Global Focus on Knowledge 2005
Science of Matter

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

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Research Center for the Early Universe(RESCEU)

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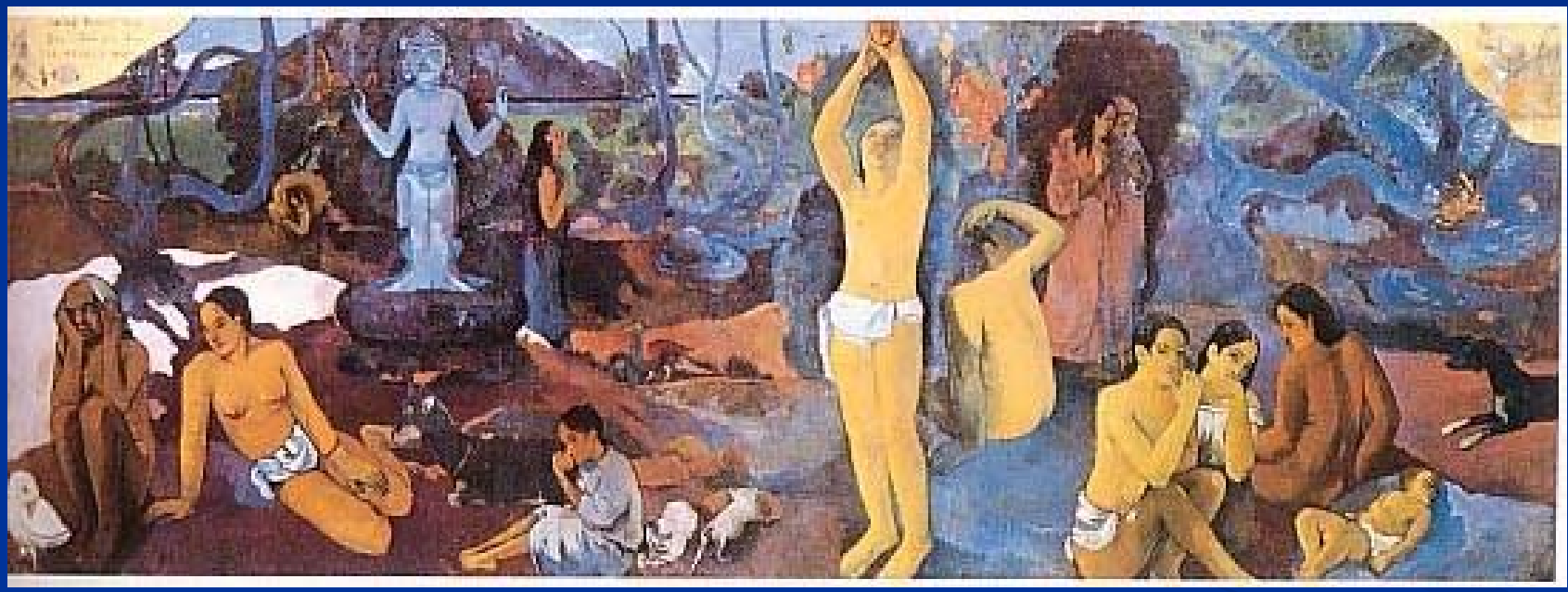
Introduction

- Throughout history, we human beings have searched for our place in the cosmos.
- Encouraged by this intellectual curiosity, we have studied our world and become a survivor in the process of natural selection.
- We have chosen to develop a huge brain in our feeble body as a survival tactic.
- In the 20th century, we learned the mechanisms at both extremes; from the elementary particles to the end of the universe. The physical laws of the evolving universe were studied though, remain incomplete.

Learning the World Means the Learning About Ourselves.

"Where do we come from?" "What are we?" "Where are we going?" Gauguin's masterpiece during his later years.



Museum of Fine Arts, Boston ‡

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

The Universe: the Location of Human Beings in the Physical World

- Human bodies are made of hydrogen, which was instantly filled by the Big Bang, and the chemical elements such as carbon, nitrogen, and oxygen combined through the supernova explosion.
- The galaxy, the Sun, the Earth, and the lives on Earth of humanity were born during the structural evolution of the universe.
- Life is another phase of its own functional morphology of matter. In addition, the evolution of living organisms is another phase of its own evolution of matter. The brain function follows the principles of magnetism and chemical reaction.
- Evolutionary psychology treats the human mind as a product of evolution. Nevertheless, whether the human brain made up of physical principles actually has free will or not, has not yet been found.

An objective learning of the self may provide guides to life.

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

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

How Do We Understand the Physical World?-Structural Hierarchy of Matter-

- History
- Structural hierarchy of the physical world
- World of the atomic nucleus and its birth
- World of the elementary particle and its birth
- Dark matter and dark energy
- Where are the end points of the structural hierarchy?

History: How Do We Conceive of the Physical World?

Start from a human-scale perspective to a larger-scale perspective .

- The visible world seen by the human eye.

Small world: insects, the sand, and the soil.

Large world: large-size animals, mountains, oceans, continents, and the earth.

The visible world by tools.

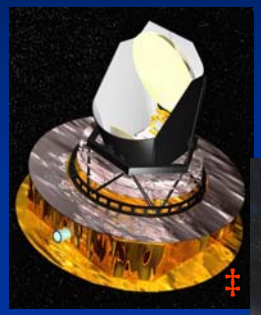
Cosmic expansion

Small world: microscopes, electron microscopes, and accelerators.

Large world: telescopes.

Not only can we conceive of visible light, but we can also conceive of waves including radio waves, gamma rays: every wavelength of the electromagnetic waves, particle beams, neutrinos, and gravity waves.

Telescopes: Deeper, Wider, Multiwavelength, Particle Beams, Neutrinos, and Gravity Waves



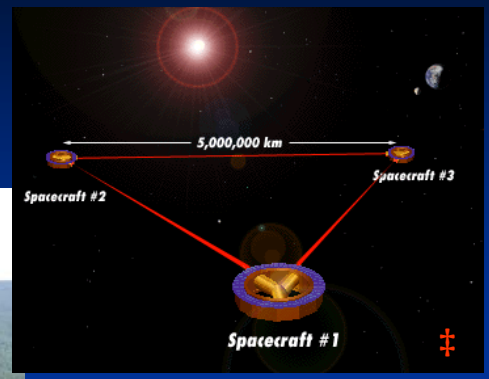
PLANCK (20

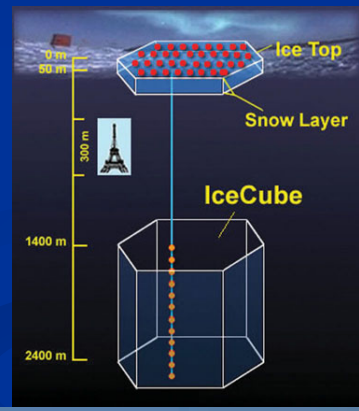
ALMA

Astro-F (IRIS)

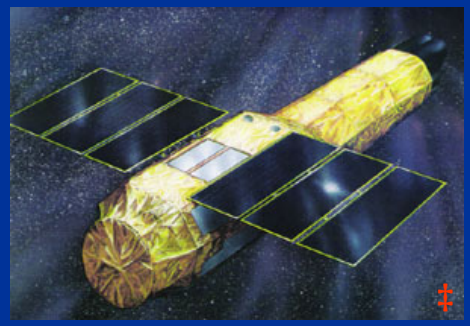
SDSS Telescope

LISA



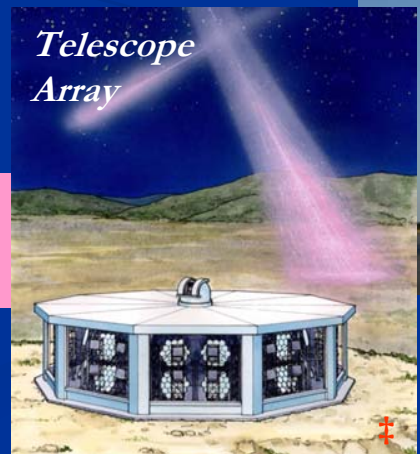


"CANGAROO" Telescope



astroEII

Subaru Telescope

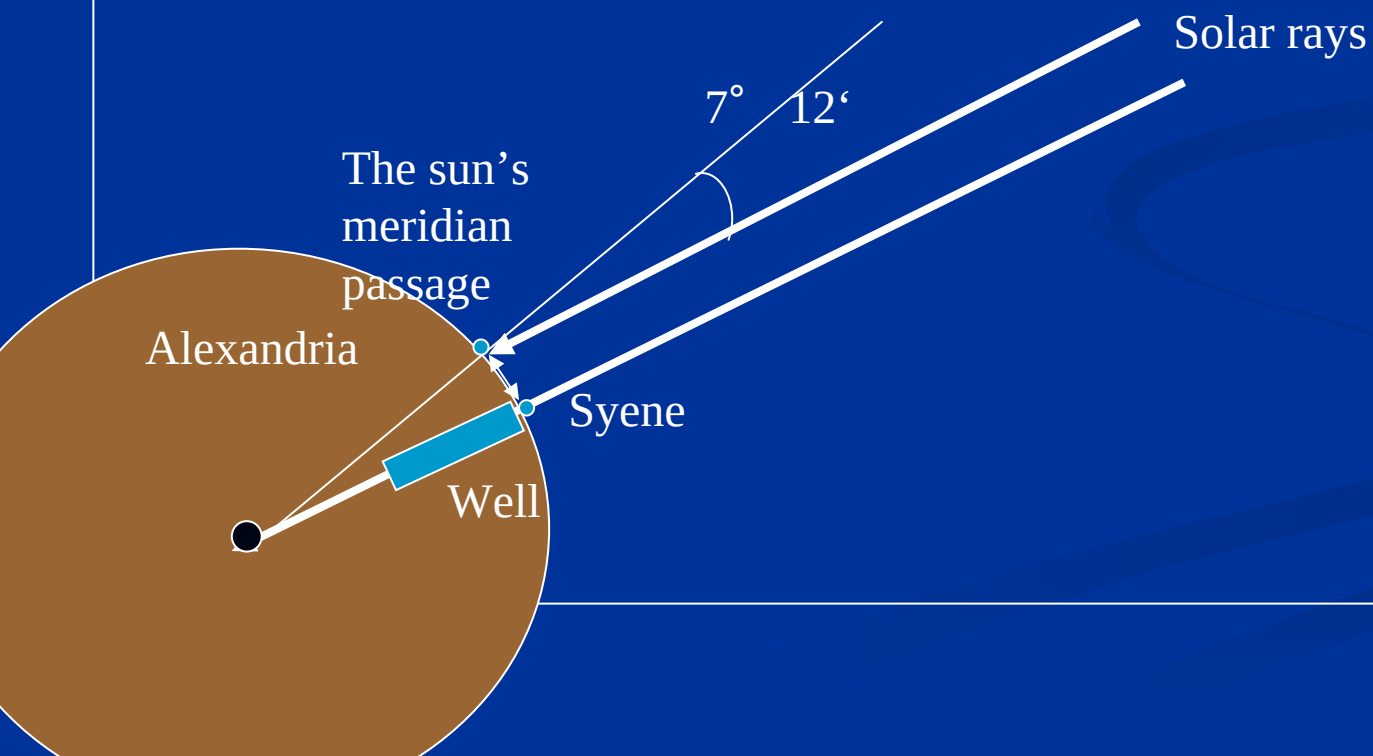


BESS

The Macroscopic System

- The Earth 6,000 km

Eratosthenes (ca. 276-ca.196 BC) 7,400 km



The Macroscopic System Aristotle's system

- The Earth 6,000 km Eratosthenes (ca. 276-ca.196 BC)
- The solar system

  5.5 light hours (distance to Pluto)

  Aristotle (ca. 384-ca.322 BC)
- The galaxy (Milky Way Galaxy)

  The radius of fifty thousand light years. W. Herschel (18C) and Kapstein (1915)
- Superclusters and the Great Wall

  A few hundred million light years.
- The farthest reach of the observable universe

  Between 10 to 20 billion light years.

and its Structural Hierarchy

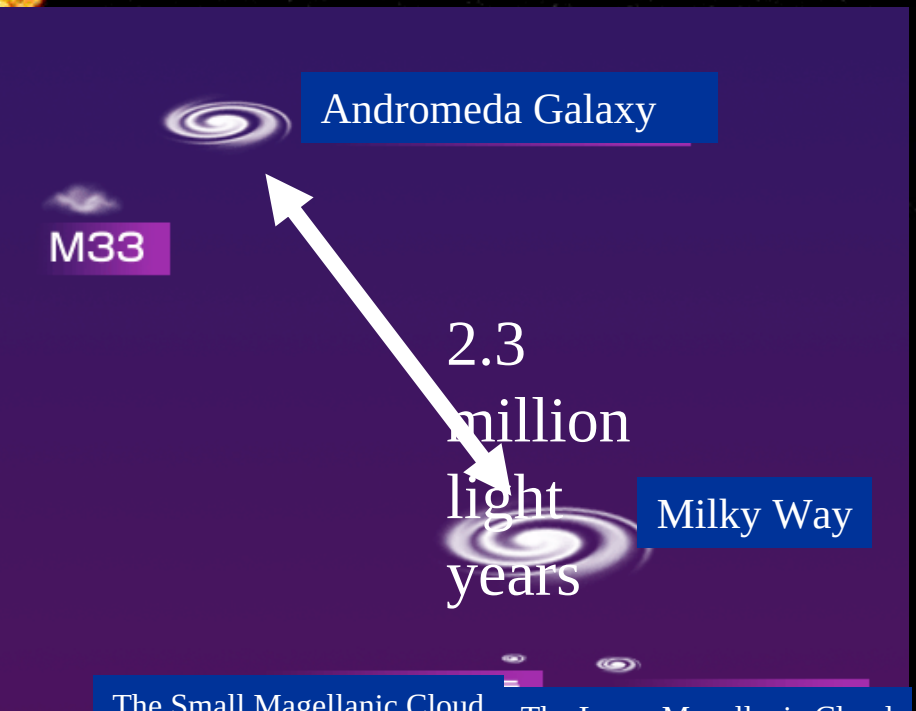
SDSS Project

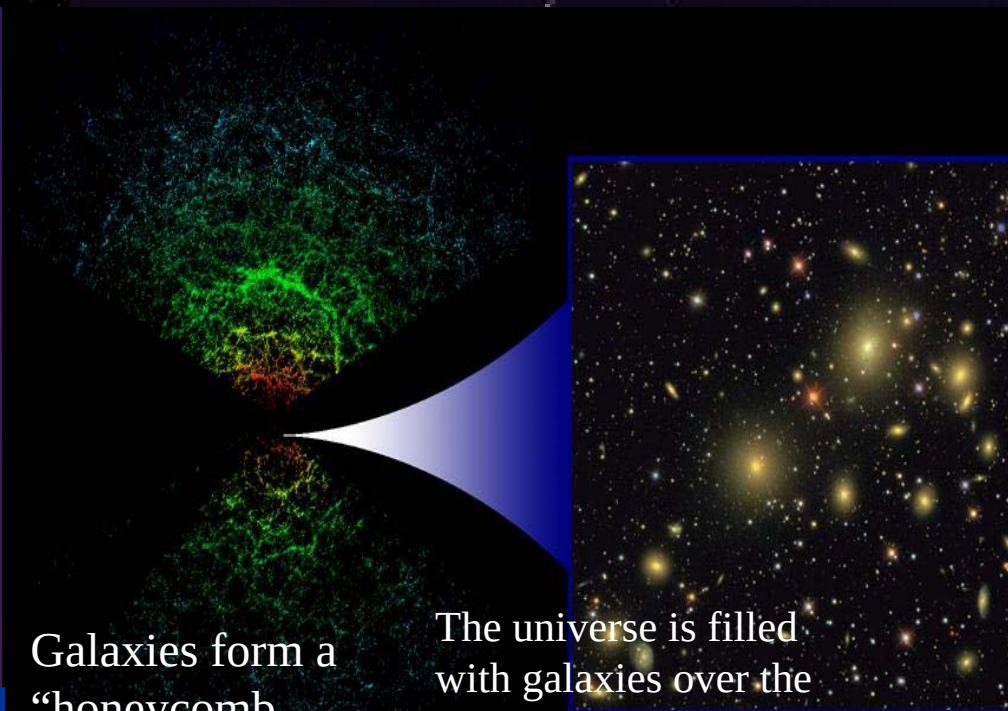
COBE/DIRBE

/TNPJP/nineplanets/Sudo

Solar system

The galaxies of one hundred billion stars hang together in clusters, containing countless number of galaxies in the universe.



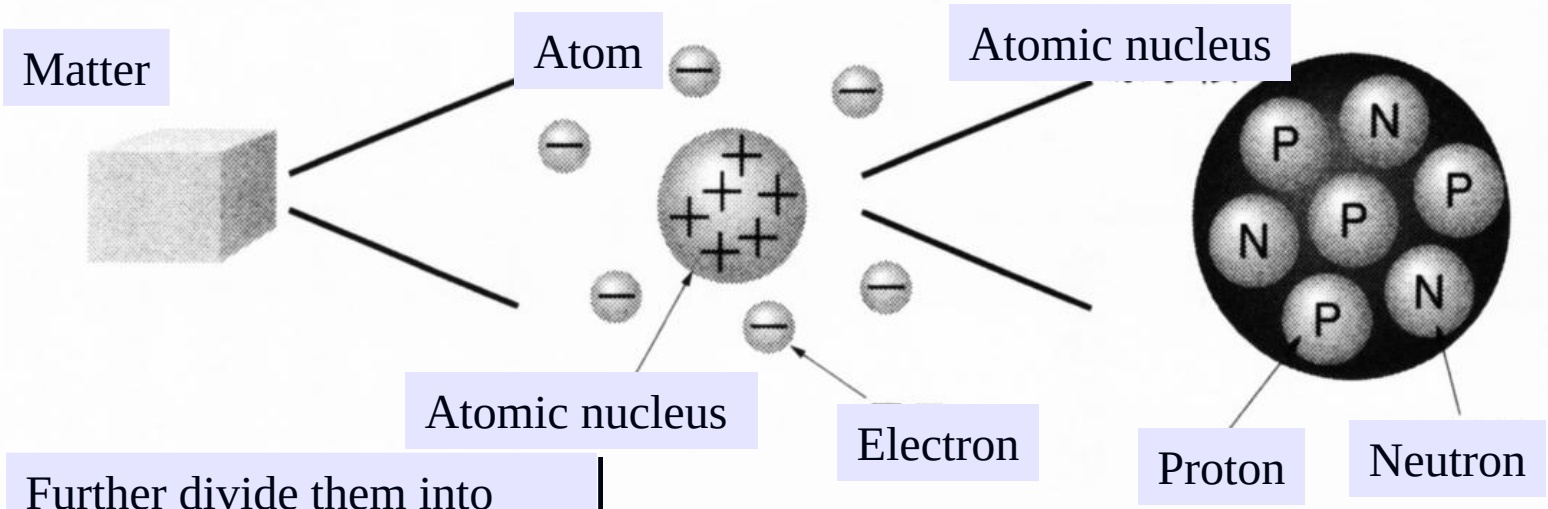


Galaxies form a "honeycomb

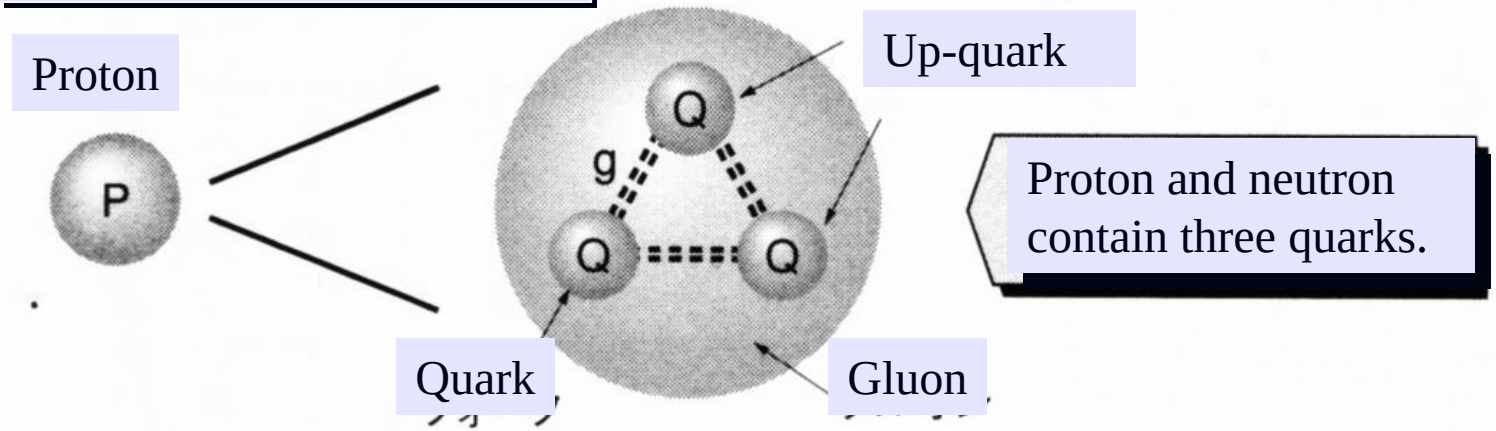
The universe is filled with galaxies over the

The Microscopic System

Let us divide a matter into smaller pieces.



Further divide them into smaller pieces.



Proton and neutron contain three quarks.

The Microscopic World

- The world of microbes. ~100 nanometer

  Optical microscope: A. Leeuwenhoek (1632-1723) was the first to discover microbes by monocular glasses.

- The world of molecules and atoms $\geq$ 0.3 nanometer

  Invention of the electron microscope by Max Knoll and Ernst Ruska. (1931) The scanning transmission electron microscope (STEM) is used these days.

- The world of the atomic nucleus and elementary particles $\leq 10^{-14}$ meter

  Particle accelerator: Lawrence invented cyclotrons.(1930)

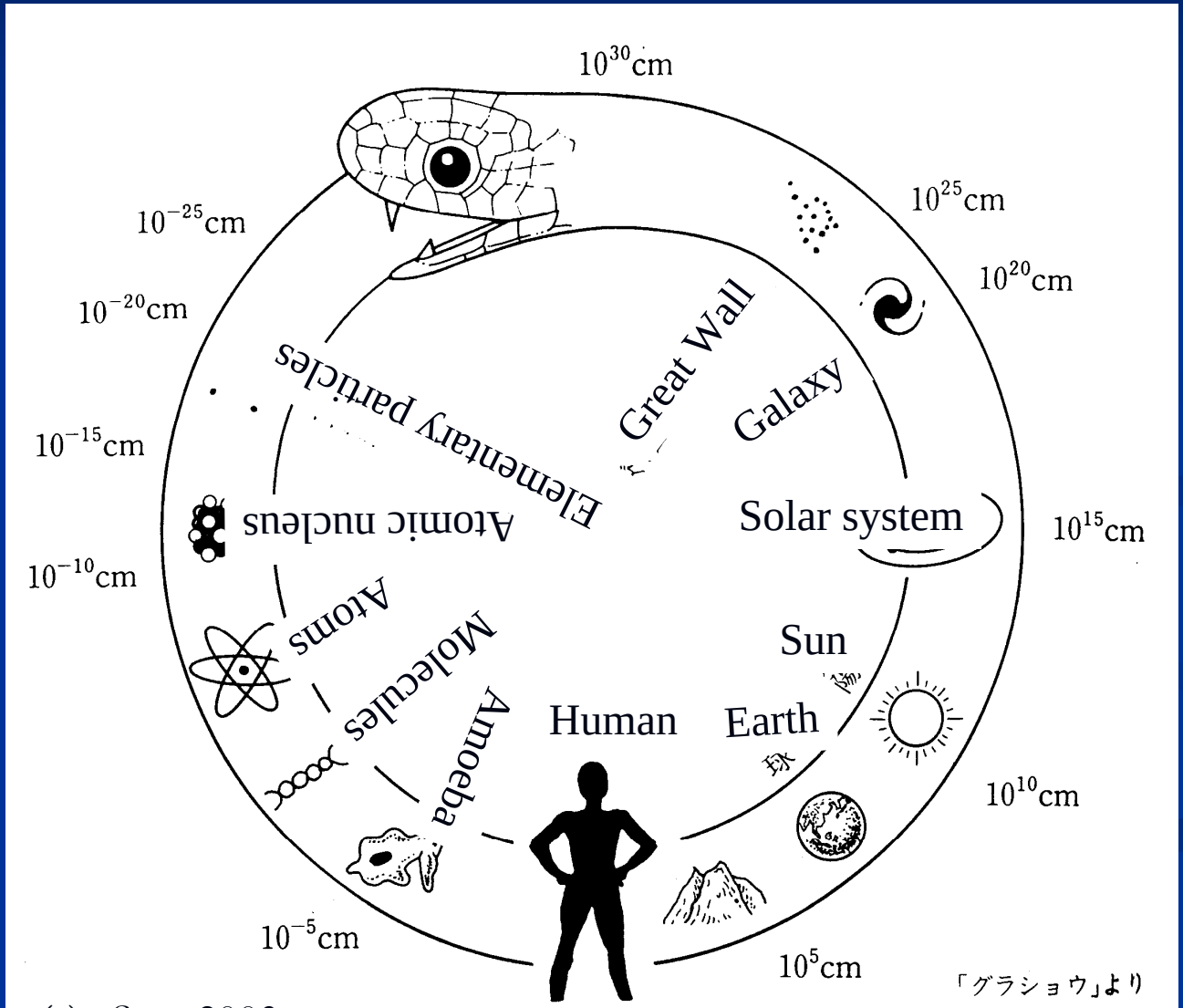
$$\left(G\hbar / c^3\right)^{1/2}$$

- The Planck length (theoretical research) ~ 10^{-36} meter

  The smallest measurement in space: quantum fluctuation in space. (no more production of BH and WH)

  Planck constant h, velocity of light C, and gravitational constant G.

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



In Search of the Smallest Measurement of Matter

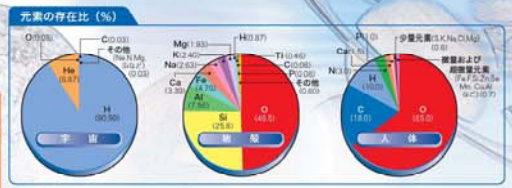
The atomic theories of ancient Greece.

- Thales (ca. 624-ca.547 BC) The world originated from water.
- Empedocles (ca. 493-ca.433 BC) The world is made of four elements: water, air, earth, and fire.
- Democritus (ca.460-ca.370 BC) All matter is made of indivisible “atoms.”

These days: All ordinary matter is made of atoms; the fundamental unit of the elements.

元素周期表

Periodic Table of the Elements



メンデレーエフ (Dmitrij Ivanovich Mendeleev, 1834－1907)
1869年、ロシアのペテルスブルグ大学の化学者メンデレーエフは、当時知られていた63種類の元素を (1) 原子量の順に並べ、(2) 酸素や塩素と結合してできる酸素の組成（たとえば、ナトリウムはNaClを、マグネシウムはMgCl₂をつくる）などの性質が周期的に変化する法則（周期律）を見いだした。性質が似た元素が同じ列にくるように配列した周期表をつくった。その表のなかには空欄があり、当時知られていなかった元素の性質を予言した。初めはメンデレーエフの周期表は注目されなかったが、1875年にガリウムが、1886年にゲルマニウムが発見され、それらの性質が彼の予言のとおりであったため、世界的に信頼された。
現在では周期表は、すべての人が用いる化学や物理学の基本となっている。

族 1 2 13 14 15 16 17 18

周期 1

1 Hydrogen 水素 1.008

2 Helium ヘリウム 4.003

2

3 Lithium リチウム 6.941

4 Beryllium ベリリウム 9.012

5 Boron ホウ素 10.81

6 Carbon 炭素 12.01

7 Nitrogen 窒素 14.01

8 Oxygen 酸素 16.00

9 Fluorine フッ素 19.00

10 Neon ネオン 20.18

3

11 Sodium ナトリウム 22.99

12 Magnesium マグネシウム 24.31

13 Aluminium アルミニウム 26.98

14 Silicon ケイ素 28.09

15 Phosphorus リン 30.97

16 Sulfur 硫黄 32.07

17 Chlorine 塩素 35.45

18 Argon アルゴン 39.95

4

19 Potassium カリウム 39.10

20 Calcium カルシウム 40.08

21 Scandium スカンジウム 44.96

22 Titanium チタン 47.87

23 Vanadium バナジウム 50.94

24 Chromium クロム 52.00

25 Manganese マンガン 54.94

26 Iron 鉄 55.85

27 Cobalt コバルト 58.93

28 Nickel ニッケル 58.69

29 Copper 銅 63.55

30 Zinc 亜鉛 65.39

31 Gallium ガリウム 69.72

32 Germanium ゲルマニウム 72.64

33 Arsenic ヒ素 74.92

34 Selenium セレン 78.96

35 Bromine 臭素 79.90

36 Krypton クリプトン 83.80

5

37 Rubidium ルビジウム 85.47

38 Strontium ストロンチウム 87.62

39 Yttrium イットリウム 88.91

40 Zirconium ジルコニウム 91.22

41 Niobium ニオブ 92.91

42 Molybdenum モリブデン 95.94

43 Technetium テクネチウム (98)

44 Ruthenium ルテニウム 101.1

45 Rhodium ロジウム 102.9

46 Palladium パラジウム 106.4

47 Silver 銀 107.9

48 Cadmium カドミウム 112.4

49 Indium インジウム 114.8

50 Tin スズ 118.7

51 Antimony アンチモン 121.8

52 Tellurium テルル 127.6

53 Iodine ヨウ素 126.9

54 Xenon キセノン 131.3

6

55 Cesium セシウム 132.9

56 Barium バリウム 137.3

57 Lanthanum ランタン 138.9

58 Cerium セリウム 140.1

59 Praseodymium プラセオジム 140.9

60 Neodymium ネオジム 144.2

61 Promethium プロメチウム (145)

62 Samarium サマリウム 150.4

63 Europium ユウロピウム 152.0

64 Gadolinium ガドリニウム 157.3

65 Terbium テルビウム 158.9

66 Dysprosium ジスプロシウム 162.5

67 Holmium ホルミウム 164.9

68 Erbium エルビウム 167.3

69 Thulium ツリウム 168.9

70 Ytterbium イッテルビウム 173.0

71 Lutetium ルテチウム 175.0

7

87 Francium フランシウム (223)

88 Radium ラジウム (226)

アクチノイド系 89 ～ 103

104 Rutherfordium ラザホージウム (261)

105 Dubnium ドブニウム (262)

106 Seaborgium シーボーギウム (263)

107 Bohrium ボーリウム (264)

108 Hassium ハッシウム (265)

109 Meitnerium マイトネリウム (268)

110 Darmstadtium ダームスタチウム (269)

111 Roentgenium レントゲニウム (272)

112 元素 (277)

113 元素 (278)

89 Actinium アクチニウム (227)

90 Thorium トリウム 232.0

91 Protactinium プロトアクチニウム 231.0

92 Uranium ウラン 238.0

93 Neptunium ネプツニウム (237)

94 Plutonium プルトニウム (244)

95 Americium アメリシウム (243)

96 Curium キュリウム (247)

97 Berkelium バークリウム (247)

98 Californium カリホルニウム (251)

99 Einsteinium アインスタイニウム (252)

100 Fermium フェルミウム (257)

101 Mendelevium メンデレビウム (258)

102 Nobelium ノーベリウム (259)

103 Lawrencium ローレンシウム (262)

Li リチウム
ブラウン管用蛍光剤(CdS)
イタイイタイ病はCd中毒
カドミウム 112.4
48 Cadmium

In インジウム
熱線反射性の蒸着ガラス
放射性同位体は医療診断剤
インジウム 114.8
49 Indium

Sn スズ
青銅(Cu-Sn合金)
曇り防止ガラス
スズ 118.7
50 Tin

Sb アンチモン
スチック, カーテン, マットレス)
半導体, DVDディスクの材料
アンチモン 121.8
51 Antimony

Te テルル
モルファス化(非晶質化))
赤外線検出材料(Sn-Pb-Te)
テルル 127.6
52 Tellurium

I ヨウ素
ヨウ素デンプン反応：青紫色
人工降雨用の種結晶(AgI)
ヨウ素 126.9
53 Iodine

Xe キセノン
プラズマディスプレイパネル(PDP)の充填ガス
キセノン 131.3
54 Xenon

Na ナトリウム
11 Sodium

Mg マグネシウム
12 Magnesium

K カリウム
19 Potassium

Ca カルシウム
20 Calcium

Rb ルビジウム
37 Rubidium

Sr ストロンチウム
38 Strontium

Cs セシウム
55 Cesium

Ba バリウム
56 Barium

Fr フランシウム
87 Francium

Ra ラジウム
88 Radium

Hg 液体金属：温度計や体温計
蛍光灯にはHg蒸気を封入
補聴器などの水銀ボタン電池
水俣病は有機水銀が原因
水銀 200.6
80 Mercury

Tl 心臓の断層写真
放射性同位体は心筋の診断剤
低温用温度計(HgにTlを混ぜる)
遠赤外線用の光学材料
ネズミの駆除に使うこともある
タリウム 204.4
81 Thallium

Pb Battery
鉛蓄電池や自動車バッテリー
活字用合金, はんだ(Pb-Sn合金)
放射線のしゃへい剤(鉛ガラス
はテレビのブラウン管に使用)
鉛 207.2
82 Lead

Bi 低融点合金(ヒューズや火災
用自動スプリンクラーの口金)
セラミックスやガラスの製造
次硝酸ビスマスは胃がいよう薬
ビスマス 209.0
83 Bismuth

Po 半減期 138日
キュリー夫妻が発見
アルファ線源や中性子源
原子力電池
最も毒性が強い元素
ポロニウム (210)
84 Polonium

At サイクロトロン国産1号機(1937年)
ギリシャ語の「不安定astatos」が語源
1940年にカリフォルニア大学
のサイクロトロンを用いて発見
半減期は8.1時間
アスタチン (210)
85 Astatine

Rn 最も重い気体
放射性Raから微量発生
ラドン泉・ラジウム泉
半減期は3.8日
ラドン (222)
86 Radon

1996年2月9日, ドイツの重イオン科学研究所で発見された元素.
半減期0.00028秒 (277)
112 元素

2004年7月23日, 日本の理化学研究所で発見された新元素.
半減期0.0003秒
113 元素 (278)

※ここに示した原子量は, 各元素の詳しい原子量の値を有効数字4桁に四捨五入してつくられたもので, IUPAC原子量委員会で承認されたものである.
安定同位体がなく, 同位体の天然存在比が一定しない元素はその元素の代表的な同位体の質量数を( )の中に示している.
※元素名のうち, AlはAluminium, CsはCaesiumと表記することもある.
※半減期は同位体のうち最も長いものを示してある.

一家に1枚周期表

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大学), 高尾正敏(松下電器産業株式会社), 壬生
●イラストレーター：山崎 猛

Periodic Table of the Elements

:Essential elements to human body in sufficient quantity.

:Essential elements to human body in very small quantities.

:Elements possibly essential to human body.

Period \ Group	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 Hydrogen H																	2 Heliur He
2	3 Lithium Li	4 Beryllium Be											5 Boron B	6 Carbon C	7 Nitrogen N	8 Oxygen O	9 Fluorine F	10 Neon Ne
3	11 Sodium Na	12 Magnesiu Mg											13 Aluminum Al	14 Silicon Si	15 Phosphorus P	16 Sulfur S	17 Chlorine Cl	18 Argon Ar
4	19 Potassium K	20 Calcium Ca	21 Scandium Sc	22 Titanium Ti	23 Vanadium V	24 Chromium Cr	25 Manganese Mn	26 Iron Fe	27 Cobalt Co	28 Nickel Ni	29 Copper Cu	30 Zinc Zn	31 Gallium Ga	32 Germanium Ge	33 Arsenic As	34 Selenium Se	35 Bromine Br	36 Kr Krypto Kr
5	37 Rubidium Rb	38 Strontium Sr	39 Yttrium Y	40 Zirconium Zr	41 Niobium Nb	42 Molybdenum Mo	43 Technetium Tc	44 Ruthenium Ru	45 Rhodium Rh	46 Palladium Pd	47 Silver Ag	48 Cadmium Cd	49 Indium In	50 Tin Sn	51 Antimony Sb	52 Tellurium Te	53 Iodine I	54 Xenon Xe
6	55 Cesium Cs	56 Barium Ba	57～71 Lanthanum	72 Hafnium Hf	73 Tantalum Ta	74 Tungsten W	75 Rhenium Re	76 Osmium Os	77 Iridium Ir	78 Platinum Pt	79 Gold Au	80 Mercury Hg	81 Thallium Tl	82 Lead Pb	83 Bismuth Bi	84 Polonium Po	85 Astatine At	86 Radon Rn
7	87 Francium Fr	88 Radium Ra	89～103 Actinium	104 Rutherfordium Rf	105 Dubnium Db	106 Seaborgium Sg	107 Bohrium Bh	108 Hassium Hs	109 Meitnerium Mt	110 Darmstadtium Ds	111 Roentgenium Rg	112 (GSI)	113	114	115	116	117	118

57～71 Lanthanide series	57 Lanthanum La	58 Cerium Ce	59 Praseodymium Pr	60 Neodymium Nd	61 Promethium Pm	62 Samarium Sm	63 Europium Eu	64 Gadolinium Gd	65 Terbium Tb	66 Dysprosium Dy	67 Holmium Ho	68 Erbium Er	69 Thulium Tm	70 Ytterbium Yb	71 Lutetium Lu
89～103 Actinide series	89 Actinium Ac	90 Thorium Th	91 Protactinium Pa	92 Uranium U	93 Neptunium Np	94 Plutonium Pu	95 Americium Am	96 Curium Cm	97 Berkelium Bk	98 Californium Cf	99 Einsteinium Es	100 Fermium Fm	101 Mendelevium Md	102 Nobelium No	103 Lawrencium Lr

The World of Atoms

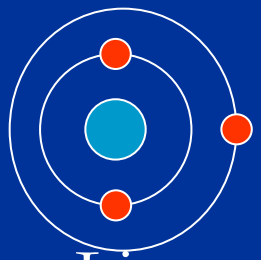
An atom is composed of a nucleus and the electrons that are traveling in orbit around it.

H

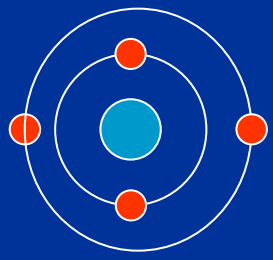
He

N=1 can contain 2 electrons.

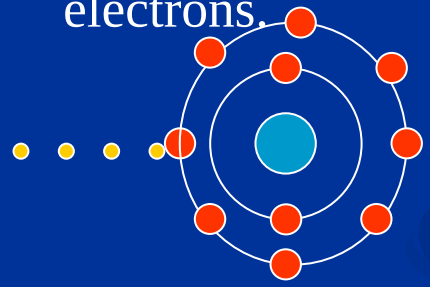
N=2 can contain 8 electrons.



Li

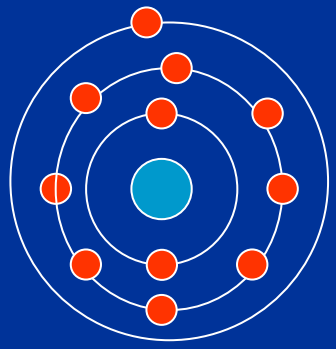


Be



Ne

Chemical characteristics of the elements are determined mostly by the characteristics of electrons in the outermost orbit or the ones in the second outermost orbit.

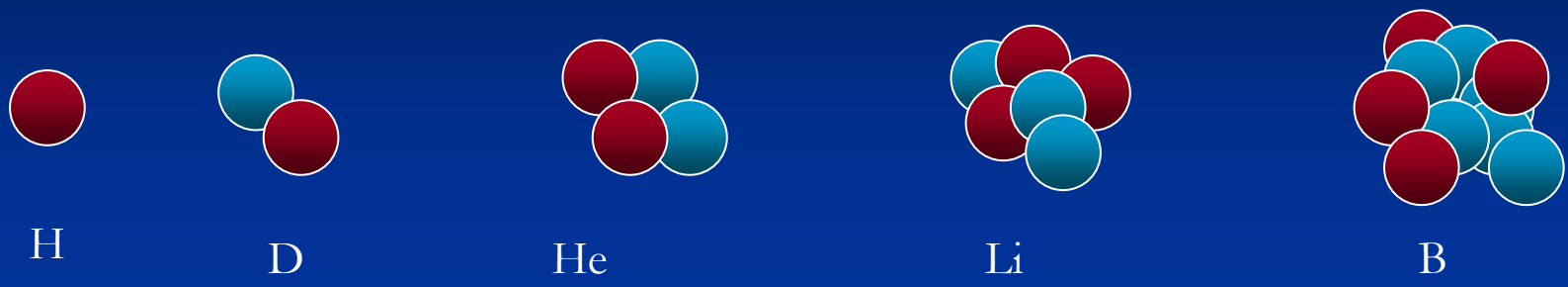


Na

N=3 can contain 18 electrons.

Periodic table stems from periodicity of the electron's shell structure.

Atomic Nucleus is a Cluster of Protons and Neutrons



All matter naturally existing on the Earth is composed of three particles: protons, neutrons, and electrons.

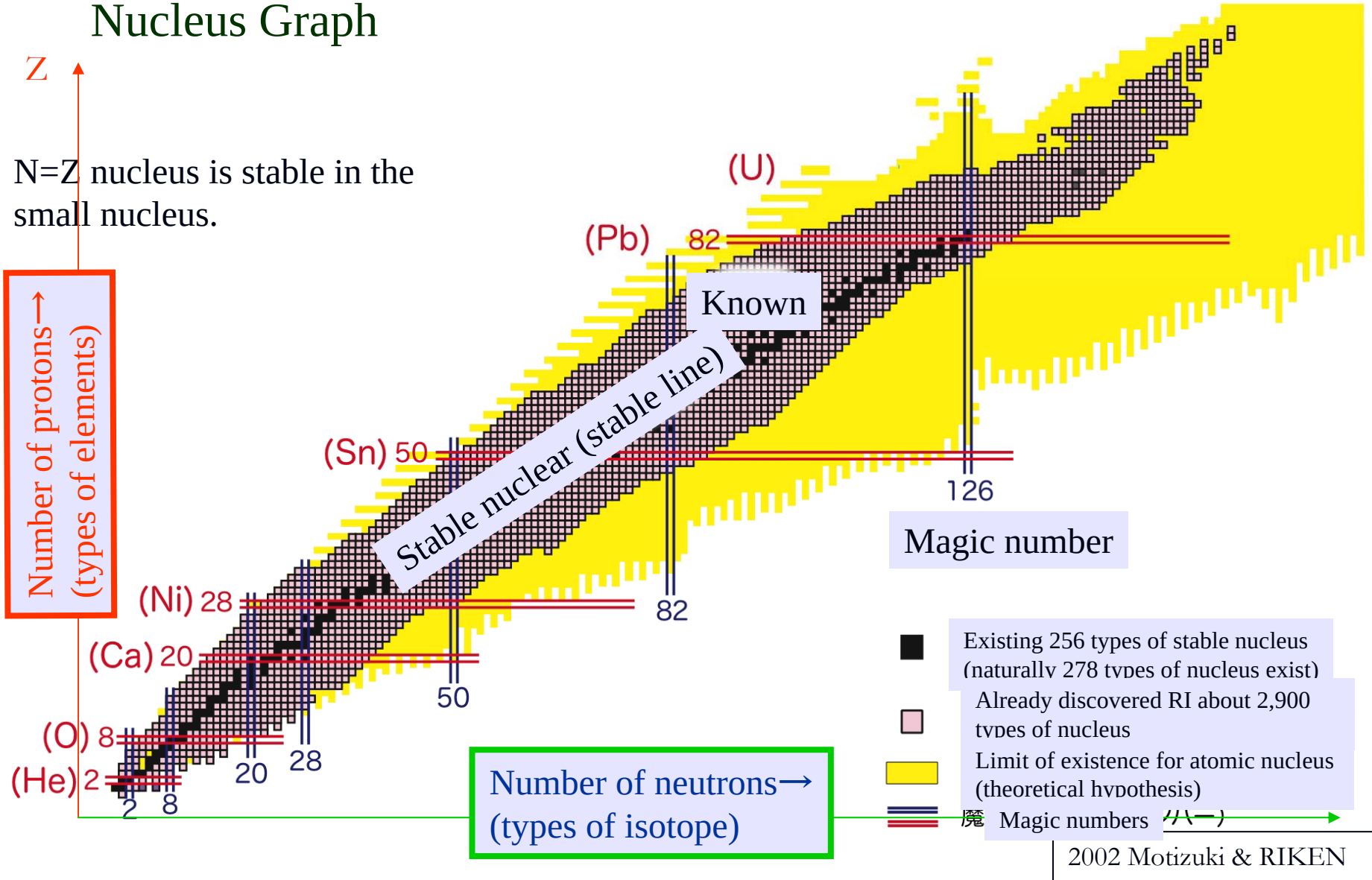
Protons bonds with neutrons by the force called nucleus force.

The physical world is extremely rich in its structure.

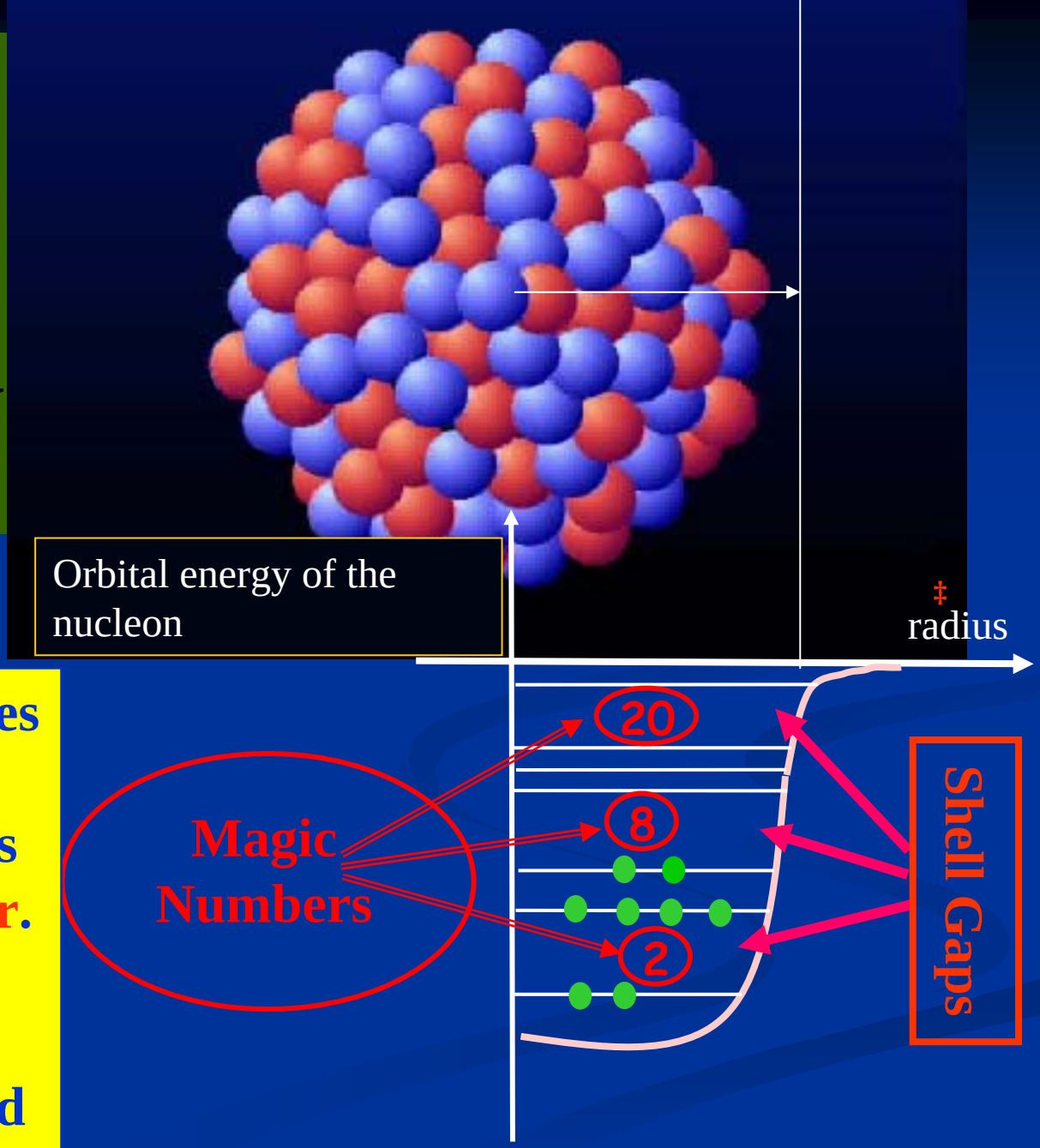
It is amazing to learn how this complex, diverse, and rich world is made of only three kinds of particles: the proton, the neutron, and the electron.

The World of the Atomic Nucleus

Nucleus Graph



Magic Numbers Follow the Periodic Law of the Atoms

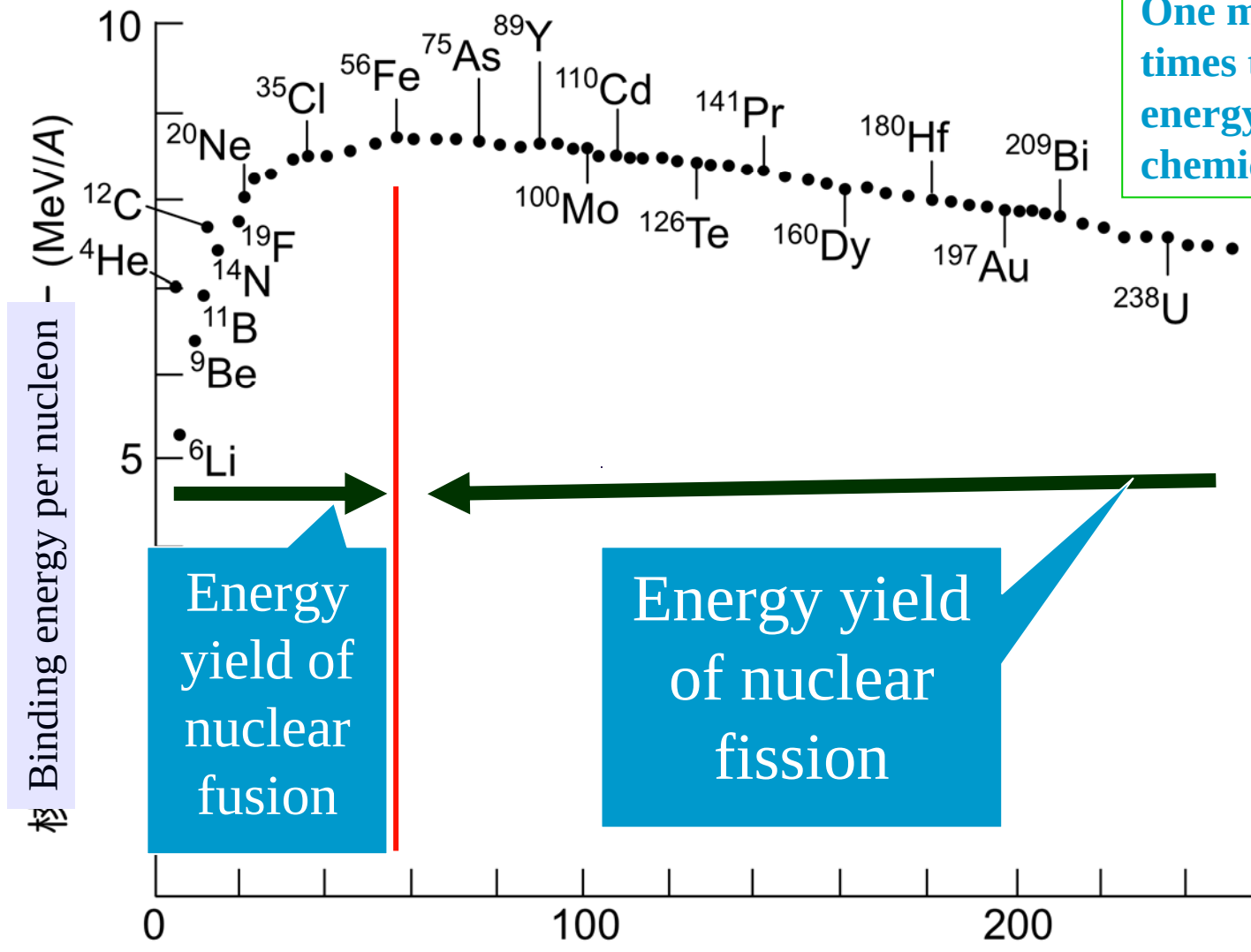


The amount of particles stuck in the orbits below the shell gaps is called a magic number.

A structure of such orbital energy is called shell structure.

K.Otsuka

The Binding Energy of the Atomic Nucleus



The Most Familiar Energy In Our Everyday Life is Nuclear Energy

4 Hydrogen Helium

$+2e^{+}+2\nu_e+26.7MeV$

Consists mostly of light and thermal energy, which will be emitted from the surface of the Sun ten to one hundred years later.

- Energy of the Sun is the energy of the nuclear fusion.

  Direct sun light, the solar battery, the hydraulic power generation, and the fossil fuels (coal, mineral oil, and natural gas) all come from the same source; nuclear energy.

$$p + p \rightarrow {}^{2}H + e^{+} + \nu_e$$

$$p + e^{-} + p \rightarrow {}^{2}H + \nu_e$$

$${}^{2}H + p \rightarrow {}^{3}He + \gamma$$

$${}^{3}He + {}^{3}He \rightarrow {}^{4}He + 2p$$

The Most Familiar Energy In Our Everyday Life is Nuclear Energy

- Nuclear reactors and atomic bombs utilize energy of nuclear fission.

$$^{235}U + n \rightarrow {}^{137}Ba + {}^{97}Kr + 2n + Q$$

$$^{235}U + n \rightarrow {}^{95}Mo + {}^{139}La + 2n + Q$$

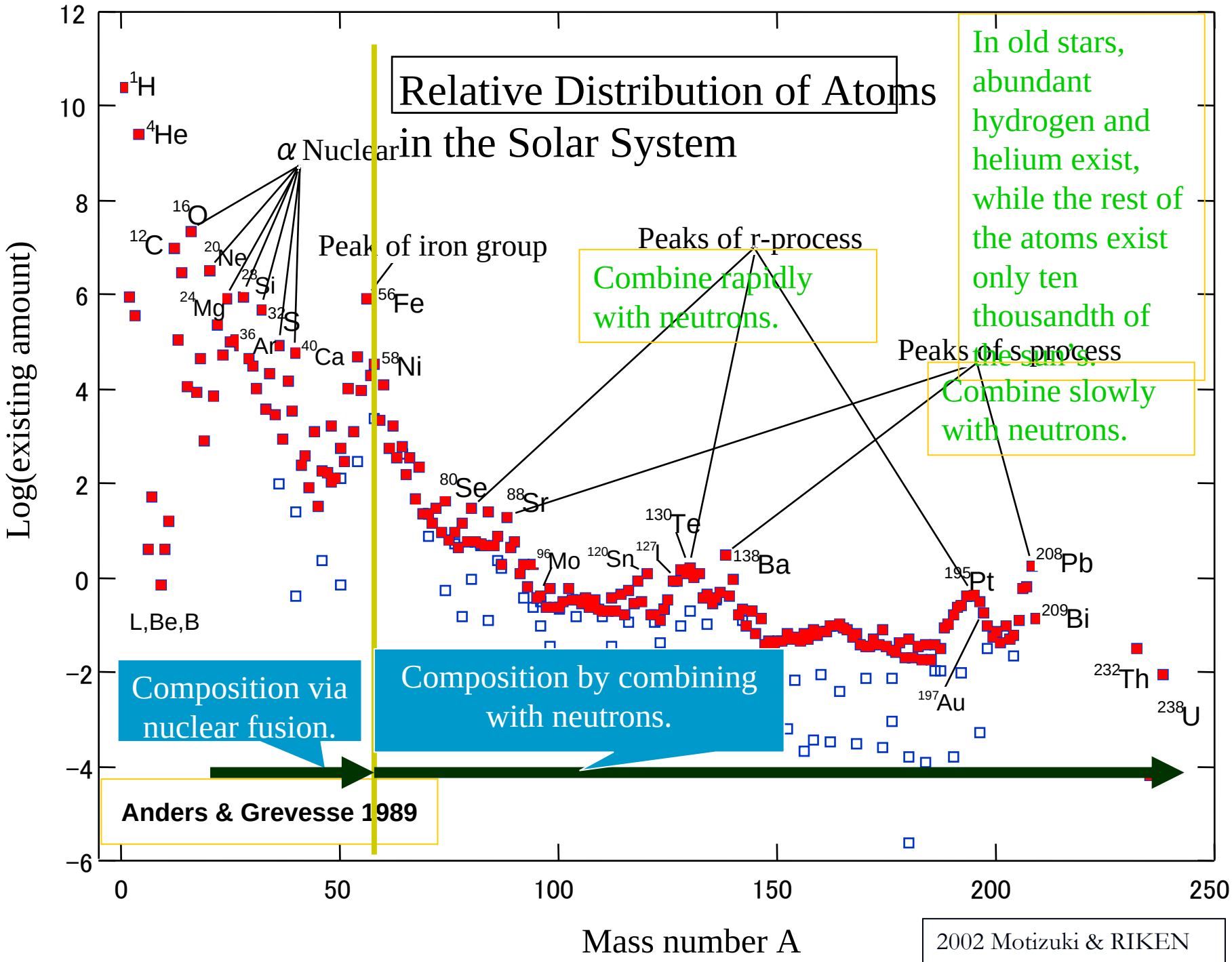
- Fusion reactors and hydrogen bombs take advantage of the energy of nuclear fusion.

Nuclear fusion energy takes place when the helium is being generated by the fusion of the deuterium and tritium.

Origin of Atoms: All Existing Atoms Including Our Body Are the Product of the Universe's History

- Lightweight atoms such as hydrogen and helium were produced in the primordial universe; the Big Bang.
- Almost all the rest of the atoms are composed in the inner part of a star in a supernova explosion.

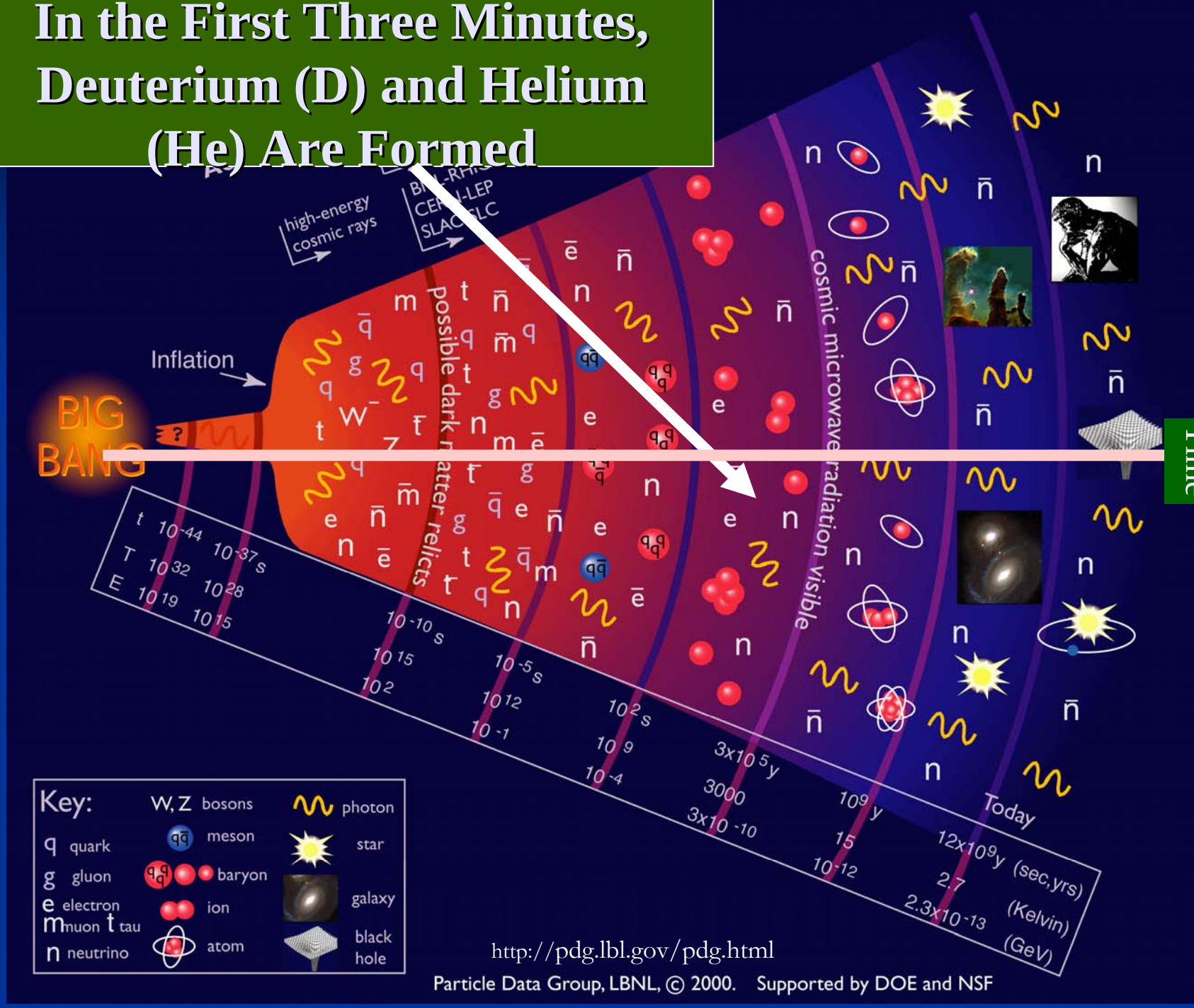
We are made of stardust.


Relative Distribution of Atoms in the Solar System
In old stars, abundant hydrogen and helium exist, while the rest of the atoms exist only ten thousandth of the sun's.
Peaks of r-process
Combine rapidly with neutrons.
Peaks of s-process
Combine slowly with neutrons.
α Nuclear
Peak of iron group
Log(existing amount)
Mass number A
Composition via nuclear fusion.
Composition by combining with neutrons.
Anders & Grevesse 1989
2002 Motizuki & RIKEN

Gamov's Hope

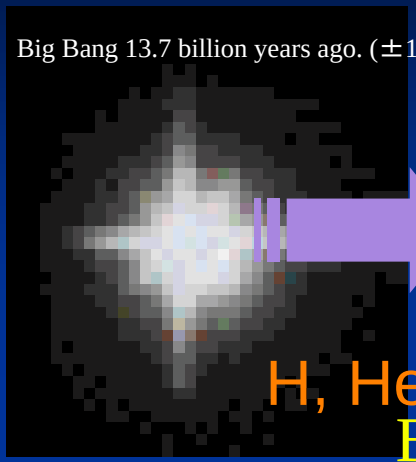
- Gamov advocated that all atoms from hydrogen to uranium were created in the Big Bang. (1946)
- A predominant theory back then; the expansion of a cold universe, which could not explain further beyond the generation of iron. The composition distribution of the atoms was not revealed.
- In order to explain the composition of naturally-existing atoms, Gamov noticed the necessity of the hot fireball model.
- **The Big Bang theory was proposed.**
- However, the standard Big Bang model of nuclear conversion suggests only the formation of up to lithium is possible.

In the First Three Minutes, Deuterium (D) and Helium (He) Are Formed



Systemic Circulation of Matter Caused by Supernova

Big Bang 13.7 billion years ago. (±1%)



H, He

The first formation of a star: 200 million years after the birth of the universe.

Inner part of a massive star:

C, N, O, and Fe

BH, NS, (WD)

Supernova explosion.

Birth of next generation star.

C, N, O,
Si, Fe
Au??, U??

The supernova remnant forms interstellar m

Triggered by other supernova.

Accumulating 83 types of heavy atoms:

4.6 billion years ago.

Birth and evolution of life.

We Are Made of Stardust

Until a hundred years ago, the atom was considered to have existed from the beginning of the universe as a fundamental component necessary to construct the world.

We have learned both theoretically and observationally that the composition of the atom is a product of the universe's evolution. The progress in nuclear physics, astrophysics, and the establishment of quantum theory and relativity theory have helped to reveal the answer.

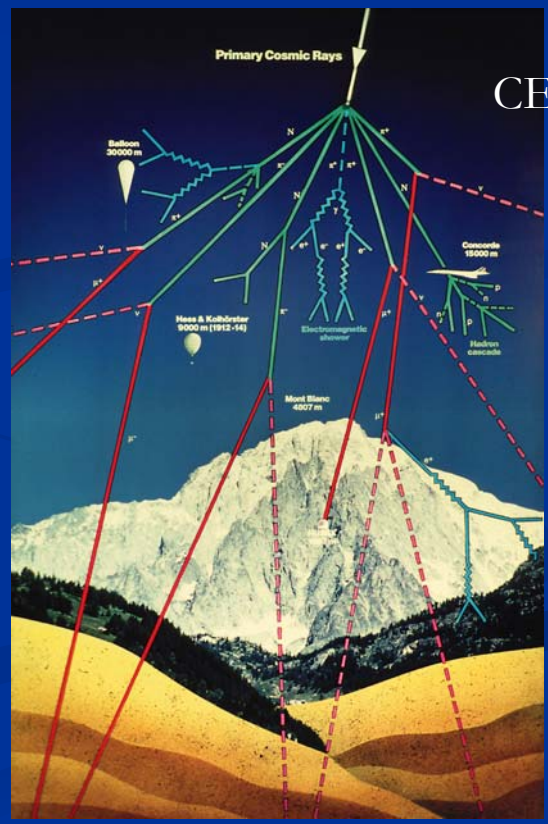
We can trace back the origin to the Big Bang.

In the interminable cycle from the star forming to the gas and dust, the atom is continuously composed in the evolution of universe as if a wander in *samsara*.

The World of Elementary Particles

Three Types of particles (protons, neutrons, and electrons) and photons form the physical world.

Ever since the discovery of positrons in 1932 and muons in cosmic rays in 1937, there have been many discoveries of unstable elementary particles.



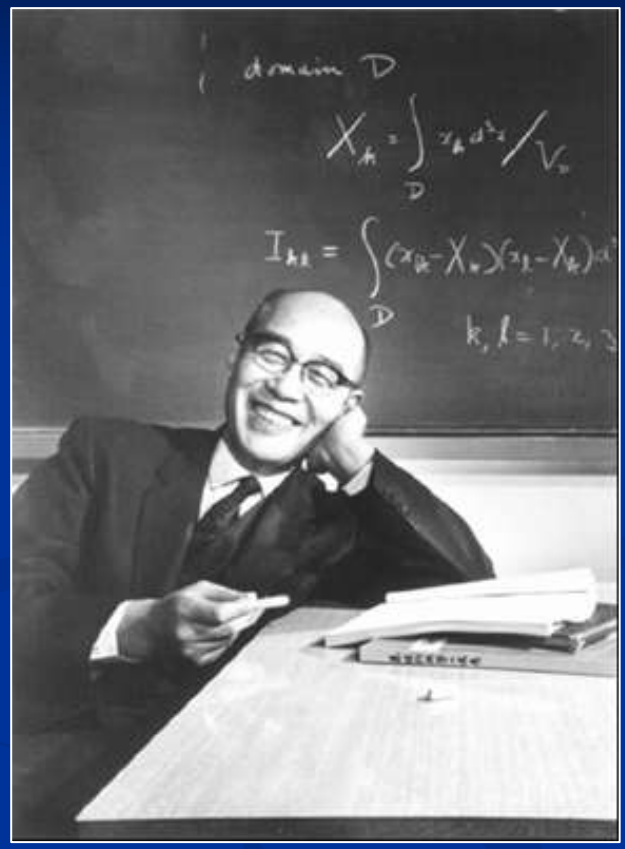
CERN

Positron: positively charged antiparticle of the electron.

http://public.web.cern.ch/Public/Welcome.html

Hideki Yukawa's Meson Theory (1934)

- What kind of force is applied between protons and neutrons to form the atomic nucleus?
- Yukawa proposed a theory of nuclear force and the existence of meson in the nucleon such as protons and neutrons
- Yukawa predicted the existence of mesons in 1934. At that time, only a few elementary particles were known.

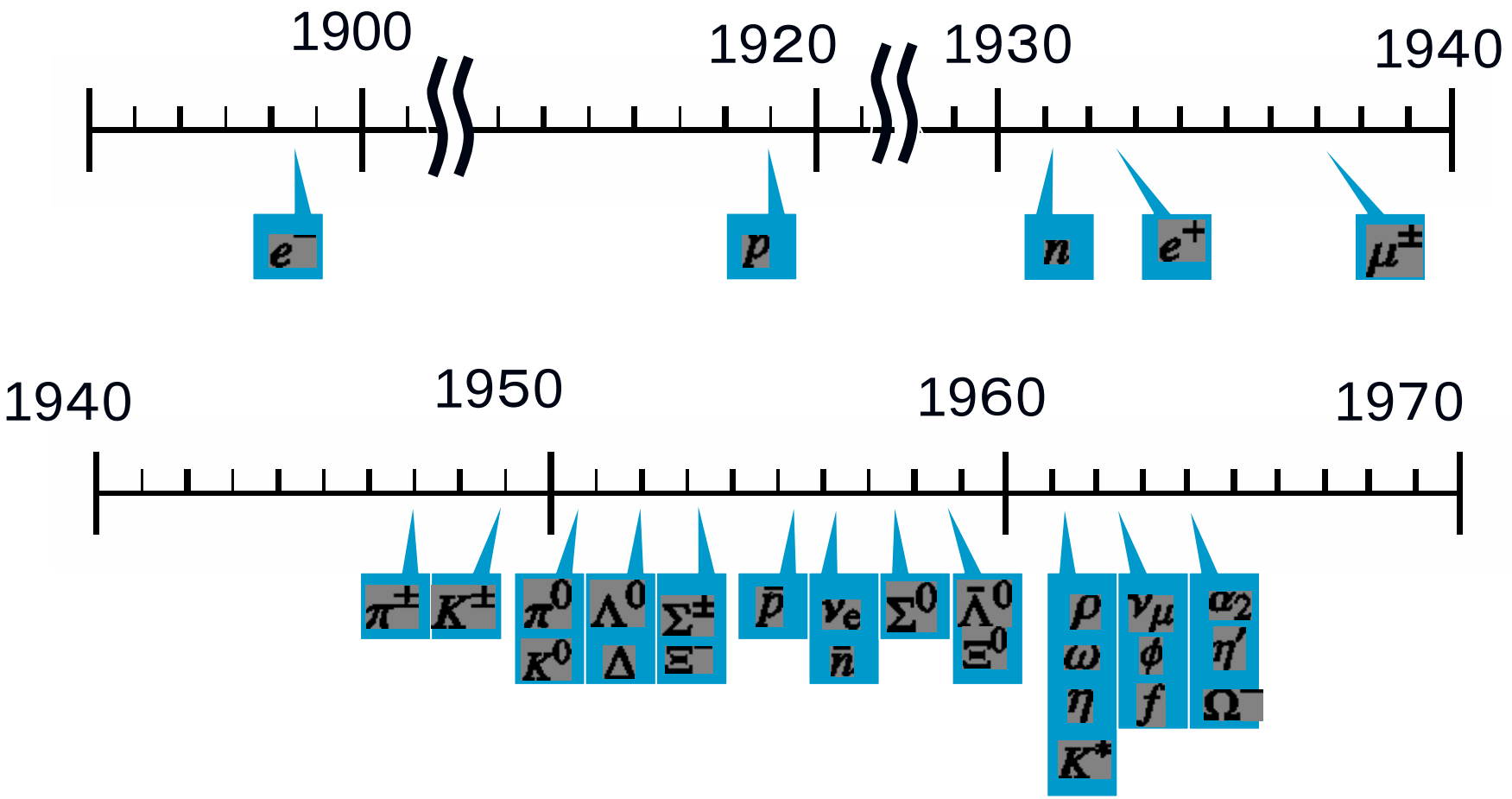


The first Japanese to be awarded Nobel prize.

photo by Karsh, Ottawa, Dec.1969

The nuclear force is the source of the atomic bomb as well as the energy source of a star such as the sun.

Streams of Discovery Over New Elementary Particles



Classification of Elementary Particles

Due to the development of better accelerators, new elementary particles in cosmic rays were discovered one after another.

- Two types of elementary particles.
  - Fermion: half-integer spin
    Proton, neutron, electron, and the respective antiparticles. $s = \frac{1}{2}, \frac{3}{2}, \cdots$
  - Boson: integer spin
    Photon and π meson. $s = 0,1,2,\cdots$

  (According to the supersymmetry theory, fundamental particles come in pairs.)

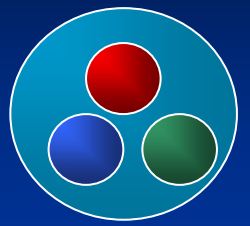
- In another way of classification, there are two types of elementary particles as well.
  - Particle: proton, neutron, and electron.
  - Antiparticle: antiproton, antineutron, and positron.

  When a particle and its associated antiparticle collide, they annihilate each other with the emission of light. (Does the other side of contrasting world exist?)

Hadron (Baryon and Meson) is Made of Quarks M. Gell-Mann (1964)

Baryon and Antibaryon

Hadron: Approximately 120 Types.



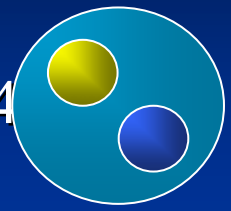
Symbol	Name	**Quark content**	Electric charge(e)	Mass (GeV/c^2)	Spin
p	proton	uud	1	0.938	1/2
$\bar{p}$	antiproton	$\bar{u}\bar{u}\bar{d}$	-1	0.938	1/2
n	neutron	udd	0	0.940	1/2
Λ	lambda	uds	0	1.116	1/2
Ω^-	omega	sss	-1	1.672	3/2

Hadron (Baryon and Meson) is Made of Quarks

M. Gell-Mann (1964)

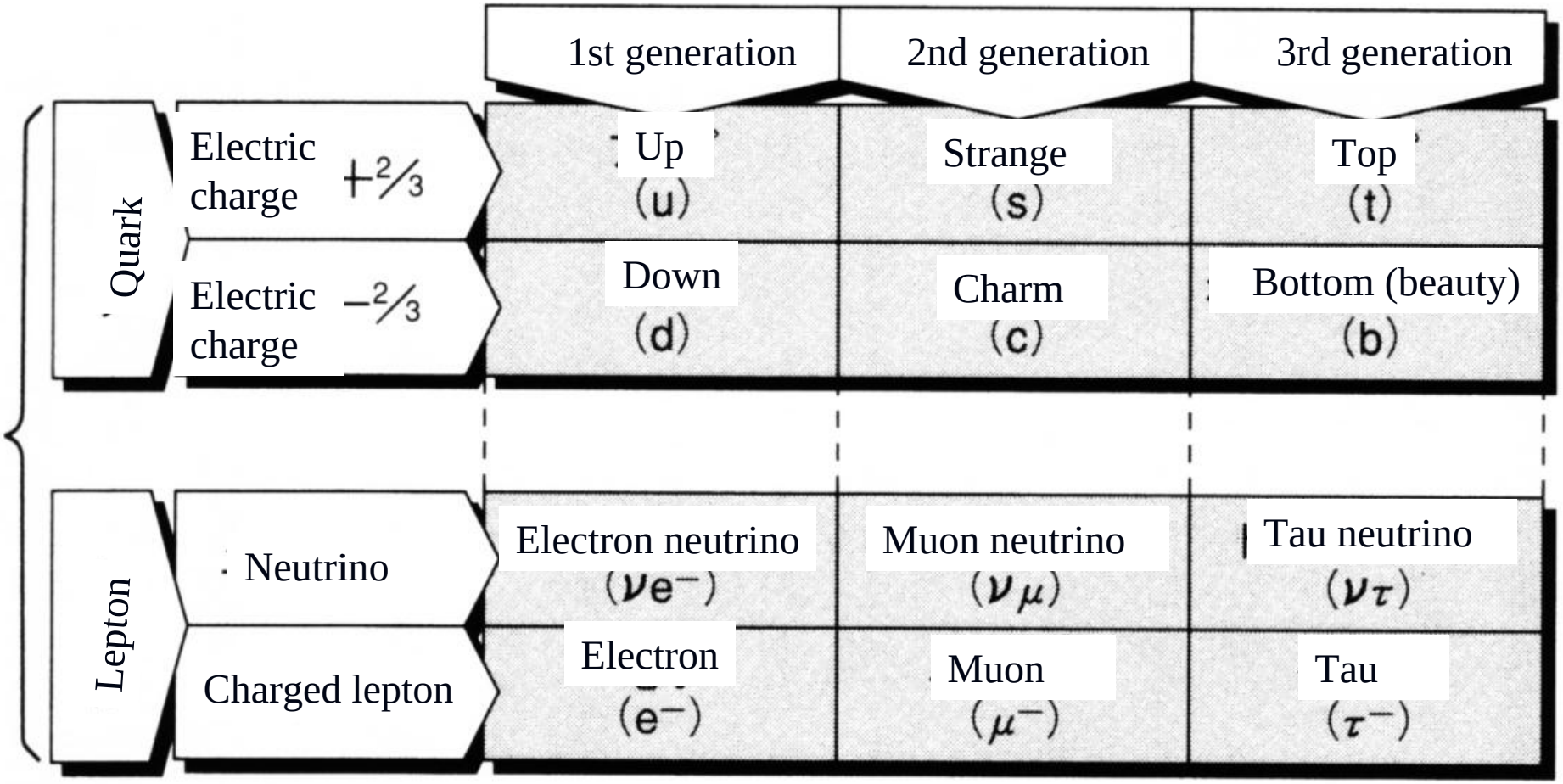
Meson

Hadron that follows Bose statistics: approximately 14

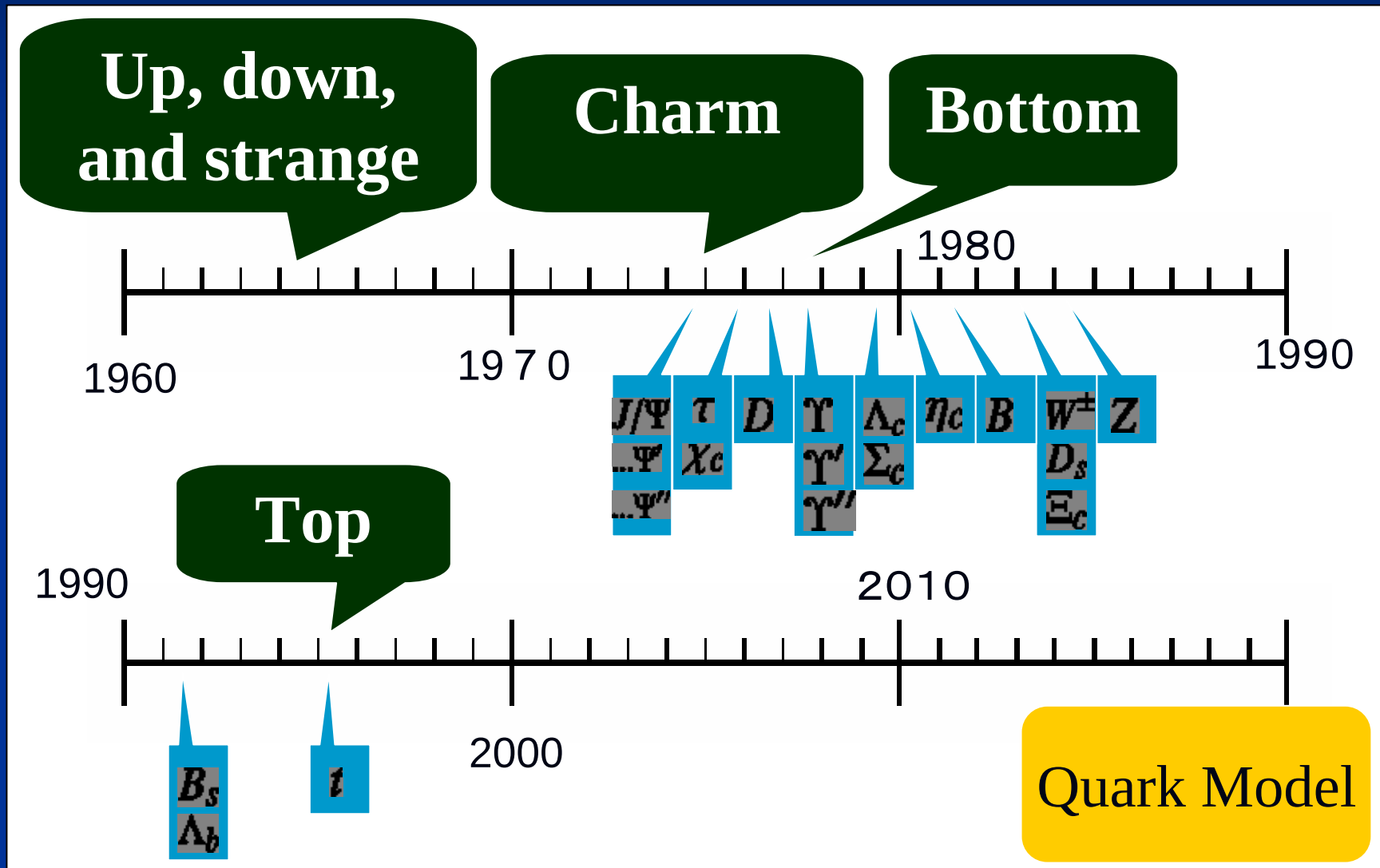


Symbol	Name	Quark content	Electric charge(e)	Mass (GeV/c^2)	Spin
π^+	pion パイオン	$u\bar{d}$	+1	0.140	0
K^-	kaon ケイオン	$s\bar{u}$	-1	0.494	0
ρ^+	rho ロー中間子	$s\bar{d}$	+1	0.770	1
B^o	B-zero Bゼロ	$d\bar{b}$	0	5.279	0
η_c	eta-C イータC	$c\bar{c}$	0	2.980	0

Fundamental Particles are Classified into Either Quarks or Leptons

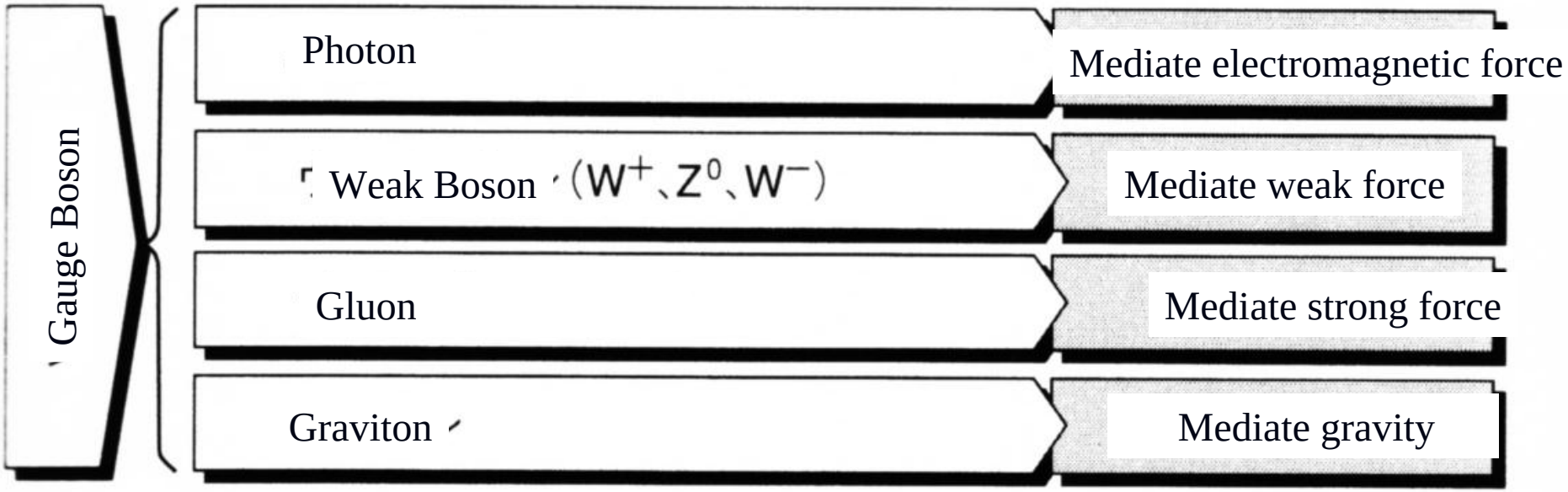


All Predicted Quarks are Discovered



Elementary Particles which Mediate Forces

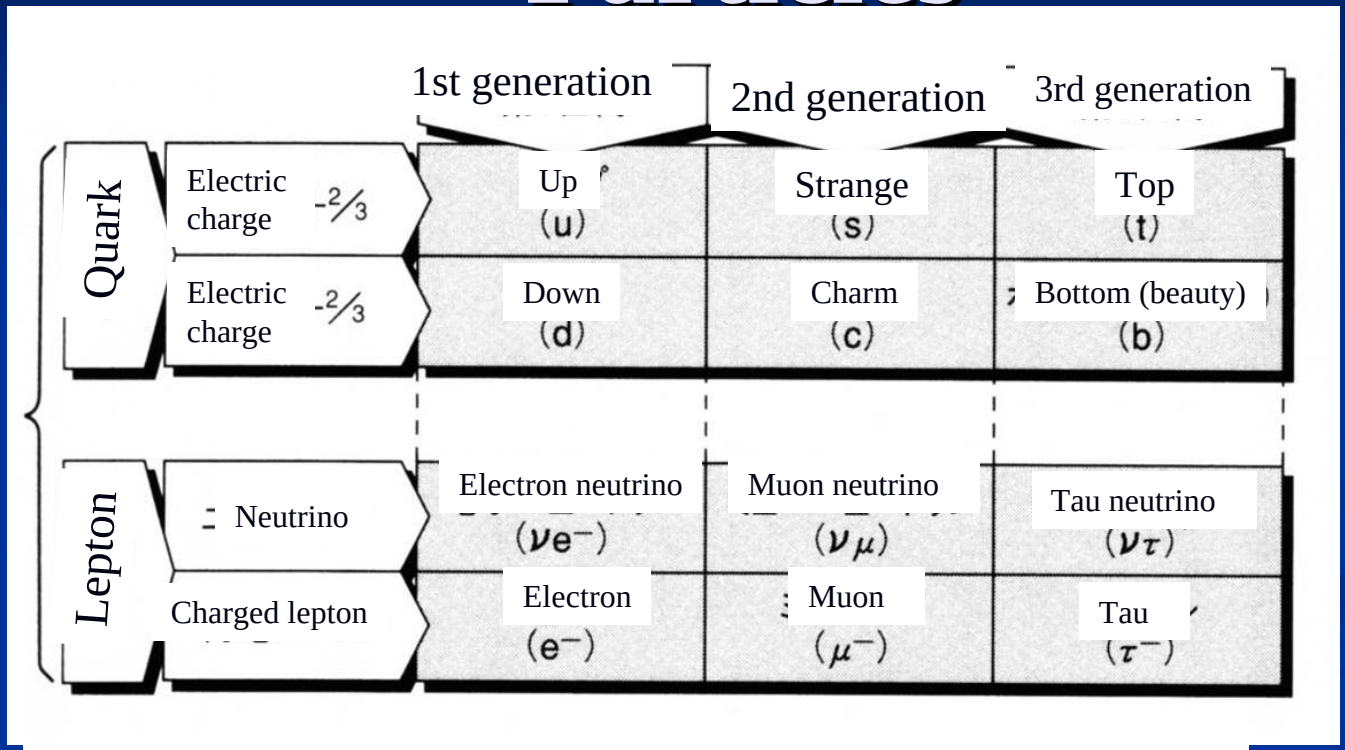
W^+,W^-, and Z are also discovered in1982 and 1983.

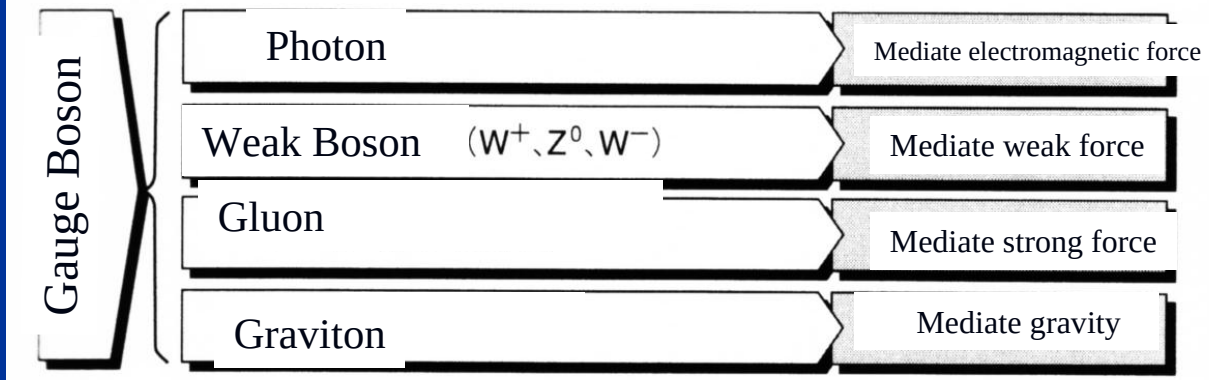


The strong force mediator, Gluon cannot be detected by itself alone.

Graviton has not yet discovered.

Summary:Present Elementary Particles





Does a Supersymmetry Particle Exist?

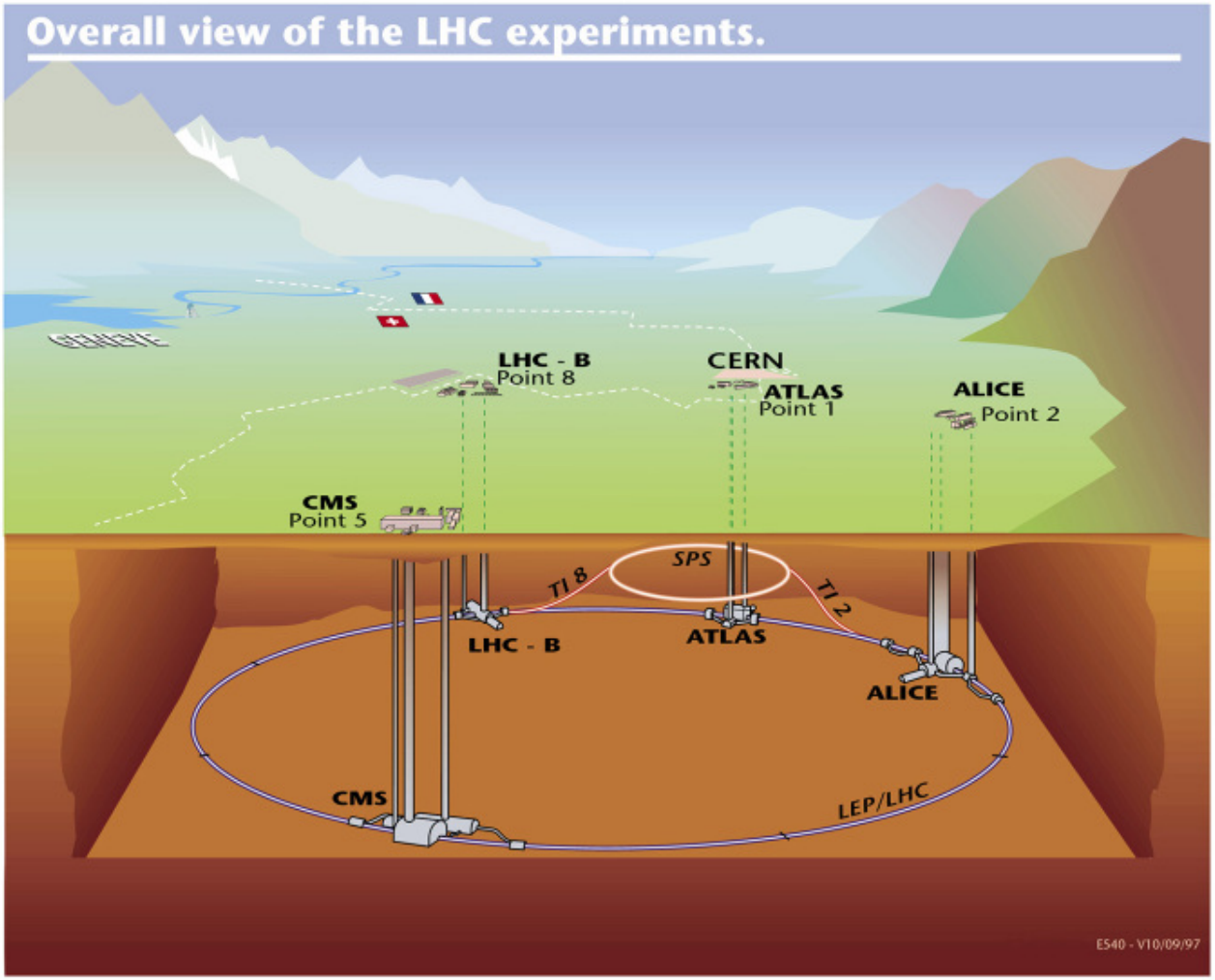
Supersymmetry: symmetry property in which elementary particles must come in pairs. Each pair of particles have different spins.

Superpartner: Every fermion has an associated boson superpartner, and every boson has an associated fermion superpartner.

Ordinary Particles	⟷	Superpartner (very large mass)
Quark		Scalar quark
Electron		Scalar electron
W boson		Wino (Chargino)
Z boson		Zino (Neutralino)
Photon		Photino
Gluon		Gluino
Graviton		Gravitino

Neutralino: A mixed state of zino, photino, and higgsino.

Discovery of Superpartner and Verification of Supersymmetry are the Biggest Assignments for Elementary Particle Physics



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

World's largest particle accelerator:

LHC

Located in suburb of Geniva.

The size of Yamanote Line in Tokyo.

50 m underground.

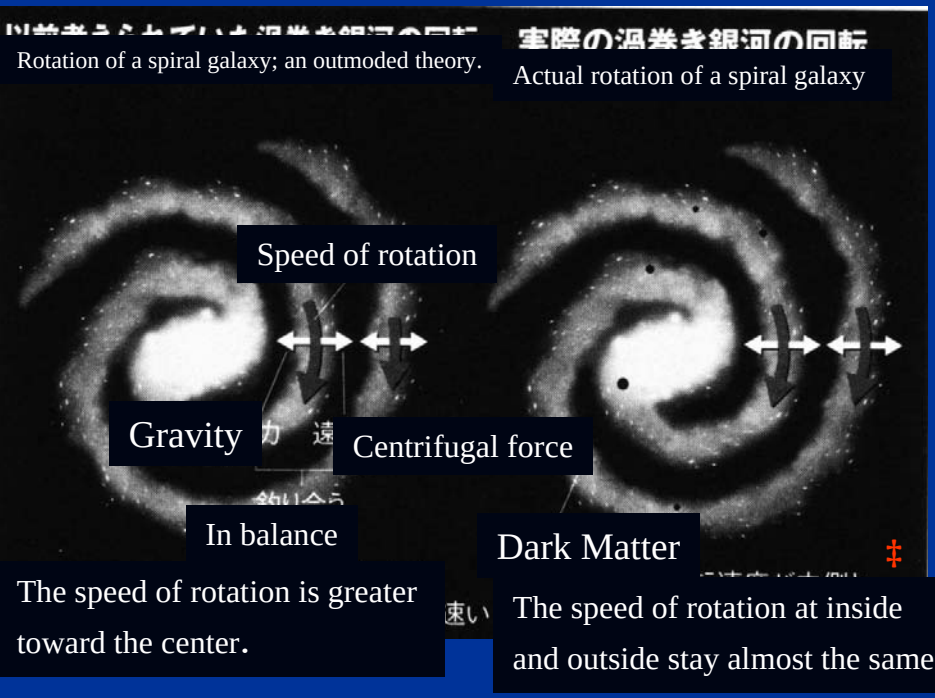
University of Tokyo

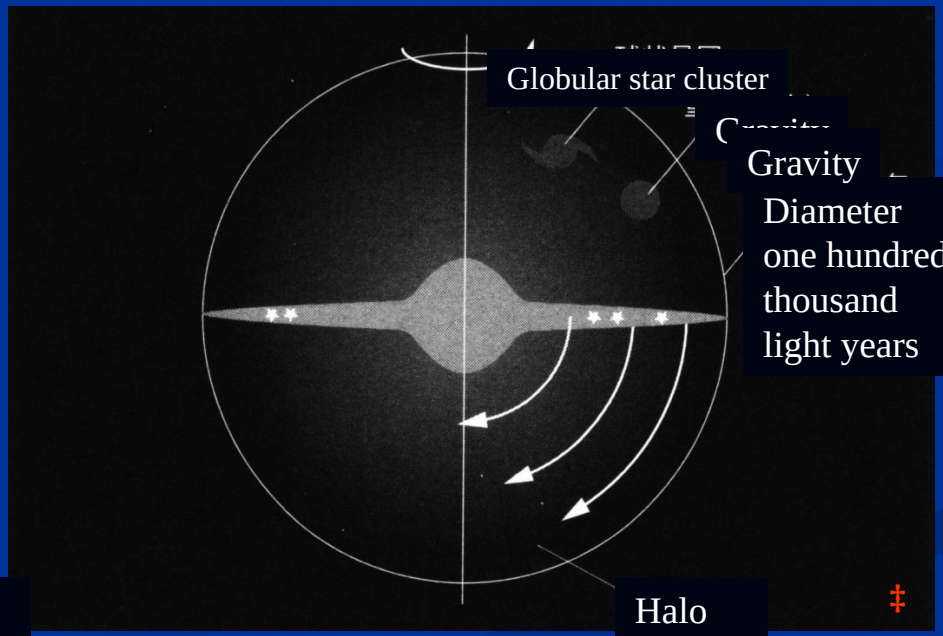
International Center for Elementary Particle Physics (ICEPP) collaborates with the ATLAS experiment.

Can Neutralinos be a Strong Candidate of the Dark Matter?

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

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





(c)Sato 2003

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

What is the True Nature of Dark Matter?

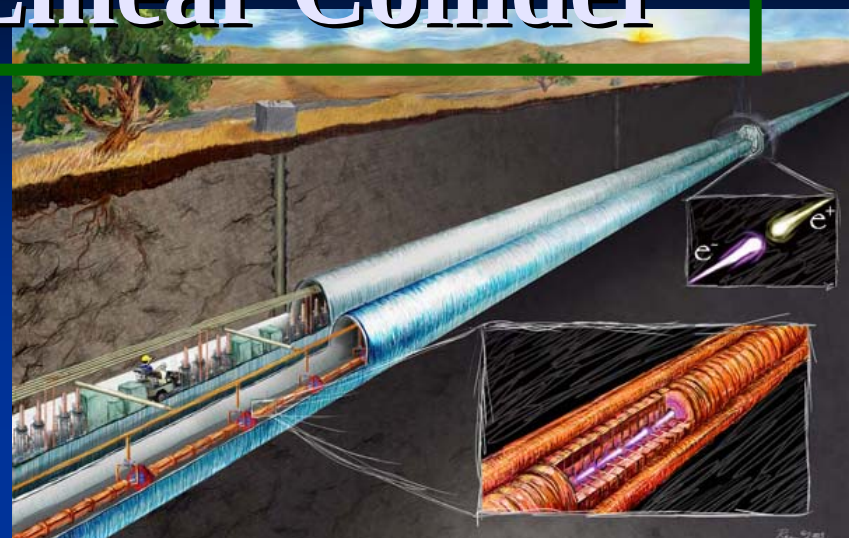
Classification	Candidate	Mass	Temperature at formation
熱い（Hot）	Lightweight neutrino	$\lesssim$30eV	3MeV
冷たい（Cold）	Primitive Black Hole	10^{15}g$<$	100MeV$<$
	Quark Nugget	$\lesssim 5\times10^{24}$g	$\sim$100MeV
	Heavy neutrino	3GeV$\lesssim$	100MeV$\lesssim$
	Supersymmetry particle	1keV$\sim$1TeV	$\sim$100GeV
	Neutralino		$10^{8}\sim10^{19}$GeV
	Axion	10^{-5}eV$\lesssim$	$\lesssim10^{12}$GeV
	Monopole	$\sim10^{16}$GeV	$\sim10^{15}$GeV
	Pyrgon	10^{19}GeV$\sim10^{-5}$g	$\sim10^{19}$GeV
	Shadow matter		
Baryonic	Brown dwarf star	About the mass of Jupiter	
	White (black) dwarf star	About the mass of the sun	
	Black Hole	Twice the mass of the sun	

Are There Any Generations Beyond Quarks and Leptons? Are They the Origin of Particles?

- With current particle accelerator experiments with the highest energy, no trace of future generations, the fourth, nor the fifth generations have been identified.
- Likewise, the quark and lepton are the point particles, in which no measurement of their sizes have been conducted.

1. Does matter have infinite hierarchy? How many layers do onions have?
2. Progress has brought us into the era of only one highest energy particle accelerator in the world.
3. Do we have to wait for a new invention of particle accelerator (microscope) to further explore the elementary particles?

The International Linear Collider



2005 INTERNATIONAL LINEAR COLLIDER WORKSHOP

LCWS 05

Stanford, California, USA 18-22 March, 2005

40-km, Electron-Positron Collider: >>100 billion yen

ILC http://www.interactions.org/cms/

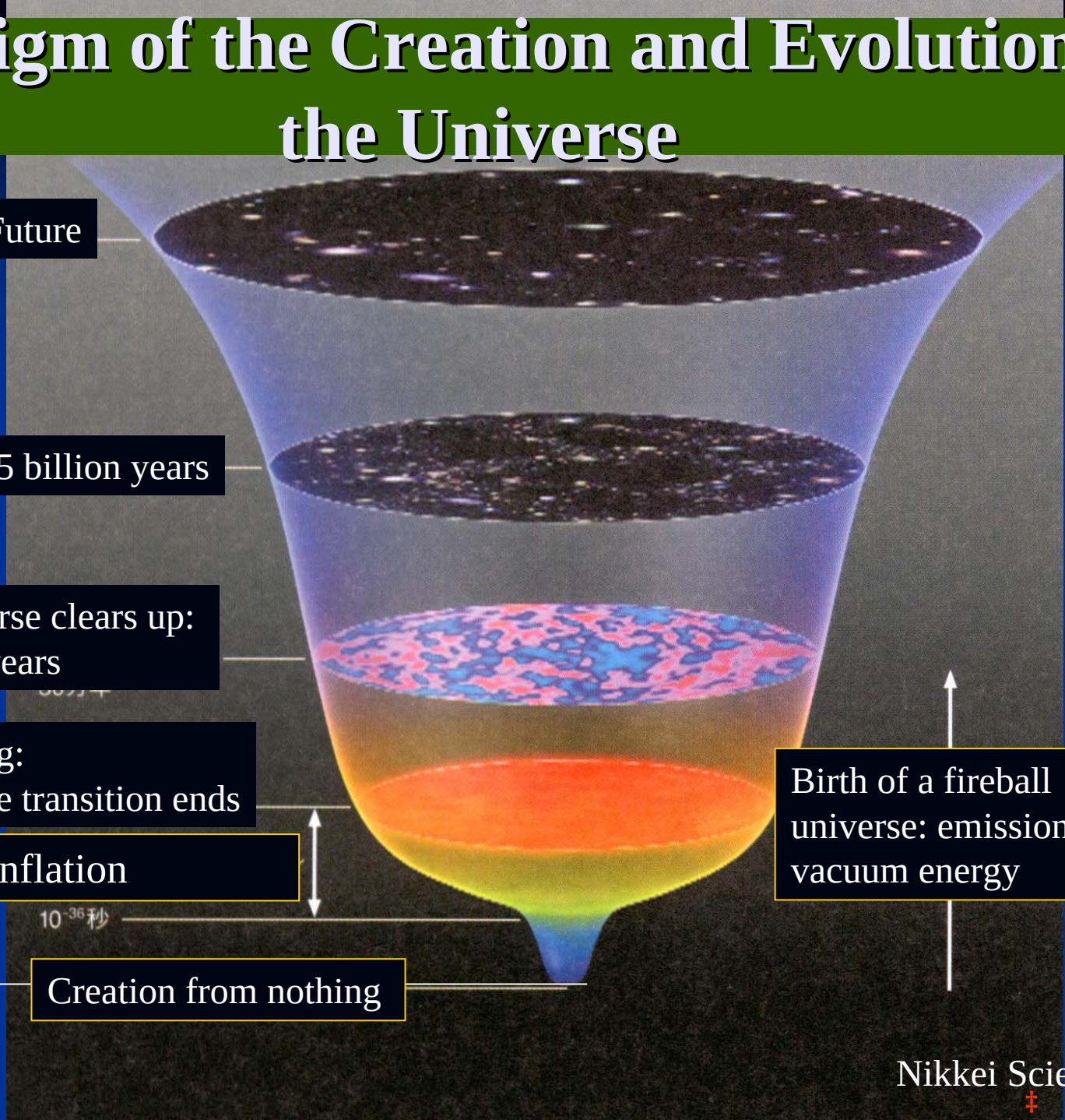
The Birth of Elementary Particles

- Paradigm of modern cosmology:
- 1. The quantum gravity effect created an infinitesimal universe.

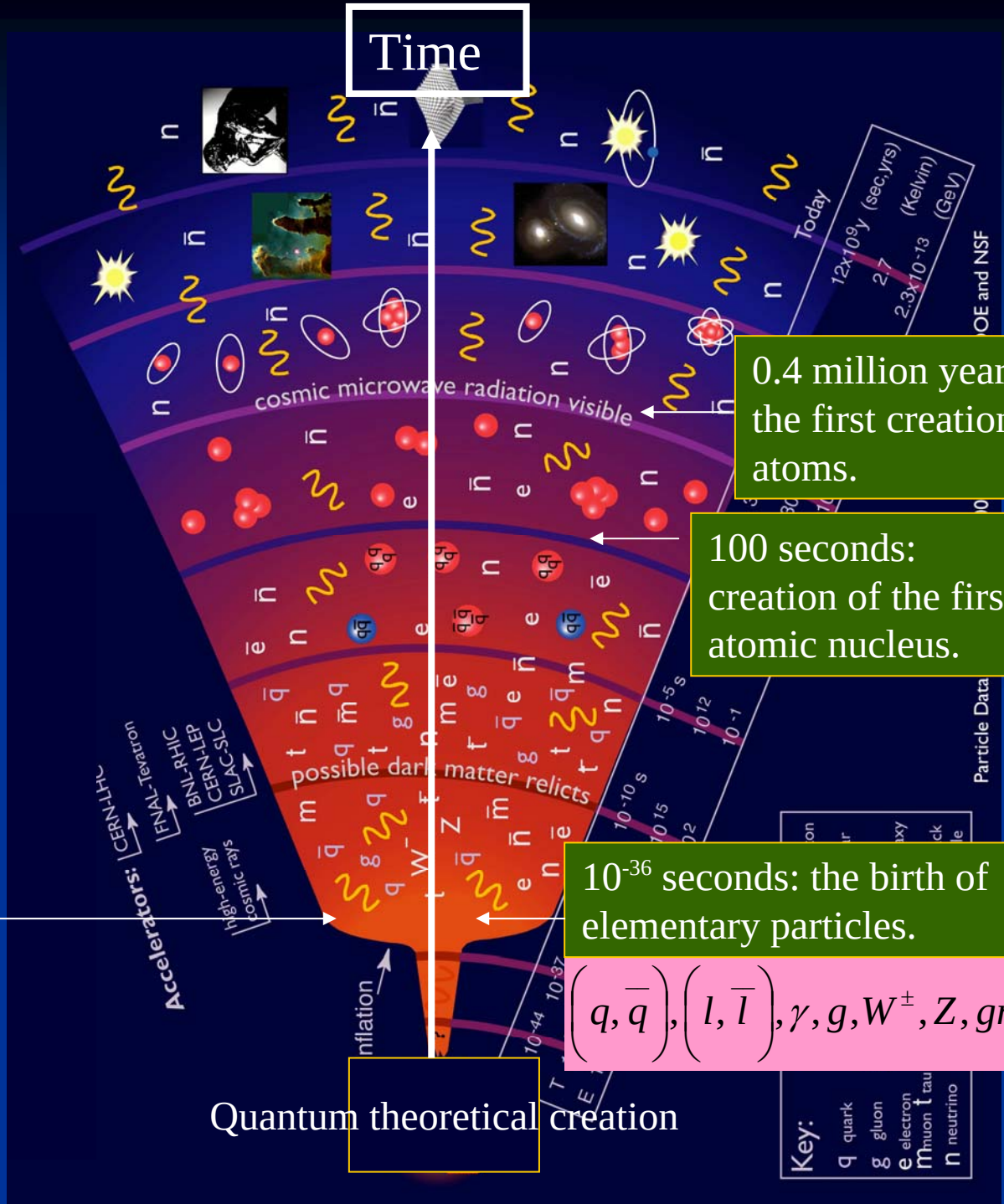
2. The repulsive force applied to the vacuum energy of a new born universe, and which caused the inflation.

3. During the process toward the end of the inflation, the vacuum energy was converted into the thermal energy; quarks, antiquarks, leptons, and antileptons were produced in pairs.

Paradigm of the Creation and Evolution of the Universe



Evolution of Elementary Particles and Matter by Standard Model



0.4 million years: the first creation of atoms.

100 seconds: creation of the first atomic nucleus.

10^{-36} seconds: the birth of elementary particles.

$$\left(q,\bar{q}\right),\left(l,\bar{l}\right),\gamma,g,W^{\pm},Z,gr$$

End of inflation:

birth of a fireball universe.

Quantum theoretical creation

Particle Data Group, LBNL
http://pdg.lbl.gov/pdg.html

Why Our Universe Form Physical World? Is There a Non-physical World?

- The laws of the physics suggest the symmetry property of particles and antiparticles.

  What caused the physical world to appear so asymmetrical?

A. Sakharov (1966): participated in the Soviet atomic bomb project. Known as the father of the H-bomb. He later turned to be an advocate of the reform of the Soviet Union.

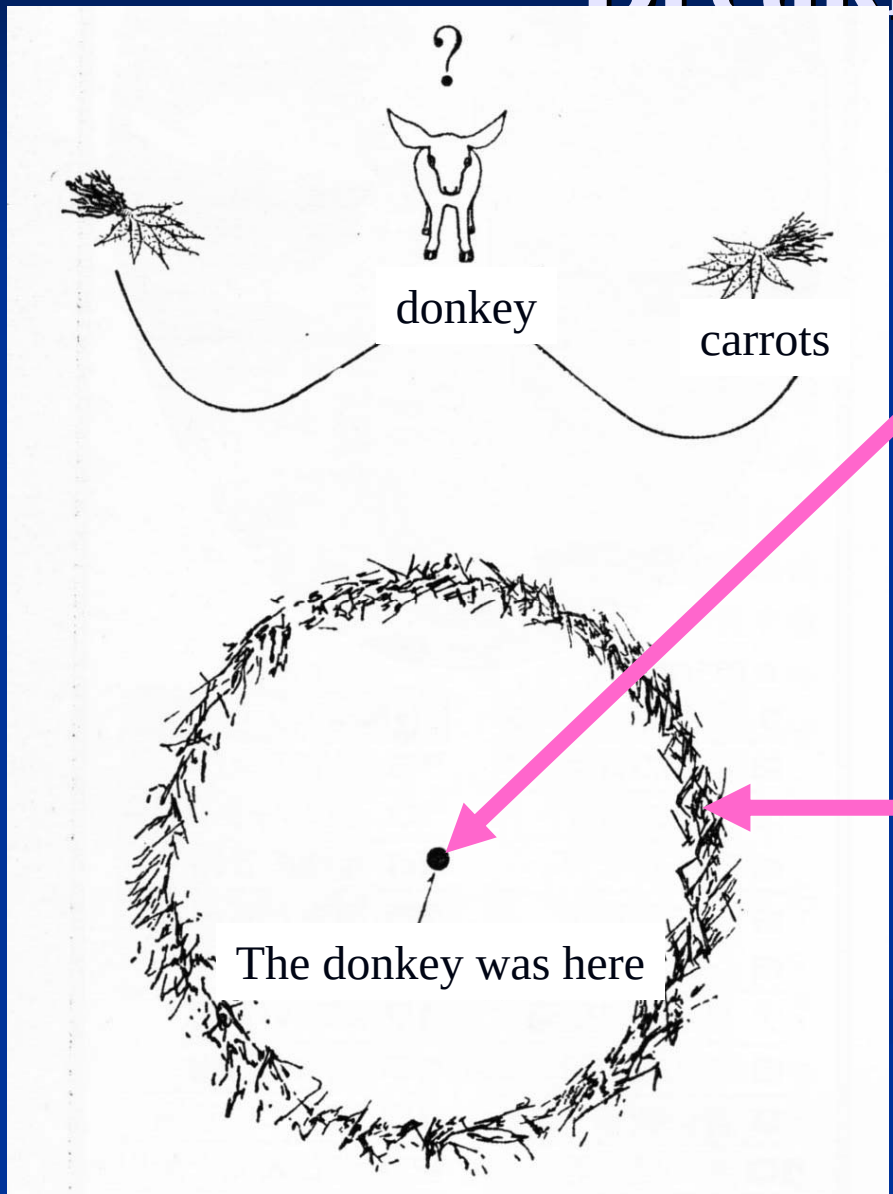
The theory associated with the origin of asymmetrical "physical" and "non-physical" world in the universe: symmetry property of the particular law was broken, thus generating greater number of particles [physical] over the antiparticles [non-physical]. (Yoshimura argued, based on the Grand Unified Theory.)

A. Sakharov
http://www.photos.aip.org/

Symmetry in Physics and Asymmetry in the Subsistent Universe

1. Physical laws assume symmetry relation between matter and antimatter.
2. If the physical laws held its symmetry property, can we suppose the symmetry breaking be carried even in reality?
3. The physical world must be realized in a particular place, while non-physical world is realized in another distinctive place.

The Spontaneous Symmetry Breaking



Physical laws strictly follow the bilateral symmetry.

The symmetry will ultimately be broken due to its unstable state.

Nature, 1969.

Search For Antimatter and Non-physical World

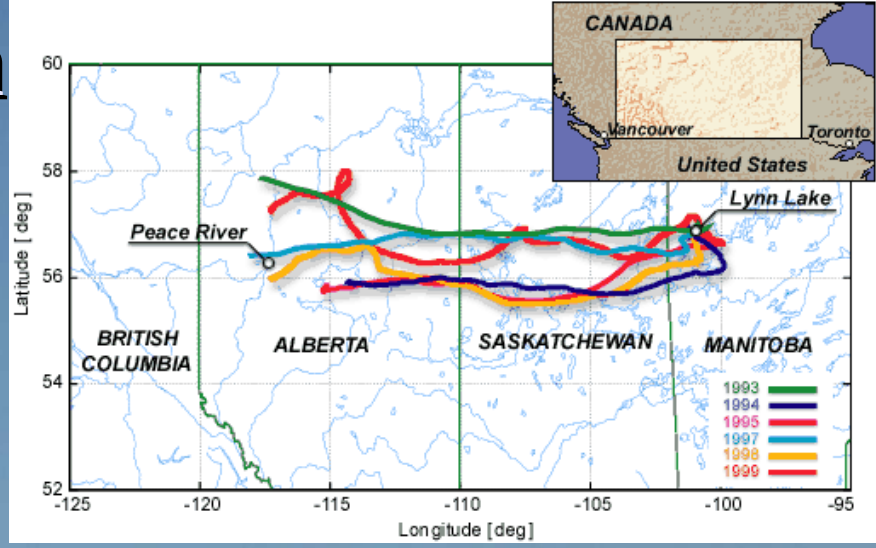
The measurement of antiprotons in the cosmic radiation and the detection of the antihelium can help to reveal the possible existence of non-physical world.

The antiprotons, on the one hand, are generated by the collision of cosmic rays, thus excluded from the evidence in verifying the non-physical world. The antiheliums, on the other hand, are generated by nuclear fusion between antiprotons and antineutrons, which can only take place in the stars during the Big Bang in the non-physical world.

BESS Experiment (Balloon Experiment with Superconducting Spectrometer): Japan-America Collaboration was launched by the late Dr. Orito and Dr. Yamamoto.

An instrument, a huge balloon loaded with a superconducting magnet, was carried to detect antimatter: measurement of antiprotons, detection of antiheliums in the cosmic radiation.

BESS Experiment in Canada



BESS Experiment

Launched at Lyn Lake, and recovered in the Alberta area after a few days flight.

Experiment in Antarctica (December, 2004)

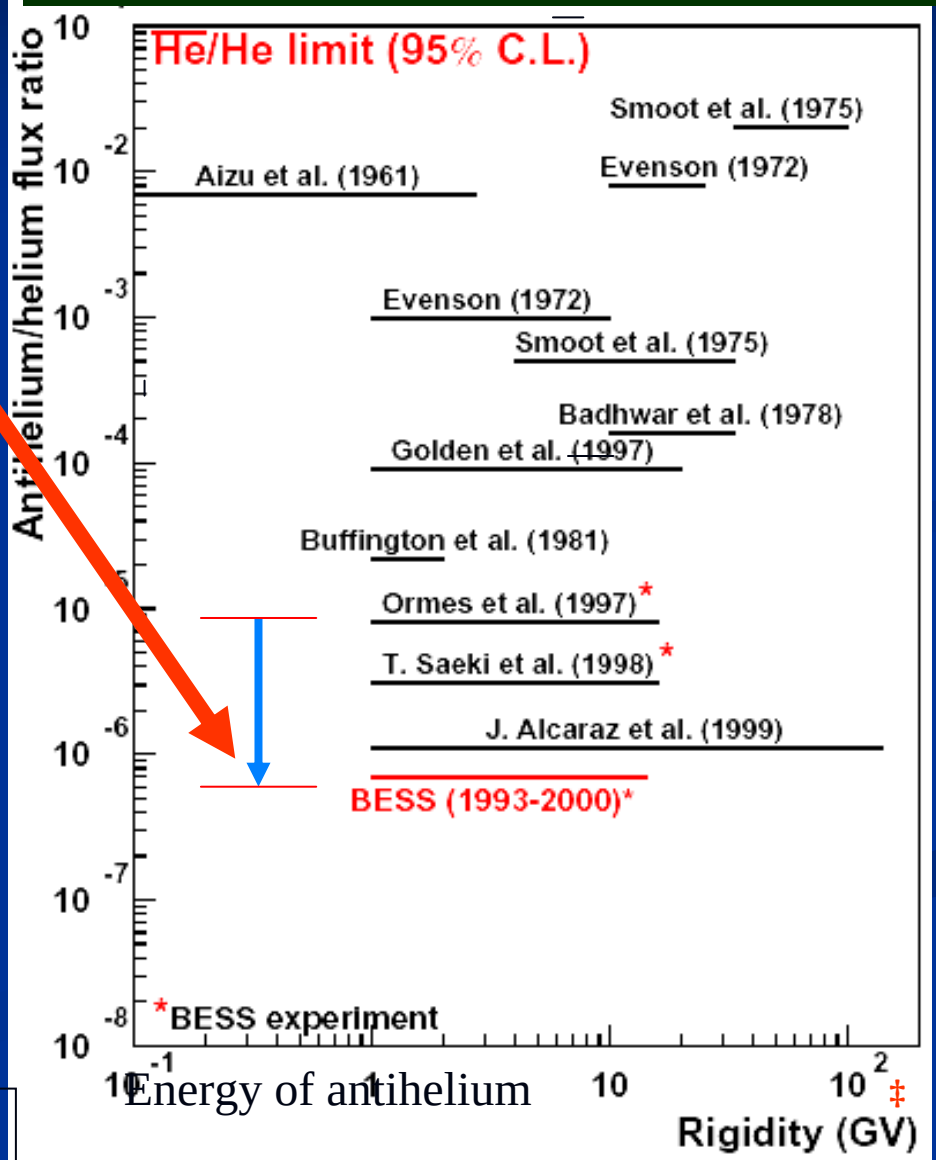
BESS Experiment

BESS Experiment Results (Chronological Order)

Among the detected 6.6 million heliums, no antihelium has been found.

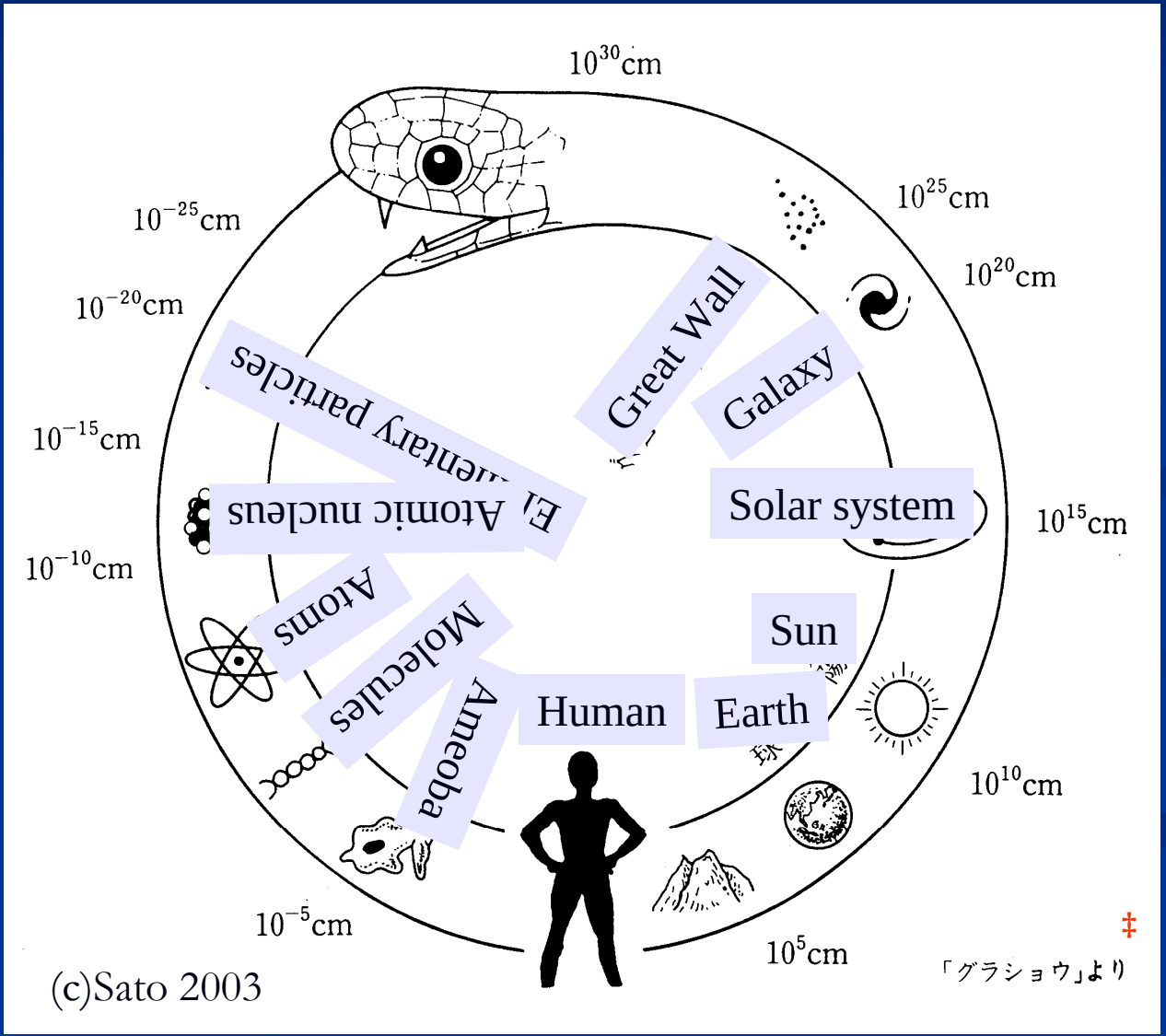
Possible existence of non-physical world has not been confirmed in this experiment.

Antihelium ratio upper limit



BESS Experiment collaboration

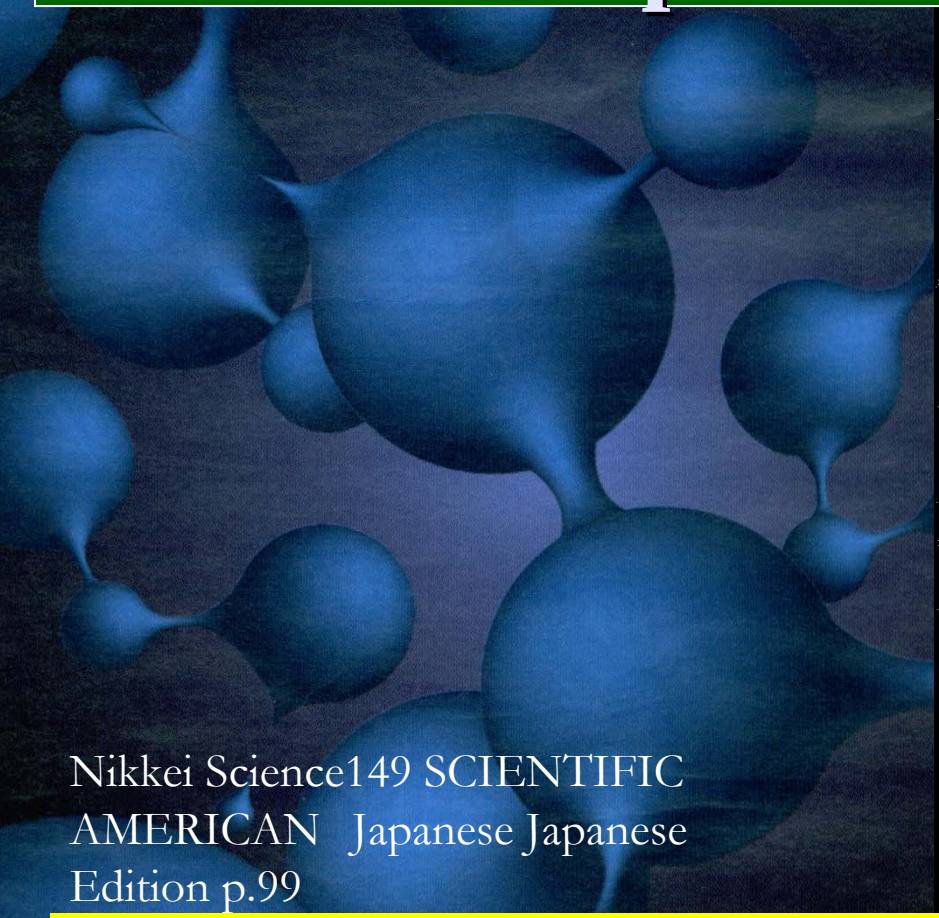
We have learned the structure of the physical universe from microcosmic to macrocosmic in 60 digits, which solidly following the physical laws.

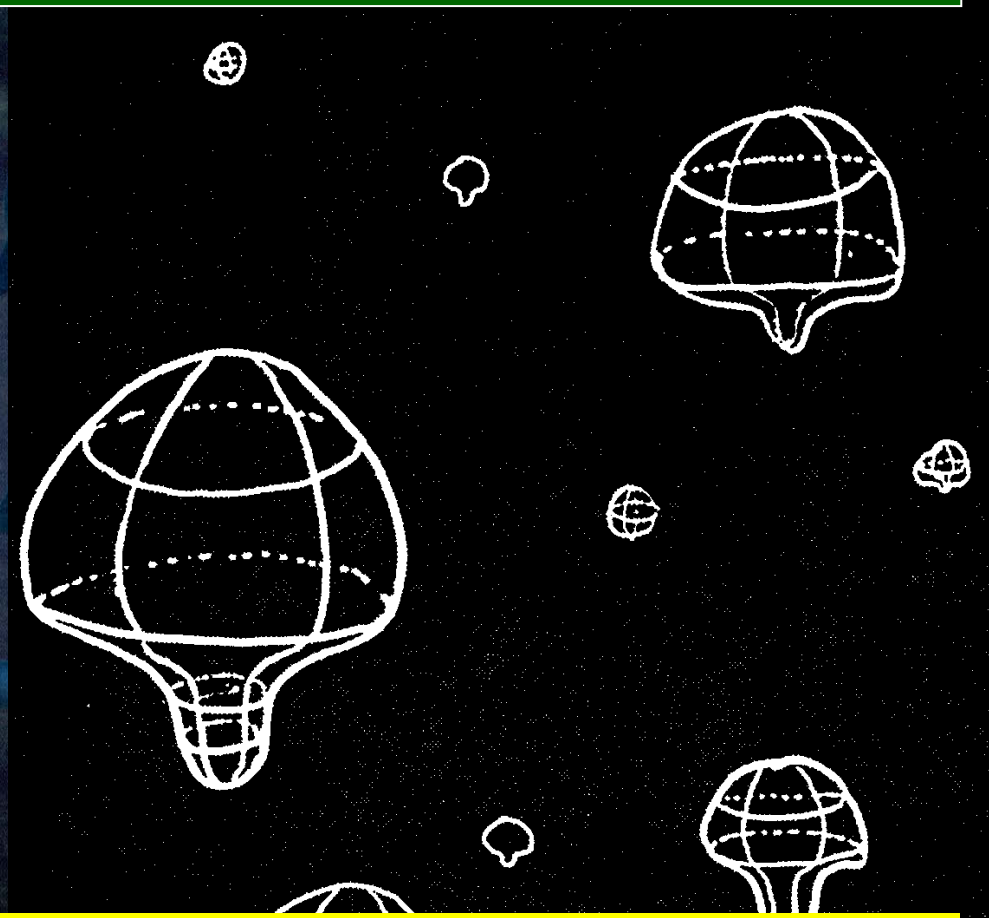


Is This the Ultimate End of the Layer?

- Are the quark, lepton, and gauge boson the smallest units among the physical world? Does the smallest unit of particles really exist ? Could it be the ten-dimensional space-time “string”?
- Are there any larger physical constituents underlying further beyond the 11 to19 billion years of the observational end.
- Is there any possibilities for existence of other universes beyond our space-time manifold?

Do Other Universes Exist Beyond Our Own Space-time Manifold?





Nikkei Science149 SCIENTIFIC AMERICAN Japanese Japanese Edition p.99

Multiverse (countless number of universe) **M. Rees**

-possibility and nature of other universe beyond our own universe-

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