UNIT 3 INTRODUCTION TO COSMOLOGY

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3.0 OBJECTIVES

- To introduce the students to the basic notions of physical cosmology.
- To make them aware of the early (religious) history of cosmology
- To familiarise them with some of the complex issues related to the origin, nature and end of the universe.

3.1 INTRODUCTION

This unit tries to introduce the topic of cosmology. After studying the origin, nature and destiny of the universe, it looks into the Indian and Greek cosmologies. Then it takes up some important issues in contemporary scientific cosmology. Our aim is to show the religious beginnings of today's scientific cosmology.

3.2 ORIGIN, NATURE AND DESTINY

Cosmology ("study of universe" from Greek "*kosmos*" meaning "universe"; and "logia, "study"), in strict usage, refers to the study of the Universe in its totality as it is now (or at least as it can be observed now). Though the word cosmology is recent (first used in 1730 by the rationalist philosopher, Christian Wolff), the study of the universe has a long history involving science, philosophy, esotericism, and religion.

In recent times, physics and astrophysics have played a central role in shaping the understanding of the universe through scientific observation and experiment. The physical cosmology is primarily shaped through both mathematics and astronomical observation by the analysis of the whole universe. This discipline focuses on the universe as it exists on the largest scale and at the earliest moments. It is generally understood to begin with the Big Bang that is thought to have emerged roughly 13.5-13.9 billion years ago (Cosmology 2011).

From its beginnings scientific cosmologists propose that the history of the universe has been governed entirely by physical laws. Theories of an objective universe governed by physical laws were first proposed by Roger Bacon. Contemporary cosmologist Steven Weinberg echoes the same sentiment: “The universe itself acts on us as a random, inefficient, and yet in the long run effective, teaching machine.… our way of looking at the universe has gradually evolved through a natural selection of ideas."

Philosophical Cosmology, as distinct from physical cosmology, draws data from physical cosmology and focuses on critical reflection as to the origin, nature and destiny of the universe. Metaphysical assumptions and implications are also brought into it. Between the domains of religion and science, stands the philosophical perspective of metaphysical cosmology. This ancient field of study seeks to draw intuitive conclusions about the nature of the universe, man, the Divine and their relationships based on the extension of some set of presumed facts borrowed from spiritual experience and observation (Cosmology 2011).

But metaphysical cosmology has also been observed as the placing of man in the universe in relationship to all other entities. This is demonstrated by the observation made by Marcus Aurelius of a man's place in that relationship: "He who does not know what the world is does not know where he is, and he who does not know for what purpose the world exists, does not know who he is, nor what the world is." This is the purpose of the ancient metaphysical cosmology. Cosmology is often an important aspect of the creation myths of religions that seek to explain the existence and nature of reality. In some cases, views about the creation (cosmogony) and the end (eschatology) of the universe play a central role in shaping a framework of religious cosmology for understanding humanity's role in the universe.

3.3 INDIAN COSMOLOGY

In India science and religion are not opposed fundamentally are seen as parts of the same great search for truth that inspired the sages of Hinduism, Buddhism, and Jainism. Thus, in the Hindu scientific approach, understanding of external reality depends on also understanding the godhead. In all Hindu traditions the Universe is said to precede from the gods. Fundamental to Hindu concepts of time and space is the notion that the external world is a product of the creative play of *maya (illusion)*. Accordingly the world as we know it is not really real but illusionary. The universe is in constant flux with many levels of reality; the task of the saint is find release (*moksha*) from the bonds of time and space (Hindu Cosmology 2006).

Therefore, one of the ancient Hindu books describes thus: "After a cycle of universal dissolution, the Supreme Being decides to recreate the cosmos so that we souls can experience worlds of shape and solidity. Very subtle atoms begin to combine, eventually generating a cosmic wind that blows heavier and heavier atoms together. Souls depending on their karma earned in previous world systems, spontaneously draw to themselves atoms that coalesce into an appropriate body." Hindu cosmology envisaged the universe as having a cyclical nature. The end of each *kalpa* brought about by Shiva's dance is also the beginning of the next. Rebirth follows destruction and the cycle goes on. Thus in Hindu cosmology the universe is, according to mythology and Vedic cosmology, cyclically created and destroyed. The following symbolic

representation of the creation of the world by Brahma is insightful. The life span of Lord Brahma, the creator, is 100 'Brahma-Years'. One day in the life of Brahma is called a *Kalpa* , which is calculated to be 4.32 billion years. Every *Kalpa* Brahma creates 14 Manus one after the other, who in turn manifest and regulate this world. Thus, there are fourteen generations of Manu in each *Kalpa* (one day of Brahma). Each Manu's life consists of 71 *Chaturyugas* (quartets of *Yugas* or eras) which in turn is is composed of four eras or Yugas: *Satya*, *Treta*, *Dwapara* and *Kali*.
The span of the *Satya Yuga* is 1,728,000 human years, *Treta Yuga* is 1,296,000 human years long, the *Dwapara Yuga* 864,000 human years and the *Kali Yuga* 432,000 human years. When Manu perishes at the end of his life, Brahma creates the next Manu and the cycle continues until all fourteen Manus and the Universe perish by the end of Bramhma's day. When 'night' falls, Brahma goes to sleep for a period of 4.32 billion years, which is a period of time equal one day (of Brahma) and the lives of fourteen Manus. The next 'morning', Brahma creates fourteen additional Manus in sequence just as he has done on the previous 'day'. The cycle goes on for 100 'divine years' at the end of which Brahma perishes and is regenerated. Bramha's entire life equals 311 trillion, 40 billion years. Once Bramha dies there is an equal period of unmanifestation for 311 trillion, 40 billion years, until the next Bramha is created (HC 2011).

The present period is the *Kali Yuga* or last era in one of the 71 *Chaturyugis* (set of four Yugas/eras) in the life one of the fourteen Manus. The current Manu is said to be the seventh Manu. As such the Kali Yuga began in 3102 BC, at the end of the *Dvapara Yuga* that was marked by the disappearance of Vishnu's Krishna avatar. The beginning of the new Yuga (era) is known as "*Yugadi*/*Ugadi*", and is celebrated every year on the first day (*Paadyami*) of the first month (*Chaitramu*) of the 12-month annual cycle. The *Ugadi* of 1999 begins the year 1921 of the *Shalivahana* era (5101 *Kali Yuga*, 1999 AD). The end of the Kali Yuga is 426,899 years from 1921.

Overview of Yugas

1. *Satya Yuga* (*Krita Yuga*):- 1,728,000 Human years
2. *Treta Yuga*:- 1,296,000 Human years
3. *Dwapara Yuga*:- 864,000 Human years
4. *Kali Yuga*:- 432,000 Human years (5,111 years have passed; 426,889 years remain). *Kaliyuga* started in 3102 B.C.; CE 2009 corresponds to *Kaliyuga* year 5,111

The *Nasadiya Sukta* of the Rig Veda describes the origin of the universe. The Rig Veda's view of the cosmos also sees one true divine principle self-projecting as the divine word, *Vaak*, 'birthing' the cosmos that we know, from the monistic Hiranyagarbha or Golden Egg. The Hiranyagarbha is alternatively viewed as Brahma, the creator who was in turn created by God, or as God (Brahman) Himself. The Universe is preserved by Vishnu (The God of Preservation) and destroyed by Shiva (The God of Destruction). These three constitute the holy Trinity (*Trimurti*) of the Hindu religion. Once the Universe has been destroyed by Shiva, Brahma starts the creation once again. This creation-destruction cycle repeats itself almost endlessly as described in the section above on Brahma, Manu and the *Yugas* (HC 2011).

The Puranic View

The later Puranic view asserts that the Universe is created, destroyed, and re-created in an eternally repetitive series of cycles. In Hindu cosmology, a universe endures for about 4,320,000 years—one day/*Kalpa* of Brahma, the creator) and is then destroyed by fire or water elements. At this point, Brahma rests for one night, just as long as the day. This process, named *Pralaya* (Cataclysm), repeats for 100 Brahma years (311 trillion, 40 billion human years) that represents Brahma's lifespan. It must be noted that Brahma is the creator but not necessarily regarded as God in Hinduism because there are said to be many creations. Instead, he is regarded as a creation of the Supreme God or Brahman.

We are currently believed to be in the 51st year of the present Brahma's life and so about 158.7 trillion years have elapsed since the birth of Brahma. After Brahma's "death", it is necessary that another 100 Brahma years pass until he is reborn and the whole creation begins anew. This process is repeated again and again, forever (HC 2011 and Raman 2004).

Both the Rig Veda and Brahmanda Purana describe a universe that is cyclical or oscillating and infinite in time. The universe is described as a cosmic egg that cycles between expansion and total collapse. It expanded from a concentrated form — a point called a Bindu. The universe, as a living entity, is bound to the perpetual cycle of birth, death, and rebirth. The *Padma Purana* discusses about the number of different types of life-forms in the universe. According to the *Padma Purana*, there are 8,400,400 life-form species, 900,000 of which are aquatic ones; 2,000,000 are trees and plants; 1,100,000 are small living species, insects and reptiles; 1,000,000 are birds; 3,000,000 are beasts and 400,000 are human species (HC 2011).
Unlike the West, which lives in a historical world, India is rooted in a timeless universe of eternal return: everything which happens has already done so many times before, though in different guises. Hinduism arose from the discoveries of people who felt that they had gained an insight into the nature of reality through deep meditation and ascetic practices. Science uses a heuristic method that requires objective proof of mathematical theories. Yet both have proposed similar scenarios for the creation of the universe. (Hindu Cosmology 2006).

Check Your Progress I
Note: Use the space provided for your answers.

1) How is cosmology related to cosmogony and eschatology?
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2) Give a brief account of the *Puranic* view of the universe.
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3.4 GREEK BEGINNING

The Greek worldview gave us the basis for scientific cosmology. Closely tied to the pseudo-science of astrology, it continued from ancient Greece through medieval Islamic civilization to seventeenth-century Europe (CHP 2011).

Plato and Aristotle

Underlying the Greek worldview was the philosophy of Plato. He sought a deeper level of reality than that accessible to the senses. He also pursued a simple theory about the universe which had incredible explanatory power. The result was a belief in uniform, circular motion. This belief dominated the thinking of many Western astronomers and cosmologists for two thousand years.

The task for astronomers was to ascertain the motions of the planets. Sky-watchers in the ancient Middle East, Central America, and China made many observations. From their tables of numbers, they devised schemes to predict future movements in the heavens, unlike the colorful myths proposed by the Babylonians, Mayans, and early Chinese sky-watchers. It is no exaggeration to claim that scientific cosmology — the search for a picture of the universe that would make sense with no mention of divine beings — began with the Greeks. They sought to look beyond the patterns of numbers to something fundamental. Under Plato's influence, Greek thinkers attempted to devise combinations of uniform circular motions that would reproduce the observed motions, which were far from regular.

Greek philosopher-scientists set themselves the task of envisioning the universe as a set of physical objects. Plato's pupil Aristotle came to dominate thinking in this field. Where Platonists thought in terms of the idealized mathematics of two-dimensional circles, the Aristotelians envisioned actual three-dimensional spheres (CHP 2011)

Aristotle taught that rotating spheres carried the Moon, Sun, planets, and stars around a stationary Earth. The Earth was unique because of its central position and its material composition. All generation and corruption occurred in the "sublunar" region, below the Moon and above the Earth. This region was composed of the four elements: earth, water, air, and fire. Beyond the Moon was the unchanging and perfect celestial region. It was composed of a mysterious fifth element. Greek philosophers estimated the distance to the Moon, and even tried to calculate the size of the entire universe, which believed to be finite. The outer sphere of the stars carried them on their nightly course around the Earth. The natural place for earthy material was down at the center of the universe. Earthy material tended to move to its natural place, toward the center of the world. Flames moved upward to reach their natural place at the top of the sublunar region. There could be no other worlds scattered throughout this universe, because their earthy nature would have forced them to move toward their natural place at the center. With the Earth at its center and the sphere of the stars its outer boundary, the Aristotelian cosmos consisted of little more than our solar system.

Claudius Ptolemy

Continuation of the Greek tradition of Plato and Aristotle is exemplified in the work of Claudius Ptolemy. He systematized hundreds of years of Greek geometrical cosmology with rigorous demonstrations and proofs (CHP 2011). Ptolemy wrote his mathematical treatise, later named the Almagest, in about 150 A.D. He worked out geometrical systems of compound motions on two-dimensional circles to match the observed motions. The heavens were not made of rocks, metal, or other earthy material, but of some divine celestial material. This offered no obstruction to the passage of one part through another. In his later book, Planetary Hypotheses, Ptolemy used three-dimensional hollow spheres, arranged one within another and surrounding the Earth. There was no empty space between the spheres. The thickness of each shell accommodated small motions in and out from the Earth. The rotating sphere itself carried the planet or Sun or Moon in its orbit around the Earth. According to him, the spheres rotated because that was their natural motion. It was proper, Ptolemy believed, to attribute uniform circular motion to the planets because disorder and nonuniformity were alien to divine things. The study of astronomy, dealing with divine things, was especially useful for elevating the human soul.

3.5 THE ARAB CONTRIBUTION

As the Roman Empire fell and civilization in Europe collapsed, the rising Islamic civilization rescued Ptolemy's cosmology — and improved upon it. The entire system was transmitted back to the West as learning revived there toward the end of the Middle Ages. Translations reveal the transitions. Ptolemy's mathematical treatise came to be called "greatest." (CHP 2011) This was transliterated into Arabic and prefaced with the definite article *al* ("the," also seen in words like algebra and star names like Aldebaran). Translated from Arabic into medieval Latin, Ptolemy's book became "The Almagest." The Arabs also taught the West "Arabic" numerals, the place-value system of calculating using zero (which was invented in India), and many trigonometric techniques, all originally from India, and made important mathematical advances of their own.

Islamic civilization enjoyed a high level of scientific work. Astronomy was important for giving times of prayer (from the altitude of the Sun or stars), and the qibla, or sacred orientation: worshippers anywhere in the world needed to know the direction of Mecca so they could face it while praying, and mosques were oriented toward the holy city. The astrolabe was the fundamental astronomical instrument, serving as a clock and navigational tool. Islamic princes also constructed giant instruments to measure the positions of planets and stars for astrological purposes. Among the Arabs and Persians were great calculators and mathematicians who worked to improve the cosmological explanation of astronomical measurements. For example, Nasir al-din al-Tusi at Maragha produced a particularly innovative addition to Ptolemy's circular motions. The "Tusi couple" calculates a linear motion from a combination of uniform circular motions (CHP 2011).

In his revolutionary work on the solar system published in 1543, Copernicus used a strikingly similar device. Also, Copernicus used a model for the Moon's motion identical to one devised two centuries earlier by the astronomer Ibn al-Shatir in Damascus. Copernicus cited the works of Islamic astronomers and certainly learned from them. Historians are still trying to determine the full extent of his intellectual debt. More on the history of cosmology will be taken up in the next unit. Since this is an introduction, we want to focus on some important themes of contemporary scientific cosmology.

Check Your Progress II

Note: Use the space provided for your answers.

1) Where was the natural place for earthly material for Aristotle? Why?

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2) Give a brief account of the Arab contribution to cosmology.
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3.6 SOME IMPORTANT THEMES OF SCIENTIFIC COSMOLOGY

Cosmologists study the universe as a whole: its birth, growth, shape, size and eventual fate. Contemporary cosmology began last century. The vast scale of the universe became clear in the 1920s when Edwin Hubble proved that "spiral nebulae" are actually other galaxies like ours, millions to billions of light years away (Battersby 2006). We take up some important concepts and themes to initiate ourselves into contemporary cosmology.

The Big Bang

Hubble found that most galaxies are red shifted, i.e., the spectrum of their light is moved to longer, redder wavelengths. This can be explained as a doppler shift if the galaxies are moving away from us. Fainter, more distant galaxies have higher red shift, implying that they are receding faster, in a relationship set by the hubble constant. The discovery that the whole universe is expanding led to the big bang theory. This states that if everything is flying apart now, it was once presumably packed much closer together, in a hot dense state. A rival idea, the steady-state theory, holds that new matter is constantly being created to fill the gaps generated by expansion. But the big bang largely triumphed in 1965 when Arno Penzias and Robert Wilson discovered cosmic microwave background radiation (Battersby 2006). This is relic heat radiation emitted by hot matter in the very early universe, 380,000 years after the first instant of the big bang.

Space-time Curve

The growth of the universe can be modelled with Albert Einstein's general theory of relativity, which describes how matter and energy make space-time curve. We feel that curvature as the force of gravity. Assuming the cosmological principle (that on the largest scales the universe is uniform), general relativity produces fairly simple equations to describe how space curves and expands. According to these models, the shape of the universe could be like the surface of a sphere, or curved like the surface of a saddle. But in fact, observations suggest that it is poised between the two, almost exactly flat. One explanation is the theory of inflation. This states that during the first split second of existence, space expanded at terrifying speed, flattening out any original curvature. Then today's observable universe, grew from a microscopic patch of the original fireball. This would also explain the horizon problem - why it is that one side of the universe is almost the same density and temperature as the other (Battersby 2006).

The universe is not totally smooth, however, and in 1990 the COBE satellite detected ripples in the cosmic microwave background, the signature of primordial density fluctuations. These slight ripples in the early universe may have been generated by random quantum fluctuations in the energy field that drove inflation. Topological defects in space could also have caused the fluctuations, but they do not fit the pattern well. Those density fluctuations form the seeds of galaxies and galaxy clusters, which are scattered throughout the universe with a foamy large-scale structure on scales of up to about a billion light years. All these structures form because gravity amplifies the original fluctuations, pulling denser patches of matter together (Battersby 2006).

Dark Matter

In experimental simulations of big bang it is found visible matter does not supply enough gravity to create the structure we see: it has to be helped out by some form of dark matter. More evidence for the dark stuff comes from galaxies that are rotating too fast to hold together without extra gravitational glue. Dark matter can't be like ordinary matter, because it would have made too much deuterium in big-bang nucleosynthesis. When the universe was less than 3 minutes old, some protons and neutrons fused to make light elements, and cosmologists calculate that if there had been much more ordinary matter than we see, then the dense cauldron would have brewed up a lot more deuterium than is observed. Instead, dark matter must be something exotic, probably generated in the hot early moments of the big bang - maybe particles such as WIMPs (weakly interacting massive particles) or, less likely, primordial black holes.

Dark Energy

Another dark mystery emerged in the 1990s, when astronomers found that distant supernovae are surprisingly faint - suggesting that the expansion of the universe is not slowing down as everyone expected, but accelerating. The universe seems to be dominated by some repulsive force, or antigravity, which has been dubbed dark energy. It may be a cosmological constant (or vacuum energy) or a changing energy field such as quintessence. It could stem from the strange properties of neutrinos, or it could be another modification of gravity. The WMAP spacecraft put the standard picture of cosmology on a firm footing by precisely measuring the spectrum of fluctuations in the microwave background, which fits a universe 13.7 billion years old, containing 4% ordinary matter, 22% dark matter, and 74% dark energy. WMAP's picture also fits inflationary theory. However, a sterner test of inflation awaits the detection of cosmic gravitational waves, which the rapid motions of inflation ought to create, and which would leave subtle marks on the microwave background (Battersby 2006).

The density of dark energy is far smaller than the vacuum energy predicted by quantum theory. That is seen as an extreme example of cosmological fine tuning, in that a much larger value would have torn apart gathering gas clouds and prevented any stars from forming. That has led some cosmologists to adopt the anthropic principle - that the properties of our universe have to be suited for life, otherwise we would not be here to observe it.

3.7 SOME UNANSWERED QUESTIONS

In the current cosmology, the biggest questions are still unanswered. We do not know the true size of the universe, even whether it is infinite or not. Nor do we know its topology - whether space wraps around on itself. We do not know what caused inflation, or whether it has created a plethora of parallel universes far from our own, as many inflationary theories imply.

And it is not clear why the universe favours matter over antimatter. Early in the big bang, when particles were being created, there must have been a strong bias towards matter, which the standard model of particle physics cannot explain. Otherwise matter and antimatter would have annihilated each other and there would be almost nothing left but radiation. (Battersby 2006)

The fate of the universe depends on the unknown nature of dark energy and how it behaves in the future: galaxies might become isolated by acceleration, or all matter could be destroyed in a big rip, or the universe might collapse in a big crunch - perhaps re-expanding as a cyclic universe. The universe could even be swallowed by a giant wormhole. And the true beginning, if there was one, is still unknown, because at the initial singularity all known physical theories break down. To understand the origin of the universe we will probably need a theory of quantum gravity. (Battersby 2006)

3.8 LET US SUM UP

This unit was an introductory one on cosmology. Here we dealt with the religious cosmologies and some of the important notions of today's scientific cosmology.

Check Your Progress III

Note: Use the space provided for your answers.

1) What is dark energy?

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2) What are some of the unanswered questions still remaining in contemporary cosmology?

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3.9 KEY WORDS

Cosmological Constant: The cosmological constant is a constant term in field equations of general relativity, represented by the Greek symbol Lambda, which allowed for a static universe. Later evidence supported the fact that the universe was indeed expanding and the cosmological constant was believed to be zero. Evidence in the late 1990s has begun supporting the idea that the universe is not only expanding, but that the expansion rate is actually accelerating due to the presence of dark energy. This meant that the cosmological constant wasn't just zero, as Einstein thought, but had to have a very slight positive value. Einstein quickly accepted the new evidence and told physicist George Gamow that the cosmological constant idea was the "biggest blunder" of his life.

Cosmological Principle: The assumption that on a very large scale all the matter in the universe is distributed evenly, so that hypothetical astronomers a long way from the Earth would see the same universe, on the biggest scale, as we do. The problem with testing the cosmological principle is that it operates on a scale so vast that even galaxies and clusters of galaxies are merely local clumps of material by its standards.

Doppler Shift: change in the apparent frequency of a wave as observer and source move toward or away from each other. Also called Doppler effect, it was named after Austrian physicist Christian Doppler who proposed it in 1842 in Prague, is the change in frequency of a wave for an observer moving relative to the source of the wave.

Horizon Problem: The horizon problem is a problem with the standard cosmological model of the Big Bang which was identified in the 1970s. It points out that different regions of the universe have not "contacted" each other because of the great distances between them, but nevertheless they have the same temperature and other physical properties. This should not be possible, given that the exchange of information (or energy, heat, etc.) can only take place at the speed of light. The horizon problem may have been answered by inflationary theory, and is one of the reasons for that theory's formation. Another proposed, though less accepted, theory is that the speed of light has changed over time,

Hubble Constant: is the ratio of the speed of recession of a galaxy (due to the expansion of the universe) to its distance from the observer; the Hubble constant is not actually a constant, but is regarded as measuring the expansion rate today

Nucleosynthesis: The process by which heavier chemical elements are synthesized from hydrogen nuclei in the interiors of stars.

Spiral Nebulae: a galaxy having a spiral structure; arms containing younger stars spiral out from old stars at the center.

WIMP: A subatomic particle that has a large mass and interacts with other matter primarily through gravitation. [W(eakly) I(nteracting) M(assive) P(article).

WMAP: The Wilkinson Microwave Anisotropy Probe (WMAP) — also known as the Microwave Anisotropy Probe (MAP), and Explorer 80 — is a spacecraft which measures differences in the temperature of the Big Bang's remnant radiant heat — the Cosmic Microwave Background Radiation — across the full sky.

3.10 FURTHER READINGS AND REFERENCES

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