Determination of Cardinal Directions and the Gesture of Orant

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The paper is devoted to an interesting question closely related to the orientations of graves and archaeoastronomical objects in Central Europe, namely, to the determination of cardinal directions during the period ranging from Hallstatt era to Early Middle Ages. Using exhaustive procedure, we have shown that the most likely method for the determination of cardinal directions was that based on the horizontal observation of Sun sets and rises. The intrinsic part of this method is the angle–halving which can be performed either with or without instruments. Reconstruction of the later possibility, supported also by the experimental verification, led us to the conclusion that the hypothetical attitude used for the angle–halving is to be practically identical with the so called gesture of orant, usually interpreted as a posture of early Christian prayer. Interpreting then the burial orientation as a charitable gift, we further claim that the gesture of orant, being originally used for orientation in the unknown terrain, might develop quite naturally into a ritual gesture. Cultural, historical and technical arguments in favour to this idea are given.

Keywords: archeoastronomy, gesture of orant, cardinal directions, Hallstatt, Early Middle–Ages.

Introduction

The present contribution deals with possible connection between quite a practical human activity, determination of cardinal directions, and a phenomenon of deeply spiritual nature which is in the literature generally known as a ***gesture of orant***. Although the scope of this paper is, on the purely technical grounds, limited to the region of Central Europe and to the period ranging roughly from Hallstatt era to Early Middle Ages (800 BCE – 1000 CE), we are convinced that the arguments involved may be extrapolated also for much larger period and more extended space. The evidence of knowledge of remarkably accurate determination of cardinal directions in this period is mostly based on almost exact human burial orientations which are confirmed by many archaeological excavations scattered over the whole region (BÖHM 1941, 511; POULÍK 1960, 147; WALDHAUSER & al. 1999, 166; PLETERSKI 2002, PLETERSKI– BELAK 2004) (Fig. 1). Besides, it is quite obvious that the effective travelling over the large distances as is known in the Migration period (*Völkerwanderung*) would only hardly be possible without orientation in an unknown land, requiring inevitably the reliable knowledge of cardinal directions.

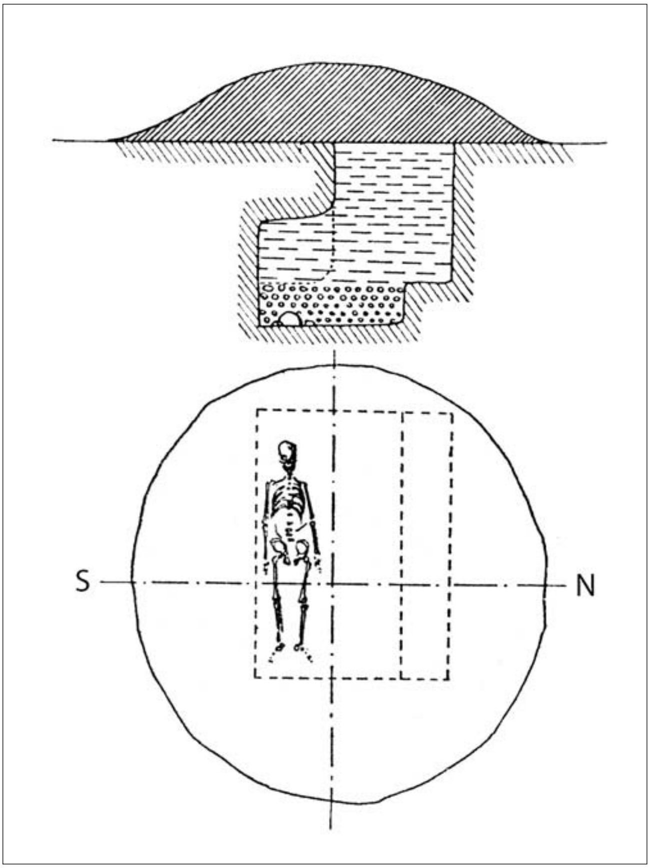

Fig. 1: An example of exactly oriented Slavic skeletal burial beneath a barrow. Věteřov–Strážovice in Moravia, 9th century CE (according to BÖHM 1941).

In order to find out the most likely technique for the determination of cardinal directions by our ancestors an ***exhaustive method*** is used. Let us first enumerate the natural phenomena and allied methods which can be taken in the said period and space into consideration in principle and then exclude those of them which are incompatible with provable facts or against to which strong objections of any kind do exist. The list of techniques potentially usable for the determination of cardinal directions is quite short looking as follows. Characteristic appearance or habitat of ***vegetation***, behaviour of some ***animals***, especially birds, ***terrestrial magnetism*** and various ***astronomical observations***.

Undoubtedly, the careful observation of ***animals and plants*** which reveal some tendencies to show the cardinal directions may be very helpful for the orientation in the unknown terrain. Nevertheless, the accuracy of these effects is rather low, strongly depending on local conditions. It is a well known fact that under unfavourable conditions the directions determined by these methods can be even inverted. We can thus take for granted, that these methods were e.g. for the relatively exact orientation of graves (accuracy better than ± 5°) practically useless.

The ***magnetic compass*** based on the interaction of some iron–rich minerals (e.g. magnetite) with oriented terrestrial magnetic field was known in ancient China (BÖTTGER 1979, 187). According to the tradition, it was discovered by a brother of the first

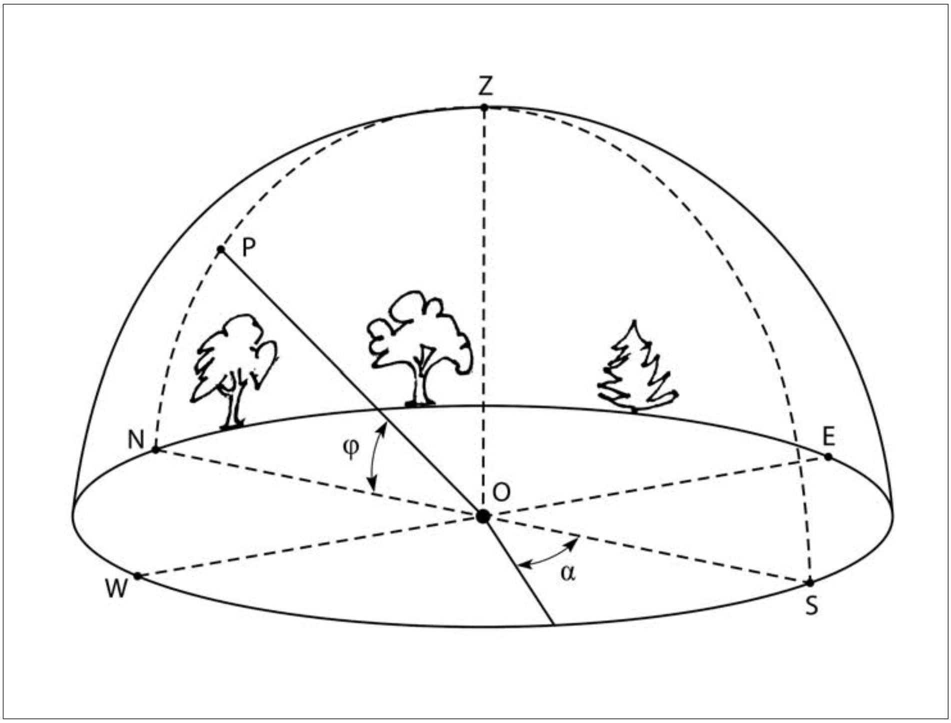

Fig. 2: Illustration of the basic concepts of the topocentric spherical astronomy.

Emperor of the Zhou dynasty (1025 BCE). However, the more reliable report comes only from the era of Qin dynasty (~200 BCE) and in some sources Emperor's geographer Zhang Heng (196 CE) is mentioned as inventor of the magnetic compass. Anyhow, this device might be thus in principle used also in Europe by e.g. Avarian invaders but as far as we know, there are no archaeological findings confirming such a hypothesis and there are no traces of later ethnographical evidence for it, either. That is why we have to leave this possibility out of consideration.

What remains are thus only various ***astronomical observations***. As we a–priori assume, in the ancient population, no knowledge of the shape and dimensions of Earth, solar system and Universe in general, we have to interpret or reconstruct all prehistoric astronomical observations as ***topocentric observations***, i.e. observations related to the observer which is considered to be in the centre of the *κόσμος*. Moreover, we are also allowed to operate only with concepts which may be derived directly from the observations made with unaided eye and without sophisticated tools.

A survey of concepts of topocentric astronomy

Before discussing the performance of different possible techniques for the determination of cardinal directions on the basis of the observation of celestial bodies, we have to recall first some elementary concepts belonging to the topocentric astronomy (see Fig. 2).

Celestial sphere is an imaginary sphere of large arbitrary radius with the observer O at its centre. The celestial sphere together with all objects projected on it appears to rotate from the east to the west around the celestial axis once every ~ 23 hours 56 minutes. (This period represents in standard astronomy the diurnal motion of Earth measured in usual solar time units.) The term of ***celestial axis*** means the straight line connecting the position of the observer O with the single stationary point on the celestial sphere called ***celestial pole*** P. (Obviously, in Europe P is the ***north celestial pole***.) The true horizon is an apparent line separating the visible part of the celestial sphere from that shaded by the Earth. The word horizon derives from the Greek *όριζων κύκλος* having the meaning »separating circle« which reflects the very essence of the concept quite well. Of course, usually the true horizon is obscured by trees, hills and other objects staying on the ground, so that this definition is not without ambiguity. Therefore, in topocentric astronomy the ***horizon*** is defined as an intersection of the plane perpendicular to the plumb–line OZ (horizontal plane) and celestial sphere. The great circle of the celestial sphere perpendicular to the horizon and passing through the pole P intersects horizon in two points. The one which is nearer to the pole P is called ***north point*** N and the other one ***south point*** S. The angle ∠NOP then defines the ***geographic latitude*** ϕ of the observer. The arc PS of the great circle NPS is called local ***meridian***. The ***azimuth*** of a celestial body is the angle α between the vertical plane containing it and the plane of the meridian measured from the south point S clockwise along the horizon. The azimuths of the cardinal points laying on the horizon are then respectively: south point (S) $\alpha = 0°$, west point (W) $\alpha = 90°$, north point (N) $\alpha = 180°$, east point (E) $\alpha = 270°$.

Astronomical determination of cardinal directions

Continuing our exhaustive process, let us now examine, step–by–step, various methods based on topocentric astronomical observations which are potentially usable for the determination of cardinal directions. The first one, very simple and popular method, which is described in practically every scouting handbook, is that using the ***North–star***. Finding out on the night sky the characteristic shape of the constellation of Ursa Minor, the North–star (Polaris, α–Ursa Minoris) lying in close vicinity of the celestial pole P can be identified. Using then plumb–line or simply estimating the vertical line passing through the North–star, the north point N on the horizon can be easily traced with an appreciable accuracy. However, as was already established by Hipparchus (~ 150 BCE), the position of celestial pole with respect to the constellations constantly changes throughout the centuries. This long term movement of Earth's axis with respect to fixed stars is due to the purely mechanical effect called precession. The circle depicted in Fig. 3 represents a locus of the north celestial pole in different epochs projected on the celestial sphere. It is seen at first glance that the contemporary North–star (Polaris, the star close to the point corresponding to +2000 CE) marks the position of the north celestial pole with remarkable accuracy. It is, however, also quite apparent that there was no »North–star« in the Hallstadtt or Migration periods marking the north celestial pole comparably well. For example, using for the determination of the north point clear fixed stars nearest to the pole which were during those periods Polaris and/or Kochab (β–Ursa Minoris), the expected error would exceed ±10°. Of course, such accuracy, being still usable for a rough orientation in an unknown terrain, is obviously not sufficient for already observed

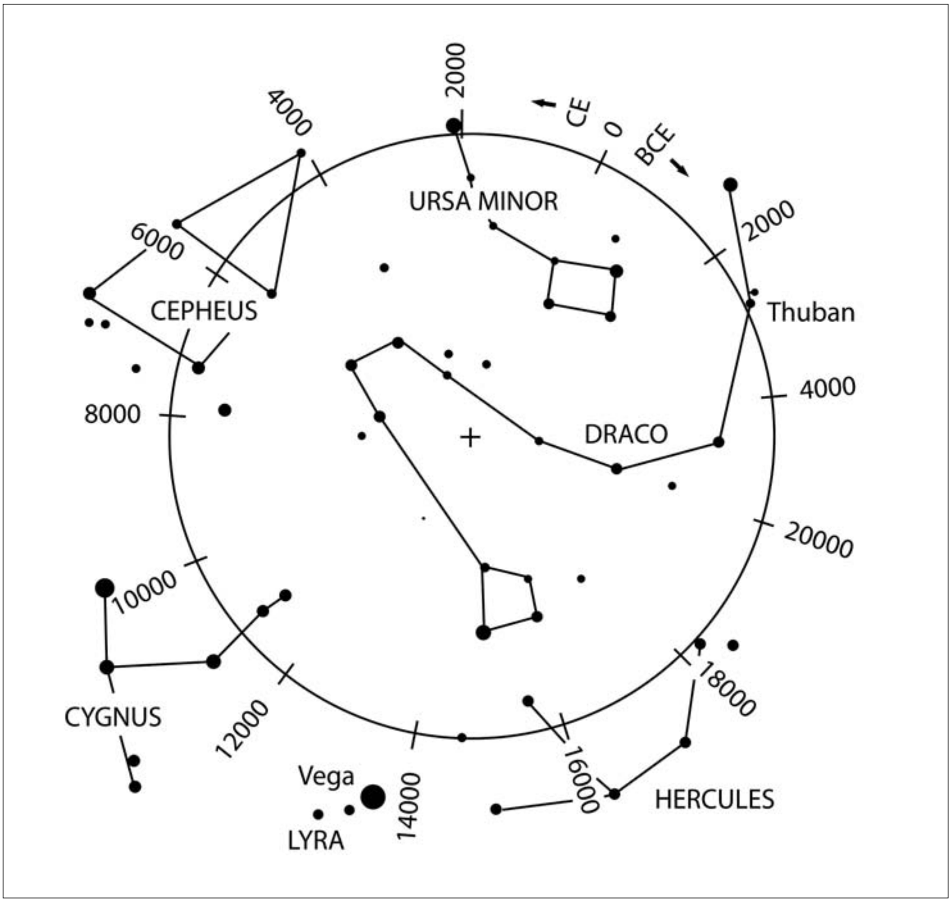

Fig. 3: The apparent path of the north celestial pole among the stars due to the precession of the Earth axis. The period of precession is approximately 26 000 years and the angular radius of precession circle ε ≈ 23.5° (ŠIROKÝ–ŠIROKÁ 1966, 29).

exact orientations of graves or temples. Strictly speaking, for such purposes and in the era we are talking about, the North–star method fails.

There is, however, another method for the determination of the north point which should be taken into consideration, in some sense generalizing the preceding North–star method. For given geographical latitude, there exist stars called ***circumpolar stars***, which due to their proximity to the celestial pole remain permanently above horizon. Obviously, the centre of the circular path of a circumpolar star is identical with the celestial pole. Observing thus at least a part of such a path, the celestial pole can be determined in principle.

As ethnographical investigations among Polynesian tribesmen have convincingly shown (ZINNER 1931, 250), the knowledge of constellations and of their relative positions on the night sky enables them, practically without any instrument, a reliable navigation. Basing on this fact, we have to acknowledge an experienced observer in European Migration period a similar ability. Nevertheless, as far as we know, any clear vestiges of such a use of e.g. circumpolar stars for the terrestrial navigation are lacking.

On the other side, the orientation of archaeoastronomical objects by means of the observation of circumpolar stars with instruments is taken by some authors for very probable. Various reconstructions of prehistoric instruments which may serve for such a purpose can be thus found in the current literature (MINISTR 2007, 28, 169 and references therein). Beside unimportant details, which are rather results of bold speculations, the suggested common idea of these instruments, an ***artificial elevated horizon*** (EDWARDS 1993, 267), seems to be plausible. The essential part of the simplest version of hypothetical apparatus was a horizontal beam (alternatively a circular wall with horizontal upper edge) realizing the artificial elevated horizon which was suspended in the height of adult man, approximately in the east–west direction. Then a point of observation, O, was chosen and fixed southward from the centre of the beam in close vicinity of the ground. In order to enable one to follow both the ascending and descending parts of the path of the preselected circumpolar star above the artificial horizon, it was further necessary to establish the dimensions of the whole arrangement by trial and error. The ascending and descending passages of the circumpolar star through the elevated horizon observed from the point O were marked on the beam by two points making the ends of a certain segment. The plumb–line dropped from the centre of this segment then defines together with the point O the northward direction. Correcting then on the basis of this measurement the original east–west lay–out of the apparatus and repeating the whole procedure few times, very high accuracy (~ ±0.2°) of the determination of cardinal direction may be finally achieved. Nevertheless, a wide use of this method is due to its numerous flaws very unlikely. The method requires, namely, a preliminary knowledge of the northward direction with the accuracy at least of ±15° and realization of a rather cumbersome apparatus. Moreover, because circumpolar stars are not simultaneously visible when the Sun is in the sky, both their ascending and descending passages through the elevated horizon can be observed only occasionally and systematic observations are thus necessary. Therefore we can claim that the method based on the observation of circumpolar stars might be useful for some special purposes (e.g. for the orientation of temples and henges) but for every–day use it is quite inconvenient.

Far more operative is the following technique using the so called ***gnomon*** (*γνώμων* = literally arbitrator, interpreter). Gnomon is undoubtedly one of the oldest astronomical instruments extensively used in various cultures throughout the ancient world (LEACH 1954, SCHLOSSER – CIERNY 1996, 62). Its, at least partial, knowledge should thus be likely also among the population we are dealing with. Gnomon is a vertical pole, symptomatically having very often a form of human figure, stuck into the horizontal ground. Watching the tip of its moving shadow the apparent path of the Sun or the Moon can be recorded and then studied in detail. A well documented method of tracing the apparent paths of the Sun is the method of ***Indian circles*** (SCHLOSSER – CIERNY 1996, 62; ZINNER 1931, 250). (Notice, following description does not apply to observations in the Polar Regions where the gnomon theory is rather complicated.) Prior to the observation a system of concentric circles is drawn on the horizontal plane having the basis of the gnomon O for its centre (Fig.4). Each passage of the tip of the shadow of the gnomon through every circle is marked. The sequences of points R_1, R_2, R_3 ...etc. then define a curve which is a conical projection of the apparent path of the Sun on the ground. The complete annual system of such curves is performed by a set of 365 hyperboles which at equinoxes degenerate to straight lines oriented in the east–west direction. For our

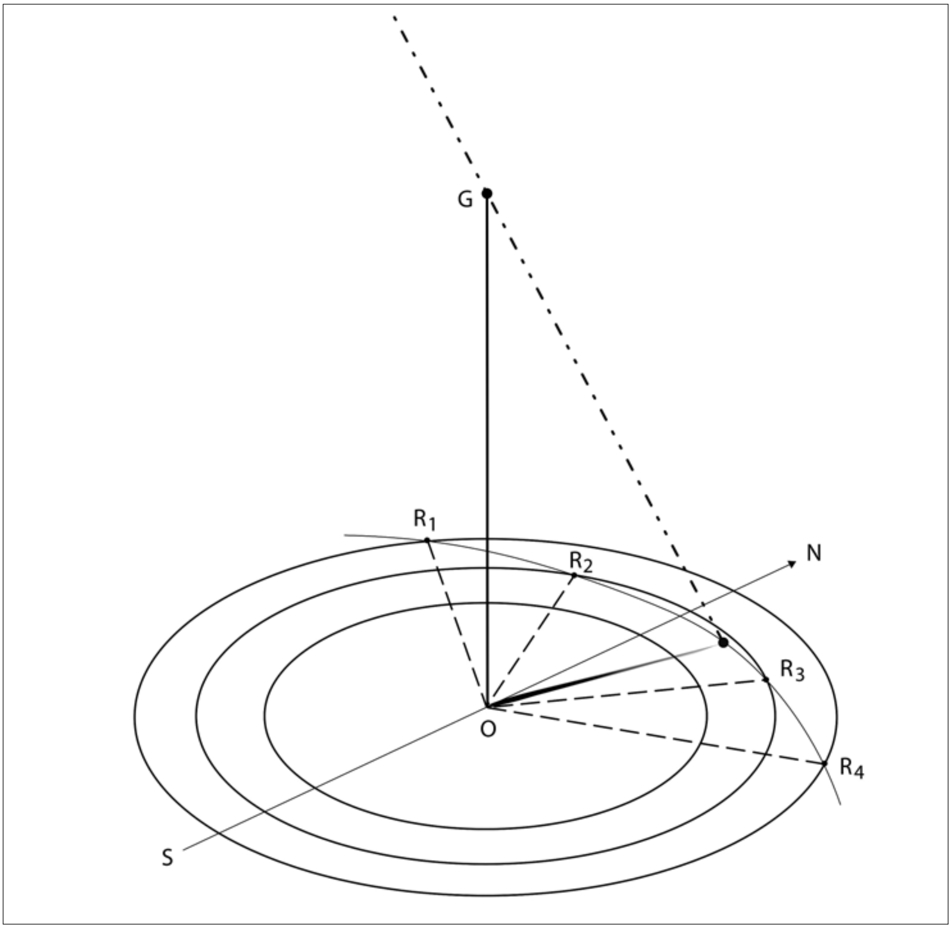

Fig. 4: Gnomon provided with a system of Indian circles, a primitive tool enabling to construct the conical projection of the apparent path of the Sun on the horizontal plane.

discussion it is an important fact that every couple of points in which a given hyperbole intersects a particular circle (i.e. R_1R_4, R_2R_3, ... etc.) defines a straight line oriented in the east–west direction, while the common axis of angles $\angle R_1OR_4$, $\angle R_2OR_3$ ... etc. defines the south–north direction. Various methods, those hypothetical included, based on these properties of the gnomon shadow, enable one to achieve a remarkable accuracy in the determination of cardinal directions but require systematic and rather time consuming (few hours) observations. On the other side, the allied techniques using shorter time intervals provide only doubtful results. As an illustration may serve a shadow–tip method recommended to soldiers of the US Army (armystudyguide.com 2006) in emergency. Accordingly, two positions of the shadow tip of an improvised gnomon about 10 minutes delayed are marked on the ground. It is then claimed that the straight line connecting these two marks is laying in the east–west direction. Evidently, it can satisfactorily work only at equinoxes or in the middle of the day when secants of the corresponding hyperbole have approximately east–west orientation. Near the solstices, early in the morning

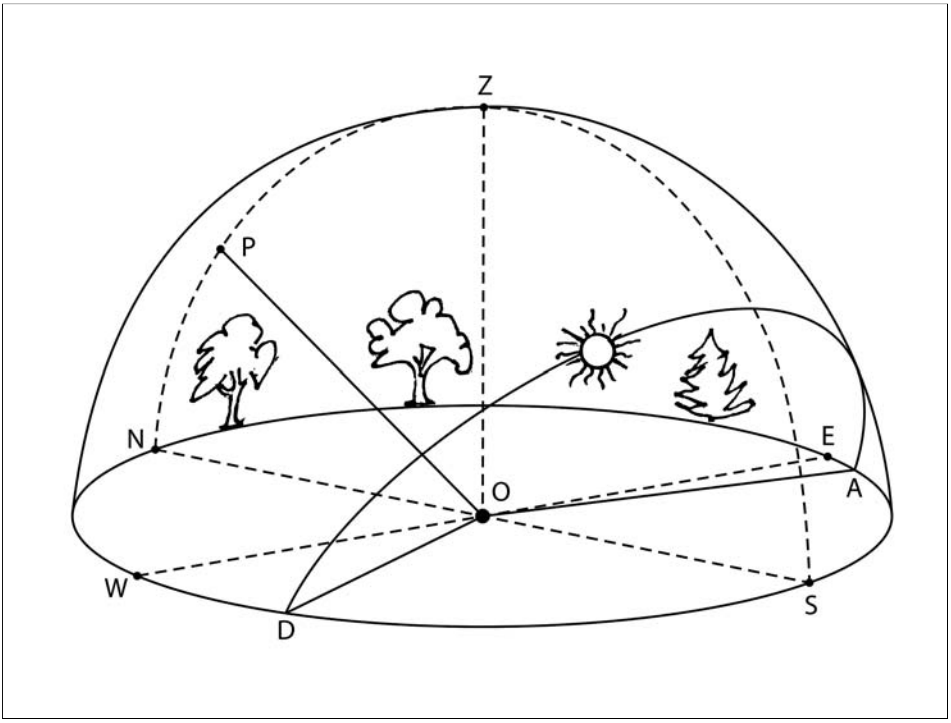

Fig. 5: Illustration showing the symmetry of apparent path of the Sun.

or in the late afternoon, the method may achieve at latitude $\phi = 50°$ a huge error of ~ ±38°. It is thus obvious that the necessity of day–long systematic observations makes the gnomon–related methods hardly compatible with the nomadic life–style so typical of the Migration period. Nevertheless, respecting the opinion of some authors (e.g. SCHLOSS-ER– CIERNY 1996), the use of gnomon for the determination of the cardinal directions cannot be, especially for settled population, excluded from the considerations.

Much more convenient, however, seems to us the following technique based on the ***horizon observation of rises and sets of celestial bodies***. The principle of this, as far as we know, most robust and reliable method is quite simple (see Fig. 5). Evidently, the circular path of a body rotating together with the celestial sphere is symmetrical with respect to the celestial axis. Therefore (if the body is not circumpolar) the points of its rise (A) and set (D) are placed on horizon symmetrically with respect to the plane of meridian. From this fact among others a consequence follows that the axis of the angle $\angle AOD$ coincides with the straight line NS connecting the south and north points.

Obviously, for the application of this method any non–circumpolar object firmly attached to the celestial sphere can be used. However, in contrast to the deserts of Egypt and Mesopotamia, in a relatively moister climate of Eastern and Central Europe, the stars near the horizon are visible only seldom because of frequent fogs and mirages near the horizon. Also the Moon is not very convenient for the everyday observations especially because there is a rather long time interval between days when both, its rise and set can be seen. The only sufficiently clear celestial body the rises and sets of which can be observed at least partially during the whole year (number of sunny days a year ≈ 75– 93, PEARSON 1897) is thus the Sun. The determination of the cardinal directions on the basis of ***observation of the Sun set and the Sun rise*** may then be reconstructed as follows (see Fig. 5):

- Mark the position on the horizon where the Sun is setting (point D).
- Wait till the morning to see the point at the horizon where the Sun rises (point A).
- Halve the angle ∠ DOA. The horizontal straight line halving this angle then defines the south–north cardinal direction. Since the positions of the Sun rise and its setting are already known, the south and north cardinal points can be easily identified.

Of course, there are points in this prescription which should be discussed in more detail. The first practical question is of how to mark the positions of the Sun set and the Sun rise. Observer can simply remember some typical structure coinciding with the setting or the rising Sun on the horizon, or the coincidence with already existing solitary object in the nearer field. In case there are no such convenient objects, a peg or stone placed on the straight line connecting the remote point on the horizon with the observer may be used for marking the direction. If the directions towards the points A and D are already fixed and properly marked in the terrain, the problem of finding the north–south direction is effectively reduced to the halving of the angle ∠AOD, i.e. to the standard procedure known from the practical geometry, which requires rather special equipment. In a minimalistic version we can, however, perform the halving of an angle using only a sufficiently long rope, arguably a very old instrument used for tracing in many ancient cultures. Let us only recall the »rope–stretchers« (*ʿαρπεδονάπται*) i.e. surveyors in ancient Egypt. There is only a little doubt about the use of the rope as a measuring device for such purposes among the Celtic and Germanic population because of a close cultural contact with Roman Empire where the use of advanced methods of practical geometry is well documented (CANTOR 1907, 104, 538). In the Slavic milieu among others the term ***vervnyj brat*** (from Slavic *vervъ* = rope, *bratъ* = brother) indicating a special social relationship among the inhabitants of huts in Slavic settlements in Ukraine the corners of which are aligned by means of a stretched rope (BARAN 1997) witnesses the exploitation of the rope for the tracing of objects. Interestingly, the traces of this tradition are likely preserved also in folk architecture of Central Europe cf. e.g. special alignment of corners of log cabins in »Nosy Lane« at Jilemnice in North Bohemia (LUŠTINEC & al. 2000, 10). The construction of the axis of the angle ∠AOD by means of a rope is a relatively simple task. Firstly, on the straight lines AO and DO two points A′ and D′ must be marked in such a way that A′O = D′O. After that exactly in the middle of the rope, which should be approximately of length ≈ 2A′D′, a knot K is bound. Both the ends of the rope are then firmly attached at points A′ and D′. Taking now the knot in hand and equally stretching both halves of the rope outwards the point O, the knot K will finally fall on the axis of the angle ∠A′OD′ = ∠AOD. The straight line KO will then be identical with the line connecting the north and south points.

The author has a little doubt that just this method or its modification was actually used in praxis because of its reliability and simplicity (KONEČNÝ 2005, 42). Besides, we can take for granted that all necessary knowledge and means for its realization were at that time currently at one's disposal. Our opinion supports also the fact that the method is marvellously exact. For example, if the geometric constructions are carefully performed, the axis of the angle ∠A′OD′ can be determined with accuracy better than ± 0.05° (RYŠAVÝ 1949, 186). The overall error of the method is thus rather due to other effects, namely, to diurnal motion of the Sun with respect to the celestial sphere and especially to the difference between astronomical and true horizon. (see Appendix 2)

Nevertheless, it is a fact of unappreciated merit that we can alternatively do without any instrument at all. Being more specific, instead of measuring instruments the ***body of the observer*** himself/herself may be used. This possibility is due to the almost perfect symmetry of a human body and to very sensitive perception of any distortion with respect to this symmetry. For example, the torsion of the resting body only about ±2° is by the receptors in the spinal column evaluated as a »large change« and corresponding postural–tonic reflexes tend to ensure the righting, i.e. the return to the relaxed position (BABSKY & al. 1982, 215).

How can be then, by means of the human body, the halving of angle carried out? The corresponding procedure may be reconstructed as follows. Freely staying observer takes up a position with outstretched hands approximately oriented towards the points A and D. In order to point at these distant points on the horizon with better accuracy, he/she has to elevate the palms to the height of eyes minimizing simultaneously their visible profile by turning them to the frontal position. By a simple trial we can convince ourselves that the realization of this attitude is very difficult without at least slight bending of the arms. Aiming alternatively at points A and D and correcting the position of the body in such a way that the arms remain outstretched symmetrically, the observer's body will finally reach a position where his/her *sagittal* plane will coincide with the plane of local meridian, or in other words, where the observer will be facing northward (or southward).

It is the principal claim of this work that observer's attitude just described and hypothetically used for the determination of the cardinal directions is in fact identical with the position known as a gesture of orant.

Gesture of orant

In the current literature the term ***orant*** or ***gesture of orant*** (from Latin *orare* = pray) refers most frequently to the posture of early Christian prayer with uplifted hands (PIJOAN 1973, 9, see Fig. 6). The figure stands upright with arms outstretched and raised to eyes height; elbows are bent and open palms are kept up or in frontal position. The gesture was very popular till the end of the ~4th century CE when a new trend characterized by exalted submissiveness to God appeared. It was then preserved only for a special use e.g. by priests during the Holy mass, while among the laymen it was shared by various gestures of atonement and prostration. The gesture of orant is interpreted, as a rule, as a reminiscence of the attitude of Jesus Christ on the cross. Nevertheless, despite this convincing interpretation we assert that the roots of the gesture must be much earlier, i.e. pre–Christian.

Indeed, besides the frescos mentioned above which are almost with certainty linked up with early Christian culture, there are artefacts undoubtedly dated well before Christian era, unambiguously documenting the gesture of orant. E.g. the findings from ancient Egypt belong among such documents. For our argumentation, however, of

Fig. 6: Orant, fresco in the catacomb of Priscilla in Rome, Italy, ~3rd century CE (according to PIJOAN 1973).

crucial importance are artefacts having their origin in the space and time we are talking about. Thus from this point of view a Hallstatt urn which was discovered in the barrow near the west Hungarian town Sopron (Ödenburg) is enormously valuable (LIETZMANN 1934), see Fig. 7. The single fact that the urn itself does not represent burial ritual related directly to a specific orientation is not decisive because at that time skeletal and cremation burials coexisted very often side–by–side in one tumulus.

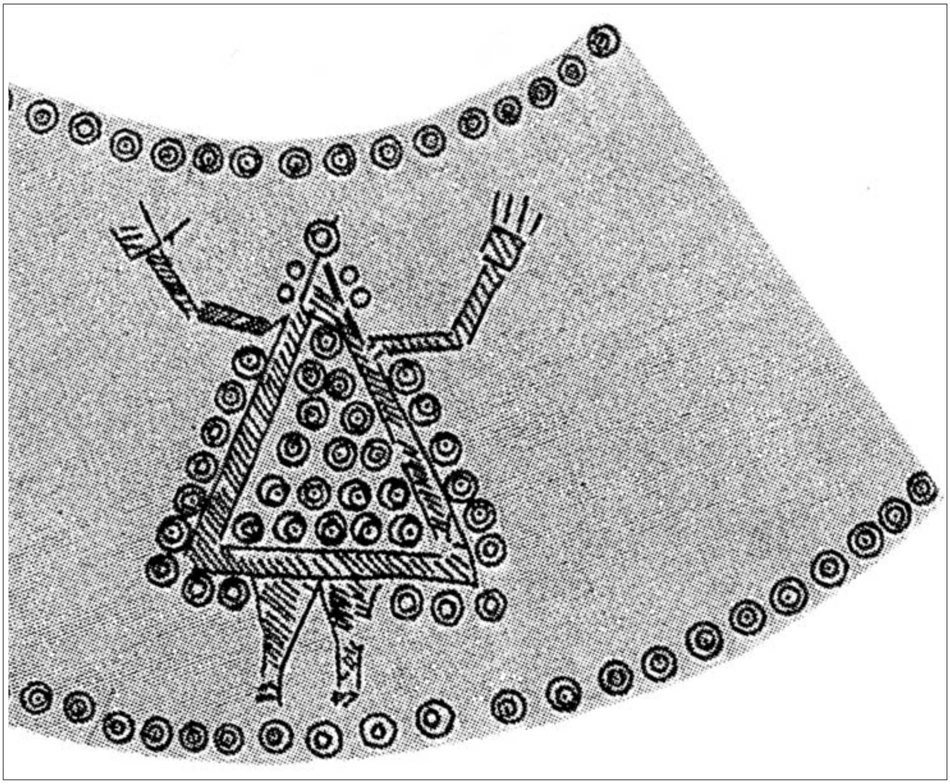

Fig. 7: Figure in an attitude of orant as depicted on Hallstatt urn found near Sopron (Ödenburg) in west Hungary (according to LIETZMANN 1934).

The abstract geometric decoration of the urn is so interesting that it is worth to describe it in detail. Besides two figures clearly demonstrating the gesture of orant which are of primary importance for this study, there are three other human figures, one of which is keeping the plumb–line, the second one is a weaver binding knots and the third one is a musician playing a tetrachord lyre (LIETZMANN 1934, FLEISCHER 1893). The upper rim of the whole scene is decorated with a line of »stars« while the band bellow the figures is filled with triangular ornaments representing a certain recurrent arithmetic sequence the last term of which corresponds to the so called »holy tetractys« (*τετρακτύς*). All the symbols on the urn thus astonishingly manifest the Pythagorean doctrine which was later codified in medieval ***quadrivium*** (Arithmetic, Geometry, Music and Astronomy). Moreover, taking into account the remarkable fact that the establishment of secret Pythagorean sect in Krotón (~500 BCE) coincides with the Hallstatt era (800 – 475 BCE), we have to conclude that the ideas traditionally attributed to Pythagoreans might be the property of much wider cultural circle then it is usually believed. Of course, in the literature we can find interpretations of the whole scene and of the particular figures differing from that just presented. One very convincing explanation may be found e.g. in (TERŽAN 1996). Nevertheless, her identification of persons making a gesture of orant with a couple of adoring women (»matrons«) is in fact not in contradiction with our interpretation above.

Anyway, regardless of all these highly interesting facts it can be taken for granted that the use of gesture of orant was not exclusively confined to the Mediterranean early Christian communities but that it was known also in the Central Europe, at least during the Hallstatt era, having a close relationship to the burial ritual and to various intellectual activities as well. The remaining point necessary to make our central hypothesis sound and complete is then the experimental proof of technical possibility and performance of the determination of cardinal directions by means of the gesture of orant.

Experiment with halving the angle using gesture of orant

In order to test the accuracy of angle–halving procedure based on the application of the gesture of orant the following experiment was made. For its realization we used a flat lawn of irregular shape and of external measure ~120 m, surrounded by trees and small bungalows. The average slope of the terrain was approximately ~1.8 %. Near the centre of the lawn a place was chosen for the »observer« (point O, see Fig. 8) and then, without special orientation, two points A′ and D′ were provided with flags. The segments OA′ and OD′ making an angle ∠A′OD′ = 140° were both 10 m long. At a distance of 11 m from the point O a point S′ was traced lying exactly on the axis of the angle ∠A′OD′. In parallel with connecting line A′D′, a survey tape was stretched in such a way that a point corresponding to 5 m mark coincided with the point S′. The tape was purposely unrolled asymmetrically and with marks not visible from the position of the observer, so that

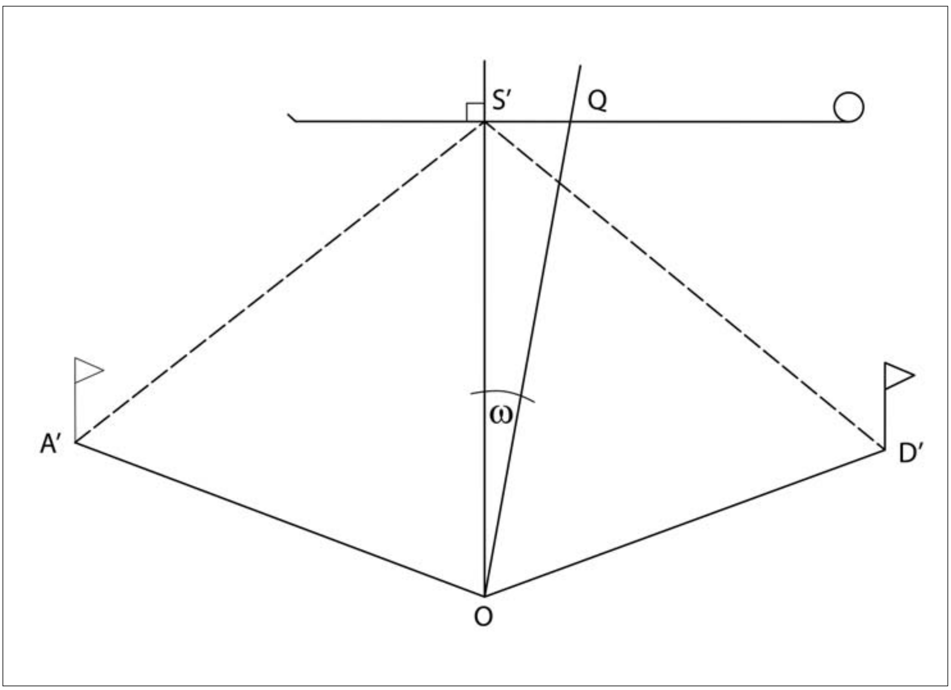

Fig. 8: A scheme of geometric arrangement used for the experimental test of accuracy of angle–halving by means of orant's gesture.

it provides no help for the determination of direction OS′. The persons, in number 17, taking part in the test, were of various age (from 10 to 58 years), sex and condition.

They were prior to the experiment informed about its purpose and also provided with necessary instructions. They were asked to take up the place at the point O making the gesture of orant and point outer edges of palms at the flags A′, D′, and simultaneously alter the position of the body till they feel themselves comfortably and without internal stresses. Afterward they should stretch their arms forward and fasten the palms together pointing in this way the apparent axis of the angle ∠A′OD′ (Fig.9). Finally, they guide a helper with lining rod into this direction, which was then in close vicinity of the tape marked by the point Q. From the measured lengths of segments QS′ the angle of deviation ω from the true direction OS′ was evaluated according to an obvious formula

$$\omega = \mathrm{arctg}\,(QS'/OS'). \qquad (1)$$

Tested persons were intently provided with no additive instruction how to »point the directions«; they simply made their best. Interestingly enough, the results were not apparently influenced by this fact, as well as by the short–sightedness, far–sightedness and even by gravidity. The only condition leading to a systematic deviation was the case, where the tested person had one leg about ~1 cm shorter. Nevertheless, for the evaluation of the results nobody and no data were excluded. For the ensemble as a whole we then obtained for the arithmetic mean of deviation from the right direction a value $\langle\omega\rangle = +1.78°$, while for the corresponding root mean square a value $\sqrt{\langle\omega^2\rangle} = 2.71°$ (RYŠAVÝ 1949, 186).

Summarizing critically the results of our experiment, it can be concluded that the skilled observer could easily achieve in the determination of cardinal directions by means of gesture of orant the accuracy limit ±5°, which was necessary, among others, for reliable orientation of the human graves.

Fig. 9: Mrs. Michaela L. demonstrates the angle–halving using the gesture of orant.

Supporting remarks

In this paragraph we would like to add some auxiliary arguments directly or indirectly supporting our central hypothesis and discuss some related cultural and technical aspects of general interest.

Let us give first linguistic arguments in favour of usage of Sun rises and Sun sets for the determination of cardinal directions. Especially in Slavic languages there is, namely, a direct link between names of cardinal directions and corresponding astronomical events. For example, in Czech (Slavic language) the names for East and West are perfectly synonymous with the names for the Sun rise and the Sun set. (i.e. (Sun)–rise = *východ* = East and (Sun)–set = *západ* = West; remarkably, the etymology of the names for the remaining cardinal directions, *sever* = North and *jih* = South, is unclear.) The traces of similar but not so direct links are preserved also in other Indo–European languages (DITTRICH 1923, 74).

There are also purely psycho–physiological reasons common to the whole mankind which makes the proposed method for the determination of cardinal directions based on the horizontal observations of the Sun accurate and reliable. The human vision, namely, being without awareness controlled by *nervus opticus*, evaluates, in contrast to e.g. photographic camera, not the apparent angular magnitudes of the observed objects but the absolute distances and dimensions of them (STERNECK 1907, 11, 43). The sensation of the space is thus very operative but, on the other side, it suffers from numerous »optical« illusions. One of the most significant illusions is erroneous estimation of vertical angles which may achieve easily deviations of ~50%. An attempt to reconcile the subjective observations and the objective measurements made by limited means, led in the antiquity to the establishment of a peculiar cosmological concept of ***firmament*** (*firmamentum*, *στερέωμα*, רקיע). Accordingly, the flat Earth was covered up with a firm transparent hyperbolic shell about ~20 km in diameter and ~3 km in height which separated the lower region filled with the aer (*αήρ*) from that filled with the aether (*αιθήρ*, *plenum*). Although the illusions reflected by this concept operate also in close vicinity of the horizon (a spectacular manifestation of such effects is e.g. an increase of apparent diameter of the Moon near the horizon) the azimuths of the rising celestial bodies at the horizon remain unaffected. This is undoubtedly why the meaningful prehistoric astronomical observations, our hypothetical method included, should be confined just to the scope of the horizontal astronomy.

The likelihood of the use of the sets and rises of the Sun for the determination of cardinal directions may be supported also by the following ethnographically well documented custom, according to which it was prohibited to burry the deceased at the same day when he/she died but only after one or more days. This custom known as »*excubiae funeris*« (= funeral guard, ZÍBRT 1894, 11), was and even till now is practiced by numerous communities at many places throughout the world. Notice, how this custom excellently fits the method of the determination of cardinal directions by means of Sun sets and rises! Indeed, in order to orient the grave properly it is necessary, prior its digging, to observe both the Sun set and Sun rise, in other words, keep minimally for one night the vigil.

On similarly practical grounds the proposed method is also convenient for orientation by travelling throughout the open landscape, e.g. via the corridor of grasslands connecting Central Asia with Central Europe. Since in comparison with today's state of the art, it was extremely difficult and dangerous to travel in dark, the nomads undoubtedly used to camp over the nights. It was then quite natural at the evening to record the horizontal position of the Sun set and early in the morning the position of the Sun rise and determine the direction for the march of the day. Combined with the knowledge of

Fig. 10: Reverse of silver end–piece of the belt, Great Moravia period, Valy u Mikulčic, grave No. 490, 9th century CE (according to POULÍK 1949).

principal rivers or mountain ranges the method may enable reliable navigation over the thousands of kilometres.

In close connection with our subject we have to stress another interesting point possibly improving our method, namely, the fact that the upright body of the observer can serve as an »animate gnomon«. At the moments just after the Sun rise or just before the Sun set the length of observer's shadow is very long. For example, if the upper edge of the Sun disk is about 1/2° above the horizon, the length of the shadow of a human figure ~1.6 m tall is $\geq 1.6 / \mathrm{tg}\,(1/2°) = 180$ m. Assuming now that the width of the shadow is smaller than, say, ~ 0.5 m the purely theoretical uncertainty in the direction must be well below ~ $\mathrm{arctg}\,(0.5/180) = 0.16$ °. Marking then evening and morning shadows and halving by means of the orant gesture the angle between them, the south–north direction can be determined without direct observation of the glowing Sun disc. Moreover, it is also evident that the idea of »animate gnomon« should be taken into consideration by interpreting the genesis and the appearance of many anthropomorphic pagan columns serving as idols (i.e. various prehistoric objects akin to the column in Zbruč, PLETERSKI–MAREŠ 2003).

Further we would like to turn reader's attention to the diversity in manifestations of the gesture of orant in pre–Christian era which is probably larger than it is usually believed. Assuming the cultural continuity, the vestiges and artefacts belonging to early Christian formations in the regions of »barbarian« Europe are of crucial significance. A figure making the gesture of orant which is depicted on the end–piece of the belt belonging to the Great Moravia period (Fig. 10) may serve as a good example of such an artefact.

Since the gesture of orant was at that time in Mediterranean and Byzantine regions already »out of fashion« and almost forgotten, we have to seek for an autochthonic source of its popularity in Central Europe, connected with pagan communities preserving pre–Christian lore. Daring to speculate, it may be related to the life–style of upper class, especially to the way of ruling (called in Slavic »*kъrmlenije*« = feeding, MERHAUTOVÁ–TŘEŠTÍK 1984, 51) characterized by permanent travelling of a local leader and his suit to and fro throughout the subordinate region. Consequently, the gesture of orant might thus rather be an archetypal symbol of travelling than that of the Christianity.

Also the oldest standing cast–work in Germany, an impressive Romanesque bronze anthropomorphic candelabrum now preserved in Erfurt Dome and generally known under the name of its probable donator as »(Heiliger) Wolfram« (de.wikipedia.org./wiki/Erfurter_Dom 2004, see Fig. 11), could be likely counted to the class of »orants«. The statue served for hundreds of years as a holder for missal, bearing for this purpose also a small table and the third candlestick on its back. Nevertheless the original form of the statue is not reliably known because it was evidently few times readjusted. (E.g. of much later origin must be the special anchoring of the statue to the socket by metallic screws!) A pattern on the back side of the left hand resembles so called Lichtenberg's figures which are, as a rule, due to the thunderbolt strokes. It may witness the fact that the statue was originally for a long time placed in the open air and not under the roof in the Dome and that the dating (1176 CE) and inscriptions are related rather to its donation then to its manufacture. Taking now into account these facts together with the fact that the statue appeared on the frontier between early Christian Ottonian Empire and not long ago conquered pagan region, we take it that this duly strange artefact fitting not

Fig. 11: Romanesque bronze candelabrum, so called »(Heiliger) Wolfram«, preserved in Erfurt Dome, Germany, 10–11th cent. CE, Ottonian Empire (Foto: A. Pleterski)

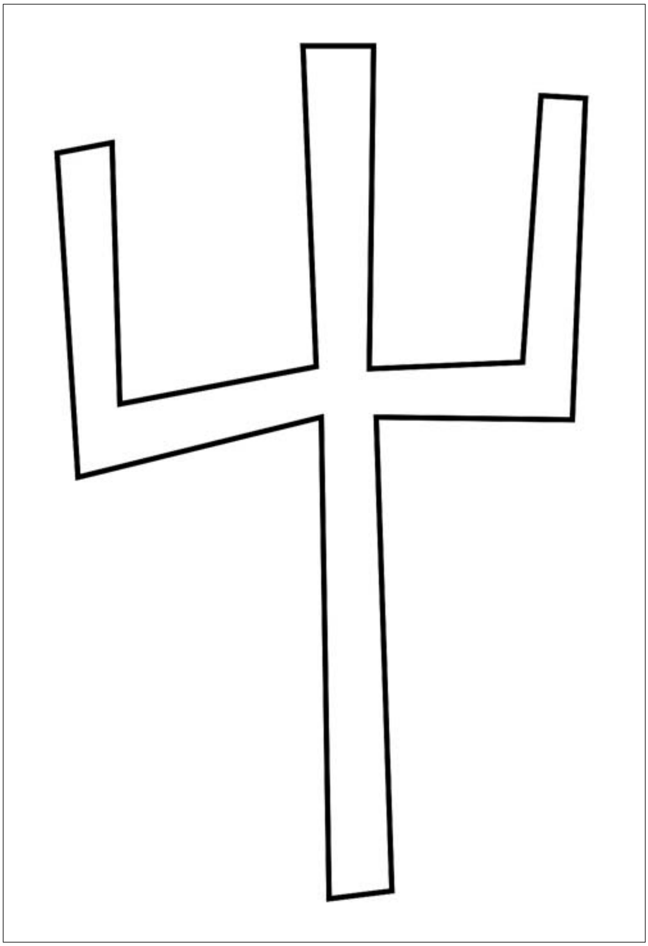

Fig. 12: A trident, typical symbol frequently chiseled into gravestones and prehistoric monuments.

very well the Christian paradigms, illustrates rather the process of transformation of the pagan community into the Christian one than the gist of Christianity itself. Figure of Wolfram which is according to the contemporary not very specific interpretation »an ascetic person throwing light of the Christian faith on the crowds«, may, of course, served as a pagan idol as well.

Important vestiges of gesture of orant likely provide also prehistoric petroglyphs scattered over the whole Europe. There is a half of dozen of symbols which may be interpreted as ideograms of gesture of orant. Among them the most significant is the symbol of trident, revealing quite suggestive graphical resemblance with attitude of a prayer making the gesture of orant (Fig. 12). In this connection a very peculiar probably south–Slavic phenomenon, called ***mirila*** should be mentioned, representing something as carefully oriented »monuments of human souls« (TROŠLEJ 2010). Such a monument was considered a true place for the last rest of the deceased whiles his/her body was buried on another place, for mourners quite unimportant.

For our argumentation of primary significance is the fact that into the mirila stones tridents are frequently engraved, as we believe the ideograms of the gesture of orant, which are in close connection with »burial« ritual, of which the exact orientation of mirila is the integral part.

At the end of this paragraph we would like to add a few words trying to account for the sense of burial orientation. A lot of diverse speculations can be found in the literature concerning this subject. Basing, nevertheless, on the hypothesis that the very purpose of charitable gifts was to improve the after–life conditions of the deceased, the interpretation of exact burial orientation is quite apparent. As the dead under the ground is evidently deprived of the possibility to determine cardinal directions, the definite lay–out of the body was nothing but a kind of charitable gift for the wandering throughout the hostile underworld, quite analogous to the vessels with meal or medicine, amulets, weapons etc. In other words, exact orientation of the body of the deceased was in such a context the act of mercy.

Conclusions

Using the exhaustive method we have concluded that the most likely technique used in the East and Central Europe for the determination of cardinal directions in the period ranging roughly from Hallstatt era to Early Middle Ages (800 BCE – 1000 CE) was that based on the halving an angle between rise and set points of the Sun.

Our reconstruction of the method hypothetically used was completed by an experiment convincingly showing that the halving procedure can be performed with sufficient accuracy (better than ~±5°) without any instruments, only by making a special gesture. As was further shown the initial position and gesture of the observer determining the cardinal directions must be practically identical with the attitude of a prayer making the gesture of orant.

This gesture traditionally connected exclusively with the early Christian culture has been proved to be actually a general cultural property of the population in the considered region and period. Interpreting then the burial orientation as a charitable gift, the gesture of orant, being originally used for orientation in the unknown terrain, might develop quite naturally into a ritual gesture.

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Appendix 1

In contrast to the stars, the Sun (and the Moon) cannot be, strictly speaking considered to be »firmly fixed« to the celestial sphere. This very fact somewhat changes our arguments given in the paragraph dealing with the Sun sets and rises. Let us therefore investigate the influence of the diurnal change of the declination δ of the Sun on the position of its sets and rises on the horizon. (Recall that the declination δ is an angular distance of celestial body from the celestial equator, the great circle which is perpendicular to the celestial axis.)

From the elementary spherical trigonometry (STUDNIČKA 1865, 8, 62) it follows that the azimuth α of a set point of a celestial body having a declination δ and observed at geographic latitude ϕ can be determined by means of a formula

$$\cos \alpha = -\sin \delta / \cos \phi. \qquad (2)$$

The azimuth of the corresponding rise point is then obviously $-\alpha$. In order to estimate the change of the azimuth $\Delta\alpha$ appearing as a consequence of change of declination $\Delta\delta$ we have to derivate both the sides of the equation above and construct the ratio:

$$\Delta\alpha / \Delta\delta = \cos \delta / (\sin \alpha \times \cos \phi). \qquad (3)$$

The effect is maximal near the equinoxes ($\delta \approx 0°$) where, according to the ephemerides (STREJC 1999), the diurnal change of declination of the Sun reaches a value of ~ 0.4°/ per day. In this case the formula above is reduced to a simple relation $\Delta\alpha \approx \Delta\delta / \cos \phi$, according to which the largest observable difference between the absolute values of azimuths of the Sun rise and the Sun set ($\phi = 50°$) is quite negligible being only $\Delta\alpha/2 \approx 0.3°$.

Appendix 2

Let us investigate the influence of the discrepancy between true and astronomical horizon on the observed azimuths of Sun's sets and rises, first particularly the change of azimuth of the point of Sun set which is due to the elevation of true horizon by the

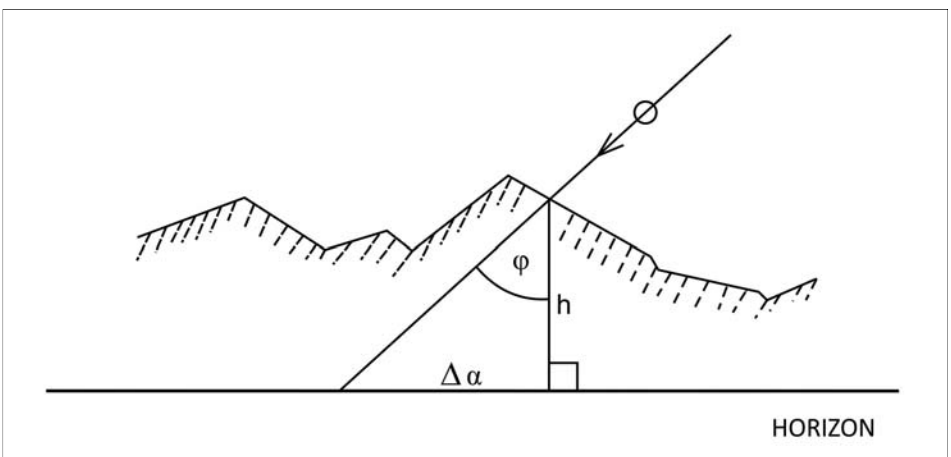

Fig. 13: The influence of shadowing of the topocentric horizon on the actually observed Sun–set azimuth.

presence of mountain range of apparent angular height h (see Fig. 13). Since the general solution of the problem provides a rather cumbersome formula, we confine our derivation only to the case of equinoxes. The result is thus valid exactly for $\delta = 0°$ and for other declinations only approximately. With this proviso, the centre of the Sun disc crossing the apparent line of the mountain range is simultaneously lying on the intersection of two great circles, one perpendicular and the other tilted about $(90° - \phi)$ with respect to the horizon. According to the »law of sine« of the spherical trigonometry (STUDNIČKA 1865, 8,62) we have $\sin \Delta\alpha \cdot \sin (90° - \phi) = \sin h \cdot \sin \phi$. Taking then into account the relation $\sin(90° - \phi) = \cos \phi$ we immediately obtain resulting formula:

$$\sin \Delta\alpha = \sin h \times \mathrm{tg}\, \phi. \qquad (4)$$

In a relatively open landscape, where the observer is at a distance of 2 km from a continuous mountain range of height ~ 300 m, the true horizon is elevated about $h \approx 8.5°$ ($\mathrm{tg}\, 8.5° \approx 300/2000$). Assuming that $\phi = 50°$, the resulting shift of the Sun–set point will be $\Delta\alpha \approx 10.1°$! In spite of the possibility that such a huge shift might be compensated by the presence of a similar mountain range on the opposite Sun–rise side, it is quite clear that just this effect is ***the most significant source of error*** of the method using observations of Sun's sets and rises for the determination of the cardinal directions. As this effect can be responsible for actually observed defective orientation of archaeoastronomical objects, ***the veracity of our hypothesis may be thus checked by direct terrain observations.***

In this connection there is another effect worth noticing. If the observer is staying on the summit of a mountain in the otherwise flat landscape the true horizon is depressed about a certain angle γ below the astronomical horizon (see Fig. 14) while the sight distance d is correspondingly enlarged. Let be SC = SB = R the radius of the Earth ($R \approx 6371$ km), CO = d sight distance to the true horizon and BO = H the relative height of the mountain above the flatland or sea. The »secant–tangent« theorem (STUDNIČKA 1865, 8,62) which claims that $OC^2 = OA \times OB$ then yields the formulae $d = \sqrt{H(2R+H)}$ and

$$\mathrm{tg}\, \gamma = d/R = \sqrt{(H/R^2)(2R+H)} \approx \sqrt{(2H/R)}. \qquad (5)$$

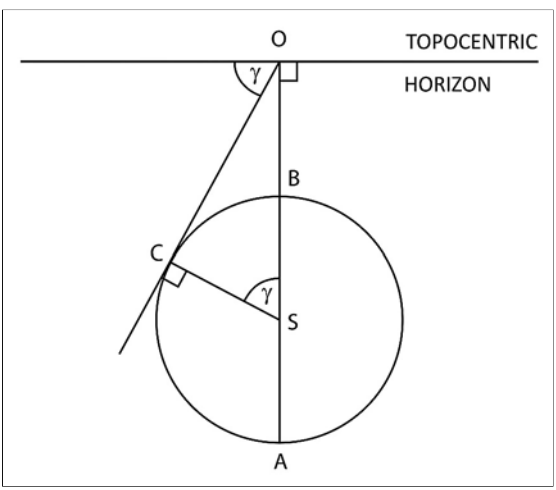

Fig. 14: Scheme to the determination of depression of the true horizon. (The height of mountain, H = BO, is for the sake of clarity of the picture largely exaggerated.)

For example, for a mountain 1 km high we obtain from the last formula an estimate

$$\gamma \approx \text{arctg}\,\sqrt{(2/6371)} = 1.015°.$$

Taking into account the fact that the apparent diameter of the Sun disc is ≈ 1/2°, the depression of the true horizon alone is almost imperceptible. Moreover, as the shift of the sunset point $\Delta\alpha$ evaluated by means of formula (4) (for $h = \gamma$, $\phi = 50°$) yields a rather small value $\Delta\alpha \approx 1.2°$, we can also conclude that the effect of depression of true horizon itself is for our purpose of no practical importance. Moreover, the effect is, as a rule, overwhelmed by distortions due to the optical refraction.

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Določitev strani neba in drža oranta

Jiří J. Mareš

Članek obravnava zanimivo vprašanje, ki je povezano z usmeritvijo grobov in arheoastronomskih objektov v srednji Evropi. Gre za določanje strani neba v času od halštatskega obdobja do zgodnjega srednjega veka. Uporabili smo obsežen postopek in pokazali, da je način določanja strani neba najverjetneje temeljil na opazovanju vzhoda in zahoda sonca. Sestavni del te metode je prepolavljanje kota, ki ga je mogoče opraviti z instrumenti, ali brez njih. Rekonstrukcija slednje možnosti, ki smo jo potrdili s poskusom, nas je pripeljala do sklepa, da je domnevna drža, ki so jo uporabljali za razpolavljanje kota, praktično istovetna tako imenovani drži oranta, ki jo običajno razlagajo kot držo zgodnjekrščanskega molilca. Če usmeritev grobov razumemo kot milost pokojnim, nadalje trdimo, da se je mogla drža oranta, ki so jo prvotno uporabljali za orijentacijo na nepoznanem ozemlju, povsem naravno razviti v ritualno kretnjo. Prikazujemo kulturne, zgodovinske in tehnične argumente za to mnenje.