THE NUCLEAR, PLASMA, AND RADIATION UNIVERSE

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"Don't you ever wonder where everybody is?"
Enrico Fermi, Summer of 1950, over lunch in reference to alien life.
Fermi Paradox
Great Filter? Answer: We are here! We are just too early!

"Two possibilities exist: either we are alone in the Universe or we are not.
Both are equally terrifying."
Arthur C. Clarke

"Consider again that dot. That's here. That's home. That's us. On it everyone you love, everyone you know, everyone you ever heard of, every human being who ever was, lived out their lives. The aggregate of our joy and suffering, thousands of confident religions, ideologies, and economic doctrines, every hunter and forager, every hero and coward, every creator and destroyer of civilization, every king and peasant, every young couple in love, every mother and father, hopeful child, inventor and explorer, every teacher of morals, every corrupt politician, every 'superstar,' every 'supreme leader,' every saint and sinner in the history of our species lived there-on a mote of dust suspended in a sunbeam."
Carl Sagan, American Astronomer

INTRODUCTION

The study of Nuclear, Plasma and Radiation phenomena is a reflection of the nature of, and an attempt at understanding and describing the universe that we belong to. Sustainable human development depends upon such an understanding, and upon using our knowledge in tackling the present and future global challenges of hunger, disease, management of natural resources, environmental pollution and global climate change. In the long term, this would help humanity spread life within and beyond the confines of our Solar System.

As the world is becoming more reliant on its scientific advancements, its leaders as scientists and engineers, as well as members of the public in general, need to be aware the role of these fundamental processes and their applications in modern society. These applications can be found in every field of Science and Engineering, at every economical and social level, and every place on Earth. Since human progress goes hand in hand with the dissemination of knowledge, improvement of human well being and increasing the potential for human development depends on the spread of such knowledge about their potential to both decision makers and the people that it touches.

For the present's perspective, people around the world are genuinely concerned about the dangers posed by nuclear weapons, are skeptical about the safety of nuclear power generation and are apprehensive about the radiological effects of natural as well as man-made radiation sources. These negative perceptions are neutralizing the potential positive contributions of Nuclear, Plasma and Radiation science to everyday life.

The word "plasma" is derived from a Greek word meaning "to mould" and was coined by Irving Langmuir based on his observations of the manner in which the positive column of a glow discharge tended to mould itself to the containing tube. David Bohm, a leading expert in twentieth century plasma physics, observed that once electrons were in a plasma, they stopped behaving like individuals and started collectively behaving as if they were a part of a larger and interconnected whole. Although the individual movements of each electron appeared to be random, vast numbers of electrons were able to produce collective effects that were surprisingly well organized and appeared to behave like a life form. The plasma constantly regenerated itself and enclosed impurities in a wall in the same way that a biological organism, like the unicellular amoeba, might encase a foreign substance in a cyst. So amazed was David Bohm by these life-like qualities that he later remarked that he frequently had the impression that the electron sea was "alive" and that plasma possessed some of the traits of living things.

Plasma cosmologist, Donald Scott, notes that: "A [plasma] double layer can act much like a membrane that divides a biological cell". A model of plasma double layers, which is a structure commonly found in complex plasmas, has been used to investigate ion transport across biological cell membranes by researchers. Plasma physicist Hannes Alfvén also noted the association of double layers with cellular structure, as had Irving Langmuir before him, who coined the term "plasma" after its resemblance to living blood cells.

Using a computer model of molecular dynamics, V. N. Tsytovich and his colleagues of the Russian Academy of Science showed that particles in a plasma can undergo self-organization as electric charges become separated and the plasma becomes polarized. Tsytovich's computer simulations suggest that in the gravity-free environment of space, the plasma particles will bead together to form string-like filaments which will then twist into helical strands resembling DNA that are electrically charged and are attracted to each other. The helical structures undergo changes that are normally associated with biological molecules, such as DNA and proteins. "These complex, self-organized plasma structures exhibit all the necessary properties to qualify them as candidates for inorganic living matter", says Tsytovich, "they are autonomous, they reproduce and they evolve".

The ionized conditions needed to form these helical structures are common in outer space. If that is so, then it will mean that plasma life forms are the most common life form in the universe, given that plasma makes up more than 99% of our universe which is almost everywhere ionized. This is in stark contrast to carbon-based life forms, which according to the Rare Earth hypothesis proposed by Peter Ward and Donald Brownlee, would be rare in the universe due to a number of factors, including the need for an acceptable range of temperatures to survive.

THE FORCES OF NATURE

It is convenient to consider four fundamental physical interactions that govern our universe. It is suggested that a general law part of the "Theory of Everything" described these forces at the time of the Big Bang when extremely large energy densities existed. These laws separated at the time of creation of our universe about 13.8 billion years ago, in the Big Bang postulated event. Scientists are still attempting at combining the description of these forces within the framework of the "General Theory." These are:

THE GRAVITATIONAL FORCE

GENERAL RELATIVITY FORMULATION

The theory of General Relativity describes the behavior of gravitation in the Universe. This theory describes gravitation as a warping of space in the presence of matter:

the more matter, the more acutely the curving of space. Relativistic models are based on a 4 dimensional space-time continuum. A special case of it that we are familiar with on Earth is Newtonian space. This kind of space is flat, and is the 3 dimensional equivalent of a 2 dimensional plane.

The theory of General Relativity does away with any need for a force of gravity, depicting the planets as following paths of least resistance or geodesics through curved space, and indicates that cosmic space can be mapped by going to 4 dimensions. The trajectory of any object describes a world line, which is a course through space and time. If an apple is falling from a tree, it is falling because space in the vicinity of the Earth is curved; it is moving downhill in the space time continuum. The moon orbiting the Earth is rolling around an inner wall of a well occupied by Earth in space-time.

In General Relativity, objects respond to the contours of space in their immediate vicinity, while in classical physics gravitation involves action at a distance. General Relativity interprets gravity, not as a force, but as an effect of hyper dimensionality on the 3 dimensional world that we are used to, and accordingly gravitation is just a consequence of geometry.

Which theory should be used in favor to another is determined by the ratio:

$$u = \frac{2GM}{c^2 r} \tag{1}$$

where c is the speed of light, G is the constant of gravitation, M is the mass of the object of interest, and r is the distance from the mass M.

NEWTONIAN APPROXIMATION

If u is less than 10^{-3}, Newtonian theory can be used. If u is around unity, General Relativity must be used. At intermediate values, the post Newtonian approximation is to be used. For the effect of the sun's gravity on Earth, $u=10^{-8}$, and Newtonian law is adequate. For the universe, $u = 10^{-2}$ to 1, and General Relativity must be used.

Newton postulated the existence of a force of gravity described by the laws of Newtonian Mechanics. On an earthly scale, it determines the mechanical interactions on our planet Earth, affects the tides, the seasons, and the weather. It is the realm of our mechanical technology in transportation: cars, trains, ships, planes and rockets.

In 1665, a year where the great plague epidemic spread in Europe, Isaac Newton is surmised to have come out with the idea of the inverse square law. Supposedly, he came out with it at his home in Woolsthorpe, England, when he saw an apple drop from a tree. He describes in his book: “Philosophiae Naturalis Principia Mathematica” published in 1687, 22 years after his supposed discovery, and after correspondence with Robert Hooke, the inverse square law of gravitation:

$$F = \frac{G m_1 m_2}{r^2} \tag{2}$$

This law describes the fact that the force F between two bodies or particles of masses m_1 and m_2 is proportional to the masses, but inversely proportional to the square of the distance r between them. The constant of gravitation G is very small. For instance, the gravitational energy between the electron and the proton is of the order of 10^{-40} times less than the electrical attracting force between them. Thus the effect of this law is negligible when we consider atomic or nuclear phenomena.

If we consider the Earth's gravitational pull on objects on it, this law becomes important. If we set:

m_1 = mass of the Earth,

and:

m_2 = the mass of an object that it exerts a gravitational pull on,

then F becomes the "weight" of m_2, or the gravitational pull of the Earth on it.

FIRST LAW OF DYNAMICS: GALILEO'S LAW

This law is the basis of science of motion or "Dynamics". Galileo introduced its initial framework with the first law of motion, which for the first time states that a force is necessary, not for motion, but for a *change* of motion:

"A body continues to move in a straight line with uniform speed if no force acts on it."

SECOND LAW OF MOTION: NEWTON'S LAW

The first law is qualitative, the second law of motion by Newton, quantifies how much force is needed to change motion:

$$\bar{F} = m\bar{a} \tag{3}$$

This states that the vector force $\bar{F}$ is equal to the mass m multiplied by the acceleration $\bar{a}$. The mass m is a measure of the quantity of matter in the body. It is also a measure of the *inertia* of the body, or its ability to resist the effect of the force as an external agent applied on it, trying to change its state of motion. The change of the state of motion for a given force is the acceleration.

The acceleration is the rate of change of velocity. Velocity is a vector quantity, containing information about both the speed and the direction of motion of an object. A change in either one or in both, leads to acceleration.

THIRD LAW OF MOTION, ACTION AND REACTION

Newton's third law of motion states that:

"Action and reaction are of equal magnitude and in opposite directions".

Treating the Earth as a sphere of mass M, and considering R as the distance to its center, the force exercised on a body of mass m on the surface of the Earth is:

$$F = \frac{GMm}{R^2} \tag{4}$$

We can define the acceleration on a body m due to the Earth's gravitation as:

$$g = \frac{Force}{m} = \frac{F}{m} = \frac{GM}{R^2} \tag{5}$$

Since G, M and R are constants, g is designated as the Earth's gravitational constant. A body at a height h above Earth has a potential energy equal to:

$$E_{potential} = mgh \tag{6}$$

A body possessing a velocity of v has a kinetic energy equal to:

$$E_{kinetic} = \frac{1}{2} m\mathrm{v}^2 \tag{7}$$

The equation of conservation of energy states that:

$$E_{potential} + E_{kinetic} = \text{Constant} \tag{8}$$

or:

$$mgh + \frac{1}{2} m\mathrm{v}^2 = \text{Constant} \tag{9}$$

If we consider the dissipative forces such as friction to be important, work has to be done to surmount them. This work normally appears as heat. If we care to include heat in our consideration, the law of conservation of energy becomes the first law of Thermodynamics.

Force fields like the Earth's gravity, electric fields and magnetic fields are conservative fields, in the sense that the work done against them is converted into the form of potential energy. This potential energy is fully recoverable as kinetic energy if needed.

In nature, the controlling forces place limitations on motion in the form of *potential barriers.* The Earth's gravity presents a potential barrier to a rocket trying to escape its pull. The *escape velocity* of a rocket of mass m can be estimated by equating its potential energy to its kinetic energy:

$$\frac{1}{2} m\mathrm{v}^2 = \frac{GMm}{R} \tag{10}$$

From which we get the rocket's escape velocity at which it must be fired to escape the Earth as:

$$v_{escape} = \left(\frac{2GM}{R} \right)^{1/2} \tag{11}$$

This escape velocity for different celestial bodies is shown in Table 1.

Table 1. The Escape Velocities of different bodies.

Celestial Body	Escape Velocity (miles/sec)
Earth	7
Moon	1.5
Sun	400
White Dwarfs	3,000
Neutron Stars	100,000

THE ELECTROMAGNETIC INTERACTION FORCE

CONCEPT OF RADIATIVE INTERACTION

The laws of Electromagnetics in the form of Maxwell's Equations describe this force. They describe an important part of human civilization, in that these laws govern biological and chemical processes. They form the basis of electrical production systems, and communications in radio, microwave, television, and other electrical and electronic technologies. They are also the basis of Plasma interactions describing processes occurring in interstellar gas, the solar corona, the Earth's ionosphere, arc discharges and in thermonuclear plasmas.

Consider two particles to possess an electrical charge. The motion of each particle will be affected by the presence of the other charged particle, and the two particles will interact. This is described in terms of the concept of *radiation* traveling from the path of the first particle to affect the other charged particle in its path. If one particle oscillates in one spatial dimension with frequency ν, the radiative interaction causes the second particle to oscillate with the same frequency ν, if we assume that the second particle has no motion other than that that arises from the influence of the first particle. The first particle is designated as the source particle, and the other particle as the detector particle.

Depending on the frequency ν of oscillation, the radiation falls in one or another category depending on the application involved. For electromagnetic radiation, moving at the speed of light c, the wavelength λ is related to the frequency ν by:

$$\lambda = \frac{c}{\nu} \tag{12}$$

Radiation's wavelengths are measured in units of the Angstrom, where:

1 Angstrom (A^o) = 10^{-8} cm = 10^{-10} m.

Table 2 displays the range of the Electromagnetic Spectrum. It can be noticed that the visible spectrum is only a minor part of it.

Table 2. The Electromagnetic Spectrum and Areas of Applications

Wavelength	Applications
10^{-4} A	Cosmic waves.
10^{-3} A	Betatron.
10^{-2} A	Gamma rays emitted by radioactive substances. Gamma ray used in medical therapy. Industrial Radiography.
10^{-1} A	Medical Radiography. x rays.
1 A	Crystallography. x rays.
10^{1} A	Soft x rays.
10^{2} A	Very soft x rays.
10^{3} A	Ultraviolet radiation.
10^{4} A	Visible light.
10^{5} A	Near Infrared.
10^{6} A	Mid Infrared radiation.
10^{-3} m	Far Infrared. Millimeter waves.
10^{-2} m	Microwave radiation, radar.
10^{-1}m	
1 m	Television.
10^{1} m	
10^{2} m	Communications.
10^{3} m	Communications.
10^{4} m	
10^{5} m	
10^{6} m	Electric waves.
10^{7} m	60 cycle (Hz) Alternating Current (AC).
10^{8} m	

Nuclear, plasma and atomic phenomena cover a much larger portion of the electromagnetic spectrum than does the visible part. X rays are primarily results of atomic phenomena, but they can result from nuclear processes such as the electron capture process. Gamma rays are primarily results of nuclear interactions in the nucleus, including the process of radioactive decay. Gamma rays can result from atomic phenomena such as those produced in thunderstorms from runaway electrons accelerated in the strong electric fields losing their energy through the bremstrahlung process. Radio waves derive from synchrotron radiation in magnetic plasmas.

MAXWELL'S EQUATIONS

Electromagnetic phenomena are described by Maxwell's equations. For the description of Electromagnetic phenomena we consider Coulomb's law in the conventional or centimeter-gram-second (cgs) unit system, describing the inverse square force F arising between two charges e_1 and e_2 with a separation distance r as:

$$F = \frac{e_1 e_2}{r^2} \qquad (13)$$

Newton's law from Eqn. 3 allows us to define the unit of force, the dyne, in terms of centimeters, grams, and seconds (cgs). The dyne is the force which, acting upon a mass of 1 gm, produces an acceleration of 1 [cm/s^2], or:

$$1 dyne = 1 \frac{gm.cm}{\sec^2}.$$

The unit of charge, called the electrostatic unit (esu) of charge or statcoulomb, using Coulomb's law, is defined as that charge e which placed 1 cm from a similar charge e, experiences a force of 1 dyne. Thus we can write that:

$$F = \frac{e^2}{r^2} \qquad (14)$$

Consequently:

$$1 esu = cm.dyne^{1/2}.$$

The unit of potential V:

$$V = \frac{e}{r} \qquad (15)$$

becomes:

$$1 statvolt = \frac{esu}{cm}$$ 1 statvolt = 1 [esu/cm].

From the definition of the Electric Field Intensity E:

$$E = \frac{e}{r^2} = \frac{V}{r} \tag{16}$$

It follows that its unit is the [statvolt/cm].

Current is defined as the rate of change of charge and consequently has the unit:

$$1 statamp = 1 \frac{statcoul}{\sec}.$$

The electromagnetic unit (emu) unit of current or abamp (absolute ampère) was originally defined as that current which, flowing in a long straight wire placed 1 cm from a parallel wire carrying the same current, results in a force per unit length of 2 dynes/ cm between the wires:

$$\frac{F}{l} = \frac{2I_1 I_2}{r} \tag{17}$$

where I_1 and I_2 are in abamp units.

In the Gaussian cgs units Ampère's law is expressed as:

$$\frac{F}{l} = \frac{2I_1 I_2}{c^2 r} \tag{18}$$

where I_1 and I_2 are in statamp units, and where the constant c is such that:

$$I[abamp] = \frac{I[statamp]}{c}. \tag{19}$$

From Ampère's law, 1 abamp = 1 dyne$^{1/2}$, and thus c has the dimensions of a velocity.

The magnetic induction B at a distance r from a long straight wire carrying a current I is written in emu units as:

$$B = \frac{2I}{r}, \text{ I in abamp,} \tag{20}$$

In the Gaussian cgs system of units it is written as:

$$B = \frac{2I}{cr}, \text{ I in statamp.} \tag{21}$$

Thus we can write for the Gauss unit of magnetic induction:

$$1 Gauss = 1 \frac{statcoul}{cm^2} .$$

The magnetic vector potential is given by:

$$\bar{B} = curl\, \bar{A} = \nabla \times \bar{A} \tag{22}$$

where $\bar{B}$ is the magnetic field and $\bar{A}$ is the magnetic vector potential.

With these units for charge, current, electric field, and magnetic induction, Maxwell's equations encompassing four laws, including two divergence and two curl vectorial operations on the electric and magnetic fields, take the form:

Faraday's Law: $$\nabla \times \bar{E} = curl\, \bar{E} = -\frac{1}{c}\frac{\partial \bar{B}}{\partial t} \tag{23}$$

Ampère's Law: $$\nabla \times \bar{B} = curl\, \bar{B} = \frac{1}{c}\frac{\partial \bar{E}}{\partial t} + \frac{4\pi}{c}\bar{j} \tag{24}$$

Coulomb's Law: $$\nabla . \bar{E} = div\, \bar{E} = 4\pi q \tag{25}$$

Gauss's Law: $$\nabla . \bar{B} = div\, \bar{B} = 0 \tag{26}$$

where q in Coulomb's Law Eqn. 25 is the charge in [statcoul/cm^2], and $\bar{j}$ is the current density in units of statamp/cm^2.

This form of Maxwell's equations is the appropriate form for microscopic phenomena, and is the form used in plasma calculations, where q and $\bar{j}$, represent the total charge and current densities respectively.

In a vacuum, where q = $\bar{j}$ = 0, Maxwell's equations can be combined to yield the wave equations:

$$\left(\nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2} \right) \bar{E} = 0 \tag{27}$$

$$\left(\nabla^2 - \frac{1}{c^2}\frac{\partial^2}{\partial t^2} \right) \bar{B} = 0 \tag{28}$$

from which c can be identified as the speed of light, c = 3 x 10^{10} [cm/sec].

LORENTZ EQUATION

If the radiative effects can be neglected, the equation of motion for a charged particle of mass m and of charge q moving in a magnetic field $\bar{B}$, and an electric field $\bar{E}$, is given by the Lorentz equation, for non-relativistic velocities:

$$\bar{F} = m\bar{a} = e\bar{E} + \frac{q}{c}(\bar{\mathrm{v}} \times \bar{B}) \tag{29}$$

where $\bar{\mathrm{v}}$ and $\bar{a}$ are the velocity and acceleration of the particle, respectively.

In the absence of an electric field, this equation shows that charged particles will rotate around the magnetic field lines. The gyro radii will depend on the masses of the particles, e.g. electrons and protons, as well as their charge. If confined by a magnetic field, the electrons in this case will have smaller radii than the protons, and will move in the opposite direction to the protons because of their opposing charge. This effect plays an important role in the magnetic confinement of plasmas in controlled thermonuclear fusion devices, as well as separation of the uranium in the electromagnetic enrichment process or Calutron.

THE WEAK INTERACTION FORCE

RADIOACTIVE DECAY

The transformations in the weak interaction force occur slowly, even though high values of energy are involved. This force of nature expresses itself the process of radioactivity, where isotopes of different elements, either naturally occurring, or artificially created transform into other isotopes.

It is the dream of the ancient alchemists come true. Radioisotopes can have deleterious effects if mishandled, but have beneficial applications in medicine, pharmacology, biology and as power sources in space exploration.

In Germany, Wilhelm C. Röntgen produced x rays in 1896. These x rays were observed to produce *Fluorescence* in the glass walls of x ray tubes and in some other materials. An incorrect idea held by scientist at this time, was they are being produced by ordinary light interacting with atoms.

In France a few months later, Henri Becquerel, in investigating fluorescence, exposed a material containing uranium to light: Potassium Uranyl Sulfate, $K_2UO_2(SO_4).2H_2O$. He noted its fluorescence when exposed to ultra violet light. He placed it then under a photographic plate wrapped in black paper with a thin sheet of silver in between. His idea was that only the x rays would be capable of penetrating the silver. After a time period, the photographic plate was developed. It was found to be exposed. So, the conclusion is that, indeed, shining light on materials causes them to emit x rays. Right? Not quite.

Becquerel had the genius and good scientific sense to check the appropriateness of his conclusion. He repeated the experiment without shining light on his uranium material, and still the photographic plate became fogged. He obtained more puzzling results: the effect was as strong with weak as with strong light, it happened in complete darkness, and for crystals always kept in the dark, and it was emitted by other uranyl and uranous salts, by solutions of uranium salts, and even by metallic uranium. He observed that the rays from uranium would discharge an electroscope. Becquerel concluded that the uranium itself was doing something to fog the photographic plate, and not the light.

Pierre and Marie Sklodowska Curie found that only thorium and uranium materials possessed that property of fogging photographic plates. This property is what came to be called *Radioactivity*. Both Mr. and Mme. Curie concentrated from large quantities of uranium ores, substances that possessed a high level of activity. These were later determined to be the elements radium and polonium. Since uranium has an atomic number of 92, whereas radium has an atomic number of 88, it became clear that uranium was transforming into radium.

The Curies wife and husband team found radium in the barium fraction chemically separated from pichblende, a dark ore of uranium containing about 75 percent U_3O_8. With concentrated radium samples, the Curies made measurements of the heating effect, and found it to be in the range of 100 calories per hour per gram of radium.

J. J. Thomson and others, in their studies of x rays, were then developing an understanding of the ionization of air molecules. In the Curie laboratory, ionization currents were measured with an electrometer.

Ernest Rutherford made measurements of the absorption of the rays emitted by radioactive materials in metal foils. He found one component of the radiation absorbed in the first few thousands of a centimeter of aluminum, and it was called: α radiation. Another component of the radiation was absorbed in 100 times the previous thickness of aluminum, and was named β radiation or beta rays.

For the beta rays, Rutherford found that the ionization effect decreased exponentially by a factor of:

$$\frac{I}{I_0} = e^{-\mu d} \tag{30}$$

when d centimeters of absorber were present. The linear attenuation coefficient μ, was about 15 [cm^{-1}] for aluminum and increased with the increased atomic weight of other metallic foils.

W. H. Bragg in 1904 discovered that the α radiation did not follow the same behavior as the β radiation, but rather that it had a definite range in materials.

Magnetic and electrostatic deflection experiments lead to the recognition of the alpha and beta rays as being in fact particles. The beta rays were found to be electrons moving close to the velocity of light. The alpha rays were found to be helium ions traveling at one tenth the velocity of light.

An even more penetrating radiation that is not deviated by magnetic nor electrostatic field was detected and given the name: γ rays. It was later realized that it was electromagnetic waves, of higher frequency and shorter wave length than x rays.

From the large amounts of lead found in uranium ores shown in Table 3, it was also realized that Pb was the ultimate product. Rutherford and Frederick Soddy, realized that the activity of radioactive substances diminished in intensity with a characteristic time specific to different substances. They also realized that the radioactivity process was accompanied with a change of the chemical properties of the substances at hand. By 1903, they worked out the transformation schemes of radioactive substances in the form of the radioactive decay schemes. It was later found by N. R. Campbell that radioactivity can occur in elements lighter than lead, in potassium and rubidium. The idea of the atomic nucleus did not come out until eight years later.

Table 3. Uranium and thorium ores.

Ore	Chemical Composition	Uranium [percent]	Thorium [percent]
Autunite	Calcium Uranyl Phosphate, $Ca(UO_2)_2(PO_4)_2.8H_2O$, Greenish yellow, rhombic	50	
Carnotite	Potassium Uranyl Vanadate, $K(UO_2)VO_4.nH_2O$, Yellow, hexagonal, rhombic.	45	
Monazite	Phosphates of Cerium Earths and Thorium, $CePO_4 + Th_3(PO_4)_4$, Red, brown, yellowish brown, monoclinic		16
Pilbarite	Thorium Lead Uranate and Silicate, Yellow	25	25
Thorianite	Thorium and Uranium Oxides, ThO_2, UO_2, with Rare Earths Oxides, Gray, greenish or brownish black, cubic, amorphous.	4-40	30-82
Thorite or Organite	Thorium Ortho-Silicate, $ThSiO_4$, Brown or black, Orange-yellow, tetragonal.		70
Uraninite or Pitchblende	Uranium Oxide UO_2 to U_3O_8, with rare earth and other oxides, Grayish, greenish, brownish black, cubic, amorphous.	68-80	0-10

THE STRONG INTERACTION FORCE

FUSION PROCESS

This force governs the processes occurring within the nucleus of the atom such as nuclear reactions in general. The processes of fission and of fusion are nuclear phenomena. Thus, reactions occurring in current fission reactors, as well as those that will occur in future fusion reactors are governed by its laws. Nuclear reactions induced by neutrons for the creation of radioactive isotopes fall within that description. Nuclear fusion reactions in the stars, the process of nucleo-synthesis and cosmic rays creation are within the realm of this force.

Radioactivity could not be construed to be the source of energy in stellar atmospheres since their abundance there is so low. J. Perrin in 1920, considered the light nuclei that are more abundant. He suggested that the hydrogen nuclei in the sun could fuse together with a release of energy Q according to the equation:

$$4H \rightarrow He^4 + Q \tag{31}$$

Since protons are held together in the nucleus, it was postulated that they are being held by the nuclear force, which is active only for particles that are close together.

NEUTRON AND NEUTRINO

James Chadwick in 1932 discovered the neutron as a constituent of nuclei, and it was considered as a constituent of the atomic nucleus, with the entire particle in the nucleus, protons and neutrons, being able to attract each other by the strong nuclear interaction force.

Wolfang Pauli suggested another particle, the antineutrino to conserve energy and parity in nuclear reactions.

This was promptly followed by the discovery of the positron or positive electron in 1932 by C. D. Anderson, P. M. Blackett, and G. P. S. Occhialini.

It is interesting to notice that the strong and weak interaction forces both coexist inside the atomic nucleus, as exemplified by the following weak transformations that can be undergone by the proton and the neutrons which are themselves held together by the strong interaction force inside the nuclei:

$${}_0n^1 \rightarrow {}_1p^1 + {}_{-1}e^0 + \nu^* \tag{32}$$

$${}_0n^1 + \nu \rightarrow {}_1p^1 + {}_{-1}e^0 \tag{33}$$

$${}_1p^1 + {}_{-1}e^0 \rightarrow {}_0n^1 + \nu \tag{34}$$

$${}_1p^1 \rightarrow {}_0n^1 + \nu + {}_{+1}e^0 \tag{35}$$

where: n is neutron, p is proton, ν is neutrino, and ν^* is the antineutrino.

THE NUCLEAR ORIGIN OF OUR UNIVERSE

STANDARD MODEL OF COSMOLOGY, THE BIG BANG

According to the Standard Model of Cosmology, all the matter and energy in the cosmos were concentrated into a space smaller than a dime. From that infinitely dense and hot speck, an explosion that is referred to as the Big Bang, occurred about 13.8 billion years ago. The early universe would have initially expanded at faster than the speed of light. Since then the universe has been expanding and cooling.

The Big Bang is the accepted mainstream theory of cosmology, has a Biblical Old testament origin in the Book of Genesis, and has a large following of physicists who emphasize the role of gravitational forces in shaping the universe.

There exists a minority alternate cosmological theory followed by cosmologist Alvén and primarily electrical engineers of an Evolutionary Universe where a major role is given to electric and magnetic fields acting over long distances on a cosmological scale.

STANDARD MODEL PARTICLES

Subatomic particles fall into two categories: fermions and bosons. These two categories each contain pretty diverse sets of particles, but they are grouped together because they also have some important commonalities. The particles that serve as the building blocks of matter are all fermions. Atoms are made of protons, neutrons and electrons. Electrons are fermions, and so are quarks, which combine to build protons and neutrons.

Quarks appear to occur in nature only in groups, most commonly groups of 2 or 3. A proton contains two up quarks and one down quark, while a neutron consists of one up quark and two down quarks; the quarks are held together in the nucleus by other particles called gluons. Mesons consist of 2 quarks – a quark and an anti-quark. There are six basic types of quark, beguilingly named Up, Down, Bottom, Top, Strange, and Charm.

Out of the four forces currently recognized in the universe – electromagnetism, gravity and weak and strong nuclear forces – quarks are most closely associated with the strong nuclear force, which controls most of their dynamics. But quarks also have some interaction with the weak force, e.g. the weak force can cause the transmutation of quarks into different quarks, a phenomenon that underlies some kinds of radioactive decay such as beta decay.

Bosons are also important, for example photons, the particle-physics version of light, are bosons. Gravitons, the gravity particles proposed by certain theories of gravitation, would also be bosons.

The nucleus of an atom contains protons and neutrons. The electrons are arranged in multiple shells around the nucleus, due to the Pauli Exclusion Principle. Also note this sort of "solar system" model of particles as objects orbiting other objects is just a heuristic approximation; there are many other complexities and a more accurate view would depict each particle as a special sort of wave function.

Fermions, unlike bosons, obey the Pauli Exclusion Principle, which says that no two identical fermions can occupy the same state at the same time. For example, each electron in an atom is characterized by a unique set of quantum numbers (the principle quantum number which gives its energy level, the magnetic quantum number which gives the direction of orbital angular momentum, and the spin quantum number which gives the direction of its spin). If not for the Pauli Exclusion Principle, all of the electrons in an atom would pile up in the lowest energy state (the K shell, the innermost shell of electrons orbiting the nucleus of the atom). But the exclusion principle implies that the different electrons must have different quantum states, which results in some of the electrons getting forced to have different positions, leading to the formation of additional shells in atoms with sufficient electrons.

The composition of matter and antimatter according to the Standard Model of particle physics is described as:

1. **Neutral atoms**

Atoms have an outer negative electron shell surrounding an inner positive core composed of protons and neutrons.

2. Protons and neutrons
Protons and neutrons are in turn of three elementary particles designated as quarks.

3. Quarks and Leptons
Six types of quarks: Up, Down, Strange, Charm, Bottom, and Top have been identified, in addition to six types of Leptons: Electron, Electron neutrino, Muon, Muon neutrino, Tau and Tau neutrino. These constitute matter with 8 of the 12 occur in high energy states. Only the two quarks: Up quark, Down quark, and the two Leptons: Electron and Electron neutrino occur in normal matter.

4. Higgs Field and Higgs Boson

The Standard model also predicts the existence of the Higgs Field composed of Higgs Bosons which gives the other particles their mass. The analogy of the Higgs Field is to water in which small fish encounter small resistance moving through the field of water and hence are analogous to small particles, whereas large fish encounter a larger resistance moving through the field and hence are characterized by a larger mass. The Higgs Bosons constitute the Higgs Field in analogy to the water molecules composing the water medium.

5. Antiparticles

Each particle has a corresponding antiparticle with opposite properties. For instance the electron has a negative charge while its antiparticle as the positron has a positive charge. When matter and antimatter meet, their mass annihilates into radiation carrying out their energy. Our universe is composed primarily of matter. Antiparticles are produced in the process of radioactive decay as positrons and in particle accelerators with a great expense of energy. The antiparticles include antileptons, antiquarks, antiprotons and antiprotons and possibly antiatoms in antimatter universes.

UNIVERSE EVOLUTION

In the first moments after the postulated Big Bang cataclysmic event, the universe would have been a single hot dense entity in which all the forces of nature that we know today: the strong or nuclear force, the weak interaction, the gravitational, and the electromagnetic forces, were unified. In the first hundred billionth of a second after the Big Bang, the four forces of nature separated one by one in a series of rapidly occurring phase transitions.

The most elementary particles would have been the quarks and gluons floated freely for a while. In the final phase transition of the early universe at about one hundred thousands of a second after the Big Bang, they became bound together to form the protons and neutrons that make ordinary matter.

Three minutes after the Big Bang protons and neutrons bound together to form nuclei of hydrogen and helium in the process of nucleo-synthesis. At the age of 300,000 years electrons and nuclei joined to form the first neutral nuclei. The heavier elements such as nitrogen, oxygen, iron and copper were created much later in the stars. Stars started developing when the universe was 100 million to 1 billion years old.

When the electrons and nuclei combined, the temperature of the universe was about 3,000 Kelvin. Since then, the universe expanded and cooled such that its present day temperature is just 3 Kelvin, corresponding to the microwave radiation background that permeates the universe since the separation of radiation and matter.

The concept that expansion started from a small egg of matter needs to be modified. The Big Bang would have had no center, since it would have occurred everywhere at once.

Recent evidence shows that the universe today is not slowing down its expansion as was thought for a while. It is in fact accelerating. This suggests that empty space is filled with a background energy density that exists everywhere. It creates gravitational repulsion rather than attraction, causing the universe to expand faster and faster, rather than slowing the universe down, which is the way we know gravity to work. An appropriate description of the situation is something that we do not know about on Earth, and tantamount to the existence of the opposite of gravity or antigravity. The concepts of "dark matter" and "dark energy" are suggested to explain the situation.

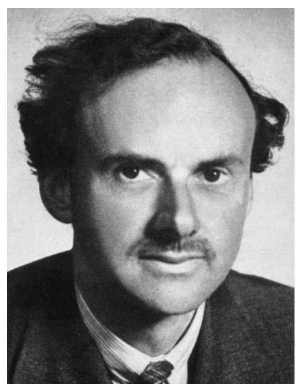


Figure 1. Paul Dirac suggested the presence of dark matter.

It is assumed that in the early stages of the universe a hot mixture of radiation in the form of photons, electrons, positrons, protons, neutrinos and antineutrinos, existed in thermal equilibrium. From that time on, the universe evolved through the following stages:

1. **Big Bang**: (t = 0)
High energy density level prevailed.

2. **Inflation**:
The universe expands to astronomical proportions.

3. **Formation of particles and antiparticles:**
The elementary particles such as quarks and electrons are formed along with their antiparticles in a process of constant symmetric interaction.

4. **Annihilation of particles and antiparticles**: (t = fraction of a second)
Protons and antiprotons are formed then immediately annihilate each other almost completely. A small excess of matter remains from which our known universe emerges.

5. **Nucleo-synthesis**: (t = 100 seconds)
As the temperature cools down to 1 billion degrees C, the protons and neutrons start forming simple element nuclei.

6. **First neutral atoms formation**: (t = 380,000 years)
Matter and radiation decouple from each other. The universe turns transparent. This state can still be detected in the cosmic radiation background.

6. **Creation of complex matter**: (t = 100 million to 13.8 billion years)
Stars and galaxies form 9.1 billion years after the beginning.

Table 4. Evolution of matter in the early stages of the known universe.

Age [sec], [yrs]	Dimension [cm]	Temperature [K]	Energy [GeV]	Predominant particles	Physical Phenomena
					Postulated Big Bang
10^{-44} s		10^{32}	10^{19}	photon γ	Quantum gravity era
10^{-37} s		10^{28}	10^{15}	γ tau t, t^* quarks q, q^* gluon g, neutrinos ν, ν^* electrons e, e^* muons μ, μ^* bosons W^-, Z,	Probable era of inflation
10^{-10} s		10^{15}	10^2	γ tau t, t^* quarks q, q^* gluon g, neutrinos ν, ν^* electrons e, e^* muons μ, μ^*	Possible dark matter relics. Strong, weak, electromagnetic and gravitational forces appear
10^{-5} s		10^{12}	10^{-1}	γ neutrinos ν, ν^* electrons e, e^* meson qq^* baryons qqq, $q^*q^*q^*$	Formation of protons and neutrons from quarks
10^{-2} s	1.5×10^8	3.0×10^{10}			n/p = 1
10^{-1} s	1.5×10^9	1.0×10^{11}			n/p =0.61
1 s	1.5×10^{10}	1.0×10^{10}			Neutrinos escape n/p = 0.32
13.8 s	2.1×10^{11}	3.0×10^9			${}_1D^2$, ${}_2He^4$ formation
10^2 s		10^9	10^{-4}	γ neutrinos ν, ν^*	

				electrons e, e^* ion	
160 s (3 m)					Synthesis of hydrogen and helium nuclei
$2x10^3$ s (35 m)	$3.0x10^{13}$	$3.0x10^8$			${}_2He^4$ / ${}_1H^1$ = 0.22-0.28 e / p = 1
300,000 y					First atoms form
$3x10^5$ y		3,000	$3x10^{-10}$	γ neutrinos ν, $ν^*$ atoms	Cosmic microwave radiation visible
$2.2x10^{13}$ s ($7x10^5$ y)	$3.3x10^{23}$	$3.0x10^3$			Neutral atoms form
$100x10^6$ y					First stars, galaxies and quasars appear
10^9 y		15	10^{-12}	γ neutrinos ν, $ν^*$ stars galaxies	
$12x10^9$ y		2.7	$2.3x10^{-13}$	γ neutrinos ν, $ν^*$ black holes	Modern galaxies appear
13.8 billion y					Present day

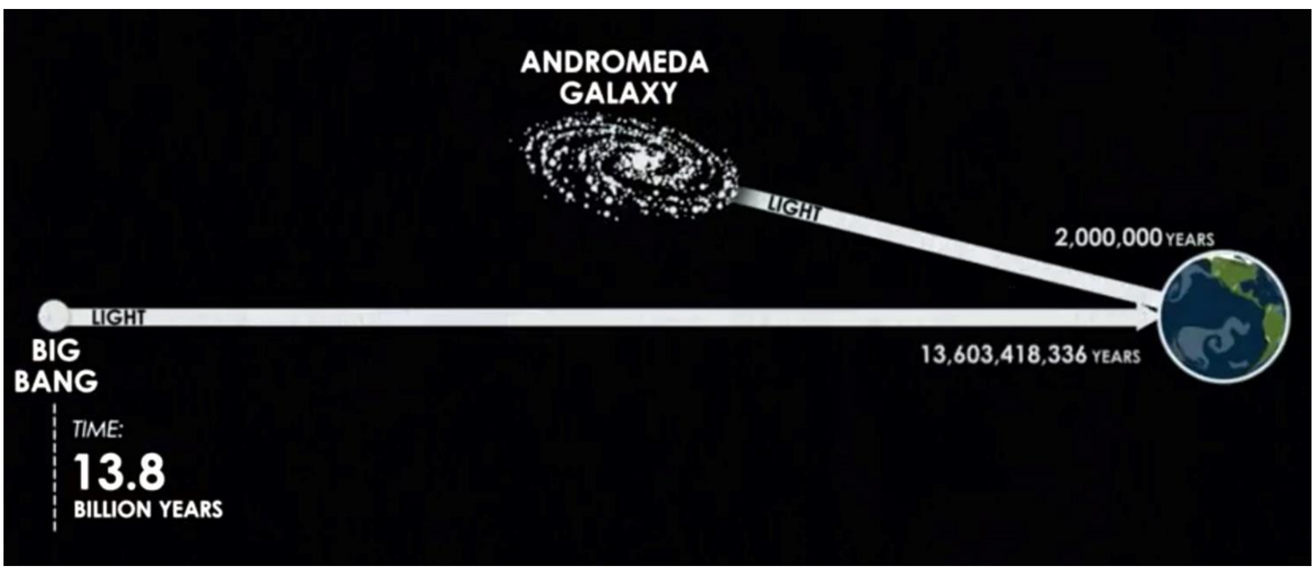


Figure 2. The big Bang 13.8 billion years ago. Not to scale.

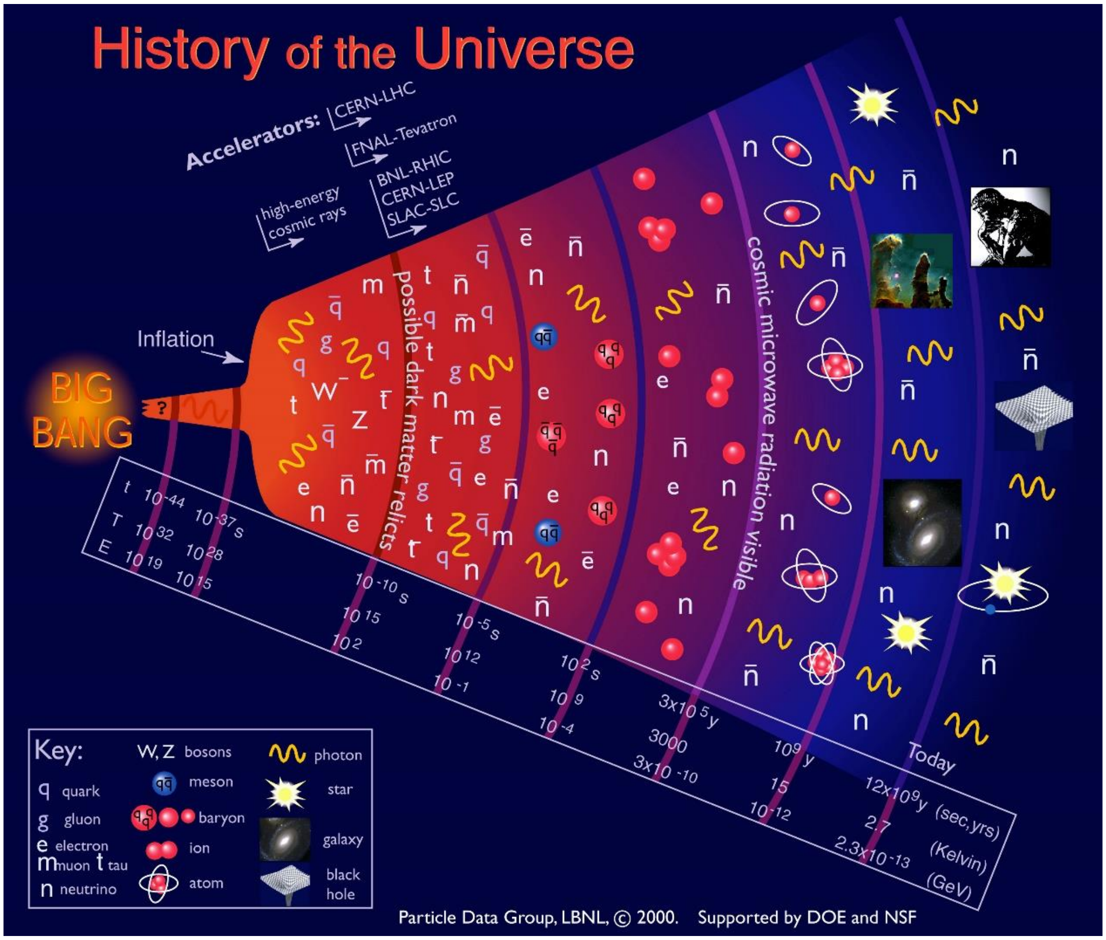


Figure 3. History of the formation of the universe.

The term “radiation” is used since particles with large random speeds close to the speed of light would behave more like radiation than like particles. This stage corresponds to an age of about 10^{-2} second after the postulated Big Bang, where the temperature would be around 10^{11} K and the neutron to protons ratio would be 1.

At this stage the density of matter was so high as to hold the neutrinos within the characteristic size of the early universe. Under present circumstances, neutrinos have minimal interaction with matter and can travel without interaction through several light years of Pb thickness.

The characteristic size of the universe is expressed in terms of the Hubble constant H at that time as:

$$L = \frac{c}{H} \tag{36}$$

where H = 530 [km/(second. mpc)], and: c is the speed of light: $3x10^{10}$ [cm/sec].

Here 1 parsec (pc) corresponds to 3.26 light years, and 1 mpc is 1 million parsecs. One parsec is the distance at which the radius of the Earth's orbit around the sun subtends an angle of 1 second of an arc. A star at a distance of 1 parsec would undergo an oscillation through an angle of 2 arc seconds in its position on the celestial sphere due to the yearly motion of the Earth around the sun.

For the early universe,

$$H = \frac{2}{t} \tag{37}$$

where: t is the age of the universe.

Eliminating the Hubble constant from the last two equations, we get;

$$L = \frac{1}{2}ct \tag{38}$$

Thus at t = 10^{-2} sec, the size of the universe was of the order of:

$$\begin{aligned} L &= ½ \times 3 \times 10^{10} \times 10^{-2} \\ &= 1.5 \times 10^{8} \text{ cm} \\ &= 1.5 \times 10^{6} \text{ m} \\ &= 1.5 \times 10^{3} \text{ km.} \end{aligned}$$

At that initial time, the light particles such as photons, electrons or neutrinos predominated over protons or neutrons by a ratio of about 10^9. As shown in Table 4, the predominance of antineutrinos and positrons produced rapid changes of protons to neutrons, and vice versa:

$$\nu^* + {}_1p^1 \leftrightarrow {}_{+1}e^0 + {}_0n^1 \tag{39}$$

Similar inverse reactions were caused by the predominance of neutrinos and electrons:

$$\nu + {}_0n^1 \leftrightarrow {}_{-1}e^0 + {}_1p^1\,\nu \tag{40}$$

At time 10^{-1} second, the universe would have cooled to about $3\text{x}10^{10}$ K, and expanded to L = $1.5\text{x}10^4$ km, with a subsequent reduction in density. The lower mass of the proton compared with the neutron at this lowered temperature favors its abundance to a neutron to proton ratio of about 0.61.

At about 1 sec, the cooling had proceeded to about 10^{10} K and the universe has expanded to L= $1.5\text{x}10^5$ km, allowing the neutrinos and antineutrinos to escape due to the lower density. The positrons and electrons are disappearing through the *annihilation* process:

$${}_{+1}e^0 + {}_{-1}e^0 \rightarrow 2\gamma \tag{41}$$

where matter transforms into electromagnetic radiation.

At higher temperature, this disappearance rate was balanced by a larger rate of electron-positron pair production from photons:

$$\gamma + \gamma \to {}_{+1}e^0 + {}_{-1}e^0 \tag{42}$$

which is the inverse reaction to the annihilation one in Eqn. 41.

The neutron to proton ratio is further reduced to 0.32, but the neutrons and protons still remain separate due to their high energies.

At around 13.8 seconds, the temperature would have dropped to $3x10^9$ K, and the universe expanded to $2.1x10^6$ km. At this lower temperature deuterium is formed according to Gamow's cosmological scenario through the reaction:

$${}_0n^1 + {}_1p^1 \to {}_1D^2 \tag{43}$$

These deuterons would be transformed through interaction with neutrons and protons to tritium and ${}_2He^3$:

$${}_0n^1 + {}_1D^2 \to {}_1T^3 \tag{44}$$

$${}_1p^1 + {}_1D^2 \to {}_2He^3 \tag{45}$$

The addition of a proton to the tritium produced would produce ${}_2He^4$:

$${}_1p^1 + {}_1T^3 \to {}_2He^4 \tag{46}$$

The addition of a neutron to ${}_2He^3$ would have also produced ${}_2He^4$:

$${}_0n^1 + {}_2He^3 \to {}_2He^4 \tag{47}$$

Combining the last equations, two at a time, yields the following result:

$${}_0n^1 + {}_1D^2 + {}_1p^1 + {}_1T^3 \to {}_1T^3 + {}_2He^4 \tag{48}$$

$${}_1p^1 + {}_1D^2 + {}_0n^1 + {}_2He^3 \to {}_2He^3 + {}_2He^4 \tag{49}$$

Tritium and the He^3 isotope act here as catalysts and cancel out from both sides of the equations, yielding:

$${}_0n^1 + {}_1D^2 + {}_1p^1 \to {}_2He^4 \tag{50}$$

$${}_1p^1 + {}_1D^2 + {}_0n^1 \to {}_2He^4 \tag{51}$$

Here $_2He^4$ is formed from neutrons, proton and deuterons through a process where tritium and $_2He^3$ act as catalysts. According to the Einstein-deSitter model, a helium production amounting to about 22-28 percent of the primeval mass would result.

At 2,000 seconds, the temperature would have decreased to about $3x10^8$ K, and the universe characteristic size increased to $3x10^8$ km. The nuclear processes now stop and the helium to free protons ratio is frozen. The electron to protons ratio is now about unity. The free electrons still block radiation and the universe is still opaque.

When the temperature dropped to around 3,000 K, after about $2.2x10^{13}$ seconds, or $7x10^5$ years, the characteristic size of the universe is now $3.3x10^{23}$ cm, or $3.3x10^8$ km. The electrons can be held to the nuclei through chemical binding into neutral atoms. Radiation can travel now unimpeded by free electron absorption. The universe changed from a radiation dominant phase to a matter dominant phase. At this stage the proportion of deuterons has stabilized around a mass fraction of 1/5,000.

This mass fraction for deuterons is found on the Earth, sun and in meteorites. It is far too high to be explained on the basis of the process of nucleo synthesis in the stars.

Processes at the surfaces of the stars involving high speed particles can explain the creation of some deuterium and other nuclei such as $_2He^3$, $_3Li^6$ and $_3Li^7$, as shown in Table 5.

Deuterium, as an isotope of hydrogen, is however unique, and has such a large mass fraction that it may have been only been created through primeval nucleo synthesis.

Table 5. Mass fraction and cosmic abundance of some light nuclei thought to have originated from primeval nucleo-synthesis

Nuclei	Mass Fraction	Cosmic Abundance (Si = 1)
$_1H^1$	-	$3.18x10^4$
$_1D^2$	$2x10^{-4}$	$5.20x10^{-1}$
$_2He^3$	$6x10^{-5}$	$3.70x10^{-1}$
$_3Li^6$	$1x10^{-9}$	$3.67x10^{-6}$
$_3Li^7$	$1x10^{-8}$	$4.58x10^{-5}$

FORMATION OF THE SOLAR SYSTEM AND EARTH

The original subatomic particles came together to make nuclei of the two lightest elements: hydrogen, and helium. Although the universe was, and is still expanding, hydrogen and helium gases gather as giant clouds, which eventually became the galaxies. The first stars formed within these galaxies. Hydrogen and helium were combined through the process of nucleo-synthesis into a large variety of chemical elements in the super dense, super hot cores of dying stars.

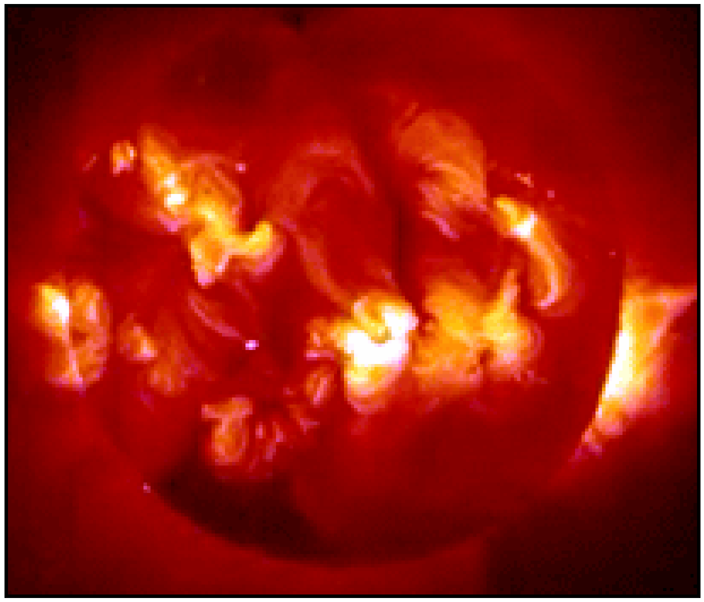


Figure 4. Solar flare showing its plasma eruptions. Source: NASA.

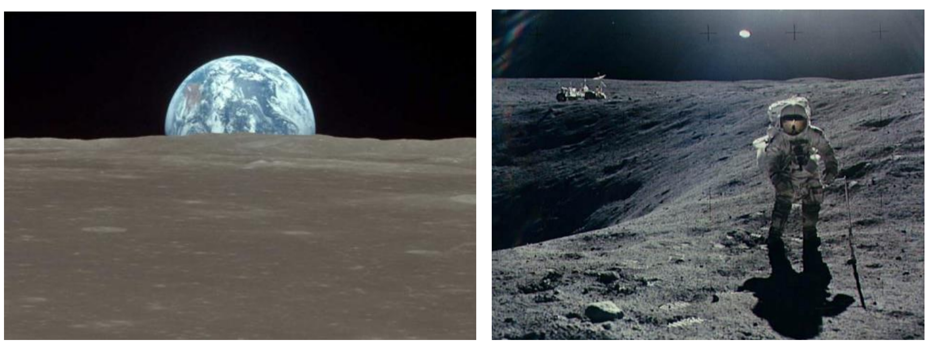


Figure 5. The planet Earth as seen from its moon from the Apollo space missions. Source: NASA.

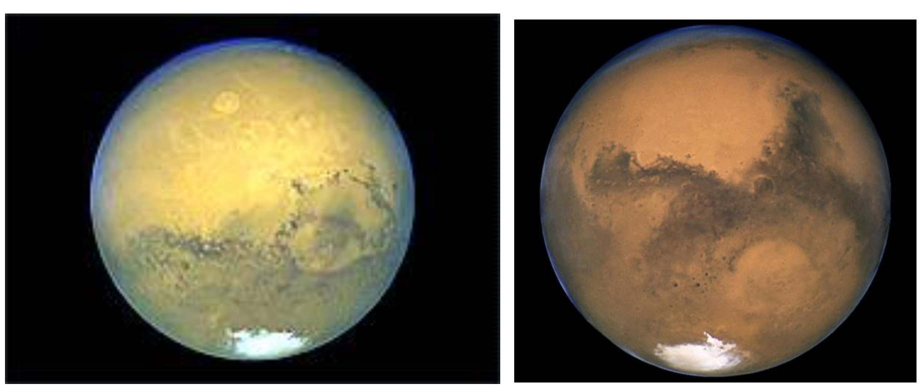


Figure 6. Hubble space telescope pictures of Mars showing ice at its south pole. Source: NASA.

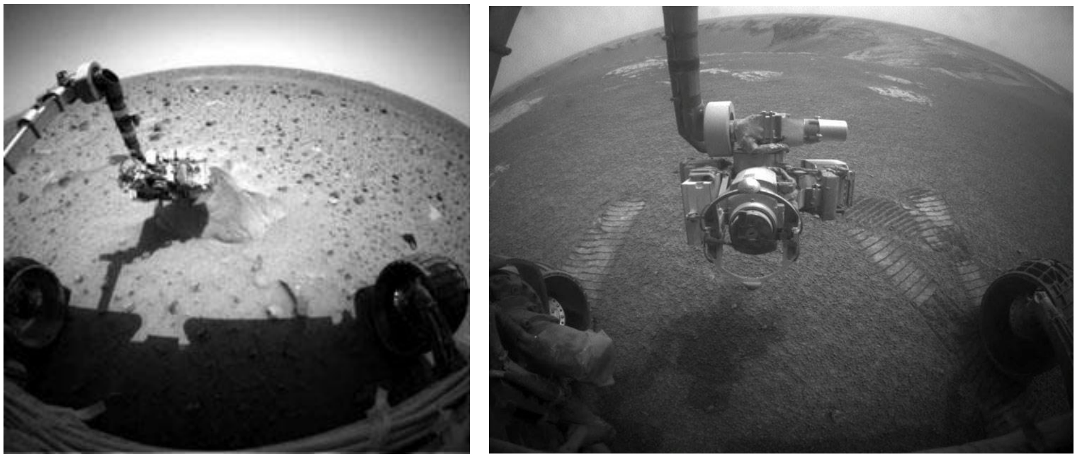


Figure 7. Spirit rover arm using an alpha particle x ray spectrometer to determine the elemental composition of the Mars surface's rocks, 2004. Source: NASA.

Many stars were born and died before the genesis of our sun. The nuclear energy release in the stars primarily converts hydrogen into helium. Roughly 4.6 billion years ago, near our solar nebula, which was the cloud of matter that was to become our solar system, a star several times more massive than the sun ran out of hydrogen in its core. Without energy to hold pressure in the core, it collapsed inwards. This collapse generated another form of energy: *gravitational potential energy*. This is the energy of objects moving under the effect of the force of gravity. The liberation of enormous amounts of gravitational potential energy made the star so hot that helium in its core ignited into a fusion reaction. This process led to the nucleo-synthesis of intermediate elements, from lithium to iron.

Over time the helium fuel was exhausted, and its core experienced another collapse sending a strong shock wave through the Milky Way Galaxy. This is the process denoted as a "Supernova." From the light and medium elements, the heavier elements such as gold, lead and uranium were formed in this process. The explosion burst the star apart, shooting its newly formed elements in the Nebula beyond. The shock wave that accompanied it fragmented and compressed the gases composing the Nebula into large gas clouds.

In one of the clouds, the passage of the shock wave caused large turbulence, liberating different types of energy in matter which would become our solar system. Gravity pulled the moving matter inwards, with the release of gravitational potential energy. Kinetic energy was released from the collision of small particles of dust and gas together, forming larger ones.

Gravity continued to pull matter to the cloud's center, which increased the core's gravity. The angular momentum, which is the rotational momentum of a spinning object, caused the cloud to spin slowly. The remaining gas that was not pulled to the center formed a large disk that spiraled outwards. In this disk were simple organic molecules, the initial hydrogen from the Big Bang, as well as the elements created in supernova explosions.

Within about 50 million years, the continuous collapse of the center created so much temperature that the material in the center, primarily hydrogen and helium, started undergoing a fusion reaction, and the sun was created. As the internal pressure in the sun built up, the gravitational collapse ceased. Temperature extremes of 20 degrees C in the center, to –270 degrees C at the outer reach existed. This low temperature still exists at the outer reaches of the solar system, and necessitates the use of radioisotope power generators to heat up the equipment and generate electricity in space probes sent to explore the outer planets.

In a model of the formation of the planets, the matter in the cooling disk condensed about 4.6 billion years ago, with gravity attracting the heaviest elements to the center. Light gaseous elements near the sun, or the *volatiles*, vaporized. They bound together in the colder regions of the disk forming methane, ammonia and water. Molecules collided and coalesced into specks, pebbles, rocks and boulders. In ten million years, planetesimals with tens of kilometers in diameter formed. Larger bodies were formed eventually through accretion forming the planets. The metallic sulfides and rocky silicates compounds became the solid matter inner planets: Mars, Earth, Venus and Mercury.

The hydrogen primarily found in methane, ammonia, hydrogen sulfide and water, formed the outer gaseous planets: Jupiter, Saturn, Uranus, and Neptune.

Pluto, no longer classified as a planet, is an icy object much like a comet, as part of the Kuiper belt.

It took about 100 million years for the planetary accretion process to occur. The Earth grew from cosmic dust to its present size in about 70 million years.

Other objects reside in our solar system. Asteroids have the same composition as the inner planets, primarily rock and metal. Most of them exist in the asteroid belt between Mars and Jupiter, and could have the remnants of a failed planet, that never formed because of a gravitational disruption by Jupiter. Comets exist in the far reaches of the solar system beyond Neptune. They are composed of rock and frozen water, methane, ammonia and hydrogen sulfide.

Moons of planets in the solar system have varied compositions. Titan is a frozen world of hydrocarbons that evaporate and condense and form lakes and shores on its surface.

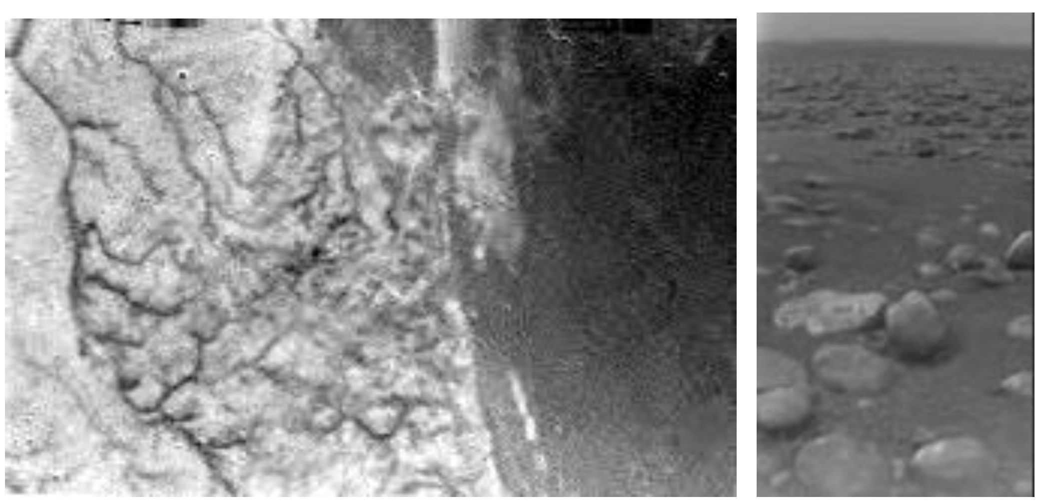


Figure 8. The Cassini space mission to Saturn and its Huygens probe revealed that the moon Titan is formed of solid, liquid and gaseous methane (left). Surface and boulders on the surface of Titan (right). Source: NASA.

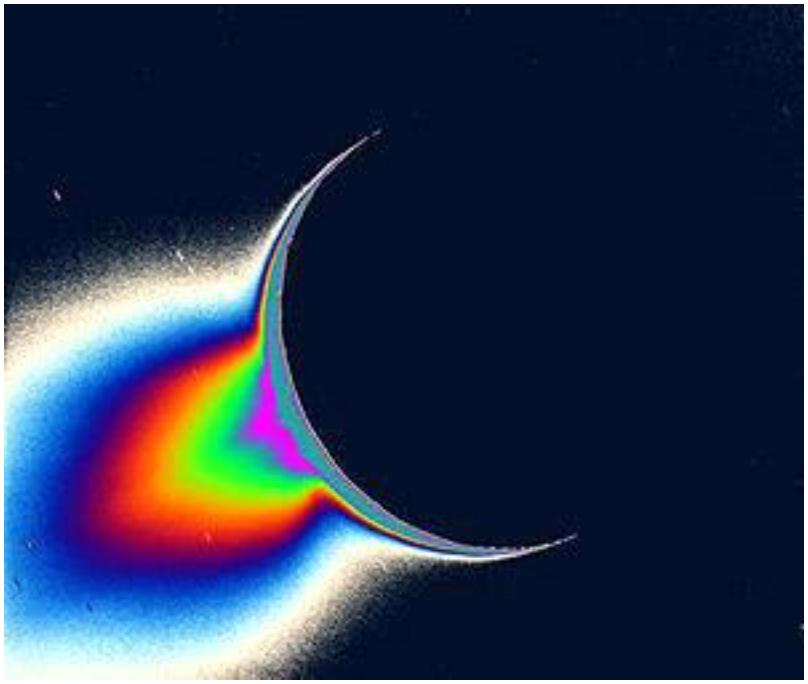


Figure 9. Cassini's space probe picture of Saturn's moon Enceladius reveals jets of evaporated hydrocarbons, 2006. Source: NASA.

The initial Earth incorporated all material it found in its path. A process of homogenization followed by differentiation layered it in its present core, mantle and crust structure. The accretion process provided heat energy from collisions and the release of kinetic energy, and the further compression of the planet masses toward their core provided gravitational energy. Many elements in the early solar system were radioactive, and nuclear energy was also released through radioactive decay.

Early forms of life on Earth date back to 4 billion years with the appearance of self replicating molecules. It is thought that Homo Sapiens originated in Africa around 100,000 years ago, a very small fraction of the age of the universe.

KEPLER SEARCH FOR OTHER PLANETS

The Kepler NASA's planet-hunting telescope discovered three planets that seem ideal places for some sort of life to flourish. A distant duo called Kepler-62e and Kepler-62f are the best candidates for habitable planets that astronomers have found so far.

In four years that Kepler has been trailing Earth's orbit, the telescope has found 122 planets outside our solar system. Many planets are not in the habitable zone where it is not too hot and not too cold for liquid water. The few found in that ideal zone were just too big. Those are likely to be gas balls like Neptune, not suitable for life.

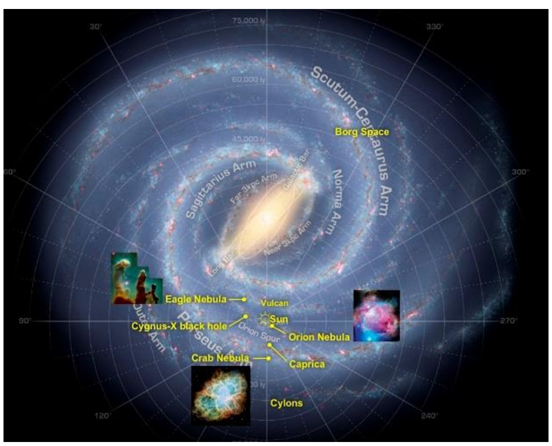
Kepler-69c is a third planet that is about 70 percent larger than Earth and orbiting a different star is considered as a super Earths because of their large sizes. At least 1,200 light-years away, none of these planets are close. In the future small planets closer to Earth are expected to be located.

THE MILKY WAY GALAXY

The galactic center of the Milky Way galaxy has been imaged by the NASA's Chandra x ray observatory, launched in 1999. It shows in Fig. 8 hundreds of white dwarf stars, neutron stars and black holes in a fog of 100 million K hot gas. In the super hot gas new stars are being born. Old stars are exploding into supernovae explosions. Black holes are swallowing in clouds of matter. A dense screen of dust, gas and the glare of millions of stars obscure the center.

The solar system, including the sun and Earth is halfway out of the galaxy's spiral arms at about 25,000 light years from the center. Ordinary telescopes are unable to obtain a clear picture of the center. However x rays generated at the center do penetrate the dust. The Chandra telescope picture covers an area 400 light years high and 900 light years long, with a light year about 6 trillion miles. The galactic center contains hundreds of white stars, which are hot dwarf stars. Neutron stars, the remnants of medium sized stars also exist. Stellar black holes, which are massive stars that have collapsed into a point of such high density that not even light can escape from it, exist there.

Most notable is a massive black hole that exists at the center of the galaxy. The hot gases at the center of the galaxy circulate outward, cooling the edges of the galaxy, and then stream back into the center. This gas could be distributing throughout the galaxy many of the heavier elements such as carbon that were synthesized in stars explosions.



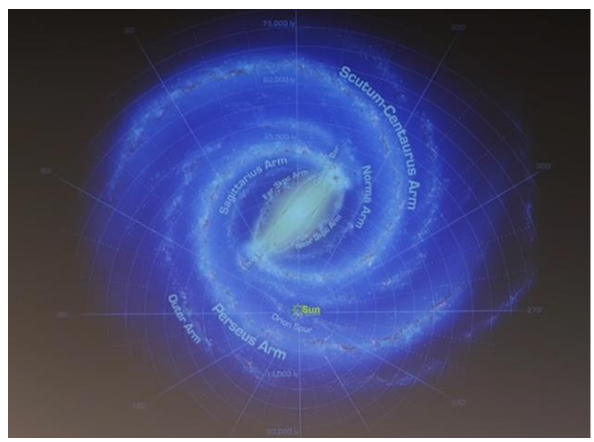


Figure 10. Milky Way Galaxy.

Figure 11. An image of the Milky Way galactic center. The super massive black hole at the center of the galaxy is located inside the bright white patch near the center of the image. Source: NASA.

THE COSMIC SCALE

The cosmic scale covers a large range, from the size of nuclei up to the stars and galaxies. The focus of nuclear, plasma and radiological science lies primarily at the level of the atomic nucleus at 10^{-14} m, and, to a lesser extent, at the level of the overall atom at 10^{-10} m.

From this perspective, it can be noticed that the nucleus possesses a characteristic length of 10^{-12} cm. This is only 1/10,000 of the characteristic length of the atom at 10^{-8} cm. To measure nuclear areas or cross sections, the convention is to use the square of the characteristic length of the nucleus, and call it as the barn unit:

$$1 \text{ barn} = 10^{-24} \text{ cm}^2$$

Workers in the field of cross sections measurements, in a humorous mood, in called such a small object as the atomic nucleus by the name of such a large object as a barn

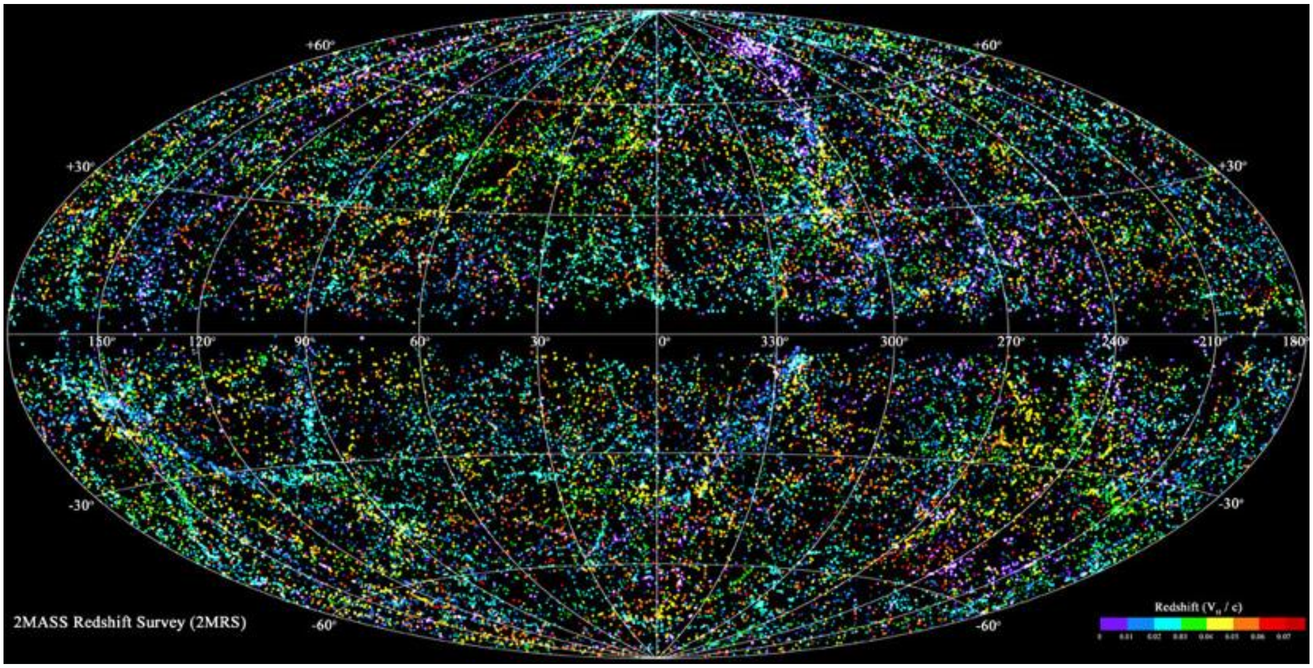


Figure 12. Map of the known universe. The midplane part of picture is obscured by the Milky Way Galaxy. Source: NASA.

Neutron scattering experiment suggest that the nucleus is a sphere with a radius given by:

$$R = 1.25 \times 10^{-13} A^{1/3} [cm], \qquad (52)$$

where A is the atomic mass number.

On the other end of the scale, the Earth has a radius of 6,400 km or 6.5 X 10^8 cm. The distance from the Earth to the sun is about 1.5 x 10^{13} cm, or about 23,500 times its radius. The outermost known large icy object in the solar system is Pluto at 10^6 times the radius of the Earth at a distance that is 40 times away from the sun than the Earth. Our Milky Way galaxy contains about 10^{11} stars distributed over a large distance. The appropriate unit of distance here is the light year unit, which is the distance traveled by light in a year:

$$1 \text{light} - \text{year} = 9.46 \times 10^{17} \text{cm} .$$

The distance of our solar system to the center of the galaxy is approximately 30,000 light-years. Another useful unit to measure such large distances is the parsec (pc), defined as:

$$1 \text{parsec} = 3.26 \text{ light-years} .$$

The parsec is the distance at which the radius of the Earth's orbit subtends an angle of one second of an arc. The distance between other galaxies in our universe and between clusters of galaxies is expressed in terms of the million parsecs (mpc) unit. Some large clusters have diameters of 5 mpc, and some super clusters, which are groups of clusters have diameters of about 50 mpc. Our telescopes can access region at about 3,000 mpc, which is at about 10 billion light years. Since we are looking at light that originated at the initial time of the creation of our universe, we are in fact looking into the past, and this distance of 10 billion light years constitutes the characteristic scale of our universe.

To get a feel of the place of atoms and nuclei in the cosmic scale, Table 7 shows the dimensions in meters of cosmic objects.

The scope of Nuclear Science is the very short distances on the cosmic scale, covering nuclear sizes and gamma rays, from the 10^{-10} to the 10^{-15} meter scale.

Table 6. Dimensions in meters of cosmological objects.

Dimension (m)	Cosmic Object
10^{-15}	Neutrons, protons
10^{-14}	Atomic nucleus
10^{-13}	
10^{-12}	Wave length of 1 MeV γ-ray
10^{-11}	
10^{-10}	Atom
10^{-9}	Sugar molecule
10^{-8}	Large molecules
10^{-7}	Bacterial virus
10^{-6}	Animal virus
10^{-5}	Blood cell Bacteria Wave length of visible light
10^{-4}	Grain of sand
10^{-3}	Flea
10^{-2}	Cherry fruit
10^{-1}	Mouse
1	Humans
10^{1}	Dinosaur House
10^{2}	Skyscraper
10^{3}	
10^{4}	Neutron Star
10^{5}	
10^{6}	
10^{7}	Earth
10^{8}	
10^{9}	Sun
10^{10}	
10^{11}	Size of Earth's orbit
10^{12}	Pluto's orbit

10^{13}	
10^{14}	
10^{15}	
10^{16}	Distance to nearest star
10^{17}	
10^{18}	
10^{19}	
10^{20}	Size of Milky Way Galaxy
10^{21}	Distance to nearest galaxy
10^{22}	
10^{23}	
10^{24}	
10^{25}	Distance to distant galaxies
10^{26}	Distance to edge of visible universe

HIGGS BOSON, THE GOD PARTICLE

Small armies of physicists and engineers are dedicated to the discovery of an elementary particle central to the modern conception of nature. The particle is called the Higgs boson, after Peter Higgs, an English physicist who conceived its concept in 1964. It is said to be responsible for endowing the other elementary particles in the universe with mass.

Particles may be construed to possess shoes to which mud sticks, and the Higgs particles are part of the mud.

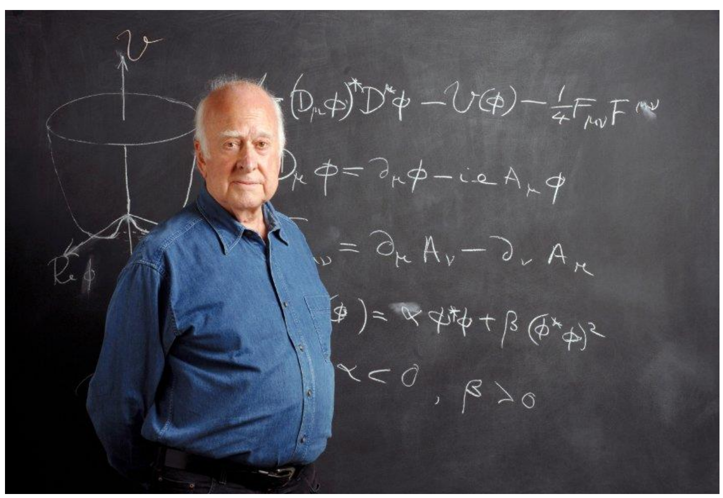


Figure 13. Peter Higgs, after whom the Higgs Boson is named.

Leon M. Lederman, the former director of the Fermi National Accelerator Laboratory, or Fermilab near Chicago, Illinois, USA, referred to the Higgs as “the God particle” in the book of the same name he published with the science writer Dick Teresi in 1993. It made metaphorical sense, because the Higgs mechanism made it possible to simplify the universe, resolving many different seeming forces into one, like tearing down the Tower of Babel.

This particle is the last piece of mystery in the Standard Model, which is a model containing all the elementary particles and intending to explain all particle interaction in particle physics. Higgs was proposed by three teams of theorists in 1964: François Englert and Robert Brout, Gerald Guralnik, C. R. Hagen, and Tom Kibble (GHK), and Peter Higgs, whom the particle was named after. Higgs is known to be the last particle which holds a critical explanation of where the mass of all matter comes from.

The Higgs has lived up to its name. Several Nobel Prizes have been awarded for work on the Standard Model, of which the Higgs is the central cog. Billions of dollars are being spent on particle accelerators and experiments to find it and figure out how it really works.

In experiments in December 2011, two groups, which run giant particle detectors named Atlas and CMS from the CERN particle collider in Switzerland reported bumps in the data in the range of 124-126 GeV suggesting the presence of the Higgs boson. Fermilab physicists in the USA have found a broad hump in their data in the region of 115-135 GeV. Those results came from combining the data from two detectors operated on the Tevatron: the Collider Detector at Fermilab, and DZero. In comparison, a proton is about 1 GeV, and an electron is about 0.51 MeV.

Researchers at the European Organization for Nuclear Research (CERN) announced on July 4th 2012 that they may have discovered the Higgs boson with a mass of 125 GeV. It is a Higgs-like particle at 5-sigma significance, which is the standard to claim a discovery in particle physics. This number translates to a 99.9999 percent confidence level that the observed event is not a statistical fluctuation.

Higgs-likes means it has some of the properties that agree with the predicted properties of the Higgs bosons; however, there are other properties needed to be tested with more data. The particle, the heaviest subatomic particle yet, has only been a theory. In 1964, British scientist Peter Higgs first speculated of its existence to explain how the universe formed into stars and planets after the Big Bang about 13.8 billion years ago. It has become the missing link in the Standard Model, which has since dominated scientific thinking about how the universe is put together. The Higgs boson particle was supposed to have lent mass to other particles helping them coalesce into galaxies that could support life.

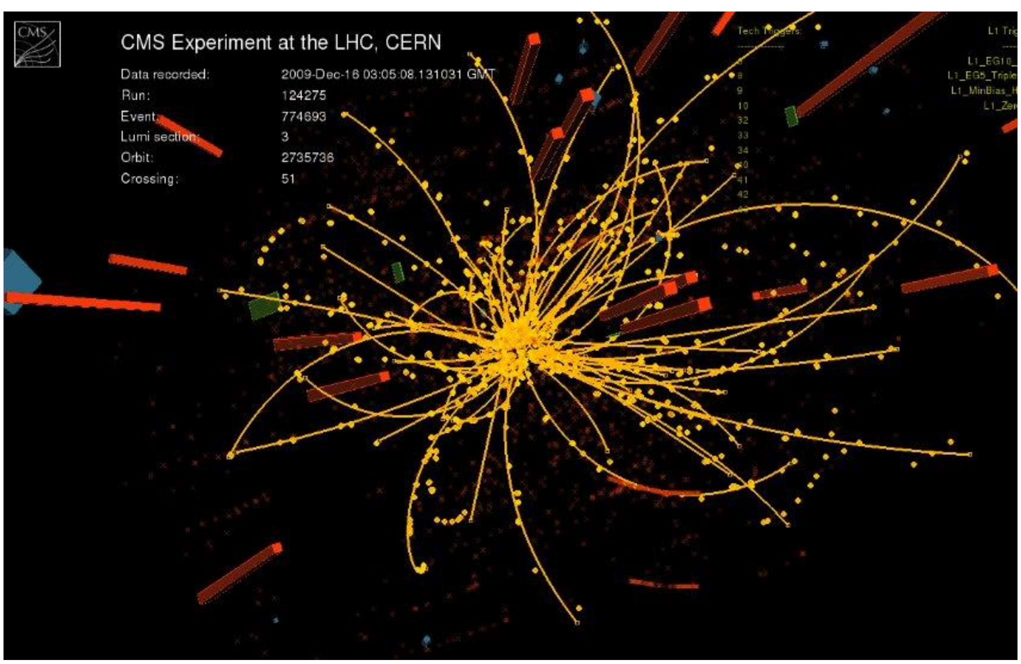


Figure 14. Large Hadron Collider (LHC) depiction of proton-proton collision from the Compact Muon Solenoid (CMS) detector at CERN.

The announcement came after a decades-long hunt that has taken place at CERN's $10.5 billion Large Hadron Collider, located along the border between France and Switzerland. The LHC, which is made up of a 27 kms (17 miles) ring of superconducting magnets 100 meters (330 feet) underground, is the world's biggest and most powerful particle accelerator. Researchers fire beams of particles at each other with velocities close to the speed of light. When they collide, they create millions of particles that mimic the universe fractions of a second after the Big Bang.

Still, the discovery of the Higgs boson only sheds light on a model which describes matter, which makes up about 4 percent of the universe. The rest of the universe, made up of dark energy and dark matter, still remains shrouded in secrecy. With modesty and humility, we must admit that our present state of scientific knowledge about the universe is just the 5 percent that we can detect, see and understand.

LARGE HADRON COLLIDER, LHC

INTRODUCTION

The Large Hadron Collider (LHC) will search for the Higgs Boson, the theoretical particle described by Peter Higgs in 1964. It could explain how matter possesses mass. Given the energies involved in the experiments, scientists are confident they will find something, whether or not it is Higgs boson.

Built underground near Geneva, Switzerland, it is 27 kilometers in circumference and uses powerful superconducting magnets kept at a cryogenic temperature of minus 271 degrees Celsius, to accelerate protons to 99.9999991 percent of the speed of light, before colliding them into each other.

It cost €6.4 billion or $9.2 billion, most of it contributed by the European countries. The data collected by its detectors will be analyzed by 60,000 computers throughout the world.

Many physicists are hoping that the LHC will provide proof of the veracity of string theory, a theoretical construct meant to smooth out inconsistencies between the General Theory of Relativity and Quantum Mechanics.

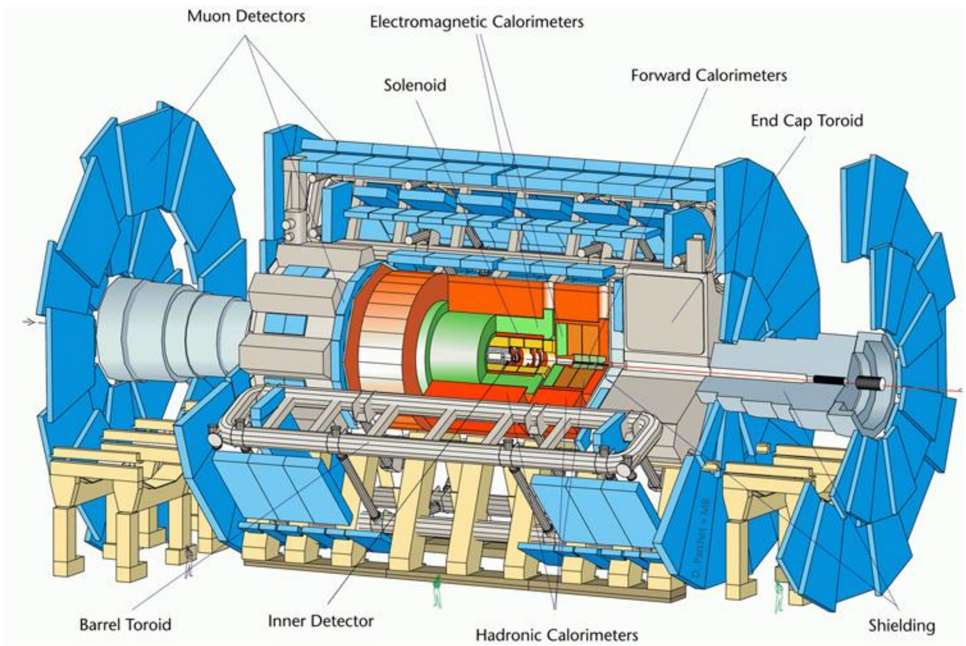


Figure 15. Schematic of the detectors part of the Large Hadron Collider (LDC). Source: CERN, Switzerland.

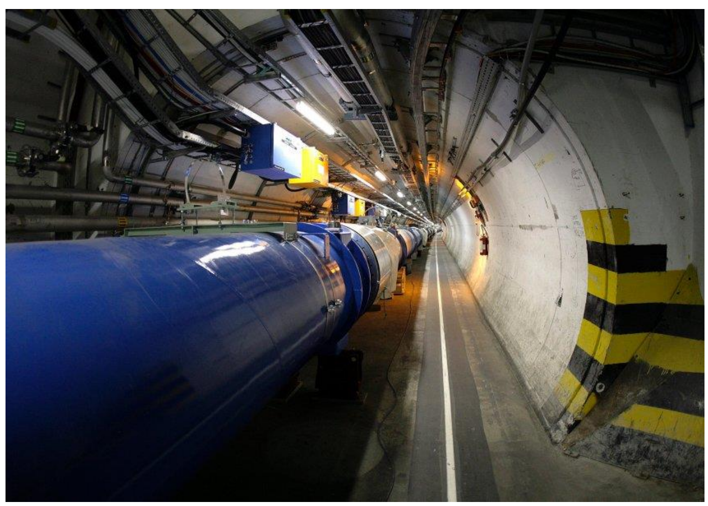


Figure 16. Tunnels of the Large Hadron Collider, LHC.

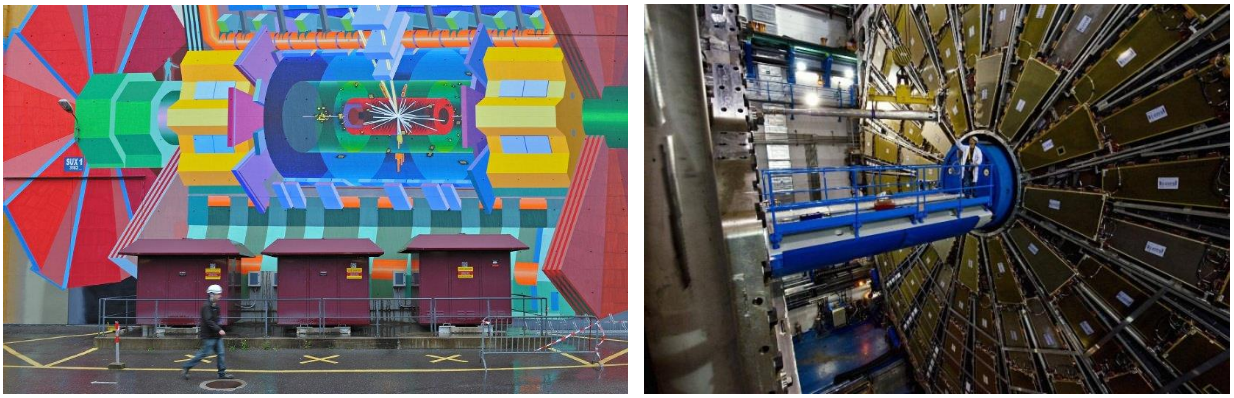


Figure 17. Atlas detector at CERN.

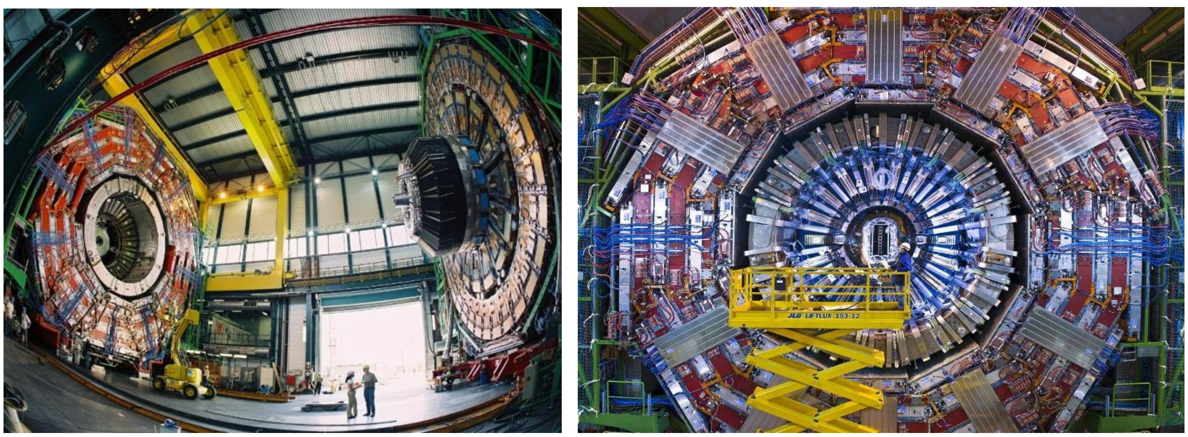


Figure 18. Compact Muon Solenoid Detector, CMS.

MINI BLACK HOLES

Some fear that the LHC could create a mini-black hole that could continue growing and swallow the Earth in the process. CERN insists the LHC is safe, however

A scientist at the University of Tübingen, Dr. Otto E. Rössler, has lent academic weight to the possibility of the creation of mini black holes that would be just one billionth of a billionth of a gram in weight and would be extremely unstable.

According to a theory developed by the physicist Stephen Hawking, they would vanish almost instantaneously: a phenomenon known as Hawking radiation.

Some physicists are hoping the Large Hadron Collider will allow them to observe, however briefly, the creation of these, so far theoretical, tiny black holes.

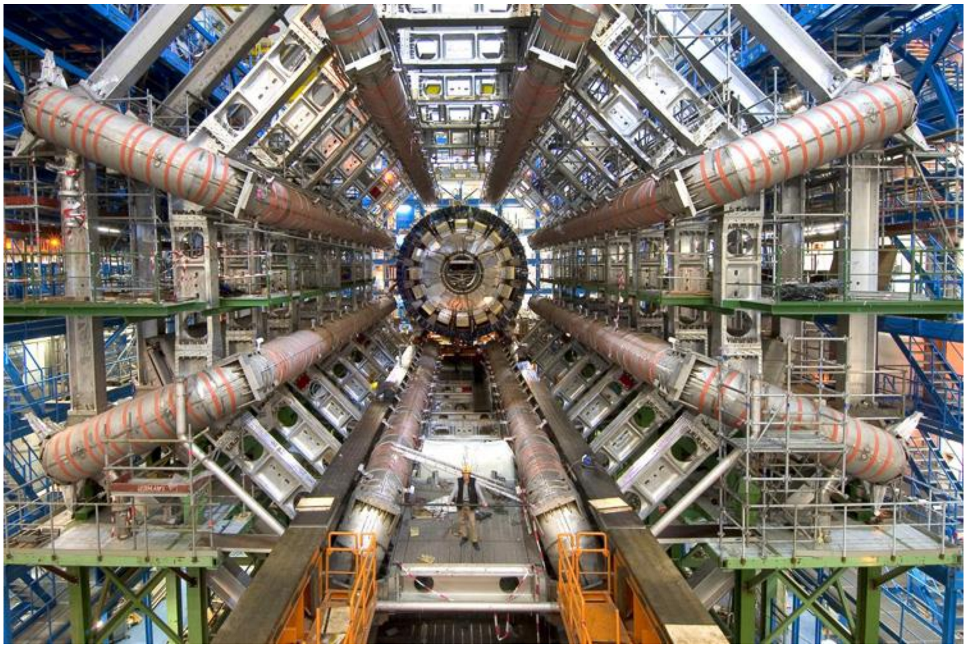


Figure 19. The Large Hadron Collider (LHC), CERN Laboratory, Switzerland.

STRING THEORY

One of the goals of the project is to create conditions very much like those in the first milliseconds of the universe's existence, right at the beginning of the Big Bang.

By doing so, those who ascribe to string theory, a mathematical construct seen by many as a possible means of unifying quantum mechanics with general relativity or the "Theory of Everything," hope to find physical proof of an idea which has until now been little more than an exercise in theoretical physics.

String theory predicts the existence of a number of dimensions beyond the four we are aware of, as well as a number of ultra-tiny particles and anti-particles that have not yet been observed.

Because the Large Hadron Collider is so much larger than any particle accelerator ever built, some see it as the best chance yet to find those particles or those dimensions.

STRANGELETS CREATION

Other than mini black holes, "strangelets;" a potential by product predicted by some physics theories could transform the Earth into a lump of uninhabitable "strange matter."

Some scientists contend that even if the chance of things going wrong is infinitesimally small, the potential disaster is unimaginably large. The question of "'How improbable does a catastrophe have to be to justify proceeding with an experiment?' seems never to have been seriously examined," wrote University of Cambridge physicist Adrian Kent in a 2003 paper.

CERN asserts that: "It is impossible for microscopic black holes to be produced at the LHC. Were they created, they would disappear immediately."

Strangelets too were discounted: "According to most theoretical work, strangelets should change to ordinary matter within a thousand-millionth of a second."

FILAMENTS OF DARK MATTER

Using the ultraviolet light from distant quasars, astronomers have found about 40 percent of the missing “normal” matter in the cosmos in hot gas clustered around filaments of dark matter crisscrossing the space between the galaxies.

Much of the missing "normal" matter in the cosmos has been found clustered around wispy ropes or filaments of invisible matter spanning the space between the galaxies. These filaments form part of the weblike superstructure of the universe, within which galaxies are embedded.

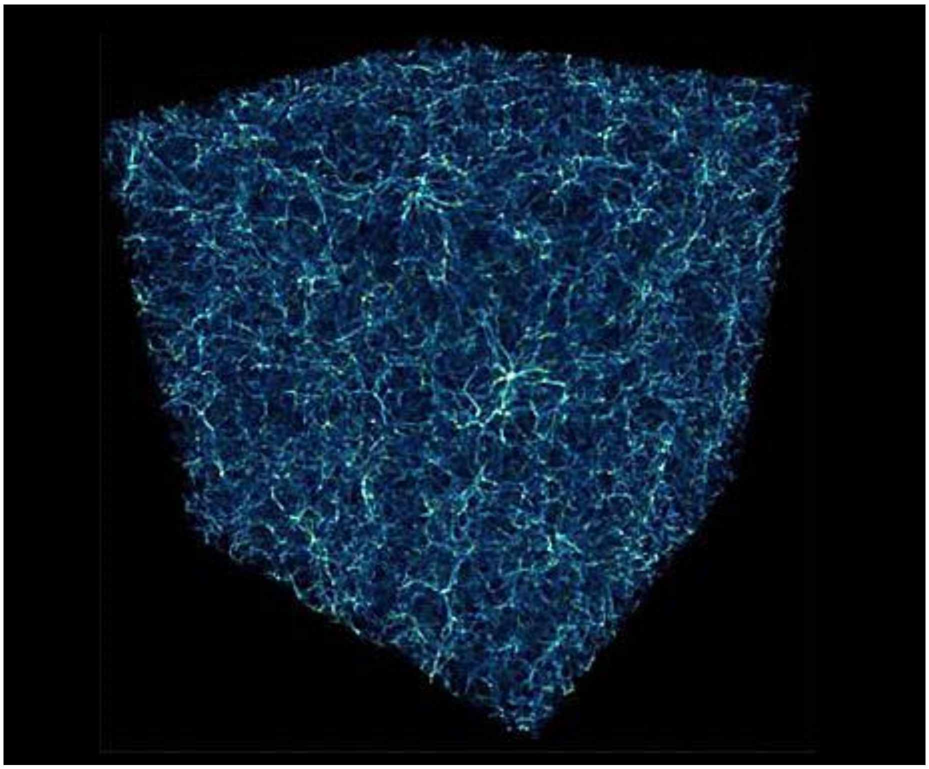


Figure 20. Computer simulation of “normal” matter congregating around filaments of “dark” matter criss-crossing the space between the galaxies over a region of space spanning 1.5 light years on the side. Source: University of Colorado at Boulder.

Yet, with billions of visible galaxies, astronomers have not been able to account for the majority of normal, or baryonic matter believed to have been created by the Big Bang. There was a suspicion that the missing normal matter is hidden in the intergalactic medium or the space between the galaxies, but they could not prove it.

The ultraviolet light emitted by distant galaxies with radiation spewing black holes at their centers or quasars, act like lighthouses piercing a fog, revealing gases that are too hot to be detected by optical scans but too cool to be seen by x ray probes. Using this observation, scientists found evidence that about 40 percent of the missing baryonic matter is concentrated around filaments that crisscross the intergalactic medium.

BARYONIC MATTER

Regular visible matter is made up of protons, neutrons, and other subatomic particles collectively called baryons.

Baryonic matter only accounts for about 5 percent of the universe, and galaxies, stars, planets, and all life forms are thought to represent about just 1/10 of that 5 percent. The rest of the universe is in the form of a mysterious invisible substance called dark matter and an unknown force that is causing the universe's expansion to accelerate called dark energy.

Using NASA's Hubble and FUSE space observatories, Shull and Danforth from the University of Colorado at Boulder examined light from 28 distant quasars scattered across the night sky. As some of the quasars' light travels through space, it pierces filaments of dark matter and gas. Atoms of neutral hydrogen and charged oxygen clustered around the filaments absorb portions of the quasar's ultraviolet light, creating dark bands in the spectrum that reaches Earth. By analyzing this altered light, scientists can determine the position of a filament and the amount of normal matter gathered around it.

BRAIN MODEL OF THE UNIVERSE

Scientists think dark matter filaments are part of a larger cosmic web connecting vast dark matter islands. Together the filaments and islands form a hidden support structure for galaxies that could be likened to a dense cluster of brain cells connected by gangly appendages. Normal matter is drawn toward this dark cosmic web by gravity and flows within and around it like electric impulses coursing through neurons. Wherever normal matter concentrates within the web, the galaxies and galaxy clusters have formed. Recent observations confirm that much of the universe's baryons flow through the filaments.

But even with these new discoveries, more than half of the universe's baryonic matter is still unaccounted for. Scientists think the remaining missing matter most likely exists in the form of extremely hot gas that also floats between the galaxies. This gas is heated to millions of degrees and will require future x-ray telescopes to detect it.

FATE OF MILKY WAY GALAXY

Caleb Scharf, an astrophysicist and director of Columbia’s University Astrobiology Center describes his perspective about the fate of our Milky Way Galaxy [7]:

> “The Milky Way, which contains our solar system, is a big spiral galaxy. The 200 billion stars in this disk stretch across a diameter of 100,000 light-years. Our parent star is positioned toward the outer edge of it. Every 210 million years, our solar system circum-navigates the galaxy. Since the sun formed more than 4.5 billion years ago, it has made this round trip more than 20 times.
>
> Our biggest neighbor is the Andromeda galaxy, separated from the Milky Way by a gaping void 2.5 million light-years across. Our eyes see Andromeda as only a hazy patch. In reality, its light spreads across the sky in a great band some six times the size of the full moon. Andromeda is a giant spiral, too, but appears older than the Milky Way. Its baby stars form at one- third to one-fifth the rate of those in the Milky Way.
>
> In 4 billion to 5 billion years, the curved space-time containing Andromeda and the Milky Way will cause them to merge. In fact, they have already started falling toward each other. Although this encounter will happen at a velocity of more than a hundred miles a

second, it will not exactly be a collision. There is so much space between the tiny points of condensed matter in stars that the galaxies will simply drift and flow into each other over hundreds of millions of years. Eventually, the combined content of these two great systems may settle into something resembling an elliptical galaxy, and Andromeda and the Milky Way will be no more.

Regardless of the outcome, by the time this slow collision begins, our sun will have used up the hydrogen fuel in its core, which will contract inward. The shrinking interior will get hotter, flooding the solar atmosphere with radiation, and the sun will grow to a bloated red-giant star, engulfing what remains of Earth and the other inner planets. This tiny scrap of rock and water that, in just a few billion years, nurtured life from microscopic single-celled organisms to beings like us will be erased. Until then, we have a chance to understand what makes the Milky Way tick, how it compares with all other galaxies and what exactly made one of its planets come to life."

FATE OF PLANET EARTH

SUPERCONTINENT FORMATION

Geologists suggest that a new supercontinent, Pangaea Ultima, will form in the next 200 to 250 million years. The American, European, and African continents will converge, starting with the disappearance of the Mediterranean Sea followed by the disappearance of the Atlantic Ocean. Australia will be joined to Antarctica. As the supercontinent takes shape, there will be large fluctuations of atmospheric oxygen and temperatures resulting in mass extinctions.

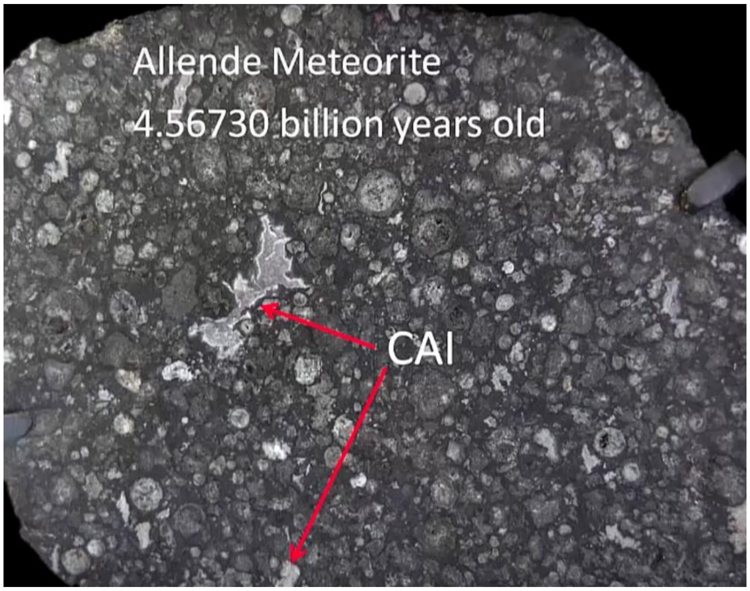


Figure 21. The Allende meteorite contains Ca and Al from the time of formation of the solar system from the effect of a supernova on the solar nebula 4.6 billion years ago. The Al^{27} has since decayed into Mg^{27}.

FLOOD BASALTS ERUPTIONS

Flood basalts are igneous areas that cover thousands of square kilometers and erupt over a mantle hotspot for a few million years. The Colombia Plateau of Idaho, Oregon, and Washington, the Ongong Plateau of Java, the Dekkan Traps of India, and the Siberian Traps of Russia,are examples. These lavas eruptions release large amounts of gases and cause extreme climate change and may cause mass extinctions.

It is thought that the eruptions of the Siberian basalts are responsible for the Permian-Triassic extinction of species 250 million years ago, while the Dekkan basalts may have contributed to the Cretaceous-Paleocene extinction at 66 million years.

The Iceland volcanic field is an incipient flood basalt province. Because of Iceland's location on the Mid-Atlantic Ridge, an oceanic spreading center that also overlie a mantle hotspot, the potential for gigantic eruptions is greatly enhanced.

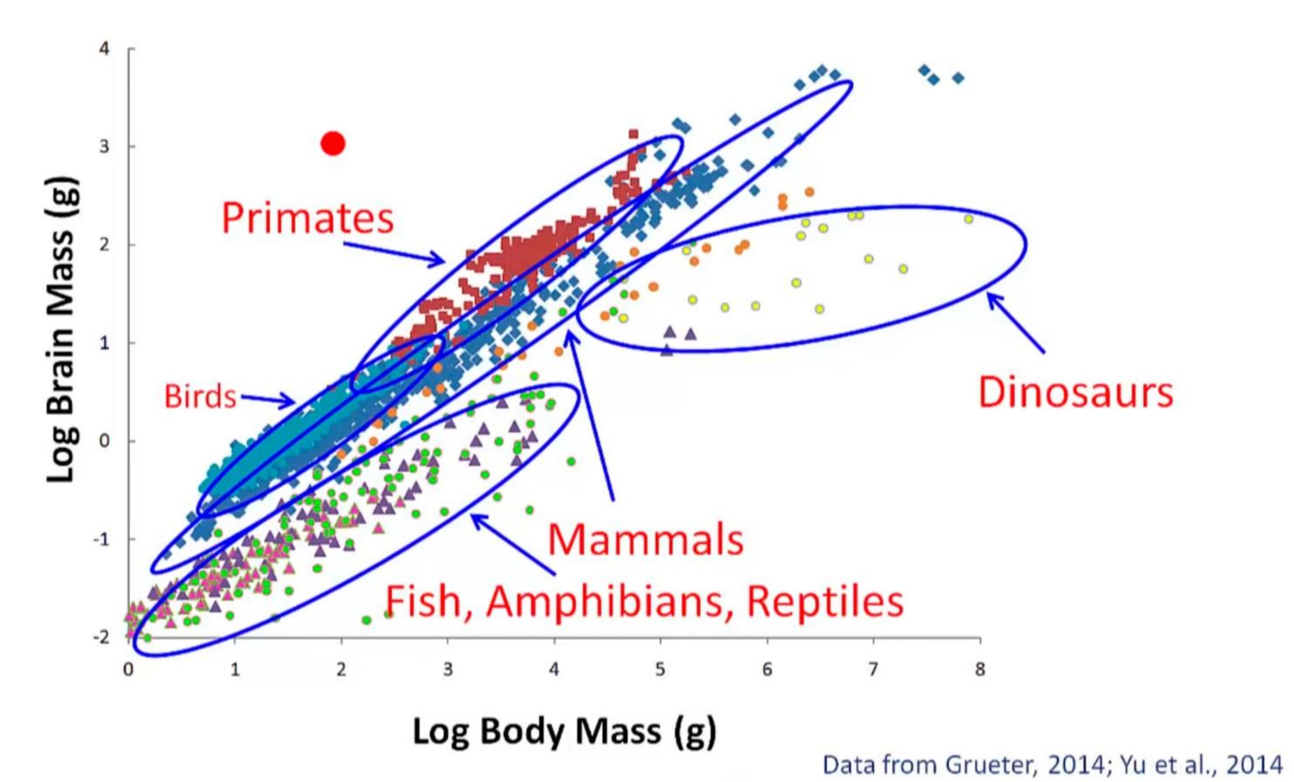


Figure 22. Brain mass and body mass and the emergence of humanity.

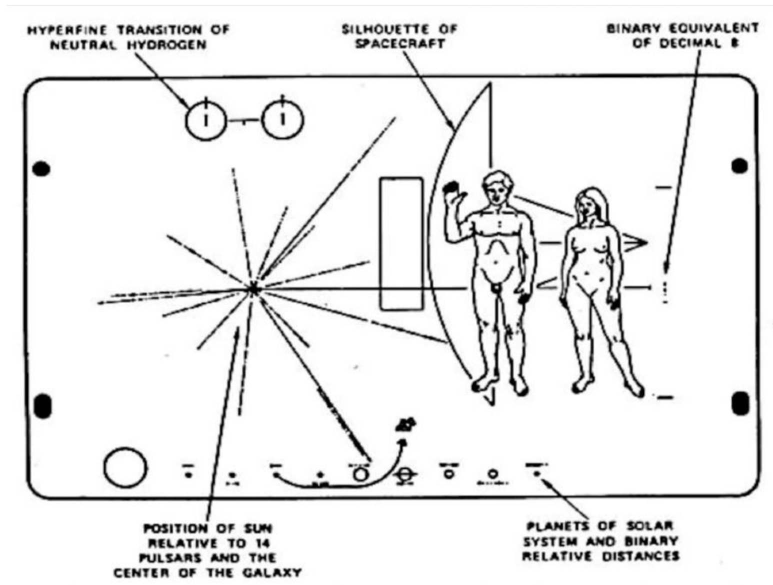


Figure 23. Pioneer 10 space craft plaque announcing the presence of humanity.

Figure 24. Pictorial announcement of the presence of humanity to the rest of the universe.

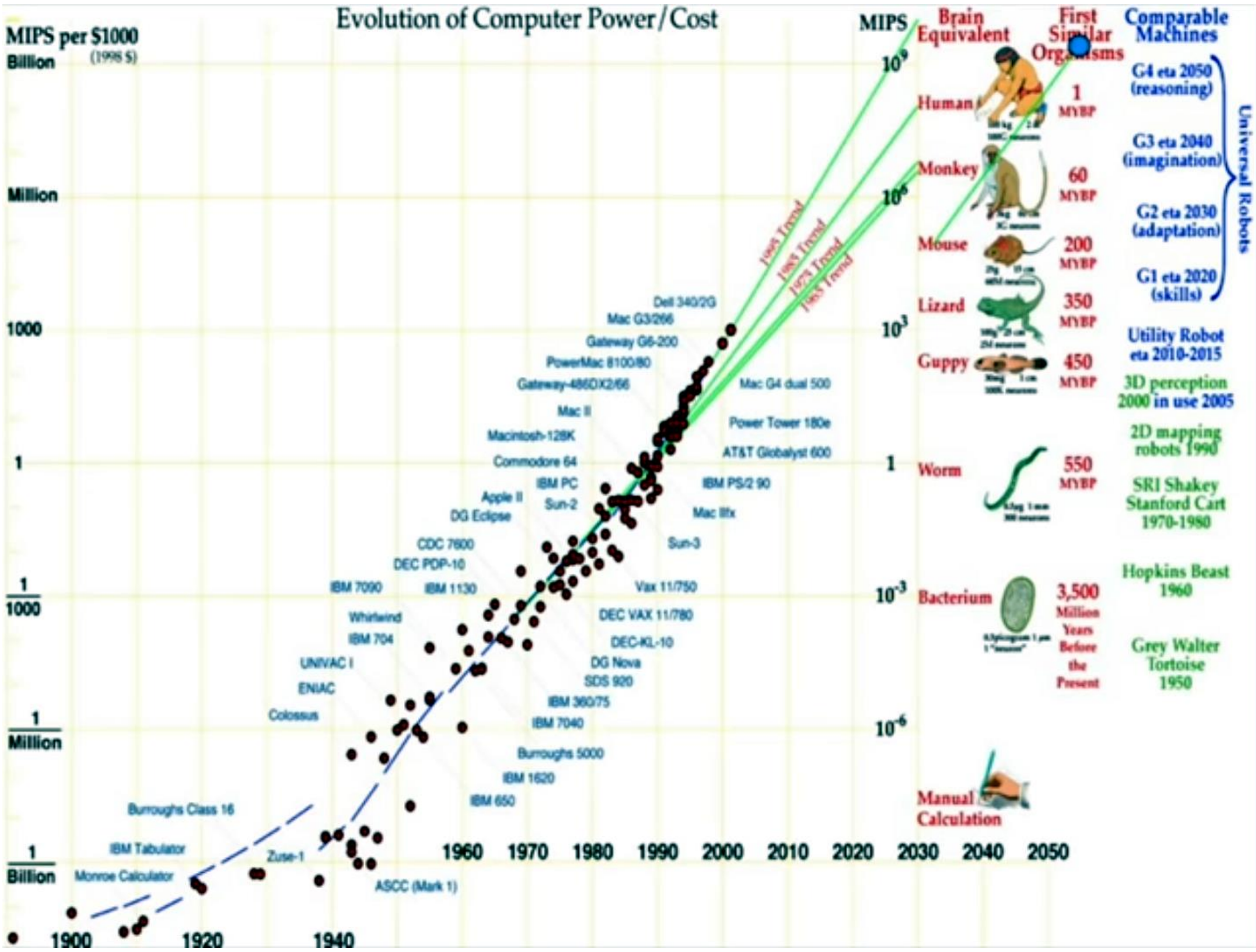


Figure 25.Evolution of computer power toward singularity.

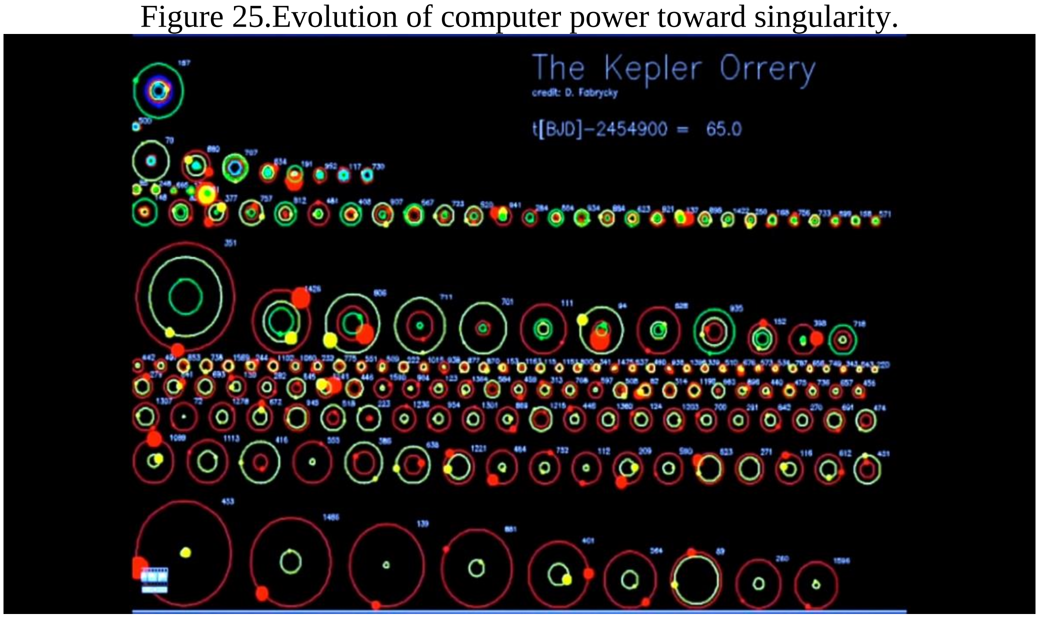


Figure 26. Kepler space telescope discovered exoplanets.

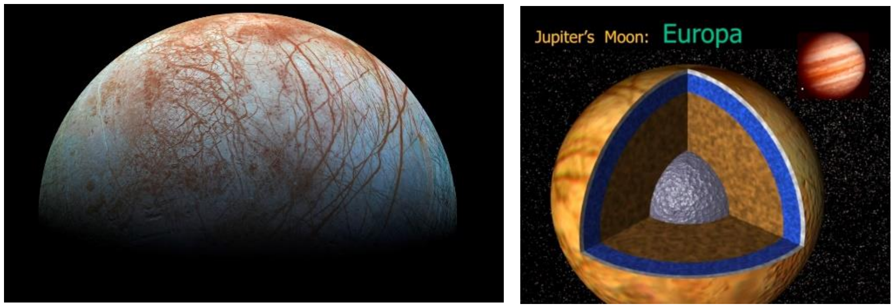


Figure 27. Ocean under Europa's 30 miles thick ice crust may harbor bacterial life.

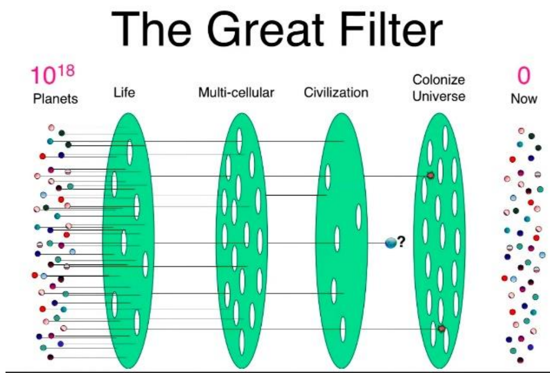


Figure 28. The Great Filter.

PAST SURVIVED FILTERS

1. Peaceful galaxy
2. Peaceful planet
3. RNA reproduction
4. Cells reproduction
5. Eukaryotes or complex cells survival
6. Sexual reproduction
7. Large brains
8. Civilization birth

POSSIBLE FUTURE FILTERS

1. Asteroid or comet impact
2. Global pandemic
3. Nuclear war
4. Earthquake swarms
5. Super-volcanic eruptions
6. Close supernova
7. Solar mass ejection
8. Robot rebellion

9. No starships
10. Loss of survival desire

MASS EXTINCTIONS

Global mass extinctions have occurred five times since the end of Cambrian time 500 million years ago, giving an average periodicity of 100 million years. There have also been many smaller extinction events in the geological record since the end of Precambrian time.

Mass extinctions with the percentage of all species that disappeared include: the Ordovician-Silurian: 85 percent; the late Devonian: 75 percent; the Permian-Triassic: 96 percent; theTriassic-Jurassic: 50 percent; and the Cretaceous-Tertiary: 65 percent. Extinctions have been correlated with astral impact events, flood basalt eruptions, and abrupt climate changes. Catastrophic methane release from the oceans is been proposed as a mechanism for past and future mass extinctions.

EFFECT OF THE SUN'S AGING

Life forms could survive on the Earth for the next 1.0 to 1.1 billion years. However as its mature star, the sun, uses up its nuclear fuel, it will grow hotter and expand in size. The Earth will thus also warm up significantly, its water will evaporate and escape from the upper atmosphere into space leaving the planet without surface water and therefore, without life as it is known today.

At 2.0 to 2.5 billion years in the future, the radioactive material in the Earth's interior will have substantially decayed and geothermal heat generation will be significantly reduced. The magma mantle currents and crustal plate tectonic movements would cease. The rotating outer core of the Earth would be no more molten and the Earth will lose its internal dynamo and hence the protection of its magnetic field. The solar wind would evaporate its remaining water turning it into a desolate dry desert like the planet Mars which does not have the benefit of a magnetic field.

At the time of merger between the Milky Way galaxy and the Andromeda galaxy, within 5.4 billion years, the 10 billion-year old sun star will have fused most of its hydrogen into helium atoms and would turn into a giant red star. It will expand in size during the next billion years and gobble up the inner planets, including Earth. In the longer term it will burn itself out into a white dwarf at the age of 11.2 billion years.

Life as it exists today would have by then disappeared, and our descendants would have evolved sufficiently to having found a way to escape the confines of their dying planet, spreading life into space and onto other hospitable moons, planets and universe(s).

POSTULATED FATE OF THE UNIVERSE

The universe has been expanding since its beginning albeit at a changing rate. During the inflationary period over the few first hundred million years the expansion rate was faster than it is now. The present rate of expansion is estimated at 1 part per 14×10^9 per year. Several theories exist about the future of cosmic evolution.

Cyclic universe theory

At larger than a critical density, it is thought that the universe would continue expanding for another 10 billion years at a decreasing rate of expansion until the gravitational forces would predominate leading to a collapse of the universe upon itself. After another 25 billion years it would become again a small hot dense spot starting another cycle of expansion and collapse or reincarnation with a period of 35 billion years.

Steady state universe theory

At below the postulated critical density, the expansion would slow down and eventually stop. There may still be a process of solar systems and stars death and rebirth and the universe may not initially change much. However, a heat death would occur with an evolution toward an eternal constant temperature.

Runaway inflationary universe theory

This would consist of continuous expansion and cooling of space where eventually the rate of expansion exceeds the speed of light. In this sobering scenario, the stars would ultimately die and an Earth observer would not be capable of detecting their dark and cold remnants. Unfortunately, the latest cosmic radiation data point to a universe that is currently expanding at an ever expanding rate. The possible explanation offered by scientists is that the universe is filled with dark energy as an anti gravitational repulsive force. Moreover, they postulate that this repulsive force is getting stronger. The observational evidence for the runaway expansion suggests a composition of the universe as given in Table 7.

M-Theory of multiple universes

M-theory was initially advanced by Caltech's Richard Feynman. It posits that multiple universes are created out of nothing, with many possible histories and many possible states of existence. In only a few of these states would life be possible, and in fewer still could something like humanity exist.

COSMIC MICROWAVE BACKGROUND

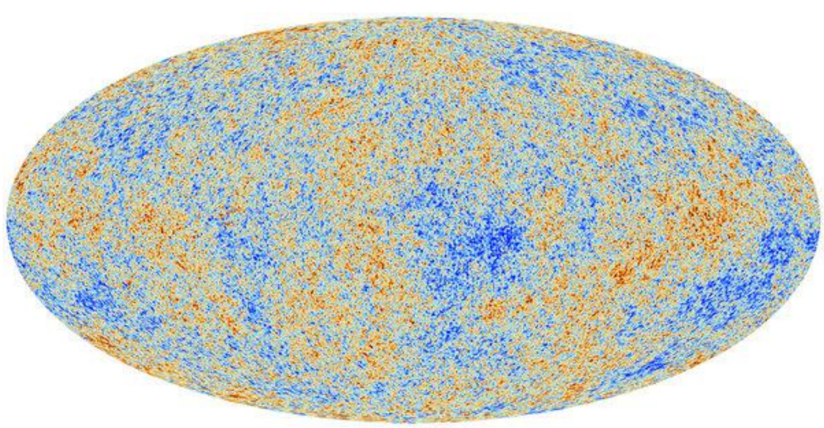


Figure 29. Cosmic microwave heat background by Planck's satellite, 370,000 years after Big Bang. Source: European Space Agency.

Microwaves importance in cosmology was discovered by accident in 1965 by a pair of Bell Laboratories radio astronomers, Arno Penzias and Robert W. Wilson, who later won the Nobel Prize in Physics. Using balloons, a U-2 spy plane and a series of satellites like the WMAP, astronomers have been teasing out the detailed features of this radiation. Recorded by the European Space Agency's Planck satellite, the heat map of the cosmos as it appeared 370,000 years after the Big Bang, shows cosmic space as speckled with faint spots from which galaxies would grow over billions of years.

The cosmos appears dominated by dark energy that seems to be pushing space apart and the almost-as-mysterious dark matter that is pulling galaxies together. The universe seems to have endured an explosive inflation, which was the driving force in the Big Bang.

Within the standard cosmological framework, puzzling anomalies exist that may yet lead theorists back to the drawing board. The universe appears to be slightly lumpier, with bigger and more hot and cold spots in the northern half of the sky as seen from Earth than toward the south, for example. And there is a large, unexplained cool spot in the northern hemisphere.

The microwaves detected by the Planck date from 370,000 years after the Big Bang, which is as far back as optical or radio telescopes will ever be able to see. The patterns within them date from less than a trillionth of a second after the Big Bang, when the universe would have undergone a violent burst of expansion known or inflation that set cosmic history on the course it has followed ever since.

By analyzing the relative sizes and frequencies of spots and ripples over the years has allowed astronomers to describe the birth of the universe to great precision. It seems the universe is 13.8 billion years old, instead of 13.7 billion, and consists by mass of 4.9 percent ordinary matter like atoms, 27 percent dark matter and 68 percent dark energy.

A surprise is that the universe is expanding slightly more slowly than previous measurements had indicated. The Hubble constant, which characterizes the expansion rate, is 67 km/sec per megaparsec according to Planck. Recent ground-based measurements combined with the WMAP data gave a value of 69, offering enough of a discrepancy to make cosmologists revise their computer simulations of cosmic history. This could mean that dark energy, which is speeding up the expansion of the universe, is more complicated than cosmologists thought.

The notion of inflation has been the backbone of Big Bang theorizing for 30 years. Under the influence of a mysterious force field during the first trillionth of a fraction of a second, what would become the observable universe ballooned by 100 trillion trillion times in size from a subatomic pinprick to a grapefruit in an eye-blink.

Submicroscopic quantum fluctuations in this force field are what would produce the hot spots in the cosmic microwaves, which in turn would grow into galaxies. Cosmologists still do not know what might have caused inflation. The Higgs boson is providing evidence that the kinds of fields that can provoke such behavior really exist.

THE SEARCH FOR DARK MATTER AND ANTIMATTER

Cosmologists have a general agreement that the universe is expanding at an increasing rate. According to astronomy, that does not make sense, and dark matter and energy are invoked to explain the unseen phenomena.

Table 7. Postulated composition of the universe.

Universe components	Percentage
Black matter keeps galaxies from gravitationally dislocate.	27
Dark energy as poorly understood invisible property of space accelerating the expansion of the universe.	68
Normal matter as protons, planets, stars and galaxies.	4.9

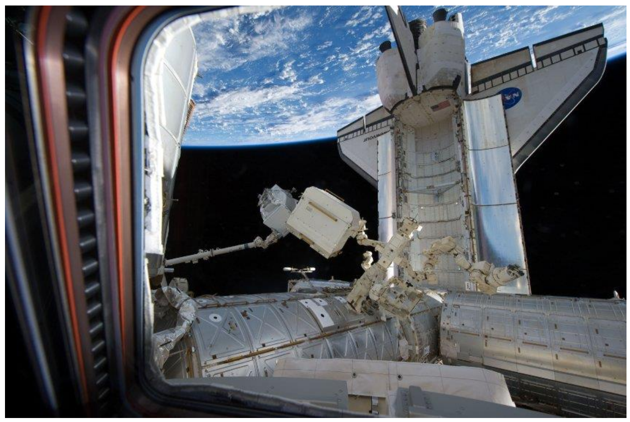


Figure 30. The Alpha Magnetic Spectrometer is looking on the International Space Station is looking for traces of antimatter in space. Source: NASA.

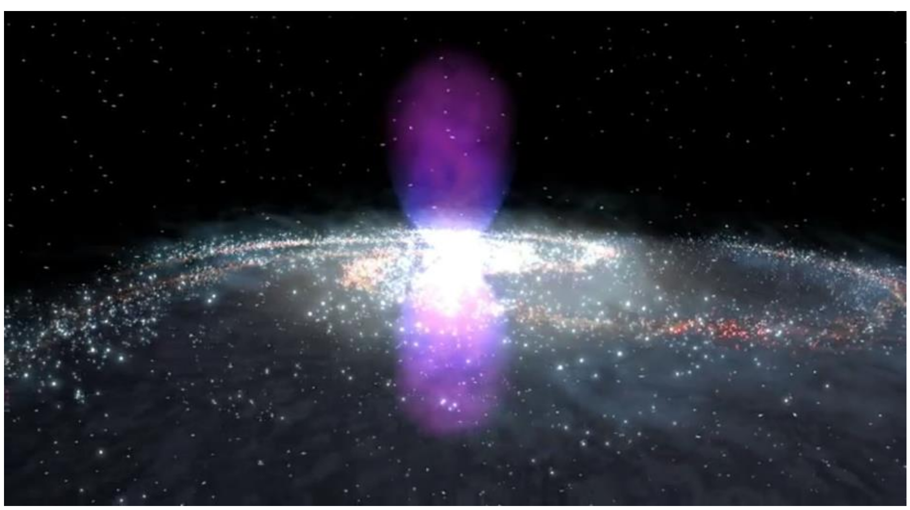


Figure 31. Antimatter halos emitted from massive black hole at the center of the Milky Way galaxy. Source: NASA.

Figure 32. Thunderstorms generate antimatter particles that can be trapped in the Earth’s magnetic field. Source: NASA.

Dark matter bends entire groups of galaxies with a force that is greater than the gravitational force of all the tens of thousands of suns combined. It is estimated to make up more than 80 percent of all matter but leaves behind little signs of its existence.

The total mass of dark matter rushing through the Earth is estimated to be only a single kilogram at any given moment. Nevertheless, there is still enough dark matter to form entire spiral galaxies since the WIMP particles also make their way into a place where there is nothing else: the almost endless vastness of the universe.

For about 80 years, astronomers have suspected that the universe contains dark matter. The term was coined by Fritz Zwicky, a Swiss astrophysicist, in 1933. It was only in the 1970s that scientists started trying to prove its existence. In 1980, USA astronomer Vera Rubin predicted that it would be found within a decade. More than 30 years later, the ghost particles are still at large. About a dozen experiments are underway worldwide to track it down, all of which are hidden deep inside mountain tunnels.

Italy’s Gran Sasso National Laboratory is shifting its emphasis from studying neutrinos to the search for dark matter. It is positioned in a tunnel that was drilled into the 2,900 m (9,500 ft) in height Gran Sasso Massif Mountain. The tunnel is 10 kms (6.2 miles) long and is topped by 1,400 meters of rock at its midpoint. The experiment involves ultra-sensitive detectors searching for the traces of invisible particles. About 1,000 physicists from 32 nations are conducting experiments in the facility. Most of them define dark matter as a still unknown type of massive particle. The galaxies could not exist without the dark matter. Visible matter alone is not sufficient to hold the rotating islands of stars together with their reciprocal gravitational forces.

Weakly Interacting Massive Particles, WIMPs

Scientists suspect that the answer to the question of what holds the galaxies together lies in the Weakly Interactive Massive Particles or WIMPs, which are massive hypothetical particles that could be heavier than the heaviest conventional atoms, though they hardly interact at all. WIMPS have remained invisible to partcle detectors, but they are assumed to exist everywhere around us. Billions of them rush through people, buildings and entire planets every second as if they were mere phantoms.

XENON100 Experiment

WIMPs are theoretical particles, but physicists are keen to prove their existence because their weak interaction with ordinary matter makes them excellent dark matter candidates. Elena Aprile, professor of physics at Columbia University, has been trying to observe this interaction with the XENON100 experiment in Italy.

The detector is composed of a refrigeration unit filled with 161 kg (355 pounds) of liquefied xenon, and the hope is that a WIMP's energy will penetrate the surface and interact with the xenon. The assumption is that a small flash of light will be produced if a WIMP collides with a xenon atom, thereby making the presence of dark matter indirectly perceptible.

Unfortunately, Aprile hypothesizes, there is only one reaction per year per ton of dark matter, so catching WIMPs takes a lot of patience. While Aprile's project detected six possible WIMPs in 100 days from January to May of 2011, three turned out to be electronic noise, and two more were found to be detection errors resulting from the radioactive nature of the experiment. With the other five ruled out, there was no sufficient evidence to support the idea that the final possible find was truly a WIMP.

The experiment uses one of the world's most sensitive cameras, though it only has 178 pixels. These light sensors are focused on a small barrel holding 100 kgs or 220 lbs of liquefied xenon. The xenon is cooled to - 100 degrees Celsius or - 148 degrees Fahrenheit. A newer version of the experiment using a ton of xenon, or about 10 times the current amount is planned.

DAMA Experiment

Competing teams of scientists have been competing in the WIMP wars. Another experiment is conducted by Rita Bernabei, a professor from Rome called DAMA. The design of the experiment depends on the premise that if dark matter fills the entire universe the Earth, as it orbits the sun, would have to move sometimes with and sometimes against the current of massive, invisible particles. The highest speed of the Earth relative to this particle flow occurs around June 2. In early June 2012, Bernabei's detector has registered an increase in particle collisions, just as it has for a decade. The DAMA team can specify the weight of the WIMPs with some accuracy, calculating that they are about as heavy as helium atoms. But this value is significantly lower than what most theorists expect it to be. The DAMA experiment also captures far more potential dark matter particles than theorists have predicted. Corroboration in the southern hemisphere is needed.

Filtering out Extraneous Radiation Sources

In the Xenon100 experiment, a constant electrical storm takes place within the xenon container witn an event about every second. The majority of events cannot be caused by collisions with dark matter, but by interfering radiation sources that must be filtered out. Of the millions of flashes they have registered, the Xenon researchers have only accepted three that merit careful future analysis.

Sources of radiation exist from cosmic rays, in the surrounding rock, the container and the air. Multiple shielding layers surround the dark matter detector. A layer of plastic protects against cosmic radiation from space. The plastic itself also emits radiation, thus a copper shield is added in front of it. The steel frame around the experiment emits radiation, and has to be shielded with a layer of lead. The lead also emits radiation, especially if it has been recently mined.

The most important protection against cosmic rays radiation from space is the 1,400 meters of dark dolomite rock separating the laboratory from the sky above. The rock shields the experiment as effectively as a 100-meter-thick slab of lead or 3,700 meters of water. Down in the tunnels, cosmic radiation is a million times weaker than it is on the Earth's surface, even though even that still causes disturbances.

The radioactive noble gas radon is evaporating underground as a decay product in the uranium and the thorium decay chains in the rocks underground. To protect against radon, filtered air is pumped into the containers at high pressure, as is done in clean rooms. Hopefully, only dark matter which penetrates everything -should reach the reaction container.

The Cuore experiment

In the Cuore experiment scientists use old lead from a sunken Roman trading ship. Lying on the seafloor for about 2,000 years, the lead is almost radiation-free.

Soudan Mine Experiment

In the Soudan Mine, an old iron mine in the USA state of Minnesota, two experiments are being conducted using methods similar to those of the DAMA experiment. The researchers are measuring the deformation of semiconductor crystals caused by collisions with WIMPs. One detector has reportedly already measured dark matter, while the other one has not.

Gravitational Lensing

Einstein predicted that the gravity of large objects could bend light to a noticeable degree. This is evident in a solar eclipse when the rays of the sun bend around the moon going toward Earth, and it is also one of the ways that scientists can detect the presence of dark matter indirectly. Katherine Freese, physicist and professor at the University of Michigan, studies far-off stars to see how their light is distorted on its path to Earth. Findings by her and other scientists studying gravitational lensing suggest that there must be much more dark matter than ordinary matter in the universe to account for the large distortion that appears.

Modified Newtonian Dynamics, MOND

In April 2012, a report by the European Southern Observatory, in Chile, had searched the movements of 400 stars in the vicinity of the sun for signs of dark matter and found nothing.

Carlos Frenk, a professor at the University of Durham, research group fed observation data from dwarf galaxies into computer models. The result is that dark matter appears to be warmer, and thus more energy-rich, than expected, if it exists at all. Frenk says that it is unclear whether dark matter can even be found. He considers the possibility that the laws of gravity could simply be adjusted to prove the existence of galaxies, according to a hypothesis called Modified Newtonian Dynamics (MOND).

On the other hand an international team around Jörg Dietrich, an astronomer from the University Observatory Munich, believes that it has convincingly detected a giant filament of dark matter forming a bridge between a pair of galaxy clusters 2.7 billion light-years away.

THE SEARCH FOR DARK ENERGY

Supernovae

An astrophysicist at the Lawrence Berkeley National Laboratory and professor at the University of California, Berkeley, Saul Perlmutter was one of the scientists behind the discovery of the accelerating universe that shook the astronomy world. His team observed a large cluster of galaxies, attempting to spot a supernova in a distant galaxy. By observing where these supernovae came from, Perlmutter and his team also saw how much that particular cluster of galaxies had changed since that explosion. Gathering evidence from other supernovae showed an even more interesting result: The expansion of the universe was decelerating up until five billion years ago, but is now rapidly expanding, caused by the fact that dark energy makes up about 70 percent of the universe. Perlmutter is collaborating with research teams from seven countries to continue measuring the universe's rate of expansion.

Multiple Universes Hypothesis

Brian Greene suggests of the possibility of multiple universes in his book: "The Hidden Reality." He hypothesizes that when the Big Bang occurred and the universe began to form as pockets of gas opened up, other pockets could have opened up alongside ours, potentially creating other universes. Perhaps, he says, our universe was one of the fortunate ones that ended up with just the right amount of dark energy to forge stars and galaxies, and eventually foster human life. This suggests that we are living in a Goldilocks universe at just the right temperature of the porridge.

CURVATURE COSMOLOGY

A static universe may provide a better explanation for the properties of the cosmos than the Big Bang Theory and avoids the nagging problems of dark matter and dark energy.

The common attribute of all Big Bang cosmologies is that they are based on the assumption that the universe is expanding. However examination of the evidence for this expansion favors a static universe.

David Crawford considers the major topics of: Tolman surface brightness, angular size, type 1a supernovae, gamma ray bursts, galaxy distributions, quasar distributions, X-ray background radiation, cosmic microwave background radiation, radio source counts, quasar variability and the Butcher--Oemler effect. An analysis of the best raw data for these topics shows that they are consistent with expansion only if there is evolution that cancels the effects of expansion.

An alternate cosmology, curvature cosmology, is in full agreement with the raw data. This tired-light cosmology predicts a well defined static and stable universe and is fully described. It not only predicts accurate values for the Hubble constant and the temperature of cosmic microwave background radiation but shows excellent agreement with most of the topics considered. Curvature cosmology also predicts the deficiency in solar neutrino production rate and can explain the anomalous acceleration of the Pioneer 10 satellite.

The idea that the universe began in an event called the Big Bang some 13 billion years ago has a special place in science and in our society and has a religious origin in the Bible Book of Genesis.

The evidence is persuasive. Distant galaxies all appear to be moving away from us at great speed, which is exactly what you'd expect if they were created in a Big Bang type event many billions of years ago. Such an event might also have left an echo, exactly like the one we can see as the cosmic microwave background radiation.

The Big Bang seems so elegant an explanation that we are prepared to overlook the one or two anomalies that don't quite fit, like the fact that distant galaxies aren't travelling fast enough to have moved so far since the Big Bang, a problem that inflation was invented to explain. Then there are the problems of dark matter and dark energy, which defy explanation.

A legitimate question is whether there is an alternative hypothesis that also explains the observations. David Crawford at the University of Sydney in Australia gives us another. He says all this can be explained just as well by a static universe in which the space-time continuum is curved. He says this explains most of the major characteristics of our universe without the need for dark matter or dark energy. Neither is there any need for inflation in a static universe.

He has to make one or two new assumptions but he argues these are no more difficult to swallow than things like inflation which we have to accept in the Big Bang model. His main idea, which he has championed for a couple of years now, is that the red-shift associated with distant galaxies is caused by the interaction of photons with other low energy photons in curved space, an idea called the tired-light model.

For such an effect to operate, space would have to be filled with a high-temperature plasma which would be easily identified by the light it emits. Crawford says the observed x-ray background radiation between 10 and 300 keV could easily be the signature of such a plasma. The cosmic microwave background, he says, can also be explained like this: it is by high energy electrons in this plasma that interact with photons passing through.

Red shift data is also used to infer the rotation rates of galaxies. These seem to be spinning so fast that they ought to fly apart--so astronomers have hypothesized that they must contain mountains of dark matter to provide the gravitational tug to hold them together. Crawfrod says this problem disappears is the red shift effect comes not from the movement of the galaxies but from the new plasma effect in curved space between here and there. A similar kind of reasoning does away with the need for dark energy too.

This model explains at least one thing that leaves conventional cosmologists scratching their heads: the strange deceleration of the Pioneer spacecraft at the edge of the Solar System. This is construed to be caused by the interaction between the spacecraft, the cosmic plasma and interplanetary dust, which must be a little denser than current estimates.

SUPERSYMMETRY

The Standard Model only describes 4-5 percent of our known universe. About 25 percent is made up of dark matter that keeps the rotating galaxies from flying apart. That cannot be explained with visible matter alone. Dark energy accounts for the 75 percent that remain. It causes the universe to expand at an ever faster rate. We still do not understand the mechanism which expands space equally in all directions. The Higgs field, which is part of the Higgs particle possesses a characteristic that fits with dark energy as it acts in all directions simultaneously.

Scientists suspect that there is a similar field beyond the Standard Model represented by the other end of the bridgehead. The Higgs boson particle that helps provide all other particles with mass has been found and it completes the Standard Model of physics. Scientists will thrive to find the path in this model through which they can advance to the remaining 95 percent of the universe.

Supersymmetry is the theory which holds that every particle also has a shadow particle -- a mirror world predicted by the theory of anti-matter. Supersymmetry's lightest particle could be stable enough to be within the reach of the Large Hadron Collider (LHC) accelerator. It would be a good candidate for understanding dark matter.

DISCUSSION

Protons were fired at each other at the LHC accelerator which was then shut down for two years for maintenance work. When restarted, step by step the energy was doubled allowing the generation of particles with greater mass exceeding the threshold to dark matter. Antihydrogen and antihelium atoms were detected.

Energy and not the size of particles is what matters. A suggestion is that the next project would be an accelerator that fires electrons at positrons turning matter into energy through the annihilation process of matter and antimatter. That would provide a new view of matter, and of the Higgs particle. Some region of the world should volunteer to adopt such an undertaking.

EXERCISE

1. The energy of a photon is expressed as: $E = h\nu$, where h is Planck's constant and ν is the electromagnetic radiation's frequency. Compare the energy carried by photons in units of electron-volts (eV) in different parts of the electromagnetic spectrum:

a. The visible region.

b. The x-ray region.

c. The gamma ray region, which is of particular interest for nuclear phenomena.

Note: $h = 4.136 \times 10^{-15}$ [eV.sec]

APPENDIX

SIX BLIND MEN

"In a distant village, lived six blind men. One day the villagers announced, "Hey, there is an elephant in the village today."

They had never seen or felt an elephant before and so decided, "Even though we would not be able to see it, let us go and feel it anyway." And thus they went down to the village to touch and feel the elephant to learn what animal this was and they described it as follows:

"Hey, the elephant is a pillar," said the first man who touched his leg.
"Oh, no! it is like a rope," argued the second after touching the tail.
"Oh, no! it is like a snake," the third man spouted after touching the trunk.
"It is like a big hand fan" said the fourth man feeling the ear.
"It is like a huge wall," sounded the fifth man who groped the belly.
"It is like a spear," Said the sixth man with the tusk in his hand.

They all fell into heated argument as to who was right in describing the big beast, all sticking to their own perception.

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