

# The History of the Universe in 1000 Words or Less

The origin and fate of the universe



Manjunath.R

## **The History of the Universe in 1000 Words or Less:**

**The origin and fate of the universe**



"The only true wisdom is in knowing you know nothing."

– Socrates

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## Dedication

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I **dedicate** this book to everyone who has contributed significantly to our understanding of the universe as a whole, why it is the way it is, and why it even exists.

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## Acknowledgements

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Without the amazing work of some renowned cosmologists and physicists, their creativity, and their inventiveness in the field of cosmology, this book would not have been accomplished. I would like to use this opportunity to thank my dearest friend and well-wisher "**Lawrence**" for his unwavering support during the **COVID crisis** and for giving me access to all the resources I needed to finish this book. I want to express my gratitude to my family for their support and encouragement as I wrote this book, especially to my **mother**, who has been a tremendous source of inspiration in my life. I owe a lot of gratitude to my mother for teaching me how to be perseverant and strong in life. Finally, I want to emphasize how crucial patience is when writing a book or taking on any other project in life.

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"Through our eyes, the universe is perceiving itself. Through our ears, the universe is listening to its harmonies. We are the witnesses through which the universe becomes conscious of its glory, of its magnificence."

—Alan Wilson Watts



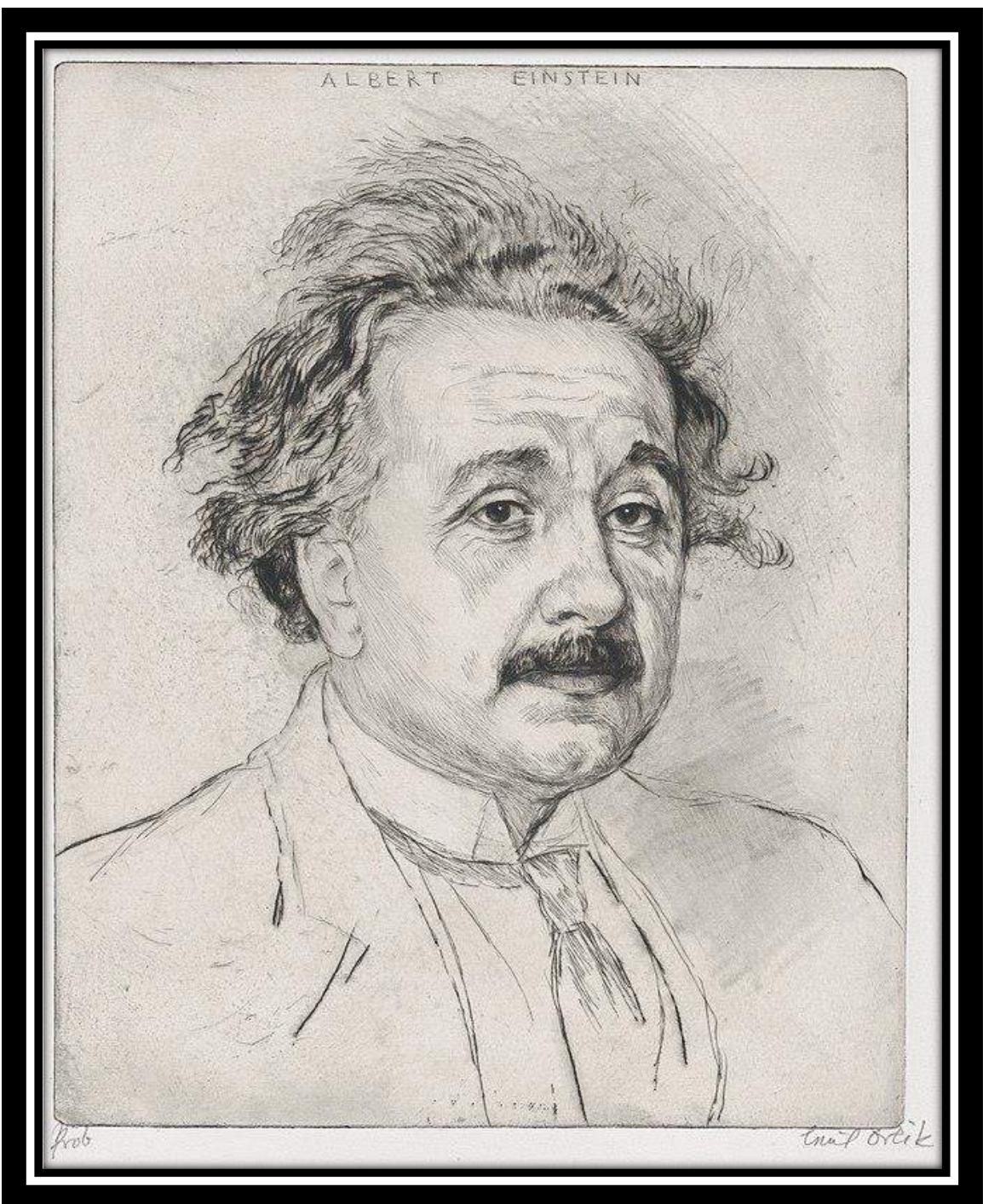
## Introduction

**Each** theoretical model approach has had some degree of success, and string theoretical physicists' approaches in particular are proving to be effective in solving several challenging cosmological issues. But neither **loop quantum gravity** (where the idea that space itself is formed of small loops is presented) nor **string theory** has undergone experimental investigation. The hard "**Theory of everything**," which would explain everything from fundamental particles and their interactions to the universe's overall structure, is still unknown to us at this time. **Even** if we start out figuring the cosmos is already pretty damn difficult, all we need to know right now is that it's a lot more challenging than we might believe. **We** human beings – who are ourselves mere collections of **fundamental particles of nature** – **unsure of why there is a Higgs boson and why it has the mass that it has** – try to wonder, seek answers and gazing at the immense heavens above, we have always asked a multitude of questions: What does matter consist of? Why does gravity seem so odd? Why does it seem like time moves in only one direction? How old is the Universe? What happened to all the antimatter? How does life begin? Can a single unified theory of physics be discovered? **How were the heavier elements, such as uranium and iron, created?** What is space and time made of? What kind of thing is consciousness? What are the underlying principles of quantum theory? **How are we going to combine Einsteinian relativity and quantum mechanics?** What sort of physics exists outside of the standard model? Is it necessary to develop a new theory of light and matter to account for what arises at very high energy and temperatures? **What is gravity, anyway?** What is the currently most accepted model for the Universe? Are there any other dimensions? Do we really exist in a false vacuum? Do the forces of the cosmos converge into one? Are there naked singularities? Where does quantum strangeness stop? **What was there prior to the Big Bang?** We advance in time for what reason? Why are there three dimensions in space? Can energy be created out of nothing? How long is the life of a proton? The universe is vast, but is it infinite? How did the cosmos start? **Where did we come from?** Why is there a time arrow? **Exist there worlds outside our own?** What will happen to the universe? Does string theory hold true? Is chaos governed by order? Was the universe's entropy exceptionally low when the Big Bang created it, 14 billion years ago? Many others! These questions continue to trouble scientists

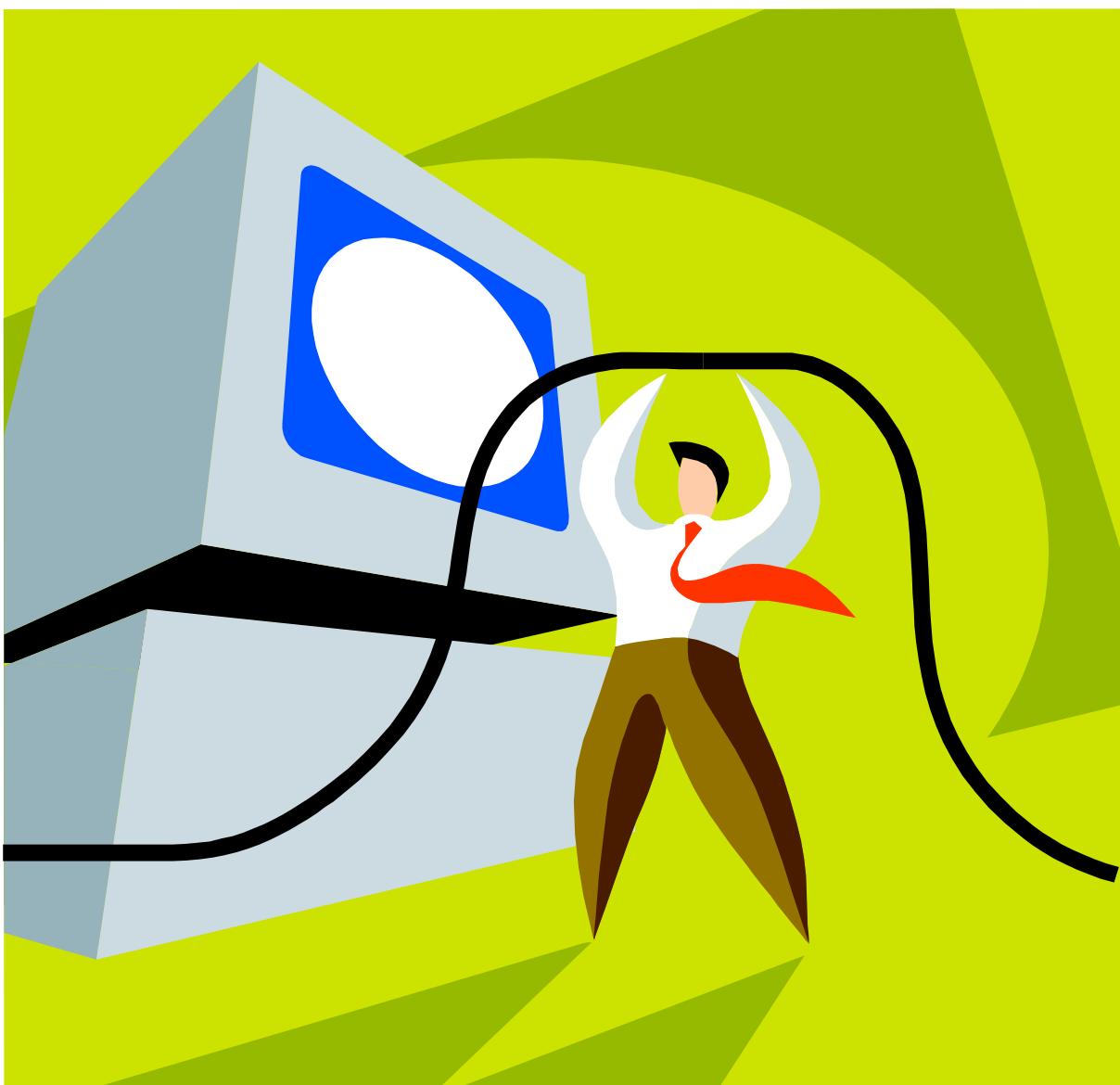
despite the massive amounts of data coming in from observatories around the globe and from particle physics experiments like the **Large Hadron Collider in Switzerland**, as well as despite the countless hours that astronomers and physicists spend in front of a blackboard or running computational simulations.

The **standard model of particle physics** is an incredible accomplishment. But we are aware of its limitations. There is no gravity in it. Dark matter and dark energy are not discussed. However, there are currently no alternatives that are better. Recent cosmological findings demonstrate that **ordinary matter** and **dark matter** still fall short of fully explaining the universe's overall structure. There is a third constituent present, but it isn't matter; it's a hypothetical kind of **dark energy** that acts as the opposite of gravity by exerting a repellent, negative force. One of the main initiatives that have united cosmologists and particle physicists together is the search for the underlying principles and physical laws that we need to advance beyond the physics of today. This book is a glimpse into the **living story of our universe** and a clear, readable and self-contained introduction to the story of how our understanding of the cosmos has evolved significantly over time. It fills the gap and addresses the issues that are important to everyone, or at least to everyone reading this book, and it inspires us to explore the entire cosmos from creation to ultimate destruction, with a wealth of secrets at every turn with an improved comprehension of what time is and what makes it unique.

This book concentrates on presenting the subject from the understanding perspective of cosmology and brings the reader right up to date with curious aspects of cosmology established over the last few centuries. This book assumes **cosmology a journey not a destination** and the advance of knowledge is an infinite progression towards a goal that forever recedes. This book will be of interest to students, teachers and general science readers interested in fundamental ideas of cosmology from the infinitely hot and dense **Big Bang** to the present day and on into the future. No physicist today would boldly proclaim that our understanding of the ever-expanding physical cosmos is nearly complete. On the alternative, every recent revelation would seem to open a **Gordian knot** of new, more complicated cosmological challenges.

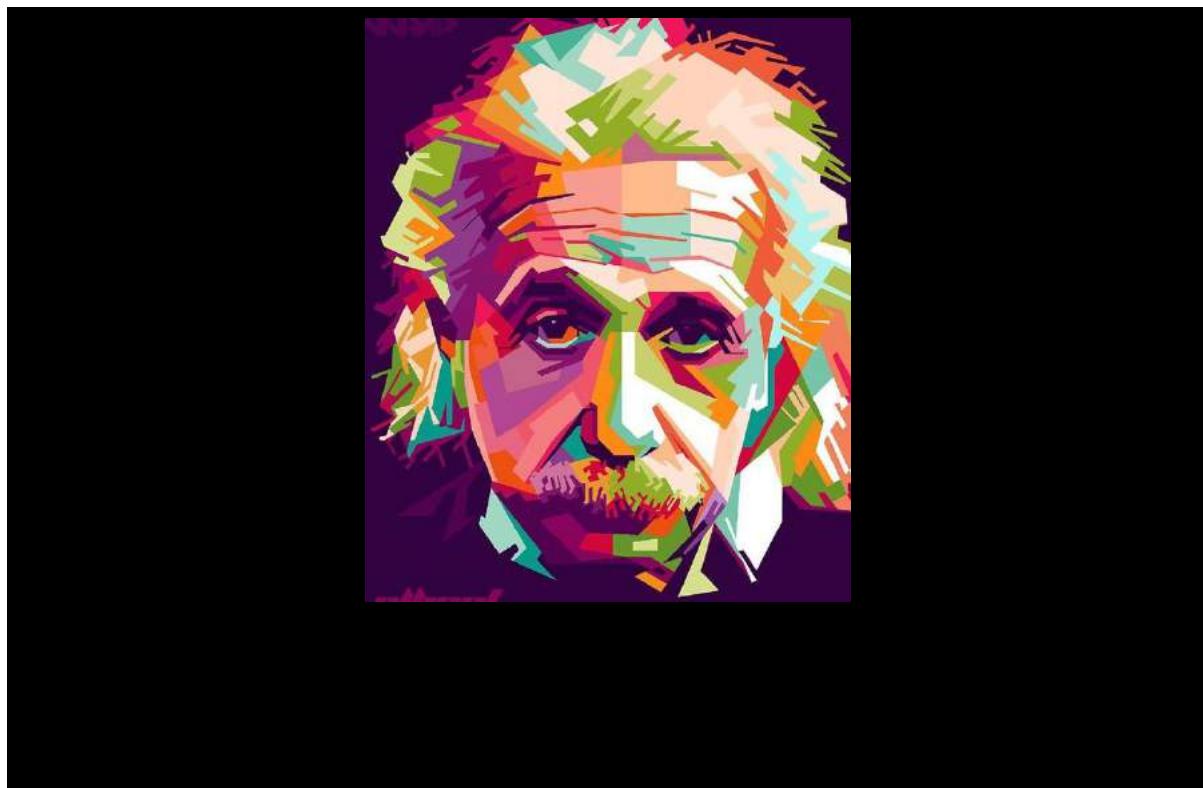


Albert Einstein



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## THE HISTORY OF THE UNIVERSE IN 1000 WORDS OR LESS

**The effort to understand the universe is one of the very few things that lifts human life a little above the level of farce, and gives it some of the grace of tragedy.**

– Steven Weinberg

- **Cosmic Event** in which our universe was born.
- **Cosmic Inflation** in which the **Grand Unified Force** was separated into the Four Forces of Nature (**gravity, electromagnetic, the weak force and the strong force**) as We Now Know Them, and the space expanded by a factor of the order of  $10^{26}$  over a time of the order of  $10^{-36}$  to  $10^{-32}$  seconds to Many Times Its Original Size in a Very Short Period of Time – Rapid expansion in which the universe super cooled, though not Quite as Quickly from about  $10^{27}$  down to  $10^{22}$  Kelvins.
- There were 2 types of fundamental particles: quarks and leptons. Quarks felt the strong interaction, leptons did not. Both quarks and leptons felt the other three interactions.
- **PARTICLE-ANTIPARTICLE ANNIHILATION** in which All the Antiparticles in the Universe Annihilated Almost All the Particles, Creating a Universe Made Up of Matter and Photons (which did not possessed electrical charge nor did they had any rest mass) and no antimatter. This process satisfied a number of conservation laws including:
  - **Conservation of electric charge:** The net charge before and after is zero.
  - **Conservation of momentum and energy:** The net momentum and energy before and after is zero.

If the positron and the electron were moving very slowly, then they went into orbit round each other producing a quasi-stable bound atom-like object called positronium. **Positronium** was very unstable: the positron and the electron invariably destroyed each other to produce high energetic gamma photons.

- DEUTERIUM AND HELIUM PRODUCTION in which Many of the positively charged Protons and electrically neutral Neutrons in the Early Universe Combined to Form Heavy Hydrogen and Helium. The proton was composed of two up quarks and one down quark and the neutron was composed of two down quarks and one up quark.

$$\text{Charge on the up quark was } +\frac{2}{3} \times 1.6 \times 10^{-19} \text{ coulombs}$$

$$\text{Charge on the down quark was } -\frac{1}{3} \times 1.6 \times 10^{-19} \text{ coulombs}$$

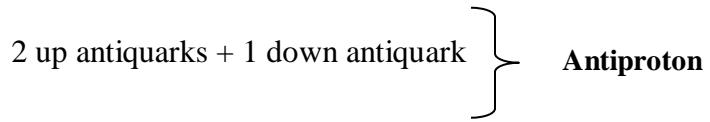
The charge on the proton was approximately  $+ 1.6 \times 10^{-19}$  coulombs and that on the electron was  $-1.6 \times 10^{-19}$  coulombs.

**Intrinsic energy of a proton or a neutron** was = Kinetic Energy of quarks +  
Potential Energy of quarks + intrinsic energy of quarks

- RECOMBINATION in which Electrons Combined with Hydrogen and Helium Nuclei, Producing Neutral Atoms. A neutrino was passed through matter then it reacted with a proton to produce a positively charged particle with the same mass as the electron—this particle was the positron. The properties of the strong force were such that the quarks did not all stick together in one large mass (otherwise the newly born universe would have been a huge lump of fundamental constituent of matter). The strong force ensured that quarks and antiquarks could only stick together in groups of three:

or

$$2 \text{ up quarks} + 1 \text{ down quark} \quad \left. \right\} \quad \text{Proton}$$



or as a quark and an antiquark pair (up quark + up antiquark).

- GALAXY FORMATION in which the Milky Way Galaxy (consisted of  $\approx 10^{11}$  stars) was Formed – TURBULENT FRAGMENTATION in which a Giant Cloud of Gas Fragments broke into Smaller Clouds, which later Became Protostars – MASSIVE STAR FORMATION in which a Massive Star was Formed. The star's gravity tried to squeeze the star into the smallest ball possible. But the nuclear fusion reaction in the star's core created strong outward radiation pressure. This outward radiation pressure resisted the inward squeeze of a force called **gravity**.
- STELLAR EVOLUTION in which Stars Evolved and Eventually Died – IRON PRODUCTION in which Iron was Produced in the Core of a Massive Star, Resulting in a Disaster called SUPERNOVA EXPLOSION in Which a Massive Star Ended Its Life by Exploding outpouring electromagnetic radiation over a very short period of time – STAR FORMATION in which the Sun was Formed within a cloud of gas in a spiral arm of the Milky Way Galaxy. There was a mass limit to neutron stars. It was approximately about 4 solar mass. Beyond this limit the degenerate neutron pressure was not sufficient to overcome the gravitational contraction and the star collapsed to black holes. There was no mass limit to the mass of a black hole.
- PLANETARY DIFFERENTIATION in which the vast disk of gas and debris that swirled around the sun giving birth to planets, moons, and asteroids. Planet Earth is the third planet out – VOLATILE GAS EXPULSION in which the Atmosphere of the Earth was Produced – MOLECULAR REPRODUCTION in which Life on Earth was created.
- PROTEIN CONSTRUCTION in which Proteins were built from organic compounds that contain amino and carboxyl functional groups (**Amino Acids**) – FERMENTATION in which Microorganisms Obtained Energy by converting sugar into alcohol – CELL DIFFERENTIATION in which dividing cells changed their functional or phenotypical type and Eukaryotic Life had a beginning.

- RESPIRATION in which Eukaryotes Evolved to Survive in an Atmosphere with Increasing Amounts of Oxygen – MULTICELLULAR ORGANISMS CREATION In Which Organisms Composed of Multiple Cells emerged – SEXUAL REPRODUCTION in Which a New Form of Reproduction Occurred and with the invention of sex, two organisms exchanged whole paragraphs, pages and books of their DNA helix, producing new varieties for the sieve of natural selection. And the natural selection was a choice of stable forms and a rejection of unstable ones. And the variation within a species occurred randomly, and that the survival or extinction of each organism depended upon its ability to adapt to the environment. And organisms that found sex uninteresting quickly became extinct.
- EVOLUTIONARY DIVERSIFICATION in which the Diversity of Life Forms on Earth Increased Greatly in a Relatively Short Time – TRILOBITE DOMINATION In Which Trilobites (an extremely successful subphylum of the arthropods that were at the top of the food chain in Earth's marine ecosystems for about 250 million years) Ruled the Earth.
- LAND EXPLORATION In Which Animals First Venture was Onto Land – COMET COLLISION in which a Comet smashed the Earth – DINOSAUR EXTINCTION In Which an asteroid or comet slammed into the northern part of the Yucatan Peninsula in Mexico. This world-wide cataclysm brought to an end the long age of the fossil reptiles of the Mesozoic era (**dinosaurs**)
- MAMMAL EXPANSION in which Many Species of warm-blooded animals with hair and backbones was developed – HOMO SAPIENS MANIFESTATION In Which our caveman ancestors Appeared in Africa from a line of creatures that descended from apes.
- LANGUAGE ACQUISITION in which something called curiosity ensued which triggered the breath of perception and our caveman ancestors became conscious of their existence and they learned to talk and they Developed Spoken Language – GLACIATION in which the formation, movement and recession of glaciers Began.
- INNOVATION in which Advanced Tools were Widely made and Used – RELIGION In Which a Diversity of Beliefs emerged – ANIMAL DOMESTICATION in which Humans Domesticated Animals.

- FOOD SURPLUS PRODUCTION In Which Humans Developed and promoted the practice of cultivating plants and livestock – INSCRIPTION In Which Writing was Invented and it allowed the communication of ideas.
- WARRING NATIONS In Which Nation Battled Nation for Resources – EMPIRE CREATION AND DESTRUCTION In Which the First Empire in Human History Came and went – CIVILIZATION In Which Many and Sundry Events Occurred.
- CONSTITUTION In Which a Constitution was Written to determine the powers and duties of the government and guarantee certain rights to the people in it – INDUSTRIALIZATION in Which Automated Manufacturing and Agriculture Revolutionized the World – WORLD CONFLAGRATIONS In Which Most of the World was at War.
- FISSION EXPLOSIONS In Which Humans Developed the most dangerous weapons on earth (**Nuclear Weapons**) – COMPUTERIZATION In Which Computers were Developed to carry out sequences of arithmetic or logical operations automatically.
- SPACE EXPLORATION In Which Humans Began to Explore Outer Space which fuelled interest in exploring and discovering new worlds – pushing the boundaries of the known – and expanding scientific and technical knowledge – POPULATION EXPLOSION In Which the Human Population of the Earth Increased at a Very Rapid Pace.
- SUPERPOWER CONFRONTATION In Which Two Powerful Nations Risked it All – INTERNET EXPANSION In Which a Network of Computers Developed to carry out a vast range of information resources and services.
- RESIGNATION In Which One Human Quitted His Job – REUNIFICATION In Which a Wall went Up and Then Came Down.
- WORLD WIDE WEB CREATION In Which a New Medium was Created to meet the demand for automated information-sharing between scientists in universities and institutes around the world – COMPOSITION In Which a Book was Written – EXTRAPOLATION In Which Future Events were Discussed.

**Nothing happens until something moves.**

– **Albert Einstein**

Ever since the beginning of **human civilization**, we have not been in a state of satisfaction to watch things as incoherent and unexplainable. While we have been thinking whether the universe began at the big bang singularity and would come to an end either at the big crunch singularity, we have converted at least a thousand joules of energy in the form of thoughts. This has decreased the disorder of the human brain by about few million units. Thus, in a sense, the evolution of human civilization in understanding the universe has established a small corner of the order in a **human brain**. However, the burning questions still remain unresolved, which set the human race to keep away from such issues. Many **early native postulates** have fallen or are falling aside – and there now alternative substitutes. In short, while we do not have an answer, we now have a whisper of the grandeur of the problem. With our limited brains and tiny knowledge, we cannot hope to have a complete picture of unlimited speculating about the gigantic universe we live in.

In 1911, fresh from completion of his PhD, the young Danish physicist Niels Bohr left Denmark on a foreign scholarship headed for the Cavendish Laboratory in Cambridge to work under J. J. Thomson on the structure of atomic systems. At the time, Bohr began to put forth the idea that since light could no longer be treated as continuously propagating waves, but instead as discrete energy packets (as articulated by Planck and Einstein), why should the classical Newtonian mechanics on which Thomson's model was based hold true? It seemed to Bohr that the atomic model should be modified in a similar way. If electromagnetic energy is quantized, i.e. restricted to take on only integer values of  $h\nu$ , where  $\nu$  is the frequency of light, then it seemed reasonable that the mechanical energy associated with the energy of atomic electrons is also quantized. However, Bohr's still somewhat vague ideas were not well received by Thomson, and Bohr decided to move from Cambridge after his first year to a place where his concepts about quantization of electronic motion in atoms would meet less opposition. He chose the University of Manchester, where the chair of physics was held by Ernest Rutherford. While in Manchester, Bohr learned about the nuclear model of the atom proposed by Rutherford. To overcome the difficulty associated with the classical collapse of the electron into the nucleus, Bohr proposed that the orbiting electron could only exist in certain special states of

motion - called stationary states, in which no electromagnetic radiation was emitted. In these states, the angular momentum of the electron L takes on integer values of Planck's constant

divided by  $2\pi$ , denoted by  $\hbar = \frac{h}{2\pi}$  (pronounced h-bar). In these stationary states, the electron

angular momentum can take on values  $\hbar, 2\hbar, 3\hbar\dots$  but never non-integer values. This is known as quantization of angular momentum, and was one of Bohr's key hypotheses. Bohr Theory was very successful in predicting and accounting the energies of line spectra of hydrogen i.e. one electron system. It could not explain the line spectra of atoms containing more than one electron. For lack of other theories that can accurately describe a large class of arbitrary elements to must make definite predictions about the results of future observations, we forcibly adore the theories like the big bang, which posits that in the beginning of evolution all the observable galaxies and every speck of energy in the universe was jammed into a very tiny mathematically indefinable entity called the **singularity** (or the primeval atom named by the **Catholic priest Georges Lemaitre**, who was the first to investigate the origin of the universe that we now call the big bang). This extremely dense point exploded with unimaginable force, creating matter and propelling it outward to make the billions of galaxies of our vast universe. It seems to be a good postulate that the anticipation of a mathematically indefinable entity by a scientific theory implies that the theory has ruled out. It would mean that the usual approach of science of building a scientific model could anticipate that the universe must have had a beginning, but that it could not prognosticate how it had a beginning. Between 1920s and 1940s there were several attempts, most notably by the British physicist **Sir Fred Hoyle** (a man who ironically spent almost his entire professional life trying to disprove the big bang theory) and his co-workers: **Hermann Bondi and Thomas Gold**, to avoid the cosmic singularity in terms of an elegant model that supported the idea that as the universe expanded, new matter was continually created to keep the density constant on average. The universe didn't have a beginning and it continues to exist eternally as it is today. This idea was initially given priority, but a mountain of inconsistencies with it began to appear in the mid 1960's when observational discoveries apparently supported the evidence contrary to it. However, Hoyle and his supporters put forward increasingly contrived explanations of the observations. But the final blow to it came with the observational discovery of a faint background of microwaves (whose wavelength was close to the size of water molecules) throughout space in 1965 by Arno Penzias

and Robert Wilson, which was the "**the final nail in the coffin of the big bang theory**" i.e., the discovery and confirmation of the cosmic microwave background radiation (which could heat our food stuffs to only about -270 degrees Centigrade — 3 degrees above absolute zero, and not very useful for popping corn) in 1965 secured the Big Bang as the best theory of the origin and evolution of the universe. Though **Hoyle** and **Narlikar** tried desperately, the steady state theory was abandoned.

With many bizarre twists and turns of Humanity's deepest desire for knowledge, super strings – a generalized extension of **string theory** which predicts that all matter consists of tiny vibrating strings and the precise number of dimensions: ten and has a curious history (It was originally invented in the late 1960s in an attempt to find a theory to describe the strong force). The usual three dimensions of space – **length, width, and breadth** – and one of time are extended by six more spatial dimensions – blinked into existence. Although the mathematics of super strings is so complicated that, to date, no one even knows the exact equations of the theory (we know only approximations to these equations, and even the approximate equations are so complicated that they as yet have been only partially solved) – The best choice we have at the moment is the **super strings**, but no one has seen a superstring and it has not been found to agree with experience and moreover there's no direct evidence that it is the correct description of what the universe is. Are there only 4 dimensions or could there be more: **(x, y, z, t) + w, v, ...?** Can we experimentally observe evidence of higher dimensions? What are their shapes and sizes? Are they classical or quantum? Are dimensions a fundamental property of the universe or an emergent outcome of chaos by the mere laws of nature (which are shaped by a kind of lens, the interpretive structure of our human brains)? And if they exist, they could provide the key to unlock the deepest secrets of nature and Creation itself? We humans look around and only see four (three spatial dimensions and one time dimension i.e., space has three dimensions, I mean that it takes three numbers – length, breadth and height– to specify a point. And adding time to our description, then space becomes space-time with 4 dimensions) – why 4 dimensions? Where are the other dimensions? Are they rolled the other dimensions up into a space of very small size, something like a **million million million million millionth of an inch** – so small that our most powerful instruments can probe? Up until recently, we have found no evidence for signatures of extra dimensions. No evidence does not mean that extra dimensions do not exist. However, being

aware that we live in more dimensions than we see is a great prediction of theoretical physics and also something quite futile even to imagine that we are entering what may be the golden age of cosmology even our best technology cannot resolve their shape.

For n spatial dimensions: The gravitational force between two massive bodies is:  $F_G = \frac{GMm}{r^{n-1}}$ ,

where G is the gravitational constant (which was first introduced by **Sir Isaac Newton** (who had strong philosophical ideas and was appointed president of the Royal Society and became the first scientist ever to be knighted.) as part of his popular publication in 1687 "**Philosophiae Naturalis Principia Mathematica**" and was first successfully measured by the English physicist Henry Cavendish), M and m are the masses of the two bodies and r is the distance between them. The electrostatic force between two charges is:  $F_E = \frac{Qq}{4\pi\epsilon_0 r^{n-1}}$ , where  $\epsilon_0$  is the absolute permittivity of free space, Q and q are the charges and r is the distance between them.

What do we notice about both of these forces? Both of these forces are proportional to  $\frac{1}{r^{n-1}}$ . So in a 4 dimensional universe (3 spatial dimensions + one time dimension) forces are proportional to  $\frac{1}{r^2}$ ; in the **10 dimensional universe** (9 spatial dimensions + one time dimension) they're proportional to  $\frac{1}{r^8}$ . Not surprisingly, at present no experiment is smart enough to solve the problem of whether or not the universe exists in 10 dimensions or more (i.e., to prove or disprove both of these forces are proportional to  $\frac{1}{r^8}$  or proportional to a value  $> \frac{1}{r^8}$ ). However, yet mathematically we can imagine many spatial dimensions but the fact that that might be realized in nature is a profound thing. So far, we presume that the universe exists in extra dimensions because the mathematics of superstrings requires the presence of ten distinct dimensions in our universe or because a **standard four dimensional theory** is too small to jam all the forces into one mathematical framework. But what we know about the spatial dimensions we live in is limited by our own abilities to think through many approaches, many of the most satisfying are scientific.

Among many that we can develop, the most well-known, believed theory at the present is the standard four dimensional theory. However, development and change of the **theory always occurs as many questions still remain about our universe we live in**. And if space was 2

dimensional then force of gravitation between two bodies would have been =  $\frac{GMm}{r}$  (i.e., the

force of gravitation between two bodies would have been far greater than its present value). And if the force of gravitation between two bodies would have been far greater than its present value, the rate of emission of gravitational radiation would have been sufficiently high enough to cause the earth to spiral onto the **Sun even before the sun become a black hole** and swallow the earth. While if space was 1 dimensional then force of gravitation between two bodies would have been =  $GMm$  (i.e., the force of gravitation between two bodies would have been independent of the distance between them).

The selection principle that we live in a region of the universe that is suitable for intelligent life which is called the **Anthropic principle** (a term coined by astronomer **Brandon Carter** in 1974) would not have seemed to be enough to allow for the development of complicated beings like us. The universe would have been vastly different than it does now and, no doubt, life as we know it would not have existed. And if spacial dimensions would have been  $>$  than 3, the force of gravitation between two bodies would have been decreased more rapidly with distance

than it does in three dimensions. (In three dimensions, the gravitational force drops to  $\frac{1}{4}$  if one

doubles the distance. In four dimensions it would drop to  $\frac{1}{5}$ , in five dimensions to  $\frac{1}{6}$ , and so on.) The significance of this is that the orbits of planets, like the earth, around the sun would have been unstable to allow for the **existence of any form of life** and there would have been no intelligent beings to observe the effectiveness of extra dimensions.

Although the proponents of string theory (which occupies a line in space at each moment of time) predict absolutely everything is built out of strings (which are described as patterns of vibration that have length but no height or width — **like infinitely thin pieces of string**), it could not provide us with an answer of what the string is made up of? And one model of

potential multiple universes called the **M Theory** – has eleven dimensions, ten of space and one of time, which we think an explanation of the laws governing our universe that is currently the only viable candidate for a "**theory of everything**": the unified theory that Einstein was looking for, which, if confirmed, would represent the ultimate triumph of human reason—predicts that our universe is not only one giant hologram.

Many theoretical physicists and scientists of a fast developing science have discussed about mass annihilation at different times. Even a level one graduate know that when an electron and a positron approach each other, they annihilate i.e., destroy each other. This process what a quantum physicists call the mass annihilation. During the process their masses are converted into energy in accordance with  $E = mc^2$ . The energy thus released manifests as  $\gamma$  photons. A positron has the same mass as an electron but an opposite charge equal to +e. The energy released in the form of  $2\gamma$  photons during the annihilation of a positron and an electron is therefore:  $E = 2hv = 2m_0c^2$  where  $m_0$  is the rest mass of the electron or positron.

$$2hv = 2m_0c^2$$

Since  $v = c/\lambda$ . Therefore:

$$\lambda = \frac{h}{m_0c}$$

But  $h/m_0c = \lambda_C$  (the Compton wavelength of the electron or positron). Therefore:  $\lambda = \lambda_C$  (i.e., wavelength of the resulted gamma photon is = Compton wavelength of the annihilated electron or positron).

$$\lambda_C \rightarrow \frac{h}{m_0c}$$

Is it a cutoff at which relativistic quantum field theory becomes crucial for its accurate description? The Compton wavelength of the electron or positron characterizes the length scale at which the wave property of an electron or a positron starts to show up. In an interaction that is characterized by a length scale larger than the Compton wavelength, electron or positron behaves classically (i.e., no observation of wave nature). For interactions that occur at a length scale comparable than the Compton wavelength, the wave nature of the electron or positron begins to take over from classical physics.

From the relativistic energy equation:

$$E = \sqrt{p^2c^2 - m_0^2c^4}$$

For a photon with no rest mass can still have relativistic energy. If  $m_0 = 0$ , then

$$E = pc$$

The conservation laws:

#### **CONSERVATION OF ELECTRICAL CHARGE:**

In any reaction the total charge of all the particles entering the reaction = the total charge of all the particles after the reaction.

#### **LEPTON CONSERVATION:**

In any reaction the sum of lepton numbers before the interaction = the sum of lepton numbers after the interaction

- electron number
  - muon number
  - tau number
- } **Lepton numbers**  
↓

**Always conserved** when a massive lepton decays into smaller ones

Muon  $\rightarrow$  muon neutrino + electron + antineutrino

**Electron number:** 0 = 0 + 1 + 0

**Muon number:** 1 = 1 + 0 + 0

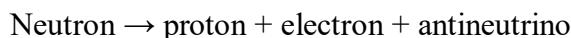
**Tau number:** 0 = 0 + 0 + 0

### **CONSERVATION OF BARYON NUMBER:**

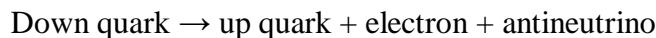
In any reaction the sum of baryon numbers before the interaction = the sum of baryon numbers after the interaction

have far-reaching implications as fundamental to our understanding of the physical world which we do not see violated. They serve as a strong constraint on any thought-out explanation for observations of the natural world in any branch of science. These laws govern the behavior of nature **at the scale of atoms and subatomic particles**. As a result of the particle-particle interaction 2 things may happen:

- Particles are attracted or repelled
- The particles are changed into different particles

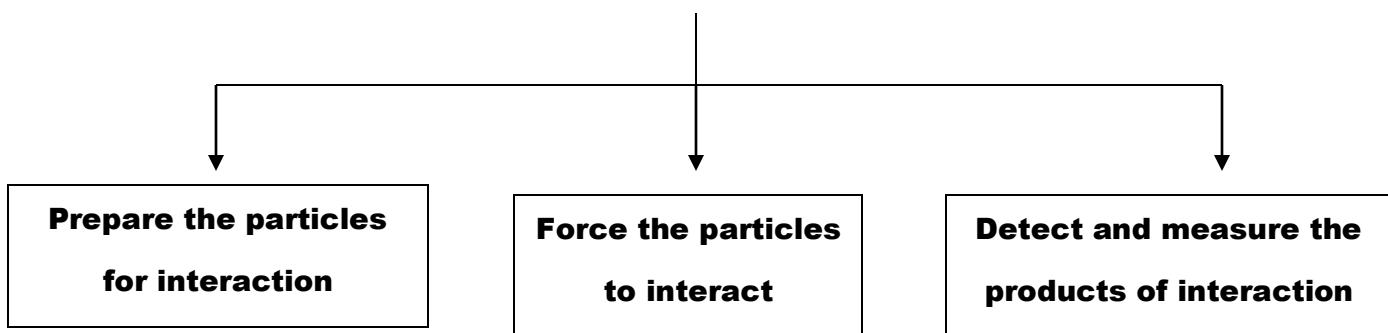


**At the quark and lepton level:**



<b>Thomson's model</b>	<b>Rutherford model</b>
The atom is composed of electrons surrounded by a soup of positive charge to balance the electrons' negative charges	The negatively charged electrons surround the nucleus of an atom

### **Particle physics experiment**



**Positron is captured by antiproton and an atom of antihydrogen is formed**

The **threshold temperature** of the electron is:

$$T = \frac{m_0 c^2}{k_B}$$

and so once the universe has cooled below this temperature the electrons and antielectrons annihilate each other and the electron become a very rare object – compared to photons.

$$mc^2 = KE + m_0 c^2$$

For particles moving at speeds close to that of light:

$$KE \gg m_0 c^2$$

$$mc^2 \sim KE$$

Hence the material particles behave similarly to the radiation photons.

**Open universes** are spatially infinite in extent and will expand forever.

**Closed universes** are spatially finite in extent and will re-collapse eventually and have a density  $> \frac{3H^2}{8\pi G}$ .

**Quarks** possess a fundamental property called color which comes in 3 types: red, blue and green and **Antiquarks** come in 3 types: antired, antiblue and antigreen. Leptons do not possess color and so do not feel the strong interaction.

## **Cosmic microwave background**



The electromagnetic radiation left over from the hot big bang or the time when the universe began.

## **Cosmic rays**



**High energy protons** that have their origin in the solar wind produced by the sun

## **Dark matter**

Matter that does not absorb, reflect or emit **electromagnetic radiation** and so cannot be astronomically observed directly.

**Hot dark matter particles move close to the speed of light.**

**Cold dark matter particles move at speeds very much slower than light.**

**6 flavors of quark:** up, down, strange, top and bottom

**6 flavors of lepton:** electron, electron-neutrino, muon, muon-neutrino, tau and tau-neutrino

**Gluons** → excitations of the strong field

**Photons** → excitations of the electromagnetic field

Proton is not a **stable subatomic particle** and will decay by a process that does not conserve baryon number. So far there has been no experimental observation of proton decay.

**Leptons** can interact via all the fundamental forces except the strong force.

Neutrinos have no electrical charge so they can only interact via the weak force

**Inflation** predicts that  $\Omega = \frac{8\pi G\rho}{3H^2} = 1$ , a prediction that we live in a flat universe – being conceived out by recent research into the cosmic microwave background and confirmed by supernova data.

### **Quantum electrodynamics**

**(QED)**

The theory of the electromagnetic force

### **Quantum chromodynamics**

**(QCD)**

The theory of the strong force

Particles can only spin at a rate that is a multiple of  $\hbar$ .

Fermions (**quarks and leptons**) spin at odd multiples of  $\frac{\hbar}{2}$

Bosons (**photons and gluons**) spin at  $\hbar$  or  $\frac{\hbar}{\pi}$

### **Supersymmetry**

The theory predicts that every fermion particle should have a boson equivalent (e.g. a **quark will have a squark**) and that every boson should have an equivalent fermion (e.g. **photon and photino**).}

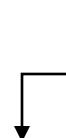
**Grand unified theories** (GUTs) → electroweak + strong force

**Theories of everything** (TOEs) → electroweak + strong force + gravity

The best candidate TOE at the moment is **superstring theory** – although this is not fully developed mathematically as yet.

**A law is universal** so far as we have been able to test it, it applies everywhere and at every time, past, present and future.

The rate of change of velocity = acceleration → caused by **force**



**Object's mass multiplied by its acceleration**

**Inertia** = resistance to change in velocity and it increases with the mass =  $\frac{\text{Energy}}{c^2}$  of the object

- **Solid** → strong bonds
- **Liquid** → weak bonds
- **Gas** → no bonds

**Atomic nuclei** → combination of quarks

Increasing the kinetic energy  $KE = \frac{mv^2}{2}$  of the atoms weakens the forces that hold atoms together. Heating increases the KE of atoms and causes the matter to move from solid phase (ice) to liquid phase (water) to gas phase (vapor).

**The wave-like nature of radiation explains:**

Reflection	Refraction	Diffraction
Interference	Doppler effect	

**Quantum mechanics**

Description of phenomenon on small scales where classical physics breaks down

## **Collisional excitation**

Excitation of an atom can occur when 2 atoms collide.

**Due to having twice the charge as a proton, helium nuclei require twice as much velocity to fuse.**

**Axion** is a hypothetical elementary particle postulated by the **Peccei–Quinn theory** in 1977 to explain why charge parity (CP) invariance holds in the strong interactions but not in the weak interactions.

## **Big Bang**

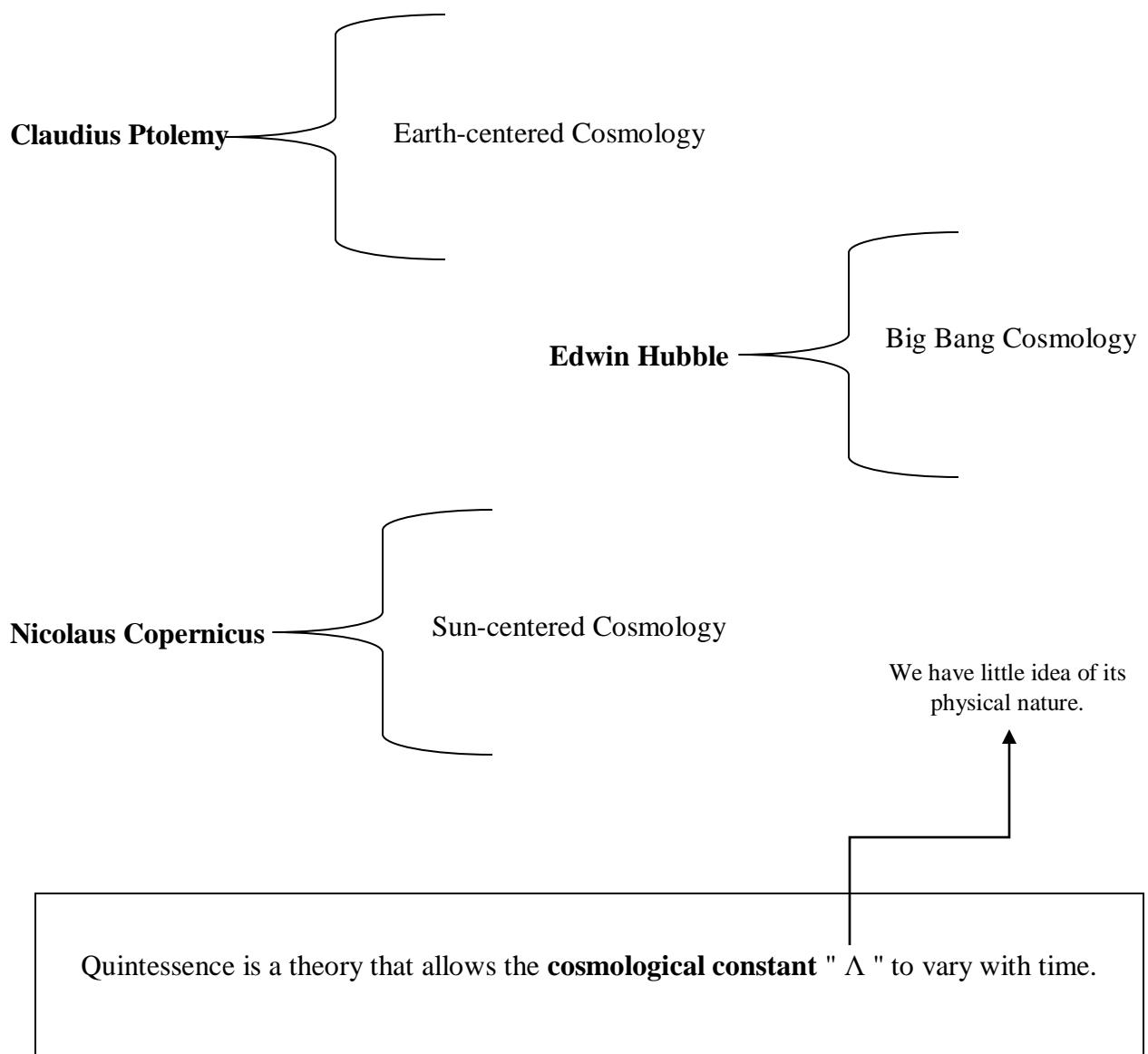


Prevailing cosmological model explaining the origin of the observable universe supported by accelerated expansion of the universe, observed cosmic microwave background radiation and Nucleosynthesis

**Charge Parity (CP) Invariance explain the excess of matter over antimatter**

## Spheres of Earth

- Lithosphere – Rock
- Atmosphere – Air
- Hydrosphere – Water
- Biosphere – Life



## Universe: Open, closed, or flat?

**Three possibilities:**

**Open**

- Negative curvature
- Infinite in extent
- Will expand forever (not enough matter to halt expansion → Big Freeze)

**Closed**

- Positive curvature
- Finite in extent
- Will collapse (enough matter to halt expansion → Big Crunch)

**Flat**

- In essence, no curvature
- Infinite in extent
- Expansion will stop at infinite time

- **Big Bang theory:** universe created from dense primeval fireball.
  - **Steady state theory:** matter continuously created with net constant density.

The minimum velocity that a moving particle must possess to escape from the gravitational pull of a star of mass  $M$  and radius  $R$  and move outward into space is:

$$v_{\text{escape}} = \sqrt{\frac{2GM}{R}}$$

where  $G$  is the Newtonian gravitational constant.  $v_{\text{escape}}$  is increased by either adding mass to the star (raising  $M$ ) or contracting it (decreasing  $R$ ).

When  $v_{\text{escape}} = c$ , then

$$R \rightarrow R_s = \frac{2GM}{c^2}$$

Even light cannot escape



The star becomes a black hole

For a black hole of one solar mass:  $M \sim 2 \times 10^{30} \text{ kg}$ ,

$$R_s \sim 3 \text{ km}$$

**The electromagnetic and weak interactions lose their symmetry below 100 GeV**

**Big Bang model rests on 2 theoretical foundations:**

- The general theory of relativity
- The cosmological principle (The universe is both isotropic and homogeneous)

**100 billion stars in Milky Way**  
**10% with planetary systems**  
**1% of planetary systems have habitable planets**

### **Thomson scattering**



**The elastic scattering of electromagnetic radiation photon  
by a free charged particle when the photon's wavelength  
exceeds the particle's Compton wavelength**

- **Flat universe:** A cosmological model in which the average density perfectly matches the critical density, below which the universe neither expands freely nor contracts back to its original size.
- **Helioseismology:** The discipline that studies solar wave oscillations.
- **Hubble–Reynolds law:**

$$I = \frac{I_0}{(1 + \frac{R}{R_H})^2}$$

where  $I$  is the surface brightness of the elliptical galaxy at radius  $R$ ,  $I_0$  is the central brightness and  $R_H$  is the radius at which the surface brightness of the elliptical galaxy is diminished by a factor of 1/4.

- **Induced Compton scattering:** Compton scattering caused by an extremely strong radiation field, as seen in pulsars and compact radio sources.
- **Optical double star:** When observed via a telescope, two stars that are not physically connected and are frequently separated by a large distance appear to be close to one another.
- **Radiometric dating:** Using a radioactive isotope, a **radioisotope dating method** can determine **how extremely old something is**, such as a fossil, a rock, or a hardwood remnant.
- **r process:** The rapid neutron capture method that creates the neutron-rich isotopes of elements other than iron (approximately from germanium to uranium and possibly further to at least a few **transuranics** that are no longer present in the solar system).
- **Symbiotic stars:** Stars that have characteristics of both cold giants and extremely hot stars.
- **Vacuum fluctuation:** The phenomenon whereby particle and antiparticle pairs haphazardly appear and vanish in space and time as a result of the uncertainty principle,

$\Delta E \times \Delta t \geq \frac{\hbar}{2}$ . According to the uncertainty principle, a fluctuation  $\Delta E$ , where  $\Delta E$  is the **energy** or

**mass  $\times c^2$**  involved in the fluctuation, can continue no longer than  $\Delta t = \frac{\hbar}{2\Delta E}$ .

- **Zeeman Effect:** When a light source is placed in a **strong magnetic field**, a spectral line splits into two or more components that have slightly different frequencies.

Considering the area of an event horizon of a black hole  $A = 4\pi R_S^2 = \frac{16\pi G^2 M^2}{c^4}$  and taking the derivative of the

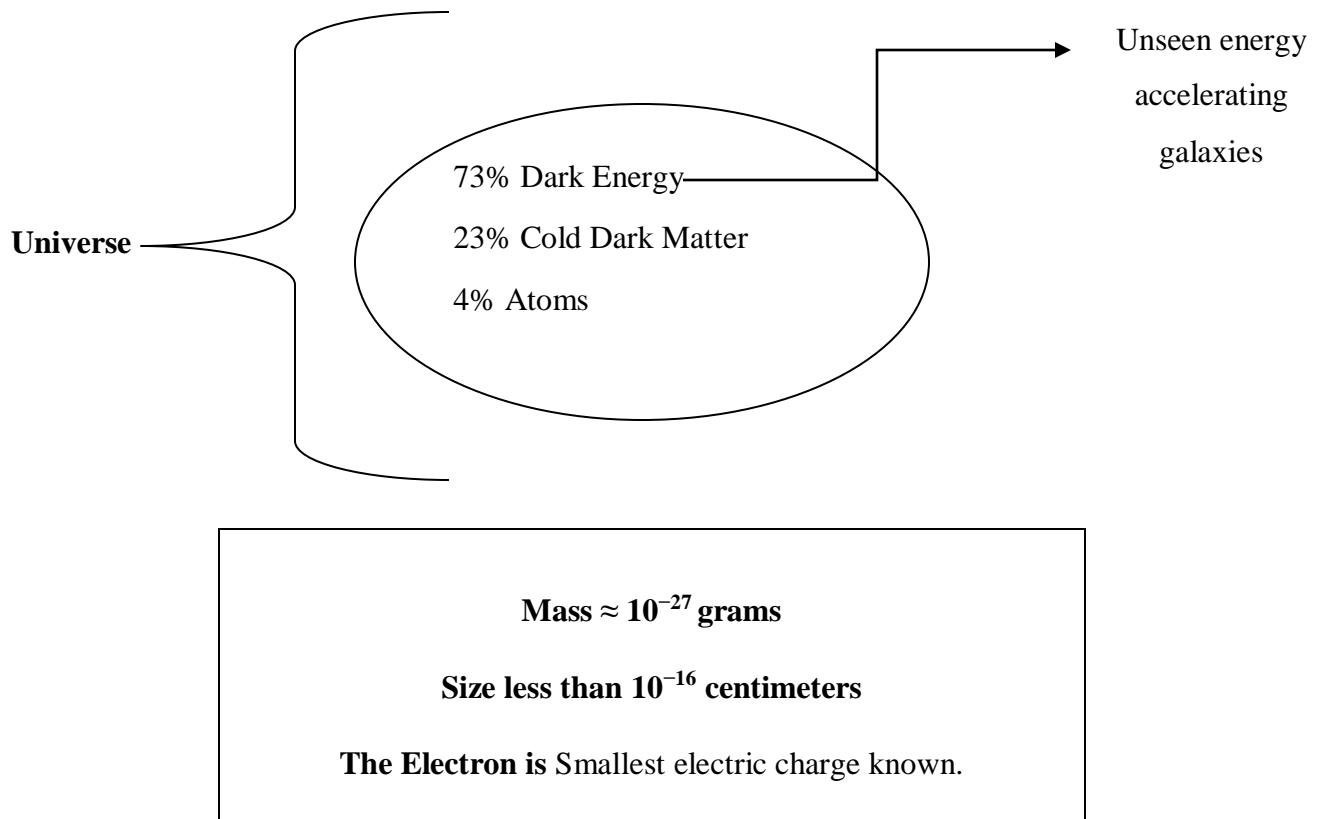
equation:  $A = \frac{16\pi G^2 M^2}{c^4}$  we get:  $dA = \frac{32\pi G^2 M}{c^4} \times dM$  or

$$dM = \frac{c^4 dA}{32\pi G^2 M}$$

The total energy of the black hole is  $E = Mc^2$ , hence  $dE = dMc^2$ , and the temperature of the black hole is:  $T_{BH} = \frac{\hbar c^3}{8\pi k_B GM}$ , so we can write:  $dE = \frac{\hbar c^3}{8\pi k_B GM} \times \frac{k_B c^3 dA}{4\hbar G}$

$$\boxed{dE = T_{BH} \times dS_{BH}}$$

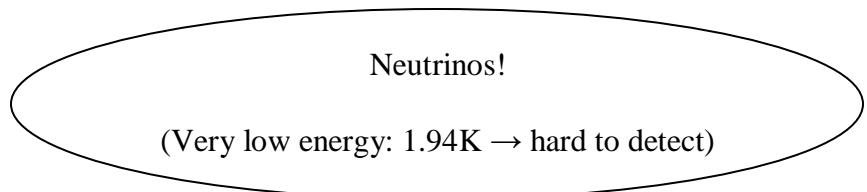
where  $S_{BH}$  is the thermodynamic entropy of the black hole



### Olber's Paradox

If the Universe were:

- 1) infinitely large,
- 2) infinitely old,
- 3) filled isotropically with stars,



Then the night sky would not be dark

- Uniform, "Fossil" Light from the Big Bang
  - Isotropic (2.7 K everywhere)
  - Unpolarized
- } **Cosmic microwave background**

Belgian astronomer and cosmologist **George Lemaitre** proposed the idea that the universe was expanding in 1927. He named it the "**Hypothesis of the primeval atom**".

**Protons** and **neutrons** combined to make long-lasting helium nuclei when universe was  $\sim 3$  minutes old.

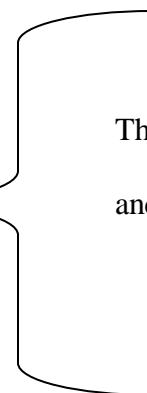
### DARK MATTER



Matter that does not shine or absorb light, and has therefore escaped direct detection by electromagnetic transducers like telescopes, radio antennas, X-ray satellites...

**One light year** → The distance that light travels through space in one year.

### NEBULAR MODEL



The sun and planets formed from a cloud of gas and dust that collapsed because of gravity.

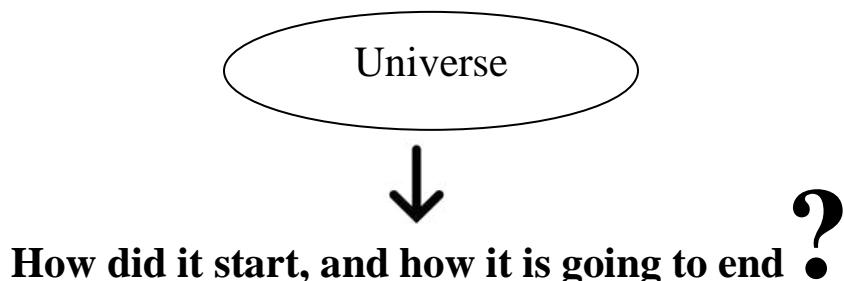
### Hubble's Law:

- More Distant Galaxies Recede Faster

General Theory of Relativity (Albert Einstein 1915)

Predicts that gravitational waves propagate at the speed of light.

Describes gravity in terms of the warping of space-time by the presence of mass and energy.



$$dE = -p dV$$

Volume V of an expanding universe grows, so its energy decreases if pressure p is positive.

**Total** energy of matter and of gravity (related to the shape and the volume of the universe) is conserved, but this conservation is somewhat unusual:

The sum of the energy of matter and of the gravitational energy is equal to zero.

"It is said that there is no such thing as a free lunch. But the universe is the ultimate free lunch".

– Alan Guth

### Comets are made up of:

- The nucleus
- The coma
- The ion tail
- The dust tail

At the Planck Distances:

Small, Planck-sized Black Holes pop out of vacuum and disappear within Planck time:

$$\sqrt{\frac{\hbar G}{c^5}}$$

**Planet** → derived from a Greek word that means "wanderer".

Stars moving away = Red shift

Stars moving toward = Blue shift

Greater the shift = faster the speed

**QUANTUM FIELD THEORY**

Matter is composed out of elementary particles bound together by forces, mediated by exchange of other elementary particles.

**Supergiant star** → **Core collapse** → **Neutrinos**



They are among the most abundant particles in the gigantic Universe, and still are hard to detect. They're similar to electrons, but they have no electrical charge and their mass is almost zero, so they interact very little with normal matter as they stream through the Universe at near light-speed. Billions of them are zipping through human body right now. Hence, they are also called "**ghost particles**."

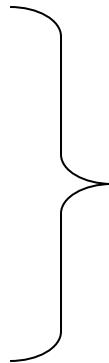
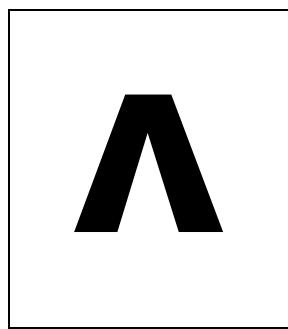
<b>How does the universe work?</b>	<b>Why does it work that way?</b>
<ul style="list-style-type: none"><li>• Observe the universe</li><li>• Precise measurements</li><li>• Is it testable?</li></ul>	<ul style="list-style-type: none"><li>• Look for abstract ideas</li><li>• Mathematical models</li><li>• Unified descriptions</li></ul>
<b>Experimental physics</b>	<b>Theoretical physics</b>

- In 1962, The U.S. Blew Up A **Hydrogen Bomb** In Space That Was 100 Times More Powerful Than Hiroshima.
- Astronauts on the **International Space Station** Witness around 15 Sunrises and 15 Sunsets Every Day.
- In 1977, We Received A Signal From **Deep Space** That Lasted 72 Seconds. We Still Don't Know How Or Where It Came From.

### **Cherenkov radiation**



Produced by charged particles when they pass through an optically transparent medium at speeds greater than the speed of light in that medium



The energy density associated with the empty space which explains the observed accelerated expansion of the universe

**Cosmological Principle:** the universe is the same everywhere and in all directions.

### **Double Beta Decay:**

A nuclear transition in which an initial nucleus ( $Z, A$ ), with atomic number  $Z$  and mass number  $A$  decays to  $(Z + 2, A)$  emitting two electrons and two antineutrinos in the process

Type I supernova explosion	Type II supernova explosion
Explosion of a smaller star that is being fed fuel from a companion star	Explosion of a massive star that has run out of nuclear fuel



**Catastrophic stellar explosion** in which so much energy (nearly of the order of  $10^{42}$  J) is released that the explosion alone can outshine for weeks an entire galaxy of billions of stars

**Electricity + magnetism → theory of electromagnetism**

**Electromagnetism + weak interactions + strong interactions**



**Grand Unification theory**

**Virtual particle**

{ Its energy is less than its rest mass energy }

**Supersymmetry** → a space-time symmetry that would imply the existence of a "superpartner" for every elementary particle

**Our Sun will become a white dwarf  
in about five billion years**

**Sunyaev-Zeldovich effect**

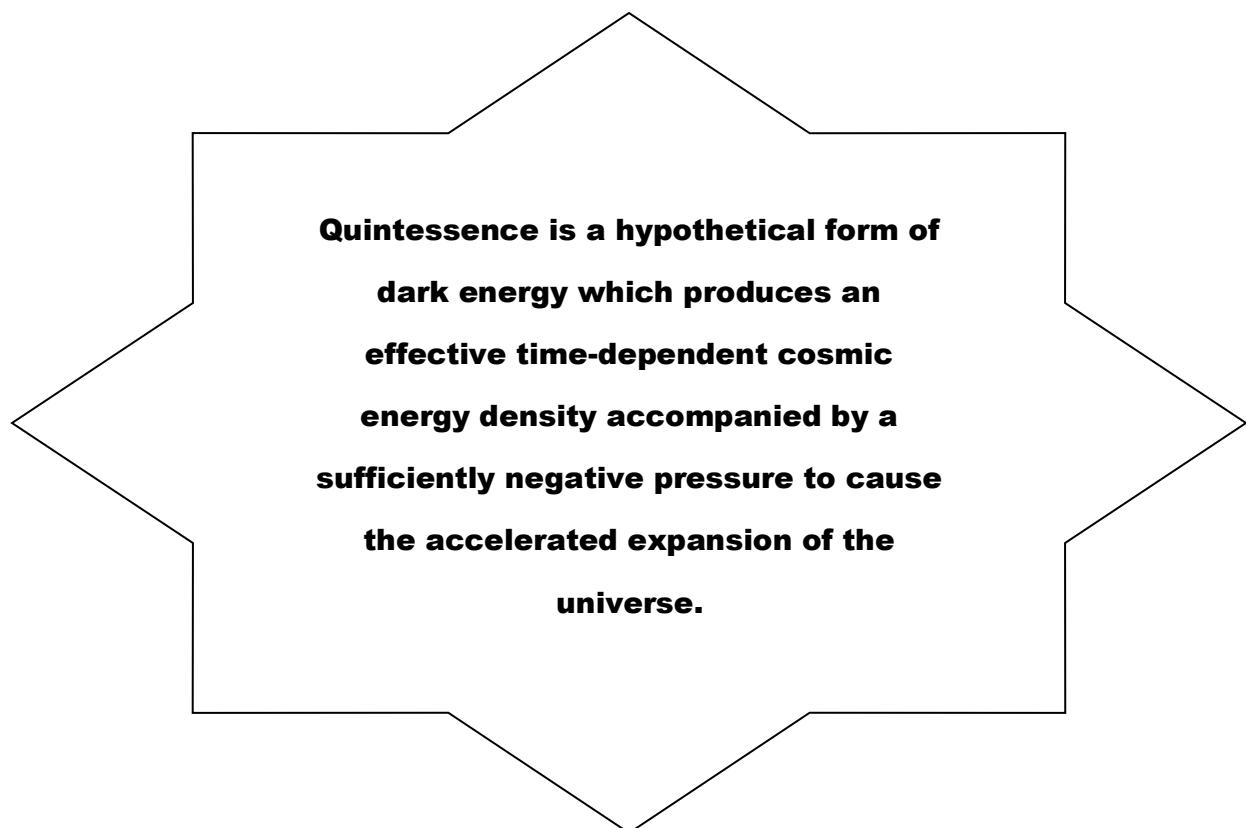


Scattering of cosmic microwave background radiation photons by rapidly moving electrons in the hot gas in clusters of galaxies

Due to its factor of uncertainty, German physicist **Albert Einstein** rejected the theory of quantum mechanics

- **String theory** (the standard description of the gigantic cosmos by replacing all matter and force particles with just one element: **Tiny vibrating string**) attempts to resolve the incompatibility between General theory of Relativity and quantum mechanics and to unify them.

<b>Redshift</b>	<b>Gravitational redshift</b>
A shift to longer wavelengths of spectral lines in the radiation emitted by an object caused by relative motion of the emitting object away from the observer	A shift to longer wavelengths of spectral lines in the radiation emitted by a body in a gravitational field



**Quark-Gluon Plasma**

**Hadron**

Particle with strong interactions

**Atoms are dissociated into electrons and nuclei**

**Atomic nuclei are dissociated into protons and neutrons**

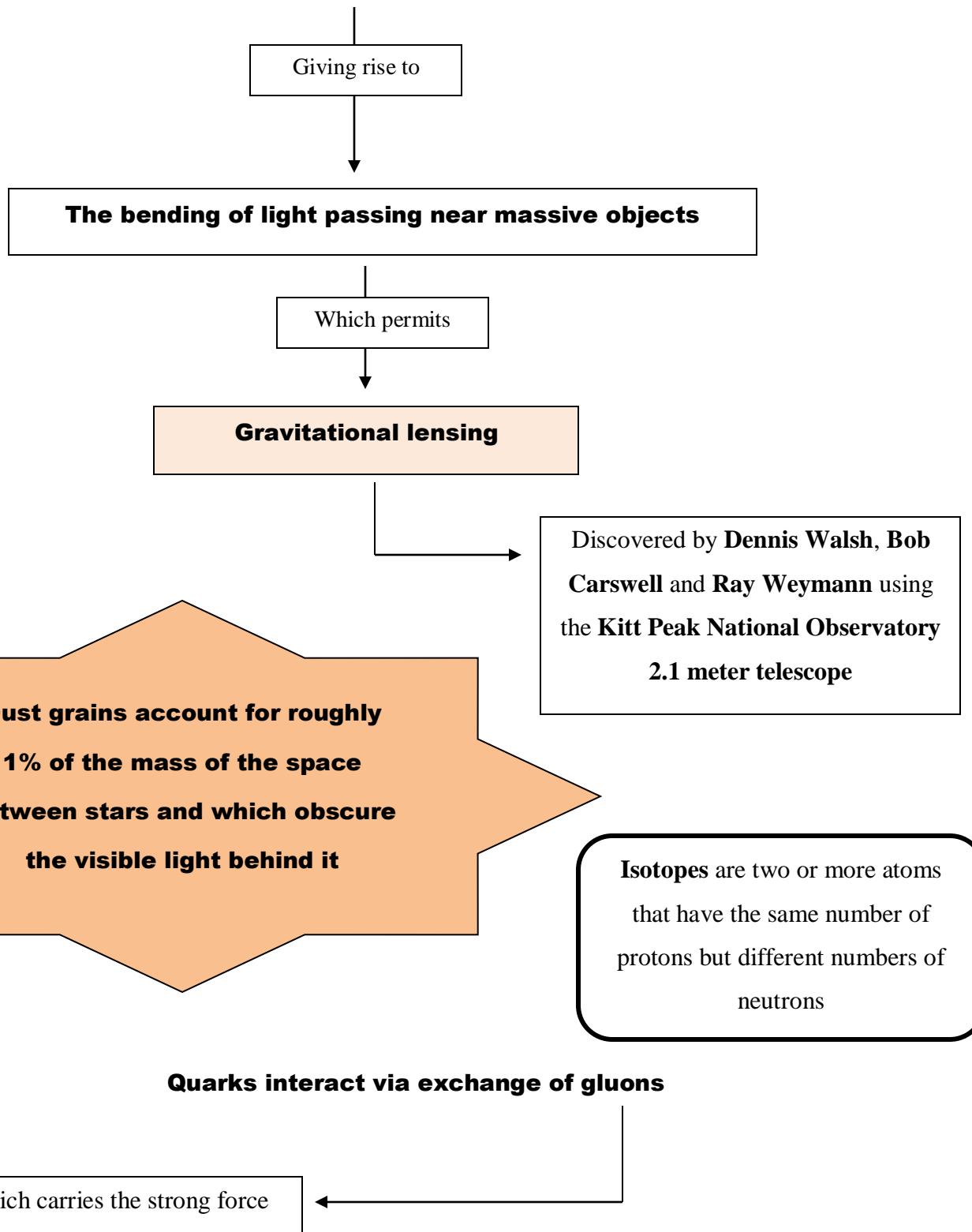
**Protons and neutrons are dissociated into quarks and gluons**

This was the case before about **a ten thousandth of a second** into the **hot Big Bang** where atoms were at sufficiently high temperature and density

**A sterile neutrino is one that is not paired up with one of the three charged leptons (electron, muon and tau) in the standard model of particle physics.**

**Mesons** are hadronic subatomic particles composed of an equal number of quarks and antiquarks which do not exist in ordinary matter but have been observed in the laboratory and cosmic rays.

## **Mass and energy make space curved**



<b>Geocentric Model of the Universe</b> (Ptolemaic Model)	<b>Heliocentric Model of the Universe</b> (Copernican Model)
<b>Earth centered model of the universe</b> (Earth at the center)	<b>Sun centered model of the universe</b> (Sun at the center)

A cosmic mystery of immense proportions, once seemingly on the verge of solution, has deepened and left astronomers and astrophysicists more baffled than ever. The crux ... is that the vast majority of the mass of the universe seems to be missing.

— William J. Broad

[Reporting a Nature article discrediting explanation of invisible mass being due to neutrinos]

**When magnifying matter, the fundamental constituents appear to be point-like. But if we were able to magnify even more, what would they look like? String theory presents a possibility to unify particle physics with gravity provided that the particles are string-like at a length scale of  $10^{-33}$  m.**

– Martin Lübecke

If you leave at Age of 15 in a Spaceship at Speed of Light and Spends **5 Years in Space**, when you get back on Earth you will 20 Years old. But all of your Friends who were 15 when you Left, will be 65 Years Old at that Time.

If you fall into black hole, you will able to see both the Universe beginning and ending due to **Time Dilation**.

If not for a force called gravity, we would all go zinging off into outer space.

The faster you move, the shorter and the heavier you are. **And that is the theory of relativity.**

Did you know that the static on your television is caused by radiation left over from the **Big Bang**?

**Motion and gravity makes the clock tick slower.**



## BIG BANG THEORY

Describes earliest moments of Universe

### Beginning of Universe



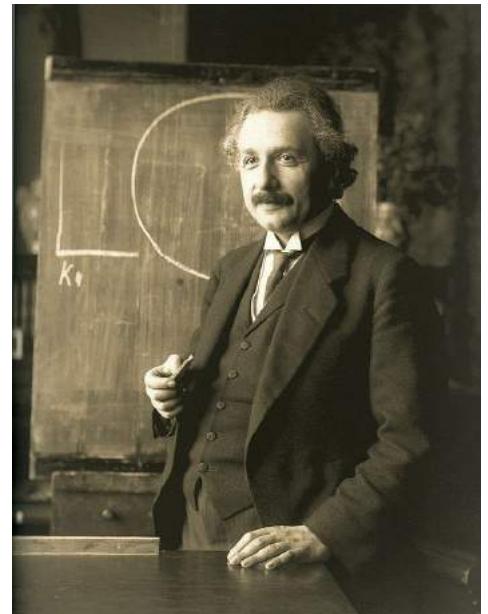
### Beginning of TIME

- **Flatness problem:** Why is the density in the Universe almost critical?
- **Horizon problem:** Why is the large scale of the Universe so smooth?

Einstein presented his general theory of relativity in 1916, but for an entire century nobody could find physical proof of black holes. In 2016, scientists finally detected gravitational waves that emitted from two black holes colliding, proving that such weird things not only exist, but that Einstein was right all along.

A human being is part of the whole, called by us "**Universe**"; a part limited in time and space. He experiences himself, his thoughts and feelings as something separated from the rest—a kind of optical delusion of his consciousness. This delusion is a kind of prison for us, restricting us to our personal desires and to affection for a few persons nearest us. Our task must be to free ourselves from this prison by widening our circle of compassion to embrace all living creatures and the whole of nature in its beauty. Nobody is able to achieve this completely but the striving for such achievement is, in itself, a part of the liberation and a foundation for inner security.

— **Albert Einstein**



It took 15 years for **Einstein's**  
**Relativity theory to make him**  
**famous**

**Albert Einstein's general theory of relativity** was proved in 1919 during a solar eclipse.

**In 1927, a Belgian cosmologist and a Catholic priest, GEORGES LEMAITRE proposed the Big Bang theory to reconstruct the 13.9 billion year story of the universe**

A **theory of cosmology** in which the expansion of the universe is presumed to have begun with a primeval explosion

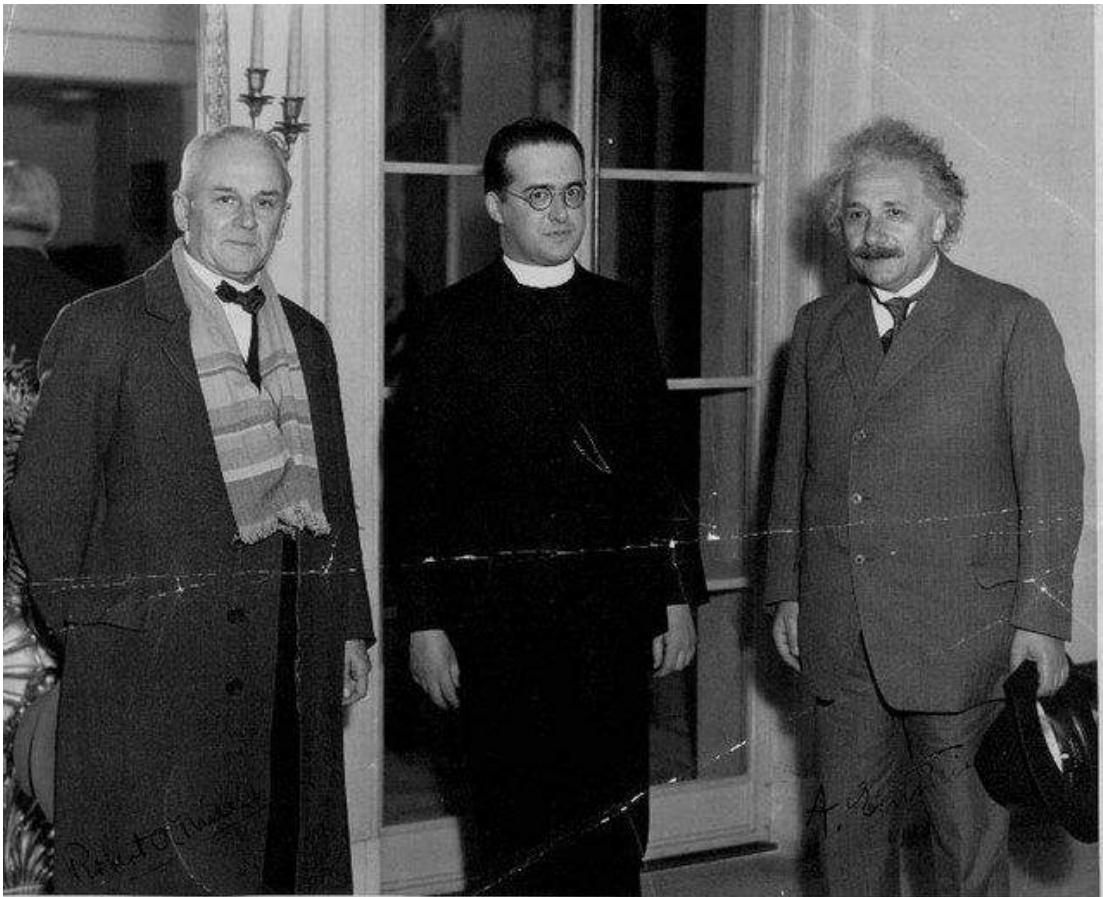
When an object is receding, its light gets stretched (**redshifted**). When the object is approaching, its light gets compressed (**blueshifted**).

**Albert Einstein** Did Not Win the Nobel Prize for His **Theory of Relativity** in 1921 but For the **Photoelectric Effect**

**Albert Einstein's general theory of relativity suggests that the sun's gravity bends the path of light from distant stars. It's a testable prediction, but only during a total solar eclipse.**



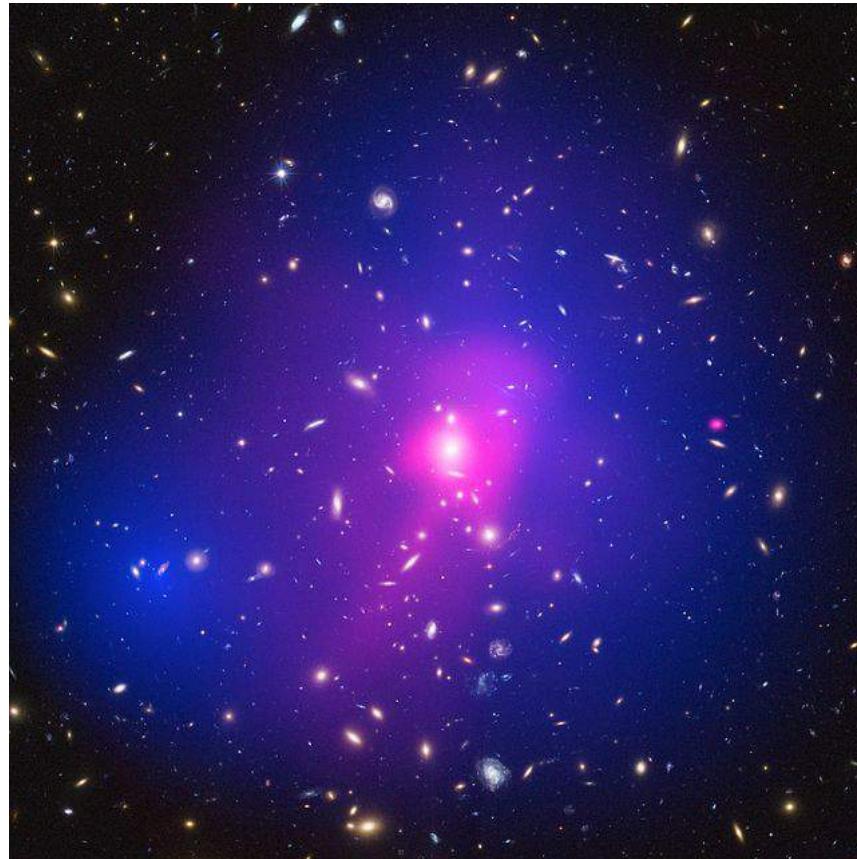
*A. Einstein*



**Robert A. Millikan, Georges Lemaître and Albert Einstein at California Institute of Technology, January 1933**

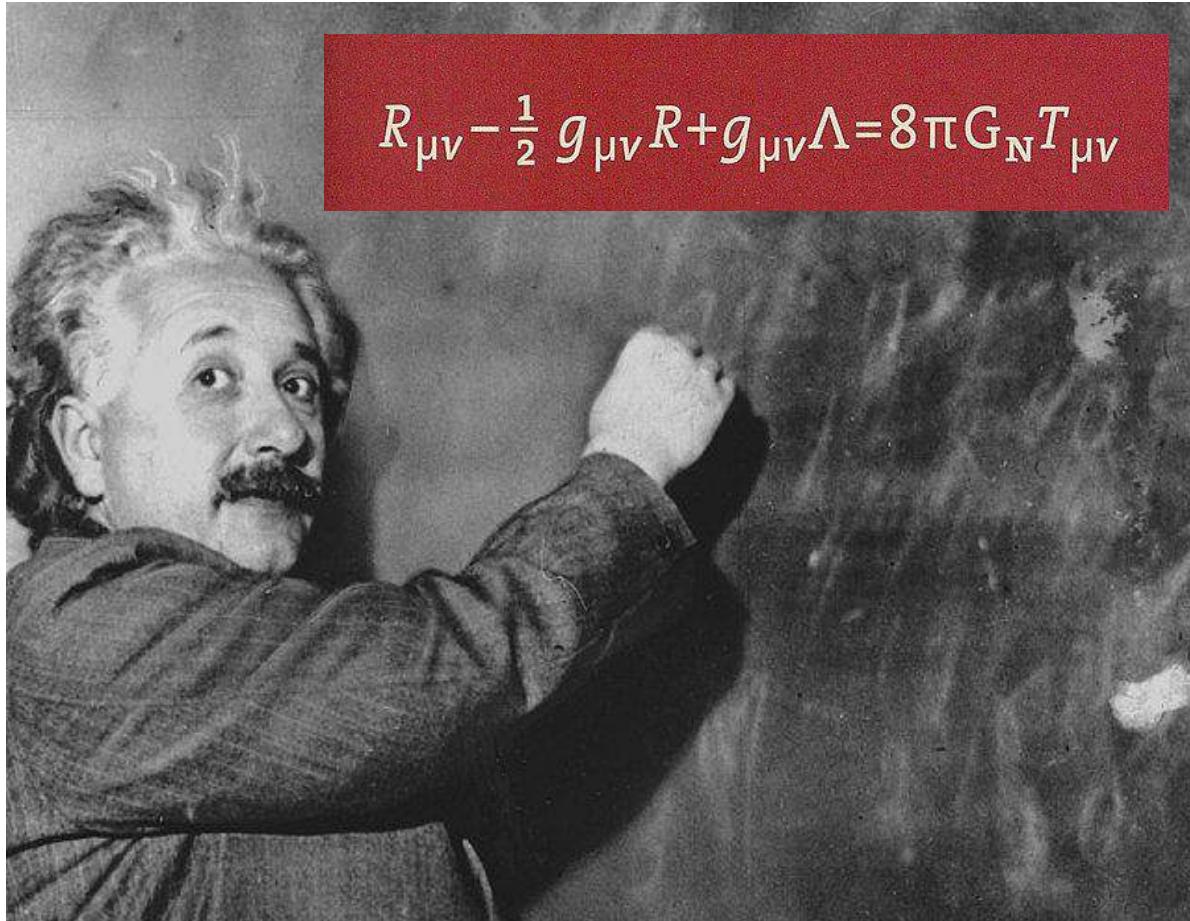
"I found it very ugly indeed that the field law of gravitation should be composed of two logically independent terms which are connected by addition. About the justification of such feelings concerning logical simplicity it is difficult to argue. I cannot help but feel it strongly and I am unable to believe that such an ugly thing should be realised in nature."

**- Albert Einstein, in a Sept. 26, 1947, letter to Georges Lemaître**



**Dark matter (blue) in galaxies, dissociated from plasma (pink)**

**Although the Cosmic microwave background is nearly uniform, there are tiny fluctuations in its temperature due to variations in the density of the early universe. These tiny fluctuations reveal the early stages of galactic structure formation.**



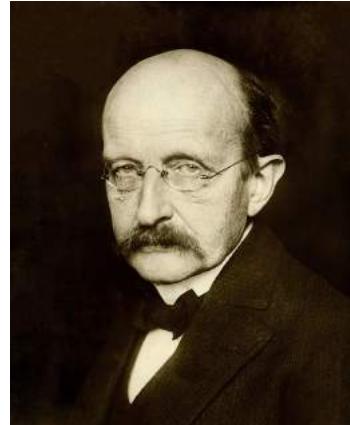
**When a particle and its antiparticle annihilate each other – release a pair of high energy gamma photons.**

### **Would the tidal forces kill an astronaut?**

**For small black holes whose Schwarzschild radius is much closer to the singularity, the tidal forces would kill even before the astronaut reaches the event horizon.**

Since gravity weakens with distance, the earth pulls on your head with less force than it pulls on your feet, which are a meter or two closer to the earth's center. The difference is so tiny we cannot feel it, but an astronaut near the surface of a black hole would be literally torn apart.

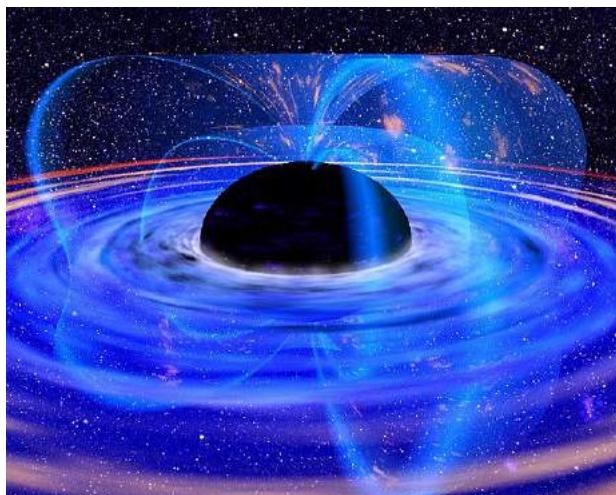
An experiment is a question which science poses to Nature, and a measurement is the recording of Nature's answer.



—MAX PLANCK, 1858 TO 1947

If the production of microscopic black holes is feasible, can the LHC create a black hole that will eventually eat the world ?

The **black holes** of nature are the **most** perfect macroscopic objects there are in the universe: the only elements in their construction are our concepts of space and time.



*S Chandrasekhar.*

— Subrahmanyan Chandrasekhar

Light takes billions of years to reach us from a galaxy

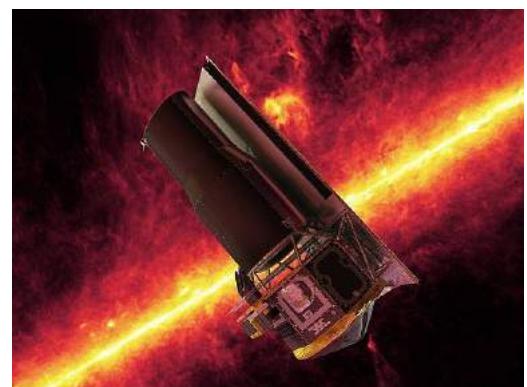
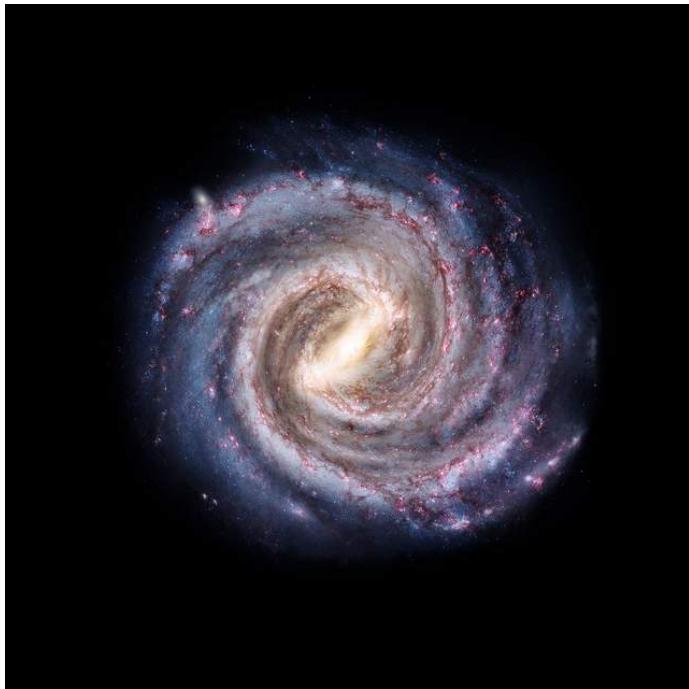
Galaxy —————→ Earth

Light takes 4.3 years to reach us from  $\alpha$  Centauri

$\alpha$  Centauri —————→ Earth

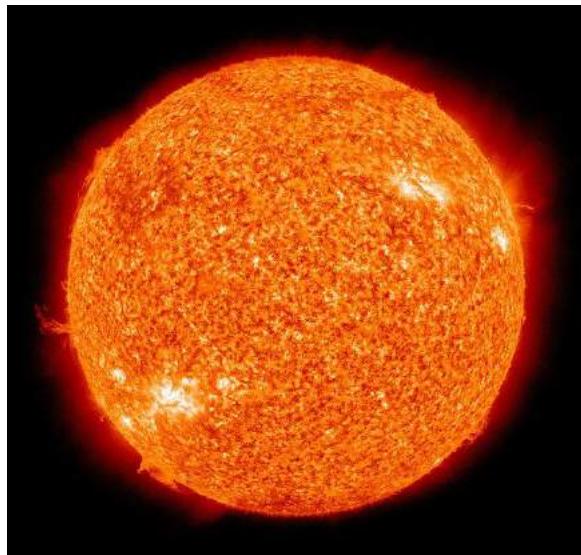
Light takes 8 minutes to reach us from the sun

Sun —————→ Earth

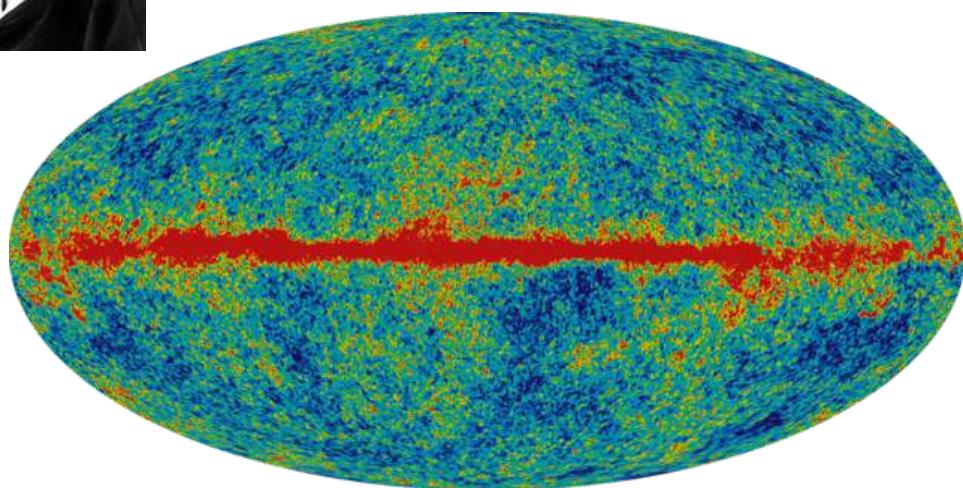
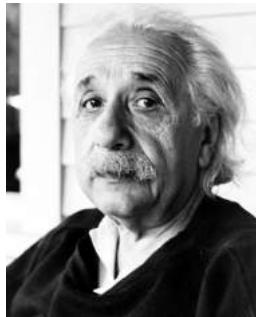


**The Milky Way consists of hundreds of billions of stars and has a black hole at its center.**

The Einsteinian theory of general relativity provides the framework to study the large-scale structure of the Universe



**Sun emits  $2 \times 10^{38}$  neutrinos per second but only 30 neutrinos are interacting in a person per year**



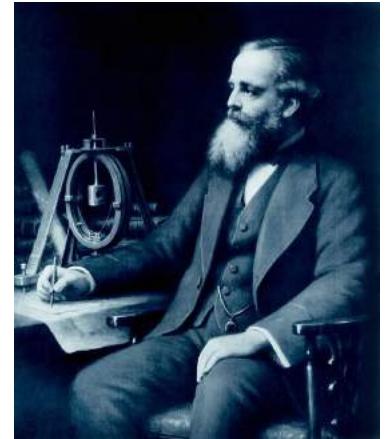
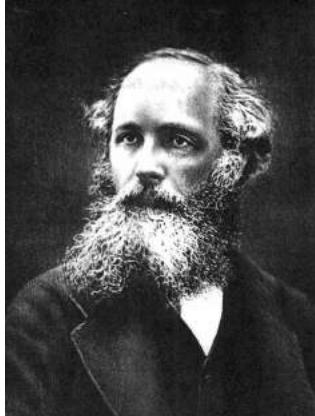
Simulation of the map of the cosmic microwave background that is being obtained by NASA's Microwave Anisotropy Probe (MAP) shows that the CMB is not perfectly smooth. But has Ripples in it.

$$\nabla \cdot \mathbf{E} = \rho$$

$$\nabla \times \mathbf{B} - \frac{1}{c} \frac{\partial \mathbf{E}}{\partial t} = \frac{\mathbf{j}}{c}$$

$$\nabla \cdot \mathbf{B} = 0$$

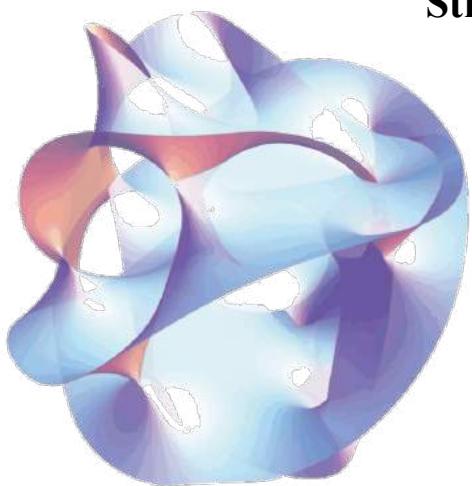
$$\nabla \times \mathbf{E} + \frac{1}{c} \frac{\partial \mathbf{B}}{\partial t} = 0$$



### Maxwell's equations for electromagnetism

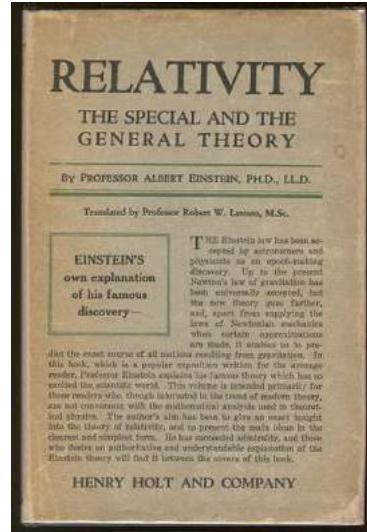
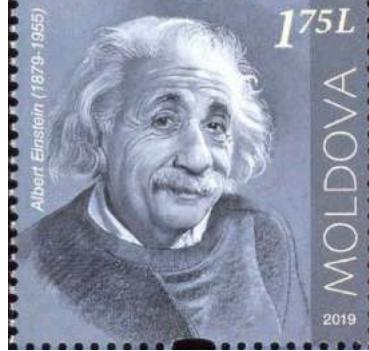
The entire electromagnetic spectrum — from radio waves to gamma rays, most of the light in the universe — resembles nothing but transverse waves of energy  $E = hc/\lambda$ , which in turn are vibrating Maxwell force fields differing only in their wavelength  $\lambda = h/p$ .

## String Theory



Different vibrations → Different particles

String combinations → Particle interactions



**Albert Einstein and J. Robert Oppenheimer at Caltech in 1939. They probably were, at that moment, discussing the prevention of black holes by neutron-star formation.**

In life, everything is relative - except Einstein's theory: **Leonid S. Sukhorukov**

Decoding the **quantum mechanics** to find the solution to the Schrodinger equation for the hydrogen atom in arbitrary electric and magnetic fields. If we can, we know everything about the system.



$$i\hbar \frac{\partial}{\partial t} \Psi(\mathbf{r},t) = \left[ -\frac{\hbar^2}{2m} \nabla^2 + V(\mathbf{r}) \right] \Psi(\mathbf{r},t)$$

*Erwin Schrödinger*

Science is a game—but a game with reality, a game with sharpened knives ... If a man cuts a picture carefully into 1000 pieces, you solve the puzzle when you reassemble the pieces into a picture; in the success or failure, both your intelligences compete. In the presentation of a scientific problem, the other player is the good Lord. He has not only set the problem but also has devised the rules of the game—but they are not completely known, half of them are left for you to discover or to deduce. The experiment is the tempered blade which you wield with success against the spirits of darkness—or which defeats you shamefully. The uncertainty is how many of the rules God himself has permanently ordained, and how many apparently are caused by your own mental inertia, while the solution generally becomes possible only through freedom from its limitations.

— Erwin Schrödinger

## Thermal energy

Heat

The flow of thermal energy

The energy contained within a system that is responsible for its temperature

$$\text{Joule} = \text{Newton} \times \text{meter} = \frac{\text{Kilogram} \times (\text{meter})^2}{(\text{second})^2}$$

Heliocentrism

In the center of all rests the Sun

"For those who want some proof that physicists are human, the proof is in the idiocy of all the different units which they use for measuring energy."

The object will also move in a straight line in the absence of a net external force.

— Richard P. Feynman

### Conservative force

The total work done in moving a particle from one point to another is independent of the path taken by the particle.

- Gravitational
- Electric
- Elastic

### Non-Conservative force

The total work done in moving a particle from one point to another is dependent of the path taken by the particle.

- Friction
- Air resistance
- Tension in cord

**1 horsepower = 33,000 foot pounds per minute**

**1 horsepower = 550 foot pounds per second**

### Translational

Force = mass × acceleration

For every action there is an equal and opposite reaction.  
(Here action and reaction refer to forces.)

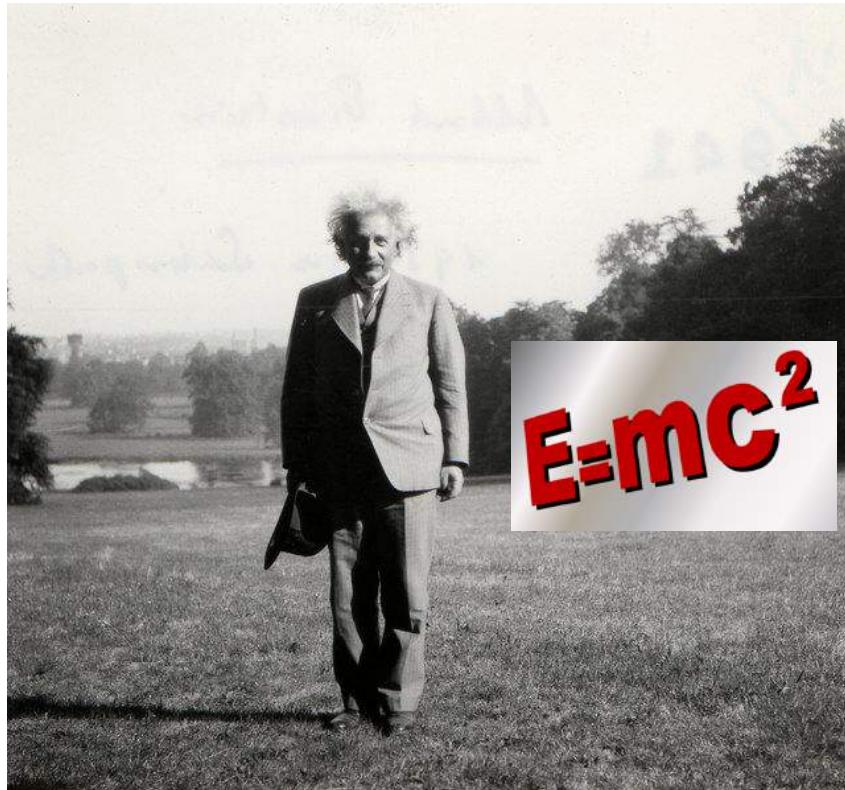
Power = Force × velocity

### Rotational

Torque = moment of inertia × angular acceleration

For every action there is an equal and opposite reaction.  
(Here action and reaction refer to torques.)

Power = Torque × angular velocity



### **Pauli's letter of the 4th of December 1930**

Dear Radioactive Ladies and Gentlemen,

As the bearer of these lines, to whom I graciously ask you to listen, will explain to you in more detail, how because of the "wrong" statistics of the N and Li<sup>6</sup> nuclei and the continuous beta spectrum, I have hit upon a desperate remedy to save the "exchange theorem" of statistics and the law of conservation of energy. Namely, the possibility that there could exist in the nuclei electrically neutral particles, that I wish to call neutrons, which have spin 1/2 and obey the exclusion principle and which further differ from light quanta in that they do not travel with the velocity of light. The mass of the neutrons should be of the same order of magnitude as the electron mass and in any event not larger than 0.01 proton masses. The continuous beta spectrum would then become understandable by the assumption that in beta decay a neutron is emitted in addition to the electron such that the sum of the energies of the neutron and the electron is constant...

I agree that my remedy could seem incredible because one should have seen these neutrons much earlier if they really exist. But only the one who dare can win and the difficult situation, due to the continuous structure of the beta spectrum, is lighted by a remark of my honoured predecessor, Mr Debye, who told me recently in Bruxelles: "Oh, It's well better not to think about this at all, like new taxes". From now on, every solution to the issue must be discussed. Thus, dear radioactive people, look and judge.

Unfortunately, I cannot appear in Tubingen personally since I am indispensable here in Zurich because of a ball on the night of 6/7 December. With my best regards to you, and also to Mr Back.

Your humble servant,

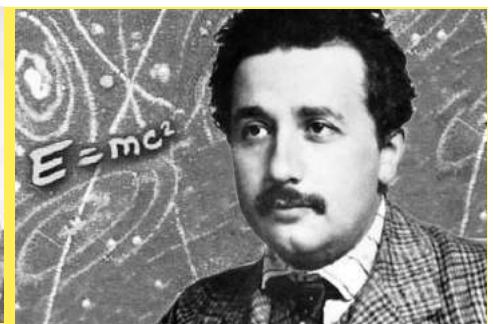
**Small amounts of antimatter constantly rain down on Earth in the form of cosmic rays and energetic particles from space.**



W. Pauli



The physicists Paul Dirac, Wolfgang Pauli and Rudolf Peierls, c 1953



Quantum Mechanics and General Relativity do not work together What about:

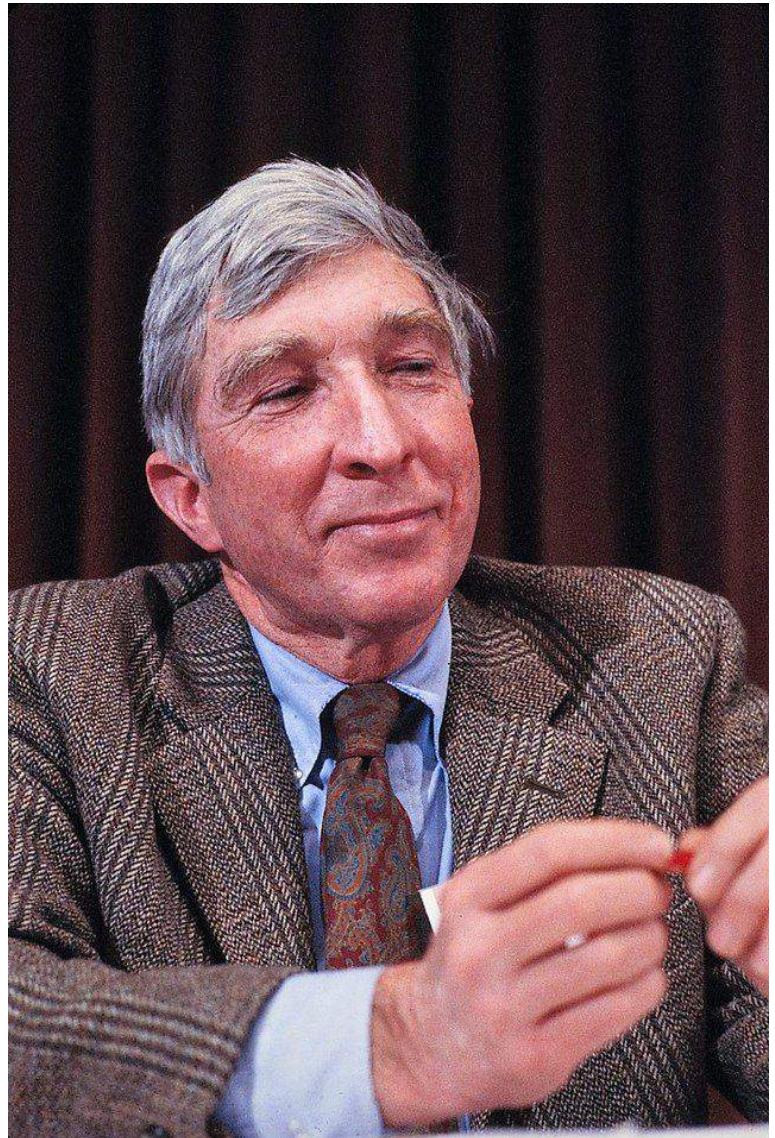
- Before the Big Bang?
- Black holes?

Neither theory can predict what happened...

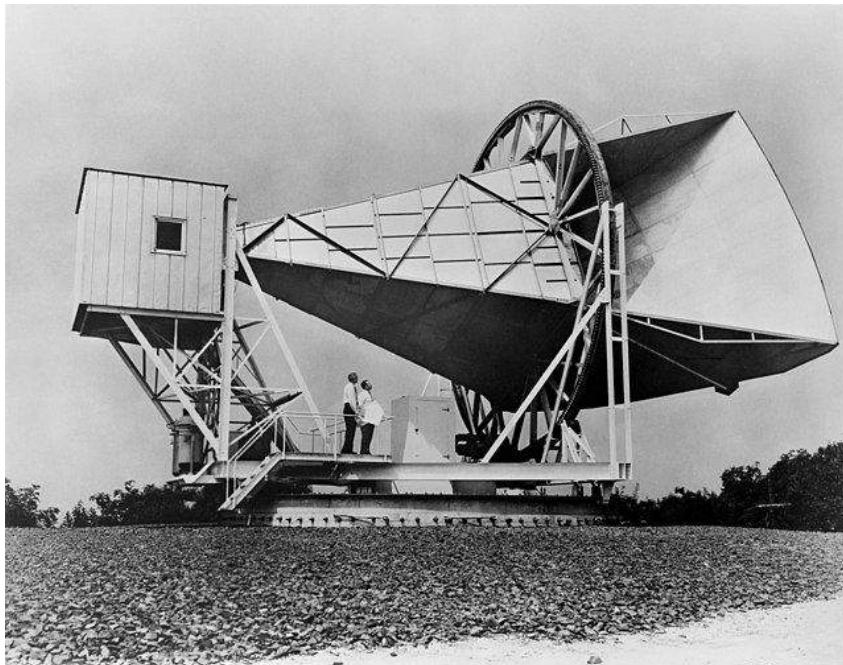
### **Cosmic Gall**

by John Updike (1932–2009)

Neutrinos, they are very small.  
They have no charge and have no mass  
And do not interact at all.  
The earth is just a silly ball  
To them, through which they simply pass,  
Like dustmaids down a drafty hall  
Or photons through a sheet of glass.  
They snub the most exquisite gas,  
Ignore the most substantial wall,  
Cold-shoulder steel and sounding brass,  
Insult the stallion in his stall,  
And, scorning barriers of class,  
Infiltrate you and me! Like tall  
And painless guillotines, they fall  
Down through our heads into the grass.  
At night, they enter at Nepal  
And pierce the lover and his lass  
From underneath the bed - you call  
It wonderful; I call it crass.



*john updike*



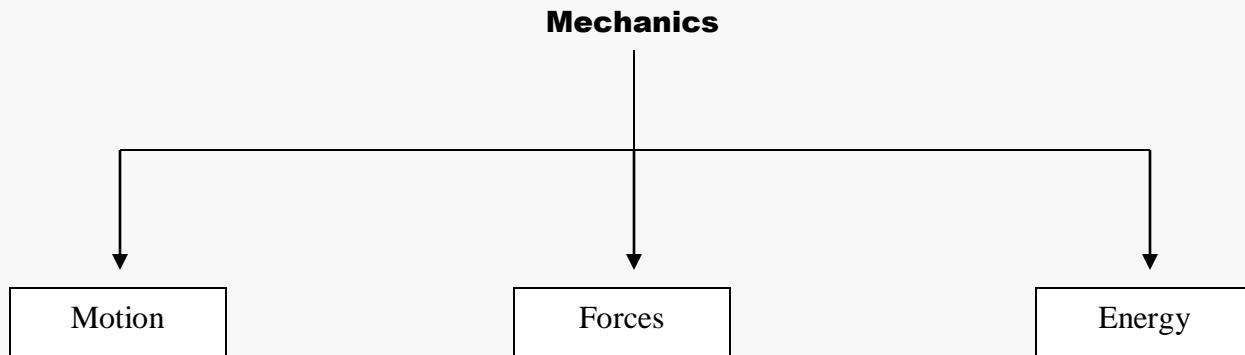
Arno Penzias and Robert Wilson  
and the historic Bell Labs horn  
antenna, discoverers of the relic  
Cosmic Microwave Background  
of the Big Bang.

"Gravity is the force that rules the Universe. To understand its workings, to the finest degree, is to understand the very nature of our celestial home."

– M. Bartusiak in Einstein's Unfinished Symphony

The **objects of different masses** are accelerated towards the earth at the same rate, but with different forces.

**Gravitational lensing:** The big galaxy cluster at the center of the image acts like the lens of a telescope. Any light from a distant object would converge as it passes around the galaxy. When we gaze at the distant galaxy, we see a ring like pattern called Einstein ring, an optical illusion caused by general relativity.



<b>Kinematics</b>	The science of describing the motion of objects
<b>Dynamics</b>	The science of describing the motion of objects under the action of forces
<b>Statics</b>	The branch of mechanics dealing with objects at rest or in equilibrium

Who would set a limit to the mind?  
 Who would dare assert that we  
 know all there is to be known?

— Galileo Galilei

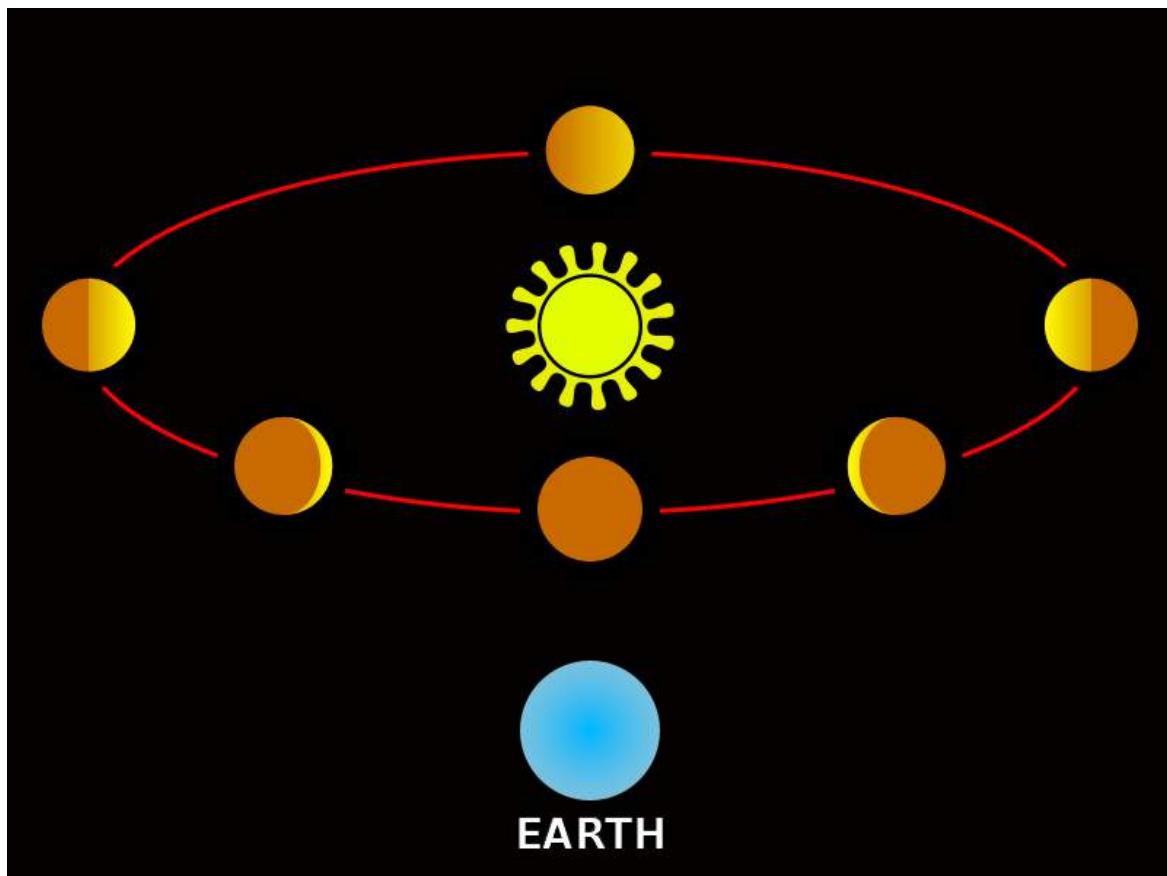
**Energetics**

**A branch of mechanics that deals primarily with energy and its transformations**

### Motion

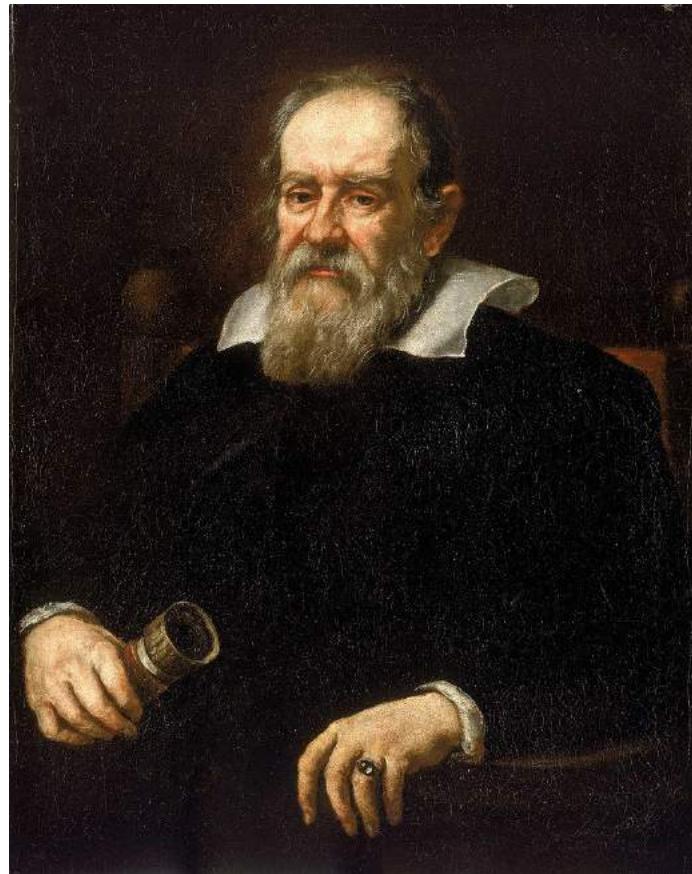
- **Translational motion:** Motion that results in a change of location
- **Oscillatory motion:** To and fro motion of the object about its fixed position
- **Rotational motion:** Motion that occurs when an object spins
- **Random motion:** Kind of motion where an object moves in any direction and the direction keeps changing continuously

**Kuiper belt** – a region of the Solar System extending from the orbit of Neptune (at 30 AU) to approximately 50 AU from the Sun (consists mainly of small bodies or remnants from the Solar System's formation).

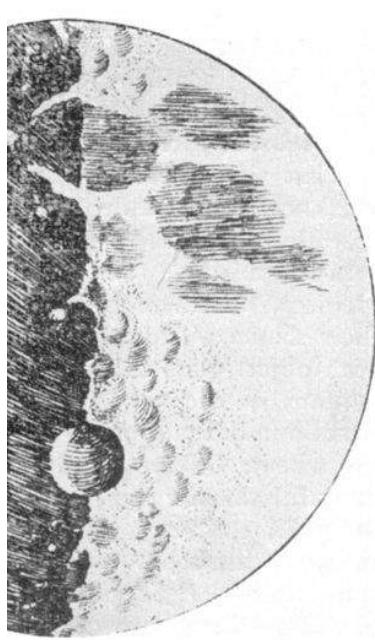


The phases of Venus, observed by Galileo in 1610

**Gamma ray bursts may happen when a neutron star falls into another neutron star or black hole. The resulting explosion sends out particles and radiation all over the spectrum.**



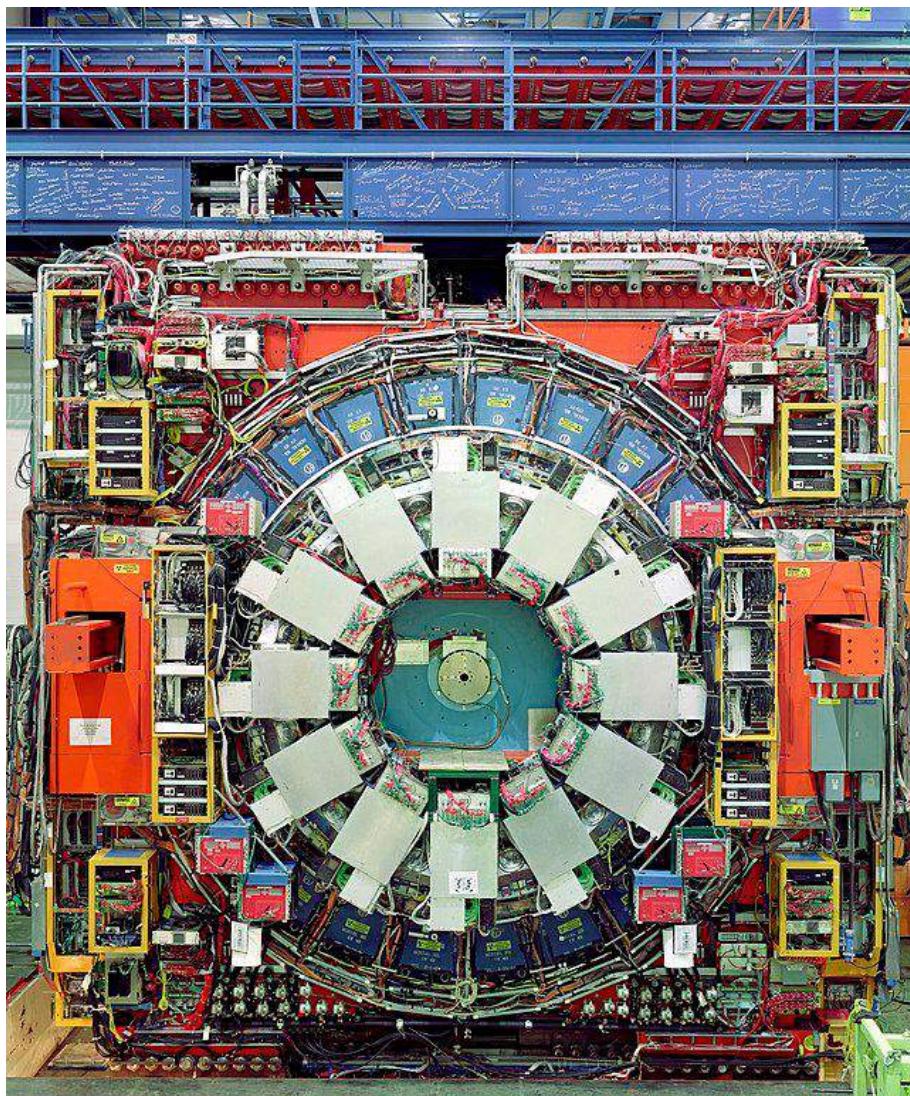
*Galileo Galilei*



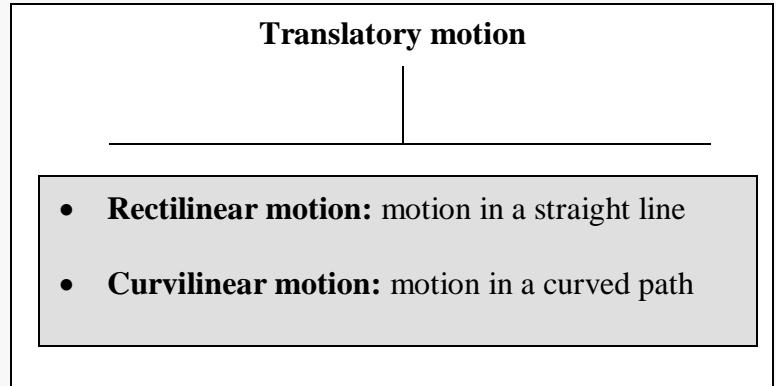
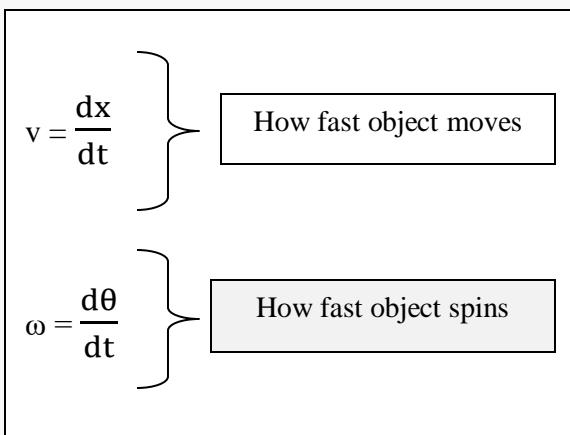
Galileo's drawing of the Moon

A virtual-particle pair has a wave function that predicts that both particles will have opposite spins. But if one particle falls into the black hole, it is impossible to predict with certainty the spin of the remaining particle.

– S. W. Hawking



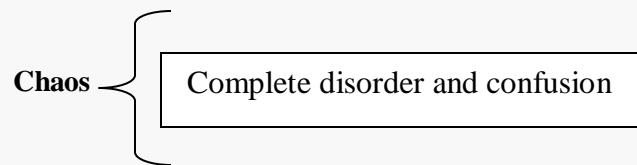
The Collider Detector at Fermi lab where the top quark was discovered



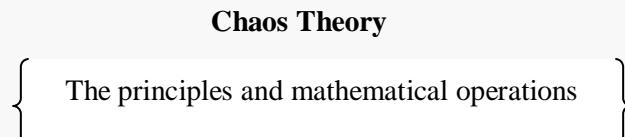
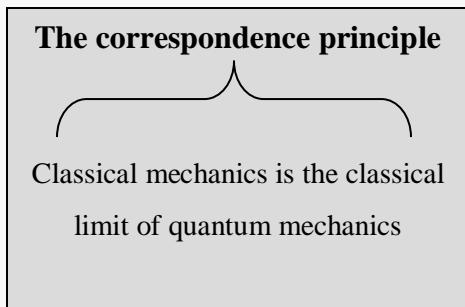
- **Uniform motion:** The motion of an object along a straight line with steady speed
 

{ Zero acceleration }
- **Non-Uniform motion:** The motion of an object along a straight line with variable speed
 

{ Non-Zero acceleration }



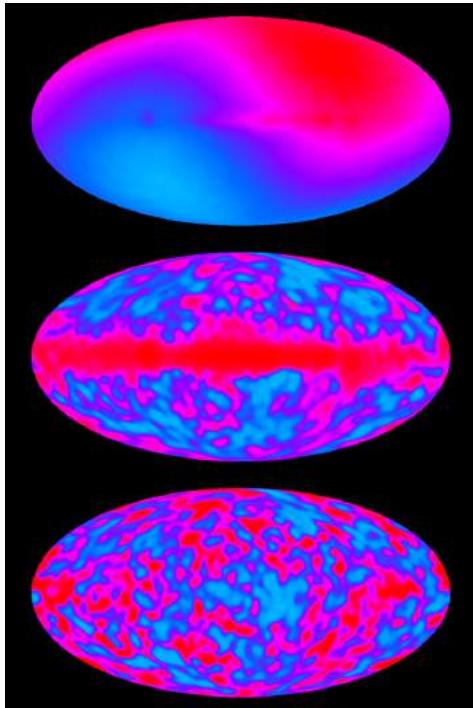
**Quantum mechanics is not chaotic – but probabilistic.**



**Classical probability** is a simple form of probability that has equal odds of something happening.

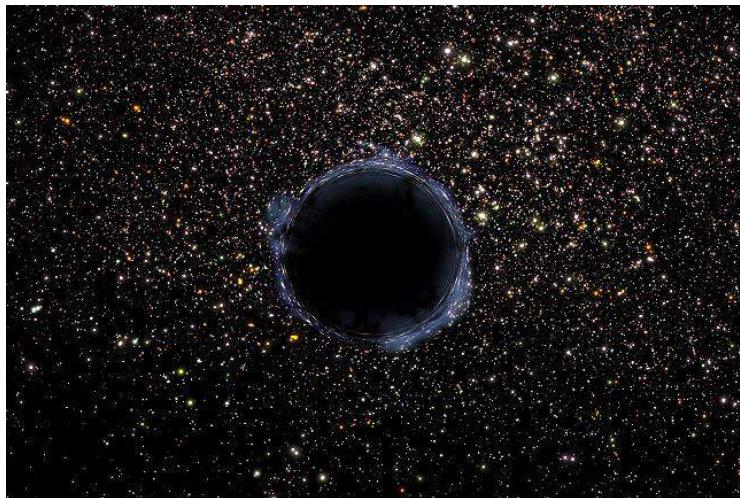
Deal with **nonlinear** things that are effectively impossible to predict or control, like turbulence, weather, the stock market, our brain states, and so on.

**Quantum chaos is a branch of physics which is concerned with establishing the relation between chaotic systems quantum systems.**



**The full sky map made by the COBE satellite DMR instrument, showing evidence for the wrinkles in time.**

The different frequencies of light appear as different colors.



**Black Hole in the universe**

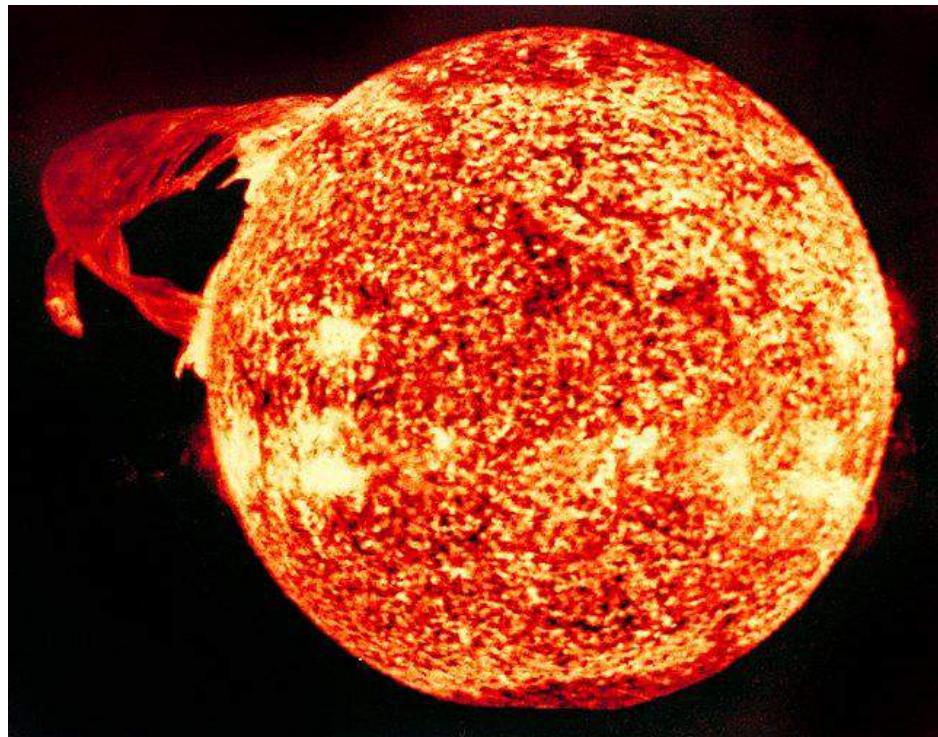
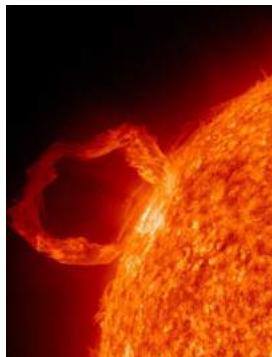
"The area formula for the entropy – or number of internal states – of a black hole suggests that information about what falls into a black hole may be stored like that on a record, and played back as the black hole evaporates."



– S.W. Hawking

Dark matter was first proposed by **FRITZ ZWICKY** in 1933.  
Although he proposed this almost a century ago, dark matter is  
still a mystery that everyone yearns to resolve.

When we place two long parallel uncharged plates close to each other, virtual particles outside the plates exerts more pressure than the virtual particles inside the plates, and hence the plates are attracted to each other, which we call the "**Casimir effect**."



A sudden emission of superhot gas containing charged particles which is interpreted as a massive solar super storm can narrowly blast the Earth back into the Dark Ages (by damaging satellite microchips and disrupting power grids).

## Why the Quarks feel the strong force, leptons do not?

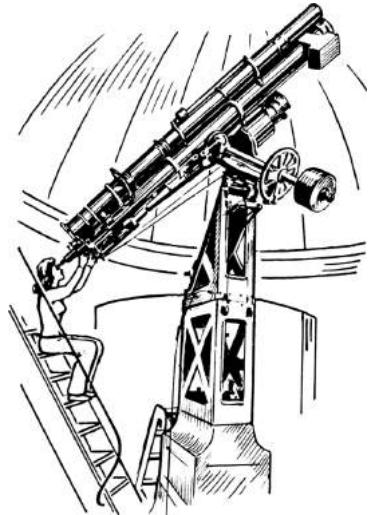
If the leptons would have felt the strong force, then they would have combined to form different particles.

The entire picture of Particle Physics would have been quite different.

Long-duration gamma ray bursts are associated with the deaths of massive stars in a specific kind of explosion called a **supernova**.

## The Drake Equation

$$N = R^* \cdot f_p \cdot n_e \cdot f_l \cdot f_i \cdot f_c \cdot L$$



- $N$  = number of civilizations with which humans could communicate
- $R^*$  = the rate at which stars are born in the galaxy,
- $f_p$  = the fraction of these stars that have planets,
- $n_e$  = the number of planets for each star that have the conditions for life,
- $f_l$  = the fraction of planets that actually develop life,
- $f_i$  = the fraction that develop intelligent life,
- $f_c$  = the fraction that are willing and able to communicate, and
- $L$  = the expected lifetime of a civilization.

- **Motion** is the change of state of an object.

The equation  $v = \sqrt{gh}$  gives the speed  $v$  with which apple hits the ground after falling from a tree.



The velocity is proportional only to the square root of the height.

**The larger  $p = mv$  is, the harder it is to stop the object.**

### Galileo's principle of relativity



It is impossible by mechanical means to say whether we are moving or staying at rest

**The force of gravitation between the sun and the earth:**

**Entropy** measures the degree to which energy is mixed up inside a system.

$$F_{G_{\text{sun-earth}}} = \frac{GM_{\text{sun}}m_{\text{earth}}}{r^2}$$

$$F_{G_{\text{sun-earth}}} = \frac{(6.673 \times 10^{-11}) (2 \times 10^{30}) (6 \times 10^{24})}{(1.5 \times 10^{11}) (1.5 \times 10^{11})} = 3.557 \times 10^{22} \text{ N}$$

**The force of gravitation between the earth and the moon:**

$$F_{G_{\text{earth-moon}}} = \frac{GM_{\text{earth}}m_{\text{moon}}}{r^2}$$

$$F_{G_{\text{earth-moon}}} = \frac{(6.673 \times 10^{-11})(6 \times 10^{24})(7.4 \times 10^{22})}{(3.84 \times 10^5)(3.84 \times 10^5)} = 2 \times 10^{26} \text{ N}$$

$$\left. \begin{array}{l} \frac{F_{G_{\text{sun-earth}}}}{F_{G_{\text{earth-moon}}}} = 0.00017785 \\ F_{G_{\text{sun-earth}}} < F_{G_{\text{earth-moon}}} \end{array} \right\}$$

### **Titius-Bode Law:**

The **distance d** of the  $n^{\text{th}}$  **planet** from the Sun is given by:

$$d = a + 2^n b \text{ with } a = 0.4 \text{ AU and } b = 0.3 \text{ AU}$$

The integer take values  $n = -\infty$  for mercury,  $n = 0$  for Venus,  $n = 1$  for the Earth, and so on.

Planet	n	Actual distance in AU	Predicted distance in AU
Mercury	$-\infty$	0.387	0.4
Venus	0	0.723	0.7
Earth	1	1.00	1.0
Mars	2	1.52	1.6
Planetoids	3	2.2 to 3.2	2.8
Jupiter	4	5.20	5.2
Saturn	5	9.55	10.0
Uranus	6	19.2	19.6
Neptune	7	30.1	38.8
Pluto	8	39.5	77.2

Led **Johann Titius** to predict the existence of another planet between Mars and Jupiter in what we now recognize as the asteroid belt.

Predicted the amount of space between the planets

## Refraction

Waves change direction when they change medium

When waves add up or cancel each other out: they interpenetrate each other.

## Heisenberg's Uncertainty Principle:

$$\Delta p \times \Delta x \geq \frac{\hbar}{2}$$

$$m \Delta v \times \Delta x \geq \frac{\hbar}{2}$$

$$\Delta v \geq \frac{\hbar}{2 m \Delta x}$$

Only for the exceedingly small masses of atoms and subatomic particles the product of the uncertainties becomes significant.

The position and the velocity of a subatomic particle cannot both be measured exactly, at the same time – even in theory.

$$\Delta p \times \Delta x \geq \frac{\hbar}{2}$$

$$\Delta k \times \Delta x \geq \frac{1}{2}$$

$$\Delta p = \frac{h}{\Delta \lambda} = \hbar \Delta k$$

$k$  = angular wave number

{ It is impossible to specify both the position of a light signal and its wavelength with full precision }

## Loschmidt's number

The number of gas molecules in one cubic centimeter at 0° C and one atmosphere pressure

$2.687 \times 10^{19}$  molecules per cubic centimeter

## Did you know that

By analyzing the Stellar Spectrum, one can determine both the temperature of a star and the composition of its atmosphere.

Electric and magnetic forces are far stronger than gravity, but remain unnoticeable because every macroscopic body contain almost equal numbers of positive and negative electrical charges (i.e., the electric and magnetic forces nearly cancel each other out).

The wavelength of a wave is the distance between successive peaks or troughs



Niels Bohr



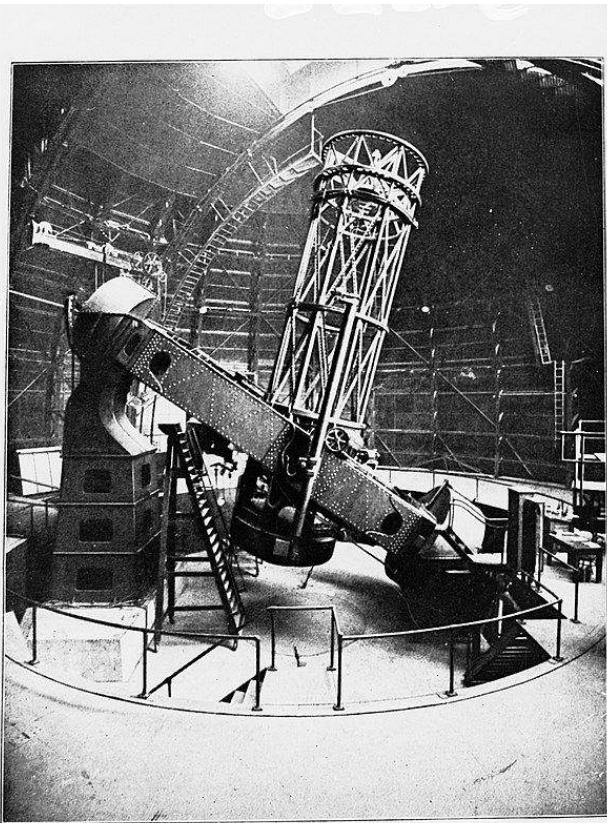
Bohr and Margrethe Nørlund on their engagement in 1910

Niels Bohr imagined the atom as consisting of electron waves of wavelength  $\lambda = h/mv$  endlessly circling atomic nuclei. In his picture, only orbits with circumferences corresponding to an integral multiple of electron wavelengths could survive without destructive interference (i.e.,  $r = n\lambda/mv$  could survive without destructive interference).

**Light waves are similar to water waves. Both are characterized by their wavelength, speed and frequency (or period).**

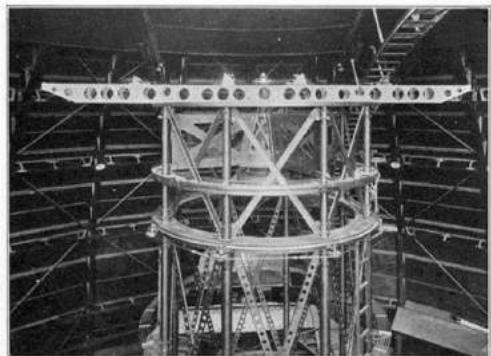
To make a planet move at a high speed in a small orbit requires a strong gravitational force.

To make the same planet to move at a low speed in a large orbit requires only a weak gravitational force.



THE ONE HUNDRED INCH HOOKER TELESCOPE.

[Fig. 6.]



**The 100-inch Hooker telescope at Mount Wilson Observatory**

The unification of so called weak nuclear forces with the Maxwell equations is what known as the Electro weak theory. And the electroweak theory and QCD together constitutes the so called **Standard Model of particle physics**, which describes everything except gravity.

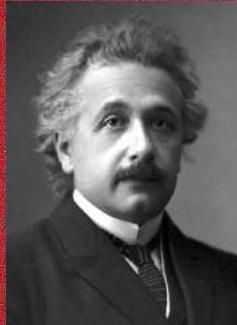
**Are there elementary particles that have not yet been observed, and, if so, which ones are**

**they and what are their properties ?**

When a wave source moves toward an observer, its waves appear to have a shorter wavelength. If the wave source moves away, its waves appear to have a longer wavelength. This is called the **Doppler Effect**.

$$w = \frac{u+v}{1+\frac{uv}{c^2}}$$

$$t' = t \sqrt{1 - \frac{v^2}{c^2}}$$



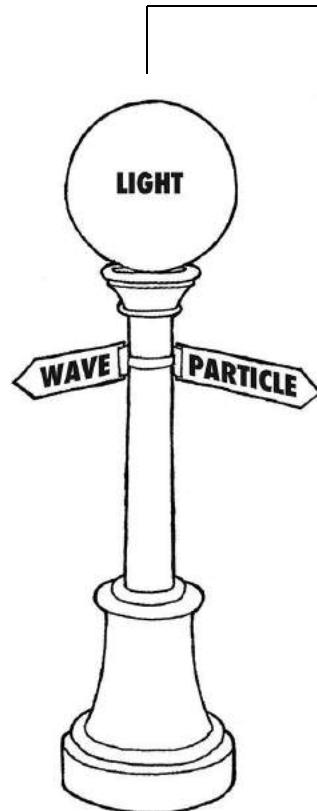
$$E = mc^2 = \sqrt{m_0^2 c^4 + p^2 c^2}$$

**Black Holes have no Hair, Says  
no Hair Theorem:**

Wait, What? Explaining the Black Hole  
The answer is then simple.

**Mass, Charge, and Angular Momentum**

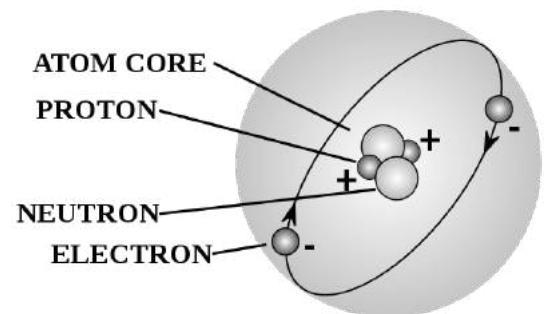
**The unification of two is  
the duality of one...**



**I'm a particle or a wave? I'm  
not sure about that..**



Material, such as gas, dust and other stellar debris that approach the black hole prevent themselves from falling into it by forming a flattened band of spinning matter around the event horizon called the **accretion disk**. And since the spinning matter accelerates to tremendous speeds ( $v \approx c$ ) by the huge gravity of the black hole the heat and powerful X-rays and gamma rays are released into the universe.



**Atom Structure**



**The total solar eclipse of July 11, 1991,  
photographed from near La Paz, Mexico. The hot  
outer atmosphere of the Sun, the corona, is clearly  
visible**

Like the formation of bubbles of steam in boiling water – Great many **holograms** of possible shapes and inner dimensions were created, started off in every possible way, simply because of an uncaused accident called spontaneous creation. Our universe was one among a zillion of holograms simply happened to have the right properties – with particular values of the physical constants right for stars and galaxies and planetary systems to form and for intelligent beings to emerge due to random physical processes and develop and ask questions, Who or what governs the laws and **constants of physics**? Are such laws the products of chance or a mere cosmic accident or have they been designed? How do the laws and constants of physics relate to the support and development of life forms? Is there any knowable existence beyond the apparently observed dimensions of our existence? However, M theory sounds so bizarre and unrealistic that there is no experiment that can credit its validity. Nature has not been quick to pay us any hints so far. That's the fact of it; grouped together everything we know about the history of the universe is a fascinating topic for study, and trying to understand the meaning of them is one of the key aspects of modern cosmology— which is rather like plumbing, in a way.

And as more space comes into existence, more of the dark energy (an invisible and unexpected cosmological force which was a vanishingly small slice of the pie 13.7 billion years ago, but today it is about three times as much as visible matter and dark matter put together and it eclipses matter and hides in empty space and works for the universe's expansion i.e., **pushes the edges of the universe apart** – a sort of anti-gravity) would appear. Unfortunately, no one at the present time has any understanding of where this "**undetected substance**" comes from or what exactly it is. Is it a **pure cosmological constant** (an arbitrary parameter from general relativity, has been taken to be zero for most of the twentieth century for the simple and adequate reason that this value was consistent with the data) or is it a sign of extra dimensions? What is the cause of the dark energy? Why does it exist at all? Why is it so different from the other energies? Why is the composition of dark energy so large (of about 73% of our universe – we only make up **0.03% of the universe** which include stars orbiting their galaxies much too fast to be held in orbit merely by the gravitational attraction of the observed galactic stars )?

String theory (**a cutting-edge research that has integrated [Einstein's] discoveries into a**

**quantum universe with numerous hidden dimensions coiled into the fabric of the cosmos**  
**- dimensions whose geometry may well hold the key to some of the most profound questions ever posed)** gives us a clue, but there's no definitive answer. Well, all know is that it is a sort of cosmic accelerator pedal or an invisible energy what made the universe bang and if we held it in our hand; we couldn't take hold of it. In fact, it would go right through our fingers, go right through the rock beneath our feet and go all the way to the majestic swirl of the heavenly stars. It would reverse direction and come back from the stately waltz of orbiting binary stars through the intergalactic night all the way to the edge of our feet and go back and forth. How near are we to understand the dark energy? The question lingers, answer complicates and challenges everyone who yearns to resolve. And once we understand the dark energy, can we understand the birth and the death of everything in the **mankind's observable universe**, from a falling apple to the huge furnace (that burns billions of pounds of matter each second and reaches temperatures of tens of millions of degrees at its core) and the earth (standing at the center of the universe, surrounded by eight spheres carrying all the known heavenly bodies) is also an?

Entropy (a thermodynamic quantity -- first introduced by the German physicist **Rudolf Clausius** (1822–1888) – a measure of untidiness in a system and a measure of how much information a system contains) is defined as:  $S = k_B \ln \{\text{number of states}\}$  which, for N particles of the same type, will be:

$$S = k_B \ln \{(\text{no of one-particle states}) N\}$$

$$S = k_B N \ln \{\text{a not-too-big number}\}$$

$$S = k_B N$$

This means: the more particles, the more disorder. The entire universe is getting more disordered and chaotic with time i.e., the entropy of the universe is increasing toward greater disorder. And this observation is elevated to the status of a law, the so called **Second law of thermodynamics** (which was discovered by the great German physicist, **Ludwig Boltzmann** who laid down the second law of thermodynamics, committed suicide in 1906, in part because of the intense ridicule he faced while promoting the concept of atoms) i.e., the universe will tend toward a state of maximum entropy, such as a uniform gas near absolute zero (at this point, the atoms themselves almost come to a halt) and that there is nothing we have to do about it. No

matter how advanced our conditions would be right for the generation of thoughts to predict things more or less, even if not in a simplest way, it can never squash the impending threat of the second law of thermodynamics (that will eventually result in the destruction of all intelligent life) nor it can bring us close to the answer of why was the entropy ever low in the first place. This makes cosmology (the study of the universe as a whole, including its birth and perhaps its ultimate fate) a bit more complicated than we would have hoped.

Explaining everything ... is one of the greatest challenges we have ever faced. Hence, it has been an endeavor of science to find a single theory which could explain everything, where every partial theory that we've read so far (in school) is explained as a case of the one cogent theory within some special circumstances. Despite being a mystery skeptic, the **Unified Field Theory** (which **Albert Einstein** sought [but never realized] during the last thirty years of his life and capable of describing nature's forces within a single, all-encompassing, coherent framework) presents an infinite problem. This is embarrassing. Because we now realize before we can work for the theory of everything, we have to work for the ultimate laws of nature. At the present, we're clueless as to what the ultimate laws of nature really are. Are there new laws beyond the apparently observed dimensions of our universe? **Do all the fundamental laws of nature unify?** At what scale? Ultimately, however, it is likely that answers to these questions in the form of unified field theory may be found over the next few years or by the end of the century we shall know can there really be a complete unified theory that would presumably solve our problems? Or are we just chasing **a mirage**? Is the ultimate unified theory so compelling, that it brings about its own existence? However, if we – a puny and insignificant on the scale of the cosmos – do discover a unified field theory, it should in time be understandable in broad principle by everyone, not just a few people. Then we shall all be able to take part in the discussion of the questions of how and when did the universe begin? Was the universe created? Has this universe been here forever or did it have a beginning at the Big Bang? If the universe was not created, how did it get here? If the Big Bang is the reason there is something rather than nothing, and then before the Big Bang there was NOTHING and then suddenly we got **A HUGE AMOUNT OF ENERGY** where did it come from? What powered the Big Bang? What is the fate of the Universe? Is the universe heading towards a Big Freeze (the end of the universe when it reaches near absolute zero), a Big Rip, a Big Crunch (the final

collapse of the universe), or a Big Bounce? Or is it part of an infinitely recurring cyclic model? Is inflation a law of Nature? Why the universe started off very hot and cooled as it expanded? Is the Standard Big Bang Model right? Or is it the satisfactory explanation of the evidence which we have and therefore merits our provisional acceptance? Is our universe finite or infinite in size and content? What lies beyond the existing space and time? What was before the event of creation? Why is the universe so uniform on a large scale (even though uncertainty principle – which fundamentally differentiates quantum from classic reasoning—discovered by the German physicist **Werner Heisenberg** in 1927 – implies that the universe cannot be completely uniform because there are some uncertainties or fluctuations in the positions and velocities of the particles)? Why does it look the same at all points of space and in all directions? In particular, why is the temperature of the cosmic microwave background radiation so nearly the same when we look in different directions? Why are the galaxies distributed in clumps and filaments? When were the first stars formed, and what were they like? Or if string theory (which is part of a grander synthesis: M-theory and have captured the hearts and minds of much of the theoretical physics community while being apparently disconnected from any realistic chance of definitive experimental proof) is right i.e., every particle is a tiny one dimensional vibrating string of **Planck length** (the smallest possible length i.e., Planck time multiplied by the speed of light)?

Why most of the matter in the Universe is dark? **Is anthropic principle a natural coincidence?** If we find the answers to them, it would be the ultimate triumph of human reason i.e., we might hold the key to address the eternal conundrum of some of the most difficult issues in modern physics. Yet those difficult issues are also the most exciting, for those who address big, basic questions: What do we really know about the universe? How do we know it? Where did the universe come from, and where is it going? It would bring to an end a long and glorious lesson in the history of mankind's intellectual struggle to understand the universe. For then we would know whether the laws of physics started off the universe in such an incomprehensible way or not. **Chances are that these questions will be answered** long after we're gone, but there is hope that the beginnings of those answers may come within the next few years, as some aspects of bold scientific theory that attempts to reconcile all the physical properties of our universe into a single unified and coherent mathematical framework

begin to enter the realm of theoretical and experimental formulation.

Up until recently, a multitude of revolutions in various domains, from literature to experimental science, has prevailed over established ideas of modern age in a way never seen before. But we do not know about what is the exact mechanism by which an implosion of a dying star becomes a specific kind of explosion called a **supernova**. All that we know is that: When a massive star runs out of nuclear fuel, the gravitational contraction continues increasing the density of matter. And since the internal pressure is proportional to the density of matter, therefore the internal pressure will continually increase with the density of matter. And at a certain point of contraction, internal pressure will be very much greater than gravitational binding pressure and will be **sufficiently high enough to cause the star to explode**, spraying the manufactured elements into space that would flung back into the gas in the galaxy and would provide some of the raw material for the next generation of stars and bodies that now orbit the sun as planets like the Earth. The total energy released would outshine all the other stars in the galaxy, approaching the luminosity of a whole galaxy (will nearly be the order of 10 to the power of 42 Joules). In the aftermath of the supernova, we find a totally **dead star, a neutron star** – a cold star, supported by the exclusion principle repulsion between neutrons – **about the size of Manhattan** (i.e., ten to 50 times the size of our sun).

Why are there atoms, molecules, solar systems, and galaxies? What powered them into existence? How accurate are the physical laws and equations, which control them? Why do the Fundamental Constants of Nature have the precise values they do? The answers have always seemed well beyond the reach of **Dr. Science since the dawn of humanity** – until now (some would claim the answer to these questions is that there is a transcendent God (a cosmic craftsman – a transcendent being than which no being could be more virtuous) who chose to create the universe that way according to some perfect mathematical principle. Then the question merely reflects to that of **who or what created the God**). But the questions are still the picture in the mind of many scientists today who do not spend most of their time worrying about these questions, but almost worry about them some of the time. All that science could say is that: The universe is as it is now. But it could not explain why it was, as it was, just after the Big Bang. **This is a disaster for science**. It would mean that science alone, could not predict

how the universe began. Every attempt is made to set up the connection between theoretical predictions and experimental results but some of the experimental results throw cold water on the theoretical predictions.

Back in 1700s, people thought the stars of our galaxy structured the universe, that the galaxy was nearly static, and that the universe was essentially unexpanding with neither a beginning nor an end to time. A situation marked by difficulty with the idea of a static and unchanging universe, was that according to the **Newtonian theory of gravitation**, each star in the universe supposed to be pulled towards every other star with a force that was weaker the less massive the stars and farther they were to each other. It was this force caused all the stars fall together at some point. So how could they remain static? Wouldn't they all collapse in on themselves? A balance of the predominant attractive effect of the stars in the universe was required to keep them at a constant distance from each other. Einstein was aware of this problem. He introduced a term so-called **cosmological constant** in order to hold a static universe in which gravity is a predominant attractive force. This had an effect of a repulsive force, which could balance the predominant attractive force. In this way it was possible to allow a static cosmic solution. Enter the **American astronomer Edwin Hubble**. In 1920s he began to make observations with the hundred inch telescope on Mount Wilson and through detailed measurements of the spectra of stars he found something most peculiar: stars moving away from each other had their spectra shifted toward the red end of the spectrum in proportion to the distance between them (This was a **Doppler effect of light**: Waves of any sort – sound waves, light waves, water waves – emitted at some frequency by a moving object are perceived at a different frequency by a stationary observer. The resulting shift in the spectrum will be towards its red part when the source is moving away and towards the blue part when the source is getting closer). And he also observed that stars were not uniformly distributed throughout space, but were gathered together in vast collections called galaxies and nearly all the galaxies were moving away from us with recessional velocities that were roughly dependent on their distance from us. He reinforced his argument with the formulation of his well-known **Hubble's law**. The observational discovery of the stretching of the space carrying galaxies with it completely shattered the previous image of a static and unchanging

cosmos (i.e., the motivation for adding a term to the equations disappeared, and Einstein rejected the cosmological constant a greatest mistake).

We story telling animals (who **TALK ABOUT THE** nature of the universe and discuss such questions as whether it has a beginning or an end) often claim that we know so much more about the universe. But we must beware of overconfidence. We have had false dawns before. At the beginning of this century, for example, it was thought that earth was a perfect sphere, but latter experimental observation of variation of value of "**g**" over the surface of earth confirmed that earth is not a **perfect sphere**. Today there is almost universal agreement that space itself is stretching, carrying galaxies with it, though we are experimentally trying to answer whether cosmic [expansion will] continue forever or slow to a halt, reverse itself [and] lead to a **cosmic implosion**. However, personally, we're sure that the accelerated expansion began with a state of infinite compression and primeval explosion called the hot Big Bang. But will it expand forever or there is a limit beyond which the average matter density exceeds a hundredth of a billionth of a billionth of a billionth ( $10^{-29}$ ) of a gram per cubic centimeter so-called **critical density** (the density of the universe where the expansion of the universe is poised between eternal expansion and recollapse)... then a large enough gravitational force will permeate the cosmos to halt and reverse the expansion or the expansion and contraction are evenly balanced? We're less sure about that because events cannot be predicted with complete accuracy but that there is always a degree of uncertainty.

The picture of standard model of the Forces of Nature (a sensible and successive quantum-mechanical description developed by **1970s physicists**) is in good agreement with all the observational evidence that we have today and remains consistent with all the measured properties of matter made in our most sophisticated laboratories on Earth and observed in space with our most powerful telescopes. Nevertheless, it leaves a number of important questions unanswered like the unanswered questions given in **The Hitchhiker's Guide to the Galaxy (by Douglas Adams)**: Why are the strengths of the fundamental forces (electromagnetism, weak and strong forces, and gravity) are as they are? Why do the force particles have the precise masses they do? Do these forces really become unified at

sufficiently high energy? If so how? Are there unobserved fundamental forces that explain other unsolved problems in physics? Why is gravity so weak? May because of hidden extra dimensions? Very likely, we are missing something important that may seem as obvious to us as the earth orbiting the sun – or perhaps as ridiculous as a tower of tortoises. Only time (whatever that may be) will tell.

**The theory of evolution** (which predicts: that the use of antiviral or antibacterial agents would result in the emergence of resistant strains. This principle is, of course, a mainstay of contemporary medicine and asserts that the **natural selection** is a choice of stable forms and a rejection of unstable ones. And the variation within a species occurs randomly, and that the survival or extinction of each organism depends upon its ability (an internal force or tendency) to adapt to the environment) lined up pictures of apes and humans and claimed that humans evolved from apes (i.e., the chimpanzee and the human share **about 99.5 per cent** of their evolutionary history). This spilled out onto the corridors of the academy and absolutely rocked **Victorian England to the extent that people** just barely raised their voice contradicting the biblical account of creation in the lecture hall rips of the architrave. And despite more than a century of digging straight down and passing through the fossil layers, the fossil record remains maddeningly sparse and provides us with **no evidence that show evolutionary transition development of one species into another species**. However, we are convinced that the theory of evolution, especially the extent to which it's been believed with blind faith, which may turn to be one of the great fairy tales for adults in the history books of the future. Like raisins in expanding dough, galaxies that are further apart are increasing their separation more than nearer ones. And as a result, the light emitted from distant galaxies and stars is shifted towards the red end of the spectrum. Observations of galaxies indicate that the universe is expanding: the distance  $D$  between almost any pair of galaxies is increasing at a rate  $V = HD$  – beautifully explained by the Hubble's law (the law that agrees with Einstein's theory of an expanding universe). However, controversy still remains on the validity of this law. **Andromeda, for example, for which the Hubble relation does not apply**. And quantum theory (The revolutionary theory of the last century clashed with everyday experience which has proved enormously successful, passing with flying colors the many stringent laboratory tests to which it has been subjected for almost a hundred years) predicts that entire space is not continuous

and infinite but rather quantized and measured in units of quantity called Planck length ( $10^{-33}$  cm – the length scale found at the big bang in which the gravitational force was as strong as the other forces and at this scale, space-time was "**foamy**," with tiny bubbles and wormholes appearing and disappearing into the vacuum). However, at the present there is no conclusive evidence in favor of quantization of space and time and moreover nobody knows why no spatial or time interval shorter than the Planck values exists?

For length: Planck length (a hundred **billion billion times** [ $10^{20}$ ] smaller than an atomic nucleus)  $-1.6 \times 10^{-33}$  centimeter.

For time: Planck time  $-5 \times 10^{-44}$  seconds.

On the other hand, there is no evidence against what the quantum model inform us about the true nature of reality. But in order to unify **Albert Einstein's general relativity** (a theoretical framework for understanding the universe on the largest of scales: the immense expanse of the universe itself and it breaks down at times less than the Planck time and at distances smaller than the Planck length, predicts the existence of **wormhole** – a passageway between two universes – gives us a better way of grasping reality than Newtonian mechanics, because it tells us that there can be black holes, because it tells us there's a Big Bang) with the quantum physics that describe fundamental particles and forces, it is necessary to quantize space and perhaps time as well. And for a universe to be created out of nothing, the positive energy of motion should exactly cancel out the negative energy of gravitational attraction i.e., the net energy of the universe should be = zero. And if that's the case, the spatial curvature of the universe,  $\Omega_k$ , should be = 0.0000 (i.e., perfect flatness). But the **Wilkinson Microwave Anisotropy Probe (WMAP)** satellite has established the spatial curvature of the universe,  $\Omega_k$ , to be between **-0.0174** and **+0.0051**. Then, how can it cost nothing to create a universe, how can a whole universe be created from nothing? On the other hand, there is a claim that the sum of the energy of matter and of the gravitational energy is equal to zero and hence there is a possibility of a universe appearing from nothing and thus the universe can double the amount of positive matter energy and also double the negative gravitational energy without violation of the conservation of energy. However, **energy of matter + gravitational energy is = zero** is only a claim based on Big Bang implications. No human being can possibly know the precise energy content of the entire universe. In order to verify the claim that the total energy content of the universe is exactly zero, one would have to account for all the forms of energy of matter

in the universe, add them together with gravitational energy, and then verify that the sum really is exactly zero. But the attempt to verify that the sum really is exactly zero is not an easy task. We need precision experiments to know for sure.

Gazing at the at the blazing celestial beauty of the night sky and asking a multitude of questions that have puzzled and intrigued humanity since our beginning – **WE'VE DISCOVERED** a lot about our celestial home; however, we still stand at a critical cross road of knowledge where the choice is between spirituality and science to accomplish the hidden truth behind the early evolution of the universe. In order to throw light on a multitude of questions that has so long occupied the mind of scientists and the people who have argued over the years about the nature of reality and whose business it is to ask why, the philosophers: Where did we and the universe come from? Where are we and the universe going? What makes us and the universe exists? Why we born? Why we die? Whether or not the universe had a beginning? If the universe had a beginning, why did it wait an infinite time before it began? What was before the beginning? Is our universe tunneled through the chaos at the Planck time from a prior universe that existed for all previous time? We must either build a sound, balanced, effective and extreme imaginative knowledge beyond our limit. **Many theories were put forth by the scientists** to look into the early evolution of the universe but none of them turned up so far. And if, like me, you have wondered looking at the star, and tried to make sense of what makes it shine the way it is. Did it shine forever or was there a limit beyond which it cannot or may not shine? And, where did the matter that created it all come from? Did the matter have a beginning in time? Or had the matter existed forever and didn't have a beginning? In other words, what cause made the matter exist? And, what made that cause exist? Some would claim the answer to this question is that matter could have popped into existence 13.9 billion years ago as a result of just the eminent physical laws and constants being there. **Any "meta" or "hyper" laws of physics** that would allow (even in postulate) a matter to pop into existence are completely outside our experience. The eminent laws of physics, as we know them, simply are not applicable here. Invoking the laws of physics doesn't quite do the trick. And the laws of physics are simply the human-invented ingredients of models that we introduce to describe observations. They are all fictitious, as far as we find a reference frame in which they are observed. The question of matter genesis is clear, and deceptively simple. **It is as old as the question of what was going on before the**

**Big Bang.** Usually, we tell the story of the matter by starting at the Big Bang and then talking about what happened after. The answer has always seemed well beyond the reach of science. Until now.

Over the decades, there have been several heroic attempts to explain the origin of matter, all of them proven wrong. One was the so-called **Steady State theory**. The idea was that, as the galaxies moved apart from each other; new galaxies would form in the spaces in between, from matter that was spontaneously being created. The matter density of the universe would continue to exist, forever, in more or less the same state as it is today. In a sense disagreement was a credit to the model, every attempt was made to set up the connection between theoretical predictions and experimental results but the Steady State theory was disproved even with limited observational evidence. The theory therefore was abandoned and the idea of spontaneous creation of matter was doomed to fade away into mere shadows. As crazy as it might seem, the matter may have come out of nothing! The meaning of nothing is somewhat ambiguous here. It might be the pre-existing space and time, or it could be nothing at all. After all, no one was around when the matter began, so who can say what really happened? The best that we can do is work out the most vain imaginative and foolish theories, backed up by numerous lines of scientific observations of the universe.

**Cats are alive and dead at the same time.** But some of the most incredible mysteries of the quantum realm (a jitter in the amorphous haze of the subatomic world) get far less attention than Schrödinger's famous cat. Due to the fuzziness of **quantum theory** (that implies: the cosmos does not have just a single existence or history), and specifically Heisenberg's uncertainty principle (which fundamentally differentiates quantum from classic reasoning – discovered by the German physicist **Werner Heisenberg** in 1927), one can think of the vacuum fluctuations as virtual matter – antimatter pairs that appear together at some time, move apart, then come together and annihilate one another and revert back to energy. Spontaneous births and deaths of roiling frenzy of particles so called virtual matter – antimatter pairs momentarily occurring everywhere, all the time – is the evidence that mass and energy are interconvertible; they are two forms of the same thing. If one argue that matter was a result of such a fluctuation. So then the next question is what cause provided enough energy to make the virtual matter – antimatter pairs materialize in real space. And if we assume some unknown cause has teared the

pair apart and boosted the separated **virtual matter – antimatter into the materialized state**. The question then is what created that cause. In other words, what factor created that cause? And what created that factor. Or perhaps, the cause, or the factor that created it, existed forever, and didn't need to be created. The argument leads to a never-ending chain that always leaves us short of the ultimate answer. Unfortunately, **Dr. Science cannot answer these questions**. So, the problem remains. However, quantum origin and separation of the matter still delights theoretical physicists but boggles the mind of mere mortals, is the subject of my thought; have the quantum laws found a genuinely convincing way to explain matter existence apart from divine intervention? If we find the answer to that, it would be the **ultimate triumph of human reason** – for then we would know the ultimate Cause of the Matter. Over the decades, we're trying to understand how the matter began and we're also trying to understand all the other things that go along with it. This is very much the beginning of the story and that story could go in, but I think there could be surprises that no one has even thought of. Something eternal can neither be created nor destroyed. The first law of thermodynamics (a version of the law of conservation of energy, adapted for thermodynamic systems) asserts that matter or energy can neither be created nor destroyed; it can be converted from one form to another.

The overwhelming experience of experimental science (science based on experimental research that plays the role of **testing hypothesis**, typically in controlled laboratory settings) confirms this first law to be a fact. But if the matter prevails in the boundary of understanding in that it neither started nor it ends: it would simply be. What place then for an evidence exposing that we live in a finite expanding universe which has not existed forever, and that all matter was once squeezed into an infinitesimally small volume, which erupted in a cataclysmic explosion which has become known as the Big Bang. However, what we believe about the origin of the matter is not only sketchy, but uncertain and based purely on human perception. There is no reliable and genuine evidence to testify about how the matter began and what may have existed before the beginning of the matter. **The laws of physics tell us that the matter had a beginning**, but they don't answer how it had begun. Mystery is running the universe in a hidden hole and corner, but one day it may wind up the clock work with might and main. The physical science can explain the things after big bang but fails to explain the things before big bang. We know that matter can be created out of energy, and energy can be created out of

matter. This doesn't resolve the dilemma because we must also know where the original energy came from.

The electrostatic and gravitational forces according to **Coulomb's and Newton's laws** are both inverse square forces, so if one takes the ratio of the forces, the distances cancel. For the

electron and proton, the ratio of the forces is given by the equation:  $\frac{F_E}{F_G} = \frac{e^2}{4\pi\epsilon_0 G m_p m_e}$ , where  $e$

is the charge  $= 1.602 \times 10^{-19}$  Coulombs,  $G$  is the gravitational constant,  $\epsilon_0$  is the absolute permittivity of free space  $= 8.8 \times 10^{-12} \frac{F}{m}$ ,  $m_p$  is the mass of the proton  $= 1.672 \times 10^{-27}$  kg and

$m_e$  is the mass of the electron  $= 9.1 \times 10^{-31}$  kg. Plugging the values we get:  $\frac{F_E}{F_G} = 10^{39}$  which

means:  $F_E > F_G$ . So, it was argued by a German mathematician, theoretical physicist and philosopher (some say it was **Hermann Weyl**), if the gravitational force between the proton and electron were not much smaller than the electrostatic force between them, then the hydrogen atom would have collapsed to neutron long before there was a chance for stars to form and life to evolve.  $F_E > F_G$  must have been numerically **fine-tuned** for the existence of

life. Taking  $\frac{F_E}{F_G} = 10^{39}$  as an example in most physics literature we will find that gravity is the

weakest of all forces, many orders of magnitude weaker than electromagnetism. But this does not make sense any way and it is not true always and in all cases. Note that the ratio  $\frac{F_E}{F_G}$  is not a universal constant; it's a number that depends on the particles we use in the calculation. For example: For two particles each of Planck mass (mass on the order of **10 billion billion times**

that of a proton) and Planck charge the ratio of the forces is 1 i.e.,  $\frac{F_E}{F_G} = 1$ . Moreover, when the

relativistic variation of electron mass with velocity is taken into account then the ratio  $\frac{F_E}{F_G}$

becomes velocity dependent.

Does our universe exist inside a black hole of another universe? The question lingers, unanswered until now. Even though the existence of alternative histories with black holes, suggests this might be possible i.e., our universe lies inside a black hole of another universe, we

cannot prove or disprove this conjecture any way. Meaning that the event horizon of a black hole is boundary at which nothing inside can escape and then how might one can cross its event boundary and testify whether or not our universe exist inside a black hole of another universe. Thus we cannot answer the central question in cosmology: **Does our universe exist inside a black hole of another universe?** However, the fact that we are simply an advanced breed of talking monkeys surviving on a sumptuous planet, have been reckoning at least from last hundred years – turning unproved belief into unwavering existence through the power of perception and spending our brief time in the sun working at understanding the deepest mysteries of nature by doing repeated calculations and getting some answer that seem very likely makes us feel something very special-- a bit premature to buy tickets to the nearest galaxy to visit the next goldilocks planet or hunt dinosaurs.

The physicist has been spending a month, as he or she does each year, sequestered with colleagues, such as fellow theoretical physicists, to discuss many great mysteries of the cosmos. But despite its simple approximation as a force, and its beautifully subtle description as a property of space-time which in turn can be summarized by Einstein's famous equation, which essentially states: **Matter-energy → curvature of space- time**, we've come to realize over the past century that we still don't know what gravity actually is. It has been a closed book ever since the grand evolution of human understanding and all physicists hang this book up on their wall and distress about it. Unhesitatingly you would yearn to know where this book comes from: is it related to metaphysical science or perhaps to the greatest blast puzzles of physics still to be discovered, like cosmic string and magnetic monopoles? Nobody knows and for the moment, nature has not said yes in any sense. It's one of the **10,000 bits puzzling cosmic story** with a cracking title. You might say the laws of physics designed that book, and we don't know how they designed that book. The elevated design of this book, an extract of which appears in the cosmic art gallery, sets out to the belief that it must have designed as it could not have created out of chaos. In some sense, the origin of the cosmic problem today remains what it was in the time of **Newton** (who not only put forward a theory of how bodies move in space and time, but he also developed the complicated mathematics needed to analyze those motions) – one of the greatest challenges of 21<sup>st</sup> Century science certainly keep many an aficionado going. Yet, we toasting each other with champagne glasses in laboratories around the world-- have

made a bold but brilliant move. In less than a hundred years, we have found a new way to wonder what gravity is. The usual approach of science of constructing a set of rules and equations cannot answer the question of why if you could turn off gravity, space and time would also vanish. In short, we don't have an answer; we now have a whisper of the grandeur of the problem. We don't know exactly how it is intimately related to space and time. It's a mystery that we're going to chip at from quantum theory (the theory developed from **Planck's quantum principle and Heisenberg's uncertainty principle** which deals with phenomena on extremely small scales, such as a millionth of a millionth of an inch). However, when we try to apply quantum theory to gravity, things become more complicated and confusing.

Mankind's deepest desire for scientific intervention introduced a **new idea that of time**. Most of the underlying assumptions of physics are concerned with time. Time may sound like a genre of fiction, but it is a well-defined genuine concept. Some argue that time is not yet discovered by us to be objective features of the mundane world: even without considering time an intrinsic feature of the mundane world, we can see that things in the physical world change, seasons change, people adapt to that drastic changes. The fact that the physical change is an objective feature of the physical world, and time is independent of under whatever circumstances we have named it. Others think time as we comprehend it does not endure beyond the bounds of our physical world. Beyond it, maybe one could run forward in time or just turn around and go back. This could probably mean that one could fall rapidly through their former selves. In a bewildering world, the question of whether the time never begin and has always been ticking, or whether it had a beginning at the big bang, is really a concern for physicists: either science could account for such an inquiry. If we find the answer to it, it would be the ultimate triumph of human justification for our continuing quest. And, our goal of a complete description of the universe we live in is self-justified. The understanding we have today is that time is not an illusion like what age-old philosophers had thought, but rather it is well defined mathematical function of an inevitable methodical framework for systematizing our experiences. If one believed that the time had a beginning, the obvious question was how it had started? The problem of whether or not the time had a beginning was a great concern to the **German Philosopher, Immanuel Kant** (who believed that every human concept is based on observations that are operated on by the mind so that we have no access to a mind- independent

reality). He considered the entire human knowledge and came to the conclusion that time is not explored by humans to be objective features of the mundane world domain, but is a part of an inevitable systematic framework for coordinating our experiences. How and when did the time begin? No other scientific question is more fundamental or provokes such spirited debate among physicists. Since the early part of the 1900s, one explanation of the origin and fate of the universe, the Big Bang theory, has dominated the discussion. Although singularity theorem (a theorem showing that a singularity, a point where **general relativity** (a theory which predicts that time would come to an end inside a **black hole – an invisible astrophysical entity** that no one has seen, but scientists have observed gravitational evidence consistent with predictions about it, so most scientists believe it exists) breaks down, must exist under certain circumstances; in particular, that the universe must have started with a singularity) predicted that the time, the space, and the matter or energy itself had a beginning, they didn't convey how they had a beginning. It would clearly be nice for singularity theorems if they had a beginning, but how can we distinguish whether they had a beginning? In as much as the time had a beginning at the Big Bang it would deepen implication for the role of supreme divine creator (that much of humanity worships as the source of all reality) in the grand design of creation.

But if it persists in the bounds of reason in that it has neither beginning nor end and nothing for a Creator to do. What role could ineffable benevolent creator have in creation? Life could start and new life forms could emerge on their own randomly sustaining themselves by reproducing in the environment fitted for the functional roles they perform. Personally, we're sure that the time began with a hot Big Bang. But will it go on ticking forever? If not, when it will wind up its clockwork of ticking? We're much less sure about that. However, we are just a willful gene centered breed of talking monkeys on a minor planet of a very average galaxy. But we have found a new way to question ourselves and we have learned to do them. That makes us something very special. Moreover, everything we think we understand about the universe would need to be reassessed. Every high school graduate knows cosmology, the very way we think of things, would be forever altered. The distance to the stars and galaxies and the age of the universe (13.7 billion years – number has now been experimentally determined to within 1% accuracy) would be thrown in doubt. Even the expanding universe theory, the Big Bang theory, and black holes would have to be re-examined. The Big Bang theory of universe

assumes the present form of the universe originated from the hot fire ball called singularity and it assumes time did not exist before the Big Bang. But **Erickcek** deduced on the basis of **NASA's, Wilkinson Microwave Anisotropy Probe (WMAP)** that the existence of time and empty space is possible before the Big Bang.

But what would happen if you travel back in time and kill your grandfather before he conceives your father? Would the arrow of time reverse? Because motion makes the clock tick slower, can we travel back in time and kill our grandfather before he conceive our father? If not, why the universe avoids the paradox? **Time Travel – Science Fiction?** Taking the laws of physics and punching them in the stomach and throwing them down the stairs – it's possible for you to break the universal speed limit. It is mind boggling to think about it – you're actually travelling backwards in time. What if you went back in time and prevented big bang from happening? You would prevent yourself from ever having been born! But then if you hadn't been born, you could not have gone back in time to prevent big bang from happening. The concept of time travel may sound something impressive and allow science fiction like possibilities for people who survived from the past, but somewhat it seems to be incredible like seeing **broken tea cups gathering themselves together off** the floor and jumping back on the table promoting cup manufacturers go out of business. However, travelling through time may not be the far-fetched science fiction theory. At the same time, can we open a portal to the past or find a shortcut to the future and master the time itself is still in question and forbidden by the second law of thermodynamics (which states that in any closed system like universe randomness, or entropy, never decreases with time). Of course, we have not seen anyone from the past (or have we?).

We asked how stars are powered and found the answer in the transformations of atomic nuclei. But there are still simple questions that we can ask. And one is: Is our universe merely the by-product of a cosmic accident? If the universe were merely the by-product of a grand accident, then our universe could have been a **conglomeration of objects** each going its own way. But everything we see in the universe obeys rules which are governed by a set of equations, without exception – which give philosophy a lot more attention than science. However, this does not mean that the universe obey rules because it exists in a plan which is created and shaped by a

grinding hand.

Maybe the universe is a lucky coincidence of a grand accident emerged with ingredients such as space, time, mass, and energy exist in one-to-one correspondence with the elements of reality, and hence it obeys a set of rational laws without exception. At this moment it seems as though Dr. Science will never be able to raise the curtain on the mystery of creation. Moreover, traditional philosophy is dead, that it has not kept up with modern developments in science, and there is no reason at justifying the grinding hand because **the idea of God is extremely limited** and goes no further than the opening sentence of the classical theology (which has always rejected the idea that God can classified or defined), and much is still in the speculative stage, and we must admit that there are yet no empirical or observational tests that can be used to test the idea of an accidental origin. No evidence. **No scientific observation. Just a speculation.** For those who have lived by their faith in the power of reason, the story may end like a bad dream since free will is just an illusion.

From the Big Bang to the Bodies such as stars or black holes including basic facts such as particle masses and force strengths, the entire universe works because the laws of physics make things happen. But if Meta or hyper laws of physics were whatever produced the universe then what produced those laws. Or perhaps, the laws, or the cause that created them, existed forever, and didn't need to be created. We must admit that there is ignorance on some issues, that is, we **don't have a complete set of laws ....** We are not sure exactly does the existing laws hold everywhere and at all time. Dr. Science gives us a clue, but there's no definitive answer to provide a purely natural, non-causal explanation for the existence of laws of physics and our place in it. So let's just leave it at the hypothetical laws of physics. The question, then, is why are there laws of physics? And we could say, well, that required a biblical deity, who created these laws of physics and the spark that took us from the laws of physics to the notions of time and space. Well, if the laws of physics popped into existence 13.8 billion years ago with divine help whatsoever, like theologians say, why aren't we seeing a at least one evidence of an ineffable creator in our observable universe every now and then? The origin of the Meta or hyper laws of physics remains a mystery for now. However, recent breakthroughs in physics, made possible in part by fantastic revolutionary understanding of the true nature of the

mathematical quantities and theories of physics, may suggest an answer that may seem as obvious to us as the earth orbiting the sun – or perhaps as ridiculous as earth is a perfect sphere. We don't know whatever the answer may be because the **Meta or hyper laws of physics** are completely beyond our experience, and beyond our imagination, or our mathematics. This fact leads us to a big mystery and awaits the next generation of high energy experiments, which hope to shed light on the far-reaching answer that might be found in the laws that govern elemental particles.

Who are we? We find that we intelligent apes who have only recently left the trees, live on an fragile planet of a humdrum star by a matter of sheer luck or by divine providence, lost in a galaxy tucked away in some forgotten corner of a universe in which there are far more galaxies than people. Sending the **Beatles song across the Universe** and pointing the telescopes in Deep Space Network towards the **North Star, Polaris**, we seek to find intellectual beings like us outside the sheer number of planets, vast ocean of existence, our solar system, and our own Milky Way galaxy. How awe hunting for them across the empty stretches of the universe would be to acquire a bit of confirmation that either we're alone in this universe or we are not. However, we are not the only life-form in the universe, is reasonable to expect since we have no reason to assume that ours is the only possible form of life. Some sort of life could have happened in a universe of greatly different form, but

## Where's the evidence?

The Burden of evidence is only on the people who regard themselves as reliable witnesses that sightings of UFOs are evidence that we are being visited by someone living in another galaxy who are much more advanced enough to spread through some hundred thousand million galaxies and visit the Earth. An alien, like the teapot, is a hypothesis that requires evidence.

The known forces of nature can be divided into four classes:

**Gravity:** This is the weakest of the four; it acts on everything in the universe as an attraction. And if not for this force, we would go zinging off into outer space and the sun would detonate

like trillions upon trillions of hydrogen bombs.

**Electromagnetism:** This is much stronger than gravity; it acts only on particles with an electric charge, being repulsive between charges of the same sign and attractive between charges of the opposite sign. More than half the gross national product of the earth, representing the accumulated wealth of our planet, depends in some way on the electromagnetic force. It lights up the cities of New York, fill the air with music from radios and stereos, entertain all the people in the world with television, reduce housework with electrical appliances, heat their food with microwaves, track their planes and space probes with radar, and electrify their power plants.

**Weak nuclear force:** This causes radioactivity and plays a vital role in the formation of the elements in stars. And a slightly stronger this force, all the neutrons in the early universe would have decayed, leaving about 100 percent hydrogen, with no deuterium for later use in the synthesizing elements in stars.

**Strong nuclear force:** This force holds together the protons and neutrons inside the nucleus of an atom. And it is this same force that holds together the quarks to form protons and neutrons. Unleashed in the hydrogen bomb, the strong nuclear force could one day end all life on earth.

The inherent goal of unification is to show that all of these forces are, in fact, manifestations of a single super force. We can't perceive this unity at the low energies of our everyday lives, or even in our most powerful accelerators (capable of accelerating particles nearly up to the speed of light) at Fermi lab or **LHC, the Large Hadron Collider**, at CERN (European Centre for Nuclear Research), in Switzerland. But close to the Big Bang temperatures, at inconceivably high energies...

If the forces unify, the protons – which make up much of the mass of ordinary matter – can be unstable, and eventually decay into lighter particles such as antielectrons. Indeed, several experiments were performed in the **Morton Salt Mine in Ohio** to yield definite evidence of proton decay. But none have succeeded so far. However, the probability of a proton in the

universe gaining sufficient energy to decay is so small that one has to wait at least a million million million million years i.e., longer than the time since the big bang, which is about ten thousand million years.

## **Relative Strength of the Four Forces**

### **Force: Nuclear**

Relative Strength:  $10^3$

### **Force: Electromagnetic**

Relative Strength: 1

### **Force: Weak**

Relative Strength:  $10^{-11}$

### **Force: Gravitational**

Relative Strength:  $10^{-39}$

### **Proton feel**

Nuclear force: Yes

Electromagnetic force: Yes

Weak force: No

Gravitational force: Yes

### **Neutron feel**

Nuclear force: Yes

Electromagnetic force: No

Weak force: No

Gravitational force: Yes

### **Electron feel**

Nuclear force: No

Electromagnetic force: Yes

Weak force: Yes

Gravitational force: Yes

The eminent laws do not tell us why the initial configuration was such as to produce what we observe. For what purpose? Must we turn to the **anthropic principle for an explanation?** Was it all just a lucky chance? That would seem a counsel of despair, a negation of all our hopes of understanding the unfathomable order of the universe. However, this is an extended metaphor for many puzzles in physics uncovered with painstaking labor, and it is especially relevant to particle physics. Still, particle physics remains unfathomable to many people and a bunch of scientists chasing after tiny invisible objects.

If string theory is correct, then every particle is nothing but a vibrating, oscillating, dancing filament named a string. A string does something aside from moving – it oscillates in different ways. Each way represents a particular mode of vibration. Different modes of vibration make the string appear as a dark energy or a cosmic ray, since different modes of vibration are seen as different masses or spins.

If **Higgs theory (which is the last piece of the Standard Model that has still eluded capture – which is one of the theories LHC experimentalists hope to discover and it is the capstone for conventional big bang cosmology --which biblical creationists reject)** is correct, then a new field called the Higgs field which is analogous to the familiar electromagnetic field but with new kinds of properties permits all over the space (considered the origin of mass in Grand Unified Theory – a theory that unifies the weak, strong, and electromagnetic interactions, without gravity). Different masses of the particles are due to the different strengths of interaction of the particle with the Higgs field (more the strength of interaction of the particle with the Higgs field, more the mass of the particle). To make this easier for you, let's say it is cosmic high-fructose corn syrup – the more you go through it, the heavier you get.

Which explanation is right?

Higgs theory runs rampant in the popular media claiming that String Theory Is Not The Only Game In Town. However, by the end of the decade, we will have our first glimpse of the new physics, whatever it well may be

## STRING or HIGGS

The new physics will point to even more discoveries at the TeV scale and opens the door beyond the Standard Model and raise new questions like: if the Higgs field generate masses for the W and Z, and for the quarks and leptons – does it generate its own mass and if so how? What is its mass?

Dr. Science remains silent on the profound questions. Ultimately, however, one would hope to find complete, consistent answers that would include all the mathematical techniques as approximations. The quest for such answers is known as the **grand unification** of the two basic partial theories: **the general theory of relativity** (which states that space and time are no longer absolute, no longer a fixed background to events. Instead, they are dynamical quantities that are shaped by the matter and energy in the universe) and quantum mechanics (a theory of the microcosm which has upended many an intuition, but none deeper than this one – developed by 1900 physicists in response to a number of glaring problems that arose when 19th century conceptions of physics were applied to the **microscopic world**, where subatomic particles are held together by particle like forces dancing on the sterile stage of space- time, which is viewed as an empty arena, devoid of any content). Unfortunately, however, these two theories are inconsistent with each other – i.e., **quantum mechanics and general relativity** do not work together. How the ideas of general relativity can be consolidated with those of quantum theory is still a? Until we progress closer toward the laws that govern our universe.

The latest theory of subatomic particles (the quantum theory) gives an estimated value of vacuum energy density that is about 120 orders of magnitude larger than the measured value — claiming our best theory cannot calculate the value of the largest energy source in the entire universe. Dr. Science advances over the wreckage of its theories by continually putting its ideas to experimental test; no matter how beautiful its idea might be; it must be discarded or modified

if it is at odds with experiment. It would have been clearly be nice for quantum theory if the value of vacuum energy density were in the order of  $10^{-96}$  kg per cubic meter, but the measured value were in the order of  $10^{-27}$  kg per cubic meter. Thus, the best candidate we have at the moment, the quantum theory, brought about its downfall by predicting the value of vacuum energy density that is about 120 orders of magnitude larger than the measured value.

We a lot of exposure with darkness and disbelief and a state of not having an immediate conclusion, and this vulnerability is of great significance, I think. When we don't comprehend the mind of nature, we are in the middle of darkness. When we have an intuitive guess as to what the outcome is; we are unsealed. And when we are fairly damn sure of what the final result is going to be, we are still in **some uncertainty**. And uncertainty being too complex to come about randomly is evidence for human continuing quest for justification. Sometimes, very hard, impossible things just strike and we call them thoughts. In most of the self-reproducing organisms the conditions would not be right for the generation of thoughts to predict things more or less, even if not in a simplest way, only in the few complex organisms like us spontaneous thoughts would generate and what is it that breathes fire into a perception. The human perception is enormous; it's extensive and unlimited, and outrageous that we can ask simple questions. And they are: **What the dark energy is up to?** What it is about? Why this mysterious form of energy permeates all of space blowing the galaxies farther and farther apart? How accurate are the physical laws (which are essentially the same today as they were at the time of **Newton despite the scientific revolutions and paradigm shifts**), which control it? Why it made the universe bang? Unfortunately, the laws that we are using are not able to answer these questions because of the prediction that the universe started off with infinite density at the big bang singularity (where all the known laws would break down). However, if one looks in a commonsense realistic point of view the laws and equations which are considered as inherent ingredients of reality – are simply the man-made ingredients introduced by the rational beings who are free to observe the universe as they want and to draw logical deductions from what they see – to describe the objective features of reality. The scientific data is fallible, changeable, and influenced by scientific understanding is refreshing. Here's an example of what I mean. In most physics textbooks we will read that the strength of the

electromagnetic force is measured by the dimensionless parameter  $\alpha = \frac{e^2}{4\pi\hbar c\epsilon_0}$  (where e is the charge  $= 1.602 \times 10^{-19}$  Coulombs,  $\epsilon_0$  is the absolute permittivity of free space  $= 8.8 \times 10^{-12} \frac{F}{N\cdot m^2}$ , c is the speed of light in vacuum (an awkward conversion factor for everyday use because it's so big. Light can go all the way around the equator of the Earth in about 0.1 seconds) and  $\hbar$  is the reduced Planck's constant), called the fine structure constant, which was taught to be constant became variant when the standard model of elementary particles and forces revealed that  $\alpha$  actually varies with energy.

Quantum field theory = {Group theory + quantum mechanics}

$\lim_{N \rightarrow \infty}$  Quantum mechanics = Quantum field theory

The **Quantum theory of electrodynamics** (a relativistic quantum field theory or a quantum field theory – arguably the most precise theory of natural phenomena ever advanced which seems to govern everything small – through which we have been able to solidify the role of photons as the "**smallest possible bundles of light**" and to reveal their interactions with electrically charged particles such as electrons, in a mathematically complete, predictive, and convincing framework) and **General Relativity** (which dominates large things and is now called a classical theory which predicts that the universe started off with infinite density at the big bang singularity) both try to assign mass to the singularity. But according to generally accepted history of the universe, according to what is known as the hot big bang model. At some finite time in the past i.e., between ten and twenty thousand million years ago. At this time, all matter (which is characterized by the physical quantity we define as mass) would have been on top of each other – which is called the singularity, the density would have been **INFINITE**. Under such conditions, all the known laws of science would break down. However, a good mathematical theory can prove anything with that amount of wiggle room, and findings are really determined by nothing except its desire. For all theoreticians and tens of thousands of university graduates at least know, the universe started off with infinite density at the hot big bang singularity with infinitely hot temperatures. And at such high temperatures that are

reached in thousands of H-bomb explosions, the strong and weak nuclear forces and the gravity and electromagnetic force were all unified into a single force. What was before the Big Bang? Was the Big Bang created? If the Big Bang was not created, how was this Big Bang accomplished, and what can we learn about the agent and events of creation? Is it the product of chance or was it designed? What is it that blocked the pre-Big Bang view from us? Is Big Bang singularity an impenetrable wall and we cannot, in physics, go beyond it? To answer one question, another question arises. **Erickcek's model** suggests the possibility of existence of space and time before the big bang. But the world famed Big Bang theory abandons the existence of space and time before the big bang. Both the theories are consistent and based upon sophisticated experimental observations and theoretical studies. Truth must be prejudiced with honest scientific inquiry to **illuminate the words of Genesis**. And this is possible only if the modern scientific community would simply open its eyes to the truth.

Do black holes really exist? If they exist, why we haven't observed one hole yet? Can black holes be observed directly, and if so, how? If the production of the tiny black holes is feasible, can particle accelerators, such as the **Large Hadron Collider (LHC) in Switzerland** at the famed **CERN nuclear laboratory** create a micro black hole that will eventually eat the world? If not – if there are no black holes, what are the things we detect ripping gas off the surface of other stars? What is the structure of space-time just outside the black hole? Do their space times have horizons? : are the major questions in theoretical physics today that haunts us. The effort to resolve these complex paradoxes is one of the very few things that lifts human mind a little above the level of farce, and gives it some of the grace of province inspiring new ideas and new experiments.

Since gravity weakens with distance, the earth pulls on your head with less force than it pulls on your feet, which are a meter or two closer to the earth's center. The difference is so tiny we cannot feel it, but an astronaut near the surface of a black hole would be literally torn apart. Most people think of a black hole as a voracious whirlpool in space, sucking down everything around it. But that's not really true! A black hole is a place where gravity has gotten so strong that even light cannot escape out of its influence.

## How a black hole might be formed?

The slightly denser regions of the nearly uniformly distributed atoms (mostly hydrogen) which lack sufficient energy to escape the gravitational attraction of the nearby atoms, would combine together and thus grow even denser, forming giant clouds of gas, which at some point become gravitationally unstable, undergo fragmentation and would break up into smaller clouds that would collapse under their own gravity. As these collapses, the atoms within them collide with one another more and more frequently and at greater and greater speeds – the gas heats up i.e., the temperature of the gas would increase, until eventually it becomes hot enough to start nuclear fusion reactions. And a consequence of this is that the stars like our sun (which are made up of more than one kind of gas particle) are born to radiate their energy as heat and light.

But the stars with a physical radius smaller than its **Schwarzschild radius** further collapse to produce dark or frozen stars (i.e., the mass of a star is concentrated in a small enough spherical region, so that its mass divided by its radius exceeds a particular critical value, the resulting space-time warp is so radical that anything, including light, that gets too close to the star will be unable to escape its gravitational grip).

And these dark stars are sufficiently massive and compact and possess a strong gravitational field that prevent even light from escaping out of its influence: any light emitted from the surface of the star will be dragged back by the star's gravitational attraction before it could get very far. Such stars become black voids in space and were coined in 1969 by **the American scientist John Wheeler "the black holes"** (i.e., black because they cannot emit light and holes because anything getting too close falls into them, never to return). Classically, the gravitational field of the black holes (which seem to be among the most ordered and organized objects in the whole universe) is so strong that they would prevent any information including light from escaping out of their influence i.e., any information sent down the throat of a black hole or swallowed by a black hole is forever hidden from the outside universe (this goes by the statement that "**black holes have no hair**" — that is, they have lost all information, all hair, except for these three parameters: its mass, spin and charge), and all one could say of the gravitational monster what

the poet Dante said of the entrance to Hell: "All hope abandon, ye who enter here." Anything or anyone who falls through the black hole will soon reach the region of infinite density and the end of time. However, only the laws of classical general relativity does not allow anything (not even light) to escape the gravitational grip of the black hole but the inclusion of quantum mechanics modifies this conclusion— quantum fields would scatter off a black hole. Because energy can be created out of nothing, the pair of short-lived virtual particles (one with positive energy and the other with negative energy) appears close to the event horizon of a black hole. The gravitational might of the black hole inject energy into a pair of virtual particles ... that tears them just far enough apart so that one with negative energy gets sucked into the hole even before it can annihilate its partner ... its forsaken partner with positive energy... gets an energy boost from the gravitational force of the black hole ... escape outward to infinity (an abstract mathematical concept that was precisely formulated in the work of **mathematician Georg Cantor** in the late nineteenth century)... where it appear as a real particle (and to an observer at a distance, it will appear to have been emitted from the black hole). **Because  $E= mc^2$  (i.e., energy is equivalent to mass)**, a fall of negative energy particle into the black hole therefore reduces its mass with its horizon shrinking in size. As the black hole loses mass, the temperature of the black hole (which depends only on its mass) rises and its rate of emission of particle increases, so it loses mass more and more quickly. We don't know does the emission process continue until the black hole dissipates completely away or does it stop after a finite amount of time leaving black hole remnants.

The attempt to understand the Hawking radiation has a profound impact upon the understanding of the black hole thermodynamics, leading to the description of what the black hole entropic energy is.

$$\text{Black hole entropic energy} = \text{Black hole temperature} \times \text{Black hole Entropy}$$

This means that the entropic energy makes up half of the mass energy of the black hole. For a black hole of one solar mass ( $M = 2 \times 10^{30} \text{ kg}$ ), we get an entropic energy of  $9 \times 10^{-46} \text{ joules}$  – much higher than the thermal entropic energy of the sun.

It is only theoretically possible that black holes with mass  $M =$  mass of the electron could be created in high energy collisions. No black holes with mass  $M =$  mass of the electron have ever been observed, however – indeed, normally the creation of micro black holes (with mass  $\leq$  mass of the electron) take place at high energy (i.e.,  $>10^{28}$  electron volts – roughly greater than million tons of **TNT explosive**), which is a quadrillion times beyond the energy of the LHC. Even if the quantum black holes (with mass  $\leq$  mass of the electron) are created, they would be

extremely difficult to spot - and they are the large emitters of radiation (because  $T = \frac{\hbar c^3}{8\pi GMk_B}$ )

and they shrink and dissipate faster even before they are observed. Though the emission of particles from the primordial black holes is currently the most commonly accepted theory within scientific community, there is some disputation associated with it. There are some issues incompatible with quantum mechanics that it finally results in information being lost, which makes physicists discomfort and this raises a serious problem that strikes at the heart of our understanding of science. However, most physicists admit that black holes must radiate like hot bodies if our ideas about general relativity and quantum mechanics are correct. Thus even though they have not yet managed to find a primordial black hole emitting particles after over two decades of searching. Despite its strong theoretical foundation, the existence of this phenomenon is still in question. Alternately, those who don't believe that black holes themselves exist are similarly unwilling to admit that they emit particles.

In the nuclear reaction mass of reactants is always greater than mass of products. The mass difference is converted to energy, according to the equation which is as famous as the man who wrote it.

For a nuclear reaction:  $p + Li_7 \rightarrow \alpha + \alpha + 17.2 \text{ MeV}$

**Mass of reactants:**

$$p = 1.0072764 \text{ amu}$$

$$Li_7 = 7.01600455 \text{ amu}$$

$$\text{Total mass of reactants} = 7.01600455 \text{ amu} + 1.0072764 \text{ amu} = 8.02328095 \text{ amu}$$

**Mass of products:**

$$\alpha = 4.0015061 \text{ amu}$$

$$\text{Total mass of products} = \alpha + \alpha = 2\alpha = 8.0030122 \text{ amu}$$

As from above data it is clear that

Total mass of reactants is greater than Total mass of products. The mass difference ( $8.02328095 \text{ amu} - 8.0030122 \text{ amu} = 0.02026875 \text{ amu}$ ) is converted to energy  $18.87 \text{ MeV}$ , according to the equation  $E = mc^2$ . However, the observed energy is  $17.2 \text{ MeV}$ .

Expected energy =  $18.87 \text{ MeV}$  (i.e.,  $0.02026875 \text{ amu} \times c^2$ )

Experimentally observed energy =  $17.2 \text{ MeV}$

Expected energy  $\neq$  observed energy

Energy difference =  $(18.87 - 17.2) \text{ MeV} = 1.67 \text{ MeV}$

Where the energy  $1.67 \text{ MeV}$  is gone? The question is clear and deceptively simple. But the answer is just being blind to the complexity of reality. Questions are guaranteed in Science; Answers aren't.

If we could peer into the fabric of space-time at the Planck length (the distance where the smoothness of relativity's space-time and the quantum nature of reality begin to rub up against each other), we would see the 4 dimensional fabric of space-time is simply the lowest energy state of the universe. It is neither empty nor uninteresting, and its energy is not necessarily zero (which was discovered by **Richard Dick Feynman**, a colorful character who worked at the California Institute of Technology and played the bongo drums at a strip joint down the road—for which he received Nobel Prize for physics in 1965). Because  $E = mc^2$ , one can think that the virtual particle-antiparticle pairs of mass  $m$  are continually being created out of energy  $E$  of the 4 dimensional fabric of space-time consistent with the **Heisenberg's uncertainty principle of quantum mechanics** (which tells us that from a microscopic vantage point there is a tremendous amount of activity and this activity gets increasingly agitated on ever smaller distance and time scales), and then, they appear together at some time, move apart, then come together and annihilate each other giving energy back to the space-time without violating the law of energy conservation (which has not changed in four hundred years and still appear in **relativity** and **quantum mechanics**). Spontaneous births and deaths of virtual particles so called **quantum fluctuations occurring everywhere**, all the time – is the conclusion that mass and energy are interconvertible; they are two different forms of the same thing. However, spontaneous births and deaths of so called virtual particles can produce some remarkable problem, because infinite number of virtual pairs of mass  $m$  can be spontaneously created out

of energy E of the 4 dimensional fabric of space-time, does the 4 dimensional fabric of space-time bears an infinite amount of energy, therefore, by Einstein's famous equation  $E = mc^2$ , does it bears an infinite amount of mass. If so, according to general relativity, the infinite amount of mass would have curved up the universe to infinitely small size. But which obviously has not happened. The word virtual particles literally mean that these particles cannot be observed directly, but their indirect effects can be measured to a remarkable degree of accuracy. Their properties and consequences are well established and well understood consequences of quantum mechanics (which states that the position of a particle is uncertain, and therefore that there is some possibility that a particle will be within an energy barrier rather than outside of it. The process of moving from outside to inside without traversing the distance between is known as **quantum tunneling, and it is very important for the fusion reactions in stars like the Sun**). However, they can be materialized into real particles by several ways. All that one require an energy = energy required to tear the pair apart + energy required to boost the separated virtual particle- antiparticles into real particles (i.e., to bring them from virtual state to the materialize state).

When Einstein was 26 years old, he calculated precisely how energy must change if the relativity principle was correct, and he discovered the relation  $E= mc^2$  (which led to the Manhattan Project and ultimately to the bombs that exploded over **Hiroshima and Nagasaki** in 1945). This is now probably the only equation in physics that even people with no background in physics have at least heard of this and are aware of its prodigious influence on the world we live in. And since c is constant (because the maximum distance a light can travel in one second is  $3 \times 10$  to the power of 8 meter), this equation tells us that mass and energy are interconvertible and are two different forms of the same thing and are in fact equivalent. Suppose a mass m is converted into energy E, the resulting energy carries mass = m and moves at the speed of light c. Hence, energy E is defined by  $E= mc$  squared. As we know c squared (the speed of light multiplied by itself) is an astronomically large number:  $9 \times 10$  to the power of 16 meters square per second square. So if we convert a small amount of mass, we'll get a tremendous amount of energy. For example, if we convert 1kg of mass, we'll get energy of  $9 \times 10$  to the power of 16 Joules (i.e., the energy more than 1 million times the energy released in a chemical explosion. **Perhaps since c is not just the constant namely the maximum distance**

**a light can travel in one second but rather a fundamental feature of the way space and time are married to form space-time.** One can think that in the presence of unified space and time, mass and energy are equivalent and interchangeable. But WHY? The question lingers, unanswered. Until now.

However, the equation  $E = mc^2$  (where E is energy, m is mass, and c is the speed of light). People often employ this equation to calculate how much energy would be produced if, say, a bit of matter was converted into pure electromagnetic radiation. (**Because the speed of light is a large number, the answer is a lot—the weight of matter converted to energy in the bomb that destroyed the city of Hiroshima was less than one ounce.**) But the equation also tells us that if the energy of an object increases, so does its mass, that is, its resistance to acceleration, or change in speed) has some remarkable consequences (e.g. conversion of less than 1% of 2 pounds of uranium into energy was used in the atomic bomb over Hiroshima and body at rest still contains energy. When a body is moving, it carries an additional energy of motion called kinetic energy. In chemical and nuclear interactions, kinetic energy can be converted into rest energy, which is equivalent to generating mass. Also, the rest energy can be converted into kinetic energy. In that way, chemical and nuclear interactions can generate kinetic energy, which then can be used to run engines or blow things up). Because  $E = mc^2$ , the energy which a body possess due to its motion will add to its rest mass. This effect is only really significant for bodies moving at speeds close to the speed of light. For example, at 10 percent of the speed of light a body's mass M is only 0.5 percent more than its rest mass m, while at 90 percent of the speed of light it would be more than twice its rest mass. And as an body approaches the speed of light, its mass raise ever more quickly, it acquire infinite mass and since an infinite mass cannot be accelerated any faster by any force, the issue of infinite mass remains an intractable problem. For this reason all the bodies are forever confined by relativity to move at speeds slower than the speed of light. Only tiny packets/particles of light (dubbed "**photons**" by chemist Gilbert Lewis) that have no intrinsic mass can move at the speed of light. There is little disagreement on this point. Now, being more advanced, we do not just consider conclusions like photons have no intrinsic mass. We constantly test them, trying to prove or disprove. So far, relativity has withstood every test. And try as we might, we can measure no mass for the photon. We can just put upper limits on what mass it can have. These upper limits are

determined by the sensitivity of the experiment we are using to try to weigh the photon. The last number we can see that a photon, if it has any mass at all, must be less than  $4 \times 10$  to the power of  $-48$  grams. For comparison, the electron has a mass of  $9 \times 10$  to the power of  $-28$  grams. Moreover, if the mass of the photon is not considered to zero, then quantum mechanics would be in trouble. And it also an uphill task to conduct an experiment which proves the photon mass to be exactly zero. Tachyons the putative class of hypothetical particles (with negative mass:  $\mathbf{m} < 0$ ) is believed to travel faster than the speed of light. But, the existence of tachyons is still in question and if they exist, how can they be detected is still a? However, on one thing most physicists agree: (Just because we haven't found anything yet that can go faster than light doesn't mean that we won't one day have to eat our words. We should be more open-minded to other possibilities that just may not have occurred to us). Moreover, in expanding space – recession velocity keeps increasing with distance. Beyond a certain distance, known as the Hubble distance, it exceeds the velocity greater than the speed of light in vacuum. But, this is not a violation of relativity, because recession velocity is caused not by motion through space but by the expansion of space.

$E = h\nu$  (which implies the energy a photon can have is proportional to its frequency: larger frequency (shorter wavelength) implies larger photon energy and smaller frequency (longer wavelength) implies smaller photon energy) – because  $h$  is constant, energy and frequency of the photon are equivalent and are different forms of the same thing. And since  $h$  – which is one of the most fundamental numbers in physics, ranking alongside the speed of light  $c$  and confines most of these radical departures from life-as-usual to the microscopic realm – is incredibly small (i.e.,  $6 \times 10$  to the power of  $-34$  — a decimal point followed by 33 zeros and a 6 — of a joule second), the frequency of the photon is always greater than its energy, so it would not take many quanta to radiate even ten thousand megawatts. And some say the only thing that quantum mechanics (the great intellectual achievement of the first half of this century) has going for it, in fact, is that it is unquestionably correct. Since the Planck's constant is almost infinitesimally small, quantum mechanics is for little things. Suppose this number would have been too long to keep writing down i.e.,  $h$  would have been  $= 6.625 \times 10$  to the power of 34 Js, then quantum mechanical effects would have been noticeable for macroscopic objects. For example, the De Broglie wavelength of a 100 kg man walking at 1 m/s would have

been =  $\frac{h}{mv} = (6.625 \times 10^{-34} \text{ Js}) / (100\text{kg}) (1\text{m/s}) = 6.625 \times 10^{-34}$  to the power of 32 m (very large to be noticeable).

Are Neutrinos Massless? If not they could contribute significantly to the mass of the universe? Evidence of neutrino oscillations prove that neutrinos are not massless but instead have a mass less than one hundred-thousandth that of an electron. The work on atomic science in the first thirty five years of this century took our understanding down to lengths of a millionth of a millimeter. Then we discovered that protons and neutrons are made of even smaller particles called quarks (which were named by the Caltech physicist **Murray Gell-Mann**, who won the **Nobel Prize in 1969** for his work on them). We might indeed expect to find several new layers of structure more basic than the quarks and leptons that we now regard as elemental particles. Are there elementary particles that have not yet been observed, and, if so, which ones are they and what are their properties? What lies beyond the quarks and the leptons? If we find answers to them, then the entire picture of particle physics would be quite different.

Experimental evidence supporting the **Watson and Crick model** was published in a series of five articles in the same issue of Nature – caused an explosion in biochemistry and transformed the science. Of these, Franklin and Gosling's paper was the first publication of their own x-ray diffraction data and original analysis method that partially supported the Watson and Crick model; this issue also contained an article on DNA (a main family of polynucleotides in living cells) structure by **Maurice Wilkins and two of his colleagues, whose analysis supported their double-helix molecular model of DNA**. In 1962, after **Franklin's death**, Watson, Crick, and Wilkins jointly received the Nobel Prize in Physiology or Medicine. From each gene's point of view, the 'background' genes are those with which it shares bodies in its journey down the generations. **DNA (deoxyribonucleic acid)** – which is known to occur in the chromosomes of all cells (whose coded characters spell out specific instructions for building willow trees that will shed a new generation of downy seeds). Most forms of life including vertebrates, reptiles, Craniates or suckling pigs, chimps and dogs and crocodiles and bats and cockroaches and humans and worms and dandelions, carry the amazing complexity of the information within the some kind of replicator—molecules called DNA in each cell of their body, that a live reading of

that code at a rate of one letter per second would take thirty-one years, even if reading continued day and night. Just as protein molecules are chains of amino acids, so DNA molecules are chains of nucleotides. Linking the two chains in the DNA, are pairs of nucleic acids (**purines + pyrimidines**). There are four types of nucleic acid, adenine "A", cytosine "C", guanine "G", and thiamine "T." An adenine (**purine**) on one chain is always matched with a thiamine (**pyrimidine**) on the other chain, and a guanine (**purine**) with a cytosine (**pyrimidine**). Thus DNA exhibits all the properties of genetic material, such as replication, mutation and recombination. Hence, it is called the molecule of life. We need DNA to create enzymes in the cell, but we need enzymes to unzip the DNA. Which came first, proteins or protein synthesis? If proteins are needed to make proteins, how did the whole thing get started? We need precision genetic experiments to know for sure.

A theory is a good theory if it satisfies one requirement. It must make definite predictions about the results of future observations. Basically, all scientific theories are scientific statements that predict, explain, and perhaps describe the basic features of reality. Despite having received some great deal, discrepancies frequently lead to doubt and discomfort. For example, the most precise estimate of sun's age is around 10 million years, based on linear density model. But geologists have the evidence that the formation of the rocks, and the fossils in them, would have taken hundreds or thousands of millions of years. This is far longer than the age of the Earth, predicted by linear density model. Hence the earth existed even before the birth of the sun! Which is absolutely has no sense. The linear density model therefore fails to account for the age of the sun. Any physical theory is always provisional, in the sense that it is only a hypothesis: it can be disproved by finding even a single observation that disagrees with the predictions of the theory. Towards the end of the nineteenth century, physicists thought they were close to a complete understanding of the universe. They believed that entire universe was filled by a **hypothetical medium called the ether**. As a material medium is required for the propagation of waves, it was believed that light waves propagate through ether as the pressure waves propagate through air. Soon, however, inconsistencies with the idea of ether begin to appear. Yet a series of experiments failed to support this idea. The most careful and accurate experiments were carried out by two Americans: **Albert Michelson and Edward Morley** (who showed that light always traveled at a speed of one hundred and eighty six thousand miles a

second (no matter where it came from) and disproved **Michell and Laplace's idea** of light as consisting of particles, rather like cannon balls, that could be slowed down by gravity, and made to fall back on the star) at the Case School of Applied Science in Cleveland, Ohio, in 1887 – which proved to be a serve blow to the existence of ether. All the known subatomic particles in the universe belong to one of two groups, Fermions or bosons. Fermions are particles with integer spin  $\frac{1}{2}$  and they make up ordinary matter. Their ground state energies are negative. Bosons are particles (whose ground state energies are positive) with integer spin 0, 1, 2 and they act as the force carriers between fermions (For example: The electromagnetic force of attraction between electron and a proton is pictured as being caused by the exchange of large numbers of virtual massless bosons of spin 1, called photons).

**Positive ground state energy of bosons plus negative ground state energy of fermions = 0**

But Why? May be because to eliminate the biggest infinity in supergravity theory (the theory which introduced a superpartner to the conjectured subatomic particle with spin 2 that is the quanta of gravity "the graviton" (called the **gravitino, meaning "little graviton," with spin  $\frac{3}{2}$** ) – that even inspired one of the most brilliant theoretical physicists since Einstein "Stephen Hawking" to speak of "the end of theoretical physics" being in sight when he gave his inaugural lecture upon taking the **Lucasian Chair of Mathematics at Cambridge** University, the same chair once held by **Isaac Newton** – a person who developed the theory of mechanics, which gave us the classical laws governing machines which in turn, greatly accelerated the Industrial Revolution, which unleashed political forces that eventually overthrew the feudal dynasties of Europe)?

There is strong evidence ... that the universe is permeated with dark matter approximately six times as much as normal visible matter (i.e. invisible matter became apparent in 1933 by Swiss **astronomer Fritz Zwicky** – which can be considered to have energy, too, because  $E = mc^2$  – exist in a huge halo around galaxies and does not participate in the processes of nuclear fusion that powers stars, does not give off light and does not interact with light but bend starlight due to its gravity, somewhat similar to the way glass bends light). Although we live in a dark matter

dominated universe (i.e., dark matter, according to the latest data, makes up 23 percent of the total matter/energy content of the universe) experiments to detect dark matter in the laboratory have been exceedingly difficult to perform because dark matter particles such as the neutralino, which represent higher vibrations of the superstring – interact so weakly with ordinary matter. Although dark matter was discovered almost a century ago, it is still a mystery shining on library shelves that everyone yearns to resolve.

Opening up the splendor of the immense heavens for the first time to serious scientific investigation. On the short time scale of our lives, not surprisingly, we underwent many transformations in our slow, painful evolution, an evolution often overshadowed by religious dogma and superstition to seek the answer to the question from the beginnings of our understanding. No progress was made in any scientific explanations because the experimental data were non-existent and there were no theoretical foundations that could be applied. In the latter half of the 20th century, there were several attempts such as quantum mechanics (the theory of subatomic physics and is one of the most successful theories of all time which is based on three principles: (1) **energy is found in discrete packets called quanta**; (2) matter is based on point particles but the probability of finding them is given by a wave, which obeys the Schrödinger wave equation; (3) a measurement is necessary to collapse the wave and determine the final state of an object), the "**big bang**," probability theory, the general relativity (a theoretical framework of geometry which has been verified experimentally to better than 99.7 percent accuracy and predicts that the curvature of space-time gives the illusion that there is a force of attraction called gravity) to adjust to ensure agreement with experimental measurements and answer the questions that have so long occupied the mind of philosophers (from **Aristotle to Kant**) and scientists. However, we must admit that there is ignorance on some issues, for example, "*we don't have a complete theory of universe which could form a framework for stitching these insights together into a seamless whole – capable of describing all phenomena.... We are not sure exactly how universe happened.*" However, the generally accepted history of the universe, according to what is so-called the big bang theory (proposed by a Belgian priest, **Georges Lemaître**, who learned of Einstein's theory and was fascinated by the idea that the theory logically led to a universe that was expanding and therefore had a beginning) has completely changed the discussion of the origin of the universe from almost

pure speculation to an observational subject. In such model one finds that our universe started with an explosion. This was not any ordinary explosion as might occur today, which would have a point of origin (center) and would spread out from that point. The explosion occurred simultaneously everywhere, filling all space with infinite heat and energy. At this time, order and structure were just beginning to emerge – the universe was hotter and denser than anything we can imagine (at such temperatures and densities (of about a trillion trillion trillion trillion trillion (1 with 72 zeros after it) tons per cubic inch) gravity and quantum mechanics were no longer treated as two separate entities as they were in point-particle quantum field theory, the four known forces were unified as one unified super force) and was very rapidly expanding much faster than the speed of light (this did not violate Einstein's dictum that nothing can travel faster than light, because it was empty space that was expanding) and cooling in a way consistent with **Einstein field equations**. As the universe was expanding, the temperature was decreasing. Since the temperature was decreasing, the universe was cooling and its curvature energy was converted into matter like a formless water vapor freezes into snowflakes whose unique patterns arise from a combination of symmetry and randomness. Approximately  $10^{-37}$  seconds into the expansion, a phase transition caused a cosmic inflation, during which the universe underwent an incredible amount of superliminal expansion and grew exponentially by a factor  $e^{3Ht}$  (where H was a constant called **Hubble parameter** and t was the time) – just as the prices grew by a factor of ten million in a period of 18 months in Germany after the First World War and it doubled in size every tiny fraction of a second – just as prices double every year in certain countries. After inflation stopped, the universe was not in a de Sitter phase and its rate of expansion was no longer proportional to its volume since H was no longer constant. At that time, the entire universe had grown by an unimaginable factor of  $10^{50}$  and consisted of a hot plasma "**soup**" of high energetic quarks as well as leptons (a group of particles which interacted with each other by exchanging new particles called the W and Z bosons as well as photons). And quarks and gluons were "**deconfined**" and free to move over distances much larger than the hadron size ( $>>1$  fm) in a soup called quark gluon plasma (QGP). There were a number of different varieties of quarks: there were six "**flavors**," which we now call up, down, strange, charmed, bottom, and top. And among the leptons the electron was a stable object and muon (that had mass 207 times larger than electron and now belongs to the second redundant generation of particles found in the **Standard Model**) and the tauon (that

had mass 3,490 times the mass of the electron) were allowed to decay into other particles. And associated to each charged lepton, there were three distinct kinds of ghostly particles called neutrinos (the most mysterious of subatomic particles, are difficult to detect because they rarely interact with other forms of matter. Although they can easily pass through a planet or solid walls, they seldom leave a trace of their existence. Evidence of neutrino oscillations prove that neutrinos are not massless but instead have a mass less than one- hundred-thousandth that of an electron):

- the electron neutrino (which was predicted in the early 1930s by Wolfgang Pauli and discovered by **Frederick Reines and Clyde Cowan** in mid-1950s)
- the muon neutrino (which was discovered by physicists when studying the cosmic rays in late 1930s)
- the tauon neutrino (a heavier cousin of the electron neutrino)

Temperatures were so high that these quarks and leptons were moving around so fast that they escaped any attraction toward each other due to nuclear or electromagnetic forces. However, they possessed so much energy that whenever they collided, particle – antiparticle pairs of all kinds were being continuously created and destroyed in collisions. And the uncertainty in the position of the particle times the uncertainty in its velocity times the mass of the particle was never smaller than a certain quantity, which was known as Planck's constant. Similarly,  $\Delta E \times \Delta t$

was  $\geq \frac{h}{4\pi}$  (where  $h$  was a quantity called **Planck's constant** and  $\pi = 3.14159 \dots$  was the

familiar ratio of the circumference of a circle to its diameter). Hence the **Heisenberg's uncertainty principle** (which captures the heart of quantum mechanics – i.e. features normally thought of as being so basic as to be beyond question (e.g. that objects have definite positions and speeds and that they have definite energies at definite moments) are now seen as mere artifacts of Planck's constant being so tiny on the scales of the everyday world) was a fundamental, inescapable property of the universe. At some point an unknown reaction led to a very small excess of quarks and leptons over antiquarks and antileptons — of the order of one part in 30 million. This resulted in the predominance of matter over antimatter in the universe. The universe continued to decrease in density and fall in temperature, hence the typical energy

of each particle was decreased in inverse proportion to the size of the universe (since the average energy – or speed – of the particles was simply a measure of the temperature of the universe). The symmetry (a central part of the theory [and] its experimental confirmation would be a compelling, albeit circumstantial, piece of evidence for strings) however, was unstable and, as the universe cooled, a process called spontaneous symmetry breaking phase transitions placed the fundamental forces of physics and the parameters of elementary particles into their present form. After about  $10^{-11}$  seconds, the picture becomes less speculative, since particle energies drop to values that can be attained in particle physics experiments. At about  $10^{-6}$  seconds, there was a continuous exchange of smallest constituents of the strong force called gluons between the quarks and this resulted in a force that pulled the quarks to form little wisps of matter which obeys the strong interactions and makes up only a tiny fraction of the matter in the universe and is dwarfed by dark matter called the baryons ( protons – a positively charged particles very similar to the neutrons, which accounts for roughly half the particles in the nucleus of most atoms – and neutrons – a neutral subatomic particles which, along with the protons, makes up the nuclei of atoms – belonged to the class baryons) as well as other particles. The small excess of quarks over antiquarks led to a small excess of baryons over antibaryons. The proton was composed of two up quarks and one down quark and the neutron was composed of two down quarks and one up quark. And other particles contained other quarks (strange, charmed, bottom, and top), but these all had a much greater mass and decayed

very rapidly into protons and neutrons. The charge on the up quark was  $= + \frac{2}{3} e$  and the charge

on the down quark was  $= - \frac{1}{3} e$ . The other quarks possessed charges of  $+ \frac{2}{3} e$  or  $- \frac{1}{3} e$ . The charges of the quarks added up in the combination that composed the proton but cancelled out in the combination that composed the neutron i.e.,

$$\text{Proton charge was } = \left( \frac{2}{3} e \right) + \left( \frac{2}{3} e \right) + \left( -\frac{1}{3} e \right) = e$$

$$\text{Neutron charge was } = \left( \frac{2}{3} e \right) + \left( -\frac{1}{3} e \right) + \left( -\frac{1}{3} e \right) = 0$$

And the force that confined the rest mass energy of the proton or the neutron to its radius was

so strong that it is now proved very difficult if not impossible to obtain an isolated quark. As we try to pull them out of the proton or neutron it gets more and more difficult. Even stranger is the suggestion that the harder and harder if we could drag a quark out of a proton this force gets bigger and bigger – rather like the force in a spring as it is stretched causing the quark to snap back immediately to its original position. This **property of confinement** prevented one from observing an isolated quark (and the question of whether it makes sense to say quarks really exist if we can never isolate one was a controversial issue in the years after the quark model was first proposed). However, now it has been revealed that experiments with large particle accelerators indicate that at high energies the strong force becomes much weaker, and one can observe an isolated quark. In fact, the standard model (one of the most successful physical theories of all time and since it fails to account for gravity (and seems so ugly), theoretical physicists feel it cannot be the final theory) in its current form requires that the quarks not be free. The observation of a free quark would falsify that **aspect of the standard model**, although nicely confirm the quark idea itself and fits all the experimental data concerning particle physics without exception. Each quark possessed baryon number =  $\frac{1}{3}$  : the total baryon number

of the proton or the neutron was the sum of the baryon numbers of the quarks from which it was composed. And the electrons and neutrinos contained no quarks; they were themselves truly fundamental particles. And since there were no electrically charged particles lighter than an electron and a proton, the electrons and protons were prevented from decaying into lighter particles – such as photons (that carried zero mass, zero charge, a definite energy  $E = pc$  and a momentum  $p = mc$ ) and less massive neutrinos (with very little mass, no electric charge, and no radius — and, adding insult to injury, no strong force acted on it). And a free neutron being heavier than the proton **was not prevented from decaying into a proton** (plus an electron and an antineutrino). The temperature was now no longer high enough to create new proton–antiproton pairs, so a mass annihilation immediately followed, leaving just one in  $10^{10}$  of the original protons and neutrons, and none of their antiparticles (i.e., antiparticle was sort of the reverse of matter particle. The counterparts of electrons were positrons (positively charged), and the counterparts of protons were antiprotons (negatively charged). Even neutrons had an antiparticle: antineutrons. A similar process happened at about 1 second for electrons and positrons (positron: the antiparticle of an electron with exactly the same mass as an electron but

its electric charge is +1e). After these annihilations, the remaining protons, neutrons and electrons were no longer **moving relativistically and the energy density of the universe** was dominated by photons – (what are sometimes referred to as the messenger particles for the electromagnetic force) – with a minor contribution from neutrinos. The density of the universe was about  $4 \times 10^9$  times the density of water and much hotter than the center of even the hottest star – no ordinary components of matter as we know them – molecules, atoms, nuclei – could hold together at this temperature. And the total positive charge due to protons plus the total negative charge due to electrons in the universe was = 0 (Just what it was if electromagnetism would not dominate over gravity and for the universe to remain electrically neutral).

And a few minutes into the expansion, when the temperature was about a billion (one thousand million; 10 to the power of 9) kelvin and the density was about that of air, protons and neutrons no longer had sufficient energy to escape the attraction of the strong nuclear force and they started to combine together to produce the universe's deuterium and helium nuclei in a process **called Big Bang nucleosynthesis**. And most of the protons remained uncombined as hydrogen nuclei. And inside the tiny core of an atom, consisting of protons and neutrons, which was roughly  $10^{-13}$  cm across or roughly an angstrom, a proton was never permanently a proton and also a neutron was never permanently a neutron. They kept on changing into each other. A neutron emitted a  $\pi$  **meson** (a particle predicted by Hideki Yukawa (for which he was awarded the Nobel Prize in physics in 1949) – composed of a quark and antiquark, which is unstable because the quark and antiquark can annihilate each other, producing electrons and other particles) and became proton and a proton absorbed a  $\pi$  meson and became a neutron. That is, the exchange force resulted due to the absorption and emission of  $\pi$  mesons kept the protons and neutrons bound in the nucleus. And the time in which the absorption and emission of  $\pi$  mesons took place was so small that  $\pi$  mesons were not detected. And a property of the strong force called asymptotic freedom caused it to become weaker at short distances. Hence, although quarks were bound in nuclei by the strong force, they moved within nuclei almost as if they felt no force at all.

Within only a few hours of the big bang, the Big Bang nucleosynthesis stopped. And after that,

for the next million years or so, the universe just continued expanding, without anything much happening. Eventually, once the temperature had dropped to a few thousand degrees, there was a continuous exchange of virtual photons between the nuclei and the electrons. And the exchange was good enough to produce — what else? — A force (proportional to a quantity called their charge and inversely proportional to the square of the distance between them). And that force pulled the electrons towards the nuclei to form neutral atoms (the basic unit of ordinary matter, made up of a tiny nucleus (consisting of protons and neutrons) surrounded by orbiting electrons). And these atoms reflected, absorbed, and scattered light and the resulted light was red shifted by the expansion of the universe towards the microwave region of the electromagnetic spectrum. And there was cosmic microwave background radiation (which, through the last 15 billion years of cosmic expansion, has now cooled to a mere handful of degrees above absolute zero ( $-273^{\circ}\text{C}$  – the lowest possible temperature, at which substances contain no heat energy and all vibrations stop—almost: **the water molecules are as fixed in their equilibrium positions as quantum uncertainty allows**) and today, scientists measure tiny deviations within this background radiation to provide evidence for inflation or other theories).

The irregularities in the universe meant that some regions of the nearly uniformly distributed atoms had slightly higher density than others. The gravitational attraction of the extra density slowed the expansion of the region, and eventually caused the region to collapse to form galaxies and stars. And the nuclear reactions in the stars transformed hydrogen to helium (composed of two protons and two neutrons and **symbolized by  ${}^2\text{He}^4$** , highly stable—as predicted by the rules of quantum mechanics) to carbon (with their self- bonding properties, provide the immense variety for the complex cellular machinery— no other element offers a comparable range of possibilities) with the release of an enormous amount of energy via Einstein's equation  $E = mc^2$ . This was the energy that lighted up the stars. And the process continued converting the carbon to oxygen to silicon to iron. And the nuclear reaction ceased at iron. And the star experienced several chemical changes in its innermost core and these changes required huge amount of energy which was supplied by the severe gravitational contraction. And as a result the central region of the star collapsed to form a neutron star. And the outer region of the star got blown off in a tremendous explosion called a supernova, which outshone

an entire galaxy of 100 billion stars, spraying the manufactured elements into space. And these elements provided some of the raw material for the generation of cloud of rotating gas which went to form the sun and a small amount of the heavier elements collected together to form the asteroids, stars, comets, and the bodies that now orbit the sun as planets like the Earth and their presence caused the fabric of space around them to warp (more massive the bodies, the greater the distortion it caused in the surrounding space).

The earth was initially very hot and without an atmosphere. In the course of time the planet earth produced volcanoes and the volcanoes emitted water vapor, carbon dioxide and other gases. And there was an atmosphere. This early atmosphere contained no oxygen, but a lot of other gases and among them some were poisonous, such as hydrogen sulfide (the gas that gives rotten eggs their smell). And the sunlight dissociated water vapor and there was oxygen. And carbon dioxide in excess heated the earth and balance was needed. So carbon dioxide dissolved to form carbonic acid and carbonic acid on rocks produced limestone and subducted limestone fed volcanoes that released more carbon dioxide. And there was high temperature and high temperature meant more evaporation and dissolved more carbon dioxide. And as the carbon dioxide turned into limestone, the temperature began to fall. And a consequence of this was that most of the water vapor condensed and formed the oceans. And the low temperature meant less evaporation and carbon dioxide began to build up in the atmosphere. And the cycle went on for billions of years. And after the few **billion years, volcanoes ceased to exist.** And the molten earth cooled, forming a hardened, outer crust. And the earth's atmosphere consisted of nitrogen, oxygen, carbon dioxide, plus other miscellaneous gases (hydrogen sulfide, methane, water vapor, and ammonia). And then a continuous electric current through the atmosphere simulated lightning storms. And some of the gases came to be arranged in the form of more complex organic molecules such as **simple amino acids (the basic chemical subunit of proteins, when, when linked together, formed proteins)** and carbohydrates (which were very simple sugars). And the water vapor in the atmosphere probably caused millions of seconds of torrential rains, during which the organic molecules reached the earth. And it took two and a half billion years for an ooze of organic molecules to react and built earliest cells as a result of chance combinations of atoms into large structures called macromolecules and then advance to a wide variety of one – celled organisms, and another billion years to evolve through a highly

sophisticated form of life to primitive mammals endowed with two elements: genes (a set of instructions that tell them how to sustain and multiply themselves), and metabolism (a mechanism to carry out the instructions). But then evolution seemed to have speeded up. It only took about a hundred million years to develop from the early mammals (the highest class of animals, including the ordinary hairy quadrupeds, the whales and Mammoths , and characterized by the production of living young which are nourished after birth by milk from the teats (**MAMMAE, MAMMARY GLANDS**) of the mother) to Homosapiens. This picture of a universe that started off very hot and cooled as it expanded (like when things are compressed they heat up ... and, when things ... expand ... they cool down) is in agreement with all the observational evidence which we have today (and it explains **Olbers' paradox**: The paradox that asks why the night sky is black. If the universe is infinite and uniform, then we must receive light from an infinite number of stars, and hence the sky must be white, which violates observation). Nevertheless, it leaves a number of important questions unanswered:

Why the universe started off very hot i.e., why it violently emerged from a state of infinite compression? Why is the universe the same everywhere i.e., looks the same from every point (homogeneous) and looks the same in every direction (isotropic)? If the cosmic inflation made the universe flat, homogeneous and isotropic, then what is the hypothetical field that powered the inflation? What are the details of this inflation?

Much is explained by protons and electrons. But there remains the neutrino...

$\approx 10^9$  neutrinos / proton. What is their physical picture in the universe?

What is our physical place in the universe?

Present 13.8 billion years after the Big Bang

We can only see the surface of the sky where light was scattered.

The big bang theory, on its own, cannot explain these features or answer these questions because of its prediction that the universe started off with infinite density at the big bang

singularity. At the singularity (a state of infinite gravity), all the known physical laws of cosmology would break down: one couldn't predict what would come out of the infinitely dense Planck-sized nugget called the **singularity**. The search for the origin and fate of the universe (which is determined by whether the Omega ( $\Omega_0$ ) density parameter is less than, equal to or greater than 1) is a distinctly human drama, one that has stretched the mind and enriched the spirit. We (**a species ruled by all sorts of closer, warmer, ambitions and perceptions**) **are all, each in our own way, seekers of an absolute limit of scientific explanation (that may never be achieved)** and we each long for an answer to why we exist... as our future descendants marvels at our new view of the universe ... we are... contributing our wrong to the human letter reaching for the stars. In the millennia of Homo sapiens evolution, we have found it something quite . . . puzzling. Even that great **Jewish scientist Albert Einstein** (**who freed us from the superstition of the past and interpreted the constancy of the speed of light as a universal principle of nature that contradicted Newtonian theory**) sustained a mystical outlook on the universe that was, he said, constantly renewed from the wonder and humility that filled him when he gazed at the universe. I wonder, can our finite minds ever truly understand such things as mysticism and infinity?

**Undisturbed space + rigid mass → distorted space**



**The universe is a pretty big place seems like an awful waste of space.**

- Nearest star: 4.22 light years.
- Nearest galaxy: 2.44 million light years.

- Galaxies within our horizon are now 40 billion light years away.
- Universe beyond horizon: 10 to the 10 to the 100 times bigger.

### **The Goldilocks Planet is not all that well suited for human life.**

- 2/3 salt water unfit for drinking.
- Humans are restricted only to surface.
- Atmosphere does not block harmful ultraviolet radiation which causes skin cancer and other genetic disorders.
- Natural calamities like floods, earthquakes, famine and droughts, diseases like cancer, AIDS, kill millions millions of people yearly.

Only two photons of every billion emitted by sun are used to warm the Earth surface, the rest radiating uselessly into space. And lack of oxygen and cosmic microwave background radiation (which is well characterized by a  $(2.728 \pm 0.002)$  Kelvin black body spectrum over more than three decades in frequency) prevents humans from spending years in outer space.

The fine tuning coincidences are updated and refurbished and have been somewhat misleadingly categorized under the designation **anthropic principle**, a term coined by astronomer **Brandon Carter in 1974** – which states that the physical properties of the universe are as they are because they permit the emergence of life. This teleological principle tries to explain why some physical properties of matter seem so fine-tuned as to permit the existence of life -- and are widely claimed to provide *prima facie* evidence for purposeful design—a design with life and perhaps humanity in mind. However, fine tuning coincidences are only needed to fill in the details of evidence for the existence of insulated interpositions of Divine power. If the universe were congenial to human life, then we would expect it to be easy for humanlike life to develop and survive throughout the vast stretches of the universe (an intricately complex place). We must admit that much of what we believe, including our fundamental coincidences about the universe is a blind leap of faith. We, after all, carbon-based biological systems operating a billion times slower than computer chips made of silicon, can carry the implications of the illusion of intelligent design about as far as we can imagine we could go -- classifying as an

argument from design is the contemporary claim that the laws and constants of physics are "fine-tuned" so that the universe is able to contain life – which is commonly -- have been publicized in the popular print media, featured in television specials on PBS and BBC, and disseminated through a wide variety of popular and scholarly books, including entries from prestigious academic publishing houses such as Oxford and Cambridge University Presses -- but misleading. Furthermore, blind faith can justify anything and we have no reason to conclude that earthlike planets and sunlike stars and life itself are far too complex to have arisen by coincidence or could not have had a purely accidental origin because astrobiologists have now demonstrated that captured material from a comet -- analyzed immediately after striking Earth so that effects of contamination by earthly matter are minimal-- possessed lysine, an amino acid, in the sample, suggesting that the evolution of life on Earth had only begun after accidental jump-start from space i.e., the first ingredients of life accidentally came from space after Earth formed.

## **LONG STANDING QUESTIONS**

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- Are there undiscovered principles of nature: new symmetries, new physical laws?
- How can we solve the mystery of dark energy? Are dark energy and the Higgs field related?
- What are neutrinos telling us? Is dark matter made up of weakly interacting massive particles (something like heavy versions of the neutrinos)?
- What is dark matter? How can we make it in the laboratory?
- Why are there so many kinds of particles? Why the Higgs exists and who its cosmological cousins are?
- Which particles are travelers in extra dimensions, and what are their locations within

them? Is our Universe part of a Multiverse?

- How did the universe come to be? What happened to the antimatter? What do we learn about the early Universe from experiments at the LHC? Can precise measures of the distribution of galaxies and DM/DE?
- Why there is missing energy from a weakly interacting heavy particle? Is the direct discovery of the effects of extra dimensions or a new source of matter- antimatter asymmetry possible? An all- embracing theory of physics that unifies quantum mechanics (which applies to the very small: atoms, subatomic particles and the forces between them) and general relativity (which applies to the very large: stars, galaxies and gravity, the driving force of the cosmos) would solve the problem of describing everything in the universe from the big bang to subatomic particles? Our leading candidate for a theory of everything is known as M-theory. It grew from a merger of the two seemingly different approaches: 11-dimensional supergravity and 10-dimensional superstring theory. Could this be the final theory of everything? What do observations of galaxies at early times tell us about how galaxies were made?

### **Mapping the dark universe**

### **PROFILING THE INVISIBLE**

### **Is Cosmology about to SNAP?**

### **Or does it explain everything about the universe?**

To answer these most challenging questions about the nature of the universe and led down open doors into new insights and findings, all the approaches must converge. Results from

accelerator experiments at LHC must agree with most powerful and insightful astrophysical observations and results from sophisticated data. However, the experiments necessary to go beyond the existing knowledge of standard physics are rapidly becoming prohibitively expensive and time consuming and the macroscopic experiments are difficult to perform in the laboratory as subatomic reactions at the incredible energy scale of  $10^9$  GeV -- which is far beyond the range of our largest particle accelerators and it is the biggest embarrassment in all of modern physics and if you listen closely, you can almost hear the dreams of physicists everywhere being shattered.

**Do you realize that if you fall into a black hole, you will see the entire future of the Universe unfold in front of you in a matter of moments and you will emerge into another space-time created by the singularity of the black hole you just fell into?**

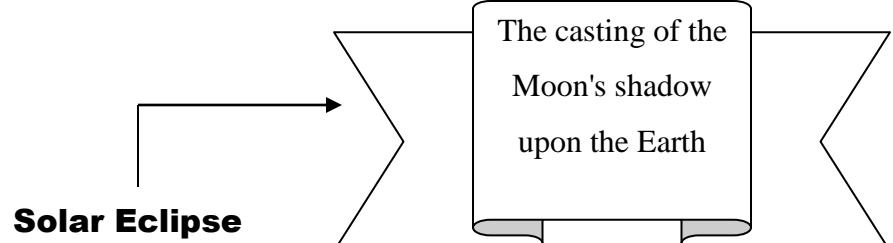
Neil deGrasse Tyson

#### **Uncertainty Principle**

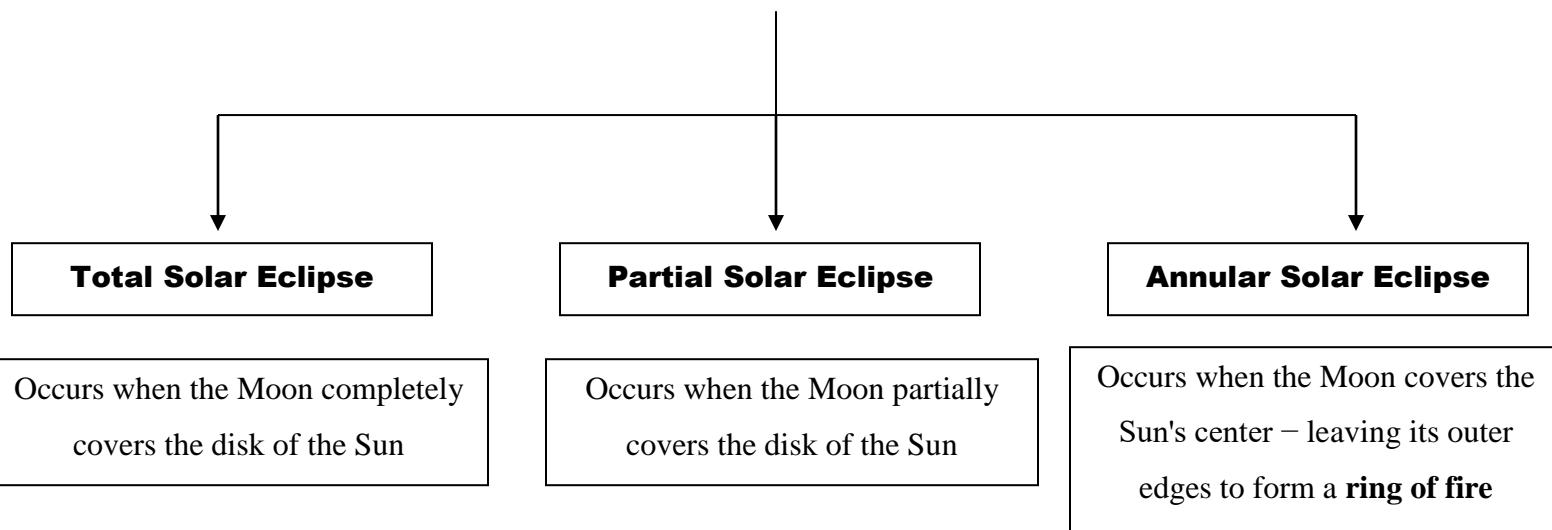


It is not possible to know with unlimited precision both the position and momentum of a particle.

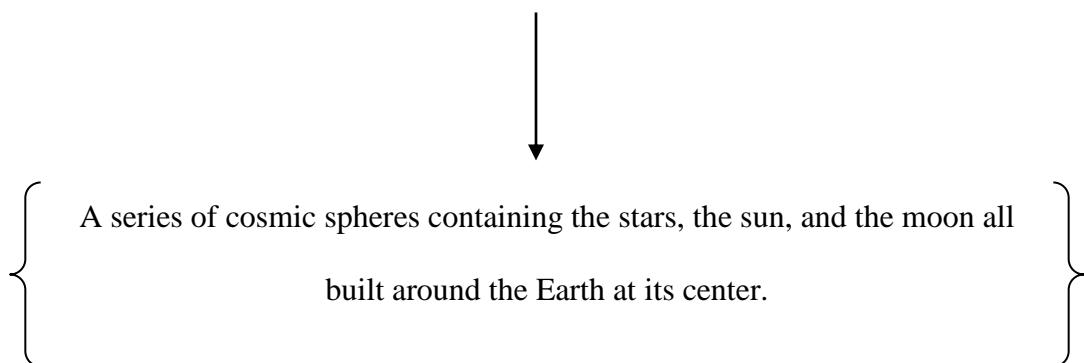
**The Moon's orbit is inclined with respect to the Earth's orbit about the Sun. As a result, a lunar eclipse is not seen every new moon.**



(Occurs when the moon gets between Earth and the sun)



### **Eudoxian Model of the universe**



- From the shore, only the upper parts of a ship are seen, due to the curvature of the Earth.
- **Terminal velocity** → The maximum velocity reached by a falling object – as a result of friction with the medium through which it falls.

Aristotle	Galileo
The heavier <b>the objects are</b> , the quicker they will fall	The mass of an object make no difference to the speed at which it falls

**If I have seen a little further it is by standing on the shoulders of giants.**

– Newton, in a letter to Robert Hooke

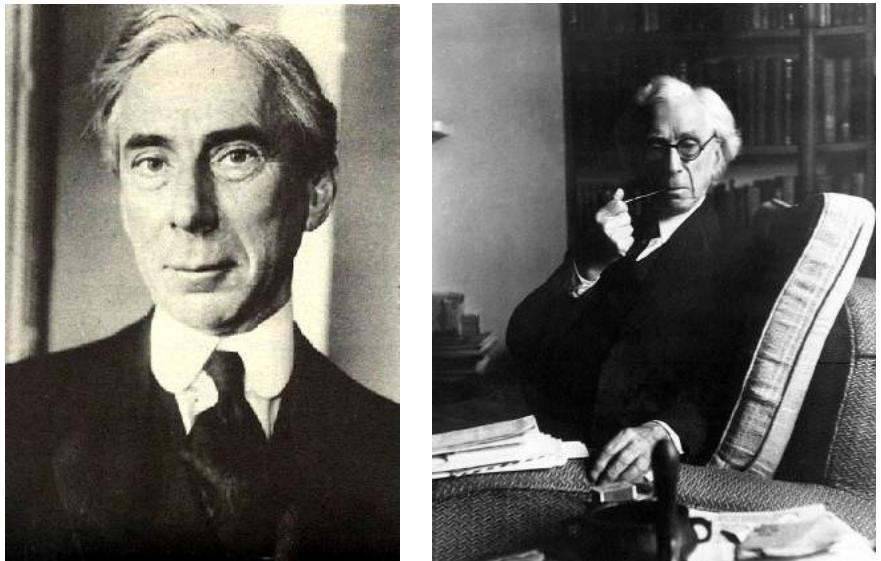
English natural philosopher and scientist **Henry Cavendish (1731–1810)** measured the Newtonian gravitational constant, **G**, by using two massive lead balls to attract two smaller masses, causing the wire from which they were suspended to twist.

The theory that there is an ultimate truth, although very generally held by mankind, does not seem useful to science in the sense of a horizon toward which we may proceed, rather than a point which may be recalled.

– **Gilbert Lewis, The Anatomy of Science (1926)**

### **Properties of light:**

- light bends
- light reflects
- light carries energy
- light can travel long distances – even through a vacuum
- light comes in many colors
- white light is the combination of all colors in the color spectrum
- light is emitted by hot objects



Physics is said to be an empirical science, based upon observation and experiment. It is supposed to be verifiable, i.e. capable of calculating beforehand results subsequently confirmed by observation and experiment.

What can we learn by observation and experiment?

Nothing, so far as physics is concerned, except immediate data of sense: certain patches of colour, sounds, tastes, smells, etc., with certain spatiotemporal relations.

The supposed contents of the physical world are *prima facie* very different from these: molecules have no colour, atoms make no noise, electrons have no taste, and corpuscles do not even smell.

If such objects are to be verified, it must be solely through their relation to sense-data: they must have some kind of correlation with sense-data, and must be verifiable through this correlation alone.

But how is the correlation itself ascertained? A correlation can only be ascertained empirically by the correlated objects being constantly found together.

-- **Bertrand Russell, in The Relation of Sense-Data to Physics, 1914**

$$\text{Force} = \text{mass} \times \text{acceleration}$$

The more mass an object possess – the more force we need to accelerate it.

The greater the force, the greater the object's acceleration

**Whether we are moving down a road or through space, the relative position of nearer and farther objects changes as we go**

### Quantum theory

Forces arise from the exchange of force-carrying particles

**Cosmic censorship conjecture**

**Thermonuclear reactions**

Heat-induced nuclear reactions

Every singularity must possess an event horizon

**The principle of relativity**

### Metaprinciple

A principle that all physical laws should obey

**Price's theorem**

All properties of a black hole that can be converted into radiation will be converted into radiation and will be radiated away completely – thereby making the black hole "hairless."

**Quantum field** → A field that is governed by the laws of quantum mechanics.

### **Schwarzschild geometry**

The geometry of spacetime around and inside a Schwarzschild black hole

## **DECODING THE UNIVERSE SINCE 1905**

Atom → nucleus → proton → quark

So, particle physics finished.....

Or is it not?

### **If it is not, then what completes the particle physics?**

After a duration of a thousand years, the power of astrology broke down when, with Copernicus, Kepler, and Galileo, the progress of astronomy overthrew the false hypothesis upon which the entire structure rested, namely the geocentric system of the universe. The fact that the earth revolves in space intervened to upset the complicated play of planetary influences, and the silent stars, related to the unfathomable depths of the sky, no longer made their prophetic voices audible to mankind. Celestial mechanics and spectrum analysis finally robbed them of their mysterious prestige.

— Franz Cumont

**If one tries to describe a gravitational singularity using Einsteinian General Theory of relativity alone, one finds that tidal gravity and spacetime curvature are infinitely strong there. Quantum gravity probably supersedes these infinities by quantum foam.**

# Conclusion

**Has the universe always existed or did something exist before it?** To address this question, which appears to be as old as human civilization itself, we need a **working theory of quantum gravity** and a new understanding of time. The question is not just relevant to cosmology; in fact, it offers potential avenues for deciphering the underlying physics of our universe. Despite some significant achievements, not all problems have been resolved. **Neutrinos** were previously believed to be massless, however new discoveries suggest that they may actually have a little mass. We still don't know what dark matter and dark energy are, or how they influence the behavior of the cosmos, despite their dominance in the universe. The whole form of the laws of nature is not yet well understood. Without this knowledge, we are unsure of how far we can advance in our quest to comprehend the universe's future. **Will it keep growing indefinitely?** Is inflation a natural law? Or will the universe eventually collapse? Why is the future so different from the past or why is there an arrow of time? **Does the universe have an infinite lifespan?** Will there ever be a "huge crunch," will the universe continue to expand indefinitely, or what? What does space's topology look like? **Can one travel through time?** Will there ever be a space colony? **Is there a unified theory of physics?** Or can these questions not be answered? Theoretical developments and new observational findings are pouring in quickly and we have learned more about our celestial home and how it works. Despite the fact that **Dr Science** has the solutions to many cosmological and astrophysical issues that our forefathers would never have thought we'd be able to solve, there are still a lot of big questions that haven't yet received completely satisfactory answers.

**What takes place within a black hole?** It can seem pointless to attempt to respond to this question. No one of us will fall into a region of spacetime whose gravity is so intense that nothing – not even light or other electromagnetic waves – can escape it, and even if we did, we wouldn't be alive to tell about it. We would be "**spaghettified**" by the black hole's tidal forces long before we hit the event horizon, the point of no return. There are cosmological mysteries

everywhere we turn. The set of equations that characterizes the nature of chaos is difficult for physicists to precisely solve. The universe is a curious place, brimming with wonder and magnificence as well as a myriad of questions left unanswered and unexplained mysteries. **Cosmology** is a very dynamic and intriguing field that involves the looking for the fundamental physics laws and the scientific study of the big-scale characteristics of the universe as a whole. New understandings of the huge universe emerged at the beginning of the 20<sup>th</sup> century. The answers to the ages-old queries are nearing completion through observations of outer space. What brings us here? **What is our origin?** Are space and time fundamental or emergent? Is there a beginning to the cosmos, or is it eternal? **Why the cosmos so perfectly balanced that life is possible in it?** Why is matter present in the cosmos but not antimatter? Whether the universe would end in fire or ice? **Why are there three dimensions in space?** If not for the well-known three dimensions, the cosmos would go incorrect, but theories of everything suggest there should be additional dimensions. **What are we completely missing?** Theoretical physicists proclaim that the inadequacy of our current technology limits us from noticing extra dimensions. Even though we – **a distinct species of the hominid family** – may never be able to observe these extra dimensions directly, astrophysicists and particle physicists may be able to use their instrumentation to find signs of their existence.

A black hole only emits a steady trickle of thermal radiation known as Hawking radiation due to **quantum indeterminacy**. Although **Hawking radiation** has never been seen, if it does exist, it might be able to transport information lost when objects fall into black holes. We do not yet understand fully what consciousness is and how it arises from the functioning of the brain, despite the fact that it is a key element of human experience. **Gravity**, one of the primary forces in the cosmos, is a topic of **Albert Einstein's General Theory of Relativity**. The underlying principle is that gravity is a curving or warping of space rather than an unseen force that draws objects together. An object warps the space around it more drastically the more massive it is. The physical features of nature at the size of atoms and subatomic particles are described by the fundamental physics theory known as **Quantum Mechanics**. **Quantum Mechanics** and **General Relativity** do not work together. What about: **Before the Big Bang?** Neither theory can predict what happened. The unification of so called **weak nuclear forces** with the **Maxwell**

**equations** is what known as the **Electroweak theory**. And the **electroweak theory** and **quantum chromodynamics** together constitutes the so called **Standard Model of particle physics**, which describes everything except gravity. Even hundreds of years later, the desire to comprehend the interconnected nature of the universe and how we fit within it is still intense. In some ways, the universe does prove to be much bigger and more magnificent than our progenitors could have ever imagined, which makes puzzles about its beginnings and design much more appealing to research. We are unable to travel back in time to the beginning of the universe, but by using a variety of hints and theories, we can conjure up a scenario for how things got started. Asking the questions: **Was there truly a singularity in the beginning? Do black holes actually defy all laws of conservation, with the exception of the laws of conservation of energy, momentum, angular momentum, and electric charge? Can we harness the energy that is hidden in empty space?** And trying to understand what is visible to us while pondering the nature of the cosmos. We are interested in discovering a comprehensive theory of everything that encompasses gravity, quantum mechanics, and all other physical interactions. If we succeed in this, we will truly comprehend the universe and our place in it.

What lies beyond the cosmological horizon is more challenging to determine than the size of the visible universe. To figure out, we still have a long way to go. **Questions abound in cosmology.**

There is always something new to learn in cosmology, even if it's just answering a question we've never thought to ask before. This is what keeps cosmology so exciting and intriguing. **Albert Einstein** and **Stephen William Hawking**'s goal of encapsulating the operation of the entire cosmos in a single mathematical equation is still a goal pursued by current physicists and cosmologists. The strength of magnetic interactions is governed by the **fine structure constant**,

**alpha**, which is frequently written. It is, in fact, quite close to being  $\frac{1}{137}$ . This number is

peculiar since stable matter wouldn't exist if it were any different. One of the best physical theories ever created incorporates the majority of **quantum mechanics' discoveries**, enabling physicists to predict and categorize fundamental particles and force carriers during the past half-century. However, physicists have not yet made a significant discovery that might contradict the **standard model of physics**. Even heavier elements, including **iron**, have been created by the

**powerful supernova explosions** that occasionally occur in the most massive stars. The origin of the heaviest elements, like as lead and uranium, is still somewhat a mystery. It is not surprising that astrophysicists and cosmologists have some extremely fundamental concerns about the world on their brains as cosmology is all about exploring the deepest secrets in nature.



## GLOSSARY

- **Absolute zero:** The lowest possible temperature at which substances contain no heat energy.
- **Acceleration:** The rate at which the speed of an object is changing and it is given by the equation:
$$a = \frac{dv}{dt}$$
- **Anthropic principle:** We see the universe the way it is because if it were different we would not be here to observe it through a gigantic telescopes pointing deep into the immense sky – merely stating that the constants of nature must be tuned to allow for intelligence (otherwise we would not be here). Some believe that this is the sign of a cosmic creator. Others believe that this is a sign of the multiverse.
- **Antiparticle:** Each type of matter particle has a corresponding antiparticle – first predicted to exist by **P. A. M. Dirac.** When a particle collides with its antiparticle, they annihilate, leaving only pure energy in the form of discrete bundle (**or quantum**) of electromagnetic (**or light**) energy called photons.
- **Atom:** The basic unit of ordinary matter, made up of a tiny nucleus (**consisting of positively charged protons and electrically neutral neutrons – which obey the strong interactions**) surrounded by orbiting negatively charged weakly interacting particles called the electrons.
- **Big Bang:** The singularity at the beginning of the universe. The titanic explosion that created the universe, sending the galaxies hurtling in all directions. When the universe was created, the temperature was extremely hot, and the density of material was enormous i.e., infinite. The big bang took place 13.7 billion years ago, according to the **WMAP satellite.** The afterglow of the big bang is seen today as the **cosmic background microwave radiation (of temperature 2.7 degrees above absolute zero).** There are three experimental "proofs" of the big bang: the redshift of the galaxies, the cosmic background microwave radiation, and nucleosynthesis of the elements.

- The observation of red shift is a key piece of evidence for the Big Bang theory about the origin of the Universe.
- The other key piece of evidence for the **Big Bang theory** is cosmic microwave background radiation {CMB – A fossil from the early universe! – Released when atoms formed (300,000 year)}.

- **Rotating black hole:** A black hole that possesses spin angular momentum
- **Charged black hole:** A black hole that possesses electric charge
- **Virtual black hole:** A black hole that momentarily exists as a result of a quantum spacetime fluctuation

- **Stellar black hole:** A huge star's gravitational collapse led to the creation of a black hole. Its mass ranges from three solar masses to several tens of solar masses.
- **Intermediate-mass black hole:** A black hole whose mass is significantly more than stellar black hole but considerably less than supermassive black hole.
- **Supermassive black hole:** Largest class of black hole in a galaxy, with a mass that is millions to billions of times greater than that of the Sun.
- **Stellar evolution:** The process by which a star goes through a series of drastic changes during the course of its lifetime.
- **Gravitational collapse:** A stage in a star's evolution where the star's internal pressure is insufficient to keep it at a stable size, causing its mass to collapse in on itself under the influence of gravity, eventually creating a black hole or neutron star and occasionally being followed by a supernova explosion. A key mechanism for how structures arise in the universe is gravitational collapse.
- **Quark star:** A hypothetical class of compact, unusual star – that is between a neutron star and a black hole in terms of density – whose extremely high core pressure and temperature have driven nuclear particles into the continuous state of quark matter, which is made up of free quarks.
- **Exotic star:** A hypothetical compact star made of elements other than electrons, protons, and neutrons that is protected from gravitational collapse by degeneracy pressure or other quantum features.
- **Primordial black hole:** A hypothetical kind of black hole created by the extreme density of matter present during the early expansion of the cosmos, rather than by the gravitational collapse of a large star.
- **Dark star:** A hypothetical object that is consistent with Newtonian mechanics and has a massive mass – possess a surface escape velocity that equals or exceeds the speed of light.
- **Dark-energy star:** A hypothetical compact astrophysical object where infalling matter passes through the event horizon and is transformed into vacuum energy or dark energy.
- **Ring singularity:** The ring-shaped gravitational singularity of a rotating black hole, or a Kerr black hole.
- **Black hole star:** A hypothetical kind of highly luminous and massive star that could have existed early in the evolution of the universe. The energy in a black hole star would originate from matter falling into a black hole at its centre rather than from nuclear fusion, which powers modern stars.
- **Black hole information paradox:** A paradox that arises when general relativity and quantum mechanics' predictions are combined.
- **Cauchy horizon:** A boundary within a black hole where the concept of determinism fails and the past no

longer dictates the future.

### **Cosmic censorship hypothesis**



**Every time an object collapses to the point where a singularity is created, a black hole is created, hiding the singularity behind the horizon and making it completely invisible to everyone outside the black hole.**

### **Schwarzschild metric**

**The Schwarzschild solution that describes the gravitational field surrounding spherical, uncharged, non-rotating black holes**

- **Big crunch:** The singularity at the end of the universe i.e., the final collapse of the universe. If the density of matter is large enough (**Omega – The parameter that measures the average density of matter in the universe – being larger than 1**), then there is enough matter in the universe to reverse the original expansion and cause the universe to recollapse. Temperatures rise to infinity at the instant of the big crunch.
- **Big freeze:** The end of the universe when it reaches near absolute zero. The big freeze is probably the final state of our universe, because the sum of Omega and Lambda is believed to be 1.0, and hence the universe is in a state of inflation. There is not enough matter and energy to reverse the original expansion of the universe, so it will probably expand forever.
- **Big Bang nucleosynthesis:** The production of deuterium, Helium-3 and Helium-4 (the latter to about 25% mass fraction) in the first 500 to 1000 sec of the early universe. These light isotopes, plus measurable amounts of lithium-7 and trace amounts of elements B, Be, are the result of non-equilibrium nuclear

reactions as the universe cooled to about 10 to the power of 8 K. Heavier isotopes were produced in stellar nucleosynthesis.

- **Black hole:** A region of space-time from which nothing, not even light, can escape, because gravity is so strong and escape velocity equals the speed of light. Because the speed of light is the ultimate velocity in the universe, this means that nothing can escape a black hole, once an object has crossed the event horizon. Black holes can be of various sizes. Galactic black holes, lurking in the center of galaxies and quasars, can weight millions to billions of solar masses. Stellar black holes are the remnant of a dying star, perhaps originally up to forty times the mass of our Sun. Both of these black holes have been identified with our instruments. Mini-black holes may also exist, as predicted by theory, but they have not yet been seen in the laboratory conditions.
- **Black Hole Escape Velocity:** It is widely held by astrophysicists and astronomers that a black hole has an escape velocity  $c$  (or  $c$ , the speed of light in Vacuum).
- **Zero point Energy:** an intrinsic and unavoidable part of quantum physics. The ZPE has been studied, both theoretically and experimentally, since the discovery of quantum mechanics in the 1920s and there can be no doubt that the ZPE is a real physical effect.
- **Casimir effect:** The attractive pressure between two flat, parallel metal plates placed very near to each other in a vacuum. The pressure is due to a reduction in the usual number of virtual particles in the space between the plates. This tiny effect has been measured in the laboratory. The Casimir effect may be used as the energy to drive a time machine or wormhole, if its energy is large enough.
- **Chandrasekhar limit:** The maximum possible mass of a stable cold star (i.e., 1.4 solar masses), above which it must collapse into a black hole.

- **Kerr metric:** The most typical asymptotically flat, stationary solution of the Einstein-Maxwell equations in general relativity that depicts the geometry of empty spacetime surrounding an uncharged, rotating black hole.
- **Reissner–Nordström metric:** The static solution to the Einstein-Maxwell field equations, which describes the gravitational field surrounding spherical, charged, non-rotating black holes.
- **Kerr-Newman metric:** The solution of the Einstein–Maxwell equations in general relativity, which describes the spacetime geometry around spherical, charged, rotating black holes.

## Eternal inflation



**A hypothetical inflationary universe model – an extension of the Big Bang hypothesis – which states that once inflation begins, it never fully ends. Instead, it ends in places where universes come into being.**

- **Conservation of energy:** The law of science that states that energy (or its equivalent in mass) can neither be created nor destroyed i.e., they never change with time. For example, the conservation of matter and energy posits that the total amount of matter and energy in the universe is a constant.
- **Coordinates:** Numbers that specify the position of a point in a 4 dimensional space-time.
- **Cosmological constant:** A mathematical parameter (which measures the amount of dark energy in the universe) introduced by Albert Einstein to give space-time an inbuilt tendency to expand. At present, the data supports density parameter + cosmological constant = 1, which fits the prediction of inflation for a flat universe. Cosmological constant, which was once thought to be zero, is now known to determine the ultimate destiny of the universe.
- **Cosmology:** The study of the universe as a whole.

**One coulomb of charge** is that charge which when placed at rest in vacuum at a distance of one meter from an equal and similar stationary charge repels it and is repelled by it with a force of  **$8.99 \times 10^9$  Newton**.

- **COBE:** The Cosmic Observer Background Explorer satellite.
- **Dark matter:** Invisible Matter usually found in a huge halo around galaxies, clusters, and possibly between clusters, that cannot be observed directly but can be detected by its gravitational effect and they does not interact with light. As much as 90 percent of the mass of the universe may be in the form of dark matter and

they makes up 23 percent of the total matter/energy content of the universe. According to string theory, dark matter may be made of subatomic particles, such as the neutralino, which represent higher vibrations of the superstring.

- **Duality:** A correspondence between apparently different theories that lead to the same physical results.
- **Einstein-Rosen bridge:** A thin tube of space-time linking two black holes.
- **Electric charge:** A property of a particle by which it may repel (or attract) other particles that have a charge of similar (or opposite) sign.
- **Electromagnetic force:** The force of electricity and magnetism that arises between particles with electric charge; the second strongest of the four fundamental forces –which obeys Maxwell's equations.
- **Electron:** A negatively charged subatomic particle with negative electric charge that orbits the nucleus of an atom and determines the chemical properties of the atom.
- **Electroweak unification energy:** The energy (around 100 GeV) above which the distinction between the electromagnetic force and the weak force disappears.
- **Elementary particle:** A particle that, it is believed fundamental building block of Nature, cannot be subdivided and are not composed of other simpler particles.
- **Event:** A point in space-time, specified by its time and place.
- **Event horizon:** The boundary of a black hole. The point of no return, often called the horizon.
- **Electromagnetic wave:** A wave in which electric and magnetic fields are perpendicular to each other and also perpendicular to the direction of propagation of wave.
- **Exclusion principle:** The idea that two identical spin-1/2 particles cannot have (within the limits set by the uncertainty principle) both the same position and the same velocity. This means that two electrons cannot occupy precisely the same point with the same properties, so that there is a net force pushing the electrons apart (in addition to electrostatic repulsion).
- **Electric Current:**

$$\text{If the rate of flow of charge is steady: } I = \frac{q}{t}$$

$$\text{If the rate of flow of charge varies with time: } I = \frac{dq}{dt}$$

$$\text{Ohm's Law} \rightarrow \text{Resistance} = \frac{\text{potential difference}}{\text{Current}}$$

- **Field:** Something that exists throughout 4 dimensional fabric of space -time, as opposed to a particle that exists at only one point at a time.
- **Frequency:** For a wave, the number of complete cycles per second.
- **Fermi Level:** The highest energy level in the conduction band occupied by electrons in a crystal at absolute zero temperature. The energy corresponding to this energy level is called Fermi energy.
- **Gamma rays:** Electromagnetic rays of very short wavelength, produced in radio-active decay or by collisions of elementary particles.
- **General relativity:** Einstein's theory of gravity based on the idea that the laws of science should be the same for all observers, no matter how they are moving. It explains the force of gravity in terms of the curvature of a four dimensional space-time; so that the curvature of space-time gives the illusion that there is a force of attraction called gravity. It has been verified experimentally to better than 99.7 percent accuracy and predicts the existence of black holes and the expanding universe. The theory, however, break down at the center of a black hole or the instant of creation, where the theory predicts nonsense. To explain these phenomena, one must resort to a theory of subatomic physics.
- **Geodesic:** The shortest (or longest) path between two points.
- **Grand unification energy:** The energy above which, it is believed, the electromagnetic force, weak force, and strong force become indistinguishable from each other.
- **Grand unified theory (GUT):** A theory which unifies the electromagnetic, strong, and weak forces (but not gravity). The proton is not stable in these theories and can decay into positrons. GUT theories are inherently unstable (unless one adds super symmetry). GUT theories also lack gravity. (Adding gravity to GUT theories makes them diverge with infinities.)
- **Imaginary time:** Time measured using imaginary numbers.
- **Inflation:** The theory which states that the universe underwent an incredible amount of superluminal expansion at the instant of its birth i.e., A distance of one nanometer was enlarged to a quarter of a billion light-years.
- **Hyperspace:** Dimensions higher than four.

**Like the Moon, Mercury has no atmosphere and its surface is full of craters.**

**A day on Mars is 24 hours 40 minutes and a year lasts for 1.88 Earth years**

**Venus is covered by a thick cloud mainly consisting of Sulphuric acid droplets.**

**Most of the mass of the solar system is contained in the Sun.**

Total angular momentum of all the planets is more than the angular momentum of the Sun.

**Nebular hypothesis**

Our solar system is formed due to gravitational contraction of the rotating interstellar cloud called the solar nebula

**Because the Sun and the planets are formed from the same rotating nebula:**

The direction of rotation of the Sun and the directions of revolution of most of the planets are the same.

**Extra-solar planets: Planets exist outside the solar system**

The formation of a planet involves 3 phases:

1. Formation of a minute planet.
2. Formation of a small celestial object that is the size of a moon or a bit bigger.
3. Stabilization of the planet.

- **Light cone:** A surface in space-time that marks out the possible directions for light rays passing through a given event.
- **Light year:** The distance light travels in one year, or approximately 5.88 trillion miles (9.46 trillion kilometers).
- **LIGO:** The Laser Interferometry Gravitational-Wave Observatory, based in Washington state and Louisiana, which is the world's largest gravity wave detector.
- **LISA:** The Laser Interferometry Space Antenna- which is a series of three space satellites using laser beams to measure gravity waves. It is sensitive enough to confirm or disprove the inflationary theory and possibly even string theory.
- **Magnetic field:** The field responsible for magnetic forces, now incorporated along with the electric field, into the electromagnetic field.
- **Muon:** A subatomic particle identical to the electron but with a much larger mass. It belongs to the second redundant generation of particles found in the Standard Model.
- **Mass:** The quantity of matter in a body; its inertia, or resistance to acceleration.
- **Microwave background radiation:** The remnant radiation (with a temperature of about 2.7 degrees K) from the glowing of the hot early universe (big bang), now so greatly red-shifted that it appears not as light but as microwaves (radio waves with a wavelength of a few centimeters). Tiny deviations in this background radiation give scientists valuable data that can verify or rule out many cosmological theories.
- **Naked singularity: A space-time singularity without an event horizon.**
- **Neutrino:** An extremely light (possibly massless) subatomic particle that react very weakly with other particles and may penetrate several light-years of lead without ever interacting with anything and is affected only by the weak force and gravity.
- **Neutron:** A neutral subatomic particle, very similar to the proton, which accounts for roughly half the particles in an atomic nucleus. Neutron left alone for 15 minutes will decay into electron, proton, neutrino (very light, chargeless lepton).
- **Neutron star:** A cold collapsed star consisting of a solid mass of neutrons — which is usually about 10 to 15 miles across — supported by the exclusion principle repulsion between neutrons. If the mass of the neutron stars exceeds (3- 4 solar masses) i.e., if the number of neutrons becomes  $\geq 5.9 \times 10^{57}$ , then the

degenerate neutron pressure will not be large enough to overcome the gravitational contraction and the star collapses into the next stage called black holes.

- **No boundary condition:** The idea that the universe is finite but has no boundary (rooted in the Euclidean formalism) to account for the initial conditions in the big bang.
- **Nuclear fusion:** The process by which two nuclei collide and coalesce to form a single, heavier nucleus.
- **Nucleus:** The tiny core of an atom, which is roughly  $10^{-13}$  cm across, consisting only of protons and neutrons, held together by the strong force.
- **Particle accelerator:** A machine — based in Geneva, Switzerland — that, using electromagnets, can accelerate moving charged particles, giving them more energy.
- **Phase:** For a wave, the position in its cycle at a specified time: a measure of whether it is at a crest, a trough, or somewhere in between.
- **Photon sphere:** An area or region of space where gravity is so strong that photons are forced to travel in

orbits. Because  $r = \frac{3GM}{c^2}$  — photon spheres can only exist in the space surrounding an extremely compact object (a black hole or possibly an "**ultracompact**" neutron star).

- **Photon:** A quantum of light (which was first proposed by Einstein to explain the photoelectric effect—that is, the fact that shining light on a metal results in the ejection of electrons).
- **Planck's quantum principle:** The idea that light (or any other classical waves) can be emitted or absorbed only in discrete quanta, whose energy E is proportional to their wavelength  $\lambda$  (i.e.,  $E = \frac{hc}{\lambda}$ ).
- **Positron:** The (positively charged) antiparticle of the electron.
- **Primordial black hole:** A black hole created in the very early universe.
- **Negative energy:** Energy that is less than zero.
- **Proton:** A positively charged subatomic particle, very similar to the neutron, that accounts for roughly half the particles in the nucleus of most atoms. They are stable, but Grand Unification theory predicts that they may decay over a long period of time.
- **Pulsar:** A rotating neutron star that emits regular pulses of radio waves.
- **Quantum:** The indivisible unit in which waves may be emitted or absorbed.

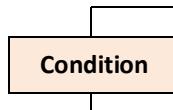
### Bohr Correspondence principle

The nuclear forces account for the attractive force between:

- a proton and a neutron
- 2 protons
- 2 neutrons

For large orbits and for large energies, quantum calculations must agree with classical calculations.

**Semi-classical physics** → a theory in which one part of a system is described quantum mechanically whereas the other is treated classically.



Einstein's special theory of relativity → classical mechanics	velocities are very small compared to the speed of light
Einstein's General theory of relativity → Newtonian gravity	weak gravitational fields
Statistical mechanics → thermodynamics	the number of particles is large
Laplace's theory of celestial mechanics → Kepler's theory of celestial mechanics	interplanetary interactions are ignored

**Electrons can exist in states of positive energy as well as negative energy states:**

$$E = \pm \sqrt{m_0^2 c^4 + p^2 c^2}$$

- The positive root permits the total energy "E" of an electron to have any value from  $m_0 c^2$  to  $+\infty$
- The negative root permits the total energy "E" of an electron to have any value from  $-\infty$  to  $-m_0 c^2$

As momentum increases

The formation of a non-radioactive element from a radioactive element constitute

Disintegration Series	Parent Element	Last Stable element
Thorium Series	$_{90}\text{Th}^{232}$	$_{82}\text{Pb}^{208}$
Neptunium Series	$_{93}\text{Np}^{237}$	$_{83}\text{Bi}^{209}$
Uranium Series	$_{92}\text{U}^{238}$	$_{82}\text{Pb}^{206}$
Actinium Series	$_{92}\text{U}^{235}$	$_{82}\text{Pb}^{207}$

{ The naturally occurring radioactive elements conform to 4 radioactive series }

- **Quark:** A subatomic particle that makes up the proton and neutron and feels the strong force. Three quarks make up a proton or neutron, and a quark and antiquark pair makes up a meson.
- **Quantum chromodynamics (QCD):** The theory that describes the interactions of quarks and gluons.
- **Quantum mechanics:** The theory developed from wave equations, Planck's quantum principle and Heisenberg's uncertainty principle. No deviation from quantum mechanics has ever been found in the laboratory. Its most advanced version today is called quantum field theory, which combines special relativity and quantum mechanics. A fully quantum mechanical theory of gravity, however, is exceedingly difficult.

According to Quantum Mechanical Laws, the energies of electrons in a free atom cannot have arbitrary values but only some definite (quantized) values.

- **Quasar:** Quasi-stellar object. They are huge galaxies that were formed shortly after the gigantic explosion called the big bang.
- **Quantum foam:** Tiny, foam like distortions of 4 dimensional fabric of space-time at the level of the Planck length.
- **Radioactivity:** The spontaneous breakdown of one type of atomic nucleus into another.
- **Red shift:** The reddening or decrease in frequency of light from a star that is moving away from us, due to the Doppler effect.
  - Light from far away has more time to stretch
  - Light from nearby sources gets stretched less
  - Longer wavelength → redder light → far away light more red shifted
  - **Hubble's Expansion Law** → The farther away the galaxy, the bigger the redshift.
- **Refraction:**
  - Fact #1 → As light goes from one medium to another, the velocity CHANGES!
  - Fact #2 → As light goes from one medium to another, the path CHANGES!
- **Singularity:** A point in space-time at which the space-time curvature becomes infinite – which represent a breakdown of general relativity, forcing the introduction of a quantum theory of gravity.

### Length Contraction:

$$L = L_0 \sqrt{1 - \frac{v^2}{c^2}}$$

For  $v = 0.9c$ :

$$L = 0.44L_0.$$

The notable consequences of the Heisenberg's **uncertainty principle**:

- The path of a particle is not defined in **quantum physics** (the study of matter and energy at the most fundamental level).
- Electrons do not exist inside the nucleus of the atom.
- **Atomic oscillators** possess a certain amount of energy, known as the zero-point energy, even at absolute zero temperature.

That is the measured length is less than half of the proper length. If  $v \ll c$ , then  $L$  and  $L_0$  are nearly equal. At low velocities, relativity approaches classical mechanics — our everyday experiences have negligible relativistic effects.

**An inertial frame is a frame of reference in which Newtonian first law holds well.**

### The Galilean principle of relativity:

If two cars are moving at the same speed in the same direction, then a passenger in either car will not be able to notice that either car is moving.

- The **special theory of relativity** deals with observations made in inertial frames.
- The **general theory of relativity** deals with observations made in non-inertial frames.

### The relativity of simultaneity

**The negative outcome of the Michelson-Morley experiment (1887)**

**The aether did not exist**

2 events are defined to be simultaneous if an observer measures them as occurring at the same time. They are not necessarily simultaneous to all observers — **simultaneity** is not absolute.

- **Singularity theorem:** A theorem that states that the universe must have started with a singularity.
- **Space-time:** The four-dimensional space whose points are events.
- **Spatial dimension:** Any of the three dimensions that are space like – that is, any except the time dimension.
- **Special relativity:** Einstein's 1905 theory based on the idea that the laws of science should be the same for all observers, no matter how they are moving, in the absence of gravitational phenomena. Consequences include: time slows down, mass increases, and distances shrink the faster you move. Also, matter and

energy are related via  $E = mc^2 = \frac{m_0 c^2}{\sqrt{1 - \frac{v^2}{c^2}}}$ . One consequence of special relativity is the atomic bomb.

- **Spectrum:** The different colors or component frequencies that make up a wave. By analyzing the spectrum of starlight, one can determine that stars are mainly made of hydrogen and helium.
- **Spin:** An internal property of elementary particles.
- **Stationary state:** One that is not changing with time.
- **Supernova:** An exploding star. They are so energetic that they can sometimes outshine a galaxy.
- **String theory:** A theory of physics based on tiny vibrating strings, such that each particle is described as a wave on a string. It is the only theory that can combine gravity with the quantum theory, making it the leading candidate for a theory of everything.
- **Strong force:** The strongest of the four fundamental forces, with the shortest range of all. It holds the quarks together within protons and neutrons, and holds the protons and neutrons together to form atoms.
- **Steady state theory:** The theory which states that the universe had no beginning but constantly generates new matter as it expands, keeping the same density.
- **Uncertainty principle:** The principle, formulated by Heisenberg, that one can never be exactly sure of both the position and the velocity of a particle; the more accurately one knows the one, the less accurately one can know the other.

$$\Delta x \times \Delta p \geq \frac{\hbar}{2}$$

$$\Delta E \times \Delta t \geq \frac{\hbar}{2}$$

- **Virtual particle:** In quantum mechanics, a particle that briefly dart in and out of the vacuum but can never be directly detected, but whose existence does have measurable effects. They violate known conservation laws but only for a short period of time, via the uncertainty principle.
- **Wave / particle duality:** The concept in quantum mechanics that there is no distinction between waves and particles; particles may sometimes behave like waves, and waves like particles.
- **Wavelength:** For a wave, the distance between two adjacent troughs or two adjacent crests.
- **Weak force:** The second weakest of the four fundamental forces – which is carried by the  $W^-$  and  $Z$  bosons – that makes possible nuclear decay. It affects all matter particles, but not force carrying particles.
- **Weight:** The force exerted on a body by a gravitational field. It is proportional to, but not the same as, its mass.
- **White dwarf:** A stable cold star consisting of lower elements such as oxygen, lithium, carbon, and so forth, supported by the exclusion principle repulsion between electrons.
- **Wormhole:** A passageway between two universes or a thin tube of space-time connecting distant regions of the universe. Wormholes might also link to parallel or baby universes and could provide the possibility of time travel.

- **Nova:** A star that suddenly gets very brighter for a short period of time.
- **Radio Astronomy:** The examination of celestial bodies that emit radio waves.
- **1 curie:** Amount of radioactive material undergoing  $3.7 \times 10^{10}$  disintegrations per second.
- **Meteoroid Stream:** Stream of tiny solid particles that have been emitted by active comets and maybe by some asteroids that are close to Earth.
- **Micrometeorite:** A space particle that has survived entering the atmosphere of Earth and is no bigger than a sand grain.
- **Persistent train:** The lingering glow caused by ionization in the upper atmosphere after a meteoroid has passed.
- **Meteorite:** A naturally occurring material with extraterrestrial origin that survives passage through the atmosphere of Earth and hits the ground.
- **Barycenter:** The center of mass of a system of bodies that orbit one another. For example: the center of mass of the solar system or the Earth–Moon system.

- **External Reality Hypothesis (ERH):** There exists an external physical reality completely independent of us human beings.
- **Mathematical Universe Hypothesis (MUH):** External physical reality is a mathematical structure.

- **Constant of aberration:** The ratio of the mean orbital speed of the Earth to the speed of light.
- **Deflection of light:** The deviation of a photon's apparent path from a straight line caused by the Sun's gravitational field.
- **Light-time:** How long it takes for light to reach Earth from a celestial body.
- **Lunation:** The time interval between two successive New Moons.
- **Parsec:** The distance to an object with an annual parallax of one second of arc **or the distance at which one astronomical unit subtends an angle of one second of arc.**
- **Photometry:** A field of physics concerned with measuring light intensity.
- **Sunyaev–Zeldovich effect:** A process where **CMB** (cosmic microwave background) photons would encounter high-energy electrons in a galaxy cluster, increasing the energy and frequency of the photons.
- **Abney's law of additivity:** Any spectrum decomposition of the light's components adds up to the source's total luminous power.
- **Absolute space and time:** Even if there were no objects, space and time would still exist since they are independent of them.

**Classical Relativity** → Black holes does not emit radiation

**Quantum field theory + General Relativity** → Black holes emit radiation and eventually disappear

Fundamental constant	Included when
Speed of light	Things are fast
Newtonian Gravitational constant	Things are massive
Planck's constant	Things are quantum and small
Boltzmann's constant	Things are hot

**A lot of prizes have been awarded for showing the universe is not as simple as we might have thought.**

— Stephen W. Hawking

- **Cosmic strings:** The mysterious objects that may have originated in the early Universe, but for which there is no proof at this time. Theoretical physicist **Tom W. B. Kibble** first proposed them in the late 1970s as a potential outcome of several field theories, such as the well-known Higgs theory.
- **Gravitational waveform:** A curve that depicts how a gravitational wave's disturbance changes over time.
- **Phase transition:** Thermodynamic transition of a state of matter from one form to another. Water cooling and turning into ice is an illustration of a phase transition.
- **Chaotic Inflation:** The idea that the inflation is a natural and possibly even unavoidable result of the chaotic initial conditions in the primordial universe.
- **Classical Physics:** Physics without consideration for quantum physics or the theory of relativity.
- **Condensed matter physics:** The branch of physics that studies the macroscopic and microscopic physical characteristics of matter, particularly the solid and liquid phases that result from electromagnetic forces between atoms.
- **Electron volt:** A unit of energy that is around  $1.602 \times 10^{-12}$  erg or  $1.602 \times 10^{-19}$  Joules. The amount of energy that one electronic charge gains as it goes across a one volt electric potential difference.
- **Inflaton particle:** A hypothetical particle that would have been responsible of the inflation of the universe just after the Big Bang.
- **Inflaton field:** A hypothetical scalar field which would have caused the inflation of the universe just after the Big Bang.

**Einstein's General Theory of Relativity:**

Gravity → Curved Space time

### Kaluza-Klein Theory



**A hypothesis that aims to integrate the two of the four fundamental interactions – electromagnetism and gravitation**

## **Electroweak Theory**



**A hypothesis that seeks to unify two of the four fundamental interactions- electromagnetism and weak nuclear force**

- **Luminosity:** The intrinsic brightness of a celestial object.

## **M-theory**



**A theory that predicts an eleven-dimensional universe with a unification of gravity, the weak and strong forces, and all other string theories**

**Will M Theory ultimately prove to be the theory that combines the**

**basic forces of nature is still a ?**

- **Liquid crystal:** A state of matter that possesses properties that falls midway between those of a liquid and a solid crystal.
- **Hartle–Hawking state:** Prior to the Big Bang, the Universe was a singularity in both space and time. It has not always existed. Instead, the Big Bang, which occurred around 15 billion years ago, was the origin of the cosmos and time itself.
- **Planck Epoch:** The earliest time in the cosmic evolution, shortly following the Big Bang, usually observed at or near one Planck time ( $10^{-43}$  seconds), when all fundamental forces of nature were unified.

- **Quantum cosmology:** A theory that seeks to extend gravitational physics beyond Albert Einstein's theory of general relativity by incorporating quantum mechanics to provide a quantum mechanical description of the cosmos.
- **Quark-Hadron transition:** Approximately one millionth of a second after the Big Bang, this phase transition took place. At this point, the quark-gluon plasma encountered a phase transformation that caused quarks to condense into hadronic matter, or nucleons.
- **Particle cosmology:** Astroparticle physics that deals with the investigation of the early universe up until about  $10^{-11}$  seconds after the Big Bang.

If a black hole have entropy " $S_{BH} = \frac{k_B c^3 A}{4G\hbar}$ ", it should have a temperature " $T_{BH} = \frac{\hbar c^3}{8\pi G M k_B}$ ".

$$S_{BH} = \frac{k_B c^3 A}{4G\hbar}$$

One of the most elegant equations we've come across so far is the Bekenstein Entropy Equation. It includes four universal physical constants that we are currently aware of.

### The second law of Black hole thermodynamics



**The area of event horizon of a black hole is a non-decreasing function of time**

$$\frac{dA}{dt} \geq 0$$

The area of event horizon of a black hole always increases

The black hole entropy always increases

This "law" was disproved by Sir Stephen Hawking's discovery that black holes radiate, which causes both the black hole's mass and the size of its event horizon to shrink with time.

Black Hole Temperature  $\propto$  Surface Gravity of a Black Hole

Black Hole Entropy  $\propto$  Area of Event Horizon of a Black Hole

### **The Zeroth law of black hole Thermodynamics:**

The surface gravity is constant on the event horizon of a Schwarzschild Black Hole

### **The third law of black hole Thermodynamics**



A black hole cannot form in the face of diminishing surface gravity. In other words, surface gravity equal to 0 is not possible.

- **Kaon:** A strange meson that weighs almost half as much as a proton.
- **Tau:** A fundamental lepton having a mass that is approximately 3,500 times that of the electron.
- **Pion:** A meson having a mass that is 1/7 the proton's mass.
- **Alpha particle:** A  ${}^4\text{He}$  atom's nucleus composed of two neutrons and two protons.
- **Cherenkov radiation:** A charged particle that moves through a transparent medium faster than the speed of light in that medium produces photons of visible radiation. Cherenkov radiation is the name given to these photons.
- **Quantum mechanical tunneling:** A quantum mechanical phenomenon by which a particle has a chance of crossing a potential energy barrier even though it lacks the energy to do so.
- **Decay series:** The process wherein consecutive nuclides decay until a stable nuclide is created.
- **Electron capture:** The radioactive process of decay wherein an atom's inner orbital electron is taken up by its nucleus, accompanied by the neutrino's emission and the conversion of a proton to a neutron.
- **Ionizing radiation:** A form of high-energetic radiation with sufficient energy to ionize an atom or molecule by removing its electrons.

- **Carbon-14 dating:** A technique of carbon dating that uses the characteristics of a radioactive carbon isotope to estimate the age of a material made of organic matter. It is based on the radioactivity of carbon-14.
- **Nuclear reaction energy:** The energy generated in a nuclear reaction.
- **Range of radiation:** The maximum distance that radiation can travel through a substance.
- **Radioactivity:** The natural phenomenon by which some unstable nuclei spontaneously split into new, more stable nuclei while simultaneously releasing energy and particles.
- **Blackbody:** An idealized physical object that is the perfect radiation emitter and absorber.
- **Blackbody radiation:** The radiation that a blackbody emits.
- **Electric dipole moment:** An electric dipole is formed by two point charges "+q" and "-q" separated by a distance "r". The electric dipole moment is defined as  $\mu = q \times r$ .
- **Fissile nucleus:** A nucleus that can undergo fission after absorbing a thermal or slow neutron.
- **Fission:** The process whereby a larger atom splits into two or more smaller atoms.
- **Fission products:** The smaller atoms that remain following the fission of a larger atom.
- **Fusion:** The process of combining two or more smaller atoms into a larger atom.
- **Induced radioactivity:** Radioactivity produced by bombarding a stable nucleus with charged particles from particle accelerators or with neutrons in a nuclear reactor.
- **Infrared radiation:** A type of electromagnetic radiation with a wavelength longer than visible light.
- **Ion:** An atomic particle with a positive or negative electrical charge.
- **Isomer:** Two molecules that are structurally distinct but have the same molecular formula.
- **Isomeric transition:** A nuclear phenomenon in which a nucleus with extra energy after an alpha or beta particle is emitted emits energy without altering the number of protons or neutrons in the nucleus.
- **Isotopes:** Atoms of the same element with different numbers of neutrons but the same number of protons.

- **Standard Model:** Gauge theory addressing the electroweak and strong interactions.
- **Transmutation:** The process through which an element changes into another by a nuclear reaction.
- **Ultraviolet radiation:** A kind of non-ionizing electromagnetic radiation with a wavelength of 10 nm to 400 nm, longer than X-rays but shorter than visible light, and emitted by the sun and artificial sources like tanning beds.
- **X-radiation:** Electromagnetic radiation – which is typically created during transitions of an atom's inner electrons. Its wavelength falls between gamma and ultraviolet radiation.
- **Radionuclide:** An unstable isotope of an element that spontaneously decays or disintegrates and releases radiation.
- **Chain reaction:** When the byproduct of one nuclear fission reaction triggers the occurrence of more nuclear fission reactions, a nuclear chain reaction results.

Controlled Fission chain reaction → Nuclear power

Uncontrolled Fission chain reaction → Nuclear weapon

- **Prompt neutron:** Neutron released instantly by a fissioning nucleus in nuclear fission reaction.
- **Delayed neutron:** A neutron that a fission product nucleus emits during beta disintegration after a significant amount of time has passed since the fission.
- **Fossil fuel:** A carbon-based fuel, such as coal, oil, or gas that is thought to have originated from living things. Energy is produced by burning it with oxygen.
- **Transuranic elements:** The chemical elements with atomic number higher than uranium's atomic number. These elements are all radioactively unstable and undergo radioactive decay.
- **Ampere:** The International System of Units' measure for electrical current. An electrical charge of one coulomb ( $6.24 \times 10^{18}$  electrons) that passes a particular point in one second is represented by one ampere of current.
- **Anisotropic universe:** A cosmos that is expanding in different directions and at different rates.

- **Apollo asteroids:** A group of near-Earth asteroids found by German astronomer **Karl Reinmuth** in the 1930s and named after the 1862 Apollo mission.
- **DNA (deoxyribonucleic acid):** The genetic material that serves as the blueprint for a cell's structure and function in humans and nearly all other animals.
- **Positron emission:** A proton inside a radioactive nucleus is transformed into a neutron during a process known as **beta decay**, which further results in the release of positron and electron neutrino.
- **Annular eclipse:** A solar eclipse in which the sun's outermost edge is still observable and appears as a bright ring around the moon.
- **Archimedes' principle:** A force equivalent to the weight of the displaced liquid lifts an object that is half or completely submerged in a liquid.
- **Asterism:** A group of stars that is smaller than a constellation.
- **Astrochemistry:** The study of how abundant atoms, ions, radicals and molecules are, how they behave, and how they interact with radiation photons in the universe. The field combines aspects of astronomy and chemistry.
- **Astrometry:** The determination of celestial object locations and movements.
- **Atmosphere:** A layer of gas or layers of gases that surround the planet Earth and are held in place by its gravitational field. These layers include **the troposphere** (which extends up to about 10 to 17 km), **the stratosphere** (which extends up to about 55 km), **the mesosphere** (which extends up to about 80 km), and **the ionosphere** (which extends up to over 150 km). The atmosphere's overall mass is roughly  $5.3 \times 10^{18}$  kg, or one millionth of the mass of the entire planet.
- **Back scattering:** Scattering at angles larger than 90 degrees.
- **Baryogenesis:** Phase of the universe's early evolution where baryons were created from quarks.

There are still issues with the Big Bang Theory despite the fact that there is evidence that the Big Bang actually did happen. Initial density perturbation, as well as the flatness problem, horizon problem, and monopole problem, cannot be explained by the Big Bang theory.

- **Binary black holes:** 2 black holes orbiting one another, much like stars in a binary system. A **binary system** of two black holes may radiate away a significant amount of orbital energy through the emission of **gravitational radiation**. Orbital energy loss may also cause **orbital decay**, which causes the 2 black holes to spiral down toward one another until they eventually merge to form a **single black hole**.
- **Bioluminescence:** Light generated by living organisms as a consequence of the transformation of chemical energy into radiant energy.
- **Carbon star:** A luminous red giant star that is an asymptotic giant branch star and whose atmosphere is richer in carbon than oxygen.
- **Catastrophic formation of solar system:** A theory explaining how the solar system came to be based on the idea that the Sun and another massive object (**presumably another star**) collided or came dangerously close to colliding, giving rise to the planets and other smaller objects in the solar system.
- **Chemically peculiar stars:** Stars, at least in their outer layers, have significantly unusual metal abundances.
- **Closed universe:** A universe with a finite size but no center or edge, where space-time curves back on itself. From a "**big bang**," it expands to its greatest point before returning to a "**big crunch**" of extreme density and temperature.
- **Cold plasma:** When a plasma is almost completely ionized, it is sometimes regarded as being "**hot**," and when only a small portion—for example, 1% of the gas molecules—are ionized, it is characterized as being "**cold**".
- **Compton cooling:** The decrease in an electron's energy brought on by interacting with a photon. The energy of the incident photon plus a portion of the electron's kinetic energy is diverted as a photon of higher energy if the electron's kinetic energy is sufficiently high in comparison to the incident photon.
- **Coronal mass ejection (CME):** An eruption in the lower corona that causes particles to be ejected from the sun into interplanetary space.
- **Magnetosphere:** A region of space near a celestial object where its magnetic field has an effect on charged particles.
- **Metallicity:** A measure of the amount of elements heavier than hydrogen or helium that are produced by nucleosynthesis in stars.

- **Moonbow:** A rainbow that forms when raindrops or mist reflect and refract moonlight.
- **Net photosynthetic rate:** The total rate of photosynthetic CO<sub>2</sub> fixation minus the rate of CO<sub>2</sub> loss during respiration.
- **Newtonian cosmology:** A group of universe models built using hydrodynamic and Newtonian mechanics principles.
- **Non-thermal radiation:** The radiation is referred to as "non-thermal radiation" if its properties are independent of the source's temperature.
- **Computational cosmology:** The use of numerical simulations to model the formation of structure in the universe.
- **Numerical relativity:** One of the domains of **Albert Einsteinian general theory of relativity** that solves and analyses problems using numerical techniques and algorithms.
- **Occultation:** The full blockage of a celestial object's light, most often a star, by another celestial object, like a planet or satellite.
- **Perturbation theory:** A helpful tool that may be used to examine challenges in astrophysics, high-energy physics, and basic concerns in gravity. It can be applied to problems ranging from classical physics to quantum physics.
- **Photoinhibition:** The process of decreasing **photosynthetic rate** with increased irradiation, resulting from surpassing the photosynthetic capacity.
- **Photoionization:** The dissociation of matter into electrically charged particles as a result of electromagnetic radiation's interaction with the matter.

**Ionization of atoms and  
molecules by photons**

- **Planetary radio astronomy:** A subfield of astronomy that studies radio emissions from the planets in our solar system.
- **Protosun:** The early sun, which emerged from a molecular cloud shortly before or immediately after it started to produce internal energy through nuclear processes.

- **Radio absorption:** Radio waves being absorbed as a result of an electromagnetic wave interacting with free electrons in the ionosphere.
- **Seismotectonics:** A field of study that uses earthquakes to study plate tectonics.
- **Quiet sun:** The region of the solar surface that is free of sunspots, solar flares, or solar prominences.
- **Solar neutrinos:** Electron neutrinos with low energy produced during solar nuclear reactions and observed from Earth. Fewer are observed than what is predicted by standard physics and astrophysics.
- **Subdwarf:** A star that is smaller in size, less luminous and of lower metallicity than a main sequence star of the same spectral type.
- **Tidal radius:** The radius within which all the luminous matter of a galaxy is contained.

**"By 2100, our destiny is to become like the gods we once worshipped and feared. But our tools will not be magic wands and potions but the science of computers, nanotechnology, artificial intelligence, biotechnology, and most of all, the quantum theory."**



**— Michio Kaku, Physics of the Future: How Science Will Shape Human Destiny and Our Daily Lives by the Year 2100**

# The Greatest Scientific Questions Unanswered

**Are we alone in this mystic universe?**

**Is there a God?**

**How vast is space?**

**Where and how did life first emerge on Earth?**

**Can one travel through time?**

**Will there ever be a space colony?**

**In what way will the cosmos end?**

**What is the purpose and meaning of time?**

Every issue we might imagine to ask has been raised by human beings throughout mankind history, and many of them have also been addressed. But there are still a few issues that haven't been answered, and sadly, it appears that they will likely remain unresolved until humanity ceases to exist.

## Best Cosmology Books of All Time:



- **A Brief History of Time**

Book by Stephen Hawking

- **Cosmos**

Book by Carl Sagan

- **The Fabric of the Cosmos**

Book by Brian Greene

- **The Elegant Universe**

Book by Brian Greene

- **The Big Picture: On the Origins of Life, Meaning, and the Universe Itself**

Book by Sean Carroll

- **A Universe from Nothing: Why There Is Something Rather Than Nothing?**

Book by Lawrence M. Krauss

- **The First Three Minutes: A Modern View of the Origin of the Universe**

Book by Steven Weinberg

- **A Short History of Nearly Everything**

Book by Bill Bryson

- **The Grand Design**

Book by Stephen Hawking

- **Death by Black Hole: And Other Cosmic Quandaries**

Book by Neil deGrasse Tyson

- **Pale Blue Dot: A Vision of the Human Future in Space**

Book by Carl Sagan

- **The Hidden Reality: Parallel Universes and the Deep Laws of the Cosmos**

Book by Brian Greene

- **The Universe in a Nutshell**

Book by Stephen Hawking

- **Astrophysics for People in a Hurry**

Book by Neil deGrasse Tyson

- **Parallel Worlds: A Journey through Creation, Higher Dimensions, and the Future of the Cosmos**

Book by Michio Kaku

- **Big Bang: The Origin of the Universe**

Book by Simon Singh

- **Our Mathematical Universe: My Quest for the Ultimate Nature of Reality**

Book by Max Tegmark

- **A Briefer History of Time**

Book by Stephen Hawking, Leonard Mlodinow

- **Reality Is Not What It Seems: The Journey to Quantum Gravity**

Book by Carlo Rovelli, Simon Carnell, Erica Segre

- **Einstein: His Life and Universe**

Book by Walter Isaacson

- **Black Holes and Time Warps: Einstein's Outrageous Legacy**

Book by Kip S. Thorne, Stephen Hawking

- **The Demon-haunted World: Science As a Candle in the Dark**

Book by Carl Sagan

- **Origins: Fourteen Billion Years of Cosmic Evolution**

Book by Neil deGrasse Tyson, Vikas Adam, et al

- **The Theory of Everything: The Origin and Fate of the Universe**

Book by Stephen Hawking

- **Brief Answers to the Big Questions**

Book by Stephen Hawking

- **Black Holes and Baby Universes**

Book by Stephen Hawking

- **The Black Hole War: My Battle with Stephen Hawking to Make the World Safe for Quantum Mechanics**

Book by Leonard Susskind

- **The Varieties of Scientific Experience: A Personal View of the Search for God**

Book by Carl Sagan, Ann Druyan

- **Hyperspace: A Scientific Odyssey Through Parallel Universes, Time Warps, and the Tenth Dimension**

Book by Michio Kaku

- **Just Six Numbers: The Deep Forces That Shape the Universe**

Book by Martin Rees

- **The Inflationary Universe: The Quest for a New Theory of Cosmic Origins**

Book by Alan Guth

- **Coming of Age in the Milky Way**

Book by Timothy Ferris

- **From Eternity to Here: The Quest for the Ultimate Theory of Time**

Book by Sean Carroll

- **Seven Brief Lessons on Physics**

Book by Carlo Rovelli

- **Billions and Billions: Thoughts on Life and Death at the Brink of the Millennium**

Book by Carl Sagan

- **The Life of the Cosmos**

Book by Lee Smolin

- **The 4% Universe: Dark Matter, Dark Energy, and the Race to Discover the Rest of Reality**

Book by Richard Panek

- **Welcome to the Universe: An Astrophysical Tour**  
Book by Neil deGrasse Tyson
- **The Holographic Universe: The Revolutionary Theory of Reality**  
Book by Michael Talbot
- **The Road to Reality: A Complete Guide to the Laws of the Universe**  
Book by Roger Penrose
- **The Structure of Scientific Revolutions**  
Book by Thomas S. Kuhn and Ian Hacking
- **Contact**  
Book by Carl Sagan
- **Three Roads To Quantum Gravity**  
Book by Lee Smolin
- **The Illustrated A Brief History of Time and The Universe in a Nutshell**  
Book by Stephen Hawking
- **The Fabric of Reality: The Science of Parallel Universes--and Its Implications**  
Book by David Deutsch
- **Relativity: The Special and the General Theory**  
Book by Albert Einstein, Nigel Calder
- **The Goldilocks Enigma: Why Is the Universe Just Right for Life?**  
Book by Paul Davies

- **The Whole Shebang: A State-of-the-Universe[s] Report**

Book by Timothy Ferris

- **The Cosmic Landscape: String Theory and the Illusion of Intelligent Design**

Book by Leonard Susskind

- **Cycles of Time: An Extraordinary New View of the Universe**

Book by Roger Penrose

- **Warped Passages: Unraveling the Mysteries of the Universe's Hidden Dimensions**

Book by Lisa Randall

- **The Sleepwalkers: A History of Man's Changing Vision of the Universe**

Book by Arthur Koestler, Herbert Butterfield

- **Einstein's Dreams**

Book by Alan Lightman

- **Why Does E=mc<sup>2</sup>? (And Why Should We Care?)**

Book by Brian Cox, Jeff Forshaw

- **How the Universe Got Its Spots: Diary of a Finite Time in a Finite Space**

Book by Janna Levin

- **Time Reborn: From the Crisis in Physics to the Future of the Universe**

Book by Lee Smolin, Henry Reich

- **Until the End of Time: Mind, Matter, and Our Search for Meaning in an Evolving Universe**

Book by Brian Greene

- **Physics of the Impossible**

Book by Michio Kaku

- **The Feynman Lectures on Physics**

Book by Richard P. Feynman

- **The Accidental Universe: The World You Thought You Knew**

Book by Alan Lightman

- **Why Does the World Exist? An Existential Detective Story**

Book by Jim Holt

- **The Beginning of Infinity: Explanations That Transform the World**

Book by David Deutsch

- **The Science of Interstellar**

Book by Kip Thorne and Christopher Nolan

- **An Introduction to Modern Cosmology**

Book by Andrew Liddle

- **The Edge of Physics: A Journey to Earth's Extremes to Unlock the Secrets of the Universe**

Book by Anil Ananthaswamy

- **Something Deeply Hidden: Quantum Worlds and the Emergence of Spacetime**

Book by Sean Carroll

- **Black Holes: The Reith Lectures**

Book by Stephen Hawking

- **The Trouble with Physics: The Rise of String Theory, the Fall of a Science and What Comes Next**

Book by Lee Smolin

- **We Have No Idea: A Guide to the Unknown Universe**

Book by Jorge Cham, Daniel Whiteson

- **The Lost World of Genesis One: Ancient Cosmology and the Origins Debate**

Book by John H. Walton

- **How I Killed Pluto and Why It Had It Coming**

Book by Mike Brown

- **Universe: The Definitive Visual Guide**

Book by Martin Rees

- **Origin Story: A Big History of Everything**

Book by David Christian

- **The Particle at the End of the Universe: How the Hunt for the Higgs Boson Leads Us to the Edge of a New World**

Book by Sean Carroll

- **The Magic of Reality: How We Know What's Really True**

Book by Richard Dawkins

- **Rare Earth: Why Complex Life Is Uncommon in the Universe**

Book by Peter D. Ward, Donald Brownlee

- **The Greatest Story Ever Told—So Far: Why Are We Here?**

Book by Lawrence M. Krauss

- **The Universe in Your Hand: A Journey Through Space, Time, and Beyond**

Book by Christophe Galfard, Ray Chase, et al

- **The Case for a Creator: A Journalist Investigates Scientific Evidence That Points Toward God**

Book by Lee Strobel

- **Astrophysics and the Evolution of the Universe (Second Edition)**

Book by Leonard S Kisslinger

- **Cosmology**

Book by Steven Weinberg

- **Wonders of the Universe**

Book by Brian Cox

- **Degree in a Book: Cosmology: Everything You Need to Know to Master the Subject - in One Book!**

Book by Dr Sten Odenwald

- **Programming the Universe: A Quantum Computer Scientist Takes on the Cosmos**

Book by Seth Lloyd

- **Higher Speculations: Grand Theories and Failed Revolutions in Physics and Cosmology**

Book by Helge Kragh

- **Einstein's Cosmos: How Albert Einstein's Vision Transformed Our Understanding of Space and Time**

Book by Michio Kaku

- **Human Universe**

Book by Professor Brian Cox, Andrew Cohen

- **Six Easy Pieces: Essentials of Physics By Its Most Brilliant Teacher**

Book by Richard P. Feynman

- **Broca's Brain: Reflections on the Romance of Science**

Book by Carl Sagan

- **The Universe Within: Discovering the Common History of Rocks, Planets, and People**

Book by Neil Shubin

- **The Last Three Minutes: Conjectures About The Ultimate Fate Of The Universe**

Book by Paul Davies

- **The Quantum Universe: Everything That Can Happen Does Happen**

Book by Brian Cox

- **Cosmic Connection: An Extraterrestrial Perspective**

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- **The Day We Found the Universe**

Book by Marcia Bartusiak

- **Wrinkles in Time**

Book by George Smoot, Keay Davidson

- **Beyond Einstein: The Cosmic Quest for the Theory of the Universe**

Book by Michio Kaku, Jennifer Trainer Thompson

- **The Kemetic Tree of Life Ancient Egyptian Metaphysics and Cosmology for Higher Consciousness**

Book by Muata Ashby

- **The Tao of Physics: An Exploration of the Parallels between Modern Physics and Eastern Mysticism**

Book by Fritjof Capra

- **Cosmicomics**

Book by Italo Calvino, William Weaver



## **One final thought:**

If you feel that this information has been useful to you, please take a moment to share it with your friends on LinkedIn, Facebook and Twitter. Think about leaving a quick review on **Google Play Books** if you think this book has given you insight into the grand narrative of the cosmos from a fresh, inspired perspective and you have learnt something valuable.

**Cosmology** is a study area that combines the astronomy and physics in an endeavour to comprehend the physical universe as a cohesive whole. It is both incredibly fun and fascinating. I want to spread my passion to as many individuals as I can. I also hope that this isn't the end of your quest for solutions to the mysteries that have plagued mankind since its beginning. What role does humanity have in the universe's 14 billion year history? What role does humanity play in the history of this planet? How does humanity participate in the complex chain of life here on Earth?

**Thank you!**

This book is an insightful, understandable, and contemporary perspective on the largest scientific mysteries and provides insight into complex universe-related concerns. The book provides answers to questions about what makes up the majority of the universe, what existed prior to the Big Bang and what exists outside of our universe, whether time always moves forward, whether the universe is infinite or constrained by physical laws, the size of space, and the mass of the universe. This book takes us on an incredible journey through the past, present, and future as well as through physics, astronomy, and mathematics. It demystifies for laymen concepts like antimatter, quarks, black holes, dark energy, and the big bang and completely changes how we view the universe and its fundamental truths.

## The History of the Universe in 1000 Words or Less

The origin and fate of the universe

