PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY A
MATHEMATICAL, PHYSICAL & ENGINEERING SCIENCES

On the Results of an Examination of the Orientations of a Number of Greek Temples with a View to Connect these Angles with the Amplitudes of Certain Stars at the Time the Temples were Founded, and an Endeavour to Derive therefrom the Dates of their Foundation by Consideration of the Changes Produced upon the Right Ascension and Declination of the Stars by the Precession of the Equinoxes

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XVI. *On the Results of an Examination of the Orientations of a number of Greek Temples with a view to connect these Angles with the Amplitudes of certain Stars at the time the Temples were founded, and an endeavour to derive therefrom the Dates of their Foundation by consideration of the Changes produced upon the Right Ascension and Declination of the Stars by the Precession of the Equinoxes.*

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Communicated by Professor J. NORMAN LOCKYER, *F.R.S.*

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[*Preliminary Observations.*—MY attention was directed to the above subject by Mr. LOCKYER, who, in the course of his study of the Egyptian temples and the stars which appear to have determined their orientation, was led by a cursory examination of some of the Greek temples to think it likely that the same principle prevailed there also, and, knowing that I was in possession of some measurements which would help in the inquiry, invited me to look into the matter with him. On comparing notes, we found much to promise that a practical correspondence between the Egyptian and the Greek monuments would be found; so that it evidently became worth while to go more fully into the examination of the Greek remains. On the branch of the subject connected with Egypt Mr. LOCKYER has published several articles in 'Nature;'* and in May, 1891, gave a lecture to the Society of Antiquaries, which was held in the rooms of the Royal Society; and there is an article by him bearing on the question in the 'Nineteenth Century' (July, 1892). On the Greek branch I made a preliminary statement to the same Society in February, 1892, an abstract of which was published in 'Nature' on the 25th day of that month.

Unknown to Mr. LOCKYER until after he had been for some time engaged in this research, several articles had been contributed to the 'Rheinisches Museum für Philologie,'† by Herr NISSEN, of Bonn, following an exactly similar line of inquiry, and embracing both Egyptian and Greek monuments. In Herr NISSEN's researches there is some want of exactitude in the measurements which he has used, which interfere with the accuracy of some of the conclusions arrived at. There is, however, much of interest and value in the learning which he has brought to bear on the subject.

* April 16, May 7 and 21, June 4, and July 2, of 1891; and Jan. 28 and Feb. 18, of 1892.

† Particularly the volumes for 1885 and 1887.

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As respects Egypt, there is the strongest possible evidence that, when a temple was built, the direction of the axis was pointed to the place on the horizon where some conspicuous star would rise or set. There is distinct hieroglyphical evidence that such was the case. Mr. LOCKYER has referred to these records at some length in 'Nature' for Jan. 18, 1892. I quote here one passage, being a translation from an hieroglyphical relation of the rebuilding of a temple in the time of Seti I., about 1445 B.C.:—" The living God, the magnificent son of Asti (a name of Thoth), nourished by the sublime goddess in the temple of the sovereign of the country, stretches the rope with joy. With his glance at *Ak* (the middle ?) of the Bull's Thigh constellation, he establishes the temple-house of the mistress of Denderah, as took place before." At another place the King says:—" Looking to the sky at the course of the rising stars (and) recognizing the *Ak* of the Bull's Thigh constellation, I establish the corners of the temple of her majesty."

The point being considered as proved that the axis of a temple was pointed to the rising or setting of some particular star, the next step is to discover which star was chosen; and if this can be found, an astronomical clue to the date of the foundation is at once obtained; for, though the *amplitude* of the star—that is, its angular distance from true east or west at rising or setting—by reason of the precession of the equinoxes, would not now coincide with the orientation angle, the date at which it did so can be exactly recovered.

And there is seldom much difficulty in discovering the star, for the stars which could have been observed in a given direction, and bright enough to be seen through an atmosphere always somewhat hazy at low altitudes, are not numerous, so that there is little chance of error in deciding which was the star that suited the orientation.

Besides the hieroglyphical, there is good architectural evidence of stellar orientation. There are instances in Egyptian temples where the doorways have been altered, so as to keep a rising or setting star in view as it deviated from the axis which at first had been directed towards it; and when this plan could succeed no longer, in more than one instance a new temple, following the same cult, has been founded alongside of the earlier one, at a different orientation angle, for the purpose of continuing the observation of the same star.

In the first place, it may be convenient if I explain very briefly how it is that the precession of the equinoxes comes into play in this inquiry.

It is well and generally known that the orbit of the earth is in the form of an ellipse, situate in a plane passing through the Sun and through the centre of the earth, and called the plane of the ecliptic; and that the earth's diurnal rotation takes place upon an axis inclined to the plane of the orbit, at an angle at present measuring about twenty-three degrees and a half, but which fluctuates very slowly between small limits.

Celestial objects are measured upon an imaginary sphere, of indefinite diameter, centrally placed with regard to the earth, in two different ways. The starting points on one system are on the great circle which lies in the plane of the orbit, called the Ecliptic circle, and the measures taken at right angles to it are called latitudes. The coordinate measures round its circumference are called longitudes, exactly analogous to the measures of Geography, excepting that the longitudes are only reckoned in one direction, viz., from west towards east. The other system of measures employs the same imaginary sphere, but the great circle which is used is that which lies in the plane of the earth's Equator, and the measures from it are called declinations instead of latitudes, and the coordinate measures are called right ascensions instead of longitudes, which are reckoned as in the other case, only from west towards east. Thus the place of a star may be given either in latitude and longitude, or in right ascension and declination; and if nothing occurred to disturb the mechanical conditions of the orbit, this alternative reckoning would remain constant, or altered only by the exceedingly slow proper motion of some of the stars; and the summer and winter solstices and the spring and autumn equinoxes would occur in each succeeding year at the exact moment when the sun occupied the same longitude as on the previous one. This, however, is found not to be the case; and the first recorded statement of the fact is attributed to the Greek astronomer, HIPPARCHUS. It must, however, have been practically known to the Egyptians long before his time. The explanation was reserved for NEWTON, who showed that owing to certain gravitational reactions upon our planet, especially on the part of the Moon, the earth's polar axis, whilst remaining nearly constant in its inclination to the plane of the ecliptic, is continually deflected in such a manner that the recurrence of the equinoxes (of which the exact moment can be more easily observed than that of the solstices) is accelerated to the extent of about the twentieth part of a degree annually. This movement necessarily disturbs the relation which exists at any particular epoch between the latitude and longitude, and the right ascension and declination reckonings. During the course of a few years, indeed, the difference is not great, but when years are counted by thousands, the changes in right ascension have to be reckoned in hours. And although the latitude is not much affected, the changes in declination are generally large, sometimes northerly and sometimes southerly, according to the position of the object. It necessarily follows that, together with the declination, the amplitudes of stars at their rising and setting are altered; and thus it has happened that stars once chosen for orientation purposes, after a few hundred years, could by no contrivance be retained in view, but as the law of the variation has been ascertained, the date can be computed when the amplitude of the star and the orientation angle coincided.

In Greece nothing, so far as we know, has been recorded either in history or by inscriptions which offers a parallel to what has been found on this subject in the Egyptian hieroglyphics referred to above; but architectural evidence is not wanting of a character corresponding with that which has been found in Egypt, showing the changes of structure arising out of the precessional movement. The Greek examples, which can be cited, are the two Minerva temples on the Acropolis at Athens, both of which in their orientation can be referred to the Pleiades (a constellation sacred to the goddess) at different epochs; and at Rhamnus the remains of the two temples of Themis and Nemesis, which evidently followed the same cult, are found side by side, with a difference in their orientation exactly tallying with the precessional movement of Spica.* In the well-preserved temple at Ægina the western wall of the cella has been pierced excentrically by the doorway, and apparently for the object of enabling the setting of Antares to be observed from the adytum. There may have been other examples of the same kind, but the doorways of very few of the earliest temples in the country have been sufficiently well preserved to decide whether the same thing may or may not have been done.

The orientation of temples may be divided into two classes, Solar and Stellar. In the former the orientation lies within the solstitial limits, so that its angular distance from true east and west does not exceed the amplitude of the Sun at the solstices. The stellar orientation exceeds this limit. In Greece there are comparatively few of the latter class.—April 17, 1893.]

The orientation angles given in the lists which follow were obtained from azimuths taken from the Sun or the planet Venus. In almost every case two or more sights were taken. Observations of stars at night were also used from time to time, to test the performance of the theodolite. Magnetic variations were also observed in most instances, which confirmed the opinion I had already arrived at that, owing to local attractions, magnetic bearings were not sufficiently exact for the purposes of this inquiry. The height subtended by the visible horizon opposite the axis of the temple was also in every case observed.

For the present it may be treated as a postulate that in any temple oriented within the solstitial limits of its latitude, the axis was so directed that, on the great festival of the year, the first beam of the rising Sun should fall upon the statue centrally placed in the temple, or on the incense altar in front of it; and as obviously the priests would desire to have due warning of the Sun's approach, it was also arranged that some bright star or constellation should rise or set *heliacally* where it could be seen from the adytum. By heliacal rising or setting, a phrase used in many passages of ancient writers, is meant, that such star should be just visible before the light of the rising Sun should be too powerful. This interval of time would vary according to circumstances, but it would generally require that the depression of the Sun below the horizon should be about ten degrees. Previous to the invention of water clocks or other artificial means of measuring time, the rising or setting of the stars would have been the only reliable chronometers at night.

In the following list the orientation angles are measured from the south and round by way of west, north, and east :—

* At Tegea also there are divergent foundations, which appear to correspond to changing amplitudes of α Arietis.

Athens. Lat. 37° 38′ 20″.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Archaic Temple of Minerva	260° 55′	A	Amplitude of Star or Sun	+7° 51′ 26″	+12° 16′	Pleiades (η Tauri), rising
		B	Corresponding altitude	3° 20′ E.	2° 40 E.	
		C	Declination	+7° 50′	+11° 20′	
		D	Hour angles	$6^h\ 8^m\ 24^s$	$7^h\ 29^m\ 37^s$	
		E	Depression of Sun when Star was heliacal	. .	10°	
		F	R.A.	$0^h\ 34^m\ 50^s$	$1^h\ 56^m\ 3^s$	
		G	Approximate date . .	B.C. 1530, April 20, 21		
Jupiter Olympius, older foundation	268° 0′	A	Amplitude of Star or Sun	+3° 8′	+2°	α Arietis, rising
		B	Corresponding altitude	5° 0′ E.	4° 31′ E.	
		C	Declination	+6° 15′	+4° 21′ 10″	
		D	Hour angles	$5^h\ 44^m\ 51^s$	$7^h\ 15^m\ 36^s$	
		E	Depression of Sun when Star was heliacal	. .	12°	
		F	R.A.	$23^h\ 19^m\ 0^s$	$0^h\ 39^m\ 45^s$	
		G	Approximate date . .	B.C. 1202, March 30, 31		
Hecatompedon, on site of present Parthenon	257° 7′	A	Amplitude of Star or Sun	+10° 8′	+15° 52′ 41″	Pleiades, rising
		B	Corresponding altitude	2° 45′ E.	2° 25′ E.	
		C	Declination	+9° 58′	+13° 57′	
		D	Hour angles	$6^h\ 17^m\ 18^s$	$7^h\ 37^m\ 56^s$	
		E	Depression of Sun when Star was heliacal	. .	10°	
		F	R.A.	$0^h\ 54^m\ 5^s$	$2^h\ 16^m\ 20^s$	
		G	Approximate date . .	B.C. 1150, April 26		
Nike Apteros, or Wingless Victory	275° 43′ 17″	A	Amplitude of Star or Sun	+5° 28′ 59″	−5° 43′ 17″	Spica, setting
		B	Corresponding altitude	3° 0′ W.	5° 22′ E.	
		C	Declination	+6° 10′	−1° 12′ 5″	
		D	Hour angles	$6^h\ 4^m\ 0^s$	$6^h\ 59^m\ 0^s$	
		E	Depression of Sun when Star was heliacal	. .	12° 20′	
		F	R.A.	$10^h\ 46^m\ 0^s$	$23^h\ 49^m\ 0^s$	
		G	Approximate date . .	B.C. 1130, March 17		

Athens. Lat. 37° 38′ 20″—(continued).

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Older Erechtheum, foundations under present Temple	251° 39′	A	Amplitude of Star or Sun	−21° 4′	+18° 21′	Antares, setting
		B	Corresponding altitude	3° 0′ W.	0° 50′ E.	
		C	Declination	−14° 31′	+14° 54′	
		D	Hour angles	$4^h\ 59^m\ 0^s$	$7^h\ 54^m\ 0^s$	
		E	Depression of Sun when Star was heliacal	. .	12°	
		F	R.A.	$13^h\ 35^m\ 0^s$	$2^h\ 28^m\ 20^s$	
		G	Approximate date . .	B.C. 1070, April 29		
Earlier Temple of Bacchus	255° 7′ 42″	A	Amplitude of Star or Sun	+10° 42′ 5″	+16° 41′ 26″	Pleiades, rising
		B	Corresponding altitude	3° 30′ E.	3° 3′ E.	
		C	Declination	+10° 35′	+15°	
		D	Hour angles	$6^h\ 15^m\ 24^s$	$7^h\ 43^m\ 43^s$	
		E	Depression of Sun when Star was heliacal	. .	10°	
		F	R.A.	$1^h\ 0^m\ 41^s$	$2^h\ 29^m\ 0^s$	
		G	Approximate date . .	B.C. 1030, April 29		
Diana Brauronia .	288° 22′ 49″	A	Amplitude of Star or Sun	−19° 20′ 18″	−18° 22′ 49″	Constellation Aquarius, ζ Aquarii, rising.
		B	Corresponding altitude	6° 15′ E.	5° 59′ E.	
		C	Declination	−11° 6′	−10° 49′ 9″	
		D	Hour angles	$4^h\ 51^m\ 37^s$	$6^h\ 56^m\ 42^s$	
		E	Depression of Sun when Star was heliacal	. .	17°	
		F	R.A.	$20^h\ 13^m\ 0^s$	$22^h\ 18^m\ 0^s$	
		G	Approximate date . .	B.C. 580, Feb. 21, 22		

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Olympia. Lat. 37° 38′.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
The Heræum, or Temple of Juno	266° 13′ 58″	A	Amplitude of Star or Sun	+7° 35′	+3° 46′	Spica, rising
		B	Corresponding altitude	3° E.	1° 40′ E.	
		C	Declination	+7° 40′	+4° 0′ 1″	
		D	Hour angles	$6^h\ 9^m\ 2^s$	$7^h\ 3^m\ 10^s$	
		E	Depression of Sun when Star was heliacal	. .	10°	
		F	R.A.	$10^h\ 29^m\ 4^s$	$11^h\ 23^m\ 12^s$	
		G	Approximate date . .	B.C. 1445, September 12		
The Temple of Jupiter	262° 37′ 46″	A	Amplitude of Star or Sun	+8° 38′	+7° 22′ 14″	α Arietis, rising.
		B	Corresponding altitude	3° 0′ E.	1° 42′ E.	
		C	Declination	8° 40′	+6° 52′ 22″	
		D	Hour angles	$6^h\ 11^m\ 37^s$	$7^h\ 34^m\ 52^s$	
		E	Depression of Sun when Star was heliacal	. .	14° 12″	
		F	R.A.	$23^h\ 40^m\ 0^s$	$1^h\ 3'\ 5''$	
		G	Approximate date . .	B.C. 790, April 6		
The Metroum, or Temple of Cybele	281° 47′ 2″	A	Amplitude of Star or Sun	+9° 28′ 13″	−9° 47′ 2″	α Arietis, setting
		B	Corresponding altitude over roof of ancient Heræum	5° 45′ W.	2° E.	
		C	Declination	+11° 0′	−6° 30′	
		D	Hour angles	$6^h\ 4^m\ 50^s$	$6^h\ 53^m\ 10^s$	
		E	Depression of Sun when Star was heliacal	. .	14° 6′	
		F	R.A.	$0^h\ 2^m\ 0^s$	$13^h\ 0^m\ 0^s$	
		G	Approximate date . .	B.C. 360, October 9		

The Hiero of Epidaurus. Lat. 37° 35′.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Asclepieion or Temple of Esculapius	259° 24′ 50″	A	Amplitude of Star or Sun	+6° 19′	+10° 35′	Pleiades (η Tauri), rising
		B	Corresponding altitude	7° E.	6° 10′ E.	
		C	Declination	+9° 15′	+12° 8′	
		D	Hour angles	5^h 53^m 16^s	7^h 31^m 41^s	
		E	Depression of Sun when Star was heliacal	. .	10°	
		F	R.A.	0^h 47^m 35^s	2^h 26^m 0^s	
		G	Approximate date . .	B.C. 1275, April 28, 29		
Temple of Diana .	255° 49′	A	Amplitude of Star or Sun	−13° 7′ 43	+14° 11′ 0″	β Scorpii, setting
		B	Corresponding altitude	3° W.	6° 10′ E.	
		C	Declination	−8° 30′	+14° 59′ 5″	
		D	Hour angles	4^h 57^m 0^s	7^h 59^m 0^s	
		E	Depression of Sun when Star was heliacal	. .	13°	
		F	R.A.	13^h 32^m 0^s	2^h 29^m 0^s	
		G	Approximate date . .	B.C. 780, April 29		

Tegea. Lat. 37° 27′ 45″.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Temple of Minerva	This I could only obtain approximately from walls, not of the Temple itself, which are shown on the German plan in 'Mittheilungen.' 267° 12′ 30″	A	Amplitude of Star or Sun	+5° 3′ 45″	+0°	Spica, rising
		B	Corresponding altitude	+3° 0′ E.	+3° 5′ E.	
		C	Declination	+5° 51′	+1° 52′ 12″	
		D	Hour angles	6^h 2^m 45^s	6^h 56^m 32^s	
		E	Depression of Sun when Star was heliacal	. .	10°	
		F	R.A.	10^h 48^m 13^s	11^h 43^m	
		G	Approximate date . .	B.C 1075, September 18		

The above can only be regarded as a possible solution.
Should the Temple be re-examined by excavation more exact data could be obtained.
(See note on this Temple at p. 833.)

Rhamnus. Lat. 38° 13′.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Temple of Themis	268° 30′ 14″	A	Amplitude of Star or Sun	+5° 16′ 36″	+1° 29′ 46″	Spica, rising
		B	Corresponding altitude	3° 0′ E.	1° 22′ E.	
		C	Declination	+6° 0′	+2° 1′ 15″	
		D	Hour angles	$6^h 3^m 37^s$	$6^h 57^m 39^s$	
		E	Depression of Sun when Star was heliacal	. .	10°	
		F	R.A.	$10^h 47^m 53^s$	$11^h 41^m 55^s$	
		G	Approximate date . .	B.C. 1092, September 17		
Temple of Nemesis	271° 24′ 50″	A	Amplitude of Star or Sun	+2° 45′ 30″	−1° 24′ 50″	Spica, rising
		B	Corresponding altitude	3° 0′ E.	2° 0′ E.	
		C	Declination	+4° 5′	+0° 7′ 37″	
		D	Hour angles	$5^h 57^m 19''$	$6^h 51^m 32^s$	
		E	Depression of Sun when Star was heliacal	. .	10°	
		F	R.A.	$11^h 4^m 52^s$	$11^h 58^m 50^s$	
		G	Approximate date . .	B.C. 747, September 22		

Nemea. Lat. 37° 49′.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Temple of Jupiter	250° 39′ 18″	A	Amplitude of Star or Sun	−21° 56′	+19° 20′ 42″	Constellation Aquarius, ζ Aquarii, setting
		B	Corresponding altitude	7° 30′ W.	6° 35′ E.	
		C	Declination	−12° 16′ 20″	+19° 18′ 39″	
		D	Hour angles	$4^h 41^m 3^s$	$8^h 1^m 7^s$	
		E	Depression of Sun when Star was heliacal	. .	10°	
		F	R.A.	$19° 47^m 40^s$	$8^h 30^m$	
		G	Approximate date . .	B.C. 1040, July 27, 28		

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Corfu. Lat. 39° 36′.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Temple at Kardaki, near the city	274° 39′ 35″	A	Amplitude of Star or Sun	−1° 45′ 42″	−4° 39′ 35″	γ Pegasi, rising
		B	Corresponding altitude	3° 0′ E.	0° E.	
		C	Declination	0	−3° 35′ 20″	
		D	Hour angles	$5^h\ 43^m\ 19^s$	$7^h\ 21^m\ 56^s$	
		E	Depression of Sun when Star was heliacal	. .	17° 15′	
		F	R.A.	$21^h\ 48^m\ 23^s$	$23^h\ 27^m\ 0^s$	
		G	Approximate date . .	B.C. 875, March 10, 11		

Sunium. Lat. 37° 38′ 48″.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Temple of Minerva	284° 9′ 7″	A	Amplitude of Star or Sun	+12° 27′	−14° 9′	Pleiades (η Tauri), setting
		B	Corresponding altitude	3° W.	0° E.	
		C	Declination	+11° 40′	−11° 9′ 39″	
		D	Hour angles	$6^h\ 21^m\ 6^s$	$6^h\ 15^m\ 29^s$	
		E	Depression of Sun when Star was heliacal	. .	10°	
		F	R. A.	$1^h\ 9^m\ 52^s$	$13^h\ 46^m\ 27^s$	
		G	Approximate date . .	B.C. 845, October 21		

Corinth. Lat. 37° 55′ 0″.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Temple. Dedication unknown	249° 10′	A	Amplitude of Star or Sun	−23° 26′	+20° 50′	Antares, setting
		B	Corresponding altitude	3° 15′ W.	55′ E.	
		C	Declination	−16°	+16° 53′	
		D	Hour angles	$4^h\ 50^m\ 37^s$	$8^h\ 13^m\ 0^s$	
		E	Depression of Sun when Star was heliacal	. .	13° 40′	
		F	R.A.	$13^h\ 50^m\ 0^s$	$2^h\ 54^m$	
		G	Approximate date . .	B.C. 770, May 6		

Bassæ. Lat. 37° 25′.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Temple of Apollo Epicurius	The axis of temple 108° 26′ 6″ But there was an Eastern doorway 270° 26′ 6″	A	Amplitude of Star or Sun	+3° 11′	−0° 26′ 6″	Spica, rising
		B	Corresponding altitude	3° 0′ E.	0° 45′ E.	
		C	Declination	+3° 57′	+0° 6′ 37″	
		D	Hour angles	$5^h\ 57^m$	$6^h\ 50^m\ 8^s$	
		E	Depression of Sun when Star was heliacal	. .	10°	
		F	R.A.	$11^h\ 5^m\ 50^s$	$11^h\ 59^m\ 0^s$	
		G	Approximate date . .	B.C. 728, September 22		

Platæa. Lat. 38° 13′.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Unnamed temple. Possibly Juno	280° 38′ 10″	A	Amplitude of Star or Sun	+9° 50′	−10° 38′ 10″	α Arietis, setting
		B	Corresponding altitude	3° 0′ W.	3° 1′ E.	
		C	Declination	+9° 31′	−6° 19′ 35″	
		D	Hour angles	$6^h\ 14^m\ 46^s$	$6^h\ 56^m\ 12^s$	
		E	Depression of Sun when Star was heliacal	. .	15°	
		F	R.A.	$23^h\ 48^m$	$12^h\ 59^m$	
		G	Approximate date . .	B.C. 650, October 9		

Lycosura. Lat. 37° 23′.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Temple of Despoina	272° 11′ 4″	A	Amplitude of Star or Sun	−1° 2′	−2° 11′ 4″	γ Pegasi, rising
		B	Corresponding altitude	+3° 0′ E.	0° 35′ E.	
		C	Declination	+1° 0′	−1° 25′	
		D	Hour angles	$5^h\ 48^m\ 56^s$	$7^h\ 35^m\ 56^s$	
		E	Depression of Sun when Star was heliacal	. .	19° 40′	
		F	R.A.	$22^h\ 0^m$	$23^h\ 47^m$	
		G	Approximate date . .	B.C. 650, March 16		

Ephesus. Lat. 37° 56′ 30″.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Temple of Diana. Old foundation, found by Mr. Wood, beneath the fourth century temple*	275° 21′ 5″	A	Amplitude of Star or Sun	+0° 25′ 0″	−5° 21′ 5″	Spica, rising
		B	Corresponding altitude	6° 0′ E.	4° 55′ E.	
		C	Declination	+3° 57′	−1° 10′ 43″	
		D	Hour angles	$5^h\ 41^m\ 49^s$	$6^h\ 47^m\ 2^s$	
		E	Depression of Sun when Star was heliacal	. .	10°	
		F	R.A.	$11^h\ 5^m\ 48^s$	$12^h\ 11^m\ 0^s$	
		G	Approximate date . .	B.C. 715, September 25		

Ægina. (1) Lat. 37° 45′. (2) Lat. 37° 44′ 30″.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
(1) Temple of Minerva, on the mountain called Jupiter Panhellenius	249° 0′ 27″	A	Amplitude of Star or Sun	−23° 55′	+20° 59′ 33″	Antares, setting
		B	Corresponding altitude	3° 0′ W.	1° 20′ E.	
		C	Declination	−16° 45′	+17° 0′ 33″	
		D	Hour angles	$4^h\ 49^m\ 20^s$	$8^h\ 11^m\ 30''$	
		E	Depression of Sun when Star was heliacal	. .	14° 50′	
		F	R.A.	$13^h\ 57^m$	$2^h\ 57^m\ 50^s$	
		G	Approximate date . .	B.C. 630, May 7		
(2) Temple at the harbour	280° 16′ 3″	A	Amplitude of Star or Sun	+10° 19′ 40″	−10° 16′ 3″	α Arietis, setting
		B	Corresponding altitude	3° 0′ W.	2° 40′ E.	
		C	Declination	+10° 0′	−6° 27′	
		D	Hour angles	$6^h\ 15^m\ 53^s$	$6^h\ 32^m\ 34^s$	
		E	Depression of Sun when Star was heliacal	. .	14° 25′	
		F	R.A.	$23^h\ 53^m\ 0^s$	$13^h\ 1^m\ 15^s$	
		G	Approximate date . .	B.C. 550, October 9		

* It will be observed that the orientation of this temple at Ephesus is nearly the same as that of Nike Apteros at Athens, and there is not much difference either in the latitude or in the apparent height of the mountain eastwards; but in this case the rising, and in the other the setting of Spica has been adopted. This choice has been influenced by archæological considerations; and in this case the large amount of margin allowed for the star's amplitude appears to be justified by the very wide central intercolumnations of this temple.

Megalopolis. Lat. 37° 25′.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Temple of Jupiter Soter	279° 42′ 28″	A	Amplitude of Star or Sun	+9° 42′ 28″	−9° 42′ 28″	α Arietis, setting
		B	Corresponding altitude	3° 20′ W.	3° 10′ E.	
		C	Declination	+9° 43′ 53″	−5° 26′ 40″	
		D	Hour angles	$6^h\ 13^m\ 8^s$	$6^h\ 46^m\ 37^s$	
		E	Depression of Sun when Star was heliacal	. .	12° 30′	
		F	R.A.	$23^h\ 50^m$	$12^h\ 49^m\ 45^s$	
		G	Approximate date . .	B.C. 605, October 6		

Argos. Lat. 37° 41′ 13″.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Heræum Temple of Juno.—The later Temple close to the site of the earlier (For latter, see p. 833).	285° 59′ 20″	A	Amplitude of Star or Sun	−15° 41′ 13″	−15° 59′ 20″	Constellation Aquarius, ζ Aquarii, rising
		B	Corresponding altitude	3° E.	2° 30′ E.	
		C	Declination	−10° 28′	−11° 1′ 12″	
		D	Hour angles	$5^h\ 11^m\ 39^s$	$7^h\ 5^m\ 15^s$	
		E	Depression of Sun when Star was heliacal	. .	19° 34′	
		F	R.A.	$20^h\ 21^m\ 58^s$	$22^h\ 15^m\ 34^s$	
		G	Approximate date . .	B.C. 425, February 21		

It will be noticed that the amplitudes given amongst the solar elements of the above list in the majority of cases agree exactly with the temple's orientation, but that in a few cases—and in Athenian temples only*—a somewhat more northerly amplitude has been taken. This has been adopted from finding that if the exact orientation angle had been used the Sun's depression would not have been sufficient to allow the stars to be sufficiently well observed, but that if the Sun had risen in a line with the northern jamb of the eastern doorway or columnar opening of the peristyle (a deviation of which the amount can be fairly well defined), not only could the solar and stellar elements be harmonized, but it would have had the advantage also of giving a longer arc of solar illumination on the statue.

As an example of the way by which the elements given in the list have been arrived at, I will give a sketch of the method used in one particular case, viz., that of

* That is not reckoning the late example at Olympia (the Metroum), and the very doubtful case of Tegea when, as in its place in the list, referred to Spica.

the great Temple of Jupiter at Olympia. On the list it is shown that this temple has an orientation angle of 262° 37′ 46″, which gives the eastern axis an amplitude of 7° 22′ 14″ north. The eastern mountains subtend an angle of 2° 4′.

I assume that in the climate of Greece no star with which we are concerned in this inquiry, excepting Sirius, could be expected to be seen under ordinary circumstances heliacally at an angle less than 3° (independent of refraction) above the true horizon. I have indeed myself seen Rigel heliacally, and in the same direction as the Sun, at a lower elevation;* but allowing for variation of weather and the glow which skirts the horizon when the sun is about 10° below it, I consider the altitude of 3°, as above stated, the proper angle to take for the stars generally. When there is a mountain high enough to exclude the glow referred to, it is favourable for the detection of the star, but that is not the case at Olympia. The Sun, however, is differently situated, and in the climate of Greece can be reckoned upon to throw a strong illumination as soon as a quarter of his refracted orb is clear of the visible horizon. This at moderate altitudes allows the reduction of the apparent height of the mountain by 0° 22′.

We have then to determine the Sun's place in the case before us, having the Sun's amplitude 7° 22′ 14″, an altitude of 1° 42′, and the terrestrial latitude. Applying the formula

$$\text{Sin } \delta = \cos \text{zenith dist} \times \cos \text{colat} + \sin \text{zenith dist} \times \sin \text{colat} \times \sin \text{ampl},$$

we obtain for the Sun's declination + 6° 52′ 22″.

This, at the value of the obliquity at, say, 800 years B.C., gives for the Sun's R.A., $1^h\ 3^m\ 15^s$.

Applying the same formula for a star having the same amplitude, but with an altitude of 3°, we obtain for its declination 7° 40′.

* I made, with such opportunities as presented themselves, naked-eye observations of heliacal stars. The following appear to be the most valuable.

	Name of Star.	Magnitude.	Altitude of Star.	Sun's depression.	Difference of azimuth Sun and Star.
Sunset, April 19. At sea. Latitude about 37° 50′	ζ Argus . .	2	9° 47′	10° 49′	102°
	γ Andromedæ	2	9 0	12 0	17
Sunrise, April 26. Livadia. Latitude 38° 26′	20 Libræ . .	3	9 0	10 17	163
Sunset, May 1. At Sea. Latitude about 39° 50′	ε Canis Major	1·5	7 20	8 0	76
	Rigel . . .	1	2 40	9 48	41

The stars on the occasions above recorded were distinctly seen, and were found in the open sky—in most cases with the distraction of ship-lights about. These observations by no means show the limiting angles of visibility of heliacal stars by younger eyes looking from a darkened chamber through a narrow opening and towards points in the horizon where it would be known that the stars must rise. Three degrees appears to have been about the angle considered necessary by PTOLEMY. (See BIOT, 'Recherches sur l'Année Vague des Égyptiens.')

It is now necessary to inquire if there be any bright star or star group which, at a date consistent with archæological possibilities, would have had a declination near the above, and also such right ascension that it could also have been heliacal. At this stage of the inquiry we may find by an approximate method the time that such a star would take to pass from altitude 3° to the meridian, and this would be about $6^h\ 8^m$, and that it would require the Sun to rise from $1\frac{1}{4}$ to $1\frac{1}{2}$ hours later (that is, the Sun must be so much further from the meridian in R.A.) to enable the star to be seen.

We have therefore now to find a star of which the R.A. is approximately $23^h\ 40^m$ and the declination $+ 7° 40'$.

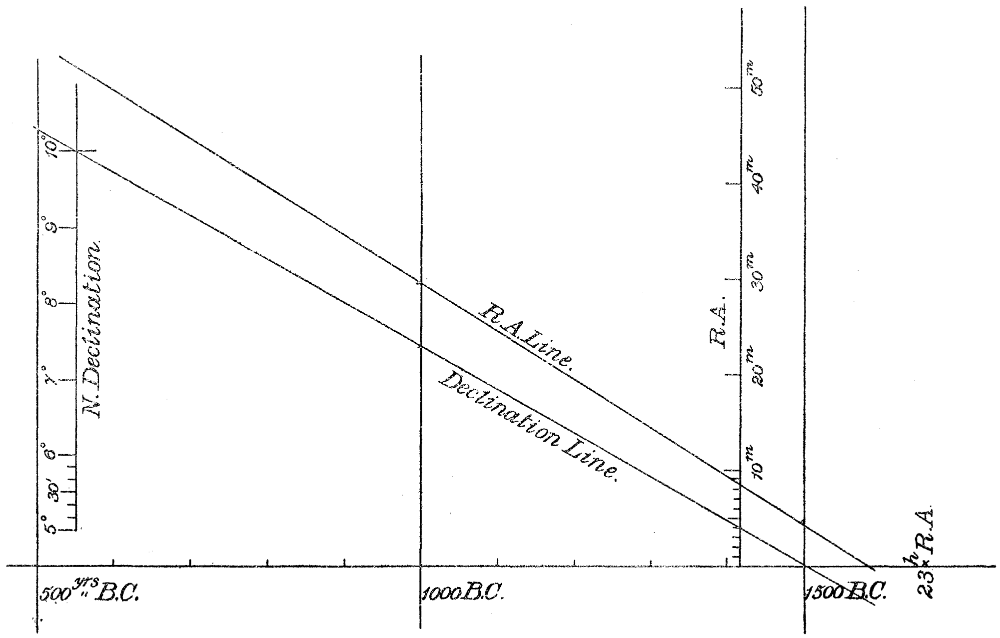
The search for the star may be made in several ways. From the R.A. and declination given above, a celestial latitude and longitude might be computed for some probable archæological epoch and recomputed into modern right ascensions and declinations, or with the latitude so obtained and the longitude adjusted for the amount of precessional movement we might refer to maps, such as those of the British Association, which show both the R.A. and declination, and the latitudes and longitudes of stars. A ready approximate method is afforded by the globe described by Mr. LOCKYER* on which the pivot can be shifted so as to suit the movements of the pole for different epochs. I have found that on a stereographic projection of the sphere, taken on the pole of the ecliptic, but showing R.A. hours and parallels of declination, the approximate places of stars as affected by precession can readily be found by marking the point under consideration, together with the straight line which coincides with the solstitial colure and the pole of the ecliptic, on tracing paper, and, keeping the latter mark superimposed, making the tracing paper revolve round the point on the projection which represents the pole of the ecliptic ; it may thus be made to indicate both the R.A. and declination at a different date, which latter also is measured by the angle through which the colure line has revolved.

In the case before us, the place representing $23^h\ 40^m$ R.A. and $+ 7° 40'$ declination on being turned about till it reached an angle of polar movement due to about 2650 years, reckoned back from 1850 A.D., rested upon the modern place of α Arietis and pointed out this star for more rigid calculation. It should be mentioned that there are in every case of intra-solstitial orientations four possible solutions of this step. The Sun's amplitude may be due either to the spring or the autumnal place, and the star might be heliacal either at rising or setting. I have tried these four possible solutions in the case of every temple of which I had the requisite data by the approximate method above described, and have never failed in one of early date to find one solution, and *in no case more than one.*

When, as in this case, we have found the star (and it should be noticed that this star—the brightest of the first sign of the zodiac and therefore most fitting for a temple of Jupiter—is also the time star to the Olympieum at Athens, and apparently

* 'Nature,' January 28, 1892.

to other temples of the same deity) it becomes necessary to find for it exact places for several epochs by the formulæ proper for precessional movement, and then it suffices to draw upon paper curves passing through the places so found; from which curves those due to intermediate dates may be taken with sufficient accuracy. This has been done on the following figure which represents the precessional movements of α Arietis.



In this diagram, years B.C. are measured horizontally from left to right. The R.A. and declination measure vertically.

Let now the hour angle of the star be taken with the approximate declination as stated above, + 7° 40′, and let also that of the Sun be computed, combining its declination of + 6° 52′ 22″ with an assumed depression below the horizon which on trial may be reasonably taken at 12°, as the star, though a bright one, is not of the first magnitude, and the horizon is comparatively low. When the difference between the two hour angles has been deducted from the Sun's R.A. to give that of the star, let the latter be compared with the places on the diagram and it will be found that the correspondences are close, though not exact—and further, that a few trials of small variations of declination point out that a very near approach can be made by making the star's declination + 8° 40′ which implies an amplitude of + 8° 38′ (not much more than 1° from the axis) and therefore well within the allowable distance. Nothing more is now required than a small addition to the Sun's depression, and a complete correspondence will be the result between the star's R.A. and its declination. 790 B.C. is the date due to that particular place on the diagram, and this has to be taken as the approximate date of the first foundation of the temple, and this coincides extremely well with the chronology of the development of Olympia. The temple now extant, however, would probably have been a rebuilding on the same lines, and 100 years or thereabouts would not have rendered the same star unfit for use as a time warner.

As respects the amount of solar depression in the above given list, I have used even with the brightest stars a minimum of 10° as the proper measure for heliacal observation.* I have ranked the Pleiades amongst the brightest stars on account of the brilliant effect upon the eye produced by concentration: but in all cases of secondary or smaller magnitudes they will be found to be combined with a greater degree of solar depression. This does not come from arbitrary assumption in the calculation. The computer has no choice in the matter beyond some slight liberty that may be taken with the amplitudes. The Sun's right ascension and the place of the star govern the solution.

Up to this point the connection has been in great measure assumed between the orientation of the temple, the sunrise, and the heliacal star. It is proposed in the remarks which follow to endeavour to justify this confidence.

I may consider it as sufficiently shown by M. BURNOUF ('Légende Athénienne'), and by Herr NISSEN in various articles published in the 'Rheinisches Museum,' and by Mr. LOCKYER in 'Nature,' that with the ancients the most approved time for adoration was the moment of sunrise. The principle prevailed not only with the Egyptians and the Greeks but also with the Romans. 'VITRUVIUS,' IV., 5, is very precise on the point; and it may also be gathered from the following passages:—

> Surgit, et ætherii spectans orientia solis
> Lumina, rite cavis undam de flumine palmis
> Sustulit, &c. VIRG. 'Æn.,' VIII.

and

> Antequam stantes repetat paludes
> Imbrium divina avis imminentum,
> Oscinem corvum prece suscitabo
> Solis ab ortu. HOR. 'Od.,' III., 27.

It is obvious that the priests would desire to have warning of the Sun's approach in time to make preparations for special functions on the great festival of the year belonging to any particular temple. Before the invention of the water-clock, or other artificial way of measuring time, the heavenly bodies at their rising or setting—the only points in their course when their positions could be accurately observed—were the only reliable time markers. The heliacal rising or setting of particular stars is referred to in many passages of ancient writers—meaning the time when the star could just be seen as it rose or set before the light of the rising Sun should be too powerful. And different periods of the year are referred to by the mention of these

* PTOLEMY appears to have adopted 11° of solar depression for Egyptian heliacal observation. But in Greece there are almost always mountains obstructing the true horizon—a circumstance greatly in favour of the observer as already noticed. (See BIOT, 'Recherches sur l'Année Vague des Égyptiens,' p. 58.)

phenomena. In the 'Agamemnon' of ÆSCHYLUS the fall of Troy is said to have taken place at the setting of the Pleiades. Two unhealthy periods of the year are intended by HORACE in the passage, 'Od.' iii., 1,

"Nec sævus Arcturi cadentis
Impetus aut orientis Hædi."

That the first beam of sunrise should fall upon the statue centrally placed in the adytum of a temple, or on the incense altar in front of it, on a particular day, it would be requisite that the orientation of the temple should coincide with the amplitude of the Sun when it rose above the visible horizon, be it mountain or plain.

That a star should act as time warner, it was necessary that it should have so nearly the same amplitude as the Sun that it could be seen from the adytum through the eastern door, if it was to give warning at its rising, or to have a similar but reversed amplitude towards the west if its heliacal setting was to be observed, and it follows that in the choice of the festival day and the corresponding orientation of the temple on these principles, both the amplitude of the Sun at its rising, and that of the star eastwards or westwards, as the case might be, would have to be considered in connection with one another.

From what has been said it is obvious that in the intra-solstitial temples the list of available bright stars and constellations is, in the first place, limited to those which lie within a few degrees of the ecliptic, and it will be found that in the list above given, and those which follow (if we omit Eleusis, where the conditions were exceptional), all but one of the stars are found in the zodiacal constellations. A very great limitation is imposed, in the second place, by one of the conditions being the heliacal rising or setting of those stars from which the selection has to be made, so that when both these combined limitations are taken into account it becomes improbable to the greatest degree that in every instance of intra-solstitial temples of early foundation of which I have accurate particulars—being twenty-eight in number, and varying in their orientation from 21° north to 18° south of the true east—there should be found a bright heliacal star or constellation in the right position, at dates not in themselves improbable, unless the temples had been so oriented as to secure this combination.

Besides these there are on the list of those I have examined seven temples, evidently of comparatively late foundation, of which two only admit of stellar time warning. The others, of which the sites were in the great cities of Athens and Ephesus, were probably at the time of their foundation within a region of artificial time measures. The use of the stars, too, may at last have become discredited on account of the discovery of the continuity of the precessional movement.

We see, then, that there is strong ground for considering the orientation of a temple with reference both to the Sun and to some time-warning star, and, especially as it will be shown, that in later temples, respecting which alone we have any information available, the solar coincidences correspond in several cases with what is known historically of the dates of the principal festivals.

We may feel satisfied that the axis of the temple shows in general the line of the Sun's approach. In the lists given above there are but three clear exceptions to this rule—exceptions already referred to.

The star, however, in the case of any temple would answer the purpose of a time-warner, provided it showed itself from the adytum at any point within the eastern opening, if rising, or the western if setting, and some amount of uncertainty may arise in settling the date of the temple's foundation from this cause—but when the solar and stellar elements are properly combined, the margin of possible error is not great, because the right ascension of the Sun can be calculated rigidly, and this determines that of the star very closely, by deducting from the Sun's R.A. the interval of time required for the heliacal observation of the star, and when once the star's right ascension is established, its declination, and the date corresponding to its place, become known.

In the majority of cases above given—about two-thirds of the number—the dates are clearly earlier than any remains at present visible, but it is not so altogether. At Athens, in the Archaic temple, there are parts of the foundations which cannot but go back to a very early date, and at the temple of Jupiter Olympius, there is a wall of rude workmanship of a date much anterior to the works of PISISTRATUS, which are themselves intermediate in date between this wall and the present Cossutian temple. The angle, also, is different from that of the remains at present visible. The remains of the earlier temple of Bacchus must also be very old. At Rhamnus, the temple of Themis has the appearance of great antiquity, and there are traces at Sunium of a structure underneath the existing temple which seem of a date not inconsistent with that which has been deduced from the orientation. At Ephesus there are foundations of three temples lying one over the other. The middle one was the work of CRŒSUS. The lowest of the three may quite well have been as early as 715 B.C., and in five examples where we have architectural remains standing, namely, the temple at Corinth, both those at Ægina, the later Heræum at Argos, and the Metroum at Olympia, I see no reason for dissenting from the dates derived from the orientation. And even in the case of the Heræum at Olympia, it may be noticed that although the date of the existing structure (unquestionably the most ancient example of temple architecture in Greece, of which any remains are standing above ground) would scarcely, consistently with architectural analogy, be placed so early as the middle of the fifteenth century B.C., yet it might have been almost coëval with the establishment of the Dorian supremacy in the Peloponnesus in the middle of the eleventh century, and if at that date it had been built parallel to the lines provided for a more ancient shrine of the orientation date, the statue might have been still illuminated by the rising Sun, preceded by the same time-warning star—Spica. Both sun and star, indeed, would have demanded a certain amount of change of amplitude, but still within the limits of the eastern opening.

In addition to the above list, is the great temple of Eleusis. Its orientation lies just within the solstitial limits. There could scarcely have been any observation of stars towards the west, as in that direction the temple is completely blocked by the terraced rock; but it may have had openings to the north and south as well as the east. I do not find any heliacal star eastwards bright enough to be of any service, but a very conspicuous one, Fomalhaut, would set towards the south in the direction of a cross axis of the temple at an epoch of about 1300 B.C., but neither is this heliacal.

There can be little doubt, however, that the star which was peculiarly connected with the worship of this temple was the great dog-star, Sirius—a star which has been shown by Mr. LOCKYER to have played a great part in the orientation of some of the Egyptian temples. The date corresponding to the rising of this star at an amplitude identical with that of the temple, would be 2100 B.C., and as the hour would be near to midnight at the time of year when the Eleusinian mysteries (as known by later records) were celebrated, we may use this circumstance with great probability to assist in the inquiry. As respects the amplitude of the star, it is not unlikely that when the temple was built, the axis, like some of the temples at Athens, was so directed that the star should first show itself towards the northern jamb of the eastern opening, as this would allow it to traverse a more extensive arc than if it rose exactly on the axis. If we assign two degrees for this deviation, the date would be 1400 B.C., and the day of the month for midnight rising September 13.

The elements so assigned are as follows:—

Eleusis. Lat. 38° 2′ 15″.

Name of Temple.	Orientation angle.			Elements.	Name of Star.
Temple of Ceres .	296° 51′	A	Amplitude	24° 51′ S.	Sirius, rising
		B	Corresponding altitude	2°	
		C	Declination	−18° 0′ 56″	
		D	Hour angles	$4^h\ 49^m\ 52^s$	
		E	R.A.	$4^h\ 15^m$	
		F	Approximate date . .	1400 B.C., September 13	

It should be observed that Sirius was not at the period under discussion favourably situated for determination of date, as derived from its precessional movement, because a small variation of amplitude and its corresponding effect upon the declination would produce a very large alteration in respect of time, and we have here no help from the sun's R.A. I think, however, we may fairly conclude that the date must have been somewhere between 1300 B.C. and 1500.

The day of the month on which the mysteries commenced in historical times is considered to have been September 16. This it will be seen is very close to the calculation derived from the midnight rising of Sirius as above given. The dates when the sun would rise on the axis of the temple would be either January 21 or November 21, which days do not seem to have had any association with the mysteries.

There remain also amongst the temples which I examined, five, of which the orientation lies between the solstitial limits, all of them apparently of late foundation, which do not appear to have any connection with heliacal stars; namely, at Athens, the Theseum, the later Erechtheum, the later Temple of Bacchus, and the existing Jupiter Olympius; and at Ephesus the latest of the three great temples of Diana. The orientation of these temples can supply no data for pointing out the year of their foundation, but it may throw light upon the month and day of their principal festivals.

The Theseum, with orientation angle 283° 6′ 2″, had the sun rising over Hymettus in the direction of its axis on March 2 or October 10. The festival of the Thesea is considered to have been held on October 8 or 9.

The axis of the later Erechtheum—orientation angle 265° 9′ 22″—was visited by the rising sunbeam on April 4 or September 7. Or, if the Sun at its rising was made to appear towards the northern door jamb, which as before observed seems to have been the arrangement in some other of the Athenian temples, and if the amplitude be increased by 2°, the days would be either April 8 or September 3. The third of September is the assigned date of a great festival—the Niceteria—held in this temple.

The later Temple of Bacchus, at Athens, of which the orientation angle is 255° 49′ 30″, would have received the first sunbeam along its axis on April 23 or August 18. That of Jupiter Olympius is 270° 5′ 2″. The sunrise dates would be March 26 or September 15. The axis of the later temple at Ephesus, of which the orientation angle is 284° 35′ 17″, would have coincided with sunrise on February 28 or October 14.

Lastly, amongst the temples which I examined I met with five examples outside the solstitial limits, temples, namely, which at no time of the year could have had a sunbeam coinciding with their axes—and with these I may associate two others which I did not visit and of which I can give no exact measures, and a site which I did visit, but where no antique remains are actually visible, namely, that of the former Temple of Venus, at Ancona.* If, as may be presumed, the present cathedral is built on the old foundations, the orientation would in this case also be extra-solstitial.

These temples were very probably arranged, as many of those in Egypt appear to have been, so as to coincide with the rising or setting of some star. In five cases of those referred to, the peculiarity of the site must have influenced the direction of the axis. I have not yet subjected any of these to sidereal discussion; the list is as follows:—

1. The great temple at Delphi, which has not yet been excavated, and where con-

* Ante domum Veneris quam Dorica sustinet Ancon. JUV., 'Sat.' IV.

sequently I was only enabled to take the bearings of certain ancient walls, which appear to have had some connection with the temple, and which cannot fail to be carefully co-related to it when the excavations under the French Archæological School are sufficiently advanced to show how the temple actually stood.

The well-known wall of the inscriptions, or rather the stylobate of the Stoà of the Athenians in front of it, has an orientation angle of 231° 34′ 31″, and the altitude of the mountain at right angles to it is 3° 10′.

2. The Doric temple at Mycenæ, which rests partly on the ruins of an archaic palace, has an orientation of 173° 20′. The mountain to the north is very near and high; that to the east I found to be 7° 44′, and that to the west 2° 40′. To the south it was not measured.

3. The Cabeirion temple, near Thebes, has an orientation angle of 186° 27′ 45″. In this temple there is a cross wall at a different angle to what it would be if square with the main axis, viz., 257° 57′ 35″, looking east. There is a clear view to the north, where the mountain's altitude is 1° 37′, but the temple is inclosed on the three other sides by near hills. The lowest is that to the east, with an altitude of 8° 38′.

4. In their search for the Athenian Agora, the German Archæological School discovered a small temple lying in the direction of the valley, between the Areopagus and the Pnyx. Its orientation angle is 317° 28′ 21″. I did not ascertain the altitude of the hills around. The clearest view would have been towards the north-west, where the altitude of Mt. Parnes would be less than 3°. It is a very small temple, and its position could not but have been determined by the valley in which it is situated.

5. The temple of Diana Propylæa at Eleusis has an orientation angle of 313° 43′ 13″. The mountain heights are much the same as those opposite the great temple already given.

6 and 7. The other two temples referred to above are those of Elateia, in Bœotia, and Vakklia, in Arcadia, near where the Ladon falls into the Alpheus. The latter temple is described as built upon the ridge of a hill.

8. The walls of the cathedral at Ancona, which, as already observed, it is reasonable to suppose rest upon the foundations of the Temple of Venus, have an orientation angle of 223° 11′ 23″. The east and west views would have been practically unobstructed.

It is quite possible that, in the case of 2, 3, 6, and 7, the Sun, at its rising, could have been admitted by an eastern doorway, as at Bassæ.

If the temples be arranged according to the heliacal stars which have been shown in the above pages to have coincided within close limits with their axes, they will be grouped as follows, in order of the dates which have been assigned to the different temples :—

		B.C.	
Spica	The Heræum of Olympia	1445	Rising star.
	Nike Apteros, Athens	1130	Setting „
	T. of Themis, Rhamnus	1092	Rising „
	„ Minerva, Tegea	1075 uncertain*	Rising „
	„ Nemesis, Rhamnus	747	Rising „
	„ Apollo, Bassæ	728	Rising „
	„ Diana, Ephesus	715	Rising „
α Arietis	Jupiter Olympius, Athens	1202	Rising „
	T. of Jupiter, Olympia	790	Rising „
	T. at Platæa	650	Setting „
	T. of Jupiter, Megalopolis	605	Setting „
	T. at the harbour, Ægina	550	Setting „
	The Metroum, Olympia	360	Setting „
The Pleiades (η Tauri)	The archaic Temple of Minerva, Athens	1530	Rising „
	The Asclepieion, Epidaurus	1275	Rising „
	The Hecatompedon, Athens	1150	Rising „
	The earlier T. of Bacchus, Athens	1030	Rising „
	T. of Minerva, Sunium	845	Setting „
Antares	Earlier Erechtheum, Athens	1070	Setting „
	T. at Corinth	770	Setting „
	T. on the Mountain, Ægina	630	Setting „
Constellation Aquarius	T. at Nemea (Jupiter)	1040	Setting „
(ζ Aquarii)	Diana Brauronia, Athens	580	Rising „
	Later Heræum, Argos	425	Rising „
γ Pegasi	T. at Kardaki, Corfu	875	Rising „
	T. of Despoina, Lycosura	650	Rising „
β Scorpii	T. of Diana, Epidaurus	780	Setting „
Sirius	T. of Ceres, Eleusis	1400	Rising „

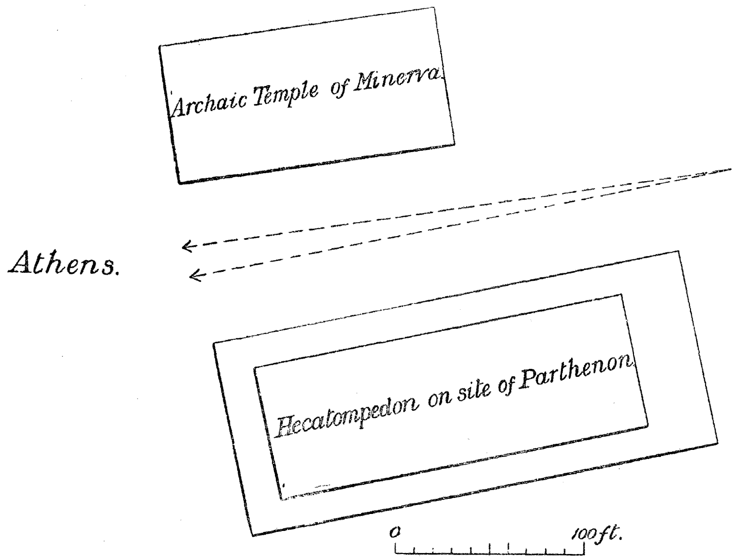
If the list be arranged according to the time of year on which the rising Sun coincided with the orientation, they would group as follows :—

Feb.	21.	Diana Brauronia, Athens.
„	„	Later T. at Argos.
Mar.	10.	Kardaki, Corfu.
„	16.	Despoina at Lycosura.
„	17.	Nike Apteros, Athens.
„	30.	Jupiter Olympius, Athens.
April	6.	T. of Jupiter at Olympia.
„	20.	Archaic T. at Athens.
„	26.	Hecatompedon, Athens.
„	29.	Earlier T. of Bacchus, Athens.
„	„	Older Erechtheum, Athens.
„	„	Asclepieion, Epidaurus.
„	„	T. of Diana, Epidaurus.
May	6.	T. at Corinth.
May	7.	T. on Mountain, Ægina.
July	27.	T. of Jupiter, Nemea.
Sept.	12.	The Heræum, Olympia.
„	13.	T. of Ceres, Eleusis.
„	17.	„ Themis, Rhamnus.
„	18.	„ Minerva, Tegea (?).*
„	22.	„ Nemesis, Rhamnus.
„	25.	„ Diana, Ephesus.
„	„	„ Apollo, Bassæ.
Oct.	6.	„ Jupiter, Megalopolis.
„	9.	T. at Platæa.
„	„	T. near harbour, Ægina.
„	„	The Metroum, Olympia.
„	21.	T. of Minerva, Sunium.

* See note, p. 817.

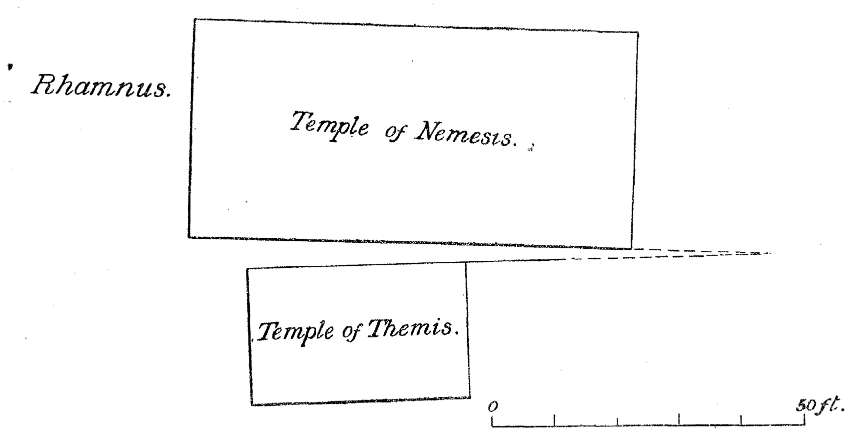
It will be seen from the above list that the dates resolve themselves almost entirely into spring and autumn festivals, as if for intercession for a favourable harvest to come, and for thanks for the harvest granted.

Fig. 1.



Block plan of the two principal temples of Minerva on the Athenian Acropolis. The northern, which was the more ancient of the two, appears to have been oriented so as to observe the Pleiades heliacally about B.C. 1500. The southern temple, which occupied part of the site of the present Parthenon, had a more northerly orientation so as to follow the more northerly declination of the same star group,

Fig. 2.



The two temples at Rhamnus, having the same cult, showing that the northern of the two, which was built later than the other, had the more southerly orientation. In this case, a star, Spica, which was changing its declination from north to south, had to be followed.

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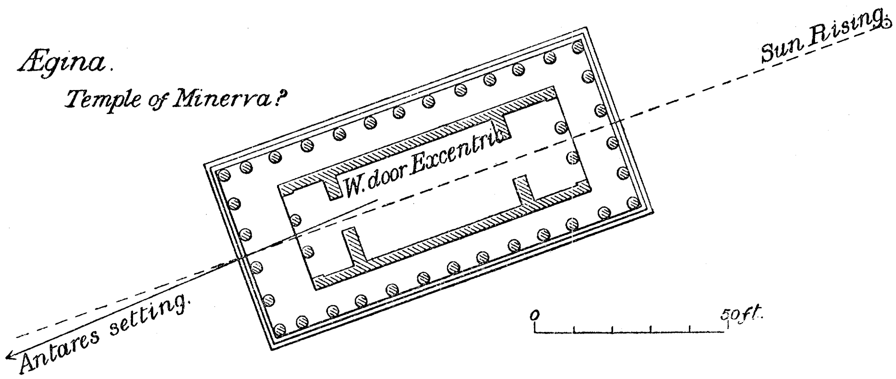
Fig. 3.



Plan of the temple on the mountain at Ægina. In this case, a setting star having a more southerly amplitude than the orientation had to be observed. The western door of the cella of the temple is built considerably out of the centre so as to enable the star to be observed from the adytum.

[Since this paper was first communicated to the Society, I have examined the five cases of extra-solstitial temples, of which I had taken particulars, and have found in them much to confirm the general theory.

To begin with two that stand nearly north and south—one being the Doric temple, built on the Acropolis of Mycenæ, at some period much subsequent to the great Cyclopean walls (for it is built on the ruins of the palace of the ancient kings) and the other, the Cabeirion temple to the westward of Thebes, and about three miles distant from it.

It may be presumed that both these temples had eastern doorways for the admission of the Sun at its rising, to the interior of the cella, as was the case at Bassæ, although the evidence which was preserved at Bassæ is wanting in these two examples; but at Mycenæ, at any rate, it may be inferred from the position of the mountains round about the temple which would have blocked any stars in the directions of the axis, both north and south, whilst the eastern flank is much less obstructed. Working upon that theory, we may obtain from the orientation the following solution, which agrees very well with what is known respecting the history of the place.

Mycenæ. Lat. 37° 43′ 20″.

Orientation angle of assumed eastern doorway.			Stellar elements.	Solar elements.
263° 19′ 40″	A	Amplitude	+ 6° 40′ 20″	+ 6° 40′ 20″
	B	Corresponding altitude . .	8°	7° 22′
	C	Declination	+ 10° 8′ 44″	+9° 45′ 51″
	D	Hour angle	$5^h\ 50^m\ 25^s$	$7^h\ 28^m\ 49^s$
	E	Depression of Sun	. .	11°
	F	R.A.	$23^h\ 53^m\ 43^s$	$1^h\ 32^m\ 7^s$
	G	Approximate date	B.C. 540	
			α Arietis rising	

The Cabeirion temple, near Thebes, is surrounded by hills, except towards the north. Of the other three sides, the eastern is least obstructed, so that the Sun could enter the temple by an eastern door about half-an-hour after sunrise. In this direction, however, I can find no suitable star which could be combined with the Sun heliacally at any permissible epoch—and this, whether it be sought at right angles to the axis of the temple, or in the direction of the cross wall which has been mentioned. But a time-warning star, northwards on the true axis of the temple, can be found, and a very significant one it is, namely, γ Draconis. This star seems to have been a favourite at the Egyptian Thebes—as well as other places in that country—as has been shown by Mr. LOCKYER, in 'Nature,' for February 18, 1892, and in the 'Nineteenth Century,' No. 185, p. 46. It is well-known that the Bœotian Thebans called their city "The City of the Dragon," claiming their descent from the fabled Dragon's teeth sown by their founder. In this temple, therefore, we have astronomic confirmation of the tradition that CADMUS introduced the worship of the Egyptian as well as that of the Phœnician deities.

As γ Draconis is only a second magnitude star, it is more likely to have been used as a time-warner, than for such purposes as the more brilliant stars may be supposed to have been used at dead of night for producing a mysterious glow by reflection from polished surfaces according to the hint given by HERODOTUS when speaking of a temple at Tyre :* "Καὶ ἐν ἀυτῶ ἦσαν στῆλαι δυό, ἡ μὲν χρυσοῦ ἀπέφθου ἡ δὲ σμαρὰγδου λίθου, λάμποντος τὰς νύκτας μέγαθος." But, although this might have succeeded with the light from Sirius, Arcturus, or Capella, γ Draconis is more likely to have waited on the Sun as a time-warner. If so, we may base our calculations on its first appearance at the western limit of the north opening, thus anticipating the actual orientation angle by about two degrees. This would take place shortly after the lower transit of

* 'HEROD.,' Book II., p. 44.

the star—below the pole—for at the epoch we are considering, it would not have dipped below the horizon, as it does now. The elements would be as follows :—

Thebes. Lat. 38° 19′ 30″ N.

Orientation angle of assumed eastern doorway.			Stellar elements.	Solar elements.
276° 27′ 45″	A	Amplitude	+ 85° 50′	− 6° 27′ 45″
	B	Corresponding altitude	3°	8° 20″
	C	Declination	+ 54° 28′ 13″	+ 0° 21′ 12″
	D	Hour angle	..	6^h 41^m 28^s
	D′	In case of star reckoned from lower transit	0^h 28^m 41^s	..
	E	Sun's depression	..	11°
	F	R.A.	16^h 46^m 50^s	11^h 56^m 45^s
	G	Approximate date	1160 B.C., September 20	
		γ Draconis rising after transit below the pole		

As respects the time of year, the date is suggestive, since it agrees almost exactly with that of the celebration of the Eleusinian mysteries.

The remaining three of the five temples in this group cannot have been solar temples at all, as their orientation lies outside the solstitial limits; neither could the sunrise have been admitted at an eastern doorway. The question to be considered is whether there is reasonable probability of a bright star having been used in the manner suggested above and explained by the passage from Herodotus there quoted and further confirmed by parallel cases in Egypt. It seems essential to a solution of this character that the star which is found to fit the orientation should be among the most brilliant.

At Eleusis, besides the Temple of the Great Mysteries, there is the Temple of Diana Propylæa, of which the orientation angle is 133° 43′ 13″, or 313° 43′ 13″, according as we take the axis at its north-west or south-east direction. To the south-east no suitable star offers itself. In the other direction there are two, both first magnitude stars, namely, Arcturus and Capella. I give the elements of both; but, for a reason to be mentioned, I think Capella, which almost equals Arcturus in brightness is the most probable.

Eleusis. Lat. 38° 2′ 15″.

Orientation angle.					
133° 43′ 13″ or 313° 43′ 13″	A	Amplitude	+ 43° 43′ 13″	A	+ 43° 43′ 13″
	B	Corresponding altitude	4° 30′	B	4° 30′
	C	Declination	+ 36° 13′ 39″	C	+ 36° 13′ 39″
	D	Hour angle	$7^h\ 46^m\ 33^s$	D	$7^h\ 46^m\ 33^s$
	E	R.A.	$12^h\ 9^m\ 0^s$	E	$1^h\ 54^m\ 49^s$
	F	Approximate date	770 B.C., July 16–17	F	1010 B.C., Feb. 18-19
		Arcturus setting midnight			Capella setting midnight

The *Little Mysteries*, Eleusinian, are considered to have been celebrated about the 19th February, which exactly agrees with the appearance of Capella at midnight on the axis of this temple. The orientation day of the solar Temple of *Diana Brauronia* at Athens has been shown to have been the 21st of the same month.

At Athens there is a small temple having this kind of orientation lately discovered by the German archæologists in searching for the ancient Agora. It also points nearly north-west and south-east. This orientation appears to admit of a solution similar to that of the temple at Eleusis last mentioned, through Arcturus setting about B.C. 700, but I reserve the list of the elements as the local altitudes require confirmation.

The last temple on the list is that of the presumed Sanctuary of Venus at Ancona. The commanding site occupied by the mediæval Duomo is stated to have been that of the ancient temple, and there seems no reason to doubt this tradition. In that case the walls of the church would probably rest upon the old foundations. It seemed, therefore, worth while to examine their orientation, which gave for this angle 223° 11′ 23″, which is equivalent to a northern amplitude of 46° 48′ 37″, and, combining this with the latitude and the usual altitude for a star, elements are obtained as below.

Ancona. Lat. 43° 37′ 7″.

Orientation angle.				
223° 11′ 23″	A	Amplitude	46° 48′ 37″	Arcturus rising
	B	Corresponding altitude	3°	
	C	Declination	+ 34° 16′ 38″	
	D	Hour angle	$8^h\ 16^m\ 50^s$	
	E	R.A.	$12^h\ 15^m\ 20^s$	
	F	Approximate date	620 B.C.; if midnight, Nov. 16–17	

Besides the temples already mentioned, I have examined, with the help of approximate data, several other examples, especially from Sicily and Naucratis. The indications appear to be favourable, but, as I have not sufficiently exact material to work upon, it seems better not to make any further reference to them here.—April 17, 1893.]

ADDENDUM.—August 4, 1893.

Since the date on which I brought the above list before the Royal Society, I have received, through the kindness of Dr. WALDSTEIN, the relative position of the earlier and later Heræum at Argos, from which the following elements have been deduced for the former :—

Argos. Lat. 37° 41′ 16″.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Ancient Argive Heræum	287° 13′ 20″	A	Amplitude of Star or Sun	−15° 4′ 58″	−17° 13′ 20″	Antares, rising
		B	Corresponding altitude	3° 0′ E.	2° 30′ E.	
		C	Declination	−10°	−11° 58′ 24″	
		D	Hour angles	$5^h\ 13^m\ 4^s$	$6^h\ 15^m\ 40^s$	
		E	Depression of Sun when Star was heliacal	..	10°	
		F	R.A.	$12^h\ 51^m\ 48^s$	$13^h\ 54^m\ 24^s$	
		G	Approximate date . .	B.C. 1760		

Instead of the elements given above (p. 812) for Tegea, I propose an amendment based on the following considerations, namely :—In the plan published by the German archæologists ('Mittheilungen des Archaeol. Instituts,' 1883) are shown some foundations, named "*Antikes Fundament*," close to the eastern front of the main temple, which make an angle—by measurement, 4° 11′—in a more southerly direction than the other. Architectural fragments, also, of a very ancient character, were found. Judging from this, the later temple appears to have been built so as to follow the same star as the earlier, the elements being as follows :—

Tegea. Lat. 37° 27′ 45″.

Name of Temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of Star.
Old Temple of Minerva	271° 23′ 30″	A	Amplitude of Star or Sun	+3° 0′	−1° 23′ 30″	α Arietis, rising
		B	Corresponding altitude	3° 0′	4° 0′ 0″	
		C	Declination	+4° 12′ 15″	+1° 19′ 52″	
		D	Hour angles	$5^h\ 57^m\ 45^s$	$7^h\ 9^m\ 23^s$	
		E	Depression of Sun when Star was heliacal	. .	12° 12′	
		F	R.A.	$23^h\ 0^m\ 22^s$	$24^h\ 12^m\ 0^s$	
		G	Approximate date . .	B.C. 1580,	March 22-23	
Later Temple of Minerva	267° 12′ 30″	A	Amplitude of Star or Sun	+6° 31′ 6″	+2° 47′ 30″	α Arietis, rising
		B	Corresponding altitude	3° 0′ E.	2° 22′ E.	
		C	Declination	+7° 0′ 0″	3° 39′ 12″	
		D	Hour angles	$6^h\ 6^m\ 21^s$	$7^h\ 14^m\ 13^s$	
		E	Depression of Sun when Star was heliacal	. .	12° 30′	
		F	R.A.	$23^h\ 25^m\ 20^s$	$0^h\ 12^m\ 30^s$	
		G	Approximate date . .	B.C. 1080		