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Zeit ist Macht. Wer macht Zeit?
Time is power. Who makes time?

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The Antikythera Mechanism and astronomical knowledge: users and benefits

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Zusammenfassung

Der Mechanismus von Antikythera und das astronomische Wissen: Anwender und Vorteile

Der Antikythera Mechanismus wird oft als »der erste Computer der Welt« bezeichnet und ist ein einzigartiges mechanisches Gerät, das als Teil der Luxusfracht eines Schiffes in der Nähe der Insel Antikythera unterging. Im Jahre 1902 wurde die Vorrichtung als astronomisches Gerät erkannt und seither wird seine Ausgestaltung und Funktionsweise in der Forschung kontrovers diskutiert. In den letzten Jahrzehnten ist man sich nun bezüglich seiner Konstruktion einig geworden, was wiederum zur Beantwortung weiterer Fragen führen könnte. In diesem Beitrag wird weder die Frage des Herstellers noch die nach der Zeit und dem Ort der Herstellung erörtert; stattdessen soll das Augenmerk auf die Funktion und die Nutzer des Mechanismus gelegt werden: Handelt es sich um ein Lehrmittel oder Demonstrationsmodell? Könnte es für astrologische Zwecke verwendet worden sein? Welchen Nutzen zogen seine Besitzer und Anwender daraus?

Summary

The Antikythera Mechanism, often described as »the world's first computer«, is a unique mechanical device, part of the luxury cargo of a ship that sank near the island of Antikythera. From the moment it was identified as an astronomical device, in 1902, there were controversies among specialists about its nature and functions. During the last decades, a consensus reconstruction has been established which can help to answer other questions. Here, we do not discuss the question of its creator, nor the date and place of its creation, but focus on its use and users: was it an educational or demonstration tool? Could it have been used for astrological purposes? What benefits did it confer on its owner and user?

A mechanism in a ship

The Antikythera Mechanism is at present the only extant geared astronomical device from Hellenistic antiquity. Mentions of geared devices, and devices that were probably driven by gears, exist in various ancient Greek and Latin texts, but until the discovery of this particular mechanism (from now on, the »Mechanism«), most such devices were considered, at best, as lost inventions about which one could only speculate, at worst as fictions. Oddly enough, we owe the preservation of the Mechanism, albeit incomplete and shattered into fragments, to a disaster which preserved its metal (mostly bronze) components from being recycled: sometime around 60 BC, the ship in which it was being transported from somewhere in the Aegean regions to somewhere further west (perhaps Italy, perhaps somewhere else along the Adriatic coast) was wrecked off the island of Antikythera. The cargo of the ship included many works of art (bronze and marble statuary) and luxury objects (fine glassware), some of which at least were probably intended for wealthy Roman buyers. Golden earrings and a stash of silver coins indicate that there were also some well-off passengers on board. These objects (Fig. 1), including the remains of the Mechanism (Fig. 2), were salvaged by sponge divers in 1900–1901 and ended up in the National Archaeological Museum in Athens (Jones 2017, 1–15). Why was the Mechanism travelling with these artifacts? Was it cargo, or part of a passenger's baggage, or an instrument of the ship? As we will see, it was almost certainly not an article of ship's equipment. Here, we will not discuss the so-called »treasure«, namely the works of art of the cargo; this subject is well documented in

Fig. 1 The 2012 National Archaeological Museum of Athens exhibition *The Antikythera Shipwreck: The Ship, the Treasures, the Mechanism.*

Abb. 1 *Die 2012 gezeigte Ausstellung* The Antikythera Shipwreck: The Ship, the Treasures, the Mechanism *[Das Schiffsunglück in Antikythera: Das Schiff, die Schätze, der Mechanismus] im Archäologischen Nationalmuseum Athen.*

Fig. 2 The 82 fragments of the Antikythera Mechanism, National Archaeological Museum, Athens inv. X 15087, as displayed in the 2012 Antikythera Wreck exhibition.

Abb. 2 *Die 82 Fragmente des Mechanismus von Antikythera in der* Antikythera Shipwreck *Ausstellung im Archäologischen Nationalmuseum in Athen, Inv. Nr. X 15087.*

many publications, culminating with the splendid catalogue of the 2012 exhibition of most of the objects recovered from the shipwreck (Kaltsas et al. 2012). Our scope is to understand the role of the Mechanism, based on its functions, and the kinds of »power« that devices like it (for it certainly was not unique) might have conferred on their possessors. We will keep just one crucial link with the sunken ship: the fact that the Mechanism was, like the other objects in the cargo, an expensive, even a luxury object, that was probably ordered by or sold to a wealthy person, though an atypical one for whom a rather arcane scientific machine was a desirable outlet for one's affluence.

The present consensus reconstruction

In speaking of a »consensus« reconstruction, we do not mean that every recent scholar who has written about the Mechanism agrees on every point, but that among those – one or two dozen perhaps – who have engaged in serious examination of the available evidence (direct examination, radiography and tomography, photography and Reflectance Transformation Imaging, as well as comparative study of other sources from antiquity and archival material), most would accept most of the elements of the reconstruction (Jones 2017, 47–62). According to this, the Mechanism (Fig. 3a–b) when intact was roughly the size and shape of a shoebox standing on one end, about 30 cm tall, 17 cm broad, its depth from front to back uncertain but not less than 10 cm (Allen et al. 2016, 24–32). The front and back faces were metal plates on which various dials, scales, and Greek text were inscribed, perforated by holes and slots for moving pointers that indicated the various »outputs«. The other faces were wooden, with a knob or crank projecting from one side constituting the single »input«. The basic principle was that turning the input knob (by hand) clockwise represented moving forward in simulated time, about five turns being equivalent to one year. The outputs, in most cases indicated by the pointers moving along scales, represented ways of counting the passage of time or astronomical events that took place during that time.

The fragments contain enough parts of the back dial face and enough gears (complete or broken) still in their original locations and still interconnected to make possible a nearly complete and, so far as it goes, secure reconstruction of most of the back-face outputs, which included the following:

- The date selected via the input knob, displayed to a resolution of a single lunar month – by eye one might estimate the rough stage of the month, but not single days – expressed according to the lunisolar calendar in use in several localities of north-west Greece, which was probably the same as the calendar of Corinth. The calendar display was structured with respect to intercalary months and lengths of months by a 19-year so-called »Metonic cycle«. A subsidiary display can be conjectured that grouped every four »Metonic cycles« into 76-year so-called »Callippic cycles« that reconciled the calendar exactly with an average year length of 365 ¼ days.
- The selected date, displayed to a resolution of a fraction of a year, within the recurring 4-year cycle in which the various Panhellenic athletic competitions (including the Olympic games, the other three most prestigious games, and two rather minor regional ones) were repeated.
- The selected date, displayed to a resolution again of a single lunar month, within the 223-lunar-month so-called »Saros cycle« in which dates that are candidates for lunar or solar eclipses usually repeat. The months of the cycle in which eclipses were possible were marked with inscriptions from which one could read off some predicted characteristics of the relevant eclipses. Again, a subsidiary display grouped every three Saros cycles into a 669-month so-called Exeligmos cycle whose duration was an integer number of days.

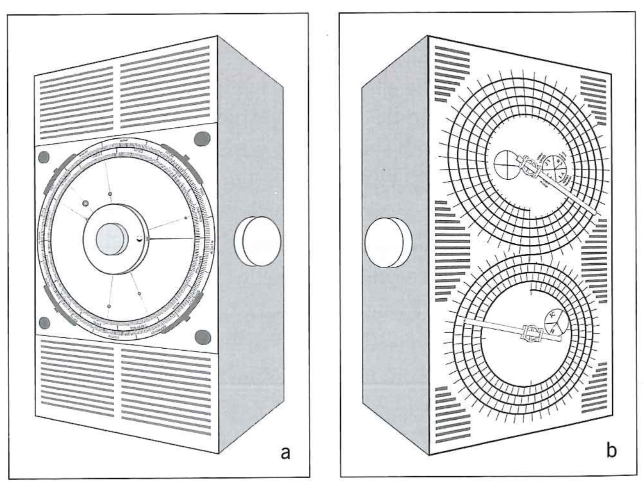

Fig. 3a–b Consensus reconstruction of the Antikythera Mechanism: **a** front face, in version with revolving pointers for the planets; **b** back face.

Abb. 3a–b *Allgemein akzeptierte Rekonstruktion des Mechanismus von Antikythera:* **a** *Ansicht von vorne mit Drehzeigern für die Planeten;* **b** *Ansicht von hinten.*

The same »module« of extant gears also drove outputs on the front dial face. This face is less well represented in the fragments, but we do have portions of two concentric, graduated, circular scales that enclosed a large dial in the middle of the face, and a shallow cylindrical element resembling a jar lid that was originally mounted in the middle of this dial. There is no evidence of any other dials on the front. The outputs that we can be quite sure of are these:

- The position (longitude) of the Sun in the zodiac on the selected date, displayed to a resolution of single degrees. Some degree marks were also inscribed with index letters keying to a list of annually repeating phenomena – solstices, equinoxes, dates when various stars and constellations began or ceased to be visible just after sunset or just before sunrise.
- The position of the Moon in the zodiac on the selected date, displayed to a resolution of single degrees.
- The phase of the Moon on the selected date, visually represented by a revolving parti-coloured ball seen through a circular orifice in the cap-like component.
- The selected date displayed according to the Egyptian calendar (which had constant 365-day years), to a resolution of a single day.

The fragments also include parts of two metal plates that were separate from the »shoebox« and might have functioned as protective covers for the dial faces. These were inscribed with texts that contain clear indications that the front dial also showed the positions of the five planets known in antiquity (Mercury, Venus, Mars, Jupiter, and Saturn) in the zodiac on the selected date. There are also some slight but suggestive physical remains of what could have been the mounting of a lost second »module« of gears supporting these planetary outputs, and a single gear in an isolated fragment that might have belonged to the planetary module.

The details of how this planetary display on the front dial looked and operated are open to two alternative hypotheses that are both compatible with the (frustratingly gappy) testimony of the »back cover« inscription. In one version, the plate between the cap-like feature and the scales was inscribed with concentric circles representing the nested ethereal »spheres« of the Sun and the planets, while the position in the zodiac of each body was indicated by a revolving pointer carrying a little ball standing for the planet itself at the appropriate radial distance from the centre (Freeth/Jones 2012). In the other version, instead of pointers, the gearwork drove mobile concentric rings that filled the space within the scales and represented the ethereal spheres, with little embedded balls standing for the visible bodies (Jones 2011; Freeth et al. 2021). Either way, the front dial was a schematic image of the cosmos in motion.

Controversies

Within a few days after the main fragments of the Mechanism were first noticed in the National Archaeological Museum of Athens in May 1902, controversy broke out concerning the functions and purpose of the object (Jones 2017, 16–29); a variety of hypotheses were reviewed in an early monograph on the subject by one of the combatants, K. Rados (1910). At this point, and for the next half century, no one was really able to make correct sense of many of the observable features of the fragments, and the only solid consensus was about its mechanical nature and its link to astronomy, which had been established thanks to the very first inscribed words that were deciphered: »sun«, »ray« and »Venus« (Aphrodite). There was also near consensus among the very first people that inspected the fragments of the Mechanism: since it was found on a ship, it must have been part of its equipment, as some kind of navigational instrument. But there was no consensus on its function: suggestions included an astrolabe, a marine odometer, and a kind of clock. Rados himself was swayed by the arguments of the German classicist A. Rehm (which were never formally published) that the Mechanism was a mechanical planetarium representing a geocentric planetary system, not a navigational tool but a »wonder-working« device »with which the culturally superior Greece impressed its Roman master« (Rehm 1905, 29 f.). D. J. de Solla Price, whose researches on the Mechanism from the late 1950s to the early 1970s marked a substantial advance in our understanding of the exterior layout and interior gearwork, designated it a »calendar computer«, since so far as he was able to determine, the outputs were limited to representing uniform motions of the Sun and Moon through the zodiac and lunations (Price 1974)[1]. Subsequent investigations, nota-

1 We prefer the expression »calculating machine« to »computer« since the latter is now so strongly associated with programmable, digital computers as opposed to analogue devices with a specific application.

bly by M.T. Wright and by the Antikythera Mechanism Research Project (Freeth et al. 2006; Freeth et al. 2008), led to the present consensus reconstruction of the Mechanism's functions as described above, as a combination of a planetarium display on the front face and a display of calendrical and astronomical cycles on the back face.

So far as concerns the question of the Mechanism's purpose, the huge progress in our knowledge of what it did and showed has more or less decisively ruled out any navigational purpose: to the extent that ancient navigation relied on astronomy, it utilised kinds of observation and information in which the Mechanism could have had no role, for example identifying circumpolar constellations. The Mechanism was not ship's gear but either cargo, like the statuary and glassware, or a passenger's property, like the jewellery and coins. There remain two credible possibilities for its purpose. If the intention was to calculate the specific quantitative data that could be read off the dials corresponding to a chosen date, such as the locations of the Sun, Moon, and planets in the zodiac, the one context in the last centuries BC in which this would have been *useful* knowledge was astrology. If the intention was the »big picture« formed in a more qualitative way out of the combination of displayed data, we are dealing with an instrument meant for instruction. Although the present authors lean towards an understanding of the Mechanism as a didactic object (partly because some of the displayed data, in particular the cycle of Panhellenic festivals, had no significance in ancient astrology), in what follows we want to broaden consideration to what might have been a whole family of gearwork planetaria that might have come out of the same workshop but with outputs and displays customised for different kinds of user, both educators and astrologers, and we try to imagine what difference it might have made for either class to be able to own one.

An educational and demonstration tool?

The passage in ancient literature that is most often invoked to supply a »back story« for the Antikythera Mechanism is near the beginning of Cicero's philosophical dialogue *On the Commonwealth* (*De Re Publica* 1.21–22), written when its author (Fig. 4) was in his fifties, but set more than three quarters of a century earlier, in 129 BC, well before Cicero was born. One of the speakers reminisces about an occasion nearly forty years earlier still, when a mechanical planetarium, a so-called *sphaera*, that had been made by Archimedes and carried off, after Archimedes's death in the sack of Syracuse in 212 BC, by the Roman general Marcellus, was brought out by Marcellus's grandson – still in working order! – to be exhibited to a gathering of elite fellow Romans. Ancient philosophical dialogues were fictional compositions, and it might be asked why this episode should be taken as an account of things that really happened any more than the episode of the playwright Aristophanes's hiccups in Plato's *Symposium*. But even if taken at face value, it tells us nothing about the *intended* context of use of Archimedes's, or anybody else's, mechanical simulation of the cosmic system.

A decade after completing *On the Commonwealth*, Cicero dropped an allusion in his dialogue *On the Nature of the Gods*

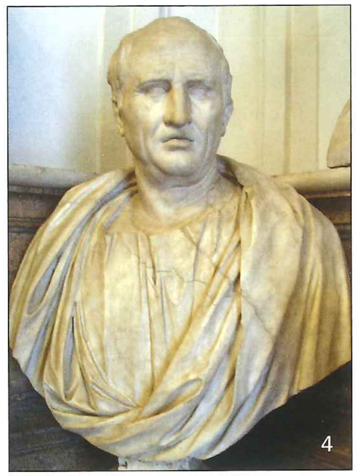

Fig. 4 Bust of Cicero, 1st century AD, Musei Capitolini inv. MC0589.

Abb. 4 *Büste des Cicero, 1. Jh. n. Chr., Kapitolinische Museen, Inv. Nr. MC0589.*

Fig. 5 Bust of Posidonius, 1st century BC, Museo Archeologico Nazionale di Napoli inv. 6142.

Abb. 5 *Büste des Posidonios, 1. Jh. v. Chr., Archäologisches Nationalmuseum Neapel, Inv. Nr. 6142.*

to another *sphaera* whose functions were similar to those he had attributed to Archimedes's invention. This time the dialogue is set shortly after Cicero's return to Rome in 77 BC following two years of educational travels in Greece and Asia Minor, and he inserts himself as a silent witness to the disquisitions on theology that he puts in the mouths of three philosophically inclined Romans of the older generation. In the course of an *a fortiori* argument that, since human artifacts such as ships and sundials are immediately recognised as made by reason and for a purpose, the cosmos that contains them and their inventors must partake in reason and purpose too, Cicero's spokesman for Stoicism, Balbus, invokes as his supreme example of a manifest production of human ingenuity the »*sphaera* that our friend Posidonius has recently fashioned« (*De natura deorum* 2.88). This has something of the ring of truth: there is no particular reason why Balbus should be made to associate a planetarium with the Stoic philosopher Posidonius (Fig. 5) other than because Cicero knew that he had one, and indeed he had probably seen it when he had been in Rhodes and studied with Posidonius (*De natural deorum* 1.7). Even if it *is* a fiction, Cicero is at least informing us that a planetarium device comparable to the Antikythera Mechanism (»the single turnings of which produce the same effect for the Sun and for the Moon and for the five wandering stars as they produce in the heavens in single days and nights«) is something a philosopher might choose to have.

A couple of remarks need to be made about the passage. First, when Balbus says that Posidonius »fashioned« the *sphaera*, this should probably be understood as »commissioned«; we do not have to imagine that he handled the tools or for that matter that he was responsible for the design in either the mechanical or the scientific sense. Secondly, there is one point of divergence between the described planetarium and the Antikythera Mechanism, implied in the phrase quoted in the preceding paragraph: a single turn of the input drive of the Mechanism was equivalent to nearly eighty days of simulated

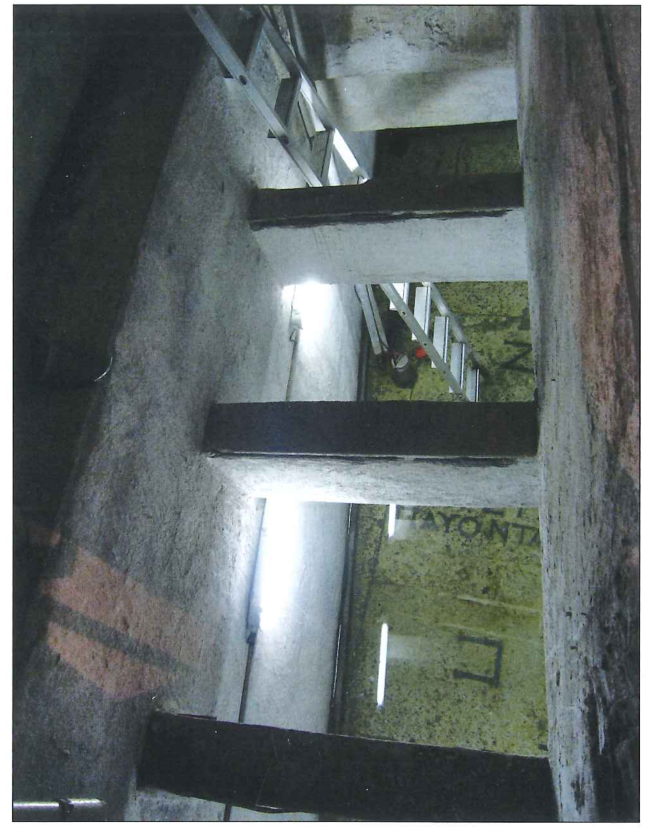

Fig. 6a Surviving portion of a monumental meridian, the so-called *Horologium Augusti*, late 1st century BC, with annual astronomical and meteorological events labelled in Greek, in the Campus Martius, Rome.

Abb. 6a *Erhaltenes Fragment eines monumentalen Meridianinstruments, des sogenannten* Horologium Augusti, *mit astronomischen und meteorologischen Ereignissen in griechischen Buchstaben; spätes 1. Jh. v. Chr., Marsfeld, Rom.*

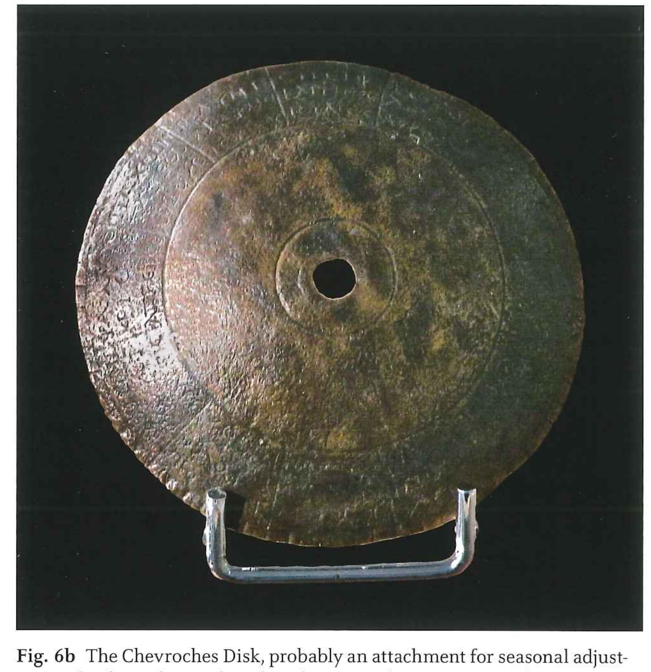

Fig. 6b The Chevroches Disk, probably an attachment for seasonal adjustment of a clepsydra, with zodiacal signs and Egyptian month names inscribed in Greek; 4th century AD (?), found at Chevroches, France, Musée de Jublains.

Abb. 6b *Die Scheibe von Chevroches. Wohl ein Zusatzelement für die saisonale Anpassung einer Klepsydra mit Sternzeichen und ägyptischen Monatsnamen in griechischen Buchstaben; 4. Jh. n. Chr. (?) Fundort Chevroches, Frankreich, Musée de Jublains.*

time, not a single day and night. But even if we believe that Cicero probably saw Posidonius's device in action, how accurately did he remember the details of its operation more than three decades later, and how important was it to him to get the details right in this philosophical context? After all, the dialogue form gave its author license to bend historical facts for the sake of the narrative or argumentative flow.

At issue here is, what would Posidonius have wanted a planetarium for? The relevant considerations are that Posidonius was a Stoic philosopher with very broad interests in natural and physical phenomena but not, so far as our evidence suggests, any deep knowledge of or involvement in astronomical and mathematical research; that, though in origin an »outsider« from Apamea in Syria, he held high enough social status in Rhodes to hold public office and to be sent on an embassy to Rome; and that he was renowned as a teacher, whose pupils included elite Romans like Cicero as well as Greek would-be intellectuals (Edelstein/Kidd 1972–1999). Posidonius would have had no need for an astronomical calculating device, but in the »classroom« (whatever that meant exactly – we know little about how philosophical education worked in this period) it would have been a powerful and versatile didactic resource.

A class on astronomy at Posidonius's academy would not have resembled one of Hipparchus's treatises on theoretical investigations of the motions of the Sun and Moon so much as Geminus's popularising *Introduction to the Phenomena* (Evans/Berggren 2006) – in fact, Geminus, a younger contemporary of Posidonius, also wrote a book on meteorology that was explicitly based on Posidonius's work, and one might like to imagine him as the teaching assistant who substituted for the venerable master on »astronomy afternoons.« The basics of geocentric cosmology, the relative distances of the Sun, Moon, and planets from the Earth, their wandering tracks through the zodiacal belt, the Moon's phases and the calendar structures based on them, eclipses, the uses of stars as weather-predictors: these are all topics of chapters in Geminus's *Introduction*, presented at a level accessible to a lay reader who has learned the basics of geometry. Every one of them also features among the Antikythera Mechanism's displays.

The power Posidonius's *sphaera* would have conferred was partly didactic. A visual representation of cycles of time and celestial motions and phenomena would have had an immediacy that words could not replace, and the accelerated time scale of the device made it possible to illustrate effects that could take years or decades to happen in the actual skies of Rhodes. For a Stoic philosopher, moreover, the coordination of all these cycles so that a single input drive caused all the diverse motions, fast and slow, uniform and non-uniform, natural and societal, to happen simultaneously, would have conveyed a lesson of massive theological and even ethical significance supervening over the particular phenomena, with the designer and operator becoming an image of the wise and benevolent intellect who governs the cosmos and human lives. Cicero, though not himself a Stoic, clearly held to this teaching all his life.

But of course there was also a less altruistic aspect. The Greek-speaking regions of the eastern Mediterranean abounded with teaching philosophers, but few could have accessed or afforded an intricate mechanical cosmos, so Posidonius's *sphaera* would have reinforced his prestige among his intellectual rivals. It also was a concrete manifestation of the »superiority« of Greek wisdom and science in a world already dominated militarily and politically by Rome; one can compare the use of Greek as the language and script of inscriptions on sundials and other scientific objects found in the »Latin« western part of the Roman Empire (Fig. 6a–b). Notably, the Antikythera Mechanism bears displays explicitly relating to Greek institutions (local lunisolar calendars and Panhellenic athletic competitions) but not at all to Roman ones.

A tool for astrology?

As discussed above, we believe that the specific Mechanism whose fragments we have was intended to be a prestigious didactic instrument, displaying a wide range of information relating to topics loosely understood in its period to come within the scope of *phaenomena* or *astrologia/astronomia* (which were more or less interchangeable terms covering astronomical knowledge and the range of its applications). This would have been true also of the *sphaera* that Cicero's advocate of Stoicism, Quintus Lucilius Balbus, alludes to as having been »recently made by our friend Posidonius« (*quam nuper familiaris noster effecit Posidonius, De Natura Deorum* 2.87–88 – the dialogue is set in or soon after 77 BC). Nevertheless, many of its functions would have had pertinence for the astrology that was rapidly gaining a prominent, if controversial, popularity throughout the Roman world in the first century BC, and it would not have required extensive modifications to transform the Antikythera Mechanism into a specifically astrological device. Could there have been a place for gearwork mechanisms in the practice of Greco-Roman astrology?

Astrology fell into several divisions, with the principal types being the »general« astrology of making forecasts of meteorological, climatic, social, and political events covering entire regions and peoples on the basis of prominent, omen-like astral phenomena, the »horoscopic« astrology of making predictions pertaining to an individual on the basis of the arrangement of the heavenly bodies at the instant of birth, and the »catarchic« astrology of evaluating dates and times as auspicious or not for various activities. Though ultimately derived from Mesopotamian traditions of astral omen interpretation (best represented in theory and practice by the numerous tablets of omen compendia and the letters and reports of scholars specialising in omen observation and interpretation recovered from 7th century BC Nineveh), in the Mediterranean world general astrology was most strongly associated with Egypt, and the phenomena that were supposed to bear the greatest astrological significance were the annual first morning rising of »Sothis« (Sirius), whose significance arose from its coinciding with the onset of the Nile flood, and eclipses.

Egyptian »Sothis texts«, fragmentarily preserved in Demotic and Greek papyri (Hughes 1951; Haslam et al. 1998, 130–133; Ryholt 2013, 33 f.) and in compressed form in Greek in the astrological treatise of Hephaestio of Thebes (early 5th century AD, 1.23), made pronouncements for the coming year in Egypt and various neighbouring and more distant regions keyed to which signs of the zodiac each planet occupied on the date of Sothis's rising. This was dangerous knowledge: statements speaking of, say, the death of the king of Egypt or sedition or revolt would be applicable to the current Ptolemaic ruler or, later, the Roman emperor. A device like the Antikythera Mechanism that marked the annual first risings and settings of stars on its zodiac dial while displaying the places of the Sun, Moon, and planets in the zodiacal signs could obviously serve as a key to the relevant Sothis texts for the year, but the possessor might want to be careful about drawing too much attention to this application!

When it comes to eclipses, treated as astral omens, there are fewer relevant papyri (Ryholt 2005, 162), though one Demotic papyrus preserves what appears to be, by some margin, the earliest known Egyptian astral omen text (Parker 1959); but again we have Hephaestio's summary of the Egyptian teachings (1.21), which offers a concrete connection to the Antikythera Mechanism. Forecasts, similar in character to those of the Sothis texts, are associated with the time of an eclipse (within blocks of seasonal hours of the day or night), the colour of the eclipsed disk, and the direction of the wind at the beginning and end of the event (Montelle 2011, 147–154). These are precisely the items of predicted information associated with possible eclipses inscribed in the so-called eclipse »glyphs« of the Mechanism's Saros Dial and the Back Plate Inscription (Anastasiou et al. 2016, 192–209). Treating wind directions and eclipse colourations as predictable aspects of eclipses does not sit well with our modern tendency to portray the Mechanism as a manifestation of a »rational« cosmology, and in none of its other predictive functions is a concern with astrological beliefs so demonstrable.

Catarchic astrology differed from the other principal kinds in that it was to some degree accessible to lay users without the need to consult an astrologer (Jones 2017, 236). According to a widely held principle, the character of a day as favourable for important actions or not depended on the »aspects« or angles between the Moon and each of the planets in the zodiac, with alignment in the same zodiacal sign, the diametrically opposite sign, or signs separated by one, two, or three intervening signs having definite positive or negative consequences. A common aid for making these evaluations was an *ephemeris*, a sort of calendar table giving the Moon's calculated position day by day through each month of the year, together with positional information for the slower-moving planets. In principle it would seem at first that a mechanised planetarium like the front dial of the Antikythera Mechanism would offer a visual alternative to an *ephemeris*, perhaps with attachments to the pointer or ring representing the Moon to highlight the places of the zodiac where other bodies would be in aspect with the Moon. However, it would not have worked very well, at least so long as the gearwork was comparable to that of the Antikythera Mechanism, because the displayed positions of the Moon were subject to rather large errors (Edmunds 2011), while the resolution of the display was not fine enough to indicate the times of day or night when the

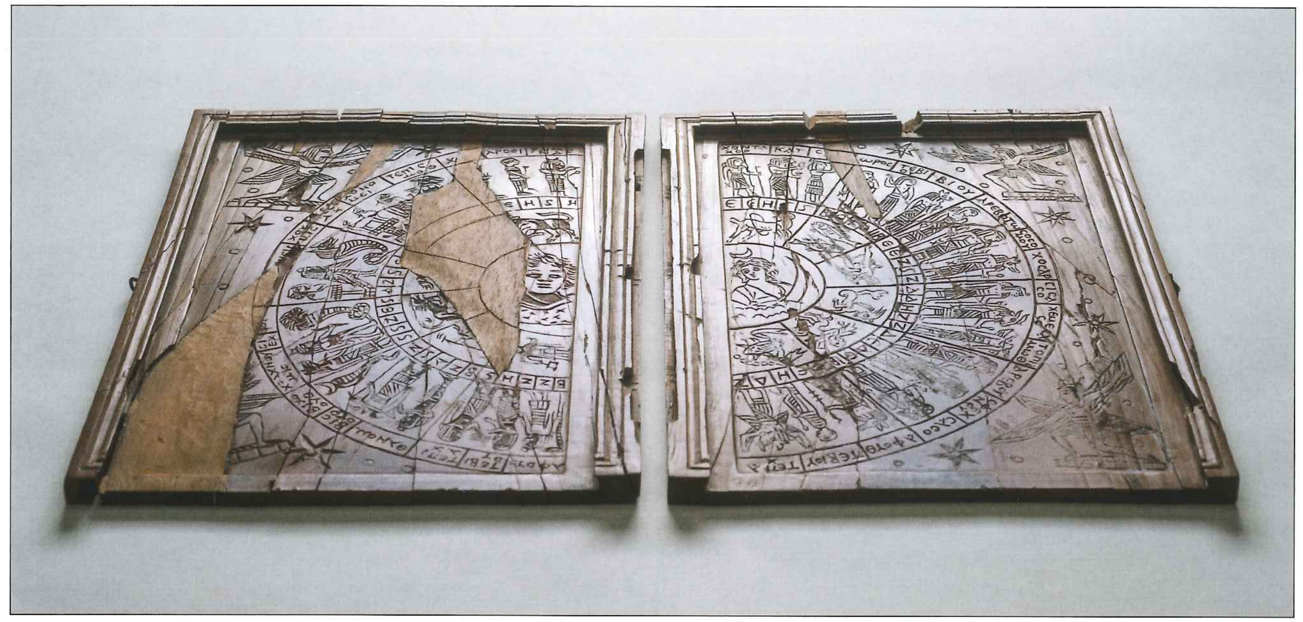

Fig. 7 Astrologer's boards for displaying a horoscope, ivory and wood, 2nd century AD, found at Grand (Vosges), France. Concentric rings divide the zodiac into its individual signs, »terms«, and decans, with busts representing the Sun and Moon in the middle. Musée départmental d'art ancien et contemporain, Épinal.

Abb. 7 *Astrologische Tafeln für die Darstellung eines Horoskops; Elfenbein und Holz, 2. Jh. n. Chr., Grand (Vosges), Frankreich. Der Tierkreis ist mit konzentrischen Kreisen in die individuellen Tierkreiszeichen, »Perioden« und Dekane eingeteilt. Die Büsten in der Mitte stellen Sonne und Mond dar.* Musée départmental d'art ancien et contemporain, Épinal.

Moon crossed the boundaries of zodiacal signs, changing the day's character at the moment of transition.

The central activity of an ancient astrologer, meanwhile, was to make pronouncements and forecasts concerning an individual based on the individual's horoscope, the configuration of the Sun, Moon, and planets in the zodiac and with respect to the local horizon and meridian at the moment of the individual's birth. Hence a common term for an astrologer, one of the few that specifically designated this profession as distinct from astronomers or mathematicians, was *genethlialogos*, »nativity-interpreter«. Horoscopic astrology, like catarchic astrology, did not involve any observation of the heavenly bodies, but depended on computed data. Typically, a client would provide the astrologer with a birthdate and time and, if needed, the place of birth (the client's own, or perhaps those of a child or other relation). Normally the astrologer would then consult almanacs – tabulations of precomputed zodiacal positions of the heavenly bodies covering a span of past dates – or numerical tables designed to enable such positions to be calculated for any given date, and compile a list of the positions of the Sun, the Moon, and the five planets on the given birthdate. Using other tables or methods of calculation, the astrologer would also determine the ascendant, that is, the point of the zodiac that was rising on the eastern horizon at the moment of birth, and, optionally, the other points of the zodiac that were crossing the horizon and meridian planes. The Greek term for the ascendant, *horoskopos* or »hour-watcher«, is the origin of the modern designation of the entire record of the celestial configuration of the nativity as a »horoscope«; in antiquity it might be called a *thema* or *diathema*, »disposition«. The astrological interpretation pertaining to the individual was then composed out of a vast repertoire of assumed significances of particular combinations of the astral data, which was recorded in astrological manuals, though a good astrologer probably committed much of it to memory.

The client could take away a written copy of the horoscope: we have hundreds of such personal horoscopes on papyri from Greco-Roman Egypt, and others on different media, including graffiti written on walls[2]. Most are terse lists of the data following the name and birthdate of the individual; rarely, the data are represented in a circular diagram; and a client who was willing to pay for it could obtain a more extended prosing-out of the horoscope taking up a substantial length of papyrus roll, sometimes in a calligraphic hand. No matter which format was used, however, the written horoscope hardly ever contained any statements explaining the meaning of the astronomical configuration for the individual who was born with it. This must have been conveyed in an oral consultation.

Something of the powerful emotive experience a consultation could assume is conveyed by an anecdote that Suetonius records in his *Life of Augustus* (94.12), pertaining to a period in 45–44 BC when Octavian, the future Augustus, had been sent by his soon-to-be-assassinated great-uncle Gaius Julius Caesar to Apollonia in Epirus for the sake of his education. Octavian and his friend Agrippa went to visit the studio (*pergula*) of the astrologer (*mathematicus*) Theogenes. Agrippa's turn to provide his nativity data came first, and Theogenes forecast for him »great and almost unbelievable things«. When his

2 Neugebauer/van Hoesen 1959; Baccani 1992; Jones 1999; Heilen 2015, I, 213–330.

turn came, Octavian, »out of fear and shame that he might be found out to be lesser«, resisted revealing his own birthdate; when he finally yielded to entreaties (from Agrippa? from Theogenes?) and stammered out the date, Theogenes »leaped up and reverenced him«.

Suetonius elides some steps that would surely have stretched out these rather histrionic proceedings. The birthdates, presumably expressed in the irregular Roman calendar preceding Julius Caesar's reform, which had just recently been instituted, and with the birthyears perhaps designated by the Roman consuls, would have had to be converted somehow into whatever calendar system Theogenes's tables employed, possibly the Egyptian calendar with years counted, say, from the death of Alexander (323 BC). Then Theogenes would have had to resort to his almanacs or tables to compile the horoscope and draw his astrological inferences from it. This could hardly have taken less than a couple of hours, or perhaps he told the young men to come back tomorrow. We are not told whether Theogenes showed them the actual horoscopic configuration, but this was evidently part of many consultations, and for greater impact it could be displayed visually by arranging markers such as coloured stones on a circular zodiacal board. Several such boards survive (Heilen/Greenbaum 2016, 126–134) (Fig. 7), and the manner of their use is vividly illustrated in the fanciful tale of the rascally pharaoh-magician Nectanebo's seduction of Alexander's mother Olympias in the fictional *Life of Alexander* of pseudo-Callisthenes (3rd century AD?)[3]. Nectanebo, having been stricken with desire for Olympias at first sight, tells her that he is learned in many arts of divination, including horoscopy, and he pulls out an ivory horoscope board, ostensibly to answer her inquiries on the basis of her horoscope but covertly to check whether her horoscope was compatible with his own:

> »While saying this, he brought out a precious royal board, which words cannot adequately describe, made of ivory and ebony and gold and silver, inscribed in three belts, having in the first circle the 36 decans, in the second the 12 zodiacal signs, and in the middle the Sun and Moon; and he put it on a stool. Then, likewise opening a little ivory box, he emptied out the seven stars and the *horoskopos*, comprising eight intaglios, and composed and endowed the vast heavens with light in a little circle, first setting down the Sun made of crystal, the Moon of adamant, Mars of blood-red stone, Mercury of green stone, Jupiter of ethereal stone, Venus of sapphire, Saturn of serpentine, the *horoskopos* of marble. And he said, ›Tell me, Queen, the year, month, and day and hour of your birth‹. And when she had stated them, Nectanebo calculated his own and her nativities, to see if they had a compatible arrangement of stars«[4].

This bit of theatre would have been enacted over and over, if a bit less grandly, by genuine astrologers to impress their clients with a picture of the cosmos caught in the moment of shaping a puny human's life.

Magician though he was, pseudo-Callisthenes's Nectanebo deploys a zodiac board that was much like the extant examples, though fashioned of the richest materials; a static, two-dimensional snapshot of the ever-moving three-dimensional cosmos (Fig. 8). When the poet Nonnus of Panopolis (5th century AD?) imagines a divine astrologer, the prophetic god Astraeus, casting and interpreting the horoscope of Persephone for her mother Demeter, he provides him with a *moving* image of the cosmos, a true sphere, though small enough to be set on the lid of a chest, and by setting it spinning by hand, he causes the *ersatz* heavenly bodies to cycle about into the positions they held at the ill-fated daughter's nativity.

Astraeus's microcosm calls to mind M.T. Wright's ingenious conjectural reconstruction of an Archimedean mechanical globe, whose gearwork, simulating the planets' motions, is driven simply by imparting a spin that represents the daily revolution of the celestial sphere about the Earth in a geocentric cosmology (Wright 2017). Wright's globe, if its like really existed in antiquity, would not have been a practical astrologer's tool, because, operating as it does on a time scale counted in single days, it would have required many thousands of hand-imparted turns to set the simulated date to that of a nativity that could fall anywhere within a span of several decades. But it is tempting to suggest that Nonnus was inspired not merely by the static device of an astrologer's zodiac board but by a mechanical version that, like the Antikythera Mechanism's front face, as we conjecture it to have looked and operated, enabled the astrologer who could afford such a contrivance to stupefy the client with an array of coloured simulacra of the heavenly bodies dancing their courses into the fatidic pattern of the horoscopic instant. The design of the dial might differ from what we reconstruct for the Antikythera Mechanism, giving up the representation of relative distances of the heavenly bodies from the Earth, which was not of much concern in astrology, and instead incorporating the astrologically important divisions of the zodiacal signs into decans and other so-called »dignities«, as was done on zodiac boards.

In the context of this horoscopic application, the mechanism would function simultaneously as a calculating device (circumventing the need to go off to the back room of the astrologer's studio to consult tables) and a wonder-working display. Admittedly it would not yield all the critical information for the horoscope, since it would operate on a scale of temporal intervals larger than a day, not on the short-time scale in which the zodiac revolves relative to the horizon and meridian, generating the rapidly changing ascendant and midheaven points. Those things too, however, could have been found visually rather than by calculation, and before the very eyes of the client, using a different variety of analogue calculator, an armillary comprising fixed rings for the horizon and meridian, graduated mobile rings for the ecliptic and celestial equator, and perhaps, to bring out the idea of the armillary as a model of the cosmos, a little terrestrial globe in the middle. The presence of images of ringed globes – albeit often with

3 *Historia Alexandri Magni, recensio vetusta* 1.5–7 in Kroll 1926; translation by A. Jones.

4 *Historia Alexandri Magni, recensio vetusta* 1.5–7 in Kroll 1926; Nectanebo then proceeds to answer Olympias's question whether her husband is about to abandon her, self-servingly laying the ground for his magic-aided seduction and siring of Alexander.

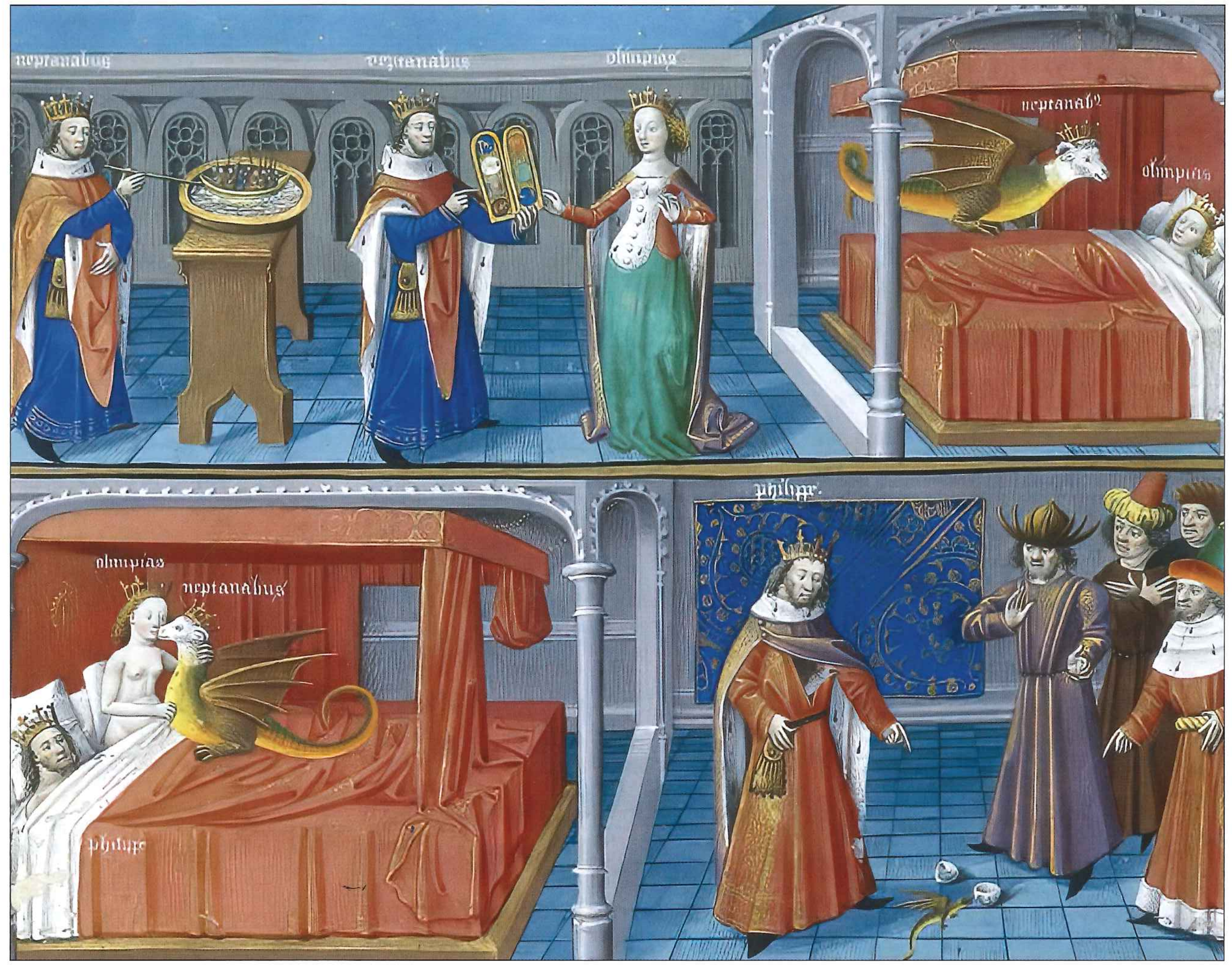

Fig. 8 Episodes from Nectanebo's seduction of Olympias, illustrating Vincent de Beauvais's *Speculum historiale*, 1463, Bibliothèque nationale de France MS Fr. 50 f. 120v. In the top centre, Nectanebo shows Olympias the astrological boards, as imagined by the medieval artist, Maître François.

Abb. 8 *Episoden der Verführung der Olympias durch Nektanebos aus dem* Speculum historiale *von Vincent de Beauvais, 1463, Französische Nationalbibliothek, MS Fr. 50 f. 120v. In der Mitte oben zeigt Nektanebos Olympias die astrologischen Tafeln; nach dem Mittelalterkünstler Maître François.*

Fig. 9a Armillary sphere represented in the pediment of the temple complex at Aquae Sulis (Bath), United Kingdom, 1st century AD (?), Roman Baths Museum.

Abb. 9a *Armillarsphäre in einer Darstellung am Giebeldreieck des Tempelkomplexes von Aquae Sulis (Bath), Großbritannien, 1. Jh. n. Chr. (?), Roman Baths Museum.*

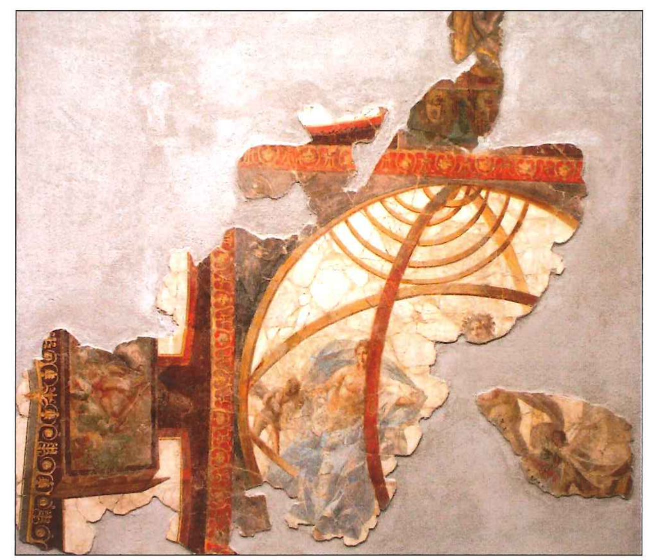

Fig. 9b Roman wall painting representing a somewhat garbled armillary sphere, 1st century BC or AD, Stabiae (Castellammare di Stabia), Italia, Antiquarium Stabiano.

Abb. 9b *Römische Wandmalerei mit einer etwas schwer erkennbaren Armillarsphäre, 1. Jh. v. Chr. oder 1. Jh. n. Chr., Stabiae (Castellammare di Stabia), Italien, Antiquarium Stabiano.*

garbled geometry – in Greco-Roman visual culture (Fig. 9a–b) is perhaps an indication that it was not only in specialised astronomical settings that such objects could be seen[5].

Conclusion

Since Price began publishing articles drawing attention to the Antikythera Mechanism (the earliest preceded his first direct examination of the fragments by several years), modern interest and astonishment at this artifact has focused on the technological aspects and its place in the history of calculating devices. Gearwork technology is not well represented in the surviving Greco-Roman mechanical literature, and a device that employed complex, multi-branching gear trains to generate rates of output rotations in nontrivial, scientifically meaningful ratios was a revelation, whereas at first the scientific goals of this apparatus appeared to be at a rather modest level compared with what we knew Hellenistic astronomy was capable of. Even the discovery (Freeth et al. 2006) that the Mechanism employed a pin-and-slot coupling of epicyclic gears (Wright 2005, 61 f.) to effect a periodic variation in the apparent speed of the Moon, such as would result from uniform motion along an eccentric circular path with a slowly advancing apogee, tended to raise the Mechanism's reputation on the mechanical as much as on the astronomical side. It continues to be popularised under the sobriquet, misleading in more ways than one, of »the world's first computer«.

For the most likely ancient possessors and users of devices like the Antikythera Mechanism, their real value was of a different kind. The teacher of natural philosophy had little need of such an object's computational power, while for the astrologer it was just a more expensive alternative to almanacs and tables, and not necessarily one that required less effort to use. For both, the unique power of the mechanism lay in its visual impact on student or client, its capability to collapse space and time so that the wondering gaze could embrace the orderliness of the cosmos, its dominion over the human world, and the prestige of the owner as well.

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5 Arnaud 1984, 73–77; von Boeselager 1983, 56–60 with Fig. 29–30; Berggren/Jones 2000, 38–40; 112–117.

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