1 Cosmology

When Ymir lived long ago
Was no sand or sea, no surging waves.
Nowhere was there earth nor heaven above.
But a grinning gap and grass nowhere.
Voluspa,[1] about 1000 AD

1.1 General principles

Cosmology is a science about the Universe as a whole. In a wider meaning, especially in the historical context, there are included into the cosmology also the philosophical problems of the relations between human beings and the world. However, here we will restrict the meaning of cosmology to the physical cosmology, which is based on astronomical observations and physical experiments and theories. This does not mean that we can ignore in the cosmology either the existence of life or the problems of the mind and the process of the recognition of the Universe. The later indicate the limitations of the contemporary cosmological theories and the former gives some restrictions to physically plausible models via the so-called *anthropic principle*, according to which from the variety of all physically possible models of the Universe there are acceptable only those, which enable the rise of human beings.[2] In this sense, the cosmology studies on the most general level the conditions for the cosmobiology, which, in turn, can be treated as one of its observational tests.

The definition of the subject of cosmology indicates its peculiarity between the natural sciences: it deals with (by definition) a single object; it is observational and theoretical but by no means experimental science; in principle, it comprises all other sciences. Another feature of cosmology (which is to some extent common to other empirical sciences also) is the interlink between the observation and the theory: the theory should be based on the results of observations, however, the correct interpretation of the observations requires the proper theory.

The range of the space studied by the cosmology was growing throughout its historical evolution proportionally to the size of the region reachable by the contemporary observational techniques. The experience from these observations is then usually extrapolated to the space (and time) beyond these limits. In this sense, it may seem to be exaggerated to take the results of cosmology at any stage as a given model of the whole Universe. However, modern physics yields the insight into the laws of nature which allows us to treat the results as more reliable than a mere assumption. Especially the general theory of relativity, which gives a close connection between the geometry of the space-time and its matter content, allows us to judge (with limitations which are obvious) that our present observations are approaching the limits of the part of the Universe, which in principle is observable.

To be able to extrapolate to the whole Universe the results obtained from the astronomically observable part of it (the so-called *Meta-galaxy*) there is used an assumption named the *Copernican principle*. This can be formulated as: "The Earth does not have a privileged position in the Universe." This principle is often replaced by a more restrictive *cosmological principle*, according to which: "The Universe is (when averaging over a sufficiently large area) homogeneous and isotropic."

The above formulation (as well as the name) of the Copernican principle reflects the negation of the former anthropocentric views on the Universe and should be understood in a more general sense that there is no special position (body) in the Universe at all, but for each one there exists another one which is more or less equivalent.[3] The cosmological principle could be (with many obstacles)

[1]Translated by W.H. Auden and P.B. Taylor.

[2]This condition of existence of an observer is thus a selection effect. Intuitively, the assumption of its applicability is the existence of many universes, only some of which satisfy the conditions required for the rise of life. A possibility of spontaneous creation of such separated space-time regions as a quantum fluctuation in a larger physical space is investigated in the framework of the quantum field theory.

[3]In the discussion of the conditions for life we shall see that the position of the Earth satisfies several special, but not exceptional conditions.

tested observationally. The results of such studies are not conclusive, so we have to take it as a conjecture which implies the simplest cosmological models.

Together with the assumption of the homogeneity of the Universe in time,[4] the cosmological principle leads to inner contradictions, the so-called *cosmological paradoxes.* The best known is the *Kepler – Olbers* paradox (named also *the dark sky paradox*), according to which the whole sky should have the mean brightness of the surface of a star.[5] This conclusion can be understood from the viewpoint of thermodynamics as the thermodynamic equilibrium of surfaces of stars with the interstellar radiation.[6] The Universe should approach this equilibrium (the so-called *thermal death of the Universe*) also in the case of violation of the homogeneity in time, like it would be in the case of rise of stars in a finite past.[7]

One possibility to solve the Kepler – Olbers paradox is by the so-called *hierarchical cosmologies* suggested by I. Kant. According to such theories, the matter is concentrated into spatially isolated clusters of different orders in such a way, that each cluster of a given order is an element of a higher order cluster.[8] An example is the hierarchy atom – star – galaxy – cluster of galaxies. The mean density of mass is decreasing with the increasing order of the cluster. Hierarchical models satisfy the Copernican principle, but violate the cosmological principle. In nature, there may exist an even more general fractal structure of clustering, which includes both the homogeneous distribution as well as the clustering, not only on integer but a continuous set of orders. Moreover, this generalized hierarchical structure need not be fixed, but it can be subjected to an evolution in time.

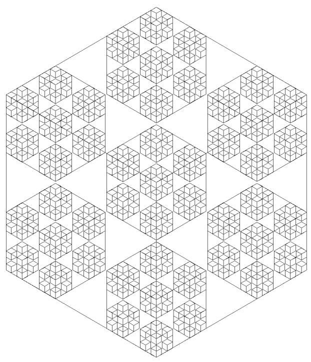

Figure 1: Four orders of 3-dim. Cantor discontinuum (the empty central part of each interval is slightly bigger than $\frac{1}{3}$ in the figure).

[4]If a violation of basic physical principles of conservation is allowed, the static state of the Universe must be assumed as an additional condition to its time homogeneity.

[5]The reason is that the intensity of light is constant along the ray and each ray should intersect the disc of some star, because the solid angle spanned by a typical star decreases with the square of its distance, while the number of stars in a spherical shell of constant thickness increases in the same rate. This argument was first used by J. Kepler in his *Disertatio cum Sidereus nuncius* against Galileo's speculations about the infinite Universe of stars concluded from his discovery of stellar consistence of the Milky Way. Just Kepler formulated some time before the law of decrease of the radiative flux with the square of distance. This law was an inspiration for Newton's gravitation law, from which, however, an analogous gravitational paradox can be constructed. Olbers rediscovered the optical paradox as an analogue to the gravitational one.

[6]The obscuration of distant stars, which is really observed, seemed to be the solution of the dark sky paradox. However, the thermodynamic arguments show that the cold clouds should be heated soon and start glowing.

[7]Such an explanation is sometimes claimed to be an alternative explanation to the Big-bang model. However, without the Big-bang, the synchronous ignition of stars in a finite past is unphysical and only temporarily helping, while in the Big-bang models the thermodynamic equilibrium was originally valid with the radiative temperature gradually decreasing, and only later a rise of stars contributed to a reheating of the intervening matter.

[8]A mathematical model of such a configuration is the set of points, the coordinates of which can be written in the form $x = \sum_{i=-\infty}^{\infty} c_i 10^i$, where $c_i = +1, 0, -1$. The same configuration of the points around the interval $\langle -1, 1 \rangle$ is then repeated aground $\langle 9, 11 \rangle$, but there is an empty space in $\langle 2, 8 \rangle$. The set is self-similar on all decimal scales. Another example is the Cantor discontinuum, which is self-similar on the scales of integer powers of 3, and on each scale the central third of the characteristic interval is empty.