THE ROLE OF INFORMATION IN THE EVOLUTION OF THE UNIVERSE

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1. Definition of Information. The standard model views information as something private and secondary to matter and its energy content. It takes matter and its energy as the primary basis, and information only as a description or "shadow" of reality. However, in recent decades, with the development of physical cosmology, information theory, cybernetics, quantum theory and synergetics, there is a clear need for a more fundamental definition of information.

In accordance with the above, information, in the author's opinion, is a universal fundamental category, the totality of all possible information about the world and each individual part of it. It is not just a means of describing objects, "data" about their composition and functionality, but the logical basis of the material and sensible components in inseparable unity, allowing systems to form stable structures, laws and functional relations. It is the organizing principle determining the evolution of the Universe.

2. Information, matter and energy. Information, being non-material and a logical abstraction, is inactive in itself. The exchange of information and its impact on the surrounding reality becomes possible only if it is superimposed on material carriers, be they field or material elementary particles, atoms, molecules, cells or more complex structures – stars, galaxies, living organisms and technological networks. Connecting with material carriers, information becomes part of di-namic processes of signal exchange. These signals have a dual nature and include:

2.1. Energy component. The transfer of any information is inextricably linked to the transfer of energy, which exerts a force effect on the receiver. Even in quantum systems, when we speak about state transfer, we are talking about interactions having energy equivalent.

2.2. Information component. It is this component that determines the form, meaning and character of interaction. If the energy component sets the possibility of influence, the information component directs, modifies and diffuses this influence, forming its semantic character.

Thus, for example, in the initial Universe in the epoch of recombination electrons and protons united first into isolated hydrogen atoms. They did not exchange information signals because there were no material carriers of information in the environment surrounding them inside and outside the atoms. Therefore, neither they nor their systems as a whole (hydrogen atoms) did not change on average, i.e. they kept their state unchanged for a long time. When, however, in the vicinity of hydrogen atoms other similar atoms appeared, breaking the symmetry, there was an exchange of information, the carriers of which became photons. Under the action of the energy component, the atoms converged or separated. Multiple repetition of this process took the character of self-learning and evaluation of the conditions of the greatest stability. Under its influence, the network chose the connection of atoms that provided greater stability and increased functionality. Then came a long stagnation, during which star formation took place. Only after the resumption of thermosynthesis and the emergence of helium, lithium, oxygen, carbon, nitrogen, other light and medium elements of the Men-deleyev table in the depths of stars, there was another qualitative leap, in the process of which the rocky planets were formed. As a result, conditions for the formation of the simplest chemical compounds, including water, carbon dioxide and simple organic compounds, were created. The final result of this process was the emergence of large networks (organic polymers) with differential functionality, complementing one another, with one replicating system encoding all the various functions.

By interacting, material objects created complex structures, stable patterns and new levels of organization. Thus, the Universe after the Big Bang gave birth to many elements of the material totality, which, exchanging information and emergent complexity, increased their organization. The further process, from the origin of life to man and his creative activity, continued according to the described, but much more complex scheme.

3. Formation of information networks. Thus, even at the level of elementary particles, interactions can be interpreted as an exchange of information about the states of systems. As atoms, molecules, protostars and galaxies are formed, this process scales up, forming a similar information network. In such networks, interacting objects “learn” from each other – not in the cognitive, human sense, but in the systemic sense: stable structures are fixed, unstable ones are destroyed, new combinations are tested for strength.

At higher levels of organization, for example, in bio-logical systems, this process acquires obvious features of self-learning and adaptation.

Living organisms perceive signals from the environment, form internal representations (neural or genetic codes), and, changing, "test" new combinations of traits and behavioral strategies. Thus, the evolution of life can be viewed as a process of information transmission, accumulation, processing and analysis, where information networks – from genetic codes to brain neural connections – play a key role.

Evolution, like everything in Nature, does not proceed smoothly. Periods of quantitative accumulation of changes are replaced by qualitative leaps, in which new properties or level of organization is manifested.

4. The logic of evolutionary leaps. The law of evolution. Let $f(t)$ be some function from time, which describes the state of the innovation level (quality) realized in practice in the process of evolution by the given moment of time.

Further, according to the above, we assume that in the process of evolution the achieved innovation level is not developed from scratch, but on the basis of the achievements of the previous development. In this regard, it is logical to assume that the process of innovative development accelerates over time.

Let us choose some initial moment t_0 on the time scale, coinciding with the present time, which is $t_0 = 13{,}8 \cdot 10^9$ years from the big bang.

Then, with the passage of time, the interval between the time t_i the occurrence of the next jump and the initial, i.e. today's time, will decrease, and the corresponding innovation level and innovation speed will increase.

Proceeding from the fact that Nature always chooses the most economical solutions, let us assume, in this connection, that the dependence of the innovation rate on time has the simplest form, i.e., that the rate of technological progress df / dt is inversely proportional to the change in the time t under consideration.

In this case we can write that $\frac{df}{dt} = \frac{k}{t}$, or $df = k\frac{dt}{t}$, whence, integrating the obtained equation taking into account the discreteness of the process under consideration and initial conditions, we obtain

$$\Delta f_i = k \ln \frac{t_i}{t_{i+1}},$$

where $\frac{t_i}{t_{i+1}}$ (i =0,1,2…) is the ratio of the time of the nearest i-th jump to the time of the next jump, counted from the present time of the system development.

It follows from this relation that:

$$\frac{t_i}{t_{i+1}} = e^{\Delta f_i} \ .$$

Let us also assume that the law of increasing level of innovation is given by a simple relation:

$$\Delta f_i = ki\left(f_i = f_0 + ik\right).$$

This means that time is postponed by us in logarithmic scale on a natural logarithmic scale so that:

$$t_i = \frac{t_{i=1}}{e^i},$$

where e ≈2.72 is the base of the natural logarithm.

The relations obtained by us can be considered, taking into account the adopted approximations, as a theoretical law of evolution, i.e., the creative development of the Universe and all its systems. This is confirmed by the practice of the Universe development.

Let us consider, in this connection, the fundamental stages of evolution that really occurred and are occurring (see the table 1).

From the table, which shows the time of occurrence of the fundamental stages (jumps) of development, we can see that evolution really occurs in accordance with the specified logarithmic law. The maximum discrepancy between the actual and theoretical data does not exceed plus or minus 20 %. If we take into account the approximations of the dating of the actual stages, it should be considered a good approximation.

It follows from the analysis of the above data that evolutionary development occurs with a good enough approximation according to the proposed law of logarithmic distribution of developmental jumps and stagnations on the time scale.

It is about peculiar phase transitions in information networks: as long as the accumulation of small changes does not reach a critical level, the system remains stable. When the information stock crosses a certain threshold (bifurcation point), a “leap” occurs – the birth of a new quality. This mechanism can be traced in various contexts: in macroscopic processes, cosmic evolution (formation of the first stars, galaxies), in biological evolution (appearance of replicators and protein coding, multicellularity, photosynthesis, co-cognition) and even in technological evolution (information revolution, artificial intelligence).

Table 1

Fundamental stages of development	Time t_i, years ago		t_i/t_{i+1}
	Actual	Theoretical	
Big Bang	$13{,}8\cdot10^9$	$13{,}8\ 10^9$	e^0
The solar system and life on Earth	$4{,}6–4{,}1\cdot10^9$	$5{,}00\cdot10^9$	e^1
Symbiosis. Multicellular life	$1{,}7\cdot10^9$	$1{,}86\cdot10^9$	e^2
Photosynthesis. Plants	$5{,}4–7{,}0\cdot10^8$	$6{,}85\cdot10^8$	e^3
Permian extinction. Mammals	$2{,}5\cdot10^8$	$2{,}52\cdot10^8$	e^4
Primates	$0{,}85\cdot10^8$	$0{,}92\cdot10^8$	e^5
Great apes	$3{,}50\cdot10^7$	$3{,}40\cdot10^7$	e^6
Australopithecines	$4{,}40\cdot10^6$	$4{,}60\cdot10^6$	e^8
Homo habilis	$2{,}00\cdot 10^6$	$1{,}69\cdot10^6$	e^9
Mastering fire	$6{,}00\cdot 10^5$	$6{,}22\cdot10^5$	e^{10}
Homo sapiens. Neanderthal	$2{,}0–1{,}60\cdot 10^5$	$2{,}28\ 10^5$	e^{11}
Emergence of consciousness	$8\cdot10^4$	$6{,}010^4$	e^{12}
Modern humans	$3{,}0\cdot10^4$	$3{,}1\cdot10^4$	e^{13}
Transition from gathering and hunting to production. Agriculture	$11{,}0\cdot10^3$	$11{,}30\cdot10^3$	e^{14}
Near Eastern and Eastern civilization. Emergence of ancient civilization	$4{,}010^3$	$4{,}17\cdot10^3$	e^{15}
Late antique civilization	$1{,}5\cdot10^3$	$1{,}54\cdot10^3$	e^{16}
Age of Renaissance	$5{,}5\cdot10^2$	$5{,}60\cdot10^2$	e^{17}
Scientific and technological revolution	$2{,}0\cdot10^2$	$2{,}07\cdot10^2$	e^{18}
Information Revolution	$5{,}5\cdot10^1$	$7{,}60\cdot10^1$	e^{19}

5. Philosophical and scientific implications. The presented approach changes our perception of the Universe and evolution. If information is not just a reflection of reality, but its fundamental component, then evolution can be understood not as purely random changes of matter and energy, but as a directed process in which information acts as a kind of "catalyst" of orderliness and complexity. This does not imply the presence of a predetermined goal or telos, but indicates certain regularities that support the transition to more complex levels of organization.

From the point of view of science, this concept pushes for an interdisciplinary dialog between physics, information theory, biology, cybernetics, neuroscience, and philosophy of consciousness.

6. Conclusion. Information, considered as a universal logical category, is not reduced to passive data. Its role in the evolution of the Universe can be characterized as catalyzing: information, connecting with material carriers and energy flows, determines the nature of formation of structures, their stability, ability to adaptation and complication.

In-depth study of this concept can clarify the mechanisms of formation of complex systems, both inanimate (cosmic) and animate (biological), as well as transitional forms (technological, information-computer). The final understanding of the role of information in the ordered evolution of the Universe is yet to be formed, but the approach laid down here opens wide horizons for further theoretical and practical research.

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АДАПТИВНЕ ОСВІТНЄ СЕРЕДОВИЩЕ: ОСОБЛИВОСТІ ЗАСТОСУВАННЯ ШТУЧНОГО ІНТЕЛЕКТУ

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Задля відповідності сучасним викликам і потребам суспільства, традиційні освітні середовища потребують змін, зокрема, з врахуванням того, що інтеграція штучного інтелекту (ШІ) в освіту відкриває нові горизонти для персоналізації та підвищення якості навчання. Водночас, з тим, щоб ШІ став інструментом для підтримки, а не заміни педагога, важливим убачається забезпечення балансу між автоматизацією та людським фактором. Штучний інтелект відкриває нові можливості для трансформації освіти, але його впровадження має