

SPASH ASTRONOMY

CHAP. 3: DISCOVERING THE LAYOUT OF THE SOLAR SYSTEM OVERHEAD LECTURE NOTES

1. What is the solar system?

We now conceive the solar system as the Sun and all the planets orbiting around it with their satellites, together with innumerable, small interplanetary bodies, called asteroids and comets, also orbiting around the Sun.

2. What were two important clues that Mercury and Venus were closer to the Sun than the Earth?

1). Mercury never strayed more than 28 degrees from the Sun and Venus never strayed more than 47 degrees. This means that Mercury and Venus are always fairly close to the direction of the Sun. All other planets can appear at any angular distance from the Sun along the zodiac. Because Mercury and Venus are closer to the Sun they came to be called inferior planets, while more distant planets are called superior planets. (Figure 3-1 page 53)

2). Ancient astronomers observed actual transits, or passages of an inferior planet directly between the Earth and the Sun. Mercury is too small to see without a telescope but transits of Mercury are more common. The next transit of Mercury is May 7, 2003 and the next transit of Venus June 8, 2004.

3. What is retrograde motion?

Observers found that as Mars approaches a point opposite the Sun in the midnight sky, it slow down, reverses itself, and drifts westward in so-called retrograde motion for some days before resuming its normal eastward (prograde) motion. (Figure 3-2 page 54)

4. What was the main problem with the Ptolemaic Earth centered model of the solar system that Ptolemy perfected back in 140 A.D.?

The main problem was new epicycles had to be added to make positions agree with observations, and the calculations became even more complicated.

William of Occam (1340 A.D.) enunciated his famous principle, called Occam's razor, which states:

Among competing theories, the best theory is the simplest theory - that is, the one with the fewest assumptions. I call it K.I.S.S. (Keep It Simple Stupid).

5. What was the Copernican revolution?

The Copernican revolution was an intellectual revolution that abolished the old theory of an Earth-centered universe with the discovery that the Sun is at the center of the solar system, with Earth moving around it. This revolution took place from roughly 1540 to 1690 (150 years).

6. Write at least three interesting facts about Nicholas Copernicus (born: 2/14/1473):

- 1). He was the son of a Polish merchant.
- 2). He made his first astronomical observations at age 24.
- 3). At age 31 he observed a rare conjunction that brought all five known planets as well as the Moon into the constellation of Cancer.
- 4). In 1512 he circulated a short comment containing the essence of his new thesis: The Sun is the center of the solar system, the planets move around it, and the stars are immeasurably more distant.
- 5). He continued his studies but, fearing controversy, delayed publication for many years. Late in life, Copernicus prepared a synthesis of all his work, *De Revolutionibus* (On Revolutions, 1543). In this book he laid out and explained the evidence about the solar system's arrangement.

"Although this may appear incomprehensible and contrary to the opinion of many, I shall, if God wills, make it clearer than the Sun, at least to those who are not ignorant of mathematics."

He was ill in his last year, and the first copies of his book were reportedly delivered to him on the day of his death, in 1543, at age 70.

- 6). In 1616, the Catholic church banned reading of *De Revolutionibus* "until corrected".

7. What did Giordano Bruno do to deserve being burned at the stake?

About 1584, Bruno, a 36 year old Italian theologian and naturalist, vigorously defended the Copernican view. Bruno expanded on the Copernican cosmology. The stars, he said, were all worlds like the Sun. Many planets might orbit around them, offering abodes for other races. In 1592, he was arrested by the Inquisition, a church court established to detect and punish heresy. In 1600, after eight years of investigation of his philosophical and political views, he was burned at the stake.

8. Name at least two interesting bits of information concerning Tycho Brahe (1546-1601):

1). Brahe was a flamboyant naturalist who wore a silver nose to cover a dueling mutilation and he died painfully over 11 days from a bladder that burst during a banquet.

2). With funds from the king of Denmark, he built the first modern European observatory, named Uraniborg (Sky Castle), at his island home near Copenhagen.

3). By demonstrating that stars and other bodies show no angular shift in position as our position shifts with rotation of Earth, Tycho proved that stars and planets were many times farther away than the Moon, for which he could detect a shift (called parallax).

4). His pension withdrawn by the king of Denmark, Tycho moved to Prague in 1599, where he was joined in 1600 by a 30 year old assistant named Johannes Kepler.

5). When Tycho died in 1601, Kepler inherited the great compendium of Tycho's observation, with all its potential for fruitful analysis.

9. Name at least two interesting bits of information concerning Johannes Kepler (1571-1630):

1). With Tycho's material, Kepler found after all the centuries of debate over the arrangement of circular orbits, the orbit that fitted Mars' motion best was not a circle at all, but an ellipse. Kepler found that Mars' orbit is an ellipse that is almost circular and that the Sun lay exactly at one focus.

2). Kepler published his three laws of planetary motion in two books, New Astronomy (1609) and The Harmony of the Worlds (1619). The three laws of planetary motion are:

1). Each planet moves in an ellipse with the Sun at one focus.

2). The line between the Sun and the planet sweeps over equal areas in equal time intervals.

3). The ratio of the cube of the semimajor axis to the square of the period (of revolution) is the same for each planet. (This is sometimes called the harmonic law.) The semimajor axis, or average distance from the Sun to the Earth's elliptical orbit, is one astronomical unit.

$$a^3/p^2 = (a \text{ AU})^3/(1 \text{ y})^2 = 1/1 = 1.00$$

3). Note: Although Kepler found the orbits of the planets to be ellipses, he found them only slightly elliptical - that is, they are nearly circular. (My note: That is what probably threw off earlier observers.)

4). In explanation of retrograde motion Kepler's laws taken together state: is that any planet moves faster than any other planet farther away from the Sun. Thus Earth moves faster in its orbit than Mars. Therefore, Earth catches up to Mars like the faster driver on the inside track at a race.

19. State at least two interesting bits of information concerning Galileo Galilei (1564-1642):

- 1). He was an Italian scientist who perfected the telescope and began astronomical observations with it in late 1609.
- 2). In 1610 he had made some of the most important observations ever. For example, he found four satellites revolving around Jupiter - proving at last that some bodies do not revolve around the Earth. Also, he found that the planet Venus undergoes a variety of phases, from crescent to nearly full. In Ptolemaic theory, Venus could only have crescent phases, so here was proof that the Ptolemaic model of Venus' orbit was wrong.
- 3). He saw mountains on the moon, and emphasized that the Moon was a world, with geological features, like Earth. And he saw spots on the Sun, showing that these were not polished celestial orbs, as the ancients surmised.
- 4). In 1632, Galileo's great book Dialogue of the Two Chief World Systems appeared where he featured a fictionalized debate between Copernican and Ptolemaic advocates.
- 5). In 1633, 69 year old Galileo was ordered to Rome to stand trial before the Inquisition. The Inquisition jurors were inclined to be lenient only if Galileo repudiated his work.
- 6). The elderly Galileo saw no point in getting himself killed; his book was already published, and he had faith that intelligent people could see the truth through telescopes or in print. So he recited a prepared recantation and was sentenced to prison, a sentence commuted by the pope to house arrest on Galileo's own estate, where he died in 1642.
- 7). In 1757, Galileo's book was removed from a list of books banned by the Catholic church. In 1983 Pope John Paul II took up Galileo's case, and in 1992 he formally proclaimed that the Catholic church had erred in condemning Galileo.

If you want to get a real taste of Galileo's life read Galileo's Daughter.

11. State at least three interesting bits of information concerning Isaac Newton ((1642-1727):

- 1). Newton is the man usually deemed the greatest physicist who ever lived.
- 2). Between the ages of 23 and 25 he almost single-handedly developed calculus, discovered the principle of gravitational attraction and certain properties of light, and invented the reflecting telescope. Newton once said that he made his discoveries "by always thinking about them, "a trait that no doubt contributed to his reputation for absentmindedness.
- 3). At age 41, Newton began writing his famous Principia, a revolutionary compendium of physics, and published it three years later in 1687. He became president of the Royal Society at 60, died at 84 in 1727, and was buried in Westminster Abbey.

4). In 1666, as he sat alone in a garden, he fell into a speculation on the power of gravity: that as this power is not found sensibly diminished at the remotes (height) to which we can rise, neither at the top of the loftiest buildings, nor even on the summits of the highest mountains, it appeared to him reasonable to conclude that this power must extend much farther than was usually thought; why not as high as the moon, said he to himself?

5). Newton's law of universal gravitation. Every particle in the universe attracts every other particle with a force proportional to the product of their masses and inversely proportional to the square of the distance between them.

6). Newton's three laws of motion.

1). The law of inertia. A body at rest stays at rest, and a body in motion moves at constant speed in a straight line unless a net force acts on it.

2). $F = ma$ For every force acting on a body, there is a corresponding acceleration proportional to and in the direction of the force and inversely proportional to the mass of the body.

3). For every action there is an equal and opposite reaction.

7). It is possible to derive all three of Kepler's laws from Newton's laws. This exercise shows that if Newton's laws are true, the Copernican theory and Kepler's laws also have to be true. Thus Newton's laws completed the Copernican revolution.

8). By the time of Newton's death, at age 84 in 1727, the solar system was conceived essentially as we see it today, lacking only the discovery of the three outer planets.

12. What is Bode's rule (1772)?

Write down a row of 4's, one for each planet, and add the sequence, 0,3,6,12,24, and so on, doubling each time. By dividing the sums by 10, you get the number a AU's between each planet and the Sun. This is a handy way to remember planetary positions.

Bode's rule was strengthened with the discovery of Uranus at its predicted position in 1781. But the discovery of Neptune in 1846 and Pluto in 1930 were off using his rule.

