AIA Lecture Program, October 2006

The Greek Planetarium: a new reconstruction of the Antikythera Mechanism

M.T. Wright,
Imperial College, London.

I am delighted to be here to speak to you, and I thank the *Archaeological Institute of America* for making it possible. *[I believe my good friend Marvin Bolt first put my name forward, and I am glad to repay, in this small way, the kind encouragement that Rod and Madge Webster showed me years ago when I first met them. It is a privilege to give this lecture dedicated to Rod's memory.]* I am here to talk about a mechanical marvel, an astronomical instrument from the Hellenistic world; but I must tell you how I started on the road that has led me to this room.

When I was a boy, my Greek master pressed me to read a recent book. John Chadwick's *The Decipherment of Linear B* was the enthralling story of the genesis and fulfilment of a boyhood dream: of how, building on the work of others – notably Alice Kober – Michael Ventris had learned to read Mycenaean Greek. And ever after that, I longed for my own Linear B to decipher. I planned to tell you how I found it, when I came to reject the accepted reconstruction of this artefact; how I went on to study it for myself; and how, decades later, I arrived at the better solution that is illustrated by my working model. As a lover of truth I would have discussed some remaining uncertainties, but I might have concluded by saying that my reconstruction was probably as good as any that could be achieved.

Then the sky fell down! Just a few days ago I saw the findings of other people working on this same artefact. While I spent time, relying on my own ingenuity, patience and pocket-money, the Antikythera Mechanism Research Project rolled into town with big money that bought them the best in modern imaging technology and a substantial support team; and it has paid off for them. They now propose a modification of parts of my reconstruction, and almost certainly they are right.

Tonight's problem is that I was shown this material in confidence. I won't confuse you by discussing features that I now think are incorrect, but I may not talk about the alternatives. However, most of my reconstruction remains unaffected; for example, with just a few hours at the bench making alterations, I shall be able to convert this model to agree with the new findings. It’s been rather harder to cut my lecture to pieces and join the bits differently, and you must forgive me if you notice gaps in what I say. These correspond to details that I may not mention.

I began to live my boyhood dream in 1974. I had left the study of Classics, in favour of Mathematics and Physics, and by then I was a junior curator at the Science Museum working on the history of mechanical engineering. One day a new publication caught my eye: *Gears from the Greeks*, by Derek de Solla Price, Professor of the History of Science at Yale. This was my enthralling introduction to the Antikythera Mechanism.

Price set the scene with a vivid description of the instrument’s accidental discovery, and I recommend his account wholeheartedly. Later writers have added spurious touches; I, on the other hand, will stick to the barest facts.

In 1900 some Greek sponge-divers sheltered from a storm in the lee of the small Greek island Antikythera. Safe after the storm, they explored the sea bottom in this unfamiliar place, and found the wreck of a ship with a cargo that included ancient statues. On reporting their find to the authorities, the divers were employed by the Government to recover what they could.

Many fine pieces were recovered, and a great mass of fragments. This “Antikythera Treasure”, now known to be the remains of a cargo of mixed luxury goods dating from about 86 B.C., mostly Hellenistic in origin, was all taken to the National Museum in Athens. The artefact that forms my subject was noticed there, amongst the smaller finds, some months later: corroded, encrusted fragments of bronze, but with some small toothed gears and Greek lettering showing on the surface.

Legible snatches of inscription indicated an astronomical purpose, so it became known as “the astrolabe”. It is no such thing, but the world over, any vaguely astronomical instrument of uncertain purpose tends to be called an astrolabe; it sounds so learned! In fact, there was no hope of understanding it, even after cleaning, until it had been subjected to radiography, and that done only in the early 1970s. X-rays revealed the great extent of detail hidden within the fragments, as though half a dozen alarm clocks had been squashed together, which led Price to offer a reconstruction of the instrument.

The central part of Price's paper was a treatment of the artefactual evidence and the reconstruction that he built on it. The largest fragment contains most of the gearing, and a piece of one of the dials. The next piece contains more of the dial, and the two fit together. Another substantial fragment includes a large corner of a separate dial. Price described a bronze instrument in a wooden case, with dials on two opposite faces connected by gearing inside, all probably moved by hand. Before talking about what the dials showed, here's a thumbnail sketch – hoping I won't insult the experts – of a little ancient astronomy.

Here's the Earth, at the centre of a sphere that carries the stars. Dűrer shows most of the stars cut away, leaving just rings and a circular band round the middle. The Sun, Moon, and planets move round this band, the Zodiac, while the whole thing – stars, Zodiac and everything on it – rolls over, day and night, and the Earth remains stationary at the centre. The Antikythera Mechanism is not concerned with the daily rolling motion, but with the slower motion of the Sun and Moon as they creep round the Zodiac.

The stars are grouped into constellations imagined to depict creatures with names. The ones on the Zodiac, "The Ram, The Bull, The Heavenly Twins, …" and so on, give us a convenient way of describing position along it. Here, for example is Taurus, the Bull, according to al-Sufi.

We can't see where the Sun is in the Zodiac directly, but we can judge its place by looking at the constellations that show up near it. Here our astronomer is looking at Taurus in the West, just after sunset. The Sun, just below the hill, is in the next constellation, Aries. As days pass he will see Taurus a little lower, as the Sun creeps along its back towards its head. One full circuit of the Sun round the Zodiac, say from Aries back to Aries again, is what we call a year, nearly 365¼ days. With Taurus in the evening sky, we know it is Spring.

The Moon travels much faster, making its circuit in a month, but here we need to be careful about definitions. New Moon, with the Moon immediately next to the Sun, was about a day ago, but our astronomer couldn't see that directly either. This is his first sighting of the new crescent, about a day later; and each night he finds the Moon higher, further to the left and fatter. After half a month it is Full, and he can see it rising in the East.

Meanwhile Taurus has disappeared from the evening sky, and it too appears in the East, just before dawn. And there, after 27 nights, is the Moon, back at the same place in Taurus. This full circuit of the Zodiac is one sort of month, the *tropical* or *sidereal* month of roughly 27⅓ days. But the Sun has moved on, and the Moon hasn't yet caught it up. It will be about another two days before our astronomer sees the New Moon once more, at sunset. The period from New Moon to next New Moon is the "synodic month", about 29½ days.

Astronomers expressed these awkward numbers in terms of one another, using *period relations*, and the Greeks knew a convenient one: in 19 years there are 235 synodic months or (235 + 19) = 254 tropical months.

Now we can appreciate Price's reconstruction. We begin with his gearing scheme. The central loop of gearing – coloured blue – begins at the centre and comes back to it again, with an overall gear ratio 19 : 254. The numbers tell us that this gearing connected pointers showing the movement of the Sun and the Moon in the Zodiac. The loop begins at a wheel for which one revolution represents a year – I call it the Mean Sun wheel – and ends with the spindle at its centre for which one turn represents a tropical month. Pointers, driven by these two, move over a Zodiac dial; but the central spindle and the wheel rotate in opposite directions, so Price introduced an extra wheel – purple – to reverse the motion and make the Sun and Moon move in the same direction across the sky.

Here is the "front" dial. The inner ring is the Zodiac, and the outer one is an annual calendar, on which the Sun pointer also indicated the date. You might set the instrument to a required date, and then read off the place in the Zodiac of the Sun and Moon.

The "back" dial had two displays. As the diagram shows – in green – the upper one was driven in a straightforward way from the Sun motion at the front, making it a sort of year counter, though Price was vague about the details. The arrangement for driving the other was more surprising.

You see – in yellow – two connections from the blue gearing to the orange section, which is a differential gear. Its function was to take the motions of the Sun and Moon in the Zodiac, from the front dial, and yield the difference between them through the red gears to drive a display at the lower back dial. The pointer there would rotate once in a synodic month, showing the age or phase of the Moon. After all, it is the *difference* between the motions of Sun and Moon in the sky that gives rise to the phases of the Moon.

Price called the instrument a "calendar computer", but he never actually explained how it might have been used, or for what. In a sense that did not matter. His essential point was that here, in what was *by centuries* the earliest known example of toothed gearing, was direct artefactual evidence for highly accomplished mechanical skill at an astonishingly early date. He closed his paper with a masterly appraisal of what this meant to the history of science and technology.

I was thrilled to read all this; but I was also troubled because I just couldn't follow all of Price's arguments. Then the reality of every-day work called, and I had to put the puzzle aside. That might have been that, except that nine years later – in 1983 – a man walked into the museum carrying parts of an instrument, engraved in Greek and including gear wheels.

I worked on this instrument with a colleague who demonstrated that it dated from about 500 A.D., making it the world's *second*-oldest geared mechanism. We called it the Byzantine Sundial-Calendar: portable sundial on the front, luni-solar calendar on the back worked by gears inside. Dealing with it from a mechanical point of view, this was my initiation into both ancient technology and archaeo-astronomy. News of a second Greek geared instrument brought Derek Price to London to meet us and see the instrument, just days before he died. I got impatient with delays in having work done, so I took a few days off and made this reconstruction myself, and learned a whole lot more about the instrument in the process. *And it was at a conference about sundials, where we had gone to announce our findings, that I met Madge and Rod Webster.*

So it was on this job that I first really discovered the value of making things as an aid to thinking. It brought me into contact with the scholarly world and some of its great characters. Moreover, it forced me to go back and read again through *Gears from the Greeks*. Nine years on, having gained a little confidence and a dash of scepticism, I saw why I hadn't followed Price's arguments: they were not sound, and probably his reconstruction was not right.

I don't say this to disparage Price's work, especially since mine has now, in turn, been improved upon, but to explain my motivation. Here was an important insight into scientific and technical history, supported by one artefact which seemed not to have been properly understood. Here was my Linear B, still waiting to be deciphered! Together with the late Allan Bromley, I went to Athens to examine the original for myself.

It was immediately clear that Price had missed a number of significant details and that a number of his observations were demonstrably wrong. In all, astonishingly little of his reconstruction seemed secure. Nothing could be taken on trust; every detail had to be investigated anew.

We needed our own radiographs. Now, the gearing lies in a number of closely-packed layers. A radiograph is merely a shadow-picture which does not distinguish the layers, and it was clear that Price had difficulty in sorting out which layer each wheel belonged to. So I devised and built apparatus to take to Athens for use with the museum's X-ray tube, which allowed us to carry out a simple form of tomography. By preparing and collating sequences of plates, we could determine the depths of individual features.

This technique produces images that are rather hard to read, not the sort of tidy computer-enhanced images that are now familiar as the output of CAT scanning. But the *resolution* of my images was first-class, and they provided very useful information on the internal mechanical arrangement.

A crucial point emerged about that blue loop of gearing that connects the Sun and Moon pointers. These wheels are at the heart of the gearing system, and they lie right in the middle of the biggest fragment. The diagram is drawn as though all the wheels were placed side-by side in a line, but in reality they are grouped in a cluster.

To the left is Price's drawing of what he thought he saw, with the gear engagements shaded. To the right is a close-up from one of my radiographs with circles drawn round the tips of teeth, showing engagements where the circles overlap a little and the tomographic sequence shows that the wheels are at the same level. Now compare the two, and you can see how Price was mistaken. The loop of gearing takes in two extra wheels, on a further arbor. These have equal numbers of teeth, so the ratio remains unchanged, but the extra wheel-pair reverses the sense of rotation.

This alteration tidies up Price's reconstruction by doing away with the need for the purple reversing wheel; with the extra wheel-pair included, the Mean Sun wheel and the central spindle now turn the *same* way. But in reality the alteration spells disaster, because it reverses one of the inputs to Price's differential gear, through the yellow connections. The consequence is that the differential would have generated not the difference but the sum of the motions of Sun and Moon, a quantity meaning …precisely nothing! So there was no quick fix for Price's gearing scheme; it had to be reworked from the beginning. My tomography solved the immediate problem, by showing that one of the yellow connections, an intelligent guess on Price's part, does not actually exist.

After getting the *arrangement* right, the next thing needed was a new estimate of the number of teeth on each wheel. Most of the wheels are incomplete and many are truly ruined. The spacing of the hand-cut teeth is in places alarmingly far from uniform. Therefore determining the numbers is a significant problem. I approached it by getting our radiographs digitized, and applying simple computer-aided analysis to the geometry. Data points taken from the images of the surviving teeth were fed into a program written by my son. Here they were analysed for circularity and spacing, and then compared to equally-divided geometrical "models", searching for acceptable fits, combining strict geometry with an element of experienced judgement as to just what would be workable.

In many cases my analysis showed a more secure result than that adopted by Price. In others there was a *wider* margin of uncertainty, typically where the wheel is badly wrecked and my detailed analysis shows that the spacing of the teeth is far from uniform. Overall, there was a gain. It was clear that there was no scope for teasing the numbers back and forth in the way that most earlier students of this instrument had done.

So now I was equipped to study the function of the gear train. One thing you notice when you look at this diagram is that the gearing is arranged in separate sections. This encouraged me to think about the sections separately, and enabled me to disentangle the problem, or so I thought. From the modified version of Price's diagram, we move to my version. With hindsight I can say that that this was a mistake; thinking in sections made me overlook the hint of a vital lost link between the green and the orange sections. I saw it and thought about it, but I put it down as evidence that the instrument had been altered.

We shall look at this back part of the instrument next, for several reasons. Price assumed that most of the instrument survives, but I will argue that quite a lot is lost from the front. So it is a reasonable plan to deal first with the part that we agree is reasonably complete, before talking about restoring what is not.

Applied to the geometry of the fragments of the back dial, the same computer-aided analysis led to a new understanding of its design. The scales are spirals: the upper of five, and the lower of four turns. This is an ingenious way of fitting a long scale, with many divisions, while keeping it legible. The analysis also corrected the spacing of the fragments, leading to a good estimate of the size and number of teeth of a vital wheel lost from the centre of the upper back dial, just at the break.

Taken together, these steps led to the discovery of the period of rotation of the main pointer on the upper back dial, 47 synodic months; in five turns the dial displays the 235 months and 19 years of the period relation that we met before. Further wheels, lost at the edges of the fragments, are restored to carry motion on to the subsidiary pointer. Traces of hidden lettering read in radiographs shows that each turn of this pointer indicated the 76-year Callippic period, which was used to keep count of long intervals of time between astronomical events. Besides serving as a basic counter, this display could be used in conjunction with the front dial to convert between the Egyptian solar calendar, used by astronomers, and any of the several lunar civil calendars used in Hellenistic times.

So much for the green section; now for the orange and red parts: with just one input, the orange part was changed from a differential gear with an impossible function to an assembly that modified the velocity ratio of the red train leading to the lower back dial. Price's use of this dial, as a display of the synodic month, looked less and less plausible. The synodic month is after all displayed on the upper dial, on a small scale, and again on the front dial, as you will see in a moment, in a beautiful and clear display of the Moon's phase. Besides, the arrangement of the dial, as a four-turn spiral, did not suit such a function. By elimination, the only function that seemed to fit, both mechanically and with reference to known astronomical preoccupations and interests of its time, was eclipse-prediction, a function strongly hinted at by one of the fragmentary inscriptions on the outside of the instrument. That deduction was correct, but the detail shown here is not.

We now turn to the front of the instrument. Here I agree with Price in having pointers for the Sun and Moon moving over the Zodiac dial, but this beautiful device for displaying the phase of the Moon, as part of the Moon pointer, is my contribution, reconstructed on the basis of a component stuck in the corrosion-products behind the dial. It relies purely on the movement of the Moon pointer past the Sun pointer to rotate the little ball, so it is quite independent of the other pointers that you see here. (We will come to them in a moment.) Exactly the same moon-phase device re-emerges as a feature of mediaeval clock dials, and there it almost always shows the day of the month as well. I have added a corresponding day-of-the-month scale here, as part of the Sun pointer.

Now you may recall that my revision of Price's reconstruction left the space between the Mean Sun wheel and the dial itself empty. Here is the Mean Sun Wheel.. There must have been a good reason why this wheel was made far larger than any other in the instrument, and the evidence is there if we have eyes to see it. Firstly, there are clear traces on the wheel of the loss of some further structure once built on it, Secondly, the wheel rotated about a fixed boss with a square top. Together these provide strong evidence that there was epicyclic mechanism here: wheels, carried round on the Mean Sun wheel, were made to rotate by running round a stationary central wheel which was fitted to the square.

In order to grasp what this might mean, we need a little more astronomy. One of the fundamental principles of Greek astronomy was the idea that the motions of the Sun, Moon and planets all ought to be capable of being described as combinations of uniform circular motions. This could be done by using epicycles: imaginary rotating circles stacked one on another, like a crazy mobile wedding cake.

We begin with the simple case of the Sun. Earlier, we settled for a picture in which the Sun moved round the sky in a circle. The snag was that careful measurement of the length of the seasons – from equinox to solstice, solstice to equinox, and so on, showed that the seasons were unequal in length; but in each season the Sun makes just a quarter of its circuit. In other words, the Sun goes round the Zodiac with varying speed.

About 140 B.C., Hipparchos devised a solar theory – a mathematical model for the sun's motion – according to which the Sun does indeed seem to move at constant speed around a circle, but the centre of the circle is shifted away from the Earth. When the displacement is correctly chosen, this fits the facts rather well.

Hipparchos himself recognized that it comes to the same thing if we add a constant offset to a circular motion that *is* centred on the Earth. Here is a demonstration; the Sun is perched on an epicycle that remains fixed in direction as the wheel it rides on turns round, and so it traces out the offset circle.

This is a very easy system to mechanize, as you will see in a moment; and in an instrument used for eclipse-prediction the failure to model both the solar and the lunar theories of Hipparchos would lead to disappointing results. But mechanism modelling the solar theory is not the only possible explanation of the evidence and, since it can easily be made very compact, on its own it doesn't adequately explain the large size of the Mean Sun wheel.

Now we get more ambitious, and discuss the movements of the planets. These fall into two groups: Mercury and Venus, having – in post-Copernican terms – orbits within the Earth's, were known as the *inferior planets*. we always see them near to the Sun. The others, with orbits outside the Earth's, can be seen at any distance from the Sun round the Zodiac, even directly opposite, "in opposition". They were known as the *superior planets*. We shall see that the groups have to be treated slightly differently, but the essential problem is much the same for each planet: once in a while it appears to stop, dodge backwards, and then move forward again. Today we can understand this as the result of an inferior planet overtaking Earth, or of Earth overtaking a superior planet. Here, for example, is a retrograde episode for Mars, which takes place as Earth breaks the rules of athletics and "laps" it on the inside. But how could the ancient astronomer describe, or account for, this appearance?

Epicycles offered a solution. Imagine the planet perched on a rotating epicycle, while the centre of the epicycle moves round the Earth on a circle called the *deferent*. We can recognize the two circular motions as corresponding to the motion of the Earth round the Sun and the motion of the planet round the Sun; by combining them we reproduce the effect that we see from Earth. If the epicycle turns fast enough there are times when the planet seems to go backwards.

In the simplest epicyclic system the epicycle rotates at a constant rate, while its centre moves, also at a constant rate, round the deferent, and the deferent has its centre at the Earth. This version was studied by Apollonios of Perga, about 200 B.C., who devised a theorem about the stationary points. But it cannot give a very good approximation to reality: from the modern point of view it is equivalent to assuming that the Earth and planets move steadily in perfectly circular orbits round the Sun, and we know that isn't true. With further complication, this model grew to become the remarkably successful Ptolemaic theory; but in its simple form, appropriate to the time of the Antikythera Mechanism, it has the advantage of being easy to mechanize.

Remember that one of the circles represents the path of the Earth round the Sun – or the Sun round the Earth – and so it makes one revolution in a year. For the inferior planets this is the bigger circle, and so it becomes the deferent. The centre of the epicycle goes round the Earth in one year, along with the Sun.

So here is another use for the epicyclic mechanism on the Mean Sun wheel: it can model the solar theory, but it can equally well model the motion of Mercury or Venus; so now we have *three* possible functions for the lost gearing. This shows how all three can fit at once.

The epicycle for Venus has to be large, and *this* offers the best explanation for the large size of the Mean Sun wheel; but a wheel large enough to carry an epicycle for Venus to a sufficient scale – as this one is – has room for epicycles for Mercury and the Sun also, and the three-branched gear train driving them at their different rates fills much of the available space rather comfortably. The slotted arms engage pins on the epicycles representing the Sun and the planets, and carry their angular motion up to pointers on the dial above. This photograph shows the model before I had made the back part.

To recapitulate: There are features of the original fragment that I take as evidence for mechanism that modelled the theories of the Sun, of Venus and of Mercury.

The first function *must* have been present;
the second provides the only rational explanation for the size of the wheel;
and the third has to be included with the second, for the sake of consistency.

The last argument can be extended: having included Mercury and Venus, the designer would have wished to include Mars, Jupiter and Saturn as well.

We saw that for the inferior planets, Mercury and Venus, the epicycles rotate at different rates but go around the Earth together at the rate of the Mean Sun. For the superior planets, Mars, Jupiter and Saturn, the model is inverted: for these three the once-a-year rotation is the smaller circle, and so it becomes the epicycle. The three epicycles all rotate at the rate of the Mean Sun, but they move around the Earth at *different* rates.

So, to manage the superior planets mechanically, each has to have its own platform, and the simplest way to manage is that is to have three separate assemblies. All three work in exactly the same way, but of course the proportions of the epicycle discs and the tooth-counts of the gears differ. Let's see one in pieces; this is Jupiter.

The first central wheel is driven at the rate of the Mean Sun wheel. This rate of rotation is transferred to the epicycle disc – no matter how the platform may turn – by a system of two equal wheels connected by an idle wheel. This is exactly the same system as that used in modelling Hipparchus's theory of the Sun, except that *there* the central wheel was fixed and the arrangement was put in motion by driving the platform. In each case the idle wheel had a second role, as part of a compound train. In the Sun-and-inferior-planet assembly the train drives the epicycles for Mercury and Venus; in the superior-planet assemblies the train leads back to engage a fixed central wheel to make the platform itself rotate. In other words, the elements in these superior-planet assemblies mirror exactly those in the Sun-and-inferior-planet assembly, but the role of each element is inverted, just as the roles of epicycle and deferent circle are inverted in the planetary theory.

Although this mechanism for the superior planets is entirely my invention, all the elements in each assembly correspond to analogous elements in the Sun-and-inferior-planet assembly, and the principle and outline arrangement of *that* was deduced from artefactual evidence. The three assemblies stack in the box, one above another, and are driven by a side arbor taking motion from the Mean Sun wheel. Here, in the original, we see a pair of blocks riveted to the frame plate which I interpret as the means of fixing a footstep bearing for just such a side arbor. Unless another explanation for these blocks can be found, then they show that there *was* further wheelwork above the Mean Sun wheel; and in the context, by far the most probable function for it would be the modelling of the theory of the superior planets, just as I have suggested.

So we arrive at a complete instrument. The stepped form of the case, with its mitred corners, is attested by small fragments of woodwork that were embedded in the mass of accretions and corrosion products on the original. In my reconstruction, this case holds everything together in correct alignment: frame plate, stages for the superior planets, dials, and the socket bearing for the contrate wheel by which the instrument is driven. If you were to put the thing in seawater for 2000 years, it would probably break up very much as the original has done!

In the course of this rational reconstruction I have faced choices: some fairly trivial but others – in particular concerning the planetary mechanism – less so. In these cases I have deliberately chosen solutions as *complicated* as I think the original designer might have wished for, in the light of the astronomy of his time, so far we understand it. At the same time, though, everything that I have added is fully compatible with the original fragments, and every additional mechanical feature is based on precedent found in them. I have also kept strictly within the bounds of what we can be sure the workman of the time could have achieved. In this way I have forestalled any argument that what I propose is either anachronistic or unworkable; and if this is true of the complex version that I have actually made, there can be no doubt that it is true of any simpler version. Computer modelling is all very well, but the hard reality of metal carries more conviction.

It is however the *principle* of reconstruction as a planetarium, rather than the detail of any model illustrating it, that I urge as a serious suggestion. Altering the back of the instrument to correspond to the new findings need not precipitate any change to the planetarium display that you see at the front; if anything, the new evidence will actually reinforce my argument. But even for those who err on the side of caution, doubting whether the Antikythera Mechanism ever included such indications of planetary motion, my reconstruction serves to illustrate the degree of mechanical sophistication that we might expect of those other instruments that certainly did. Here is Cicero, writing about one attributed to Archimedes, which Marcellus, the general who sacked Syracuse, took back to Rome:

> Moreover, this type of instrument includes the motion of the Sun, the Moon and the five [planets], which cannot be shown on a solid sphere. The genius of Archimedes was especially remarkable, because he devised it so that a single adjustment should drive all the various movements at their different rates. When Gallus worked the instrument, the Moon

> passed the Sun in the same number of turns of the bronze mechanism as it takes days in the sky in reality; thus a solar eclipse would occur on the model just as in the sky, and the Moon would fall into the cone which represented the shadow of the Earth… [and so on]

So here is Cicero, referring to a different Hellenistic instrument; and elsewhere he refers to yet another. It was during his lifetime that the ship, loaded with luxury goods and Westward-bound from the Aegean, was wrecked on the little island of Antikythera. Had it not been for that accident the instrument that I have described might have graced the household of some proud Roman owner … perhaps, even, earned a tantalizing mention in literature … and then been lost. It is thanks to the shipwreck, and to the lucky chance of its discovery in modern times, that the Antikythera Mechanism survives to give us a unique glimpse of a tradition of astronomical instrument making of which we knew very little, and of the wonderful mechanical technology of antiquity of which we would otherwise know almost nothing. Ladies and gentlemen, I give you the Greek planetarium.