An Examination of the Antikythera Mechanism

Kyle Derby MacInnis

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Abstract

At the turn of the 20^{th} Century, Greek divers uncover a shipwreck off the coast of Antikythera, and contained within it is a device of ancient origin. Through decades of research the device known as the Antikythera Mechanism has been analyzed and examined. While mysteries remain, its functionality has been generally agreed upon, but nothing like it has ever been found before. Its complexity challenges our previously held notions on the extent of Greek technology.

Discovery

It was the turn of 20^{th} Century, the date was April 15, 1900: Easter Sunday and day of the full moon.[1] A group of Greek sponge divers had found themselves off the coast of a small island named Antikythera which lies in the Aegean between Crete and mainland Greece.[2] The divers were not used to diving this particular area, having found themselves pushed off course due to a storm which forced them to take anchor.[3] Having the opportunity, the divers chose to check out the sea bed and search for sponges. One of the divers, a man named Elias Stadiatos, would discover beneath them a Roman shipwreck filled with an abundance of lost Greek treasures estimated to have sunk sometime during the 1^{st} Century BCE.[4] The ship is thought to have been on its way from Rhodes towards Rome carrying a mass of looted treasure before misfortune caused the Roman merchant ship to sink.[5] Within its hull, it contained numerous statues, a collection of amphorae, and dozens of coins. It had been the bronze and marble statues that caught Stadiatos' attention at first, in turn leading to the discovery of the wreck, but they would not be

[1] Vallianatos, 2012; fullmoon.info, 2015
[2] Edmunds & Morgan, 2000
[3] Ibid.
[4] Haughton, 2007; Pastore, 2010
[5] Vallianatos, 2012

what would make this shipwreck significant.[6] Rather, it would turn out to be a collection of calcified bronze lumps that would become the objects of true importance of the sunken vessel.

After the discovery, and with the help of the Greek archaeologists, all of the the artifacts extracted from the site were sent to the National Museum of Greece in Athens. Originally, the bronze lumps were listed on record as an astrolabe, an old navigational instrument useful in astronomy, and were somewhat disregarded amongst the rest of the artifacts. This all changed in May of 1902 when the chalky object broke apart within the museum and it was discovered that a complex gear structure existed within it. Whilst it had originally been thought to be an astrolabe, after examination by a naval officer, he stated in 1905 that it was much too complex to be an astrolabe, owing to the arrangement of the gears. Due to its complexity and unknown function, this ancient geared device was dubbed the *Antikythera Mechanism* after the place of its founding. In all of known history, nothing similar has ever been found that predates it, making it the worlds oldest known geared device of such complexity, and because of the nature of the internal workings, it has forced us to reexamine our view on the level of technology available to the Greeks circa 100 BCE. Despite these realizations, little to no research was done on the device for decades, and it wasn't until the work of

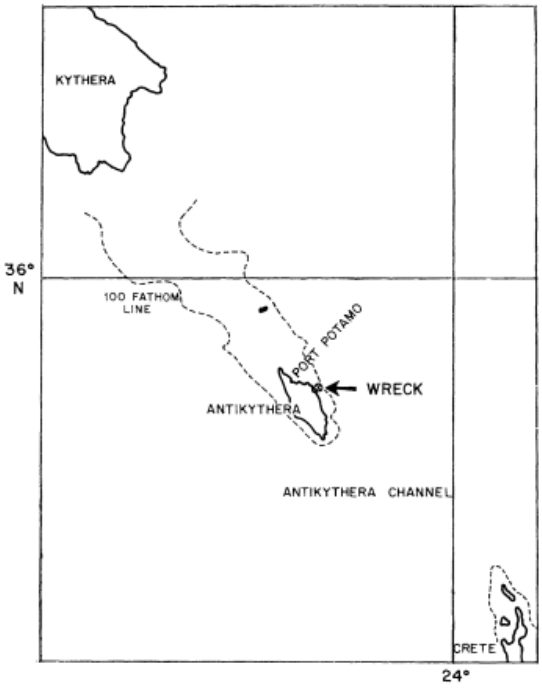

Figure 1: Location of shipwreck

[6]Ibid.
Fig.1. - Image From: Price, 1974. p.6
Edmunds, 2014
Vallianatos, 2012
Edmunds & Morgan, 2000
Vallianatos, 2012
Edmunds & Morgan, 2012

Derek de Solla Price did any real headway begin.

Deciphering the Mechanism

For the first 50 years after it was discovered, the Antikythera Mechanism remained in the National Museum of Greece shrouded in mystery. No one had yet any real understanding of the device, and yet despite its enigmatic character, little to no research was done on it. That was, until the British professor Derek de Solla Price became interested in the device. In 1951, Derek de Solla Price, a British physicist who was a history of science professor at Yale, became fascinated with the Antikythera Mechanism. He spent 8 years arduously examining the corroded device, analyzing what gears could be seen through the calcified buildup, attempting to discern their intended purpose. After years of painstaking work, he had finally developed a theory as to the function of the mechanism's design. The purpose, stated Price, of the Antikythera Mechanism was an early analog computer designed to perform astronomical calculations. The exact extent of the calculations was hitherto unknown, and in 1959, Price published an article in *Scientific American*, entitled "An Ancient Greek Computer" in which he stated his theory on the device. Within the article Price also suggests that the Antikythera Mechanism is in fact the most complicated artifact known from that time period, and predates previously known technological advancements by 1500 years. Following publication, it would take Price another twenty years before he could expand

Figure 2: The Antikythera Mechanism

Fig.2. - Image From: Price, 1974. p.24
Charette, 2006
Vallianatos, 2012
Price, 1959
Ibid.
Ibid.

on his theory.

Price's theory held merit, but the evidence available was still partial and incomplete. In 1971 and in order to better understand the inner workings of the corroded device, Dr. Price contacted a Greek physicist, Dr. Karakalos. His request was for Dr. Karakalos to X-Ray the device and provide detailed radiographs of the inner workings for Price to study. Karakalos agreed, and in 1972 he began taking hundreds of X-Ray images of the Mechanism. The radiographs provided Price with information he needed to expand his theory, and over the next couple years he compiled his findings into one of the principal works on the Antikythera Mechanism, *Gears from the Greeks*, published in 1974. This book laid the groundwork and provided a solid foundation for research into the device. Contained within it, were some notable analyses of the internal workings that proved that the device was much more technically advanced than previously thought. One such feature was the presence of a differential turntable within the gear train, a technology which wasn't rediscovered until 1575 CE, roughly 1600 years later. It was with this pivotal technology that the complexity of the device can truly be admired, for it allowed the movement of both the Sun and the Moon be consistent with phases of the Moon. In addition to describing the inner workings of the device, the images also provided Price with clearer inscriptions which he translated within his book. The inscriptions too supported Price's theory, and together with his detailed schematics would set the stage for more research into the an-

Figure 3: Radiograph - Showing Internal Components

Fig.3. - Image From: Price, 1974. p.29
Vallianatos, 2012
Ibid.
Price, 1974
Edmunds & Morgan, 2000; Vallianatos, 2012
Edmunds & Morgan, 2000

tiquated Mechanism. Research such as that done by researchers such as Michael Wright, Mike Edmunds, Feeth et al., as well as the Antikythera Mechanism Research Project (AMRP) group.

Constructing the Mechanism

Since Price's work, *Gears from the Greeks*, was published, many proposed designs have surfaced as to what the original may have looked like. Most of these designs share similarities with each other and appear to be based on Price's initial proposal. The differences are relatively minor and are mainly conjecture that propose additional missing gears for increased functionality. Despite the differences, most of the designs agree on these key features, namely: the presence of two spiral dials on one side representing the Saros(Eclipse Periodicity) and Metonic(Solar and Lunar Periodicity) cycles; on the opposing side, a third dial showing position of the Sun and the Moon as well as the Moon's phase, and calendrical information pertaining to the date such as month, zodiac, and day; it is also widely accepted that a four-year Olympiad cycle was also included on the device to either emphasize the Olympic Games, or for the purpose of maintaining accuracy across multiple years. Some designs have also accepted that there may have been additional dials or pointers and gear trains supporting positional information for each of the 5 known planets of the time - Venus, Mercury, Mars, Jupiter, and Saturn - but this is generally conjecture and is based more on the inscriptions found on the casing, than the actual gears present. As such,

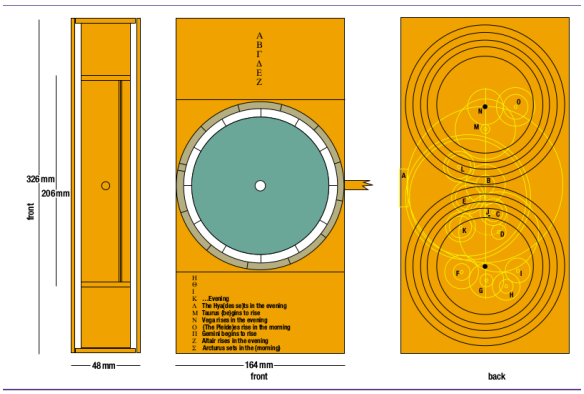

Figure 4: Proposed Model of the Dials

Wright, 2012
Fig.4. - Image From: Edmunds & Morgan, 2000. p.6.10
Edmunds & Morgan, 2000
Price, 1974; Wright, 2012
Price, 1974; Wright, 2012
Edmunds & Morgan, 2000; Ball, 2008
Gourtsoyannis, 2010; Marchant, 2010; Wright, 2012

differences on how such dials were implemented have arose, but there is little evidence available to either prove or disprove the existence of these additional gears, and it is very possible that such dials were indeed added through the use of additional differential gear trains.

The Antikythera Mechanism was originally encased in a wooden frame. The dimensions of which are estimated to be 315x190x100 mm. On the two broad faces of this case were positioned the three dials: two on the back side for the Meton and Saros cycles, and one on the front side for the Babylonian calendar. On the faces of the Mechanism were inscribed instructions for the use of the device including a list of associated meanings and descriptions. Price included many of his translations, and their meanings correlated with his theory. The dials themselves were inscribed with information as well. The Saros Spiral contained information relating to the Solar and Lunar Eclipses, while the Meton Spiral indicated the periodic cycle of the Moon and Sun, and finally the Calendrical dial was inscribed with information relating to the date including information on the Zodiac and month. On these dials, pointers traced out complex patterns showing the relative position of the celestial bodies known to the Greeks at the time.

Figure 5: 3D Representation of Mechanism

In *Gears from the Greeks*, Price included schematics of the device's internal workings as he had deciphered them. From the radiographs, Price was able to locate the existence of 30 gears which due to the pressure of the sea, and the corrosion on the device had stayed very nearly in place and thus allowed him to determine their interconnectedness. In his design, he described the machine as being powered by a crankshaft in which a single turn of

Fig.5. - Image From: Edmunds & Freeth, 2011. p.37 - - Copyright Images First Ltd. 2011
Price, 1974; Wright, 2012
Freeth et al., 2006
Edmunds & Morgan, 2000; Wright, 2012
Price, 1974
Ibid.

the crankshaft represented one year.

Turning the crankshaft engaged the drive wheel which in turn was connected to a differential turntable that applied the necessary calculations to each of the connected pointers. It was with these calculations, and the necessary inscriptions to the appropriate dials, that the device could be used to predict the astronomical positions of the Sun, Moon, Earth and other planets. While only 30 gears could be identified, it is almost certainly the case that other gears have been lost or destroyed through time. Evidence for the missing gears stems mainly from the existence of a yet-unused gear found on the differential turntable. Such a gear suggests that at one time, this gear was used for something - reinforcing the idea that the planets may have had their own differential gear trains as previously mentioned.

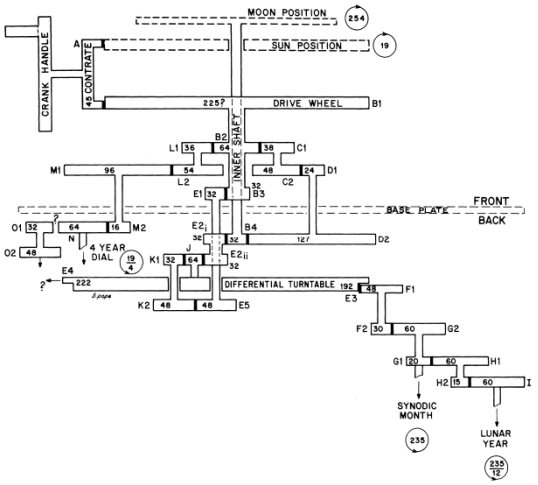

Figure 6: Price's Proposed Gear Train

Revolutionary Ideas

So what was so revolutionary about this discovery in the middle of the Aegean? Why does a fancy piece of clockwork mean so much to our understanding of history, and particularly to our chronology of scientific ideas? The answer to this has to do with the differential turntable found within the device, and its relationship to the heliocentric theory of solar system, the very same theory "rediscovered" by Copernicus over 1500 years later. Indeed, the very use of the differential turntable within the Mechanism suggests that the Hellenistic scholars knew of heliocentric nature of the solar system and that they may have been inspired by Aristarchus who espoused the idea, and who had a select group of followers.

Fig.6. - Image From: Price, 1974. p.43
Ibid.
Edmunds & Freeth, 2011
Pastore, 2010
Ibid.

Additionally, it has been proposed that possibly the device was invented by Hipparchus as he did work on the procession of the equinoxes and his ideas are present within the design; he was also a proponent of Aristarchus' heliocentric model. We may never know for certain who created the device, but future insights may provide enough clues such that we may be able to form an educated guess as to who the inventor of the Mechanism really was.

As much as the original inventor of the Antikythera Mechanism eludes researchers, so too does its original purpose. While it now quite clear what the gear train's function was designed to calculate, the exact purpose of the device remains elusive. It is not known whether the device was created for temporal, social, or navigational purposes. Not to mention, whether or not it was accurate enough for such intended purposes. Some suggest it may have been nothing more than a academic venture with few practical uses intended and instead was developed as an educational tool or exploratory instrument. Others suggest that these devices were widespread and point at the quality of craftsmanship as evidence of that. Despite the variety of opinions, most scholars agree that it was unlikely this was a one-off item, and most likely the reason for their absence has more to do with social factors such as recycling and cultural pressures than it does with rarity. But a question remains, why was the knowledge lost in time?

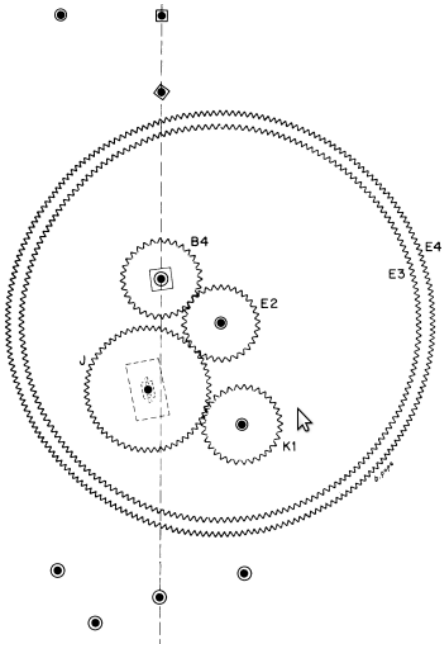

Figure 7: Differential Turntable Found inside

Ibid., Marchant, 2006
Fig.7. - Image From: Price, 1974. p.40
Edmunds & Morgan, 2000; Edmunds, 2014
Edmunds, 2014
Edmunds & Morgan, 2000;

Conclusions

The original inventor and the intended purpose for the Antikythera Mechanism may never be fully understood, but even without that knowledge, the device has the power to restructure our view of technological progress. The Hellenistic scholars knew more about the nature of the Cosmos than had been previously theorized. This Mechanism shows that the Greeks were 1500 years more advanced than previously assumed; had incorporated technological insights into modeling elliptic periods with eccentric gears and differential turntables; and were capable of modeling epicentric representations of the celestial bodies. Until well into the 20^{th} Century, this information had been hidden from scholars, and only due to fortuitous circumstances involving the Mechanism, has it been possible to rediscover what was lost. This champions the cause that researching previously unknown technology can help us unlock some of the mysteries of the ancient world and can provide insight into their understanding and so too expand our own. With all the time that has passed the Human race, how much more information is hidden from our understanding, and how much did the ancient scholars really know?

References

Ball, Philip. 2008. 'Complex Clock Combines Calendars'. *Nature* 454 (7204): 561-561. doi:10.1038/454561a.

Charette, François. 2006. 'Archaeology: High Tech From Ancient Greece'. *Nature* 444 (7119): 551-552. doi:10.1038/444551a.

Edmunds, M.G. 2014. 'The Antikythera Mechanism And The Mechanical Universe'. *Contemporary Physics* 55 (4): 263-285. doi:10.1080/00107514.2014.927280.

Edmunds, Michael, and Tony Freeth. 2011. 'Using Computation To Decode The First Known Computer'. *Computer* 44 (7): 32-39. doi:10.1109/mc.2011.134.

Edmunds, M. G., and Philip Morgan. "The Antikythera Mechanism: still a mystery of Greek astronomy?." *Astronomy & geophysics* 41, no. 6 (2000): 6-10.

Freeth, T., Y. Bitsakis, X. Moussas, J. H. Seiradakis, A. Tselikas, H. Mangou, and M. Zafeiropoulou et al. 2006. 'Decoding The Ancient Greek Astronomical Calculator Known As The Antikythera Mechanism'. *Nature* 444 (7119): 587-591. doi:10.1038/nature05357.

Freeth, Tony, Alexander Jones, John M. Steele, and Yanis Bitsakis. 2008. 'Calendars With Olympiad Display And Eclipse Prediction On The Antikythera Mechanism'. *Nature* 454 (7204): 614-617. doi:10.1038/nature07130.

Fullmoon.info,. 2015. '* Full Moon Calendar 1900 *'. http://www.fullmoon.info/en/fullmoon-calendar/1900.html.

Gourtsoyannis, Elias. 2010. 'Hipparchus Vs. Ptolemy And The

Antikythera Mechanism: Pinâ€“Slot Device Models Lunar Motions'. *Advances In Space Research* 46 (4): 540-544. doi:10.1016/j.asr.2009.08.030.

Haughton, Brian. 2007. *Hidden History*. Franklin Lakes, NJ: New Page Books.

Marchant, Jo. 2006. 'In Search Of Lost Time'. *Nature* 444 (7119): 534-538. doi:10.1038/444534a.

Marchant, Jo. 2010. 'Ancient Astronomy: Mechanical Inspiration'. *Nature* 468 (7323): 496-498. doi:10.1038/468496a.

Pastore, Giovanni. 2010. 'Antikythera Calculator Advances Modern Science Of 19 Centuries'. *Advances In Space Research* 46 (4): 552-556. doi:10.1016/j.asr.2010.04.002.

Price, Derek J. de Solla. 1974. *Gears From The Greeks*. Philadelphia: American Philosophical Society.

Price, Derek J. de Solla. 1959. 'An Ancient Greek Computer'. *Sci Am* 200 (6): 60-67. doi:10.1038/scientificamerican0659-60.

Vallianatos, Evaggelos. 2012. 'Deciphering And Appeasing The Heavens: The History And Fate Of An Ancient Greek Computer'. *Leonardo* 45 (3): 250-257. doi:10.1162/leon_a_00367.

Weinberg, Gladys Davidson, Virginia R. Grace, G. Roger Edwards, Henry S. Robinson, Peter Throckmorton, and Elizabeth K. Ralph. 1965. 'The Antikythera Shipwreck Reconsidered'. *Transactions Of The American Philosophical Society* 55 (3): 3. doi:10.2307/1005929.

Wright, Michael T. *The Front Dial of the Antikythera Mechanism*. Springer Netherlands, 2012.