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The formation of a single star planetary system and heat balance of the planets

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Abstract

This paper considers the principles of planetary formation under gravitational compression of a calm, isolated, rarefied gas-dust cloud, different from the compression of a dense gas-dust cloud of a star cluster. The distinctive feature of such compression is the instantaneous formation at a certain stage of the evolution of a gas-dust cloud of a dense, high-energy plasma that makes up a protoplanetary nebula, in which heavy chemical elements are generated. A hypothesis of the scheme of a possible nucleosynthesis is presented. The new conditions for the formation of a protoplanetary cloud, regardless of the hypothesis put forward, entail a fundamentally new concept of planetary evolution. Almost from the very first moments of the formation of a protoplanetary cloud, the proto-nuclei of future planets with their intrinsic magnetic field and complex structure are formed even before the formation of protoplanets. Formed in a same spatial zone within a same process the proto-nuclei are the progenitors of all types of planets of stellar system, i.e., cores are not formed within planets due to gravitational differentiation and high pressure generated by gravitational forces, but rather the planets emerge from proto-nuclei. After a certain, relatively short period of time, the protoplanetary cloud becomes flat and splits into two rings with a gap between them. The type of planet that is formed depends on the place where it is formed. According to physical laws, only young planets can cool down. Therefore, the Earth, which is no longer a young planet, does not cool down.

***Keywords*:** gravitation; formation of planets and asteroids; planetary core; magnetic field of a planet; gravitational differentiation.

1. Introduction

This work is a continuation of the analysis of the gravitational compression of a gas-dust cloud in outer space, begun by Belyaev in [1], in which the compression of not just a gas-dust cloud, but a single, rarefied and calm cloud was considered. The solitary cloud means that it is closed and is in relative isolation of the chosen physical system where external factors and matter do not have a tangible effect on the cloud in question. The rarefaction of a gas-dust mixture is understood as the practical realization of such initial conditions of gravitational compression of the cloud, when "the free path between collisions of the cloud particles with each other is less than or equal to the value of their radial displacement caused by gravitational attraction" (see [1]). Calmness (unperturbedness) of the gas-dust mixture is understood as the absence of initial turbulent pulsations, convective flows, common rotation.

Additional new nuances of the formation of a single star system from a calm and rarefied gas-dust cloud are considered in this paper, with an emphasis on the issues of planet formation and the properties of the planets being formed. Moreover, as already discussed in [1], the considered version of the initial state of the cosmic gas-dust cloud is not just a special theoretical case, but, most likely, refers to our Solar system. Furthermore, in the case of a single, rarefied, and calm gas-dust cloud, the mechanism of its gravitational compression seems to be fundamentally different, not coinciding with the existing concepts.

All astronomers are already accustomed to the fact that any accretion process onto a heavy massive object is always accompanied by a rotational movement of the captured matter around this object. In most cases, this is indeed the case, since during gravitational capture of a passing space object, the heavy object first converts its rectilinear motion into an orbital one, and only then, due to various physical effects, the orbit of the captured object contracts, and it falls onto the heavy object. However, this does not happen immediately, so the orbital motion can be clearly and continuously observable. The action of pulling the substance from a less massive object with orbital motion to a more massive object is also accompanied by a rotational effect, thus, an accretion disk is formed.

A strictly head-on rectilinear collision of random space objects is very unlikely. However, it is important to understand that not all collisions are accompanied by the appearance of orbital motion. For example, in the work of Belyaev [2] it was shown that when one object catches up with another, their collision is not always accompanied by mutual rotation around a common centre of mass. Consequently, the actions of quasar nuclei are not associated with large accretion disks, but with extended rectilinear tails from matter accelerating towards them.

Similarly, for a single, rarefied and calm gas-dust cloud, the mechanism of its gravitational compression cannot be accompanied by vortex or rotational processes. The appearance of rotational motion around its axis of the nascent star and the orbital motion of the peripheral zone of the cloud still needs to be explained by internal factors. An attempt to do so was made in [1].

The most active star formation always occurs in dense gas-dust zones, in which the future stellar system acquires angular momenta of motion for the entire isolating zone as a result of the influence of a perturbing external factor. This means that the original gas-dust cloud was not isolated. As a result, both the nascent star and the nebular cloud are characterized by interconnected rotation. It just so happens that the models of formation of stars and planets refer only to this most common case. The compression of a solitary rarefied calm gas-dust cloud has never before been considered by anyone.

To be more precise, the gravitational compression of a cool solitary gas-dust cloud has already been considered before. But, nevertheless, from the previous positions: in the process of gravitational compression of a cloud that is large in size and mass there are gravitationally unstable zones, in which, among other things, single stars can form. Moreover, an indispensable attribute of such isolation is the initial rotation of the entire volume of the zone (the process of isolation is determined by the rotation parameters).

The existing models naturally and comprehensively describe the processes of formation of stars and planets for the cases mentioned. In these models, the gas-dust mixture behaves like a gas, but only as a dusty gas that can be more efficiently heated by electromagnetic radiation compared to a dust-free gas. In other words, the gas-dust cloud is assumed to be single-phased. However, the appearance of rotation leads to the effect of dust gathering into a flat disk; from a certain point in time, dust begins to be considered as a separate subsystem of a gas-dust cloud. The basics of the theory of the formation of stellar systems are described in the work of Prialnik [3].

This work is devoted to establishing the principles of planet formation not just for a single star, but for one that is the only daughter star born from the original gas and dust cloud. However, under the above mentioned initial conditions of the state of such a gas-dust cloud, which in practice are realized in clouds with low initial temperature, it is inadmissible to consider a dusty gas, and it is necessary to separately monitor the results of compression of the dust and gas components of the cloud. In other words, during gravitational compression of a calm rarefied gas-dust cloud in outer space, its gas and dust subsystems are capable of showing their unique individual characteristics. This is the main reason that new models of gravitational compression of gas-dust clouds need to be developed in addition to the existing models.

In the work [2], mentioned above, a dust cloud was described as such a system, the elements of which unite their masses, when they collide with each other. This definition of a dust cloud made it possible to schematically and graphically demonstrate the inevitable consequence of its gravitational compression: the highest density of matter in a cloud that is still compressing, i.e., in the initial and middle stages of the compression process, is formed at the periphery of the cloud, is a very important aspect, which is not taken into account by modern astronomy, but has fundamental consequences.

The works of Belyaev [4,5] discussed new aspects of the gravitational compression of a gas cloud, primarily with the examination of the emerging energy balance in the process of star formation. Taking into account the uncovered features of the compression of dust and gas clouds, the division of the system of a single calm rarefied gas-dust cloud into two subsystems made it possible to discover the following effect in [1]. The tendency of dust to accumulate at the periphery leads to the situation of a radial head-on collision of the compacted peripheral layer with another compacted layer moving towards it from the centre of the cloud, the occurrence of which is closely related to the features of the compression of the gas subsystem. Obviously, the fundamental differences in the compression schemes for gas-dust clouds with different initial conditions will lead to new conditions for the process of planet formation for calm rarefied clouds. Accordingly, the properties of the planets of dense equatorial star clusters of galaxies and multiple star systems can be radically different (!) from the properties of planets of single star systems, including the planets of the Solar system. Significant differences should be expected not only in the resulting properties of the planets, depending on the prevailing conditions in their formation zone, but also in the distribution of forms and types of matter along the radial directions from the stars.

Attempts to build a unified evolutionary theory of planetary formation are primarily associated with space research of our solar system because modern models of planetary formation are not subdivided into fundamentally different subvariants from each other. However, the structure of the Solar system with scattered rocky and gas planets and asteroid belts and diverse structures of the planets, is so complex that existing models, frankly, cannot cope with describing it. The inability to cope is, most likely, due to different initial conditions of planetary formation for a single star, in contrast to those accepted today. In other words, one should not strive to build a unified theory of planetary formation. It must inevitably be broken up into separate directions, depending on the initial conditions.

There are 4 rocky planets in the solar system: Mercury, Venus, Earth, Mars, 2 gas giants: Jupiter, Saturn and 2 ice giants, which are inferior in size to gas giants: Uranus, Neptune. Rocky planets have a compound core, presumably metallic, a mantle of silicate rocks, a crust, and an atmosphere much smaller in thickness than the planet's radius. According to the thermal regime, the orbit of Mercury belongs to the region of very warm planets, the orbit of Venus to the region of warm planets (even though the temperature on the surface of Venus is higher than on Mercury due to the greenhouse effect), the orbit of the Earth to the region of cool planets, the orbit of Mars and the main asteroid belt to the region cold planets. It is assumed that the composition of gas giants at the initial stages of their evolution is close to the composition of the host star. Jupiter and Saturn are predominantly composed of hydrogen and helium. Neptune and Uranus are composed of rocks surrounded by water, ammonia, methane, hydrogen sulphide, classified as ice, and their atmospheres are made up of hydrogen and helium. According to the thermal regime, the orbits of Jupiter and Saturn belong to the region of very cold planets, and the orbits of Neptune and Uranus belong to the region of ice planets. Additional information about the planets of the solar system will be given below in the text as the need arises.

As already discussed in [1], modern astrophysical models assume that almost all the original dust of a gravitationally compressing single gas-dust cloud at a certain stage of cloud compression is absorbed by a proto-star that has already formed by the beginning of planetary formation. The residual fraction of dust is bundled up into a protoplanetary disk, in which dust particles grow rather quickly in size (up to 1 cm or more), and then the processes of planet formation are initiated. When the density of matter in a turbulent multicomponent gas-dust disk exceeds a certain threshold, gravitational instability sets in and dust clumping begins. There is still no one coherent theory that describes how lumps the size of meters form from dust grains of centimetres, and then, what is even more unclear, how from such enlarged lumps the planetesimals of kilometres in size are formed. After that planetesimals form protoplanets by colliding with each other. There are also a lot of questions for this stage of evolution. Further merging of protoplanets completes the prehistory of the formation of planets, forming their basis and turning over time into planetary cores. However, understanding of the processes of formation of planetary cores is non-existent (the meaning of this statement will be deciphered step by step in the text below).

The hypothesis of planetesimals for the solar system, when protoplanets are formed from planetesimals, and protoplanets, colliding with each other, form the cores of the planets, is currently dominant. The theory of planetesimals is supported by the recent discovery made by the Japanese researchers Arimatsu *et al.* [6] using the transit method of small objects (several kilometers in diameter) in the Kuiper belt. They identified these objects as planetesimals.

A route different from the planetesimal version of the explanation of the processes of planetary origin is provided by such a strong clumping of dust, in which a collapse occurs, forming a dense structure, which later becomes not only the center of accretion, but also the core of the future planet. However, the main difficulty of this hypothesis is associated with the need for a very dense protoplanetary disk. But, currently available theoretical studies cannot yield the possible ways of the formation of such a disk.

Today it is accepted that the main criterion that determines the very different final properties of planets is the amount of thermal energy received from the host star in the process of their evolution, which determines the thermal regime of formation of each particular planet under consideration. At that, fundamental differences begin at the stage of planetary origin. For example, beyond the snow line, at which the energy from the star becomes so low that volatile compounds are in a solid state (volatiles in the solid state in astrophysics are usually called the generalized term "ice"; of course, the distance from the star to the snow line will depend on the power of the star and the type of volatiles), there are fewer silicates in the planetesimals, which are replaced by ice.

One cannot disagree with the fact that the heat of a star has a colossal effect on the evolution of planets. But if we turn to the Solar system, then it is exceptionally difficult to explain the evolution of the planets using only this factor. For example, one factor that can be used to explain the formation of protoplanets from planetesimals in the orbits of gas giants, however, difficulties arise when doing the same in the orbits of ice giants. Of course, for each observed fact, over time, it is possible to find some sort of explanation. However, each fact requires us to come up with individual approaches that do not automatically follow as self-evident consequences from the fundamental sequence of evolutionary stages. Therefore, there is a growing impression that the processes occurring during planetary formation in a single star system must be characterized by some additional features that are not taken into account by modern theories. Moreover, the new planetary systems being discovered do not follow the picture of the Solar planetary system.

Firstly, new planetary systems being discovered are not necessarily flat. Secondly, the orbits of the planets in most cases have large eccentricities. Thirdly, the distribution of planets and their properties contradict the prevailing ideas about planetary formation. It is, however, rather difficult to talk about the properties of exoplanets. The transit photometry search method allows us to measure the radius of exoplanets, and the method of radial velocities to determine their minimum mass (if there is data on the tilt of the exoplanet's orbit to the line of sight, the exact value of its mass is determined). The combined use of these methods makes it possible to estimate the average density of exoplanets. Spectral analysis for exoplanets is difficult, and analysis at different wavelengths is the most acceptable for a transit planet that occasionally hides behind its star. Ultimately, using all the methods available to astronomers, the temperature regime of the exoplanet is estimated, and its physical nature and chemical composition are predicted. In most cases, sufficient information can be collected only for hot Jupiters (gas giants that can exceed Jupiter in size and mass and have orbits very close to their star) or young gas giants that have heated up from the inside. In other words, currently the properties of exoplanets are mostly described only by theoretical assumptions.

However, even the available information is sufficient to raise questions. For example, hot Jupiters, according to modern concepts, should not exist at all. But there are many of them. In addition, ice giants and solid-state exo-Earths can be found in the hot planet zone. And this baffling, since according to modern concepts, the planets are not formed in these zones, but they arrive there. But if the gas giants can theoretically reduce their orbits effectively, getting into the circumstellar zone, previously cleared by the host star, they can finally quite effectively clean up their new orbit close to the star and make it relatively stable, then ice giants, and, especially, terrestrial planets can no longer actively approach their star at the beginning, and then rotate around it for a long time in close proximity.

There are also questions about the structure and composition of exoplanets, since there are gas giants with very low and very high average density among the discovered planets. In such cases, the planets with an exceptionally low average density are even more perplexing. It becomes unclear what the core should be like to keep a large amount of gases around it. To be more precise, the greatest bewilderment is caused not by the large mass of the nucleus, but by the way of its formed. After all, if the core is formed due to the forces of gravity in an unstable gas-dust cloud, then, in a zone enriched with a gas, a Jupiter-like planet should be formed. And in this case, first, a formation so heavy must be created that it would be able to effectively capture gas, and only after that can it enter the gaseous environment for its transformation into a gas giant. And since by the time such a heavy formation appears, the gas should already have been squeezed out by the stellar wind into distant orbits, it becomes unclear how the resulting formation can increase its orbit for gravitational capture of the squeezed gas.

But even when exoplanets resemble the planets of the Solar system in terms of the ratio of their size to average density, questions still remain about their formation. For example, an explanation of the reasons for the possible absence of rocky planets in the planetary system is required, even in the case when it is formed from a gas-dust, and not just a gas cloud. Another example is the need to explain how super-Earths, which are massive solid planets, gas dwarfs and mini-Neptunes are formed in extra-solar systems. Especially since the detection of massive solid exoplanets has become commonplace in observational practice.

Thus, no universal description of the planetary formation mechanism has yet been created. Since it is being developed on the basis of experimental data for the Solar system, for which the primary initial conditions are assumed to be incorrect, without taking into account its isolation from the surrounding environment, not only does it fail to make a coherent description of the formation of planets for our solar system, but it also complicates the understanding of the appearance of exoplanets, because the assumptions made for the Solar system are automatically transferred to all extrasolar planetary systems. Of course, the question of the possibility of the existence of another process of planet formation, different from that in the planetary system of a single star, does not arise.

It is useful to note here that any version of planet formation must consider the formation of planetary cores. However, for obvious reasons, we do not know about the existence of cores in planets of other stellar systems. Therefore, although universal algorithms for the formation of planets for an arbitrary star system are always discussed, really, they are all built on the basis of ideas about the evolution of the Solar system.

Although we can only guess about the existence of cores in exoplanets with certain characteristics, and the magnetic fields of the planets cannot be measured, nevertheless, indirect calculations help to determine not only the probability of the presence of a magnetic field, but even to estimate its magnitude. The existence of the magnetic field is a particularly important characteristic of a planet. The magnitude of the magnetic field is determined, for example, by the results of estimates of the loss of hydrogen by the exoplanet by studying the radiation of the atmospheres of exoplanets in the field of radio waves, which indirectly indicate the speed of rotation of the planet and its magnetic field; by estimating the size of hot Jupiters from the point of view of their additional heating and expansion, arising due to the interaction of the stellar wind with the magnetic field of the planet and other indirect methods. There have even been attempts to trace the energy bursts of the host star (stellar flares and spots) that could be caused by the magnetic field of hot Jupiters. But such attempts have so far been unsuccessful.

In general, for large exoplanets, a preference is given to the option of their formation due to direct gravitational collapse in the spiral sleeves of the protoplanetary disk. But the formation of small exoplanets and planets of the Solar system, which happens due to direct gravitational collapse has so far been impossible to recreate using numerical modelling. Therefore, for the Solar system, the preference is still given to the planetesimal version.

Nevertheless, this approach to describing the way planets are formed has many difficulties. These can, for example, be associated with a rapid reduction in the orbits of planetesimals or with an insufficient frequency of their collisions (the number of planetesimals in the proto-nucleus is huge, but the formation time of the proto-nucleus should not exceed the lifetime of the protoplanetary disk). However, these difficulties can be overcome to some degree. But the greatest difficulties are associated with the need to explain not only the nature of the planet's magnetic field generators, but also the evolutionary justification of their appearance.

Today, it is believed that the methods of generating magnetic fields in rocky planets and in gas giants are different. The magnetic fields of rocky planets are generated in their cores. Ferromagnets cannot create a magnetic field, since they have magnetization only at temperatures below the Curie point, and the values of these temperatures are relatively small. Nevertheless, there is an explanation for the appearance of a magnetic field in rocky planets. But this mechanism, which has no theoretical alternative today, imposes significant restrictions on the ways that the cores of rocky planets form. Experiments carried out under terrestrial conditions have demonstrated the possibility of the existence of a mechanism for generating a magnetic field described by the dynamo theory. This mechanism requires the rotation of a liquid, electrically conductive core and the presence of convection in it. Thus, the dynamo theory necessitates the accumulation of an electrically conductive fluid in the centre of the future planet.

There is no doubt that a planet has a heavy core. It is assumed that at the initial stage of the formation of rocky planets, their composition was homogeneous and subsequently stratified due to gravitational differentiation. There exists another explanation, according to which the core of the planet was formed due to the bombardment of this planet with iron meteorites that existed independently of stone meteorites. However, at present it is not considered, since it is believed that iron meteorites can only form in the depths of a planet that has already disintegrated for some reason, i.e., at the initial stage of planetary formation, iron meteorites cannot yet exist.

Thus, firstly, the core in the central zone of the rocky planet should be not just heavy, but electrically conductive and liquid, and, secondly, to explain the formation of the core, at the moment, only one physical mechanism on which theorists can rely has been identified - this is gravitational differentiation.

Since a liquid metal core should form in the centre of the future rocky planet due to gravitational differentiation (today it is generally accepted that the core of an Earth-like planet should consist of iron and nickel), then at the initial stages of the planet's evolution it should be completely or partially melted. The energy of the bombardment of the forming planet (dust, meteorites, asteroids, and other large objects) may well be enough to melt the substance. The energy of radioactive decay, the share of which is still significant at the early stages of the evolution of the solar system, can also be added to this energy. Therefore, there are no fundamental problems with the possibility of the appearance of molten matter at the first stages of planet formation.

Moreover, many facts indicate the turbulent processes of the early stages of planet formation. For example, it is likely (but not necessary) that Mercury's hard shell was destroyed as a result of a collision with a space object because its structure practically consists only of the core. The Moon probably appeared because of a collision of the Earth with a space object and took up part of the Earth's mantle. Perhaps, the crust of the northern hemisphere of Mars is thinner than the crust of the southern one due to the overflow of molten crust after the collision of Mars with a space object.

Even though there are no fundamental problems with the energy required to melt the rocks of the forming planets, the practical implementation of the process of gravitational differentiation is not clear. When completely melted, molten iron does not mix with molten silicate, and metal does not pass through silicates in centrifuges. Liquid iron also cannot penetrate solid silicate. If the solid silicate is melted by 40% or more, then liquid iron permeability appears. However, the final picture of gravitational differentiation is still not clear. Below, in the section on the physical properties of planets, the issue of gravitational differentiation will be discussed in more detail. This will be done not from the point of view of details, not with reference to certain types of substances and forms of their existence, not taking into account the viscosity of substances, wettability and their other physical properties, but from the fundamental general positions of the very principle of gravitational differentiation, which will show that the accumulation of heavy elements in the centre of mass, and not in the middle layers of a massive object, is impossible - this will not be allowed by the laws of physics.

Studies of the Earth have revealed that its core has a complex structure. In a simplified approach, the core can only be divided into two zones: a solid inner one and a fluid outer one. In reality, the physical properties of the inner and outer cores are inhomogeneous and have some kind of, not yet clearly identified, complex structures. For example, Zhang *et al.* suggest the presence in the outer core of the "snowing" slurry layer formed by fractional crystallization of the *Fe* alloy, while the heavy fractions of the layer fall as precipitation on the surface of the solid core [7]. In general, today the dominant assumption that the core was initially completely liquid, and only then, due to the planet's heat losses (due to the heat flow from the core), a solid inner core was formed. The scatter of estimates of the certain time of the beginning of the formation of the inner core is very large. These estimates are based on two approaches.

The first approach is related to the determination of the required minimum heat flow from the inner core to the outer one and, then, through the mantle and crust, into space. The fact is that today it is assumed that a strong magnetic field of the Earth could be created primarily due to vortex movements in the liquid outer core. To maintain the continuity these vortex motions, a heat flow from the inner core to the mantle through the thickness of the outer core is required. Since there are practically no heat sources in the solid core (one cannot count on gravitational differentiation in the inner core, and the accumulation of radioactive isotopes, if heating occurs due to them, still needs to be explained), practically the entire heat flow will be provided by the crystallization energy of the liquid outer core on the surface (or not far from it) of the solid inner core. This approach has an additional benefit, since during crystallization, a residual liquid with a higher content of light elements will be formed in comparison with the surrounding outer layers of the liquid core, which will enhance convection. However, this already makes it necessary to explain where the heat from the inside of the solid inner core is transferred to. In other words, it is not clear why crystallization should occur near the surface of a solid core and what physical phenomena cause it. This is especially true if we assume that the inner core is hotter than the outer one (today this is the generally accepted position that has never been questioned). One way or another, this hypothesis of the emergence of the inner core exists. The time of the appearance of the inner core, estimated by this approach, considering its present size, definitely indicates a much later appearance than the formation of the planet and the liquid core.

A similar result can be obtained using the second approach: paleomagnetic studies, which study the dynamics of changes in the Earth's magnetic field over a long period of time by analysing rocks from different historical periods. But, of course, this approach is indirect and strongly depends on the accepted interpretations of the observed changes in the magnetic field.

However, there is another nuance that is difficult to explain regardless of the time when the inner core formation occurred. Various studies indicate that the density of the Earth's inner core is less than the density of iron-nickel alloys, which indicates a high content of impurities of light elements. Considering that currently the only possible approach to the formation of the initial liquid core is gravitational differentiation, the presence of a large number of light elements in the solid core is puzzling.

Moreover, analyses of xenoliths show the presence of a large amount of siderophile (iron-like) elements in them, i.e., it remains unclear why these elements were not captured by the core during its formation.

The list of questions could be extended. For example, it would be useful to explain what physical processes caused heavy metal cores to be formed in light asteroids. Or how the core of the Moon was formed, which is similar in structure to the Earth’s core, considering an insignificant mass of the Moon (the discovery of a two-phase core in the Moon in 2011 was reported by two independent groups: Rene Weber *et al.* and Raphael Garcia *et al.*, see, for example, [8], and the studies of Garrick-Bezel *et al.* [9] testify to the magnetic field that once existed near the Moon). But the information provided is already enough to understand how far we still are from even a grotesque explanation of the planetary formation processes in the Solar system, not to mention the details of these processes.

Undeniably, there are also many uncertainties in the formation of magnetic fields in gas and ice giants. After all, it is fundamentally impossible to use seismographs for these planets due to their lack of a solid surface (for example, a probe, sent to study the atmosphere of Jupiter, lost contact with an unmanned spacecraft Galileo reaching a depth of 160 km, without encountering any obstacles along the way). Therefore, there are only theoretical assumptions about the structures of the planets.

Jupiter and Saturn have the most powerful magnetic fields in the solar system. It is assumed that they are generated in the outer cores of planets by liquid metallic hydrogen. Uranus and Neptune also have strong magnetic fields, but weaker than those of Jupiter and Saturn. They also have complex geometry and are characterized by large quadrupole moments. It is assumed that in Uranus and Neptune, the magnetic fields are generated in the mantle in thin spherical layers of electrically conductive fluids from ammonia, methane and water due to the hydromagnetic dynamo.

In conclusion of the introductory part, it should be noted that although the conclusion about dense peripheral layers of a gravitationally contracting dust cloud, which is the basis of the proposed theory of gravitational compression of a single, rarefied and calm gas-dust cloud in outer space, is simple and undeniable, there is a complicating factor that required additional publications. The fact is that the existing gravitational effect of the compacted peripheral layer on the internal substance contradicts vector analysis: a corollary of the Gauss theorem is violated. This problem was casually mentioned in [2], and later it was detailed for the gravitational field in the work of Belyaev [10]. After that, Belyaev's article on the incorrectness of the corollary of the Gauss theorem with a generalization for any physical field [11] was published (in the current context, we are talking only about one corollary related to the statement about the absence of a physical field inside a closed cavity; other corollaries for spherically symmetrically located sources of the physical field, in particular, the possibility of replacing a set of sources with an equivalent point source, are restricted in this work by the range of applicability). In general, the conclusions obtained in [1,2,4,5,10,11], including the existing gravitational field inside matter with a spherically symmetric mass distribution, regardless of the presence of cavities inside the matter, allowed Belyaev to present a new view on cosmological questions about the birth of the Universe and the distribution of matter in the Universe [12].

2. Principles of formation of a protoplanetary cloud and planets of a single star

So, in [1], the principles of gravitational compression of a single, rarefied and calm gas-dust cloud were discussed in detail. It was shown that in the process of compression, the separation of the dust component from the composition of the cloud starts before the ignition of the star. Dust begins to accumulate in two zones: in the centre of the cloud and at its periphery. Moreover, most dust accumulates in the peripheral zone and is accompanied by the enlargement of dust particles without disturbing the general direction of their radial movement towards the centre. By the time the star is ignited, regardless of the initial size of the gas-dust cloud, the peripheral dust layer has time to accelerate almost to the second cosmic velocity, the value of which is determined by the mass of the original cloud. The onset of thermonuclear reactions in the central zone of the cloud generates a second annular dusty zone that enlarges and condenses dust particles, which after a certain period of time begins its acceleration towards the periphery either in a gradual or, most likely, in an explosive process. At a certain point in time, a head-on collision of two compacted dust layers occurs.

Until the moment of collision, the radial velocity components dominate, and the velocity components that are tangential to the spherical surfaces cantered in the cloud centre of mass are random and insignificant for all peripheral elements of the system, including gas particles. At the time of ignition of a single star, the protoplanetary disk is also absent, in contrast to the recently formed concept, i.e., there is spherical symmetry. The spherical symmetry is violated only due to the elongation of the inner dust layer, accelerating towards the periphery and carrying the rotational moments of motion together with its constituent particles. The collision of dust layers leads to the formation of a protoplanetary zone, at first close to a spherical shape, but sharply elongating and rotating. The rotation of the flare star also appears only with the beginning of the acceleration of the inner dust zone towards the periphery. In other words, an igniting star and a protoplanetary zone, which, almost instantly, in astronomical standards, turn into a flat disk, acquire torques together in a single process almost simultaneously. This most likely happens due to a thermonuclear explosion at the periphery of the core of the gas-dust cloud with preceding appearance in the structure of the core of magnetic fields that break the central symmetry (for more details, see [1]).

Is the protoplanetary zone that appears in the described way capable of generating new physical processes that were not taken into account earlier?

In work [4] mentioned above discussed that the structures with a degenerate electron or neutron gas are not thermodynamic systems and cannot be characterized by the parameters "temperature" and "pressure". In the existing theories used to describe the state of degenerate structures, the temperature dependence disappears, but the pressure continues to enter into the equations of state, although such a parameter should not be considered a statistical quantity anymore, but a conditionally effective one, because the rate of transfer of momentum through a unit of surface for degenerate particles that did not exchange momentum and energy in statistical collisions can in no way be real pressure. In this regard, a well-grounded and reasoned assumption was made that the degenerate structure is not a new form of the phase of state of matter, but represents new forms of the existence of matter, complementing the already known forms of existence. For example, a structure with a degenerate electron gas can be considered a stable system (that is, existing without external disturbances for an arbitrarily long period of time), but capable of being excited by external energy, like the system of an "atom", and the atomic nucleus and a structure with a degenerate neutron gas can be considered stable "elementary particles" that are not systems and are not capable of being excited. Accordingly, the structure with a degenerate neutron gas cannot cool down; therefore, it should not be characterized by thermal electromagnetic radiation, nor by neutrino emissions. The variety of properties of neutron stars does not indicate different forms of existence of a structure with a degenerate neutron gas or a different thermodynamic state of this structure, but shows a variety of methods for capturing and retaining the substance surrounding the degenerate structure. Moreover, as atomic nuclei can become other isotopes when capturing neutrons, so can structures with a degenerate neutron gas in a certain range of their masses become capable of capturing matter, while maintaining their stability. It is useful to note that the indicated general properties of matter with a degenerate structure as a special case fully satisfy the hypothesis of the existence of stars with strange stable quark matter. To consider these general properties as contrived is a psychological error associated with the prevailing stereotype of describing basic physical issues.

Hence, the formation of a degenerate structure is a qualitative transition from one form of existence of matter to another. Existing physical theories can predict the appearance of degenerate structures depending on the density of matter (degeneration processes occur at high densities), but they cannot to predict the resulting density of matter formed from the collision of unit masses with each other, depending on their energies. Therefore, assumptions that collisions of high-energy material lumps with each other can hypothetically lead to the formation of degenerate structures have never been made. Experimental observations have also never been conducive to such an assumption.

At first glance, it may seem that the question posed is not only irrelevant, but even absurd, since it makes no sense: it is almost impossible to compress matter to ultra-high pressures and densities, even diamond anvils are unable to cope with such a task. One can try to argue that it is not necessary to create ultra-high pressure, you just need to accelerate the set of protons to energies above the threshold for thermonuclear fusion and make them collide, because we know that the forces of close interaction must work in a structure with a degenerate neutron gas. However, in theoretical terms, such an attempt can only be perceived with a smile, and the results obtained on modern accelerators demonstrate its erroneousness.

Moreover, the forces of gravity are so weak that an object even with the mass of the Sun will not be able to accelerate a proton to an energy above the threshold for fusing with another proton in a thermonuclear reaction. Indeed, a proton accelerated by the force of the Sun's gravity to the second cosmic velocity, initially at rest relative to the Sun at a sufficiently remote distance from it, will acquire kinetic energy of only $3.2 \cdot 10^{-16}$ J (2.0 keV), which is about 300 times lower than the reaction threshold of one proton with another. If we consider the acceleration of three hundred somehow interconnected protons, the total energy will increase to the threshold value for a single proton. However, if we consider collisions of identical objects, the Coulomb barrier will also increase. The situation will be the same for heavier atomic nuclei.

At the same time, we know that although the gravitational forces of the Sun are not capable of accelerating external protons to the threshold energy of thermonuclear fusion, it is the very same weak gravitational forces that once heated the hydrogen gas in the Sun's core to the ignition temperature of the cycle of thermonuclear reactions, and support it to this day. This happened because the forces of gravity do not work in isolation, but together with the laws of statistics for a thermodynamic system.

If a high-speed collision of unit masses occurs, the laws of statistics will come into work in the resulting plasma. Moreover, tunnelling effects are also active. Therefore, the expectation that separate thermonuclear reactions will appear is justified. But can individual thermonuclear reactions help to increase pressure? It is clear that they cannot, they can only lead to the opposite effect i.e., to the scattering of the substance.

So, are all expectations in vain? It turns out that they are not. Indeed, a locally increasing pressure will lead to the scattering of matter if there is no enclosing surface around this focus. The closed volume radically changes the situation. For example, the forces of gravity in the Sun create a shell that holds the hydrogen-helium mixture in its centre, and thereby create conditions for maintaining thermonuclear reactions. Moreover, this shell is "elastic", allowing it to maintain heat release in an automatic mode in accordance with the energy balance of the Sun. If the "shell" is "fixed" in some way, then an almost unlimited increase in pressure is possible ("almost" because, among other reasons, the fuel reserves in a closed volume are limited).

What will happen if we collide two high-speed continuous gas-dust layers enriched with dust conglomerates instead of high-speed unit masses? And what if explosive processes from collisions of single masses will not occur singularly, but all around, and the system will become conditionally infinite? And what if hard electromagnetic radiation and high-energy elementary particles will appear in conditionally infinite plasma that heat the plasma? And what if the Lawson criterion is met not for supporting of thermonuclear reactions in the entire plasma, but for the operation of local foci of thermonuclear fusion (inertial confinement fusion) inside this plasma? And what if shock waves and interference processes begin to form? It is clear that the situation will be radically different. And the result will depend on the characteristics of the colliding gas-dust layers.

Let us assume that the initial shape of the protoplanetary cloud is not spheroid, as suggested in [4], but spherical. Let us conditionally assume that the collision occurred in the region of the

Earth's orbit at a distance of $11.5 \cdot 10^{11}$ m from the Sun in a layer that is $2 \cdot 10^{3}$ m thick. In reality, the collision might have occurred closer, and the thickness of the head-on collision layer, determined by the involvement of the main part of the dust particles in the collision acts of their total number, might have been significantly thinner. The head-on collision zone can be taken as the early protoplanetary cloud in its initial state, which will be an open system due to the continuing replenishment by delayed dust particles. In connection with the accepted overestimated geometric factors, the expected estimated volume of the protoplanetary cloud can be considered overestimated as well. Now let us assume that not all of the original dust of the cloud became part of the composition of the protoplanetary cloud, but only half of it, i.e. about 10^{28} kg (in fact, as estimated in [1], significantly less than one percent of the total amount of dust will not get into the protoplanetary cloud, i.e. the accepted estimate of the presence of a solid component in the protoplanetary cloud is underestimated by about two times). Then the volume of a spherical cloud of the initial protoplanetary zone will be $5.7 \cdot 10^{25}$ m^3, and the minimum value of the average cloud density, excluding the gas component in the same volume, will be 177 kg/m^3. Although this density is not only significantly less than the density of a neutron star or nuclear density, but it is even smaller than the densities of iron and silicates, it, nevertheless, significantly exceeds the density of gases. If gas molecules under normal conditions have velocities mainly in the range of (200…700) m/s, then the considered dust particles have initial velocities before collision exceeding $6 \cdot 10^{5}$ m/s. Taking into account the obtained values of an average minimum density and velocities of colliding layers, it is obvious that protoplanetary cloud will be characterized by very intense exchange processes. And not just exchange processes, but those associated with the release of energy (exothermic processes) also. If we take into account the fact that the intensity of the energy release in individual processes can be very high and will be accompanied by shock waves, then the formation of local regions of supercritical density will become very likely.

It turns out that the possibility of the formation of degenerate structures is not a fantasy. It is clear that it is impossible to obtain a rigorous substantiation of the emergence of formations with degenerate structures at this stage. Not only because this should be done not by lone individuals, but by scientific teams, but also because so far, the scientific community does not have enough fundamental knowledge to solve such a problem. But could it be that all of these are fantasies that do not deserve attention, on the justification of which it is unreasonable to spend money and time?

The fact that a single rarefied gas-dust cloud will begin to form a peripheral layer, which is compacted with dust conglomerates, falling at the second cosmic velocity onto the cloud core, is indisputable. The fact that a second compacted layer will begin to form in the central zone of the cloud at the periphery of its core is also beyond doubt. We do not know whether this second layer will be gradually dispelled from the core and will continue to thicken in orbits more remote from the centre, or whether it will be accelerated into a characteristic, acute form. The existence of a thermonuclear explosion in the cloud core, although very plausible, is still only an assumption. However, any head-on collision of the layers (clusters) is inevitable. The formation of the clusters of a continuous high-energy plasma layer of high density, which includes heavy ions, at the collision front is inevitable. Everything else associated with the formation of objects with degenerate structures – although not unfounded, is still only assumptions, and so far only speculative assumptions.

It turns out that the developed scheme of compression of a single, rarefied, calm gas-dust cloud, firstly, must really work, there can be no alternative options, and, secondly, it carries with it colossal possibilities of a new understanding of the planetary formation process. In other words, the result obtained, associated with the formation of a dense high-energy plasma protoplanetary cloud in a future single star system, is not just a fairly reliable theoretical prediction, but a prediction that can help make a fundamental breakthrough in the theory of planetary evolution of a single star system. A breakthrough that will provide active exclusion of contradictions in the explanation of the observed properties of the solar planetary system and planetary systems of other single stars. Since the proposed scheme of compression of a single gas-dust cloud is relevant, further comprehensive study of it is required, including hypothetical possibilities. Therefore, the question of the possibility of the formation of objects with degenerate structures in a protoplanetary cloud is also relevant, although its reliability at this stage is not clear. But further material will show that the situation is similar to that with quarks: even if there are no quarks, it would still be necessary to try to invent them. Without objects with a degenerate structure, it is unlikely that it will be possible to build a coherent theory of planet formation for a single star system.

In addition, if we take into account the possibility of the formation of objects with degenerate structures in a protoplanetary cloud, then not only will new possibilities appear in the explanations of difficult and previously inexplicable questions (in particular, with the magnetic fields of planets), but conditions will also be created for a deeper development of physics.

Due to astronomical observations, certain restrictions may appear on the stability of the existence of various forms of matter: the principles of stability of heavy atomic nuclei and formations with degenerate structures may become clearer. In general terms, this issue can be characterized as follows.

The last stable chemical element in the periodic table is lead. All the heavier chemical elements are radioactive, and as their atomic numbers increase, their half-lives decrease. Nevertheless, an island of relative stability for uranium and thorium suddenly appears: the half-lives of some of their isotopes have allowed these isotopes to survive in nature from the moment the formation of the Solar system. However, as the serial numbers of the chemical element continue to grow, the stability of their nuclei decreases again. The developed shell model of the nucleus made it possible to explain the stability of chemical elements with atomic numbers up to lead and the appearance of a relatively stable region of thorium and uranium. In addition, the model predicted the emergence of an island of stability in the region of superheavy elements with atomic numbers from 112 to 116, despite the instability of the nuclei of chemical elements with atomic numbers greater than

100 predicted back in 1939 by Bohr, Wheeler and, independently, Frenkel, who developed the liquid drop model of the nucleus in 1936. However, by now, 118 chemical elements have already been discovered, and the hopes for the discovery of an island of stability of the super-heavy elements have not been justified.

Ambiguities with stability ranges also exist for objects with degenerate structures. For objects with degenerate electron gas, there is an upper threshold for object mass, defined by the Chandrasekhar limit, at which the compressing effect of gravitational forces throws the system into a state with degenerate neutron gas. In turn, the upper threshold for an object with a degenerate neutron gas is determined by the critical mass that causes this object to turn into a black hole. Currently, there are no theories which would explain what real physical mechanisms would make such a transition possible. Not to mention the fact that the very concept of a "black hole" has no physical meaning (see [4]). Therefore, it is more correct to assume that the indicated upper limit does not refer to a transition to a new state, but serves as a threshold for the stability of a structure with a degenerate neutron gas: objects of large masses, taken as black holes, should be composite, consisting of a set of objects with a degenerate neutron gas. Nothing is currently known about the lower mass limits for the existence of degenerate structures. It is clear that objects with a degenerate neutron gas can theoretically have a mass that is less significant in comparison with the Chandrasekhar limit, if a method for such a strong compression of objects of lower mass is created. But the lower mass limits of stability of objects with a degenerate neutron or electron gas is not known. How these structures disintegrate is also not known. But there is no doubt that the lower threshold exists, otherwise such objects would have been discovered long ago.

It is known that the production of all heavy chemical elements, heavier than hydrogen, is carried out in the stars that ignite thermonuclear reactions in their depths. In the distribution of the binding energy of nucleons, depending on the atomic number of the nucleus, there is an "iron peak", due to which the final products of exothermic thermonuclear reactions are the elements of this peak. The lightest stars mainly produce only helium. In heavier stars, which begin to use helium as fuel, a carbon-oxygen core is formed. However, further cycles of thermonuclear reactions are not initiated for masses less than eight solar masses. At a certain stage of evolution, these stars turn into red giants, which after a certain period of time shed their shells with the formation of a planetary nebula, which includes heavy chemical elements, usually up to oxygen. After the ejection of its envelope, a stable white dwarf remains as a remnant of a star, which can no longer be considered a source of heavy chemical elements. In the relatively light stars under consideration, chemical elements with large atomic numbers do not appear. This is despite the fact that in red giants, the processes of nucleosynthesis associated with "slow" capture of neutrons are still triggered. However, a noticeable amount of heavy chemical elements begins to appear only when the masses of stars approach eight solar masses. Moreover, as the mass of a star approaches this value, at the stage of transformation of a star into a red giant, the probability of its explosion increases, i.e. it becomes supernovae. In this case, the chance of an explosion with a complete scattering of matter, i.e. with a scattering of the central parts of the star as well, is quite high. Such explosions are called Type *Ia* supernovae, and they are the most significant source of iron dust formations. If the explosion is not complete and occurs with the formation of a remnant, then with a star mass of more than 12 solar masses, it is not a white dwarf that will remain in the remnant, but a neutron star. With such explosions, a mechanism of "rapid" capture of neutrons is triggered, due to which very heavy chemical elements can form.

But, despite the fact that the principles of the formation of heavy chemical elements in the Universe as a whole are clear, an overabundance of elements of the iron peak and isotopes with an even number of protons is observed for the solar system. There are also too many heavy chemical elements. To explain the observed chemical composition of the solar system, Bartos and Marka had to assume that two neutron stars merged before its birth [13]. But, firstly, in [1] it was explained that the solar system, according to the results of astronomical observations, can be attributed to a singular system, which is not consistent with the merger of neutron stars that occurred immediately before the birth of the solar system (tens of millions of years) and in its immediate vicinity. Secondly, at this time there is no complete and clear picture with an explanation of the isotopic composition of the solar system.

If the above hypothesis of mass formation in the first moments of the formation of a protoplanetary cloud of unstable formations with degenerate structures will be confirmed, then the picture of the initial isotopic composition of the solar system might become more understandable. Moreover, the expectations of the existence of new super-heavy chemical elements with long half-lives, capable of maintaining their concentrations at the level that could be detected by modern devices, will be pointless. Spectral analysis has also not yet found elements in space that are heavier than uranium and thorium. It will also be pointless to expect that stable objects with degenerate structures with their small masses exist.

At the same time, under certain conditions, it is quite acceptable to expect the possibility of the formation in the nascent protoplanetary cloud of local regions with a multitude of objects with a degenerate structure that have arisen close to each other, which managed to somehow interact with each other before their decay. Moreover, such interactions, as the existing knowledge of the microworld demonstrates, is quite capable of increasing the decay time of interacting elements. Therefore, it is possible that the solid central zones of the nuclei of future planets already formed in the first moments of the formation of the protoplanetary cloud, and immediately began to accrete by a plasma layer. This assumption greatly simplifies the solution to the problem of describing the emergence of the planet's magnetic field even at the proto-nucleus stage. This assumption, of course, is still very crude and requires significant scientific research and substantiation.

If the above assumption is not taken into account, then in the case that only dense and high energy plasma, which does not include solid formations in its composition, exists at the first stages of the appearance of a protoplanetary cloud, the reason for the formation in the expanding plasma layer of liquid nuclei of future planets, which have not yet had time to gain their mass, becomes easily explainable. However, the method of differentiation of matter in the nucleus remains unknown.

Therefore, the hypothetical appearance of relatively large formations of temporarily stable grains with degenerate structures, possessing a complex magnetic field and beginning to actively collect the surrounding plasma with an ordering of its magnetic field, is quite attractive, though unsubstantiated. At least this is not contrary to the principles of physics. We are talking about a hypothetical formation with a complex orbital structure, like structures with generalized electron shells, which soon turns into a single ordinary solid formation due to grains with degenerate structures exploding non-simultaneously in their orbits. It is possible that such hypothetical formations, due to their bulkiness, turned into ordinary solid formations with only a partial scattering of matter.

Of course, at this speculative stage, it could also be assumed that smaller formations with degenerate structures merge into one large one. But then, in the case of instability of the degenerate structure, its decay will take place with the inevitable complete scattering of matter. And in the case of stability, such a structure will not be able to allow acoustic waves through it (since objects with a degenerate structure are not a thermodynamic system, they are not able to conduct sound). Taking into consideration the fact that the inner core of the Earth allows seismic waves to pass through it, it most likely consists of ordinary solid matter.

It is useful to emphasize once again that the assumption that a formation appears from temporarily stable grains with degenerate structures at this stage is unfounded. But positive expectations can be associated with it.

Firstly, grains with degenerate structures, having not yet had time to decay, contribute through their magnetic fields to the effective selection of the metal into the outer layer formed around their aggregate. The decay of these grains should occur soon enough. However, if it occurs without a complete dispersal of matter and the formation of an ordinary solid structure, devoid of its own magnetic field, then the electrically conductive liquid layer lingering around it, taking into account the prehistory, may be able to launch a magnetic dynamo. Moreover, liquid layers and magnetic fields of such formations during their subsequent collisions with each other can facilitate their unification with the preservation of the structure and intrinsic magnetic field of the already united formation, instead of the dispersal of matter.

Secondly, at least some possible explanation for the release of energy from the central zone of the core of the future planet appears, because only heavy isotopes can be the decay products of grains with degenerate structures, and most of them will be radioactive. At the same time, which is very important, radioactive decay will not only serve as an active and long-lasting source of energy, but its products will begin to fill the solid inner core with light elements.

Thirdly, a more logical explanation for the presence of a large number of heavy chemical elements emerges. This is a very important factor, which almost proves the existence of formations with degenerate structures in the protoplanetary cloud, since the initial isotopic composition at the early stages of the formation of the solar system has no explanation. However, this will be discussed later in the article.

If we ignore the hypothetical unstable grains with degenerate structures, then for new models of planetary formation in conditions completely different from those assumed by modern science, which will be characterized by high energies and high densities of matter, there will still be a lot of room. And the fact that these new conditions are realized in space, including our solar system, is indisputable. The following characteristic features of the planetary formation process in a dense high-energy zone can be distinguished.

The chaotic movement of the elements of the protoplanetary cloud can be considered the first distinctive feature. This is not about the presence of individual orbits with large eccentricities for the entire countless number of elements of the already flat protoplanetary cloud. The existence of such orbits still needs to be explained. And we need to explain them; otherwise there will not be numerous processes of collisions. And after that, the circular orbits of the planets need to be explained. In this case, we are talking about a truly chaotic movement, like that of gas molecules.

According to the discovered mechanism of the formation of a protoplanetary cloud of a single star, formed from a separate gas-dust cloud that does not generate other stars, orbital motion began to form for the entire protoplanetary cloud due to numerous successive collisions of elements merged after a head-on collision of two dense zones of a gas-dust cloud. In successive collisions, firstly, the original, oppositely directed radial components of the velocities of the elements of the colliding densified zones are extinguished, and, secondly, the torque is transmitted from the elements of the inner zone, which has been moving since before the collision of zones from the star. Owing to the ongoing collisions, the spherical layer of the protoplanetary cloud is intensely stretched into a flat disk, characterized by circular motion. But the elements of the disk still inevitably retain their chaotic movement within this disk. Only due to the initial randomness of the movement of the elements of the disk and its high density, the planets grow effectively and at the end of their evolutionary path find themselves in circular orbits.

It is useful to note that accretion and gravitational attraction between objects of approximately equivalent masses do not cause chaotic movement of elements. Gravity only increases the frequency of collisions of the elements of the protoplanetary cloud with each other, which would also occur in the absence of mutual gravitational attraction (modern theories suggest that frequent collisions of the elements of the protoplanetary cloud with each other are due precisely to the gravitational attraction arising between them).

The second distinctive feature is as follows. As soon as a rotating dense disk of protoplanetary matter is formed, the processes of dividing the disk into fragmentary rings become quite natural.

As mentioned earlier, the protoplanetary disk is born from a spherical or spheroidal layer of high-energy multicomponent matter. But this layer is formed as a result of the collision of the fronts of the compacted zones of the gas-dust cloud. And the thin front layers are followed by more rarefied layers with slower dust particles. Radial directions of motion are extinguished only for particles of dense frontal zones. The deeper parts of the colliding zones introduce radial impulses and increase the thickness of the cross layer, thus, increasing the randomness of the movement of its elements. A substance entering the internal orbits should be absorbed by the host star in a fairly short time. Moreover, the flow of matter towards the star, taking into account the higher density and energy of the falling peripheral compacted layer in comparison with the inner layer which is colliding and moving in the opposite direction to it, should be dominant. The observed ratio of the mass of the initial dust of the gas-dust cloud and the solar planetary system definitely confirms this position. The substance moving towards the periphery must slow down due to the forces of gravity of the star and form orbital motion in distant orbits.

Since the collisions of the elements of the protoplanetary cloud are frequent and intense, the spherical layer of the cloud is flattened into a disk in a very short time. Therefore, the disc should immediately be formed with the rudiments of two rings: a massive main inner ring and a light outer ring. The substance of these rings initiates the work of clearing the area between them from dust. Thus, the process of the initial basic formation of various zones for the subsequent growth of planets in them is rather short-term and universal for all single stars, not only for the Sun. It is associated with just three zones: the massive inner ring, the gas gap, and the lightweight outer ring.

The third distinctive feature stems from the first two. Since all the main processes of the evolution of the protoplanetary cloud occur at the initial moment in a thin layer of the cross zone of the collision of two dense layers of the gas-dust cloud, and after that the main matter is concentrated in the massive inner ring of the protoplanetary cloud formed on the skeleton of the cross zone, it is natural to expect that the inner ring will also be the progenitor of seed formations for all future planets of the planetary system. Although the bulk of the matter from the inner ring zone is lost and absorbed by the star, but this is just details. Let us call the expected seed formations proto-nuclei. The proto-nuclei will be the same for all future planets because the process of their formation is faster in comparison with the process of dividing the protoplanetary cloud into characteristic zones.

The fourth distinctive feature follows from the previous three. Although all planets are formed on identical proto-nuclei, the properties of protoplanets, and especially of the already formed planets, depend on the external conditions of the planet-forming zones, in which the proto-nuclei are. But first, the proto-nuclei must be distributed around the star in a certain way. In the inner massive ring, the heaviest proto-nuclei undergo multidirectional bombardment by the lighter components of the ring and quite frequent collisions with formations close to them in mass, which slows their escape from the ring. As a result, the heaviest proto-nuclei predominantly remain in the inner ring which is associated with the formation zone of rocky planets. The fastest light proto-nuclei, in case of avoiding their collision with heavier proto-nuclei, have the highest speeds and slow their movement to the periphery of the forming star system in the outer light ring. For the Solar system, this ring is associated with the zone of ice planets. Initially, the gap between the inner and outer rings is quite dense, but gradually clears up, transferring its substance to the inner and outer rings. For the Solar system, the annular gap falls on the zones of cold and very cold planets. After some time, the protoplanets remaining in the annular gap quickly clear their orbits completely, this includes the ejection of excess protoplanets, and gain critical masses capable of effectively pulling in the surrounding gas.

Of course, all the distinctive features of the compression of an isolated rarefied gas-dust cloud in a calm initial state determine only the general principles and directions of the processes taking place. A more coherent and specific discussion is possible only on the basis of building a model.

But from these generalized distinctive features it is already possible to draw a rather important and inevitable conclusion that shifts the paradigm of the theory of planet formation. A conclusion that does not need additional substantiation of its truth. It is necessary, in the theory of planetary evolution of certain single stars, in particular the solar system, to change a concept: the planetary nuclei were formed not due to gravitational compaction of the central zones of massive clusters, accompanied by gravitational differentiation, but before the formation of protoplanets. First, proto-nuclei appeared, and then, due to accretion, protoplanets began to actively grow, almost immediately forming the magnetic properties of future planets, even before the appearance of a thick layer of the mantle, or trapped gas, or ice. It is useful to emphasize the last phrase: we are not only talking about the proto-nuclei of future rocky planets. However, the formation of giant planets on seed protoplanets with existing magnetic fields does not mean that the strong magnetic fields of these future planets are caused by strong magnetic fields of proto-nuclei. The magnetic fields of the proto-nuclei could only contribute to the formation of their specific generators of the magnetic field in these planets (primary magnetic fields are necessary to excite a magnetic dynamo).

The results obtained by Williams and Mukhopadhyay [14] on determining the ratio of neon isotopes in samples from deep mantle plumes of the Earth, compared with samples of the mid-ocean-ridge basalts, lunar soil and meteorites, including carbonaceous chondrite meteorites, obtained by Williams and Mukhopadhyay [14], can be considered an experimental confirmation of the conclusion about the rapidly proceeding and very quickly ending initial stage of planetary formation for the solar system. As a result of the study of the samples, it was concluded that deep mantle plumes contain gas from a protoplanetary cloud (nebular gas). And this means that the majority the Earth's mass was gained before the dissipation of the protoplanetary disk.

Similar conclusions were made by Mundl *et al.* [15] based on the determination of the isotopic composition of tungsten and helium in basalts from islands located above special hotspots originating from "mega-ultra-low-velocity zones" at the core-mantle boundary for seismic waves (the composition of tungsten and helium isotopes is standard for other hot spots).

It is believed that the light tungsten isotope ^{182}W did not exist in the protoplanetary cloud but that it was formed from the isotope of gallium ^{182}Hf, which has a half-life of only 8.9 million years. Since the light tungsten isotope was almost absent in the samples taken, and the concentration of the helium isotope ^{3}He, which could only have been captured from the protoplanetary cloud (^{4}He is formed in radioactive decays), was high, it was concluded that the samples were fragments of the primary protoplanetary matter. This means, firstly, that the core had already been formed in the first stages of the Earth's evolution, and, secondly, as a result of convective processes in the mantle and deep melting of sinking rocks (if sinking rocks exist), not all of the material had time to mix and become homogeneous.

Using the example work [15], it is useful to draw attention to another very important factor. Due to the very short lifetime of the ^{182}Hf isotope, 50-60 million years after its appearance, it should have completely decayed. Two conclusions can be drawn from this. The first is that the source of this hafnium isotope could not have been a supernova explosion or a merger of neutron stars. The second is that the countdown of the lifetime of most heavy isotopes started from the moment the protoplanetary cloud appeared (!). In fact, this is a direct proof of the above hypothesis of the emergence of unstable formations with degenerate structures at the time of the formation of a protoplanetary cloud.

There is another interesting observation. O'Neil *et al.* determined the absolute age of rocks from the greenstone belt, mined in the village of Nuvvuagittuq in Quebec, Canada [16]. According to the results of the analysis of the isotopes of samarium and neodymium, they determined the age of the samples to be 4.28 billion years. Moreover, in that work, based on the results of analyses, it is even assumed that the ocean could already have existed at that time. If the age of the Earth is taken as 4.54 billion years, then it seems that the Earth's crust was formed after 260 million years.

The most ancient sedimentary rocks on Earth have not survived to this day. But the lithosphere already existed at the earliest stage of the planet's origin, as evidenced by the samples of zircon up to 4.4 billion years old found in igneous rocks of a later period. This happened because the entire primary lithosphere of the Hadean period was processed in the mantle layer in the subsequent geological Archean era, but the zircon was preserved and was redeposited into sedimentary rocks of the Archean period.

A very recent study published by Tarduno *et al.* [17] found that the Earth's magnetic field existed as early as 4.2 billion years ago! They studied the magnetization inclusions of magnetic minerals with samples of ancient zircon. The main difficulty they had to overcome was to show that the detected magnetization is not secondary.

All processes associated with the Moon are also short-lived. As mentioned above, the Moon not only has a solid and liquid core, but it also used to have its own magnetic field. Moreover, recent studies by Tikoo *et al.* [18] revealed that the Moon's magnetic field existed longer than originally thought. Lunar swirls indirectly indicate the possibility that it had an atmosphere in the early stages of its existence (but this cannot serve as a proof of the existence of a lunar atmosphere).

Formation of the Moon and its core cannot be explained by the contraction of matter into a lump somehow ejected from within the Earth or captured by the Earth. The Moon and the Earth also did not form in initially joint, but as results of relatively independently occurring processes, as if in the neighbourhood. The moon was formed as the result of the collision of the Earth with a planet (called Theia) on the core of this planet that was preserved after the collision. This presumably happened 5-30 million years after the formation of the Earth. Since the Moon's core is small in diameter, it is difficult to assume that Theia was comparable in size to Mars, as is the case with existing models. Theia's dimensions must have been significantly smaller. However, the interactions of the magnetic fields of the two planets during their collision could have certain effects that need be taken into account when simulating this collision. The magnetic fields of such small objects with rocky formations (Teia and the Moon), and the very fact of the existence of a complex-structured core in the absence of a heavy and very thick mantle around it, unambiguously indicate that the approaches to explaining the processes of formation of the nuclei of planets of a single star are wrong.

In general, such rapid processes of formation of the Earth and the Moon cannot be explained by modern models. This is possible only under different initial conditions, when the bases of the planets were created almost immediately after the appearance of the protoplanetary cloud, while the cloud remained dense enough for the final formation of the initial form of planets.

The result of the work of Pravdivtseva *et al.* [19] can be considered as indirect evidence in favour of the existence of a dense protoplanetary cloud at the beginning of the evolutionary path of our solar system. When studying samples from the Allende meteorite, they found silicon carbide grains of the initial gas-dust cloud in a calcium-aluminum-rich inclusion (CAI) (the conclusions about the pre-solar origin *SiC* were made based on the isotopic composition of accompanying noble gases). It is believed that CAIs were formed near the young Sun at temperatures of about 1500 K, which silicon carbide grains can withstand only for a short time and therefore were unable to get inside the CAIs. The existence of a dense protoplanetary cloud makes it possible to explain such experimental observations.

Thus, the general conclusion obtained on the basis of the distinctive features of the initial characteristics of the protoplanetary cloud of a single star arising from an isolated, calm and rarefied gas-dust cloud, including the Sun, is not based on assumptions, for example, on the assumption of the appearance in the protoplanetary cloud in the first moments of its appearance of formations with degenerate structures, but is strict, can be formulated as follows: all the planets of a single star evolve on proto-nuclei that are uniform in structure, formed in a single general process, having an internal solid and external electrically conducting liquid core, initially possessing magnetic fields, and the further process of the formation of protoplanets is not lengthy and occurs even before the dispersion of the protoplanetary cloud.

The result of this chapter is the finding of the following planet formation algorithm for a single star formed from an isolated, calm and rarefied gas-dust cloud.

The formation of a protoplanetary cloud can be considered an instantaneous process, concentrating not just the residual part, but all the dust of the original gas-dust cloud in the zone of initial protoplanetary cloud. The protoplanetary cloud is formed due to the collision of the front parts of the oppositely moving peripheral and inner compacted layers of the gas-dust cloud with large radial velocities. The process of formation of proto-nuclei of future planets occurs almost instantly, but the processes of formation of protoplanets and the characteristic zones for their further evolution are already much more stretched over time. The proto-nuclei of all future planets are formed in a single process, in a single local zone; the protoplanets form in two annular zones separated by a gap; and the final formation of planets takes place in three zones, including the gas-filled gap. All proto-nuclei have a solid inner and liquid outer core and are characterized by their own magnetic field, which subsequently, depending on environmental conditions, can weaken and even completely disappear in the finally formed core of the planet. However, the damped magnetic fields of protoplanets can facilitate the formation of a magnetic dynamo in the outer layers of the planet. The orbital motion of matter begins to form only with the appearance of a protoplanetary cloud. The appearance of heavy chemical elements is also associated with the moment of the emergence of the protoplanetary cloud. Heavy chemical elements must be few and of a limited variety, and short-lived isotopes must be completely absent in the initial dust of a calm rarefied gas-dust cloud, from which a single and isolated star is formed.

What follows is not statements, but assumptions. However, these are not just assumptions, but very weighty assumptions. It is most likely that heavy chemical elements appear due to the decay of unstable formations with degenerate structures (it is practically impossible to offer another source). It is also very likely that these unstable formations with degenerate structures provide the inner cores of planets with a future source of energy.

Distinctive characteristic features of the planetary system of a single star, formed from a rarefied calm gas-dust cloud, may be as follows:

- small total mass of planets in comparison with the mass of a star;
- the planetary system is flat with planetary orbits being close to circular;
- the absence of hot macro-planets (hot Jupiters and hot super-Earths);
- the mandatory presence of rocky planets;
- the concentration of rocky planets only in close and medium orbits;
- the presence of magnetic fields in most planets;
- the presence of heavy chemical elements.

3. Heat balance of an arbitrary planet and the Earth

Another important aspect, planned for discussion in the framework of this work, is the substantiation, based on underlying approaches, of the impossibility of maintaining high temperatures in the central zones of the planets due to the gravitational energy of these planets. In this case, we will talk about all the planets, not only about the planets of single star systems.

Today it is generally accepted that the temperature in the centre of any planet is at maximum. Since the planets are no longer compressing as a whole, and the forces of gravity are cannot do the work of compressing all the matter that makes up the planet, due to which the matter of the planet can be heated, and modern approaches cannot rely on the energy of radioactive decay in the centre of the planet (the hypothesis of the formation of planetary nuclei from unstable degenerate structures, firstly, is raised in this work for the first time, and, secondly, it is not universal and is suitable only for certain initial conditions for the formation of a stellar system), the hypothesis of heating the core of the planet by gravitational differentiation has become generally accepted. Moreover, if we go straight to the thermal balance of the Earth, we are not talking about the residual heat of the planet's core, which was once released by gravitational differentiation during the formation of the core, we are talking about a heat source that is still working today. But this is an obvious mistake. The point is not even that the division into fractions in the bowels of the Earth for the current stage of its evolution is practically not identified in observations, but that gravitational differentiation cannot warm up the centre of the planet in principle.

The essence of gravitational differentiation can be explained as follows. Near the surface of the earth, all objects accelerate equally in free fall. However, if you put light and heavy weights of the same shape on the support, then the heavy weight deforms the support material more than the light weight. Elements of a homogeneous mixture of a solid will also behave in a similar manner: heavy elements will have a predominant direction of diffusion towards the centre of mass of the solid, thus replacing the light elements. Due to this effect, the forces of gravity acquire an additional opportunity to perform work, despite the stationary fixed geometric dimensions of a solid object, the substance of which creates a gravitational field. In general, there is no compression, so there is no work performed by the forces of gravity. However, the work is still being performed on individual elements of the system, i.e. differentially. And since work is performed, heat must be generated. But it is important to understand that heat is released not at the centre of mass of the system, but locally, in elementary volumes of matter. Subsequent heat transfer processes are already secondary processes that do not determine the initially emerging temperature gradient inside the planet, but only set trends for its change.

Let's look closer at the nuances of the process of gravitational differentiation in an arbitrary planet. The gravitational forces act on the peripheral elements of the object more significantly than on the central ones, regardless of the distribution of the density of matter inside the object. Therefore, if the initial temperature is taken to be the same throughout the volume, the temperature will begin to increase from the periphery, remaining unchanged at the centre of mass.

It is also useful to note that force can only be balanced by force, so the forces of gravity are not resisted by temperature, but by pressure. And pressure depends not only on temperature, but also on density. Therefore, a single act of diffusion of a heavy element towards the centre, due to the geometric factor, will increasingly increase the pressure due to an increase in density (not by giving the maximum momentum to the heavy element by the forces of gravity, with which it will begin to share with its neighbours, increasing the temperature, but due to the appearance of small collective movements of neighbours associated with the act of forced displacement of this heavy element, with a change in the equilibrium positions between them that had developed before this introduction, increasing the stored potential energy, i.e. increasing the pressure). Therefore, not only will the forces that induce directional diffusion decrease with depth, but their effect on the rise in temperature will also decrease.

These were general considerations, not related to the phase or chemical composition of the substance or to the distribution of the density of the substance over the volume. Therefore, they are valid for all planets. For this reason, in the absence of heat losses from the planet's surface, the maximum temperatures from gravitational differentiation should be observed at the periphery, and in the presence of heat losses - in the middle zones of the object. Physical laws make it impossible for the central zones to have maximum temperature due to gravitational differentiation. The given argumentation is exhaustive and obvious; a special mathematical substantiation of this issue is not required to understand its essence. In addition, due to gravitational differentiation, the gradients of the chemical potential for heavy elements towards the centre also decrease over time. This means that maximum temperatures cannot be observed in the centre of mass of the planet if there is no independent heat source there. This is an obvious mistake of all modern theories of planet formation without exception.

The pressure, in fact, is must increase towards the centre, since the short-range repulsive forces between the elements of the substance transfer the arising layer-by-layer increase in pressure deep into the substance, in the direction of the perturbation of each layer. But growth towards the centre of pressure is one thing, and a completely different aspect is the nature of the temperature distribution. An increase in pressure towards the centre cannot cause an increase in temperature in equilibrium processes: the temperature must equalize regardless of the pressure distribution. This can be easily verified in laboratory by simple experiments, in which the gravitational field can be replaced by an electrostatic field. These are the laws of physics that must not be forgotten. The temperature cannot rise towards the centre. It can be maximum only if it was at maximum at the initial moment of time. And over time, in the absence of an energy source, the temperature peak in the central zone must subside. And if there is gravitational differentiation, then the temperature in the centre should become even lower in comparison with the temperatures of the more outer layers (!).

Along the way, it is useful to draw attention to another obvious and inevitable result of the general analysis of the occurrence of gravitational differentiation processes: the maximum concentration of heavy elements should be established not at the centre of mass of the object, but in its middle layers due to the inevitable decrease in the mass flow along the sections of the cones having radial axes with vertices in the centre of mass, in the direction of their tops (in the vicinity of the tops of all cones, the concentration of heavy elements will be close to the preliminary, i.e., to the initial, concentration).

Now it's time to talk about the energy balance of the planets.

First, it is useful to state obvious statements of a very general plan because fundamental errors in explanations of the reasons for the developing temperature regime of an arbitrary planet, which counter the law of conservation of energy, in the media, and in educational literature too, are very common.

The temperature regime of the planet is highly dependent on its proximity to the star. But it is a mistake to think that even a fraction of the energy received from a star in a stationary steady-state regime remains inside the planet (except for the formation of hydrocarbon deposits or the occurrence of any endothermic chemical processes on the planet's surface, i.e., if you do not include the energy stored on the planet into its energy balance). This conclusion does not depend on the characteristics of the planet. Of course, the greenhouse effect or some other effects that change the temperature regime of the planet are possible. But the zero-energy balance for the planet must be preserved: whatever amount of heat it receives from the star, it must give exactly the same back into outer space. There can be no other alternatives. The resulting temperatures on the planet become exactly what they are so that the zero balance is maintained.

Even if the planet has an internal source of heat, the zero balance of the heat received from the star and given to outer space must be preserved. Furthermore, the amount of heat released by the internal source must be added to the heat losses related to the thermal balance of the planet with the star. The proximity of the planet to the star, firstly, cannot "lock" the internal heat source, even if its power is insignificant in comparison with the energy received from the star (provided that the power of the source does not depend on temperature, since the thermal regime of a planet depends on external conditions), and, secondly, the losses from the planet cannot be compensated for by the heat received from the star, but such statements are very common. With a steady exchange of external energy, the planet cannot cool down or heat up, regardless of the presence or absence of an internal source of energy. In turn, if an internal source is present, then whatever power is generated energy from the internal source of the planet, the same amount of power will be lost to outer space associated with internal energy release, regardless of the energy exchange of external energy. Moreover, the internal source of energy must be depletable (there are no perpetual motion machines). And the temperature regime of the planet will not change this situation. But the very temperature regime of the planet, of course, depends on and is determined by the components of the energy balance.

The average equilibrium points depend on the external and internal energy flows. But the amount of energy given away will always be equal to the total amount of energy received. Thus, the characteristics of the planet and its proximity to the star, as well as the presence of internal sources of energy, determine the temperature regime of the planet, but do not disturb the energy balance. Of course, it is important to understand that we are talking about previously established regimes.

It is very important to note that when the internal sources of energy were discussed it was "switched on" sources that were meant. After all, sources that have a reserve of energy may be switched off. For example, the internal thermal energy stored by the planet, characterized by heat capacity (residual heat), may well serve as an internal source of energy, but only if the outflow of energy from the planet is not blocked (when blocked, the system is isolated, its internal energy does not change, the available energy reserve cannot manifest itself as a source of energy). The establishment of an equilibrium average temperature of the planet in heat exchange with an external energy source can be considered a particular case of "blocking" the outflow of heat stored by the planet. If the amount of heat received from space is equal to the amount of heat given back over average time intervals, then no matter how high the equilibrium average temperature of the planet is, it will remain the same in the future: the law of conservation of energy will not allow the planet to cool down.

Now all that has been said can be detailed and explained using the example of the planet Earth. Moreover, the existing layouts of the energy balance for the Earth always include errors.

First, let’s talk about the external heat received from the Sun. All the figures given below differ in various sources, so they should be taken not as strictly established values, but as demonstrative ones. The average power of solar radiation on the Earth’s orbit is approximately 1.4 kW/m^2. About 40% of radiation is reflected, the rest of the rays are absorbed. The energy of the Sun’s radiation, received by the Earth’s surface, is distributed into infra-red reradiation, evaporation of water, photosynthesis of living organisms and heating the atmosphere through heat transfer. The atmosphere, besides the convective heat transfer from the surface of the Earth, also receives the energy of low-frequency acoustic radiations of the ocean. The wind energy and acoustic waves of turbulent wind pulsations, in the end, also turn into heat energy of the atmosphere. Besides, the atmosphere itself absorbs 17-25% of the Sun’s radiation, falling onto the Earth. The main part of the received atmospheric energy is again cyclically transmitted onto the Earth’s surface. However, regardless of the distribution of the energy received by the Earth from the Sun, it must re-emit all of it (with the exception of a small part associated with photosynthesis) into space, i.e. the heat removal capacity averaged over the year and over the entire surface of the Earth will be about 0.8 kW/m^2.

Now let’s talk about the heat loss from the bowels of the Earth. The average heat flow through the outer surface of the Earth is approximately 50 mW/m^2 (various other values can often be found in literature, up to 90 mW/m^2, but this does not matter for the current reasoning). Despite the fact that the value of the flow from the Earth's interior is four orders of magnitude (!) less than the heat flow diverted to outer space, which is on average equivalent to the flow of external energy received, the energy flow from the internal source will inevitably be added fully to the superior heat flow associated with the external energy balance.

If the heat flow of the removed internal energy was provided by internal energy sources located in the centre of the Earth, then the internal thermal energy diverted from the Earth's surface to outer space would not only strictly determine the heating power of the central zone of the Earth, but would also maintain the established temperature gradients along the Earth's radius. However, modern estimates indicate that the number of radioactive elements in the crust and layers of the upper mantle at depths of up to 90 km is capable of blocking this heat flow with a large margin (2-3 times). It turns out that the frontier surface of the "Earth" system is self-heating. This means that the Earth does not cool down, and the residual heat cannot be a component of heat losses (in the literature, such statements are found constantly and sometimes the share of residual heat is even determined to be up to 50%). Moreover, over 4.5 billion years the planet had to cool down to an equilibrium temperature determined by the exchange of external energy with the environment, even in the complete absence of internal heat sources (internal sources raise the equilibrium temperature, thereby accelerating the achievement of zero value for the residual heat flow into the environment). Moreover, it makes no sense to assert that it is required to clarify the average heat flow from radioisotopes occurring in the upper layers of the Earth. Whatever the result of the refinement may be, the obtained conclusion about the absence of cooling of the Earth is natural and inevitable!

The Earth either turned into a thermostat and does not have "switched on" (working) energy sources in the inner zone of its structure, or this heat flow should be noticeably lower in comparison with the heat lost by the planet and be directed to heating the inner zones of the Earth. In any case, the heat flow into the environment does not determine (!) the heat flow from the central zone of the Earth. It only sets the upper limit of the capacity of the internal heat source, and the power itself can be very low, up to the complete absence thereof. Taking into account the geometric factor (the average radius of the Earth is 6371 km, the inner core is 1220 km, the outer core is 3480 km), the heat flux from the central heat source should be below 1.4 W/m^2 across the boundary between the solid and liquid core and below 0.2 W/m^2 across the boundary between the core and the mantle, and the total power of the source should be below $2{,}5\cdot10^{13}$ W. With average heat losses of 90 mW/m^2 from the Earth's interior from its outer surface, the upper limit for the power of the internal source will be $4{,}5\cdot10^{13}$ W. This value does not differ much from the previous one and does not change the upper threshold, the value of which is at the level of 10^{13} W.

Estimates of the required minimum heat flux from the inner core to the mantle needed to maintain the Earth's geomagnetic field vary greatly, and the values provided in the literature are on the order of ($10^9 \ldots 10^{11}$) W. Moreover, these values can be considered the upper limit, since the dynamo theory allows the generation of a magnetic field in the absence of a heat flow. But it is unlikely that it will be possible to achieve the calculated power of the magnetic field, which reaches the real observed values, without a heat flow through the outer core. But in any case, the result obtained is 2-4 orders of magnitude lower than the just given value of the upper limit of the power of the internal source.

The conclusion that the heat from the deep bowels of the Earth is not lost does not mean that the generator of the Earth's magnetic field is eternal, since it will never freeze. Its freezing, indeed, is postponed for a long time. But the temperature throughout the Earth's thickness will inevitably even out. And if the generation of the magnetic field is supported by the heat flow from the inner core through the outer core to the mantle, then this support of the work done by the generatir decreases with time. But where is this heat directed if there are no losses from the Earth's surface from deep energy sources (losses from the surface are completely determined by an additional internal energy source which is located close to the surface)?

Since we can observe horizontal movements of the tectonic plates of the Earth, there must be an energy source that feeds this process. The convective processes in the mantle must claim this role. Considering that active processes of separation of matter in the mantle in the modern era are impossible, convection can only be thermal. But there is no heat loss from the deep bowels of the Earth. Therefore, thermal convection is associated not with maintaining the existing temperature gradient across the thickness of the mantle, but only with the process of gradual temperature equalization, but with an additional consumer of energy coming from below: plate tectonics. Another additional consumer of energy coming from below is volcanic activity. The power required to support these processes is difficult to estimate. But roughly, it can be estimated to be around 10^{12} W. Although tectonic and volcanic phenomena originate deep in the bowels of the Earth, nevertheless, their replenishment is inevitable, and significant, with the energy of superficially occurring radioactive isotopes.

Thus, the upper limit of the power of the heat source of the inner core is approximately $(10^{9}…10^{12})$ W. This energy is distributed between maintaining the Earth's geomagnetic field and heating the mantle (with a gradual levelling of its temperature). Of course, these figures are estimates. Heating of the mantle, if there is an energy source in the inner core, is inevitable. But it is possible that the heat flow set by the temperature difference between the inner core and the mantle is strongly diminished in the outer core due to the generation of a magnetic field (the outer core, as it were, has a very high thermal resistance).

Since the temperature of the mantle is gradually levelling off, and the Rayleigh number depends on the temperature difference, the intensity of convection must decline with time. Of course, heat transfer processes due to thermal conductivity also contribute to the equalization of the mantle temperature. But to determine the contribution of these processes to the final result, not general reasoning, but specific models with a specific composition, phase state and parameters of the substance, are required. In this work, only general principles are considered that determine the occurrence of certain physical processes in the planets.

4. Conclusion

The scheme of gravitational compression of an isolated, calm, rarefied gas-dust cloud in outer space considered in [1] made it possible not only to determine the characteristic features of the formation of a single star, which distinguish them from the processes of star formation in dense gas clusters, but also to take a fresh look at the formation of a planetary system near such a star. In this work, it is shown that the process of planet formation for such a variant of evolution is characterized by a significantly greater activity of all the resulting processes associated with much higher energies and densities of the substance that makes up the protoplanetary cloud, than those considered in modern models. In addition, all processes associated with the increases of masses of future planets and with the formation of their magnetic fields are transient.

The protoplanetary cloud of a single isolated star does not form gradually, taking a long time pulling into a disk and concentrating dust to the point of its instability, but almost instantly, due to the collision of the fronts of dense and high-energy layers of a gravitationally contracting gas-dust cloud, moving in radial directions towards each other. The initial shape of the protoplanetary cloud is close to spherical, but the formation of a flat structure due to the collision energy occurs very quickly.

Almost all the dust of the original gas-dust cloud partakes in the formation of the protoplanetary cloud, which by the time of the final formation of the planets is almost completely absorbed by the star.

The protoplanetary cloud at the initial moment of its appearance is a dense and high-energy plasma, in which acts of fusion and decay of elementary particles occur, high-frequency electromagnetic radiation arises, numerous sources of powerful spherical diverging and even converging shock waves appear, and explosions of thermonuclear fuel occur in inertial traps with the formation of new shock waves. Numerous high-energy processes most likely lead to the formation of numerous unstable formations with degenerate structures, immediately decaying and producing a large number of heavy isotopes. At least, the isotopic analysis of tungsten and helium in the rocks of certain volcanic deposits indicates, as mentioned above in the text, that the heavy chemical elements originated in the protoplanetary cloud (heavy chemical elements, most of which turn out to be radioactive, cannot be characteristic of an isolated solitary gas-dust clouds from which a single star with its planetary system is subsequently formed). It is practically impossible to suggest a mechanism for the generation of heavy chemical elements, other than from the decay of unstable formations with degenerate structures. Therefore, the hypothesis put forward for the appearance of formations with degenerate structures in the protoplanetary cloud looks convincing and fits well into the sum of the observed facts for the planets of the solar system, which cannot be explained by any other prehistory.

This paper makes the assumption that in individual local zones the density of unstable formations with degenerate structures is so high that they form single lumps of orbitally connected formations with degenerate structures, the lifetime of which increases due to such a combination. The total geometrically complex magnetic field around such a lump pulls the plasma around it from the surrounding space, triggering the iron separation mechanism during the formation of this layer. The subsequent decay of unstable formations with degenerate structures that make up the lump, forms a single solid-state formation of heavy elements, many of which are radioactive. Such a solid-state formation loses its own magnetic field, but is surrounded by a layer of liquid metal in which a magnetic dynamo is initiated. Such micro-formations in mutual collisions are capable of creating larger formations with the same structure and with the preservation of a working magnetic hydro-dynamo. Quite quickly, such formations become so large that they turn into proto-nuclei of future planets, which consist of solid and liquid parts, have an internal source of radioactive decay energy and their own magnetic field. Thus, protoplanetary proto-nuclei are formed in a single process and in a single spatial zone at the very initial stage of the formation of a protoplanetary cloud.

At the same time, the processes of the formation of proto-nuclei are accompanied by the process of expansion of the protoplanetary cloud to the periphery and the discharge of the main part of solid-state formations onto the star. The shape of the protoplanetary cloud becomes close to flat, and the entire cloud is already characterized by orbital motion. But a characteristic feature of such a protoplanetary cloud, due to the prehistory of its origin, is the chaotic movement of the elements that make up the cloud in the coordinate system associated with the average orbital motion of the cloud elements. In this case, the frequency of collisions of the elements of the cloud with each other is determined by the kinetics of their movement, and not by gravitational attraction to each other. Gravitational attraction only increases the effectiveness of such collisions, but does not determine them.

After that the process of the division of the protoplanetary cloud into two rings, which was initiated in the spherical protoplanetary cloud, which has already become flat, is completed. The inner ring is the primary one, it is larger and denser. Protoplanets begin to form from proto-nuclei in it. Individual proto-nuclei from the inner ring fall into the outer ring, which also begin to turn into protoplanets, but under different conditions. The formation of protoplanets helps to gravitationally synchronize the movement of matter in circular orbits. The majority of the protoplanets of the inner ring goes into internal orbits and is absorbed by the star, a small part remains in the ring, acquiring circular orbital motion, and individual protoplanets fall into the gap between the rings, helping to finally clear it of dust. Single protoplanets remain in the gas gap between the rings, forming almost circular orbits. The protoplanets of the outer ring, taking into account the gravitational interaction with the protoplanets of the gas gap, which got there from the inner ring, reduce their number to a minimum and also move to circular orbits.

Thus, all protoplanets of a single isolated star are formed from the same proto-nuclei carrying magnetic fields and having solid inner and liquid-metallic outer cores. In the future, the magnetic fields of proto-nuclei may disappear, but their presence contributes to the formation of layered spherical magnetic hydro-generators around them.

Due to the final clearing of the orbits of the surviving protoplanets from space debris, the final stage of planet formation takes place. The properties of planets formed from protoplanets are completely determined by the zone of their final formation.

Planets that have cleared their orbits and finally formed enter a period of relaxation to establish equilibriums for all processes occurring in their depths and on the surface. The temperature regime of the planet is determined by heat exchange with the host star. After a certain period of time, quite short by astronomical standards, the planets stop cooling. The internal sources of the planets also quickly adjust the temperature regime of the planet for a corresponding discharge of energy into space, in which the amount of energy produced by the internal source balances with the heat lost by the planet into space. Thus, only young planets can cool down, and old planets do not lose their internal heat.

Heat losses of the Earth into space are determined by radioactive elements located near the surface. The Earth, as a relatively aged planet, does not cool down. Gravitational differentiation cannot warm up the cores of any planets, and in the case of the Earth, it is probably almost completely absent. But the moderate generation of energy in the solid core of the Earth takes place due to radioactive decay. This energy is spent on maintaining the Earth's geomagnetic field and on heating the mantle, accompanied by the movement of tectonic plates and volcanic activity. But the main energy contribution to the last two phenomena is still made by radioactive sources of the upper layers, and the main consumer of the energy of the inner core, most likely, is the generator of the magnetic field of the outer core.

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