

1. Details of Module and its structure

Module Detail	
Subject Name	Geography
Course Name	Geography 01 (Class XI, Semester - 1)
Module Name/Title	The origin and evolution of the earth – Part 1
Module Id	kegy_10201
Pre-requisites	Basic understanding of origin and evolution of the earth
Objectives	After going through this Module, the learners will be able to: <ul style="list-style-type: none">• Enumerate different hypothesis of the origin of the earth• Explain the origin of the earth and universe• Describe the mechanism of the formation of solar system• Describe the Big Bang Theory• Comprehend the formation of stars• Explain the evolution of the lithosphere, atmosphere, hydrosphere and origin of life
Keywords	Nebular Hypothesis, Binary Hypothesis, Tidal Hypothesis, Big Bang Theory, Star/ Planet/ Moon Formation, Evolution of Life

2. Development Team

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Introduction

Viewed from space, the planet Earth appears as a round ball that shines bright and blue. Aristotle, a Greek Philosopher, believed that the Earth was at the centre of the universe and that the moon, sun, planets and stars orbited around it. Indian astronomer Aryabhata, however, believed in heliocentric solar system. Today, we know that the sun is a star and the planets revolving around it came out of it in the distant past. The sun, its planets and the satellites of the planets constitute the solar system. Planets differ in size, constituent matter and temperature. All these characteristics are related to their respective distances from the sun. The Earth is one of the small inner planets, along with Mercury, Venus and Mars. Inner planets comprise of heavy elements and are closest to the sun. The earth is, however, the only planet with conditions favourable for the sustenance of life.

EARLY THEORIES

Origin of the Earth

A large number of hypotheses were put forth by different philosophers and scientists regarding the origin of the earth. One of the earlier and popular arguments was by German philosopher Immanuel Kant. The origin of the earth emphasize that the planet originated as a hot gaseous mass. This mass of gas was very hot in the beginning. After getting cooled, it became liquid and then turned into solid. An early theory was put forth by Kant, which is popularly known as the gaseous hypothesis. Mathematician Laplace revised this theory in 1796. It is known as Nebular Hypothesis.

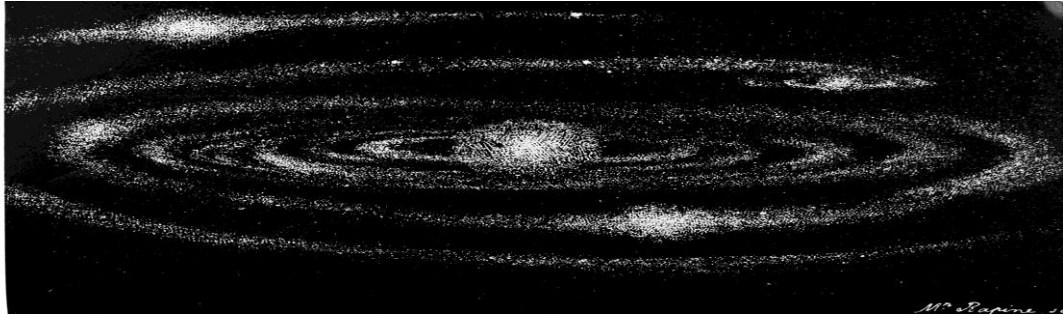


Fig. No. 01; Nebular hypothesis

Source:https://upload.wikimedia.org/wikipedia/commons/8/8a/Astronomy_photo%3B_nebular_hypothesis_of_Laplace_Wellcome_M0006119.jpg

The hypothesis considered that the planets were formed out of a cloud of material associated with a youthful sun, which was slowly rotating. The process of nebular hypothesis may very briefly be put into the following steps:

- German philosopher, Kant and French mathematician, Laplace postulated the concept of Nebular Hypothesis.
- It was assumed that the earth, planets and sun originated from the existing Nebula.
- Nebula was large cloud of gas and dust particles and substances. It rotated slowly.
- Gradually it cooled and contracted. Due to contraction/ reduction in the radius, its spinning speed increased.
- The contracted ring was separated because of greater centrifugal force of the nebula.
- This separated ring cooled and took form of a planet.
- On repetition of this process, all other planets came into being.
- The farthest planet was formed in the beginning and closet planet came into existence at the latest.
- The central remaining part of the nebula became sun of today.

This theory considers earth as having been formed through the solidification of the mass of a ring thrown away by a cooling and rotating nebula (sun). The number of thrown off bodies from the nebula are considered to be the number of planets in our solar system we do have today.

Later in 1900, Chamberlain and Moulton considered that a wandering star approached the sun. As a result, a cigar-shaped extension of material was separated from the solar surface. The passing star moved away, the material separated from the solar surface continued to

revolve around the sun and it slowly condensed into planets. Sir James Jeans and later Sir Harold Jeffrey supported this argument.

The hypothesis put forth by Jeans and Jeffrey assumes origin of the earth on the basis of the presence of two nebulae. This is called the tidal hypothesis. At a later date, it was argued that there was another companion star to the sun. Both were coexisting before the birth of solar system. This line of thought is called binary hypothesis:

- According to this hypothesis a large nebula was wandering in the space.
- This wandering nebula came very close to another smaller nebula (our sun of today).
- The gravitational pull of the wandering star was enormous.
- It caused a huge tidal upsurge on the surface of the smaller nebula (our sun).
- As the larger nebula (big passing star) moved away from the smaller one in its journey.
- The matter rising as a tidal wave from the surface of the smaller nebula was pulled towards it and was drawn to a distance from which it could not come back to the parent body (Figure 2).
- However, it could not follow the large nebula also and as it went away quickly.
- The detached matter started revolving round its parent body (sun).
- On cooling, the detached matter condensed and thus, the planets were formed.
- Our earth is one of them.
- The cigar-shaped arrangement of the planets going away from the sun, with the smallest planets located closest and farthest from the sun and the larger ones occupying intermediate positions, strengthens this view.

In 1950, Otto Schmidt in Russia and Carl Weizsacker in Germany revised the 'nebular hypothesis', but they differ in the mechanism of their explanation. They considered that:

- The sun was surrounded by solar nebula (gaseous substances) containing mostly the hydrogen and helium along with dust.
- The friction and collision of particles led to formation of a disk-shaped cloud.
- This cloud was getting compressed slowly and slowly.
- The compression led to the compaction of the materials.
- The compacted lump kept on enlarging with further accumulation of the matters.
- In this process, planets of our solar system were formed.

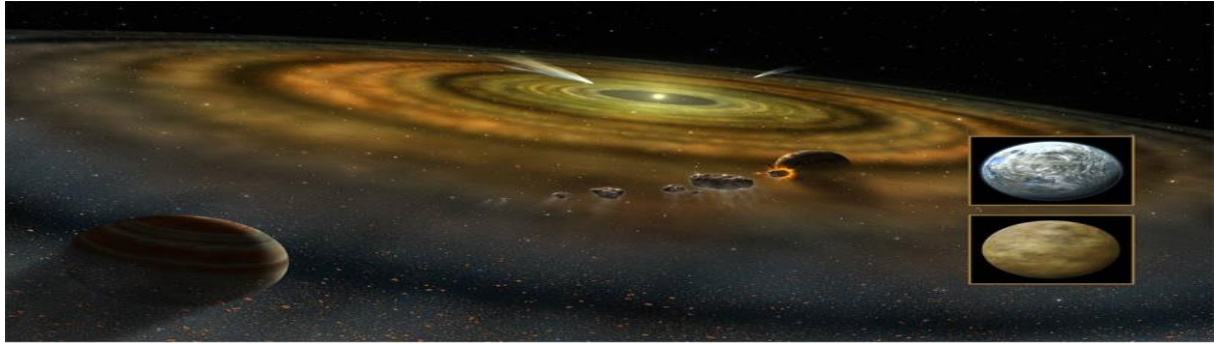


Fig. No. 02: Various planet formation processes, including exocomets and other planetesimals, around Beta Pictoris, a very young type A V star
Source:https://en.wikipedia.org/wiki/Nebular_hypothesis#/media/File:NASA-ExocometsAroundBetaPictoris-ArtistView.jpg

As long as our knowledge kept on expanding, scientists started to think not only about the explanation of earth or solar system but also about the whole of the universe. This thought gave the birth of the concept of explaining the mystery of the universe.

MODERN THEORY

Origin of the Universe

The most popular argument regarding the origin of the universe is the Big Bang Theory. It is also called expanding universe hypothesis. Edwin Hubble, in 1920, provided evidence that the universe is expanding. As time passes, galaxies move further and further apart. You can experiment yourself and find what the expanding universe means.

Activity

- Mark several points on the flattened balloon.
- This balloon represents the galaxies for your experimentation.
- Now, if you start filling up the air in the balloon, the points marked on the balloon will appear to be moving away from each other as the balloon expands. Similarly, the distance between the galaxies is also found to be increasing and thereby, the universe is considered to be expanding.
- However, you will find that besides the increase in the distances between the points
- on the balloon, the points (bodies/ matters) themselves are expanding.
- This is not in accordance with the real situation.

- Scientists believe that though the space between the galaxies is increasing, observations do not support the expansion of galaxies (bodies/ matters).
- So, the balloon example is only partially correct.



Fig. No.03: Experiment on expanding balloon

The above illustration reveals how the universe is expanding with the passage of time. It is a very simplified illustration of big bang theory. It is quite clear that the expansion is taking place in all three dimensions simultaneously

Source: <http://www.bigstretchuniverse.com/assets/118/Expanding%20Balloon%2003.jpg>

The Big Bang Theory

The Big Bang Theory considers the following stages in the development of the universe.

(i) In the beginning, all matter forming the universe existed at one place in the form of a “tiny ball” (singular atom) with an unimaginably small volume, infinite temperature and infinite density.

(ii) At the Big Bang beginning stage the “tiny ball” exploded violently. This led to a huge expansion. It is now generally accepted that the event of big bang took place 13.7 billion years before the present. The expansion continues even to the present day. As it grew due to expansion, some energy was converted into matter. There was particularly rapid expansion within fractions of a second after the bang. Thereafter, the expansion has slowed down. Within first three minutes from the Big Bang event, the first atom began to form.

(iii) Within 300,000 years from the Big Bang, temperature dropped to 4,500 K (Kelvin) and gave rise to atomic matter. The universe became transparent.

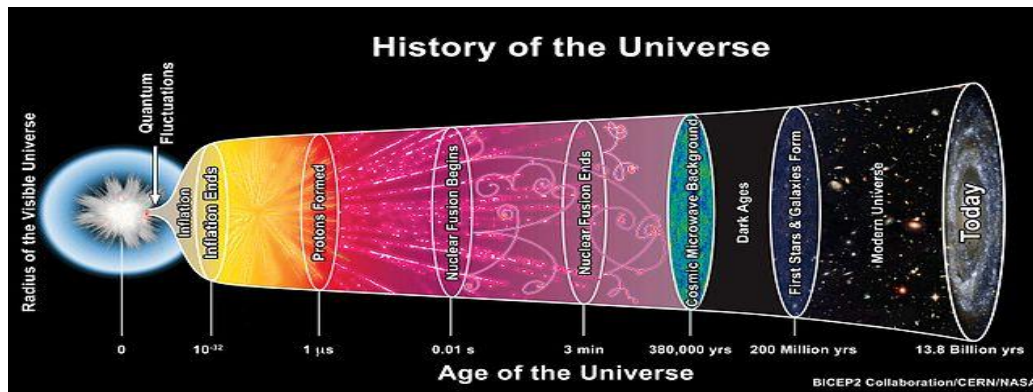


Fig. No. 04: Big Bang explosion

Source:

https://upload.wikimedia.org/wikipedia/commons/thumb/c/cf/The_History_of_the_Universe.jpg/640px-The_History_of_the_Universe.jpg

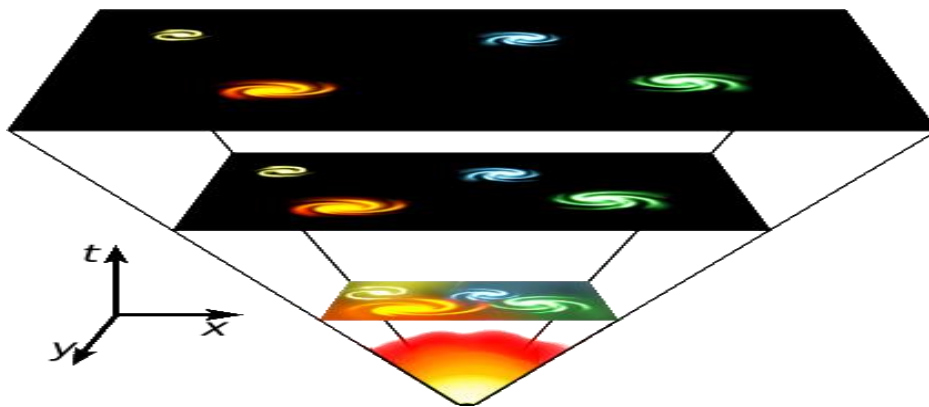


Fig No 05: Big Bang – Expanding universe

Source: https://upload.wikimedia.org/wikipedia/commons/3/37/Universe_expansion2.png

The expansion of universe means increase in space between the galaxies. An alternative to this was Hoyle's concept of steady state. This concept considered the universe to be roughly the same at any point of time. When we refer the steady state, it means the matter remains the same over time. With expanding universe, the matter is also created, and therefore, the density is maintained constantly. However, with greater scientific enquiry in recent times, the evidences advocate the expanding universe.

The Star Formation

The distribution of matter and energy was not even in the early universe. These initial density differences gave rise to differences in gravitational forces. It caused the matter to get accumulated together. These formed the bases for development of galaxies. A galaxy contains a large number of stars. Galaxies spread over vast distances that are measured in

thousands of light-years. The diameters of individual galaxies range from 80,000-150,000 light years. A galaxy starts to form by accumulation of hydrogen gas in the form of a very large cloud. The large body of hydrogen clouds called nebula. Eventually, growing nebula develops localised bundles of gas. These bundles continue to grow into even denser gaseous bodies. Later, these large gaseous bodies formed stars. The formation of stars is believed to have taken place some 5-6 billion years ago.

A light year is a measure of distance and not of time. Light travels at a speed of 300,000 km/second. Considering this, the distances the light will travel in one year is taken to be one light year. This equals to 9.46110 trillion km. The mean distance between the sun and the earth is 149,598,000 km. In terms of light years, it is 8.311 minutes.

Formation of Planets

The following are considered to be the stages in the development of planets:

- The stars are localised lumps of gas within a nebula. The gravitational force within the lumps leads to the formation of a core. Around this core a huge rotating disc of gas and dust develops around.
- In the next stage, the gas cloud starts getting condensed and the matter around the core develops into small and rounded objects. By the process of cohesion, these objects develop into planetesimals. These objects start becoming larger in size due to collision, and gravitational attraction causes the material to stick together. Planetesimals are a large number of smaller bodies.
- In the final stage, these large number of small planetesimals accrete to form a fewer large bodies in the form of planets.

OUR SOLAR SYSTEM

Our Solar system consists of eight planets. The nebula from which our Solar system is supposed to have been formed, started its collapse and core formation sometime 5.0 to 5.6 billion years ago and the planets were formed about 4.6 billion years ago. Our solar system consists of the sun (the star), 8 planets, 63 moons, millions of smaller bodies like asteroids and comets and huge quantity of dust-grains and gases. Large number of asteroids is present between Mars and Jupiter.



Fig No 06 The solar system

Source:https://upload.wikimedia.org/wikipedia/commons/1/14/The_new_Solar_System%3F.jpg

Out of the eight planets Mercury, Venus, Earth and Mars are called as the inner planets as they lie between the sun and the belt of asteroids. The other four planets Jupiter, Saturn, Uranus and Neptune are called the outer planets. Alternatively, the first four are called Terrestrial, meaning earth-like as they are made up of rocks and metals, and have relatively high densities. The rest four are called Jovian or Gas Giant planets. Jovian means Jupiter-like. Most of them are much larger than the terrestrial planets and have thick atmosphere, mostly of helium and hydrogen. All the planets were formed in the same period sometime about 4.6 billion years ago.

The difference between Terrestrial and Jovian planets can be attributed to the following conditions:

- The terrestrial planets were formed in the close vicinity of the parent star where it was too warm for gases to condense to solid particles. Jovian planets were formed at quite a distant location.
- The solar wind was most intense nearer the sun; so, it blew off lots of gas and dust from the terrestrial planets. The solar winds were not all that intense to cause similar removal of gases from the Jovian planets.
- The terrestrial planets are smaller and their lower gravity could not hold the escaping gases.

Till recently (August 2006), Pluto was also considered a planet. However, in a meeting of the International Astronomical Union, a decision was taken that Pluto like other celestial objects (2003 UB313) discovered in recent past may be called 'dwarf planet'.

	<i>Mercury</i>	<i>Venus</i>	<i>Earth</i>	<i>Mars</i>	<i>Jupiter</i>	<i>Saturn</i>	<i>Uranus</i>	<i>Neptune</i>
Distance	0.387	0.723	1.000	1.524	5.203	9.539	19.182	30.058
Density@	5.44	5.245	5.517	3.945	1.33	0.70	1.17	1.66
Radius	0.383	0.949	1.000	0.533	11.19	9.460	4.11	3.88
Satellites		0	1	2	About 53	About 53	About 27	13

* Distance from the sun in astronomical unit i.e. average mean distance of the earth is 149,598,000

km = 1 @ Density in gm/cm³

Radius: Equatorial radius 6378.137 km = 1

Source: <http://planetarynames.wr.usgs.gov/page/planets>

The Moon

The moon is the only natural satellite of the earth. Like the origin of the earth, there have been attempts to explain how the moon was formed. In 1838, Sir George Darwin suggested that initially, the earth and the moon formed from a single rapidly rotating body. The whole mass became a dumb-bell-shaped body and eventually it broke. Another view point was put forth that the material forming the moon was separated from what we have at present the depression occupied by the Pacific Ocean.

However, the present scientists do not accept either of the explanations. It is now generally believed that the formation of moon, as a satellite of the earth, is an outcome of ‘giant impact’ or described as “the big splat” . A body of the size of one to three times that of mars collided into the earth sometime shortly after the earth was formed. It blasted a large part of the earth into space. This portion of blasted material then continued to orbit the earth and eventually formed into the present moon about 4.44 billion years ago.



Fig No07: The big splat – formation of the Moon

Source:https://en.wikipedia.org/wiki/Giant-impact_hypothesis#/media/File:Artist%27s_concept_of_collision_at_HD_172555.jpg

Evolution of the earth

The planet earth initially was a barren, rocky and hot object with a thin atmosphere of hydrogen and helium; This is far from the present day picture of the earth. Hence, there must have been some events– processes, which may have caused this change from rocky, barren and hot earth to a beautiful planet with ample amount of water and conducive atmosphere favouring the existence of life. In the following section, you will find out how the period, between the 4,600 million years and the present, led to the evolution of life on the surface of the planet. The earth has a layered structure. From the outermost end of the atmosphere to the centre of the earth, the material that exists is not uniform. The atmospheric matter has the least density. From the surface to deeper depths, the earth's interior has different zones and each of these contains materials with different characteristics.

Evolution of Lithosphere

The earth was mostly in a volatile state during its primordial stage. Due to gradual increase in density the temperature inside has increased. As a result the material inside started getting separated depending on their densities. This allowed heavier materials (like iron) to sink towards the centre of the earth and the lighter ones to move towards the surface. With passage of time, it cooled further and solidified and condensed into a smaller size. This later led to the development of the outer surface in the form of a crust. During the formation of the moon, due to the giant impact, the earth was further heated up. It is through the process of differentiation that the earth forming material got separated into different layers. Starting from the surface to the central parts, we have layers like the crust, mantle, outer core and inner core. From the crust to the core, the density of the material increases.

Evolution of Atmosphere and Hydrosphere

The present composition of earth's atmosphere is chiefly contributed by nitrogen and oxygen. There are three stages in the evolution of the present atmosphere. The first stage is marked by the loss of primordial atmosphere. In the second stage, the hot interior of the earth contributed to the evolution of the atmosphere. Finally, the composition of the atmosphere was modified by the living world through the process of photosynthesis.

The early atmosphere, with hydrogen and helium, is supposed to have been stripped off as a result of the solar winds. This happened not only in case of the earth, but also in all the terrestrial planets, which were supposed to have lost their primordial atmosphere through the impact of solar winds.

During the cooling of the earth, gases and water vapour were released from the interior solid earth. This started the evolution of the present atmosphere. The early atmosphere largely contained water vapour, nitrogen, carbon dioxide, methane, ammonia and very little of free oxygen. The process through which the gases were outpoured from the interior is called degassing. Continuous volcanic eruptions contributed water vapour and gases to the atmosphere. As the earth cooled, the water vapour released started getting condensed. The carbon dioxide in the atmosphere got dissolved in rainwater and the temperature further decreased causing more condensation and more rains. The rainwater falling onto the surface got collected in the depressions to give rise to oceans.

The earth's oceans were formed within 500 million years from the formation of the earth. This tells us that the oceans are as old as 4,000 million years. Sometime around 3,800 million years ago, life began to evolve. However, around 2,500-3,000 million years before the present, the process of photosynthesis got evolved. Life was confined to the oceans for a long time. Oceans began to have the contribution of oxygen through the process of photosynthesis. Eventually, oceans were saturated with oxygen, and 2,000 million years ago, oxygen began to flood the atmosphere.

Geological Time Scale

<i>Eons</i>	<i>Era</i>	<i>Period</i>	<i>Epoch</i>	<i>Age/ Years Life/ Major Events Before Present</i>	<i>Life/ Major Events</i>
	Cainozoic (From 65 million years to the present times)	Quaternary	Holocene	0 -10,000	ModernMan
Pleistocene			10,000-2million	HomoSapiens	
Tertiary		Pliocene	2-5million	Early HumanAncestor	
		Miocene	5-24million	Ape:Flowering Plants andTrees	
		Oligocene	24-37million	AnthropidApe	
		Eocene	37-58Million	Rabbits and Hare Small	
		Palaeocene	57-65Million	Mammals: Rats –Mice	

	Mesozoic 65 -245 Million	Cretaceous Jurassic Triassic		65-144Million 144-208Million 208-245Million	Extinction of Dinosaurs Age of Dinosaurs Frogs and turtles
	Palaeozoic 245 -570 Million	Permian Carboniferous Devonian Silurian Ordovician Cambrian		245-286Million 286-360Million 360-408Million 408-438Million 438-505Million 505-570 Million	Reptile dominate-replace Amphibians First Reptiles: Vertebrates :Coal beds Amphiians First trace of life on land: Plants First Fish No terrestrial Life: Marine Invertebrate
Proterozoic Archean Hadean	Pre- Cambrian 570Million -4,800 Million			570-2,500Million 2,500-3,800Million 3,800-4,800Million	Soft-bodied arthropods Blue green Algae: Unicellular bacteria Oceans and Continents form – Ocean and Atmosphere are rich in Carbondioxide
Originof Stars Supernova Big Bang	5,000-13,700 Million			5,000Million 12,000Million 13,700Million	Originofthesun Originoftheuniverse

Origin of Life

The last phase in the evolution of the earth relates to the origin and evolution of life. It is undoubtedly clear that initially the earth or even the atmosphere of the earth was not conducive for the development of life. Modern scientists refer to the origin of life as a kind of chemical reaction, which first generated complex organic molecules and assembled them.

