# Midday Shadows and Functionality of Central Pillars in Enclosure D at Portasar (Göbekli Tepe)

H.A. Malkhasyan *

NAS RA V. Ambartsumian Byurakan Astrophysical Observatory (BAO), Armenia

**Abstract**

This study investigates the potential shadow-tracking functionality of Pillars 18 and 31 in Enclosure D at the Pre-Pottery Neolithic site of Portasar (Göbekli Tepe). Based on simplified three-dimensional modeling, photometric analysis, and simulations using Stellarium 24, the research focuses on the midday shadow dynamics during the year's key solar events: the solstices and equinoxes. The findings indicate that the grooves on the upper sections of the Pillars, as well as symbolic carvings—such as the bucranium, the "H" symbol, and the "lunisolar" motif—may have served as solar or lunar shadow markers aligned with the culmination points of the Sun and the Moon. Specifically, the bucranium appears to correspond to the culmination of the Taurus constellation (particularly the Pleiades), while the position of the "lunisolar" symbol coincides with the equinoctial noon and possibly with lunar or solar eclipses. These results support the hypothesis that the central Pillars functioned as an integrated shadow-measuring system, potentially enabling Early Neolithic communities to mark key calendrical thresholds throughout the year.

***Keywords:*** *Göbekli Tepe, Enclosure D, Pillar 18, Pillar 31, Winter solstice, Equinox, Shadow tracking, Archaeoastronomy, Solar observation, Neolithic astronomy.*

## 1. Introduction

The megalithic complex of Portasar (Göbekli Tepe), dated to approximately 9600–8800 BCE (Dietrich, 2011, Dietrich & Schmidt, 2010), is one of the most prominent monuments of the Pre-Pottery Neolithic period. The T-shaped Pillars erected in the center of the structures, particularly Pillars 18 and 31 of Enclosure D—stand out for their anthropomorphic form and richly symbolic reliefs. Alongside archaeological discoveries (Schmidt, 2006), these Pillars have also become the focus of astronomical interpretations.

A number of hypotheses have been proposed regarding both the orientation of the Pillars and the potential astronomical significance of their iconography. In particular, researchers have considered the possibility that the structures were aligned (Figure 1 b) to observe stars such as Deneb ($\alpha$ Cygni) (Collins & Hale, 2013) and Sirius ($\alpha$ Canis Majoris) (Magli, 2015). Furthermore, the imagery on Pillar 43 has been interpreted in relation to constellations (Sweatman & Tsikritsis, 2017, Vahradyan & Vahradyan, 2010). More recently, the V-shaped symbols on Pillar 43 have been proposed to represent a lunisolar calendrical system (Sweatman, 2024).

Although interpretations of iconography are diverse, many remain abstract or speculative (Banning, 2023) due to the lack of a clear methodological framework. A relatively new line of inquiry considers the potential shadow-casting function of the T-shaped Pillars, suggesting that they may have been used to measure time through the shadows cast by the Sun or Moon. Although this perspective has been mentioned by several authors (Dendrinos, 2016, Martirosyan, 2024, Villamarin, 2020), it has not yet been subjected to a systematic and empirically grounded investigation.

In our previous study dedicated to the astronomical function of Pillar 27 in Enclosure C at Portasar, we examined four distinct directions defined by the Pillar's structure and bas-relief features.

*malkhasyan.hayk84@gmail.com

The analysis revealed a possible shadow-tracking function resulting from the T-shaped form and placement of the Pillar, which correlates with the annual variation in the solar culmination altitude and aligns with potential star observation dates—particularly around the spring and autumn equinoxes (Malkhasyan, 2024). The observational functionality was described on the basis of measurable and verifiable data, albeit with a certain degree of simplification.

This study aims to analyze the dynamic interplay of shadows cast by Pillars 18 and 31 of Enclosure D at Portasar throughout the year, using the aforementioned methodological framework. The focus is placed on the equinoxes and solstices, with particular attention to how the T-shaped architectural form of the Pillars influences shadow behavior during the culmination moments of the Sun and Moon. This approach enables the interpretation of the iconography not merely as symbolic but also as a functional component of a broader observational system.

## 2. Material and Methods

### 2.1. Selection of the Studied Pillars

The central Pillars No. 18 and No. 31 of Enclosure D at Portasar (Göbekli Tepe) (Figure 1) were selected for this study based on several objective criteria:

• Compared to the central Pillars of other enclosures, these are relatively well preserved;

• Their upright positions and geographic orientations are considered close to their original state (Schmidt, 2006);

• The Pillars bear rich iconography, with certain motifs recurring on other Pillars, making their interpretation potentially applicable to broader analysis;

• From the available publications, it was possible to extract dimensional data for Pillars 18 and 31 that are reasonably suitable for shadow modeling.

a) b)

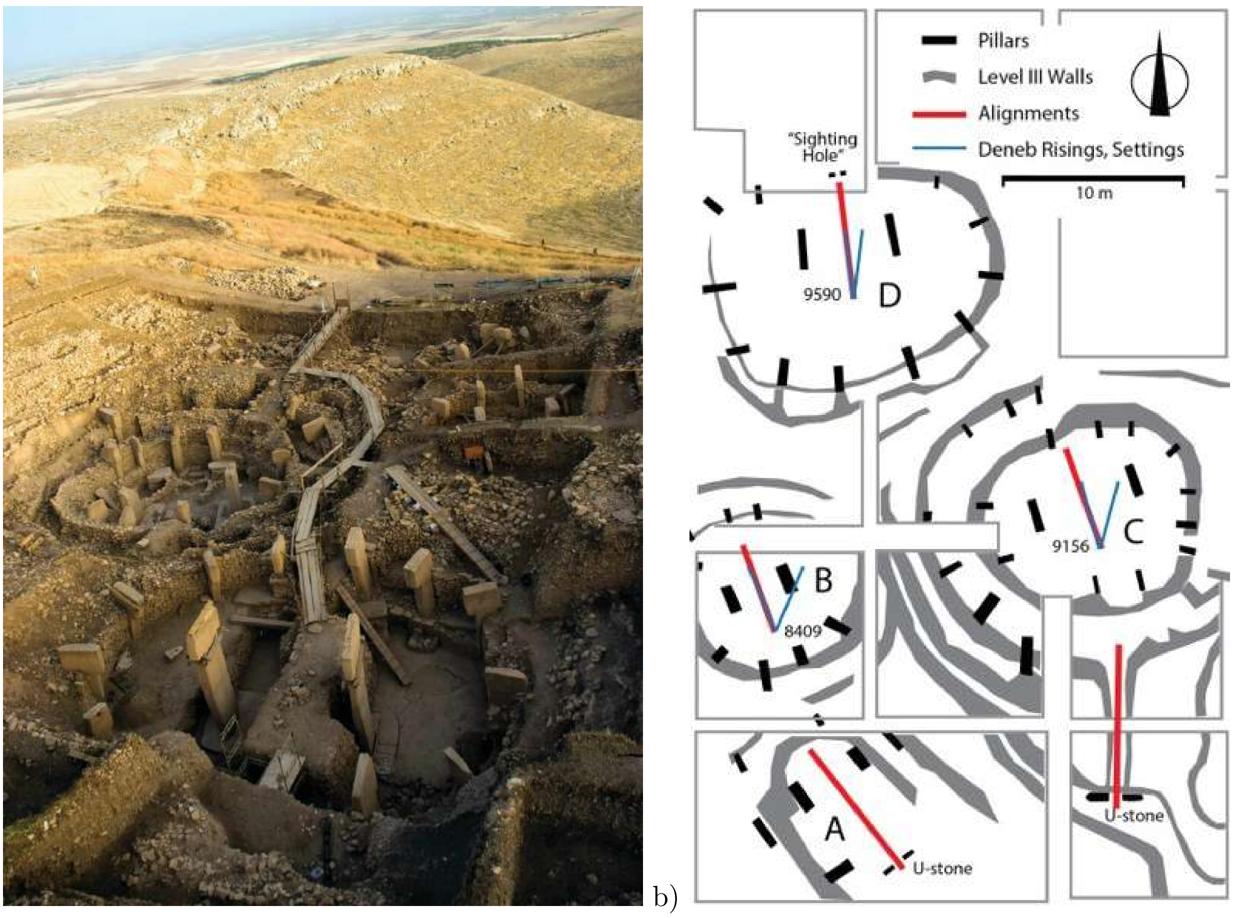


Figure 1. a) Monument overhead southern view of the main excavation area (photograph N. Becker c. DAI) (Dietrich *et al.*, 2012); b) The main Enclosures' orientations are indicated (Banning, 2023).

### 2.2. Iconography of the Pillars Capitals

At the top of Pillar 31 is a carving that resembles the head of a horned animal (bucranium) (Schmidt, 2006), from which the "shoulders" rise at a certain angle and then bend downward along the eastern and western faces of the Pillar (Figure 2). In contrast, Pillar 18 does not feature a bucranium. Instead, it displays an "H"-shaped symbol with a central perforation, followed by a horizontally positioned crescent and a circular symbol with a central hole—interpreted as a "luni-solar" motif (Schmidt, 2006) (Figure 2). Other iconographic differences between the two Pillars are also evident, but will not be addressed here.

### 2.3. Parameters of the Experimental Model of the Studied Pillars

Given the limited availability of precise published measurements for the Portasar monument, the shadow modeling for this study was carried out based on a simplified model of the central Pillars of Enclosure D (see Table 1). This model was constructed by synthesizing available measurement data, published architectural plans, and photographic analysis (De Lorenzis & Orofino, 2015, Henkley & Gopher, 2020, Schmidt, 2006). In the simplified model, the Pillars are placed in a vertical (upright) position and are oriented horizontally with an azimuth of 173°.

It should be noted that the asymmetry in Pillar thickness and the surface relief details are not expected to significantly affect the qualitative assessment of shadow dynamics and were therefore omitted in the modeling process.

The resulting data are interpreted not as absolute quantitative results but rather as qualitative observations aimed at revealing the possible shadow-tracking functionality of the pillars.

Table 1. Parameters used in constructing the simplified model of the central Pillars.

| No. | Parameter | Value | Source |
|---|---|---|---|
| 1 | Orientation of Pillar width (azimuth) | 173° | (De Lorenzis & Orofino, 2015) |
| 2 | Pillar thickness | 0.3 m | Scaled analysis from photographs |
| 3 | Width at the base | 1.2 m | Scaled analysis from photographs |
| 4 | Width at the top | 1.8 m | Scaled analysis of the site plan |

### 2.4. Shadow Observation Conditions

The geographic latitude used for the simulation was 37°13′ N, corresponding to the actual location of the monument. Shadow dynamics were analyzed using the Stellarium (2024) astronomical software, configured to match the estimated archaeological dating of Enclosure D (c. 9500 BCE) (Dietrich & Schmidt, 2010).

### 2.5. Selection of Examination Dates

Four key dates of astronomical significance were chosen for examination. The vernal and autumnal equinoxes (henceforth referred to collectively as Equinox, or EQ) were treated together, as the differences in shadow dynamics between them are negligible.

- Winter Solstice (WS) – December 21 (midday A=173°, h=27°)
- Equinox (EQ) – March 21 and September 23 (midday A=173°, h=51-54°)
- Summer Solstice (SS) – June 21 (midday A=173°, h=78°)

The observations take into account the Sun's movement between azimuths 173° and 180°, during which no significant change in its angular elevation is recorded (Stellarium, 2024).

## 3. Results and Discussion

The analysis of shadow dynamics reveals several patterned correspondences between the iconographic elements present on the southern surfaces of the Pillars and their spatial positions. The following sections sequentially present the specific findings and their interpretations based on the observed shadow behavior and iconographic correlations.

### 3.1. Winter Solstice and Equinox

During the WS, when the Sun reaches its southernmost position, the shadows cast by the central Pillars do not align with each other in any way. In the morning, they appear roughly in the northwest and disappear in the northeast by evening. Due to the T-shaped structure of the Pillars, the upper section of their southern faces is shaded at midday, as illustrated in Figure 2. On the upper part of Pillar 31, distinct horizontal grooves can be seen. The upper groove likely corresponds to the shadow boundary at midday during the WS, while the lower groove marks that of the Equinox (Figures 2 and 3). Consequently, during approximately six months between the autumn and vernal equinoxes, the midday shadows on the southern faces of these T-shaped Pillars shifts within the boundaries defined by these grooves and symbols (Figure 4).

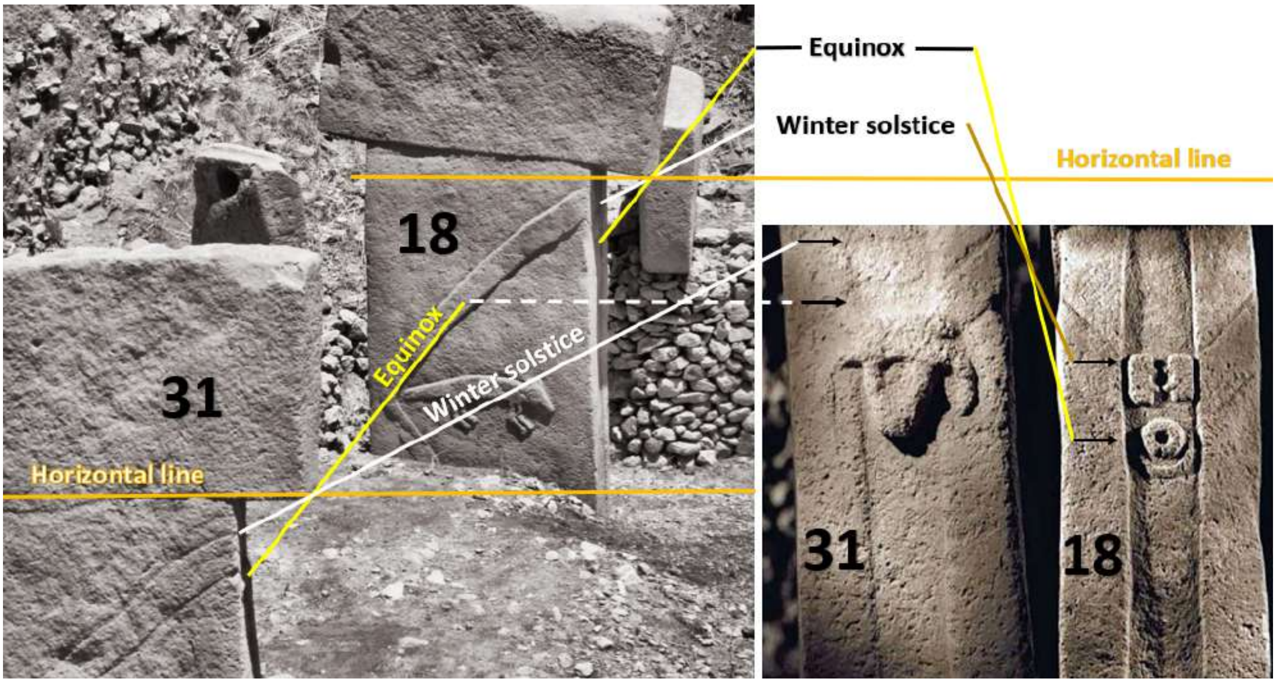


Figure 2. On the photographs indicate the directions of sunlight at noon on the days of the equinox (when the Sun's altitude angle is h=51–54°) and the winter solstice (h=27°) in relation to Pillars 31 and 18. The photograph was taken at a time when the bases of the Pillars had not yet been excavated by archaeologists, and thus may be considered closer to their original appearance (Schmidt, 2006).

### 3.2. Summer Solstice

At noon on the summer solstice, the shadow cast by the top of the Pillar during the Sun's culmination, when its zenith distance is approximately 12°, reaches about the level of the depicted fox figure: $L = 0.3 / \tan(12^\circ) \approx 0.3 / 0.2126 \approx 1.41$ m, and thus does not reach the belt symbol.

The same applies even in the case of the Moon at maximum declination. At this latitude, the zenith distance of the Moon at its culmination during its maximum standstill is about 7, which yields a shadow length of $L = 0.3 / \tan(7^\circ) \approx 0.3 / 0.1228 \approx 2.44$ m.

However, the distance between the belt and the top of the Pillar is at least 3 m, making it impossible for the shadow to reach the belt under either scenario.

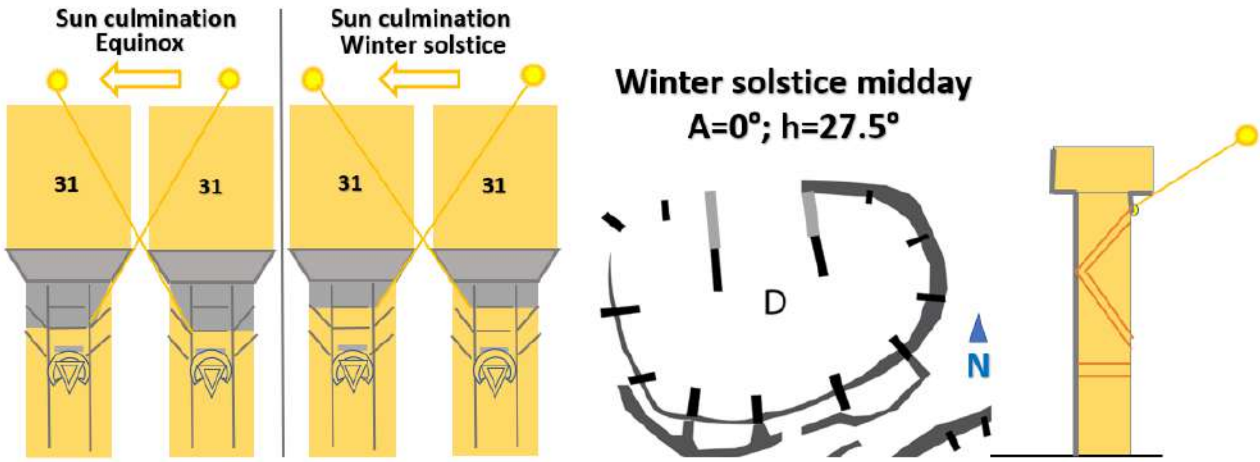


Figure 3. The schematic illustrates the movement of the shadow on the southern face of Pillar 31 at noon during the Equinox and the WS, respectively.

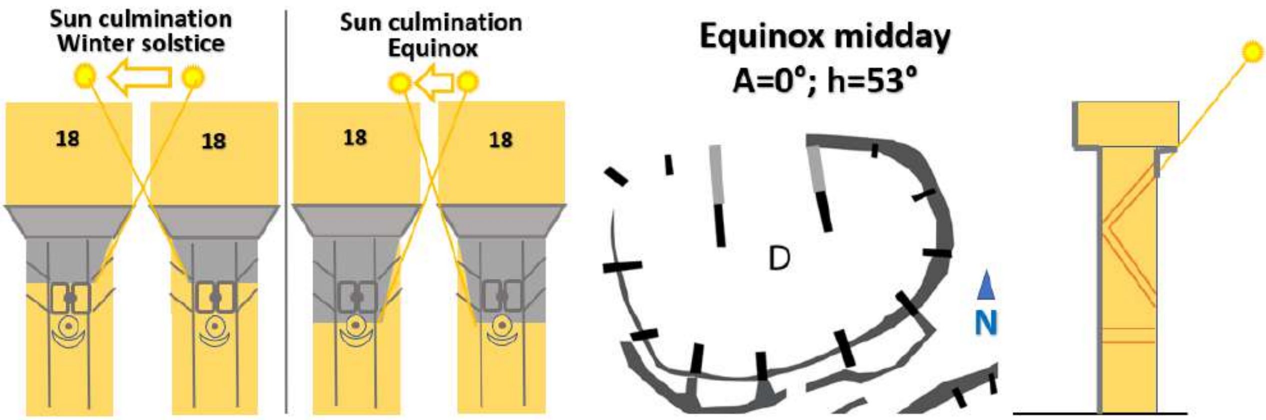


Figure 4. The schematic illustrates the movement of the shadow on the southern face of Pillar 18 at noon during the Equinox and the WS, respectively.

### 3.3. Interpretation of the Symbols Based on Their Marker Function

The bucranium (bull's head) motif depicted in the upper part of Pillar 31 can be clearly associated with the Taurus constellation, and more specifically with the Pleiades, whose heliacal risings during the relevant millennium occurred around the time of the winter solstice. The shadow would also appear on the upper section of the Pillar at midnight, when the Moon—while crossing the ecliptic plane—would transit through the point of the winter solstice, i.e., within the domain of Taurus. At the same time, the bucranium is positioned near the lower groove, corresponding to the midday shadow boundary during the Equinoxes (Figures 2 and 3), which can be interpreted through the culmination (disappearance at the highest position) of the Taurus constellation just before the vernal equinox sunrise and (appearance at the highest position) shortly after the autumn equinox sunset.

It should be noted that possible observations of the Pleiades culmination on the equinoxes were also revealed during the analysis of Pillar 27 of Enclosure C (Malkhasyan, 2024). Thus, the symbolic and functional interpretation of the bucranium on Pillar 31 not only appears contextually valid but also coincides with results obtained independently elsewhere at the site.

Moreover, in the ancient world, the Moon was often associated with cows. A notable example is found in the Sumerian poem "Lugalbanda in the Mountain Cave," which refers explicitly to *"Like the dispersed holy cows of Nanna (the Moon God)"* (ETCSL, (2025) line 133). A full Moon culminating at the winter solstice point would be observed at midnight during the summer solstice, and likewise at the autumnal equinox point during the spring equinox midnight. Of course, these dates would not always precisely align with the Moon's phase or position, but a deviation of a few days is entirely acceptable—particularly considering that many religious systems embrace such natural variations, giving rise to moveable feasts.

For instance, the Armenian Apostolic Holy Church celebrates the Feast of the Holy Resurrection (Easter) on the first Sunday following the full Moon after the vernal equinox (Liturgical Calendar, 2025). This important calendrical-religious principle resonates well with the "luni–solar" symbol carved on the upper part of Pillar 18, which clearly marks the equinox. Positioned above it, the H-shaped symbol—featuring a central indentation (see Figsures 2 and 4)—can be interpreted in relation to the consistent shaft of light that appears between the Pillars during the winter daytime between the autumn and vernal equinoxes (Figure 4).

It should be noted that the periodic deviations of the Moon's orbit (± 5°) relative to the ecliptic would necessarily manifest in slight variations in shadow length. This implies that the Moon's monthly oscillations would produce subtle yet observable changes at the upper parts of the Pillars. Consequently, through long-term systematic observation, it would have been possible to predict lunar and solar eclipses.

Thus, the symbolic imagery on the upper parts of Pillars 31 and 18 can be fully interpreted in light of shadow dynamics.

### Concluding Remarks

The results obtained demonstrate that the central Pillars 18 and 31 of Enclosure D at Portasar (Göbekli Tepe) were not merely symbolic or iconographic elements but may have functioned as components of an operative system designed for astronomical observations, particularly shadow measurement.

Analysis of the midday shadow dynamics throughout the year reveals consistent correlations with the grooves and symbols on the southern surfaces of the Pillars. The relief carvings on the upper portions of the Pillars can be fully interpreted as shadow markers corresponding to significant solar and lunar observations—specifically the winter solstice and the equinoxes.

- Upper horizontal and oblique grooves – Mark the shadow limit at midday during the winter solstice.
- Lower horizontal and oblique grooves – Mark the shadow limit at midday during the equinoxes.
- Bucranium (bull's head) – A symbolic reference to the Taurus constellation, particularly the Pleiades cluster (and possibly the Moon); it may also signify the culmination of the Pleiades during the equinoxes.
- H-shaped symbol with central depression - Represents the permanent gap between the Pillars' daytime shadows during winter, indicating horizontal movement.
- Luni–Solar symbol – Refers to the solar and lunar conditions during the equinoxes, potentially including eclipses.

Thus, the central Pillars of Portasar were likely constructed as part of a calendrical system based on both solar and lunar cycles. Moreover, their T-shaped design itself finds a functional justification within this shadow-measuring framework.

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