IGOR GUREVICH

SOME WORKS ON PHYSICAL INFORMATICS

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THE INSTITUTE OF INFORMATICS PROBLEMS OF THE RUSSIAN ACADEMY OF SCIENCES

SENIOR RESEARCHER;

COMPANY "HETNET CONSULTING"

CHIEF SYSTEMS DESIGNER

MIPT. THE DEPARTMENT "MANAGEMENT CHALLENGES"

LECTURER

Correspondence should be addressed: Molodeznaya st, 3-523, Moscow, Russia.

Email: iggurevich@gmail.com;

Tel.: +7495-930-61-50;

Fax: +7495-995-25-01.

CONTENT

After the title of each work the place and time
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ABOUT PHYSICAL INFORMATICS

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***Abstract*.** Physical informatics is information background of physics: informatics laws have general, universal character, operate in all possible universes with different physical laws. Informatics laws precede physical laws. Definitions and estimates are given for information characteristics of physical systems (fundamental and elementary particles, atoms, molecules..., star objects, galaxies,…, the Universe as a whole). Information restrictions on interaction of physical systems are received. Physical Informatics is Science of modern Information in Physical and Chemical Systems, including Quantum Informatics, and is the basis of Informatics of the Living Systems. Informatics laws together with physical laws will allow to open all secrets of nature, in particular, to construct the theory of quantum gravitation.

***Keywords*—** Physics, Informatics, Physical informatics

1. INTRODUCTION

Ursul A.D. predicted in 1968 in his book [1] "The Nature of the information: " The properties of space and time will be studied by methods of information theory more than ever before when they were mainly studied by methods of physical theory (e.g., special and general theories of relativity, Einstein). So, physics and information theory interpenetrate each other, that, in general, leads to the creation of two major synthetic disciplines - the special application of information theory (and most likely, a number of its branches - a thermodynamic and quantum) physics and information". The interpenetration of physics and information theory in the development of informatics has formed a synthetic discipline "Physical informatics" [2, 3].

2. SOME HISTORY

Many eminent scholars have noted the importance of information [1, 4-6]. J. Wheeler, "My life in physics seems to me to split into three periods. The first of them, stretching from the beginning of my career and the beginning of the 1950s, I was captured by the idea that "Everything is a particle." I was looking for ways to build all the basic elements of matter (neutrons, protons, mesons, etc.) of the lightest, most fundamental particles - electrons and photons. The second time I call the "All is a field". Now I have caught a new idea: "Everything is a information" (1962); E. Steen (2000) "... identify some of the laws that are similar to the laws of conservation of energy and momentum, but used in relation to the information and determine the most quantum mechanics "; B.B. Kadomtsev (1999): "In going to study increasingly complex systems is the structural and information aspects of their behavior and development of the foreground and the dynamics of creating a framework for Information Development. In view of quantum processes in the microcosm of the world the picture becomes even more complex and richer in terms of information behavior. "For the first time an analysis of physical processes using the concepts of information has been made by A. Einstein (1905). L. Szilard (1929), analyzing the thought experiment, "Maxwell's demon", has shown that the entropy lost by the gas due to separation of molecules on the slow and fast, exactly equal to the information received, "Maxwell's demon." I. Von Neumann (1932) introduced the notion of quantum entropy. Neumann’s entropy of a pure state, by definition, is zero, but physicists tend to describe and study quantum systems using this entropy. Shannon (1948) introduced the concept of information entropy. Information defined by the Shannon entropy in bits (nats) is a universal measure of uncertainty (information) of the classical and the quantum systems. The systematic application of information theory to the analysis of physical phenomena and processes was apparently first performed by Brillouin (1960). "We now introduce a distinction between two kinds of information: 1) free information, which occurs when possible cases are treated as abstract and has no particular physical significance, and 2) the associated information (bound information), which occurs when possible cases can be presented as a microstate of a physical system. "L. Brillouin (1959) showed that a binary unit of information equals to the energy of the Boltzmann constant multiplied by temperature and estimated by the volume of information contained in a physical law. Penrose (1989), Hawking (2005) and others have used information-based approach to the process of formation of black holes. "Can information disappear during the formation of a black hole? Where can it go? The black hole swallowed distorts of information, but does not destroy it completely. During evaporation of a black hole information comes out of its embrace. " A. Zeilinger (1999) put forward the following principle as the foundation of all possible quantum theory, presenting two of his statements: 1) an elementary system represents the truth value of a proposition, and 2) an elementary system carries one bit of information. S. Lloyd (2001) postulated: 1) the theorem Margolis-Levitin, and 2) the total number of bits available for processing in the system is limited by the entropy of the system. 3) The rate of flow of information is limited by the speed of light. These three limits are applied to assess the ability to process information universe. In particular, it is estimated, and the total number of bits available in the universe to compute, and number of elementary logical operations that can be performed on these bits during the lifetime of the universe. The total number of bits of matter (the result of the author, 1989). Gurevich I.M. (1989-present) organizes knowledge in complex systems, information practices on the basis of their research informatics laws and conducts studies of complex systems based on these laws. The main results of the author are: the assertion of the existence of natural laws more general than the physical ones – the laws of informatics, defining, limiting physical phenomena and processes [5, 6], and prior to physical laws, the wording of the laws of science; the estimate of information volume in the universe. The number of scientists, who use the information approach and information methods in physics research, is increasing rapidly. At the beginning of 2010 there are many interesting works, including works by Erik Verlinde. Lee Smolin. N Jarmo Makela. Rong-Gen Caia, Li-Ming Caob, and Nobuyoshi Ohta. Lorenzo Maccone [5-6].

3. DEFINITION OF INFORMATION

Along with matter and energy the Universe contains, includes information. Information is an integral part of the Universe. The fundamental principle of quantum mechanics postulates that elementary physical system carries one bit of information. “Information is heterogeneity, stable for some definite time” [4]. Regardless of the nature of heterogeneity, would it be letters, words, phrases or - elementary particles, atoms, molecules, or - people, groups, societies, etc. "By information we mean a stable for some time heterogeneity arbitrary physical nature. Thus, a character in a book, an atom, molecule, an elementary particle, a star, drawing, painting, plowed fields, woods and other heterogeneities contain and carry information. "Classes of heterogeneities: physical, chemical, biological, geological, technical, social, economic [4-6]. The measure of the degree of heterogeneity or information is Shannon's information entropy (entropy, by Neumann’s definition, can not be used as a measure of heterogeneity, since it is zero for a pure state which has a structure) and other information characteristics (information divergence, joint entropy, mutual information). This leads to the use of information research methods as information itself, and its related matter and energy. This approach provides new and sometimes more general results with respect to the results obtained on the basis of only physical laws. Ursul A.D. in 1968 in his book "The Nature of the information. Philosophical essay" [1] gave a close to the above definition of information:" ... first of all, information related to diversity, difference, and secondly, with reflection. Accordingly, it can be determined in the general case, as reflected by the diversity. Information - this variety, which contains one object for another object (in their interaction) ... But information can be viewed as diversity that is the result of reflection as to the object itself, that is self-reflection. ... Information is a property of matter, which is universal ... The concept of information reflecting both objectively real, independent of the subject property is inanimate and animate nature, society, and the properties of knowledge and thinking ... Information in this way is inherent in both material and ideal. It is also applicable to the characterization of matter, and the characterization of consciousness. If the objective information can be considered property of matter, the ideal, subjective information is a reflection of the objective, material information" "V.M. Glushkov in a number of characteristic information as a measure of heterogeneity in the distribution of energy (or matter) in space and time ... there is information to the extent that there are material bodies, and therefore he created heterogeneity". Interestingly, in his book Ursul A.D. noted that "heterogeneity - is another expression of the form diversity."Information - is stable for some time diversity (heterogeneity) of any physical nature (animate and inanimate matter, society, mind), described and studied by all applied sciences, which has a number of properties, primarily a reflection. Informatics is the science of information. The subject area of informatics: Natural systems (living and nonliving), a system created by civilization, including social and economic systems. The study of information laws (in specific subject areas and in general). There is not a single definition of science, which would not be a special case of this definition. This definition can not affect, limit anyone's research interests, can not cancel, deny any known or future directions of research" [5].

4. PHYSICAL INFORMATICS. MAIN RESULTS

Physical Informatics is the science that studies physical systems by information methods. This discipline is created, mainly in the works of Gurevich I.M. [3-6]. It is shown that information laws together with physical laws can be an effective tool for understanding natural systems and the Universe as a whole. The relationship between physical (mass, energy,

entropy,…) and information characteristics (uncertainty (information) and information divergence joint information entropy, mutual information, differential information capacity of matter) makes it possible to use information research methods assessing the physical characteristics of
systems. Information laws (the laws of informatics) are universal, operate in all possible universes. The main characteristics of heterogeneities (information) of physical systems are: uncertainty (information) [7] and information divergence [8] observed (observable in quantum mechanics called any physical quantity that can be measured, and the results of the experiment must be real numbers) and states (the state of a physical system
defined by the vector in a Hilbert space), which characterizes the volume of information (information capacity) of the heterogeneity; joint information entropy [7], which characterizes the unitary transformation; mutual information [7], which characterizes the interaction of physical systems; differential information capacity of matter [5, 6]. Physical systems, objects, the observable are described by the information characteristic - uncertainty (information). A measure of uncertainty (information) is Shannon’s information entropy, defined as functional on wave function or amplitudes of probability. C. Shannon [7] has entered the concept of information entropy. Entropy of a discrete random variable: $H=-\sum p_i \log_2 p_i$ [bit] ($H=-\sum p_i \ln p_i$. [nat]), Entropy H of a continuous random variable $H(x) = -\int p(x)\log_2 p(x)dx$ [bit], ($H(x) = -\int p(x) \ln p(x)\, dx$ [nat]). *Heterogeneity of physical system is described by information characteristic of divergence, defined as functional on wave function or amplitudes of probability*.
Presence and properties of the heterogeneity set by distribution P, will be estimated by information divergence $D(P / R)$ [8] distributions P concerning uniform distribution R $D(P / R) = -\int P(x)\cdot\log_2 (P(x)/R(x)\cdot dx$, where $P(x)$ - the distribution corresponding to heterogeneity, and $R(x)$ - uniform distribution to interval $0 \le x \le a$.

$R(x) = \begin{cases} 0 \text{ if } -\infty < x \le 0 \\ \frac{1}{a} \text{ if } 0 < x \le a \\ 0 \text{ if } a < x \le \infty \end{cases}$. If $P(x)$ is defined on interval $0 \le x \le a$ information divergence is equal to $D = -\log_2 a - \int_0^a P(x)\cdot \log_2 P(x)dx = N - \log_2 a$.

Information divergence concerning uniform distribution differs from uncertainty (information entropy) on $-\log_2 a$.

Unitary transformations are described by the information characteristic of joint entropy [7].

Let's define the unitary operator (transformation), unitary matrix $U = \|u_{ij}\|$ Shannon matrix $SH(U) = \|u_{sh\,ij}\| = \|u_{ij} / \sqrt{n}\|$, $i, j = 1,...,n$ which elements are elements of a unitary matrix, divided on $\sqrt{n}$.

Let's define on Shannon matrix the final probability space: set Ω of elementary events (outcomes) is made by steams of basic vectors y_i, x_j bases y and x; their probability measure is set by squares of modules of elements in Shannon's matrixes $p_{ij}(SH(U)) = |u_{ij}|^2 / n$ (probability of joint realization of

states y_i and x_j at measurement of states y in basis x). $\sum_{i,j=1}^{n} p_{ij}(SH(U)) = \sum_{i,j=1}^{n} |u_{ij} / \sqrt{n}|^2 = \frac{1}{n} \sum_{i,j=1}^{n} |u_{ij}|^2 = 1$. At such definition of final probability space for considered unitary matrix $U = \|u_{ij}\|$ at measurement of states y in basis x the probability of realization y_i and x_j is equal to $p_{ij}(SH(U)) = (1/n)|u_{ij}|^2$, $\sum_{i=1}^{n} p_{ij}(SH(U)) = \sum_{i=1}^{n} (1/n)|u_{ij}|^2 = 1/n$, $\sum_{i=1}^{n}\sum_{j=1}^{n} p_{ij}(SH(U)) = \sum_{i=1}^{n}\sum_{j=1}^{n})1/n)|u_{ij}|^2 = 1$. Thus, the matrix of joint probabilities $P(SH(U)) = \left\| |u_{sh\,ij}(U)|^2 \right\| = \left\| |u_{ij}|^2 / n \right\|$ is defined on Shannon's matrix to a matrix unequivocally. Using a matrix of joint probabilities, we will define the joint entropy corresponding to unitary matrix $U = \|u_{ij}\|$.

$$H(U) = H(P(SH(U))) = -\sum_{i=1}^{n}\sum_{j=1}^{n} |u_{sh\,ij}(U)|^2 \log_2 |u_{sh\,ij}(U)|^2 = -\sum_{i=1}^{n}\sum_{j=1}^{n} (|u_{ij}|^2 / n) \log_2 (|u_{ij}|^2 / n).$$

Interaction of physical systems, objects is described by the information characteristic - the manual information.

The manual information I_{xy} of random variables x and y is equal to [7]. $I_{xy} = N_x + N_y - N_{xy}$, where N_x, N_y - uncertainty (information entropy) random variables x and y; N_{xy} - joint uncertainty (information entropy) random variables (x, y). The communication information can be considered as a measure of entanglement of physical systems.

Differential information capacity of matter [4, 5].

There are some types of matter with different dependence of volume of the information (information capacity) on mass, including: - Linear for usual substance $I \propto M$, - Square-law for black holes $I \propto M^2$, Linearly-logarithmic for neutron stars and white dwarfs) $I \propto M \log_2 M$. Generally, mass dependence of information volume in substance looks like $I = f(M)$. Variation of information volume in matter dI at variation of its mass dM is defined by differential of function $I = f(M)$ $dI = (df(M)/dM)dM = f'(M)dM$. The derivative of information volume on mass $(dI/dM) = (df/dM) = f'(M)$ $[bits/kg]$ is characterized by differential information capacity matter - to change the mass of matter per unit ($dM = 1$) changes the volume of information in the matter to the extent equal to the differential information capacity $dI = f'(M)$.

The informatics laws of nature are [4-6]: the law of simplicity of complex systems, the law of uncertainty (information) conservation, the law of finiteness of complex systems characteristics, the law of necessary variety by Ashby W. (1956), and the theorem of Gödel K. (1931). The main principle of quantum mechanics by Zeilinger (1999) is: elemental physical systems contain (carry) one bit of information. The law of finiteness of complex systems characteristics and the principle of necessary variety by Ashby impose restrictions on the topology and symmetry of the universe. The main results obtained earlier by the author, published in [5-6, 9-10]. Further, and in the report [11] new results of the author are presented.

1) Fundamental limits on information capacity storage devices and on productivity of informational systems. Estimates of the amount of information in the atoms, amino acids, nitrogenous grounds, the differential information capacity of a substance are determined by fundamental limits on information capacity storage devices. Differential information capacity of storage devices, built on the basis of atoms does not exceed $\approx 10^{-28}$ bits/kg, and the information capacity of the storage mass 1kg $\leq 10^{28}$bits, and it can be increased by no more than 10^{14} times. The last limitation is the most powerful fundamental limit on the nature of information capacity of natural and artificial systems.

The difference between the energies of the basis states of the hydrogen atom, considered as a q-bit, impose fundamental limitations on the speed of computing devices. The number of operations is satisfied by a hydrogen atom, a q-bit, limited $k_{op/s} = 2\Delta E/\hbar \approx 1,5 \cdot 10^{12}$ operations per second. The productivity of the computer built from atoms of hydrogen, which mass is one kg, is not more than 10^{39} op/sec. Restrictions 10^{28} bit/kg, 10^{39} (op/sec)/kg you can be added a number of fundamental natural limits, including the speed of light, the elementary charge, Planck's time, ...

2)The program Estimations of Information Characteristics of Molecules (EICM) is designed to calculate the informational characteristics of the molecules (the volume of information in the structure of the molecule, the volume of information in the molecule), a description which is stored in An Information Portal to Biological Macromolecular Structures (Protein Data Bank): http://www.rcsb.org/pdb/home/home.do. The method and algorithm for calculation of volume of information in the structure of molecules, the molecules are developed by I.M. Gurevich and M.P. Evstigneev. The program is designed by M.A. Puchkov.

• Gurevich I.M. and American, Canadian, European, Chinese... scientists confirm the primacy of information laws.

• Information laws (the laws of informatics) define and limit the laws of physics.

• Use of information laws (laws of informatics) in conjunction with physical laws to reveal all the secrets of nature, in particular, to construct a theory of quantum gravity.

5. CURRENT PROBLEMS OF PHYSICAL INFORMATICS

Taking into account the received results we list the current problems of physical informatics.

1.Development of information research methods of physical systems - physical informatics.

2.Evaluation of information characteristics (information entropy, information divergence, a joint information entropy, mutual information and differential information capacity) of physical, chemical and biological systems.

3.Estimates of the amount of information in physical, chemical and biological systems.

4.Derivation from the laws of informatics physical laws.

5.Joint application of energy conservation law and uncertainty (information) conservation law for calculating the characteristics of physical systems and processes.

6.The study of information interaction of physical systems.

7.Formation of information restrictions on the formation, development, interconversion of physical, chemical and biological systems.

8.The study of information characteristics of quantum computers and quantum computing.

9.Formation of fundamental constraints on the characteristics of information systems.
10.Estimation of volume of information that defines the appearance and development of the universe. Estimation of heterogeneities mass containing this information.
11.Study of the universe's expansion as the cause and source of forming information in the universe.
12.Formation constraints on the control of the universe.
13.Formation of restrictions on the cognition of the universe.
14.The study of methods of forming the classical (memorized, copied) information in the universe.
15.Analysis of information characteristics of extraterrestrial civilizations.
16.Determination of the minimal cognition subject.
17.Study on a compact representation of knowledge and conservation of the accumulated knowledge of civilization.
18.Development of information bases of the theory of quantum gravity, "Theory of Everything."

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«ALL FROM A BIT»

J.A. Wheeler

Along with matter and energy the Universe contains, includes information. Information is an integral part of the Universe. Each physical system along with physical characteristics has information characteristics. Information is inseparably linked with matter and energy. Scientists study physical characteristics and physical laws when they study informational characteristics and informational laws. The report provides an overview of the fundamental results obtained by the outstanding scientists: Einstein A., Neumann M., Shannon C., Wheeler J., Janes E., Brillouin L., Everett. H., Zeilinger A ., Lloyd S., … The findings of investigation gained by the author, including the results published in the works of the International conferences «Problems of Cybernetics and Informatics» are enumerated. The basic result of the author is formulation of nature’s laws by means of more general, than physical - informatics laws [1-6]. The author conducts research of complex systems, including physical systems, in terms of informatics laws. The informatics laws define, limit physical phenomena and processes. The informatics laws precede the physical laws. The quantity of scientists using the information approach and information methods in physical researches, quickly increases. There are many works that appeared in the beginning of 2010. Among them there are the following works [7-12].

The 1-st approach. (Gurevich)

The starting positions. Information is physical heterogeneity. The information characteristics of heterogeneity: Shannon's information entropy, information divergence, joint entropy, communication information [14]. The informatics laws of nature are [1-6]: the law of simplicity of complex systems; the law of uncertainty (information) conservation; the law of finiteness of complex systems characteristics; the law of necessary variety by W. Ashby; the theorem of K. Gödel. The main principle of quantum mechanics by A Zeilinger: elementary physical systems contain (carry) one bit of information [15].

The law of finiteness of complex systems characteristics and the principle of necessary variety by W.Ashby impose restrictions on topology and symmetry of the Universe: time is one-dimensional Euclidean space. Space is three-dimensional Euclidean space. Time is homogeneous. Space is homogeneous. Space is isotropic. Space is flat. The Universe is four-dimensional pseudo-Euclidean space. The law of simplicity of complex systems, the law of information conservation impose restrictions on physical transformations of the space-time and transformation of internal symmetry: jacobian transformations are equal to 1. Transformations are linear. Equality to one of the determinant of linear transformation defines, that among the space-time transformations only translations and own rotations are physically possible. Irreversibility of time, not the own rotations, reflexions are forbidden and physically cannot be possible (1989) [1]. Equality to one of the determinant of linear transformation defines, that among transformations of the internal symmetry, only unimodular transformations are physically possible.

Restrictions on symmetry of the space-time define physical laws of conservation. The homogeneity of time defines the law of energy conservation. The homogeneity of space defines the law of impulse conservation. Isotropic spaces define the law of conservation of impulse momentum. The principle of field interaction imposes restrictions on interaction process: the interaction of particles is carried out through corresponding fields. A particle «does not need to know interaction laws it must feel a field».

The law of simplicity of complex systems and the law of information conservation allow to select the most simple models, adequately describing the Universe: the Universe is identical to Metagalaxy; the Universe is a homogeneous object; the Universe is an isotropic object; the Universe is a flat object. Increase in the scale factor of inflationary expansion of the Universe makes approximately $\approx 10^{45}$ times.

It is shown, that the estimates of the joint entropy of matrixes mixture of electroweak interaction according to different independent experimental data, are close to the estimates of the joint entropy of matrixes mixture of quarks. It testifies to the uniform informational and physical nature of strong and electroweak interaction.

Taking into account Zeilinger's principle the basic information principles of quantum mechanics construction are defined. In particular, necessity of sharing the law of energy conservation and the law of uncertainty (information) conservation is defined.

Hawking's formula for the black holes (informational spectrum of radiation) is deducted (2007) [4]. The formula for the informational spectrum of radiation of neutron stars and white dwarfs is deducted (2009) [6].

Existence of several types of substance with different dependence of information content I on mass M (including, linear for usual substance and for dark substance $I \propto M$, square for black holes $I \propto M^2$, linearly-logarithmic for neutron stars and white dwarfs $I \propto M \log_2 M$, zero for dark energy $I \equiv 0$) is disclosed (2007-2009) [4-6].

Consumption of energy (mass) for the creation of microinformation and classical information (remembered, played back) for different types of matter are determined.

At standard model of the Universe expansion the mass of usual substance decreases. At expansion of the Universe with acceleration the mass of usual substance in the beginning decreases, reaches a minimum, and then increases (2007) [4].

Existence of optimal black holes is disclosed and characteristics of optimal black holes (minimising the volume of information in a part of the Universe, and the Universe as a whole) are researched (2007) [4].

The structure of the Universe with the information minimum is determined. Limitations on the volume of information in the Universe are defined.

At the approach 1 for the estimate of information volume in physical system the use of holographic principle is not required. The procedure of the estimate of information volume in physical objects consists in the following. At first the volume of information in the lower level objects – the fundamental particles (leptons and quarks) is estimated. According to Zeilinger's principle, we consider, that in the lower level objects - one bit of information contains. Further the volume of information in the objects of the second level is estimated. It is equal to the total of the information volume of

objects of lower level plus the volume of information contained in the structure of the object of the second level of hierarchy (mesons, baryons). The volume of information in the structure of object of the second level is estimated on a wave function of the object of the second level. The volume of information in objects of the following levels is similarly estimated.
Direct estimates of information content in physical systems are given (2007-2009) [4-6].
It is shown, that the space uncertainty (information) on the particle layout in space spots the Newtonian gravitational potential (the first derivative of information on radius), strength of gravitational field (the second derivative of the information on radius): the type of gravitational potential is $\propto 1/r$ (2008, 2009) [4, 6], the type of strength of gravitational field is $\propto 1/r^2$ (2008, 2009) [4, 6]. The same is true for Coulomb interaction potential and field intensity strength of Coulomb interaction.

It is shown, that to four known types of interaction (gravitational, electromagnetic, strong and weak) one should add one more type of interaction - informational interaction (2007) [4].

` The informational models of cosmological objects (black holes, neutron stars, white dwarfs, stars of solar type) are developed (2007-2009) [4-6]. The procedure is developed and the estimates of information volume in cosmological objects is given (2007-2009 [4-6].

. The informational limitations on forming and merging of black holes are received (2008-2009) [5-6].
Existence of initial discontinuities of the Universe (with the use of informational divergence) is proved. The estimates of initial discontinuities mass of the Universe are given.

Expansion of the Universe from initial heterogeneity generates new heterogeneity (information). The Universe expansion is the reason and source of information formation. Various physical processes in the extending Universe form information (1989 - 2009) [1-6].

. Curvature of the Universe also generates heterogeneity (information).
It is shown, that the volume of information, shaped in a frame of reference, moving with acceleration, is equal to $I = -\log_2 J = -\log_2 \sqrt{1 - ax/c^2} \approx ax/c^2$. J - jacobian, a-acceleration, x-coordinate, c-speed of light [6, the second issue of the book]. We will pay attention to the analogy to the effect Unru. Appearance of thermal radiation in an accelerated frame of reference in the absence of this radiation in a counting inertial system is the appearance of additional information in an accelerated frame of reference in the absence of this information in a counting inertial system.

The estimates as far as possible and as low as practicable, and also of the flowing volume of information in the Universe are given. The estimates of the main informational characteristics of the Universe are given (1989 - 2009) [1-7].
Statement of the Universe management problem is given (2007) [3].
From the informational point of view the necessity of physical systems description (quantum mechanics) by means of nonclassical probabilistic logic is defined (2009) [6].
It is shown, that in all possible Universes the informatics laws and likewise physical conservation laws operate (2009) [6].

The logic structure of nature's laws governs the stages of the Universe emergence and development. From two events in the Universe life there is earlier that event, which logically precedes the other. During the initial moments of time information laws of nature operated. The information laws either have been set in initial "design" of the Universe, or were contained in initial heterogeneity of the Universe or have been set from the outside of the Universe.

Expansion of the Universe from the initial heterogeneity has generated the heterogeneity (information): various types of interaction; various types of particles and fields corresponding to them; various types of atoms, molecules; various types of stars, planets; the Life, …

The 2-nd approach (Lisi, Verlinde, … [8-13]).

The starting positions: the first law of thermodynamics, the second law of thermodynamics, holographic principle, Hawking's formula, Unru effect.
Unru effect (radiation Unru): predicted by a quantum theory effect of observation of the thermal radiation in the accelerated frame of reference in the absence of this radiation in the inertial system of counting. The temperature of the observable Unru radiation expresses the same formula, as the temperature of Hawking's radiation, it depends not only on the superficial gravitation, but also on the acceleration of frame of reference $T = \hbar a / 2\pi kc$. a-acceleration, c-speed of light, $\hbar$-reduced Planck constant, k-Boltzmann constant. The volume of information in physical systems is evaluated on the basis of the holographic principle.
The main effects: proceeding from the principle of maximum entropy the necessity of probability description of physical systems (quantum mechanics) (2006 [8] is stated, from informational aspect are spotted: the law of gravitation (2009-2010 [9-11], the second Newton's law (2009-2010) [9-11], Fridman's equations (2010) [12], irreversibility of time (2009) [13] is shown.

Conclusion

The works of the author and foreign scientists (American, Canadian, European, Chinese …) are confirming primacy of informational laws: the informational laws (informatics laws) define and restrict the physical laws; the informatics laws have general, universal character, operate in all possible universes, even in the universes with different physical laws. The given data show, that the priority use of informational methods of physical systems research belongs to the author, though the last results of foreign scientists are very interesting and important. The informatics laws together with the physical laws will make it possible to open all secrets of nature, in particular, to construct the theory of quantum gravitation.

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INFORMATION AS HETEROGENEITY

(Gurevich I.M. Information as a universal heterogeneity. /In Russian/. Information Technology. № 4. M. 2010. Pp. 66–74
Gurevich Igor. Information as heterogeneity. 01(04)/2011.
http://sites.google.com/site/glosariobitrum/Home/informacion-como-heterogeneidad/information-as-heterogeneity)

Abstract: Information is heterogeneity of any nature, stable for some definite time. If we want to create "Science of Information" we must use single, unified, unique definition of "information" concept. The rationale of this single definition of information can be based on the laws of development (evolution) of the Universe. About 10 billion years ago there was no life in the Universe. There was information only in the form of physical heterogeneity. Its existence does not depend on the Existence of the Observer. Heterogeneity (elementary particles, atoms, molecules, …) possess is certain information (and physical) characteristics, properties (information properties of the first order), in particular they contain certain volume of information. Interaction of heterogeneities leads to the change of their information characteristics. An observer appeared (very approximately) some billion years ago and gave new properties (information properties of the second order) to information in biological form – heterogeneity, created by life – Perception (3.8 billion years ago), Memory, Formation (Creation), Consciousness, Thinking (200 million years ago), Imagination, Mind, Intelligence, Knowledge, Cognition, Representation, Content, Meaning, Value. ... (some million years ago), … The new synthetic discipline which is uniting physicist and information theory was given the name «Physical Informatics». Physical Informatics is the Science of modern Information in Physical and Chemical Systems, including Quantum Informatics, and is the basis of Informatics of the Living Systems. The main questions of physical Informatics are enumerated, which the author researched. Using the definition of information, properties of information; we can create science of information.
Keywords: Modern Informatics, Physical Informatics, Information (Informatics) Laws

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1. Science of Information

D. Doucette (2010) has defined "Science of Information": "In establishing the new evolved information discipline, there should be some initial awareness that information is a part of all elements, systems, conditions and is therefore also an integral part of the other individual disciplines and sciences. While studying information phenomena, it is essential to look beyond the limitations of how human being use and perceive information, or even how living organisms use information. It is proposed that information is a continuous evolving process that exists in some simple to complex form at every stage of development across all science and academia domains as well as being a significant part of everything that exists. Information is a trigger mechanism, emphasis and nutrient for not only information activities but also all physical biological elements, systems and activities".

2. Definition of the "information" concept

If we want to create "Science of Information" we must use single, unified, unique definition of "information" concept.
I suggested this definition (Gurevich, 1989). "Information is heterogeneity, stable for some definite time". Regardless of the nature of heterogeneity, would it be letters, words, phrases or - elementary particles, atoms, molecules, or - people, groups, societies, etc.
Let us give definitions of homogeneity and heterogeneity (Gurevich, 2009, 2010a). Consider a set of elements. If the elements are the same, identical (not different from each other), then the set is homogeneous. If the elements are not the same, not identical (different from each other), then the set is no homogeneous.
The measure of the degree of heterogeneity or information is Shannon's information entropy and other information characteristics (information divergence, joint entropy, communication information).

The proposed definition and Shannon information entropy (Shannon, 1948) and other information characteristics can describe information (heterogeneity) of any nature. See, please, table 2.

Table 1

Type of information	**Time of existence of the heterogeneity**	**Type of heterogeneity**
Classical information	Time of existence of the heterogeneity is infinite $t_n = \infty$.	This is absolutely stable heterogeneity.
Macroinformation (*Chernavsky, 2004*)	Time of existence of heterogeneity is not less than the time of existence of the system $t_n \geq t_s$	This is essentially stable heterogeneity.
Information	Time of existence of the heterogeneity is not less than the time of existence of the system, but more then the time course of processes in the system $t_{n1} \leq t_n \leq t_s$	This is stable heterogeneity
Microinformation (*Chernavsky, 2004*)	Time of existence of the heterogeneity is essentially less than the time of existence of the system $t_n < t_{n1}$	This is unstable heterogeneity.

t_s - the time of existence of the system,

t_n - the time of existence of the heterogeneity,

t_{n1} - the time course of processes in the system.

Remarks 1.

In 1968 Ursul A.D. (Ursul, 1968).based on philosophical considerations, gave a definition of information, that is close to mine. I learned about it recently (late 2010) when I read the second edition of Ursul's book. Next, I cite references to the second edition of Ursul's book (Ursul, 2010).

«… first, information is linked to a variety, distinction, secondly, with reflexion. According to it information can be spotted in the general case as the reflexion variety. Information is a variety which one object contains about the other object (in the course of their interaction)... But information can be considered as variety which is as sort of reflexion effect by the object itself, i.e. self-reflexion. … Information expresses property of a substance which is general. … Concept of information is information reflexion as objective-real property of objects not dependent on the subject lifeless and wildlife, a society, and property of knowledge, thinking …, thus, is proper both to material, and ideal. It is applicable and to the substance performance, and to the consciousness performance. If objective information can be considered as property of substance the ideal, subjective information is reflexion of objective, material information». p. 228-229.

«Information theory methods will study properties of space and time, more than basically physical theories (for example, A. Einstein's special and common relativity theories) were engaged till now. So, the physicist and information theory interpenetrate each other, that in general carries on to making of two main synthetic disciplines - special applied information theory (and most likely, some its branches - thermodynamic, quantum) and the informational physics» p. 92-93.

«V.M. Glushkov characterizes information as heterogeneity in energy distribution (or substances) in space and in time …

The information exists so far as there are the material bodies and, therefore, the heterogeneities created by it». P. 67. «Heterogeneity is other expression of variety». P. 68.

Remark 2.

Heterogeneities can be used for storage of information (preferably the fermions) and transmission (preferably the bosons) (Gurevich , 2007, 2009).

Remark 3.

Fluctuations - random deviations from the mean values of physical quantities characterizing the system from a large number of particles caused by thermal motion of particles or quantum-mechanical effects, are not stable for some time, and therefore in fixed systems do not carry information. In non-stationary systems (eg, in the Universe), the fluctuations can generate information.

Remark 4.

Should be Remark that the author suggested that not only the more general definition of information, but also the most simple definition of information. He uses only one of the most general mathematical concepts - the notion of set.

3. Information properties of the first order

Information (heterogeneity) is an objective reality. The existence of information (heterogeneity) does not depend on availability of an Observer.

Heterogeneity (elementary particles, atoms, molecules, …) possesses certain information (and physical) characteristics, properties (properties of the first order), in particular they contain certain volume of information.

4. Information properties of the second order

Existence of an Observer [José María Díaz Nafría, 2010] can give (heterogeneity) new properties to information (information property of the second order) – Perception, Memory, Formation (Creation), Consciousness, Thinking, Imagination, Mind, Intelligence, Knowledge, Cognition, Representation, Content, Meaning, Value. ...
Observer is forming a hierarchy of information properties of the following orders.
Observer:
Perceives, locates, remembers information (heterogeneity).
Generates system of standards (concepts) describing information (heterogeneity).
Generates language of the description of information (heterogeneities).
Describes information (heterogeneity). Classifies information (heterogeneity).
Generates information base (heterogeneity) (knowledge base).
Generates , forms (creates) new information (heterogeneity).
Makes information actual (within the limits of possibilities).
At work with information (heterogeneities) an Observer is forming Mind, Intelligence.
The level of Mind, Intellect of an Observer is defined by the volume of processed (stored) information and productivity (speed) of work with information.
An Observer may not notice or ignore Existence of information (heterogeneity).
In the article (Florio Antonio) a possible scheme of building information properties of the second order on the basis of information properties of the first order is described.
Now an Observer is forming a hierarchy of information properties of the following orders.

5. Information properties of the first order impose fundamental restrictions on information characteristics of the second level

Information properties of the first level impose fundamental restrictions on information characteristics of the second level: restrictions on a memory size and productivity of information systems, perception of the natural (physical, chemical and biological) systems of an Observer.

Estimates of information volume in atoms, amino acids, nitrogenous bases, differential information capacity of usual matter, determine fundamental limits on information capacity storage devices. Differential capacity information of storage devices, constructed based on atoms combinations, does not exceed $\approx 10^{-25}$ bits/kg, and the information capacity of the storage mass 1kg $\leq 10^{25}$ bits and it can be enhanced with respect to the current level of no more than by $\approx 10^{11}$ times.

Differential information capacity of storage devices, built on the basis of atoms does not exceed $\approx 10^{-28}$ bits/kg, and information capacity of the storage mass 1kg $\leq 10^{28}$ bits, and it can be increased by no more than 10^{14} times.

The difference between the energies of the basis states of hydrogen atom, considered as a q-bit, impose fundamental limitations on the speed of computing devices. The number of operations is satisfied by hydrogen atom, a q-bit, limited $k_{op/s} = 2\Delta E / \hbar \approx 1{,}5 \cdot 10^{12}$ operations per second. Restrictions 10^{28} bit/kg, $\leq 1{,}5 \cdot 10^{12}$ op / sec You can add the number of fundamental natural limits, including the speed of light, elementary charge, Planck's time, ... (Gurevich, 2010).

Observational limits and perception (José María Díaz Nafría, Mario Pérez-Montoro, 2010). The following fundamental conclusions can be forwarded extracted, which concern what can be known about the object causing an observed wave phenomenon: The number of details to be found in the environment due to the presence of the object is finite. Such number depends on the surface bounding the object and not on its volume. The volumetric distribution of an object cannot be known only based on its manifestations on the environment. The description of the object that can be achieved corresponds to a projection of the inner heterogeneities over a bounding surface. These four conclusions establish fundamental limits to the observation problem, not attached to the specificity of our organs of animal or human sensibility, but to the differences that can merely be found in the environment and the maximal knowledge that could be derived concerning the object causing these differences.

6. Set of systematic definitions of information

«Because the concept of information is so complicated, we may have a set of systematic definitions of information: ontological information, epistemological information and so on in good order; instead of seeking only one single definition of information» (Zhong Y. X., 2011).

I cannot agree with this view. If we use different definitions of information we will receive assessments, results that cannot be compared, which is impossible to generalize.

7. The laws of development (evolution) of the Universe.and information

The rationale of a single definition of information can be based on the laws of development (evolution) of the Universe [Universe, 2011].
According to modern concepts, the observed universe today originated 13,7 ± 0,13 billion years ago from some initial singular state with enormous temperature and density and has since continuously expanded and cooled.
13,7 +1 E (-6) s - Hadron era (fusion of quarks into hadrons).
13,7 +1 E (-4) s - Lepton era (leptons and photons, electrons and neutrinos with their antiparticles, as well as protons and neutrons).
13.7 + 200 s - starts the synthesis of deuterium, helium and lithium. The temperature drops to values at which nucleosynthesis is more impossible, and the chemical substance of chemical composition remains unchanged until the birth of the first stars.
13.7 + 200 s - 4.6 billion years –forms large-scale structure of the Universe.
The formation of the solar system began about 4.6 billion years ago with the gravitational collapse of a small part of a giant interstellar molecular clouds.
Much of the substance turns out to be, in the gravitational center of the collapse with the subsequent formation of stars - the Sun.
The formation of the Earth began about 4.5 billion years ago, with the following (very approximate) date:
• 3.8 billion years ago first not nuclear organisms (prokaryotes) appeared;
• 3 billion years ago the first organisms capable of photosynthesis turned out;
• 2 billion years ago the first cells with the nucleus (eukaryotes) appeared;
• 1 billion years ago the first multicellular organisms appeared;
• 500 million years fish and proto amphibians appeared;
• 475 million years terrestrial plants appeared;
• 400 million years insects and seeds appeared;
• 360 million years ago the first amphibians appeared;
• 300 million years ago the first reptiles appeared;
• 200 million years ago the first mammals appeared;
• 150 million years ago the first bird appeared;
• 2,5 million years ago came the Homo genus;
• 200 thousand years ago people acquired a modern look.
Thus, about 10 billion years ago there was no life in the Universe. There was information only in the form of physical heterogeneity. Its existence does not depend on Existence of an Observer. Heterogeneity (elementary particles,

atoms, molecules, …) possess certain information (and physical) characteristics, properties (information properties of the first order), in particular they contain certain volume of information. Interaction of heterogeneities leads to change of their information characteristics.

An Observer appeared (very approximately) some billion years ago and gave to information (heterogeneity) new properties (information properties of the second order) – Perception (3.8 billion years ago), Memory, Formation (Creation), Consciousness, Thinking (200 million years ago), Imagination, Mind, Intelligence, Knowledge, Cognition, Representation, Content, Meaning, Value. ... (some million years ago), …

There are Time, Events in the Universe life, Information properties of the first and the second order

See, please, table 2.

Table 2

Time, Events in the Universe life, Information properties of the first and the second order

Years ago	Events in the Universe life	Information properties of the first order	Information properties of the second order
13.7 billion	Big bang	There is information only in the form of physical heterogeneity	No
13.7 billion +10^(-6) sec	Hadrons era (fusion of quarks into hadrons)	There is information only in the form of physical heterogeneity	No
13.7 billion +10^(-4) sec	Lepton era (leptons and photons, electrons and neutrinos with their antiparticles)	There is information only in the form of physical heterogeneity	No
13.7 billion + 200 sec	Starts the synthesis of deuterium, helium and lithium. The temperature drops to values at which nucleosynthesis is more impossible, and the chemical substance chemical composition remains unchanged until the birth of the first stars.	There is information only in the form of physical and chemical heterogeneity	No
From 13.7 billion + 200 sec to 4.6 billion	Forming large-scale structure of the Universe	There is information only in the form of physical and chemical heterogeneity	No
4.6	The solar system was	There is information only in	No

billion	formed	the form of physical and chemical heterogeneity	
4.5 billion	The earth was formed	There is information only in the form of physical and chemical heterogeneity	No
3.8 billion	Life originated. The first not nuclear organisms (prokaryotes) appeared	There is information in the form of physical, chemical and biological heterogeneity	Perception
2 billion	The first cells with the nucleus (eukaryotes) appeared	There is information in the form of physical, chemical and biological heterogeneity	Perception
1 billion	The multicellular organisms appeared	There is information in the form of physical, chemical and biological heterogeneity	Perception, Memory, Formation (Creation).
500 million	The fish and the proto amphibians appeared	There is information in the form of physical, chemical and biological heterogeneity	Perception, Memory, Formation (Creation), Consciousness, Thinking.
475 million	The terrestrial plants appeared	There is information in the form of physical, chemical and biological heterogeneity	Perception, Memory, Formation (Creation), Consciousness, Thinking.
400 million	The insects and the seeds appeared	There is information in the form of physical, chemical and biological heterogeneity	Perception, Memory, Formation (Creation), Consciousness, Thinking.
360 million	The amphibians appeared	There is information in the form of physical, chemical and biological heterogeneity	Perception, Memory, Formation (Creation), Consciousness, Thinking.
300 million	There were first reptiles	There is information in the form of physical, chemical and biological heterogeneity	Perception, Memory, Formation (Creation), Consciousness, Thinking.
200 million	The first mammals had appeared	There is information in the form of physical, chemical and biological heterogeneity	Perception, Memory, Formation (Creation), Consciousness, Thinking.
150 million	The first birds appeared	There is information in the form of physical, chemical and biological heterogeneity	Perception, Memory, Formation (Creation), Consciousness, Thinking.
2.5 million	The genus homo came	There is information in the form of physical, chemical and biological heterogeneity	Perception, Memory, Formation (Creation), Consciousness, Thinking.
200 thousand	People acquired a modern look	There is information in the form of physical, chemical and biological heterogeneity	Perception, Memory, Formation (Creation), Consciousness, Thinking, Mind.
Several thousand	A science formed	There is information in the form of physical, chemical and biological heterogeneity	Perception, Memory, Formation (Creation), Consciousness, Thinking, Imagination, Mind, Intelligence, Knowledge, Cognition, Representation, Content, Meaning, Value. ...
Now		There is information in the form of physical, chemical and biological heterogeneity.	Perception, Memory, Formation (Creation), Consciousness, Thinking,

		Physical Informatics formed.	Imagination, Mind, Intelligence, Knowledge, Cognition, Representation, Content, Meaning, Value. ... Observer is forming a hierarchy of information properties of the following orders.

Since 3.8 billion years ago to the present time information has material basis (it is information in the form of physical, chemical and biological heterogeneity) and information as the product of life (Perception, Memory, Formation (Creation), Consciousness, Thinking, Imagination, Mind, Intelligence, Knowledge, Cognition, Representation, Content, Meaning, Value. ...).

Information properties of the second order at the period from 3,8 to 1,0 billion years (life originated. The first not nuclear organisms (prokaryotes) appeared. The first cells with the nucleus (eukaryotes) appeared) should be specified with the development of microbiology of the Universe.

8. Some classes of homogeneities and heterogeneities

Natural
Inorganic, including physical
biological
environmental
other
Artificial
material
abstract (ideal)
abstract material
Mixed
socio-technological
organizational and technical
socio-economic
other

9. Some examples.

Physical homogeneities
Space
Time

Element
Communications
Subsystem
System
Module
Block
Device
Product
Complex
Network
Biological homogeneities
Chromosomes in the cells of one organism
Hierarchy of biological heterogeneities
Amino acid
Protein
Nucleotides
DNA
RNA
Cell
Cytozoon
Virus
Bacterium
Multicellular organism
Population
Socio-economic homogeneity
Money
The hierarchy of socio-economic heterogeneity
Individual
Family
Group
Nation
Production unit
Industry sector
National economy
Country
Civilization

Each level of the hierarchy of heterogeneity of any type contains various elements. At each level of the hierarchy of heterogeneities the probability of realization of each element (in the discrete case) and the distribution function of the density distribution of elements (in the continuous case) can be determined.

10.Physical Informatics

The new synthetic discipline which is uniting physicist and information theory was given the name «Physical Informatics».

Let’s enumerate the main questions of physical Informatics, which the author researched.

Information methods of physical systems research. The laws of informatics.

Evaluation of information entropy, information divergence, a joint information entropy, information, communication, differential data capacity of physical, chemical and biological systems.

Estimates of volume of information in the physical, chemical and biological systems (fundamental and elementary particles, atoms, molecules, gases, liquids, solids, stars, black holes ,..., RNA, DNA, cells, viruses, organisms, ..., a man, the Universe).

The laws of physics as a consequence of the laws of informatics.

Calculations of physical processes (e.g., particle decay, nuclear reactions).

Characteristics and properties of information interaction of physical systems.

Informational constraints on the formation, development, interconversion of the fundamental and elementary particles, atoms, molecules, gases, liquids, solids, stars, black holes ,..., RNA, DNA, cells, viruses, organisms, ...

Fundamental limitations on memory capacity and productivity of information systems.

The volume of information that determines the possibility of creation and development of the Universe. The mass of the initial heterogeneity of the Universe.

Expansion of the Universe - the cause and source of information in the Universe (the structure of the Universe, the cosmological objects, including stellar systems, civilizations, Mind, Intelligence, Knowledge, Cognition).

Models and methods of management of the Universe. Management of development of the Universe from within. The need for external management for expansion, development of the Universe?

The need for classical objects, classical logic, classical information for the existence and understanding the Universe.

Life as an effective way to formation of the classical information in the Universe.

Information characteristics of civilizations in the Universe. Possible influence of civilizations on expansion, development of the Universe. Cognition of civilization in the Universe.

Characteristics of the minimal subject of knowledge.
Methods and tools for the compact of submission of knowledge. Methods and means of preserving the accumulated of civilization knowledge .
Information foundations of the theory of quantum gravity, "Theory of everything".

Conclusion

Information is heterogeneity of any nature, stable for some definite time. The rationale of this single definition of information can be based on the laws of development (evolution) of the Universe.
About 10 billion years ago there was no life in the Universe. There was information only in the form of physical and chemical heterogeneity. Its existence does not depend on the Existence of an Observer. Heterogeneity (elementary particles, atoms, molecules, …) possesses certain information (and physical) characteristics, properties (information properties of the first order), in particular they contain certain volume of information. Interaction of heterogeneities leads to change of their information characteristics.
An Observer appeared (very approximately) some billion years ago and gave new properties (information properties of the second order) to information in biological form – heterogeneity, created by life – Perception (3.8 billion years ago), Memory, Formation (Creation), Consciousness, Thinking (200 million years ago), Imagination, Mind, Intelligence, Knowledge, Cognition, Representation, Content, Meaning, Value. ... (some million years ago), …
Now an Observer is forming a hierarchy of information properties of the following orders.
The new synthetic discipline which is uniting the physicist and information theory was given the name «Physical Informatics».
Using the definition of information, properties of information resulted from the article; we can create science of information.

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Zhong Y. X. e-mail, January 12, 2011

INFORMATICS LAWS ARE

INFORMATION BACKGROUND OF PHYSICS.

PHYSICAL LAWS AND PROPERTIES OF NATURE

AS CONSEQUENCE OF INFORMATICS LAWS

(Gurevich I.M. Information characteristics of physical systems. /In Russian/. Sevastopol. 2010. Pp. 162-222.
Gurevich I.M. Physical laws and properties of nature as a consequence of informatics. /In Russian/. Materials of international scientific seminar "Modern problems in applied mathematics, informatics, automation, control. - Sevastopol: SevNTU, 2012. - Pp. 36-52)

Abstract: The work confirms priority of information laws (informatics laws), which are the basis of physical informatics. Physical informatics is information background of physics: informatics laws define and restrict physical laws; informatics laws have general, universal character, operate in all possible universes with different physical laws. Informatics laws precede physical laws. Definitions and estimates are given for information characteristics of physical systems (fundamental and elementary particles, atoms, molecules..., star objects, the galaxies,…, Universe as a whole). Information restrictions on interaction of physical systems are received. It is shown, that physical laws and properties of the nature are consequence of the informatics laws, in particular, laws of conservation of energy, an impulse, the moment of an impulse, a charge, all fundamental interactions laws of electromagnetic, weak and strong interaction. Restrictions are defined on the formation of physical systems of q-bits, and model design of physical systems of q-bits? It is shown, that for formation of fundamental particles it is necessary no less than six q-bits. Physical Informatics is Science of modern Information in Physical and Chemical Systems, including Quantum

Informatics, and is the basis of Informatics of the Living Systems. The informatics laws together with the physical laws will allow to open all secrets of nature, in particular, to construct the theory of quantum gravitation.

Keywords: Informatics, Physical Informatics, Information (Informatics) Laws

1. Introduction

Along with matter and energy, the Universe contains information. Information is an integral part of the Universe. Each physical system has, along with physical characteristics, information characteristics. Information is inseparably linked with matter and energy. Scientists study physical characteristics and physical laws when they study information characteristics and information laws. This article provides an overview of the fundamental results obtained by the outstanding scientists Einstein A. [1], Neumann M. [2], Shannon C. [3], Wheeler J. [4], Penrose R. [5], Brillouin L. [6], Zeilinger A. [7], Lloyd S. [8], Lisi A. [9], Chernavsky D. S. [10]. The basic finding by the author is formulation of nature's laws by means of more general than physical informatics laws [11-23]. At the end of 2010 I read Ursul's book «Nature of information» [2 issues] [24], which he wrote in 1968 [25]. He has made the single, unified, unique definition of the "information" concept close to my definition: «Information theory methods will study properties of space and time, while basically physical theories (for example, A. Einstein's special and common relativity theories) till now were engaged. So, the physicist and information theory interpenetrate each other, that in general carries on to making of two main synthetic disciplines - special applied information theory (and most likely, some of its branches - thermodynamic, quantum) and the informational physics» [24], p. 92-93. … Information exists so far as there are material bodies and, therefore, heterogeneities created by it». [24], P. 67.
This synthetic discipline has received the name: physical informatics. The author conducted research of complex systems, including physical systems, in terms of informatics laws. Informatics laws define and limit physical phenomena and processes. Informatics laws precede physical laws. The number of scientists using the information approach and information methods in physical research is quickly increasing.

2. The list of the main results of the author

Information is physical heterogeneity. The information characteristics of heterogeneity: Shannon's information entropy, information divergence, joint entropy, communication information [11, 12, 18, 20, 21, 23]. The informatics laws of nature are [11, 12, 18]:

The law of simplicity of complex systems. *Such variant of complex system is realized, survives which possesses the minimum complexity.*

The law of simplicity of complex systems is realized by nature in a number of constructive principles:

" Occam Razor "; hierarchical modular construction of complex systems; symmetry; simmorfoz**,** stability; field interaction (interaction through the carrier or interactions through space-time status, for example, curvature of space-time); extreme uncertainty (functions of characteristics distribution have extreme uncertainty).

The law of conservation of uncertainty (information). *Uncertainty (information) of the isolated (closed) systems is saved at physically realized transformations and only at physically realized transformations.*

The law of finiteness of information characteristics of complex systems. *All kinds of interaction between systems, their parts and elements have final speed of distribution. The speed of change of system states of elements is also limited.*

In any system of coordinates information on event is always final. Duration of signal ΔT is always more than zero ($\Delta T > 0$). Information on coordinates of physical systems in our Universe is limited by 333 bits.

The law of necessary variety by W. Ashby. *For effective functioning of system a variety of operating body should be no less than variety of management object.*

Uncertainty (information) is the basic characteristic of a variety of systems. The law of necessary variety by W. Ashby is also realized in a number of concrete principles:

Shannon theorems, Kotelnikov theorem, Kholevo theorem, Brillouin theorem, theorem of Margolis-Levitin.

Gödel theorem of incompleteness. *In the rich enough theory (containing on arithmetic) there are always* unprovable *true assertions.*

The law of systems complexity growth. During *systems evolution its uncertainty (systems information) grows.*

Le Chatelier Principle. *External influence discomposing system, calls in it the processes, aspiring to weaken results of this influence.*

The main principle of quantum mechanics by A. Zeilinger: *Elemental physical systems contain (carry) one bit of information* [7].

Existence of several types of substance with different dependence of information content I on mass M (including linear for usual substance and for dark substance $I \propto M$, square for black holes $I \propto M^2$, linearly-logarithmic for neutron stars and white dwarfs $I \propto M \log_2 M$, zero for dark energy $I \equiv 0$) was disclosed [18, 21, 23].

Consumption of energy (mass) for the creation of microinformation and classical information (remembered, played back) for different types of matter was determined.

In the standard model of the universe, the expansion of the mass of usual substance decreases. In the expansion of the universe with acceleration, the mass of usual substance in the beginning decreases, reaches a minimum, and then increases [18, 21, 23].

The joint use the physical law of energy conservation and the information law of uncertainty (information) conservation enables us to determine Hawking's formula for black holes (information spectrum of radiation) [18, 23].

The formula for the information spectrum of radiation of neutron stars and white dwarfs was deducted [21, 23].

Existence of optimal black holes was disclosed, and characteristics of optimal black holes (minimizing the volume of information in a part of the universe and the universe as a whole) were researched. The structure of the universe with the information minimum was determined. Limitations on the volume of information in the universe were defined [17, 18, 21, 23].

At author's approach for the estimate of information volume in a physical system, the use of holographic principle was not required. Direct estimates of information content in physical systems were given [21-23]. The procedure for estimating information volume in physical objects consisted of the following. At first, the volume of information in the lower level objects – the fundamental particles (leptons and quarks) was estimated. According to Zeilinger's principle, we considered that, in the lower level objects, one bit of information was contained. Further, the volume of information in the objects of the second level was estimated. It was equal to the total of the information volume of objects of lower level plus the volume of information contained in the structure of objects of the second level of the hierarchy (mesons, baryons). The volume of information in the structure of objects of the second level is estimated on a wave function of the objects of the second level. The volume of information in objects of additional levels is similarly estimated [21-23].

It is shown that the space uncertainty (information) on the particle layout in space spots the Newtonian gravitational potential (the first derivative of information on radius) and the strength of gravitational field (the second derivative of the information on radius): the type of gravitational potential is $\propto 1/r$, the type of strength of gravitational field is $\propto 1/r^2$ [20, 21, 23]. The same is true for the Coulomb interaction potential and the field intensity strength of the Coulomb interaction.

It was shown that, to four known types of interaction (gravitational, electromagnetic, strong, and weak); one should add one more type of interaction - information interaction [18, 20, 21, 23].

Information models of cosmological objects (black holes, neutron stars, white dwarfs, and stars of solar type) were developed [18, 19, 20, 21, 23].

Information limitations on forming and merging of black holes were received [19, 21, 23].

The existence of initial discontinuities of the universe (with the use of information divergence) was proven. The estimates of the initial discontinuities mass of the universe were given [23].

Expansion of the universe from initial heterogeneity generates new heterogeneity (information). The universe expansion is the reason and source of information formation. Various physical processes in the extending universe form information [11, 12, 18, 20, 21, 23].

The curvature of the universe also generates heterogeneity (information) [18, 20, 21, 23].

It was shown that the volume of information, shaped in a frame of reference, moving with acceleration, is equal to $I = -\log_2 J = -\log_2 \sqrt{1 - ax/c^2} \approx ax/c^2$. J - jacobian, a-acceleration, x-coordinate, c- speed of light. We will pay attention to the analogy to the effect Unru. The appearance of thermal radiation in an accelerated frame of reference in the absence of this radiation in a counting inertial system is the appearance of additional information in an accelerated frame of reference in the absence of this information in a counting inertial system [21, 23].

Estimates of the maximum volume and minimum volume, the current volume of information in the Universe were given. The estimates of the basic information characteristics of the universe were given [11, 12, 20, 21, 23].

A statement of the universe management problem was given [18].

From the information point of view, the necessity of a physical systems description (quantum mechanics) by means of nonclassical probabilistic logic was defined [21, 23].

It is necessary to notice, that from the principle of maximum entropy Lisi gets the necessity of the probability description of physical systems (the necessity of quantum mechanics) [9].

It was shown that, in all possible universes, the informatics laws and likewise physical conservation laws operate [18, 20, 21, 23].

The logic structure of nature's laws governs the stages of the Universe's emergence and development. From two events in the universe's life, there is an earlier event that logically precedes the other. During the initial moments of time, information laws of nature operated. The information laws either have been set in the initial "design" of the Universe or were contained in the initial heterogeneity of the Universe or have been set from the outside of the universe [21, 23].

The expansion of the Universe from its initial heterogeneity has generated the heterogeneity (information): various types of interaction; various types of particles and fields corresponding to them; various types of atoms, molecules; various types of stars, planets; life …[18, 20, 21, 23].

3. Let's look at some of the author's results in more detail

3.1. Information interaction

The interaction of the linked (entangled) states and subsystems of the quantum system helps to estimate the mutual information. The linked (entangled) states, subsystems differ on the value of communication information. The unit of interaction of the linked (entangled) states and subsystems of the quantum system is the bit. Therefore, interaction of the linked (entangled) states and subsystems of quantum system is information interaction. The interaction of the linked (entangled) states and subsystems does not depend on their layout in space or the distance between them. It follows from an information conservation law of uncertainty (information). At a change of coordinates, orientation in space separate q-bits and subsets q-bits, and the linked (entangled) state as a whole uncertainty (information) of interaction is saved.

It is possible to translocate q-bits, parts of the linked (entangled) subsystems, with any velocity from each other, saving the value of information interaction.

The maximum information interaction between subsystems A and B of systems $A+B$ is determined by the volume of uncertainty (information) in subsystems and is equal to $I_{AB\max} = \log_2 d$, where d is the dimension of the subsystems.

It is necessary to add to the four known types of interaction (gravitational, electromagnetic, strong, weak) one more type of interaction - the information interaction [18, 20, 21, 23].

3.2. Estimations of the volume of information in the systems consisting from *n* of elementary systems (q-bits)

The author shows [18, 21, 23] that the physical system can be represented as a direct sum of direct products of the q-bits. Therefore, it is necessary to assess the volume of information in q-bits systems. Zeilinger [7] proposed the Foundational Principle for Quantum Mechanics: An elementary system carries 1 bit of information. Let's estimate the volume of information in the system consisting of n elementary systems (n q-bits). In the beginning, we shall consider systems with equiprobable basic states.

Let us assume that a system consists of noninteracting n q-bits. The q-bit is described by the wave function $\psi = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$. Here $|0\rangle, |1\rangle$ are basic states of the q-bit. Measurements of the q-bit states will give the states $|0\rangle$ and $|1\rangle$ with probabilities equal to $\frac{1}{2}$. Uncertainty N_1 (information I_1) of the q-bit is equal to 1 bit $N_1 = I_1 = H_1 = -(\frac{1}{2}\log_2\frac{1}{2} + \frac{1}{2}\log_2\frac{1}{2}) = 1$. Here H is the information entropy [3].

Hence, in the system consisting of n, not cooperating q-bits with equiprobable basic states that the volume of information I_n is proportional to the number of q-bits n and equal to n bits. This determines the minimal volume of information in the system of n q-bits with the equiprobable basic states. This explains the linear dependence of the volume of information on mass in usual substances (in fundamental particles - quarks, leptons, photons).

Let us assume that a system consists of n q-bits interacting in pairs with equiprobable states and is described by the following wave function $\psi_n = \frac{1}{\sqrt{2}}(|0_1\rangle|0_2\rangle...|0_n\rangle + |1_1\rangle|1_2\rangle...|1_n\rangle)$. Every q-bit i has the wave function $\psi_i = \frac{1}{\sqrt{2}}(|0_i\rangle + |1_i\rangle)$. ($|0_i\rangle, |1_i\rangle$ are basic states of the i-th q-bit. The information of communication $I_{ij} = H_i + H_j - H_{ij}$ [3] of the pair of interacting q-bit ij described by the wave function $\psi_{ij} = \frac{1}{\sqrt{2}}(|0_i\rangle|0_j\rangle + |1_i\rangle|1_j\rangle)$ is equal to 1 bit [13].

The volume of the information of communication in the system consisting of n q-bits interacting in pairs with equiprobable basic states is equal to

$I_{n\,com} = \frac{n \cdot (n-1)}{2}$ bits. The total volume of information I_n in the system containing n q-bits interacting in pairs with equiprobable basic states, is equal to $I_n = n + \frac{n \cdot (n-1)}{2} = \frac{n \cdot (n+1)}{2}$ bits. This determines the maximal volume of information in the system consisting of n q-bits. At $n >> 1$ the volume of information in the system of n q-bits interacting in pairs is equal to $I_n \approx \frac{n^2}{2}$. This explains the quadratic dependence of the volume of information on the mass in black holes. The system consisting of n q-bits interacting in pairs contains n bits more information than the system consisting of $n-1$ in pairs interacting q-bits: $I_n - I_{n-1} = \frac{n \cdot (n+1)}{2} - \frac{(n-1) \cdot n}{2} = n$.

Let us assume that the system consists of n q-bits, where they make groups of k q-bits and each of the q-bits interacts only with q-bits of the group (we consider that n is divided by k). The volume of information in groups consisting of k in pairs interacting q-bits with equiprobable basic states is equal to $\frac{k \cdot (k+1)}{2}$ bits. Hence, in the system of n q-bits with limited interaction there are $I_{n/k} = \frac{n}{k} \frac{k \cdot (k+1)}{2} = \frac{n \cdot (k+1)}{2}$ bits. This explains the linear dependence of the volume of information on mass of composite particles in usual substance (for example, in elementary particles – baryons, mesons and also atoms).

In general the volume of information I_n in the system consisting of n q-bits with equiprobable basic states, is not less than n bits and no more than $\frac{n \cdot (n+1)}{2}$ bits.

3.3. Information estimate of the mass of initial heterogeneities of the Universe

The results obtained with the help of information considerations lead to the following basic conclusions: the universe, at the extension, generates discontinuities (information) from initial heterogeneities (information) [26]; we showed that, at the initial time, the heterogeneity of usual substance matter and dark substance in the universe exist; we show that, at the initial time, the heterogeneity of dark energy in the universe did not exist; the laws of nature and physical laws completely determine that the development, properties, and characteristics of the Universe must be contained in the initial heterogeneity of our Universe. Physical laws operate in our universe from the moment of time of not less than *t=1E-44 s*.

For a record, fixing the natural laws and physical laws, the certain volume of classic information I_{pf} is needed. Consequently, the volume of classic information I_{hty} in the initial heterogeneity of the universe must be not less than volume of the classic information is in the natural laws and physical laws $I_{gty} < I_{pf}$.

The mass of the initial heterogeneity is more then 1E+15*I_{pf}*k*T/c^2*, or the mass of the initial heterogeneity is proportional to the volume of classical information in physical laws and is inversely proportional to the square root of the time of life of our universe and inversely proportional to the square of the speed of light.

The mass of the initial heterogeneity of the Universe required to memorize or store t physical laws (*1E+7* classical bits) at the temperature of the universe *1E+12K* (the lifetime of the universe *1E-5*s) is about *1E-8kg* (about one Planck's mass).

To get the 1E+7 classical bits of information at the time t = E-34s, with the Fridman's expansion of the universe, it needs approximately 1E+5 classic bits at the time t = E-44 s or the mass of the initial heterogeneity of the universe of approximately 1E+12kg. At the sedate extension of the universe from 1E-34 s to 1E-10 s from 1bit of classical information 160 bits of classical information were formed. Therefore, for deriving 1E+7 bits classical information at the moment of 1E-10 s it is necessary to have 1E+5 classical bits at the moment of 1E-34 s or approximately the mass 1E+7kg. This, apparently, is impossible. Therefore, the initial information is assumed to be generated, appreciably, at the inflationary extension of the Universe.

At the inflationary extension of the Universe from 1E-34 s to 1E-32 s, from one bit of classical information containing in initial heterogeneities of the universe 1E+3 bits of classical information are shaped. At the inflationary extension from 1E-34 s to 1E-32 s and the further sedate extension of the universe from 1E-32 s to 1E-10 s from one bit of classical information 1E+5 bits of classical information are shaped. For deriving 1E+5 bits of classical information at the moment of 1E-10 s, it is necessary to have about 1E+5 bits classical information at the moment of 1E-34 s or the mass 1E+4kg. This is an estimate of the mass of initial heterogeneity of the universe at the moment of 1E-34 s, the mass that is necessary for containing (storing) physical laws of nature.

It testifies in favor of the improved hypothesis to the initial information [27]: «... At the moment of *1E-34s*, the Universe as a whole has been concluded in the field with the radius of *1E-24sm*... In this size already there was heterogeneity of mass of the order *1E+4kg* from which all information in the Universe future was generated...».

3.4. Information volume in our Universe

Information is inseparably linked with matter and energy. Information is physical heterogeneity steady for certain time, heterogeneity of matter and energy [11, 12, 18, 20, 21, 23]. The energy necessary for the formation of one bit of microinformation [10] is equal to $E_{bit} = kT \ln 2$ [6]. The mass necessary for the formation of one bit of microinformation is equal to $m_{bit} = kT \ln 2 / c^2$. The values of energy and mass of the carrier of 1 bit of microinformation are resulted at temperatures of 3K (300K).
The minimum energy for 1 bit is equal to 4,141E-23 (4,141E-21) joule. The minimum mass for 1 bit is equal to 4,608E-40 (4,608E-38) kg. On the average in atoms for 1 bit of information it is used $\approx 1,69 \cdot 10^{-28}$ kg of mass of substance (for example, in the atom of hydrogen it is used $\approx 1,6 \cdot 10^{-28}$ kg, in the atom of lithium - $\approx 1,93 \cdot 10^{-28}$ kg). It is approximately by $\approx 10^{12}$ times more than the mass necessary for the formation of one bit of microinformation.
The reason and source of information formation is expansion of the Universe and initial heterogeneity. At symmetry infringement between weak and electromagnetic interactions in the universe, it is formed 10^{90} bits. The information mechanism of particles formation in the inflationary Universe generates the quantity of particles, comparable with the standard estimation of the number of particles in the Universe, - an order of 10^{80} - 10^{90}.
The minimum possible volume of information in the universe with prevalence of substance is $\approx 1,7 \cdot 10^{79}$ in the Universe with prevalence of radiation is $\approx 10^{91}$ bits. The greatest possible volume of information in the Universe is $\approx 10^{120}$ bits [18, 20, 21, 23]. Growth of volume of information at sedate expansion of the Universe is $\propto \log_2 t$. Reduction of density of information at sedate expansion of the Universe is $\propto (\log_2 t) / t^2$. The growth of information volume at inflation expansion of the Universe is $\propto \alpha t$. The reduction of density of information at inflation expansion of the Universe is $\propto te^{-3\alpha t}$.

3.4.1. Information volume in some fundamental, elementary particles and atoms

Fundamental particles are the simplest physical systems (elementary systems by Zeilinger, 1999).
There is 1 bit in a lepton. There is 1 bit in a quark. One photon with circular polarization contains 1 bit. One photon, z^0-boson—product of electroweak interaction—contains 0,78 bits.
Elementary particles represent physical systems of the second level of complexity.
There are 9,422 bits in a proton, a neutron (taking into account the structure of protons and neutrons, the information in quarks, and the colors of quarks).
Atoms represent physical systems of the third level of complexity.
There are 11,422 bits in the atom of hydrogen (taking into account the structure of atom, the information in protons and electrons). There are 39,688 bits in the atom of helium. … There are 109,642 bits in the atom of carbon. … There are 544,21 bits in the atom of iron (26th element). There are 2334,436 bits in the atom of uranium, ... In the above-mentioned cases the structure of atoms and external uncertainty of electrons is not considered.
The estimates of the joint entropy of matrixes mixture of electroweak interaction (1,7849; 1,7787; 1,7645; 1,7945), according to different independent experimental data, are close to the estimates of the joint entropy of matrixes mixture of quarks (1,7842, 1,7849) [20, 21, 23].

3.4.2. Information volume in stars

The sun contains $\approx 1,3 \cdot 10^{58}$ bits. The white dwarf of solar mass contains $\approx 1,24 \cdot 10^{59}$ bits. The neutron star of solar mass contains $\approx 2,38 \cdot 10^{59}$ bits.

3.4.3. Optimal black holes

The existence of matter of two types – with square-law and with linear dependence of information volume on mass – is the source, the reason of existence, of optimal black holes which minimize the volume of information in any region of the universe and in the universe as a whole.
The information volume and the mass of optimal black holes, that are yielded by deciding the direct problem (minimization of volume of information in the system (usual substance – black hole) for a given mass of the system) and the dual problem (maximization of mass of the system (usual substance – black hole) for a given volume of information in the system) respectively, coincide.

There are $\approx 10^{62}$ bits in the optimal black hole generated in the system «radiation (photons) - black hole» at the temperature of radiation - 2,7K. There are $\approx 2,57 \cdot 10^{38}$ bits in the optimal black hole generated in the system «hydrogen (protons) - black hole».
At the temperature of radiation $T = m_p c^2 / 9,422k \ln 2 = 1,555 \cdot \mathrm{E} + 12$ K (at the time from «the Big Bang» of the universe 10^{-5}), the mass of the optimal black holes that have arisen in the systems «radiation - black holes» is equal to the mass of the optimal black holes which have arisen in the systems «hydrogen (protons) - black hole».
In masses of the optimum black holes shaped from various types of atoms of ordinary substances or a mixture of various types of atoms of ordinary substances, information contents are approximately identical.
The black holes of solar mass contain $\approx 7,72 \cdot 10^{76}$ bits. The black holes in centers of galaxies contain $\approx 10^{90} - 10^{107}$ bits.

3.4.4. Information volume in galaxies

In galaxies having 10^{11} stars, there are about 10^{69} bits. In galaxies having 10^{11} of stars and containing, in kernels, super massive black holes with the mass of $\approx 10^{6} - 10^{10}$ of solar mass, there are $\approx 10^{99} - 10^{107}$ bits.

3.4.5. Information dependence of temperature of radiation on mass

For a black hole, the dependence of temperature on mass (Hawking's spectrum) looks like $T = (\hbar c^3 \ln 2) / (4\pi GMk)$. For a neutron star, the dependence of temperature on mass (an information spectrum) looks like $T = (m_n c^2) / k(9,422 + \log_2 M / m_n)$.

3.4.6. Information restrictions at creation of black holes from stars

The mass of the black hole formed from the star of the sun’s type is no more than $\approx 8 \cdot 10^{20}$ kg.
The mass of the black hole formed from the white dwarf of solar mass is no more than $\approx 2,5 \cdot 10^{21}$ kg.

The mass of the black hole formed from the neutron star of solar mass is no more than $\approx 4{,}17 \cdot 10^{21}$ kg.
Note: The black hole at formation uses only part of mass. Other mass, in the form of usual substance, dissipates in surrounding space, and other objects can be formed of it.

3.4.7. Information restrictions at the merging of black holes

At the merging of two black holes with the mass M_1 M_2, without the use of additional usual substance, the mass of the resulting black hole is less, than $\sqrt{M_1^2+M_2^2}$.
At the merging of two black holes with the mass M_1 M_2, with the use of additional usual substance, the mass of the resulting black hole is more than $\sqrt{M_1^2+M_2^2}$.

3.4.8. Classical information

Nitrogenous basis contains $\log_2 4 = 2$ bits of the classical information (macroinformation).
Amino acids contain $\log_2 20 = 4{,}32$ bits of the classical information. For 1 bit of information formed by amino acids and nitrogenous basis, 4,43E-25 and 1,05E-25kg of mass are needed. Redundancy of classical information formed by life, in relation to micro information, at the temperature of 300K is greater by a factor of $\approx 10^{13}$. Proteins and DNA for the formation of 1 bit of information use mass by three orders more than atoms. Hence, life is an effective way of forming classical information. Proteins of yeast contain about 2,000 bits of classical information. One chromosome of a person contains $(1-5) \cdot 10^8$ bits of classical information. One person contains $\approx 10^{26}$ bits of classical information.
Biomass of the Earth contains about 10^{40} bits of classical information. If 100% of the Earth's mass is used for the formation of live substance, it will generate about 10^{50} bits of classical information. If 1% of the universe's mass is used for the formation of live substance, it will generate approximately 10^{75} bits of classical information. $10^{40} - 10^{77}$ bits is a range of possible volume of classical information in the universe defined by the data known now.
The volume of classical information formed by terrestrial civilization is $< 10^{30}$ bits/year. Parity of volumes of information in the universe in a year,

generated by matter and civilization is $\approx 10^{-49}$. The share of information formed by civilization on one star system is equal to 10^{-27}. It shows that the contribution of terrestrial civilization to information formation of the universe is now insignificant.

3.4.9. Fundamental limits on information capacity storage devices

Regarding estimates of the information volume in atoms, amino acids, nitrogenous bases, the differential information capacity of a substance determines the fundamental limits of information capacity storage devices. The differential information capacity of storage devices, based on a combinations of atoms, does not exceed $\approx 10^{-25}$ bits/kg, and the information capacity of the storage mass 1kg $\leq 10^{25}$ bits; it can be enhanced with respect to the current level of no more than $\approx 10^{11}$ times.

The differential information capacity of storage devices, built on the basis of atoms, does not exceed $\approx 10^{-28}$ bits/kg, and the information capacity of the storage mass 1kg $\leq 10^{28}$ bits; it can be increased by no more than 10^{14} times.

3.4.10. Fundamental restrictions on productivity of information systems

The difference between the energies of the basis states of the hydrogen atom, considered as a q-bit, impose fundamental limitations on the speed of computing devices. The number of operations a hydrogen atom can perform as a q-bit is limited to $k_{op/s} = 2\Delta E / \hbar \approx$ 1,5*10^{12} operations per second. The productivity of a computer built from atoms of hydrogen, whose mass is one kg, is not more than 10^{39} op/sec. Given the restrictions of 10^{28} bit/kg and 1,5*10^{12} op / sec, you can add a number of fundamental natural limits, such as the speed of light, the elementary charge, Planck's time, and so on.

3.4.11. Cognitive process of the Universe

The universe, the information volume of which is finite, is effective and completely knowable [15, 18].

The subject of the cognitive process is a classical object (for example, terrestrial civilization).

In the course of the universe's cognitive process, compression of information is not less than $\approx 10^{20}$ times and no more than $\approx 10^{76}$ times. The gravitation law, in particular, compresses the information than by no less of a factor than $4 \cdot 10^{183}$.
Interpretation of cognitive process by methods of quantum mechanics (the description and measurement) on the basis of information parities is possible. The knowledge is carried out through a hypothetical information channel – "the knowledge channel of nature." The limited throughput of "the knowledge channel of nature" defines as impossible "exact" (in classical sense) descriptions and measurements of quantum objects. To increase the accuracy (uncertainty) of the description/measurement of one of the components, an Observer is compelled to reduce accuracy (uncertainty) of the description/measurement of the other.

3.4.12. Information unity of all possible universes

As heterogeneity should exist in the universes with any physical laws, the approach that is based on information properties of heterogeneities of any nature and corresponding information laws and restrictions, and also physical laws of conservation following from them, extends on all possible universes. Thereby, physical laws of conservation and information restrictions in other possible physical laws in different universes are identical. Does it mean that all possible universes are identical?

4. Approach 2 [Verlinde, 2010].

There are many works that appeared in the beginning of 2010. Among them was Verlinde [28]. The starting position is: the first law of thermodynamics, the second law of thermodynamics, holographic principle, Hawking's formula, and Unru effect.
For information, such aspects are noted: the law of gravitation [28, 29, 30], Friedman's equations [31], irreversibility of time [32] is shown.

5. Physical laws and properties of nature as consequence of informatics laws

5.1. The Universe's structure

Assertion 5.1.1. *The Universe is arranged by the simplest images. The description (theoretical model) of the Universe should be the simplest.*

Simplicity, complexity of systems is defined by information volume contained in them (volume of information necessary for their description).

Assertion 5.1.2. *The Universe represents hierarchical set of physical systems.*

From a principle of hierarchical construction of complex systems, of the law of simplicity of complex systems follows the proof that complex systems have hierarchical modular structure.

5.2. Classical and quantum physics

Assertion 5.2.1. *Axioms of classical and quantum physics can be formulated in a classic language.*

The classical logic - the term used in the mathematical logic in relation to this or that logic system, indicate, that for the given logic all laws of (classical) calculation of assertions, including the law of an exception of the third, are fair. The multitude of axioms of classical and quantum physics is limited and is consistent. There are no indemonstrable true assertions among them.

Assertion 5.2.2. *All assertions about physical systems cannot be formulated in a classic language.*

For the formulation of assertions about physical systems the language of quantum physics should be used.

Owing to Gödel theorem the physics can not be limited to classical theories in which frameworks there are always indemonstrable true expressions that describe potentially unlimited number of assertions about physical systems. It explains obligatory existence of the quantum physics describing physical systems by probability characteristics.

Assertion 5.2.3. *Application of the principle of the maximum information entropy at restrictions on the sum of probabilities of ways (=1) and the average action allows to receive distribution of probabilities of ways, statistical sum, average action and wave function of a way* [9].

The quantum mechanics based on the theory of information demands introduction of the basic physical principle: existence of the universal pool of action similar to the thermostat for initial ensemble.

Canonical ensemble - statistical ensemble, responding physical system which exchanges energy with environment (thermostat), being from it in thermal balance, but does not exchange substance as it is separated from the thermostat by an impenetrable partition for particles. The description of the system in the form of Feynman integral is $Z = \sum_{path} e^{-\frac{1}{i\hbar}S}$. The sum (integral) on all ways to classical configuration space, and S - the classical action set for each way. Each observer interacts with probability, p [path] = p [q (t)] (in abbreviated form p [q]). The information - the negative logarithm of probability for a way − log p [path] is - quantity of information received by the observer if the system, is on a corresponding way. The information entropy characterizing the system, is equal to $H = -\sum_{path} p[path]\log_2 p[path] = -\int Dqp[q]\log_2 p[q]$. For any system restriction is $1 = \sum_{path} p[path] = \int Dqp[q]$.

In case of statistical thermodynamics it is supposed, that the system is in balance with the thermostat of the set temperature. Similarly, in the quantum mechanics it is supposed, that the system is in balance with universal storehouse of actions.

$$\bar{S} = \langle S \rangle - \sum_{path} p[path]S[path] = -\int Dqp[q]S[q].$$

Maximizing entropy, taking into account the resulted restrictions, we will receive distribution of probabilities of ways, the statistical sum and average action: $p[q] = \frac{1}{Z}e^{-\alpha S[q]}$, $Z = \int Dqe^{-\alpha S[q]}$, $\bar{S} = \int DqS[q]p[q[= -\frac{\partial}{\partial\alpha}\log_2 Z$. $\alpha = \frac{1}{i\hbar}$. $i\hbar \leftrightarrow k_B T$.

The probability of a choice of way $p(q', t') = \Psi(q', t')\Psi^*(q', t')$ is expressed through wave function $\Psi(q', t') = \frac{1}{\sqrt{Z}}\int_0^{q(t')=q'} Dqe^{-\alpha S^{t'}}$.

Assertion 5.2.4. *Combination of classical addition of probabilities of distinguishable alternatives to a classical choice of one of several equiprobable ways leads to quantum mechanical wave rule of addition of amplitudes.*

Let's consider transition of object from an initial state *s* to the final state *f* in two distinguishable ways. According to the rule of addition of probabilities of independent events the probability of this transition is equal to $\omega_{s\to f} = \omega_{1\ s\to f} + \omega_{2\ s\to f}$, *or* $|\langle f|s\rangle|^2 = |\langle f|s\rangle_1|^2 + |\langle f|s\rangle_2|^2$. At identical to each way probability of transition uncertainty is equal to amplitude of probability of transition

$$N_{2\ s\to f} = -\log_2 2|\psi|^2.$$

At two indiscernible ways of transition from uncertainty of transition two distinguishable ways subtract the information of a choice of one of two equiprobable ways of transition $I_2 = - log_2 2 = - 1$.
Hence, uncertainty of transition of object from an initial state s to the final state f will be equal in two indiscernible ways to the sum of uncertainty of transition in two distinguishable ways and information of a choice of one of two equiprobable ways of transfer (with a return sign): $N_{2\, s\to f} = N'_{2\, s\to f} - I_2 =$ $= - log_2 2/\psi/^2 - log_2 2 = - log_2 4/\psi/^2 = - log_2 /2\psi/^2$. The size standing under the sign of the module expresses a rule of addition of amplitudes of probability of transition. Let's consider transition of object from an initial state to the final state f by m distinguishable ways. According to the rule of addition of probabilities of independent events the probability of this transition is equal to $\omega_{s\to f} = \Sigma_i\ \omega_{i\, s\to f}$, or $/<f/s>/^2 = \Sigma_i\ /<f/s>_i/^2$. At identical to each way of transition uncertainty of transition of bits is equal to amplitude of probability of transition $N_{m\, s\to f} = - log_2 m/\psi/^2$. At indiscernible ways of transition to uncertainty of transition for m distinguishable ways the information of a choice of one of m equiprobable ways (with a sign a minus) is added: $I_m = log_2 m$. Hence, uncertainty of transition of object from an initial state to the final state f indiscernible m will be equal to the sum of uncertainty of transition for distinguishable m ways and uncertainty of a choice of one of m equiprobable ways of transition:

$$N_{m\, s\to f} = N'_{m\, s\to f} - I_m \,.\ N_{m\, s\to f} = - log_2 m/\psi/^2 - log_2 m = - log_2 m^2 /\psi/^2 =$$

$$= - log_2 /m\psi/^2.$$

The size standing under the sign of the module expresses the rule of addition of amplitudes of probability of transition. The combination of classical addition of probabilities at distinguishable alternatives with a classical choice of one of several equiprobable ways leads to quantum mechanical wave rule of addition of amplitudes.

5.3. Description of physical systems

Assertion 5.3.1. *Physical systems, the objects observed are described by wave function or the amplitude of probability depending on quality parameters and variables physical characteristics.*
Assertion 5.3.2. *The square of the module of wave function or amplitude of probability is density of probability or probability.*
Assertion 5.3.3. *Physical systems, objects, the observable are described by the information characteristic - uncertainty (information). A measure of*

uncertainty (information) is the Shannon information entropy, defined as functional on wave function or amplitudes of probability.

C. Shannon [3] has entered the concept of information entropy. Entropy H of a discrete random variable: $H = -\sum p_i \log_2 p_i$ [bit] ($H = -\sum p_i \ln p_i$. [nut], Entropy H of a continuous random variable $H(x) = -\int p(x)\log_2 p(x)dx$ [bit], ($H(x) = -\int p(x) \ln p(x)\, dx$ [nut]).

Assertion 5.3.4. *Heterogeneity of physical system is described by the information characteristic of - divergence, defined as functional on wave function or amplitudes of probability.*

Presence and properties of the heterogeneity set by distribution P, will estimate information divergence $D(P / R)$ [33] distributions P concerning uniform distribution R

$$D(P / R) = -\int P(x)\cdot\log_2 \frac{P(x)}{R(x)}\cdot dx = -\int P(x)\cdot\log_2 P(x)\cdot dx + \int P(x)\cdot\log_2 R(x)\cdot dx ,$$

Where $P(x)$ - the distribution corresponding to heterogeneity, and $R(x)$ - uniform distribution to interval $0 \le x \le a$

$$R(x) = \left\{ \begin{array}{l} 0 \text{ if } -\infty < x \le 0 \\ \frac{1}{a} \text{ if } 0 < x \le a \\ 0 \text{ if } a < x \le \infty \end{array} \right\} .$$

If $P(x)$ is defined on interval $0 \le x \le a$ information divergence is equal to

$$D = -\int_0^a P(x)\cdot \log_2 \frac{P(x)}{\frac{1}{a}} \cdot dx = -\int_0^a P(x)\cdot \log_2 (a \cdot P(x))dx .$$

$$D = -\int_0^a P(x)\cdot \log_2 (a \cdot P(x))dx = -\int_0^a P(x)\cdot \log_2 a \cdot dx - \int_0^a P(x)\cdot \log_2 P(x)dx =$$

$$-\log_2 a - \int_0^a P(x)\cdot \log_2 P(x)dx = N - \log_2 a .$$

Information divergence concerning uniform distribution differs from uncertainty (information entropy) on $-\log_2 a$.

Assertion 5.3.5. *Unitary transformations are described by the information characteristic - joint entropy.*

Let's define for the unitary operator (transformation), unitary matrix $U = \|u_{ij}\|$ Shannon matrix $SH(U) = \|u_{sh\,ij}\| = \left\|\frac{u_{ij}}{\sqrt{n}}\right\|$, $i, j = 1,...,n$ which elements are elements of a unitary matrix, divided on $\sqrt{n}$.

Let's define on Shannon matrix final probability space: set Ω of elementary events (outcomes) is made by steams of basic vectors y_i, x_j bases y and x; their probability measure is set by squares of modules of elements Shannon's matrixes $p_{ij}(SH(U)) = \frac{|u_{ij}|^2}{n}$ (probability of joint realization of states y_i and x_j at measurement of states y in basis x). $\sum_{i,j=1}^{n} p_{ij}(SH(U)) = \sum_{i,j=1}^{n} \left|\frac{u_{ij}}{\sqrt{n}}\right|^2 = \frac{1}{n}\sum_{i,j=1}^{n} |u_{ij}|^2 = 1$. At such definition of final probability space for considered unitary matrix $U = \|u_{ij}\|$ at measurement of states y in basis x the probability of realization y_i and x_j is equal to $p_{ij}(SH(U)) = \frac{1}{n}|u_{ij}|^2$, $\sum_{i=1}^{n} p_{ij}(SH(U)) = \sum_{i=1}^{n} \frac{1}{n}|u_{ij}|^2 = \frac{1}{n}$, $\sum_{i=1}^{n}\sum_{j=1}^{n} p_{ij}(SH(U)) = \sum_{i=1}^{n}\sum_{j=1}^{n} \frac{1}{n}|u_{ij}|^2 = 1$. Thus, the matrix of joint probabilities $P(SH(U)) = \left\||u_{sh\,ij}(U)|^2\right\| = \left\|\frac{|u_{ij}|^2}{n}\right\|$ is defined on Shannon's matrix to a matrix unequivocally. Using a matrix of joint probabilities, we will define the joint entropy corresponding to unitary matrix

$$U = \|u_{ij}\|.\ H(U) = H(P(SH(U))) = -\sum_{i=1}^{n}\sum_{j=1}^{n} |u_{sh\,ij}(U)|^2 \log_2 |u_{sh\,ij}(U)|^2 = -\sum_{i=1}^{n}\sum_{j=1}^{n} \frac{|u_{ij}|^2}{n}\log_2 \frac{|u_{ij}|^2}{n}.$$

Assertion 5.3.6. *Interaction of physical systems, objects is described by the information characteristic - the mutual uncertainty (mutual information).*

The mutual information entropy I_{xy} of random variables x and y is equal to [3]. $I_{xy} = N_x + N_y - N_{xy}$, where N_x, N_y - uncertainty (information entropy) random variables x and y; N_{xy} - joint uncertainty (information entropy) random variables (x, y). The mutual information can be considered as a measure of entanglement of physical systems.

5.4. Information restrictions on physical transformations

Assertion 5.4.1. *Transformations* U *of the state* $|\psi\rangle = \sum_x c_x |x\rangle$ *in the complex Euclidean space, saving probability structure of a state* (*the sum of probabilities received at measurement of one of the basic states* x *for the initial state* $|\psi\rangle = \sum_x c_x |x\rangle$ *equal to unit* $\langle|\psi\rangle\||\psi\rangle\rangle = \sum_x |c_x|^2 = 1$, *and the sum of probabilities received at measurement of one of basic states* x *for the final state* $U|\psi\rangle = U\sum_x c_x |x\rangle = \sum_x c_{ux} |x\rangle$ *equal to unit* $\langle|U\psi\rangle\||U\psi\rangle\rangle = \sum_x |c_{ux}|^2 = 1$*), are unitary.*

Unitary transformation is a linear transformation $x'_i = u_{i1}x_1 + u_{i2}x_2 + ... + u_{in}x_n$ (i = 1, 2..., n) with the complex factors, saving invariable the sum of modules sizes $|x'_1|^2 + |x'_2|^2 + ... + |x'_n|^2 = |x_1|^2 + |x_2|^2 + ... + |x_n|^2$.

Let's consider any state of physical system $|\psi\rangle = \sum_x c_x |x\rangle$. Decomposition factors on the allocated basis (classical states) are called as amplitudes, and the square of the module of amplitude $|c_x|^2$ is equal to probability of system in state x, i.e. the probability of basic state x at measurement of state $|\psi\rangle = \sum_x c_x |x\rangle$ is equal to $P(|\psi\rangle, x) = |c_x|^2$. Transformations should save equality to unit of the sum of probabilities at measurement of one of the basic state x for initial $|\psi\rangle = \sum_x c_x |x\rangle$ and the final states $U|\psi\rangle = U\sum_x c_x |x\rangle = \sum_x c_{ux} |x\rangle$ $\langle|\psi\rangle\||\psi\rangle\rangle = \sum_x |c_x|^2 = 1$, $\langle|U\psi\rangle\||U\psi\rangle\rangle = \sum_x |c_{ux}|^2 = 1$. Thus, transformations should be unitary.

Assertion 5.4.2. *Transformations* O *of the state* $|\psi\rangle = \sum_x c_x |x\rangle$ *in the real Euclidean space, saving probability structure of the state (the sum of probabilities received at measurement of one of the basic state* x *for the initial state* $|\psi\rangle = \sum_x c_x |x\rangle$ *equal to the unit* $\langle|\psi\rangle\||\psi\rangle\rangle = \sum_x |c_x|^2 = 1$, *and the sum of probabilities received at measurement of one of the basic states* x *for the* *final state* $O|\psi\rangle = O\sum_x c_x |x\rangle = \sum_x c_{ox} |x\rangle$*, equal to the unit* $\langle |O\psi\rangle \| O\psi\rangle\rangle = \sum_x |c_{ox}|^2 = 1$*), are orthogonal.*

Assertion 5.4.3. *Transmitting transformations are the most simple.*

Such movement of space at which the movement of all points is equal to $y = x + z$ is called translation motion (shift). Transmitting transformations of coordinates in *n*-dimensional Euclidean space E^n are defined by no more than *n* parameters that is less in comparison with other kinds of transformations.

Assertion 5.4.4. *Linear transformations of coordinates, as well as transmitting, are the most simple transformations.*

Linear transformations of coordinates in *n*-dimensional Euclidean space E^n are defined by no more than n^2 parameters that is less in comparison with other kinds of transformations, except the transmitting ones.

Assertion 5.4.5. *The real variables are the most simple.*

The real variables are described by one number, and complex ones are described by two numbers.

Assertion 5.4.6. *In the Universe transmitting transformations of coordinates operate as the most simple.*

Assertion 5.4.7. *In the Universe linear transformations of coordinates operate as the most simple.*

Assertion 5.4.8. *The observable is the real variable as the most simple.*

Assertion 5.4.9. *At transformations of systems of coordinates uncertainty (information) is saved in that and only in that case when Jacobean transformations is equal to unit:* $J(\frac{x_1, ..., x_n}{y_1, ..., y_n}) = 1$.

Let's consider transition from coordinates $x = (x_1, ..., x_n)$ to coordinates $y = (y_1, ..., y_n)$ - $y = y(x)$. Let N_x, N_y values of the uncertainty (information) characterizing physical system in coordinates x and y, $p(x) = |\psi(x)|^2$, $p(y) = |\psi(y)|^2$.

$$N_y = -\int ... \int p(y_1, ..., y_n)) \ln p(y_1, ..., y_n) dy_1 ... dy_n = N_x - \int ... \int p(x_1, ..., x_n) \ln J(\frac{x_1, ..., x_n}{y_1, ..., y_n}) dx_1 ... dx_n .$$

The law of simplicity of complex systems demands realization in the Universe of linear transformations of co-ordinates (as the most simple).

Let's consider further linear transformations of coordinates $y = Ax$ or $y = \|a_{ij}\| x$.

In this case Jacobean is equal to a determinant of return transformation of coordinates $\det\left\|a_{ij}\right\|^{-1}$ and value of the uncertainty (information) characterizing physical system in new coordinates, equal to

$$N_y = -\int\ldots\int p(y_1,\ldots,y_n))\ln p(y_1,\ldots,y_n)dy_1\ldots dy_n = N_x - \int\ldots\int p(x_1,\ldots,x_n)\ln\left(\det\left\|a_{ij}\right\|^{-1}\right)dx_1\ldots dx_n.$$

Assertion 5.4.10. *Uncertainty (information) is saved in that and only in that case, when value of a determinant of linear transformation of coordinates is equal to one unit.*
The proof is obvious.

Assertion 5.4.11. *At global gauge transformations* $\psi'(x) = e^{i\alpha}\psi'(x)$, $\alpha = const$ *uncertainty (information) is saved.*

Let's estimate $\bar{\psi}'(x)\psi'(x) = e^{-i\alpha}\bar{\psi}(x)e^{i\alpha}\psi(x) = e^{-i\alpha}e^{i\alpha}\bar{\psi}(x)\psi(x) = \bar{\psi}(x)\psi(x)$. ($e^{-i\alpha}$ and $\bar{\psi}(x)$ - as complex numbers switch). Hence, $-\int|\psi'(x)|^2\log_2|\psi'(x)|^2 dx = -\int|\psi(x)|^2\log_2|\psi(x)|^2 dx$ - uncertainty (information) is saved.

Assertion 5.4.12. *At local gauge transformations* $\psi'(x) = e^{i\alpha(x)}\psi'(x)$ *uncertainty (information) is saved.*

Let's estimate $\bar{\psi}'(x)\psi'(x) = e^{-i\alpha(x)}\bar{\psi}(x)e^{i\alpha(x)}\psi(x)$. As $\psi(x)$ - complex number, and $e^{i\alpha(x)}$, generally a matrix, $e^{-i\alpha}\bar{\psi}(x)\psi(x)e^{i\alpha} = e^{-i\alpha}|\psi(x)|^2 e^{i\alpha} = |\psi(x)|^2 e^{-i\alpha}e^{i\alpha} = |\psi(x)|^2$ (complex number $\psi(x)$ switches with matrix $e^{-i\alpha(x)}$). Hence, $-\int|\psi'(x)|^2\log_2|\psi'(x)|^2 dx = -\int|\psi(x)|^2\log_2|\psi(x)|^2 dx$ - uncertainty (information) is saved.

Assertion 5.4.13. *Observables as real variables are represented by Hermitian operators.*

5.5. Reliability of physical transformations

Assertion 5.5.1. *Transmitting transformations save uncertainty (information), therefore owing to the law of conservation of uncertainty (information), they are physically realized.*
Owing to the law of conservation of uncertainty, transformations of the isolated (closed) systems are physically realized in the only case when they save uncertainty (information). Jacobean matrix transmitting transformation $y_i = x_i + z_i$ is equal to identity matrix

$$J\left(\frac{x_1, \dots, x_n}{y_1, \dots, y_n}\right) = E = \begin{Vmatrix} 1 & 0 & \dots & 0 \\ 0 & 1 & \dots & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & \dots & 1 \end{Vmatrix}.$$

The determinant Jacobean matrix transformation of translation (shift) is equal to one unit. The physical reliability of transmitting transformations directly follows from the law of conservation of uncertainty (information): uncertainty (information) of the isolated (closed) system is saved at physically realized transformations and only at physically realized transformations.

Assertion 5.5.2. *Own rotations are conservation uncertainty (information), therefore owing to the law of conservation of uncertainty (information), they are physically realized.*

Unitary transformations with a determinant equal to one unit are transformations of its own rotation. Such transformations save uncertainty (information), hence, in the isolated (closed) systems they are physically realized.

Remark 5.5.1. The group of unitary matrixes with a determinant equal to one unit, is isomorphic to the group of its own rotations of space, and the group of own rotations of system of coordinates.

Assertion 5.5.2. *Transformations of classical mechanics (Galilee transformations) save uncertainty (information), therefore owing to the law of conservation of uncertainty (information), they are physically realized.*

Galilee transformations leave invariable the interval $ds^2 = dx_1^2 + dx_2^2 + dx_3^2$. They can be formally considered as rotation in Euclidean 3-dimensional space.

Galilee transformations consist of three independent rotations in planes $x_i x_j$ and three transformations responding to arbitrariness in a choice of the beginning of coordinates system of $x_\mu \to x_\mu + a_\mu$ (transmitting transformations). All of them save uncertainty. Hence, Galilee transformations in the isolated (closed) systems are physically realized.

Assertion 5.5.3. *Transformations of the special theory of relativity (Lorentz transformation) save uncertainty (information), therefore owing to the law of conservation of uncertainty (information), they are physically realized.*

Lorentz transformations leave invariable the interval $ds^2 = dt^2 - dx_1^2 - dx_2^2 - dx_3^2$. They can be considered formally as rotation in pseudo-Euclidean 4-

dimensional space-time (Minkovsky space) for which turn generators in planes tx_1, tx_2, tx_3 are purely imaginary. Physically they respond to transition system of coordinates moving along the set of axes x_i. Transformations to planes $x_i x_j$ are usual rotations. Therefore Lorentz transformations consist of three independent rotations in planes $x_i x_j$ and three independent movements along the axes x_i. Besides these six transformations of symmetry in Minkovsky space four more are admissible, responding to arbitrariness in the choice of the beginning of system of coordinates $x_\mu \to x_\mu + a_\mu$ (transmitting transformations). All of them save uncertainty. Hence, Lorentz transformations in the isolated (closed) systems are physically realized.

Remark 5.5.2. To each transformation in initial n-dimensional Euclidean space E^n with coordinates x there corresponds a set of transformations in subspaces E^i of initial space E^n ($E^i \subseteq E^n$), and private transformations should conservation uncertainty also.

Assertion 4.5.4. *Reflexions, not own rotations, time inversion in isolated (closed) system are forbidden and physically unrealizable.*

Reflexions, not own rotations, time inversion are forbidden and physically unrealizable as determinants of corresponding transformations are equal to a minus unit.

Remark 4.5.3. According to the law of conservation of uncertainty (information) an isolated (closed) physical system cannot pass from the state $\psi(x)$ in the state $\psi(-x)$ (reflexion), from the state $\psi(x)$ in the state $\psi(-Ux)$ (not own rotation) and from the state $\psi(x,t)$ in the state $\psi(x,-t)$ (time inversion), but the systems described by the wave functions $\phi(x) = \psi(-x)$, $\phi(x) = \psi(-Ux)$, $\phi(x,t) = \psi(x,-t)$ can exist.

Assertion 5.5.4. *Global gauge transformations* $\psi'(x) = e^{i\alpha}\psi'(x)$, $\alpha = const$ *save uncertainty (information), therefore owing to the law of conservation of uncertainty (information), they are physically realized.*

Assertion 5.5.5. *Local gauge transformations* $\psi'(x) = e^{i\alpha(x)}\psi'(x)$ *save uncertainty (information), therefore owing to the law of conservation of uncertainty (information), they are physically realized.*

5.6. Properties of space-time

Assertion 5.6.1. *The physical realizability of transmitting transformation of time means uniformity of time.*

The given Assertion follows from the definition of uniformity of time.

Assertion 5.6.2. *The physical realizability of transmitting transformation of space means uniformity of space.*

The given Assertion follows from the definition of uniformity of space.

Assertion 5.6.3. *The physical realizability of transformation of own rotation of space means isotropy of space.*

The given assertion follows from the definition of own rotation of space.

5.7. Physical laws as consequence of informatics laws

Assertion 5.7.1. *Spatial uncertainty (information on a particle arrangement in space) defines Newton gravitational potential and Coulomb potential (the first derivative of uncertainty on radius), intensity of gravitational field and Coulomb's fields (the second derivative of uncertainty on radius).*

Newton gravitational potential in point b created mass M_a, being in point a and, $\phi = -\frac{G \cdot M_a}{r_{ab}}$, where G - a gravitational constant, r_{ab} - distance from point a to point b. Potential energy of a body with mass m_b, being in point b, is equal to $\phi \cdot m_b$, i.e. ϕ potential energy of a body of individual mass in the given point of gravitational field, and intensity of a gravitational field is equal to the gradient of gravitational potential.

Let's consider three-dimensional Euclidean space R^3. We will allocate in him a sphere with radius r and volume $V = \frac{4}{3}\pi r^3$. We will assume, that in the sphere there is a particle which radius is equal to r_0 and volume $V_0 = \frac{4}{3}\pi r_0^3$.

Uncertainty of a particle arrangement in a sphere (spatial uncertainty of a particle) is equal to

$$N = \log_2 \frac{V}{V_0} = 3\log_2 \frac{r}{r_0} = 3\log_2 r - 3\log_2 r_0 .$$

The first derivative of uncertainty on radius $\frac{dN}{dr} = \frac{3}{\ln 2} \cdot \frac{1}{r}$ to within a constant is gravitational potential of unit mass. The second derivative of uncertainty on radius $\frac{d^2 N}{dr^2} = -\frac{3}{\ln 2} \cdot \frac{1}{r^2}$ to within a constant is intensity of gravitational field. Thus, spatial uncertainty (information on a particle arrangement in space) defines Newton gravitational potential (the first derivative of uncertainty on

radius) and intensity of a gravitational field (the second derivative of uncertainty on radius).
It is similarly connected with Coulomb interaction.
Assertion 5.7.2. *From the time uniformity the law of conservation of energy follows.*
This physical assertion follows from the definition of time uniformity and Noether theorem.
Assertion 5.7.3. *From space uniformity the law of conservation of an impulse follows.*
This assertion follows from the definition of space uniformity and Noether theorem.
Assertion 5.7.4. *From space isotropy the law of conservation of the moment of an impulse follows.*
This assertion follows from the definition space isotropy and Noether theorems.
Assertion 5.7.5. *From Lagrangian invariance concerning global gauge type transformations* $\varphi' = e^{i\alpha Q}\varphi$ *where Q - a charge of* the *particle described by field* φ*, and* α *- any number which is not dependent on existential coordinates of a particle, follows the law of conservation of a charge.*
Remark 5.7.1. The group of such phase transformations *U* (1) - unitary group of an order 1 (multiplicate group of all complex numbers equal on the module to a unit. Elements of group *U* (1) define, actually, corner size: the complex number *z* can be written down as $z = e^{i\varphi}$ (and φ will be already real), and multiplication of complex numbers will pass in addition of corners. Thus, for group *U* (1) it is possible to understand all planes of the beginning around of coordinates as the group of turns of a circle, or group of turns *SO*.
Assertion 5.7.6. *From Lagrangian invariance concerning local gauge transformations of type* $\psi'(x) = e^{i\alpha(x)}\psi'(x)$, *where α (x) - generally a matrix depending on existential coordinates, laws of electromagnetic, weak and strong interaction follow*.
Through gauge invariance it is possible to describe in standard model electromagnetic, weak and strong interactions [34]. The basic characteristic describing physical system in the quantum mechanics, - wave function - is size complex. However, all observable sizes, which are under construction as bilinear combinations of wave functions, appear material. As a result it turns out, that anything in theory predictions will not change, if wave functions are multiplied by the complex number equal on the module to unit - $e^{i\alpha}$. (The Interfaced function is multiplied, accordingly, by the interfaced complex

number). Thus, the quantum mechanics is invariant global gauge transformations.

Whether is invariant to the quantum mechanics local gauge transformation $e^{i\alpha(x)}$? The quantum mechanics of a free particle appears not invariant concerning local phase rotations. For invariance restoration it is necessary to enter a new field which "feels" that internal space in which phase rotations are made. As a result, at local phase rotations will be transformed by both wave functions, and a new field and this changes in the equations compensate them, "calibrate" each other.

Absolutely similarly it is possible to enter and gauge transformations of more complex kind which are responsible for invariance in some more complex space of internal degrees of freedom. So, for example, invariance concerning rotations of quarks in color space leads also to that strong interactions and it possible to describe as gauge fields. It is impossible to describe weak interactions separately as gauge, however there is unexpectedly graceful method of the description of electromagnetic and weak interactions simultaneously as two different displays of some gauge electroweak field.

Thus, all fundamental interactions are deduced on the basis of gauge invariance. From the point of view of construction of the physical theory, it is the extremely economical and successful scheme.

Assertion 5.7.7. *From the law of conservation of uncertainty (information) Gibbs thermodynamic equation (the basic thermodynamic identity) follows.*

Let's assume, that at transition of system from an initial state to the final state the particles are formed (quanta of radiation with zero weight of rest), each of which contains I_p=1 bit and has energy $E_p = h\nu$. Owing to the law of conservation of uncertainty (information) the generated particles should possess the information equal to $\Delta I = I' - I''$, i.e. should be generated $n = I' - I'' = \Delta I$ radiation quanta. Owing to the law of the conservation of energy, the generated quanta of radiation should possess energy $nh\nu$ equal to $\Delta U = U'' - U'$. Thus, $nh\nu = \Delta U$.

We will consider that the system represents absolutely black body. Average energy of radiation is connected with temperature of thermal radiation of absolutely black body $E_p = h\nu = 2,7kT$ [35]. As $n = \Delta I$, $\Delta I \cdot 2,7kT = \Delta U$, or $T = \frac{\Delta U}{2,7k\Delta I}$.

At $\Delta S = k\Delta I$ $T = \frac{\Delta U}{2,7\Delta S}$ or $\Delta U = 2,7T\Delta S$. In differential kind $T = \frac{dU}{2,7kdI}$ or $dU = 2,7kTdI$.

At $dS = kdI$ $T = \frac{dU}{2,7dS}$ or $dU = 2,7TdS$.

Thus, from laws of conservation of uncertainty (information) and energy, in that specific case at $dS = kdI$ Gibbs thermodynamic equation (The expression for the total differential of the internal energy is called the Gibbs equation) follows: $dU = 2,7TdS$.

Generalization on more general case $dU = TdS - PdV + \sum_j \mu_j dN_j$ is made by the account of performed job and the account of addition of particles in system without fulfillment of job and addition in the right part of the corresponding composed. The difference of resulted expression from the standard form of Gibbs thermodynamic equation – the presence in the right part of factor 2,7.

Let's assume, that at transition of system from an initial state to the final state particles (hadrons are baryons and mesons are formed with nonzero mass of rest), each of which contains I_p bit and has energy $E_p = m_p c^2 + \frac{m_p c^2}{2}$. Owing to the law of conservation of uncertainty (information) the generated particles should possess the information equal to $\Delta I = I' - I''$, i.e. should be generated $n = \frac{\Delta I}{I_p}$ particles. Owing to the law of conservation of energy the generated particles should possess energy $nE_p = nm_p c^2 + n\frac{m_p c^2}{2}$ equal to $\Delta U = U'' - U'$. Thus, $\frac{\Delta I}{I_p} m_p c^2 + \frac{\Delta I}{I_p}\frac{m_p c^2}{2} = \Delta U$. We will consider, that each particle has three degrees of freedom. Then $\frac{m_p c^2}{2} = \frac{3}{2}kT$.

As $\frac{\Delta I}{I_p} m_p c^2 + \frac{\Delta I}{I_p}\frac{m_p c^2}{2} = \Delta U$, $\frac{\Delta I}{I_p} m_p c^2 + \frac{\Delta I}{I_p}\frac{3}{2}kT = \Delta U$, or $\Delta U - \frac{\Delta I}{I_p} m_p c^2 = \frac{3}{2}\frac{\Delta I \cdot k}{I_p}T$. At $\Delta S = k\Delta I$ $\Delta U - \frac{\Delta I}{I_p} m_p c^2 = \frac{3}{2I_p}T\Delta S$. In differential kind $dU - \frac{dI}{I_p} m_p c^2 = \frac{3}{2I_p}TdS$.

Thus, from the laws of conservation of uncertainty (information) and energy, in that specific case at $dS = kdI$, Gibbs thermodynamic equation: $dU - \frac{dI}{I_p} m_p c^2 = \frac{3}{2I_p}TdS$. Generalization on more general case $dU = TdS - PdV + \sum_j \mu_j dN_j$ is made by the account of performed job and the account of addition of particles in system without fulfillment of job and addition in the right part of the corresponding composed. The differences of resulted expression from the standard form of Gibbs thermodynamic equation – the presence in the left part additional composed $-\frac{dI}{I_p} m_p c^2$ and in the right part of factor $\frac{3}{2I_p}$.

As the law of conservation of energy follows from the law of conservation of uncertainty (information) thermodynamic Gibbs equation follows from the law of conservation of uncertainty (information).

From information laws of simplicity of complex systems, conservation of uncertainty (information) follow physical laws of conservation of energy, an impulse, the moment of an impulse, a charge, electromagnetic, weak and strong interaction, Gibbs thermodynamic equation.

Assertion 5.7.8. *At least six q-bits are necessary for the formation of fundamental particle.*

6. Physical Informatics

The new synthetic discipline which is uniting the physicist and information theory was given the name «Physical Informatics».

Let's enumerate the main questions of physical Informatics, which the author researched.

Information methods of research of physical systems. Laws of informatics.

Evaluation of information entropy, information divergence, a joint information entropy, mutual information, differential data capacity of physical, chemical and biological systems.

Estimates of volume of information in the physical, chemical and biological systems (fundamental and elementary particles, atoms, molecules, gases, liquids, solids, stars, black holes ,..., RNA, DNA, cells, viruses, organisms, ..., a man, the Universe).

The laws of physics as a consequence of the laws of informatics.

Calculations of the physical processes (eg, particle decay, nuclear reactions).

Characteristics and properties of information interaction of physical systems.

Informational constraints on the formation, development, interconversion of the fundamental and elementary particles, atoms, molecules, gases, liquids, solids, stars, black holes ,..., RNA, DNA, cells, viruses, organisms, ...

Fundamental limitations on memory capacity and productivity of information systems.

The volume of information that determines the possibility of creation and development of the Universe. The mass of the initial heterogeneity of the Universe.
Expansion of the Universe - the cause and source of information in the Universe (the structure of the Universe, the cosmological objects, including stellar systems, civilizations, Mind, Intelligence, Knowledge, Cognition).
Models and methods of management of the Universe. Management of development of the Universe from within. The need for external management for expansion, development of the Universe?
The need for classical objects, classical logic, classical information for the existence and understanding the Universe.
Life as an effective way to the formation of classical information in the Universe.
Information characteristics of civilizations in the Universe. Possible influence of civilizations on expansion, development of the Universe. Cognition of the Universe civilization.
Characteristics of the minimal subject of knowledge.
Methods and tools for the compact of submission of knowledge. Methods and means of preserving the accumulated of civilization knowledge.
Information foundations of the theory of quantum gravity, "theory of everything".

7. Conclusion

The new synthetic discipline which is uniting the physicist and information theory was given the name «Physical Informatics». The works of the author and American, Canadian, European, Chinese,… scientists are confirming primacy of information laws: the information laws (informatics laws) define and restrict the physical laws; the informatics laws have general, universal character, operate in all possible universes, even in the universes with different physical laws. The given data show, that the priority use of information methods of physical systems research belongs to the author, though the last results of foreign scientists are very interesting and important. The informatics laws together with the physical laws will allow to open all secrets of nature, in particular, to construct the theory of quantum gravitation.

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INFORMATION INTERACTION IS THE FIFTH TYPE OF FUNDAMENTAL INTERACTIONS

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Abstract: Information is an integral part of the Universe. By its physical essence information is heterogeneity of matter and energy. Therefore information is inseparably connected with matter and energy. The universal measure of information in physical heterogeneity is the Shannon information entropy. An information approach along with a physical one allows to obtain new, sometimes more general data in relation to data obtained on the ground of physical rules only. The results presented in this paper show the effectiveness of informational approach for studying the interactions in the Universe. The paper shows that, along with the physical interactions the gravitational, electromagnetic, strong, weak interactions exists fifth type of fundamental interactions - information interaction, whose magnitude is not dependent on distance. The existence of information interaction is determined by the entanglement of quantum states, of quantum subsystems. The magnitude of information interaction is measured in bits.
Key words: Physical interactions, quantum system, entangled states, information interaction.

1. Introduction

There are four types of physical interactions: gravitational, electromagnetic, strong and week. The force of each type of interaction depends on the distance between interacting objects. For example this force for gravitational interaction is the inverse square of the distance between the objects, for the strong interaction it decreases exponentially with the distance, interaction between quarks is proportional to the distance. The type of dependence of interaction force on distance is defined by relevant physical law [1].

Entangled states, subsystems of quantum system gives birth to the fifth type of interaction – information interaction. “Entanglement is a unique quant mechanical resource which plays key part in a number of most interesting applications of quantum calculations and quantum information; this is a kind of iron in the bronze age of classical world. Entanglement is considered a fundamental resource of nature compared in importance to energy, information, entropy or any other fundamental resource” [2]. The magnitude of information interaction is not dependent on distance [3, 4].

2. Estimate of information interaction of entangled states, subsystems

To make an estimate of connection between two q-bits it is suggested in the work [5] to use mutual information («информацию связи» in Russian [6, 7]). It is shown that information interaction of two q-bits is in the range of (0, 1), and the maximal interaction between two entangled q-bits is equal to one bit.

As interaction of entangled states is measured in information units it is natural to consider this interaction to be information.

In general connection (more precisely as it will be clear later – the magnitude of interaction) between entangled subsystems A and B of quantum system $A + B$, as well as the connection between two q-bits can be characterized by mutual information.

Mutual information of two quantities A и B communication is defined as follows [6, 7]: $I_{AB} = N_A + N_B - N_{AB}$, where I_{AB} is mutual information of subsystem A and B is $I_{AB} = N_A + N_B - N_{AB}$, N_A, N_B – uncertainty (information entropy) of subsystems A, B, N_{AB} is joint uncertainty (joint information entropy) of system $A + B$.

Joint uncertainty (joint information entropy) of the joint allocation of events x and y is equal to $N_{xy} = -\sum_{i,j} p_{ij} \log_2 p_{ij}$, where p_{ij} is probability of joint execution of the event i for x and j for y, $\sum_{i,j} p_{ij} = 1$.

For estimating mutual information of two subsystems of arbitrary system we use representation of the system in the form of Schmidt decomposition [8, 9]. We present the wave function (probability amplitude) ψ_{AB} of the system $A + B$

consisting of two entangled subsystems A and B in the form of $\psi_{AB} = \sum_{i=1}^{d} c_i |\alpha_i\rangle |\beta_i\rangle$

where d is dimensionality of subsystem A and B (dimensionality of relevant Hilbert spaces); $|\alpha_i\rangle, |\beta_i\rangle$ – are orthogonal basis vectors of subsystems A and B; while c_i – are amplitudes of vectors $|\alpha_i\rangle|\beta_i\rangle$.

The matrix of joint allocation of basis states of probabilities for subsystems of the system $A+B$ while using Schmidt decomposition is equal to

$$P_{\text{ñî âì}\ .AB} = \begin{pmatrix} |c_1|^2 & 0 & 0 & 0 \\ 0 & |c_2|^2 & 0 & 0 \\ \dots & \dots & \dots & \dots \\ 0 & 0 & 0 & |c_d|^2 \end{pmatrix},$$

and vectors of P_A^T allocation probabilities of P_B^T realization for basis vectors $|\alpha_i\rangle$, $|\beta_i\rangle$ of subsystems A, B are equal, that is

$$P_A^T = \left(|c_1|^2,\quad |c_2|^2,\quad \dots,\quad |c_d|^2\right),\ P_B^T = \left(|c_1|^2,\quad |c_2|^2,\quad \dots,\quad |c_d|^2\right).$$

That said the joint uncertainty N_{AB} of subsystems A, B for the system $A+B$, as well as uncertainties N_A, N_B of subsystems A, B discretely are equal, that is

$$N_{AB} = -\sum_{i=1}^{d} |c_i|^2 \log_2 |c_i|^2,\ N_A = N_B = -\sum_{i=1}^{d} |c_i|^2 \log_2 |c_i|^2,$$

and the mutual information I_{AB} (magnitude of information interaction) of subsystems A, B for the system $A+B$ is equal to

$$I_{AB} = N_A + N_B - N_{AB} = -\sum_{i=1}^{d} |c_i|^2 \log_2 |c_i|^2 \text{ bits.}$$

From the law of uncertainty conservation [3, 4] it follows that if a system is at the state ψ, then at changes of coordinates and orientation of q-bits, subsets of q-bits, subsystems, entangled states in general, the uncertainties of entangled states remain.

Q-bits contained in the interlinked position can be also moved relative to each other with any speed without changing the uncertainty which explains conservation of magnitude of information interaction.

By using the connection between information and entropy $S = k \cdot I$ ([6, 7] as well as between entropy and energy (potential) $dE = T \cdot dS - P \cdot dV$ (see [10, 11]) information interaction of subsystems A and B can be described in accepted units of energy (ergs, joules). The energy (potential) of interaction of subsystems A and B for the system $A+B$ (energy which is necessary to break information interaction between A and B in the accepted units of energy is equal to

$$E_{AB} = S \cdot T = k \cdot T \cdot I_{AB} \,.$$

It is evident that maximum information interaction I_{AB} of subsystems A, B for the system системы $A+B$ is equal to $I_{AB\max} = \log_2 d$ bits.

In as much as for unentangled subsystems A, B $I_{AB\min} = 0$, then information interaction $F_{I\,AB}$ of subsystems A, B for the system $A+B$ lies in the range of $I_{AB\min} \le F_{I\,AB} \le I_{AB\max}$ or $0 \le F_{I\,AB} \le \log_2 d$.

3. Examples of estimation of information interaction of entangled states

Example 1.

Let joint allocation of probabilities of subsystems A, B states for A, B the system системы $A+B$ is equal to

$$p_{ij} = \frac{1}{n^2}, \quad i, j = 1,...,n \text{, and}$$

$$P = \begin{Vmatrix} \frac{1}{n^2} & \cdots & \frac{1}{n^2} \\ \cdots & \cdots & \\ \frac{1}{n^2} & \cdots & \frac{1}{n^2} \end{Vmatrix}.$$

Joint uncertainty of subsystems A, B is

$$N_{AB} = -\sum_{i,j} p_{ij} \log_2 p_{ij} = -n^2 \frac{1}{n^2} \log_2 \frac{1}{n^2} = 2\log_2 n \,.$$

As this takes place allocations of probabilities of subsystems A, B (p_i, q_j) states and uncertainties of subsystems A, B (N_A, N_B) are equal to

$$p_i = \frac{1}{n}, \quad i = 1,...,n, \; q_j = \frac{1}{n}, \; j = 1,...,n \,;$$

$$N_A = -\sum_i p_i \log_2 p_i = -n \frac{1}{n} \log_2 \frac{1}{n} = \log_2 n \,;$$

$$N_B = -\sum_j p_j \log_2 p_j = -n \frac{1}{n} \log_2 \frac{1}{n} = \log_2 n \,.$$

Information interaction of subsystems A, B for the system $A+B$ is

$$I_{AB} = N_A + N_B - N_{AB} = \log_2 n + \log_2 n - 2\log_2 n = 0 \,.$$

In this case subsystems A, B of the system $A+B$ information does not interact.

Example 2.

Let the joint allocation of probabilities of subsystems A, B states for the system $A+B$ is equal to $p_{ij}=\frac{1}{n}\delta_{ij}$, $i,j=1,...,n$, and

$$P=\begin{Vmatrix} \frac{1}{n} & 0 & 0 & 0 \\ 0 & \frac{1}{n} & 0 & 0 \\ 0 & 0 & ... & 0 \\ 0 & 0 & 0 & \frac{1}{n} \end{Vmatrix}.$$

Joint uncertainty of subsystems A, B is $N_{AB}=-\sum_{i,j} p_{ij}\log_2 p_{ij}=-n\frac{1}{n}\log_2\frac{1}{n}=\log_2 n$.

Probabilities of subsystems A, B (p_i,q_j) states and uncertainties of subsystems A , B $(N_A,\ N_B)$ is equal to

$$p_i=\frac{1}{n},\ i=1,...,n;$$

$$q_j=\frac{1}{n},\ j=1,...,n;$$

$$N_A=-\sum_i p_i\log_2 p_i=-n\frac{1}{n}\log_2\frac{1}{n}=\log_2 n.$$

$$N_B=-\sum_j p_j\log_2 p_j=-n\frac{1}{n}\log_2\frac{1}{n}=\log_2 n.$$

Information interaction of subsystems A, B for the system $A+B$ is equal to

$$I_{AB}=N_A+N_B-N_{AB}=\log_2 n+\log_2 n-\log_2 n=\log_2 n.$$

In the given example information interaction of subsystems A, B for the system $A+B$ equals to the maximal possible information interaction.

Example 3.

Let the system $A+B$, of the subsystem A, B contains $\approx N$ bits of information. Thereat the number of q-bits in each of the interacting subsystems is approximately equals to $\approx N$ and the dimensionality of the relevant Hilbert space equals to and the information interaction of subsystems does not exceed the value of $F_{I\,AB} = \log_2 d = N$ bits. Information interaction of subsystems is determined by the volume of information in the subsystems [3, 4, 12, 13].

Inasmuch as there are 10^{90} bits of information in the Universe [3, 4, 12, 13] then one can estimate the maximal information interaction of its two subsystems.

Let the maximal possible volume of information (q-bits) in each of the interacting subsystems approximately equals to 10^{90}, and since the dimensionality of the relevant Hilbert space equals to $d = 2^{10^{90}}$, then maximal possible information interaction of subsystems in the Universe does not exceed 10^{90} bits.

All quantum objects, quantum systems and subsystems – bosons and fermions are subject to information interaction. Vacuum due to its universal aspect seems to be the way of transmitter (carrier) of information interaction (defining the carrier of information interaction is the subject of future research).

Note. Information interaction cannot be treated as a consequence and/or characteristics of the known fundamental physical interactions: gravitational, electromagnetic, strong, week, though the entangled states are made with the use of these interactions, first of all with the use of electromagnetic interaction. Such treatment is not possible to use due to the fact that information interaction does not depend on distance while all known types of interaction do.

4. Properties of information interaction

Information interaction (mutual information) of subsystems A, B of arbitrary system $A+B$, being in the state ψ, possesses the following main properties.

The information interaction of subsystems A, B is scalar.

The magnitude of information interaction of subsystems A, B is symmetrical: $I_{AB} = I_{BA}$.

The magnitude of information interaction of subsystems A, B is not negative.

The magnitude of information interaction of subsystems A, B does not exceed the value of $I_{AB\max} = N_A = N_B$.

At changes of coordinates and orientation and also speed of q-bits, subsets of q-bits, subsystems, entangled states in general, the uncertainties of entangled states remain.

5. Decoherence of the entangled states, subsystems are reducing the magnitude of the information interaction

It should be noted that in general intensity of information interaction decreases with time. The course of it is explained by decoherence of entangled states determined by interaction with external environment. In this section the ideas of article [9] are used. «Decoherence consists in attenuation (disappearance) of off-diagonal elements of systems density matrix as a result of orthogonalization of environment states corresponding to various basis states of computer. Thus for quantum computers interaction of register with uncontrolled environment, ambiguities in parameters values of control pulses, as well as uncontrolled interaction of q-bits is the origin of decoherence state of quantum computer as a whole».

In general external environment is the source of decoherence of any entangled states, subsystems. In article [9] the estimate of decoherence speed is given which was received for the model of q-bits system at the environment of interacting oscillators.

Systems with coherent environment of the type of state like “Schrodinger cat”

$\left|0_1 0_2 ... 0_n\right\rangle \pm \left|1_1 1_2 ... 1_n\right\rangle$ are subject to maximal quick decoherence. At the same time there are states that are free from decoherence. Such are the states where for one half of q-bits the state is equal to $\left|0\right\rangle$, and for another half it is equal to $\left|1\right\rangle$.

As an example of such systems for even-numbered n there is a system of the type

$\left|0_1 0_2 ... 0_{n/2} 1_{n/2+1} 1_{n/2+2} ... 1_n\right\rangle \pm \left|1_1 1_2 ... 1_{n/2} 0_{n/2+1} 0_{n/2+2} ... 0_n\right\rangle$.

In particular the states of Bell $\left|0_1 1_2\right\rangle \pm \left|1_1 0_2\right\rangle$ are free from decoherence.

Note that the vectors $\left|0_1 0_2 ... 0_{n/2} 1_{n/2+1} 1_{n/2+2} ... 1_n\right\rangle$ and $\left|1_1 1_2 ... 1_{n/2} 0_{n/2+1} 0_{n/2+2} ... 0_n\right\rangle$, which present the states free from decoherence possess equal energy. In the same way the vectors $\left|0_1 1_2\right\rangle$ и $\left|1_1 0_2\right\rangle$, containing the states of Bell free from decoherence possess equal energy.”

Thus in a general case the decoherence leads to decreasing and after the expiry of some time to disappearance of information interaction.

6. Conclusions

The paper shows that, along with the gravitational, electromagnetic, strong, weak interactions exist the fifth type of fundamental interactions - information interaction, whose magnitude is not dependent on distance.

The existence of information interaction is determined by the entanglement of quantum states, of subsystems.

In general connection (the magnitude of interaction) between entangled subsystems A and B of quantum system $A + B$, as well as the connection between two q-bits can be characterized by mutual information.

The magnitude of information interaction is measured in bits.

In a general case the decoherence leads to decreasing and after the expiry of some time to disappearance of information interaction.

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INFORMATION MODEL OF A BLACK HOLE

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The information volume of a black hole of mass $M_{чд}$ is equal to $I_{чд} = \frac{2\pi \cdot G}{\hbar \cdot c} M_{чд}^2$ nats, or $I_{чд} = \frac{2\pi \cdot G}{\hbar \cdot c \cdot \ln 2} M_{чд}^2$ bits [1-3]. The information volume contained in a black hole is proportional to its squared mass. How to explain it? Let us assume that a black hole contains n pairwise interacting particles (q-bits). Then the quadratic dependence of the volume of information in a black hole on its mass can be explained by the fact that each interaction forms 1 bit of information. The black hole is described with the wave function $\psi_n = \frac{1}{\sqrt{2}}(|0_1\rangle|0_2\rangle...|0_n\rangle + |1_1\rangle|1_2\rangle...|1_n\rangle)$. As mentioned earlier the volume of information in the system described with the present given function is equal to $I_n = \frac{n \cdot (n+1)}{2}$ bit. At $n >> 1$ the volume of information in a black hole is proportional to the black hole squared mass $I_n \approx \frac{n^2}{2}$. A black hole consisting of n particles contains information, which is n bits larger than a black hole consisting of $n-1$ particles: $I_n - I_{n-1} = \frac{n(n+1)}{2} - \frac{(n-1) \cdot n}{2} = n$.

Let us compare the estimates of squared mass of a black hole: $M^2{}_{чд} = \frac{\hbar \cdot c \cdot \ln 2}{2\pi \cdot G} \cdot I_{чд}$ (from cosmological formula [3]) and $M_{чд}^2 = n^2 \cdot m_0^2$ (squared mass n of the particles composing a black hole). We have $M_{чд}^2 = n^2 \cdot m_0^2 = \frac{\hbar \cdot c \cdot \ln 2}{2\pi \cdot G} \cdot I_{чд}$. As far as $I_{чд} = \frac{n^2}{2}$, then $n^2 \cdot m_0^2 = \frac{\hbar \cdot c \cdot \ln 2}{2\pi \cdot G} \cdot \frac{n^2}{2}$, or

$m_0^2 = \frac{1}{4\pi} \cdot \frac{\hbar \cdot c \cdot \ln 2}{G}$. Eventually we obtain the estimate of mass of particles being part of the black holes: $m_0 = \frac{\sqrt{\ln 2}}{2\sqrt{\pi}} \sqrt{\frac{\hbar \cdot c}{G}}$, that agree by its magnitude with Planck mass $m_{Pl} = \sqrt{\frac{\hbar \cdot c}{G}} \approx 2{,}17 \cdot 10^{-5}$ g:

$$m_0 = \frac{\sqrt{\ln 2}}{2\sqrt{\pi}} m_{Pl} \approx 0{,}23 \sqrt{\frac{\hbar \cdot c}{G}} = 5{,}09 \cdot 10^{-6} g.$$

Therefore, a black hole is the aggregate of particles (let us call them black particles) each having a mass equal to 0.23th of Planck mass) and interacting with all other black particles that form a black hole [4-6].

Emission and absorption of usual substance by a black hole.

Suppose that at the initial instant of time a black hole consisting of n black particles has the mass of $M_n = n \cdot m_0$ and contains $I_n = \frac{n \cdot (n+1)}{2}$ bits of information. The black hole mass changes (increases or decreases) by black particles (quanta) $\Delta M = m_0$. As far as each black hole has the sub-Planck mass m_0, then the change in energy of a black hole in such a case is equal to $\Delta E = m_0 c^2$. In the event of the loss of emission of one black particle the mass of a black hole becomes equal to $M_n = (n-1) \cdot m_0$. In this case the volume of information remaining in the black hole is $I_{n-1} = \frac{(n-1) \cdot n}{2}$ bits. Change (loss) of information in a black hole comes to n bits.

For further estimates we implement the law of conservation of uncertainty (information) [1, 4-6] and energy conservation principle.

According to the law of conservation of uncertainty (information) a change in the system "a black hole with the mass $M_n = n \cdot m_0$ – external environment" on emission of one black particle must be balanced by the occurrence of n particles containing 1 bit each: $I_n - I_{n-1} = n$ bits. It can believed that n photons of frequency ν and energy $h\nu$ emerged.

In virtue of energy conservation principle $n \cdot h\nu = m_0 c^2$ and $\nu = \frac{m_0 c^2}{n \cdot h}$. Because $m_0 = \frac{\sqrt{\ln 2}}{2\sqrt{\pi}} \sqrt{\frac{\hbar \cdot c}{G}}$, then the frequency of emitted photon must be equal to $\nu = \frac{1}{n} \cdot \frac{\sqrt{\ln 2}}{2\sqrt{\pi}} \sqrt{\frac{c^5}{\hbar \cdot G}} = \frac{4{,}34 \cdot 10^{42}}{n}$ 1/sec. Because $t_{Pl} = \sqrt{\frac{\hbar \cdot G}{c^5}} \approx 5{,}41 \cdot 10^{-44}$ sec, then

$\nu = \frac{1}{n} \cdot \frac{\sqrt{\ln 2}}{2\sqrt{\pi} \cdot t_{Pl}}$. Let us denote $\nu_0 = \frac{\sqrt{\ln 2}}{2\sqrt{\pi}} \frac{1}{t_{Pl}} = \frac{\sqrt{\ln 2}}{2\sqrt{\pi}} \sqrt{\frac{c^5}{\hbar \cdot G}} \approx 0,43 \cdot 10^{43}$ 1/sec. Then $\nu = \frac{\nu_0}{n} \cdot$.

In the case of a black hole containing one black particle the radiation frequency is maximal and in inverse proportion to Planck time unit. Similar dependences are true for absorption of photons by black holes.

Note 1. In a general case, there must appear n photons having the frequency of ν_i and aggregated energy $h\sum_{i=1}^{n} \nu_i = m_0 c^2$ equal to n bits.

Note 2. In a general case, there must appear k particles with aggregated information equal to n bits and aggregated energy $m_0 c^2$.

Note 3. In a general case, there must be absorbed n photons having the frequencies ν_i and the aggregated energy $h\sum_{i=1}^{n} \nu_i = m_0 c^2$ equal to n bit.

Note 4. In the general case, there must be absorbed k particles with aggregated information equal to n bits and aggregated energy $m_0 c^2$.

Identical dependencies are true for cases when photons are absorbed by black holes. **By virtue of the law of conservation of uncertainty (information),** the changes in the system "a black hole with the mass $M_{n-1} = (n-1) \cdot m_0 -$ external environment", when the mass of a black hole is increased by the mass of one black particle, must be determined by absorption of n particles containing 1 bit each: $I_n - I_{n-1} = n$ bit. Suppose that there had been absorbed n photons of frequency ν and energy $h\nu$. **By virtue of energy conservation principle** $n \cdot h\nu = m_0 c^2$. The frequency of each absorbed photon must be equal to $\nu = \frac{m_0^2 c^2}{M \cdot h} = \frac{\ln 2}{8\pi^2} \frac{c^3}{M \cdot G} = \frac{0,69 \cdot 10^{42}}{n}$ 1/sec. At the formation of a black hole consisting one black particle the absorption frequency is maximal and inversely proportional to Planck time unit.

Having the estimates of black holes distribution by mass one can calculate the intensity of aggregated distribution of black holes radiation by frequencies and compare them with the experiment results. From the obtained radiation frequency expression one can draw the estimate of black hole radiation temperature (as indicated by A.D.Panov).

Let us calculate the temperature of the radiation of a black hole. The temperature of thermal radiation of the black body is related to the average energy of the radiation $h\nu = 2{,}7kT$ [127], or $T = \frac{h\nu}{2{,}7k}$. Because $\nu = \frac{m_0^2 c^2}{M \cdot h} = \frac{\ln 2}{8\pi^2} \frac{c^3}{M \cdot G}$, then $T = \frac{h\upsilon}{2{,}7k} = \frac{h}{2{,}7k} \frac{\ln 2}{8\pi^2} \frac{c^3}{M \cdot G} = \frac{\ln 2 \cdot \hbar \cdot c^3}{4\pi \cdot 2{,}7 \cdot k \cdot M \cdot G}$.

This estimate of depending the radiation temperature of the mass of the black hole can be called the information dependence of the radiation temperature of the mass of the black hole that matches up to a factor $\frac{2\ln 2}{2{,}7} \approx 0{,}51$ with the assessment of Hawking $T_H = \frac{\hbar \cdot c^3}{8\pi \cdot k \cdot G \cdot M}$ presented in [7].

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OPTIMAL BLACK HOLES

(Gurevich I.M. Optimal black holes are the cosmological objects, which minimize volume of information in areas of the Universe and in the Universe as a whole. <ArXiv.org.astro-ph. arXiv: 1008.0947>. 05/08/2010. 15p.http://arxiv.org/abs/1008.0947)

Abstract

Black hole is called optimal if information content is minimal at the Universe region, consisting of usual substance and one black hole. Optimal black hole mass does not depend on the mass of the Universe region. Optimal black holes can exist when at least two types of substance are available in the Universe: with non-linear and linear correspondence between information content and mass. Information content of optimal black hole is proportional to squared coefficient correlating information content with mass in usual substance and in inverse proportion to coefficient correlating information content with black hole mass. Concentration of mass in optimal black hole minimizes information content in the system “usual substance – black holes”. Minimal information content in the Universe consisting of optimal black holes is only twice as less as information content available of the Universe of the same mass filled with usual substance only. Under the radiation temperature $T \approx 1\text{E}+12$ K the mass of optimal black holes that emerged in the systems “radiation – black hole” is equal to the mass of optimal black holes that emerged in the systems ”hydrogen (protons) – black hole”.

Keywords: Universe, Universe region, information, mass, usual substance, black hole, optimal.

1. Introduction

By using informatics approach one can theoretically demonstrate the existence of black holes that minimize information content of arbitrary region of the Universe and place lower bound limitations on information content of the Universe. The origin and cause of optimal black holes existence is the occurrence of substance of two different types: with square-law and linear-law dependence of information content on mass. In the presence of substance of only one type, the optimal black holes do not exist. The ffollowing tasks are solved. The direct task: to discover information minimum in the system "usual substance-black hole" at the given mass of usual substance and a black hole. The dual task: to discover mass maximum in the system "usual substance-black a hole" at the given information in usual substance and a black hole.

The present work reviews optimal black hole characteristics in the systems "radiation (photons) – black holes", "hydrogen (protons) – black holes" and in the system "several types of usual substance – black holes".

2. Definition of optimal black holes

Let us estimate information content of the Universe region of mass $M_{Un\ rgn}$ under the arbitrary square-law relation between information and energy (mass) of the black hole $I_{bh} = \alpha \cdot M_{bh}^2$ and arbitrary linear-law relation between information and energy (mass) of usual substance $I_{us} = \beta \cdot M_{us}$ (under arbitrary non-negative coefficients α, β) [1-3]. Aggregated information content of the Universe region of the mass $M_{Un\ rgn}$, consisting of usual substance and one black hole is equal to

$$I_{Un\ rgn} = I_{bh} + I_{us} = \alpha \cdot M_{bh}^2 + \beta \cdot M_{us} =$$
$$= \alpha \cdot M_{bh}^2 + \beta \cdot (M_{Un\ rgn} - M_{bh}) .$$

Let us find a condition for the minimum [4-8]:

$$\frac{\partial I_{Un\ rgn}}{\partial M_{bh}} = \frac{\partial (I_{bh} + I_{us})}{\partial M_{bh}} = = \frac{\partial (\alpha \cdot M_{bh}^2 + \beta \cdot (M_{Un\ rgn} - M_{bh}))}{\partial M_{bh}} = 2\alpha \cdot M_{bh} - \beta = 0 .$$

Assertion 1. $M_{Opt\ bh} = \frac{\beta}{2\alpha}$ *is black hole mass, under which information content of the Universe region of the mass* $M_{Un\ rgn}$ *consisting of usual substance and one black hole is minimal.*

Let's call the black hole *optimal* under which information content is minimal at the Universe region of the mass $M_{Un\ rgn}$, consisting of usual substance and one black hole. Black hole mass does not depend on the mass of the Universe region. Optimal black hole mass is proportional to coefficient correlating information content with usual substance mass and in inverse proportion to coefficient correlating information content with black hole mass.

Note 1. Optimal black holes can exist when at least the two types of substance are available in the Universe: with non-linear (for instance, $I = \gamma \cdot M^{\delta}$ under $\gamma > 0, \delta > 1$) and linear correspondence between information content and mass.

Assertion 2. *Information content of optimal black hole is proportional to squared coefficient correlating information content with mass in usual substance and in inverse proportion to coefficient correlating information content with black hole mass:*

$$I_{Opt\ bh} = \frac{\beta^2}{4\alpha} \textit{ bits.}$$

Note 2. We will observe *a dual task* of definition of the maximum mass $M_{Un\ rgn}$ of the system «usual substance - a black hole» at the given information content $I_{Un\ rgn}$ of the Universe region. Let's size up mass $M_{Un\ rgn}$ in the Universe region containing the given information content $M_{Un\ rgn}$ at the arbitrary square link between the information and energy (mass) of black hole $I_{bh} = \alpha \cdot M_{bh}^2$ or $M_{bh}^2 = \frac{1}{\alpha} I_{bh}$ ($M_{bh} = \frac{1}{\sqrt{\alpha}} \sqrt{I_{bh}}$), and the arbitrary linear link between the information and energy (mass) of usual substance $I_{us} = \beta \cdot M_{us}$ or $M_{us} = \frac{1}{\beta} I_{us}$ (at the arbitrary nonnegative coefficients α, β). The information of the Universe region consisting of usual substance and one black hole is equal to $I_{Un\ rgn} = I_{bh} + I_{us}$. The mass $M_{Un\ rgn}$ of the Universe region consisting of usual substance and one black hole, is equal to

$$M_{Un\ rgn} = M_{bh} + M_{us} = \frac{1}{\sqrt{\alpha}} \sqrt{I_{bh}} + \frac{1}{\beta} I_{us} = = \frac{1}{\sqrt{\alpha}} \sqrt{I_{bh}} + \frac{1}{\beta} (I_{Un\ rgn} - I_{bh}) .$$

We will discover an optimality requirement:

$$\frac{\partial M_{Un\ rgn}}{\partial I_{bh}} = \frac{\partial (M_{bh} + M_{us})}{\partial I_{bh}} =$$

$$= \frac{\partial (\frac{1}{\sqrt{\alpha}} \sqrt{I_{bh}} + \frac{1}{\beta} \cdot (I_{Un\ rgn} - I_{bh}))}{\partial I_{bh}} = \frac{1}{\sqrt{\alpha}} \cdot \frac{1}{2\sqrt{I_{bh}}} - \frac{1}{\beta} = 0 .$$

As $\frac{\partial^2 M_{Un\ rgn}}{\partial I_{bh}^2} = -\frac{1}{\sqrt{\alpha}} \cdot \frac{1}{4 I_{bh}^{3/2}} < 0$ the given requirement is a maximum requirement.

Further we have: $\frac{1}{\sqrt{\alpha}} \cdot \frac{1}{2\sqrt{I_{bh}}} = \frac{1}{\beta}$, $\frac{\beta}{2\sqrt{\alpha}} = \sqrt{I_{bh}}$ and information content in a black hole of optimum mass is equal $I_{bh} = \frac{\beta^2}{4\alpha}$. The mass of a black hole at which the mass $M_{Un\ rgn}$ of the Universe region maximum at the given information content of the Universe region $I_{Un\ rgn}$, is equal to

$$M_{Opt\ bh} = \frac{1}{\sqrt{\alpha}} \sqrt{I_{bh}} = \frac{1}{\sqrt{\alpha}} \sqrt{\frac{\beta^2}{4\alpha}} = \frac{\beta}{2\alpha} .$$

Assertion 1.a. *The Information content in a black hole at which the mass of the Universe region* $M_{Un\ rgn}$ *consisting of usual substance and one black hole and containing the given information content* $I_{Un\ rgn}$*, is proportional to a square of coefficient linking information content with mass in usual substance and inversely proportional to coefficient linking an information content with mass in a black hole:*

$$I_{Opt\ bh} = \frac{\beta^2}{4\alpha} \text{ bits.}$$

Assertion 2.a. *The mass of a black hole at which the mass of the field of the Universe* $M_{Un\ rgn}$ *containing the given information content* $I_{Un\ rgn}$ *is maximum,* consisting of usual substance and one black hole, is equal $M_{Opt\ bh} = \frac{\beta}{2\alpha}$.

Information contents and the masses gained at the solution of direct task (a minimization of information content in the system «usual substance - a black hole» at the given mass of system - assertions 1, 2) and a dual task (a maximization of mass of system «usual substance - a black hole» at the given information content) assertions 1.a, 2.a), coincide. Thereby the concept of an optimum black hole is identical and all subsequent assertions and relationships are also identical.

As far as the black hole mass under which information content is minimal at the Universe region consisting of black hole and common substance does not depend either on aggregated mass of the Universe (the Universe), or on usual substance mass in the region under study, then the minimal information content of the Universe region (the Universe) can be reached if the Universe region (the Universe) consists of optimal black holes only. The maximum number of optimal black holes of the Universe region (the Universe) is equal to

$$N_{Opt\ Un\ rgn} = \frac{M_{Un\ rgn}}{M_{Opt\ bh}} = M_{Un\ rgn}\frac{2\alpha}{\beta} \quad N_{Opt\ bh\ Un} = \frac{M_{Un}}{M_{Opt\ bh}} = M_{Un}\frac{2\alpha}{\beta}).$$

The minimal information level of the Universe region (the Universe) consisting of black holes only is equal to

$$I_{Un\ bh} = N_{Opt\ bh} \cdot I_{Opt\ bh} =$$

$$= M_{Un} \cdot \frac{2\alpha}{\beta}\frac{\beta^2}{4\alpha} = \frac{M_{Un} \cdot \beta}{2}.$$

Note 3. Hereafter for brevity sake we’ll speak about the Universe, though the assertions and expressions are also true for arbitrary regions of the Universe.

Assertion 3. *Minimal information content of the Universe consisting of optimal black holes only is twice as less as information content available of the Universe of the same mass filled with usual substance only:*

$$I_{Un\,bh} = \frac{M_{Un} \cdot \beta}{2} \ \textit{bits.}$$

Assertions 1-3 are true for any kind of linear dependence of information volume on usual substance mass. The important agents of usual substance are radiation and hydrogen. Let’s consider next the optimal black holes characteristics in the systems “radiation (photons) – black holes”, “hydrogen (protons) – black holes”, “several types of usual substance – black holes”.

3. The Universe filled with radiation

Let's consider the Universe filled with usual substance (radiation). The energy required for transfer, retrieval, record of one bit under the temperature *T* can not be less than the value $E_{min} = kT\ ln2$ [9-10]. In accordance with the Einstein equation, the mass required for transfer, retrieval, record of one bit under the temperature *T can* not be less than the value $M_{min}= (kT\ ln2)/c^2$. It is easily seen that for record of *1* bit under *T = 1* K the mass no less than $M_{bit} = E_{bit}/c^2 \approx 10^{-23}\ joule/(9 \cdot 10^{16}\ m^2/s^2) = 10^{-40}\ kg$ is needed.

As far as $\alpha = \frac{2\pi \cdot G}{\hbar \cdot c \cdot \ln 2}$, and for radiation $\beta = \frac{c^2}{k \cdot T \cdot \ln 2}$, then $M_{Opt\ bh} = \frac{\beta}{2\alpha} = \frac{\hbar \cdot c^3}{4\pi \cdot G \cdot k \cdot T}$ and information content of optimal black hole formed in the system "black hole + radiation" is equal to $I_{Opt\ bh} = \frac{\beta^2}{4\alpha} = \frac{\hbar \cdot c^5}{8\pi \cdot G \cdot k^2 \cdot T^2 \cdot \ln 2}$ bit. Let's express the obtained result as the following assertion.

Assertion 4. *Concentration of mass* $M = \frac{\hbar \cdot c^3}{4\pi \cdot G \cdot k \cdot T}$ *of optimal black hole minimizes information content in the system "photons — black holes".*

We note that the mass of optimal black hole that emerged in the system "radiation – black hole" is in inverse proportion to radiation temperature.

The total number of optimal black holes $N_{Opt\ bh}$, in the Universe of mass M_{Un} consisting of radiation and black holes is equal to

$$N_{Opt\ bh} = M_{Un} \frac{2\alpha}{\beta} = M_{Un} \frac{4\pi \cdot G \cdot k \cdot T}{\hbar \cdot c^3}.$$

Assertion 5. *The minimal possible information content of the Universe of mass* M_{Un} *consisting of radiation and black holes is equal* $M_{Un} \frac{c^2}{2 \cdot k \cdot T \cdot \ln 2}$ *to*

$I_{Un\min} = I_{Opt\ bh} \cdot N_{Opt\ bh} = \frac{M_{Un} \cdot \beta}{2} =$ *bits.*

Thus, the minimal possible information content of the Universe mass M_{Un} consisting of radiation and black holes is proportional to the mass of the Universe, the speed of light squared, inversely proportional to Boltsman constant and temperature of the Universe.

Assertion 6. *The Universe of mass* M_{Un}, *consisting of radiation and black holes, containing* $N_{Opt\ bh} = M_{Un} \frac{4\pi \cdot G \cdot k \cdot T}{\hbar \cdot c^3}$ *black holes of mass* $M_{Opt\ bh} = \frac{\hbar \cdot c^3}{4\pi \cdot G \cdot k \cdot T}$, *while each of the black holes of the given mass contains the minimal possible information content equal to*

$$I_{Un\min} = M_{Un} \frac{c^2}{2 \cdot k \cdot T \cdot \ln 2} \text{ bits.}$$

The minimal possible information content of the Universe of mass M_{Un}, consisting of radiation and black holes is proportional to the energy of the

Universe, inversely proportional to Boltsman constant and temperature of the Universe. It is notable that the minimal information content in the Universe does not depend either on gravitation constant or Plank constant

$$M_{Opt\ bh} = \frac{\hbar \cdot \tilde{n}^3}{4\pi \cdot G \cdot k \cdot T} = 9,09 \cdot 10^{25}\ \text{g} = 9,09 \cdot 10^{22}\ \text{kg}.$$

The mass of black hole under which information minimum is gained in the Universe of mass M_{Un} consisting of radiation and black holes does not depend on the gross mass of the Universe and is equal to $9,09 \cdot 10^{22}$ kg. It is approximately one seventieth of the Earth mass which is equal to $6 \cdot 10^{24}$ kg. Information content of optimal black hole is equal to $I_{Opt\ bh} \approx 1{,}26 \cdot 10^{62}$ bits. Our Universe can contain about 10^{29} black holes. The minimal information content in our Universe of the mass equal to $\approx 10^{52}$ kg, consisting of 10^{29} optimal black holes, and only of these, is equal to

$$I_{Un\ \min} = N_{Opt\ bh} \cdot I_{Opt\ bh} = \frac{c^2}{2 \cdot k \cdot T \cdot \ln 2} \approx 1{,}56 \cdot 10^{91}\ \text{bits}.$$

At $T \approx 2,7^0 10^n K$ the mass of an optimum black hole is approximately equal to $9,09 \cdot 10^{22\text{-}n}$ kg, the information volume in an optimum black hole is approximately equal to 10^{62-n} bits. So at $T \approx 2,7^0 \cdot 10^{10} K$ (the nucleosynthesis beginning) mass of an optimum black hole is approximately equal to 10^{13} kg, the information volume in an optimum black hole is approximately equal to 10^{52} bits.

Assertion 7. *Information content of the Universe of mass* $M_{Un} = 10^{52}$ *kg consisting of radiation and black holes ranges within* $10^{91} \le I_{Un\ M} \le 10^{120}$ *bits.*

Assertion 8. *Information content available in the Universe of mass* M_{Un},consisting of radiation and black holes ranges within

$$M_{Un} \frac{c^2}{2 \cdot k \cdot T \cdot \ln 2} \le I_{Un} \le M_{Un}^2 \frac{2\pi \cdot G}{\hbar \cdot c \cdot \ln 2}.$$

4. The Universe filled with hydrogen (protons)

Let us consider the Universe filled with usual substance (hydrogen). The wave function of proton with upward-directed spin [11]

$$\varphi\left(P, s_Z = \frac{1}{2}\right) = \frac{1}{\sqrt{18}}(2|p\uparrow\rangle|n\downarrow\rangle|p\uparrow\rangle + 2|p\uparrow\rangle|p\uparrow\rangle|n\downarrow\rangle + 2|n\downarrow\rangle|p\uparrow\rangle|p\uparrow\rangle -$$
$$-|p\uparrow\rangle|p\downarrow\rangle|n\uparrow\rangle - |p\uparrow\rangle|n\uparrow\rangle|p\downarrow\rangle - |p\downarrow\rangle|n\uparrow\rangle|p\uparrow\rangle - |n\uparrow\rangle|p\downarrow\rangle|p\uparrow\rangle - |n\uparrow\rangle|p\uparrow\rangle|p\downarrow\rangle - |p\downarrow\rangle|p\uparrow\rangle|n\uparrow\rangle)$$

Uncertainty (information content) of proton structure is equal to 2,837 bits. Having in mind the uncertainty of spin orientation it is necessary to add 1 bit - 3,837 bits. Information content in quarks (1 bit in each) – 3 bit. Colour information content - 2,585 bit. The total uncertainty (information content) of proton contained in the proton structure, qurks and colour and equal to 9,422 bit. Hydrogen atom in the ground state ($|IV\rangle = \frac{|+-\rangle + |-+\rangle}{2}$ [12]) contains 11,422 bits (1 bit in atomic structure, 9,422 bits in proton and 1 bit in electron).

As far as $\alpha = \frac{2\pi \cdot G}{\hbar \cdot c \cdot \ln 2}$, and for hydrogen atoms $\beta = \frac{11{,}422}{m_{\hat{a}}} \approx \frac{11{,}422}{m_p}$, then

$M_{Opt\ bh} = \frac{\beta}{2\alpha} = \frac{11{,}422 \cdot \ln 2 \cdot \hbar \cdot c}{4\pi \cdot m_p \cdot G}$ and information content of optimal black hole formed in the system “black hole + hydrogen” is equal to

$$I_{Opt\ bh} = \frac{\beta^2}{4\alpha} = \frac{(11{,}422)^2 \cdot \hbar \cdot c \cdot \ln 2}{8\pi \cdot m_p^2 \cdot G} \text{ bits.}$$

Let us define the obtained result as the following assertion.

Assertion 9. *Concentration of mass* $M_{Opt\ bh} = \frac{11{,}422 \cdot \ln 2 \cdot \hbar \cdot c}{4\pi \cdot m_p \cdot G}$ *in the optimal black hole minimizes information content in the system “hydrogen – black holes”.*

The total number of optimal black holes $N_{Opt\ bh}$, in the Universe of mass M_{Un} consisting of hydrogen atoms and blck holes is equal to

$$N_{Opt\ bh} = M_{Un} \frac{2\alpha}{\beta} = \frac{4\pi \cdot M_{\hat{A}\tilde{n}} \cdot m_p \cdot G}{11{,}422 \cdot \ln 2 \cdot \hbar \cdot c}.$$

Assertion 10. *The minimal possible information content of the Universe of mass* M_{Un}*, consisting of hydrogen atoms and black holes is equal to*

$$I_{Un\ \min} = I_{Opt\ bh} \cdot N_{Opt\ bh} = \frac{M_{Un} \cdot \beta}{2}\ M_{Un} \frac{11{,}422}{2 \cdot m_p} = 5{,}7 \frac{M_{Un}}{m_p} \textit{ bits.}$$

Thus, the minimal possible information content of the Universe, of the Universe of mass M_{Un} consisting of hydrogen atoms and black holes is proportional to the Universe mass and inversely proportional to two masses of hydrogen atom (proton).

Assertion 11. *The Universe of mass* M_{Un}*, consisting of hydrogen atoms and black holes, containing* $N_{Opt\ bh} = M_{Un} \frac{4\pi \cdot M_{Un} \cdot m_p \cdot G}{11{,}422 \cdot \ln 2 \cdot \hbar \cdot c}$ *black holes of mass* $M_{Opt\ bh} = \frac{11{,}422 \cdot \ln 2 \cdot \hbar \cdot c}{4\pi \cdot m_p \cdot G}$ *and each of the black holes of the given mass contains the minimal possible information content equal to*

$$I_{Un\min} = 5,7\frac{M_{Un}}{m_p} \text{ bits.}$$

The minimal possible information content of the Universe of mass M_{Un}, consisting of hydrogen atoms and black holes is proportional to the mass of the Universe, inversely proportional to hydrogen mass (proton). It is important to note that the minimal information content of the Universe consisting of hydrogen atoms and black holes does not depend on gravity constant, the speed of light and Plank constant.
Let us evaluate the mass of optimal black hole

$$M_{Opt\,bh} = \frac{11{,}422 \cdot \ln 2 \cdot \hbar \cdot c}{4\pi \cdot m_p \cdot G} = 1,78 \cdot 10^{14} g = 1,78 \cdot 10^{11} \text{kg.}$$

Black hole mass, under which the minimum information is gained in the Universe, the Universe of mass M_{Un} consisting of hydrogen atoms and black holes, does not depend on the gross mass of the Universe and is equal to

$1,78 \cdot 10^{11}$ kg. This is about the boundary mass of primary black hole equal to

$\approx 10^{12}$ kg. Information content of optimal black hole is equal to

$$I_{Opt\,bh} = \frac{\beta^2}{4\alpha} = \frac{(11{,}422)^2 \cdot \hbar \cdot c \cdot \ln 2}{8\pi \cdot m_p^2 \cdot G} = 3,76 \cdot 10^{38} \text{ bits.}$$

There can be about 10^{41} optimal black holes in our Universe. The minimal information content of the Universe whose mass is equal to the mass of our Universe $\approx 10^{52}$ kg, consisting of 10^{41} optimal black holes and only of these, is equal to

$$I_{Un\min} = 5,7\frac{M_{Un}}{m_p} \approx 3,31 \cdot 10^{79} \text{ bits.}$$

Assertion 12. *Information content of the Universe of mass of* $M_{Un} = 10^{52}$ *kg, consisting of hydrogen atoms and black holes lies in the range of* $10^{79} \le I_{Un\,M} \le 10^{120}$ *bits.*

Assertion 13. *Information content of the Universe of mass* M_{Un}*, consisting of hydrogen atoms and black holes lies in the range of*

$$5,7\frac{M_{Un}}{m_p} \le I_{Un} \le M_{Un}^2 \cdot \frac{2\pi \cdot G}{\hbar \cdot c \cdot \ln 2} \textit{ bits.}$$

5. Maximum information content of the Universe

The maximum possible information content available in the Universe if the latter looks like one black hole of mass M_{Un} [13]: $I_{Un\max} = \beta \cdot M_{Un} = \frac{2\pi \cdot G}{\hbar \cdot c \cdot \ln 2} M_{Un}^2$ bits. The maximum information content of the Universe is proportional to squared mass of the Universe, gravity constant, inversely proportional to Plank constant, the speed of light and does not depend on Boltsman constant and the temperature of the Universe. The maximum information content of the Universe represented by one black hole whose mass is equal to mass of our Universe ($\approx 10^{52}$ kg), is equal to $I_{Un\max} \approx 10^{120}$ bits.

6. Comparison of characteristics of optimal black holes in the systems "radiation (photons) – black holes", "hydrogen (protons) – black holes"

Let us compare characteristics of optimal black holes in the systems "radiation (photons) – black holes", "hydrogen – black holes".

The following table presents information about the characteristics of optimal black holes in the systems "black holes – radiation", "black holes – hydrogen".

Characteristic	**System "radiation (photons) – black holes"**	**System "hydrogen (protons) – black holes"**	**Note**
Factor of proportionality "information – squared mass" for black holes	$\alpha = \frac{2\pi G}{\hbar c \ln 2}$	$\alpha = \frac{2\pi G}{\hbar c \ln 2}$	
Factor of proportionality "information–mass" for usual substance	$\beta = \frac{c^2}{kT \ln 2}$	$\beta = \frac{11{,}422}{m_h} \approx \frac{11{,}422}{m_p}$	
Expression for optimal black hole mass	$M_{Opt\,bh} = \frac{\hbar c^3}{4\pi GkT}$	$M_{Opt\,bh} = \frac{11{,}422\ \ln 2\hbar c}{4\pi m_p G}$	In the system "radiation – black hole", the optimal black hole mass is inversely proportional to radiation temperature.
Estimtion of optimal black hole mass	$9{,}09 \cdot 10^{22}$ kg	$1{,}78 \cdot 10^{11}$ kg	In the system "hydrogen – black hole" the optional black hole mass is $\approx 10^{12}$ times less

			than the optimal black hole mass in the system "radiation – black hole".
Expression for estimation of information content of optimal black hole	$I_{Opt\,bh} = \frac{\hbar c^5}{8\pi G k^2 T^2 \ln 2}$	$I_{Opt\,bh} = \frac{(11{,}422)^2 \hbar c \ln 2}{8\pi m_p^2 G}$	
Estimation of information content of optimal black hole	$I_{Opt\,bh} \approx 1{,}26 \cdot 10^{62}$ bits	$I_{Opt\,bh} \approx 3{,}76 \cdot 10^{38}$ bits	In the system "hydrogen – black hole", information content of the optimal black hole is $\approx 10^{24}$ times less than information volume of the optimal black hole in the system "radiation – black hole".
Expression for estimation of the number of optimal black holes in the system with given mass	$N_{Opt\,bh} = \frac{4\pi M_{Un} GkT}{\hbar c^3}$	$N_{Opt\,bh} = \frac{4\pi M_{Bc} m_p G}{11{,}422\ \ln 2\hbar c}$	
Estimation of the number of optimal black holes in the Universe	$N_{Opt\,bh} \approx 1{,}1 \cdot 10^{29}$	$N_{Opt\,bh} \approx 10^{41}$	The number of optimal black holes in the Universe that emerged in the systems "hydrogen – black hole" is $\approx 10^{12}$ times larger than the number of optimal black holes that emerged in the systems "radiation – black hole".
Expression for estimation of the minimum information content in the system with given mass	$M_{Un} \cdot \frac{c^2}{2 \cdot k \cdot T \cdot \ln 2}$	$5{,}7 \frac{M_{Un}}{m_p}$	
Estimation of the minimum information content of the	$I_{Un\,\min} \approx 1{,}7 \cdot 10^{91}$	$I_{Un\,\min} \approx 3{,}31 \cdot 10^{79}$	The minimum information content of the Universe consisting of black

Universe			holes that emerged in the systems “hydrogen – black hole” is $\approx 10^{12}$ times less than the minimum information content of the Universe consisting of black holes that emerged in the systems “radiation – black hole”.
Expression for estimation of the maximum information content in the system with a given mass	$M_{Un}^2 \frac{2\pi G}{\hbar c \ln 2}$	$M_{Un}^2 \frac{2\pi G}{\hbar c \ln 2}$	
Estimation of the maximum information content of the Universe	$I_{Un\max} \approx 1,9 \cdot 10^{120}$	$I_{Un\max} \approx 1,9 \cdot 10^{120}$	

Note 4. Under the *radiation* temperature $T = m_p \frac{c^2}{k \cdot \ln 2 \cdot 9{,}422} = 1{,}555 \cdot E + 12$ K the mass of optimal black holes that emerged in the systems “radiation – black hole” is equal to the mass of optimal black holes that emerged in the systems ”hydrogen (protons) – black hole”. By virtue of the fact that stable hydrogen atoms do not exist under high temperatures, then in such case calculations have been done with respect to protons.

Note 5. In the period of *transition* from the Universe with predominant radiation to the Universe with predominant substance [14] (10^4>T >10^3), the mass of optimal black hole in the system “radiation – black hole” changes from 2,45E+19kg to 2,45E+20kg.

7. The systems consisting of black holes and several types of usual substance

Let us consider systems consisting of black holes and several types of usual substance, for instance, of various kinds of particles.

From informatics point of view, various types of usual substance differ in coefficient β_i standing for the use of mass per 1 bit of information $I_i = \beta_i M$.

β_i - denotes information content of the given type of usual substance.

Assertion 14. *The mass of optimal black hole in the system “sereval type of usual substnce – black holes” under which information content of the system under consideration is getting minimized, is defined by the minimal factor of* *proportionality* $\beta_{i0} = \min_i \beta_i$ *. The optimal black hole corresponds to the system "usual substance of type* $i0$ *- black holes".*

Assertion 15. *The mass of black hole under which information content is minimal, meaning information under which information content is minimal in the system "several type of usual substance –black holes", is equal to*

$$M_{Opt\ bh} = \frac{\beta_{i0}}{2\alpha}.$$

Assertion 16. *Information content of optimal black hole in the system "several types of usual substance- black holes" is proportional to squared minimal coefficient correlating information content with mass in different types of usual substance and inversely proportional to coefficient correlating information content with mass in a black hole:*

$$I_{Opt\ bh} = \frac{\beta_{i0}^2}{4\alpha} \text{ bits.}$$

As the black hole mass under which information content is minimal in *the system "several types of usual substance – black holes"*, does not depend on either the total mass of the system M, or on the mass of usual substance, then the minimum information content of the Universe is gained if the system consists ofoptimal black holes only. The maximum number of optimal black holes in *the system "several types of usual substance – black holes"*

$$N_{Opt\ bh} = \frac{M}{M_{Opt\ bh}} = M \frac{2\alpha}{\beta_{i0}}.$$

The minimum information content in *the system "several types of usual substance – black holes"*, consisting of black holes only is equal to

$$I_M = N_{Opt\ bh} \cdot I_{opt\ bh} = M \cdot \frac{2\alpha}{\beta} \frac{\beta^2}{4\alpha} = \frac{M \cdot \beta_{i0}}{2}.$$

Assertion 17. If optimum *black* holes are formed of various types of atoms of usual substance or a mix of various types of atoms of usual substance masses of optimum black holes and volumes of the information in them are approximately identical.

8. **Conclusion**

8.1. The occurrence of substance of two types: with square-law and linear-law dependence of information content on mass - is the origin and cause of optimal black holes existence that minimize information content in the arbitrary region of the Universe as well as of the Universe as a whole.

8.2. Optimal black hole mass is proportional to coefficient correlating information content with black hole mass. Optimal black hole mass does not depend on the mass of the region of the Universe where it is formed.

8.3. The present work considers characteristics of optimal black holes in the systems “radiation (photons) – black holes”, “hydrogen (protons – black holes” and in the systems “several types of usual substance – black holes".
8.4. Because the black hole mass under which information content is minimal at the Universe region consisting of black hole and usual substance, does not depend either on the gross mass of the Universe region (Universe), or on the mass of usual substance in the region under study, then the minimum information content in the Universe region (Universe) is gained if the Universe region (Universe) consists of optimal black holes only.
8.5. Black hole mass under which the minimum information content is gained at the Universe of mass M_{Un} consisting of radiation and black holes, does not depend on the gross mass of the Universe and is equal to $9{,}09 \cdot 10^{22}$ kg. It is approximately one seventieth of the Earth mass. Information content of optimal black hole is equal to $\approx 1{,}26 \cdot 10^{62}$ bits. Our Universe can contain about 10^{29} of such optimal black holes. The minimum information content of the Universe is equal to $\approx 10^{91}$ bits.
8.6. Black hole mass under which minimum information content is gained in the Universe consisting of hydrogen atoms and black holes, does not depend on the gross mass of the Universe and is equal to $1{,}78 \cdot 10^{11}$ kg. Information content of optimal black hole is equal to $3{,}76 \cdot 10^{38}$ bits. Minimum information content of the Universe whose mass is equal to the mass of our Universe that is $\approx 10^{52}$ kg, consisting of approximately 10^{41} optimal black holes and only of these, is equal to $\approx 10^{79}$ bits.
Optimal black hole mass in the systems “several types of usual substance – black holes” under which information content in the system under consideration is minimized, is determined by the type of usual substance with minimal factor of proportionality $\beta_{i0} = \min_i \beta_i$. If optimum black holes are formed of various types of atoms of usual substance or a mix of various types of atoms of usual substance masses of optimum black holes and volumes of information in them are approximately identical.
8.7. The maximum possible information content is available at the Universe if the latter appears to be one black hole. In this case it is equal to $\approx 10^{120}$ bits.

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BLACK HOLES MERGER

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Gurevich I.M. Informational constraints on the formation and merger of black holes. /In Russian/. All-Russian Astronomical Conference (WAC-2010). "From the age of Galileo to the present day." Special Astrophysical Observatory of RAS. Lower Arkhyz.)

Abstract: Physical informatics is information background of physics. Estimation of the volume of information in cosmological objects, including stars of the Sun type, neutron stars, white dwarfs, black holes is necessary for generation of restrictions for their formation, development and interconversion. Information is an integral part of the Universe. The basic law of Zeilinger's quantum mechanics postulates that the elementary physical system (in particular, fundamental particles: quark, electron, photon) bears one bit of information. By its physical essence information is heterogeneity of matter and energy. Therefore information is inseparably connected with matter and energy. The universal measure of physical heterogeneity of information is the Shannon information entropy. An information approach along with a physical one allows to obtain new, sometimes more general data in relation to data obtained on the ground of physical rules only. The author's works testify about the practicality of information laws usage simultaneously with physical rules for cognition of the Universe. The results presented in this paper show the effectiveness of informational approach for studying the cosmological objects. In future the proposed models and estimations should undoubtedly be specified and presented in more detailed way. One should point out that informational approach allows formulating restrictions on the valuations of physical systems characteristics and physical processes while the physical methods and models can describe not only the restrictions but also concrete physical "mechanisms" of restriction formation, concrete valuations of physical systems characteristics.

Keywords: Cosmological objects, Sun, neutron stars, white dwarfs, black holes, information, heterogeneity, objective reality, restrictions, the Universe.

1. Introduction

Estimation of the volume of information in cosmological objects, including stars of the Sun type, neutron stars, white dwarfs, black holes is necessary for generation of restrictions for their formation, development and interconversion. Information is an integral part of the Universe. The basic law of Zeilinger's quantum mechanics [Zeilinger, 1999] postulates that the elementary physical system (in particular, fundamental particles: quark, electron, photon) bears one bit of information. By its physical essence information is heterogeneity of matter and energy. Therefore information is inseparably connected with matter and energy.

At the end of 2010 I have read Ursul's book «Nature of information» (2-nd issue) [Ursul, 2010], which he wrote in 1968 [Ursul, 1968]. He asserted that «Information theory methods will study properties of space and time, than basically physical theories till now were engaged. So, the physicist and information theory interpenetrate each other, that in general carries on to making of two main synthetic disciplines - special applied information theory and the informational physics» [Ursul, 2010], p. 92-93. This science is called now "physical informatics".

The universal measure of physical heterogeneity of information is Shannon information entropy [Shannon, 1948], [Stratonovich, 1975]. It is important to remark that Neumann entropy cannot be applied as the universal measure of heterogeneity because it is equal to zero for structured pure state. An information approach along with a physical one allows to obtain new, sometimes more general data in relation to data obtained on the ground of physical rules only. The author's works, for instance the [Gurevich, 1989, 2007/1-4, 2009] testify about the practicality of information laws usage simultaneously with physical rules for cognition of the Universe. The estimates cited below are based on the foundational law of Zeilinger quantum mechanics i.e. "an elementary system carries one bit of information" and prove it. Elementary systems are fundamental particles (quarks, leptons, photons). Let us evaluate the volume of information in the system of n q-bits. At first we consider the systems with equiprobable basic states.

Let us consider a system consisting of two black holes. Suppose that the black holes have the mass of $M_1 = n_1 m_0$, $M_2 = n_2 m_0$ (m_0 - the minimal black hole mass, $n_1, n_2 = 1,2,...$) and contain the volume of information equal to $I_1 = \frac{n_1(n_1+1)}{2}$ and $I_2 = \frac{n_2(n_2+1)}{2}$. The mass of the system is equal to $M_{1+2} = (n_1 + n_2)m_0$, the volume of information in the system is $I_{1+2} = \frac{n_1(n_1+1)}{2} + \frac{n_2(n_2+1)}{2}$. Is it possible that a black hole is formed as a result of two given black holes merger and only two given black holes? The mass of a new black hole must be equal to the sum of the masses of the original black holes $M = M_{1+2} = (n_1 + n_2)m_0$. The volume of information in the new black hole must be equal to $I = \frac{(n_1+n_2)(n_1+n_2+1)}{2}$. It is obvious that under no masses of original black holes the volume of information in the newly formed black hole would coincide with the total volume of information in the original black holes $I = \frac{(n_1+n_2)(n_1+n_2+1)}{2} = \frac{n_1^2+n_1n_2+n_1+n_1n_2+n_2^2+n_2}{2} \neq$

$$\neq \frac{n_1^2+n_1+n_2^2+n_2}{2} = \frac{n_1(n_1+1)}{2} + \frac{n_2(n_2+1)}{2} = I_1 + I_2 .$$

Let us consider the following example. Suppose that the mass of the black holes is $M_1 = M_2 = m_0$ and they contain the volume of information equal to $I_1 = I_2 = 1$. The mass of the system is $M_{1+2} = 2m_0$, the volume of information in the system is $I_{1+2} = 1+1 = 2$.

Is it possible that a black hole is formed as a result of merging of two black holes of the minimal mass and only two given black holes of the minimal mass? The mass of a new black hole must be equal to the sum of masses of the original black holes $M = M_{1+2} = 2m_0$. The volume of information in a new black hole must be equal to $I = \frac{(1+1)(1+1+1)}{2} = 3$. Apparently the volume of information in a new black hole does not coincide with the aggregated volume of information in the original black holes.

We give a system of equations for estimation of the mass of a black hole under formation when two black holes are merged.

Let us suppose that black holes before merging possess the mass of $M_1 = n_1m_0$, $M_2 = n_2m_0$ (m_0=5,09E-09kg - is the minimum mass of the black hole n_1,n_2=1,2,...) and contains the volume of information equal to $I_1 = \frac{n_1(n_1+1)}{2}$ and $I_2 = \frac{n_2(n_2+1)}{2}$. As a result of the original black holes a black hole and usual substance are created. The mass of the black hole after the merger is equal to $M_{1+2} = nm_0$, the mass of information in the newly formed black hole is equal to $I_{1+2} = \frac{n(n+1)}{2}$. A number of particles of usual substance that have been formed after the merger is equal to x. The volume of information in the usual substance is equal to $I_{ов} = x$. The average mass of a particle of usual substance is equal to m.

From the law of conservation of uncertainty (information) it follows:

$$I_1 + I_2 = \frac{n_1(n_1+1)}{2} + \frac{n_2(n_2+1)}{2} = \frac{n(n+1)}{2} + x = I_{1+2} + I_{ов} .$$

We believe that the main energy of black holes and usual substance is concentrated in the mass. Then from the energy conservation law it follows: $M_1 + M_2 = (n_1+n_2)m_0 = nm_0 + xm$. Thus we have a two-equations system

$\frac{n_1(n_1+1)}{2}+\frac{n_2(n_2+1)}{2}=\frac{n(n+1)}{2}+x$, $(n_1+n_2)m_0=nm_0+xm$, with three unknowns n, x, m. $x\geq 0$.

Hence, $\frac{n_1(n_1+1)}{2}+\frac{n_2(n_2+1)}{2}\geq\frac{n(n+1)}{2}$, or at $n>>1$ $n^2\leq n_1^2+n_2^2$ (restriction on the mass of the black hole after merging).

Next we have $n_1^2+n_1+n_2^2+n_2-n^2-n=2x$, $(n_1+n_2)m_0=nm_0+xm$.

And $x=\frac{n_1^2+n_1+n_2^2+n_2-n^2-n}{2}$, $m=\frac{(n_1+n_2-n)m_0}{x}=\frac{2(n_1+n_2-n)}{n_1^2+n_1+n_2^2+n_2-n^2-n}m_0$. At $n>>1$

$m\approx\frac{2m_0}{n}$.

The following assertions are valid.

Assertion 1.

A black hole cannot *be created by means of merging two black holes and only two black holes. Merging of black holes can occur only with the absorption and emission of usual substance.*

Assertion 2.

A black hole cannot be created by means of merging k black holes and only k black holes. Merging of black holes can occur only with extra absorption and emission of usual substance.

Assertion 3.

A black hole can reduce its mass through emission of usual substance and only it into space. A black hole can increase its mass through absorption of usual substance and only it from space. During two black holes merger one of them should emit usual substance into space while another one should absorb usual substance from space.

Assertion 4.

During the merger of two black holes having the masses $M_1=n_1m_0$, $M_2=n_2m_0$, *without using any additional usual substance, the mass of a newly formed black hole is less than* $M_{1+2}=\sqrt{n_1(n_1+1)+n_2(n_2+1)}m_0\approx\sqrt{n_1^2+n_2^2}m_0=\sqrt{M_1^2+M_2^2}$. *During the merger of two black holes having the same masses* $M_1=M_2=nm_0$, *the mass of a newly formed black hole is less than* $M_{1+2}=\sqrt{2n^2}m_0=nm_0\sqrt{2}=\sqrt{2}M_1=\sqrt{2}M_2$. *The mass of a black hole that was formed as a result of the merger of 2 black holes of the same masses without using any additional usual substances is* $\sqrt{2}$ *times less than the sum of masses of merging black holes. The remaining mass is dissipated in space.*

Assertion 5.

During the merger of k *black holes having the mass of* $M_i=n_im_0$ *without using any additional usual substance, the mass of a newly formed black hole* *is less than* $M_{1+2+...+k} = m_0\sqrt{\sum_{i=1}^{k} n_i(n_i+1)} \approx m_0\sqrt{\sum_{i=1}^{k} n_i^2} = \sqrt{\sum_{i=1}^{k} M_i^2}$ *. During the merger of* k *black holes of the same masses* $M_i = nm_0 = M$ *without using any additional usual substance, the mass of a newly formed black hole is les than* $M_{1+2+...+k} = \sqrt{kn^2}m_0 = nm_0\sqrt{k} = \sqrt{k}M$ *. The mass of a black hole that was formed as a result of the merger of k black holes having the same masses is* $\sqrt{k}$ *times less than the sum of masses of merging black holes. The remaining mass is dissipated in space.*

Let us consider a system consisting of two black holes and usual substance. The black holes possess the same mass $M_{1,0} = nm_0$, $M_{2,0} = nm_0$ and contain the same volume of information $I_{1,0} = \frac{n(n+1)}{2}$ and $I_{2,0} = \frac{n(n+1)}{2}$. The usual substance is represented by photons having different frequencies (energy) $E = \hbar\nu$, each of them according to the foundational law of Zeilinger quantum mechanics contains one bit of information.

Assertion 6.

During the merger of k *black holes having the same masses* $M_1 = nm_0$ *and* $M_2 = nm_0$ *and containing the same volumes of information* $I_1 = \frac{n(n+1)}{2}$ *and* $I_2 = \frac{n(n+1)}{2}$ *, the absorbing black hole must absorb by* n^2 *bits information more than contained in the absorbed black hole* $I_2 = \frac{n(n+1)}{2}$ *- the absorbing black hole must absorb additionally* n^2 *particles of usual substance, each of them containing one bit of information.*

Assertion 7.

The merger of two black holes having the masses of $M_1 = n_1 m_0$ *and* $M_2 = n_2 m_0$ *and containing the volumes of information* $I_1 = \frac{n_1(n_1+1)}{2}$ *and* $I_2 = \frac{n_2(n_2+1)}{2}$ *resulting in one black hole formation, requires the usage of extra* $n_\phi = n_1 n_2$ *radiation quanta –* $n_1 n_2$ *particles of usual substance, each of them containing one bit of information.*

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INFORMATION RESTRICTIONS ON FORMATION, CHANGES AND INTERCONVERSION OF COSMOLOGICAL OBJECTS

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Introduction

Estimation of the volume of information in cosmological objects, including stars of the Sun type, neutron stars, white dwarfs, black holes…is necessary for generation of restrictions for their formation, development and interconversion.

Information is an integral part of the Universe. The basic principle of Zeilinger's quantum mechanics [1] postulates that elementary physical system (in particular, fundamental particles: quark, electron, photon) bears one bit of information. By its physical essence *information is heterogeneity of matter and energy.* Therefore information is inseparably connected with matter and energy. The universal measure of physical heterogeneity of information is Shannon information entropy [2, 3]. It is important to note that Neumann entropy cannot be applied as the universal measure of heterogeneity because it is equal to zero for structured pure state. An information approach along with a physical one allows to obtain new, sometimes more general data in relation to data obtained on the ground of physical rules only. The author's works, for instance [4, 5] testify about practicality of information laws usage simultaneously with physical rules for cognition of the Universe. The estimates cited below are based on the foundational principle of Zeilinger quantum mechanics i.e. "an elementary system carries one bit of information" and prove it. Elementary systems are fundamental particles (quarks, leptons, photons). Let us evaluate the volume of information in the system of n q-bits. At first we consider the systems with equiprobable basic states.

2. Non interacting q-bits in a system.

Suppose that a system contains n non-interacting q-bits. Let the q-bit be described by the wave function $\psi = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle)$, where $|0\rangle, |1\rangle$ - are the basic states of the q-bit [6]. While measuring the q-bit we'll obtain the basic states $|0\rangle$, $|1\rangle$ with equal probabilities $\frac{1}{2}$. Uncertainty (information) of the q-bit in the state ψ is equal to 1 bit: $N_1 = I_1 = -(\frac{1}{2}\log_2\frac{1}{2} + \frac{1}{2}\log_2\frac{1}{2}) = 1.$

Hence, the volume of information in the system containing n non-interacting q-bits with equiprobable basic states is proportional to the amount of q-bits and is equal to n bits.

This estimate determines the minimum volume of information in the system consisting of n q-bits with equiprobable basic states. **It also explains the linear dependence of the volume of information on the mass or number of particles (elementary systems) in the usual substance (fundamental particles - quarks, leptons, photons).** It also yields the main principle of A.Zeilinger quantum mechanics [1]: "We, therefore, suggest the following principle of information quantiztion: the elementary system carries (contains) 1 bit of information".

3. The system having n basic states.

Let us consider the case when the objects in the system are specified by the wave functions $\psi = \frac{1}{\sqrt{n}}(\sum_{i=1}^{n}|e_i\rangle)$. Uncertainty (information) of the object i is equal to $N_i = -(\frac{1}{n}\log\frac{1}{n} + ... + \frac{1}{n}\log\frac{1}{n}) = \log_2 n$. If the system has n basic states, then the system uncertainty (information) content is equal to $N = \sum_{i=1}^{n} N_i = -n(\frac{1}{n}\log\frac{1}{n} + ... + \frac{1}{n}\log\frac{1}{n}) = n\log_2 n$. This dependence characterizes the neutron stars and white dwarfs [7]. **Neutron stars and white dwarfs appear to be degenerate fermionic systems that fill in a zone of n states $|e_i\rangle$.**

4. Q-bits pairwise interaction in the system.

Suppose that a system contains n pairwise interacting q-bits with equiprobable basic states. The system consisting of n interacting particles (q-bits) can be described with the following wave function: $\psi_n^+ = \frac{1}{\sqrt{2}}(|0_1\rangle|0_2\rangle...|0_n\rangle + |1_1\rangle|1_2\rangle...|1_n\rangle)$. Each q-bit i possesses the wave function $\psi_i = \frac{1}{\sqrt{2}}(|0_i\rangle + |1_i\rangle)$ ($|0_i\rangle, |1_i\rangle$ - basic states of the i-th q-bit). Information on relationships between each pair of interacting q-bits i, j is equal to one unit (one bit) [8]. Let us demonstrate this. Under the linked (intricate) states of q-bits i, j the states of q-bit j is absolutely certain if the states of q-bit i is known, and vice versa the states of q-bit i is absolutely certain if the states q-bit j is known.

For the state $\psi = \frac{1}{\sqrt{2}}(|0_i\rangle|0_j\rangle + |1_i\rangle|1_j\rangle)$ the probabilities of basic states realization are equal to $P(|0_i\rangle) = P(|1_i\rangle = \frac{1}{2}$, $P(|0_j\rangle)) = P(|1_j\rangle) = \frac{1}{2}$; the probabilities of pairwise states realization are equal to

$P(|0_i\rangle|0_j\rangle) = P(|1_i\rangle|1_j\rangle) = \frac{1}{2}$. Combined probabilities are defined with matrix $\mathrm{P}_{сов} = \begin{pmatrix} \frac{1}{2} & 0 \\ 0 & \frac{1}{2} \end{pmatrix}$. Uncertainty (information entropy) of q-bits i, j is equal to $N_i = N_j = -(\frac{1}{2}\log\frac{1}{2} + \frac{1}{2}\log\frac{1}{2}) = 1$ (bit). Uncertainty (information entropy) of combined distribution of the states of q-bit i and q-bit j is equal to $N_{ij} = -(\frac{1}{2}\log\frac{1}{2} + \frac{1}{2}\log\frac{1}{2}) = 1$(bit). Information on the links of q-bits i and j is equal to $I_{ij} = N_i + N_j - N_{ij} = 1+1-1 = 1$(bit).

The volume of information in the link of a system of n pairwise interacting q-bits with equiprobable basic states described with the wave function $\psi_n = \frac{1}{\sqrt{2}}(|0_1\rangle|0_2\rangle...|0_n\rangle + |1_1\rangle|1_2\rangle...|1_n\rangle)$, is equal to $I_{n\,св} = \frac{n\cdot(n-1)}{2}$ bits.

The volume of information in the system of n pairwise interacting q-bits is formed from n bits of information available in the q-bits and $\frac{n\cdot(n-1)}{2}$ bits of information on the link between the q-bits. The total volume of information in the system containing n pairwise interacting q-bits with equiprobable basic states is equal to

$$I_n = n + \frac{n\cdot(n-1)}{2} = \frac{n\cdot(n+1)}{2} \text{ bits.}$$

This estimate determines the maximum volume of information in the system consisting of n q-bits with equiprobable basic states. *In the system containing n pairwise interacting q-bits with equiprobable basic states the volume of information is proportional to squared number of q-bits and is equal to $I_n = \frac{n\cdot(n+1)}{2}$ bit.*

The volume of information in the system of n pairwise interacting q-bits with equiprobable basic states is n bits more than in a system consisting of $n-1$ q-bit, $I_n - I_{n-1} = \frac{n\cdot(n+1)}{2} - \frac{(n-1)\cdot n}{2} = n$.

Under $n \gg 1$ the volume of information in the system of n pairwise interacting q-bits is equal to one half of squared number of interacting q-bits $I_n \approx \frac{n^2}{2}$. **As will be demonstrated below, this explains quadratic dependence of the volume of information the black holes mass.**

3. **Local q-bit interaction in the system.**

Let us consider a case when in the system of n q-bits there stand out $\frac{n}{k}$ groups of k q-bits, each of k q-bits interacting only with the q-bits of each group (suppose that n is divided by k). Then the volume of information I_k in the group of k pairwise interacting q-bits with equiprobable basic states is equal to $\frac{k\cdot(k+1)}{2}$ bits. Hence the system under consideration consisting of n q-bits contains $I_{n/k}=\frac{n}{k}\frac{k\cdot(k+1)}{2}=\frac{n\cdot(k+1)}{2}$ bits. **This explains a linear dependence of the volume of information on mass in the systems composed of compound particles of usual substance (for instance, in systems composed of elementary particles –mesons, baryons, atoms, molecules, gas, …).**

At $k=1$ the system contains the minimum information content: $I_{n/1}=n\frac{1\cdot(1+1)}{2}=n$. At $k=n$ the system contains the maximum volume of information: $I_{n/n}=\frac{n}{n}\frac{n\cdot(n+1)}{2}=\frac{n\cdot(n+1)}{2}$.

4. Restrictions on the volume of information in the system with equiprobable and non-equiprobable basic states.

In a general case, the volume of information I_n in the system of n q-bits with equiprobable basic states is no less than n bits and no more than $\frac{n\cdot(n+1)}{2}$ bits:

$$n\le I_n\le\frac{n\cdot(n+1)}{2}.$$

If we consider the systems consisting of n q-bits with arbitrary probabilities realization of basic states $|0\rangle$, $|1\rangle$, then a q-bit is described with the wave function $\psi=a|0\rangle+b|1\rangle$. While making the q-bit measurements we obtain the basic states $|0\rangle$, $|1\rangle$ with probabilities $|a|^2$, $|b|^2$. Uncertainty (information) of the q-bits in state ψ is equal to $N_1=I_1=-(|a|^2\log_2|a|^2+|b|^2\log_2|b|^2)$.

In a general case, the volume of information I_n in the system of n q-bits is larger or equal to zero bits and is not larger than $\frac{n\cdot(n+1)}{2}$ bits:

$$0\le I_n\le\frac{n\cdot(n+1)}{2}.$$

5. Formation and development (changing) of black holes.

Let us assume that a black hole of mass $M_n = n \cdot m_0$ is formed from the usual substance (radiation). As mentioned earlier, such a black hole contains $I = \frac{n(n+1)}{2}$ bits of information. Therefore, for its formation $\frac{n(n+1)}{2}$ particles of usual substance (radiation quanta) are needed, each of them containing 1 bit. For formation of a black hole of the mass equal to M kg it is necessary to form $n = \frac{M}{m_0}$ sub Planck particles and use $\frac{n(n+1)}{2} = \frac{\frac{M}{m_0}\left(\frac{M}{m_0}+1\right)}{2} \approx \frac{M^2}{2m_0^2}$ radiation quanta. Thus, for formation of a black hole with the mass of the Sun equal to $\approx 2 \cdot 10^{30}$ kg, it is necessary to form $n = \frac{M_c}{m_0} = \frac{2 \cdot 10^{33}}{5 \cdot 10^{-6}} = 4 \cdot 10^{38}$ sub Planck particles and use $\frac{n(n+1)}{2} \approx 8 \cdot 10^{76}$ radiation quanta.

It is known that during supernova explosion the radiation energy is on the order of 10^{50} erg, the maximum 10^{54} erg [11]. Whereas the average radiation frequency is 10^{18} Hz, then the supernova explosion generates $N = \frac{10^{50}(10^{54})}{10^{-27}10^{18}} = 10^{59}(10^{63})$ radiation quanta. Assuming that $\approx 100\%$ radiation quanta is used for black hole formation, then the mass of a black hole would be equal to about $M \approx \sqrt{2N} m_0 = 4{,}47 \cdot 10^{29} \cdot 5 \cdot 10^{-6} \approx 2{,}3 \cdot 10^{24}$ g.

The table 1 presents information characteristics of black holes of different masses.

Table 1.

The number of absorbed radiation quanta (the volume of absorbed information)	**The number of sub Planck particles in the newly formed black hole**	**The mass of a newly formed black hole**	**Note**
		kg	
1	1	5,09E-09	Characteristics of the minimal black hole
1E+10	141421	0,000719832	
1E+20	14142135623	71,98347	
1E+30	1,41421E+15	7,2E+06	
3,76E+38	1,78326E+19	1,78E+11	Characteristics of the optimal black hole in the system “hydrogen (protons)– black hole)
1E+40	1,41421E+20	7,2E+11	
1E+50	1,41421E+25	7,2E+16	
1E+59	1,47214E+29	2,28E+21	Characteristics of a black hole generated during the supernova explosion of radiation rate of 10^{50} erg
1E+60	1,41421E+30	7,2E+21	

1,26E+62	1,58745E+31	9,09E+22	Characteristics of the optimal black hole in the system “radiation – black hole”. See [5, 10, 12, 13]
1E+63	4,47214E+31	2,28E+23	Characteristics of a black hole generated during the supernova explosion of radiation rate of 10^{54} erg
1E+70	1,41421E+35	7,2E+26	
7,72E+76	3,92927E+38	2E+30	Characteristics of a black hole having the mass of the Sun
1E+80	1,41421E+40	7,2E+31	
1E+90	1,41421E+45	7,2E+36	
7,72E+94	3,92927E+47	2E+36	Characteristics of a black hole of 10^6 of the masses of the Sun
1E+100	1,41421E+50	7,2E+41	
7,72E+100	3,92927E+50	2E+39	Characteristics of a black hole of 10^9 of the masses of the Sun
1E+110	1,41421E+55	7,2E+46	
1E+120	1,41421E+60	7,2E+51	Characteristics of the maximum black hole

From the above chart it follows that:

- The mass of a black hole formed during the supernova explosion is close to the mass of an optimal black hole in the system “a black hole – radiation”. One can expect that during the supernova explosions the black holes be formed having masses under which information volume in the adjacent space is close to minimum.
- For the formation of black holes with the mass equal to million masses of the Sun the volume of information exceeding the volume of information of the Universe (10^{90} bits) is required [4, 5, 9, 14]. Significant volumes of information are needed for the formation of the black holes with the same mass as the Sun’s. In such case the volume of information of about 10^{76} bits is required. It means that locally (in the zone of black hole formation) there must take place intensive physical processes of radiation formation. For instance, the supernova explosions and accelerated motion of relativistic particles.

6. The volume of information in neutron stars and white dwarfs. The information model of a neutron star and white dwarf.

When evaluating the volume of information in neutron star we must take into account the volume of information in the structure of the star and in neutrons. In the neutron fermi-gas during its complete degeneration all the low energy levels are filled in up to Fermi level while all the subsequent ones remain empty. Temperature rise can change distribution of neutrons in the levels to only a small extent: a small fraction of neutrons sitting in the levels close to the Fermi level pass to the empty levels possessing bigger energy and clear the levels from which the migration took place.

The volume of information in the structure of degenerate fermi-gas is equal to N*$\log_2$ (N) bits. Here N – is the number of filled in energy levels (number of neutrons). In the neutron star N=(M/m), where M – is the mass of a neutron star, m – is the mass of neutron. The volume of information in one neutron is about 9,422 bits. The volume of information in the neutrons of the star is equal to 9,422*N bits. Aggregated volume of information in the neutron star (without considering the information in the crust nickel and iron) is approx. 9,422*(M/m) +(M/m) *$\log_2$(M/m) bits. The volume of information in a neutron star is proportional to the mass multiplied by the logarithm of dyadic mass. In a similar way one can evaluate the volume of information in white dwarfs. Recall for the sake of comparison that the volume of information in usual substance (non-interacting particles, gas) is proportional to mass, the volume of information in a black hole is proportional to squared mass.

The neutron mass is $m = 1{,}67 \cdot 10^{-27}$ kg. A number of neutrons in the star with the mass of 1,0 (1,4) of the mass of the Sun is equal to $\approx 1{,}18 \cdot 10^{57}$ ($\approx 1{,}68 \cdot 10^{57}$). Therefore, the neutron star with the mass of 1,0 (1,4) of the mass of the Sun contains $\approx 2{,}32 \cdot 10^{59}$ ($\approx 3{,}2 \cdot 10^{59}$) bits. The neutron star structure contains the amount of information, which is about two orders of magnitude more $\approx 2{,}25 \cdot 10^{59}$ ($\approx 3{,}16 \cdot 10^{59}$) bits, than in the neutrons $\approx 6{,}93 \cdot 10^{57}$ ($\approx 9{,}7 \cdot 10^{57}$) bits.

The most commonly encountered are white dwarfs consisting of carbon and oxygen with helium-hydrogen shell [7, 15]. Under the masses of white dwarfs 0.6 M_{sun} - $1.44M_{sun}$, with the radiuses equal to the Earth's the surface temperature can be relatively high (from 100,000 K to 200,000 K). The main feature of their construction is a nucleus, its gravity equilibrium being supported by degenerate electron gas whose properties do not allow any further modifications of its structure. The degenerate gas pressure puts into equilibrium the gravitation (under prescribed mass) and the loss of heat resulting from non-degenerate component of the substance does not change this pressure and the losses alone are relatively insignificant.

The fate of a supergiant star remnants depends on the mass of remaining nucleus. When hydrostatic equilibrium breaks down there occurs gravitation collapse (lasting for seconds of fractions of seconds) and if $M_{kernel}<1.4M_{sun}$, then the nucleus will shrink up to the Earth dimensions and a white dwarf is produced. If $1.4M_{sun}<M_{kernel}<3M_{sun}$, then the pressure of incumbent layers will be so strong that the electrons are "forced into" protons thus generating neutrons and emitting neutrino $p^+ + e^- \rightarrow n + \nu_e$. The so-called degenerate neutron gas is generated. The pressure of degenerate neutron gas halts the subsequent shrinkage of the star. However, it appears that part of neutron

stars is formed during supernova outbursts and appear to be the remnants of massive stars that had exploded as the Supernova of the second type.
For evaluating the volume of information available in a white dwarf of the mass of the Sun we assume that the white dwarf contains more or less equal number of atoms of carbon and oxygen. Then the total number of atoms in a white dwarf of the mass of the Sun is equal to $n_{C+O} = \frac{M_s}{(m_C + m_O)/2} \approx \frac{2\cdot 10^{30}}{13\cdot 1,67\cdot 10^{-27}} \approx 8,55\cdot 10^{55}$. The number of electrons in a white dwarf of the mass of the Sun is equal to $n_e \approx 5,99\cdot 10^{56}$. Thus the structure of a white dwarf of the mass of the Sun contains $\approx 1,13\cdot 10^{59}$ bits. The carbon and oxygen atoms of the white dwarf of the mass of the Sun contain $\approx 1,11\cdot 10^{58}$ bits. Therefore, the white dwarf of the mass of the Sun contains only $\approx 1,24\cdot 10^{59}$ bits.

Emission and absorption of usual substance by a neutron star.

The logic of derivation of estimates in the present section is identical to the logic of derivation of estimates for a black hole. Suppose that at the initial instant of time the neutron star consists of n neutrons, possesses the mass of $M_n = n\cdot m_n$ and contains $I_n = n\log_2 n + 9,422\cdot n$ bits of information. The mass of neutron star changes (increases or decreases) by neutrons (quanta) $\Delta M = m_n$. Because each neutron has the mass m_n, then the neutron star energy change in this case is equal to $\Delta E = m_n c^2$. At the loss of emission of one neutron the mass of neutron star becomes equal to $M_{n-1} = (n-1)\cdot m_n$. In this case the volume of information remaining in the neutron star is equal to $I_n = (n-1)\log_2(n-1) + 9,422\cdot(n-1)$ bits. Information change (loss) in a neutron star comes to

$$\Delta I_n = I_n - I_{n-1} = n\log_2 n + 9,422\cdot n - (n-1)\log_2(n-1) - 9,422\cdot(n-1) =$$

$$= \log_2 n + (n-1)(\log_2 n - \log_2(n-1)) + 9,422 = \log_2 n + (n-1)(\log_2(1+1/(n-1)) + 9,422 \approx \log_2 n + 9,422 \text{ (bits).}$$

For further estimates we use the law of conservation of uncertainty (information) and energy conservation principle. According to the law of conservation of uncertainty (information) any change in the system “neutron star of the mass $M_n = n\cdot m_n$ – external environment” at the emission of one neutron of a particle must be compensated by occurrence of $\log_2 n + 6,8$ particles containing 1 bit each: $I_n - I_{n-1} = \log_2 n + 9,422$ bit. Let us consider that there have emerged $\log_2 n + 6,8$ photons of frequency ν and energy $h\nu$. By virtue of the energy conservation principle $(\log_2 n + 9,422)\cdot h\nu = m_n c^2$ and $\nu = \frac{m_n c^2}{(\log_2 n + 9,422)\cdot h}$. Let us calculate the radiation temperature $T = \frac{h\upsilon}{k} = \frac{h}{k}\frac{m_n c^2}{(\log_2 n + 9,422)\cdot h} = \frac{m_n c^2}{(\log_2 n + 9,422)\cdot k}$. Estimate of dependence of the temperature of neutron star radiation on its mass (number of neutrons in a star) is presented in the table 2

Table 2.

Neutron star mass (kg)	1,67E-17	1,67E-07	1,67E+03	1,67E+13	1,67E+23	2,00E+30
Number of neutrons in the star n	1 E+10	1 E+20	E+30	10E+40	1 E+50	1,2 E+57
Number of generated photons $\log_2 n + 6{,}8$	40,02	73,23	106,45	139,67	172,89	196,41
Radiation temperature	2,55E+11	1,44E+11	9,98E+11	7,65E+10	6,21E+10	5,47E+10

Note that the given estimate does not take into account the availability of other elements in a neutron stars that decrease the radiation temperature.
Note. In a general case there must be generated $\log_2 n + 9{,}422$ photons having the frequencies of ν_i and aggregated energy $h \sum_{i=1}^{\log_2 n + 9{,}422} \nu_i = m_0 c^2$.
Similar dependencies are true for the cases when neutrons are absorbed by neutron stars. The estimate of radiation temperature of the white dwarf of the mass of the Sun was derived by using information method, which is similar to estimations of black hole and neutron star radiation temperature and is equal to about 3E+07K.
According to the law of conservation of uncertainty (information) the change in the system "neutron star of the mass $M_{n-1} = (n-1) \cdot m_n$ – external environment" at the black hole mass increase by the mass of one black particle must be conditioned by the absorption of $\log_2 n + 9{,}422$ particles containing 1 bit each: $I_{n+1} - I_n = \log_2 n + 9{,}422$ bits. Let us assume that there was absorbed $\log_2 n + 9{,}422$ photons of frequency ν and energy $h\nu$. **By virtue of the energy conservation principle** $(\log_2 n + 6{,}8) \cdot h\nu = m_n c^2$. The frequency of each absorbed photon must be equal to $\nu = \dfrac{m_n c^2}{(\log_2 n + 9{,}422) \cdot h}$ 1/sec.
Similar dependencies are also true for white dwarfs.

7. The information volume of the Sun. Information model of a star of the Sun type.

The Sun consists for the most part from hydrogen (~74% of its mass) and helium (~25% of its mass). The number of hydrogen atoms n_h in the Sun amounts to $n_h = \dfrac{M_{sun}}{m_n} = \dfrac{2 \cdot 0{,}74 \cdot 10^{30}}{1{,}66 \cdot 10^{-27}} \approx 0{,}9 \cdot 10^{57}$. The hydrogen atom contains 11,422 bits. The volume of information in the system consisting of n_h hydrogen atoms is $11{,}422 n_h$ bits. Therefore, hydrogen in the Sun contains $I_h \approx 11{,}422 \cdot 0{,}9 \cdot 10^{57} \approx 10^{58}$ bits. The helium atom (two protons, two neutrons, two electrones) contains approx 40 bits of information. The volume of information available in the system consisting of n_{hel} atoms of helium is equal to $40\ n_{hel}$ bits. Thus, helium in the Sun contains $40n_{hel} = 40 \cdot \frac{0,25 \cdot M_{sun}}{m_n} = \frac{10 \cdot 2 \cdot 10^{30}}{4 \cdot 1,66 \cdot 10^{-27}} = \frac{5 \cdot 10^{30}}{1,66 \cdot 10^{-27}} \approx 3 \cdot 10^{57}$ bits. All in all the Sun contains $\approx 1,3 \cdot 10^{58}$ bits of information.

Note. Our Galaxy contains over 10^{11} stars, the Universe contains 10^{11} galaxies. Consequently, our Galaxy and the stars contain about 10^{69} bits while the Universe and the stars contain about 10^{80} bits of information.

8. Formation of black holes from the stars

Table 3 presents the masses of black holes. Estimations were based on the assumption that black holes hase been formed from the neutron star, white dwarf of the Sun type.

Table 3.

Star type	**Star mass**	**Volume of information in the star**	**Number of sub Planck particles in the newly formed black hole**	**Mass of the newly formed black hole**
				кг
Neutron star	1,0 of the mass of the Sun	2,38E+59	7E+29	3,5E+21
Neutron star	1,4 of the mass of the Sun	3,35E+59	8E+29	4,17E+21
White dwarf	1,0 of the mass of the Sun	1,24E+59	4,9E+29	2,5E+21
Star of the Sun type	1,0 of the mass of the Sun	1,3E+58	1,2E+29	8E+20

One can see from the table 3 that the masses of black holes that can be generated during formation of black holes from neutron star, white dwarf, star of the Sun type are close to the mass of the optimal black hole (in the system “black hole – radiation”) - 8,08E+22 kg.

Suppose that original neutron star possesses a mass equal to the mass of the Sun M_n =2,00E+30 kg, consists of 1,20E+57 neutrons and contains the volume of information equal to $I_n = n(\log_2 n + 9,422)$ =2,38E+59 bits. Following the transformation a black hole and usual substance are formed. The black hole mass is equal to $M_{Bh} = km_0$ while the volume of information in the newly formed black hole is equal to $I = \frac{k(k+1)}{2}$. The number of usual substance particles formed as a result of merging is equal to x. The volume of information in the usual substance is equal to $I_{ов} = x$. The average mass of usual substance particle is equal to m.

From the law of conservation of uncertainty (information) it follows:

$$I_n = n(\log_2 n + 9,422) = \frac{n(n+1)}{2} + x = I_{чз} + I_{ов}.$$

Suppose that the main energy of black holes and usual substance is concentrated in the mass. Then from the energy conservation principle it follows: $M_n = nm_n = km_0 + xm = M_{Bh} + M_{Us}$.

We have a system consisting of two equations $nm_n = km_0 + xm$, $n(\log_2 n + 9{,}422) = \frac{k(k+1)}{2} + x$ in three unknowns n, x, m. $x \ge 0$. Therefore, $n(\log_2 n + 9{,}422) \ge \frac{k(k+1)}{2} \approx \frac{k^2}{2}$, $k \le \sqrt{2n(\log_2 n + 9{,}422)}$ and $M_{чз} = km_0 \le m_0\sqrt{2n(\log_2 n + 9{,}422)}$ (restriction on the mass of a black hole formed from a neutron star). At n=1,20E+57 $I_n = n(\log_2 n + 9{,}422)$=2,38E+59 bit $k \le \sqrt{2 \cdot 2{,}38 \cdot 10^{59}} = \sqrt{47{,}6 \cdot 10^{58}} \approx 7 \cdot 10^{29}$. As far as m_0=5,09E-09 kg, then $M_{чз} \le m_0 7 \cdot 10^{29} \approx 3{,}5 \cdot 10^{21}$kg.

Let us consider the following example. Suppose that a neutron star consists of 1,20E+57 neutrons, possesses the mass equal to the mass of the Sun M_n =2,00E+30kg and contains the volume of information equal to $I_n = n(\log_2 n + 9{,}422)$=2,38E+59 bits. The resulting black hole consists of k=3E+29 particles (it has the mass of 1,5 E+21kg and contains 4,5E+58 bits). The resulting number of usual substance particles (radiation quanta) is equal to 1,9E+59. The total mass of usual substance is equal to (2,00E+30 – 1,5E+21) kg. The average mass of particles (radiation quanta) is about E-29kg. Radiation frequency is equal to approx. $\nu = \frac{mc^2}{h} = \frac{10^{-29} \cdot 9 \cdot 10^{16}}{6{,}6 \cdot 10^{-34}} \approx 10^{21}$1/sec. This is the bottom boundary of hard gamma radiation [16]. Thus the volume of information in a neutron star of the mass of the Sun (~2,38E+59 bits) is sufficient for the formation of a black hole of the mass of ~3E+24g.

Suppose that the original white dwarf possesses the mass equal to the mass of the Sun M_n =2,00E+30kg and contains the information volume equal to 1,24E+59 bits. Because $n_e \log_2 n_e + n_{уг+к} \cdot 129{,}5 \ge \frac{k(k+1)}{2} \approx \frac{k^2}{2}$, $k \le \sqrt{2n_e \log_2 n_e + n_{c+o} \cdot 129{,}5)}$ and $M_{Bh} = km_0 \le m_0\sqrt{2n_e \log_2 n_e + n_{c+o} \cdot 129{,}5)}$ (restriction on the mass of a black hole formed from the white dwarf). When the volume of information in the white dwarf is equal to 1,14E+59 bits. $k \le 4{,}8 \cdot 10^{29}$. Because m_0=5,09E-09kg, then $M_{Bh} \le m_0 5 \cdot 10^{29} \approx 2{,}4 \cdot 10^{21}$kg.

Suppose that the original star is the star of the Sun type having the mass equal to the mass of the Sun M_n =2,00E+30kg and contains the volume of information equal to $\approx 1{,}3\cdot 10^{58}$ bits. The mass of a newly formed black hole is equal to $M_{чз} = km_0$, the volume of information in a newly formed black hole is equal to $I = \frac{k(k+1)}{2} \approx \frac{k^2}{2}$. Because the star of the Sun type contains only the usual substance, then the mass of the black hole under formation is equal to $M_{чз} = m_0 k = m_0\sqrt{2I_{ов}}$ In the case under study

$$M_{чз} = m_0\sqrt{2I_{ов}} \approx 5,09\cdot 10^{-9}\sqrt{2\cdot 1{,}3\cdot 10^{58}} = 5,09\cdot 10^{-9}\sqrt{2{,}6\cdot 10^{58}} \approx$$

$$\mathrm{M} \approx 5,09\cdot 10^{-9}\cdot 1,6\cdot 10^{29} \approx 8\cdot 10^{20}\,\mathrm{kg}.$$

9. **Estimation of the volume of information in Planck particle.**

Energy necesary for the formation of one bit is not less than $kT\ln 2$ [6, 17].
Energy necessary for the formation of one Nat is not less than kT.
Mass necessary for the formation of one bit is not less than $\frac{kT\ln 2}{c^2}$. Mass necessary for formation of one Nat is not less than $\frac{kT}{c^2}$. At Planck temperature $T_{Pl} = \frac{1}{k}\sqrt{\frac{\hbar c^5}{G}} = 1,41696\cdot 10^{32}\,K$ [18] the mass necessary for formation of one Nat is not less than Planck mass $m = \frac{kT_{Pl}}{c^2} = \frac{k}{c^2}\frac{1}{k}\sqrt{\frac{\hbar c^5}{G}} = \sqrt{\frac{\hbar c}{G}} = m_{Pl} = 2{,}17671\cdot 10^{-5} g$, the mass necessary for the formation of one bit is not less than $m_{Pl}\ln 2 \approx 0,69 m_{Pl} = 1,5\cdot 10^{-5} g$.

Hence, a Planck particle contains one Nat of information while **one Nut can be considered as Planck's basic unit of information** (one Bit is the Shannon's basic unit of information).

«Fourteen billion years ago at the birth of the Universe it was enclosed in the point with the radius of 10^{-33}cm, which is incommensurably smaller than the proton radius - 10^{-13}cm. In that volume all the information about the future of the Universe had already been built-in. The Big Bang occurred» (A.Cherepashuk [19]).

10^{-33} cm – is the size of a Planck particle. As shown earlier, Planck particle contains one Nat of information (≈ 1,45 bit) while information about the Universe contains not less than ≈ 10^{14} bits of classical information. This is the mass of the order of the mass of Planck particle [18]. But on the other hand, this mass must contain the volume of information, which is significantly larger than Planck particle at Planck temperature. Hence, all the information about the future of the Universe was enclosed in the Universe segment of the radius larger than 10^{-33} cm, or was generated at the expansion of the Universe. It is not impossible that similar informational considerations would allow to prove either independent development of the Universe determined by the information (nonhomogeneity) contained in it, or the presence of additional external control executed from outside of the Universe.

15. Conclusion

The results presented in this paper show the effectiveness of informational approach for the study the cosmological objects. In the future the proposed models and estimations should undoubtedly be specified and presented in a more detailed way.

One should point out that informational approach allows formulating restrictions on the valuations of physical systems characteristics and physical processes while the physical methods and models can describe not only the restrictions but also concrete physical “mechanisms” of restriction formation, concrete valuations of physical systems characteristics.

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INITIAL HETEROGENEITIES OF THE UNIVERSE

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"All from bit"

J.A. Wheeler

1. Introduction

Were there any heterogeneities in the Universe [1, 2, 3] at the beginning of its existence? Or heterogeneities formed later, during the expansion of the Universe's.

"Let us emphasize at once that some initial heterogeneities of the Universe are necessary as against the totally Universe the formation of large-scale structure (galaxies, their clusters) is not possible" [2, pp. 12-13]

"Some fourteen billion years ago, at the moment of birth Universe entire was confined at the radius of 10^{-33}cm, which is far less that the radius of proton- 10^{-13}cm. In that volume all the information about the future of the Universe was contained. The Big Bang took place" (We will name the given statement as a hypothesis about the initial information [4]).

To investigate the existence and characteristics of the Universe's initial heterogeneities the information approach is applicable using information entropy by Shannon [5] as a measure of heterogeneity. We shall evaluate the very existence of heterogeneity by information divergence [6, 7].

2. Definitions and designations

Let us bring forward necessary definitions. By the author's definition [8, p. 35] information –is heterogeneity that is stable for a certain time [8, стр. 35]. "We shall understand by information the stable for some definite time heterogeneities of arbitrary physical nature". Therefore a letter in a book, an atom, a molecule, an elementary particle, a star, a drawing, a picture, a ploughed land, a forest and other heterogeneities contain and carry information."

The quoted definition of information is based on the following concepts:

- Heterogeneity.
- Stable heterogeneity.
- Heterogeneity stable for definite time

Let us give definitions of homogeneity and heterogeneity.

Heterogeneity.

Let us analyze a set M, consisting of elements m. If the elements m are equal, identical (do not differ from each other), then the set M is homogeneous.

If there are not identify elements among the elements m (non-identical, different from each other) then the set M is heterogeneities. By the set as usually "one name for the sum total of all the objects, possessing given quality is understood" (Georg Kantor).

These objects are called by elements of a set.

Stability of heterogeneity – conservation of heterogeneity, its structure, characteristics.

Time of stability of heterogeneity – time of heterogeneity's existence (life), time of heterogeneity's conservation, its structure, characteristics.

"Information is fortuitous and remembered choice of one variant out of several possible and equivalent variants. The word "fortuitous" here is selected as it belongs to the process (way) of choice and therefore limits the range of the definition's application. In general the choice may be also not fortuitous (suggested), in this case they say about reception of information. Fortuitous choice corresponds to generating (that is spontaneous inception) of information. In general terms the choice may be not remembered (that is be forgotten at once). We shall call such choice microinformation. We shall call remembered choice by the macroinformation (contrary to not remembered). In all informational processes macroinformation (remembered) is used" [8]. We shall identify classic information [9] with macroinformation of D.C. Chernavsky.

Let fortuitous value x is described by the function (density) of distribution $P(x)$.

The difference of fortuitous value described by the function (density) of distribution $P(x)$ from the fortuitous value described by the function (density) of distribution $Q(x)$ is estimated by informational divergence $D(P/Q)$ of distribution P against distribution Q [6, 7]

$$D(P/Q) = -\int P(x)\cdot\log_2\frac{P(x)}{Q(x)}\cdot dx = -\int P(x)\cdot\log_2 P(x)\cdot dx + \int P(x)\cdot\log_2 Q(x)\cdot dx\,.$$

We shall estimate occurrence of heterogeneity defined by the distribution P by the information divergence $D(P/R)$ of the distribution P against uniform distribution R

$$D(P/R) = -\int P(x)\cdot\log_2\frac{P(x)}{R(x)}\cdot dx = -\int P(x)\cdot\log_2 P(x)\cdot dx + \int P(x)\cdot\log_2 R(x)\cdot dx\,.$$

$P(x)\cdot$ - is distribution characterizing required heterogeneity of the Universe in a certain instant of time.

$R(x)\cdot$ uniform distribution at the interval $0 \le x \le a$

$$R(x) = \begin{cases} 0 & \text{if } -\infty < x \le 0 \\ \frac{1}{a} & \text{if } 0 < x \le a \\ 0 & \text{if } a < x \le \infty \end{cases}.$$

If $R(x)$ is uniform distribution at the interval $0 \le x \le a$ and $P(x)$ is also defined at the interval $0 \le x \le a$ then information divergence is equal to

$$D = -\int_0^a P(x)\cdot\log_2\frac{P(x)}{\frac{1}{a}}\cdot dx = -\int_0^a P(x)\cdot\log_2(a\cdot P(x))\cdot dx\,.$$

In the same way heterogeneity is estimated by information divergence in multidimensional case.

Occurrence of heterogeneity set by the distribution P is estimated by information divergence $D(P/R)$ of the distribution P against uniform distribution R

$$D(P/R) = -\int P(x)\cdot\log_2\frac{P(x)}{R(x)}\cdot dx = -\int P(x)\cdot\log_2 P(x)\cdot dx + \int P(x)\cdot\log_2 R(x)\cdot dx\,.$$

$P(x)\cdot$ **(** $x = x_1, x_2, x_3$ **)** - is distribution characterizing required heterogeneity in a certain instant of time.

$R(x)$ ($x = x_1, x_2, x_3$)- is uniform distribution in the volume V

$$R(x) = \begin{Bmatrix} \frac{1}{V} \text{ при } x \in \mathrm{V} \\ 0 \text{ при } x \notin V \end{Bmatrix}.$$

If $R(x)$ ($x = x_1, x_2, x_3$) is uniform distribution in the volume V and $P(x)$ is also defined in the volume V, then informational divergence is equal to

$$D = -\int_{\mathrm{V}} P(x)\cdot\log_2\frac{P(x)}{\frac{1}{\mathrm{V}}}\cdot dx = -\int_V P(x)\cdot\log_2(V\cdot P(x))\cdot dx\,.$$

We have in particular

$$D(P/R) = -\int P(x_1,x_2,x_3)\cdot\log_2\frac{P(x_1,x_2,x_3)}{R(x_1,x_2,x_3)}\cdot dx_1dx_2dx_3 =$$

$$-\int P(x_1,x_2,x_3)\cdot\log_2 P(x_1,x_2,x_3)\cdot dx_1dx_2dx_3 + \int P(x_1,x_2,x_3)\cdot\log_2 R(x_1,x_2,x_3)\cdot dx_1dx_2dx_3\,.$$

$P(x_1, x_2, x_3)$ - distribution characterizing the required heterogeneity in a certain instant of time.

$R(x_1, x_2, x_3)$ - uniform distribution in the domain $0 \le x_i \le a_i$

$$R(x_1, x_2, x_3) = \begin{cases} 0 \text{ if } -\infty < x_i \le 0 \\ \frac{1}{a_i} \text{ if } \quad 0 < x_i \le a_i \\ 0 \text{ if } \quad a_i < x_i \le \infty \end{cases}, \text{ i=1, 2, 3.}$$

If $R(x)$ is uniform distribution in the domain $0 \le x_i \le a_i$ and $P(x_1, x_2, x_3)$ is also defined in the domain $0 \le x_i \le a_i$, then information divergence is equal to

$$D = -\int_0^a P(x_1,x_2,x_3) \cdot \log_2 \frac{P(x_1,x_2,x_3)}{\frac{1}{\prod_{i=1}^{3} a_i}} \cdot dx_1 dx_2 dx_3 =$$

$$= -\int_0^a P(x_1,x_2,x_3) \cdot \log_2 (\prod_{i=1}^{3} a_i \cdot P(x_1, x_2, x_3) \cdot dx_1 dx_2 dx_3 .$$

3. The consecutive order of our reasoning

1. Let us check the correctness of the conjecture about initial information and show that this hypothesis needs clarification.
2. Let us prove the existence of heterogeneities at the initial instant in the Universe.

Let us speculate that there were no heterogeneities in the Universe in the initial instant (information divergence against uniform distribution is equal to zero).

We shall depict that in this case there will not be heterogeneities in the Universe in the posterior moments of time either (information divergence against uniform distribution is equal to zero).

As long as at present it is obvious that there are heterogeneities in the Universe (clusters of galaxies, galaxies, stars, planets,…, molecules, atoms, particles) then under the logic of evidence “ad absurdum” the parent clause is not true.

It follows that in the initial instant there were heterogeneities in the Universe.

3. Let us show that homogeneity of dark energy is conserved at the expansion of the Universe.

Information divergence against uniform distribution is equal to zero at all instants of time.

4. Let us estimate characteristics of initial heterogeneities in the Universe.

So far as the very initial heterogeneities contain the laws of nature defining further development of the Universe let us estimate the volume of information contained in laws of nature (following D. Chernavsky [9] we estimate the volume of macro-information or classical information).

The estimate of classical information volume in the laws of nature and the time elapsed from Big Bang, gives estimates of the mass of the initial heterogeneities [10].

5. Let us estimate the growth of heterogeneities at the expansion of the Universe.

We define that at steady expansion of the Universe to “record” physical laws at the initial instant very big mass of heterogeneities is necessary which is apparently impossible.

Let us show that at the inflationary expansion of the Universe from the information contained in the initial heterogeneities of the Universe by the mass 10^4kg the volume of information sufficient for “recording” physical laws is formed.

This will allow clarifying the conjecture about the initial information.

4. The estimate of information volume in Planck's particle

The energy necessary for the formation of one bit is no less than $kT\ln 2$ [11, 12-13]. The energy necessary for the formation of one nut is no less than kT. The mass necessary for the formation of one bit is no less than $\frac{kT\ln 2}{c^2}$. The mass necessary for the formation of one nut is no less than $\frac{kT}{c^2}$.

At Planck’s temperature $T_{Pl} = \frac{1}{k}\sqrt{\frac{\hbar c^5}{G}} = 1{,}41696\cdot 10^{32} K$ [14] the mass m_{Nut} necessary for the formation of one nut is no less than Planck’s mass

$$m_{Nut} = \frac{kT_{Pl}}{c^2} = \frac{k\frac{1}{k}\sqrt{\frac{\hbar c^5}{G}}}{c^2} = \sqrt{\frac{\hbar c}{G}} = m_{Pl} = 2{,}17671\cdot 10^{-5} g.$$

At Planck’s temperature the mass m_{Bit} necessary for the formation of one bit is no less than 0,69 Planck’s mass $m_{Pl}\ln 2 \approx 0{,}69 m_{Pl}$:

$$m_{Bit} = \frac{kT_{Pl}\ln 2}{c^2} = \frac{k\frac{1}{k}\ln 2\sqrt{\frac{\hbar c^5}{G}}}{c^2} = \ln 2\sqrt{\frac{\hbar c}{G}} = \ln 2 m_{Pl} \approx 0{,}69 m_{Pl} = 1{,}5\cdot 10^{-5} g.$$

Thus Planck’s particle contains one nut of micro-information and one nut can be considered by Planck’s unit of information (one bit is Shannon’s unit of information).

The size of Planck’s particle is 10^{-33}cm. Planck’s particle in Planck time $\approx 10^{-44}$ s contains one nut of microinformation (≈1,45bits), while the volume of information about physical laws of the Universe is evidently much greater.

It follows that all the information about the future of the Universe was either contained in the part of the Universe, the radius of which is larger than 10^{-33}cm, or with the exception of initial bit (nut) was born at the expansion of the Universe.

Therefore the conjecture about the initial information should be clarified and developed.

5. The proof of heterogeneity existence in the Universe at the initial instant

We shall estimate the existence of heterogeneity set by the distribution P by the informational divergence $D(P/R)$ of the distribution P as respects to the uniform distribution $R(x)$. Let us prove:

Assertion 1.

Initially there were heterogeneities of usual matter in the Universe.

Suppose that at the initial instant t_0 there were no heterogeneities of usual matter: $P(x,t_0) \equiv R(x)$, that is information divergence at certain instant of time $t \geq t_0$ is also equal to zero. It means that at certain instant of time $t \geq t_0$ there were neither heterogeneities of usual matter in the Universe. But as at present there are evidently heterogeneities of usual matter in our Universe (clusters of galaxies, galaxies, stars, planets,…, molecules, atoms, particles [1, 2]) it follows that at the initial instant there were heterogeneity of usual matter in the Universe.

Note 1. This assertion is correct at any physical nature of heterogeneities, at any physical mechanism of heterogeneities generation, any physical model of heterogeneities formation. See for example, [2, 15 - 20]

Note 2. This result gives the strict argumentation by information method to the assertion of Zeldovich with coauthors quoted in the introduction.

Assertion 2.

Initially there existed heterogeneities of dark matter in the Universe.
The deduction is similar to the preceding one.

Assertion 3.

Initially and then there were no heterogeneities of dark energy. The dark energy(vacuum) was evenly distributed.

$$R(x_1, x_2, x_3) = \begin{cases} 0 \text{ if } -\infty < x_i \leq 0 \\ \frac{1}{a_i} \text{ if } \quad 0 < x_i \leq a_i \\ 0 \text{ if } \quad a_i < x_i \leq \infty \end{cases}, \text{ i=1, 2, 3.}$$

Information divergence $D(P(x)/R(x))$ of dark energy at present is equal to zero.

Then in the initial and posterior instants of time information divergence

$D(P(y)/R(y))$ of dark energy is equal to zero.

6. The estimate of characteristics of the Universe's initial heterogeneities

Let us estimate the volume of information contained at the initial heterogeneities and mass of the initial heterogeneities.

Let us formulate the required pre-requisites of the estimates.

1) Development, properties and characteristics of the Universe are completely defined by laws of nature.
2) Laws of nature are contained in initial heterogeneities of our Universe ("recorded" in initial heterogeneities of the Universe).
3) Laws of nature are characterized by the volume of classical information I_{Phl}.
4) The volume of classical information $I_{íí}$ in initial heterogeneities of the Universe should be no less than the volume of information in laws of nature $I_{Ih} \geq I_{Phl}$.

The estimate of the classical information volume contained in laws of nature.

It is difficult to define precise meaning of classical information volume contained in laws of nature; therefore we shall give several estimates.

1) If the Universe is described by n parameters then it is necessary to have n^2 of physical laws describing pairwise associations between parameters (taking account of pairwise associations). At occurrence of greater number of interrelated parameters one should take account of greater number of laws.

Let us consider that the description of one law requires I bits. Then for all n^2 physical laws describing the Universe it is necessary to have $I_{Un} = n^2 I$.

Let $n = 100$, $I = 1$Gbyte (it is more than 3000 pages of a text – which is obviously inflated estimate) then $I_{Un} = 10000$ Gbytes (10^{14} bytes) [8].

2) The volume of classical information in the course of physics containing 2000 pages is equal approximately to 10^9 bits.
3) The volume of classical information in files describing physical laws [21], is approximately equal to 10^7 bits.
4) The volume of information in the file describing Einstein equation [21], is approximately equal to 10^6 bits.

Note 3.

We shall give data described in [22, p. 180]. Till the instant of time $t = 10^{-44}$ s in the Universe the laws acted defining super associated interaction (the interaction integrating gravitational, strong, week and electromagnetic interaction).

After the instant of time $t = 10^{-44}$ s till the instant $t = 10^{-34}$ s in the Universe there acted the laws defining gravitational and great interaction (interaction integrating strong, week and electromagnetic interaction). After the instant of time $t = 10^{-34}$ s till the instant $t = 10^{-10}$ s in the Universe there acted laws defining gravitational, strong and electroweek interaction.

After the instant of time $t = 10^{-10}$ s till recent time in the Universe there act the laws defining all known types of interaction (gravitational, week, strong and electromagnetic interactions).

We shall consider in the following estimates that the laws of nature formed till the instant of time $t = 10^{-10}$ s.

The estimate of mass of initial heterogeneities defining development of our Universe.

Let us compare the mass required for the formation of one microinformation bit and one bit of classical information (macroinformation). From the estimate of mass redundancy of amino acids and basic nitrogens used for the formation of one bit of classical information with reference to mass required for one bit of microinformation we shall get the value of mass redundancy required for the formation of one bit of classical information

The estimate of mass required for the formation of one bit of microinformation.

Energy and mass required for the formation of one bit of microinformation is equal to $E_{bit} = kT \ln 2$, $m_{bit} = (kT \ln 2) / c^2$ [10, 11-12].

The values of energy and mass of one bit of microinformation carrier at the temperatures of 3K and 300K are given in the table 1.

Table 1

Energy and mass of carrier of one bit of microinformation

Temperature	T(K)	3	300
Minimal energy for 1 bit (J)	E = kT	4,14E-23	4,14E-21
Minimal mass for one bit (kg)	$M = kT/c^2$	4,61E-40	4,61E-38

The estimate of mass required for the formation of one bit of classical information.

In general for one bit of classical information in amino acids the mass of 4,43E-25kg is used, redundancy is 9,6E+14 at T = 3K, in basic nitrogens and sugar the mass of 1,05E-25 kg is used in general, redundancy at T = 3K is 1E+14. Thus, we assume that for the formation of one bit of classical information the mass of 10^{15} times greater is needed than the mass required for the formation of one bit mikroinformation.

We shall remark that in general $\approx 1,69 \cdot 10^{-28}$ kg of mass of matter is used in atoms for one bit of information (for example, there is $\approx 1,6 \cdot 10^{-28}$ kg in atoms of hydrogen, $\approx 1{,}93 \cdot 10^{-28}$ kg in atoms of lithium) which is by $\approx 10^{12}$ times greater than the mass required for the formation of one bit of microinformation.

Estimate of the mass of the initial heterogeneities.

Assuming that $E_{bit\ Mi} = kT$, $E_{bit\ cl} \approx 10^{15} E_{bit\ Mi} \approx 10^{15} kT$, then obtain the mass of the initial heterogeneities $m_{Ih} \geq \frac{I_{Ih} \cdot E_{bit\ cl}}{c^2} \geq \frac{I_{Ih} \cdot 10^{15} \cdot kT}{c^2} \geq \frac{I_{Phl} \cdot 10^{15} \cdot kT}{c^2}$.

Because $T = \frac{10^{10}}{t^{1/2}}$, then $m_{Ih} \geq \frac{10^{25} \cdot k \cdot I_{Phl}}{t^{1/2} \cdot c^2}$.

Numerical estimates of the mass of the initial heterogeneities, corresponding to the given volume of classical information in a period from 10^{-35} seconds to one second, are shown in Table 2.

We represent the estimate of mass of the initial heterogeneities for the previous examples.

1) To write a bit of classical information when the current temperature of the Universe T = 2,7 K is required the mass, not less than $M_{bit} = E_{bit} / c^2 \approx 10^{15} 10^{-23}$ J/(9 10^{16}m^2/s^2) ≈ 10^{-25}kg, and at T = 2700 K the mass not less than ≈ 10^{-22}kg is required.

2) Let the Universe be described by the n parameters. The mass, which contains information about the Universe (10^{14} bits), must be a minimum 10^{-12}kg (approximately the mass of 10^{15} protons). At the temperature of the Universe T = 2700 K is required the mass not less than 10^{9}kg (approximately the mass of 10^{18} protons).

Table 2.

Estimates of the mass of initial heterogeneties containing specified volumes of classical information in certain moments time (at a certain temperature)

Time (s)	Tempera-ture, K	Energy (Bit/J)	Mass on 10^2 BCI	Mass on 10^4 BCI	Mass on 10^6 BCI	Mass on 10^8 BCI	Mass on 10^10 BCI	Mass on 10^12 BCI	Mass on 10^14 BCI	Mass on 10^16 BCI
1E-35	3,16E+27	4,37E+04	4,86E+04	4,86E+06	4,86E+08	4,86E+10	4,86E+12	4,86E+14	4,86E+16	4,86E+18
1E-34	1,00E+27	1,38E+04	1,54E+04	1,54E+06	1,54E+08	1,54E+10	1,54E+12	1,54E+14	1,54E+16	1,54E+18
1E-32	1,00E+26	1,38E+03	1,54E+03	1,54E+05	1,54E+07	1,54E+09	1,54E+11	1,54E+13	1,54E+15	1,54E+17
1E-30	1,00E+25	1,38E+02	1,54E+02	1,54E+04	1,54E+06	1,54E+08	1,54E+10	1,54E+12	1,54E+14	1,54E+16
1E-20	1,00E+20	1,38E-03	1,54E-03	1,54E-01	1,54E+01	1,54E+03	1,54E+05	1,54E+07	1,54E+09	1,54E+11
1E-10	1,00E15	1,38E-08	1,54E-08	1,54E-06	1,54E-04	1,54E-02	1,54E+00	1,54E+02	1,54E+04	1,54E+06
1E-06	1,00E+13	1,38E-10	1,54E-10	1,54E-08	1,54E-06	1,54E-04	1,54E02	1,54E+00	1,54E+02	1,54E+04
1E-05	3,16E+12	4,37E-11	4,86E-11	4,86E-09	4,86E-07	4,86E-05	4,86E03	4,86E-01	4,86E+01	4,86E+03
1E-04	1,00E+12	1,38E-11	1,54E-11	1,54E-09	1,54E-07	1,54E-05	1,54E03	1,54E-01	1,54E+01	1,54E+03
1E-03	3,16E+11	4,37E-12	4,86E-12	4,86E-10	4,86E-08	4,86E-06	4,86E04	4,86E-02	4,86E+00	4,86E+02
1E-02	1,00E+11	1,38E-12	1,54E-12	1,54E-10	1,54E-08	1,54E-06	1,54E04	1,54E-02	1,54E+00	1,54E+02
1E-01	3,16E+10	4,37E-13	4,86E-13	4,86E-11	4,86E-09	4,86E-07	4,86E05	4,86E-03	4,86E-01	4,86E+01
1E+00	1E+10	1,38E-13	1,54E-15	1,54E-11	1,54E-09	1,54E-07	1,54E-05	1,54E-03	1,54E-01	1,54E+01

BCI - bits of classical information

3) The volume of classical information in the course of physics, containing 2,000 pages, is about 10^9 bits. At the temperature of the Universe T = 2,7 K requires the mass no less than 10^{-17}kg, and at T = 2700 K the mass no less than 10^{-14}kg (approximately the mass of 10^{13} protons) is required.
4) The volume of classical information in the files that describe the physical laws [189], is about 10^7 bits. At the temperature of the Universe T = 2,7 K the mass not less than 10^{-19}kg is required, and at T = 2700 K the mass not less than 10^{-16}kg (approximately the mass of 10^{11} protons) is required.
5) The volume of information in a file that describes Einstein equation is approximately 10^6 bits. At the temperature of the Universe T = 2,7 K the mass not less than 10^{-20}kg is required, and at T = 2700 K the mass, not less than 10^{-17}kg (approximately 10^3 the mass of protons) is required. At T = 2,7 10^{12} K requires the mass is not less than 10^{-8}kg (mass of one Planck's particle).

Table 3 shows the estimates of the mass of the initial heterogeneities of the Universe necessary for the storage of classical information about physical laws that contain 10^2 - 10^{12} bit

Table 3

Time from the beginning (s)	Temperature (K)	Mass (kg)/ 10^6 BCI	Mass (kg)/ 10^7 BCI	Mass (kg))/ 10^8 BCI
1,00E-44	1,00E+32	1,54E+11	1,54E+12	1,54E+13
1,00E-35	3,16E+27	4,86E+06	4,86E+07	4,86E+08
1,00E-05	3,16E+12	4,86E-09	4,86E-08	4,86E-07
1,00E+00	1,00E+10	1,54E-11	1,54E-10	1,54E-09

Table 4 shows the minimum and maximum estimates of the mass of initial heterogeneities of the Universe which is necessary for the storage of classical information about physical laws that contain 10^2 and 10^{14} bits.

Table 4

Time from the beginning (s)	Temperature (K)	Mass (kg)/ 10^2 BCI	Mass (kg)/ 10^14 BCI
1,00E-44	1,00E+32	1,54E+09	1,54E+21
1,00E-35	3,16E+27	4,86E+04	4,86E+16
1,00E-05	3,16E+12	4,86E-11	4,86E+01
1,00E+00	1,00E+10	1,54E-13	1,54E-01

7. Growth of heterogeneities in the expanding Universe

Consider the transition from the coordinates $x = (x_1, ..., x_n)$ to the coordinates $y = (y_1, ..., y_n)$. The new value of uncertainty (information) [6, 8], characterizing the physical system in the new coordinates is equal to the old one minus the average value of the logarithm of the Jacobian [5]:

$$N_y = -\int ... \int \ p(y_1,...,y_n))\ln p(y_1,...,y_n)dy_1...dy_n = N_x - \int ... \int \ p(x_1,...,x_n)\ln J(\frac{x_1,...,x_n}{y_1,...,y_n})dx_1...dx_n$$

.

Consider the linear transformation of coordinates $y = Ax$ or $y = \|a_{ij}\| x$. In this case the Jacobian is the determinant inversion transformation of coordinates $\|a_{ij}\|^{-1}$.

With the expansion of the Universe

$$y = kx,\ y_i = kx_i\ \ i = 1,2,3\ \ or\ \begin{pmatrix} y_1 \\ y_2 \\ y_3 \end{pmatrix} = \begin{Vmatrix} k & 0 & 0 \\ 0 & k & 0 \\ 0 & 0 & k \end{Vmatrix} \begin{pmatrix} x_1 \\ x_2 \\ x_3 \end{pmatrix}.$$

$J = |a_{ij}|^{-1} = \begin{vmatrix} 1/k & 0 & 0 \\ 0 & 1/k & 0 \\ 0 & 0 & 1/k \end{vmatrix} = \frac{1}{k^3}$ and with the transition from the coordinate system $x = (x_1, x_2, x_3)$ to the coordinate system $y = (y_1, y_2, y_3)$ new value of uncertainty (information) is equal to the old value of uncertainty (information) minus the logarithm of the determinant of the inverse transformation of coordinates: $N_y = N_x - \ln\frac{1}{k^3} = N_x + 3\ln k$.

Change of the uncertainty is $\Delta N = N_y - N_x = 3\ln k$. *By the law of conservation of uncertainty (information) [6, 8], a closed (isolated) systems change uncertainties in the system accompanied by a corresponding change of the information in the system. With increasing uncertainty in the system the amount of information in the system increases. Change of the uncertainty ΔN leads to a corresponding change in the amount of information ΔI:* $\Delta I = \Delta N$ *or* $\Delta I - \Delta N = 0$.

The uncertainty of an isolated system is conserved, whereas there may be a variety of processes defined by its own laws. If during the expansion of the universe uncertainty of particles increases (decreases), then the Universe should be formed (deformed) information in the form of heterogeneities. That is a consequence of the law of conservation of uncertainty [6, 8] which together with other laws [1-3] can explain the phenomenon of heterogeneous evolving the Universe. Consequently, the initial heterogeneities and expansion of the universe leads to the formation information which a compensating increase in uncertainty $\Delta I = \Delta N = 3\ln k$.

When the Universe expands from the size which is characterized by the value R_0 to the size which is characterized by the value R, the volume of information per particle, formed by extension, is equal to $3\log_2\frac{R}{R_0}$ bits

With the expansion of the universe from the Planck's length $10^{-33}cm$ to the current size $10^{28}cm$ the volume of information that is generated by extension of Universe, is equal to 607.8 (bits). With the expansion of the

Universe dominated by matter to the current size the volume of information per particle, formed by extension, is equal to 109.6 (bits) [8].

The growth of heterogeneities in the sedate and inflationary expansion of the Universe.

When the sedate expansion of the Universe during the period 10^{-34} – 10^{-10}s from one bit of classical information approximately 160 bits of classical information is formed. Consequently, to obtain 10^7 bits of classical information in time 10^{-10}s there were been approximately 10^5 bits of classical information at the time $10^{-34}s$ - the mass of the order of 10^7kg, this is apparently impossible. Therefore, the initial information was largely formed during the inflationary expansion of the Universe.

Let the radius of the Universe increases as $r(t) \propto e^{\alpha t}$, where $\tilde{\alpha}$ is degree of exponent. Then at the moment $t_0 + t$ the volume of information is equal to

$$I(t_0 + t) - I(t_0) = \log_2 \frac{V(t_0 + t)}{V(t_0)} = \log_2 \frac{r^3(t_0 + t)}{r^3(t_0)} =$$

$$= 3\log_2 \frac{r(t_0 + t)}{r(t_0)} = 3\log_2 \frac{e^{\alpha(t_0 + t)}}{e^{\alpha t_0}} = 3\log_2 e^{\alpha t} = \alpha t \cdot 3\log_2 e.$$

We obtain the evaluation (α = 1,15 E+34 1/sec) from the ratio of $r(10^{-32}s) = 10^{50} r(10^{-34}s)$ [22].

With inflationary expansion of the universe during the period from 10^{-34}s - 10^{-32}s from one bit of classical information contained in the initial heterogeneities of the Universe, it is generated about 10^3 bits of classical information.

During the further sedate extension of the Universe from instant $10^{-32}s$ to instant $10^{-10}s$ from each bit of the classical information it was formed about 150 bits of the classical information.

Therefore, at the inflationary extension in 10^{-34}s with - 10^{-32}s and the further sedate extension of the Universe in $10^{-32}s$ - $10^{-10}s$ from one classical bit of the information it is formed about 10^5 bits of classical information.

Thus, the classical information formed from Plank's particle obviously is not enough for "recording" of the laws of nature. For creation to the moment $10^{-10}s$ about 10^7 bits of the classical information is necessary to have at the moment of $10^{-34}s$ about 10^2 bits of initial classical information and, accordingly, the mass of heterogeneities of the Universe of the order 10^4kg, is necessary for "recording" the laws of nature.

Such is an estimate of the mass of the initial heterogeneity containing all laws of nature at moment $10^{-10}s$.

If the mass of 1 bit is the estimate for atom of hydrogen (proton) (10^{-28}кг) the mass of initial heterogeneities at the instant $10^{-34}s$ is about 10kg.

If the mass of 1 bit is the estimate for neutrino (10^{-36}kg) (minimum possible estimate) the mass of initial heterogeneities at the instant $10^{-34}s$ is about 10^{-7}kg.

It testifies in favor of the improved hypothesis to the initial information: "Some fourteen billion years ago, at the instant $10^{-34}s$ all the Universe consisted of one place with the radius of 10^{-24}cm. In that volume all the information about the future of the Universe was contained…".

The volume of microinformation in the Universe is equal now the $\approx 10^{90}$ bits [6, 8, 23, 24]. The volume of the classical information in the Universe now is no more than $\approx 10^{75}$ bits.

8. Conclusion

The results obtained with the help of information methods allow us to make the following basic conclusions.

7.1. In this paper, information methods studied, refined and developed the hypothesis of initial information: "…at the moment of birth, all the Universe consisted of one place with the radius of 10^{-33}cm... In that volume all the information about the future of the Universe was contained"

7.2. It is shown that initial heterogeneities of ordinary matter and dark matter in the Universe existed. This assertion is correct at any physical nature of heterogeneities, at any physical mechanism of heterogeneities generation, any physical model of heterogeneities formation.

7.3. It is shown that the initial heterogeneities of dark energy in the Universe did not exist.

7.4. As the very initial heterogeneities contain laws of the nature defining further development of the Universe it allows us to estimate the volume of information contained in the laws of nature. The estimate of classical information volume in laws of the nature and temporal value from the appearance of the Universe make it possible to estimate the mass of initial heterogeneities.

7.5. From for creation to the moment $10^{-10}s$ about 10^7 bits of classical information necessary to have at the moment of $10^{-34}s$ about 10^2 bits of initial classical information and, accordingly, the mass of heterogeneities of the Universe of the order 10^4kg, are necessary for "recording" of the laws of nature. Such is an estimate of the mass of initial heterogeneity containing all laws of nature at moment $10^{-10}s$.

7.6. The improved hypothesis to the initial information: “Some fourteen billion years ago, at the instant $10^{-34}s$ all the Universe consisted of one place with the radius of 10^{-24}sm. In that volume all the information about the future of the Universe was contained…”.

7.7. It is necessary to identify the initial heterogeneities with concrete physical objects.

7.8. We need to understand how in the heterogeneities of the Universe the laws of nature are written, physical laws and they how are implemented.

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ATOMS, MOLECULES AND FUNDAMENTAL RESTRICTIONS ON INFORMATIONAL CHARACTERISTICS OF SYSTEMS

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Abstract: The article shows that volume of information in the atoms, molecules, amino acids and nitrogen bases [4-7], their differential information capacity of usual substance, the mass of a hydrogen atom, the structure and the energy difference between its basis states impose fundamental limits on memory and productivity of computing devices and information systems, including Intellectual Information Technologies and Systems.

Keywords: information, atoms, molecules, amino acids, storage devices, productivity.

1. Introduction

Myths of nanotechnology inflated in order to obtain money, describe fantastic opportunities of works that are offered to finance. Although the possibilities of scientists and engineers are limited by nature itself – by structure and properties of atoms and molecules [1-3]. The article shows that volume of information in atoms, amino acids and nitrogen bases [4-7], their differential information capacity, the mass of a hydrogen atom, the structure and the energy difference between its basis states [8, 9] impose fundamental limits on memory and speed of computing devices and information systems.

2. Differential information capacity of matter

As shown in [4-7] there are some types of matter with different dependence of the volume of information (information capacity) on mass, including: - Linear for usual substance $I \propto M$, - Square-law for black holes $I \propto M^2$, Linearly-logarithmic for neutron stars and white dwarfs) $I \propto M \log_2 M$.
Generally, mass dependence of information volume in substance looks like $I = f(M)$. Variation of information volume in matter dI at variation of its mass dM is defined by differential of function $I = f(M)$

$$dI = \frac{df(M)}{dM} dM = f'(M)dM .$$

The derivative of information volume on mass $\frac{dI}{dM} = \frac{df(M)}{dM} = f'(M)$ $\left[\frac{\text{bits}}{\text{kg}}\right]$ is characterized by differential information capacity (difinformcap) of matter - to change the mass of matter per unit ($dM = 1$) changes the volume of information in the matter to the extent equal to the differential information capacity $dI = f'(M)$.

Let us estimate the volume of information in atoms, amino acids, nitrogenous bases (ordinary matter) which determine the fundamental limits on information capacity devices created by man.

Table 1 shows estimates of the volume of information in atoms [5-7].

Table 1

Element name	Charge (atomic number) - number of protons, electrons	Mass (a.e)	Mass (kg)	Volume of the information in protons, neutrons and electrons	Mass on 1 bit	difinformcap (bits/kg)
Hydrogen	1	1,00794	1,67318E-27	10,422	1,60543E-28	6,22886E+27
Helium	2	4,0026	6,64432E-27	39,688	1,67414E-28	5,97323E+27
Lithium	3	6,941	1,15221E-26	59,532	1,93544E-28	5,16678E+27
Beryllium	4	9,01218	1,49602E-26	88,798	1,68475E-28	5,93561E+27
Boron	5	10,811	1,79463E-26	99,22	1,80873E-28	5,52873E+27
Carbon	6	12,011	1,99383E-26	109,642	1,81849E-28	5,49908E+27
Nitrogen	7	14,0067	2,32511E-26	138,908	1,67385E-28	5,97425E+27
Oxygen	8	15,9994	2,6559E-26	149,33	1,77854E-28	5,62258E+27
Fluorine	9	18,9984	3,15373E-26	169,174	1,8642E-28	5,36424E+27
Neon	10	20,179	3,34971E-26	198,44	1,68802E-28	5,92409E+27
Sodium	11	22,9897	3,81629E-26	218,284	1,74831E-28	5,7198E+27
Magnesium	12	24,305	4,03463E-26	238,128	1,69431E-28	5,9021E+27
Aluminum	13	26,9815	4,47893E-26	257,972	1,73621E-28	5,75968E+27
Silicon	14	28,0855	4,66219E-26	277,816	1,67816E-28	5,95891E+27
Phosphorus	15	30,9737	5,14163E-26	297,66	1,72735E-28	5,78921E+27
Sulfur	16	32,066	5,32296E-26	317,504	1,6765E-28	5,96481E+27
Chlorine	17	35,453	5,8852E-26	346,77	1,69715E-28	5,89224E+27
Argon	18	39,948	6,63137E-26	385,458	1,72039E-28	5,81265E+27
Potassium	19	39,0983	6,49032E-26	386,458	1,67944E-28	5,95438E+27
Calcium	20	40,078	6,65295E-26	396,88	1,67631E-28	5,96548E+27
Scandium	21	44,9559	7,46268E-26	435,568	1,71332E-28	5,83662E+27
Titan	22	47,88	7,94808E-26	464,834	1,70987E-28	5,84838E+27
Vanadium	23	50,9415	8,45629E-26	494,1	1,71145E-28	5,84299E+27
Chrome	24	51,9961	8,63135E-26	504,522	1,7108E-28	5,84523E+27
Manganese	25	54,938	9,11971E-26	533,788	1,70849E-28	5,85313E+27
Iron	26	55,847	9,2706E-26	544,21	1,7035E-28	5,87028E+27
Cobalt	27	58,9332	9,78291E-26	573,476	1,7059E-28	5,86202E+27
Nickel	28	58,69	9,74254E-26	574,476	1,6959E-28	5,89657E+27
Copper	29	63,546	1,05486E-25	622,586	1,69433E-28	5,90205E+27
Zinc	30	65,39	1,08547E-25	642,43	1,68964E-28	5,91843E+27
Gallium	31	69,723	1,1574E-25	681,118	1,69927E-28	5,88489E+27
Germanium	32	72,59	1,20499E-25	710,384	1,69626E-28	5,89533E+27
Arsenic	33	74,9216	1,2437E-25	730,228	1,70316E-28	5,87142E+27
Selenium	34	78,96	1,31074E-25	768,916	1,70465E-28	5,86629E+27

Bromine	35	79,904	1,32641E-25	779,338	1,70197E-28	5,87556E+27
Krypton	36	83,8	1,39108E-25	818,026	1,70053E-28	5,88051E+27
Rubidium	37	85,4678	1,41877E-25	837,87	1,6933E-28	5,90563E+27
Strontium	38	87,62	1,45449E-25	857,714	1,69578E-28	5,897E+27
Yttrium	39	88,9059	1,47584E-25	868,136	1,70001E-28	5,88233E+27
Zirconium	40	91,224	1,51432E-25	897,402	1,68745E-28	5,92611E+27
Niobium	41	92,9064	1,54225E-25	907,824	1,69884E-28	5,88638E+27
Molybdenum	42	95,94	1,5926E-25	937,09	1,69952E-28	5,88401E+27
Technetium	43	97,9072	1,62526E-25	956,934	1,6984E-28	5,88788E+27
Ruthenium	44	101,07	1,67776E-25	995,622	1,68514E-28	5,93423E+27
Rhodium	45	102,905	1,70822E-25	1006,044	1,69796E-28	5,88942E+27
Palladium	46	106,42	1,76657E-25	1044,732	1,69093E-28	5,91389E+27
Silver	47	107,868	1,79061E-25	1055,154	1,69701E-28	5,89271E+27
Cadmium	48	112,41	1,86601E-25	1103,264	1,69135E-28	5,91244E+27
Indium	49	114,82	1,90601E-25	1123,108	1,69709E-28	5,89245E+27
Tin	50	118,71	1,97059E-25	1161,796	1,69615E-28	5,89569E+27
Antimony	51	121,75	2,02105E-25	1191,062	1,69685E-28	5,89328E+27
Tellurium	52	127,6	2,11816E-25	1248,594	1,69644E-28	5,89471E+27
Iodine	53	126,904	2,10661E-25	1240,172	1,69864E-28	5,88706E+27
Xenon	54	131,29	2,17941E-25	1288,282	1,69172E-28	5,91114E+27
Cesium	55	132,905	2,20622E-25	1298,704	1,69879E-28	5,88655E+27
Barium	56	137,33	2,27968E-25	1346,814	1,69265E-28	5,90791E+27
Lanthanum	57	138,905	2,30582E-25	1357,236	1,69891E-28	5,88612E+27
Cerium	58	140,12	2,32599E-25	1377,08	1,68908E-28	5,9204E+27
Praseodymium	59	140,9	2,33894E-25	1378,08	1,69725E-28	5,8919E+27
Neodymium	60	144,24	2,39438E-25	1416,768	1,69003E-28	5,91705E+27
Promethium	61	147	2,4402E-25	1446,034	1,68751E-28	5,92588E+27
Samarium	62	150,35	2,49581E-25	1475,3	1,69173E-28	5,91111E+27
Europium	63	151,96	2,52254E-25	1485,722	1,69785E-28	5,8898E+27
Gadolinium	64	157,25	2,61035E-25	1543,254	1,69146E-28	5,91206E+27
Terbium	65	158,92	2,63807E-25	1553,676	1,69796E-28	5,88944E+27
Dysprosium	66	162,5	2,6975E-25	1592,364	1,69402E-28	5,90311E+27
Holmium	67	164,93	2,73784E-25	1612,208	1,69819E-28	5,88862E+27
Erbium	68	167,26	2,77652E-25	1641,474	1,69148E-28	5,91199E+27
Thulium	69	168,93	2,80424E-25	1651,896	1,69759E-28	5,89071E+27
Ytterbium	70	173,04	2,87246E-25	1700,006	1,68968E-28	5,91828E+27
Lutetium	71	174,97	2,9045E-25	1710,428	1,69811E-28	5,88889E+27
Hafnium	72	178,49	2,96293E-25	1749,116	1,69396E-28	5,90332E+27
Tantalum	73	180,947	3,00372E-25	1768,96	1,69801E-28	5,88923E+27
Tungsten	74	183,85	3,05191E-25	1798,226	1,69718E-28	5,89213E+27
Reinette	75	186,207	3,09104E-25	1827,492	1,69141E-28	5,91223E+27
Osmium	76	190,2	3,15732E-25	1866,18	1,69186E-28	5,91065E+27
Iridium	77	192,22	3,19085E-25	1886,024	1,69184E-28	5,91072E+27
Platinum	78	195,08	3,23833E-25	1915,29	1,69078E-28	5,91444E+27
Gold	79	196,966	3,26964E-25	1925,712	1,69788E-28	5,88968E+27
Mercury	80	200,59	3,32979E-25	1964,4	1,69507E-28	5,89946E+27
Thallium	81	204,383	3,39276E-25	2003,088	1,69376E-28	5,90401E+27
Lead	82	207,2	3,43952E-25	2032,354	1,69238E-28	5,90883E+27
Bismuth	83	208,982	3,4691E-25	2042,776	1,69823E-28	5,88849E+27
Polonium	84	209,987	3,48578E-25	2053,198	1,69773E-28	5,8902E+27
Astatine	85	222,017	3,68548E-25	2176,684	1,69316E-28	5,9061E+27
Radon	86	131,29	2,17941E-25	2262,482	9,63285E-29	1,03811E+28
Frances	87	223,019	3,70212E-25	2188,106	1,69193E-28	5,91042E+27
Barium	88	226,025	3,75202E-25	2217,372	1,6921E-28	5,90982E+27
Actinium	89	227,027	3,76865E-25	2227,794	1,69165E-28	5,91139E+27
Thorium	90	232,03	3,8517E-25	2275,904	1,69238E-28	5,90883E+27
Protactinium	91	231,03	3,8351E-25	2267,482	1,69135E-28	5,91245E+27
Uranus	92	238,02	3,95113E-25	2334,436	1,69254E-28	5,90827E+27

Neptunium	93	237,04	3,93486E-25	2326,014	1,69168E-28	5,91129E+27
Plutonium	94	244,06	4,0514E-25	2392,968	1,69304E-28	5,90653E+27
Americium	95	243,06	4,0348E-25	2384,546	1,69206E-28	5,90995E+27
Curium	96	247,07	4,10136E-25	2423,234	1,69252E-28	5,90836E+27
Berkelium	97	247,07	4,10136E-25	2424,234	1,69182E-28	5,9108E+27
Californium	98	251,07	4,16776E-25	2462,922	1,6922E-28	5,90946E+27
Einsteinium	99	252,08	4,18453E-25	2473,344	1,69185E-28	5,91069E+27
Fermium	100	257,09	4,26769E-25	2521,454	1,69255E-28	5,90824E+27
Mendeleev	101	258,09	4,28429E-25	2531,876	1,69214E-28	5,90967E+27
Nobelium	102	259,1	4,30106E-25	2542,298	1,6918E-28	5,91086E+27
Lawrencium	103	260,1	4,31766E-25	2552,72	1,6914E-28	5,91228E+27
Rf	104	261	4,3326E-25	2563,142	1,69035E-28	5,91594E+27
Dubna	105	262	4,3492E-25	2573,564	1,68995E-28	5,91733E+27
Siborgovy	106	263	4,3658E-25	2583,986	1,68956E-28	5,9187E+27
Bohrium	107	262	4,3492E-25	2594,408	1,67637E-28	5,96525E+27
Hassium	108	265	4,399E-25	2604,83	1,68879E-28	5,92141E+27
Meitnerium	109	266	4,4156E-25	2615,252	1,6884E-28	5,92276E+27
Un-un-nuly	110	271	4,4986E-25	2663,362	1,68907E-28	5,92042E+27
Average			2,46354E-23		1,69449E-28	5,92149E+27

On the average in atoms $\approx 1{,}69 \cdot 10^{-28}$ kg of substance is used on 1-bit of information, The mean-square deviation is equal to $\approx 7{,}86 \cdot 10^{-30}$ which does not exceed 5% of the mean value. It's about $\approx 6 \cdot 10^{11}$ times more than the minimum mass necessary for the formation of one bit of microinformation at 2,7 K temperature, equal to $m_{\min} = \frac{kT}{c^2}\ln 2 = \frac{2{,}7k}{c^2}\ln 2 \approx 10^{-40}$ kg.

Table 2 shows examples of estimating the volume of information in amino acids and nitrogen bases [5-7].

Table 2

Title	Mass (a.e)	Mass (kg)	Volume of information (bits)	Mass on 1 bit (kg / bit)	Difinform-capacity (bits / kg)
Amino acids					
Alanine	89,09	1,48E-25	4,321	3,42E-26	2,92E+25
Arginine	174,2	2,89E-25	4,321	6,69E-26	1,49E+25
Aspartic acid	133,1	2,21E-25	4,321	5,11E-26	1,96E+25
Asparagine	132,12	2,19E-25	4,321	5,07E-26	1,97E+25
Valine	117,16	1,94E-25	4,321	4,50E-26	2,22E+25
Histidine	155,16	2,58E-25	4,321	5,96E-26	1,68E+25
Glycine	75,07	1,25E-25	4,321	2,88E-26	3,47E+25
Glutamic acid	147,13	2,44E-25	4,321	5,65E-26	1,77E+25
Glutamine	146,15	2,43E-25	4,321	5,61E-26	1,78E+25
Isoleucine	131,17	2,18E-25	4,321	5,04E-26	1,98E+25
Leucine	131,17	2,18E-25	4,321	5,04E-26	1,98E+25
Lysine	146,19	2,43E-25	4,321	5,61E-26	1,78E+25
Methionine	149,21	2,48E-25	4,321	5,73E-26	1,74E+25
Proline	115,13	1,91E-25	4,321	4,42E-26	2,26E+25
Serene	105,09	1,74E-25	4,321	4,04E-26	2,48E+25
Tyrosine	181,19	3,01E-25	4,321	6,96E-26	1,44E+25
Threonine	119,12	1,98E-25	4,321	4,58E-26	2,19E+25

Tryptophan	204,22	3,39E-25	4,321	7,84E-26	1,27E+25
Phenylalanine	165,19	2,74E-25	4,321	6,34E-26	1,58E+25
Cysteine	121,16	2,01E-25	4,321	4,65E-26	2,15E+25
Amount	2738,02	4,55E-24		1,05E-24	9,51E+23
Average	136,901	2,27E-25		5,26E-26	1,90E+25
Average on 1 bit	31,67	5,26E-26		1,22E-26	8,22E+25
The nitrogenous bases and sugars					
Adenine	135,13	2,24E-25	2,0	1,12E-25	8,92E+24
Guanine	151,13	2,51E-25	2,0	1,25E-25	7,97E+24
Timin	126,11	2,09E-25	2,0	1,05E-25	9,55E+24
Cytosine	111,1	1,84E-25	2,0	9,22E-26	1,08E+25
Uracil	112,1	1,86E-25	2,0	9,30E-26	1,07E+25
Deoxyribose	134	2,22E-25	2,0	1,11E-25	8,99E+24
Ribose	150	2,49E25	2,0	1,25E-25	8,03E+24
Amount				7,63E-25	1,31E+24
Average				1,09E-25	9,17E+24
Average on 1 bit				0,55E-25	1,83E+25

In amino acids and nitrogen bases $\approx 10^{-25}, 10^{-26}$ kg of substance is used on 1 bit of information, on the average. Excess of minimum mass is about 10^{15} times.

The same mass as amino acids and nitrogenous bases have atoms from 37 Y 88,9059 – yttrium; 40 Zr 91,22 – zirconium (the minimal mass) up to 81 Tl 204,37 – thallium; 82 Pb – 207,2 lead (the maximal mass). Masses of atoms are close to average mass of amino acids and nitrogenous bases 53 I 126,9045 - iodine, 54 Xe - 131,30 - xenon, 55 Cs 132,9054 - Cs, 56 Ba 137,33 - barium and 57 La 138,9 – lanthanum.

In atoms $\approx 1{,}69 \cdot 10^{-28}$ kg of mass of substance on 1 bit of information on the average is used, which is about by $\approx 6 \cdot 10^{11}$ times more than the minimal mass necessary for the formation of 1 bit of information. Proteins and amino acids for the formation of 1 bit of information use mass by a factor of $10^2 - 10^3$ more, than atoms - $\approx 10^{-25}$ kg. Consequently, coding of information by amino acids and nitrogenous bases is highly efficient.

3. The basic characteristics of hydrogen atom

Let's consider characteristics of the atom of hydrogen [8] used in the article.

The atom of hydrogen consists of proton and electron. Mass of hydrogen atom is - $m_H = 1{,}67 \cdot 10^{-27}$ kg.

The diameter of hydrogen atom is - $d_H \approx 10^{-10}$ m. The volume of hydrogen atom is - $V_H \approx 10^{-30}$ м^3.

The hydrogen atom in the ground state with the minimum energy contains 11.422 bits (one bit in the structure of the atom, 9.422 bits in proton and 1-bit in electron) [6-7].

As [9], we define the initial (non-stationary) basis states of hydrogen atom:

$|{+}{+}\rangle$ - state **1.** Both electron and proton spins are looking up. $|{+}{-}\rangle$ - state **2.** In electron spin looks down, and proton - up. $|{-}{+}\rangle$ - state **3.** In electron spin looks down, and proton - up. $|{-}{-}\rangle$ - state **4.** Both electron and proton spins look down. The first plus or minus sign refers to electron, and the second - to proton. We denote these states | 1>, | 2>, | 3> and | 4>.

Description of the dynamics of hydrogen atom is done by the following Hamiltonian matrix H_{ij}:

$$H_{ij} = \begin{pmatrix} A & 0 & 0 & 0 \\ 0 & -A & 2A & 0 \\ 0 & 2A & -A & 0 \\ 0 & 0 & 0 & A \end{pmatrix}.$$

Differential equations for the four amplitudes $\mathbf{C}_i$ of the stationary basis states have the form

$$i\hbar\dot{C}_1 = AC_1,$$
$$i\hbar\dot{C}_2 = -AC_2 + 2AC_3,$$
$$i\hbar\dot{C}_3 = 2AC_2 - AC_3,$$
$$i\hbar\dot{C}_4 = AC_4.$$

We obtain the levels of ground-state energy (the energy levels of stationary states) of hydrogen atom, by solving Hamiltonian equations. This means that we must find those special state |ψ>, for which each of the amplitudes C_i= <i| ψ> has the same time dependence, namely $e^{-i\omega t}$. Then the state will have energy E = hω. So $C_i = a_i e^{-(i/\hbar)Et}$, where the four coefficients a_i do not depend on time. Following the reduction in the overall exponential factor we get

$$Ea_1 = Aa_1,$$
$$Ea_2 = -Aa_2 + 2Aa_3,$$
$$Ea_3 = 2Aa_2 - Aa_3,$$
$$Ea_4 = Aa_4.$$

If we choose E=A**,** then $a_1 = 1,\ a_2 = a_3 = a_4 = 0$.

We assume that our first solution is the state $|I\rangle = |1\rangle = |+\ +\rangle$. $E_I = A$

The next solution will be called the state $|II\rangle = |4\rangle = |-\ -\rangle$, $E_{II} = A$.

Solutions |III> and | IV> is a mixture of the state | 2> and | 3>:

$$|III\rangle = \frac{1}{\sqrt{2}}(|2\rangle + |3\rangle) = \frac{1}{\sqrt{2}}(|+\ -\rangle + |-\ +\rangle),\ E_{III} = A,$$

$$|IV\rangle = \frac{1}{\sqrt{2}}(|2\rangle - |3\rangle) = \frac{1}{\sqrt{2}}(|+\ -\rangle - +|-\ +\rangle),\ E_{IV} = -3A.$$

Results of four fixed orthogonal (basis) states and their energy have been found. Three states have energy equal to A, and the last state-3A.
The difference in energies between the state | IV> and any of the other is equal to 4A.
The atom, which is in the state | I>, can go from there to the state | IV> and emit microwave quantum.
If one lights hydrogen gas with microwaves, there will be absorption of energy. Atoms in the state |IV> will absorb quantums of radiation and pass in one of the states with energy A, but all this only on frequency =4A|h, equal to

$$f = \frac{\omega}{2\pi} = (1\ 420\ 405\ 751{,}800 \pm 0{,}028)\ \text{Hz}.$$

This is the frequency corresponding to the wavelength of the spectral line at 1420 MHz - "21-cm line of hydrogen. Radiation with such wavelength is emitted or absorbed by atomic hydrogen gas in galaxies.

4. Hydrogen atom as a q-bit

Let us consider hydrogen atom as a q-bit (quantum bit) [10]

$$\psi_H = \frac{1}{\sqrt{2}}(|0\rangle + |1\rangle.$$

q-bit is a system having two dedicated (basic) stationary states with definite energies (|0>, |1>) and the states ψ, which can be represented in the form of linear combinations of the selected states $\psi = c_1$ |0>, + c_2 |1>, c_1, c_2 – arbitrary complex coefficients, the sum of the squares of modules of which is equal 1 $|c_1|^2 + |c_2|^2 = 1$.
The uncertainty (volume of information) of q-bit with two dedicated (basic) stationary states is equal $N = -(|c_1|^2 \ln |c_1|^2 + |c_2|^2 \ln |c_2|^2)$, where $|c_1|^2$, $|c_2|^2$ – probability of finding the q-bit in the states 1, 2. The maximal uncertainty (information) of q-bit is reached at $|c_1|^2 = |c_2|^2 = ½$ and is equal to 1 bit.
As noted in section 3 the wave functions corresponding to different power levels ($|I\rangle$, $|II\rangle$, $|III\rangle$, – levels with identical maximal energy, - $|IV\rangle$ the basic level with the minimal energy) look like [9]:

$$\left.\begin{aligned} |I\rangle &= |+\,+\rangle \\ |II\rangle &= |-\,-\rangle \\ |III\rangle &= \frac{|+\,-\rangle + |-\,+\rangle}{\sqrt{2}} \end{aligned}\right\} \text{spin} = 1.$$

$$|IV\rangle = \frac{|+\,-\rangle - |-\,+\rangle}{\sqrt{2}} \quad \text{spin} = 0.$$

In the structure of states $|I\rangle$, $|II\rangle$, volume of information is – 0 bit, and earlier, in the structure of states $|III\rangle$, $|IV\rangle$ – 1 bit.

Let the state $|0\rangle$ is identified with the basis state $|IV\rangle$ of hydrogen atom.
The state $|1\rangle$ is identified with the basis state $|III\rangle$ of hydrogen atom,
The energy difference of the basis states of hydrogen atom, considered as a q-bit, is equal to $\Delta E = E_0 - E_1 = h\nu \approx 1,054 \cdot 10^{-34} \cdot 1,42 \cdot 10^{12} = 1,5 \cdot 10^{-22}$ joule.
On the basis of the considered system of the basis states of hydrogen atom it is possible to offer one more system of basis states of the fundamental q-bit.
Let the state $|0\rangle$ is identified with the basis state $|IV\rangle$ of the hydrogen atom, and the state $|1\rangle$ is identified with the superposition of basis states of the hydrogen atom $|I\rangle$, $|II\rangle$, $|III\rangle$. $|1\rangle = \frac{1}{\sqrt{3}}(|I\rangle + |II\rangle + |III\rangle)$. Since the basic states $|I\rangle$, $|II\rangle$, $|III\rangle$, are orthogonal basis state $|IV\rangle$, then their superposition also orthogonal basis states $|IV\rangle$, and the normalization factor $\frac{1}{\sqrt{3}}$ ensures the equality to unit of the standards superposition.
And in this case, the energy difference of basis states of hydrogen atom considered as q-bit, is equal to $\Delta E = E_0 - E_1 = \hbar\nu = \hbar f \approx 1{,}054 \cdot 10^{-34} \cdot 1{,}42 \cdot 10^{12} = 1{,}5 \cdot 10^{-22}$ joule.

5. Fundamental restrictions on information capacity

Presented in sections 2-4 estimate of the amount of information, differential information capacity of atoms, as well as amino acids and nitrogen bases define fundamental limits on information capacity of storage devices $I = f(M) = \int_0^M f'(m)dm$. For ordinary matter $I = \beta M$, $f'(M) = \beta$. Differential information capacity of usual substance does not depend on its mass. For usual substance contained in atom, molecule $I_{at,mol}$ bits on 1 bit of information the mass $\beta = \frac{I_{at,mol}}{m_{at,mol}}$ is necessary. Therefore $I = \frac{I_{at,mol}}{m_{at,mol}} M$, $f'(M) = \frac{I_{at,mol}}{m_{at,mol}}$. As shown in [6], differential information capacity of atoms of different elements and, accordingly, molecules, is roughly identical.
Restriction on the information capacity, imposed by differential information capacity of inanimate matter. Atoms are elementary natural means of information storage of the information. The bottom border $G \approx 10^{-28}$ bits/kg of differential information capacity of artificial data storage device is defined on the basis of assessment of differential information capacity of atoms – $\approx 10^{-28}$ bits/kg.
Consequently, the information capacity I of artificial storage devices, built on the basis of atoms does not exceed $\leq 10^{28} M$ bits, where M - mass of

storage devices directly used for storage. Since current differential information capacity of storage devices is $\approx 10^{14}$ bit/kg [5], while for devices built on the basis of atoms, it can be increased by no more than by $\approx 10^{14}$ times. This restriction ($\leq 10^{28} M$) is the most powerful fundamental limitation dictated by nature of the information capacity of natural and artificial systems.

Restriction on the information capacity, imposed by characteristics of hydrogen atom. On the one bit in the hydrogen atom, considered as a q-bit, the nature spending $m_H = 1{,}67 \cdot 10^{-27}$ kg**.** Consequently, the information capacity I of artificial storage devices, built on the basis of hydrogen atoms used as q-bits, does not exceed $\leq 6 \cdot 10^{26} M$ bits, where M - is mass of storage devices directly used for storage - mass of hydrogen.

Restriction on the information capacity, imposed by differential information capacity organized matter. Proteins, DNA – the simplest natural storage devices, constructed by nature out atoms. The bottom border $G \approx 10^{-25}$ bits/kg of differential information capacity artificial data storage is defined on the basis of assessment of differential information capacity of proteins, DNA – $\approx 10^{-25}$ bits/kg.

Consequently, the information capacity I of artificial storage devices, built on the basis of proteins, DNA does not exceed $\leq 10^{25} M$ bits, where M - mass storage devices directly used for storage. Since current differential information capacity of storage is $\approx 10^{14}$ bit/kg [5], for devices built on the basis of combinations of atoms, it can be increased by no more than by $\approx 10^{11}$ times.

6. Fundamental restrictions on productivity

The difference between the energies of the basis states of the hydrogen atom, considered as a q-bit, impose fundamental limitations on the speed of computing devices. According to the theorem of Margolis and L. Levitin [4], the total number of elementary actions that the system can perform per second, is limited by $k_{on/c} = 2E/\hbar$: where E - is the excess of the average energy of the system over the energy of the lowest state, $\hbar = h/2\pi$ = 1,0545 10^{-34} joule - reduced Planck's constant. The number of operations is satisfied by a hydrogen atom, a q-bit, limited by $k_{op/s} = 2\Delta E/\hbar \approx 1{,}5 \cdot 10^{12}$ operations per second.

7. Fundamental restrictions on the characteristics of the computer built from atoms of hydrogen, the mass of which is one kilogram

The memory of the computer built from atoms of hydrogen, the mass of which is one kg, does not exceed 0,6 10^{27} bits. The productivity of the computer built from atoms of hydrogen, mass of which is one kg, not more than 10^{39} op/sec.

8. Restrictions on characteristics of a computer of nanorobot

In 1986, an American engineer Eric Drexler proposed using for the production of nanodevices the mechanical machines of the (100-200 nm) sizes - nanorobots [2]. These robots must collect the device directly from the atoms, so they were called assemblers. The assembler is equipped with manipulators of a few tens of nanometers and the motor to move the manipulator and the robot itself, including the gear and transmission, as well as an autonomous source of energy. Nanorobotics should consist of several tens of thousands of parts, and every detail - from one to two hundred atoms. The most important node nanorobot was the onboard computer to control the operation of all the mechanisms that determine in what place the future structure should be putting atom or molecule. Linear dimensions of this computer should not exceed 40-50 nm. The volume of PC is $V_C \approx 10^{-22}$ m^3. In such a computer 10^8 atoms of hydrogen can be accommodate. Consequently, the nanorobot's computer memory built from atoms of hydrogen does not exceed 10^8 bits, and its productivity does not exceed 10^{20} op/sec.

9. Conclusion

1, Estimates the volume of information in the atoms, amino acids, nitrogenous bases, differential information capacity of ordinary matter, are determine the fundamental limits on information capacity storage devices.

2. The volume of information in a hydrogen atom and the structure and energy difference between the basis states of the hydrogen atom, considered as a q-bit, impose fundamental limits on memory and speed of computing devices.

3. Restrictions 10^{28} bit/kg, 10^{39} (op/sec)/kg can add a number of fundamental natural limits, including the speed of light, elementary charge, Planck's time, ...

4. The resulted estimates do not consider expense of mass, energy and time for management of processes of storage of information and calculations which can repeatedly increase the mass and size and temporary characteristics of computing systems are essential (not less, than by three orders) to reduce the resulted values of memory and speed.

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THE BASIC INFORMATION CHARACTERISTICS OF OUR UNIVERSE

(Gurevich I.M. Information characteristics of physical systems. /In Russian/. Second edition refined and updated. "Cypress". Sevastopol. 2010. Pp. 212-222.
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1. Information volume in our Universe

Information is inseparably linked with matter and energy. Information [1] is physical heterogeneity steady for certain time, heterogeneity of matter and energy. The energy necessary for formation of one bit of microinformation [2] is equal to $E_{bit} = kT \ln 2$ [3]. The mass necessary for formation of one bit of the microinformation is equal to $m_{bit} = kT \ln 2 / c^2$. The values of energy and mass of the carrier of 1 bit of microinformation are resulted at temperatures 3K (300K). The minimum energy for 1 bit is equal to 4,14199E-23 (4,14199E-21) joule. The minimum mass for 1 bit is equal to 4,60858E-40 (4,60858E-38)kg. On the average in atoms for 1 bit of information is used $\approx 1,69 \cdot 10^{-28}$ kg of mass of substance (for example, in atom of hydrogen is used $\approx 1,6 \cdot 10^{-28}$kg, in atom of lithium - $\approx 1,93 \cdot 10^{-28}$kg). It is approximately by $\approx 10^{12}$ times more than the mass necessary for formation of one bit of microinformation.

The reason and source of information formation is expansion of the Universe and initial heterogeneity. At symmetry infringement between weak and electromagnetic interactions in the Universe it is formed 10^{90} bits. The information mechanism of particles formation in the inflationary Universe generates quantity of particles, comparable with the standard estimation of the number of particles in the Universe, - an order of 10^{80} - 10^{90}.

The minimum possible volume of information in the Universe with prevalence of substance is $\approx 1,7 \cdot 10^{79}$, in the Universe with prevalence of radiation is $\approx 10^{91}$ bits. The greatest possible volume of information in the Universe is $\approx 10^{120}$ bits [4-7]. Growth of volume of information at sedate expansion of the Universe is $\propto \log_2 t$. Reduction of density of information at sedate expansion of the Universe is $\propto (\log_2 t)/t^2$. Growth of information volume at inflation expansion of the Universe is $\propto \alpha t$. Reduction of density of information at inflation expansion of the Universe is $\propto te^{-3\alpha t}$.

2. Information volume in some fundamental, elementary particles and atoms

Fundamental particles are the most simple physical systems (elementary systems by Zeilinger A. [8]).

There is 1 bit in a lepton.

There is 1 bit in a quark.

One photon with circular polarization contains 1 bit.

One photon, z^0-boson - products of electroweak interaction contains 0,78 bits.

Elementary particles represent physical systems of the second level of complexity.

There are 9,422 bits in a proton, a neutron (taking into account the structure of proton, neutron, the information in quarks, colors of quarks).

Atoms represent physical systems of the third level of complexity.

There are 11,422 bits in the atom of hydrogen (1st element) - (taking into account the structure of atom, the information in protons, neutrons).

There are 39,688 bits in the atom of helium (2nd element).

There are 109,642 bits in the atom of carbon (6th element).

There are 544, 21 bits in the atom of iron (26th element).

There are 2334,436 bits in the atom of uranium (92nd element). In the above-mentioned cases the structure of atoms and external uncertainty electrons is not considered.

The estimates of the joint entropy of matrixes mixture of electroweak interaction (1,7849; 1,7787; 1,7645; 1,7945) according to different independent experimental data, are close to the estimates of the joint entropy of matrixes mixture of quarks (1,7842, 1,7849) [5].

3. Information volume in stars

The Sun contains $\approx 1,3 \cdot 10^{58}$ bits.

White dwarf with the mass of solar mass contains $\approx 1,24 \cdot 10^{59}$ bits.

Neutron star of solar mass contains $\approx 2,38 \cdot 10^{59}$ bits.

4. Information volume in black holes

Plank's black hole contains one nut of information, thereby it is possible to consider nut as one Plank's information unit (one bit is Shannon's information unit).

Existence of matter of two types: with square-law and linear dependence of volume of information on mass is source, reason of existence of optimal black holes which minimize volume of information in any region of the Universe and in the Universe as a whole.

Information and mass volumes, received at the decision of the direct problem (Minimization of volume of information in the system «usual substance – black hole» at the set mass of system) and the dual problem (maximization of mass of the system «usual substance – black hole» at the set volume of information in the system), coincide.

There are $\approx 10^{62}$ bits in the optimal black hole generated in the system «radiation (photons) - black hole» at the temperature of radiation - 2,7K. There are $\approx 2,57 \cdot 10^{38}$ bits in the optimal black hole generated in the system «hydrogen (protons) - black hole».

At the temperature of radiation $T = m_p c^2 / 9,422k \ln 2 = 1,555 \cdot \mathrm{E} + 12$ K (at the time from «the big explosion» of the Universe 10^{-5}) the mass of the optimal black holes which have arisen in the systems «radiation - black hole», is equal to the mass of the optimal black holes which have arisen in the systems «hydrogen (protons) - black hole». In transition from «the Universe with prevalence of radiation to the Universe with prevalence of substance (10^4K> T> 10^3K) the mass of the optimal black hole in the system « radiation - black hole» varies from 2,45E+19kg to 2,45E+20kg.

• The masses of the optimum black holes shaped of various types of atoms of usual substance or mixture of various types of atoms of usual substance, and information contents in them are approximately identical.

The black holes of solar mass contain $\approx 7,72 \cdot 10^{76}$ bits.

The black holes with the mass of one million solar mass contain $\approx 7,72 \cdot 10^{94}$ bits.

The black holes in centers of galaxies contain $\approx 10^{90} - 10^{107}$ bits.

5. Information volume in galaxies

In galaxies having 10^{11} of stars, there are about 10^{69} bits. In galaxies having 10^{11} of stars and containing in kernels super massive black holes with the mass of $\approx 10^6 - 10^{10}$ of solar mass, there are $\approx 10^{99} - 10^{107}$ bits.

6. Information dependence of temperature of radiation on mass

For a black hole the dependence of temperature on mass (S. Hawking's spectrum) looks like $T = (\hbar c^3 \ln 2) / (4\pi GMk)$.

For a neutron star the dependence of temperature on mass (an information spectrum) looks like $T = (m_n c^2) / k(9,422 + \log_2 M / m_n)$.

7. Information restrictions at creation of black holes from stars

The mass of a black hole formed from the star of the sun’s type is no more than $\approx 8 \cdot 10^{20}$ kg.

The mass of the black hole formed from the white dwarf of solar mass is no more than $\approx 2,5 \cdot 10^{21}$ kg.

The mass of a black hole formed from the neutron star of solar mass is no more than $\approx 4{,}17 \cdot 10^{21}$ kg.
Note. A black hole at formation uses only part of mass. Other mass in the form of usual substance dissipates in surrounding space and other objects can be formed of it.

8. Information restrictions at the merge of black holes
At the merge of two black holes having the mass M_1 M_2, without the use of additional usual substance, the mass of the resulting black hole is less, than $\sqrt{M_1^2+M_2^2}$.
At the merge of two black holes having the mass M_1 M_2, with the use of additional usual substance, the mass of the resulting black hole is more than $\sqrt{M_1^2+M_2^2}$.

9. Classical information
Nitrogenous basis contains $\log_2 4 = 2$ bits of classical information (macroinformation [2]).
. Amino acids contain $\log_2 20 = 4,32$ bits of classical information.
For 1 bit of information formed by amino acids and nitrogenous basis it is needed 4,43E-25 and 1,05E-25kg of mass.
Redundancy of classical information formed by life, in relation to micro information at the temperature of 300K is by factor of $\approx 10^{13}$ times more.
Proteins and DNA for formation of 1 bit of information use mass by three orders more than atoms. Hence, life is effective way of classical information formation.
Redundancy of classical information generated by modern civilization, in relation to microinformation is by factor of $\approx 10^{23-25}$ times more. Efficiency of nature in formation of classical information exceeds efficiency of person, a terrestrial civilization by $\approx 10^{10}$ times.
Proteins of yeast contain about 2000 bits of classical information.
One chromosome of a person contains $(1-5)\cdot 10^{8}$ bits of classical information.
One person contains $\approx 10^{26}$ bits of classical information.
Biomass of the Earth contains about 10^{40} bits of classical information. If 100 % of the Earth's mass is used for the formation of live substance it will generate about 10^{50} bits of classical information.
If 1 % of the Universe's mass is used for the formation of live substance it will generate approximately 10^{75} bits of classical information.
The greatest possible volume of classical information in the Universe is $\approx 10^{77}$ bits.

$10^{40} - 10^{77}$ bits is a range of possible volume of classical information in the Universe, defined by the data known now.

The volume of classical information formed by terrestrial civilization is $<10^{30}$ bits/year. Parity of volumes of information in the Universe in a year, generated by matter and civilization is $\approx 10^{-49}$. The share of information formed by civilization on one star system is equal to 10^{-27}. It shows that now the contribution of terrestrial civilization to information formation of the Universe is insignificant.

10. Cognitive process of the Universe

The Universe, information volume of which is finite, effective and completely knowable [9].

The Subject of cognitive process is classical object (for example, terrestrial civilization).

In the course of the Universe cognitive process compression of information is not less, than $\approx 10^{20}$ times and no more, than $\approx 10^{76}$ times.

The gravitation Law, in particular, compresses the information not less than by factor of $4 \cdot 10^{183}$ times.

Interpretation of cognitive process by methods of quantum mechanics (the description and measurement) on the basis of information parities is possible. The knowledge is carried out through a hypothetical information channel - «the knowledge channel of nature». The limited throughput of "the knowledge channel of nature» defines as impossible "exact" (in classical sense) descriptions and measurements of quantum objects. Increasing accuracy (uncertainty) of the description/measurement of one of the components, the observer is compelled to reduce accuracy (uncertainty) of the description/measurement of the other.

11. Information unity of all possible universes

As heterogeneity should exist in the universes with any physical laws the approach which is based on information properties of heterogeneities of any nature and corresponding information laws and restrictions, and also physical laws of conservation following from them, such approach extends on all possible Universes. Thereby, physical laws of conservation and information restrictions on other possible physical laws in different Universes are identical. Does ịt mean that all of possible universes are identical?

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DATA COMPRESSION BY "INTELLIGENCE" IN THE PROCESS OF COGNITION OF THE UNIVERSE

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The most inexplicable thing in the Universe is the fact that it is explicable.

A. Einstein

The paper proposes a method to estimate an information compression rate by "intelligence" in the process of cognition of the Universe based on usage of laws of informatics and the complexity theory. It is shown that the Universe is effectively cognizable.

1. Introduction

Up to now, the questions of cognizability of so complex system as nature (the universe, the world) **were discussed at a qualitative — philosophic level.**

The informatics laws give a possibility **of using quantitative estimations** when studying the problems of cognizability of complex systems including the questions of cognizability of the Universe (hereinafter its observable part is meant). As will be shown below, at a definite ratio of diversity of a complex system (an object) and an observer (a subject) and also when information is compressed by the observer, the complex systems with finite information, including the Universe, are cognizable, and, what is more, effectively cognizable.

2. Modern conceptions of cognizability

"Scientific cognition is regarded dialog" between a cognizing subject and the World (a subject in a general sense, but not as a separate person). There exist objects in the World characterized by inherent properties and laws, and we (like Columbus) discover these properties and laws by beginning an interaction (a dialog) with objects under investigation which allow us to specify and correct our knowledge. As a matter of fact, this dialog conception is a standard model of science" (Illarionov, 2002).

E. Schrodinger (2001) analyzed evolution of ideas of cognizability of nature. The search for the answer to this question was first started by the Ancient Greeks. They concluded that nature is cognizable. "All our modern way of thinking is based on the thinking of the Ancient Greeks. That is why, this is something special, something grown historically during many centuries; this is not a general, but the only possible way of thinking about nature. What are peculiar features of our scientific view of the world? One of these basic features cannot be doubted. This is a hypothesis that *the manifestation Nature can be comprehended...*

David Hume discovered that the dependence between cause and effect cannot be observed directly and forms nothing but a constant sequence. This great discovery is a fundamental epistemological discovery. This point of view, in a more complex form of philosophic positivism, was enthusiastically accepted by contemporary physicists. "However, I think it should not be stated even from the positivistic point of view that science does not express comprehension. For even if it turned out to be correct (as they claim) that we only observe and register facts and reduce them to a convenient mnemonic systematization, there still exist real relations between our discoveries in various areas of knowledge which are distant from each other and also between them and most of our fundamental general ideas. These relations are so amazing and interesting that the term "comprehension" seems to be very appropriate for us to finally realize and remember them...

There is another feature which is displayed much less clearly and openly, but which has the same fundamental significance. It is the fact that science, in its attempt to describe and understand nature, simplifies this difficult problem very much. A scientist subconsciously, almost unintentionally simplifies his task in understanding nature by excluding himself, his own personality, i.e. the subject of cognition from consideration or by cutting it from a picture that should be constructed."

A. Einstein (1952) points out the miracle of essential order of the objective world: "You find it astonishing that I speak about cognizability of the world (inasmuch as we have right to speak about it) as of a miracle or an eternal mystery. Well, a piori, we should expect of chaotic world that cannot be cognized by thinking. We only may (or we should) expect that this world obeys a law as much as we can put it in good order by our mind. It would be an order similar to the alphabetical order of words of a language. On the contrary, the order introduced by, say, Newton's theory of gravitation is of quite a different character. Though axioms of this theory are created by man, the success of this undertaking suggests an essential ordering of the objecting world for which we have no reason to expect a priori. It is just what "a miracle" is; and the more our knowledge develops, the more magic it becomes. Positivists and professional atheists consider it to be vulnerability because they are happy to think that they successfully managed not only to expel God from this world, but also "to deprive this world of miracles". It is curious that we should be satisfied with recognition of "a miracle" because we have no legal ways to get out of this situation".

G. Lemaitre: "The scientific progress consists in discovery of more and more universal simplicity. ...The previous success gives us confidence in the future of science: we understand more and more that the Universe is cognizable. ...I hope I have shown that the Universe is not beyond human contrivance. ...The Universe is not too large for a human; it exceeds neither human scope, nor abilities of human spirit" (Efremov, 1999; Godart, Heller, 1985).

The existing forms and stages of cognition are discussed by I.V. Prangishvili (2003): "... The power of universal laws and rules of nature does can give an impression that there is a creator... *Mankind observed three stages of the nature study* and states of science: *the first stage* is Ancient and Middle Ages when a comparatively nonsegmented science prevailed; *the second stage* is the stage of differentiation of science which appeared sharply in the period from the Renaissance till the middle of the XIX century and which is still lasting to some extent; *the third stage is the integration of science,* which is observed now and which will last in future.

As is known, the foundations of scientific knowledge are initial theses, *new phenomena, laws and regularities.* Scientific activity means activity both in obtaining *new* knowledge, and in applying it.

Laws and regularities of nature *are objective, independent of us just because they do not depend absolutely on wishes, will and consciousness of people.* They may not be canceled, forbidden, replaced. All occurring in the material world can be implemented only by a material law, and not by any other law or regularity.

Now the modern scientific ideology and different points of view on problems of creation of the world, of live and lifeless nature are elaborated. Various methodological approaches to comprehension of the world evolution are used, for example, reductionism, evolutionism, holism, etc."

N.S. Kardashev thinks that our neighbors can be super civilizations of age of 6-8 billion years. In his paper (Kardashev, 1997) he writes: "The analysis of currently available astronomical information points out that among extragalactic objects super civilizations can exist with technological development of 6-8 billion years, which is considerably more than the age of the terrestrial one. The age of the disk of our Galaxy exceeds 9.5 billion years if judging by observations of the oldest white dwarfs, and about 13-14 billion years, if judging by isotope abundance of particles inside some meteorites. This means that in our galaxy can exist civilizations of 6-8 billion years older than the terrestrial one. With so large difference of ages it seems indubitable that all stars in our Galaxy were studied by them long ago, and that they know well about our existence in the Solar system. New astronomical information attaches a special significance to the fundamental question which was formulated by E.Fermi in brief as long ago as 1950: "Where are all of them?" This is the greatest mystery of nature, and we must carry out research in different directions if we wish to attempt to solve it".

V.M.Lipunov (1995), who does not doubt the cognizability of the Universe and who thinks that the cognition of the Universe by the terrestrial civilization is almost finished, also discusses the question why we do not observe the cosmic super intelligence. "The silence of the Universe can be explained by supposing that technological super civilizations simply do not arise. Why? Two answers are possible: because of the loss of interest to technological development or because of destruction. Shklovsky chooses the second variant (I note, for good reason because the end of technological development is not seen yet). But then the intelligence is only a poor invention of nature, a deadlock branch. What is a concrete cause of destruction — atomic warfare, ecological disaster? It is unlikely. It is clear that in spite of all diversity of possible "local" conditions and specificities, the destruction of different civilizations must happen due to one universal reason. Which one? The universal reason of destruction of the Intelligence in the Universe can be connected to the loss of its main function —**the function of cognition...**

It is possible to perish from an atomic or biological bomb. But all this is a children's toy in comparison to what a civilization which is, say, two hundred years ahead of us could invent. Even now, within discovered laws of nature it is possible to imagine a so powerful weapon that the consequences of its application would be of galactic scale. Such a fratricidal war would be taken for a cosmic miracle. But there are no miracles!

Forces hindering the development of intelligence must be of quite a different nature. And, certainly, they must be of universal character which does not depend of concrete conditions."

K.A.Valiev thinks that information resources of nature are practically exhausted already (Valiev, 2000). "The second consideration to which I would like to draw your attention is related to the rate of cognition of the world that we picked up in the outgoing century. I have lived fifty conscious years in science. In my opinion, we are in too much of a hurry to take from nature what it can give us. Today we are close to exhaustion of atom (I think, Lenin was wrong about an inexhaustible character of atom and electron). We understood how it is constructed, and we even learnt to count with its help. I think, and many colleagues share my opinion, that we are close to exhaustion of information resource of nature on the whole. Recently, our friend, the famous scientist Zhores Alferov was complaining that one cannot expect real sensations from science in the next century, only details are left to deal with. Try to think on scales of thousands of years, and you will understand that our descendants will have no job."

One of the authors of the supersymmetry, theory the theory of "everything" — Brian Green considers that the limits of cognition will be discovered quite unexpectedly. "Explanation of everything — even in a limited sense of understanding of all aspects of interactions and elementary components of the Universe is one the greatest problems which science has ever faced... The amazement of our ability to understand the Universe on the whole vanishes readily in the century of fast and impressive progress. But it is possible that there exists a limit of cognition... However, the collision with the absolute limit of scientific explanations, but not with technical obstacles or with the current limits of human comprehension which are widening gradually, will be a shock to which we cannot be prepared by experience of the past" (Green, 2004).

These are modern views of cognizability of the world. The sections below describe ideas of quantitative estimation of cognizability of complex systems on the basis of laws of informatics and the complexity theory.

3. A property of cognizability of a complex system

The most fundamental properties of complex systems are existence, development and cognizability (Gurevich, 2003; 2004).

Consideration, study, analysis, systematization of complex systems is only possible if they exist during a definite period of time. Construction, synthesis, creation of systems makes sense when the existence during a definite time interval is supposed or required. The property of existence precedes all other properties of systems since without having the existence property the system cannot have any other properties.

Self-motion of nature is reflected in motion and change of complex systems, which causes the property of development in them, since the systems are not motionless formations and cannot exist in a frozen form. The existence of complex systems is impossible in isolation from their development.

The property of cognizability of a complex system implies the presence of the following possibilities:

—*description, construction of models, theoretical study of a complex system;*

—*measurement of parameters and characteristics of a complex system;*

—*understanding and explanation of existence, functioning, development of a complex system.*

Beside the above-listed possibilities, the property of cognizability of a complex system means, in the wide sense, the availability of additional ones:

—*creation, formation of a complex system;*

—*the control of a complex system.*

4. Uncognizability of systems with infinite information

Hereinafter, the information volume, diversity, complexity of systems is measured either by the length of the shortest description (Kolmogorov, 1965; Chaitin, 1970) or by information entropy (Shannon, 1963).

One can adduce logical and numerical justifications of impossibility to cognize systems with infinite information. "Godel showed that if we set the deduction rules and any finite number of axioms, then there exist reasonable statements which can be neither proved nor disproved. There are true properties of integers which cannot be derived from axioms. And if any of such properties is taken as a new axiom, then other unprovable properties remain. Now we know that the set of all properties of integers (i.e. the set of all true statements about them) has no finite basic set. ...The set of integers, irrational numbers, arithmetic are examples of mathematical objects, systems with infinite information. It follows from Godel's theorem, that systems containing an infinite amount of information can not be cognized. Some their properties will always remain unknown. The number of the latter will always be greater than that of the known ones" (Ruel, 2001). Furthermore, as was shown in the paper by Chaitin (1974), in systems with infinite information it is impossible to estimate the system complexity itself.

Simple quantitative estimations are not less convincing. The direct calculation attests that a civilization cannot cognize systems with infinite information. The finite volume of memory, the limited conveying capacity of communication channels and the limited efficiency of subjects of cognition (people and computers) suggest impossibility of cognition (storage, transmission, processing) of infinite amount of information during an arbitrary time interval. Ash-by's Law of Requisite Variety (Gurevich, 2003; 2004) requires that the variety of an observer should not be less than the variety of the system under cognition. In case of a system with infinite information and with an observer who has finite information, the cognition of the system in full is impossible. The observer can cognize a part of the system whose variety does not exceed the Observer's variety.

V.M.Lipunov, who was already quoted, considers that the explanation of the cognition phenomenon requires the existence of God. "You see, "the complexity" is first of all a qualitative characteristic, not a quantitative one. An infinitely complex object must consist of infinitely complex, qualitatively differing parts which are not necessarily compatible. The world or, more precisely, a system of knowledge of the world is not a set of nesting dolls. Upon cognizing part of such a complex object, we cannot be sure that our knowledge will fit well into the subsequent system of knowledge just like the small doll fits into the large one. The cognition is most likely to be a rather nonlinear process. An extreme case (but not a particular case at all!) could be so strong nonlinearity that the cognition of any part would be impossible without knowledge of the full picture. **In other words, an infinitely**

complex object is uncognizable in principle. Intelligence could not originate in an infinitely complex Universe!
The above negative thesis about the inconsistency between parts cognized sequentially is in glaring contrast with all our experience which shouts that our world is a set of nesting dolls. For example, Newton's mechanics became a part of Einstein's Special Relativity Theory which, in turn, became a part of the General Relativity Theory. This is what is called Bohr's correspondence principle."
How can the obvious contradiction be resolved? There are two solutions: either our conception of an infinitely complex object is wrong, or ***the surrounding world is not infinitely complex.*** The correct answer can be chosen only by relying on observational facts... Let us recall: the mind devoid of food perishes. The experimentally proved absence of super civilization testifies that **our Universe is too simple for intelligence.** Upon quick cognizing its laws (during several thousand years), the intelligent life exhausts all possibilities of its applications and vanishes. It is ironic that intelligence arises and perishes because of the same reason — a simple structure of our world. One can not admit simultaneously the infinite complexity of the world and its successful cognizability (i.e., practically the very existence of intelligence in an infinitely complex world) without admitting the existence of *a Super Intelligence — scientifically discovered God".* What is scientifically discovered God and what is the future science about the infinitely complex world? Is the human intelligence capable at all of creating at least a primitive model, a theory, a conception of an infinitely complex object which cannot be cognized in parts? Within the framework of modern science, it is unlikely because it is all built initially on atomic logic of a set of nesting dolls, on the recognition of the linear world, because it is the only one that is compatible with the existence of independent countable elements. Mathematical tools applied by modern physics were initially based on digital shepherd's experience of numbers: a flock of sheep can be divided into separate individuals and counted. (One should be surprised again how could science manage to penetrate into deep mysteries of the Universe and atoms with so poor mental outfit?) The classical scientific method comprises from the very beginning a progressive approach from simple to complex. "Explanation" is the sense of modern science. But the human vocabulary contains two other important words — **"comprehension" and "faith"**. One of them belongs rather to art and, especially, to literature (like science, it uses the language of words), the other one belongs to religion. But how can all that be combined together? How could one give an ethic tinge, say, to formal mathematical expressions? And how our scientifically discovered God to which the modern simple science inevitably came correlates with the religious God"? (Lipunov, 1995).

5. Cognizability of systems with finite information

Systems with finite information are a class of systems which differ considerably from systems with infinite information.

Two variants of cognition of systems with finite information are possible:

an observer is out of the system (an external subject of cognition, an observer);

an observer is inside the system (an internal subject of cognition, an internal observer).

In the latter case one may speak about the system self-cognition.

Definition 1.

A system is cognizable by an external observer if the external observer can represent all information contained in the system.

Definition 2.

An observed part of a system is cognized by an internal observer if the observer is capable of representing all information contained in the observed part of the system.

Definition 3.

A system is cognizable by an internal observer if the observer is capable of representing all information contained in the system including information about himself.

The cognizability of complex systems defined in that way is based first of all on the possibility of "copying", representation, memorization of the system variety by the observer. Science cognizes nature much more effectively by representing ordered variety of nature in the form of laws of nature which considerably compress information about objects, interrelations, phenomena and processes.

A possibility of cognizing systems with finite information is determined by Ashby's law of requisite variety.

Statement 1.

Cognition of a system with finite information by an external observer is possible if and only if the variety of the external observer exceeds the variety of the system under observation — $R_s < R_{00}$, where R_s is the variety of the system under observation; R_{00} is the variety of the external observer.

Statement 2.

Cognition of the observed part of a system with finite information by an internal observer is possible if and only if the variety of the internal observer exceeds the variety of the observed part of the system, — $R_{os} < R_0\{$, where R_{os} is a variety of the observed part of the system; $R_0 i$ is a variety of the internal observer.

Inasmuch as the inner observer is also a part of the system, the variety of the internal observer plus the variety of the observed part of the system can not be larger than the variety of the whole system (the variety is assumed to be additive) $R_{os} + R_0 i < R_s$.

For further investigation of cognizability of complex systems we will use the idea suggested by R.Solomonov (1964) and G.Chaitin (1974). "A scientist looks for a theory which agrees with all his observations. We suppose that his observations are presented by a binary sequence, and the theory is a program that counts this sequence. If the program has the same number of bits, then it is useless. If the sequence is described by the theory which is a program of length coinciding with the sequence of observations, then the observations are random, and they cannot be described, nor predicted. They **are** what they are, and that is **all.** The scientist cannot have the theory in a proper sense of this conception. He can only show what he observed to someone else and say "This was this". A result of a scientific theory is that it allows compressing many observations in several theoretical hypotheses. A theory is possible if and only if a sequence of observations is not random, i.e. if its complexity is much less than its length in bits. In this case a scientist can inform a colleague about his observations by a way which is much more efficient than only by passing his own observations. He does it by sending to his colleague a program which is his theory, and this program must have much less bits than the initial sequence of observations".

Definition 4.

A system with finite information is effectively cognizable if the information contained in it can be presented in a considerably compressed form.

Introduce a notion of "direct description of a system". Divide the system into microscopic parts (cells) *i,* i = l, 2, ...,N.

Describe a state of every part of the system $x_i = (\alpha_i, \beta_i,..., \gamma_i) = (\alpha_{1i}, \alpha_{2i}, \ldots, \alpha_{n\alpha i}; \beta_{1i}, \beta_{2i}, \ldots, \beta_{n\beta i};\ldots; \gamma_{1i}, \gamma_{2i}, \ldots, \gamma_{n\gamma i})$.

Here $\alpha_i = (\alpha_{1i}, \alpha_{2i}, \ldots, \alpha_{n\alpha i})$ – is the vector describing the state of the parameter *a* which influences the state of the part x_i,

$\beta_i = (\beta_{1i}, \beta_{2i}, \ldots, \beta_{n\beta i})$ is the vector describing the state of the parameter *P* which influences the state of the part x_i,

$\gamma_i = (\gamma_{1i}, \gamma_{2i}, \ldots, \gamma_{n\gamma i})$ is the vector describing the state of the parameter 7 which influences the state of the part x_i;

Then the direct description of a system is meant as a notation

$(x_1, x_2, ... , x_N) = ((\alpha_1, \beta_1, ... , \gamma_1), (\alpha_2, \beta_2, ... , \gamma_2), \ldots, (\alpha_N, \beta_N, ... , \gamma_N)) =$

$= (((\alpha_{11}, \alpha_{21}, \ldots,\alpha_{n\alpha 1}) (\beta_{11}, \beta_{21}, \ldots, \beta_{n\beta 1}), \ldots, (\gamma_{11}, \gamma_{2i}, \ldots, \gamma_{n\gamma 1});$

$((\alpha_{12}, \alpha_2, \ldots,\alpha_{n\alpha 2}), (\beta_{12}, \beta_{22}, \ldots, \beta_{n\beta 2}), \ldots, (\gamma_{12}, \gamma_{22}, \ldots, \gamma_{n\gamma 2})); \ldots;$

$((\alpha_{1N}, \alpha_{2N}, \ldots,\alpha_{n\alpha N}), (\beta_{1N}, \beta_{2N}, \ldots, \beta_{n\beta N}), \ldots, (\gamma_{1N}, \gamma_{2N}, \ldots, \gamma_{n\gamma N}))).$

Without any loss of generality, we will consider that the notation is made in binary units.

The length of the direct description of a system is equal to the length of the notation $(x_1, x_2, ... , x_N)$ - $L(x_1, x_2, ... , x_N)$.

By definition, complexity of a direct description of a system is equal to the length of the direct description — to the length of the notation in binary units.

It is clear that in a number of cases the system can be described shorter. It is easy to prove (by searching) the existence of the shortest description of a system with finite information. Denote its length as L_{mjra}.
Introduce a designation for comparison of values differing considerably (by many orders) — a <<< b *if* a ≈ 10^n b, и n >> 1.
Now one can specify the formal definition of an effectively cognizable system.
Definition 5.
A system is effectively cognizable if the length of the shortest description is much less than its direct description L_{min} <<< L.
Otherwise a system can be either incognizable or incognizable effectively.
Let *k* be a compression ratio of variety (information) in the process of cognition.
Statement 3.
A system with finite information is effectively cognizable by an internal observer if the variety compression ratio is not less than the value $k = (R_{os} + R_{oi}) / R_{oi}$.
Let us prove this statement.
The compressed variety of a system with finite information (the compressed variety of the observable part of the system and the compressed variety of an observer) must be concentrated (be fitted, be represented) in the observer variety $(R_{os} + R_{oi}) / k \le R_{oi}$ *i*.
Consequently, the compression ratio of variety (information) when cognizing a system with finite information must satisfy the relation $k \ge (R_{os} + R_{oi}) / R_{oi}$.

6. Features of subject of cognition

6.1. Subject of cognition

The subject of cognition (an observer) is a system carrying out cognition of a complex system (an object of cognition). The subject of cognition can be both a system that is external with respect to the object of cognition and a part of the system under cognition (the object of cognition).
If the object of cognition is the Universe, then the subject of cognition is as a matter of fact a part of the object of cognition — a part of the Universe.
Generally, the subject of cognition is "Intelligence", which directly carries out cognition, and the habitat of "Intelligence" which provides origin, existence and development of "Intelligence".
In the case of the terrestrial civilization, the subject of cognition is the whole civilization together with natural resources of the Solar system providing its origin, existence and development.

6.2. Composition of the subject of cognition

It comprises:

1. "Intelligence":

- Intellectual beings — people constituting the natural intelligence.
- Computers, devices, equipment constituting the artificial intelligence.
- Libraries, archives of knowledge providing the storing of methods and results of cognition.

2. The habitat of "Intelligence":

- The Solar system which is apparently necessary and sufficient for origin, existence and development of the subject of cognition.
- The Earth — the place of origin, initial existence and initial development of "Intelligence".
- Economics, industry providing existence and development of "Intelligence".
- Educational system, science, culture, which provide, on the whole, existence and development of "Intelligence".

3. Technological functions of "Intelligence":

- Search, selection and recording of information.
- Comparison, distinguishing, identification of information.
- Grouping, generalization of information.
- Information compression.

6.3. Properties of the subject of cognition

The subject of cognition must provide obtaining and compression of information about an object of cognition, the storing of compressed variety of the object of cognition during a certain period of time.

The subject of cognition must provide synchronization of knowledge.

The subject of cognition must be compact.

Parts of the subject of cognition must not move relative to each other at high velocity.

The subject of cognition must be a classical (not quantum) object, i.e. it must have a substantial mass and obvious properties — determinancy, reproducibility, possibility of copying and obtaining the stored information for processing.

The subject of cognition must not have excessive mass that can transform it into a neutron star or a black hole.

The subject of cognition must have "inherent" classical logic and classical (Kolmogorov's) calculus of probability corresponding to the classical logic.

The subject of cognition must be able to discover mathematical truth and to compress information.

The subject of cognition must have memory and be able to make calculation.

The variety of the subject of cognition must exceed the compressed variety of the object of cognition.

6.4. Mathematics is an integral part of "intelligence"

Discussion of the role of mathematics in the process of cognition is based on questions-ideas of A.D. Panov. Mathematical objects, operations with them, statements about relations between mathematical objects, apparently, existed before they were discovered by somebody. Evidently, the mathematical truth exists always.

All mathematics including its undiscovered parts is a complex system which develops and contains the same totality of knowledge at any moment of time, unlike the developing Universe.

Mathematics is a constant, invariable part of the Universe. Mathematics is an obligatory required tool of a subject of cognition, an integral part of "Intelligence". Abilities of the subject of cognition in cognition of the Universe enhance as new mathematical laws are discovered.

It seems likely that mastering of mathematics is a necessary condition of existence of a subject of cognition, its property, its peculiarity. Mathematics is a tool of effective cognition.

The knowledge of mathematic laws and the ability to use them can be considered to be a criterion of attribution of a subject to "Intelligence".

6.5. Diameter of the subject of cognition

The property of knowledge synchronization imposes limitation on the diameter of the subject of cognition *d* which must not exceed the quantity *d* = CT*, where c is the velocity of light, r = 1/A is the average time between changes (scientific discoveries) introduced into the system of knowledge of the subject of cognition (synchronization of changes), A is the intensity of introduction of changes in the knowledge system of the subject of cognition. Currently, A S>10 per year and r <Cl per month.

In the general case, the diameter of the subject of cognition cannot exceed a light year. Since the distance from the Earth to the nearest star *a* Cen is 4.3 light years, the diameter of the subject of cognition — a modern civilization — is limited by the diameter of the Solar system (about 10 light hours).

6.6. Classical character of the subject of cognition

The classical character of the subject of cognition (if it is able to use quantum calculus) seems to be the basic condition of possibility and efficiency of cognition.

The matter is that *classical objects and systems are self-sufficient* — they can describe and model themselves or similar ones, control themselves, "live" in their world. In doing so, they can also use other possibilities, in particular, quantum computers.

Description, modeling, alteration, control, "life" of quantum objects require classical objects — classical logic, classical information.

7. On cognizability of the Universe

7.1. Why is the Universe cognizable?

A. Einstein said in his time: "The most inexplicable thing in the Universe is the fact that it is explicable" (Hoffman, Dukas, 1972).

As was already noted, V.M.Lipunov considers that to explain cognizability of the Universe requires involvement of God. He uses the following scheme of reasoning:

1.The Universe is infinitely complex.
2.The Universe is cognizable.
3.Intelligence could not originate in the infinitely complex Universe.
4.Consequently, the explication of cognizability of the Universe requires God.

At the same time, he noted that it is possible that the Universe is not infinitely complex, but he did not discuss it. Yu.N.Efremov expressed his opinion that "the solution could be admission of the fact in which G.Lemaitre (and Spinoza earlier) was sure: our Universe is sufficiently simple for us indeed, and our intellectual instrument is proportional to our Universe in the very nature of things..." (Efremov, 1999).

So, why are complex systems with infinite information cognizable?

Why is the Universe cognizable?

Cognizability of complex systems with finite information (finite complexity, finite variety) including the Universe is explained by combination of the following factors:

1. Finite complexity of the object of cognition.
2. Rational, adequate structure of the subject of cognition — a modern civilization, "Intelligence" — the availability of means of measurement, storage and processing of information.
3. Capability of the subject of cognition for **considerable (by many orders) compression of information.**

Mechanisms of data compression may be different — hierarchical, modular structure, use of statistical properties, symmetry properties, axiomatic building of theories, introduction of laws, rules, etc.

The considerable data compression may be exemplified by game rules. "The game rules are of very short length in bits, but they carry huge information about all games that can be played" (Shvartsman, 1986), and also axioms of the group theory which code information contained in numerous lemmas, theorems, various properties of mathematical objects (as was pointed out by G.Plesnevich).

7.2. Information volume contained in the Universe

Information volume contained in the Universe is finite. The information volume in the Universe (according to Shannon (1965)) was first adduced in 1989 in a paper by the author (Gurevich, 1989). In 2001 the finiteness of information volume in the Universe was confirmed by S.Lloyd (Lloyd, 2001).

In the general case, information is non-uniformity which is stable during a certain period of time. Information in the Universe is formed as it expands by virtue of the uncertainty conservation law. The uncertainty conservation law (its informational form) makes it possible to estimate the information volume of such a closed system as the Universe and, thereby, a maximum possible complexity of natural and artificial systems. Note that the most suitable structural units of matter for the formation of information are fermions. They obey the Pauli Exclusion Principle, therefore the number of states in a system of n fermions increases as their number increases not slower than 2™. The information volume in the system increases correspondingly — not slower than n. Bosons are accumulated in one state, therefore their role in the formation of information in the Universe is essentially lower — proportional to *Inn.* At the same time, bosons can effectively carry information. In particular, photons are ideal for data transfer. It is fermions or, to put it more precisely, non-relativistic fermions — baryons, electrons, neutrino — that forms information in the Universe. Information (stable non-uniformities) is formed by non-relativistic fermions in expansion of the radiation Universe, and neutrino in expansion of the Universe with predominance of matter. Estimates show that the amount of information in the Universe is finite. At present, the information volume in the Universe is equal to ~ 10^{90} bits. Thereby, the complexity of physically realizable systems is limited. Now it cannot exceed ~ 10^{90} bits. The estimate of the current information volume in the Universe obtained by S.Lloyd is also equal to ~ 10^{90} bits.

N.S.Kardashev drew author's attention to the fact that it is possible to create arbitrarily many low-energy photons and thereby to generate an unlimited amount of information in the Universe. In this regard one can note the following:

1. In the Universe there is a finite number of photons — 10^9 per baryon (a total of ~ 10^{89}) (Dolgov, Zel'dovich, 1980).

2. A polarized photon with a given motion direction contains up to 1 bit of information; a photon with an indefinite motion direction contains several tens of bits. All photons as well as fermions contain ~ 10^{90} bits.

3.Creation of an infinite number of low-energy photons (with an arbitrary lower limit of photon energy) demands an infinite energy.

4.If it is considered that there is no lower limit of photon energy and the mass of the Universe is finite, then infinitely many photons must be created for any arbitrarily low energy level.

7.3. Estimation of the length of the direct description of the Universe

Estimate the number of cells *N* of size l in the Universe.

$$N = V^3 l^3 = (t_{вс} * c)^3 l^3 .$$

where *V* is the volume of the Universe; l is the cell size; t_{Un} is the age of the Universe; c is the velocity of light.

Every cell is described by a set of such parameters as type, number, characteristics of particles in the given cell, types, number, characteristics of fields in the given cell. Let us consider that the volume of information describing every cell depends on the cell size and is equal to 10-1000 bits.

Thus, a direct description of the Universe requires 10^{111} - 10^{184} bits. Length of direct description of the Universe is much larger (by many orders of magnitude) the information contained in the Universe: 10^{90} bits <<< 10^{111} – 10^{184} bits.

Cell size	Amount of cells	Volume estimate of info, describing every cell	Length estimate of direct description (L)
Planck length $l_{pl} = 10^{-33}$	10^{183}	10	10^{184}
Proton size $0.8 \cdot 10^{-13}$cm	10^{124}	100	10^{126}
Classical electron radius $r_e = 2.82 \cdot 10^{-13}$	10^{124}	100	10^{126}
Electron orbital radius (hydrogen atom size) $a_0 = 0{,}529 \cdot 10^{-8}$cm	10^{108}	1000	10^{111}

7.4. Relation between units of information, entropy and energy

In this section we analyze relation between units of information, entropy and energy on basis of results given in the papers by Brilluen (1960), Valiev and Kokin (2001). The information volume I is measured in bits (binary units). If a system has n equiprobable states, then the information volume obtained in realization of one of the alternatives (contained in the system) is equal to the logarithm of the number of states in which the system can be: $I = \log_2 n$.

1 bit is an information volume obtained in realization of one of two equiprobable alternatives: $I = \mathit{1bit} = \log_2 2 = 1$.

The information volume is measured in dimensionless units.

The physical entropy is measured by the logarithm of the number of microstates in

which the system can be $S = \log_2 P$, where S is the system entropy; κ is the Boltzmann constant; P is the statistical weight (the number of elementary complexes, microstates).

The entropy dimensionality is erg/degree (the energy dimensionality divided by the temperature dimensionality).

If the system has two states, then the system entropy is equal to

$$S = \kappa \ \text{In}\ 2 = 1.38 \cdot 10^{-16} \ln 2 \text{ erg/degree} = 1.38\ 10^{-23} \ln 2 \text{J/K}$$

I.e. the entropy unit is the Boltzmann constant multiplied by natural logarithm of two.

One can show that the information volume in the system of two equiprobable states is equal to one bit in information units and is equal to the Boltzmann constant multiplied by *In* 2 in the entropy units. In this sense 1 bit is equal to the Boltzmann constant.

When measuring the state of a system being in a container with temperature T with the help of a quantum of energy $h\nu$ it is necessary that this energy- be higher than the level of black body radiation kT.

$$E = h\nu \geq kT \ln 2$$

The same quantity of energy is necessary to record information, i.e. the recording of 1 bit of information requires energy not less than

$$E = kT \ln 2 \approx 10^{-16} \mathit{erg} \approx 10^{-23} \mathit{Joule}\ .$$

The recording of 1 bit requires mass not less than

$$M_{bit} = E_{bit}/c^2 \text{ » } 10^{-23}\text{Joule}/(9\text{-}10^{16}\text{m}^2/\text{c}^2) = 10^{-40}\text{kg}.$$

7.5. Estimation of mass required to record information contained in the Universe

As was shown in the previous section, the energy required to transfer, to read and to record one bit cannot be lower than *kTln2.*

At present, the temperature of the Universe is T_H ~ 3 *K*, therefore, the energy necessary for transferring or recording one bit is currently equal to *k3ln2*.

Consequently, now the energy necessary for transferring or recording one bit cannot be lower than $E_{min} \sim 3 \cdot 10^{-23}$ *Joule /bit.*

Let I_H be an information volume generated in our Universe at the present time. According to Gurevich (1989), Lloyd Seth (2001), I_H « 10^{90}*bits.*

So, the energy required for transferring or recording all information in the Universe is currently equal to E_H « $10^{90}bits$ 3 • 10^{-23} *Joule/bit* = 3 • 10^{67} *Joule.*

The mass required for transferring or recording all information in the Universe is currently equal to $m_H = E/c^2 = 3\ 10^{67}\ Joule/(9\ 10^{16}/c^2) = 3\ 10^{50}$kg.

7.6. Modern estimates of density of the Universe

Modern estimates of density of the Universe show that it is close to critical (Pavlyuchenko, 2002). The critical density of the Universe is equal to 10^{-29}g/cm^3 (the proportion of baryons being several per cent). The size of the Universe (the Hubble distance c/H) is equal to 10^{28} cm. The volume of the Universe is equal to 10^{84} cm^3.

Consequently, the mass of the universe is M « 10^{52}kg.

This means that the mass required for transferring or recording all information in the Universe is approximately 100 times less than the mass of the Universe and is approximately equal to the mass of baryons $m_n/M_H \sim 10^{-2}$.

Thus, an observer with a variety of 100 times as small as the variety of the Universe is capable to represent in himself all information contained in the Universe — the Universe is cognizable. But this observer cannot be a compact object. Therefore, in the process of cognition of the Universe, considerable data compression must be carried out — cognition must be effective.

7.7. The Universe is effectively cognizable

Statement 4 The Universe is effectively cognizable.

Proof.

1. Experience testifies that the Universe is cognizable by the terrestrial civilization.
2. At present time the mass necessary to record all information of the Universe is estimated as ~ 3 • 10^{50}kg.
3. Since one can consider that the mass of the modern civilization — the subject of cognition of the Universe — does not exceed the mass of the Solar system M_S ~ 2.0 • 10^3kg, the process of cognition compresses the variety of the Universe not less than 10^{20} times. The variety (information) compression ratio in the process of cognition of the Universe is not less than $k = 10^{20}$. In accordance with Statement 4, this just means that the Universe is effectively cognizable.
4. Suppose that all information about the Universe is contained in "Intelligence". The mass of "Intelligence" is equal to the mass of intellectual creatures and devices — $M_{id(}i$ ~ 10^{10}kg. Then the process of cognition compresses the variety of the Universe more than 10^{40} times. The variety

(information) compression ratio in the process of cognition of the Universe is not less than $k = 10^{40}$.

5.Assume that all information about the Universe is contained in the "Theory of everything". The mass of the "Theory of everything" is equal to the mass of a physical encyclopedia – $M_{pe} \sim 10^2$kg. Then the process of cognition compresses the variety of the Universe more than 10^{48} times. The variety (information) compression ratio in the process of cognition of the Universe is not less than $k = 10^{48}$.

As was noted in section 3, the cognizability in wide sense includes also a possibility of creation, construction and control of complex systems.

7.8. On creation of universes

The question about creation of universes is already being discussed. Yu.N.Efremov and A.N.Chernin (2003) discuss the idea of E.Harrison of creation of universes. "The prominent American cosmologist E.Harrison (1985) suggested the idea of creation and natural selection of universes containing intelligent life. Theoretical ways of creating universes are already known. One has only to learn to create black holes from elementary particles with energy of order of 10^{15} GeV by only 13 orders more than in our most powerful accelerators... Expanding into some other space, these holes turn into universes... Intelligent life creates new universes in an initial universe. Harrison believes that physical conditions in the new created universe would be the same as in the initial one and will be suitable for life of the same type as the initial one to originate. And this process continues eternally. Universes which are the most favorable for intelligent life are selected as being capable for reproduction... Note that this hypothesis also explains the cognizability of our Universe for us. It is created by beings whose intellectual processes and notions are similar to our's in principle, since we are, in a sense, their distant descendants. Harrison concludes that a question who created the first universe suitable for existence of beings similar to us remains open. One can appeal either to the theistic principle — the extra natural beginning or to the conception of existence of an ensemble of many universes with very different physical laws including those corresponding to a possibility of origin of intelligent life which afterward creates universes similar to the initial one. In our opinion, there is no need in the first hypothesis. In any case, most cos-mologists are sure that universes can be generated by them-selves, and their origin is in quantum fluctuations of primeval vacuum." Recently it has become known (Proceedings of science, 2005) that American scientists created a black hole under the laboratory conditions. Under the terrestrial conditions the black hole existed one billionth part of a nanosecond. Researchers used a special device (a relativistic accelerator of ions) in Brookhaven National Laboratory of New York. As a result of collision of two ions of gold in the accelerator, their nuclei decayed into quarks and gluons. In its turn, the particles formed a sphere of quark-gluon plasma which, unexpectedly for everybody, started absorbing particles generated because of the collision of nuclei. A black hole originated. Its temperature exceeded the temperature of the Sun 300 million times.

7.9. On control of the Universe

The highest form of cognition of systems is the control of them (as was pointed out to the author by V.S.Zhozhikashvili). It should be noted that V.A.Lefevre was, apparently, the first to suggest one of the methods of controlling the matter distribution in the Universe (Gindilis, 2004; Reference book on the automatic control theory, 1987). "Let us imagine that to avoid the gravitational collapse the subjects start ejecting matter from clouds of galaxies for the purpose of decreasing their density. A concrete strategy of correction could be as follows: every subject ejects matter "packed as black holes from the central part of its galaxy with a velocity sufficient for it to leave the cloud of galaxies. By such joint efforts the subjects change the character of matter distribution in the Universe and thus prolong time of their existence. Leaving aside the problem of coordination of joint efforts, there are no restrictions from physical laws which would prevent from implementation of this project."

It is necessary to learn the formulation and solution of problems of control of universes by the method of the control theory (Prangishvili, 2003; Reference book on the automatic control theory, 1987). Let us consider as an example the case of the uniform universe which is described by the Einstein equation

[1] Certainly, here the case in point is a metaphor. The generated configuration is not a "real" black hole — a collapsed body surrounded by a horizon of events.

(MacVittie, 1961):

$$\frac{dR}{dt} = R\left(\frac{\chi c^2 \rho}{3} - \frac{kc^2}{R^2} + \frac{\Lambda}{3}\right)^{\frac{1}{2}}$$

Δ is the cosmological constant; $\chi = \frac{8\pi G}{c^2}$ where G is the gravitational constant; ρ is the density of the Universe; k = +1, -1, 0; c is the velocity of light; R is the current radius of the Universe. The use of the dynamic model of the Universe for description of an object of control gives us an opportunity of classical formulation of control problems. In particular:

1. Einstein's nonlinear equations define the dynamics of the Universe.
2. Time of expansion of the Universe from radius *Ro* to radius *R* and the mass of the Universe can be considered as criteria of optimality.
3. Restrictions of the number of different types of particles in the Universe, the duration of the stages of development of the Universe can be regarded as

limitations.

4. As controlled parameters, one can regard the cosmological constant Λ, the density of the Universe, the mass distribution in the Universe (in the last case the dynamics of the Universe should be described by Einstein's tensor equations).

The solution of problems of the optimal control of the Universe will make it possible to estimate the development of the Universe and show the ability of "Intelligence" to control it.

8. Conclusion

The aforesaid allows us to make the following conclusions.

1. At the present time most of the researchers are sure that nature is cognizable — the description, measurement, understanding and explanation of physical objects, interconnections, phenomena and processes in the Universe whole are possible.
2. The informatics laws allow introducing precise definitions of cognoscibility, of cognoscibility in a wide sense, of effective cognoscibility. It also allows using quantitative methods when studying cognoscibility of complex systems.
3. In view of limitation of the observer variety, the infinitely complex systems cannot be cognized in full measure.
4. The systems with finite information are cognizable both by an external observer and by an internal one having sufficient variety at a definite compression ratio of the system variety.
5. The subject of cognition must be a compact classical object proficient in mathematics and classical logics.
6. The Universe as a system with finite information is cognizable being cognizable effectively.
7. In the course of cognition of the Universe by "Intelligence" a considerable (by tens of orders) compression of information occurs.
8. Cognoscibility of the Universe can be explained without involving God.
9. Cognoscibility of the Universe in a wide sense is in the stage of investigation. The black hole was just created. The discussion of the problems control of the universes and their development has been started.

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ON A POSSIBILITY OF SAVING "INTELLIGENCE" IN COSMIC CATACLYSMS

(Gurevich I.M. On the possibility of preserving the "Reason" in the cosmic catastrophes. /In Russian/. Bull. Special Astrophysical Observatory, Vol. 60-61, 2007. Pp. 173-174. http://w0.sao.ru/Doc-k8/Science/Public/Bulletin/Vol60-61)

There is a definite probability that existence of the terrestrial civilization (TC) may be discontinued in the near future by collision of the Earth with a massive cosmic body or by high-intensity cosmic radiation. That is why, it appears to be reasonable to discuss the problem of saving "Intelligence" and to define ways of its solution on the basis of the features of the cognition process of the Universe (Gurevich, 2004; 2006). The problem of saving "Intelligence" is one of the SETI problems and it cannot be solved without involving scientists of different professions: astrophysicists, radio physicists, biologists, psychologists and physicians, experts in cosmic engineering, and also informatics and education.

Two stages of cognition of the Universe can be marked out.

Formation of "Intelligence". The duration of this stage can be estimated from the time that has passed since the moment of origin of life (the birth of prokaryote) — 3.8 billion years (Panov, 2004), or from the time of the beginning of the solar system formation — 5 billion years, or from the time of existence of the Universe — 15 billion years.

The cognition itself of the Universe by "Intelligence" and the development of "Intelligence" in the process of cognition of the Universe. The beginning of the scientific cognition of the Universe may apparently be reckoned from the beginning of cognition of mathematical laws by the TC. The duration of this stage can be estimated from known archaeological and historical data at only several thousand years. During this time "Intelligence" considerably (by many orders) has compressed and is still compressing the information contained in the Universe (10^{90} bits) (Gurevich, 2004; 2006).

The secondary formation of "Intelligence" is highly improbable. That is why it is necessary to do everything possible to preserve "Intelligence". The following solution is offered: creation and usage of cognizing complexes — minimal subjects of cognition (MSC). To keep results of cognition and of the cognition process itself ("Intelligence") it is suggested that several "minimal" subjects of cognition to be formed and placed on the Earth, the Moon, the planets of the solar system and launched to outer space with making provision for periodic corrections of their data bases by the terrestrial civilization and starting independent operation of the MSC in the case the TC is ruined.

It is worth noting that the mankind has already been solving a problem of saving “Intelligence” in cataclysms. Several thousand years ago the Noah’s Ark saved the incipient terrestrial “Intelligence” from the Flood. The minimal subject of cognition is the Noah’s Ark of our days which is meant to save “Intelligence” in cosmic cataclysms. The MSC consists of the already formed “Intelligence” and minimal resources for its servicing.

1. The formed “Intelligence” is:

Thinking beings — people constituting the natural intelligence.

Computers, devices, equipment constituting the artificial intelligence.

Libraries, storages of knowledge providing the storing of the methods, technologies and results of cognition.

Educational means.

Facilities for the receiving and integration of the TC knowledge acquired after the beginning of independent functioning of the MSC.

Facilities of MSC activation by signals from the terrestrial civilization or by an independent decision.

2. Minimum resources of servicing the cognition process (a minimum required habitat of “intelligence”) is:

Facilities of the energy supply and life maintenance.

Motion aids.

Means of colonization of extraterrestrial objects (for example, planets in different stellar systems).

Note some peculiarities of the problem of saving “Intelligence”.

The saving of “Intelligence” along with cognition proper must become a priority problem of the Terrestrial Civilization.

The Minimal Subject of Cognition cannot be automatic. It should necessarily involve people.

The placement of the MSC in the Universe is “a flight without return” (Gindilis, 2004).

The problem of saving “Intelligence” by forming the minimal subjects of cognition is solvable to a great extent at present. Besides, the solution of the problem of forming a minimal subject of cognition cannot be postponed. In this connection we propose to include the problems of saving “Intelligence” in the Russian and international SETI programs for the nearest 10–20 years. These are the problems which can be solved on Earth or within the solar system:

Selection of knowledge and means of cognition including the education medium for the MSC.

Creation of an MSC prototype (a functional model).

Formation, training and permanent work of MSC prototype crews.

Modeling the process of the Universe cognition by the TC with the help of the MSC prototype.

Participation of the MSC prototype in the process of the Universe cognition.
Forecast of cosmic cataclysms threatening the solar system.
Determination of the minimal required number of MSCs in the Universe.
Determination of the most reliable places for location of MSCs (“a backwater”).
Computation of MSC flying paths for allocation in the nearest part of the Universe.
Creation of a protected MSC on the Earth.
Creation of a MSC on the Moon.
Creation of a MSC on one of the planets of the solar system.
When launching spaceships toward the planets of the solar system and making colonies it is necessary to implement decision for saving “Intelligence” and to realize the MSC fragments.
The problem of saving “Intelligence” is much in common to the problem of implementation of interstellar missions. That is why, the mankind readiness to interstellar missions is so important. Various aspects of the organization of interstellar missions are considered — the membership number, possible control structure, choice of a spaceship, flight velocity, comfort for the crew, food supply, readiness to flight, etc. Specific solutions are suggested and ready to implementation. Along with that, before starting real interstellar missions, a lot of scientific, technical and social problems should be solved. This will take many years. But this is already the foreseeable future.
As the solutions of suggested tasks are performed and the TC is ready to interstellar missions, several MSCs should be launched into the Universe.
The simulation of the process of cognizing the Universe and the performance of the MSC will make it possible to get an experimental answer to the question put by V.M.Lipunov “Why does the cognition of the Universe demand only several thousand years and only a few geniuses?” and also pose fundamental limitations on minimum of the necessary resources for the cognition of the Universe.

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WHAT ARE THE SIMILARITIES AND DIFFERENCES BETWEEN CIVILIZATIONS IN THE UNIVERSE?

(Gurevich I. What Are The Similarities and Differences Between Civilizations in The Universe?
Third IAA Symposium on searching for life signatures.
St. Petersburg, Russia, 2011. Programs and Abstracts. P.16)

1. Introduction

What will happen when the Earth civilization will come into contact with an extraterrestrial civilization? Will we be able to exchange information? Whether we can understand each other? Will we be helpful to each other? What is needed to "speak"? Where to start? The general answer to these questions is given in the axiom of B. Spinoza, formulated by him during the years 1662-1667. "Things which have nothing in common, may not be knowable one through another, in other words - representation one does not contain representation of the other" [1].

In other words, if civilizations have nothing in common, they will not be able find any form of interaction.

2. Common to all civilizations in the Universe

2.1. Cosmic microwave background radiation.
2.2. Starry Sky.
2.3. Elementary Particles
2.4. Atoms
2.5. Molecules
2.6. Mathematics and Informatics, common to all civilizations
2.7. Physics, common to all civilizations.
2.8. The same fundamental limitations on the amounts of memory and productivity of natural and artificial systems.
2.9. Identical information characteristics of civilizations (the amount of memory, the volume of information produced per unit of time).

3. Major potential differences among civilizations in the Universe

3.1. Starry sky - a local picture
3.2. Chemistry is not common to all civilizations. Concrete implementation of chemistry as a science is determined by the physical conditions at the site of origin and development of civilization.
3.3. Various inanimate nature and different and varied types of life (as determined by physical and chemical processes prevailing at the site of occurrence and development of civilization).
3.4. Variety of languages.

3.5. Cultural differences.
3.6. Diverse social fabric.

4. Interaction organization guidelines
4.1. Search for Extraterrestrial Intelligence (Similar physical conditions).
4.2. Messaging (overall picture of the Universe in the cosmic microwave background. Mathematics. Informatics. Physics).
4.3. The optimum technology of interaction (starting from the region of maximum generality, then in descending order of generality, combined with a mutual process of learning taking into account the cosmic distances).

Fortunately, along with many binding differences in civilizations in our Universe there should be very much in common. Thus the civilizations in our Universe can interact.

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