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WEAK VIOLATION OF ELECTRONEUTRALITY IN THE HELIOGEOSPHERES: ELECTRONEUTRALITY DISORDERS

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Abstract

We prove that the occurrence of constant fluxes of positive ions with a large ratio of the charge number (*Z*) to the mass number of the ion (*M*) — *Z*/*M* in the solar wind (SW) is due to an insignificant violation of the electroneutrality of the Sun and the entire heliosphere, the absence of Debye shielding–of the solar charge due to due to the presence of a constant flux (current) of high-energy electrons from the Sun throughout the heliosphere and the appearance for protons, alpha particles and other positive ions with a ratio $Z/M \geq 0.107$, Coulomb mirrors that reflect and accelerate them reflecting and accelerating them from the Sun. For the first time, the effective charge (1.4 kC) and other parameters of a positively charged Sun, which make it possible to estimate the electric field strength (*E*/*N*) reduced to particle density (*N*), were calculated from the ionic composition of SW (according to the minimum *Z*/*M* positive ions observed in experiments). This model allowed us to estimate the electric field intensity (*E*/*N*) reduced to the density of particles *N* in the photosphere, chromosphere, corona of the Sun ($E/N \approx 27 \cdot 10^3$ Td), heliosphere and to investigate the conditions necessary for reflection of various positively charged particles — ions from the positively charged Sun

Keywords

Solar wind, electroneutrality violation, gravitational interactions, Coulomb interactions, proton, alpha particle

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Introduction. The Space Research Institute of the Russian Academy of Sciences (IKI) holds annual conferences devoted to theoretical and experimental studies of processes in space plasma, in particular processes on the Sun, in the solar wind (SW), the ionosphere and magnetosphere of the Earth and other planets of the solar system. Despite hundreds of reports [1] devoted to the problem of the origin and description of processes in the SW, coming from the Sun to the Earth, there is currently no clear and verified by numerous experimental observations understanding of the reasons responsible for the existence of the SW, which fills the heliosphere with a density that is inhomogeneous. The main question is what causes the movement of heavy, repeatedly ionized iron ions from the Sun, the mass of which is huge and the dimensions of the cross sections are negligible [2, 3].

Some issues related to the formation of the global electric circuit of the Earth (GECE) are considered in Ref. [4]. An attempt was made to determine the conditions for the formation of an electricity source, which fairly stably maintains the potential difference between the ionosphere and the negatively charged Earth (its charge is estimated at 500 kC). According to the ideas given in Ref. [4], the main "heart of an atmospheric electric machine is a thundercloud". It is believed that electric charges in the clouds are formed in collisions of aerosols in different aggregate states. The separation of charges occurs during the interaction of charged particles with convective air flow. Unlike charged particles have significantly different masses, the rates of incidence of positive and negative charges in the Earth's gravitational field are significantly different. Thus, an attempt was made to obtain the dipole structure of thunderclouds, tens of kilometres in size [4]. A weak violation of electroneutrality and its role in lightning during the formation of charged water droplets was studied in Refs. [5, 6] and others. In these works, it is assumed that the processes of electroneutrality violation are not determined by the characteristic dimensions at the level of the Debye radius due to interference of gravitational and Coulomb potentials. It is believed that the main process is convective processes of weak charge separation into tens of kilometres. The interference of Coulomb and gravitational potentials was considered by A.S. Eddington, P. Dirac, A. Einstein and others, but only for the interaction of elementary particles [7].

Another example of the formation of complex profiles of plasma structures with dimensions exceeding the Debye radius is gas discharge. In the gas discharge, the formation of anode and cathode regions of electric potential drop, areas of negative luminescence, Faraday dark spaces, extended positive columns and various strata occur. If a significant violation of electroneutrality is possible in the near-electrode regions, then the sizes of such structures can be compared with the Debye radius. In other areas of the discharge, such as the Faraday dark space and the positive column (it can be of unlimited size), a weaker violation of electroneutrality occurs, the characteristic dimensions of these 3D structures are many times larger than the dimensions of the Debye radius. Therefore, the positive column is called positive, since it is charged by a distributed positive charge with the corresponding profile of the electric potential. This is due to the fact that electrons are more mobile due to their smaller mass than that of ions, and an excess of a positive charge arises in the discharge region, electrons are deposited in the circuit and around the experimental setups in the form of an external negative charge. The size of the positive column can reach dimensions many times larger than the Debye radius. This is due to the fact that the sizes of structures in a gas discharge are not determined by the Debye radius. In a discharge with a current, there is no complete of Debye shielding of the charges and the electric field penetrates into the plasma. This leads to drift flows of electrons and ions in opposite directions. The electric field E acts as the third component even in a simple plasma along with the concentration of electrons n_e and ions n_i. The characteristic sizes of structures in a plasma with current are determined by all processes of charge separation in the discharge gap, i.e., both by the processes of cumulation (focusing) of the charge and by the processes of its dissipation (scattering), most importantly — by the magnitude of the electromotive force (EMF). Further, we call a plasma with current (with EMF) a drift plasma, and a plasma without current (without EMF) — a stationary plasma. In a motionless plasma, a complete Debye shielding of any charges occurs; therefore, there is no electric field controlling the convective flows of charged particles. Without an electric field, there is no directed flow of charged particles in the plasma, and therefore no magnetic field. Note that the drift plasma is characterized by the ability to complex self-organization. It requires a more complex than stationary plasma theoretical description taking into account Maxwell's equations and experiments of Stoletov, Townsend and others [7]. In the present work, the methods and results of studying the electroneutrality disturbance and electric field profiles in a gas-discharge plasma are used to explain the phenomena in astrophysics, in particular, in heliogeophysics.

The fundamental principles. Let us explain and justify the method of mathematical generalized transposition (MMGT) — the method of transferring mathematical models from well-studied areas to under-studied areas to describe similar phenomena [8]. Fixed plasma is described by the theory of Debye shielding [9, pp. 403, 404].

Based on experimental observations and their agreement with the model proposed in Refs. [10, 11], we prove the existence of a complex global electric circuit in the heliosphere. This is the global electric circuit of the heliosphere (GECH) with the centre being a positively charged Sun [10, 11], into which the GECH is included as a composite and not the main element. The separation of charges in the GECE occurs as a result of convective processes at the level of: 1) a positively charged Sun; 2) negatively charged planets and dust of the solar system, which captured previously free high-energy electrons flying constantly from the Sun. The initial flow (current) of high-energy electrons from the Sun is responsible for the processes of energy exchange between electrons. These processes cause the energy distribution function of free electrons to tend to the Maxwellian (Maxwellization processes) in the plasma of the Sun and the heliosphere with the electric field of the positively charged Sun. Free high-energy electrons, like a more mobile gas, leave the Sun and the region of the fully ionized heliosphere much faster than more massive positive ions. Due to the rapid departure of some of the high-energy fast electrons from the Sun, an emf appears in the GECH. This leads to the global charge separation, the plasma nonequilibrium in the entire heliosphere and the Sun, the penetration of the electric field into the heliosphere, the reverse current of low-energy electrons and a charged negative dust charge, which seeks to compensate for this nonequilibrium. However, the speeds of negatively charged particles directed toward the Sun are significantly lower than the speeds of high-energy electrons constantly leaving the Sun. As a result, a quasi-constant effective positive solar charge is established, accelerating low-energy electron fluxes to the Sun. We will consider this solar charge as an adiabatic parameter that varies slightly with time, but significantly affects the evolution of the plasma around any star. Such a dynamic Coulomb crystal with a current from a positively charged Sun to negatively charged rotating planets is formed in the heliosphere plasma, according to the ideas given in Refs. [10, 11]. The heliosphere plasma is an active, self-organizing medium controlled by small but long-range electric fields due to the small charge of the Sun. Its properties are significantly different from the properties of a stationary plasma, where there is a complete Debye shielding of any charge and the disappearance of the electromagnetic fields controlling the flows of charged particles. Let us dwell on the classification of two types of plasma and a description of their properties:

1) active plasma due to the presence of an electric field penetrating into the plasma — drift plasma with EMF;

2) inactive plasma — motionless (without EMF external to it).

Let us consider in detail the problems or observed paradoxes — the discrepancy between experimental observations and inferior (defective) theories [12], based on the theory of Debye shielding in a stationary plasma without an electric field (without EMF).

The experimental studies of SW began more than 60 years ago in the USSR on the *Luna-2* spacecraft (SC) in 1959 and in the USA on the *Explorer 10* spacecraft in 1961). The theoretical foundations of understanding the dynamic processes of the formation of SWs were laid by E. Parker in 1957 [13]. According to existing ideas, based on the neutral SW model, its velocity in the expanding corona gradually increases due to a decrease in plasma density without experiencing jumps [14]. However, as a result of radiooccultation observations [15], it was found that in the corona region at a distance of about 10–20 solar radii there is a region of sharp increase in the SW velocity from 50 to 450 km/s. Until now, the mechanisms responsible for heating the solar corona to a temperature of $(1.5–2.0) \cdot 10^6$ K and causing it to expand from the Sun in the form of a stream of protons, alpha particles and heavier ions are still not understood within the framework of the electroneutral model of the Sun and the heliosphere [1, 2, 16]. In this case, the surface temperature of the Sun (radiation) is approximately 5700 K, and further from the Sun at a distance of 10–20 radii to $2 \cdot 10^6$ K. This is the most important problem — why far from the Sun, and specifically, at a distance of 10–20 of its radii, is the plasma temperature much higher than on the surface of the Sun? Based on the assumption of the neutrality of the Sun and the heliosphere, it is also impossible to understand the mechanisms that ensure the entry into the interplanetary space of ions heavier than protons and alpha particles (such as C^{4+}, O^{5+}, Ne^{8+}, Mg^{6+}, Si^{6+}, Fe^{6+}, Fe^{14+}, etc.) [2, 3]. All these major problems are simply enumerated, but not explained in modern monographs, conferences, and reviews, for example, see [1, 8, 16] and the references in these sources. The main question is: why are heavy iron ions not less than 6 times ionized in SW?

The positive charge of the Sun and the negative charge of the planets do not significantly affect gravity-centrifugal celestial mechanics due to the insignificance of the Coulomb attraction forces between them compared to gravitational and centrifugal forces (the ratio of the charge numbers of uncompensated positive ions to the total mass numbers Z/M for planets and the Sun is small).

Full Debye shielding of a positively charged Sun does not occur in the heliosphere; the heliosphere plasma is the drift plasma.

In this problem, an important fact verified by experimental observations using satellites and spacecraft is the reverse direction of motion of many times ionized positive SW ions from the Sun [1–3, 9–11, 13–16], and not toward the Sun. This would be understandable as the result of only gravitational attraction between the plasma structures. Accordingly, there are forces acting on positive ions and accelerating them from the Sun [10, 11]. The negative charge of the Earth is approximately 500 kC, near the Earth's surface there is a decrease in potential by 100–130 V per 1 m. Moreover, the role of Coulomb forces due to the dynamic effective charge of the Sun in the phenomenon of the reverse of gravitational forces of positive ions in the SW is still not properly analysed, except for the works [10, 11]. This work is devoted to solving this problem and criticizing the work of the followers of the Debye theory, which incorrectly apply it to describe the behaviour of charged particles of a drift plasma with current for processes in the heliosphere.

It was established that the main particles that transfer mass to the SW are protons and alpha particles [1–3, 9, 13, 16, 17]. Such a movement of positive ions, forming the SW, is possible only with a positively charged Sun and gravitational forces lower than the Coulomb forces of repulsion of these positive ions from the Sun. In this case, the effective charge of the Sun is not screened by the drift plasma of the heliosphere. So, to reflect protons from the Sun, a solar charge of 150 C is needed. We believe that global currents function in the heliosphere. Electrons not only do not compensate for the effective positive charge of the Sun, but also go far beyond the heliosphere and do not return to compensate for the charge of the Sun and the fully ionized heliosphere. All luminous plasma structures with free electrons in a gas discharge with a current and dimensions significantly exceeding the Debye radius are positively charged [18–31]. In these studies, this is justified by the fact that electrons are more mobile than ions and processes of electron-electron collisions and the formation of high-energy electron flows from the structure occur in a plasma with free electrons. In a positively charged Sun, as well as in the whole positively charged fully ionized heliosphere, also due to the Maxwellization of the distribution function of free electrons, flows of high-energy electrons are formed, directed from the Sun into the surrounding outer space. As an argument for the absence of charged structures in a gas-discharge plasma, the quasi-neutrality condition and the Debye theory of charge shielding in a plasma are given. Let us analyse such statements for a plasma, a fully ionized heliosphere with a current due to the departure of high-energy (runaway from the structure) electrons that constantly leave the Sun and the heliosphere. This provides a quasi-constant positive charge of the Sun and the entire fully ionized heliosphere.

Quasi-neutrality and penetration of electric fields into plasma. In the scientific and educational literature, various and contradictory definitions of plasma quasi-neutrality are given. The concept of “quasi” is almost. So, quasi-permanent — almost permanent. Without the prefix “quasi”, the plasma becomes electrically neutral or, according to the Poisson equation, the density of the space charge in the plasma must be zero everywhere. In the general case, a reasonable definition of the quasi-neutrality of a simple plasma is

$$\alpha_{\mathrm{i}} = (n_{\mathrm{i}} - n_{\mathrm{e}}) / (n_{\mathrm{i}} + N) \ll 1, \tag{1}$$

where n_{e} is the electron concentration; n_{i} is the concentration of positive ions; N is the concentration of neutral particles (atoms, molecules, etc.) The question remains open: how many times α_{i} is less than 1? In ordinary discharges, arcs, and in lightning, the parameter of uncompensated charge or violation of plasma electroneutrality α_i does not exceed 10^{-6}. This indicates a good quasineutrality of structures in a plasma with a powerful current and breakdown values of electric fields in lightning with a channel length of up to 2 km and a diameter of about 10 cm. At these sizes (10 cm–2 km), charged particles are controlled by an electric field penetrating into channel of a highly conductive gas discharge plasma. Only in a narrow near-cathode region of the laboratory gas discharge, the parameter of electroneutrality violation α_i is approximately equal to 1, while the electric field (E) divided by the density of the number of gas particles (N) in the cathode region significantly exceeds the breakdown values (for air, $E/N \approx 110$ Td)

Note that the definition of quasineutrality (1) or uncompensated charge is fully consistent with the words of I.S. Shklovsky. He argued [32] that one uncompensated ion is sufficient for 10^{10} compensated ions, so that the resulting electrostatic field could not escape observation. In this paper, we discuss how to determine the degree of violation of the solar electroneutrality of the Sun at the level $\alpha_i \approx 10^{-36}$ or the role of the charge of one uncompensated ion per 10^{-36} atoms or ions with charges of compensated electrons located nearby (and not beyond the Earth's orbit and of the Sun). In this case, the quasineutrality of the Sun according to (1) is preserved with great accuracy up to 36 signs, and the electroneutrality is violated at the level $\alpha_i \sim 10^{-36}$. It is proved that such a small violation of electroneutrality is sufficient to prevent the emerging electrostatic field from escaping the observation of indirect asymptotic effects, which manifest themselves in the form of the reverse motion of positive ions from the Sun [10, 11]. As a result, astrophysicists get a unique way to study the electrical parameters of the Sun, the heliosphere, other stars and galaxies from the experimentally fixed ionic composition of SW, galactic and intergalactic winds (if they do not significantly modify as they move), which are an example of drift plasmas capable of complex self-organization, as in a conventional laboratory gas discharge with current. Let us dwell in more detail on the classification and differences in processes in drift and motionless plasmas. In describing the properties of a stationary plasma, we will rely on the results presented in [9, pp. 403, 404].

Fixed plasma and its description in the framework of the Debye shielding model. To describe the phenomenon of Debye shielding of a charge in a stationary plasma, we use the materials given in Ref. [9] (Ch. 2, Section 11.3, pp. 403, 404, author D.R. Shklyar). This work claims that in most cases the charge density in a plasma at sufficiently large spatial and temporal scales is zero. This property of plasma is called quasineutrality. Another important property of a plasma is that inside a plasma there cannot be a strong quasi-constant electric field. It is argued that in a certain sense, plasma always shields external electric fields placed in a plasma of electric charges. This property of the plasma is called the Debye shielding, since the characteristic size at which the external electric field penetrates the plasma, as well as the scale at which the field of the electric charge placed in the plasma decreases, is the Debye radius λ_D determined by the relation

$$\lambda_D^2 = \frac{T}{4\pi e^2 n_0}, \tag{2}$$

where T is the plasma temperature in energy units; n_0 is the average unperturbed density of charged particles. In Ref. [9, Section 11.3, pp. 403, 404] states "... relation (2) emphasizes that in an equilibrium plasma with the same temperature of electrons and ions, the Debye radius is a characteristic of the plasma as such, and not of various particles, such as, for example, the plasma frequency for electrons." Determination of plasma quasi-neutrality according to (1), which is consistent with Shklovsky's statement, and (2) differ significantly and contradict each other. Determination of uncompensated charge (1) allows us to analyse the role of any electric fields, including those that penetrate deep into a plasma with current, according to the Poisson equation. Shklyar's stringent requirements such as "in most cases", "equal to zero" and "strong field" are neither proved nor admissible, although they are used by many astrophysicists without proper analysis of the processes of charged particle transport in a plasma with current.

An example of solving the problem of shielding an external, positive charge introduced into a plasma by a polarizing–negative–charge of charged particles of a previously neutral plasma is given in Ref. [9, p. 404]. A positive charge placing in a neutral plasma, when screened, an external positive charge moves to the outer boundaries of the plasma surrounding it and disappears there at an infinite distance from the external charge. This approach does not analyze the effect of:

1) the final dimensions of the shielding plasma, its density, *inhomogeneity*, and other parameters;

2) the possibility of a positive response of the plasma (*active inhomogeneous* plasma) to the presence of an external charge, i.e., an increase in the effective charge in the *inhomogeneous* plasma itself due to the presence of an external charge and its electric field, which affects the processes of ionization, death and transfer of charged plasma particles, for example, high-energy electrons that

intensively leave regions with a high electron temperature, which can lead to the accumulation of a positive space charge and other phenomena;

3) the departure of a small part of high-energy electrons beyond the boundaries of plasma structures. In particular, this can not only not compensate for the external charge in the heliosphere plasma, but also increase its effective effect on the active medium of an inhomogeneous plasma outside the Earth's orbit.

Debye's followers without proper analysis of the above three points simply throw away other solutions based only on a limited model of a stationary plasma. Statements of the type "... at sufficiently large spatial and temporal scales is zero" or "... there cannot be a strong quasi-constant electric field inside the plasma" [9, pp. 403, 404] it is difficult to attribute to mathematical or physically meaningful expressions and are not permissible in the theory of plasma physics, and in particular, in heliogeoplasma. In a gas-discharge plasma with a current, it was found that it is not the electric field E that determines the main processes of production and transfer of plasma particles. Under these conditions, everything is determined by the magnitude of the reduced electric field E/N (or electron temperature, which is an unequivocal function of the parameter E/N). Here N is the density of gas particles. Therefore, if the density of the number of particles N decreases faster than the electric field E, then the parameter E/N can increase in these areas, and lead to a corresponding increase in electron temperature, and to significant effects that are inexplicable from the position of the Debye theory.

According to the theory of Debye [9, pp. 403, 404], all tasks in the plasma are reduced to Debye shielding. Such an approach has led to a significant inhibition of the development of plasma sciences in the heliosphere and geospheres due to the ejection of a huge class of problems that can be solved only with a slight violation of plasma electroneutrality in the framework of determining quasi-neutrality (1), and not according to (2). Such problems relate to asymptotic paradoxes [12] and go back to paradoxes due to viscosity and other phenomena, for the description of which, in the system of equations, it is necessary to take into account the highest derivative with a small coefficient. Approach (2) leads to a paradox in a discharge in a plasma with current, similar to the D'Alembert paradox [12]. Nevertheless, this approach ("everything is neutral around the Debye radius") in astrophysics is still dominant.

If we apply the approach described in Ref. [9, pp. 403, 404], to the discharge with the current we obtain the following assumption: the current in the presence of plasma in any gas discharge is zero, since charged plasma particles completely shield the electrodes and all charged particles stand still, since there is no electric field in the plasma volume outside the region, exceeding the Debye radius.

According to the results of experiments with gas discharge tubes (with mercury), this is not at all the case. When you turn on the daylight tube with mercury vapor glows and charges move in the field along the entire length of the tube. This means that in a plasma with current there is no complete shielding of the charges of the electrodes and the electric field penetrates into the plasma with current at a distance of the discharge gap, and not at the Debye radius. Electrons move at high speeds toward the anode, positively charged ions move slower than electrons toward the cathode. This difference in the velocities of electrons and positive ions leads to the formation of an electric field intensity profile in a positively charged plasma column. The difference in their velocities determines the positive charge of all plasma luminous structures with free electrons [18–31]. Moreover, in a gas-discharge plasma, quasi-neutrality according to (1) in the volume is performed with an accuracy of the sixth sign or more. The difference in the velocities of electrons and ions is due to a significant difference in the masses of electrons and ions. In addition, in a gas discharge plasma with a penetrating electric field, the temperatures of electrons and ions differ significantly due to the intense heating of electrons in an electric field. This mass difference is ignored in the approach given in Ref. [9, pp. 403, 404]. In this case, the approach does not take into account the different behaviour of high-energy electrons and massive ions. In Ref. [9, p. 403] operate with the so-called integrable part of the electron distribution function (EDF) and ions of (charged) particles, for which one can introduce the concept of temperature and find the distribution function of electrons and ions as a function of energy and assume that their temperatures are equal. However, the velocities due to the difference in masses are not equal in this formulation. The difference in the velocities of charged particles is not taken into account when simulating a stationary plasma. The use of such an approach for modelling processes in plasma structures with a changing charge is generally not acceptable. Such a cascade of assumptions excludes from consideration a huge class of dynamic problems that can and should be solved when describing drift and pulsating phenomena in helio- and geospheres with a meagre current of high-energy electrons constantly leaving the heliosphere. Such errors lead to a series of asymptotic dynamic paradoxes, some of which will be considered here.

Let us prove that when the quasi-neutrality condition (minuscule electroneutrality violation) of the Sun is fulfilled, to within 36 digits $((n_\mathrm{i} - n_\mathrm{e}) / n_\mathrm{i} \approx 10^{-36})$, the small effective solar charge (10^3 C) and the penetration of small electric fields (10^{-5} V/m) not only protons and alpha particles from a positively charged Sun can accelerate into the heliosphere, but also heavier positively charged iron ions, ionized more than 5 times. This phenomenon is associated with the EDF Maxwellization processes in the Sun, the long-range nature of Coulomb forces and potentials, and the contactless heating of electrons and ions in the electric field of a positively charged Sun in a gas-discharge rarefied nonequilibrium heliosphere plasma with a small flux (current) of high-energy electrons from the Sun. In this case, we will consider the effective charge of the Sun as an adiabatic invariant of the entire dynamic system of the heliosphere with the Sun, planets, dust, atoms and molecules. This approach clearly does not fit into the framework for determining quasi-neutrality for a stationary plasma according to (2), but it fits into the definition of quasi-neutrality, which follows from (1) and is consistent with Shklovsky's statement [32].

The presence of positive ions in the SW clearly indicates a positive solar charge and the formation of a GECH. For the first time, the solar charge Q_S was estimated from the condition of equality of gravitational and Coulomb forces, which are acting on the 6 times ionized iron ion [10, 11]. This ion is registered in the SW in the region of the Earth [2, 3]. All Fe^{7+}…Fe^{12+} iron ions and other ions with a large ratio $Z/M \geq 0.107$ than that of Fe^{6+} + are observed in SW. Ionized iron ions of 5 and less are not recorded in the SW as many times as positive ions with $Z/M < 0.107$. In this case, C^{4+} ($Z/M = 0.33$) and O^{5+} ($Z/M = 0.33$) ions are observed in SW. This experimentally observed fact provides a basis for estimating the solar charge at the level of 1.4 kC [10, 11].

Drift plasma model. Parameters of plasma positively charged cumulatively dissipative structures in plasma with current. As shown in Refs. [18, 21–30], in plasma cumulatively dissipative (CD) structures in discharges with current, such as lightning, dotted lightning, cathode spots, positive columns, striations [22–24], etc. (Fig. 1–4), processes of formation and long-term retention of a positive charge by the entire CD structure — a plasmoid — can occur. In this case, a small part of the electrons in the laboratory facilities is deposited on their surface and requires the removal of electrostatic electricity by special rods or grounding. The accumulation of static electricity occurs where electromagnetic fields exist. For a resident of the Earth, this means that a static charge surrounds him everywhere and always. The term "CD structure" is introduced for dissipative structures in which the cumulation (focusing) forces of energy-mass-pulse flows (EMF) are significant [18, 20, 31]. It is clear that for describing even weakly charged extended structures in a plasma with current, such local parameters as the Debye radius are not very effective [27, 28]. The Debye radius is determined by the local concentration of charged particles and their temperature and determines a significant violation of electroneutrality at the level of concentration of charged particles. The profile of the electric field strength around any charged structure is determined by the total charge of the entire structure and the distance to it. Usually, astrophysicists, based on the calculated Debye radius, conclude that a structure with large characteristic dimensions is neutral. This is a mistake restraining the development of astrophysics of charged structures. Here is a simple example with an ebonite stick and woollen cloth. The friction of a stick with wool leads to the precipitation of a part of electrons on an ebonite stick. Throwing away the fabric, you can walk along the street for a long time and attract small, finely chopped pieces of paper. The question arises: how to use the Debye radius here — for the whole room or street, or not to take into account such dynamic phenomena of charge transfer at all?

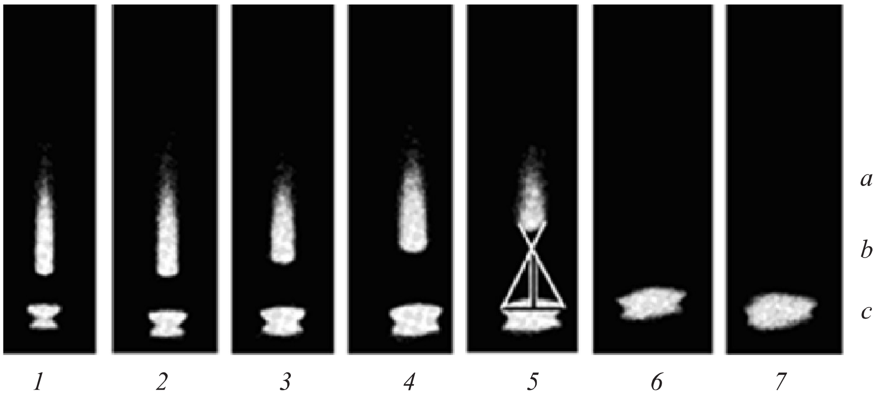

Fig. 1. Relationship between the width of a cylindrical self-focusing discharge in high purity nitrogen and current [21] I = 0,6 (*1*); 0,8 (*2*); 1,1 (*3*); 1,65 (*4*); 2,2 (*5*, determination of the libration point); 2.9 (*6*); and 3.25 mA (*7*); P = 5 Torr:
a is a positive column (with a blue luminescence diverging to the anode, which is not fixed photographically); *b* is Faraday dark space; *c* is negative luminescence (or cathode spot, lower spot flare of the cathode spot on a mirror-polished electrode)

Fig. 2. The structure of plasmoids in a discharge in a tube in high-purity nitrogen depending on the discharge current at P = 15 Torr [26, 27]. The discharge locally (window size 2 cm) in the center is outraged a beam of high-energy electrons (gas was pumped at a speed of 50 m/s from the cathode to the anode, in the direction of the arrow)

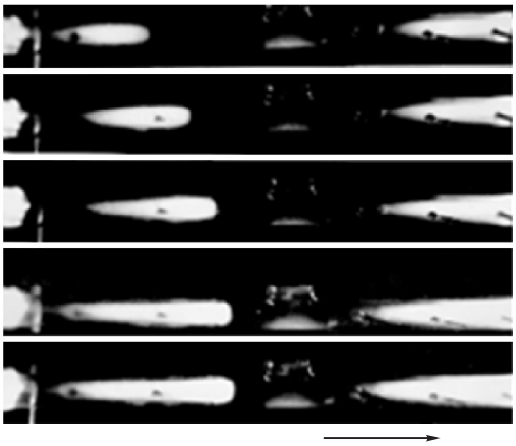

Fig. 3. Chain (dotted) lightning with internal Vysikaylo — Euler libration points between charged luminous structures against a palm tree

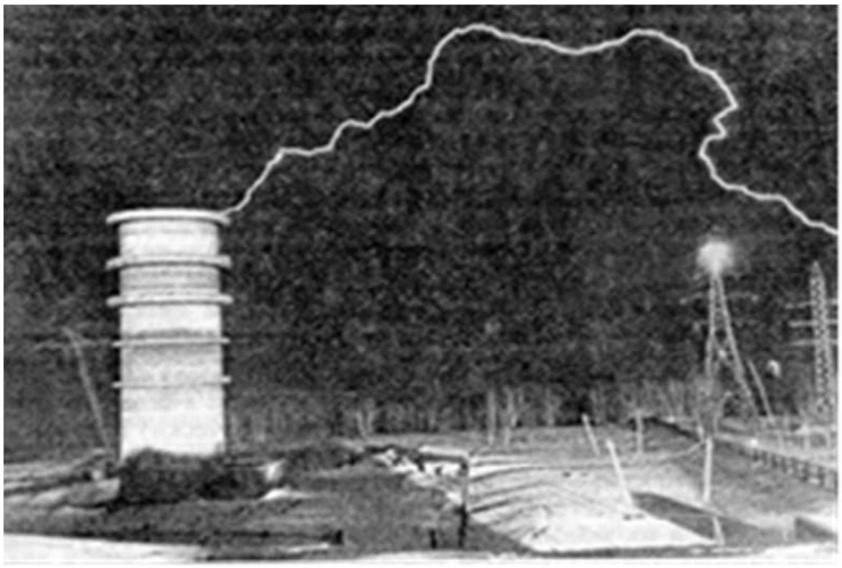

Fig. 4. Discharge in air with a persistent cross section; the glow indicates a radial focusing of the electric field (*E*/*N*) (this is an artificial lightning or a plasma jet stream in which the fluxes of electrons and ions self-focus into a cumulatively dissipative structure)

We will describe the "reverse" (against gravitational forces) motion of SW (positively charged ions). Suppose that the Sun has a small, compared with the total number of particles, uncompensated positive charge (Fig. 5). The Debye shielding of this charge does not occur due to the constant departure of high-energy electrons from the entire heliosphere, i.e., a deficit of electrons is observed in the entire heliosphere, since a small part of them went into space. To describe the transport processes in the heliosphere, we will use the experience gained in the study of laboratory gas-discharge plasma with current. The *E*/*N* parameter in a laboratory gas-discharge plasma with current is not only a control or order parameter. This parameter is a fundamental or the main parameter in a gas-discharge plasma; under various conditions of the course of the discharge, it tends to vary slightly over a wide range of changes in the discharge current in laboratory experiments. This is due to the exponential dependence of the processes of birth of plasma particles on the numerical value of this parameter. The average energy of electrons or their temperature, according to the Nernst — Townsend relation [31] (Einstein — Smoluchowskii), is determined by the relation

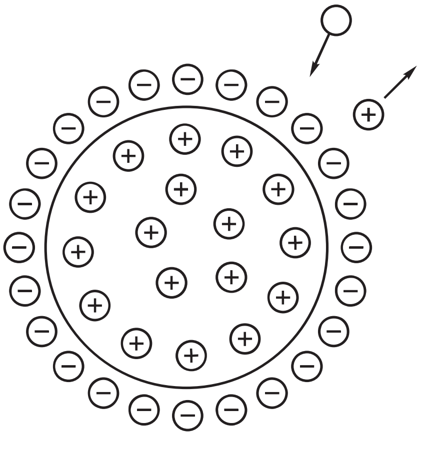

Fig. 5. Solar model as a positively charged structure with a weak violation of electroneutrality

$$T_{\mathrm{e}} \sim \frac{eD_{\mathrm{e}}}{\mu \propto (E/N)^{\zeta}}. \tag{3}$$

Here D_{e} is the diffusion coefficient of electrons; μ_{e} is their mobility. The power-law approximation (3) describes well the dependence of the rates of various transport processes and is very useful in analytical calculations of the parameters of ambipolar drift, electric or plasma winds, various types of diffusion, and shock waves of the electric field [18, 27, 28]. This law, close to “2/3” for T_{e}, operates in a wide range of the E/N parameter in a gas-discharge plasma, including a hydrogen plasma [33, p. 627, Table 1]. The temperature of electrons in a hydrogen plasma varies as the degree $\zeta = 0{,}5–0{,}8$ of this parameter in the range $E/N = 0{,}02–212$ Td. Thus, the E/N parameter is the most important parameter in a gas-discharge plasma. This parameter characterizes the external electric force that activates the medium and maintains a new ionized-excited state in it: a gas-discharge plasma and plasma structures with a weak violation of electroneutrality in a plasma with current, acting as a new phase state in a medium activated by an electric field. Townsend, based on the work of Stoletov (1889) [34], “intuitively” suggested that the rate constants of ionization of gas particles by electron impact are determined by this parameter in a gas-discharge plasma or plasma with a current. Experiments have confirmed this assumption. Townsend measured the dependences of the ionization constants in the collision of electrons with particles of a neutral gas for many types of gases and tabulated them, following Stoletov, depending on E/N, and not separately for E and N.

He showed that during gas preionization, like X-rays, and due to photoelectron emission, the same dependence of the ionization constant on *E*/*N* is obtained. It followed that the ionization coefficient for electrons detached from molecules by X-ray radiation is the same as for electrons produced as a result of photoelectric emission. This result provided direct evidence that electrons are an integral part of gas molecules and atoms. The ability to correctly use knowledge of the importance and role of the main parameters can lead to such important results. We note once again that this parameter (*E*/*P*, where *P* is the gas pressure) for gas-discharge plasma was first introduced by A.G. Stoletov [34], and Townsend referred to him work by introducing the parameter *E*/*N*. Professor S.I. Yakovlenko, who found and analyzed the work [34]. He and his co-authors formed a new understanding of the mechanism of generation of a runaway electron beam in gases. Here the role of runaway electrons from the Sun is taken into account, thereby the work is a continuation of his work and the work of his opponents and supporters.

As in the usual Stoletov — Townsend gas discharge, we will characterize the energy of charged plasma particles (electrons) in the chromosphere, the corona of the Sun, and even throughout the heliosphere in Townsend (Td) by the parameter *E*/*N (E* is the electric field in the region of the charged Sun; *N* is the density of heavy particles (nucleons) in this region). Air breakdown occurs at 60–70 Td or 20 kV/cm at atmospheric pressure, the electron temperature is about 1 eV. The average electron energy in a hydrogen plasma of approximately 1 eV is reached at $E/N \approx 30$ Td [33]. Using interpolation of the relation between the electron temperature and the parameter *E*/*N* according to (3), the calculation of T_e in the entire heliosphere will be given in other works.

Conclusion. The parameters of violation of electroneutrality are independent of the size and other physical parameters of the structure. Their values are small, but the role of Coulomb forces is comparable to or greater than the forces of gravity in a number of phenomena or processes in astro- and ordinary physics. The solutions to these problems relate to solutions to the singularly perturbed Poisson equation or to asymptotic paradoxes, when a weak violation of electro-neutrality leads to unusual or “mysterious” phenomena, for example, to the reverse movement of a positively charged cathode spot in a transverse magnetic field [18] or to SW, where protons and other positive ions move against gravitational forces if the Coulomb forces are greater than the gravitational forces [10, 11].

The concept of asymptotic paradoxes was introduced by Birkhoff in 1950 in a monograph [12], referring to the work of Oseen. Birkhoff believes that Oseen was the first to show that the presence of arbitrarily small terms of high orders in the system of differential equations can completely change the nature of the solutions. So, Birkhoff writes: "It is not always true that when a coefficient in a certain term of an equation tends to zero, then solving this equation tends to solve an equation obtained by dropping a term with this coefficient." As shown in Refs. [19, 20, 27, 30] and in the present work, this fully applies to the Poisson equation or the inclusion of a weak violation of electroneutrality (1) at the level $\alpha_{i1} \approx 10^{-36}$. And yet, the first to solve asymptotic paradoxes of this type was L. Euler. He was the first in 1767 to take into account inertia (centrifugal potential) or the term $(\mathbf{V}\cdot\nabla)\mathbf{V}$ in the momentum transfer equation and showed that the libration point L_1 between two gravitational rotating attractors decomposes (or is reflected in the centrifugal potential) into three points L_{1-3}. In 1772, J.L. Lagrange, exploring the interference of gravitational and centrifugal potentials, found two more triangular points. Now all five points are called Lagrange libration points. Without taking into account the centrifugal potential, which manifests itself in the region of the center of gravity, it is theoretically impossible to obtain libration points. Without taking into account the Coulomb potential and the profile of the E/N parameter, it is impossible to explain the features of heating of electrons and ions in the drift plasma of the heliosphere [10, 11]. Note that only in Refs. [21–23] it was first indicated that libration — cumulation points exist between similarly charged structures of any size. In these works, the libration points for electrons are classified into cumulation points of their EMIP (points discovered by Euler for gravitational rotating systems and open by P. Vysikaylo for positive rotating structures) and libration points (discovered by Lagrange for gravitating rotating systems and open Vysikaylo for positive rotating structures). If the stars are positively charged, then the libration points, the points of tangency of the Coulomb potentials, also arise between them. In the next work, the author will dwell in more detail on the effects of a weak violation of electroneutrality in the heliogeosphere.

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