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THE LIGHTING OF GOD'S FACE DURING SOLAR STANDS IN THE APOLLO TEMPLE DELPHI

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ABSTRACT

The direction of solar light and how it relates with the Apollo Temple in Delphi is investigated. Following up earlier investigation of defining the time to delivering an oracle and the historical reported position of a golden Apollo statue in the rear of the main structure (opisthodomos, adyton or Temple's sanctum) the sun lighting the statue's face during selected solar stands is virtually constructed. Based on both ancient and contemporary sources, an accurately-oriented 3D model of the Temple was created, which incorporated windows in the sanctum area. A light and shadow study followed to establish the movement of shadows and presence of sunlight around and inside the Temple, during the important days for the ancient cult. It is shown that the shining of God's golden statue would have been possible, through windows, giving a distinct impression of Apollo's presence in Delphi especially during his absence in the three winter months to the hyperborean lands between winter solstice and spring equinox.

KEYWORDS: Apollo Temple, Delphi, solar stands, lighting, oracles, calendar, solstice, equinox, 3D, adyton, rendering

1. INTRODUCTION

The ancient Greeks were capable of mastering celestial bodies' orbits and their periods, thus establishing an accurate calendar for their multiple needs e.g. cultic feasts, religious celebrations, travelling especially navigation, trade, exploration, colonization, cultivation, to mention but a few (Hannah, 2005, 2015; Castro, 2015; Blomberg & Henriksson, 1999; Seiradakis & Edmunds, 2018).

The change of the sun's orbit and position in the sky and its attribution to the deity – the sun-god - as the central figure of celestial space, as well as the depiction of the reflecting rays around its face of the statue, are most intriguing aspects related to the cult after his name, as well as the geometrical configuration of sunrise across the horizon which reveals itself at certain times throughout the day.

The Apollo Temple in Delphi was possibly the most renowned oracle sanctuary of the ancient Greek world. Prior to any major undertaking would begin, be it from declaring war to establishing a colony, from a person, or a city, but during the oracular days, the oracles of the temple were the guiding truth of god Apollo via its mediator priestess Pythia. The timing of delivered oracles were closely related to the movement of stellar objects, especially the constellations of Lyra and Cygnus, of the most important and favourite ones to Apollo. The time for prophecy would begin during March, the vernal equinox, and last until the winter solstice, when, according to legend, Apollo would leave for the land of the Hyperboreans, to cleanse himself for the killing of Python before taking over Delphi. The time to deliver an oracle at the beginning and the end 3-month period has been determined earlier for Delphi and Didyma, Hierapolis Apollo temples (Liritzis & Castro 2013; Castro et al., 2015). This was well represented in the movement of Lyra and Cygnus and their appearance or lack thereof, from the Delphic night skyscape (Fig.1).

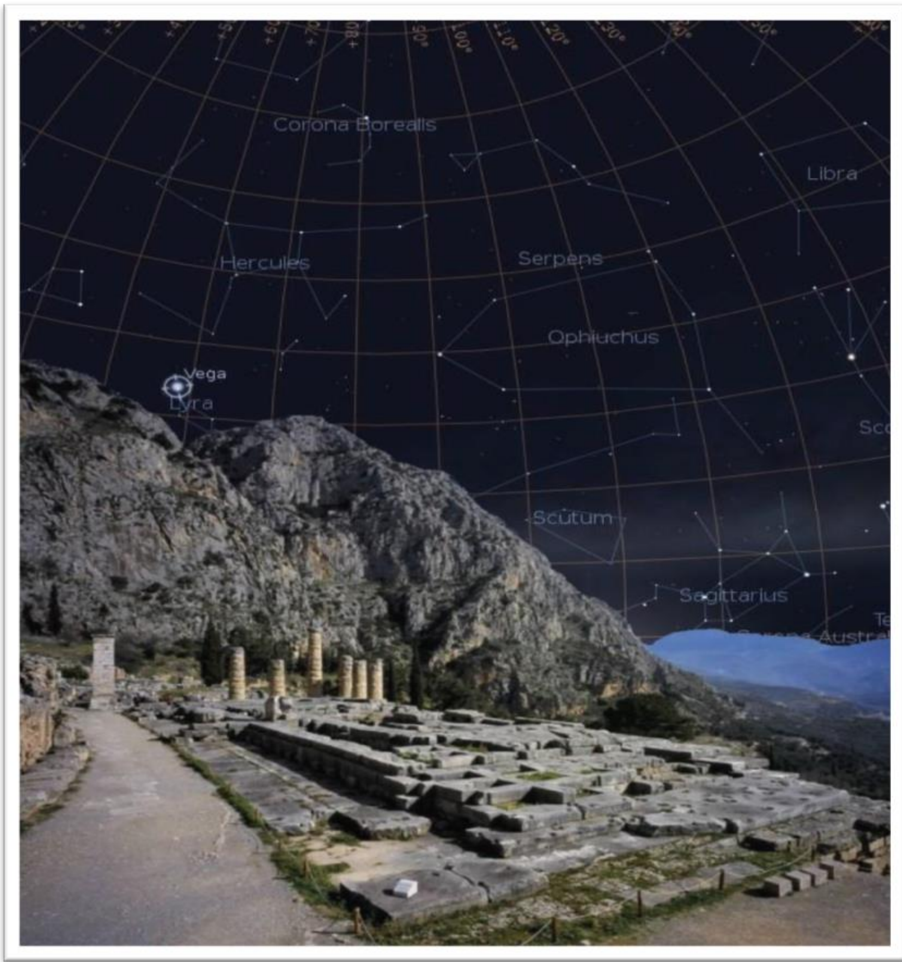


Figure 1: The heliacal rising of Vega above the Faidriades in the northeastern Delphi sky at dawn on 21 December 480 BC (Liritzis & Castro, 2015).

The Temple itself was built in that specific location and in such a way, to further enhance the mystery surrounding the oracular powers of Pythia. The site of the oracle of Apollo at Delphi was an antron (cave) or adyton (restricted inaccessible area) where, according to the geographer Strabo, fumes rose from the ground to inspire a divine frenzy.

The descriptions provided by Pausanias, document the Temple in great detail and mention a golden statue of Apollo in the inner sanctum. Aeschylus also described the statues in Hellenic temples as "golden gods who would look to the east with shining eyes (*Agamemnon*, 519-520, "*.. and I greet the palace, dear home of the Atreid king, their judgement seats and the sun-facing gods before it…*"). This strongly suggests sunlight reaching directly into the sanctum, and to the face of the statue that would be much more likely if we consider the openings of one or more windows, since it would be nearly impossible to happen with openings on the front of the Temple.

The windows would also make sense from a practical point of view, as a way to remove the hallucinating fumes emerging from the deep ground beneath opisthodomos (the intersection of two almost vertical seismic faults). The Temple of Apollo at Delphi is now known to be sited at the intersection of two major tectonic faults, the Kerna and Delphi Faults (De Boer et al., 2001) which are part of the Corinth rift zone, a region of crustal spreading. Subvertical fissures existed underneath the Temple and sheets of travertine along the largest north-northwest faults provided a pathway along which groundwater enriched with light hydrocarbon gases rose to the surface (see de Boer and Hale, 2000: Figure 7; Muller, 1992: Figure 2). Even today, the smell of hydrocarbons has been reported in the vicinity of the Temple of Apollo, as well as in the modern town of Delphi (locals to I.Liritzis, pers. commun., 2015).

The god's face shining from sunlight at some of the most important oracular dates, such as the solstices and equinoxes, would also be vital to the Temple from a religious point of view, confirming the god departure to the northern lands and his return, for the priestess to give oracles again.

Here we reconstruct on a virtual manner the concept of shining god's statue face with his departure and return from the northern lands, in relation to earlier found correlation of the constellations rise and orbits in the Delphi night sky, during the year.

Normally, at any one time, there is a reciprocal relationship between gas production at a spring and the water flow: that is, as the amount of water in a spring increases gas production reduces. But there is one exception. If the water flows from a deep-seated aquifer and flows through a shallow gas-bearing reservoir, then in that case we can expect more gas with more water production. In regions where there are seismic faults with bituminous gases this status also may change with the passage of time, as tremors may cause changes in the location of water and gas fissures. Thus, variation of gases is temperature dependent. Consequently, there were seasonal variations in gas flow through the fissures at the adyton, most obviously during winter when the temperature was lower, and the water flow was also reduced. Thus, during the winter months the '*pneuma entousiastikon* '(spirit of euphoria) was rarely triggered due to the absence of gas, and this also was the time when Apollo was away, in the land of the Hyperboreans.

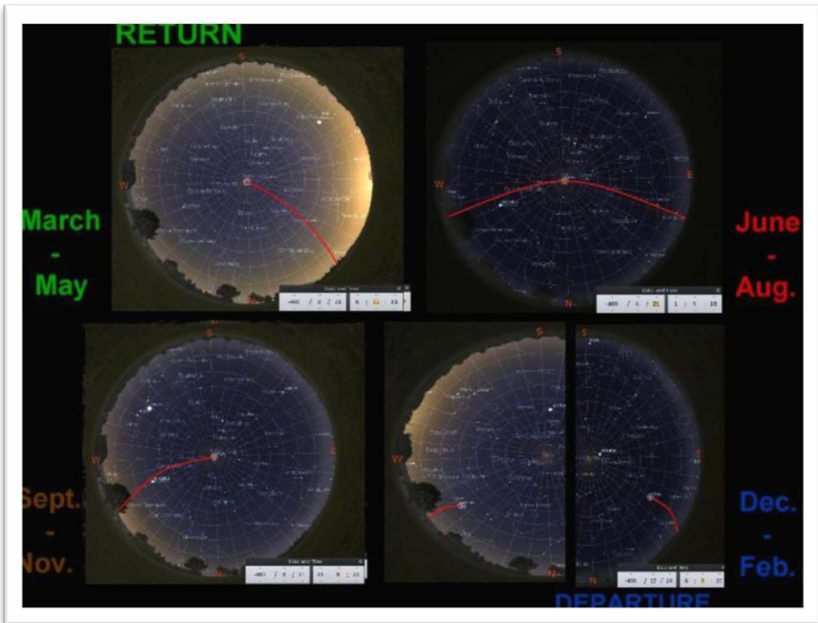


Figure 2: The transits of Lyra and Cygnus in the Delphic sky for the four seasons (after Liritzis & Castro, 2015).

Fig.2 shows the appearance of Lyra and Cygnus in the Delphic sky for the four seasons of the year. Visibility was always going to be a significant factor, as due to weather conditions in the mountains during winter sometimes it would have been difficult—if not impossible—to observe those constellations. However, their absence from the zenith at Delphi in January, February and March may have signalled the interval when Apollo was supposedly in Hyperborean lands. Obviously, the difference in the Angular Altitude of the horizon between a site on a flat landscape and one with a high rocky horizon, as at Delphi, meant that the heliacal rising of critical stars and constellations was delayed at the latter location.

The aforementioned appearance and disappearance of a particular prominent star or constellation recalls the Egyptian dating based on the Sothic cycle, that is, on the heliacal rise of Sirius. Each year for a period of seventy days Sirius was not visible due to sunlight, and its heliacal return was very important and was referred to as the coming of Sirius ʹ. The first day of the new year was marked by the first day of the lunar month immediately after the annual reappearance of this star at dawn (Castro, 2015; Ingham, 1969; Parker, 1950: 13, 29, 30-32).

Here the shining of god's golden statue is proved in relation to the absence of Apollo from holy land of Delphi, via a 3D modelling and taking into account the sunrise during the year, of declination about 47 degrees a south-eastern arc between the two solstices.

2. THE ARCHITECTURE OF THE APOLLO TEMPLE

The Temple of Apollo in Delphi is of Doric peripteron type, with a pronaos and an opisthodomos, with two Doric columns at each of their entrances. This means the main structure is surrounded by one row of Doric columns, fifteen on the larger sides and six on the smaller ones. The columns were approximately 10,7m in height and 1,6m in diameter at their base. The structure itself is measured at approx. 58,2m length and 21,7 width (Petrakos, 1971). An overview of the Temple in the sanctuary of the archaeological site of Delphi is situated in the slopes of Parnassus mountain shown here using Google Earth Pro[1] (Fig. 3).

[1] https://www.google.com/intl/el/earth/versions/

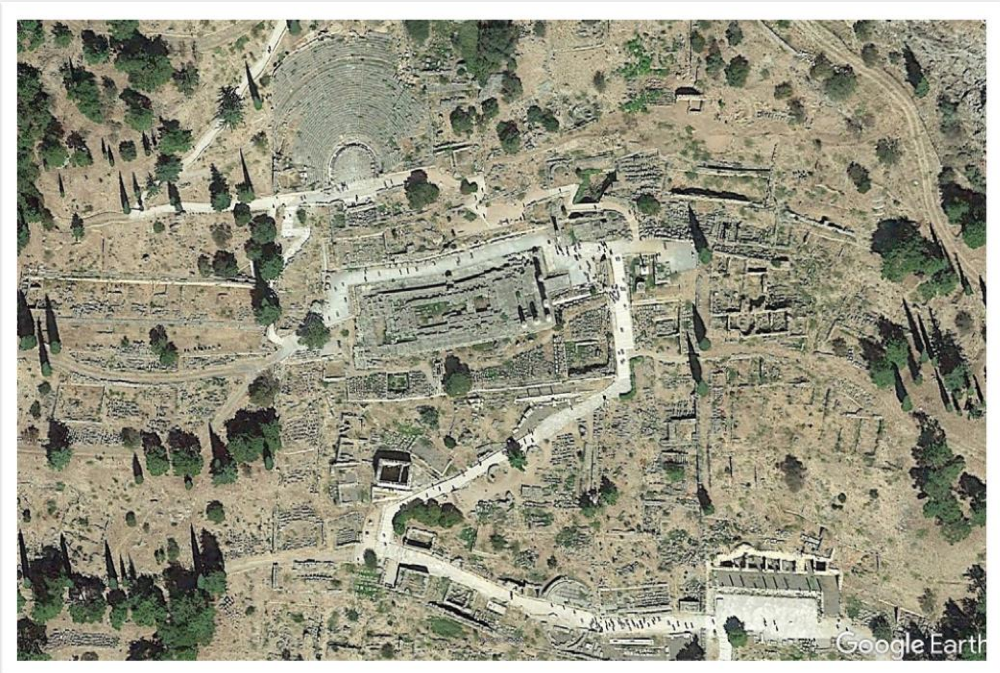
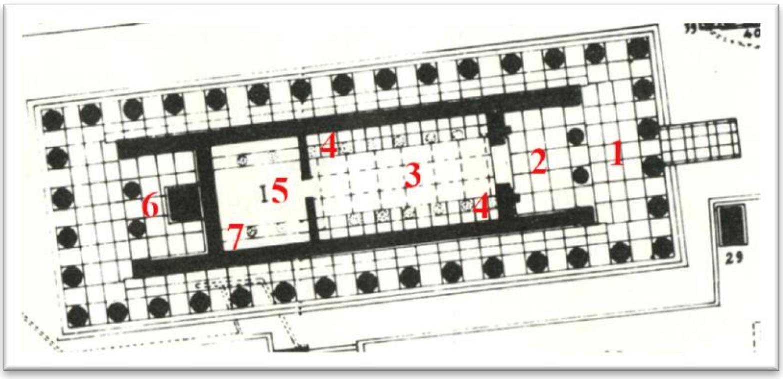


Fig. 3: An overview of the Delphic archaeological site using Google Earth Pro.

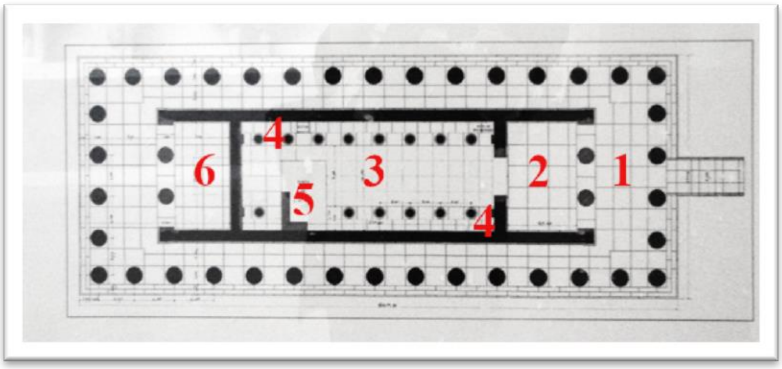
The general description of the Temple in ancient times tends to be the same in all sources. However, for the inner part of the structure, the information available to us is from Pausanias and his work *Ellados Periigisis* (Touring of Greece). According to his works, the inside of the temple was separated in 2 parts, the main temple and the sanctum. He described the main temple in some detail, but the most relevant information to this study was his description of the sanctum, where he stated he saw the omphalos, where the gases were coming out of, the tripod on which Pythia sat in order to inhale the gases and give the oracles, and a golden statue of Apollo.

The belief that this statue existed is now further enhanced, after both this and Aeschylus' description.

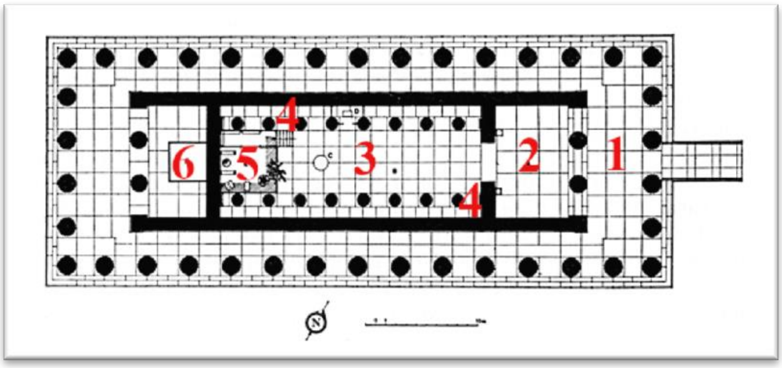
The contemporary sources on the layout of the Temple have some differences. There are three different layouts that were considered for the purposes of this study and are displayed below. In each layout, certain features have been marked as follows: 1) the entrance to the Temple, 2) the antechamber or pronaos, 3) the cella (main inner temple, sekos), 4) the inner columns, 5) the sanctum, 6) the back part of the Temple (opisthodomos) and 7) the most probable setting location for the statue of Apollo.



(A)



(B)



(C)

Figure 4: Layout of the Temple according to (A) Petrakos (Petrakos, 1971), (B) as displayed in the Archaeological Museum in Delphi, (C) according to Roux (Roux, 1976). For numbering see the text.

In Figs 4 (B) and (C) we can clearly see that the sanctum is not clearly separated from the rest of the Temple. In the case of Fig. 4 (B), perhaps a small elevation or other feature, that indicated the separation of the area from the rest of the Temple, could have existed in the past. However, that does bring into question the number of columns, which would be unequal between the two inner rows and would seem unusual. In the case of Fig 4 (C), Roux has placed the statue to the lower left corner of the area, facing towards the upper right corner. If that were true, the statue would essentially be looking towards the west, making any sort of light reaching the face impossible. In both cases, the sanctum is clearly not separate as was described by Pausanias. Therefore, the first layout was used, as it seemed the most accurate in this regard.

It has to be noted here, that the layout in Fig. 4 (A) does not clearly display the number of inner row columns. While relevant to an accurate representation of the Temple's inner rooms, they do not affect the window position directly. If the markings in the sanctum were indeed there to mark columns, as we cannot be certain if, indeed, they were such in the past, the only change that would occur would be to the statue's size, which is a completely unknown variable and was decided arbitrarily to be made fairly tall. This was done in order to make it easier both for the development of the 3D model and hence the viewer could see the statue clearly in the rendered images. For the same reason, any columns in the sanctum were not designed at all. If the columns did exist the result would be basically a smaller statue positioned forward, right next to the column, with the window moved accordingly along the wall.

The existence of openings (windows) in ancient temples is reasonably accepted, though not many preserved buildings have provided the much-desired evidence. But those at Siwa Oasis n the Temple of Ammon Ra, Egypt (see below); the earliest clay model (Fig.5A) in Heraion Argos, mid-8th c. BC (de Polignac, 1995) which imply triangular windows on the one side of the wall façade, and at Perachora (Argolid) (Fig.5B) where triangular also windows are seen along the upper part below the frieze (ceiling) (Fig.5B); and the Temple of Hephaestus in ancient agora (Thession) in Athens or Hephaesteion a well-preserved Greek temple, which remains standing largely as built, officially inaugurated in 416–415 BC, during the Peace of Nicias, preserves rectangular windows, too, with ample illumination inside (Darling, 2004).

(A)

(B)

Figure 5. A) Clay model of Temple of geometrical period from Heraeon of Argos. Apparently depicted two windows in triangular shape in the external wall (National Archaeological Museum in Athens), B) Terracotta house or temple model from Perachora, Argolid, end of the 9th c. BC. Athens, National Archaeological Museum. Bildarchiv Foto Marburg. (https://www.worldhistory.biz/ancient-history/53046-hera-of-samos.html).

3. THE VIRTUAL CONSTRUCTION TOOLS

The software that was used for the digital reconstruction was the following

1) ImageJ[2]
2) 3D Studio Max by Autodesk[3]
3) Maxwell Studio by Next Limit[4]

Initially the layout was measured using ImageJ. This software takes an input of a known distance on the image, such as the length of the Temple that was used in this case, measures it in pixels, uses that to calculate the pixel to meter ratio and then applies that ratio as its main scale. After this, it can effectively measure any line marked on the image and give an output in meters. The measurement phase was mainly done to determine distances such as the open space between columns or the inner row from the wall etc.

Having obtained the measurements, 3D Studio Max was used to create the 3D model of the Temple. Most objects were specifically designed with a very low polygon count, since the model as a whole was quite large. The statue was not designed, it is a 3D

[2] https://imagej.nih.gov/ij/
[3] https://www.autodesk.eu/products/3ds-max/overview
[4] http://www.nextlimit.com/maxwell/

scan of a cast, done by the National Gallery of Denmark, of the statue known as Apollo of the Belvedere. The model was a very detailed one, with an extremely high poly count and had to be reduced drastically in order to be easy to work with (Fig. 6). The 3D model is freely available online[5]. Finally, Maxwell Studio was used to render the scene in an above average quality, in order to get clearly visible results.

[5] https://sketchfab.com/models/fe5c0cffdc2a4f3985872212c692af0c

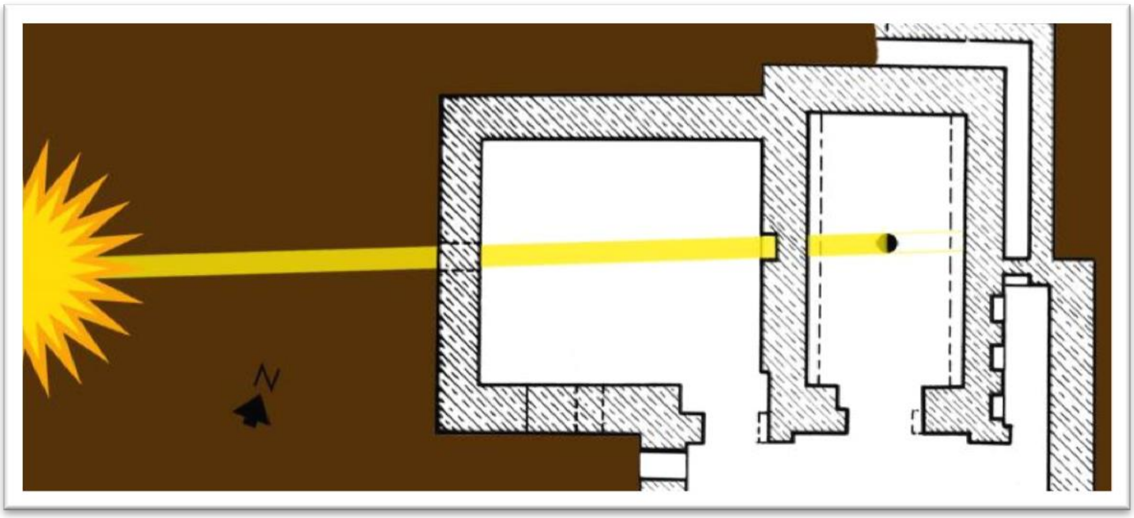
Figure 6: Belvedere's Apollo (National Gallery of Denmark, 2016)

One problem faced due to the statue and the way it was crafted, was the fact that it faces to the left, while it has significant volume on the right side. A different statue, where Apollo's hands were not extended so far from the body or one looking forward, rather than right, would make the final renders much more accurate in displaying the intended theory.

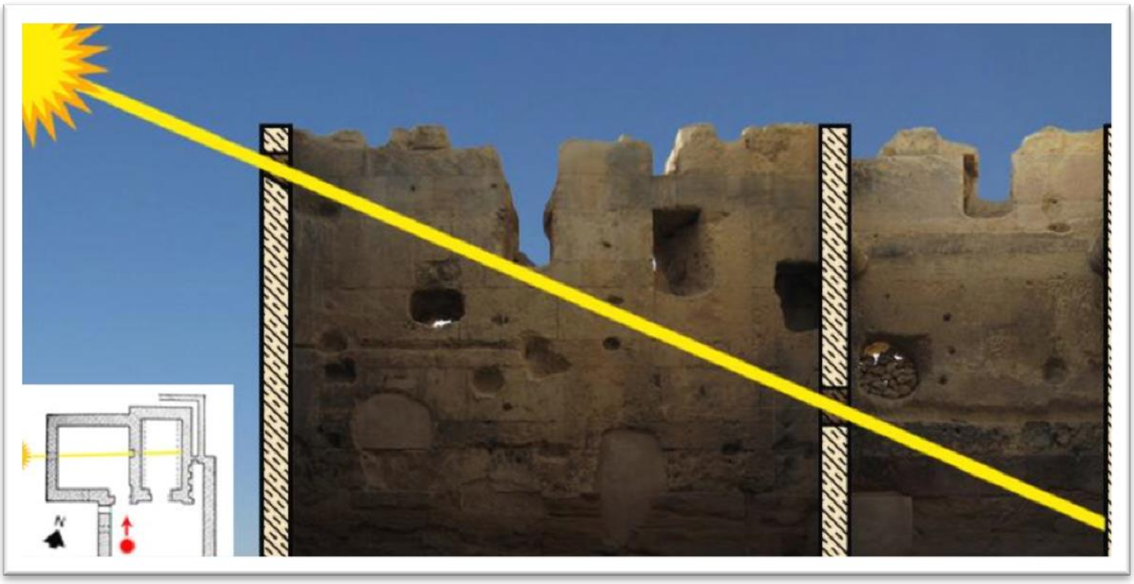
4. THE SIWAN TEMPLE OF AMMON RA

One source of inspiration concerning the windows that might have existed on ancient temples, has been the Siwan Temple of Ammon Ra, who was closely identified with Zeus in Ancient Greece and visited by Alexander the Great. The Temple, according to Bard (1999) was built approximately at the same era as the Temple in Delphi, it was also an oracular temple and was most likely built by Greek workers and possibly architects, since it displays crafting and building technology very rarely found in Egypt but was very common in Greece. According to researchers Donaldson and Itawa (Donaldson & Itawa, 2008-2018), the Siwan Temple was built with 2 very specific windows, one high on the outer east wall and one lower on the inner east wall of the sanctum as seen in Fig.7 (A) & (B). The windows are placed in such a location and lined up so that approximately seven days before the winter solstice the sun can shine through the windows into the Temple's sanctum and illuminate the statue of Ammon Ra which was possibly there. It makes sense for Ammon Ra, who was known as the Hidden One, to be illuminated only on few, very specific dates, though Donaldson and Itawa have not yet published their theories on why it was specifically a week before the solstices.

Below we can see how the sun, when visible at dawn, shone down into the Siwan Temple and the sanctum.



(A)



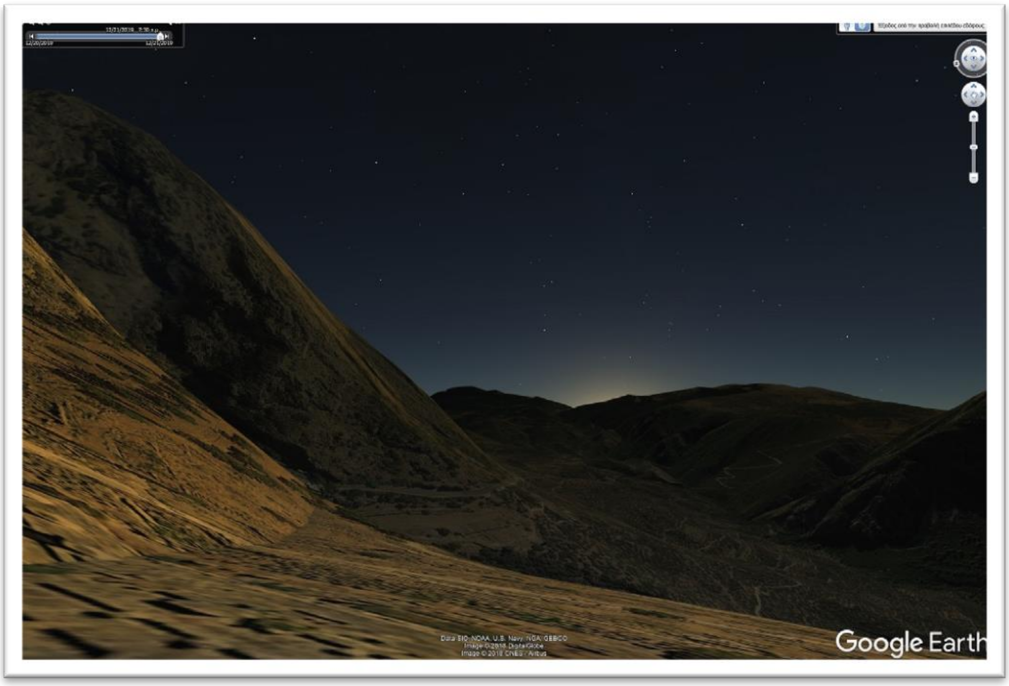
(B)

Figure 7: A) The sun shining through the windows and into the sanctum, top view, B) The sun shining through the windows and into the sanctum, cross section (Donaldson & Itawa, 2008-2018).

5. LIGHTING AND SHADOWS

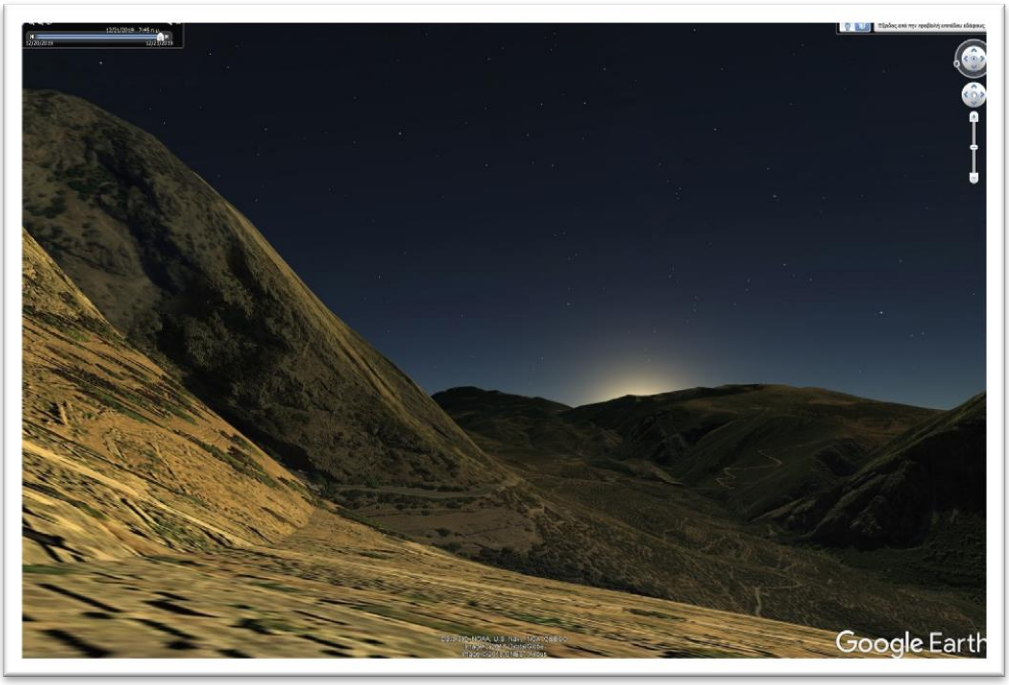
Using Google Earth Pro, we can easily see when the sun goes up past the mountainous geography surrounding Delphi, enough to shine onto the Temple, on the winter solstice, 21st of December 2019.

(A)



(B)

Figure 8: The sun rising during winter solstice over the Delphi region, as seen from the Temple's eastern side in Google Earth pro, at times A) 7:15 am, B) 7:30 am.

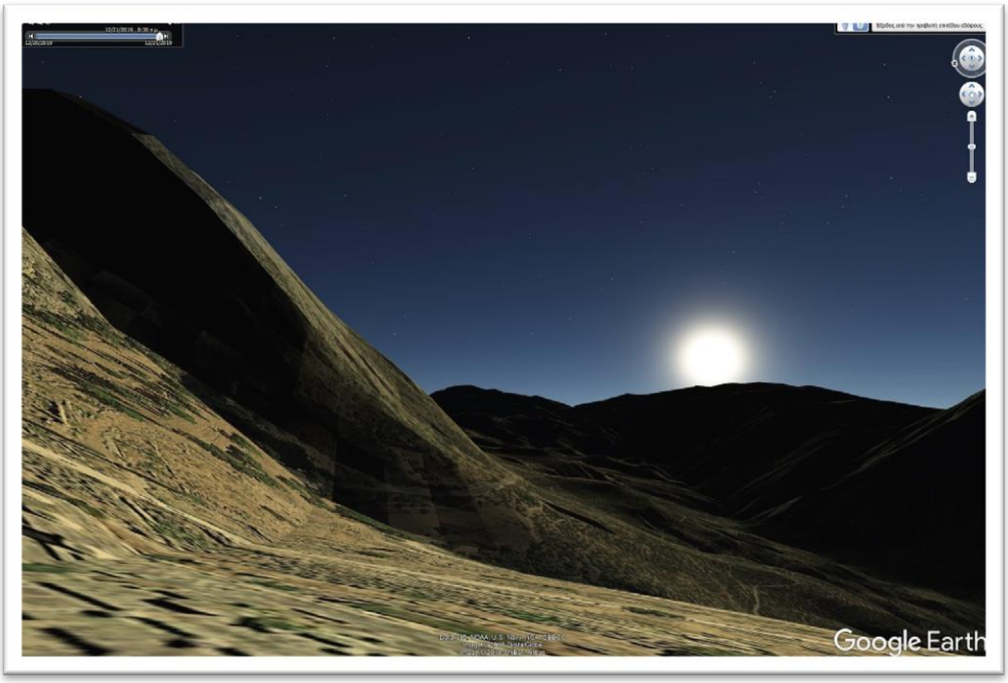


(C)

(D)

Figure 8: The sun rising during winter solstice over the Delphi region, as seen from the Temple's eastern side in Google Earth pro, at times: C) 7:45 am, D) 8:00 am.

(E)

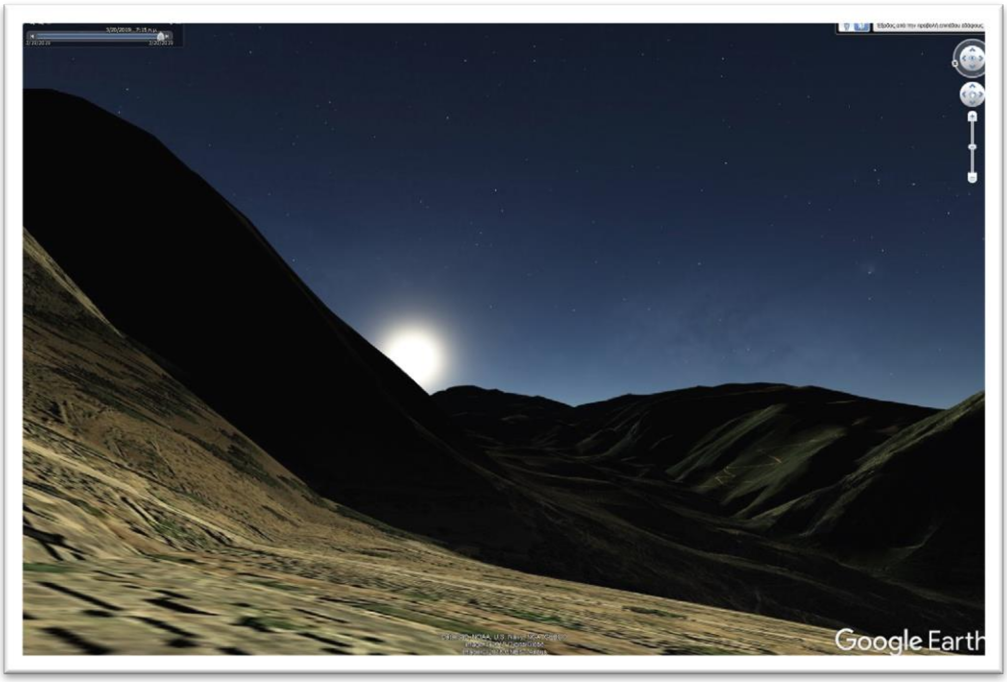


(F)

Figure 8: The sun rising during winter solstice over the Delphi region, as seen from the Temple's eastern side in Google Earth pro, at times E) 8:15 am and F) 8:30 am.

For the winter solstice, 8:15 am was picked as the time of renders, since the sun is high enough above the visible horizon to light upon the Temple's eastern side. The actual dawn, computed for a completely flat horizon, would be at approximately 7:43 am but it is clearly seen in Fig. 8 (C) that the mountains surrounding the area would block the sunlight from ever reaching the Delphi site. In Fig. 8 (D) the solar disk is barely visible over the mountains, but it still wouldn't be possible for sunlight to directly illuminate the site when appearing over the mountain. It is at 8:15 am, Fig. 8 (E) that the solar disk has risen enough over the mountains to directly illuminate the Temple. In all of the dates examined, the times for renders were chosen using this approach, examining when the sun would actually be visible from the Temple site and then the time at which the solar disk is clearly seen behind the mountains.

In Fig. 9 below we can see similar images of the sunrise, for 7:15 am for both the equinoxes (see NOTE 1].

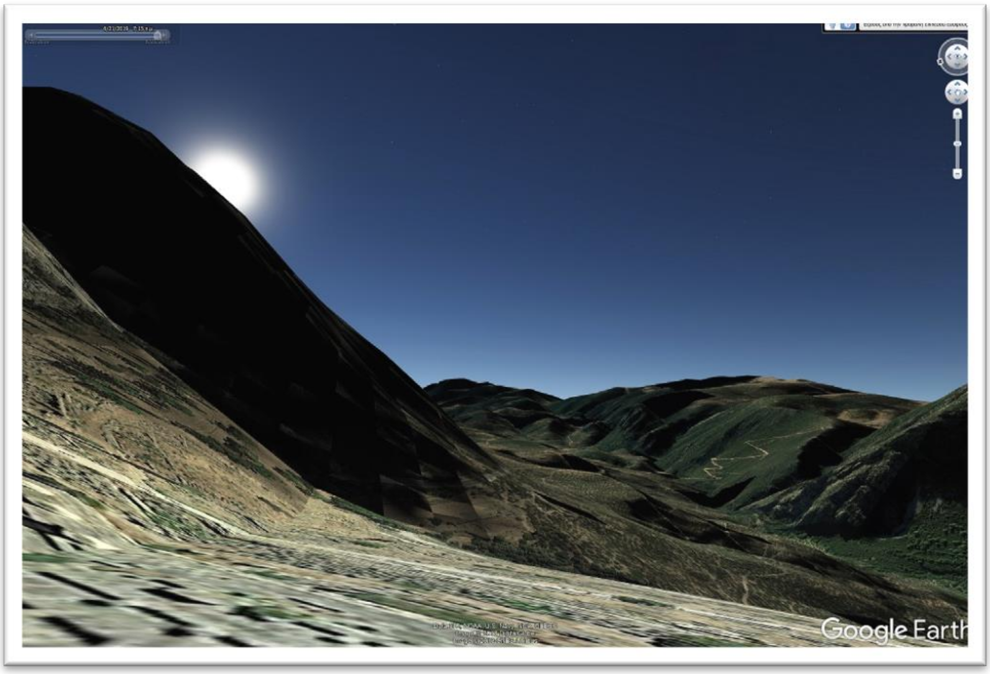


(A)

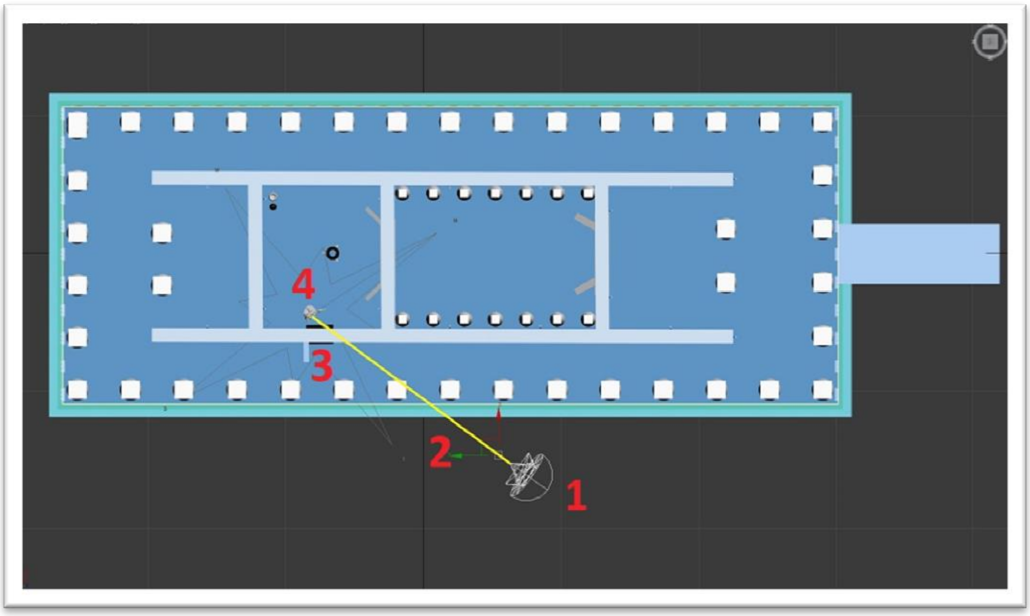
(B)

Fig. 9: The sun rising over Delphi at 7:15am during (A) the vernal equinox and (B) the autumnal equinox.

Our focus has mainly been on the winter solstice and the equinoxes, as according to earlier research (Liritzis & Castro 2013) described above, they mark the departure and return of the God from the hyper-borean lands and correspondingly the period the priestess did not deliver oracles. Despite the absence of the God the illuminated statue would indicate his spiritual presence. The results here support the theory that those were the dates the statue would be illuminated by sunlight. All four solar stands and times were rendered, and with the exception of the summer solstice, in all other three dates the sun would indeed shine through the window and into the sanctum, a few minutes after dawn. During the summer solstice, the sun indeed shines on the Delphic landscape during dawn, but the angle at which it illuminates the Temple makes it very difficult to actually reach the adyton. This is demonstrated in the following images in Fig 10.



(A)

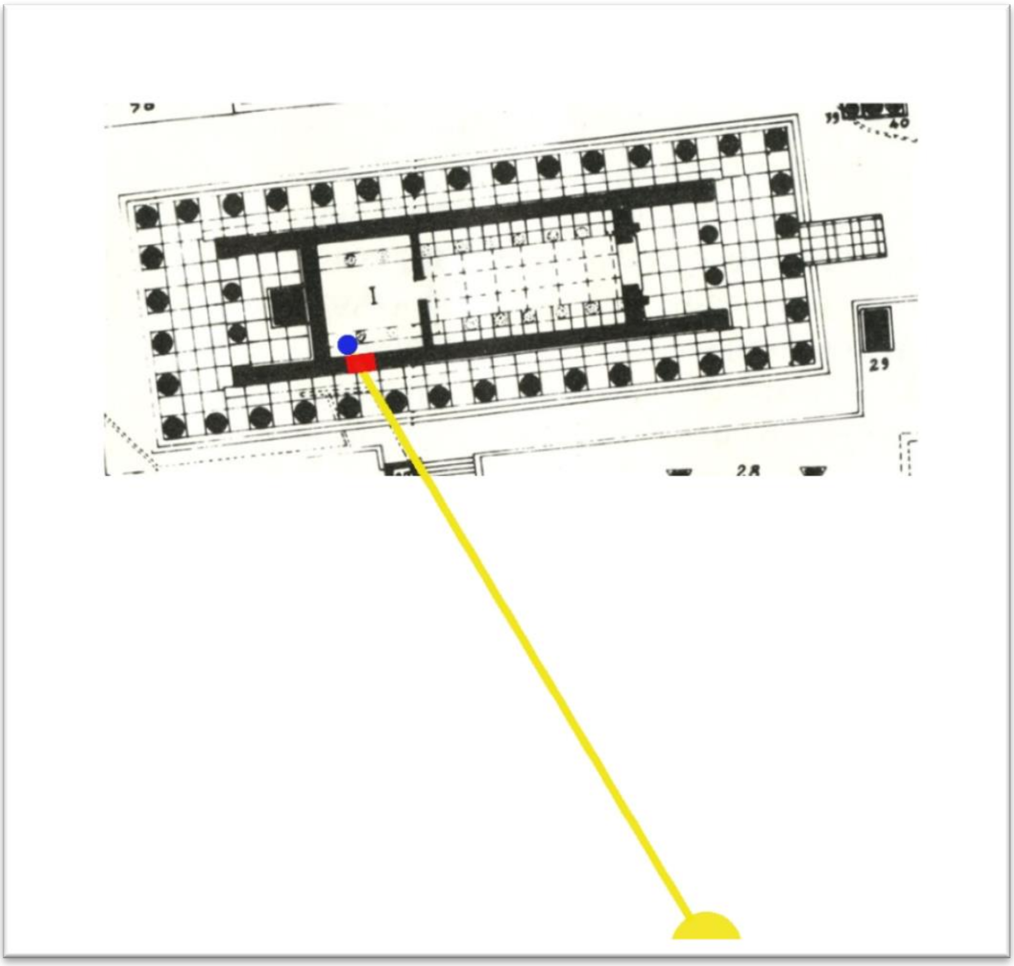


(B)

Figure 10: Summer solstice over the Delphic landscape in (A) Google Earth Pro and (B) 3D model of the Temple, top view with (1) location of the sun, (2) direction of the sunlight (blocked by pillars), (3) location of the window, and, (4) location of the statue.

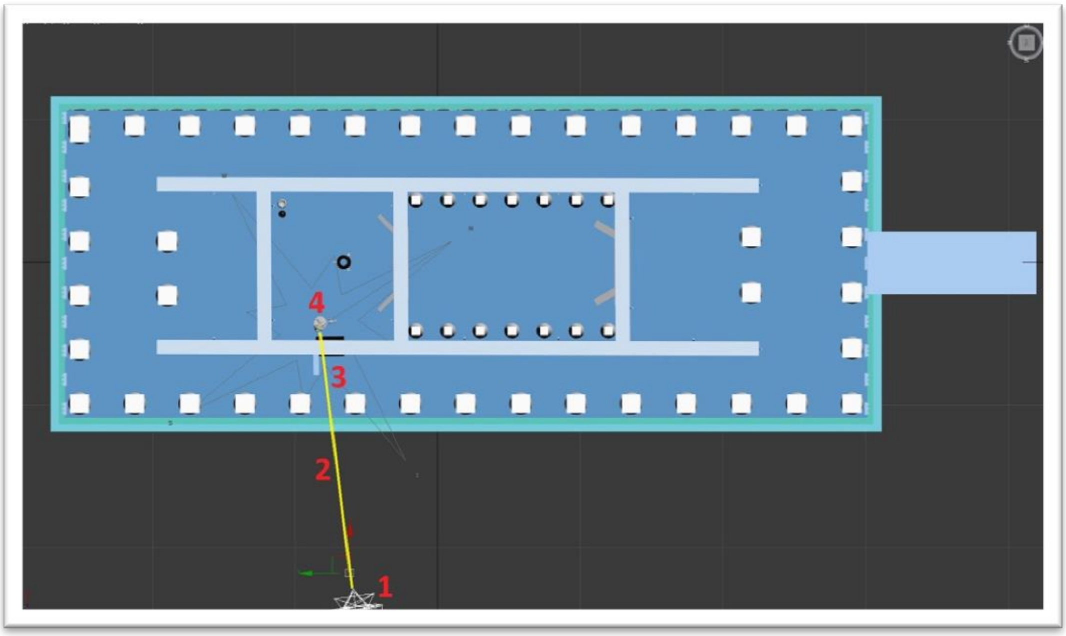
In Fig. 10 (A) is seen the actual dawn over the Temple on the 21st of June 2019 seen in Google Earth Pro, using the site of the Temple as a viewpoint. In Fig 10 (B) the same date and time was used in 3D Studio Max to illustrate how the sunlight would illuminate the Temple. For the window location picked in the renders the pillars would block sunlight at dawn. Even if the pillars or window were in a different location, sunlight still wouldn't reach the inner part of the adyton due to the high angle at which the sun appears behind the mountains at dawn.

In Fig.11 (A) the layout used for the digital reconstruction and the location that the sun would shine on, as soon as it was visible over the horizon, during dawn, on the winter solstice, is noted. Marked in red is the location that was used for the window and in blue the location of the statue. It can be clearly seen how this is the only possible location that the sun would reach the inner sanctum at dawn, since before that it has not risen above the horizon (NB: sun's orbit is an arc with oblique rising from east to west). In Fig.11 (B) the location of the sun displayed on the model is seen. The roof of the model has been hidden from view, to display the inner structure. The sun on the bottom of the image is shown as it shines down onto the Temple at early morning, when it has barely cleared the horizon line and the solar disk is visible from the Temple's location.



(A)

Figure 11: The sun shining at dawn onto the temple, winter solstice, 8:15 am, (A) on the layout used for designing the 3D model.



(B)

Figure 11: The sun shining at dawn onto the temple, winter solstice, 8:15 am, (B) on the 3D model, (top view). Marked in the image are 1) the approximate location of the sun, 2) the direction of the sunlight, 3) the window's location on the eastern wall and 4) the statue's location.

Following (Fig.12) is a front view of the 3D model. The left side pillars and wall have been hidden to display the location of the window, as well as, the angle of sunlight.

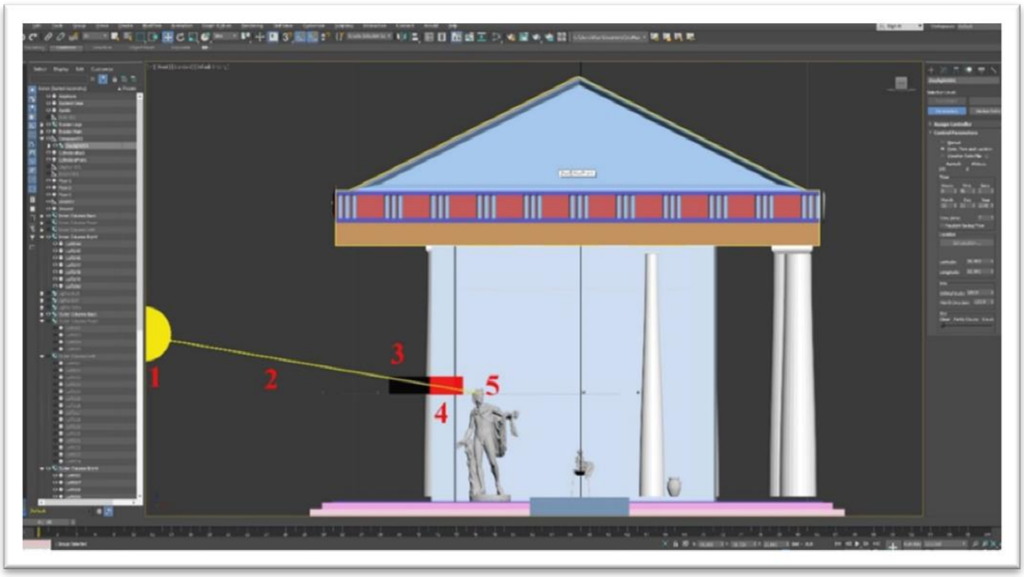
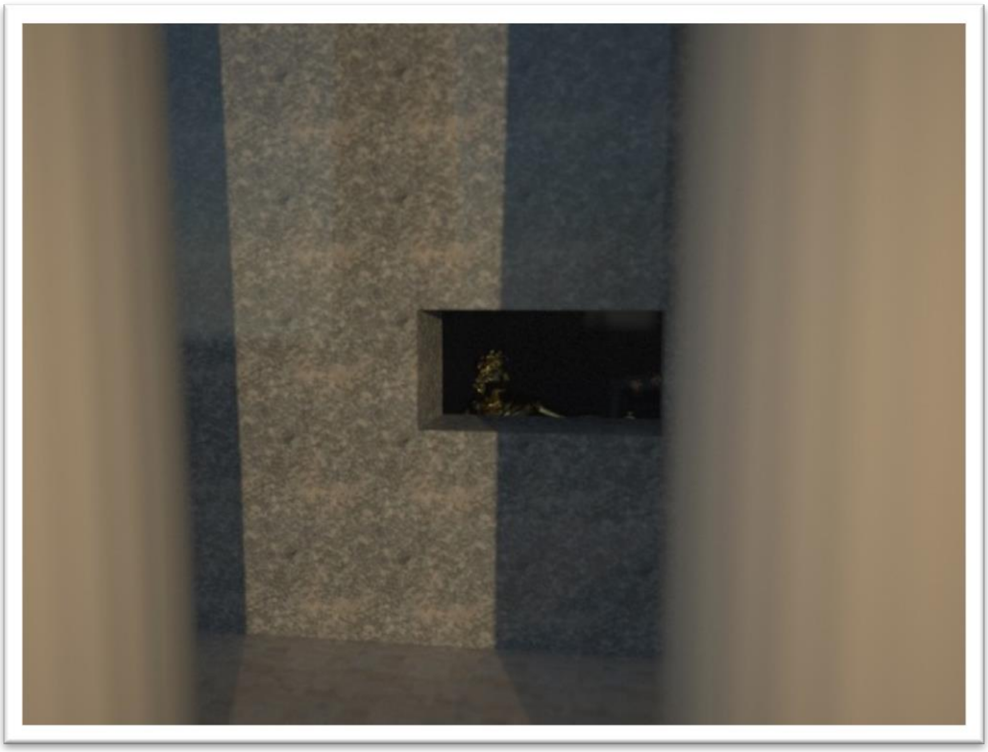


Figure 12: Sun shining into the Temple at dawn, winter solstice, 3D model (front view). Marked on the image are: 1) the approximate location of the sun, 2) the direction of the sunlight, 3) and 4) the suggested window and window panel and, 5) the statue's face, the intended target.

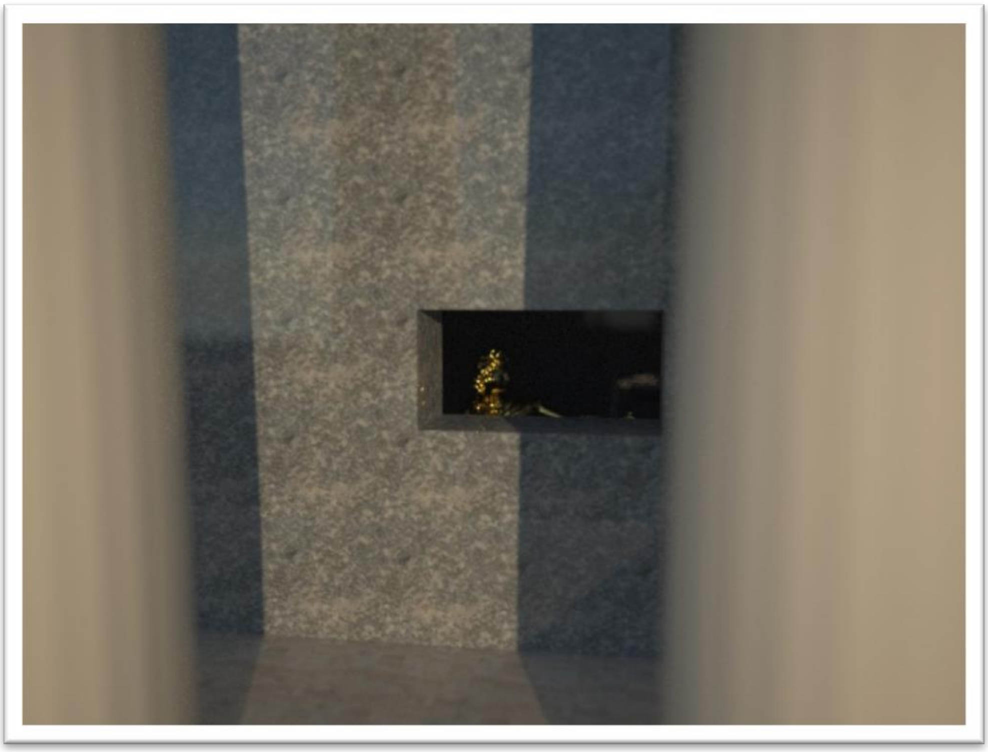
Following are the renders done from outside the temple looking at the window, to make it easier to see how the sunlight illuminates the statue, are seen in Fig.13.

(A)



(B)

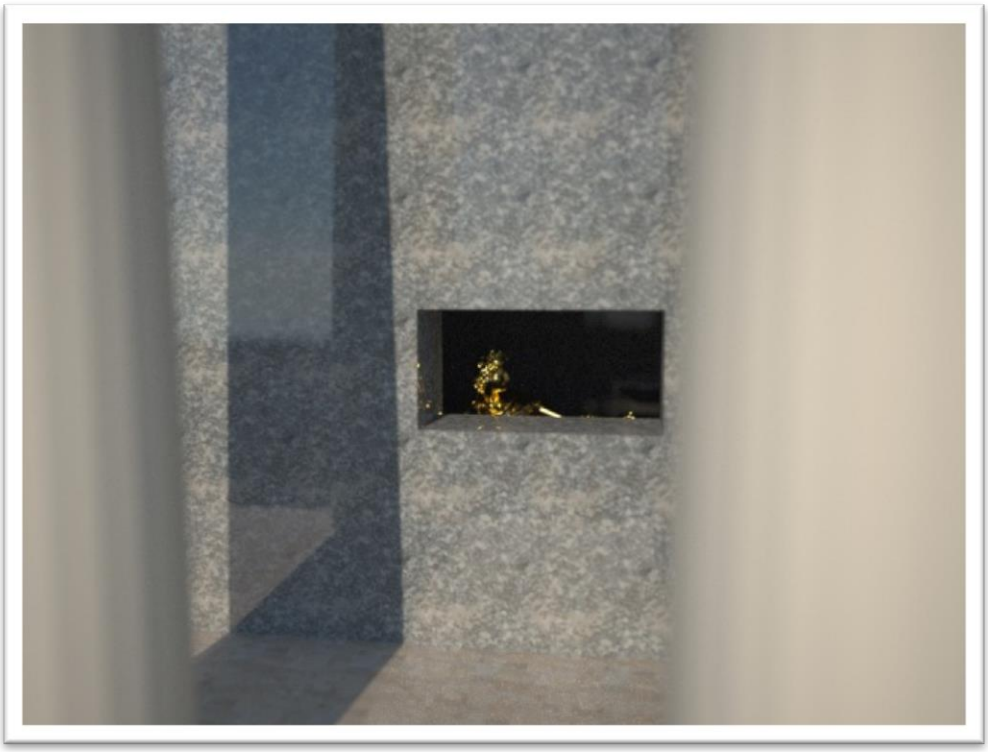
Figure 13. Render, view from outside, left side of the Temple at A) winter solstice, 08:15 am, B) winter solstice, 08:30 am.



(C)

(D)

Figure 13. Render, view from outside, left side of the Temple at C) winter solstice, 08:45 am, D) winter solstice, 09:30 am.



(E)

(F)

Figure 13. Render, view from outside, left side of the Temple at E) winter solstice, 10:30 am, F) January 30, 08:15am

(G)

(H)

Figure 13. Render, view from outside, left side of the Temple at G) autumnal equinox, 07:15 am, H) vernal equinox, 07:15 am.

During winter, the statue is illuminated, though not as much as during the equinoxes. However, since the sun is lower at the time, the statue could be illuminated for much longer during the day. The first images in Fig.13 (A) to (E) display this effect. The Fig.13 (F) simulates the sun at dawn, at January

30th, nearly a month after the winter solstice and a month before the equinox. It serves as a guideline, to indicate that the effect persists during the months between those solar stands. Figs.13 (G), (H) represent renders for equinoxes.

Fig. 14 is a view of the inside of the Temple, looking at the statue from the sanctum door, as the sun is illuminating it during winter solstice, at 10:30 am, to show approximately what a visitor to the Temple would look upon at that specified time.

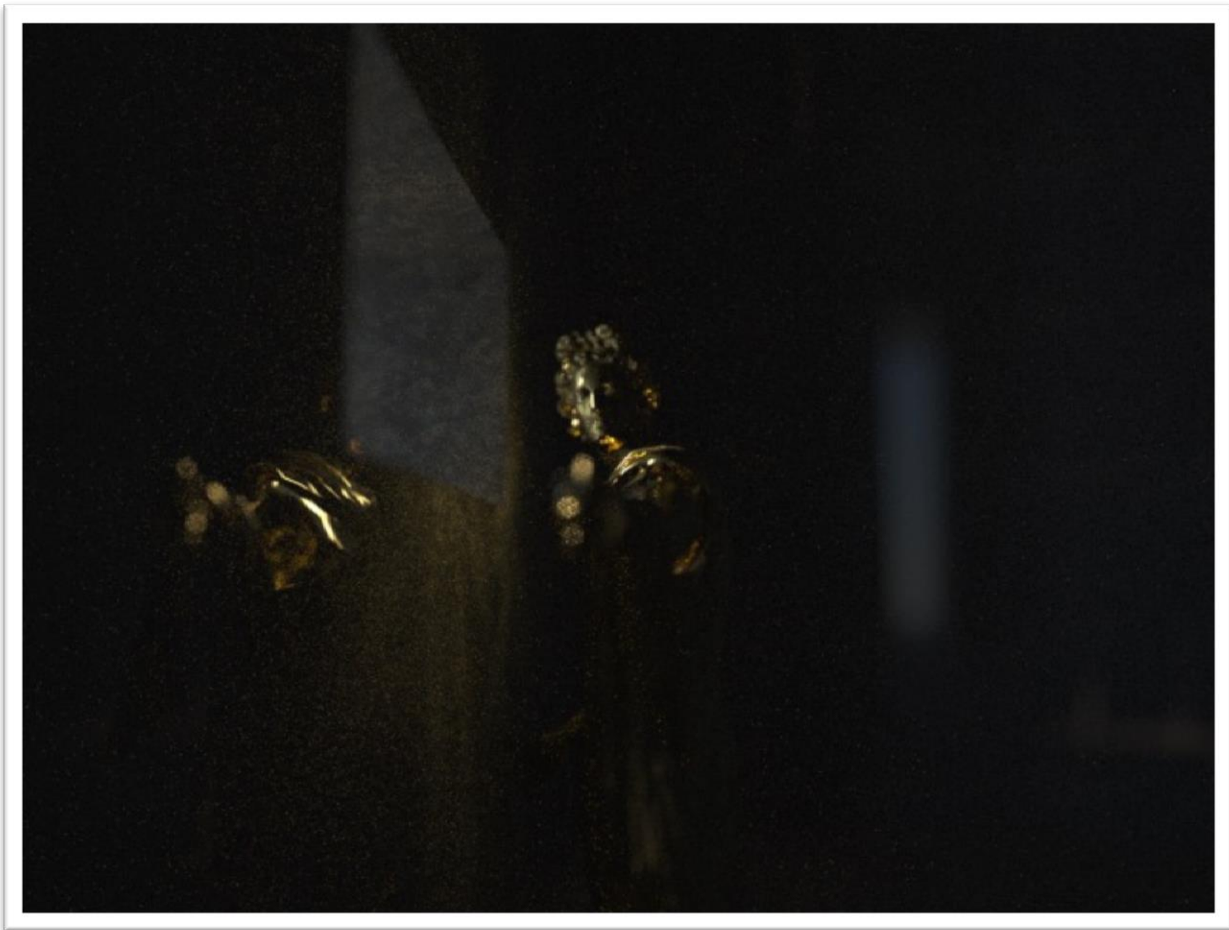


Fig. 14, view from sanctum door, 10:30 am, winter solstice.

Vitruvius suggest that most ancient Greek temples were built with such an orientation that the visitors to the temple would be facing the god's statue, which would be looking towards the west, so that the visitors would be looking at the sun and the statue at the same time. However, he did note that in many cases, this was not the rule and it was dependent on the area and the Temple. In many cases, he mentions that the temple would be oriented so that it would "look" over as much of the city as possible (Vitruvius in Morgan, 1914; Book IV, Chapter 5). In the case of this Apollo Temple, the visitors entered facing west-southwest. Therefore, this was one of the exceptions.

6. DISCUSSION & CONCLUSION

The digital reconstruction of lighting of Apollo's statue in his Delphi Temple has been achieved using modern software and accurate architectural designs of the temple, based on archaeological, historical and textural evidence. Shining of the statue's face presumes some opening (window) much like some scarce cases (Hephaestus, Siwa, Heraion clay model).

The window in the Apollo Temple, Delphi, has been designed quite large, 1 meter in height and 2 in width, compared to the one in the Siwan Temple. The window was made so large in the renderings, to properly display the statue on the inside, for the viewer's ease. It can be much smaller, at the proposed width of 1 meter, but would be harder to indicate in the renderings. The exactly similar effect was achieved using two smaller windows and could possibly be achieved with many smaller openings (some tests were made even with seven small openings). The reasoning behind using a single window was that using two or more made them very close to each other and difficult to properly see through, while looking at the digital reconstruction. The aim here is to prove whether there could be a window at such an angle and height that would allow for this effect, i.e. the sun lighting up the statue's face. There are factors unknown to us that could affect the exact renderings, most importantly the statue's size and facing, which would change our suggested location, height and size of the window.

Regarding the shining during winter solstice, i.e. the time of departure, and later through spring equinox, although he is absent, yet his spirit is present in Delphi and this may signify his ubiquitous omnipresent. Moreover, the winter solstice and spring equinox signify the timing for ceasing and delivering oracles, respectively, determined from the visibility and duration throughout the Delphic night sky of his favourite constellations rising in front of the Temple's entrance. The reconstruction in a 3D digital way of the shining of god's statue in the sanctum (adyton area) implies an opening (window), whereas the lighting and shadows produced a prodigious effect related to the myth and the time of delivering oracles.

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NOTE

[1] At equinox, the length of daytime and nighttime would be more equal if we defined sunrise and sunset to mean the time where the center of the sun's disc rose above the horizon. On an equinox, day and night are of approximately equal duration all over the planet. They are not exactly equal, however, due to the angular size of the sun and atmospheric refraction.

But that is not how sunrise and sunset are defined. Sunrise occurs when the top edge of the sun appears above the horizon. Sunset occurs when the top edge of the sun disappears below the horizon. By this definition, daytime gets a few minutes more play than nighttime at the equinoxes.

Moreover, the exact moment of equinox does not coincide at same hour thus e.g. in Athens 2019 20 Mar 23:58 EET and 23 Sep 10:50 EEST, a difference of 11 hours.

Due to time zone differences, the equinox also may occur hours or a day later in locations ahead of UTC and respectively earlier in locations behind UTC.

The March equinox marks the moment the Sun crosses the celestial equator – the imaginary line in the sky above the Earth's equator – from south to north and vice versa in September.

One of importance to archaeoastronomy is that the word Equinox may hide different definitions (see e.g., Ruggles 1997, González-García & Belmonte 2006) and each one implies different durations of day and night. Also, in the case of equilux, the word may be subject to an inherent ambiguity as then one has to define if the definition includes only when the sun is visible, or also the dusk and dawn hours (i.e. twilight). In this latter case, the definition is even more difficult to set.

To compound the issue, due to atmospheric refraction, the sun appears to be rising when in fact it is entirely below the horizon. Similarly, at sunset, when we see the sun actually setting it actually set below the horizon a few minutes earlier. This phenomenon also serves to extend daylight hours at the expense of night time.

Hence due to refraction, the difference of occurrence of the two equinoxes and direction of sun crossing the celestial equator, the position of the observer on earth, the time difference in sun rising at the same horizon point between vernal and autumnal sun rising amounts to a few minutes.

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