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Reconstructing the Antikythera Mechanism's Front Cover Plate Text and Predicting Planetary Positions and Phases

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Abstract

We present a reconstruction of the lost text inscribed on the Front Cover plate of the Antikythera Mechanism. Although the text is partially or poorly preserved, two critical findings yielded important information, results, and conclusions. The text is a general work of observational astronomy from around 180 BC; it describes the motion of the five planets and could have existed independently of the Antikythera Mechanism, since it contains no references to mechanical operational parts (e.g., a sphere or a pointer). The importance of this inscribed text lies in its ability to predict planetary positions and phases using the device without any additional complex mechanical components on the Mechanism. The text of the Front Cover plate served as the Astronomical Ephemeris for the Antikythera Mechanism's user. This is why the ancient craftsman included it on his device.

Introduction

The Antikythera Mechanism is a bronze geared time-calculating device constructed during the Hellenistic Era around 180 BC (Voulgaris et al. [1,2,3]). Through a large number of gears, axes, shafts, pointers, calibrated scales, and plates, it provided time calculations and predictions of astronomical and social events (Freeth et al. [4,5], Anastasiou et al. [6]). After being brought back to the surface in 1901 from the bottom of the sea near Antikythera, the Mechanism is now partially preserved in seven relatively large fragments (A-G) and 75 small pieces (minor fragments 1-75, see Figure 1 in Voulgaris et al. [3]). The main body of the Mechanism, which enclosed its mechanical system and the outer calculation scales, was accompanied by two cover plates, the Front and the Back plates. Each of these plates was a wooden plate with a thin sheet of copper (or bronze) that was stabilized (probably with pins). On each plate, a text in ancient Greek, written in capital letters, was inscribed. The text inscribed on the Back Cover plate was the Instruction Manual of the Mechanism (Bitsakis and Jones [7], Voulgaris et al. [8,9]), and that inscribed on the Front Cover plate provided general information regarding the timed motion of the five planets and their phases (characteristic positions); see **Table 1**. The main body of the Mechanism and the two Cover plates formed a small wooden chest (Freeth et al. [4]; see Figure 8 in Voulgaris et al. [10] and Figure 1 in Voulgaris et al. [8]). Today, the Antikythera Mechanism fragments are strongly corroded as a result of about 2000 years in the sea. The bronze has been transformed into a new rocky material, atacamite, with properties very different from those of bronze (Voulgaris et al. [10]). A portion of the Mechanism material was also dissolved in the sea as a result of the chemical reactions of copper in the bronze with the chloride in the seawater. All fragments of the Mechanism are strongly corroded, shrunk, displaced,

distorted, and irregularly deformed in 3 dimensions. Due to copper corrosion, a large portion of the thin copper plates on the two Cover plates has been lost (Bitsakis and Jones [7]; Anastasiou et al. [6]). The main text of the Front Cover plate is preserved on Fragment G (≈ H95 mm × W110 mm), which is broken into more than 30 pieces and was reassembled (probably after conservation). The restored fragment is not flattened, as shown by the tomographies, while some letters are preserved on the two small fragments 42 and 51; see **Figure 1**. In most cases, the preserved letters are difficult to read with the naked eye, but *Antikythera Mechanism Research Project* (AMRP) tomographies offer better visibility, making many letters easier to read and identify (Ramsey [11]). In other cases, even with the tomographies, the letters are difficult to identify directly because they appear as line fragments, are (extremely) blurry, or are distorted or indistinct. Yet they can still be recognized from context.

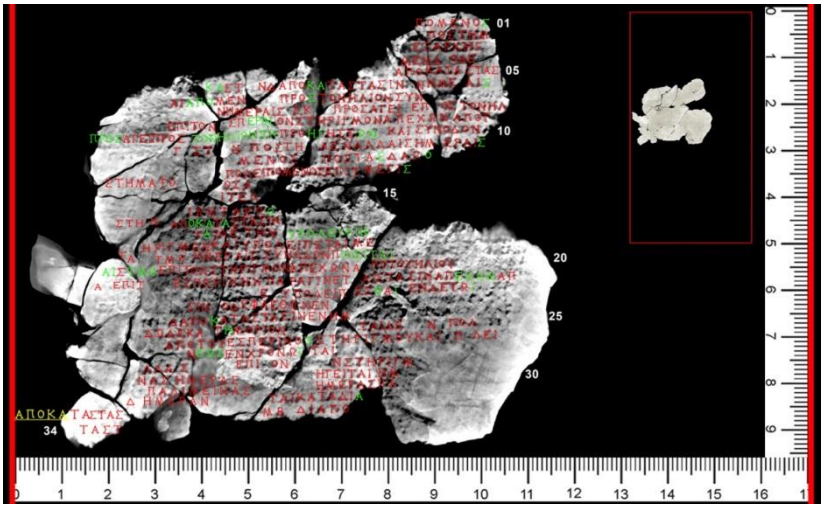


Figure 1. Multi-combined Computed Tomography (CT) of Fragment G, which preserves the largest percentage of the Front Cover Inscriptions. The two vertical lines mark the boundaries of the inscribed copper/bronze plate. The fragment's placement relative to the plate's left-right limits was arbitrarily determined by the authors. The number of letters per line, the reconstructed phrases, and the text syntax are independent of the fragment's positioning. The letters were sketched in their respective positions using the authors' TrueType font for the Antikythera Mechanism. Red letters are preserved and (about) relatively easy or less easy to recognize on the CTs. Green letters resulted from neighboring words, phrases, and syntax. The initial tomographies were generated from the AMRP Raw Volume of the fragment using the Real3D VolViCon V.4.31.0422 software and further processed by the authors. Insert: Fragment G surface inside the red contour, which represents the relative dimensions of the Front Cover plate of the Antikythera Mechanism.

Methods

Studying the preserved text of the Front Cover Plate [6], we identified two key factors for its reconstruction:

1. The preserved text shows high repetition of words and phrases and an identical pattern for presenting the planets' phases and positions, which differ only between inferior and superior planets. The preserved phrase pattern for the superior planets is extremely similar, and any specific word appears at the same distance from the planet's name.
2. The text is an observational record of the motions, phases, and timing of the five planets as seen with the naked eye. A planet's position changes relative to a "constant" reference point. Because the inferior planets are mostly visible at twilight

or dawn, the Sun serves as the reference point. The superior planets are visible at night, so the fixed stars serve as the reference point.

Observational motions of the inferior planets

Through naked-eye observation and long-term record-keeping, one can see that Mercury and Venus move in a periodic left-right oscillation along a nearly straight line. The Sun lies at the midpoint of this line. When these planets are at their maximum distance from the Sun, they stop for a couple of days, then reverse direction, head toward the Sun, pass it, head toward the other side, and when they reach a maximum distance, they stop for a few days and change direction again; see **Figure 2A**.

The time periods of left-right oscillation (from 0 to π and then from π to 2π) are not equal, i.e., the planet's west-to-east motion does not take the same duration as the east-to-west motion: There is a great difference in the motion of an inferior planet when it moves behind the Sun (far from Earth) and when it moves in front of the Sun (closer/approaching Earth): its angular velocity. Therefore, this periodic back-and-forth motion of the planet is not symmetric in duration (days). For example, the time span for Venus from its greatest morning elongation (western to the Sun) to its greatest evening elongation (eastern to the Sun) is around 444 days. The inverted direction (from the evening to the morning station) lasts around 140 days.

Observational motions of the superior planets

The motion of the superior planets is quite different: for a long time, a superior planet travels eastward relative to the stars of the Zodiac, gradually decreasing its angular velocity; then it pauses for some days, changes direction, and moves westward for a number of days; then it pauses again for some days and afterward turns back to the opposite direction, i.e., eastward. At a specific time, the planet meets the Sun (conjunction), and at another time, it is located at the opposite point relative to the Sun (opposition). When the planet returns to the initial phase, an ΑΠΟΚΑΤΑΣΤΑΣΙΣ (restitution in phase) is complete; see **Figure 2B**. Thus, each planet's restitution in phase (synodic cycle) begins from a specific starting point that must be defined.

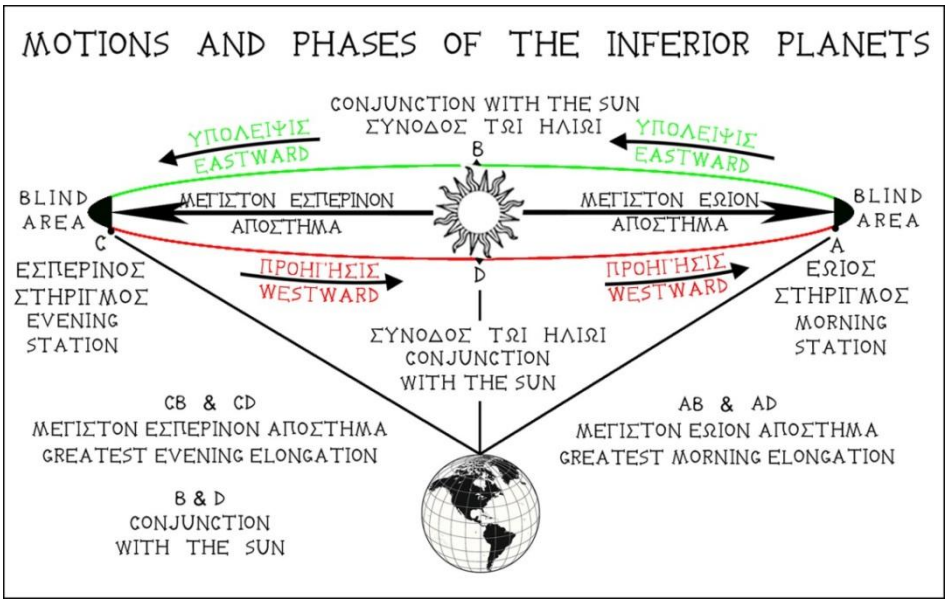


Figure 2A. A visualization of the motion of an inferior planet as observed from Earth. For the planets' directions, motions, and phases, the astronomical terms were drawn from the preserved text on the Front Cover. Stations occur at points A and C (taking into account the blind areas, see **S 6.1**), and conjunctions with the Sun occur at B and D. The right-left direction is eastward motion, and the left-right is westward. The maximum distance of the planet from the Sun (ΜΕΓΙΣΤΟΝ ΑΠΟΣΤΗΜΑ) occurs at the stations.

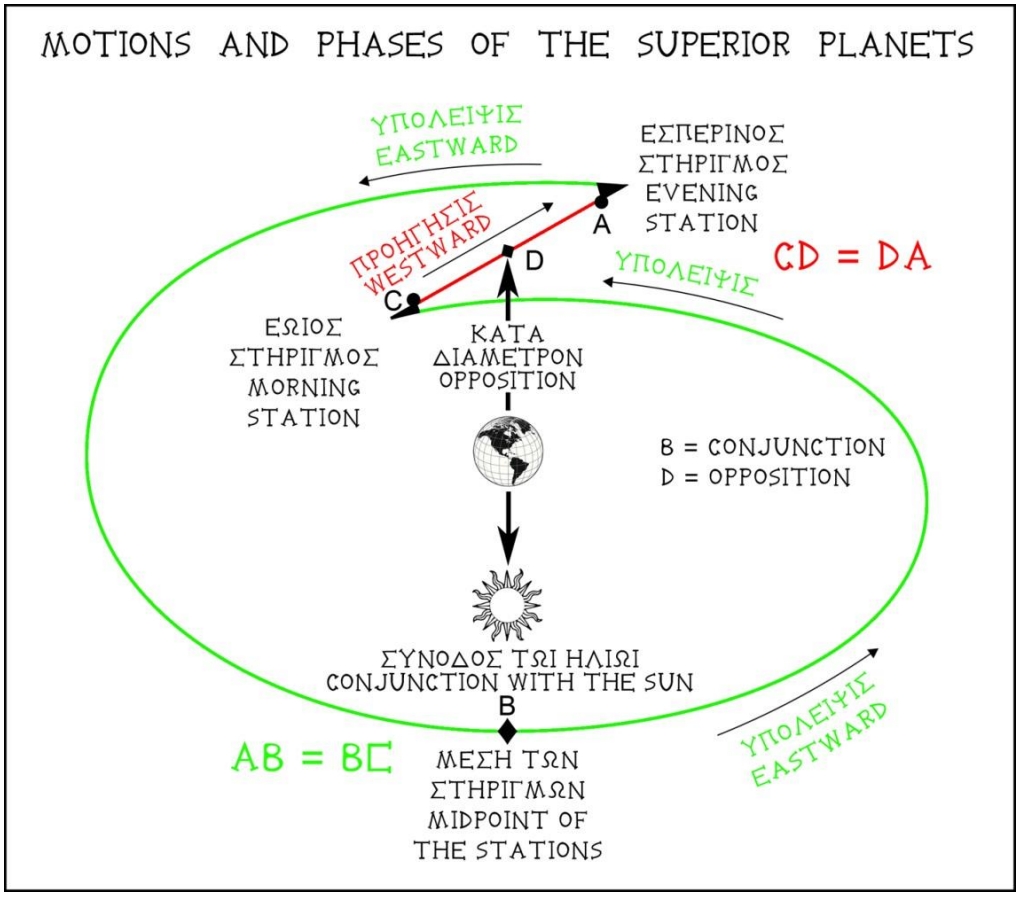


Figure 2B. A visualization of the motion of a superior planet as observed from Earth. For the planet's directions, motions, and phases, the astronomical terms were drawn from the preserved text on the Front Cover. The motion and phases of a superior planet are more complex than those of an inferior planet. One full revolution of the planet (from point A to point A through points B, C, and D) corresponds to one restitution - Apokatastasis. Moreover, in each restitution, retrograde motion repeats in a different shape, starting with the Z-shape, gradually transforming into a loop, and afterward into a straight line (see **Figure S1**). The stations occur at points A and C (the apokatastasis of the superior planets occurs at the evening station - point A). The retrograde motion occurs at night (point C to A), and the conjunction with the Sun occurs only during the day (point B). At the opposite point of point B, point D is located, which is the half retrograde distance. At this point, the planet is in opposition to the Sun. The specific positions of points A and C include the blind areas (see **S 6.1**).

Text reconstruction

Based on the phrase- and planet-phase analyses detailed in the Supplement (**S 3 - S 6**), the reconstructed parts of the text were initially combined into an integrated preliminary text, preserving the adopted left-right positioning (text boundary +5 letters before Line 33) and using a mean of about 83 letters per line (see **S 1 and Table S2**). Prior experience reconstructing the lost Back Cover text (the Instruction Manual of the Antikythera Mechanism, Voulgaris et al. [8,9]) was crucial to this effort.

Results

The final arrangement of the Front Cover plate's reconstructed text

In **Table 1**, we present the full reconstruction of the lost text of the Antikythera Mechanism Front Cover Plate in its original form (continuous writing with capital letters and no spaces between words, except for the ancient Greek numbers). Of the 41 partially preserved lines, 41+9 lines were reconstructed, including the approximately lost text for Mercury, and one introductory line (suggested by the authors) (Anastasiou et al. [6], Blass [12], Papathanassiou [13], Chez [14,15], Manitius [16], Heiberg [17], Toomer [18], Liddell et al. [19]). These 51 lines correspond to about 40% of the (estimated) 125 lines that should be inscribed on the Front Cover Plate (see **Table S15**). The preserved and reconstructed letters (including lost letters of known words) totaled about 1300, and the reconstructed text consists of about 4100 letters.

In **Table 2,** the same text is presented in polytonic form, with comments at the end. The English translation is provided in **Table 3**.

In **Figure 3,** a digital representation of the full text is shown in its original ancient Greek writing style.

Table 1: Reconstruction of the lost text, with the preserved text (in bold red) on the Front Cover of the Antikythera Mechanism

…Ι) ΑΙΕΞΥΠΟΛΕΙΨΕΩΝΚΑΙΠΡΟΗΓΗΣΕΩΝΣΤΑΣΕΙΣΚΑΙΣΥΝΟΔΟΙΤΩΝΠΛΑΝΗΤΩΝΤΩΙΗΛΙΩΙΠΑΡΑΤΙΘΕΝΤΑΙΕΝΘΑΔΕ
ΙΙ) ΟΣΤΙΛΒΩΝΔΙΑΠΟΡΕΥΘΕΙΣΤΟΝΖΩΙΔΙΑΚΟΝΚΥΚΛΟΝΚΑΙΩΣΕΠΙΤΟΥΑΥΤΟΥΖΩΙΔΙΟΥΕΝΔΕΙΣΟΙΣ $\overline{\text{MC}}$L ΑΠΟΚΑ
ΙΙΙ) ΤΑΣΤΑΣΕΙΣ $\overline{\text{PME}}$ ΠΟΙΕΙΦΕΡΕΤΑΙΔΕΠΙΤΗΝΑΥΤΟΥΠΕΡΙΦΕΡΕΙΑΝΕΙΣΚΥΚΛΟΥΣ $\overline{\text{MC}}$ ΕΚΑΣΤΗΝΔΑΠΟΚΑΤΑ
ΙV) ΣΤΑΣΙΝΕΝΗΜΕΡΑΙΣΜΙΚΡΩΙΕΛΑΣΣΟΣΙ $\overline{\text{PIC}}$ ΠΟΙΕΙΑΡΧΕΤΑΙΔΕΤΗΝΥΠΟΛΕΙΨΙΝΑΠΟΤΗΝΕΩΙΑΝΣΤΑΣΙΝΩΣΚΑΙ
V) ΑΠΟΜΕΝΤΗΣΠΡΟΣΤΟΝΗΛΙΟΝΣΥΝΟΔΟΥΥΠΟΛΕΙΠΕΤΑΙΕΝΗΜΕΡΑΙΣ $\overline{\text{MH}}$ ΠΡΟΣΔΕΤΟΕΣΠΕΡΙΝΟΝΜΕΓΙΣΤΟΝΑΠΟ
VΙ) ΣΤΗΜΑΕΝΗΜΕΡΑΙΣ $\overline{\Lambda\Delta}$ ΠΡΟΣΑΓΕΙΔΕΠΡΟΣΤΟΝΗΛΙΟΝΕΞΥΠΟΛΕΙΨΕΩΝΚΑΙΣΥΝΟΔΟΝΠΟΙΕΙΤΑΙΩΣΠΑΡΑΓΙΝΕ
VΙΙ) ΤΑΙΕΠΙΤΟΝΕΣΠΕΡΙΝΟΝΣΤΗΡΙΓΜΟΝΑΠΕΧΩΝΔΑΠΟΤΟΥΗΛΙΟΥΖΩΙΔΙΟΝ $\overline{\text{A}}$ ΜΕΙΝΑΣΔΕΠΙΤΟΜΕΓΙΣΤΟΝΑΠΟΣΤΗ
VΙΙΙ) ΜΑΗΜΕΡΑΙΣ $\overline{\text{E}}$ ΚΑΙΠΑΛΙΠΡΟΣΑΓΕΙΠΡΟΣΤΟΝΗΛΙΟΝΕΚΠΡΟΗΓΗΣΕΩΝΚΑΙΣΥΝΟΔΟΝΠΟΙΕΙΤΑΙΚΑΙΠΑΡΑΓΙΝΕ
ΙΧ) ΤΑΙΕΠΙΤΟΝΕΩΙΟΝΣΤΗΡΙΓΜΟΝΜΕΙΝΑΣΕΠΙΤΟΜΕΓΙΣΤΟΝΑΠΟΣΤΗΜΑΗΜΕΡΑΙΣ $\overline{\text{Z}}$ ΑΠΕΧΩΝΔΑΠΟΤΟΥΗΛΙΟΥΖΩΙΔΙ
Χ) ΟΝ $\overline{\text{IA}}$ ΟΤΑΝΠΑΡΑΓΙΝΕΤΑΙΕΠΙΤΟΝΕΩΙΟΝΣΤΗΡΙΓΜΟΝΩΣΠΡΟΗΓΟΥΜΕΝΟΣΑΠΟΣΤΑΣΔΑΠΟΤΟΥΗΛΙΟΥΜΕ
01) ΙΝΑΣΕΠΙΤΟΜΕΓΙΣΤΟΝΑΠΟΣΤΗΜΑΗΜΕΡΑΙΣ $\overline{\text{H}}$ ΥΠΟΛΕΙ**ΠΟΜΕΝΟΣ**ΕΠΙΤΟΜΕΓΙΣΤΟΝΕΩΙΟΝΑΠΟΣΤΗΜΑΚ
02) ΑΙΠΑΡΑΓΙΝΟΜΕΝΟΣΕΠΙΤΟΥΕΣΠΕΡΙΝΟΥΜΕΓΙΣ**ΤΟΥΑΠΟΣΤΗΜΑΤΟΣ**ΠΡΟΣΑΓΕΙΠΡΟΣΤΟΝΗΛΙΟΝΥΠΟΛΕΙΠΟ
03) ΜΕΝΟΣΚΑΙΠΡΟΣΤΟΝΕΣΠΕΡΙΝΟΝΣΤΗΡΙΓΜ**ΟΝΕΞΑΡΧΗΣΠ**=Ο===ΑΕΠΙΤΕΛΛΕΙ=====ΑΕΣΠΕΡΙΝΗΝΑΠΟΣΤΑΣΙΝΕΩΣΤΗΝΕΩΙΑ
04) ΝΣΤΑΣΙΝΕΝΗΜΕΡΑΙΣ$\overline{\Lambda\Delta}$ΑΠΟΚΑΘΙ**Σ**ΤΑΤΑΙ**ΕΙΣΔΕ**Τ**ΑΕΠΟΜΕΝΑ ΟΔΕΦΩ**ΣΦΟΡΟΣΔΙΑΠΟΡΕΥΘΕΙΣΤΟΝΖΩΙΔΙΑΚΟΝΚΥΚΛΟΝΚΑ
05) ΙΩΣΕΠΙΤΟΥΑΥΤΟΥ**ΖΩΙΔΙΟΥΕΝΔΕΙΣΟΙΣ $\overline{\text{ΥΞΒ}}$L ΑΠΟΚΑΤΑΣΤΑΣ**ΕΙΣ $\overline{\Sigma\Pi\Theta}$ ΠΟΙΕΙΦΕΡΕΤΑΙΕΠΙΤΗΝΑΥΤΟΥΠΕΡΙΦΕΡΕ
06) ΙΑΝΕΙΣΚΥΚΛΟ**ΥΣ $\overline{\text{ΥΞΒ}}$ ΕΚΑΣΤΗΝΔΑΠΟΚΑΤΑΣΤΑΣΙΝΕΝΗΜΕΡΑΙΣ $\overline{\Phi\Pi\Delta}$** ΠΟΙΕΙΑΡΧΕΤΑΙΔΕΤΗΝΥΠΟΛΕΙΨΙΝΑΠΟΤΗΝΕ
07) ΩΙΑΝΣΤΑΣΙ**ΝΩΣΚΑΙΑΠΟΜΕΝ**Τ**ΗΣΠΡΟΣΤΟΝΗΛΙΟΝΣΥΝΟΔΟΥΥΠΟΛΕ**ΙΠΕΤΑΙΕΝΗΜΕΡΑΙΣ $\overline{\Sigma\text{M}\Theta}$ ΠΡΟΣΔΕΤΟΕΣΠΕΡΙΝΟ
08) ΝΜΕΓΙΣΤΟ**ΝΑΠΟΣΤΗΜΑΕΝΗΜΕΡΑΙΣ$\overline{\Sigma\text{K}\Delta}$ΠΡΟΣΑΓΕΙΔΕΠΡΟΣΤΟΝΗΛ**ΙΟΝΕΞΥΠΟΛΕΙΨΕΩΝΚΑΙΣΥΝΟΔΟΝΠΟΙΕ
09) ΙΤΑΙΠΑΡ**ΑΓΙΝΕΤΑΙΕΠΙΤΟΝ**Ε**ΣΠΕΡΙΝΟΝΣΤΗΡΙΓΜΟΝΑΠΕΧΩΝ**Δ**ΑΠΟΤΟ**ΥΗΛΙΟΥΖΩΙΔΙΟΝ $\overline{\text{A}\angle}$ ΜΕΙΝΑΣΕΠΙΤΟΜΕΓΙΣΤΟΝΑΠΟΣΤΗΜ
10) ΑΗΜΕΡΑΙΣ $\overline{\text{KE}}$ ΠΑΛΙΠΡ**ΟΣΑΓΕΙΠΡΟΣΤΟΝΗΛΙΟΝΕΚΠΡΟΗΓΗΣΕΩΝΚΑΙΣΥΝΟΔΟΝ**ΠΟΙΕΙΤΑΙΚΑΙΠΑΡΑΓΙΝΕΤΑΙΕΠΙΤΟ
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12) ΟΝ $\overline{\text{IZ}}$ ΟΤΑΝΠΑΛΙΓΙΝΕΤΑΙΕΠΙΤΟΝΕΩΙΟΝΣΤΗΡΙΓ**ΜΟΝΩΣΠΡΟΗΓΟΥΜΕΝΟΣΑΠΟΣΤΑΣΔΑΠ**ΟΤ**ΟΥΗΛΙΟΥ=Μ**ΕΙΝΑΣΕΠΙΤΟ
13) ΜΕΓΙΣΤΟΝΑΠΟΣΤΗΜΑ**ΗΜΕΡΑΙΣ $\overline{\text{KB}}$ ΥΠΟΛΕΙΠΟΜΕΝΟΣΕΠΙΤΟΜΕΓΙΣΤ**ΟΝΕ**ΩΙΟΝΑΠΟΣΤΗ**ΜΑΚΑΙΠΑΡΑΓΙΝΟΜΕΝΟΣΕΠΙΤ
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15) ΓΜΟΝΕΞΑΡ**ΧΗΣΤ=Σ=Ο==ΑΕΠΙΤΕΛ**ΛΕΙ=====**Α**Ε**ΣΠ**ΕΡΙΝΗΝΔΑ**ΠΟΣΤ**Α=**ΣΙΝ**ΕΩΣΤΗΝΕΩΙΑΝΣΤΑΣΙΝΕΝΗΜΕΡ
16) ΑΙΣΑΠΟΚΑΘΙ**ΣΤΑΤΑΙ**$\overline{\text{PI}}$**ΒΙΩΝΤΑ**ΕΠΟΜΕΝΑ ΟΔΕΠΥΡΟΕΙΣΕΝ $\overline{\Sigma\Pi\Delta}$L ΑΠΟΚΑ**ΤΑΣ**ΤΑΣΕΙΣ $\overline{\text{PΛΓ}}$ ΠΟΙΕΙΔΙΑΠΟΡΕΥΘΕΙ
17) ΣΤΟΝΖΩΙΔΙΑΚΟΝΚΥΚΛΟΝΕ**ΚΑΣΤΗΝΔΑΠΟΚΑΤΑΣΤΑΣΙΝΕΝΗΜΕΡΑΙΣΜΙΚ**ΡΩΙΕΛΑΣΣΟΣΙ $\overline{\Psi\Pi}$ ΠΟΙΕΙΚΑΙΙΩΝΤΑΕΠΟΜΕΝΑ
18) ΜΟΙΡΑΣ $\overline{\text{IΘ}}$ ΚΑΙΔΩΔΕΚΑΤΗΜΟΡΙΟΝ**ΩΣ**ΤΕ**ΑΡΧΕΤΑΙΔΕΤΗΝΥΠΟΛΕΙΨΙΝ==Ν=Μ==ΣΑΠΕΧΩ**ΝΑΠΟΤΟΥΗΛΙΟΥΖΩΙΔΙΟΝ $\overline{\Delta\angle}$ Α
19) ΠΟΤΟΥ**ΕΣΠ**ΕΡΙΝΟΥ**ΣΤΗΡΙΓΜΟΥΚΑΙΥΠΟΛΕΙΠΕΤΑΙΜΕΧΡΙΤΗΣΕΩΙΑΣΣΤΑ**ΣΕΩΣΕΝΗΜΕΡΑΙΣ $\overline{\text{ΧΨΗ}}$ ==========

20) ΕΩΣΕΝΧΡΟΝΩΙΤ**ΑΙΣ ΤΜΘ ΗΜΕΡΑΙΣΣΥΝΟΔΟΝΠΟΙΕΙΤΑΙΤΩΙΗΛΙΩΙΜΕΣΗ**ΙΤΩΝΣΤΗΡΙΓΜΩΝΚΑΙΥΠΟΛΕΙΠΕΤΑΙΕΝΤΑΙΣΑ
21) ΛΛ**ΑΙΣ ΤΜΘ ΕΠΙΤΟΝΕΩΙΟΝΣΤΗΡΙΓΜΟΝΑΠΕΧΩΝΑΠΟΤΟΥΗΛΙΟΥΩΣ**ΑΠΟΣΤΑΣΖΩΙΔΙΟΝ Ζ∠ ΜΕΙΝΑΣΗΜΕΡΑΣ Η ΠΡΟΗΓΕΙΤΑΙ
22) ΗΜΕΡΑΣ **ΠΒΚΑΙΕΠΙΤΗΝΕΣΠΕΡΙΝΗΝΠΑΡΑΓΙΝΕΤΑΙΣΤΑΣΙΝΑΠΕΧΩΝΑΠ**ΟΤΟΥΗΛΙΟΥΖΩΙΔΙΟΝ Δ∠ ΚΑΙΠΑΛΙΜΕΙΝΑΣΕΠ
23) ΙΤΑΣ**ΔΕΗΜΕΡΑΣ Η ΠΑΛΙΝ**ΑΡΧΕΤΑΙ**ΥΠΟΛΕΙΠΕΣΘΑΙΕΝΔΕΤΩ**ΙΕΩΙΩΙΣΤΗΡΙΓΜΩΙΤΗΝ ΜΑ ΗΜΕΡΑΝΓΙΝΕΤΑΙΚΑΤΑΔΙΑΜΕΤΡΟΝ
24) ΚΑΙΕΛΑΧΙΣΤΗΝΘΕΣΙ**ΝΕ**ΣΑΠΟ**ΣΤΑΣΙΝ ΟΔΕΦΑΕΘΩΝΕΝ** ΤΜΔL **ΑΠΟΚΑΤΑΣΤΑΣ**ΕΙΣ ΤΙΕ ΠΟΙΕΙΔΙΑΠΟΡΕΥΘΕΙΣΤΟΝΖΩΙ
25) ΔΙΑΚΟΝΚΥΚΛΟΝ**ΕΚΑΣΤΗΝΔΑΠΟΚΑΤΑΣΤΑΣΙΝΕΝΗΜΕΡΑΙΣΜΙΚΡΩΙΕΛΑΣΣ**ΟΣΙ ΤϟΘ ΠΟΙΕΙΚΑΙΙΩΝΤΑ
26) ΕΠΟΜΕΝΑΜΟΙΡΑΣ Δ **ΚΑΙΔΩΔΕΚΑΤΗΜΟΡΙΟΝΩΣΑΡΧΕΤΑΙΔΕΤΗΝΥΠΟΛΕΙΨΙΝ** ======== ΑΠΕΧΩΝΑΠΟΤ
27) ΟΥΗΛΙΟΥΖΩΙ**ΔΙΟΝ** Δ **ΑΠΟΤΟΥΕΣΠΕΡΙΝΟΥΣΤΗΡΙΓΜΟΥΚΑΙΥΠΟΛΕΙΠ**ΕΤΑΙΜΕΧΡΙΤΗΣΕΩΙΑΣΣΤΑΣΕΩΣΕΝΗΜ
28) ΕΡΑΙΣ ΣΟΗ ======**ΕΤΩΝΕΩΣΕΝΧΡΟΝΩΙΤΑΙΣ ΡΛΘ ΗΜΕΡΑΙΣΣΥΝΟΔ**ΟΝΠΟΙΕΙΤΑΙΤΩΙΗΛΙΩΙΜΕΣΗΙΤΩΝΣΤΗΡΙΓΜΩΝΥΠ
29) ΟΛΕΙΠΕΤΑΙΕΝ**ΤΑΙΣΑΛΛΑΙΣ ΡΛΘ ΕΠΙΤΟΝΕΩΙΟΝΣΤΗΡΙΓΜΟΝΑΠΕΧ**ΩΝΑΠΟΤΟΥΗΛΙΟΥΩΣΑΠΟΣΤΑΣ
30) ΖΩΙΔΙΟΝ Η ΚΑΙ**ΜΕΙΝΑΣΗΜΕΡΑΣ Η ΠΡΟΗΓΕΙΤΑΙΗΜΕΡΑΣ** ΡΚΑ ΚΑΙΕΠΙΤΗΝΕΣΠΕΡΙΝΗΝΠΑΡΑΓΙΝΕΤΑΙΣΤΑΣΙΝΑΠΕΧ
31) ΩΝΑΠΟΤΟΥΗΛΙΟΥΖΩΙΔΙΟΝ Δ **ΚΑΙΠΑΛΙΜΕΙΝΑΣΤΑΣ Η ΗΜΕΡΑΣΠΑΛΙΝΑΡ**ΧΕΤΑΙΥΠΟΛΕΙΠΕΣΘΑΙΕΝΔΕΤΩΙΕΩΙΩΙΣΤΗΡ
32) ΙΓΜΩΙ**ΤΗΝ ΞΑ ΗΜΕΡΑΝΓΙΝΕΤΑΙΚΑΤΑΔΙΑΜΕΤΡΟΝ**ΚΑΙΕΛΑΧΙΣΤΗΝΘΕΣΙΝΕΣΑΠΟΣΤΑΣΙΝ ΟΔΕΦΑΙΝΩΝ ΥΚΖ
33) ΑΠΟΚΑ**ΤΑΣΤΑΣΕΙΣΕΝ**ΔΕΙΣΟΙΣ **ΥΜΒ**L **ΔΙΑΠΟΡΕΥΘΕΙΣΤΟΝ**ΖΩΙΔΙΑΚΟΝΚΥΚΛΟΝΠΟΙΕΙΕΚΑΣΤΗΝ
34) ΔΑΠΟΚ**ΑΤΑΣΤΑΣΙΝΕΝ**ΗΜΕΡΑΙΣΜΙΚΡΩΙΜΕΙΖΟΣΙ ΤΟΗ ΠΟΙΕΙΚΑΙΙΩΝΤΑΕΠΟΜΕΝΑΜΟΙΡΑΣ ΙΓ ΩΣΑΡΧ
35) ΕΤΑΙΔΕΤΗ**ΝΥΠΟΛΕΙΨΙΝΠ**======= ΑΠΕΧΩΝΑΠΟ**ΤΟΥ**ΗΛΙΟΥΖΩΙΔΙΟΝ Γ∠ ΑΠΟΔΕΤΟΥΕΣΠΕΡΙΝΟΥΣΤΗΡΙΓΜΟΥΚΑ
36) ΙΥΠΟΛΕ**ΙΠΕΤΑΙΜΕΧΡ**ΙΤΗΣΕΩΙΑΣΣΤΑΣΕΩΣΕΝΗΜΕΡΑΙΣ ΣΜΕ ========== ΕΩΣΕΝΧΡΟΝΩΙΤΑΙΣ ΡΚΒ
37) ΗΜΕΡΑΙΣ**ΣΥ**Ν**Ο****ΔΟΝΠΟΙΕΙΤ**ΑΙΤΩΙΗΛΙΩΙΜΕΣΗΙΤΩΝΣΤΗΡΙΓΜΩΝΥΠΟΛΕΙΠΕΤΑΙΕΝΤΑΙΣΑΛΛΑΙΣ ΡΚΒ ΕΠΙΤΟΝΕΩΙ
38) ΟΝΣΤ**ΗΡΙΓΜΟΝΑΠ**ΕΧ**Ω**ΝΔΑΠΟΤΟΥΗΛΙΟΥΩΣΑΠΟΣΤΑΣΖΩΙΔΙΟΝ Η∠ ΜΕΙΝΑΣΗΜΕΡΑΣ Η ΠΡΟΗΓΕ
39) ΙΤΑΙΔΕ**ΗΜΕΡΑΣ** ΡΛΔ ΚΑΙΕΠΙΤΗΝΕΣΠΕΡΙΝΗΝΠΑΡΑΓΙΝΕΤΑΙΣΤΑΣΙΝΑΠΕΧΩΝΑΠΟΤΟΥΗΛΙΟΥΖΩΙΔΙΟΝ Γ∠ ΚΑ
40) ΙΠΑΛΙΜΕ**ΙΝΑΣ**ΤΑΣ Η ΗΜΕΡΑΣΠΑΛΙΝΑΡΧΕΤΑΙΥΠΟΛΕΙΠΕΣΘΑΙΕΝΔΕΤΩΙΕΩΙΩΙΣΤΗΡΙΓΜΩΙΤΗΝ ΞΖ ΗΜΕΡΑΝΓ
41) ΙΝΕΤΑΙ**ΚΑΤΑΔΙΑΜ**ΕΤΡΟΝΚΑΙΕΛΑΧΙΣΤΗΝΘΕΣΙΝΕΣΑΠΟΣΤΑΣΙΝ ……..
42) =====Α**ΠΟΣΤ**ΑΣΙΝ ……
…) ……

Table 2: Reconstruction of the Front Cover text in polytonic ancient Greek. The corresponding line number is shown in parentheses.

Αἱ ἐξ ὑπολείψεων καὶ προηγήσεων στάσεις καὶ σύνοδοι τῶν πλανητῶν τῷ ἡλίῳ παρατίθενται ἐνθάδε. (II) Ὁ **Στίλβων**, διαπορευθεὶς τὸν ζῳδιακὸν κύκλον καὶ ὡς ἐπὶ τοῦ αὐτοῦ ζῳδίου, ἐν δὲ ἴσοις ΜζL ἀποκα(III)ταστάσεις ΡΜΕ ποιεῖ. Φέρεται δ’ ἐπὶ τὴν αὐτοῦ περιφέρειαν εἰς κύκλους Μζ, ἑκάστην δ’ ἀποκατά(IV)στασιν ἐν ἡμέραις μικρῷ ἐλάσσοσι ΡΙζ ποιεῖ. Ἄρχεται δὲ τὴν ὑπόλειψιν ἀπὸ τὴν ἑῴαν στάσιν, ὡς καὶ (V) ἀπὸ μὲν τῆς πρὸς τὸν ἥλιον συνόδου ὑπολείπεται ἐν ἡμέραις ΜΗ, πρὸς δὲ τὸ ἑσπερινὸν μέγιστον ἀπό(VI)στημα ἐν ἡμέραις ΛΔ. Προσάγει δὲ πρὸς τὸν ἥλιον ἐξ ὑπολείψεων καὶ σύνοδον ποιεῖται. Ὡς παραγίνε(VII)ται ἐπὶ τὸν ἑσπερινὸν στηριγμόν, ἀπέχων δ’ ἀπὸ τοῦ ἡλίου ζῴδιον Α, μείνας δ’ ἐπὶ τὸ μέγιστον ἀπόστη(VIII)μα ἡμέραις Ε, καὶ πάλι προσάγει πρὸς τὸν ἥλιον ἐκ προηγήσεων καὶ σύνοδον ποιεῖται. Καὶ παραγίνε(IX)ται ἐπὶ τὸν ἐῷον στηριγμόν, μείνας ἐπὶ τὸ μέγιστον ἀπόστημα ἡμέραις Ζ, ἀπέχων δ’ ἀπὸ τοῦ ἡλίου ζῴδι(X)ον ΙΑ. Ὅταν πάλι παραγίνεται ἐπὶ τὸν ἐῷον στηριγμὸν ὡς προηγούμενος, ἀποστὰς δ’ ἀπὸ τοῦ ἡλίου, με(01)ίνας ἐπὶ τὸ μέγιστον ἀπόστημα ἡμέραις Η ὑπολειπόμενος ἐπὶ τὸ μέγιστον ἐῷον ἀπόστημα, κ(02)αὶ παραγινόμενος ἐπὶ τοῦ ἑσπερινοῦ μεγίστου ἀποστήματος, προσάγει πρὸς τὸν ἥλιον ὑπολειπό(03)μενος καὶ πρὸς τὸν ἑσπερινὸν στηριγμὸν ἐξ ἀρχῆς. Π=Ο===Α ἐπιτέλλει =====Α ἑσπερινὴν ἀπόστασιν ἕως τὴν ἑῴα(04)ν στάσιν ἐν ἡμέραις ΛΔ, ἀποκαθίσταται εἰς δὲ τὰ ἑπόμενα. Ὁ δὲ **Φωσφόρος**, διαπορευθεὶς τὸν ζῳδιακὸν κύκλον κα(05)ὶ ὡς ἐπὶ τοῦ αὐτοῦ ζῳδίου ἐν δὲ ἴσοις ΥΞBL ἀποκαταστάσεις ΣΠΘ ποιεῖ. Φέρεται ἐπὶ τὴν αὐτοῦ περιφέρε(06)ιαν εἰς κύκλους ΥΞΒ, ἑκάστην δ’ ἀποκατάστασιν ἐν ἡμέραις ΦΠΔ ποιεῖ. Ἄρχεται δὲ τὴν ὑπόλειψιν ἀπὸ τὴν ἑ(07)ῴαν στάσιν, ὡς καὶ ἀπὸ μὲν τῆς πρὸς τὸν ἥλιον συνόδου ὑπολείπεται ἐν ἡμέραις ΣΜΘ, πρὸς δὲ τὸ ἑσπερινὸ(08)ν μέγιστον ἀπόστημα ἐν ἡμέραις ΣΚΔ. Προσάγει δὲ πρὸς τὸν ἥλιον ἐξ ὑπολείψεων καὶ σύνοδον ποιε(09)ῖται. Παραγίνεται ἐπὶ τὸν ἑσπερινὸν στηριγμόν, ἀπέχων δ’ ἀπὸ τοῦ ἡλίου ζῴδιον Α∠, μείνας ἐπὶ τὸ μέγιστον ἀπόστημ(10)α ἡμέραις ΚΕ, πάλι προσάγει πρὸς τὸν ἥλιον ἐκ προηγήσεων καὶ σύνοδον ποιεῖται. Καὶ παραγίνεται ἐπὶ τὸ(11)ν ἐῷον στηριγμόν, μείνας ἐπὶ τὸ μέγιστον ἀπόστημα ἐν ἄλλαις ἡμέραις ΚΕ, ἀπέχων δ’ ἀπὸ τοῦ

ἡλίου ζῴδι(12)ον Ι∠. Ὅταν πάλι παραγίνεται ἐπὶ τὸν ἐῷον στηριγμὸν ὡς προηγούμενος, ἀποστὰς δ’ ἀπὸ τοῦ ἡλίου=, μείνας ἐπὶ τὸ (13) μέγιστον ἀπόστημα ἡμέραις ΚΒ ὑπολειπόμενος ἐπὶ τὸ μέγιστον ἐῷον ἀπόστημα, καὶ παραγινόμενος ἐπὶ τ(14)οῦ ἑσπερινοῦ μεγίστου ἀποστήματος, προσάγει πρὸς τὸν ἥλιον ὑπολειπόμενος καὶ πρὸς τὸν ἑσπερινὸν στηρι(15)γμὸν ἐξ ἀρχῆς. Τ=Σ=Ο==Α ἐπιτέλλει =====Α ἑσπερινὴν δ’ ἀπόστα=σιν ἕως τὴν ἑῴαν στάσιν ἐν ἡμέρ(16)αις ἀποκαθίσταται ΡΙΒ ἰὼν τὰ ἑπόμενα. Ὁ δὲ **Πυρόεις**, ἐν ΣΠΔL, ἀποκαταστάσεις ΡΛΓ ποιεῖ, διαπορευθεὶ(17)ς τὸν ζῳδιακὸν κύκλον. Ἑκάστην δ’ ἀποκατάστασιν ἐν ἡμέραις μικρῷ ἐλάσσοσι ΨΠ ποιεῖ, καὶ ἰὼν τὰ ἑπόμενα, (18) μοίρας ΙΘ καὶ δωδεκατημόριον. Ὥστε ἄρχεται δὲ τὴν ὑπόλειψιν ==Ν=Μ==Σ ἀπέχων ἀπὸ τοῦ ἡλίου ζῴδιον Δ∠ ἀ(19)πὸ τοῦ ἑσπερινοῦ στηριγμοῦ, καὶ ὑπολείπεται μέχρι τῆς ἑῴας στάσεως ἐν ἡμέραις ΧϟΗ ========= (ἐτῶν) (20) ἕως ἐν χρόνῳ ταῖς ΤΜΘ ἡμέραις σύνοδον ποιεῖται τῷ ἡλίῳ μέσῃ τῶν στηριγμῶν. Καὶ ὑπολείπεται ἐν ταῖς ἄ(21)λλαις ΤΜΘ ἐπὶ τὸν ἐῷον στηριγμόν, ἀπέχων ἀπὸ τοῦ ἡλίου ὡς ἀποστὰς ζῴδιον Ζ∠, μείνας ἡμέρας Η, προηγεῖται (22) ἡμέρας ΠΒ καὶ ἐπὶ τὴν ἑσπερινὴν παραγίνεται στάσιν ἀπέχων ἀπὸ τοῦ ἡλίου ζῴδιον Δ∠. Καὶ πάλι μείνας ἐπ(23)ὶ τάσδε ἡμέρας Η, πάλιν ἄρχετ(αι) ὑπολείπεσθαι. Ἐν δὲ τῷ ἑῴῳ στηριγμῷ, τὴν ΜΑ ἡμέραν γίνεται κατὰ διάμετρον (24) καὶ ἐλαχίστην θέσιν ἐς ἀπόστασιν. Ὁ δὲ **Φαέθων**, ἐν ΤΜΔL, ἀποκαταστάσεις ΤΙΕ ποιεῖ, διαπορευθεὶς τὸν ζῳ(25)διακὸν κύκλον. Ἑκάστην δ’ ἀποκατάστασιν ἐν ἡμέραις μικρῷ ἐλάσσοσι ΤϟΘ ποιεῖ, καὶ ἰὼν τὰ (26) ἑπόμενα μοίρας Δ καὶ δωδεκατημόριον. Ὡς ἄρχεται δὲ τὴν ὑπόλειψιν ========, ἀπέχων ἀπὸ τ(27)οῦ ἡλίου ζῴδιον Δ ἀπὸ τοῦ ἑσπερινοῦ στηριγμοῦ, καὶ ὑπολείπεται μέχρι τῆς ἑῴας στάσεως ἐν ἡμ(28)έραις ΣΟΗ ====== (ἐτῶν) ἕως ἐν χρόνῳ ταῖς ΡΛΘ ἡμέραις σύνοδον ποιεῖται τῷ ἡλίῳ μέσῃ τῶν στηριγμῶν. Ὑπ(29)ολείπεται ἐν ταῖς ἄλλαις ΡΛΘ ἐπὶ τὸν ἐῷον στηριγμόν, ἀπέχων ἀπὸ τοῦ ἡλίου ὡς ἀποστάς (30) ζῴδιον Η, καὶ μείνας ἡμέρας Η, προηγεῖται ἡμέρας ΡΚΑ, καὶ ἐπὶ τὴν ἑσπερινὴν παραγίνεται στάσιν, ἀπέχ(31)ων ἀπὸ τοῦ ἡλίου ζῴδιον Δ. Καὶ πάλι μείνας τὰς Η ἡμέρας, πάλιν ἄρχεται ὑπολείπεσθαι. Ἐν δὲ τῷ ἑῴῳ στηρ(32)ιγμῷ, τὴν ΞΑ ἡμέραν γίνεται κατὰ διάμετρον καὶ ἐλαχίστην θέσιν ἐς ἀπόστασιν. Ὁ δὲ **Φαίνων**, ΥΚΖ (33) ἀποκαταστάσεις ἐν δὲ ἴσοις ΥΜΒL, διαπορευθεὶς τὸν ζῳδιακὸν κύκλον, ποιεῖ. Ἑκάστην (34) δ’ ἀποκατάστασιν ἐν ἡμέραις μικρῷ μείζοσι ΤΟΗ ποιεῖ, καὶ ἰὼν τὰ ἑπόμενα, μοίρας ΙΓ. Ὡς ἄρχ(35)εται δὲ τὴν ὑπόλειψιν ======== ἀπέχων ἀπὸ τοῦ ἡλίου ζῴδιον Γ∠, ἀπὸ δὲ τοῦ ἑσπερινοῦ στηριγμοῦ, κα(36)ὶ ὑπολείπεται μέχρι τῆς ἑῴας στάσεως ἐν ἡμέραις ΣΜΕ ==========(ἐτῶν) ἕως ἐν χρόνῳ ταῖς ΡΚΒ (37) ἡμέραις σύνοδον ποιεῖται τῷ ἡλίῳ μέσῃ τῶν στηριγμῶν. Ὑπολείπεται ἐν ταῖς ἄλλαις ΡΚΒ ἐπὶ τὸν ἐῷ(38)ον στηριγμόν, ἀπέχων δ’ ἀπὸ τοῦ ἡλίου ὡς ἀποστὰς ζῴδιον Η∠, μείνας ἡμέρας Η, προηγε(39)ῖται δὲ ἡμέρας ΡΛΔ, καὶ ἐπὶ τὴν ἑσπερινὴν παραγίνεται στάσιν, ἀπέχων ἀπὸ τοῦ ἡλίου ζῴδιον Γ∠. Κα(40)ὶ πάλι μείνας τὰς Η ἡμέρας, πάλιν ἄρχεται ὑπολείπεσθαι. Ἐν δὲ τῷ ἑῴῳ στηριγμῷ, τὴν ΞΖ ἡμέραν γ(41)ίνεται κατὰ διάμετρον καὶ ἐλαχίστην θέσιν ἐς ἀπόστασιν ========== (42) =====ἀπόστασιν ======…

Comments/corrections

Line 2/3: (ΠΡΟΣΑΓΕΙ ΠΡΟΣ ΤΟΝ ΗΛΙΟΝ ΥΠΟΛΕΙΠΟΜΕΝΟΣ) ΚΑΙ ΠΡΟΣ ΤΟΝ ΕΣΠΕΡΙΝΟΝ ΣΤΗΡΙΓΜ**ΟΝ** the terms ΠΡΟΣΑΓΕΙ and ΥΠΟΛΕΙΠΟΜΕΝΟΣ are implied for the phrase ΚΑΙ ΠΡΟΣ ΤΟΝ ΕΣΠΕΡΙΝΟΝ ΣΤΗΡΙΓΜ**ΟΝ**

Line 7: …Ν Α<u>Σ</u> ΚΑΙ ΑΠΟ ΜΕΝ corrected into ΕΩΙΑΝ ΣΤΑΣ**Ι<u>Ν</u> <u>Ω</u>Σ ΚΑΙ**

Line 10: ΚΑΙ ΣΥΝΟΔΟΝ <u>Α . Ω</u> corrected into **ΚΑΙ ΣΥΝΟΔΟΝ** ΠΟΙΕΙΤΑΙ

Line 13: ΗΜΕΡΑΙΣ <u>ΜΘ</u> corrected into **ΗΜΕΡΑΙΣ <u>ΚΒ</u>**

Line 16: ΑΠΟΚΑΘΙ**ΣΤΑΤΑΙ** Σ **. Β ΙΩΝ ΤΑ** corrected into ΑΠΟΚΑΘΙ**ΣΤΑΤΑΙ** Ρ**<u>Β</u> ΙΩΝ ΤΑ**

Line 20: ΤΩΙ ΗΛΙΩΙ Μ<u>Α</u>ΣΗ… corrected into **ΤΩΙ ΗΛΙΩΙ Μ<u>Ε</u>ΣΗ**Ι ΤΩΝ ΣΤΗΡΙΓΜΩΝ

Line 23: ΕΝ ΔΕ ΤΩ . . . <u>Α</u> . . . letter A corrected into I: **ΕΝ ΔΕ ΤΩ**Ι ΕΩ**<u>Ι</u>**ΩΙ

Line 27: ΖΩΙ**ΔΙΟΝ . <u>Ζ</u>** corrected into ΖΩΙ**ΔΙΟΝ** <u>Δ</u>

Line 32: Τ<u>Ω</u>Ν <u>ΡΔ</u> ΗΜΕΡΑΝ corrected into **Τ<u>Η</u>Ν <u>ΞΑ</u> ΗΜΕΡΑΝ**

Line 33: ΑΠΟΚΑ**ΤΑΣΤΑΣΕΙΣ ΕΝ Μ[…] ..[.] ΥΜΒ** corrected into ΑΠΟΚΑ**ΤΑΣΤΑΣΕΙΣ ΕΝ** ΔΕ ΙΣΟΙΣ **ΥΜΒ,** since in Line 5 **ΕΝ ΔΕ ΙΣΟΙΣ ΥΞΒL ΑΠΟΚΑΤΑΣΤΑΣΕΙΣ** is preserved.

Line 35: ……..**Τ<u>Ο</u>Ν** corrected into ΑΠΕΧΩΝ ΑΠΟ **Τ<u>Ο</u>Υ** ΗΛΙΟΥ

Table 3: English translation of the Front Cover's reconstructed text. For the reader's convenience, we have organized the sentences into self-contained units without interruption.

The stations and conjunctions of the planets with the Sun, through eastward (regressions) and westward (advances) motions, are listed here. **Mercury**, having traveled the Zodiac circle and returned to the same Zodiac sign in 46 equal years, completes 145 restitutions. It travels along its circumference, making 46 cycles, and it completes each restitution in a little less than 116 days. It begins the eastward motion from the morning station and moves eastward for 46 days to the conjunction with the Sun, and for 34 days to the greatest evening elongation. Moving eastward, it approaches the Sun and comes into conjunction. When it arrives at the evening station, distant by 1 Zodiac sign from the Sun, and having stayed (there) for 5 days at the greatest (evening) elongation, it again approaches the Sun through westward movement and comes into conjunction. And it arrives at the morning station, having stayed at the greatest (morning) elongation for 7 days, and is distant by 11 Zodiac signs from the Sun. When it again arrives at the morning station, moving westward and distant from the Sun, it stays at the greatest (morning) elongation for 8 days. Then, moving eastward from the greatest morning elongation and arriving at the greatest evening elongation, it moves eastward toward the Sun and to the evening station from the beginning. Π=O===A rises =====A … (traveling) the evening elongation to the morning station in 34 days, and it restitutes in the following Zodiac signs. **Venus**, having traveled the Zodiac circle and returned to the same Zodiac sign in 462 equal years, completes 289 restitutions. It travels along its circumference, making 462 cycles, and completes each restitution in a little less than 584 days. It begins the eastward motion from the morning station and moves eastward for 249 days to the conjunction with the Sun, and for 224 days to the greatest evening elongation. Moving eastward, it approaches the Sun and comes into conjunction. It arrives at the evening station, distant by 1 ½ Zodiac signs from the Sun, and after having stayed for 25 days at the greatest (evening) elongation, it again approaches the Sun through westward movement and comes into conjunction. And it arrives at the morning station, stays at the greatest (morning) elongation for another 25 days, and is distant by 10 ½ Zodiac signs from the Sun. When it again arrives at the morning station moving westward and is distant from the Sun, it stays at the greatest (morning) elongation for 22 days. Then, moving eastward from the greatest morning elongation and arriving at the greatest evening elongation, it moves eastward toward the Sun and to the evening station from the beginning. T=Σ=O==A rises =====A (travelling) the evening elongation to the morning station in 112 days, and it restitutes in the following Zodiac signs. **Mars**, having traveled along the Zodiac circle in 284 years, completes 133 restitutions. It completes each restitution in a little less than 780 days and moves eastward by 19 degrees and one Zodiac sign. Therefore, it begins the eastward motion ==N=M==Σ from the evening station, distant by 4 ½ Zodiac signs from the Sun, and (then) moves eastward to the morning station in 698 days =========, until, in the course of 349 days, it comes into conjunction with the Sun at the midpoint of the stations. And it moves eastward for another 349 days toward the morning station, distant by 7 ½ Zodiac signs from the Sun; it stays (there) for 8 days, (then) moves westward for 82 days and arrives at the evening station, distant by 4 ½ Zodiac signs from the Sun. After again staying (there) for these 8 days, it begins moving eastward again (toward the morning station). On the 41st day after the morning station, it reaches opposition and is at (its) minimum distance. **Jupiter**, having traveled along the Zodiac circle in 344 years, completes 315 restitutions. It completes each restitution in a little less than 399 days and moves eastward by 4 degrees and one Zodiac sign. As it begins the eastward motion ……, from the evening station, distant by 4 Zodiac signs from the Sun, it (then) moves eastward to the morning station in 278 days ========= (years?) until, in the course of 139 days, it comes into conjunction with the Sun at the midpoint of the stations. It moves eastward for another 139 days toward the morning station, distant by 8 Zodiac signs from the Sun; it stays (there) for 8 days, (then) moves westward for 121 days and arrives at the evening station, distant by 4 Zodiac signs from the Sun. After again staying (there) for 8 days, it begins moving eastward again (toward the morning station). On the 61st day after the morning station, it reaches opposition and is at (its) minimum distance. **Saturn**, having traveled along the Zodiac circle, completes 427 restitutions in 442 equal years. It completes each restitution in a little more than 378 days and moves eastward by 13 degrees. As it begins the eastward motion Π======= from the evening station, distant by 3 ½ Zodiac signs from the Sun, it (then) moves eastward to the morning station in 245 days ========== until, in the course of 122 days, it comes into conjunction with the Sun at the midpoint of the stations. It moves eastward for another 122 days toward the morning station, distant by 8 ½ Zodiac signs from the Sun; it stays (there) for 8 days, (then) moves westward for 134 days and arrives at the evening station, distant by 3 ½ signs from the Sun. After again staying (there) for 8 days,

it begins moving eastward again (toward the morning station). On the 67th day after the morning station, it reaches opposition and is at (its) minimum distance.
===== distance ======

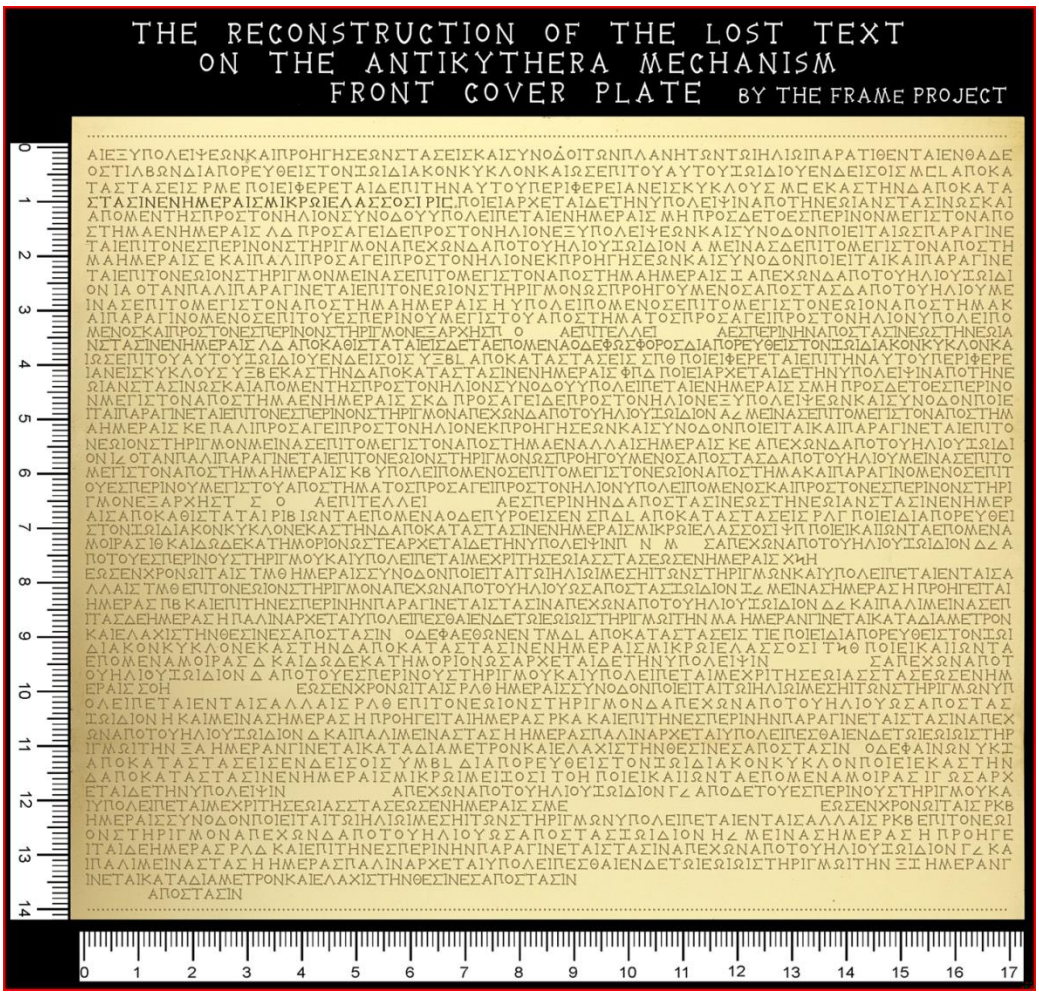


Figure 3: A realistic digital representation of the reconstructed text of the Front Cover Inscription of the Antikythera Mechanism. It contains 51 reconstructed lines, including 9 lines of nearly lost text for Mercury and one informative line that (should) introduce the reader to the following text. Ancient Greek words are written in capitals and without spaces, except when Greek letters are used for numbers, in which case a half-letter gap is added before and after the Greek numbers. Design, construction, and image by *The FRAMe Project* team.

Could the Mechanism predict the positions of the five planets using only the Front Cover text, without any additional complex mechanical systems?

The Antikythera Mechanism was a geared time-calculating device primarily based on the lunar synodic cycle and, in two cases, on the solar tropical year. This conclusion is supported by the units on its scales, which are time units (rather than degrees/position; see Table X in Voulgaris et al. [3])**.** Also, the Front Cover inscribed text provides detailed information about the motion and phases of each planet in days - units of time, e.g., *X-restitutions in Y-years*; or *it moves eastward for -Z- days*. A general, rough measurement in degrees or as a fraction of a Zodiac sign is also provided to indicate the angular distance of a planet from the Sun.

The informative text on the Front Cover of the Mechanism, entirely independent of and unrelated to the Mechanism, can be used to predict the planets' positions in the Zodiac,

thereby enabling the user to perform simple calculations. Reconstructing the lost text on the Front Cover provides an additional function on the Antikythera Mechanism (also in units of time), in which the user undertakes the largest percentage of calculations compared to the Mechanism, although the timed positions of the Sun and the Moon are calculated exclusively by the device.

Actually, by reading the Front Cover plate text, the user of the Antikythera Mechanism can calculate the position and phase of each planet at any time by using only the position of the **ΗΛΙΟΥ ΑΚΤΙΝ** pointer of the Golden sphere-Sun (Voulgaris et al. [3,20]). This procedure could be very easy to apply to the Antikythera Mechanism, without the need to construct any additional mechanical parts, such as a complex design involving a large number of gears, axles, plates, eccentric discs, bars, etc. This new operation opens new horizons for the Antikythera Mechanism's functionality and the additional information and calculations it can offer.

The Golden Sphere-Sun plays a significant role in determining the planet's phases and positions on the Zodiac Dial ring. Each planet's phase is directly related to the position of the Golden Sphere-Sun, and the position of the Golden Sphere defines the position of a planet on the Zodiac. The representation of the planets' motion, since their orbits are projected onto the Zodiac ring of the Antikythera Mechanism, is shown in **Figure 4** (the inferior planet Mercury) and in **Figure 5** (the superior planet Jupiter).

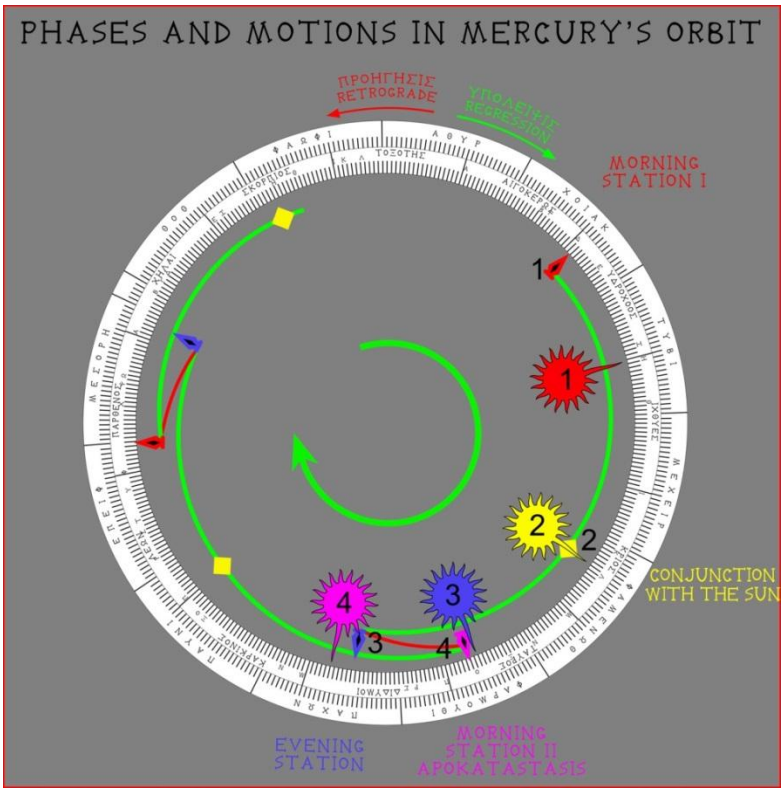


Figure 4: A graphic representation of Mercury's phases over time, shown by the position of the Golden Sphere-Sun along its path on the Zodiac Dial ring. Each Mercury phase corresponds to the position of the Golden Sphere-Sun, indicated by matching colors and numbers. For example, Mercury's initial position at morning station I (number 1, red) occurs when the Golden Sphere (in red) points to the 2nd degree of Aquarius. The conjunction with the Sun (number 2, yellow) occurs at the zodiac point where the Golden Sphere's pointer aims, i.e., at approximately the 20th degree of Aries. The planet then returns from the evening station to morning station II, moving westward (numbers 3 and 4). This return is quite short.

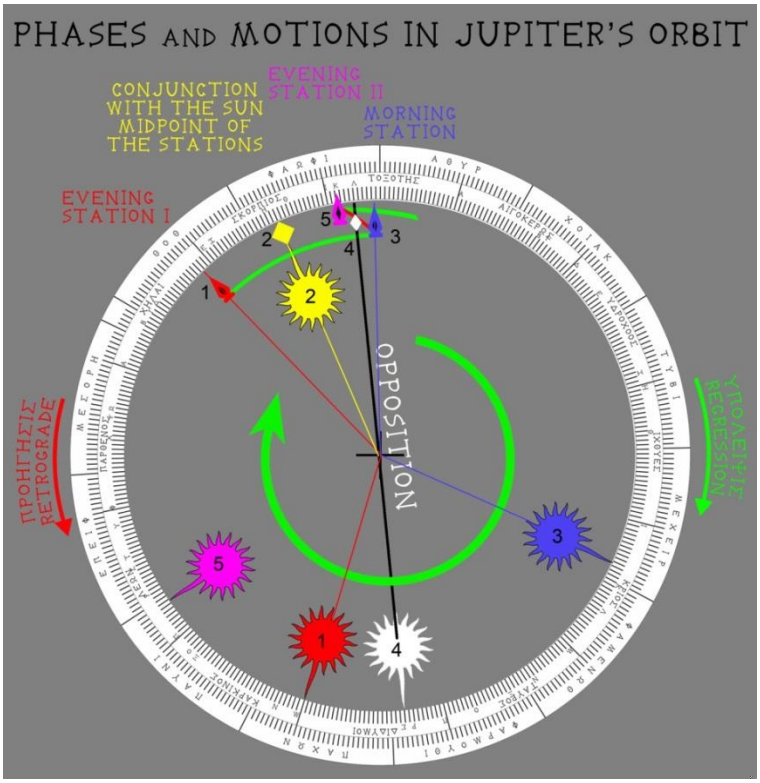


Figure 5: A graphic representation of Jupiter's phases over time, shown by the position of the Golden Sphere-Sun along its path on the Zodiac Dial ring. Each Jupiter phase corresponds to the position of the Golden Sphere-Sun, indicated by the same colors and numbers. For example, Jupiter's initial position at evening station I (number 1, red) occurs when the Golden Sphere (in red) points to the 1st day of Cancer. The planet's opposition (number 4, white) occurs when the Golden Sphere is in an antidiametrical position on the 10th day of Gemini. Between numbers 3 and 5, Jupiter's retrograde (in red) motion occurs.

The text on the Front Cover plate served as the Antikythera Mechanism's Geocentric Ephemeris for its user, providing additional information and theory for the rest of the Mechanism's procedures, which are today missing (Voulgaris et al. [3,20], Bitsakis and Jones [21], Anastasiou et al. [22], Freeth [23] (see **S 7** and **Table S15**). When combined with a reconstruction model of the Antikythera Mechanism, the Front Cover text, updated with modern dates for the planets' apokatastasis, can be used to calculate the planets' positions (see **Figure 6)**.

Who is the Constructor of the Mechanism?

Given the current reconstruction, this *bronze book of the ancient world* included all the time information, Astronomy, and naked-eye observations, which were collected many centuries before 180 BC. This incredible time-measuring device − the Antikythera Mechanism − should have been created by two people: the Instruction Manual of the Mechanism (Back Cover Inscription) preserves the phrase (Line 4): **ΥΠΟ ΔΕ ΤΟΝ ΤΩ**Ι… – *Under the guidance of …X-name*: i.e., it was created by *Y-name/person* under the guidance of *X-name/person*; a highly educated (unknown) Astronomer of that era had the data, the numerical information, and the idea of the mechanical simulation of the sky, and he cooperated with a highly experienced (unknown) Craftsman to "include" all known information about the sky and

time into a wooden box. A second option could be cooperation between a "teacher" and his "student": *Student-X constructed this device under the supervision of Engineer-Y*.

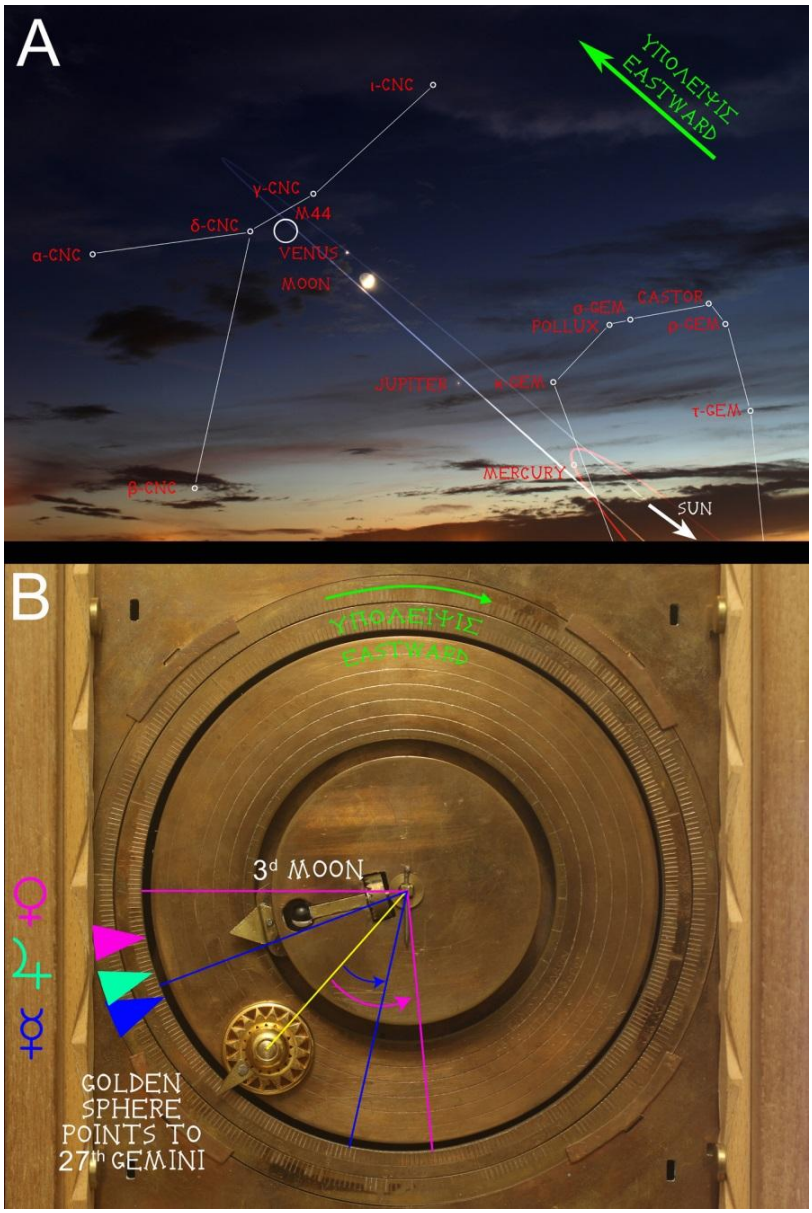


Figure 6. Panel A: Planets in the sky and the Antikythera Mechanism in modern times. This wide-angle photograph (Panel A) was taken on 17th June 2026 (4 days before the Summer Solstice on the 21st June, 1st Gemini), about 45 minutes after sunset. The photo was captured by the first author from Thessaloniki, northern Greece (Lat. 40.5°), and shows the Moon, Mercury, Jupiter, Venus, and several stars in the constellations Gemini and Cancer. The Geocentric Ephemerides for the planets (https://astropixels.com/ephemeris/ephemeris.html) provide positional information for them. Mercury's orbit was sketched in red, and Venus's in white (see additional description in the Supplementary material). **Panel B: This photo as represented on the Antikythera Mechanism Front cadran:** In the authors' functional reconstruction model of the Antikythera Mechanism (https://antikytheramechanism.pro/), the solar-ray pointer ΗΛΙΟΥ ΑΚΤΙΝ of the Golden sphere-Sun points to the 27th subdivision of Gemini. The Lunar pointer points to the 3rd subdivision of Cancer. Jupiter is on the 28th subdivision of Gemini, and Venus on the 5th subdivision of Cancer. The central angles mark the limit points of the greatest elongations of the two inferior planets from the Sun in their orbits, with Venus' in green and Mercury's in blue. At any position that locates the Golden sphere, these central angles "follow" the Golden sphere.

Discussion

Members of the FRAMe Project (https://antikytheramechanism.pro/), based on 10 years of research using visual photographs, AMRP X-ray volumes, and tomographies of the fragments, as well as on the design, construction using simple tools (non-computer-aided machines), handling, and interaction with their bronze reconstructions of the Antikythera Mechanism (including the time-consuming failures they encountered), had the opportunity to "communicate directly" with this remarkable geared time-measuring device of the Hellenistic world. The experience we gained by using this device, in correlation with its specific construction and technical characteristics, which are markedly different from modern designs and methods.

As presented in the *Protocol of Mandatory Parameters for a Research Grade Bronze reconstruction of the Antikythera Mechanism* and discussed in Voulgaris et al. [3], our published works present a strict, mechanically constrained reconstruction of the Antikythera Mechanism, based on the preserved mechanical evidence, the prototype's design and construction, the available space, the constructional characteristics of the ancient craftsman, and the mechanical limitations of the geared devices. Within this framework, the design does not support the introduction of a large number of additional gears, axles, shafts, plates, bars, spacers, discs, bearing bases, tubes, rings, pointers, spheres, side supports, non-centered extensions, off-axis rotated parts, etc., to present the motion of the planets' spheres beyond what is mechanically justified by the surviving evidence.

Moreover, based on the study of the preserved text on the Back Cover plate, which is the Instruction Manual of the Antikythera Mechanism, and its reconstruction (Voulgaris et al. [8,9]), it does not appear that the Mechanism had rotating spheres for the planets, although their names are mentioned (the direct connection of a planet's name with a hypothetical extensive mechanical system seems a large leap of logic). The circular orbits (ΚΥΚΛΟΙ) of the six planets (with the Sun considered a planet) are depicted in the Instruction Manual of the Antikythera Mechanism. These circular orbits of the planets can be presented on the Cover plate of the b1-gear (currently missing; see Voulgaris et al. [3]) as inscribed homocentric circles with their corresponding names (ordered by distance from Earth). The apokatastasis position of each planet could also be inscribed (as a radius or a dot) on its corresponding circular orbit, i.e., at a specific angle relative to the Golden sphere-Sun (see **Figure 6** and **Figure S6** and the fourth column of **Tables S7-S11**). The only two spheres-ΣΦΑΙΡΙΟΝ that are clearly and well presented are the **ΧΡΥΣΟΥΝ ΣΦΑΙΡΙΟΝ** (Golden sphere-Sun) and the ΣΕΛΗΝΗΣ ΣΦΑΙΡΙΟΝ (Lunar Sphere, which resulted from the text and Fragment C).

The Instruction Manual of the Antikythera Mechanism (Back Cover Inscription) and the Astronomical Ephemeris of the Antikythera Mechanism (Front Cover Inscription) made the Antikythera Mechanism an integrated time-measuring device, fully autonomous and independent of any external information, capable of producing time information.

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The reconstruction of the text on the Front Cover plate of the Antikythera Mechanism was one of the targeted projects of the author's team, *The Functional Reconstruction of Antikythera Mechanism – The FRAMe Project*. The text was reconstructed directly in ancient Greek by the authors, drawing on experience from reconstructing the Back Cover plate text - the Instruction Manual for the Antikythera Mechanism (begun in 2019 and published in 2026). No AI tools were used in the reconstruction.

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Data availability
The data will be made available on reasonable request.

Code availability
This article uses two non free software programs: the Real3d VolViCon [Software], Version 4.31.0422, April 2022, available at https://volvicon.com/ and the Starry Night Pro digital planetarium software, available at https://starrynight.com.

Author contributions
A.Voulg.: conceptualization, methodology, investigation, analysis, visualization, graphics, CTs, text reconstruction in ancient Greek - English translation, and writing (original draft and editing). M.P.: investigation, resources, text reconstruction in ancient Greek - English translation, and writing (review and editing). C.M.: analysis and modeling. A.Vos.: visualization, graphics, CTs. All authors reviewed the manuscript.

Competing interests
The authors declare no competing interests.

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