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On the Orientation of Certain Greek Temples and the Dates of Their Foundation Derived from Astronomical Considerations, Being a Supplement to a Paper on the Same Subject Published in the Transactions of the Royal Society in 1893

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III. *On the Orientation of certain Greek Temples and the Dates of their Foundation derived from Astronomical Considerations, being a Supplement to a Paper on the same subject published in the Transactions of the Royal Society in* 1893.

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THE paper now presented to the Royal Society is a sequel to one on the same subject read here on April 27, 1893, and published in the Transactions for that year. In that paper the subject was explained at some length; it will, therefore, be unnecessary in this to repeat more than a very few explanatory observations.

The aim of this inquiry is to deduce the date of the foundation of a Greek (or Egyptian) temple from its orientation, but I confine myself entirely to Greek temples, in which, however, the same practice was followed which had previously been reduced to a system in Egypt (*vide* 'Dawn of Astronomy,' by Sir J. N. LOCKYER). Almost all the temples in Greece and its Colonies had an Easterly frontage, and the principal religious function in each temple took place on the morning of the day when the sun, as it rose above the visible horizon, shone through the open Eastern door directly upon the sanctuary, where there was usually a statue of the deity in the centre. As some time was requisite for the priests to prepare for the ceremony, the orientation of the temple was so directed as to combine with the sunrise the previous heliacal rising or setting of some conspicuous star which could also be observed from the sanctuary. In the absence of clocks the heliacal rising or setting of stars was very greatly observed by the ancients—the meaning of the term being that the star, when very slightly above the horizon, should just be visible in the twilight, before being extinguished by the dawn. The angle of the orientation depended primarily on the time of year chosen for the principal festival, but it would be liable to a slight modification for the sake of combining an heliacal star with the sunrise, and it is the latter consideration which offers the means of determining the date of foundation, because the stars, owing to the precession of the equinoxes, are affected by a slow, but steady movement, which alters the amplitude, as it is called, of their rising or setting—viz., the angular distance from the true East or West as the case may be, and which is reckoned positive if towards the North, and negative if towards the South.

A journey to Greece and my return by way of Calabria and Sicily during the spring of 1896 has enabled me to add the orientations of a considerable number of Greek temples to the list presented to the Society in 1893. The majority of these new examples are not indeed from Greece proper but from its Colonies in Italy and Sicily, but they conform to the same general law.

Whilst at Athens I occupied a room commanding an uninterrupted view of the Eastern sky, over the ridge of Mount Hymettus, which, although the weather was by no means exceptionally fine, enabled me to obtain a good many observations of heliacally rising stars; from which I select the following as best worth recording.

Sunrise stars seen at Athens in 1896.

Date.	Name of star.	Magnitude.	Altitude.	Depression of sun below true horizon.	Difference of azimuth between star and sunrise point.	Remarks.
March 19	Mars	= 1·3	8° 30′	13° 0′	30°	Planet brilliant, but θ Capricorni (4th mag.) about 3° distant from ♂, not seen with the naked eye.
" 23	"	"	5 56	16 53	29	
" 23	α Aquarii	3·2	10 15	14 59	9	Seen distinctly.
" 25	"	"	14 37	11 42	10	Seen without doubt, but near the limit of *my* vision.
" 25	Mars	= 1·3	13 5	8 45	35	An easy object.
April 12	γ Pegasi	3	7 30	10 57	0	Doubtful.

Of this last I must observe that after finding it with the help of an opera glass I could only say that I fancied I glimpsed it with the naked eye, but it was so bright in the glass that I was of opinion that a younger sight than mine might have seen it. At the same time it ought, I think, to be judged too near the limit of visibility to warrant the use of third magnitude stars *at rising* with less than twelve degrees of solar depression. This star does occur among the orientation stars, but always when rising heliacally, with the sun at least as deeply depressed as that.

Sunset Stars.

On April 21, at sea between Corfu and Brindisi, I saw the Pleiades. Altitude of η Tauri, 10° 5′. Depression of sun, 10° 50′, and 7° difference in azimuth from the sunset point. The constellation was undoubtedly seen, but not easily.

It is obvious that in average weather the visibility of rising or setting stars in twilight must depend upon their intrinsic brightness, and on the depression of the sun, as well as on the altitude of the star; and I have invariably found that when the heliacal rising of a star of decidedly less than the first magnitude has been one of the elements of an orientation, the conditions require that the sun must have been depressed to the extent of at least 11°. This view of the matter agrees very well with such actual observation as I have been able to make. In 1892 I saw Rigel setting after sunset at 2° 40′ altitude, the sun being 9° 48′ below the horizon. In March last I saw Mars easily at his rising before sunrise, altitude 13° 5′, the sun being 8° 45′ depressed. The star magnitude of Mars at that time was about 1·3 In 1892 I had seen Antares in the morning, at an altitude of about 16°, when the sun was not more than 7° 40′ below the horizon. On an evening of the same year, I saw γ Andromedæ, second magnitude, at an altitude of 9°, when the sun had sunk to 12°. The conclusion I have come to is that (1) a first magnitude star in fair average weather in Greece or Italy could be seen, when rising heliacally, at an altitude of 3°, the sun being 10° below the horizon; (2) that a second magnitude star should require an altitude of 3° 30′ with the sun 11° depressed; but that for a third magnitude star the sun's depression should not be less than 13°, and consequently I feel that in the elements of orientations in my former paper, I had over-estimated the *heliacal* visibility of the Pleiades in treating them as equivalent to a first magnitude star. I have, since then, given a good deal of attention to this constellation. It is true that I have recorded one instance when it was seen with the sun depressed 10° 50′, but the considerable altitude of the Pleiades, 10°, was then in their favour, and I have not had the opportunity of observing them heliacally at a lower altitude. But, for the following reasons, I cannot assign to this constellation for the purpose of this inquiry, a greater heliacal value than that of a second magnitude star. When the twilight is at all luminous, or when in the neighbourhood of the moon, η Tauri seems to be shorn of the glory which surrounds it in a clear sky, when the constellation catches the eye as readily as a first magnitude star; and again, if viewed with strongly magnifying spectacles, the dispersed light seems very much inferior to that given out by Aldebaran. I am, therefore, fully persuaded that a second magnitude value for orientation purposes is the right value. I have, therefore, recalculated the elements of orientation of those temples in the first list, into which the *rising* of the Pleiades has entered, with the following results, viz.:—

Athens.—The archaic Temple of Minerva	B.C.	2020	instead of	1830.*
The Hecatompedon	,,	1495	,,	1150.
The earlier Temple of Bacchus	,,	1180	,,	1030.
Epidaurus.—The Asclepicium	,,	1370	,,	1275.†
And in the case of a second magnitude star (α Arietis) to be observed heliacally at an altitude of 3° 30′ instead of 3°:—				
Tegea.—The older temple	,,	1660	,,	1580.
The later ,,	,,	1140	,,	1080.

* In the first paper this date is given as 1530. It should have been 1830.

† As the star's altitude, owing to the mountain opposite, was considerable, viz., 7°, the sun's depression is taken at 10° 30′ instead of 11°.

With respect to the temple near Thebes, published in the former list, p. 831, some magnetic observations have been sent me which show an orientation differing by about 90° from that which I had deduced from my observations. The latter are perfectly consistent amongst themselves, but as I cannot affirm the impossibility of some accidental error, it seems best to withdraw that temple from the list, at least for the present.

The order in which the examples given below are placed, is simply that in which they were examined.

In the elements which follow, the rules which have been observed with respect to the sun's depression and the altitude of the stars, when heliacal, are generally in accordance with the remarks made above on the visibility under such circumstances of the different magnitudes. In some cases the altitudes are affected by the height of the visible horizon. The propriety of these rules appears to be strengthened by the statement of BIOT, as derived from PTOLEMY, in his 'Recherches sur l'Année Vague des Égyptiens,' p. 53, namely, that in Egypt the sun's depression for heliacal purposes was considered to be 11°. And as it has been shown by Sir J. N. LOCKYER in 'The Dawn of Astronomy' that such stars as α Columbæ and γ Draconis were included among those used for the Egyptian temples, 11° would be very suitable for a general rule; although so deep a depression would be unnecessary for a star of the first magnitude, as I have personally noticed in Greece. In a great many cases I have added the effect produced upon the dates by the variation of some of the elements. But the dates which follow the rule I believe to be the most probable, as well as the most systematic. The calculations have all been carried out to seconds of arc and time, but the results as entered, are restricted to the nearest minute. The years of the dates of the temples can, of course, be only considered as approximate; relatively, however, they may be more implicitly trusted. The days of the month given are less uncertain, as they depend upon the sun's place, which results immediately from the orientation. It is an important element, as marking the time of year of the principal festivals.

As respects the identification of the stars there is seldom much uncertainty. In the first place, for solar temples the possible stars are so few. Thirteen stars and two constellations, the Pleiades and Aquarius, make up the whole list of those that are both bright enough and near enough to the ecliptic to be seen heliacally in connection with the sun through the narrow eastern or western openings; and six of the thirteen stars, including two of the brightest, viz., Aldebaran and Regulus, do not appear to have been used.

In the former paper, p. 819, I described briefly some of the methods which may be followed in the search for the star. That which I have myself adopted is here rather more fully explained. On a stereographic projection of the sphere, taken on the pole of the ecliptic, using a mean obliquity, the pole of the equator is also shown, with R.A. hour-lines and parallels of declination, and upon it also the principal available stars, taking 1850 as the standard year, are plotted down. On this I lay a sheet of tracing paper with a straight line drawn upon it, and in the first position placed so as to coincide with the solstitial colure of the projection. Then, having found for any particular temple, by calculation from the orientation measures, the sun's declination and the corresponding vernal and autumnal places, I mark two points on the tracing paper having the same parallel of declination as the sun, but with their right ascensions less by the difference of the hour angles of the two bodies—for a first trial one hour's difference may generally be taken. I then turn the tracing paper round upon the pole of the ecliptic as a centre, following the direction of the hours of R.A. on the projection, until the straight line above-mentioned having started from the solstitial colure, makes an angle with it, corresponding to a suitable time within archæological limits. If, during that operation, one of the points marked as above, falls very near to one of the stars on the projection, it may be presumed that that star now occupies the place both in R.A. and declination of the heliacal star sought for, and has then to be examined more minutely. If the coincidence is so close that an adjustment of the amplitude within the narrow limits of the field of view will make it exact, it will give a solution of the problem for an heliacally rising star. Should, however, no star be found within range, search must be made in an almost identical manner for a setting star. (I have been, however, accustomed to search for a setting star in all cases, even after finding a suitable rising one.) The difference between the two cases will be, that when a setting star has been used its R.A. will differ from that of the sun by the sum of the sun's hour angle added to that of the star, and the declination will, in general, have a different sign from that of the sun.

Although, in working out the former list with these four lines of trial, in no case more than one solution was to be found—in the trials for the present list, in the case of two temples (viz., temple A at Selinus (p. 62), and that attributed to Minerva at Syracuse), the claims of more than one star, found in the preliminary search, have had to be considered. The former temple could have agreed either with the setting of Spica, the setting of α Arietis, or the rising of γ Pegasi. The first, however, was found to be quite inadmissible from its date, 1400 B.C., which would reach back far beyond any other Sicilian example. α Arietis would be acceptable for date, but I give the preference to γ Pegasi; on the ground that the two temples, called C and D, close adjoining, are evidently following the movement of α Arietis and are adapted for autumnal festivals; whereas γ Pegasi would provide for one in the spring, and is quite as acceptable in respect of date. In the case of the temple at Syracuse, α Arietis had to be considered as well as Spica—both rising—but the derived date (the former about 400 years earlier than the latter) as well as the greater brilliancy of the star, give Spica decidedly the preference. Besides these two temples I have met with no other uncertainties of this nature, and the two lists contain all the temples of which I have obtained sufficiently complete particulars, with the exception of three, namely, the Theseum, and the later temple of Bacchus at Athens, and the temple, as re-built, of Jupiter Olympius, and the last re-building at Ephesus, which will be mentioned in a group of temples of late foundation at the end.

The elements of orientation of four very small temples at Athens, additional to the former list, are given below. Two of them—both in the precincts of Dionysus ἐν λίμναις, recently explored by the German archæologists—are so placed that they could have had no connexion with the rising sun. The orientation of one of them is extra solstitial, and both are interfered with by high ground towards the east. It is, therefore, reasonable to inquire whether they might belong to the class of temples in which the midnight appearance of one of the brighter stars at their rising or setting at a north-westerly or south-westerly door was looked for. The first on the list was well provided for in this respect by Arcturus. The second by Antares. The date of the latter seems early, but not earlier than some of the other sanctuaries at Athens.

Athens.—Latitude 37° 58′ 20″.

Name of temple.	Orientation angle.			Elements of star.	Name of star.
Lower temple Dionysus ἐν λίμναις	317° 28′	A	Amplitude	+ 44° 28′ N.W.	Arcturus setting
		B	Corresponding altitude	3°	
		C	Declination	+ 35° 43′	
		D	Hour angle	$7^h\ 35^m$	
		E	R. A.	$12^h\ 5^m$	
		F	Approximate date .	850 B.C., July 19	
Upper temple Dionysus ἐν λίμναις	250° 30′	A	Amplitude	− 16° 30′ S.W.	Antares, setting
		B	Corresponding altitude	3°	
		C	Declination	− 11° 2′	
		D	Hour angle	$5^h\ 10^m$	
		E	R. A.	$13^h\ 2^m$	
		F	Approximate date .	1700 B.C., June 20	

The other two Athenian examples are ordinary solar temples. The first on the list is a small temple near the Olympieium and a little to the south of it, which has been very recently discovered.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Dedication unknown	274° 27′	A	Amplitude of star or sun	+ 1° 14′ E.	− 4° 27′ E.	Spica, rising
		B	Corresponding altitude	5° 20′	4° 42′	
		C	Declination . . .	+ 4° 17′	− 0° 36′	
		D	Hour angles . . .	$5^h\ 46^m$	$6^h\ 49^m$	
		E	Depression of sun when star heliacal	..	10°	
		F	R. A.	$11^h\ 3^m$	$12^h\ 6^m$	
		G	Approximate date .	780 B.C.,	Sept. 23	

The ancient Asclepieium.—There are remains of two temples very near each other in the same precinct. The foundations only remain. Those of the later temple are insufficient to supply the angle, but it was probably parallel to the adjacent stoa—if so the angle was 263° 33′, and the axis of the temple would have followed the precessional change of α Arietis at a date of about 140 years later than the other, which would agree with the architecture of the stoa.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Ancient temple of Esculapius.	264° 27′	A	Amplitude of star or sun	+ 9° 24′ E.	+ 5° 33 E.	α Arietis, rising
		B	Corresponding altitude	4°	3° 25′	
		C	Declination . . .	+ 9° 52′	+ 6° 28′	
		D	Hour angles . . .	$6^h\ 10^m$	$7^h\ 18^m$	
		E	Depression of sun when star heliacal	..	11	
		F	R. A.	$23^h\ 52^m$	$0^h\ 59^m$	
		G	Approximate date .	560 B.C.,	Apr. 5	
If the sun's depression had been 12°, the derived date would be 720 B.C.						

On revisiting the Heræum of Argos, I was enabled to measure the orientation of the older temple from the foundations of the actual cella wall, and found that the angle differed only slightly from what I had deduced for it in 1893 (see p. 833 of the former paper).

Near Argos.—Latitude 37° 41′ 10″.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
The ancient Heræum	287° 50′	A	Amplitude of star or sun	— 15° 33′ E.	— 17° 50′ E.	Antares, rising
		B	Corresponding altitude	3°	2° 49′	
		C	Declination . . .	— 10° 22′	— 12° 14′	
		D	Hour angles . . .	$5^h\ 12^m$	$6^h\ 13^m$	
		E	Depression of sun when star heliacal	. .	10°	
		F	R. A.	$12^h\ 56^m$	$13^h\ 57^m$	
		G	Approximate date .	1830 B.C.,	Oct. 24	

Variations:
- Star's altitude 3°, sun's depression 11°, date 1900
- ,, ,, 4°, ,, ,, 10°, ,, 1900
- ,, ,, 4°, ,, ,, 11°, ,, 1980

The foundations of the Temple of Apollo at Delphi have now been fully explored by the French archæologists, and there is evidence, both historical and structural, of the temple having been rebuilt—and, as it appears, rebuilt nearly, but not exactly, on the same site as before. Many fragments of an older structure have been used in the existing basement, but they are built on a line differing by about 3° from what seems to have been the original orientation, which was presumably parallel to the terrace wall—namely, the well-known wall of polygonal masonry covered with inscriptions. The orientation angle of this wall is 231° 17′, and that of the present temple 227° 53′.

The peculiar situation, a narrow ledge of moderately sloping ground on a mountain side, in a nook formed by two spurs of Parnassus, evidently determined the orientation of the temple; but this is so completely extra-solstitial, that at no period of the year could the rising sun shine along the axis. Moreover, one of the two poetic summits of the mountain, together with an eminence on the left bank of the Pleistus, preclude any sunrise illumination upon the temple for considerably more than half the year, and a favourable gap does not occur till about 12° of south amplitude, where the rising sun can surmount the hills at an altitude of 3°. The western view is less impeded: a sloping line of ground opposes itself to the axis of the present temple, at an altitude of about 3°, or, if looking parallel to the inscribed wall, about 3° 30′. It is evident, therefore, that for any solar or stellar theory on the orientation of this temple the conditions are unusually complicated. At Bassæ (*vide* p. 815 of the former paper on this subject) the temple lies very nearly north and south, but there was an eastern door to the sanctuary to admit the sunrise at right angles to the axis. In a few instances in Greece (more frequently in Egypt), when the orientation is extra-solstitial, it can be traced to the rising or setting of a first magnitude star. None of these, however, are available in this case. Sirius would, indeed, have transited the western axis, but at too great an altitude to lend any probability to the hypothesis; and it seems almost self-evident that no satisfactory explanation could be made for Apollo's temple without the sun, even though the rule may have to be somewhat exceptionally treated.

At Bassæ, as we have seen, the eastern door admitted the sunrise at right angles to the axis of the temple: at Delphi, assuming the case of an earlier temple parallel to the inscribed wall, the sunrise would strike the flank at an angle of 51° instead of 90°. At that angle seven-ninths of any opening prepared to receive it would still be available, and the oblique light so thrown would be quite as effective as, or more so than, the direct. Assuming, then, from the abundance of evidence drawn from ordinary cases, that this exceptional temple would have followed in the main the general rule, we may proceed to examine whether any suitable star can be found which, at its setting in the south-west in the direction of the axis of the temple, would have given the proper warning of the sun's approach. β Lupi, of the third magnitude, is such a star, conspicuous enough by itself as a setting star, but the more so on account of its neighbour, κ Centauri, less than a degree apart, and of not much inferior brightness. The elements would be as follows :—

Delphi.—Latitude 38° 27′ 33″.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Ancient temple of Apollo	231° 17′	A	Amplitude of star or sun	— 40° 29′ S.W.	— 12° E.	β Lupi, setting
		B	Corresponding altitude	3° 30′	3°	
		C	Declination . . .	— 28°	— 7° 39′	
		D	Hour angles . . .	$3^h\ 57^m$	$6^h\ 43^m$	
		E	Depression of sun when star heliacal	..	13° 4′	
		F	R. A.	$12^h\ 9^m$	$22^h\ 49^m$	
		G	Approximate date .	970 B.C.,	March 1.	
Later temple of Apollo	227° 53′	A	Amplitude of star or sun	— 42° 55′ S.W.	— 12° S.W.	β Lupi, setting
		B	Corresponding altitude	3°	3°	
		C	Declination . . .	— 30°	— 7° 39′	
		D	Hour angles . . .	$3^h\ 50^m$	$6^h\ 34^m$	
		E	Depression of sun when star heliacal	..	11° 23′	
		F	R. A.	$12^h\ 24^m\ 30^s$	$22^h\ 49^m$	
		G	Approximate date .	630 B.C,	March 1	

It will be seen that the star's amplitude agrees very closely with the orientation angle of the existing foundations, and the divergence of line in the two temples is accounted for, as in so many instances, by the movement of the star.

Calabrian Greek Temples.

At Taranto there is a fragment of a Doric temple of which two columns only are known to exist with their foundations, but they are in sufficient preservation to give measurements for orientation, and from these I deduce the following elements. The remains themselves have an archaic appearance suitable to the date arrived at below.

Taranto.—Latitude 40° 28′.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Dedication unknown	294° 25′	A	Amplitude of star or sun	−25° 9′ E.	−24° 25′ E.	Antares, rising
		B	Corresponding altitude	3°	1°	
		C	Declination . . .	−16° 46′	−17° 39′	
		D	Hour angles . . .	$4^h\ 43^m$		
		E	Depression of sun when star heliacal	. .	10°	
		F	R. A.	$13^h\ 55^m$	$15^h\ 4^m$	
		G	Approximate date .	640 B.C.,	Nov. 10	
If the sun's depression had been 11° the derived date would be 730 B.C.						

Metapontum.—Latitude 40° 23′.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Foundations near San-Sansoni. Dedication unknown	306° 39′	A	Amplitude of star or sun	+36° 18′ W.	−35° 27′ E.	β Geminorum, setting
		B	Corresponding altitude	4°	3°	
		C	Declination . . .	+29° 38′	−23° 46′	
		D	Hour angles . . .	$7^h\ 29^m$	$5^h\ 31^m$	
		E	Depression of sun when star heliacal	. .	10°	
		F	R. A.	$5^h\ 2^m$	$18^h\ 2^m$	
		G	Approximate date .	610 B.C.,	Dec. 21	
If the sun's depression had been 11° the derived date would be 760 B.C.						

Metapontum.—Latitude 40° 27′.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
The temple with 15 columns	276° 57′	A	Amplitude of star or sun	−1° 17′ E.	−6° 57′ E.	γ Pegasi, rising
		B	Corresponding altitude	4°	0	
		C	Declination . . .	+1° 37′	−5° 17′	
		D	Hour angles . . .	5^h 44^m	6^h 50^m	
		E	Depression of sun when star heliacal	. .	13°	
		F	R. A.	22^h 7^m	23^h 12^m	
		G	Approximate date .	580 B.C.,	March 6–7	
With solar depression 14° the derived date would be 680 B.C.						

Of the celebrated temple of Juno Lacinia, on Cape Colonna, near Croton, some foundations of the cella wall remain, and one Doric column of fine proportion is still standing, but very precariously, on the very edge of the sea cliff, which is continually falling away.

Near Croton.—Latitude 39° 1′ 48″.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Juno Lacinia	267° 26′	A	Amplitude of star or sun	+6° 45′ E.	+4° 34′ E.	α Arietis, rising
		B	Corresponding altitude	3° 30′	0	
		C	Declination . . .	+7° 27′	+3° 32′	
		D	Hour angles . . .	6^h 6^m	7^h 9^m	
		E	Depression of sun when star heliacal	. .	11°	
		F	R. A.	23^h 29^m	0^h 32^m	
		G	Approximate date .	1000 B.C.,	March 28	
In the above elements the sun's amplitude is that of the northern edge of the eastern opening, as appears to have been used in some other cases. With the same amplitude, and depression 11° 44′, the date would be 1120 B.C. If the sun had the amplitude of +2° 34′, viz., that of the temple's axis, the depression being 11°, the derived date would be 1280 B.C.						

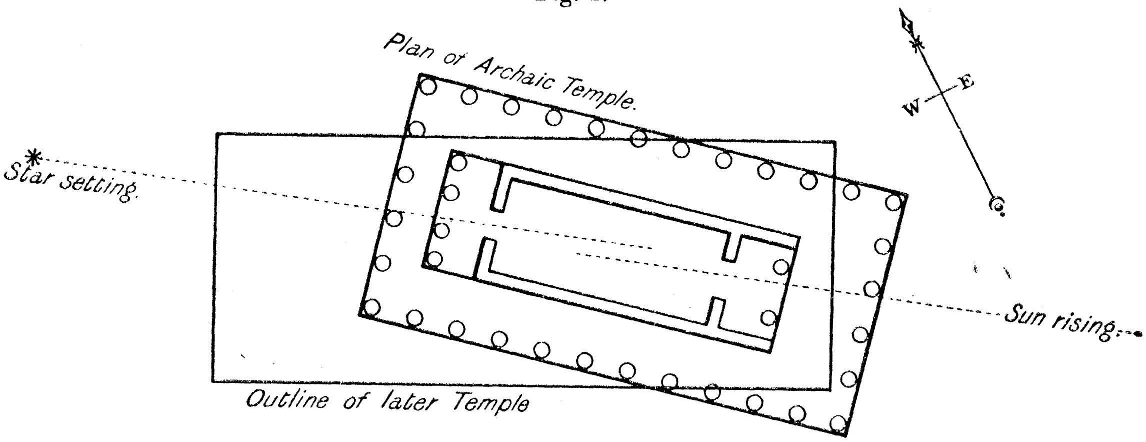
Near Gerace, amongst the remains of the ancient city of the Locri, there are two temple sites. Of these I visited one only, which is remarkable for having two temples (both Ionic) built obliquely one over the other (fig. 1), the divergence being too great to be accounted for by the movement of the same star, the orientation angle shown by the foundations of the older structure being 309° 37′ and of the later temple 296° 56′. The former is turned so much to the south of east that the sun, at its absolute rising from the sea-level towards which the front is turned, could not have shone centrally into the sanctuary, but the axis lies so near to the limiting angle of sunrise at the winter solstice that it could hardly have had any other intention than the admission of an early sunbeam. All that is necessary to assume is that in this case, as in some others, it was the northern jamb of the eastern doorway instead of the axis that was offered to the sunrise, and that also a small amount of provision was made for the very probable case of the sea horizon at the winter solstice being partially blocked by clouds, and that the effect of sunrise was looked for when it had attained a moderate altitude, which I have assumed to have been 4°. (I had supposed an analogous amount of solar altitude in the very similar case of extreme southern orientation at the temple near San Sansoni, at Metapontum.) In this case the wider intercolumniations of an Ionic temple permit a greater extension of the amplitude than would have been allowable in a Doric temple.

Locri—Latitude 38° 12′ 21″.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
The ancient temple	309° 36′	A	Amplitude of star or sun	+35° 12′ W.	−34° 44′ E.	β Geminorum, setting
		B	Corresponding altitude	4°	4°	
		C	Declination . . .	+29° 40′	−23° 47′	
		D	Hour angles . . .	$7^h\ 21^m$	$5^h\ 36^m$	
		E	Depression of sun when star heliacal	. .	10°	
		F	R. A.	$5^h\ 3^m$	18^h	
		G	Approximate date .	610 B.C.,	Dec. 21	
If the sun's depression had been 11° 9′, the date would be 770 B.C.						
Locri—The later temple	296° 56′	A	Amplitude of star or sun	+26° 57′ W.	−26° 56′ E.	β Tauri, setting
		B	Corresponding altitude	3°	0°	
		C	Declination . . .	+22° 50′	−20° 51′	
		D	Hour angles . . .	$7^h\ 0^m$	$5^h\ 57^m$	
		E	Depression of sun when star heliacal	. .	12° 11′	
		F	R. A.	$3^h\ 2^m$	$15^h\ 59^m$	
		G	Approximate date .	430 B.C.,	Nov. 23	

It is possible that, considering the lateness of the year, the sunrise might here

Fig. 1.



Locri Temples, Calabria.

In the older temple there does not seem to have been a large western doorway, but the evidence does not exclude a smaller one.

also have been looked for a little above the sea level, and, assuming an altitude of 1° on this account, the date would have been about 500 B.C.; but in ordinary fine weather the sun would cast a strong shadow the moment any noticeable part of the orb had appeared above the sea.

Sicilian Temples.

Girgenti.—Latitude 37° 18′ 36″.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Temple attributed to Juno Lacinia	264° 0′	A	Amplitude of star or sun	+7° 52′ E.	+6° E.	α Arietis, rising
		B	Corresponding altitude	3° 30′	0° 30′	
		C	Declination . . .	+9° 13′	+5° 4′	
		D	Hour angles . . .	$6^h\ 11^m$	$7^h\ 12^m$	
		E	Depression of sun when star heliacal	. .	11°	
		F	R. A.	$23^h\ 45^m$	$0^h\ 46^m$	
		G	Approximate date .	690 B.C.,	April 1	

The archæological evidence for the dedication of the above temple is not very strong, but its connection with α Arietis gives it very considerable support.

The two following examples at Girgenti, namely the temple of Hercules and the temple of Concord, have very nearly the same orientation angle.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Temple of Hercules	269° 56′	A	Amplitude of star or sun	+0° 39′ W.	+0° 4′ E.	Spica, setting
		B	Corresponding altitude	3°	0° 30′	
		C	Declination . . .	+2° 30′	+0° 22′	
		D	Hour angles . . .	5h 53m	6h 52m	
		E	Depression of sun when star heliacal	. .	10°	
		F	R. A.	11h 10m	0h 3m	
		G	Approximate date .	470 B.C.,	March 20	

The temple of Concord, of which the orientation angle is 270° 4′, would have the same star and the date about 18 years later.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
The Olympieium, sometimes called Temple of Giants	257° 35′	A	Amplitude of star or sun	+10° 44′ E.	+12° 25′ E.	α Arietis, rising
		B	Corresponding altitude	3° 30′	+0° 30′	
		C	Declination . . .	+10° 39′	+10° 9′	
		D	Hour angles . . .	6h 15m	7h 51m	
		E	Depression of sun when star heliacal	. .	15°	
		F	R. A.	23h 59m	1h 36m	
		G	Approximate date .	430 B.C.,	April 14	

See a subsequent remark on the deep solar depressions of temples of late date.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Temple of Castor	266° 0′	A	Amplitude of star or sun	+0° 14′ W.	+4° E.	Spica, setting
		B	Corresponding altitude	3°	+0° 30′	
		C	Declination . . .	+2° 0′	+3° 29′	
		D	Hour angles . . .	5h 51m	7h 18m	
		E	Depression of sun when star heliacal	. .	13° 9′	
		F	R. A.	11h 23m	0h 32m	
		G	Approximate date .	400 B.C.,	Sept. 13	

In this case, with a solar depression of 10°, the correspondence with the heliacal star would not take place till about 400 years later.

Segesta.—Latitude 37° 56′ 18″.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Dedication not known historically	264° 36′	A	Amplitude of star or sun	+ 9° 21′ E.	+ 5° 24′ E.	α Arietis, rising
		B	Corresponding altitude	4°	3° 40′	
		C	Declination . . .	+ 10°	+ 6° 31′	
		D	Hour angles . . .	$6^h\ 11^m$	$7^h\ 18^m$	
		E	Depression of sun when star heliacal	. .	11°	
		F	R. A.	$23^h\ 53^m$	1^h	
		G	Approximate date .	550 B.C.,	April 5	
With solar depression 13° the date would have worked out 830 B.C.						

*Selinus**.—Latitude 37° 35′.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Temple C	274° 52′	A	Amplitude of star or sun	+ 8° 38′ W.	− 4° 52′ E.	α Arietis, setting
		B	Corresponding altitude	3°	0° 35′	
		C	Declination . . .	+ 8° 40′	− 3° 30′	
		D	Hour angles . . .	$6^h\ 12^m$	$6^h\ 40^m$	
		E	Depression of sun when star heliacal	. .	10°	
		F	R. A.	$23^h\ 40^m$	$12^h\ 32^m$	
		G	Approximate date .	795 B.C.,	Sept. 30	
With solar depression 11° 15′ the date would be 870 B.C.						

* See the diagram of temples at Selinus on p. 62.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Temple D	276° 18′	A	Amplitude of star or sun	+ 9° 56′ W.	– 6° 18′ E.	α Arietis, setting
		B	Corresponding altitude	3°	0° 35′	
		C	Declination . . .	+ 9° 42′	– 4° 38′	
		D	Hour angles . . .	$6^h\ 16^m$	$6^h\ 36^m$	
		E	Depression of sun when star heliacal	. .	11°	
		F	R. A.	$23^h\ 50^m$	$12^h\ 42^m$	
		G	Approximate date .	610 B.C.,	Oct. 4	
Temple A	277° 21′	A	Amplitude of star or sun	– 0° 32′ E.	– 7° 21′ E.	γ Pegasi, rising
		B	Corresponding altitude	3° 30	0° 35′	
		C	Declination . . .	+ 1° 38′	– 5° 28′	
		D	Hour angles . . .	$5^h\ 47^m$	$6^h\ 50^m$	
		E	Depression of sun when star heliacal	. .	13° 13′	
		F	R. A.	$22°\ 5^m$	$23^h\ 8^m$	
		G	Approximate date .	550 B.C.,	March 5	
Temple B, a very small building, appears to be exactly parallel to Temple C.						

Syracuse.—Latitude 37° 3′ 30″.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Temple (forming part of the Cathedral) attributed to Minerva	269° 18′	A	Amplitude of star or sun	+ 3° 14′ E.	+ 0° 42′ E.	Spica, rising
		B	Corresponding altitude	3°	0°	
		C	Declination . . .	+ 4° 30′	+ 0° 34′	
		D	Hour angles . . .	$5^h\ 59^m$	$6^h\ 52^m$	
		E	Depression of sun when star heliacal	. .	10	
		F	R. A.	$11^h\ 1^m$	$11^h\ 55^m$	
		G	Approximate date .	815 B.C.,	Sept. 20	

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
The Olympieium	277° 26′	A	Amplitude of star or sun	+ 9° 51′ W.	− 5° 30′ E.	α Arietis, setting
		B	Corresponding altitude	3°	0°	
		C	Declination . . .	+ 9° 40′	− 4° 23′	
		D	Hour angles . . .	6^h 14^m	6^h 37^m	
		E	Depression of sun when star heliacal	..	10°	
		F	R. A.	23^h 49^m	12^h 40^m	
		G	Approximate date .	610 B.C.,	Oct. 3	
With solar depression 11° 7′, the date works out 695 B.C.						

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
The so-called Temple of Diana	271° 45′	A	Amplitude of star or sun	+ 1° 30′ E.	− 1° 45′ E.	Spica, rising
		B	Corresponding altitude	3°	0°	
		C	Declination . . .	+ 2° 22′	− 1° 24′	
		D	Hour angles . . .	5^h 22^m	6^h 47^m	
		E	Depression of sun when star heliacal	..	10°	
		F	R. A.	11^h 19^m	12^h 13^m	
		G	Approximate date .	450 B.C.,	Sept. 26	

South Italian Temples.

At Pæstum there are two temples—the great temple, presumably of Neptune, and a smaller temple, attributed to Ceres. There is also a large columnar structure, named the Basilica, of which the purpose has not been established. These three buildings are practically parallel with each other. The elements of orientation of one only are given.

Pæstum.—Latitude 40° 25′ 0″.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Temple of Neptune	273° 9′	A	Amplitude of star or sun	+ 1° 30′ W.	− 3° 9′ E.	Spica, setting
		B	Corresponding altitude	3°	5° 20′	
		C	Declination . . .	+ 3° 5′	+ 1° 4′	
		D	Hour angles . . .	$5^h\ 55^m$	$7^h\ 2^m$	
		E	Depression of sun when star heliacal	. .	11°	
		F	R. A.	$11^h\ 13^m$	$0^h\ 10^m$	
		G	Approximate date .	535 B.C.,	March 22–23	

The star could have been well seen *setting* with less solar depression; had this been calculated at 10°, the date would be 400 B.C., which is archæologically impossible. The only effect of the deeper depression would be to add about five minutes to the time given for preparation.

Pompeii.—Latitude 40° 45′.

Here there are two temples which can be referred to the Greek period. Of one, namely, that occupying part of the Triangular Forum, little remains but the foundation, but it was evidently a Greek Doric temple.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Temple in the Triangular Forum	301° 1′	A	Amplitude of star or sun	−26° 51′ E.	−28° 32′ E.	Antares, rising
		B	Corresponding altitude	4° 40′	4° 12′	
		C	Declination . . .	−16° 44′	−18° 15′	
		D	Hour angles . . .	$4^h\ 33^m$	$5^h\ 50^m$	
		E	Depression of sun when star heliacal	. .	10°	
		F	R.A.	$13^h\ 56^m$	$15^h\ 14^m$	
		G	Approximate date .	640 B.C.,	Nov. 12	

The other is the Temple of Isis, which seems to have been repaired, and probably considerably altered in external appearance during the interval which occurred between the earthquake, in A.D. 63, and the eruption of Vesuvius, in A.D. 79. A very noticeable point is that originally a large window-opening had been formed in the north-eastern inclosing wall of the Temenos, opposite the axis of the temple; which could have had no other purpose than that of permitting the rising sun to shine into the sanctuary. This opening, however, had been filled up with brickwork at some subsequent period. The orientation of this temple belongs to the summer solstice.

Name of temple.	Orientation angle.			Stellar elements.	Solar elements.	Name of star.
Temple of Isis	238° 39′	A	Amplitude of star or sun	+37° 18′ N.E.	+31° 21′ N.E.	β Geminorum, rising
		B	Corresponding altitude	3°	0° 49′	
		C	Declination . . .	+29° 33′	+23° 48′	
		D	Hour angles . . .	7^h 37^m	8^h 36^m	
		E	Depression of sun when star heliacal	. .	10°	
		F	R.A.	4^h 56^m	5^h 56^m	
		G	Approximate date .	750 B.C.	June 19	

The examples from Greece proper, which formed the first series of these studies, in by far the greater number of instances, demanded the hypothesis that although there was nothing inconsistent with archæological probability, yet that the date of foundation given by the orientations was much earlier than could be assigned to the existing remains on the spot, and that the walls, &c., which we are enabled to see, are those of a restoration generally on the same parallels as the original building.

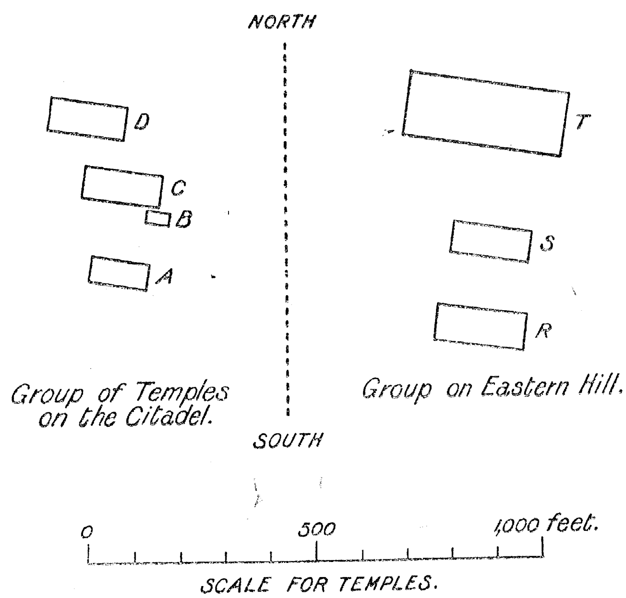
This is very much less the case in the list now produced from the Greek colonies in Magna Græcia and Sicily. In these, without the necessity of calling for a restoration, there are some very remarkable agreements between the deductions from the astronomic theory and ordinary historical data. In a few cases such as the Temple of Juno Lacinia, near Croton, the date, though still pre-historic, is nearly 900 years later than that which the same method of investigation assigns to the earliest example in Greece, and is by no means surprisingly early for a sanctuary of such celebrity. The most remarkable coincidences with the dates which might be derived from history are found in Sicily, where nearly two-thirds of the number of the examples which I have examined fall within periods of which THUCYDIDES has preserved the tradition. In his sixth book* the great historian gives a short summary of the Hellenic colonization of the island, from which historians have arrived at the following conclusions with respect to the colonization of some of the principal cities, namely :—

Naxos	735 B.C.
Syracuse	734 ,,
Thapsus	728 ,,
Gela	690 ,,
Selinus	628 ,,
Agrigentum . . .	582 ,,

* THUCYDIDES, vi., 2.

The temples of three of these towns are represented in the elements of orientations above given, and it will be seen that much more than half of the number of examples fall in with the dates derived from THUCYDIDES. As respects those which seem to require an earlier foundation, it must be borne in mind that THUCYDIDES, in naming those particular cities, is not speaking of the earliest occupation of the island, but of its colonization by expeditions from certain particular Greek states which took possession of different parts of Sicily. In the same book THUCYDIDES refers to a much more ancient colonization, in which he mentions exiles from Troy, who, after settling in Sicily, combined forces with certain Greeks from Phocis. Segesta seems to date from that period and occupation, and not only at Segesta, but elsewhere the earliest inhabitants of the country would naturally have possessed themselves of the sites most suitable for habitation and defence, and it would follow that when, in the eighth century B.C., the Greek colonists mentioned by THUCYDIDES possessed themselves of the country they would have found in some of the cities temples dedicated to the same Olympian gods that they themselves acknowledged.

Fig. 2.—Diagram of the Temples at Selinus.



The citadel group is about 1000 yards west and 600 yards south of the group on the Eastern Hill.

We learn, also, from Egyptian sources that even at the end of the fourteenth century B.C. there were alliances between the Greeks and the Sicilians. In the 5th year of RAMESES III., *i.e.*, about 1300 B.C., a combined attack was made upon Egypt by the Etruscans, Sardinians, Sicilians, Lycians, and Achæans. This account makes it extremely probable that these allies had a certain affinity with each other, and that, therefore, these Sicilians worshipped the same gods as the Achæans and

Lycians. Consequently, there is nothing archæologically inconsistent when we find a temple on a commanding site at Agrigentum, with a date as early as about 700 B.C., although the Hellenic colony, mentioned by THUCYDIDES, may not have gone there until 582. At Selinus the earliest astronomic date is about 800 B.C. This temple is that called for convenience temple C in fig. 2. It was here that the extremely archaic sculptures, now in the museum at Palermo, were found, representing Hercules carrying off the Cercopian giants, to which the date 795 seems as consistent as anything subsequent to 628 would be.

The orientation of this temple C shows that about an hour before the sun rose upon the axis, α Arietis was setting heliacally towards the West, nearly two centuries before the date of the Hellenic colonization of the city. When, however, the newcomers took possession, they would have found that the star had ceased to serve the purpose it was intended to fulfil, and accordingly it would appear that a new temple, D, was built closely adjoining it to the North at an angle sufficiently inclined to follow the star. The calculated date of this new work is eighteen years after the coming of the Hellenes. From the star α Arietis being thus connected with the orientation, it may be inferred that these two temples were dedicated to Jupiter. The fact that the achievements of Hercules had formed the subject of the metopes of the earlier temple by no means invalidates the supposition that the temple itself may have been so dedicated. The temple A falls well in the Hellenic period, and the architectural character, both of this and of temple D, appears to be in keeping with the astronomic dates. Temple B is extremely small, and is apparently parallel to the neighbouring temple C, but I did not examine it particularly. Of the group of temples on the Eastern hill I was unable from want of time to secure the orientations with sufficient exactness to justify my giving final elements. The angles, however, are approximately as below :—

	°	′
T, the great temple	276	40.
S	275	35.
R	275	40.

From these it may be inferred that the dates accord with the time of the Hellenic colonization.

At Segesta the star, α, Arietis, seems to favour the supposition that the original temple was dedicated to Jupiter. The existing structure, which from the refined character of its architecture seems to require a date of about the middle of the fifth century B.C. (which was also the epoch of a flourishing period among the Greek cities of Sicily), appears never to have been completely finished. As for the original foundation, if we accept the tradition countenanced by THUCYDIDES that the city was founded by refugees from Troy, the probability of the foundation of a temple in honour of Jupiter a century or more earlier does not require much argument.

At Agrigentum, with the exception of the temple attributed to Juno Lacinia, which has been already referred to, the astronomic and historical dates of the temples are in very close correspondence. DIODORUS informs us that the spoils obtained by the Agrigentines in their victory over the Carthaginians at Himera, B.C. 480,* enabled the inhabitants to embellish their city, but that afterwards they were in turn defeated, their city taken, and their power destroyed in 406, and that the great Temple of Jupiter, which had been completed with the exception of its roof, remained henceforth unfinished.† From these facts, in his contribution to the 'Supplementary Volume' of STUART and REVETT, Professor COCKERELL argues that that temple would probably have been commenced twenty years earlier. The orientation dates found for the Temples of Hercules, Concord, and Jupiter are respectively 470, 452, and 430 B.C. These dates, therefore, accord as strictly with the dates derived from historical probability as they do with the architectural character of the remains. Of three temples at Syracuse two fall within the historic period, and the other might be brought within it by a slight adjustment of the elements.

The orientation date derived for the great temple at Pæstum is 535 B.C. This is not only extremely accordant with the architectural character of the temple, but also with the mention by HERODOTUS of a Posidonian architect who was in repute about that time.‡

On page 825 of the former paper on this subject, I said that there were five temples of late foundation, of which I had measured the orientation, which lay within the solstitial limits, but for which I had been unable to find heliacal stars, but that the elements of two others, also of late foundation, had been included in the list. The occurrence of three temples of late foundation in the present list, which have been associated with stars, but invariably combined with a deeper depression of the sun than is found applicable to the older temples, and in this particular agreeing with the two temples of the former list just referred to, has led to a further examination of the five alluded to above, and in every case with an analogous result, namely, association with stars at a deeper depression of the sun. The following list includes all the temples of which I have the requisite data, and of which the foundation evidently falls later than the beginning of the fifth century B.C. Of fully half the number the date is accurately known.

In the case of those which are marked with an asterisk, the sun rises along the axis; of the others, in the direction of the north side of the opening.

* DIODORUS, xi., 25.

† *Ibid.*, xiii., 82.

‡ HERODOTUS, i., 167.

	Date B.C.	Name of temple.	Orientation angle.	Sun's depression.	Name of star.	Day of month.
1†	470	Theseum, Athens	283° 6′	17° 10′	Spica, rising . .	Oct. 5
2‡	445	Later Erechtheum, Athens .	265 9	12 0	α Arietis, rising .	April 9
3	About 430	*Later Temple, Locri	296 56	12 11	β Tauri, setting .	Nov. 23
4	About 430	*Girgenti, Temple of Jupiter .	257 35	15 0	α Arietis, rising	April 14
5	425	*New Heræum, Argos . . .	285 59	19 34	Aquarius, rising	Feb. 21
6	About 400	*Girgenti, Temple of Castor .	266 0	13 9	Spica, setting .	Sept. 13
7	About 360	*Olympia, the Metroum . . .	281 47	14 6	α Arietis, setting	Oct. 9
8§	355	Ephesus, the last rebuilding .	284 35	15 30	Spica, rising . .	Oct. 6
9‖	340	*Athens, new Temple of Bacchus	255 49	17 46	α Arietis, rising	April 23
10	174	*Athens, new Jupiter Olympius	270 0	12 0	Spica, setting .	March 27

In all the above cases, excepting No. 2, the depressions are quite unnecessarily deep for the purpose merely of seeing the stars distinctly. Spica or β Tauri could have been seen setting in the morning twilight with a solar depression of 8°.

Two explanations may be offered with respect to this alteration of the element of the sun's depression. One is, that attention had been called, as it hardly could help being called, to the fact that the heliacal star failed to keep its original connexion with sunrise, and that there would be a better chance of permanence if the interval between the two bodies were increased; the other is, that the temple service had become more complicated, and that more time was required by the priests for preparation. Every additional degree of sun's depression would add about five minutes for this purpose.

† The festival of the Thesea is supposed to have been held on October 8 and 9.

‡ The autumnal return of the sun to the same point of the Erechtheum would take place on September 2. There does not appear to be an heliacal star available for that occasion, but the great festival of the Niceteria in honour of the victory at Marathon is considered to have been held on the 3rd of that month, when the sun would shine fully along the axis of the temple.

§ The foundations of this great temple of Ephesus show that at the last rebuilding the orientation had been changed about 9° from the original line, for the purpose of following the movement of the star.

‖ The date of this temple is considered to be that of the alterations made in the adjoining Dionysiac theatre, under the direction of Lycurgus.