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Chapter Three

The Antikythera Device: A Working Model of the Cosmos

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A Working Model of the Cosmos

By: Alexander Jones

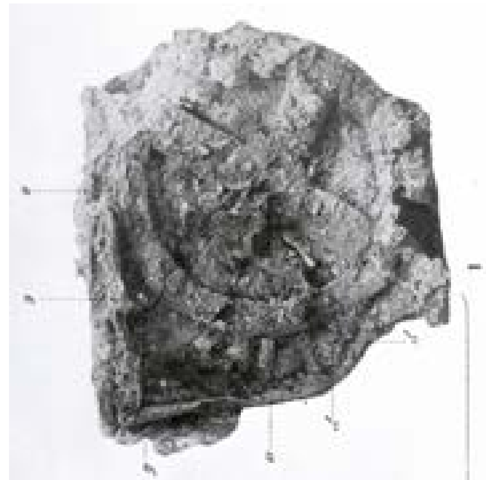
All cultures create models of the cosmos in words and images; the ancient Greeks were the first to make a mechanical working model of the cosmos.

In the spring of 1900, a group of Greek sponge divers en route to their usual diving grounds off North Africa chanced upon the site of a shipwreck dating from about 60 BCE off the small island of Antikythera, between Crete and the Greek mainland. For nearly a year, the divers labored with assistance from the Greek navy and archeological service to recover objects from the wreck, including bronze and marble statues, fine quality glassware, and other high-end items; in other words, a commercial cargo of luxury goods from cities of the

Above: Antikythera, Greece, and the Aegean. (nature.com)
Below: Sponge divers, archeologists and ministry officials, and the officers and crew of the naval transport ship Mykali at Antikythera in 1901. (Photo: Alexander Jones.)

Aegean and eastern Mediterranean, heading for markets in Italy or elsewhere in the western part of the Greco-Roman world.

Among the recovered objects deposited in the National Archeological Museum in Athens were a few heavily corroded slab-like fragments composed mostly of bronze plate. These went unnoticed until Spyridon Stais, the former minister of education who had negotiated the government's sponsorship of the diving operations, paid the Museum a visit on May 18, 1902 (according to the Julian calendar still used then in Greece, equivalent to May 31 in the Gregorian calendar). Stais noticed gears and tiny engraved Greek lettering on the fragments, and within a few days it was realized with excitement that they were the remains of some kind of astronomical device.

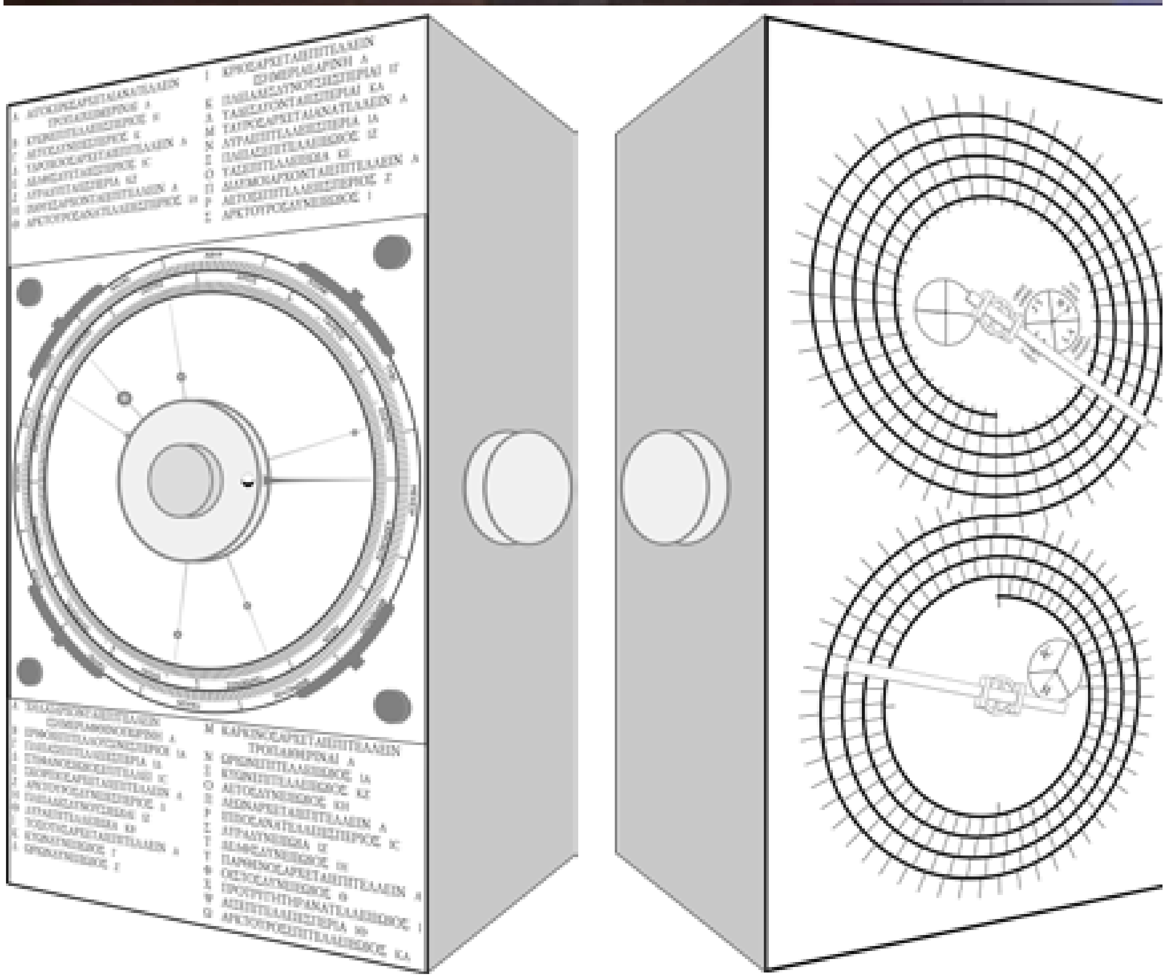

Fragment A, the principal fragment containing 27 of the 30 surviving gears, as it was in 1903 before conservation and cleaning. (Photo: Alexander Jones.)

The first big advances in making sense of the fragments were achieved by Derek de Solla Price (1922-1983), a British historian of science and technology. From the late 1950s through the early 1970s Price made several visits to Athens to study them, and through collaboration with Haralambos Karakalos, a nuclear physicist, he obtained the first x-ray radiographs of the main fragments, revealing gears and other mechanical elements that were hidden behind the surface plates. More recently, Michael T. Wright (in collaboration with Allan Bromley) and an international team called the Antikythera Mechanism Research Project have augmented and corrected Price's work using direct observation, radiography, x-ray computed tomography, and reflectance transformation imaging.

As a result, we can now say with a great deal of confidence what the Antikythera Mechanism—the name is Price's—looked like, what it did, and, in large part, how it worked. It has turned out to be the most complex and information-rich artifact of ancient science that has ever come to light.

The Antikythera Mechanism was a greatly accelerated simulator of the cosmos, as Greek astronomers around 100 BCE understood it, from an Earth-based perspective.

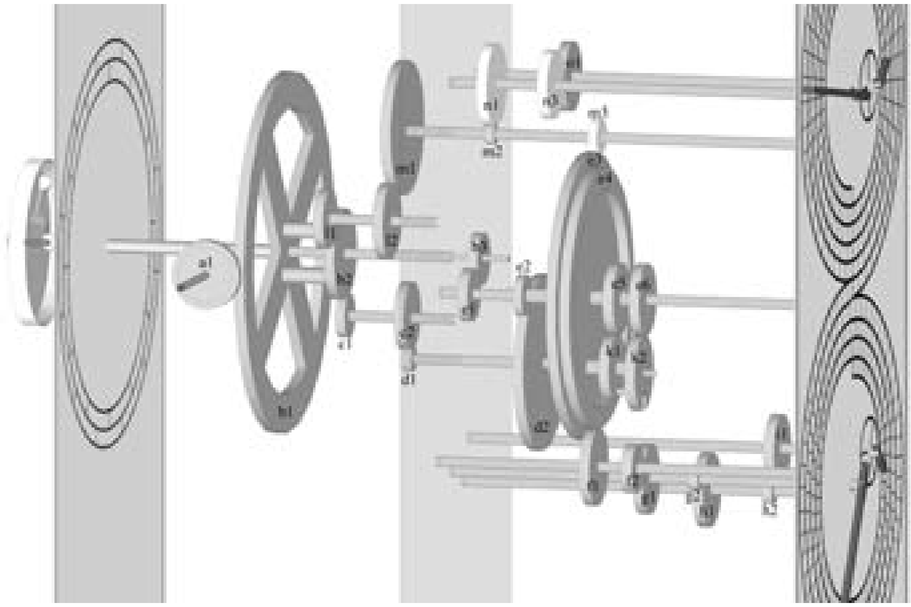
Imagine a box, slightly over a foot tall and half a foot wide, and perhaps four or five inches from front to back. The top, bottom, and sides were a wooden frame, while the front and back were bronze plates bearing various dials with moving pointers. In the middle of one side was a knob that could be turned by hand. Turning the knob clockwise meant going forward in time, at a rate of about one year for every five complete turns, and turning it counterclockwise meant going backward.



Top: The 82 known fragments as displayed currently in the National Archeological Museum, Athens. Most of the small fragments were separated from the main ones during the 20th century. (Photo: Jason Ramos)

Below: Reconstruction of the Antikythera Mechanism's exterior, front and rear views. (Alexander Jones)

On the back face there were five dials whose pointers indicated the passage of time according to a variety of time cycles ranging from four years (the cycle of the Olympic Games and other athletic festivals celebrated by the Greeks) to 76 years (the shortest calendar cycle simultaneously containing whole numbers of days, lunar months, and solar years). On the front, one big dial with seven pointers radiating from its center showed where an observer on Earth would see the Sun, the Moon, and the five planets visible to the naked eye along to a 360° zodiac scale. As one turned the input knob at a steady rate, all the pointers on the back dials would revolve at different but steady rates because they are all measuring time, but the pointers on the front would continually change in speed and some would intermittently reverse direction, just as the planets in the sky appear to do.



Exploded view of the gearwork driving the solar, lunar, and calendrical outputs. Darker gears are at least partially extant, paler gears are restored. (Image by and ©M. G. Edmunds)

The Greek and Latin literature on mechanical devices that has come down to us contains descriptions of only a few gearwork devices, chiefly odometers. The only extant example other than the Antikythera Mechanism itself is a rather simple and crude attachment to a portable sundial from about AD 500 that allowed the user to set by hand a display of the days of the week and of the lunar month. The Antikythera Mechanism was far more complicated than anything else we know of until the late Middle Ages, and it used several kinds of gearing (crown gears, epicyclic gearing, pin-and-slot engagement) that are otherwise unattested in antiquity.

Of the thirty gears that survive, twenty-nine belonged to the part of the mechanism that dealt with time cycles, eclipse prediction, the Moon’s phases, and the movements of the Sun and Moon through the zodiac. A few additional gears—four at a minimum—have to be restored to complete this module, but in all major respects we know not only what the outputs were but how they were connected to the input through a branching system of gear trains. On the other hand, the gears that led to the pointers for the five planets (Mercury, Venus, Mars, Jupiter, and Saturn) on the front dial are lost, except perhaps for the one loose gear that does not fit into the Sun-Moon-chronology module, but we know that these pointers existed, and to a considerable extent how they behaved, from information in texts inscribed in Greek on two extra plates that accompanied the Mechanism, perhaps serving as covers.

Both the extant gearwork and the inscribed texts tell us a great deal about the astronomical theories that the designer knew and was trying to emulate. Greek astronomy around 100 BCE was undergoing significant transformation through contact with the contemporary, but more mathematically advanced, astronomy of Babylonia and also in response to the demand coming from the relatively new but hugely popular practice of horoscopic astrology for positions of the heavenly bodies calculated for arbitrary dates, on the basis of which astrologers generated their prognostications.

The Antikythera Mechanism's handling of lunar motion, calendars, and eclipses was almost entirely based on two Babylonian period relations, the 19-year period that provided the structure of the Babylonian calendar from about 500 BCE on, and the 223-month Saros eclipse cycle. The mechanical basis of its simulation of the Moon's varying apparent speed, however, conforms to Greek theories based on combinations of circular motions such as those known to have been assumed by Hipparchus around 140 BCE. The theories behind the representation of the planets' motions were also geometrical in the Greek manner, and the assumed periodicities were not Babylonian.

How does our knowledge of the Antikythera Mechanism affect our understanding of the Greco-Roman world? Obviously it is a remarkable demonstration of the capability of a metalworking shop (possibly on Rhodes) to design and execute intricate precision machinery, likely under the guidance of a mathematician-astronomer collaborating with an expert and inventive mechanician. But it is also a striking illustration of the distinctive role of public science in this civilization. It was, after all, almost certainly not a tool of specialized research, nor (I would argue) was its primary purpose to calculate quantitative data, notwithstanding frequent modern characterizations of it as an ancient "computer."

As allusions to comparable devices (sphaerae) in ancient literature suggest, it was probably an educational tool, a visual and dynamic counterpart of textbooks of astronomy written for the educated layman, and also a proof of the power of the human intellect and indeed of God's. For as the Roman statesman and philosopher Cicero wrote about a similar astronomical mechanism owned by the Stoic Posidonius, "If someone took to Scythia or Britain this *sphaera* that our Posidonius has recently made, each turning of which produces the same behavior for the Sun and Moon and five wandering stars that is produced in each day and night, who in those barbarian lands would question that this *sphaera* was fashioned by reason?" (Cicero, *On the Nature of the Gods* II 88)

Alexander Jones is Leon Levy Director and Professor of the History of the Exact Sciences in Antiquity at the Institute for the Study of the Ancient World at New York University. He is the author of A Portable Cosmos, Revealing the Antikythera Mechanism, Scientific Wonder of the Ancient World (Oxford University Press, 2017).