Compass Life Adult Sunday School **History of Astronomy - I** Jeff Gordon

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**Ancient Astronomy**

The physical “heavens” both reveal God’s existence as \_\_\_\_\_ and serve as a calendar to mark regular seasons (Rom 1:19-20; Gen 1:14). Ancient astronomers observed the sun (solstice and equinox), moon, planets and stars to better predict agricultural seasons – and if possible, extraordinary events like comets, “guest stars”, or \_\_\_\_\_\_\_\_ (recorded in China from c.2137 BC). People also attributed to heavenly bodies divinity or power to control (or at least \_\_\_\_\_\_\_\_\_) important aspects of present or future life on earth (astrology). (Rom 1:22-23).

The *Babylonians* kept well-preserved and detailed records of star names and positions (grouping stars into *constellations*), risings and positions of planets, etc. They used a sexagesimal (base-*60*) numbering system and wrote their observational “diaries” on clay tablets from as early as 8th C. BC. Many years of past data enabled them to make predictions of lunar and solar eclipses and proved invaluable to later astronomers.

**The Greeks**

Thales (c. 640-562) is credited for predicting the year (585) of an eclipse (which stopped a \_\_\_\_\_\_\_). Pythagoras (c. 570-495) saw the earth as \_\_\_\_\_\_\_\_\_, and the universe as defined by \_\_\_\_\_\_\_\_\_\_ (related to music: “music of the spheres”). Empedocles (c. 450) taught that the earth was made of four basic elements: earth, water, air, and fire. After Socrates (d. 399) and Plato (d. 348) had emphasized more \_\_\_\_\_\_\_ and rigorous methods of thought, Aristotle (384-322), sought to apply these to the study of nature (including biology). The earth was obviously stationary, evidently spherical (lunar eclipses, stars above horizon), and surrounded by some 55 interacting spheres which moved sun, moon, planets, stars. Unlike earth (and its moon), the “superlunary” bodies were made of a “fifth element” (*quintessence*), were *\_\_\_\_\_\_\_\_* and did not *\_\_\_\_\_\_\_\_* (comets, e.g., were atmospheric phenomena). Aristotle saw the universe as living and purposeful. Aristarchus of Samos (310-230), estimated distance to sun and relative \_\_\_\_ of the earth, moon and sun (and saw the \_\_\_\_\_ as central). Apollonius of Perga (262-190) studied conic sections and suggested deferent and epicycle to explain \_\_\_\_\_\_\_\_\_\_ motion. Erastosthes (276-194) director of library at Alexandria, accurately measured the \_\_\_\_\_\_\_\_\_\_\_\_ of the earth. Hipparchus (160-127) accurately catalogued 850 stars using instruments he created; figured distance to moon; determined length of year within \_\_\_\_\_\_\_\_\_\_\_\_; discovered earth’s precession; accurately predicted movements in solar system. Ptolemy (c100‑c170 AD) produced his 13-section astronomical Great Treatise (“Almagest”), which catalogued 1022 stars, and named 48 constellations. His was basically Aristotle’s system with refinements (like equant and epicycle) to explain observed planetary motion. It enabled better predictions of planetary positions, useful for \_\_\_\_\_\_\_\_\_\_\_\_\_. It would remain the *accepted* cosmology until the 16th C.

Julian calendar. In the 1st C. BC, Julius Caesar commissioned Sosigenes of Alexandria to solve the problem of a 10-month error in the Vernal Equinox. He figured the year as 365.25 days, so proposed adding a day every fourth year to “catch up”. 44 BC had 445 days to bring equinox to 25 March. This was 11 minutes off and needed another correction in 1582. (Adopted in England/US 1752, Russia 1918)

Aristotle’s work had been translated into Latin and brought into Europe in the 11th/12th C. and had become entrenched in both \_\_\_\_\_\_\_\_\_\_\_\_ scholasticism and \_\_\_\_\_\_\_\_\_\_\_\_\_\_ scholarship. The *Almagest* was also translated, but complex, rare, and expensive. German astronomer “Regiomontanus” produced a much clearer abridged *Epitome of the Almagest* (pub 1496) which became widely available.

**Nicolas Copernicus** (1473-1543) was born in Torun, Poland, and attended the University of Krakow, then in Italy studied Canon Law (doc. 1503) and medicine, picking up humanistic and Platonic ideas, and an avid interest in astronomy. He had been granted office as Church Canon in Frauenburg, where he served from 1512. Students (including Copernicus) had come to regard the complex system of Ptolemy as an inelegant “\_\_\_\_\_\_\_\_\_\_\_\_\_\_”. Copernicus wrote a “Short Commentary” (1514) that outlined a basic heliocentric theory (including great \_\_\_\_\_\_\_\_\_\_\_ to the immovable stars). His magisterial work, *De revolutionibus*, a product of mostly analyzing others’ observations, was not published until 1543. Copernicus had suffered a stroke and died the day a copy reached him. Osiander, who ultimately published the work, anonymously added a \_\_\_\_\_\_\_\_\_\_\_ in the preface.

**Tycho Brahe** (1546-1601) was the last great pre-telescope astronomer, and the most \_\_\_\_\_\_\_\_\_\_\_\_. A Danish nobleman, he was given considerable funding and an island on which he built his house and observatory. He used precision instruments to measure positions, proving that a “new star”, and two bright comets (1577,85) were further away than the moon; and that the comets’ orbits would have crossed the “spheres”. But he rejected Copernicus’ moving earth and came up with his own hybrid system.

**Johannes Kepler** (1571-1630) German mathematician, & astronomer, studied planetary motion and distances, in a somewhat mystical mindset. In his *Mysterium cosmographicum* (1596) he proposed using the “5 perfect solids” as ways to space the 6 known planets – sending copies both to Tycho (whom Kepler assisted briefly in Prague in 1600) and Galileo. With Tycho’s detailed observations of \_\_\_\_\_\_, Kepler knew orbits were wrong (in every system). Finally, he came up with the simple idea to use \_\_\_\_\_\_\_\_, and it worked. His *Astronomia nova* (1609), details his first 2 “laws of planetary motion”: (1) “elliptical orbits”, and (2) “equal areas”. *Harmonicus mundi* (1619) reveals law #3: “(orbital period)2 ∝ (distance from sun)3” (and revisits the “\_\_\_\_\_\_\_\_ of the spheres”).

**Galileo Galilei** (1564-1642) constructed the first \_\_\_\_\_\_\_\_\_\_\_\_\_\_-class telescope in 1609, publishing some key subsequent findings in *Sidereus Nuncius* (Starry Messenger): (1) the moon has mountains and valleys; (2) Venus shows complete \_\_\_\_\_\_\_\_; (3) Jupiter has \_\_\_\_\_\_ moons; (4) Saturn has “handles”; (5) the Milky Way is \_\_\_\_\_\_\_; (6) (1613) the Sun has spots that show \_\_\_\_\_\_\_\_\_. Galileo believed Copernicus’ system was true (not just functional). This, plus his bellicose manner, got him in trouble twice with the Church. (1) 1613-16, he was told not to teach Copernicanism as literally true. (It seemed to contradict Biblical language, and the Church was already reactionary in the wake of the Reformation). (2) Galileo published *Dialogue on the Two Chief World Systems* (1632) with permission, promising his friend Pope Urban VII that he would treat both sides evenly. Instead he puts he Pope’s words in the mouth of the \_\_\_\_\_\_ “Simplicio”. His book was banned, he was convicted of “suspicion of heresy”, publicly renounced his “errors”, and was put under house arrest. Galileo continued very important work with respect to the dynamics of falling objects, terminal velocity, and parabolic paths of projectiles, publishing *Dialogue Concerning the* *Two New Sciences* in 1638. He both believed that the world could be *\_\_\_\_\_\_\_\_* mathematically, and proposed theories needed to be *\_\_\_\_\_\_\_\_* experimentally. Pope John Paul II formally declared Galileo had been right on October 31, 1992. (His book was unbanned in 1757.)

**Isaac Newton** (1642-1727), one of the top 3 physicists of all time, set forth \_\_\_\_\_\_\_\_\_\_ theories across multiple disciplines: optics, mathematics, cosmology, astronomy and general physics. He was born prematurely on Christmas Day (“Julian”) in Woolsthorpe, England, his father having died 3 months earlier. When Isaac was \_\_ his mother remarried and sent him to live with his grandmother. (Widowed again, she briefly took him home to unsuccessfully try to run the farm at age \_\_). In 1661 he entered to Trinity College, Cambridge, \_\_\_\_\_\_\_\_\_ for tuition until he got a 4-year scholarship in 1664. He received his BA in 1665, then the school closed due to plague, and he went back home. Over the next 2 years Newton worked out breakthroughs in calculus, optics, motion and gravitation. Newton \_\_\_\_\_\_\_\_\_\_ calculus (a bit ahead of German Gottfried Lebnitz, but unpublished, and they argued over it.) He experimented with \_\_\_\_\_\_\_\_ and proved that white light was not colored by impurities in the glass, but actually broken down into real component colors that refracted at different angles. Since this “chromatic aberration” would affect \_\_\_\_\_\_\_\_, Newton designed a reflecting \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ that used a polished mirror. In April 1667 he went back to Cambridge, received his master’s degree, then in 1669, at the age of 26 became professor of Mathematics. The Royal Society elected him a fellow, and he submitted a paper on optics in 1672. It was well-received, but also criticized (by Robert Hooke in particular) which provoked Newton’s angry outburst and lifelong resentment of Hooke. (He did not publish *Opticks* until 1704 after Hooke died. He wrote to Hooke in 1676, “If I have seen further, it is by standing on the shoulders of giants” and noted his and others’ work in the *Principia*.) In 1684, Edmund Halley came to Newton with an orbital problem he, Hooke and others were unable to solve, and Newton immediately gave him the solution having already worked it out. He wrote up the answer that year, and at Halley’s insistence (plus financial backing) Newton produced his greatest work, *Mathematical Principles of Natural Philosophy* (“*Principia*”) in 1687. In Book I of the *Principia*, he outlines 3 Laws of Motion:

(1) Inertia – an object in motion will stay in motion (unless acted on by external force)

(2) The force to accelerate an object is proportional to its mass: $\vec{F}=m\vec{a}$

(3) objects exert equal and opposite forces on each other.

In Book III he lays out the simple formula for \_\_\_\_\_\_\_\_\_\_\_\_\_ gravitational attraction (force F): $F=G\frac{m\_{1}m\_{2}}{r^{2}}$

On top of his work in science, Newton served as MP and Master of the Mint, and wrote some dubious Bible commentaries. Interaction with the work of others was more essential to his scientific discoveries than he or others often acknowledge. But Newton had put it all together. Newton’s simple and elegant laws of mechanics and gravity would guide physics and astronomy for the next 200 years.