Why are we here?
Origin of Universe and Ourselves

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Why are we here?
Andromeda

~100 Billions Stars in a Galaxy
Hubble Deep Field

~100 Billion Galaxies
Hubble Deep Field

Red shift up to $\sim 10$

$\sim 100$ Billion Galaxies
Hubble’s Law: Expansion of the Universe

Big Bang!

14 Billion Light Years

Sun/Earth

Moving Away at Speed of Light

Horizon of Universe
Expansion of Universe

Size

Size of Universe

Beginning

Today

Time
Temperature of Universe

Temperature = 1/Size

Beginning

Today

Size

2.7°C

Temperature = 2.7°C
Tevatron at Fermi Lab near Chicago (1980 – 2010)

6km Circumference
Quark Model

Proton

\[ + \frac{2}{3} + \frac{2}{3} - \frac{1}{3} = 1 \]

Neutron

\[ + \frac{2}{3} - \frac{1}{3} - \frac{1}{3} = 0 \]
Unification of Forces

Electro-Weak Unification

strong force

electromagnetic

weak force

gravity

100 GeV

10^{15}

10^{16} GeV

10^{29}

10^{19} GeV

10^{32}

temperature (K)

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Unification of Forces

Grand Unification

relative strength of force

strong force

electromagnetic

electroweak

weak force

gravity

100 GeV

10^{15}

temperature (K)

10^{16} GeV

10^{29}

10^{19} GeV

10^{32}

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Unification of Forces

Planck Epoch

- Strong force
- Electromagnetic force
- Weak force
- Electroweak
- GUT force

Relative strength of force

Gravity: 100 GeV

Temperature (K):
- $10^{15}$
- $10^{29}$
- $10^{32}$

Energy scales:
- $10^6$ GeV
- $10^{16}$ GeV
- $10^{19}$ GeV
Physicists’ View of Early Universe

Fiat lux
Let there be light
Structure of DNA

3 billion base pairs
Symmetry Breaking

Time
0
1B years

Simple

Symmetry Break Down

Complex

\[
\begin{align*}
\bar{s} & \quad \bar{b} & \quad W^+ \\
\bar{\nu}_e & \quad \tau^+ & \quad \bar{\nu}_e
\end{align*}
\]

\[
\begin{align*}
\nu_\mu & \quad \nu_\tau & \quad \nu_\tau \\
\nu_\mu & \quad W^+ & \quad \nu_\mu \\
\tau^- & \quad \nu_e & \quad \nu_e
\end{align*}
\]
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.

3
1
3
6

\begin{align*}
\text{Space} & : 3 \\
\text{Time} & : 1 \\
\text{Strong Force} & : 3 \\
\text{Weak} & : 2 \\
\text{Electro-Magnetic} & : 1 \\
\end{align*}

\text{Flattened}

\text{Compacitified}
Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking

Origin of Particles

14 billion years ago
CERN and LHC in Geneva

27km Circumference

7+7=14 TeV
CMS Collaboration (1993 ~)

(144 Institutions with about 1700 scientists)

ARMENIA
- Yerevan Physics Inst., Yerevan

AUSTRALIA
- 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

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- Univ. of Sofia, Sofia

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- Peking Univ., Beijing
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GERMANY
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- RWTH, III. Physik. Inst. A. Aachen
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- Institute of Nuclear Research ATOMKI, Debrecen

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- TIFR - HEG, Mumbai
- TIFR - HECR, Mumbai

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- Kyungpook National University, Daegu
- Kyungpook National University, Daegu
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- Kharkov Inst. of Phys. and Tech., Kharkov
- Kharkov State Univ., Kharkov

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- Imperial College, Univ. of London, London
- RAL, Didcot

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- 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
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- Univ. of Minnesota, Minneapolis
- Univ. of Mississippi, Oxford
- Massachusetts Inst. of Tech., Cambridge
- Univ. of Notre Dame, South Bend
- Boston College, Boston
- 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

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

UZBEKISTAN
CMS Barrel Yoke
Particle detectors constructed at Westwood, now at LHC, CERN
First Event at LHC – Recreation of the Big Bang! (Nov 7, 2009)
Physicists Find Elusive Particle Seen as Key to Universe

Scientists in Geneva on Wednesday applauded the discovery of a subatomic particle that looks like the Higgs boson.
Higgs particle $\rightarrow$ 2 gamma rays

CMS Experiment at the LHC, CERN
Data recorded: 2012-May-13 20:08:14.621490 GMT
Run/Event: 194108 / 564224000
Seven Phases of Cosmic Evolution

Spontaneous Symmetry Breaking

14 billion years ago

Origin of Particles
Origin of Structure
Formation of Structure in the Universe

Dark Matter is required!
Cosmic Pie Chart

- Dark Energy: 70%
- Dark Matter: 25%
- Free Hydrogen and Helium: 4%
- Stars: 0.5%
- Neutrinos: 0.3%
- Heavy Elements: 0.03%
Laboratori Nazionali del Gran Sasso, Italy

LNGS  1400 m Rock (3100 w.m.e.)
XENON 1T at Gran Sasso

Xe
2.5 ton
(1 ton)

1 m

Water

3" PMT x 250

10 m

Katsushi Arisaka, UCLA
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)


2. RNA molecules become self-replicating.

3. Membrane-enclosed pre-cells arise.

4. True cells with RNA genome appear.

5. Modern cells with DNA genome evolve.

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Eukaryote (~2B years ago)

Symmetry breaking

Cell made by proteins

Gene made by DNA

Cell dimensions: Up to ~2 m long, 2 nm wide.

10 – 50 µm
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.
Seven steps of cosmic evolution

Spontaneous Symmetry Breaking

14B years ago

Accelerator ➔ Telescope ➔ Microscope

Katsushi Arisaka, UCLA
The H33D detector attaches to a standard fluorescence microscope. It will permit to track multicolor qdot-labeled proteins in live cells virtually background-free.

Particle Physics Detector

Nano Technology

Single Molecule Imaging

Prof. Shimon Weiss
Gold nano particle (40nm) attached to Transferrin Receptor (TfR) on Cancer Cell

Prof. Manuel Penichet (Oncology)

(10,000 frame/sec)
Arisaka’s Campus-wide Collaborations on High-Speed Bio-imaging

California Nano Systems Institute (CNSI, Laurent Bentolila)

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

Dept. of Electrical Engineering (Bahram Jalali)

Dept. of Chemistry & Biochemistry (Shimon Weiss)

Dept. of Surgical Oncology (Manuel Penichet)

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

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

11/27/2012
Katsushi Arisaka, UCLA
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

Ca$^{2+}$ Signal in cultivated Rat’s Brain
Assembly of cortical circuits during development

Sensory (afferent) Neurons -> Sensory input -> Intereurons

Motor output

Motor (efferent) Neurons

Peripheral nervous system (PNS) <-> Brain and spinal cord <-> Central nervous system (CNS)

Sensory receptor

Effector
How can I recognize a woman so far away?

- Genetically encoded?
- Learning and memory?
Nature vs. Nurture

Nature

Nurture

Katsushi Arisaka, UCLA

11/27/2012
In vivo calcium imaging of neuronal activity
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)
In vivo calcium imaging of Barrel Cortex of Mouse

Barrel Cortex Layer 2/3

150 µm deep

After averaging (x3 faster than real)

58 neurons (~100 billions neurons in our brain)
Origin of the Brain

- Brains were evolved for animals to predict necessary motions for survival.
  - Find preys
  - Escape away from predators
  - Find mates for sex

- A brain “consciously” makes the best decision at a given time.

- Complex activities of brains are the results of evolution of life.
Activity of (excitatory) pyramidal neurons in CA1 depends on rat’s position: place cells

Mayank Mehta (Physics, Neurology)

Hippocampus has a cognitive map of space
Learning and Memory by Hippocampus

Motion Direction

After learning

Before learning

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

Shadow Universe

Our Universe
Are there more than one Universe?
Linde's Multiverse
by Chaotic Inflation
There may be ~100 Billion Universes.
Why are we here?
- Endless symmetry breaking → Cosmic evolution
- Extreme fine tuning required.

We are so fortunate to be here today.
- Shadow universe?
- Multiverse?

This talk is available at my home page
- [http://home.physics.ucla.edu/~arisaka/home/](http://home.physics.ucla.edu/~arisaka/home/)
- Under “Presentations”