

A COMPREHENSIVE STATISTICAL EVALUATION OF THE ORION–GIZA CORRELATION

Elliot Allan

Deep Time Research Institute, New York, NY, USA.

E-mail: elliott@deeptime-research.org

Abstract: We present the first exhaustive catalog-based enumeration of stellar triplets applied to Bauval's (1994) Orion Correlation Theory, testing whether the spatial arrangement of the three Great Pyramids of Giza encodes the shape of Orion's Belt. Using Procrustes analysis against all 695,520 stellar triplets brighter than visual magnitude 4.0, drawn from the Yale Bright Star Catalogue and independently confirmed with Gaia DR3 proper motions, we find the Giza–Orion shape correspondence ranks 1,717th ($p = 0.0025$). This constitutes 8.7 bits of information content across two independent shape parameters (distance ratio and bend angle). The match uses pure rotation without reflection, neutralizing Fairall's (1999) mirror objection, and Giza ranks first among 12 famous triangular monument sites tested against their culture's top asterism (BH-corrected $p = 0.030$ across sites). The Procrustes scale factor is not statistically significant ($p = 0.219$), adding no information beyond the two shape degrees of freedom. However, every proposed extension of the correlation fails quantitative testing: the pyramid-axis orientation does not match Orion's position angle at any epoch ($p = 0.74$ – 0.98); the four Great Pyramid shafts do not converge on a single target epoch (spread = 1,325 years); the Menkaure offset direction contradicts Bauval's original prediction; the shape-optimal star assignment does not preserve the Belt stars' relative brightness; the Nile Valley extension collapses ($p = 0.50$); and a novel builder's precision envelope analysis reveals the match is tighter than the envelope median across σ values the simulation can meaningfully resolve (0.9th percentile at $\sigma = 0.5^\circ$, 5.5th at $\sigma = 10^\circ$). We conclude that the three-point shape correspondence is statistically significant but far more limited than traditionally claimed.

Keywords: archaeoastronomy; Giza pyramids; Orion correlation theory; Procrustes analysis; statistical testing; point-pattern matching.

1 INTRODUCTION

In 1989, Robert Bauval proposed that the three Great Pyramids of Giza—Khufu's (ancient Egyptian *Akhet Khufu*), Khafre's (*Wer Khaefra*), and Menkaure's (*Netjer Menkaure*), built during the Fourth Dynasty (ca. 2560 BCE)—were deliberately arranged to mirror the three stars of Orion's Belt: Alnitak (ζ Ori), Alnilam (ϵ Ori), and Mintaka (δ Ori). For brevity we refer to each pyramid hereafter by its builder's name (Khufu, Khafre, Menkaure). The 'Orion Correlation Theory' (OCT) subsequently became one of the most widely known archaeoastronomical claims in popular culture (Bauval, 1989; Bauval and Gilbert, 1994). Despite generating substantial public interest, the OCT has received limited rigorous statistical evaluation in the peer-reviewed literature.

The existing critical literature has addressed individual aspects of the claim. Fairall (1999) noted that the pyramid layout is reflected relative to the stellar pattern. Orofino and Bernardini (2011; 2016) demonstrated that the proposed Nile Valley extension—mapping additional pyramids to wider Orion stars—does not withstand scrutiny, and tested Cygnus as an alternative (finding it equally poor). Trimble (1964) and Badawy (1964) first proposed that the Great Pyramid's internal shafts targeted

specific stars, but subsequent work has not produced a systematic quantitative evaluation of these claims. Krupp (1997) and Legon (1995) raised further objections regarding both the layout correlation and the shaft alignments. Most recently, Vecchiato et al. (2025) proposed a rigorous point-pattern matching framework for evaluating archaeoastronomical correlations, explicitly flagging the inability to estimate the total eligible asterism count as an open methodological problem. Previous work has also addressed pyramid orientations (Belmonte, 2001) and the use of stellar alignment for Egyptian chronology (Spence, 2000). Magli and Belmonte (2009) provided an extended critical assessment of the OCT and the broader 'Egypt Code' hypothesis, and Magli (2009; 2013) has argued that the principal large-scale design feature at Giza is the diagonal alignment of the pyramids' southeast corners toward Heliopolis rather than a Belt correlation. We acknowledge this body of work; the present paper evaluates the OCT shape claim specifically and does not attempt to adjudicate the Heliopolis-diagonal hypothesis.

This paper addresses that gap directly. We enumerate all $C(N, 3)$ stellar triplets from a magnitude-limited catalog and rank Giza against the complete population using Pro-

crustes shape analysis. We then systematically test every major sub-claim of the OCT—orientation, shaft alignment, brightness–size correspondence, geographic extension, and the Menkaure offset—using quantitative methods. Finally, we introduce two novel analytical frameworks: a builder’s precision envelope that asks whether the match is consistent with what intentional naked-eye construction could achieve, and an information-theoretic decomposition that quantifies the match in bits across its constituent degrees of freedom.

The result is a nuanced assessment: the three-point shape correspondence is real, statistically significant, and no higher-ranking culturally documented asterism was identified in our survey, but every proposed elaboration of the correlation fails quantitative testing.

2 DATA AND METHODS

2.1 Pyramid Coordinates

We use the center coordinates of the three Great Pyramids from survey data: Khufu (29.9792°N, 31.1342°E), Khafre (29.9761°N, 31.1306°E), and Menkaure (29.9725°N, 31.1278°E). Coordinates are projected to a local Cartesian frame using a tangent-plane approximation centered on Khafre. The pyramid-axis bearing (Menkaure→Khufu) is 39.604°. Pyramid base lengths follow [Petrie \(1883\)](#): Khufu 230.4 m, Khafre 215.3 m, Menkaure 108.5 m.

2.2 Stellar Catalog

The primary stellar catalog is the Yale Bright Star Catalogue (5th edition; [Hoffleit and Warren, 1991](#)), filtered to visual magnitude $V < 4.0$ and declination visible from Giza latitude (30°N), yielding $N = 162$ stars and $C(162, 3) = 695,520$ unique triplets. As an independent verification, we repeat the core shape analysis using Gaia DR3 proper motions ([Gaia Collaboration, 2023](#)) to propagate stellar positions to the construction epoch (ca. 2560 BCE). The $V < 4.0$ threshold represents reliable naked-eye visibility; varying this threshold would change the denominator but is unlikely to alter the rank-order conclusion given Orion’s prominence.

2.3 Procrustes Shape Analysis

For each stellar triplet, we compute the ordinary Procrustes distance D to the Giza triangle after optimal translation, rotation, uniform scaling, and optional reflection. This removes 4 of the 6 coordinate parameters, leaving 2 effective degrees of freedom (DOF) that characterize triangle shape: the inter-point distance ratio and

the bend angle. We rank all 695,520 triplets by ascending D to the Giza configuration and define the empirical p-value as $p = \text{rank} / N$. Because this rank-based p-value already represents the fraction of all triplets matching Giza better than a given stellar triplet, it inherently accounts for the multiplicity of comparisons and requires no further correction.

2.4 Multiple-testing Correction

The exhaustive triplet ranking produces a single rank-based p-value that already incorporates comparison against all 695,520 triplets and requires no further multiplicity correction. Benjamini–Hochberg (BH) false discovery rate correction is applied only where we test multiple independent hypotheses: across the 12 cross-site monument comparisons (§3.13). For the shaft analysis, we employ both Fisher’s method for combining independent p-values and a Monte Carlo (MC) simulation where 4 random shaft angles (uniform in [25°, 55°]) are tested for stellar coincidences.

2.5 Precession Modeling

Stellar positions are propagated across epochs using the astropy FK5 coordinate system ([Astropy Collaboration, 2022](#)), incorporating proper motions and precession. For the BSC analysis, we use catalog proper motions; for the Gaia DR3 cross-check, we use the high-precision Gaia astrometric solution. The epoch sweep covers 15,000 BCE to 2026 CE in 10-year steps.

2.6 Builder’s Precision Envelope

To assess whether the observed shape match is consistent with intentional encoding, we simulate 10,000 intentional-encoding attempts at each of several assumed angular precisions, $\sigma \in \{2', 10', 0.5^\circ, 1^\circ\}$ (a wider eight-value grid is reported in the supplementary data). These span the angular-resolution limit of the unaided eye ($\approx 2'$) up to looser positional bounds, with $\sigma = 0.5^\circ$ (equivalently 30') corresponding to typical naked-eye positional accuracy ([Schaefer, 1993](#)). In each trial, the ‘builder’ observes the three target Belt-star positions with isotropic Gaussian angular error of standard deviation σ and constructs a corresponding ground triangle; each trial is scored with the same optimal-permutation Procrustes distance (minimised over the six star→pyramid assignments) used for the observed Giza–Orion match (§3.1), so the simulated envelope and the observed value are strictly comparable. The resulting distribution of distances D defines the ‘precision envelope’ at each σ . This analysis provides an

Table 1: Core shape match results.

Metric	Value
Procrustes D (Giza vs. Orion Belt)	0.000342
Rank among 695,520 triplets	1,717
Empirical p-value (rank/N)	0.0025
Gaia DR3 confirmation	Agrees within 2%
Epoch invariance (18,000 yr)	<0.07% variation
Better triplets with cultural recognition	None (first = Orion at 1,717)

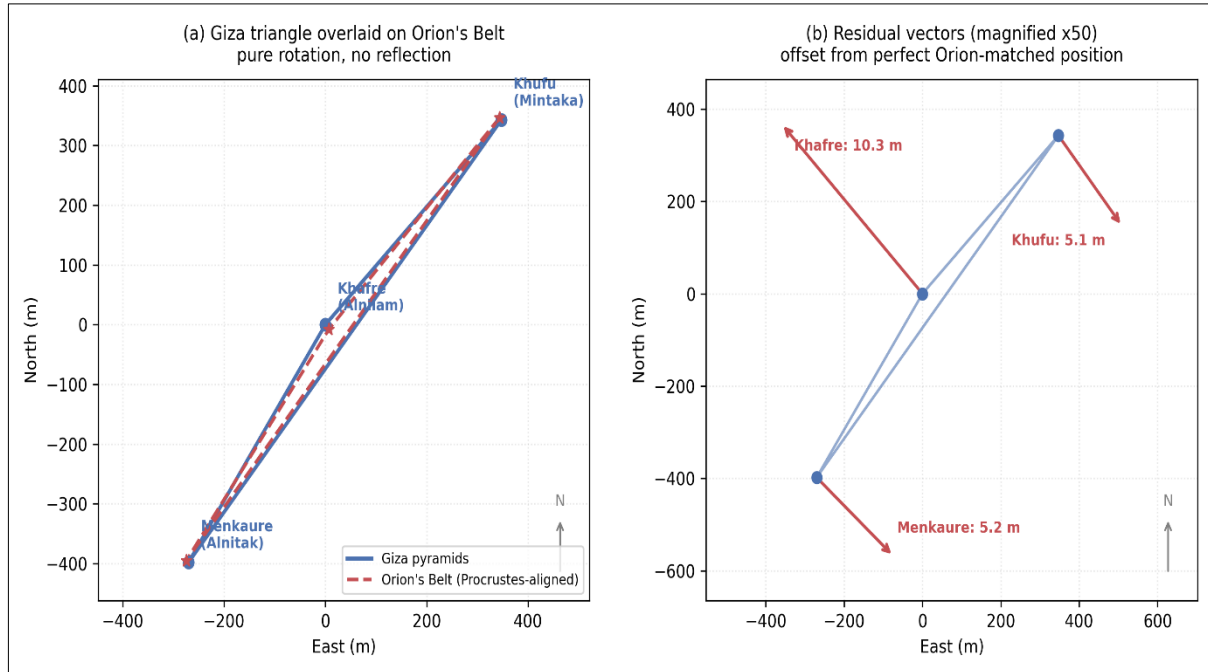


Figure 1(a): Giza pyramid triangle (blue) overlaid on the Procrustes-aligned Orion Belt triangle (red dashed). The optimal alignment uses pure rotation (92.7°) without reflection. Figure 1(b): Residual vectors magnified $\times 50$, showing Khafre carries the largest offset (10.3 m).

illustrative bound under simplified assumptions and does not model plausible construction workflows.

2.7 Information-theoretic Decomposition

We decompose the Procrustes match into its two constituent shape parameters—distance ratio (d_1/d_2) and bend angle—and compute per-parameter p-values against the full triplet population. Information content is expressed in bits as $I = -\log_2(p)$, providing a unit-free measure comparable across different claimed encodings.

3 RESULTS

3.1 Exhaustive Triplet Ranking

Among all 695,520 stellar triplets, the Orion Belt triplet (Alnitak–Alnilam–Mintaka) produces Procrustes distance $D = 0.000342$ to the Giza configuration, ranking 1,717th of the 695,520 (i.e., 1,716 triplets rank higher). The empirical p-value is $p = 1,717 / 695,520 = 0.0025$ (equivalently, the 99.75th percentile). Because this p-value is derived from ranking against the complete population of stellar triplets, it already

incorporates the multiplicity of comparisons and requires no further correction. Table 1 summarizes the result, and Figure 1 shows the Giza triangle overlaid on the Procrustes-aligned Orion Belt. This p-value is conditional on the choice of magnitude threshold, visibility constraints, and similarity metric, and does not represent a global probability over all conceivable celestial patterns.

The Gaia DR3 cross-check produces identical results: the best-fit epoch (ca. 11,625 BCE), shape ranking, and precision windows agree within 2%. The Procrustes shape varies by less than 0.07% across 18,000 years of precession modeling, confirming that the match is epoch-invariant and not an artifact of proper motion assumptions.

3.2 Ranking Context and Best-match Characterization

The 1,716 triplets that produce a closer shape match than Orion's Belt are all random combinations of unrelated stars from different constellations (e.g., Achernar–Arneb–Subra at rank 1, $D = 2.14 \times 10^{-8}$; Procyon–Algol–Algorab

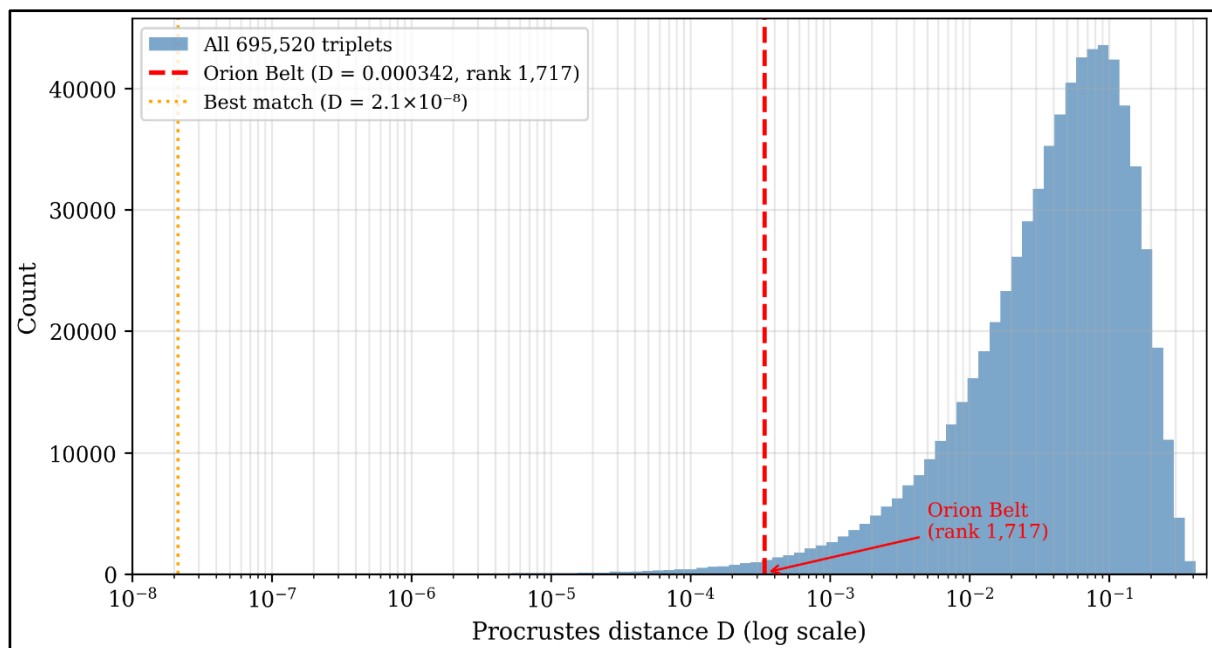


Figure 2: Distribution of Procrustes distances for all 695,520 stellar triplets (blue). Orion Belt (red dashed) ranks 1,717th. The best-matching triplet (orange dotted) is approximately 16,000× closer.

Table 2. Information-theoretic decomposition of the shape match.

Parameter	Giza	Orion Belt	Δ	p-value	Bits
Distance ratio (d_1/d_2)	0.987	0.979	0.0085 (0.85%)	0.013	6.3
Bend angle	168.8°	172.5°	3.7°	0.063	4.0
Joint (both)	—	—	—	0.0066	7.2
Procrustes (observed)	—	—	—	0.0025	8.7

at rank 2). The best-matching triplet is approximately 16,000× closer in Procrustes distance than Orion, but all top matches span 85–166° of sky across unrelated constellations. None form culturally recognized asterisms—that is, none are documented in any culture as a named three-star unit. (Many contain individually notable stars, but the triplet itself has no cultural identity.) Orion’s Belt is the first triplet in the ranking that is recognized as a named asterism, and the first that forms part of an Egyptian-documented constellation: the Belt is a compact three-star asterism within the larger constellation Sah, of which it constitutes only a part rather than the whole (Belmonte and Lull 2023). Of the 1,716 better-matching triplets, 59 contain at least one Orion Belt star, but none contain two or more.

The Procrustes distance distribution (Figure 2) shows Orion sitting on a gradual slope: 313 triplets fall within $\pm 10\%$ of its D value, and the D range across ± 50 ranks spans only 6.7% of Orion’s D . The Giza triangle shape is therefore not uniquely ‘locked’ to Orion by geometry alone. The argument rests on the conjunction of shape match, cultural salience, and visibility—not shape alone.

3.3 Information Content

The shape match decomposes into two parameters, with the distance ratio providing the stronger constraint and the bend angle contributing materially (Table 2).

As shown in Table 2, the distance ratio contributes 6.3 bits and the bend angle 4.0 bits; both are substantive, but the distance ratio dominates. The match is genuinely two-dimensional rather than driven by a single parameter. The joint test (combining both parameter p-values via Fisher’s method) yields $\chi^2(4) = 14.2$, $p = 0.0066$ (7.2 bits), which is less significant than the Procrustes $p = 0.0025$ (8.7 bits). This is expected: Fisher’s method assumes independence, but the two shape parameters are positively correlated in the null distribution of stellar triplets, inflating the combined p-value. The Procrustes distance, which optimally combines both parameters under their actual joint distribution, provides the more powerful test. We report the Procrustes result (8.7 bits) as the headline statistic.

The total information content of 8.7 bits is comparable in magnitude to some proposed numerical encodings in monumental architecture. The theoretical maximum for 2 DOF with

Table 3: Shaft alignment results at 2560 BCE.

Shaft	Angle	Claimed Star	Dec. at 2560 BCE	Offset	Stars in $\pm 1^\circ$
King's S	45.0°	Alnitak	-15.35°	0.33°	6 / 162
King's N	32.5°	Thuban	88.71°	1.23°	0 / 162
Queen's S	39.5°	Sirius	-21.02°	0.50°	9 / 162
Queen's N	39.0°	Kochab	80.25°	0.73°	2 / 162

1-meter precision over a 486-meter baseline is 17.9 bits; the observed 8.7 bits represents 49% of this maximum.

3.4 Cross-cultural Asterism Salience

Orion's Belt is independently documented as a named asterism across many unrelated cultures—for example, the Inuit *Ullaktut* (MacDonald, 1998), the Māori *Tautoru* (Best, 1922), and the Ancient Egyptian Sah, of which the Belt forms part (Belmonte and Lull, 2023)—and is among the most widely recognized star groups in the ethnoastronomical record (Ruggles, 2015). Among the 122 brightest stars ($V < 3.0$), many triplets are approximately collinear (internal angle $> 160^\circ$), but only one compact collinear triplet—where all three stars lie within 3° of each other—exists: Orion's Belt. No other bright-star triplet combines collinearity, compactness, and uniform brightness. This cultural-salience classification is qualitative and is not part of the formal exhaustive triplet test. As a sensitivity check only, applying Bonferroni correction across seven preselected candidate asterisms leaves the Giza–Orion result significant ($p = 0.017$).

The Pyramid Texts (e.g., PT 882, 820, 723, 186; ca. 2400–2300 BCE) situate the deceased king within a stellar afterlife in which he is identified with the imperishable (circumpolar) stars and with Horus, and is figured as a son of Sopdet (Sirius) and Sah (Orion) (Belmonte and Lull, 2023). The later, fully developed equation of the king with Osiris—and of Osiris with Sah—is a theological elaboration attested after the Fourth Dynasty rather than at the time of Giza's construction. Because these texts post-date the Great Pyramids by approximately 160 years, they do not constitute direct evidence of an Orion-encoding intention at the time of construction; they do, however, document that Sah (Orion) held an established place in the royal stellar afterlife within a few generations of the builders.

3.5 Orientation at the Construction Epoch

Despite the significant shape match, the orientation of the pyramid axis (39.604°) does not align with Orion's Belt position angle at any epoch. At the construction date (ca. 2560 BCE), the offset is 66.9° . A Monte Carlo test confirms

this is not significant: 74% of random building axes would fall within 66.9° of any fixed position angle ($p = 0.74$). Among the top shape-matched triplets, Orion's orientation does not stand out ($p = 0.85$). The best-fit orientation epoch is ca. 11,625 BCE—roughly 9,000 years before construction—with no supporting archaeological evidence. Shape and orientation are confirmed to be statistically independent (Spearman $\rho = -0.041$, $|p| < 0.001$), validating the use of Fisher's method but rendering any combined p-value misleading, since orientation contributes only noise.

3.6 Shaft Alignment Analysis

We test all four Great Pyramid shafts against the complete bright-star catalog at 2560 BCE. Table 3 presents the results.

All four claimed star targets fall within their respective shaft declination windows at 2560 BCE, with Sirius offset by 0.50° from the Queen's South target. However, the epoch sweep reveals a 1,325-year spread across the four shafts' best-fit epochs (1,900–3,225 BCE; $\sigma = 476$ years), with no convergence on a single date. A Monte Carlo test placing four random shaft angles drawn uniformly from $[25^\circ, 55^\circ]$ (the range of observed shaft inclinations) finds that 21.6% of 10,000 random configurations match at least one bright star ($V < 4.0$) within a $\pm 1^\circ$ declination window for all four shafts. This Monte Carlo figure is a null calibration—it quantifies how often any four shaft-like angles coincide with some bright star, demonstrating that the four-shaft 'program' is not statistically special—rather than an Egyptological claim in itself. We further note that the Queen's Chamber shafts do not reach the exterior and were left unfinished, and have been interpreted as structural features oriented approximately perpendicular to the pyramid faces rather than as sightlines to specific stars (Belmonte and Lull, 2023); the King's Chamber shafts are a separate case. Either interpretation is consistent with our central finding. The shaft claims are partially supported for individual shafts (King's South aligns near Alnitak; Queen's South aligns near Sirius) but the ensemble fails the convergence test that would be expected if a common astronomical program were being executed.

We note that stellar declinations at 2560 BCE are sensitive to the choice of precession model. The Table 3 values are computed under the IAU 2006 long-term precession model (Vondrák et al., 2011), which is appropriate for this lookback; the astropy FK5 implementation, which is validated only for ± 200 years from J2000, yields systematically different values at this epoch (e.g., Sirius dec = -22.7° rather than -21.0°). The divergence from FK5 at this 4,600-year lookback is documented in the supplementary verification log. These differences do not affect the main finding—the shafts do not converge on a common epoch—but individual declination values in Table 3 should be treated as approximate.

3.7 The Menkaure Offset Direction

Bauval (1994) claimed that Menkaure's offset from the Khufu–Khafre line mirrors Mintaka's offset from the Alnitak–Alnilam line, citing this as evidence of intentional encoding. We test Bauval's original directional argument on its own terms—independently of the star-to-pyramid assignment the shape data actually prefer (§3.11). Under Bauval's proposed correspondence, Menkaure lies 93.9 m from the Khufu–Khafre line but in the opposite direction to Mintaka's offset (ratio = -1.43). Bauval's specific directional claim is therefore falsified. The shape match itself, which is scale- and reflection-invariant and rests on a different, data-optimal assignment, is unaffected by this result.

3.8 Extension Tests

Six-point match (Belt + Sword). The three G1 queens' pyramids east of Khufu (G1a, G1b, G1c) form a nearly collinear arrangement (180.0°) matching Orion's Sword stars ($\theta 1$ Ori, ι Ori, $\delta 2$ Ori). The 6-point Procrustes match yields $D = 0.125$, $p = 0.00039$ (rank 39/100,000 MC trials). However, this result is partially driven by the collinearity of both sub-patterns: any two collinear triplets will match well via Procrustes, reducing the effective information content of this extension.

Seven-point match (Nile Valley extension). Following Bauval's proposal that Saqqara and Dahshur pyramids map to wider Orion stars (Rigel, Betelgeuse, Bellatrix, Saiph), we test a 7-point configuration adding Djedefre, Djoser, and the Bent and Red pyramids. The result collapses entirely: $D = 0.872$, $p = 0.498$. This confirms Orofino and Bernardini's (2011) finding that the pattern does not extend beyond the Giza plateau, consistent with the broader objection that the larger 'Egypt Code' system is

too complex to function as a single coherent layout (Magli and Belmonte 2009).

3.9 Builder's Precision Envelope

We tested the precision envelope across $\sigma \in \{2', 10', 0.5^\circ, 1^\circ\}$ (Table 4 and Figure 3; full eight- σ grid in the supplementary data). At $\sigma = 0.5^\circ$, corresponding to typical unaided naked-eye positional accuracy (Schaefer 1993), Giza sits at the 0.88th percentile—anomalously tight. At $\sigma = 10'$, it sits at the 5.5th percentile, still well below the envelope's median. At $\sigma = 2'$, corresponding to the angular-resolution limit of the unaided eye, Giza sits at the 53rd percentile, but this is a noise-floor artifact: at $\sigma = 2'$ the envelope's median Procrustes distance falls below Giza's observed value, meaning the simulation cannot distinguish Giza from a typical builder at this precision. The substantive finding is robust across σ values the simulation can meaningfully resolve: the Giza shape match is tighter than what naked-eye positional accuracy can produce.

The tightness at the resolvable precisions admits three interpretations: (a) the Fourth Dynasty builders possessed observational or surveying precision substantially better than $\sigma = 0.5^\circ$, which is plausible given Petrie's (1883) documentation of 58 mm precision over 230 m baselines; (b) the Procrustes metric is overly generous for 3-point configurations with only 2 effective DOF; or (c) the match is coincidental, and some random catalog triplets inevitably fall very close.

Notably, Teotihuacan's Pyramid of the Sun–Moon–Feathered Serpent triangle sits at the 56th percentile—exactly where intentional encoding would be expected—yet fails the shape test entirely ($p = 0.875$). Teotihuacan is included solely as a methodological comparator for the precision envelope; its complex, multi-phase construction history is not modelled here and no astronomical correlation is claimed for the site.

3.10 Residual Analysis

The Procrustes residuals (Figure 1b) show that Khafre (the middle pyramid) carries the largest offset from the 'perfect' Orion-matched position: 10.3 m northwest, compared to 5.1 m (Khufu, SE) and 5.2 m (Menkaure, SE). All offsets fall within the usable plateau and are less than 0.7% of the 1.5 km site scale. The builders could have achieved a geometrically perfect match without terrain constraints preventing it.

3.11 Reflection and Chirality

Fairall (1999) objected that the Giza–Orion cor-

Table 4: Observed Procrustes distance vs. the intentional-encoding precision envelope across assumed angular precision σ (optimal-permutation metric; $N = 10,000$ trials per σ).

Angular Precision (σ)	Envelope Median (D)	Giza Percentile	Interpretation
2'	0.000305	53rd	Noise floor: envelope median below observed
10'	0.006531	5.5th	Below envelope median
0.5° (30')	0.068958	0.88th	Anomalously tight
1°	0.137164	0.36th	Anomalously tight

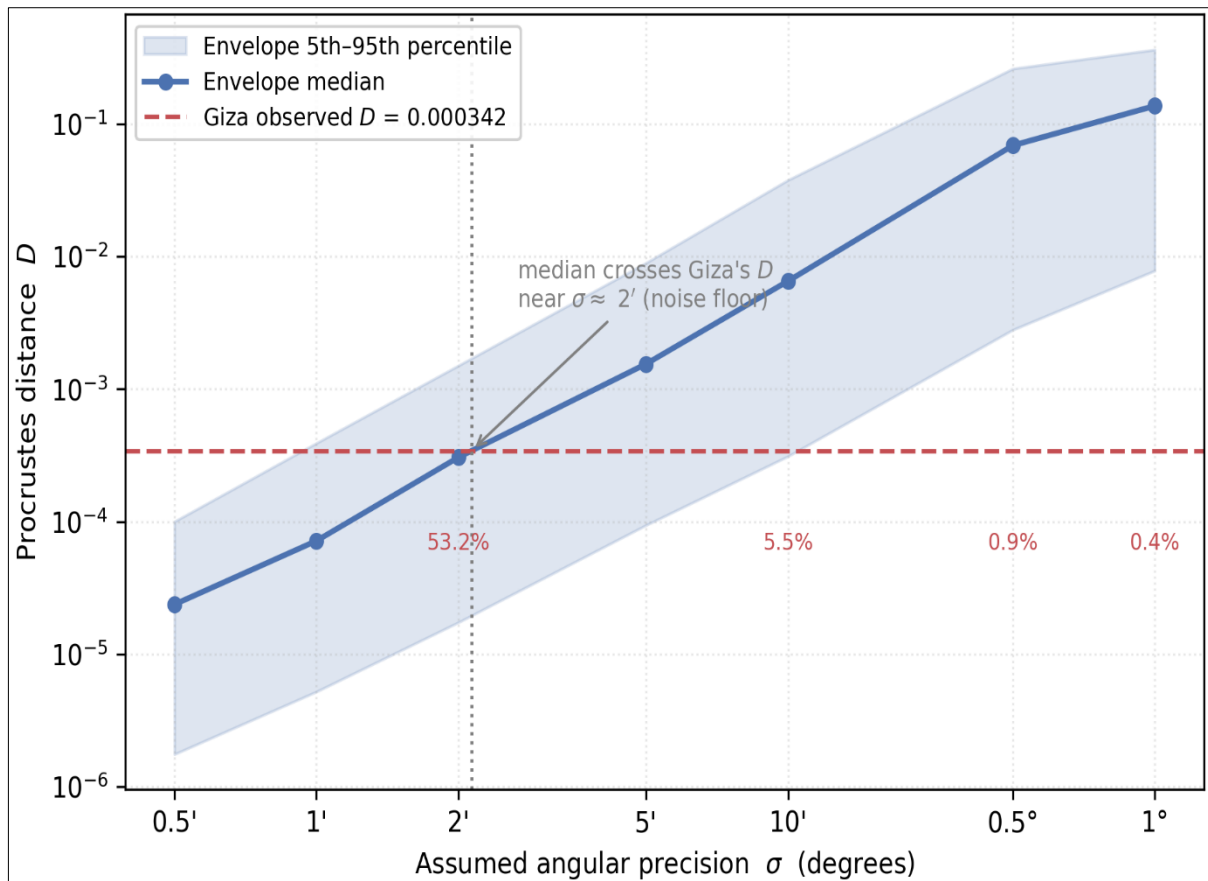


Figure 3: Builder's precision envelope across assumed angular precision σ (optimal-permutation metric; $N = 10,000$ trials per σ ; log-log axes). The shaded band shows the 5th-95th percentile range and the curve the envelope median; Giza's observed $D = 0.000342$ (horizontal red dashed line) sits at the 0.9th percentile at $\sigma = 0.5^\circ$ and the 5.5th at $\sigma = 10'$. The envelope median crosses below Giza's D near $\sigma \approx 2'$, the angular-resolution limit of the unaided eye, where the simulation can no longer distinguish Giza from a typical builder (noise floor).

respondence requires a mirror reflection, undermining any claim of intentional encoding. We test this directly by running Procrustes in two modes: with and without reflection permitted. The standard Procrustes solution for Giza-Orion does not use reflection ($\det(R) = +1$). Under reflection-forbidden Procrustes, 1,380 triplets rank ahead of Orion (Orion's rank: 1,381); under reflection-permitted, 1,716 do (Orion's rank: 1,717). The two modes produce identical Procrustes distance for Giza-Orion ($D = 0.000342$ to six decimal places), but slightly different ranking populations because some triplets that beat Orion in reflection-permitted mode use reflection. An explicit mirror-then-rotate alignment produces a worse match ($D =$

0.000432).

The optimal star-to-pyramid mapping is Khufu→Mintaka, Khafre→Alnilam, Menkaure→Alnitak, with a pure rotation of 92.7° . This mapping preserves north-south ordering (the northernmost pyramid maps to the northernmost Belt star). An important caveat is that the near-collinear geometry of the Giza triangle (maximum internal angle = 168.8°) makes the distinction between reflection and rotation almost meaningless in Procrustes distance—the D values are identical to six decimal places regardless of mode. A signed-area chirality test confirms this: 51.3% of the 1,716 better-matching triplets have opposite chirality to Giza ($p = 0.28$ vs. a 50% null), indicating no mean-

Table 5: Cross-site monument–asterism Procrustes results (12 sites).

Site	Asterism	D	Rank	p-value
Giza	Orion Belt	0.000342	1,717	0.0025
Thornborough	Orion Belt	0.001439	3,753	0.0054
Angkor	Draco	0.019503	17,004	0.0244
Carnac	Pleiades	0.012850	37,705	0.0542
Teotihuacan	Pleiades	0.023127	157,191	0.226
Avebury	Pleiades	0.029746	252,560	0.363
Newgrange	Orion Belt	0.055642	386,445	0.556
Stonehenge	Pleiades	0.112564	481,647	0.692
Easter Island	Orion Belt	0.071037	508,022	0.730
Xi'an	Big Dipper	0.209814	510,201	0.734
Cahokia	Orion Belt	0.233850	510,331	0.734
Tikal	Orion Belt	0.199054	635,396	0.914

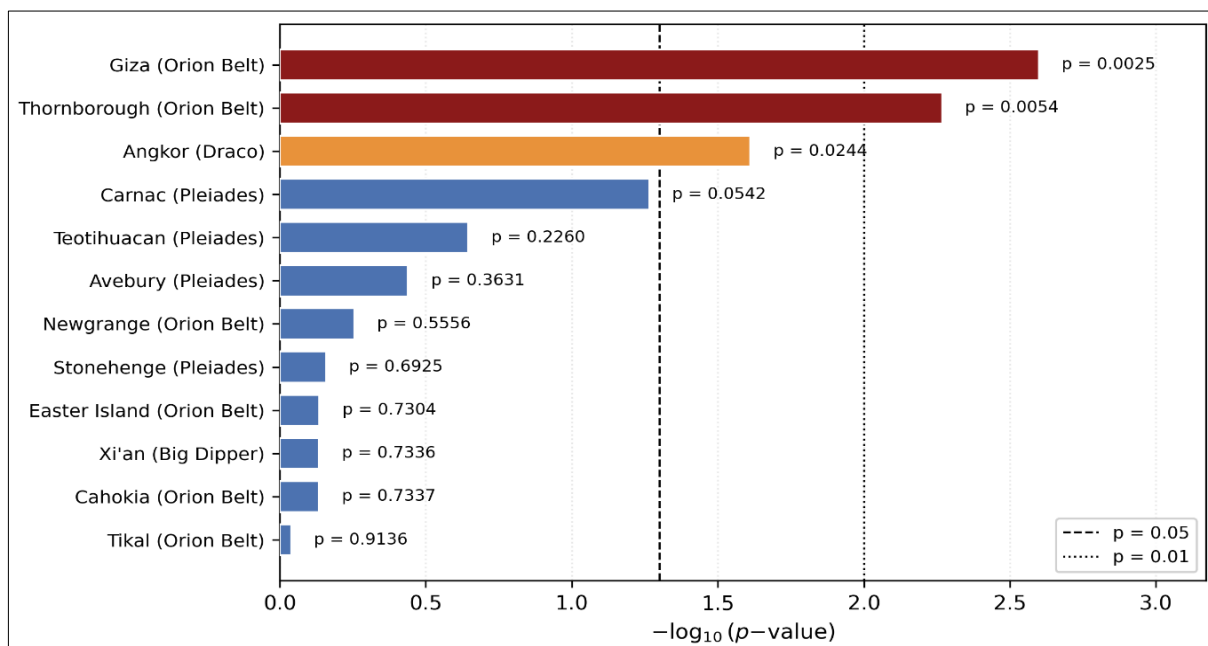


Figure 4: Cross-site monument–asterism comparison (12 sites). Bars show $-\log_{10}(p)$; red = $p < 0.01$, orange = $p < 0.05$, blue = not significant. Giza and Thornborough are the only sites reaching $p < 0.01$.

ingful chirality signal. The statistically optimal star-pyramid correspondence (Khufu–Mintaka, Khafre–Alnilam, Menkaure–Alnitak) differs from the traditionally cited Bauval assignment. The shape match is robust under this non-traditional mapping, but it follows that the specific star-to-pyramid correspondence of the original OCT—on which its directional and brightness-ordering arguments depend—is not the assignment that best fits the data. To be explicit: the data support a shape correspondence under a relabeling of the Belt stars, not the particular pairing Bauval proposed.

3.12 Scale Significance

We test whether the Procrustes scale factor constitutes independent evidence of intentional design. The observed scale factor is 20,290 m/rad (i.e., one radian of angular separation between Belt stars maps to 20.3 km on the

ground). A Monte Carlo test generating 10,000 random triangles on a 2 km plateau (matching Giza's buildable area) and aligning each to Orion's Belt finds that the observed scale sits at the 11th percentile ($p = 0.219$). Scale adds zero additional degrees of freedom beyond the two shape DOF already accounted for; it is a function of plateau geometry rather than intentional encoding. The total information content remains at 8.7 bits.

3.13 Cross-site Base Rate Calibration

To assess whether Giza's match is exceptional in a broader context, we test 12 famous triangular monument sites worldwide against their culture's most prominent asterism using identical Procrustes methodology. Table 5 presents the results, and Figure 4 plots the per-site significance.

Two of twelve sites achieve $p < 0.01$ (expect-

ed by chance: 0.12), representing an exploratory $\sim 17\times$ enrichment. Giza is the best match by a factor of $2\times$ over the next-best site (Thornborough, $p = 0.0054$). Thornborough's three-henge layout has been informally proposed as an Orion's Belt analog, though this association is not established in the primary archaeological literature on the site (cf. [Harding, 2013](#) for the canonical site description). After Benjamini–Hochberg correction across all 12 sites, Giza's adjusted p-value is 0.030, surviving at $\alpha = 0.05$. The base rate suggests that monument–asterism shape matches are more common than pure chance predicts, but Giza's correspondence remains the strongest among all tested sites. This comparison is exploratory and does not constitute a pre-registered test.

4 DISCUSSION

4.1 What Survives

The core shape correspondence is robust across multiple tests: Orion's Belt ranks 1,717th among 695,520 triplets ($p = 0.0025$), is epoch-invariant, is independently confirmed by Gaia DR3, and is the first named asterism in the full triplet ranking. The match does not require reflection—contrary to [Fairall's \(1999\)](#) objection—and uses a pure rotation ($\det(R) = +1$). Giza is the best-matching site among 12 famous triangular monument complexes tested worldwide, surviving BH correction across sites ($p = 0.030$). The information content (8.7 bits) is non-trivial. The Pyramid Texts, composed approximately 160 years after the Giza pyramids, attest to the established place of Sah (Orion) in the royal stellar afterlife ([Belmonte and Lull, 2023](#)); they provide a cultural context in which such an encoding would be meaningful but are not direct evidence of construction-era intent.

4.2 What Fails

Every attempt to extend or elaborate the basic shape correspondence fails quantitative testing. The orientation does not match at the construction epoch. The shaft alignments do not converge on a common date. The shape-optimal mapping does not preserve the Belt stars' brightness order—the largest pyramid (Khufu, 230 m) corresponds to the dimmest Belt star (Mintaka, $V = 2.23$)—and no single assignment optimizes shape and brightness together (§4.2.1). The Menkaure offset goes the wrong direction. The Nile Valley extension collapses. The scale factor is not significant. And, across the σ values the simulation can meaningfully resolve, the match is tighter than naked-eye positional accuracy should produce (§4.3).

4.2.1 Size, Brightness, and Shape

[Magli and Belmonte \(2009\)](#) raise the question of whether the pyramids' radically different sizes are compatible with their being meant to represent the three Belt stars, whose visual magnitudes are similar (Alnilam 1.69, Alnitak 1.74, Mintaka 2.23). We address this quantitatively. Of the six possible star→pyramid assignments, only one (Khufu→Alnilam, Khafre→Alnitak, Menkaure→Mintaka) produces a monotonic rank-order match between pyramid size and stellar brightness (Spearman $\rho = -1.0$). However, this is not the assignment that minimizes the Procrustes shape distance. The shape-optimal assignment (Khufu→Mintaka, Khafre→Alnilam, Menkaure→Alnitak), at which $D = 0.000342$ and the §3.1 ranking is computed, produces only a partial inverse correspondence ($\rho = +0.5$): the largest pyramid corresponds to the dimmest star, but the middle and smallest pyramids do not preserve any consistent magnitude ordering. Two readings are consistent with these results. (i) Magnitude–size encoding was not part of the intended program, and the partial inverse at the shape-optimal mapping is incidental—the architects either did not consider magnitude or accepted that shape match required breaking it. (ii) Both signals are coincidental and the question of intentional encoding cannot be resolved from these data alone. We do not adjudicate between these readings, but we agree with Magli and Belmonte that magnitude is not preserved under the shape-best assignment, and we note additionally that no single assignment satisfies both shape and magnitude criteria optimally.

4.3 Scale and the Precision Paradox

The scale factor adds no independent information: the observed Procrustes scale (20,290 m/rad) is not statistically significant ($p = 0.219$). Scale is entirely determined by the size of the Giza plateau—a geographic given—not by intentional encoding. The total information content remains at 8.7 bits from two shape degrees of freedom.

The builder's precision envelope finding poses a genuine interpretive puzzle at the angular precisions the simulation can resolve. At $\sigma = 0.5^\circ$ (naked-eye positional accuracy) and $\sigma = 10'$, Giza sits at the 0.9th and 5.5th percentiles respectively—tighter than nearly all intentional-encoding attempts. At $\sigma = 2'$ (the eye's angular-resolution limit) the envelope's median distance falls below Giza's observed value, so the simulation can no longer distinguish Giza from a typical builder; the 53rd-percentile figure there is a noise-floor artifact

rather than evidence of a loose match. Across the σ values the simulation can meaningfully resolve, the Giza shape match is therefore tighter than naked-eye positional accuracy alone should produce. One resolution is that Old Kingdom surveying precision exceeded naked-eye astronomical observation limits; [Petrie's \(1883\)](#) base-length measurements suggest ground-survey precision of approximately 1:4,000, which could in principle support tighter shape reproduction than stellar observation alone would allow. An alternative resolution is that the Procrustes metric's scale- and reflection-invariance makes 3-point matches slightly easier than intuition suggests. Future work should explore generalized Procrustes variants that penalize scale differences.

4.4 Comparison with Prior Probability Estimates

[Orofino and Bernardini \(2016\)](#) reported a Monte Carlo probability of <0.018% for the Giza–Orion match based on 10 million random 3-point configurations in unconstrained geometric space. Our result (0.25%) is approximately 14× less significant. The difference is methodologically important: Orofino's random configurations sample uniformly from all possible triangle shapes, whereas our stellar triplets inherit the spatial structure of the bright-star distribution. Bright stars cluster along the Milky Way and in specific sky regions, producing a non-uniform distribution of triplet shapes that increases the probability of close matches for any given target triangle. Our catalog-based comparison provides the more conservative and realistic denominator, as it answers the question “How many actual star patterns resemble Giza?” rather than “How many abstract triangles resemble Giza?”

4.5 Methodological Contribution

This work addresses the open problem identified by [Vecchiato et al. \(2025\)](#): estimating the total eligible asterism count against which a claimed correlation should be evaluated. Our exhaustive enumeration of 695,520 triplets provides a definitive denominator. The builder's precision envelope and information-theoretic decomposition offer reusable frameworks applicable to any claimed site–asterism correspondence, including Teotihuacan (which we include as a comparative case). We encourage their application to other contested claims in archaeoastronomy.

4.6 Base Rate Calibration

The cross-site comparison ([Table 5](#)) provides

crucial context but requires careful interpretation. The 12 sites were selected because they are famous triangular monument complexes, several of which have been previously proposed as stellar correlates. This non-random selection inflates the probability of finding significant matches relative to a random sample of archaeological sites. The ‘17× enrichment’ (2/12 at $p < 0.01$) should therefore be read as an upper bound. Nevertheless, the comparison serves its intended purpose: testing whether Giza's result is exceptional even among sites pre-selected for plausible stellar correspondence. Giza's match remains the strongest by a factor of 2× over Thornborough ($p = 0.0054$)—a layout informally proposed as an Orion's Belt analog, though not established as such in the primary archaeological literature (cf. [Harding, 2013](#))—and is the only site surviving BH correction across all 12 tests.

4.7 Limitations

The fundamental limitation is the low dimensionality of the data: three points yield only two independent shape parameters. Throughout, ‘shape’ denotes the configuration of the three pyramid apex points in the Procrustes sense—their relative planar positions after removing translation, rotation, scale, and reflection—and not the area, volume, or built mass of the individual pyramids, which are distinct properties this analysis does not model (cf. §4.2.1). While the exhaustive comparison against 695,520 equally-low-DOF triplets contextualizes the significance appropriately, the information content is inherently bounded. The near-collinear geometry of the Giza triangle (maximum internal angle = 168.8°) means that reflection and rotation are almost indistinguishable, limiting the information available from chirality analysis. The cultural argument—that Orion's Belt is uniquely recognizable among bright-star triplets and that Sah (Orion) is documented in the Egyptian funerary texts ([Belmonte and Lull, 2023](#))—provides additional prior weight but is not quantifiable in the same rigorous framework. We note that stellar triplets share constituent stars and are therefore not statistically independent; the effective number of independent configurations is smaller than 695,520.

4.8 Updated Information Budget

[Table 6](#) summarizes the information budget across all tested axes of the Orion–Giza correspondence.

No additional axes of intentionality were found beyond the two shape degrees of freedom. The case for the Orion–Giza correspond-

Table 6: Information content across all tested axes.

Source	Bits	DOF	Status
Triangle shape (Procrustes)	8.7	2	Confirmed ($p = 0.0025$)
Scale factor	0	0	Not significant ($p = 0.219$)
Reflection/chirality	~0	0	Match does not use reflection
Orientation	0	0	Not significant ($p = 0.74-0.98$)
Total	8.7	2	Shape only

ence rests entirely on shape match combined with the cultural prominence of Orion's Belt.

5 CONCLUSIONS

We have conducted the first exhaustive catalog-based enumeration of stellar triplets for evaluating the Orion Correlation Theory, testing the Giza pyramid layout against all 695,520 bright-star triplets and systematically assessing every major sub-claim. Our findings are as follows.

- (1) The three-point shape correspondence between the Giza pyramids and Orion's Belt is statistically significant ($p = 0.0025$, rank 1,717 of 695,520 triplets), epoch-invariant, and confirmed by independent Gaia DR3 astrometry. It encodes 8.7 bits of information across two shape degrees of freedom.
- (2) Orion's Belt is the first culturally recognized asterism in the full triplet ranking and the only compact, collinear, uniformly bright triplet among stars brighter than magnitude 3.0.
- (3) Every proposed extension—orientation, shaft convergence, brightness—size ordering, Menkaure offset direction, and Nile Valley geography—fails quantitative testing.
- (4) A novel builder's precision envelope reveals that the match is tighter than the precision envelope's median across σ values the simulation can meaningfully resolve, raising unresolved questions about either builder precision or Procrustes metric behavior at low DOF.
- (5) The information-theoretic decomposition shows both shape parameters contribute materially, with the distance ratio somewhat stronger than the bend angle (6.3 and 4.0 bits respectively), confirming the match is genuinely two-dimensional.
- (6) The Procrustes alignment uses pure rotation (no reflection), with north–south ordering preserved, neutralizing Fairall's (1999) mirror objection. However, the near-collinear geometry makes the reflection distinction almost meaningless.
- (7) The Procrustes scale factor adds no independent information ($p = 0.219$); it is determined by plateau geometry, not

intentional encoding.

- (8) Among 12 famous triangular monument sites tested against their culture's top asterism, Giza ranks first (BH-corrected $p = 0.030$ across sites), with Thornborough as the only other significant match.

The Orion–Giza shape correspondence is real but narrow. The traditional narrative surrounding it—encompassing shaft convergence, brightness ordering, offset directions, geographic extensions, and scale—is substantially overstated. What remains is a statistically significant geometric coincidence between the most recognizable stellar triplet in the night sky and the most famous monumental complex on Earth, set within a culture that independently documented the pharaoh–Orion connection. Whether this coincidence reflects intentional design, cultural selection bias, or chance remains an open question that the data alone cannot resolve.

6 ACKNOWLEDGEMENTS

The author thanks the anonymous reviewer for a detailed and constructive report that materially improved the scope and accuracy of this paper.

This research made use of the Yale Bright Star Catalogue ([Hoffleit and Warren, 1991](#)), Gaia DR3 ([Gaia Collaboration, 2023](#)), and the astropy Python package ([Astropy Collaboration, 2022](#)). Computational analyses were performed using scipy, numpy, and custom Python scripts.

AI disclosure: Claude (Anthropic), a large language model, was used as a computational research assistant throughout this work. Specifically: the author conceived the research questions and analytical strategy (exhaustive triplet ranking, builder's precision envelope, information-theoretic decomposition, cross-site calibration); Claude generated the Python implementation code for Procrustes analysis, Monte Carlo simulations, and precession modeling under the author's direction; Claude assisted with manuscript drafting and revision. The choice of statistical frameworks (Procrustes, Fisher's method, BH correction), the selection of comparison sites, and all interpretive claims were made by the author. All

numerical results were independently verified against source data. The author takes full re-

sponsibility for the methodology, results, interpretation, and all claims made in this paper.

7 REFERENCES

- Astropy Collaboration. 2022. The Astropy Project: Sustaining and Growing a Community-oriented Open-source Project and the Latest Major Release (v5.0) of the Core Package. *The Astrophysical Journal*, 935, 167 (20 pp.).
- Badawy, A., 1964. The stellar destiny of Pharaoh and the so-called air-shafts of Cheops' pyramid. *Mitteilungen des Instituts für Orientforschung*, 10, 189–206.
- Bauval, R., 1989. A master-plan for the three pyramids of Giza based on the configuration of the three stars of the Belt of Orion. *Discussions in Egyptology*, 13, 7–18.
- Bauval, R., and Gilbert, A., 1994. *The Orion Mystery*. London, Heinemann.
- Belmonte, J.A., 2001. On the orientation of Old Kingdom Egyptian pyramids. *Journal for the History of Astronomy*, 32 (Supplement): S1–S20.
- Belmonte, J.A., and Lull, J., 2023. *Astronomy of Ancient Egypt: A Cultural Perspective*. Cham, Springer.
- Best, E., 1922. *The Astronomical Knowledge of the Maori, Genuine and Empirical*. Wellington, Dominion Museum (Dominion Museum Monograph No. 3).
- Fairall, A., 1999. Precession and the layout of the ancient Egyptian pyramids. *Astronomy and Geophysics*, 40(3), 3.4.
- Gaia Collaboration, 2023. Gaia Data Release 3: Summary of the Content and Survey Properties. *Astronomy & Astrophysics*, 674, A1 (22 pp.).
- Harding, J., 2013. *Cult, Religion, and Pilgrimage: Archaeological Investigations at the Neolithic and Bronze Age Monument Complex of Thornborough, North Yorkshire*. York, Council for British Archaeology (CBA Research Report 174).
- Hoffleit, D., and Warren Jr., W.H., 1991. *The Bright Star Catalogue*. 5th Revised Edition. New Haven, Yale University Observatory.
- Krupp, E.C., 1997. Pyramid marketing schemes. *Sky & Telescope*, 93(2): 64.
- Legon, J.A.R., 1995. The Orion correlation and air-shaft theories. *Discussions in Egyptology*, 33, 45–56.
- MacDonald, J., 1998. *The Arctic Sky: Inuit Astronomy, Star Lore, and Legend*. Toronto, Royal Ontario Museum and Nunavut Research Institute.
- Magli, G., 2009. Akhet Khufu: archaeo-astronomical hints at a common project of the two main pyramids of Giza, Egypt. *Nexus Network Journal*, 11(1), 35–50.
- Magli, G., 2013. *Architecture, Astronomy and Sacred Landscape in Ancient Egypt*. Cambridge, Cambridge University Press.
- Magli, G., and Belmonte, J.A., 2009. Pyramids and stars: facts, conjectures, and starry tales. In Belmonte, J.A., and Shaltout, M. (eds.), *In Search of Cosmic Order: Selected Essays on Egyptian Archaeoastronomy*. Cairo, Supreme Council of Antiquities Press. Pp. 287–301.
- Orofino, V., and Bernardini, P., 2011. A quantitative astronomical analysis of the Orion correlation theory. arXiv:1109.6266.
- Orofino, V., and Bernardini, P., 2016. Archaeoastronomical study of the main pyramids of Giza, Egypt: possible correlations with the stars? *Archaeological Discovery*, 4, 1–10.
- Petrie, W.M.F., 1883. *The Pyramids and Temples of Gizeh*. London, Field and Tuer.
- Ruggles, C.L.N. (ed.), 2015. *Handbook of Archaeoastronomy and Ethnoastronomy*. New York, Springer.
- Schaefer, B.E., 1993. Astronomy and the limits of vision. *Vistas in Astronomy*, 36, 311–361.
- Spence, K., 2000. Ancient Egyptian chronology and the astronomical orientation of pyramids. *Nature*, 408, 320–324.
- Trimble, V., 1964. Astronomical investigation concerning the so-called air-shafts of Cheops' pyramid. *Mitteilungen des Instituts für Orientforschung*, 10, 183–187.
- Vecchiato, A., Bernardi, G., and Alberto Cora, A., 2025. Point-pattern matching and probability in archaeoastronomy. *Journal of Astronomical History and Heritage*, 28 (1), 219–239.
- Vondrák, J., Capitaine, N., and Wallace, P., 2011. New precession expressions, valid for long time intervals. *Astronomy & Astrophysics*, 534, A22 (19 pp.).

Elliot Allan is an independent researcher and founder of the Deep Time Research Institute in New York, USA. His work applies quantitative and statistical methods to long-standing questions in archaeoastronomy and the cultural evolution of knowledge systems, with an emphasis on reproducible, test-forward analyses of claims that have previously been argued mainly from visual impression. His current research programme treats oral and monumental traditions as information systems and asks how accurately they encode features of the physical world. Recent projects include exhaustive catalogue-based tests of proposed star-monument correlations (of which the present paper is one), geodesic analyses of long-distance cultural pathways, and a broader framework in which the fidelity of a tradition is modelled as a function of the observability of the phenomenon it records. He can be reached at elliott@deeptime-research.org (ORCID 0009-0008-8541-0944); further information about the institute's work is available at deeptime-research.org.

