MEGALITHIC ASTRONOMY: HIGHLIGHTS AND PROBLEMS

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Abstract. After a discussion of the need for statistical methods in megalithic astronomy, the interpretation of statistical results is considered, and a simple method of performing a suitable statistical test is outlined. Statistical evidence is considered next, with particular regard to the extent and limitations of the role of selection effects in the work of the Thoms. Their most recent analysis of lunar lines is discussed. Some arguments of a practical nature then follow, and the paper ends with some briefer comments on the astronomical interpretation of megalithic art, dating, and the purpose and implications of megalithic astronomy.

INTRODUCTION

The present paper is a rewritten version of a review article[1] (Heggie 1981b) which was designed as an introduction to problems of megalithic astronomy for participants at the conference in Oxford. However the resemblance is largely confined to the title and the structure. Its general purpose here is to provide a background for many of the other papers in the present volume, but the opportunity is also taken to argue the case for the use of a particular methodology in the examination of much of the evidence on megalithic astronomy, and to consider how it may be applied to one or two important bodies of data. Another purpose of this paper is to draw the attention of readers to a number of recent results which have a bearing on the subject and are perhaps not mentioned elsewhere in this volume. On the other hand nothing is said of the archaeological background to these studies, which is one of the purposes of the paper by Dr Ritchie, and little space is devoted here to the numerous important archaeological arguments which bear on the interpretation of the evidence; but many of these are discussed by several of the authors who have contributed to this book.

The idea that astronomy was one element in the function of certain megalithic sites in Britain and elsewhere is an old one, as Prof.

Atkinson mentions in his paper, but it has never flourished more vigorously than in the last two or three decades, thanks largely to the work of Prof. Alexander Thom. Though his work had begun in the 1930s, it was not until 1954 that his first paper on the subject of prehistoric astronomy appeared. In 1967 he published a book (Megalithic Sites in Britain) in which evidence from some hundreds of sites was collated (Fig.1). Much new evidence was then produced in two subsequent books (Thom 1971; Thom & Thom 1978a), where particular emphasis was laid on very accurate sightlines for the moon using distant markers, mostly natural.

The present activity in the field of archaeoastronomy in the Old World, or at least in the British context, can be seen largely as the response of experts in different disciplines to Thom's work. Among archaeologists some, such as Aubrey Burl, have selected the parts of Thom's ideas which can be absorbed most readily into a fresh but relatively conventional picture of the societies of the megalith builders. A few, notably E.W. MacKie, have considered in a more radical way what changes in the conventional picture would be required by Thom's theories. And it must be admitted that there are many archaeologists, who do not attend conferences on archaeoastronomy, who consider that his theories shed no light on these problems, for all the acknowledged excellence of his field surveys. Finally there are those with less archaeological experience, or, more often, none at all, who have responded actively to the more technical aspects of Thom's work, such as the statistical evaluation of his theories, and the associated problems of ensuring that the available data are suitable. But Prof. Thom's work has not been limited to the astronomical aspects of megalithic sites, and if the response to his work on megalithic geometry has been less vigorous, it is because the necessary methods of analysing his work in this field have proved much harder to develop. (Dr Patrick's paper in this volume marks a significant breakthrough in this respect.) Nor is Thom's influence confined to Britain, as many of the American archaeoastronomers at the Oxford symposium testified warmly to the great interest which his work has engendered in the New World also.

STATISTICAL ARGUMENTS

The need for statistical methods

The great bulk of the evidence on megalithic astronomy consists of orientations, alignments, or 'lines', directed towards a place on the horizon where a conspicuous astronomical object (sun, moon, a planet, or a bright star) rises or sets. Of course the rising and setting positions of the sun, moon and planets vary relatively rapidly, and so for them it is the extreme rising and setting positions that are generally considered. For the sun the extreme positions are those reached at the solstices, but several authors have also considered orientations for the sun at other

Fig.1. The astronomical sites listed in Thom 1967.

times of the year, as discussed, for example, by the Thoms in their paper in this volume. The rapid and relatively complicated motion of the moon makes its extremes rather involved, but at a low level of accuracy the extreme positions are simply the 'standstill' positions, to use the convenient term introduced by Thom (1971, p.18). Extreme positions for the planets may also be defined, but in fact the planets have been rarely discussed in this context.

Coupled with this variety of astronomically significant positions is an equally broad choice of megalithic orientations. These may be defined by single slabs, true alignments of standing stones, lines from the centre of a stone circle to an outlying stone, lines from one site to another, the axes of megalithic tombs, lines from a prehistoric site to a natural horizon feature (or 'foresight'), such as a hill-slope, a valley or notch, and so on.

Given this great diversity of 'targets' and orientations, one must consider the possibility that it is only by chance that one finds some sites to be astronomically orientated. Indeed we can be virtually certain that coincidences occur, and since we do not know *a priori* that the megalith-builders were interested in any particular astronomical object, it seems wise to dismiss any apparently astronomical orientations as coincidences unless there is evidence to the contrary. If we relax this attitude (and it must be said that many authors have never adopted it in the first place) then we shall be in grave danger of writing books and papers whose rightful place is on the fiction shelves. The fact that it has been ignored so often possibly accounts for the general air of controversy in which debates on megalithic astronomy tend to have been conducted. If indeed a body of evidence does not allow us to conclude that the orientations involved are not just coincidences, it is perhaps to be expected that an enthusiastic archaeoastronomer and a careful archaeologist can come to diametrically opposed conclusions.

The stress which is laid on statistical methods here (and in Prof. Freeman's paper in this volume) reflects the nature of the evidence available for the study of megalithic astronomy. One can imagine plausible circumstances in which the importance of such methods might be much diminished. In his paper in this volume Dr MacKie expresses the hope that a site might be found which, on excavation, decisively supports only an astronomical interpretation. Were such a site to be found then statistical evidence would have only a small role to play with regard to that site and others like it. But at present no such key site is known, and the great bulk of the evidence requires statistical evaluation if we are not to be misled by it. The study of Mayan astronomy, on the other hand, exemplifies a field where the statistical evaluation of orientations is of relatively minor importance, because information from orientations is supported by evidence of the most decisive kind, in the form of a decipherable astronomical notation. At the Oxford conference, several European participants voiced some dismay at the lack of statistical analysis of the evidence on native American astronomy, but it may be argued that this reflects the rather supplementary role which the study of orientations plays in much of this work. The great difference in the nature of the evidence available on the two sides of the Atlantic is one of the points to which Prof. Pedersen also draws attention in his paper in this volume.

In the context of megalithic astronomy, other evidence of a decisive kind (i.e. apart from orientations) has not yet turned up, and orientations are the basic evidence on which the hypotheses have to be tested. And to establish that the orientations one finds are not coincidences one has to show, if possible, that one finds more orientations towards phenomena of astronomical importance than would be expected to occur by chance. The most important role of statistics in this context is, in effect, to calculate the probability of obtaining by chance a number of orientations not less than the number actually found in the investigation under study. If the orientations have nothing to do with astronomy and are essentially random, then the probability thus found is unlikely to take very low values. Sometimes, as with the statistical test devised by Freeman & Elmore (1979), the results are not expressed directly in terms of probabilities, but they can still be interpreted qualitatively in much the same way.

Interpretation of statistical results

Before considering how the probability is to be calculated, we must discuss how the results are to be interpreted. If the probability obtained is not very low, then we have little reason to reject the notion that the orientations are random. (This is not to say that the orientations are not deliberate, however, for one might contemplate the suggestion that the sites were orientated on non-astronomical objects, such as hills, or sacred places, or routeways. The point is that, even if such a suggestion were correct, we would have no reason to expect more orientations with apparent astronomical significance than we would expect from a genuinely random set.) If, on the other hand, the probability turns out to be very small, then we have strong grounds for rejecting the notion that the orientations are random, but we must take care before coming to the obvious conclusion that they are genuinely astronomical. Low levels will occur only rarely if the orientations are random, but they will occur. In the same way, if we look through enough sets of randomly generated data, we will be able to select one or more which look very non-random. This is the lesson which the rather outré example in Dr MacKie's paper in this volume ought to teach us. Unless our data have been selected objectively, the obvious conclusions may easily be false ones, and Aubrey Burl's recommendation (see his paper in this volume) that one should study groups of monuments, rather than individual examples selected from such groups, can be seen as a safeguard against this.

The most important selection effects that can endanger the statistical analysis of megalithic orientations are concerned with the selection of the sightlines themselves. It has been realised for a long time (Thom 1955) that it is difficult to be objective about this, and it is no less difficult to try to apply strict selection criteria retrospectively. Nevertheless this must be attempted if we are to derive meaningful conclusions from most of the existing evidence for megalithic astronomy, at least until we possess fresh bodies of data prepared according to stricter selection criteria. (In his paper in this volume Dr Ruggles offers us precisely this prospect.)

This emphasis on selection criteria should not obscure the other problems associated with the statistical investigation of orientations, though they are often more easily overcome. For example, one must try to minimise the influence exerted by the data on the formulation of the particular astronomical hypothesis to be examined.

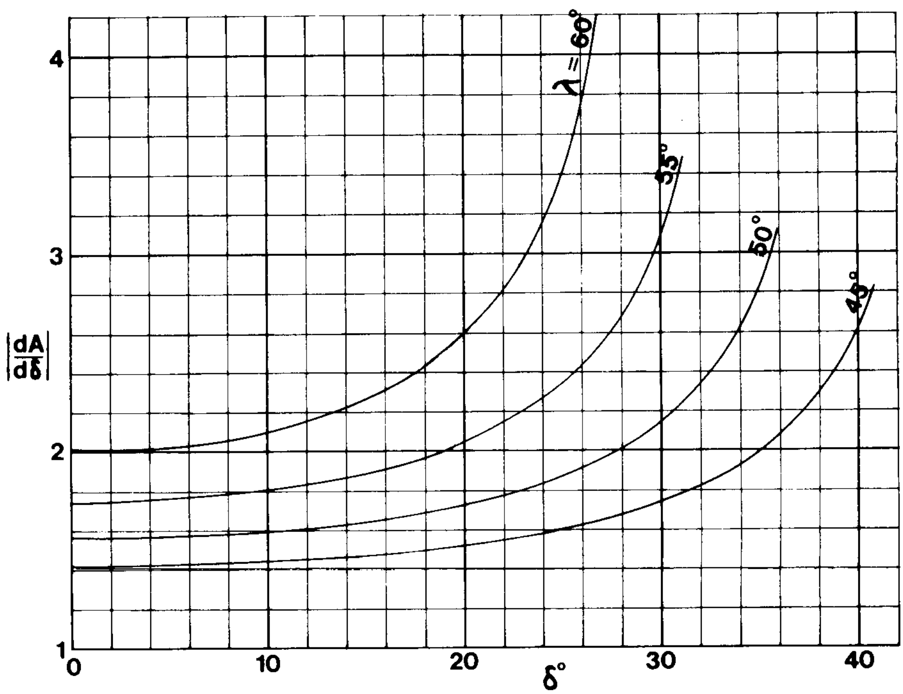
A simple statistical method

Finally we come to the way in which the probability is to be calculated, i.e. the probability that a set of random orientations would yield (by chance) the number of astronomically significant lines that we actually find, or even more. A simple and rough (but widely applicable) method of doing so will now be described.

Several pieces of information are required, namely

(i) the tolerance, t, i.e. how closely an orientation must agree with an astronomically significant direction to be included. The tolerance may depend on the accuracy with which the direction of the orientation can be defined, in which case it will generally be expressed in terms of azimuth. But it may also be expressed in terms of declination, and then it can be converted approximately into an equivalent tolerance in azimuth by multiplying by the quantity $|dA/d\delta|$ (the rate of change of azimuth with declination). For many approximate purposes this may be read from Fig.2. As an example, an orientation to some point on the sun's disc at a solstice must indicate a declination within approximately $16'$ of that of the sun's centre, i.e. the tolerance in declination is $16'$, since this is the mean apparent radius of the disc. Since the declination is about 24°, at the latitude of Stonehenge ($51^\circ.2$) $|dA/d\delta|$ is about 1.9, leading to a tolerance in azimuth of about $30'$.

Fig.2. The factor $|dA/d\delta|$. The graph is entered by declination (δ) and latitude (λ). The curves were calculated for the case of zero horizon altitude, and the sign of the declination is irrelevant. It is not possible to obtain accurate values from these graphs at declinations close to the colatitude ($90^\circ - \lambda$).



(ii) the number of astronomically significant positions. These must be chosen fairly (Hawkins 1968), so that if the position of sunrise at the equinox is included, then so must the position at sunset. Again, if we wish to test the hypothesis of the solstitial orientation of the axis of Stonehenge, we must include both sunrise and sunset at both solstices, i.e. four positions in all.

(iii) the probability, p, that a single random orientation would be regarded as astronomically significant. In straightforward cases this is simply the number of significant positions times twice the tolerance in azimuth (since an orientation may deviate on either side of the precise astronomical direction under consideration), divided by 360°. If we are testing the solstitial hypothesis for the orientation of the axis of Stonehenge, then $p = 4 \times 2 \times 30' / 360^\circ = 0.011$, approximately.

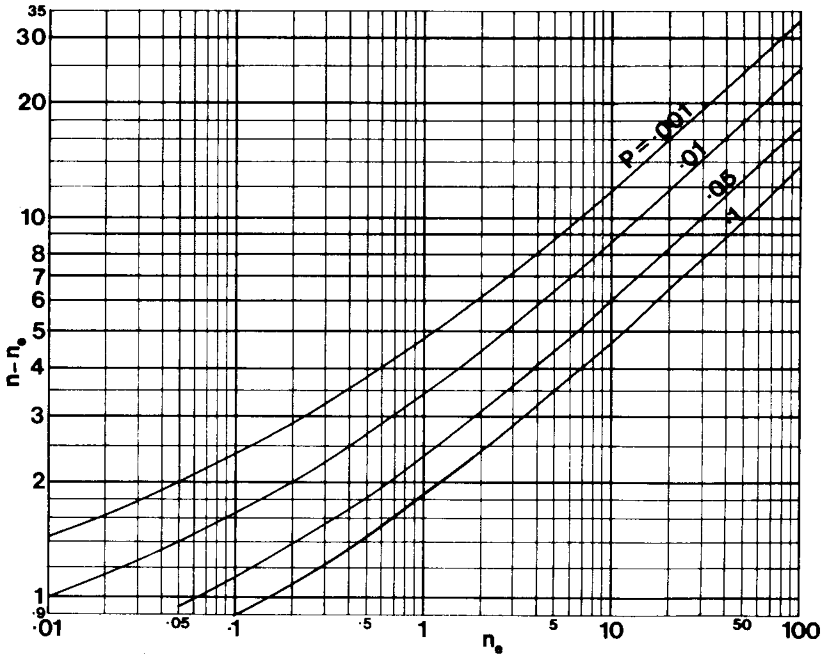
(iv) the total number of orientations, N, in the sample, i.e. including both astronomical and non-astronomical orientations. What is actually needed is the total number of available orientations from which the sample was selected, and it is often difficult to find information on this. Indeed it is at this point that it is frequently necessary to make some allowance for unwritten or faulty selection criteria. In the case of the axis of Stonehenge, however, it is clear that one should take N=1, since the axis is much the most clearly defined orientation at Stonehenge, and may be regarded as the unique principal orientation of the monument (cf. Prof. Atkinson's paper in this volume).

(v) the actual number, n, of astronomical orientations in the sample. For example, since the axis of Stonehenge does actually indicate a point on the sun's disc at the position of midsummer sunrise at the time of its construction (this can be inferred from the data given by Thom & Thom 1978a, p.150), we have n=1.

Now we have to calculate the probability, P, that at least n lines out of a sample of N random orientations will indicate some astronomical position within the stated tolerance. If n and N are both 1, as in the test of the axial orientation of Stonehenge, then obviously P=p. In other cases, P may be calculated from expressions based on the binomial distribution (the standard formula is given, for example, in Heggie 1981a, p.242), or from an approximation based on the Poisson distribution. For the latter purpose we need also

(vi) the expected number, n_e, of astronomical orientations, which is just the average number that would be expected to occur in a sample of N random

Fig.3. Probability, P, of obtaining at least n astronomical orientations by chance. The average number that would be expected by chance is denoted by n_e. Above the line P = 0.001, the value of P is below 0.001; below the line P = 0.1, the evidence for astronomical orientations is not statistically significant. For restrictions on the applicability of this graph see the text.



orientations, i.e. $n_e = Np$. If N is large and n_e is small then the Poisson approximation is satisfactory, and then the probability P can be read from Fig.3, which is entered by the expected number n_e and the excess of the actual number over the expected number, i.e. $(n-n_e)$. Actually, the probabilities obtained from this graph are also approximately correct in other circumstances, e.g. when $n = 1$ and n_e is very small, but without any restriction on N. Indeed the correct result for the Stonehenge problem ($n_e = 0.011$, $n = 1$) can be obtained approximately from this graph.

STATISTICAL EVIDENCE

Early statistical investigations

Some of the earliest statistical arguments are to be found in a book by R. Müller published in 1936. One of the sites to which they were applied is a group of rings at Odry (near Czersk, Poland), but in fact these are much younger than the sites normally considered in studies of megalithic astronomy (see Dobrzycki 1963, and the paper in this volume by Sadowski *et al.*). Müller also rediscussed some earlier statistical results on a group of lines by J. Hopmann, and showed that nothing of statistical significance survived when one took into account all the possible sightlines - an early case of retrospective correction for selection effects.

Now we come to the early work of Professor Thom. His first paper on megalithic astronomy (Thom 1954) contained no statistical analysis of the type we are considering, but such an analysis, using the data from this paper, has been attempted recently (Heggie 1981a, pp.153f.), and the conclusions are as follows. Formally there is statistically significant evidence for solstitial orientations (of three distinct structural types, but analysed together) in Thom's paper. This is true even if we are rather strict in omitting sightlines over which, in Thom's opinion as expressed here and in later books and papers, some doubt exists. Furthermore Thom's own selection criteria in this paper seem to have been quite strict, to the extent, incidentally, of excluding sightlines (such as that to the south-west at Ballochroy, Argyll) which have been brought subsequently to some prominence in later papers and which, if retained, would have strengthened the evidence for megalithic astronomy. These solstitial sightlines also strongly suggest that it was not just any point of the solar disc, but one or other limb, towards which they were directed, though no probability level was calculated for this result.

Professor Thom's second paper dealing with megalithic astronomy