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The Antikythera Mechanism

Posted on 01 October 2019

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Alexander Jones looks at the history of one of the great technical achievements of the ancient world.

On December 23, 1819, less than two months into his appointment as Keeper of the Vatican Library, Mgr. Angelo Mai addressed a letter to Pope Pius VII announcing that he had discovered two palimpsest manuscripts whose reused parchment leaves preserved several ancient Latin (and Gothic) texts that had not otherwise survived to modern times. In particular, one of them () contained large portions of Cicero's dialogue ("On the Commonwealth"), from which only the *Vat. lat.*

5757 (<https://digi.vatlib.it/mss/detail/Vat.lat.5757>)

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narrative sections of the sixth (and final) book known as the "Dream of Scipio" was hitherto believed to have been handed down. In this passage, Scipio Aemilianus, the second century

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Figure 1: Scipio Aemilianus with his adoptive grandfather Scipio Africanus and his father Lucius Aemilius Paulus among the celestial spheres, from a 15th century manuscript of Macrobius' commentary on the "Dream of Scipio."

https://digitalcollections.library.harvard.edu/catalog/990095012660203941_FHCL.HOUGH:26540653

Mai's palimpsest revealed that Scipio's dream of looking down upon the actual heavenly bodies and their spheres was counterbalanced by another narrative near the beginning of Book 1 in which one of the dialogue's interlocutors recalls an assemblage of distinguished Romans of the previous generation examining and admiring Archimedes's ingenious , a *sphaera* bronze hand-driven mechanism that the diverse revolutions of the Sun, Moon, and planets. *simulated*

shipwreck off the island of Antikythera in the straits between Crete and the Peloponnese, and on this occasion he was shown some of the recovered artifacts. As contemporary newspapers reported, Stais noticed, among various small corroded bronze fragments that were as yet unidentified, two that bore the remains of toothed gear wheels and traces of inscribed Greek lettering. Only a miserable handful of letters could be read, but among them were $\text{H}\Lambda\text{I}\text{OY}$, “of the Sun,” and $\text{A}\Phi\text{P}\text{O}$, likely part of the usual Greek name for the planet Venus (“the star of Aphrodite”), so it was quickly realized that the device had to do with astronomy, and there was some speculation that it might have been a navigational instrument. On the other hand, the German classicist and epigrapher Albert Rehm, who examined the fragments in 1905-1906, observed a number of features that suggested to him that these were the remains of a gear-driven planetarium, just the kind of mechanism that Cicero had described, and presumably belonging to the ship's cargo or of a passenger's baggage. But Rehm never published his arguments, and a half century would pass before real progress would be made in understanding the nature and purpose of this intriguing object.

By the 1950s, what had originally been two fragments, then three, then four as additional pieces were identified (FIGURE 2), had become more than thirty, not counting a box of extremely tiny flakes and crumbs, as a result of conservators' separating fused components as well as some accidental fractures.

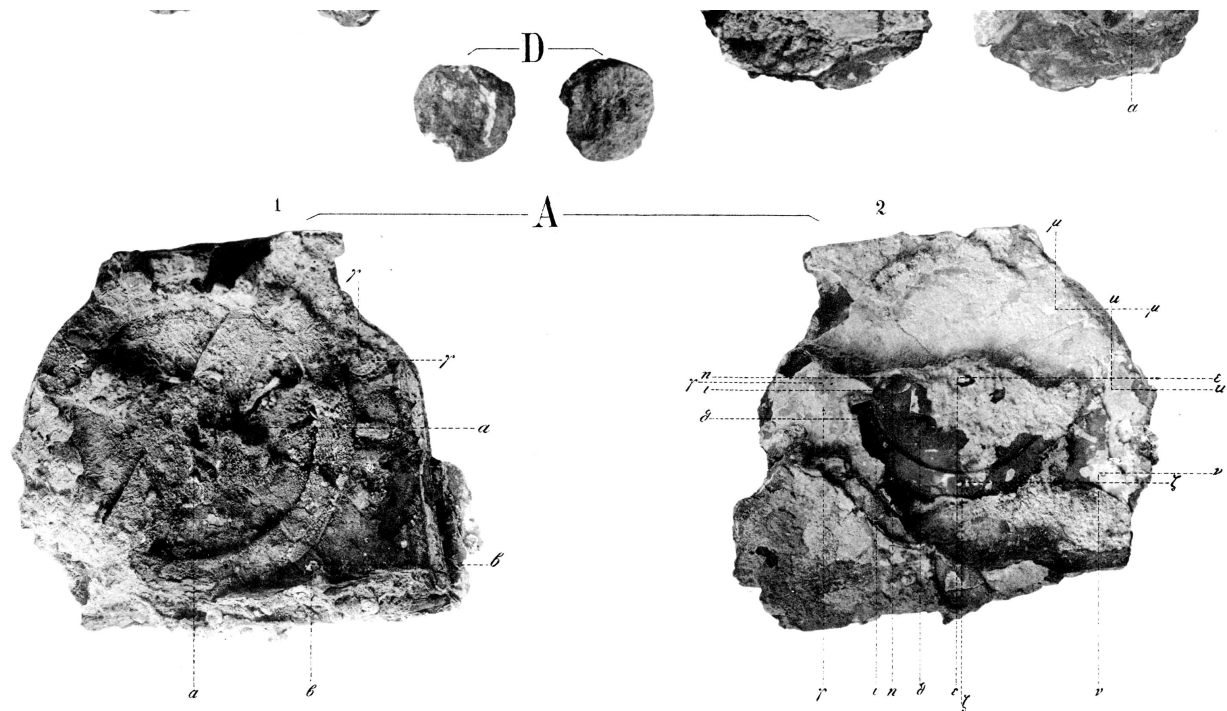


FIGURE 2. The four fragments of the Antikythera Mechanism known in 1902, before cleaning and conservation. Svoronos, Ioannis N, *Ὁ Θησαυρὸς τῶν Ἀντικυθήρων*, Athens: Beck & Barth, 1903, plate X (<https://archive.nyu.edu/handle/2451/59968>)

It was at this stage that Derek de Solla Price entered the story of the Antikythera Mechanism (he gave it this name, and it stuck). A historian of science who took a special interest in early scientific instruments and the evolution of clockwork, Price learned of the Mechanism from the few published descriptions, and, struck by the evident complexity of the gearwork despite the fact that it was centuries older than anything else comparable that he knew of, he spent ten days in the summer of 1958 examining the fragments, assisted by a specialist in Greek inscriptions, George Stamiris. Price was the first to realize that the surviving gears—he could see at least 20, most of them in the largest fragment—had not been disturbed in their positions, though many were broken, so that in principle it ought to be possible to reconstruct a large part of the system of connections. Moreover, he recognized how the largest fragments

front and back faces in the form of pointers revolving around dials with inscribed scales. One of the dials, the single one on the front face, could be identified: it had two concentric scales graduated respectively into the twelve signs and 360° of the zodiac and into the twelve months and 365 days of the Egyptian calendar year, and it must have had a pointer representing the annual circuit of the Sun through the zodiac.

Price was initially impeded from going beyond these fundamental but limited insights by two difficulties: the inscriptions along the scales of the four dials on the back face were almost entirely illegible or unintelligible, and parts of the surviving gearwork were hidden behind other components and layers of material. Eventually, in the early 1970s he enlisted the collaboration of Haralambos Karakalos, a radiophysicist, who succeeded in making x-ray radiographs of the principal fragments and, with his wife Emilia, estimated the numbers of teeth on each gear. Using the new data, Price conjectured a partial reconstruction of the Mechanism's gear trains according to which the front dial had pointers representing not only the Sun's motion through the zodiac but also the Moon's, while the back dials represented various cycles of time relating to calendars and periodic astronomical phenomena. Price published his cumulative observations and reconstruction in 1974 in a monograph with the title .

Gears For the Greeks

This turned out not to be the last word. In the late 1980s and early 1990s, motivated by suspicions that Price's reconstruction was neither complete nor entirely correct, Allan Bromley and Michael T. Wright studied the fragments closely, using direct inspection, x-ray radiography, and linear tomography (a technique generating radiographs that were sharp in a chosen plane section of the object and progressively more blurred above and below that plane, thus yielding information about the fragments' three-dimensional structure). Then in 2005

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FIGURE 3. The three principal fragments of the Antikythera Mechanism as currently displayed in the National Archaeological Museum, Athens. Photo Dimitris Kamaras, (CC BY 2.0)

<https://www.flickr.com/photos/127226743@No2/21909935875/in/photolist-zo79B6-9JGsPT-2eEtSQG-ppmMhd-NRtZZ7-Kmkuvw-ppmNzU-5THUmo-8FvHN8-4aR85Y-5TDzzr-JsGBRS-Kmkjis-NWHR6c-yr5rx3-KhgAKT-zn3tmG-a35TT8-5kyPpG-MaiGZY-MMfvdH-9sWGrF-JsA9Lm-5TJ1SQ-7n74T4-zoprfx-KmjECY-Kmkojb-KmjS9o-JY9MeE-JsGnQA-LDRbDY-KiWkAF-LpyoTp-MiCxyt-JsEVHM-Kpay2a-KeSNqL-Kmee1A-JsGJQG-JY94Mb-KeSXjh-JY4oCY-JsALD3-Kp5B4c-3pq9dm-31fprE-K5STW1-KeU6Gh-KeMygJ>

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data is that the texts inscribed on and around the dial scales and on other metal plates can now be read (http://www.brepols.net/Pages/ShowProduct.aspx?prod_id=ON-M1-F1-04010366-1)

much more extensively and accurately, even when they are concealed inside the fragments. By providing evidence that complements and confirms the evidence from the physical remains, the inscriptions have played a major role in completing the current consensus reconstruction.

The reconstruction is most complete with respect to the dials of the back face and the gearwork that drove their pointers.

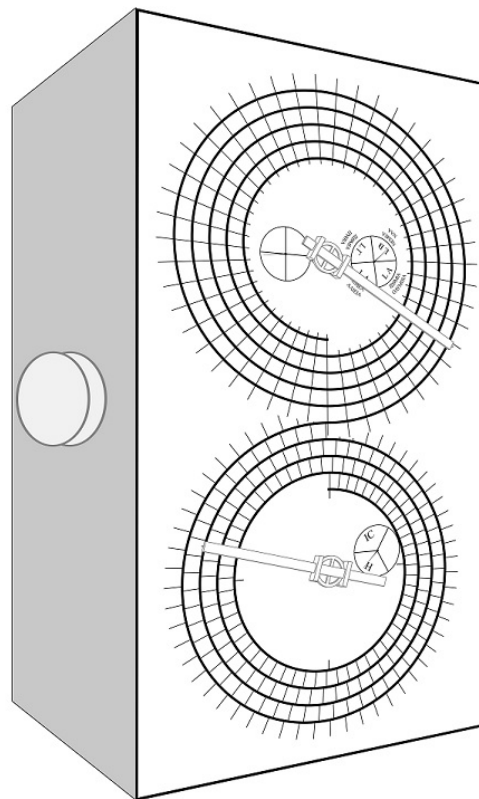


FIGURE 4. Reconstruction of the Mechanism's back face. Some inscriptions are omitted. (Alexander Jones) (<https://archive.nyu.edu/handle/2451/59967>)

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some 13; the scale was inscribed with month names belonging to the calendar of Corinth, which was also used in many cities in and around Epirus in northwest Greece. Inside this spiral, and right of its centre, a small dial displayed the four-year cycle of Panhellenic athletic festivals (the Olympic, Nemean, Pythian, and Isthmian games as well as the comparatively minor Naa of Dodona and Halieia of Rhodes), and on the other side of the center, another small dial (now lost, but known from the inscriptions) displayed a 76-year calendar cycle that was a slight refinement of the 19-year cycle. In the lower half, another spiral dial making four complete turns represented a 223-lunar-month cycle enabling one to predict possible lunar and solar eclipses, while a small dial inside the spiral was for a tripling of this eclipse cycle for the sake of predicting the times of day or night when eclipses would take place.

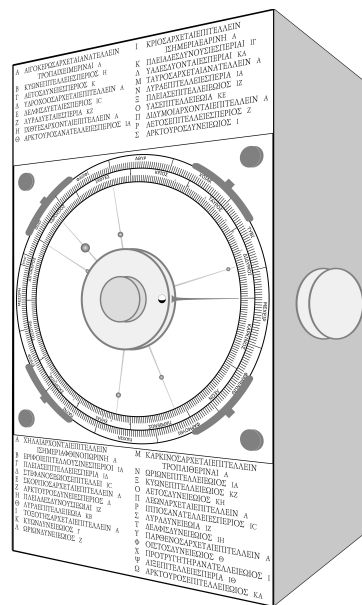


FIGURE 5. Reconstruction of the Mechanism's front face. (Alexander Jones)

(<https://archive.nyu.edu/handle/2451/59967>)

phase in the form of a revolving half-white-half-black ball seen through a circular window.

Was the front dial (as Rehm conjectured but Price came to doubt) a planetarium with pointers *complete*

for the five planets Mercury, Venus, Mars, Jupiter, and Saturn? While studying the fragments, Michael Wright came to the conviction that it was, in part because of various physical features that seemed to be vestiges of lost gearwork that did not belong to the Sun-Moon-calendars system, in part because of the apparent reference to Venus in the inscriptions, and also because ancient literary references such as Cicero's to astronomical mechanisms described full planetaria. Moreover, of the 30 surviving gears, the 29 that are still attached to the larger fragments are all accounted for in the consensus reconstruction, but a single isolated gear is not, so it must have been a component of beyond the established functions of the six dials. But

something

the decisive evidence is in the newly legible inscribed texts. One, the so-called "Back Cover Inscription," turns out to be an inventory of the dials and other external features of the Mechanism, in which the reference to Venus occurs in the context of descriptions of a system of pointers for the front dial, decorated with small balls representing the Sun and all five planets, while the other, the "Front Cover Inscription," is a summary of the cycles of forward and backward motion of each planet through the zodiac.

This observed behaviour of the planets, changing speed and even reversing direction in their circuits of the zodiac, could not have been simulated by normal engagements of gears through interlocking teeth; they require some special device such as a slotted arm made to swing back and forth by a pin mounted on a revolving gear's face, or a pair of gears with slightly offset axles, one driving the other by means of a pin-and slot. As it happens, such a pin-and-slot pairing survives as part of the gear train driving the Moon's pointer, where it is now understood to cause a slight variation in the Moon's speed in its motion through the zodiac, a phenomenon now explained as due to the Moon's elliptical orbit.

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knowledge, on the other hand, we can contextualize it in a long and rich tradition of astronomical time-reckoning, eclipse prediction and interpretation, and mathematical modelling of the celestial motions that can be traced back to fifth century BC Greece and still earlier to the Mesopotamian astral sciences. Though researchers starting with Price have characterized it as a kind of computer, it was probably not built as a tool for calculating data, but as a didactic image of the cosmos that made visible the interconnectedness of a plethora of celestial and mundane phenomena governed by time and periodicity, a kind of mechanical textbook of astronomy.

Alexander Jones, a classicist and historian of the ancient mathematical and physical sciences, is the author of

A Portable Cosmos: Revealing the Antikythera Mechanism, Scientific Wonder of the Ancient World

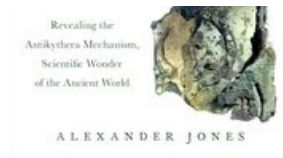
, published by Oxford University Press (available in hardcover and paperback). He is currently Leon Levy Director of the Institute for the Study of the Ancient World at New York University.

His page on the ISAW site is:

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