APOLLONIUS'S THEOREM (ca. 270 B.C.)

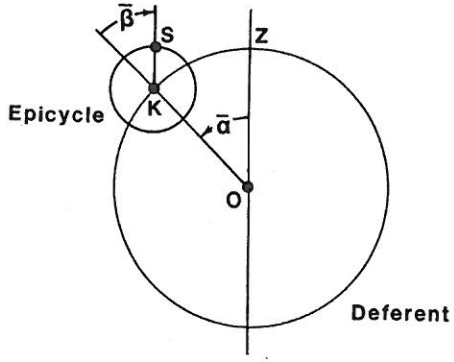

FIGURE 5.7. Concentric deferent and epicycle model for the motion of the Sun. The Sun *S* moves on an epicycle while the center *K* of the epicycle moves around a deferent circle centered on the Earth *O*. Both motions are completed in one year. Thus, angles $\bar{\beta}$ and $\bar{\alpha}$ are always equal.

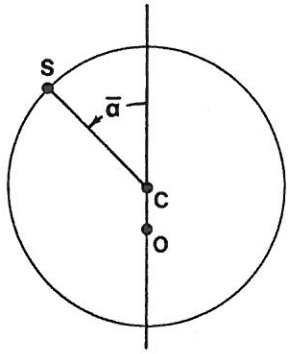

FIGURE 5.8. The eccentric-circle model for the motion of the Sun. Angle $\bar{\alpha}$ is called the mean anomaly.

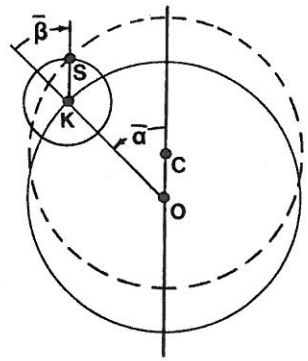

FIGURE 5.9. Equivalence of the concentric-plus-epicycle model (fig. 5.7) to the eccentric-circle model (fig. 5.8). If the radius *K* of the epicycle is equal to the eccentricity *OC* of the eccentric, and if the rates of motion are chosen so that one always has $\bar{\beta} = \bar{\alpha}$, the two models are mathematically equivalent.

The Two Fundamental Evidence Problems in Astronomy

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1) Determining distances of objects from the Earth, for parallax angles generally too small to measure

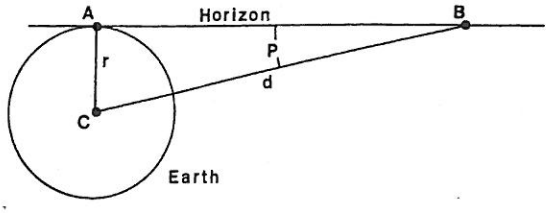
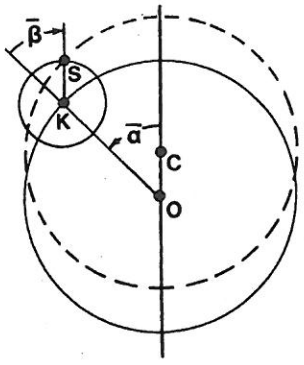


FIGURE 1.45. Horizontal parallax. Angle *P* is the horizontal parallax of a celestial object (such as the Moon) located at *B*.

2) Distinguishing real from merely apparent motions and real changes in motion from merely apparent ones



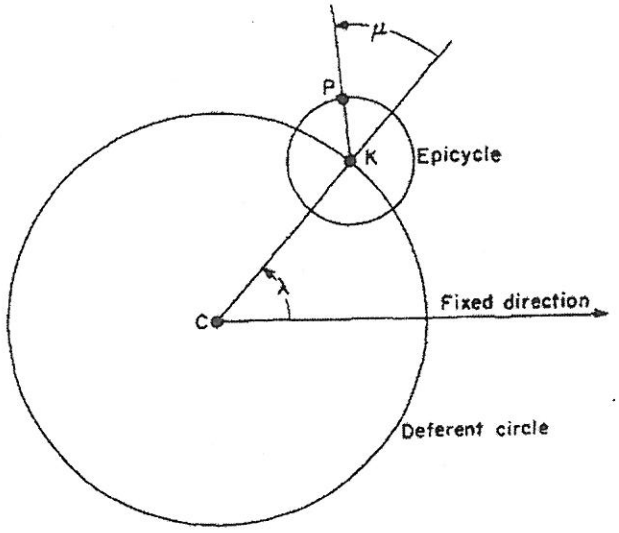


Fig. 5. Zero-eccentricity version of Ptolemy's model.

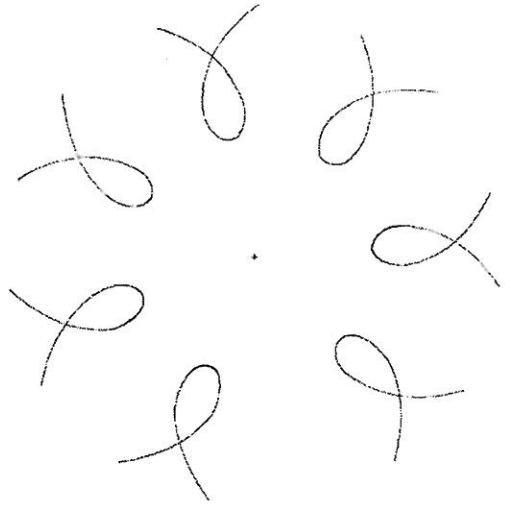


Fig. 4. Retrograde loops of Mars generated by the zero-eccentricity model of Fig. 5.

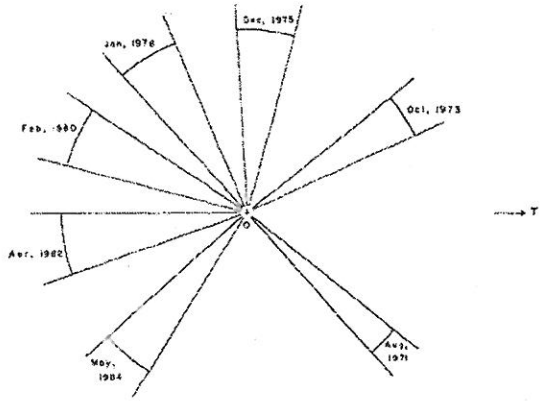


Fig. 6. Retrograde arcs of Mars, 1971–1984. The Earth, from which all observations are made, is marked O. ♈ indicates the direction of the vernal equinox. Longitudes are measured counterclockwise from this direction.

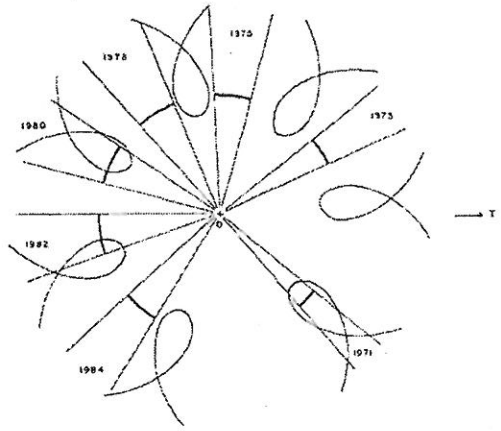


Fig. 7. The retrograde loops predicted by a zero-eccentricity model of Mars superimposed on the planet's actual retrograde arcs. This figure results from the superposition of Fig. 4 and Fig. 6.

Otto Neugebauer's Tri-Partite Division of the History of Orbital Astronomy

- **Before Ptolemy's *Almagest***

- **From Ptolemy's *Almagest* to Newton's *Principia***

- **After Newton's *Principia***