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THE CREDIBILITY OF ARCHAEOASTRONOMY: A SUGGESTION FROM PHARMACOLOGY?

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ABSTRACT

Mankind has been observing the sky since ever and also intentional human activity of interpreting what is seen in the sky is very old. The usefulness of studies aimed at analyzing the possible astronomical content of ancient structures and artifacts is thus not in doubt. However, many archaeologists still do not acknowledge Archaeoastronomy as a useful subsidiary science for Archaeology. This situation is mainly due to two factors. On the one hand, many archaeoastronomical works devoid of any scientific content continue to discredit even the most serious researches in the field. On the other hand, the purely humanistic formation of most archaeologists does not incline them to accept the evidence that archaeoastronomers present in support of their arguments. While the first problem can hopefully find a solution with a strict self-control of the archaeoastronomical community, the solution of the latter is more complex. Actually, the difficulty of proving the presence of astronomical contents in an ancient artifact is, in large measure, real and certainly not ascribable only to the lack of scientific expertise. However, the problem of the credibility of a scientific study is indeed becoming more and more serious in all disciplines. In fact, the pressure in the whole scientific community to increase one's output, for a positive assessment of the activities of a researcher, is causing numerous cases of poor scientific ethics. Obviously this situation has very negative consequences especially in those disciplines, such as clinical trials, which have a strong social impact. For this reason, the community of Pharmacology scholars is considering to introduce a standard procedure, which is to be explicated in the evaluation of the credibility of the results of a research. We will show how a similar standard procedure can be adapted to increase also the credibility of the archaeoastronomical studies.

KEYWORDS: Archaeoastronomical methods

1. INTRODUCTION

Mankind observed the sky since the beginning of its evolution. Maybe, these observations started even before the origin of the *Homo Sapiens* since ethology clearly demonstrates that many animal species use the stars as a means to find the direction for their migrations (Sandberg et al., 2000).

Astronomy too, the human activity devoted to the interpretation of what is seen in the sky, is very ancient, so ancient that we don't know when it started. For instance, Rappenglueck (1998) suggested that some paintings of the Lascaux cave (16500 BP) represent constellations such as Pleiades and most of the historians of religion ascribe to the observation of the sky a fundamental role in the development of the concept of "Sacred" (e.g., Ries, 2012).

For sure, many cultures of the Bronze Age built structures dedicated to the observations of the sky in order to gather calendric information, necessary to establish the dates of rites and the right times for agricultural activities. However, proofs of the use of astronomical observations finalized to the measure of time and to rites associated to celestial divinities are present in most cultures everywhere in the world and in all epochs.

Archaeoastronomy consists in determining the astronomical content in structures and artifacts of archaeological interest, with the aim to help the archaeologist understanding of the symbolic world and/or the practical needs of the civilization that produced them (Sinclair, 2006). It is therefore essentially a "subsidiary science of archeology", as the radiocarbon dating and many other sciences.

Archaeoastronomy has, however, a substantial difference when compared to the other Archaeology subsidiary sciences for these can tell us when and how an artifact was produced, where its material comes from, what its builders ate, what animals they bred, etc. These are all very useful information, but only Archaeoastronomy could give us an indication about why the artifact was created and information about the symbolic world of those who built it (Polcaro & Polcaro, 2009).

The usefulness of Archaeoastronomy is thus unquestionable and its credibility within the scientific community is steadily increasing, thanks to the multi-year effort of his most serious scholars. However, many archaeologists still do not accept the Archaeoastronomy as a useful subsidiary science for Archaeology.

This situation is largely due to two factors. On the one hand, the constant presence in the media of archaeoastronomical works devoid of any scientific value continues to discredit even the most serious researches in the field. On the other hand, the purely humanistic formation of the vast majority of archaeologists (especially in Europe) makes it difficult for them to consider as conclusive the evidence that archaeoastronomers present in support of their arguments.

While we can hope to find a solution to the first problem with a strict self-control of the archaeoastronomical community (as also SEAC has been doing for years), the solution to the second problem is more difficult.

2. THE DIFFICULTY OF PROVING THE PRESENCE OF ASTRONOMICAL CONTENTS IN AN ANCIENT ARTEFACT

Actually, the difficulty of proving the presence of astronomical contents in an ancient artefact is, in large measure, real and certainly not ascribable only to the lack of scientific expertise, and even less to a bias by those who do not accept the hypothesis of its presence.

This is because the astronomical content of an artefact of archaeological interest can be translated into symbols (paintings, graffiti, and sculptures) and, if these symbols are explicit enough, in principle their astronomical interpretation is accepted without problems.

However, more commonly, the astronomical content is translated into orientations of structures in directions in which an astronomical phenomenon appears that should be credited by builders with a symbolic (association with celestial deities) or practical (calendar) value or, most frequently, with both.

The problem arises because almost all cultures know at least the cardinal directions and the ones of sunrise and sunset at the solstices. Even in the simplest case of a solar alignment, an archaeoastronomer must then consider at least 8 directions in azimuth on the horizon. Since practical considerations imply that any alignment should be considered with the uncertainty of at least $\pm1°$, these 8 basic directions cover 16° on the 360° of the horizon, corresponding to 4.4%. This corresponds to one probability out of 22 of chance coincidence of an alignment with one of the eight fundamental solar directions (i.e. 2.08 σ in Gaussian statistics: Schaefer, 2006)

Therefore, the probability that an alignment in one of the eight fundamental solar directions is due to chance is significantly high and the fact of finding in a structure such an alignment does not prove in itself that it was intended by builders.

Following Schaefer (2006), in order to claim an astronomical orientation, three conditions must be satisfied: the orientation must be statistically significant (at least 3 σ, better 4 σ), archaeological evidence of its intentionality must be present, anthropological evidence of the symbolic value connected to the claimed astronomical orientation must be found. Schaefer's test is certainly able to give strong support to the existence of an astronomical alignment in the case of a properly conducted survey. In some special cases, it also allows to give good evidence of a solar alignment in a single monument (see, e.g., Polcaro & Ienna, 2008).

Table I. The brightest stars.

V Mag	Bayer designation	Proper name
−1.46	α Cma	Sirius
−0.72	α Car	Canopus
−0.27	α Cen AB (α1 Cen)	Rigil Kentaurus, Toliman
−0.04	α Boo	Arcturus
0.03	α Lyr	Vega
0.08	α Aur	Capella
0.053	α Aql	Altair
0.053	α Cru	Acrux
0.067	α2 Aur	Capella B
0.42	α Ori	Betelgeuse
0.50	α Eri	Achernar
0,042	β Cen	Hadar, Agena
0,059	α Tau	Aldebaran
1.04	α Vir	Spica

However, this test is not applicable if you want to search for a stellar orientation in a single monument.

In fact, let us consider the brightest stars, those that, in our funny astronomical jargon, are defined as having a visual magnitude less than 1 (Table I).

They are 16 and each of them is certainly bright enough to be recognized from the most ancient age. Considering that each of them must be associated, at a given epoch, with a direction for its heliacal rise and set, the directions to consider are 32. Taking into account the uncertainty of ±1°, these directions cover 64° of the 360° of the horizon. The probability that an alignment happens by chance in one of these directions is thus =64/360 =~ 1/6 =~ 18%

The probability that the coincidence is accidental is thus very high.

If we consider that the positions of the heliacal rise and set of these stars have shifted over the millennia, and if we look even at coincidences with heliacal rise and set of the, still very bright, 92 second magnitude stars or even of the approximately 2000 third magnitude stars, not to mention the planets, we must agree with Schaefer (2006) that

"All archaeological sites have many indicated directions, the horizon is full of significant directions, and overlaps are inevitable, so all sites will have directions which could be claimed to be significant as based on the site plan alone."

Certainly, the situation can improve if we demonstrate through a survey that many similar contemporary monuments have the same stellar alignment. However, it is very difficult that we can find a statistically sufficient number of such monuments.

On the other hand, we know that many cultures have used the stars as a timing reference and have associated them with myths and cults: just think of Hesiod, the ancient Egyptian or Mesopotamian pantheon, etc.

Therefore, what we have said does not mean that archaeoastronomers should not look for stellar or planetary alignments. This only means that a measure, however precise it might be, cannot prove that these alignments are not by chance. They can thus only be suggested as a hypothesis, but you should not expect that archaeologists will accept this hypothesis based only on such a measure.

3. THE CREDIBILITY OF A SCIENTIFIC STUDY: THE CASE OF PHARMACOLOGY

However, the problem of the credibility of a scientific study is indeed becoming more and more serious in all disciplines. In fact, pressure on the whole scientific community to increase one's output, for a positive assessment of the activities of a researcher, is causing numerous cases of poor scientific ethics, ranging from scarcely proper data analysis to real scientific fraud.

Obviously, this situation has very negative consequences especially in those disciplines, such as clinical trials, which have a strong social impact.

For this reason, the community of Pharmacology scholars is considering to introduce a standard procedure, which is to be explicated in the evaluation of the credibility of the results of a research (Begley, 2013).

This procedure is based on six tests, and therefore is jokingly called "casting out six".

These are the tests proposed by Begley (2013) and a brief explanation of each of them:

Were studies blinded?

Most pharmacological studies are not blinded. Furthermore, by some estimate on large samples of Pharmacology papers, less than 20% of Methods sections even do not mention whether the work was blinded to prevent experimenter bias and in most cases the blinding methodology is not included.

Were experiments repeated?

Single experiments are sadly commonplace in the pharmacological literature. Papers often does not report replicate values, nor are aggregate numbers often used. It is true that it is a complex task, repeating multiple times some long term animal trials, and often critical reagents are expensive, but repeating studies before publishing should be the rule.

Were all results shown?

Results from multiple studies are rarely shown in the same paper, while usually only the "representative" example (read = best single result) is often reported. Furthermore, outliers often disappear from figures.

Were positive and negative controls shown?

The use of both positive and negative controls to benchmark an experimental system is frequently not done. Selection of the right controls is also an issue.

Were reagents validated?

Validated reagents are essential to draw robust conclusions. Authors should highlight where the validated reagents were obtained.

Were the statistical tests appropriate?

Statistics is a big gap for most pharmacological papers. Proper reinforcement of studies with a pre-agreed stat plan is a rarity. Showing numbers and error bars in figures is important.

Of course, these tests relate to the specific characteristics of biology and pharmacology and not all of them are directly applicable to other disciplines. However, keeping the basic principles in mind, although applying them in another way, this procedure could be very useful for Archaeoastronomy too.

4. THE "CASTING OUT SIX" IN ARCHAEOASTRONOMY

Here I will try to translate these tests in terms suitable to our discipline.

Were studies blinded?

Following the Oxford English Dictionary, a blinded experiment is an experiment in which information about the test is kept from the participant until after the test. Blind testing is used wherever items are to be compared without influences from testers preferences or expectations. In nuclear and particle physics experiments, in order to remove this possible bias, the experimental result is hidden from the analysts until they have agreed, based on properties of the data set other than the final value, that the analysis techniques are fixed.

In our case, this simply means that we must not formulate the hypothesis of a given astronomical orientation before getting data.

Were experiments repeated?

It is true that, in the field work, the time available for measurements is often limited by practical and economic reasons. However, the result of a few measures taken hurriedly is always unreliable.

Repeating measurements and testing the hypothesis on many similar artefacts from the same archaeological context before publishing should be the rule.

Were all results shown?

This applies without modification: sometimes only one out of ten possible orientations is considered and a single result that could suggest an astronomical orientation is presented, while the other nine orientations from the same context are ignored.

If you measure a possible alignment in a structure, but there are other similar structures around (or in any case in the same archaeological context), which do not show it, it is evident that the alignment found is random.

Were positive and negative controls shown?

All alternative hypotheses (e.g. topographical causes, nature of the soil, solar irradiation, etc.) must be considered.

Were reagents validated?

This rule remains valid by replacing the word "reagents" with "tools".

We must properly calibrate the instruments that we are using.

If we use a compass, we have clearly to explain how we calculated the magnetic declination.

If we took data from a published plan, we must have the certainty that North is marked correctly.

We must take into account the physical horizon and any further barriers to the visual.

Were the statistical tests appropriate?

Statistics is a big gap also for most archaeoastronomical papers. Proper reinforcement of studies with a pre-agreed stat plan must be used. Furthermore, showing numbers and error bars in figures is important. In the case of a survey, the sample that we measured must be statistically significant (large enough, free of selection effects, etc.)

However, the major problem is how we evaluated the correlation with the "null hypothesis" (i.e. the random orientation). This comparison should be made on the assumption, not on the measure. The measurement can have an uncertainty as small as you want, but it will only tell you that the artefact is actually pointing in one direction, where maybe a given astronomical phenomenon occurs. However, only the comparison between the probability that this alignment is intentional and that it is instead random (such as, for example, the one given by the Schaefer's test for solar alignments) provides a proof.

5. CONCLUSION

After all, these are very simple rules, but they are also very clear and understandable even to those unfamiliar with the "hard sciences“, and following them carefully will surely lead us to be more and more accepted by archaeologists, provided, of course, they are able to preventively distinguish us from those doing pseudo-archaeology.

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