I. Introduction: Key Historical Events, Measurements, & Math Models

Key Mathematical Concepts for Correct Modeling of Planetary Motion

127 AD: Ptolomy proposed epicycle geocentric model of universe. This theory holds for 1500 years.
1543: Copernicus prosed the Heliocentric Model of the Universe. Galileo's telescope verifed this from the orbit of Venus.
1605: Kepler's Laws describe the Elliptical Model for Planet's Orbits. Lunar Conic Model, Time of Flight, Polar Model.
1686: Newton's Laws (supercede Kepler's) and Einstein's GR gives value for the precession of the perihelion of Mercury.

Key Concepts and Discoveries (Measurements) of Cosmology of Galaxies

1. Birth of Cosmology: Mathematical Basis of ΛCDM Cosmology: **Einstein's General Theory of Relativity (GR)**
In 1917 Einstein developed his General Theory of Relativity (GR), the general tool of Modern Cosmology.

2. 1912 Vesto Slipher, using spectroscopy, discovered the redshift of galaxies. Used Doppler Effect to calculate velocities.

3. **In 1922 Friedmann developed a solution of GR** that showed that the universe is not static, but predicted that the universe will expand. In 1927 Lemaitre came up with a model that included mass density and pressure. He showed a linear relationship between expansion of the universe and distance. This relationship was verified by redshift measurements by Slipher & Hubble's measurement of distance to galaxies. Hubble made the correlation between velocity and distance.

4. In 1929, measurements of the distance and the velocity of how fast galaxies are moving away from us were made by Edwin Hubble. The correlation he discovered between distance and velocity is know as **Hubble's Law**.
In 1932, **Einstein and de Sitter** solved GR for an expanding ($\lambda = 0$), Hubble H_o, finite mean density, flat universe.

4. In 1948 prediction of existence of Cosmic Microwave Background Radiation (**CMB**) made by George Gamow.

5. In 1950's it was thought that the light elements, such as hydrogen and helium. were formed in stars. However, the observed **% of helium was too high to be formed from the interior temperatures of stars**. The percentage of Helium can be explained by the BBT, i.e., the universe was so hot that it could produce a high percentage of helium.

6. In 1964 Penzias and Wilson, while calibrating a radio telescope accidentally **discovered this (CMB)**. Based on GR, the discovery of CMB, and Hubble's Law the **ΛCDM Theory was proposed**. To verify that the CMB originated from a BB, in **1989 the COBE** spacecraft was launched to determine if the temperature variations of the CMB were consistent with the ΛCDM cosmological framework. The uniformity of CMB agreed with BBT predictions.

7. Observations of rotational velocity of galaxies **implied the existence of a new form of matter**: **Cold Dark Matter.**

8. 1960's: The **Development of the ΛCDM** (Lambda Cold Dark Matter) Model

9. In the 1980s the **Concept of Inflation** was proposed to explain the fine tuning of the universe. Cosmic inflation, cosmological inflation, or just inflation, is a theory of exponential expansion of space in the early universe. The inflationary epoch is believed to have lasted from 10^{-36} seconds to between 10^{-33} and 10^{-32} seconds after the ΛCDM. It requires significant fine tuning, degree depends on model. XIX discusses the serious problems with the validity of this theory.

10. 1992: Discovery of the **anisotropic nature** of the universe in the **CMB**. Requires corrections to FRW model.

11. In 1998, it was observed that the **rate of expansion of the universe increase**d. This increase was attributed to a new form of energy called **dark energy**. In 2022, it was found to increase **5% to 9% even faster than thoug**ht.
The Greek letter Λ (lambda) is used to represent the cosmological constant, which is currently associated with a vacuum energy or dark energy in empty space that is used to explain the contemporary accelerating expansion of space against the attractive effects of gravity. A cosmological constant has negative pressure.

Satellite Space Telescopes: 1989 NASA COBE, 1990 NASA and ESA Hubble, 2009 Planck, 2021 JWST.

The High-Precision Era of Cosmology

\This refers to the period starting in the **late 1990s and early 2000s** when cosmology transitioned from a largely theoretical field with significant uncertainties to a **precise, data-driven science**. This transformation was driven by high-resolution observations of the cosmic microwavec (CMB), large-scale galaxy surveys, and supernova studies.

Key Milestones of the High-Precision Era

Cosmic Microwave Background (CMB) Measurements:

Hubble Space Telescope (1990) (90-2,500 nm):
Hubble contributed to precision measurements of the Hubble constant through distance-ladder observations.
NASA COBE (1989):
First detected CMB anisotropies, confirming early universe structure formation.
BOOMERANG & MAXIMA (1998–2000):
Provided detailed maps of the CMB power spectrum.
WMAP (2003–2013):
Precisely determined key cosmological parameters (age, composition, curvature).
Planck (2009–2018):
Achieved even higher precision, refining the standard cosmological model.
Type Ia Supernovae & Dark Energy (1998–1999):
James Webb Space Telescope Probing the Early Universe 2021--- (Infrared 600-28,500 nm):
While not specifically dsesigned to probe the CMB, it contributes significantly by the Discovery of Ancient Galaxies: JWST has observed galaxies that existed approximately 290 million years after the ΛCDM, providing insights into the formation and evolution of the earliest cosmic structures ***z > 10-15.*** It was designed to last at least 5 and 1/2 years.
Identification of Massive Early Galaxies: The telescope detected six massive galaxies formed between 500 to 700 million years post-ΛCDM. These galaxies challenge existing theories of galaxy evolution due to their substantial mass & density.
Observations from the Supernova Cosmology Project and the High-Z Supernova Search Team showed that the universe's expansion is accelerating.
This led to the discovery of dark energy, now estimated to make up ≈68% of the universe's energy budget.

Large-Scale Galaxy Surveys:
Sloan Digital Sky Survey (SDSS) (2000–present): Mapped millions of galaxies, measuring large-scale structure and baryon acoustic oscillations (BAOs).
2dF Galaxy Redshift Survey (1995–2002) or 2dFGRS: 2dF used the two-degree field spectroscopic facility on the Anglo-Australian Telescope out to z ~ 0.2. Provided key constraints on matter density and galaxy clustering.
ΛCDM Model Confirmation:

The Lambda Cold Dark Matter (ΛCDM) model became the standard framework, describing a universe composed of ≈68% dark energy, ≈27% dark matter, and ≈5% normal matter.
Baryon Acoustic Oscillations (BAOs) & Precision Distance Measures:
BAOs, detected in galaxy clustering patterns, provided an independent "standard ruler" for measuring cosmic expansion.

Impacts of the High-Precision Era

Cosmological Parameters Now Known to Percent-Level Accuracy:
Age of the Universe: 13.8 billion years
Hubble Constant (H_0): 67 to 74 km/s/Mpc (some tension remains between Planck and local measurements)
Matter Density (Ω_m): 0.31, Dark Energy Density ($\Omega\Lambda$): 0.69

Shift from High Precision Parameter Estimation to Fundamental Physics:

Questions about the nature of dark energy, dark matter, and potential physics beyond ΛCDM.

The Universe is big in both space and time, and for much of human history it has been largely beyond the reach of our boldest ideas and most powerful instruments. The birth of modern cosmology was roughly 100 years ago. Albert Einstein had introduced General Relativity, the first theory of gravity and space-time capable of describing the entire Universe, and the first cosmological solutions had been found (e.g., the de Sitter, Friedmann, and Lemaître solutions as well as Einstein's static model). At about the same time, George Ellery Hale and George Willis Ritchey invented the (modern) reflecting telescope, and Hale moved astronomy to the mountaintops of California—first Mount Wilson and, later, Palomar Mountain. With bold ideas and new instruments, astronomers were ready to explore the Universe beyond our own Milky Way galaxy and began to discover and understand the larger picture.

Hale's second big reflector, the 100-inch Hooker telescope, enabled Edwin Hubble to discover that galaxies are the building blocks of the Universe today and that it is expanding—the signature of its big bang beginning. While it took a few years to connect the solutions of General Relativity to the observational data, the basics of the big bang model were in place.

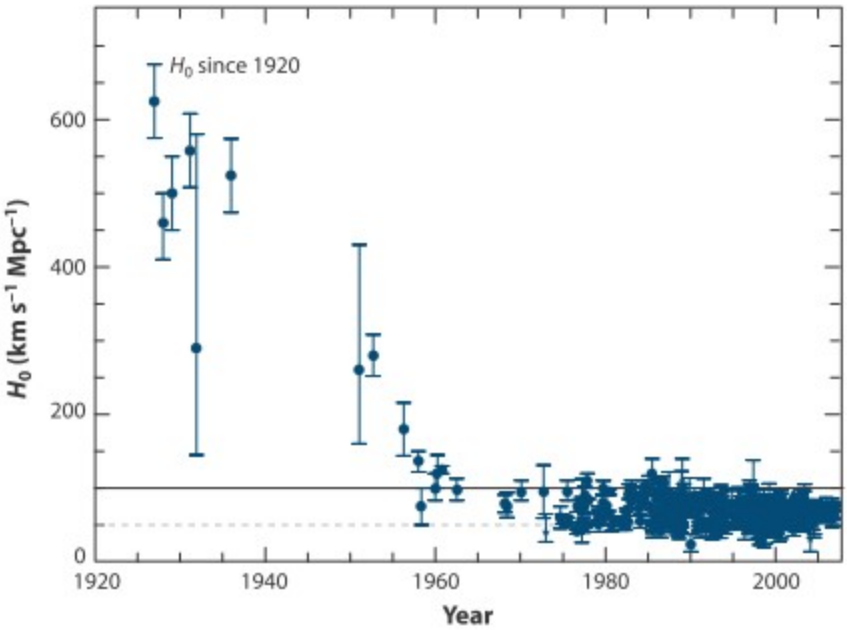
.In 1972, years before Standard Model referred to the remarkable theory that describes quarks and leptons. This Standard Model (Weinberg's Classic "Gravitation and Cosmology") traces the Universe from a hot soup of hadrons at around 10^{-5} s through the synthesis of the light elements (largely ^{4}He with trace amounts of D, ^{3}He, and ^{7}Li) at a few seconds to the formation of neutral atoms and the last scattering of CMB photons at around 400,000 years after the big bang, and finally to the formation of stars and galaxies.

The triad of the expansion, the light-element abundances, and the blackbody spectrum of the CMB provided an equally strong observational foundation. Note: The deceleration parameter, q_0, is discussed here for historical context.

In 1970, Sandage summed up cosmology as the search for two numbers, H_0 and q_0. The expansion rate of the Universe, H_0, also sets the age of the Universe, $t_0 = aH_0^{-1}$, with the deceleration parameter q_0 determining the constant a. And for a universe made up only of matter, q_0 , the ratio of the matter density to the critical density (Ω_0), and the curvature radius of the universe are related: $q_0 = \Omega_0 /2$ and $Rc = H_0^{-1}/|\Omega_0 - 1|^{1/2}$. It would take until 2000 and the Hubble Space Telescope (HST) Key Project to pin down H_0 with a reliable **error estimate**:

$H_0 = 72 \pm 2 \pm 6$ km s^{-1} Mpc^{-1} (statistical and systematic).

"Low-precision" versus "High-precision" Cosmology



H_0 measurements from 1920 to 2020.

By 1970, most measurements were between 50 and 100 km s^{-1} Mpc^{-1}, but with unrealistically small error bars. The Hubble Space Telescope Key Project changed that with its 2000 determination, $H_0 = 72 \pm 2 \pm 6$ km s^{-1}Mpc^{-1}. As for q_0 it has been replaced by other cosmological parameters that better capture the physics and that can be measured with accuracy and precision.

Three Contrasting World Views Concerning the Validity of ΛCDM Singularity Hypothesis

#1: *An Introduction To Modern Cosmology*, Andrew Liddle

Four Observational Evidences for the ΛCDM Model:

1. The expansion of the universe according to Hubble's law (as indicated by brightness and redshifts of galaxies),
2. The discovery and measurement of the Cosmic Microwave Background Radiation (CMB),
3. The relative abundances of light elements produced by ΛCDM nucleosynthesis.
4. Observations of Galaxy formation and evolution and Agreement of Different Tests for the Age of the Universe

"The development of cosmology will no doubt be seen as **one of the scientific triumphs of the twentieth century**. At its beginning, cosmology hardly existed as a scientific discipline. By its end, the Hot ΛCDM cosmology stood secure as the accepted description of the Universe as a whole. The turn of the millennium saw the establishment of what has come to be known as the Standard Cosmological Model, representing an almost universal consensus amongst cosmologists as to the best description of our Universe."

#2. *Dismantling the ΛCDM, Reasons Why to Reject the Big-Bang Theory*, Alex Williams, J. Hartnett

The theory lacks a credible and consistent mechanism for the Origin of the Universe before the CMB.

"The big-bang universe begins in a singularity (entire universe crushed into a point of infinite density) and there is no known mechanism to start the universe expanding out of the singularity — the equations in the theory **only work after the expansion has begun**. It then requires a hypothetical period of stupendous inflation and stopping at a precise point to halt the universe from recollapsing. It further requires incredible fine tuning to maintain stability for a flat universe. Its mechanism for turning primordial energy into matter would produce equal amounts of matter and anti-matter but our universe is made only of matter. It is inconsistent with Thermodynamics. **It cannot explain the low entropy at the initial expansio**n." The detailed particle physics mechanism responsible for inflation is not known. It has to violate physical laws and appeal to unknown forces (dark energy) and substances (dark matter) to explain what we observe.

#3. Theological Arguments for Age of "Firmament"/Galaxy: God Created Firmament/Galaxy in 2 Days.

Epistemological Foundations and Assumptions (*The Lost World of Genesis One*, John Walton (ANE Texts)

1. Define a test for determining the Truth of a Proposition:
   The Law of Non-Contradiction: This law states that a truth proposition cannot be both statement A (what it is) and statement non-A (what it is not) at the same time and in the same relationship. One implication of this is that the vast corpus of Physics is self-consistent and thus passes the Law of Non-Contradiction.
2. 2 + 2 always equals 4. This is true for all time & everywhere in space. This establishes that Mathematics is always valid.
   For example, this law is true in the garden of Eden before the fall, in heavenly places, & everywhere in this universe. By extension, this implies that the Laws of Mathematics hold everywhere in space and for all time.
   With regard to math and logic, the above 2 + 2 always equals 4 implies that the logical mind of man (not necessarily his moral compass) is not impaired by the fall of Adam. Luther said truth comes from the Bible and Reason.
3. Law of Cause and Effect - As a generalization, the cause must always be greater than the effect. Cause for BBT.
4. Space and Time had a beginning. Refer to Section XXXIII Proof of the Borde-Guth-Vilenkin (BGV) Theorem.
5. **Moses Observed:** sky above, ground below, & a horizon (**firmament** above), with water surrounding ground, above the firmament, and below the ground (the deep). **Genesis 1:1-2**: "In the beginning God created the sky and the land. ... And the Spirit of God moved upon the face of the waters". **Gen 1:6-8** "And God said, Let there be a firmament in the midst of the waters, and let it divide the waters from the waters. And God made the firmament, and divided the waters which were under the firmament from the waters which were above the firmament: and it was so. And God called the firmament Heaven. And the evening and the morning were the second day." God Created the Firmament in two Days.
6. Physicist Eugene Wigner wrote a paper on the "*The Unreasonable Effectiveness of Mathematics in the Natural Sciences*." One of the implications of this is the wonder that the mind of man can understand the depths of the laws of Physics. A theological explication of this mystery is given in the Book of Genesis 1:27: "*So God created man in his own image, in the image of God he created him; male and female he created them*." Thus man, being made in the image of God (Imago Dei), is thus capable by God's design to understand the Laws of Physics and Math, as created by God.
7. Lifetimes: The sun has enough nuclear fuel to run for about 10 billion years and about half of it has been used up.
   The half-life of Uranium 238 is measured to be about 4.5 billion years. Elements heavier than UR have short half-lives.

The Nature of Science: Physics or Metaphysics - Limits to the Legitimate Realm of Physics

Unspoken Assumptions

Most people today believe because they have been taught it is so, that physics can explain the Origin of the universe. This is the Assumptions of Naturalism: The idea that matter is all there is. Upon this rests the current orthodoxy of cosmology.

What is Science? The Era of Post Empirical Science

The philosopher Karl Popper argued that what distinguishes a scientific theory from pseudoscience and pure metaphysics is the possibility that it might be falsified on exposure to empirical data.
In other words, a theory is scientific only if it has the potential to be proved wrong.
Some argue we live in the era of post empirical science. Major Concepts such as a Multiverse, Bouncing Universe, or 24 Dimensional String Theory can never be falsified. By Popper's criteria, these concepts do not constitute areas of legitimate scientific inquiry. One can hold the position that String Theory is manifestly false. It fails all predictions.

***Lost World of Genesis*, John Walton: There are Conceptual Limits to Science**

"**Based on the concept of the Scientific Principle, Science can only study things that happen more than once**. By this definition, many areas of Cosmology can never be verified or falsified. These areas would be in the **realm of speculati**on. To explain something means to describe the unknown in terms of the known. **Unknown concepts such as Dark Energy or Cold Dark Matter do not do well to further elucidate area of inquiry.** They are **more in the arena of Metaphysics rather than Physics.**The deeper we look into Physics and also the Biological Structure of the human cell, the deeper we see into a perhaps never ending depth of complexity."

Distinguishing Between the Realms of Myth, Philosophy, Explanations, Metaphysics, and Science

One case where science crosses over into religion is **The Beginning of Our Universe**. Physicists have put forward many theories for it: a ΛCDM, a big bounce, a collision of higher-dimensional membranes, a gas of strings, a network, a 5-dimensional black hole, and many more. But the scientifically correct answer is, that we don't know how the universe came into existence. There are good reasons to think we will never know. A greater cause, that transcends the physical realm, may be the origin. Many are unwilling to accept this as a possibility. Many fill this knowledge gap with tall tale creation myths, written in the language of Mathematics, such as a landscape of multiverses populated with googles of string topologies.
Einstein's quote from first page:

"*Time and again the passion for understanding has led to the illusion that man is able to comprehend the objective world rationally by pure thought without any empirical foundations – in short, by metaphysic*s."

The Origin, Purpose, and Destiny of the Universe: Perceived Tension Between Cosmology and Christianity

Christianity is consistent with the Big Bang Theory. Genesis 1:3 And God said "*Let there be light*" and there was light. Genesis is consistent with the Ex Nihilo creation of the cosmos. Chronologically, the different concepts men have had about the nature of the universe were: First Pagan God Centered, then Earth Centered, then Sun Centered, then the Great Enlightenment Material Centered, and presently, the latest Science of Cosmology Centered. The telescope was the instrument that falsified a number of astronomical world views. With respect to origin, what is the greatest possible cause, the Universe or God? With respect to these, what is the greatest possible explanation for our reality: Explanations for the physical properties and interactions of matter/energy or a Transcendent Being? Which is the more Transcendent origin? Our Perceptions and Theories about the Physical or God? The Law of Cause and Effect: The cause must always be greater than the effect. Who or What is a Self-Consistent cause to explain the creation of time?
Which is the more real? Abstract Field Theories about Matter, Tensor Field Equations, and Singularities or the Spiritual Influence of a Creator God who is the Creator of the Esoteric Field Theories of Physics, Math, and the Imago Dei Mind? Philosophically, the only ultimate origin is God who transcends a mere physical universe.

In the end, only a Supreme Law Giver, is the creator of the Laws of Physics and Mathematics. He is, by Definition, the Great Lawgiver of the Universe. He is the one explanation for the fine-tuning of the laws of Physics and cosmology. All truth, including the physical, is God's truth. **Thus there is no tension between Material Cosmology and the Biblical Old and New Testaments** as long as the Biblical Account of Creation is not interpreted out of the context of the age and culture in which it was written. For Genesis, it is in the context of the age, culture, and World View of Moses and **the children of Abraham coming out of Egypt seeing Only the Milky Way Galaxy stars, sun, and moon.**