

great and small Epicycle; or else by means of an Eccentric and Epicycle, modified from Ptolemy's, for reasons which we shall shortly mention. This mode of representing the motions of the planets continued in use, until it was expelled by the discoveries of Kepler.

Besides the daily rotation of the earth on its axis, and its annual circuit about the sun, Copernicus attributed to the axis a "motion of declination," by which, during the whole annual revolution, the pole was constantly directed towards the same part of the heavens. This constancy in the absolute direction of the axis, or its moving parallel to itself, may be more correctly viewed as not indicating any separate motion. The axis continues in the same direction, because there is nothing to make it change its direction; just as a straw, lying on the surface of a cup of water, continues to point nearly in the same direction when the cup is carried round a room. And this was noticed by Copernicus's adherent, Rothman,<sup>3</sup> a few years after the publication of the work *De Revolutionibus*. "There is no occasion," he says, in a letter to Tycho Brahe, "for the triple motion of the earth: the annual and diurnal motions suffice." This error of Copernicus, if it be looked upon as an error, arose from his referring the position of the axis to a limited space, which he conceived to be carried round the sun along with the earth, instead of referring it to fixed or absolute space. When, in a Planetarium (a machine in which the motions of the planets are imitated), the earth is carried round the sun by being fastened to a material radius, it is requisite to give a motion to the axis by *additional* machinery, in order to enable it to *preserve* its parallelism. A similar confusion of geometrical conception, produced by a double reference to absolute space and to the centre of revolution, often leads persons to dispute whether the moon, which revolves about the earth, always turning to it the same face, revolves about her axis or not.

It is also to be noticed that the precession of the equinoxes made it necessary to suppose the axis of the earth to be not *exactly* parallel to itself, but to deviate from that position by a slight annual difference. Copernicus erroneously supposes the precession to be unequable; and his method of explaining this change, which is simpler than that of the ancients, becomes more simple still, when applied to the true state of the facts.

The tendencies of our speculative nature, which carry us onwards in

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<sup>3</sup> Tycho. Epist. i. p. 184, A. D. 1590.