Lecture 8: Beyond Earth

Introduction

This final lecture explores the broader cosmic context of life, examining meteorites, comets, the origin of life, exoplanets, extraterrestrial intelligence, and our role as sentient observers of the universe.

Meteors, Comets, and Time Capsules

- **Tycho Brahe** showed comets were not atmospheric but celestial.
- **Comets** were considered omens—terms like *disaster* derive from "bad star."
- **Meteor showers** result from Earth intersecting comet debris.
- Tracked telescopically via **trails** that distinguish meteors from stars.

Terms:

- **Meteoroid**: Rock/metal in space
- **Meteor**: Burns in Earth's atmosphere
- **Meteorite**: Lands on Earth

Meteorites contain the chemistry of early solar system formation, including lunar and Martian fragments. **Widmanstätten patterns** in metal meteorites form only in microgravity.

Cosmic Collisions and Life

- The **Moon** likely formed when Earth was struck by a Mars-sized object (*Theia*).
- The Moon stabilizes Earth, produces tides, and shields Earth from impacts.

- **Cometary bombardment** likely delivered water to Earth.
- Earth's water is thin—if it were 30% more, Earth would be entirely oceanic.
- **Dinosaur extinction**: A 66-million-year-old impact paved the way for mammals and, eventually, humans.

The sequence of these collisions appears highly fine-tuned for complex life to emerge.

Antarctica and Meteorites

- Meteorites are collected in Antarctica due to its pristine, icy landscape.
- **ALH 84001**: A meteorite from Mars once thought to show microfossils—debated to this day.
- They're named for landing locations (e.g., *Campo del Cielo*, *Allan Hills*).
- Chemical analysis distinguishes genuine meteorites from ordinary rocks.

Panspermia and Origins of Life

- Life could have been seeded via meteorites (panspermia).
- Earth and Mars likely exchanged material.

Essential Ingredients:

- **Liquid water**
- **Organic molecules**
- **Energy source**

Moon-driven tides may have created nutrient-rich environments necessary for life.

Darwin's "Warm Little Pond"

- Hypothesis: Life formed in a pond with the right chemicals, heat, and lightning.
- **Miller-Urey Experiment** simulated this and produced amino acids.

DNA vs. RNA:

- **DNA** stores genetic info.
- **RNA** may have come first—can replicate and catalyze reactions.

The "RNA world" hypothesis posits RNA preceded DNA in early life.

Exoplanets and Alien Life

- **Kepler** and **TESS** telescopes found Earth-like planets.
- **Goldilocks zone**: not too hot, not too cold, ideal for liquid water.
- Spectroscopy during transits can reveal **biosignatures** in planetary atmospheres.

Possible indicators of life:

- Oxygen
- Methane
- Artificial chemicals (signs of technology)

Fermi Paradox

If life is common in the universe, where is everyone?

Possible answers:

- They're ignoring us.
- They destroyed themselves.
- They haven't detected us yet.
- We are the first or only.

SETI & Breakthrough Initiatives

- **Breakthrough Listen**: scanning radio signals from stars.
- **Breakthrough Starshot**: sending laser-powered micro-probes to Alpha Centauri.

Reflections on Our Place in the Universe

Carl Sagan's *Pale Blue Dot*

"That's home. That's us... every human being who ever was lived out their lives on a mote of dust suspended in a sunbeam."

Science and Wonder

- **Walt Whitman**: Poetry doesn't need science.
- **Richard Feynman**: Understanding increases beauty.

"It does not do harm to the mystery to know a little about it." – Feynman

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Closing Thoughts

We've traveled from ancient sky watchers to cutting-edge telescopes. We studied:

- Stars and galaxies
- The Big Bang and dark energy
- Life's possible cosmic origins

The future:

- **Nancy Roman Telescope**
- **Simons Observatory**
- **IceCube Neutrino Detector**
- New discoveries on exoplanets, cosmic inflation, and more.

Thank you for exploring the cosmos. Stay curious. Keep looking up.