MALS: THE RETROGRADE MOTION OF THE PLANETS

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Introduction

01° Ancient astronomers were deeply impressed by the apparent regularity of the motions of the Stars. Looking to the southern sky at night, they noted that the Stars rose continually at various places on the eastern horizon, passed from east to west through the southern sky, and set at corresponding places on the western horizon. The Stars followed parallel arcs of circles in the southern sky. Looking to the northern sky at night, they noted that the Stars moved in circular paths counter clockwise about a special place in the northern sky. They called that motionless place the Celestial Pole. It seemed to them that the Stars were set like jewels in a grand Celestial Sphere, centered upon the spherical Earth, and that this grand Sphere turned once daily, counter clockwise, at constant angular speed about the axis defined by the center of the Earth and the Celestial Pole. This elegant view of the motions of the Stars explained most of what they saw in the southern and northern skies; most, but not all.

02° Ancient astronomers noted anomalies in the motions of certain Stars. These Planets (wanderers) followed novel courses, joining the Stars in the daily rotation of the Celestial Sphere but (against the background of that regular motion) drifting slowly from west to east along the arc of a great circle transverse to the arcs of the Stars in the southern sky. Astronomers called that great circle the Ecliptic. Moreover, the drift of the Planets from west to east along the Ecliptic showed a bizarre feature. Occasionally, one of the Planets would cease its drift from west to east, turn back west for a time, then turn back east again to resume its course. Ancient astronomers called this phenomenon the Retrograde Motion of the Planets. They sought to explain it in terms of the motion they thought appropriate to the Stars, namely, circular motion at constant speed. The problem of devising such an explanation was the Fundamental Problem of ancient astronomy.

03° In due course, Hipparchus (200 b) put forward a construction in terms of Spinning Circles, by which to approximate the observed motions of the Planets. (In retrospect, we might compare his construction to the operation of a

Spirograph.) His construction, centered upon the Earth, served as the base for mathematical astronomy for more than 1800 years.

Controversy

04° The models developed by ancient astronomers from the method of Hipparchus proved elegant in design but faulty in application. For the prediction of the future positions from the present positions of the Planets, they required frequent revision. The giant of classical astronomy, Ptolemy (200 a), found this circumstance unacceptable. He modified the method of Spinning Circles with the intent to insure long term accuracy. One may say that he sacrificed purity of form for precision in prediction. Specifically, he introduced the notorious Equant.

Diagrams

05° In the first class meeting (09/02/2015), we will present simple "movies," based upon computer graphics programs, to illustrate the method of Spinning Circles and, just as well, to illustrate the effects of the Equant.

Revolution

06° The followers of Ptolemy developed his methods ad libitum. (Through the Middle Ages, Arabic astronomers carried the matter to a state of extreme complexity.) The Goal? To reach ever greater levels of precision in prediction. The Motivation? Within the social and political structures of Europe, to meet, in particular, the demands of the Catholic Church – specifically, to set a common date for the celebration of Easter throughout the Mediterranean World.

07° The introduction of the Equant by Ptolemy violated the underlying principle of explanation (by means of circular motion at constant speed) thought by ancient astronomers to be appropriate to the problem of Retrograde Motion. Copernicus (1473 – 1543 a) objected strongly to such a violation. Following a lifetime of study, he found and proposed a remarkable transformation of the current models. He returned to the purity of the model of Spinning Circles (excising the Equant) BUT he placed the center of the apparatus not at the Earth but at the Sun. Under his proposal, he found that the retrograde motion of the Planets disappeared. Such motion was, in fact, an illusion, created by the entrenched practice of viewing the Solar System not from its "natural" center at the Sun but from the "artificial" center at the Earth.

08° In one stroke, Copernicus solved by elimination the problem of Retrograde Motion of the Planets. However, one must acknowledge that his models were no more accurate and no less complex than the models of Ptolemy. Moreover, they introduced a welter of consequent puzzles. Now the Earth must rotate about its axis (so that Night follows Day) and must revolve around the Sun (so that Winter follows Summer) at rates the magnitudes of which were to every sensible person absurd. Now birds must fly against ferocious winds. Material bodies must fall toward the moving center of the Earth. How? Why? Would thoughtful people discard the stable structures of Classical Astronomy and Aristotelean Physics merely to simplify the problem of the anomalous motion of the Planets?

09° Yes, they would, and they did just that. Following a complex, sometimes violent struggle, they formed a new World Order. Such is the story of this Course.

10° In the title of the fundamental work by Copernicus:

On the Revolutions of the Heavenly Spheres

one finds the word, referring to the motions of the Planets, which forever after has been exploited in studies of events and processes characterized by rapid transformation of state. One may cite, for example, the American Revolution. In this light, it seems ironic that Copernicus initiated in 1543 the revolution which bears his name while Newton brought the process to its definitive close in 1687, 144 years later:

The Principles of Natural Philosophy

In the meantime, enter Clavius, Galileo, and the Telescope.