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THE ASTRONOMICAL MONUMENTS OF ATHENS

Evangelia Panou, Efstratios Theodossiou, Vassilios N. Manimanis and Konstantinos Kalachanis

Department of Astrophysics-Astronomy and Mechanics, School of Physics, National and Kapodistrian University of Athens, Panepistimiopolis, Zographos 157 84, Athens, Greece

***Corresponding author*:** Evangelia Panou

ABSTRACT: In the capital of Greece, Athens, several monuments of some astronomical significance are preserved till now. These monuments are: the Athenian Calendar in Panagia Gorgoëpikoos or St. Eleftherios church, the clepsydrae of the Ancient Agora Museum in Athens, the seven sundials of the National Archaeological Museum of Athens and the sundial on the south slope of the Acropolis hill. The Athenian Calendar in Panagia Gorgoëpikoos church is a personified relief depiction which refers to the months, the seasons, the weather conditions, the daily occupations of the Athenian people and to the zodiacal signs; the clepsydrae of the Ancient Agora Museum was an instrument for the measurement of time in the ancient law courts; the sundials of the Archaeological Museum of Athens, the Acropolis' sundial and the sundials of the Tower of the Winds used for time measurements in sunny days. From the study of the geometrical characteristics of these astronomical monuments specific information concerning the measurement of time in antiquity is obtained.

***Keywords*:** Athenian Calendar, Athens, clepsydra, sundials.

INTRODUCTION

I. The Athenian Calendar in Panagia Gorgoëpikoos (St. Eleftherios) church

Panagia Gorgoëpikoos is a small church to the south of the Orthodox Cathedral (*Mitropolis*) church, in the historical center of Athens. The church was constructed in the ruins of the ancient sanctuary, which was dedicated to ancient Greek goddess Eileithyia. Initially, the church was dedicated to Panagia Gorgoëpikoos and nowadays is dedicated to St. Eleftherios (Neroutsos, 1889). Above the central entrance of this small church there is immured a carved frieze of great archaeological, historical and even astronomical significance.

The architectural style of this temple is cross-like, with a tripartite church porch or narthex, while with its well-preserved eight-sided dome (made of bricks) it is the most characteristic example of an "Athenian-type" church. Its walls, particularly in their lower parts, are composed of non-decorated marble pieces, while their upper parts are full of 90 Greek, Roman and Byzantine reliefs (Theodossiou and Manimanis, 2003). In addition, there are reliefs of the 9th and 10th centuries with Eastern motives, and sculptures depicting prizes of Panathenaic Games and Roman trophies. Today the temple is a chapel of great historical value, as it is preserved in its prototype form, while the marble sculptures and carvings with animals, flowers, branches and human figures immured in its walls have their own archaeological value.

The most characteristic element of this temple of St. Eleftherios, which drew the attention of several researchers, is its so-called frieze. This frieze was initially a unique relief work of art made of white Pentelic marble, which later was cut into two pieces and was immured in the western side of the temple, above its main entrance. The total immured part of the work is shorter than its initial size by approximately 2/12 of the original. This part was either cut in purpose during the placement of the frieze, so that the length of the two pieces would fit in the temple's side, or it broke accidentally. A peculiar characteristic of the frieze is that its two pieces were immured in the wrong order: the first one was immured in the place of the second one and vice-versa. The size of the pieces is (2.74 + 2.99) m × 0.53 m with their carved part being 0.23 m high (Thiele, 1898). The placement of the pieces caused various interpretations of religious or ethnological character; these interpretations were associated with the calendar and the dates of festivals of the ancient Athenians and Romans, which always had as astronomical points of reference

the equinoxes and the solstices. Another unusual characteristic of the frieze are the three crosses inscribed within circles, which were added subsequently at different points of the relief in an attempt to transform the original work into a Christian decoration. This frieze is the only ancient Athenian, but also ancient Greek sculpted illustrated calendar that has been preserved to this day. Its depictions represent the months of the ancient Athenian calendar (Table I), from which information about the way of life and the activities of the ancient Athenians can be obtained. By observing the symmetry, the order of the depicted human figures on the frieze and the part of the sculpture that was removed prior to its incorporation in the wall, we can discern ten sections, more or less of equal dimensions. The missing two sections were representing the months Anthesterion and Elaphebolion, deduced on the basis of the whole frieze's structure (Svoronos, 1900).

The frieze was also called a zodiac, because the presence of zodiacal signs was especially prominent at the end of each section. The following signs are depicted, arranged in astronomical order: *Scorpius*, *Sagittarius*, *Capricornus*, *Aries*, *Taurus*, *Gemini*, *Cancer*, *Leo* (all these represented by male figures), *Virgo* (represented by a female figure) and finally the sign of the Scorpion's Claws or *Libra*. Each section begins with a male figure, which represents the month. Each month corresponds to one section and their order is the following: Pyanepsion, Maemacterion, Poseideon, Gamelion, Munychion, Thargelion, Scirophorion, Hecatombaeon, Metageitnion, Boedromion. These male figures have certain common characteristics: All of them face towards their zodiacal sign, turning away from the previous section, while their clothing is similar to that of the ancient Athenian citizens. The most important is that their clothing changes according to the temperature of the month represented by each one. This is more evident when the months are grouped into five seasons: *Metoporon* (meaning 'after the fruits') with only one month (Pyanepsion), *Winter*, *Spring* and *Summer*, each having three months, and finally *Autumn* with two months (Metageitnion and Boedromion). In Winter, the man is dressed with thick clothes and shoes. In Thargelion, the first month of Summer, the respective figure is half-naked. In the second month, Scirophorion, the figure is depicted totally nude and protects his head and eyes with his hand from the solar rays of the warmest days of the year. In the third month, Hecatombaeon, the man is dressed in light clothing, because the heat is less and the summer is about to pass. Finally, in the two autumnal months the man appears again with substantial clothing in order to face the imminent cold weather of autumn.

The carved depictions of the frieze also personify time periods called *ora* and *kairos*. The word *ora* is used to denote the following meanings: given time, time period, season of the year, weather, part of the day or night, hour (the 1/12 of the day or 1/24 of the day-and-night period), proper time or period for something (e.g. time to sleep, time for lunch). The word *kairos* is used to denote the following meanings: proper season or moment, critical moment, opportunity, time of maturity, time span, period. On the depictions of the frieze, the *orae* have the meaning of hour or moment appropriate for certain activity, and have the following names: *Teleti*, *Spondi* (time for agreement, armistice or offering), *Gymnastiki*, *Mousiki*, *Orchesis* (dancing), *Kypridos Acmi* (honeymoon), *Artemis* (time for hunting and sailing), *Pherousa* (harvest time). As *kairos* are characterized the scenes with the names: *Arotos* (tillage season), *Sporos* (sowing season), *Trygetos* (vintage, grape-gathering season), *Hieros kairos Panathineon* (celebrating the Panathenaea festival), *Tragodos* (tragedy season), *Agones* (time for exercising), *Gamos* or *Nymphios* (marriage season), *Heracles* (time or season of apples), *Dioskouroi* (sailing season), *Hippasion* (time for equestrian games), *Vouphonos* (heat wave season), *Pan* (spring time for grazing), *Kyon Sirios* (season of etesian winds). In Tables I and II are given the months with the respective season of the year, as well as the *kairos*, the *ora* and the zodiacal sign of each month/section of the frieze of the ancient Athenian calendar.

Table 1. The ancient Athenian months

Year				
Winter half		Summer half		
Winter	Spring	Summer	Autumn	*Metoporon*
Maemacterion	Anthesterion	Thargelion	Metageitnion	Pyanepsion
Poseideon	Elaphebolion	Scirophorion	Boedromion	
Gamelion	Munychion	Hecatombaeon		

Table 2. Kairos, ora and the sign of the sections/months of the ancient Athenian calendar as depicted on the frieze from left to right

	Correlation of the depictions with time periods and signs			
Section	Month	Kairos	Ora	Sign
1	Pyanepsion	Metoporon, *Trygetos*	*Pherousa*	Scorpio
2	Maemacterion	Winter (*kairos* of 3 and 6 months), *Arotos*, *Sporos*	—	Sagittarius
3	Poseideon	*Agones*	*Gymnastiki*	Capricornus
4	Gamelion	*Nymphios* or *Gamos*	*Kypridos Acmi*	Aquarius
5	Anthesterion	Spring (*kairos* of 3 months), *Pan*	*Mousiki*, *Orchesis*	Pisces
6	Elaphebolion	*Tragodos*	*Spondi*	Aries
7	Munychion	—	*Artemis*	Taurus
8	Thargelion	Summer (*kairos* of 3 and 6 months)	—	Gemini (Dioskouroi)
9	Scirophorion	*Vouphonos*	—	Καρκίνος
10	Hecatombaeon	*Hieros kairos Panathineon*, *Kyon Sirios*	*Teleti*	Leo
11	Metageitnion	*Heracles*	2-month *ora* of autumn	Virgo
12	Boedromion	*Hippasion*		Libra

Each section of the frieze contains elements of astronomical significance; it refers to the 12 lunar months (of 29 and 30 days alternatively) of the ancient Athenian lunisolar calendar of 354 days, starting with the month Pyanepsion (Theodossiou and Manimanis, 2003). The personified relief depictions of the frieze, which refer to the months, the seasons, the weather conditions, the daily occupations of the Athenian people and to the zodiacal signs, are still placed at the same site without any obvious deterioration up to this day.

II. The clepsydra of the Agora (Greek marketplace)

The clepsydra (water clock) of the classical Athenian Agora belongs to the permanent collection of the Ancient Agora Museum, in Athens, inside a glass showcase (no. 27). The accompanying note informs about its use in the ancient Athenian law courts and an illustration of the way it operates is also present.

This clepsydra is dated from the classical period, in late 5th century BC, and it was discovered inside a well at the southwest side of the Ancient Agora place. It is a ceramic (clay) vessel of approximately hyperboloid or conical shape, with dimensions smaller than 30,0 cm. It bears two handles for its transportation, a hole for the outflow of excessive quantity of water near the limb and a small hole next to its base.

The particular water clock was a property of the Antiochis Athenian "tribe", a fact testified by the inscription *ANTIOXIDOS* on the side surface of the vessel. Another indication, *XX* , denoted that the vessel's capacity was 2 *choes* (12 choes were equal to 1 *metretes* or 39.40 liters).

The water clock was an instrument for the measurement of time in antiquity. Its use is testified in Greece since the late 7th century BC and in Egypt since 1550 BC (or, according to the American archaeologist and historian J.H. Breasted, since 1400 BC), so it was one of the oldest instruments used for time measurement. Clepsydrae in antiquity were widely used for measuring small time intervals, the durations of which could not be determined by astronomical observations (that is, by observing the movements and the phases of the heavenly bodies), and this was the case even for longer time spans when the day was cloudy. Actually, the early water clocks were calibrated with a sundial. The principle of their operation was based on the continuous flow of water between two vessels placed at different levels. The etymology of the word points to the fact that the water of the upper vessel was "stolen" through the hole at its base and was concentrated in the lower vessel.

The use of the clepsydra in the law courts, and probably also at the assembly (ecclesia) of the Athenian democracy, as an instrument for measuring the length of the orations, was extensive. The court buildings were in the western part of the Athenian Agora, which was itself an important decision-making place, and they were erected in the beginning of the classical period, starting in 479 BC. The main reason for the intense building activity was the Persian wars of 480-479, which destructed this part of the city. In 465 BC the circular building of Tholos was erected in order to house the Prytaneion and the new Bouleuterion, a site where the state archives were being kept and, in parallel, a place of worship.

Information about the use of clepsydrae in the ancient law courts is supplied by many ancient authors. A typical source is the great philosopher Aristotle, who, in his work *Constitution of the Athenians* (*Athenaion Politeia*) reports that in the courts there were water clocks equipped with small pipes of outflow, and from the quantity of water in their interior the duration of orations and of the trial was determined (Aristotle, 1928).

The clepsydra of the Athenian Agora, like the various ancient water clocks, was an indispensable element of the Athenian public life. It was used for timing short orations. The maximum volume of water that could be stored in the vessel was 6.57 liters, which corresponded to a time span equal to 6.16 minutes. This, however, does not mean that all the orations lasted for just 6.16 minutes. The judges, according to the seriousness of the case, used to allot to the opposite parts equal time spans, which could be any multiple of the above duration. Some of them finished their oration before the water of the upper vessel was exhausted, the most experienced ones finished along with the fall of the last drops of water, while a few ones even bribed the *epimeletes* (the person responsible for the water clock's operation) in order to speak for more time. The *epimeletes*, when ordered by the judges, stopped the flow of water by placing a plug in the lower hole of the upper vessel, so that witnesses could testify and documents could be read (Theodossiou and Danezis, 1994).

The precision of the Athenian Agora clepsydra as an instrument was adequate for its usage. Of course, it was influenced by parameters that changed the available volume of the vessel and the rate of the water flux, such as solid residue at the bottom that could partly block the hole, due to dirt in the water. However, the flux was also influenced by the construction characteristics of the clepsydra, and this was taken care of: Because of the change of the water level inside the vessel, the diameter of the vessel at its upper part should be greater than that at the base, so that timekeeping would be more accurate.

III. The sundials of the Archaeological Museum of Athens and the conical sundial of the Acropolis

A number of seven ancient Greek sundials from the Hellenistic, Roman and late ancient periods are kept in the Archaeological Museum of Athens. Six of them are kept in the storehouse of the museum's collection of sculptures and the seventh one, which is considerably heavier, is placed at the exposition site of the museum's internal garden. These seven sundials are listed in the museum's catalog under the index numbers 3156, 3157, 3158, 3159, 3220, 13365 and 13366. The first four of these were recovered from the ruins of the Theatre of Dionysus, on the south slope of the Acropolis hill, while for the three

others the place of discovery is not known. There is one more sundial, similar to these but bigger in shape, which is still located on the south slope of the Acropolis.

Sundials were used in antiquity for time measurement during the sunny days of the year. From the position and the motion of their gnomon's shadow on their plate, the true solar time of the place was determined.

The sundial No. 3156 is conical and it has been dated in the Hellenistic or Roman period (Kraus, 1991). It is made of white marble and it is incorporated into a base that bears to the left and right two feet of a lion. Its height ranges from 47.0 to 50.0 cm, its width from 41.0 to 43.0 cm and its depth from 15.0 to 30.0 cm. The depth of the construction's top is 31.0 cm and the depth of its base 28.0 cm; the whole construction weights approximately 80.00 Kg. Visible wear exists at the base (the lion's toes), while the conical surface, i.e. the "plate" of the sundial, is preserved in good condition. Eleven hour lines can be discerned, along with the curves of the summer solstice, the winter solstice and the equinoxes. Between the 6th and the 7th hour line there is a crack, while alterations can be also observed at the end of the 1st and the 2nd hour lines, and much heavier ones from the 8th to the 11th hour lines. The gnomon of the sundial, a horizontal gnomon, has been lost. This sundial has been constructed for geographical latitudes of 33 to 34 degrees (Panou, 2014).

The sundial with index catalog number 3157 is also of conical type and of the same period as the previous one (Kraus, 1991). It is made of white marble and it is incorporated into a marble base that also bears lion's feet. The sundial's height ranges from 28.8 cm to the right to 29.5 cm to the left. Its depth ranges from 26.0 to 26.8 cm, while its width from 34.1 to 34.2 cm. It weighs approximately 48.20 Kg. Visible alterations exist in the top view and in the front view of this sundial. The edge regions to the right and to the left of the dial's surface show loss of pieces and they have pointed protuberances. The dial consists of two pieces that are united; along the line of separation between the two pieces there is also loss of small quantities of marble. Otherwise, the dial is preserved in relatively good condition. The 11 hour lines, the curves of the solstices and the equinoxes are clearly visible, with the exception of the edge of the 1st hour line and the respective arc of the summer solstice curve, which are missing due to the loss of marble. In the place of the lost gnomon there is a square hole with a side of 4 cm; along its brink there are traces of metal. This sundial has been constructed for latitudes of approximately 36^{o} (Panou, 2014).

The sundial with index catalog number 3158 is conical and dates from the Roman period (Kraus 1991). It is made of Pentelic marble and it also incorporates a marble base with lion's feet. Its depth ranges from 17.4 to 18.3 cm and its width from 24.2 to 24.4 cm. The whole construction has a cube-like appearance 22.2 cm high; its weight is 16.40 Kg. There are a few points of obvious damage on the top side of the sundial and smaller damage at the base (the feet of the lion). The dial is preserved in good condition. The 11 hour lines, the curves of the solstices and the equinoxes are clearly visible on its surface. The bronze horizontal gnomon has also been recovered, a rare case of an ancient bronze artifact – probably a part of its edge is missing. The sundial has been constructed for latitudes of approximately 40^{o} (Panou, 2013c).

The sundial with index catalog number 3159 is a cylindrical one and it is arguably dated in the late antiquity (Kraus 1991). It is made of marble and it incorporates a marble base of parallelogram cross-section; its weight is 7.10 Kg. Its depth ranges from 9.5 to 12.0 cm, its width from 25.2 to 25.4 cm and its height from 13.7 to 15.6 cm. There are obvious alterations at the front side, especially on the right-hand side of the dial, where a part of the 10th and the 11th hour lines beyond the curve of the equinoxes is missing. The left-hand side of the dial's surface bears a prominent crack accompanied by missing pieces of marble. The 11 hour lines, the curve of the winter solstice and the curve of the equinoxes are clearly visible. The gnomon of this sundial has been lost (Panou, 2013d).

The sundial with index catalog number 3220 is of apparently cylindrical type according to its characteristics, and dates from the Roman period or from the late antiquity (Kraus, 1991). It is made of white marble and it incorporates a base with lion's feet. The dial's height ranges between 22.0 and 23.0 cm. Its width is 43.0 cm, while its depth is 18 cm. The length of the back arc-like semi-perimeter is 63.0 cm. its weight is 29.70 Kg. The dial is not preserved in good condition: Only 9 hour lines are visible and start from an almost horizontal line at the upper part of the dial A striking incision is also visible on the dial's surface, which starts from the middle of the 2nd hour line, it approaches the horizontal line and ends just beyond the 6th hour line. After the end of the 5th hour line there is a conspicuous circular hole; the hole's inner diameter is 2.8 cm, while its outer rim has a diameter of 4.2 cm. The sundial's gnomon has been lost (Panou, 2013d).

The sundial with index catalog number 13365 is of the semicircular flat type and was constructed during the late antiquity (Kraus, 1991). It is made of marble, in the form of a semicircular disc, and weighs 4.30 Kg. The sundial's height along the meridian line is 22.0 cm, its width is 31.0 cm and its depth 3.0 cm. The dial and the gnomon's hole are preserved in rather good condition. On the dial's surface are clearly carved 11 hour lines and other 2 horizontal ones, approximately 26.0 cm long, well-fitted in the semicircle's diameter. Equally obvious is the curve of the summer solstice and less visible that of the winter solstice (Panou, 2013).

The sundial with index catalog number 13366 is spherical and was constructed during the Roman period (Kraus, 1991). It is made of marble and it incorporates a base with lion's feet. It weighs 7.80 Kg. The height of this sundial ranges from 20.0 to 23.0 cm, its depth is up to 21.0 cm and its width is 17.0 cm. Neither the base, nor the dial's surface is preserved in good condition: Only six hour lines are clearly visible, along with parts of two curves, probably of the winter solstice and of the equinoxes (Panou, 2013b).

The sundial located in situ on the south slope of the Acropolis hill is conical and was dated in the Hellenistic or Roman period. It is made of white marble (Kraus 1991). The height of the sundial is 86.0 cm, its depth 82.0 cm and its width 123.0 cm. Both its supporting base and dial's surface are preserved in very good condition, with the exception of some alterations and loss of marble on the dial's front edge. The 11 hour lines are clearly visible, as well as the curves of the summer solstice, the winter solstice and the equinoxes. The gnomon of this sundial has been lost.

IV. The Tower of the Winds

To the north of the Acropolis hill, in the eastern part of the Roman Agora of Athens, stands the so-called Tower of the Winds. It was built *circa* 50 BC by Andronikos Kyrrhestos (Andronicus of Cyrrhus) and is considered one of the most important ancient monuments of Athens with some astronomical significance. It is arguably the oldest meteorological and time-keeping station in the world. It is also known as "Kyrrhestos' Clock" after its creator or "Temple of Aeolus" from the inscriptions of the eight wind names on its surface (Noble and de Solla Price, 1968).

The Tower is made of Pentelic marble and has an octagonal shape, without any columns. It presents a Doric interior and a Corinthian exterior. The monument suffered serious damages during various periods, which are still evident.

On the top of the monument (at a height of 13.50 m) there is a cavity, a possible indication of the support base of the bronze weather vane, which had the form of Triton (a sea deity in Greek mythology) and has been lost. This Triton held with the one hand his tail and with the other a rod; this hand could rotate and showed the direction of the wind. The Tower has two entrances, a northeastern and a northwestern one. On each side there is a winged figure carved in relief, representing one of the eight principal winds, along with its symbol and name. These names are: Boreas (north), Skiron (northwest), Zephyr (west), Lips (southwest), Notos (south), Euros (southeast), Apeliotes (east), Caecias or Kaikias (northeast). Under the eight winds there are carvings that represent the hour lines of the eight vertical sundials of the Tower. In this way, the monument served both as a weather station (with its weather vane) and as a "time station" through the indications of the shadow on the surface of the sundials. The merchants visiting the Agora to sell their goods were informed about the time of the day from this clocktower's sundials.

There are windows on the northern, the southern and the western side of the monument. Of special significance is the existence of the northern window, which is symmetrically placed on its wall, at the middle of the respective sundial and right under the figure of Boreas. This sundial is unique in its kind, since its central part is empty. This is because the Sun illuminates the northern side only just after sunrise and before sunset, and this only during the summer months.

One more sundial of the Tower has a distinct geometry from the rest: that on the southern side. It is a sundial of different shape, since the other seven sundials have a flat surface, while this one has a curved cylindrical surface.

The Tower of the Winds could operate as a time station even during cloudy days or at night. This was because in its interior operated a water clock. Its function was based on the continuous flow of water from an upper reservoir to another one, located at a lower level. The water was coming down from a spring in the Cave of Pan, on the northern slope of the Acropolis hill, by free flow. A special pipe carried this water in a large upper reservoir that supplied the water clock with water at a constant hydraulic pressure. Near the top of this reservoir there was an overflow control, so that changes of the flux of the incoming water could be compensated for. The overflowing water was channeled through a special pipe in the central part of the Tower to be used for other purposes. At the bottom of the upper reservoir there was a hole that allowed the water to flow towards the lower reservoir. This flow was controlled by a regulating valve, so that the lower reservoir would be filled completely in 24 hours. The lower reservoir was equipped with a floater that rose along with the water level. A thin bronze chain connected to this floater transferred its motion to a special device at the center of the Tower. After 24 hours, when the lower reservoir was full and the floater had reached its highest level, a valve opened at its bottom and all the water was removed. This cycle was repeated every 24 hours.

The Tower of the Winds was one of the best-designed, geometrically constructed and functionally accurate monuments of antiquity for the measurement of time and the determination of the weather. The measurement of time was taking place irrespective of the weather conditions. During sunny days the time was determined by the sundials, while during cloudy days or during the night it was determined by the water clock that operated in the interior of the Tower. The design of that clock was so accurate that it operated smoothly even during the most rainy days, for all 24 hours. The provision for overflow and a regulating valve increased its accuracy in the measurement of time. The Tower of the Winds can undoubtedly be characterized as the most accurate and versatile device of ancient Athens for time measurements..

CONCULSION

The ancient astronomical monuments of Athens yield many elements about the everyday life of ancient Athenian citizens. Athenians had their lives and occupations organized according to the season of the year, the month and the proper hour for each activity. The sense of time as depicted in the calendar on the ancient carved frieze, and its measurement starting from the movements of the celestial bodies (sundials) or the water flux (clepsydra – water clocks) were well-known for them and they

were handled with great accuracy and precision. This means that the ancient Athenians had an idea of the natural quantity called "time" and of the notion of time duration, for both long and short time intervals, having also the ability to invent and construct the respective structures for their measurement.

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