DETERMINISTIC MECHANISM OF IRREVERSIBILITY

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Abstract

The analytical review of the papers devoted to the deterministic mechanism of irreversibility (DMI) is presented. The history of solving of the irreversibility problem is briefly described. It is shown, how the DMI was found basing on the motion equation for a structured body. The structured body was given by a set of potentially interacting material points. The taking into account of the body's structure led to the possibility of describing dissipative processes. This possibility caused by the transformation of the body's motion energy into internal energy. It is shown, that the condition of holonomic constraints, which used for obtaining of the canonical formalisms of classical mechanics, is excluding the DMI in Hamiltonian systems. The concepts of D-entropy and evolutionary non-linearity are discussed. The connection between thermodynamics and the laws of classical mechanics is shown. Extended forms of the Lagrange, Hamilton, Liouville, and Schrödinger equations, which describe dissipative processes, are presented.

Keywords: irreversibility, classical and quantum mechanics, evolution, entropy, symmetry, Hamilton's formalism.

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Introduction

The successes of mechanics in the 18-th century prompted Boltzmann to create a mechanistic picture of the world in accordance with Darwin's theory of evolution [1-5]. But at the very beginning of the Boltzmann's researches, Poincare pointed him on the contradiction between mechanistic model of the world and reality. This contradiction consisted in that that according to the formalisms of classical mechanics, the dynamics of systems, unlike evolutionary processes in the nature, is reversible [2]. Later it became clear that fundamental physics, built on the basis of the formalisms of classical mechanics, is able to describe the dynamics of systems only near equilibrium, but cannot describe the processes of their emergence and evolution [6].

Today the probabilistic mechanism of irreversibility is accepted [1-3]. This mechanism has been proved by using of the hypothesis about existence of external fluctuations acting on the Hamiltonian system. The necessity of the hypothesis is connected with the fact that Hamiltonian systems that are exponentially unstable in the Lyapunov sense are irreversible only in the presence of arbitrarily small random external fluctuations. This is proved by the method of the Hamiltonian systems dynamics analyzing in the phase space. In nature, all systems are open and always are under the influence of external random fluctuations. Therefore such a probabilistic explanation of the mechanism of irreversibility satisfied most physicists, even supporters of determinism.

But, nevertheless, the question raised by Boltzmann about the possibility of creating a physical theory of evolution remained unsolved. Indeed, the found mechanism is a probabilistic nature, and the absence of the deterministic mechanism of irreversibility (**DMI**) means impossibility of constructing of the deterministic of the worlds physical picture. Indeed, without DMI it is unclear whether it is possible, and if it possible, then how to build the theory of evolution. It is because not clear how order can be emerges from chaos, if irreversibility has a random nature. There are works in which it is asserted that without the DMI the laws of physics cannot be closed [6]. Without DMI it is difficult to connect thermodynamics, statistical physics, and kinetics with the deterministic laws of the classical mechanics. It is difficult also to eliminate contradictions in explaining the nature of symmetry breaking in the micro- and macro systems [2]. Without DMI, the "phenomenon of life" remains "terra incognita" [7]. Despite of the existing probabilistic mechanism of the irreversibility, despite the development of statistical physics, modern numerical methods for solving complex tasks of astrophysics, molecular dynamics, quantum mechanics, the absence of DMI created great difficulties. Thus, the question about existence of DMI remained relevant and therefore the physics society related this problem with the problem of the "arrow of time" [2, 4, 8].

An analysis of numerous unsuccessful attempts to find DMI within the framework of formalisms of classical mechanics let to suggest that there is no solution in it frames. But is it means that solution of the DMI problem absent and within the laws of classical mechanics? It is hardly so. Indeed, the domain of using formalisms of mechanics is more limited then the region of the using of the classical mechanics laws. Indeed, the applicability of the formalism is limited by the systems with holonomic connections. Therefore the description of non-holonomic systems, for which symmetry breaking of the time takes place, remains outside of the framework of formalisms [9, 10]. This is strong argument in favor of the need for search of DMI in the frames of the classical mechanics laws. Obviously, the search for DMI should be carried out on the basis of a principally different approach than the search of the probabilistic mechanism of irreversibility.

The probabilistic mechanism of irreversibility was found as a result of studying of the Hamiltonian system's trajectories mixing in the phase space. The irreversibility of the trajectory is appeared due to existence of the fluctuations of external influences on the system. To avoid using of the probabilistic laws and hypotheses, it was decided to seek DMI, relying directly on the laws of classical mechanics.

It was decided to seek of the DMI by the way of analytical description of friction, which directly leads to irreversibility. The nature of friction is that the body's motion energy irreversibly passes into the body's thermal energy. It is follow from this fact that to find DMI it is necessary to find of the system's motion equation describing the transformation of the body's motion energy into its internal energy. But in Newtonian mechanics there is no such equation, because this mechanics was constructed for the body's model in the form of a ma-

terial point (**MP**), which has no internal energy [10]. Hence the need to construct of the mechanics of structured particles (**SP**), in which the SP is used instead of the MP in the motion equation itself was appeared. As a model of SP, it is possible to take a system of potentially interacting MPs. Such motion equation can describe the processes of transforming of the body's motion energy into its internal energy. **That is, instead of studying the mixing processes of phases trajectories of the system in phase space within the framework of the Hamiltonian formalism, how it was made in the search and study of the probability mechanism of irreversibility [2], it is proposed to study the process of transforming the energy of the ordered motion of the system into its internal energy of chaotic motion of its elements, relying on the laws of classical mechanics.**

In this paper is submitted the most complete description of the ideas that formed the basis of the DMI. The history of solving the irreversibility problem is briefly described. It is explained: why within the framework of the laws of classical mechanics, based on the ideas of the symmetry of space and time, DMI must exists; how the concept of the D-entropy is appearing; how thermodynamical and statistical laws can be explained with the help of DMI; what a role DMI in physics is.

1.1 A brief history of the development of the irreversibility problem

It is almost impossible to embrace the long and, sometimes, tragic history of solving the irreversibility problem. From the time of Boltzmann to the present, it is difficult to find a well-known physicist who would have passed this problem without paying proper attention to it. Therefore, here we confine ourselves to those works that not only paved the way for its solution, but also made a great contribution to the foundations of modern fundamental physics.

The formulation of the irreversibility problem belongs to Boltzmann [1-3]. His H-theorem and the corresponding explanation of irreversibility, was based on the ergodic hypothesis, which developing to the present time [11, 12]. According to this hypothesis, all microstates of the system are equally probable and averaging over ensemble of systems is equivalent to averaging over time, and the system itself during of overwhelming time is in equilibrium state. But Boltzmann's explanation of the mechanism of irreversibility was confronted with insurmountable contradictions, known as the paradoxes of Zermelo and Loschmidt. The main contradiction to which pointed out to him Poincare, is a fact that the dynamics of the Hamilton systems are reversible. And in spite of the fact that characteristic time of reversibility can be very big, this contradicts to the H-theorem [2, 13]. Nevertheless, as a result of work on the problem of irreversibility, Boltzmann made a significant contribution to the foundations of the molecular-kinetic theory. For example his kinetic equation was obtained based on the hypothesis of equiprobability for impact parameters of the colliding particles. This equation is in excellent agreement with experiments, although there is still no consensus relative to the rigor of this hypothesis [3, 17].

Serious attempts to find the mechanism of irreversibility, basing on the already known fact of thermal radiation of the bodies, Planck undertook. He, like his predecessors, sought him, relying on the canonical formalisms of classical mechanics. In his evidence, he, like Boltzmann, could not overcome the contradictions of the proposed mechanism with the Poincaré theorem on the reversibility of Hamiltonian systems. And although the problem of irreversibility remained unsolved, Planck received the famous formula of the blackbody radiation and also introduced the concept of quantum of energy that was the beginning of the quantum mechanics [14-16].

Gibbs laid the foundation of the strict statistical theory for systems close to equilibrium, with-out an exit out of limits of a formalism of classical mechanics [1, 17, 18]. He, using the idea of representing equilibrium systems in the form of an ensemble of equivalent subsystems, actually proved that systems close to the equilibrium state are Hamiltonian. Thus, Gibbs circumvented the probabilistic meaning of the initial and boundary conditions and was able to take advantage of the determinism of classical mechanics. As it later became clear, the success of his theory is explained by the fact that for systems close to equilibrium in the linear approximation there are no collective internal non-potential forces that cause macroscopic flows of particles and energy. Therefore, for them, the Hamiltonian formalism, constructed under the condition that there are no internal

collective non-potential forces, is acceptable. Thus, Gibbs gave a general method, which applicable to solving almost all statistical tasks, but the field of use of his method is limited by the systems, which close to equilibrium [17].

Einstein is also paid attention to the irreversibility problem. He made serious attempts to construct a kinetic theory and to understand the nature of the second law of thermodynamics [19]. Einstein adhered to deterministic ideas in physics, and explained the statistical regularities in the dynamics of systems due to inability to set initial and boundary conditions. Many of his results, which were obtained in 1902-1905, in fact, confirmed the Gibbs theory.

Liouville made an important contribution to the solution of the irreversibility problem. Seeking to find its solution within the framework of classical mechanics, he proved that only systems that can be split into subsystems with one degree of freedom by passing to independent canonical variables are integrable [2]. But, as it turned out, such a splitting is possible only when the interactions between the subsystems are potential. And this is equivalent to the requirement of fulfilling the condition of holonomic connection. At the same time, Poincaré proved that nonequilibrium dynamical systems, as a rule, are not integrable. However, the condition of the potentiality of the interaction forces of elements implies the potentiality of collective forces between their systems. Therefore, as it follows from the Hamiltonian formalism, the problem can always be reduced to integrable systems with one degree of freedom [9]. Here there is a contradiction. On the one hand, it was proved that the class of integrable systems is very narrow. On the other hand, the condition of holonomic connection, that was adopted an a priori, equivalent to the condition of the potentiality of the interaction forces of systems, should ensure the integration of any natural systems. This raised the question of the generality of the hypothesis about the potentiality of collective forces between systems used in the derivations of the principle of least action [9].

The difficulties in solving the irreversibility problem within the framework of formalism of mechanics led to the creation of a phenomenological theory of nonequilibrium thermodynamics for the description of irreversible processes in nonequilibrium systems (**NS**). A significant contribution to its development was made by Onsager. An conclusion, that follows from this theory, that is very important for understanding of irreversibility problem is that the flows of substance and energy in the NS are nonlinear and have an order of smallness not lower than the second [14, 17].

The discovery of deterministic chaos in the simplest Hamiltonian systems, caused by the exponential instability of their dynamics, gave rise to great hopes for solving the irreversibility problem. The theory of such chaos was built on the basis of the laws and principles of classical and quantum mechanics. As it turned out, chaotic dynamics is observed even in the simplest Hamiltonian systems of the pendulum type [2, 20, 21]. For systems with chaotic dynamics, it was possible to introduce of the entropy concept, linking it with the Lyapunov exponents, which determine the rate of chaos increasing in the systems [2, 21]. From here, the mechanism of intermixing and decoupling of correlations became clear. But attempts to connect the mixing with irreversibility, demanded again to accept a hypothesis of “coarse grain” of phase space which is equivalent to a hypothesis of random external fluctuations [2].

Kolmogorov, Arnold, and Moser proposed the so-called KAM theory (Kolmogorov-Arnold-Moser). In it, the non-integrability problem associated with the destruction of certain integrals of motion was considered as a new starting point for the further development of the theory of deterministic chaos [2, 21]. These ideas were confirmed by the existence of the DMI.

Numerous attempts have been made to solve the irreversibility problem within the framework of the laws of quantum mechanics [22]. But quantum mechanics, in particular the Schrödinger equation, were built on the basis of formalisms of classical mechanics. Therefore here again these attempts to explain of the irreversibility nature have collided with the Poincaré theorem about reversibility of Hamiltonian systems. Moreover, the task was complicated by difficulties in understanding the physical meaning of the Heisenberg uncertainty principle [14, 15].

A significant contribution to understanding of the nature of deterministic chaos was made the results of research on a hard spheres and disks. These studies were beginning from the work of Krylov [23, 24]. They found their continuation in the works of Sinai [11, 12]. As a result of the studies of such systems, it was established that the mixing is characteristic of them. Based on these investigation was proposed K-entropy. K-entropy connects dynamic and probabilistic parameters of systems. But the limitations of the Lorentz systems used in theories collided with a number of insurmountable obstacles in understanding the nature of irreversibility. First, these systems were difficult for to analytical analyze of the problem. Second, such models and approaches to their analysis were useful only for studying the evolution of the system in the configuration space, and questions about Maxwellization of the particle velocities remain open. Thirdly, the Lorentz systems help to understand the role of instability in the creating of chaos. But at the same time, these systems do not convenient in understand of the energy exchange between the elements. It creates some difficulties for DMI explanation.

That the attractors are absent in Hamilton systems forced Prigogine to assume idea about limitation of fundamental physical laws. Without having found the nature of these restrictions, Prigogine actually added the probabilistic principles to physical laws. It was equivalent to postulation of the law on irreversibility [1]. After Prigogine, works appeared in which considerable efforts were made to justify the existence in nature of random fluctuations on the basis of the principle of uncertainty and other quantum-mechanical concepts.

When trying to expand the field of statistical physics, an empirical method of non-extensive thermodynamics emerged for weakly nonequilibrium systems. This made it possible to determine the distribution functions of weakly nonequilibrium systems and to study the connection between thermodynamic and mechanical parameters [25].

Klimontovich made a substantial contribution to the solution of the irreversibility problem by developing the foundations of the statistical theory of open systems. He suggested the key idea about the need to take into account the structure of a continuous medium at all levels of its description based on the results of studying the kinetic properties of continuous media. This idea served as a strong argument in favor of the fact that the dynamics of any systems is determined both by the symmetries of space and their internal symmetries. In his theories, he, like many of his predecessors, relied on statistical laws [26]. Klimontovich made a fundamental contribution to the developing knowledge of open nonequilibrium systems which, in effect, are practically all natural objects.

Thus, as a result of studying the nature of the irreversibility of systems, a probabilistic mechanism of irreversibility was found. He allowed connected the irreversibility of processes in nature and the determinism of the formalisms of classical mechanics with the help of probabilistic laws. By the way the statistical and kinetic methods for studying equilibrium and nonequilibrium systems were created. The methods for analysis of deterministic chaotic processes are developed. The limitations of the class of integrable systems were established. The nonlinearity of the processes of interaction of systems, the destruction of integrals of motion in the processes of system's dynamics, the necessity taking into account the structural character of the systems' elements already in the initial equations, and so on were found. It is obviously that all these results served as the starting point for the DMI search.

1. DYNAMICS OF THE DISKS SYSTEMS

The search of the DMI was beginning from the study of the dynamics of the simplest models of systems that have already been used to study the nature of irreversibility. These include billiards, Lorentz gas, elastically colliding disks [2, 11, 12, 24]. Their research has led to results that have made it possible to come to an understanding of the nature of irreversibility. In particular, the role of exponential instability in systems was established; the property of their mixing was studied. These properties are the basis of the probabilistic mechanism of irreversibility [1-4]. Based on these results, but used of the different approach, the search for DMI for disk systems was started.

The dynamics of disk systems was studied on the basis of the motion equation of colliding disks, which was obtained based on the matrix of pair collisions [27-30]:

$$\dot{V}_k = \Phi_{kj}\delta(\psi_{kj}(t))\Delta_{kj} \tag{2.1}$$

where $\psi_{kj} = [|l_{kj}(t)| - D]/|\Delta_{kj}|$; $\delta(\psi_{kj})$ – is a delta function; $l_{kj}(t) = z_{kj}^0 + \int_0^t \Delta_{kj} dt$ – is a distance between centers of the colliding discs; $\Phi_{kj} = i(l_{kj}\Delta_{kj})/(|l_{kj}|\,|\Delta_{kj}|)$; $z_{kj}^0 = z_k^0 - z_j^0$ – is the initial values of the coordinates of disks; D – is a disks diameter. Strikes are considered central, friction is neglected. The masses and diameters of the disks are assumed equal to unity. Moments of collision and the colliding partners defined by the condition, $\psi_{kj} = 0$.

In previous of disks dynamics studies, the processes of mixing in phase space and growth of entropy were analyzed [1-4]. But in studies of DMI the work of external forces on the motion of the center of mass (**CM**) of the disk system, and on the change of its internal energy was considered [27-29]. Here the internal energy of the disks system is a sum of the kinetic energies of the discs motion relative to the CM. The most important result of these investigations was that when the number of disks in the system is large enough, its internal energy could only increase. It gave the grounds to assume that the structure of bodies has to play a key role in DMI.

These investigations allowed to introduce the concept of D-entropy, defining it as the ratio of the increment of the internal energy of the discs system due to the motion energy to the total value of the internal energy [30, 31]. The violation of the time symmetry is determined by a violation of the invariance of the motion energy of the system as a result of its transformation into internal energy. The D-entropy determines the measure of such a violation.

In general, the study of disks systems led to the following conclusions [27-30]: the laws of mechanics do not prohibit DMI; DMI most likely should be associated with the transformation of the motion energy of systems into its internal energy; the interaction of disks is a necessary factor for the emergence of DMI. Thus, the study of disks systems testified that the bodies' structure is a necessary factor of DMI. It means that search of DMI has to be executed, having taken into account a role of structure of bodies in their dynamics by studying of the nature of transformation of the motion energy of systems to their internal energy.

A further search for DMI based on disks systems collided with a number of difficulties due to the limited applicability of these models. These difficulties are related to the use of the condition of pair collisions, with simplifications of disk system models. The fundamental difficulty was that the proof of the irreversibility of the disk's system was obtained based on the hypothesis of equiprobability for impact parameters of the discs. This hypothesis is beyond doubt, since it follows from the homogeneity of space. Moreover, this hypothesis was used by Boltzmann for obtaining of the kinetic equation [14]. Therefore the proof of irreversibility constructed on its basis is already probabilistic, but it was necessary to show that irreversibility follows analytically from the dynamical laws. Therefore, to continue the search for DMI, a model of the body was taken in the form of a system of potentially interacting MPs. This model is convenient because all bodies can be specified by the MP system, the dynamics of which can be analytically described in the frame of the classical mechanics laws.

3. DYNAMICS OF A SYSTEM OF POTENTIALLY INTERACTING MP

3.1. The principle of symmetry duality in the dynamics of systems

Thus, the study of the disks systems dynamics confirmed the idea that DMI should be sought by the way of studying transformation of the systems' motion energy into their internal energy. Such transformation takes place, for example, when the brick slips down along the inclined rough surface. To check this conclusion, it was necessary to obtain equations that allow us to analytically describe the transformation of the body's motion energy into internal energy.

In the approximation of local thermodynamic equilibrium in the frame molecular-kinetics theory all bodies can be considered as NS. In statistical physics and kinetics, NS can be presented by a set of equilibrium SPs, which moved relatively to each other [14, 17]. This makes it possible to study the processes of equilibration in closed NSs as a result of transforming the energies of the relative motions of the SP into their internal energy. The equilibrium corresponds to zero energy of the relative motions of the SP [17]. Therefore as the SP model it is possible to take of the equilibrium system consisting from the large number of potentially interacting MPs. The equilibrium of SP means that for any partition of the SP into subsystems, these subsystems are also in equilibrium and their relative velocities equal to zero. This property of equilibrium systems will be used to prove DMI. The uses of SP, as an NS element, allow to describe the processes of changing of the SP motion energy as a result of its transformation into internal energy, relying on the laws of classical mechanics. Let us consider how the motion equation of the SP was found.

An analysis of the works devoted to the search for an irreversibility mechanism within the framework of formalisms of classical mechanics pointed out that DMI, most likely, does not exist in this framework. Indeed, the formalisms of classical mechanics follow from the laws of mechanics only if using certain restrictions. Therefore, it is possible that DMI was disappearing due to these restrictions. Subsequently, this assumption was confirmed [30, 32]. That is, the equation that describes the processes of converting the motion energy into internal energy must follow directly from the fundamental concepts of classical mechanics. Such concepts are energy, momentum, and the force which determine of their transformation [9].

The motion of each MP of the system gives a contribution, both into internal energy and into the motion energy of system. The change with time of the ratio of these contributions is characterizes dissipation. Let us explain how this change can be described with the help of the motion equation of the system if this equation will be obtained from the condition of invariance of the total energy, represented as the sum of the motion energy and internal energy.

Changes in the motion energy and internal energy of the system depend only on external forces. The motion energy is determined by the mass of the system, the external field of forces and the speed of motion of the system's CM. The internal energy is defined by the motions of all MPs relative to the CM in the force field under the condition that the sum of their moments is equal to zero. Both types of energies of the system depend on the work of external forces, which goes both to its movement and to a change of internal energy. Therefore, the motion equation of the system is determined not only by the symmetries of space, as in the case for an unstructured body or MP, but also by its internal symmetries. This obvious statement is a key to constructing the system's motion equation. Therefore, it was called the principle of dualism of the symmetry (**PDS**) [30, 31]. The formulation of the PDS is as follows: the dynamics of bodies is determined both by their internal symmetries and the symmetries of space. We see that the PDS just corresponds to the fact that friction is determined by the efficiency of converting the motion energy into internal energy. Therefore the system's motion equation will describe dissipation, if it will construct in accordance with the PDS.

To each symmetry group there correspond invariants [33, 34]. The invariants of the dynamic groups of symmetries are energies. The homogeneity of time is associated with the invariance of the motion energy of the systems. Transition of the ordered motion energy of systems into the energy of the MPs chaotic motion, is equivalent to breaking the symmetry of time. Therefore for the description of dynamics of system with taking into account such transition, its total energy needs to be submitted in such coordinate system in which it is equal to the sum of the motion energy and internal energy. By similar way the body's energy is represented at the description of dynamics of bodies with rotation [10, 33]. The group of variables that determine the internal energy has been called micro-variables. The group of variables that determine the motion energy of the system has been called macro-variables. Let us show below how in these variables the total energy of the

system decays into the motion energy and internal energy and how the motion equations of the system can be obtained from the energy represented in this way [30-32].

3.2. The system's motion equation

Let us take the system from N potentially interacting of unit mass MPs. From a condition of potentiality of forces for MP their additivity follows. Therefore the forces acting on each MP are equal to the sum of forces from all other MP and external forces. The forces between MP are determined by the distance between them. The kinetic energy of the system is equal to the sum of the kinetic energies of the MP. I.e., $T_N = \sum_{i=1}^{N} m v_i^2 / 2$, where v_i - is a velocity i-th MP in the laboratory coordinate of the system. The potential energy of the MP system in the field of external forces is -U_N^{env} which equal of the sum of potential energy of MP. The potential component of the internal energy is composed of the energies of pair interactions of MPs with each other. It is equal to $U_N^{ins}(r_{ij}) = \sum_{i=1}^{N-1}\sum_{j=i+1}^{N} U_{ij}(r_{ij})$, where i, j are the numbers of MP, $i, j = 1,2,3...N$; $r_{ij} = r_i - r_j$ is a distance between i and j MP. In addition, there is still a contribution to the internal energy of the potential energy of the field of external forces.

The energy of the system in the laboratory coordinate system has the form [30, 31]:

$$E_N = T_N + U_N^{ins} + U_N^{env} = const \tag{3.1}$$

Let us rewrite eq. (3.1) in micro - and macro variables. We call the corresponding coordinate system a dual coordinate system. First of all, we will show that in dual coordinate system the system's energy is equal the energy of the motion CM and the sum of energy of the relative motions of MP. After that we will show that the sum of the kinetic energies of the relative motions of the MP coincides with the sum of the kinetic energies of the motion of the MP relative to the CM of the system.

The quadratic function of the kinetic energy can be written in terms of a quadratic function, in which the arguments are the relative velocities of the MP and the velocity of the CM of the system. This follows from the equality: $N \sum_{i=1}^{N} v_i^2 = (\sum_{i=1}^{N} v_i)^2 + \sum_{i=1}^{N-1}\sum_{j=i+1}^{N} v_{ij}^2$. Let us carry out the substitution in this equality: $V_N = (\sum_{i=1}^{N} v_i)/N$ - is a velocity of the CM; $v_i - v_j = v_{ij} = \dot{r}_{ij}$. As a result, we get: $T_N = [M_N V_N^2 + m/N \sum_{i=1}^{N-1}\sum_{j=i+1}^{N} v_{ij}^2]/2$ (a). Now we carry out the substitution in (3.1): $v_i = V_N + \tilde{v}_i$, where $\tilde{v}_i$ - is a velocity of MP in relative of the CM. Because $\sum_{i=1}^{N} \tilde{v}_i = 0$, then we will have: $T_N = M_N V_N^2/2 + \sum_{i=1}^{N} m\tilde{v}_i^2/2$ (b). As it follows from (a) and (b),the sum of the energies of the relative motions of the MP and the energy determined by the sum of the kinetic energies of the motion of the MP relative to the CM are coincide. Thus, the kinetic energy of the system, represented in the micro - and macro variables, is divided into the sum of the kinetic energies of the MP relative to the CM and the kinetic energy of the CM motion of the system.

The potential component of the energy of the motion of the system is determined by the sum of potential energies of all MPs in the field of external forces. It corresponds to the potential energy MP, equal to the mass of the system and located at the CM point. The potential component of the internal energy is related to the interaction energy of the MP. It depends on the micro variables and is determined by the symmetries of the system. In the general case, the inhomogeneous field of external forces can contribute to the potential component of the internal energy. The terms that determine this contribution depend on the micro variables. The independence of micro and macro variables is a mathematical reflection of the PDS and indicates on the presence of two invariants corresponding to two symmetry groups that determine the motion of bodies [30]. The movement of a body is connected with one type of symmetry; the internal energy is connected with the se-

cond type of energy. I.e. dynamics of system is unambiguous function micro - and macro parameters. Thus, micro - and macro variables belong to two different symmetry groups.

In the laboratory coordinate system, the full energy of each MP is a mix from the motion energy and internal energy but in dual coordinate system these parts of energy separated. That is, in dual coordinate system it is possible to study the processes associated with the transformation of the energy of motion into internal energy. The expression for energy in dual coordinate system can be written as:

$$E_N = E_N^{tr} + E_N^{ins}, \tag{3.2}$$

where $E_N^{ins} = T_N^{ins} + U_N^{ins}$ - is internal energy, dependent on the micro-variables; $T_N^{ins} = \sum_{i=1}^{N} m\tilde{v}_i^2 / 2$ - is a kinetic component of the internal energy of the body, $E_N^{tr} = T_N^{tr} + U_N^{tr}$ - is a motion energy, T_N^{tr} - is a kinetic motion energy of the CM of the system, depending on the macro variables.

In accordance with eq. (3.2), the law of conservation of the system's energy is: the **sum of the motion energy and internal energy of the system is preserved along its trajectory.**

Differentiating the energy of the system (3.2) with respect to time, we obtain [30, 31]:

$$V_N M_N \dot{V}_N + \dot{E}_N^{ins} = -V_N F^{env} - \Phi^{env}, \tag{3.3}$$

where $F^{env} = \sum_{i=1}^{N} F_i^{env}(R_N, \tilde{r}_i)$, $\dot{E}_N^{ins} = T_N^{ins}(\tilde{v}_i) + U_N^{ins}(\tilde{r}_i) = \sum_{i=1}^{N} \tilde{v}_i (m\dot{\tilde{v}}_i + F(\tilde{r}_i)_i)$, $M_N = mN$, $F_i^{env} = \partial U^{env} / \partial \tilde{r}_i$, $\Phi^{env} = \sum_{i=1}^{N} \tilde{v}_i \, F_i^{env}(R_N, \tilde{r}_i)$.

Eq. (3.3) determines the change of the motion energy and internal energy of the system in an external field along its trajectory and the right-hand side determines the work of external forces.

Multiplying eq. (3.3) by V_N then dividing it by V_N^2, leaving the inertial force on the left-hand side, we obtain of the system's motion equation [31]:

$$M_N \dot{V}_N = -F^{env} - \alpha_N V_N, \tag{3.4}$$

where $\alpha_N = (\Phi^{env} + \dot{E}_N^{ins}) / V_N^2$ -is a coefficient that determines the change of internal energy.

The first term on the right-hand side of eq. (3.4) is the force which applied to the CM of the system. It determines the system's motion as a whole. The second term depends on the micro - and macro variables. It determines the change of the internal energy. Because of the presence of this term, the symmetry of eq. (3.4) differs from the symmetry of Newton's equation. That is, the motion energy for the system, in contrast to the motion equation of the MP, in the general case is no invariant. This means the possibility of breaking the symmetry of time. As can be seen from eq. (3.4), the work of external forces in the general case does not coincide with the work on the displacement of the system, because part of this work is transformed into internal energy.

Let us consider the mechanism of violation of the motion energy invariant based on the eq. (3.3). Suppose that inequality $R >> \tilde{r}_i$ have a place. Than the force F^{env} can be decomposed into a small parameter $\tilde{r}_i / R$. Keeping in the expansion the terms of zero and first orders of smallness, we will write: $F_i^{env} \approx F_i^{env}\big|_R + (\tilde{r}_i \cdot \nabla) F_i^{env}\big|_R$. Because $\sum_{i=1}^{N} \tilde{v}_i = \sum_{i=1}^{N} \tilde{r}_i = 0$ and $\sum_{i=1}^{N} F_{i0}^{env} = N F_{i0}^{env} = F_0^{env}$, we will have from equation (3.3):

$$V_N(M_N\dot{V}_N)+\dot{E}_N^{ins}\approx -V_N F_0^{env}-\sum_{i=1}^{N}(\tilde{r}_i\cdot\nabla)F_i^{env}\Big|_R\tilde{v}_i\,. \tag{3.5}$$

The second term on the right-hand side of eq. (3.5) simultaneously depends on the micro - and macro variables, which belongs to different symmetry groups. Therefore this nonlinear term is bisymmetric. In the presence of a gradient of external forces this term isn't equal to zero. In this case, the micro - and macro variables are hooked, and the transformation of the motion energy into the internal energy is possible. If the gradients of the external forces are small, then by the disturbances of the equilibrium SP can be neglected. But the internal energy of the equilibrium system cannot be transformed into energy of motion. This means the irreversibility of the SP dynamics. The nonlinearities determining the changes of the motion energy of the systems due to its transformation into internal energy are responsible for the symmetry breaking. These nonlinearities we will call evolutionary nonlinearities.

Violation of the time's symmetry is necessary, but not sufficient condition for DMI. This can be seen on the example of passage of an oscillator through a potential barrier, when the internal energy can both increase and decrease depending on the initial phase of the oscillator [35, 36].

Eq. (3.4) generalizes the equations of Aristotle and Newton. Indeed, Aristotle argued that the speed of the body is proportional to the force. According to eq. (3.4), this is true when the frictional force is equal to the driving external force. Newton's motion equation asserts that acceleration is proportional to the external force. According to eq. (3.4), this case has a place when the external forces are homogeneous, or when the change in internal energy due to friction can be neglected.

Let us consider the other way receiving of the system's motion equation by summarizing the changes of energy for all MPs of the system. This way will allow divided of the forces in the right-hand side of the motion equation on the forces that change internal energy and forces that move the system as a whole [38-41]. Only the condition of additivity of work of the external and internal forces operating on MP is used on this way. Differentiating with respect to time the energy of the MP system in the field of external forces, we obtain:

$$\begin{aligned} &v_1(\dot{v}_1+F_{12}+F_{13}+...+F_{1N}+F_1^0)+v_2(\dot{v}_2-F_{12}+F_{23}+...+F_{2N}+F_2^0)+\\ &+v_3(\dot{v}_3-F_{13}-F_{23}+...+F_{3N}+F_3^0)+.....+v_N(\dot{v}_N-F_{1N}-F_{2N}-...+F_{N-1,N}+F_N^0)=0 \end{aligned} \tag{3.6}$$

Where F_i^0 -is external force, acted on i-th MP; F_{ij} - is interaction force i and j MP; $m_i=m_j=1\forall i,j;i,j=1,2,...N$.

It is important to note that the condition of holonomicity of constraints used in the derivation of the Lagrange equation is equivalent to the condition that each term of eq. (3.6) is equal to zero [9, 10]. In this case we will have motion equation for each MP:

$$\dot{v}_i=-F_i^0-\sum_{i=1}^{N-1}\sum_{j=i+1}^{N}F_{ij} \tag{3.7}$$

The system's motion equation has a form:

$$M_N\dot{V}=-\sum_{i=1}^{N}F_i^0 \tag{3.8}$$

Here $V=1/N\sum_{i=1}^{N}v_i$; $M_N=Nm=N;m=1.$.

The eq. (3.8) is obtained by summarizing of eq. (3.7) [10]. The derivation of eq. (3.8) by summarizing eq. (3.7) for all MP led to the loss of the work which go on the change of internal energy. To take this work into account, the motion equation should be obtained directly from eq. (3.6) without using any hypotheses. This can be done by transformation of eq. (3.6) to the new micro - and macro variables, and then grouping the

terms so as to write the equation in these new variables. Transformation of eq. (3.6) to new variables is carried out by means of the following equalities: $\sum_{i=1}^{N} v_i \dot{v}_i = NV_N \dot{V}_N + (\sum_{i=1}^{N-1} \sum_{j=i+1}^{N} v_{ij} \dot{v}_{ij}) / N$; $F_{ij}^0 = F_i^0 - F_j^0$; $\sum_{i=1}^{N-1} v_i \sum_{j=i+1}^{N} F_{ij} = \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} v_{ij} F_{ij}$; $\sum_{i=1}^{N} v_i F_i^0 = V_N \sum_{i=1}^{N} F_i^0 + (\sum_{i=1}^{N} \sum_{j=i+1}^{N} v_{ij} F_{ij}^0) / N$. By grouping the terms of eq. (3.6) in according with these equalities, taking into account that $F_{ij}^0 = -F_{ji}^0$, we will obtain: [30, 38]:

$$NV_N \dot{V}_N = -V_N \sum_{i=1}^{N} F_i^0 - \frac{1}{N} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} v_{ij} (\dot{v}_{ij} + F_{ij}^0 + NF_{ij}), \tag{3.9}$$

Multiplying eq. (3.9) by V_N and dividing by V_N^2, we obtain of the system's motion equation:

$$M_N \dot{V}_N = -\sum_{i=1}^{N} F_i^0 - \frac{V_N}{NV_N^2} \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} v_{ij} (m\dot{v}_{ij} + F_{ij}^0 + NF_{ij}) \tag{3.10}$$

Eqs. (3.6, 3.9, 3.10) are equivalents because the eq. (3.9) is obtained from eq. (3.6) as a result of the transition to micro - and macro variables. The eq. (3.8) is not equivalent with eq. (3.6). Indeed, it was obtained by summarizing of the eq. (3.7). But because the sum of the internal forces is equal to zero, the terms of the motion equation, which connected with the changes of the internal energy, have disappeared. Moreover, the eq. (3.7) follows from eq. (3.6) only when each terms of eq. (3.6) are equal to zero. It is also limitation its generality. Therefore, the eq. (3.8) is a particular case of eq. (3.10) and the eq. (3.8) true only in the case of absence of gradients of external forces. Indeed, under this condition we obtain from (3.10):

$$M_N \dot{V}_N = -\sum_{i=1}^{N} F_i^0 \quad \text{(3.10a)} \qquad\qquad \sum_{i=1}^{N-1} \sum_{j=i+1}^{N} v_{ij} (m\dot{v}_{ij} + NF_{ij}) = 0 \quad \text{(3.106)}$$

Eq. (3.10) corresponds to eq. (3.4) and has a different symmetry than eq. (3.8). Eq. (3.10a) is the eq. (3.8). Eq. (3.10b) determines the motion of the MP within the system and corresponds to the law of conservation of internal energy.

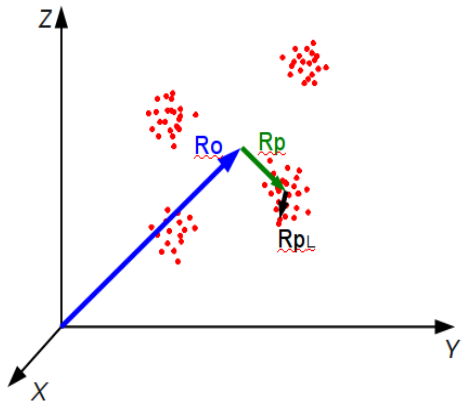
Eq. (3.8) can be obtained directly from the Lagrangian [9]. This follows from the fact that the Lagrange formalism, like the eq. (3.8), is derived from the laws of classical mechanics under the condition that the hypothesis of holonomic of constraints is fulfilled [9]. Because the nonholonomic constraints, that are causes of the DMI, are excluded, the Hamiltonian systems are invertible [38, 41]. That is, the reversibility of Hamiltonian systems is connected with the limitations of formalism, and not with the limitations of the laws of mechanics.

Thus, as it follows from eqs. (3.4, 3.10) the dynamics of SP with a sufficient number of MPs in the region of gradients of external forces is irreversible. Below we will consider how based on the PDS it is possible to show the presence of DMI for NS.

4. EVOLUTION OF NONEQUILIBRIUM SYSTEMS

4.1. Formalisms of nonequilibrium systems

As noted, the NS can be represented as a set of moving relative to one another SPs. Therefore it is possible to determine the NS state by the point in the phase space of 6K-1 measurements, where K is the number of SPs entering into the NS. Accordingly, the position of each SP is given by three coordinates and three components of the momentum of their CM. We call this space an S-space to distinguish it from the phase space for Hamiltonian systems. Points of S-space characterize the evolution of NS.



The internal energy of the moving SP is change. Therefore, for one point of the S-space can be

corresponds different values of the internal energy of the SP. This ambiguity is eliminated if S-space to add by the space of micro variables that determine the internal energies of the SP. Let us call this dual spase as SD-space. For the case when the SP in equilibrium the SD-space is a simplest. In this case the additional space is reduced to the K - dimensional space, because the internal states of SPs are determined by their internal energies [14, 17]. The equilibrium state will correspond to the fact that the state vector of the system will lie in D - space.

Fig. 1. Structure of non-equilibrium system.

NS can be consid-ered as the third stage of the substance hierarchical ladder: MP $\Rightarrow$ SP $\Rightarrow$ NS.

Let's take NS consisting of identical SPs, containing the equal quantity of MP. The mass of NS is equal $M_{NS} = NKm$ (see Fig.1). The energy equations for NS are compiled similarly as the energy equation of the SP; only instead of the MP it takes the SP.

$$E_{NS} = \{M_{NS}V_{NS}^2/2 + U_{NS}^0\} + \{\sum_{p=1}^{K} M_{SP}V_{SPp}^2/2 + \sum_{q=1}^{K-1}\sum_{p=1+q}^{K} U_{p,q}\} + \sum_{p=1}^{K}\{\sum_{l=1}^{N} m\, v_{pl}^2/2 + U_p\} \quad (4.1)$$

$M_{SP} = mN$ - is a mass of each SP; $U_P = \sum_{i_p=1}^{N-1}\sum_{j_p=i_p+1}^{N} U_{i_p,j_p}(r_{i_p,j_p})$ - is internal potential energy for p -th SP, due to interaction of each MP from this SP; r_{i_p,j_p} - is a distance between i_p -th and j_p -the MP from p -th SP; V_{SP_p} - is a velocity of p -th SP; $U_{p,q} = \sum_{l_{q_j}=1}^{N-1}\sum_{l_{P_i}=1+l_{q_j}}^{N} U_{p_i,q_j}(r_{p_i,q_j})$ - is a potential energy of MP interaction from different p -th and q -th SP; r_{p_i,q_j} -is a distance between p_i -th and p_j -th MP from p -th and q -th SP. That is, the third term in eq. (4.1) determines the potential energy of the interactions of all SP.

The first term in eq. (4.1) is the energy of the NS motion. It consists of the kinetic energy of the NS motion and its potential energy in the field of external forces. The second term is the sum of the energies of the relative motions of all the SPs and their interaction energies. The third term in eq. (4.1) determines the kinetic and potential energy of the MP in SPs. The fourth term, U_{NS}^0, determines the potential energy of the NS in the field of external forces.

In the general case, the work of external forces is spent on the motion of the NS in space and on the change of its internal energy. The internal energy is composed of the kinetic energies of the SP motion relative to the CM of the NS, their potential energy of interactions, and also from their internal energies. The internal energy of the SP is composed of the kinetic energies of the motion of the MP relative to the CM of the corresponding SP and from the potential energies of MP interactions. The hierarchy of independent variables that determine the dynamics of the NS corresponds to the PDS at each hierarchical level.

If the NS is closed, then it go to equilibration, because the energy of the relative motions of the SP will go into their internal energy. As a result, the NS turns into the equilibrium system. It follows that the possibility of the existence of stationary NS can realized only due to the flows of external energy that compensate the dissipation of the energies of the relative motions of the SP.

The study of the NS is performed based on various empirical modifications of the kinetic equations [14, 17]. These equations were constructed based on the formalisms of classical mechanics. In turn, these formalisms were constructed based on the Newton's motion equation for MP under the condition that the condition

of holonomic constraints is fulfilled [9, 10]. As already noted, the holonomic constraints led to the loss of the possibility description of irreversible processes within the framework of canonical formalisms [10, 13]. But we can eliminate this drawback by obtaining the extended Lagrange, Hamilton, and Liouville equations. Their derivation carried out in an analogous way, as in the classical case, but instead of the Newton's motion equation must use the SP motion equation.

Following on the standard procedure of the obtaining of the Lagrange equation [9, 10], but using of the motion eq. (3.4) for i-th SP from the NS, we will have [28]:

$$\sum_{i=1}^{N}(\frac{d}{dt}\frac{\partial L_p}{\partial v_i}-\frac{\partial L_p}{\partial r_i})=\sum_{i=1}^{N}\Phi_i^p=\Phi^p\,. \tag{4.2}$$

Here Φ_i^p - is a non-potential part of the forces, acted of the i-th MP, from p- th SP, $i=1,2,3...N$, Φ^p - is a resulting forces, changing of the internal energy of p- th SP. These forces define the second term of the right-hand side of the eq. (3.10) or eq. (3.4).

Let us note that such a form of the Lagrangian equation is known [42]. But the important difference is existed. In the eq. (4.2) the Φ^p is a deterministic force that followed from the right-hand side of the eqs. (3.4, 3.10), but forces in is empirical.

From eq. (4.2) we obtain by standard way the Hamilton equations [28]:

$$\frac{\partial H_p}{\partial r_i}=-\dot{p}_i+F_i^p,\ \frac{\partial H_p}{\partial p_i}=v_i\ , \tag{4.3}$$

Here H^p - is a Hamilton function for p-th SP, p_i -is a momentum of i –th MP.

From here we can obtain the extended Liouville equation for the SP which has the form [28]:

$$\frac{df_p}{dt}=\frac{\partial f_p}{\partial t}+\sum_{i=1}^{N}\{v_i(\partial f_p/\partial r_i)+\dot{p}_i(\partial f_p/\partial p_i)\}=-f_p\sum_{i=1}^{N}\partial F_i^p/\partial p_i \tag{4.4}$$

Here $f_P-$is a distribution function MP in p -th SP, v_i, r_i, p_i - is a velocities, coordinates and momentum for i- th MP, N- is a quantity of MP in SP, F_i^p - is a external forces, acted on i-th MP.

The right-hand side of eq. (4.4) is not equal to zero when the gradient of the external forces that change the internal energy of the SP is exists. Eqs. (4.2-4.4) are applicable to describing equilibration of NS, because they take into account the compressibility of the S-space due to the transition of the motion energies of the SP into their internal energy. The S-space of the system in the equilibrium or in nonequilibrium steady state coincides with the usual phase space.

Formally, the solution of eq. (4.4) has a form:

$$f_p=f_0\exp\{-\int(\sum_{i=1}^{N}\partial F_i^p/\partial p_i)dt\} \tag{4.5}$$

It is follows from the eq. (4.5), that the distribution function equilibrates due to transforming of the energy of the relative motions of the SP into the internal energy. For NS a stationary state is also possible, when the influx of energy is equal to its outflow. The stationarity of the NS is possible only when the equilibrium body radiation is taken into account [14-16]. Therefore the problem of establishing a stationary state is beyond of the framework of classical mechanics.

The extended Poisson brackets for NS are constructed, as is eq. (4.4). The invariants they determine depend on the micro - and macro variables [30]. Their main invariant is the sum of the motion energy and internal energy.

Let us show how taking into account of the dissipative forces in the systems moving in inhomogeneous fields of forces will lead to a modification of the principle of least action.

The condition of holonomic connection is equivalent to the potentiality of the collective forces that determine the motion of the system. This is evident from the fact that the Lagrange equation can be obtained at either by variation method and by integrating of the d'Alembert equation with respect to time, if the external forces are potential. Integrating the d'Alembert equation with fixed initial and final points of the trajectory of the system, we obtain [9]:

$$\int_{t_1}^{t_2} \delta w dt = \delta \int_{t_1}^{t_2} L dt = \delta A = 0, \tag{4.6}$$

where $A = \int_{t_1}^{t_2} L dt$ - is action, L_0 - is canonical Lagrangian for holonomic systems.

Eq. (4.6) is the principle of least action. According to this principle, the system's motion occurs in such a way that a definite integral with fixed initial and final positions of the system has a stationary value with respect to any possible changes in its trajectory. Hence, for potential collective forces, we have [9, 10]: $\delta A = 0$. This case has a place for the systems near equilibrium. In the inhomogeneous field of forces, instead of eq. (4.6), we have [39, 40]:

$$\int_{t_1}^{t_2} \delta w dt = \delta \int_{t_1}^{t_2} L dt = \delta A^d \neq 0 \tag{4.7}$$

Here A^d - is a term, due to the nonlinear transformation of the system motion energy into internal energy. In the simplest case, it A^d is a bilinear function. Eq. (4.7) can be called as the **extended principle of least action.** Unlike the classical principle of least action, its right-hand side is not equal to zero. According to eq. (4.2) its right-hand side is equal to:

$$A^d = \delta \int \sum_{i=1}^{R} (\Phi_i dr_i) dt \tag{4.8}$$

In general, the canonical equations of formalisms of classical mechanics are a particular case of the corresponding extended formalisms, which constructed based on the SP motion equation.

4.2. Evolutionary nonlinearity and irreversibility

Let us show the existence of DMI for NS using the analysis of evolutionary nonlinearity which responsible at the violation of temporal symmetry [38-41]. We assume that the NS is represented by a set of SP, whose total momentum is zero. We use the obvious fact that the irreversibility of NS means the predominance of positive fluxes of internal energies of the NS due to the energy of relative motions more than negative flows.

Let us ΔE^{tr} - is a part of energy of SPs relative motion, which is transformed into the internal energy of SP. In according with the eq. (3.4), the value ΔE^{tr} is determined by the bilinear terms of the expansion of the field of external forces, which depend on the macro - and micro variables. These variables determine the motion of the SP and their MP, respectively. Therefore the value ΔE^{tr} has a second order of smallness, i.e. $\Delta E^{tr} \sim \varepsilon^2$, where $\varepsilon << 1$ - is a small parameter, for example, the ratio of the characteristic scale of the SP to the characteristic scale of the inhomogeneity of the force of field [17]. Then we have $\Delta E^{tr} / E^{\text{int}} << 1$ and a violation of the SP equilibrium is neglected. As it was shown above, it means irreversibility of SP and therefore, irreversibility of NS.

When we have sufficiently large gradients of forces into NS, equilibrium of SP is violated. Then each SP can be submitted by a set of equilibrium subsystems moving relative to each other. In this case, to increase the internal energy of the SP, we can write: $\Delta E^{tr} = \Delta E^{tr}_{ins} + \Delta E^{h}$, where ΔE^{tr}_{ins} is increment of energy of the relative movement of subsystems, ΔE^{h} - is increment of internal energies of subsystems. I.e. $\Delta E^{tr}_{ins} < \Delta E^{tr}$. In this case, only the part of the energy of the relative motions of the subsystems, which we denoted as ΔE^{tr}_{ret}, can return to the energy of the motion of the SP. The value ΔE^{tr}_{ret}, as the value ΔE^{tr}, is determined by the bilinear functions of variables of the motion energy of the subsystems of the SP and the energy of the motion of the SP. I.e., ΔE^{tr}_{ret} is a second-order term of the smallness of these variables. But because $\Delta E^{tr} \sim \varepsilon^2$, then $\Delta E^{tr}_{ret} \le \varepsilon^4$. Provided that the subsystems, on which the SP has disintegrated, are equilibrium systems, we will have: $\Delta E^{tr} > \Delta E^{tr}_{ret}$. It is means of irreversibility.

Hence the question about irreversibility is the question of about inequality $\Delta E^{tr} < \Delta E^{tr}_{ret}$. Let us show that the inequality $\Delta E^{tr} > \Delta E^{tr}_{ret}$ always have a place only for large systems.

Thus, DMI for NS is caused by an of the motion energies of SP into their internal energies. The irreversible transformation has a place for strong and for weak interaction of SP. Equilibrium corresponds to zero values of energies of the relative motions of SPs. Let us show how this conclusion was confirmed by numerical calculations of the motion equation of SP in an inhomogeneous field of forces [30, 35, 36].

Firstly, the numerical calculations and analysis for oscillator motion, basing on the eqs. (3.4, 3.10), were performed. For him, the effect of subbarrier passage was discovered, that is, when the energy of the barrier is greater than the motion energy of the oscillator's, but less than its total energy. This effect is due to the nonlinear conversion of internal energy into motion energy [30, 36]. The fact that such transformation of the energy has a place also follows from the statistical theory [17]. Indeed, according to the theorem about fluctuations of quadratic functions, their magnitude is proportional to $1/\sqrt{N}$. I.e., for a small systems the inequality $\delta E^{tr}_{ret} > \Delta E^{tr}$ have a place in some case (here the sign δ is used to denote the fluctuations of the corresponding values). But with the increase in the number of MPs in the system, part of the internal energy transforming into its motion energy decreases in proportion $1/\sqrt{N}$ and when $N > N_0$, the inequality $\Delta E^{tr} > \Delta E^{tr}_{ret}$ will always hold. The question naturally arises: is such a behavior of fluctuations follow from the deterministic equation (3.4)? To answer this question, numerical calculations of the change in the D-entropy for systems with different numbers of MPs were performed on the basis of eq. (3.4), when they move through a potential barrier [30, 36]. The calculations were carried out 400 times at a constant value of the energy for a given number of MP, but for different initial states of the system. This made it possible to determine the dependence of the fluctuations of the D-entropy from the initial states of the system and from the values of the energy and the number of MPs in the system. As a result, it was found that fluctuations of the internal energy decrease with increasing number of MP. Moreover, the decrease coincided with the statistical law of fluctuations of quadratic functions $\delta E^{tr} \sim 1/\sqrt{N}$ [30]. This means that statistical law follows from the laws of classical mechanics.

Numerical calculations for systems of potentially interacting MPs have shown that when the number of MP in the system is less than 64, the D-entropy can be either positive or negative [36]. But if N> 64, then for all 400 calculations inequality $\delta E^{tr}_{ret} < \Delta E^{tr}$ have a place. This means that for N> 64, the inequality $\delta E^{tr}_{ret} < \Delta E^{tr}$ holds for all initial conditions. The number 64 was called the first critical number of the system, when it becomes irreversible.

If N > 1000, the increase of the internal energy ceases to depend on the increase of the number of MP. This number was called the second critical number. It means that if N>1000, then the thermodynamic description is

valid. Obviously, in the general case, these critical numbers will depend on the parameters of the problem, for example, from the width and height of the barrier. Thus, the statistical laws for dynamical systems, in particular the law of energy fluctuations, are a consequence of the motion equation of the system. That is, the motion of the system to an equilibrium state corresponding to its maximum probability follows from the laws of mechanics. This allows us to state that the domain of validity of statistical laws is determined by the deterministic laws of physics. Probabilistic laws can be considered as possible simplifications. This is in good agreement with [42], where it was asserted that "irreversibility is qualitative: the more particles in the system, the more irreversibly it behaves.

For the NS stationarity, it is necessary to have equality $\Delta E^{tr}_{ret} = \Delta E^{tr}$ on all hierarchical levels of matter, but the description of the nature of the establishment of the stationary state goes beyond the laws of classical mechanics, since stationarity arises from the thermal radiation of the body, determined by the Planck formula [14-16]. In statistical physics, the tendency of the NS to equilibrium is proved by varying the entropy of the NS under the conditions of the existence of its maximum in the equilibrium state, and the fact that the maximum entropy corresponds to the states in which the system exist a maximum time.

The equilibrium state of the NS corresponds to zero values of the motion energy of the SP [14, 17]. That is, the kinetic energy of relative motions of SP near equilibrium satisfies the condition: $T^{tr}_{K} \to 0$ for, where K is the number of the SP. According to the principle of least action, equilibrium is also a stable state [30]. All this facts agrees with DMI.

Here are some more arguments in favor of DMI. The probability mechanism is based on the fact that arbitrarily small fluctuations for exponentially unstable Lyapunov systems lead to irreversibility. This was proved by studying the dynamics of the Hamiltonian system in phase space. But if this was the only mechanism for irreversibility, the question would arise, how in the same systems an order is formed that we observe in everyday life. It is unclear how fluctuations can create the order. For DMI the answer to this question exists. Indeed, according to the mechanics of the SP, in order to create and maintain order, it is necessary to compensate for the energy of the relative motion of the SP, which passes into internal energy, by an external influx of energy into the NS. That is, external constraints need to be set so that they support stationary a given nonequilibrium state. With the help of the probabilistic mechanism of irreversibility, the questions about validation of the laws of thermodynamics, statistical physics, kinetics, etc., cannot be solved. But these questions are naturally solved in the framework of mechanics of SP.

4.3. The thermodynamics of the gas of structured particles and the D-entropy

Up to now a justification of thermodynamics empirical laws is realized only in the frame of statistical physics [17, 18]. But the justification of thermodynamics in the frame of classical mechanics laws was absent [14, 17, 43]. Mechanics SP allows you to do this. Indeed, the mechanics of SP, like thermodynamics, is built on the basis of a dual representation of the energy of the system. According to eq. (3.2), the total differential of the work of external forces with respect to the displacement of SP can be written as follows:

$$dU^{sp} = \delta A^{\text{int}} + \delta A^{tr} \ , \tag{4.9}$$

where δA^{int} - is a change of the internal energy; δA^{tr} - is a change of the motion energy. By analogy with thermodynamics, expression (4.9) can be called the mechanical principle of energy.

The thermodynamic principle of energy is written as follows [14]:

$$dU = \delta Q - \delta A \tag{4.10}$$

Here U - is the adiabatic potential, Q - is a thermal energy, A - is a work of external forces to change the volume of the system.

The mechanical principle of energy does not exclude the possibility of taking into account the violation of the symmetry of time that arises when the SP moves in an inhomogeneous field of forces. Such a symmetry breaking is caused by a violation of the invariance of the energy of the motion of the SP as a result of its transformation into internal energy.

Let us compare the thermodynamic and mechanical principles of energy. Both in mechanics of SP and in thermodynamics, structured bodies with internal energy are studied. The mechanics of SP, like thermodynamics, rely on the ideas of the molecular-kinetic theory [1]. The common for the thermodynamic and mechanical principle of energy is that they both follow from the PDS. They take into account the role of the work of external forces, which is change the internal energy. But there are differences. While the mechanical principle of energy is the complete work of external forces over a system, the thermodynamic principle of energy includes only work on changing the internal energy of the system. This work is equal to the sum of work on changing the volume of the body and changing the thermal energy. Hence, for the adiabatic potential U, equality $U = E^{\text{int}}$ holds, which is quite natural, since the adiabatic potential corresponds to the law of conservation of the internal energy of the system.

Thus, in the SP mechanics, unlike thermodynamics, the work of external forces is fully considered, including the work on the displacement of the system, although the work on changing the internal energy in the SP mechanics is not divided into work on changing its volume and heat, as is done in thermodynamics. When analyzing the evolution of the NS, which are almost all natural objects, there is no need for such a separation. In addition, in the mechanics of SP, the gradient of the external field of forces is taken into account, due to which a transformation of the motion energy of the SP into its internal energy occurs. In thermodynamics, the motion energy of the system and the forces changing it are not considered [2]. Consequently, the mechanical principle of energy is the total work of external forces in moving the system and changing its internal energy, and the thermodynamic principle of energy includes only work on changing its internal energy, which divided into work for change the volume of the system and its heating.

Although the thermodynamic principle of energy differs from the mechanical one, these two principles are qualitatively similar. Indeed, the work on changing the volume of the body corresponds to the work on moving the SP, by a set of which the body can be approximated. And the thermal energy is equivalent to the sum of the internal energies of the SP. Consequently, the thermodynamic and mechanical principles of energy in their physical essence coincide. That is, the differences between the mechanics of SP and thermodynamics are not of a qualitative nature, as in the case of the difference between Newtonian mechanics for structureless bodies and mechanics of SP. Therefore, the mechanics of the SP allows us to substantiate thermodynamics within the framework of the laws of classical mechanics.

The generality of the SP mechanics is much higher than the generality of thermodynamics. All collective parameters characterizing the thermodynamics of a gas can be obtained by integrating the dynamic parameters of the SP mechanics. The SP mechanics allows us to justify not only the laws of thermodynamics within the framework of the fundamental laws of physics, but also the laws of nonequilibrium thermodynamics describing nonequilibrium processes in continuous media on the basis of the equations of mass, energy, momentum, and entropy balance [1, 3].

The similarity of the thermodynamic and mechanical principles of energy makes it possible to introduce into the SP mechanics the deterministic concept of entropy, defining it as $\delta E^{\text{int}} / E^{\text{int}}$. It was called the D-entropy [31, 32, 41]. The D-entropy determines the total work of external forces with respect to the change in the internal energy of the system E^{int}. The Clausius entropy is a particular case of the D-entropy. For the D-entropy, the second law of thermodynamics is valid: $dS^d / dt \geq 0$. For a closed NS whose volume does not change, the D-entropy is determined by the amount of energy of the relative motions of the SP that have

passed into their internal energy. That is, the physical meaning of the D-entropy is that the energy of the ordered motion of SP passes into the energy of chaotic motion of the MP. For equilibrium state of the system, it is characteristic that the total momentum vector of any selected equilibrium subsystem is zero. This can serve as a definition of equilibrium.

The change in the D-entropy for NS is determined by the sum of the increments of the entropies of each SP. This can be written as follows [28, 30]:

$$\Delta S^d = \sum_{L=1}^{R} \left\{ N_L \sum_{k=1}^{N_L} [\int \sum_s F_{ks}^L v_k dt] / E_L \right\} \tag{4.11}$$

E_L -is internal energy L-SP; F_{ks}^L -is a force, acting on the k -th MP of the SP from the side of the MP of the other SP; s - is external MPs with respect to L -SP, interacting with its k -i MP; v_k -is a speed of the i-th MP.

The D-entropy is applicable not only for SP, but also for systems with a small number of MPs. We have already noted above that a change in the D-entropy of a small system can turn out to be negative [41]. For the D-entropy of systems moving in an inhomogeneous force field, there is a minimum number N1 of the number of MPs in the system, when the entropy increases monotonically. There is also a second number, N2, after which the D-entropy goes to the asymptotic. In the general case, these critical numbers depend on the parameters of the problem, for example, on the width and height of the barrier. Thus, D-entropy allows us to determine the scope of thermodynamics on the basis of the laws of classical mechanics.

Let us show how the D-entropy allows us to justify the Boltzmann entropy. Its expression, determined through the distribution function of the system f_p, has the form [17]:

$$S^B = -\int f_p \ln f_p dpdq . \tag{4.12}$$

Let us prove the eq. (4.8) relying on the SP mechanics. For this we show that $dS^B / dt \neq 0$ because of the presence of forces that are a consequence of the deterministic laws of mechanics [10]. Differentiating the entropy with respect to time, we obtain:

$$\frac{dS^B}{dt} = \int (1 - \ln f_p) \frac{df_p}{dt} dpdq . \tag{4.13}$$

However, according to the canonical Liouville equation, we have: $df^p / dt = 0$ [14, 17]. It follows that $dS^B / dt = 0$. This contradicts the second law of thermodynamics. Within the framework of the probability mechanism of irreversibility, the contradiction is removed by coarse-grained the phase space [2]. To do this, they introduce a coarse-grained distribution function, defined as follows: $F = (\int f_p d\Gamma) / \delta\Gamma$, where $\delta\Gamma$ -is a region of phase space coarse-grained.

For a coarse-graining of the phase space, as a rule, the constant of Planck has been used [1]. For a coarse-grained distribution function **F**, eq. (4.13) is not equal to zero. But such a substantiation of the Boltzmann entropy meets with the great difficulties. The point is that the nature of coarse-grain of the phase space is not known [2]. Therefore, this rationale of the Boltzmann entropy is not rigorous. For eliminating this difficulty we can use the extended Liouville equation obtained in the frames of the SP mechanics. Relying on it, we obtain inequality: $dS^B / dt \neq 0$. It is due to taking into account of the transformation of the motion energy of the body into its internal energy. Thus, according to eq. (4.4), we have:

$$\frac{dS^B}{dt} = -\int (1 - \ln f_p) f_p (\sum_{k=1}^{T} \frac{\partial F_k^p}{\partial p_k}) dpdq \neq 0 \tag{4.14}$$

Eq. (4.14) corresponds to the physical meaning of entropy and the second law of thermodynamics. It is not equal to zero, because for NS the next condition is fulfilled: $\sum_{k=1}^{T} \partial F_k^p / \partial p_k \neq 0$ [30]. Thus, the Boltzmann entropy equation follows from the SP mechanics. There are reasons to say that basing on the SP mechanics we can prove other formulas of the entropy and also Boltzmann's kinetic equation.

In general, the D-entropy has a simple physical meaning. It characterizes that part of the work of external forces that goes into its internal energy. For D - entropy there are no problems of its calculation for open NSs, and probabilistic types of entropy become equivalent to it in special cases of conservative systems [42].

The importance of D-entropy is also connected with the fact that the formation of attractors is possible only for dissipative systems [21]. This means that the existence of DMI in classical mechanics indicates the possibility of studying the processes of formation of structures within the frames of the laws of classical mechanics. This leads to the conclusion about the infinite divisibility of matter. Indeed, if we approve that the evolutionary development of matter going from the simple to the complex, then we must accept that the primary elements of matter must have a structure. Otherwise, they would not have been able to arise or form systems because attractors arise only in the presence of dissipation. In turn, dissipation is possible only for structural elements. The fact that D-entropy determines dissipative forces is important for the search of the nature of fundamental forces. It is no accident that these forces try to explain based on the nature of entropy [44-46].

5. The expansion of quantum mechanics

Quantum mechanics in process of its development has been meeting with difficulties that are related to the limitations of principles, postulates, and the simplifications of models that are inevitably used in the construction of any branch of physics. The Schrodinger equation is a basis of the quantum mechanics [47-49]. The Schrödinger equation is reversible and linear. It is leads to considerable difficulties in its use for describing processes in quantum systems, in particular, which are connected with violation of the time symmetry [22, 49].

The Schrodinger equation is obtained based on the principle of least action and the Hamilton-Jacobi equation. Therefore, it is quite natural that the limitations of the formalisms of classical mechanics cause the limitations of quantum mechanics. It is logical to assume that the approaches to removing these limitations are analogous to the approaches used to extend classical mechanics. Here we briefly explain how and what limitations of quantum mechanics will appear due to limitations of classical mechanics, based on which the Schrödinger equation was constructed, and how they can be removed basing on PDS.

The main difference between quantum mechanics and the classical one is that a quantum-wave dualism is inherent for the micro-particles. In accordance with this, energy and impulse of micro-particles it is possible to write down as functions of frequency and wavelength [47, 48]: $p = \hbar\nu / c = 2\pi\hbar / \lambda$, $k = p / h$. Here $\hbar = h / 2\pi$ - is a Planck's constant; c - is a light velocity; $\omega = 2\pi\nu$ - circular frequency; λ is a de Broglie wavelength. This allowed describing the dynamics of the quantum particle by the wave function. For free microparticles, the wave function has the form of a plane monochromatic de Broglie wave [47]:

$$\psi_i(r,t) = Ae^{i(kr-\omega t)/h} = Ae^{i(pr-Et)/h} \quad (5.1),$$

Schrödinger drew attention to the important correspondence between the Hamilton-Jacobi equation and the geometric optics equation [47]:

$$u^2\nabla^2\psi(r,t) - \partial^2\psi(r,t) / \partial t^2 = 0, \quad (5.2)$$

The correspondence is that the action S is equivalent to the phase of the wave (see the Hamilton-Jacobi equation [9, 10]).

If we substitute into eq. (5.2) $u = E/(\sqrt{2m(E-U)})$, m - is a mass of microparticles, U - is a potentials energy, and also take into account that $\partial^2\psi(r,t)/\partial t^2 = -\omega^2\psi(r,t)$, $E\psi(r,t) = i\hbar\partial\psi(r,t)/\partial t$, then the next equation will be obtained [47]:

$$i\hbar\frac{\partial}{\partial t}\psi = \left\{-\frac{\hbar^2}{2m}\nabla^2 + U(r,t)\right\}\psi \tag{5.3}$$

This is the Schrodinger wave equation for the microparticle.

If the energy and momentum are replaced by the corresponding operators, then similarly we obtain the Schrodinger equation for the system of micro-particles [48]:

$$\{i\hbar\frac{\partial}{\partial t} + \sum_{i=1}^{N}[\frac{\hbar^2}{2m_i}\nabla_i^2 - U(r_i,t)] - W_{\text{int}}(r_1, r\ ...r_N)\}\psi(r_1, r_2, ...r_N, t) = 0 \tag{5.4}$$

where $W_{\text{int}}(r_1, r\ ...r_N)$ - is interaction energy of microparticles, depending on the distances between them; $i = 1,2...N$; $U(r_i)$ - is a potentials energy of the i -th microparticles in the external fields.

On the way to solving eq. (5.4), problems arise that are analogous to the problems of many bodies in classical mechanics. As in the case of classical mechanics, the variables of eq. (5.4) are interdependent in the laboratory coordinate system. Therefore, we begin from the fact: for the description of systems of the interacting micro-particles in quantum mechanics, eq. (5.4) must be transformed in accordance with the PDS. That is, the energy should be given by the invariant sum of the system's motion energy and internal energy. As in classical mechanics, this can be done by submitting the energy operator in micro and macro variables. First we show how to do this for a simple system. In the stationary case, equation (5.4) for the oscillator has the form [38, 39]:

$$\{E + [\frac{\hbar^2}{2M}\nabla_R^2 - U(r,R)] + [\frac{\hbar^2}{2\mu}\nabla_r^2 - W_{\text{int}}(r)]\}\psi(r,R) = 0\,. \tag{5.5}$$

Here $M = m_1 + m_2$, $\mu = m_1 m_2/(m_1 + m_2)$, E_{cm} - is a motion energy of CM, $E_{\text{int}} + E_{cm} = E$, $r = r_1 - r_2$, $R = (m_1 r_1 + m_2 r_2)/(m_1 + m_2)$ - is a CM coordinates, E_{int} - is internal energy of the system.

To obtain the extended Schrödinger equation for a system from the N particles, it is necessary to rely on the total energy which submitted in micro- and macro variables. For quantum mechanics this means that the Hamiltonian operator must be represented in the form of operators describing the internal dynamics of the system and the operators that determine the motion of the system. Making this representation, we will have [39]:

$$\{i\hbar\frac{\partial}{\partial t} + \frac{\hbar^2}{2M}\nabla_R^2 - U(\tilde{r}_1, \tilde{r}_2, ...\tilde{r}_N, R, t) + \sum_{i=1}^{N}[\frac{\hbar^2}{2m}\nabla_{\tilde{r}_i}^2 - W_{\text{int}}(\tilde{r}_i)]\}\psi(\tilde{r}_1, \tilde{r}_2, ...\tilde{r}_N, R, t) = 0 \tag{5.6}$$

Here R - is a CM coordinates. The $\tilde{r}_i$ - is a coordinates i - th particles relative to the CM.

For stationary case the eq. (5.6) has the form:

$$\{E + \frac{\hbar^2}{2M}\nabla_R^2 - U(\tilde{r}_1, \tilde{r}_2, ...\tilde{r}_N, R) + \sum_{i=1}^{N}[\frac{\hbar^2}{2m}\nabla_{\tilde{r}_i}^2 - W_{\text{int}}(\tilde{r}_i)]\}\psi(\tilde{r}_1, \tilde{r}_2, ...\tilde{r}_N, R) = 0 \tag{5.7}$$

Let us call this equation as extended Schrödinger equation. Unlike the classical Schrödinger equation, it takes into account the transformation of the motion energy of a quantum system into its internal energy. Such a transformation, as in the case of classical mechanics, arises when the system moves in an inhomogeneous field of external forces. It is therefore natural to conclude that such a transformation of the motion energy into internal energy leads to DMI.

The proposed extension of the Schrödinger equation leads to an interesting possibility of explanation of the nature of the Heisenberg uncertainty principle: $\Delta p \Delta r \geq \hbar$, which plays a fundamental role not only in quantum mechanics, but also in all physics.

There are, at least, two approaches to the interpretation of the uncertainty principle [42, 49]. Bohr claimed that he should be accepted as a real manifestation of nature, without trying to seek an explanation. Einstein considered it as a limitation, or a shortcoming of the theory itself. From the position of the structured matter at all its hierarchical levels, one can offer one more explanation of the uncertainty principle, which corresponds to Einstein's point of view.

It was noted here, according to the laws of mechanics, matter is infinitely divisible. Therefore, at the quantum level, any particle must be a system and have internal energy. Then the nature of the uncertainty principle can be explained by the transformation of the interaction energy of the particles into the internal energy of the reaction products. Hence, in accordance with the uncertainty principle, we have in eq. (4.4): $A^d \geq h$. By the way, this is a confirmation of the validity of the hypothesis that the phase space is coarse-grain. The coarsening volume ε can be chosen as $\varepsilon \geq h$ [2]. Then we can assume that fundamental particles are oscillators with a de Broglie wavelength, and Planck's constant determines their minimal internal energy. In this case, as it follows from eqs. (3.4, 3.10), the trajectory of microparticles consisting of a set of oscillators is determined by the nature of the change, both of the motion energy and internal energy, and this can lead to a wave trajectory of the particle due to oscillations.

In general, the extended Schrödinger equation makes it possible to describe the processes of breaking the symmetry of time, as well as the dissipative processes in quantum systems.

6. STAGES OF SOLVING THE IRREVERSIBILITY PROBLEM

Thus, within the framework of the laws of classical mechanics for body models constructed in accordance with the molecular-kinetic theory, we come to the necessity of the existence of DMI. The DMI is determined by an irreversible transformation of the energy of the ordered motion of systems into the energy of chaotic motion of their elements. Such a transformation is possible when the system moves in an inhomogeneous field of external forces. It is follows from the laws of Newtonian mechanics. The search for DMI consisted of three stages: the study of disk systems; studying systems of potentially interacting MPs; study of the NS.

At the first stage, the equilibration of the disks systems was studied. It was found that the process of equilibration of the disks systems is connected with the transformation of the motion energy of the disk systems into their internal energy. To substantiate irreversibility of the disks systems, we had to use the statistical hypothesis about the equal probability of the disc's impact distances. But there was a task to explain to irreversibility, using only the laws of classical mechanics. Therefore, for further explanation of the deterministic irreversibility, it was decided to use a system of potentially interacting MPs.

At the second stage, the dynamics of systems of potentially interacting MP was studied. Their research was carried out on the basis of the PDS. According to PDS the energy needs to be represented in the form of the sum of energy of the motion of system, and its internal energy. This representation of energy was accomplished by transition to two groups of micro - and macro variables. From the dual representation of energy in these groups of variables, the motion equation of MP systems was obtained. From this motion equation follows of the transformation of the motion energy into internal energy, when the system moves in an inhomogeneous field of forces. This transformation is determined by bilinear terms, which depended from the micro - and macro variables. According to the SP motion equation, for external fields of forces with

gradients such a transformation is irreversible. It was shown that the absence of DMI within the framework of the canonical formalisms of classical mechanics is due to the hypothesis of holonomic connection. This hypothesis was used for derivations of these formalisms. The hypothesis excludes from the formalism equations the processes of nonlinear transformation of the motion energy into internal energy, and therefore excludes DMI.

At the third stage, the dynamics of the NS, represented by the set of SPs, was studied. The existence of DMI for NS is shown. Using the SP motion equation, the extended Lagrange, Hamilton, and Liouville equations are obtained. These equations describe the dissipative processes in NS.

D-entropy as a parameter characterizing the transformation of the motion energy into the internal energy of the system was studied. D-entropy is defined as the ratio of the increment of the internal energy of the system to its total magnitude. For small systems, the D-entropy can be either positive or negative. Based on the PDS and D-entropy, with the help of the mechanics of SP it is shown that for the large systems near equilibrium the second law of thermodynamics are fulfilled.

If accept that the formation of natural systems are go from the simple systems to systems with more complexity, then according to the laws of classical mechanics we come to the conclusion about the infinite divisibility of matter. It is explain by the fact that the formation of structures is impossible without dissipation. But dissipation is possible only for systems [21].

A special class of nonlinearities is singled out. This class of nonlinearities was called evolutionary nonlinearity. Evolutionary nonlinearity is responsible for the: violation of symmetry in the NS in inhomogeneous fields of forces; the dissipative processes; the formation of attractors.

An extended Schrödinger equation describing dissipative processes in the quantum systems is proposed.

7. CONCLUSION

In the beginning the studying of the irreversibility problem led to the probabilistic mechanism of irreversibility. The justification of the probabilistic irreversibility mechanism based on the statistical physics laws. This mechanism has been found in result of researches of mixing properties of the phase trajectories of Hamiltonian systems. The nature of mechanism consists in that that in the presence of arbitrarily small external random influences on Hamiltonian systems, their trajectories in phase's space is irreversible [2]. But the question of the existence of DMI within the framework of the laws of fundamental physics remained open.

Because all attempts to find DMI within the frames of formalism of the classical mechanics were unsuccessful, searches of DMI were carried out already within the framework of the laws of classical mechanics. The DMI was found on the basis of studying the properties of the transformation of the system's motion energy into its internal energy.

Search DMI was carried out on the basis of the system's motion equation. This equation was obtained from energy, leaning on PDS. According to PDS, dynamics of systems is defined both by the symmetries of space and by the symmetries of the system. The energy of the system was presented in the form of the sum of the motion energy and internal energy. This representation of energy was realized in the two spaces of independents micro - and macro variables that determine of the internal energy and the motion energy, respectively.

The systems' motion equation for SP was obtained as a result of identical transformations of the equations for the energy flows without using any conditions or hypotheses, as was done when obtaining the canonical Lagrange equation. The motion equation for SP is asymmetric with respect to time reversal, because contains bilinear terms that depend on the micro - and macro variables. These terms determine the mutual transformation of the two types of energy. The violation of the time symmetry arises in the existence of an inhomogeneity of the external field of forces. The nonlinearities that determine the breaking of the time symmetry has been called evolutionary nonlinearities. According of the SP motion equation, irreversibility is due to the fact that the internal energy of equilibrium systems cannot be transformed into their motion

energy. Thus, unlike the MP's motion equation, the SP motion equation is applicable for describing the dynamics of systems with non-holonomic constraints.

All natural objects are NS. In the approximation of local thermodynamic equilibrium NS can be represented as a set of SPs in motion relative to one another. DMI for NS is caused by the transformation of the energy of the relative motion of the SP into their internal energy. Such a transformation is determined by the terms of the evolutionary nonlinearity not lower than the second order of smallness. The reverse transformation of the internal energy into the motion energy is determined by terms not lower than the fourth order of smallness. Because for large systems the terms of the second order of smallness are always larger than the terms of the fourth order of smallness, this leads to equilibration. For small systems, in accordance with the law of fluctuations of quadratic functions, the terms of the fourth order of smallness for certain initial states of the system can turn out to be commensurable with terms of the second order of smallness. In these cases the internal energy of the system can return into motion energy. Such cases have a place for oscillator dynamics in inhomogeneous fields of forces. If the NS consists of a small number of equilibrium subsystems, then in an inhomogeneous field of external forces the energy of the relative motions of the subsystems can go over into the energy of motion of the entire NS.

The violation of the invariance of the motion energy of the system made it possible to introduce the concept of D-entropy, defining it as the ratio of the change of the internal energy of the system to its magnitude due to motion energy. For small systems, the D-entropy can be either positive or negative. For large systems near equilibrium, the D-entropy coincides with the Clausius entropy.

Although the SP mechanics are at the initial stage of the construction, it allowed to justify the laws of thermodynamics and statistical physics. For example it allowed justifying the law of fluctuations $1/N^{1/2}$. This indicates that probabilistic laws that simplify the analysis of systems, as well as the physical concepts constructed on their basis, are follow from the laws of classical mechanics. It was shown on the example of the Boltzmann's entropy.

The extended Schrödinger equation has been constructed basing on PDS. It allows one to describe the violation of the time’s symmetry in the dynamics of quantum systems.

As it follows from SP mechanics, the matter is infinite divisible [50]. This infinite divisibility is consistent with the mathematical description of the processes of the appearance of attractors, the transformation of order into chaos and chaos in to the order. This also agrees with the assertion that bodies are a hierarchy of open non-equilibrium dynamical systems embedded in each other.

The SP mechanics are applicable to different fields of physics. It allows calculate the energy fluxes in the universe, since galaxies, stars, planets move in the self-consistent force fields. Its use should be help to correct the problem of mass and energy for the universe [51]. It is difficult to understand the nature of nuclear processes in high-energy physics without taking into account the internal structure of micro particles.

The existence of the DMI showed that the development of physics can go not only along the path of revealing the essence of new physical phenomena, but also as a result of removing restrictions for already existing theories. After all, DMI was found due to the fact that at the stage of constructing the equation of motion of bodies, the structure of matter was taken into account.

As for future prospects, the studies of the system’s mechanics, the mechanism of breaking the time’s symmetry, the proposed class of evolutionary nonlinearities, the corresponding mathematical apparatus, etc. should contribute to the development of physics in general and for created of the evolution's physics in particular.

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