The Importance of Cosmological Principles for Research in Cosmology

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Any cosmological consideration must be based on one or more cosmological principles. Six of them are described namely: The Ancient Hindu, the Ancient Greek, the Genuine Copernican, the Generalized Copernican, the Perfect and the Anthropic Ones. Some cosmological principles have common properties, some are contradictory; some are logically independent, some - dependent. Cosmological principles influence not only interpretation of results but they influence the results of cosmology as such. A consciousness of problems connected with cosmological principles is necessary when getting in touch with cosmology.

Key words: Cosmology, Cosmological Principle

1. Introduction

The cosmological principle intruded itself to the scene of modern science through the back door and remained there many years

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anonymously and even imperceptibly. A seemingly trivial simplifying assumption introduced by Albert Einstein, Alexander Friedmann and others for easier solving of equations describing the Universe as a whole, was, in the course of time recognized as a source of radical conclusions and was related to the ideas of Copernicus about equivalence of observers located on various planets. This way the notion was born of the generalized Copernican Cosmological Principle, also called the Ordinary, the Narrow, or the Weak Cosmological Principle.

Soon, this time from beginning consciously, a concept of a more rigorous principle was introduced to the science. This is called the Perfect Cosmological Principle.

Later on, it was discovered that the ancient "pre-scientific" cosmological considerations were also based on certain cosmological principles. This way, historical studies of ancient views on the Universe as a whole led to reconstruction of the cosmological principles of the ancient Greek culture and the even older ancient Hindu culture.

One could search for similar general considerations in other past cultures like the old Persian, Egyptian, Babylonian, *etc.* But what remained from these cultures that are only stories (myths) about particular celestial bodies like the Sun, Moon, Earth, but not broad views which could be compared with today's cosmological views. Was it an actual lack of interest of these civilizations of the Universe as a whole, or perhaps just lack of written documents witnessing their attitude toward the entire Universe; anyway, it is impossible to reconstruct more historical cosmological principles until the time of Copernicus, who put into motion the today so-called Genuine Copernican Cosmological Principle.

On the other side there appeared in the last decades a rather new concept of the Anthropic Principle, which by some is already

proclaimed as a new cosmological principle, perhaps the principle of the future.

Thus we find in the scientific literature described at least five different cosmological principles. Three of them are historical: the Ancient Hindu, the Ancient Greek, and the Genuine Copemican. Two are modern: the Generalized Copernican as well as the Perfect One. Besides, there exists the sixth, the Anthropic Principle which pretends to be accepted as a cosmological principle also.

What is then, and what should be in fact, a cosmological principle in general? A most general law of nature?. A philosophical outlook upon the Universe with no significance for the science? A free mathematical assumption? An unnecessary simplification of the reality helpful for some formal considerations? Is it not better to restrain from using any of them?

Such questions are not empty academic problems, but emerge before every consciously working cosmologist. They are of prime importance not only for interpreting the obtained results, but also for solving problems and even for setting problems.

2. Methodological Necessity of Using a Cosmological Principle

To the domain of astronomy belongs to observe what is observable direct or indirect in the Universe and to explain this in terms of other areas of knowledge: Today mainly in terms of mathematics, physics and chemistry. Cosmology differs from astronomy in that it wants to give scientific statements about the Universe as a whole. The Universe may be finite and accessible to (direct or indirect) observations in every spot and in every moment of time at least in the past, or there may be regions of space and/or epochs of time for which we cannot get any information from observations. In the first case,

one could reduce cosmology entirely to astronomy. In the second case, however, cosmology has to fill up, somehow, all the areas of spacetime which are inaccessible to observations.

There exists no final proof that the first possibility is not the eventual one. Nevertheless, the prevailing opinions and theories say that the Universe, even if finite spatially, hides some of its parts behind the cosmological horizon in space and behind some past evolutionary epochs impenetrable neither for observations nor for reliable physical theories based on actual experiments. Cosmological principles are just the general assumptions serving for filling up blanks in the general "map" of the spacetime. In the first line - all blanks which are fundamentally not accessible for observations. Occasionally, they can be used also for filling blanks which are not yet penetrated observationally.

A cosmological principle as far as it helps to penetrate a strange evolutionary epoch can also serve as a base for formulating laws of physics, not testable direct in laboratories or in astronomical observatories.

3. Main Characteristics of the Known Cosmological Principles

a. *The Ancient Hindu Cosmological Principle.* This principle reconstructed and described by Rudnicki (1982) expressed in today's terms says: The Universe is infinitely heterogeneous; our Earth is not an exceptional feature, neither in space nor in time, but it is also not typical, not average (it is impossible to obtain any mean, any average value out of infinitely dispersed parameters).

Since the mathematics wasn't created until now, the means to describe the infinite heterogeneity, no definite cosmological models

based on this cosmological principle can be calculated mathematically.

b. *The Ancient Greek Cosmological Principle.* Reconstructed and formulated by Heller (Heller & Rudnicki, 1973) says that the natural center or quasi-center of the Universe (of the frame **of** reference) is the Earth, which is a unique feature in time and space. Several geometrical figures possessing centers or quasi-centers (single distinguished points) were already known to ancient Greeks. Thus many mathematical cosmological models based on this principle have been developed starting from antiquity. The best known among them are the systems of Hipparchus, Ptolemy and Tycho Brahe. This cosmological principle brings no other restrictions on the structure of the Universe except that certain quasi-symmetries about the point have to be maintained and, of course, the consistence with observational data must be preserved in the observable part of the Universe. This last condition stays also for models based on other cosmological principles.

c. *The Genuine Copernican Cosmological Principle* says that the Universe observed from every planet looks roughly the same. The original cosmological model of Copernicus was based on it. Also the system of Tycho Brahe made use of it. The overall cultural and philosophical implications of this principle were significant indeed, but of higher importance for cosmology as such is the next one.

d. *The Generalized Copernican Cosmological Principle* also called *The Ordinary, The Narrow* or *The Weak Cosmological Principle.* It says that the Universe looks roughly the same not only when seen from every planet but from every point in every direction (the Universe is homogeneous and isotropic). This principle not only suggests the general structure of the Universe but literally dictates how to fill the picture of the Universe in all its blanks, in all non-observable areas of space:

just by duplicating the picture which is seen in the observable areas. This is really, in spite of its names 'weak' and 'narrow,' a powerful cosmological principle carrying binding consequences. introduced in the beginning of the 20th century by Einstein, Friedmann and others, as a seemingly harmless simplification when solving equations. It produces the, later so-called, Hubble Law $V_r = H_r$, the simplest linear relation between the distance r and the relative velocity V_r between two points in the Universe (compare *e.g.*, Bondi 1952). This consequence was so unexpected that many cosmologists in the beginning of the 20th century, including Einstein himself, took at first the Hubble Law as a consequence of a general relativity rather than of accepted cosmological principle. Only subsequent methodological investigation made it clear that when assuming the generalized Copernican Principle one must obtain the Hubble Law when using any theory of gravitation or none of them, *e.g.*, the cosmology of Robertson (1935, 1936) and Walker (1936). on the other side, if only to skip this principle, one can obtain relativistic models of the Universe where Hubble Law is not binding (Taub 1951). But even today there appear in bad popular literature statements like the Hubble Law follows theoretically from the general relativity.

Sometimes the Genuine Copernican and the Generalized Copernican Cosmological Principles are considered to be identical or at least very close to each other (*e.g.*, Bondi 1952). But in fact, :he differences between them are not negligible at all (*e.g.*, the first one allows for a center of the Universe, the second does not.) Some ideas of the latter can lead us even back, above Copernicus, to some of the ancient Greek or even Hindu ways of thinking. Edward R. Harrison (1981) connects this principle with Aristarchus of Samos rather than Copernicus and calls it the Aristarchean Principle. In fact, all (but one) or Aristarchus' writings were gone astray. There is known only that he claimed that the Earth rounds the Sun. This statement can be

considered as an incipience of the Copernican Model of the Universe rather than the Copernican Cosmological Principle. No evidence was known until now that Aristarchus proclaimed his own cosmological ideas, and, if so, that they were not (like ideas of some other Greek philosophers) a late reflection of the Ancient Hindu Cosmological Principle rather than early anticipation of the Generalized Copernican Principle. This particular problem will be discussed elsewhere in a philosophical periodical. Leaving it aside, we distinguish here, after Edmund Skarzynski, the Genuine and the Generalized Cosmological Principles of Copernicus.

The Ordinary 'narrow' Cosmological Principle leads to explicit filling of the areas of space unaccessible for our observational knowledge. I prefer not to plunge here into the problem a observational possibility to falsify or to confirm the Hubble Law. This problem is discussed adequately in many papers of Halton Arp (*e.g.*, 1987), William Tift (*e.g.*, Tift and Cocke 1989), Vera Rubin (*e.g.*, 1986), T. Jaakkola (*e.g.*, 1984) and others, as well as in papers of their adversaries. For the present purpose, it is important to consider the Hubble Law as a consequence of the Generalized Copernican Principle. From this follows the Big Bang Hypothesis with all it consequences of exotic states of the matter in the vicinity of the initial (or final) singularity. There is little hope to investigate thoroughly those exotic states by experimental or theoretical means a physics. Therefore, in order to fill the time-blanks in our picture of the Universe, in an identical way, like the space-blanks are filled when assuming the Generalized Copernican Principle, a more rigorous cosmological principle:

e. *The Perfect Cosmological Principle* was introduced by Herman Bondi and Thomas Gold (1948). It says that the Universe observed from every point in every direction and in every time looks roughly the same. This principle brings more restrictions on the possible

solutions than the former principle does. The only solution based on this principle, found until now, which can be considered more or less consistent with observations in the observable part of the Universe, is the Steady State model. It requires the steady creation of the matter. This principle is not a favorite one among cosmologists but in fact is the only one known today which makes it possible to have complete picture of the Universe in all its spacetime extent: simply in every space area and in every time everything looks *ex definitione* (roughly) the same like in our observable spacetime neighborhood. We may here leave aside the problem whether this picture is a realistic one.

The Generalized Copernican Principle comes to life with research of early relativists who fo the first time in the history of science were dealing with spacetime as one entity instead of dealing separately with space and with time. Strangely enough they introduced the Narrow Principle concerning the three dimensions of space only. The Perfect Principle is much more relativistic in the sense that it concerns time as well. It applies to all four dimensions of spacetime. Not only the genuine but also the Generalized Copernican Principles could appear before formulation of the notion of spacetime. The Perfect Principle could not be conceived without the notion of spacetime which appeared (at least in its scientific sense) first with the relativity theory. The Perfect Principle is a logical fulfillment of the Generalized Copernican Principle in the same way as the last one is consequent fulfilment of the ideas standing behind the Genuine Copernican Principle. The evolutionary chain of these three principles does not reveal any bifurcation.

f. *The Anthropic Principle.* Formulated by various authors in various manners (*e.g.*, Carr 1982) can be expressed as follows: there exists in the Universe a physical being, intelligent an striving to knowledge; out of this assumption all the physical laws and physical constants can be deduced in narrow intervals of their values. Again, I

don't like to plunge into complicated logical and methodological problems whether the partisans of this principle are gifted enough in fantasy when imagining the 'intelligent and striving to knowledge being' very similar to themselves (to the human being), excluding such possibilities that such a being can be assembled out of loose parts like a family of bees in a beehive (the intelligence of a beehive is bigger than the sum of intelligence of its member bees), or just be an agglomeration of physical fields with no significant participation of particles, *etc.* For the sake of the present considerations, it is important only to point our attention to the fact that even if the Anthropic Principle is a real cosmological principle and says much more than 'a human being as it is may exist in the Universe as it is,' it can provide, to be sure, expectations about the laws of physics and values of parameters in these laws (physical constants) but is not in force to produce any definite model of the Universe. In this respect (not in the others) the Anthropic Principle, when considered as a cosmological principle, is similar to the Ancient Hindu Cosmological Principle. And indeed, to obtain models of the Universe, the adherents of this principle make in general simultaneously use of another cosmological principle Usually it is the generalized Copernican Cosmological Principle (or its consequence: the Big Bang). Connecting these two principles one can deduce the general spacetime picture of the Universe as well as the physical laws governing in it.

4. Comparison of Cosmological Principles

Various cosmological principles often have some properties in common. The three: Ancient Hindu, Generalized Copernican and Perfect Principles do not permit the existence of a center of another privileged point in the Universe. All the six give the possibility to

consider the Universe to be infinite. But only Ancient Greek, Genuine Copernican, Generalized Copernican and Anthropic Principles give as well the opposite possibility to consider it as finite. Some principles are independent in a logical sense. They may or may not be accepted jointly, *e.g.*, the world system of Tycho Bnahe was based simultaneously on Ancient Greek and Genuine Copernican Principles But the system of Hipparchus, based on Ancient Greek Principle, was contradictory to the Copernican Principle. Some principles are dependent, *e.g.*, one cannot accept the Perfect Principle without accepting the content of the Generalized Copernican Principle. Some are contradictory Such are the Ancient Hindu and Generalized Copernican.

A consequence of adoption of a cosmological principle can be a definite model of the Universe (steady-state as a consequence of the Perfect Principle), or just a class of models (models with Hubble Law as a consequence of the Generalized Copernican Principle: The constant H may be an arbitrary function of time, positive, negative or equal zero). Some cosmological principles describe rather detailed structure (the Ancient Hindu and Anthropic) and are unable to produce any models without further binding assumptions.

5. Conclusions

No field of human knowledge can be practiced automatically without adding conscious human decision and interpretation. It is, however, hard to find another field of science which depends as intrinsically on human outlook upon nature, as the cosmology depends. Without choice of any basic assumption, called a cosmological principle, this field of knowledge cannot be practiced at all And when accepting one of the cosmological principles, the obtained results depend materially or the choice.

Thus an inevitable and basic problem for any extragalactic astronomer is whether to limit himself to pure astronomy, to investigation of well-defined particular part of spacetime neighboring to us, or to accept consciously, being aware of all consequences, one (or more) of the cosmological principles and to dare to investigate the entire Universe as one entity.

A consequence of the first possibility, if the decision has to be honest, is that one should get rid of all 'generally accepted' results of any cosmological investigations. Also physicists and other scientists should be warned from making use of any cosmological results concerning Hubble Law problem of singularity, nucleosynthesis in early Universe, *etc.* They should be informed that these 'results' are just products of pure human fantasy, not real science. Such attitude is, of course, possible. But I don't think that many will choose it as their own.

The second possibility would be easy if we could consider cosmological principles (or better, one specified cosmological principle) as belonging to the realm of laws of nature. But out of the systematic review of different cosmological principles given in section 3, it becomes clear that no one cosmological principle, formulated until now, has a character of a particular law of nature or of generalization of already known laws. Besides, as it is known (compare *e.g.*, Bonnor and Ellis, 1979 or Stoeger, *et al.*, 1987), no attempt to test any cosmological principle observationally or experimentally gave until now any decisive, negative or positive results. Impulses to create cosmological principles come more or less consciously from the kind of scientific perceptions (observations, experiments) characteristic to given epochs. But cosmological principles do not directly result from these perceptions, rather they are supplementary to the accepted laws of nature.

This is a matter of more humanistic considerations (*e.g.*, Rudnicki 1982) to show the connections between various cosmological principles and philosophical attitudes of given epochs. For the present paper it is important however to mention that those principles change together with human views of the world from one epoch to another. The very mechanistic minded epoch brought to life the generalized Copernican and the perfect principles. Today, when the reductionism of biological phenomena to chemical and physical ones becomes less popular, the Anthropic Principle appears on the cosmological scene. We cannot consider this process as a finished one neither are we able to forecast in which direction it will go further.

Since cosmological principles are not laws of nature, but are products of human thinking, whoever, in spite of all dangers, wants to practice cosmology and is going to take it seriously as a branch of real science, must trust to the process of thinking. He must accept the fact that not only when we see something we get some information of it, but when we think of something we get some information as well, provided our thinking is reliable. When accepting this, we can consciously evaluate the existing cosmological principles and strive to formulate more realistic ones. How to think reliably is not a problem of astronomy or cosmology and it has to be referred here to works from the area of theory of knowledge (Steiner 1978, 1981) and methodology of science (Rudnicki 1989, Zwicky 1957, 1959, 1969).

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