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ARISTARCHUS OF SAMOS AND COPERNICUS

A famous passage about Aristarchus of Samos is found in Archimedes' *Sand-Reckoner*:

According to Aristarchus' hypotheses, the fixed stars and the sun remain stationary. On the other hand, the earth revolves around the sun along the circumference of a circle lying amid the course [of the planets]. The sphere of the fixed stars has the same center as the sun [and is virtually infinite].

These propositions, formulated with magisterial succinctness by a great mathematician, contain the essence of the heliostatic, heliocentric, and geokinetic system later propounded by the founder of modern astronomy, Nicholas Copernicus (1473–1543). Indeed, the striking similarity between the two sets of concepts, ancient and modern, led to the labeling of Aristarchus as “The Ancient Copernicus.”¹

What did the modern Copernicus know about the ancient Copernicus? In particular, was the modern Copernicus familiar with the discussion of Aristarchus in Archimedes' *Sand-Reckoner*?

An all but completely affirmative answer to this question was given thirty-six years ago by two authors, who asserted “the almost certain acquaintance of Copernicus with the *Sand-Reckoner*.”² These two “authors have made it very plausible that Copernicus knew the *Sand-Reckoner* and could thus have been influenced by Aristarchus' ideas,” according to a well-known historian of ancient astronomy.³ These authors “argued the almost certain acquaintance of Copernicus with

1 Thomas Heath, *Aristarchus of Samos, the Ancient Copernicus* (New York 1959; reprint of Oxford 1913 edition).

2 Rudolf von Erhardt and Erika von Erhardt-Siebold, “Archimedes' Sand-Reckoner, Aristarchos and Copernicus,” *Isis* 33 (1941–1942) 578.

3 Otto Neugebauer, “Archimedes and Aristarchus,” *Isis* 34 (1942–1943) 4.

Archimedes' *Arenarius*, the work that contains the most authoritative and best account of Aristarchus' theory," according to a recent study.⁴

How could Copernicus become acquainted with Archimedes' *Sand-Reckoner*? Its Greek text was first published in March 1544, nearly a year after Copernicus died on 24 May 1543. Consequently, he never saw the *Sand-Reckoner* printed in Greek. This first edition of Archimedes' works in Greek, with the *Sand-Reckoner* at pages 120–127, was accompanied by a separately paginated translation of these works into Latin, with the first printed Latin translation of the *Sand-Reckoner* at pages 155–163. By the same token, therefore, Copernicus never saw a Latin version of the *Sand-Reckoner* in print.

Did he see a manuscript copy of the *Sand-Reckoner*, either in Greek or in Latin or in both classical languages? The foremost astronomer of the fifteenth century, Johannes Regiomontanus (1436–1476), copied with his own hand the Greek text, as well as a Latin version, of the *Sand-Reckoner* while he was in Italy. From that country Regiomontanus took his Archimedes manuscript with him to Nuremberg, where it is still preserved in the municipal library.⁵ Did Copernicus see this Regiomontanus manuscript? There is no indication that Copernicus ever set foot in Nuremberg. If he had, and if he knew about the Aristarchus passage in the *Sand-Reckoner*, and if he had heard of the Regiomontanus manuscript, he still would have had no access to it. For after the death of Regiomontanus, his papers passed to his pupil Bernard Walther (about 1430–1504), "a melancholy and taciturn man, who withheld them from use and refused to let anyone so much as inspect them. Even after Walther's death in 1504 the books and instruments . . . remained for some time in the hands of the executors."⁶ Surely Copernicus never saw the *Sand-Reckoner*'s Aristarchus passage in Regiomontanus' Archimedes manuscript in Nuremberg.

But what about Italy, where Copernicus was a student from 1496 to 1503? The aforementioned two authors, who asserted "the almost certain acquaintance of Copernicus with the *Sand-Reckoner*," also stated that Copernicus "at least knew of Giorgio Valla, who died in 1499."⁷ Valla died on 23 January; the year was 1499 according to the Venetian calendar

4 William Harris Stahl, *Martianus Capella and the Seven Liberal Arts* (New York and London 1971) 176.

5 Nuremberg, Stadtbibliothek, Cen V, 15, with the *Sand-Reckoner* at folios 161–172; see Ernst Zinner, *Leben und Wirken des Johannes Müller von Königsberg genannt Regiomontanus*, 2nd ed. (Osnabrück 1968) 322–323.

6 Hans Rupprich, "Willibald Pirckheimer," in *Pre-Reformation Germany*, ed. Gerald Strauss (London 1972), p. 412.

7 P. 600 of the work cited in note 2, above.

then in use, but 1500 according to the present calendar.⁸ Not only did Copernicus know of Valla, he also made extensive use of Valla's posthumous *De expetendis et fugiendis rebus*, which was published in Venice in December 1501. Although Valla included his own translation of some of Archimedes' writings in this massive posthumous encyclopedia, the *Sand-Reckoner* was completely omitted from its forty-nine Books.⁹ Therefore, neither in Italy nor in Nuremberg, neither from Regiomontanus nor from Valla, did Copernicus learn about the *Sand-Reckoner's* invaluable discussion of Aristarchus.

The external evidence that Copernicus did not know about Aristarchus' heliocentrism from Archimedes' *Sand-Reckoner* is confirmed by the internal evidence provided by Copernicus' own writings. He never claimed that he was the first geokineticist. In fact, he searched for and named as many of his predecessors as he could trace. In the Dedication of his *Revolutions (De revolutionibus orbium coelestium* [Nuremberg 1543]) he announced:

At first I found in Cicero that Hicetas supposed the earth to move. Later I also discovered in Plutarch [Copernicus refers to Pseudo-Plutarch, *The Opinions of the Philosophers*] that others were of this opinion. I have decided to set his words down here, so that they may be available to everybody: "Some think that the earth remains at rest. But Philolaus the Pythagorean believes that, like the sun and moon, it revolves around the fire in an oblique circle. Heraclides of Pontus and Ecphantus the Pythagorean make the earth move, not in a progressive motion, but like a wheel in a rotation from west to east about its own center."

Moreover, in Book I, Chapter 5, of the *Revolutions* Copernicus remarked:

Heraclides and Ecphantus, the Pythagoreans, as well as Hicetas of Syracuse . . . rotated the earth in the middle of the universe. . . . That the earth rotates, that it also travels with several motions, and that it is one of the heavenly bodies, are said to have been the opinions of Philolaus the Pythagorean.

From these two retrospective passages of the *Revolutions* dealing with the ancient geokineticists, Aristarchus is conspicuously absent. For this absence, two explanations are available:

- (1) Copernicus had no satisfactory evidence permitting him to group Aristarchus with the other four geokineticists; or

8 J. L. Heiberg, *Beiträge zur Geschichte Georg Vallas und seiner Bibliothek* (Leipzig 1896) 41 (=XVI. Beiheft zum Zentralblatt für Bibliothekswesen).

9 For Valla's Greek sources, see J. L. Heiberg, "Philologische Studien zu griechischen Mathematikern, III, Die Handschriften Georg Vallas von griechischen Mathematikern," *Jahrbücher für classische Philologie*, 1881, Supplementband P12, 375-402, especially 380-386.

- (2) Copernicus possessed such evidence, and deliberately suppressed it.

The second alternative is based on a deleted passage in the autograph manuscript of Copernicus' *Revolutions*. This manuscript is now preserved in the Jagellonian Library of the University of Cracow, where Copernicus was a student in his late teens and early twenties. A photo-facsimile of his autograph manuscript was recently published.¹⁰ It plainly shows the deleted passage (folio 11 verso), which said, in part:

Philolaus was aware that the earth could move. Aristarchus of Samos was also of the same opinion, as some people say.

These deleted lines make quite clear Copernicus' unfamiliarity with the Aristarchus passage in the *Sand-Reckoner*. Had Copernicus realized that he could cite Archimedes as his authority for Aristarchus as a fifth geokineticist, he surely would not have submerged that renowned mathematician in an anonymous and undistinguished group of "some people" (*nonnulli*). Nor would Copernicus have confined his remark about Aristarchus to the earth's mobility, had he learned about the additional features of Aristarchus' astronomy from Archimedes' report: the sun's immobility and centrality, the stars' immobility and enormous remoteness. Had Copernicus known that he could align the great Archimedes on his side, that he could add the distinctively Aristarchan insights to those proclaimed by the other four geokineticists, he would have leaped with joy. For he was painfully aware that, with the theologians and Aristotelian philosophers certain to denounce him, he needed all the support he could muster.

Copernicus' explicit citations of Cicero and [Pseudo-] Plutarch point to the same conclusion as the history of the *Sand-Reckoner* in manuscript and in print: Copernicus was not familiar with that work by Archimedes. The Syracusan's numerous treatises on the mathematical sciences were virtually a closed book for Copernicus, who mentioned Archimedes in only three connections:

- (1) Archimedes made the year $365\frac{1}{4}$ days long (*Revolutions*, Book 3, Chapter 13);
- (2) Archimedes used a square in determining the area of a circle (Book 3, Chapter 13, a deleted passage); and
- (3) Archimedes set limits to the value of π (Book 4, Chapter 32).

The length of the year, the area of a circle, and the value of π were not discussed in the *Sand-Reckoner*. Nothing in Copernicus' writings suggests that he knew Archimedes' *Sand-Reckoner*, or that he ever heard of it.

10 Nicholas Copernicus, *Complete Works*, I (London/Warsaw 1972).

Without access to Archimedes' *Sand-Reckoner*, how did Copernicus learn that, according to Aristarchus, the "earth could move"? A copy of Aristarchus' own presentation of his geokineticism found its way into the hands of Archimedes, who was some twenty-five years his junior. With reference to this copy, Archimedes said in the *Sand-Reckoner*: "Descriptions of some hypotheses were made public by Aristarchus." Unfortunately, those descriptions did not survive. Copernicus never saw them, any more than he ever saw Archimedes' account of them in the *Sand-Reckoner*.

But Copernicus did see the statement that "the earth moves" attributed to Aristarchus in Pseudo-Plutarch's *Opinions of the Philosophers*, Book 2, Chapter 24. From Book 3, Chapter 13, of that work he quoted in the original Greek the passage in his Dedication of the *Revolutions* that was translated above. Unquestionably, therefore, Copernicus had a copy of the Greek text of Pseudo-Plutarch's *Opinions*.

Yet Copernicus did not quote from its Book 2, Chapter 24, as he did from its Book 3, Chapter 13. Why not? According to Book 2, Chapter 24, "Aristarchus makes the sun stationary among the fixed stars." Today we are not shocked by a stationary sun among the stars. But for the ancients and Copernicus, the sun was much closer to the earth than the stars were. As though an intrastellar sun were not strange enough, *Opinions*, Book 2, Chapter 24, also attributed to Aristarchus the opinion that "the earth moves around the solar circle." The expression "solar circle" was left unexplained in the *Opinions*. Perhaps it referred to the sun's annual circular orbit in the pre-Aristarchan astronomy, which held the central earth stationary. If so, Aristarchus' mobile "earth moves around the solar circle" of the pre-Aristarchans. Then, the earth's orbit would be somewhere among the stars. This weird cosmos did not appeal to Copernicus, a practical astronomer with both his feet planted firmly on solid ground. In Copernicus' judgment, Aristarchus forfeited his membership on the team of respectable ancient geokineticists by locating his moving earth among the stars.

Since Copernicus quoted the original Greek of *Opinions*, Book 3, Chapter 13, he had access to a copy of *Plutarchi opuscula LXXXVII* (Venice 1509). He likewise used Valla's *De expetendis et fugiendis rebus*, where Books 20–21 were Valla's own translation of the *Opinions*. In his characteristic way, however, Valla gave no indication that his Books 20–21 were his own rendering of a Greek text. From Valla, Copernicus took numerical values and expressions which he repeated in his own *Revolutions*, Book 1, Chapter 10. In Book 3, Chapter 2, Copernicus made a mistake previously made only by Valla. Copernicus' use of Valla is therefore indisputable. But Valla's Book 21, Chapter 24, was even worse than the Greek text of the *Opinions*. For, Valla had Aristarchus "locate

the sun beyond the fixed stars.” In general, the intellectual level of Valla’s vast encyclopedia was so low that Copernicus never mentioned Valla’s name. But Copernicus had great respect for Plutarch, whom he (mistakenly) regarded as the author of the *Opinions*. Nevertheless, Book 2, Chapter 24, of the *Opinions* was so obviously garbled that Copernicus would not attribute that mess to Plutarch. Hence he resorted to the conveniently vague formula “some people” when he mentioned Aristarchus’ geokineticism in the passage he later deleted.

Why did he delete this passage? Was Copernicus trying to hide any indebtedness to Aristarchus? If so, why did he allow Book 1, Chapter 5, to be printed with its attribution to Philolaus of the opinion that the earth is a heavenly body endowed with several motions, including rotation? Was Philolaus respectable, and Aristarchus not?

Copernicus quoted from *Plutarchi opuscula LXXXVII*. This volume contained, besides the spurious *Opinions*, Plutarch’s authentic dialogue on *The Face in the Moon*. Its interlocutors were reminded that a famous philosopher believed that it was the duty of the Greeks “to indict Aristarchus of Samos for impiety in imputing motion to the Hearth of the Universe.” These interlocutors needed no reminder that in Plato’s *Phaedrus* (247A) the expression for the immobility of the earth was: “in the house of the gods, the Hearth stands still.” In Plutarch’s *Face in the Moon*, the indictment continued:

According to Aristarchus’ hypotheses, the heaven stands still whereas the earth revolves along an oblique circle. At the same time the earth rotates around its own axis.

The earth’s rotation was not explicitly mentioned as an integral feature of Aristarchus’ astronomy in Archimedes’ *Sand-Reckoner*, which rather focused attention on the earth’s revolution around the sun. The only clear statement that Aristarchus’ earth also rotated occurs in Plutarch’s *Face in the Moon*. Had Copernicus known this passage, he would have specified how Aristarchus’ earth moved. Instead, he said nothing more than that it moved. Hence, Copernicus did not know Plutarch’s *Face in the Moon*.

Its passage about Aristarchus appears on page 932 in *Plutarchi opuscula LXXXVII*. From page 313 in that volume Copernicus took the Greek quotation in the Dedication of his *Revolutions*. For him, the doxographical *Opinions* had great importance. The rest of that bulky volume was not used by Copernicus, a busy canon with very little spare time for reading. He would have advanced his cause considerably had he not overlooked the valuable reference to Aristarchus in Plutarch’s *Face in the Moon*. Copernicus’ only reference to Aristarchus’ geokineticism was deleted with the rest of the deleted passage. But the purpose of the dele-

tion was not to get rid of the name of Aristarchus, who was mentioned elsewhere in the *Revolutions*.

The deleted passage consists of about eight hundred words, in exactly ten of which Aristarchus is mentioned or in about $1\frac{1}{4}\%$ of the entire deletion. Had Copernicus wanted to get rid of a potentially dangerous association with Aristarchus, all he had to strike out was those ten words. Their presence in the deleted passage is of such minor significance that removing them would not have impaired the rest of the passage in any way whatsoever. The bulk of the passage consists of Copernicus' translation into Latin of an ancient Greek letter. Its text had already been printed. Then Copernicus acquired a copy of a book containing an expert Latin translation of the letter by a highly reputable authority. What would be the sense of publishing a second translation of the letter? Instead of doing so, in the part of the *Revolutions* that he wrote last, Copernicus briefly summarized the contents of the letter while suppressing his translation of it.

With this deletion, Aristarchus disappeared from the *Revolutions* as a geokineticist. But he remained as having "found the same obliquity of the ecliptic and equator as Ptolemy, $23^{\circ}51'20''$ " (Book III, Chapter 2). "According to Ptolemy, the obliquity of $23^{\circ}51'20''$ did not change at all in the four hundred years from Aristarchus of Samos to his own time" (Book III, Chapter 6). "The natural year, which is also called the tropical year, is determined by Aristarchus of Samos as containing $365\frac{1}{4}$ days" (Book III, Chapter 13). Neither of these two values, $23^{\circ}51'20''$ and $365\frac{1}{4}$ days, can be found in Aristarchus' extant writings. Nor were they ever attributed to Aristarchus by anybody before Copernicus. Why did he make these two mistakes?

Copernicus says: "according to Ptolemy." What access to Ptolemy did Copernicus have? The Greek text of Ptolemy's *Syntaxis* was first printed in 1538. A copy reached Copernicus too late to exert any significant effect on the composition of the *Revolutions*. Lacking the Greek text, whether in print or in manuscript, Copernicus perforce had to rely on a Latin translation. In the main he used the translation published in Venice in 1515. This was not a recent rendering based on Ptolemy's Greek text and made by a scholar who knew both Greek and astronomy. Instead, it was a medieval translation based, not on Ptolemy's Greek text, but on a previous translation from Greek into Arabic. In passing in this way from Greek into Arabic, and then from Arabic into Latin, Ptolemy suffered grievously.

In particular, names of Greek astronomers mentioned by Ptolemy became distorted. Thus in Book VII, Chapter 1, the 1515 edition referred to observations by "Arsatilis" and Timocharis. What Greek astronomer lay behind "Arsatilis"? Copernicus guessed "Aristarchus." In his personal

copy of the 1515 edition, which is now in the library of the University of Uppsala in Sweden, Copernicus underlined "Arsatilis" on folio 75 verso (Book VII, Chapter 3) and replaced it by Aristarchus in the margin.¹¹ In a letter dated 3 June 1524, Copernicus referred to "Aristarchus and Timocharis," and he also said that Ptolemy "joined Aristarchus to Timocharis of Alexandria as his contemporary."¹²

Later Copernicus discovered the correct equation, $Arsatilis = Aristyllus$. On folio 73 recto (Book VII, Chapter 1) of his copy of the 1515 Ptolemy, Copernicus made the proper substitution of Aristyllus for Arsatilis.¹³ By the same token, in his autograph manuscript of the *Revolutions* (folio 78 verso, line 2), where Copernicus had originally written "Aristarchus," he replaced that misnomer by the appropriate name, Aristyllus.

On the other hand, Copernicus left "Aristarchus" unchanged in two other related passages (folio 73 recto, lines 20, 28, and folio 79 recto, line 16). When Copernicus had to make a change somewhere in his autograph manuscript, he did not always systematically hunt for the other passages where corresponding changes were then required. As a result of this erratic procedure, his autograph is riddled with many internal inconsistencies.

Copernicus discovered the blunder in his equation $Arsatilis = Aristarchus$ after 3 June 1524. He may have seen the light after getting hold of a copy of the 1528 Latin translation of the *Syntaxis*. This was made directly from the Greek, without any Arabic detour. Some of Copernicus' expressions (*Revolutions*, Book I, Chapter 7) unmistakably echo the 1528 translation.

This helped him somewhat, but did not clear up all the difficulties. For instance, the $23^{\circ}51'20''$ obliquity was really ascribed by Ptolemy to Eratosthenes, not to Aristarchus. In like manner, the $365\frac{1}{4}$ day length of the year was attributed to Callippus, which became "felis" in the 1515 edition. The same length of the year was misattributed by Copernicus to Archimedes ("Arsamides" in the 1515 edition). The latter might have made an error of $\frac{1}{4}$ day, Hipparchus ("Abrachis") surmised. Somehow, a possible error of $\frac{1}{4}$ day was misread as $365\frac{1}{4}$ days as the length of the year.

Poor Copernicus, his imperfect sources led him to confuse Aristarchus with Eratosthenes and Callippus. He never quite achieved a clear separation of Aristarchus from Aristyllus. At best, his picture of Aristarchus of Samos was sadly out of focus. That is why his greatest heliocen-

11 Ludwik Antoni Birkenmajer, *Mikotaj Kopernik* (Cracow 1900) 256, no. 64.

12 Edward Rosen, *Three Copernican Treatises*, 3rd ed. (New York 1971) 101, 103.

13 Birkenmajer 256, no. 59.

trist predecessor, Aristarchus, the first astronomer to make the earth revolve as a planet around a stationary sun, failed to appear alongside others of like mind in the printed version of the *Revolutions*.

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