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Persian Astronomy in the Greek Manuscript *Linköping kl. f.* 10*

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This paper is a study of an astronomical text redacted in Greek, contained in the fifteenth-century manuscript Linköping kl. f. 10 (henceforth **F**). This text consists of a coherent group of instructions on how to use a structured set of astronomical tables stemming from Islamic tradition, redacted primarily in Persian in the thirteenth century, then translated by Byzantine scholars into Greek, and spread among Byzantine scholars from the beginning of the fourteenth century.[1]

2. Astronomical texts and tables between the Il-khanate and Byzantium

In the thirteenth century, astronomical tables stemming from Persia were mostly produced by Islamic scholars. The area, stretched out today between Iran and Azerbaijan, was ruled by the Mongols of the Il-Khanids dynasty. Due to their interest in astronomy and astrology, after the conquest of that region, they hired the Islamic astronomers already settled there and employed them in the new observatories that they built,

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[1] For more details on the exchanges between Persian and Byzantine scholars see Tihon 1987, Tihon 1990 and Ragep 2014. This introduction is indebted to those papers.

notably that of Maragha, founded in 1259 by the Il-khan Hulaghu, and that of Tabriz, founded not much later by Ghazan Khan.[2]

Information on the scientific exchanges between Persia and Byzantium appears in the introduction to the so-called *Persian Syntaxis*, an astronomical handbook on Persian tables redacted in Greek at around 1347 by Georgios Chrysokokkes.[3] He reports that he learned astronomy a few years before, in Trebizond, a city with a good tradition of astronomical studies, by a priest called Manuel, an otherwise unknown figure. The latter had practiced astronomy learning from Gregorios Chioniades, a Byzantine scholar who had travelled to Tabriz at the end of the thirteenth century in order to learn astronomy from the Persian scholar Šams al Dīn al-Buḫārī, whose works Chioniades had translated and brought to Trebizond.[4] Chioniades is the author of the most ancient translations into Greek of works of Persian astronomy, or, better, these translations are to be ascribed to him: the *Zīj as-Sanjarī* (composed around 1120) by al-Ḫāzinī, and the commentary of the aforementioned Šams al Dīn al-Buḫārī on the *Zīj al-ʿAlāī*, a work of the Arab astronomer Al-Fahhād (composed around 1176).[5] There is evidence to suggest that at the beginning of the fourteenth century some Persian astronomical treatises were known in a Greek-Byzantine environment and were circulating among scholars, if not in Constantinople, for sure in Trebizond.

I would like to draw attention to the fact that the astronomical texts we are considering deal with "practical" astronomy, not with theoretical astronomy. The handbooks mentioned, in contrast with major works such as Ptolemy's *Almagest* or *Planetary Hypothesis*, do not concern themselves with the mathematical and physical foundations of astronomy, but consist simply of instructions on how to use structured sets of astronomical tables. Learning how to use astronomical tables was

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2 Tihon 1987 and Saliba 1991. See also North 2008, 204-214.

3 Mercier 1984. This text constitutes the subject of my ongoing research project. There is an old unpublished thesis on the subject, *Etude sur la syntaxe perse des Georges Chrysococces* by Françoise Oerlemans, supervised by J. Mogenet, but this resource could not be accessed.

4 See Ragep 2014.

5 See Leichter 2004, 6-12. Editions of Chioniades's works: Pingree 1985, Paschos-Sotiroudis 1998, Leichter 2004.

possible even without being aware of the theories behind them. That is why astronomical handbooks were so popular.

In late Byzantium, the genre of the astronomical handbook for a set of tables was not new to Greek tradition. The most ancient Greek source on this is the *Small commentary on Ptolemy's Handy Tables* by Theon Alexandrinus (4th century CE).[6] But in the thirteenth century Ptolemy's *Handy Tables* were not up-to-date anymore. Importing tables from Islamic tradition, therefore, was a quick way for Byzantine scholars to have and practice astronomy through up-to-date tables. Those tables could help them in fixing the calendar, computing the date of Easter and predicting celestial phenomena like eclipses, which Byzantine scholars were fond of. Though up-to-date, these tables were not necessarily more reliable; in fact, Ptolemaic tables (from the *Handy Tables* and from the *Almagest*), with which Byzantine scholars were probably more familiar, were still in use. For instance, in order to compute eclipses, the renowned scholar John Chortasmenos still applied Ptolemaic methods and combined them with the Persian ones; however, he still calculated eclipses through the *Almagest*.[7] Once the Persian tables were imported, instructions on how to use them were also required, because astronomical tables, despite their user-friendly format, are not easy for non-experts. These tables consisted of structured lists of astronomical values (numbers) based on parameters set out in Ptolemy's *Almagest*. The values shown by the tables must be combined by precise operations to compute an astronomical magnitude at a given time.[8] While it is likely that Chioniades's instructions are translations from Persian, other extant instructions were redacted by Byzantine scholars directly in Greek.

The text at ff. 1–27 of manuscript **F** belongs to this genre. Such works were redacted by fourteenth-century Byzantine scholars in order to explain how to use the imported Persian tables. The text in F is entitled Παράδοσις εἰς τοὺς περσικοὺς κανόνας τῆς ἀστρονομίας, i.e. «Instructions for the Persian Tables of Astronomy» (henceforth *Paradosis*).

[6] Edition: Tihon 1978.

[7] Caudano 2003.

[8] On the *Handy Tables* and their mathematics: Neugebauer 1975, 2, 969–1028.

3. The *Paradosis* of the Persian Tables[9]

The *Paradosis* in manuscript **F** comments on the tables provided at ff. 33-80v of the same **F**. Such tables were computed for the years 1408/09 CE onwards, while the computations in the texts are arranged for the year 1352 CE, except for one case for the year 1347 CE. Further hints in the texts contained in the *Paradosis* of **F** suggest that this witness was composed in the first half of the fifteenth century, not before 1408/09, as we will see.

As a handbook, the *Paradosis* underwent several modifications with regard to structure and content. **F** is not the earliest version of the *Paradosis*, whose most ancient extant witnesses are datable to the middle of the fourteenth century (around 1352 CE). An alternative redaction of the text is also extant. It is a part of a wider work: it consists of the *Third Book* of Theodoros Meliteniotes' *Tribiblos Astronomike*, redacted before 1368 (henceforth *Book III*).[10]

According to modern scholarship on the *Paradosis*, the main questions around this text can be summarized as follows: 1) who is the real author of the text: Isaak Argyros,[11] Theodoros Meliteniotes,[12] or someone else? This opus is sometimes ascribed to Isaac Argyros, or to Georgios Chrysokokkes.[13] The latter attribution is found in **F**; the ascription to Meliteniotes is due to textual evidence (see below); 2) what are the relationships between the *Paradosis* and Meliteniotes' *Book III*? To solve these problems, I investigated the textual tradition of the *Paradosis* for my PhD thesis.[14] The most ancient witness is found to be the one contained in manuscript Florence, *Laurentianus pluteus* 28.13 (**L**),

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9 Here I summarize the results I explained more accurately in Bardi 2018b. Please refer to that article for a more detailed description of my survey on the textual tradition of the *Paradosis* and the related bibliographical references.

10 The first two books of the *Tribiblos* are edited in Leurquin 1990-1993.

11 PLP 1285.

12 PLP 17851.

13 PLP 31142.

14 PhD thesis (LMU München) entitled 'Persische Astronomie in Byzanz. Ein Beitrag zur Byzantinistik und zur Wissenschaftsgeschichte', forthcoming or in the series Münchner Arbeiten zur Byzantinistik, Neuried: Ars Una.

which was penned by Isaac Argyros before 1374.[15] As was already known from the research by Giovanni Mercati,[16] the original astronomical work by Meliteniotes (*Tribiblos*) is transmitted in manuscript *Vaticanus graecus* 792 (**X**), written by Meliteniotes himself before 1368. Georgios Chrysokokkes indeed also authored a handbook for Persian tables around 1347, but it is different from the *Paradosis* and earlier than the latter; it is the so-called *Persian Syntaxis*.[17] This handbook and the *Paradosis* both comment on similar sets of tables, sharing most of the astronomical parameters.[18]

A comparison of all the texts of the redactions by Meliteniotes and the *Paradosis* suggests that manuscript **L** is witness to an ancient stage of composition of this text, as argued on the basis of corrections and style. It is likely that **L** is nearer to the original composition than the redaction of Meliteniotes. However, the latter is the author of an enriched and refined version of the *Paradosis*, which constitutes *Book III* of his astronomical opus. The scribe of the most ancient extant witness of the *Paradosis* is Argyros, but he cannot be considered the true author of this opus with certainty, because he does not write his name in the title in **L**. However, the relationships between the two redactions do not provide clear evidence to decide in favor of the one author rather than the other. On this account, I looked for further hints by analyzing the astronomical terminology in both redactions.

My hypothesis of a relationship between the *Paradosis* and the redaction of Meliteniotes is confirmed by the analysis of the Arabic terminology used in the two redactions. Amid Byzantine Palaiologan astronomy, the oldest occurrences of Arabic astronomical terminology referring to thirteenth-century Islamic tables are provided by the translations of Chioniades.[19] All of these terms are translated into Greek by Chrysokokkes in his *Persian Syntaxis* (ca. 1347), as I have argued from

[15] The hand was already recognized by Mondrain 2012, 630. On the manuscript see Gentile 1994, 93-94.

[16] Mercati 1931, 174-179.

[17] Mercier 1984.

[18] Mercier-Tihon 1998, 287.

[19] See the glossary provided by Pingree 1985, 395-401.

the inspection of several witnesses to this text.[20] Therefore, just before the middle of the fourteenth century, Byzantine scholars in Trebizond and Constantinople[21] had at their disposal a full account of Arabic astronomical terminology in Greek for using the Persian tables.[22] But both Argyros and Meliteniotes, though they wrote after Chrysokokkes and commented on the same set of Persian tables, provide Greek astronomical terms accompanied by a loan-word of the Arabic term. This suggests that they undertook a work of erudition, because they set the etymological term as a *glossa*, while these same terms were put in the main level of the clause by Chioniades. The fact that Meliteniotes provides these *glossae* more systematically than Argyros suggests a later composition stage than Argyros's. At any rate, they could write Greek terminology with perfect ease, because they relied on the work by Chrysokokkes, which was for sure at their disposal.[23] It is likely that Meliteniotes added the Arabic terminology not provided in the *Paradosis* from the *Zīj* that Chioniades had transcribed in *Laur. Plut.* 28.17.[24]

The comparison of the two redactions also suggests that L is an epitome (a summarized version) of Meliteniotes. However, this hypothesis cannot be really entertained, because there are many other witnesses of the

[20] I inspected the following witnesses to Chrysokokkes's *Syntaxis*: *Ambrosianus* E 80 *sup*. (Martini–Bassi 294) ff. 69v–173; *Ambrosianus* I 112 *sup*. (Martini–Bassi 469) ff. 2–111; *Leidensis* BPG 74E ff. 80–85v; *Leidensis Voss*. *Misc*. 47, ff. 1–7; *Londinensis Burneianus* 91 ff. 39–100v; *Marcianus graecus* VI. 9 (coll. 1066), ff. 145–156v; *Marcianus graecus* Z. 309 (coll.300) ff. 41–66v; *Marcianus graecus* Z. 327 (coll. 642) ff. 24–48v; *Parisinus graecus* 1310 ff. 282v–287v; *Paris*. *gr*. 2401 ff. 1–40; *Paris*. *gr*. 2461 ff. 151v–188; *Paris*. *gr*. 2402 ff. 1–36; *Paris*. *suppl*. *gr*. 20 ff. 75–82; *Paris*. *suppl*. *gr*. 565 ff. 306–449; *Paris*. *suppl*. *gr*. 689 ff. 15–52; *Paris*. *suppl*. *gr*. 1190 ff. 10–14; *Scorialensis* Eta V 3 (Andrés 415), ff. 5r–v, 38–60; *Scorialensis* Rho. I. 14 (Revilla 14) ff. 17–42, 57–58; *Scorialensis* Sigma. I. 11 (Revilla 71), ff. 2–51; *Taurinensis* C. III. 07;ff. 3–136; *Taurinensis* B.II.18 ff. 12-73; *Vat*. *gr*. 209 ff. 1–17; *Vat*. *gr*. 210 ff. 8–35v; *Vat*. *gr*. 1058 ff. 92–118v; *Vat*. *gr*. 1852 ff. 408–415v; *Vindobonensis phil*. *gr*. 87 ff. 1–47v; *Vind*. *phil*. *gr*. 108 ff. 33–159v; *Vind*. *phil*. *gr*. 190 ff. 86–254v.

[21] Chrysokokkes studied in Trebizond and his *Syntaxis* is very likely composed for colleagues in Constantinople.

[22] The thirteenth-century Persian astronomical handbooks kept Arabic terminology for technical terms.

[23] Some texts and tables of the *Paradosis* and the *Book III* refer to Chrysokokkes's work.

[24] Tihon 1987, 479.

Paradosis which would serve better than **L** as epitomes: they were all transcribed later than Meliteniotes's *Book III* (composed not later than 1368). In addition, such witnesses, though surely later than **L**, are not direct copies of **L**, but belong to a different family of manuscripts.
While the relationship between the redactions and the question of the author are an intriguing issue, the inspection of the textual features is a complicated task as well. The *Paradosis* is handed down in 25 copies, while the redaction of Meliteniotes is only extant in two manuscripts. The following list numbers all the extant witnesses to the *Paradosis*. The division into two manuscript families was made mainly on the basis of textual macro-variants, such as accretions or omission of whole chapters or long texts portions.

Family of **L**

L *Laurentianus Plut.* 28.13, ff. 2–17	**J** *Laurentianus Plut.* 28.16, ff. 3–20v
K *Marcianus graecus* Z 336, ff. 12–28	**S** *Vaticanus Palatinus graecus* 278, ff. 13–27v

Family of **M-CFPQ**: group of **CFPQ**

Q *Parisinus graecus* 2501, ff. 1–31v	**C** *Oxoniensis Canonicianus gr*. 81, ff. 1–88
E *Oxoniensis Baroccianus* 58, ff. 1–42v	**Z** *Lugdunensis Vossianus graecus* F 9, ff. 22–23
P *Parisinus graecus* 2107, ff. 141–145v, 160v–161r, 164v–166r, 191v, 193v–194r, 198v–201r, 205r–207v, 214r–215v	**G** *Guelferbytanus Gudianus graecus* 40, ff. 16r–20v
H *Vaticanus graecus* 1852, ff. 430–454v	**F** *Lincopensis* kl. f. 10, ff. 1–25r
V *Lugdunensis Vossianus graecus* Q 44, ff. 1–23v	**326** *Marcianus graecus* Z 326, ff. 29r–54v

Family of **M-CFPQ**: group of **M**

M *Marcianus graecus* Z 323, ff. 71–94v	**U** *Vaticanus graecus* 1058, ff. 130–142
A *Taurinensis* B.II.18, ff. 83r–115r	**W** *Taurinensis* C.III.7, ff. 57r–80v
D *Oxoniensis Seldenianus* 6 (*Seldenianus supra* 7), ff. 36v–47v	**N** *Marcianus graecus* Z 328, ff. 30–60v
O *Marcianus graecus* Z 333, ff. 146–176v	**T** *Vaticanus graecus* 1047, ff. 12–39v
R *Parisinus supplementum graecum* 754, ff. 181r–183r	**B** *Londinensis Burneianus* 91, ff. 10–28v

A partial witness of the *Paradosis*, not belonging to any defined family, is provided by the manuscript *Ambrosianus* E 80 sup., ff. 220r–226v. The textual transmission is characterized by an intricate wood of textual variants, with several degrees of significance. As a consequence, most of the stemmatic relationships could be established only through macro-variants, i.e. accretions or omission of chapters, or longer textual portions. These phenomena find their cause in the sectional structure of the *Paradosis*: its chapters are mostly independent from each other, so they could be put in different positions without affecting the coherence of the whole opus. After the middle of the fourteenth century, accretions of chapters into the original structure of the *Paradosis* became more and more frequent, depending on the personal interest of the scribe of the manuscript. The additional chapters deal often with solar and lunar conjunctions, eclipses, and chronology (conversion methods between the Byzantine and the Persian calendar). This is in accordance with the astronomical interests of late Byzantine scholars. Among the fifteenth-century copyists of the *Paradosis* and *Book III*, John Chortasmenos[25] (Y), Bessarion[26] (O), and Isidore of Kiev[27] (H) are the most notable figures.

As for the text-structure, each chapter of the *Paradosis* provides a

25 Hunger 1969.

26 Märtl-Kaiser-Ricklin 2014.

27 Mercati 1926.

theoretical part and a practical part. The former explains how to compute an astronomical magnitude; the latter shows how to apply the theory expounded in the former to a precise example (usually for 25 December of the year 1352 CE). Eventually the computations are summarized, either in textual or in tabular form. The Greek language of the *Paradosis* displays the usual features of style of mathematical procedures and algorithms. This style features the "procedural language" and the "algorithmic language", in the terminology adopted by Fabio Acerbi.[28] Briefly, the procedures describe chains of operations through a normative syntax based on participial forms and the future indicative; they never feature numbers (conversion factors and non-variable values excepted), but long denotative expressions to describe the astronomical magnitudes involved in the computation; they are aimed at providing the most general description of a well-defined operation. The algorithms employ the second person of the imperative mood to describe an operation, always feature a paratactic syntax, and are aimed at summing up the operations expounded in the procedural part through applying them to a computation sample.[29]

4. The *Paradosis* of F

The version of the *Paradosis* in **F** includes the main structure of 18 chapters provided by manuscript **L**, but not exactly as it is preserved in **L**. Compared to it, the scribe of **F** introduces the following changes: [the numbers between parentheses refer to the chapter of **L**]

L	**F**
1. Παράδοσις εἰς τοὺς Περσικοὺς κανόνας τῆς ἀστρονομίας «Instructions for the Persian Tables of Astronomy»	1 = (1)

[28] This terminology is adopted from a masterly article by Fabio Acerbi, who detected and described the stylistic codes of Greek mathematical language for the first time. See Acerbi 2012.

[29] See Acerbi, 'I codici stilistici', 183-193 for a full description of these terms.

2. Περὶ τῶν παρὰ Πέρσαις τεσσάρων κεφαλαίων τῶν τε ἁπλῶν ἐτῶν, τοῦ μηνὸς ἡμερῶν τε καὶ ὡρῶν ἀπὸ τῆς ἔγγιστα παρελθούσης μεσημβρίας καὶ μήκους τῆς ὑποκειμένης πόλεως «On the Persian four sections, namely, that of the simple years, of the month and the day and the hours from the most recent midday, and that of the longitude of the town taken at issue»	2 = (2)
3. Περὶ τῆς τοῦ ἡλίου κατὰ μῆκος ψηφοφορίας «On the computation of solar longitude»	3 = (3)
4. Περὶ τῆς κατὰ τοὺς τρεῖς τρόπους διακρίσεως τῶν ὡρῶν «On the adjustment of the hours according to the three ways»	4 = (4)
5. Περὶ τῆς κατὰ μῆκος τῆς σελήνης ψηφοφορίας «On the computation of lunar longitude»	5 = (5)
6. Περὶ τῆς διορθώσεως τῶν ἐποχῶν ἡλίου καὶ σελήνης «On the correction of the position of sun and moon»	6 = (6)
7. Περὶ τῆς τοῦ ἡλίου λοξώσεως «On solar obliquity»	7 = (7), but without practical part
8. Περὶ τῶν συνδέσμων τοῦ τε ἀναβιβάζοντος καὶ τοῦ καταβιβάζοντος «On the nodes, the ascending one and the descending one»	8 = (8)
9. Περὶ τοῦ πλάτους τῆς σελήνης «On lunar latitude»	9 = (9)
10. Περὶ τῆς τῶν πέντε πλανωμένων κατὰ μῆκος ψηφοφορίας «On the computation of the longitude of the five planets»	10 = (13), but with an accretion
11. Περὶ τῶν κατὰ πλάτος ἀπὸ τοῦ διὰ μέσων τῶν ζῳδίων ἀποστάσεων τῶν τριῶν πλανωμένων Κρόνου Διὸς καὶ Ἄρεως «On the computation of the distance in latitude from the ecliptic of the three planets Saturn, Jupiter and Mars»	11= (14)
12. Περὶ τοῦ πλάτους Ἀφροδίτης καὶ Ἑρμοῦ «On the latitude of Venus and Mercury»	12 = (15)

13. Περὶ συνοδικῶν καὶ πανσεληνιακῶν συζυγιῶν «On synodic syzygies and full moons»	13 = (16)
14. Περὶ τῶν ἐκλειπτικῶν ὅρων ἡλίου καὶ σελήνης «On the limits of the eclipses of the Sun and the Moon»	14 = (10)
15. Περὶ σεληνιακῶν ἐκλείψεων «On lunar eclipses»	15 = (11)
16. Περὶ ἡλιακῶν ἐκλείψεων «On solar eclipses»	16 = (12)
17. Περὶ τῆς ἀπὸ ζῳδίου εἰς ζῴδιον μεταβάσεως ἡλίου τε καὶ σελήνης καὶ τῶν πέντε πλανωμένων ἀστέρων «On the passage from sign to sign of the Sun, the Moon and of the five planets»	17 = (17)
18. Περὶ τῆς παραυξήσεως τῶν κανονίων τῶν ἁπλῶν ἐτῶν ἡλίου σελήνης καὶ τῶν λοιπῶν «On the increment of the tables of the simple years of the Sun, the Moon and the rest»	18 = (18)
	19 [Περὶ ὡροσκόπου]
	20 Τεχνολογία ἀκριβὴς περὶ τῆς ὥρας συνόδου ἤτοι πανσελήνου
	21 [on the conjunctions of the planets]
	22 Περὶ τῆς καταλήψεως τοῦ ἔτους τῶν Περσῶν
	23 [how to convert from a year to another]

	24 [the ecliptic, the zodiac, the signs]
	25 Περὶ τοῦ πόσον κινεῖται ἕκαστος τῶν ἀστέρων τὸ νυχθήμερον
	26 [how to convert from a year to another]

In **F**, the chapters about the planetary motions (10, 11, and 12) are shifted after the chapters about the syzygies (solar and lunar conjunctions) and eclipses (i.e. 13, 14, 15, 16). This arrangement resembles the structure of the astronomical work by Stephanus Alexandrinus.[30] Therefore, it cannot be an accident that an excerpt from the treatise of Stephanus is found written at f. 29 in the same manuscript, **F**.[31] The presence of this fragment argues for Stephanus being the conscious model of the arrangement of the *Paradosis* text.

As for the stemmatic relationships of this *Paradosis*, **F** contains significant textual differences compared to the manuscripts of the family **L** and the group of **M**. That is why I conclude that it belongs to the group CFPQ in the family M-CFPQ. On this account, I provided a sub-archetype in common with *Parisinus graecus* 2501, *Canonicianus graecus* 81, and *Parisinus graecus* 2107. These relationships are mainly established thanks to the omission of *glossae* containing technical loanwords from Arabic, a common feature of **CFPQ**. In the following, I provide

[30] Edition of Stephanus Alexandrinus's commentary in Lempire 2016. Stephanus is the author on a handbook on how to use Ptolemy's *Handy Tables*. He recalculated the tables, originally shaped on the meridian of Alexandria, for the meridian of Constantinople, in 610/620 CE. On this account, his handbook is considered the first work of Byzantine astronomy.

[31] See critical text Lempire 2016, 86.4-88.6.

some examples of the omissions common to **CFPQ** of *glossae* containing transliterated Arabic terms from the chapter on the computation of the motion of the Sun in longitude:

> κατὰ τὸ πρῶτον σελίδιον τὸ ἐπιγεγραμμένον ἔτη ἁπλᾶ περσικά κατὰ δὲ Πέρσας ἀλμανσοῦντα
> «in the first column entitled "single Persian years" (for the Persians ἀλμανσοῦντα) »

The term ἀλμανσοῦντα should be pronounced in Greek /almansuta/, which corresponds to the Arabic المبسوطة, i.e. in Persian transcription *al-mabsuta*, in Arabic *al-mabsūṭa*. The scribe of **F** omits κατὰ δὲ Πέρσας ἀλμανσοῦντα.

> τὰ παρακείμενα αὐτῷ ζῴδια μοίρας καὶ λεπτὰ κατὰ τὸ δεύτερον σελίδιον, ὃ κίνησις μέση ἐπιγέγραπται περσικῶς δὲ ἄλ βασάτ
>
> «The signs, degrees and minutes near to it in the second column, which is entitled "mean motion" (in Persian ἄλ βασάτ) »

The term ἄλ βασάτ should be pronounced in Byzantine Greek as /al-uasat/. This corresponds to the Arabic الوسط, in Persian transcription *al-vasat*, in Arabic transcription *al-wasaṭ*. The *glossa* περσικῶς δὲ ἄλ βασάτ is omitted by **F**.

The same stylistic attitude is to be found in **F** in correspondence to the following terms, which are provided in the oldest versions of the *Paradosis*:

Greek	Greek transcription	Arabic	Arabic transcription	Meaning
ἀαπέτ	*Aapet*	هابط	*hābiṭ*	descending
ἄλ μανσοῦντα	*Almansuta*	المبسوطة	*al-mabsūṭa*	Single (year)
ἄλ βασάτ	*Al basat*	الوسط	*al-wasaṭ*	Mean (motion)

ἄλ χασάτ	*Al chasat*	الخاصة	*al-ḫāṣṣa*	Proper (motion)
ἄουτζ	*Aoutz*	اوج	*awj*	Apogee
βασὰτ μαντάλ	*Basat mantal*	وسط معدّل	*wasaṭ muʿaddal*	Modified mean motion
ἐκτλεῦ	*Ektleu*	اختلاف	*iḫtilāf*	Anomaly
ἐτᾶ/ἐσᾶ ἄρζ	*Eta arz*	حصة عرض	*ḥiṣṣa ʿarḍ*	Lunar longitude
ἰστιμά	*Istima*	اجتماع	*ijtimāʿ*	Conjunction
ἰστικπάλη	*Istikpale*	استقبال	*istiqbāl*	Opposition
μάρκαζ	*Markaz*	مركز	*markaz*	Centre/centrum
μουκκαούμ	*Mukkaum*	مقوّم	*muqawwam*	corrected
ντζαὴρ χαλιτάτ	*Ntzair chalitat*	جزائر خالدات	*jazāʾir ḫālidāt*	Fortunate Isles
σααέτ	*Saaet*	صاعد	*ṣāʿid*	ascending, rising
σαμάλ	*Samal*	شمال	*šamāl*	North
ταντὶλ ἀλάχιρ	*Tantil alachir*	تعديل الآخر	*taʿdīl al-āḫir*	Second equation
ταντὶλ ἀουάλ	*Tantil aual*	تعديل الأول	*taʿdīl awwal*	First equation
ταντὶλ τζατζουβὰλ	*tantil tzatzouval*	?	*taʿdīl* + ?	equation of the Sun
τζανούπ	*Tzanup*	جنوب	*janūb*	South
χασὰ μαντάλ	*Chasa mantal*	خاصة معدّلة	*ḫāṣṣa muʿaddil*	Modified proper motion

The detected terms are Arabic astronomical terms, mediated through

Persian. The Arabic origin is explained for three reasons:

1) the doubling of consonants occurs (e.g. *muqawwam*);

2) most of the words contain the letters ث ح ذ ص ض ط ظ غ (e.g. *hābiṭ*);

3) the root of the listed terms consists of three consonants, which occurs in the same sequence in different words (e.g. *taʿdīl* and *muʿaddil*).

The Arabic origin of the astronomical words is indeed not surprising, for the Arabic scientific texts redacted before the Ilkhanids' conquest of Persia were later translated into Persian. This language shares the same alphabet, therefore scholars kept the technical terms unvaried. Moreover, **F** provides a text about determining the time of true syzygies, additional to chapter 13. This addition is in common to manuscript **H** and other manuscripts of the group of **M**, namely **B**, **T**, **O**, and **326**. Differently from **T** and **O**, which provide the additional text as an independent chapter, **F** reports that text as part of chapter 10 (13**L**). The same happens in **H**, **B**, and **326**.[32]

The scribe of **F** adds further additional chapters (see above). The first one deals with the main lines of a horoscope (chapter 19), then one on the determination of syzygies (20) and conjunctions between planets (21), elementary notions of astronomy (24), the motions of the planets during a day (25) and about the conversion between different calendars (22, 23, 26).

Chapter 22 is worthy of note. It is arranged for the conversion of dates between Persian, Arabic, Byzantine and Hebrew eras; chapters 23 and 26 between Persian and Byzantine calendars. Not accidentally, manuscript **F** also contains Jewish astronomy: at ff. 111–124r, the scribe copies Michael Chrysokokkes's *Six Wings*, which is a translation into Greek (ca. 1435) of a work by the astronomer Immanuel Bonfils, a Jewish scholar who redacted an opus aimed at calculating eclipses, composed around 1360 in Tarascon (Southern France).[33] The text 22**F** is also provided by other manuscripts containing the *Paradosis*, for instance Q (ff. 27-28), that inserts this text into the main structure of the *Paradosis*, while it appears as an independent text in **X** (f. 21r), **C** (f. 73r), and **326** (f. 51). This text is also shared by two manuscripts dependent from **M**,

[32] The text is edited in Bardi 2018a, 19–20.

[33] Edition: Solon 1968.

namely **O** (f. 264v) and **K** (f. 1r). In the latter, the text is added by a later scribe, who modifies the *Paradosis* by means of adding texts from **M**.

The scribes of **Q**, **F**, and **326**, are very similar. Nevertheless, the textual variants allow one to surmise that in the group **CFPQ**, **F** shares also a sub-archetype with **H** and **P**, because of long portions of texts in common within the eighteen chapters of the basic structure on the handbook. Moreover, the *Paradosis* of **F** has a very similar copy in the witness **326** (ff. 29r–54r).[34] The latter is a partial witness, for it contains the basic chapters from 8 (partially) until 18, alongside chapters 19 to 26 as **F**, but with minimal textual variants.

The numbers in parentheses stand for the chapter of **L**.

F	**326**
1 = (1)	not provided
2 = (2)	not provided
3 = (3)	not provided
4 = (4)	not provided
5 = (5)	not provided
6 = (6)	not provided
7 = (7), but without computations	not provided
8 = (8)	8 = (8)
9 = (9)	9 = (9)
10 = (13), but with accretion	10 = (10)
11= (14)	11= (11)
12 = (15)	12 = (12)
13 = (16)	13 = (13), with accretion
14 = (10)	14 = (14)
15 = (11)	15 = (15)

[34] See Mioni 1985, 50–52. The *Paradosis* was not recorded in the catalogue. I discovered it by inspecting the manuscript.

16 = (12)	16 = (16)
17 = (17)	17 = (17)
18 = (18)	18 = (18)
19 [Περὶ ὡροσκόπου]	19 Περὶ ὡροσκόπου
20 Τεχνολογία ἀκριβὴς περὶ τῆς ὥρας συνόδου ἤτοι πανσελήνου	20 Τεχνολογία ἀκριβὴς περὶ τῆς ὥρας συνόδου ἤτοι πανσελήνου
21 [on the conjunctions of the planets]	21 Περὶ τοῦ πῶς δεῖ εὑρίσκειν τὴν ὥραν καθ᾽ ἣν οἱ ἀστέρες μετὰ τῆς σελήνης μοιρικῶς σχηματίζουσιν
22 Περὶ τῆς καταλήψεως τοῦ ἔτους τῶν Περσῶν	22 Περὶ τῆς καταλήψεως τοῦ ἔτους τῶν Περσῶν
23 [how to convert from a year to another]	23 *De commutatione annorum*
24 [the ecliptic, the zodiac, the signs]	24 *De ecliptica, de signis zodiaci, de rationibus signorum zodiaci*
25 Περὶ τοῦ πόσον κινεῖται ἕκαστος τῶν ἀστέρων τὸ νυχθήμερον	25 Περὶ τοῦ πόσον κινεῖται ἕκαστος τῶν ἀστέρων τὸ νυχθήμερον
26 [how to convert from a year to another]	26 *De commutatione annorum*

As the manuscript **326** provides the same additional chapters, it belongs to the group of **CFPQ** and finds in **F** the closest witness. But **326** displays two significant variants which cannot locate it more precisely in the stemmatic relationships. First, it exhibits a chapter structure similar to the original, and secondly, it preserves the Arabic loanwords and transcribed them in the text in the *glossa* position, as **L** does. Therefore, it is hard to locate the exact position of **326** in the textual transmission of the *Paradosis*. The additional chapters assure its belonging to the group of

F, yet the loanwords in **326** bar the hypothesis of a common archetype with **F**. However, its nearness to **F** is confirmed by the fact that codex **326** also contains an incomplete version of the *Six Wings*, as **F** does. Unlike **F**, however, **326** provides a set of tables computed from the year 1436/37 CE. Given the incomplete state of **326**, it was not possible to say more on its stemmatic nature.
Eventually, it is possible that the *Paradosis* of **F** is the antigraph for **V** (15th–16th centuries), a late copy which does not provide computations. They share minimal textual variants: **V** exhibits exactly the same chapter structure as **F** and the same locations for the computations on the page, but these are left blank in **V**. The scribe did not finish his task.

5. A brief overview of the Persian tables of F

The computational methods expounded in the chapters of the *Paradosis* refer to the astronomical tables provided after it. The set of tables is based on Persian years, according to the era of the Persian King Yazdegerd of the Sassanians. This era counts from his ascending to the throne on June 16, 632 CE. A Persian year consists of 12 months, each of 30 days, and an additional month of 5 days. No leap years are considered. Therefore, 1 day will be lost every four years in comparison to the Julian calendar used in Byzantium. The Byzantines used to reckon from the creation of the word (*Annus mundi*), i.e. September 1, 5509 BCE. The situation gets more complicated, because the computations in the text of the *Paradosis* reckon the years from the Incarnation of Christ, i.e. 5500 BCE, starting from December 25. The difference is 9 years and 116 days as against the *Annus mundi*. All these factors make the computations with the Persian tables complicated already from the start. This situation explains why conversion methods are provided in the additional chapters of **F**.

The geographical reference in the tables hinges upon a town with longitude 72° from the Fortunate Isles, called Τυβήνη (Tybene). This name could well be the transcription of the ancient Armenian capital *Dvin*, because the Byzantine pronunciation of Greek should be /divini/, but its precise identification is still problematic, and the Greek word might be the result of a transcription error. The town named could also designate Tabriz in Iran.[35] Further investigations on geographical tables are needed in order to shed new light on this issue.

The methods of the *Paradosis* show a combination of Islamic and Ptolemaic computations. For instance, the computations for the motions of the Sun and the Moon are based on Islamic methods. In this instance, the reader can avoid the interpolation typical of the *Handy Tables* and does not have to determine whether the corrections to the mean values are to be added or subtracted, because the Islamic tables of this Persian set provide displaced tables for the Sun and the Moon, so that the corrections are always positive, i.e. they need to be added to the results of the mean motion of Sun and Moon.[36] In other words, these computations are more user-friendly than those one had to do according to Ptolemaic methods. By contrast, the computation on how to find the time from mean to true syzygy is similar to the one provided by the *Small Commentary to the Handy Tables of Ptolemy* by Theon Alexandrinus, and the table of mean syzygies is based on the Julian calendar, instead of the Persian one. But the computation for the eclipses is based again on Persian methods. This mixture of Ptolemaic and Islamic methods is not new in the computations of eclipses in Byzantium,[37] and it is attested in all the other witnesses to the *Paradosis*.

The main parameters of the tables of Naṣīr al-Dīn al-Ṭūsī's *Zīj-Īlkhānī* (mid-thirteenth century) should be identified as the model, for the most part, for the set of tables of the *Paradosis*, with the exception of the tables for the syzygies.[38] An ongoing survey will shed new light on this issue. Most of the titles of the tables, once penned in red ink in **F**, are completely faded. Therefore, it is not easy to recognize their contents at first glance. By comparing this set with the other manuscripts (listed above in section 3), there is evidence to suggest that these tables are the same set as the oldest witnesses (e.g. **L**), but they are shifted to more recent years. While **L** and **X** provide astronomical tables from the

[35] Mercier 1984, 56–58.

[36] On displaced tables see Chabás-Goldstein 2013.

[37] See Caudano 2003.

[38] Mercier-Tihon 1998, 287. On Al-Ṭūsī's work see Kennedy 1956: 125 and 161-162.

Persian year 720 (1350 CE) onwards, the tables of **F** start from the Persian year 778 (i.e. 1408/09). This date is the same as the year provided by the computation sample of some additional texts in **F**.

6. Final remarks

The observations in this paper allow reaching several conclusions. The analysis of the *Paradosis* of **F** shows that this text and the related tables were composed not before the year 1408/9 CE. The scribe of **F** shapes the structure of the *Paradosis* following the model of the commentary by Stephanus Alexandrinus. This major change in the transmission of this text is witnessed by one direct copy of **F**, the manuscript **V**.

As for the scribe/compiler of **F**, he is still unidentified. However, one may note that his hand is similar to that copying **Q** and **326**.

The remark at f. 1r of **F** furnishes tantalizing hints for the history of this manuscript. The signature of the Italian scholar Lucrezio Palladio degli Olivi[39] attests that the manuscript was preserved in some scholarly collection in Padua or Venice in the seventeenth century. Only in 1757, **F** became an item of the Stiftsbibliotek Linköping in Sweden.

Another manuscript similar to **F** was likely available in Venice in the seventeenth century, namely **326**, because at that time the Biblioteca Marciana, where **326** is preserved to date, was already in activity as an institution. In addition, another witness of the *Paradosis* (**E**) was owned by a sixteenth-century Venetian scholar, namely the mathematician Francesco Barozzi.[40] On this account, **F** is witness to a kind of *Nachleben* of a Byzantine handbook of Islamic Tables in Renaissance Europe. The transmission of this set of Islamic tables in Europe is not confined to Italy and to antiquarianism; for instance, the renowned French astronomer Ismaël Bullialdus used the tables commented on in the *Persian Syntaxis* and had some of them printed in his work *Astronomia Philolaica* (Paris, 1645); moreover, the German orientalist Ja-

[39] See http://marciana.venezia.sbn.it/immagini-possessori/972-palladio-degli-olivi-lucrezio; accessed May 11, 2018.

[40] On Barozzi see Rose 1977.

cob Christmann provides and comments on the Persian calendar based on the *Paradosis* in an Appendix to his *Muhamedis Alfragani arabis, Chronologica et astronomica elementa et palatinae bibliothecae veteribus libris versa expleta et scholiis expolita* (Frankfurt am Main, 1590, reprinted in 1618).

Both manuscripts **326** and **F** provide a collection of Islamic astronomy commented by Byzantine astronomers alongside Jewish astronomy (Immanuel Bonfils' *Six Wings*, translated into Greek by Michael Chrysokokkes). The coexistence of these different astronomical traditions in the same *codex* explains why the scribe added chapters on the conversion between Persian, Jewish and Byzantine eras (such as 22**F**). All of this suggests also that, in the first half of the fifteenth century, some exchanges between Jewish and Byzantine astronomers may have occurred. At the present state of research, one of the main contents of such cross-cultural exchanges is constituted by Islamic (Persian) tables, such as those commented in **F**. In fact, recent scholarship on the Byzantine versions of Islamic tables in Persian has placed attention on a mid fifteenth-century handbook by Rabbi Mordecai Comtino and on a late fourteenth-century translation from Greek by Solomon ben Eliahu of a Byzantine handbook on Persian tables.[41] Notably, Comtino concludes his handbook on the Persian addressing a criticism to Argyros, accusing him of underestimating the accuracy of the Persian tables.[42]

Moreover, **F** contains copies of astronomical texts by Isaac Argyros, Ptolemy and also the *proemium* of the renowned astronomical poem by Aratus, the *Phaenomena*. Therefore, **F** constitutes a collection of texts stemming from different cultural traditions collected in one volume. Selecting texts about astronomical topics from different traditions is a widespread habit in fifteenth-century Byzantium, as shown by many other extant Byzantine scientific miscellaneous manuscripts, including several *codices* containing the *Paradosis* listed above (see section 3), containing such as **M**, a voluminous *codex* providing sets of tables and methods of Ptolemaic (Theon's and Stephanus' handbooks and *Handy Tables*) and Islamic astronomy (*Paradosis* and related tables).

[41] Mercier-Tihon 1998, 259–261.

[42] Mercier-Tihon 1998, 260.

In sum, since the history of astronomy in fifteenth-century Byzantium is characterized by cross-cultural exchanges, it cannot be satisfactorily narrated by describing transfers of knowledge through static and linear lines.[43] Rather, scholarly networks of Christians and Jews are the likely actors of this interplay. In this field, the survey on the *Paradosis* transmitted by **F** has shown that astronomical handbooks in fifteenth-century Byzantium are very likely a locus of contact between different cultural traditions and religious communities, a historical landscape which is worth investigating in greater depth in future research.

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Abbreviations:

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[43] See the remarks on the historiography of science on cross-cultural exchanges by Ben-Zaken 2010, 163–166 and by Brentjes-Fidora-Tischler 2014.

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