THE NURAGHIC WELL OF SANTA CRISTINA, PAULILATINO, ORISTANO, SARDINIA. A VERIFICATION OF THE ASTRONOMICAL HYPOTHESIS: WORK IN PROCESS, PRELIMINARY RESULTS

ARNOLD LEBEUF

"*O that the ladder to heaven were longer*
And the lofty mountain loftier!
Then I would fetch and offer to my lord
The waters of life
Which Tsukuyomi treasures,
And restore him to youth and life"

Manyoshu (Shinkokai 1965, p.306).
[Tsukuyomi is a Moon goddess].

Abstract

The Nuraghic well of Santa Cristina, Sardinia has been regarded as a ritual monument built to receive moonlight on its water mirror at the time of the meridian passage of the moon when it reaches its highest point in the sky during and around the major northern lunistice. In this paper we investigate the precision that could have been achieved and conclude that the well could indeed have served as an instrument for measuring the lunar declination during half of the draconic cycle of 18.61 years.

Key words: Moon, Lunar standstill, sacred well, Nuraghic culture, camera obscura, eclipses, Phoenicians.

Introduction

The sacred well of Santa Cristina is situated in the neighbourhood of the small city of Paulilatino, in the Oristano province of Sardinia. Its coordinates are: 40º3'41" North, 8º43'58" East. This construction, built of perfectly hewn stones of greyish-black basalt, has been dated by the archaeologists to about the year 1000 BC (Lilliu 1998, p.529; 2006, p.72; Santoni 1990, p.169-193). It belongs to the so-called Nuraghic culture of the late Bronze Age. The Santa Cristina well impresses the visitor first of all because of the perfection of its masonry and the extreme elegance of its architectural proportions. It is unquestionably a masterpiece, combining unusual restraint in its general appearance with an incredible architectural complexity. At Santa Cristina, the horizontal layers of stones are painstakingly worked and aligned. They are set in place without cement, stone on stone, almost without any interstices. In contrast to other buildings of the same type, each successive layer is set slightly back from the one beneath it, leaving at each level a space, a narrow margin of about two centimetres. This layout must be functional, since it not only complicates dramatically the geometry of each stone to be hewn or carved and the general process of construction but also weakens these upper edges, exposing them to the further risk of being broken. Of nearly a hundred Nuraghic wells known in the island, almost all are built of rough stones: only three are of carved stones, and only Santa Cristina is preserved in its integrity.

The general shape of the well is that of a long bottle. Each horizontal layer is circular, with the upper opening measuring 27 cm and the diameter of the lower part at water level being 255.5 cm. The upper opening is 643 cm above the water level.

The staircase leading down to the water is a monumental construction trapezoidal in shape. The upper step measures 347 cm while the lower one is only 140 cm. The side walls of the staircase are built of horizontal layers of stones as is the tholos of the well itself. The overhangs of the layers of stone catch the sunlight during the day and the moonlight at night, producing various extremely beautiful optical effects.

The Astronomical Function

In 1972, Carlo Maxia and Lello Fadda, building upon a proposal of Eduardo Proverbio, presented an hypothesis concerning the astronomical function of this unique construction. According to these authors, the meridian diagonal from the upper southern edge to the northern lower edge of the well is inclined at an angle of 11.5

degrees to the zenith. Subtracting 11.5 degrees from the latitude (40º 3' 41" North), we obtain roughly 28.5 degrees. This value is very important because it represents approximately the lunar declination at the time of the major northern lunistice. It is regrettable, then, that although this idea was published several times in successive papers and repeated by different authors, it has not been better developed and more precisely described. The different articles by Maxia and Proverbio only present approximate measurements and the plan, copied many times, lacks any sort of precision. I have known of these hypotheses since their publication, but it was only on the occasion of the 2005 SEAC conference in Sardinia that I had the opportunity to visit the monument. The first thing that struck me was the unparalleled perfection and regularity of the circles formed by the edges left between the layers of stones. I reasoned, then, that if the approximate measurements made by Proverbio could be confirmed, and that indeed every 18.5 years the moonlight reached the water mirror at the time of the major northern lunistice[1], then the other levels could have indicated the successive lunistitial moon declinations during the rest of the draconic cycle or part of it. If this were true, then this building would have been much more sophisticated that had hitherto been proposed, and we would have to consider it not to be only a symbolic and ritualistic construction but also a scientific instrument capable of measuring the declination of the moon at the lunistice over a much larger part of its cycle, and with much higher precision. One detail of the construction had also attracted my attention: although all of the layers of stones are approximately of the same height, about 30 cm, one of them is conspicuously larger, about 45 cm, and this was surely significant.

I returned to Santa Cristina in 2005, 2006, and 2007, first of all to observe the phenomenon of the lunar illumination of the edges between the layers of stone in the well and to verify the supposed optical effects, but also of course to take a series a measurements with the utmost care. We need two series of complementary measurements: first those of the architecture itself by classical triangulation, and then time measurements of the moments when each successive edge of a stone layer becomes illuminated by the moon, i.e. the moments of first contact. We can then calculate the corresponding altitude and declination of the moon for each point of contact, which gives us a means of checking the plan and, eventually, of seeing if it could have been improved.

[1] By this term, we mean the northern lunistice occurring at the time of major standstill, i.e. the furthest northerly declination ever reached by the moon.

The Archaeology and Documentation

Of all the published plans, none was acceptable for archaeoastronomical studies. The best ones were those drawn by Prof. Enrico Atzeni who was in charge of the archaeological investigation and the restoration of the well in 1967-1973 and 1977-1983. The restoration is perfect but unfortunately the archaeological investigation was stopped before completion and leaves many questions unanswered. Considering that the work was not finished on such an important site, Professor Atzeni did not judge it suitable to publish his results, which he considers incomplete. So I had to draw the plans anew.

Description of the Phenomenon of the Moonlight Descending the Well of S.Cristina

Owing to the proper motion of the Earth from West to East on its axis, the Moon, like all other celestial bodies, moves through the sky from East to West. When it is high enough in the sky, its light entering through the upper opening reaches the first edge, between the first and second layers of stones inside the well (Bb in my 2007 plan). We must wait for some time until the moon gains enough altitude for its light to reach the second edge, separating the second and third layers. The time taken to reach each successive level decreases steadily from one step to the next as the moon gains altitude. When the moonlight reaches the bottleneck (F-J of the plan), its rays are tangential to the wall of the well and so the light progresses more rapidly from one row to the next. If we look from the inside of the well, that is to say from the lower steps just over the water mirror, it is impossible to determine the exact number of layers illuminated from the top because the line of sight is tangential to the inner wall of the well and all the upper marks are confounded. Nor is it possible to count the number of steps still untouched by the light, starting from the water level, because we are in total darkness. In fact, comfortable and precise observation only becomes possible from the moment the light reaches the lower edge of the single larger layer of stones (Kk - Ll) which is easily visible from the lowest steps of the monumental entrance. We will designate the lower edge of this larger layer (Ll) to be level zero. The descending light creates a ladder. Because we are in a camera obscura, in the dark, the only way to count the number of steps illuminated is to rely on the larger space defined by the two lines of light marking the upper and lower edge of the broader layer of stones, which is different from all the others in size. It then becomes easy to count the number of illuminated rows

starting from level zero. This reveals the reason for this architectural anomaly.

Because the upper opening is circular and the light falls upon the wall at a slant, the spot of light is elongated, creating a long ovaloid shape with a sharper lower end. Because of the bottleneck profile of the wall, there comes a moment when the ladder of light separates into two parts. The lower one then starts to form a kind of elongated mandorla, which glides slowly along the wet surface of the wall towards the bottom of the well. As the mandorla of light progresses down the wall, then if the water source falling along the wall is not too abundant and the water's surface is calm enough, we can see the reflection of the light ladder in the water mirror. The two ladders move towards each other and allow the observer to identify the exact moment when the light reaches the water's surface, i.e. when the two points merge together. As the Moon's altitude increases still further, the column of moonlight moves further onto the water's surface and the upper steps switch off one after the other. During my observations, there were always at least two steps lit over the water, and we shall see why.

The lunar spotlight bathes in the water for about half an hour and then the layers light up one after the other upwards, the ladder progresses back up, the movement is inverted (with some change in azimuth) and the light returns back, up and finally out of the well.

The declinations obtained for the Moon at the time of its maximal advance on the water mirror fully confirmed Proverbio's hypothesis, but with a degree of precision unsuspected by that author. The result of these new measures appears on the 2007 plan drawn at a scale of 1:10. It is likely that new measurements will be necessary to verify our results before full publication, but we will be content for now with the calibrated measurements of the site plan and the full list of original time measurements given in Tables 1 and 2 (for the original measurements see the tables that accompany the Lebeuf 2007 plan).

Explanation

The analysis of these measurements shows clearly that it is not possible to suppose for one instant that such a unique, precise and effective construction could result from chance, fortune or accident.

Nowadays, two layers of stones remain lit even when the moonlight is in its lowest position, but at the time of construction, in the tenth or eleventh century BC, the absolute maximum of the Moon's declination was 29º6', and then the moonlight would have entered the water mirror completely without continuing to cast any light at all on the wall. At such times the circle of moonlight was tangential to the larger circle of the water mirror. This bathing of the moonlight lasted for some 15–20 minutes before the moonlight started to climb up again out of the water. The actual gap between the two circles cannot have differed from perfect tangency by more than two or three arc minutes. So the absolute maximum of the Moon at major lunistice (maximal inclination of the orbit) could be determined very precisely. This marks the passage of the ascending node of the lunar orbit through the vernal point (ecliptic longitude 0º). At around this time an observer would notice the months during which the Moon reaches this extreme and the months when it only approaches it, leaving one step lit. This would give him information about the wobble. The absolute maximum can only be reached during September and March, when the sun passes near to the nodes which are then on the equinox points of the ecliptic.

This interest in meticulous observations of the draconic cycle, lunistices and associated nodal positions is fully confirmed by the other limit, marked as level zero (Kk -Ll). This layer of stones, distinguished by its size and its optical function as a point of absolute reference in the camera obscura of the well, corresponds very precisely to the declination of the Moon when it passes the medium lunistice – when the nodes are near to the solstitial colure. Let us explain this point. The declination of a star illuminating this row zero is 23º15'. We might immediately be tempted to interpret this declination as that of the Sun at summer solstice (currently 23º26'), but this would be a mistake. While the declination of the solstitial Sun is now 23º26', at the time of the construction it was 23º49'. This difference makes the solar explanation unacceptable because the declination of the Sun at the solstices is extremely easy to establish with a margin of error not exceeding one arc minute even by the most primitive means (we could even accept up to three minutes for the sake of generosity). Moreover, the observation of the solstice itself is of very limited interest, and it would be most astonishing to find that so much art, science and skill was expended in building such a monument when a simple stele or any mark on the horizon would have offered the same advantages (or even more precision if it is distant from the observation point).

However, if we consider the declination of the Moon at the lunistice, 23º15' corresponds exactly to the medium lunistice in the year 1000 BC. The medium lunistice can be defined as the moment when all the perturbations of the lunar orbit merge together and disappear. Knowing this position permits one to define the ecliptic longitude of the nodes (see the graph at the

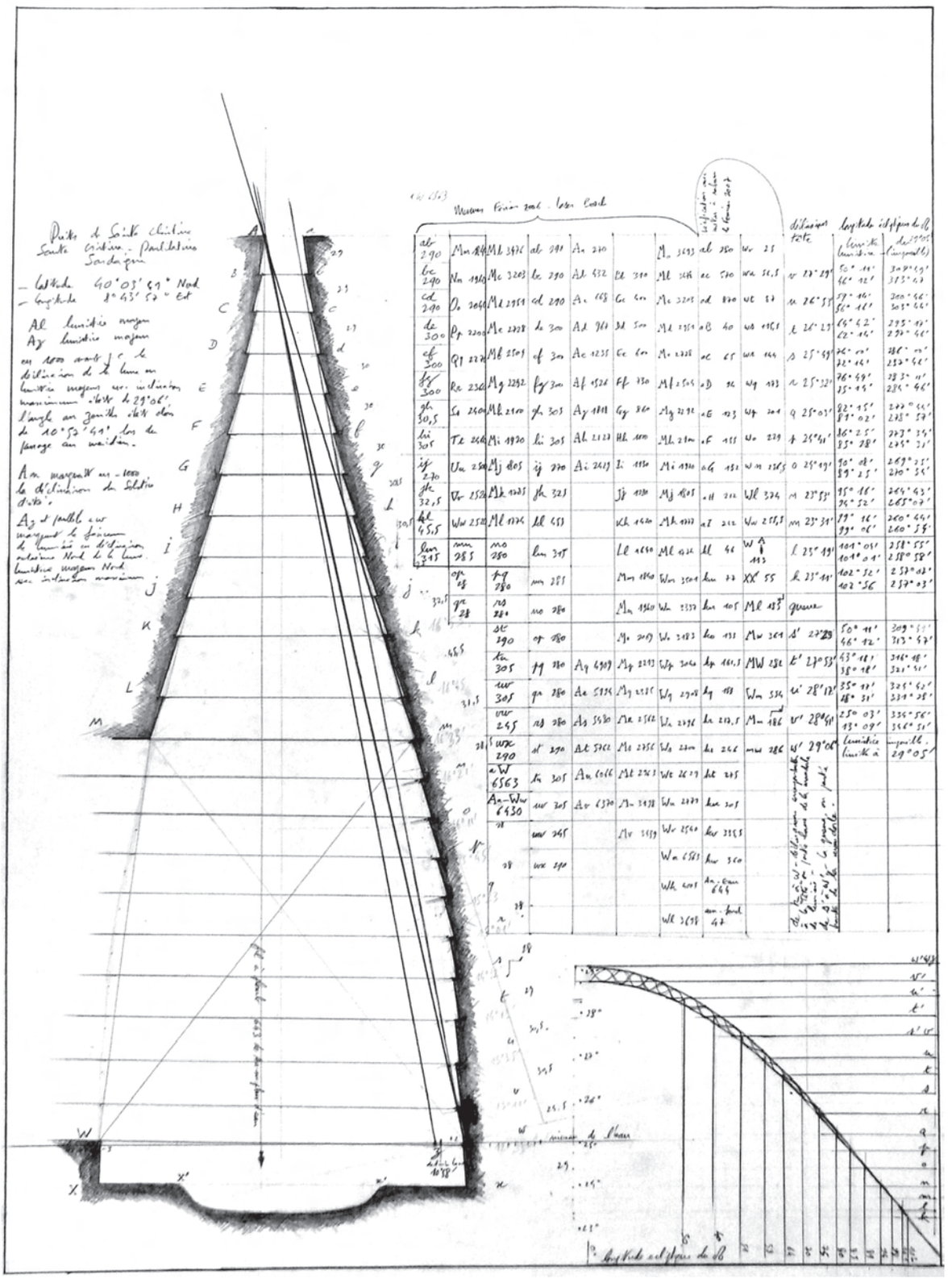

Fig.1. Plan of the well at Santa Cristina, A. Lebeuf, 2007.

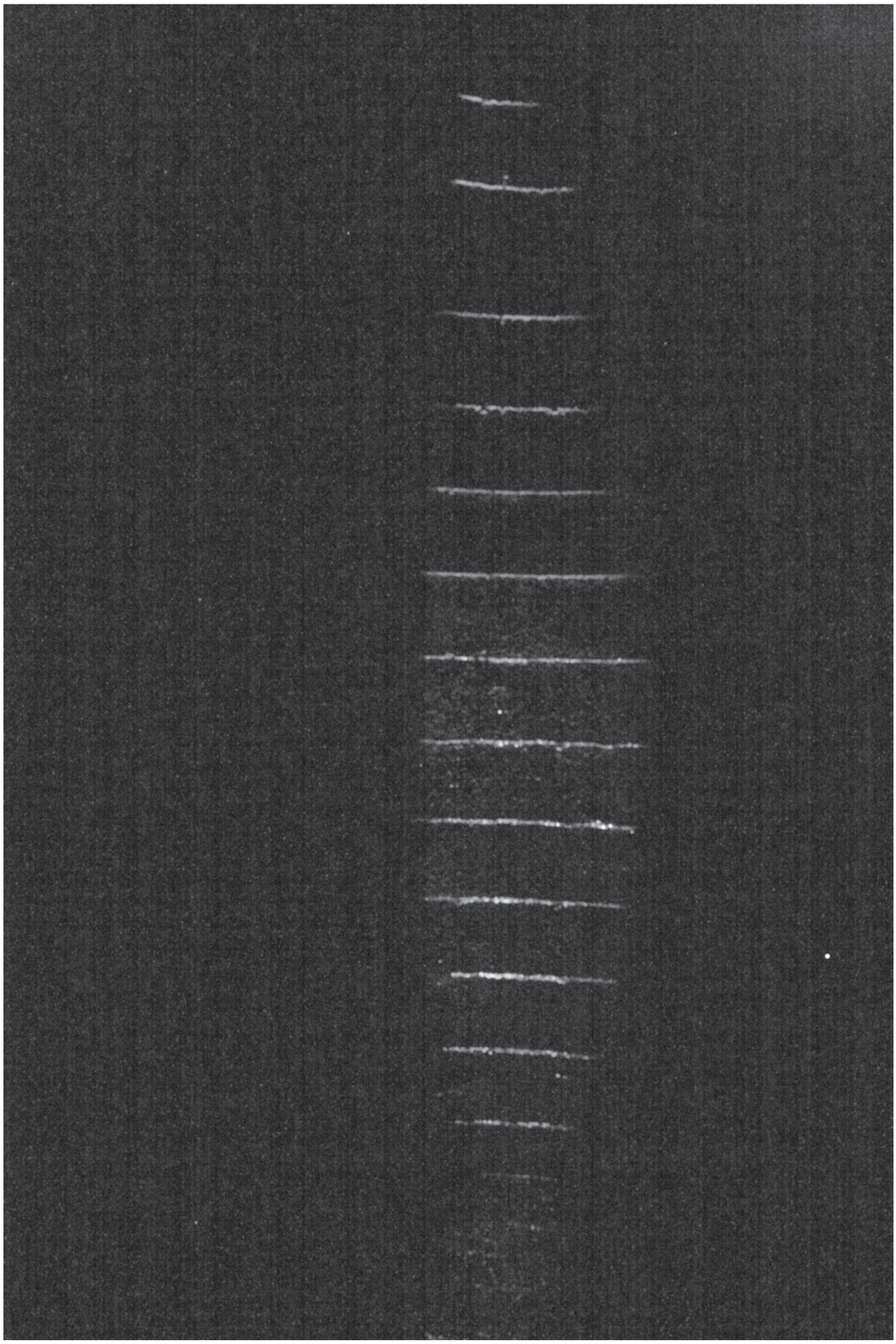

Fig.2. The ‘ladder’ of light in the sacred well at Santa Cristina. Photograph by Tomasz Stanco.

bottom right corner of the plan in Lebeuf 2007). This privileged moment does not occur at a longitude of 90° measured from the vernal point, as we might expect, but at around 102-103°. I shall return in a later paper to a detailed explanation of these technical issues, but for the interested reader I would mention that I have discussed these questions elsewhere: see Lebeuf bibliography.

The perfect concurrence of so many significant aspects forming a system with a surprising degree of precision could not have arisen by chance. Furthermore, the sacred well at Santa Cristina may not be the only example of a lunar observatory belonging to the Mediterranean Bronze Age, although it is probably the best preserved.

A large number of quasi-historical, legendary and mythological sources associate the wells with dragons, mirrors, camerae obscurae and astronomy as well as with priestesses for a Moon cult and sacrificial victims. The recording and analysis of legends, myths and iconography is currently being undertaken and the ritual aspects are being studied: the full results will be published later. For now, we shall present just the plans and measurements of the monument, and the tables of measurementss with their corresponding declinations.

These plans and measurements demonstrate the perfect efficiency of the well as an instrument for measuring the declinations of the Moon at the moments of the lunistices and thus constitute an excellent means of predicting eclipses. I plan to proceed with this study and later to present a full and detailed report duly augmented with historical, legendary, mythological, ethnographical and iconographical materials showing that the hypothesis is well supported historically and culturally. I also hope to proceed with the study of more of these wells in order to check if the case is unique or can be confirmed by other examples.

Were it confirmed, we would then be confronted with new problems. Is the scientific community ready to accept a monument of art and science such as this within a Bronze Age pastoral clan culture?

Acknowledgments

I received support for this investigation from the Institute for the History of Religions at Cracow University and from the Dean of the Faculty of Philosophy at Cracow University (fund for scientific research). I am also indebted to the Sardinian friends and colleagues who greatly assisted me during my observations, for their help in transporting me to the archaeological sites at night, and their warm hospitality. I am also grateful for their interest in my investigations and for offering me the possibility of presenting my hypothesis and results at a lecture organized at Santa Cristina during my third trip. I shall certainly not forget the scholarly assistance of the librarians in Cagliari who located old and rare publications and offered me a set of photocopies.

My particular thanks are due to Enrico Atzeni, Julio Cannella, Salvatore Cossedu, Rosanna Delogu, Mariola Flis, Giovanna Manunzo, Antonio Piras, Marcello Ranieri, Angelo Saba, Tomasz Stanco, Lukasz Trzcinski and Mauro Zedda.

References

LILLIU, G., 1988. *La civilta dei Sardi dal paleolitico all'eta dei nuraghi*. Torino: Nuova Eri Edizioni Rai.

LILLIU, G., 2006. *Sardegna nuragica.* Nuoro: Il maestrale.

LEBEUF, A., 1989. L'Observatoire astronomique de la cathédrale Saint-Lizier de Couserans. *Publication de l'Observatoire astronomique de Strasbourg: Astronomie et Sciences Humaines*, 3, 39-78.

LEBEUF, A., 2003. *Les éclipses dans l'ancien Mexique.* Kraków: Jagellonian University Press.

MAXIA, C. and FADDA, L., 1972. Il misterio dei nuraghi rivelato con l'astroarcheologia. Cagliari: Ed. Castello.

MAXIA, C. and PROVERBIO, E., 1973. Orientamenti astronomici di monumenti nuragici. *Rend. Ist. Lombardo, Accad. Sci. Lettere, Cl. Sci*. A, Vol. 107, 298 - 311 = Pubbl. Stn. Astron. Int. Latitudine, Carloforte-Cagliari, Nuov. Ser., No. 28.

ROMANO, G. 1992. *Archeoastronomia italiana*, Padova: CLEUP.

SANTONI, V., 1990. *I templi di eta nuragica, in La civilta nuragica*. Milano: Elemond editori, Electra.

SHINKOKAI, N.G., transl., 1965. *Manyoshu*, New York: Columbia University Press.

Table 1. Table of the light measurements in the Santa Cristina Well

-X marks indicate the number of layers illuminated from the moment of formation of the mandorla of light for each level reached.
-The bold **X** marks and declinations show the extrapolation on the water mirror (water's surface).
-Row B is the first edge formed at the limit between the first and second layer of stones counting from the top. When the light falls at an angle to the plane of the meridian, we observe non-negligible torsions in the calculation.

Row	Date hour	Alti-tude	Decli-nation	Date our	Alti-tude	Decli-nation	Date-hour	Alti-tude	Declin-ation	Date-hour	Altitude	Declin-ation	Date-hour	Alti-tude	Dec-lin-ation								Declin (Tail)	Declin. (cali-brate (Head)
	15.XII 05			18.XII 05			7.II 06			28.I 07			29.I 07											
B																								
C																								
D																								
E																								
F																								
G	22:19	70°09'	20°14'																					
H	22:24	70°56'	21°01'																					
I	22:32	72°09'	22°14'	00:24	71°51'	21°56'																		
J	22:34	73°02'	23°06'																					
K	22:37	73°27'	23°32'	00:33	73°04'	23°09'	19:24	72°51'	22°56'															23°12'
0				00:35	73°12'	23°16'				18:50	73°12'	23°16'	19:44	73°09'	23°13'	X							25°25'	23°15'
1				00:38	73°32'	23°36'	19:28	73°25'	23°29'	18:52	73°28'	23°32'	19:46	73°23'	23°37'	X								23°33'
2	22:39	73°43'	23°48'	00:39	73°38'	23°42'	19:31	73°48'	23°44'	18:54	72°44'	23°48'	19:48	73°39'	23°43'	X	X						25°50'	23°45'
3	22:41	74°00'	24°04'		73°44'	23°49'	19:33	74°04'	24°09'				19:50	73°56	24°00'	X	X							24°00'
4	22:44	74°24'	24°28'		74°09'	24°13'	19:35	74°19'	24°14'	18:57	74°06	24°10'	19:52	73°13'	24°17'	X	X	X					26°27	24°16'
5	22:46	74°39'	24°44'	00:48	74°31'	24°35'	19:38	74°41'	24°46'	19:01	74°36'	24°57'	19:55	74°36	24°40'	X	X	X						24°44'
6	22:49	75°02'	25°06'	00:52	74°51'	24°56'				19:04	74°57'	25°01'	19:58'	75°00'	25°04'	X	X	X	X				26°57'	25°02
7	22:51	75°17'	25°21'	00:58	75°18'	25°22'				19:07	75°17'	25°21'	20:01	75°22'	25°36'	X	X	X	X	X			27°33	25°25'
8	22:56	75°51'	25°55'	01:07	75°48'	25°42'				19:12	75°48'	25°52'	20:05	75°50'	25°53'		X	X	X	X	X		28°18	25°50'
9	23:01	76°22'	26°27'							19:16	76°11	26°15	20°12	76°35	26°39'			X	X	X	X	X	***28°33'***	26°27'
10	23:08	77°01'	27°06'							19:23	76°45	26°49'	20:15'	76°52'	26°56'				X	X	X	X	***28°50'***	26°57'
11 water	23:14	77°28'	27°33'								77°05'	27°13'	20:22	77°28'	27°32'					**X**	**X**	**X**	***29°06'***	27°26'
water	23:20	77°50'	27°54'										20:28	78°18'	28°22'						**X**	**X**		
max	23:35	78°14'	28°18'										20:38	78°27'	28°30'							**X**		
water	23:52	77°46'	27°50'										20:56	78°16'	28°26'									
													21:07	77°44'	27°48'									

Table 2. Measurements of the declination of the moon passing the meridian corresponding to each of the layers of stone in the Santa Cristina well

"Head" signifies the lowest point of light impact on the light ladder, while "tail" means the upper point of the light ladder. The third column marks the corresponding ecliptic longitudes of the ascending node for each level. The calculation reflects the situation for the year 1000 B.C. We see that row zero (L) perfectly marked the crossing point of the lunar perturbations and permitted the precise determination of the ecliptic longitude of the nodes of the moon's orbit.

Level	Declination	Longitudes of the ascending node of the moon's orbit.	Longitudes of the descending node of the moon's orbit.
K (head)	23º 12'	Medium lunistice. 102 º 53' / 102 º 56'	Medium lunistice. 257 º 07' / 257 º 04'
L (head) 0	23º 15'	**102 º 20" / 102 º 21'**	**257 º 40' / 257 º 39'**
M (head) 1	23º 31'	99 º16' / 99 º06'	260 º 44' / 260 º 54'
N (head) 2	23º 53'	95 º 16' / 94 º52'	264 º 43' / 265 º 07'
O (head) 3	24º 19'	90 º 08' / 89 º 25'	269 º 25' / 270 º 34'
P (head) 4	24º 41'	86 º 25' / 85 º 28'	273 º34' / 274 º 31'
Q (head) 5	25º 03'	82 º 15' / 81 º 02'	277 º 44' / 278 º 57'
R (head) 6	25º 32'	76 º 49' / 75 º14'	283 º 11' / 284 º 46'
S (head) 7	25º 49'	74 º00' / 72 º 14'	286 º 00' / 287 º 46'
T (head) 8	26º 29'	64 º 42' / 62 º 14'	295 º 17' / 297 º46'
U (head) 9	26º 55'	59 º 14' / 56 º 16'	300 º 46' / 303 º 44'
V (head) 10	27º 29'	50 º 11' / 46 º 12'	309 º 49' / 313 º 47'
W(head in water)	27º 33'	50 º 11' / 46 º 12'	309 º 49' / 313 º 47'
S' (tail)	27º 33	50 º 11' / 46 º 12'	309 º 49' / 313 º 47'
T' (tail)	28º 18'	43 º 18' / 38 º 18'	316 º 18' / 321 º 41'
U' (tail)	28º 33'	35 º 17' / 28 º 31'	324 º 42' / 331 º 28'
V' (tail)	28º 50'	25 º 03' / 13 º 09	334 º 56' / 345 º 51'
W'(tail)	29º 06'	0 º Major lunistice	180 º Major lunistice (i.max). The moonlight leaves the wall and illuminates the water mirror (water's surface).

Received: 29 October 2007; Revised: 20 September 2008

NURAGŲ KULTŪROS SANTA KRISTINOS ŠALTINIS (PAULILATINO, ORISTANO, SARDINIJA). ASTRONOMINĖS HIPOTEZĖS VERIFIKAVIMAS: PIRMIEJI REZULTATAI

Arnold Lebeuf

Santrauka

Santa Kristinos šaltinis trykšta šalia nedidelio Paulilatino miestelio, Oristano provincijoje, Sardinijoje. Jo geografinės koordinatės – 40º3’41,43” šiaurės platumos, 8º43’57,08” rytų ilgumos.

Tai nepaprastai preciziškai tašytų pilkai juodo bazalto akmenų statinys, archeologų datuojamas apie 1000 m. pr. m. e., taigi priklauso vėlyvojo bronzos amžiaus laikotarpiui, vadinamajai Nuragų kultūrai.

1972 m. Karlas Maksia (Carlo Maxia) ir Ledo Fada (Lello Fadda) išplėtojo Eduardo Proverbijo (Eduardo Proverbio) mintį, suformuluodami hipotezę apie astronominę šio unikalaus statinio paskirtį. Anot pirmųjų dviejų autorių, meridiano įstrižainė, einanti nuo viršutinio pietinio iki apatinio šiaurinio šulinio kampo, sudaro 11,5° kampą, o šis atitinka Mėnulio deklinaciją didžiosios šiaurinės Mėnulio lunisticijos metu. Deja, K. Maksijo ir E. Proverbijo straipsniuose buvo pateikti tik apytiksliai objekto matavimai, o planas stokojo tikslumo.

Jeigu Mėnulio šviesa iš tiesų pasiekdavusi Santa Kristinos šaltinio vandens paviršių meridianinio perėjimo į svarbiausią lunisticiją metu, tai akmeninės matuoklės laipsniai buvo apšviečiami vienas po kito, laipsniškai, ir šviesa, tokiu *camera obscura* principu projektuojama ant sienos, sudarė tarytum kopėčių efektą. Jeigu tai būtų tiesa, tai reikštų, jog analizuojama akmenų struktūra buvo kur kas tobulesnė, nei manyta iki šiol. Taigi turėtume kalbėti ne apie simbolinę ritualinę konstrukciją, o pirmiausia apie mokslinį instrumentą, kuris teikia galimybę matuoti Mėnulio deklinaciją daug ilgesnėje jo judėjimo ciklo atkarpoje. Ir svarbiausia, tai daryti su daug didesniu tikslumu.

Mano dėmesį taip pat atkreipė viena konstrukcijos detalė – visos akmenų eilės yra maždaug to paties aukščio, apie 30 cm, ir tik viena yra akivaizdžiai didesnė – apie 45 cm aukščio. Šis išskirtinumas veikiausiai turi kokią nors specialią prasmę, kurią dar reikėtų išsiaiškinti.

Nauji tyrinėjimai, sudarytas tikslus planas ir keturios serijos Mėnulio šviesos matavimų, atliktų Santa Kristinos šaltinio statinio viduje, aiškiai rodo, jog ši akmeninė konstrukcija galėjo turėti instrumento tikslioms lunisticijų deklinacijoms nustatyti ir Mėnulio orbitos mazgų ekliptinei ilgumai apskaičiuoti funkciją.

Vertė Vykintas Vaitkevičius