Archaeoastronomy, Bayes Theorem and the Law

In recent years it has become fashionable in academic circles to apply statistical and mathematical probability theories such as Bayes Theorem to the evidence for astronomical alignments at prehistoric sites. The most influential book on this subject was *Bayesian Approach to Interpreting Archaeological Data* (1996) by C.E.Buck, W.G.Cavanagh and C.D.Litton. This idea was in turn taken up by Clive Ruggles in various articles and especially in his *Astronomy in Prehistoric Britain and Ireland* (1999).

Archaeologists have resisted the ideas of archaeoastronomy throughout the twentieth century, but especially since the publication of Professor Thom's books and articles from the 1960s onwards. In order to assess the validity of his work – which, in view of his academic qualifications and reputation should have been easily accepted – archaeologists realised that they would have to acquire the knowledge of some basic astronomy, and very few were prepared to make this effort. If they were not prepared to learn about the cycles of the sun and moon, however, it is even less likely that they would be prepared to master systems of mathematical probability. The introduction of such ideas has therefore held back the subject still further.

It may be useful, however, for those people who are interested in the examination of astronomical alignments at prehistoric sites to know that the English legal system has also looked at the Bayesian approach to establishing truth and has thoroughly rejected it. The reasons for this, and their relevance to archaeoastronomy, are examined in this article.

First of all, why is it so difficult to claim that a megalithic site is deliberately aligned to the appearance of the sun or moon on nearby horizons at significant moments in their cycles? The argument by Clive Ruggles and others is that the sites are usually so ruined by the passing of time that one cannot often rely on the position of particular stones being in their original place. One cannot know whether the horizons, too, were bare or forested at the time of the site's construction. So at any one individual site, it could be claimed that the alignment of stones to a horizon notch or slope could simply be coincidental, not part of the original design. Many of these sites are complex and clearly served different functions – a gathering place for rituals, a burial ground etc. – as well as marking points in the calendar. If one chooses only certain stones, claiming that they were used for an astronomical alignment, it can be argued that one is simply selecting the data to prove one's theory and ignoring the rest. So another layer of academic activity is introduced – the application of a statistical theory with its appearance of objectivity in assessing the facts.

It is worth stressing, incidentally, that the problems do not lie with the solar and lunar astronomy. It is comparatively straightforward to take into account the change in the tilt of the earth, precession, refraction on the horizons and, of course, the delightful reliability

of the repeated cycles of the luminaries! Without accurate dates for the sites, the alignment of stars cannot be taken into account, since they appear to move comparatively quickly along the horizons, but there is plenty of work to be done on the connection between the megaliths and the sun and moon without worrying about the difficulty of star alignments.

So who was Bayes and what was his theory? Thomas Bayes was an English nonconformist minister and amateur mathematician in the eighteenth century. He worked out a system which decided the extent of probability of a claim based not only on relevant facts that might help to prove a theory but also on prior beliefs and assumptions. The subjective hunches and the more objective facts are then quantified according to a formula.

To a statistician the Bayesian approach may be viewed "simply as a formal way of dealing with life's ubiquitous problem of learning from experience" (Buck et al:1991:811), but to a non-statistician it appears to be a process that would add several years of extra training in statistics to the already demanding requirements of becoming an archaeoastronomer. This would not invalidate the Bayesian approach, of course, in itself. If it could be shown to be necessary, or even just useful, to approach prehistoric sites in this way, then archaeologists and historians would have to reconcile themselves to the study of mathematical probability theories. Archaeologists and historians, however, are used to assessing probability by employing straightforward reasoning without the use of mathematics and need much convincing that the engagement with mathematical equations, summations, integrals, derivatives, products and exponential expressions will ultimately get them any further!

Prior beliefs are always going to be present in any person weighing up a problem and one can understand the attraction of examining these first and honestly declaring them as part of the process. However, they need not be quantified and, whether quantified or not, another person assessing the same problem may totally disagree with these prior assumptions. They will therefore equally disagree with the outcome of the mathematical process. The quantification can also seem to be disguising the initial biases within the equation, whereas an open declaration in words of one's prior assumptions is clear to all.

In a Court of Law, the probability of the evidence is constantly being presented and tested and a jury of ordinary people is expected to be able to understand the distinctions in the range between certainty and possibility. Lord Justice Hoffmann wrote:

> There are few things about which anyone can say that he feels absolutely certain, but short of this point there is a wide spectrum of possible degrees of conviction. One may say that, on the evidence, the happening of an event was remotely possible, reasonably possible, more probable than not, very probable, almost certain.
>
> (Hoffmann: 1981: 363-4)

These distinctions are similar to the ones used by Professor Thom in his *Megalithic Sites in Britain*, where he simply produced a table of sites divided into three classes, according

to his conviction of their relative certainty. His description of his method was in his usual style – honest, unpretentious and exact. (Note, however, that he uses the word "line" where now the word "alignment" is more usually chosen):

> The most difficult part of the whole investigation is to decide when to include a line and when to exclude it. The decision must always be a matter of personal opinion and is influenced by the viewpoint and the other lines with which, at the time, it is being compared. An attempt to get some measure of objectivity, however small, in the material presented … has been made by dividing the lines into three classes, A, B and C.
>
> Class A contains those lines which it is considered would be accepted by any unbiased observer.
> Class B contains borderline cases which some people might accept and others discard.
> Class C contains lines which would be excluded from a statistical analysis. For example, a line from a site to an impressive natural foresight is marked C when its only claim is that it gives one of the declinations in which we are interested…etc.
>
> (Thom:1967:97-101)

One can see from this explanation that Professor Thom was extremely careful and excluded alignments that I personally would probably have left in. He was highly conscious of the statistical arguments that would be used against his work and tried to circumvent them by employing some of the top mathematicians and statisticians in the country to check his methods and figures. Nevertheless the list referred to above contains some 200 alignments found acceptable even by his own high standards.

The inability of the Bayesian Method to deal with complex issues, whether a prehistoric site or a human crime, is well-illustrated by attempts to use it to settle legal cases, later overthrown by the Court of Appeal. For example in the case of *R. v Adams, Court of Appeal (Criminal Division) 26 April 1996* Bayes' Theorem was used in the original trial to test the probability, based on DNA testing, of the defendant being guilty of rape. The unusual demands that the presentation of evidence in statistical form made on the jury caused the case to go to appeal and the Court of Appeal handed down its own judgement on the use of Bayesian statistics. Since its points are directly relevant to archaeoastronomy, I shall quote them in full:

1. The apparently objective numerical figures used when applying Bayes' theorem might conceal the element of judgement on which the calculation was depended.

2. Bayes' theorem required that items of evidence be assessed separately, but this was too rigid an approach for the jury. The cogency of evidence has, in part, to be assessed in the light of a chain of evidence.

3. Jurors evaluate evidence not by means of a formula, but by the joint application of their common sense and knowledge of the world to the evidence before them.

4. The jury would find it difficult to apply the theorem during their deliberations. Jurors might differ in the figures to be attached to each item of evidence, and any compromise would not adequately reflect the jurors' views. The jurors would not be able to reconcile the individual views about the evidence if they used Bayes' theorem.

5. The introduction of Bayes' theorem into a criminal trial plunges the jury into inappropriate and unnecessary realms of theory and complexity deflecting them from their proper task.

(R.v Adams, Court of Appeal (criminal Division) 26 April 1996 quoted in Redmayne: 2004:1-20)

To summarise these points, Bayes theorem was considered by the Court of Appeal to add unnecessary realms of complexity and to be too formulaic for a jury to form an opinion on the guilt or innocence of a defendant. Clear and rational judgement is essential on the part of jurors, but this particular mathematical probability theory did not aid in that process. Rather, it deflected the jury into concentrating on the application of the method rather than the central problem of deciding on guilt or innocence.

The second point made by the Court of Appeal is particularly relevant to the assessment of astronomical alignments. Bayes' Theorem requires that items of evidence be assessed separately, yet many small points may indicate the probability of an alignment. A row of stones may be too broken and their authentic positions in too much doubt for a precise alignment to be measured accurately. But the commanding position of the site, for instance, and the presence nearby of more certain astronomically aligned stones or structures with orientation to cardinal points may tip the scales of probability that the original stone row would not by itself be able to do.

These facts can be included in the application of Bayes' Theorem but then each has to be quantified separately rather than held together in the mind as a totality. Even more unquantifiable and yet part of the total picture of the site are folk stories and legends about it, rituals still practised there at key moments in the solar or lunar calendar, ancient tracks leading up to it, the general shape of the landscape in which it is set and so on. With experience of many similar sites, a judgement can be made and defended by registering and assessing all the details as a whole.

The judgement so reached may be incorrect but so may the judgement based on mathematical probability. Archaeologists are used to the fact that there is rarely sufficient information to be found at a prehistoric site to ensure the reliability of any theory about its use. Nevertheless theories, however temporary, have to be formed.

If as a society we are prepared to impose heavy sentences (even, in the past, capital punishment) on people in our law courts on the basis of "proof beyond reasonable doubt", then the same standard would seem to me to be acceptable in the assessment of the likely use of a prehistoric site. As the famous judge Lord Denning definitively stated:

> [The degree of cogency required in a criminal case before an accused person is found guilty] is well settled. It need not reach certainty, but it must carry a high degree of probability. Proof beyond reasonable doubt does not mean proof beyond the shadow of a doubt. The law would fail to protect the community if it admitted fanciful possibilities to deflect the course of justice. If the evidence is so strong against a man as to leave only a remote possibility in his favour which can be dismissed with the sentence 'of course it is possible, but not in the least probable', the case is proved beyond reasonable doubt, but nothing short of that will suffice…
>
> (Miller v. Minister of Pensions: [1947] 2ALL E.R. 372)

For the assessment of the use and purpose of a complex prehistoric site, therefore, there will equally never be a method that produces total certainty, only a belief "beyond reasonable doubt" based on common sense and knowledge of archaeology and astronomy. Other methods of quantifying likelihood seem to me to be unnecessary obstacles set up to deflect the energy of archaeoastronomers and put off the day when archaeologists will have to face up to the fact that they have been collectively avoiding the most important facts about the prehistoric sites they have been studying.

Irene Earis.