An Examination of the Antikythera Mechanism

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April 6, 2015

Abstract

At the turn of the 20^{th} Century, Greek divers uncover a shipwreck off the coast of the island of Antikythera. Within the ship is a device of ancient origin. Older than any known mechanical clocks, the device known as the Antikythera Mechanism has perplexed researchers since its discovery. While mysteries remain, its functionality has been generally agreed upon, but nothing like it has ever been found before, and its complexity forces us to revisit 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 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 Sea between Crete and the Greek mainland.[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] Seeing an 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 had caught Stadiatos' attention in turn leading to the discovery of the wreck, but the statues would not

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

be the objects which would make this shipwreck significant.[6] In truth, it would turn out to be a calcified bronze lump that would become the object of true importance on this 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 lump was listed on record as an astrolabe, an old navigational instrument useful in astronomy, and was 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 purpose, this ancient geared device was dubbed the *Antikythera Mechanism* after the place of its discovery. In all of known history, no precursor has ever been found, making it the worlds oldest known geared device of such complexity. Additionally, because of the nature of the internal workings, it has forced us to reexamine our view on the extent 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 Derek de

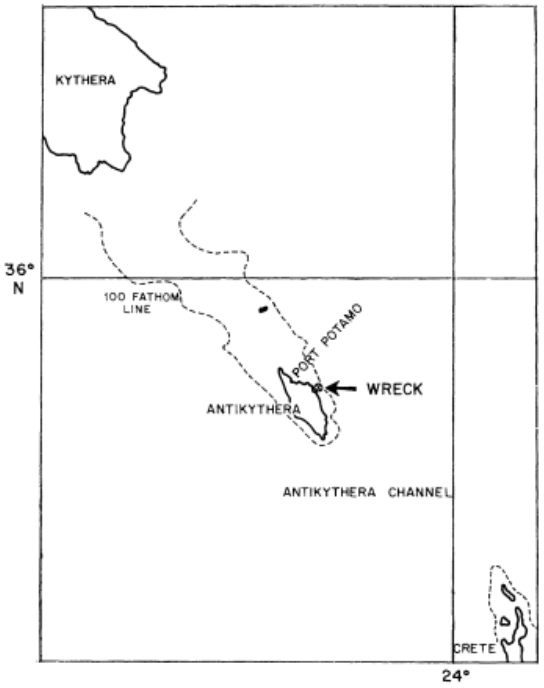

Figure 1: Location of shipwreck

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

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, Price, a British physicist who at the time was a professor on the History of Science 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 functional purpose 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 stated 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, the device garnered a little more attention, but it would take Price

Figure 2: The Antikythera Mechanism

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

another twenty years before he could expand on his theory into something more concrete.

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, entitled *Gears from the Greeks*, published in 1974. This book laid the groundwork and provided a solid foundation for research into the nature of the device. Contained within it, were some notable analyses of the internal workings that showed the device was in fact 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 could truly be admired, for its presence allowed for the movement of both the Sun and the Moon be consistent with the phases of the Moon. In addition to describing the inner workings of the device, the images also provided Price with more detailed inscriptions which he then proceeded to translate within his book. The inscriptions too supported Price's theory, and together

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

with his detailed schematics would set the stage for future research into the antiquated Mechanism. Research such as the work done by Michael Wright, Mike Edmunds, Feeth et al., as well as the Antikythera Mechanism Research Project (AMRP) group all built off of the work set forth by Price.

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 many are mainly conjecture that propose additional missing gears for increased functionality. Despite the differences between them, most of the designs agree on the following 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 of the Meton Cycle. 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

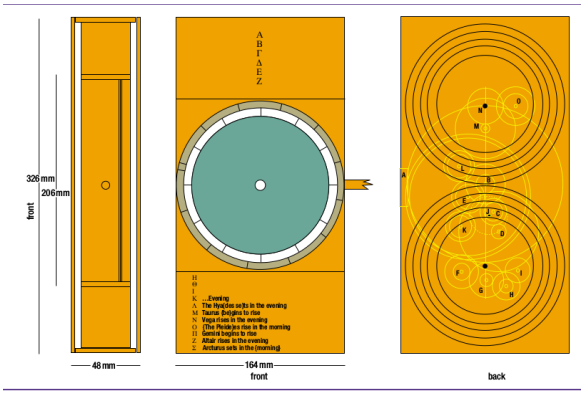

Figure 4: Proposed Model of the Dials

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

on the casing, than the actual gears present. As such, differing opinions on how such dials were or could be 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, but alas such evidence has either been lost or destroyed.

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 this third dial, pointers traced out the relative positions 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 de-

Gourtsoyannis, 2010; Marchant, 2010; Wright, 2012
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.

sign, he described the machine as being powered by a crankshaft in which a single turn of 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. The existence of the unused gear suggests that at one time, this gear had a purpose - reinforcing the idea that the planets may have had their own differential gear trains as previously mentioned.

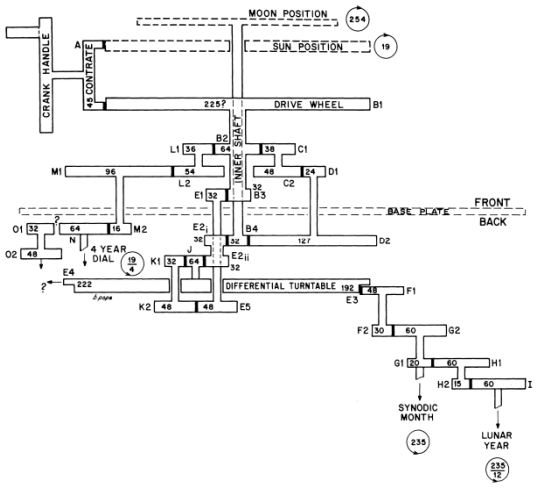

Figure 6: Price's Proposed Gear Train

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

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

may have been inspired by Aristarchus who espoused the idea, and who had a select group of followers. 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. While these hypotheses do have a certain romanticism about them, we may never know for certain who created the device, but through further research we may be able to provide enough clues such that one day the identity of our mysterious inventor may come to be known.

As much as the original inventor of the Antikythera Mechanism eludes researchers, so too does its original purpose. While it is now quite clear what the gear train's function was designed to calculate, namely the positional movement of the celestial bodies, 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 its intended purposes. Some have suggested that the device 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, stating that such quality would have been preceded by possibly generations of training necessary to pass on the knowledge. 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

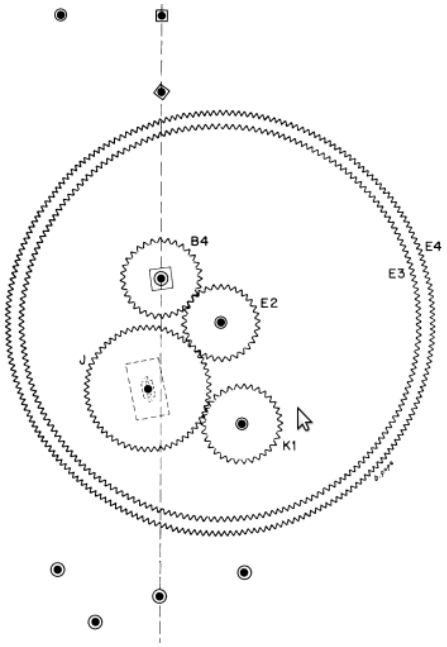

Figure 7: Differential Turntable Found inside

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

absence has more to do with social factors such as the relative scarcity of metal leading to recycling, and possibly the effects of cultural pressures, than it does with rarity. But a question remains, why was the knowledge lost in time if such an instrument was wide spread? Again we may never learn the true reasons.

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 our technological progress. The Hellenistic scholars knew more about the nature of the Cosmos than had been previously theorized, and this can have huge effects on our previously asserted theories. The Antikythera 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 epicyclic calculations on the movement 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 discovery of the Mechanism, has it been possible to rediscover what was lost. This champions the cause to continue researching previously unknown technology in the hopes that it can help us unlock some of the mysteries of the ancient world. With these mysteries unlocked, they provide insight into how the ancients people understood the world around them, and by understanding their view, so too can we 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?

Edmunds & Morgan, 2000;

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