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# SOLSTICE ORIENTATION OF THE ST NICHOLAS' CHURCH MONASTERY STUDENICA, SERBIA

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**Abstract:** St Nicholas' Church of the Serbian monastery Studenica was erected in 13th century, before 1230. This is a modest one-nave building with an entrance on the west and the apse on the east side. In order to explain a large deviation of the longitudinal axis of the church from the south-east direction, the following has been done: 1) deviation of the longitudinal axis of the church from the east direction (24o to the NE) was accurately measured; 2) a corresponding sector of true horizon of the church was constructed in the orthographic transverse map projection; 3) the position of the point where ends the line of observation in the vertical axis of the church and the position of the point of actual Sunrise of Summer Solstice were determined topographically on the true horizon. Since the distance between these points is about 1.5o, it can be said that the proto-master probably founded the Church St Nicholas on the basis of Summer Solstice. A direct check made on 21st of June, 2011 confirmed the accuracy of the applied method.

**Key words**: mathematical geography, archeoastronomy, church orientation, the St Nicholas' church, the Studenica monastery

## Introduction

In the Serbian monastery Studenica, thirty meters southeast of the Virgin Church (Fig. 1) stands the St Nicholas' church (43° 29' 10.6" N, 20° 32' 13.2" E, 488 m altitude). Based on the age of frescoes it is known that the church existed before 1230 (Čanak-Medić, Kandić, 1995).

St Nicholas' church is a modest one nave building of elongated rectangular base (9.5 x 5 m), with a semicircular apse at the east and with a west porch, which is preserved only in the foundations (Fig. 2). With the exception of the corners, the church was built of crushed stones and plate stones and pebbles. The door is on the west, opposite the door is a window in the apse, and the two windows are on the side walls of the nave.

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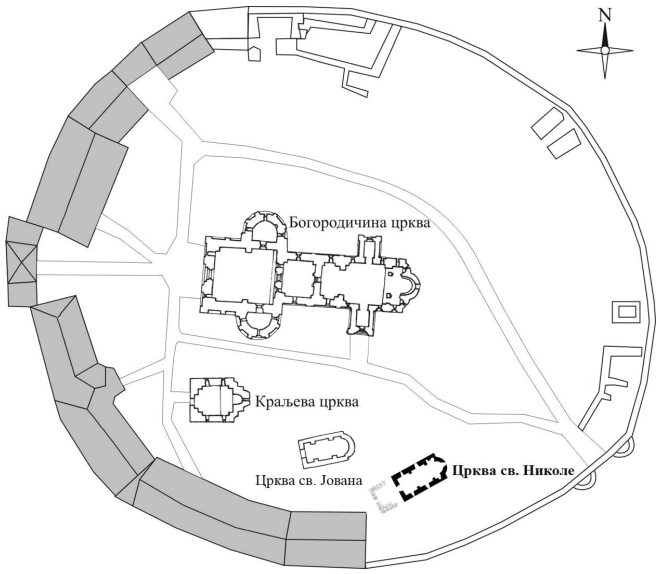


Figure 1. Plan of the Serbian monastery Studenica (43 ° 29 '11 "N, 20 ° 32' 13" E, 486 m )

Since the longitudinal axis of the St Nicholas' church significantly deviates from the eastern direction (Fig. 1), it cannot be seen that this is dictated by the configuration of the terrain, it was interesting to try to find a rational explanation. Extremely "summer" orientation of the church eliminates any connection with the sunrise on 19$^{th}$ of December, the date dedicated to St Nicholas, the patron of the church.

Figure 2. St Nicholas' church: views from the northeast (left), from the west-northwest (right, above) and from the east-northeast (right, down)

## Definition of Task

First of all, the explanation that the proto-master did not know how to determine the cardinal points of the word should be rejected – because he knew, and in many ways (Tadić, 2004) – and focus the attention on the possibility that the proto-master, by founding the church on the specific day, its longitudinal axis directed toward the rising Sun. This possibility can be checked by solving a series of tasks:

- To determine the geographical azimuth ($A_N$) of the longitudinal axis of St Nicholas' church, i.e. its deviation $\Delta A$ from the east direction;
- Calculate the local angle ($\alpha$) which with the horizon of St Nicholas' church covers the line of observation in the vertical line of the longitudinal axis of the church;
- Calculate the declination ($\delta$) at which the Sun can have the position ($h = \alpha$, $A_N$) above the horizon of St Nicholas' church;
- Determine the dates (day and month) that correspond to the calculated declination, according to Gregorian and Julian calendars.

With the set dates, it remains to determine whether they, perhaps, had some astronomical or theological meaning.

## Results

Since there is no reliable data related to the value of geographic azimuth of the longitudinal axis of St Nicholas' church[2], on-site measurements had to be done. The checked gnomic methods were used (Fig. 3):

- Measuring of the angle that the shadow of the plummet forms with the southern wall of the church at the actual solar noon (Tadić, Petrović, 2010) or at any time during the daylight (Tadić, Petrović, 2011);
- Measuring of the angle that the shadow of the marble door frame forms on the floor of the church at the moment when the Sun is exactly in the

[2] Existing plans differ and are unreliable. On them, for example, the longitudinal axis of the Holy Mother church has an ideal east-west orientation, while it deviates from that direction $5^o$ to the southeast.

west (when the Sun in the afternoon crosses the first vertical) (Fig. 2, right) or at any time during the daylight[3].

Figure 3. St Nicholas's church on 21st of June: shadow of the northeast corner when the Sun is exactly in the east (left), shadow of the west corner when the Sun is exactly in the south (centre) and shadow of the door frame on the floor of the church when the Sun is exactly in the west.

The mean value of geographical azimuth of the longitudinal axis of St Nicholas's church was obtained on the basis of measurements performed on several occasions in both variants of both methods, and checked on aerial shot, is $A = 66^{o.}$ This means that the longitudinal axis of the church deviate $24^{o}$ from the eastern point, to the northeast (Fig. 3).

The natural profile of the terrain was plotted on the topographic map on the longitudinal axis of St Nicholas' church, on which were, then, defined the relative height of point C in relation to the church, where the line of observation tangents profile, ($\Delta H = 299.7$ m), and the distance of that point from the church ($d = 1624.3$ m). Based on these values, the location angle, $\alpha = 10° 15' 41"$ was calculated.

In the next phase of work, based on horizon coordinates of the Sun ($h = \alpha = 10° 15' 41"$, $A_N = 66°$) (Tadić, Petrović, 2011), declination of the Sun was calculated, $\delta = 24° 23' 31"$.

[3] The geographic azimuth could be determined also by measuring the angle that the shadow of the northeast corner covers with the plain of northwest wall at the time of the morning Sun passing through the first vertical (Fig. 2, left) or by measuring the angle that the shadow of the west corner of the church covers with the plain of northwest wall at the true Sun noon (Fog. 2, centre). These measurements were not performed because of the rough corners of the church, as well as of the sidewalk, surrounding the church.

But this was a stopping point – the calculated value of the Sun declination is larger than the maximum value ($\delta = \varepsilon = 23° 27'$) which means that the longitudinal axis of St Nicholas' church is beyond the true horizon over which the Sun rises over the year.

## Discussion and Conclusion

The east side of the horizon is the sector along which the points of Sunrise move over the year. On the latitude of the Monastery Studenica, it is, rounded up, the sector that ranges 66° 32', from the point of east 33° 16' toward the south, and from the point of east toward north, but during the Equinox Sun rises in the east, and sets in the west of the horizon. The longitudinal axis of St Nicholas' church deviates from the eastern direction $\Delta A = 24°$ to the northeast (Fig. 1), which fits within the boundaries of the mentioned sector. This, however, applies only to the points of Sunrise over the mathematical horizon, while the points of Sunrise, for the landscape "scenes", in the summer half of the year, always shifted toward the point of east, and in the winter half of the year, from it.

Thus, over the horizon of St Nicholas' church, the Summer Solstice Sun theoretically rises at 4h 57min, in point $E_1$ ($h = 0°$, $\Delta A = 33° 16'$). When does it really rise, and at which point of true horizon, can be determined by direct observation, or graphically, after constructing the required sector of the true horizon in some of azimuth map projection (Fig. 4).

Figure 4, shows, in transverse orthographic projection of the celestial sphere, eastern sector of horizon, mathematical and actual. True horizon is obtained by connecting points whose position is determined by the profile constructed above the set of line drawn on every $2^o$ in the range of geographic azimuth from $56^o$ to $90^o$. Then over the true horizon was drawn a projection of the northern celestial meridian and determined their section: $h = 10° 44'$, $\Delta A = 22° 15'$. Orthographic projection shows that the difference of azimuths of the longitudinal axis of St Nicholas' church and azimuth of the actual Sunrise of the Summer Solstice is only 1° 45'. This was to be checked.

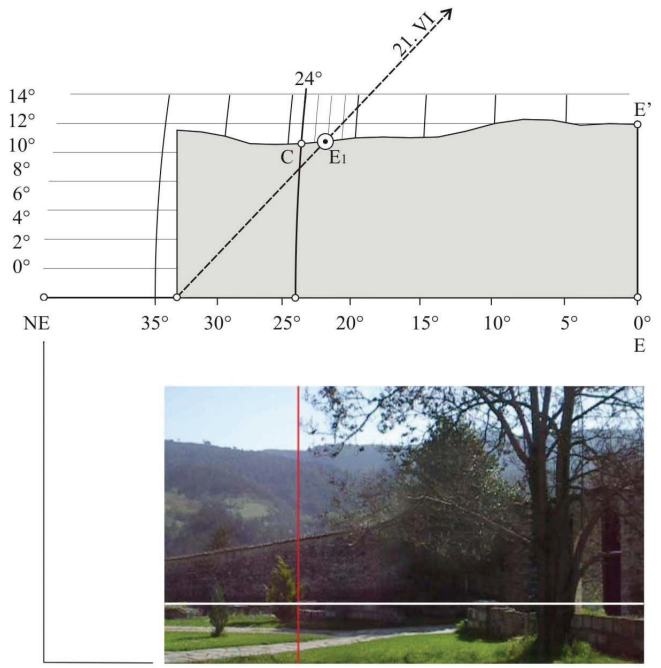


Figure 4. Summer Solstice point of Sunrise over the true horizon of St Nicholas' church, determined in orthographic transverse projection.

For this purpose, the Sunrise of the Summer Solstice 2011 was photographed, from St Nicholas' church, from the altar partition through the window in the apse (Fig. 5)[4]. The Sun appeared right, east, from the axis of the window (from the longitudinal axis of the church), and the made recording confirmed the accuracy of the results graphically obrained[5].

The Sun appeared at 06h 08min (81 minutes after the theoretical rise). On the basis of that time can be calculated the geographic azimuth of the Sun, $A_N = 67°$ 36', which means that is only 1° 36' larger than the azimuth of the longitudinal axis of the church.

[4] More effective would be a record of the window reflection on the descended curtain of the altar partition, but the idea came late.

[5] The record also confirms the accuracy of determining geographic azimuth of the longitudinal axis of the church in the first part of the task.

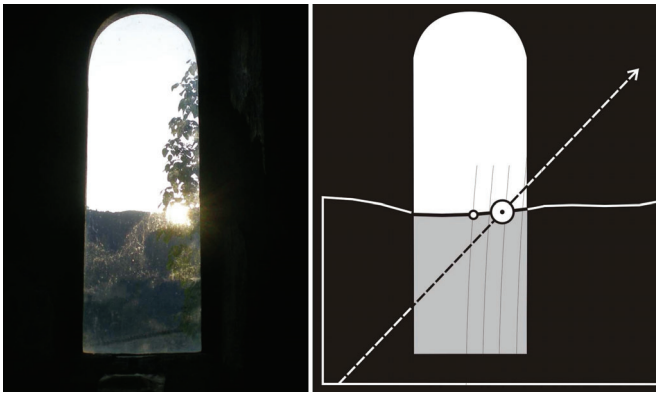

Figure 5. Sunrise on 21st of June, 2011, photographed through the window in the apse of St Nicholas' church

On this basis, and having in mind that the actions required for the founding of the church (positioning of the altar, marking of axis and all four corners of the foundation of the church) could not be performed in an ideal manner, it can be said that the longitudinal axis of St Nicholas' church of the monastery Studenica is directed towards the point of Sunrise during the Summer Solstice.

"Summer" orientation of the longitudinal axis of the churches is much more common that the "winter" because it is related to the beginning of construction season. Within the summer orientation, the rarest is Solstice. Liritzis and Vassiliou (2007) state that the orientation for over 800 Europen churches has been determined, but the Solstice orientation was not often found; of 12 Byzantine churches which they have analyzed in Greece, for only two they found a possible Solstice orientation. Among 20 churches whose orientation was analyzed by Раппопорт (1994) within the study of construction medieval Russia, there is no one with Solstice orientation.

Among the monastery churches which are protected as immovable cultural property of great importance, particularly summer orientation have the Church of St Savoir, monastery Zica (43.5$^o$ NE), the church of the Dormitory of the Holy Mother monastery Gračanica (17$^o$ NE) and the Church of Holy Trinity monastery Manasija (33$^o$ NE). Solstice orientation has only the Church of Holy Trinity, but only theoretically, on mathematical horizon, while on true horizon of Manasija Sun never rises in that direction. Orientation of the longitudinal axes of the other medieval churches in Serbia has yet to be studied; it is an extensive work since, for example, only in the river basin of Studenica there are over thirty churches with construction methods similar to the St Nicholas' church

monastery Studenica (Đurić and assoc., 1990). For now, we know that the early Christian church (5/6 century) on Kopaonik, located in the open below the ridge Heaven's Chair (1793 m altitude), is oriented towards the point of Summer Solstice Sunrise (Tadić, Tošić, 2011).[6]

In astronomical sense, the appearance of the rising Sun through the window in the apse of St Nicholas' church, was a sign to the monks of the monastery Studenica that the Sun reached its peak and that it power would decline from that moment, that the longest day of the year started and also the summer.[7] In theological sense, that day announced the day of St John the Forerunner (Midsummer), religious holiday that is celebrated on 24th of June[8] by Julian calendar (1230 – 30th of June), and on which the Church transferred[9] the former celebration of Summer Solstice[10].

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[6] This is important to note since the assumption that the church of St Nicholas, for their worship of God, had probably build the builders of Holy Mother church, might be too easily abandoned (or before or along with it) who, presumably had been brought from the coast, bringing with them the Roman style of building and along with it a specific way of orientation which had a long tradition.

[7] One cannot say "and the beginning of the new year" since that beginning was among our people in connection with the Winter Solstice: "Therefore, so many New Year's customs were related to Christmas, the holiday of Winter Solstice, customs still practiced, it can be seen that since the ancient times, the year started precisely at that time." (Jankovic, 1951, page 169).

[8] 7th of July according to Gregorian calendar

[9] "Apart from Christmas as the most important, there were other holidays dedicated to Sun, in spring in connection with spring Equinox, and in summer in Solstice . These holidays are now hidden under the Christian holidays". (Jankovic, 1951, page 87)

[10] There is believe among the Serbs that the Sun on Midsummer stops three times what is easily explained from the astronomical point of view. This is originally, Summer Solstice, the day when the declination of the Sun changes the slowest, so the Sun in its seeming motion seems to stop three times ("Solstice").

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