

GEMMA FRISIUS: A CONVINCED COPERNICAN IN 1555

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Gemma Frisius (1508–1555), cosmographer from Louvain, editor and continuator of Peter Apian's *Cosmography*, author of the 16th century's best-selling manual of *Arithmetics*, maker of globes, maps of the world and various instruments, inventor of new methods of topographical triangulation and maritime orientation, consistently demonstrated great interest in the Copernican system, from the hopes he expressed after reading the *Narratio prima*¹ of Rheticus, via the favourable judgements of the *De Revolutionibus* pronounced in the *De Radio* and the *De Astrolabo*², through to the preface to the *Ephemerides* of his pupil Stadius³. It is this latter text that I would like to examine in more detail here. As one of Gemma's very last writings, it has every chance of reflecting his decided opinion. It is also the only text by Gemma to consider the question of heliocentrism in full. And in this regard, it is arguable that its real profundity has not hitherto been recognised⁴.

¹ See especially the letter to Dantiscus of 1541, published by F. Van Ortoy, *Bio-bibliographie de Gemma Frisius, fondateur de l'école belge de géographie, de son fils Corneille et de ses neveux les Arsenius*, Brussels, Hayez, 1920 (repr. Amsterdam, 1966), pp. 409–410, as well as the French translation and detailed commentary in: G.J. Rheticus, *Narratio prima*, ed. and trans. by H. Hugonnard-Roche & J.-P. Verdet, with the collaboration of M.-P. Lerner & A. Segonds, Wrocław, Ossolineum, 1982, pp. 248–249.

² *De Radio astronomico et geometrico...*, Antwerp-Leuven, 1545, 29 v°, 34 v° 35 v°, etc.; *De Astrolabo catholico...*, Antwerp, 1556, 13 r°, 31 v°, 34 r°-v°, etc.

³ Johan van Staeyen (Stadius) van Loenhout (1527–1579) was Gemma Frisius' pupil before becoming mathematician and astronomer to the duke of Savoy and to the prince-bishop of Liège, Robert de Bergen; he was subsequently appointed professor at the Collège Royal in Paris. The *Ephemerides* of 1556 (*Ephemerides novae et exactae... ab anno 1554 ad annum 1570*, Cologne, 1556) were followed in 1560 by the *Tabulae Bergenses*, named after the prince-bishop of Liège and intended to provide an instrument that was easier to consult than Rheinhold's *Prutenic Tables*.

⁴ On Gemma Frisius and Copernicus, see especially: G. McColley, "An Early Friend of the Copernican Theory: Gemma Frisius", *Isis*, 1937, pp. 322–325; A. de Smet, "Copernic

Stadius' *Ephemerides* were published in 1556, after Gemma's death. The latter's preface is dated March 1555. These *Ephemerides* are, with those by the Englishman John Feild, which appeared in the same year, the first to be based on the *Prutenic Tables*, devised by Erasmus Reinhold on the basis of the *De Revolutionibus*. It is worth noting that they borrow from Gemma a "*Tabula stellarum fixarum*" and a "*Tabella civitatum aliquot insigniorum*", which had first appeared in the 1548 edition of another of his works *De Principiis astronomiae et geometriae*.

The tone of Gemma's preface is unusual: vehement, polemical and marked by great rhetorical power. The author offers a quite solemn treatment of *truth*, which is presented as "the queen and just overseer of all the arts" ("*omnium artium Regina & iusta gubernatrix*"). His adversaries are presented as a pack of dogs ("*oblatrantium turba*") and as croaking jackdaws ("*garriant graculi*"). The only other passage which is comparable with this preface from the point of view of vehemence of tone is the digression against homocentric systems in the *De Radio*⁵. This similarity in itself indicates that, regardless of the tone of other passages, which merely discuss the precision of observations and the correctness of calculations, Gemma was by no means indifferent to the question of the choice of a world system. The nature of the works he published – most of which were manuals on the use of instruments – probably explains in large measure the sparing nature of his explicit contributions to the cosmological debate. But it must not be allowed to conceal the real interest he took in the matter. It can only be regretted that he did not have the time to write the *Theoricae planetarum* announced in 1545 in the *De Radio*⁶. What is more, the very importance that he attributed to observation and to instruments was probably not just due to a cosmographer's concern for mainly practical matters. His taste for exactitude and precision, which prefigures

et les Pays-Bas", *Janus*, LX (1973), pp. 13–23; id., "Gemma Frisius et Nicolas Copernic", *Der Globusfreund*, XXI–XXIII (1972–74), pp. 72–78; E.H. Waterbolk, "The 'Reception' of Copernicus's Teachings by Gemma Frisius (1508–1555)", *Lias*, I (1974), pp. 225–241; G. Vanpaemel, "Het copernicanisme aan de oude Leuvense universiteit", in C. Opsomer (ed.), *Copernicus en Galilei in de wetenschapsgeschiedenis van België*, Brussels, Palais des Académies, 1995, pp. 101–122; F. Hallyn, "La Cosmologie de Gemma Frisius à Wendelen", in R. Halleux *e.a.*, *Histoire des sciences en Belgique des origines à 1815*, Brussels, Crédit Communal, 1998, pp. 145–167.

⁵ *De Radio*..., 29b: "Hic autem lubet ridere quorundam audaciam, qui ut suis inventis fidem faciant, auctoritatemque concilient, negant plane Solis aut Lunae magnitudinem secundum visum variari, nempe illos in homocentricis moveri cum asserere studeant, haec experimenta, quae facile illorum fundamenta subvertunt, ridendo contemnunt."

⁶ *De Radio*..., A ii r°: among the works he wants to undertake ("*alia partim animo iam concepta, partim adhuc per tempus invenienda vel facienda*"), Gemma mentions *Novae Planetarum theoricae multo quam antea verisimiliores et motui apparenti accommodatiores*.

that of Tycho Brahé, can also be linked with the need to bring clarity to the cosmological debate in the years immediately following the appearance of the *De Revolutionibus*. This in any case is the way in which Gemma's efforts are depicted by Rheticus in 1550 in the preface to his *Ephemerides novae*. Written eleven years after the appearance of the *Narratio prima*, and eight years after that of the *De Revolutionibus*, this preface returns to the conversations in which Copernicus had explained to Rheticus the main difficulties that contemporary astronomy was running up against. Relating these reflections to the present day, Rheticus adds:

He [Copernicus] gave me much advice and many suggestions, and especially urged me to concentrate on observing the fixed stars. When the highly learned Gemma Frisius holds the view that this is what needs to be done, I believe that, like a new Copernicus for our age, he is laying solid foundations for this science and, as is right, I admire him with all my heart.⁷

A look in detail at the preface to Stadius' work makes clear that it consists of two parts. The first part is devoted to a critique of astronomical tables prior to those of Reinhold. It is presented as an exhortation addressed to Stadius, encouraging him to publish new ephemerides, despite his fears. Stadius should not feel compelled to publish by Gemma, but by a concern for truth, which, in this field, cannot be oppressed, as it is a matter not of authority, but of observation and demonstration. To be sure, Stadius will immediately come under attack. He will be charged with seeking to supplant the *Alphonsine Tables*, which have been in use for generations. He will be accused of deliberately espousing paradox, for who will believe that the earth is in motion and the sun is at rest? The differences between the new tables and the old ones will be adduced as evidence: for Mercury, a difference of 10 to 11°, for Mars, of 4°, and for the Sun, of 50'. But these differences do not in the least diminish the worth of Stadius' work. On the contrary, they merely serve to show up the errors in the old tables. Gemma cites his own personal observations, which have proven the superiority of the *Prutenic Tables* over the others for him. One day, the star Regulus, forecast at 5° 22' 8" in Leo by the *Alphonsine Tables*, was observed by him at 5° 23' 20" in that constellation – an observation which only the *Prutenic Tables* predicted correctly. Likewise, he noticed a conjunction between Saturn and Mars which preceded the forecasts in Stöffler's ephemerides by more than six days. One can only laugh at

⁷ Rheticus, *Narratio prima*, op. cit., p. 223.

those who predict the equinox up to twelve hours early. In short, one must follow Stadius in taking as one's starting-point Reinhold's tables, which are themselves founded on Copernicus⁸: "Concerning these, therefore, no-one may tender any criticism unless he has employed the same principles himself, in other words *observations and demonstration* [...] Here, in truth, lies the task, here the labour, and thus is opened the way to the stars."

After this very long but ultimately predictable attack on the usefulness of the traditional tables, Gemma finally comes to the question of the world systems on which the different tables are founded: "So much for the diversity of tables and the authority of their authors. There now remains the final problem concerning the earth's motion and the paradox of the sun at rest at the centre of the world."⁹ I shall examine this section step by step, seeking to tease out its implications. I shall proceed in five steps, following the text and quoting the most important sentences in bold.

1. Gemma starts by introducing the question of the exact nature of hypotheses:

"As they [the expected adversaries and critics of Stadius] have no idea about philosophy or the method of demonstration, they understand neither the causes of hypotheses nor how they should use them. For hypotheses are not put forward by their authors as if they had to be expressed in this way and could not be constructed otherwise."¹⁰

These lines, which reject the presentation of hypotheses as necessary truths, may be compared with theses put forward by Aristotle, and in particular with what he says about comets in the *Meteorologica*¹¹: "We consider a satisfactory explanation of phenomena inaccessible to observation to have been given when our account of them is free from impossibilities."

In 1567, Christian Wursteisen directly echoed this passage, when he

⁸ "De his igitur nemo censuram ferre poterit, nisi qui eisdem principijs usus, hoc est, τοῖς φαινόμενοις καὶ ἀποδείξεσι [...] Verum hoc opus, hic labor est, sic patet iter ad astra." Here and elsewhere, the use of italics in the translation marks the use of Greek terms in Gemma's Latin text.

⁹ "Ac tantum de diversitate tabularum & de authorum autoritate. Restat iam ultimus nodus de terrae motu, solisque in mundi centro quiescentis τὸ παράδοξον."

¹⁰ "Verum quum & philosophia, & demonstrationis methodo careant, non intelligunt hypothesis causas & usum. Non enim illa statuuntur ab authoribus, tanquam necessario ita se habere debeant, neque aliter constitui possent."

¹¹ Aristotle, *Meteorologica*, I, 7 (344 a 5–8), in *Complete Works*, Princeton, Princeton University Press, 1984, vol. II, p. 562.

wrote in his commentary on Peurbach's *Theoricae novae*¹²: "Thus, regarding those objects which do not fall within the scope of our senses, we believe we have taken our demonstrations sufficiently far when we have brought them back to possible causes, in other words those from which no absurdity results." Pierre Duhem, who cites this passage and compares it with Aristotle, draws attention to the injunction to avoid the "absurd", which, he says, will soon be the principal objection to the adoption of the Copernican system.

Copernicus himself had foreseen the objection¹³: "This is why, when I realised how *absurd* this *akroama* will be deemed by those who know that the view that the earth is motionless at the middle of the sky and forms its centre is confirmed by the judgement of the centuries, if I by contrast assert that the earth moves: for a long time I wondered whether I should publish my commentaries, which were written to demonstrate its motion ..." The "absurdity" lies, according to these lines, in the failure to conform with "the judgement of the centuries", it characterizes a hypothesis whose implications seem irreconcilable with a commonly adopted theory or viewpoint¹⁴. And sure enough, it was along such lines that Clavius, for example, would denounce the absurdity of heliocentrism:

If Copernicus' position did not encompass any falsehood or absurdity, it is clear that there would be some doubt regarding which of the two opinions, that of Ptolemy or that of Copernicus, one should follow (on the question of what view should be taken of these phenomena). But as Copernicus' position contains numerous absurdities and errors, such as claiming that the earth does not lie at the middle of the firmament, that it moves with three motions (by what process this can occur, I can scarcely understand, as according to the philosophers a single motion is appropriate for a single body), and that the Sun has been placed at the centre of the world and is devoid of all motion. Now, all this is against

¹² P. Duhem, "Sozein ta fainomena." *Essai sur la notion de théorie physique de Platon à Galilée*, reissued Paris, Vrin, 1994 (first ed. 1908), p. 95.

¹³ Copernicus, *De Revolutionibus*, letter to Paul III, my translation. On the signification of the Greek term *ἀκροάμα*, see my article "L' *absurdum* *ἀκροάμα* de Copernic", *Bibliothèque d'Humanisme et Renaissance*, LXII (2000), pp. 7–24.

¹⁴ Cf. P. Machamer, "Fictionalism and Realism in Sixteenth Century Astronomy", in R. Westman (ed.), *The Copernican Achievement*, Berkeley-Los Angeles-London, University of California Press, 1975, p. 348: "In the 16th century, one important form of argument is that which involves attributing an absurdity to an opponent's position. Roughly characterized, this seems to involve showing that the opponent's theory or point of view leads to a conclusion which contradicts (or at least, seems incompatible with) an accepted basis, i.e. a substantive or philosophical claim accepted as true by the proponent (and his friends)."

the common teaching of the philosophers and astronomers, and plainly contradicts what Holy Scripture teaches us in several places ...¹⁵

For Clavius, therefore, those things are “absurd”, “*quae cum communi doctrina philosophorum et astronomorum pugnant*”, in other words anything opposed to a paradigmatic treatment of questions concerning the earth or the sky. However, the next part of Gemma’s text contains a shift of meaning which leads to a different assessment of the absurdity of a hypothesis.

2. “But [hypotheses are formed] so that, once we have accepted that they are not entirely absurd, but are in keeping with the principles of nature, we may have a precise explanation for the motions, corresponding to the visible positions of the stars in the sky, for future, past and present alike.”¹⁶

Here then, two conditions are defined by Gemma that a hypothesis must satisfy.

Firstly, it may not be “absurd”. By opposition, “absurdity” is implicitly defined as whatever is contrary to the “principles of nature”. But what are those “principles”? Should they be sought in authoritative texts, in the “*communis doctrina*” to which Clavius refers? Or must one compare those texts with observed data in order to arrive at them? The next part of the argument will clear up this point.

A second requirement is set to do with correspondence to reality and with effectiveness for the purposes of calculation: a hypothesis must provide a precise method for calculating the positions actually occupied by the heavenly bodies in the past, present and future. This is, of course, the most commonly accepted requirement. The entire first part of the preface, with its

¹⁵ C. Clavius, *In Sphaeram Ioannis de Sacro Bosco commentarius...*, Rome, 1581, p. 437: “Quod si positio Copernici nihil falsi et absurdi involueret, dubium sane esset, utri opinioni, Ptolemaeinae, an Copernici potius (quod attinet ad huiusmodi phaenomena tuenda) adhaerendum esset. Sed quoniam multa absurda et erronea in Copernici positione continentur, ut quod terra non sit in medio firmamenti, moveaturque triplici motu, quod quae ratione fieri possit, vix intelligo, cum secundum philosophos uni corpori simplici unus debeatur motus: et quod Sol in centro mundi statuatur, sitque omnis motus exers. Quae omnia cum communi doctrina philosophorum et astronomorum pugnant, et videntur iis, quae sacrae litterae plerisque locis docent, contradicere...” On Clavius, see J.M. Lattis, *Between Copernicus and Galileo. Christoph Clavius and the Collapse of Ptolemaic Cosmology*, Chicago, Univ. of Chicago Press, 1994.

¹⁶ “Sed ut assumptis non prorsus absurdis, sed naturae congruis exordiis, habeamus certam rationem, motuum correspondentem, in coelo conspicuis stellarum locis, tam pro tempore futuro vel elapso, quam pro praesenti.”

references to the errors in the various astronomic tables, has already emphasised that only the *Prutenic Tables*, based on Copernicus, satisfy it. The next part of the argument therefore focuses, highly logically, on the requirement to avoid the “absurd”.

3. **“Although, in fact, Ptolemy’s hypotheses are at first sight more plausible than those of Copernicus, they commit a not inconsiderable number of absurdities; when the stars are understood to be moving irregularly in their circles, they lack explanations of the phenomena as clear as those of Copernicus. For Ptolemy states that the three upper planets (to give an example), when they are “akronic”, or diametrically opposite the Sun, are always at the perigee of their epicycle, and this is a fact. But Copernicus’ hypotheses take account of this fact as a necessity, and demonstrate why.”**¹⁷

The passage offers an example of an “absurdity” in Ptolemy’s system, concerning the motions of the upper planets in their epicycle. But it is clear from the start that Gemma will not refer to an incompatibility with a “*communis doctrina*”, since he states his wish to compare the power of causal explanation of the two systems and introduces Aristotle’s technical vocabulary in this connection.

That the upper planets are the closest to the earth when they are or diametrically opposite the sun, results from the earth’s motion in the Copernican system: the shortest distance implies that the earth lies on the radius which links the upper planet to the sun; and if this is true, the sun and the planet really are diametrically opposed compared with the earth, because they correspond to the centre and a point on the circumference intersected by the radius of the circle of the upper planet which passes through the earth. If, on the contrary, it is supposed that the earth lies motionless at the centre of the world, all one can do is point to the coincidence of the two phenomena (the planet’s proximity and the interposition of the earth between the planet and the sun), without providing any explanation.

The example had already been given by Copernicus himself (*De Revolutionibus*, I, 10). What is interesting here is that Gemma refers to the Ar-

¹⁷ “Quamvis vero hypotheses Ptolemaei prima facie sint plausibiliores, quam Copernici, non pauca tamen illae absurda committunt, dum stellae in suis circulis inaequaliter moveri intelliguntur, tum non habent tam evidentes τῶν φαινομένων causas, atque illae Copernici. Nam quod tres superiores planetae (ut demus exemplum) ἀκρόνυχτοι, sive e diametro Solis positi semper sint in perigeo sui epicycli, assumit Ptolomaeus atque hoc est τὸ ὄτυ. Verum Copernici hypotheses idem illud necessario inserunt, ac demonstrant δι’ ὅτυ.”

istotelian distinction between two types of demonstration: ἀποδείξις τοῦ ὅτι (*demonstratio quia*) and τοῦ δι' ὅτι (*demonstratio propter quid*). In the *Posterior Analytics* (I, 13), this distinction is illustrated by an astronomical example, concerning the observation that, unlike the stars, the planets do not twinkle¹⁸. Hence the following two syllogisms:

- I. The planets do not twinkle.
That which does not twinkle is close to the earth.
Therefore the planets are close to the earth.
- II. That which is close to the earth does not twinkle.
The planets are close to the earth.
Therefore the planets do not twinkle.

The two arguments lead to a correct conclusion. But the first merely brings together two facts, without linking them in a causal order; it remains at the level of τὸ ὅτι. The argument τὸ ὅτι is merely founded on the concomitance of two phenomena; it does not describe the necessary relationship which links them, nor, of course, the meaning of that relationship. By means of an argumentation τοῦ ὅτι, one may even draw a true conclusion from false premises¹⁹. The second syllogism, by contrast, proceeds from a cause to its effect, supplying the explanation, the δι' ὅτι or *propter quid* for the absence of twinkling in the planets. It establishes a necessary relationship between the statements. A demonstration δι' ὅτι supposes that the middle term of the syllogism (“being close to the earth”) is the immediate cause of an effect, i.e. that it is always present when the effect occurs, and only when it occurs.

The distinction between the two forms of demonstration constitutes an important theme in Renaissance works on astronomy and physics²⁰. Useful light can be thrown on Gemma's position by a comparison with some of these texts.

In the preface to Reinhold's commentaries on Peurbach's *Theoricæ novæ* (Wittenberg, 1542), Melanchthon states that Ptolemy offers a systematic,

¹⁸ The example is repeated by Copernicus in his *Letter against Werner* and in the *De Revolutionibus* (I, 10).

¹⁹ Cf. *Prior Analytics*, II 2 53 b 5 ss., and II 4 57 a 38 ss. In his discussion of heliocentrism, Clavius supplies several examples: “Omnis planta est sensitiva. Omne animal est planta. Igitur omne animal est sensitivum. [...] Omnis lapis est rotundus. Omnis stella est lapis. Igitur omnis stella est rotunda.” (*In Sphaeram...*, ed. cit., p. 435.)

²⁰ Cf. N. Jardine, “The Forging of Modern Realism: Clavius and Kepler against the Sceptics”, *Studies in History and Philosophy of Science*, X (1979), pp. 141–173, and id., “Epistemology of the Sciences”, in C. Schmitt & Q. Skinner (eds.), *The Cambridge History of Renaissance Philosophy*, Cambridge, Cambridge University Press, 1988, pp. 685–711.

geometric explanation of phenomena, whereas Peurbach only proceeds according to $\tau\omicron \delta\iota$. In his commentary, Reinhold takes up the distinction and attributes a discourse $\tau\omicron\upsilon \delta\iota \delta\iota$ to Ptolemy alone. Regarding the moon, he writes²¹: “You see the $\delta\iota \delta\iota$ of this part of astronomy, and the subtlety and skill with which Ptolemy investigates the causes of these phenomena by means of observation.”

A similar distinction is drawn by Erasmus Oswald Schreckenfuchs in another commentary on Peurbach, published in 1556. He writes that Peurbach “treated everything according to $\tau\omicron \delta\iota$, because this is the easiest method for beginners. He described phenomena without adding any demonstrations or looking for their causes. For example, he stated that Mercury attains its perigee and its apogee twice during a single revolution, without showing why this is so. By contrast, Ptolemy, as the “*artifex summus*”, “proceeds according to the $\delta\iota \delta\iota$ ”; he looks for and discovers causes, showing that the centre of Mercury’s deferent does not coincide at all with the centre of the world, but is mobile – as is the case with the Moon²².

Schreckenfuchs knew Copernicus, and praised him, as had Reinhold after reading the *De Revolutionibus*, from which he borrowed calculatory estimates for his *Prutenic Tables*, but without departing from the geocentric paradigm. For both of them, the world *system*, in which *causes* must be located, the $\delta\iota \delta\iota$ of phenomena, remains the Ptolemaic system. Copernicus merely made the task of calculation easier, and heliocentrism did not offer the causal explanation, the *propter quid* for phenomena. Gemma’s position is radically different: for him, it is Ptolemy who simply provides $\tau\omicron \delta\iota$ (similar in this respect to what Peurbach provides according to Reinhold and Schreckenfuchs), whereas the $\delta\iota \delta\iota$ must be sought in Copernicus’ system.

²¹ Reinhold, *Theoricæ novæ planetarum Georgii Purbachii* [...] *pluribus figuris auctis, et illustratae scholiis*..., pref. by Melanchthon, Wittenberg, 1543. Quoted by Duhem, *op. cit.*, p. 83. In 1542, Reinhold was already familiar with Copernicus via the *Narratio prima*, as is shown by other passages cited by Duhem, *op. cit.*, p. 72. Moreover, Gemma was familiar with the commentary on the *Theoricæ novæ*, as he refers to it in connection with the *camera obscura* in his *De Radio*, chap. 18.

²² E.O. Schreckenfuchs, *Commentaria in novas theoricæ planetarum Georgii Purbachii*, Basel, H. Petrus, 1556, a 3 i r°: “Tradidit omnia secundum $\tau\omicron \delta\iota$, si quidem incipientibus hæc ratio tradendi est, ob suam facilitatem, commodissima. Proponit enim res ut sunt, absque ullis demonstrationibus. Ptolemaeus vero tanquam artifex summus, arripuit viam tradendi secundum $\delta\iota \delta\iota$. Quid multis? author iste proposuit diligentissime in hoc libello nuda ac breviter præcepta & regulas absque ullis causis & demonstrationibus, ut dictum est paulo ante. Ponit enim Mercurium verbi gratia, bis in una revolutione terræ proximum fore, ac bis ab ea maxime removeri quare hoc fiat non ostendit. Sed Ptolemaeus, qui secundum $\delta\iota \delta\iota$ incedit, quaerit causas, quibus inventis, demonstrat centrum deferentis epicyclum esse mobile, sicuti in Luna, & esse prorsus extra mundi centrum.”

In the preface to Stadius' *Ephemerides*, Gemma thus reveals himself to be markedly more Copernican than his German contemporaries. In referring to the upper planets, he even puts forward an argument whose importance was later also noticed by Kepler, who went so far as to state it on several occasions. Thus he writes in the *Mysterium cosmographicum*:

Similarly the ancients rightly wondered why the three superior planets are always in opposition to the Sun when they are at the bottom of their epicycles, but in conjunction when they are at the top [...] In Copernicus's theory the reason is easily supplied. For it is not Mars on an epicycle but the Earth on its own circle which causes this variation.²³

And in his *Apologia pro Tychone*, he likewise remarks:

Copernicus wanted to simultaneously demonstrate the cause and the necessity of the three upper planets always being at the bottom of their epicycle when they are in opposition with the sun, [and] at the top when they are in conjunction. [...] In Copernicus, the cause is easily found. For it is not Mars in its epicycle, but the earth in its orbit which causes this variation.²⁴

The closeness of Gemma's and Kepler's views on this point did not escape Riccioli, who, in his *Almagestum novum*, brought together the passages from the preface for Stadius and the quotation from the *Mysterium cosmographicum*²⁵. We may in any case note that the preference given to Copernicus here is not based purely on calculatory and instrumental superiority, but concerns the system's intrinsic logic.

4. "And [Copernicus' hypotheses] attribute practically no absurdity to natural motions, as a result of which a more complete knowledge of the distances between the planets is drawn hence than from other hypotheses."²⁶

Gemma remains very discreet about Copernican physics, contenting himself with the comment that they attribute "practically no absurdity to nat-

²³ Kepler, *Mysterium cosmographicum. The Secret of the Universe*, I, transl. A.M. Duncan, New York, Abaris Books, 1981, p. 81.

²⁴ Kepler, *Apologia pro Tychone contra Ursum*, I, ed. and transl. in N. Jardine, *The Birth of History and Philosophy of Science ...*, Cambridge, Cambridge University Press, 1984, p. 90.

²⁵ Riccioli, *Almagestum novum*, Bologna, 1656, VII, III, xi.

²⁶ "Neque quicquam fere absurdum naturalibus motibus committunt, unde hic amplior cognitio de planetarum distantis colligitur, quam ex illis."

ural motions". Yet the recognition of multiple "natural" motions in the earth, like the attribution of its own centre of gravity to each planet, was in flagrant contradiction with Aristotelian physics. Copernican physics could not be reconciled with the "*doctrina communis*", and therefore contained significant "absurdities" in the sense in which the term was used at that time. Moreover, such "absurdities" would be severely criticised subsequently, as we learned from the example of Clavius, who sees this as one of the main arguments for rejecting the Copernican system²⁷. For Gemma, however, this physical "absurdity" seems far less important than the mathematical coherence introduced by Copernicus in the planetary system. This eliminates another type of "absurdity", concerning logical inconsistency. The soundness of heliocentrism's internal logic is reflected in the better knowledge ("*amplior cognitio*") it affords of the distances between the planets. Gemma obviously has in mind the famous "symmetry" of the Copernican world, i.e. the proportionality of the planets' revolution times and their distances from the centre²⁸. Ptolemy arranged the planets in a concentric order in which, in principle, revolution time increased with distance from the earth; in fact, however, the times taken by the Sun, Venus and Mercury to go round the Earth were the same, although they were located in different orbs. This inconsistency between principle and fact disappears in Copernicus' system, in which all the planets have different revolution times, the length of which increases with their distance from the centre. A logical "absurdity" is thus eliminated, the facts fit with the principle, and knowledge of the planets' distances has been improved on, as one can now precisely define the order of succession of all the planets.

5. "Better still, if someone wishes, he can assign to the sky those motions of the earth that [Copernicus] adds to the first two, and use the same calculation procedures. But that highly learned and intelligent man considered it inadvisable, on account of these undisciplined minds, to invert the entire system of his hypotheses, and he contented himself with having established that which was sufficient for the true discovery of phenomena."²⁹

²⁷ For details, cf. J.M. Lattis, *op. cit.*, chap. V.

²⁸ Copernicus, *op. cit.*, p. 41: "Finally, concerning the main thing, i.e. the form of the world and the exact symmetry of its parts, they were unable either to find it or to recreate it." For a more detailed discussion of this "symmetry", cf. my *The Poetic Structure of the World*, New York, Zone Books, 1990, chap. 3.

²⁹ "Quin si quoque quispiam velit, poterit illos motus terrae, quos praeter duos primos ponit, ad coelum referre ac uti iisdem Canonibus calculorum. Sed non placuit viro doctissimo & prudentissimo, ob ingenia haec indomita, totam Hypothesium suarum ordinem invertere, contentus statuuisse, quae ad veram τῶν φαίνωμένων inventionem sufficerent."

The text is extremely clear. Gemma passes in silence over the earth's diurnal and annual motions, as though these simply have to be accepted. But he speaks out in a more nuanced manner regarding the third motion. Copernicus assigned the third motion to the earth in order to uphold the consistency of his system, but its effects (the seasons, the precession of the equinoxes, the obliquity of the ecliptic) can also be attributed to celestial motions. Light can be shed on this reservation, regarding the third motion alone, by reading a number of passages of *De Astrolabo*. In the following extract, Gemma describes the equivalence between the two mechanisms:

Since the opportunity arises, we shall now say a few words regarding the motion of the fixed stars, but I shall now follow the tables or canons of Copernicus to discover the position of the tail of Ursa Major in Roman times, because these alone correspond to the experience of the foregoing observations. And so that this may be understood by all those who are interested, we shall change the names and titles he uses into terms which are more easily grasped by everyone. Thus, let the motion that he calls the precession of the equinoxes be the motion of the ninth sphere, whose period is 25,816 years. And let the motion of the anomaly be the motion of the eighth sphere, one revolution of which is completed in 1,717 years. It follows that since, according to Copernicus, the point of the mean equinox was remote from the first star of Aries in the time of Christ – or [in other words] the first star of Aries was itself remote, by its mean motion (which we place in the ninth sphere) from the equinox or from the intersection of the ecliptic of the eighth sphere and of the equator – by $5^{\circ}32'$ [...] The root of the anomaly or the motion of the eighth sphere at the time of Christ was, according to the same Copernicus, $6^{\circ}45'$.³⁰

The precession of the equinoxes contains two aspects: a continuous motion and a *trepidation* or variation in the speed of this motion. Copernicus dis-

³⁰ “Dicemus autem per oportunitatem de fixarum motu aliqua, verum nunc sequar Copernici tabulas seu Canones ad inveniendum locum caudae Ursae Maioris ad tempus urbis Romae. Quoniam hae solae experientiae praecedentium observationum respondent. Atque haec ut et studiosis omnibus intelligantur permutabimus nomina appellationesque quibus ille utitur in eas quae ab omnibus facilius percipiuntur. Motus igitur praecessionis aequinoctiorum ab illo appellatus sit motus nonae sphaerae, cuius periodus est 25816 annorum. Motus vero anomaliae sit motus octavae sphaerae cuius integra rotatio una perficitur annis 1717. Quoniam ergo secundum Copernicum tempore Christi punctum aequinoctij mediocri erat remotum a prima stella Arietis, vel ipsa prima stella Arietis mediocri motu (quem nonae sphaerae ponimus) abscesserat ab aequinoctio seu intersectione eclipticae octavi orbis et aequatoris per 5 partes et 32 scrupula. [...] Iam vero radix anomaliae [sic] seu octavi orbis motus tempore Christi secundum eundem Copernicum erat 6 partibus 45 scrupulis.” (*De Astrolabo*, 44 a–b).

tinguishes two components in his third motion, producing a conical motion of the earth's axis. One complete period of continuous motion takes 25,816 years, whereas one cycle of trepidation lasts 1,716 ans³¹. Gemma describes how the two components of the earth's third motion may be related to motions of the celestial spheres, according to traditional conceptions: in Peurbach, for example, who adopts the Alphonsine model, the continuous motion becomes dependent on the ninth sphere, which turns in the opposite direction to the tenth or first mobile (in 49,000 years according to the *Alphonsine Tables*), and the trepidation depends on the eighth, which turns about the ecliptic of the ninth and thus causes the irregularities identified (with a periodicity of 7,000 years according to the same tables). As can be seen, Gemma transposes the Copernican periodicities in the traditional framework.

Another passage of the *De Astrolabo* is important for a proper understanding of Gemma's attitude:

Regarding the stars' longitudes, let others extract them from whatever tables or canons they like; I for my part prefer to follow those which I find correspond more precisely to both the Ancients' and our own observations, in other words the canons of Copernicus which Erasmus Reinhold has also followed in the *Prutenic Tables*. For the data found in the *Alphonsine Tables* depart by more than one degree from the apparent positions in the sky, as we have often experienced. Nor do they agree with the observations of others. I will not discuss here the theses regarding such motions or the motion of the eighth sphere or of the earth, because I know that when motions are invented orbits can easily be imagined along which such motions can be effected, either in the sky or sometimes on earth, according to one's fancy. But this debate must not be allowed to hold back those who are more skilled, since they know that orbits, epicycles and other such things have been formed to enable calculations to be made rather than that we might believe that such things really exist in nature. Even Ptolemy, who teaches that the same motion may be explained by an epicycle or by an eccentric, says this. But this lies outside my subject.³²

In these lines, once again, Gemma does not take up a position regarding

³¹ The obliquity of the ecliptic, which Gemma does not refer to here, follows a periodicity which is double that of the trepidation (3,436 years) whose cycle commences at the same moment.

³² "Quod ad longitudes stellarum attinet, colligat alius ex quibuslibet tabulis seu canonibus, ego malo sequi illos quos experientiae cum veterum tum nostrae exactius respondereprehendo, hoc est Copernici canones quos & Erasmus Reinheldus in tabulis

the choice between a third motion of the earth or the addition of new spheres. However, he does add that the epicycles and eccentrics have been introduced as calculation aids, rather than as celestial realities. Here he introduces an argument often expressed in the 16th century³³. Should it be concluded from this that the entire representation of the planetary motions, and hence also that of the earth, is no more than a matter of astronomic fiction? Such an interpretation would be in contradiction with the lines of the preface to Stadius, where it is clearly stated that only the third motion can be called into question. How can these two texts be reconciled? The thesis regarding the earth's annual motion should doubtless be dissociated from the representation of that motion. Whether this latter is conceived of as including an epicycle or not is a matter of practical convenience, of effectiveness for calculation purposes. But the fact that an annual motion has every chance of being real and that it may be adopted as a truth, in whatever form it occurs, is another matter on which the preface to Stadius seems to leave no doubt.

The comparison between the preface to Stadius and the *De Astrolabo* shows that Gemma Frisius' position is carefully thought out, complex and nuanced. He takes as his basis a profound knowledge of questions of observation and of mathematical representation, together with an epistemological thinking which has its roots in the Aristotelian theory of knowledge. The combination of these factors brings him to the recognition of the mathematical truth of the earth's first two motions: "veram τῶν φαينوμένων inventionem". But he makes no pronouncement regarding the third motion, or the way in which the second is effected.

All of this demonstrates both conviction and prudence. The world's best mathematical system is heliocentric, to be sure. But uncertainties remain, regarding the number of the earth's motions and the exact way in which the planets in general perform their revolution around the Sun. We may also note that Gemma strongly emphasises the demonstrative superiority of heliocentrism when it comes to explaining phenomena mathematically, but that he scarcely touches on the physical implications of the matter.

Prutenicis observavit. Nam Alphonsinorum inventa plus integra parte aberrant ab apparentibus in coelo locis, ut saepius experti sumus. Neque cum aliorum observatis congruunt. Hic vero de thesibus talium motuum et de motu octavi orbis aut terrae nihil agam, quod sciam inventis motibus facile confingi orbes posse, per quos tales motus absolvantur, seu in coelo seu interdum in terra si quis velit. Sed haec disputatio non admodum distinere debet eruditiores, qui norunt orbes, Epicyclos, aliaque talia ad calculi inventionem constituti potius, quam ut revera credamus tales extare in rerum natura. Quod et Ptolomaeus fatetur, qui eundem motum et per Epicyclum et per Eccentrum exhibere posse docet. At haec praeter propositum..." (*De Astrolabo*, 31b–32a.)

³³ Cf. N. Jardine, *The Birth of History and Philosophy of Science...*, (*op. cit.*) pp. 225–258, *passim*.

It should doubtless be concluded that “truth” does not necessarily mean “reality”. We should remember that at the start of the passage we have analysed, Gemma acknowledged that “hypotheses are not put forward by their authors as if they had to be expressed in this way and could not be constructed otherwise.” This seems to mean that, for him, scientific truth is not necessarily ontological truth. At the very least, it seems justified to attribute to Gemma an attitude which could be described as “prudent realism”, distinct from both radical realism and the various forms of scepticism. In Gemma’s view, positing the double motion of the earth means more than employing an alternative calculation strategy: it is the best approximation of reality, the best “truth” we possess, because it offers greater effectiveness and above all the best consistency and the strongest mathematical explanatory power.

In all of this, Gemma’s attitude is not fundamentally different from that of Copernicus, who also refers to uncertainties and expresses reservations about some of his propositions – and in fact on precisely those points on which Gemma is also hesitant. In his explanation of the obliquity of the ecliptic, he acknowledges that he is employing hypotheses which are merely probable, using expressions such as “*simplici coniectura*” or “*coniectura satis probabili*”³⁴. Elsewhere (III, 20), the *De Revolutionibus* proposes three equivalent models for the Sun’s motion: the double epicycle, the eccentric epicycle, and the double eccentric, all of which are accompanied by the following comment: “And since all ways lead to the same number, I could not easily say which is correct, but only that, that perpetual consonance of numbers and appearances obliges us to believe that it is one of them.”³⁵ When a fourth possibility is then added (III, 25), Copernicus comments: “But we shall say more about this question in our explanation of the five wandering planets and we shall decide as far as we can, regarding it enough to apply calculations which are certain and not erroneous to the Sun’s apparent motion.”³⁶

If Gemma had accepted the truth of all the particular constructions of the heliocentric system, he would in short have been more Copernican than Copernicus himself.

³⁴ Cf. N. Swerdlow, “On Copernicus’ Theory of Precession”, in R. Westman (ed.), *The Copernican Achievement* (o.c.), pp. 73 and 75. Swerdlow also notes that between the manuscript and the printed text, Copernicus adapts certain data to the theory.

³⁵ “Cumque tot modi ad eundem numerum sese conferant, quis locum habeat haud facile dixerim, nisi quod illa numerorum ac apparentium perpetua consonantia credere cogit eorum esse aliquem.”

³⁶ “Sed de haec quaestione plura dicemus, in quinque stellarum errantium explanatione, quae pro posse nostro etiam decidemus, satis esse putantes, si iam certos numeros minimeque fallaces adsciverimus apparentiae Solari.”