

# Decoding the Heavens: A 2,000-Year-Old Computer— and the Century-Long Search to Discover Its Secrets

*Reviewed by Christián Carman*

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**Decoding the Heavens: A 2,000-Year-Old  
Computer—and the Century-Long Search to  
Discover Its Secrets**

*Jo Marchant*

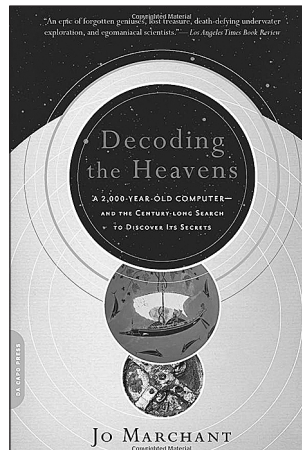
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In 1980, Nobel Prize winner Richard Feynman visited the National Archaeological Museum of Athens. While he saw incredibly beautiful statues that expressed the best of Greek art, he became fascinated with just one object: item 15,087. In a letter to his family, he said that he didn't see anything really unusual in the museum except for one thing: "Among all those art objects there was one thing so entirely different and strange that it is nearly impossible. It was recovered from the sea in 1900 and is some kind of machine with gear trains, very much like the inside of a modern wind-up alarm clock. The teeth are very regular and many wheels are fitted closely together. There are graduated circles and Greek inscriptions. I wonder if it is some kind of fake."

Where did this object come from? At the beginning of the twentieth century, a group of Greek sponge divers, led by Dimitrios Kontos, concluded their fishing season in North Africa and returned home. On their way back, while they crossed the channel between Kythera Island and Crete, a severe storm forced them to stop on a small island named Antikythera. After the storm they began to dive off the coast of Antikythera, hoping to supplement



their catch. One of the divers, after diving down 42 meters, returned clearly upset, saying he had seen human bodies at the bottom of the sea. Captain Kontos immediately descended and returned minutes later holding a human arm—of a bronze statue. It was the first archeological shipwreck and, so far, the most important.

The treasures found fill several rooms today at the National Archaeological Museum of Athens: beautiful bronze statues, jewelry, weapons, and furniture. But there were also fragments that, when they split open, contained what appeared to be some kind of navigation device, the device that caught Feynman's attention and that is now known as the Antikythera Mechanism. *Decoding the Heavens* by Jo Marchant tells the story of this device.

A study of the ceramics and other daily-use items found in the shipwreck—including some coins recovered in a second expedition led by Jacques Cousteau in the 1970s—concluded that the objects date from around 80–50 BC. A sample of the wood of the ship dated by the carbon-14 method showed that the ship had been built at least 100 years before the shipwreck. The fragments of the Mechanism show clear signs of having suffered the inhospitality of the sea for two millennia. However, it is still possible to see clearly many of the gears in the Mechanism, some fragmented scales, a few pointers, and several words in Greek.

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The style of the script of these inscriptions helps to date the construction of the Mechanism between 150–100 BC, although an error of a century before or after those dates cannot be ruled out.

After a century of research, we have a fairly complete idea of the structure and operation of the Mechanism: it was a sort of computer that, when one moved a handle, predicted astronomical and other events through a series of pointers on different scales. The entire Mechanism was made of bronze and was protected by a wooden case the size of a large dictionary. The fact that the Greeks could have built such a complex geared mechanism is certainly revolutionizing our knowledge of the history of technology. Not only is the Mechanism fascinating in itself but the research into its use and the history of its discovery make a compelling story. Marchant's book is simply captivating as it highlights the mysteries of the research in a way more reminiscent of crime novels than of scientific books.

Important research on the Antikythera Mechanism was done in the first half of the twentieth century, but a detailed understanding of its structure and function had to wait until the 1950s. Derek de Solla Price, a scholar from Yale University, with the help of Charalambos Karakalos, was the first to obtain radiographs of the fragments to see in detail how many gears the mechanism had, how many teeth each gear had, and how they were connected. In this way he discovered, for example, that one pointer would show the position of the sun in the zodiac and another the position of the moon and that the moon pointer revolved 254 turns for every 19 turns of the sun pointer (the ancient Greeks knew that in 19 years there are almost exactly 254 lunar sidereal months).

In one of the extant fragments of the Antikythera, there are remnants of two concentric rings. On the inner ring one can read the word *XELAI*, which means Libra in Greek. The marks inscribed on this ring allow us to conjecture that there were 360 marks divided into twelve sections, each one corresponding to a zodiac sign. We can then guess that this was a part of a zodiac dial on which pointers showed the positions of the sun and moon. On the outer ring we can read the names of months in the Egyptian calendar. We can also infer that that ring had 365 divisions, corresponding to the 365 days of the year. We know that Greek astronomers used the Egyptian calendar because of its simplicity, since it always had 365 days without leap years. Because it takes the sun one year to traverse the zodiac, one arrow could show both the position of the sun in the zodiac and the day of the year.

In the inner ring one can see some small letters close to the marks. They are in alphabetical order: alpha, beta, gamma, etc. Price deciphered the meaning of these letters. According to his analysis, they belong to a *parapegma*, which was

a stellar calendar that indicated which stars rise or set at the sunset or sunrise. So, when the sun pointer pointed to a certain letter, one could read on the front of the Mechanism what star would rise or set that day. Usually, these *parapegmata* also include some atmospheric phenomena, such as winds, storms, etc., but as far as we know, there is no mention of atmospheric phenomena in the Antikythera Mechanism.

Price thought that, with his research, the Antikythera Mechanism would be accorded a distinguished place in the history of astronomy and technology, but this was not the case. Otto Neugebauer, the greatest authority on the subject and Price's mentor, published the monumental *History of Ancient Mathematical Astronomy* in 1975, a couple of years after Price's work on the Antikythera. HAMA, as it is often called, comprises 1,456 pages over three volumes and mentions the Antikythera only in one footnote—and a very critical one indeed. Someone said metaphorically that this constituted the second shipwreck of the Antikythera Mechanism.

But the story continues. The next protagonist is Michael Wright, who was curator of mechanical engineering at the London Science Museum. Having read Price's work, Wright found several errors and has worked hard since the 1990s to correct them and to discover new features of the Antikythera. Wright designed and built with his own hands a tomography scanner and for several summers traveled to Athens to study the fragments with an Australian colleague, Alan Bromley.

We can mention three important contributions of Wright. First of all, he proposed that the Mechanism should be understood as a planetarium, i.e., that it shows not only the positions of the sun and the moon but also of the five planets known at the time the Antikythera was built: Mercury, Venus, Mars, Jupiter, and Saturn. There was one pointer for each planet, all concentric like the hands of a clock and each turning at its own speed, with those of the moon and sun and sharing the same zodiac scale. New discoveries published last year confirm Wright's intuition. In addition, the planetary pointers exhibit retrograde motion that reflects the known retrograde motion of the planets. Nevertheless, the exact way in which the Antikythera models planetary motion is conjectural: the gears are missing, so the proposals for how the Mechanism worked cannot be directly tested.

The second of Wright's proposals is related to a strange cap found in the back of one fragment of the Antikythera. The cap has a hole in one of its borders and a gear close to its center. Wright realized the purpose of this strange device. The cap was attached to the moon pointer so that the cap went once around the dial each sidereal month. The gear on the cap turns a little sphere, which rotates at the rate of the synodic month. The

sphere, representing the moon, was probably half white (or silver) and half black, and as it rotated it showed the lunar phases.

The third of Wright's contributions is related to the calendar. As already mentioned, the Egyptian calendar has 365 days without leap years. This means that, every four years, the calendar ring would be misaligned by one day with respect to the zodiac ring. Now, Price discovered that below the calendar ring there are little holes, one per day, but he didn't know why they were there. Wright realized that these little holes serve to move the calendar ring by one day. He showed that the calendar ring was not attached to the Mechanism, but it was movable and it could have had pins that, if located in these holes, would keep the ring fixed.

At the beginning of the new millennium, the British filmmaker Tony Freeth and the astronomer Mike Edmunds (Cardiff University) created the Antikythera Mechanism Research Group, an international multidisciplinary team whose aim is to decipher the mysteries of the Antikythera. The team got permission to work directly with the fragments and to apply two new technologies to their examination.

Freeth convinced X-Tek, a company specialized in building very powerful tomography scanners, to build a new scanner designed to look at the Antikythera fragments. The scanner was able to take ten images per millimeter. After uploading all the information into their software, the team was able to reconstruct the fragments in three dimensions, greatly assisting new research.

Second, the team used a technique known as PTM (Polynomial Texture Mapping) developed by Tom Malzbender, an employee of Hewlett Packard, which involves taking pictures of an object with a fixed camera but with flashes at many different angles in such a way that, when you examine the pictures using special software, you can play with light and see even the slightest surface irregularity. This helps in the reading of the Greek characters and scale marks. Malzbender developed this technique so as to show shadows in a more realistic way in animated films. Later he realized that the technique would be very helpful for reading ancient inscriptions.

Using these two technologies, Freeth's team has succeeded in reconstructing much of the Mechanism and has made important new discoveries. One is related to the way the Mechanism showed the sidereal motion of the moon. Although the moon never exhibits retrograde motion, the irregularities in its motion are notorious. Of course, Greek astronomers had a geometrical model reflecting this motion using an epicycle and a deferent. Now Freeth and his team discovered that the same nonuniformity is present in the Antikythera's pointer for the moon, so that the pointer has the same motion that the moon would have according

to the geometrical Greek model just mentioned. This nonuniform motion was performed by what is perhaps the most striking and surprising feature of the Antikythera Mechanism: the pin-and-slot device for producing the irregularities in the lunar motion. This clever device, mentioned nowhere in the ancient astronomical literature, produces a back-and-forth oscillation that is superimposed on a steady progress in longitude. The key part of the device is the pin of one gear that, when introduced in a slot in another gear slightly off-center with respect to the first, moves the second gear at the average rate of the first one. However, because of the eccentricity, the second gear has a nonconstant motion. This nonuniform motion is transmitted through a gear chain to the moon pointer.

Freeth's team also managed to understand almost everything on the back of the Mechanism. Their work suggests that on the back of the Mechanism there were two large dials, one next to and above the other, together with some subsidiary rings inside them. The upper ring was a complex luni-solar calendar, while the lower ring was an eclipse predictor.

The lower ring was divided into 223 cells (each corresponding to a synodic month) distributed over four turns of a spiral. Most cells are empty, but in the months in which an eclipse would take place, the cell indicated that an eclipse would happen, the time at which it would happen, and whether it would be a solar or a lunar eclipse. Eclipses repeat every 223 months in a pattern known as the Saros cycle. If a solar eclipse took place today, then 223 months from now a very similar solar eclipse would take place. Therefore, that pointer could be used for predicting eclipses indefinitely. But the prediction of the succeeding cycles is not perfect. From one cycle to another, the occurrence of eclipses shifts 8 hours. The shift is compensated for by a subsidiary mechanism inside the Saros ring: this subsidiary ring turns very slowly (one turn every 54 years, that is, every three Saros cycles), indicating whether one needs to add 8 hours, 16 hours, or nothing to the value of the time inscribed in the cell.

The luni-solar calendar on the upper back ring is based on the Metonic cycle. According to this cycle, 235 synodic months are almost exactly 19 years. Therefore, this calendar repeats every 19 years. It is interesting to note that, because every Greek city had its own calendar, the month names of the extant part of the dial allow Freeth's team to conjecture that the Mechanism was made to be used in Corinth or any of its colonies; one of them was Syracuse.

Now, we know that Archimedes lived in Syracuse, making him an extraordinary candidate for the originator of the Mechanism. It seems that the Antikythera Mechanism was built at least a decade after the death of Archimedes, so he probably is

not the maker of this particular device, but he could have started the tradition. As is patent from the complexity of the Antikythera, this is probably not the first such mechanism ever made.

The luni-solar calendar has two subsidiary dials inside: one revolved once every 76 years (i.e., four Metonic cycles) and indicated when one day had to be skipped in the Metonic calendar (once every four cycles) in order to correct it. The second—one of the most amazing—revolved one revolution every 4 years and was divided into four cells: in them we can read the names of the Pan-Hellenic games, so that the arrow indicates what games would be played that year: the Olympics, the Nemean games, etc.

So in one device you can learn the position of the sun and moon (and probably also the planets) in the zodiac, and the day of the year; you have an eclipse predictor that tells you the time and kind of eclipse, and you also know whether you have to add 8 or 16 hours to the time indicated; you have a luni-solar calendar that tells you which years have 12 and which have 13 months, which months have 29 and which have 30 days, which day would be omitted in case you have a 29-day month, when you have to omit one day every 76 years for correcting the calendar; and, finally, you know which

Pan-Hellenic games would take place that year. It was like a tablet PC of ancient times!

The research is still in progress, and every year new discoveries arise. The Antikythera Mechanism probably still has some mysteries to reveal, and the best way to be prepared to understand it is to read Jo Marchant's book.

Marchant invested several years in research, and the dedication and seriousness with which she directed that research is reflected in the book. She does not avoid technical issues when they are necessary and usually presents them clearly. It is a self-contained book: you have in it all the astronomical and historical knowledge that you need to understand the story of the Antikythera. Marchant documents her sources well and also provides a Further Reading section. Inevitably, the book contains some imprecisions. Nevertheless, it is, all in all, an excellent book that tells a fascinating story in a fascinating way. *Decoding the Heavens* is, I think, required initial reading for anyone seeking an introduction to the story of the research into the mysteries of the Antikythera Mechanism.

## Book Review

# Seduced by Logic

*Reviewed by Judith V. Grabiner*

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**Seduced by Logic: Émilie du Châtelet, Mary Somerville and the Newtonian Revolution**

*Robyn Arianrhod*

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In a world where over 30 percent of American Ph.D.'s in mathematics are earned by women, we forget how rare female mathematicians have been in the past. Counting the women with well-documented contributions to mathematics before the nineteenth century can be done on the fingers of one hand. Each of these women "made it" only because of highly unusual circumstances. For

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instance, in the case of Hypatia of Alexandria (c. 370–415 CE), her father was the mathematician Theon of Alexandria. Maria Gaetana Agnesi (1718–1799), who had an on-the-make father who showed her off as a prodigy, also benefited from liberal religious trends in eighteenth-century Italy. Sophie Germain (1776–1831) grew up in a Paris home that was a meeting place for intellectuals, and as mathematics in Revolutionary France became more widely accessible through lectures and notes from the École Polytechnique, adopted a male pseudonym to correspond with Lagrange and Gauss. The first actual European Ph.D., Sofya Kovalevskaya (1850–1891), came from an influential Russian family but had to contract a fictitious marriage in order to leave her home country to study mathematics in Germany. As Londa Schiebinger has documented in her magisterial *The Mind Has No Sex* (Harvard, 1989), various theories about the nonintellectual nature of women reinforced