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The Good Word

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PART II: ANCIENT TO MODERN COSMOLOGY

by Dr. Seraphim Steger

HISTORICAL MODELS OF THE COSMOS:

ANCIENT GREEK ASTRONOMERS: [1]

The ancient Greeks, specifically the Ionian school of philosophers (6th-4th century BC), are credited with the first move from a mythological, supernatural view of the Universe to a natural, mechanistic view based on reason, observation, and the application of geometry. **Anaximander** proposed a model which had a cylindrical Earth at rest in the center of the Universe, surrounded by air then one or more spherical shells with holes in them. These appeared as stars due to the rim of fire that lay beyond the solid sphere (see Fig. 1).

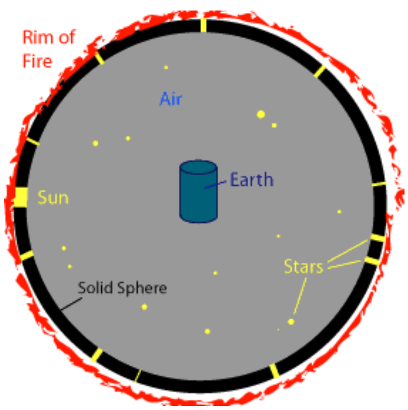

Figure 1: Anaximander's Model

Anaximander's model proposed the concept of spheres surrounding the Earth which profoundly influenced astronomy and cosmology for the next two millennia. **Anaximenes** refined Anaximander's model by suggesting that the stars were fixed onto a solid, transparent crystalline sphere that rotated about the Earth. [Note: This is a likely source for the idea of the heavens having a vault-like dome -- giving rise to the use of the term *stereoma*, in the Greek speaking world, and *firmamentum* in the Latin speaking world for translating the Hebrew word רָקִיעַ *raqiya*, *expanse*.]

Later Ionians contributed more ideas and observational discoveries. **Anaxagoras** (*c*.500-428 BC) realized that the Moon shone by reflected sunlight, had mountains, believed it was inhabited, and believed that the sun was not a god but a large fiery stone much larger than Greece and residing a large distance from Earth. **Empedocles** (490-430 BC) suggested that light traveled fast but not at infinite speed**.** **Democritus** (*c.* 460-370 BC) proposed not just an atomistic model of matter but also correctly proposed that the Milky Way was composed of thousands of unresolved stars.

PYTHAGORAS

Pythagoras (c. 580 - 500 BC) is credited with postulating a spherical earth since it always cast a perfectly round shadow, not an ellipse, on the moon during eclipses. He also realized that *Phosphoros*, the morning star and *Hesperos*, the evening star were in fact the same object, the planet Venus. He and his followers believed in the concept of the *cosmos*: a well-ordered, harmonious Universe. His school placed great importance on the power and aesthetics of geometry and mathematics [an approach very much in in vogue in modern cosmology] rather than experiments and observation. Regular geometrical solids, especially the sphere, were revered and they sought to find harmonies and ratios in the natural world.

PLATO (428 - 348 BC)

Plato, an Athenian philosopher and a pupil of Socrates, expressed his views on the Universe in his dialogue *Timaeus*. To Plato the Universe was perfect and unchanging. Stars were eternal and divine, embedded in an outer sphere. All heavenly motions were circular or spherical as the sphere was the "perfect" shape, an idea which became ingrained until the time of Johannes Kepler. Because Plato thought that the visible world was only a dim representation of the real world, he was not concerned with direct observations, but with philosophy.

ARISTOTLE (384 - 322 BC)

Aristotle, a pupil of Plato and the tutor of Alexander the Great also wrote on astronomy and the physics of motion in *On the Heavens* and in *Physics*.

Aristotle saw all matter on Earth as being composed of combinations of only four elements; earth, air, fire and water with the properties of dry, cool, hot, and moist. The stars were made of a separate fifth element, *quintessence* and were incorruptible and eternal.

1. Abridged and adapted from the Australia National Telescope Facility at https://www.atnf.csiro.au/outreach/education/senior/cosmicengine/classicalastronomy.html

Motion in the heavens was natural, unforced and circular so that the planets and sun orbited a fixed, unmoving spherical earth in circular orbits. They were perfect. On earth, however, matter was corruptible and subject to decay. Motion was linear with objects requiring a force acting on them to stay in motion.

Aristotle's own model of the Universe had a series of 53 concentric, crystalline, transparent spheres rotating on different axes. Each sphere was centered on a stationary earth so the model was both geocentric and *homocentric* (i.e., concentric nested spheres). Stars were fixed on the outer sphere. The moon marked the boundary between the unchanging, constant heavens and the corruptible earth. According to Aristotelian cosmology it was only within the sub-lunary sphere, that is, between the earth and moon, that changeable phenomena such as comets could exist. Supra-lunar comets were not thought possible, nor stars changeable such as supernovas, since such phenomena would violate his principles. Aristotle's philosophical ideas of the cosmos would reign supreme for centuries despite observations to the contrary, so great was his stature.

Interestingly, one of the Pythagoreans, **Aristarchus of Samos** (c. 310 - 230 BC) proposed a model that placed the sun at the center -- a *heliocentric* Universe. His model would be familiar to us today as a reasonable description of the solar system containing those planets visible to the naked eye. All the planets up through Saturn, including the earth, revolved around a fixed sun in circular orbits. The earth rotated once a day on its axis and the moon revolved about the earth.

Aristarchus' heliocentric model did not gain wide acceptance for several reasons:

(1). His concept of a moving Earth defied common sense -- we obviously do not feel the Earth spinning or moving through space.

(2). His idea contradicted the prevailing view of motion espoused by Aristotle.

(3). Parallax was not seen (because of the extreme distance between the earth and the stars -- see Fig. 2).

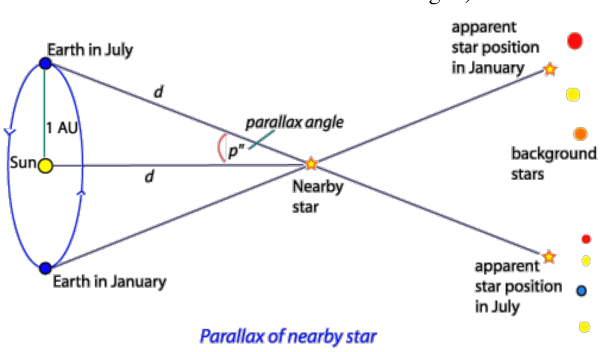

Figure 2: Parallax in a heliocentric model. This diagram greatly exaggerates the effect and is not to scale.

Under Aristarchus' model, the closer stars should show a periodic shift in position to and fro against more distant stars over the course of a year as the earth orbited the sun. However, parallax shift only was first confirmed in AD 1838 with careful telescopic observations. Unfortunately Aristarchus' original writings were lost in the destruction of the Great Library of Alexandria in AD 415.

Claudius Ptolemy (AD 120-180)

The last of the great classical astronomers, **Claudius Ptolemy** lived in Alexandria. He is chiefly remembered for his vast work on astronomy, known as the *Almagest* [meaning *"The Greatest"* in Arabic] in which he catalogued 1,022 stars. In it he also proposed a model of the Universe that profoundly influenced Western and Arabic thought for the next 1,500 years.

Ptolemy relied heavily on tools invented by and observations made by earlier astronomers especially **Apollonius** (262 - 190 BC), who had developed the concepts of the *eccentric* and the *epicycle* to better explain retrograde planetary motions and luminescence.

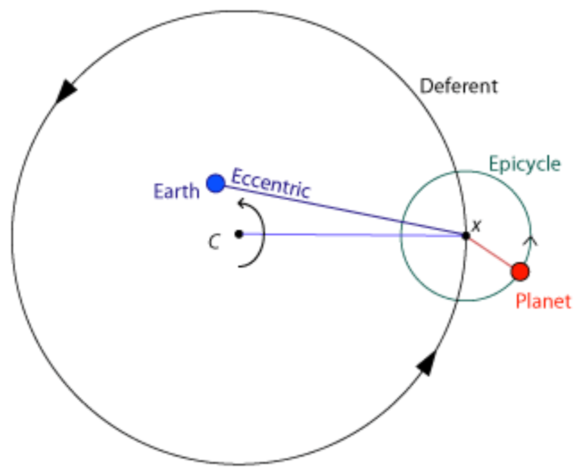

Figure 3: The Epicycle, Deferent and Eccentric. A planet orbits point *x* in a circular path called the epicycle. The deferent is the circular path that point *x* takes around the center of motion, *C*. This is not the same point as the location of the Earth. The offset is called the eccentric. Different planets would have different eccentrics, deferents and epicycles. The resultant path traced out by a planet could account for retrograde motion and variations in brightness . (Credit: *R. Hollow* CSIRO)

Ptolemy's model was to become accepted as the standard for the next 1500 years. It had a spherical, unmoving (i.e., *geostatic*) Earth in the central region of the Universe, its *natural* place. It was not strictly *geocentric* as the model used eccentrics. Stars were fixed on a celestial sphere 10,000 Earth diameters from the the center. That sphere rotated once every 24 hours. The sun, moon, and the five planets had their motions explained by combinations of epicycles, deferents and eccentrics. In total some seventy circles and 8 concentric spheres were required.

However, to best fit observations and still abide by Aristotelian philosophical principles, he introduced the first "fudge-factor" in astronomy, the *equant* -- the point around which motions of four epicycles appeared uniform. The equant did not coincide with the center of a planet's deferent, and each planet had its own equant.

St. Basil the Great (AD 330-378), schooled in Greek astronomy in Athens, accepted the geocentric spherical earth model of Ptolemy, but added a 9th concentric sphere (that of the celestial waters above the expanse) beyond the 8th sphere of the fixed stars, which separated the world of material creation from the world of God.[2]

Ascent of Observational Science:[3]

Nicolaus Copernicus (1473-1543)

Copernicus studied classics and mathematics at Krakow in his native Poland, canon law in Bologna and Ferrara and medicine at Padua in Italy.

Because Ptolemy's work failed to predict a conjunction of Jupiter and Saturn in 1504 by 10 days time, Copernicus was driven to develop his own model (Fig. 4) in which a spherical earth rotates daily on its axis while it and the other planets each orbit the sun.

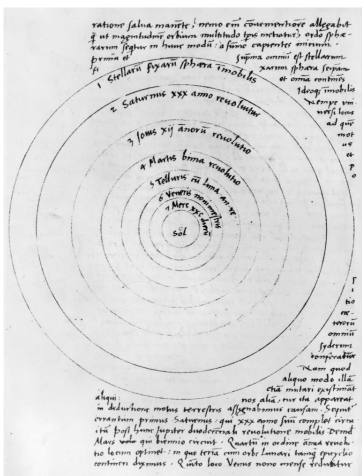

Figure 4: Copernicus' manuscript illustration of the solar system.

The period of the planets' orbits increases with increasing distance from the sun. Because the sun was not exactly at the center of the planetary orbits thus strictly speaking the model is *heliostatic* rather than *heliocentric*. There were several advantages of Copernicus' model over that of Ptolemy. Nonetheless, it failed to immediately supplant Ptolemy's model for a few reasons:

1. No annual stellar parallax could be detected. Copernicus correctly explained that the stars were at such a vast distance that any parallax would be very small and difficult to detect.
2. It required a moving Earth, which would contradict Aristotelian physics.
3. By removing the Earth from its "natural" place in the center it was philosophically and theologically unacceptable to many scholars.
4. It was more complicated and no more accurate than Ptolemy's in predicting planetary positions.

Thomas Digges (1546-1595)

Thomas Digges was an English mathematician and astronomer. An early advocate of the heliocentric model, Digges went beyond Copernicus by postulating that instead of the stars being attached to a celestial sphere, stars were distributed at various distances in an infinite Universe -- the first to suggest such a Universe.[4]

Tycho Brahe (1546 - 1601)

Tycho Brahe was the greatest astronomical observer of the pre-telescope era. His observations using massive instruments of his own design resulted in 10-fold more accurate measurements, greatly improving the existing star and planetary tables of the 1560's.

In November 1572 a new star appeared in the constellation Cassiopeia. Brahe's observations showed that it was motionless relative to nearby stars suggesting to him that it was in fact a star and not a tail-less comet. Five years later he observed a bright comet and discerned no parallax and placed it at least six times further from Earth than the Moon. Both of these observations challenged the Aristotelian orthodoxy -- the stars were supposed to be changeless and perfect and comets were supposed to be confined to the sub-lunary sphere, that is between the Earth and Moon.

Johannes Kepler (1571 - 1630)

Johannes Kepler worked as Tycho Brahe's assistant for the last year of Brahe's life. Kepler tried to fit Tycho Brahe's data to the Copernican model but consistently arrived at errors of at least eight seconds of arc, small but not insignificant. He was finally forced to abandon the Greek philosophical concept of uniform circular orbital paths, but it was to take him several years of painstaking, methodical calculations before he arrived at an alternate model that fitted Brahe's 20 years of data on Mars, that the orbital paths were ellipses. His results were published in 1609 in his work *Astronomica nova* (New Astronomy). In it he explained that all planets orbit the Sun in elliptical orbits with the Sun at one common focus. They also move more quickly

2. Theodosiou, Efstratios; Manimanis, Vassilios; and Dimitrijevic, Milan S., *The Contribution of Byzantine Priests in Astronomy and Cosmology: I. The Church Fathers: The Three Bishops St. Basil the Great, St. Gregory of Nazianzus, and St. John Chrysostom*, ***European Journal of Science and Theology***, (2011)7(2), p. 36, https://www.academia.edu/13587691

3. Abridged and adapted from the Australia National Telescope Facility at https://www.atnf.csiro.au/outreach//education/senior/cosmicengine/renaissanceastro.html unless otherwise stated.

4. Faulkner, D, *An Evaluation of Astronomical Young-Age Determination Methods 2: Solar, Stellar, Galactic, and Extragalactic*, ***Answers Research Journal***, Vol.12, 2019, pp. 329-349.

when their orbit is closer to the sun. He also noted that planets more distant from the Sun take longer to complete their orbits. However, he was never able to explain why.

THE PREEMINENCE OF TELESCOPE ASTRONOMERS: GALILEO GALILEI (1564 - 1642)[5]

In 1609 after learning about this new optical device, Galileo began building his own telescopes with greater and greater refinements to systematically observe the night sky. His use of the telescope undermined the tenets of Aristotelian motion and physics, and thereby ushered in a new era in observational science.

According to Aristotelian principles the Moon was above the sub-lunary sphere and in the heavens, hence should be perfect. However, Galileo found the *"surface of the moon to be not smooth, even and perfectly spherical … but on the contrary, to be uneven, rough, and crowded with depressions and bulges. And it is like the face of the earth itself, which is marked here and there with chains of mountains and depths of valleys."*

Even using his telescope the stars still appeared as points of light. Galileo correctly reasoned that this was due to their immense distance from Earth which, in turn, explained the failure of astronomers to detect the stellar parallax predicted by Copernicus' heliocentric model. On turning his telescope to the band of the Milky Way Galileo saw it resolved into thousands of hitherto unseen stars, just as Democritus had proposed.

Galileo correctly inferred that Jupiter had orbiting satellites from his nightly observations that four objects moved from night to night, sometimes disappearing behind or in front of the planet. Today these four satellites are known as the Galilean satellites: Io, Europa, Ganymede, and Callisto. For the first time, objects had been observed orbiting another planet, further weakening the validity of the Ptolemaic model, since the earth was clearly seen to not be at the center of all motions.

With his telescope Galileo saw that the planet Venus went through a complete set of phases similar to the moon. For Venus to exhibit a full range of phases, it must orbit the sun. Hence this simple observation disproved the Ptolemaic modes, opening the door to the heliocentric theory. In 1613 he published a letter announcing his discovery of sunspots. By monitoring the sunspots he discovered that the Sun rotated once every 27 days and that the spots themselves changed. Thus, Aristotle's concept of a perfect, unchanging Sun became untenable through Galileo just as his uniformly circular planetary orbits became untenable through Kepler.

SIR ISAAC NEWTON (1642 - 1727)

Isaac Newton is the pivotal figure in the scientific revolution of the 16th and 17th centuries. He discovered the multicolor composition of white light with the use of a prism thereby laying the foundation for modern optics and spectroscopy. In mathematics he invented calculus. His work on the laws of motion and of universal gravitation became the basis of modern physics and celestial mechanics until eclipsed by Einstein's Special and General Theories of Relativity.

During 1665-6 Newton developed his ideas on optics and light, planetary motions, and the concept of gravitation. He had developed a corpuscular theory of light (that light is a particle, i.e., the *photon*) and built the first successful reflecting telescope, thus eliminating the troublesome chromatic aberration inherent in the lenses of refracting telescopes.

Newton's scientific legacy rests primarily on his ***Philosophiae Naturalis Principia Mathematica*** (Mathematical Principles of Natural Philosophy), generally known as ***Principia.*** The book was published in 1687 with Edmond Halley's funding and urging. In it Newton penned his detailed exposition of the concepts of force and inertia which are summarized eloquently in his three *Laws of Motion*:

1. **Law I:** An object remains at rest or in a state of uniform motion unless acted on by an unbalanced force.

3. **Law II**: *The alteration of motion is ever proportional to the motive force impressed; and is made in the direction of the right line in which that force is impressed.* This is now commonly referred to as Force = mass x acceleration and emphasizes the directional nature of force.

5. **Law III**: *To every action there is always an equal and opposite reaction: or the mutual actions of two bodies upon each other are always equal and directed to contrary parts.*

He then applied them to the motions of other bodies such as planets in space. He applied his mathematical techniques to investigate the nature of the force between the earth and the moon, and the earth and the sun. His solution was the force of gravity which obeyed an inverse-square relationship to the distance between two objects and resulted in elliptical orbits of the planets as calculated by Kepler. Newton applied his law of universal gravitation to accurately predict the motions of planets, the orbits of comets, and even account for tides on earth (thus removing any doubt about the solar system's heliocentricity).

The success of his law of gravitation was confirmed in 1758 when a bright comet (Halley's) returned as predicted earlier by Edmond Halley.

Newton's scientific contributions profoundly influenced subsequent generations. Although a non-trinitarian, and thought by some to be an Arian heretic,

5. Abridged and adapted from the Australia National Telescope Facility at https://www.atnf.csiro.au/outreach/education/senior/cosmicengine/galileo_newton.html

Newton saw God as the masterful creator whose existence could not be denied in the face of the grandeur of all creation. He also rejected rationalist philosopher and mathematician scientist Gottfried Leibnitz's thesis that God would necessarily make a perfect world which requires no intervention from the creator. Moreover, Newton warned against using the law of gravity to view the Universe as a mere machine, like a great clock [in contrast to most modern scientists who attribute everything to the laws of physics, including ones not yet discovered!]:

"This most beautiful system of the sun, planets, and comets, could only proceed from the counsel and dominion of an intelligent Being … This Being governs all things, not as the soul of the world, but as Lord over all; and on account of his dominion he is wont to be called *Lord God* παντοκράτωρ [pantokratōr], or *Universal Ruler* … The Supreme God is a Being eternal, infinite, and absolutely perfect."[6]

However, the Enlightenment and 19th century Methodological Naturalism progressively sought to remove theology entirely from science. This culminated in the divorce of theology from science in the 20th century in the minds of most serious scientists. Mathematics and the Laws of Physics now ruled supreme over creation in the academic world.

Einstein, Friedmann, and General Relativity[7]

Albert Einstein (1879 - 1955)

The theoretical physicist Albert Einstein is known for multiple scientific breakthroughs including:

1. The **Photoelectric Effect**: By considering light to behave as discrete particles called *photons* rather than as a wave Einstein successfully applied the concept of the discrete package of energy, the quantum, discovered by the German physicist **Max Planck**, to explain the *photoelectric effect*. It was for his work on this topic and not relativity that Einstein was awarded the Nobel Prize in Physics in 1921.

2. The **Special Theory of Relativity**: Einstein's work on special relativity changed the way we view time and mass. It introduced the concepts of *time dilation* and *length contraction*. But the key concept in special relativity is that the two-way speed of light, c, is the same for any observer in an unaccelerated frame of reference. Two observers, one moving much faster than the other, both measure the speed of light to be the same. From this premise we get some interesting phenomena:

a. Rather than being fixed, the mass of an object is dependent on its speed. As an object approaches the speed of light, its mass increases. This *relativistic* mass increase has been measured to high precision in many situations.

b. Einstein also realized that a direct relationship existed between energy and mass -- that the two were interchangeable. This gave rise to his famous equation: $E = mc^2$, where E is energy, m is the mass of an object and c is the two-way speed of light in a vacuum.

The importance of this relationship is that a small amount of mass can be converted into a large amount of energy. This realization ultimately led other scientists to the discovery of nuclear *fission* (the splitting of the atom) and the development of atomic weapons in the Second World War. It also provided an explanation for the source of energy in stars such as our Sun. Nuclear *fusion*, in which light nuclei such as hydrogen fuse together, produce a new, heavier nucleus in which the mass is slightly less than the mass of the original nuclei. The extra mass is converted into high energy gamma ray photons. Nuclear fusion now plays a fundamental role in today's evolutionary theories of the formation of stars and planets.

3. The **Theory of General Relativity**

"In November of 1915 Albert Einstein published the crowning conclusion of his General Theory of Relativity: a set of sixteen differential equations describing the gravitational field.[8] Solutions to these equations are called *metrics*, because they show how distance-measuring and time-measuring devices (such as rulers and clocks) behave. The equations are so difficult to solve that new metrics, giving solutions under specific conditions, now appear only once every decade or so. Metrics are foundational; they open up new ways to understand space and time. For example, the first metric after Einstein's work, found by Karl Schwarzschild in 1916, not only explained the detailed orbits of planets, but also pointed to the possibility that *black holes* might exist."[9]

By 1916 Einstein had extended his earlier work on relativity to encompass more general situations including gravity and accelerated motion. This became known as the general theory of relativity, a new theory of gravity. He derived it from a key postulate, the *principle of equivalence* between inertia and gravity. An object with mass not only possesses inertia but actually warps or curves space around it. It affects spacetime. Motion and forces act along straight lines but where space is curved due to the presence of matter, the path followed by an object or light also appears curved.

The predicted curvature of light around a massive object was verified by British astrophysicist **Sir Arthur Eddington** in 1919. Observations made by his teams in Brazil and West Africa measured the apparent shift in light from a star close to the Sun during a solar eclipse, fitting Einstein's predictions. This successful confirmation was largely responsible for the rapid acceptance of Einstein's work and his global fame.

Furthermore, general relativity accounted for the observed precession of the perihelion of Mercury about the Sun and, much later, the observed difference in hydrogen master clocks in satellites orbiting Earth compared with those on the ground.

General relativity is not just an interest to astrophysicists and gravitational wave physicists. The modern GPS satellite system can only function due to the application of general relativistic corrections to the orbits of each of the over twenty

6. https://en.wikipedia.org/wiki/Religious_views_of_Isaac_Newton#God_as_masterful_creator

7. Abridged and adapted from the Australia National Telescope Facility at https://www.atnf.csiro.au/outreach//education/senior/cosmicengine/einstein.html

8. Einstein, A., *Zur allgemeinen Relativitätstheorie*, ***Sitzungsberichte der Preussischen Akademie der Wissenschaften Berlin***, Nov. 4, 1915, pp. 778–786. https://echo.mpiwg-berlin.mpg.de/ECHOdocuView?url=/permanent/echøeinstein/sitzungsberichte/199SW1KB/index.meta&pn=1

9. Humphreys, Russ, *New Time Dilation Helps Creation Cosmology,* ***Journal of Creation,*** (2008), 22(3):84-92. https://creation.com/new-time-dilation-helps-creation-cosmology

satellites in the system. The growing commercial, military and safety applications of such navigation systems show the relevance of general relativity in the modern world.

Aleksandr Friedmann (1888 - 1925)

Friedmann was a Russian mathematician and meteorologist whose key insight was to realize that there was no one unique solution to Einstein's equations, rather there was a whole family of solutions possible. This family of solutions thus allowed for different cosmological models of the Universe.

In Friedmann's models the only force he considered was gravitation. His model Universes were:

a. ***homogeneous*** (the same everywhere on a large enough scale, thus unbounded, i.e., infinite) [a big philosophical assumption as we shall see],

b. ***isotropic*** (looking the same in every direction),

[These 2 assumptions constitute what is know as the *cosmological principle*, an important fundamental assumption underlying much of modern cosmology.]

c. And, most importantly, they incorporate the concept of ***expansion,*** and in some cases, contraction of the fabric of the Universe.

Einstein had originally envisioned the Universe as static. But Friedmann provided the theoretical framework for an expanding Universe within spacetime using the mathematics of general relativity.

Georges Lemaître

Friedmann's work was independently verified in 1927 when the Belgian astrophysicist and priest **Georges Lemaître** derived the same solutions. He was totally unaware of Friedmann's earlier work. Lemaître also realized that newly discovered galaxies could be used to show expansion of the Universe.

Lemaître went on to apply thermodynamics and quantum theory to consider the entropy (the state of order/disorder) of the Universe. He realized that if the disorder increased over time then the converse should also apply. If one went back in time, then disorder should decrease. This led him in 1927 to propose the concept that the Universe began as a *primeval atom* [again a huge philosophical assumption]. His theory suggested that all of the mass-energy (10^{51} kg) of the Universe was concentrated in a single super-atom about one astronomical unit across (the distance of the earth from the sun, i.e., 93 million miles). The primeval atom would then fragment and the Universe expand. Lemaître's concept was the precursor to the big bang model. [But how did that primeval atom arise?]

Edwin Hubble (1889-1953) & the Expanding Universe[10]

Astronomer Vesto Slipher, working at the Lowell Observatory in Flagstaff, AZ, was first to measure the *Doppler shift* of spectral lines from spiral nebulae in 1912. By 1925 he had shown that most exhibited ***redshifts*** in their spectral lines. He interpreted this as meaning the nebulae were in fact moving away from us and consequently causing their spectrums to be shifted to longer, i.e., *redder* wavelengths. He also calculated that the Andromeda spiral nebula was moving towards us at 300 km/sec exhibiting *blueshift* = shorter bluer wavelengths while the more distant nebulae were moving away at 1,100 km/sec. These speeds exceeded that of any known individual star in the Milky Way.

By 1923 Edwin Hubble had begun using the 100 inch Hooker Telescope at the Mount Wilson Observatory in the San Gabriel mountains north of Pasadena, CA (the largest telescope in the world at that time) to study the Andromeda Nebula M 31. He identified some stars that vary their brightness in a regular cyclic way. They followed a cyclic luminosity relationship in which the longer the period of a cycle, the more intrinsically luminous they were. These types of stars are called *Cepheid variables*. By serial photography Hubble was able to document these Cepheids over time and measure their varying brightnesses to determine their periods. He could then apply a period-luminosity relationship to estimate the distance to the stars and hence the distance to the Andromeda Nebula that contained them. By 1924 Hubble had "calculated" that the distance to the Andromeda Nebula was 900,000 light years.

Hubble then extended Slipher's work by taking long exposures of the spectra of faint galaxies. By measuring the amount of shift of specific spectral lines relative to those produced by reference arc lamps he was able to calculate values for the galaxy velocities. A few nearby galaxies had velocities that meant they were moving towards our own Milky Way, that is their lines were *blueshifted* but most exhibited redshift and hence had *recession velocities*. The majority of galaxies therefore "appeared" to be moving away from our own galaxy. Hubble found that that those with a smaller image in a photograph had higher redshifts. He assumed that these galaxies were similar to each other in size. so those that appeared smaller must be further away [another big assumption] (see Figure 5 next page). By plotting the velocity of the galaxies against their distance he came across an interesting relationship. This is now known as Hubble's law and is shown in Figure 6 (next page).

In Figure 6 note that the more distant a galaxy is, on average, the faster it appears to be receding from us. In fact Hubble realized he could fit a linear relationship to his data, as shown by the pale blue line of best fit. The slope of this line is a constant and is now known as the

10. Abridged and adapted from the Australia National Telescope Facility at https://www.atnf.csiro.au/outreach//education/senior/cosmicengine/hubble.html

Hubble constant, H_0. This relationship is expressed as $v = H_0 d$ where H_0 is Hubble's constant, v is the recession velocity and d is the distance.

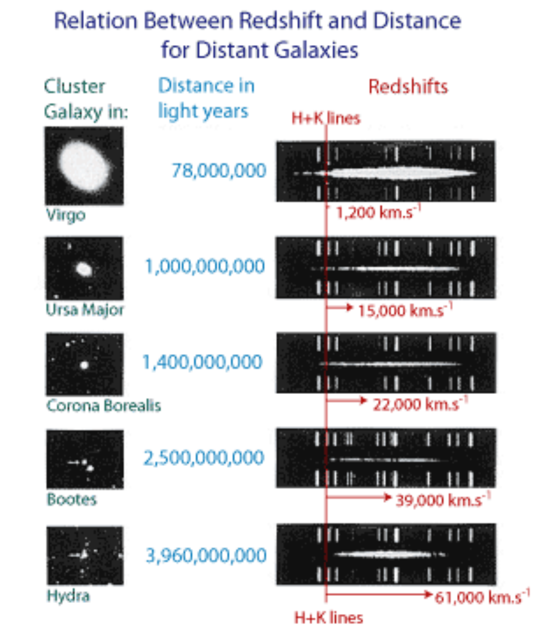

Figure 5: Hubble's observations of galaxies with the redshift in their spectral lines.

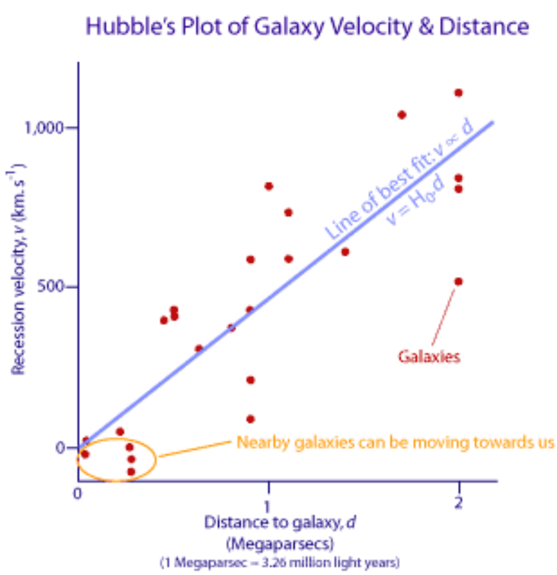

Figure 6: Hubble's distance-velocity relationship for galaxies based on his original data (published in 1929). This is now known as *Hubble's Law* and has been interpreted as evidence for an expanding Universe.

Once we look past the gravitational effects in nearby galaxies, Hubble's velocity-distance relationship suggests that galaxies are moving away from one another with the more distant galaxies appearing to be moving away faster than the closer ones. This result was interpreted by mainstream cosmologists to mean that the Universe is expanding!

"The spectra of galaxies were redshifted in agreement with the Doppler effect, and the observed linear relation between distance and red-shift, now called the Hubble law, seemed to imply large receding velocities of distant galaxies and an enormous amount of kinetic energy. These velocities also indicated that all matter originated from a dense and hot state, the "Big Bang", several billion years ago. This was recognized in 1929 by Fritz Zwicky[11] who, in order to avoid what was considered "extraordinary implications" [of a geocentric Universe], suggested another mechanism to explain the observed red-shift in which photons lose energy as they propagate through space [Zwicky's *tired light theory* due to gravitational drag]. However, working with Einstein's equations of general relativity, Friedman and Lemaître found solutions in which space was expanding. Their solutions became accepted as the mechanism producing the observed red-shifts and are today part of the current favored [academic] hypothesis of the formation of the Universe."[12]

Nevertheless, in 1935 Hubble expressed the following concern:

" ... the possibility that red-shift may be due to some other cause, connected with the long time or distance involved in the passage of the light from the nebula to observer, should not be prematurely neglected."[13]

He was suggesting that there could be other mechanisms causing light to be redshifted besides recession of the galaxies due to the *Doppler Effect*, i.e., effects from the passage of light through the vast distances of the cosmos and its interactions with space and matter.

We also need to understand that Hubble was not a believer in a Divine Creator. He believed that the Universe was the product of random chance and the laws of physics. That his measurements indicated the galaxy redshifts were proportional to their distances in all directions from earth shocked him as being quite significant. So in 1937 he wrote:

"**Such a condition would imply that we occupy a unique position in the Universe, analogous, in a sense, to the ancient conception of a central earth. The hypothesis cannot be disproved ... But the unwelcome supposition of a favored location must be avoided at all costs.**"[14]

What prompted this comment was that he believed he was seeing galaxies speeding away from him by the same proportion *in all directions*, and the more distant the faster they moved. With the redshifts interpreted as being caused by the recession speed of the galaxies, it appeared as if the earth was located in the center of an expanding Universe, i.e., a *geocentric* Universe. That would mean that the earth is unique, something special in God's creation, -- a proposition that Hubble rejected

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Dr. Seraphim Steger, Editor, The Good Word
c/o St. Seraphim of Sarov & St. John of Kronstadt Orthodox Church
6063 Lake Murray Blvd.
La Mesa, CA 91942-2506,
U.S.A.

as unwelcome purely on philosophical grounds. In 1947 Hubble was again expressing doubts about an expanding Universe and wrote that redshifts result from some *hitherto-undiscovered mechanism*.[15]

The other key point arising from the Hubble Law relation is that, if we go back in time, galaxies must have been closer together. Space was smaller. If you extrapolate back far enough the Universe must have been concentrated at one point in space. This is the big philosophical assumption of modern astronomers and physicists who hold a totally naturalistic and evolutionary view for its creation and who also champion a great age for the Universe. Thus, they assume that if H_0 provides us with a value for the current rate of expansion, then its inverse, $1/H_0$, tells us the *Hubble time* which is a measure of the age of a Universe expanding at a constant rate [another very big assumption]. Hubble calculated a value for H_0 of 500 km per second per megaparsec (Mpc). One Mpc is about 3.26 million light years. Astronomers use the parsec as the unit of distance measure rather than the light year. Using this value resulted in a calculated age of the Universe of 2×10^9 years, that is, 2 billion years.

At the time Hubble's data clashed with radiometric dating values for the age of the Earth that ranged from 3 to 5 billion years among evolutionary scientists. How could the Universe be younger than the stars or planets it contained? But in the 1950s a "*recalibration*" of the Cepheid period-luminosity relationship provided an older age for the Universe -- 10-20 billion years.

Recent projects to measure the expansion of the Universe involve a range of methods and don't rely solely on observations of Cepheids to calibrate their data. For example, the research groups of the European Space Agency's Gaia EDR3 spacecraft, measured the distances to 1.3 billion stars by parallax from the Gaia EDR3 from its perch 1 million miles high while orbiting the sun and creating a 3-dimensional map. In 2020 after measuring 75 more Milky Way Cepheids using both parallax and the Period-Luminosity relation, they recalibrated the extragalactic distance ladder and refined the determination of the Hubble constant. Adam Riess' (Johns Hopkins University) team has used the new data to calculate the expansion rate at 73.2 kilometers per second per megaparsec (3.26 million light years of distance) with a margin of error of just 1.8%.[16] That has resulted in a "recalculated age" of 13.6 billion years for the Universe among evolutionary astrophysicists.

That rate of expansion is 8% faster than the 67.4 km/sec/mpsec calculated in 2021 by Wendy L. Freedman (University of Chicago)[17] from using red giant star luminosity instead of Cepheid luminosity. This new Tip of the Red Giant Branch (TRGB) methodology has emerged as one of the most precise and accurate means of measuring distances in the local universe, yielding a similar rate of expansion as predicted by the current Lambda Cold Dark Matter (ΛCDM) cosmology model.

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