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On Planning in Science : an Attempt to Confront the History of Science with Contemporaneity

Organon 6, 87-95

1969

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ON PLANNING IN SCIENCE

An Attempt to Confront the History of Science with Contemporaneity

It is said that history is the teacher of life but this saying does not seem to be treated too seriously. The more so that next to this there are other sayings such as "times are changing" or "history never repeats itself", which condone those who do not want to go through a painstaking study of the story of mankind or to draw any conclusions from it.

I do not know if there are fields of activity in which this attitude might be recognized as justified, but in science this is something that must be called an obscurantist attitude. I do not mean individual scientists solving this or another problem; to them, looking backward may sometimes even constitute a psychological encumbrance which prevents them from casting, a new look at their problems. Instead, I have in mind mainly the managers of science, those who are responsible for its organization or for which is generally called the planning of science. In this field we may frequetly come across situations so queer or even unwholesome that it is only by taking recourse to history that we may extricate ourselves from these situations.

The word "planning" itself has in science a meaning quite different from those in the other fields of human action. The construction of a building or machine may be realized strictly according to a plan devised before. It is different in science. There, we do not plan the results of investigations but, to put it shortly, the contents of the questions put to nature or to a set of phenomena being the object of investigation. And, as a rule, we do not know what answer we shall get. Were it otherwise, then discoveries should be made already in the course of planning itself, and the realization of the plans would be simply unnecessary. Plans would then serve at most to test our expectations. But this occurs very rarely in science, and is characteristic of rather trivial and unimaginative experiments.

This is not to mean that while planning an experiment or series of investigations an individual scientist makes no conjectures concerning the ultimate results of the investigations. However, expectations of this type are psychological processes that frequently hinder conspicuously the solution of many problems, for they often become false suggestions restricting the scientist's field of perception and drifting him off the correct direction. This is one reason why so many scientists very reluctantly display their plans; it is not by superstition, as many people falsely presume, nor because of modesty. This attitude results from the conviction that in trying to formulate some vague conjectures the scientist may slip into taking them for his own *a priori* certainty, which at some moment may hide truth from him.

The harmfulness of this type of planning is rather well expressed by Bertolt Brecht in his play *Life of Galileo,* in which he makes Galileo say: "Meine Absicht ist nicht, zu beweisen, dass ich bisher recht gehabt habe, sondern: herausfinden, ob. Ich sage: lasst alle Hoffnung fahren, ihr, die ihr in die Beobachtung eintretet... Ja, wir werden alles, alles noch einmal in Frage stellen... Und was wir heute finden, werden wir morgen von der Tafel streichen und erst wieder anschreiben, wenn wir es noch einmal gefunden haben. Und was wir zu finden wünschen, das werden wir, gefunden, mit besonderem Misstrauen ansehen. Also werden wir an die Beobachtung der Sonne herangehen mit dem unerbittlichen Entschluss, den *Stillstand* der Erde nachzuweisen! Und erst wenn wir gescheitert sind, vollständig und hoffnungslos geschlagen und unsere Wunden leckend, in traurigster Verfassung, werden wir zu fragen anfangen, ob wir nicht doch recht gehabt haben und die Erde sich dreht!" [1]

It may be argued that a scientist's study-room or laboratory is something different from a scientific council in a big research institute or from the department of planning in a ministry, that planning is carried out differently here and there. True, but we must remember that in each process of synthesis or integration the result is largely dependent on the specific properties of those magnitudes that play the roles of components or "differentials" in it. In our case, the differentials are the intentions or dreams of individual scientists or of some schools. I use the word dream deliberately, because it seems to me a more correct description of the state of scientists who are just meditating upon a new problem for investigation than planning or intentions. These specific aspects of the scientist's work must not be overlooked or neglected whenever a synthesis or planning are being made (and planning is an integrating activity), otherwise science may lose its discovering quality. I am sure that many a plan devised without considering these elements of scientific work became a grave of science, though it is never written

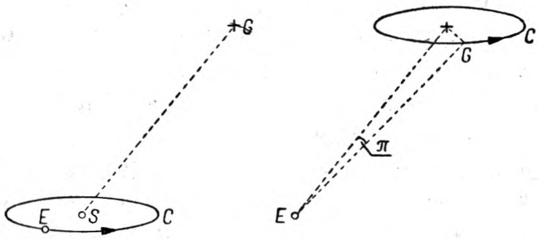
[1] Quoted from: Bertolt Brecht, *Leben des Galilei,* scene 9, Philip Reclam, Leipzig 1968, pp. 77—78.

or spoken about. Not many people are capable of admitting that they made mistakes, whereas accusations made by others always tend to become a controversial issue.

It is at this point that the suggestions drawn from history may prove valuable and instructive. For this purpose, I wish to mention two events from the history of astronomy which are separated by more than 300 years and yet have much in common. The latter of these events belongs to what is sometimes called recent history: it occurred in our times.

Soon after the publication of Copernicus' *De Revolutionibus*, and even before, astronomers hastily started looking for arguments that would either support or sap the heliocentric theory of the "Sarmatian" astronomer. One type of observations seemed to all the simplest way to get the feeling of certainty in the choice of one of the two systems—the heliocentric or the geocentric; namely the observations of certain parallactic shifts of the positions of stars or, shortly, of the parallax, which was also used to denote the angular size of such shifts on the sky.

Let us take a star *G* (cf. figure below) which is in rest with respect to the Sun *S*. If, following Copernicus, we assume that the Earth together with the observer moves round the Sun along a circle, it will mean that by transferring the frame of reference from the Sun to the Earth we shall be observing the motion of the star along a circle which is exactly the same as that along which the Earth moves around the Sun: this we learn from the principle of relativity of motion (discovered already by Galileo). This is of course true of any star without exception in our



With respect to the Sun (*S*) the star (*G*) is in rest (left figure). With respect to the Earth (*E*) the star (*G*) moves along a circle (*C*), which is identical with the Earth's orbit (right figure). The parallax (π) is the observed angular displacement of the star.

environment, the assumption that they are in rest with respect to the Sun being of no essential significance. Now we can allow for them to move with the provision that to the motion of each of them we add geometrically a circular motion of a period of one year. The latter motion is called the parallactic motion. We ought to remember that astronomers observe exclusively angles on the sky, and the farther the object under observation the smaller its angular size. If the stars are very distant from the Earth, the angles corresponding to their parallactic shifts, and, consequently, the values of parallax, become small.

In those times, it did not occur to anybody that stars are so distant from the Sun that their parallactic shifts cannot be observed by means of astronomical instruments of measurement accuracy of 1′. Therefore nearly all 16th and 17th century astronomers were busying themselves with measurements of the positions of stars in different seasons of the year in hope to discover the phenomenon of parallax. These observations, however, had given no results because—as it was discovered later—the parallactic values of the nearest stars are of the order of 1″, which is much below the accuracy of measurements available then.

Some interpreted this failure as an argument against the heliocentric theory; among them Tycho Brahe, who refuted Copernicus' theory only on account of this failure and created instead his own conception of the Universe. But most astronomers approached it correctly, *i.e.* as a proof that the stars were more distant from the Sun than it had been thought previously. They repated their observations employing more precise instruments, and again without success. At each attempt the dimensions of the Universe were growing in their eyes, and that lasted for 200 years!

The first positive results of observations of stellar parallaxes were not obtained before the beginning of the 19th century. By that time, owing to the work of Newton and of many other astronomers, nobody doubted that the Sun is indeed the centre of motion of the planets and the Earth. One might think, then, that the whole plan for the measurements of parallactic shifts was futile. Fancy those many people and virtually centuries of their work! Simply terrible.

But astronomers by no means attribute low value to that plan or to the fact that when the search for arguments in favour of the heliocentric theory ceased to be necessary astronomers continued in their efforts to discover the phenomenon of parallax.

For, by accurate measurements of the positions of stars in different seasons of the year J. Bradley discovered the aberration of stellar light at the beginning of the 18th century, and less than a century later W. Herschel discovered the orbital motion of the components of double stars. Both discoveries were then of paramount importance not only in astronomy but also in physics (while being an excellent corroboration of Copernicus' idea at the same time).

The phenomenon of parallax itself became a method of determining the distances of stars from the Sun. Though not too precise and very limited in practice, this method has the advantage of being entirely kinematic, devoid of all presuppositions or hypotheses, whereas in the other methods of establishing the distances of stars from the Sun widely used today some or other assumptions concerning the composition or the luminosities of the stars are made. Therefore the method of parallaxes is nowadays used as a basis for the "calibration" of results obtained by the other methods of determining the distances of stars from the Sun.

Now let us move to our days. A few years ago astronomers exhibited a sudden growth of interest in a problem which is perhaps as old as the hills. It concerns the answer to the question whether there are thinking creatures of at least a rough similarity to ourselves in the Universe?

This sudden interest in an old problem is closely associated with the extension of the observation possibilities of modern astronomy to very long waves of the order of metres and centimetres. Needless to say, we have in mind radioastronomy, a product of the postwar period.

What is essential is that in the domain of radio waves stars and the planets are almost entirely "dark", whereas in the domain of visible radiation stars are extremely bright bodies. The activity of a conjectural thinking creature in the domain of radio waves may equal, or even exceed, what nature produces on the nearest star, which means that signals emitted by the creature in that domain of radiation may reach us without being "jammed down" by the radiation of "its sun". Meanwhile, no creature can produce in laboratories any source of visible radiation that would equal the Sun.

With the moment of having got receivers of the electromagnetic radiation that comes to us from space the problem of "listening-in" to signals emitted by conjectural intelligent inhabitants of some planet became a practical issue. Numerous meetings and discussions were organized to decide the radio wavelength on which the listening-in ought to be carried out. In these discussions, which were sometimes stormy and very controversial, many different problems were dealt with: among them the problems of methods of decoding the possible messages, of conveying information by means of signs as well as numerous issues requiring the participation of cyberneticists and experts on electronis. There was also one question on which I wish to stop for a moment: what are the chances for a success in that listening-in? Is it not grossly wasteful of men and means to concentrate the efforts of very many astronomers on this kind of radio observations? In this situation, some astronomers who were anxious to start the listening-in observations tried, rather naively, to calculate the probability of obtaining results reasoning more or less as follows.

There are thousands of millions of stars in the Universe. It is highly probable that around many of them run planets roughly similar to the Earth. It is probable that there are creatures with a level of technology and science approximating ours on many of them. These creatures may wish to communicate about themselves...

This reasoning is based on a false interpretation of the law of large numbers which, in our case, can be formulated as follows: among an enormous number of objects there must be many that have a lot of similar characteristics. This inference is not correct unless accompanied by a specification as to which characteristics are at stake, what is the probability of occurrence of these characteristics and, finally, what is meant by "similar".

To illustrate the inaccuracy of the reasoning in question let us bring it down to the Earth inhabited by several thousand million people. An inexperienced scientist might infer from this that there must be at least several tens of people very similar to one another. However, if we made such a selection and brought together all of them, the mother of any of them would easily recognize her son among all others. What is the relevance of the law of large numbers in this case?

Therefore it seems that no calculations of the probability of success in the listening-in to messages from intelligent creatures have any sense (still worse, they often do harm to the issue by their arbitrariness or obvious ignorance). We must therefore frankly admit that we simply know nothing about whether we shall succeed in picking up messages from intelligent creatures from the outer world in a year or in a thousand years, which by no means should discourage us if we recall what happened in the domain of searching for parallaxes of stars.

The listening-in observations have been continuing for but a few years and astronomers have already noted down one success, although not the one they expected. Namely, they have discovered in space not less than four objects called "pulsars" (from "to pulse") that emit very short signals lasting barely 0.016 of a second (or perhaps even less) *at equal intervals*. These intervals amount to a second with a fraction in the cases of three pulsars, and to about one quarter of a second in the case of the fourth of the objects discovered.

By now, the attempts to identify the newly discovered objects have brought no results, mainly because their positions on the sky are not known so accurately as it is needed for identification. It seems that one of the pulsars is a weak bluish star that, nevertheless, is visible in both old (1897) and modern photographs. However, an examination of photographs of the object furnished no new data. Radioastronomers continue to observe the pulsars "in the dark", finding them on the sky by using the known approximate co-ordinates, which by no means prevents them from discovering many interesting properties in these objects.

But these impulses, which recur with extreme regularity, have different intensities. The records of the impulses can be compared with a fence made of very thin pales (*e.g.* 1 cm diametre) distributed in equal distances of about a metre from one another. What is important is that the lengths of the pales are unequal, and that the changes in the lengths from one to the other pales are great and exhibit no regularity.

One might think that this is only an apparent irregularity and that it is just in this that the information conveyed to us from intelligent creatures of other planets is contained. Unfortunately, we shall see in a moment that this does not seem to be a right hypothesis.

Carrying out observations of pulsars at different wavelengths from 3.68 metres, at which the first discovery was made, to 74 centimetres it was noticed that the phenomenon of emitting the impulses occurs throughout the range of these wavelengths (altough the intensity of impulses distinctly decreases together with passing to the shorter waves). Probably, impulses will also be found at longer wavelengths, where no pulsars have been observed so far.

If these signals (impulses) were indeed emitted by a thinking creature, that would be fantastic wastefulness! To communicate with the neighbours it is sufficient to use signals emitted within a very narrow interval of wavelength of the order of millimetre or still less. The extension of the interval of wavelengths to several metres is equivalent to a thousandfold increase of the energy output into space! What is the sense of that? Simple calculations show that a pulsar at a distance of several hundred light years from us has in this case produce 10^{12} times more electric energy than what is at present produced by all people on Earth.

For these reasons astronomers tend to regard the pulsars as space bodies in which processes of "natural pulsation" of such short periods and with such regularity that is actually observed are taking place.

This interpretation also creates many difficulties. True, we do know many pulsating stars, but of different, much longer periods of pulsation. For the period of pulsation depends primarily on the size of the star and on its mean density. If the star pulsates as quickly as it is observed in the pulsars, its size must be extremely small and its mass extremely large. We have to do with something like that in the case of the white dwarfs but calculations indicate that the period of their pulsation cannot be shorter than 8 seconds. Therefore, pulsars must be still smaller and more condensed than the white dwarfs.

Here, one is reminded of what is called "neutron stars", which are hypothetical objects that so far never been observed and which, owing to a considerable condensation that may occur in a neutron gas, may have a density amounting to 10^{13} grams per cm^3. They may also pulsate in periods of similar range.

Astronomers calculated that this kind of pulsations must bring about on the surface of the star shock waves which give huge accelerations to the free electrons in the atmosphere of the star. If these electrons are in an electromagnetic field, the acceleration will manifest itself in a strong radio-wave emission of periodical variability and in sudden flares of short-wave radiation (X-rays). Such phenomena were actually observed on the sky from the space ships. Thus, one can expect that many sources of X-rays discovered recently by astronomy directly in space will prove to be identical with pulsars.

In outlining the problem of pulsars I do not intend to disparage the efforts and work that group of astronomers who are searching for proofs of the existence of intelligent life beyond the Earth by way of radio-wave emission observations. Nor of those who are impatiently looking forward to solving this issue by the astronomers. For the problem in question is of paramount importance for the natural sciences as a whole, and the plan for handling the problem seems, at the present level of technology, most correct. And the fact that we try to interpret the discovery of the pulsars quite differently from what was intended previously is by no means a failure of those enthusiastic about finding a thinking creature beyond the Earth; rather, it is a success considering what has been said at the beginning.

For both events, that from before three hundred years and the recent one, show many analogies, although they involve different astronomical problems. In both cases, while setting out to make investigations the astronomers were unable to calculate the probability of attaining positive results, even approximately. If, by some chance, our Sun together with its planets were situated in another place within the Galaxy, a place less densely "populated" by stars than our environment, the parallaxes of stars would be ten or more times smaller than they have actually appeared to be. How much longer should we have to wait for a success? And what would be the positive effect of such waiting?

But let us skip conjectures and face reality. It seems that the examples cited are fairly typical of the natural sciences. True, these examples must not be generalized but they cannot be brushed aside off hand without taking any indications for that domain of human activity which is generally called the management of science.

It would be unwise to dispense scientists from any responsibility for the realization of plans devised by them; but it would be still worse to press them to carry out pedantically their original plans, especially within the time limits intended previously, as it happens here and there. The former would mean anarchy, the latter a beaurocratic slavery destructive to science. Therefore, a compromise has to be looked for in order to be able not only to estimate the chances of obtaining the result intended but also the chances of obtaining any result of greater or smaller importance to science. In the latter case, a great many factors must be taken into account: primarily the "width" of the subject of investigation, which to a broad extent is decisive in obtaining a positive result in any case. Not insignificant is also a critical estimate of the working techniques, both in theoretical and experimental work, since this also plays some role in the possibilities of obtaining unintended results. And, finally, the scope of the knowledge and skill of people who are setting out to the realization of the plan.

That requires from the administrator (manager) a kind of co-operation with the team of scientists realizing the plan; therefore the administrator must have some preparation in the field of science that he manages as well as in several related sciences (to estimate correctly the links between the various sciences).

The days in which science was managed by monarchs and millionaires, who occasionally founded excellent institutes and observatories, belong to the past. They have been replaced by experts with no lesser abilities or knowledge than scientists themselves but with a somewhat different ability of anticipation characteristic of many-sided minds. Their rank within the social hierarchy of importance must by no means be lower than that of the scientist; it rather ought to be higher, since the social significance of their activity is actually very great. I should not be surprised to learn one day that the committee of the Nobel Prize has established one more category of awards—to those who have essentially contributed to the organization of science in the world.