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Entropy and evolution

(November 11, 2012. Updated: December 26, 2020)

Introduction

At all levels in our Universe, we observe processes that are seemingly far from thermal equilibrium. It is logically to assume that the Universe entropy does not increase, but is decreasing one. However, the decrease of entropy in the Universe is possible only if the Universe is a thermodynamically open system, and consequently the outflow of entropy is greater than the inflow. In such a system, some progressive evolution (exactly distant from the equilibrium state) is not possible only, but also necessary.

1. Life from the Schrödinger's viewpoint

E. Schrödinger considered the functioning of a living organism and noted that this one continuously increases its entropy and, thus, regularly approaches the dangerous state of maximum entropy, which leads its death. The organism can avoid this state and remain alive only using constantly extracting energy and negative entropy from its environment (food, oxygen) by doing work and dissipating a heat (as well as carbon dioxide and other waste products) into the environment. When we are talking, for example, about a human person, the energy consumed by him leads not only support the current life activity, but also creating a "surplus" product, i.e. the common needs of the community (the evolution of society).

One can also imagine an artificial robot that extracts energy using a solar battery (or from external batteries). Further, it dissipates the received energy on work (and emits a heat), at least partially related to the search for new batteries, and thus supports its " vital activity" (Fig. 1)

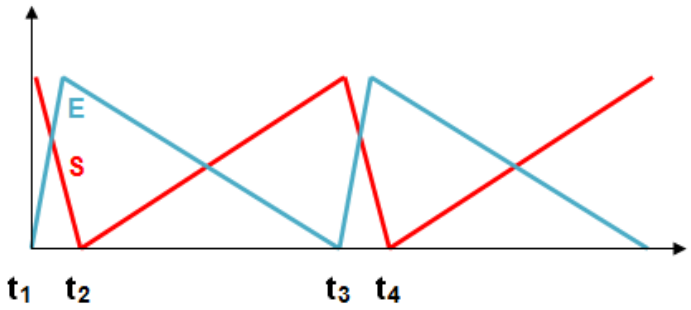

Figure 1. Life cycles of a robot

Stages $t_1 - t_2$ ($t_3 - t_4$, ...) are energy the **E** extracting periods from the outside, the entropy **S** drops inside the organism. Stages $t_2 - t_3$, ... are energy **E** consumption periods to produce a work, followed by the release of a heat and an entropy **S** accumulation inside the body.

In addition to the feeding and searching for food instinct, there are several other mechanisms that affect the decrease in entropy of animals and humans:

- The instinct of competition and social dominance, which ensures the structuring of society.

- The instinct of reproduction, which ensures the conservation and accumulation of hereditary population information.
- The ability to learn and accumulate experience, which ensures the accumulation of information resources of the individual and society.
- The ability to communicate ensures the accumulation of the information resource of the individual and society.

2. Energy and entropy flows in the system “Star-Planet-Space“

What happens in the system "Star (Sun) – Planet (Earth) – Space”? The star is a hot spot in the sky! It is in a thermodynamically non-equilibrium state: a small area that is occupied by the sun has a temperature much higher than that of the remaining part of the Sun. Thanks to this, we have a powerful source of a low-entropy. Earth receives energy from this hot spot in a low-entropy form (relatively few visible light photons) and re-emits it to the cold regions of the sky in a high-entropy form (many infrared photons). The incoming and outgoing thermal energy Q is about the same, but the temperature T_1 of the "heater” is close to 6000K, while the temperature T_2 of the "cooler" is about 3K, so the flow of entropy entering the Earth is less than the flow of entropy leaving it.

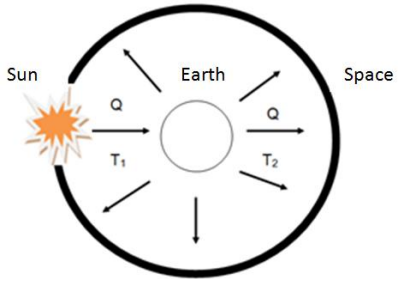

Figure 2. Negative entropy “pumping” as the basis for the evolution of a planet
T_1 - temperature of the "heater”, T_2 - temperature of the "cooler“

$$dS = \frac{dQ}{T_1} - \frac{dQ}{T_2}. \quad \text{Since } T_1 > T_2, \text{ then } dS < 0.$$

Here the processes of energy consumption and return are separated not in time, but in space. A part of the accumulated provides a reserve of "free" energy, which can be converted into useful work.

Green plants, consuming energy in a low-entropy form, simultaneously provide for themselves the necessary low-entropy, and also the carbon and oxygen separation for us. Due to the absorption of photons, electrons reach the highest biopotential in a plant photosystems. From this high energy level, they descend discretely (by steps) to the lowest energy level in the biosphere – the water level. The energy given off by electrons at each step of this ladder is converted into chemical bonding energy and, thus, drives the life of animals and plants. The water's electrons are integrated by plants, and cellular respiration gives rise to water again. This process forms an electronic cycle in the biosphere, the source of which is Sun.

In reality, some (relatively small) portion of the energy coming from Sun is not re-radiated into space, but in the form of so-called “free” (ordered) energy it is accumulated on Earth and can be converted into useful work. Thanks to this energy, various chemical, biological and social systems on Earth are able to move away from the state of equilibrium, filling new non-equilibrium niches. In particular, the accumulated reserves of various types of energy allow mankind to create structures, transport means, to transform the natural habitat, and accumulate information resources.

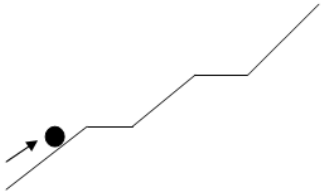

Figure 3. Graded evolution

The input of energy from outside raises the system to a potential "hills", removing them from the equilibrium "lowest" energy state. For example, a recent experiment – a powerful laser beam simulating the impact of a meteorite into a mixture of formamide and clay (the chemical medium of ancient Earth) – triggered a variety of chemical reactions, resulting in all four nucleotide bases of RNA (adenine, cytosine, guanine, uracil) [1].

At the same time, the laws of nature provide metastable niches (horizontal regions) using selection rules similar to the Mendeleev table, which locally prevent the system from returning to its original state and, thus, violate the reversibility of small movement along the "hill" (see Fig 3). This is a well-studied situation in the theory of dissipative processes.

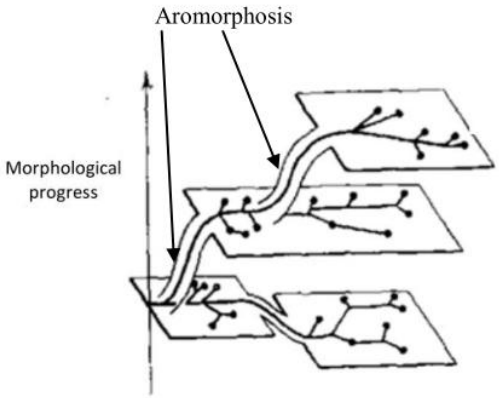

Figure 4. Multilevel progress of evolution

The good biological example may be considered: when by the time the competitive lines of evolution are exhausted at one level, there is a transition to the next level (see Fig. 4). Analysis of data concerning the origin of terrestrial vertebrates allows to conclude that the organism undergone the aromorphosis (=arogenesis) not only improves the general degree of organization, but also becomes able to survive in much more complex and diversified environment than its ancestors and, consequently, expands the ancestor's adaptive zone. Aromorphosis occurs when the ancestral taxon specializes in a narrow adaptive zone having vacant neighboring zone which might be occupied. The aromorphic adaptations are formed very slowly in the course of so-called coherent evolution by accumulation of certain multiply adaptations and by their coordination with each other. In the end, the set of these adaptations overrides the oscillation range of environmental conditions in the ancestral adaptive zone and can be considered as a preadaptation to adaptive zone expansion. However, appearance of a few detached features does not help to widen an ancestral adaptive zone. Taxon becomes really aromorphic only due to the simultaneous formation of all adaptations allowing the expansion of ancestral adaptive zone, i.e. successful exploration and occupation of neighboring adaptive zone.

3. Conflict between reality and the theory of the Universe "thermal death"

Applying the Second Principle of Thermodynamics to the Universe as a physically *closed* system leads to a striking contradiction between theory and experience. The Universe should be close to a state of complete physical equilibrium, but the actual observable properties of nature convince us that the properties of nature (the entire observable part of the Universe) have nothing in common with the properties of an equilibrium system. Particularly, in [3] authors reported that they have measured the optical linear polarization of quasars belonging to Gpc scale quasar groups at redshift $z \sim 1.3$. Out of 93 quasars observed, 19 are significantly polarized. The quasar polarization vectors are either parallel or perpendicular to the directions of the large-scale structures to which they belong. Statistical tests indicate that the probability that this effect can be attributed to randomly oriented polarization vectors is on the order of 1%. Authors also found that quasars with polarization perpendicular to the host structure preferentially have large emission line widths while objects with polarization parallel to the host structure preferentially have small emission line widths. Considering that quasar polarization is usually either parallel or perpendicular to the accretion disk axis depending on the inclination with respect to the line of sight, and that broader emission lines originate from quasars seen at higher inclinations, authors conclude that quasar spin axes are likely parallel to their host large-scale structures.

Moreover, the present state of the Universe must have emerged from a state with lower entropy, etc. Therefore, its initial state should have had extremely low entropy, i.e., an extremely low probability of realization, which has no explanation yet. Modern physics proposes as "straws" General Relativity, i.e. overall cosmological expansion of the Universe means the dependence of its metrics on time. So, the "bound" conditions for it are not stationary, the world as a whole should be considered to be a system in a variable gravitational field, for which the Second Law of Thermodynamics may to not be fulfilled [4].

4. Alternative cosmological model and entropy flows

Since 1993 I developed the alternative cosmological model (Spherical Expanding Universe Theory – SEUT) [5]. Accordingly with it, our Universe presents the 3D shell of a 4D spherical black hole in some super-universe. This BH has the size corresponding with the gravitational radius of our Universe whose matter average density ρ_0 is nearly 10^{-29} g/sm3. This corresponds to the *critical* density $\rho_{cr} = 3/(8\pi R_G^2)$ of collapsing object, where the gravitational radius $R_G=2GM/c^2$, M is the object mass, G is the gravitational constant, c is the velocity of light. Let us compare ratio (ρ/ρ_{cr}) for different astrophysical objects:

Table 1

Ratio (ρ/ρ_{cr}) for different astrophysical objects

Object	**Mass M (kg)**	**Radius R (m)**	**Gravitational radius R_G (m)**	**$(\rho/\rho_{cr}) = (R_G/R)^3$**
Earth	$6\cdot10^{24}$	$6\cdot10^{6}$	10^{-2}	$\sim 10^{-26}$
Sun	$2\cdot10^{30}$	$7\cdot10^{8}$	$3\cdot10^{3}$	$\sim 10^{-16}$
Milky Way	$3\cdot10^{42}$	$\sim 10^{19}$	$\sim10^{15}$	$\sim 10^{-12}$
Universe	$\sim 10^{53}$	$\sim 10^{26}$	$\sim 10^{26}$	~ 1

I suppose an alternative cosmological model of our Universe (see [5]), in which our Universe expansion may be explained by a matter and energy *absorption from the outside* (not by an explosion process)! So, our Universe is thermodynamically open system. I also believe that it has not only the energy and matter flows source, but also the drains for them, namely "ordinary" (internal) BHs inside our Universe. If so, one can consider the Universe like some heating machine that receives a negative entropy flow from outside and sends positive entropy

flow to internal BHs (Fig. 5). Such presentation just corresponds with Sections 1 and 2 paradigms.

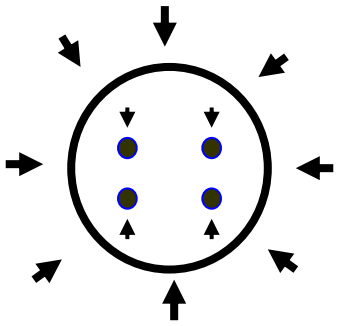

Figure 5. Our universe as a working medium of heating machine:
entropy flows from the external super-universe and inside interior BHs

If our universe is a black hole and is growing, then its entropy would seem to be increasing. How can this be reconciled with the statement that the entropy of the Universe must be decreasing? The point is that from the total entropy we must *subtract* the entropy of internal black holes, which, according to recent estimates [6], is now 5 orders of magnitude higher than the entropy of all other matter in the observable part of the Universe[1]. If the number and size of internal black holes are large enough, then their total entropy increases *faster* than the external entropy of the Universe. For example, assuming that the amount of internal black holes is $N \sim R^3$, and the surface of each hole grows no slower than $\sim R^2$, we obtain an estimate for the total entropy of internal black holes $S_{int} \sim R^5$. At the same time the universe itself must have entropy $S_{ext} \sim R^2$ (or, for some reasons, $\sim R^3$). Here R is the radius of the Universe.

In order for the processes of self-organization and ordering to occur in a complex system, it must be open, since a closed system, in accordance with the laws of thermodynamics, must eventually come to a state with maximum entropy and stop any evolution. In non-equilibrium conditions, the relative independence of the system elements gives way to the corporate behavior of the elements.

In States far from equilibrium, bifurcation points and attractors appear. The fundamental principle of self-organization is the emergence of a new order and complexity of systems through *fluctuations*: in complex open systems , due *to the influx of energy* from outside and the strengthening of disequilibrium, deviations increase over time, accumulate, and cause the effect of collective behavior of elements and subsystems. The stage of self-organization occurs only in the case of the predominance of positive feedback acting in an open system over negative feedback. Such, for example, are the mechanisms of phase transitions of matter or the formation of new social formations.

Self-organization in complex open systems leads to the appearance of the "arrow of time" in Nature, which is opposite to the direction of the "arrow of time" in a closed system, leading to "heat death".

Conclusion

So, in the proposed model, the entropy of the Universe **decreases**, not increases. The cosmological arrow of time in our Universe has a thermodynamic origin and is primary in relation to other arrows of time-biological (direction of evolution) and psychological.

[1] The Cosmic event horizon entropy is $\sim 10^{122}\ k_B$, the Supermassive BH entropy is $\sim 10^{103}\ k_B$, etc [6].

Note that strongly gravitational physical systems have *a negative* heat capacity. In other words, stars radiate their energy and heat up , and BHs absorb this energy and cool down . It also follows that the temperature difference and distance from the equilibrium state in galaxies should increase rather than decrease over the course of billions of years.

Finally, the 3-dimensional super -spherical surface, which represents our Universe, is in contact with the external super-universe at every point, i.e. matter, energy and information are "created" (come from outside) at every point in our Universe. Therefore, in contrast to a BH, such a "white hole" in relation to it should be thought as an absolutely global and eternal object.

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