Spring 1974

Theories on Planetary Motions

Jerry Thomason

Ouachita Baptist University

THEORIES ON PLANETARY MOTIONS

Honors Special Studies
Spring, 1974

Jerry Thomason

TABLE OF CONTENTS

PREFACE

Anyone who has gazed into the starry sky with awe and amazement has often wondered what holds things together, where space ends and if there is no end, what wonders are beyond. The planets that are contained in this solar system and the growth of theories of the causes of the motions of these bodies are just some of the many wonders that a person can research.

In this work, I have intended to trace more or less a history of man's theories that govern the motions of the planets. I must admit that I will not cover by far all the theories of the growth of theories in this paper, but I will treat those that, to me, had the greatest influence on the generation preceding and including our time of modern astronomy.

GENERAL INFORMATION

The motions of the planets are dominated by the sun. The sun is essential. This solar system depends on the sun for radiant energy. It is also the bond that holds the bodies that we are in direct relation with, on their prospective courses. The sun comprises 99.87 percent of the matter in the solar system.[1] It is this great mass that causes the sun to be such a gravitational glue. If somehow the gravitational force of the sun could be turned off, each planet, asteriod, and comet would move away in an essentially straight-line path: the solar system would adjourn once and for all.[2]

Our earth is one of mine planets that are dominated by the sun. Mercury and Venus are closer to the sun than the earth and the others are farther away. All nine travel in the same direction and very nearly in the same plane (the plane of the sun's equator).

Unlike a star, which burns, creating light, the planets reflect light. Also stars are gaseous bodies with tremendous heat. The planets are much smaller than stars and are cool, hard, compact bodies.

"Planet" comes from the Greek word "planetos" which means "wanderer". They are so-called because they move in such a manner that was difficult for the Greeks to explain.

The nine planets are generally classified in either one of two ways. They are grouped either by reference to the earth or by reference to the asteroid belt that lies between Mars and Jupiter.

When the earth is the reference point the planets are termed as being inferior or superior. Inferior would be the planets that lie between the earth's orbit and the sun. There are two such planets: Venus and Mercury. Superior planets orbit the sun in paths that lie outside the earth's orbit.

Planets can also be classified by their physical nature. The first four (Mercury, Venue, Earth and Mars) are sometimes called the terrestial planets. This is because they are very similar to the earth. They are comparatively small in size, have a high average density, rotate slow, and have few or no satellites.

The other planets (except Pluto) are termed the "Jovian" planets because they are similar to Jupiter. These planets lie on the other side of the asteroid belt. They rotate fast and have many satellites. They are large in size and are low in average density.

Pluto is classed by itself. It is sometimes referred to as the enigmatic planet. It is smaller and rotates slower than other Jovians. It is believed to have been a satellite of Neptune eons past.

OBSERVED CHARACTERISTICS OF THE PLANETS:

Planets do not appear in all parts of the sky,. They are close to the ecliptic within the zodiac. Only Mercury and Pluto vary significantly and this is only be a few degrees. As the planets move through the skies in their daily flight, they appear to move like the stars in an east to west motion. The complication factor in the analysis of the planetory motions is that their apparent wanderings in the sky resulted from the combination of their own motions and the earth's orbital revolution.[3] All have a westward diurnal motion with the stars, and all move gradually eastward among the stars until they return to approximately their original positions.[4]

The motion of the planets on their orbital paths are not uniform. Occasionally the planet appears to move in the opposite direction. It retrogresses. The earth catches up with and passes the planet and as the earth speeds on by the planet appears to move in retrograde motion.

The planets are also associated with a particular time unit known as the synodic period. This is the length of time that a planet appears in the same position in the zodiac. It is the length of time required for the fast-moving planet to gain a lap on the slower-moving one.[5] Because of each planets own speed in its orbit around the sun, each planet has a different synodic period. Each planet's synodical revolution, in relation to the earth, in days are: Mercury, 116; Venus, 584; Mars, 780; Jupiter, 399; Saturn, 378; Uranus, 370; Neptune, 367; Pluto, 367.[6]

The three main features of planetary motion which call for explanation are (1) location near the ecliptic, (2) direct and retrograde motion, and (3) synodic periods.[7]

All theories that have been proposed by man have had agreement on the first feature. The downfall of a theory is the result of observations of the last two features. As observations increase throughout the ages, dissention over the last two features would cause a theory to become irrelevant.

GREEK THEORIES

The Greeks were forerunners of scientific thought and methodology. Aristotle was their leader. His theory to explain the apparent motions of the heavens was based on a two-sphere universe concept. The earth and moon was one sphere with the earth at the center and the moon on the surface. The other planets and heavenly bodies were confined to the outer sphere. His theories were greatly expanded by his contemporaries in the Greek world. These students of both Aristotle and Plato used the step by step approach of modern scientific methodology. Aristotle must be counted as the most comprehensive and influential cosmologist of the ancient world.[8]

Eudoxus was the first to expand the Greek theories of spheres. He did this around the fourth century B.C. He was the pupil of Plato and his theory was a central feature of Aristotle's world-picture which was the next, more general version of the Ptolemaic system.[9]

In Eudoxus' planetary system each planet was placed upon the inner sphere of a group of two or more interconnected, concentric spheres whose simultaneous rotation about different axes produced the observed motion of the planet.[10] Two or three spheres can approximately represent the total motion of the sun and of the moon, but they cannot account for the retrograde motions of the planets, and Eudoxus' greatest genius as a geometer was displayed in the modification of the system that he introduced in treating the apparent behavior of the remaining five planets.[11] He kept expanding the spheres until his theory was composed of 27 transparent spheres. They were centered on the earth and each turned at its own uniform rate around a given axis.

One sphere carried the stars from east to west. Combinations of others represented motions of the sun, moon, and the known planets. A given planet was attached to the equator of a sphere which turns around its poles; the poles of this sphere in turn were attached to a second bigger sphere which turned at another rate around its two poles; and so on.[12]

Similar theories extended the version of Eudoxus. Calliphus was one, and even Aristotle composed a theory which consisted of 55 spheres. Heraclides asserted that the earth rotates from west to east daily and also that Mercury and Venus move around the sun.[13]

According to the Greeks were next in the heavens to the "Primum mobile" (the prime mover).[14]

Aristarchus was the first to use a heliocentric theory. He held the opinion that the sun was the central body about which the earth moved in its orbit, but was unable to support his theory by convincing argument. He thus had few followers and his theory fell into oblivion.[14]

The concentric sphere theories were inadequate for astronomers. The spheres would be invariant in distance from the earth. But planets appear brighter and therefor seem closer to the earth, when they retrogress.[15] The theory failed to explain this change of brightness during the synodic period.

THE THEORY OF EPICYCLES

Since the Greeks were persistant in their belief in the geocentric universe they had to devise additions to their theories. Such a theory was the theory based on Epicycles and deferents. This new mathematical mechanism for the planets consists of a small circle, the epicycle, which rotates uniformly about a point on the circumference of a second rotating circle, the deferent.[16]

This concept was lain by Apollonius in the latter half of the third century B.C. Hipparchus added to the theory. Ptolemy's Almagest has the works of Hipparchus. Hipparchus is not only renowned for his epicycle theory but he also made a legacy of his observations. Ptolemy inherited this legacy to form a highly satisfactory geocentric theory of the motions of the bright planets.[17]

The complete theory of the Epicycles is a joint result of Appollonius, Hipparchus, and Ptolemy.

THE PTOLEMAIC SYSTEM

The following lay the foundations of the Ptolemaic System: (1) The earth is stationary; (2) the earth is the center; and (3) the celestial bodies move in perfect circles at a constant speed.

These assumptions can be reconciled. The moon and sun revolve easterly around the earth. The moon requires 27.3 days and of course the sun requires a year. The movements of the planets are explained by the use of epicycles and diferents, to explain the retrograde motions.

There are a number of reasons why the Ptolemaic Theory lasted for so long. The main reason is that it accounted for the movement of the universe. Following Ptolemy there was an era of non-progress in Astromonu. The Ptolemaic system was kept alive by the Moslems. They translated the theory so more people could read and understand the theory.

THE COPERNICAN REVOLUTION

A period of transition dominated the world around the

14th century known as the Renaissance. This period revealed a rediscovery of the classical Greeks. Thus a learning by reason instead of revelation began to come about. Man must turn to nature. This brought about a contrast to old ideas that the home was unique, big, and firm and the sky was little, far away, etheral and used to tell time and fortune. New thoughts abounded everywhere. People were outward. The voyages of discovery, around 1500, extended man away from home. Magellan proved that there was no central geographic location. This period of Reformation destroyed Rome as the center of Christian thought.

Nicolaus Copernicus developed a new theory out of this transition period. He was born in 1473 in Poland and in 1543 his work, De Revolutionibus Orvium Coelstium, was published the same year he died.

These are the Assumptions made by Copernicus; (1) the celestial sphere is stationary, (2) the sun is the center of the universe, and (3) celestial bodies move in perfect circles at constant speeds.

What led Copernicus to make this daring statement that the earth was not the center of the universe? People believed that God put them on the earth because the universe was centered around it.

Copernicus was only looking for a theory that would make the motions of the heavens coordinated with a theory that was simplier.

His theory states that the earth rotates daily from west to east. It also revolves annually in an orbit around the sun. Planetary retragrade motions are explained simpler. He puts a new definition on the sidereal day. He also says that the stars are fixed. He did not throw away the use of epicycles. He used them to explain retrograde motions and to represent noncircular motion at variable speeds. The use of epicycles did not disappear until Kepler, 10 years later.

Why was Copernicus' system accepted over Ptolemy even though both are adequate to explain the motions?

The main reason is simplicity. Copernicus was able to satisfy himself that the planetary loops and the change in intensity of light could be explained without the complicated machinery of epicycles.[18] According to Copernicus, the motion that Ptolemy had explained with major epicycles was really the motion of the earth, attributed to the planets by a terrestial observer who thought himself stationary.[19] If the earth was allowed to rotate, retrogression and the change in brilliancy can be easily explained. All scientists agree that the epicycle theory is a wonderful scientific theory; in other ways, it is a nightmare. After all, the scheme is intended as a descriptive one- that is, a device to make it easiér to rememver and predict the motions. One begins to wonder whether the motions are not more simple when they are considered just as they are, rather than with such a complicated mechanism to explain them.[20]

It took several years for the world to accept Copernicus' theories. It has religious implications of both the Catholics and the Protestants. Man became just a speck of dust clinging tenaciously for his dear life, on the surface of the earth as it majestically swings around the sun.[21]

There were also scientific objections to the new theory. Some scientists believed that a rotating earth would effect falling bodies. Also, that revolution would cause that stars to move in a loop. Besides, Copernicus' original theory did not simplify Ptolemy's that much. It still used epicycles, but not the major ones. This is John Milton's description from his Paradise Lost;

> . . . . the sphere
> with centric and eccentric scribbled o'er
> Cycle and epicycle, orb in orb
> fits Copernicus fully as well as Ptolemy.[22]

Only the stoutest of mathematically trained people chose the Copernican theory over the Ptolemaic system.[23] But by weighing the many facts, astronomer's accepted Copernicus. It was clear that the poter planets, Mars, Jupiter and Saturn, were above the sun, and the moon was below it. Where was Venus and Mercury? Putting them below the sun would serve to fill the great space between it and the moon, but then Venus would require a huge epicycle. Moreover, one would expect to see transits - passages of Mercury and Venus across the face of the sun- and none were abserved. From antiquity came a suggestion that the orbits of Mercury and Venus were centered on the sun, but this would make them anomalus among the planets.

A motion of the ecliptic would produce gross changes in steller latitudes, which were measured from the ecliptic, and such changes had never been observed.[24] On the basis of Copernican theory was built the structure of modern astronomy.[25]

KEPLER'S LAWS OF PLANETARY MOTION

Three great astronomer's who contributed to the laws of planetary motions were Tycho Brahe, Galileo Galilei, and Johannes Kepler. These three were vital in the transformation from the Ptolemaic to the Copernican system.

Tycho is most famous for his very accurate observations of the positions of the stars and planets.[26] These precise observations were made entirely without the aid of a telescope.[27] In 1572 he observed the nova, or new star, Cassiopica, which for a few weeks revealed Venus is brilliant; no longer could the celestial sphere be regarded as absolutely changless.[28] His obervations of lunar and planetary positions where measured to an accuracy of 1 or 2 minutes of an arc in angular measures. He totally observed for 20 years and recorded everything. He did this with the most precise instruments of his time of which most were of his own design.

Although he is most noted for his accurate observations, he did develope a conception of the universe that was Ptolemaic in nature. It was a hybrid similar to Heraclides. He pictured the moon and sun as spheres that moved around the earth and the five known planets moved around the sun. The reason why he objected to a sun-centered universe was because he failed to detect the annual paralles of stars.

Tycho made further contributions to astronomy. His studies of the comet of 1577 showed that a comet is not an atmospheric phenomenon and it moved in an oval-shaped path. Here was the first suggestion that celestial bodies move in noncircular orbits. From his vast collection of data, Kepler was able to go to work immediately in trying his hand at a new theory of planetary motions which would fit Tycho's date.[29]

Galileo Galilei was the first to ever turn a telescope to the sky. His telescope changed the terms of the riddle that the heavens presented to astronomers,and it made the riddle vastly easier to solve,for in Galeleo's hands, the telescope disclosed countless evidences for Copernicanism.[30] By looking at Jupiter, Galileo was able to view a miniature Copernican universe. He saw the moons of Jupiter. He saw small things moving around big things, and the innermost moves faster than the outermost. He also saw that the earth was not unique in having moons.

By his telescope, Galileo saw that Venus showed different phases like the moon. By Ptolemaic theory, Venus must be either new or cresent, whereas Copernican theory can predict all phases.

In the meantime, Copernus' book was banned. Galileo wrote <u>Dialogue of the Two Principal Systems of the World, Ptolemaic, and Copernican</u>, in which the comparison of the two theories takes place. The book was pro-Copernican and it too was banned and Galileo had to renounce his faith. Unable to perform astronomy anymore, he worked on kinematics and laid the foundation for Newton, the founder of classical mechanics.

Kepler was a protege of Tycho Brahe. He was a mathematician under Tycho before Tycho's death. He thus acquired the vast collection of data that Tycho had accumulated. Kepler, unlike Tycho, was full of praise for the sun-centered planetary system, but his data did not confirm mathematically. Kepler was acutely and unconfortably aware of the incongruous residues in the De Revolutionibus, and he took it upon himself to eliminate them by exploiting fully the earth's new status as a planet governed, like the other planets, by the sun.[31]

As a prelude to his laws, Kepler had to map the orbits of the planets, particularlly Mars. In order to achieve this he compared the direction of Mars at two instants separated by the Martian sidereal period, 687 days. Mars had thus traveled 360° around the sun. He came up with a map of the Martian orbit in terms of "astronomical units". He now had the orbit of Mars mapped. He then mapped the orbit of the earth from which Mars is observed. Again and again Kepler was forced to change the combination of circles used in computing these orbits. He worked out a circular orbit for Mars that came within eight minutes of arc of Tycho's observations of that planet.But because Kepler knew that Tycho's data were accurate to within as little of four or five minutes of arc, he discarded the assumption of a circular orbit, started his calculations afresh and eventually arrived at an elliptical orbit that fitted the observations.[32]

Kepler now had his three laws of planetary motions. The first two appeared in 1609, and the third in 1619. These laws are summarized as follows:

1. The planets move in elliptical orbits with the sun at one of the faci.
2. The straight line joining the sun and any planet sweeps out equal areas in equal intervals of time.
3. The squares of the orbital periods of the planets are proportional to the cubes of their mean distances from the sun.[33]

These three laws, although purely descriptive, are an immense advance over the epicycle theory. Perhaps they are most important in that they separate the different mechanical features that need explanation.[34] He believed that mathematically simple laws are the basis of all natural phenomena and that the sun is the physical cause of all celestial motions.[35] To him the third law in and of itself explained why the planetary orbits had been laid out by God in the particular way that they had, and that sort of explanation, derived from mathematical harmony, is what Kepler continually sought in the heavens.[36] The fundamental principles underlying Kepler's laws, and from which they are deduced, were not understood until later in the seventeenth century, by Sir Isaac Newton.[37]

NEWTON'S LAWS OF MOTION AND GRAVITATION

For the Copernican Revolution to continue its acceptance in the world it needed yet another man and his theories. It required such men as Galileo and Kepler, who made it the foundation of a new natural philosophy, and finally Newton, who provided a coherent world mechanics based on universal gravitation.[38]

Newton, the greatest genius of the Renaissance, was borm in 1642, the year of Galileo's death. He had developed most of his calculations and new thoughts before he was the age of 24, and he is known as the greatest physical scientist. His works appeared in the "Principia", published in 1687. His contribution to planetary theory was to unite the celestial planets with the things of the earth in one all-embracing theory of motions: he discovered and he verified that the same laws of nature work throughout our solar system.

Newton's three famous laws can be generalized in the following:

1. A body at rest or in uniform motion will remain at rest or in uniform motion unless some external force is applied to it.[39]
2. When a body is acted upon by a constant force, its resulting acceleration is proportional to the force and inversely proportional to the mass.[40]
3. To every action force there is an equal and opposite reaction force.[41]

The first law implies that motion is the natural state of the universe. Newton took the view that a force is not needed to produce velocity but that it is needed to produce a change of velocity, or an acceleration.[42] Uniform motion can never be realized in nature. The best example is an isolated star. The isolated star moves in a straight line because only weak forced act upon it. The reason why the isolated star does not show uniform motion is that the path of such a star is curved by the weak pull of the central of mass of the stars in our galaxy. For every 1,000,000 miles of forward travel the star is deviated sidewise about two-tenths of an inch.[43]

The second law is often stated algebreacally in the form:

$$F = M X A$$

where F is the force, M is the mass, and A is the acceleration. Force and acceleration are vector quantities. They both have magnitude and direction. Orbital motions are vector quantities. Their velocity is accelerated toward the center by the gravitational pull of the sun. Acceleration is produced not only when a velocity changes in magnitude but also when it changes in direction. And a planet traveling along an elliptical course is changing its direction of motion all the time.[44] The planets orbits are trajectories constantly being bent towards the center of attraction to which each is subordinate.[45]

The third law states that forces come in pairs. This law is sometimes difficult to appreciate. If motions come in pairs that are equal, how can anything move? Why doesn't the earth move to meet a falling object? The reasons are because the earth's mass is so large and it would be hard to accelerate.

Newton is probably more famous for his Law of Gravitation. Although Newton's laws of motions serve as the foundations of mechanics and are applicable to forces of all types, something more was needed to account for the specific way that planets move. If these laws are valed, then how do they relate to the empirical findings of Kepler?[46]

Newton knew that the surface rate of acceleration was 32 $^{ft}/_{s^2}$. He also knew that the acceleration of the moon toward the earth is 32 $^{ft}/_{min.^2}$. These are in a ratio of 3600. The moon's distance is 240,000 miles and the earth's radius is 4,000 miles. The acceleration of an object therefore appears to be proportional to the inverse square of its distance from the center of the attracting body.[47] This is in the form:

$$F = G \frac{M_1 \; M_2}{D^2}$$

where F is the force, M_1 and M_2 are the masses of the bodies, D the distance between them, and G is a constant that has the value of 6.67×10^{-8} $^{cm^3}/_{gm\ S^2}$.

Newton was able to deduce all three of Kepler's laws of planetary motion, thus carrying over this descriptive system into a perfect casual description of the motion of the planets.[48] In order for his laws to be valid, this was a necessity.

Newton assended Kepler's first law by changing the orbit from an ellipse to a conic section. There are many different paths for a conic section. The eccentricity of a conic section is a measure of distance from a point on a conic to a focus and the distance from the point to the directric. The conic sections and their eccentricity are:

Circle - 0	Ellipse - 0-1
Parabola - 1	Hyperbola 1.

The straight line is also a conic path.

These various types of orbits can be obtained by placing an object 1 a.u. from the sun, shoot the object at right angles to the sun, and vary the spads of each shot.

The first object will be shot at zero speeds. The object will be at rest relative to the sun. The orbit is a line and the object will strike the sun in 65 days.

We will fire the next object at 2 $^{mi}/_{s}$. The resulting motion will be an elliptic of high eccentricity. The aphelion distance will be 1 a.u. and the perhelion will be only a small margin. The major axis will be from the shooting point to the sun.

If we next fire an object at about 10 $^{mi}/_{s}$, we will have an ellipse of lower eccentricity. The aphelion will be 1 a.u. and perhelion will be 0.17 a.u. The orbital period will be longer than the 2 $^{mi}/_{s}$ firing and shorter than the earths.

The circular velocity can be deduced from Newton's work by substituting in the formula:

$$V^2_{circ} = \frac{GM}{D}$$

where G is the gravitational constant, M = 2.00 X 10^{33} gm and D = 1 a.u. = 1.50 X 10^{13} cm. With these values the circular velocity comes out to 18.5 $^{mi}/_{s}$. The sun will be the center of the circle. This is the approximate speed of the earth in its motion around the sun.

When the firing speed is the square roat of 2 times the circular velocity the path becomes a parabola. The object will move on a one way path to infinity. It will excape solar gravitation. This required speed can be found by using the formula:

$$V^2_{par} = \frac{2GM}{D} .$$

The parabolic velecity is also called the escape velocity.

As we further increase the speed the path will become a hyperbola.

If we now approach infinite speeds some interesting things happen. The eccentrity approaches and the object moves in a straight line. It will require no time for the object to get from the sun. The pull of the sun has no time to attract. This example is beyond the possibility of experience. The velocity of light is the greatest speed that passes by the sun. This light will move hyperbollically with an enormous eccentricity. The deflection of the light is about 0.004".

Newton also generalized the harmonic law of Kepler's. Kepler stated this law in the form $P^2 = Ka^3$. Newton evaluated K and completely stated Kepler's law by:

$$P^2 = \frac{4\pi^2 a^3}{G(M_1+M_2)} \quad .$$

We can now find masses from observed periods and mean distances. The sun's mass can be found from a planet's orbital size and period. The planet's mass can be found from its orbital size and the period of a satellite. We can often neglect the smaller mass.

<u>EINSTEIN AND RELATIVITY</u>

Newton's Law was unchallenged for many years. Albert Einstein created a new law which gave a more general theory of gravitation. This theory is called the general theory of relativity. It measures motion of an object relative to other objects. It says that there is no such thing as absolute motion, that no place or motion is more exalted than any other. This theory differs from Newton's only for objects in very rapid relative motion.

In the realm of orbit theory only two observational tests for the Einstein theory have been devised.

The first is that: the line joining the sun and the planets perhelion should rotate slowly eastward. The faster-moving planets show the greatest effect. For Mercury's perhelion to make one revolution requires 3 million years. More precisely, Einsteins predicted angular rate is 43.2" per century, but nearly all of this is accounted for by the pertwibing gravitational forces of other planets on Mercury.[49] The remaining amount is 42.6" ± 0.9" per century. Before relativity, Mercury's motion was believed to be caused by an intra-Mercurical planet called Vulcan.

The second is the gravitational deflection of light. This should be about 1.75" according to Einstein. Newton Predicts only half as much. Evidence points to Einstein.

The general theory of relativity has given us a new and superior theory of gravitation. Its impact on cosmology is great, but on planetary motions it is relatively minor, but nevertheless significant.[50] These irregularities......must be taken into account when calculating the exact position of a heavenly body.[51]

WORLDS IN COLLISION

This is the title of a book by Immanuel Velikovsky about a theory as to the origin of the universe. The book was published in 1950 and a great deal of havoc followed it. Scientists were so tatally against this man's theories that they threatened the Macmillian Publishing Company with a boycott of its textbooks if it did not quit printing the book. The book is past its 72nd printing much to the dismay of Macmillian and Company.

Velikovsky studied many ancient texts, including the Bible, and from Greeks, Babylonians, Aztecs, Mayas, and other manuscripts. He found a vast similarity in the writings.

He believes that around 1500 B.C. the planet Jupiter spewed forth a gigantic mass of material that streaked along, cometlike, sideswiping earth and Mars several times and finally settled into a circular orbit around the sun as the planet we now call Venue. Among the natural catastrophes resulting from these collisions, he believes, were the Biblical ten plagues in Egypt, the parting of the Red Sea, the rain of manna from heaven and the apparent stopping of the sun in its course during Israellite battle.[51]

Velikovsky was finally given the chance to give a verbatim report of his theory in March of this year. The reason because of recent discoveries that has proved his assertions chiefly by deep-space probes. He accurately postulated, for example, the existence of radios emissions from Jupiter, the fact of volcanic activity on the moon, the discovery that Venus is a hot planet, and the recognition that earth is girdled by a magnetosphere.[52]

CONCLUSIONS

The problems presented by the motions of our solar system are very far from being solved. We have witnessed a continual interplay for over two thousand years between the observed facts of planetary motions and the theories developed to account for them. We have also witnessed a theory based solely from historical texts. From Eudoxus spheres onward different theories have fallen flat on their faces. We can not say that the theories that we use today will not become obsolete as time goes on, because in all probability they will change.

FOOTNOTES

1. Stanley, Wyatt, Principles of Astronomy (Boston: Allyn and Bacon, 1964). p. 145.

2. ibid.

3. George Abell, Exploration of the Universe (New York: Holt, Rinehart, and Winston, 1969). p. 28.

4. Thomas S. Kuhn, The Capernican Revolution (New York: Vintage Books, 1959). p. 45.

5. Abell, op. cit., p. 37.

6. Luman H. Long, ed., The World Almanac of Facts, p. 215.

7. Wyatt, op. cit., p. 148.

8. Clive Kilmister, The Nature of the Universe (New York: E. P. Dutton, 1971). p. 30.

9. ibid.

10. Kuhn, op. cit., p. 55.

11. ibid., p. 56.

12. Wyatt, op. cit., p. 149.

13. ibid.

14. A. Weigert and H. Zimmermann, A Concise Encyclopedia of Astronomy (New York: American Elsevier, 1968). p.20.

15. Kuhn, op. cit., p. 59.

16. ibid.

17. Wyatt, op. cit., p. 150.

18. Kilmister, op. cit., p. 33.

19. Kuhn, op. cit., p. 166.

20. Kilmister, op. cit., p. 33-34.

21. S. P. Mizeva, "Nicholaus Copernicus", Science Vol. 97 (Feb. 26, 1943), 192-194.

22. F. Cajori, "Johannes Kepler, 1571-1630", Scientific Monthly, Vol. 30 (May, 1930) pp. 385-393.

23. Wyatt, op. cit. p. 153.

24. Jerome R. Rawetz, " Orgins of the Copernican Revolution", Scientific American, Vol. 215 (Oct. 1966), p. 91,93.

25. G. Sonnedecker, "He Spun the Earth", Science News Letter Vol. 43 (May 22, 1943), p. 330.

26. Abell, op. cit., p. 40.

27. J. Christianson, "Celestial Palace of Tycho Brahe", Scientific American, Vol. 204 (Feb. 1961) p. 119.

28. Wyatt, op. cit., p. 153.

29. ibid., p. 154.

30. Kuhn, op. cit., p. 219.

31. ibid., p. 210.

32. op. cit., p. 120.

33. Harvey White. Modern College Physics,(Princeton, New Jersey: D. Van Nostrand, 1966) p. 107, 108.

34. Kilmister, op. cit., p. 35.

35. Kuhn, op. cit., p. 214.

36. ibid. p. 217.

37. Wyatt, p. 161.

38. op. cit., p. 88.

39. White, op. cit., p. 33.

40. ibid., p. 37.

41. ibid., p. 56.

42. op. cit., p. 35.

43. Wyatt., op. cit., p. 161.

44. op. cit., p. 36.

45. Lucien Rudaux and G. de Vaucoulers, Larousse Encyclopedia of Astronomy (London: Paul Hanlyn, 1962) p. 15.

46. op. cit., p. 162.

47. ibid., p. 163.

48. op. cit., p. 37.

49. op. cit., p. 169.

50. ibid.

51. "Velikovsky and the AAAS: Worlds in Collision", Science News, Vol. 105 (March 2, 1974), p. 132.

52. "Scientists in Collision", Newsweek, Vol. 83 (Feb. 23, 1974) p. 58.

BIBLIOGRAPHY

Abell, George, Exploration of the Universe New York: Holt, Rinehart and Winston, 1969.

"A Miniature Solar System and its Problems". Scientific American, Vol. 146 (March 1932), pp. 142-145.

"Answer to my Critics". Harper, Vol. 202 (June, 1951), pp. 51-57 and 63-66.

Blanco, V. M. and McCuskey, S. W., Basic Physics of the Solar System. Reading, Mass.: Addison-Wesley, 1961.

"Book Arouses Controversy". Science News Letter, Vol. 57 (April 15, 1950), p. 229.

Brandt, John C. and Hodge, Paul W., Solar System Astrophysics. New York: McGraw-Hill, 1964.

Cajori, F., "Johannes Kepler, 1571-1630". Scientific Monthly, Vol. 30 (May, 1930), pp. 385-393.

Christianson, J., "Celestial Palace of Tycho Brahe". Scientific American, Vol. 204 (Feb. 1961) pp. 118-128.

Hayle, F., "Nature of the Universe". Harpers, Vol. 201 (Dec., 1950) pp. 23-31.

Kuhn, Thomas S., The Copernican Revolution. New York: Vintage Books, 1959.

Larrabee, E., "Scientists in Collision" Was Velikovsky Right?" Science Vol. 227 (Aug., 1963), pp. 48-50. (Dec., 1963) pp. 83-87.

Long, Luman H., ed., The World Almanac.

Kilmister, Cline, The Nature of the Universe. New York: E. D. Dutton, 1971.

Mizeva, S. P., "Nicholas Copernicus". Science, Vol. 97 (Feb. 26, 1943), pp. 192-194.

Munitz, Milton K. Ed., Theories of the Universe. New York: The Free Press, 1957.

"Planets", Compton's Pictured Encyclopedia, Vol. II, pp. 351-355.

"Planet Paths Calculated for Next Hundred Years". Science News Letter, Vol. 59 (Jan. 13, 1951), p. 19.

Puri, O. P., Concepts in Physical Science, Reading, Mass.: Addison-Wesley, 1971.

Rawetz, Jerome R., "Origins of the Copernican Revolution". Scientific American, Vol. 215 (Oct. 1966) pp. 88-95.

Rudaux, Lucien and Vancoulers, G. de, Larousse Encyclopedia of Astronomy. London: Paul Hamlyn, 1962.

Santillana, G. de, "Greek Astronomy". Scientific American, Vol. 180 (April, 1949) pp. 44-47.

"Scientists in Collision". Newsweek, Vol. 83, (Feb. 23, 1974), p. 58.

Sonnedecker, G., "He Spun the Earth". Science News Letter Vol. 43 (May 22, 1943) pp. 330-331.

Velikovsky, Immanuel, Worlds in Collision. Garden City, New York: Doubleday, 1950.

Velikovsky and the AAAS: Worlds in Collision". Science News, Vol. 105 (March 2, 1974), p. 132.

Weigert, A. and Zimmermann, H., A Concise Encyclopedia of Astronomy, New York: American Elsevier, 1968.

"When Heresy Flowered". Newsweek, Vol. 25 (March 26, 1945) p. 90.

White, Harvey E., Modern College Physics. Princeton, New Jersey: D. Van Nostrand, 1966.

Wyatt, Stanley P., Principles of Astronomy. Boston: Allyn and Bacon, 1964.