Cosmos - New Dimensions: RSTV – In Depth

Anchor – Teena Jha

What's in the news?

- On 8th October, 2019 the Royal Swedish Academy of Sciences announced the **2019 Nobel Prize for Physics**.
- Three scientists have been awarded the prize for their **contribution to the understanding of the evolution of the Universe and Earth's place in it**.
- One half of the Nobel Prize is given to the **Canadian-American scientist James Peebles**, for **"theoretical discoveries in physical cosmology".**
- The other half has been given jointly to **Swiss astronomers Michel Mayor** and **Didier Queloz** for their **discovery of an Exoplanet orbiting a Solar type star**.

What is Cosmology?

- Cosmology is a **branch of astronomy** that concerns the study of the **origin and evolution of the Universe from the Big Bang** to today and on into the future.
- As recently as 1960 Cosmology was widely regarded as a branch of Philosophy. It has since transitioned to an extremely active **area of mainstream physics and astronomy** particularly due to the application to the **early universe of atomic and nuclear physics** on the one hand and to a **flood of data coming in from telescopes operating across the entire electro-magnetic spectrum** on the other.

Two fundamental premises:

Present models of the Universe hold two fundamental premises. The **Cosmological Principle** and **Dominant role of gravitation**.

- Derived by Hubble, the **Cosmological Principle** holds **that if a large enough sample of galaxies is considered, the universe looks the same from all positions and in all directions**.
- **Gravitation is the most important force in shaping the Universe**.

Two Main theories:

The Big-Bang Hypothesis and **the Steady state Hypothesis are the two main theories,** with many variations in each basic approach.

- **Steady State Theory** states "Universe expands; new matter is continuously created at all points in space left by the receding galaxies. It implies that the Universe has always expanded with no beginning and no end, at a uniform rate. Also, that it will always expand and maintain a constant density.
- **Big-Bang Theory** states "At the beginning of time, all of the universe's matter and energy was concentrated in a very dense state from which it exploded, with the resultant expansion continuing until the present. The Big-Bang is dated between 10 and 20 billion years ago.

The earlier **Pre-Ptolemic theories** believed that the **Earth was the centre** of the universe. However, with the acceptance of the **Helio-centric theory**, the nature and extent of the Solar system began to be realised. The Milkyway came to be called as a galaxy and was thought to constitute the entire universe with the Sun at or near its centre. **Modern estimates show** the size of galaxy to have a **diameter of about 100,000 light years with the Sun near the edge of the disc, about 28,000 light years from the centre**. And that the universe is **born** out of an **explosion 13.8 billion years ago**.

The crux of today's cosmological paradigm is that in order to a mathematically unified theory, valid for the entire universe, one must accept **that 95% of our cosmos is furnished by completely unknown elements and forces for which there is no empirical evidence**.

Understanding of the Evolution of the Universe:

- Microwaves have wavelengths in the range of millimetres. This has been long compared to visible light. The **Cosmic Microwave Background (CMB)** consists of light in the microwave range because the expansion of the universe stretched the light so much. Microwave radiation is invisible light.
- The CMB was detected first in 1964, winning for its discoverers a Nobel Prize in **1978**.
- James Peebles predicted the existence of **Cosmic Microwave Background Radiation**, the so called **afterglow of the Big-bang**.
- His work is focused largely on Cosmic Microwave Background radiation, which is electromagnetic radiation left over from the early universeonce it had cooled sufficiently following the Big Bang.
- By studying the CMB, scientists have been able to determine the age, shape and

contents of the Universe.

- Peebles realised that measuring the CMB's temperature could provide information about **how much matter had been created in the Big Bang**.
- He also saw that the **release of this light played a role in how matter could form clumps** creating what we now see as **galaxies**. This was a major breakthrough.
- He is credited with developing **theoretical tools** that allowed scientists to perform **cosmic inventory of what the universe is made from**.
- He interpreted **first rays showing that ordinary matter makes up just 5% of its known contents**, the rest of it being **dark matter** and **dark energy**.
- By measuring the speeds of rotating galaxies, scientists were able to see that a lot of mass needed to be there that would hold the galaxies together with the strength of their gravitational attraction. **Before Peebles intervened, the missing mass was attributed to neutrinos.**
- Peebles instead said this is due to a hitherto unknown type of "dark" matter particles. However, while they could "see" a portion of this mass, a large part of it could not be seen. Hence the **mass missing from view was named "dark" matter**.

What is an Exoplanet?

- An exoplanet or extra-solar planet is a **planet outside the solar system**.
- **1917:** The first evidence of an exoplanet called **Van Maanen 2** was noted, but was rejected.
- **1988:** Saw the first scientific detection of an Exoplanet.
- **1992:** First confirmation of detection of exoplanet came, with the discovery of several terrestrial mass planets orbiting **PSR B1257+12**. Named **Lich**, it is located 2300 light years from the Sun, in the constellation of Virgo.
- **1995:** First confirmation of an exoplanet orbiting a main sequence star was made when a giant planet was found in a four day orbit around the nearby star **51 Pegasi**.
- **1996-2006:** Atleast 100 exoplanets were recognised.
- Some Exoplanets have been imaged directly from telescopes but a vast majority have been detected through indirect methods such as **transit method** and **the radial velocity method**.
- Most recent Exoplanets were discovered either by detecting the **effect of the**

gravitational pull of the planet on its host star or by catching the planet as it passes in front of its star and slightly dims it.

- **21 planets** beyond our Solar System **have a chance to host life**.

Discovery of Exoplanet:

- In **1995**, Mayor and Queloz announced the **first discovery of an Exoplanet orbiting a Solar type star 51 Pegasi, in Milkyway Galaxy**.
    - The star 51 Pegasi, was located about **50 light-years away** in the direction of our **constellation Pegasus** the Flying Horse.
    - Astronomers officially designated the new planet as **51 Pegasi b**, in accordance with nomenclature already decided upon for extrasolar planets.
    - The bmeans that this planet was the first discovered orbiting its parent star.
    - So far, **this planet is the only one known in this system**.
    - The planet is a **gas giant**; a type that astronomers had expected would orbit the outer regions of its solar system. The planet was as big as Jupiter (1,300 times Earth's volume) but very close to its star (taking just 4 days to orbit; it is 10 times closer to its star, than Mercury is to Sun).
    - This led to theories that described how **large gas balls formed at the edges of their solar systems and then spiralled inwards**.
    - It was also a sign that the other planetary systems might not be like our own.
- The discovery started a revolution in astronomy.
- About **4000 Exoplanets** have since been found in the Milkyway **challenging the preconceived ideas about planetary systems**.
- Until the discovery, **gas giants were presumed to be cold**, formed a **great distance from their stars**.
- Now, it is accepted that these hot gas giants represent what Jupiter would look like if it were suddenly transported closer to the Sun.
- Its because of this discovery that we know today that about a quarter of all stars have a planet of Earth's size and surface temperature with the **potential of hosting liquid water and the chemistry of life on its surface**.

What is a Rouge Planet?

- A planet that does not orbit any star is called a **Rouge Planet**.
- Such a planet orbits a **galactic center directly**.
- Such objects have been **ejected from the planetary system** in which they formed or have never been gravitationally bound to any star or brown dwarf.
- Rouge planets in Milky Way number in billions.
- Because of their large distance, scientists learn about them through **remote observations** using telescopes and other equipments.

Discovery of Exoplanets:

Hubble Space Telescope:

- Launched into **low orbit in 1990, NASA's Hubble Space Telescope** has not only discovered a variety of transitic exoplanets but has **characterised the atmospheres** of some of them.
- Hubble remains in operation and has recently **discovered water on an exoplanet for the first time**.
- **K2-18b** is **eight times the mass of Earth** and is the **only known exoplanet to have water, habitable temperatures that could be potentially habitable**.

Spitzer Space Telescope:

- Launched in **2003**, Spitzer Space Telescope **observes exoplanets in infrared wavelengths**.
- It is planned to **retire** in **January 2020**.

Kepler Space Telescope:

- Launched in **2009** into an **Earth trailing Helio-centric orbit**, NASA's Kepler was designed to **continuously monitor approximately 1,50,000 main sequence stars** in a fixed field of view for four years.
- **Kepler Telescope** has detected more than **five lakh stars** and **2,662 exoplanets**, before its retirement in **2018**.

TESS Space Mission:

- The **Transiting Exoplanet Survey Satellite** was launched in 2018 by **NASA**.
- It is an **all-sky survey mission** that will discover thousands of exoplanets around nearby bright stars.
- It is designed to search for exoplanets using the **transit method in an area 400 times larger than that covered by the Kepler mission**.

Details on Nobel Prize in Physics:

- This was the **113th Nobel Prize in Physics** awarded since 1901.
- Of the 113 awards, **47** have been given to a **single laureate**.
- Only **three women** have been awarded it so far: **Marie Curie in 1903**, **Maria Goeppert-Mayer in 1963** and **Donna Strickland in 2018**.
- Research by **James Peebles, Michel Mayor** and **Didier Queloz** - winners of the Nobel Prize in Physics 2019, on planets and the Big bang has **transformed the idea of the Cosmos**.