11 The Final Boundary. The Ecclesiastic Ban on Copernicanism

By the mid-seventeenth century, while the Portuguese philosophy professors increasingly adhered to the cosmological ideas that stemmed from the Tychonic system, in Europe, some Jesuit astronomers seemed gradually less confident about the truthfulness of this planetary system. Although geocentrism remained an article of faith, they started looking at the rival Copernican model with fresh eyes.

After the condemnation of 1616, it was possible to delve into the Copernican system as long as it was considered a simple hypothesis or a tool for astronomical computation. As such, it was taught for decades in Jesuit colleges throughout Catholic Europe. As in Lisbon, Jesuit professors usually closed the exposition of Copernicus's theories by stressing its biblical caveat and physical implausibility.

Nevertheless, as the seventeenth century progressed, the 'physical' arguments became a source of more serious contention. In this context, an increasing number of Jesuit astronomers adhered to the Galilean reasoning based on the application of his proto-inertial physics and mechanics to the cosmological discussion. This was the case, for example, of Andreas Tacquet, Honoré Fabri and Charles François Milliet Dechales, mathematicians who, based on the Galilean tradition, refuted all the physical arguments traditionally evoked in favour of a motionless Earth and showed a true interest in Copernican cosmology. Accordingly, as Ivana Gambaro has convincingly demonstrated, by the late 1650s and the 1660s, a more ambiguous attitude towards the Copernican system emerged within this scholarly community. After Riccioli's attempt to prove the Earth's immobility and to justify Galileo's condemnation in his *Almagestum novum* (1651), the leading authori-

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ties of the Jesuit mathematical community tended to recognise that Copernicus's heliocentric system offered a simpler and more reliable account of the celestial phenomena.[1]

In Lisbon, this novel approach to the study of world systems was epitomised very early on by the Belgium-trained English Jesuit John Rishton, who taught mathematics at Santo Antão in the 1651-52 academic year. He was the first Jesuit mathematician at the Lisbon College to take the Copernican system seriously as a viable model. Nevertheless, unlike Riccioli, who by then had published a comprehensive analysis of the heliocentric system (*Almagestum novum*, 1651), he did not aim to give a definitive treatment of the subject. Therefore, Rishton did not enter into detail on the use of mathematical arguments in the physical debate, as some of his Jesuit confrères did. The discussion on the Copernican system arose in the context of his mathematical course.[2]

The viability of this system stemmed first from the mathematical equivalence that existed between the planetary system of Ptolemy and that of Copernicus.[3] Even though the argument was not new, it was crucial to Rishton's reasoning in favour of the plausibility of the geo-heliocentric model. The English mathematician proved his point by drawing two partially juxtaposed circumferences representing respectively the apparent motion of the Sun around the Earth and the annual motion of the Earth orbiting the Sun (**[fig. 13a]**, Document IX). These circumferences share two equal semidiameters that account for the motions around the 'eccentre' and the Earth or the Sun, according to the different models. Since these two semidiameters are not only equal but also parallel to each other, and the Sun and the Earth were supposed to move at the same pace in both planetary models, the true and apparent motions of the Sun could be transposed to the Earth.[4] Moreover, Rishton proceeded to demonstrate that the equinoxes and the solstices, as well as the precessional movement of the Firmament and the slow movement of the vernal equinox, could easily be explained by the heliocentric model. Thus, he concluded that "all the celestial phenomena can be solved by Copernicus's system".[5]

Having solved the issues related to mathematical astronomy, Rishton concentrated his efforts on the physical discussion. He aimed to refute the traditional arguments according to which Copernicus's model was physically absurd. Being closely acquainted with the plurality of arguments raised against Copernicus, he knew that one of the central issues was the Aristotelian theory of motion, which stood in deep contrast to the Earth's diurnal rotation and orbital revolution around the Sun. As Rishton recalled, the traditional astronomers argued, along with Aristotle, that the Earth could neither move with two (or more) different motions nor perform a circular and perpetual motion. Being a simple body, the Earth could have only one nat-

1 Gambaro, "Geo-heliocentric Models".

2 After introducing his students to the theory of the spheres and trigonometry, Rishton examined the fundamentals of the "elemental sphere", in which he included the discussion on the astronomical systems. Then, he continued with lectures on geometry, spherical trigonometry and its use in geography, nautics and astronomy. He also lectured on mathematical instruments, including sundials and "pantometra".

3 Curiously enough, the geo-heliocentric system of Tycho Brahe was not discussed in this point.

4 For further details, see Proposition 3 below.

5 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 140*v*.

ural movement. Furthermore, the terrestrial elements consisted of earth and water and, therefore, were supposed to move in straight lines towards the centre of the universe.

Rishton stood up to both these Aristotelian criticisms. As regards natural motion, he refuted the principle according to which a simple body could not perform more than one simple motion by claiming that the motions that Copernicus assigned to the Earth were not contrary among themselves. He insisted that a sphere can move with a straight motion and, at the same time, move circularly around its centre. These movements occur on different planes, and thus they were not contrary when judged by reference to the same fixed point.[6] As far as the inability of the Earth to move in perpetual circles is concerned, the English Jesuit conceded that the Earth's motion is violent. Nevertheless, he added that the straight motions of the heavy bodies towards the centre of the universe and the motions of the planets are also violent. Therefore, he claimed that "the centre is no more appropriate to the Earth than any other place".[7] Furthermore, despite being subject to a violent motion, the Earth keeps constantly moving around the Sun and its axis because the extrinsic cause that moves it always operates in accordance with the same virtue and in the same manner.[8] Thus, Rishton dissociated the notion of a violent motion from the idea of temporal finitude raised by Aristotelian philosophers.

In his effort to argue that the Copernican theory did not necessarily run counter to physics, the English mathematician denied some of the central tenets of the Aristotelian natural philosophy, such as the theory of motion and natural places, and more particularly the idea that heavy bodies move towards the centre of the world in straight lines because of their internal nature. Rishton explicitly refuted this idea. According to him, the motion of natural bodies was produced by external causes or by a motive soul. In his words, "no body requires [a particular] motion because there is no principle in the matter inclining it to motion: therefore, the motion of bodies either proceeds from extrinsic causes or from the living soul (*alma vivente*): thus, it is not proper to the [heavy] body as such to seek the place below".[9] This is the reason why he considers the straight motion of the heavy bodies towards the centre of the world or the circular motion of heavenly bodies to be a violent and not a natural motion, as Aristotelians claimed. Rishton did not enter into the discussion of celestial dynamics. Nevertheless, taking into account the Jesuit criticism of the animate nature of celestial bodies, it is most likely that, alongside his confrères Borri and Fallon, who had previously taught mathematics in Lisbon, he endorsed the view that celestial bodies were moved by unrelenting and unvarying angels.

Moreover, from the physical point of view, Rishton considered that the Earth did not risk collapsing if it moved because the Earth was supposed-

6 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 141*r*. It is interesting to note that Clavius had already applied the same sort of argument in his dispute with the advocates of homocentric cosmologies. Clavius, *In sphaeram* (1611), 29.

7 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 141*v*.

8 Rishton, *Curso de Mathematica*, BNP, PBA. 54, ff. 141*r*-141*v*.

9 Rishton, *Curso de Mathematica*, BNP, PBA. 54, ff. 113*v*-114*r*: "Nenhum corpo de sua materia pede mouimento quia não se vê principio nenhum na materia que a incline a mouimento: ergo o movimento dos corpos ou procede de causas extrínsecas ou da alma viuente: ergo não he proprio do corpo ut tale buscar o lugar mais abaixo".

ly provided with a "unifying virtue" that constantly keeps together all its parts, "overcom[ing] the violence of the movement".[10] Rishton elsewhere described this "unifying virtue" as an attractive virtue that entices two bodies according to their density/rarity and distance (he gave no mathematical treatment of this correlation). As far as the heavy bodies are concerned, they were supposedly attracted to the centre of the Earth, the uppermost heavy body, the core from which this attractive virtue emanates. Rishton designated this attractive virtue "gravity" (*gravidade*). In his words:

> Gravity consists of the mutual attractive virtue of two bodies according to their density or rarity,[11] through which, if separated but within the sphere of the virtue, they would join each other – if there is no further impediment – and remain unified in the same body. This virtue is so suitable for the bodies that they cannot be separated without destruction of the nature. This notion stems from the experiments made on gravity. First, [we see that] the earth tends towards the Earth, and air to the air, because each one of these elements has a mutual attractive virtue that led them to unite with its whole and similar. This theory is also proven by the movement of the heaviest things through straight lines perpendicular to the Earth's surface. This happens because the attractive virtue occurs not only in the body that descends but is also very much found on Earth, from whose centre it spreads everywhere in straight lines like the rays of the Sun. A similar body must therefore be attracted by this attractive virtue, conforming its motion to the direction of these rays, which are perpendicular to the surface of the Earth. Accordingly, those things that we call heavy will always descend perpendicularly to the surface of the Earth.[12]

This powerful virtue that emanates from the centre of the Earth not only impedes the Earth from collapsing but also accounts for the fact that buildings would not fall if the Earth moved. They would be pushed towards the centre of the Earth in straight lines perpendicular to the Earth's surface, resisting the fast movement of the Earth around its axis. Furthermore, an extra force does not affect the buildings because the air also moves with the Earth's axial rotational movement.[13] The association of gravity with the air movement alongside the terrestrial motion also explains why an object

10 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 141*v*.

11 Literally, "which symbolise between them in the density or rarity of their parts".

12 Rishton, *Curso de Mathematica*, BNP, PBA. 54, ff. 114*r*-114*v*: "A grauidade consiste na mutua vertude atractiua de 2 corpos, que simbolisam entre si na densidade, ou raridade das partes por meio da qual a virtude sendo separadas com tanto que huma parte estiver dentro da sphera da virtude da outra se leuam a unirse entre si senão ouuer empedimento e unidas se conseruem na mesma figura; esta vertude he tão própria dos corpos que se lhes não pode separar sem destruição da natureza. A qual difinição posta dasse a resão das experiencias, que se achão açerca da grauidade. Primeira quia a terra vai para a terra, e ar para o ar, quia cada hum destes tem mutua virtude atractiua para unierse com seu todo e semelhante. Dasse tambem a resão do mouimento das cousas mais graues perpendicularmente a superficie da terra por linhas rectas quia como quer que esta virtude atractiua não só se da no corpo que desse mas muito na terra donde se defunde por todas as partes a roda por linhas rectas saindo radicalmente do centro como os rayos do Sol, força he que o corpo semilhante se deixe arrabatar desta virtude atractiua, e que se conforme em seu mouimento à direcção destes rayos, os quaes são perpendiculares a superficie da terra et consequenter as cousas que chamamos graues sempre desecerão perpendicularmente para a superficie da terra". Cf. Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 142*r*.

13 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 142*r*.

that is thrown upwards always falls in the same place. It shares gravity with the Earth and moves with the air.[14]

This line of reasoning only applies, however, to inanimate bodies. Rishton made this point by using the well-known example of the flight of birds. As the English Jesuit acknowledged, those who stand against the Earth's rotational movement argue that, if the Earth moved, birds flying for a long time in the air would not be able to find their nest and would fly more easily towards the east than towards the west. Rishton contended that this would not be the case because the birds are involved in the motion of the air and thus – the reader deduces – conserve the Earth's rotational motion. Nevertheless, this air movement did not carry birds along with it. Like all beings that are provided with the capacity of self-movement, birds could move wherever they wished because air moving at the same pace as the Earth would not push them. Here, the analogy with the prototype of animate beings is clear: "moving the air with the same speed as the Earth does neither hamper nor help the movement of man. Thus, we see that a man in a ship walks as easily for or against the motion of the ship".[15]

Although Rishton never quoted Galileo in his lecture notes, the resemblance between his position and that put forward by Salviati on the second day of Galileo's *Dialogue Concerning the Two Chief World Systems* is astonishing. Rishton's reasoning reverberates in Salviati's words, according to which "what keeps that motion unaltered in the birds is the air itself through which they wander. This, following naturally the whirling of the earth, takes along the birds and everything else that is suspended in it".[16] Rishton also followed Galileo's argument about birds' self-movement ability. As Salviati argued, birds can adjust their velocity to the Earth's rotational motion by adding or subtracting simple degrees of diurnal motion.[17]

The influence of Galileo is even more consequential in Rishton's definitive argument that, "if the Earth were to move, such a move would not be felt by men".[18] Although again omitting his source of inspiration, Rishton clearly drew on the Galilean argument that motion is relative to the position of the observer against a frame of reference. Should the observer move with the Earth, with no external reference point, he could not notice the Earth's motion. As the English Jesuit expressed it:

> Let us suppose that, according to the sentence of Copernicus, the starry sky does not move, the Sun occupies the centre of the world, and the Earth moves with diurnal and annual movements. It shall be proved that the observer would not perceive such a movement because motion is detected only with reference to a fixed point. If the observer is placed not far away from the moving object or at least with respect to the objects that move slower or faster to one another […], it would be impossible to perceive their motion because the [moving] objects keep the same dis-

14 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 142*r*.

15 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 143*r*.

16 Galileo, *Dialogue Concerning the Two Chief World Systems*, 213.

17 Galileo, *Dialogue Concerning the Two Chief World Systems*, 216.

18 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 134*v*.

tance between themselves and the observer.[19]

Provided with this key notion, Rishton was in an excellent position to tackle the case of the bullets shot towards the east and the west. As the argument goes, a bullet shot in the same direction of terrestrial rotation (eastwards) was supposed to range much farther than one shot in the opposite direction (westwards). As this is not the case, the conclusion to be drawn was that the Earth does not rotate around its axis. Rishton contended this conclusion by distinguishing two different planes, one measuring the range of the shot relative to an observer placed on the Earth's surface – the 'space of Earth' – and the other relative to the 'space of the world'. If the shot is observed in a position relative to the moving Earth, the range covered by the bullets shot eastwards is the same as that covered by the bullets shot westwards (one league, in Rishton's example). Nevertheless, if the same shot was analysed by an observer placed far away from the Earth, the bullet shot towards the east would be seen moving much farther than the westward projectile. In fact, observed from a position with reference to the universe, the relative distance travelled by the bullet shot eastwards corresponds to nine leagues, comprising the absolute distance covered by the bullet (one league) plus the distance traversed by the gun following the rotational motion of the Earth (eight leagues to the east, according to Rishton). Nevertheless, in the case of the bullet shot westwards, the relative distance equals seven leagues to the east, corresponding to the absolute distance travelled by the bullet (one league to the west) minus the distance traversed by the gun (eight leagues to the east). Thus, for an observer placed on the Earth's surface, both bullets range approximately the same distance.[20]

Rishton concluded, therefore, along with Galileo,[21] that, if the Earth rotated around its axis, as Copernicus argued, an observer placed on the Earth's surface could not perceive the difference in the bullets' eastward and westward movements. From this point of view, the English Jesuit had no doubt that "the system of Copernicus is not physically impossible" (*O sisthema de Cupernico não he naturalmente impossiuel*).[22]

Nevertheless, Rishton recognised that there were a few arguments against the possibility of terrestrial movement. Among these were the reason derived from astronomy, namely the fact that astronomers observed no stellar parallax, which was an expectable phenomenon in Copernicus's hypothesis **[fig. 12]**. The probable lack of scale of the universe thus discouraged contemporary astronomers from advocating this hypothesis.[23]

However, the main obstacle to the adoption of Copernicanism was a theological one: "the authority of the Sacred Scripture, which in various places clearly attributes motion to the Sun and stillness and stability to the Earth", Rishton claimed, quoting the common passages from the *Bible*.[24] Further-

19 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 134*v*.

20 Rishton, *Curso de Mathematica*, BNP, PBA. 54, ff. 142*v*-143*r*.

21 Galileo discussed the question of the east-west gunshot in the second day of his *Dialogue* (Galilei, *Dialogue*, 195-8). Rishton's analysis is a subsidiary of this discussion.

22 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 140*v*.

23 Rishton, *Curso de Mathematica*, BNP, PBA. 54, ff. 143*v*-144*v*.

24 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 146*v*: "Probatur tertio praecipue pela authoridade da sagrada scriptura a qual sinaladamente em varios lugares atribue mouimento ao

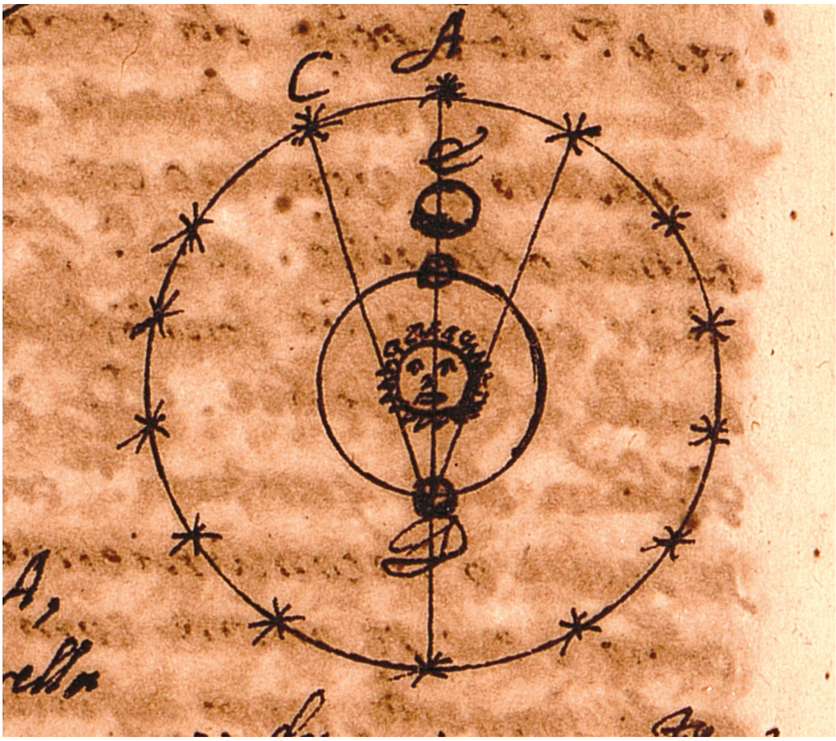

Figure 12 Rishton's demonstration of the lack of stellar parallax in Copernicus's planetary system (Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 143*v*)

more, the English Jesuit asserted that the *Bible* should be "explained literally" and according to the "unanimous consensus of Saint Fathers".[25] Finally, the professor of mathematics evoked the celebrated condemnation of Galileo by Pope Urban VIII and the inquisitorial cardinals: "it should be referred that the collegium of cardinals established by Urban VIII to examine ecclesiastical controversies has prohibited the opinion of the terrestrial movement".[26]

In the age of confessionalisation, the adoption of Copernicanism was impossible for someone restrained by the dictates of the Council of Trent, such as John Rishton. Although not based on the specific proto-inertial arguments

Sol, e quietude, ou firmeza a terra" ('It is proved in the third place, mainly by the authority of the sacred scripture, which in several places explicitly attributes movement to the Sun, and stillness, or firmness to the Earth').

25 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 147*r*: "Notesse primeiro que he regra de S. Agostinho para interpretar as sagradas scripturas, que se ande explicar literalmente se senão seguir absurdo, ou implicação do sentido literal. Notesse segundo que não he licito interpretar as sagradas scripturas contra o unanimo consensso dos Santos Padres e todos elles concordam no mouimento do Sol, e firmeza da terra" ('Firstly, one should note that, according to the rule of St. Augustine for interpreting the sacred scriptures, these are to be explained literally if no absurdity or contradiction of the literal sense follows from it. Secondly, one should note that it is not licit to interpret the sacred scriptures against the unanimous consensus of the Holy Fathers, and they all agree on the movement of the sun and the firmness of the earth').

26 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 147*r*: "Notesse terceiro que o collegio dos cardeaes, o qual tribunal foi instituido por Urbano 8 para difinir controversias ecclesiasticas proohibio a opinião do mouimento da terra".

developed by Galileo, he was aware of the critical arguments used in the *Dialogue Concerning the Two Chief World Systems* in favour of heliocentrism. Nevertheless, biblical literalism, the Patristic consensus and the ecclesiastic ban remained the last and decisive boundary preventing him, as a Catholic astronomer, from adhering to the ideas of Copernicus.

Such being the case, the geo-heliocentric system of Tycho Brahe emerged as the only solution that Rishton and the entire community of Jesuit astronomers ought to be following.[27] The Tychonic system was the achievable compromise between ancient Ptolemy and modern Copernicus:

> [Copernicus] observed that the planets, provided with their proper motions, revolved around the Sun as their centre [and], therefore, the system of Ptolemy could not be true. For the same reasons, Tycho Brahe, a renowned astronomer, tried to open his safe path between the principles of Ptolemy's ancient system and those of Copernicus's modern system. He rejected what seemed false in both systems and chose what appeared to be according to reason and the truth of celestial phenomena; he reversed both the systems and created [a new] one.[28]

Similarly to his fellow Jesuits, who taught mathematics at the College of Santo Antão before him, Rishton endorsed the geo-heliocentric system put forward by Tycho Brahe. Furthermore, he explicitly conceived it as a 'compromise' system, a system that conciliates the mathematical innovations of Copernicus's heliocentric and geokinetic views with the biblical imperatives of an immobile Earth. From this point of view, the adoption of the cosmological ideas of a Lutheran astronomer made the Copernican shift acceptable from a mathematical and physical perspective. Ecclesiastic authority remained as the last boundary.

27 It is important to note that, despite Rishton seeming to be well informed about books that had only just been published (for example, quoting from the influential *Cursus Philosophicus* by the Portuguese Jesuit philosopher Francisco Soares, published in 1651, f. 147*r*), he made no reference to Riccioli's *Almagestum novum* (Bologna, 1651).

28 Rishton, *Curso de Mathematica*, BNP, PBA. 54, f. 133*r*: "[Copérnico] obseruou que os planetas com seus mouimentos proprios rodeauão o Sol, como seu centro; portanto o sisthema de Tholomeu não pode ser verdadeiro pelas quaes resões Thico bray insigne Astronomo intentou abrir hum caminho seguro entre os principios do sisthema antigo de Tholomeu, e o moderno de Cupernico. Engeitou o que parecia falso em ambos e escolheo aquillo que parecia conforme a resão, e verdade dos phaenomenos celestes, inuertou ambos os sisthemas e fes hum só".

Document IX

Capítulo 3º
Do lugar e estabilidade da Terra. John Rishton, *Curso de Mathematica*, BNP, PBA. 54, ff. 134*v*-143*v*

Proposição 1ª
Referem-se várias hipóteses ou sistemas do mundo

Proposição 2ª
Dado que a terra se mouesse o tal mouimento não se auia [de] sentir dos homens

Suponhamos que o ceu estrellado não se moue, e que o sol ocupa o centro do mundo, e a terra se mouesse com mouimento diurno, e annuo [conforme] a sentença de Cupernico. Se a de prouar que a vista não auia de perceber o tal mouimento.

Prova-se quia a vista não percebe mouimento senão por ordem a ponto fixo, e que não está mui remota do objecto mouel, ou por lo menos em respeito de alguma cousa que se moue mais tarda, ou velozmente que outra, do que resulta mais, ou menos distância entre os objectos quia assi os objectos [que] guardam a mesma distância entre si e a vista obram no olho da mesma maneira nem há por onde se possa colher mouimento e assi vemos que [f. 134*v*] os nauegantes, quando estam dentro da nao que vai andando, não podem distinguir com a vista que a nao anda cuja resão he asima dita quia todas as partes da nao se mouem com o mesmo mouimento e guardam entre si o mesmo sitio, e distância, e distão igualmente da vista: ergo não ha por onde se possa colher o mouimento local da nao: cuja resão he quia o mouimento não sendo objecto proprio da vista não se percebe imediatamente em si: ergo se todas as outras cousas ficam da mesma maneira não se percebera o mouimento mas em caso que a terra se mouesse todas as cousas auiam de guardar o mismo sitio, e a mesma distancia entre si, e o olho: ergo o tal mouimento não se auia de perceber, quod erat demonstrandum.

Proposição 3ª

Se a terra se mouesse com mouimento annuo, e o sol estiuesse quedo no centro, como no sisthema [de] Cupernico seguirsehia o mesmo mouimento apparente do Sol que no sisthema de Tholomeu

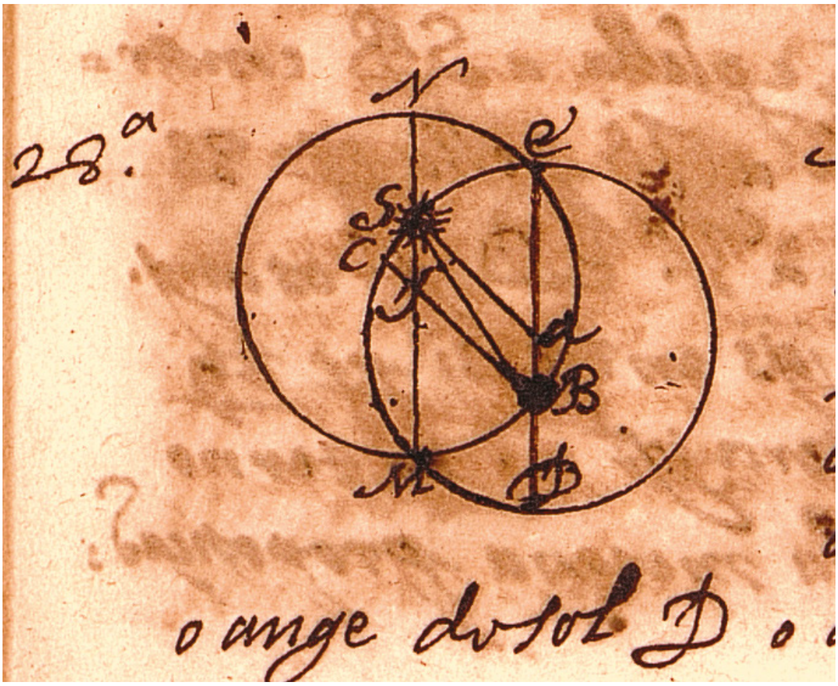

Figure 13a John Rishton's representation of the Sun annual motion according to the Ptolemaic system

Seja o orbe annuo do sol, ou linha ecliptica no sisthema de Tholomeu na figura 28a [here fig. 13] ESD cujo centro A; lugar da terra, B a linha da excentricidade BA, a qual continuada por ambas as partes athe a circunferência o ponto [E] sera o auge do sol D o antauge, ou perigeo. [f. 135*r*] Mouesse o sol de seu apogeo te o ponto S tirasse as linhas AS BS manifesto he que a linha do mouimento meio do sol sera AS, e o [angulo do] mouimento meio EAS, a linha do mouimento verdadeiro BS o qual também se chama apparente, e o angulo EBS o angulo do mouimento verdadeiro, ou apparente, e o angulo BSA a paralaxe do orbe annuo, ou distância entre o mouimento meio e o apparente do Sol, agora do centro da terra B tiresse a linha BC paralela a AS e em BC tomesse a linha BJ igual a linha AS do ponto J ao interuallo JB descreuesse o circolo NBM, o qual sera igual ao circulo ESB [*sic*, ESD] difere do circulo por serem os semidiametros iguais, paralela construção e lançada do ponto J em S huma linha a qual se continua por ambas as partes te NM, e ponhamos que o Sol esteja immouel no ponto S, e que a terra se moua no orbe annuo MBN, cujo centro J, excentricidade JS auge M, anteauge N, e mouase a terra de seu auge M te o ponto B e no mesmo tempo em que no hypotesis de Ptholomeu que o sol se mouia no seu E ate o ponto S. Digo que em ambos os casos assi o mouimento apparente, como o meyo do Sol serà apparentemente igual.

Quia a linha JB sendo igual e paralella a SB [*sic*, SA] construçcção [*sic*, consequentemente] a linha AB sera igual, e paralella a JS pella proposição 35 [*sic*, 33] do livro [I dos *Elementos* de Euclides], ergo a linha NM será paralella à linha ED, ergo os angulos alternos EBS, MSB, seram iguais entre si [pela] proposição 29 do livro e o angulo externo EAS sera igual ao externo opposto alternativamente MJB, pella mesma proposição [f. 135*v*] mas o angulo MJB he mouimento meio da terra e MSB mouimento seu apparente do lugar do sol, S e o mouimento meio do sol como està dito he o angulo EAS e o apparente visto da terra he o angulo EBS, ergo em ambas as hipotesis assi o mouimento verdadeiro como o meio he apparentemente igual.

Corollarios

Daqui se enfere tambem que em caso que o sol fosse [i]mouel, e a terra se mouesse no orbe annuo a mesma avia desser a paralaxis do orbe annuo em ambas hipotesis, quia em caso do mouimento do sol o angulo BSA he a paralaxi do orbe annuo, ou a distância entre o mouimento verdadeiro e [o] meio, em caso de mouimento da terra e quietude do sol SBJ, mas estes dois angulos são iguais por ser alternativamente oppostos e as linhas AS, JB paralellas [pela] proposição 29 do livro, ergo a mesma auia de ser a paralaxi do orbe annuo em ambas as hipotesis.

Inferesse tambem que a distância do sol a terra auia de ser amesma em ambos os casos, poes a mesma linha SB he a distância do sol em ambos os casos, ergo etc.

Inferesse [em] terceiro [lugar] que a excentricidade do orbe annuo seria a mesma quia AB [é] igual a linha SJ na mesma figura 28a.

Quarto quia a mesma equação do tempo auia de ser em ambas as hipotesis ASB igual ao angulo SBA [*sic*, SBC].

[Por] ultimo se infere que a mesma opposição, e conjunção dos planetas auia de acontecer porquanto estes dependem do mouimento annuo do sol, e dos planetas, e como quer que [f. 136*r*] o mouimento apparente do sol he o mesmo, e o mouimento dos planetas não se muda, seguesse que o mesmo auia de ser nas conjuncões, e opposições, e os demais aspectos dos planetas com o sol.

Proposição 4ª
Do mouimento annuo do sol no sisthema de Cupernico se segue o mouimento diurno [ff. 136*v*-137*v*]

Proposição 5ª
Explicansse os equinocios, e os solsticios na hipotesis do mouimento da terra [ff. 137*v*-139*r*]

Proposição 6ª
Explicasse como se saluão os outros mouimentos na mesma hipotesi [ff. 139*r*-140*v*]

Proposição 7ª
O Sisthema de Cupernico não he naturalmente impossiuel

Primeiro quia não importa cousa que contem em si implicação ou absurdo contra as Leis da natureza: ergo não he impossiuel. [f. 140*v*] Oppones primo he impossiuel que o mesmo corpo se moua com dois mouimentos diverços mas na dita hipotesis a terra mouesse com dois, e mais mouimentos diverços: ergo a dita hipotesis he impossiuel. Consequentia patet minor consta ex dictis. Probatur maior, quia se hum corpo se mouesse com diverços mouimentos sequeretur que o mesmo corpo natural podia estar em dois lugares diverços: siquidem diversus motus diversum consequentur ubi: ergo por dois mouimentos diuersos alcançaria dous ubis diuersos. Repondeo negando maiorem do primeiro silogismo; nem a premissa he efficas, quia ainda que seja impossiuel que o mesmo corpo se moua por dois mouimentos totalmente contrarios ou para termos [?] oppostos, contudo he certo, que hum corpo se poder mouer com varios mouimentos não sendo os otros dos taes mouimentos entre si contrarios; assi vemos que hum globo se moue em plano com mouimento recto progressiuo, e no mesmo tempo se moue com mouimento circular a roda de seu centro; os quaes mouimentos estam tam longe de encontrar hum ao outro, que se ajudam entre si; e se o globo for de matéria mais pesada de huma parte que da outra logo se notara outro mouimento de declinação, e não serà o mouimento por linha recta no plano.

Agora applicando isto a nosso propósito, Digo, que os ditos mouimentos que a dita hipotesis attribue a terra não são contrários entre si, ou para termos oppostos, e assi não se segue implicação alguma.

Oppones secundo, o mouimento sircular não pode ser natural à terra, porquanto he corpo graue: mas todo o corpo graue uai naturalmente para o centro do mundo: ergo a terra naturalmente se ade mouer com mouimento recto para o centro do mundo, e consequentemente o mouimento sircular não pode competir a terra. [f. 141*r*] Respondeo concedendo maiorem et negando minorem, quia o mouimento recto dos corpos graues para o centro do mundo he igualmente violento, como o mouimento circular ut sequitur probatum est nem a terra appetece mais o centro, que qualquer outro lugar.

Jubebis [?] pello menos o mouimento da terra sera violento: ergo não pode ser perpetuo. Respondeo primo que argumento ande soltar todos, quia este mouimento da terra nesta hipotesis não he mais violento, que os outros mouimentos dos planetas, os quaes etiam são corpos graues, como a terra. Respondeo secundo negando consequentiam nem aquelle principio em que se funda de força do argumento he verdadeiro sinão quando as cousas excentricas que obram tem virtude deffectiua, e fatigauel, mas no nosso caso a causa excentrica que assiste sempre obra eodem modo, e com a mesma virtude: ergo, não se segue que ainda que este effeito seja violento, não seja perpetuo, nem isso acontesse sò no mouimento da terra, mas também nos planetas, etc.

Arguira alguem contra esta solução, que da tal violencia se seguiria destruição da terra, quia a agitação he inimiga da união das partes. Respondeo primo que com mais resão se pode temer, que os corpos celestes se desfação, que a terra: por serem seus mouimentos mais velozes. Respondeo secundo que a virtude unitiva das partes da terra he tanta, que sem difficuldade vence a violencia do mouimento que he igualissimo. [f. 141*v*]

Oppones quarto se a terra se mouesse seguirsehia, que todos os ediffícios auião de cair. Respondeo negando sequellam verdade he que se este mouimento fora tremulo se auia de seguir este effeito, como vemos nos terremotos, mas sendo uniforme, e rigular e pezando sempre os edificios por linhas rectas para o centro não ha que timer que aja menos firmeza nos edificios, em caso de mouimento da terra, do que se senão mouesse, praecipue se dicermos que juntamente com a terra o ar vezinho tambem se leua com o mesmo mouimento.

Oppones quinto contra esta sentença, seguirsehia do mouimento da terra, que as cousas lançadas para sima não auiam de cair ponto do mesmo lugar donde se lançarão, quia estando separadas da terra a qual se moue entre tanto mui veloxmente para o oriente, a deçida do corpo graue correspondera a outro ponto da terra mais occidental. Respondeo primo que se o ar não se mouesse também por ventura teria este argumento alguma difficuldade, mas mouendosse e todas as outras cousas, que participam alguma cousa da grauidade com o mesmo mouimento da terra; força he que todas as cousas lançadas para sima caiam da mesma sorte na hipotesis do mouimento da terra, como se estiuesse firme.

Replicasse pello menos seguirsehia, que se duas balas de artelharia se desparassem huma para o oriente, outra para poente com o mesmo impeto, a bala, que se desparasse para o oriente auia de chegar mais longe, que a que se dispara para o occidente; porquanto o mouimento proprio se ajuntou com o mouimento do impulso da poluora, os quaes ajudam hum ao outro; porem na segunda o mouimento impulso da força da poluora se encontra com o mouimento [f. 142*r*] proprio, e consequenter não podem deixar de retardar hum ao outro.

Confirmasse esta objecção do mouimento de duas embarcações huma, das quaes nauega com mare, e vento em popa, e outra com vento, mas contra mare, certo he que a primeira nauegara mais depreça, que a segunda porquanto os dois impulsos do vento, e mare ambos concorrem, e hum ajuda a outro: mas no segundo caso se encontram e o mais fraco impulso impede ao mais forte.

Respondeo se este argumento proua alguma cousa seria que a terra de facto não se moue, mas não fas nada contra a possibilidade deste mouimento que defendemos. Respondeo secundo ou esta comparação dos dois mouimentos se fas em respeito do espaço do mundo, que as duas balas andam, ou em respeito do espaço da terra, se em respeito do primeiro [?] que a bala atirada para o oriente anda mais, que a bala atirada para o occidente; se em respeito do interuallo da terra, digo que ambos os mouimentos ou são iguais, ou pello menos a distância he tam pouca que senão sente. Declarasse isto mais explicando a qualidade de ambos os mouimentos, mouesse a primeira bala, que se dispara para o oriente com o impeto da poluora huma legoa v.g. no spaço de hum minuto de tempo e quia o mouimento da terra he muito mais velox no mesmo tempo se mouera perto de 8 legoas para o mesmo oriente, e quia a bala participa tambem deste mouimento mouerse ha 9 legoas para o oriente, em respeito do spaço do mundo, e huma sò em respeito da terra, quod idem est caira huma legoa distante do spaço da terra, onde se disparou, mas a bala que se disparou para o occidente com igual impeto no spaço de hum minuto se mouerà [f. 142*v*] tambem huma legoa; e porquanto o mouimento que abala participa da terra he 8 vezes mais velox, e encontrando com este, abala em respeito do espaço do mundo a de bater tanto, quanto he o mouimento impulso, e assi mouera 7 legoas do occidente para o oriente em respeito do spaço do mundo, e chegara huma legoa para o occidente em respeito do lugar, onde se disparou: De modo que os mouimentos das duas balas comparados em respeito do spaço da terra, ou he igual ou a distância he tam pouca, que senão ve. Porem em respeito do spaço do mundo ha tanta distância entre os mouimentos quanta he a soma de ambos os mouimentos em razão[?] do spaço da terra.

Quanto à confirmação [?] totum o que dis, mas dahi não se segue, que o mouimento das balas seja desigual em respeito do espaço da terra, senão do mundo.

Outras objeccões são semelhantes a esta a primeira, que o passaro que voa no ar, para buscar que comer não auia de achar o ninho. A segunda que quem anda para o oriente auia de ir com mais facilidade, e menos canceira do que o que anda para o poente. Respondeo à primeira que visto que o ar se moue que tambem a aue juntamente com o mouimento da terra, e o ar não se segue o inconueninte. A segunda Respondeo negando sequellam, quia como o ar se moue com a mesma velocidade que a terra não impede, nem ajuda o mouimento do homem, e assi vemos que quem anda em hum nauio tam facilmente anda contra o mouimento do nauio, como sim elle.

Que do mouimento a terra auia de aqueser, quia o mouimento principaliter violento est causa caloris sed este calor não se percebe: ergo a terra não se moue. Respondeo primo que este argumento não impugna a possibilidade do mouimento senão do mouimento actual. Respondeo secundo negando o asumpto se se entende de calor sensiuel, quia não vemos que o mar aquesa com o mouimento o qual etiam he violento, e aquelles corpos só aquecem com mouimento que são em potencia calidos. [f. 143*r*] O ultimo argumento contra esta sentença he, que os fructos da terra não auião de crescer se a terra se mouesse com mouimento diurno. Respondeo negando sequellam poes vemos por experiência que se huma pouca de terra se puzer em hum vaso, e se preparar [?] diuidamente e se puzer ao ar, e as influencias do ceo em algum nauio sem embargo do mouimento do nauio não he menos apta para producir flores, e outros fructos, que se semeam. [f. 143*v*]

Document IX

Chapter 3

English translation. On the Earth's place and stability. John Rishton, *Curso de Mathematica*, BNP, PBA. 54, ff. 134*v*-143*v*

Proposition 1
Various hypotheses or systems of the world

Proposition 2
If the earth were to move, men would not feel such a movement

Let us suppose that, according to the sentence of Copernicus, the starry sky does not move, the Sun occupies the centre of the world, and the Earth moves with diurnal and annual movements.

It shall be proved that the observer would not perceive such a movement because motion is detected only with reference to a fixed point. If the observer is placed not far away from the moving object or at least with respect to the objects that move slower or faster to one another […], it would be impossible to perceive their motion because the [moving] objects keep the same distance between themselves and the observer. [f. 134*v*] Accordingly, we see that, while inside a ship that is moving, the sailors cannot perceive the motion of the ship because of the reason mentioned above, that is, all the parts of the ship are moving with the same motion, keeping the same place and distance between them. Furthermore, they are equally distant from the observer. Therefore, there is no way to perceive the ship's local movement. Thus, if the movement is not subject to the observer, it cannot be perceived. Therefore, if the Earth moved, all things [in it] would keep the same distance between themselves and the observer; therefore, its movement would not be perceived, *quod erat demonstrandum*.

Proposition 3

If the Earth moved with an annual movement, and the Sun remained stationary in the centre [of the universe], as in the system [of] Copernicus, the same apparent movement of the Sun would follow as in the system of Ptolemy

Let ESD, in figure 28a [here **fig. 13**], be the Sun's yearly orb or the ecliptic line according to the system of Ptolemy, whose centre is A; the place of the Earth, B; and the eccentricity line, BA, which continued to both parts of the circumference, the point [E] corresponds to the Sun apogee, and D the anti-apogee (*anteauge* in Portuguese) or the perigee. [f. 135*r*] If the Sun moves from its apogee to the point S and the lines AS BS are drawn, it is obvious that the line of the middle motion of the Sun will be AS, and the [angle of the] middle motion EAS; the line of the true motion, which is also called apparent, [corresponds to] BS, and the angle EBS [corresponds] to the angle of the true or apparent motion; the angle BSA is the parallax of the annual orb or the distance between the middle and apparent motions of the Sun. Now from the centre of the Earth B draw the line BC parallel to AS and in BC consider the line BJ equal to the line AS. From the point J to the semicircle

JB, draw the circle NBM, which will be equal to the circle ESB [*sic*, ESD]. It differs from this circle because the semidiameters are equal in parallel construction. From the point J in S launch a line which continues on both sides to NM, and let us assume the Sun is immovable in point S, and the Earth moves in the yearly orb MBN, whose centre is J, the eccentricity is JS, the apogee is M, the anti-apogee [or perigee] is N. Let move the Earth from its apogee M to the point B spending the same time as the Sun when it moves from E to the point S in the Ptolemaic hypothesis. I declare that the apparent and the middle motions of the Sun will be apparently equal in both cases.

Because the line JB is equal and parallel to SB [*sic*, SA], the line AB will consequently be equal and parallel to JS by the proposition 35 [*sic*, 33] of the book [I of Euclid's *Elements*]; therefore, the line NM will be parallel to the line ED and the alternate angles EBS, MSB will be equal between themselves [by] the proposition 29 of the book and the external angle EAS will be equal to the external opposite MJB, by the same proposition. [f. 135*v*] The angle MJB is the middle motion of the Earth and MSB is its apparent motion from the place of the Sun S, and the middle motion of the Sun – as already declared – is the angle EAS and the apparent motion seen from the Earth corresponds to the angle EBS angle. Therefore, in both hypotheses, both the true and the middle motions are apparently equal.

Corollaries

From here it is also emphasised, [first], that in case the Sun rested still and the Earth moved in the annual orb, the parallax of the annual orb should be the same in both hypotheses, because, in the case of the moving Sun, the angle BSA is the parallax of the annual orb or the distance between the true and the middle motions; in the case of the motion of Earth and the stillness of the Sun, the parallax corresponds to SBJ. Since these two angles are equal because they are alternatively opposite and the lines AS and JB are parallel [by] proposition 29 of the book, the parallax of the annual orb would, therefore, be the same in both hypotheses.

[Second], it would also infer that the distance from the Sun to the Earth would be the same in both cases, because the line SB corresponds to the distance from the Sun in both cases; therefore etc.

Third, the eccentricity of the yearly orb would be the same because AB equals the line SJ in the same figure 28a [here **fig. 13b**].

Fourth, because the equation of time would be the same in both hypotheses, that is ASB equal to the angle SBA [*sic*, SBC].

Finally, it follows that the same opposition and conjunction of the planets had to happen because they depend on the annual motion of the Sun and planets, and since the apparent motion of the Sun is the same and the motion of the planets does not change, it follows that the same conjunctions and oppositions and other aspects of the planets with the Sun had to take place.

Proposition 4
The diurnal movement follows from the yearly movement of the Sun in Copernicus's system [ff. 136*v*-137*v*]

Proposition 5
Explanation of the equinoxes and the solstices according to the hypothesis of the Earth's movement [ff. 137*v*-139*r*]

Proposition 6
Explanation of how to save the other movements according to the same hypothesis [ff. 139*r*-140*v*]

Proposition 7
The system of Copernicus is not physically impossible

First, one should not consider something that has in itself an implication or an absurdity against the laws of nature: therefore; it is not impossible. [f. 140*v*] *Oppones primo*, it is impossible for the same body to move with two distinct movements, but in the above-mentioned hypothesis the Earth moves with two and more distinct movements: therefore, the above-mentioned hypothesis is impossible. *Consequentia patet minor consta ex dictis. Probatur maior*, because if a body moved with different movements *sequeretur* [i.e. 'it would follow'] that the same body could be in two different places: *siquidem diversus motus diversum consequentur ubi*: therefore, by following two different motions, it would reach different places (*ubis*). I answer *negando maior* of the first syllogism. The premise is not effective because even if it is impossible for the same body to move with two totally opposite movements and opposite directions, however, there is no doubt that a body can move with several movements, if those movements are not contrary to each other. So we see a globe can move in a plane with a straight progressive motion and, at the same time, move with a circular motion around its centre, movements which never collide with each other and, in fact, help each other mutually; and if the globe is made of up heavier matter in one part than in the other part, soon another motion of declination – which will not be in a straight line in the plane – will be noticed.

Now applying this [conclusion] to our purpose, I declare that the above-mentioned movements that the [Copernican] hypothesis attributes to the Earth are not contrary to each other or do not move in opposite directions. Therefore, no implication follows from it.

Oppones secundo, the circular motion cannot be natural to the Earth, because the Earth is a heavy body, and every heavy body naturally moves towards the centre of the world. Therefore, the Earth would naturally move with a straight motion towards the centre of the world. Consequently, the circular motion cannot be attributed to the Earth. [f. 141*r*] *Respondeo concedendo maiorem et negando minorem*, because the straight motion of the heavy bodies towards the centre of the world is equally violent in the same manner as the circular motion, *ut sequitur probatum est*, the centre is no more appropriate to the Earth than any other place.

Jubebis [?], at least, the Earth's movement must be violent. Therefore, it cannot be perpetual. *Respondeo primo* that this reason should solve all the others because, according to this hypothesis, the Earth's motion is no more violent than the other motions of the planets, which, like the Earth, are heavy bodies. *Respondeo secundo negando consequentiam*, by claiming that the principle on which the strength of the argument is based is not true except when the extrinsic operating causes have a defective and limited virtue. But in our case, the extrinsic cause is always operating in the same way and with the same virtue. Therefore, it does not follow that even if this effect is violent it is not perpetual, nor does it happen only in the Earth's motion, but also in the planets etc.

Someone shall argue against this solution that it would follow, from such a violent motion, the destruction of the Earth because the physical movement is the enemy of the unification of the parts. I argue first that more reasonably should one fear the collapse of the heavenly bodies than the Earth, for they move much faster. I argue second that the unifying virtue of the parts of the Earth is so great that without difficulty it overcomes the violence of the movement, which is always the same. [f. 141*v*]

Oppones quarto that if the Earth were to move, all the buildings would fall. *Respondeo negando sequellam*, this effect would indeed follow if this motion were tremulous, as we see in earthquakes, but being uniform, regular, and always pushing the buildings to the centre by straight lines, there is no reason to fear that buildings are less resistant in case the Earth moves than if it stands still, especially if we consider that the air also moves with the same motion along with the Earth.

Oppones quinto against this sentence that it would follow from the movement of the Earth that the things thrown upwards would not fall in the same place from where they were previously thrown up, because being separated from the Earth, which is moving very fast towards the east, they would drop in a more occidental point of the Earth. *Respondeo primo* that this argument would be right if the air did not move, but since it moves along with all the things that partially share the gravity with the motion of the Earth, the objects thrown upwards will necessarily fall in the same way regardless of the movement or the steadiness of the Earth.

Some would at least contend that if two artillery bullets were fired, one to the east and the other to the west, with the same momentum, the bullet fired to the east would reach farther than the one fired to the west. This would happen because the momentum generated by the gunpowder's impetus was joined to the proper momentum, collaborating with each other. Nevertheless, in the second case, the momentum generated by the gunpowder's impetus faces the proper motion [f. 142*r*] and *consequenter* they can only delay each other.

This objection is corroborated by the movement of two ships, one of which goes with the flow and the wind behind, and the other with the wind behind, but against the flow. There is no doubt that the first ship will sail faster than the second one because, in this case, both the impulses of the wind and the flow concur, and one helps the other, while, in the second case, both impulses collide and the weaker one slows the stronger.

Respondeo, if this argument proves anything, it would be that the Earth in fact does not move, but it does not stand against the possibility of this movement that we defend. *Respondeo secundo* that either this comparison of the two movements is made with respect to the space of the world, in which the two bullets move, or with respect to the space of the Earth. If it is made with respect to the former, the bullet shot to the east moves farther than the bullet shot to the west; if it is made with respect to the Earth's space, I declare that both movements are equal, or at least the difference in distance is so small that no one could perceive it. Further explanation of the quality of both the movements is required to prove this point. The first bullet, which is shot towards the east with the gunpowder's impetus, moves one league, e.g. in the space of one minute. Nevertheless, since the movement of the Earth is much faster, moving in the same time close to eight leagues to the east, and the bullet takes part of this movement, the bullet shot towards the east moves nine leagues to the east with respect to the space of the world but only one with respect to the Earth, *quod idem est*, it will fall one league away from the place on Earth where it was fired. Nevertheless, the bullet that was shot to the west with the same impetus will also move one league in one minute, [f. 142*v*] but, since the movement it shares with the Earth is eight times faster, when the bullet encounters the terrestrial movement, with respect to the space of the world, it would move as much as the impetus's movement. Therefore, it would move seven leagues from the west to the east with respect to the space of the world, and one league to the west with respect to the place from where it was fired. Accordingly, if we compare the movements of the two bullets with respect to the space of the Earth, they are either equal or the difference in the distance reached is so short that it is not perceptible. Nevertheless, with respect to the space of the world, there is as much distance between the two motions as the sum of both motions in relation to the space of the Earth.

As for the confirmation, [I agree with] *totum* [i.e. 'all'] you say, but it does not follow from that that the movement of the bullets is different with respect to the space of the Earth, but only with respect to the world.

There are other similar objections, [namely] that the bird that flies in the air in search of food on its way back would not find the nest. The second states that the bird that flies towards the east would go more easily and with less fatigue than the one that flies towards the west. *Respondeo* to the first argument that there is no such reason because the air is also moving together with the bird and the Earth. *Respondeo negando sequellam* to the second argument, because moving the air or at same speed as the Earth does neither hamper nor help the movement of man. Thus, we see that a man in a ship walks as easily for or against the motion of the ship.

[A further objection claims] that the movement would warm the Earth *principaliter* because the local movement *est causa caloris sed* this heat is not perceptible: ergo the Earth does not move. *Respondeo primo* that this argument does not object to the possibility of motion but only to the actual movement. *Respondeo secundo*, denying the subject if the topic of discussion is the sensible heat. We do not see the sea warming because of the motion, which is violent. Only the potentially hot bodies warmed because of the movement. [f. 143*r*] The last argument against this sentence is that the earthly fruits would not grow if the Earth moved with a diurnal motion. *Respondeo sequellam*, because we see by experience that if a little portion of earth is put into a pot, is well prepared and exposed to the air and to the celestial influences within a ship, it will be no less fit to produce flowers and other fruits, which are sown regardless of the ship's movement. [f. 143*v*]