Appendix

The Fallacy of the Equant

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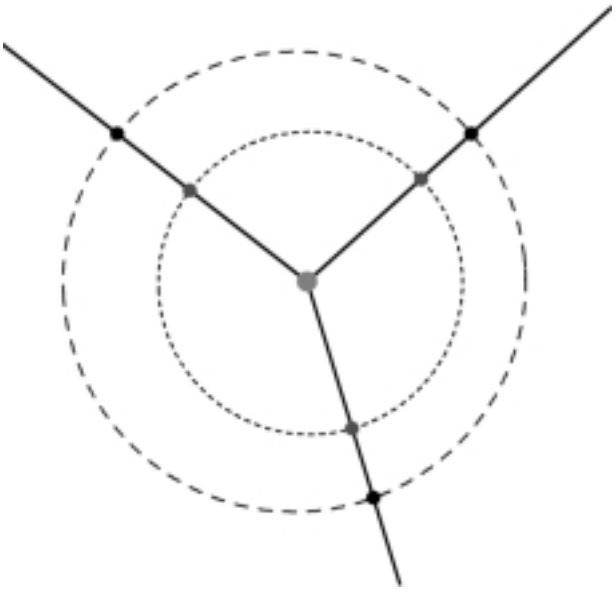
> Moreover, it is no less false that the center of the world is within the earth than that it is outside the earth; nor does the earth or any other sphere even have a center. For since the center is a point equidistant from the circumference and since there cannot exist a sphere or a circle so completely true that a truer one could not be posited, it is obvious that there cannot be posited a center [which is so true and precise] that a still truer and more precise center could not be posited. Precise equidistance to different things cannot be found except in the case of God, because God alone is Infinite Equality. Therefore, He who is the center of the world, viz., the Blessed God, is also the center of the earth, of all spheres, and of all things in the world. Likewise, He is the infinite circumference of all things.
>
> —Nicolaus of Cusa, ***De Docta Ignorantia***

In Part II of his ***The New Astronomy,*** Johannes Kepler takes up the motion of Mars, having identified two *a priori,* axiomatic assumptions which had bounded the investigations of astronomy up to that time: that the planets move in perfect circles, and that an equant point can be found for the orbit—a point from which the planet could be observed to move at a constant speed, traversing equal angles in equal times—a point of uniformity. Rather than this approach to investigating the apparently irregular motion of Mars, Kepler's healthier mind posed the question: What are the characteristics of change of Mars' apparent motion?[1]

Planets moving through the heavens have an inequality

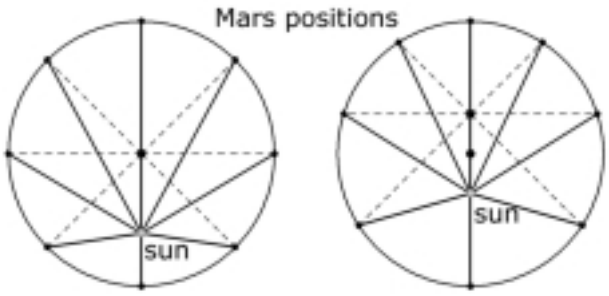
1. The website of the LaRouche Youth Movement has an extended pedagogical discussion of ***The New Astronomy,*** chapter by chapter, with animations to help the reader. For this point, see www.wlym.com/~animations/16/aside.html

in their motion caused by the changing position of our Earth from which we observe them. This inequality can be removed by using select observations of the planets: those taken at opposition, where their position is the same whether the Sun or the Earth is observing them:



Kepler eliminates the effect of the motion of the Earth on the perceived position of Mars by using observations at opposition. This way, Kepler can "watch" Mars from a fixed point, the Sun. Even in this motion of Mars as observed from the Sun, an inequality remains: Mars has a position against the zodiac at which it moves fastest, and one at which it moves slowest.

This figure indicates two methods to account for this unequal motion, the eccentric and the equant:



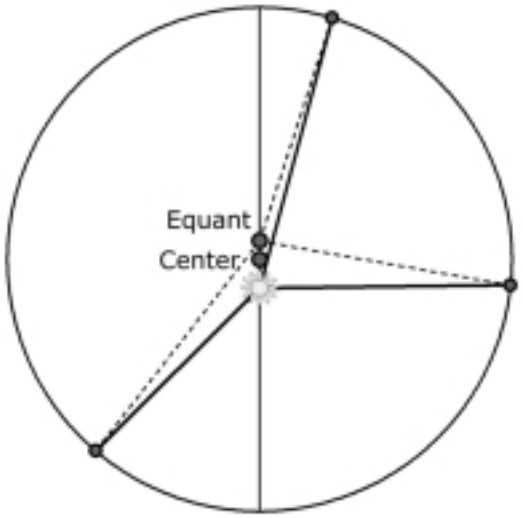
In the eccentric model (left), where the point of uniform motion is the center of the orbit, the off-center observer perceives the planet as having a changing speed. The equant model (right) has two "centers," a center of motion (the equant, top) around which the planet traverses equal angles in equal times, and a center of orbit (center), from which the planet maintains a constant distance, while seen by the observer (at the Sun for Copernicus, the Earth for Ptolemy). Both models cause an apparent change in the speed of the planet, as perceived by the Sun, but do so at different rates. Ptolemy introduced the equant because he found that it best represents the motions for the superior planets.[2]

From Ptolemy until Kepler, the idea of uniform motion, the axiomatic, *a priori* assumption of a characteristic of uniformity being inherent in the universe, remained as unchallenged by the scientific community as today's cult-like belief in the Second Law of Thermodynamics.

Kepler's Model

Kepler, assigned by Tycho Brahe to work out the motion of the planet Mars, had 12 opposition observations at his disposal when he composed ***The New Astronomy.*** By selecting four of these observations, he was able to bring out an irony.

The apparent distance in the sky between Mars' location at two different oppositions indicates the angle between those two actual positions of Mars as seen from the Sun. The time between oppositions indicates the angle between the positions of Mars as seen from the equant. With four such observations, Kepler used a difficult and time-consuming process to compose the most accurate model ever created for predicting the location of Mars on the zodiac; he calls it his vicarious hypothesis.



The three points on the line of apsides (the line connecting the locations of fastest and slowest motion) are, from the top, the equant, the center, and the Sun. The eccentricity—the distance form the Sun to the center—is 11.3% of the radius of the orbit.

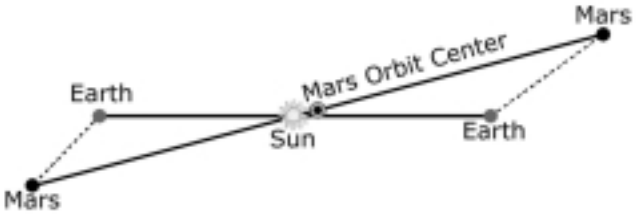
By drawing lines from the equant corresponding to the

2. www.wlym.com/~animations/part2/16/aside.html

times of the 12 oppositions, and comparing the hypothesized location of Mars with that actually observed, Kepler finds the error of his model to be within the limits of observation.[3] If any possible error is too small to be perceived, does this mean he has found the truth?

Another Determination of Eccentricity

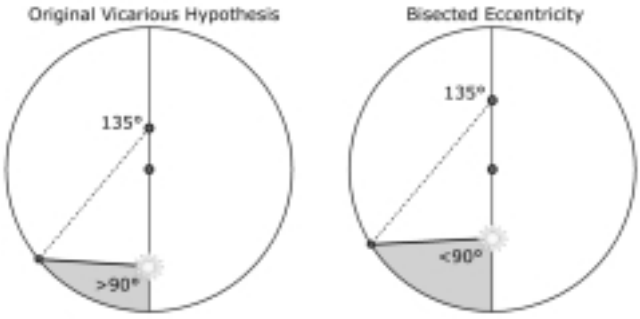
Kepler then set about to check this eccentricity, by using measurements not of longitude along the zodiac, but of latitude north or south of it:



By observing the latitude of Mars north and south of the plane of the ecliptic—the plane of the Earth's motion around the Sun—and using some trigonometry, Kepler could determine how far Mars is from the Sun at its limits. The mean of these two lengths lets him determine the location of the center of Mars' orbit, and its distance from the Sun—the eccentricity. But, this eccentricity (determined to be 8.0-9.9% of the size of the orbit) does not match the eccentricity determined by the vicarious hypothesis (11.3%). But how can Mars have one eccentricity when investigated according to longitude, and another when investigated according to latitudes?

A Crack

In an attempt to reconcile these two eccentricities, Kepler adjusts his vicarious hypothesis to put the center of the orbit midway between the equant and the Sun. (This is known as bisecting the eccentricity.) He thus applies the eccentricity determined by latitudes to the functionally perfect vicarious hypothesis model.



In this diagram with greatly exaggerated eccentricity, the perceived position of Mars as seen from the Sun changes when the eccentricity is bisected. The angle between Mars and the line of apsides is greater than 90° in the unbisected vicarious hypothesis, and less than 90° in the bisected version.

The perfection of the vicarious hypothesis is lost when the eccentricity determined by latitudes is introduced. When drawing lines from the equant at angles determined by the times of opposition, Kepler finds a gap: This model is about 8 minutes of arc off for the opposition of 1582, a crack seen not passively by the senses, but actively, creatively experienced by the mind. Kepler writes:

> *Therefore, something among those things we have assumed must be false. But what was assumed was: that the orbit upon which the planet moves is a perfect circle; and that there exists some unique point on the line of apsides at a fixed and constant distance from the center of the eccentric about which point Mars describes equal angles in equal times [the equant]. Therefore, of these, one or the other or perhaps both are false, for the observations used are not false.*
>
> *Now, because they could not have been ignored, these eight minutes alone will have led the way to the reformation of all of astronomy.*

What is the implication of this new category of experience for the practice of Man's mastery over nature? Kepler is now able to demonstrate the required existence of a universal, physical (not geometrical) principle of gravitation. The unavoidable, paradoxical implications of the use of the equant force the mind to a new sort of wonder. To attempt to present Kepler's discovery of universal gravitation, without a thorough working-through of the paradox of the equant, were to proffer an answer to an audience incapable of posing the right question.

3. Try it on this sheet. You can, by referring to the time between Kepler's oppositions, draw lines from the equant, and then see if the Sun would see those Mars positions correctly. Three are drawn on this image already.


Johannes Kepler

FOR MORE INFORMATION, SEE **www.wlym.com/~animations/**

4. One minute of arc is one-sixtieth of a degree of the night-time sky, and is about the perceived width of a pencil lead held eight feet away from your eye.