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## The Church of the Holy Apostles in Thessalonike: A study of the natural light\*

*With six plates*

### 1. INTRODUCTION

A distinctive characteristic of Palaiologan churches is the upward surging of the dome, a desperate attempt to explore the limits of technical possibilities. The superb sense of elevation and exaltation in the central spaces of the churches of this period is intensified by the natural light that enters through the windows of the dome and the lateral walls. The colour and quantity of the light that enters a church, along with the light that emanates from the symbols, forms and colours within it, lends the space spirituality and creates a suitable aesthetic atmosphere<sup>1</sup>.

Within this framework we will attempt in this study to interpret the role of the natural light entering the Church of the Holy Apostles in Thessalonike<sup>2</sup> (pl. 1a).

The church of the Holy Apostles is believed to have been the katholikon of a monastery of the Theotokos, near the Litea gate, south of the Hagiou Demetriou Street and is on the lower western fringes of

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<sup>1</sup> J.C. MARGADE, For the Light, Light and Colour in the Russian Avant-Garde, in: The Costakis Collection from the State Museum of Contemporary Art at Thessalonike. Köln 2004, 434–436; In the 14<sup>th</sup> century, when independent schools began to spring up in Russia, the art of the icon arrived with the theology of divine energies and Hesychasm, as formulated by the great thinker from Thessalonike, Gregory Palamas. In the wake of Gregory of Nyssa in particular, Gregory Palamas asserts the inaccessibility of the Divinity in its essence (*ousia*) to any human or even angelic vision. Yet from the unassailable shadows emanate energies, a light that illuminates all creation at its core. This is no longer the light of the physical sun, but that of the Three Suns of the divine, a light coming from the shadows which irradiates all creation and knows no tangible shadow. It is the 'light of Tabor', the light that the disciples of Christ saw during His transfiguration on Mount Tabor; K. KALOKYRIS, Ἡ Θεολογία τοῦ φωτός καὶ ἡ παλαιολόγια ζωγραφικὴ (Ὁ Παλαμισμὸς στὴ βυζαντινὴ τέχνη), in: KB' Demetria Symposium Christianike Thessalonike. Palaiologeios Epoche. Thessalonike 1987, 343–354.

<sup>2</sup> A. XYNGOPOULOS, Η ψηφιδωτὴ διακόσμησης του ναοῦ των Αγ. Αποστόλων Θεσσαλονίκης. Thessalonike 1953; M. CHATZIDAKIS, Βυζαντινὴς Θεσσαλονίκης Εγκώμιον. *Nea Hestia* (1995) 514–522; G. VELENIS, Οι Ἅγιοι Ἀπόστολοι τῆς Θεσσαλονίκης καὶ ἡ Σχολὴ τῆς Κωνσταντινούπολης, in: Akten XVI. Int. Byzantinistenkongress, II/4 (= *JÖB* 32/4). Wien 1982, 457–467; Ch. BAKIRTZIS – P. MASTORA – St. VASSILIADOU – N. PASSALIDIS, Lessons learned in mosaic maintenance: the case of the wall mosaics in the church of the Holy Apostles in Thessalonike, in: 9<sup>th</sup> International Committee for the Conservation of Mosaics conference, Hammamet 2005 [in press]; S. TAMBAKI, Η Θεσσαλονίκη στις περιγραφές των περιηγητῶν 12<sup>ος</sup>–19<sup>ος</sup> αἰ. (*Byzantina Mnemeia* 10). Thessalonike 1998, 71–77; E. KOURKOUTIDOU-NIKOLAIDOU – A. TOURTA, Περίπατοι στη βυζαντινὴ Θεσσαλονίκη. Athens 1997, 141; Ch. MAUROPOULOU-TSIOUMI, Βυζαντινὴ Θεσσαλονίκη. Thessalonike 1992; ΕΑΔΕΜ, Μνημειακὴ ζωγραφικὴ στη Μακεδονία κατὰ τον 14<sup>ο</sup> αἰ., in: Β' Symposio. E Makedonia kata ten epoche ton Palaiologon. Thessalonike 1992, 399–410; Ch. STEPHAN, Die Mosaiken und Fresken der Apostelkirche zu Thessalonike. Baden-Baden 1986; M.L. RAUTMAN, The Church of the Holy Apostles: A Study in Early Palaiologan Architecture. (PhD) Indiana University 1984.

the city 10 meters from the west city wall.<sup>3</sup> The church was connected with Patriarch Niphon I between 1310 and 1314. He appears three times, as patriarch and as founder, in inscriptions on the church façade.<sup>4</sup> Of the monastery precinct the gate on the south side has survived. North of the katholikon and within the monastery precinct there is still a large cistern, which collected the spring water from Asvestochori and Retziki area in the North of Thessaloniki. The monastery covered an area of more than 10,000 m<sup>2</sup>, which was much larger than that of the Peribleptos (St Panteleemon) monastery, located in the densely populated late Byzantine central lower city.<sup>5</sup>

The period when the Holy Apostles church was founded is considered to be the “golden era” of Thessalonike<sup>6</sup>.

Our research was motivated by the conditions of intense lighting that prevail today in the naos and are a result of recent restoration work<sup>7</sup>. The subject is rather complex as many factors are involved, such as the orientation of the church, its geometric proportions<sup>8</sup>, later interventions<sup>9</sup>, visual transmittance and the colour of the glass window panes<sup>10</sup>.

## 2. THE ORIENTATION OF THE CHURCH

In the first phase of the investigation the following were determined: a) the orientation of the church, with the aid of a compass; b) the azimuth of the sun at sunrise for Thessalonike’s latitude (40° 42’).

The measurements revealed that the main axis of the church has a SE-NW orientation<sup>11</sup>. The deviation is 112° from north<sup>12</sup>; i.e. 12° more easterly than the other churches located in the Thessalonike conurbation<sup>13</sup>. An extension of the central axis to the south-east coincides geographically with the eastern slopes of Mt Chortiates.

<sup>3</sup> Ch. BAKIRTZIS, The Urban Continuity and Size of Late Byzantine Thessalonike. *DOP* 57 (2003) 36–64; R. JANIN, Les églises et les monastères des grands centres byzantines (Bithynie, Hellepont, Latros, Galèsios, Trébizonde, Athènes, Thessalonique). Paris 1975, 352–354.

<sup>4</sup> J.M. SPIESER, Inventaire en vue d’un recueil des inscriptions historiques de Byzance, I. Les inscriptions de Thessalonique. *TM* 5 (1973) 168–170; N. NIKONANOS, Οι Άγιοι Απόστολοι Θεσσαλονίκης. Thessalonike <sup>3</sup>1998, 27.

<sup>5</sup> A. ORLANDOS, Ἡ κινστέρνα τῶν 12 Ἀποστόλων. *Maked* 1 (1940) 377–383; BAKIRTZIS, Urban Continuity 60.

<sup>6</sup> N. MOUTSOPOULOS, Μορφές και χώρος στην παλαιολόγεια αρχιτεκτονική, in: Β’ Symposio. E Makedonia kata ten epoche ton Palaiologon. Thessalonike 1992, 289–371; K. BAROUTAS, Το πρόβλημα της ελευθερίας στην βυζαντινή τέχνη. Athens 2002.

<sup>7</sup> The restoration work was carried out by the 9<sup>th</sup> Ephorate of Byzantine Antiquities and involved the cleaning of mosaics and the replacement of the glass in the triple-light windows in the tympana of the cross-arms and the windows of the central dome. Since this work was completed the naos has been intensely luminous.

<sup>8</sup> N. MOUTSOPOULOS, Harmonische Bauschnitte in den Kirchen vom Typ kreuzförmigen Innenbaus im griechischen Kernland. *BZ* 55 (1962) 274–291; R.G. OUSTERHOUT, The Architecture of the Kariye Camii in Istanbul (*DOS* 25). Washington, D.C. 1987, fig. 49; I.G. ILIADIS, The natural lighting of the mosaics in the Rotunda at Thessalonike. *Lighting Research and Technology* 33/1 (2001) 13–24 and IDEM, The Panagia Kosmosoteira at Pherai (Vera): The natural lighting of the katholikon. *JÖB* 55 (2005) 229–254.

<sup>9</sup> P. VOCOTOPOULOS, The Role of Constantinopolitan Architecture during the Middle and Late Byzantine Period, in: Akten XVI. Int. Byzantinistenkongress, I/1 (= *JÖB* 31/1). Wien 1982, 551–573.

<sup>10</sup> E. KOURKOUTIDOU-NIKOLAIDOU, Υαλοπίνακες και υαλοστάσια στο Βυζάντιο, in: History and Technology of Ancient Glass, international seminar, ed. A. ANTONARAS – G. KORDAS. Athens 2002, 119–127.

<sup>11</sup> Th. ANTONAKAKE, Lighting and spatial structure in religious architecture: a comparative study of a Byzantine church and an early Ottoman mosque in the city of Thessalonike, in: 6<sup>th</sup> international Space Syntax symposium. Istanbul 2007, 1–14. According to the author, the Church of the Holy Apostles was dedicated to the Theotokos and is orientated in such a way as to celebrate the Assumption (15<sup>th</sup> August), with its central axis aligned 112° degrees from north, so that on 15 August 1313 the left-hand jamb of the central window would have been in a direct line with the altar. However, the latest measurements have revealed that the central axis of the church has a SE-NW orientation and that in August, after sunrise, the first rays of the sun enter diagonally through the east window of the dome. Furthermore, it has been discovered that in spring and autumn sunrise coincides with the church’s central axis.

<sup>12</sup> The azimuth is measured from the north.

<sup>13</sup> These churches are orientated is 124° from north. A. BANTELLAS – P. SAVVAIDOU – I. DOUKA, Ο προσανατολισμός των εκκλησιών της Θεσσαλονίκης. *Kleronomia* 15 (1983/2) 321–336; Ch. PAPAGEORGIOU, Ο αστρονομικός προσανατολισμός ναών, συναγωγών και τζαμιών της Θεσσαλονίκης παράλληλα προς τον άξονα της Εγνατίας οδού. *Epistemonike Epeterida tu Kentru Istorias Thessalo-*

As far as the azimuth is concerned, it was found that 1) in spring and autumn the point at which the sun rises coincides with the church's central axis, with a small deviation from month to month; 2) in winter it coincides with the axis of the southern sanctuary windows, while 3) in summer it coincides with that of the northern ones. This particular choice of orientation determined the alignment of the whole building in relation to the path of the sun. Thus the church's windows (those in the dome and the tympana) possess a specific orientation and the light is directed at certain points of the interior, creating effects which might be described today as random phenomena.

The block of flats that has stood since 1950 on the east and north-eastern sides of the church obstructs the entry of light in the mornings. Direct sunlight enters the church about an hour later than it would do otherwise.

### 3. GEOMETRIC PROPORTIONS

Some years ago Hans Buchwald showed that Church E at Sardis was laid out using a simple method of *quadratura* and he suggested that the use of this method was probably widespread in Byzantine architecture and worthy of further investigation<sup>14</sup>. In their study of the Church of the Holy Apostles, Kuniholm and Striker<sup>15</sup> showed that the *quadratura* method had been applied in the ground-plan of the church.

Taking the findings of this research further, we discovered that the ground plans and transverse section<sup>16</sup> of the church is an inscribed square in a circle with a side length of 12 m and a diagonal of 17 m<sup>17</sup> (Fig. a). The ratio of the diagonal to the length of the square's sides is  $\sqrt{2}$ <sup>18</sup>. The building is exceptionally well – proportioned. If we also take into consideration the fact that Palaiologan intellectuals regarded Thessalonike as a cradle of Greek culture<sup>19</sup>, then it would be interesting to find out if this symmetry has a deeper significance.

In order to address this issue, we looked further back into the history of mathematical thought, and specifically at the 'irrational – asymmetrical numbers' of Euclid, the Pythagoreans<sup>20</sup> and Plato. The dis-

nikes (1990) 25–38; I.G. ILIADIS, The orientation of the Byzantine churches in Eastern Macedonia and Thrace. *Mediterranean Archaeology and Archeometry* 6 (2007/3) 209–214.

<sup>14</sup> H. BUCHWALD, Sardis Church E – A Preliminary Report. *JÖB* 26 (1977) 265–299.

<sup>15</sup> P.I. KUNIHOLM – C.L. STRIKER, Dendrochronology and the Architectural History of the Church of the Holy Apostles in Thessalonike. *Zeitschrift für Geschichte der Baukunst* 20 (1990) 14–15.

<sup>16</sup> KUNIHOLM – STRIKER, Dendrochronology, fig. 8, in which shows the *quadratura* is almost identical to the ground plan in Fig. a, although it provides a different interpretation.

<sup>17</sup> The total area of the square is 144 m<sup>2</sup>.

<sup>18</sup> H. BUCHWALD, Lascarid Architecture. *JÖB* 28 (1979) 262–296, figs. 3–9. Of particular interest is the way in which the church of the Latomou Monastery has been laid out the  $\sqrt{2}$  formula has evidently been applied in the ground-plan; IDEM, The Geometry of Middle Byzantine Churches and Some Possible Implications. *JÖB* 42 (1992) 293–329; N. ΜΟΥΤΣΟΠΟΥΛΟΣ, Οι εκκλησίες της Καστοριάς 9<sup>ος</sup>–11<sup>ος</sup> αι. Τα βυζαντινά μνημεία της δυτικής Μακεδονίας. Thessalonike 1992. The ground-plan of Hagios Stephanos and Taxiarches are based on the  $\sqrt{2}$  formula; Ch. Bouras, Βυζαντινές Αναγεννήσεις και ή αρχιτεκτονική του 11<sup>ου</sup> και 12<sup>ου</sup> αι. *DChAE* (1969) 247–274.

<sup>19</sup> E. ΚΥΡΙΑΚΟΥΔΙΣ, Το κλασικιστικό πνεύμα και η καλλιτεχνική ακμή στη Θεσσαλονίκη κατά την περίοδο των Παλαιολόγων, in: *Aphieroma ste mneme tou Sotiri Kissa*. Thessalonike 2001, 219–249.

<sup>20</sup> N. TAYLOR, Η αρμονία των Πυθαγορείων. Η Μαθηματική Έννοια της αρμονίας στο μουσικό σύστημα των Πυθαγορείων. Athens 2000, 67f.: Η ανακάλυψη ότι η διαγώνιος ενός τετραγώνου είναι ασύμμετρη προς τις πλευρές του, έγινε δυνατή μέσα από την οπτική λειτουργία του νου. Αυτό που δεν μπορούμε να εκφράσουμε με αριθμητικούς όρους, μπορούμε να το παραστήσουμε γεωμετρικά φέρνοντας έναν κύκλο πάνω στη διαγώνιο. Κατ' αυτόν τον τρόπο παριστάνεται μπροστά στα μάτια μας αυτό που δεν εκφράζεται, το άλογο, το οποίο έγκειται σε αυτό που υπολείπεται του τετραγώνου, μια και ο κύκλος εγγράφεται πάνω στη διαγώνιο που είναι ασύμμετρη προς τις πλευρές του τετραγώνου; G. LYKOURAS, Για τη μουσική γεωγραφία των Δελφών. *Archaiologia* 86 (2003) 88–91; A. ΠΑΠΑΝΙΚΟΛΑΟΥ, Μαθηματικά – Μουσική – Αρχιτεκτονική στην Αρχαία Ελλάδα (*Demosieumata tou Archaiologikou Deltiou* 72). Athens 2000, 27: Η όλη διαδικασία ορισμού των διαμέτρων του κίονος έγινε με άρρητο τρόπο. Θα ήταν όμως δυνατόν να προσεγγιστεί και με ρητό τρόπο; Η απάντηση είναι καταφατική έστω και εάν εμφανίζεται λιγότερο ακριβής ως προς τις μετρημένες τιμές. Στην περίπτωση αυτή θα χρησιμοποιηθούν τα ζεύγη 12/17 και 29/41 των πλευρικών και διαμετρικών αριθμών των Πυθαγορείων της προσεγγίσεως της διαγωνίου του τετραγώνου από την πλευρά αυτού και ο λόγος όμως 17/12 δεν είναι παρά

covery of asymmetrical numbers and their application in the proportions of volumes had already been attempted in the theory of music<sup>21</sup>.

The Akathistos Hymn is an example of this from Byzantine hymnology. According to B. Sarris<sup>22</sup>, the structure of the Akathistos Hymn is based on a system of symbolic numbers based on the number 12 and its square root.

If one also bears in mind the claims that there was an unbroken continuity between Greek antiquity and the Byzantines and that the Classical tradition was often a source of inspiration for the occasional 'Byzantine renaissances' in arts and literature, and that Byzantine artistic circles were particularly influenced by the spirit of ancient Greece<sup>23</sup>, then it is easy to understand why the mathematical thinking of the Pythagoreans may have been applied in the laying-out of churches<sup>24</sup>.

Moreover, the claim that the katholikon was dedicated to the Theotokos<sup>25</sup> is supported by the fact that she is the subject of the iconographical programme in the ambulatory of the church and is also depicted in a representation with the church's second owner.

## 4. THE NAOS

### 4.1 THE COLOUR OF THE LIGHT

The color of the glass in the windows is an important factor as it determines the percentage of light that enters the church and therefore contributes to the final aesthetic effect. The quantity of light passing through the glass in the windows was measured with a portable light meter measuring lux and chroma<sup>26</sup>. The glass panes in the triple-light windows of the cross-arms and the dome had recently been replaced. The transmittance level was found to be 50%<sup>27</sup>. The colour of the glass in the windows of the naos is yellow, while in the exonarthex, where the window panes are of clear transparent glass, it is white.

Thus, the sun rays that enters through the triple windows changes the colours of the west and north wall paintings, particularly the deep azure, azure, light blue, purple, red and rosy tones (pl. 1b, 1c). When

ο μέσος αριθμητικός ανάλογος των  $1+1/2$  και  $1+1/3$ , των οποίων η διαφορά είναι τα  $9/8$ ; Christiane L. JOOST-GAUGIER, *Measuring Heaven: Pythagoras and his influence on thought and art in antiquity and the middle ages*. New York 2006, 222–245.

<sup>21</sup> TAYLOR, αρμονία 68–73.

<sup>22</sup> B. SARRIS, Η ποιητική του Ακάθιστου Ύμνου. *Byzantiaka* 20 (2000) 139–152.

<sup>23</sup> E. ΚΥΡΙΑΚΟΥΔΙΣ, Το κλασικιστικό πνεύμα 241: Η βυζαντινή κοινωνία ήταν κάτω από την άμεση επιρροή των κλασικιστικών ιδεών. Το ίδιο συνέβαινε και με την παλαιολόγεια Θεσσαλονίκη, η οποία στα μάτια των λογίων της εποχής λογιζόταν ως κοιτίδα του ελληνικού πολιτισμού, αναλαμβάνοντας ως προς αυτό το σημείο το ρόλο της αρχαίας Αθήνας, ενώ στα εγκώμια του αγίου Δημητρίου ο πολιούχος της πόλης παραβλλόταν με τον Αριστοτέλη, τον Φίλιππο και τον Αλέξανδρο; G. ΠΡΟΚΟΠΙΟΥ, Ο κοσμολογικός συμβολισμός στην αρχιτεκτονική του βυζαντινού ναού. Athens 1980, 165–175; E. KITZINGER, The Hellenistic Heritage in Byzantine Art Reconsidered, in: Akten XVI. Int. Byzantinistenkongress, I/2 (= *JÖB* 31/2). Wien 1981, 657–675.

<sup>24</sup> The recent conclusions that resulted from the research of natural light in the Katholikon of Panagia Kosmosoteira at Pherai (1152) showed that in the structure of the church there was applied the ratio  $17 / 12 = \sqrt{2}$  and, because of the geometric proportions of the church, the natural light enters in determined points of internal space and in certain wall paintings. The width and the height of the church are 17 m and with section proportion 5:7:5. The conclusions were presented by I. ILIADIS – CH. BAKIRTZIS, Lighting in the Kosmosoteira church, in: 4<sup>th</sup> International Symposium on Thracian Studies. Byzantine Thrace: Evidence and Remains, Komotina 2007 [in press]. The geometric proportions of the Panagia Kosmosoteira coincide with those of the Holy Apostles at Thessalonike.

<sup>25</sup> A. ΧΥΝΓΟΡΟΥΛΟΣ, Ἡ Μονὴ τῶν Ἁγίων Ἀποστόλων ἢ Μονὴ τῆς Θεοτόκου. *Hell* 4 (1953) 726–735; K. ΚΑΛΟΚΥΡΙΣ, Ὁ ναὸς τῶν Ἁγίων Ἀποστόλων Θεσσαλονίκης καὶ ἡ εἰκονογραφία αὐτοῦ. *Epistemonike Epeterida Theologikes Scholes Thessalonikes* 14 (1969) 111–12: Γίνεται ἀναφορά στὴν τοιχογραφία τῆς Ρίζας τοῦ Ἰεσσαί, τὴν τοιχογραφία τοῦ Γεδεῶν πέζοντος τὸν πόκον διὰ νὰ ἀποστᾶξει τὴν δρόσον, σκηνὴν ἢ ὅποια προέρχεται ἀπὸ το 6ο κεφ. τοῦ βιβλίου τῶν Κριτῶν καὶ ὑπενθυμίζει τὸν στίχον τοῦ Ἀκαθίστου Ὑμνου: Χαίρε ὁ πόκος ὁ ἔνδροσος ὃν Γεδεῶν, Παρθένε, προεθεάσατο, ὡς ἐπίσης καὶ τὴν ἄσπilon σύλληψιν του Χριστοῦ κατέβη ὡς ὑετὸς ἐπὶ πόκον.

<sup>26</sup> Minolta CL-200 Chroma meter.

<sup>27</sup> On a cloudy day when the illuminance before the glass is 3080 lux and by the glass is 1550 lux. Therefore, the factor of the glass is  $\tau = 1550 / 3080 = 0.50$  or 50%. Also, on a sunny day when the illuminance outside is 100,000 lux, in the centre of the church it is 3000 lux.

the entering light is diffuse, then its colour of light is white and so that it does not change the colour of the north wall paintings (pl. 1b).

As far as the mosaics are concerned, it was practically impossible to take any measurements because of their great height above the ground. With the naked eye, however, it was possible to discern chromatic divergences of light, especially in the mosaics on the pendentives. The visual effect, however, is influenced by the neutral tones, which cover an extensive part of the surface.

So far hardly any special studies have been carried out on the conditions of natural lighting in the interior of Byzantine churches<sup>28</sup> that focus on the polychromy of Byzantine glass window panes<sup>29</sup>. The fantastic colour effects that light produced in the interior of churches is well known from written sources<sup>30</sup>.

To obtain an idea of the aesthetic effect that natural light used to create in the Church of the Holy Apostles, it is necessary to investigate the spectrum of light of glass panes from other monuments of this period, as no glass panes from this particular monument have survived.

Our research to determine the chromaticity co-ordinates began with the study of glass fragments from the monuments on Mt Papikion (12<sup>th</sup> c.), which were kindly made available to us by fellow researcher and archaeologist Nikolaos Zekos<sup>31</sup>. The fragments were transparent and of a green or light green colour and a thickness ranging from 1 to 3 mm. Some fragments from the Lenos church were painted. Their colour was a transparent light green and there were drawings on their surfaces (painted window glass?) (pl. 1d). Also, most of them were circular in form, with a diameter ranging between 0.15 and 0.19 m. At the outside edge they were 1mm thick, while in the centre they were up to 3mm thick. Measurements

<sup>28</sup> R. WEBB, *The Aesthetics of Sacred Space: Narrative, Metaphor, and Motion in Ekphraseis of Church Buildings*. *DOP* 53 (1999) 59–74. On p. 73 the author comments: The attention paid to the effects of light and variegated color, for example, has been shown to reflect wider aesthetic theories: L. JAMES, *Light and Colour in Byzantine Art*. Oxford 1996; FRANCESCA DELL'ACQUA, Ninth-century window glass from the monastery of San Vincenzo al Volturno. *Journal of glass studies* 39 (1997) 33–41 and L. JAMES, *The stained-glass windows from the Chora and Pantocrator: a Byzantine mystery*, ed. H. KLEIN, *Restoring Byzantium: The Kariye Camii in Istanbul and the Byzantine Institute restoration*. New York 2004, 68–77; EADEM, *Enhancing Luxury through Stained Glass, from Asia Minor to Italy*. *DOP* 59 (2005) 193–211.

<sup>29</sup> The same type of glass was placed many years ago in the windows of the sanctuary apse of Acheiropoitis Church. The question, however, arises: can this type of glass be placed in Early Christian Churches and in this 14<sup>th</sup>-century church? C.J. LAMM, *Das Glas von Samarra*. Berlin 1928, 370–372; G.R. DAVIDSON, *A medieval glass factory at Corinth*. *AJA* XLIV/3 (1940) 322, fig. 23, 73–76; A. MEGAW, *Notes on recent work of the Byzantine Institute in Istanbul*. *DOP* 17 (1963) 333–371; V. FRANCOIS – J.M. SPIESER, *Pottery and Glass in Byzantium*, in: *The Economic History of Byzantium. From the Seventh through the Fifteenth Century*, II, ed. A.E. Laiou (*DOS* 39). Washington, D.C. 2002, 593–609; M. VICKERS, *A painted window in Saint Sophia at Istanbul*. *DOP* 37 (1983) 165–166; E. KOURKOUTIDOU-NIKOLAIDOU, *Vitraux paléochrétiens à Philippes*, in: *La Grecia paleocristiana e bizantina = XXXI Corso di cultura sull'arte Ravennate e Bizantina*. Ravenna 1984, 277–296; I. KANONIDES, *Ανασκαφή εργαστηρίου υαλοργιάς στην πλατεία Διοικητηρίου της Θεσσαλονίκης*, in: *Β' Synedrio Margariton Mylopotamou Rethymnes Kretes*. Athens 2002, 143–151; J. HENDERSON – M. MUNDELL-MANGO, *Glass at Medieval Constantinople. Preliminary Scientific Evidence*, in: *Constantinople and its hinterland*, ed. C. MANGO – G. DAGRON (*Society for the Promotion of Byzantine Studies. Publications* 3). Aldershot 1995, 333–356; A. ANTONARAS, *Εισαγωγή στην ιστορία του γυαλιού*, in: *History and Technology of Ancient Glass*, international seminar, ed. A. ANTONARAS – G. KORDAS. Athens 2002, 177–192; A. ANTONARAS, *Early Christian glass finds from the Museum Basilica, Philippi*. *Journal of glass studies* 49 (2007) 47–56; L. JAMES, *Byzantine glass mosaic: some material considerations*. *BMGS* 30/1 (2006) 29–47; R.G. BURNAM, *Medieval stained glass practice in Florence, Italy: The case of Orsanmichele*. *Journal of glass studies* 30 (1988) 77–93; V. RAQUIN, *The visual designer in the middle ages: The case for stained glass*. *Journal of glass studies* 28 (1986) 30–39.

<sup>30</sup> P. MICHELIS, *Αισθητική θεώρηση της βυζαντινής τέχνης*. Athens <sup>5</sup>1990, 121–126. On p. 123 the author comments: Τα υαλοστάσια μέσα από διαφανή υλικά έδιναν μαγικούς τόνους στο φως έγχρωμα. Η χρωματική αυτή φαντασμαγορία με τη θέρμη της αυξάνει του ενιαίου χώρου την ένταση και τη δύναμη, γι' αυτό σ' όσους ναούς τα διαφανή υλικά αντικαταστάθηκαν με λευκούς κοινούς υαλοπίνακες, η ατμόσφαιρα του εσωτερικού ατόνησε; N. CHATZIDAKIS, *Βυζαντινά Ψηφιδωτά (Ελληνική Τέχνη)*. Athens 1992; L. THEIS, *Lampen, Leuchten, Licht*, in: *Byzanz – Das Licht aus dem Osten. Kult und Alltag im Byzantinischen Reich vom 4. bis 15. Jahrhundert*. Mainz 2001, 53–64; L. BOURAS, *Byzantine Lighting Devices*, in: *Akten XVI. Int. Byzantinistenkongress, II/3 (= JÖB 32/3)*. Wien 1982, 479–491; J. POTAMIANOS, *Το φως στη βυζαντινή εκκλησία*. Thessalonike 2000; J.L. HEILBRON, *The sun in the church: cathedrals as solar observatories*. Cambridge, Mass. 2001.

<sup>31</sup> N. ZEKOS, *Τα αποτελέσματα των ανασκαφικών ερευνών στο Παπικίον Όρος*. *BF* 14 (1989) 677–693.

were taken in the sunlight and the transmittance of the glass<sup>32</sup> was found to be between 30% and 60%<sup>33</sup>, while the light through the glass fragments was found to be almost white.

A second measurement was carried out on small glass fragments from Panagia Kosmosoteira at Pherai<sup>34</sup>. These fragments were transparent, light olive in colour and 1mm. thick. From the measurements the light through the panes was also found to be of a whitish hue.

A third measurement was taken from panes of glass from Basilica C at Philippi<sup>35</sup>, which were light green and light olive in colour. The chromatic factors of the natural light coincided with those in the previous measurements, i.e. they were also found to be of a whitish hue.

A final measurement was carried out on another two glass fragments. The first, from the Church of Hagios Panteleimon in Thessalonike, was painted, light olive-yellow in colour, and dated to the 16<sup>th</sup>–17<sup>th</sup> c., while the second, from the region of the Rotunda in Thessalonike, was olive green in colour. The chromatic factors of both glass fragments were measured and also found to be of a whitish hue<sup>36</sup>.

The above results reveal the important role played by the transparency of the glass and, to a lesser extent, its colour. Consequently, the glass panes that we investigated did not significantly alter the colour of the sunlight entering the churches. However, the question that arises is precisely what effect light passing through painted window glass had. That was a question Megaw sought to answer in his hypothetical arrangement of figured window-glazing in the main apse of the South Church of Zeyrek Camii (Pantokrator).

Consideration of this matter gives rise to a number of general questions, such as: in which windows of a church were painted glass panes installed? Did the painted glass cover entire windows and if so, would such glass not have conflicted with the effect of the church's mosaics, as they were situated so close to them? Personally, I consider it more likely that the painted glass windows were located in the main apse and occasionally in the dome or even in certain selected windows.

From the measurements that have been carried out in Byzantine churches, we know that the only direct light that enters the windows of the main apse is that which shines in the morning, and this usually only reaches as far as the altar. Consequently, natural light entering a church through window glass would influence the colour of light in the church's interior only to a limited extent.

#### 4.2 THE DISTRIBUTION OF LIGHT

P. Michelis<sup>37</sup>, N. Nikonanos<sup>38</sup> and N. Moustopoulos<sup>39</sup> have published short reports on the natural light in the interior of the Church of the Holy Apostles. In order to draw firmer conclusions about the way in which natural light is distributed in the Church of the Holy Apostles, it was necessary to experience the lighting conditions in the church's interior for at least two years<sup>40</sup>.

<sup>32</sup> Y. TRIANTAFYLIDIS, Στοιχεία φυσικού φωτισμού τῶν βυζαντινῶν ἐκκλησιῶν (*Demosieumata tou Archaiologikou Deltiou* 3). Athens 1964, 90–102.

<sup>33</sup> The original glass panes would have admitted a greater amount of light as the samples we studied were covered by a layer of oxidation that limit the amount of light passing through them.

<sup>34</sup> Ch. ΒΑΚΙΡΤΖΙΣ, Φέρες-Κοσμοσώτειρα. *AD* 47 (1997) 506–507.

<sup>35</sup> The measurement was carried out in the glass conservation laboratory at the Museum of Byzantine Culture in Thessalonike.

<sup>36</sup> White light shows off the true chromatic composition of mosaics and wall paintings. Otherwise, if the light that reached the interior of churches possessed certain (basic) colours, then the colours of the mosaics and wall paintings would appear different.

<sup>37</sup> MICHELIS, Αισθητική θεώρηση 234–235: Ἡ ὑπερβολή στήν ἔξαρση τῆς κατακόρυφης εἶναι φανερώτερη στούς Ἁγίους Ἀποστόλους.

<sup>38</sup> ΝΙΚΟΝΑΝΟΣ, Ἅγιοι Ἀπόστολοι; S. ČURČIĆ, Gračanica. King Milutin's Church and Its Place in Late Byzantine Architecture. University Park – London 1979, 40–43.

<sup>39</sup> ΜΟΥΤΣΟΠΟΥΛΟΣ, Μορφές 310–311.

<sup>40</sup> For this research the relevant permission was granted by the Hellenic Ministry of Culture, following a recommendation by the Ephorate of Byzantine Antiquities in Thessalonike.

During the course of the research a series of observations were made on the path of the sun and the directions of its rays within the interior of the church, together with a series of measurements (in Lux) at certain points in the church, at different times of the day and during different seasons of the year. The measurements were taken in conditions of sunlight, for only then can the strong variations of light be observed. In cloudy weather<sup>41</sup>, on the other hand, the lighting is even and lacks any distinctive features.

The dates which are mentioned in this study follow the Gregorian calendar which is in use today. For greater accuracy, however, these should be converted to the Julian calendar by subtracting thirteen days in each case.

In the natural lighting of any church, it is the orientation of the building which is the most significant factor. Thus, every church building is given a specific orientation in relation to the orbit of the sun so that the sun's beams will enter the interior of the church in a particular direction. The result is rather complex as the church's geometric proportions also play a role. It is interesting, though, that these two factors are inter-related and combine to produce an aesthetic effect of high quality.

In the case of the Church of the Holy Apostles, upon entering the building one faces the sanctuary and thus the long central axis is accentuated. Between the entrance, however, and the central part of the church one passes through no section that is lit in a different manner. From the full light of the western ambulatory, which plays the role of an exonarthex, you enter the dark esonarthex and then the main part of the church, where the natural light enters through the large triple windows in the cross-arms. Here the dominant feature is the vertical axis with its powerful sense of elevation and exaltation of Almighty God.

#### 4.2.1 *The central dome*

When winter passes and the position of the sun changes, the light initially (09.00)<sup>42</sup> focuses on the western surface of the internal drum of the dome, below the point where the prophets are depicted (pl. 2a) and then on the NW pendentive of the central dome, where the Evangelist Luke is depicted<sup>43</sup> (pl. 2b). A few minutes later the light moves round to the northern half of the western barrel vault, where it 'scans' the lower part of the mosaic bearing the depiction of the Entry into Jerusalem.

During the summer (06:50) the light beams from the dome are directed onto the Evangelist Mark (Ppl. 3a). As the height of the sun increases, the light beams gradually move towards the southern half of the western barrel vault, where they scan the lower part of the Transfiguration, in which the Apostles Peter, James and John are depicted<sup>44</sup> (Pls. 3b-c). In this representation three light beams are depicted, which emanate towards each Apostle from the luminous disk that surrounds Jesus.

The light later moves lower, to the western wall above the imperial gate<sup>45</sup>, to the point where the Dormition of the Theotokos is depicted (pl. 3d).

<sup>41</sup> Observations and readings in cloudy conditions were made throughout the course of the investigation. The results, however, revealed that in these conditions the lighting of the church is uniform. This means that the light is diffuse in all parts of the church; sometimes it is very bright and at others dim, even gloomy. This is the time when artificial lighting should be used. In these conditions, therefore, it is difficult to draw conclusions.

<sup>42</sup> The tall buildings that were built after 1950 obstruct the sun's beams in the first few hours after sunrise.

<sup>43</sup> N. GIOLES, *Ο βυζαντινός τρούλλος και το εικονογραφικό του πρόβλημα*. Athens 1990, 138: Από το τέλος όμως του 9ου αιώνα με την σταθεροποίηση της μετεικονομαχικής καταστάσεως στην πρωτεύουσα, θα εγκαταλειφθεί η άμεσα από την αυτοκρατορική εθιμοτυπία επηρεασμένη διάταξη και θα εμφανισθεί η περισσότερο μυστικιστική και συμβολική ιεράρχηση των αγίων προσώπων γύρω από τον Παντοκράτορα που πηγάζει από τα λειτουργικά κείμενα και αποσκοπεί στην προβολή του δια μέσου των αιώνων έργου της Θείας Οικονομίας για τη σωτηρία του ανθρώπου. Θα προταθούν έτσι οι προφήτες των αποστόλων και το πρόγραμμα αυτό θα κυριαρχήσει από τη στιγμή που εμφανίστηκε στο ναό του Στυλιανού Ζαούτζη.

<sup>44</sup> In this mosaic three beams of light are depicted falling on the Apostles, all of which emanate from the luminous disk that surrounds Christ.

<sup>45</sup> The height of the gate is equal to that of columns.

At about 10:00 the sun's rays are directed through the imperial gate and into the esonarthex, where they are reflected on the floor and diffused. The esonarthex is flooded with light (pl. 4a). These lighting conditions are more intense during the spring and summer.

Observing the path of the sun's rays, we can see that they pass through three points: the window in the dome, the top point of the imperial gate and the middle of the esonarthex (Fig. b). We may conclude, therefore, that the architect designed the imperial gate so that it would be high enough for the sun's rays to penetrate into the esonarthex. Before sunset, in winter, the light beams from the dome focus on the NE pendentive, where the Evangelist Matthew is depicted (pl. 4b). During the spring and summer they focus on the Holy Mandylion and on the Evangelist John respectively.

#### *4.2.2 The triple-light windows*

During the summer the sun rises on the north side of the church's central axis. The light enters through the northern triple-light window and is directed onto the western half of the northern barrel vault, where the Crucifixion is depicted. This is the only time that the light enters through the northern triple window (pl. 4c).

During the winter, the sun rises on the south side of the central axis and the light enters through the southern triple-light window, falling on the western half of the southern barrel vault, where the Baptism is depicted. When the sun approaches the N-S axis, the light enters through the southern triple-light window and focuses on the mosaic depicting the Presentation of the Virgin in the Temple (pl. 5a) and on the western and northern wall-paintings.

When the sun is exactly on the N-S axis, the light crosses the church, passing under the northern arched door towards the northern gallery (Fig. c and pl. 5b).

At 15:30 the light focuses on the NE column and on the wall painting on the north wall, where St. George and St. John the Theologian are depicted (pl. 5c). Furthermore, the surface above the NE and SE columns is brightly illuminated, where there was probably once a representation of the Annunciation (pl. 5d). In the afternoon, in spring and summer, when the sun is on its longest orbit of the year, the light enters the church through the western triple-light window and is directed onto the eastern side of the northern barrel vault and into the sanctuary. Before sunset the light focuses on the eastern side of the southern barrel vault, where the Nativity is depicted.

#### *4.2.3 Northern and southern galleries*

In the mornings, in spring, the light is directed onto the SW pendentives of the small NE and NW domes, respectively. In addition, the light passes through the eastern windows of the small NW and SW domes and reaches the columns of the exonarthex. Observing the path of the light beams, we can see that the following points lie on the straight line that they trace: the window in the small dome, the arch in the gallery and the column base.

At noon, the light enters through the southern window of the small SW dome and is directed into the esonarthex, under the groin vaults. The light is reflected and diffused into the whole of this space.

In the spring and the summer, before sunset, the light passes between the columns of the western gallery; crosses the entire length of the southern gallery and reaches the wall painting depicting the Tree of Jesse (Pl. 6a, 6b).

## 5. CONCLUSIONS

The dimensions, form and size of the windows, openings and arches in the interior of the church allow light not only to shine on the spaces near the windows but also to cross the entire building, sometimes



penetrating the esonarthex and sometimes the northern gallery. Consequently, certain choices in the geometric proportions of the church have an additional significance, if they are examined in terms of the way in which they handle incoming light.

The accentuation of the vertical axis is intensified partly by the structural proportions of the church's interior and partly by the distribution of natural light. The intermediate section of the church, i.e. the space between the tops of the columns and the base of the dome, is 7m high and greater than the other two parts, i.e. the height of the columns and that of the dome, a feature which is not observed in any other church of this period. This architectural choice led to the construction of large triple windows in the cross-arms, which are the basic source of light in the naos.

Christ Pantokrator and the prophets are illuminated by indirect light (reflected and diffused) and no direct light<sup>46</sup>. This corresponds exactly with Xyngopoulos' comments on the colour tesserae in the prophets. The importance of this phenomenon is underlined by the additional fact that the prophets are depicted in the dome over the windows. Consequently, if the light were direct, then this would lead to the inversion of the existing hierarchical arrangement of holy figures, as Christ is the 'Source of Light' and the prophets are united to God and receive His holy energies.

In contrast to the mosaics in the dome, the Evangelists are illuminated by direct sunlight<sup>47</sup>. In terms of colour, they differ from the depictions of the Prophets. The mosaicist has used tesserae with more luminous colours and more intense tones. This of course is absolutely consistent with the way in which the mosaics are illuminated. Since new panes of glass were installed in the triple windows of the cross-arms, the central part of the church has been very bright, while the dome has become dimmer.

Personally, I believe that the hierarchical arrangement of holy figures in the church has somehow been reversed. The complex character of the monument is not immediately revealed to visitors. Their attention is focused mainly on the mosaics in the barrel vault and the wall paintings and only incidentally on the dome.

<sup>46</sup> ILIADIS, natural lighting 13–24. The golden tesserae reflected the light inside the dome. The colour of the reflected light depends on the colours on the surfaces of the mosaics.

<sup>47</sup> GIOLES, βυζαντινός τρούλλος 197: 'Ο θεολογικός σκοπός τῆς μετατροπῆς αὐτῆς ἦταν νά δηλωθεῖ μέ ἀμεσότητα στούς πιστούς ἡ σημασία τῶν εὐαγγελικῶν κειμένων γιά τήν Ἐκκλησία, μέσω τῶν ὁποίων ὁ Παντοκράτορας ἀσκεῖ τό ἔργο τῆς σωτηρίας τοῦ ἀνθρώπου. Οἱ εὐαγγελιστές περισσότερο ἀπό τούς ὑπόλοιπους ἀποστόλους συνετέλεσαν μέ τά κειμενά τους, στά ὁποῖα κατέγραψαν τή θεία διδασκαλία στή διάδοση τῆς θείας ἀληθείας καί στήν ἐπανασύνδεση τῶν δεσμῶν τοῦ ἀνθρώπου μέ τον Θεό. Τό τελευταῖο δηλώνεται παραστατικά μέ τήν τοποθέτηση τῶν εὐαγγελιστῶν στά σφαιρικά τρίγωνα τοῦ ναοῦ. Σημεῖο πού σύμφωνα μέ τήν κοσμολογική σημασία τοῦ βυζαντινοῦ ναοῦ, εἶναι ὁ σύνδεσμος τοῦ οὐρανοῦ καί τῆς γῆς, ἡ γέφυρα ἐπικοινωνίας μεταξύ τῶν δύο κόσμων.

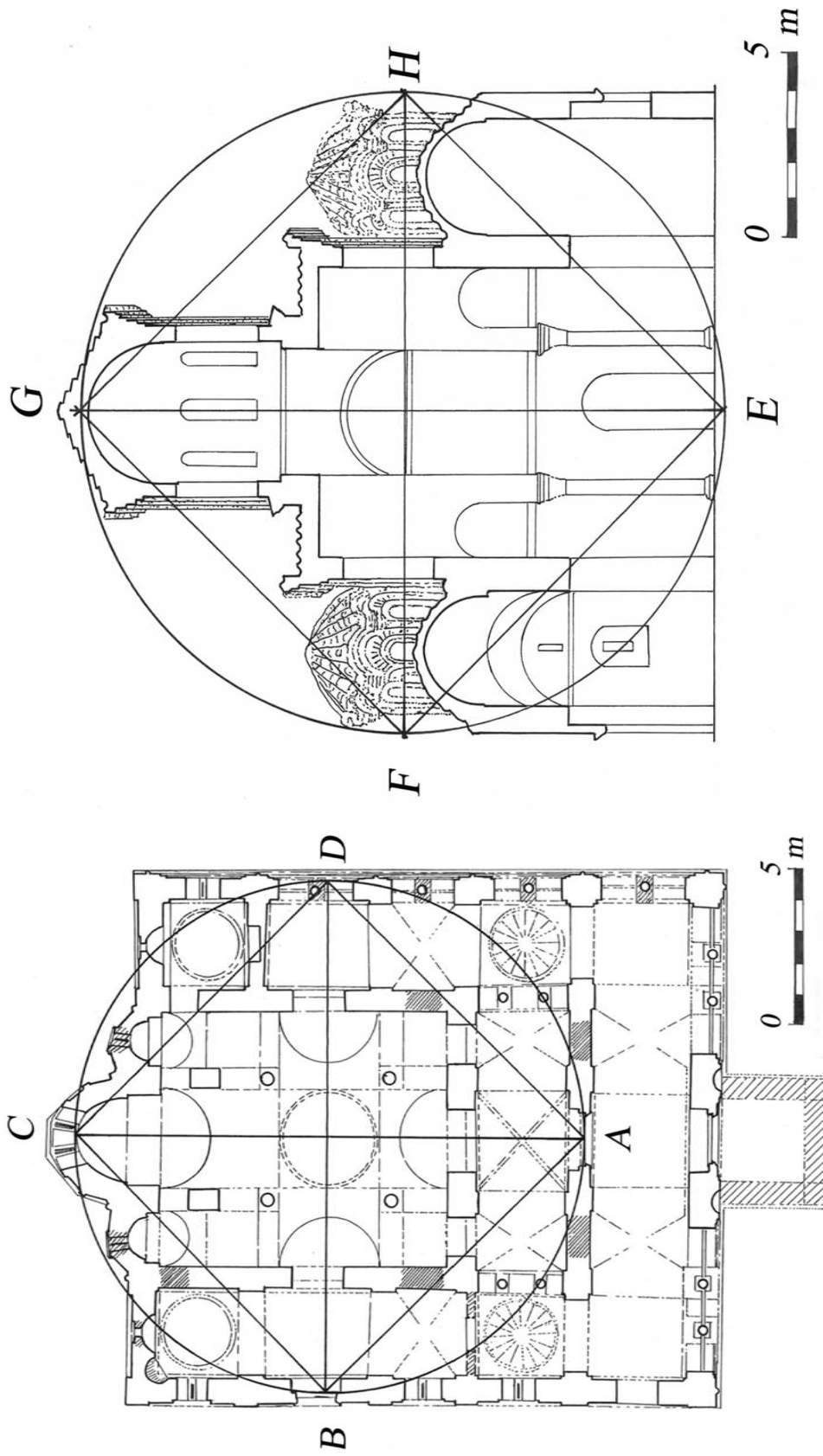


Fig. a: The Holy Apostles. Plan and transverse section through naos showing geometric proportions (drawing: F. Kontakou based on G. Velenis)

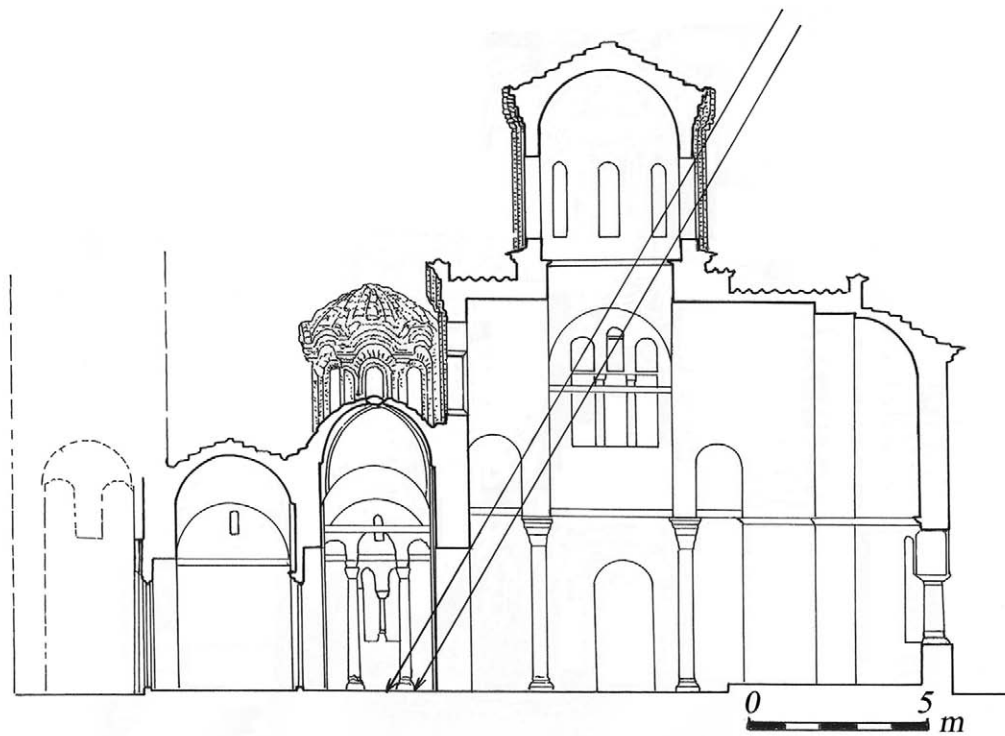


Fig. b: Longitudinal section showing the direction of sun rays through the dome's window towards the esonathex (drawing: F. Kontakou based on G. Velenis)

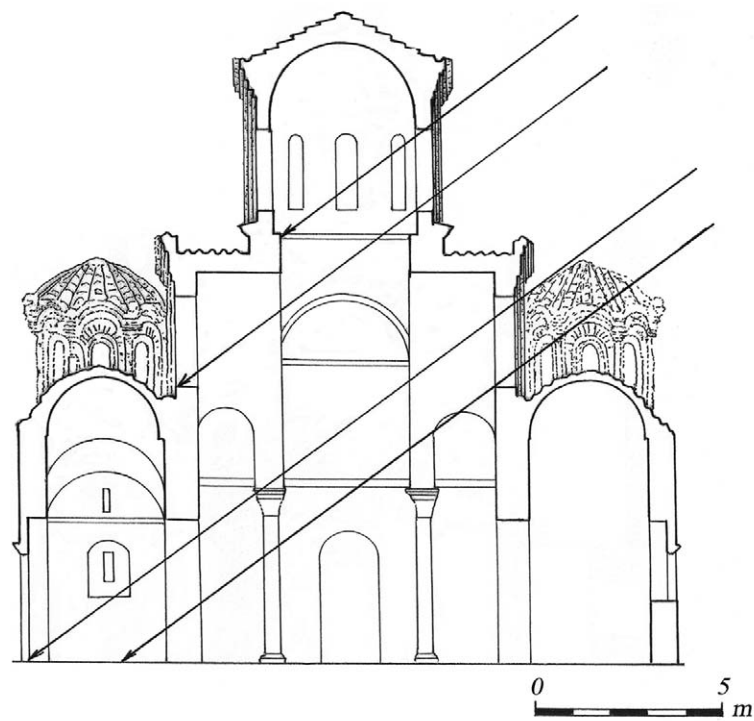


Fig. c: Transverse section showing the direction of sun rays through the window of the dome and the South triple light window (drawing: F. Kontakou)

