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The planetary increase of brightness during retrograde motion: An *explanandum* constructed *ad explanantem*

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ABSTRACT

In Ancient Greek two models were proposed for explaining the planetary motion: the homocentric spheres of Eudoxus and the Epicycle and Deferent System. At least in a qualitative way, both models could explain the retrograde motion, the most challenging phenomenon to be explained using circular motions. Nevertheless, there is another *explanandum*: during retrograde motion the planets increase their brightness. It is natural to interpret a change of brightness, i.e., of apparent size, as a change in distance. Now, while according to the Eudoxian model the planet is always equidistant from the earth, according to the epicycle and deferent system, the planet changes its distance from the earth, approaching to it during retrograde motion, just as observed. So, it is usually affirmed that the main reason for the rejection of Eudoxus' homocentric spheres in favor of the epicycle and deferent system was that the first cannot explain the manifest planetary increase of brightness during retrograde motion, while the second can. In this paper I will show that this historical hypothesis is not as firmly founded as it is usually believed to be.

1. Introduction

According to Simplicius (*On the Heaven*, 2, 12; Bowen, 2013: 136), Plato put forward to astronomers the following question: "By hypothesizing which smooth and orderly motions will the phenomena of the motions of the wandering [stars] be saved?" Most scholars call into question that Plato really put forth this demand (Knorr, 1991: 319-320). The demand, however, authentically reflects the bases of any research program on astronomy in Ancient Greece. The first complete planetary system that fulfilled the Platonic request emerged almost immediately after: Eudoxus of Cnidus, one of Plato's most prominent disciples proposed the model of homocentric spheres. This model was universally known since it was proposed and partially modified by another of Plato's disciple, Aristotle (*On the Heavens* II,12, 291b-293a, Allan, 1955; Metaphysics Λ, Tredennick, 1935). Eudoxus managed to explain the movements of the planets, with its variations only using spheres, all rotating with uniform motion and concentric to the Earth. The secret was to give to each sphere a certain angular speed and to attach the axis of each sphere to the immediately outer sphere at a certain angle: the combination of the movements of the spheres could produce the non-uniform motions of the Sun, Moon and planets. The system was so complex that it was completely understood only in the nineteenth century. It was Giovanni Schiaparelli (1875) who had the merit of showing how the Eudoxian homocentric spheres could produce the retrograde motion of the planets, producing the famous *hipopede*.[1] See Fig. 1.

The homocentric sphere model was not only the brilliant idea of an isolated genius; it was a real research program with important improvements made by Callippus and Aristotle (Mendell, 1998; Schiaparelli, 1875). At some point in the century after the death of Aristotle, however, the theory was abandoned. A new model, based on epicycles and deferents, appeared probably within a few

[1] Newer proposals compete today with that of Schiaparelli. See Mendell, 1998 and Yavetz, 1998.

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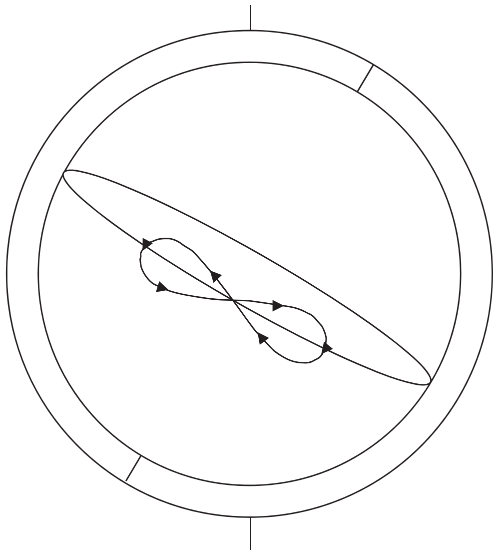

Fig. 1. Retrograde motion in Eudoxian model.

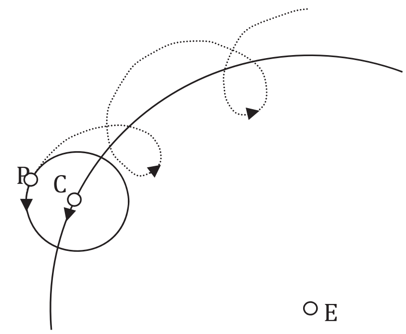

Fig. 2. Retrograde motion in the simplest version of the epicycle and deferent system. The planet (P) rotates around the center of the epicycle, point C, which rotates around E, the center of the Earth in a deferent. Both P and C rotate on the same sense.

decades after or before 200 BC (Evans et al., 2013: 149-151). This model was a different research program, probably proposed by Apollonius but improved by Hipparchus and Ptolemy. It became the reigning astronomical paradigm until the Copernican Revolution. According to the epicycle and deferent simplest version, a planet revolves in a small circle called epicycle, the center of which revolves around the Earth in another circle called deferent. In the case of the planets, the deferent is responsible for the position of the planet on the Zodiac, while the epicycle is responsible for the retrograde motion: the planet retrogrades once per turn of the epicycle. Both the epicycle and deferent rotate in the same direction, therefore, the retrograde motion is produced when the planet is closest to the earth, because at that point the tangential speed of the epicycle and deferent go in opposite directions. See Fig. 2.

At least in a qualitative way, both the homocentric sphere and the epicycle and deferent models could explain the retrograde motion.[2] There was, however, another fact that remained unexplained, i.e., another *explanandum*: during their retrograde motion, planets increase their brightness. Thus, assuming that the absolute size of celestial bodies does not change, it was natural to interpret the change in brightness as a change in distance. Technically, a change in apparent size, and not a change in brightness, would imply a change in distance. Before the introduction of the telescope, however, brightness was mistaken with apparent size, because to the naked eye a brighter planet seems bigger. For us today, brightness and apparent size are different magnitudes, but for the Ancients a change in brightness was the same as a change in apparent size, which implied, consequently, a change in distance (cfr. Goldstein, 1996: 1-2).

Whereas for the Eudoxian model planets are always equidistant from the Earth, for the epicycle and deferent model, planets change their distance from the Earth, getting closer during their retrograde motion. This difference is usually argued to be the main reason for the rejection of Eudoxus' homocentric spheres in favor of the epicycle and deferent model, because the former cannot explain the manifest planetary increase of brightness during retrograde motion, while the latter can.

Certainly, this difference is not the only one between these two models: the Eudoxian proposal had in its favor that it was by far more faithful to the idea of making the center of the universe the center of all celestial motions, given that for the epicycle and deferent model the planets revolved around a theoretical center which not only was not the Earth, but it was movable. On the contrary, the epicycle and deferent system had in its favor that it was much simpler to understand and by far more flexible and powerful than Eudoxian spheres.

Nevertheless, the main reason given for the rejection of Eudoxus' homocentric spheres in favor of the epicycle and deferent system is still the impossibility of the first to explain the patent change of brightness during retrograde motion. Many scholars who made important contributions to the history of Ancient astronomy, such as Thomas Heath, Giovanni Schiaparelli or John L. Dreyer, agree with this assertion. Heath (1913: 221) affirms that "what was ultimately fatal to it [i.e., to the theory of concentric spheres] was of course the impossibility of reconciling the assumption of the invariability of the distance of each planet with the observed differences in the brightness, especially of Mars and Venus". Schiaparelli ([1926], 1998: 122) is on the same path when states that: "of these difficulties, the most formidable was this: that according to the homocentric sphere hypothesis, the distance and the brightness (according to the ideas of that time) of each celestial body would have to remain absolutely invariable, because they are carried out over a spherical surface concentric with the Earth; whereas observations of the brightness of the planets appeared very different at different times, especially in the case of Mars and Venus." Dreyer (1953: 141) also agrees when affirming that: "the homocentric system never received any further development or improvement, simply because, as Simplicius tells us, the great change in the brightness of the planets, especially Venus and Mars, rendered the idea of each planet being always at the same distance from the earth utterly untenable."

Furthermore, many philosophers of science offer the same explanation. For example, in his very influential (at least among philosophers of science and teachers) *Copernican Revolution*, Thomas Kuhn (1957: 58-59) explains that "…all homocentric systems have one severe drawback which in antiquity led to their early demise. Since Eudoxus' theory places each planet on a sphere concentric with the earth, the distance between a planet and the earth cannot vary. But planets appear brighter, and therefore seem closer to the earth, when they retrogress. During antiquity the homocentric system was frequently criticized for its failure to explain his variation in planetary brilliance, and the

[2] "At least in a qualitative way" because, as I will show later (Section 5), the Eudoxian model (as well as some versions of the epicycle and deferent model) was not capable of making Venus and Mars move in retrograde motion at the periods that they actually do.