ENVIRONMENTAL GEOSCIENCES

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Lecture-1

Introduction to the Origin of the Earth

Welcome to the SWAYAM NPTEL course on Environmental Geosciences. In this course, the first module is Introduction to the Origin of the Earth, Internal Structure, Concepts of Atmosphere, Hydrosphere, Lithosphere and their Constituents and Plate-tectonics. So today's first lecture is on the Introduction to the Origin of the Earth. In this first lecture, the two important concepts will be covered first is the overview of the earth and its origin since the subject is environmental geosciences so related to the earth and second is the hypothesis for the origin see first I will discuss about the just a brief introduction about the origin of the earth. The study of earth's origin actually offers insight into the formation and evolution of not only our planet but also the solar system and the broader cosmos.

So understanding the Earth's beginning requires a multidisciplinary approach that encompasses fields such as astronomy, geology, physics and chemistry. This chapter will provide an introduction to the Earth's origin, tracing the journey from cosmic dust to the planet teeming with life that we know today. So in general, the theories of origin of the solar system is divided into two broader groups. The first is the evolutionary theories and second is the catastrophic theories. Now let us understand what is evolutionary theories and catastrophic theories.

The evolutionary theories suggest that planets are formed during the evolution of the sun, that's why it is called as evolutionary theories. Here, the good example is the nebular hypothesis, one of the hypothesis for the origin of the earth. Second is the catastrophic theories, are those theories which imagine that planets are formed by some special accident or some catastrophe, such as close approach of two stars or by collision of two stars. However, as the stars are so far apart in the galaxy, the possibility of such a catastrophe is extremely rare. The best example of these catastrophic theories are the planetesimal hypothesis and the gaseous tidal hypothesis.

So, in general, if you will know that the best known hypothesis for the origin of the earth is the nebular are the nebular hypothesis, planetesimal hypothesis, gaseous tidal hypothesis and gas dust cloud hypothesis. Now one by one we will understand about these hypothesis. So the nebular hypothesis was proposed by Immanuel Kant and Pierre-Simon Laplace in the 18th century to explain the origin of the earth and the solar system. So this is the first hypothesis given by Kant and Laplace. The hypothesis suggests that the sun and planets including the earth, formed from a rotating disc-shaped nebula which is a cloud of hot gas.

So pictorial view is given here. You can see nebular hypothesis nicely dealt. In the figure A you can see this nebula is the shaded portion. This is the shaded portion which is nebula bulging at the equatorial zone. It is bulging in the equatorial zone.

Now bulge portion is the dotted one. These are the dotted one. Now in the figure B, if you will just move to the figure B, you can see this bulge portion, this bulge portion, it is just separated from the main nebula. So it is separated from the main nebula. So the bulge portion is separated out in the form of ring.

It is just separated out in the form of ring. In the figure C, if you will see, the ring, the bulge portion at the equatorial zone, the ring has just coalesced to form a globe. So, now it has formed a globe. Globe means, say, one planet. So, this planet or the planet rotates around the nebula in its orbit.

So, this is the just telling about that the planet is rotating just around the nebula so these are the this is the nebula in the first figure also we have seen nebula is the shaded portion here also we are seeing so only the burst portion has just coalesced and form a ring and it is also moving around the nebula so this is about the hypothesis given by the Kant and Laplace. What are the important stages of the hypothesis? The first stage is the initial nebula. Nebula is nothing but it is a large hot gaseous nebula rotating along its axis with the equatorial zone beginning to get excited because of the centrifugal force. So, shaded area, bulged portion is dotted. So, we have seen in the figure bulged portion was dotted.

Now, in the figure B, we have seen that the separation of gaseous ring. So, as the nebula continues to contract and rotate faster, the equatorial bulged portion separates from the central mass forming a gaseous ring that is the separated ring. We have seen in the figure also. Now, in the stage C, it is the formation of the planets. The gaseous rings coalesces ultimately to form a globe, that is one planet, which begins to rotate around the central nebula in its orbit, that is shown by the dotted circle.

Multiple similar rings form for other planets also. So in this way, the nebular hypothesis has discussed about the formation of the different planets. Now, the nebular hypothesis was but not favored because of sub-defects. So, what are the defects? The first defect is showing the energy distribution issue.

So, nebular hypothesis does not satisfy the principle of conservation of angular momentum in the solar system. So, this is the first drawback because of which it was not favored. Second defect was that the theory does not explain properly the method of coalescence of the rings, which we have seen the coalescence of the rings also in the nebular hypothesis stage C. So to form the globular planets, since there is a greater chance of formation of number of smaller globes from each one of the rings. So because of these two defects, it was not favored. So nebular hypothesis was not favored.

After this nebular hypothesis, in the year 1904, Moulton and Chamberlain, the two scientists, they have proposed the planetesimal hypothesis for the explanation of the origin of the Earth and the solar system. So, this hypothesis, planetesimal hypothesis, suggests that a larger star passed nearer to the Sun causing tidal distortions on the Sun's surface. So what is happening these distortions combined with the eruptive forces in the Sun which is known as solar prominences led to the disruption of the Sun's mass. As it is very much clear in the figure also you can see as a result of these forces large amount of gaseous material were ejected from the sun into the space and these ejected bolts of solar material were subjected to further cooling and solidification into tiny particles called planetesimals. So, this hypothesis again fails because of improper explanation about all fundamental regularities of the solar system and ultimately this theory is also rejected.

So in the figure also you can see A and B represents two positions of the approaching star and bolts have been shot from the sun. So in this figure, we can see these are the bolts which have just ejected out from the sun. So this theory also fails because it was not following the fundamental regularities of the solar system. Next theory came as gaseous tidal hypothesis. So this hypothesis was proposed by Jens and Jeffries in the year 1925.

They have suggested that planets formed from a tidal disturbance caused by a large star passing near the sun. So, in this hypothesis, posits a biparental origin of the solar system like the planetesimal hypothesis but differs in its explanation of the events leading to the formation of the planets. So, this hypothesis has not clearly told, how the planets have been formed. Yes, it is very much similar or near to the similar to the planetesimal

hypothesis, but differing in the explanation of the events, which is just telling about the formation of the planets. So, this hypothesis, key points where the stars approach.

A large star approached the sun, raising a tidal force on the sun's surface. This tidal force caused a gaseous bulge Second step in this hypothesis is the formation of the spindle-shaped gaseous mass. As the star moved away, the tidal bulge detached from the Sun, taking the shape of a spindle, thickest in the middle. So spindle in general remains thickest in the middle.

And third step of this hypothesis is the breaking of the gaseous mass. So the spindle shaped mass broke into ten pieces, nine pieces condensed and formed the planets, whereas one piece broke further into smaller fragments forming the planetoids. So the gaseous tidal hypothesis was also not favored because it has some defects. So what are the defects? Again the angular momentum, important defect.

The passing star could not give enough angular momentum to form the planets. And second defect is about the dissipation. The detached gaseous mass would dissipate into space not forming the solid planets. So these are few defects because of which this hypothesis has also been rejected. Then came the gas dust cloud hypothesis.

This hypothesis actually suggested that the solar system formed from a rotating disk of gas and dust around the sun with planets forming from the condensation of materials at different distances based on temperature. So this is the hypothesis related to the gas, dust, cloud. It was again rejected because it couldn't explain the angular momentum distribution between the sun and the planets. Lacked of evidence for the sun's early magnetic field and failed to adequately explain how the planets, particularly in the outer solar system, condensed from gas and dust. So, in this way, this hypothesis was again rejected.

Then, one new theory came and that theory is the Big Bang Theory, named as Big Bang Theory. This is the most widely accepted modern theory regarding the origin of the earth named as the Big Bang theory. The Big Bang theory proposed by George Lemaitre in the year 1920s suggests that the universe began from a single primordial atom. So this universe began from a single primordial atom. Scientists estimated that the age of the universe to be approximately 13.7 billion years.

Scientific consensus were there. The Big Bang theory is widely accepted by the scientific community as the most accurate explanation for the origin of the universe and the earth.

In the Big Bang theory, there are several stages including the inflationary expansion, the formation of quarks and hadrons, primordial nucleosynthesis, creating hydrogen and helium, the dark time of photon decoupling, the formation of the first stars and galaxies, the evolution into the present universe, and eventually the heat death where the universe reaches maximum entropy. So these are a few of the stages through which the Big Bang theory was explained.

Here you can see in the figure also that it has started from the single primordial star and from then it is just the first step is the inflationary expansion. Then the quarks and hadrons have just taken place. Just you can see hadronic era is there. Then expansion take place, primordial nucleosynthesis, which I have discussed in the previous slides. Then creation of hydrogen and helium atoms.

It is just the creation of hydrogen and helium atoms. This is the dark time. After the dark time is the formation of the first star and galaxies, the formation of first stars and galaxies. After the formation of the first star and galaxies, the present universe, you can see, and then the heat death is there. There are several black holes, quantum evaporation, etc. So accelerated expansion takes place.

So this figure tells us about how the Big Bang theory has been explained with the different stages of the formation of the universe. So in this way, here we can summarize this Big Bang theory as because of the focusing on inflationary expansion, then the quarks, hadrons, nucleosynthesis and many more. So in inflationary expansion, the inverse undergoes rapid exponential expansion, growing by a factor of at least 10^{26} in a fraction of a second. This rapid expansion smooths out the inverse, leading to the homogeneous and isotropic state. And then the quantum fluctuations during inflation set the stage for the future structure of the inverse.

Second is the quarks and hadrons. Here you can see the inverse goes down enough for quarks to form protons and neutrons. Quarks and anti-quarks annihilate each other, leaving a slight excess of matter. And the inverse is a hot, dense soup of particles with no atoms yet. So this is the second stage we have seen in the diagram also.

Then the primordial nucleosynthesis we have seen. Protons and neutrons begin to combine to form light nuclei like deuterium (hydrogen), helium-3 and helium-4. Then around three minutes after the Big Bang, the universe is cool enough for nuclear reactions to form the first elements. The abundance of hydrogen and helium with trace element

lithium is set at this stage in the primordial nucleosynthesis stage. Then the creation of hydrogen and helium.

Hydrogen and helium, mostly Helium-4, dominate the elemental composition of the early universe. Helium-3 and a small amount of lithium also form, but in lesser quantities. These elements become the building blocks for the later stars and galaxies later stars and galaxies then the dark time stage is coming after recombination the inverse enters the dark ages where no stars have yet formed the inverse is filled with neutral hydrogen and helium, and it remains opaque to light until the first stars form. There is no visible light yet, and the universe is dark, dominated by hydrogen gas.

And next stage is the formation of first stars and galaxies, 100 million to 1 billion years. The age, the first stars form from the gravitational collapse of gas clouds, igniting nuclear fusion. The first galaxies also begin to form as these stars group together under gravity. This marks the end of the dark ages as stars emit light and radiation begins to ionize the surrounding gas, leading to re-ionizations. So this is just after the dark time, the first formation of the stars and galaxies.

Then the present inverse, the inverse has expanded significantly and is now filled with billions of galaxies, stars, planets and other cosmic structures. Dark matter and dark energy are essential components that affect the universe expansion and structure. The universe continues to expand and stars continue to form and die. So after the present universe stage comes the heat death stage. Over trillion of years the universe will continue expanding and cooling.

Stars will eventually burn out and galaxies will drift apart. Heat death refers to a state where the inverse reaches thermodynamic equilibrium, no usable energy remains and everything is uniformly cold and dark. So it represents the final stage of the inverse where all activity ceases. So these are some of the stages of the Big Bang Theory. If I will just tell you about the summary of the origin of the Earth, about the first lecture.

See, The first hypothesis was the Nebular hypothesis where it was told that sun and planets form from a rotating gas cloud and fails because of the angular momentum conservation doesn't explain planet formation. The first hypothesis was the Nebula hypothesis where it was told that sun and planets form from a rotating gas cloud and fails because of the angular momentum conservation doesn't explain planet formation. Second was the Planetesimal hypothesis in the year 1925. Planets formed from tidal disturbances by a passing star. Insufficient angular momentum and gas would dissipate.

This is the failure, reason of the failure of this hypothesis. Third was the gaseous tidal hypothesis. In the year 1904, it was just came. Stars tidal forces formed planets from debris near the sun. This also fails because it doesn't explain the solar system regularities.

Fourth was the gas-dust cloud hypothesis. It came in the early 20th century. Planets form from a rotating disk of the gas and dust. This was the concept. But fails because it doesn't explain angular momentum or the outer planet formation.

And the latest one is the modern theory, that is the Big-Bang theory in the year 1920s, given by George Lemaitre. The universe began from a single primordial atom and expanded. Why accepted? Because supported by cosmic background radiation, redshift and galaxy formation. So this is all about the different hypothesis proposed by different scientists at different time about the origin of the earth and its concepts.

So thank you very much to all.