3. The (other) wandering stars or planets known before 1781: Mercury, Venus, Mars, Jupiter, and Saturn
    a. Mercury and Venus always near the Sun, reaching "maximum elongations"
    b. Mars, Jupiter, and Saturn not so constrained: conjunctions and oppositions
    c. Mars in opposition every 780 or so days, Jupiter every 400 or so days, and Saturn every 380 or so days
4. Primary motion of each of the planets is again eastward, with some variability, along the zodiac, but each wanders north and south of the ecliptic
    a. Division of the motion into two components: longitudinal motion along the ecliptic, and latitudinal motion perpendicular to it
    b. Each planet's latitudes are separate from all the others, but no planet visible to the naked eye ever wanders very far from the ecliptic: no more than roughly 9 deg
5. Each of the planets has its own distinctive period for completing one circuit with respect to the fixed stars, which the Babylonians had determined to high precision several centuries B.C.
    a. Mean motion -- average number of eastward degrees per day -- varies from planet to planet
    b. Mercury fastest, then Venus, Mars, Jupiter, and Saturn, with the Moon faster than Mercury, and the Sun between Venus and Mars

C. The Problem of the Planets

1. In addition to their normal eastward motion, the five planets also on regular occasions exhibit "retrograde motion" -- a daily westward motion
    a. Appear to come to a stop, reverse direction for a few days, then again stop and resume their normal motion, describing “loops” as shown in the NASA photographs for Mars in Appendix
    b. E.g. time between two consecutive beginnings of retrograde motion for Mars is roughly 780 days, for Jupiter roughly 400, and for Saturn around 380
    c. Graphical display in the Appendix exhibits the pattern for Jupiter over one ancient period
2. Points at which planets appear to come to a stop are called "stationary points", with planets speeding up and slowing down in between
    a. Points at which motion reverses, with a certain number of days between consecutive points
    b. Another prediction -- i.e. calculational -- problem of ancient astronomy: not just when retrograde motion begins on the average, but also the variations from one case to another
    c. Mean time of return to e.g. stationary point at beginning of retrograde motion called the “synodic period” because it involves longitudinal relationship of planet to earth and sun
    d. Babylonians had also worked out the synodic periods of all of the visible planets several centuries B.C.
3. A basic regularity to the pattern -- e.g. 780 days between periods of retrograde motion for Mars, with roughly the same number of days of retrograde motion in each loop

a. But marked variations within this pattern, and hence different loops from one occasion to another: e.g. 760 days one time, 775 another, etc.

b. Planetary speeds vary too: e.g. roughly 40 percent variation in apparent longitudinal motion per day of Mars from one extreme to another while away from retrograde

4. Each of the five planets has its own distinct basic pattern of periods of retrograde motion, and its own distinct pattern of variations on this basic pattern

a. Can be seen in examples of Mars and Jupiter, where loops vary

b. An anomaly on top of the anomaly of retrograde motion

c. Well before 300 B.C. the Babylonians had discovered "great cycles" in which the patterns of retrograde loops and timings of stationary points repeat: e.g. 71 years for Jupiter (see Appendix for others)

5. The problem of the planets: give an account ('***logos***') of retrograde motion, including basic pattern, size of loops, and variations for each of the five planets

a. Not to predict longitude and latitude every day

b. Focus instead on salient events – i.e. ***phenomena***: conjunctions, oppositions, stationary points, longitudinal distance between them

c. For the Babylonians, just predict; for the Greeks, to give a geometric representation of the constituent motions giving rise to the patterns

6. Classical designations: "***the first inequality***": variation in mean daily angular speed, as in 40 percent variation for Mars and smaller variation for Sun; "***the second inequality***": retrograde motion, as exhibited by the planets, but not the sun and moon

D. Classical Greek Solutions

1. Various classical solutions to the problem, but with epicylic theory coming to dominate for the second inequality in the 3rd century B.C.

a. No evidence of motion of earth, hence reasonable to conclude that retrograde motion arising from motion on a second circle -- i.e. an epicycle, the center of which moves along a circle called the "deferent"

b. Epicycle consistent with planets being brightest during retrograde motion

c. Aristarchus in 3rd century B.C. the one notable exception, who had the earth and the five planets going around the sun

2. In 4th century B.C. Eudoxus had devised a system of nested homocentric spheres in response to the problem -- see Aristotle, *On the Heavens* and quote from *Metaphysics* (Lambda) in the Appendix

a. Basic idea of solid spheres retained in epicycle theory

b. But with spheres rotating on rotating spheres instead of nested homocentric spheres

3. Most of what we know about Eudoxus's solution comes either from Aristotle (or from modern efforts to recreate it on the basis of what Aristotle says