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THE KNOWLEDGE OF TERRITORY IN ANCIENT CIVILIZATIONS TEMPLES AND SACRED SITES AS PREHISTORICAL GEODETIC NETWORKS?[1]

1. Introduction

We are concerned with a period of history to be approximately identified with a phase, during which the transition occurred from autarkic villages towards city-state organization. This required, as a pre-requisite, some adequate knowledge of territory. This was essential for travel, migrations, commerce, power, defense, economic and military expansion. Moreover, whenever society and economy were not yet suitably organized, migrations were sometimes a strict necessity, in order to get rid of natural catastrophes, as a fundamental aspect either of the fight against starvation or for survival.

Sometimes the landscape was suited for an easy orientation (e.g. such as in the Etruscan territory, and whenever some reasonably dense network of natural hills, or reference features, allowed for an easy orientation). Under other conditions, however, they lacked adequate reference points, and the unique reliable help could derive only from astronomical observations. This was important for sailing among islands (rather than for bordering coasts). But, it was also a fundamental difficulty when moving within some large, almost totally flat, land, with a very poor human occupation of territory. In all such cases, the large rivers, whenever available, were the unique constraint, as they divided the territory into natural, although very wide, sub-regions. Orientation for travellers was in any case difficult, and often critical for survival.

The problem is still up-to-date in a few areas of the world. For example, we basically don't know the way by which Polynesians oriented themselves in the XVIII century, when James Cook first explored the Pacific ocean. Even nowadays, we don't know the way by which Bedouins orient themselves in Sahara, or Eskimoes in polar regions, etc. Understanding such items is fundamental for solving archaeological and proto-historical problems.

In early Mesopotamia, or in Egypt, or in Ionia, when no track existed, and the population density was extremely low, and mainly during the migrations for occupying the islands in the Aegean sea, the natural reference points in the landscape were eventually very limited, or sometimes even absent. Therefore, they strictly needed for some early "geodetic network", suitable for orientation, and that had to be as simple as needed for being used by any person having some adequate, although limited, training.

[1] A more extensive account of this study, within the more general frame of archaeoastronomy, is given by Gregori, Gregori 1996.

The inferences guessed here below are that: *(i)* in the Aegean Sea, the natural reference points of such a "geodetic network" were the islands themselves; *(ii)* in western Anatolia and Greece, they set up a system of temples and sacred sites; *(iii)* in Egypt, maybe, there was a network of obelisks (and of other landscape elements, such as pyramids); *(iv)* in other areas, maybe, there was something equivalent, that has to be suitably assessed.

A guess, however, is a mere speculation, until an "experimental" proof, based on observational evidence, is suitably achieved. The purpose of the present contribution is to invite archaeologists and historians to prepare suitable data sets, by which it is possible to carry out one such rigourous check, aimed either at confirming or at denying such a hypothesis.

Differently stated, computer applications in archaeology are usually concerned with data handling dealing with information *(i)* either collected within a museum, or *(ii)* found during one particular excavation of a specific site, or *(iii)* when surveying all findings related to some archaeological area (an ancient town or so). The present concern is rather devoted to investigating the eventual apparent rules that determined in proto-historical times the choice of the sites where some settlements, or religious buildings and their respective dedications, or obelisks, etc. were located. That is, we propose to assess the large-scale pattern or rationale of the organization of an ancient territory. The purpose is to investigate whether they eventually set up some actual "geodetic" network suited for traveller orientation.

Some already available observational evidence, and some relative proposed interpretation that we found in the literature, are first presented, dealing either with the Anatolian-Aegean-Greek world, or with ancient Egypt. Then, a short account and discussion is given concerning the basic methodology of our proposal.

The analysis here proposed can be considered as a concrete example of "cognitive archaeology" (refer to the contributions by DORAN, GARDIN and ORLANDI in this volume). Cognitive archaeology, however, has a much wider perspective and ambition than either the simple problem of orientation alone, or the knowledge of territory. On the other hand, a key-aspect and requirement of the scientific method is the application of Ockham's razor[2], that, in general, can be practically used only whenever problems are reduced and simplified as much as possible, so that they deal only with a few basic, although self-contained, items. Knowledge proceeds by small subsequent steps

[2] «Entia non sunt multiplicanda praeter necessitatem», or «Frusta fit per plura quod potest fieri per pauciora» – William of Ockham (or Occam) «venerabilis inceptor», «doctor invincibilis», born close to the end of the XII century, dead in 1349 or 1350, Franciscan. Occanism can be considered as an actual precursor of Galileo – Refer to the competition between the Domenican and the Franciscan theological schools. "Simplicity" in science had relevant implications and debates in the history of science. It finally lead to the present formulation of variational principles, a most important logical tool either in classical, or in relativistic, or in quantum physics. Refer e.g. to Bochner (1966), Enriques and de Santillana (1936), Kline (1972), and Yourgren and Mandelstan (1968).

and improvements. The knowledge of territory is, perhaps, one such simple self-contained fundamental "technical" aspect, a pre-requisite for developing a civilization. If we afford in understanding the rules that governed such a phenomenon in proto-historical societies, we have thus defined a starting frame within which more ambitious improvements and refinements can be attempted, at a second time, on a sound grounding.

2. The needed database

We want to encourage archaeologists and historians to prepare a list, as complete as possible, of all temples and sacred sites that existed in antiquity within some given area of a limited extension, and, in the case of Egypt, a list of all sites where it is known that either an obelisk or a pyramid was erected.

In general, we refer both to existing archaeological relics, and to the as yet unexcavated sites. There is no formal need for getting a strictly exhaustive list, in the fact that our proposed algorithm can effectively work even whenever some fraction of the original information is eventually lost.

The area of interest ought to be reasonably wide, of the size e.g. either of western Anatolia plus Aegean Sea and Greece, or of Magna Grecia, or of Egypt, or of Mesopotamia, or of some area of comparable size in Central America, etc.

Every datum should specify the latitude and longitude of every listed site. Moreover, also the following data are most important, whenever available: *(i)* the God to which that site was dedicated; *(ii)* the astronomical orientation of the building; *(iii)* the location within the building, and/or eventually also in its surrounding area, of the different decorations, every one with its own mythological implications.

All such information will be important for checking *a posteriori* the reliability of our proposed interpretation. Whenever available, it is therefore extremely important to record all this, even when the information is not completely certain, as its reliability can also be checked *a posteriori*. In fact, in general, the database ought to be as complete as possible, as the more exhaustive it is, the more detailed will be the historical information that can be derived by it. Nevertheless, our proposed algorithm can provide with some objectively reliable results depending on the actual availability and precision of the prime input from observations. An algorithm should never provide with more "physical" information than what is objectively contained within its observational data input: a numerical result always comes out from a computer, but its actual "physical" significance must always be critically and severely considered.

Concerning the astronomical orientation of buildings, it appears that a very frequent method that is commonly applied by archeologists is by means of the compass. This is definitely unacceptable, as it often introduces large errors, particularly in volcanic areas (and in the ancient Greek, Etruscan and Roman worlds volcanic areas are very frequent).

3. The evidence within the Greek world

The already available observational evidence supporting our proposal relies on a study by Richer (1989). His concern, however, is limited to religious implications. We reinterpret his inferences in terms of the practical application by ancient travellers to the orientation problem.

Greek temples and sacred sites were located according to some apparently unexplained rationale, independent of the location of villages or towns. Richer (*ibidem*) claims that they conventionally defined, within some given area of interest for their travels, one *omphalos*-site, and an azimuthal frame of reference centred on it, and that was fixed with respect to the Earth surface.

Suppose to divide the full circle of *360°* into *12* sectors *30°* each: instead of using degrees for expressing angles, one can thus use *12* symbols, almost like hieroglyphs, for expressing either one of such *12* azimuthal sectors. Such hieroglyphs were well known: the zodiacal signs.

The Zodiac was formerly defined for measuring a celestial longitude. However, in principle, the zodiacal signs could be used also for measuring every azimuthal angle other than celestial longitude. Essentially, this is the same as we do nowadays, by which we use a unit (degree of angle) for expressing the size of any given angle, whether it is a celestial longitude or the measure of the slope of a hill, or else. Such ancient people used a *30°* unit, and instead of using a figure (e.g. as we do by using *25* for specifying an angle of *25°*), they used a hieroglyph, that had the same purpose of our figure *25*.

According to Richer (*ibidem*), this was made by the ancient Greeks. Every town was thus associated with one given azimuth, or hieroglyph, identified with the Zodiac sign associated with its azimuth, reckoned with respect to the given and conventionally pre-chosen *omphalos*: as a matter of fact, the earliest coins had no name of the town that issued them, rather they were recognized only by the zodiacal sign conventionally assigned to that town[3].

Moreover, the dedication of a town or of a temple was according to the association of its specific zodiacal sign with a given God, according to their

[3] Some information about zodiacal signs is as follows. Their definition in the present form apparently dates back to the VIII century BC (Fagan 1951, and Gleadow 1968, quoted by Richer 1989). The name "Zodiac" derives from "animals", as the largest part of constellations was represented by animals. The origin of their symbols, however, as we know them at present, is unknown. They seem to appear first within some Greek manuscripts of the late middle ages (Encyclopedia Britannica, "Zodiac", ed. 1962). The indication of the sign that has to be associated with any given observed phenomenon in the sky ought not to be intended only as referring to the constellation within the ecliptic plane (Richer 1989). Rather, every sign was intended as characterizing one entire meridional sector of the sky, from the ecliptic plane through the celestial pole. Moreover, every zodiacal sign was associated with its respective opposite sign, i.e. located at a relative azimuthal distance of 180°. According to Griaule (1966), some symbols that seem almost coinciding with some former zodiacal signs can, perhaps, be recognized in the Dogon culture in present Mali, close to the huge bend of the Niger river. They could, therefore, be remnants of some former cultural links, existing prior to the separation between the western and the Copt civilization following the conquest by the Arabs. The problem is open.

mythological standards. Moreover, every temple was suitably oriented in order to point towards some other temple, etc.

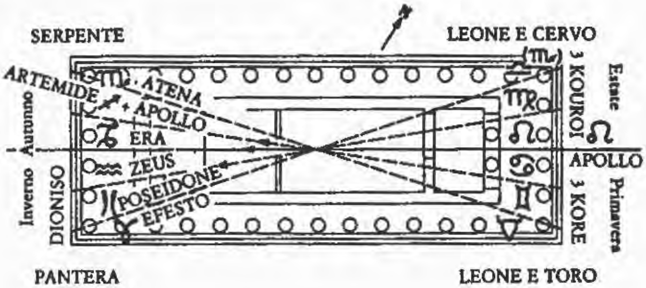
This entire system resulted to be a very clever "technical" tool for orientation problems. In fact, every traveller, located anywhere within that given territory, had thus to search for the closest temple or sacred site: from its dedication he knew immediately his position with respect to the *omphalos*, while from its orientation he knew in what direction he had to move.

In this way, mythology was a very easy and effective practical tool for training people: a few easy-to-remember stories, and the knowledge of only *12* symbols, or hieroglyphs, i.e. the zodiacal signs, were perfectly suited for recognizing either a coin, or a town, even for measuring angles (instead of using the less known degrees, although with a $\sim 30°$ precision), and mostly for orientation purposes, during commercial trips, seasonal transfers, migrations, military expeditions, etc. either on land or by sea. The *12* zodiacal symbols were, therefore, a first very effective, and easy-to-remember, "alphabet", suited for communicating important information, such as the town that issued a given coin, the essential "geodetic" assistance to travellers, to merchants, to "explorers", to armies, etc., and finally a way of providing a unit for measuring angles. Mythology and zodiacal signs were the actual knowhow needed by every learned person of that time. The religion appears to us to be, maybe naive, compared with the great achievements of philosophy. Nevertheless, it was a highly practical and effective tool for organizing everyday life and society.

Moreover, even the decoration on the metopes and on the pediments of the Greek temples had a specific "technical" (non-artistic) purpose: for a person located at the centre of the temple, the decoration (on the outside of the building) located in a given azimuthal direction had a specific association with the God and zodiacal sign of that given azimuth (Fig. 1). Hence, the mythology of the stories, represented on the metopes and on the pediments by skilful artists, was a crucial key for getting some fundamental "technical" information for travellers. This was actual applied science, prior to being the creative expression by an artist.

Four different *omphaloi* systems have been recognized by Richer (*ibidem*), that were centred, respectively, at Sardes, Delos, Delphi, and Ammonium (Figg. 2, 3, 4). It is impressive the location of the four *omphaloi* on the vertices of two isosceles triangles. We note that the triangle Sardes-Delos-Delphi could be determined by line-of-sight measurements, by means of fires during clear nights. But, the way by which they afforded in determining the relative exact longitude of Ammonium and of Delos appears a mystery[4]. It is

[4] Even as late as during the XVIII century the determination of longitude was a paramount and difficult problem. The hope of solving it by means of the compass pushed governments to invest in expeditions for carrying out geomagnetic measurements. Such records are now very useful to us. Galileo had proposed in 1616 the correct solution of the longitude problem, by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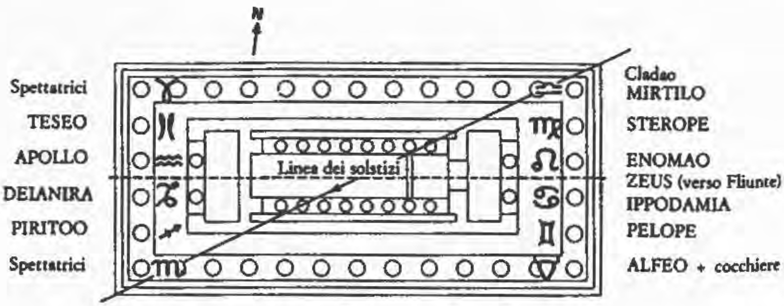
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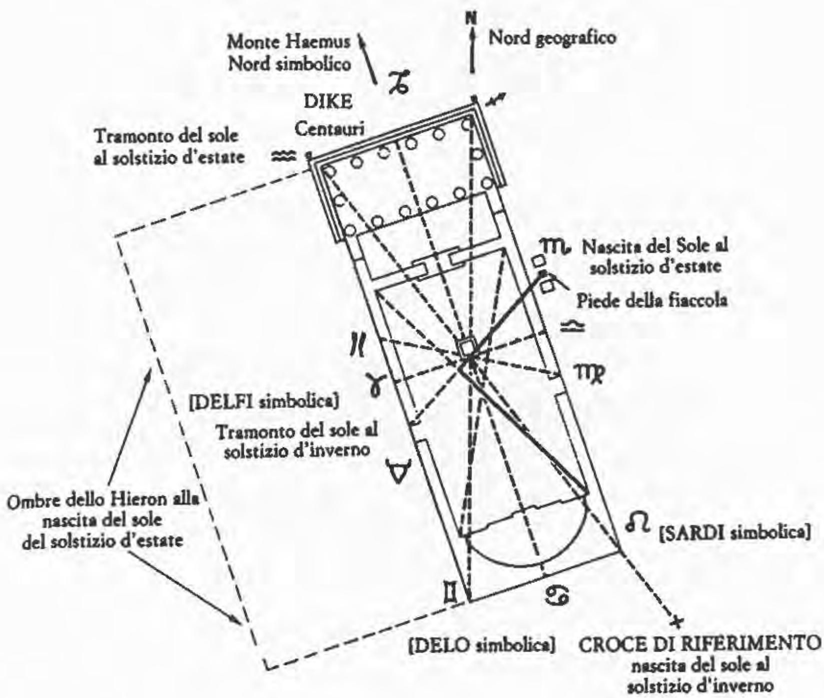
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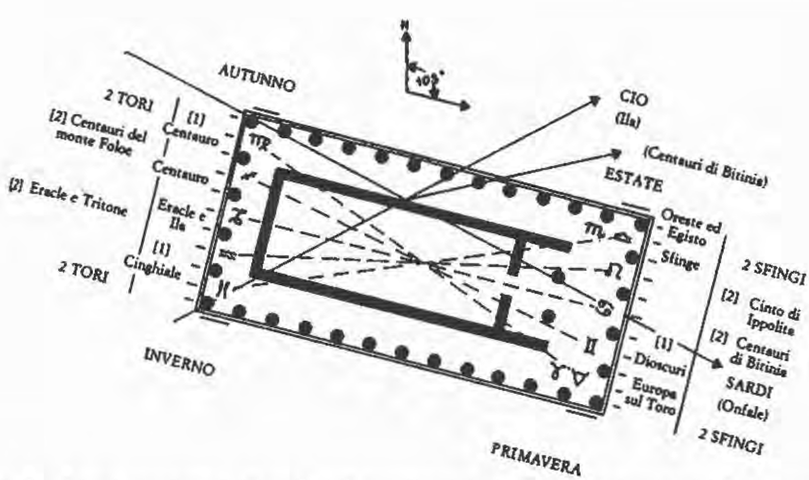

(d)

Fig. 1, a-d – Some examples of zodiacal interpretation of the decoration of metopes and pediments in a few Greek temples (figures borrowed from RICHER 1989, see text). Considering every temple as the centre of an azimuthal frame of reference, every azimuth was associated with a zodiacal sign, that was related to some God according to the mythological standards of that time. Top to bottom: Delphi (temple of Apollo); Olympia (temple of Zeus); Samotracia (Hieron); and temple of Assus (Troas).

premature to say whether this was a coincidence or not. In fact, appealing to chance and coincidence, or to superstition or religious believes, often is only the bad way by which a researcher avoids the effort and responsibility for attempting at finding some actual explanation of an observed fact. Therefore, one should be very careful prior to stating that something is only a matter of a coincidence.

In any case, this entire scheme clearly envisages that ancient Greeks had a remarkable (and as yet unexpected) knowledge of their territory, and were evidently capable of measuring alignments by means of fires, etc. For example, Richer (*ibidem*) emphasizes that several texts mention fires located on elevated sites. They used them for communication. One such mention is found e.g. at the beginning of *Agamemnon* by Aeschilus. The use of visual direct contacts for communication remained basically up-to-date until the very recent invention of the telegraph – Carl F. Gauss (*1777-1855*) and Wilhelm E. Weber (*1804-1891*) developed two kinds of such instruments] and of radio communication by Guglielmo Marconi (*1874-1937*) at the beginning of our century (SMITH 1976).

means of telescope observations of Jupiter's satellites. But, apparently he was not believed (BROWN 1949; CARACI 1979; SCANDALETTI 1981). In the opposite case, we would now probably miss the largest part of the remarkable historical collection of compass records. The ephemeris' of the Jovian satellites were first published in 1668 by Gian Domenico Cassini (1625-1712).

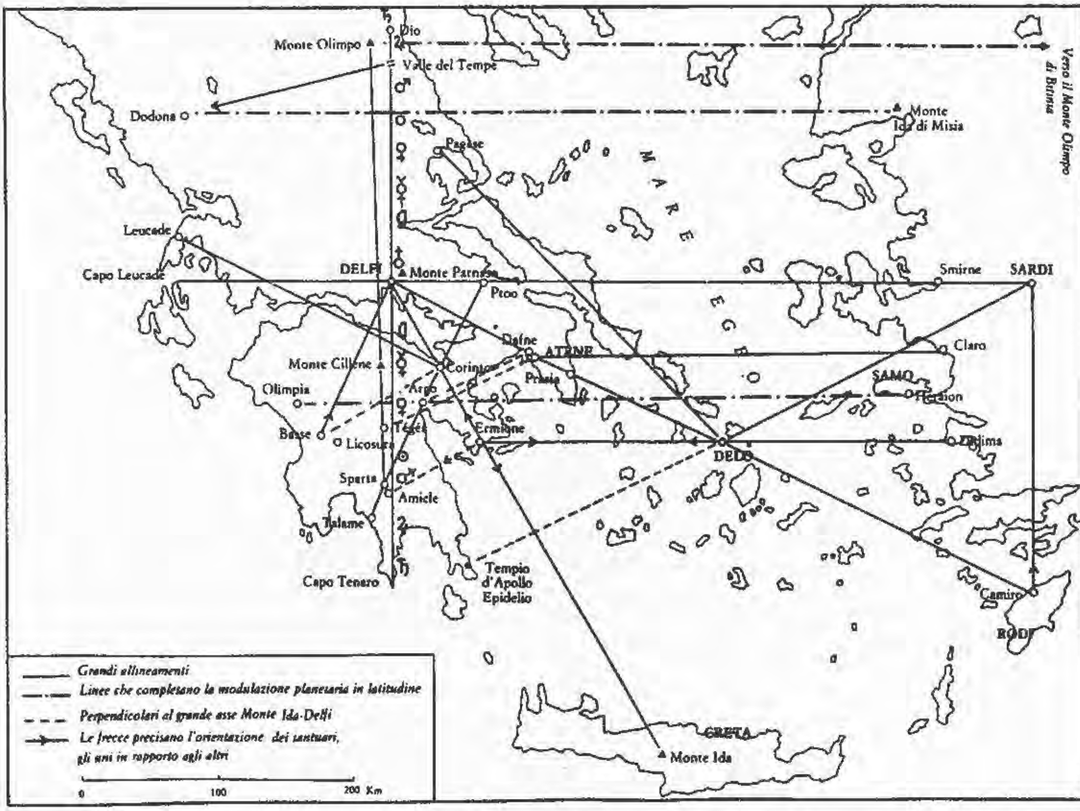

Fig. 2 – "*The great alignments*" (from Richer 1989, see text). The two lines across Delos and Sardes, respectively, are two parallels almost exactly at ~ 1 mutual latitudinal difference, with an error of $\pm\ \sim 0.05$, equivalent to an linear distance on Earth's surface of $\pm 5\ km$ (standard deviation). This cannot be a matter of chance. They could actually afford in getting such a precision by means of wooden palls erected on flat platforms (see text).

One additional and definitely very impressive regularity is the alignment (Richer 1989) of several sites along two parallels almost exactly at $1°$ relative difference in latitude. The two lines are, respectively, across Didyma, Delos, Hermion, Lycosura, and across Malatya, Sardes, Smyrna vetus, Ptoon (a mountain close to Acraephium), Delphi, Naxus (in Sicily) (Fig. 2). Only Naxus has a larger deviation ($\sim 0.4°$ in latitude, or $\sim 45\ km$ on Earth's surface) from such an apparent rigourous geometrical law. Maybe, its apparent alignment could be a coincidence. But, the two lines have all the afore-mentioned sites (except Naxus) aligned with an impressive precision, with a standard error-bar of $\sim \pm 0.05°$ in latitude, equivalent to a linear error-bar on Earth's surface of $\sim \pm 5\ km$. Refer to Gregori, Gregori (1996) for details. By sure, it is practically impossible that such a result is only a matter of coincidence.

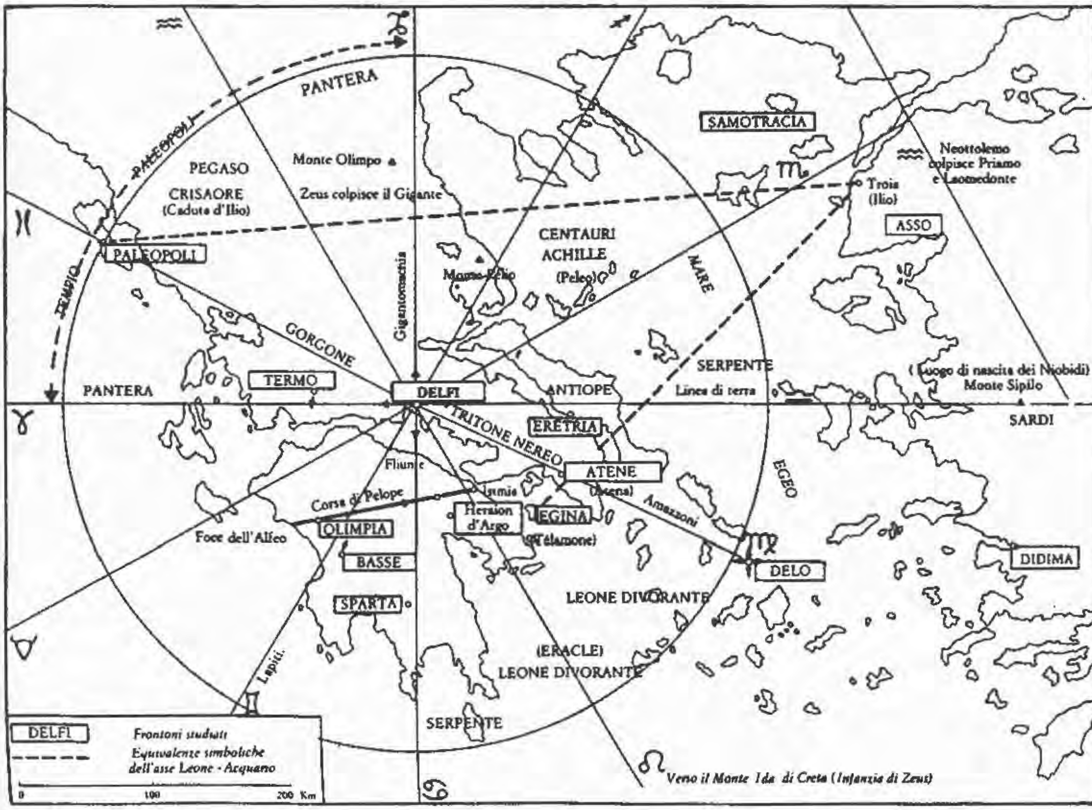

Fig. 3 – "*The sculptured pediments and the zodiacal geography*", or the *omphalos* system centred at Delphi (from RICHER 1989, see text).

Upon a specific analysis, the authors have shown that such ancestor astronomers could afford in getting such a high precision by means of wooden palls a few metres tall, vertically erected over some very smooth horizontal platform, provided that they measured both the pall height and its shadow with a precision of a few millimetres. Namely, they had to set up, within a temporary network, a few such very smooth platforms, every one a few metres wide, with a vertical pall erected on it, a few metres tall. Then, they had to monitor the shadow projected by the Sun on every such platform, during a few to several days (the best precision could be attained close to winter solstice). In this way, they could recognize the length of the shadow of the pall, at local noon on different days. Then, they could easily envisage the maximum length of the shadow that was observed on winter solstice (even provided that on that given day the sky was overcast, they could get the needed inference by means of an easy interpolation). Finally, they could know

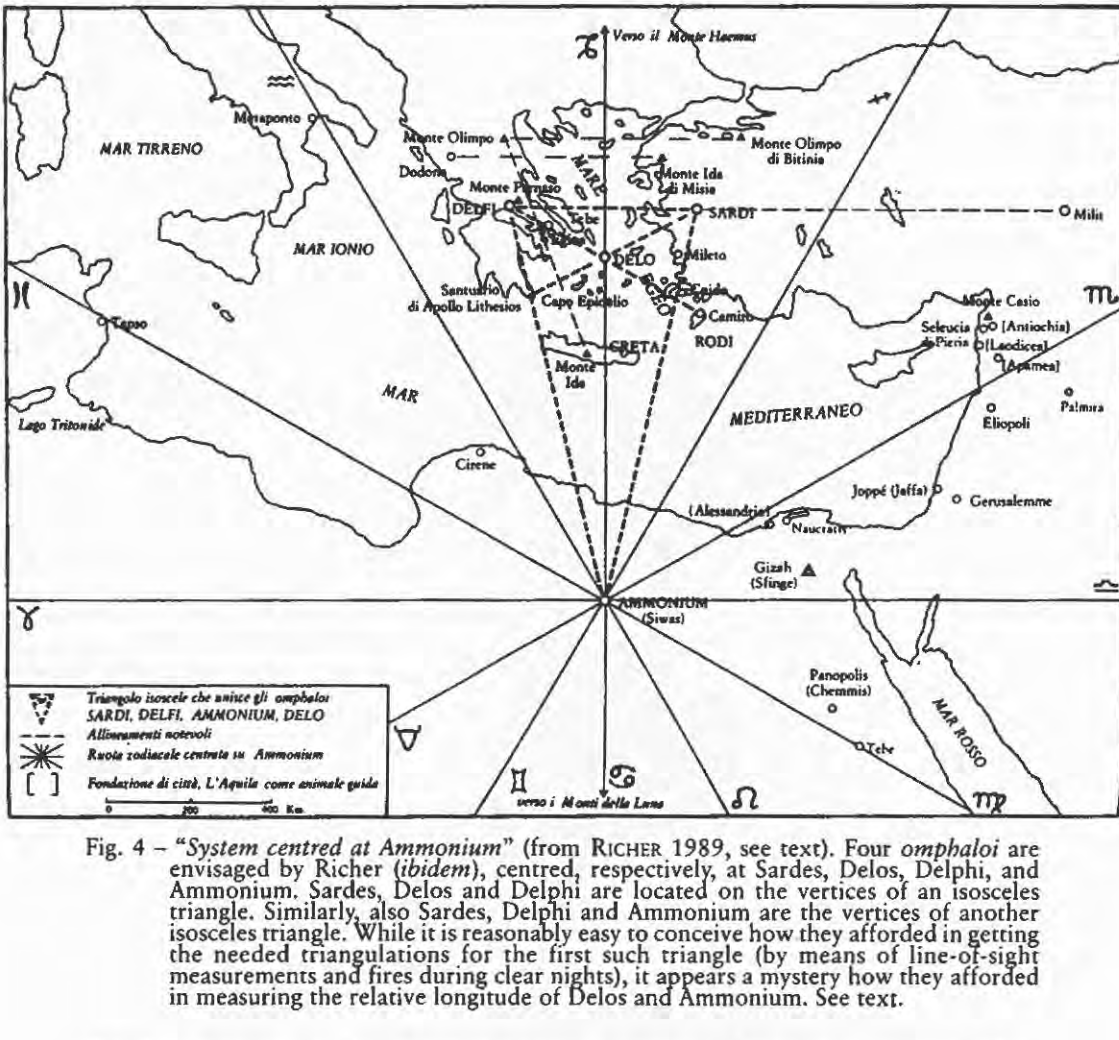

Fig. 4 – "*System centred at Ammonium*" (from RICHER 1989, see text). Four *omphaloi* are envisaged by Richer (*ibidem*), centred, respectively, at Sardes, Delos, Delphi, and Ammonium. Sardes, Delos and Delphi are located on the vertices of an isosceles triangle. Similarly, also Sardes, Delphi and Ammonium are the vertices of another isosceles triangle. While it is reasonably easy to conceive how they afforded in getting the needed triangulations for the first such triangle (by means of line-of-sight measurements and fires during clear nights), it appears a mystery how they afforded in measuring the relative longitude of Delos and Ammonium. See text.

the elevation angle of the Sun at noon on winter solstice at every such platform, by considering the ratio between the length of the shadow and the height of the pall. Now, if they wanted to search for a site that had some given solar elevation angle at noon on winter solstice, and if such a solar elevation angle was different from all values that they actually measured within their platform network, they could easily infer, by intuitive interpolation, what site, located somewhere inside their network, fitted with their requirement.

Perhaps, on a speculative basis, a reasonable guess is that menhirs and ziqqurats (such as also Monte d'Accoddi, close to Sassari in Sardinia) could be reminiscent of such a wooden-pall astronomy: they ought to be some kind of a surviving stone-version of a fairly common wooden astronomical tool, that was used as a standard at those times. A ziqqurat was in fact an elevated platform (for getting a free horizon above all houses or huts), a status symbol for the town, and (maybe) one point of a "geodetic" network. Refer to GREGORI, GREGORI 1996 for more extensive discussion.

4. THE EVIDENCE IN EGYPT

The present available observational base seems more limited compared to the afore-mentioned case dealing with Greece. It is based on a study by GOYON (1977).

The actual very first origin of obelisks is unknown. According to Goyon (*ibidem*), the builders of pyramids could not use the plumb-line, either due to the shape *per se* of a pyramid, or due to the temporary structures that had to cover the outer surface of the pyramid during its building, structures needed for sliding up the construction material. Therefore, the high precision they got (and they had to require it, due to the size of the construction) could be achieved only by means of a reference point on the horizon, e.g. just like an obelisk with a reflecting convex metal disk shining on top of its *pyramidion* (or "benben" stone).

For example, Strabo (XVII, 1, 30) mentions a tower-observatory that existed at Kerkasôre on the western coast, where Eudoxus of Cnidos and Plato carried out a series of astronomical observations. According to Goyon (*ibidem*), several checks agree in identifying such an observatory with the sight-temple by Cheops, that was later re-cycled as an observatory by Egyptian astronomers (and it was destroyed, on some time after the period of the occupation of Egypt by the Romans, as it was used as a quarry for excellent limestone).

Egyptians used detailed ground-surveying, by using either the Nile itself as a natural reference frame, or by means of the "*betamists*" (who walked and counted steps; FISCHER 1975). They surveyed in this way all Egypt down to Aswan, and maybe farther south. But, ground-surveying was shortly getting into large errors, unless their measurements were constrained by some suitable sight-elements on the horizon. Therefore, from such a viewpoint, we propose that obelisks, with their shining *pyramidion* and (perhaps) reflecting disk, were maybe an effective "geodetic network", in addition to being (according to Goyon) reference-points for the builders of pyramids.

Summarizing, we guess that ancient Egyptians afforded in controlling their huge territory, from the Mediterranean coast down to Aswan and farther southward, by using both the Nile as a natural reference frame, and some suitable network of obelisks that, in addition to other eventual reference points already existing in the landscape such as the pyramids, ought to help the "*betamists*" in drawing their accurate cadastral charts. Such a "geodetic" network was fundamental for ruling the territory. The assistance to travellers for orientation was indeed less important, in the fact that when the territory is well known, and some elementary road system is tracked, travellers have several easier and more direct references directly on the ground, almost like the present tourist-signs.

In this respect, when the Romans entered into the scene, the territory was already fairly well known. Hence, they needed for no such "geodetic network". They used an excellent road communication system for managing their huge territory by rapid movements of their armies. Their maps were very detailed road-maps, but out-of-scale, as they did not mind about distorting either sea-surface or linear distances. Maps had only to contain precise information, almost like direction signs, for every interested traveller.

5. The algorithm and the analysis

The methodological approach is based on the well known "scientific method", that for clarity purposes is briefly synthesized in Table 1 and in Fig. 5 (the sequence order is left to right). The first row in Table 1 specifies the acronyms of every logical stage. The second and third rows specify the eventually different terms used, respectively, either in archaeology or in the natural sciences. The fourth row specifies the character, i.e. whether every respective step implies arbitrariness or not. The last row indicates the reference to the legend, where some additional specifications are given.

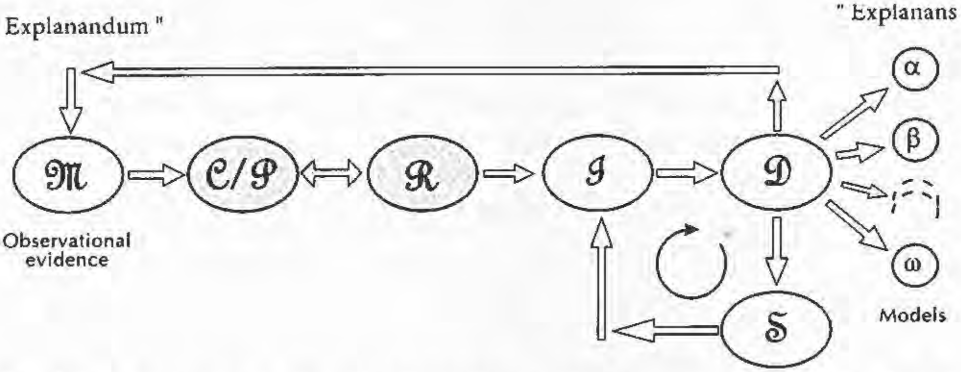

Fig. 5 – The stages of the cognitive process (the "scientific method"). See Table 1. The morphological stage *M* applied to the observational database (*Explanandum*), is followed by the "incoding" or parametrization stage *C/P* and by the choice of a rationale or of the working hypotheses (stage *R*). The stages *C/P* and *R* unavoidably imply an intrinsic arbitrariness (hence, the different shading in this sketch). The next step is the inductive stage *I* followed by the deductive stage *D*. Different checks can now be carried out. On one side, one can "forecast" some features of the "system", and make reference anew to the original observations, in order to check whether the facts "forecasted" by deduction correspond to what actually occurred. On the other hand, it is possible to carry out a statistical search for a possible coincidence (stage *S*). When all such checks have been carried out, the final result is a set composed of either none, or just one, or several, possible explanation models (*Explanans*), here called α, β, etc. See text.

[Read left to right, as in figure 5]	$\mathcal{M}$ [descriptive, or morphological, or naturalistic]	$C/\mathcal{P}$ [defining the "incoding", or the parametrization]	$\mathcal{R}$ [choosing the rationale, or the working hypotheses]	$\mathcal{I}$ [induction]	$\mathcal{D}$ [deduction]	$\mathcal{S}$ [statistical search for random coincidences]
name in archaeology [the object, or the "system", to be investigated is mankind]	descriptive	defining the "incoding"	"	"	"	"
name in natural sciences [the object, or the "system", to be investigated is the ensemble of natural phenomena]	morphological, or naturalistic	defining the parametrization	"	"	"	"
character	objective	arbitrary	arbitrary	strictly logical	subjective when defining axioms, then strictly logical	arbitrary when mixing data, then strictly logical
comments	(1)	(2)	(3)	(4)	(5)	(6)

Table 1 – The stages of the cognitive process (the "scientific method").

Legend: (1) - The observional database includes its own error bars; (2) - The system has an almost infinite number of degrees of freedom (*d.o.f.*). Human mind has limited capability of understanding. Hence, we must use a dramatically simplified number of parameters or quantities, that we suppose can be sufficient for providing a description of the observations in terms of "simple" relations between a few observed facts. The degree of arbitrariness depends on the accuracy that is required for the description (or "interpretation") of observations. There is no way of avoiding such an intrinsic and relevant limitation. Only observations (including their respective intrinsic error bars) are the actual truth (according to what we can really know), while the "incoding" or parametrization is already a strictly limiting step of our cognitive process, a dramatic way of confessing our incapability to face the problem of treating the almost infinite number of *d.o.f.* There is no "absolute" true way of "incoding" or parametrizing the "system". Simplicity is a heavy drawback that is intrinsic to the limitation of human understanding; (3) - The cognitive process is to be identified with a search for some "simple" interpretative scheme, that should explain some relevant features of the observations, in terms of some relations between a limited set of parameters. Therefore, some working hypothesis, or a rationale, is often implicitly introduced, almost an unconscious choice of a way for reasoning. Sometimes, however, this stage is a minor source of arbitrariness, compared to other stages. The choice of the working hypotheses can be interactive with the inductive stage, in the fact that one re-chooses a different set of working hypotheses after applying a first induction analysis, etc. The ultimate goal of the cognitive process is in envisaging some "simple" and (as far as possible) exhaustive interpretative scheme. Hence, the researcher can attempt at optimizing his arbitrary choices for getting a more satisfactory final result; (4) - The inductive stage is objective *per se*. In several practical applications, however, it is often identified with some standard statistical data handling and analysis. But, such a limitation is a definitely oversimplifying approach, and it is, therefore, a frequent source of unfortunate misunderstanding (see text); (5) - The definitions of axioms must be constrained by Ockham's razor. Deduction must finally provide with specific information on the "system", that should allow for carrying out tests by means of the available (and as yet unexploited) observational evidence; (6) - Upon reconsideration *(i)* of the available observational database, *(ii)* of the "*incoding*" or parametrization, *(iii)* of the working hypotheses (that are the almost unconscious but actual backbones of the entire analysis), the researcher atempts at investigating the robustness of his model derived by means of his analysis, when considering the limited amount of cognitive information that is obiectively contained within his available observations (and relative error bars). The doubt is that some inferences of his analysis are only a result of chance or coincidence, rather than an indicator of some actual empirical law relating to each other different aspects or quantities characterizing the description of his "system". Hence, the researcher attempts at envisaging some suitable way of mixing up, randomly, a suitable subset of the prime parameters, that were defined during the "incoding" or parametrization stage. If the final result of the analysis is almost the same, or in any case very similar, independent of such a random mixing, this implies that his proposed interpretation and model is basically poorly constrained by actual observations, in the fact that even by substantial differences in the database one always gets practically the same result. In such a case, such a result appears, therefore, some consequence of the arbitrariness that is implicit in the definition of the cognitive process and its consequent application, rather than a reliable evidence strictly provided and constrained by observations. In contrast, if the result is not robust with respect to the random mixing of the input data, the researcher can be confident in the fact that his conclusions appear to be constrained by the actual observations, that cannot be mixed, as the specific mutual associations of the different observed parameters and quantities has some intrinsic "physical" motivation, typical of some rationale intrinsic to the nature of the "system".

Upon a closer inspection of the present specific application, the observational database is the information related to the existence of a temple at some given site, and dedicated to some given God. Latitude, longitude, and the God of dedication, are the "parameters" got by means of our "incoding". The rationale or working hypothesis is the eventual existence of a "geodetic" network, as mentioned in the previous sections, the existence of which has to be tested. By means of such a data set, and of such a rationale that we arbitrarily chose *a priori*, it is possible to carry out an inductive analysis, that should provide with the inference of the possible structure of one *omphalos*, or a few *omphaloi*, within that given area. Two steps can now be carried out.

On one side, deduction can be applied, and inference can be made about the existence and dedication of several possible other temples or sacred sites that were not included within the original database. A check between such "forecasted" sacred sites, and their existence and dedication by means of suitable new excavations, could result in an important support to the reliability of the conclusions inferred by our entire analysis.

Other important checks can be carried out by means of the decoration of temples, where specific mythological scenes ought to be suitably located with respect to an azimuthal reference frame centred at the centre of the temple itself. We note that, at such a stage, the "incoding" or parametrization of our "system" is being re-considered, in the fact that some "parameters" (i.e. the information provided by the decoration that we had neglected in our first computation), are now fed into our analysis in order to get confirmation of our speculated model. That is, the deductive stage allows for reconsidering and somehow weakening the arbitrariness of the constraints imposed by the need for simplicity of human mind, that compelled us to assume an "incoding" that limited the description of our "system" only to a few figures, i.e. the latitude and longitude of every site, plus its dedication, while neglecting the decoration details.

On the other hand, another possibility is that one can mix up, randomly, the dedications of every temple or sacred site, while keeping fixed their actual geographical coordinates. Then, one can re-apply the same algorithm as before, by means of such a randomly mixed database. Such a random mixing and re-analysis can be repeated iteratively several times, hundreds or thousands of times, etc. If the computer finds some *omphaloi* system for every such choice, this means that the information provided by the dedication of temples and sacred sites is mathematically insufficient for providing reliable evidence of one given *omphaloi* system. In fact, in such a case, a large number of possible different choices of *omphaloi* is presumably possible, always being basically in agreement with the prime observational evidence. Hence, the Richer hypothesis ought to be considered as a fascinating and intriguing speculation, although with no actual, objective, reliable support from observations.

In contrast, if such a random search shows that a reasonable *omphaloi* system can be inferred only, or almost only, when the actual dedication of temples and sacred sites is kept just like it was formerly suggested by observations when preparing the starting database, such a fact *per se* is a "proof" that observational data actually and definitely support Richer's hypothesis.

From a methodological viewpoint, an important warning ought to be emphasized. It is concerned, in general, with all kinds of applications of mathematical statistics to an observational data set. Such a warning applies either to archaeology or to "exact sciences" as well, and it is presently the source of frequent errors and misunderstanding within the geophysical literature. Consider Fig. 6a: it is a redrawing of a well known concept (see e.g. the contribution by GARDIN, present volume). Let us specify it with a little more detail, and redraw it as in Fig. 6b. This means that exact sciences, or humanities, specify their actual requirements through common sense, and thus feed their needs into mathematics, that finally provides them with the optimal formal algorithm to be applied in data handling, for getting a reliable final result.

The drawback, however, is that the link between common sense and mathematics is often almost unconsciously cut down (Fig. 6c). For example, this occurs whenever a mathematician is generally appealed to, for getting some indication about some algorithm to be applied to data analysis. The mathematician often specifies that, provided that the observations satisfy to some suitable hypotheses (e.g. the data information is uniform both in space and time, its error-bars are independent of either space or time, etc.) a suitable algorithm can be envisaged, etc. The crucial point is that an observational database, that was collected in the laboratory while carrying out an experiment in either physics, or chemistry, or biology, normally satisfies to such constraints (in fact, in the case that a database does not satisfy to such conditions, let us eventually repeat the experiment as many times as needed until we get a reliable database, that fits with our requirements).

In contrast, when we investigate some natural or historical phenomenon, within the evolving framework of either mankind or environment, we cannot "repeat the experiment". Therefore, the database is intrinsically incomplete, heterogeneous, with error-bars that are different during historical time, etc. Owing to such several reasons, the researcher of every given specific discipline must provide, through common sense, the suitable inputs to the mathematician, who must try to find out what algorithm is respectful of the intrinsic character and limitations of the available observational database, rather than simply "assuming" on a mere speculative basis that the database itself satisfies to some fanciful homogeneity conditions, so that some specific nice logics and algorithms can be applied.

Differently stated, a physicist must have the "physical feeling" of phenomena (*c.i.f.*, or "*con intuito fenomenale*", said Enrico Fermi), a physician the "clinical feeling", an engineer the "practical feeling", a historian the "historical feeling" (that distinguishes him from a mere chronicler), etc. Instead, a mathematician is normally concerned with a solipsistic search for the inti-

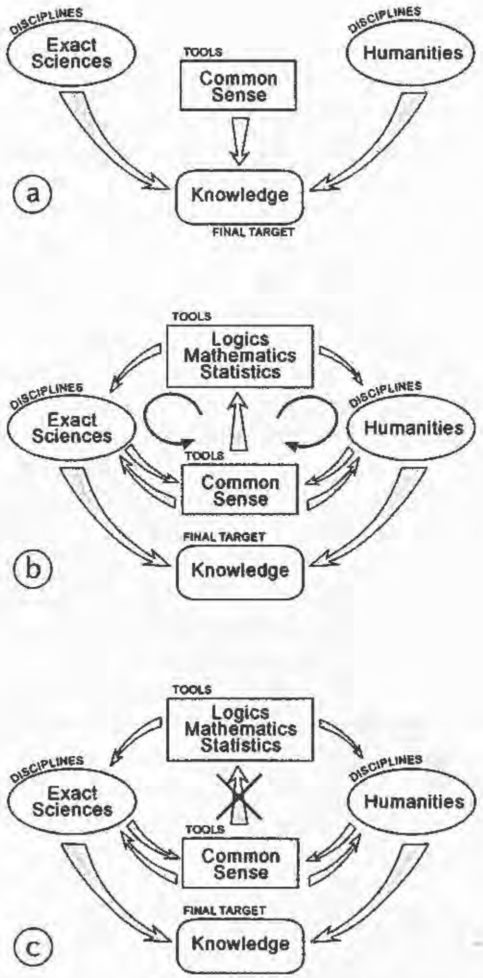

Fig. 6 – a) Our knowledge is the final target of a sum of contributions from the disciplines of exact sciences and of humanities. The tools are here simply indicated in terms of "common sense". Redrawn according to a sketch shown by GARDIN, this volume.
b) Slight modification of Fig. 6a, where it is specified the role of logics, mathematics, and statistics. A mutual interaction between common sense and the disciplines (of either branch) must provide mathematics etc. with some information, that is critically essential for defining the algorithms that ought to be applied for an optimum analysis of observations. This results into some kind of logical "circulation" by which the cognitive process iteratively improves itself. The final step is the output provided to "Knowledge" by either set of disciplines.
c) The same as Fig. 6b, where, however, the input from common sense into mathematics etc. is cut down. The afore-mentioned logical "circulation" is stopped. Mathematics provides both kinds of discipline with mathematically rigourous algorithms, that, however, are eventually intrinsically logically unsuited for the specific application of concern in every case. This is a very frequent case in the present geophysical literature, and it should be avoided, as it originates misunderstandings and a great waste of efforts and time. See text.

mate logical rules that relate some arbitrary axioms with some important and implicit inferences and conclusions. But, a mathematician is normally outside the basic problems, the rationale, and the viewpoints of the applied scientist or historian. Archaeologists, historians, and even scientists, often ask the mathematician to feed into the analysis *his own* common sense. But the common sense of the mathematician can never be inspired by the knowledge of the system that the archaeologist, the historian, or the scientist can have. In contrast, it is extremely important that the scholar, who must apply mathematics, actually relies only, and strictly only, on his own common sense, without delegating a mathematician to do so. Otherwise, even the best mathematician shall provide with highly sophisticated and rigourous formulas, that, however, will be eventually even completely meaningless, and sometimes even misleading, when applied to that given problem.

Such an important item was very authoritatively stressed[5] by TUCKEY (1977), who distinguishes between the *exploratory* data analysis, that ought not to be confused with the *confirmatory* data analysis. Tuckey (*ibidem*) states that, in general, there is no ideal perfect rule to be applied to any given observational data set. He recommends to display the data in as many ways as possible, and to infer, intuitively, all possible apparent evidences, then to try to improve the analysis by new, usual or unusual, tests and computations, and new ways of representing the data set, etc. Direct visual inspection on the observed data set (when they are represented in some suitable and convenient form) can result of paramount importance, even much better than by a formal numerical analysis by computer. Visual inspection plus computer analysis should be combined, but, one should never uncritically rely on standard formulas. Realism and common sense appear in any case fundamental for analysing uneven, incomplete, and scanty data series. Tuckey (*ibidem*) states (italics, bold, and capital letters are by himself):

> «Consistent with this view, we believe, is a clear demand that pictures based on exploration of data should *force* their message upon us. Pictures that emphasize what we already know – "security blankets" to reassure us – are frequently not worth the space they take. Pictures that have to be gone over with a reading glass to see the main point are wasteful of time and inadequate of effect. **The greatest value of a picture** is when it *forces* us to notice **what we never expected to see.**
>
> ....
>
> The best way to **understand what CAN be done is no longer** – if it ever was – **to ask what things could,** in the current state of our skill techniques, **be confirmed** (positively or negatively). Even more understanding is *lost* if we consider each thing we can do to data *only* in terms of some set of very restrictive assumptions under which that thing is best possible – assumptions *we know we CANNOT check in practice.*
>
> ....
>
> **Today, exploratory and confirmatory can – and should – proceed side by side.**»

[5] Prof. John W. Tuckey is the "father" of power spectra.

More specifically, the confirmatory analysis appears particularly difficult when applied to a historical data series, as the standard statistical tools are not suited for it. When the database is poor, we must try to get out of it as much information as possible, but without "forcing" it to provide those evidences that it objectively could never give, because of its intrinsic limits. Sophisticated statistical tools can be applied only whenever it is possible to acknowledge the actual viability of their implicit hypotheses in every specific application.

The cooperation of the mathematician can be of paramount importance either as a consultant when attempting at applying the common sense *of the researcher* to the available mathematical algorithms, or when applying the confirmatory analysis, after having accomplished the interpretation of the database in terms of sound and not-merely-mathematical arguments[6].

6. Conclusion

The control of territory was often essential, in several different aspects, either for survival, or for the development of civilization.

It appears that Greeks used the Aegean islands, and a suitable network of sacred sites and temples, as an effective "geodetic network". Mythology (Zodiac, etc.) was the easiest possible tool for training people in using such a highly sophisticated, although impressively simple, reference frame. Greeks afforded in measuring the latitude with a linear error-bar on Earth's surface as small as $\sim\pm 5\ km$ (standard deviation). Hence, it is possible that they afforded in getting the needed skill for setting up such a relevant *omphaloi* system.

Egyptians maybe used obelisks (presumably in addition to natural elements within the landscape, such as the pyramids themselves) as reference points either for keeping the construction of pyramids within the required precision, or for drawing their accurate cadastral maps, or ultimately for ruling a huge territory.

Moreover, provided that all such inferences are correct, what about Magna Grecia? Coastlines were a natural reference. Nevertheless, it appears very likely that, if they developed such a sophisticated *omphaloi* system in Greece, they also set up something analogous in their new, wealthy, and scientifically very developed, colonies. But, what about Mesopotamia (a "geodetic network" composed of ziqqurats?), or about Central America, or elsewhere? The Romans no more needed for such "geodetic networks", as the territory was already fairly well known at their time. They used roads for managing their huge territory, for commerce, and for military control. Hence, their charts contained very detailed information about roads and travel-times, although they were out-of-scale, as they did not mind about seas or about

[6] For example, some items, from such a viewpoint, concerned with the analysis of either climatic, or volcanic, or seismic, historical data series are discussed by Gregori (1990) and Gregori *et al.* (1992 and 1994), and references therein.

keeping the invariance of the linear distances on maps.

Science always proceeds by means of speculation, provided that it is later on suitably and carefully checked, and "proved", by observational data. Whenever a hypothesis can be checked, every scientist is deontologically obliged to do it. "Opinion science", i.e. claiming whether something appears more or less believable or not, etc. is considered, by "exact" scientists, as one of the most unfortunate, although very common, bias of present science, a real dangerous poison for our knowledge.

We don't claim that the afore-mentioned speculations about ancient Greeks and Egyptians are actual truth. We claim that it is practically and effectively possible to attempt at testing such a hypothesis. Hence, this must be done. If such an attempt will result successful, it will be a sound starting point for the future concrete development of cognitive archaeology, in the fact that the location of relevant buildings or sites should thus reveal an intrinsic logical rationale applied by the ancient builders. On the basis of such an assessment and knowledge, it will be possible to search for additional "rules" or "laws" that were an intrinsic feature characterising such ancient societies: such features were the output of thought, not of chance or of the disorder descending from either superstition, or exotic, or fanciful, religious believes.

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BIBLIOGRAPHY

BOCHNER S. 1966, *The Role of Mathematics in the Rise of Science*, Princeton, NJ (USA), Princeton University Press.

BROWN L.A. 1949, *The Story of Maps*, Little, Brown and Company, Boston, Mass., re-published in 1979, Dover Publications, Inc., New York.

CARACI G. 1979, *Il "negozio delle longitudini" e Galileo*, Genova.

ENRIQUES F., DE SANTILLANA G. 1936, *Compendio di storia del pensiero scientifico dall'antichità fino ai tempi moderni*, Bologna, Zanichelli (reprinted 1973).

FAGAN C. 1951, *Zodiacs Old and New*, London.

FISCHER I. 1975, *The figure of the Earth. Changes in concepts*, «Surveys Geophys», 2, 3-54.

GLEADOW R. 1968, *Les origines du zodiaque*, Paris.

GOYON G. 1977, *Le secret des bâtisseurs des grandes pyramides*, Paris, Editions Pygmalion, Paris, trad. ital., Roma 1990, Newton Compton Editori.

GREGORI G.P. 1990, *A few mathematical procedures for the analysis of incomplete historical data series*, in W. SCHRÖDER (ed.), *Advances in Geosciences*, Interdivisional Commission on History of IAGA, Bremen-Roennebeck, 80-127.

GREGORI G.P., BANZON V., LEONARDI R., DE FRANCESCHI G. 1992, *Geomagnetic activity vs. volcanic cycles, and their forecasting. Application to Etna and Vesuvius*, in W. SCHRÖDER, J.P. LEGRAND (edd.), *Solar Terrestrial Variability and Global Change*, Interdivisional Commission on History of IAGA, Bremen-Roennebeck, 188-222.

GREGORI G.P., BANZON V., COLACINO M., DE FRANCESCHI G., DIODATO L., PAVESE M.P., SANTOLERI R. 1994, *Floods, climatic anomalies, and explosive vulcanism: a four-decade cycle?*, in W. SCHRÖDER, M. COLACINO (edd.), *Geophysics: Past Achievements and Future Challenges*, Interdivisional Commission on History of IAGA, Bremen-Roennebeck, 109-133.

GREGORI G.P., GREGORI L.G. 1996, *Viewpoints in archaeoastronomy. An invitation to the archaeology of Earth's science*, in W. SCHRÖDER, M. COLACINO (edd.), *Global Change and History of Geophysics*, Interdivisional Commission on History of IAGA, Bremen-Roennebeck, 228-288.

GRIAULE M. 1966, *Dieu d'eau*, Librarie Arthéme Fayard, Paris, trad. ital. Milano 1968, Casa Editrice Valentino Bompiani & C.

KLINE M. 1972, *Mathematical Thought from Ancient to Modern Times*, Oxford, Oxford University Press.

RICHER J., 1989, *Geografia sacra del mondo greco*, (III expanded edition, in Italian, Rusconi, Milano). The I and II editions were published in 1967 and 1983 in French by Guy Trèdaniel Editions de la Maisnie, Paris.

SCANDALETTI P, 1989, *Galileo privato*, Milano, Camunia.

SMITH E.K. 1976, *The history of the ITU, with particular attention to the CCITT and the CCIR, and the latter's relations with URS*, «Radio Sci.», 11, (6), 497-507.

TUCKEY J.W. 1977, *Exploratory Data Analysis*, Reading, Massachusetts, Addison-Wesley Publ. Co.

YOURGRAU W., MANDELSTAM S. 1968, *Variational Principles in Dynamics and Quantum Theory*, New York, Dover Publications.

ABSTRACT

A hypothesis is proposed dealing with the way by which ancient societies could get knowledge and control of their territory, by means of some kind of a former "geodetic" network, conceived as some basic frame reference for orientation of travellers. Mythology was a practical and effective tool for training people. The zodiacal signs appear to be almost some kind of a "universal" former "alphabet", suitable either for characterizing every given town, or for measuring angles of any kind, or for assisting a traveller in his orientation. In the Aegean Sea the natural reference points where the islands themselves. In western Anatolia and Greece, they set up a system of temples and sacred sites. In Egypt, maybe, there was a network of obelisks and pyramids. In other areas, maybe, there was something equivalent. Some observational evidence is already available, and some proposed interpretation can already be found in the literature, dealing either with the Anatolian-Aegean-Greek world, or with ancient Egypt. In any case, ancient Greeks were apparently capable of estimating the latitude of a site with a high precision ($\sim \pm 0.05°$ latitude, equivalent to $\sim \pm 5\ km$ on Earth's surface; standard deviation). Such items are here briefly reviewed. Then, it is shown how a suitable file containing latitude, longitude, and dedication, of all temples and sacred sites of a given area (or the location of obelisks and pyramids that existed in Egypt) can allow for a formal analysis capable of assessing whether such a hypothesis is only a simple although fascinating speculation, or whether it is supported by objective observational evidence.