Early Views of the Solar System

- General Greek Principles of Science
    - Nature can be understood
        - Not just randomly occurring phenomena
    - The diverse behavior observed in nature is held together in patterns that are orderly
    - Tendency to "Save the Phenomenon."
        - Anthropic principle; Goldilocks principle; Fine tuning
        - We're in the perfect place to observe everything.
- Euclid – 600 BC
    - What he got right
        - Predicted solar eclipses
        - Moon shines due to reflected sunlight
        - Universe explainable by ordinary knowledge and reason
    - What he got wrong
        - Thought earth was a flat, rotating disk.
- Pythagoras – 530 BC
    - First to suggest that Earth is a sphere.
    - One of the earliest advocates of a geocentric solar system
        - Earth at center, surrounded by system of concentric, rotating, transparent spheres.
        - Bodies attached to spheres in this order:
            - Moon, Mercury, Venus, Sun, Jupiter, Saturn, Stars.
- Philoaus – 410 BC
    - Suggested Earth moves around a central fire
    - Not the sun
    - What were his new ideas?
- Aristotelian Universe – 340 BC
    - In ancient times, philosophers argued from **first principles**, things that were accepted as obviously true.
    - First: The earth is round
    - Gave 4 reasons for roundness:
        - Symmetry: The sphere is a perfect shape.
        - Elements have their natural places: Earth's pieces fall naturally to Earth's center, pressing it into a spherical shape (circular reasoning).
        - Shadow: Lunar eclipse shadow (Earth's shadow on Moon) is always circular (what if Earth was a circular disk?)
        - North Star: Polaris gets higher in the sky the further north one goes.
    - Second: the earth was located in the center of the cosmos
    - Third: the heavens were perfect, the earth, imperfect
    - All the cosmos traveled in perfect circles around us
    - Plato pushed this, his student, Aristotle adopted it

    - He gave us the Aristotelian way of looking at the cosmos.
    - Geocentric universe with all the heavenly objects moving in uniform circular motion
    - Aristotelian concepts dominated ancient ideas about the universe for thousands of years
    - Two major themes:
        - Our place in the cosmos (center)
        - The character of planetary motion (uniform circular motion)
- Aristarchus – 240 BC
    - Rotation of earth on its own axis accounts for daily motion of stars
    - Earth revolves around Sun in a yearly orbit
        - He had it right before 200 BC. But his ideas failed to catch on.
- Eratosthenes – 235 BC
    - Calculated earth's radius to within about 5% accuracy
    - Basic method
        - Measured shadow lengths at two different cities directly North-South of each other (Syene and Alexandria)
        - Calculated Earth's circumference and radius using geometry
        - Central angle = 7.5 degrees, 500 miles from A to S, times 48 = 24,000 miles;
        - Actual angel = 7.2 degrees, 500 mi X 50 = 25,000 miles.
- Ptolemy – 120 AD
    - Great ancient astronomer of the 2^{nd} century
    - Wanted to put it all this orbital motion into a mathematical model
    - Final effort to "Save the Phenomenon"
    - No significant changes for 1200 years.
- Why did they think we were in center anyway.
    - Popular worldview
    - The Sun *appears* to rise, transit the sky, and set
    - It doesn't *feel* like we are moving
- Parallax
    - The apparent motion of an object because of the motion of the observer.
    - If we were going around the sun, the background stars should change position.
    - They do, but not a lot since they are so far away.
- Planetary motion was difficult for the ancients to explain
    - Planets (wanderers) would suddenly backtrack
        - Called retrograde motion.
- Ptolemy tried to explain retrograde motion with epicycles on deferents
    - all in an attempt to keep the Aristotelian (geocentric) view of the cosmos.
- Copernicus – 1500 AD
    - Polish monk; **re**discovered the heliocentric model of the universe
    - But being for heliocentrism was being against Aristotle, and against the church.

    - Finished in 1530, Copernicus wrote De Revolutionibus, but didn't give permission til he was dying.
    - Most important idea was putting the sun at the center
    - With the sun at the center, the whole universe was simplified and elegant, and could explain things like retrograde motion
    - We, moving faster on the inside, see other planets 'seem' to move backwards
    - Copernicus insister in circular orbits, so he had to come with his own epicycles so it worked better (elliptical)
    - His model was incorrect but his hypothesis with the sun in the center was correct
    - But without a telescope, it couldn't be substantiated with evidence.
    - And his circle obsession meant it couldn't predict things very well.
    - It upset people because their whole universe changed, so it wasn't accepted for a long time.
- Tycho Brahe – 1500s
    - Greatest pre-telescopic observational astronomer.
    - In 1572 he saw a supernova which he called a new star.
    - So the new star challenged Ptolemy and Aristotle
    - Brahe wrote a book on it called De Stella Nova
    - Danish king gave his place to build observatory.
    - Here Tycho shows off the latest mural quadrant with tools like there he observed the heavens and took over 20 years of data (without telescopes)
    - Earth was at the center, but all the other planets went around the sun.
- Kepler – 1600s
    - Copernican; wrote a book *Mysterium Cosmographicum* which tried to prove that planets were solids with spacers
    - Discovered that Mars moves in an ellipse, not a circle and that it travels at different speeds.
    - Wrote about this in *The Harmony of the Worlds*
    - Led to his three fundamental laws of planetary motion
        - First law relies on the ellipse
            - An oval drawn around two points
            - Points called foci
            - Semimajor axis (a) = half the longest diameter
            - Eccentricity (e) is half the distance between the foci divided by the semimajor axis.
            - A circle is an ellipse with e = 0
            - Greater e → more elliptical
            - States that all planets travel in ellipses with the sun at one focus.
        - Second law (Equal Areas-Equal Times)
            - States that planets sweep out equal areas in equal times
            - Translation: they go faster when closer to the sun because of gravity.

        - Third Law states that the closer a planet is to the Sun the shorter its 'year.
        - Equation T^2 = R^3 (T = time; R = avg distance between the planet and the sun). Distance has to be expressed in AU; time has to be corresponding time for earth (1 year)
    - Kepler never knew why his laws worked, just that they did.
- The Rudolphine Tables
    - Finished the tables in 1627
- Galileo Galilei
    - Telescope that pushed him over the top; it was a recent invention to examine the sky and gather evidence for the heliocentric view.
    - Discovered that the moon was not perfect; wasn't a perfect sphere
    - A lot more stars than people thought.
    - The Milky Way and the rest of the heavens is substantial, like the earth, not ethereal.
    - He saw four little 'stars' near Jupiter that were orbiting Jupiter. So not everything orbits either. If Jupiter can move and take its moons with it, so could earth.
    - The sun has spots (it's not perfect) and that it rotated.
    - He observed that Venus went through phases…it can only have phases if it goes around the sun.
- The birth of Modern Science
    - Nothing more than a logical way of observing, studying, or thinking about nature
    - Scientific method was developed by Roger Bacon in 13th century
    - Cause and effect. 17th century, Francis Bacon
- Isaac Newton and Orbital Motion