Introduction to Physics Research
Origin of Universe and Ourselves

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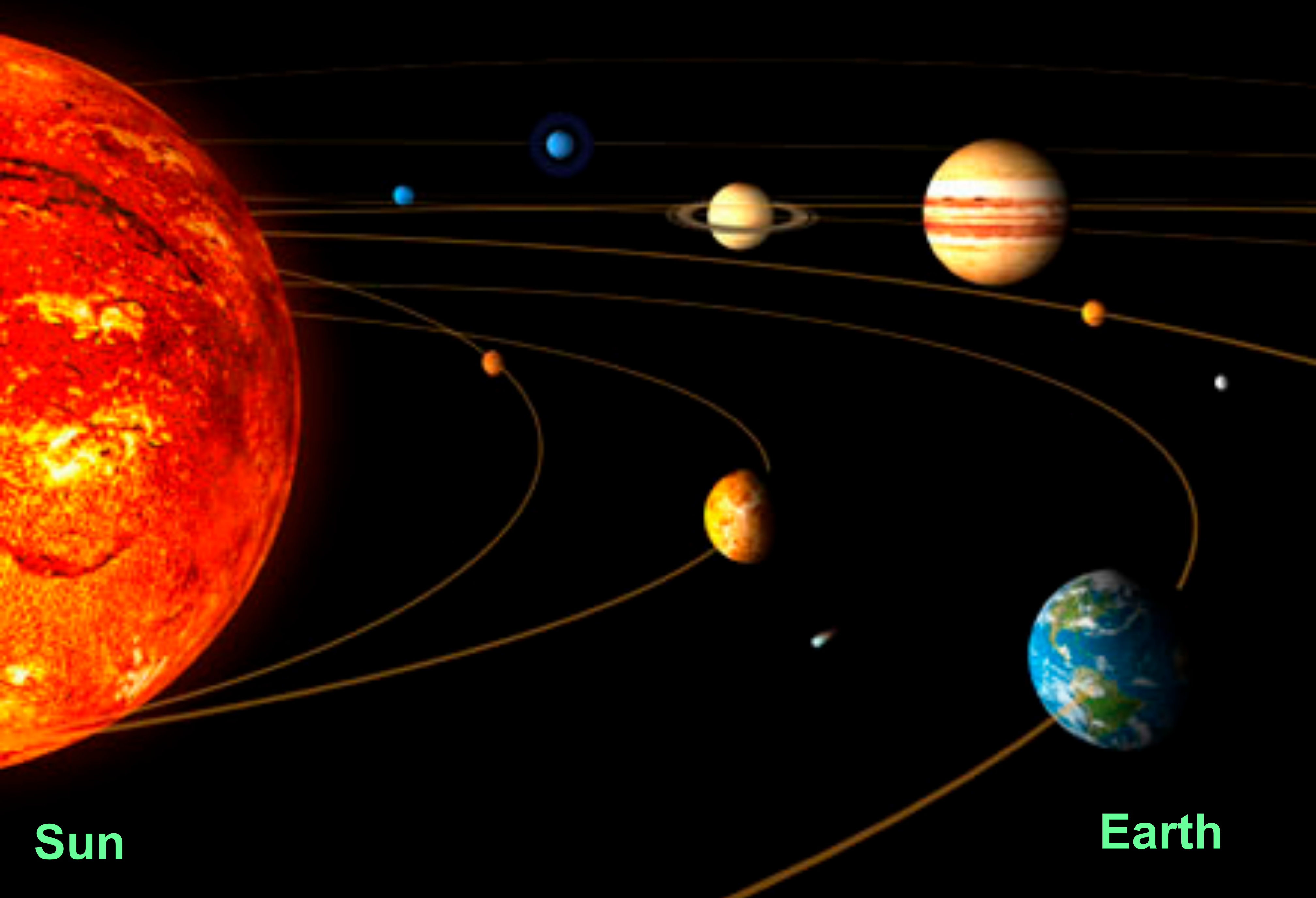
Why are we here?

Solar System



History of Life and the Human beings

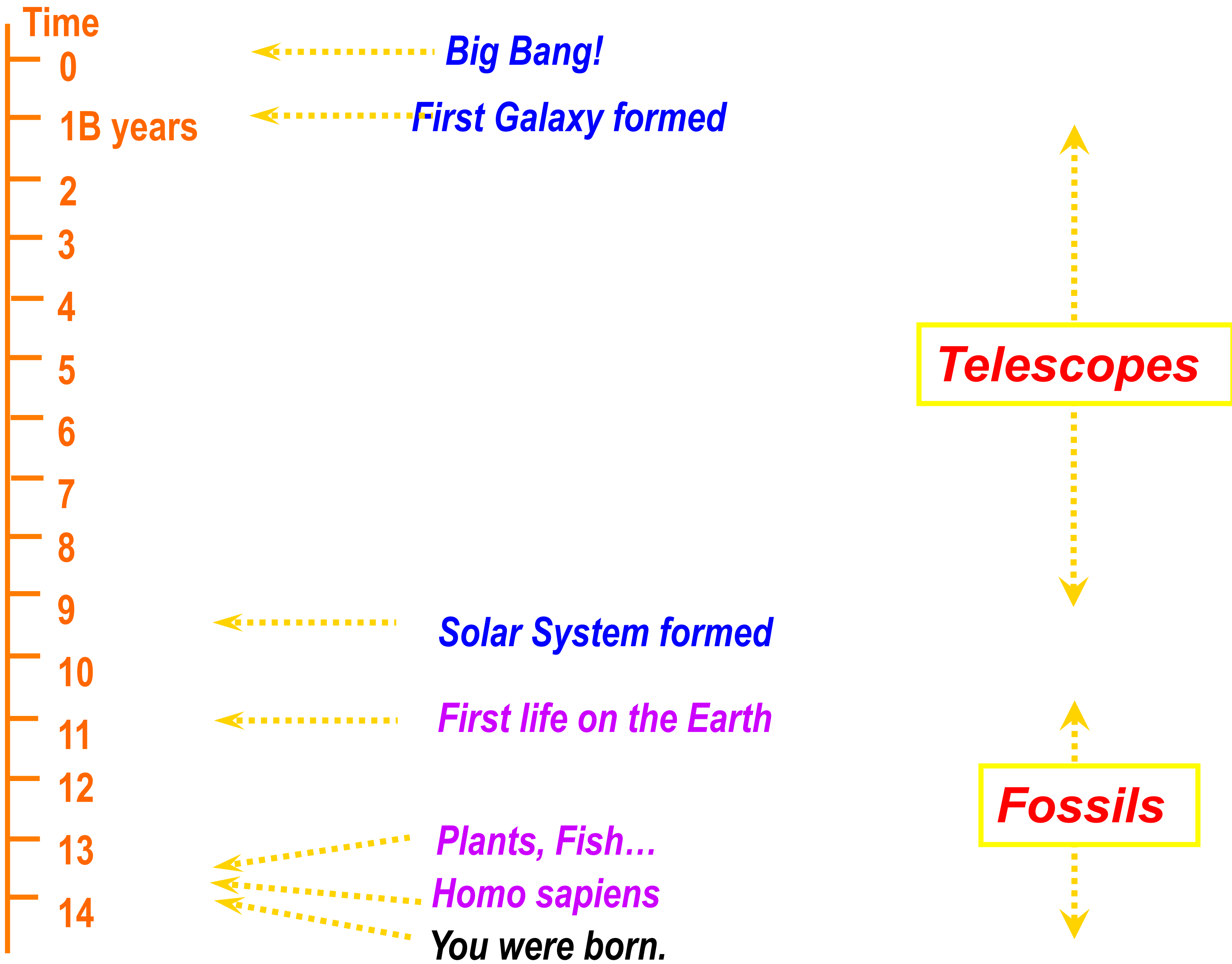
Time	
10B years	*Big Bang!*
	Solar System formed
1Billion	*First life on the Earth*
	Plants, Fish…
100M	
10M	*Mammals*
1Million	*Homo sapiens*
100,000	
10,000	
1,000	*Jesus Christ was born.*
100	*Einstein was born.*
10	*You were born.*
1 year	
100 days	
10 days	
1 day	
10 hours	
1 hour	*You woke up this morning.*
10 minutes	
1 minute	*You saw this viewgraph.*

Fossils

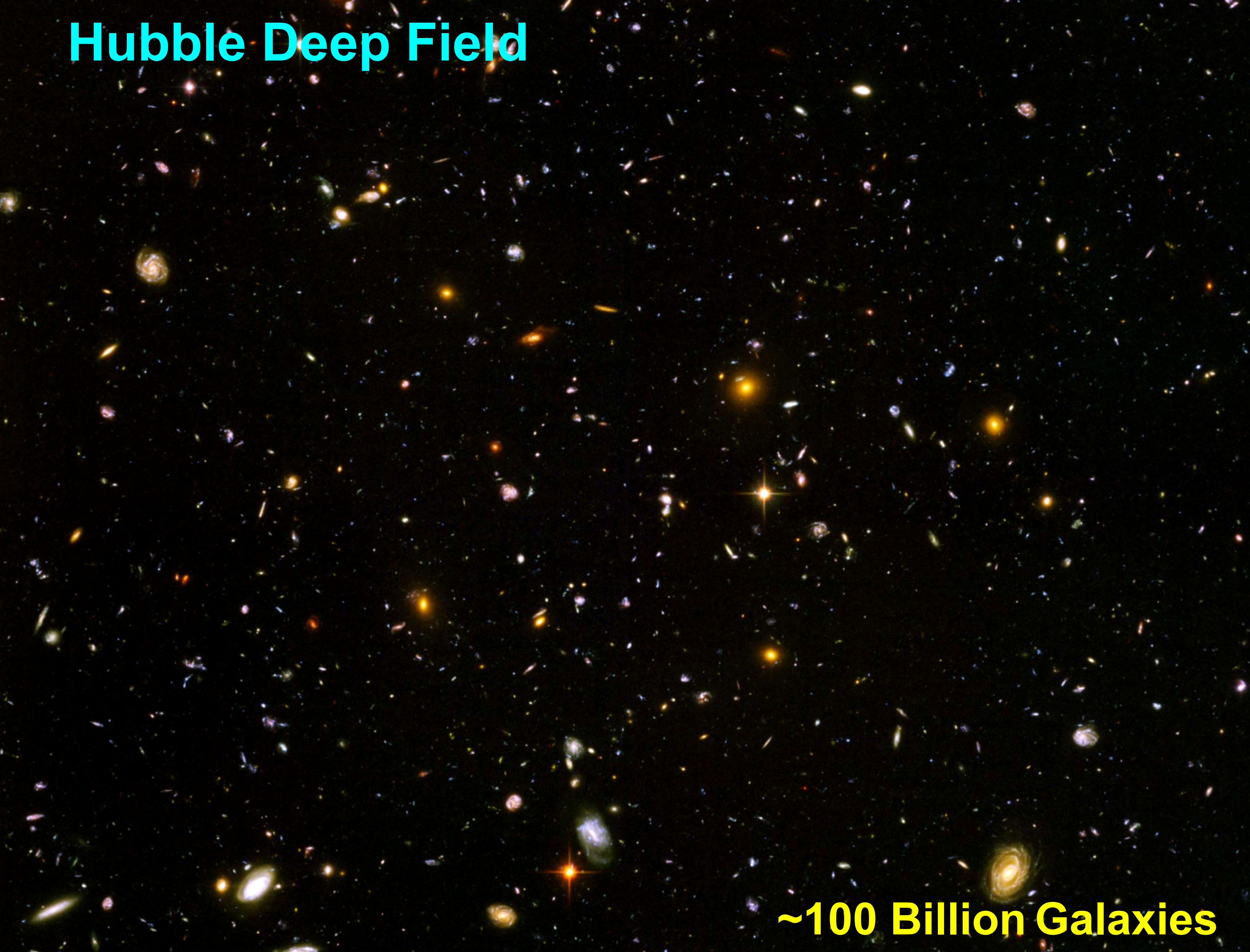
Written Documents

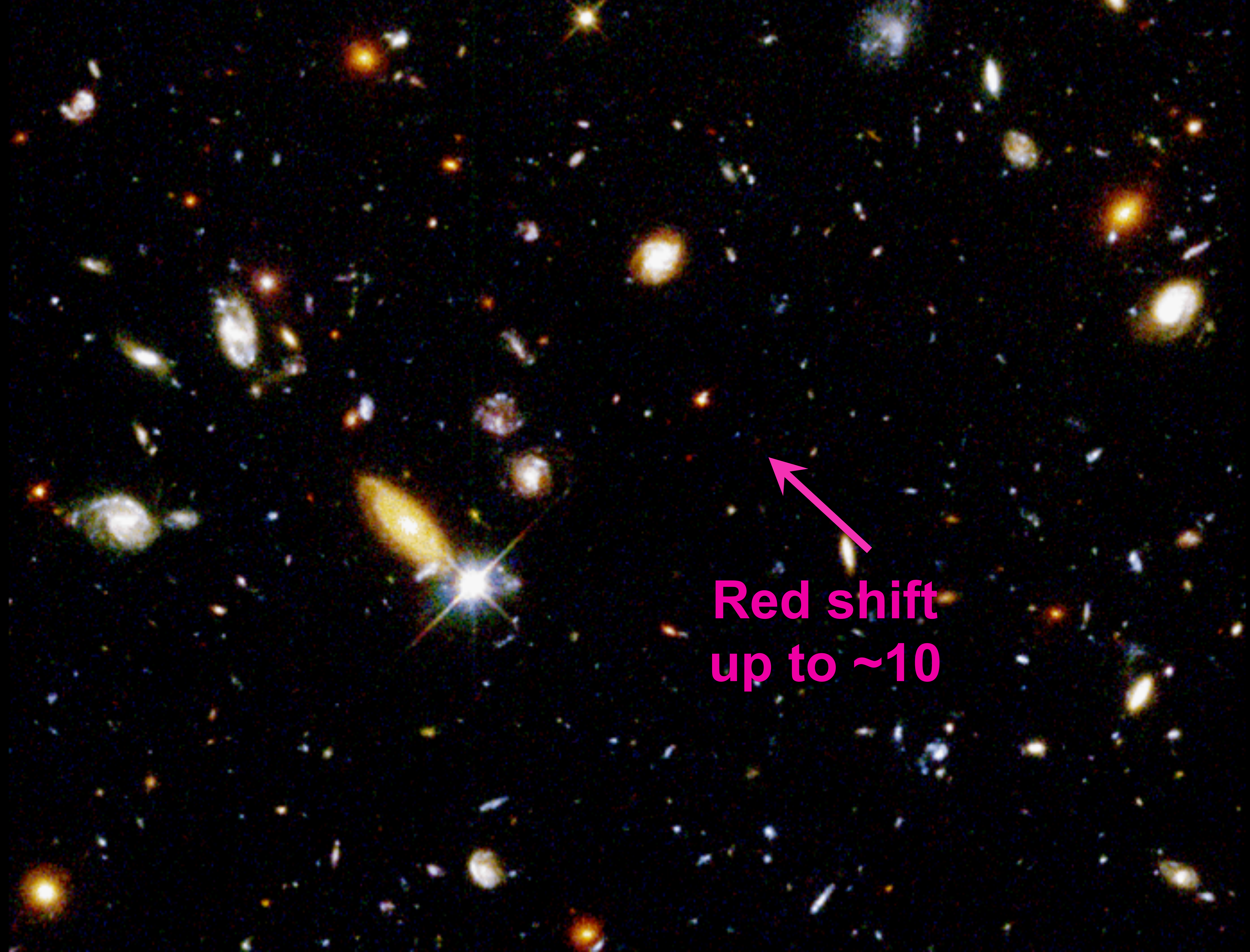
Videos, Pictures

Brief History of Universe and Life



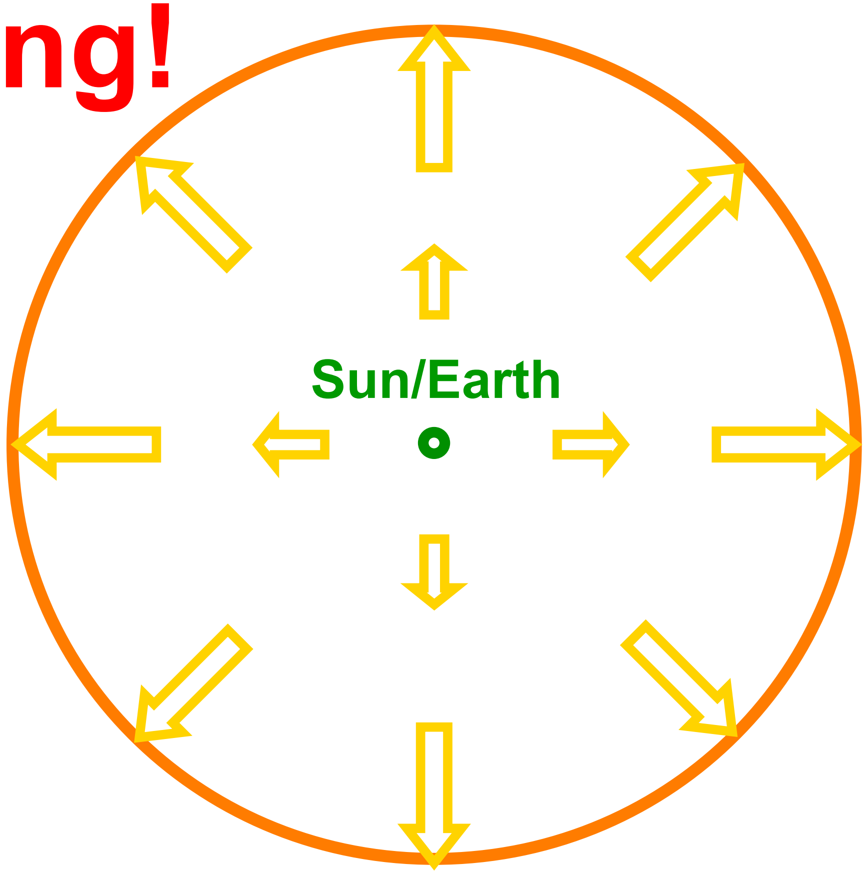

Andromeda
~100 Billions Stars in a Galaxy


Hubble Deep Field
~100 Billion Galaxies


Red shift
up to ~10

Hubble's Law: Expansion of the Universe

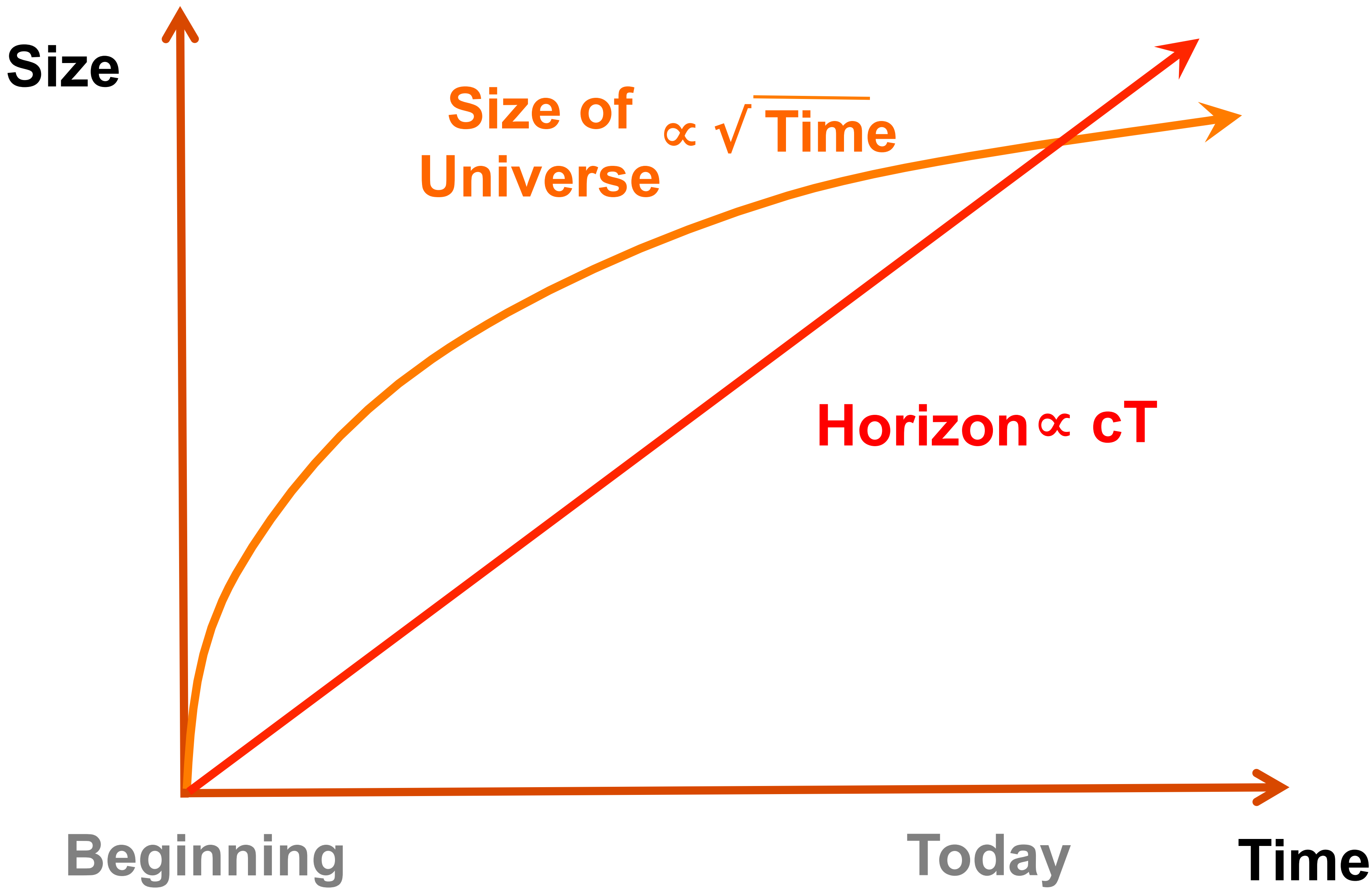
Big Bang!



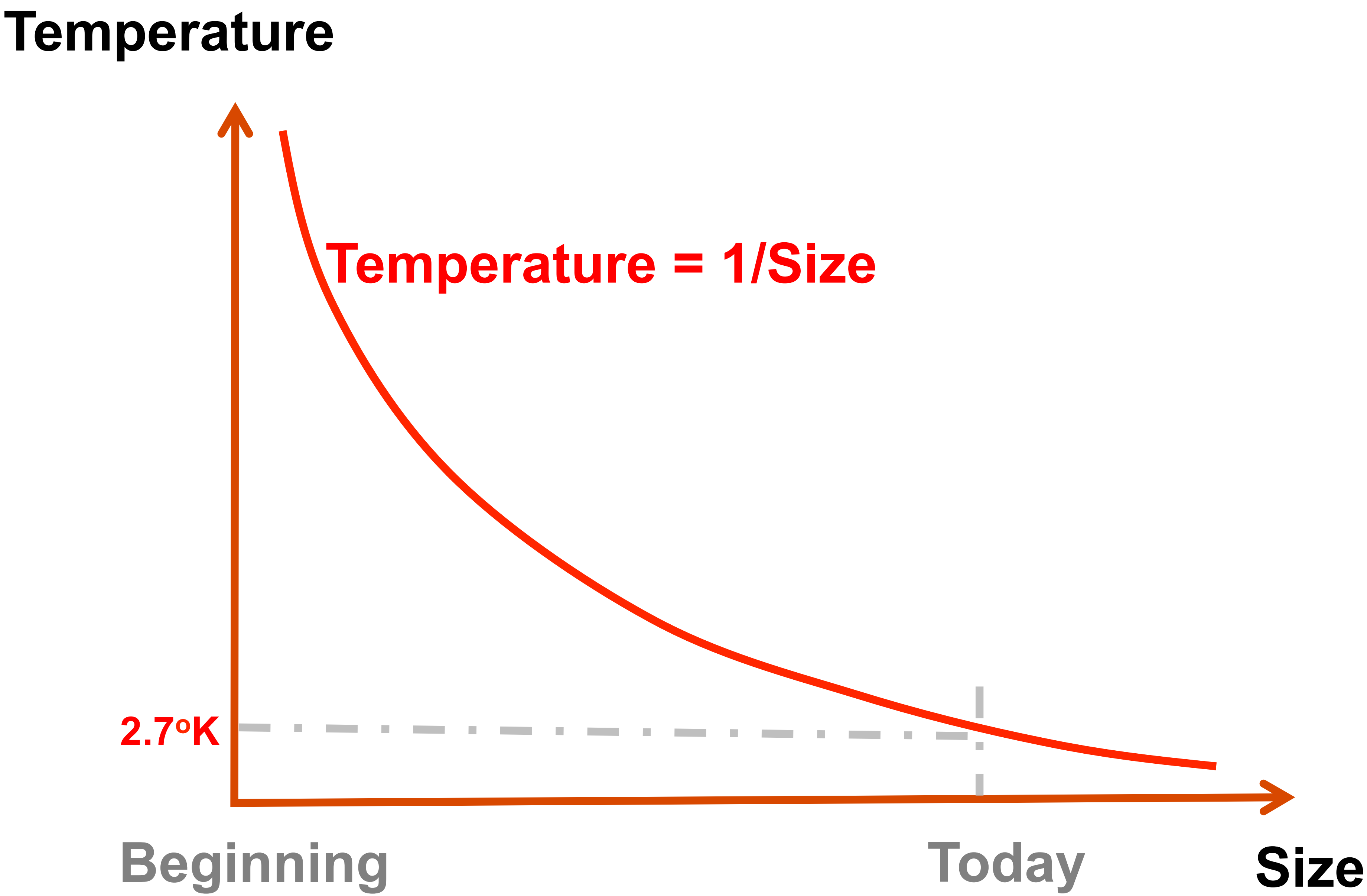
14 Billon Light Years

Moving Away at Speed of Light

Expansion of Universe

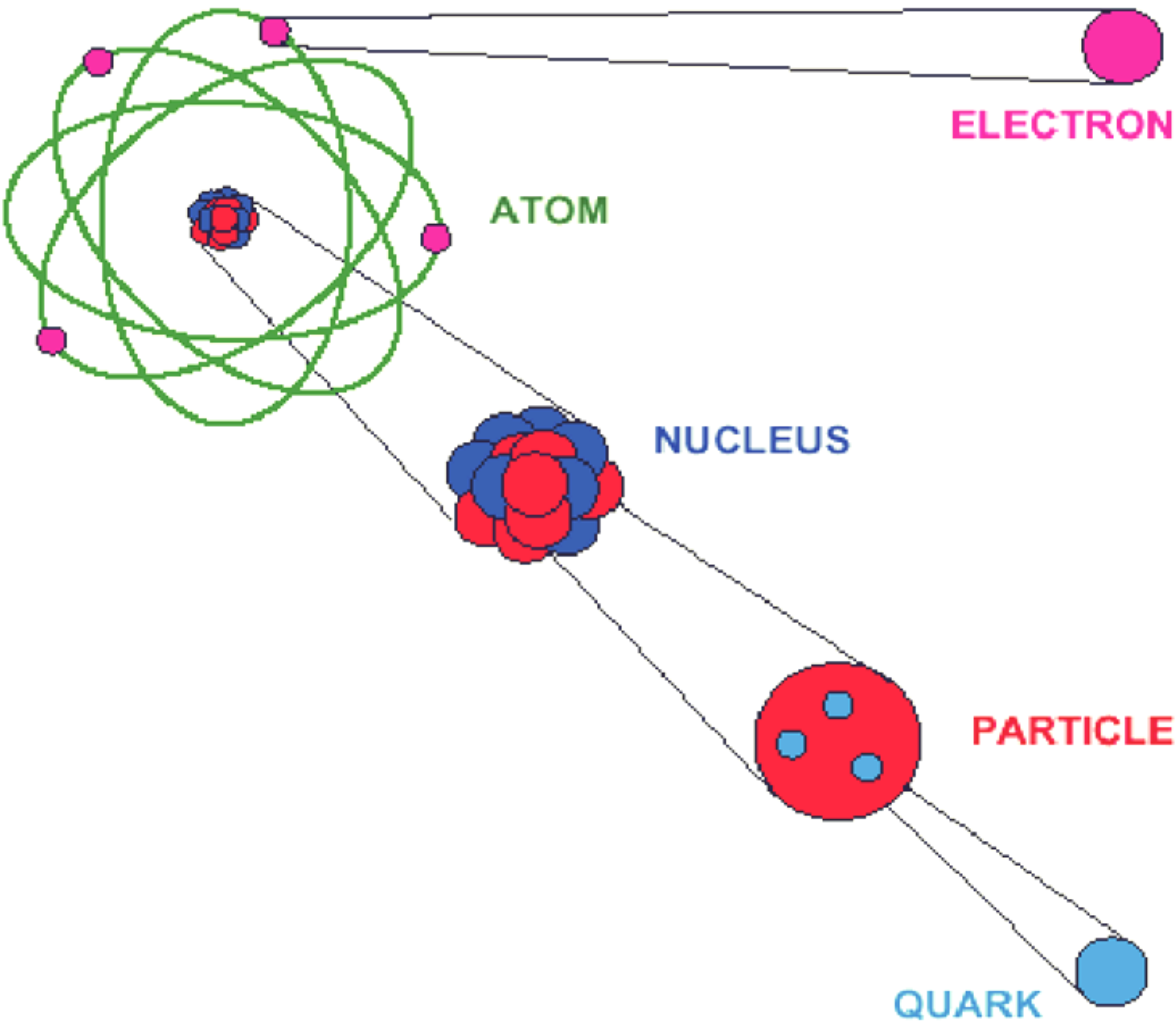


Temperature of Universe



Tevatron at Fermi Lab near Chicago (1980 – 2010)

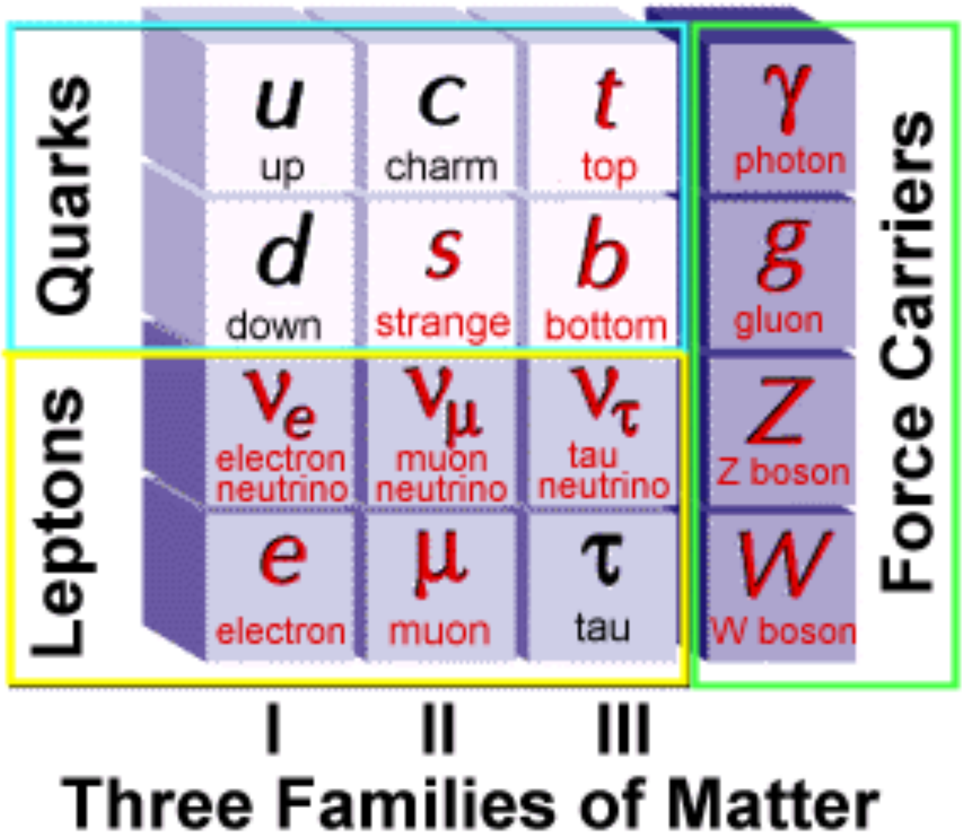
Elementary Particles



Elementary Particles

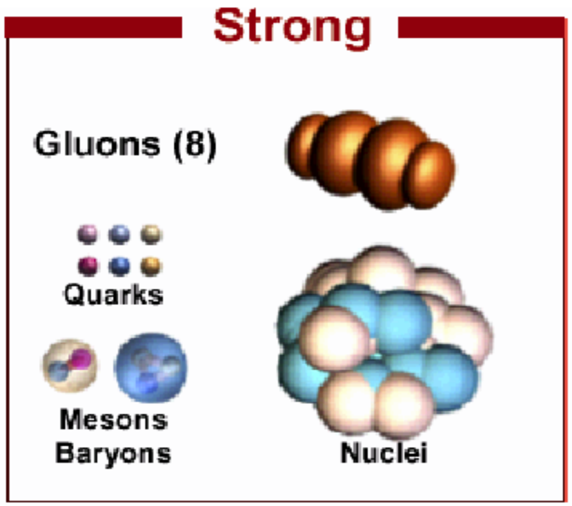
Fermion Boson

Charge		Charge
+2/3		0
-1/3		0
0		0
-1		±1

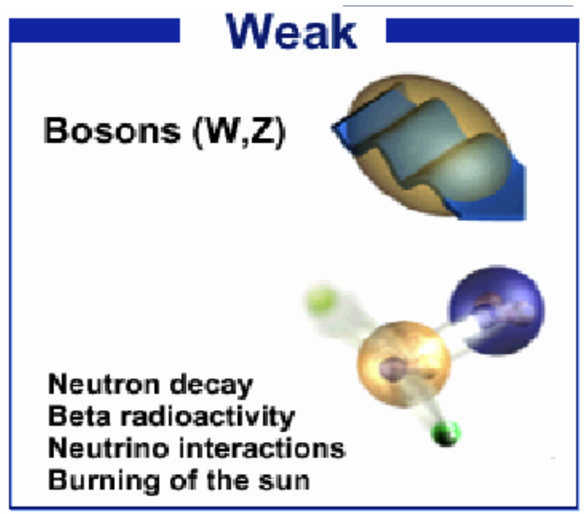


+ Anti-particles

Elementary Particles and Forces

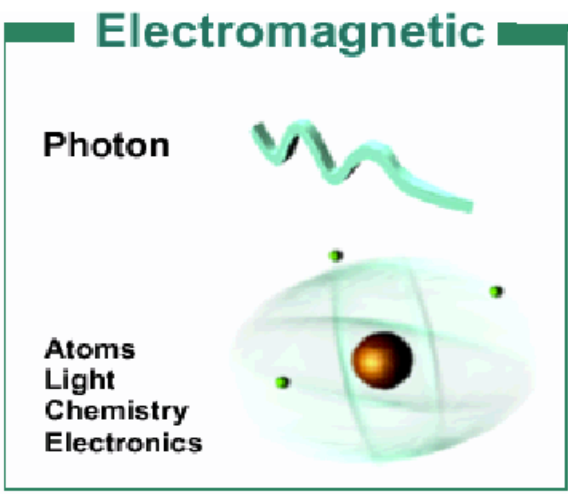


1

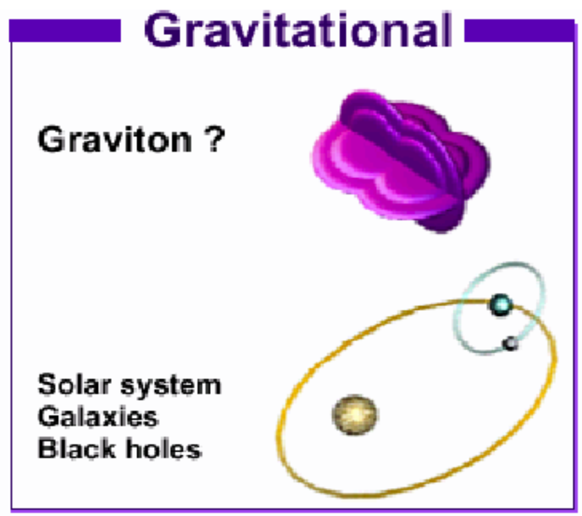


10^{-13}

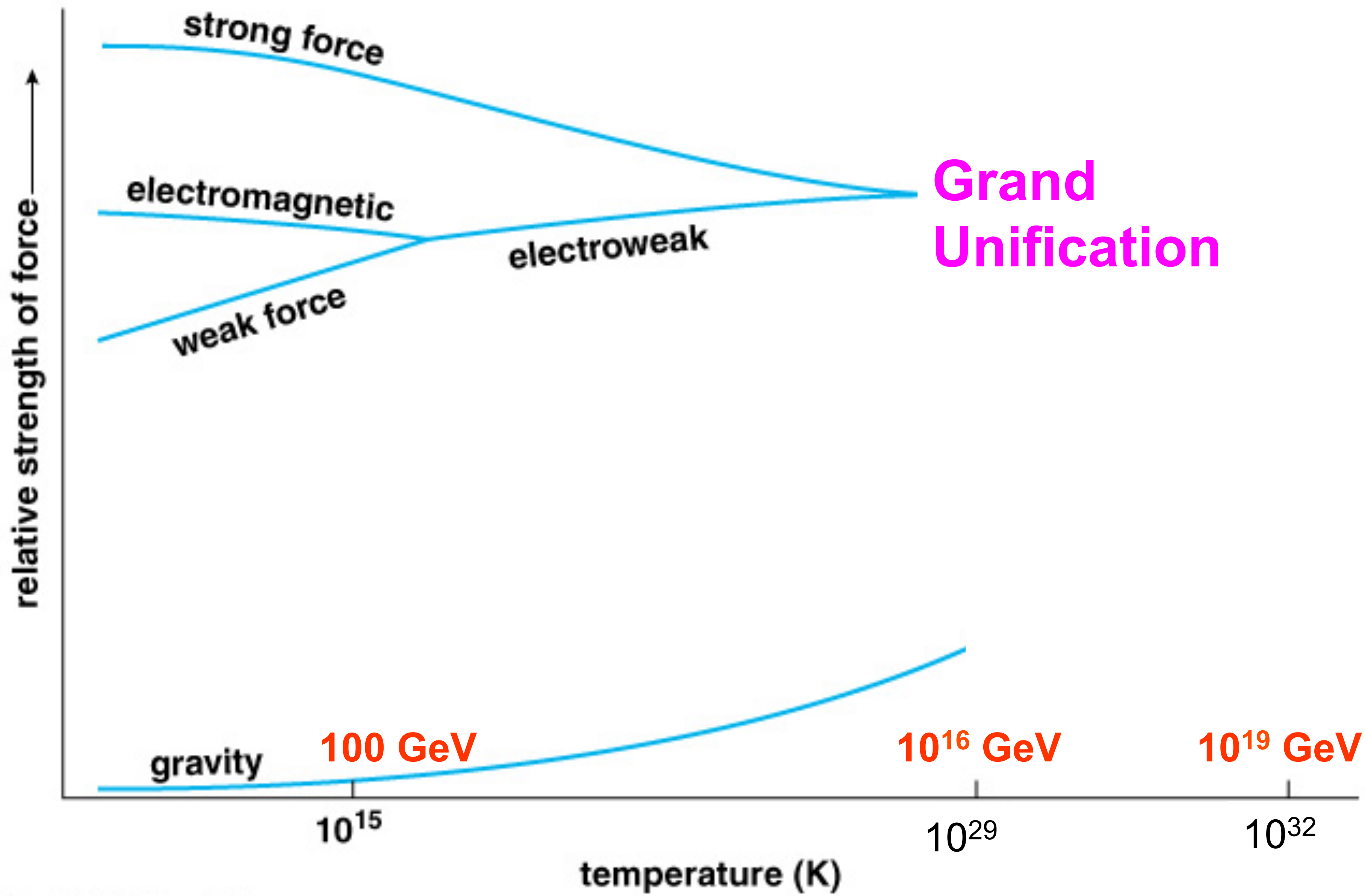
10^{-2}



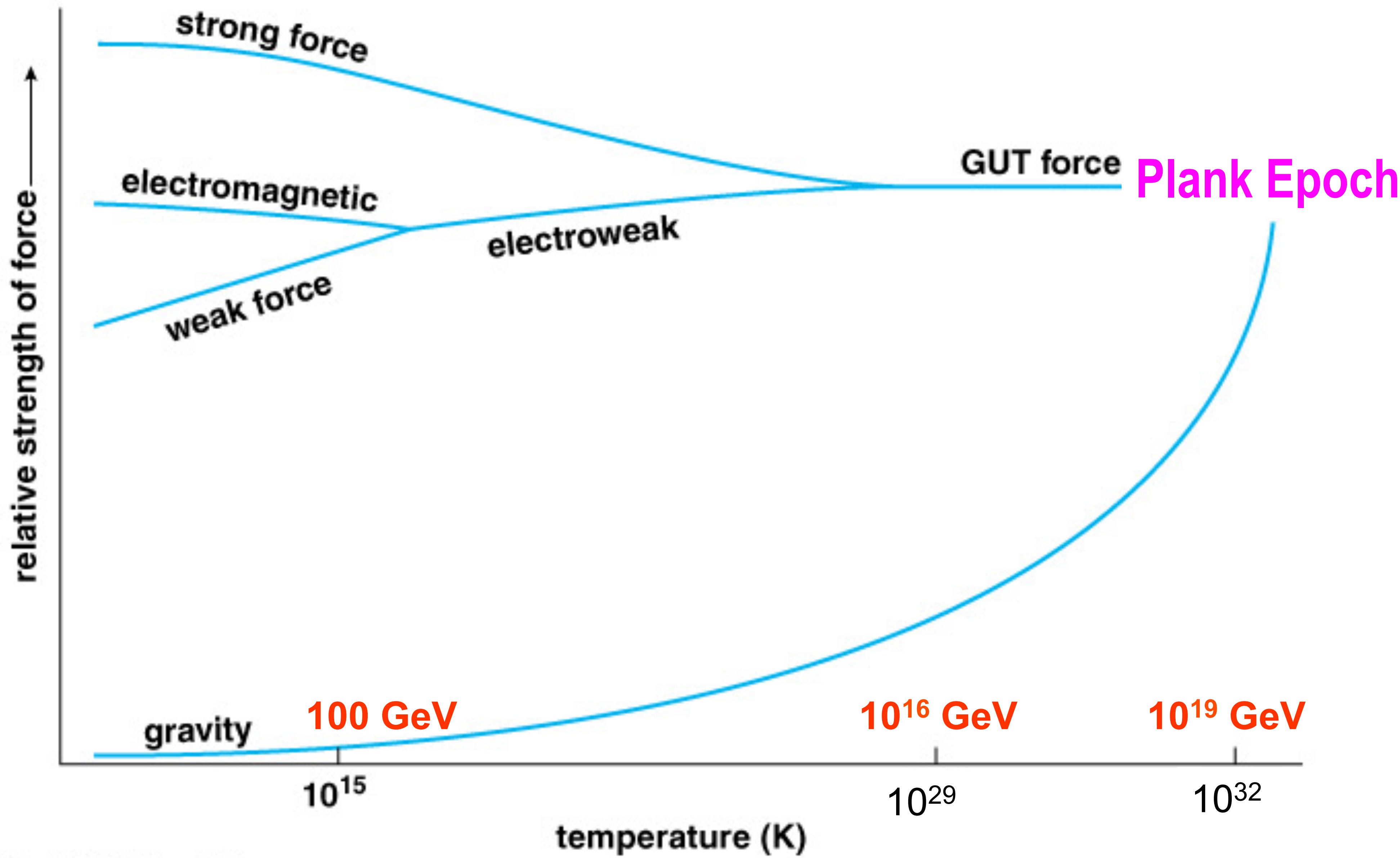
10^{-38}



Unification of Forces (1980)



Unification of Forces (1980)

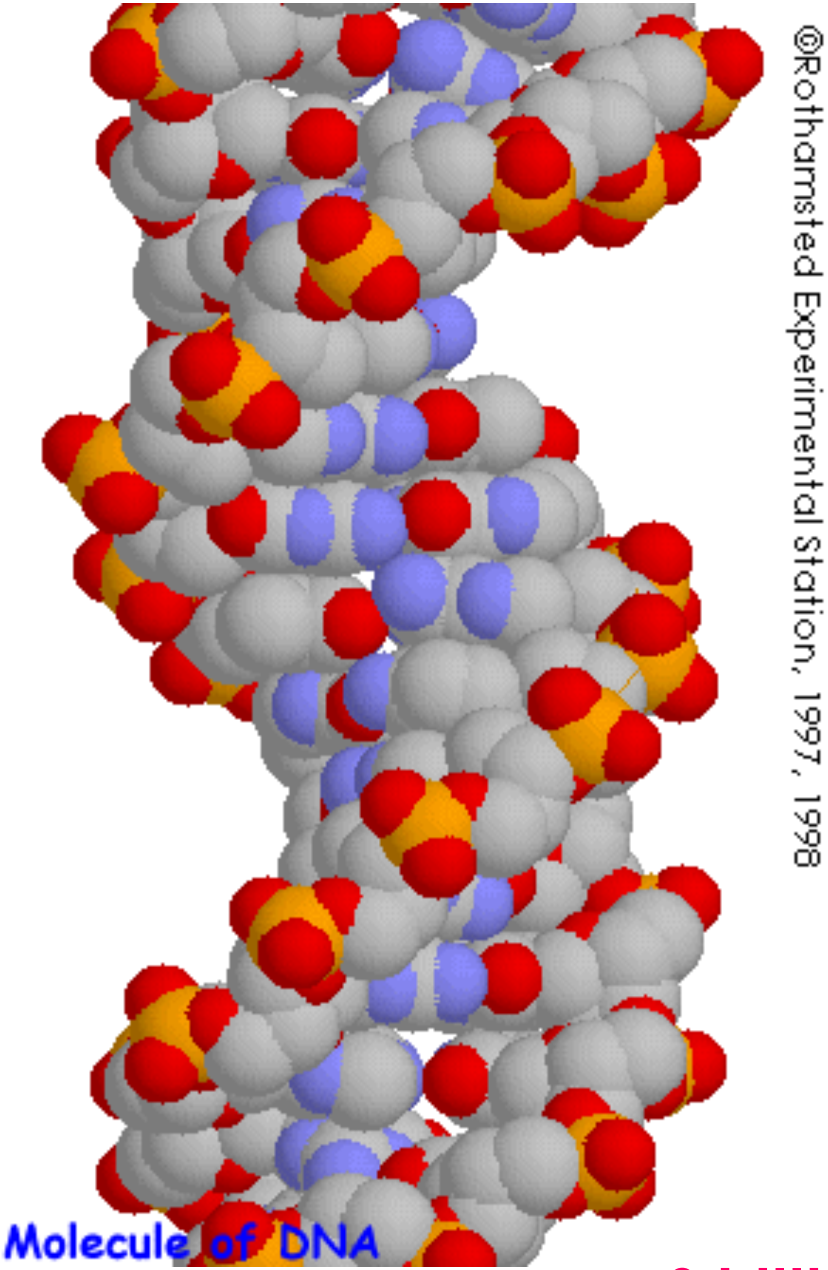


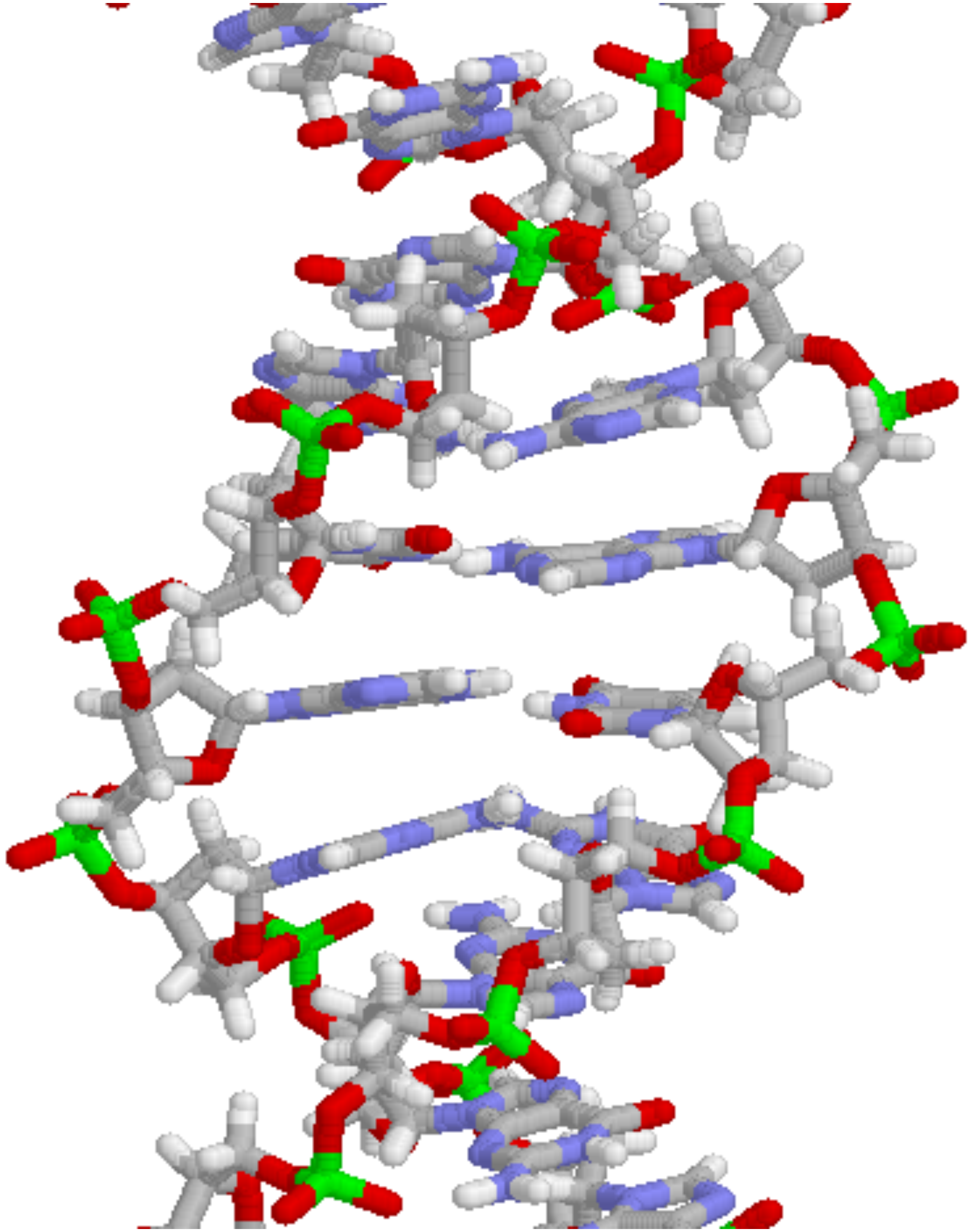
Physicists’ View of Early Universe

Fiat lux

Let there be light

Structure of DNA





3 billion base pairs

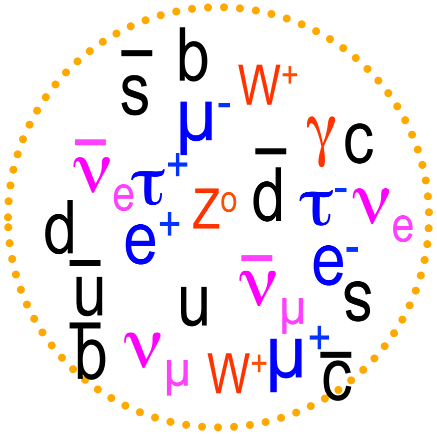
Symmetry Breaking

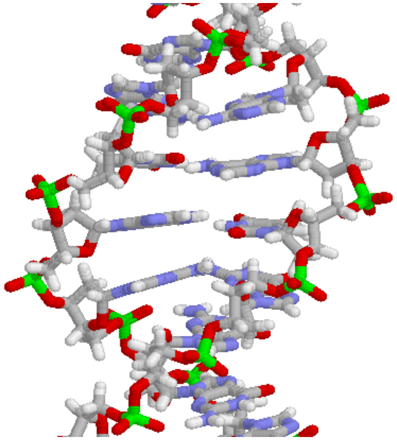
Time
0
1B years
2
3
4
5
6
7
8
9
10
11
12
13
14

Simple

Symmetry Break Down

Complex





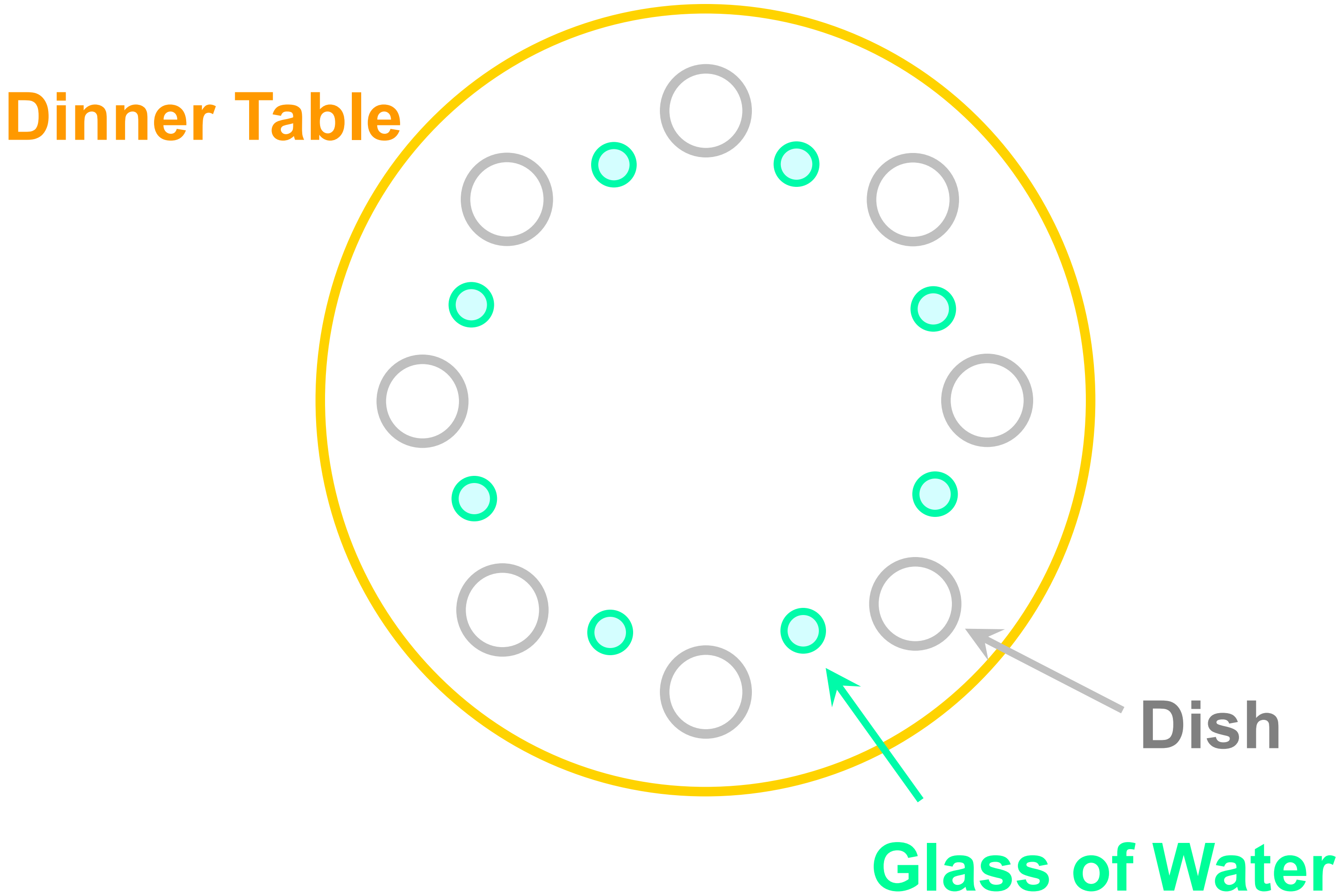
The Beginning

- Everything was the same ↔ Perfect symmetry.
  - All the particles are the same as photons.
  - All four forces are the same.

- The Universe was <u>10 dimension</u>.

4	3	Space	→	*Flattened*
	1	Time		
6	3	Strong Force		*Compacitified*
	2	Weak		
	1	Electro-Magnetic		

Spontaneous Symmetry Breakdown at a Dinner Table

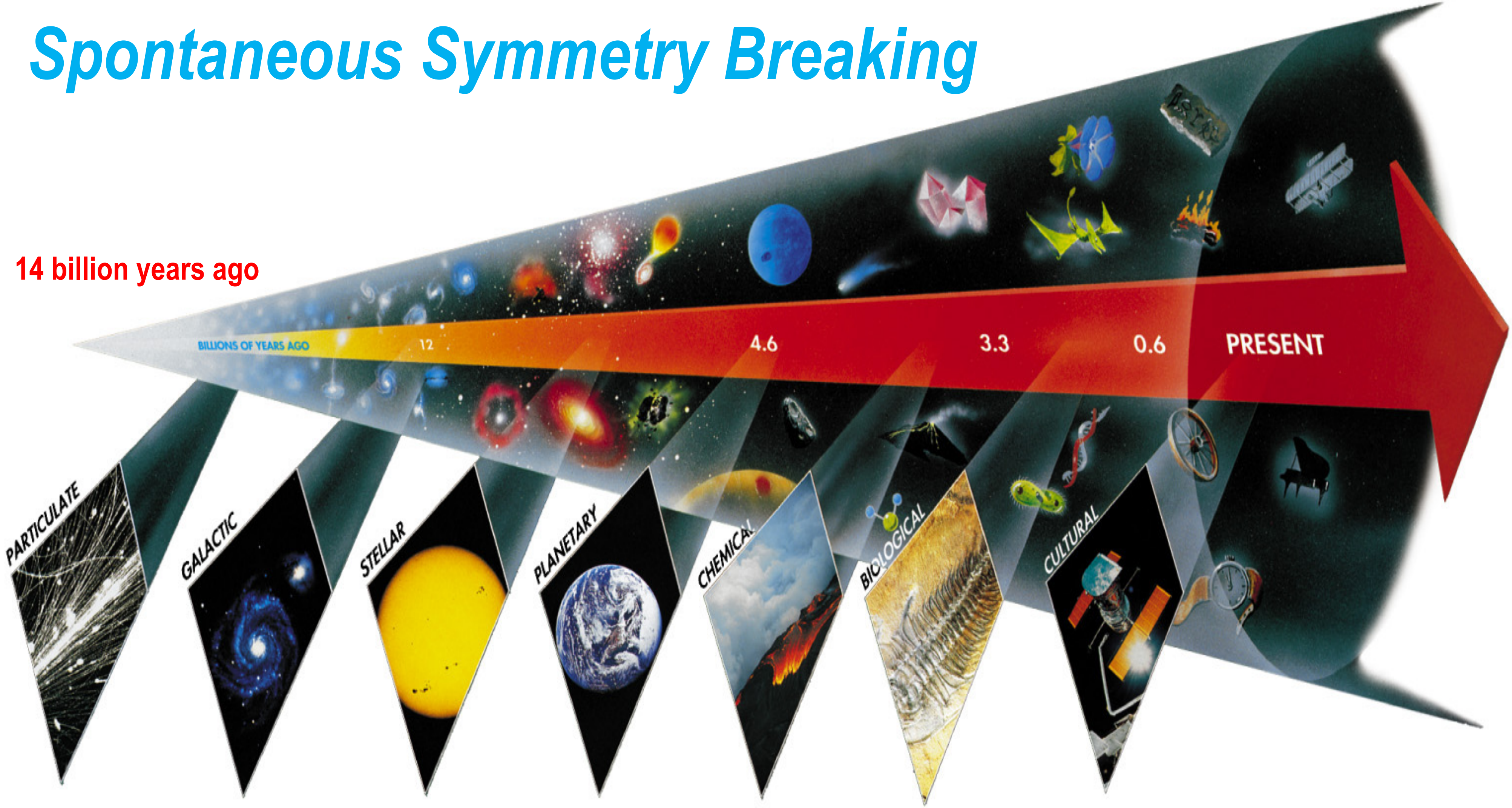


by Nambu Yoichiro

Seven Phases of Cosmic Evolution

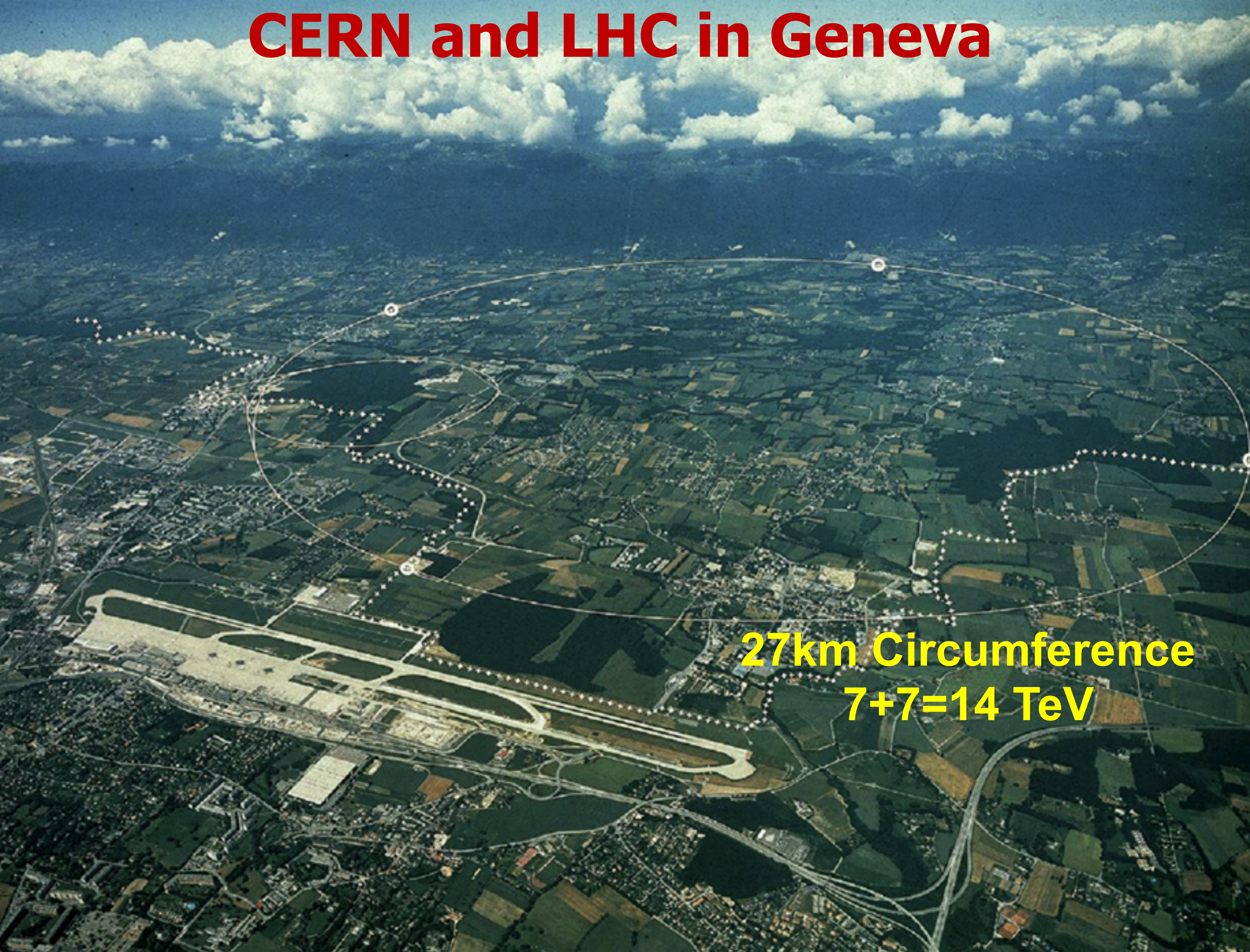
Spontaneous Symmetry Breaking

14 billion years ago



Origin of Particles

CERN and LHC in Geneva



LHC Tunnel with Magnets

CMS Collaboration (1993 ~)

(144 Institutions with about 1700 scientists)

ARMENIA
- Yerevan Physics Inst., Yerevan

AUSTRIA
- HEPHY, Wien

BELARUS
- Institute of Nuclear Problems, Minsk
- National Centre of Part. and HEP, Minsk
- Res. Inst. of Applied Physical Probl., Minsk
- Byelorussian State Univ., Minsk

BELGIUM
- Univ. Instelling Antwerpen, Wilrijk
- Univ. Libre de Bruxelles, Brussels
- Vrije Universiteit Brussel, Brussels
- Univ. Catholique de Louvain, Louvain-la-Neuve
- Univ. de Mons-Hainaut, Mons

BULGARIA
- Inst. for Nucl. Res. and Nucl. Energy, Sofia
- Univ. of Sofia, Sofia

CHINA, PR
- Inst. of High Energy Physics, Beijing
- Peking Univ., Beijing
- Univ. for Science & Tech. of China, Hefei, Anhui

CROATIA
- Tech. Univ.of Split, Split
- Univ. of Split, Split

CYPRUS
- Univ. of Cyprus, Nicosia

ESTONIA
- Inst. of Chemical Phys. and Biophys., Tallinn

FINLAND
- Helsinki Institute of Physics, Helsinki
- Dpt.of Phys., Univ.of Helsinki, Helsinki
- Univ. of Jyväskylä, Jyväskylä
- Helsinki University of Technology, Helsinki
- Univ. of Oulu, Oulu
- Tampere Univ. of Tech., Tampere

FRANCE
- LAPP, IN2P3-CNRS, Annecy-le-Vieux
- IPN, IN2P3-CNRS, Univ. Lyon I, Villeurbanne
- LPNHE, Ecole Polytech., IN2P3-CNRS, Palaiseau
- DSM/DAPNIA, CEA/Saclay, Gif-sur-Yvette
- IRES, IN2P3-CNRS - ULP, UHA, LEPSI, Strasbourg

GEORGIA
- High Energy Phys. Inst., Tbilisi State Univ., Tbilisi
- Inst. of Physics Academy of Science, Tbilisi

GERMANY
- RWTH, I. Physik. Inst., Aachen
- RWTH, III. Physik. Inst. A, Aachen
- RWTH, III. Physik. Inst. B, Aachen
- Humboldt-Univ. zu Berlin, Berlin
- Inst. für Exp. Kernphysik, Karlsruhe

GREECE
- Univ. of Athens, Athens
- Inst. of Nucl. Phys. "Demokritos", Attiki
- Univ. of Ioánnina, Ioánnina

HUNGARY
- KFKI Res. Inst. for Part. & Nucl. Phys., Budapest
- Kossuth Lajos Univ., Debrecen
- Institute of Nuclear Research ATOMKI, Debrecen

INDIA
- Panjab Univ., Chandigarh
- Bhabha Atomic Res. Centre, Mumbai
- Univ. of Delhi South Campus, New Delhi
- TIFR - EHEP, Mumbai
- TIFR - HECR, Mumbai

ITALY
- Univ. di Bari e Sez. dell' INFN, Bari
- Univ. di Bologna e Sez. dell' INFN, Bologna
- Univ. di Catania e Sez. dell' INFN, Catania
- Univ. di Firenze e Sez. dell' INFN, Firenze
- Univ. di Genova e Sez. dell' INFN, Genova
- Univ. di Padova e Sez. dell' INFN, Padova
- Univ. di Pavia e Sez. dell' INFN, Pavia
- Univ. di Perugia e Sez. dell' INFN, Perugia
- Univ. di Pisa e Sez. dell' INFN, Pisa
- Univ. di Roma I e Sez. dell' INFN, Roma
- Univ. di Torino e Sez. dell'INFN, Torino

KOREA
- Cheju National University, Cheju
- Chonnam National University, Kwangju
- Choongbuk National University, Chongju
- Dongshin University, Naju
- Kangnung National University, Kangnung
- Kangwon National University, Chunchon
- Kon-Kuk University, Seoul
- Korea University, Seoul
- Kyungpook National University, Taegu
- Pohang University of Science and Technology, Pohang
- Gyeongsang National University, Jinju
- Seonam University, Namwon
- Seoul National Univ. of Education, Seoul
- Wonkwang University, Iri

PAKISTAN
- Quaid-I-Azam Univ., Islamabad
- Ghulam Ishaq Khan Institute, Swabi

POLAND
- Inst. of Exp. Phys., Warsaw
- Soltan Inst. for Nucl. Studies, Warsaw

PORTUGAL
- LIP, Lisboa

RUSSIA
- JINR, Dubna
- Inst. for Nucl. Res., Moscow
- Inst. for Theoretical and Exp. Phys., Moscow
- P.N. Lebedev Phys. Inst., Moscow
- Moscow State Univ., Moscow
- Budker Inst. for Nucl. Phys., Novosibirsk
- Inst. for High Energy Phys., Protvino
- Petersburg Nucl. Phys. Inst., Gatchina (St Petersburg)

SLOVAK REPUBLIC
- Slovak University of Technology, Bratislava

SPAIN
- CIEMAT, Madrid
- Univ. Autónoma de Madrid, Madrid
- Univ. de Oviedo, Oviedo
- IFCA, CSIC-Univ. de Cantabria, Santander

SWITZERLAND
- Univ. Basel, Basel
- CERN, Geneva
- Paul Scherrer Inst., Villigen
- Inst. für Teilchenphysik, ETH, Zurich
- Univ. Zürich, Zurich

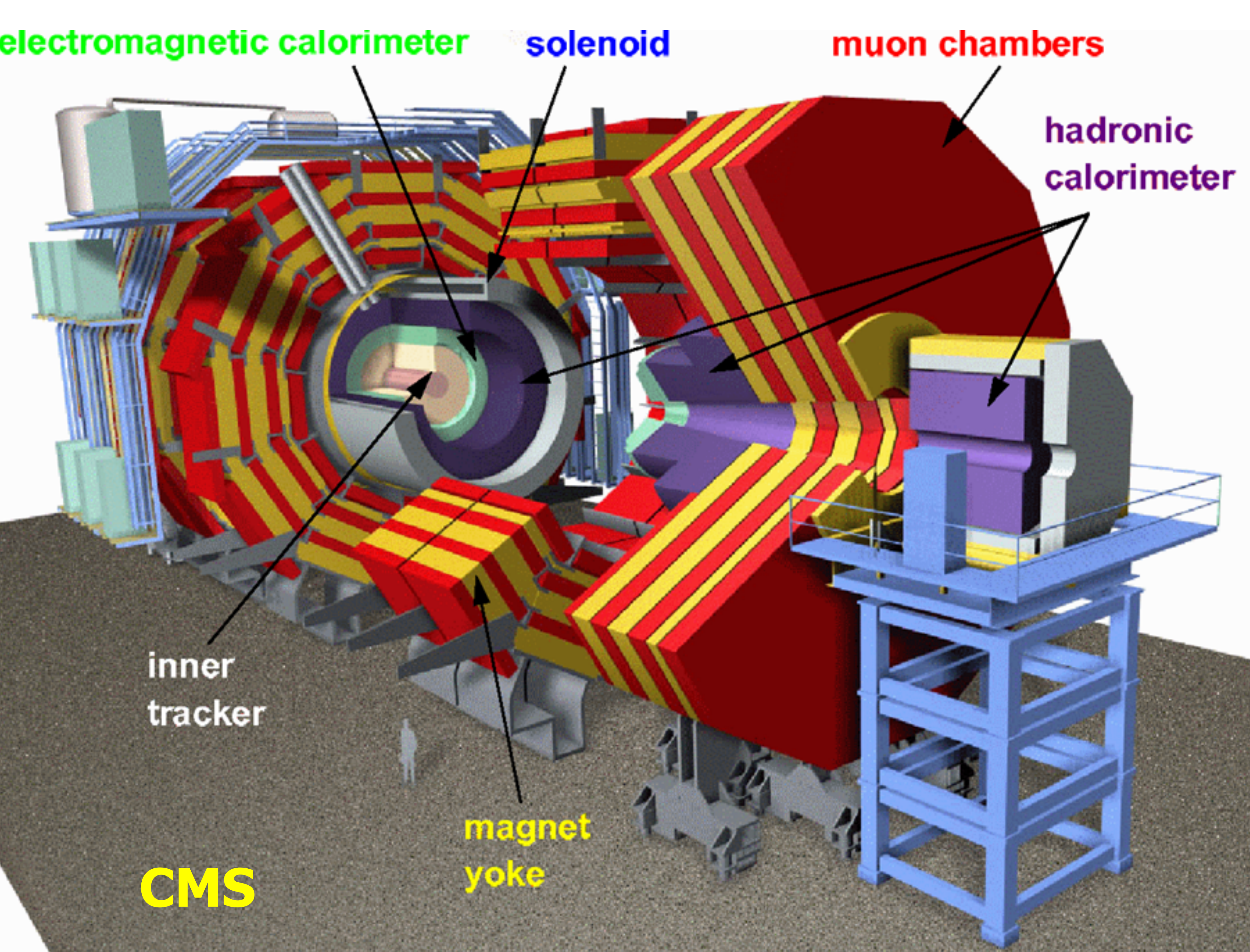
TURKEY
- Cukurova Univ., Adana
- Middle East Technical Univ., Ankara

UKRAINE
- Inst. of Single Crystals of Nat. Acad. of Science, Kharkov
- Kharkov Inst. of Phys. and Tech., Kharkov
- Kharkov State Univ., Kharkov

UNITED KINGDOM
- Univ. of Bristol, Bristol
- Brunel Univ., Uxbridge
- Imperial College, Univ. of London, London
- RAL, Didcot

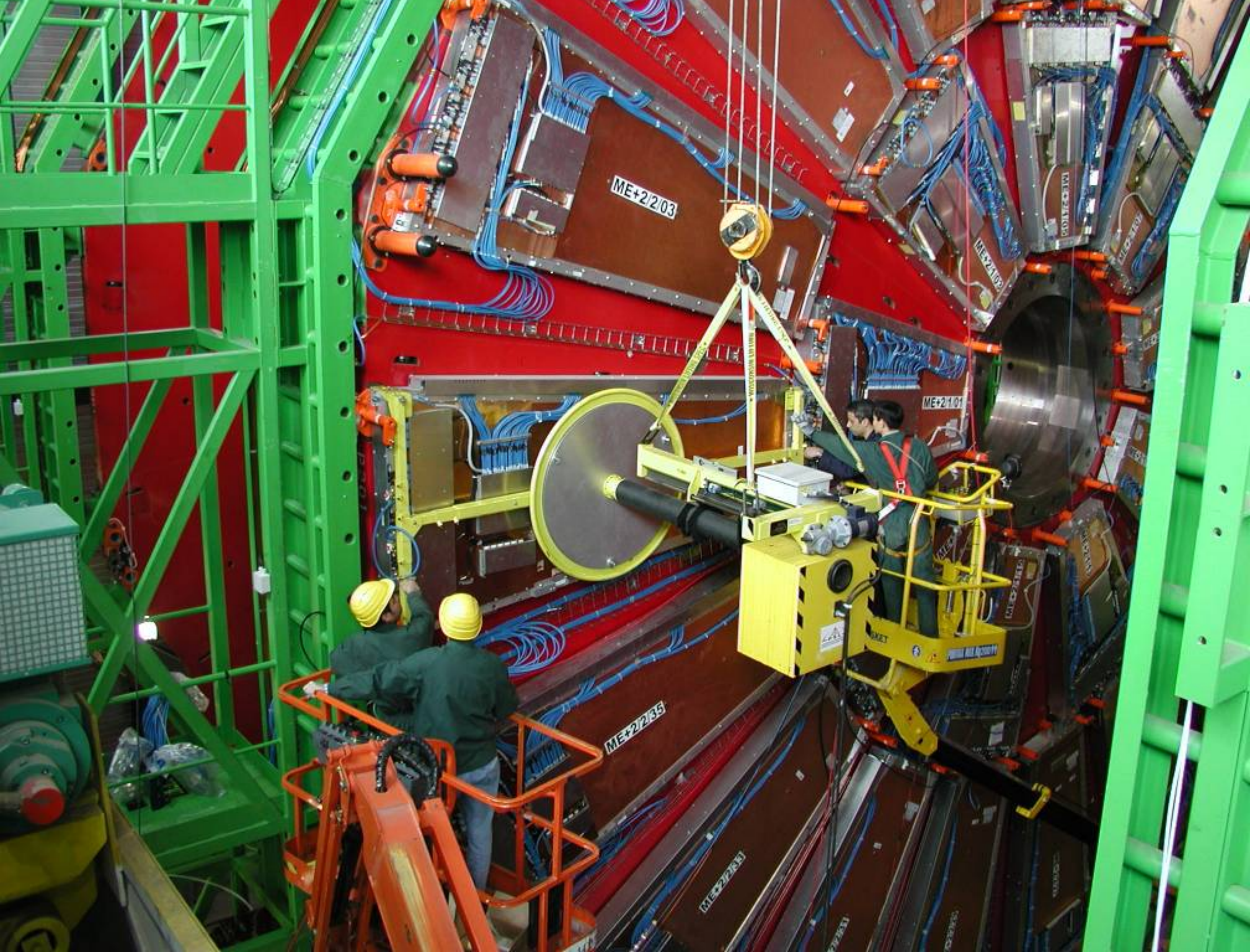
USA
- Univ. of Alabama, Tuscaloosa
- Iowa State Univ., Ames
- Boston Univ., Boston
- California Inst. of Tech., Pasadena
- Carnegie Mellon Univ., Pittsburgh
- Univ. of Illinois at Chicago, Chicago
- Fairfield Univ., Fairfield
- Fermi National Accelerator Lab., Batavia
- Florida State Univ. - HEPG, Tallahassee
- Florida State Univ. - SCRI, Tallahassee
- Univ. of Florida, Gainesville
- The Univ. of Iowa, Iowa City
- Johns Hopkins Univ., Baltimore
- LLNL, Livermore
- Los Alamos Nat. Lab., Los Alamos
- Univ. of Maryland, College Park
- Univ. of Minnesota, Minneapolis
- Univ. of Mississippi, Oxford
- Massachusetts Inst. of Tech., Cambridge
- Univ. of Nebraska-Lincoln, Lincoln
- Northeastern Univ., Boston
- Northwestern Univ., Evanston
- Univ. of Notre Dame, Notre Dame
- The Ohio State Univ., Columbus
- Princeton Univ., Princeton
- Purdue Univ., West Lafayette
- Rice Univ., Houston
- Univ. of California, Riverside
- Univ. of Rochester, Rochester
- Rutgers, the State Univ. of New Jersey, Piscataway
- Texas Tech Univ., Lubbock
- Univ. of Texas at Dallas, Richardson
- Univ. of California at Davis, Davis
- UCLA, Los Angeles
- Univ. of California San Diego, La Jolla
- Virginia Polytech. Inst. and State Univ., Blacksburg
- Univ. of Wisconsin, Madison

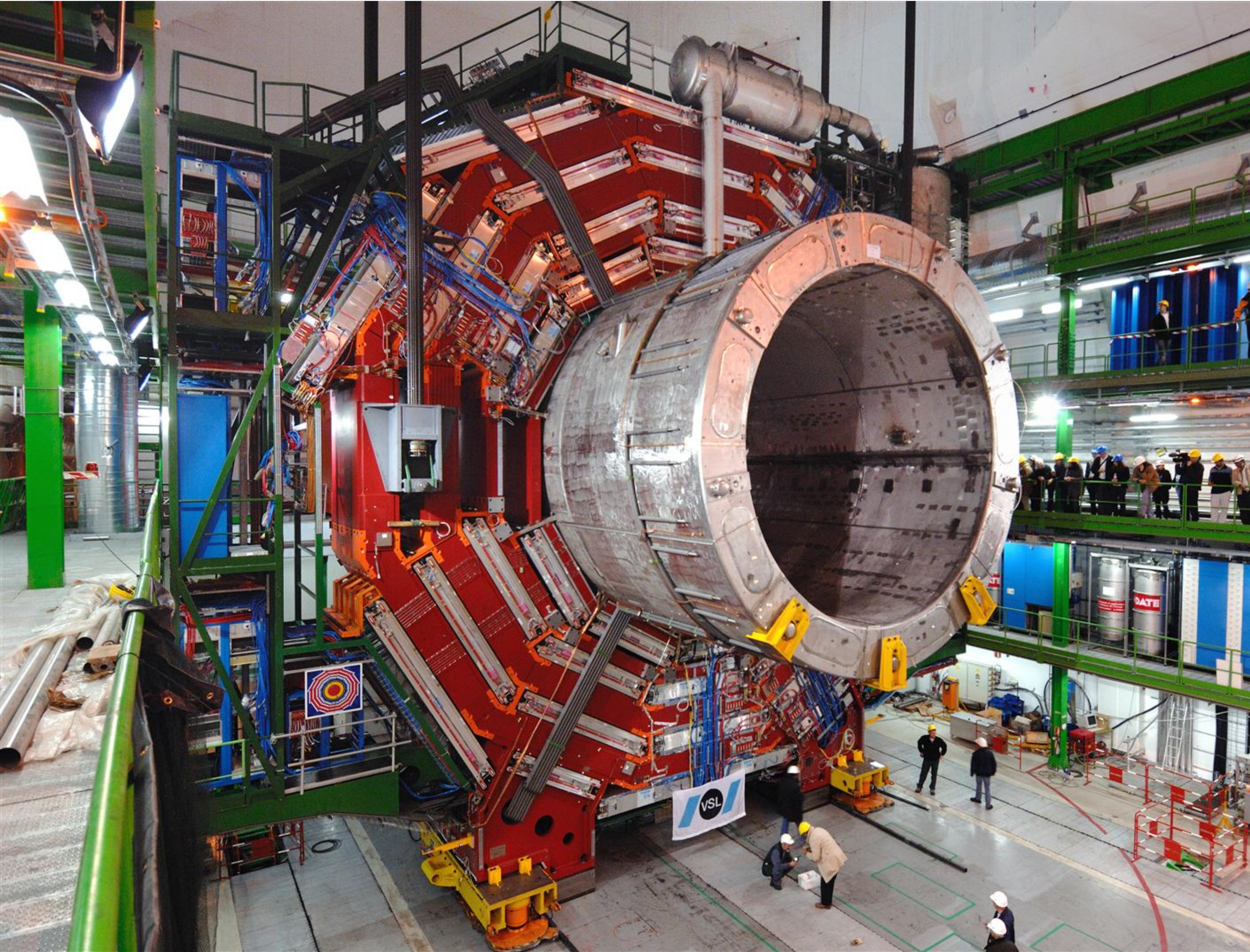
UZBEKISTAN
- Inst. of Nucl. Phys. of the Uzbekistan Acad. of Sciences, Tashkent

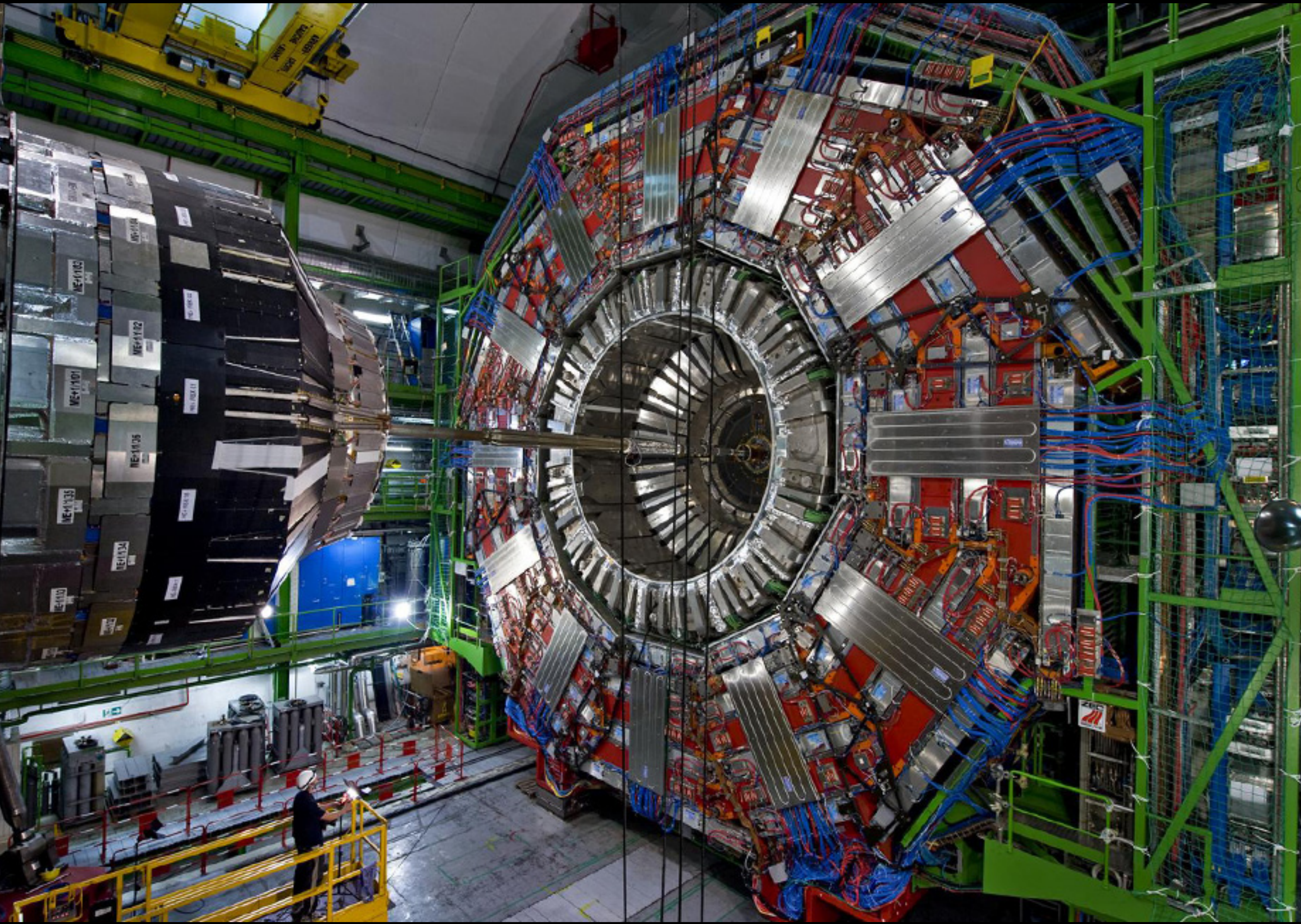


electromagnetic calorimeter
solenoid
muon chambers
hadronic calorimeter
inner tracker
magnet yoke
CMS

CMS Barrel Yoke

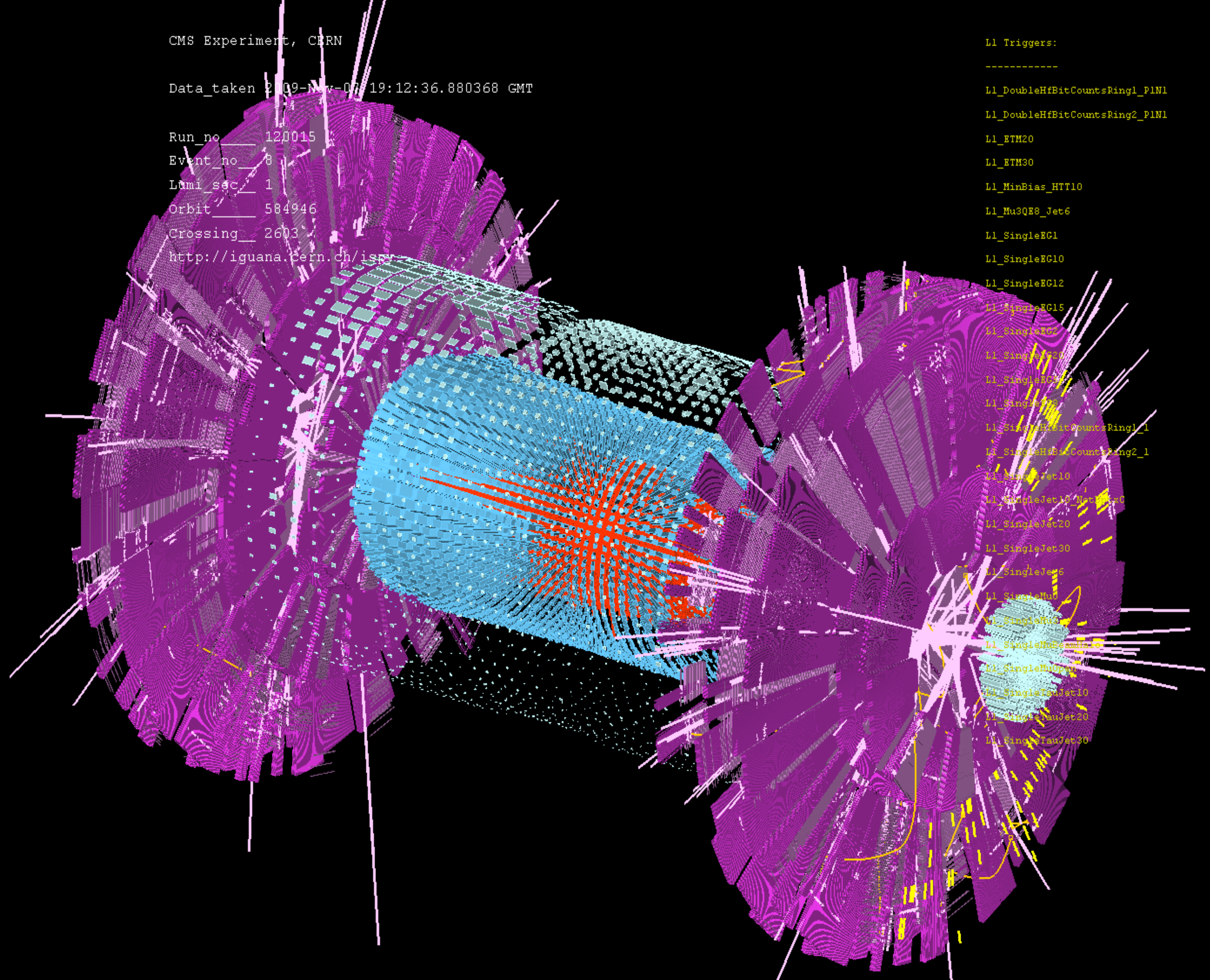

ME+2/2/03
ME+2/1/01
ME+2/2/35


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)

Los Angeles Times

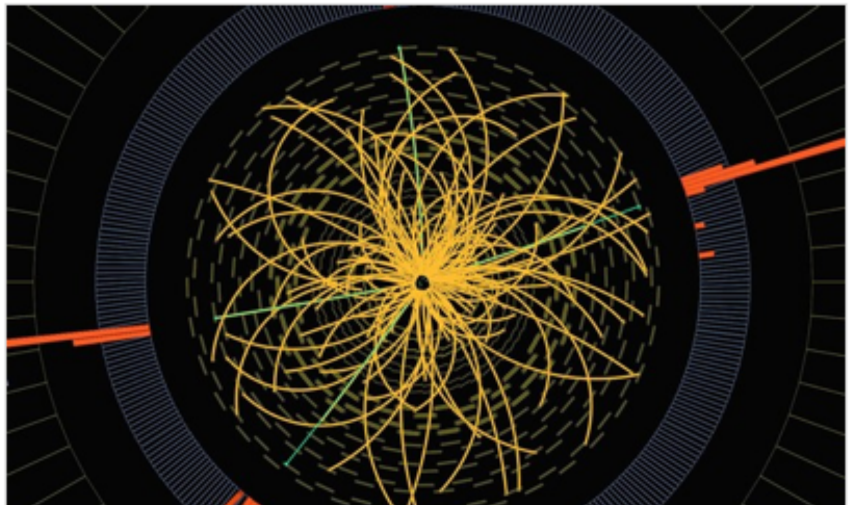
Physicists find 'tantalizing hints' of Higgs boson 'God particle'

Two team
Geneva sa
boson, or

News release on July 4^{th} !

December 13, 2011 | By Eryn Brown, Los Angeles Times

Physicists announced Tuesday that they had detected "tantalizing hints," but not definitive proof, of the long-sought Higgs boson, the so-called God particle that is crucial to physicists' understanding of why mass exists in the universe.



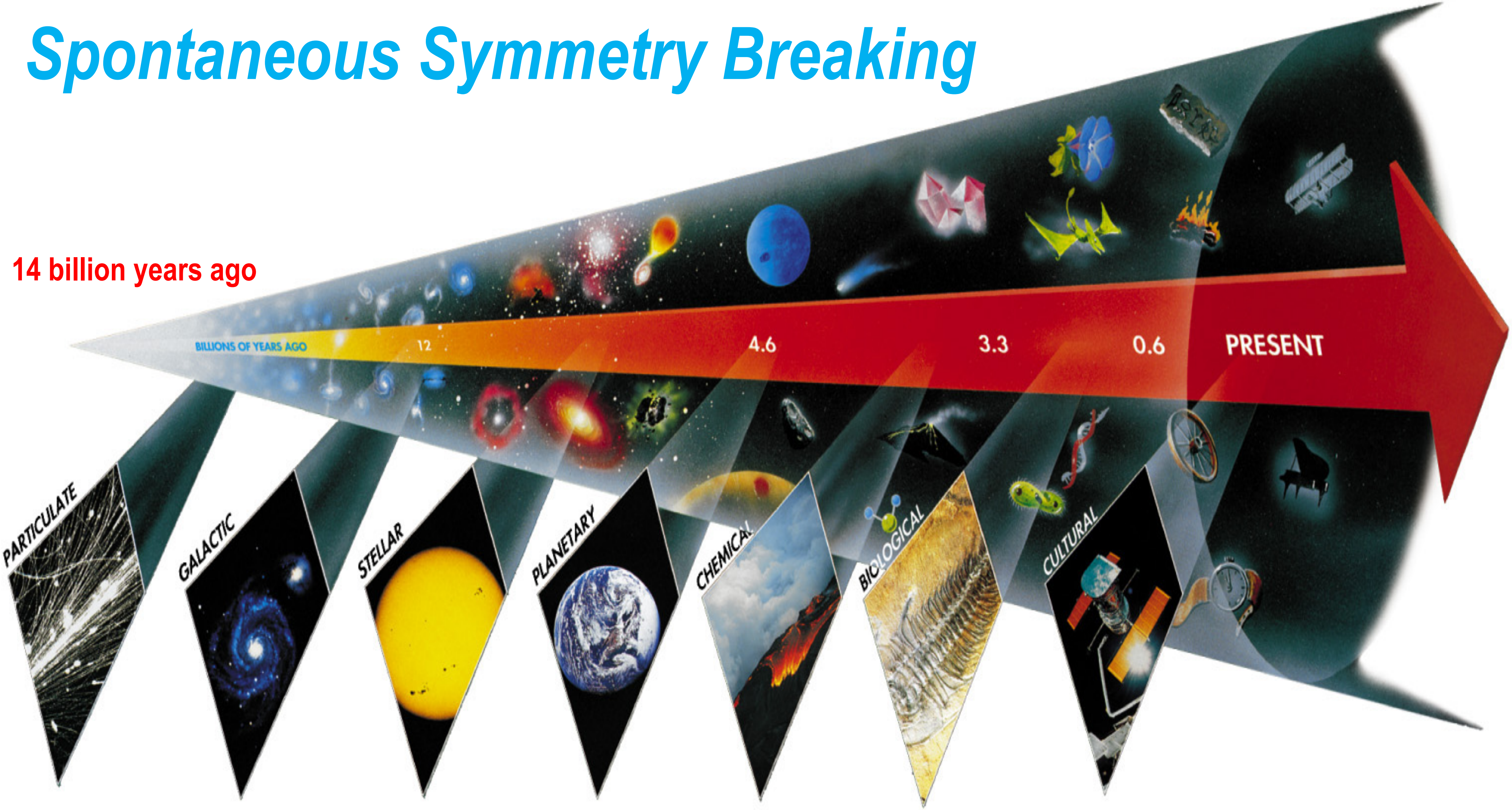
A graphic shows traces of a proton collision measured in a detector at the... (CERN)

Two large teams of scientists based at the Large Hadron Collider near Geneva separately saw what they believe are telltale tracks of the maddeningly elusive particle in the aftermath of about 400 trillion proton collisions carried out since January.

Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking

14 billion years ago

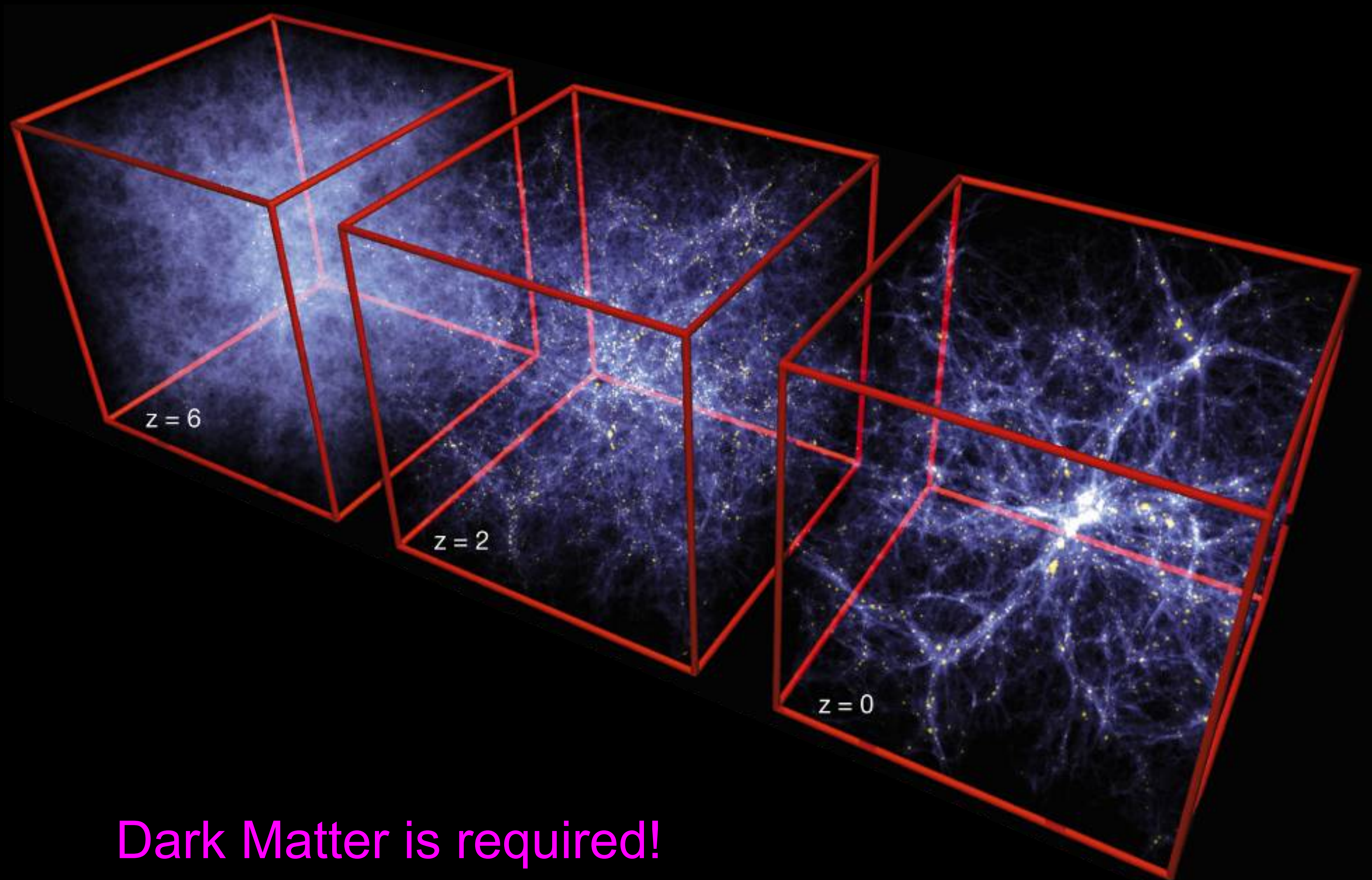


Origin of Particles

Origin of Structure

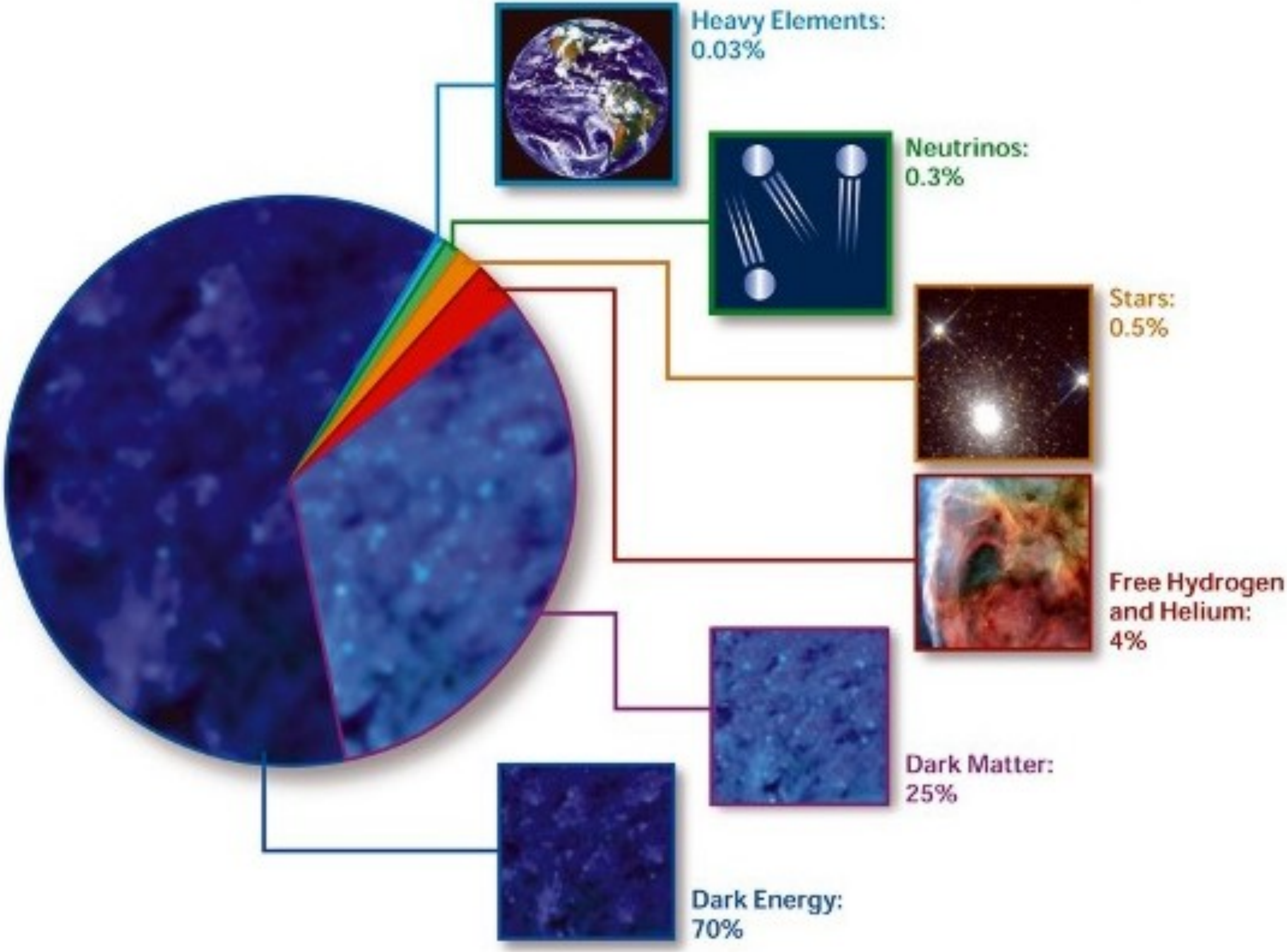

ANDROMEDA
GALAXY
Dark Matter is required!

Formation of Structure in the Universe



Dark Matter is required!

Cosmic Pie Chart

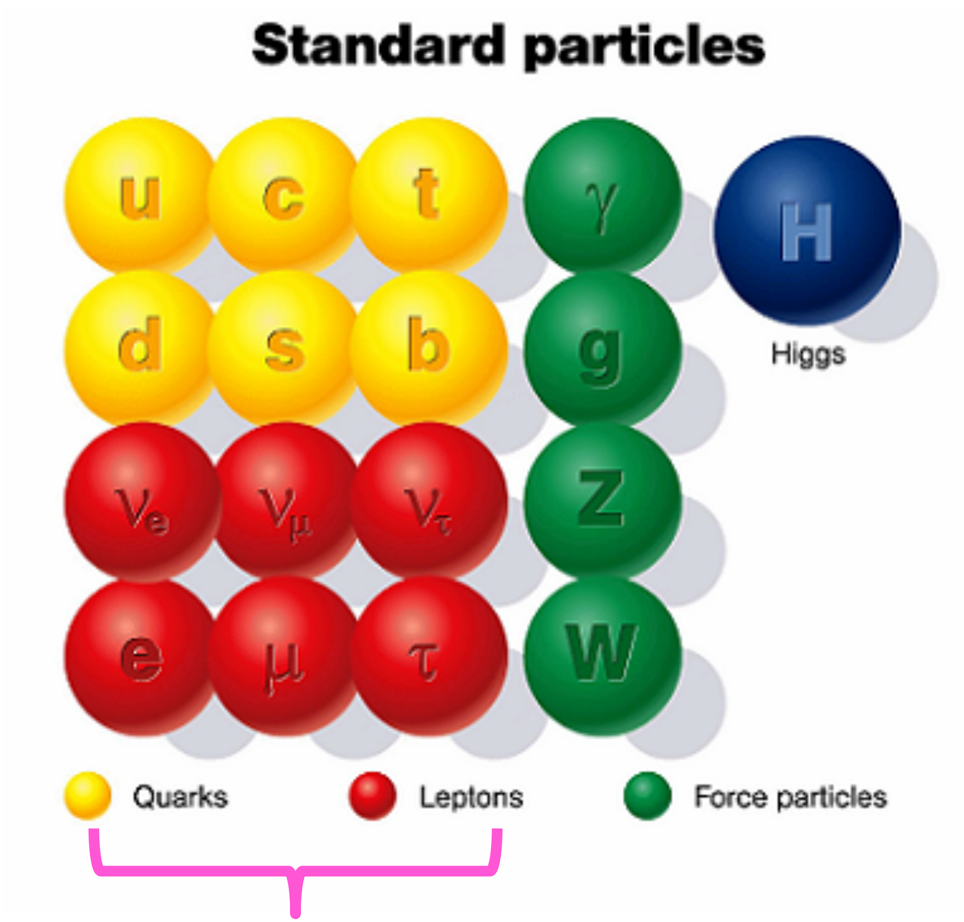


What is Dark Matter?

- **Must be a heavy particle**
  - Only weakly interacting.
  - Gravitationally attracted.

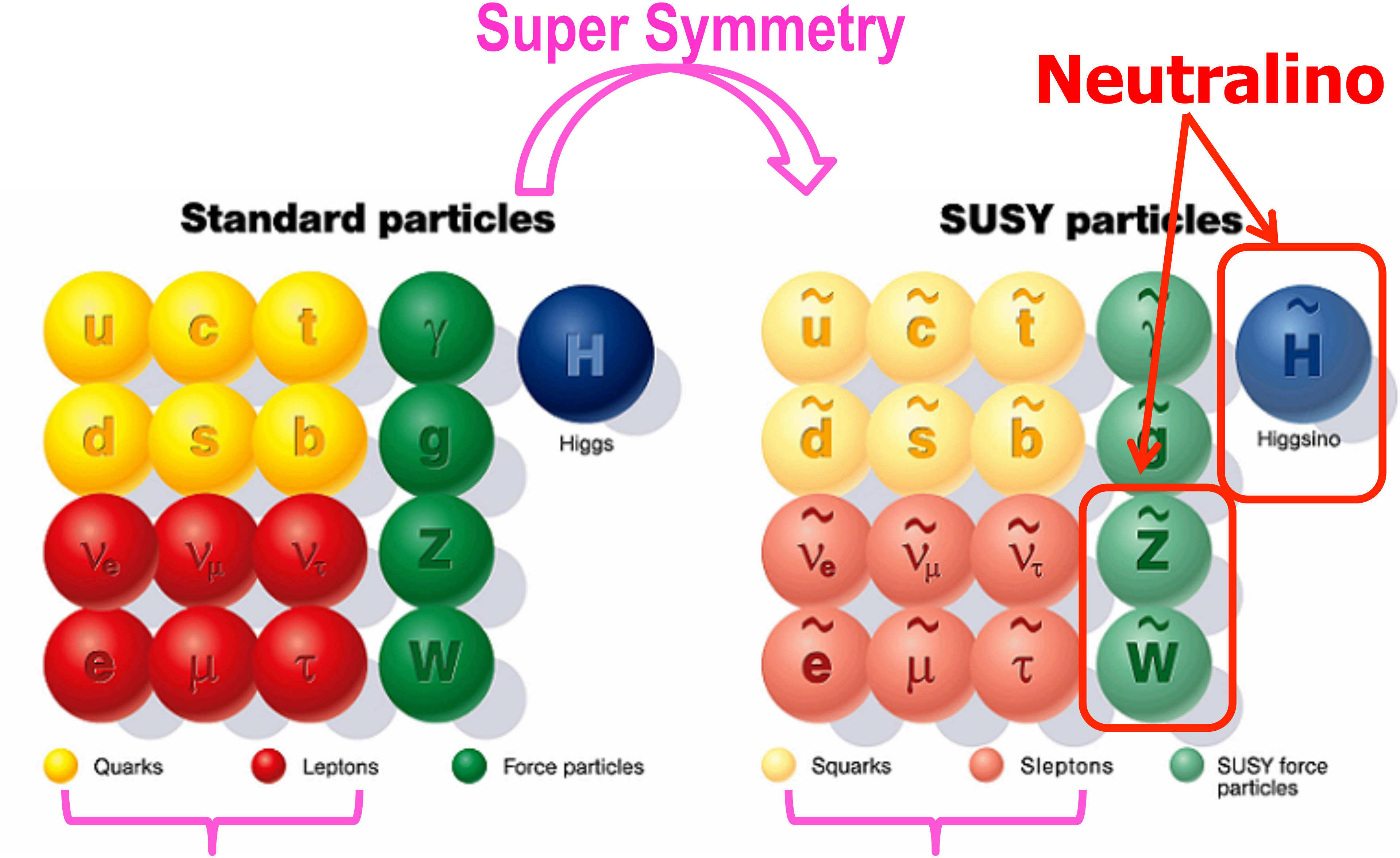
- **Candidates**
  - "MACHO" (Massive Compact Halo Objects) X
    - →Baryonic Dark Matter
  - Heavy Neutrino X
    - →Hot Dark Matter
  - "WIMP" (Weakly Interacting Massive Particle"
    - →Cold Dark Matter

SUSY Particles and Neutralino



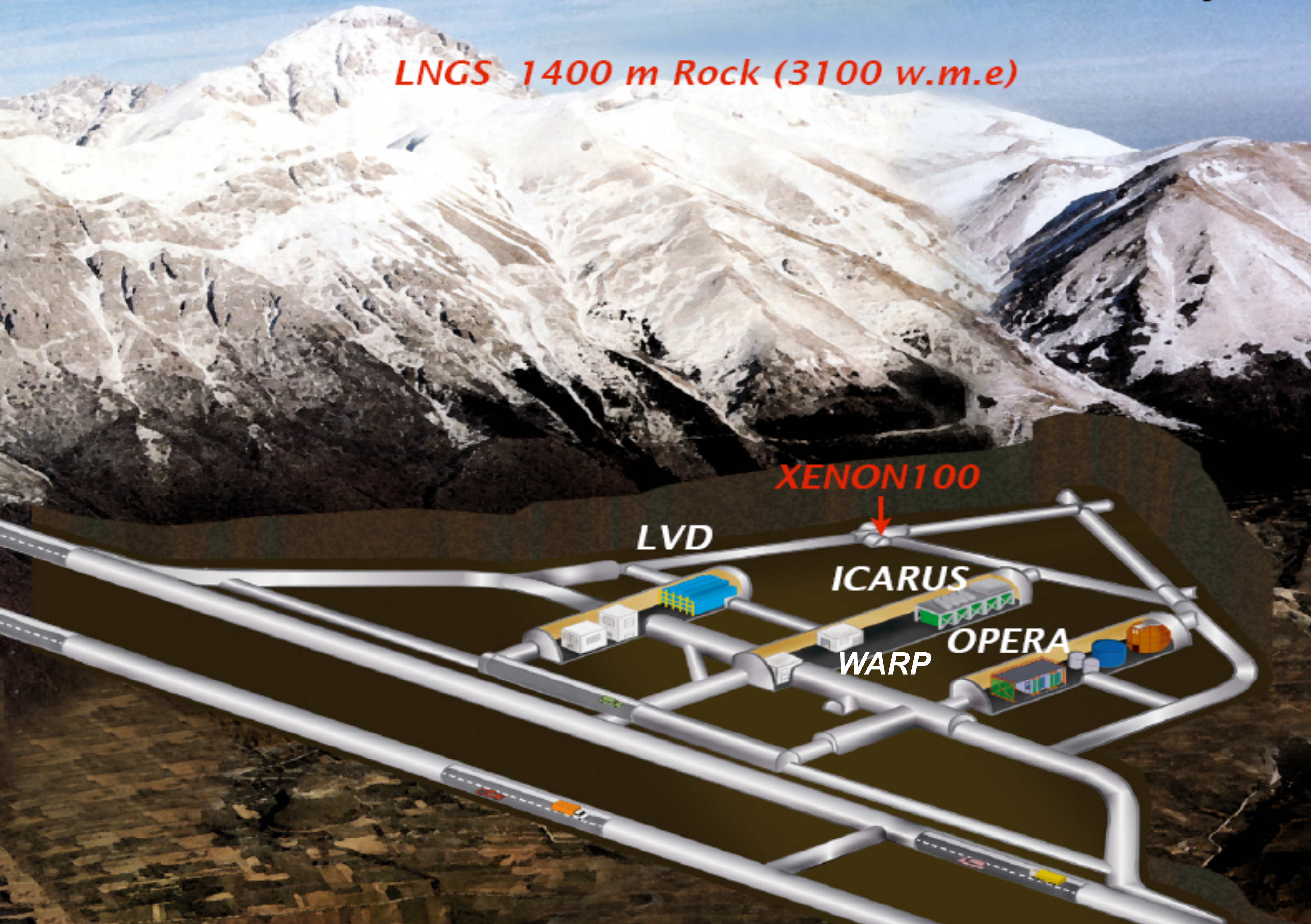
Spin 1/2 1 0

SUSY Particles and Neutralino

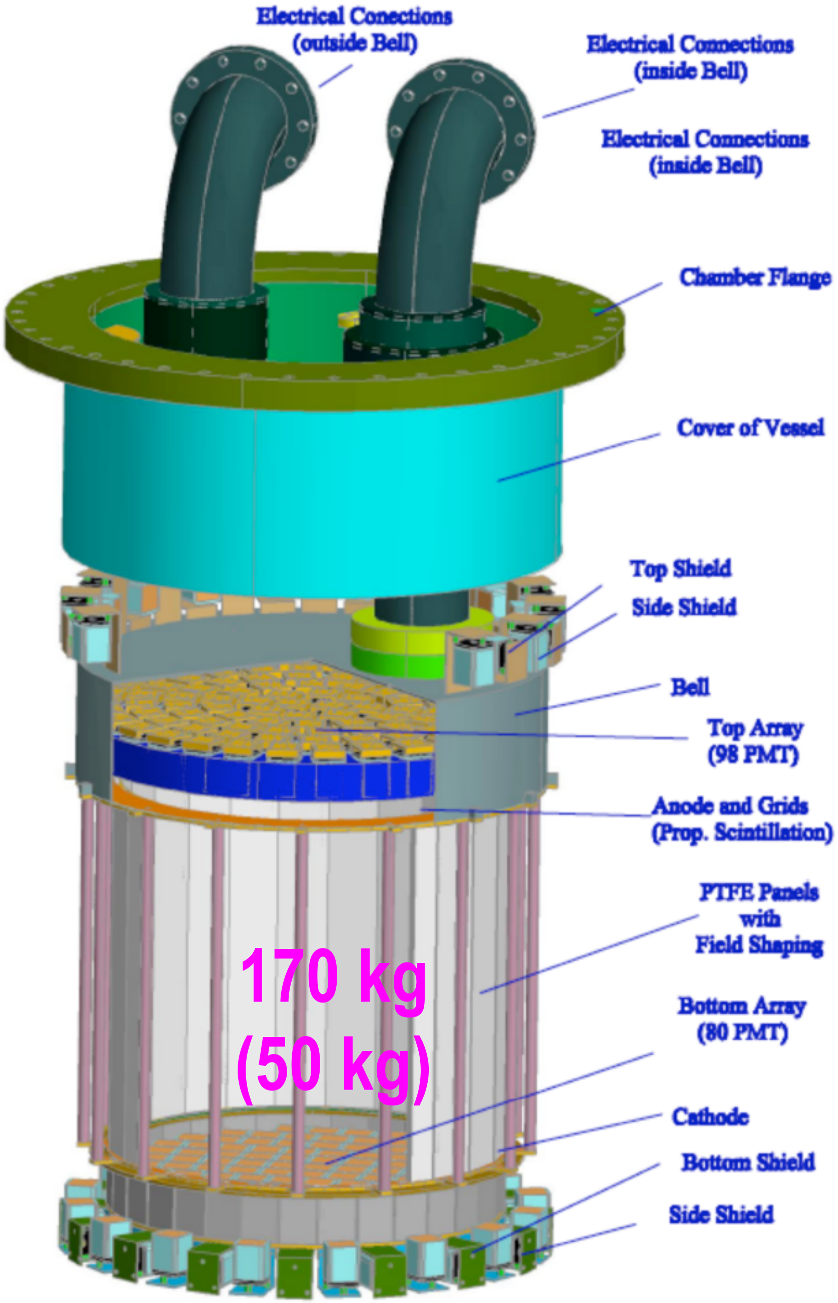


Spin 1/2 1 0 0 1/2 1/2

Laboratori Nazionali del Gran Sasso, Italy

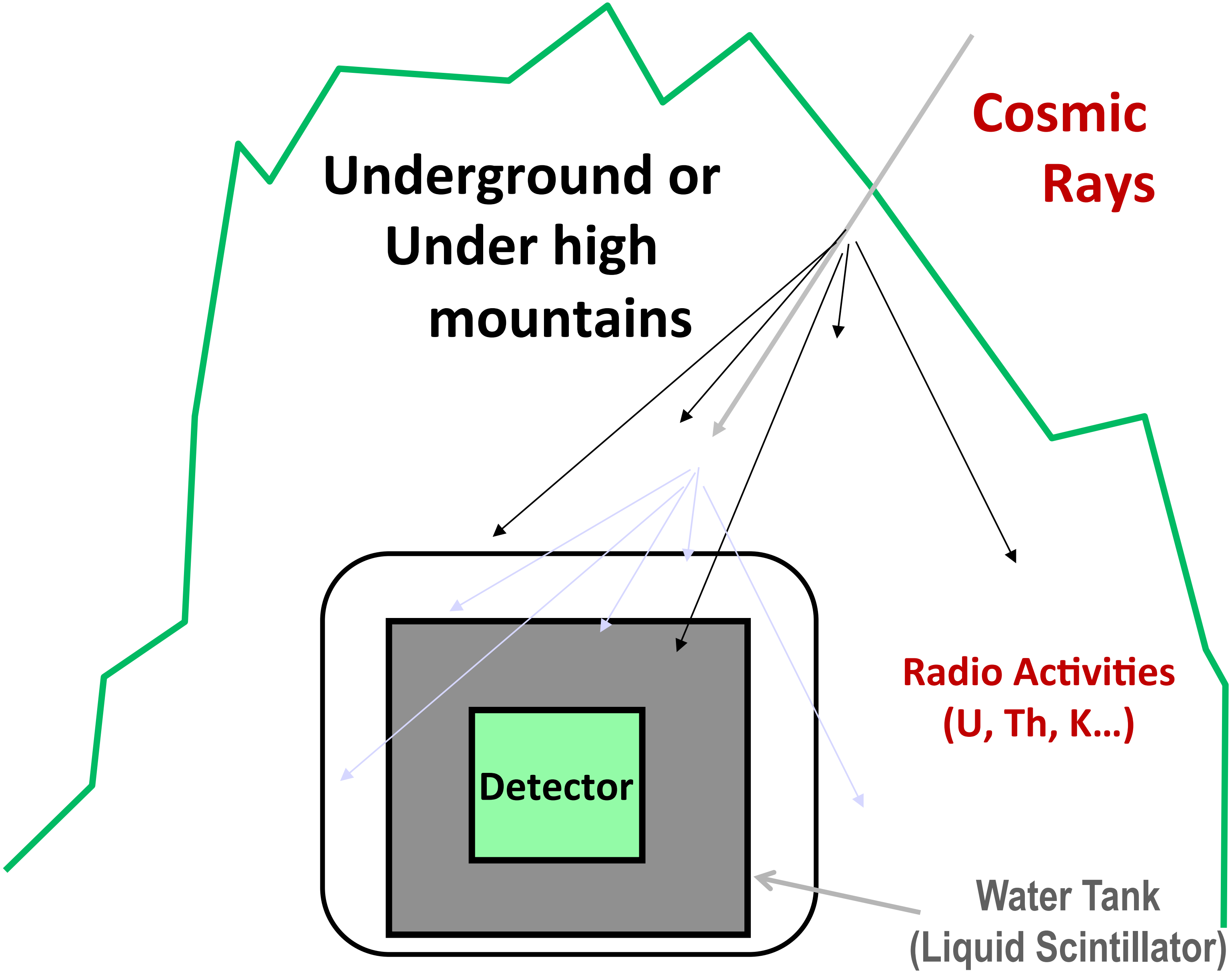


XENON100 Detector



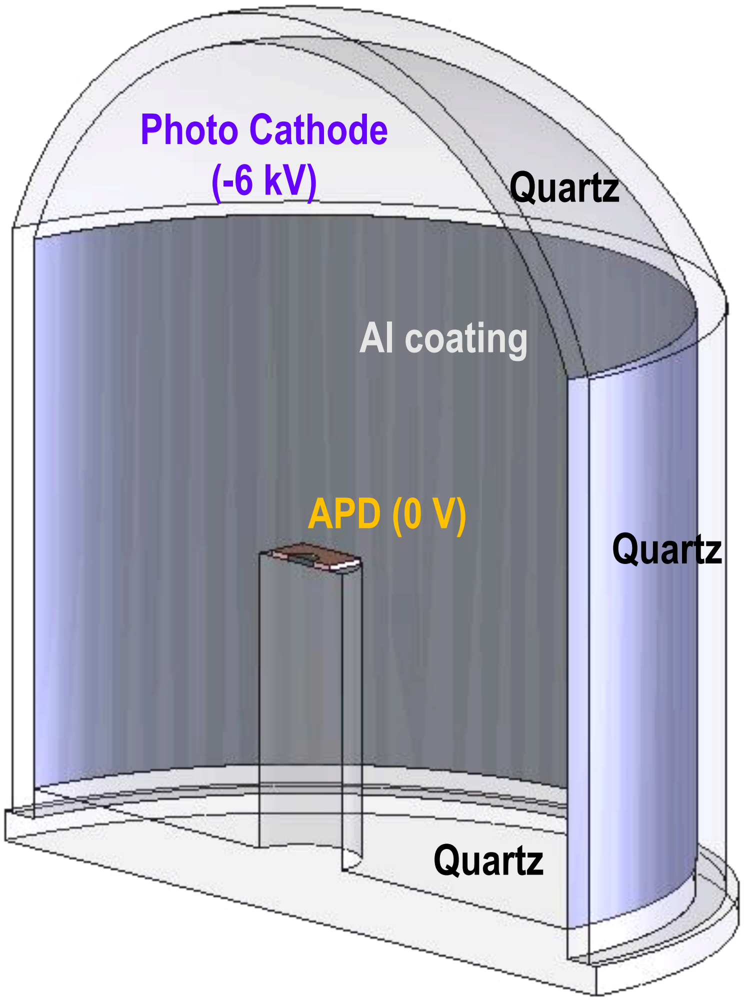
XENON100 Detector (2009)

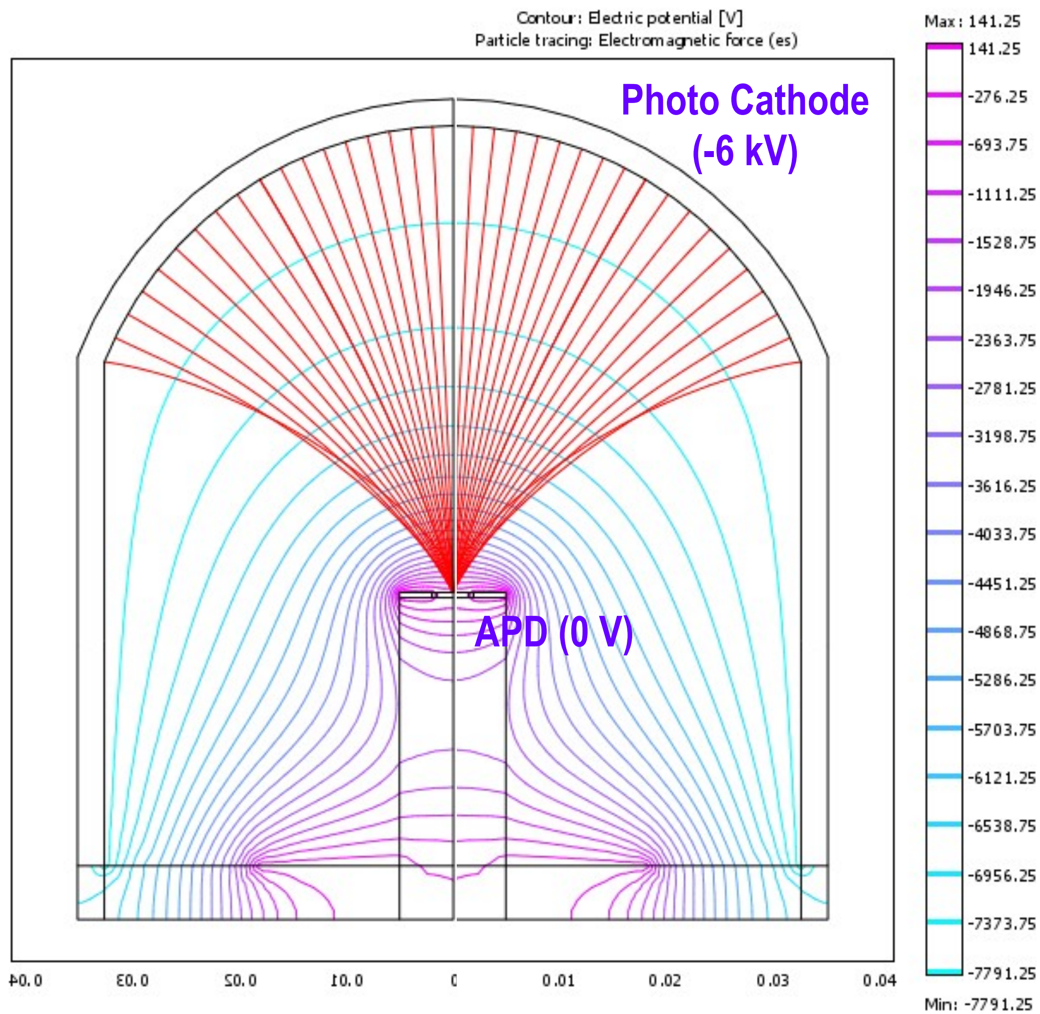
Where backgrounds come from?



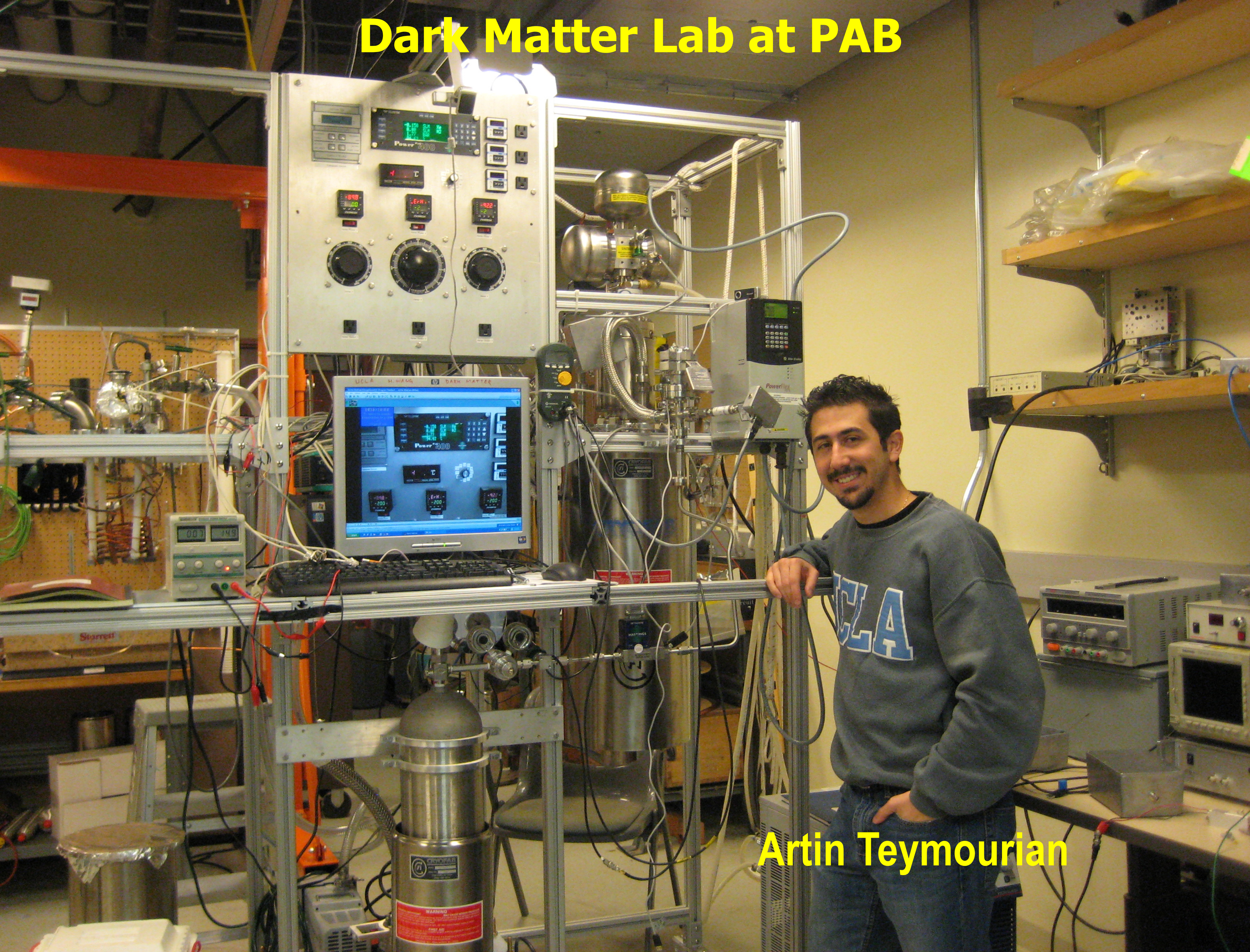
Ultimately photon detectors are the major source of backgrounds.

Structure and Electron Trajectories of 3” QUPID

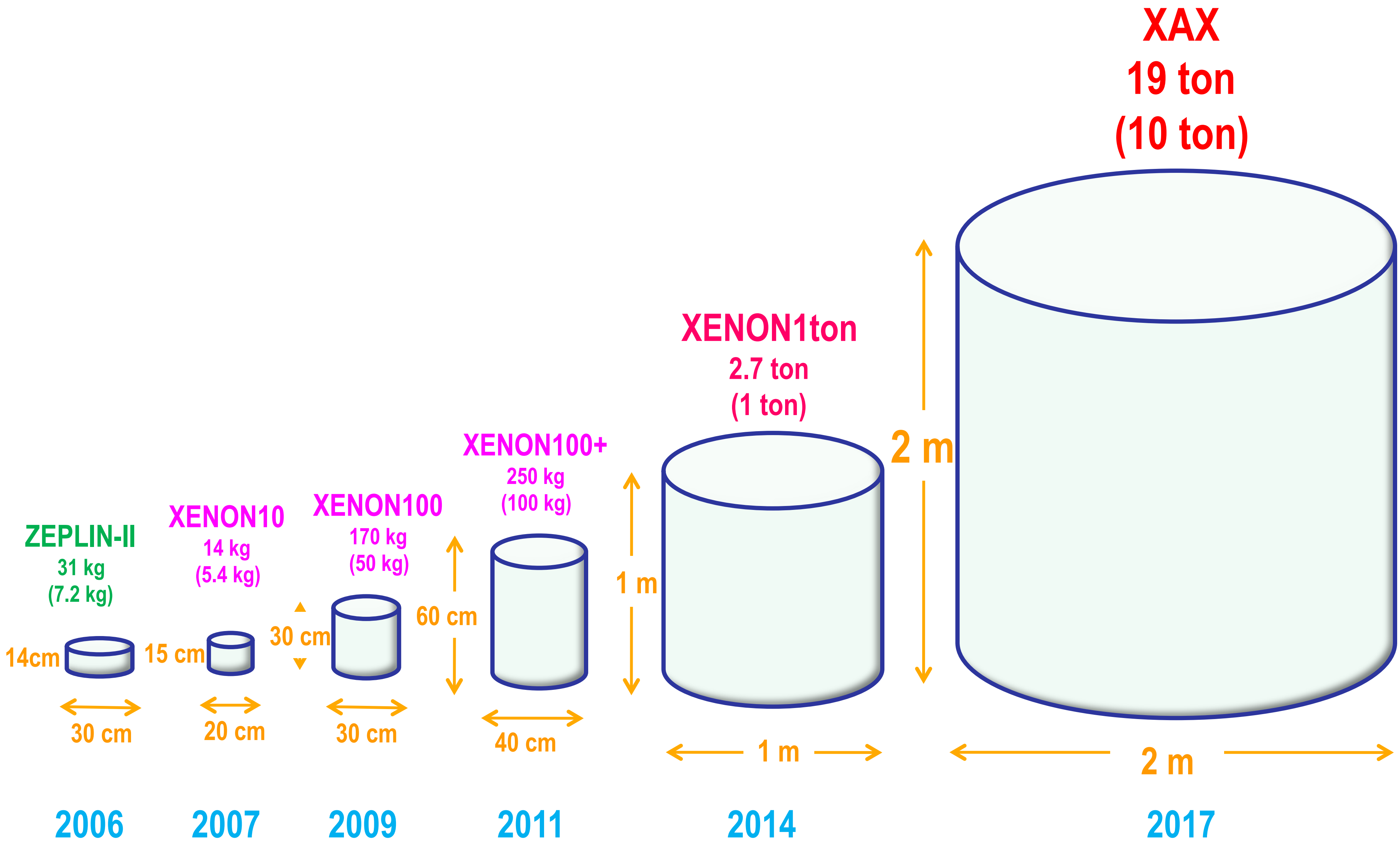




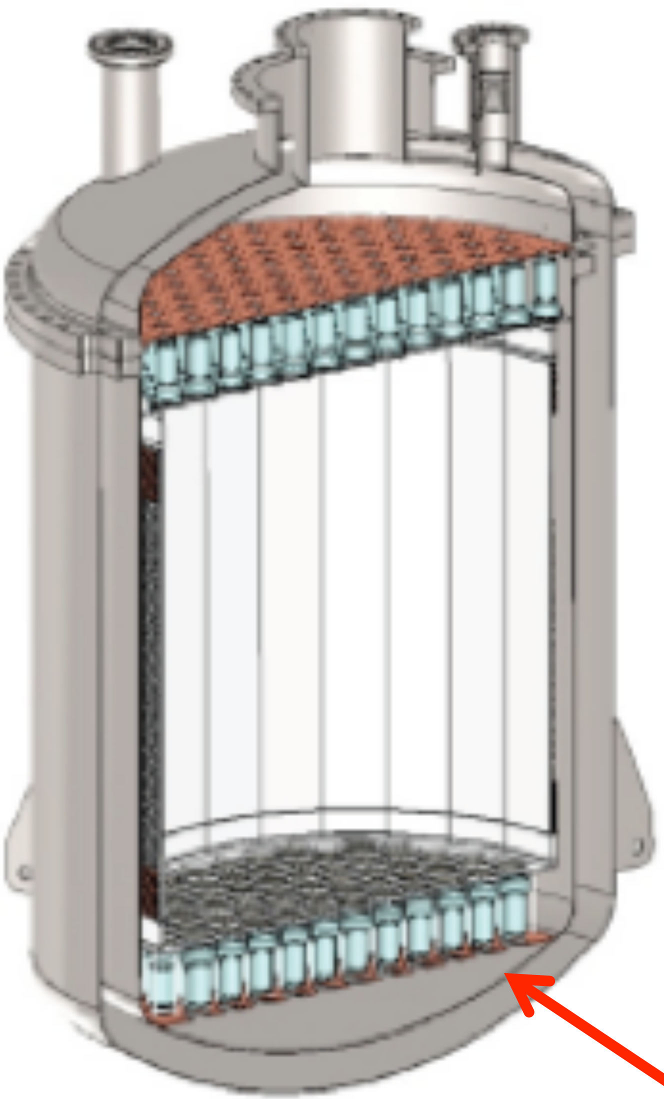
Mechanical Samples on Base plate

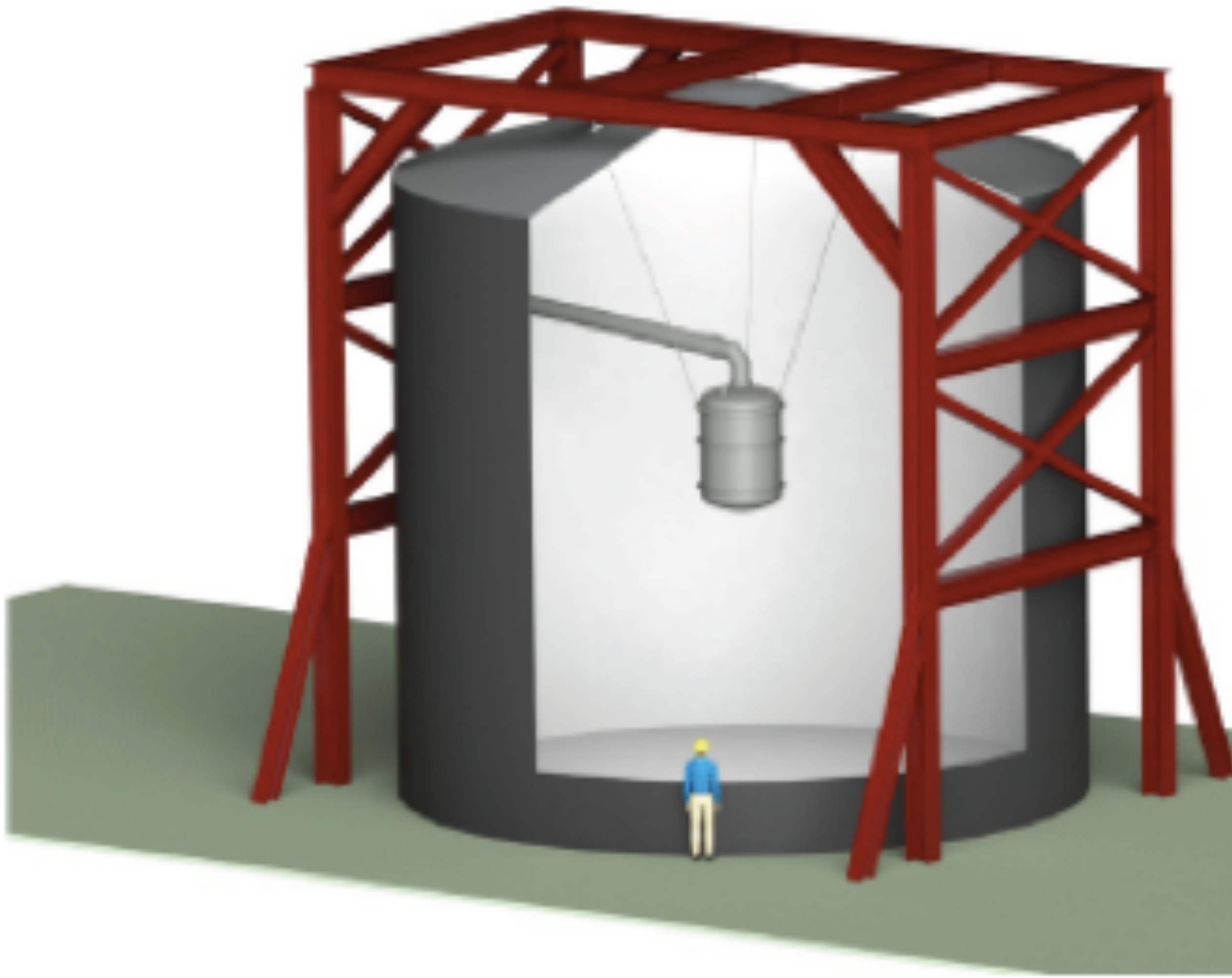

Dark Matter Lab at PAB
Artin Teymourian

Comparison of Detector Size



XENON1T

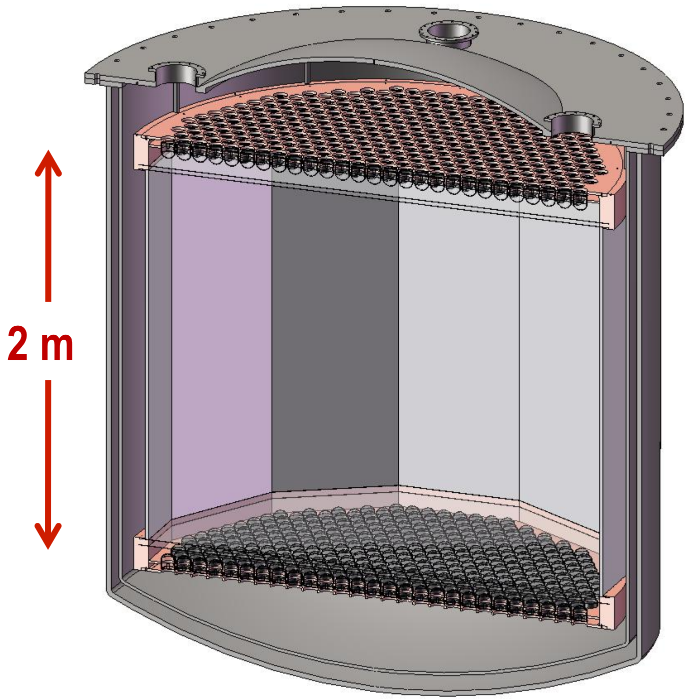




Alex's Project

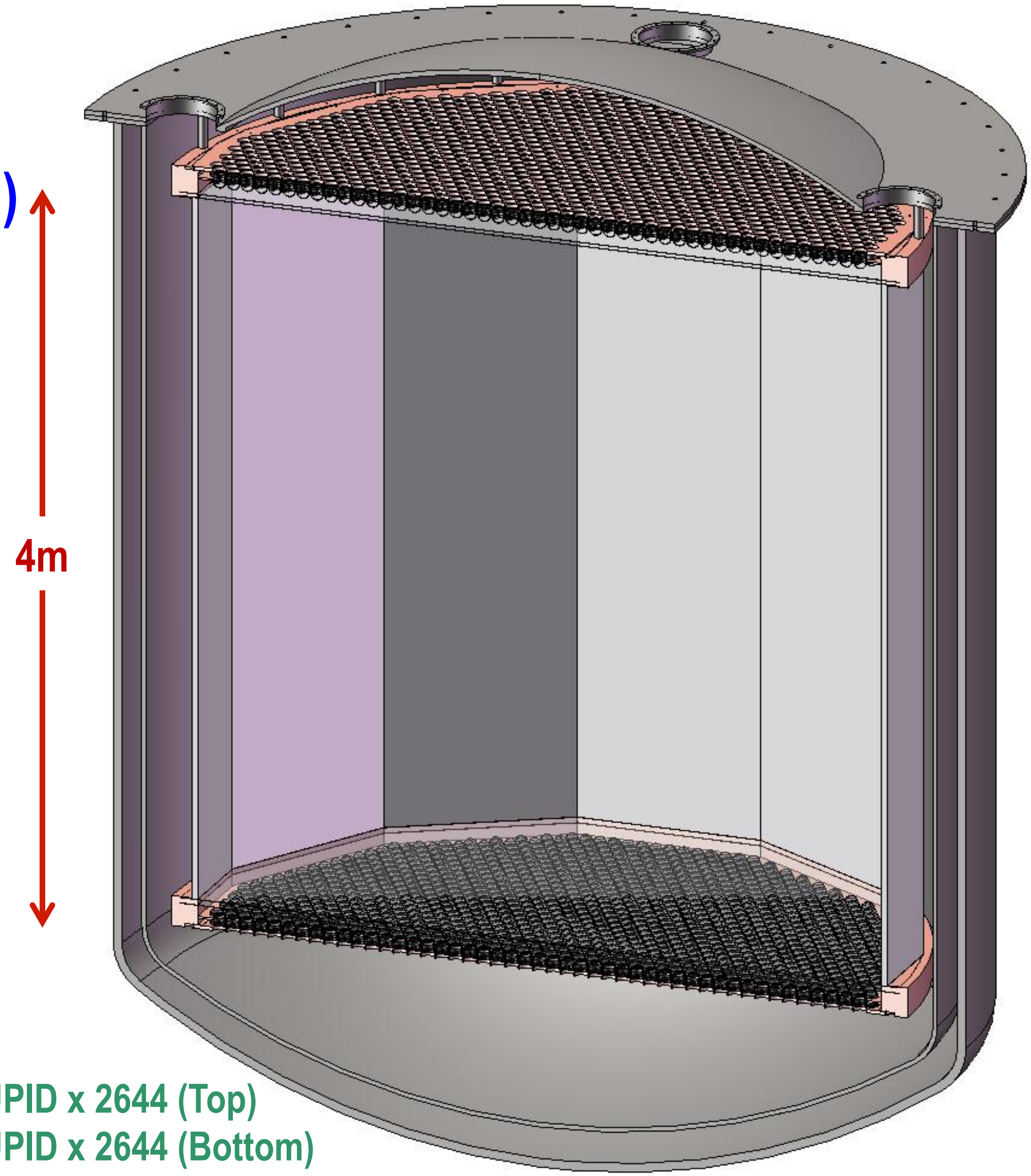
MAX Detector (G3)

Xe
20 ton
(10 ton)



3” QUPID x 595 (Top)
3” QUPID x 595 (Bottom)

^{40}Ar
70 ton
(50 ton)

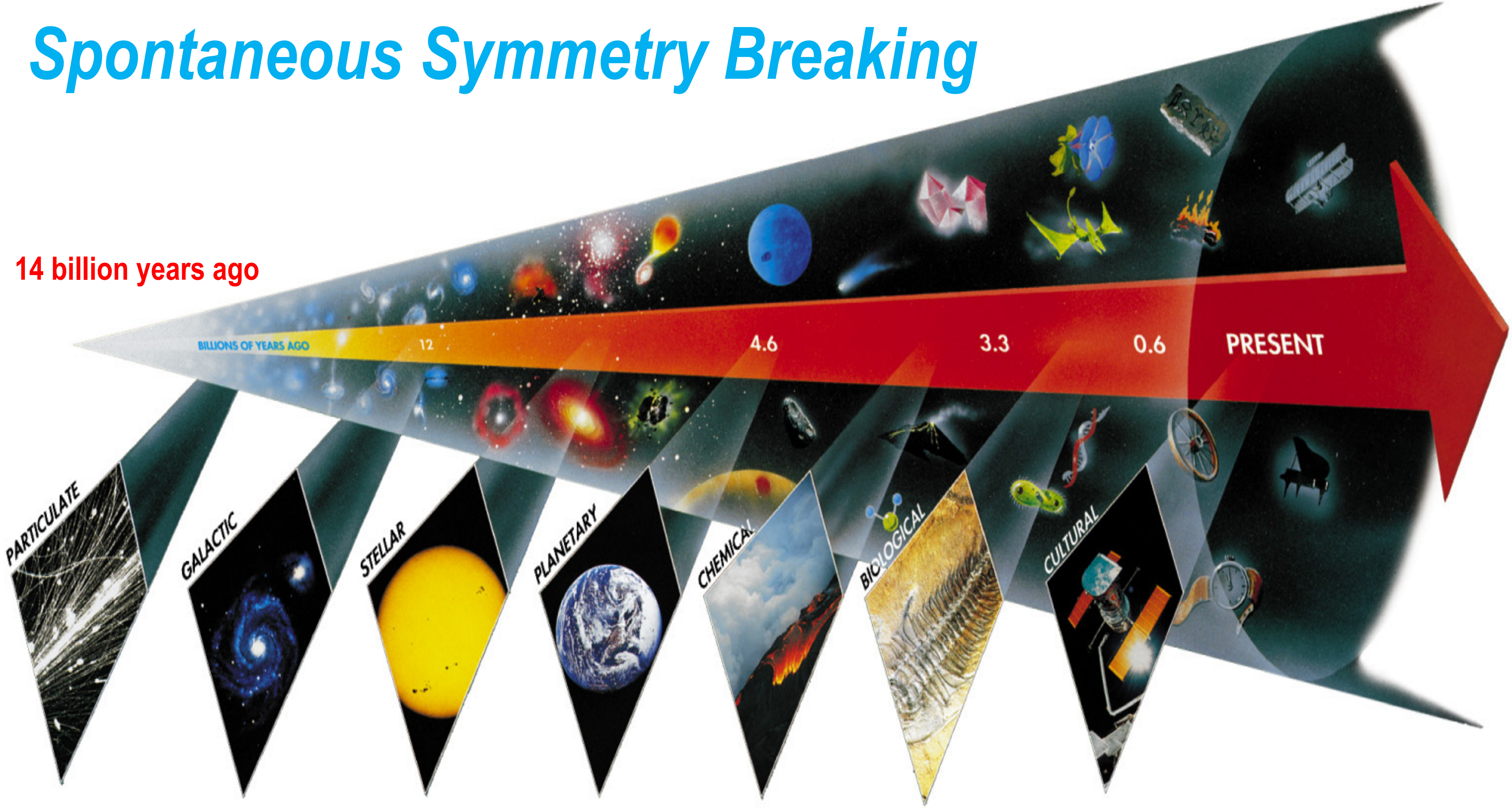


3” QUPID x 2644 (Top)
3” QUPID x 2644 (Bottom)

Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking

14 billion years ago

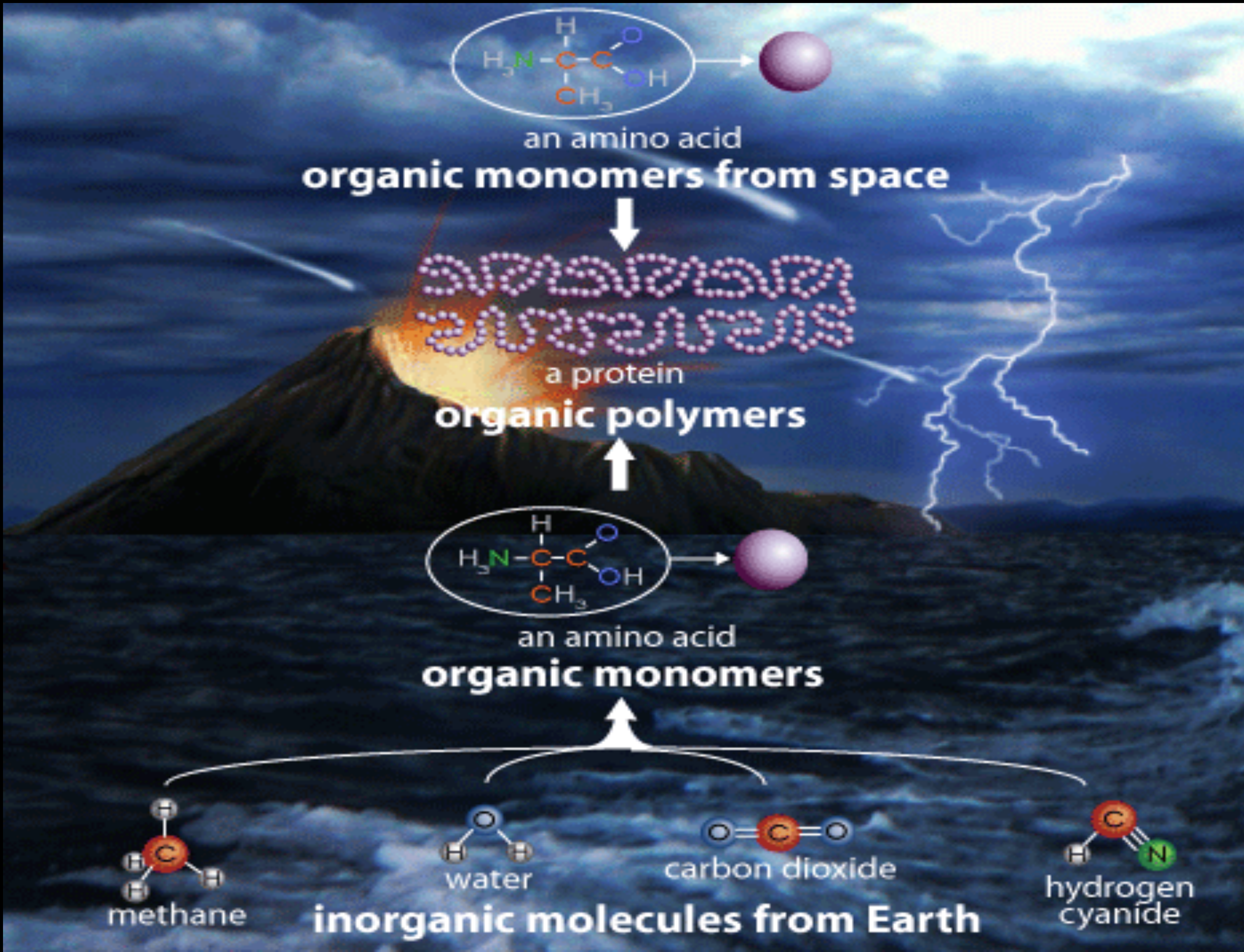


Origin of Particles

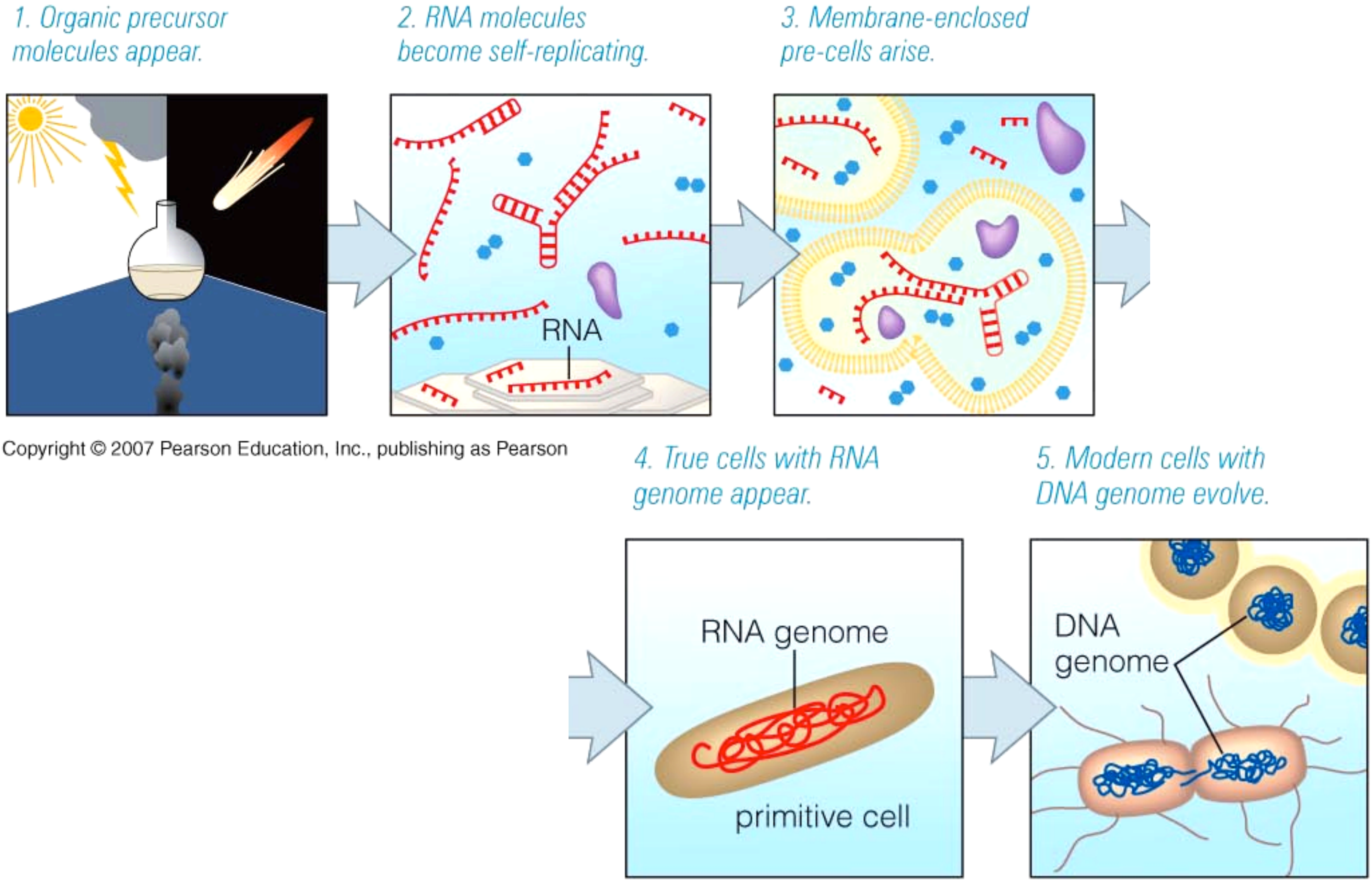
Origin of Structure

Origin of Life

Organic Polymers (4.5B → 4B years)



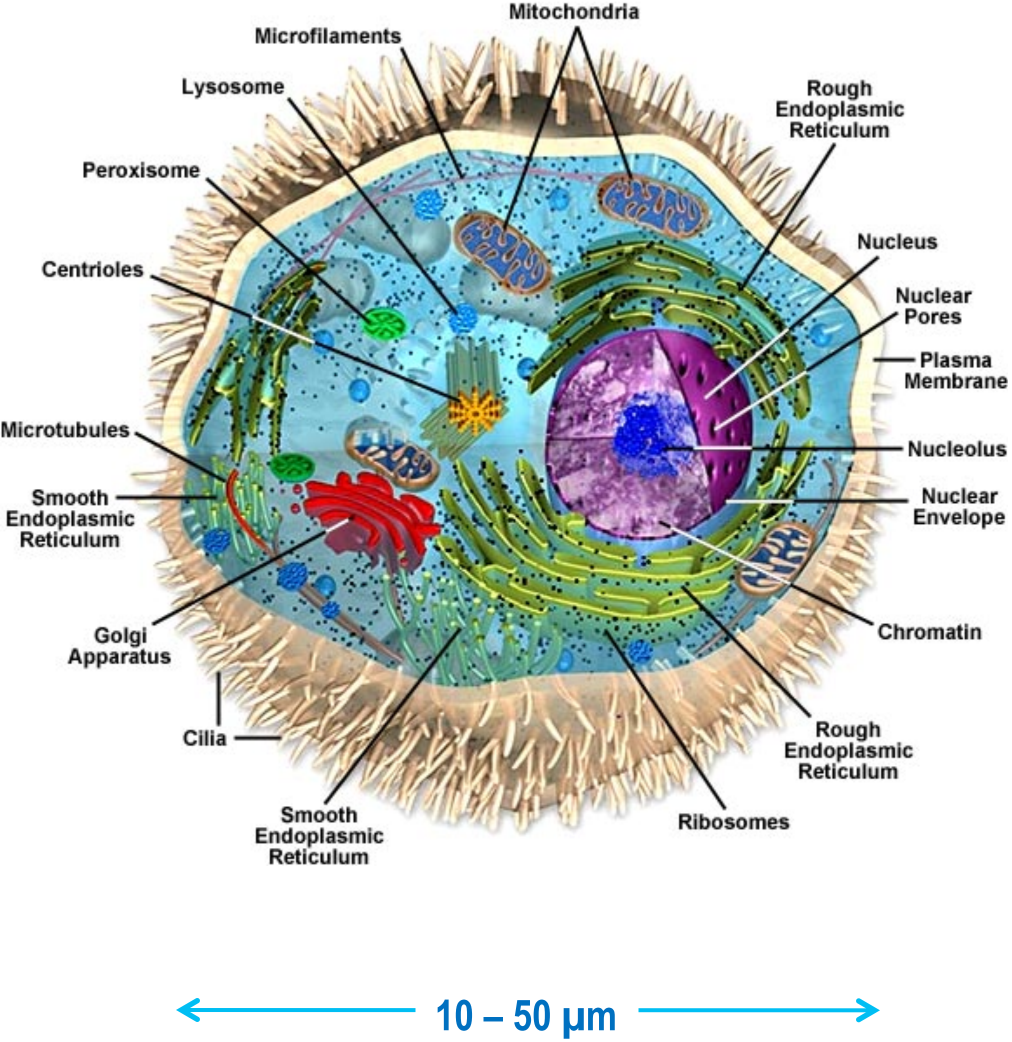
RNA Word (4B → 3.5B years ago)

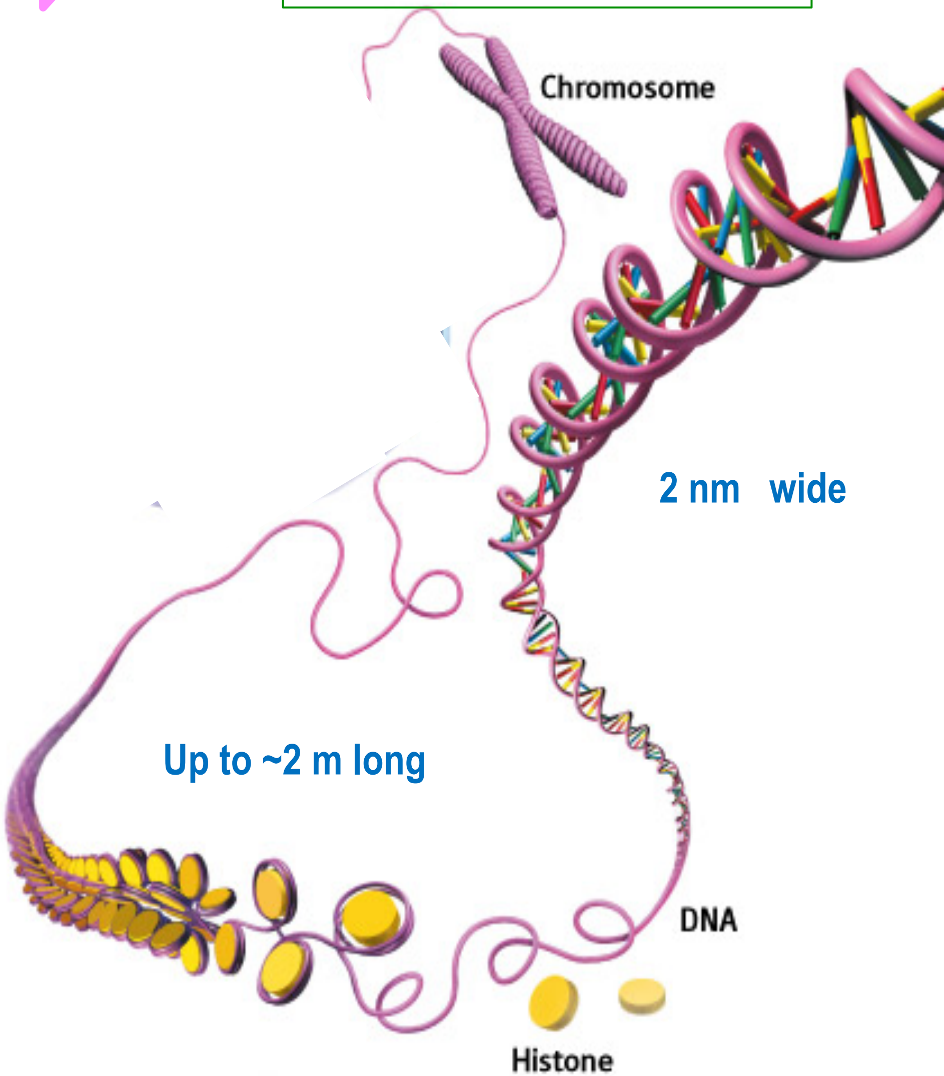


Eukaryote (～2B years ago)

Symmetry breaking

Cell made by proteins ⟺ Gene made by DNA





How to observe the “Origin of Life”

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

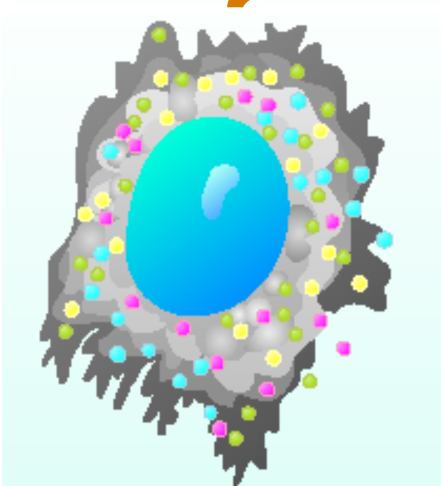
  Telescope ↔ Microscope

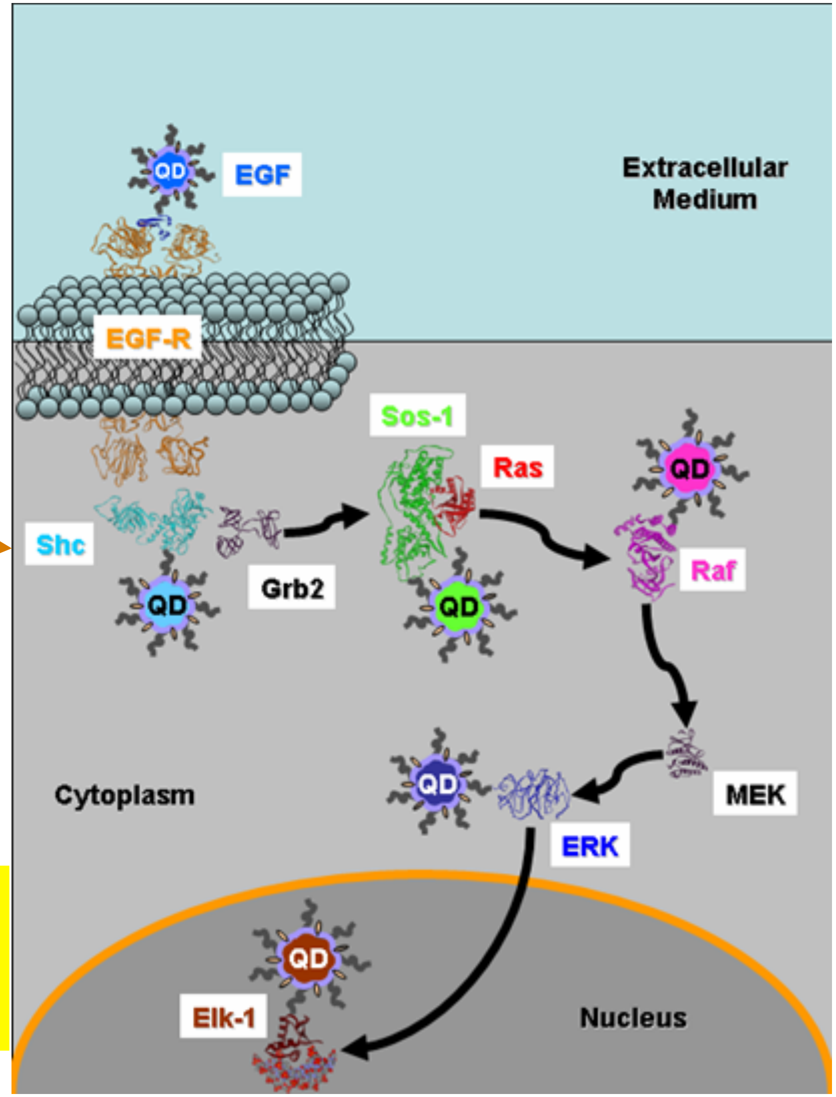
- We must look for “Live Life”

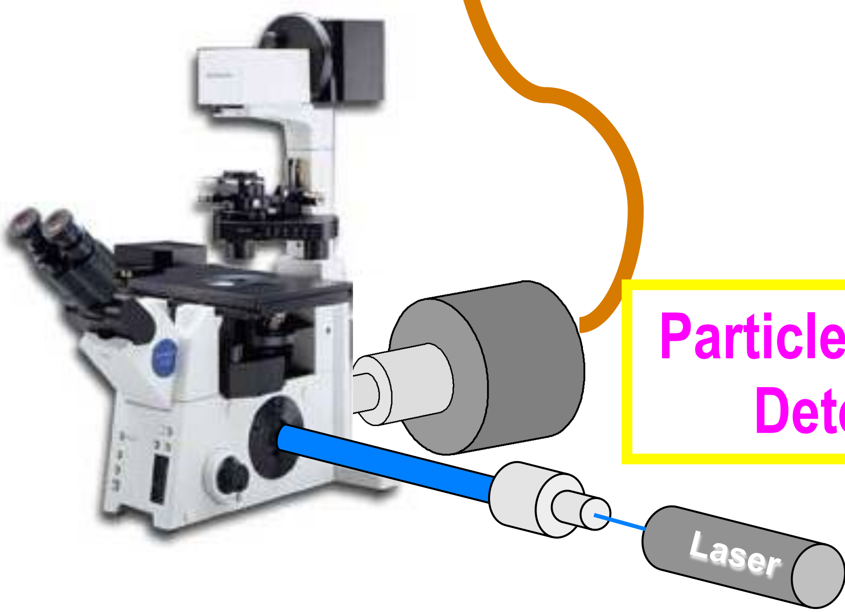
- Take advantages of the state of art “Photon Detectors” in particle physics.

Single Molecule Imaging

Nano Technology





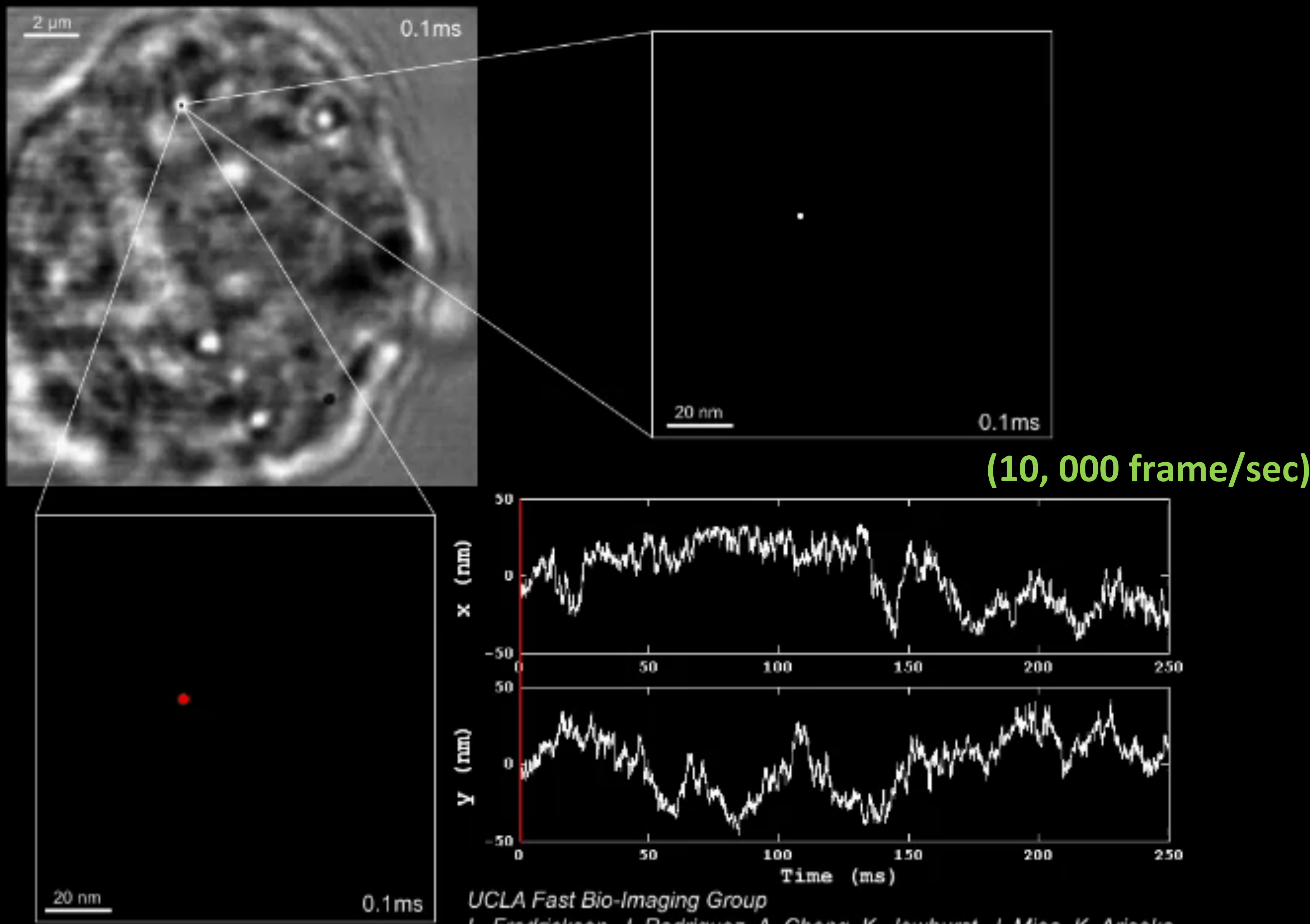


Particle Physics
Detector

Prof. Shimon Weiss

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

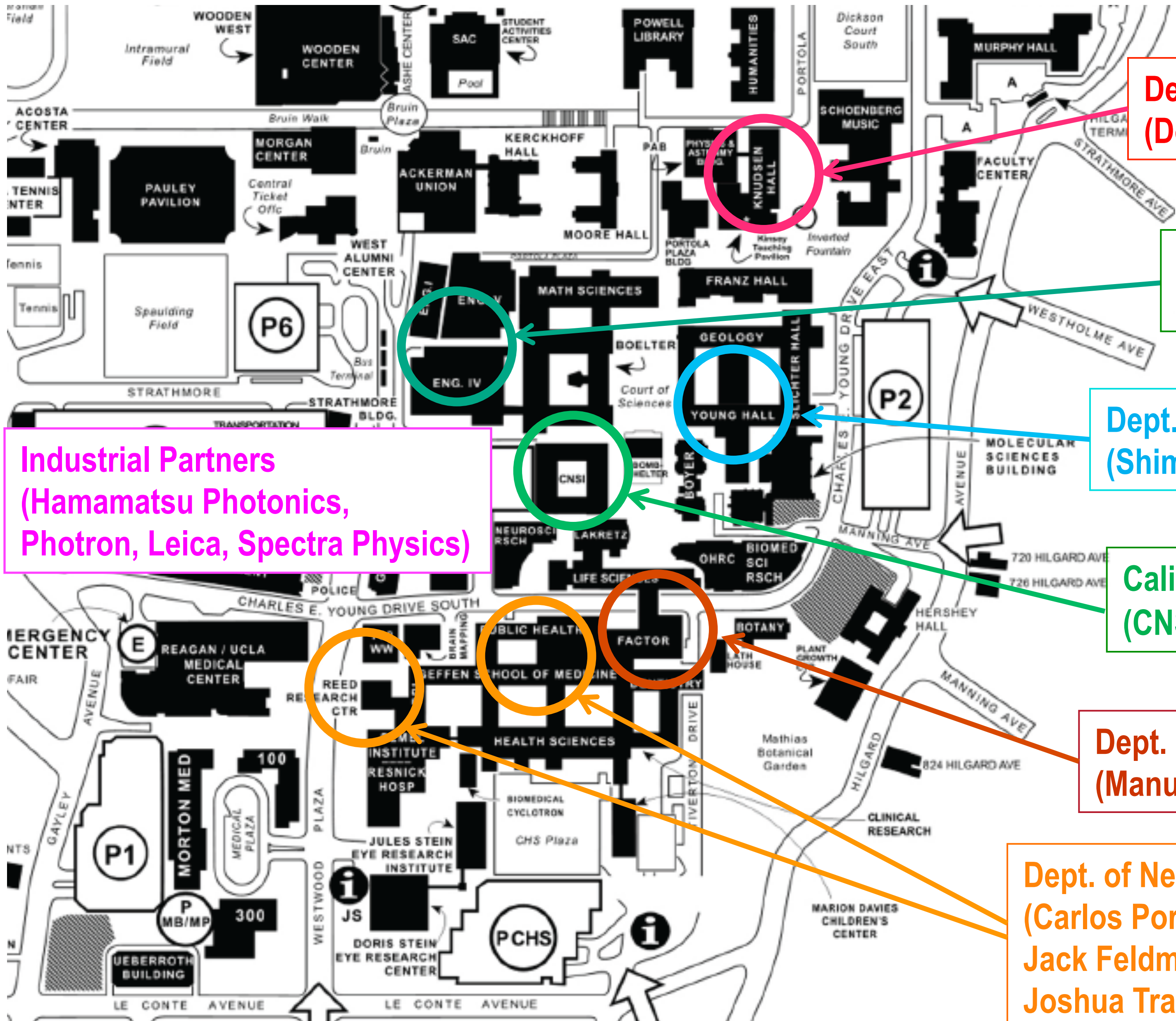
Prof. Manuel Penichet (Oncology)



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



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

Dept. of Electrical Engineering
(Bahram Jalali)

Dept. of Chemistry & Biochemistry
(Shimon Weiss)

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

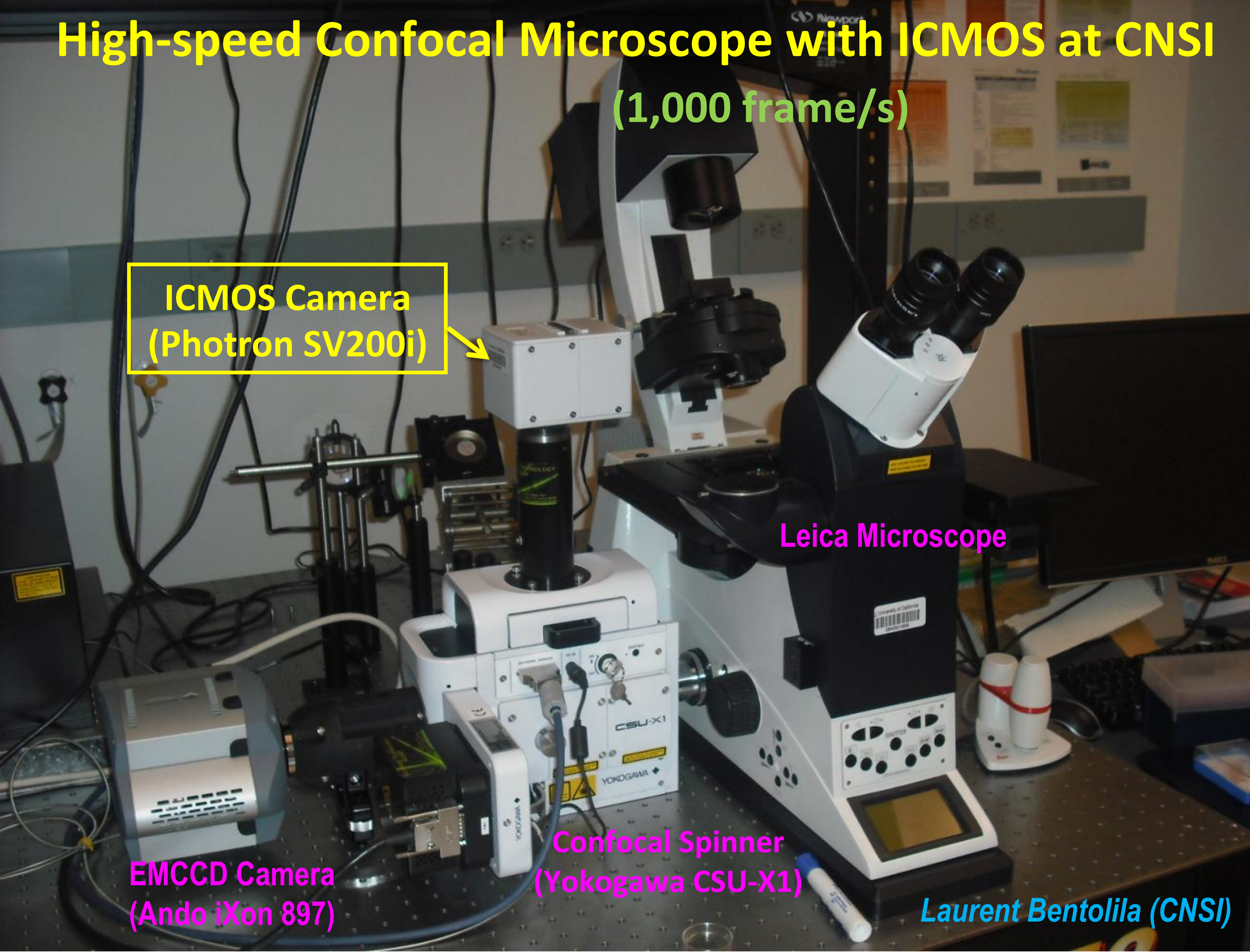
California Nano Systems Institute
(CNSI, Laurent Bentolila)

Dept. of Surgical Oncology
(Manuel Penichet)

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

High-speed Confocal Microscope with ICMOS at CNSI

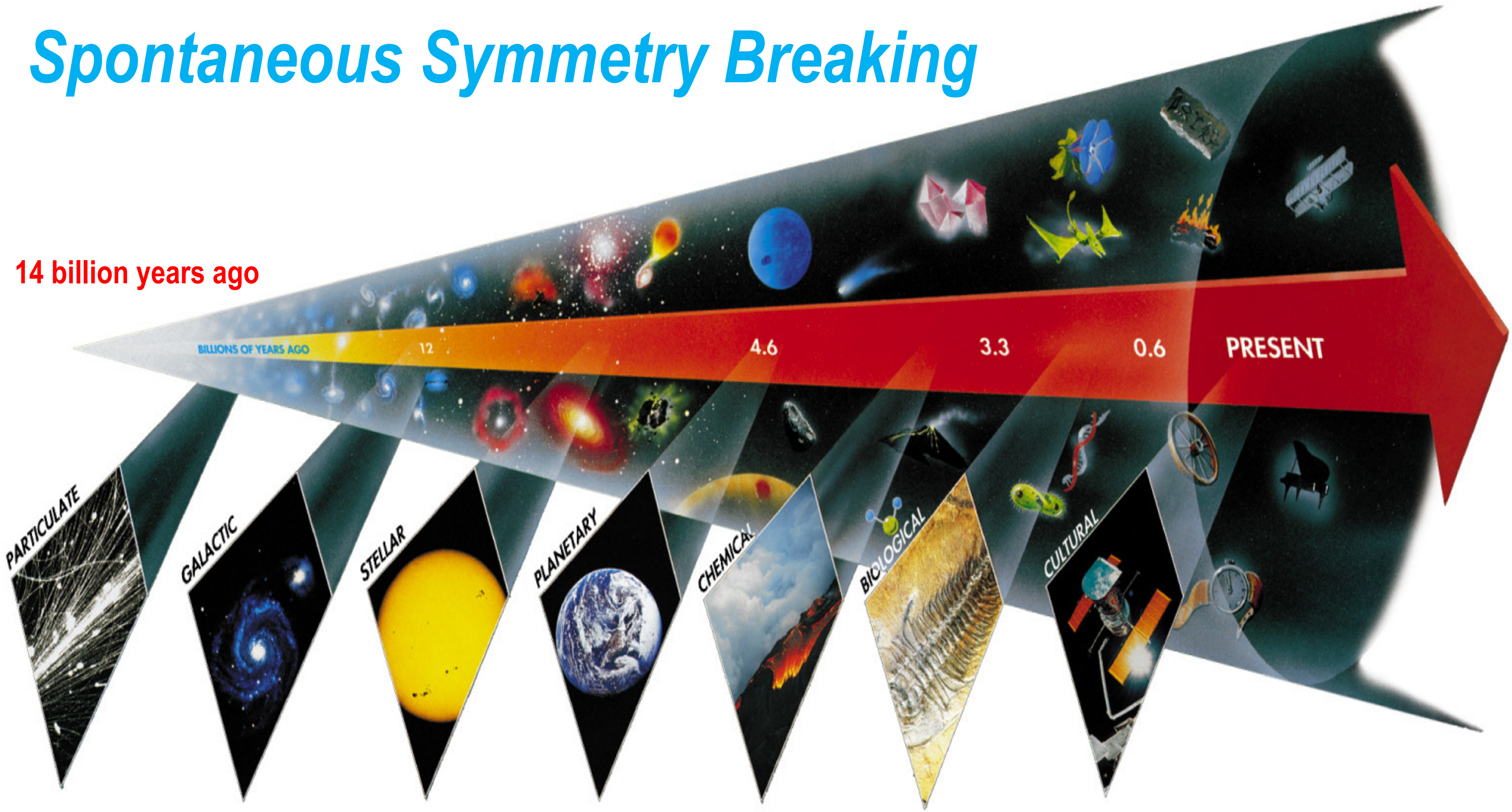
(1,000 frame/s)



Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking

14 billion years ago



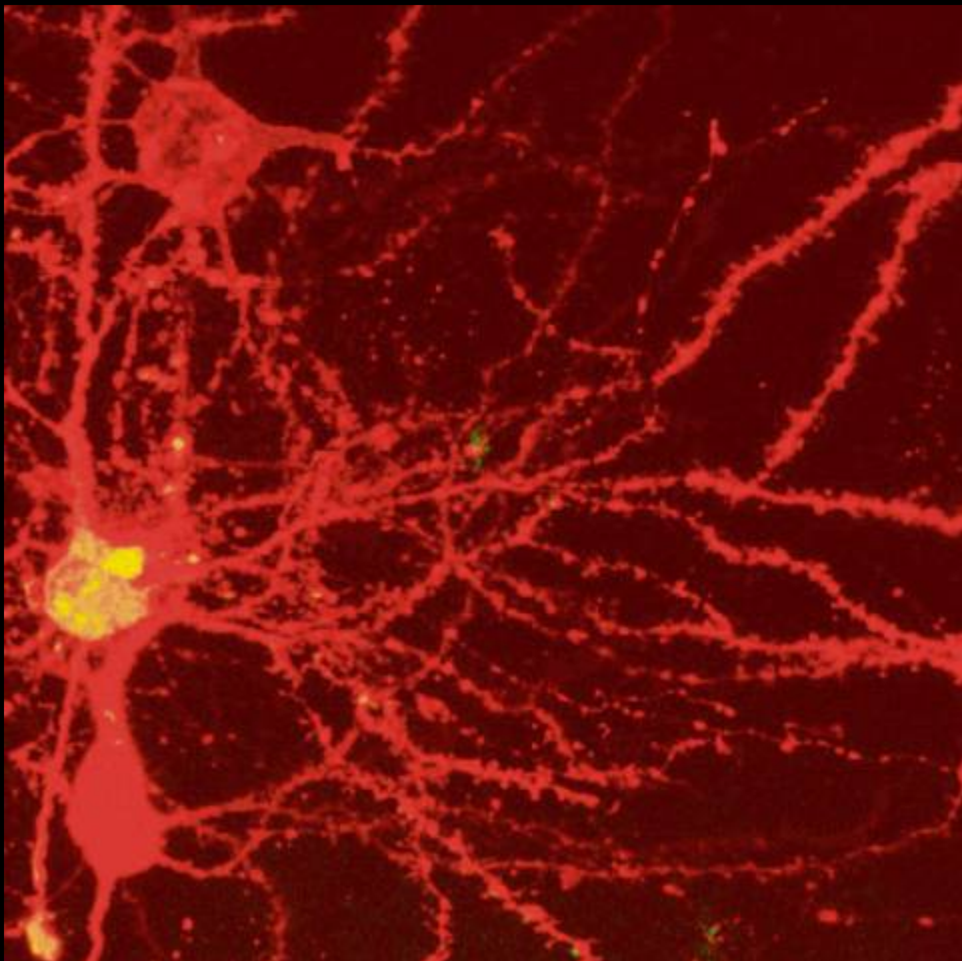
Origin of Particles

Origin of Structure

Origin of Life

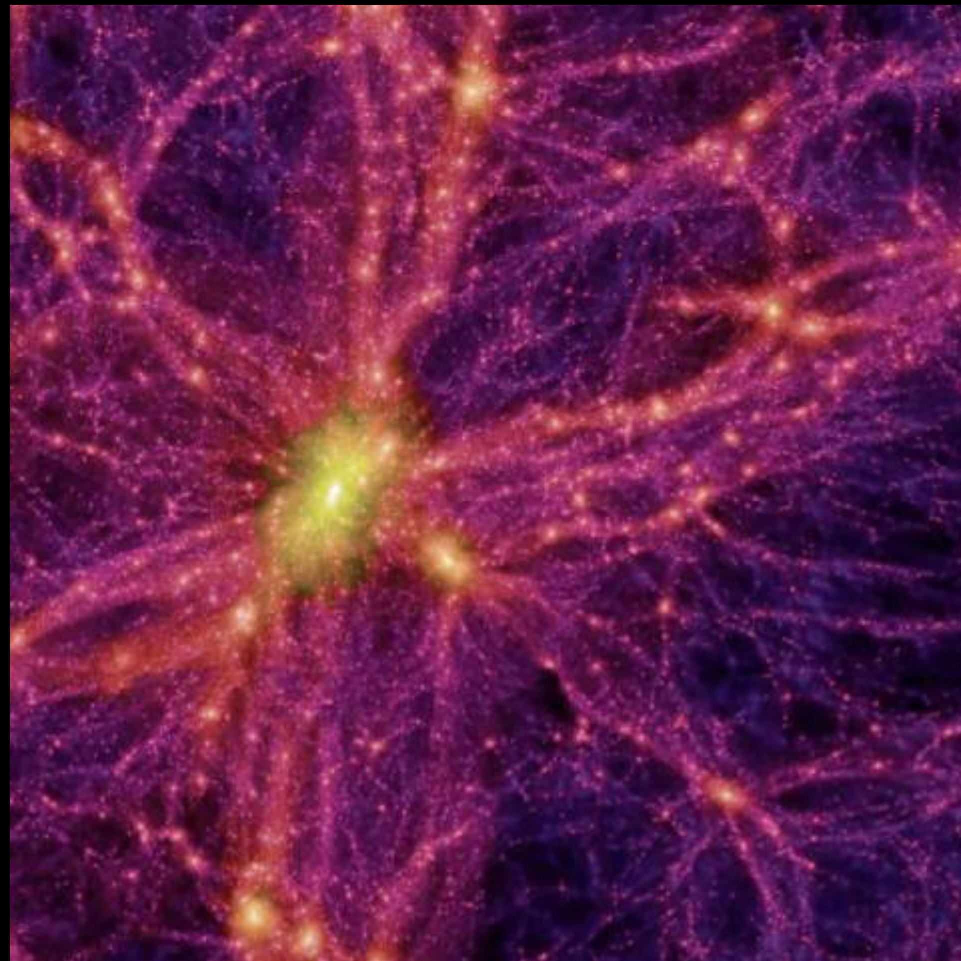
Origin of Consciousness

Brain



100 Billions Neurons

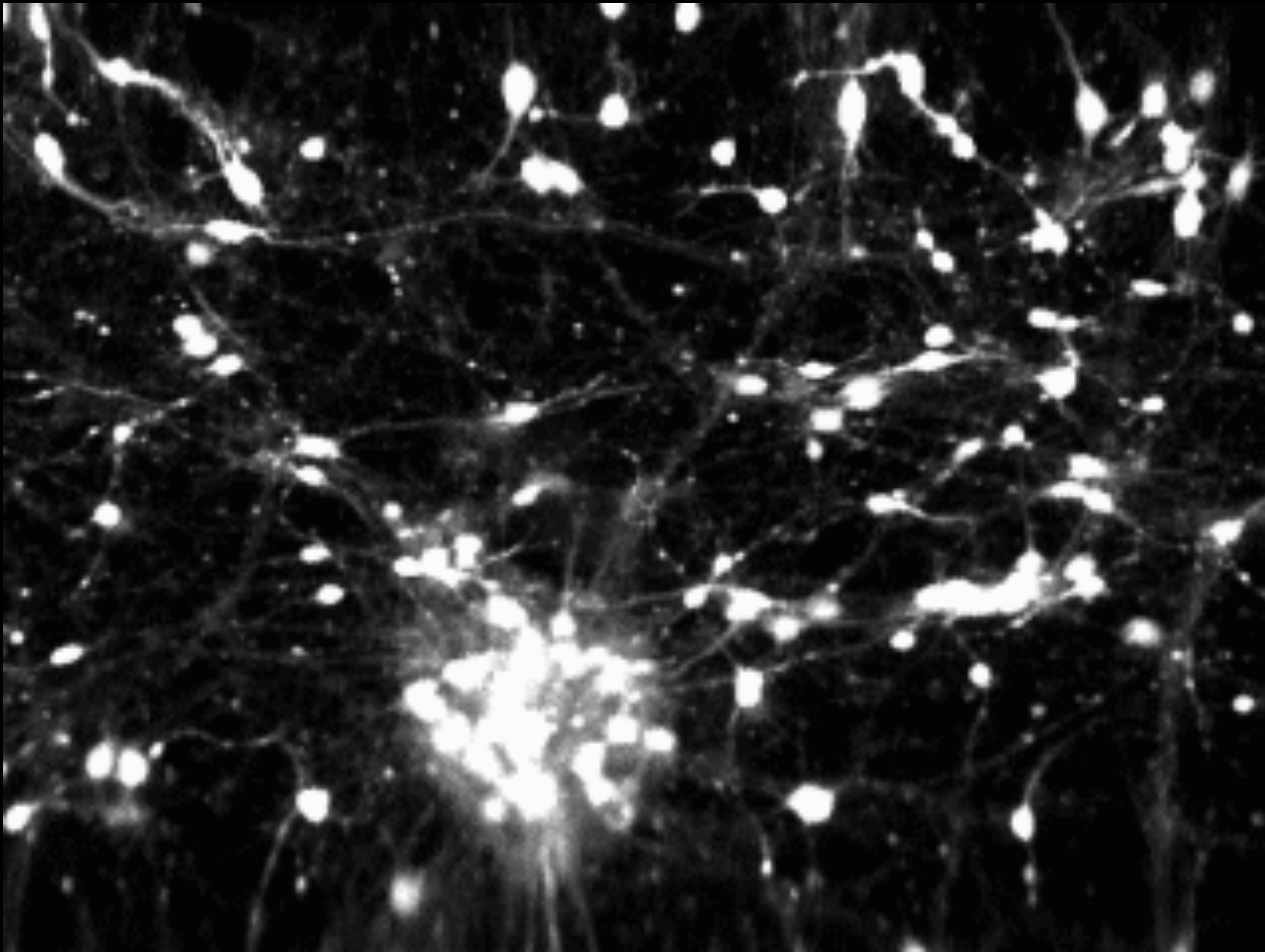
Universe



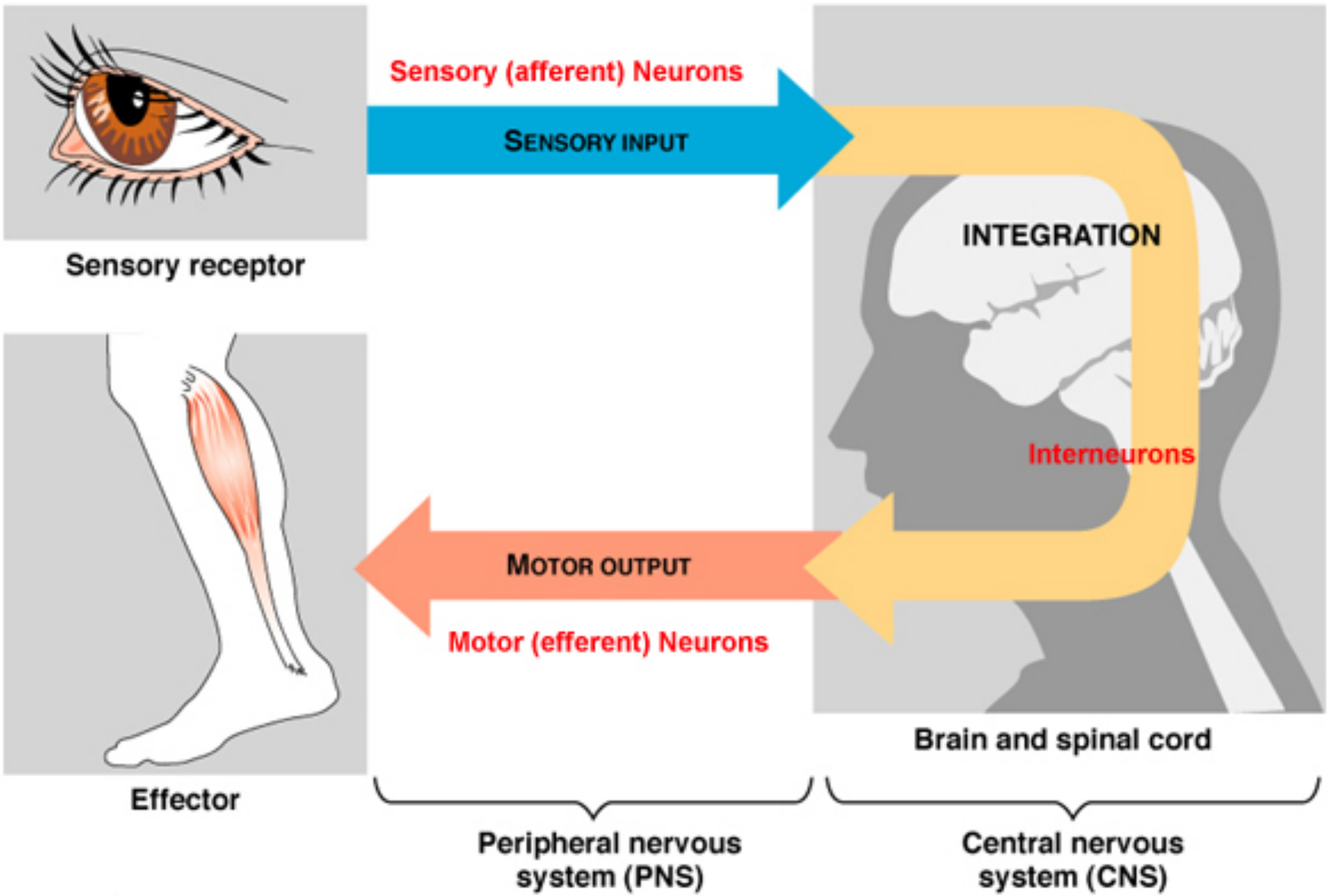
100 Billions Galaxies

New York Times 8/21/2006

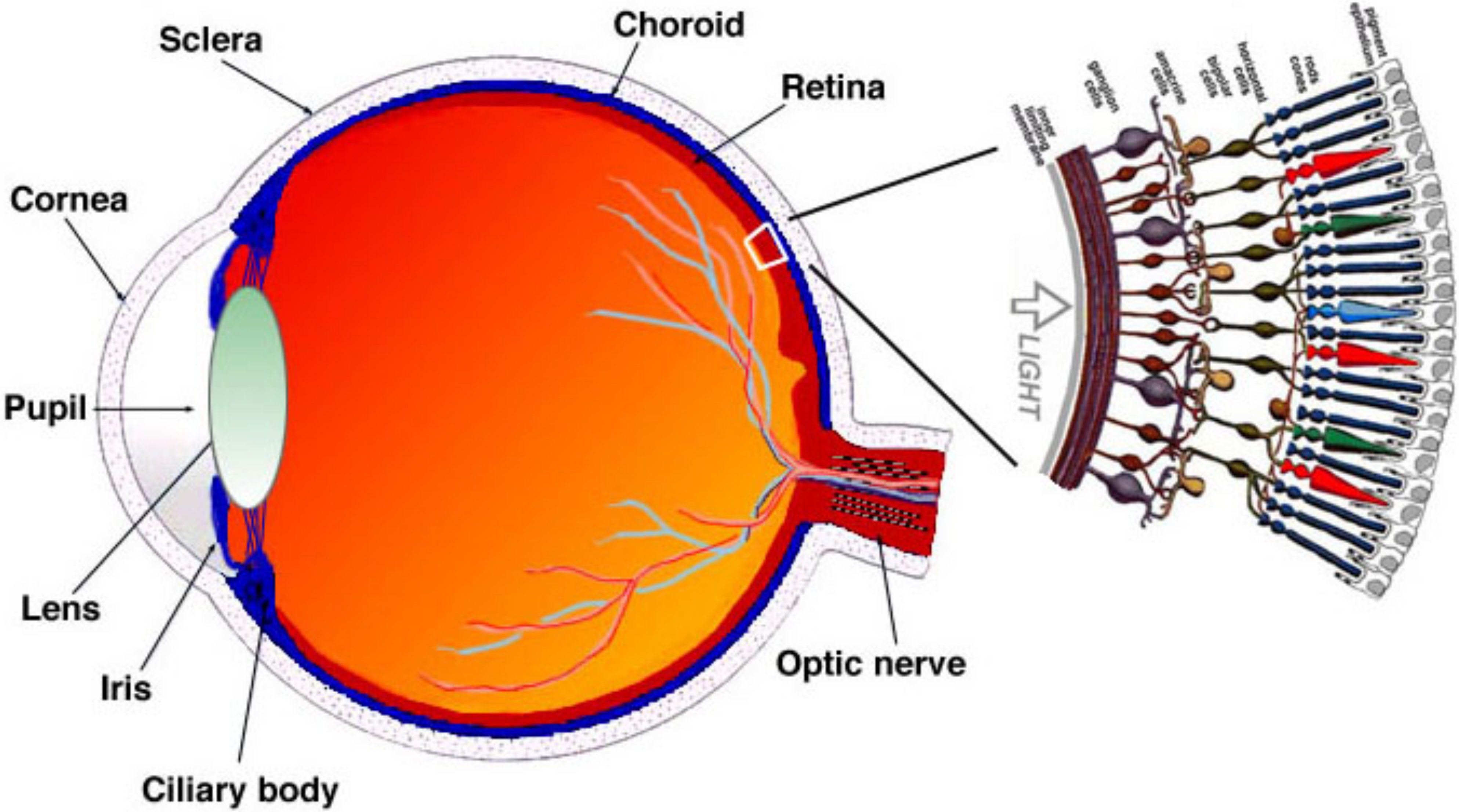
Ca^{2+} Signal in cultivated Rat's Brain



Assembly of cortical circuits during development



Human Eyes

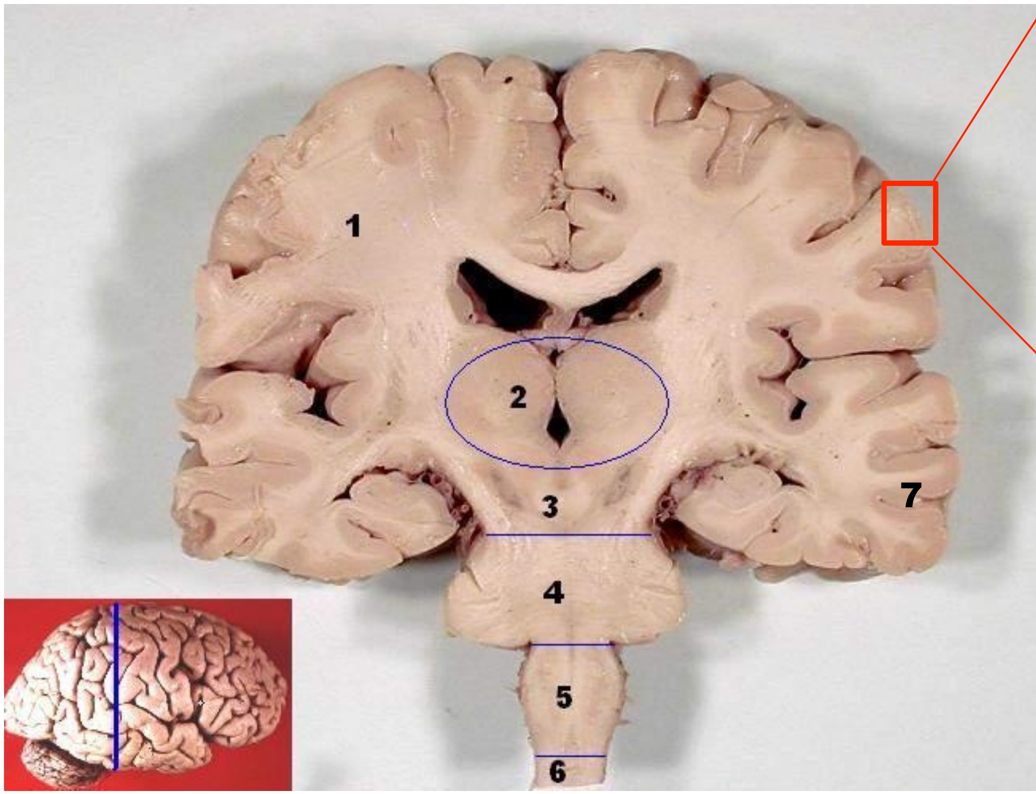

Sclera
Choroid
Retina
Cornea
Pupil
Lens
Iris
Ciliary body
Optic nerve
inner limiting membrane
ganglion cells
amacrine cells
bipolar cells
horizontal cells
rods cones
pigment epithelium
LIGHT

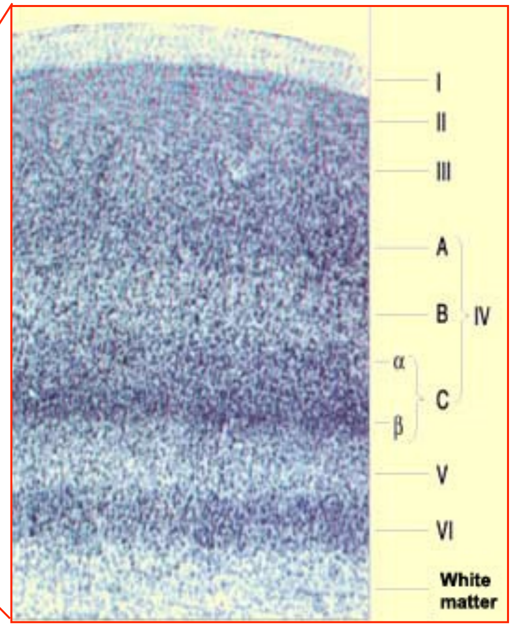
How can I recognize a woman so far away?

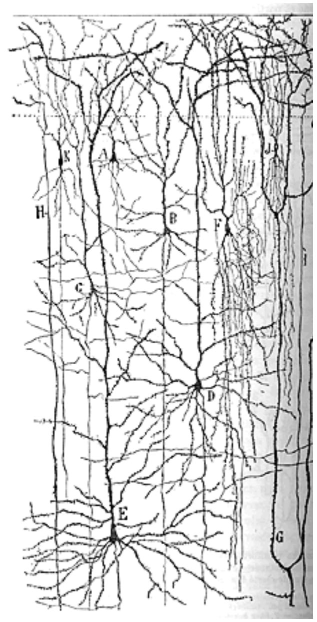
- Genetically encoded?
- Learning and memory?

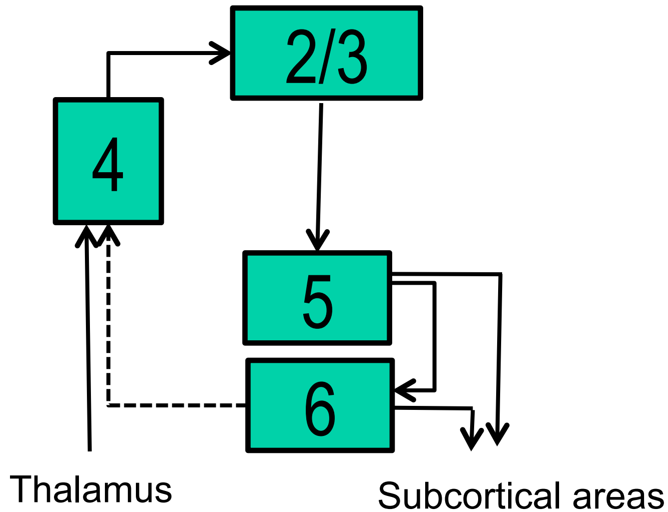
The Cerebral Cortex

Conscious



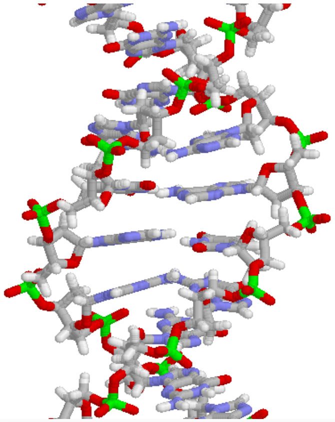


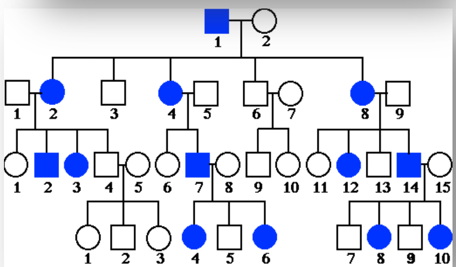




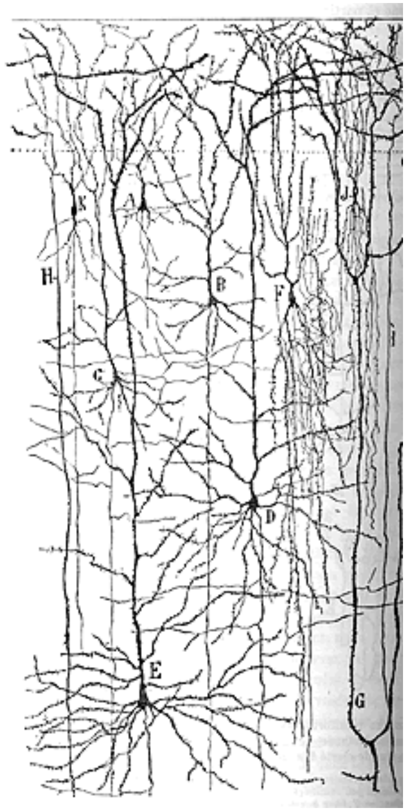
Unconscious

Nature vs. Nurture

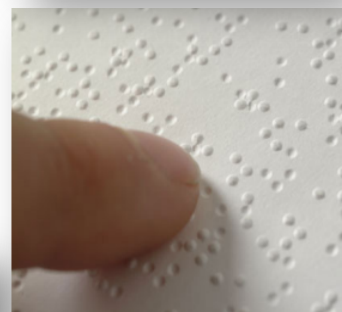
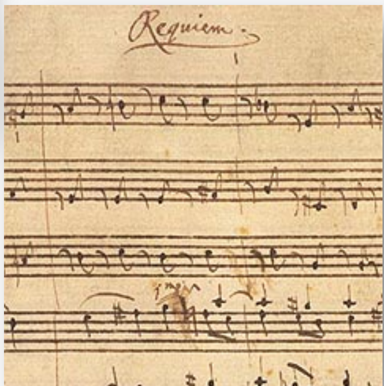


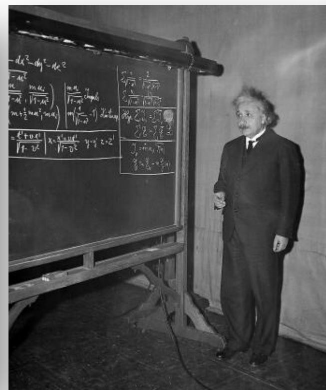


Nature

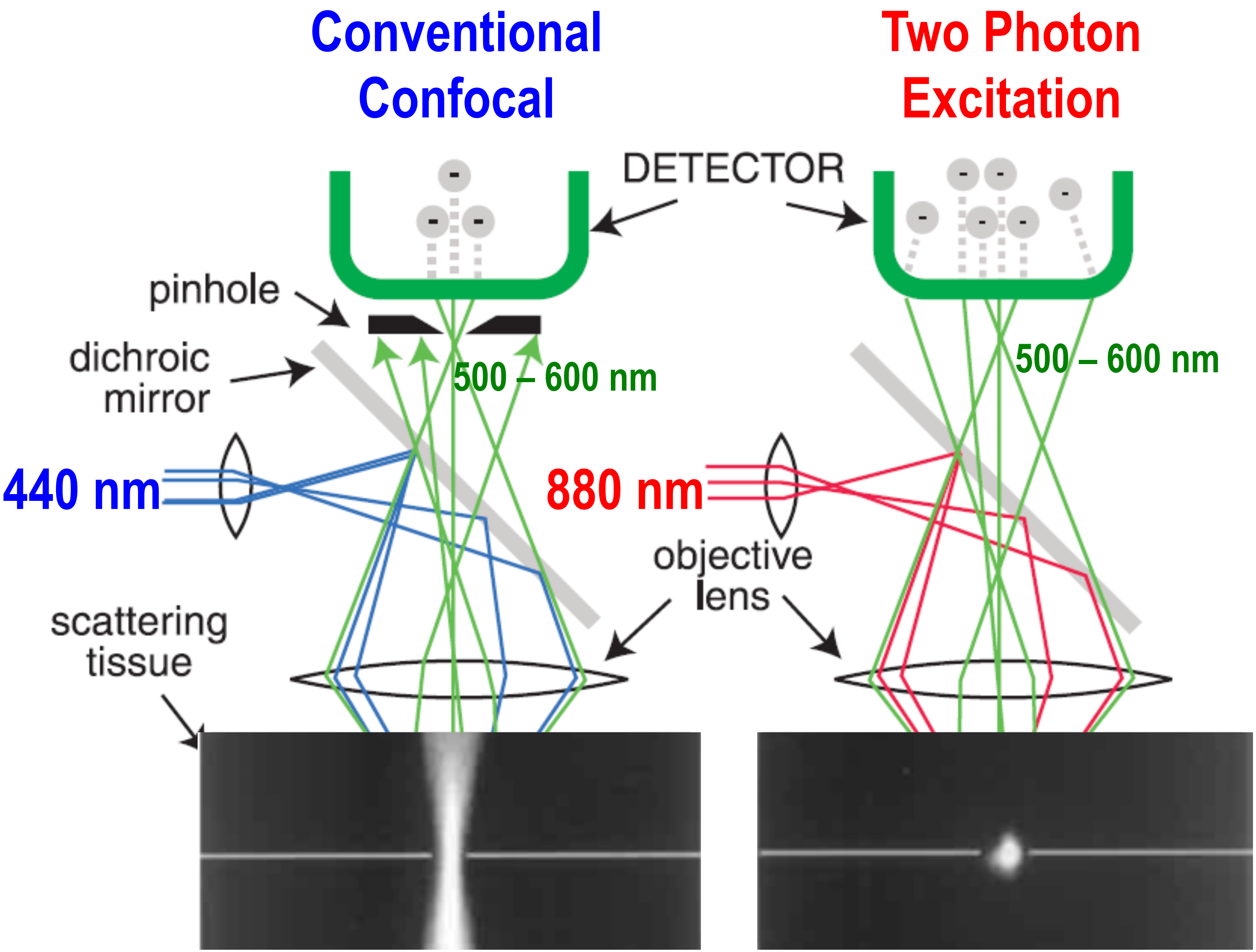


Nurture

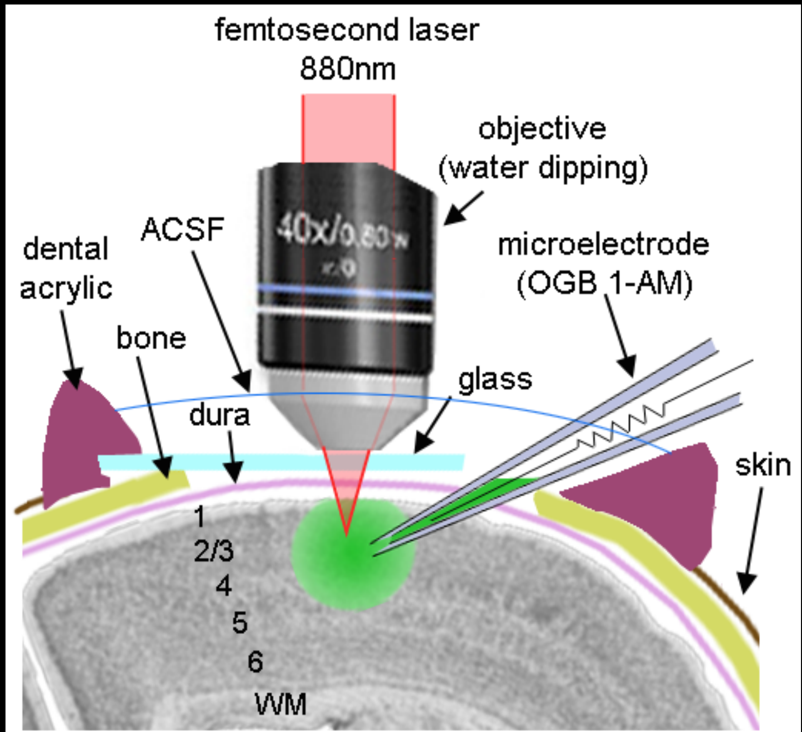


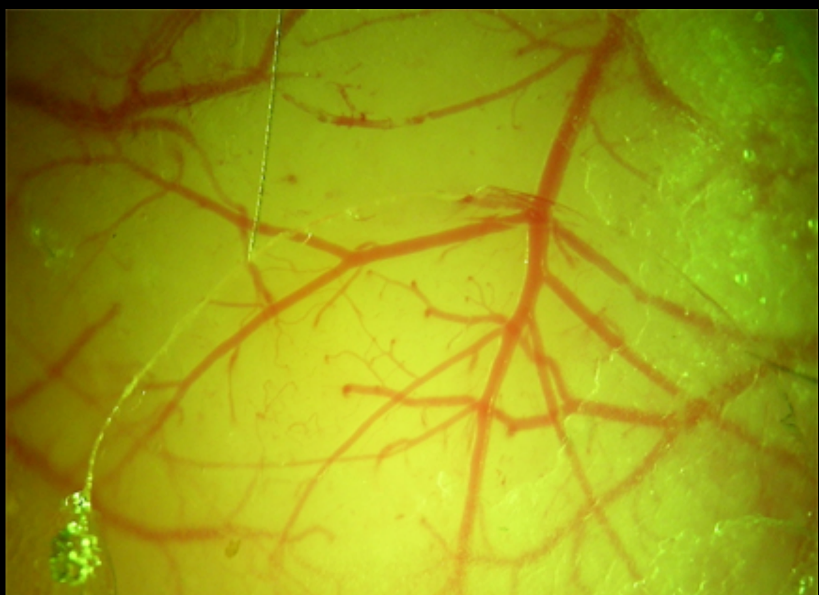


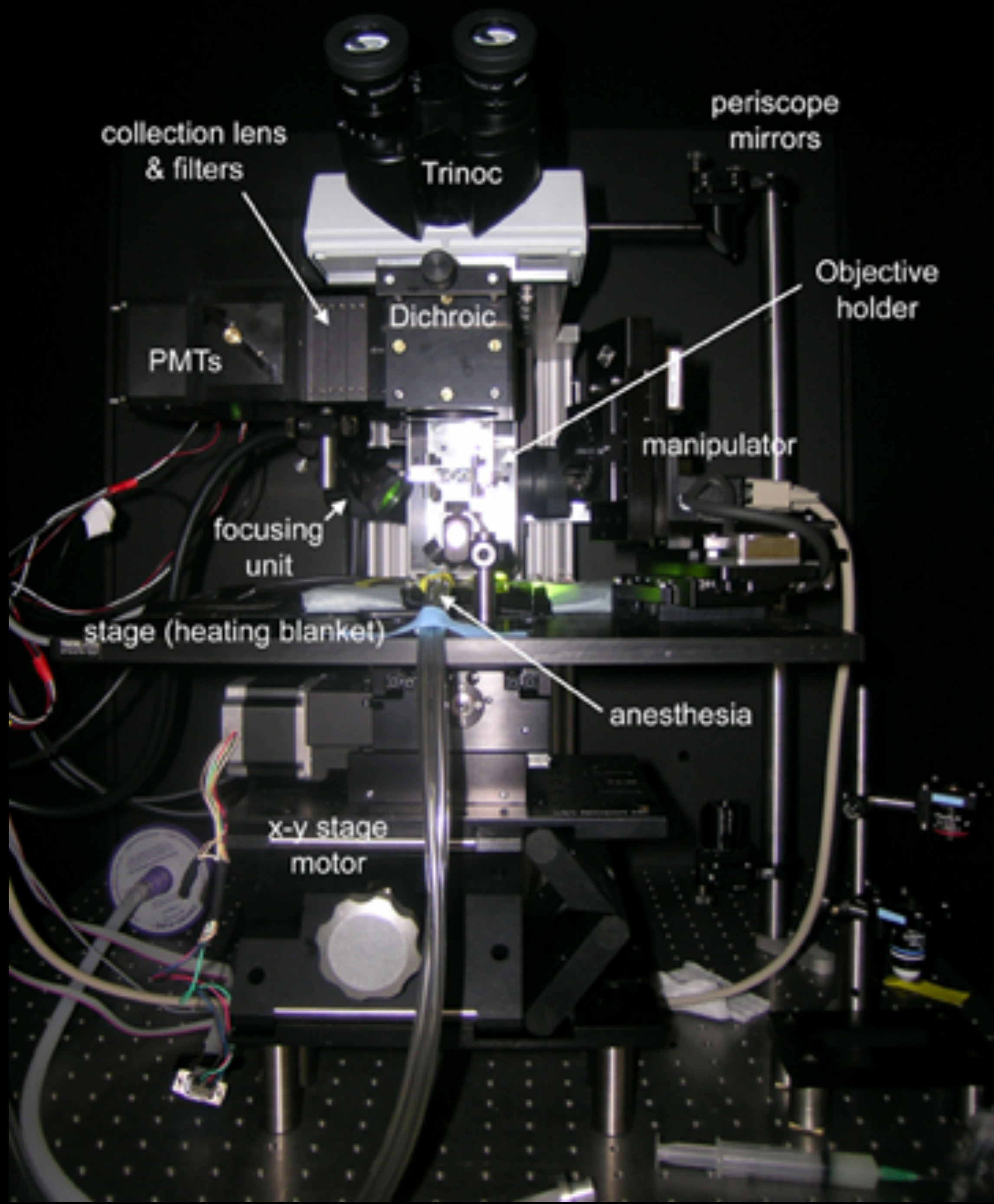
Mutiphoton Microscope



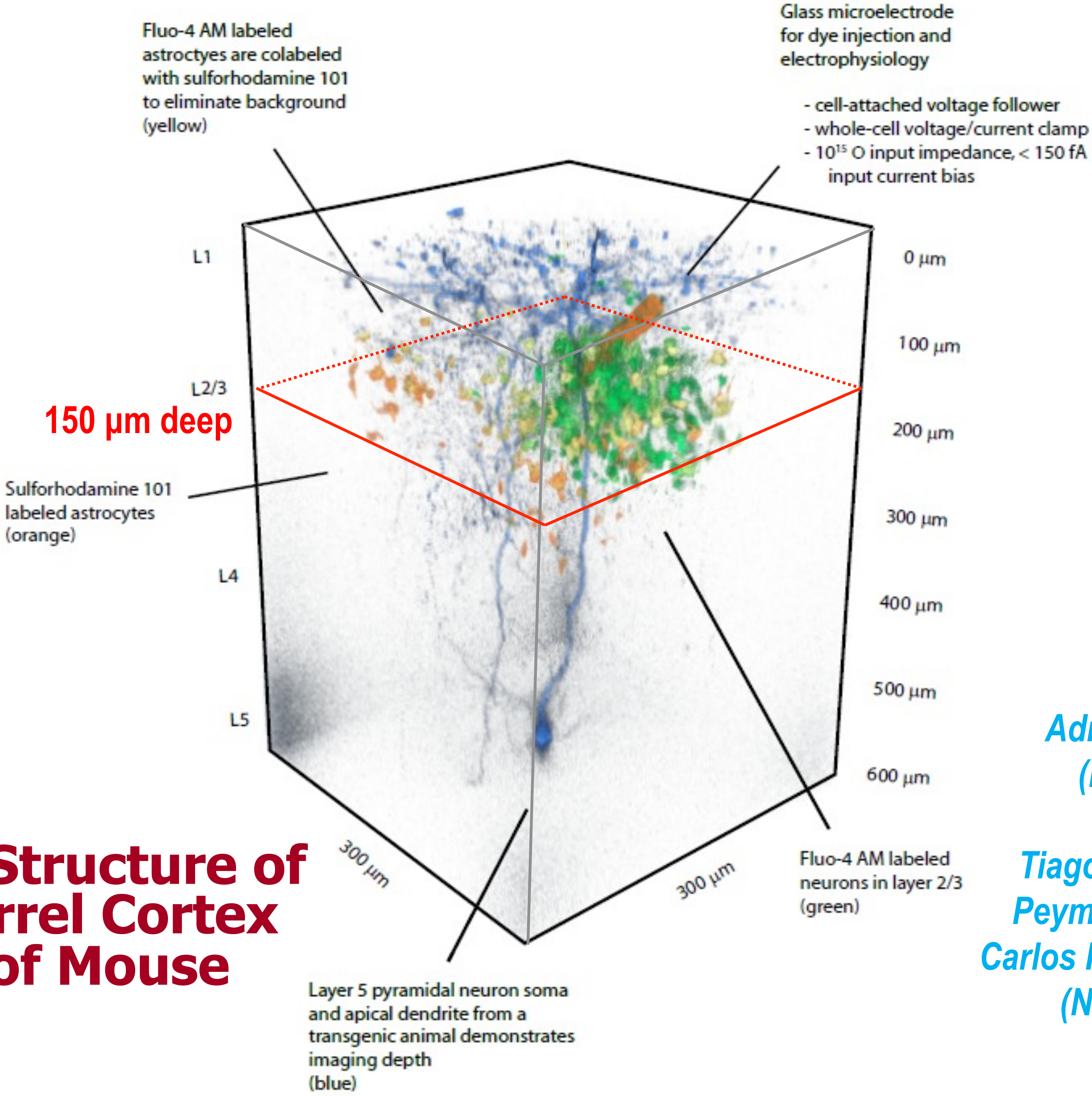
In vivo calcium imaging of neuronal activity







3D Structure of Barrel Cortex of Mouse



Adrian Cheng (Physics)

Tiago Goncalves, Peyman Golshani, Carlos Portera-Cailliau (Neurology)

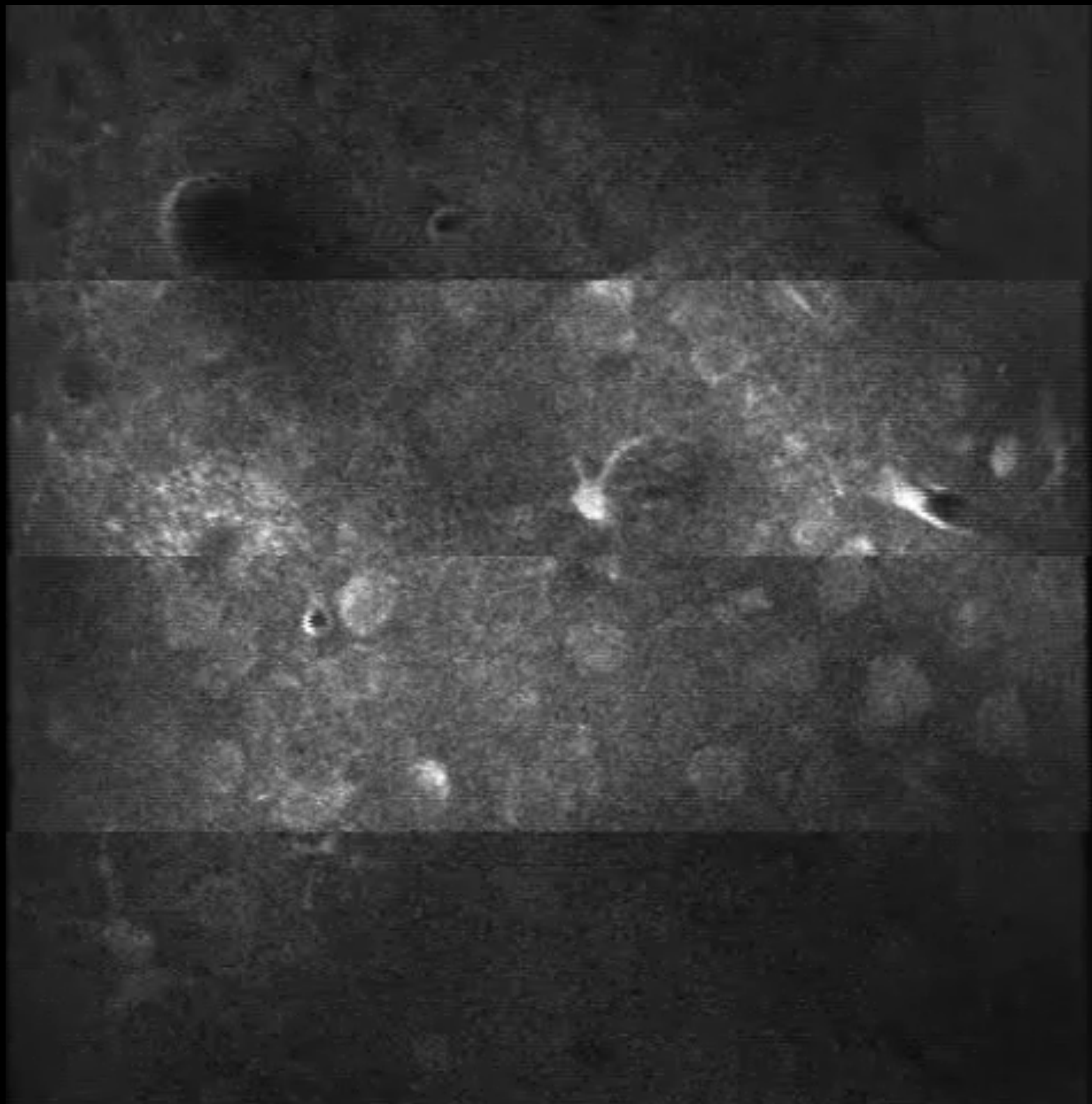
In vivo calcium imaging of Barrel Cortex of Mouse

Barrel Cortex
Layer 2/3

150 µm deep

240 fps
Raw Data

(x3 faster than real)



Beam 1 (0 ns)

Beam 2 (+3 ns)

Beam 3 (+6 ns)

Beam 4 (+9 ns)

300 µm

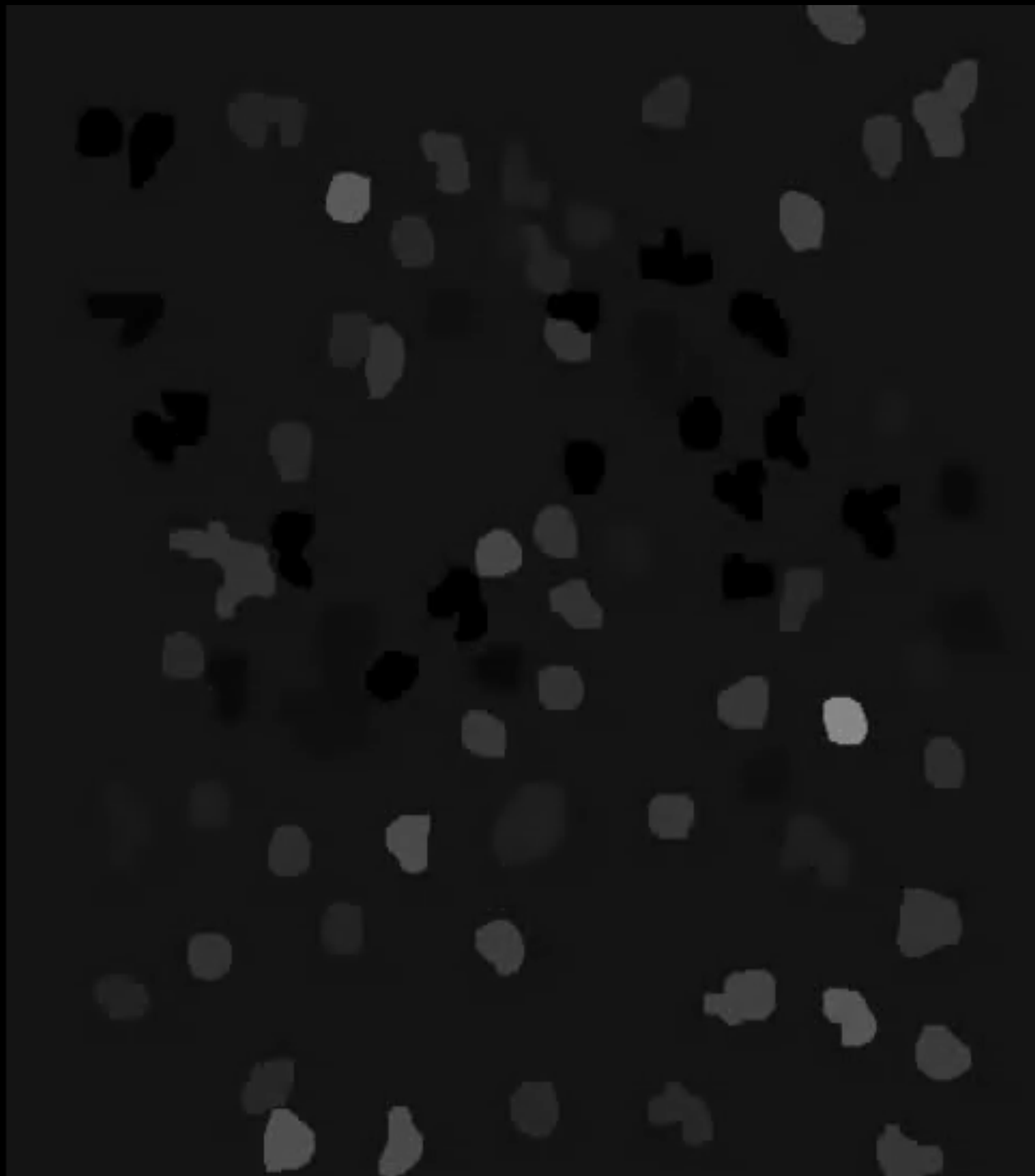
In vivo calcium imaging of Barrel Cortex of Mouse

Barrel
Cortex
Layer 2/3

150 µm
deep

After
averaging

(x3 faster
than real)



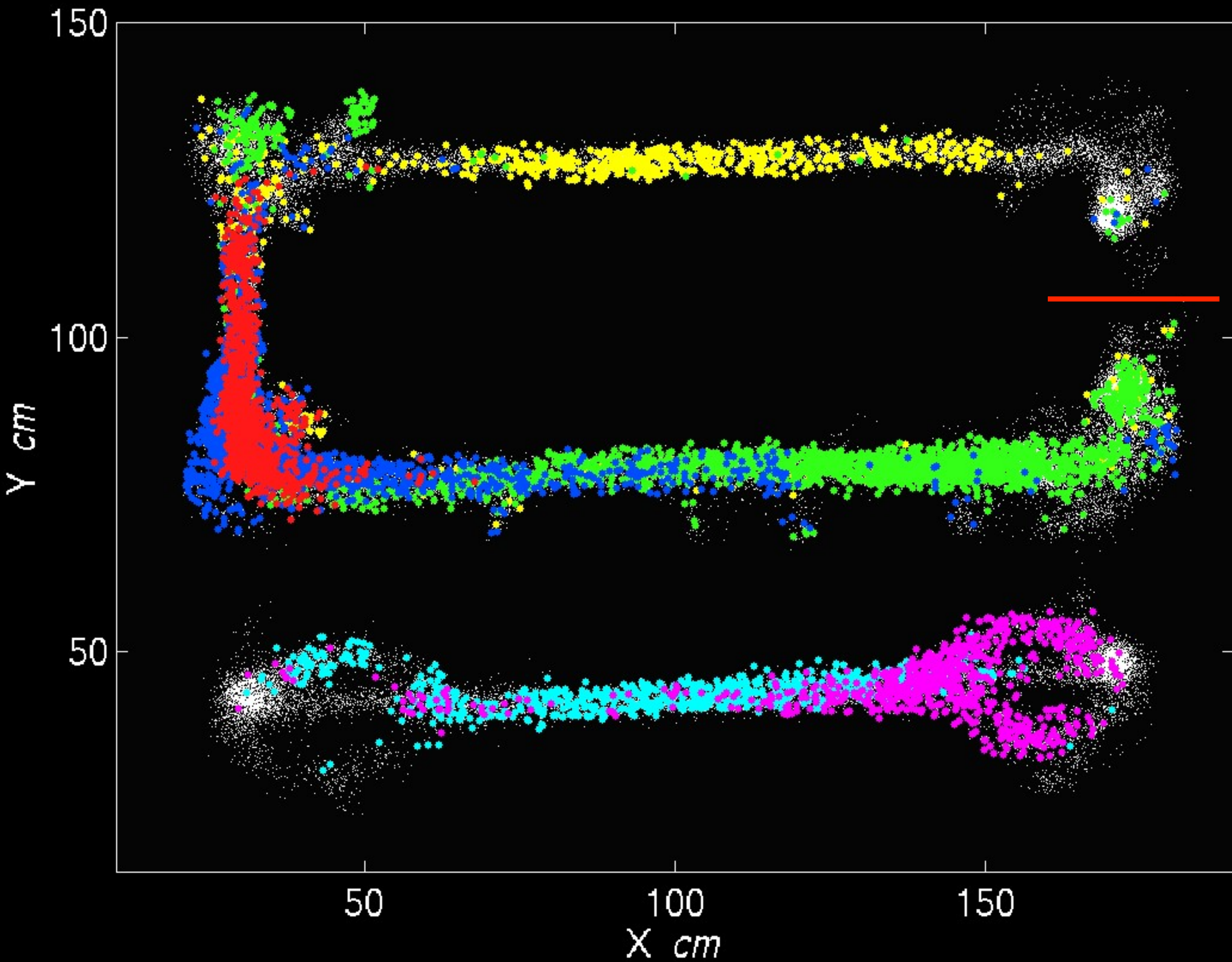
300 µm

58 neurons

(~100 billons
neurons
in our brain)

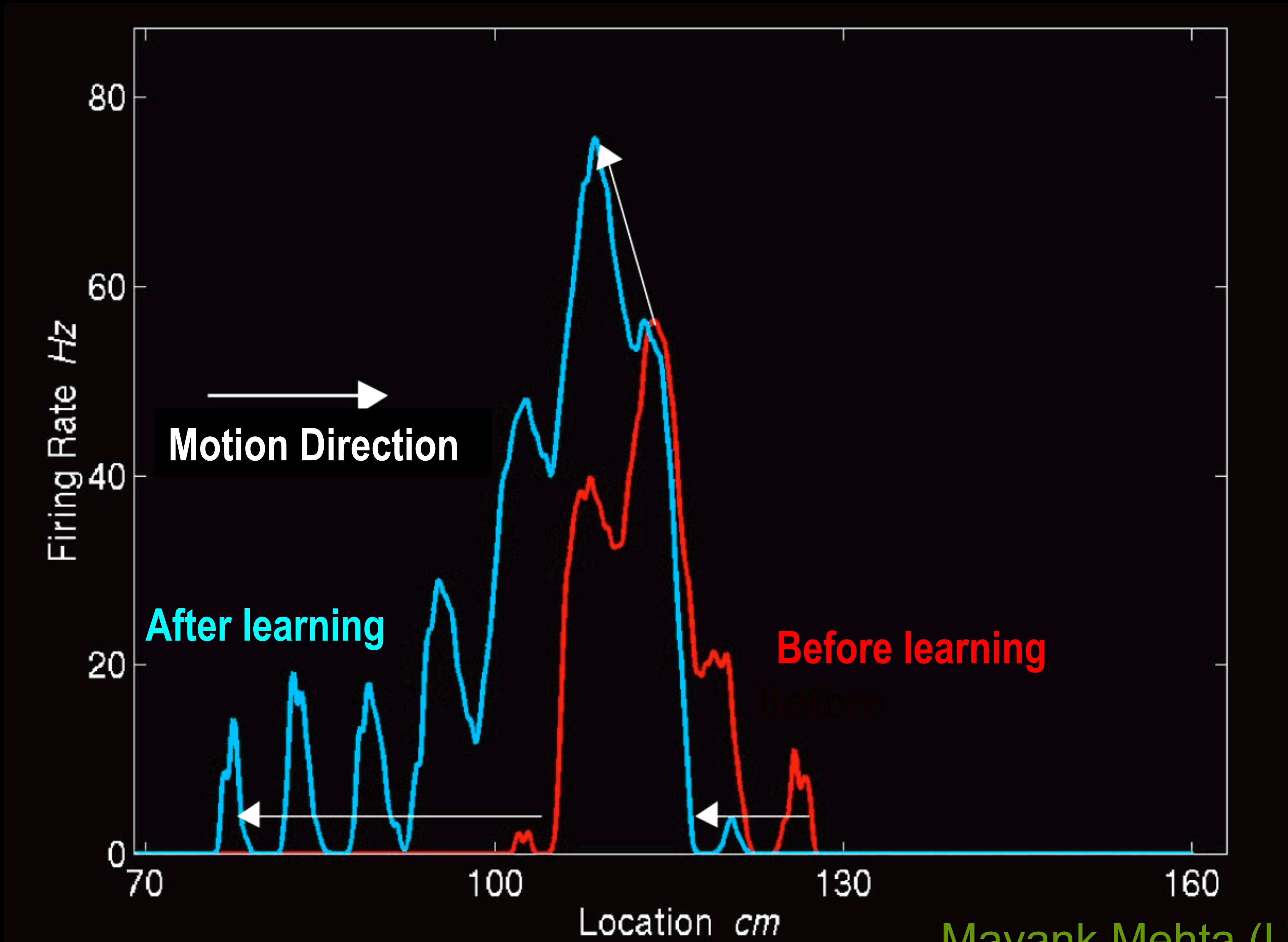
Activity of (excitatory) pyramidal neurons in CA depends on rat's position: place cells

Mayank Mehta (Physics, Neurology)



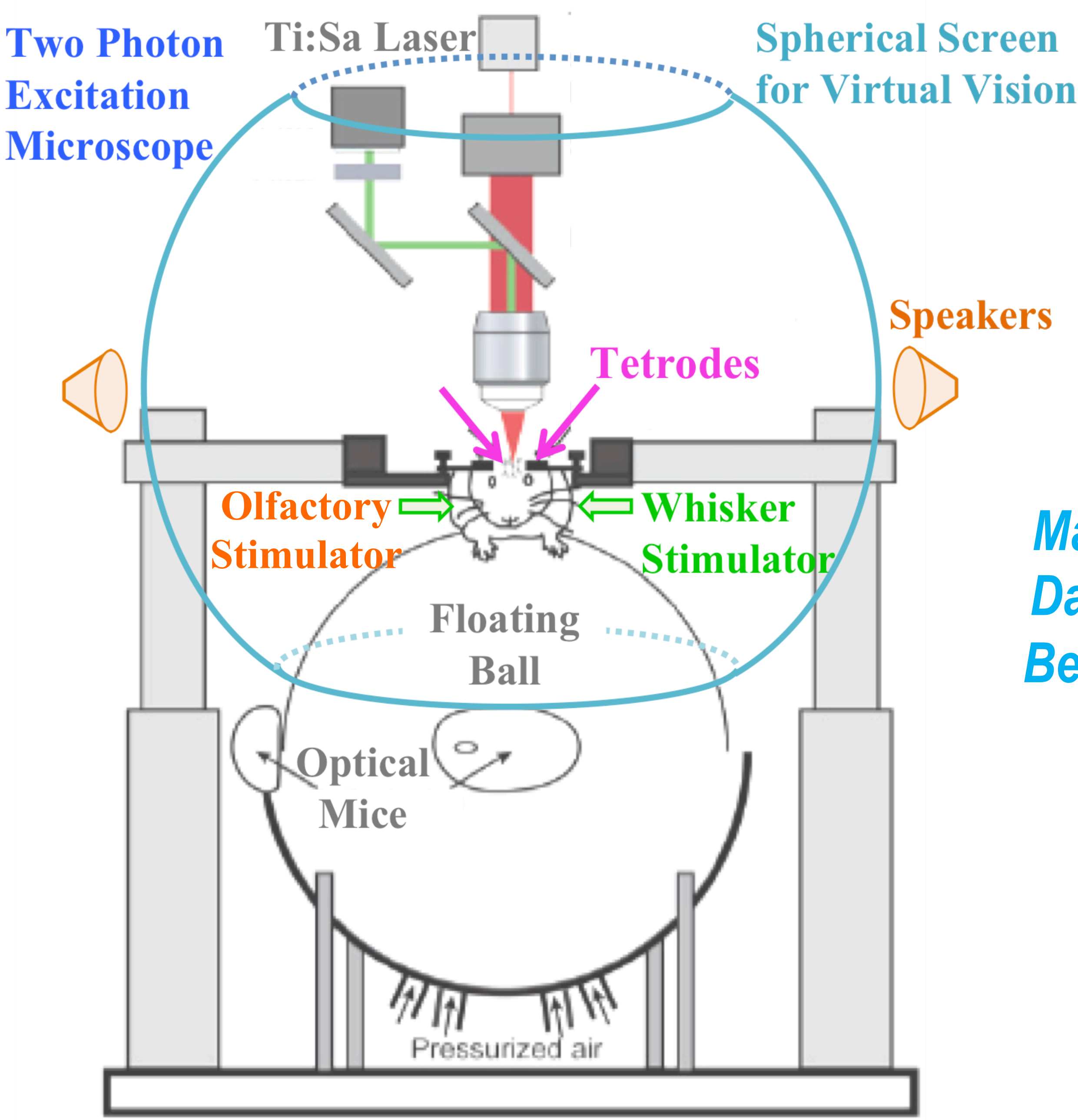
Hippocampus has a cognitive map of space

Learning and Memory by Hippocampus



Mayank Mehta (UCLA

Virtual Reality Experiment on Awake Rats

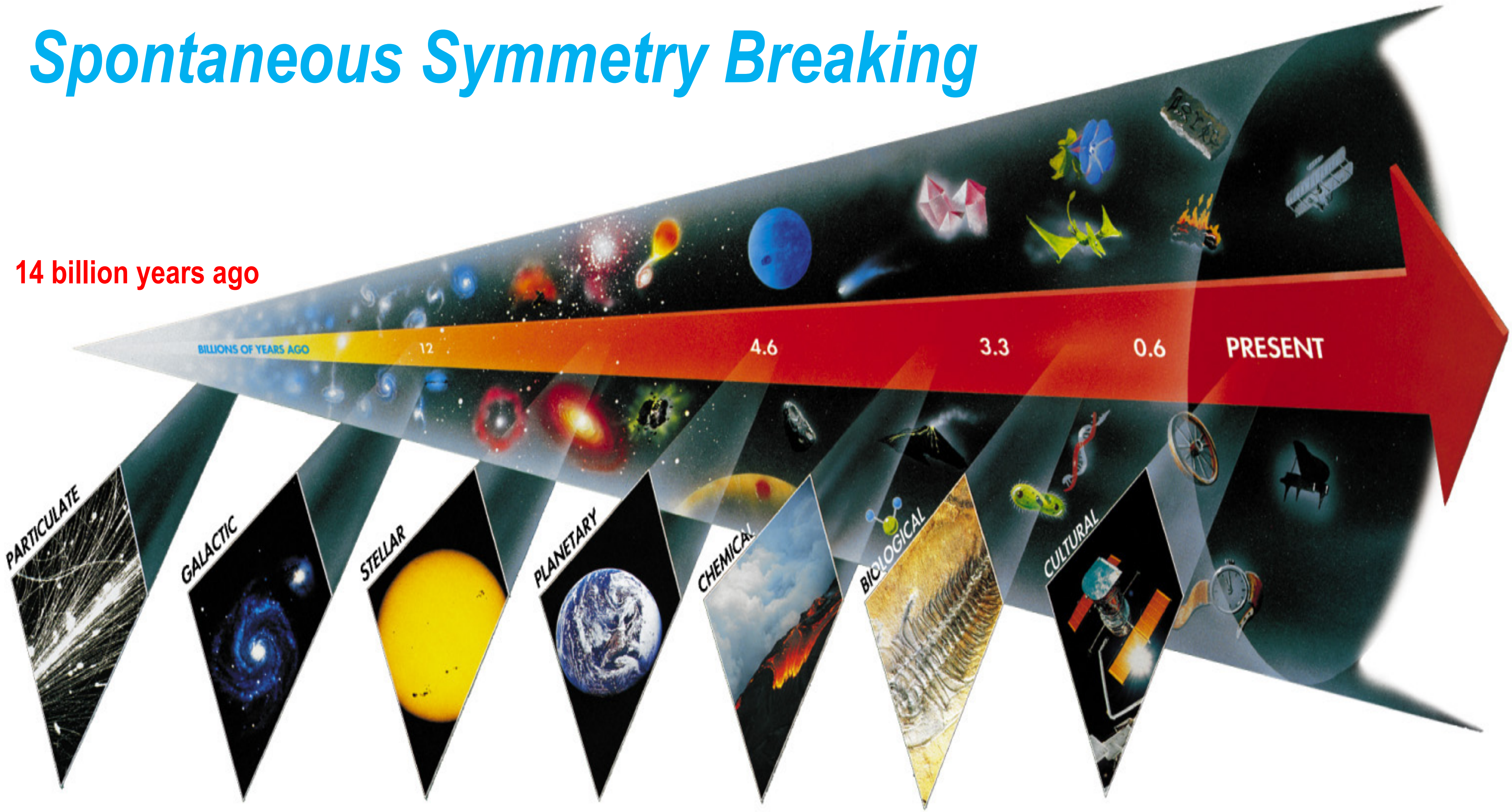


Mayank Mehta
Daniel Aharoni
Bernard Willers

Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking

14 billion years ago



Origin of Particles

Origin of Structure

Origin of Life

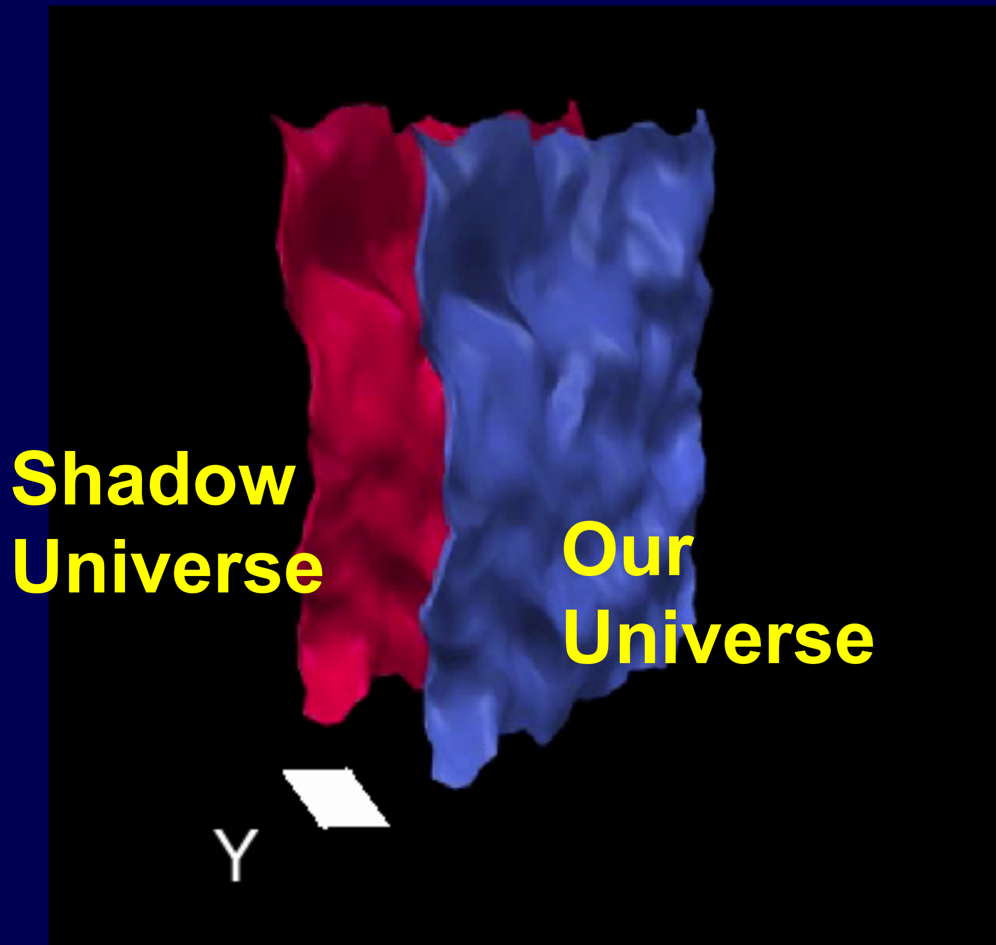
Origin of Consciousness

Why are we here?

Cyclic Model

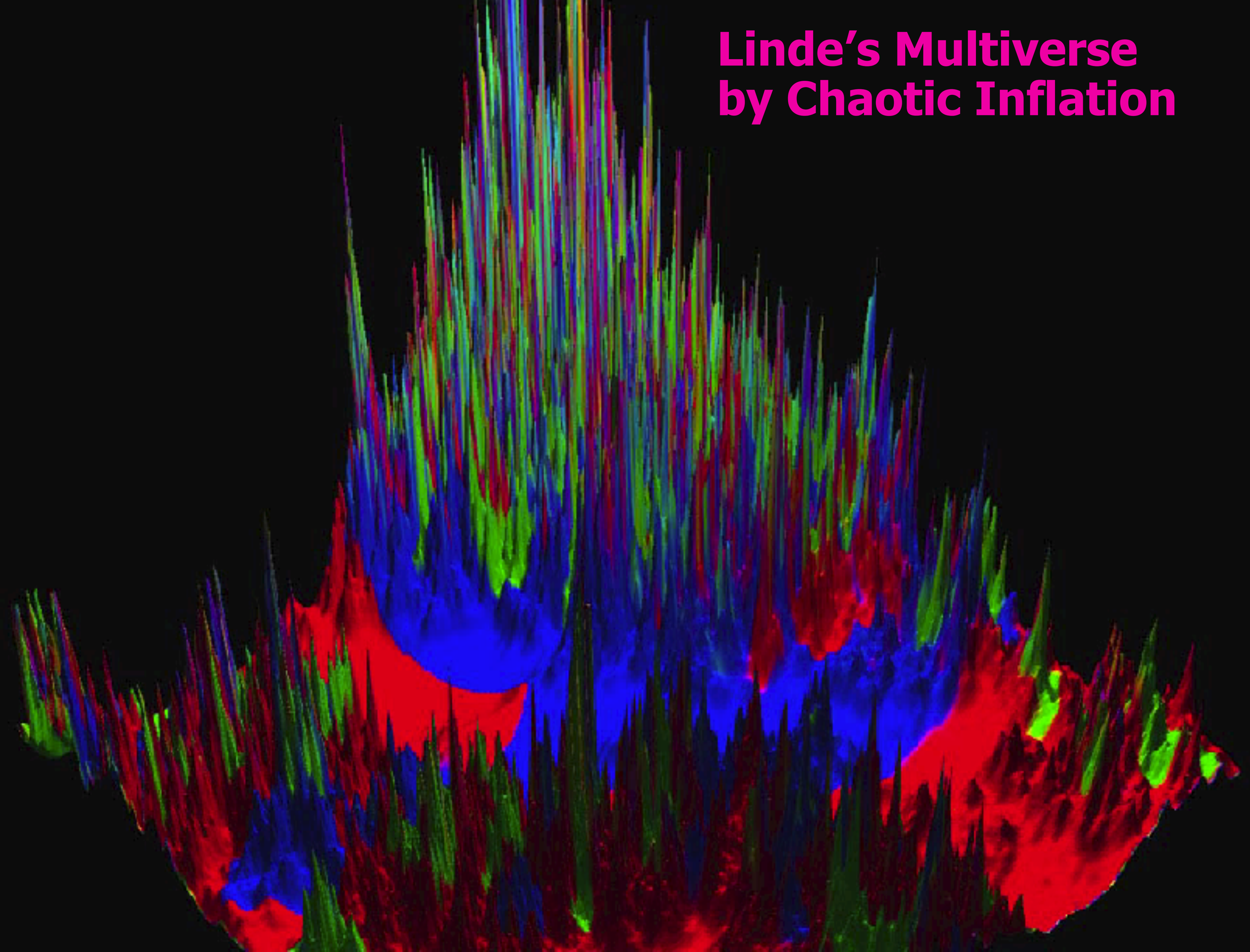
"bang"
radiation
matter
dark energy
"contraction"
"crunch"

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