Origin of Universe and Ourselves

Katsushi Arisaka

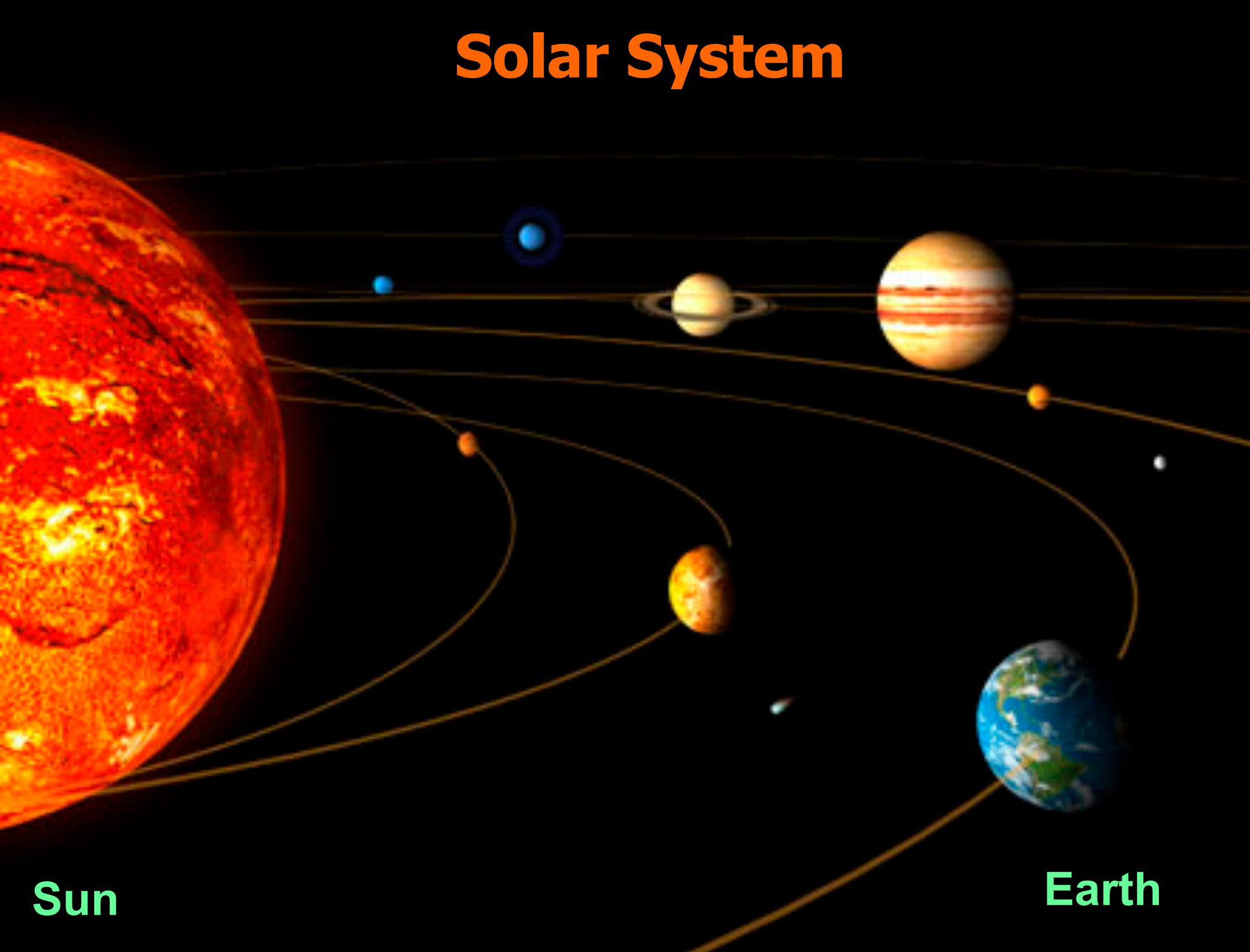
University of California, Los Angeles
Department of Physics and Astronomy

arisaka@physics.ucla.edu

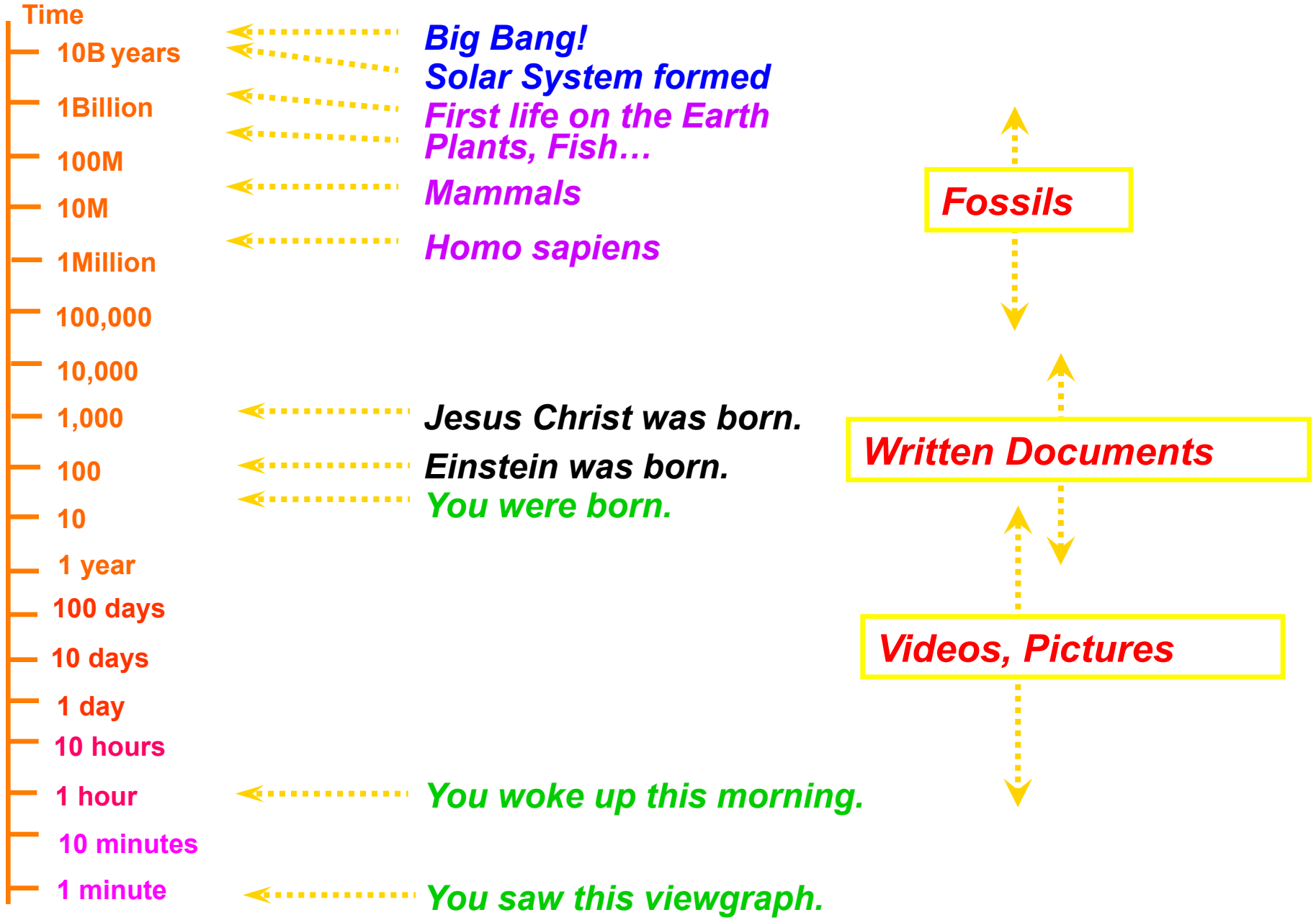


Why are we here?

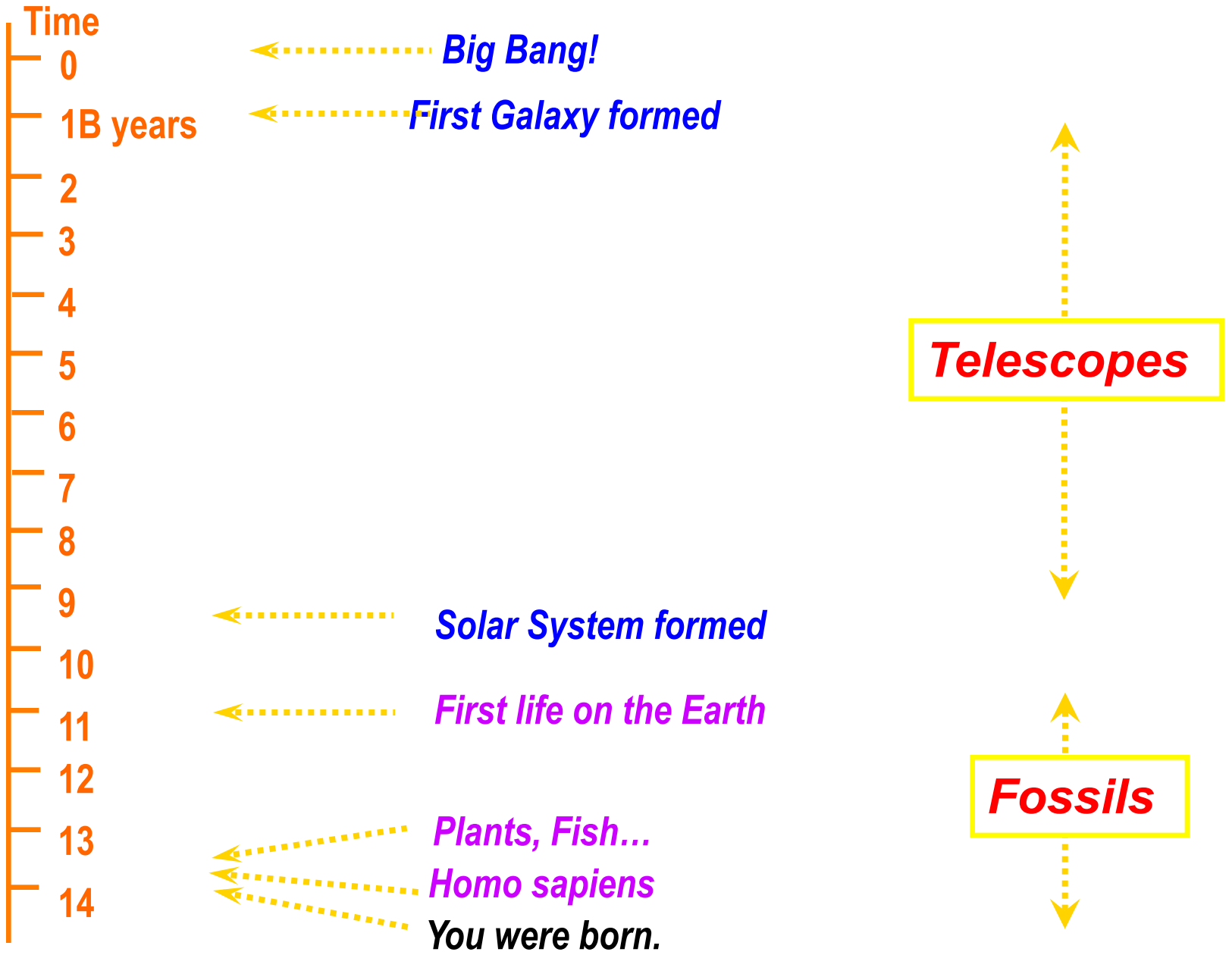
Solar System



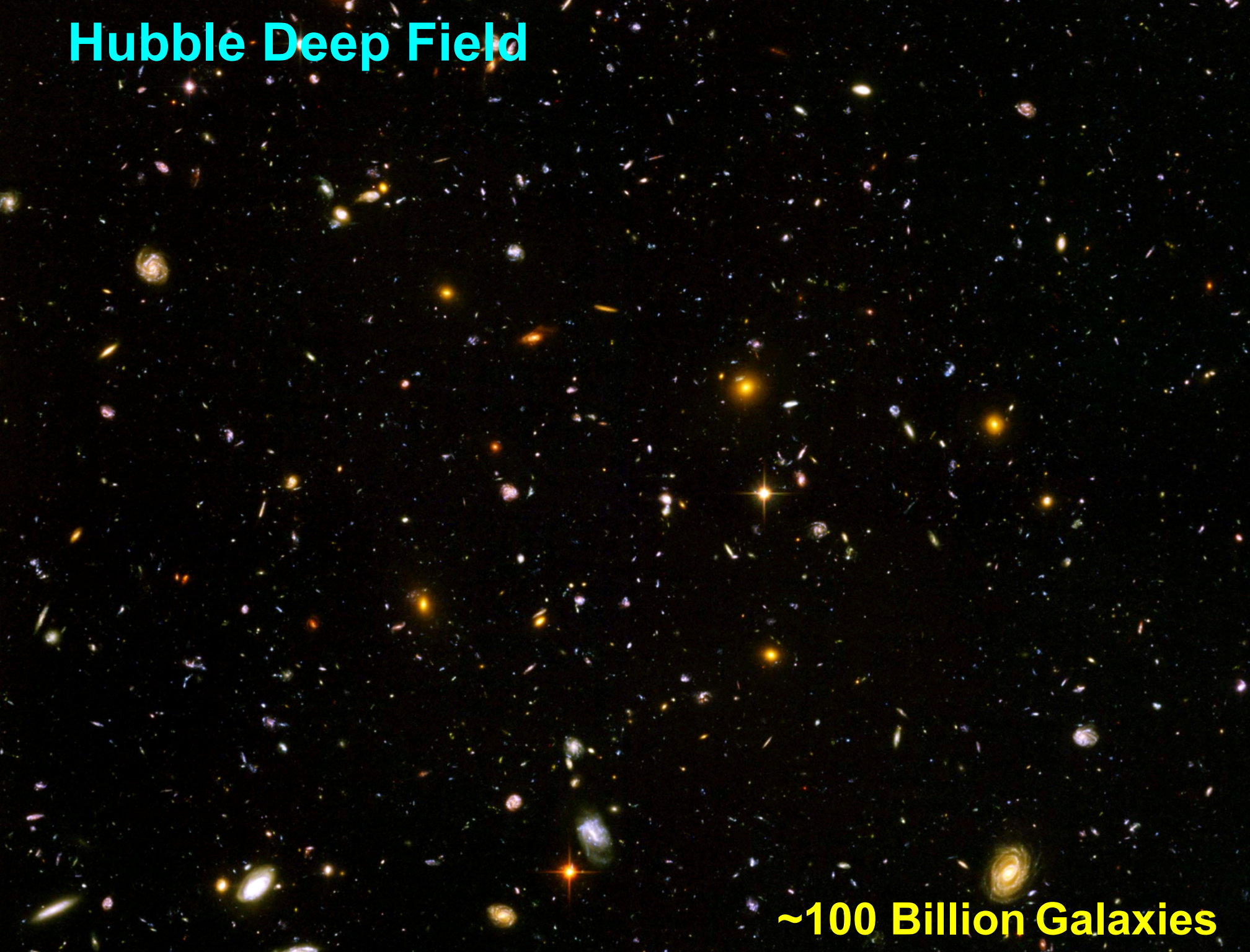
History of Life and the Human beings

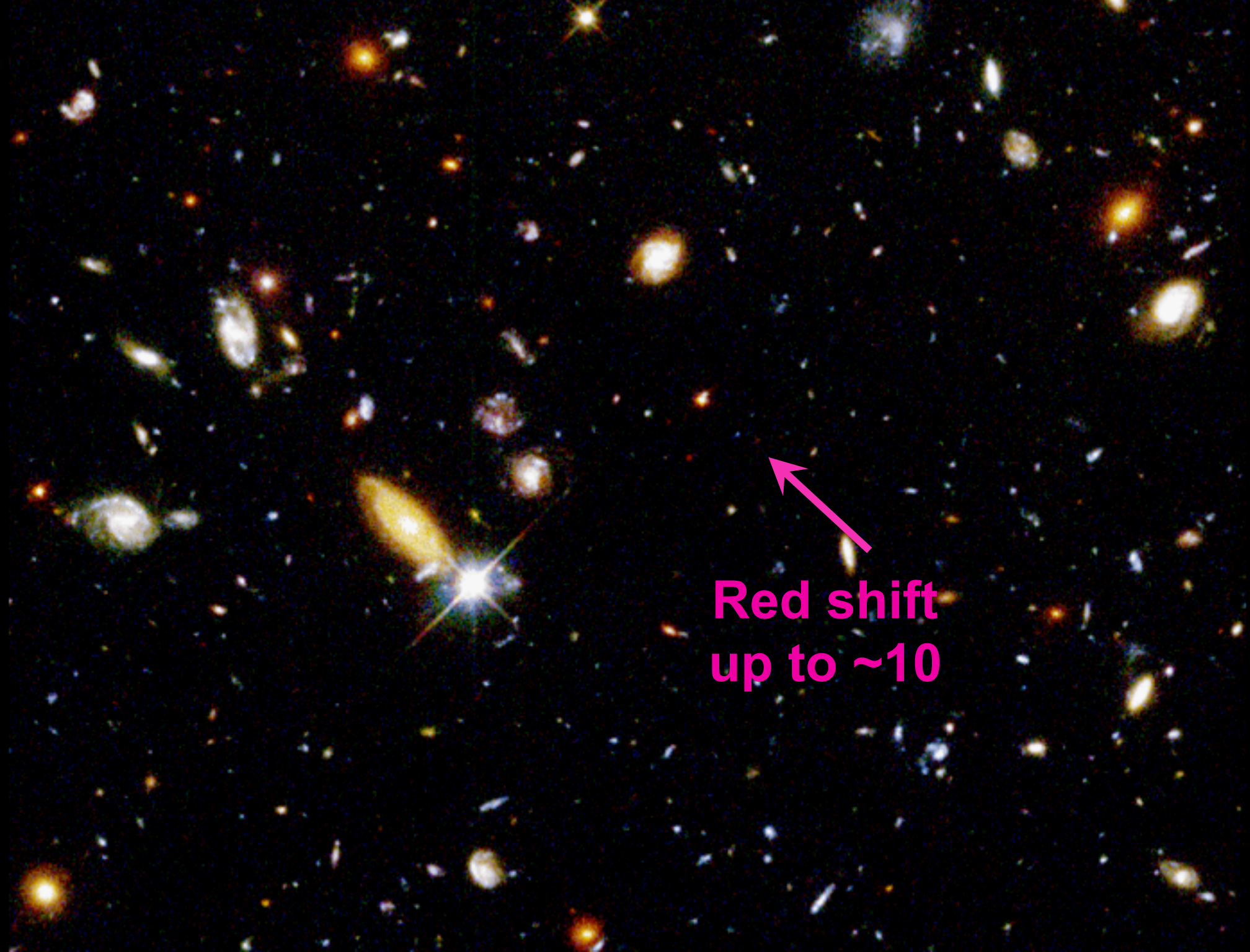


Brief History of Universe and Life



~100 Billions Stars in a Galaxy

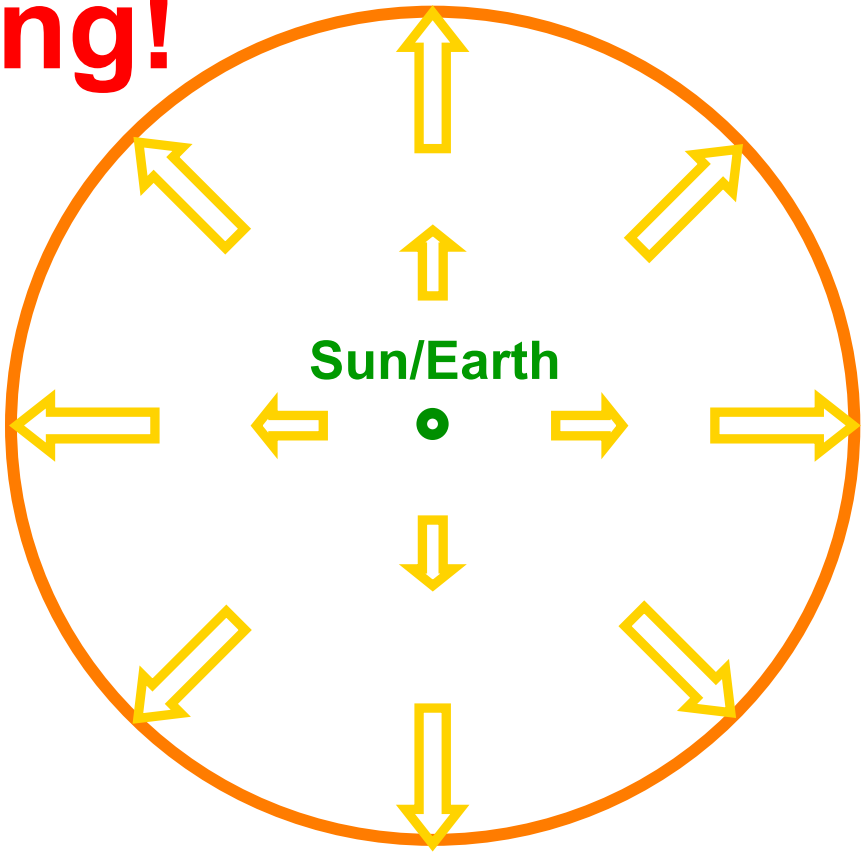

Hubble Deep Field
~100 Billion Galaxies


Red shift
up to ~10

Hubble's Law: Expansion of the Universe

Big Bang!

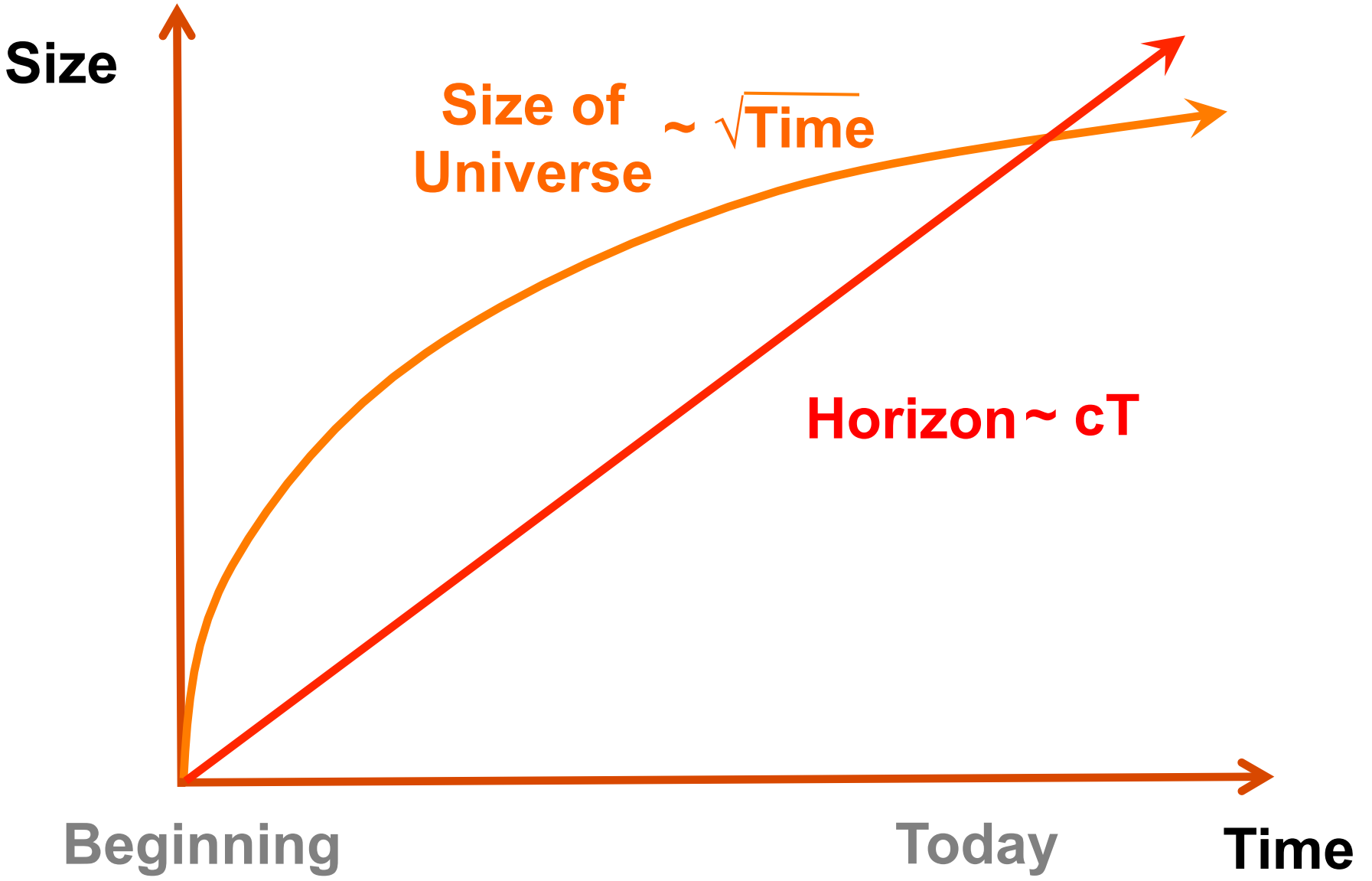
Horizon of Universe



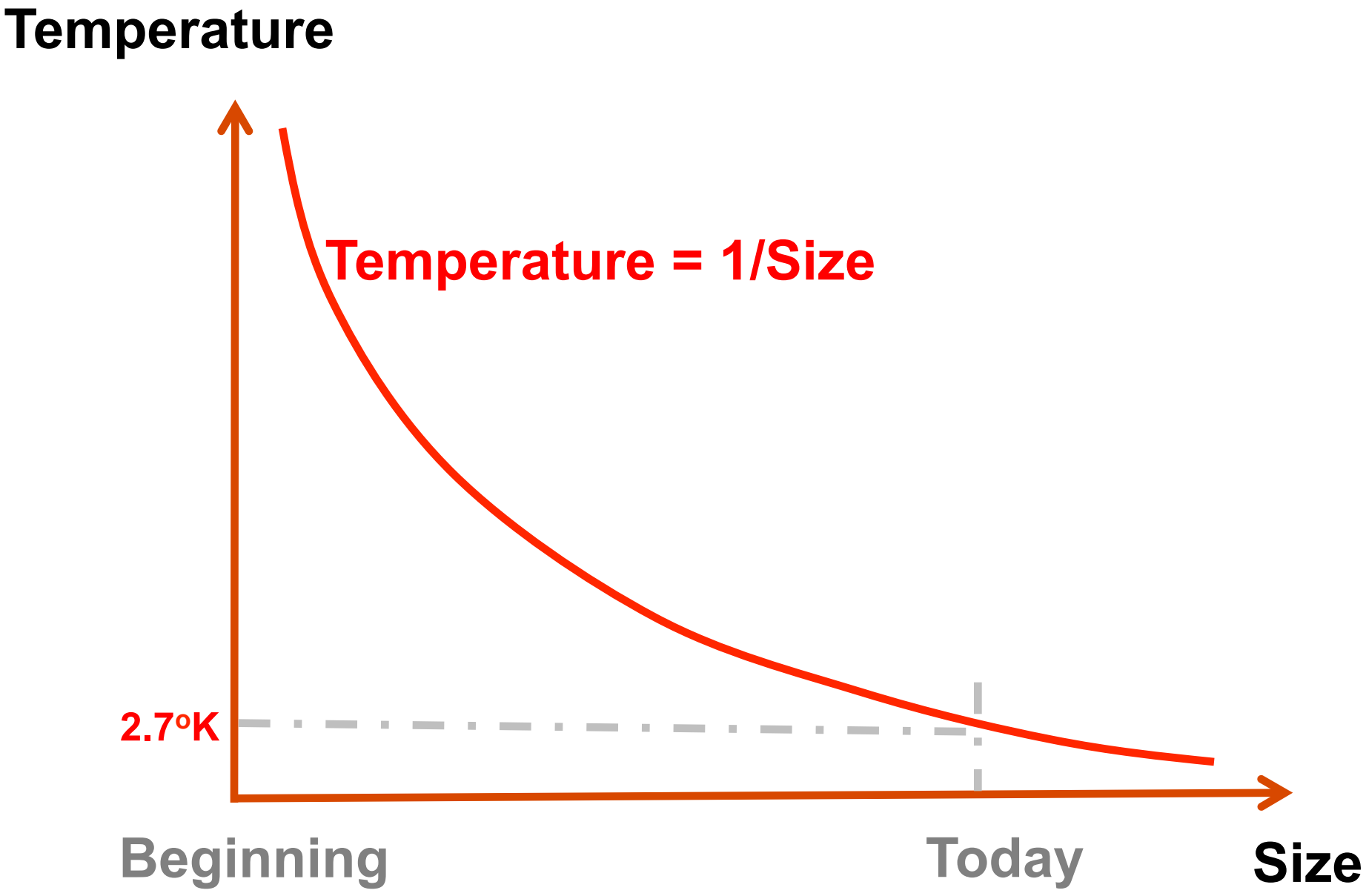
14 Billon Light Years

Moving Away at Speed of Light

Expansion of Universe

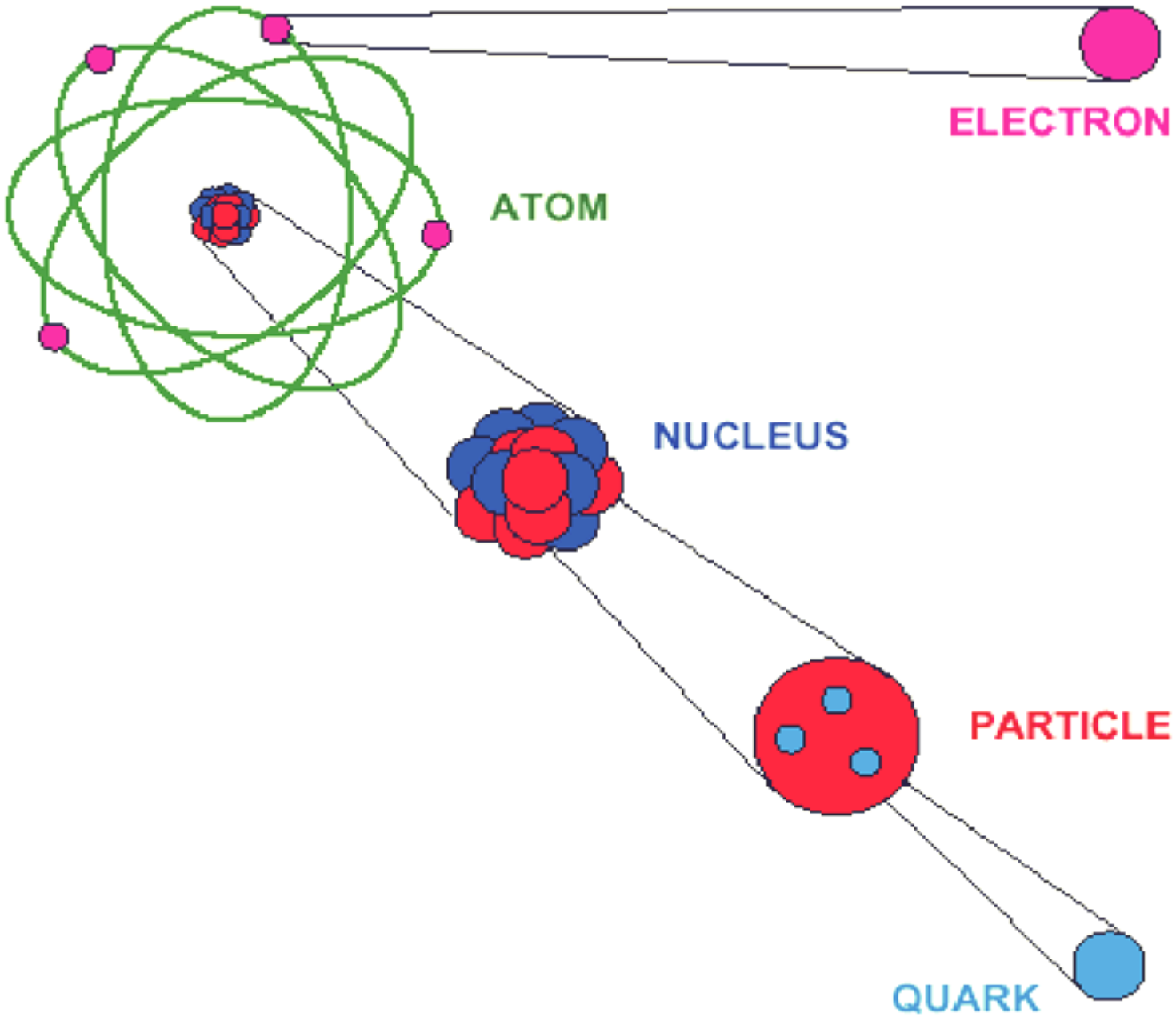


Temperature of Universe



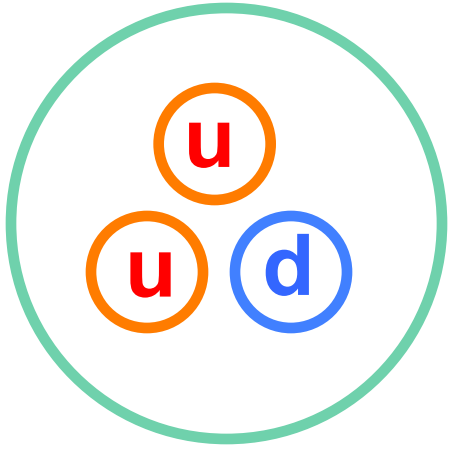
Tevatron at Fermi Lab near Chicago (1980 – 2010)

Elementary Particles



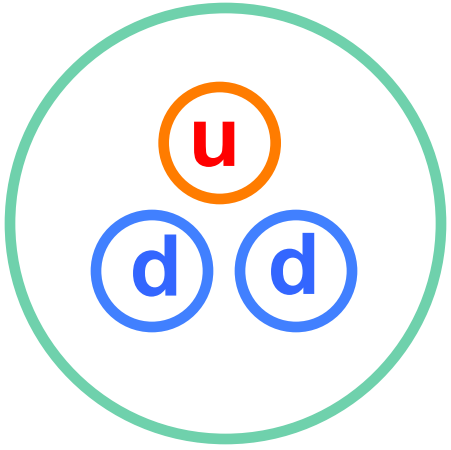
Quark Model

Proton



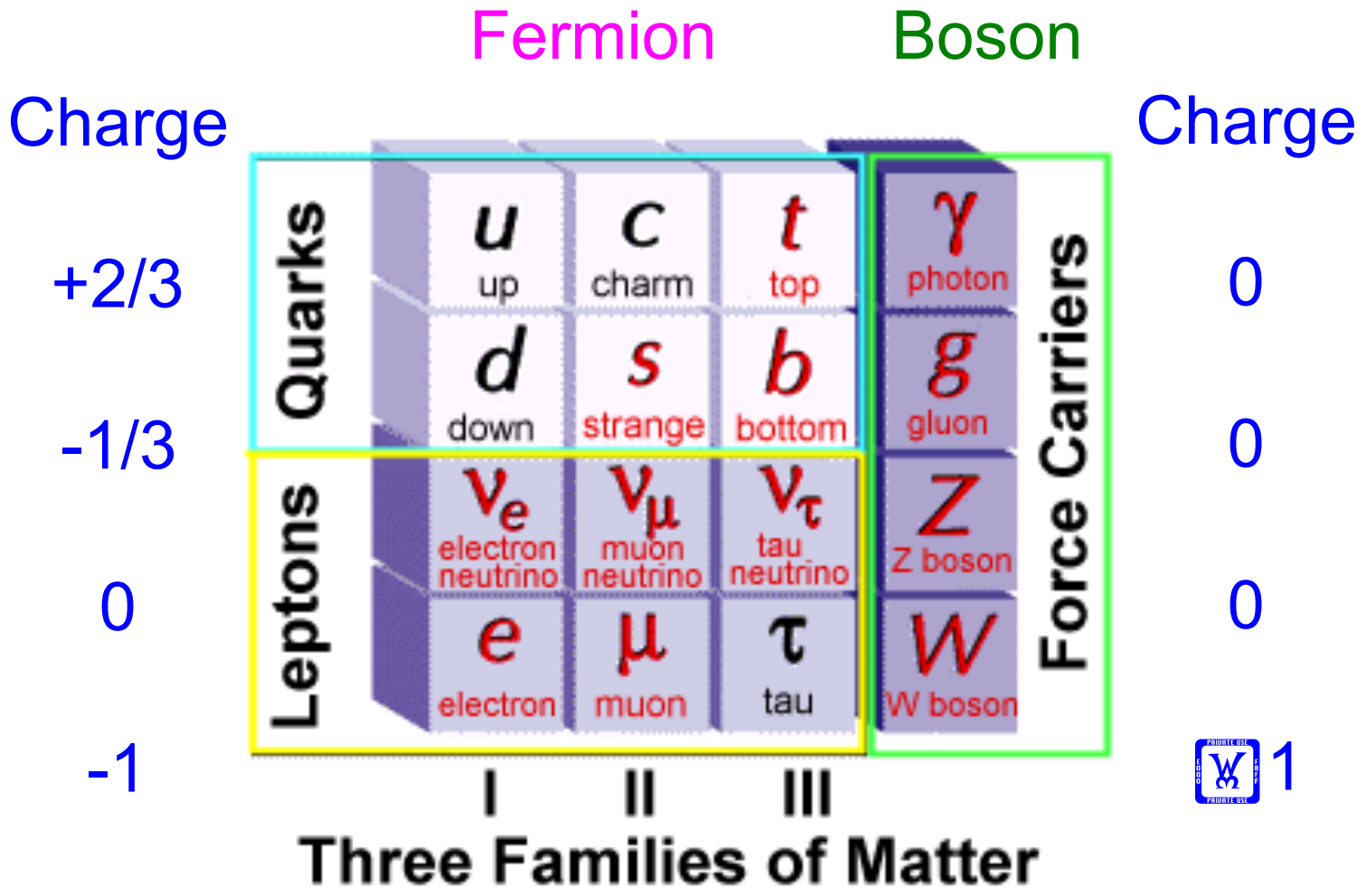
+ 2/3 + 2/3 – 1/3 = 1

Neutron



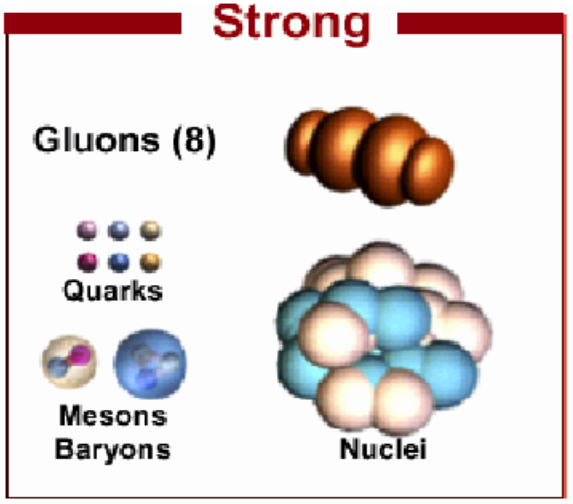
+ 2/3 – 1/3 – 1/3 = 0

Elementary Particles

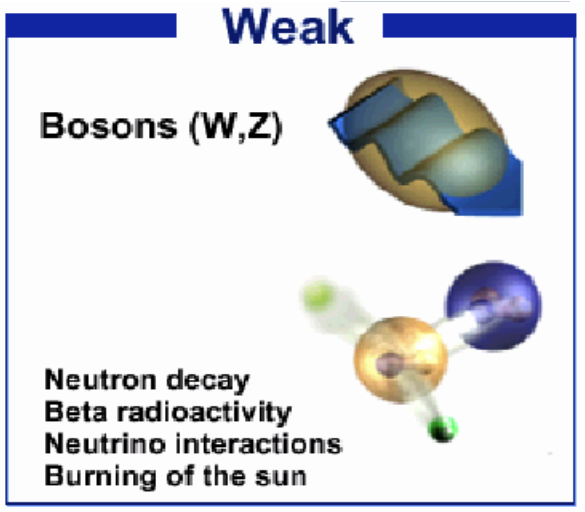


+ Anti-particles

Elementary Particles and Forces

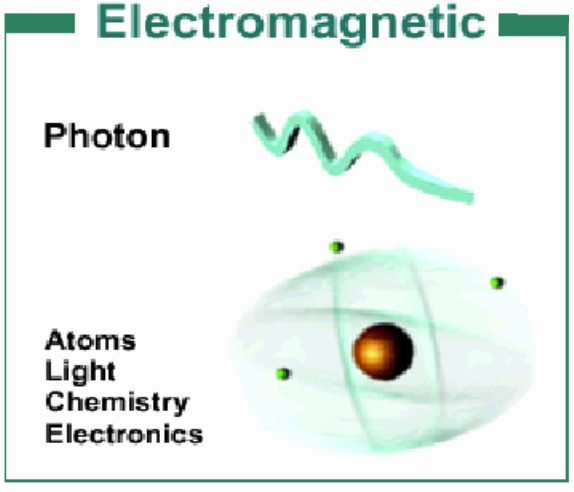


1

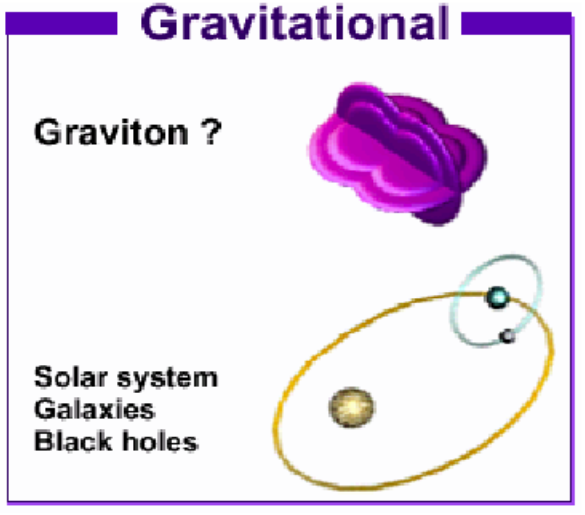


10^{-13}

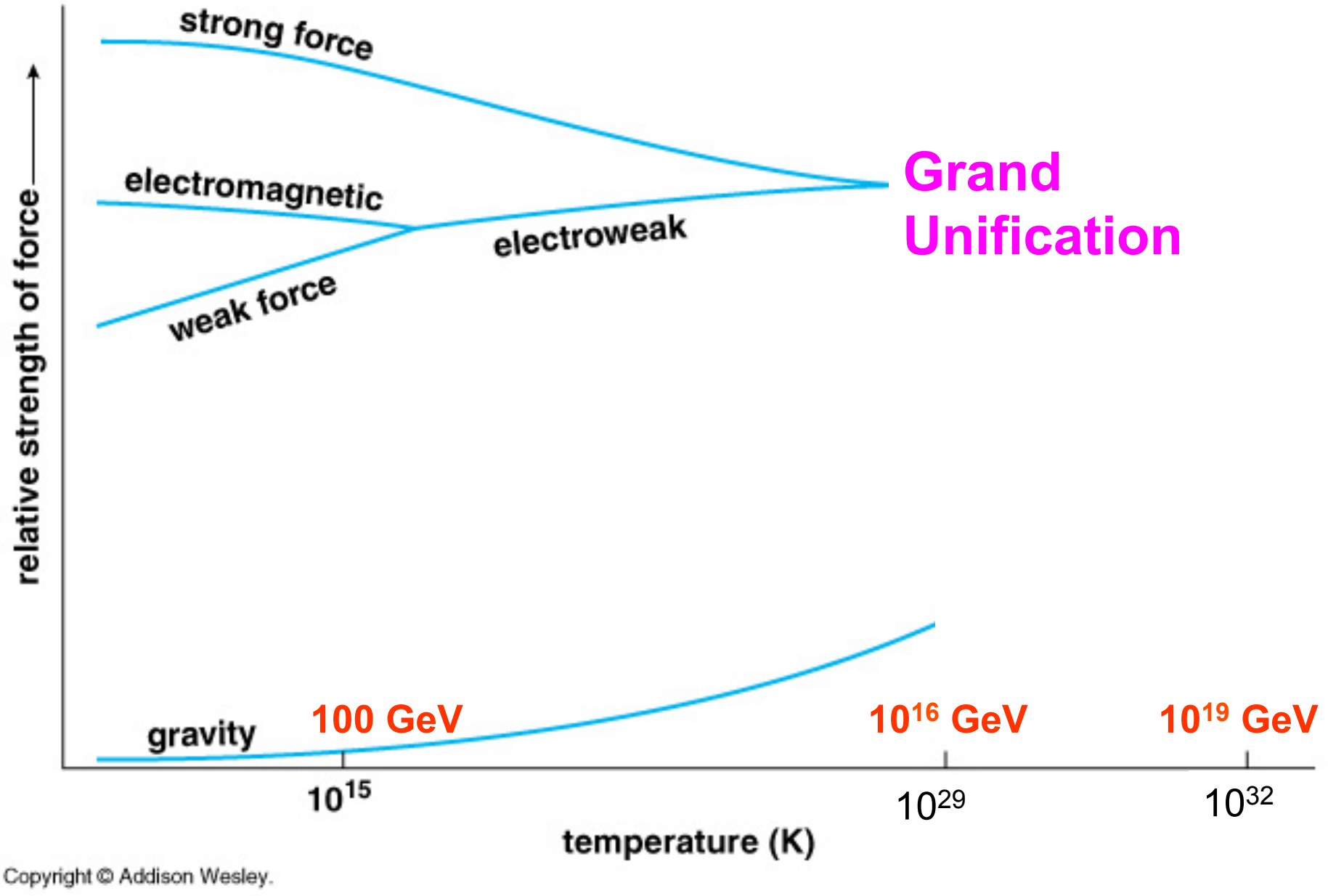
10^{-2}



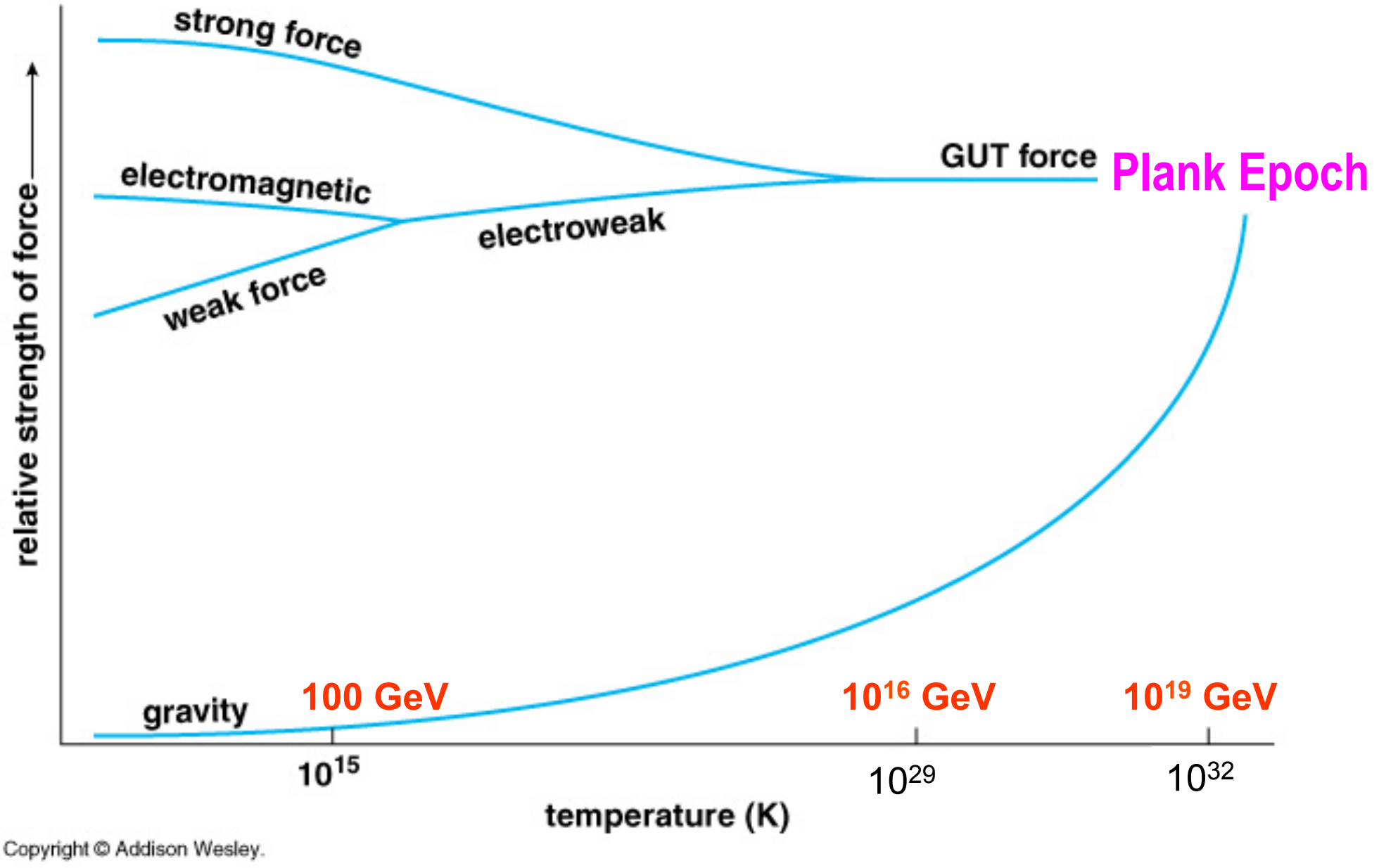
10^{-38}



Unification of Forces (1980)



Unification of Forces (1980)

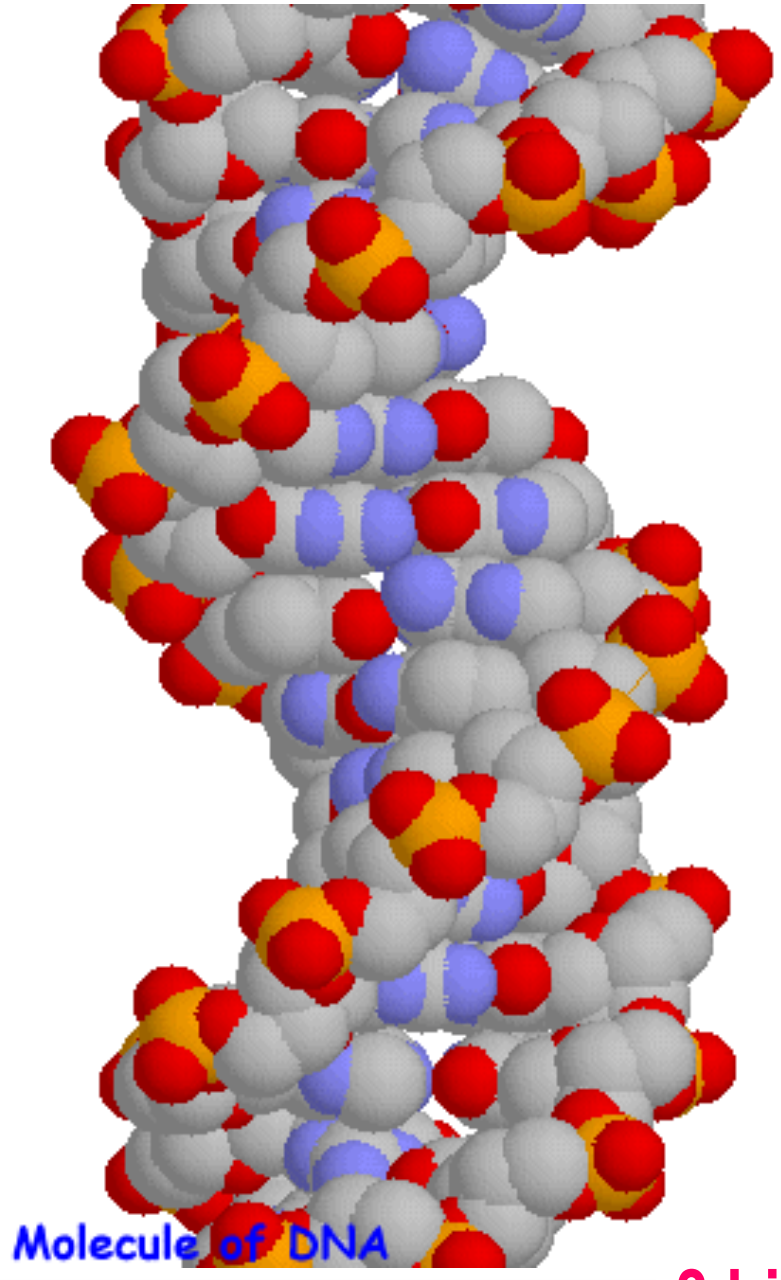


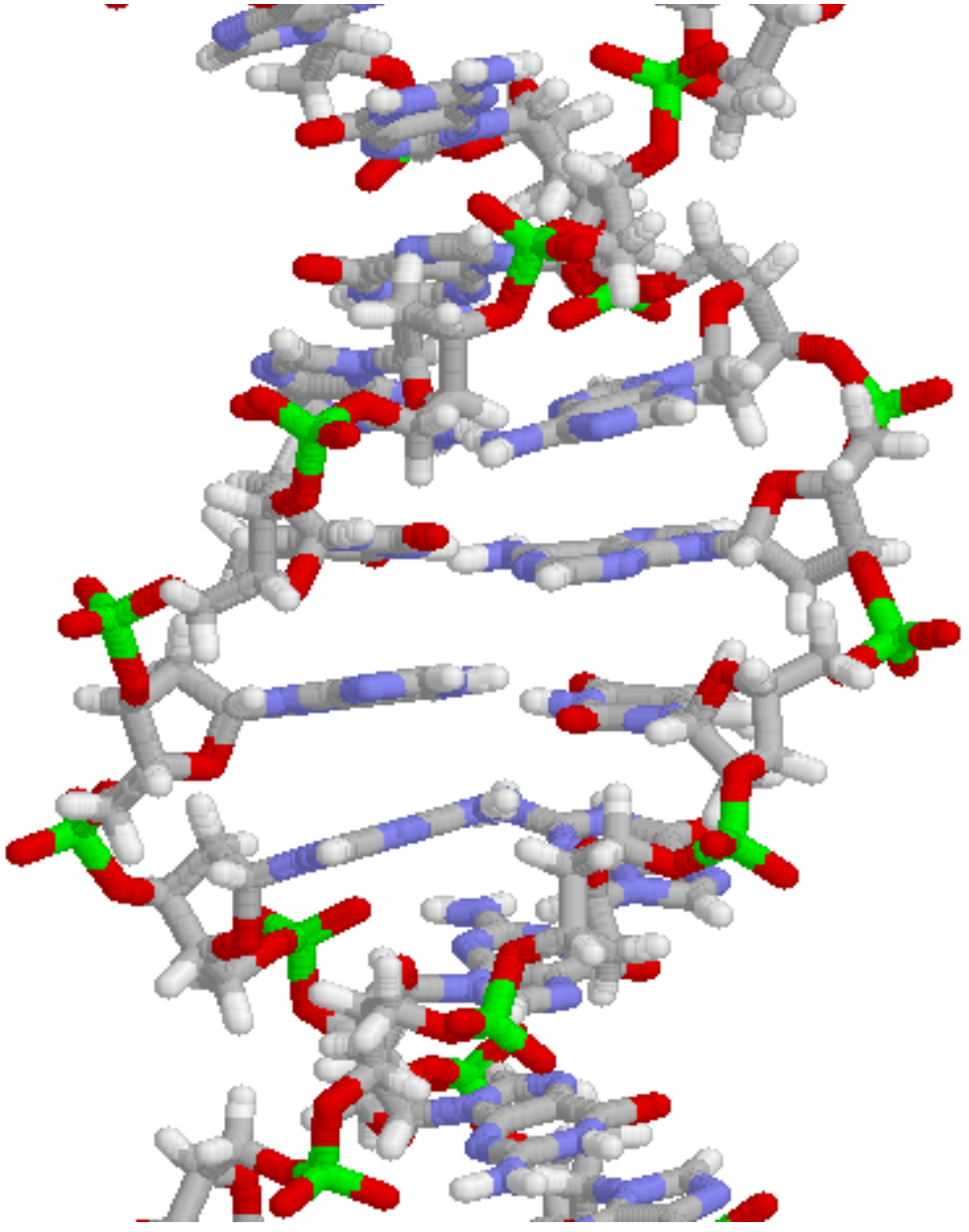
Physicists' View of Early Universe

Fiat lux

Let there be light

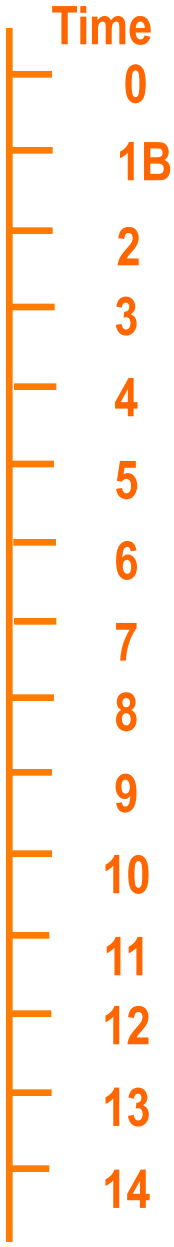
Structure of DNA





3 billion base pairs

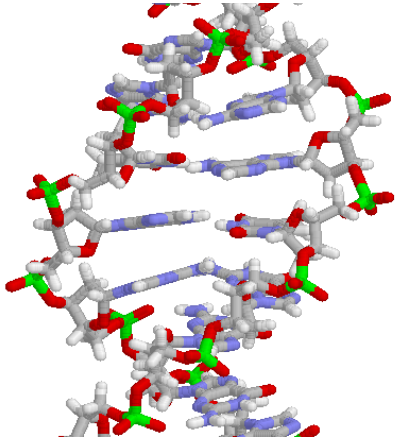
Symmetry Breaking



Simple

Symmetry Break Down

Complex

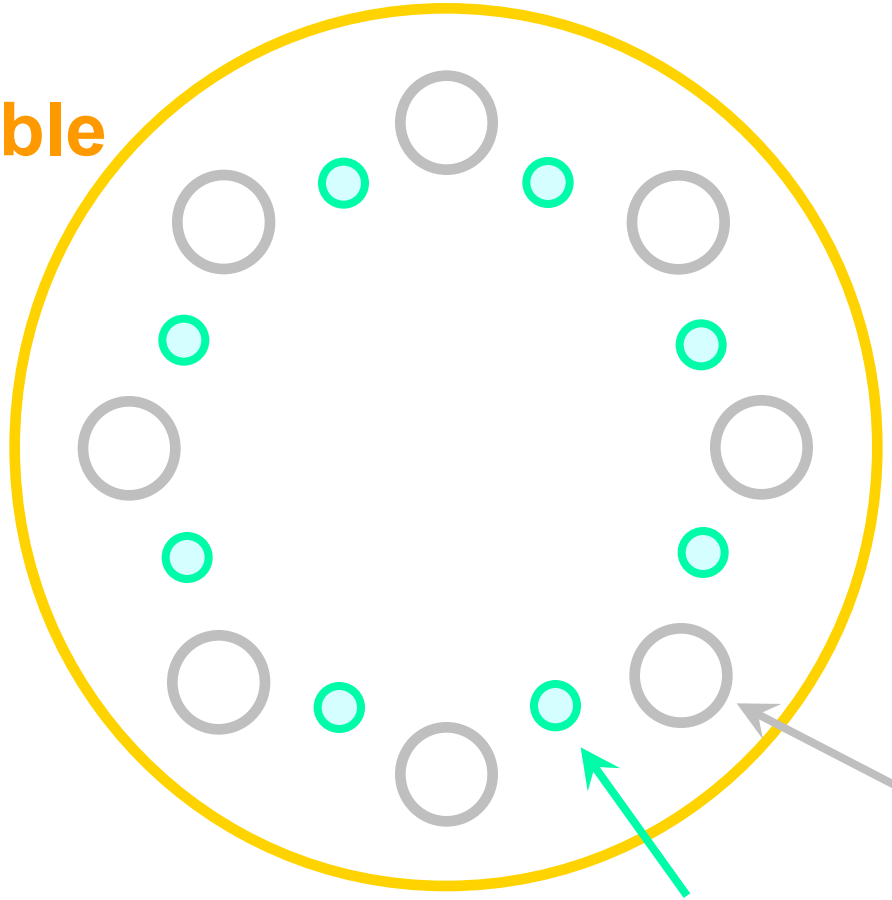


The Beginning

- **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.**

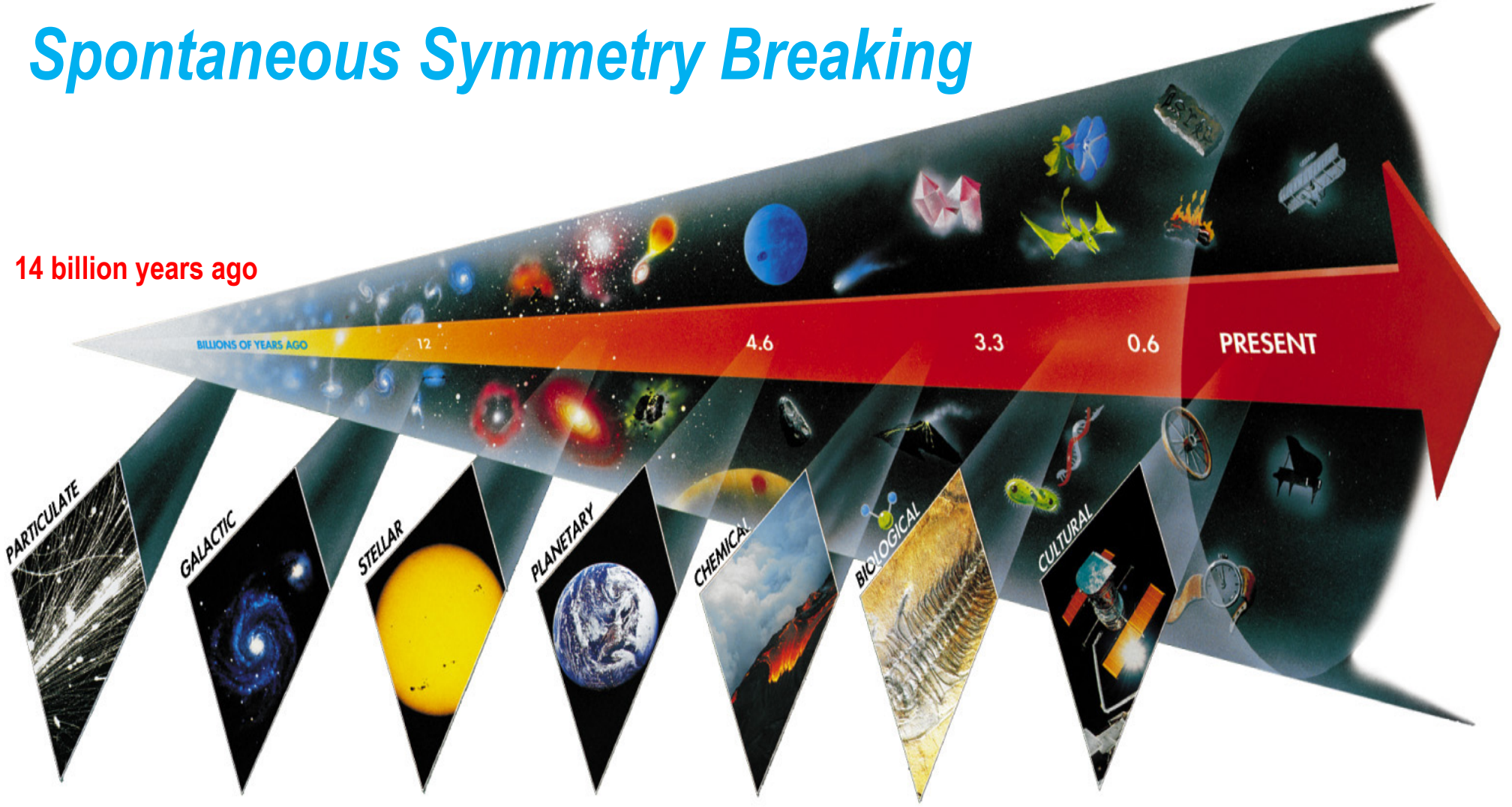
Spontaneous Symmetry Breakdown at a Dinner Table



by Nambu Yoichiro

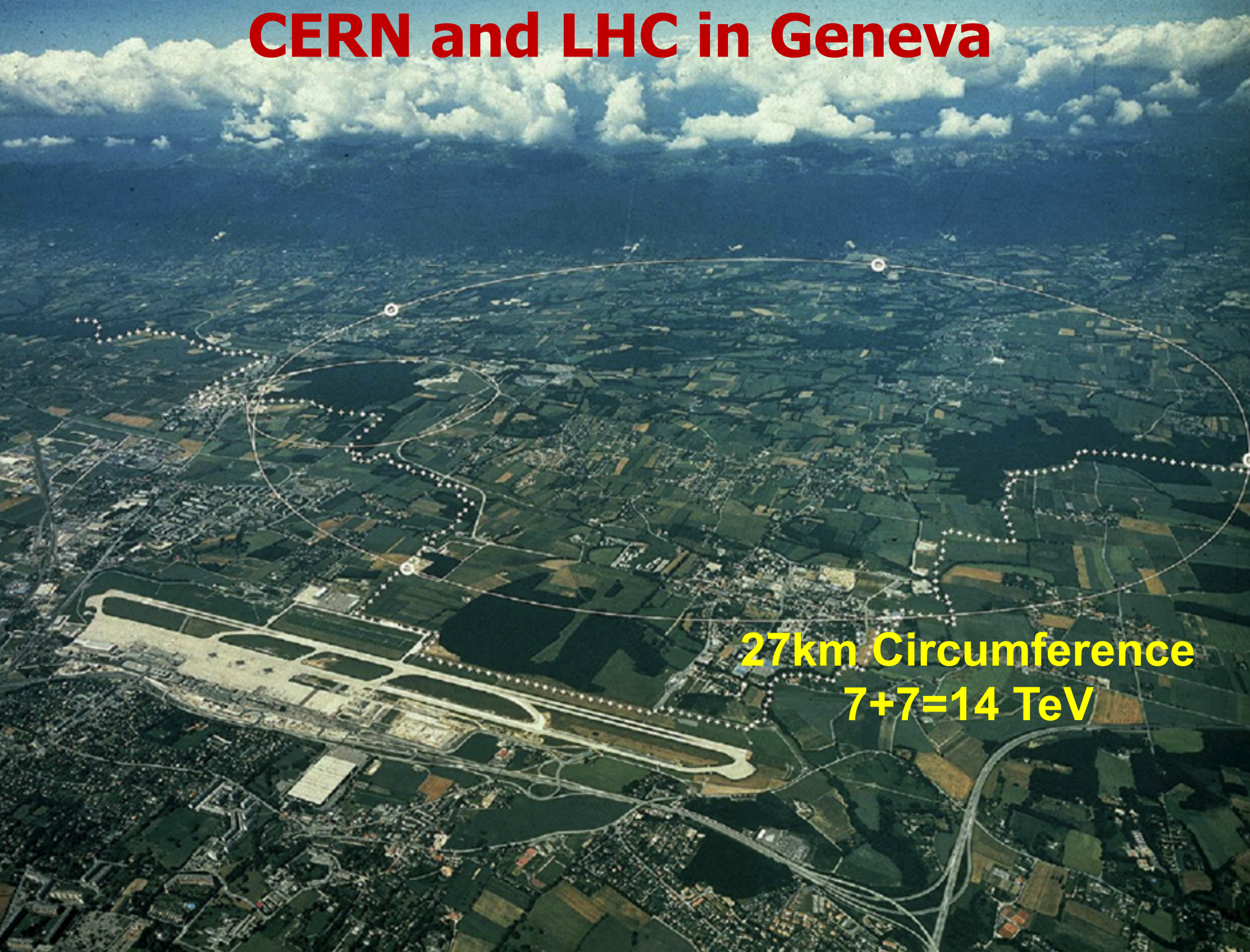
Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking



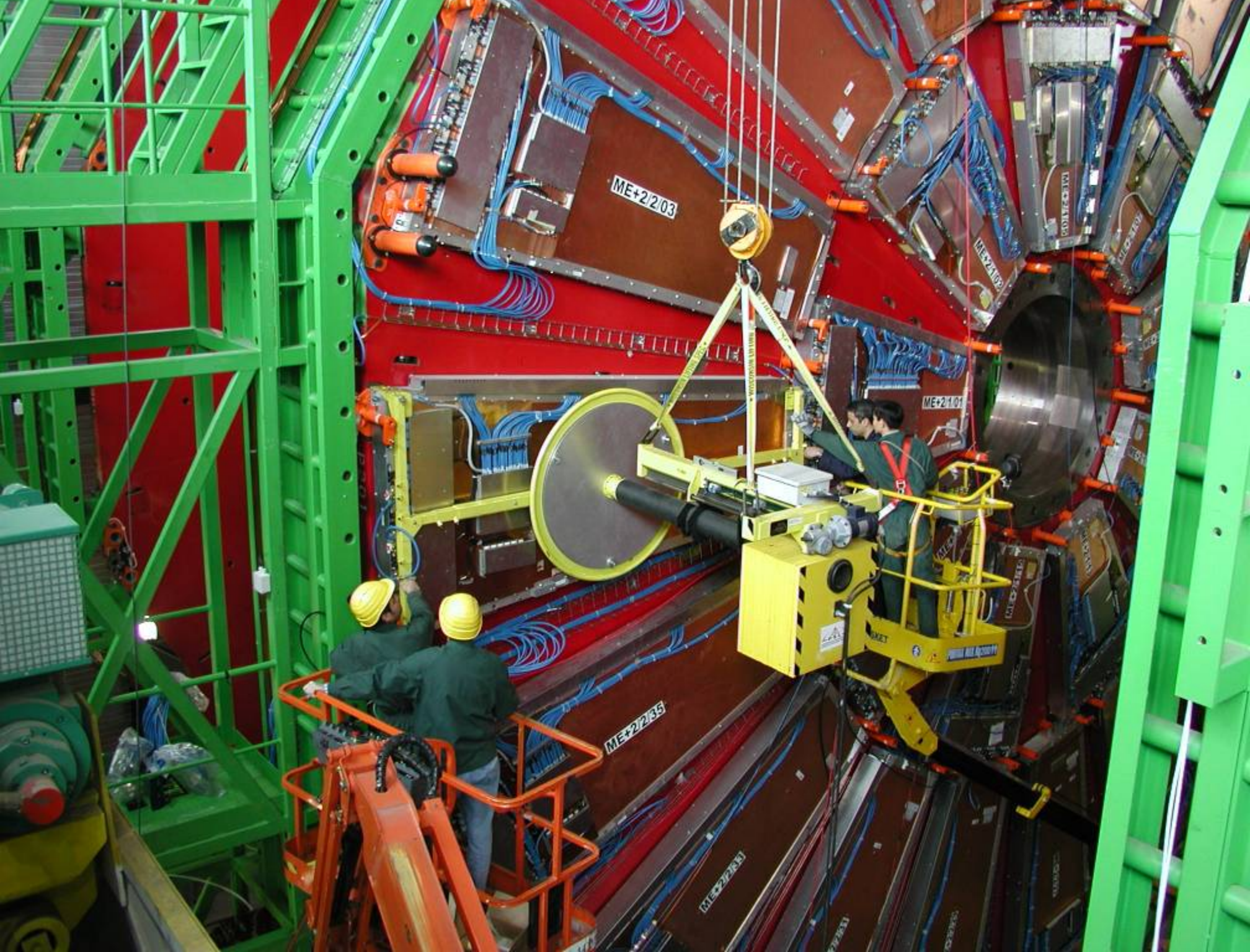
Origin of Particles

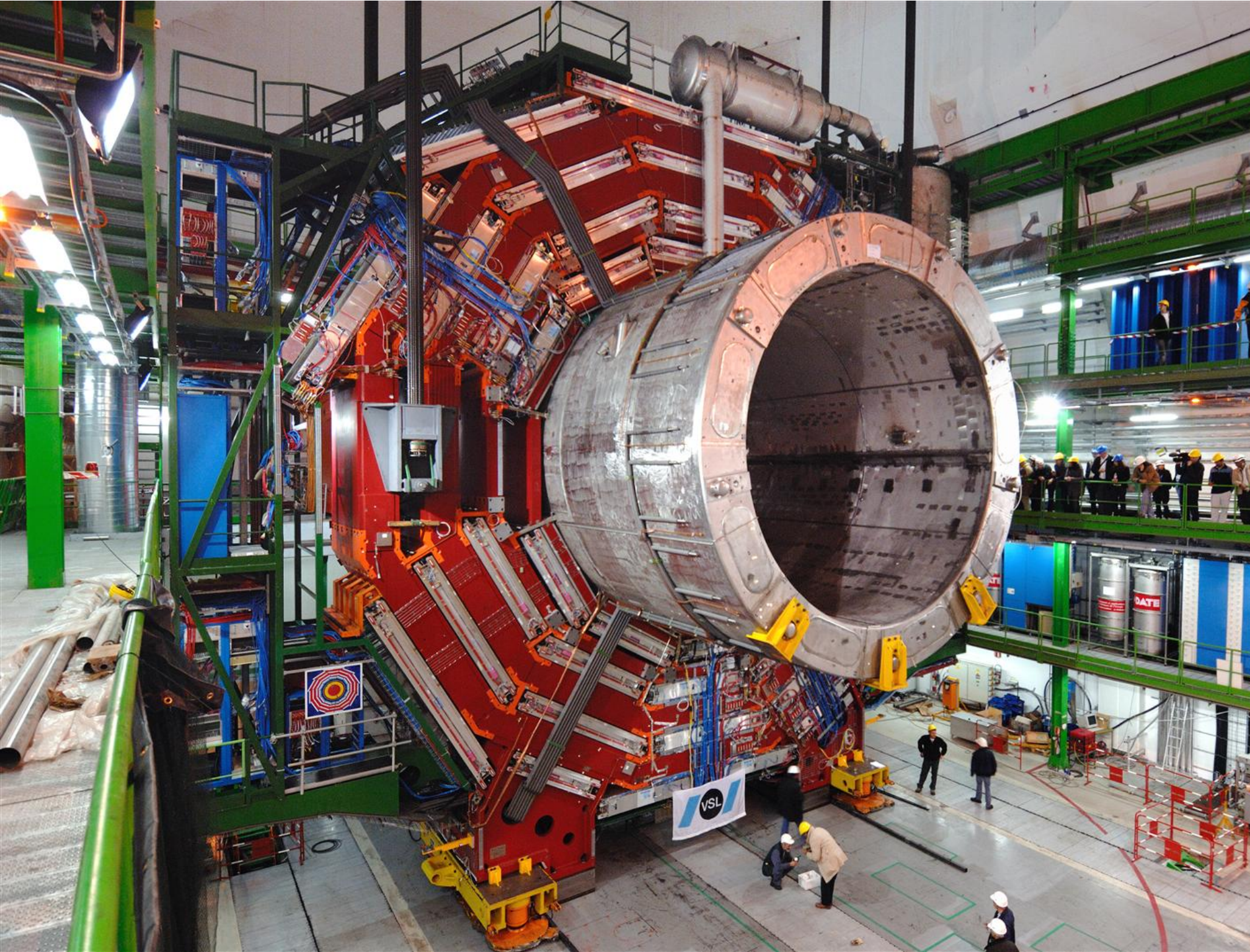
CERN and LHC in Geneva

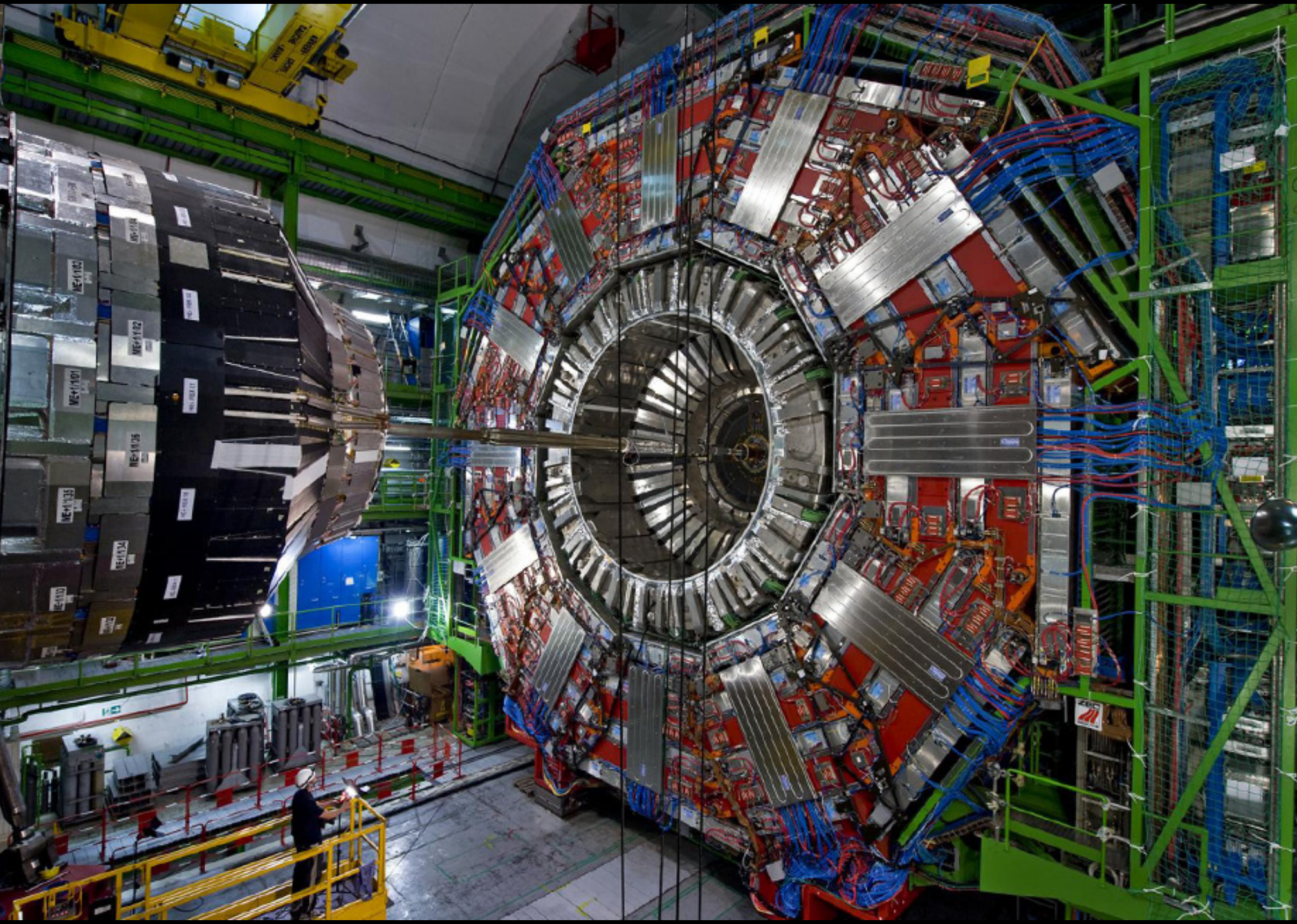


LHC Tunnel with Magnets

CMS Barrel Yoke

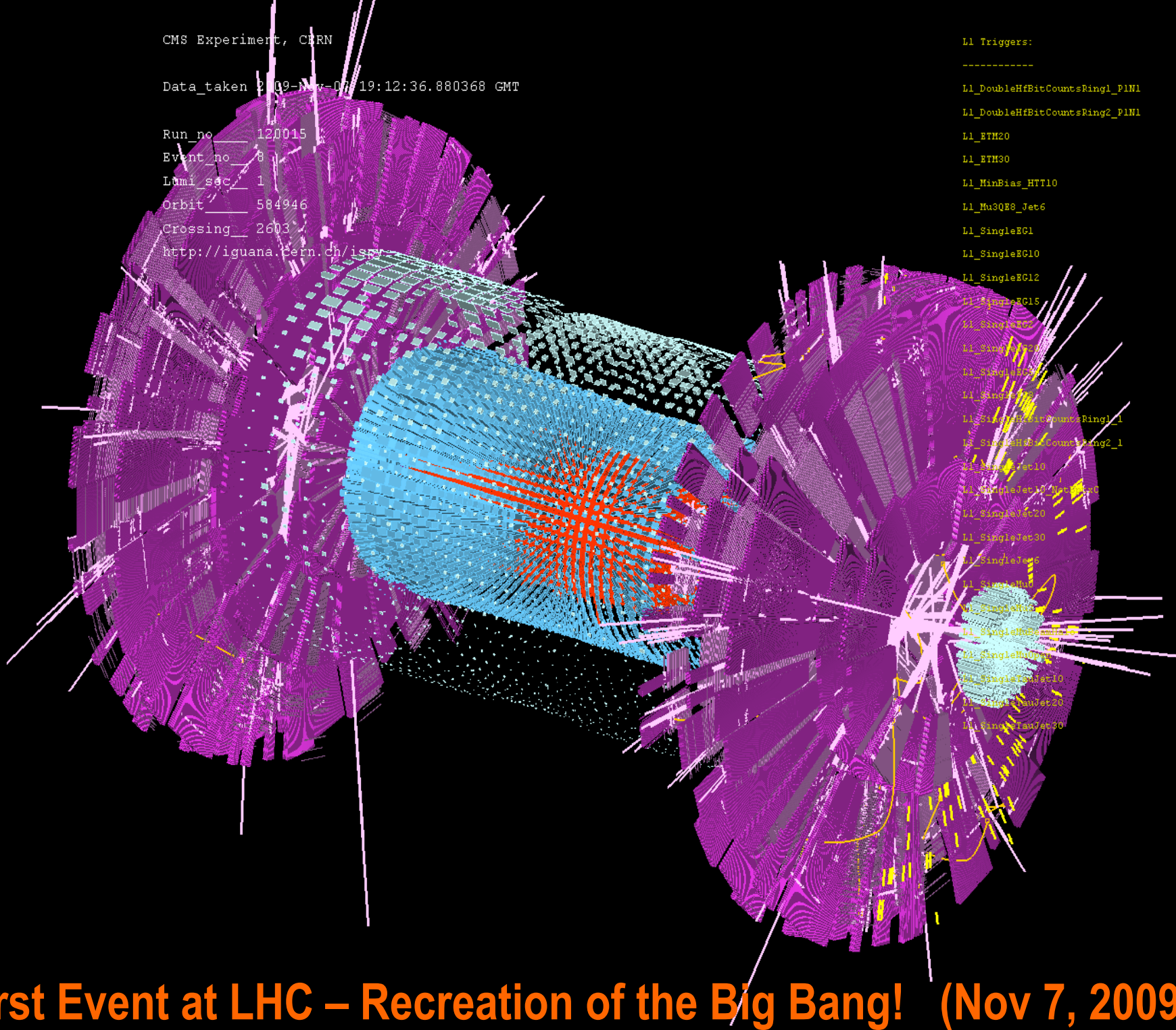

ME+2/2/03
ME+2/1/01
ME+2/2/35


VSL



Particle detectors constructed at Westwood, now at LHC, CERN

Sept 15, 2008 Issue



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

The New York Times

Science

Physicists Find Elusive Particle Seen as Key to Universe

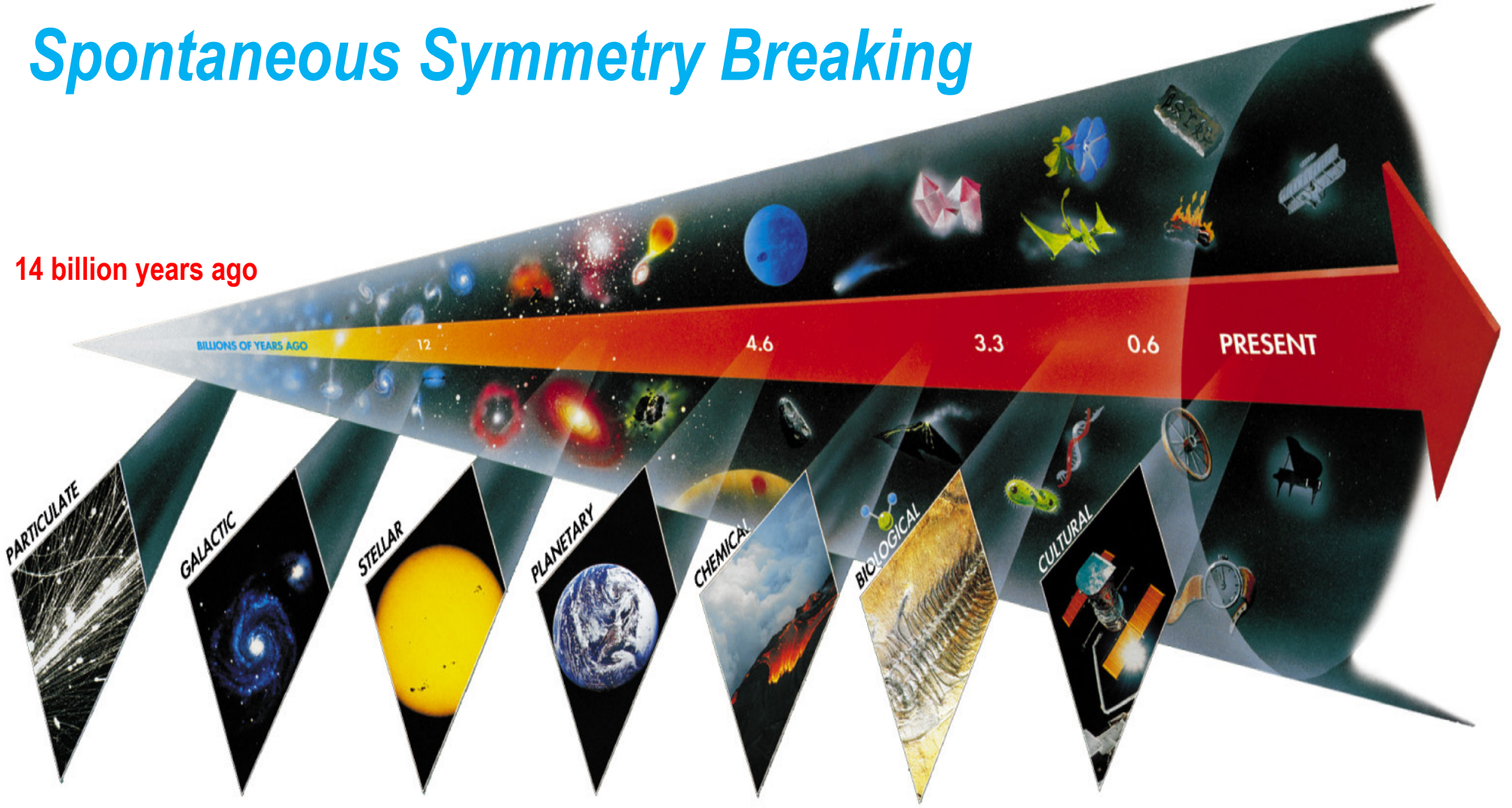
Pool photo by Denis Balibouse

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

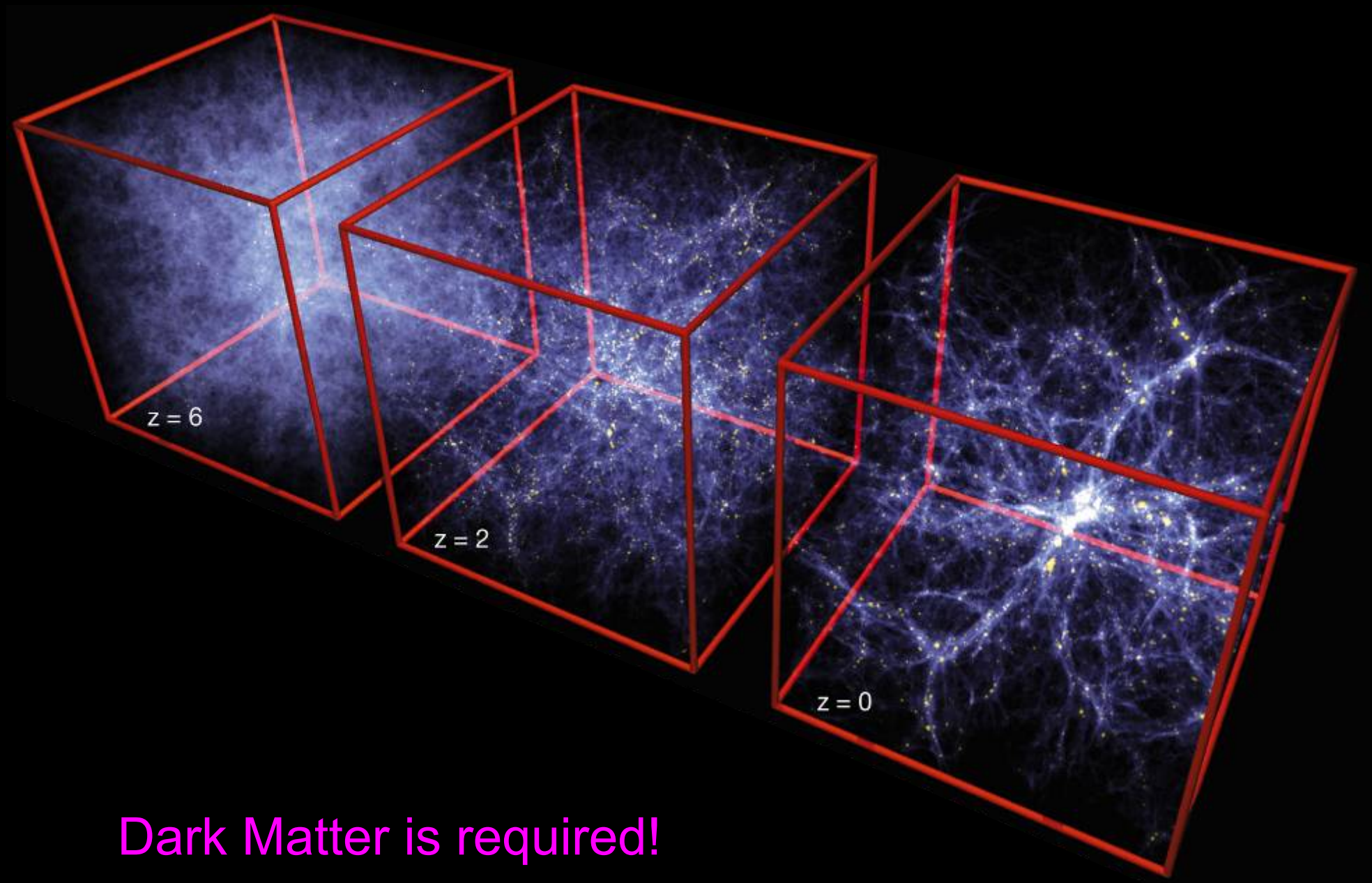


Origin of Particles

Origin of Structure


ANDROMEDA
GALAXY
Dark Matter is required!

Formation of Structure in the Universe



Dark Matter is required!

Cosmic Pyramid

Baryonic Matter

Metal 0.03%

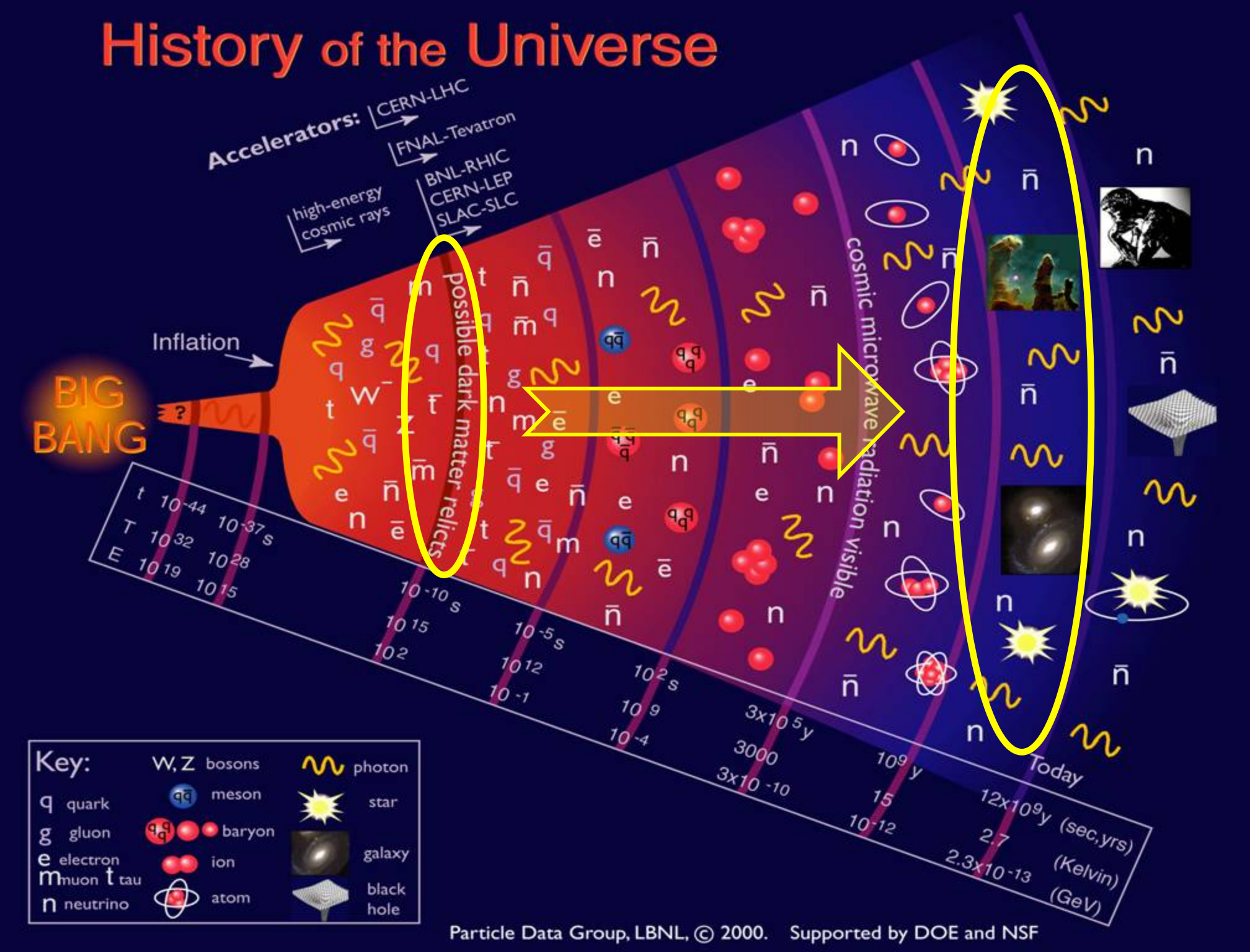
Star 0.4%

Gas, Dust 4.2%

Dark Matter 23%

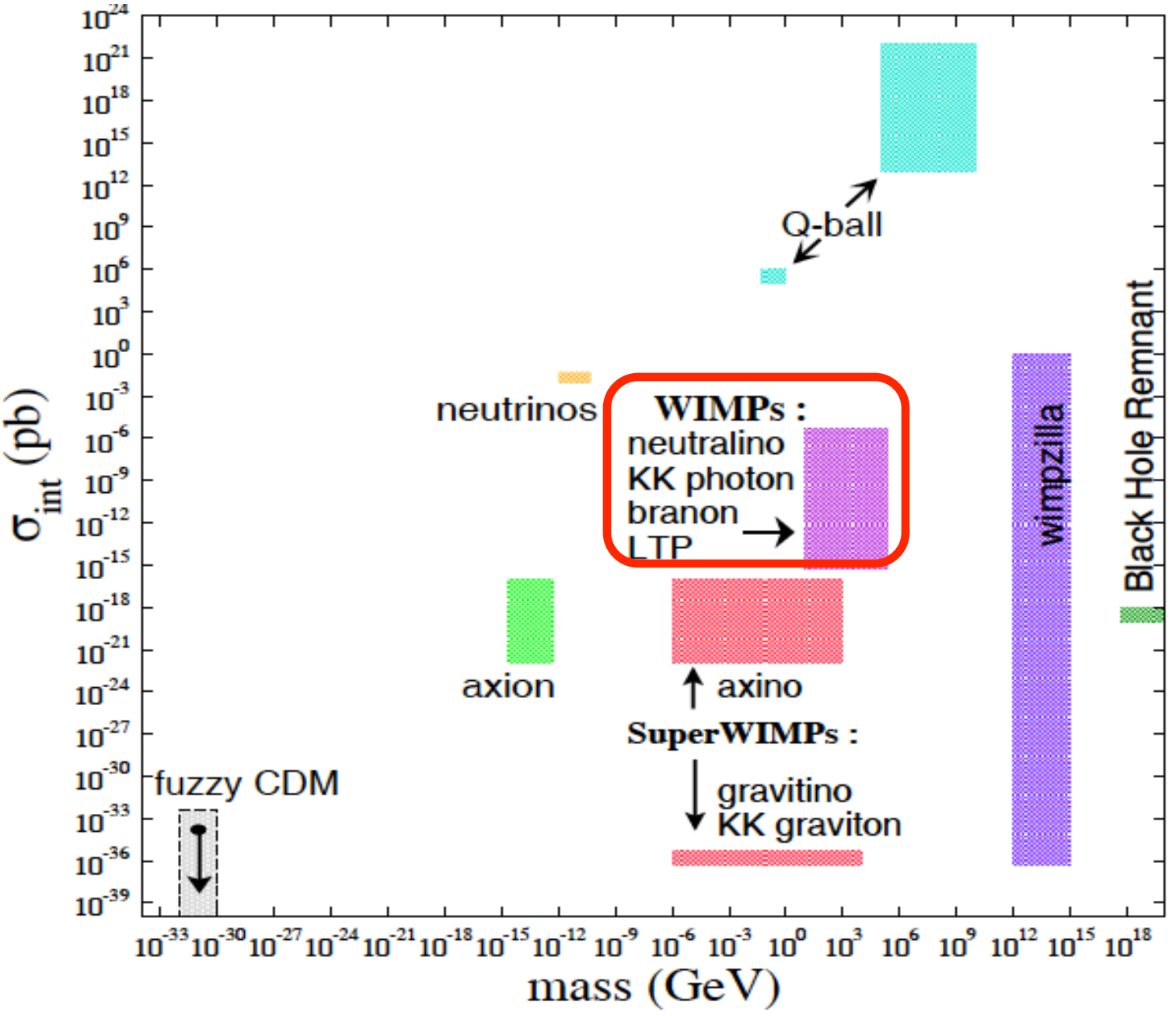
Dark Energy 73%

History of the Universe

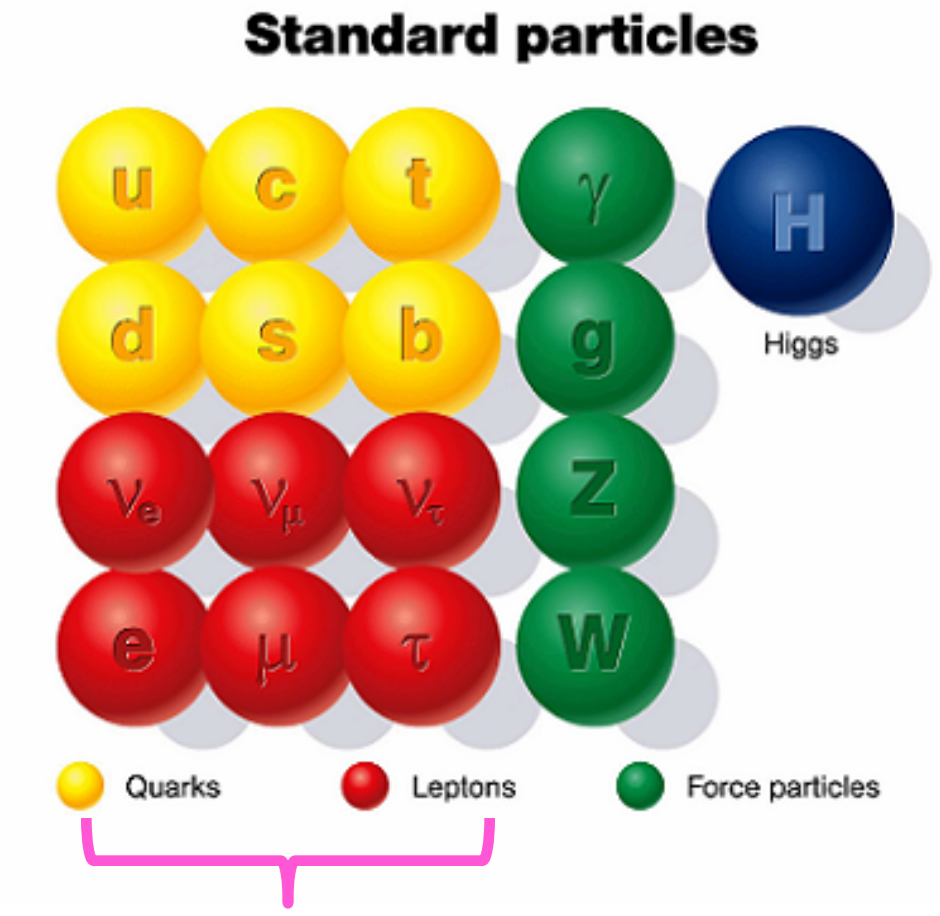


Particle Data Group, LBNL, © 2000. Supported by DOE and NSF

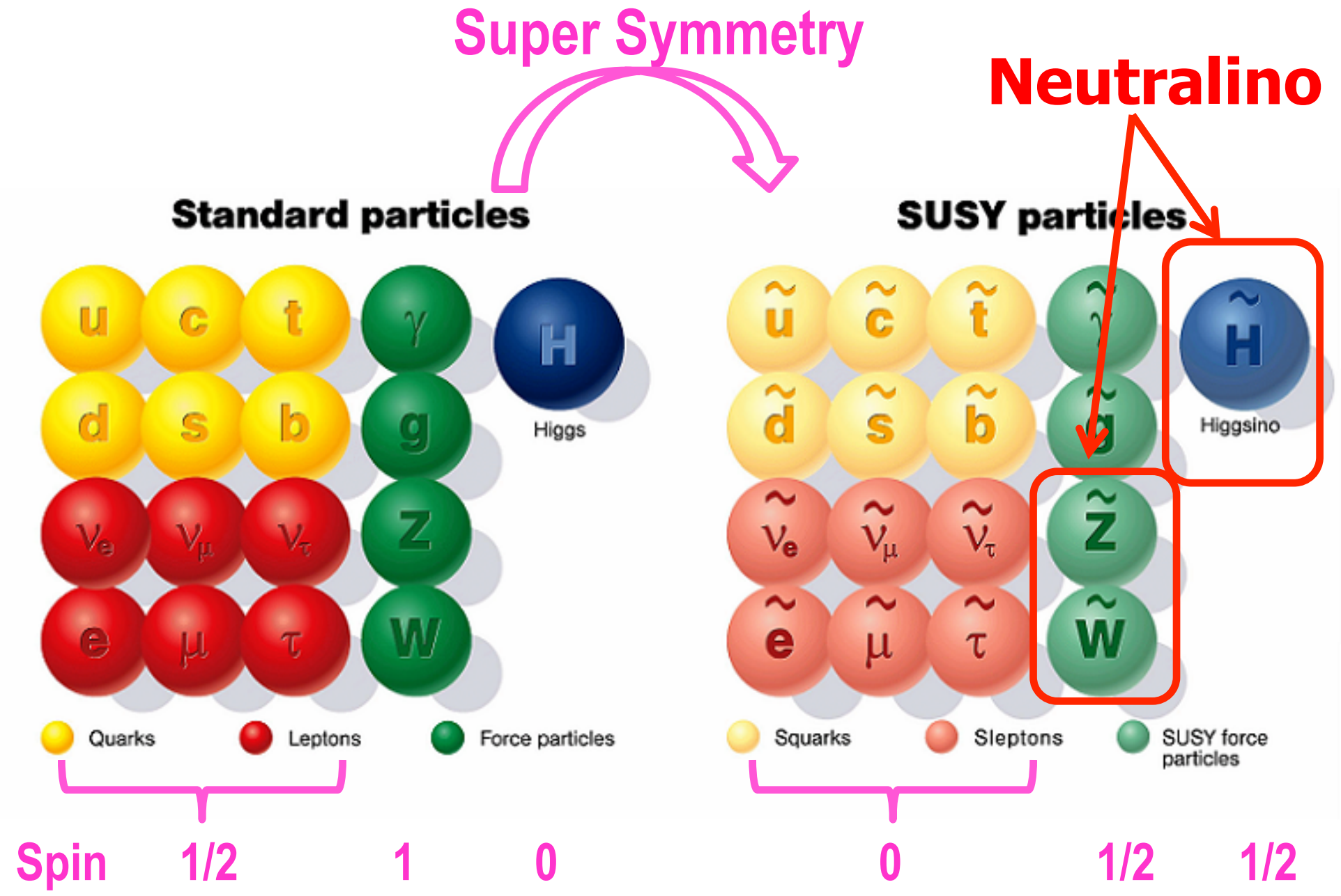
What is Dark Matter?

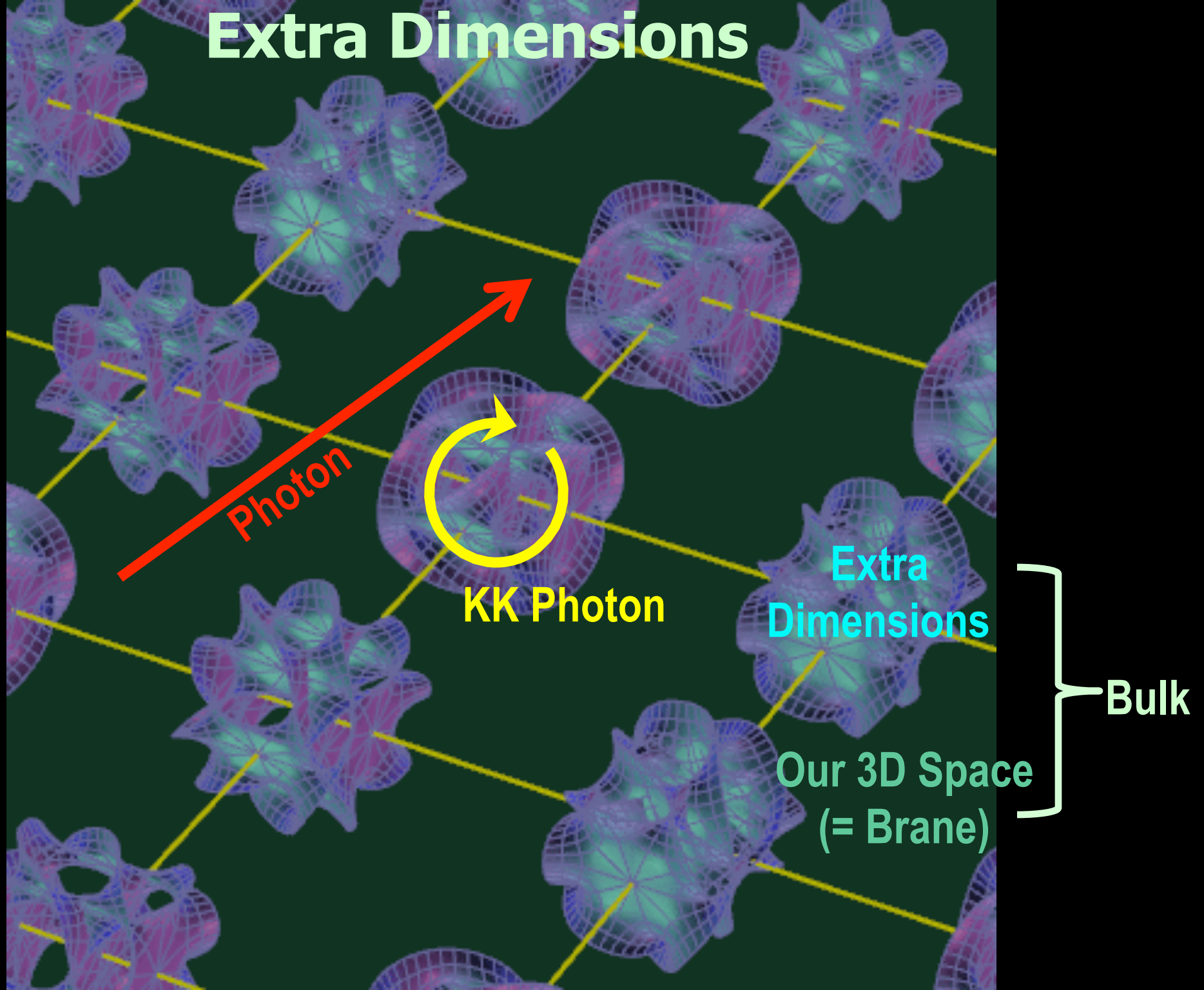


SUSY Particles and Neutralino



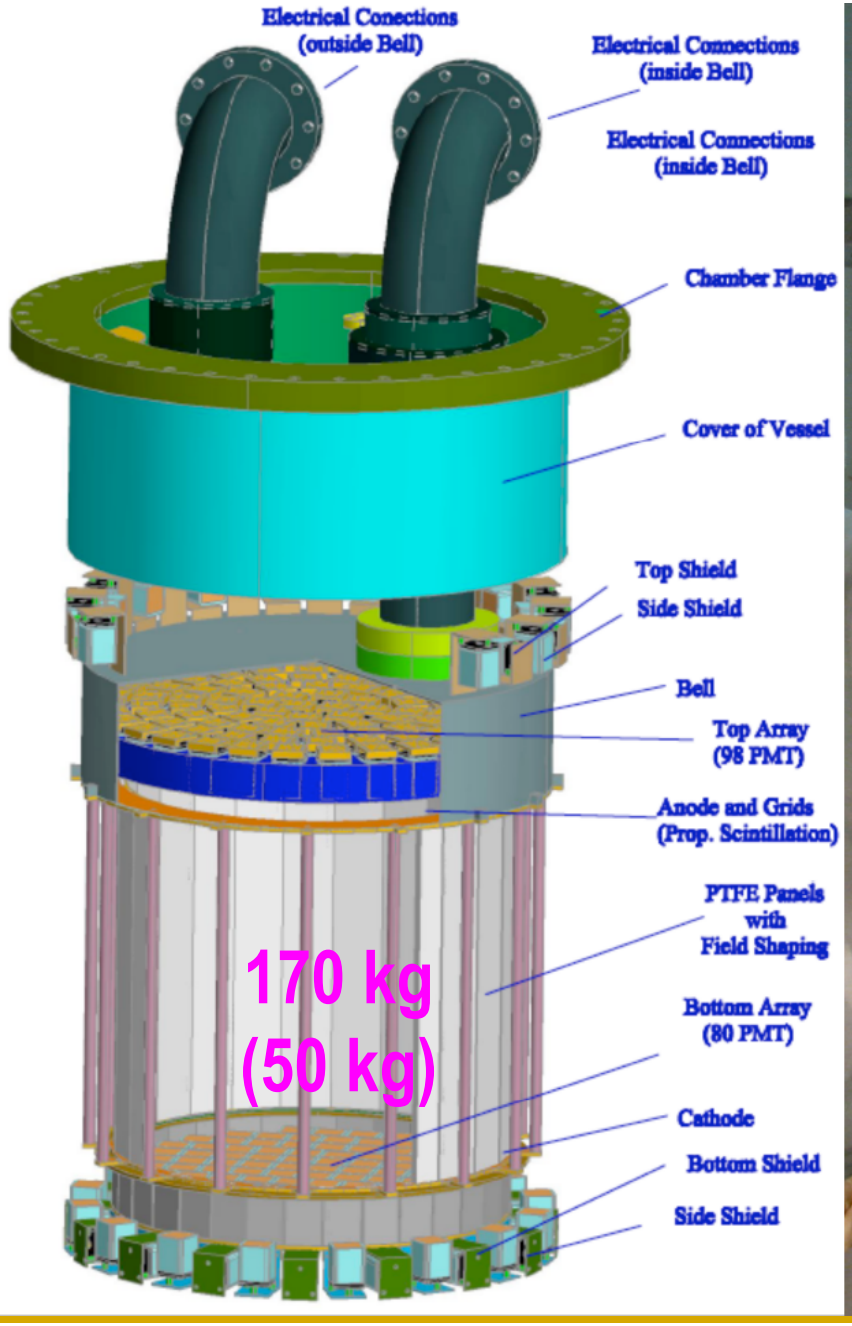
SUSY Particles and Neutralino




Extra Dimensions
Photon
KK Photon
Extra Dimensions
Bulk
Our 3D Space
(= Brane)

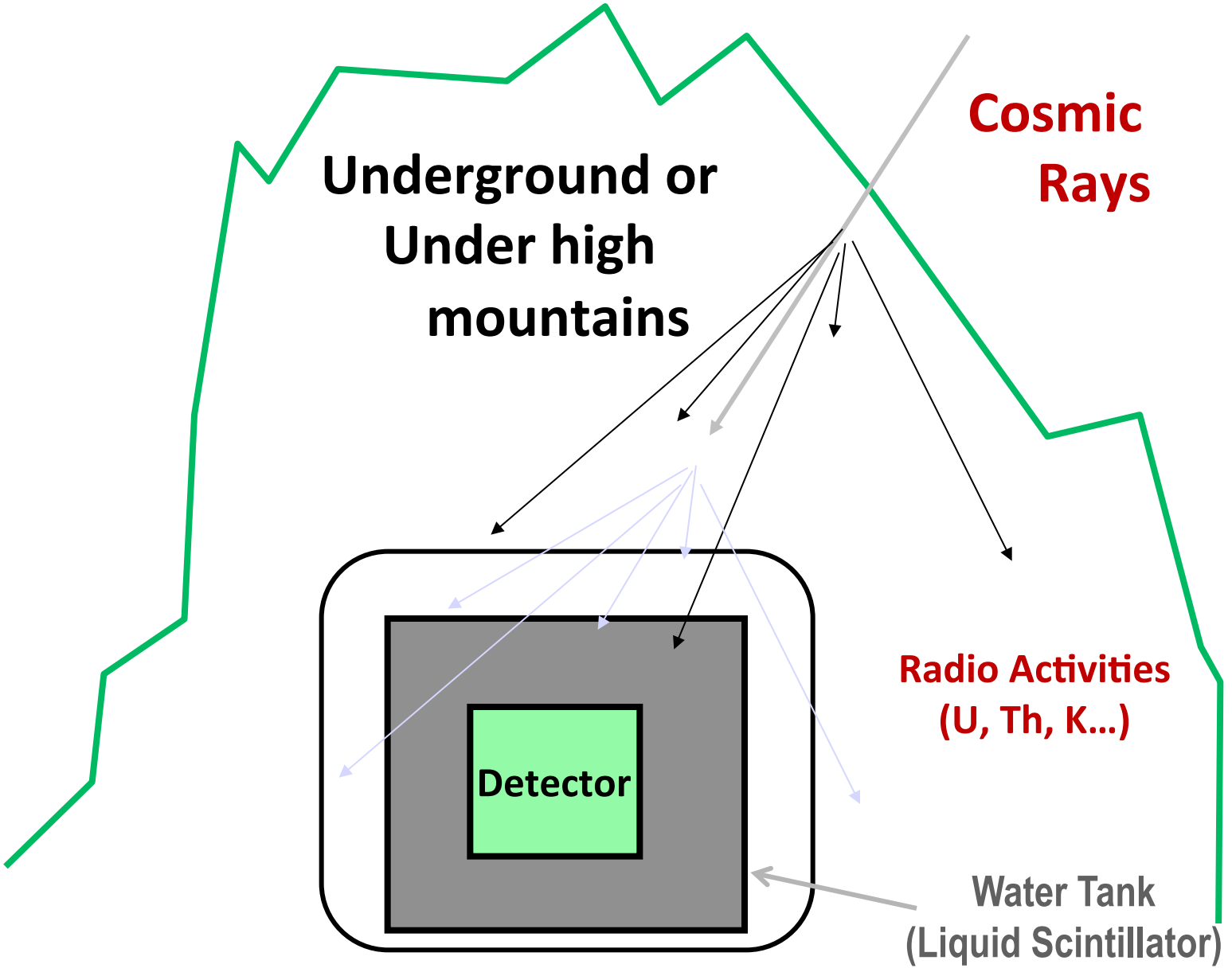

Laboratori Nazionali del Gran Sasso, Italy
LNGS 1400 m Rock (3100 w.m.e)
XENON100
LVD
ICARUS
OPERA
WARP

XENON100 Detector



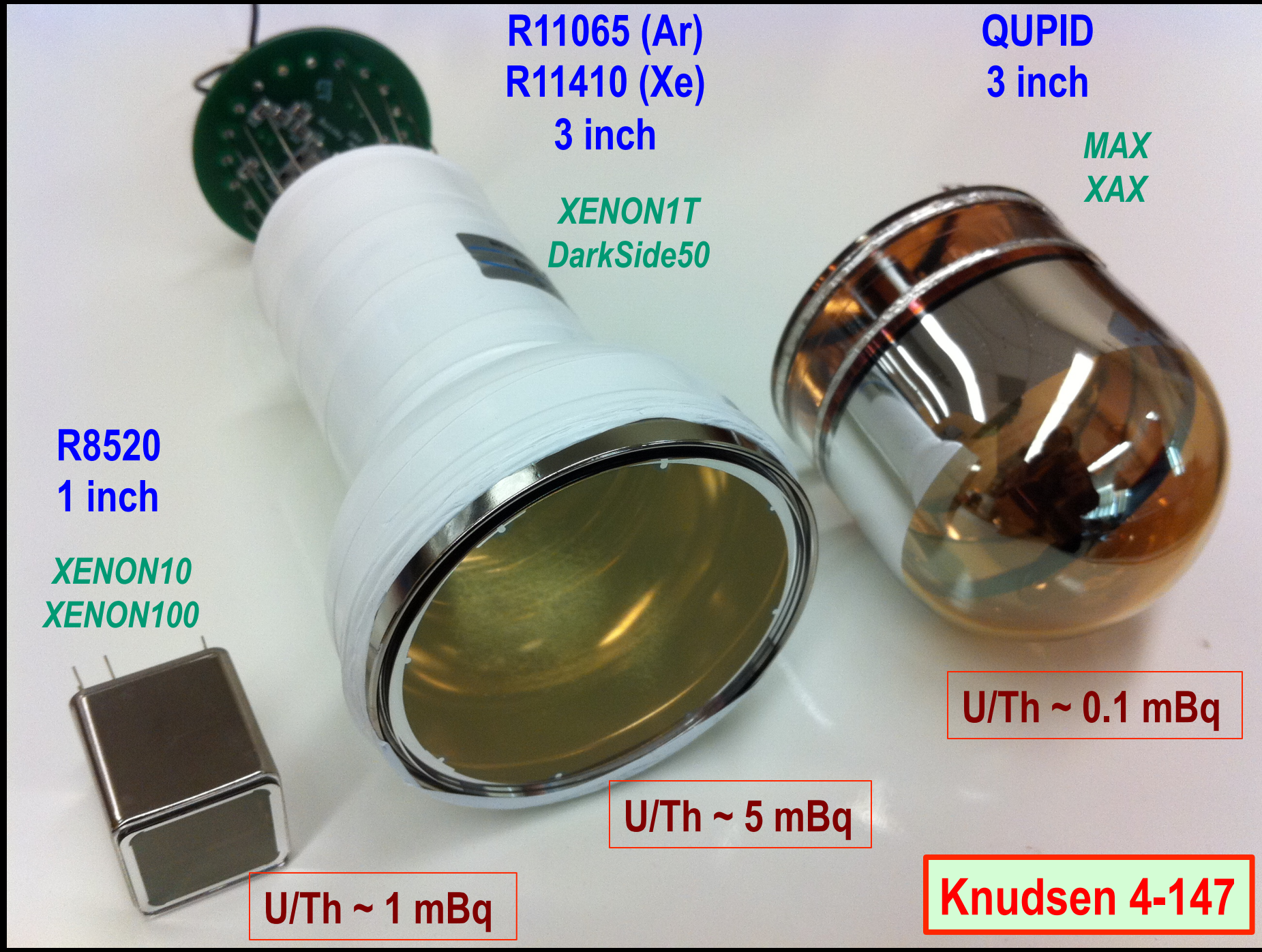
XENON100 Detector (2009)

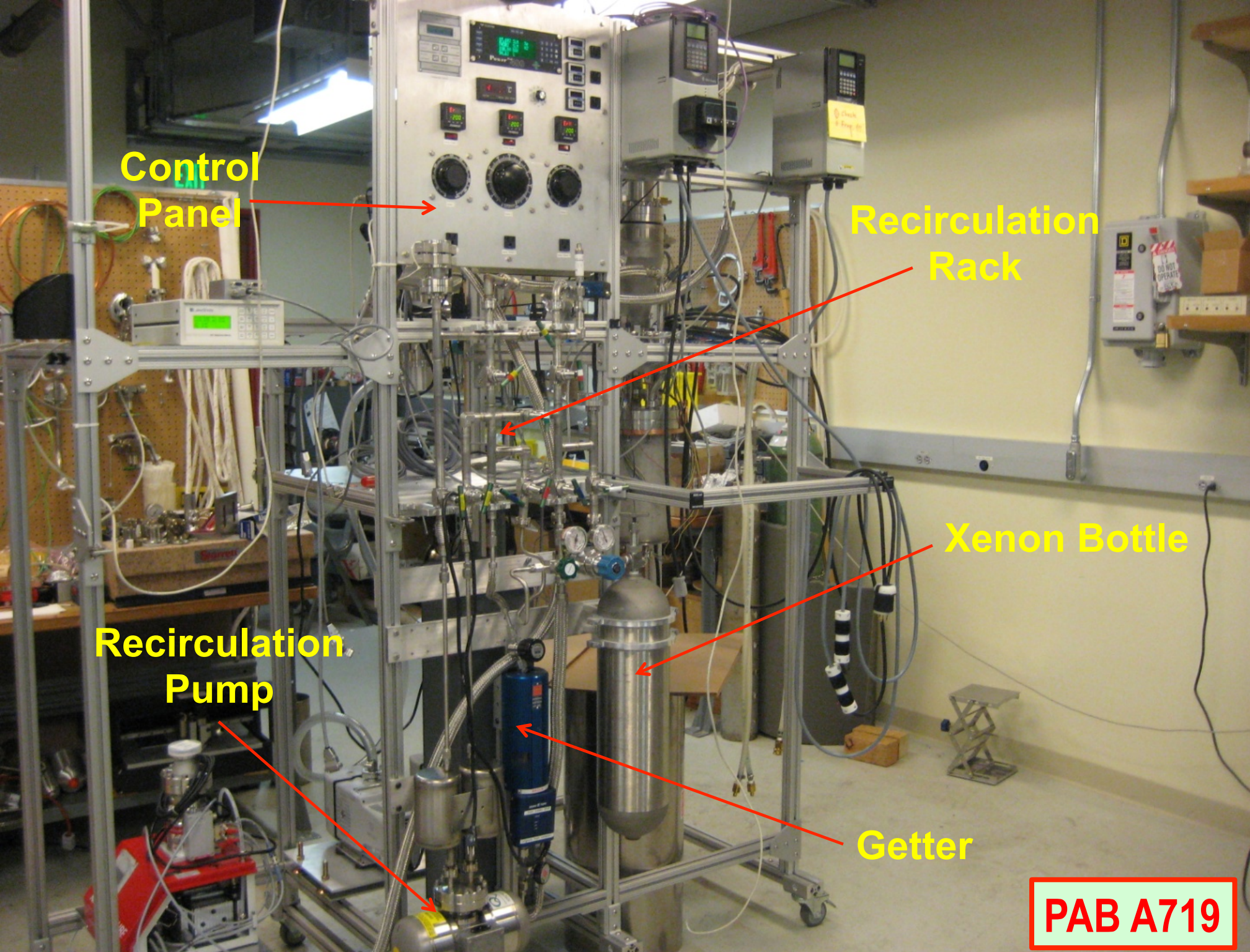
Where backgrounds come from?



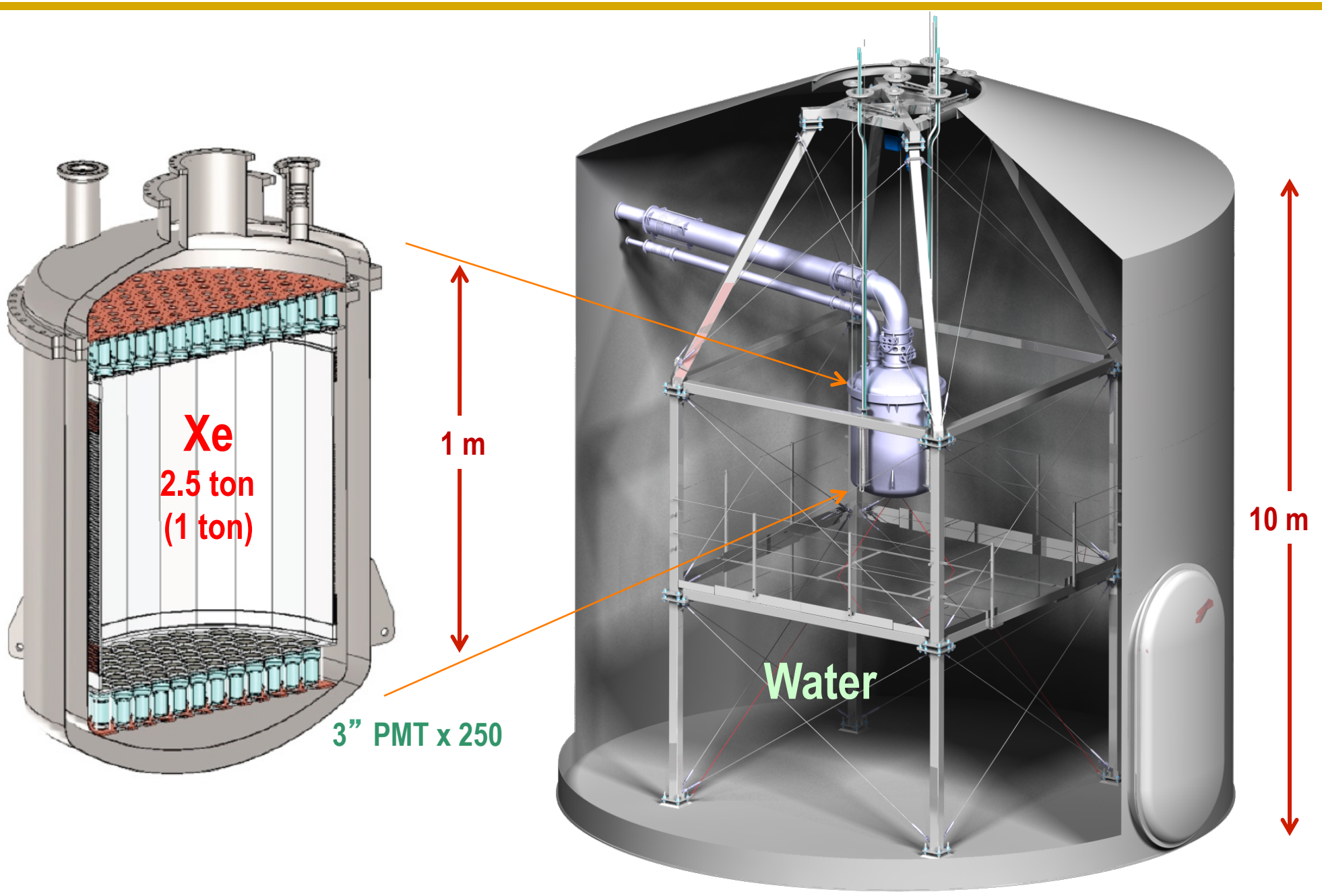
Ultimately photon detectors are the major source of backgrounds.

Comparison of Photon Detectors from Hamamatsu

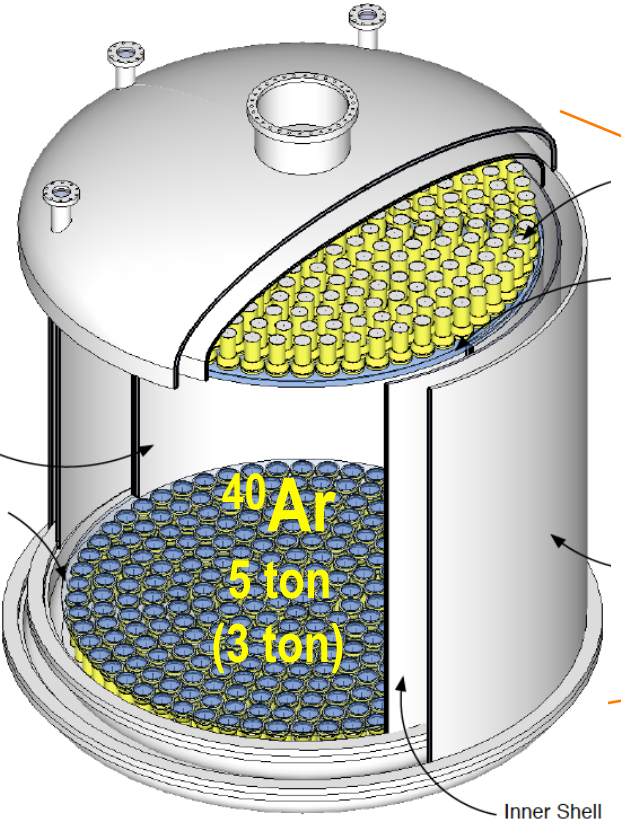



Control Panel
Recirculation Rack
Xenon Bottle
Recirculation Pump
Getter
PAB A719

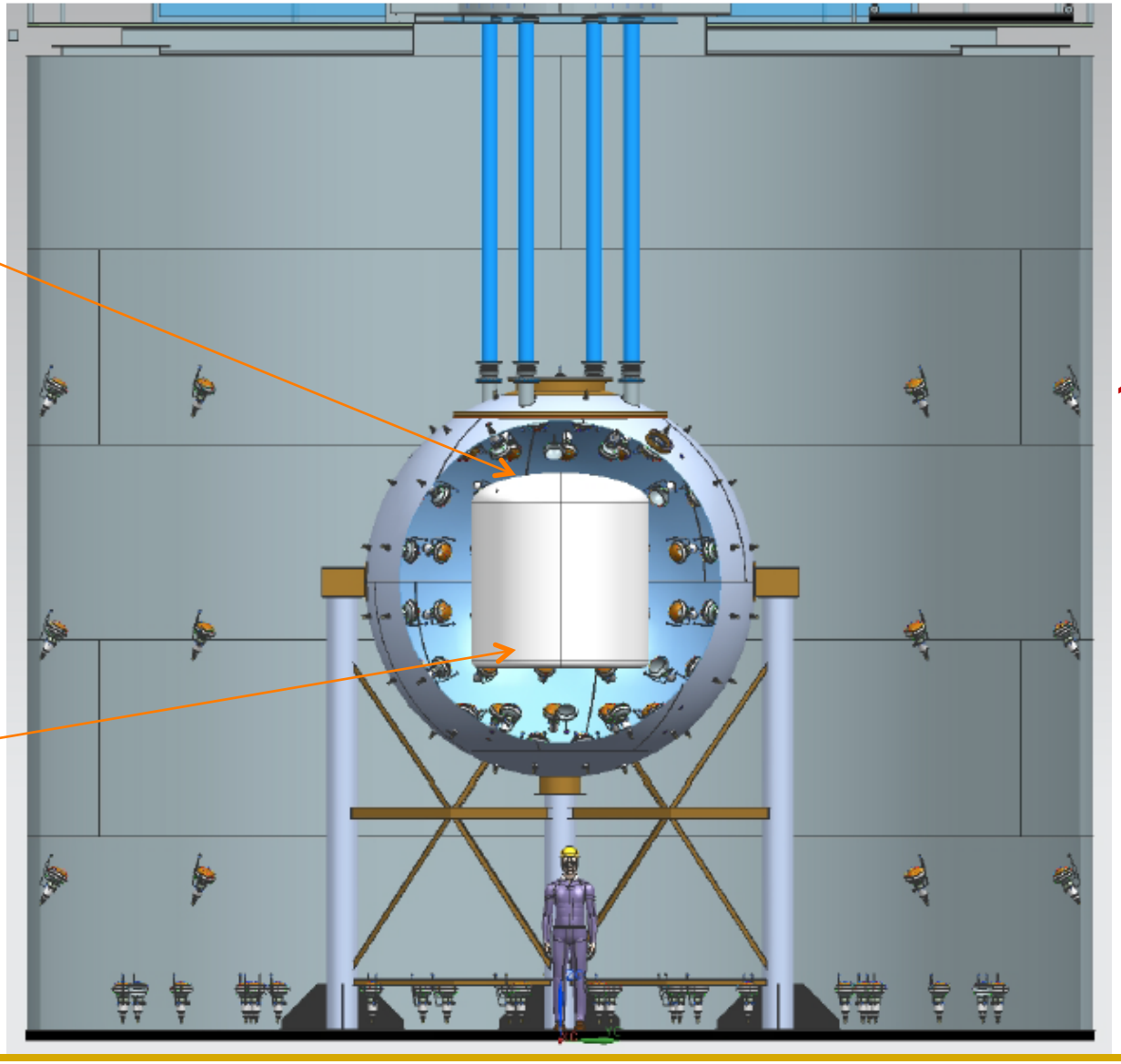
XENON1T at LNGS



DarkSide 5T at Gran Sasso

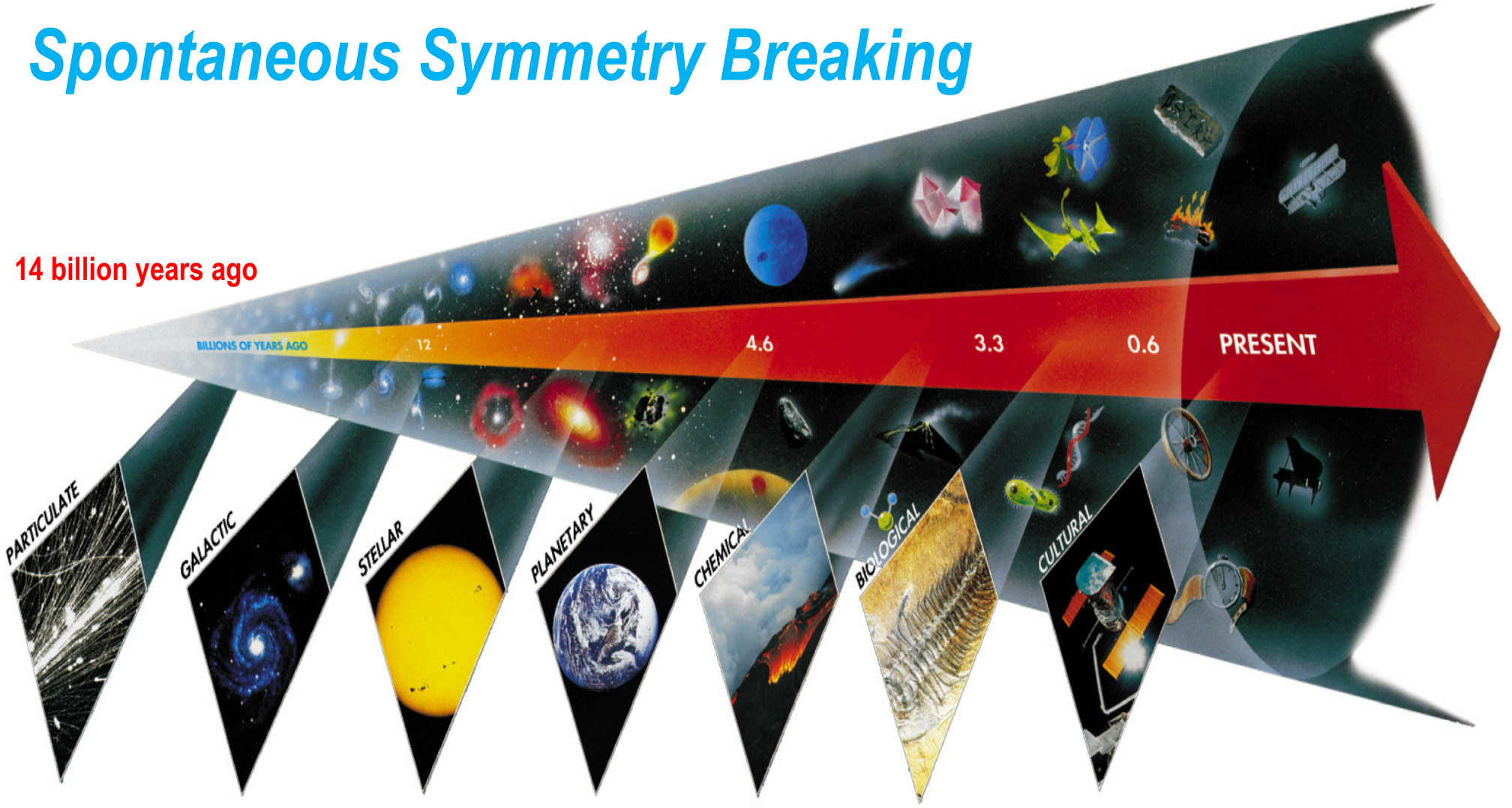


3" PMT x 600



Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking

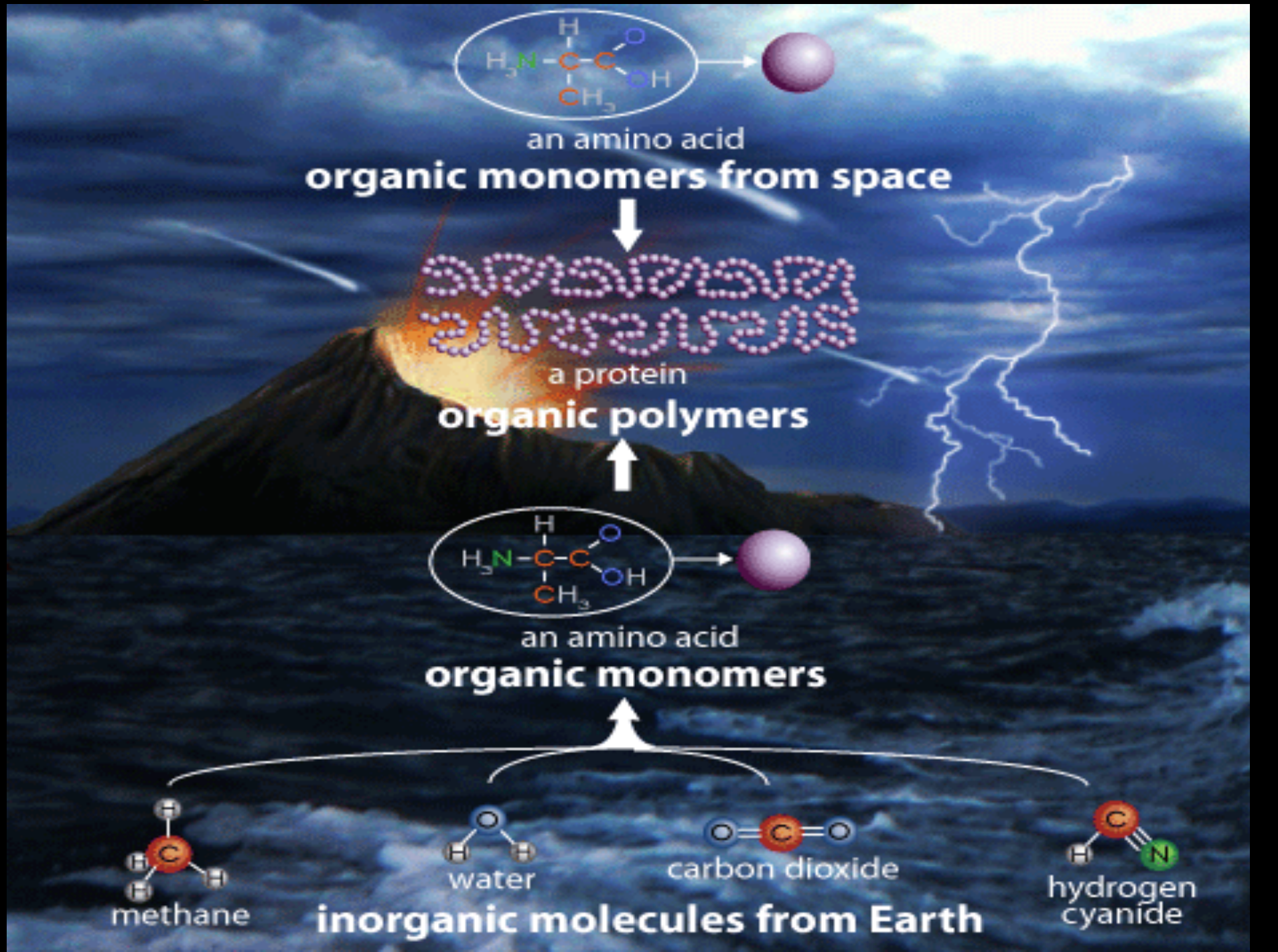


Origin of Particles

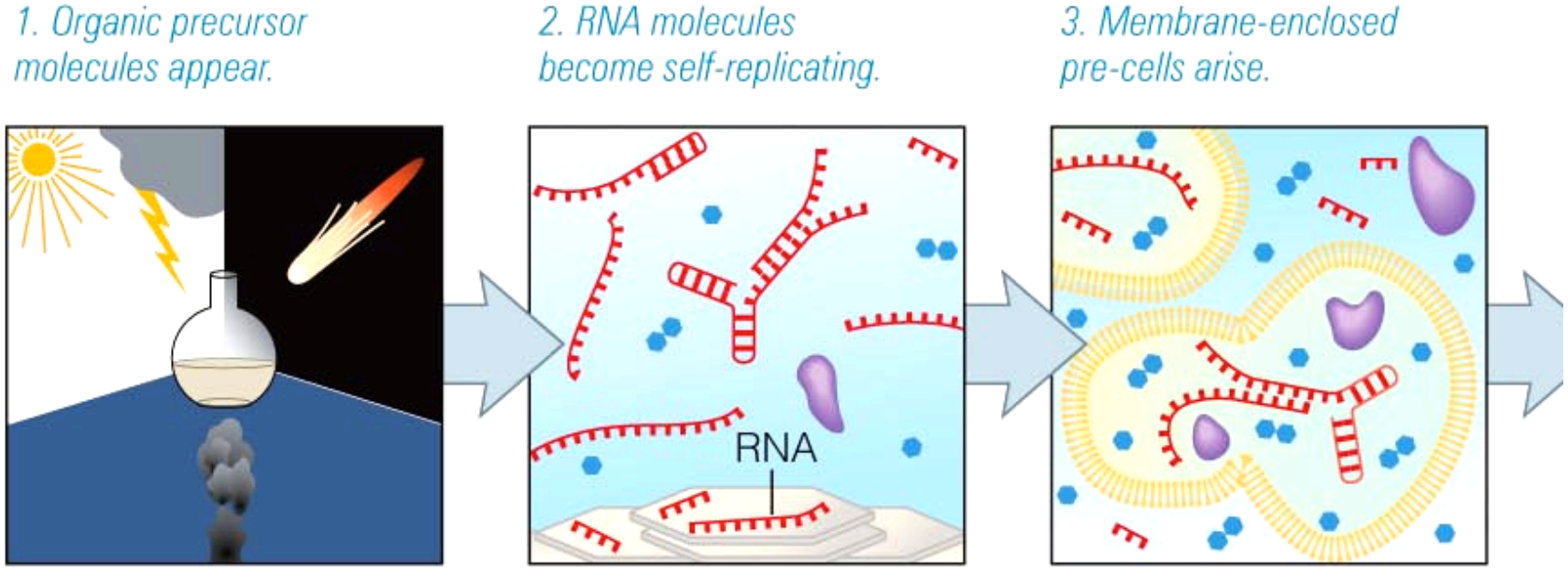
Origin of Structure

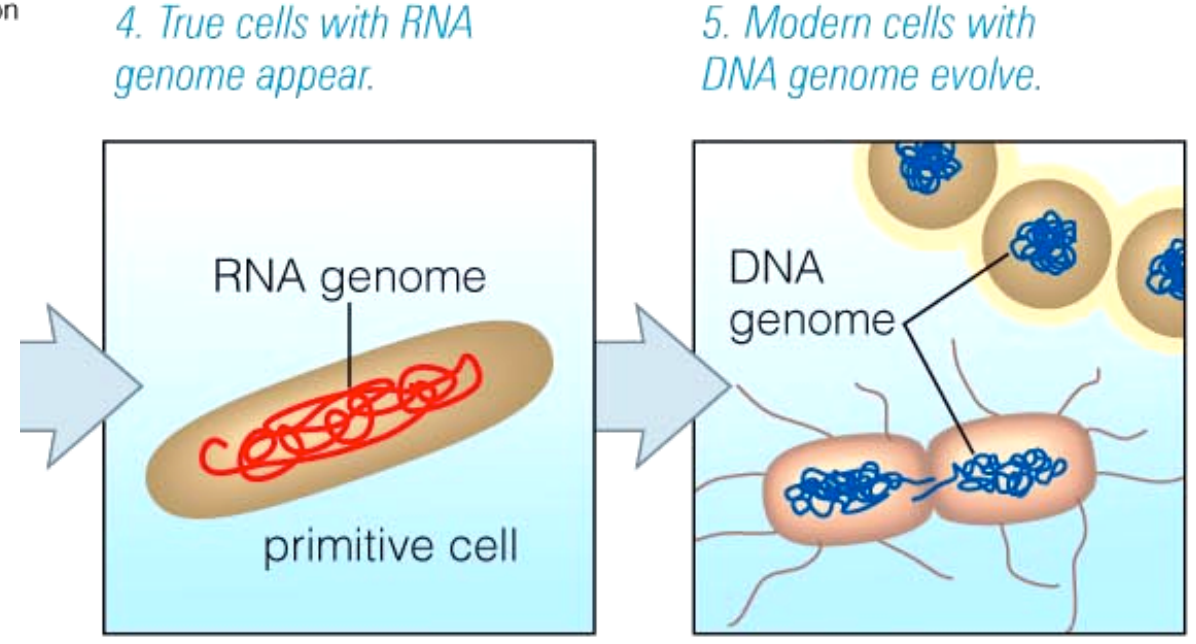
Origin of Life

Organic Polymers (4.5B → 4B years)



RNA Word (4B → 3.5B years ago)

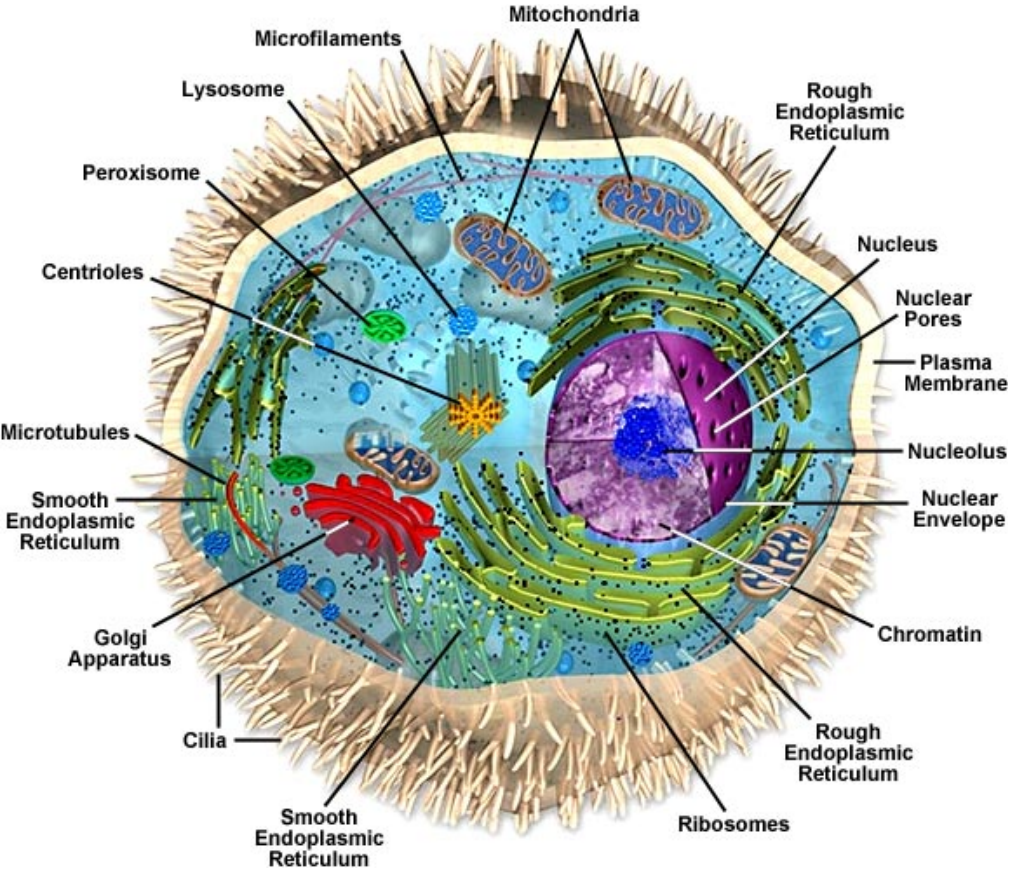




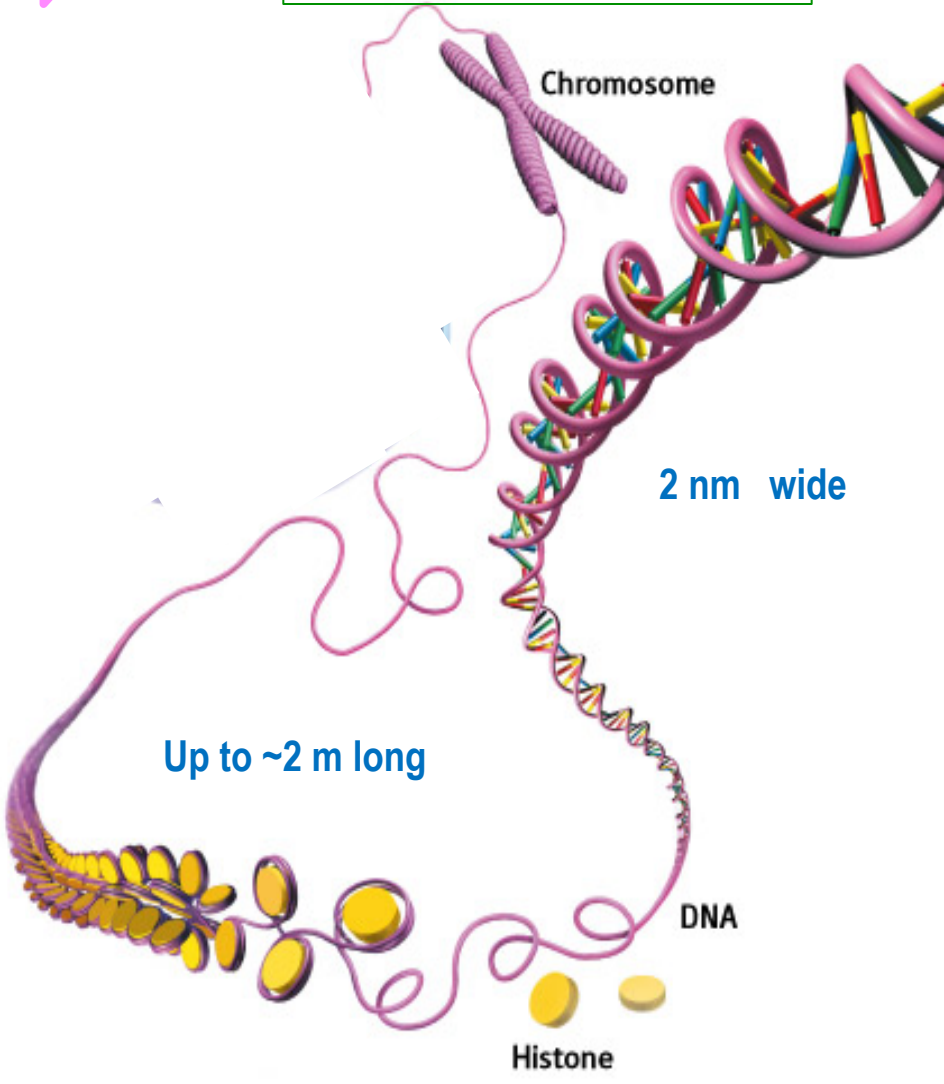
Eukaryote (~2B years ago)

Symmetry breaking

Cell made by proteins ⟺ **Gene made by DNA**



10 – 50 μm



How to observe the "Origin of Life"

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

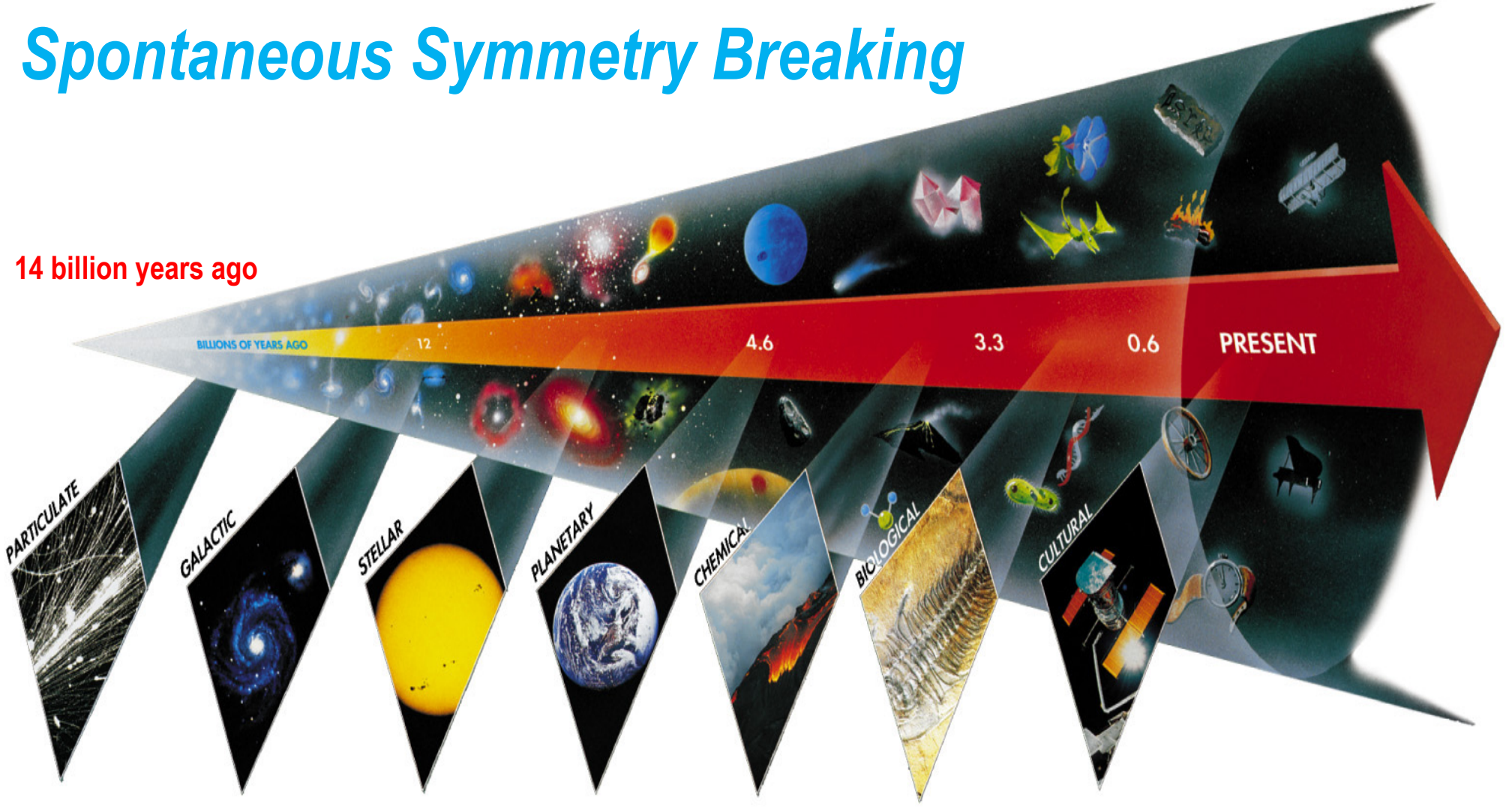
  Telescope vs. Microscope

- We must look for "Live Life"

- Take advantages of the state of art "Photon Detectors" in particle physics.

Seven Phases of Cosmic Evolution

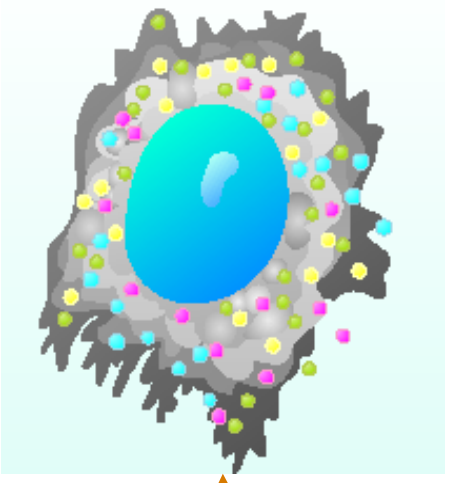
Spontaneous Symmetry Breaking

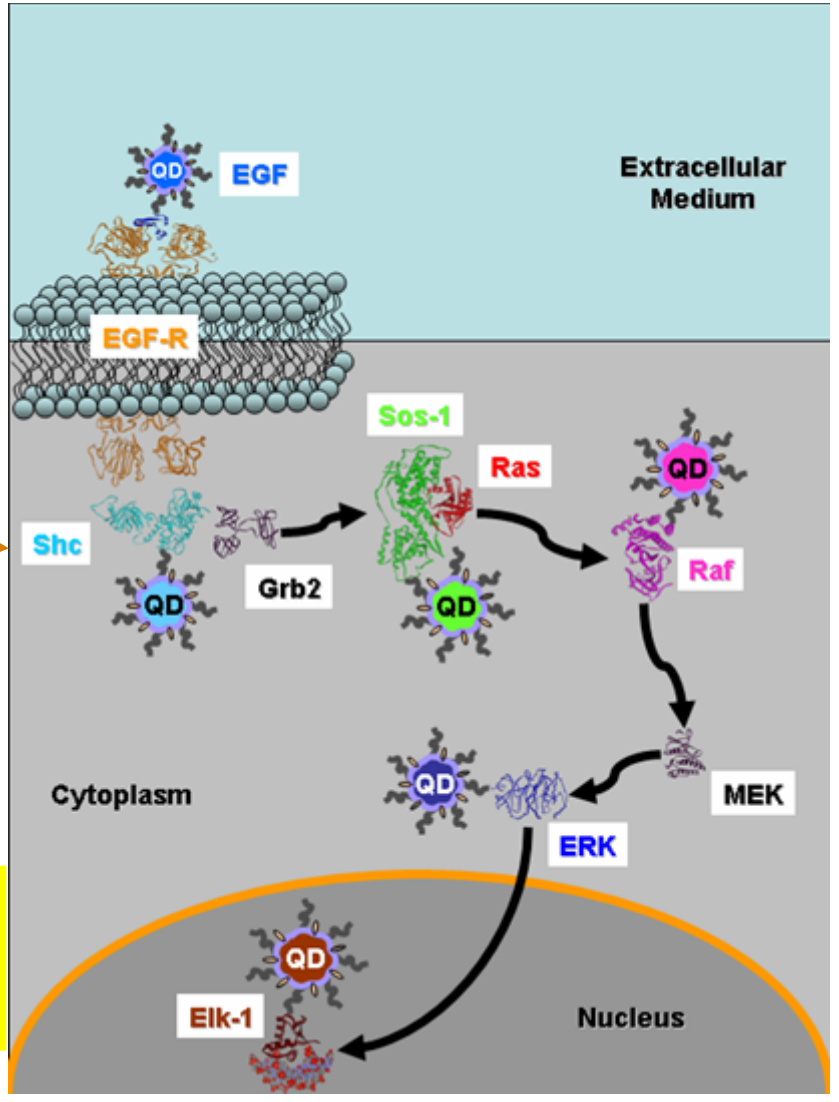


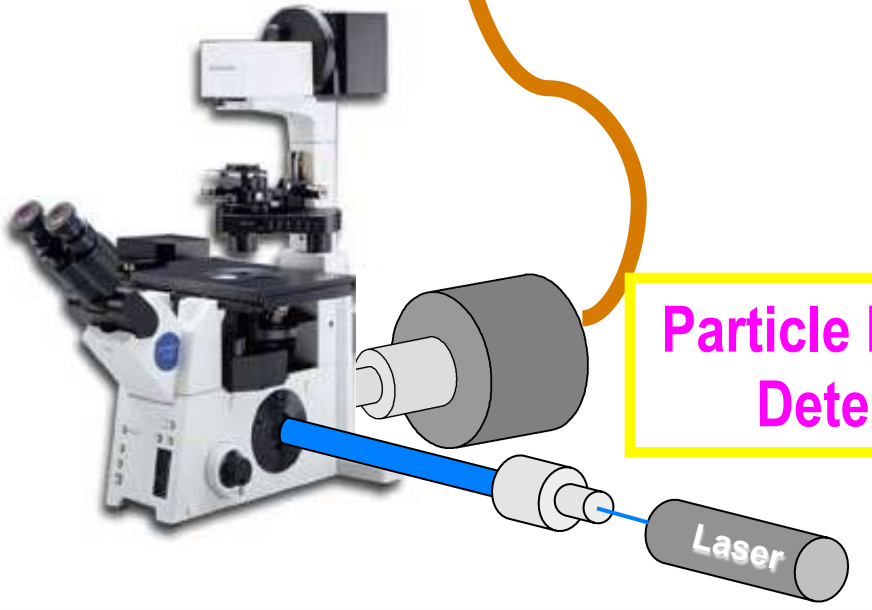
Accelerator ← **Telescope** → ← **Microscope** →

Single Molecule Imaging

Nano Technology





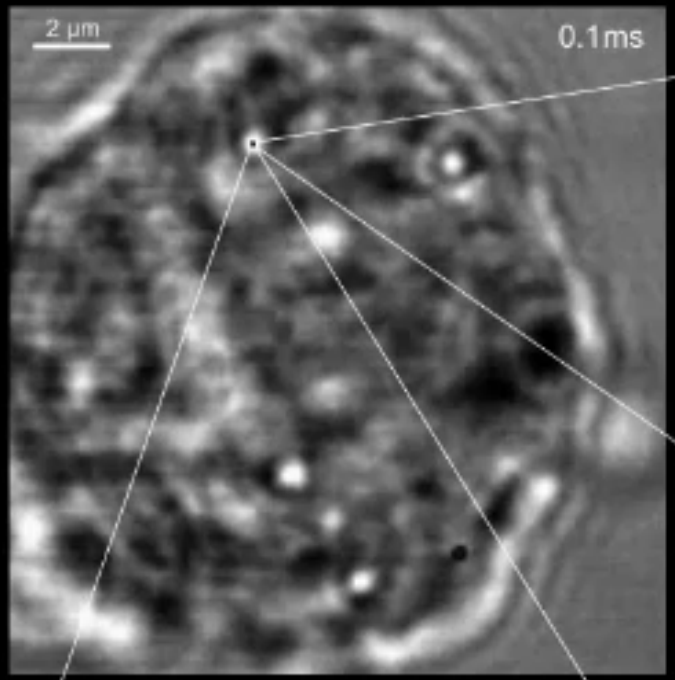


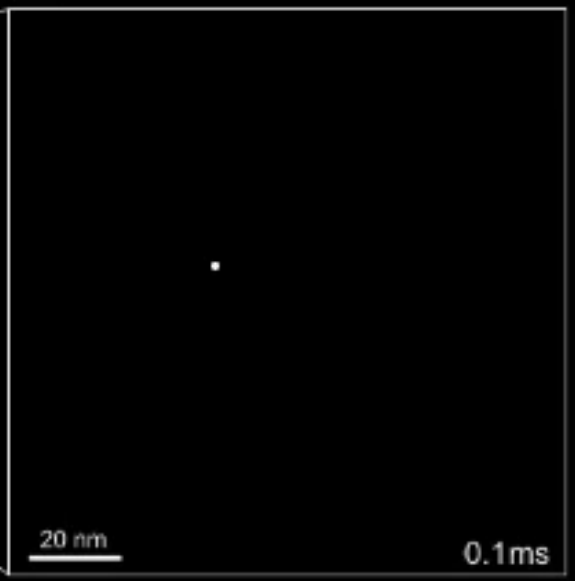
Particle Physics Detector

Prof. Shimon Weiss

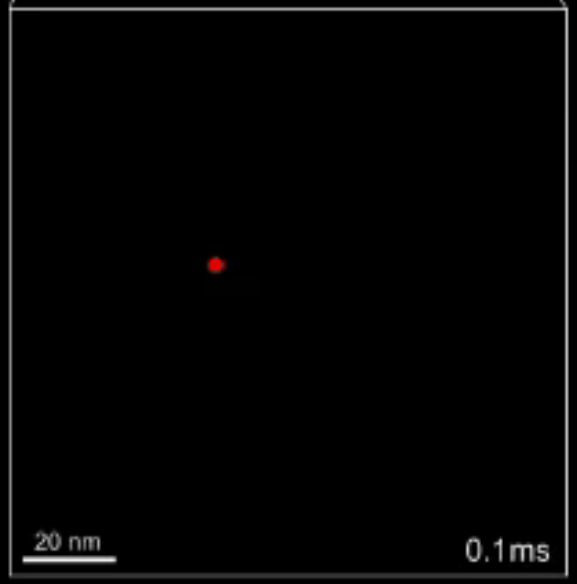
Gold nano particle (40nm) attached to Transferrin Receptor (TfR) on Cancer Cell

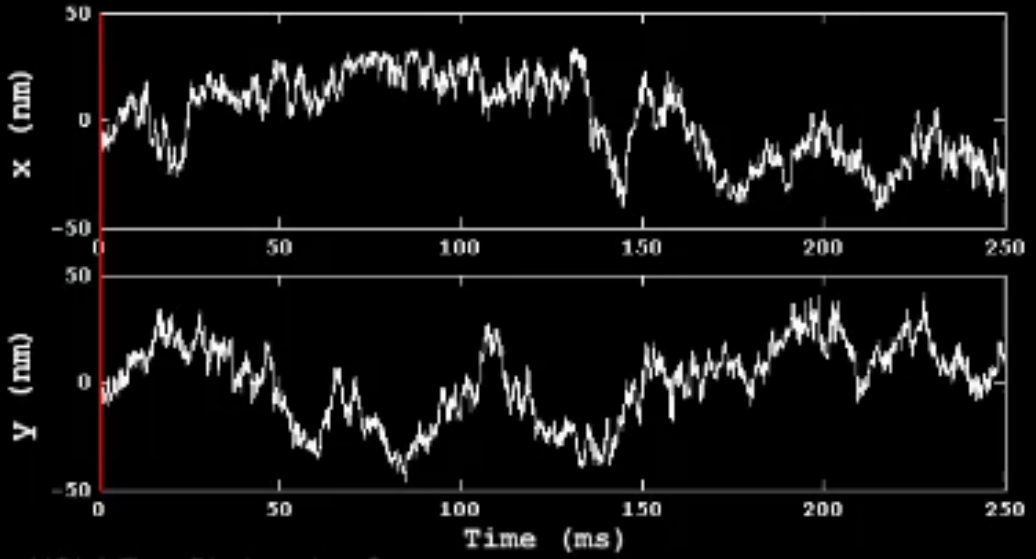
Prof. Manuel Penichet (Oncology)





(10, 000 frame/sec)

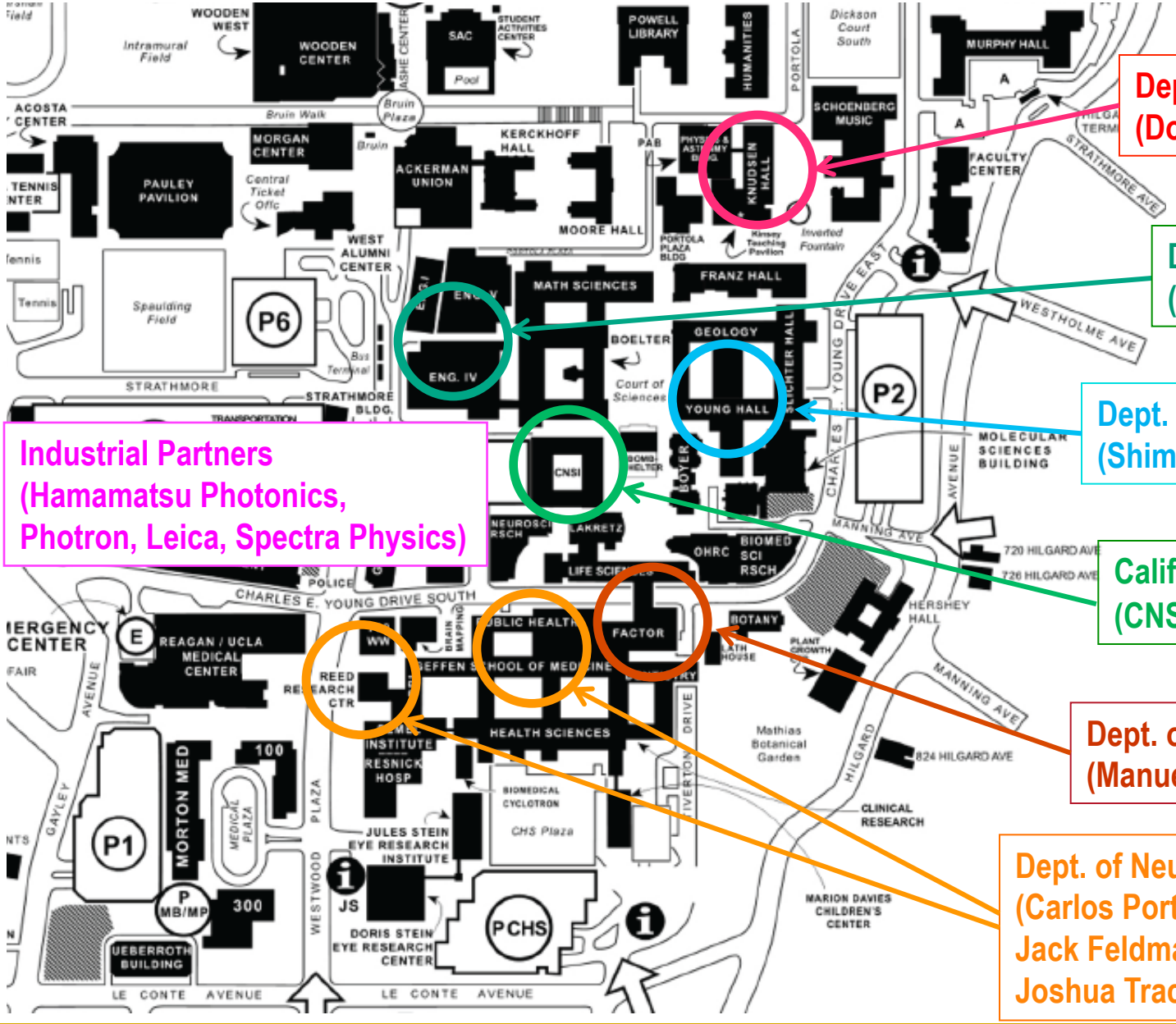




UCLA Fast Bio-Imaging Group

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

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



Industrial Partners
(Hamamatsu Photonics,
Photron, Leica, Spectra Physics)

Dept. of Physics & Astronomy
(Dolores Bozovic, Mayank Mehta)

Dept. of Electrical Engineering
(Bahram Jalali)

Dept. of Chemistry & Biochemistry
(Shimon Weiss)

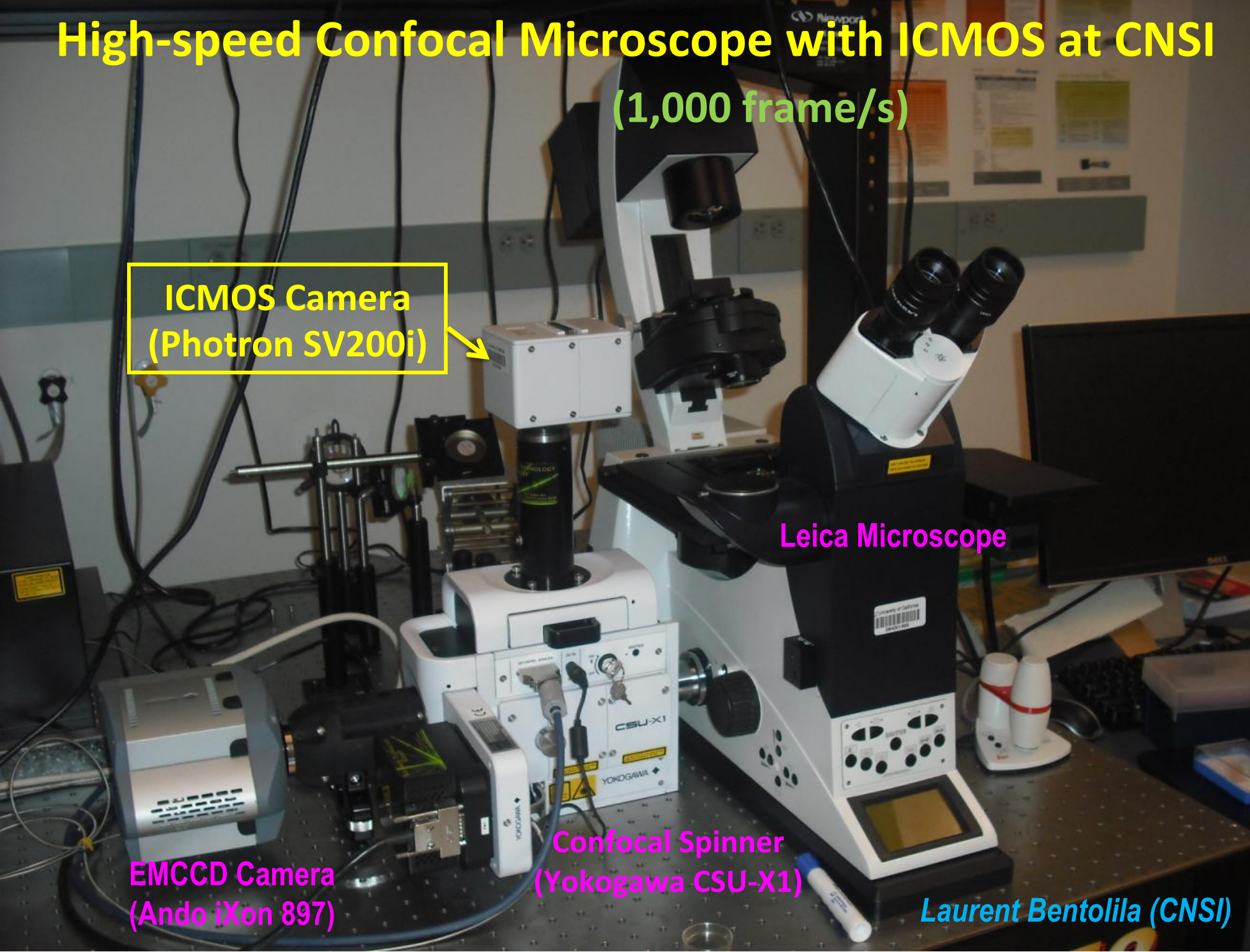
California Nano Systems Institute
(CNSI, Laurent Bentolila)

Dept. of Surgical Oncology
(Manuel Penichet)

Dept. of Neurology & Neurobiology
(Carlos Portera-Cailliau,
Jack Feldman, Tom Otis,
Joshua Trachtenberg)

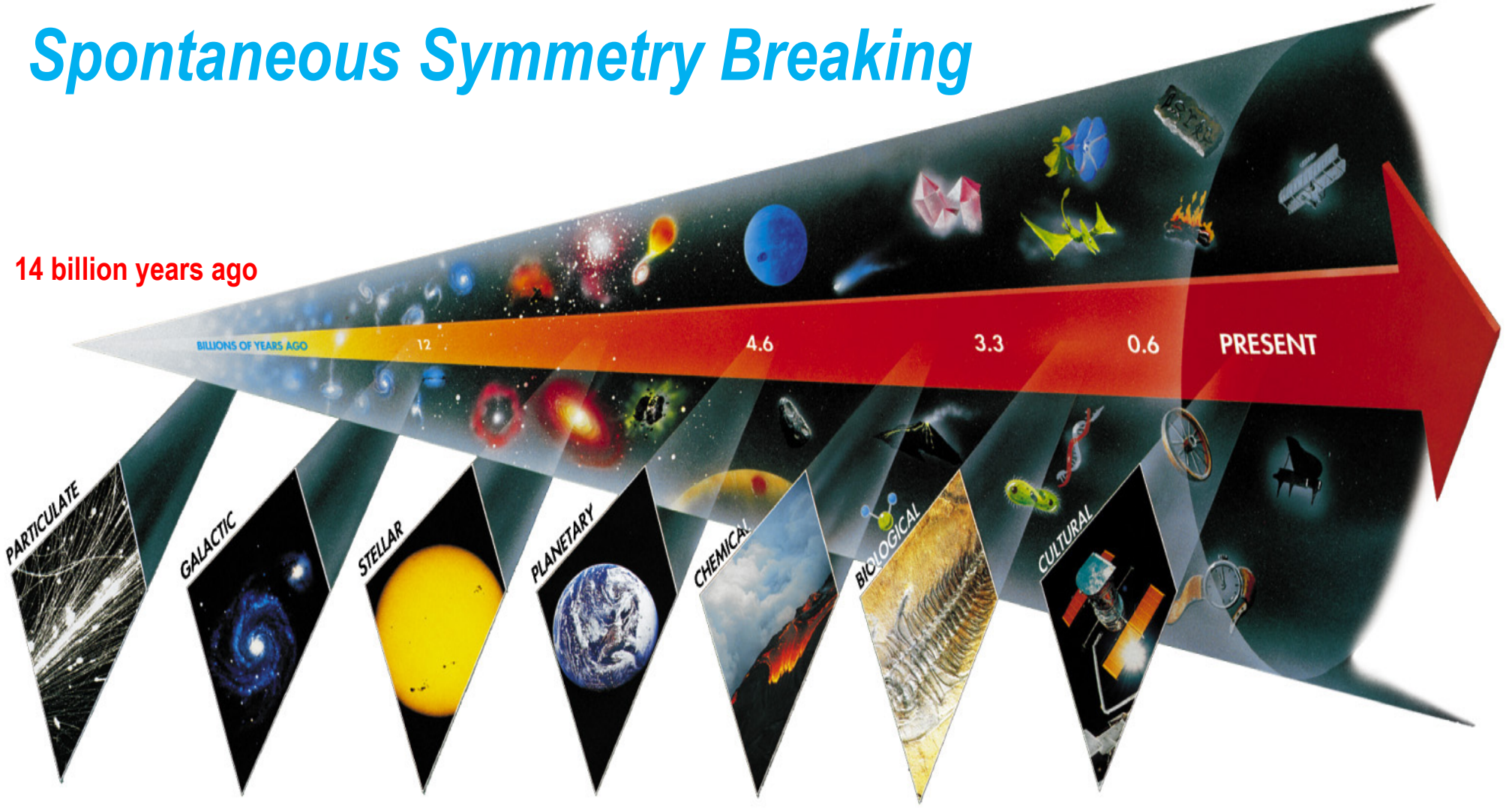
User-shared Core Facility of High-speed Microscopes at CNSI

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



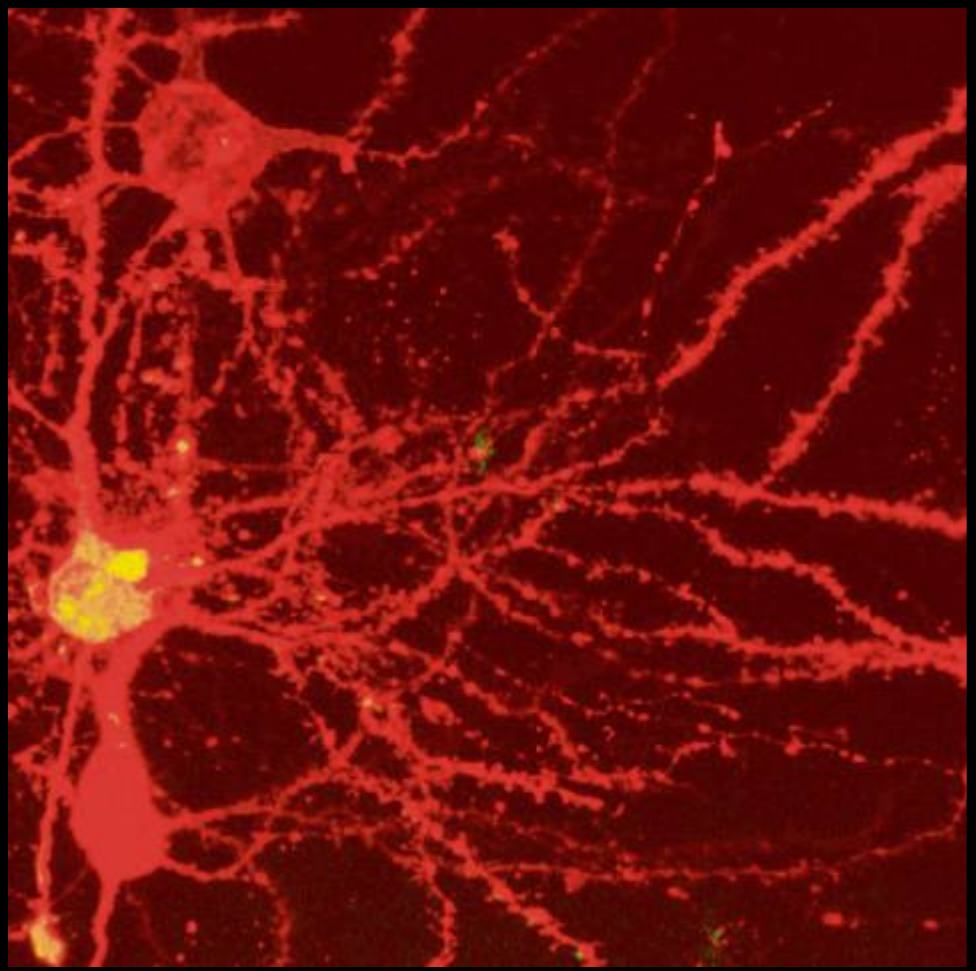
Origin of Particles

Origin of Structure

Origin of Life

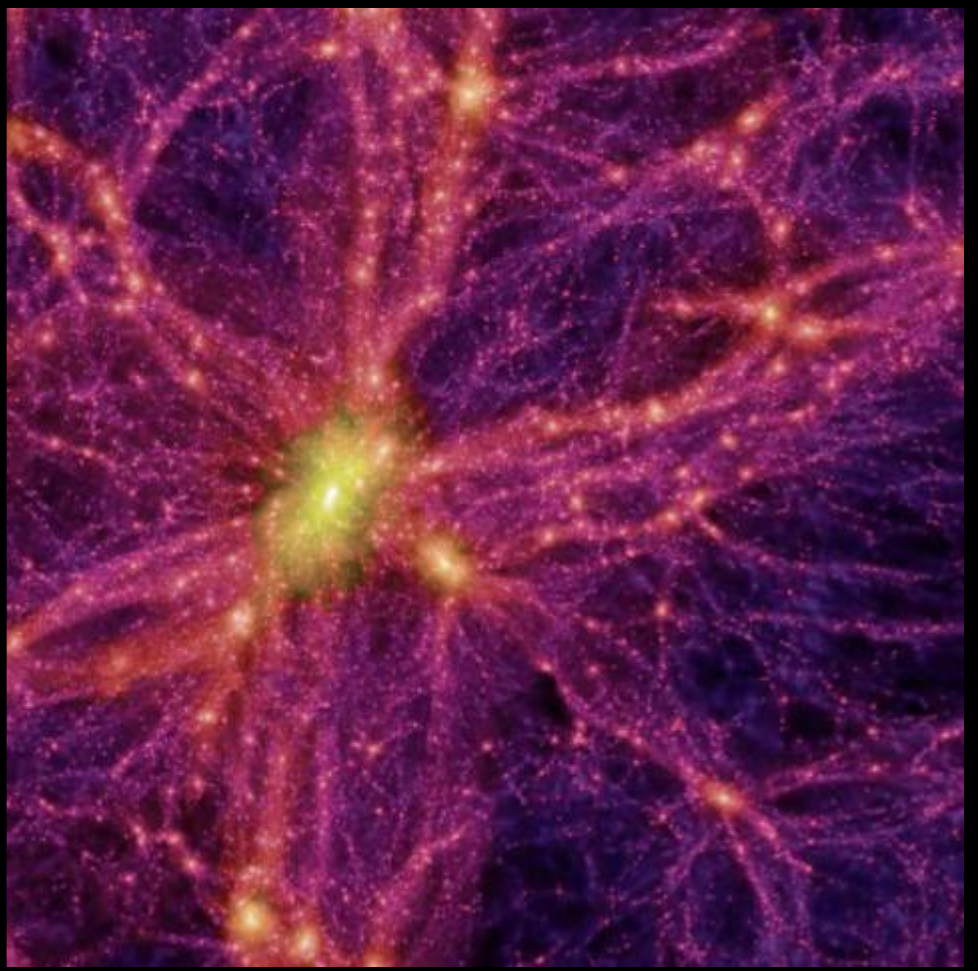
Origin of Consciousness

Brain



100 Billions Neurons

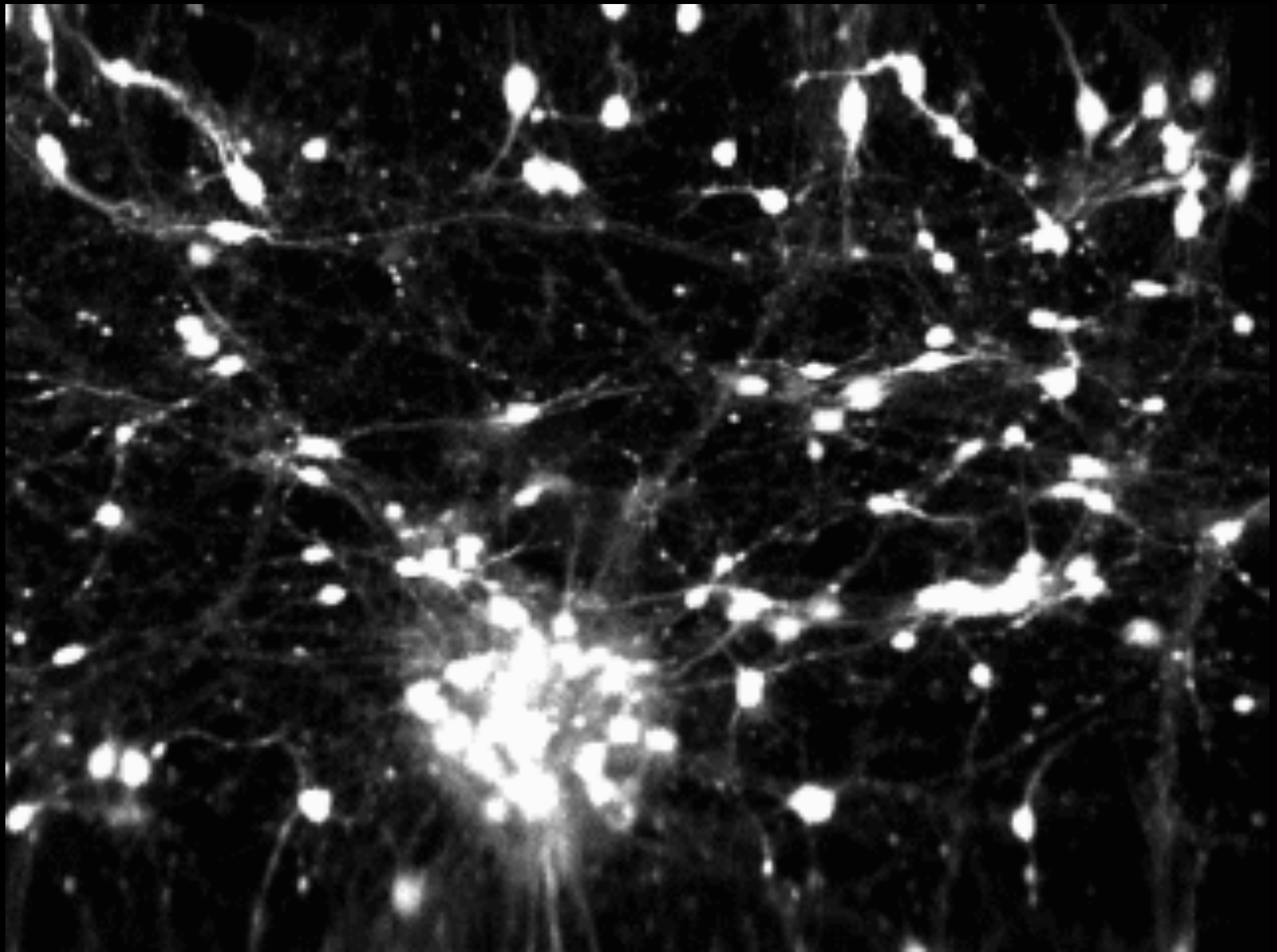
Universe



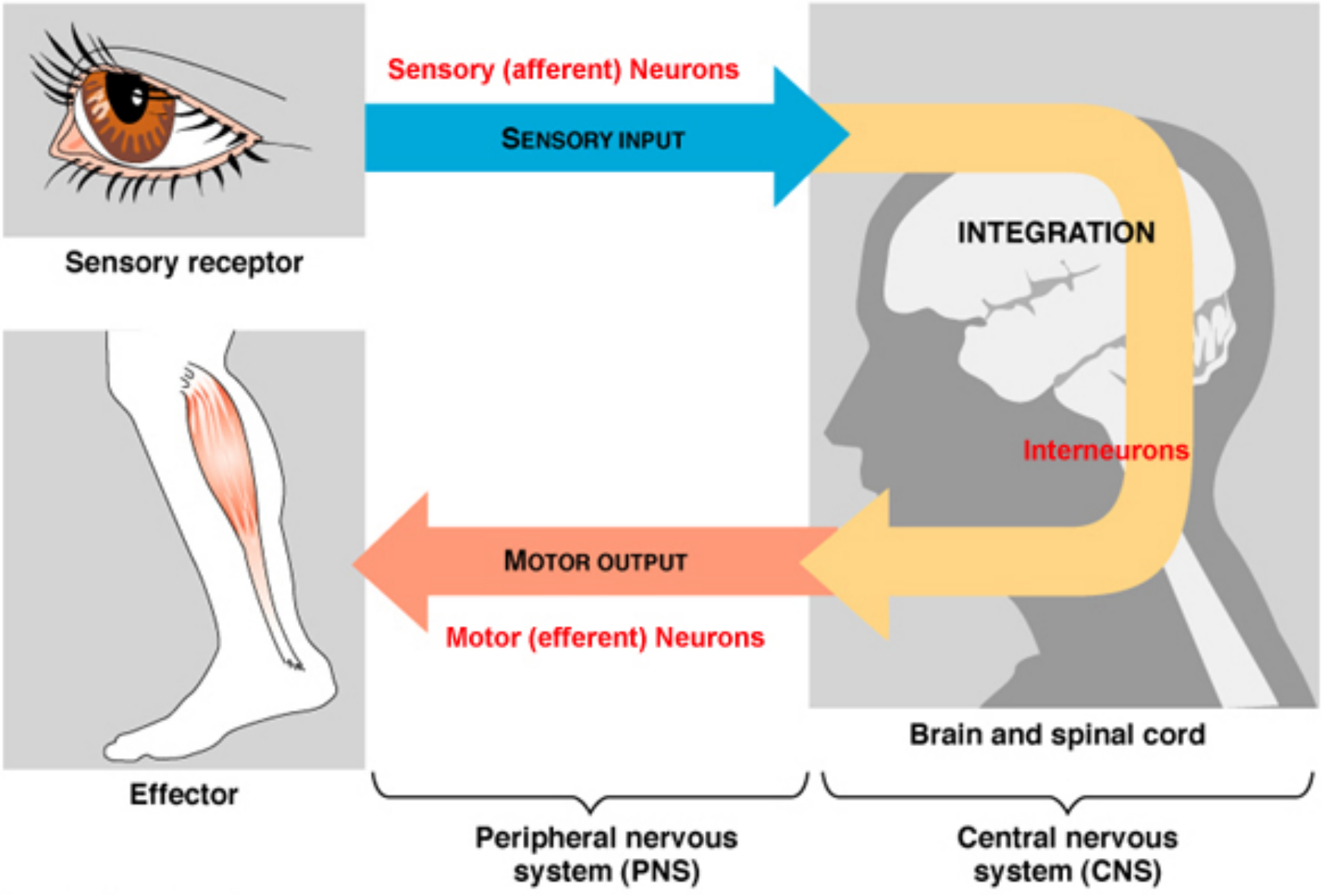
100 Billions Galaxies

New York Times 8/21/2006

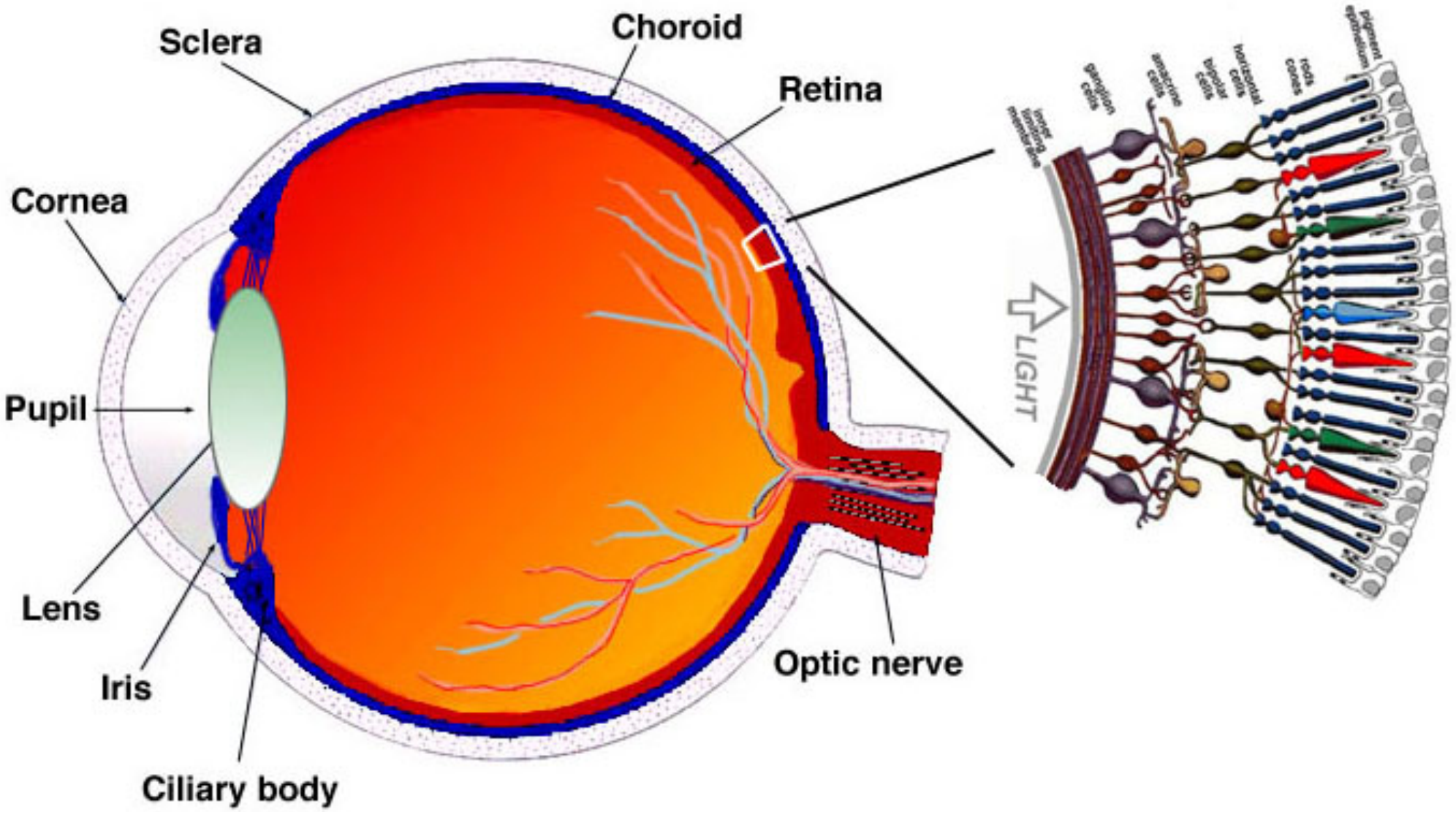
Ca^{2+} Signal in cultivated Rat's Brain



Assembly of cortical circuits during development



Human Eyes

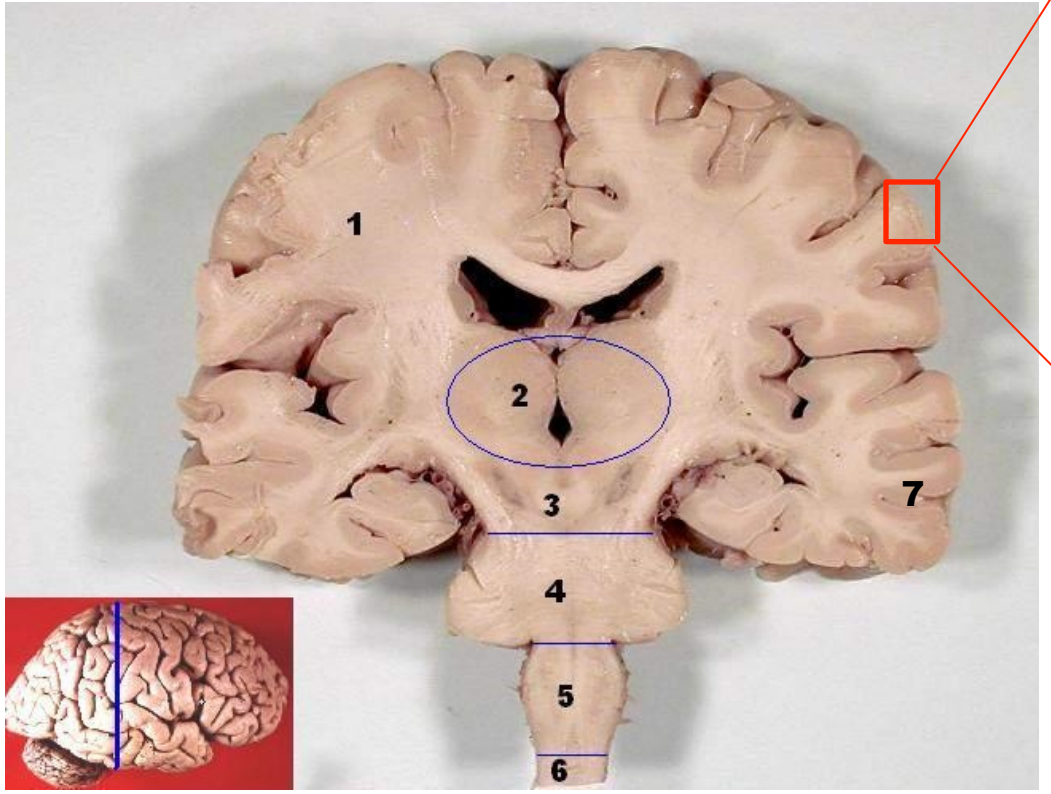

Sclera
Choroid
Retina
Cornea
Pupil
Lens
Iris
Ciliary body
Optic nerve
LIGHT
ganglion cells
amacrine cells
bipolar cells
horizontal cells
rods
cones
pigment epithelium

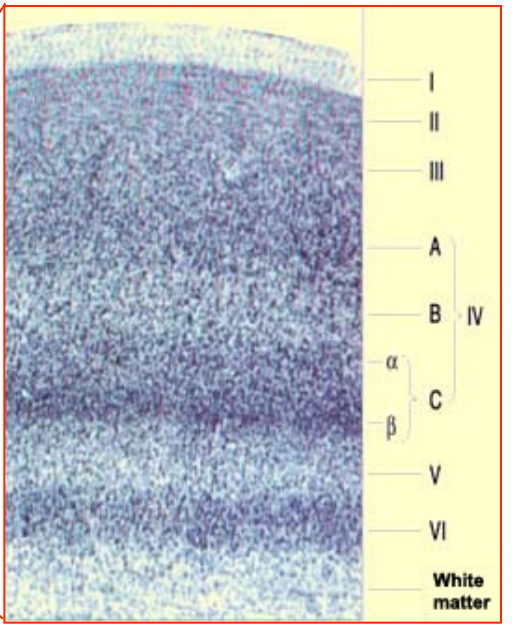
How can I recognize a woman so far away?

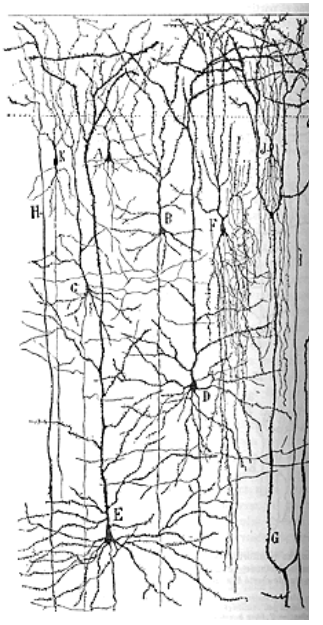
- Genetically encoded?
- Learning and memory?

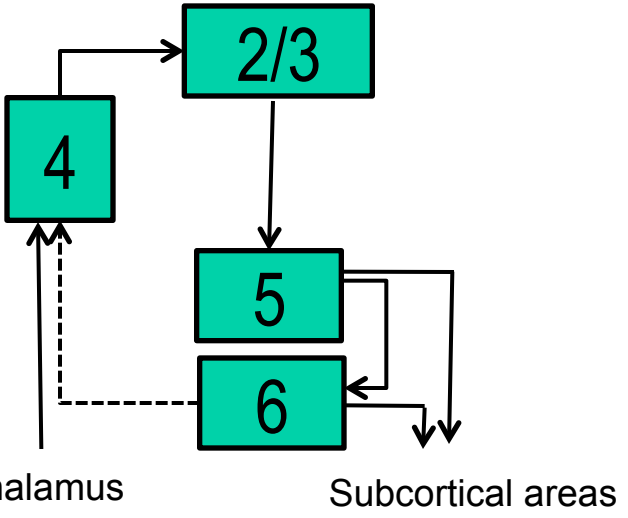
The Cerebral Cortex

Conscious



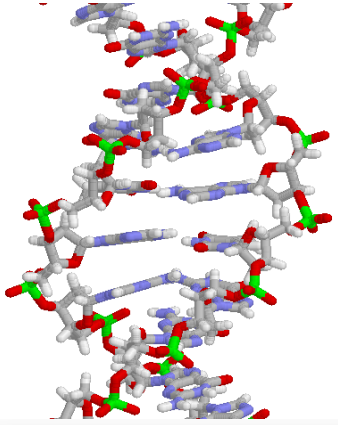


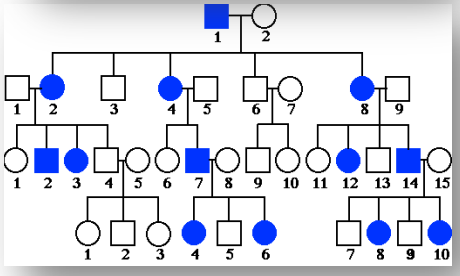




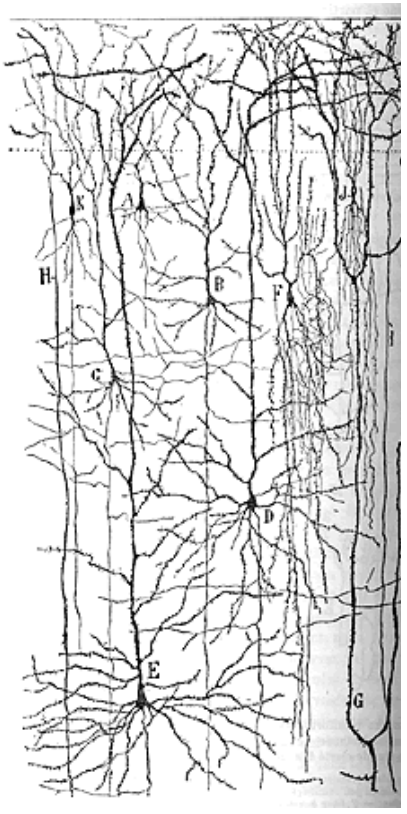
Unconscious

Nature vs. Nurture

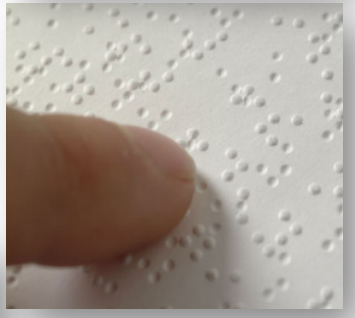


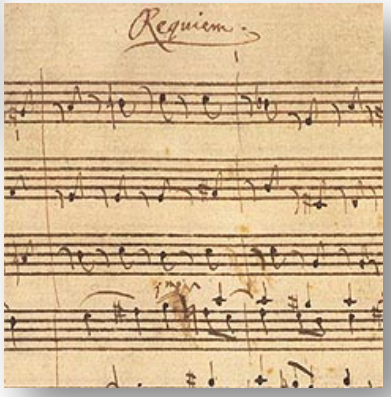


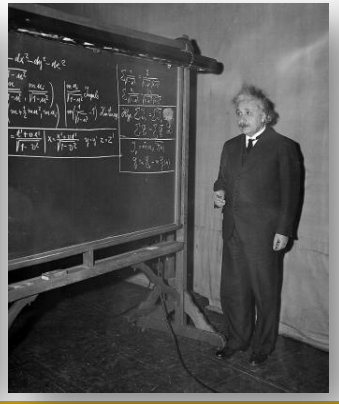
Nature



Nurture

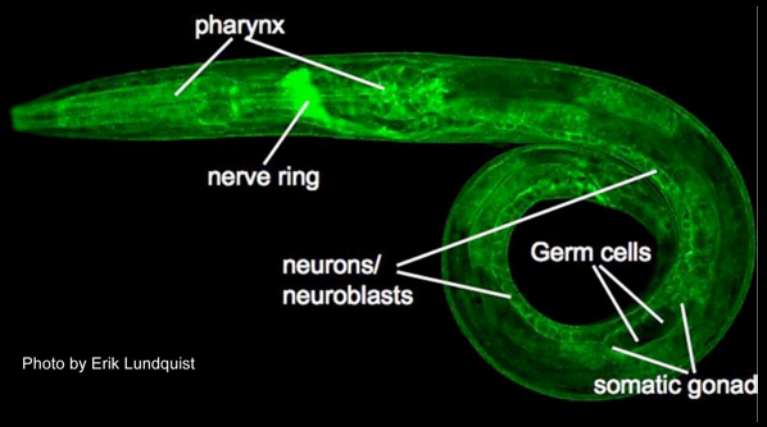






From No Brain to Big Brain

Paramecium (Single Cell)



C. elegans (302 neurons)

Zebrafish (~10,000 neurons)

Bullfrog (~10^7 neurons)

Rat (~10^8 neurons)

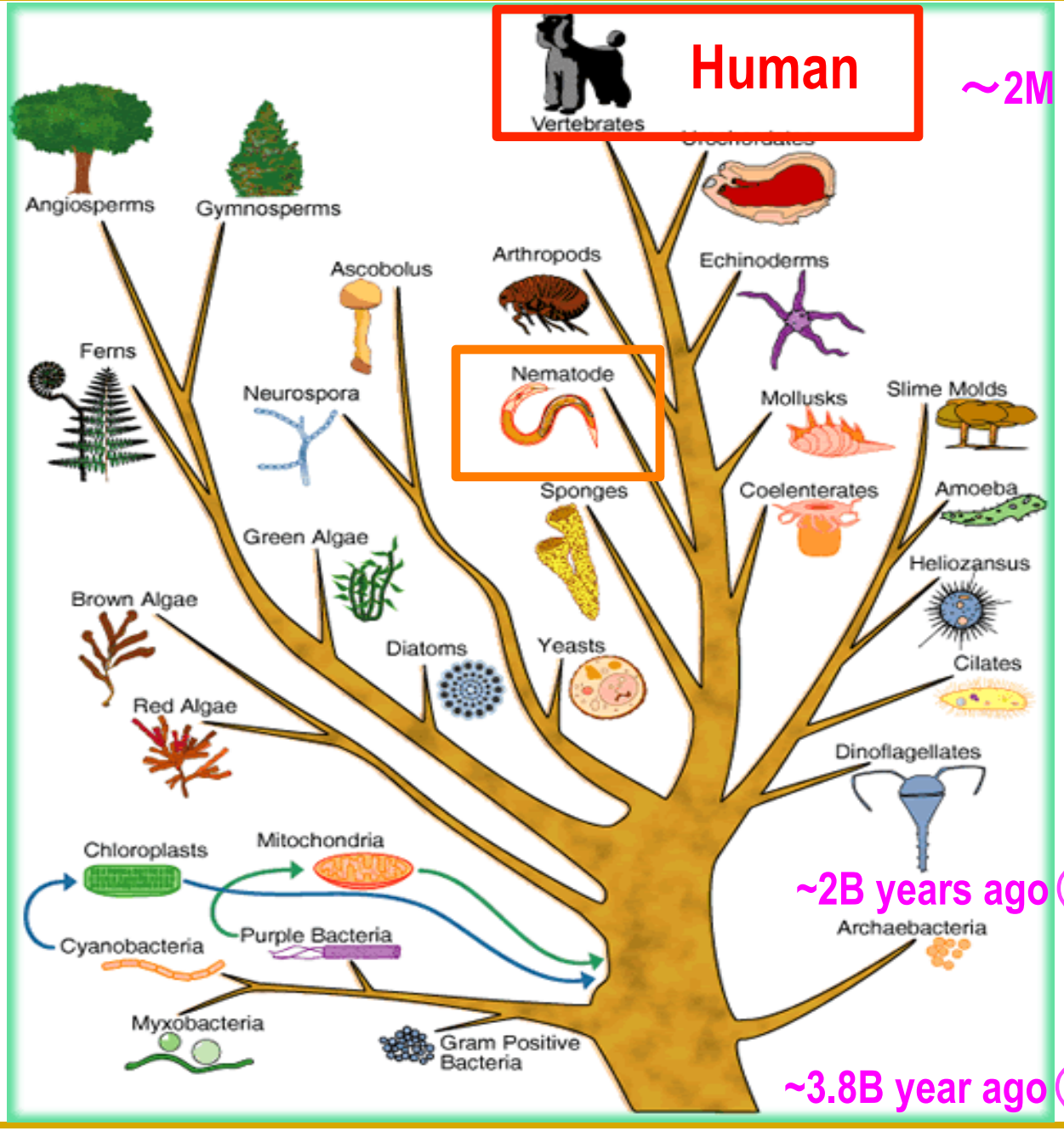
Introduction

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)

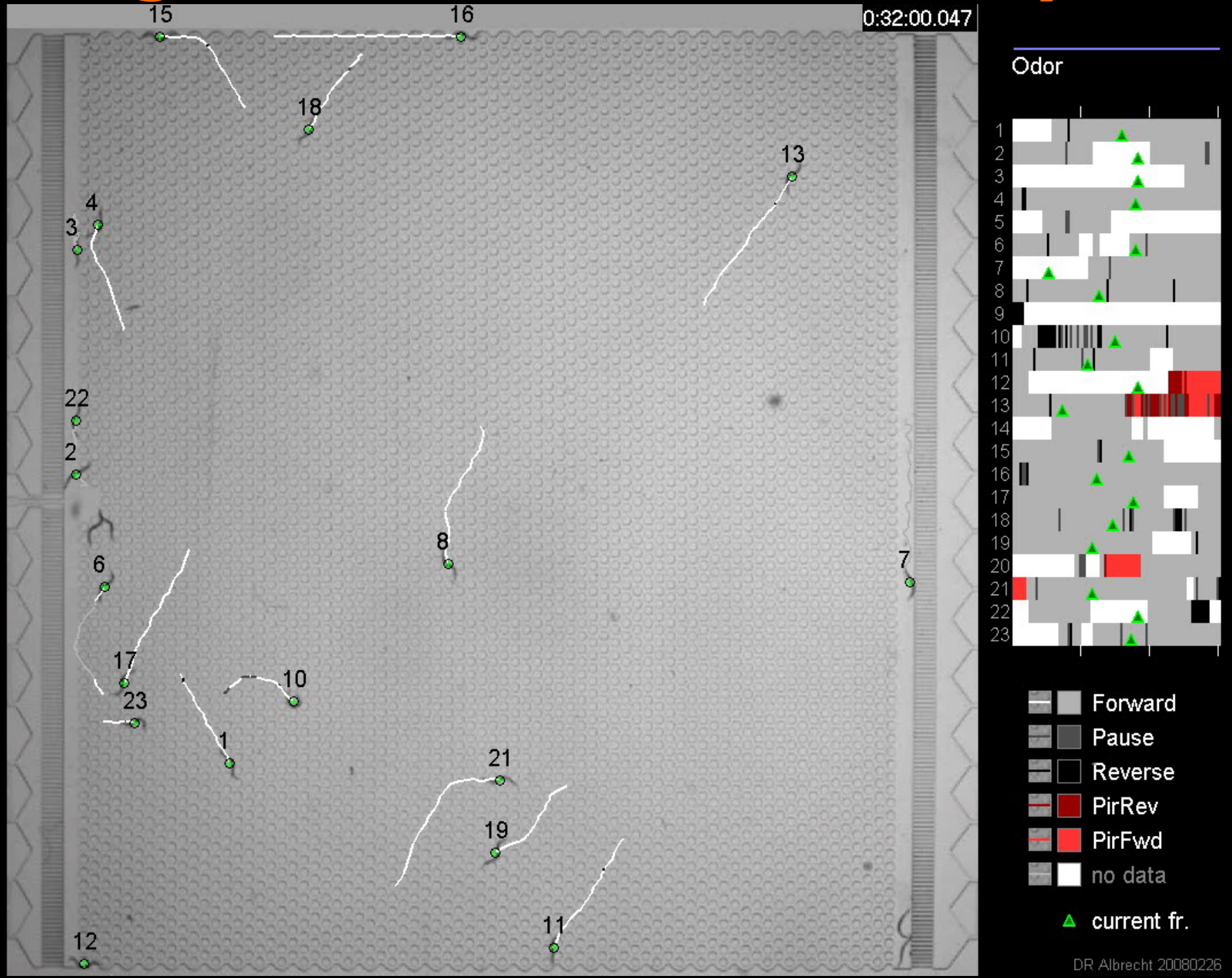
Tree diagrams of evolution

Plants

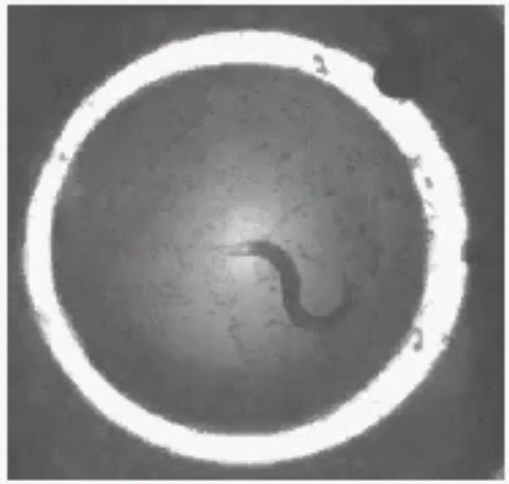


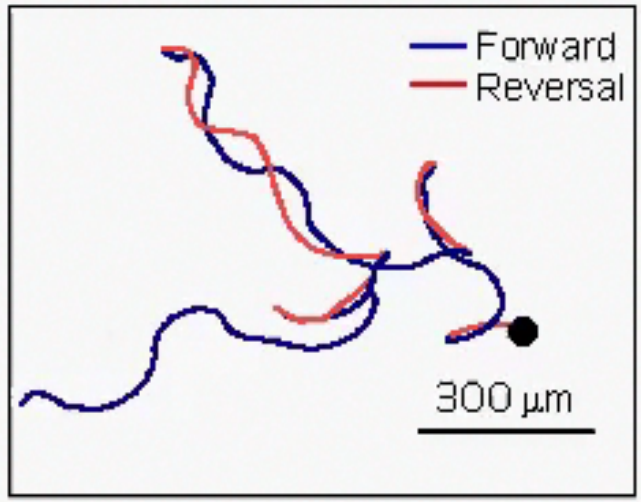
Animals

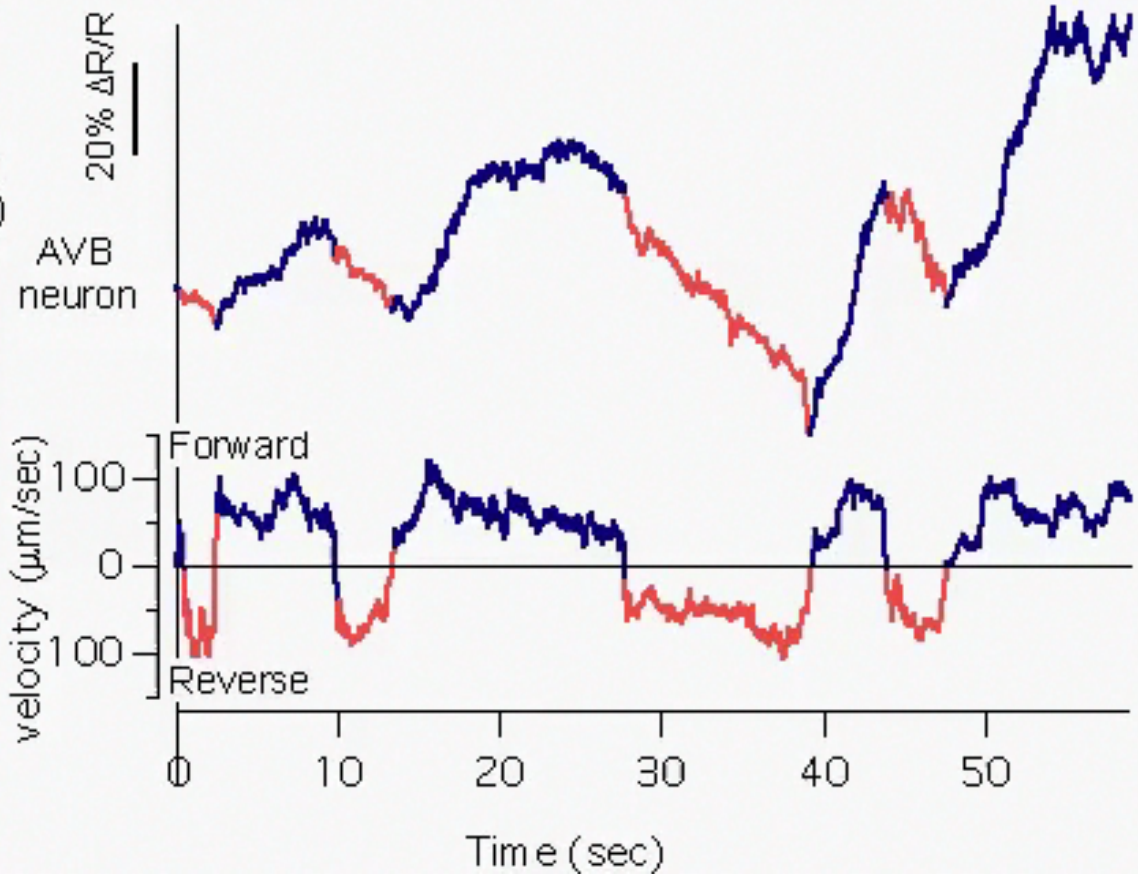
High-content behavioral analysis



Supplemental movie 3
Faumont *et al.*, 2011

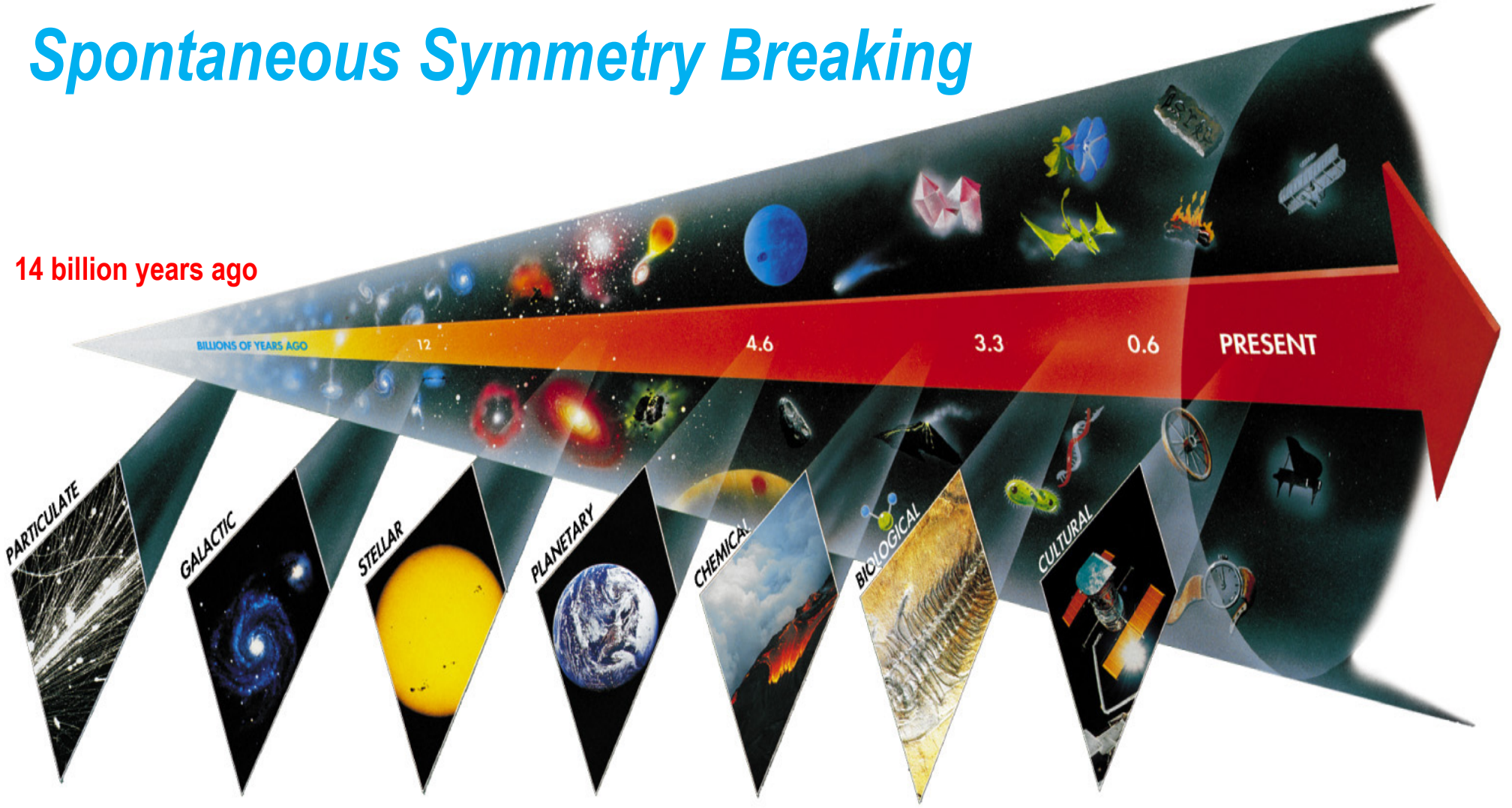






Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking

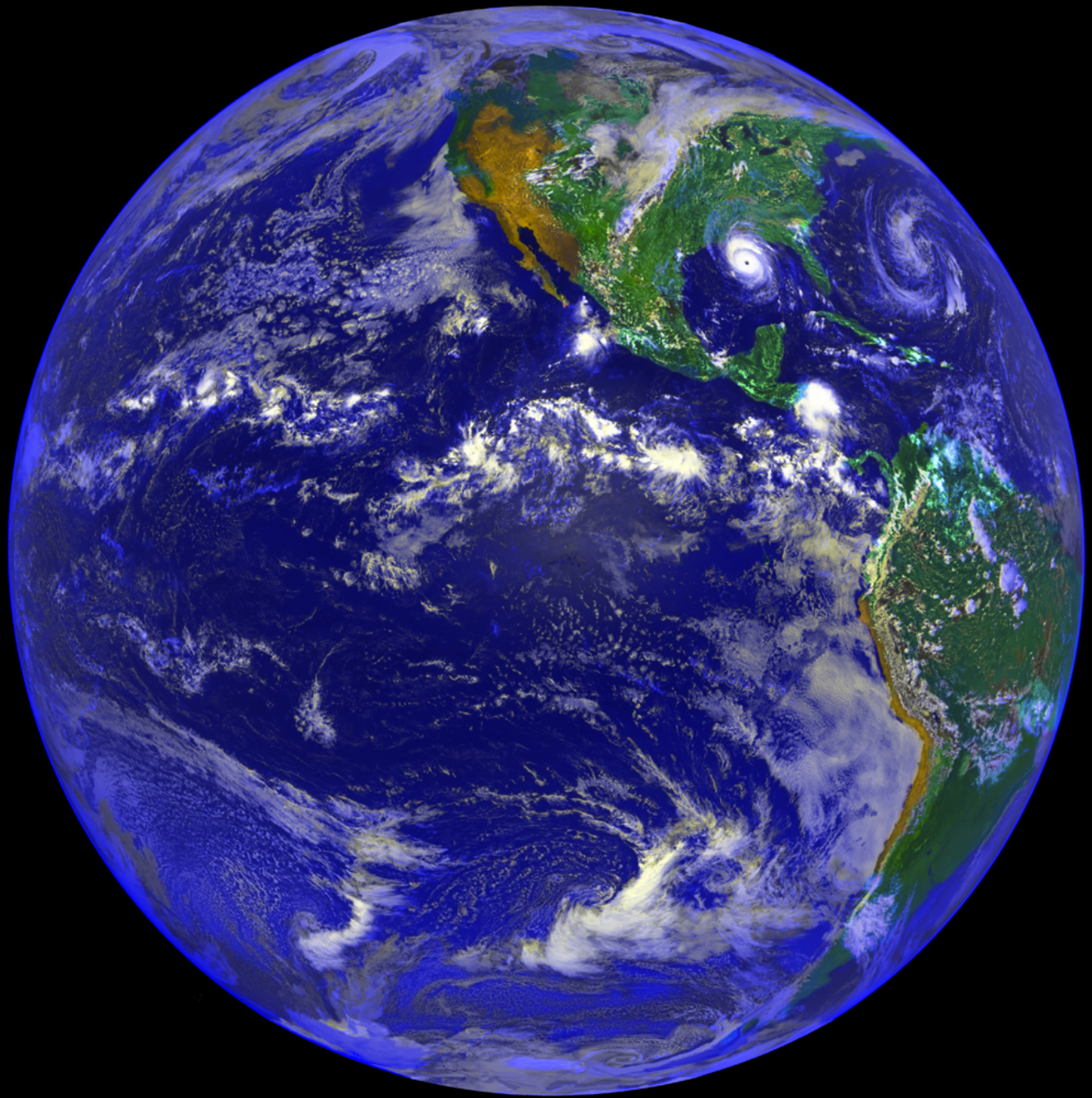


Origin of Particles

Origin of Structure

Origin of Life

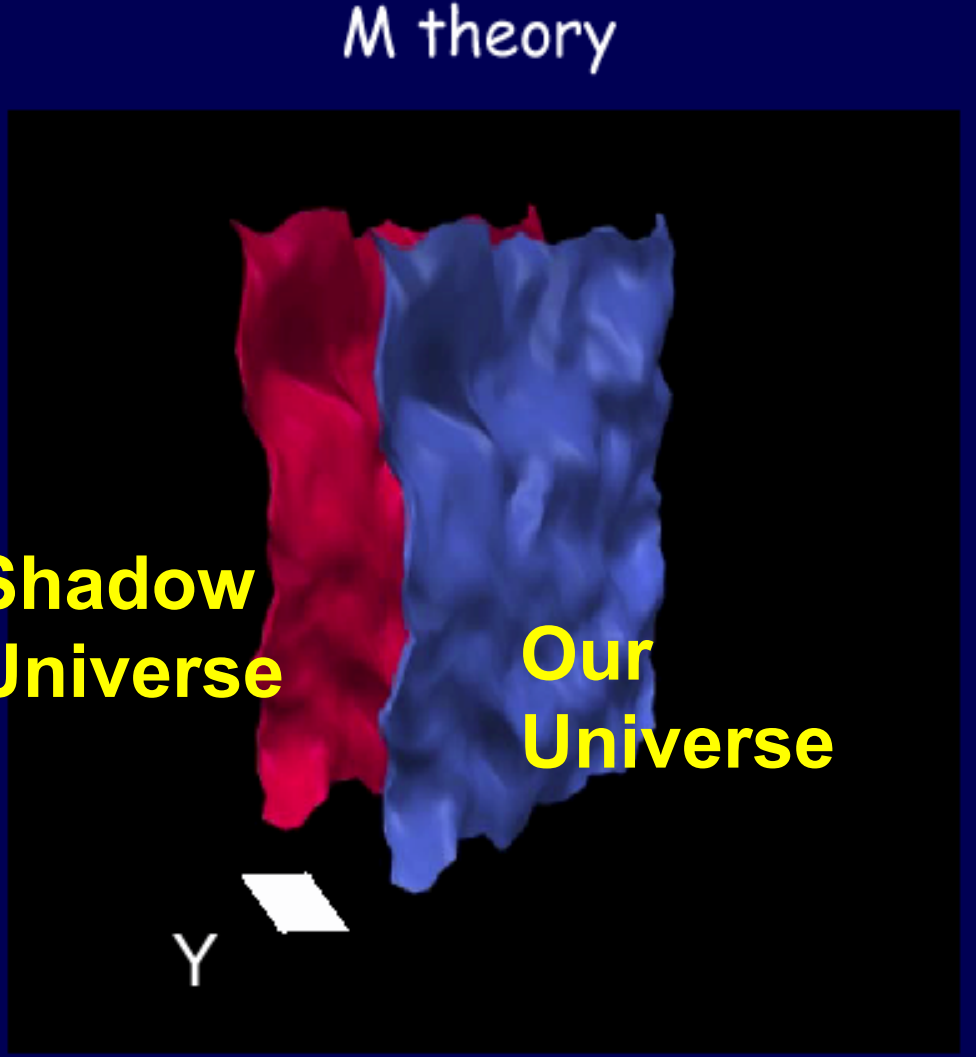
Origin of Consciousness



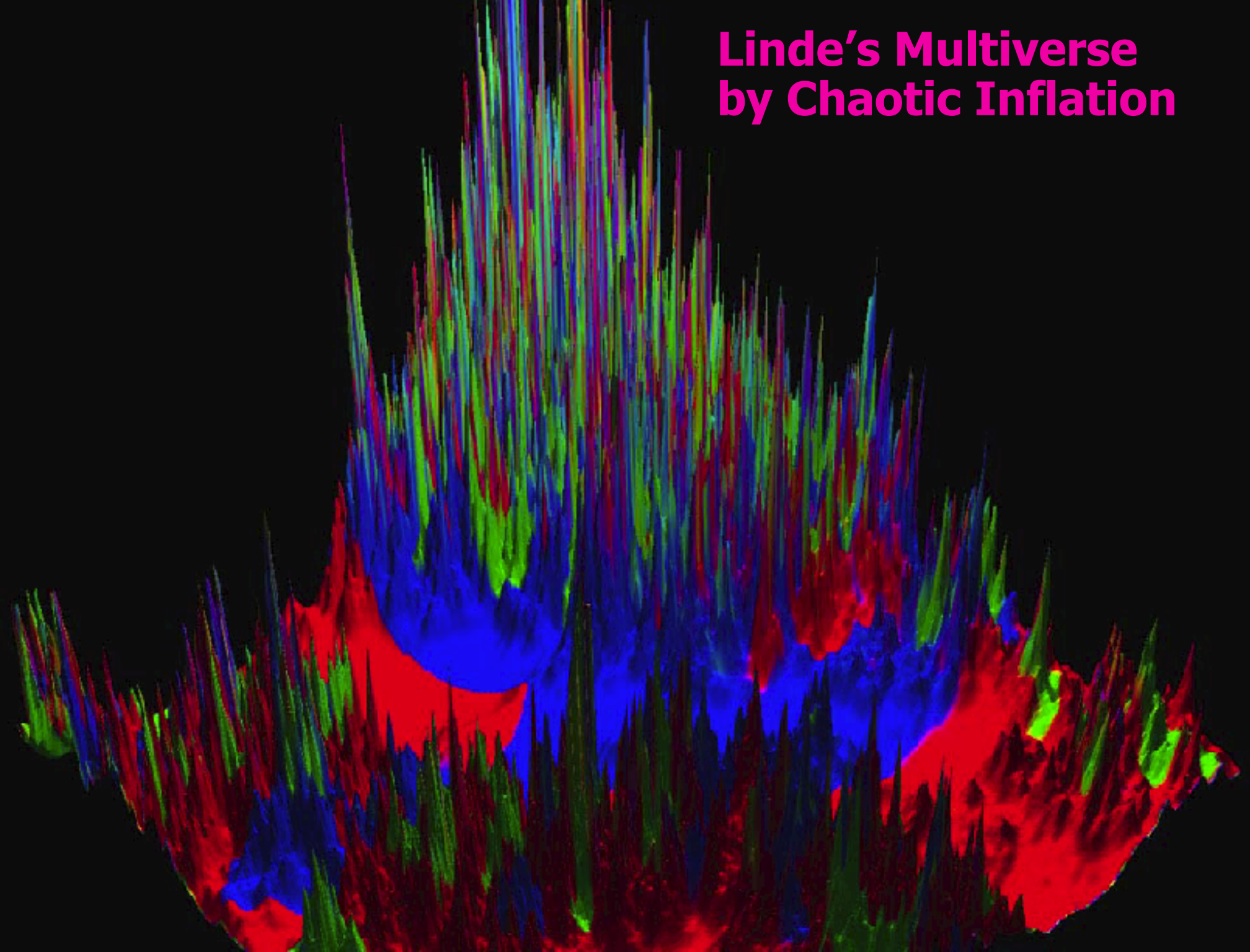
Why are we here?

Cyclic Model

"bang"
radiation
matter
dark energy
"contraction"
"crunch"

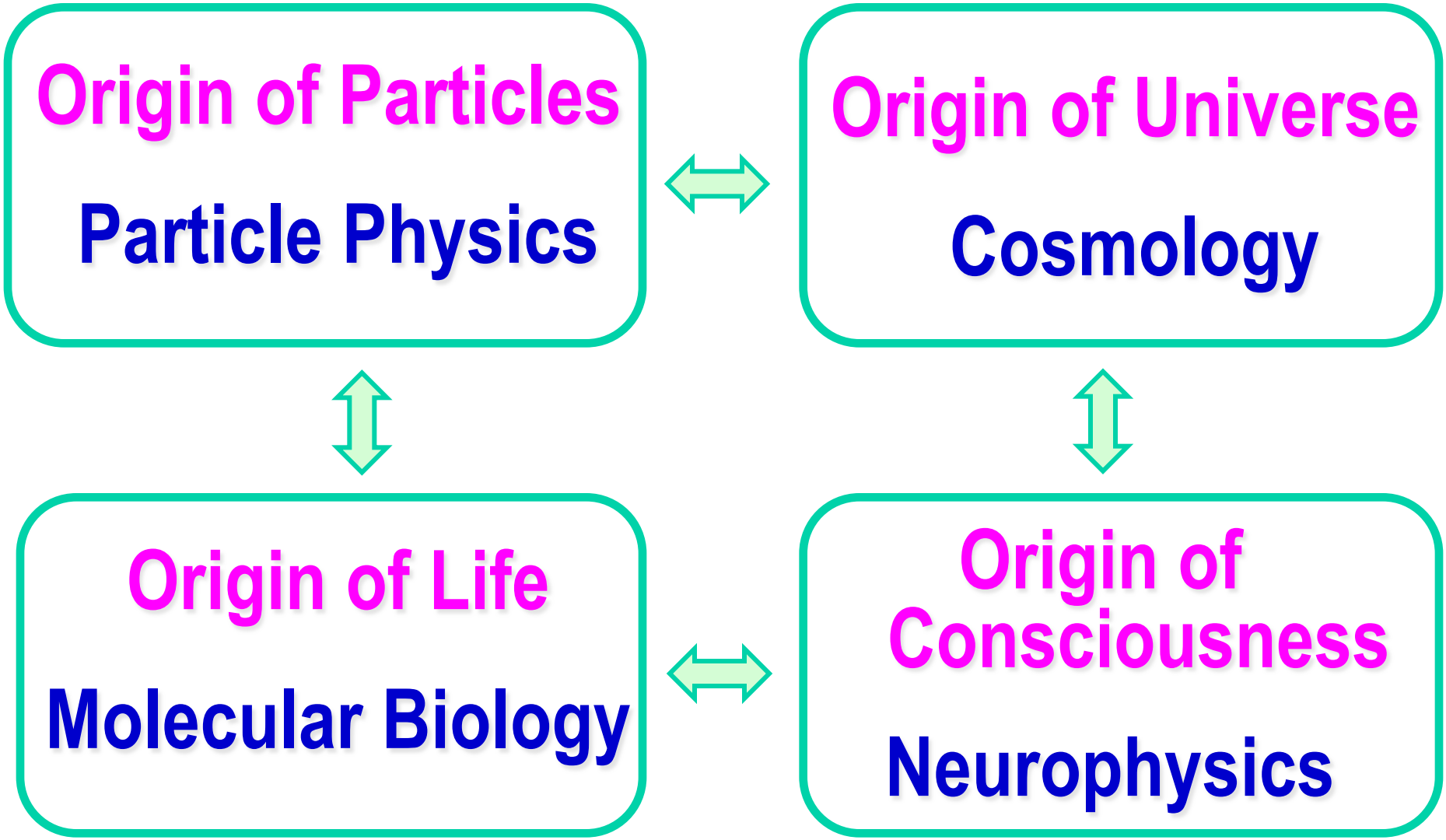


Are there more than one Universe?


Linde's Multiverse
by Chaotic Inflation


There may be ~100 Billion Universes.

Four Major Science



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)