Astronomy 301

CLASSNOTES 5

KEY TOPICS FROM CHAPTERS 4 and 5

Keep an eye on the astronomy, not the details of the historical order of events, names, and idiosyncrasies of the major players.

The absence of a measurable parallax led to the false conclusion that the Earth did not move. An equally valid conclusion is that the Earth moves around the Sun but the stars are at such large distances that no stellar parallax is observable unless very precise measurements are made of stars' positions.

Consider Ptolemy's model of the solar system and imagine yourself face to face with him: how would you without a telescope try to persuade him of the falseness of his views -- or at least persuade him that there was a viable alternative?

Why did Copernicus prefer his heliocentric model of the solar system? Why is it a superior model to Ptolemy's? Note how the heliocentric model explains retrograde motion in a straightforward way (Figure 4-9). Take time to understand this figure.

Copernicus placed the Sun at the center of the solar system. He assumed planets made circular orbits around the Sun. From this starting point, **three** important results followed:

- a ready explanation for the retrograde motion of superior planets.
- estimate of a planet's sidereal period from an observation of its synodic period.
- the relative sizes of planetary orbits.

NOTE: Seeds does not mention the second two results.

Brahe was a fascinating character, but his major contribution to our story was his 20year record of observations of positions of stars, Sun, and planets. Note too his work on the supernova of 1572.

Kepler took Brahe's observations and deduced the basic properties of planetary orbits for the first time. His predecessors had assumed orbits (and epicycles) were circular. Kepler showed orbits were elliptical. Note Kepler's law of planetary motion. How did Kepler derive these laws?

Galileo Galilei was the first astronomer to use a telescope. He discovered the phases of Venus -- be sure you can explain why this was the death knell for the Ptolemaic

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solar system. (Ptolemy and friends understood the origins of the Moon's phases.) He discovered the Jovian satellites. (Why did this make Ptolemy's supporters uncomfortable?) Galileo discovered sunspots and observed the lunar surface. (Why did these discoveries upset some people?) Galileo also, I think, estimated the average distances between stars from the assumption that the stars and the Sun were about equally luminous. Galileo's conclusion led Pascal (1623-1662) to remark:

[I feel] engulfed in the infinite immensity of spaces whereof I know nothing, and which know nothing of me, I am terrified.... The eternal silence of these infinite spaces alarms me.

Newton provided the key to the mechanism behind the solar system. To do this, he had to develop first his three laws of motion (Table 5-1). Today these -- certainly the first one -- seem to be common sense, but this was not so in the seventeenth century.

Newton's First Law

Unless a force acts, an object continues at rest or moves at a constant velocity in a straight line.

Newton's Second Law

Application of a force leads to an acceleration -- a change of velocity, a change of direction, or a combination of the two. Newton's Second Law of Motion may be written as:

Force = Mass x Acceleration

The acceleration is proportional to the force and in the direction of the force.

Orbital motion is a continuous acceleration. What, Newton asked, is the force causing this acceleration? He 'invented' the force of gravity to explain the fall of an apple to earth, the motions of the Moon and planets, etc.

Note the **law of gravitation**:

$$F = G \frac{Mm}{r^2}$$

With this law, Newton could show quite readily that planets had to obey Kepler's three laws. With the law of gravitation one could predict the future positions of planets to great accuracy. When much later the orbit of Uranus showed it departing from the predicted one, it was supposed that an even more distant planet was pulling Uranus out of its predicted orbit. The position of this planet -- Neptune -- was predicted and the planet found on the basis of these predictions. This was a triumph for gravitation.

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The orbit of Mercury, however, was not predicted correctly by Newton's law of gravitation. This failure was a factor that led Einstein to develop his 'General theory of relativity.'

Measuring the Sun's Mass

The Sun, the principal mass in the solar system, exerts a force

$$F = G \frac{M_{Sun}M_{planet}}{r^2}$$

on the planet where r is the radius of the planet's orbit. (The planet exerts an equal force on the Sun.) The planet's response to this force -- its acceleration -- is

$$a = \frac{F}{M_{planet}}$$

by the second law of motion. You will see that the mass of the planet appears top (in F) and bottom of this equation:

$$a = \frac{1}{M_{planet}} G \frac{M_{Sun}M_{planet}}{r^2}$$
$$= G \frac{M_{Sun}}{r^2}$$

Galileo faced the Inquisition because of a conflict between two ways of knowing and understanding the world. The Church taught faith and understanding through revelation, but the scientists of the age were inventing a new way to understand nature that relied on evidence. In astronomy, evidence means observations, so our story turns now from the philosophical problem of the place of the earth to the observational problem of the motion of the planets.

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Does this imply that science will ultimately leave no place for religion?

Religions die when they are proved to be true. Science is the record of dead religions.

Oscar Wilde (1854-1900)

Religion is a way of life and an attitude to the universe. It brings man into closer touch with the inner nature of reality. Statements of fact made in its name are untrue in detail, but often contain some truth at their core. Science is also a way of life and an attitude to the universe. It is concerned with everything but the nature of reality. Statements of fact made in its name are generally right in detail, but can only reveal the form and not the real nature of existence. The wise man regulates his conduct by the theories both of religion and science. But he regards these theories not as statements of ultimate fact, but as art forms.

J.B.S. Haldane (1892-1964)

Science without religion is lame, religion without science is blind.

Albert Einstein (1879-1955)

The means by which we live have outdistanced the ends for which we live. Our scientific power has outrun our spiritual power. We have guided missiles and misguided men.

Martin Luther King (1929-1968)

So, the planet's acceleration and, hence, the time it takes the planet to orbit the Sun depends on the mass of the Sun and the radius of the orbit but **not** on the mass of the planet. If we can measure the radius of the orbit, we can with a little algebra derive the mass of the Sun.

How might we determine the mass of the planet?