

# University Lecture

## 2. The Birth of Matter -Elementary Particles, Atoms, and the Universe-

The University of Tokyo, Theoretical  
Astrophysics Group (UTAP)

Research Center for the Early  
Universe(RESCEU)

Katsuhiko Sato

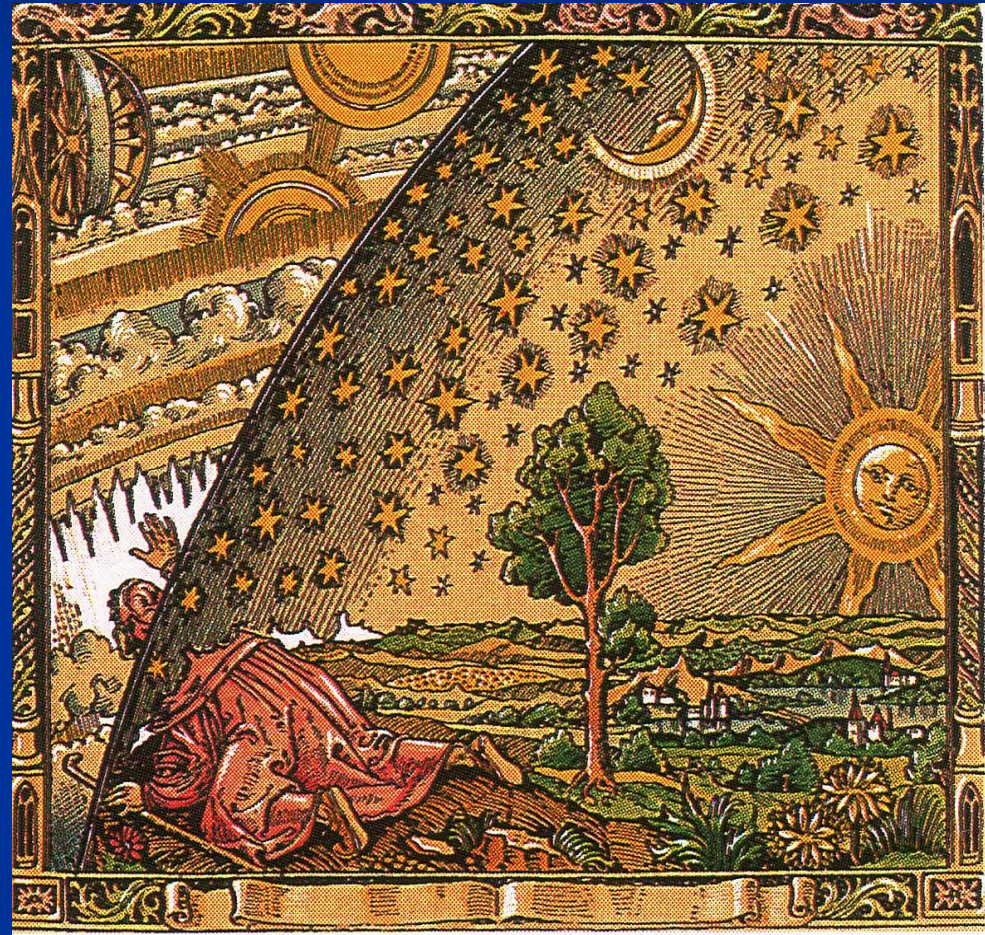
## 2. The Birth of Matter

### -Elementary Particles, Atoms, and the Universe-

- Lecture 1      How do we conceive of the physical world? –structural hierarchy of matter-
- Lecture 2      The motion of the physical world –physical laws-
- Lecture 3      Space-time –the “stage” of matter-  
Space-time and matter unite in motion to determine the structure of world
- Lecture 4      The creation and evolution of the universe –  
for a comprehensive understanding of nature-

# Evolution of the Universe – for an Unified Outlook on Nature-

- 1. What is cosmology?
- 2. Relativistic cosmology.
- 3. The Big Bang universe.
- 4. The Unified Theory and the creation of the universe.
- 5. Observational proof.
- 6. Dark matter and the dark energy problem.
- 7. Summary



# 1. What is Cosmology?

**According to Huainanzi,**

**宇宙 (The universe) stands for:**

**宇: all sides and verticals = space**

**宙: past, present and future = time**

**The universe is a compound of matter  
existence and space-time within it.**

General relativity, the physics of space and time, is essential to the scientific investigation into the beginning of the universe.



# **Since the Start of History, Human Beings Have Been Asking Themselves Questions About the World They Inhabit.**

- What do we find in the world a farther distance away? Is there an end to this world?
- Has this world always looked the same? Is there a beginning to this world?

**These questions have been asked since ancient times in mythology and philosophy.**



Snorri Sturluson

# ♦ EDDA ♦

New complete translation by  
Anthony Faulkes



## Edda: Viking Sagas of Medieval Iceland

In the beginning of time,  
there was nothing, no sand,  
no ocean, and no cold waves  
existed. The ground had no  
directions, and the sky did not  
exist but instead, a huge crack  
opened its mouth in the sky.  
No trees nor flowers were to  
be seen.

# Shiva (The Destroyer)

He stands on his right foot and dances with his left foot up to create (Brahma), preserve (Vishnu), and destroy (Shiva) the universe.

**Hindu trinity= Trimurti**

The drum in the right hand of Shiva expresses the creation of the universe.

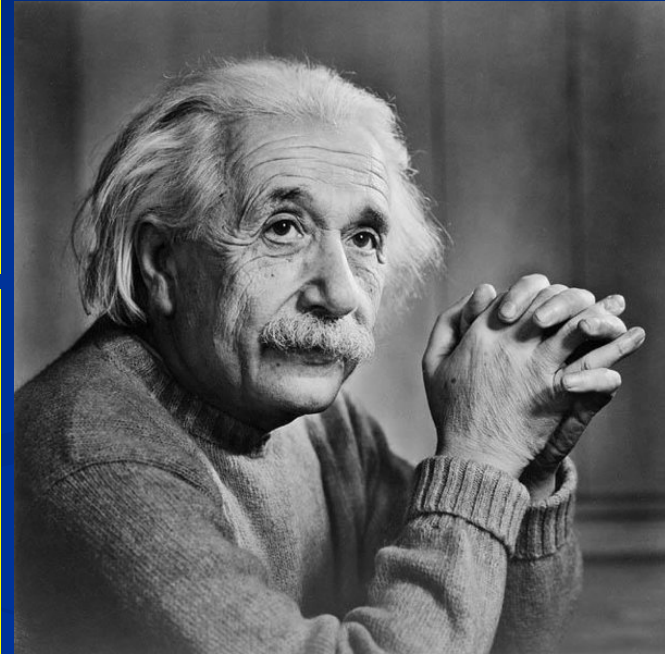




# The Creation of the Universe: Quotations by Einstein

“I am curious about the principles in which God created the universe upon. The rest is matter of such trivia.”

“What I am most curious about is that whether God had other alternative of choices in creating the universe”



Now we can answer these questions in scientific language.



## 2. Relativistic Cosmology

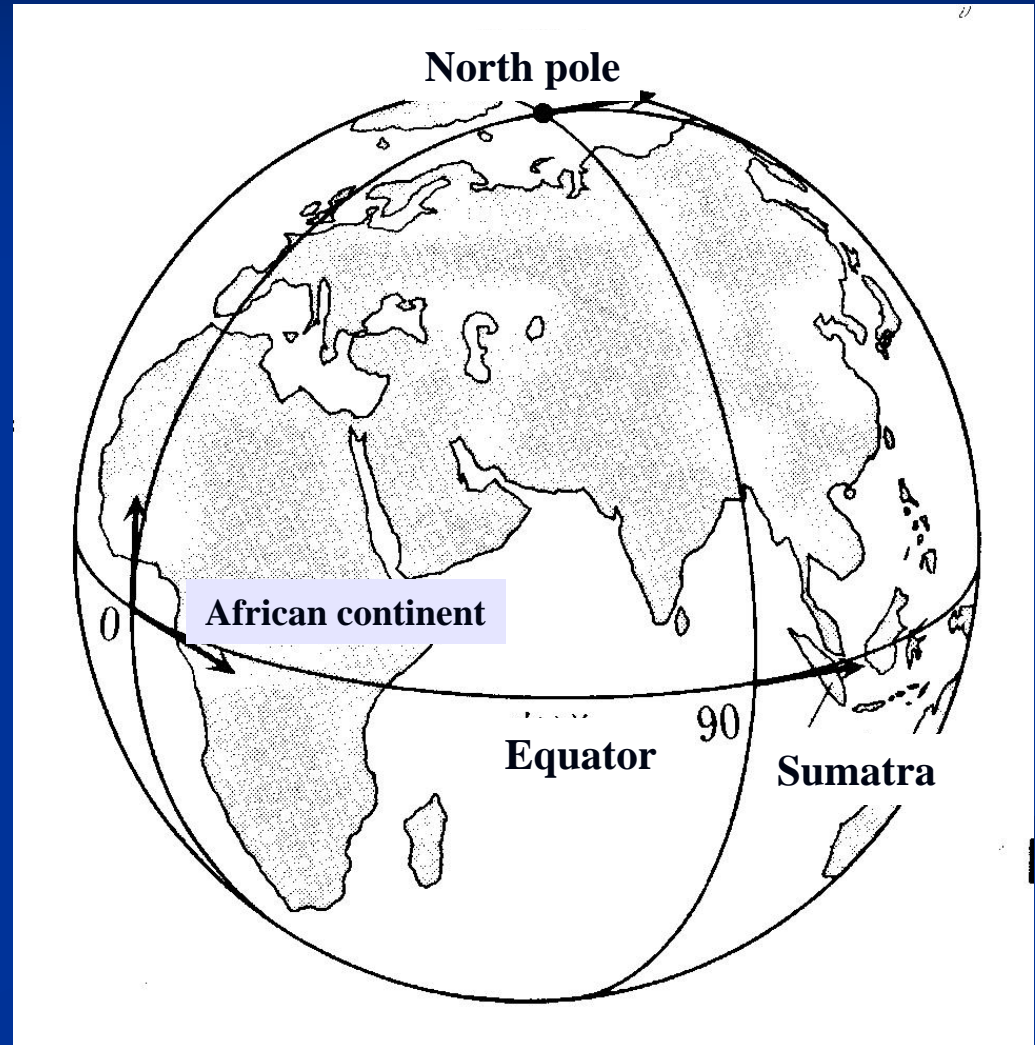
Einstein's static universe (1917) A model that has no contraction or expansion.

Surface of the four dimensional sphere (three-dimension) is fit in the four-dimension Euclidian space. Lower the dimensions by one to obtain a surface similar to the Earth.

Positive curvature.

A model of a closed (finite) universe.

Yet, there is no end.



# Einstein was Convinced of an Eternal and Unchangeable Universe.

Einstein's static universe (1917)

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

The quantity representing space-time geometry.

The quantity representing universal gravitation.

Cosmological constant (force of repulsion in the universe: spaces pushing each other) is introduced to balance the universal gravitation of contracting force to create the static model of the universe.

# Freidman's Model of the Universe (1922)

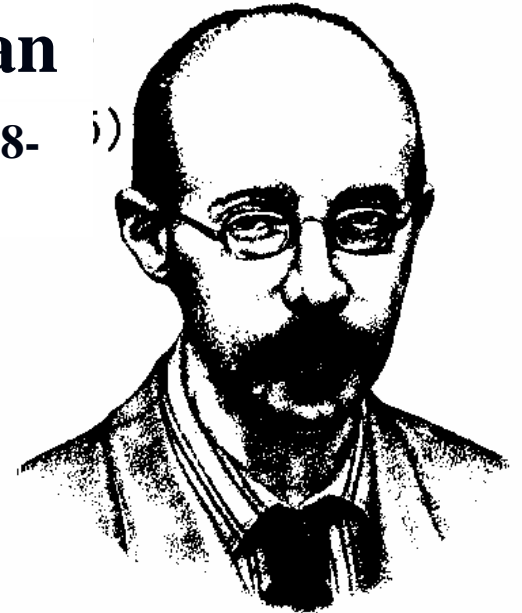
Freidman used Einstein's equation to show the expansion of the universe.

Einstein's equation should satisfy the cosmological principle (uniform and isotropic universe) in the universe.

$$\dot{R}^2 + K = \frac{8\pi G}{3} \rho R^2$$

## ● Freidman

(Russia: 1888-1925)



Sato, Katsuhiko. *Uchu wa Wareware no Uchu Dakedewa Nakatta*. Tokyo: PHP Research Institute, 2001. p.35

R: cosmic scale term

$= +1$

$K = 0$

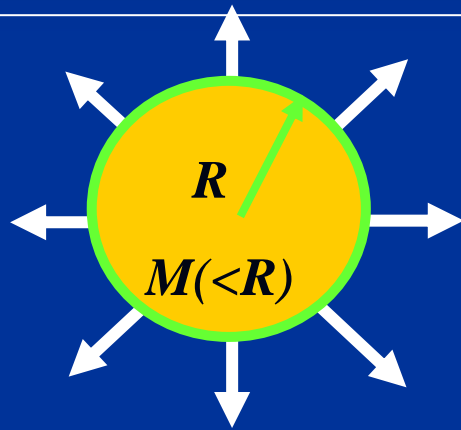
$= -1$

Curvature  
code



# Freidman's Model of the Universe (1922)

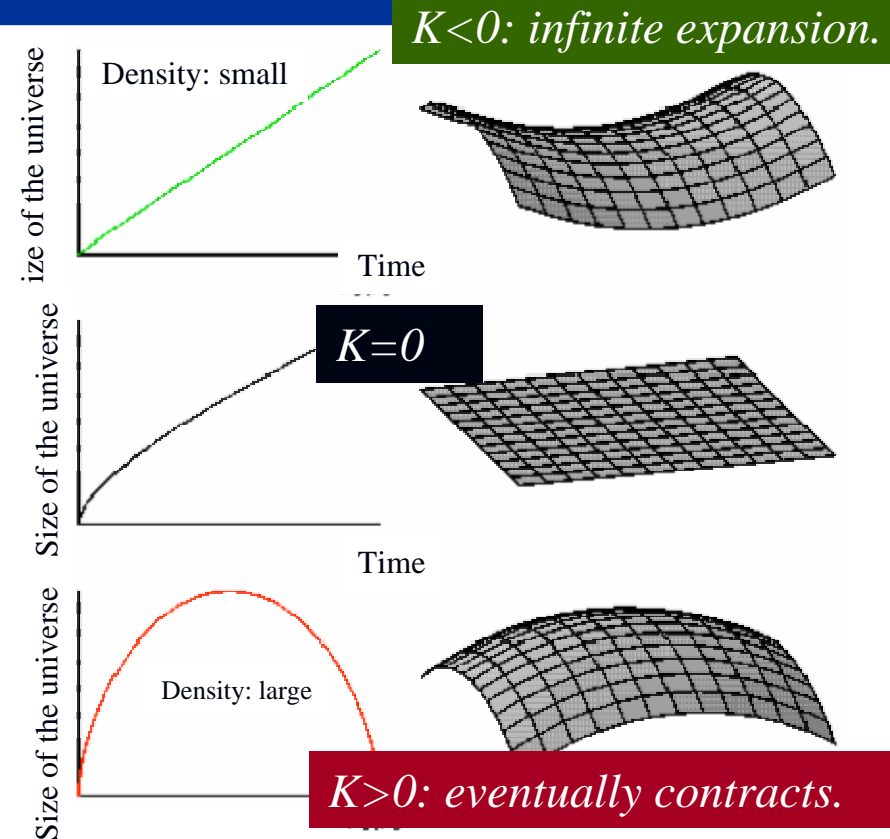
Einstein's equation transforms into the time variation equation of the radius of uniform density sphere.



$$\frac{\dot{R}^2}{2} - \frac{GM}{R} = -\frac{K}{2},$$

$$M \equiv \frac{4\pi}{3} \rho R^3$$

**$G$ :** Newton's gravitational constant.  
 **$M$ :** Mass of a sphere with radius  $R$ .  
 **$K$ :** Total energy of the system (constant).  
 **$\rho$ :** Average mass density of sphere of radius  $R$ .

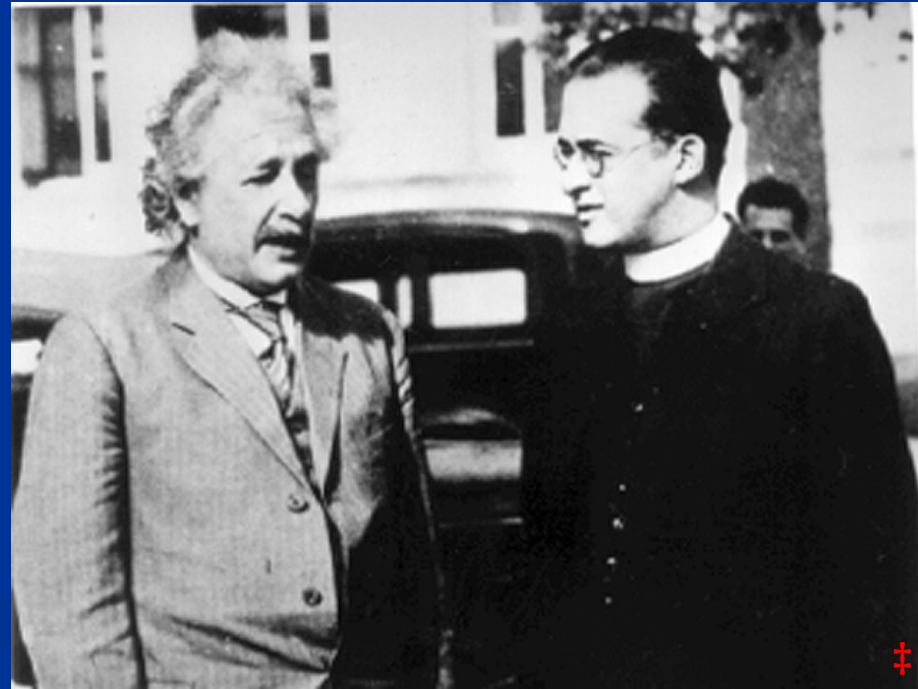


# Freidman's Thesis Examination Report by Einstein:

Somewhat haughtily, Friedmann's results are suspicious and that he [Einstein] found there are errors; after the correction, Friedmann's solution was reduced to a stationary one.  
( Blackholes and Universe, by I. Novikov, 1990.)

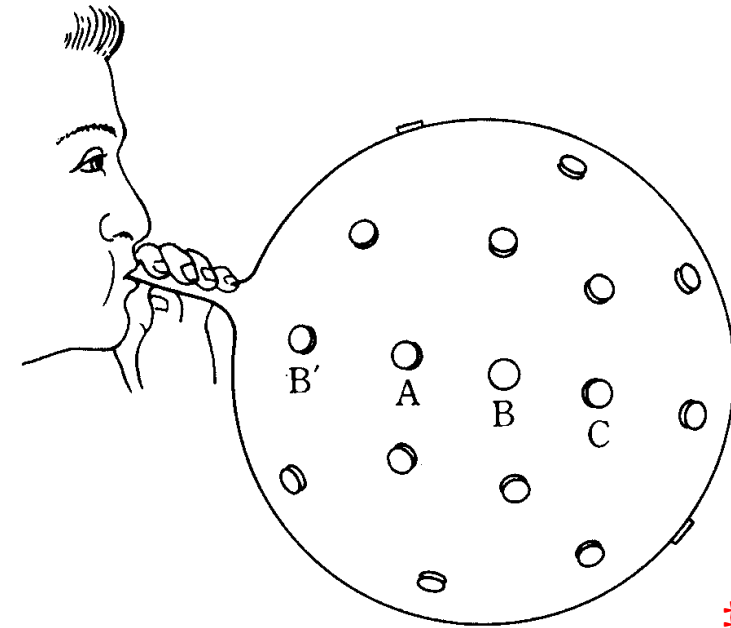
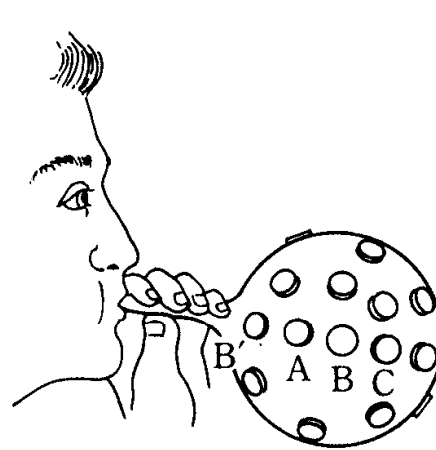
G. Lemaitre (1927) also claimed the expansion model of the universe.

Einstein made a comment to Lemaitre: Your calculations are correct, but your physical insight is abominable. (5th Solvay Conf.1927.)



Sato, Katsuhiko. *Uchu wa Wareware no Uchu Dakedewa Nakatta*. Tokyo: PHP Research Institute, 2001. p.93

# The Discovery of the Inflating Universe (E.Hubble,1929)



Sato, Katsuhiko. *Uchu na Wareware no Uchu Dakedewa Nakatta*. Tokyo: PHP Research Institute, 2001. p.103

## Hubble's law:

The farther the distance of the galaxy, the faster the speed of receding.

It was a huge discovery deserving the several Nobel prizes awarded at once for this.

Our universe is not eternal or unchangeable anymore, but rather a dynamically evolving entity.



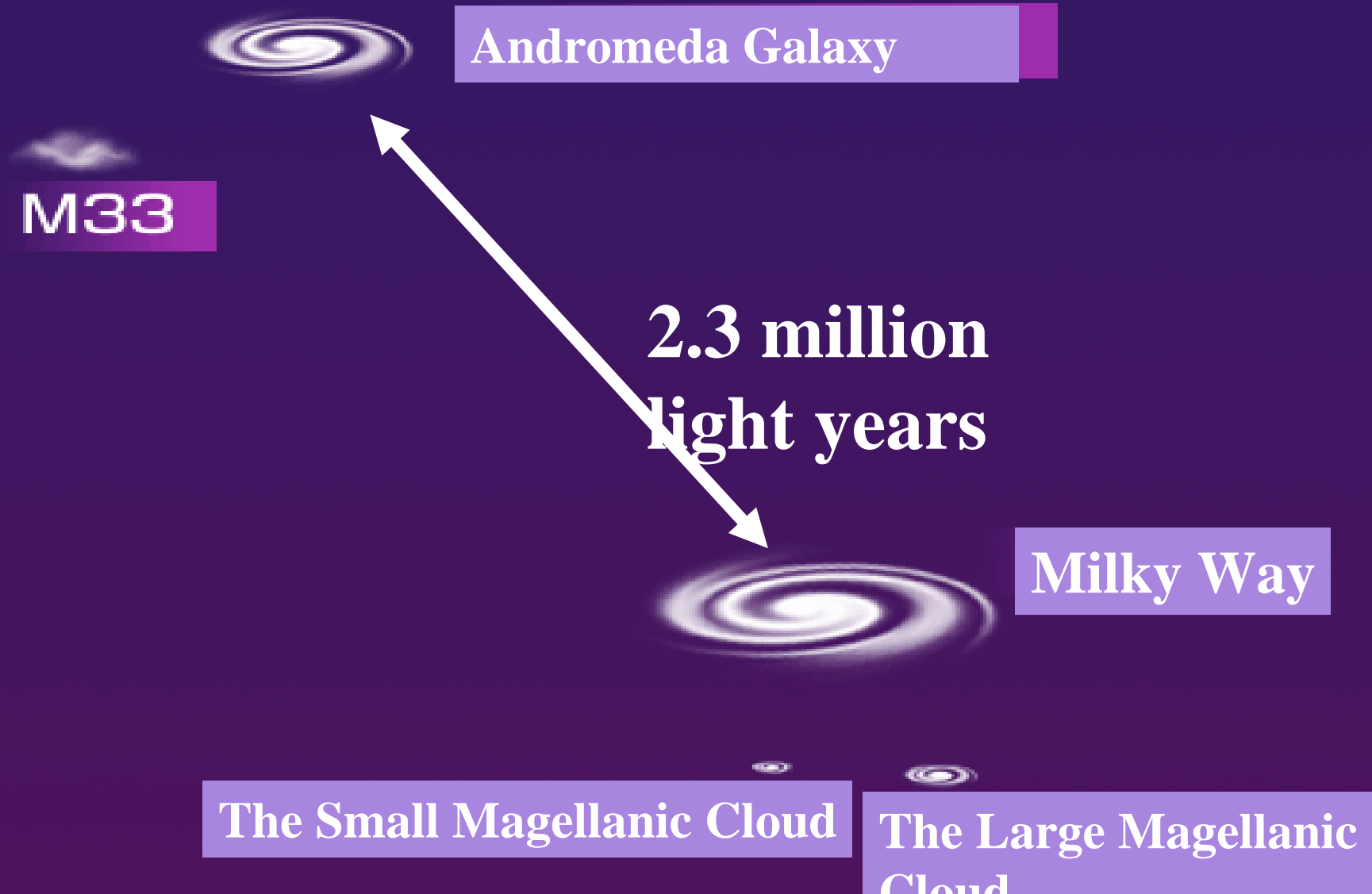


# The Galaxy is the Fundamental Celestial Structure of the Universe

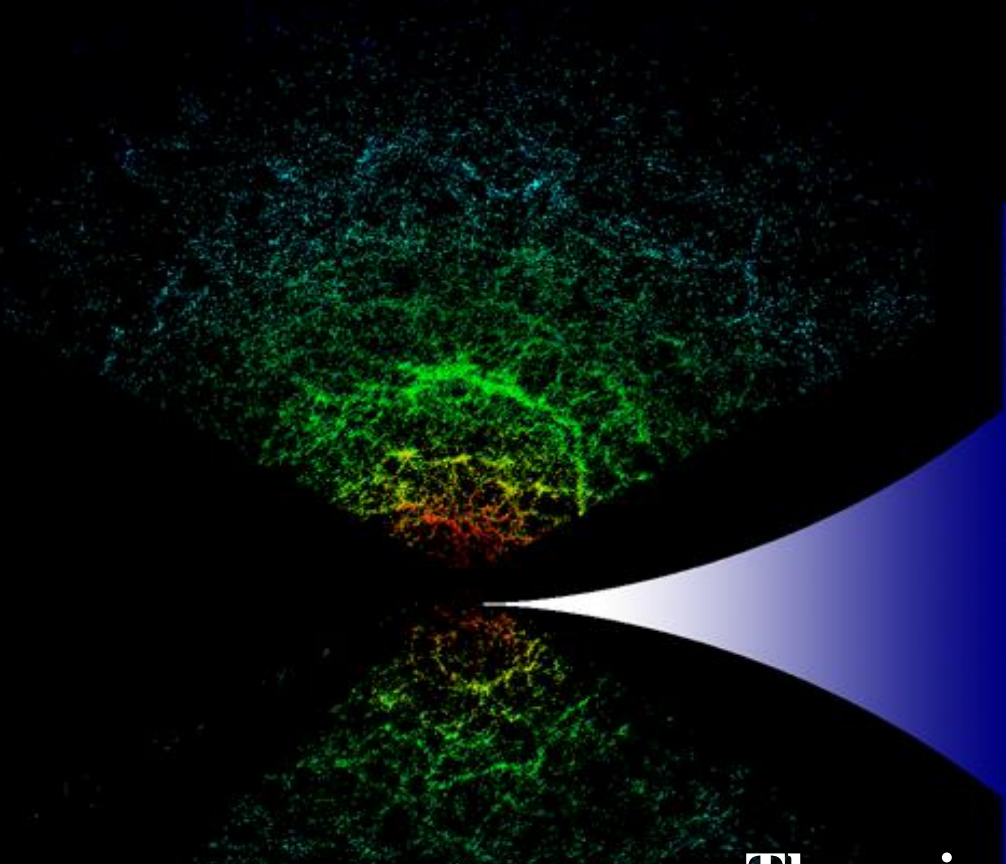


<http://www.solarviews.com/cap/ds/milkyway.htm>

# The Galaxy is the Fundamental Celestial Structure of the Universe



# The Galaxy is the Fundamental Celestial Structure of the Universe



Galaxies form a “honeycomb structure”.



**The universe is filled with galaxies over 10 billion light years apart: Galaxy**



# Hubble Space Telescope



出典: [http://www.spacetelescope.org/images/html/hubble\\_shuttle.html](http://www.spacetelescope.org/images/html/hubble_shuttle.html)

Credit: NASA/ESA

- On April 24<sup>th</sup>, 1990, a space telescope (2.4-meter aperture) was launched into space. The unclear images obtained during the beginning stage were fixed by the space shuttle Endeavor, and achieved a resolution of 0.1 arc second in December 1993.
- Measurement of the expansion rate of the universe and Hubble's constant.

The age of the universe is approximately 14 billion years.

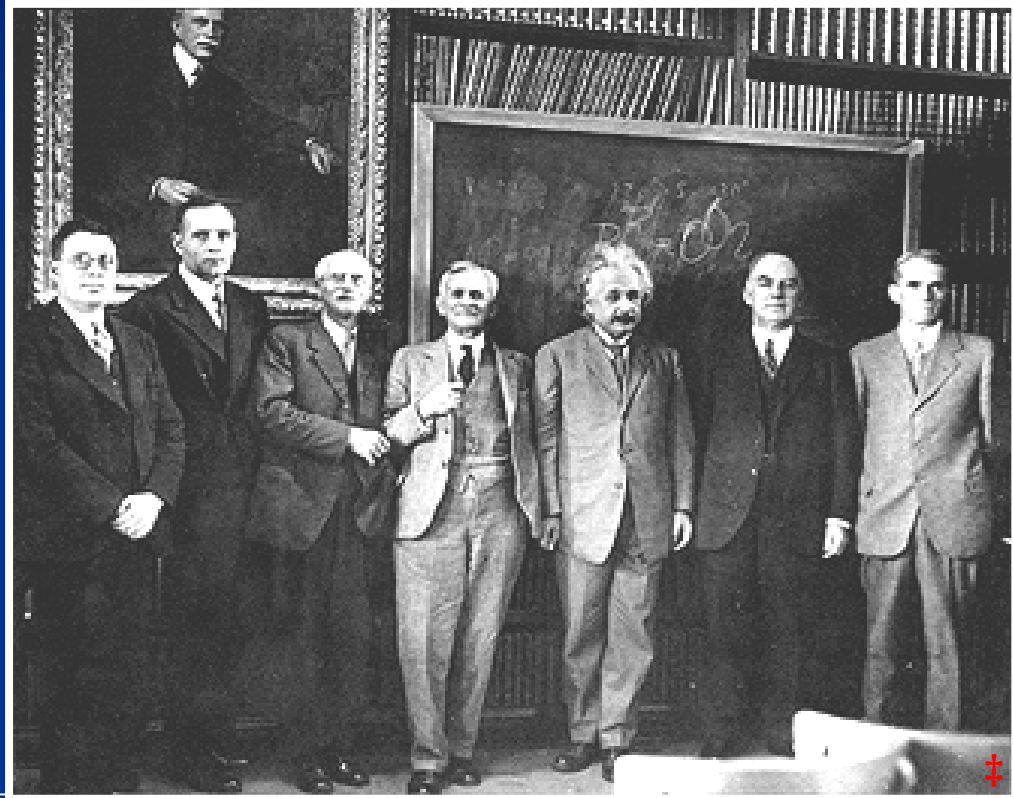


出典: <http://hubblesite.org/gallery/spacecraft/10/>

Credit: NASA/STSci

# Einstein, “Consideration of the Cosmological Constant was the Biggest Mistake in My Life.”

In 1931, Einstein visited the Mount Wilson Observatory.



<http://www.mtwilson.edu/History>

Einstein was frustrated that he was not able make a prediction of the expanding universe because he did not himself believe the prediction of his own equation. Nevertheless, the introduction of the cosmological constant itself is one of Einstein's most brilliant works. .

# The Introduction of the Cosmological Constant was not the Biggest Mistake in His Life!

■ The immediate expansion and inflation during the primordial state of the universe is due to the corresponding force of repulsion to the vacuum energy. Mathematically, the vacuum energy is the same as the cosmological constant. The recent measurement shows that present universe is expanding at the accelerating speed. There is the possibility of a second phase of inflation.

Einstein's cosmological constant made a comeback!

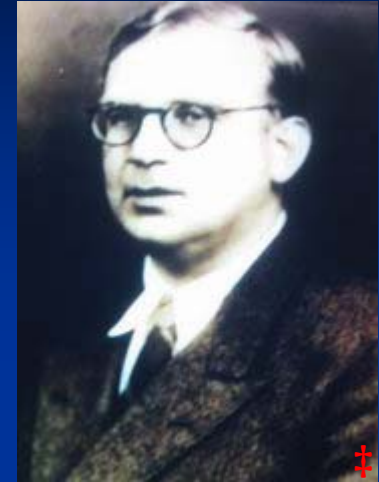
See the second half of the lecture for a detailed explanation.



# 3. Big Bang Model of the Universe Was Established

1. Gamov claimed, based on nuclear physics, that the origin of universe is a hot fireball. (1946)

Hydrogen and helium constitute the most abundant elements in the universe; the heavy elements constitute a very small amount. To make a proof of this, a huge atomic nucleus of the primordial state of the universe must split at a very high temperature.



Gamov (U.S.A., 1904-1968)

2. The discovery of cosmic microwave background radiation.  
(1965) Proof for the initial hot fireball universe.

Penzias

(U.S.A., 1933-)



Wilson

(U.S.A., 1936-)



**A huge accomplishment in physics!**

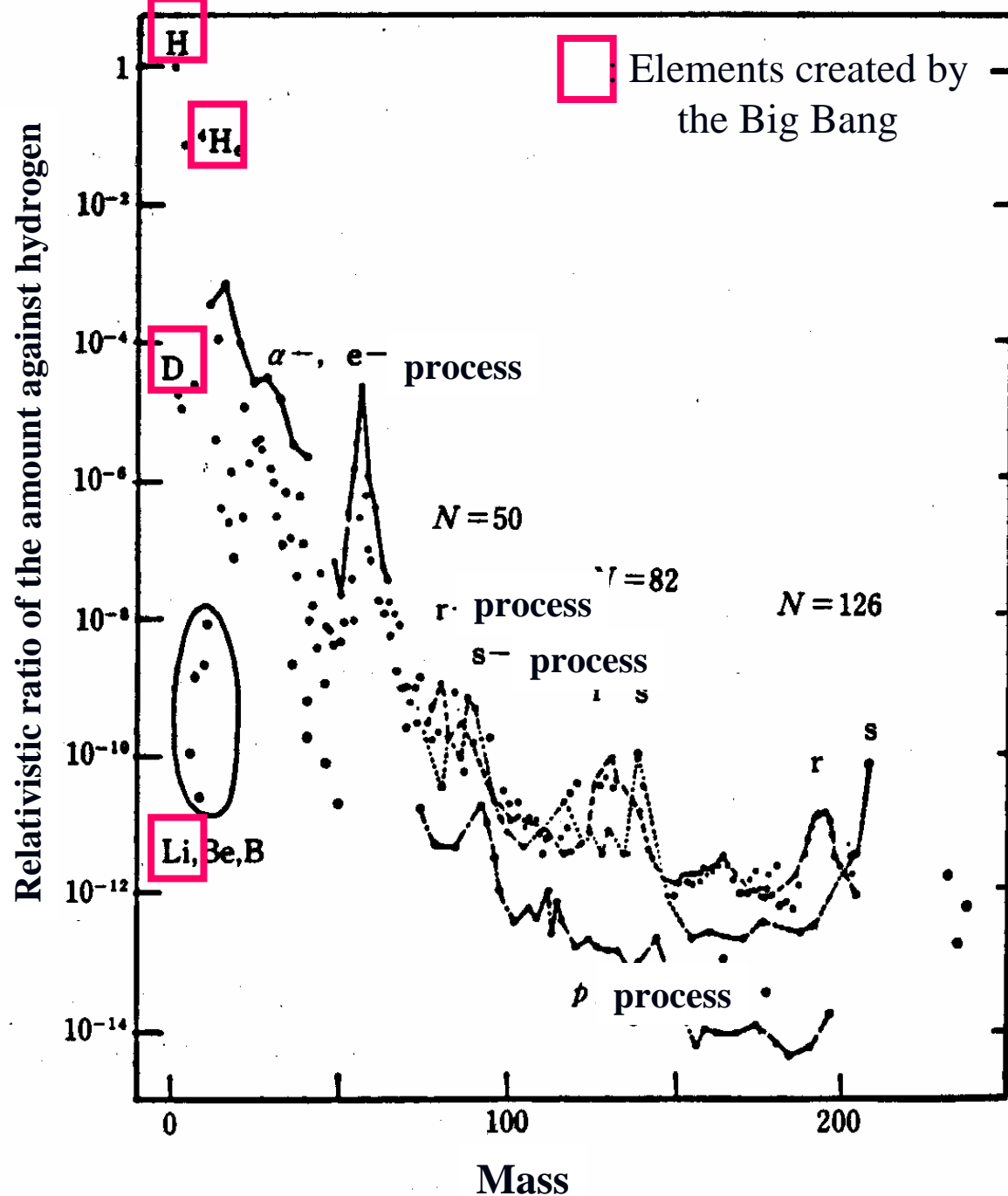
# Composition

## Ratio of Elements in the Universe

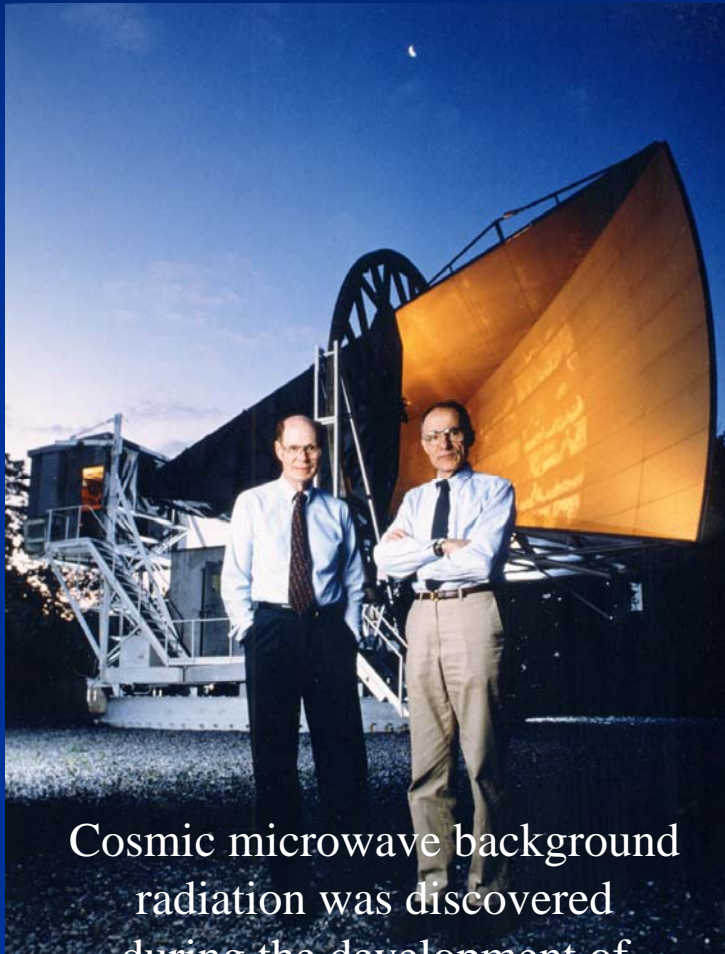
Gamov made an attempt to prove the distribution of the elements all at once by the Big Bang.

Only light elements (H, D, He, and Li) are created by the Big Bang.

The rest of the elements are created inside stars.



# The Proof of a Fireball Universe: Microwave Background Radiation

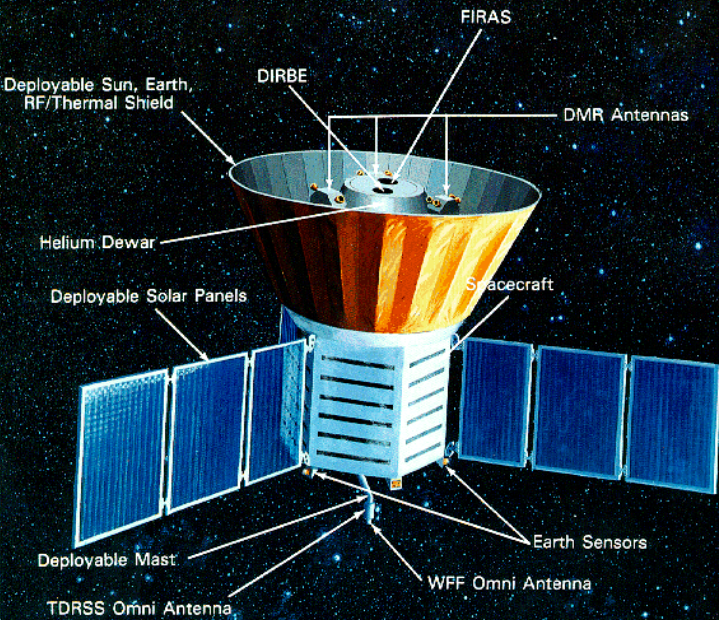


Cosmic microwave background radiation was discovered during the development of space communications technology; Telstar satellite.

- Gamov's collaborators ( Alphe and Herman) theoretically suggested the existence of radiation in their research of the origin of the elements.
- The present fireball temperature is cooled down to 5K.
- In 1965, Penzias and Wilson of Bell Labs measured the temperature at 3.5K.
- The present temperature is measured as  $2.728 \pm 0.002\text{K}$ .

# Cosmic Microwave Background Radiation Showed the Complete Black Body Radiation (Planck Distribution).

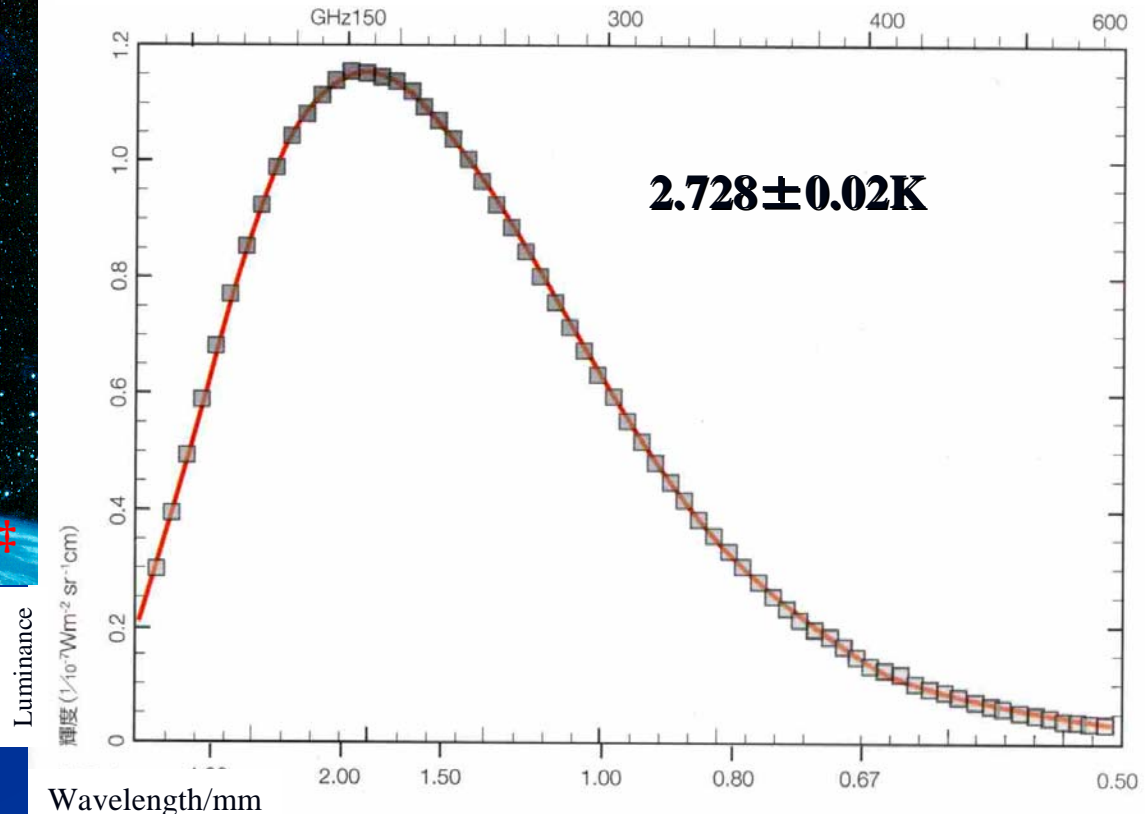
(1992)



COBE Satellite:

Cosmic microwave background radiation exploring satellite.

Cosmic microwave background radiation spectrum observed by COBE satellite





# 4. The Unified Theory and the Creation of the Universe

Theoretical problems for the Big Bang model of the universe.

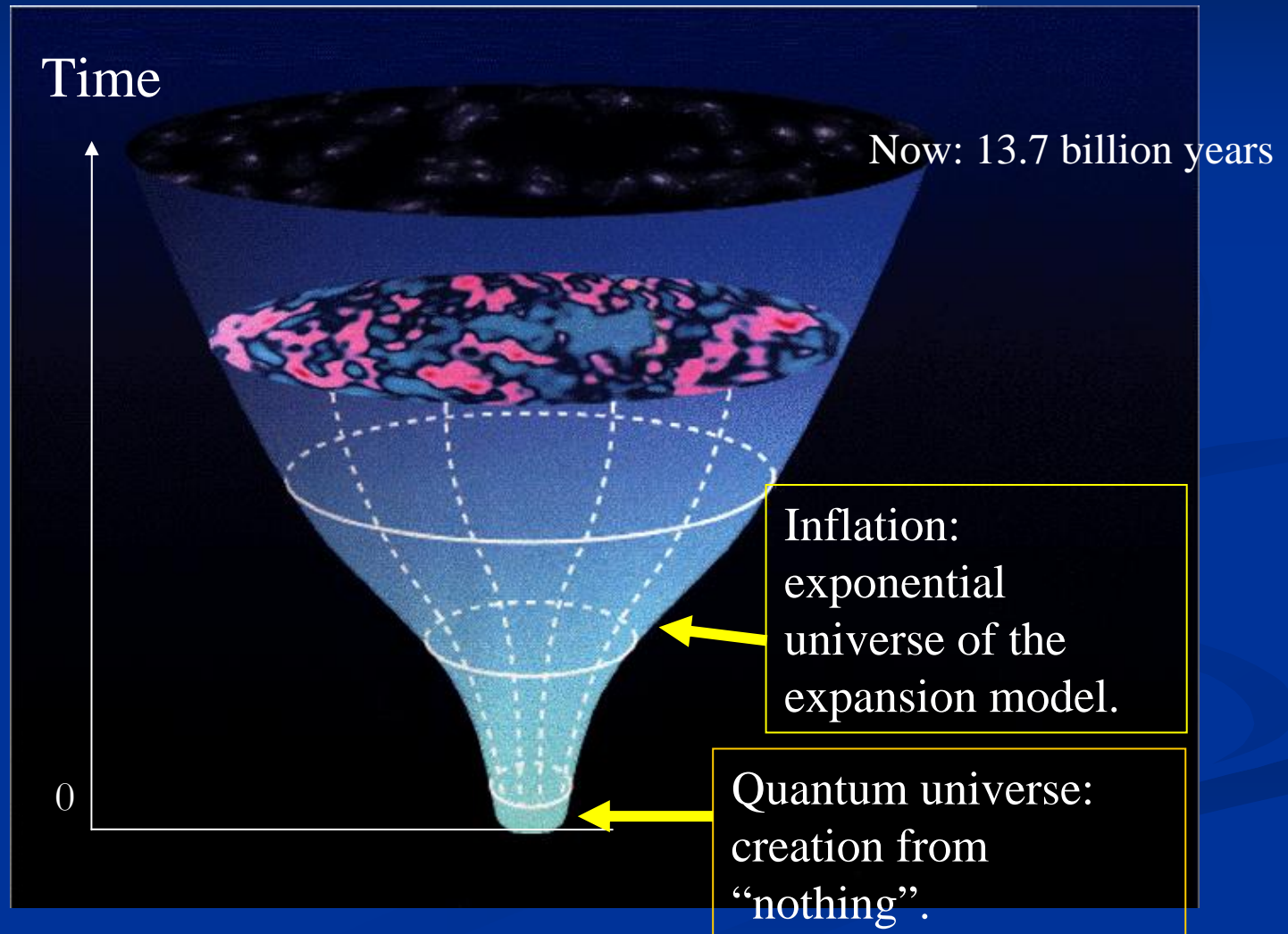
The Big Bang model must consider and start from the singularity point of space-time, in which physics fails.

—A single blow by God; is beyond the physical laws.—

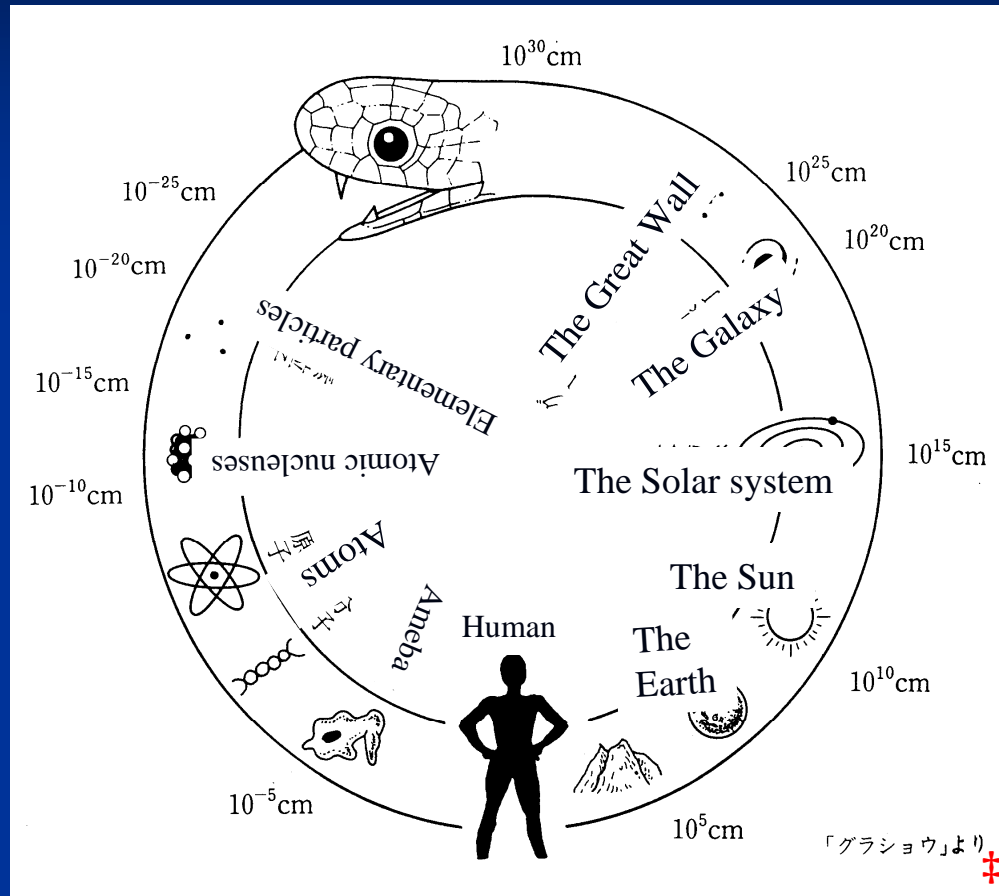
Problems for the Big Bang model of the universe.

- 1. Why does the universe start from a fireball?
- 2. The structural origin of the present universe has not yet been explained. Even though an attempt in preparation for the seeds of the galaxy and the cluster of galaxies is made during the primordial state of the universe, which should be done beyond the celestial horizon (causality).
- 3. The homogeneous problem: it remains yet another mystery why cosmic microwave background radiation is homogeneous far beyond the celestial horizon (causality).
- 4. The surface smoothness problem: from a relativistic point of view, the extremely smooth properties that the universe possesses is considered very mysterious.

# To Solve These Problems, Inflation Theory and Quantum Creation Have Been Studied.



In order to investigate the origin of the universe, which is the investigation of the biggest physical existence, we need to know the laws of the smallest elementary particles.



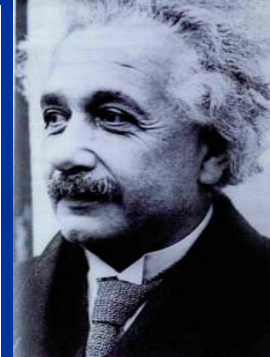
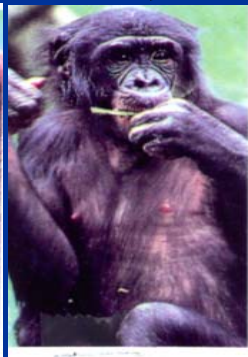
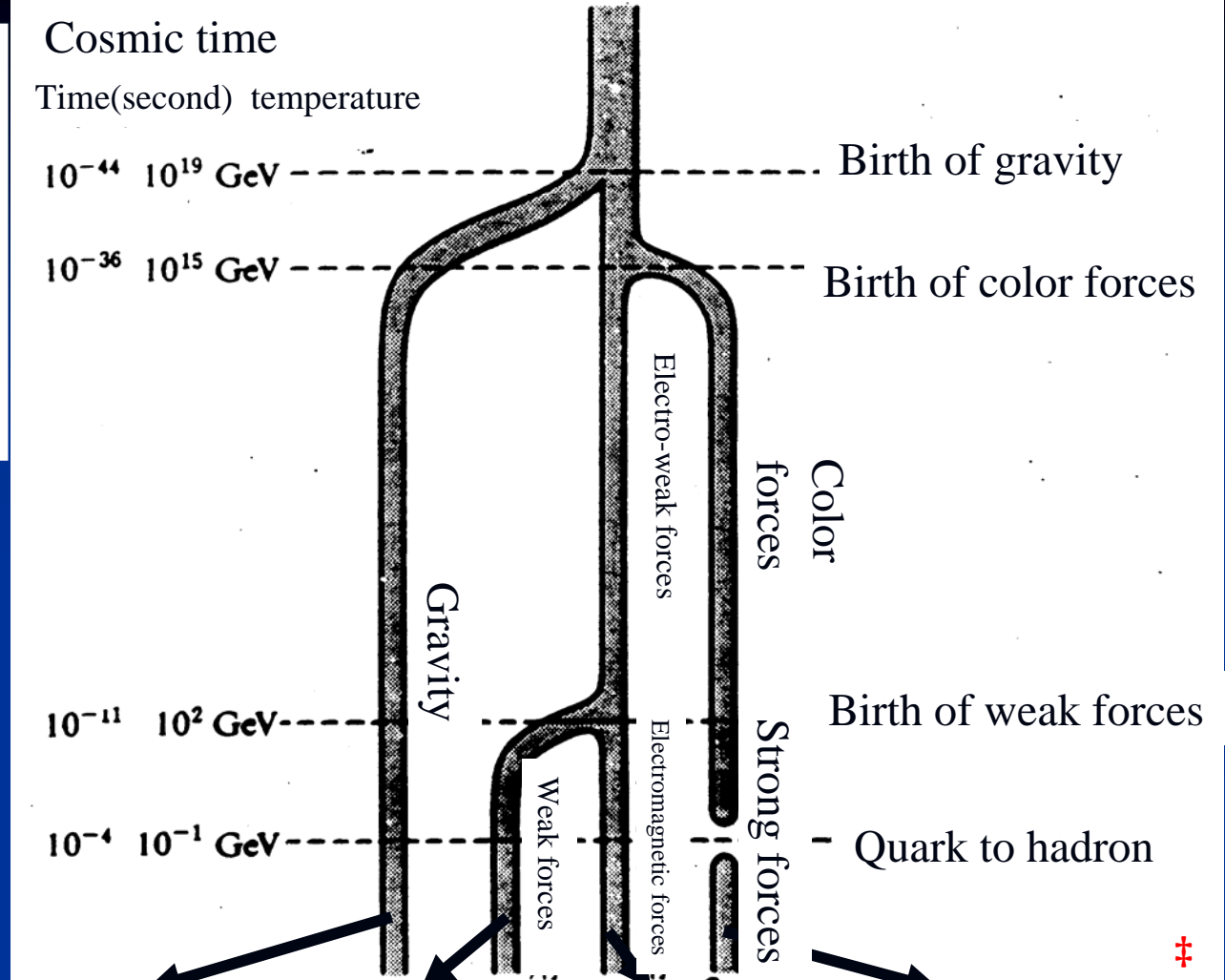
Ouroboros

Sato, Katsuhiko. *Uchu 96% no Nazo*. Tokyo: Jitsugyo no Nihon Sha, 2003 p.61

However incomplete, “the unified theory of force” has become a key to the the primordial state, and the creation of the universe.

# “Evolution of Force” predicted by the unified theory

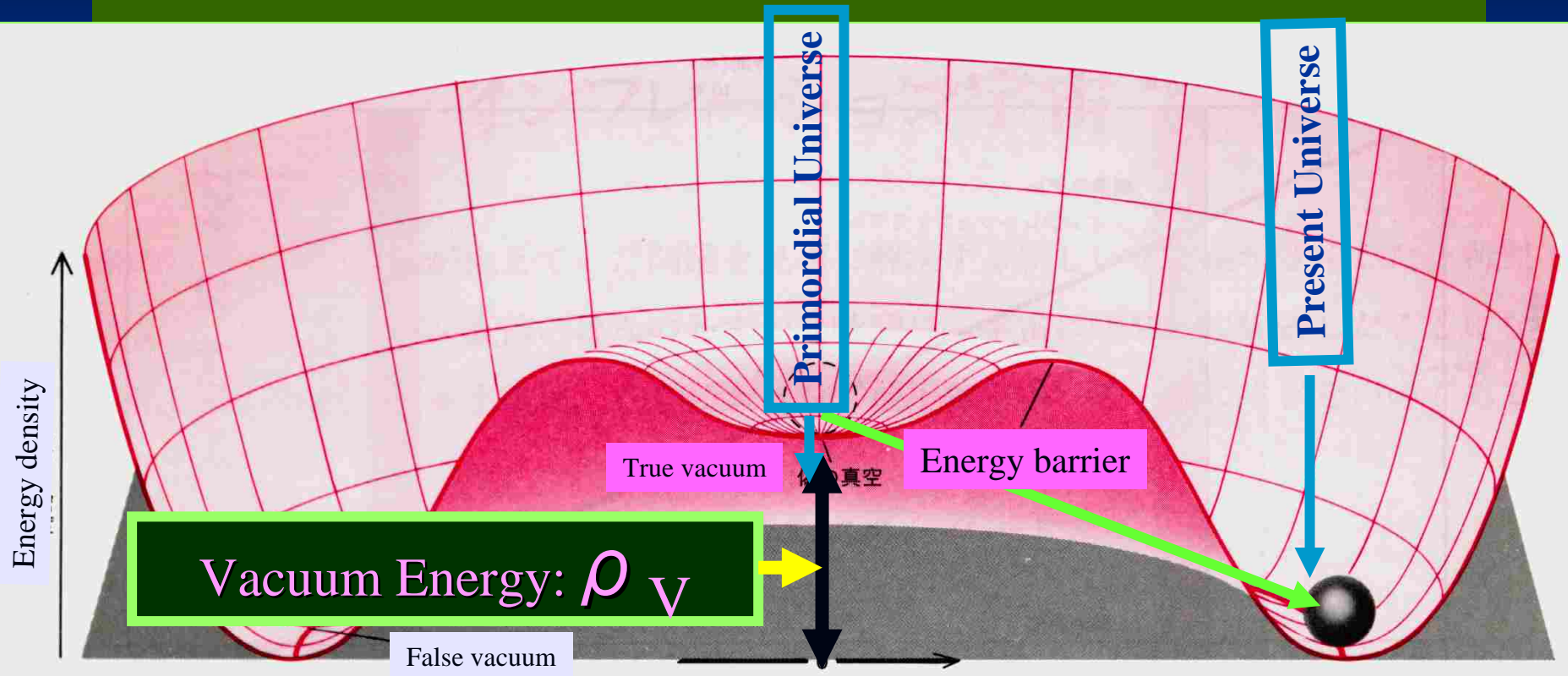
Likewise, during the evolution of creation, the force splits into branches as it evolves.





# Vacuum Phase Transition

can Split the Force into Branches



Sato, Katsuhiko. *Uchu 96% no Nazo*. Tokyo: Jitsugyo no Nihon Sha, 2003 p.127

The universe of immediately after the creation, was filled with vacuum energy! The density of the vacuum energy remains constant until phase transition occurs:  $\rho_V$ .

Vacuum Energy Density  $\rho_v$  Plays the Same Role as  
Einstein's Cosmological Constant  $\Lambda$ .

$$\Lambda = \frac{8\pi G}{c^4} \rho_v$$

Einstein's cosmological constant is spotlighted again at the  
primordial state of the universe!

The force of repulsion (the force between spaces) acting on the  
vacuum energy causes the universe to a rapid, accelerating  
expansion.




This is called the **Inflation** of the universe.

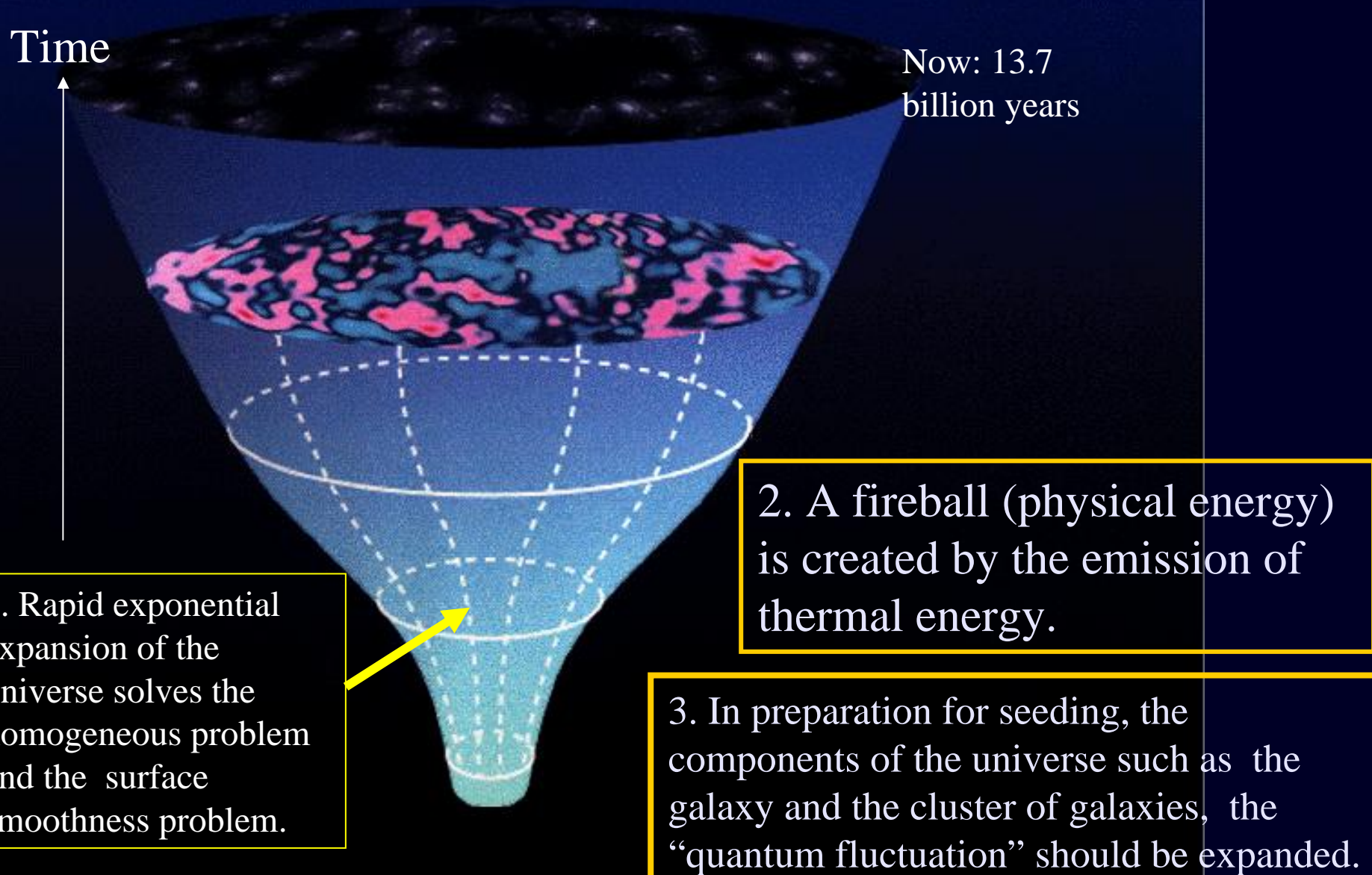
# Is Inflation a Mechanism Done With a Magic Wand?

- Vacuum energy density remains constant until phase transition occurs.  
No matter how much the universe expands, vacuum energy density will never be smaller. In proportion to the increasing volume, the greater vacuum energy density of the whole universe becomes. ( Equivalent to the equation of state for the fluid  $p(\text{pressure}) = - \rho c^2 (\text{energy density})$  )
- The universe is rapidly expanded by the forces of repulsion acting on vacuum energy.
- It seems as if physical energy in the universe is created from nothing.
- The rapidly increased vacuum energy is transformed into thermal energy the phase transition, and a huge fireball universe was created.

Quarks and leptons are made of vacuum energy.

Vacuum energy   $\gamma, \rightarrow q + \bar{q}, \rightarrow e^- + e^+, \rightarrow \nu + \bar{\nu}, \dots$

# Inflation Theory and its Prediction





# **“The Birth of Matter”; the Ultimate Beginning is Inflation**



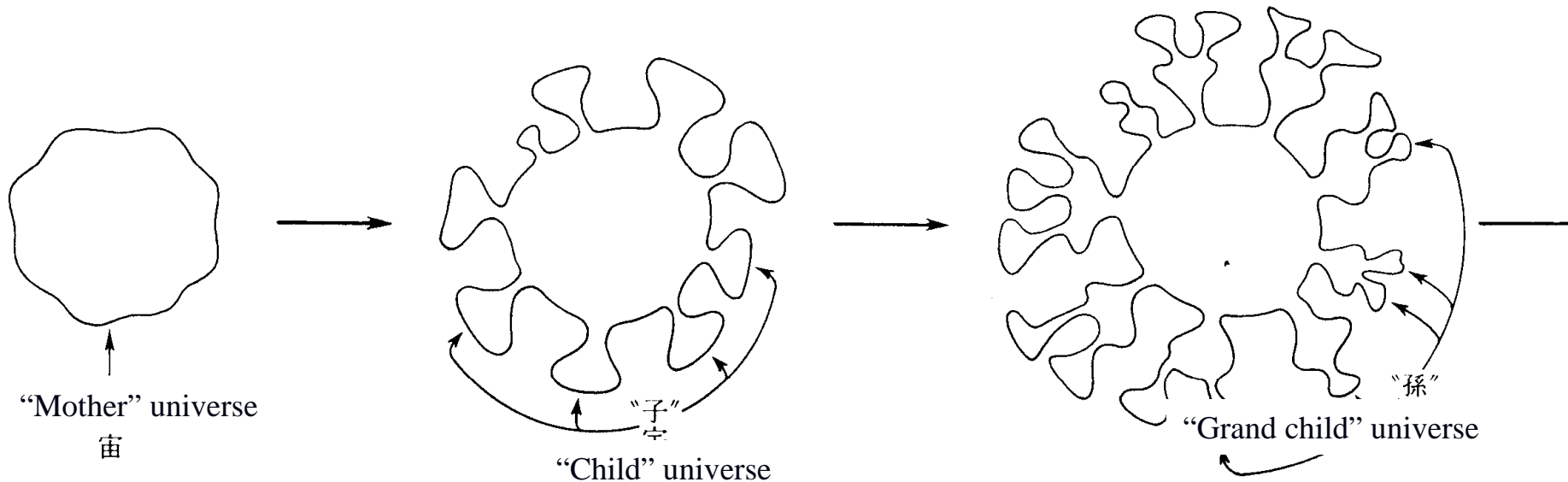
Apparently, “The birth of the physical universe and its structure” was a “quantum fluctuation” during the inflation period.



Inflation is not just a mechanism of physical matter, but rather it is a mechanism of the creation of countless universes.

# The Creation of the Multiverse

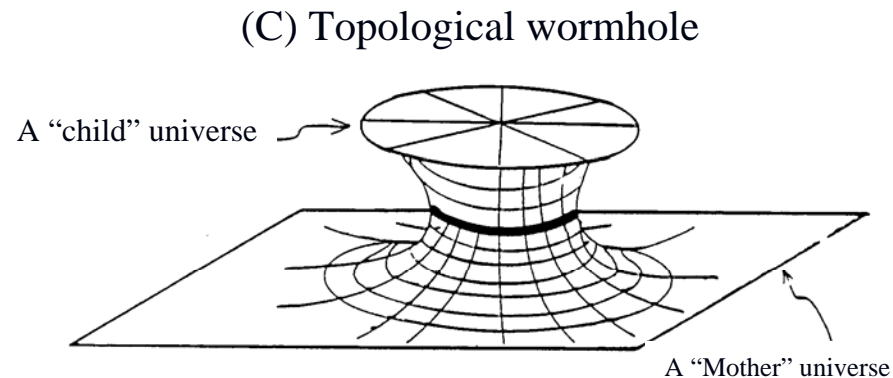
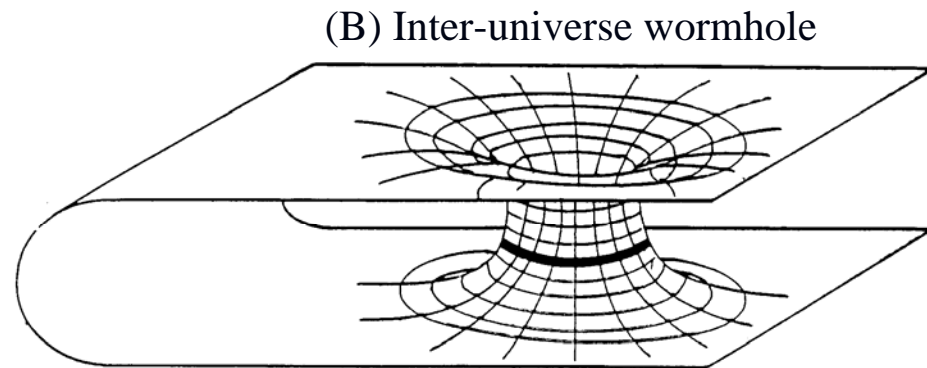
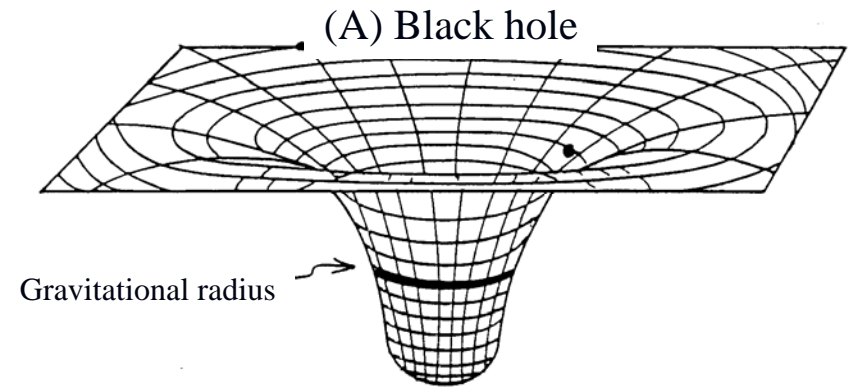
## An Infinite Number of Universes Are Created During the Inflation Period



**Multiverse .**

**The universe belongs to others as well**

# The “Child” Universe is Created Through Mushroom-Shaped Wormholes



**Heaven in a  
Bottle (Book  
of Later Han)**

費長房



All sorts of  
delicacies  
and luscious  
drinks are  
found in the  
bottled  
heaven.

Sato, *Tsubono Nakano*  
*Ucyu*, Futami Shobo  
Publishing, Co., Ltd.,  
1990.



# Summary of Inflation Theory

## 1. The mechanism of the creation of the Big Bang universe (a fireball universe).

- ①Expansion of the small quantum universe into a macro-universe.
- ②Expansion of the quantum fluctuation as a preparation for the structural universe.
- ③Transformation of vacuum energy into thermal energy. Permeates the universe with physical energy.

(While the unified theory remains incomplete, the field of inflation also remains unknown. It is hypothetically called the inflation field.)

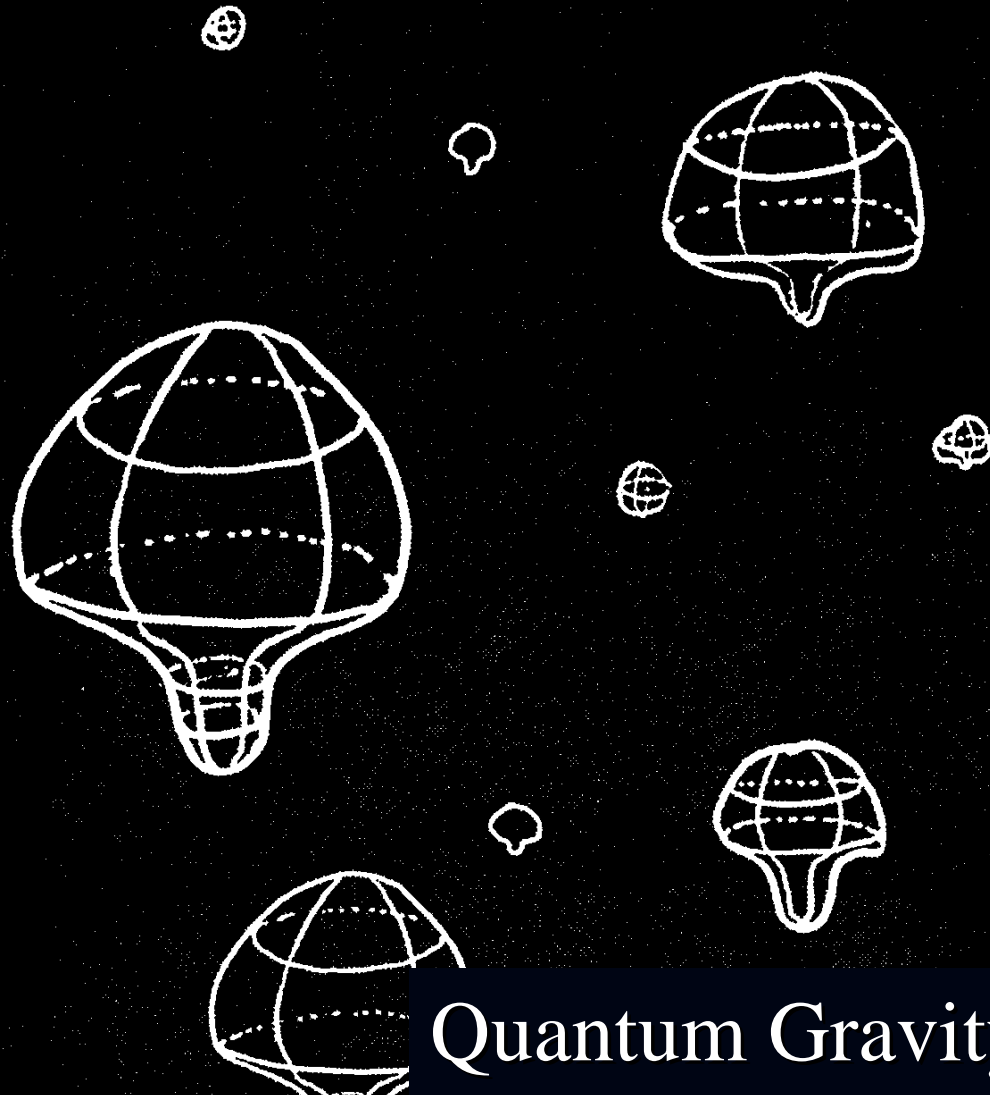
## 2. The mechanism of the creation of an infinite number of universes.

“Mother” universe to the “child” universe, and to the “grand child” universe... infinite creation of universe.

Now the question is how the “mother” universe is created.

# The Creation of Universes From Nothing !

A. Vilenkin (83)

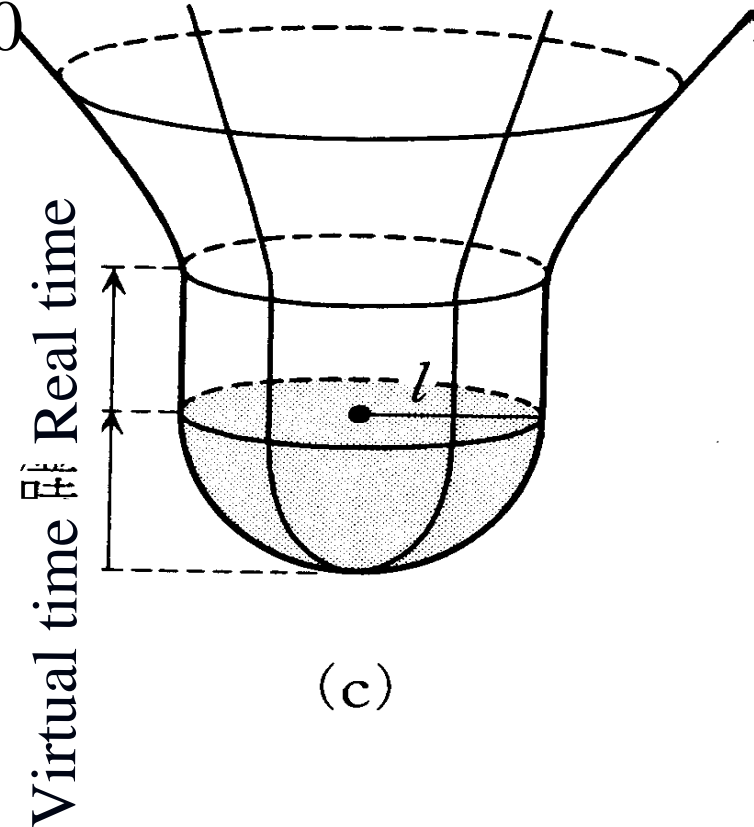
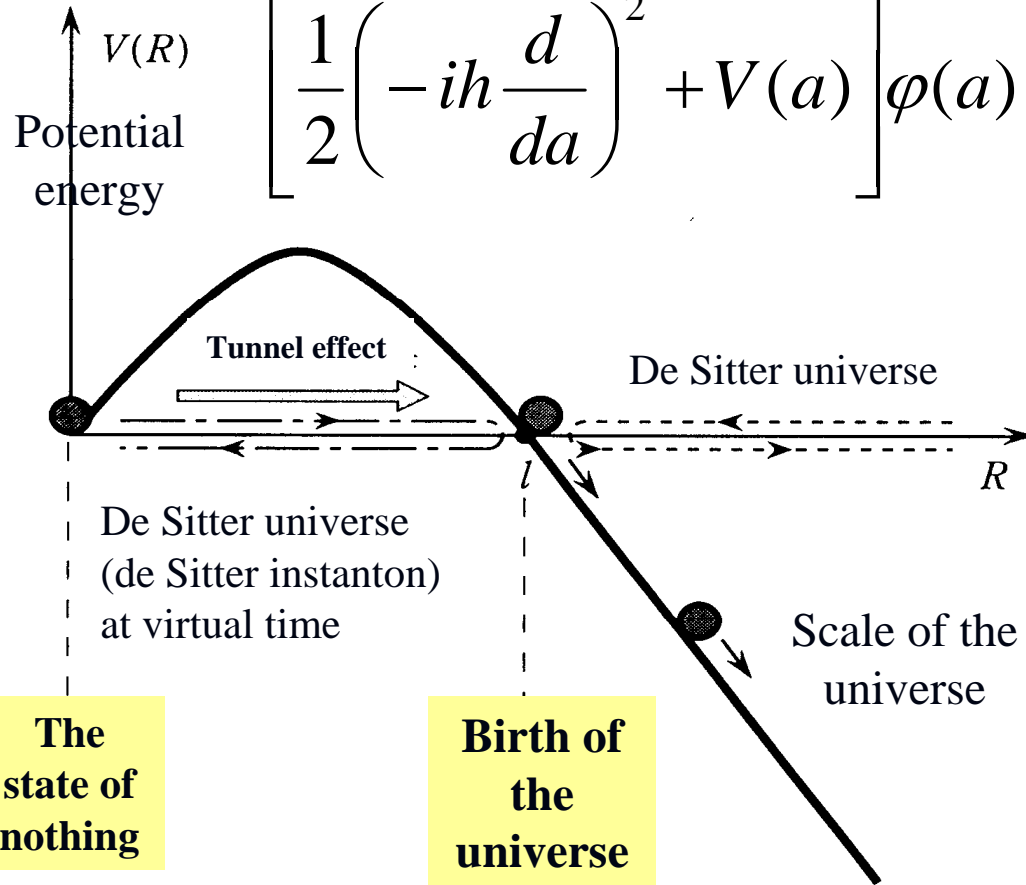


Quantum Gravity

# Creation from “Nothing” and Creation from Infinity

Wheeler-DeWitt equation (Schroedinger's equation for the universe)

$$\left[ \frac{1}{2} \left( -i\hbar \frac{d}{da} \right)^2 + V(a) \right] \varphi(a) = 0$$



# Paradigm for the Creation of the Present Universe and its Evolution

1. The universe was created from “nothing”.
2. A newborn quantum universe went through an inflation process to become a huge universe. Physical energy is generated by the emission of latent heat, followed by the creation of a fireball universe.
3. Preparation for the basic structure of the universe is completed by the expansion of the quantum fluctuation during the inflation period.
4. With further process of expansion in the quantum fluctuation, the galaxy and the cluster of the galaxies gradually appeared as

An observation of a distant universe means an observation of the past. Principally, it is possible to observe the moment of origin from the present time.



# 5. Observational Proof

Distance

Cosmological time

Origin of univers  
Inflation

0

300,000 year The clear weath

1 billion-years Quasar  
10 billion-years

14 billion-years The Great wall

100 million-light-years

1 million-light-years

10,000 light-years

The Milky Way Galaxy

100 light-years

Peripheral stars

15 billion-years

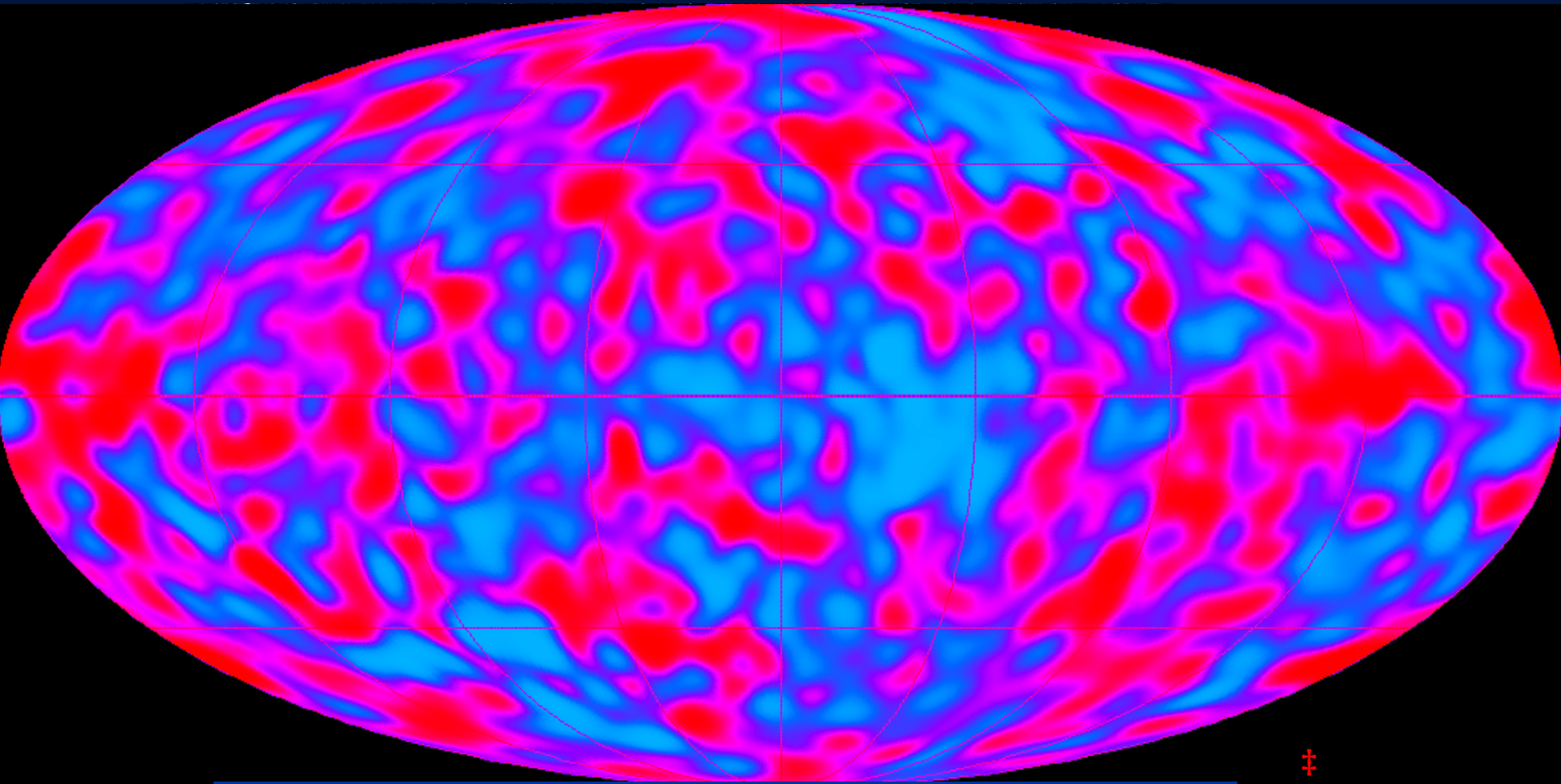
The Earth

Sato, Katsuhiko. *Uchu 96% no Nazo*. Tokyo: Jitsugyo no Nihon Sha, 2003 frontispiece



**We can see the past by observing the distance further away.**

# Inflation Theory Has Been Verified by Observation.



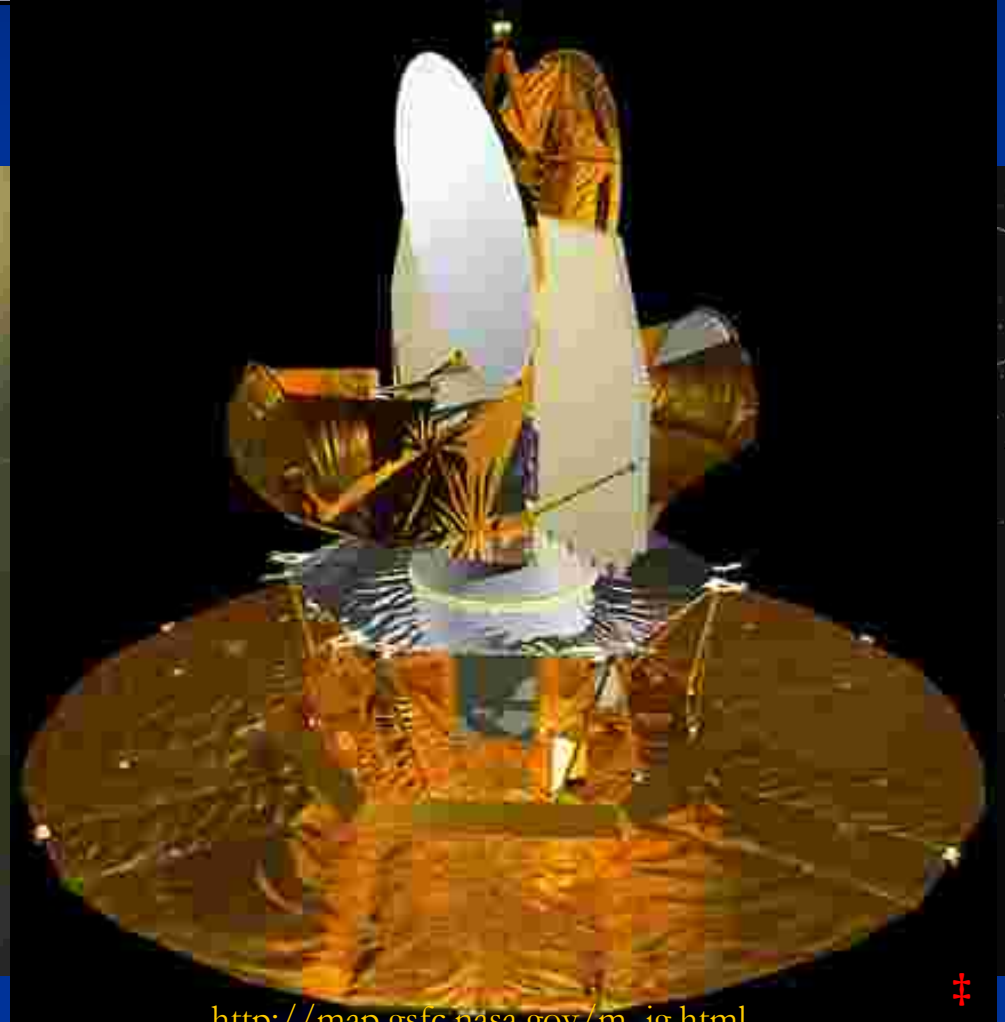
[http://lambda.gsfc.nasa.gov/product/cobe/cobe\\_images/cmb\\_fluctuations\\_big.gif](http://lambda.gsfc.nasa.gov/product/cobe/cobe_images/cmb_fluctuations_big.gif)

COBE satellite sent back pictures of the universe of approximately three hundred thousand years after the beginning of the universe. The satellite provided the seed for the formation of the universe. This, interestingly enough, coincided with the seed by quantum fluctuation of what inflation theory predicted.

# In February, 2003, NASA's WMAP Satellite Verified Inflation Theory by More Accurate Observation



[http://map.gsfc.nasa.gov/m\\_ig.html](http://map.gsfc.nasa.gov/m_ig.html)



[http://map.gsfc.nasa.gov/m\\_ig.html](http://map.gsfc.nasa.gov/m_ig.html)

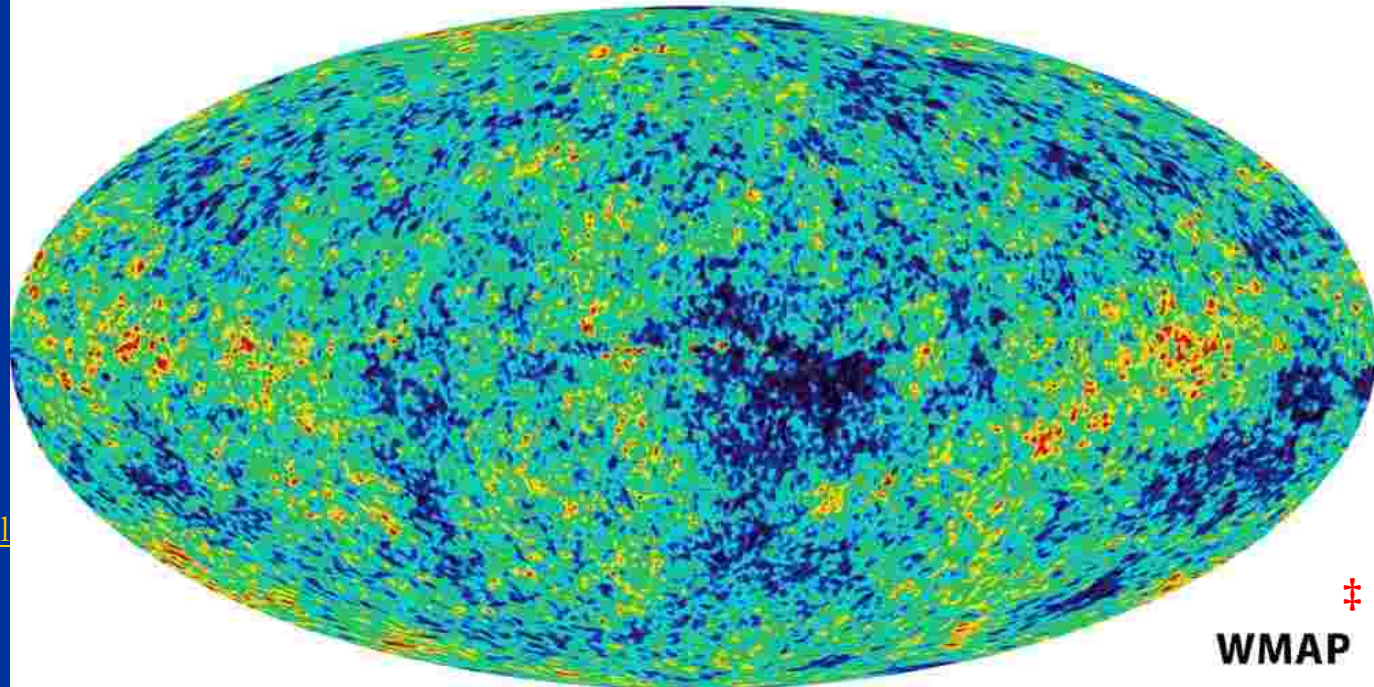
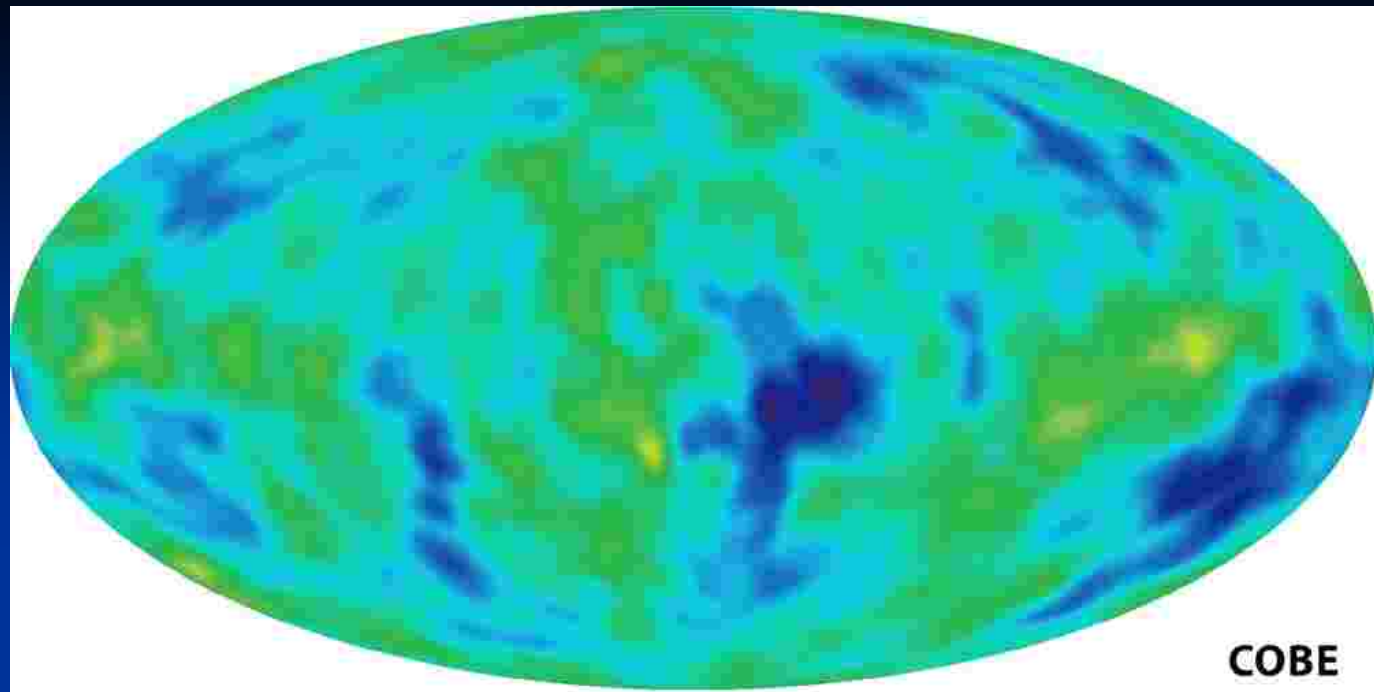


# The Map of the Universe 38,000 Years After the Big Bang, Sent Back by the WMAP Satellite

The age of the  
universe has been  
determined to be  
 $13.7 \pm 2$  billion  
years old!

[http://map.gsfc.nasa.gov/m\\_or.html](http://map.gsfc.nasa.gov/m_or.html)

Sato, Katsuhiko. *Uchu 96% no  
Nazo*. Tokyo: Jitsugyo no Nihon  
Sha, 2003 frontispiece





# Achievements of Cosmic Background Radiation Observation

- Cosmic geometry: extremely smooth.

Density parameter:  $\Omega = 1.02 \pm 0.02$

- The irregularity and the seed for the formation of the universe discovered by the observation coincided with the quantum fluctuation during the inflation period.

Power Law exponent:  $n = 0.93 \pm 0.03$

- The age of the universe is  $13.7 \pm 2$  billion years old.

# At 6 P.M. October 22nd, B.C. 4,000

J. Ussher, Anglican Archbishop, from Ireland, calculated the time for the creation of the universe.

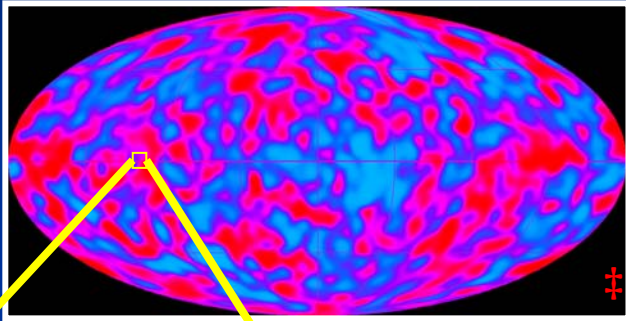


- Ussher, a clergyman of Charles I, calculated the time of the events described in the Old Testament with additional consideration of the events described in the New Testament. (1650)
- - Adam was 130 years old when Seth was born. Seth lived 800 years and had sons and daughters. Adam lived for 930 years. ... M.Gorst, *The Search for the Beginning of Time*, 2001

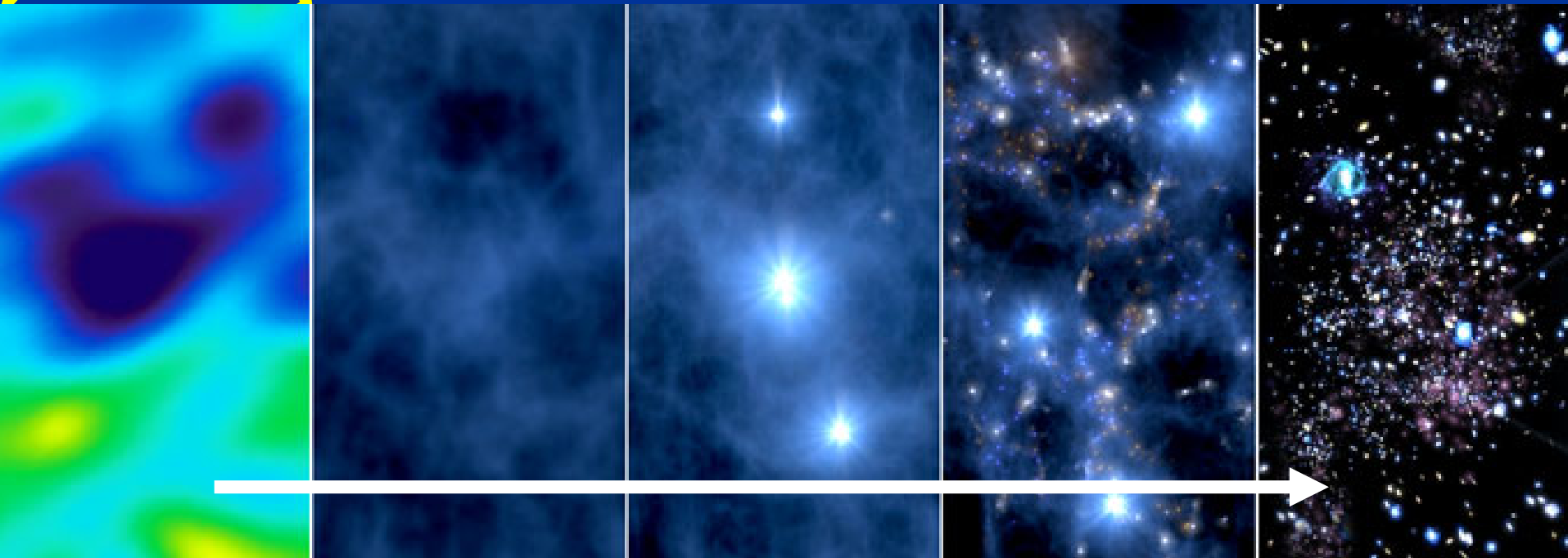
JACOBUS USSERIUS, ARCHIEPISCOPUS ARMACHANUS,  
TOTIUS HIBERNIAE PRIMAS.  
London: Printed for Nath. Ratcliff and Isac Robinson at the Kings Arms in St Pauls Church-yard 1650.

# Computer Simulation of the Formation of the Universe

- “Seed of formation” was observed by COBE/WMAP.
- This seed becomes an initial condition; matter is gathered around by the force of gravity followed by the formation of a galaxy, a cluster of galaxies, and the Great Wall.



[http://lambda.gsfc.nasa.gov/product/cobe/cobe\\_images/cmb\\_fluctuations\\_big.gif](http://lambda.gsfc.nasa.gov/product/cobe/cobe_images/cmb_fluctuations_big.gif)



# **Computer Simulation of Large-scale Structure Formation in the Universe; From Quantum Fluctuation to “Seed”, and To a Galaxy and a Cluster of Galaxies**

## **Structure Formation in the Cold Dark Matter Model of the Universe**

**Kyoto University**

**Kohji Yoshikawa**

**Shanghai Astronomical Observatory**

**Jing Yipeng**

**The University of Tokyo**

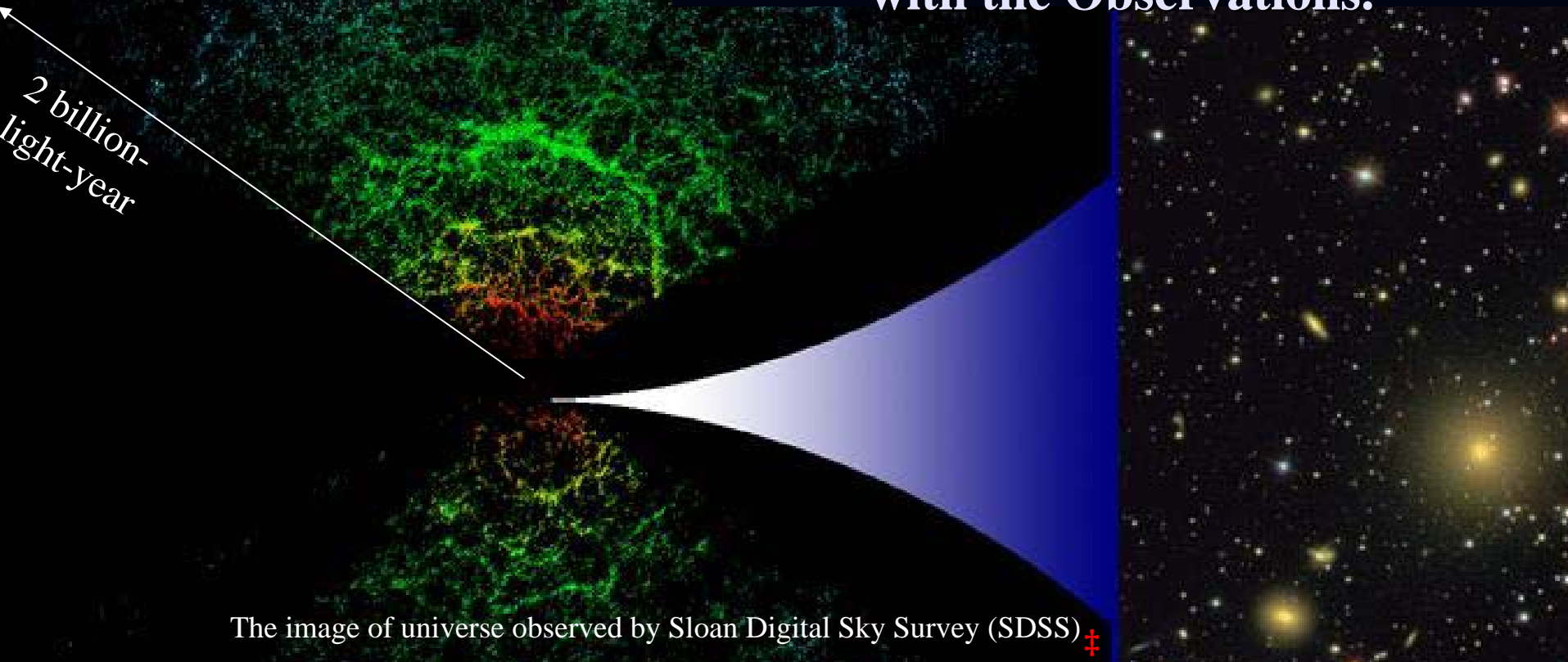
**Yasushi Suto**

**Computer**

**National Astronomical Observatory of Japan  
Research Center for the Early Universe, School of Science,  
The University of Tokyo**



**Great Progress in Observational  
Cosmology Showed Large-scale  
Structure Formation in the Universe.  
The Simulation Very Much Agreed  
with the Observations.**



We can say, inflation is “a microscope”, that expands quantum fluctuation in the 100 digit-scale. Observation of large-scale structures in the universe equals the observation of quantum fluctuation.

# **Creation and Evolution of the Universe: the Outline Established**

**Observation agrees with the theory almost completely!**

One hundred years after the discovery of Einstein's theory of relativity, we have finally come to learn the outline of evolution and the structure of the universe in which we belong; our position in the universe has changed accordingly.

But,

**The broader the region of our knowledge becomes, the broader the frontier zones become, thereby the greater the number of mysteries appear.**

# 6. The Problem of Dark Matter and Dark Energy

Does the identity of the constituents of the universe remain unknown?

- Ordinary matter : 4%

Composes our bodies and the stars shining in the sky.

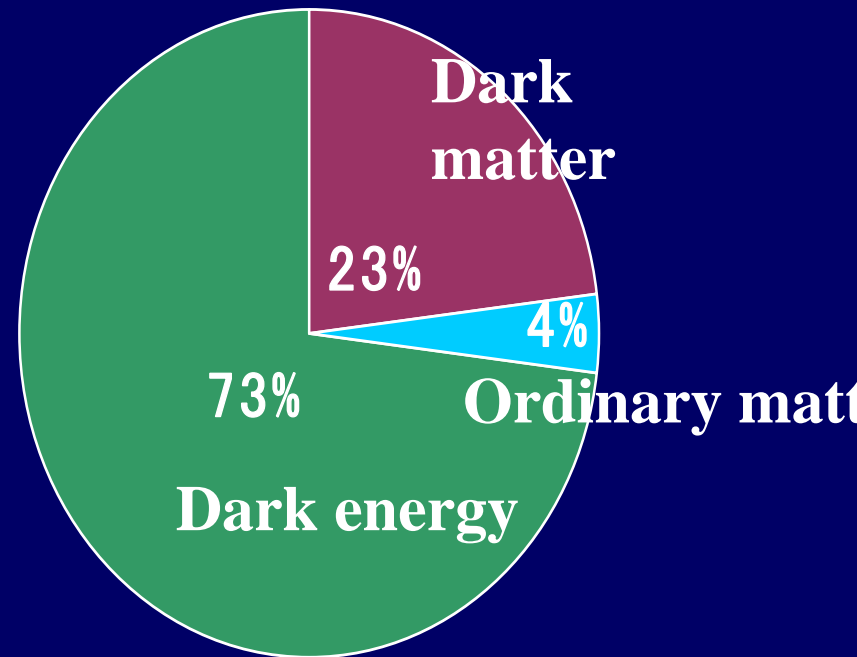
- Dark Matter: 23%

Unknown matter that fills the inside of the galaxy and the cluster of galaxies.

- Dark Energy: 73%

Unknown vacuum energy that spreads uniformly in the entire universe.

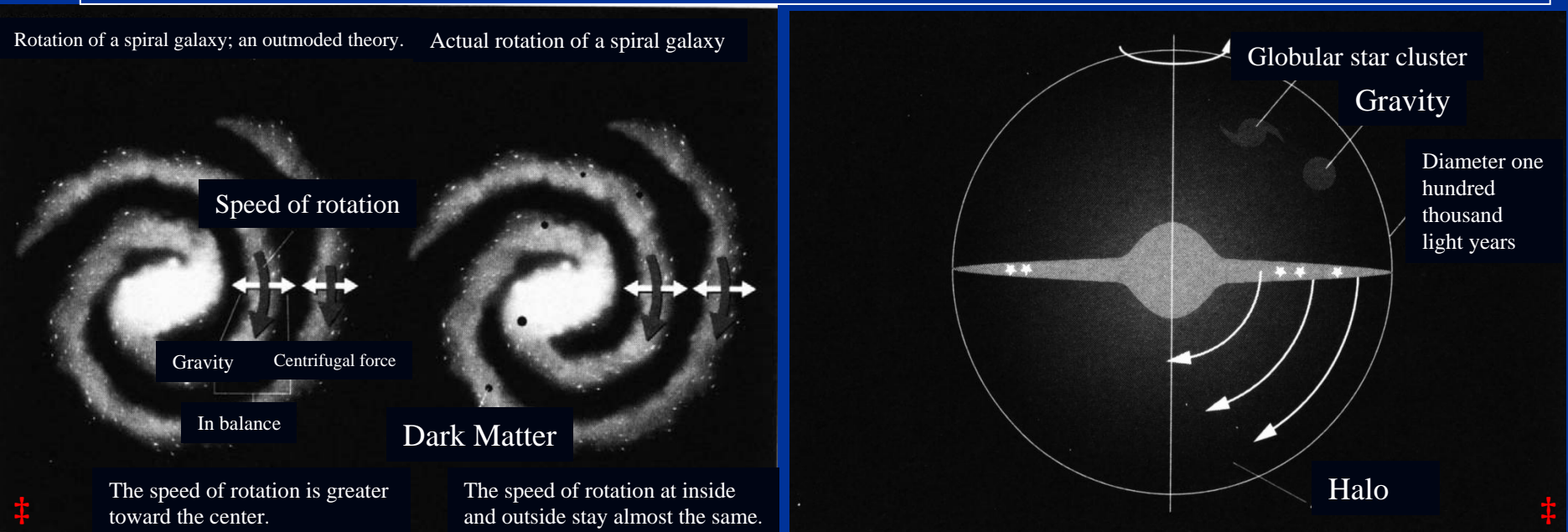
## Composition of the Universe



# Dark Matter

**Dark Matter:** We understand the existence of Dark Matter by observing the point where it seems as if it is covering the inner periphery of the galaxy, the cluster of galaxies, and the supercluster of the galaxies to form a source of unseen gravity. It is as yet an unidentified source of gravity.

Dark Matter consists of roughly 23% of the total physical energy in the universe.



Sato, Katsuhiko. *Uchu 96% no Nazo*. Tokyo: Jitsugyo no Nihon Sha, 2003 p.205

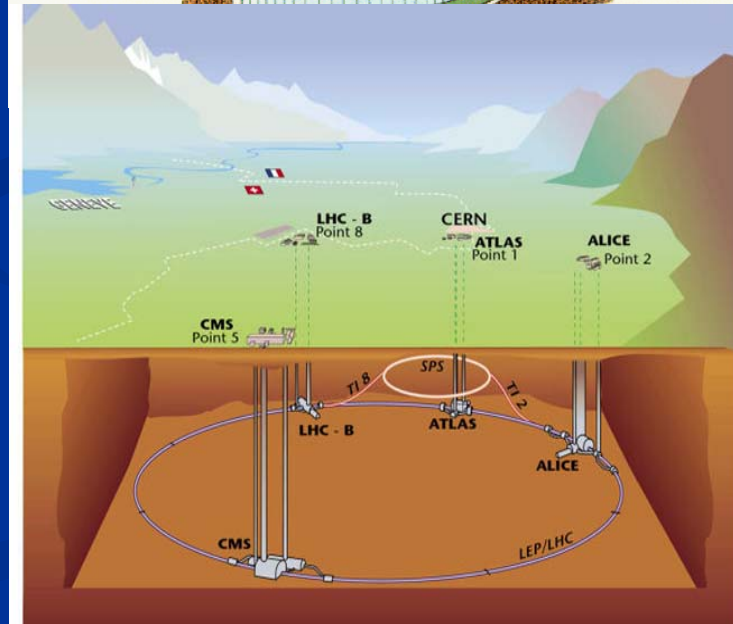
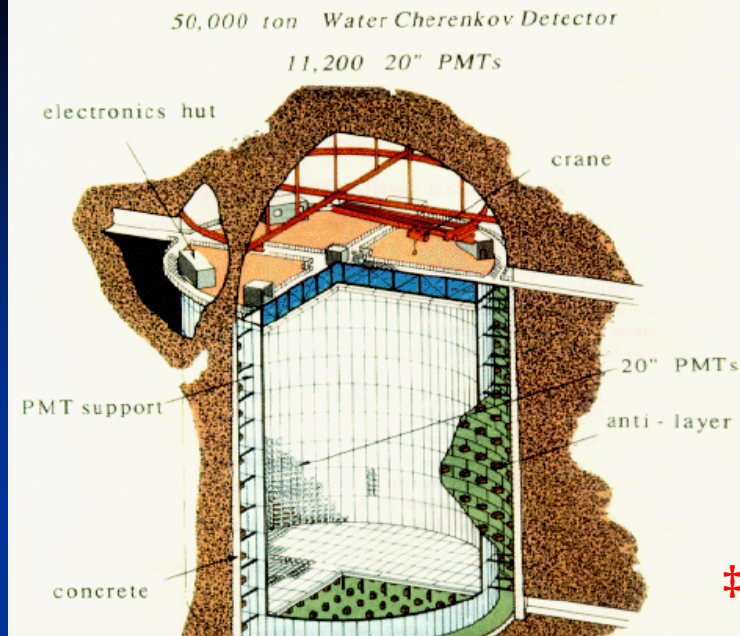
Dark matter has at least 10 times the total mass of the visible stars in our galaxy.



# Dark Matter Candidates and the Probe

- Non-zero mass of neutrino  
(left almost no possibilities)
- Neutralino  
(A hypothetical particle that the supersymmetric theory predicts)
- Axion
- Matter in the adjacent “Brane Universe”??
- ■ ■ ■ ■ ■

The Super KamiokaNDE identified the non-zero mass of the neutrino; however, it requires one hundred times the discovered mass of neutrino to become Dark Matter.



LHC may imply Dark Matter candidates.

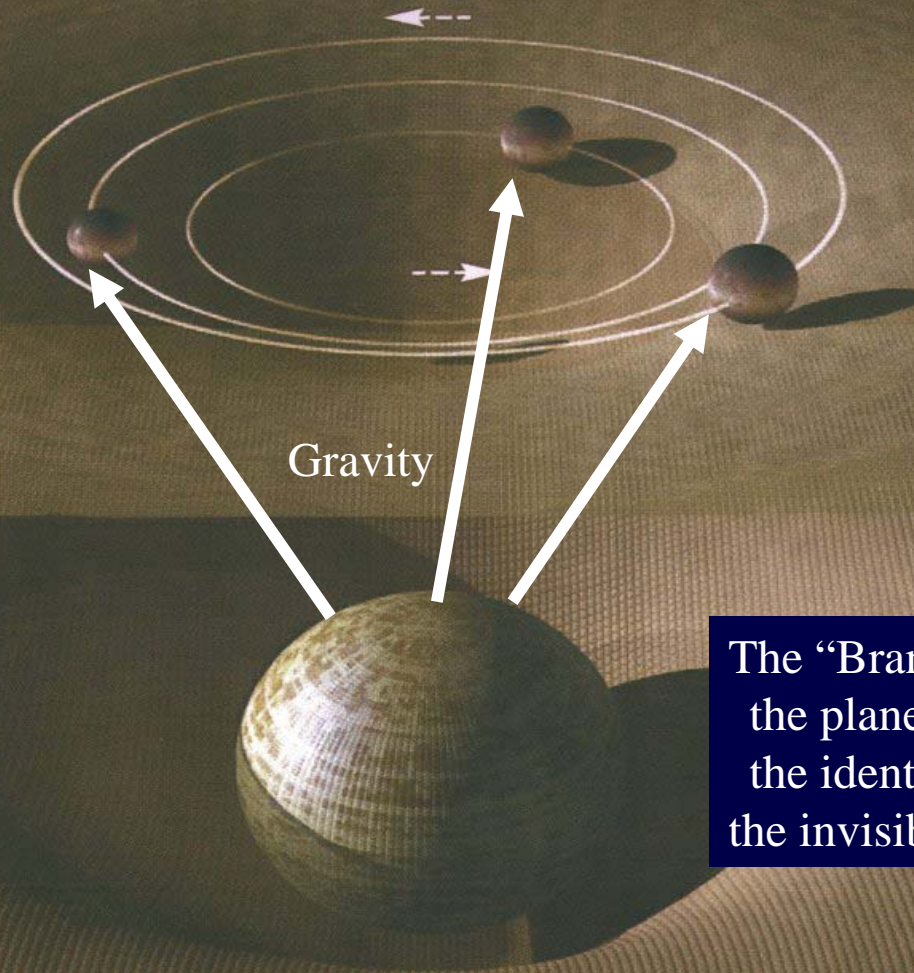
CERN: <http://public.web.cern.ch/Public/Welcome.html>

# Shadow World

The “Brane Universe” floats on the ten-dimension universe.

“*This*” world (three-dimensional)

“*That*” world (three-



The “Brane Universe” next to the planets may possibly be the identity of Dark Matter; the invisible source of gravity

S.Hawking, The Universe in a Nutshell



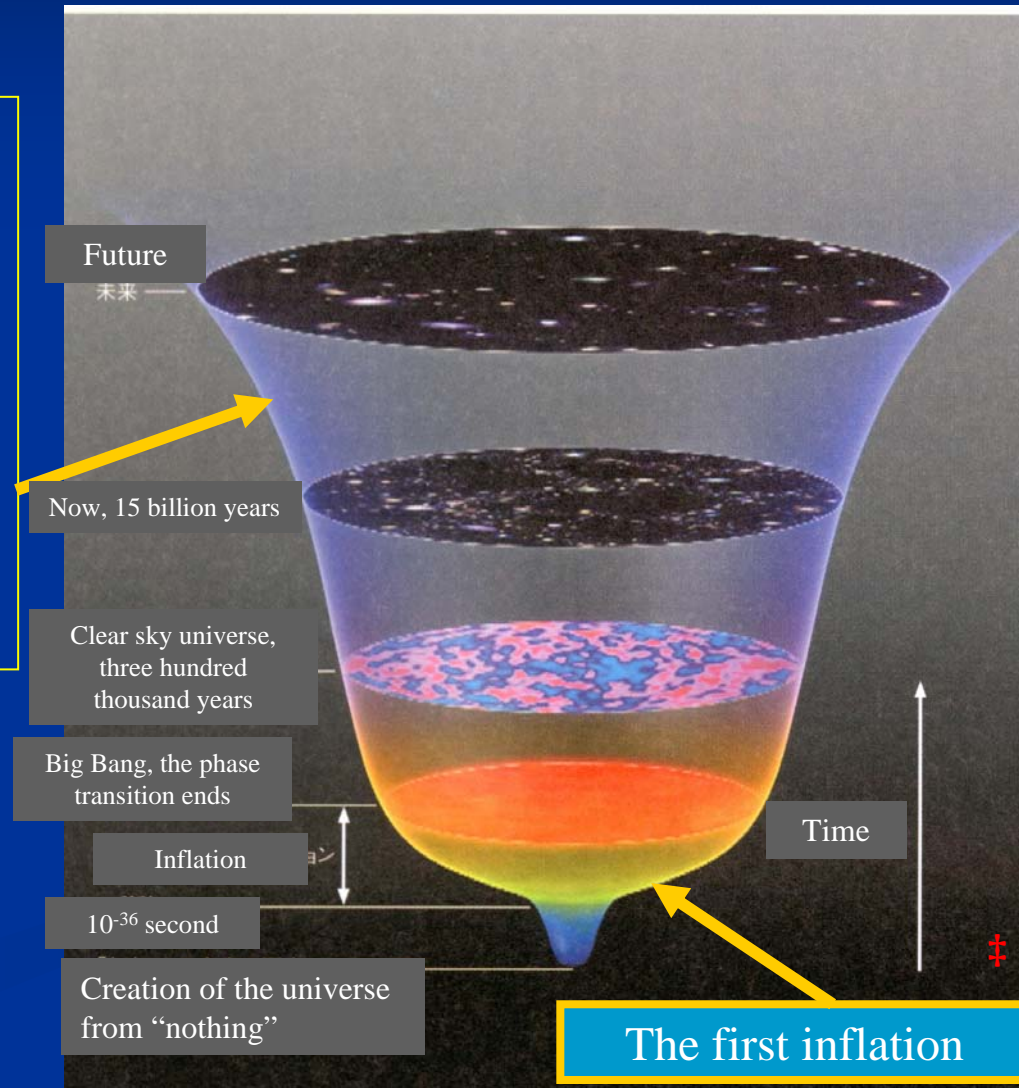


# The Discovery of Dark Energy

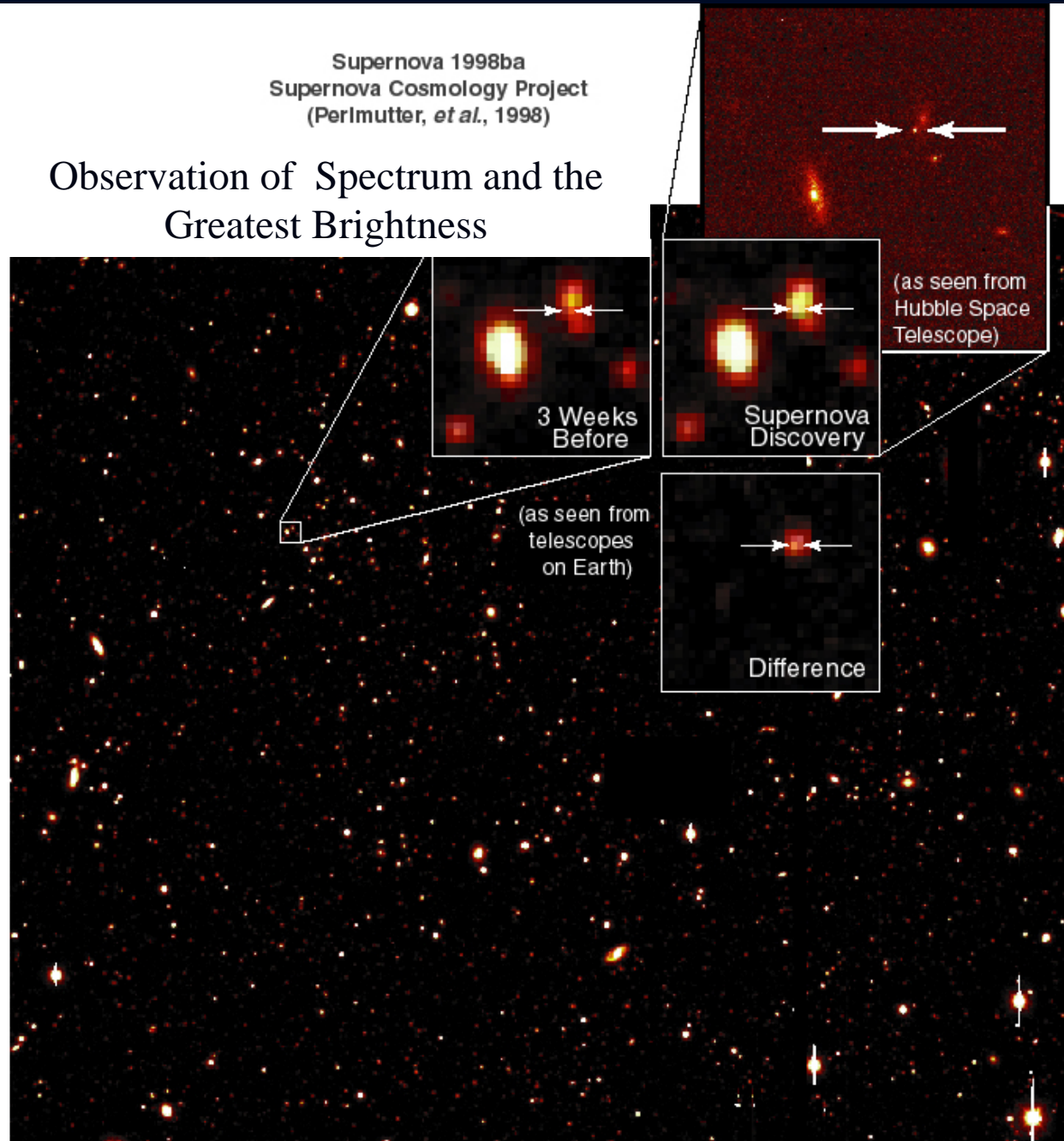
The U.S. Scientific Journal *Science* in 1998 Named the “The Breakthrough of the Year” as the **Discovery of Vacuum Energy**.

Has the universe  
broken into the second  
period of inflation due  
to the force of repulsion  
on vacuum energy?

Two different research groups reported the observation of distant supernova. They discovered that Dark Matter makes up about 70% of the all energy in the universe. (Permuter et al, '98, Schmitdt et al, '98)



**Observation of a  
Distant  
Supernova  
Revealed that  
the Universe is  
Filled with  
Vacuum Energy  
Also Confirmed  
by the WMAP  
Satellite**



# Einstein's Cosmological Constant Has Also Been Revived for Use in Explaining the Present Universe!

Einstein's Cosmological Constant was  
not his greatest blunder, but it turned  
out to be one of his greatest  
achievements.

Still, the identity of this force, the  
Cosmological Constant, remains  
unknown.



# The Problem of Dark Energy

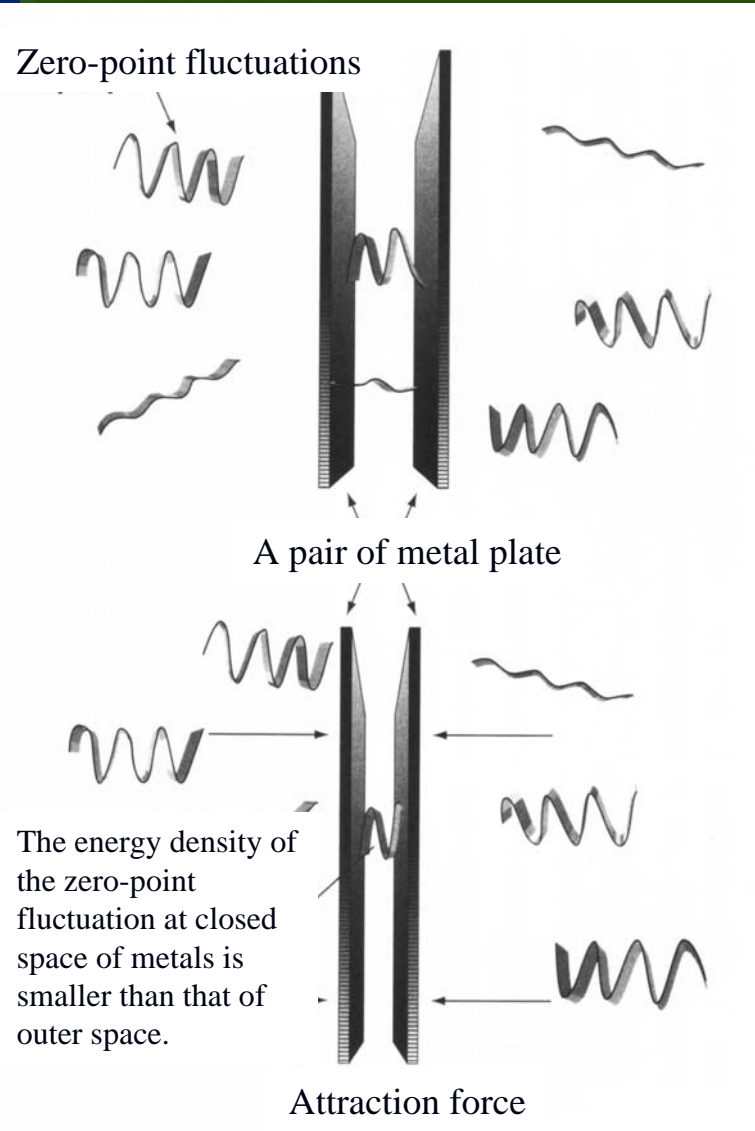
At the beginning of the discovery, dark energy was called vacuum energy. After consideration of the possible change in energy values relative to the ageing of the universe, the energy was called “dark energy”.

1. What is the identity (physical entity) of dark energy?

2. Cosmological coincidence problem: why after about ten billion years from the creation of the universe has the universe again begun its second period of inflation?

3. Will this energy eventually disappear in the same way as the first inflation did?

# Measurement of the Energy Difference in a Vacuum – Casimir Effect



Quantum mechanically, the vacuum field possesses fluctuation.

**Energy of zero-point oscillation= vacuum energy**

The space between a pair of metal plates is forced to attract each other because the space possesses smaller zero-point energy than the open outside space.

The absolute energy of vacuum energy is not measurable; however, the energy difference is measurable.

S. K. Lamoreaux, 1997.  
U. Mohiden, A. Roy, 1998.

# Coincidence Problem

- Can we reach relevant testimony by depending only on human reasoning?

Myriads of universes exist, with each possessing different vacuum energy (cosmological constant). Only the intellectual souls (human being) are recognized among the countless number of universes.

- In a universe, that possesses above the present level of vacuum energy, the formation of celestial bodies will not be carried out thereby, no intellectual soul would be created. All recognized universes are the ones having approximately the same level or below the level of vacuum energy presently measured. By S. Weinberg, 1989.

# The Future of the Universe

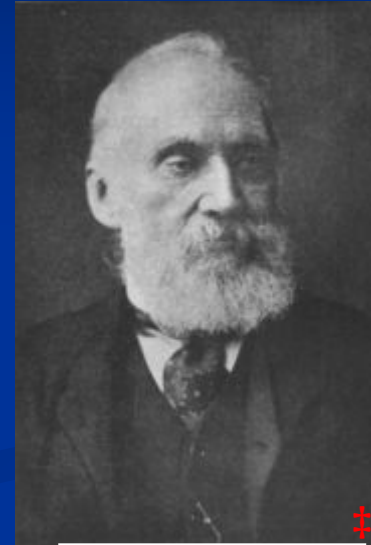
- How long will this accelerated expansion continue? Is there any possibility of “phase transition” occurring, that will cause the dark energy to fade away?
- If the accelerated expansion is to continue, the region of our influence, the physical region, will become more narrow. We human beings are no longer allowed to explore into the infinite universe.
- If the accelerated expansion is halted, we may be able to take a journey into the realm of infinity. There is also the possibility that the universe will begin to collapse.



# New Mysteries Arise from the Expansion of Our Knowledge; What is Dark Matter and Dark Energy?

Lord Kelvin pointed out the existence of two clouds which overshadowed the clarity of physics at that time: detecting the **non-existence of ether** and blackbody radiation. Apparently, the two problems were the keys to modern physics: **relativity theory** and quantum theory.

Do both dark energy and dark matter hold new and important clues to physics?



Lord Kelvin  
William Thomson

**Innovative physics of the 21<sup>st</sup> century should be able to reveal a clear picture of the universe by solving such mysteries as dark matter and dark energy.**

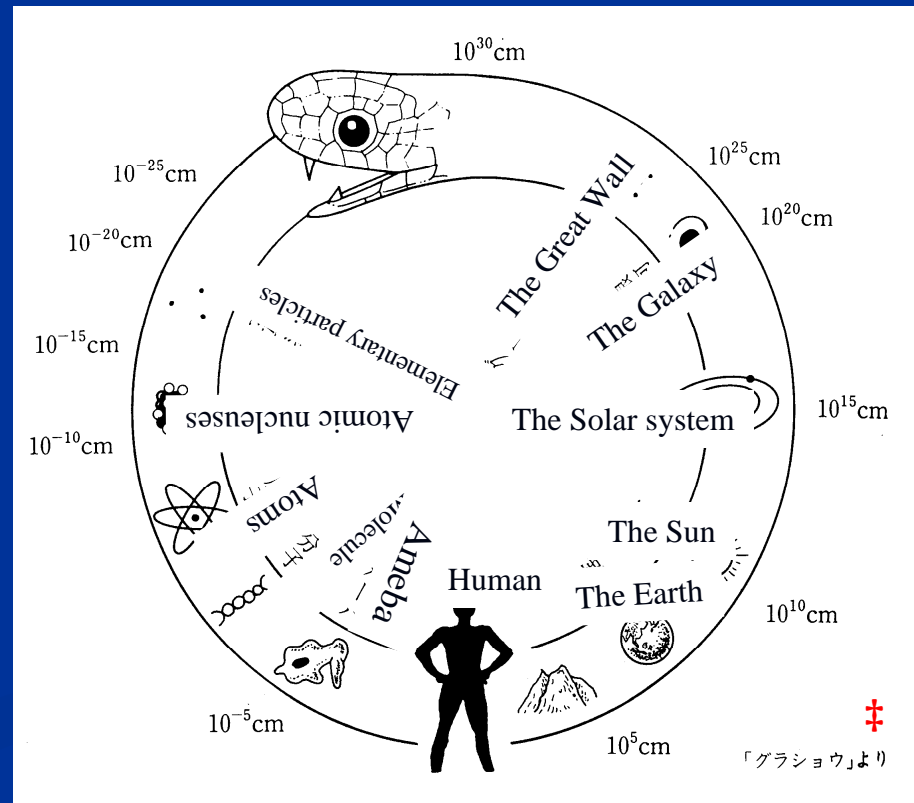
# 7. Summary

We have learned the structure of the physical universe from microcosmic to macrocosmic in 60 digits, which solidly following physical laws.

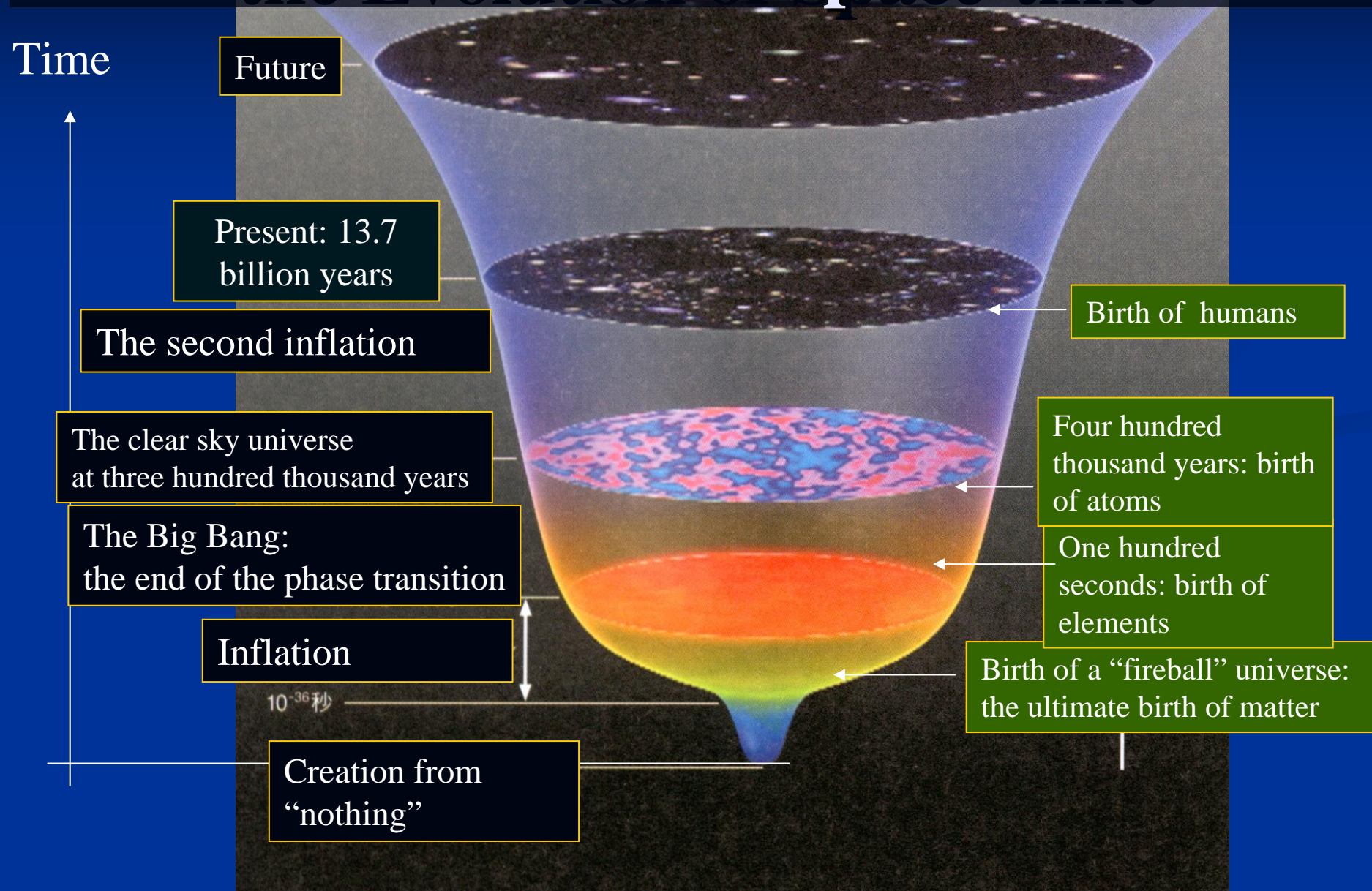
Is this, however, the end of the hierarchy?

- Is the ten-dimension “string” the original shape of matter?
- Is there any other structure consisting of an amount of physical matter beyond the observation of the ten billion years of the universe?
- Is there any other universe outside the space-time manifold universe that we inhabit.

Does an unified theory exist, and if it does then what does it look like?

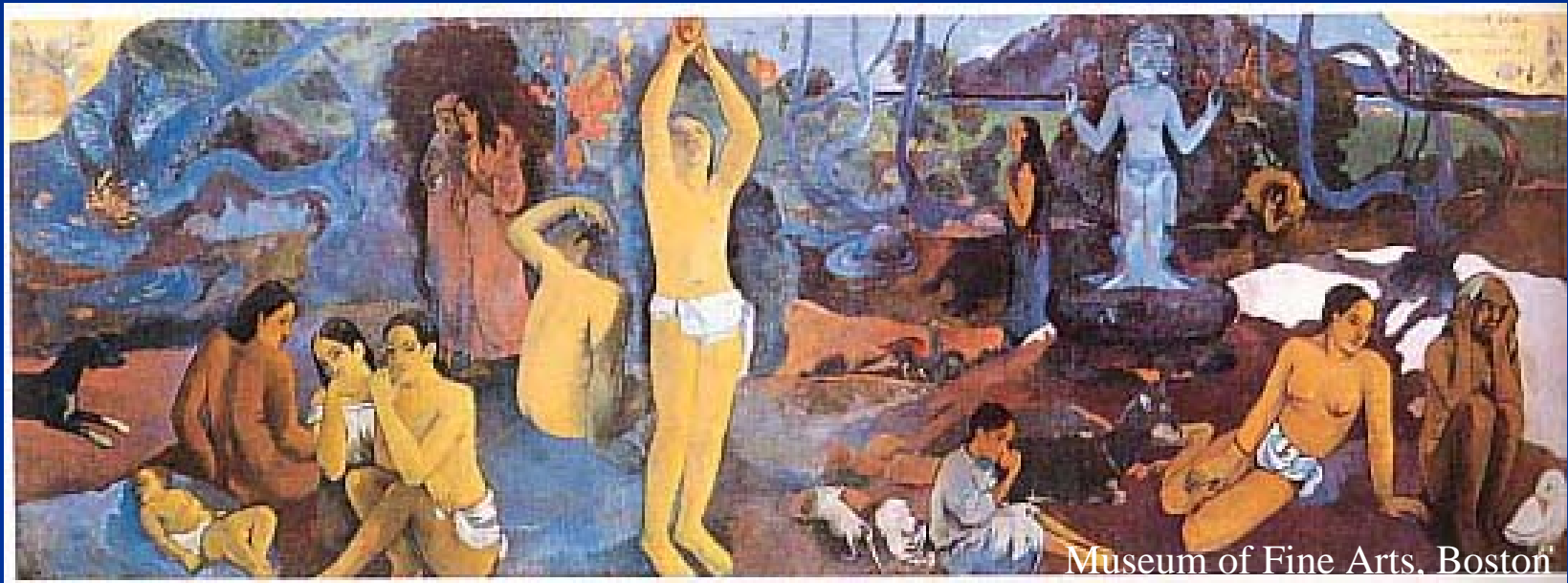


# The Birth of Matter is Associated with the Evolution of Space-time



# Learning About the World Means the Learning of Ourselves.

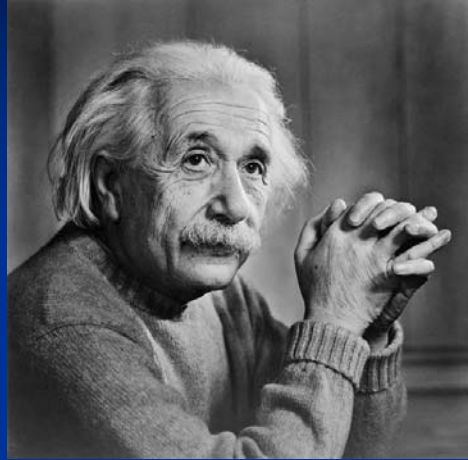
“Where do we come from?” “What are we?” “Where are we going?” Gauguin’s masterpiece during his later years.



- In the physical world of the universe;  
**We know who we are.**
- Human beings are the most fascinating creature existing in the universe.



# Quotation by A. Einstein



As far as the laws of mathematics refer to reality, they are not certain; and as far as they are certain, they do not refer to reality.